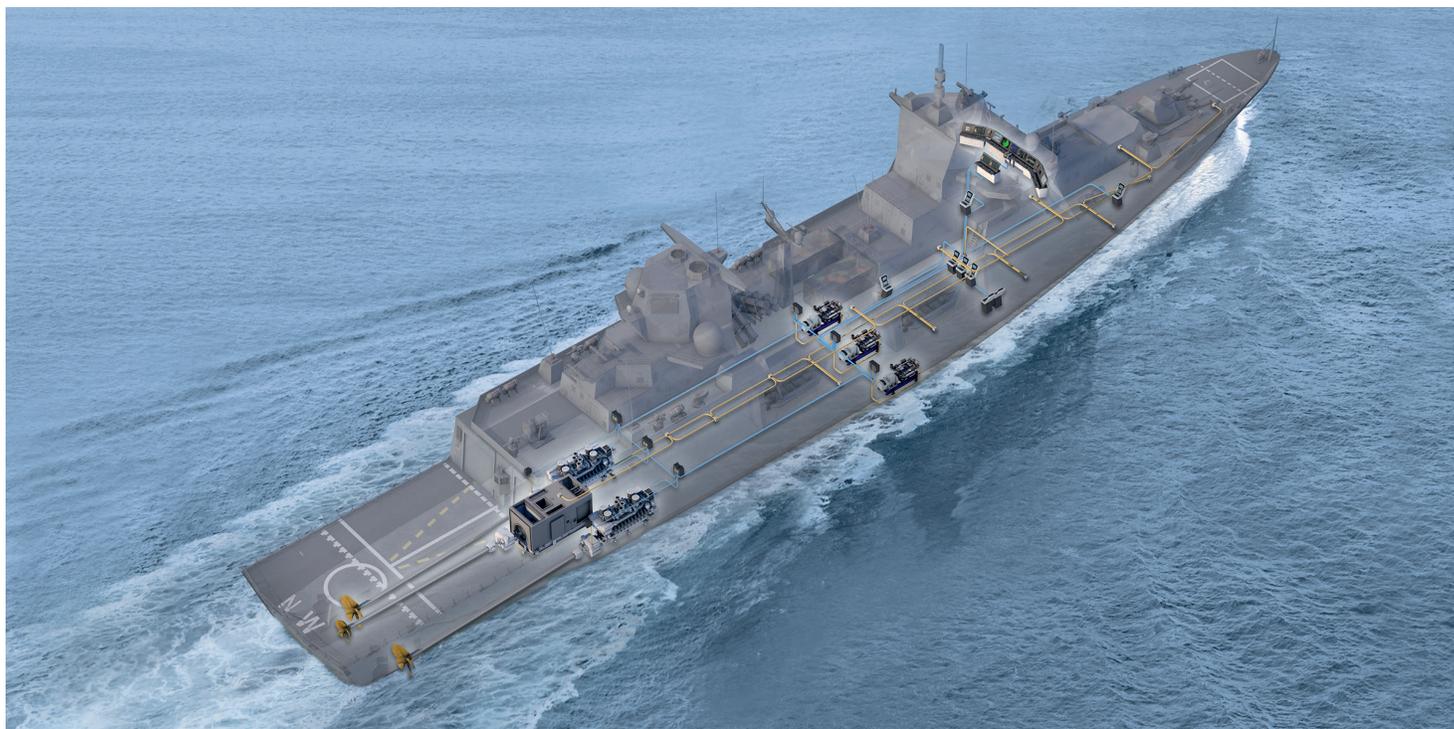


Callosum Automation System: Equipment Health Monitoring enables maximum availability and low life-cycle costs for deployed vessels



Authors:

