HM Ships Albion and Bulwark
The Royal Navy's first warships with a Platform Management System

BY

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ABSTRACT

After decades of having discrete machinery control systems which have been well proven in operational conditions, but often using expensive 'bespoke' hardware and software, the Royal Navy is procuring its first integrated Platform Management System (PMS) for two new major warships. Based around customized Commercial Off the Shelf equipment it will not only control main and auxiliary machinery and electrical distribution but also integrate these items with the damage control functions. This article will describe the physical and software attributes of the system and examine the radical (for the RN) proposed operating philosophy particularly in the area of how critical information in times of damage will be disseminated around the ship. This in turn, together with the inherent flexibility, which the PMS provides, will allow personnel who have traditionally not had control of machinery to be able to take direct control of an incident. The anticipated benefits of PMS include a substantial reduction in the number of personnel required to operate the main and auxiliary machinery, a lower procurement and through life cost and a quicker reaction time to any incidents onboard.

Fig.1 — Artist Impression of a LPD

Background

The Royal Navy is currently procuring two new Landing Platform Dock (LPD) warships (Fig.1), to be named HMS *Albion* and *Bulwark*, with an in service date of 2003. These warships will replace the 1960's built HM Ships Fearless and Intrepid. Each of the new 18,000 tonne ships are designed to land over 400 fully equipped troops with their vehicles and support equipment over a beach onto a potentially hostile shore whilst acting as the brigade headquarters for an amphibious assault of more than 3000 troops. Designed and built in the UK, Albion and Bulwark (FIG.1) will be first RN warships to be fitted with a Platform Management System (PMS) and a fully integrated electrical propulsion system.

Concept

Even the most recent RN warships such as the Type 23 frigate have had separate systems to control the main and auxiliary machinery, the electrical generation and distribution and provide damage control surveillance. The PMS to be fitted in the LPD(R) will incorporate all of this in one ship wide system allowing exchange of information and transfer of control across traditional lines of demarcation. This will allow key personnel such as the Damage Control Officer and his team to able to exercise direct control of the ventilation and fire main whilst tackling incidents. Also the Captain and his command team in the operations room will have access to instantly updated information on damage incidents and machinery availability as it is now recognised that the internal battle management of a warship is an important factor in maintaining the continued operational capability of the unit.

Technical

Prime contractor for the design and build of the ships is BAE Systems (Marine) Ltd (formerly VSEL), based at Barrow in Furness, UK with the PMS being designed and manufactured by CAE of Montreal, Canada. The PMS is based on CAE's proven naval technology but also includes new applications such as:

- Stability calculations (for intact and damage states)
- The incorporation of Royal Navy damage control techniques
- The integrated electric propulsion system.

The PMS consists of commercially based PCs (Dual Pentium) in 22 ruggedised consoles (FIG.2) with a Windows NT operating system and 21 VME Remote Terminal Units (VRTUs) all connected by a dual redundant ethernet databus. Power back up to the PMS components is supplied via Uninterrupted Power Supplies Each console is multifunctional allowing the transfer of activities to other locations in the event of console or compartment unavailability. A description of the consoles and their functions is included later in the article.

In normal mode all control will be through the consoles (monitor screens, tracker balls and keyboards) via Human Machine Interface (HMI) pages, but full local control of the machinery (on plant control) is included if PMS is unavailable.

PMS also includes interfaces with other networked systems such as the Platform Information Distribution System (PIDS) which carries information on ships speed, wind direction, etc. and it is planned at a future stage to interface PMS with the Operational Information System (OIS) which carries tactical information. This linkup would permit an even faster exchange of information between the command team and the supporting departments during hostilities or exercises. Overall this PMS represents the highest degree of automation yet seen in the RN.

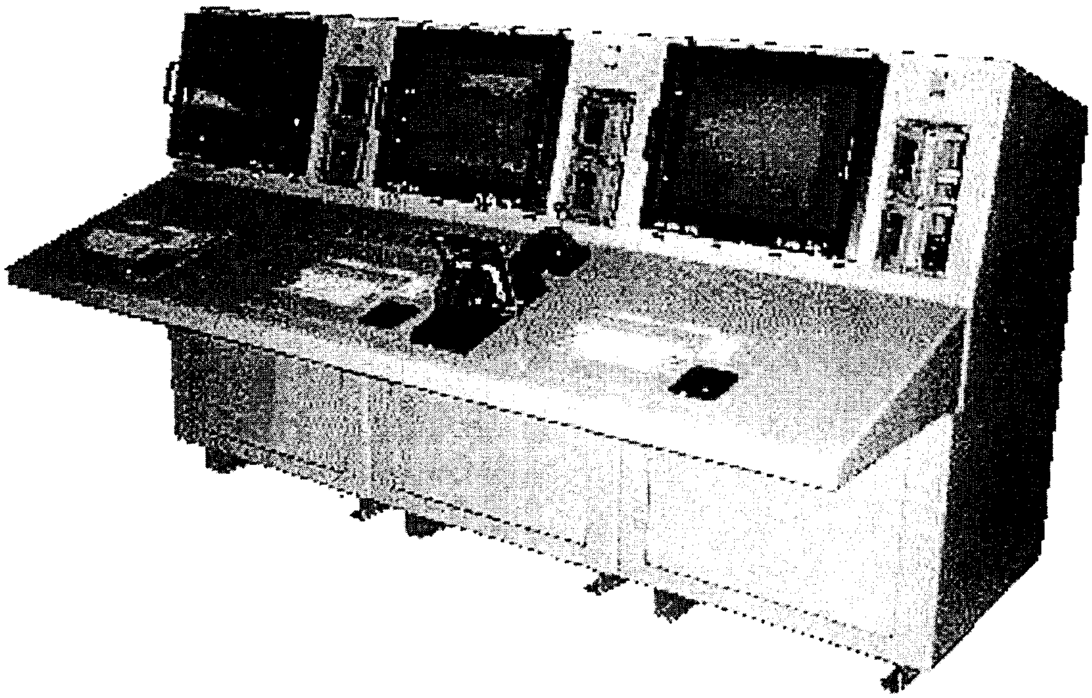

FIG.2 — 3 BAY CONSOLE
(AUXILIARIES/PROPULSION/ELECTRICAL OPERATORS)

