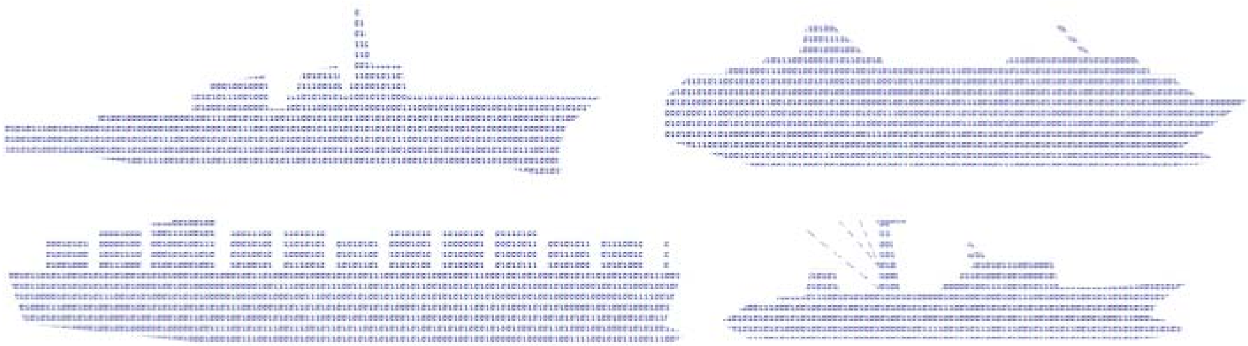
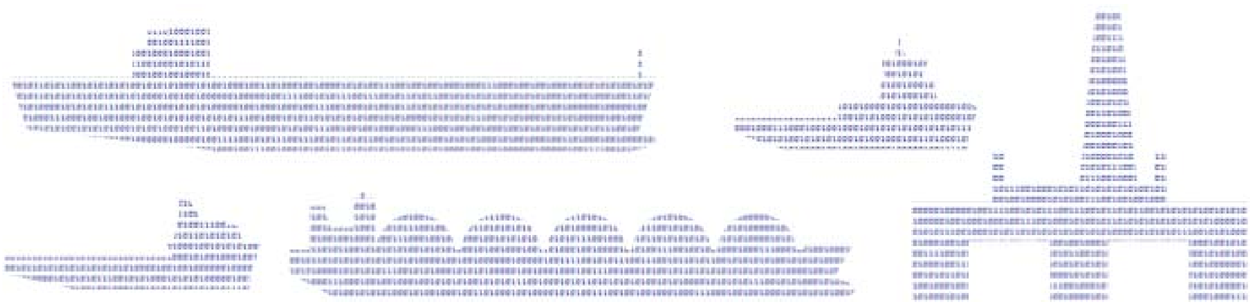


Bringing the industrial internet to the marine industry and ships into the cloud



Rob Bradenham   Ken Krooner

October 2013

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Executive Summary

The industrial internet concept, connecting machines and using automated data analytics along with domain expertise to optimize operations and maintenance, has already created significant value in many industries like power generation and commercial aviation and is now becoming a reality for the marine industry. While the opportunity across industries will exceed 10 trillion dollars per year in the next 15 years, the opportunity for asset owners, operators and managers to reduce costs, improve fuel efficiency, and increase uptime and reliability is approximately 20 billion dollars today and will exceed 50 billion dollars by 2030. Potential annual value creation for individual ships could be as high as $1M or greater when considering potential fuel savings, optimizing maintenance, decreasing downtime and increasing utilization[1].

This opportunity exists across sectors, ranging from super-tankers to inland tugboats and offshore platforms and takes into account savings across fuel and maintenance, increases in uptime and productivity and decreases in risk associated with non-compliance, specifically with regards to environmental regulations. Figure 0 lays out major value creation levers for a large cargo vessel (e.g., tanker, container, roll-on roll-off, etc). While newer vessels will have the greatest potential value creation due to existing sensors and technology infrastructure, there are likely between 20,000 and 30,000 vessels in the global fleet today which likely create an attractive ROI. These vessels already have sufficient sensors and robust enough technology infrastructure such that the required investment level is minimal and the value gained from the existing onboard data will enable substantial improvement in how the business is operated. While there is tremendous value at stake, it will also take individual owners and operators time to fully capture the value. In the mean-time, before performance analytics are fully incorporated into all business processes, even

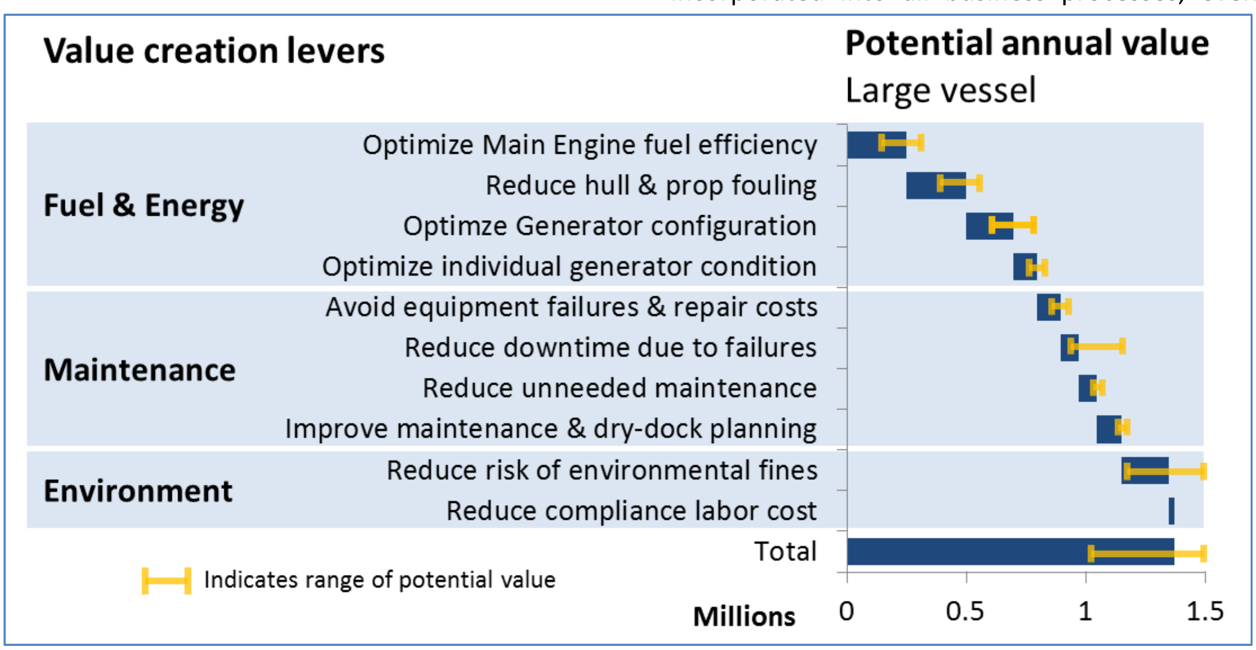


Figure 0: Value creation levers and potential value creation using data analytics

partially capturing the value in the short term will be attractive to many owners and operators.

