Chapter 6

Integrated bridge systems

6.1 Introduction

The 20th century saw many milestones in terms of nautical events and much was learnt from such events for the benefit of those seafarers that came afterwards. Starting with events such as the sinking of the Titanic in 1912 with its impact on the Safety of Life at Sea, the use of wireless telegraphy and, continuing throughout the century, the increasing use of electronics and satellites for navigation and communication purposes.

During that time there was a realization for the need to set up international bodies with a view to the harmonization, and the international recognition, of standards for ships involved in international trading. Bodies set up during the 20th century to monitor and influence these trends included the following.

6.1.1 International Maritime Organization (IMO)

Originally set up as the Inter-Governmental Maritime Consultative Committee (IMCO) in 1958, the name was changed in 1982. Its first task was to adopt a new version of the International Convention for the Safety of Life at Sea (SOLAS) and this was completed in 1960. The best known of the responsibilities of the IMO is the adoption of maritime legislation. About 40 conventions and protocols have been adopted by the organization and amended as necessary to keep pace with the changes in world shipping. The IMO has 158 member states and is based in London, England.

6.1.2 The International Standards Organization (ISO)

This is a non-governmental organization established in 1947 with a view to promoting the development of standardization in the world, facilitating the international exchange of goods and services, and developing co-operation in the areas of intellectual, scientific, technological and economic activity. The work of the organization results in international agreements, which are published as International Standards. There are more than 130 countries represented within the organization which is based in Geneva, Switzerland.

6.1.3 The International Electrotechnical Commission (IEC)

Established in 1906, the organization has more than 50 member countries covering 85% of the world's population. Standards established are used in more than 100 countries and there are approximately 200 Technical Committees (TCs) of which TC80 is an important part (see Section 6.3). The IEC collaborates with the ISO in matters of mutual interest and both organizations co-operate on a joint basis with the International Telecommunications Union (ITU). Like the ISO, the IEC is a non-governmental body while the ITU is part of the United Nations organization with governments as its members. The IEC is based in Geneva, Switzerland.

6.2 Design criteria

In the 1960s Planned Ships Bridges were available from at least one manufacturer and fitted on some vessels. This was probably the first attempt to construct a bridge within design concepts that took into consideration the operational requirements of the vessel. Integrated navigation systems and integrated bridge systems have evolved from those days and the concept is now accepted, with a variety of systems available from many different manufacturers.

Certain classification societies have initiated terms of carriage requirements if particular notations are specified for a vessel. A leading influence has been Det Norske Veritas (DNV) of Norway, a member of the International Association of Classification Societies (IACS). The Association was formed in 1968 and claims that ‘At the heart of ship safety, classification embodies the technical rules, regulations, standards, guidelines and associated surveys and inspections covering the design, construction and through-life compliance of a ship’s structure and essential engineering and electrical systems.’ More than 90% of the world’s merchant tonnage is classed by the 10 members and two associates of IACS. IACS members include the American Bureau of Shipping (ABS), Germanischer Lloyd and Lloyds Register of Shipping, together with societies from China, France, Italy, Japan, Korea, Norway and Russia. IACS has held consultative status with the IMO since 1969 and is the only non-government organization with observer status able to develop rules. The DNV rules for ships are as follows.

- To reduce the risk of failure in bridge operation, causing collisions, groundings and heavy weather damages and to minimize the consequences to ship and complement, should an accident occur.
- To include relevant requirements and recommendations from the IMO.
- To include relevant international standards within the rules or indicating the points in which they differ.

The various classification societies have adopted different standards although discussions on establishing international performance standards for integrated bridge systems have progressed under the direction of the IEC’s Technical Committee 80 (TC80). Progress has been made on type approval and system notation.

The integrated bridge system should be designed and installed as a physical combination of equipment or systems using interconnected controls and displays. Workstations should provide centralized access to all nautical information. The type of operational function carried out from the bridge would include navigation, communications, automation and general ship operation. Manufacturers can provide shipbuilders and potential shipowners with computer-generated drawings of how a particular bridge layout would look when installed. One such diagram produced by Litton Marine Systems is shown in Figure 6.1.

In the absence of any internationally-agreed operating standards, from either the IMO or national authorities, reliance must be placed on industry guidelines and standards which do exist for bridge layout and equipment. These include the ISO standard for ‘bridge layout and associated equipment.’

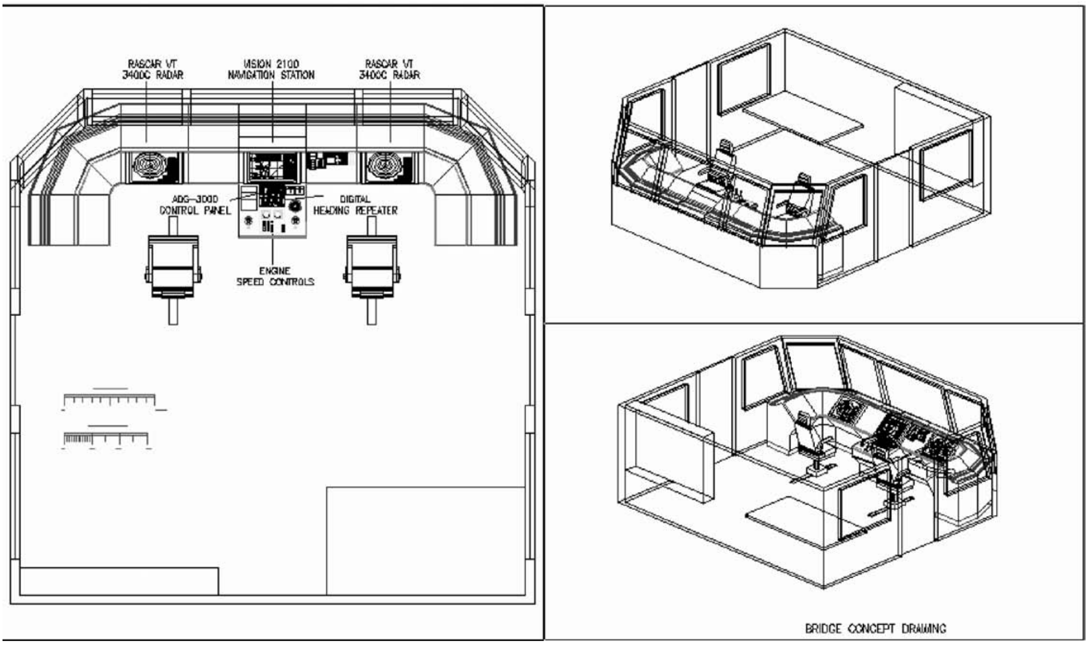


Figure 6.1 Line drawing of an integrated bridge system. (Reproduced courtesy of Litton Marine Systems.)

An IEC definition of an integrated bridge system states that such a system must be capable of carrying out at least two of the following functions:

- navigation planning
- passage execution and manoeuvring
- collision and stranding avoidance
- communications
- machinery control and monitoring
- loading and discharge of cargo
- safety and security
- management.

The integrated bridge system that meets these requirements must provide: redundancy in the event of system failure; the use of standardized equipment interfacing; the centralization of all nautical data and alarms; and the use of suitable displays to allow the monitoring of sensor data. The fact that current trends involve a reduction in manning levels suggests that the few members of a crew on the bridge must be capable of interpreting and responding to the multitude of information and alarms being presented to them. This would involve improvements in training and system documentation for the crews.

The DNV rules specify design criteria for particular workstations namely:

- traffic surveillance/manoeuvring
- navigation

- route planning
- manual steering
- safety operations
- docking operations
- conning operations.

In each case the tasks that have to be performed are specified and the siting of relevant instruments/ equipment required for those tasks is defined. As an example, the workstation for navigation is specified to enable the following tasks to be performed:

- determine and plot the ship's position, course, track and speed;
- effect internal and external communications related to navigation;
- monitor time, course, speed and track, propeller revolutions, pitch indicator and rudder angle.

The following instruments and equipment should be installed within reach:

- navigation radar display and controls
- chart table
- relevant position fixing systems (GPS and Loran-C)
- VHF unit
- whistle control.

Instruments, indicators and displays providing information considered essential for the safe and efficient performance of tasks at the navigation workstation should be easily readable from the workstation. These instruments, indicators and displays should include:

- gyro repeater
- rudder angle indicator
- depth indicator
- clock
- propeller RPM indicator
- pitch indicator (where fitted)
- speed and distance indicator.

Means to be used at intervals for securing safe course and speed in relation to other ships and safety of bridge operation should also be easily accessible from the navigation workstation. Such means include:

- instruments and equipment installed at the workstation for traffic surveillance/manoeuvring
- internal communications equipment
- central navigation alarm panel (if provided)
- wipers and wash controls for the windows within the required field of vision.

DNV specification for one-man bridge systems in an unbounded voyage area, known as DNV-W1, requires an Automatic Navigation and Track-keeping System known as ANTS. The specification requires integration of the following:

- Electronic Chart Display and Information System (ECDIS)
- automatic steering system (including software for calculation/execution of adjustments for the maintenance of pre-planned routes)

- differential GPS (2)
- gyrocompass (2)
- speed over ground (SOG) and speed through water (STW)
- course alteration warnings and acknowledgement
- automatic safety contour checking and alarming during voyage planning and execution
- capacity to create own electronic charts from paper charts for areas not covered by ENCs issued or certified by official sea chart authorities.

In addition to the above functional requirements, ANTS also places great emphasis on suitable technical documentation.

The requirements for ANTS place additional demands on certain aspects of the system. For example, the accuracy of the ship's heading should be a value that has been corrected for any errors typical of the source of the heading input, and at least one of the gyrocompasses should be provided with an automatic system for the correction of errors caused by speed and latitude. The steering system should also keep automatic track-keeping of the ship within the limits set on both sides of the pre-planned track and should provide the capability to steer the ship along a route consisting of straight and curved lines by both automatic and manual input of turn orders. The speed input should have sufficient accuracy to safeguard the quality of position fixing by dead reckoning. The system should be provided with a filtered position from the GPS receiver and when performing turns, the system should be provided with the most accurate real-time position. The quality of the integrated position fixing system should be monitored and a warning should appear if the quality is below an acceptable limit.

The need for integration has meant that there has been a tendency to move away from sourcing equipment from a variety of manufacturers and attempts to integrate disparate pieces of equipment, to single-sourcing a package of equipment from just one manufacturer. Many manufacturers, aware of the requirement, now offer complete systems with all the necessary interfacing requirements guaranteed. The use of standard modules and interfaces, not only for navigation but also for other bridge functions, such as communications, engine monitoring and control, power supply etc., is likely to produce cost savings and reduce the amount of equipment required. Factors such as the reduced number of consoles, reduced installation and interfacing costs, more cost-effective design, installation and testing requirements have to be taken into account.

