INTEGRATED MONITORING AND CONTROL SYSTEM FOR GERMAN NAVY K130 CORVETTES

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ABSTRACT

In the late 1990s, a quantum leap in the abilities of Integrated Monitoring and Control Systems (IMCS or IPMS) was realised on key programmes such as the German Navy’s new F124 Frigates, Royal Netherlands Navy’s new LCF Frigates, and the Indian Navy’s Project 17 Gas Turbine Frigates. This paper provides an overview of the IMCS implemented on the K130 Corvettes as well as other key programmes and discusses enhancements and lessons learned from the previous generation of implementations.

KEY WORDS

Automation, Integrated Platform Management System, ship controls, damage control, machinery control.

1. INTRODUCTION

In 2003, L-3 MAPPS was awarded the contract for the supply of the Integrated Monitoring and Control System (IMCS) for the German Navy’s new K130 class Corvettes. The contract followed the previous award of the F124 Class Corvettes, and provided an opportunity for all involved parties to learn from and build on the experience from the previous programme. Several new features were added as a result, and the K130 IMCS is among the most advanced platform control systems currently at sea.

2. K130 INTEGRATED CONTROL AND MONITORING SYSTEM

Proven Approach

The IMCS being implemented for the K130 Corvettes is an advancement of similar systems that have been selected for over 140 warships in 18 navies of the world; it has accumulated close to 7 million hours of operational experience and provides customers with a proven yet modern approach to platform management.

The collective experience of L-3 MAPPS, ThyssenKrupp Marine Systems, the Bundesamt für Wehrtechnik und Beschaffung, and the Deutsche Marine from the F124 Frigate programme was applied to the K130 IMCS, and as a result, several lessons learned from the F124 and other programmes were considered during the development of the K130 IMCS.

System Architecture

The general architecture of the K130 IMCS is the same as that of the F124. The K130 IMCS is a distributed open-architecture real-time digital control system. As shown in Figure 1, this open architecture system comprises multifunction control consoles and Remote Terminal Units (RTUs). The RTUs are used for process level data acquisition and control while the consoles provide the human-machine interfaces (HMI) for the operators at various shipboard locations. This distributed system offers reduced complexity and increased fault-tolerance as compared to “client-server” or “multiple master” architectures. In the L-3 MAPPS IMCS software architecture, there is only one software version for the data acquisition level and one version for the HMI, with both versions built on the same core software. All system elements (i.e. RTUs, consoles, local operating panels etc.) also share a common database, which is constantly updated on every change in sensor value or operator initiated process. System wide connectivity is provided by a dual redundant and fault tolerant fibre-optic Ethernet databus using ring topology, and supporting a reliable multicast protocol.

Figure 1 - K130 IMCS General Architecture

One important element of the K130, which we believe represents a trend in the industry, is the composition and distribution of signals. The F124 class, a 6000 tonne frigate, comprises about 8000 signals associated with the
IMCS, of which about 5000 were hardwired, i.e. connected directly to the dedicated input/output boards of the RTUs, with the remaining signals coming through serial links. The K130 is a much smaller ship at 2000 tonnes, however, the signal count rivals the F124 at close to 7000! Of these signals, only about 2500 are hardwired, and 4500 signals are received through serial links interfacing to the local controllers of various ship machinery. This trend shows three things; first that equipment suppliers are able to provide increased intelligent monitoring units at the local levels, second, that more and more systems are being automated and controlled from the IMCS, and third, that many navies and shipyards are specifying increasingly complex ship platform automation systems, rather than simple remote control and monitoring systems.

A very important element to consider about this trend is the need to have open architecture systems, both at the hardware and software level. Standardisation of the protocols for equipment connected by serial links is definitely increasing, however, having an open architecture at the software and hardware level ensures that that any future equipment containing new or non-standard serial link connections or protocols can be easily integrated into the IMCS throughout the life of the ship. L-3 MAPPS approach has consistently been to allow industry to define serial protocols, and to provide the means to interface to any of them, rather than try to impose the use of particular protocols for the equipment suppliers. This approach avoids the use signal conditioners or protocol converters that can reduce data latency and add an additional point of failure to the overall system.

**Human Machine Interface**

The HMI component of the IMCS covers not only the basic mimic pages which allow the operator to view and control various system elements, but also advanced features such as Alarm Management, Data Logging, Trending, Battle Damage Control System, Closed-Circuit-Television (CCTV) and an interface to the Combat Direction System.

**General**

The Human Machine Interface of the K130 IMCS is an advanced version of that implemented on F124 and is a consistent application for complex warships needs; however, several important new features were added as a result of experience gained on the F124 and other programmes.

