# Marine's Digital Revolution

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This paper is part of a series from GE's Chief Economist, Marco Annunziata, exploring the next generation of industrial progress. Other papers in this series include:

- *The Moment for Industry (2015)*
- *The Future of Work (2014)*
- *The value of interconnectedness (2014)*
- *The Industrial Internet @ Work (2013)*
- *Industrial Internet: Pushing the boundaries of men and machines (2012)*
- *By industry:*
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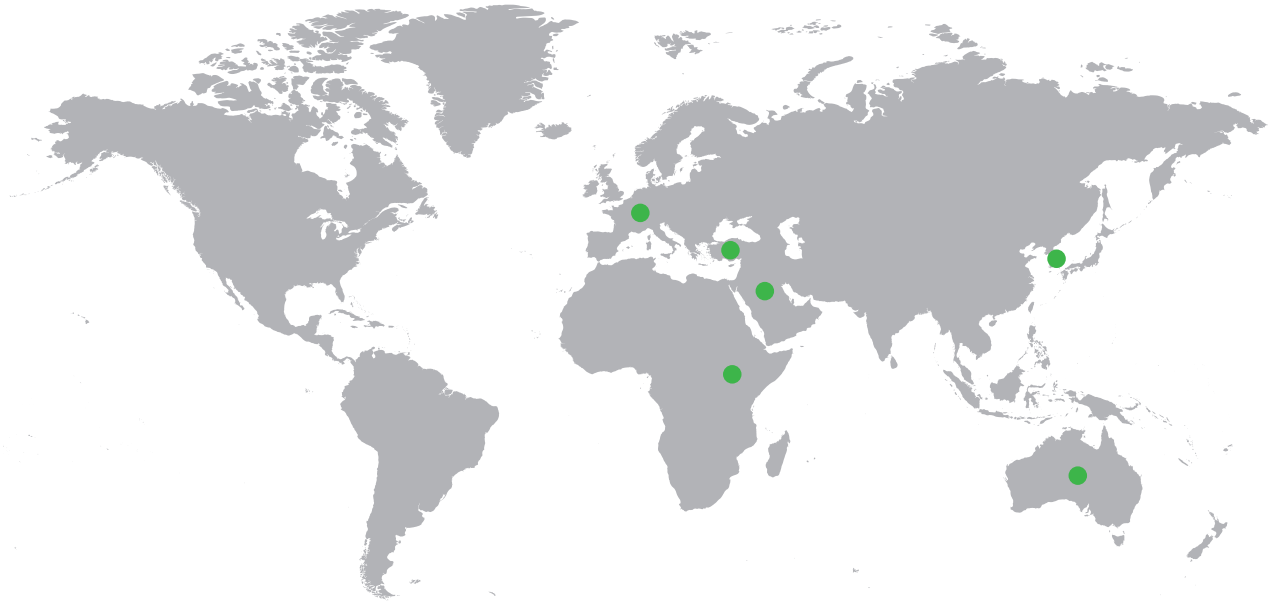
  - *Powering the Future (2015)*
- *By region:*
  - *The future of work in Africa: Building strong workforces to power Africa's growth. (2015)*
  - *The future of work in Australla: Building the third wave of growth (2014)*
  - *The future of work in Turkey (2014)*
  - *The state of European innovation (2014)*
  - *Industrial Internet: A European Perspective (2013)*



# Executive Summary

The Marine industry faces substantial pressure: global trade has decelerated and commodity prices have declined, just as a prolonged shipbuilding cycle resulted in significant overcapacity. The ensuing struggle for market share, via fiercer competition and consolidation, underscores the need for greater efficiency in shipping. Marine offshore is also under pressure, as the sharp decline in oil prices has changed the economics of the oil and gas industry. At the same time, large cohorts of experienced workers are set to retire in the next 5-10 years, posing the risk of a shortage of critical skills.

The marine industry must meet these challenges in an environment shaped by three trends: Global economic rebalancing will see sustained growth in south-south trade and the rising importance of Asia as both a source and destination market; natural gas will play an increasingly important role as both a shipped commodity and a fuel; and environmental regulations will become more stringent.

The answer to these challenges lies in innovation. A new generation of digital technological advances can bring substantial benefits to the Marine sector. Industrial Internet solutions can use data and analytics to deliver better insights on asset conditions and performance, enabling predictive maintenance and reducing nonproductive time, a major source of inefficiency and financial losses. Digital models can simulate the performance of alternative systems configurations on a vessel in different environmental conditions. This allows substantial improvements already at the design stage, resulting in greater operational efficiency. Industrial Internet solutions can provide better visibility on the location and performance of entire fleets, improving routing, performance, and the speed and efficiency of maintenance and repairs. Digital solutions can also mitigate the aging workforce challenge, by allowing experienced operators in a centralized location to monitor and support multiple vessels, and making it easier for workers to share, store and access information. Advances in user interface are critical to the effectiveness of these applications.

Reaping these benefits will require investment in digital solutions and capabilities. Business models will have to evolve towards a more data-driven approach and allow a greater scope for collaboration. A high degree of interoperability will be needed to accelerate the development and deployment of efficiency-enhancing solutions. New digital technologies will have to be safeguarded with state of the art cyber security. Finally, the industry will have to create a robust pipeline of talent to meet the demands and opportunities of the digital era.

