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Remote Monitoring – Bridging the Technology Gap between Workboat Operations and Other Industries

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SYNOPSIS

Having real time data on important equipment during workboat operations has already proven to be beneficial to owners, ensuring that a high level of safety and efficiency is achieved. Collecting and analysing such 'big data' using the latest technologies, and thereby understanding equipment performance, allows for operational fine tuning. It can also provide significant benefits in areas such as life-cycle cost improvement, safety, planned maintenance, performance benchmarking, emissions reduction, key component wear rates and long term equipment reliability improvements by OEMs.

This paper investigates today's capabilities, and considers how these technologies – already well established in other similar B2B industries such as turbomachinery, power plants and commercial vehicles – can be harnessed more extensively in the marine workboat sector.

INTRODUCTION

Today it is possible to collect enormous amounts of data from multiple pieces of equipment and use networking systems to securely transfer this information to virtually anywhere in the world. This technology is referred to as the Internet of Things (IoT)[1] and, looking ahead, such systems will likely become more widespread at a very rapid rate.

How can the marine industry in general, and, more specifically, stakeholders in the marine workboat sector, take full advantage of this ongoing technological evolution? The ability to monitor the important performance and safety data of onboard equipment (such as engines, gearboxes, thrusters and propellers) for a vessel working at sea offers tremendous opportunities to improve the efficiency and reliability of the workboat over its lifetime. In addition, to be able to carry out this monitoring activity in a location remote from the vessel allows for expert analysis of the data. This in turn paves the way for improvement adjustments, or preventative condition based maintenance (CBM) of the equipment.

Of course, remote monitoring (RM) is not a new concept, but merely collecting vast amounts of raw data is not the most important point to consider. The critical questions are:

- How can you extract the useful information?
- What can be learnt from its analysis?
- How can this be provided to help an operator improve the safety, efficiency and reliability of a workboat fleet?

OTHER MONITORING METHODS

Use of the very latest RM technologies and capabilities, targeted at the sensors of essential components, is the most modern way to provide protection to valuable pieces of equipment, such as the engines. However, it is important to remember that this is not the only method capable of being employed, and RM may also be considered as an enhancement to more traditional monitoring processes. For example, analysis of operating fluids must also play a part in the overall protection package for onboard equipment. Sampling and subsequent laboratory analysis of lubricant oils, fuels and coolants continues to be a very useful element of the CBM toolbox, playing a vital role in ensuring that the engine is healthy and operating in the most efficient conditions.[2]

HOW RM WORKS, AND WHAT IS PROVIDED TODAY

RM, and its extension CBM, can be roughly broken up into three functional areas, explained below. In the

OPV									
Lube oil system	Lube oil temp. Engine In	Lube oil pressure Engine In	Lube oil pressure Turbocharger In	Lube oil temp. Turbocharger Out					
Fuel oil system	Fuel oil temp. Engine In	Fuel oil pressure Engine In	Fuel oil viscosity Engine In	Fuel admission (fuel rack pos.)	Suction throttle position	Rail pressure	Temp. Flush valve	Injection duration	Saftey valve temp.
Air system	Exhaust gas temp. Cylinder Out	Exhaust gas temp. Turbocharger In	Exhaust gas temp. Turbocharger Out	Turbocharger speed	Charge air pressure	Charge air temp. Cylinder In	Air pressure Compressor In	Air temp. Compressor Out	Ambient air temp.
Powertrain system	Main bearing temp.	Splash oil temp.	Generator power	Engine speed					
Auxiliary system	Start air pressure	Stop air pressure	Control air pressure						
Cooling system	Coolant pressure Engine In	Coolant pressure Intercooler LT In	Coolant temp. HT Engine In	Coolant temp. HT Engine Out	Coolant temp. Intercooler HT In	Coolant temp. Intercooler LT In	Nozzle coolant pressure In	Nozzle coolant temp. In	

Figure 1: A typical example of the sensor package fitted to an MAN Diesel & Turbo medium speed marine propulsion engine

following examples, marine engines have been used, but the same process would equally apply to other items of workboat equipment, such as gearboxes, thrusters, large pumps or motors and propellers.