Operating philosophy

In normal operating circumstances at sea, control of main and auxiliary machinery is vested in one operator in the SCC, with damage control surveillance carried out by a second operator on an adjacent console. On the bridge the quartermaster has control of the ships speed, but only monitors the remainder of the machinery. This is achieved by utilization of a 'Station In Control' (SIC) philosophy and the use of passwords that designate the degree of control an operator may exercise. Thirteen SICs have been designed and include:

- Thrust
- Propulsion control
- Auxiliaries
- Electrical generation and distribution
- Fire and flood surveillance
- Ventilation Control.

Most are designed to be operated by junior rates.

One operator or a single console can be in charge of more than one SIC group. But only the operator who has the SIC of a group has control over that machinery, with the exception of some of the Damage Control groups which can have several operators contributing to the control of that group. In times of potential danger or during action stations control of separate groups of machinery and systems is passed out to other operators via an 'offer' and 'accept' procedure as the SCC, HQ1 and FRPPs are then fully manned. Each operator then has control of the services that they need to perform their function. Supervisory control is maintained at all times by the supervisors having the privilege to 'take' control of a SIC, without reference to the present operator, for example during a machinery breakdown. The level of control and the privileges are allocated by having differing levels of authority dependent on the operator's

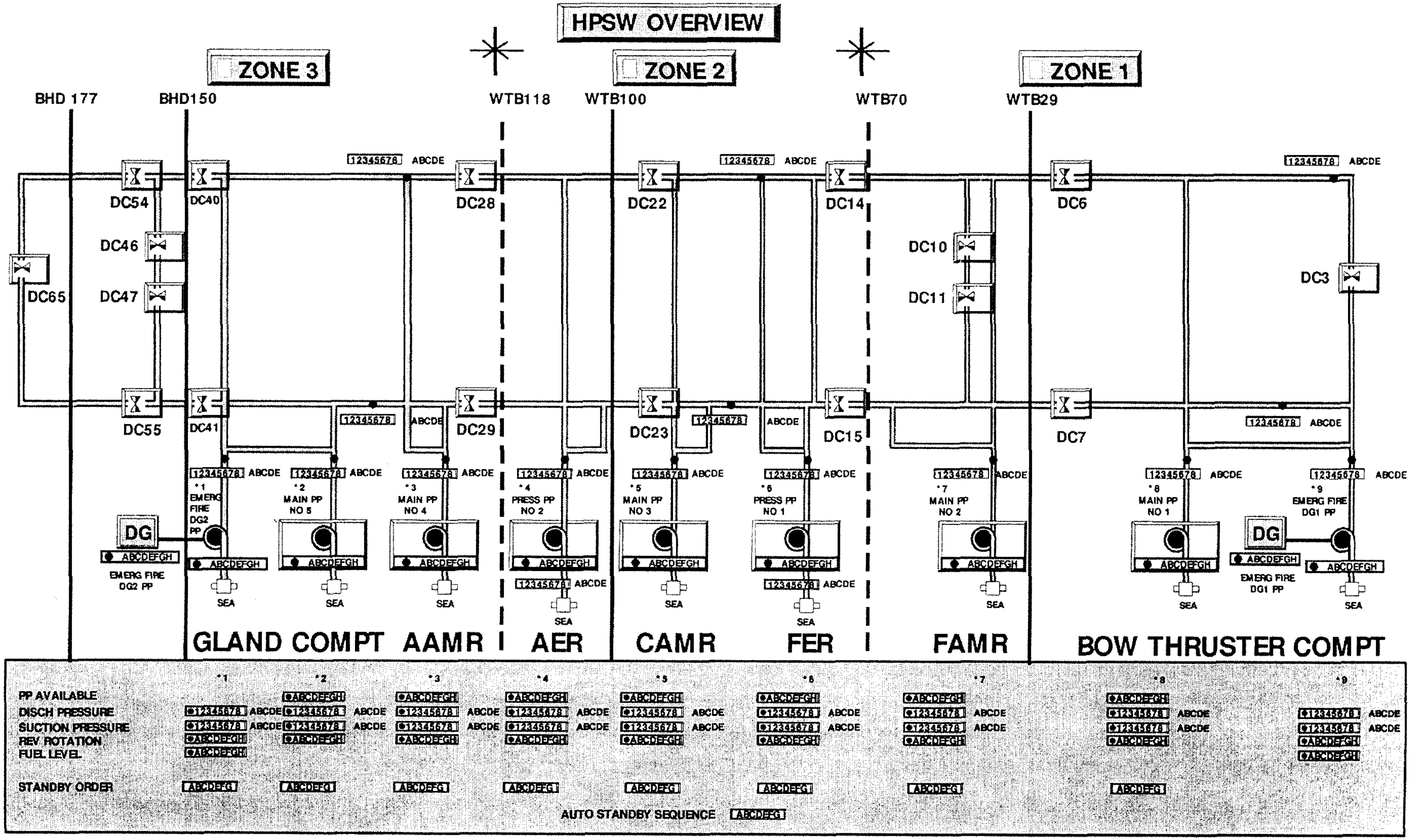

FIG.3 — HMI SAMPLE PAGE — HPSW SYSTEM

password, which in turn is linked to the training, and competence of the operator. The password allocation also ensures a high level of security to permitting only those with the appropriate level of training to have access or alter the information contained within PMS. This includes limiting the access of onboard personnel to minor changes only, which do not effect the main software. However as the password functions are themselves software controlled the appropriate support authority, in light of operating experience, could easily alter them.