To capture this opportunity, asset owners and operators will need to bring together equipment with sensors, software analytics and the right people. While the marine industry has historically followed other industries in terms of technology, bringing these three components together is no longer a futuristic vision, but a present day reality. Equipment is being installed with more and more sensors and often that data is being integrated into more comprehensive monitoring and control systems. Software and technology solutions to analyze the data are either coming from the naval defense world or land-based solutions are being converted to marine applications. Bringing the right, intuitive technology solution enables an easier transition for the marine industry to begin incorporating the industrial internet into how they operate their assets and businesses.

This white paper walks through the opportunity open to the marine industry in terms of revenue, savings and increased return on investment. In addition to exploring the opportunity, this white paper lays out some of the challenges and enablers that organizations need to consider when defining their strategy for capturing value from the industrial internet.

To capture the value and differentiate oneself from one's competition, owners and managers will have to transform their organizations. Not only will new technology be needed, both in terms of equipment, data integration and software analytics, organizations will have to evaluate their human capital and make investments in people. While traditional maintenance and operations skillsets will not become obsolete, they must be augmented by data analytics capabilities. Training of existing personnel will be needed to provide some level of data analytics capability and many organizations will need to bring in new resources, likely from other industries, to provide deeper data analytics expertise.

The industrial internet presents an exciting opportunity for the marine industry. There is huge potential for value creation, however, there are many challenges to making this happen. Organizations need to think through what opportunities they are going to focus on across time horizons, both short term and long term. This strategic thinking should be used in making short term decisions to ensure that investments made to solve short term goals are aligned with longer term objectives as well. In addition to developing a strategy for how to incorporate some of the exciting technology now available, leaders must also think through all aspects of organizational change to ensure a return on investment. In many situations, the value creation will be shared between various stakeholders: owners will capture value from higher asset utilization and decreased maintenance costs while charterers or operators will capture value from fuel efficiency improvement. For many organizations, the industrial internet presents an opportunity to increase profitability, provide greater customer value and create differentiation in the market. For those who do not proactively begin to incorporate data analytics into how their decision making and operations, there is a risk of becoming less competitive in an increasingly challenging market and falling behind.

Overview of the industrial internet concept

The industrial internet concept is quickly transforming into the next industrial revolution. It is becoming more widespread across a variety of industries from power generation and healthcare to commercial aviation and manufacturing.

McKinsey & Company estimated that in 2025, the industrial internet will be creating 2.7-6.2 trillion dollars per year of value – making it one of the most 'under-hyped' technologies today and projected to create more economic impact than advanced robotics, and more than energy storage, 3-D printing, and advanced materials, combined[2].

Cisco has estimated that the "internet of things" would connect 50 billion devices and create over 14 trillion dollars of additional profits over the next decade in increased productivity[3].

General Electric estimated the market for industrial internet technology and services to grow to $500B by 2020[4].

The basic concept is connecting machines with each other and with people to get more out of assets, help people be more productive, make supply chains more efficient, enhance customer experience and drive innovation. There are three primary components of the industrial internet. General Electric, in their recent whitepaper "Industrial Internet: Pushing the Boundaries of Minds and Machines" defines these as: Intelligent Machines, Advanced Analytics and People at Work[5].

Newer ships launched recently are equipped with more sensors, providing more and more performance and condition data that can be used to operate and maintain equipment at a higher performance level and lower cost. This wealth of data, while it can create value, does create a challenge as it is overwhelming without analytical tools. For example, a new vessel today might have over 1000 data points, which would create 2.6 billion pieces of data over a month. When extrapolated across a fleet of 100 assets, this equals more than 3 trillion data points per year. Software analytics can integrate a variety of data sources in a variety of formats and use automated algorithms to help users make sense of the data, turning it into actionable information. Lastly, the new information is consumed by people as they make more informed decisions ranging from planning maintenance to optimizing equipment configuration to prioritizing resources across an enterprise. To transform the data into actionable information, people involved need to have domain expertise in how the machines operate, how the business works, and how to analyze data. These people need access to the data and information through multiple channels, including web, mobile, intelligent reports, and enterprise applications.

The application of the industrial internet stretches across countless sectors – in the words of McKinsey & Company, the global consultancy, the industrial internet will include, "monitoring the flow of products through a factory to measuring the moisture in a field of crops to tracking the flow of water through utility pipes"[6].

This new industrial revolution is projected to create significant value for those who embrace it. Cisco, at the Internet of Things World Forum, defined the opportunity as, "The Internet of Everything brings together people, process, data and things to make networked connections more relevant and valuable than ever before - turning information into actions that create new capabilities, richer experiences, unprecedented economic opportunity for businesses, individuals