Mario Schulte

Equipment Health Monitoring Project

Bartosz Kowalinski

Project Leader Equipment Health Monitoring

Oliver Haller

Team Leader Marine Automation

Naval forces throughout the world are currently experiencing major changes in the roles they are required to perform. Their own needs are changing in response. Today's modern maritime defence organizations already have to complete long-term missions in remote regions – and they need to do it with reduced crews that may well be redeployed after just a few months. Missions like these can last several years and they are only possible if vessels can operate without major overhaul and can be maintained by on-board crews. That is only achievable with the aid of a sophisticated automation system. In future, continuous access to extensive and reliable data on vessel status will be essential if naval forces are to plan operations more effectively and reduce costs. This calls for an Equipment Health Monitoring System (EHMS) that can provide real-time information on the condition of the vessel and its propulsion system. Service and maintenance assignments shall not rely on fixed schedules but are to happen in response to actual equipment condition. The MTU Equipment Health Monitoring System, an extension of the company's Callosum Ship Automation System, meets all these demands. It analyses and presents digital engine data to further enhance vessel availability whilst simultaneously cutting life-cycle costs.

**1. Equipment Health Monitoring System:
Definition**

Equipment Health Monitoring (EHM) is a complete concept for maintaining and monitoring ship propulsion and on-board systems. EHM systems generate a real-time picture of the technical status of a vessel or even

of an entire fleet, providing continuous access to information on the condition of every on-board system for monitoring and analysis. That makes them highly effective tools for increasing the availability of vessels a reducing life-cycle costs. In addition, an EHM system simplifies maintenance of ship propulsion systems by



Figure 1: Visualisation of operating hours and upcoming maintenance for the complete propulsion and on-board electric power generation system in Callosum MT.

automatically displaying information on maintenance work due and providing step-by-step animations, illustrations and explanations on how to carry it out. The EHMsystem from MTU is part of the company's proven Callosum Automation System (Fig. 1).

2. Callosum: The modern naval vessel's nervous system

MTU's Callosum Automation System is one of the world's most modern monitoring and control systems for naval vessels. Its development has benefited from decades of experience in automation technology built up by the company which supplied its first automation system as long ago as 1964. Since then, more than 5,000 vessels have been equipped with MTU automation systems.

MTU developed its integrated ship automation system Callosum specifically to meet the requirements of naval vessels like corvettes and frigates as well as other governmental ships. Like its eponymous counterpart in the human brain (the corpus callosum) MTU's automation system exists to facilitate coordination and the exchange of information between various subsystems. With Callosum, these are the different equipment systems on board a ship – propulsion, on-board electric power generation and, for example, the cooling water system. The concept integrates acquisition, data-linking and visualization in a single user-friendly system (Fig. 2 and 3).

Callosum comprises four modules that can be installed and used individually or combined to suit the customer's needs. Callosum MC (Integrated Monitoring and Control System) is the basic monitoring and control system that allows crews to monitor and control the entire propulsion system, on-board electric power generation and all other subsystems on the vessel. The other three Callosum modules provide the ideal complements: Callosum DC (Battle Damage Control System) guarantees precise damage location and rectification, for example, in the event of fire, flooding or collision. Callosum TS (Onboard and Land-based Training System) offers realistic crew-training scenarios whilst Callosum MT (Maintenance Support System) provides support covering on-board service and maintenance issues.

3. Callosum MT: Service and maintenance with EHM functionality

MTU designed and developed its Callosum MT maintenance and service system specifically for long-term, high seas missions. With its new functions, Callosum MT serves as a high-performance Equipment Health Monitoring System capable of playing a significant role in increasing vessel availability, enhancing reliable operational planning and cutting maintenance and materials costs in order to meet the demands that modern maritime defence forces will face in the future.

Callosum MT bundles all available data on the propulsion

and on-board electric power generation systems, employs sophisticated techniques to analyse that data and then makes the results accessible for the crew on all of the displays in the automation system network. Data can also be stored and transmitted for further analysis at a later point.

Callosum MT is based on three mutually complementary modules covering three different maintenance aspects. Corrective Maintenance covers support in concrete fault events whilst Preventive Maintenance covers servicing on the basis of a digitised maintenance schedule. To some extent, the Condition-Based Maintenance module can be seen as the master element as it facilitates supervision of the vessel on the basis of the actual condition of the equipment fitted. The system utilizes the latest analysis techniques to evaluate sensor data and make results available.