Control functions

The PMS incorporates five levels of control:

- Automatic
- Operator initiated automatic
- Remote manual
- Direct local control
- Servo manual.

Automatic control, designed to reduce operator workload, includes for example an algorithm to start and parallel additional generators if power demand increases. Most actions such as starting and stopping machinery are achieved by the remote manual function and an example of servo manual is the inclusion of throttle levers at both the quartermaster and propulsion operator's consoles.

HMI pages and Stateboards

Because of the high number of SIC groups and the large and diverse nature of the machinery indication being controlled and monitored by PMS, it is not practical to have the status of all machinery displayed in the SCC at the same time. Therefore the principle means of control of the machinery is through approximately 60 HMI pages (FIG.3) which will be displayed on console VDUs. Split into logical areas such as propulsion, ventilation and auxiliaries, these pages given a diagrammatic representation of the machinery with easily recognizable icons for each component. As the status of the machinery changes, the icon will change colour and an adjacent 'dialogue' box will indicate running, tripped, out of service etc. The HMI pages can be read by anybody logged on, but only the operator that holds the SIC for that machine can change the status by means of 'clicking on' the component and using the drop down menu that appears. The layout of the HMI pages incorporates human factors advice and the use of 'hyperlinks' between allied pages e.g. from a Diesel Generator HMI page to the HMI page that controls lubricating oil distribution. This means a reduction in the time spent by operators in switching between HMI pages, an important consideration during the reaction to an emergency in a lean manned ship. Within the HMI pages are a number of 'software emergency stops', again designed to reduce operator workload and increase the speed of response. These software emergency stops are in addition to dedicated trips e.g. ventilation crash stops that are included on some consoles.

Also included are a series of machinery and damage control stateboards which can be accessed by the ship's management team to quickly assimilate information on machinery availability or the status of any damage. Most entries on the stateboards are automatically updated but there are also areas for free text notes and manual entry to tailor the stateboards to the situation (FIG.4).