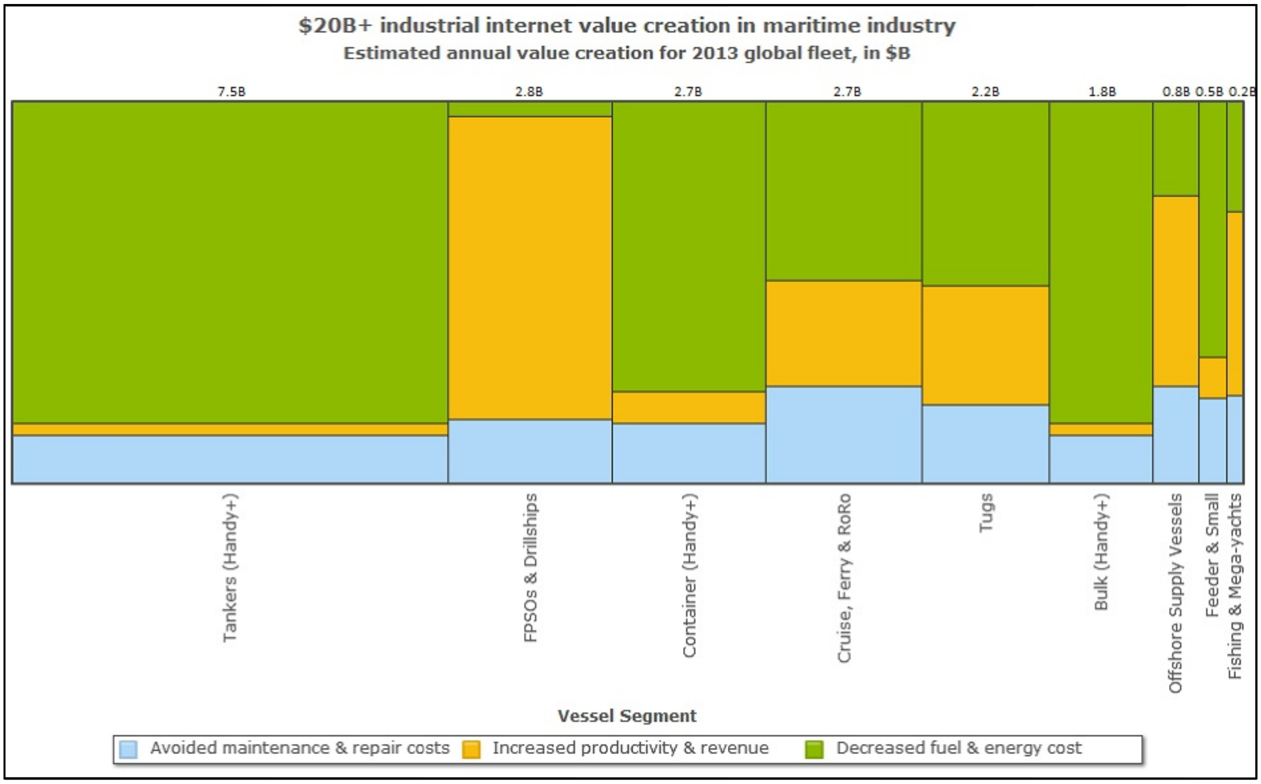


Figure 1: Estimated value creation opportunity for industrial internet application in the marine industry[1]

and countries."[7] In the industrial space, these new capabilities can help to identify potential issues prior to failure, better plan maintenance, and finely tune equipment to optimize energy efficiency. The industrial internet will also enable 'richer experiences' – creating transparency to allow asset owners, managers, operators, customers, suppliers and regulators to better communicate and work more closely to create mutual value.

While the industrial internet stands to create significant value for a broad range of stakeholders, adoption is projected to be similar to other technology revolutions. While the industrial internet has moved beyond only early adopters, and large manufacturers such as GE, Cisco, Siemens, and others are making it a key component of their strategy, many asset owners and operators are not coming along as fast. Cisco Chief Operating Officer Gary Moore added, "This past February we hosted 68 customers and partners from 18 countries to talk about the Internet of Things. We brought them all together and helped them start the dialog and think about processes, standards and how do we monetize this moving forward? Companies that don't embrace this are going to get left behind."[8]

Opportunity in Marine

The industrial internet concept can be applied across almost all aspects of the marine industry. Segments from fishing to container shipping to offshore oil and gas stand to increase performance tremendously by enabling their equipment to provide people with actionable information to make better decisions. Across segments, the marine industry will benefit from using the data to reduce fuel consumption, increase equipment reliability, decrease maintenance costs, and ensure environmental compliance. Based on the global fleet as of 2013, the value creation potential is estimated at approximately 20 billion dollars. With more new-builds being equipped with smarter machines and more robust technology infrastructure, that value creation potential is projected to grow at 15-20% per year for the next 5 years. While all sectors in marine would like equipment that operates more efficiently and does not fail, some sectors have specific opportunities to create value.[9]

Container Ships: On one end of the marine spectrum, container ships can apply the concept to increase equipment reliability and thus increase schedule reliability, deliver better value to their customers and differentiate themselves. They can also use the existing data onboard to operate their ships more efficiently such as optimizing the configuration of generators based on the actual electrical load and the actual performance of those specific generators onboard that specific ship. Container ships can also utilize the real-time electrical load on the ship (with changes primarily driven by the number of refrigerated containers being transported) and optimize the vessel speed to minimize total fuel consumption, including both propulsion fuel consumption as well as electrical generation consumption. This can translate to millions of dollars per year in fuel consumption reduction and hundreds of thousands of dollars per year in maintenance cost avoidance. Not to mention the incremental value of more revenue and greater customer value with a more reliable asset.

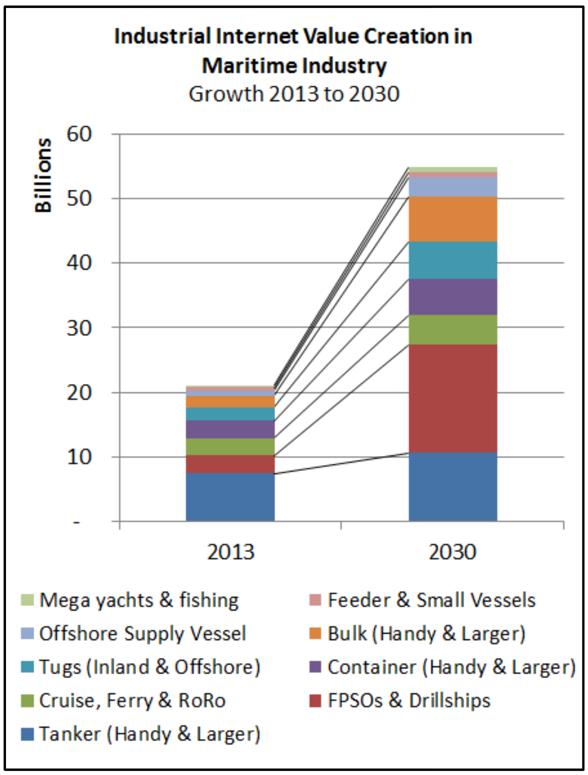


Figure 2: Estimated growth in value creation for industrial internet application in the maritime

Fishing: In a different sector, the fishing segment, engines, generators, fishing gear, and even refrigeration equipment can provide operators with valuable information to reduce fuel consumption, maximize uptime and ensure their catch is stored properly on the way to market. This can mean the difference between rushing back to port to save a catch or not having visibility into a potential freezer issue and losing that inventory to spoilage. This can translate into up to 8 million pounds of fish inventory saved and revenue increased as well as hundreds of thousands of dollars in fuel and maintenance costs avoided.[10]

Offshore: In the off-shore industry, every minute of downtime can cost thousands of dollars. A few days, or even a few hours, early notice of an impending failure can enable an organization to react before the actual failure and move in a more coordinated manner to minimize downtime and reduce the cost of that action. Improving uptime can create millions of dollars in accelerated revenue for an offshore platform or a FPSO (Floating Production Storage and Offloading) facility.

For those that serve the offshore industry, most notably OSV (Offshore Supply Vessel) operators, the industrial internet will be quite helpful as well. In addition to enabling better maintenance and operational decisions to drive increased uptime, reliability and asset performance, operators will be able to better communicate equipment status and condition to their customers and enable their customers to make better decisions to drive their business.

The benefits for most sectors can be categorized a few ways. First, there are benefits by shifting to Condition Based Maintenance (CBM), both reducing maintenance costs as well as energy consumption. It is easy for maintenance planners to defer maintenance when there is not a clear reason for why it is necessary now. For example, what could be a $5,000 maintenance event (fuel injector maintenance) could easily be lined out to save $5,000, only to have that issue propagate into a $750,000 top end overhaul during dry dock. By doing the right maintenance, at the right time, at the right cost, surprises could be avoided during extended maintenance periods. In this example, there is value created by returning the cylinder to “like new” condition and minimizing excessive fuel consumption.