With these conditions in place, digital technologies offer an unprecedented opportunity to transform the Marine industry. They can substantially reduce nonproductive time in both shipping and offshore; cut fuel consumption; improve operational efficiency for individual assets and entire fleets; enable better market intelligence, planning and routing; and accelerate the development of green vessels. Shipping vessels and offshore rigs can be made digitally intelligent right from the design phase, yielding greater efficiency and flexibility. Digital innovation can allow the Marine industry to meet the challenges of today and position itself for better growth and margins in the decades to come.

# A Cyclical Industry In A Volatile World: Global Backdrop And Trends

About 90 percent of the world's goods are transported over water, and shipbuilders prospered as global trade boomed in the decade before the global financial crisis. Even after the 2009 global recession, growth in shipbuilding activity continued, and, in 2010, orders were growing at over 8%[1].

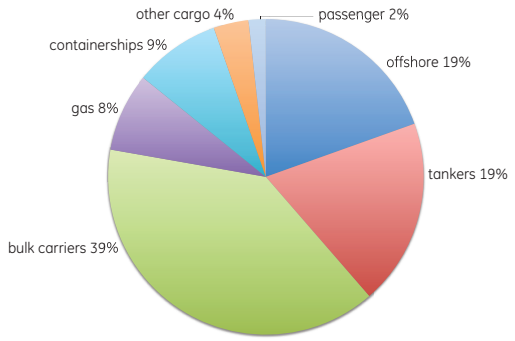
Marine operators, focused on expanding capacity, bought more and bigger ships than ever— the typical ship now carries about 10,000 20-foot equivalent units (TEU), which is five times the capacity of the typical vessel built in the 1990s. Private equity investors became strongly involved in the sector, offsetting the decline in traditional bank financing, as banks faced higher funding costs and tighter capital requirements after the global financial crisis. Combined with relatively attractive prices for newly built vessels, this has supported a sustained growth in orders.

Since its 2012 peak, however, shipbuilding has continued at a more moderate and sustainable pace: following an additional 4.1% growth during 2013, the world fleet reached 1.69 billion DWT by January 2014. Despite a year-on-year drop of nearly 20% compared with 2013, last year saw around $100 billion in new ship contracts. The highest investment was in the high value offshore sector and the volume bulk carrier market.

With a global order book of around 5,000 ships to be built and around 8,000 more forecast to be ordered by 2020, the shipbuilding industry retains some forward visibility. But long order-to-delivery cycles for large and complex vessels make investment decisions difficult, and it can be difficult for the industry to make timely adjustments to market conditions, thereby extending the cycles we have mentioned.

[1]Clarkson, Newbuilding Market Report (2015)

**Figure 1**
*Global orderbook by vessel type[1]*




Europe still dominates as a ship-owning region, with around a 45 percent share of the global fleet, but Asia-Pacific's investment has been growing steadily for the past 20 years, from just over 30 percent to 40 percent in 2015. China is driving investment in shipping assets, investing over $11 billion in 2014, a close third behind the United States and Greece. $5 billion of this was invested in specialized tonnage, including gas carriers.

Meanwhile, however, macro conditions have become less favorable. The recovery in the global economy, after an initial strong rebound, has been lackluster. Moreover, the recovery in global trade has been less dynamic than the overall economic rebound: international trade has grown by no more than 2.5-3% per year since 2012, in line with global output, while in the previous two decades it had grown at twice the rate of global output, as displayed in Figure 2. This seems to reflect, at least in part, greater recourse to various forms of protectionist measures, which have slowed the expansion of trade flows compared to the pre-crisis period.

**Figure 2**
*Growth in world GDP and international trade*

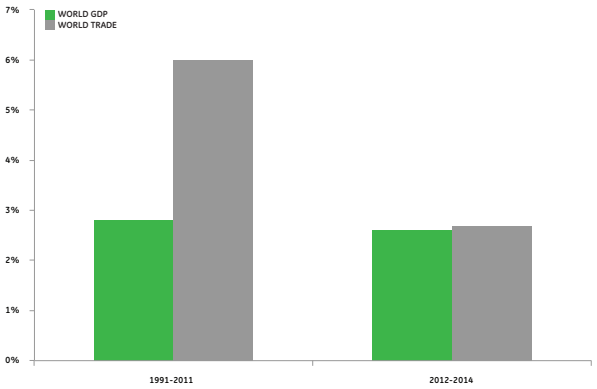
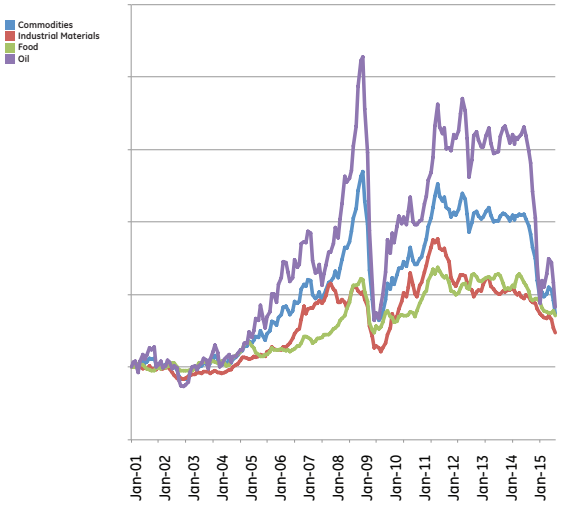
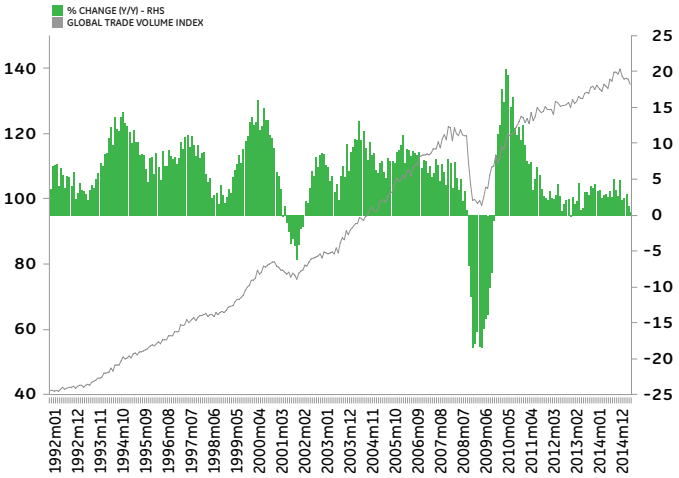