6.3 Standards

Those organizations involved in the production of world standards are the International Standards Organization (ISO), the International Electrotechnical Commission (IEC), and the International Telecommunications Union (ITU). The first two organizations work closely together and, as they both have their headquarters in Geneva, some facilities have been amalgamated.

The International Maritime Organization (IMO) is responsible for defining the requirements for marine equipment but it does not provide sufficient specification detail for manufacturers to design specified equipment or for national maritime authorities to provide test and approval facilities for the equipment. Thus, the IEC and ISO standards are designed to allow the necessary specification requirements for design, testing and approval.

The IEC has several Technical Committees working in specialized technical areas. The IEC Technical Committee 80 (IEC TC80) covers the area of 'Marine Navigation and Radio communication Equipment and Systems' and was formed in 1980. IEC TC80 responsibility is to concern itself with the development of international technical standards for the navigation and radio communication equipment designated by the IMO for mandatory carriage on vessels covered by the SOLAS (Safety of Life at Sea) Conventions.

IEC TC80 currently has 10 working groups:

- WG1 radar and ARPA
- WG1A Track control
- WG4 Terrestrial position-fixing aids
- WG4A Global Navigation Satellite Systems (GNSS)
- WG5 General requirements
- WG6 Digital interfaces
- WG8 Global Maritime Distress and Safety System (GMDSS)
- WG8A Automatic shipborne Identification Systems (AIS)
- WG10 Integrated navigation systems
- WG11 Voyage data recorders.

Until fairly recently there were two other TC80 working groups: WG7 Electronic chart display and information system (ECDIS) and WG9 Integrated bridge systems for ships. The latter group was responsible for the publication in April 1999 of IEC 61209 'Maritime navigation and radio communication equipment and systems – Integrated bridge systems (IBS) – operational and performance requirements, methods of testing and required test results'. This document covers features such as: data exchange, displayed information, system configuration, human factors, alarms, training facilities, power supplies and failure analysis. This latter point is doubly important as it has implications in other areas such as training facilities.

6.4 Nautical safety

All aspects of bridge operation have evolved because of the requirement for the safety of the ship, crew and, where applicable, the passengers. The safety philosophy is encapsulated within the rules of Det Norske Veritas (DNV) and the following is reproduced from the DNV rules, part 6, chapter 8 with their kind permission.

6.4.1 Safety philosophy

To achieve optimum safety and efficiency in bridge operation the rules address the total bridge system, which is considered to consist of four essential parts.

- The technical system which deduces and presents information as well as enabling the proper setting of course and speed.
- The human operator who is to evaluate available information, decide on the actions to be taken and execute the decisions.
- The man/machine interface which safeguards that the technical system is designed with due regard to human abilities.
- The procedures which shall ensure that the total bridge system performs satisfactorily under different operating conditions.

6.4.2 Scope of rule requirements

These are set out in each section of the Rules for Nautical Safety and reflect the different factors that affect the performance of the total bridge system and are intended to regulate the following areas.

- Design of workplace, based on the analysis of functions to be performed under various operating conditions and the technical aids to be installed.
- Bridge working environment, based on factors affecting the performance of human operators.
- Range of instrumentation, based on information needs and efficient performance of navigational tasks.
- Equipment reliability applicable to all types of bridge equipment, based on common requirements to ensure their suitability under various environmental conditions.
- Specific requirements to different types of bridge equipment, based on the facilities required for the performance of their specific functions.
- Man/machine interface, based on the analysis of human limitations and compliance with ergonomic principles.
- Qualifications, based on the competence required for mastering rational navigational methods and relevant technical systems installed on board the ship.
- Operating procedures, based on the work organization needed to make the bridge system function under different operational situations.
- Information on the ship's manoeuvring characteristics, based on the manoeuvres commonly used in various operational situations.
- Tests and trials for new ships, based on the need to ensure that technical systems perform in accordance with their specifications before being relied upon and used in practical operation.
- Reporting system, from ships in service, on bridge instrument failures, based on the information needed to detect their factual reliability level.
- Survey schemes for ships in service, based on the follow-up and testing required to safeguard that bridge systems maintain their reliability.

6.5 Class notations

The Rules for Nautical Safety are divided into three class notations. Two class notations represent the minimum requirements within bridge design, instrumentation and procedures whereby NAUT-C covers bridge design and W1-OC, in addition, includes instrumentation and bridge procedures. The third class notation, W1, extends the basic requirements for bridge design and instrumentation and additionally requires information on the manoeuvring characteristics of the ship and an operational safety manual for safe watchkeeping and command of the ship.

NAUT-C covers bridge design, comprising the following main areas:

- mandatory and additional workstations
- field of vision from workstations
- location of instruments and equipment.

W1-OC covers bridge design, instrumentation and bridge procedures comprising the following main areas:

- NAUT-C
- range of instrumentation
- instrument and system performance, functionality and reliability
- equipment installation
- monitoring and alarm transfer system
- procedures for single-man watchkeeping.

W1 covers W1-OC and extensions within the following areas of W1-OC:

- design of one-man workstation
- field of vision astern
- range of instrumentation
- instrument performance
- automation level
- qualifications.

Also covered is information on the manoeuvring characteristics of the ship comprising the following main items:

- speed at different settings
- steering ability
- turning ability
- stopping ability.

There is also a requirement for an operational safety manual comprising the following main items:

- bridge organization and responsibilities
- watchkeeping procedures
- system fall-back procedures
- accident and emergency procedures.

6.6 Bridge working environment

Ships requesting class notation NAUT-C, W1-OC or W1 should comply with rules for bridge working environment which specifies vibration levels, noise, lighting, temperature, ventilation, surfaces, colours and the safety of personnel.

6.6.1 Equipment carriage requirements

Ships requesting class notation W1-OC are equipped with the following systems:

- course information systems (two gyrocompasses or one gyro + one TMC)
- steering systems (manual and automatic steering)
- speed measuring system (water speed, > 40 000 tons gross, dual axis)
- depth measuring system (over 250 m length, two transducers)
- radar systems (two radars, at least one X-band)
- traffic surveillance systems (ARPA)
- position fixing systems (Loran-C, GPS)
- watch monitoring and alarm transfer system
- internal communication systems
- nautical safety radio communication systems
- sound reception system (technical device to receive signals).

Additional equipment required for class notation W1 includes:

- steering system with rate of turn indicator
- course information system, which should have two independent gyrocompasses
- speed measuring system, through the water, which should provide information for traffic surveillance system
- Electronic Chart Display and Information System (ECDIS)
- Automatic Navigation and Track-keeping System (ANTS)
- conning information display
- central alarm panel
- wind measuring system.

6.6.2 General bridge equipment requirements

The rules specify the following:

- environmental conditions
- location and installation of equipment
- electrical power supply, alarms, performance confirmation and failure protection
- computer-based systems and software quality.

6.6.3 Specific requirements for different types of bridge equipment

Ships requesting class notation W1-OC shall comply with specific requirements for the following systems:

- course information system (speed and latitude correction)
- steering systems (manual override control and rate of turn display)
- speed measuring system (if bottom track then up to 200 m depth)
- depth measuring system
- radar systems (two floating EBLs, interswitch, ship track monitoring)
- traffic surveillance systems (ARPA with two guard zones)
- position fixing systems (performance standards)
- watch monitoring and alarm transfer system
- internal communication systems
- nautical communication systems
- sound reception system.

Class notation W1 requires in addition the following systems:

- Electronic Chart Display and Information System (ECDIS)
- Automatic Navigation and Track-keeping System (ANTS)
- conning information display
- central alarm panel.

6.6.4 Man/machine interface

Ships requesting class notation W1-OC or W1 must comply with the rules in this section. All instruments must be logically grouped according to their functions within each workstation. Their location and design should give consideration to the physical capabilities of the human operator and comply with accepted ergonomic principles. The amount of information to be presented for conducting the various tasks, as well as the methods of displaying the information needed, should give consideration to the capabilities of the human operator to understand and process the information made available. The rules specify the following:

- instrument location and design
- illumination and individual lighting of instruments
- requirements for the man/machine dialogue of computer-based systems.

6.7 Ship manoeuvring information

Ships requesting class notation W1 must comply with rules for manoeuvring information.
Information about the ship's manoeuvring characteristics, enabling the navigator to safely carry out manoeuvring functions, shall be available on the bridge. This section deals with: the manoeuvring information to be provided, and the presentation of the manoeuvring information.

The provision of manoeuvring information should include:

- speed ability
- stopping ability
- turning ability
- course change ability
- low-speed steering abilities
- course stability
- auxiliary manoeuvring device trial
- man-overboard rescue manoeuvre.

The presentation of manoeuvring information should include:

- pilot card
- wheelhouse poster
- manoeuvring booklet.

6.8 Qualifications and operational procedures

Class notation W1-OC specifies responsibilities of shipowner and ship operators, qualifications and bridge procedures. Class notation W1 has extensions to responsibilities, qualifications, bridge procedures, and a special requirement for operational safety standards.

6.8.1 Operational safety manual

This is a requirement for class notation W1 to obey the following guidelines.

1 Organization:
  - general
  - bridge organization

- responsibilities of shipowners and ship operators
- responsibilities of the master
- responsibilities of the officer in charge of single-man watchkeeping
- qualifications of bridge personnel
- manning
- safety systems – maintenance and training.

2 Daily routines:
- general
- look-out
- changing of the watch
- periodic checks of navigational equipment
- log-books
- communications and reporting.

3 Operation and maintenance of navigational equipment:
- general
- radars/ARPA
- automatic pilot
- gyro and magnetic compasses
- echo sounder
- speed/distance recorder
- electronic position fixing aid
- electronic navigational chart
- automatic navigation and track-keeping system
- hydrographic publications
- emergency navigation light and signal equipment.

4 Departure/arrival procedures:
- general
- preparation for sea
- preparation for arrival in port
- embarkation/disembarkation of pilot
- master/pilot information exchange.

5 Navigational procedures:
- general
- helmsman/automatic pilot
- navigation with pilot embarked
- navigation in narrow waters
- navigation in coastal waters
- navigation in ocean areas
- navigation in restricted visibility
- navigation in adverse weather
- navigation in ice
- anchoring.

6 System fall-back procedures:
- general
- bridge control/telegraph failure
- gyrocompass failure
- steering failure
- auxiliary engine failure
- main engine failure.

6.8.2 Contingency and emergency manual

1 Contingency and emergency organization:
- general
- duties and responsibilities.

2 Accident procedures:
- general
- collision
- grounding
- fire/explosion
- shift of cargo
- loss of buoyancy/stability.

3 Security procedures:
- general
- sabotage threat/sabotage
- hijacking threat/hijacking
- piracy
- local war situation
- criminal act committed on board
- detention/arrest.

4 Emergency procedures:
- general
- emergency notification
- abandon ship preparations
- lifeboat evacuation
- helicopter evacuation
- use of other evacuation equipment.