In addition to CBM, there is also CBO – Condition Based Operations. CBO is where operators use real-time data and analytics to make better operational decisions to optimize the operation of the asset. Examples of CBO include using real-time performance data to optimize which generators are being utilized for different electric demand situations, and using real-time performance data to optimize speed, trim and draft. Both the CBM and CBO philosophies can be acted upon by onboard and onshore users. Onboard users can use real-time information to make better maintenance and operations decisions, while shore-based users can use the information to plan more effectively at the enterprise level and manage operator performance across assets. In the marine space, not only will operators and managers onboard and onshore benefit from the industrial internet, all levels of leadership as well as external stakeholders stand to see benefits. Senior management can have a better understanding of the health of their enterprise, prioritize issues across a fleet and measure the impact of their policy decisions.

Vessel lifecycle will be an important factor in how the industrial internet is adopted in the marine space. New vessels are often being built with significant sensoring and a strong

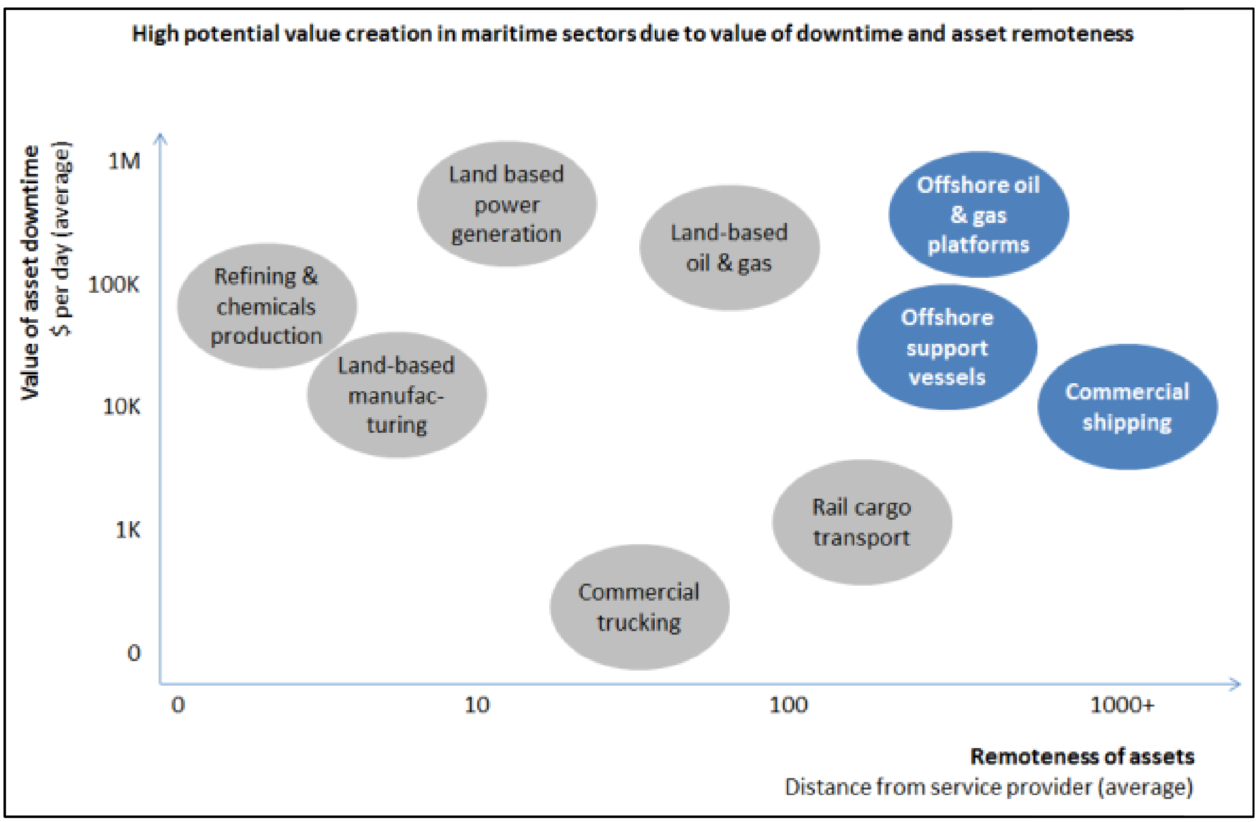


Figure 3: Comparison industries based on average value downtime and average remoteness of assets from service providers[1]

technology infrastructure. This will make it easier for data to be consumed by analytics applications in order to convert it into actionable information. Onboard new builds, the required investment could be very low, enabling fast payback times and therefore fast adoption of the industrial internet concept. Older ships, without electronic engines and little sensorization, will face a different required investment than newer ships with built in sensors to capture value. Owners of older, existing ships must weigh the increased investment in sensors, data integration, networking and communications with the potential return. While the benefits will likely significantly overcome the required investment for higher value assets, it will be less clear cut for older, lower value vessels with little existing technology infrastructure.

Based on an analysis of the approximately 100,000 ships in the global fleet today, there are 20,000-30,000 ships sailing the oceans that already have some technology infrastructure in place and would be able to easily justify the investment required to start taking advantage of the onboard data. This number is expected to grow at 3,000-7,000 per year, with most new-builds incorporating a solid technology infrastructure in the shipyard during construction. Based on the breadth of potential impact across all marine sectors, the industrial internet has the potential to create an estimated 20 billion USD of value per year for both the existing marine fleet and even more for new build vessels in the future. We project the market for applying the industrial internet concept in the marine industry will exceed one billion dollars in the next five years, including sensors, computer hardware, software, communications, and services.

Value of the Industrial Internet in Marine

The marine industry stands to reap significant rewards from applying the industrial internet concept. Like other industries, improvements can be expected in fuel and energy efficiency, reliability and availability of assets, worker productivity, value delivered to the customer and greater supply chain and logistics efficiency. There are unique aspects of the marine industry that will increase the value creation for specific market segments or technology applications.

Maintenance

With assets operating all over the world, including some of the most remote locations on the planet, the potential value created by improving how maintenance is conducted is higher than in industries with greater asset concentration and easier access. Any improvements in maintenance planning and moving more maintenance from unscheduled to scheduled will help to reduce costs associated with emergent work, which are magnified when assets are greatly dispersed and in remote locations. For instance, instead of having to air freight repair parts to a remote location and scrambling technicians to respond, using performance and monitoring data from the equipment to better predict potential issues will enable them to be resolved when it is more convenient or cost effective, instead of upon failure.

The marine industry also operates much more complex assets, which include equipment manufactured by multiple OEMs and requires a very diverse skill set to operate and maintain. This complexity, combined with the continued pressure to reduce crew size and costs, creates a mismatch between the skills required to successfully operate and maintain all of the equipment, and the skills and experience that the onboard crew actually has. For land-based industries, this same imbalance exists, however, the cost of having a central expert drive down the road to an asset that requires attention is much less than having someone fly to a remote port to help a ship's crew address a technical problem.