**Figure 3**
*Commodity Prices Indices (IMF)*




The commodity cycle also turned: Falling commodity prices (Figure 3), against a surging U.S. dollar, have placed a downward pressure on global trade, which is measured in dollars. But a similar picture comes out also when measured in volume terms, as shown in Figure 4. The volume of globally traded goods has grown at a 2.8% average rate over the past four years - less than half that of the previous two decades. Other measures of transportation costs tell a similar story: most notably, the Baltic Dry Index—a leading measure of shipping costs of bulk commodities—has hit an all-time low in early 2015.

**Figure 4**
*Volume of global trade*




Source: The Netherlands Bureau for Economic Policy Analysis

[1]Clarkson, Newbuilding Market Report (2015)

*The combination of deteriorating macroeconomic conditions and a prolonged shipbuilding cycle has resulted in an overcapacity situation that has brought the sector under substantial pressure.*

The unfavorable macroeconomic developments have also weighed on the ultimate customers of the marine industry, and they responded with an effort to reduce costs in orders to improve margins—resulting in additional pressure on operators and shipbuilders. These pressures have manifested themselves in:

1. **An intensified struggle for market share, including via fiercer price competition:** China already leads the world in the scale of its shipbuilding industry, providing the majority of the world's bulk tanker workhorses. But there are clear signs it intends to reposition itself and to go head-to-head with Korea, the world's number one in valued-added, high-performance shipbuilding. This applies not only to merchant shipping, but also notably leverages China's energy interests—supplying vessels for its developing domestic oil and gas sector. The shift includes reshaping China's shipbuilding infrastructure, which grew unsustainably during the 2010-2012 shipbuilding boom years. This reshaping includes a dramatic reduction in the number of active yards, with capacity down nearly 25% compared with three years ago. The new focus on quality and upskilling are both important if China is to be taken seriously at the top end of the market.

2. **A trend towards consolidation:** The number of active shipyards is declining considerably, dropping 20 percent to 420 between 2014 and 2015. We are likely to see this trend continuing as cost pressures and market constraints bite.

3. **Heightened tensions between ship builders, focused on low-cost construction; ship owners, focused on asset management; and carriers, focused on improving margins in the transportation business:**

A recent study by the McKinsey Global Institute notes that the container shipping industry has been "highly unprofitable over the past five years." Industry earnings before interest and tax had enjoyed robust growth with limited volatility between 2003 and 2008. After a sharp collapse and strong rebound driven by the 2009 global recession, they have been characterized by small gains and high volatility during 2012-13. Overcapacity and intensified competition combined to drive freight rates to a 10-year low in 2013, with low rates also in the liner market[2].

Industry operators feel the pressure: in a recent survey by Norton Rose Fullbright, only one third of shipping industry respondents characterized conditions in the sector as positive, compared to about 90% of respondents in the aviation and rail transport sectors[3]. In the previous year's survey, close to 70% of shipping industry respondents saw market conditions as positive. The sharp decline in the share of positive responses illustrates how the challenging market conditions are increasingly being felt.

Survey respondents unequivocally identified overcapacity as the single biggest reason for their pessimism, together with the level of shipbuilding orders, which is likely to cause overcapacity to persist in the future. The survey also confirmed that the industry remains poised for further consolidation: 29% of respondents identified M&A as the optimal investment opportunity in the industry, and an additional 28% pointed to joint ventures, alliances and pools. This is matched by a strong belief among industry participants that the largest players in the sector will become increasingly dominant.

Shipping is not the only area of the marine industry to have come under pressure. The rapid and sharp decline in oil prices has had a profound impact on the whole oil and gas industry. The decline has been driven to a large extent by supply-side developments, notably (i) advances in shale technology, that have allowed the US to dramatically increase supply, overtaking Saudi Arabia; and (ii) the decision by key low-cost OPEC producers, in particular Saudi Arabia, to maintain elevated production levels in order to maintain or gain market share, rather than reducing output to support the price.