5 Miscellaneous:
- general
- dead or injured person aboard
- man overboard
- search and rescue actions
- stowaways
- political refugees
- missing or lost person
- documentation and reporting
- press releases.

6.9 Bridge equipment tests

Ships requesting class notation W1-OC or W1 must comply with rules for equipment tests. After installation of equipment, on-board testing shall be performed in order to ascertain that the equipment, as installed, operates satisfactorily.

It should be noted that reliable figures for all aspects of equipment performance/accuracy cannot be established by the on-board testing required for classification. Hence, to ensure that equipment performance is in accordance with specifications, shipowners are advised to choose equipment that is type approved.

A detailed test programme for the on-board testing of equipment should be submitted for approval at the earliest possible stage before sea trials. The following systems are tested according to general requirements for testing of equipment:

- gyrocompass
- automatic steering system
- rudder indicator(s)
- rate-of-turn indicator
- speed log
- echo sounder
- radar system
- ARPA system
- electronic position fixing systems
- watch monitoring and alarm transfer system
- internal communication systems
- nautical communication system
- sound reception system
- computer system(s)
- Electronic Chart Display and Information System (ECDIS)
- Automatic Navigation and Track-keeping System (ANTS)
- conning display.

6.10 Examples of integrated bridge systems

A variety of manufacturers offer a range of integrated bridge systems that can be tailored to fit the requirements of the user. Some of these systems will be described in this section. The systems selected come from leading manufacturers in this field.

6.10.1 Voyager by Furuno Electric Co. Ltd

An automatic navigation system designed by Furuno to meet the requirements for one-man bridge operation and the new ECDIS standards is the Voyager Integrated Bridge System. The system was designed to meet the class notation W1-OC of DNV, Norway. The system is modular which allows it to be set up to meet the requirements of the user and to provide capability for future expansion of the system as necessary. The complete system requirement comes from a single supplier with the claimed benefits of:

- increased safety
- increased cost-effectiveness
- increased navigation efficiency.

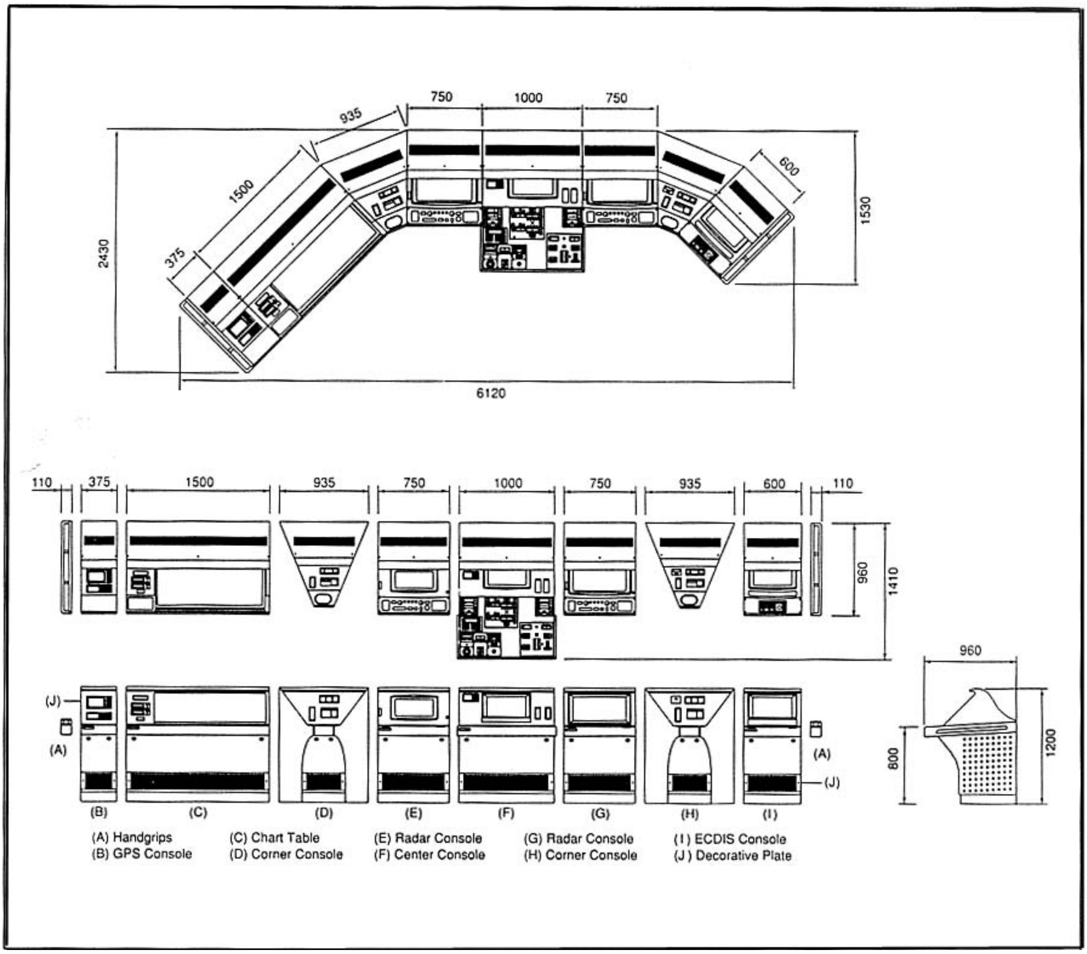


Figure 6.2 Components of the Voyager integrated bridge system. (Reproduced courtesy of Furuno Electric Co. Ltd.)

The modular nature of the system components can be seen from Figure 6.2 which shows a possible bridge layout using the Voyager system. Figure 6.3 shows one module, that of the ARPA/Radar which is module E/G in Figure 6.2.

Main functions of Voyager

There are three main functions of the system:

- electronic chart display and user interface
- position calculation and track steering
- automatic steering of the vessel.

Each of the main functions is performed using an individual processor as indicated in Figure 6.4. This guarantees real time data processing for critical applications such as positioning and steering.

Figure 6.3 Voyager ARPA console. (Reproduced courtesy of Furuno Electric Co. Ltd.)

The system has built-in dual displays to satisfy the requirement for separate ECDIS and conning monitors. The ECDIS monitor provides the main display and user interface for the navigation system, while the conning monitors display the most important navigational sensor data in a graphical form, i.e. gyrocompass, speed log etc.

The navigation system is operated through a control panel that has dedicated function and execute keys for fast, easy operation. The steering functions are performed on their own operation control panel that integrates all functions for automatic steering. A block diagram that shows these control panels and also indicates all inputs to the navigation and track-keeping processor is shown in Figure 6.5. Figure 6.5 also indicates the type of interface connection that exists between a particular sensor and the processor.

Electronic chart display and user interface

For this system the electronic chart functions are designed to meet the performance standards for the ECDIS as laid down by the IMO and the IHO. More details on these requirements can be found in

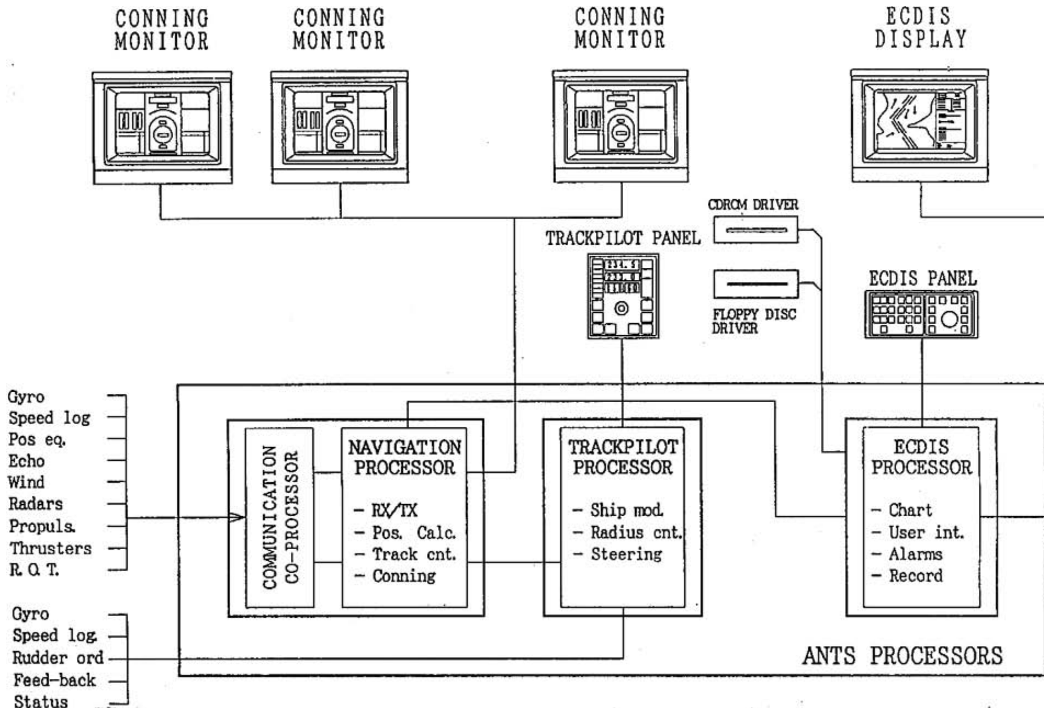


Figure 6.4 Block diagram of the Voyager integrated bridge system. (Reproduced courtesy of Furuno Electric Co. Ltd.)

Chapter 7. ECDIS functions are performed on their own computer unit, housed in the same electronic cabinet, so as to optimize graphical performance and cost, especially when a second chart display is necessary.

The main features of the ECDIS are:

- presentation of an electronic version of a sea chart, based on the latest ENC format using a 21- (or 29-) inch high resolution colour display
- multiple navaid interface for GPS/DGPS, gyrocompass, speed log, echo-sounder etc.
- capable of use with both ENC and ARCS
- route planning and route monitoring
- primary and secondary route planning facilities
- grounding warnings
- user generated navigational safety lines which are overlaid on the radar screen
- user selectable chart layer presentation
- navigational tools such as VRM, EBL, track-ball
- display of ARPA targets
- voyage recording to meet standards
- user generated information note-books
- display of alarms
- MOB and event functions
- dedicated function keys for scale up/down, standard display, TM-reset and other functions which are the most often used functions.