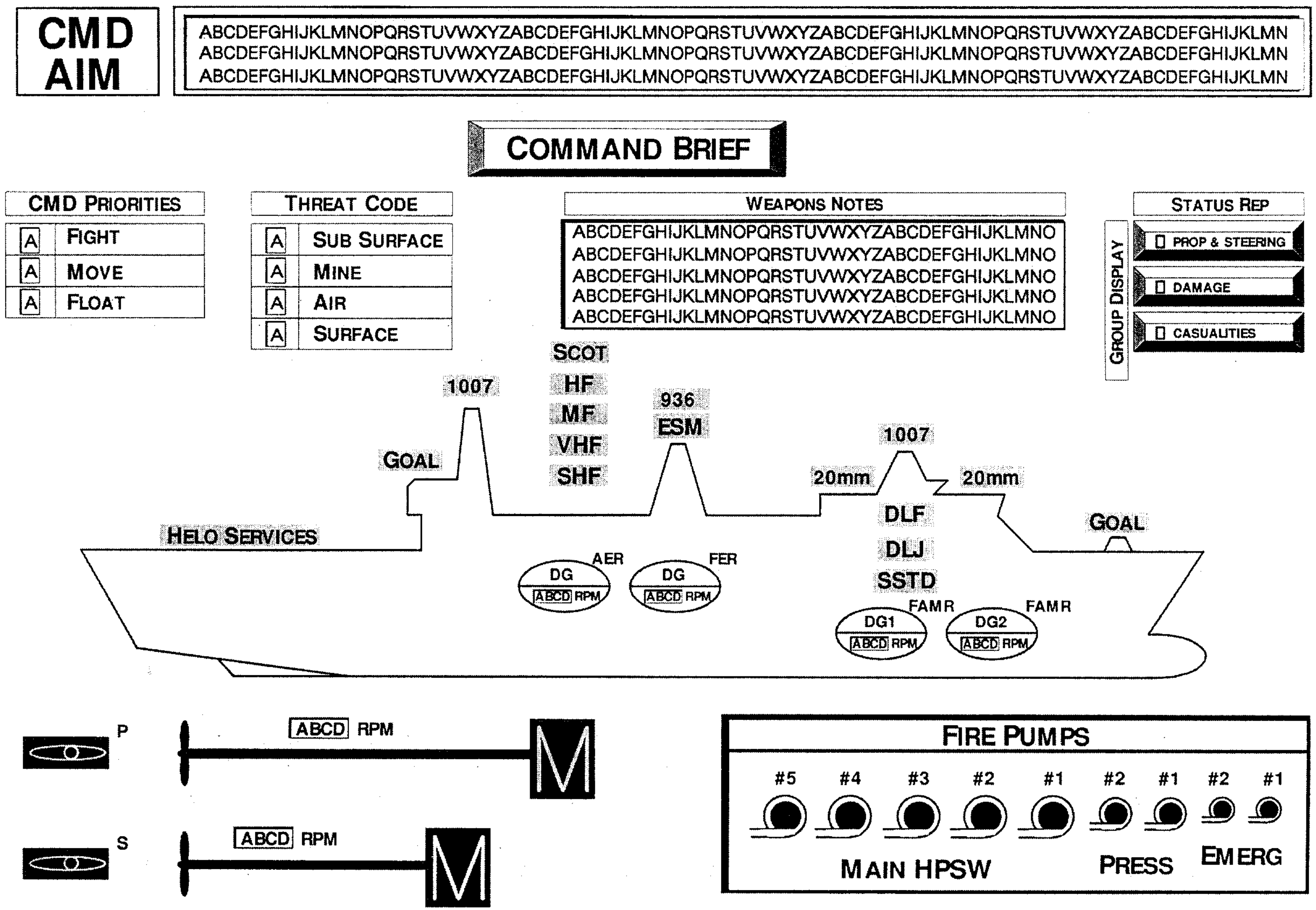

FIG.4 — STATEBOARD EXAMPLE — COMMAND BRIEF
(SINCE UPDATED TO REFLECT AMENDED COMMAND PRIORITIES)

Damage Control

Damage control functions are an integral part of the PMS but represent a radical departure from current RN practice. Currently RN ships mark incidents using wax pencils on a plastic covered copy of a paper drawing of the ship and its compartments with very little or no linking of the fire and flood alarms or door and hatch monitoring to this whole ship incident board. This is obviously very labour intensive and there is much opportunity for confusion as the Incident Board Operators (IBOs) in the FRPPs, Operations room and weapon section base attempt to duplicate the markings on the main HQ1 incident board by listening