This has significantly heightened the stress on higher-cost oil and gas producers, including Offshore. Predicting future oil prices is extremely hard, and the surprising pace and depth of the 2014-15 decline suggestions caution in any forecasts.

[2]UNCTAD (2014) Review of Maritime Transport.
[3]Norton Rose Fullbright (2015), "The Way Ahead transport survey."

However, based on macro and technology developments, it seems prudent not to count on a substantial recovery in oil prices in the near future. Marine offshore operations will therefore face very strong pressure to increase efficiency and reduce costs, so as to improve margins and profitability even in lower oil price environment that could prove to be long-lived.

Meanwhile, the military side of the Marine sector also shares some of these challenges. In many countries across the world, governments have to contend with higher public debt burdens and the need to improve public finances. As a consequence, military budgets are often being squeezed, affecting the naval forces as much as others. At the same time, a more balanced global growth and intensified geopolitical concerns have underscored the strategic importance of sea-lanes, which are crucial for the transport of energy, other raw materials, and finished goods. Naval forces are therefore under greater pressure to guarantee operational readiness and faster reaction speed, even with fewer resources at their disposal.

# Looking Forward

Against this challenging backdrop, three key trends will shape the environment for the marine industry:

## Global growth and global economic rebalancing

The global economy will continue to expand at a moderate pace, and global rebalancing will continue, with Emerging Markets (EM) accounting for an increasing share of the global economy. Emerging Asia is poised to remain the most dynamic area, followed by Sub-Sahara Africa, and the Middle East and the North Africa region.

**Global economic rebalancing will continue to reshape the direction of global trade,** with the following key implications:

1. The rising importance of Asia as a both a source and destination market
2. The continued growth in the importance of South-South trade
3. The rising importance of intra-regional trade

Note that emerging economies already account for a growing share of global seaborne trade, with Asia as the most important hub. **The world's top 20 containers ports account for nearly half of global container port throughput[4]. Of these twenty top ports, fifteen are in emerging Asia.**

The rising importance of Asia will be driven largely by China and India. **India** has the potential to become a strong engine of regional and global growth for a protracted period, if its favorable demographics are supported by stronger investment in infrastructure and a renewed push on liberalization measures and other steps to improve the business environment. **China** will continue to rebalance its economy towards domestic consumption and away from investment. At the same time, China's urbanization process will proceed apace. Moreover, China is committed to invest in infrastructure in its more remote and less developed regions, and to strengthen its trade links with the rest of the world, as targeted under the "One Belt, One Road" initiative. All this will continue to drive robust demand for oil, gas, coal, iron ore and other raw materials. Rapid growth in Sub-Sahara Africa (SSA) will also play an important role in reshaping global trade patterns. Indeed, several countries in the region plan investments in ports and other infrastructure needed to better connect SSA to global trade networks—these include Ghana, Namibia, Nigeria, Kenya, Tanzania and South Africa.

Global trade is likely to keep expanding in line with global GDP. Large-scale protectionism has been avoided so far, but progress on multilateral trade agreements has been limited, and the focus is likely to remain on regional trade deals.

## Changes in the global energy landscape

**The shale revolution in the US** has reduced the country's oil imports, with a dampening effect on the tanker trade. This impact is likely to continue: while lower oil prices have led to a reduction in the active rig count, they have not yet resulted in a significant decline in production that could trigger a renewed increase in energy imports. As a consequence, **oil exports will continue to be redirected towards Asia,** which is the region where strong economic growth will fuel sustained energy needs, and oil producers have already refocused their efforts towards increasing market shares. Refining capacity is also shifting to Asia, further contributing to the redirection of tanker trade flows. This is likely to lead to **the emergence of new long-haul routes, and to an increase in ton-miles traffic for crude tankers.**

[4]As of 2013, according to UNCTAD (cit).

**The "Age of Gas,"** the increasing role that natural gas is set to play in energy generation, will be another key factor. US supply capacity will increase in the years ahead. But other areas of the world are also working to increase their gas supply capacity in Asia, Africa and Latin America. Projects to boost production and exports are underway in Australia and Indonesia, while Singapore and Malaysia are building port terminals equipped for both the import and the export of liquefied natural gas (LNG). China, India and other Asian countries are also contemplating additional facilities for LNG imports. In China, gas will play an important part in making the country's energy system cleaner, supporting the government's anti-pollution effort without compromising the pace of economic growth.

As gas continues to play a more important role in the global supply and demand for energy, it will increasingly be traded internationally and will have a greater impact on shipping routes and trends. East Asia countries are key importer of LNG fuel, including Japan (35% share), Korea (17%), China (8%), India (8%) and Taiwan (5%)[5].

## Environmental goals and regulations

**In order to reduce greenhouse gas emissions, the International Maritime Organization adopted a set of technical and operational measures in 2012,** and these came into force in early 2013. Efforts are also being made to reduce pollution from other toxic substances caused by burning fuel oil, in particular sulphur oxides and nitrogen oxides. The IMO adopted additional guidelines and amendments in April 2014.

**Environmental regulations** have an important impact on the industry through several channels:

They can increase the costs for access and operations at ports, as some are beginning to adopt financial incentives to improve environmental safety (for example, the Busan Port Authority offers a 15% discount on port dues to ships that meet a specified minimum efficiency score).