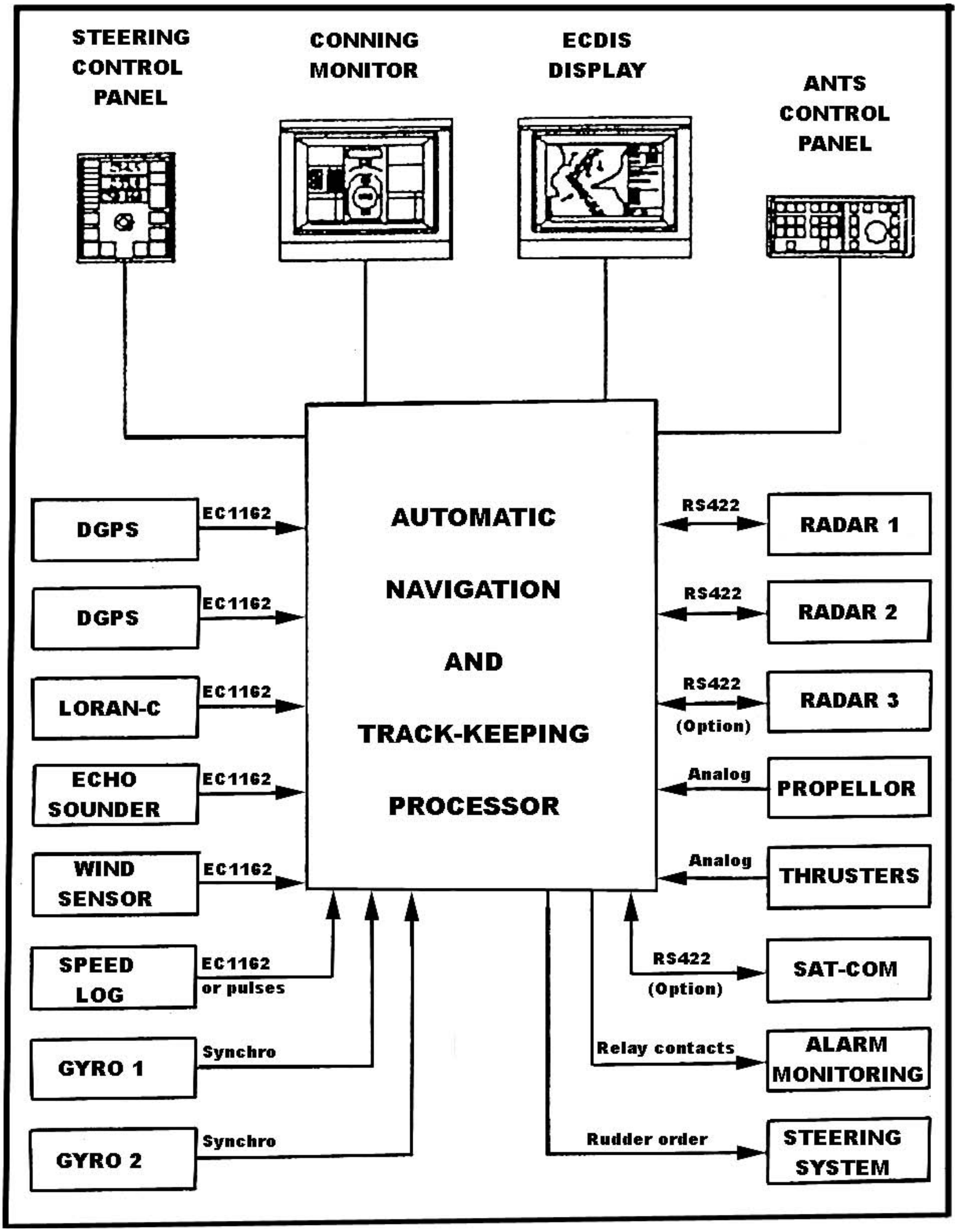


Figure 6.5 Block diagram of Voyager automatic navigation and track-keeping system (ANTS). (Reproduced courtesy of Furuno Electric Co. Ltd.)

The option of fitting a second ECDIS computer and display, to meet the required back-up arrangements in case of an ECDIS failure, is available. If fitted, the second ECDIS computer is linked to the first through a local area network (LAN).

Position calculation and track steering

The ship's position is calculated from the position sensors using the information from the gyrocompass and speed log. The position calculation is based on Kalman filter technology, which is capable of using different types of sensors and in operator-defined configurations.

Because of the need to allow for time-critical operations in position calculation and track steering, a separate processor is used for these functions. The main features of this processor are:

- interface to all external devices
- position calculation based on Kalman filter technology
- position quality calculation and alarm
- off-track calculation and alarm
- waypoint pre-warning and waypoint alarm
- graphical process and display for conning information.

Automatic steering function

The system includes a complete radius/track controlled autopilot for safe and automatic steering of the vessel with the functions and operations meeting the DNV-W1 requirements. The autopilot is fully integrated into the system allowing it to be easily controlled and operated.
The main features of the automatic steering system are:

- speed adaptive operation
- radius controlled turns
- direct gyro and log inputs for accurate and reliable performance
- user selectable steering modes
- gyro mode (rudder limit controlled)
- radius mode (immediate course change)
- programmed radius mode (programmed course change)
- programmed track mode (position referenced course change)
- precision track steering with pre-memorized waypoints
- relaxed track steering with pre-memorized waypoints.

The autopilot system has its own operation control panel for logical, simple to use operation while two separate operation control panels can be installed for special applications.

Interface specifications

The Voyager has a wide and flexible interface structure that allows for the system to be easily set up and configured for use. Both analogue and serial digital interfaces are available. The available interfaces to other systems are:

- gyrocompass: one analogue and one serial (NMEA) or two serial (NMEA)
- rate-of-turn gyro: analogue or serial (NMEA)
- speed log: pulse type or serial (NMEA)

● position receivers:	up to five serial inputs (NMEA)
● echo sounder:	serial input (NMEA)
● wind sensor:	serial input (NMEA)
● rudder angle:	analogue or serial (NMEA)
● propeller RPM/pitch:	analogue or serial (NMEA)
● thrusters:	up to four analogue inputs.

The autopilot interface requirements are:

● gyrocompass:	two 1:1 synchros or high update rate serial inputs (NMEA)
● speed log:	200 p/nautical miles pulses or serial input (NMEA)
● rudder order:	analogue output (0.25 V/degree) or solid-state solenoid outputs
● steering status:	galvanically isolated contacts.

If a direct solenoid type of steering order is required then an optional feedback unit and solenoid drive distribution box is required.

Electrical specifications

The following supplies are required with battery back-up in case of supply failure:

navigation system	24 V d.c. supply (250 W approx.)
alarm supply	24 V d.c. supply (10 W approx.)
display monitors	230 V a.c. or 110 V a.c.

6.10.2 NINAS 9000 by Kelvin Hughes

Kelvin Hughes, the Naval and Marine division of Smiths Industries Aerospace, offer a fully integrated navigation system. Units from the Kelvin Hughes Nucleus Integrated Navigation System (NINAS) are used together with ancillary navigational equipment from specialist manufacturers.

The advantages claimed for the NINAS 9000 system include the following.

- Any number of auxiliary consoles can be added to the basic radar and navigation displays
- The use of modules gives flexibility in the final arrangement adopted by the ship owner and ship operator
- The centre consoles can be adapted to accept equipment from a number of Kelvin Hughes preferred third party suppliers
- The system is based around the proven nucleus2 6000 radar systems which are available with a variety of antennas and transmitters.

A possible bridge layout for a large passenger-carrying vessel is shown in Figure 6.6.

The wheelhouse layout consists of a centre-line steering console, two mid-position (manoeuvring and pilot) and two enclosed bridge wing consoles. The manoeuvring and pilot stations consist of a dedicated radar and a dedicated ECDIS/conning display, both being type approved CRT equipment. The centre-line station has two multifunctional LCD displays, which connect to any of three radar processors, for use as a remote operating station for either of the two ECDIS displays or as a remote operating station for any other function as required. The two stations at each wing bridge perform a similar function to that of the centre-line station.

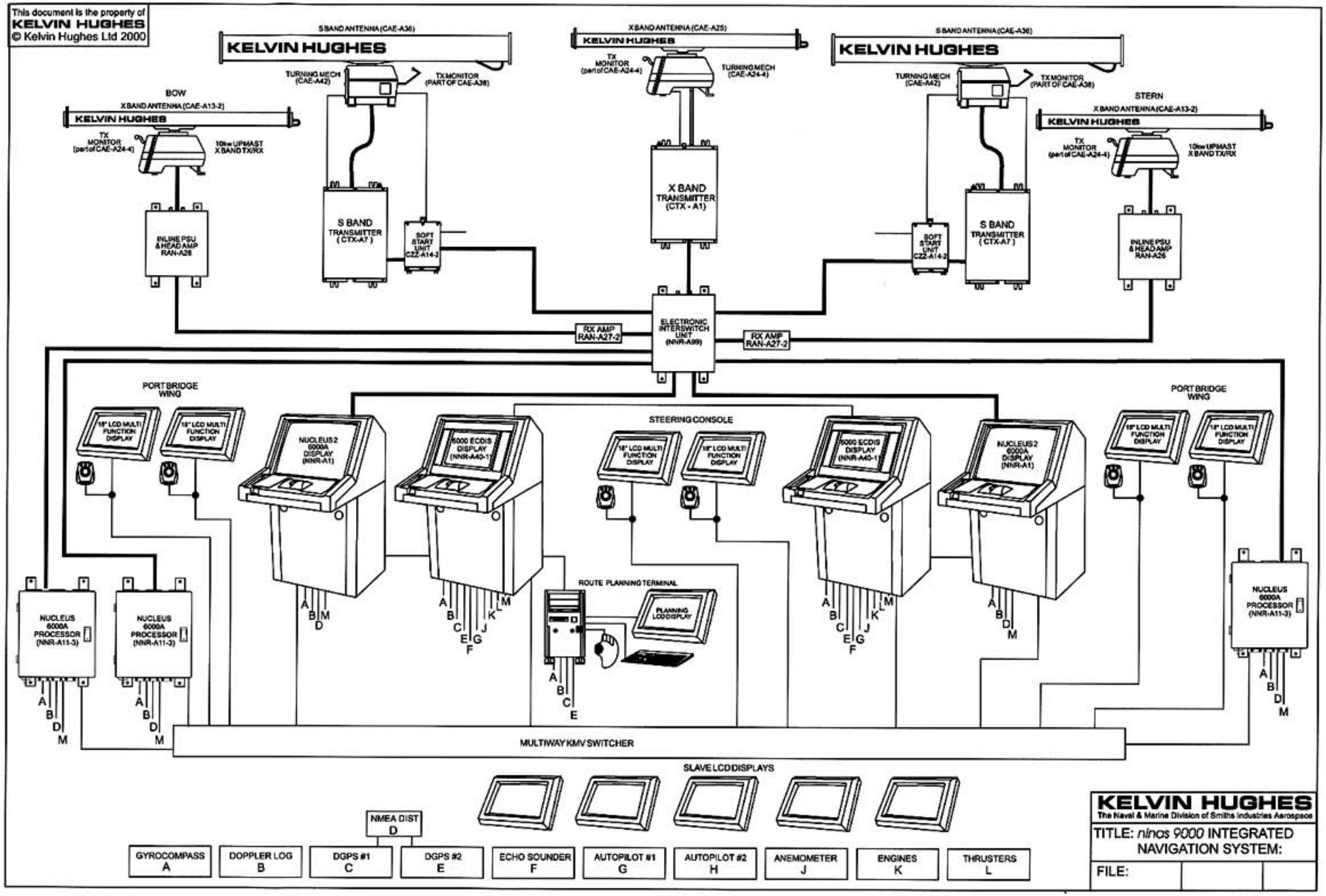


Figure 6.6 NINAS 9000 integrated bridge system. (Reproduced courtesy of Kelvin Hughes.)