3.1 Corrective Maintenance

With the introduction of the Corrective Maintenance module, MTU set new benchmarks for automation systems. When Callosum MT's electronic diagnostics program detects irregularities, signs of wear or functional defects, the system does more than simply report them automatically to the vessel's crew. The report also includes information on the source of the fault. Once the crew has located that source, the system automatically guides it through the appropriate repair process: The components and tools needed



Figure 2: Control centre with Callosum displays.

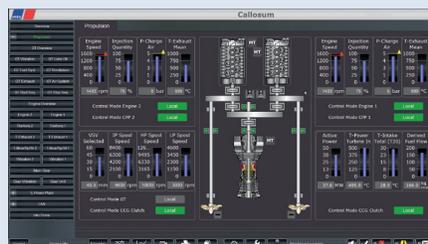


Figure 3: Callosum can also monitor and control combined propulsion systems.



Figure 4: 3D videos provide precise instructions to staff on how to perform repairs.

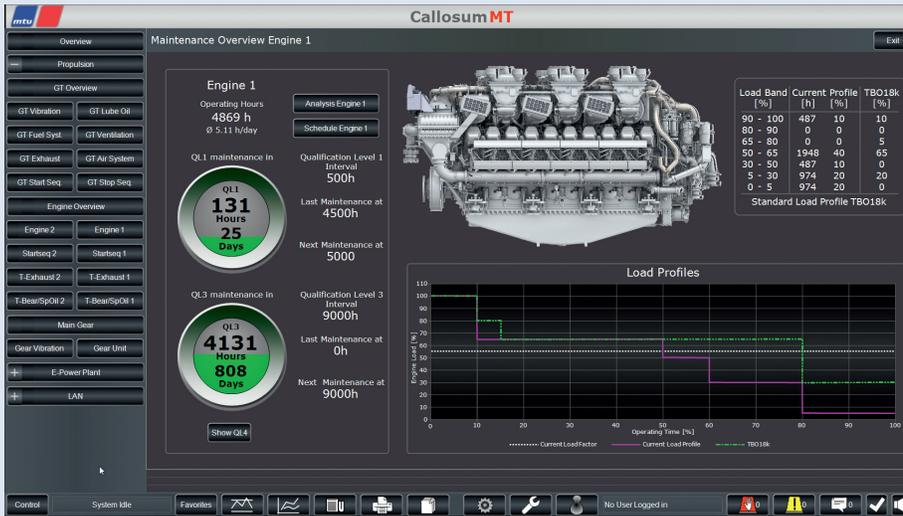


Figure 5: Real-time comparison of actual load profile with planned operating load.

(including ID numbers) for repairs are displayed. 3D videos provide precise instructions to staff on how to perform the individual step (Fig. 4).

3.2 Preventive Maintenance

Callosum MT with the EHM function now also offers a digital maintenance schedule based on the actual load profile of the engine in service. On purchase, users of MTU engines for naval vessels specify how their engines are to be operated after commissioning. Selection is made from a range of load profiles and appropriate maintenance schedules are then determined depending on the relative proportions of operation within the different load ranges. The aim is to ensure that components are replaced before a defect occurs. In planning its maintenance intervals, MTU is able to draw on decades of experience and expertise gained from working with customers throughout the world.

Until recently, vessel operators and crews had little accurate idea of the load profiles their engines actually operated in practice. Frequent crew changes have aggravated the situation. Now, the extended version of Callosum MT gives crews continuous oversight of their

engines' operating load. The automation system screens provide clear and intuitively comprehensible views showing engine operating hours, what maintenance procedures are due and when (Fig. 1). For the first time, crews can now also see the extent to which the load profile details originally agreed actually match operational reality and whether or not the maintenance intervals need to be modified (Fig. 5).