In addition to geographic remoteness and asset complexity, executing in-depth maintenance often involves putting a vessel into dry-dock. This is a significant expense, both in terms of cost of dry-docking the vessel as well as the downtime created. As such, there is a significant incentive to ensure that all maintenance to be completed during the dry-dock period is understood and can be planned prior to the vessel entering dry-dock in order to avoid expensive delays and penalties by extending the period in dry-dock. This increases the incentive to have a thorough understanding of the performance and health of all of the equipment onboard on a continuous basis. This information can be used to accelerate or defer maintenance, as well as manage the maintenance planning process to most efficiently take advantage of defined maintenance periods.

Applying the industrial internet concept to marine maintenance will enable a shift from the "operate-break-fix" paradigm to a "predict-optimize-prevent" paradigm. This shift will help reduce maintenance costs (preventive maintenance instead of high-cost overhauls or replacements) and reduce operational downtime. Condition Based Maintenance (CBM) is often referred to in the marine industry as the next shift in maintenance philosophies. The industrial internet concept of bringing together data producing machines, analytics software and people is necessary to effectively move to CBM. In addition to CBM, this also enables Condition Based Operations. CBO is focused on the 'optimize' step in "predict-optimize-prevent". By enabling operators to use information produced by their equipment and analytics to make better real-time decisions, operators can better configure and operate their equipment to maximize reliability today and optimize total cost of ownership, including maintenance costs, in the future.

Using automated analytics to drive towards actionable metrics to create value
Illustrative metrics

	Today	With basic data collection	With automated analytics
Fuel & energy efficiency	Total fuel per week or month	Main engine fuel consumed per hour Generator fuel consumed per hour	Real-time or average main engine fuel consumed per ton * mile (through water) Real-time or average generator (or main engine) fuel consumed per kWh power produced kW of shaft torque required to achieve a speed through water
Maintenance	Time since last overhaul	Engine hours since last overhaul Lube oil pressure (once per day)	Real-time and average actual turbocharger efficiency Hours at full load with high exhaust gas temperature Trend of lube oil pressure with engine operated at steady state Real-time or average cooler or condenser condition

Figure 4: Potential improvement in management metrics

The maintenance benefits of the industrial internet will be captured by multiple stakeholders. Owners and charterers will, of course, be able to reduce the amount they spend on maintenance. Ship-management companies will be able to reduce their costs in delivering the maintenance. Guenter Sell, a Chief Engineer with Bernhard Schulte Ship-management who is involved in monitoring and analyzing shipboard data, described the benefits as "Not only am I able to assess the equipment performance over time, with qualified data, I am also able to have more constructive discussions with the land-based technical superintendent. For example, after creating the visibility, I was able to work through a long term sensor problem with the technical superintendent and get it resolved."[11] Classification society surveyors who service the industry by ensuring ships are seaworthy and safe will be able to reduce their survey costs by doing assessments electronically. Finally, OEMs will be able to deliver service more efficiently and effectively, and reduce their cost to serve their aftermarket customers. As an example, Jaime Tetrault, Director of Product Support for Caterpillar Marine Power Systems frames the future as, "Selling solutions moves the suppliers into a proactive mode, partnering with the operators and predictably anticipating operational challenges and preventing them. It includes extending maintenance intervals, optimizing vessel performance and fuel consumption, reducing manpower requirements, and eventually and possibly even changing the owner environment into remote and non-remote engaged operators."[12]

This sharing of savings creates a situation where one single stakeholder may not be able to achieve a necessary business case for investment. In this case, multiple stakeholders must work together, sharing in both the investment costs, as well as the return, to make the entire value chain more efficient.

Fuel and Energy

The marine industry brings together the complexity of both power generation assets (main engines, generators) and energy consumption assets (shaft, compressors, air conditioning, water production, electronics, etc). While many industries focus their efforts on just one piece of this (i.e., electric utilities are just focused on delivering electricity at the lowest possible cost, and most manufacturing facilities are focused on consuming as little electricity as possible), a ship has to focus on both the energy production and consumption sides of the equation. This complexity underscores the value that collecting operational and condition data in real-time and automatically analyzing can have above what an onboard operator can do with simple spreadsheets. For large cargo ships, owners and operators have already acted on many of the 'low hanging fruit' opportunities for energy efficiency, such as slow-steaming. The next wave of increased efficiency will require optimizing the entire ship as a system, instead of just a single asset (i.e., the main engine in the case of slow-steaming). The broad range of stakeholders in the marine industry add to the complexity of managing fuel without transparency – according to Piotr Kos, Technical Superintendent with Bernhard Schulte Shipmanagement, "Just having the daily fuel consumption by equipment and being able to provide that transparency to owners eliminates miscommunication and helps to get ahead of conflicts and resolve them before they even start."[13]

Another complexity in the marine space that the industrial internet will help overcome is the variable cost of fuel and energy. For a container ship steaming with a full load of refrigerated containers, the electrical load created by those containers will cause the total fuel consumption to increase. There is a balance between burning more fuel to arrive at the destination port sooner and burning more fuel to keep the refrigerated containers cool at sea at a slower speed. This same concept applies to all types of vessels that carry cargo, as their draft and displacement will change, and thus the amount of power required to maintain a given speed will change. In some situations, this will enable onboard operators to fine tune the engine speed and engineering plant configuration to optimize fuel consumption for a given voyage or load. In other situations, the onboard crew will need to maintain schedule, despite the increased cost. This transparency is required not onboard, but by shore-based fleet managers who can use that information as they are planning ship schedules and better optimize for total profitability. In this way, they can have the necessary data to manage trade-offs between increasing fuel consumption to increase speed and the revenue implications of slowing down to conserve speed.

Since ships are designed to handle the ever changing onboard energy requirements, there are numerous configurations of generators and energy consumers that can be used in different situations. As these equipment age and wear, their energy production and consumption will vary. In addition, specific generator combinations will become more or less efficient at different load levels. Using the actual, recent performance data of specific pieces of equipment, rather than just manufacturer's specifications for that equipment model, or even initial test results, the configuration can be optimized for fuel efficiency given the actual present conditions and required current applications.

Like maintenance savings, fuel and energy savings will also be shared by several stakeholders. Owners and ship-management companies often are not responsible for fuel cost in the short run, but are incentivized to improve their fuel efficiency to make their vessels more attractive to charterers. Charterers, who are often responsible for purchasing fuel, are often not in the position to make long term investments in a vessel, as their charter contract may only be a fraction of the estimated payback for a technology investment. Owners will need to take some risk in making technology investments, and then actively market the benefits to prospective charterers to achieve either higher effective charter rates or higher utilization.