Display systems

1 Radar displays

The two radar displays are 26-inch PPI, rasterscan ARPA radar displays with 10 range scales 0.25–96 nautical miles presented in relative motion, true motion and centred display true motion. There is auto tracking capability for up to 50 targets with a choice of manual or auto acquisition of targets using guard zones or footprint acquisition. The display has as standard parallel index lines, a flexible mapping system with a map storage capacity of 64K byte showing, for example, 100 maps of 80 elements.

The display has an interfacing capability of two RS232 bi-directional serial links and four NMEA opto-isolated inputs. The input capabilities are:

- GPS/Loran; waypoints; route; chart 'puck' position
- steering sequence; man overboard position; turning radius data
- serial link data from navigation display.

Output capabilities are tracker ball position and target data to ECDIS. A tracker ball and three buttons control all the radar display functions with external tracker-ball capability from each bridge wing.

2 ECDIS displays

The two ECDIS displays are IEC 1174 type approved 20-inch displays with the following functions.

- Operates with Windows-NT operating software with multi-window display showing S57 ed.3 ENC vector charts and/or ARCS/NOAA (BSB) raster charts. These may be viewed simultaneously or independently in variably sized windows.
- Graphic overlay of ownship symbol, route, waypoints, target vectors and trails on chart.
- Radar interlay of radar target echoes on chart. The interlay technique places the radar information video plane below that of the overlay to avoid obstruction of essential information.
- The ECDIS display can also act as a slave radar display by having its own radar video processing functions that allow independent control of the radar image on the ECDIS.
- North-up, course-up and head-up ENC chart presentation.
- Route safety zone function which provides a three-dimensional guard zone around own ship to monitor ship draft against chart depths and ships air draft against chart clearances to improve safety when on passage or route planning.
- Automatic plotting of time on chart with plot-on-demand function for special events.
- Passage calculator that allows route planning from the ECDIS screen. This allows calculation of distances, ETA, required speed for specific ETA and other navigational computations. This may be carried out locally or at a networked optional route planning workstation.
- Planning may be carried out visually with waypoints being dragged to modify legs and to allow the route to pass around obstacles.
- Uses ENC chart embedded database for interrogation feature, which allows the operator to request pop-up window information for any buoy, light etc. Also menu selection allows ECDIS or traditional chart symbols to be viewed for buoys and lights. There are six ENC colour palettes for optimal viewing in all light conditions.
- Continuous display of own ship heading, speed, position and depth on right side of the screen.
- Automatic Navigation and Tracking System (ANTS) interface to autopilot, allowing automated route sailing and constant radius turns.
- ECDIS display may be controlled either from the local tracker ball and three-button screen control unit (SCU) or from the remote display.

Additional functions within the ECDIS systems include a conning display, featuring the display of real-time vessel's position upon the chart in use, while displaying navigational and dynamic data in side panels. Data displayed includes:

- position
- heading
- speed (dual axis)
- depth
- wind (true and relative)
- route data
- engine RPM
- engines and thrusters.

3 Centre line console multi-function displays
Two 20-inch LCD displays that are capable of operating in the following modes.

- Fully independent radar displays capable of controlling any one of the five main radar transmitters.
- Remote radar displays capable of controlling any one of four main radar transmitters via another display (in the event of failure of the unit's own processor).
- Remote ECDIS/Conning display.

Additional functions that could also be allowed include:

- CCTV
- control and command monitoring
- alarm monitoring.

4 Bridge wing multi-function displays
Two 18-inch LCD displays that are capable of operating in the following modes.

- Fully independent radar displays capable of controlling any one of the five main radar transmitters.
- Remote radar displays capable of controlling any one of four main radar transmitters via another display (in the event of failure of the unit's own processor).
- Remote ECDIS/conning display.

Additional functions that could also be allowed include:

- CCTV
- control and command monitoring
- alarm monitoring.

5 Route planning terminal
A 17-inch LCD display with a dedicated processor designed in the same manner as an IEC 1174 type approved ECDIS display. The route planning terminal is installed as a slave unit to allow off-line route planning at the chart table position. The unit includes dedicated interfaces to log, gyro and GPS to allow it to act as a back-up ECDIS in the event of failure of the main units. Features are as for the type approved ECDIS, with the exception of radar interlay and target data.

Other components of the total system include the following.

- *Radar transmission system*. This comprises a five-way interswitched X and S band system allowing independent control of individual systems and complete interswitching of all radars.
- *Autopilot and steering system*. A system with full ANTS functionality when connected to the ECDIS. The system has inputs for both gyrocompass and magnetic compass heading data. During the normal operating mode the headings from both gyrocompass and magnetic compass are produced in the independent course monitor. In the event of a gyrocompass failure all major receivers of the gyrocompass heading, such as radar, Satcomm, GPS and digital repeaters, can be switched over immediately to the heading from the magnetic compass from the course monitor.
- *Gyrocompass system*. This is a microprocessor-controlled digital system designed as a single unit with control and display unit in the front cover. The control and display unit can be removed from the housing and installed at a position (e.g. a bridge console) remote from the gyrocompass. The gyrocompass has an integrated TMC function, gives a rate-of-turn (ROT) output, has seven independent RS 422 and NMEA 0183 serial outputs and complies with DNV-W1.
- *Magnetic compass*. The system includes aluminium alloy binnacle, magnetic flat glass compass, a fluxgate pick-off with an integrated sine/cosine interface, bypass arrangements, azimuth devices, electronic compasses, and magnetic compass autopilots (TMC). Variation correction, gyro/TMC changeover etc. is incorporated in the gyrocompass monitor/changeover system. System uses gyro repeaters for indication when TMC is selected at the compass monitor.
- *Dual axis Doppler log*. The log is a two-axis system, the data obtained from the speed log is longitudinal and transversal bottom-track speed and depth, and longitudinal water-track speed. The log provides simultaneous W/T and B/T speeds of ±30 knots with 0.1 knot scale and depth. Bottom-track speed and depth are displayed from 3 to 300 m. Data from the log is transmitted to the log processing unit (LPU) which serves as a data concentrator/distributor in the system. The LPU is programmed according to the geometry of the ship and the position of the transducer. With this information the LPU computes transversal speeds of bow and stern. The system comprises two independent log systems each with a dedicated display at the chart table. Log selection for output to other repeaters, integrated bridge system etc. is via a selector switch at this position.
- *Echo sounder*. This unit can be operated as a single or dual frequency unit with up to four transducers. The display offers five basic ranges between 0 and 2000 m. The high resolution LCD display allows continuous observation of bottom recordings and shows all relevant navigation data. The display includes continuous indication of digital depth and range. Bottom alarm can be set at any required depth. The unit can store the last 24 h data together with the position so that a printout can be made if required.
- *DGPS*. The receiver automatically locates the strongest transmitting beacon station and lock on in seconds. In the case of signal loss it automatically switches over to an alternative station ensuring a strong signal at all times. A navtalk NMEA distribution unit is included which is fed with the output from both DGPS receivers and supplies 10 buffered outputs. In the event of failure of the primary DGPS the system automatically switches to the secondary.
- *Loran-C*. The system uses the Furuno LC-90 Mk-II receiver. Full details of this receiver can be found in Chapter 4.
- *Bridge alarm system*. This is a central alarm/dead man system which meets the highest current classification society bridge alarm specification. The system is capable of handling 40 opto-isolated switched inputs. Alarms are managed and displayed in order of priority. It is connected interactively to the integrated navigation system to allow the alarms to be repeated on the ECDIS.

6.10.3 Sperry Marine Voyage Management System – Vision Technology (VMS-VT)

The Sperry VMS-VT system, provided by Litton Marine Services, is a computer-based navigation, planning and monitoring system which typically consists of two or more computer workstations connected by a local area network (LAN). A typical arrangement for a VMS-VT system is shown in Figure 6.7.

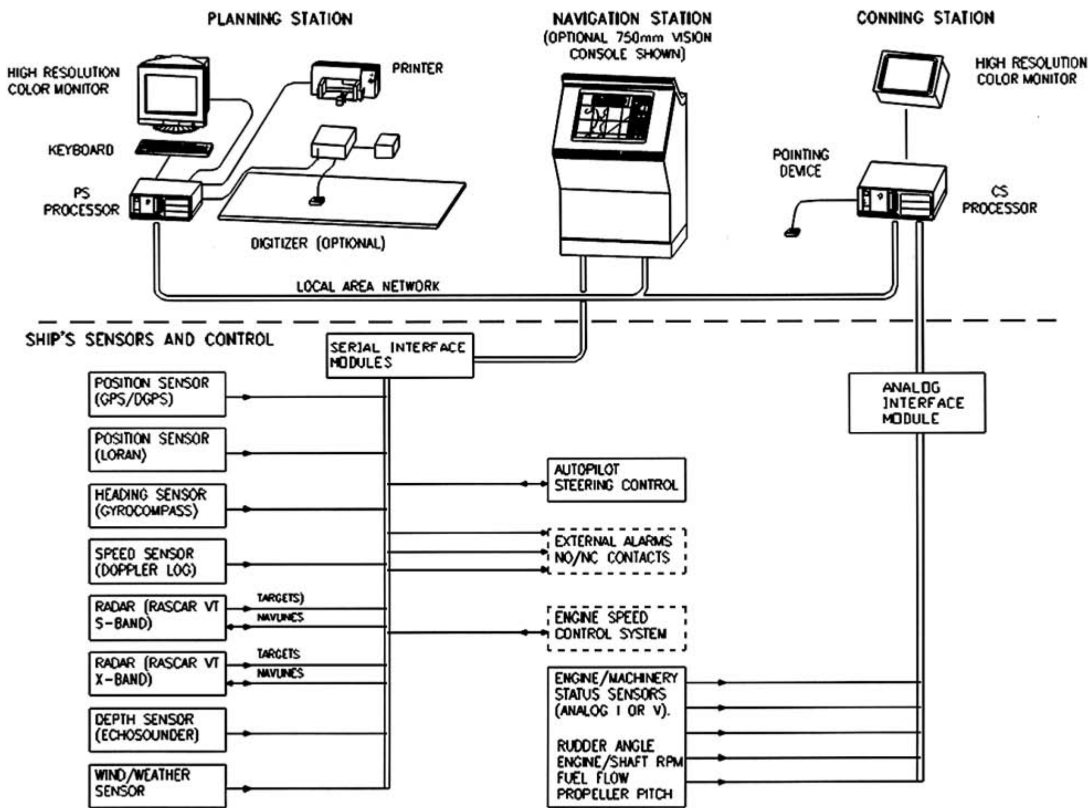


Figure 6.7 Typical arrangement for the Voyage Management System – Vision Technology (VMS-VT). (Reproduced courtesy of Litton Marine Systems.)