Fuel-inefficient and highly polluting ships face a rising risk of being prohibited from traveling on certain shipping routes, which could force them to take longer and costlier detours.

About one half of shipping respondents in the Norton Rose Fullbright survey have pointed to environmental issues as having the largest regulatory impact on their industry, and constitute a key area of operational business concern. Environmental regulations are already having a significant impact on operational costs, and are likely to become more stringent in the coming years. Shipbuilders and operators will therefore have a rising incentive to identify and implement efficiency-enhancing solutions for "green ships," in order to reduce the environmental impact of their operations.

This also creates a powerful incentive for a broader adoption of LNG as fuel. In recent years, fuel has become one of the largest operational costs for shipping lines, in some cases accounting for as much as 30-50% of total operational costs[6]. While the decline in world oil prices since mid-2014 has alleviated the pressure, pushing the share towards the lower end of the range, fuel costs are set to remain an important share of variable costs. Moreover, global fuel prices are subject to a very high margin of uncertainty, due to technical, economic and geopolitical considerations—which is reflected in a corresponding high uncertainty on operational costs for shipping operators, a very important risk factor.

Solutions that improve fuel efficiency can therefore have a major impact on the bottom line. These can include operations improvements to save time and allow for lower speeds at sea, such as faster loading and offloading in ports and better routing. More directly, new technologies on Combined Gas and Steam power generation turbines (COGES) are set to increase the role of LNG as a fuel supply, as the new, more compact turbine design allows substantial reduction in emissions, meeting existing regulations with no exhaust treatment or methane slip. These turbines give operators the flexibility to choose the less expensive fuel, depending on market conditions, and their more compact design leaves more room for cargo.

A number of shipping companies could benefit from a data-driven approach to route planning and network management—and new industrial internet solutions including trip optimization software and better weather monitoring software can yield important savings on this front. Better hull design can also help reduce fuel consumption—this is now becoming possible thanks to a convergence of big-data industrial internet solutions and advanced manufacturing techniques that help simulate how different vessel designs would perform in different seafaring

[5]Sorce: International Group of Liquefied Ntural Gas Importers GIIGNL, http://www.giignl.org/.
[6]See the latest "The New Climate Economy" report (2015) http://newclimateeconomy.report/.

conditions. Onboard solutions to improve energy efficiency through enhanced energy storage and vessel-wide power management can also bring a major contribution here.

*In particular, as we will see in the next session, hybrid propulsion systems can offer substantial efficiency gains: combinations of gas-powered units and auxiliary electric propulsion systems enable a ship's operator to choose the most effective and efficient form of propulsion depending on weather, sea conditions and other operational factors. This can translate into very significant fuel savings.*

## Other factors

These industry-specific factors will also play an important role:

The trend towards **larger vessels** is likely to continue. Global growth will boost demand for goods, and larger vessels can be more cost efficient for the shipping of larger volumes of merchandise. Remote offshore exploration and extraction also requires the greater resilience and capabilities of larger vessels. This trend poses some challenges. Combined with increased shipping volumes and the possibility of more frequent extreme weather events due to climate change, the trend creates a greater risk of accidents and lost cargo, it poses infrastructure challenges for ports called on allowing the operation of larger vessels; and it increases the complexity of offshore operations.

**Urbanization** will proceed apace, contributing to increase localized pressure on ports. A Lloyds Register study indicates that by 2030, 8 of the 10 largest cities will be port cities. This raises the risk of costly delays in loading and unloading at ports.

As global growth and rebalancing continues, **competition** in the shipbuilding and marine industry will intensify. China has already begun to challenge the dominant role of Korea and Japan in shipbuilding, and of Greece in vessel ownership and operations. Looking forward, other countries, such as India, Brazil, Vietnam and the Philippines, will be increasingly important contenders.

An additional macro trend impacting the Marine industry is **demographics:** many countries around the world have begun to experience significant population aging, and this is projected to continue and intensify in the coming decades. It is impacting mostly advanced economies, particularly Japan, but is also very pronounced in China and some other emerging markets.
As a consequence of population aging, Marine and other industries will face the simultaneous retirement of large cohorts of experienced workers over the next 5-10 years, with fewer younger workers ready to replace them. The situation was made worse when both experienced and new apprentice positions were cut in the last financial crisis. This could create a sudden **shortage of critical skills** that could impair the operational efficiency of marine sector companies.

The challenge might be especially severe in specialist sectors and specific markets as the geographic distribution of opportunities changes, and as the industry faces the need for a new "smart ship," technology-driven skills mix. Shortage in skilled workers risks driving project rates higher.

These trends will intensify the pressure on all links in the marine value chain. For vessel owners/operators, the focus will be on optimizing operations/reducing operational costs. For shipbuilders, it will be on building more efficient vessels at competitive prices. For marine offshore operators, it will be on reducing costs and raising efficiency. Across the board, the industry will need to cope with a prospective shortage of experienced specialized workers.

This multidimensional set of challenges requires all industry players to think in innovative ways. We believe the strongest potential comes from the new wave of digital solutions that are now being developed, and that can also help address many of the industry's crucial pain points.

[18] Source: Clarksons Research.