Environment

There is significant value that can be created from an environmental perspective in the marine industry. The transportation sector, as a whole, accounts for 13% of the total, global greenhouse gas emissions.[14] Marine, with many applications consuming heavy fuel oil, is a significant driver. This has led to various international, national and local organizations to impose stricter regulations on the types of fuel being consumed and resulting emissions. In addition to emissions regulations, the commercial shipping industry is coming under increasing scrutiny with regards to how ballast water is exchanged or treated to prevent the introduction of invasive species. Lastly, the industry continues to operate with regulations around discharges, including oily waste. Both ballast and oily waste systems can be monitored and automatically analyzed to ensure compliance and transparency for a wide variety of stakeholders.

The industrial internet will not only enable vessel owners, managers and operators to have visibility into the actual performance and operation of their equipment, it will also enable information to be collected much more efficiently, removing some workload from an already overburdened crew. According to Karen Hughey, President of ABS Nautical Systems, "The future of operational optimization and regulatory compliance in the marine and offshore industries lies in the ability to collect, analyze and act upon real-time data gathered from operations around the world."[15] Regulatory organizations will also eventually move to electronic reporting, using actual data from the equipment, whether it be an oily water separator or an emissions monitoring sensor, to be transmitted ashore and automatically verify compliance without any human intervention.

As emissions regulations and markets develop, the application of the industrial internet in the marine space will enable asset owners to make informed decisions as to how to operate assets most efficiently and profitably within the regulations in a given geography and take advantage of environmental incentives or market opportunities.

In contrast to fuel and maintenance incentives, almost all stakeholders are incentivized to ensure environmental compliance. While the value to an individual ship-owner or charterer is likely to be less than potential fuel or maintenance savings, environmental compliance is likely to be an initial driver for many owners, managers and charters to make investments in the technology onboard their vessels.

Enablers and challenges in marine

There are several challenges that will need to be overcome for the broader industrial internet: increased sensors and smarter equipment, increased bandwidth to share data, open standards to communicate across different types of equipment and systems, more advanced analytics, and people with the skills and domain expertise to turn that data into actionable information. These same high level challenges are essentially the same as those facing the marine sector in the adoption of the industrial internet, however, the details of what enablers will help overcome these challenges vary from other, traditional land-based industries.

Smart equipment and data Integration

While equipment is becoming more sensorized, there is still 'dumb equipment' being installed on ships without significant sensors and not integrated into the technology infrastructure. This is definitely changing and some early adopter ship and asset owners are driving this forward.

Military vessels have taken the first step in data integration with the US Navy's LCS (Littoral Combat Ship) having the diesel generators, diesel engines, gas turbines, reduction gears, combining gears, lube oil, shaft bearings, water jets, air conditioning plants and water desalinization plants integrated, with data and analytics available onboard and onshore.[16]

Commercial owners are also moving this direction. For example, HGO InfraSea Solutions' newest vessel, the *Innovation,* was launched with a technology backbone that integrates four asynchronous thruster motors, four azimuth propellers, three motors and bow thrusters, six diesel engines, the electrical jack-up system, bridge control system, dynamic positioning system, wave radar, S-Band radar, three X-Band radars, ECDIS – all available throughout the ship's LAN[17].

Bernhard Schulte Shipmanagement has become a leader in retro-fitting non-new build ships by integrating data for a container ship, the Gabriel Schulte, from the main diesel engine, four generators, torque meter, coriolis fuel flow meters, the ballast and fuel management system, the lube oil system, oily waste system, GPS and the ECDIS system. Bernhard Schulte also enabled this data to be available to shore

Raw data to analytics to create value in maritime industry

	Equipment & raw sensor data	Data integration & management	Data validation & qualification	Automated analytics	Business intelligence
Description	Streaming, real-time, data available from variety of sensors and data sources	Consolidation of data from multiple sources into single framework	Ensure data is valid and filter to desired data for analysis	Convert data into actionable information	Provide visibility for different stakeholders & connect with business systems
Output	Real-time, single point raw data	Real-time and historical data from all sensors	Real-time and historical qualified data	Vessel & equipment health & performance	Fleet analytics & performance, input into business systems
Value	Real-time alarms via onboard control system	Logging of equipment hours, cumulative fuel consumption	Trending of equipment performance	Predict problems, make better decisions, reduce fuel consumption	Prioritize resources & initiatives across enterprise
Onboard	Yes	Yes	Yes	Yes (vessel analytics)	Yes (link with vessel systems)
Onshore	NA	Requires high bandwidth connection to stream raw data ashore	Requires high bandwidth connection to stream raw data ashore	Yes (utilize fleet data & enterprise software)	Yes (link with enterprise systems)

Figure 5: Data to information flow in the marine industry

based analytics and users to turn the data into actionable information to create value for their customer. This integration enables the onboard Master and Chief Engineer, as well as the shore-based fleet manager, technical superintendent and owner to have transparency into the health and performance of the ship, including fuel consumption, power production, equipment health and environmental compliance[18].

Communications bandwidth

Ship-owners continue to upgrade their ship-to-shore communications as the cost of satellite communications decrease to less than $1 per megabyte of data.[19] This cost level reduces the impact of communications on the overall business case. With the utilization of existing satellite networks continuing to increase, the per-unit cost will continue to decrease over time.

As the amount of data onboard gets larger, there are many creative solutions for identifying the right data to be sent ashore, instead of just streaming it all. Various forms of compression, qualification and validation can be used to reduce the required data to a more manageable level that will further reduce costs. For example, a large, modern vessel might have 500-1000 data points available once per second. There is no reason to have each data point transmitted ashore every second. Instead, analytics can be used to validate and qualify the data to ensure that the right data is selected and transmitted ashore.

Open standards to share data across machines

Historically, each OEM that was involved in data integration would have their own data protocol for transferring data or making it available to other systems. This increased the integration costs to bring together data from relevant equipment, for example a main engine, fuel flow meter, torque meter and ECDIS system. While other industries, such as the power generation industry, have already moved to common open standards data protocols, the marine industry is just starting to move this direction. Instead of a different proprietary data interface for each piece of equipment, more and more marine equipment is starting to communicate with Modbus, NMEA or OPC standards. This is enabling new-build ships to more easily transition to the industrial internet. In addition to enabling communications across systems, open standards will also allow for the creation of standard equipment hierarchies across maintenance management programs, Classification equipment registries, and OEM equipment databases. These standard hierarchies will help facilitate seamless data sharing between different potential data consumers to maximize value creation for vessel owners. While most OEMs are adopting this approach, there are some who are maintaining their own internal, proprietary data protocols, thus limiting the amount of integration that can be achieved. If other industries, which have moved this direction previously, provide a good prediction of potential marine industry dynamics, than OEMs who do not adopt open standards data protocols will be penalized by the market, as their solutions will be less valuable than if they are were able to easily integrate with the broader industrial internet.