The primary HMI is in the form of the multifunction control consoles in the Machinery Control Room (MCR). Control consoles are also provided at damage control section bases and on the bridge. HMI in engine rooms and other machinery spaces are provided by Local Control Stations, featuring the same capabilities as the MCR consoles. A portable operator station (Laptop PC), connected to any of the ten data bus connectors, serves as an additional or emergency control console, or as a diagnostic terminal for system troubleshooting using built-in test equipment and software.

Control and monitoring from consoles is performed through the use of high-resolution colour LCD monitors that display ergonomically designed graphical pages of the platform machinery and systems. Each console is fully multifunctional and can perform any and all functions of the IMCS provided the appropriate authorisation (password-controlled) and the “station-in-control” transfer protocols are respected.

This provides a very high level of redundancy and survivability as total platform control can be exercised from several widely separated locations on the ship. Figures 2 and 3 show the main propulsion and auxiliary consoles currently installed on the K130.

![Figure 2 – K130 Propulsion Console](image1.png)

![Figure 3 – K130 Auxiliary Console](image2.png)

L-3 MAPPS has accumulated a significant amount of experience and expertise in the implementation of
ergonomically designed custom-tailored graphical mimic pages. It has preferred simplicity and well-researched symbology as compared to the distracting effects of extravagant colour use or artistically rendered symbols. The HMI pages are designed to provide the necessary information to the operator, thus ensuring easily readable displays without overloading the operator’s capabilities. A structured windows approach can also be used with four smaller windows simultaneously displayed on the screen allowing the operator to manage several different systems at the same time. The HMI is always custom-tailored to match the end-user’s machinery control doctrine and symbology preferences, i.e. there are no “standard” mimic pages that are offered, but every page is submitted to and approved by the end-user, prior to implementation.

Several different types of pages are used to display plant overviews, machinery data, system schematics, trending displays, alarms, events, and fault messages. The parameter update or “refresh” rate of the HMI is currently 200 msec, which is also the time required to display a new page.

While the colour screens provide the ability to monitor and control every aspect of the platform, the IPMS includes a limited amount of dedicated instrumentation for emergency or remote control from the control rooms. Propulsion throttle levers are located on the Bridge, and in the Machinery Control Room. They can be set to communicate propulsion orders directly to the IMCS from the bridge, or can be used in telegraph mode, where the propulsion orders from the bridge are confirmed and executed by the operators in the MCR. The system also acts as an IMCS independent emergency telegraph system with repeaters located in the machinery spaces.

Another unique feature of the K130 and F124 IMCS is the ability to link the IMCS of several ships together or to a shore-based station, allowing one ship or a port station to monitor and control other ships. Therefore, while the Corvettes are along-side, only one machinery control room needs to be manned, leaving the crew of the other ships free for other duties.

**Alarm Management**

The IMCS features an elaborate alarm processing subsystem which reduces operator loading by filtering out nuisance alarms and providing context sensitive displays based on the nature and severity of the alarm. In systems with a large number of sensors this becomes a critically important feature to help maintain operator effectiveness under both normal and emergency conditions. Audible and visual annunciation are used to alert the operator to the occurrence of alarms, warnings and faults. Acknowledgment of such annunciation is typically based on the function allocated to each position i.e., the auxiliaries operator (irrespective of his physical location in the ship) acknowledges auxiliaries alarms, warnings and faults. The L-3 MAPPS IMCS provides an alarm response time of 500 msec, as compared to classification society requirements of less than one second.

**Data Logging and Trending**

The IMCS continuously records the changes in sensor data and the control commands together with the date and time stamps for each value. Short term data storage, comprising the last 24 hours, is available at each console whereas long term data storage is provided by a USB connected removable storage device. This data can be viewed on board and also analysed in shore-based facilities.

Sensor information and other system data can also be selected by the operator to be stored and displayed graphically together with the relevant alarm and warning limit thresholds. One black and white laser and three colour printers provide the ability to obtain hardcopy logs of events, alarms and the colour graphic screens for archival purposes.

**Closed-Circuit-Television (CCTV)**

To enhance the manpower reduction features of the IMCS, L-3 MAPPS has integrated a digital closed-circuit television system to provide video monitoring of the ship’s machinery spaces and other locations. Seven web-based colour CCD cameras are connected to the IPMS consoles using an independent network to allow the console screens to display the video image in a screen window which can be maximized to use the full screen area. To provide the most flexibility, any camera can be selected for display on any console. A powerful feature of the integration of the systems is that specific alarms, such as fire or flooding alarms trigger the automatic display of the relevant camera images at specific consoles.