Figure 6.7 shows three workstations, providing a navigation station, a planning station and a workstation designated as a conning station. The navigation station is usually located in the conning position. All VMS-VT functions are available at this station except chart digitizing and chart additions.

The planning station is usually located in the chart room and has a high-resolution monitor and printer which can provide hard copies of voyage data. Separating the planning station from the navigation station allows an operator to effect voyage planning or chart editing at the planning station without interfering with conning operations at the navigation station. The display at the navigation station is also available at the planning station so that the ship's position can be monitored at either location. A typical VMS-VT main display is shown in Figure 6.8.

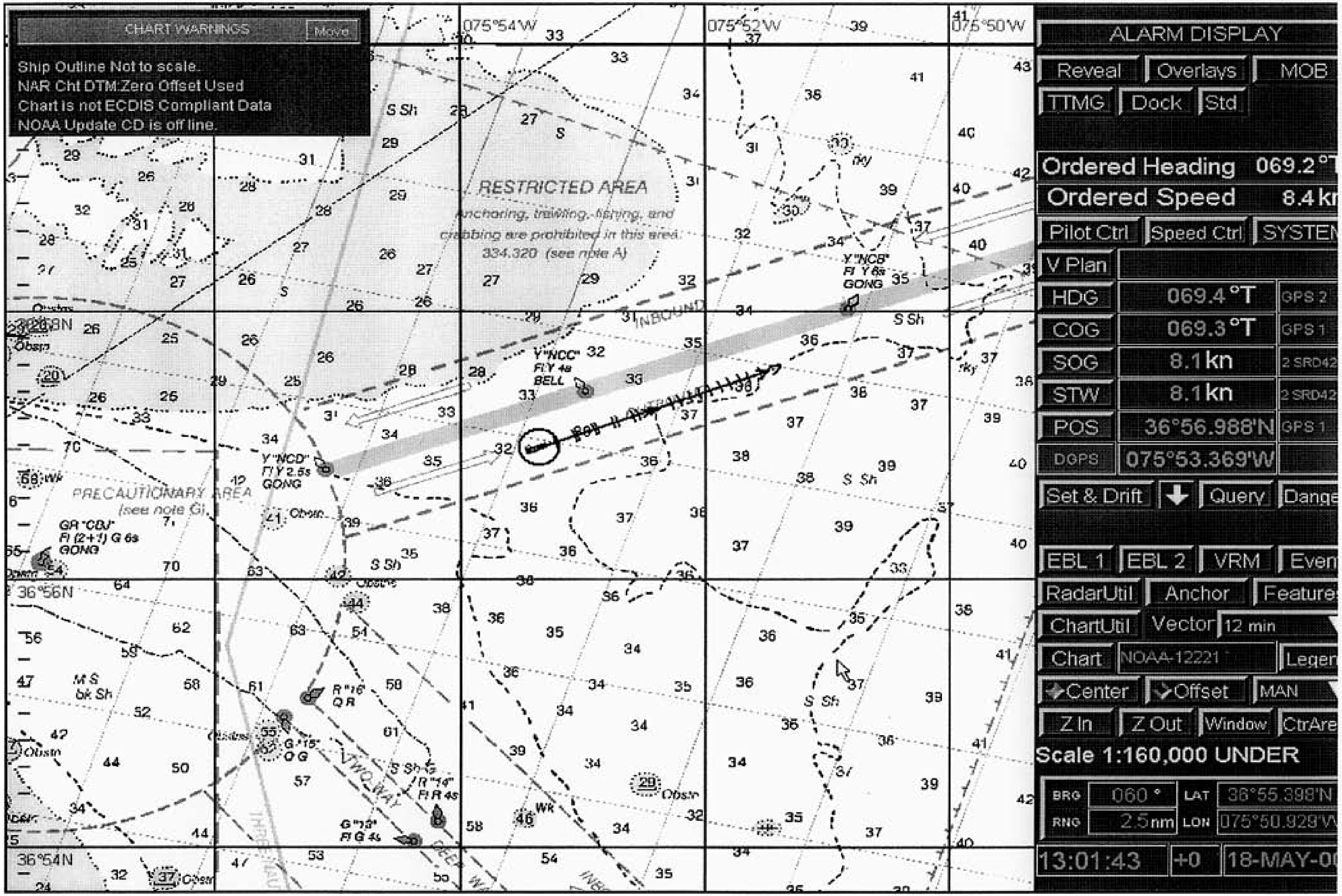
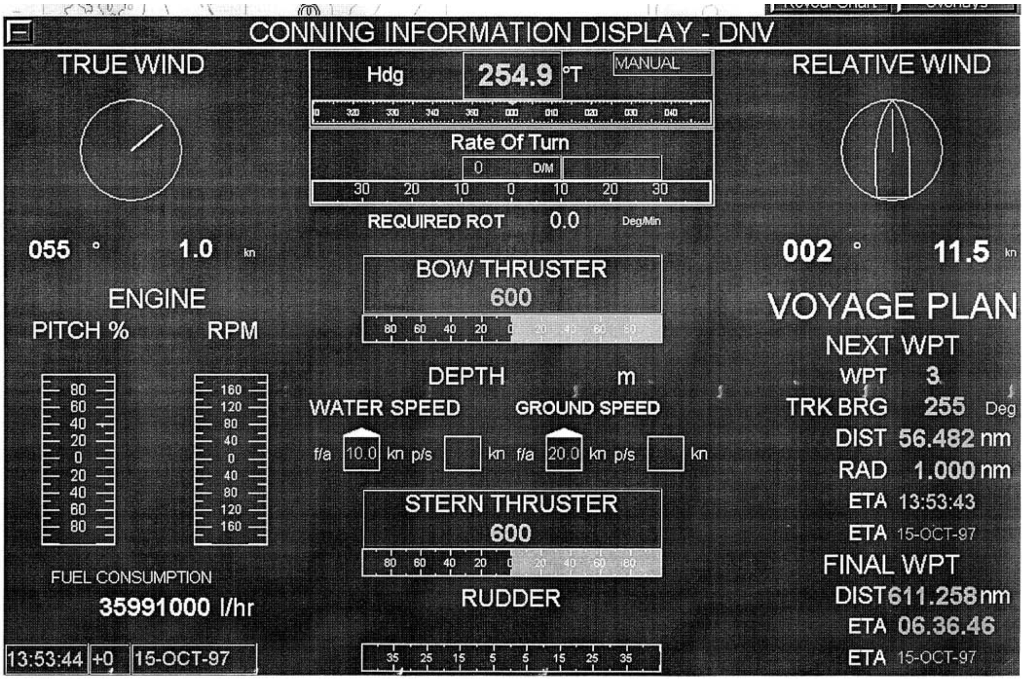


Figure 6.8 VMS-VT main display screen showing own ship's position, heading and speed using an electronic chart. (Reproduced courtesy of Litton Marine Systems.)



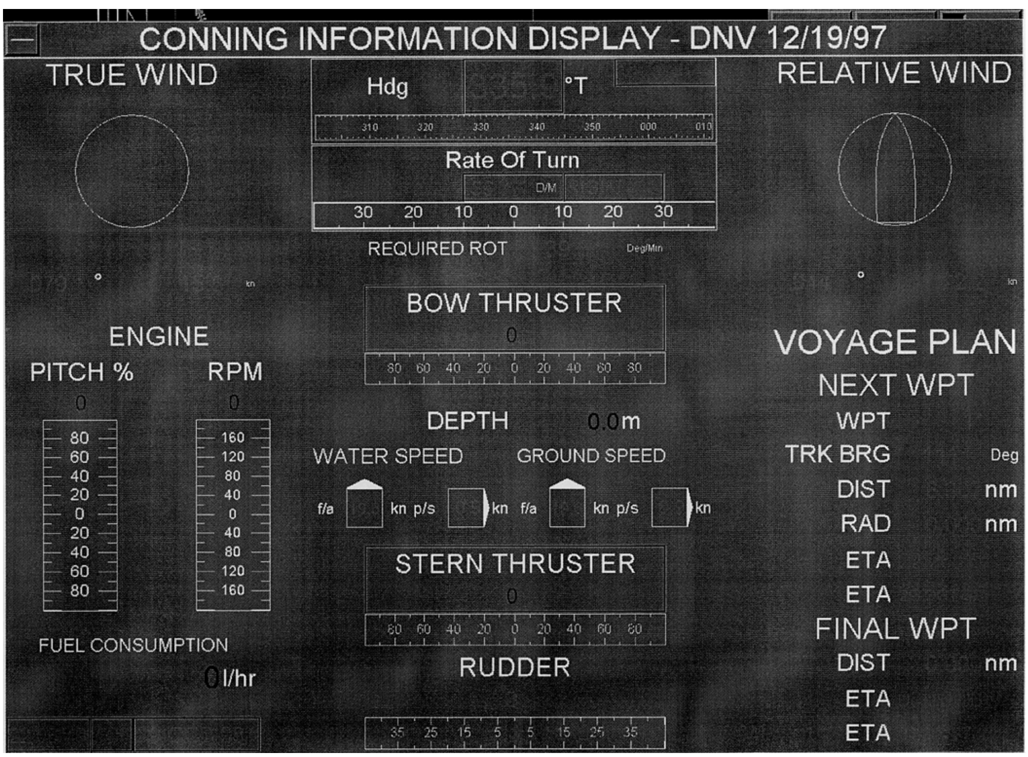


Figure 6.9 Examples of VMS-VT conning information display screens. (Reproduced courtesy of Litton Marine Systems.)

The conning station is usually configured to display a single page of specific navigation data as specified by regulatory group requirements. For this arrangement a pointing device is not provided since the display is non-interactive. At the conning station the screen is known as the conning information display (CID). Where possible the navigational and meteorological digital data is presented on the CID screen graphically to mimic analogue instruments in order to make it easier for an operator to assimilate and manage data quickly. The data presented is updated continuously and has a fixed layout pattern so that particular data is always available at the same location. A similar CID page is often available as a large display overlay screen at the VMS-VT navigation station and planning station (see Figure 6.9).

DNV on the screen displays of Figure 6.9 refers to the classification society Det Norske Veritas, Norway.

An engineering information display, as shown in Figure 6.10, can be provided as a display overlay screen at the VMS-VT navigation station and planning station or as a full-screen display at a dedicated monitor. The system can also be configured to display other pages such as a performance monitor window as shown in Figure 6.11.

As Figures 6.9–6.11 indicate, the main advantage of the VMS-VT system is its flexibility in presenting information that can be displayed in a manner that meets the customer's requirements.