Data collection

An array of sensors, mounted on the engine, continuously monitors many essential parameters of performance and safety, including critical temperatures, gas or fluid pressures and flow rates. These sensors also have pre-designed critical levels, and will trigger an alarm and/or a shutdown if the minimum or maximum safety parameter is exceeded. These limits are determined from the application of operating profile experience and an extensive product performance knowledge-base *(Figure 1)*.

Data transfer

The collected sensor data is then transferred to a remote destination. This can be accomplished in different ways, subject to the contracted agreement between the operator and the OEM, as well as the level of GPS capability or internet availability at the vessel's normal operating location.

For example, a harbour tug is likely to remain operating within range of land-based internet or mobile 3G/4G networks for much of the time, and this offers a relatively low cost way to transmit data when compared to a satellite GPS network. Transmission could be arranged as a continuous stream of performance data, or bundled data packages sent on a daily or weekly basis. With regard to engine safety, the vessel might only be required to send data when a critical safety parameter has been exceeded.

Another very important factor to consider is data security. Equipment data will be transferred over a public internet or GPS system, and, as such, the risk of hacking is very real, either into the equipment itself or the customer's or OEM's IT system or local network. In addition to standard means of protection, such as password protection and access permissions, robust firewalls must be employed at both ends of the data transfer network to ensure that the sent data remains confidential at all times *(Figure 2)*.[3]

Data analysis and recommendations

Once the data has transferred to its predetermined destination, which could be the fleet manager's office or

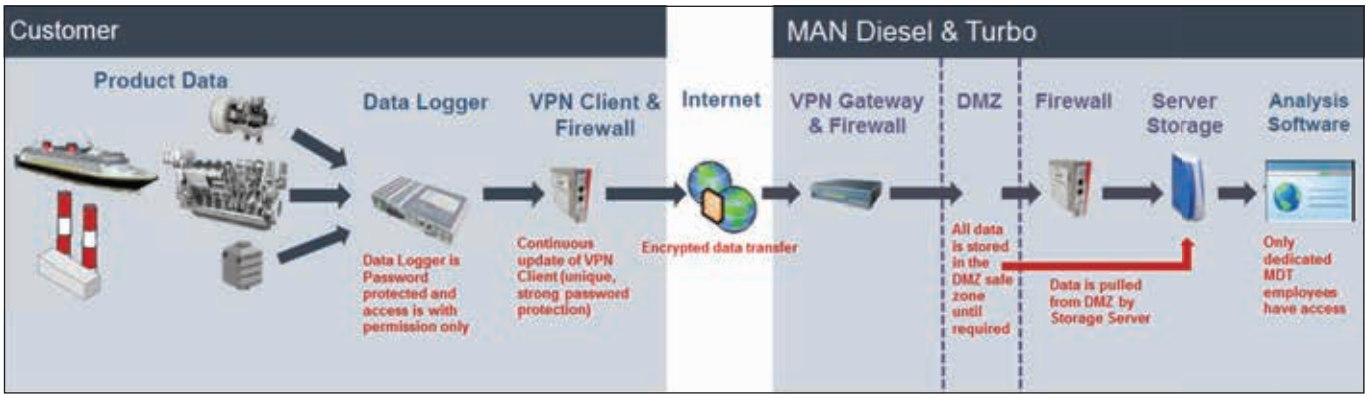

Figure 2: An example of some of the measures taken for data protection and security employed by the MAN Diesel & Turbo RM network[3]

the OEM's local aftermarket support hub, smart analysis software as well as the experience-based knowledge of experts is employed to review the received raw data. The resulting analysis of engine performance and safety data can then provide important information in order to determine factors such as potential operating cost reductions and improved engine reliability.

Some typical examples of these benefits include:

- An analysis of engine (vessel) load cycles within the workboat fleet, enabling benchmark comparisons for optimisation of specific engine settings to minimise fuel consumption, as well as reducing emission levels;
- Determining a planned critical maintenance schedule, which improves fleet management efficiency and optimisation of workboat fleet availability;
- Quick diagnosis of faults, enabling rapid repair and return to operation, and reducing workboat downtime;
- Early identification of potential risks of component failure beforehand, leading to replacement during normal maintenance cycles;
- Improving long term engine reliability through the re-engineering of identified potential weak areas or components.