Advanced analytics

Equipment OEMs and software providers are focusing on how to utilize available data to create actionable information to help drive better operational and maintenance decisions. Many OEMs are starting to use data from their specific piece of equipment to help ship owners and operators operate or maintain their equipment more effectively. If this trend continues with each OEM providing their own 'industrial internet' solution, only for their equipment, owners and operators will become overwhelmed with information technology and not get the value out of each system. In addition, each component on the ship is not operating in isolation and needs to be analyzed as part of the larger system. For instance, an increase in fuel consumption could be driven by decreased engine condition, change in fuel pressure, increased fuel temperature, lack of maintenance, increased marine growth on the hull, a fouled propeller, heavier than expected sea state, higher speed requirements, headwinds, or a different fuel type among many other potential reasons. If the engine is analyzed in isolation, it may lead to an issue not being identified or an incorrect diagnosis and a decision being made without the most accurate and comprehensive information.

Integrated analytics that consume data from multiple sources and help users transform that data into actionable information are the logical next step in the marine industry. As many vessels already have sensors and some level of data integration, monitoring and analytics solutions should be flexible enough to leverage existing onboard systems such as integrated control systems, stand-alone sensors, navigation systems, and ballast and tank management systems. This is necessary to minimize up-front investment in sensors and data integration to maximize the owner's return. Early adopters are starting to move this direction, with the MV Gabriel Schulte described above being a good example.

Another challenge in the marine industry regarding analytics is how to deal with real-time data analytics onboard a vessel, near-real-time analytics on-shore, and the additional ship and shore based business systems (i.e., maintenance planning, purchasing, supply chain, fuel management, cargo management, etc.). The software package needs to enable ship and shore based users to interact with data and create actionable information.

In addition to the analytics to transform data into actionable information, data validation and qualification must also occur. Unlike many land-based industries and other transportation industries, marine assets are operated in a variety of different ways. While a cargo airplane essentially has four modes, with all engines being used for all four: taxi, take-off, cruise and landing; a commercial container ship can operate at a variety of speeds, plant configurations, displacement/drafts, electrical loads, acceleration/deceleration, weather conditions, etc. In the airplane example, it may be fairly simple to compare a data point from multiple flights. In the marine industry, data should be qualified and validated to ensure like data points are being compared, both over time and across vessels.

These analytics must not only take the manual effort out of moving from raw data to actionable information, they must also be easy to use with minimal training. For example, the user interface should be simple and intuitive to enable an onboard operator or a shore-based manager to utilize the software with as little as an hour of training. As discussed below, there is a role for skilled data analysts, however, the analytics software must facilitate an understanding of equipment health and performance even for those without data analytics skills.

Custom Applications

In addition to common focus areas of overall maintenance, equipment reliability, general fuel efficiency and environmental compliance, specific sub-sectors within the marine industry will require 'custom applications' to realize the full potential of the industrial internet. These custom applications might be focused on specialty equipment that is only used in a specific sector or optimizing within a specific business model. While there will be a need for sector specific customer applications, there will also still be the need for the open standards platform that will encompass the common infrastructure (data collection, management, qualification, automated analytics) and functionality (analytics focused on reliability, fuel efficiency and the environment) as well as provide an open standards interface to allow integration of custom applications. These applications might be supplied as add-on modules by the open standards platform provider, or they may be developed either in-house or by a sector focused supplier. Outlined below are a few examples of the types of custom applications that would create additional value in specific sectors.

Tow configuration optimization for tugs. By utilizing actual performance data from a variety of sources, including engine performance, power, speed through water, tow diagrams, etc., tug operators will be able to better understand exactly what factors cause a specific configuration of barges to be more efficient than others. Automated analytics could enable a tug operator to clearly understand how water conditions, tug power, and operational constraints impact fuel efficiency of a given barge configuration. This information can be leveraged to optimize profit in their specific business situation through reducing fuel consumption or reducing time to detach and add barges along a voyage.

Combined engine & compressor analytics in offshore. Many offshore platforms utilize a combined engine and compressor set for compressing and storing natural gas. To better understand the efficiency and health of the overall system, the system should be assessed as a whole instead of just standard analytics for the engine and standard analytics for the compressor.

Generator configuration for container ships. Container ships often experience high fluctuations in electrical load due to refrigerated containers being on-loaded and unloaded in various ports. With 3-5 generators onboard many container ships, there are often multiple combinations of generators that produce the required electricity. Most power management systems today will help determine the number of generators needed based on OEM guidance. In practice, specific generators will perform differently over time and at various loads. This results in fuel efficiency differences between generator combinations, even with the same number of generators online (for example, using generators 1, 2 & 3 or using 1, 2 & 4 or 2, 3 & 4). By better understanding the actual, recent performance of those specific generators, operators can have transparency into the optimal configuration for a specific load level at that point in time.

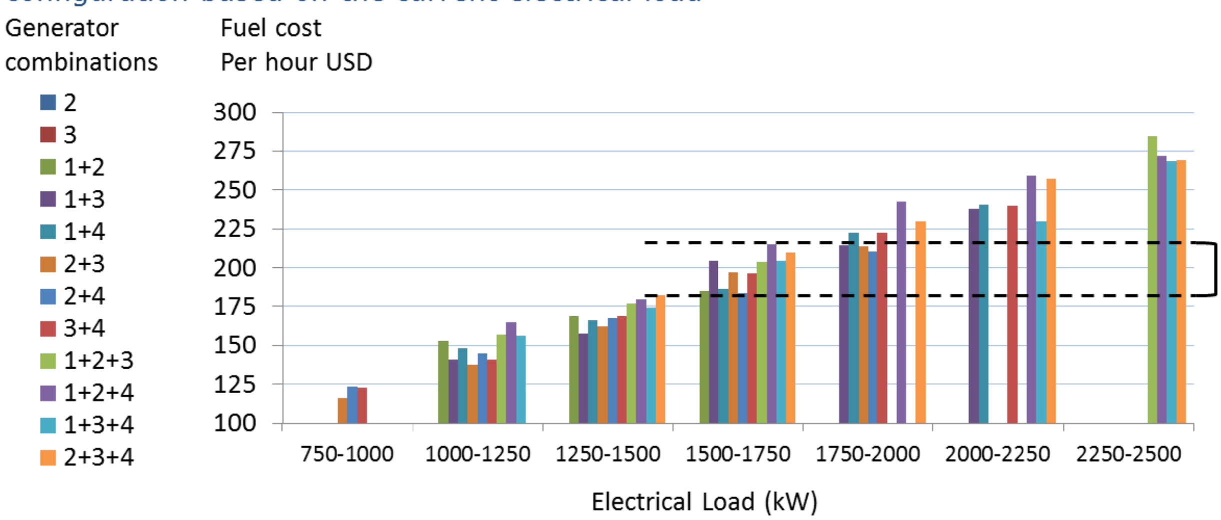
These are just three examples of the types of custom applications that can be used in specific marine sectors. Other custom applications could be developed to better understand hull & propeller efficiency for specific ship types, efficiency/effectiveness of dynamic positioning systems, fuel efficiency of refrigeration, dredge productivity, optimizing LNG-tanker speed with real-time boil-over analysis, etc. These should all be able to interact with open standards platforms that will integrate, validate, analyze and share data.