# **Digital solutions:** the future of the Marine industry

Just as the marine industry faces these challenges, a new set of innovations is transforming industry at an accelerating pace, driven by the merging of digital and physical technologies - what GE called the Future of Work. These innovations can change the face of the Marine industry.

The Future of Work is driven by three interrelated and mutually reinforcing trends:

1. **The Industrial Internet,** which merges big data with big iron, integrating cloud-based analytics with industrial machinery, resulting in greater efficiency and reduced downtime
2. **Advanced Manufacturing,** which weaves together design, product engineering, manufacturing, supply chain, distribution and servicing into one cohesive intelligent system, delivering greater speed and flexibility at lower costs
3. **The Global Brain,** the collective intelligence of human beings across the globe integrated by digital communication, resulting in crowdsourcing, open collaboration, and a much faster pace of innovation

The innovations of the Future of Work are turning traditional industrial assets into interconnected devices, full-rights members of the Internet of everything. They are also changing the nature of economies of scale, and blurring the lines between manufacturing and services. Industrial companies that learn how to combine the digital and the physical can unlock new value for both customers and shareholders through greater efficiency and productivity.[7]

**This digital revolution is poised to deliver transformational opportunities to the marine sector. These opportunities are, paradoxically, greatly underestimated at this stage.** In the transport sector survey mentioned above, respondents in the shipping industry showed very little optimism that technological improvements could represent a valuable investment opportunity in the sector.

This skepticism is not too surprising. To some extent, it reflects an understandable instinct on the part of industry participants to turn to familiar and trusted responses to address the pressing challenges they face. Moreover, it echoes a skepticism often heard in the broader debate on the power of digital innovation to boost growth, productivity and incomes. Some economists argue that the new wave of innovations cannot match the productivity-enhancing power of the original industrial revolution[8].

We hold a different view[9]. **We believe that this new wave of**

[7]Annuziata (2014), "The value of interconnectedness", GE White Papers.
[8]See, for example Robert Gordon (2012) "Is US economic growth over?" NBER working paper 18315.
[9]See Annunqiata and Evans (2012) "The Industrial Internet: pushing the boundaries of men and machines", GE White Papers.

**innovations will prove if anything more powerful than the original industrial revolution. We also think its benefits will become apparent over the next several years, as new data-driven solutions are developed and implemented at scale across industry.** A digital revolution needs a platform, and GE has recently developed **Predix**, the operating system of the Industrial Internet. Predix is a cloud-based platform, built to handle industrial-grade big data, guarantee the highest level of cyber security and facilitate interoperability across industries. This common platform will accelerate the development of Industrial Internet solutions, spurring the rise of an Industrial App Economy comparable to that of the consumer sector.

In the case of the marine industry, traditional strategies to reduce costs and improve margins can now only deliver limited incremental gains. Future of Work innovations will be a game changer, by unlocking the value of greater data-driven information, and turning the industry's assets into interconnected assets whose performance can be greatly enhanced along entirely new dimensions:

**A systematic approach to gathering and analyzing data can greatly improve visibility over asset conditions and performance.** This, in turn, can deliver powerful insights on how to improve efficiency, predict potential failures with greater accuracy, and reduce unplanned downtime.

**A further level of efficiency gains can be achieved through insights on the entire set of a vessel's systems,** understanding and optimizing the interdependencies of their performance.

**The third level of digitally driven gains can be obtained by analyzing and optimizing the routing and performance of entire fleets of vessels, based on real-time information on their locations, conditions and performance.**

## Optimizing asset performance and on-board system performance

Given the increased pressures on margins and profitability, Non-Productive Time (NPT), the time that a vessel spends without performing revenue-generating activities, is a major source of inefficiency and financial losses. A single drill ship, for example, loses an average of $12 million a year due to NPT. Reducing NPT requires a different approach to asset and operations optimization.

New digital technologies can reduce NPT by delivering deeper insights on the conditions and performance of individual machines. Advanced analytics can leverage the large amount of data collected on the performance of similar physical assets to comSpile a historical baseline and compare it to the performance of a specific individual machine, monitored in real time. Deviations from the baseline are flagged and analyzed, and help predict the likelihood of specific equipment failures well in advance. Operators can then plan preventive maintenance, avoiding failures and the resulting unplanned downtime.

Given the interaction and interdependence of the different assets on a vessel, it is also important to develop advanced analytics that can offer a holistic view of the different systems operating on board. The condition and performance of any individual machine depend on the performance of all other components. Analytics should therefore also perform system monitoring and system optimization algorithms. These can further enhance predictive insights, allowing the foresight of any failure or performance loss that one asset might experience as a consequence of the behavior of other assets on the vessel. They can also identify operational settings that will maximize the efficiency of not just one machine, but also the entire set of systems on the vessel.

## Optimizing from design to operations

Increasing a vessel's energy efficiency is extremely important—and extremely complex. It starts at the design stage: shipbuilders need to determine the optimal size of a ship's thrusters and how to configure the electrical system to power the thrusters in the most economical and reliable way. More broadly, understanding how a vessel's different systems will perform in different conditions – depending on the intended use and routes, the volatility of environmental conditions, and the possible need to redeploy the vessel to alternative courses or uses – can give crucial insights into how the vessel should be optimally designed in the first place.