WHERE RM IS USED IN TODAY'S MARITIME SECTOR

Many equipment providers today offer numerous RM and CBM packages, in ship building as well as ship operating industries. These packages vary considerably in terms of features, ranging from simple remote alarm warnings to very complex analysis of equipment performance, which can be followed up by comprehensive improvement and predictive maintenance recommendations.

MAN PrimeServ Online Service[4] offers a secure connection to continuously monitor engines. This gives the customer the security of knowing that a connection is present in an emergency, and that they therefore do not have to take any action at the same time. If an operator needs assistance with an engine issue, a service engineer from the online service centre can connect to the engine and look for the best solution together with the customer.

Figure 3 provides a typical example of where RM can prevent a potentially catastrophic and very expensive engine failure. In this case, fluctuating and rising exhaust gas temperatures were identified from the engine data. Using experience, it was possible to provide a narrowed-down list of potential causes to the onboard engineers. One of these was minor damage of the thrust pad, an early indicator of more serious issues. Upon local inspection, this was confirmed as being the likely root cause of the problem and a replacement was provided. Without such early identification and subsequent action the thrust pad would likely have broken completely, leading to the failure of a whole cylinder, which in turn could have caused damage to the camshaft.

With expert analysis and operational experience, this kind of failure was prevented and significant costs saved. If an automatic algorithm for this particular event