Skilled data analysts with marine domain expertise

Bringing together data from the variety of shipboard equipment is only the first step in creating value with the industrial internet. Value is actually created by transforming that data into actionable information that can be used by onboard operators as well as shore-based management to make better operational, maintenance and management decisions. To facilitate the transformation of raw data into actionable information, skilled data analysts, with deep marine domain expertise, will be needed to either conduct analysis or configure

Optimize generator configuration

Illustrative example of using actual generator fuel performance to optimize the configuration based on the current electrical load



In this case, optimizing the generator configuration based on real-time electrical load could save up to $35 per hour or ~$300K/year

Figure 6: Illustration of using actual generator performance data to optimize generator configuration for a given electrical load

automated analytics in software.

Data analysts will need to combine the skills and experience gained as a Chief Engineer or a Technical Superintendent (e.g., how equipment operates, troubleshooting, repairs, etc.) along with the ability to analyze data. This data analysis skill set is very different and will be new to many Chief Engineers and Technical Superintendents. Automated analytics that are incorporated into a software program will make it easier to bridge the gap between the current capabilities and the required capabilities to maximize value capture from ships connected to the industrial internet.

Organizations will also look to augment their existing technical teams with analysts who may not have deep marine domain expertise, but will be able to help Chief Engineers and Technical Superintendents maximize the value of the data and analytics. Skilled data analysts combined with a robust technical system would be able to take the troubleshooting findings from one vessel and create new algorithms that can instantly be applied across a fleet – all from the shore-based office.

This data analyst role will also extend beyond just technical ship-management. Fleet managers and trade-managers can use this data to better optimize route planning or vessel dispatch resulting in fuel savings, as well as optimization of the entire system to use assets based on their current performance and expected reliability.

Aligning and serving different stakeholders

The marine industry presents another challenge with the broad range of stakeholders involved. There is the owner of the vessel who purchases the vessel and may or may not play a part in operations. Often, there is a ship-management company, who is responsible for crewing the vessel, maintenance, fuel and other operational aspects. Vessels are often chartered by another company who will often pay a daily rate plus the fuel consumption. In addition, there is the onboard crew, usually hired by the ship-management company with varying levels of experience in the industry and on that specific ship. Outside of the ship ownership and operational stakeholders, there are classification societies, who help ensure ships are seaworthy and safe. OEMs stay engaged beyond the initial building with service contracts and support. Each of these stakeholders has different incentives, and sometimes these incentives are at odds with each other. With this wide range of stakeholders, the value of the industrial internet will likely be shared across many of them creating inefficient decision making as to whether to invest in new sensors, technology infrastructure, software or people. Organizations that are able to align different stakeholders to focus on delivering their service most efficiently will be able to make the right investments and outperform those not able to reach a consensus across their stakeholders.

In addition to aligning stakeholders to make better investment decisions, a monitoring and analytics solution must allow for stakeholders in different roles to interact with the technology in different ways. Onboard operators must be able to use data and analytics to make better operational and maintenance decisions, often in real-time. Shore based managers must be able to look across a fleet and across time to understand variations in performance and impact of maintenance and efficiency initiatives. Senior executives must be able to gain transparency into enterprise health and prioritize resources more effectively across the enterprise.

Conclusions

The industrial internet presents a huge opportunity to the marine industry, with the potential to create over 20 billion dollars of value annually. While only a minority of vessels are currently positioned to begin to capture the industrial internet benefits, that number will grow significantly, as almost every new-build ship is having technology built in to capture these benefits.

The benefits to marine stakeholders are significant. Substantial fuel savings, reduction in maintenance and repair costs, and greater assurance of environmental compliance are the largest drivers.

Organizations need to start thinking now about how they are going capture benefit from the industrial internet. Many marine organizations need to bolster their technology and data analysis capabilities to take advantage of the opportunity. Those that don’t make these organizational investments risk becoming less competitive and being left behind. The marine industry has the opportunity to learn from other industries which are further down the “industrial internet” road, such as commercial aviation and power generation. Learning from these industry examples will help marine organizations mitigate challenges and minimize costs.

Many companies are already beginning to invest in ‘data collection’. This is causing as many challenges as it is value creation. Often, this data, if just collected, is overwhelming and will either paralyze decision making or simply be ignored. Real-time, automated analytics on the vessel and on shore are necessary to transform raw data into actionable information that can be used to make better operational and maintenance decisions. Proven technologies that leverage the established infrastructure of GPS, communications satellites, control systems, and the internet can use automated analytics to help make better decisions and be internalized within an organization to ensure intellectual property, developed with the analytics, is protected as a competitive advantage.

Stakeholders must work together to achieve these benefits. Since the benefits are often split amongst multiple stakeholders, multiple stakeholders must align on the business case and come together to share in the initial investment, as well as the follow-on savings. This applies to industry providers, especially equipment OEMs. Open standards will enable value creation for a variety of players and will be one factor that contributes to who the market rewards and who the market penalizes. Non-traditional stakeholders, such as software companies and technology companies from outside of the marine space, will introduce new capabilities to marine customers. With such significant value creation possible for a wide variety of stakeholders, and a different set of capabilities required to capture that value, some companies will make sound investments and further differentiate themselves in the marketplace, while others are at risk of not acting, or delaying action, and potentially falling behind their competition. Each organization will need to define how it is going to approach the industrial internet, what capabilities will be needed, and how to make the right investment trade-offs to achieve specific strategic objectives. The common imperative for all organizations, whether it is a ship-owner, operator, manager, shipyard, technology company, or OEM, is to begin addressing this now and not be left behind as others move forward.

About the authors

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Rob Bradenham is the General Manager of ESRG, a leader in marine data analytics software. ESRG's flagship product, OstiaEdge, can help owners and operators reduce fuel consumption, optimize maintenance costs, reduce downtime and ensure regulatory compliance. Mr. Bradenham has spent most of his professional career in maintenance and operations of industrial equipment, both as an Associate Partner with McKinsey & Co, the global management consultancy, where he served a wide-range of large industrial organizations on their operations and maintenance, and as officer in the US Navy, where he managed maintenance and operations on surface ships. Mr. Bradenham has a Bachelor's Degree in Finance and a Master of Business Administration from the University of Virginia.

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About ESRG

Since 2000, ESRG has provided leading edge data analytics and remote monitoring technology to support commercial and defense marine engineering operations. Machinery owners and operators turn to ESRG for expertise in data integration, automated analytics, reporting and dashboards. ESRG's OstiaEdge®, is a Platform as a Service, which combines onboard data acquisition, qualification and analysis, shore based analytics and workflow management as well as business intelligence features. OstiaEdge, which is based on Reliability Centered Maintenance (RCM) principles, enables users to implement Condition-Based Maintenance (CBM) and Condition-Based Operations (CBO) to increase reliability, achieve greater asset productivity, reduce fuel and energy consumption and decrease operating costs.

Endnotes

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