Advanced manufacturing and Industrial Internet techniques are now being used exactly to leverage data and computer models in order to simulate how different conditions can impact the performance and financial viability of a machine, a system of machines, and even an entire factory. These techniques can now enable sophisticated digital simulations that make use of mathematical models to simulate dynamic positioning in different combinations of weather and other marine conditions.

The potential of these digital simulations can be maximized through a cooperative approach: Designers, engineers and operators can collaborate to bring together their understanding of a vessel's power systems and all other relevant technical characteristics, so that all can be encompassed—and their interactions captured—in the digital

simulations. This can enable true optimization at the vessel design stage, which in turn will help maximize the efficiency and performance of a vessel's assets and systems once in operation. This approach can yield superior outcomes compared to the more traditional strategy of adding components once the ship has already been built.

## Optimizing offshore vessel and fleet management

Once the configuration of a vessel's systems has been optimized, starting at the design stage, and digital solutions are in place to enable preventive maintenance and help to optimally monitor and control on-board assets and systems, the challenge shifts to the optimal management of both individual assets and entire fleets. Data and analytics can deliver extremely powerful insights, and advanced monitoring and control systems can greatly enhance the self-regulating and automated response abilities of physical assets, reducing the need for human intervention.

But an operator's effective management of the vessel's systems remains crucial, and this management now requires the ability to monitor, understand and control a larger number of complex variables and sophisticated insights. This is where user interface advances can be most helpful. User interfaces must be intuitive, to provide the operator with immediate situational awareness and to allow her to quickly focus on the key issues, turning data into knowledge. These interfaces must direct the operator's attention to the most critical and urgent aspects, while allowing her to easily dig deeper into any additional relevant details.

User interface technology is at the heart of the minds and machines symbiosis: it must distill the real-time analytical insights that are a machine's comparative advantage, and express them in a way that the human mind finds intuitive and accessible, so that the operator can best express the abilities that are her comparative advantage—in this case seamanship and ship handling.

Similar digital solutions can also assist the optimal management of a fleet's operations. For example, software that tracks the global positioning of all vessels in a fleet can compile data on the performance of their systems, and allow predictions that can help optimize routing choice and adjustment. It can match ship positioning with the location of ports, repair facilities and spare parts depots to expedite maintenance and repairs; it can combine fleet movement information with other macro and micro economic data, yielding greater market intelligence visibility on activity in specific regions and areas, and helping guide business growth strategy.

Critically, too, the digital environment can facilitate having off-vessel experts, lightening the burden of skills shortage, increasing responsiveness and enabling cross-fleet technical coverage by technology specialists without the need to be present on each vessel.

## The way forward

Solutions along the lines discussed in this section are already being developed and deployed. More will follow. All industry players are well aware of the pain points to be addressed, and the power of digital solutions is becoming increasingly apparent, in Marine as in other industries.

As the magnitude of the potential benefits also becomes clearer, efforts to develop and adopt digital solutions will accelerate. We are just at the beginning of a process that can deliver tremendous benefits to the industry. The key is to start switching mindsets, to think in terms of the benefits that digital technologies can bring, and to start leveraging them at a faster pace.

## GE Marine has already developed a number of industrial internet solutions. They bring together a unique mix of equipment, software, analytics and operational expertise.

### SeaStream™ Insight

Powered by the proven Predix platform, gathers data on the condition and performance of equipment across a vessel's different systems and provides insights on the efficiency of the assets' operations and the risk of failures, enabling preventive maintenance, avoidance of unnecessary time-based maintenance schedules, and the reduction and eventual elimination of unplanned downtime. SeaStream™ Insight leverages the power of Smart Signal software, an especially powerful application that can identify impending equipment failures weeks and even months in advance. A key feature of SeaStream™ Insight is that it can provide multiple parties with instant and simultaneous visibility on asset conditions and performance: operators, GE experts and third-party experts can be given access to real-time data and collaborate on immediate troubleshooting solutions. This multiple-party visibility and collaboration is made possible by Predix's cyber security features, which ensure the safety and privacy of the data transmitted.

Enables both asset optimization and system optimization: it provides real-time condition monitoring of individual equipment, and, at the same time, it provides operators with a holistic and consistent view of the different systems operating on the vessel. Ultimately Insight knowledge can provide the visibility to reduce project risk, and fleet-level indicators form a vital part of owner and operator enterprise-level planning, allowing for more-informed investment and operational decision making,

### Vessel Performance Analyzer (VesPA)

Is a real-time configurator that allows shipbuilders and vessel operators to compare multiple electrical configurations at the design phase, so as to understand which configuration of power, propulsion and electrical systems will best match the specific performance requirements. In addition, VesPA allows operators to calculate the annual operational expenditures associated to each different configuration, so that design and equipment selection can be targeted to reduce operational expenditures through reduced fuel consumption. VesPA also allows optimizing of the thrusters rating to meet specific environmental targets—a key enabler of green vessels. The optimization process performed via VesPA offers much higher precision and speed than previous optimization strategies: the simulation and configuration exercise can be performed in as little as one hour anywhere in the world—compared to the 16 hours required by manual processes.