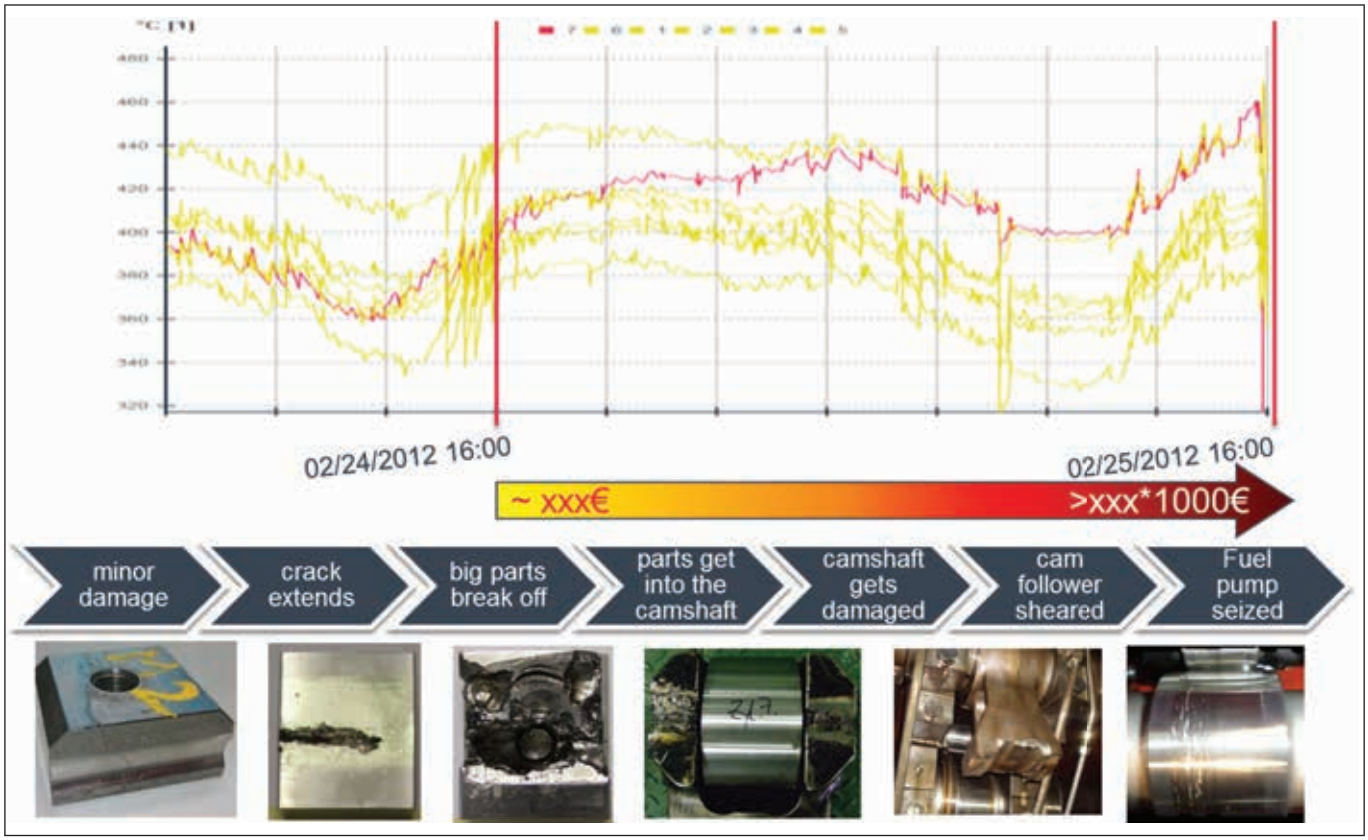

Figure 3: RM can prevent a potentially catastrophic and very expensive engine failure

had been implemented, however, there would have potentially been quantities of false alarms, leading to faulty conclusions and a waste of the onboard engineers' time.

To prevent such a situation from even developing, engine operating data can be transmitted daily to dedicated servers via a secure VPN tunnel, where it is automatically analysed by sophisticated software as well as by technical specialists. Measurement data from more than 100 vessels, including exhaust values, bearing temperatures, speed, oil pressure and air temperature, arrives at MAN's online service centre. The engineers can analyse up to 140 engine operating parameters, depending on engine type, and between 1.5-3MB of engine data is recorded every single day for each engine.

A broad spectrum of diagnostic options is available to prevent an emergency, beginning with a simple sensor defect detection and extending to long-term trend analysis, in which discrepancies can be spotted before an alarm is triggered. For example, there could be marked pressure variations in the lube oil system of the diesel unit. The experts ashore would suspect a soiled pilot valve to be the cause and pass this information on to the onboard vessel engineers. Today's propulsion equipment is complex – any irregularities detected may have a number of causes. Experts onshore may not only pinpoint the irregularity, but specialists can make recommendations as to how it can be eliminated. In clear cases, even the replacement spare part number can be provided, if required. The continued existence of a fault can also be tracked by online service centre experts.

Figure 4 shows a CBM case study for a diesel propulsion engine where RM and online service support prevented an alarm due to lubricant oil contamination. The chart shows that over a period of eight months the main bearing temperatures gradually increased (as indicated by the trend line). Expert analysis and experience suggested that this could be due to oil contamination or viscosity change, and following data extrapolation techniques it was possible to notify the customer 10 weeks in advance that a lubricant oil change should be undertaken to avoid triggering an alarm, which would likely result in an inconvenient engine shutdown.

In multiple-engine systems, detailed reports on each engine are produced for the chief engineer, or site reports produced to give managers an overview of the equipment installation. A traffic-light system indicates the condition of the engine and possible abnormalities. It is important always to explain to the customer what the problem is, where it occurs and how it can be resolved. A red light indicates that something has to be done immediately to maintain high engine reliability. A yellow light shows that the engine is not running at optimum levels, but that availability is not yet in jeopardy. Online service experts can also offer advice on how to change settings in order to operate the engine(s) more efficiently in a specific operating environment.