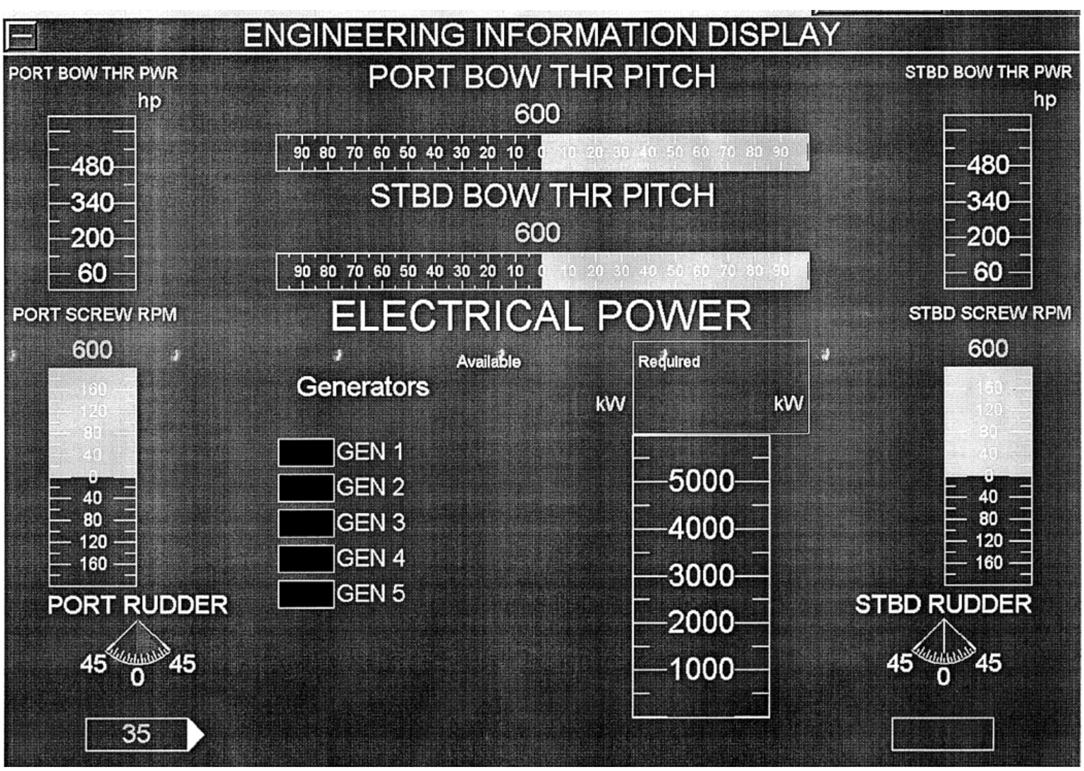


Figure 6.10 Example of VMS-VT engineering information display screen. (Reproduced Courtesy of Litton Marine Systems.)

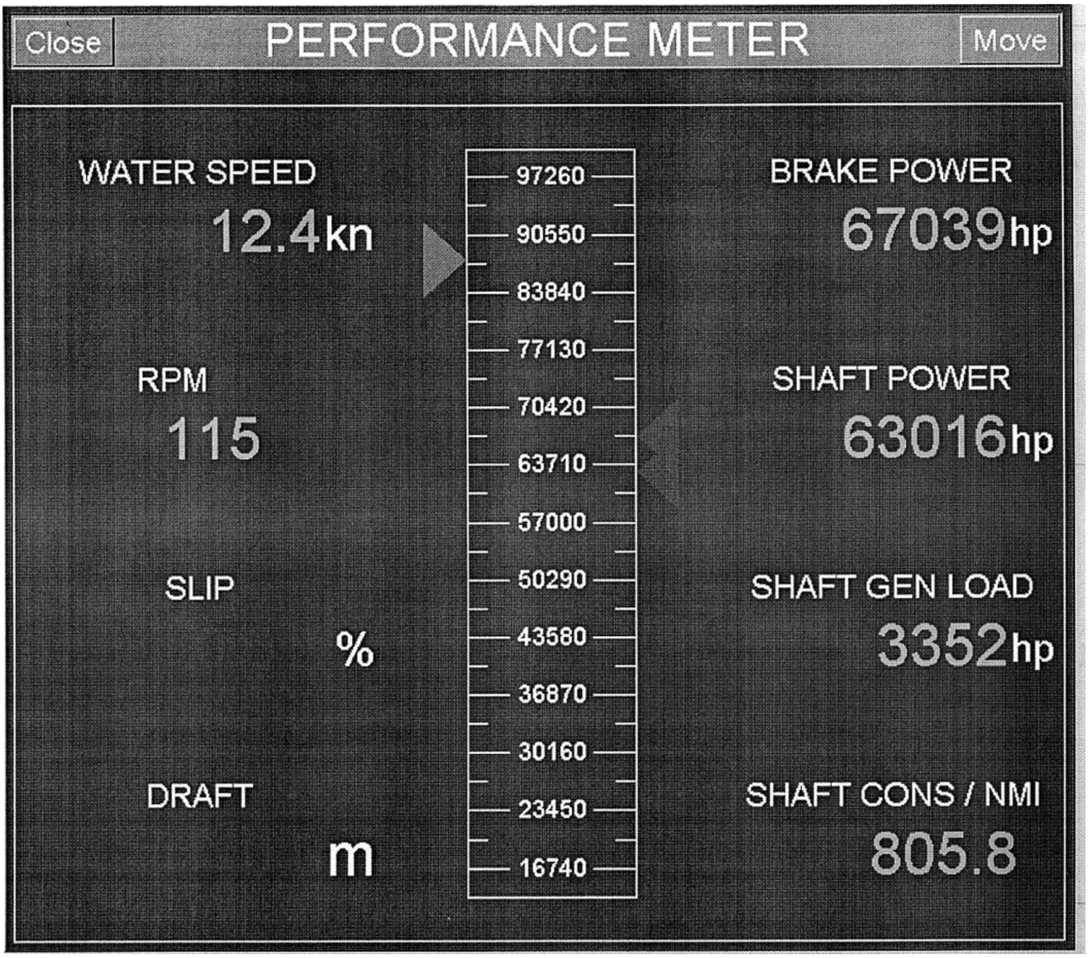


Figure 6.11 Example of VMS-VT performance monitor window. (Reproduced courtesy of Litton Marine Systems.)

Basic VMS-VT functions include:

- integration of data from various sensors
- data sharing on a local area network (LAN)
- display of real-time sensor information
- display of electronic charts with ownship position
- creation of a voyage plan
- execution of a voyage plan
- display of electronic bearing lines (EBLs)
- display of variable range markers (VRMs)
- comprehensive alarm and operator message system
- printing of ship's navigation data.

Optional VMS-VT functions include:

- autopilot control
- speed order control
- display of radar target information
- DNV certified track keeping
- ECDIS S-57 or digital navigational chart (DNC) display
- interface to voyage recorder
- creation and editing of charts using the digitizer or chart additions editor
- providing data to docking displays
- providing precision manoeuvring displays
- man overboard display
- providing data to a conning station
- display of engine room data
- display of meteorological data.

Computers required for essential and important functions are only to be used for purposes relevant to vessel operation and the VMS-VT is normally configured to prevent the operator from installing or running any other application.

A VMS-VT application that includes some of the optional functions mentioned above is shown in Figure 6.12.

Among the displays shown in Figure 6.12 is an ECDIS that uses digital chart data to produce a chart display (see Chapter 7 for more information on ECDIS). The VMS-VT system has the capability to catalogue and display many types of chart formats including commercially available scanned charts produced by official hydrographic offices and/or commercially produced vector charts. Chart formats differ but VMS-VT can be configured at the factory or on the ship to use the chart format specified

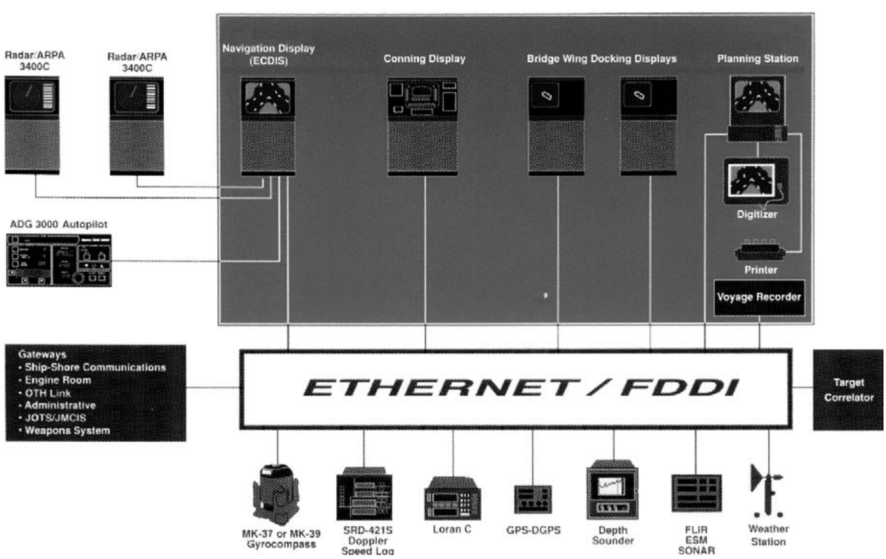


Figure 6.12 Block diagram of the VMS-VT system. (Reproduced courtesy of Litton Marine Systems.)

by the customer. Reference to Chapter 7 will show that an ECDIS must use an electronic navigational chart (ENC) which possesses a single universal data format and they must be 'official' charts in that they are issued on the authority of a government authorized hydrographic office.

Available chart formats include: S57 charts; NIMA (National Imagery and Mapping Agency) DNC charts; British Admiralty ARCS raster charts (BA charts); BSB format charts such as those issued by the National Oceanic and Atmospheric Administration (NOAA); and digitized charts. Electronic charts can be retrieved from CD-ROM disks or from the computer hard disk if the required chart has been stored there.

The VMS-VT Planning Station may include a digitizer pad so that staff can create electronic charts. The digitizer can also be used to edit these electronic charts when a published Notice to Mariners updates the corresponding paper chart. The charts are stored as individual files in the VMS-VT workstations. Those charts digitized at the planning station can be copied to floppy disks for back-up storage and for transfer between ships. A standard 1.44M byte floppy disk can hold about 20 detailed charts. The digitizer can also be used to create navlines with a latitude/longitude reference, which can be transferred and displayed on the RASCAR radars.

Sensor data integration and display

A major feature of the VMS-VT system is the ability to receive sensor data from the local area network and from direct hardware interfaces. The primary type of sensor data processed by the system is navigational information, which includes:

- heading
- speed over the ground
- speed through the water
- geographic position
- set and drift
- course over the ground.