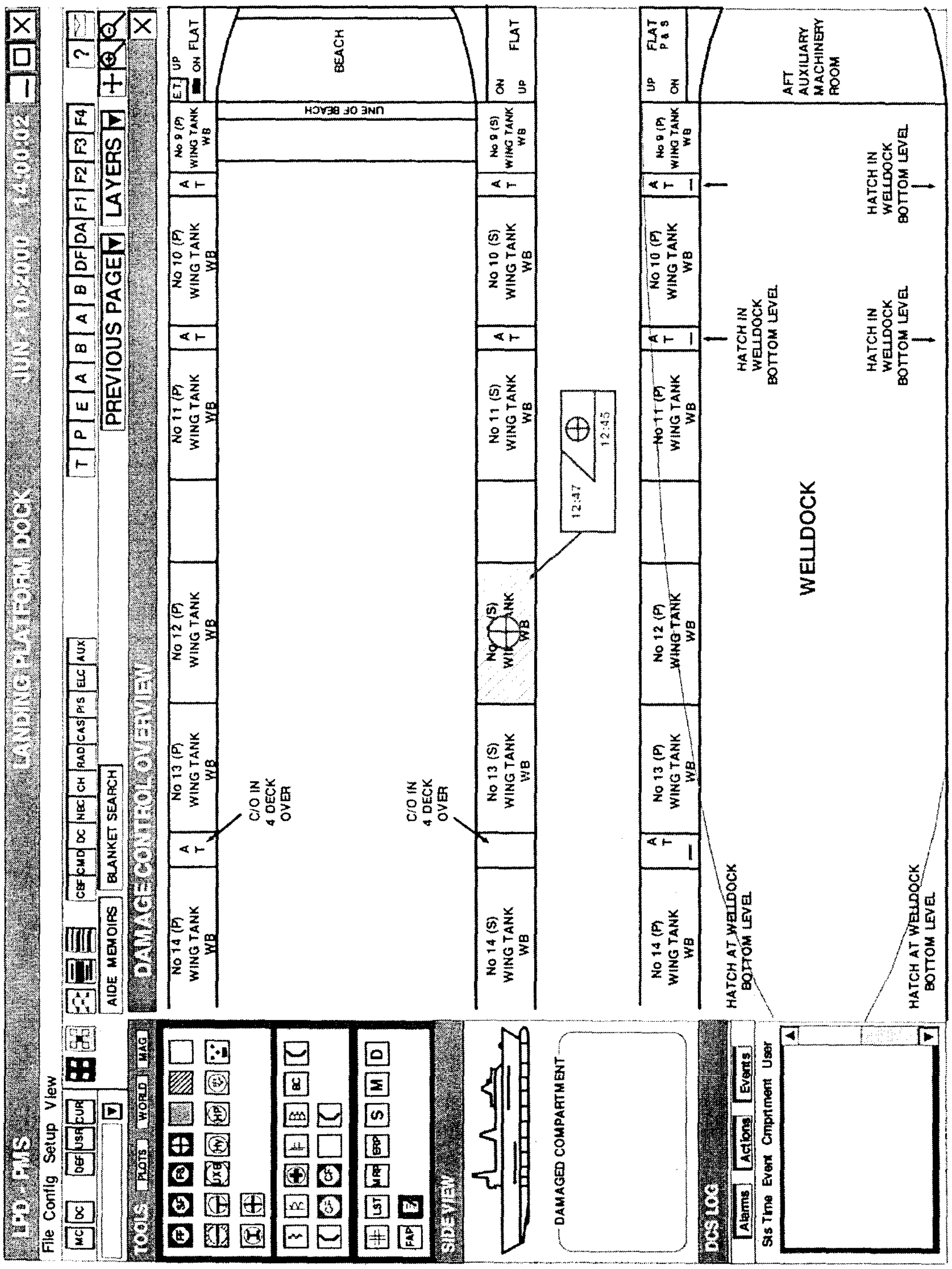

FIG.5 — EXAMPLE OF DAMAGE CONTROL STATEBOARD

to incident reports on a open voice communications network. PMS gives a very different approach with the physical whole ship incident board replaced by a electronically produced detailed deck plan. The deck plan can be displayed either whole on the large screen display or at any console but the operators can also select individual decks, areas or compartments, and there is also a zoom function (FIG.5). As the scale of the displayed area increases, more layers of detail such as the position of firefighting equipment, compartment location codes etc., are automatically shown. This automatic layer facility ensures the screen remains uncluttered and therefore enables the operator to concentrate on managing the incident. These layers can also be enabled at any scale if required. Detailed compartment information on power supplies, vent arrangements etc. known as a killcard, will be stored electronically and it will be easily accessible on screen when the compartment is displayed. Because PMS also monitors 140 door and hatch positions, 600 flood and fire alarms and the chemical and radiological detectors, should any of these be triggered, the compartment affected will be automatically displayed on the detailed deck plan with the correct RN symbology for the incident. Once the operator accepts the alarm the incident is time stamped and plotted. As the incident progresses further information can be added, adjacent incidents can be 'merged' or 'de-merged' etc. and the movement of personnel or equipment can be plotted. Free text notes can also be added to the deck plan. With the same information being displayed at all terminals, any confusion between HQ1 and the FRPPs should be much diminished and the potential exists for activities of the crew to be better co-ordinated than in present warships.

Ballasting and Stability

The primary weapon of the ship is the ability to transport and land the embarked force with their equipment. Therefore the ability to embark or discharge ballast water to maintain stability when loading and unloading equipment and to flood the integral Welldock to operate the four 170 tonne landing craft is crucial to the operational task. The quantity of fluids in all water and fuel tanks is constantly monitored and the operator can enter details on such items as disposition of vehicles in the tank deck. This enables PMS to accurately advise the operator, via a stability software programme, which contains all the hydrostatic details of the updated Stability State. This software programme can also be used for predicting the state of the ship after damage. The same operator will also control the ballast pumps and valves via PMS, again achieving a substantial reduction in manpower.

Diagnostics, Fault finding, Reports and Trending

As befits any modern control system, PMS incorporates a self-diagnostic facility to assist the maintainer to identify and correct any faults that develop in sensors, signals, the ethernet communication or other parts of the PMS hardware. Operators are alerted to any fault by an on screen message, allowing them to decide to continue with PMS control or opt for a reversionary mode. Comprehensive operator and maintainers manuals are to be provided as part of the procurement contract. Other functions of PMS are the ability to store data for the composing of reports e.g:

- At times of watch change
- The ability to carry out trend analysis of data onboard
- To download electronic information for record keeping or further analysis ashore.

The onboard trend analysis allows up to ten separate files to be created and graphically displayed, each with twenty signals, which have sample rates of between 1/10 seconds and 1 hour set by the operator. This facility is expected to be very useful during machinery trials e.g. after a period of maintenance or as an aid to fault diagnostics.

Hardware Description

Remote Terminal Units (RTUs):

There are twenty-one RTUs (FIG.6) on the vessel. Their function is to provide the interface between the PMS and the ship's equipment it monitors and controls. Each RTU chassis houses a Pentium based master processor card. This card provides the communication channels to the two ship's data communication buses in addition to one RS-422 and one RS-232 communication port. The processor card contains a replica of the ship's database and the S/W necessary to monitor and control the equipment directly connected to it. Installing the monitoring and control function as close as possible to the actual machinery increases the survivability of the system and reduces risk. In case of catastrophic damage to the databus or the control centre, it will still be possible to control the machinery from the RTU position provided it is fitted with a HMI such as a Local Operating Panel. In any case, the RTU would have the ability to either keep the equipment running or initiate a safe shut down depending on the situation and the control sequences coded into it.