All engines are designed for particular tasks, whether for producing electricity in a power plant or propulsion on a workboat. However, even in the same application, not all engines behave in the same way. This can be taken into consideration by monitoring an electronic

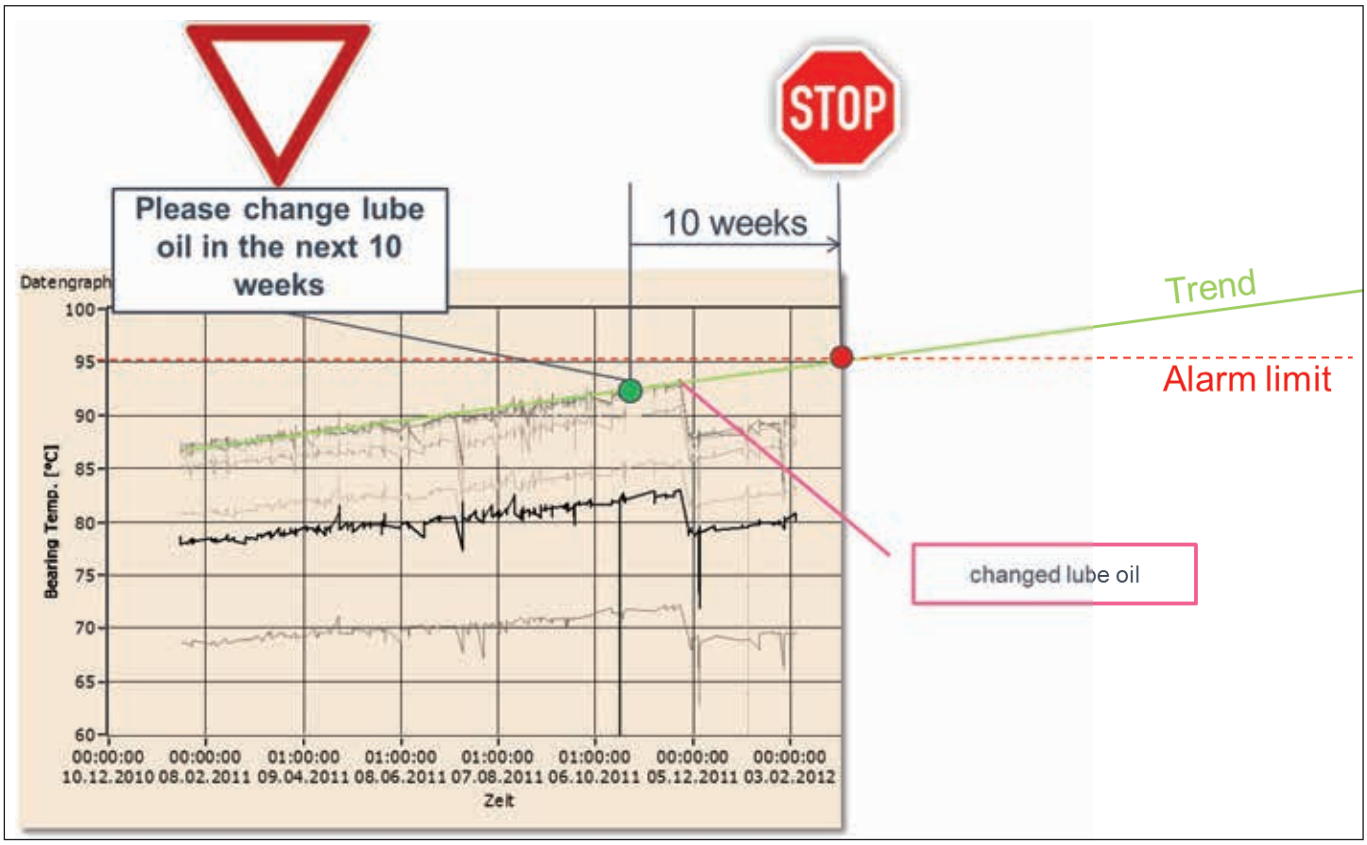

Figure 4: CBM case study for a diesel propulsion engine

'fingerprint' of every engine. If this changes over time, the engine's efficiency changes also. An online service will try to ensure that the fingerprint remains the same for as long as possible, by comparison of the optimum engine condition with its momentary status on a continuous basis.