**Interface to the Combat Direction System**

As with the F124, a key aspect of the K130 IPMS is its integration with the ship’s Combat Direction System (CDS) in order to achieve a total ship control capability. On K130, the two systems communicate through the K130 intranet via a gateway and provide the exchange of data for specific functions provided by each system, as well as e-mail services and limited access to the IMCS through a “CDS login”. All IMCS pages can be displayed directly at CDS workstations, allowing combat operators immediate access to the status of systems critical to them. Several specialised pages have also been developed for the CDS operators, which present overview information and status for selected systems critical to the CDS. (Example in Figure 4). CDS operators can set the ship combat status, which, when executed and confirmed by the IMCS...
operator, will be the basis to configure the platform systems to meet that status. For example, if the ship goes into combat-ready status, upon confirmation of the event by the IMCS operator, several automatic sequences are initiated to achieve tasks such as bringing all generators up and on-line, reconfiguring fuel, chilled water, ventilation systems etc., and preparation of damage control auxiliaries such as the fire main system.

In case of damage to equipment or systems critical to the CDS, the CDS operator can set the repair priority to various equipment. This information is received at the IMCS, and specifically is used by the damage control headquarters to facilitate the dispatch of repair teams.

**Battle Damage Control System**

One of the defining features of L-3 MAPPS IMCS is the complete and seamless integration of the Battle Damage Control System (BDCS). The BDCS is a powerful tool that not only provides operators with a graphical interface to quickly and easily identify ship emergencies or casualties, it more importantly is complemented with tools that help the operator to manage an on-board emergency.

The typical damage control overview page shown at Figure 5 has four “child” windows. The main window presents the ship General Arrangement Plan (GAP), and the child windows provide manual plotting capabilities, ship side-view, alarms and warning overviews, and the damage control log. The basic layout of the typical ship GAP is shown in 3-D (ISOGAP) or 2-D. In the case of the K130, a new feature has been added to switch between 3-D and 2-D while maintaining the same deck level and zoom factor (Figure 6). A two-dimensional view has been determined to provide better visibility in some cases when ship systems or equipment are presented as overlay on the GAP. The GAP at the overview level shows only high-level information such as critical alarms. As the zoom factor is increased, additional pre-determined information becomes available (see Figure 7). For example, as the zoom factor is increased, detailed information, such as section markings, room numbers etc. become visible. This again ensures that the overall information presented does not overload the operator. In addition, selected ship systems such as fuel bunkers, electronic equipment rooms, and ammunition rooms, can be presented as an overlay, on the GAP page, by activating them with the layer feature seen on the right side of Figures 5 and 6. These ship systems can be set to show at all zoom levels, or only at predetermined zoom levels. For example, if a crew member assigned to fight a fire needs to know where the closest fire hose connection point is, there is an available GAP layer that shows fire hose connection points. By navigating to the area of the fire, the operator can provide information on all available hose sockets in a given section, right down to the corridor or room number. Other examples of ship systems that can be presented as an overlay on the GAP page are fuel systems, ammunition bunkers, sea water cooling systems, and cable routings. On a ship such as the K130, typically, there are about 20 to 30 different ship systems that can be activated on the GAP page.
Navigation within the GAP is easily achieved using normal windows style navigation concepts such as zoom or rubber-band to focus on a particular area of interest, point and click to select and area or compartment, and right click to obtain further options such as CCTV view or killcard access. Any damage or emergencies captured by the IMCS sensors are automatically plotted on the GAP page. The plotting window allows operators to manually plot reported emergencies, based on verbal or other reports. All plots on the GAP are available to all users within the IMCS, including the CDS operators. For added ease of navigation, the side-view of the ship is shown to assist in navigating within the gap while at higher zoom levels. Clicking on a deck and section of the side view automatically changes the operators GAP view to the area that was selected. Finally the alarm and event window allows operators to navigate directly to an alarm or event by clicking on the relevant alarm.

Killcards are another powerful feature of the BDCS. Whereas killcards have existed previously as written checklists to the damage control crew, integration of the killcards means not only that the checklist has been integrated into the IMCS, but that the functions of the killcard (starting stopping equipment and/or automatic sequences) has also been automated. Figure 8 shows a typical killcard. A new feature added to the K130 IMCS is a killcard builder. This feature was added as a result of the experience on the F124 programme. The F124 killcards were designed and implemented during the design and construction of the frigate. Following the commissioning of the ships, and the experience of operation, it was recognised that some of the procedures originally provided for handling different emergencies could be improved or are actually handled differently. As a result, the Navy can now modify killcards online. This enables the Navy to adapt killcards, often conceived during the design phase and without the benefit of the experience of operating the ship over a long period of time, to the actual operating environment of the ship. The killcard builder not only allows the operator to enter the procedural information, but also gives access to machinery commands and automatic sequences.
may be considered to be confirmed automatically if two separate and unique sensors (e.g. smoke and flame detector) both report a fire. Fires where only one sensor has been activated can be confirmed manually. Once the fire event is confirmed, several automatic sequences can be initiated depending on the doctrine of the Navy. Typically, these sequences involve closure of doors and ventilation system to isolate the blaze, initiation of automatic fire-fighting procedures if the room is so equipped, and the starting of fire-main pumps and opening of valves. It also involves starting pumps and opening valves to remove standing water caused by the fire hoses, and configuring the HVAC system to evacuate smoke once the fire has been extinguished. These automatic procedures apply equally to flood and NBC events.