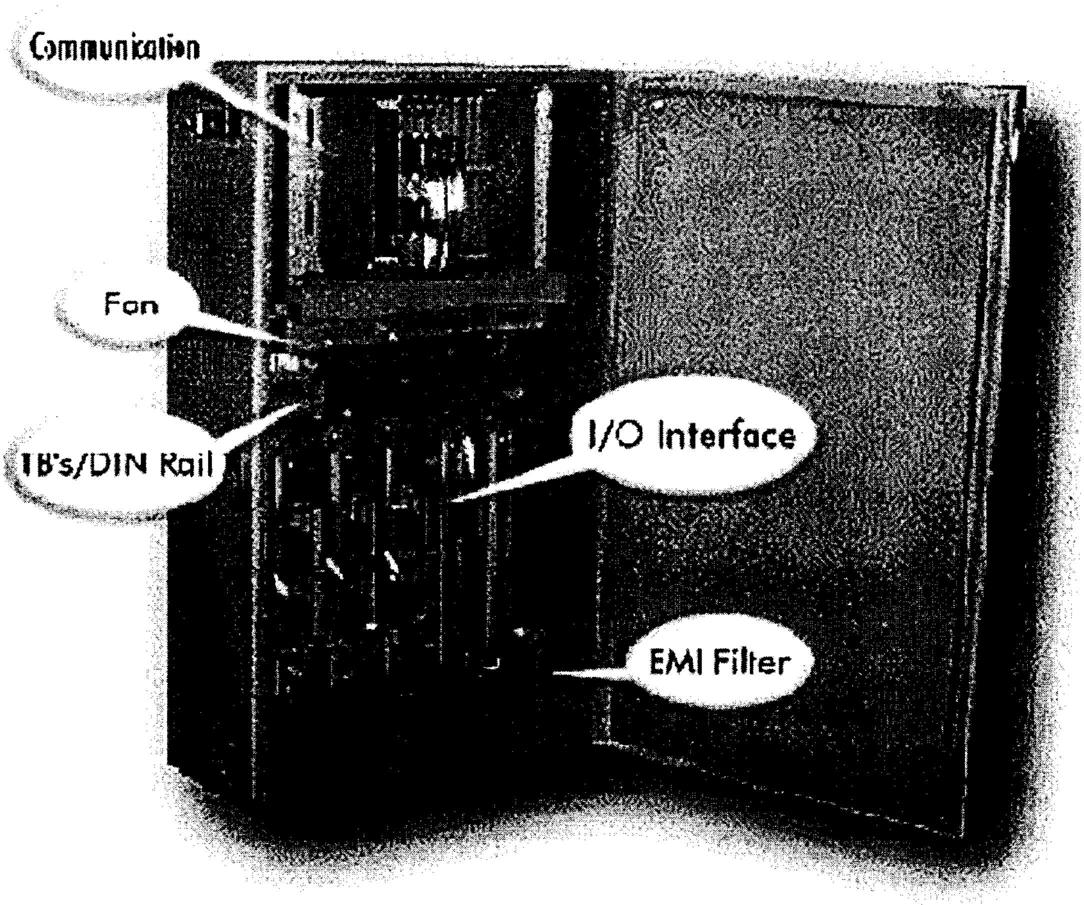

FIG.6 — RTU

Databus

The ship is fitted with a dual redundant Ethernet databus. The role of the databus is to carry information from one node (console, RTU, FRPP etc.) to another so that each node's database is constantly updated as status changes. The databus itself is made of a thick coaxial copper cable conforming to the IEEE 802.3 Ethernet specification. Each databus is independent of the other and they both carry the same information. Each node accepts the information that arrives first and discards the duplicate information that arrives next from the redundant bus. The two databus are run in different geographical locations on the ship (i.e. port and starboard sides) to ensure maximum survivability of the system. In the event one cable should be cut, it would cease functioning but the other databus would remain unaffected. Bridging the damaged section would easily and quickly repair the damaged databus. The loss of the damaged node would not affect the network and the communication between the remaining stations would continue in a normal manner.

Transceivers

In order to connect a node (console, RTU etc.) to the Ethernet databus, it is necessary to install a transceiver. The transceiver is a small box, very rugged, with a 'T' connection on its top allowing it to connect two segments of the databus together. The signal fed to the box is relayed to the node via a drop cable through a D sub connector located at the bottom of the transceiver. The other end of the drop cable connects to a standard Ethernet card housed inside the console computer or to the RTU controller card. Each of the databus requires its own transceiver for each of the nodes. This means that each node needs two transceivers; one per databus. The main advantage of this arrangement is that it does not require to physically bring the two databuses together to connect to a node, thus ensuring a good level of survivability. In addition it also simplifies the layout and routing of the main databus cable from one end of the ship to the other.

Consoles

There are eleven full size consoles fitted in the LPD-R. Each console is meant to be operated by an operator in a seated position. They contain an 'off the shelf' ruggedised high end computer in its base. The computer houses two (dual) Pentium II processors @ 266 MHz, 256 MB of RAM memory and runs under the Windows NT operating system.

The desk area is fitted with a standard 'off the shelf' ruggedised QWERTY keyboard and a trackball. There is also a set of dedicated trip buttons located above the keyboard. These trips are used for emergency shut down of specific components and are directly hardwired to the equipment they are meant to protect. Each console is fitted with its specific set of trip buttons related to the equipment the console would normally control. The top portion of the console is fitted with a 20 inch ruggedised colour Cathode Ray Tube (CRT).

The console computer houses a replica of the database, constantly updated via its Ethernet connection, as well as all software necessary to provide the proper interface to the operator (pages, navigation functionality etc.). It also houses the software of applications using direct interaction with the operator such as ballast and Damage Surveillance And Control (DSAC) functions for example.

Local Operating Panels (LOPs)

There are five identical LOPs (FIG.7) fitted in the LPD-R. Three are used for on site (plant) machinery control and two are used for DSAC operations. The LOP is of a ruggedised design and is bulkhead mounted. It houses a dual Pentium II 300 MHz processor and runs under Windows NT. It is fitted with a retractable QWERTY keyboard and trackball and has a 13 inch colour TFT display. It is intended to be used by an operator in a standing position.

Each LOP used for machinery control has a direct connection to a specific RTU and they are all located in different engine rooms. An LOP can perform the full functionality of a console but is mainly intended to be used as a plant operating position when deemed necessary. Its direct connection to a dedicated RTU, via serial link, also permits it to keep controlling the machinery connected to this RTU in case of major damage resulting in the loss of both Ethernet databus.