Most marine propulsion suppliers offer similar equipment and services to those described above, while others provide alternative RM packages, including complete equipment support suites, where not only their own installed equipment is monitored, but also a complete pre-defined selection of critical machinery and components on board the vessel.[5-11] There are other examples of providers who supplying standalone monitoring devices that can be quickly and easily adapted and set up for any equipment brand and required parameters.[12]

RM SYSTEMS USED IN OTHER INDUSTRIES TODAY

RM systems are also employed in other industries *(Figure 5)*. For example, in steam turbine machinery strict compliance with a specified steam quality, by using suitable water treatment and conditioning, is fundamental for the avoidance of potential damage to the turbine and steam-carrying plant components. Even short-term operation of a steam turbine unit outside specified operating conditions can lead to impairment or damage. To protect the turbine from damage due to deposits and corrosion, an online analytical system will constantly monitor the steam quality to identify and provide an alert, therefore avoiding expensive risk of failure.[13]

In addition, in the field of powerplants, RM and CBM equipment and infrastructures as described above are installed in many global locations, and are already providing customers with many significant benefits on a daily basis, including:

- Plant efficiency improvements (eg, multiple engine power levels and, therefore, fuel consumption, are matched to typical load profiles)
- Preventative maintenance solutions (eg, lubrication oil, exhaust gas and main bearing temperature analysis)
- Long-term trend analysis to safely and precisely implement any necessary adjustments, specific to the customer's plant, equipment and operating profiles.

Another industry where significant RM capability is already implemented is the automotive sector. Commercial vehicle manufacturers are developing complex RM systems that provide new business and value-added models in support of increased operational efficiency for their end-customers. These customers, such as supermarket chains, are logistical providers on a meta-level and merely operate trucks as part of the process of transferring goods from A to B. Therefore, the real added value of these platforms is not for the truck buyer, but is aimed at the complete logistics provider.

Coming in varying degrees of complexity, these systems not only include engine or equipment maintenance and safety monitoring, they also include logistics planning and tracking tools, as well as vehicle fleet management[14.] Driver training programmes connected with improving operational efficiency are also well developed in support of online efficiency monitoring.

Figures 6 and 7 show the 'RIO' concept[15], by which

Industries / RM Features	Marine	Powerplant	Turbo-machinery	Commercial vehicles
Condition-based maintenance	●	●	●	
Efficiency calculations	●	●	●	●
Equipment safety monitoring	●	●	●	
GPS tracking	●			●
Fuel media quality monitoring			●	
Historical date storage		●	●	
Logistics/workload management				●
Operator efficiency training				●

Figure 5: A comparison of RM and CBM technologies in different industries

Figure 6: Challenges addressed by the RIO concept

MAN Truck & Bus uses RM and CBM in the commercial vehicle industry. RIO is a logistical concept working on a meta-level, incorporating every aspect of the logistical B2B supply chain. This means that a single monitoring platform handles everything along the supply pathway, including vehicle location and availability, and advanced notification for service and maintenance planning purposes. It is not just confined to the truck's engine. The system also monitors all aspects of vehicle equipment and performance, providing feedback for improvement opportunities. In addition, it also allows other vehicle brands to be monitored in the same manner, so that an entire fleet can be monitored in the same way.

ADAPTING THESE TECHNOLOGIES TO WORKBOAT APPLICATIONS

Some of the RM features shown in *Figure 5* are already in use in the marine market sector:

- Condition based maintenance. OEMs are already providing recommendations, based on RM data analysis;
- Efficiency calculations. Calculations are provided to show where fuel efficiency benefits can be achieved based on load profile analysis;
- Equipment safety monitoring. Key components, such as engines, are already fitted with numerous sensors to retrieve operational performance data, which can be analysed;
- GPS tracking. All sea-going workboats are equipped with some form of GPS tracking equipment.

Which other aspects of RM have a chance to be developed, presenting the operator with additional benefits?

- Fuel media quality monitoring. Today, fuel sampling and analysis is possible manually. In the future, as with the steam analysis described above, it may be possible to remotely monitor fuel quality and cleanliness to offer early indications of contamination before any damage can be done to components such as fuel injectors.
- Historical data storage. Provision of a database for harbour layout, local ambient conditions, tugboat utilisation data at a particular port, and vessel status and location tracking. This may provide a useful opportunity for the fine tuning of operational profiles of workboats in particular locations.