The VMS-VT sorts the data by type and provides a separate source window for each type of data. To display the source window for a particular data type requires the operator to select the appropriate button on the main menu. Each source window lists a group of sensors appropriate to the data type. The present data from each sensor is included in the window so that the best source can be selected from the list. As an example the position source window, as shown in Figure 6.13, is displayed by selecting the POS button on the main menu.

The position source window provides a list of all the configured position sensors along with the present data from each sensor. The operator may select the desired source of position data from this list or may open source windows for other types of navigational data in a similar manner.

Radar target data

The VMS-VT system allows access and display of target information from multiple ARPA radars. The Litton Marine Systems RASCAR radar contains a target data logging switch for the target data logging option. If required, all the connecting RASCAR radars can send their target data allowing the operator to choose the source of ARPA target information. Radar data is automatically processed into a single target list so that if two radars have acquired the same target it will be displayed as one target at the VMS-VT. Symbols representing radar targets are displayed on the electronic chart. Each target symbol includes a speed vector, history dots and an identification number (ID).

A typical bridge layout with VMS-VT installed is shown in Figure 6.14.

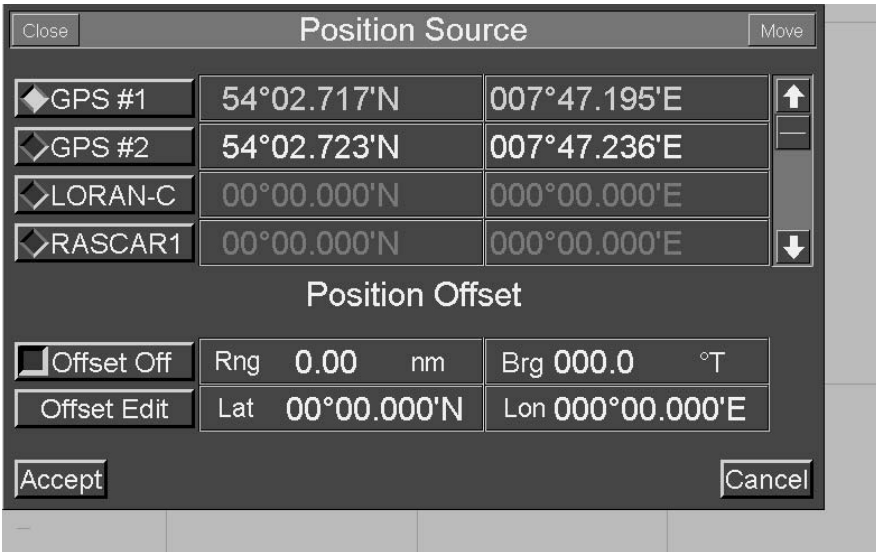


Figure 6.13 Example of VMS-VT position source window. (Reproduced courtesy of Litton Marine Systems.)

Figure 6.14 A typical integrated bridge VMS-VT installation. (Reproduced courtesy of Litton Marine Systems.)

6.11 Glossary

ABS	American Bureau of Shipping.
AIS	Automatic Identification System.
ANTS	Automatic Navigation and Track-keeping System. A system which automatically keeps a ship along a safe pre-planned track.
ARCS	Admiralty Raster Chart Service. The UKHO proprietary Raster Navigational Chart.
ARPA	Automatic Radar Plotting Aid.
Bridge	The area from which the navigation and control of the ship is managed.
Bridge system	The total system required for the performance of bridge functions, including bridge personnel, technical systems, man/machine interface and procedures.
Bridge wing	That part of the bridge on each side of the wheelhouse which extends to the ship's side.
CCTV	Closed Circuit Television. A system that allows monitoring of positions remotely by using cameras and monitor screens.
Coastal waters	Waters that encompass navigation along a coast at a distance less than the equivalence of 30 min of sailing with the relevant ship speed. The other side of the course line allows freedom of course setting in any direction for a distance equivalent to at least 30 min of sailing with the relevant speed.
Conning position	A place on the bridge with a commanding view, which provides the necessary information and equipment for a conning officer (pilot) to carry out his functions.
Conning information display (CID)	A display which clearly presents the state and/or value of all sensor inputs relevant to navigation and manoeuvring as well as all corresponding orders to steering and propulsion systems.
Display	The means by which a device presents visual information to the navigator.
DGPS	Differential Global Positioning System.
DNV	Det Norske Veritas. A member of IACS.
Docking	Manoeuvring the ship alongside a berth and controlling the mooring operations.
EBL	Electronic bearing lines.
ECDIS	Electronic Chart Display and Information System. The performance standard approved by the IMO and defined in publications from the IHO (Special Publications S-52 and S-57) and IEC document 1174.
ENC	Electronic Navigational Chart. Those charts, manufactured for use with ECDIS, which meet the ECDIS performance standards and are issued by or on the authority of government-authorized hydrographic offices.
Ergonomics	Application of the human factors implication in the analysis and design of the workplace and equipment.
ETA	Estimated time of arrival.
GMDSS	Global Maritime Distress and Safety System.
GNSS	Global Navigation Satellite System. The use of GPS for civilian purposes.
GPS	Global Positioning System. A satellite navigation system designed to provide continuous position and velocity data in three dimensions and accurate timing information globally.

Helmsman	The person who steers the ship when it is under way.
IACS	International Association of Classification Societies. Classification embodies the technical rules, regulations, standards, guidelines and associated surveys and inspections covering the design, construction and through-life compliance of a ship's structure and essential engineering and electrical systems.
IEC	International Electrotechnical Commission. The organization which produces world standards in the area of electrical and electronic engineering.
IEC TC80	A technical committee of the IEC that covers the area of Marine Navigation and Radio Communication Equipment and Systems.
IHO	International Hydrographic Organization. A grouping of national hydrographic offices responsible for promoting international standards in the fields of hydrographic surveying and chart production.
IMO	International Maritime Organization. A specialized agency of the United Nations and responsible for promoting maritime safety and navigational efficiency.
ISO	International Standards Organization. A non-governmental organization working to produce international agreements that are published as International Standards.
ITU	International Telecommunications Union.
LAN	Local area network.
LCD	Liquid crystal display. A form of display where the display elements are typically dark coloured alphanumerics on a grey screen. The display is easily read even in bright light conditions.
MOB	Man overboard.
Narrow waters	Waters that do not allow the freedom of course setting to any side of the course line for a distance equivalent to 30 min of sailing with the relevant ship speed.
Navigation	The determination of position and course of a ship and the execution of course alterations.
NMEA	National Marine Electronics Association. An organization comprising manufacturers and distributors. Responsible for agreeing standards for interfacing between various electronic systems on ships. NMEA 0183 version 2.3 is the current standard.
Manoeuvring	The operation of steering systems and propulsion machinery as required to move the ship into predetermined directions, positions or tracks.
Monitoring	The act of constantly checking information from instrument displays and environment in order to detect any irregularities.
Ocean areas	Waters that encompass navigation beyond the outer limits of coastal waters. Ocean areas do not restrict the freedom of course setting in any direction for a distance equivalent to 30 min of sailing with the relevant ship speed.
PPI	Plan position indicator. A type of radar display.
Route planning	Pre-determination of course and speed in relation to the waters to be navigated.
Route monitoring	Continuous surveillance of the ship's position and course in relation to a pre-planned route and the waters.
RPM	Revolutions per minute.

Screen A device used for presenting visual information based on one or more displays.

SOLAS Safety of Life at Sea. The International Convention for the Safety of Life at Sea, Chapter V Safety of Navigation, Regulation 20, Nautical Publications requires that 'All ships shall carry adequate and up-to-date charts, sailing directions, lists of lights, notices to mariners, tide tables and all other nautical publications necessary for the intended voyage.' SOLAS does not apply universally and some vessels, such as ships of war, cargo ships of less than 500 GRT, fishing vessels etc are exempt from the SOLAS requirements.

VRM Variable range markers.

Watchkeeping Duty undertaken by an officer of the watch. The officer of the watch is responsible for the safety of navigation and bridge operations until relieved by another qualified officer.

Waypoint A point entered into a computer and used as a reference point for navigational calculations. Planned voyages would have a series of waypoints indicating legs of the voyage. A modern computer is capable of storing multiple waypoints.

Wheelhouse Enclosed area of the bridge.

Workstation A position at which one or more tasks constituting a particular activity are carried out.

6.12 Summary

- Organizations such as the IMO, ISO and IEC have established international recognition of standards for ships involved in international trading.
- The integrated bridge system should be designed and installed as a physical combination of equipment or systems using interconnected controls and displays.
- Rules from classification societies, such as DNV, specify design criteria for bridge workstations, defining tasks to be performed and the siting of equipment to enable those tasks to be performed.
- The IEC Technical Committee (TC80) has produced a publication IEC 61209 covering operational and performance requirements, methods of testing and required test results for integrated bridge systems.
- To achieve optimum safety and efficiency in bridge operation, the classification society rules address the total bridge system that is considered to consist of four essential parts, namely the technical system, the human operator, the man/machine interface, and the procedures.
- The Rules for Nautical Safety are divided into three class notations: NAUT-C covers bridge design; W1-OC covers bridge design, instrumentation and bridge procedures; and W1 covers W1-OC and extensions within specified areas of W1-OC.
- Equipment carriage requirements are specified for ships according to the requested class notation.
- An operational safety manual is a requirement for class notation W1 and should obey the following guidelines: organization, daily routines, operation and maintenance of navigational equipment, departure/arrival procedures, navigational procedures, and system fall-back procedures.
- Ships requesting class notation W1-OC or W1 must comply with rules for bridge equipment tests. After installation of equipment on-board testing shall be performed in order to ascertain that the equipment, as installed, operates satisfactorily.

- A variety of manufacturers offer a range of integrated bridge systems that can be tailored to fit the requirements of the user.

6.13 Revision questions

1. Describe briefly the design criteria that define an integrated bridge system.
2. Describe briefly the equipment requirements for an automatic navigation and track-keeping system (ANTS).
3. Discuss the DNV rules for design criteria for bridge workstations and comment on the implications of such rules in terms of the tasks that have to be performed and the siting of relevant instruments/equipment required for those tasks.
4. What are the four essential parts that have to be considered to achieve optimum safety and efficiency in bridge operation.
5. Discuss the rule requirements set out in each section of the DNV Rules for Nautical Safety and comment on the different factors that affects the performance of the total bridge system.
6. What do you understand by class notations? Discuss the differences between the class notations NAUT-C, W1-OC and W1.
7. What do you understand by the term ‘general bridge equipment requirements’. What are the specific requirements for different types of bridge equipment?
8. Comment briefly on the rules for manoeuvring information. What type of information should be included in the provision of manoeuvring information? What form should the presentation of manoeuvring information take?
9. Describe the requirement for bridge equipment testing. Mention the type of equipment to be tested and discuss the reasons for the requirement for testing.
10. Refer to one of the examples of an integrated bridge system discussed in Section 6.10 and discuss how the system is organized to meet the requirements for such a system as specified in Sections 6.2, 6.3 and 6.4.