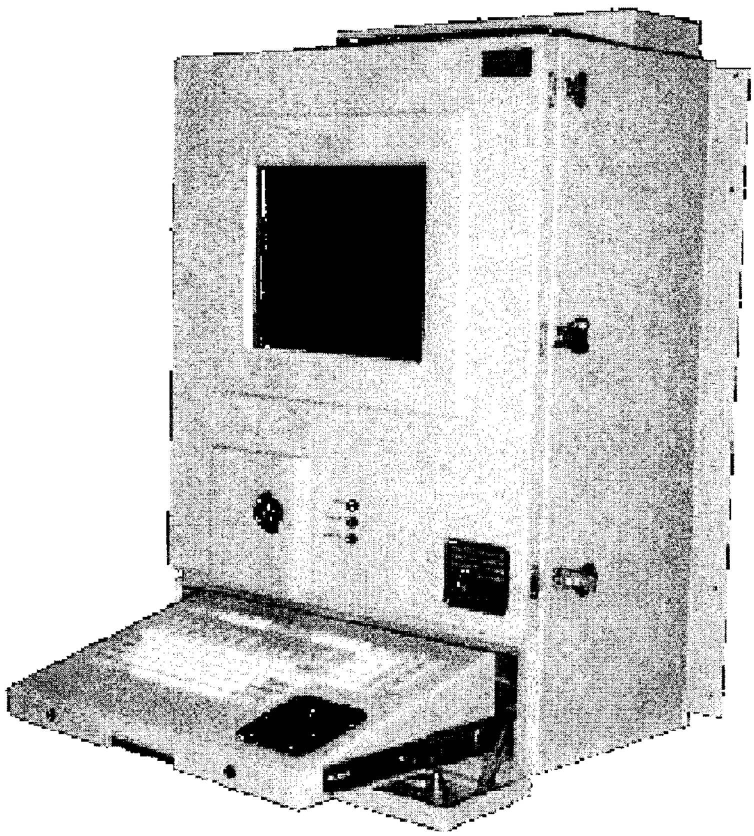

FIG.8 — LOP

Fire and Repair Party Positions (FRPPs)

There are five FRPPs (FIG.8) installed in the LPD-R. They are of ruggedised design and consist of a dual Pentium II 300 MHz PC mounted in a stand. The top section of the stand is fitted with a QWERTY keyboard, trackball and a 21 inch colour CRT.

The FRPPs are placed in various zones of the ship and are intended to provide DSAC access to the fire and repair parties in a compact environment where a full size console would take too much place. Like other stations, they can also be used for any other PMS function such as machinery control if necessary.

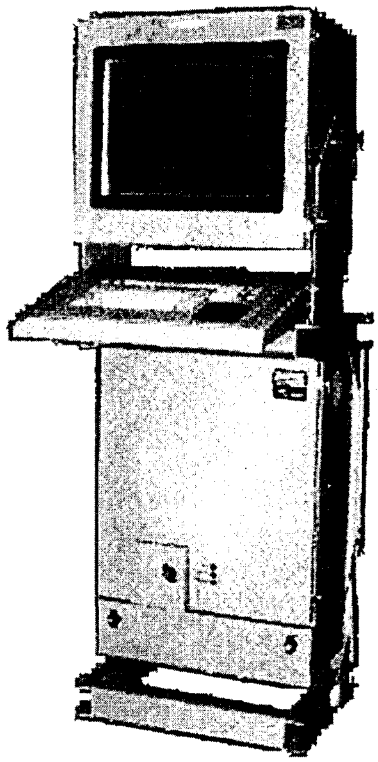

FIG.8 — FRPP

Large Screen Displays

There are two, 67 inch diagonal, large screen displays fitted in the SCC/HQ1. One is connected to the machinery supervisor console and the other is connected to the Damage Control Officer (DCO) console. The operators can select to display any page on their large screen and the page displayed can be different to the one displayed on their own console. This functionality provides an easy mean of briefing the people present in the SCC/HQ1 on a specific issue without having to gather around a console and constantly disturb the operator and his colleagues from their duties.

Bridge Wing Panels

There is a panel installed on each of the two bridge wings. Each panel is fitted with a series of gauges providing steering and propulsion information. The panel itself is a small box (50 x 30 x 25 cm) especially designed for an external environment and is bulkhead mounted. The gauges are protected by a front door fitted with a glass. Lighting of the gauges can be dimmed from the bridge console to adapt to the external light conditions.

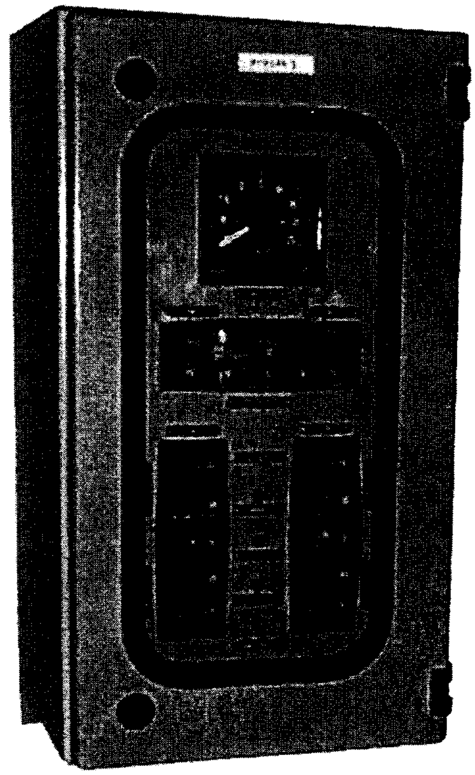

FIG.9 — BRIDGE WING PANEL

Printers

There are three laser printers provided on the PMS. They are directly connected to the Ethernet databus and can be accessed by anybody just like in an office environment. Two printers are located in the SCC/HQ1 and one is located in HQ2. Printers can be used to print a mimic page, logs, events, warning or alarm lists etc.