Figure 7: Visual representation of the RIO concept

Industries / RM Features	Marine	Powerplant	Turbo-machinery	Commercial vehicles	Workboats ● Existing ○ Future
Condition-based maintenance	●	●	●		●
Efficiency calculations	●	●	●	●	●
Equipment safety monitoring	●	●	●		●
GPS tracking	●			●	●
Fuel media quality monitoring			●		○
Historical date storage		●	●		○
Logistics/workload management				●	○
Operator efficiency training				●	○

Figure 8: A comparison of RM and CBM technologies in different industries, including workboats

- Logistics/workload management. As already employed in the commercial vehicle industry, fully integrated, close management of vessel workloads could include mobile phone apps providing alerts and real time updates, planned maintenance cycles, and efficiency calculations against known benchmarks.
- Operator efficiency training. Hands-on as well as classroom-based training of workboat crews may ensure that the crew operates in all locations at optimal levels.

Figure 8 shows a comparison table once again, but now with an additional column showing potential future features for the workboat industry.

FUTURE OUTLOOK

The marine industry has traditionally been a late adopter of new technologies, usually favouring established solutions and waiting for other industries to take the risks and reap the rewards.

It is widely acknowledged that in the last decade major breakthroughs, which will affect all aspects of both personal and professional relationships, have been experienced. Several governmental or corporate initiatives are already in place to drive and manage this transformation, with 'Industry 4.0' being the most well-known. Furthermore, the rate of technological innovation has dramatically increased over time, together with the swiftness and impact on existing business models and practices. The diffusion of machinery at the end of 19th century took decades to take hold. The IT revolution affected the world in less than a decade. It can be reasonably assumed that these new technological breakthroughs will transform the status quo in just a few years.

As such, it is highly questionable whether the traditional conservative approach is a wise, safe, or even feasible policy. A stagnating marine market will put further pressure on operators, leaving late adopters no comfort zone to relax in. On the other hand, a blind, unfocused adoption of RM and CBM will be ineffective and uselessly expensive.

Operating on the edge of the marine industry, with interfaces and influences with other markets, tugboats are already exposed to the new challenges, and are also closer to the new opportunities. Sailing close to shores and docking frequently, tugboats are ideal technology demonstrators with little or no investment in complex network infrastructure. They also have straightforward performance metrics and high marketing exposure. For the tugboat industry, stable, secure and rapid access to the wealth of onboard data will finally pave the way for much more effective predictive maintenance, a discipline long sought-after by operators but rarely fully accomplished.

Predictive maintenance will not be the only short-term target. Smarter automation systems are already capable of interpreting data in order to discriminate between real malfunctions and false alarms, such as faulty sensors, hugely increasing the system robustness and reliability. The same technology powers assistive systems, which are able to detect potentially dangerous

conditions not only at equipment level but also at ship operation level, while providing guidance and even overriding human error.

At a different level, data can already be used to identify valuable patterns in vessel operation, allowing optimisation of equipment usage and crew training. Aggregated data is currently sold as a valuable source of information in related industries, enabling brand new business opportunities. Alternatively, high market visibility can be achieved by joining one of several 'Open Data' initiatives, backed by many governmental agencies as well as private companies.

Medium-term applications will include fully interconnected fleets across different operators, to allow flexible and efficient market responses, along the lines of modern car-sharing. As crazy at it might sound, an Uber equivalent for tugboats and workboats might be closer than it seems. Taking the above example from the commercial vehicle industry as a baseline, it is easy to anticipate a future trend where one monitoring platform will handle all workboat service in terms of vessel availability, such as the power/hour ratio, onboard equipment safety and servicing notifications, and all different OEM equipment, completely interlinked within a fleet.

Prospects over the longer term are even more extreme, and clearly point towards unmanned autonomous vehicles. In the public and private transportation industries, this is not a hypothesis any more: the transition to implementation is expected to happen in less than 20 years.

Marine operators will have more time to adapt, but even with their conservative and cautious approach, they will not be immune to the effects of automation on the whole economic and social environment. A successful transition will be much easier for those already operating smart vessels, as they will have the right experience, knowledge and mindset to properly evaluate the risks and opportunities.

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