The wear that engine components undergo is linked directly to the load they are exposed to during operation. Load profile analysis is therefore a crucial factor in evaluating engine condition. For example, where engines have been running at full load for longer than originally assumed, servicing may be needed earlier than scheduled to avoid unplanned downtime. By the same token, load profiles that are less demanding than expected can result in extended maintenance intervals and modified schedules. This concept significantly improves the reliability of vessel availability calculations and reduces the risk of unexpected downtime. In addition, the timing and scope of maintenance processes can be significantly improved – with all the attendant potential cost savings that brings.

The need to consult printed maintenance schedules and operating instructions is a thing of the past because now all of these individual documents are integrated in the automation system. That makes handling support materials much simpler and it significantly reduces crew training requirements.

3.3 Condition-Based Maintenance

Condition-Based Maintenance offers the potential for far-reaching improvement in the operation and maintenance of ship propulsion systems. With this new capability, Callosum enables the continuous provision of information about propulsion system health in real time. The concept is based on 'big data' evaluation techniques implemented by MTU specialists with long years of experience and a close knowledge of specific customer requirements. In future, the concept will make it possible to match engine maintenance schedules much more accurately to actual engine condition.

Among the techniques MTU employs to achieve this goal are the trending function and baseline analysis. The trending approach involves collecting and analysing large quantities of measured engine data. All binary and



Figure 6: The trending function for relevant engine metrics helps to prevent damage.



Figure 7:
Baseline analysis helps to identify potential faults before they occur.

analog data are logged at least once an hour, or whenever a change of more than 1% occurs, and are saved in a dedicated storage. This makes it possible, for example, to recognize how different engine parameters behaved prior to a fault event. This is the first stage in realizing a ‘machine learning’ process that involves the generation of knowledge from experience. Artificial systems learn from examples and can generalize on them once the learning phase is complete. Once Callosum has completed the learning phase, if similar data are recognized in an engine during actual operation, an alarm can be triggered before the related fault re-occurs (Fig. 6). The engine is effectively protected and damage is prevented.

Baseline analysis also helps to identify potential faults before they occur. Initially, this involves collecting and storing measured engine data during trials before the vessel goes into operational service. The relation between vital parameters is then compared – for

example, the relation between load and fuel-oil consumption or between power and exhaust gas temperature. The resultant baselines illustrate how a ‘healthy’ engine behaves. To make sure that the baselines remain accurate, they need to be regularly updated manually to reflect the relevant applications, environmental factors and other operating parameters that influence engine behaviour.

During operation, Callosum MT displays actual values and compares them with baselines in real time (Fig. 7). If values over- or undershoot specified tolerance limits, the system generates a heads-up message so the crew can take action to avoid potential problems and prevent any serious damage. Heads-up warnings derived from baseline analysis are generated before an ‘acute’ alarm is triggered.

Callosum MT is capable of implementing and displaying these analyses for all MTU marine engines. System

architecture also accommodates the Rolls-Royce MT30 marine gas turbine so that a highly efficient EHMS function is likewise available for combined propulsion systems that include Rolls-Royce components.

4. Conclusion

With Callosum and its latest Equipment Health Monitoring capability, MTU is able to offer the automation system of the future on a platform that has been convincingly proven many times over under operational conditions. With the enhancement of Callosum, MTU today already meets demands that modern naval forces can expect to face in the future. It makes reliable and plannable long-term missions possible even for vessels with small and frequently changing crews. The automation system utilizes the latest analysis techniques like machine learning to minimize maintenance needs, to increase availability and planning reliability for forces on active missions and to cut life-cycle costs.

MTU Friedrichshafen GmbH
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The MTU brand is part of Rolls-Royce Power Systems, providing high-speed engines and propulsion systems for marine, rail, power generation, oil and gas, agriculture, mining, construction and industrial, and defense applications. The portfolio is comprised of diesel engines with up to 10,000 kilowatts and gas engines up to 2,530 kilowatts power output. MTU also offers customized electronic monitoring and control systems for its engines and propulsion systems.



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