The BDCS is also equipped with a system that enables the main damage control operators to request the transfer of personnel or materiel to a particular location electronically, without the need for verbal communication.

Data Acquisition and Automation

With almost 7000 sensors and actuators to manage, the IMCS must provide a flexible and effective approach to data acquisition and control. This is achieved through the use of variable density Remote Terminal Units that are able to interface to a wide variety of sensors and actuators. Such interfaces are either directly wired to the plant devices or can be provided through serial links and Fieldbuses.

The modern IMCS must be seen as more than a remote control and monitoring system though. The power an IMCS brings to a ship is not just to centralise the data on an operator screen that allows an operator to react in case of an alarm or a propulsion order, etc. The capability of a modern IMCS is only realised when the shipyard and/or end-user have clearly defined their automation doctrine and requirements. All machinery on the K130 Corvette is automated to the customer requirements. This may sound standard, but with 7000 sensors on a 2000 tonne ship, it is clear that this is not just another remote control and monitoring system, and that the level of automation is extremely high. The algorithms that are implemented help to reduce the normal load on the operator, and also allow for reduced watchstanding in the MCR during normal sailings.

The data acquisition units or RTUs are based on open architecture backplane electronic modules, which integrate both signal conditioning and processing functions, and provide optical isolation for field signals. Choosing an open architecture system has the benefit of assisting obsolescence management. Hardware that is built to open and internationally available standards that include a specific form-factor as well as electrical interfaces ensures that hardware will be available on the market for many years to come. The RTUs acquire plant sensor data, perform plausibility tests, check for limit violation, transmit the data to other IMCS subsystems as required, process automatic control sequences, output control signals to actuators, and perform on-line and off-line built-in tests. The automatic propulsion control and power management software are resident in the RTUs together with control software for other platform machinery and systems. The exact same software resides in every RTU. The RTU software is pre-loaded on the CPU, so there is no need to download software from a server in case of re-installation. On power-up, the RTU recognises its function (propulsion RTU, Electrical RTU, etc), and uses only those software modules applicable. These units are ruggedised for installation in warship machinery spaces and can withstand the most stringent environmental specifications.

Due to space restrictions on board smaller vessels, in some cases, one RTU enclosure can contain two processors, which are completely independent of each other, even in power supply. Such a configuration has been used on some RTUs on the K130, and has received classification approval from Germanischer Lloyds.

On Board Training System

The IPMS includes an advanced OBTS capability whereby the operator consoles can also operate in training mode. An independent databus interconnects the operator consoles to facilitate full-mission team training or individual operator training on board the ship. One of the consoles can be designated as the instruction facility while the other consoles are operated in training mode. One or several of the consoles must be in control mode to manage the ship while the rest of the consoles are used for training. The Deutsche Marine’s requirement to be able to switch from training mode to real mode within one second was achieved through the use of a keyboard/video/mouse (KVM) switch on the console which switches the console hardware to the completely independent OBTS computers. It is also possible, depending on customer requirements to have the OBTS reside on the same computer as the control software, and such implementations have been Class approved. In this case, L-3 MAPPS has the flexibility to tailor the system to the customer requirements.

The OBTS uses real-time high fidelity simulation models of the ship’s hull and platform machinery and systems and includes an emulation of RTU automation functionality. Pre-defined customised training scenarios can be executed or a new scenario created by the instructor on-board the ship. Training data is generated by high fidelity real-time simulation models, and the operator consoles behave exactly as they do during normal control mode operation. The exact same HMI software is used in OBTS mode, thus providing very high levels of training realism. The same
software is also used for shore-based training facilities. This has the added benefit of eliminating trainer obsolescence which can be experienced if the training system or trainer is purchased from a third-party. Any update to the IMCS software is automatically extended to the OBTS and shore-based trainers. L-3 MAPPS’ expertise in both simulation and controls technologies were used by the company to implement pioneering OBTS functionality on warships in the late 1980’s.

3. CONCLUSION
Platform automation has become an integral part of the design and planning of all modern warships and is continuously increasing in complexity. The K130 platform automation system, or IMCS, was successfully implemented and benefitted from the applied knowledge of end-user, prime contractor, shipyard and IMCS supplier.

BIOGRAPHY AND CONTACT INFORMATION

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