Plug-in Port

There is one special plug-in port provided in the alternative weapons section base. This unit consists of a small box housing two D-Sub connectors. Each connector leads to a dedicated transceiver and therefore provides access to each of the two databus. This has been fitted as an emergency connection to the PMS should other control options (locations) become untenable.

PMS Expandability

Although the PMS as installed on the LPD-R will provide thorough monitoring and control functionality, the inherent design of the PMS architecture could cater relatively easily for further expansion of the functionality provided. A few examples of possible additions to the system are listed below.

On Board Training System (OBTS)

An OBTS is a valuable training tool that allows real life training of the operators. It requires to model the ship' systems and build/configure an Instructor Operating application that will allow the instructor to run a training session as he wishes. Typically, this additional software is installed in all consoles. This allows the instructor to sit at any console of his choice and exit the PMS control application and enter the training mode application. The instructor can choose to train one or several students during the same session. Students sit at any available PMS console that is also brought into the training mode. A training session can be based on a pre-configured scenario or the instructor can build his own scenario or he can also modify online a pre-configured scenario to tailor it to the needs of the moment by injecting faults where he wants. Faults can be trigged manually or based on an event or time elapsed.

This type of training allows for a much more realistic approach as the students are actually confronted to perform their actions in real time using exactly the same tool (PMS) that will be available to them in real life. This contrasts with a conventional training session where most of the vital corrective actions following a major incident are not actually performed but rather described verbally to the instructor because of the risk involved in actually running the drill in its entirety. The possibility of going through a full scenario and get the operator to actually respond to problems injected by the instructor or created by his own actions is certainly a valuable improvement over conventional training. All pages used by the operators are the same as under normal PMS control. Upon switching from PMS control from the training mode, the station of the student or instructor is disconnected from the two PMS control buses and the console is brought on line as an additional dedicated OBTS Ethernet bus.

Advisory Systems

Refining the coverage of the advisory system functions could also further expand the PMS capability. This could, for example, include such things as:

- Calculation of remaining capacity of fuel, firemain, fresh water.
- Optimization of support functions based on threat levels
- Incorporation of CD-ROM libraries and associated hyperlinks through CD-ROM towers etc.

There are numerous software functions that can be easily added on to a system such as the LPD-R with no negative impact on the existing system. These functions may therefore be developed as the needs arise or simply when the budget becomes available. Therefore the system has the flexibility to relatively easily adapt to changes or new requirements.

Remote Monitoring Connection

Expandability of the system can also include such thing as a remote ship monitoring connection. This feature can allow the monitoring of an unmanned vessel from a sister ship berthed alongside or via a shed located on the jetty. The principle is to let one console operating on the unmanned ship and connect a dedicated link to another console or PC on the sister ship or even ashore. The remote computer can then be operated using exactly the same monitoring and control pages than on the unmanned ship by creating an X-Terminal connection to the console left running on the ship to be remotely monitored/controlled. The X-Terminal mode means that the PMS application software is actually running from the unmanned ship console and that monitoring and control functions available at the remote PC are actually performed on the unmanned ship but are only displayed on the remote PC. This X-Terminal approach allows the ship to be monitored without having to ensure that the monitoring position has exactly the same software version or database as the ship to be monitored since the monitoring PC is only displaying the information coming from the monitored ship.

To add on this function, it is necessary to install a connection box around the shore connections area and have a permanent cable run to one of the consoles onboard the ship. This connection box is simply a connector plate mounted at the bottom of the box. A ship to ship connection can then be established with a sister ship by connecting the two PMS shore connection boxes with a cable. The same arrangement is also valid for a connection ashore. In addition to this hardware, an X-Terminal protocol/function must also be added to the PMS software.

Plug-in Connection Ports Functionality

As previously described in the PMS hardware description, the LPD-R is fitted with a special plug-in connection port. This port can allow access to the databus via a portable station in case of emergency. At this time, the ship has only one dual access port (connected to the two Ethernets) but additional ports could also be installed on the ship to provide a better ship coverage of these emergency connections. Ideally, one single access (one Ethernet) emergency port is provided for each zone of the ship. Half the plug-in ports are connected to one Ethernet and the other half are connected to the second Ethernet. Each emergency port requires to have one transceiver added on the network to be accessed. This additional transceiver is then connected with the actual port via a drop cable. The port itself consists of a small box housing a D-Sub connector where the portable unit connects. A high-end notebook is also required to connect to the port. The PMS software is loaded on the notebook and the unit then simply needs to be plugged-in to one of the ports to have the functionality of a console.

Benefits

The ease of machinery control, the co-ordinated nature of damage control and the speed of information distribution means that PMS allows full advantage to be taken of current lean manning initiatives. The numbers of marine engineering personnel required to operate the main and auxiliary machinery has reduced from 12 to 3 when compared to the existing LPDs in RN service primarily due to PMS. Significant savings in through life costs are predicted due to selection of 'commercial off the shelf' equipment and such equipment more readily lends itself to upgrade and modification than 'bespoke' items procured for a small number of applications. Availability and reliability information predicts that PMS will be robust and reliable and with sufficient redundancy to overcome unavailability caused by damage. The software based nature of the system allows the maintainer to reconfigure some functions whilst larger changes such as redrawing a HMI page or writing a new algorithm for an automatic control function do not require a physical reconfiguration.

Conclusion

The procurement of a PMS for the new LPDs represents a significant change in the way the Royal Navy will control and monitor the machinery and damage control functions aboard a major warship. The use of customized commercial equipment promises significant savings in both procurement and through life costs not least in the reductions in crew complement over earlier ship designs.

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