### SeaStream™ Dynamic Positioning (DP)

Allows operators to identify, set and control the best course for the ship, giving the operator visibility and control over an increasingly large and sophisticated set of vessel systems, with an intuitive user interface that enhances situational awareness and allows the operator to quickly focus on key issues. The system has been developed by leveraging GE's user interface expertise to address views and concerns gathered from mariners at the design stage. The user interface delivers all the needed information in the most intuitive and accessible way, allowing mariners to focus on seamanship and ship handling. This results in improved operator comfort, safety and efficiency. SeaStream™ DP also has an Energy Efficient mode, which uses predictive software to anticipate position and heading variation, and limit excessive power and thrust changes. Through this technology, the system could **save operators as much as 10% in fuel usage.**

### GE Marine Mapper

Provides visibility on the positioning of GE's entire installed base of over 1,000 ships, stores information on all ships, including identity of owners and operators, and displays service centers and part depots with contact details. The system will also allow for including details of the equipment installed on each vessel, and tracking history of the routes followed. This will yield improved market intelligence allowing users to: better understand equipment and vessel performance in different conditions, including through comparisons across the installed base; ensure faster repairs and maintenance; through greater visibility on activity in individual regions and areas.

# Sizing the opportunity

The solutions described above highlight the substantial benefits that Future of Work innovations have already brought within reach for the marine industry, helping industry participants address all the key pain points that have emerged in this phase of the cycle. These solutions can increase efficiency, reduce operational expenditures and fuel burn, reduce downtime, optimize routes, improve safety, and meet more stringent environmental requirements.

More will follow—this technological revolution is still in the early stages and has only now reached an inflexion point, where the development and diffusion of its innovations is poised to accelerate dramatically.

The benefits delivered through **unprecedented gains in productivity and efficiency will have a powerful impact on the global economy.** Industry represents about one-third of global economic output, with manufacturing accounting for between 15 and 20%[10]. **The scale of global industrial operations implies that even small efficiency gains translate into substantial aggregate economic gains.** In 2012, we estimated that just a 1% efficiency improvement would yield some $90 billion savings in the Oil and Gas industry over a fifteen-year period, over $60 billion each in the power industry and the health care industry, and about $30 billion each in aviation and in rail transport.

Our estimates of one-percent efficiency gains show the benefits that even marginal performance improvements can bring to industry. But as Industrial Internet applications are being developed and deployed across sectors, they deliver much larger gains in terms of reduced energy consumption, increased uptime, efficiency and profitability.

It is easy to see the potential impact in Marine. We know from the industry that up to 50% of downtime can be taken up with analysis to get to the root cause of a failure in order to fix it. If we take the offshore mobile drilling example, an improvement in unplanned downtime of 20% could be worth over $0.5 billion to the industry every year.

**Digital innovations can also help the industry address the looming skills challenge,** in at least two ways[11]. First, advanced remote monitoring and control solutions will allow experts in a centralized location to support multiple vessels, troubleshooting issues remotely and offering advice and guidance to on-board personnel. The skills of a smaller number of experts can then be leveraged across a wider share of the global fleet.

Second, digital innovations can help capture, store and access all relevant information: technical manuals and procedures can be digitized and made accessible via portable devices; new digital tools can help guide technicians through maintenance and repair operations, and, in the process, capture and store the way in which the operations are carried out and the interaction of field technicians with centralized control centers, **building a digital twin of the experience**

[10]Annunziata, M. and Evans, P. (2012). "The Industrial Internet: Pushing the Boundaries of Minds and Machines," GE White Paper, http://www.ge.com/docs/chapters/Industrial_Internet.pdf. Industry accounts for about one quarter of economic activity in advanced economies and over one third in emerging economies.

[11]For a more detailed discussion of how Industrial Internet innovations can augment the skills and efficiency of the labor force, enhancing collaboration and knowledge transfer, see Annunziata and Evans (2013), "The Industrial Internet @ Work," GE White Paper.

**accumulated by workers through years of operations in the field.** This will make it much easier for younger and less experienced workers to tap the "institutional memory" accumulated in the sector. Domain expertise will remain extremely important. In fact, developing and upgrading the right skills for the workforce of the future is one of the key prerequisites for success, as we will discuss in the next section, but, by augmenting the skills of the workforce, digital innovations will give another powerful contribution to enhancing efficiency and will considerably lessen the potentially adverse impact of workforce aging in the coming years.

These same solutions can help naval forces address their challenges. The ability to switch to predictive, condition-based maintenance, and to reduce fuel consumption, helps reduce costs in an environment of tighter budget constraints. Improved asset visibility and a better use of data and information can help naval commanders ensure operational readiness and faster reactions to changing circumstances.

**Technical innovations in marine will continue to contribute to global trade and economic growth.** The focus on trade agreements and protectionist measures can often overshadow the technical achievements that are probably more important and fundamental to the degree of economic globalization that we take for granted today. The cumulative gains of higher efficiency, lower operating costs, faster speed, and greater reliability of the marine transport system enable the shipments of raw materials and manufactured goods on an unprecedented scale[12]. Advances in information and communication technologies have also contributed to the expansion of the scope of goods and services that are traded, and the growing complexity of the production processes that bring them about.

In an era of rapid technological change, it is hard to envision all the economic and social implications of new technologies. Several important future technologies could potentially prove disruptive to the global trading system in the coming decades. Technologies like 3D manufacturing and advances in robotics will reduce the cost advantage of low-skilled labor, and could therefore reduce advanced economies' demands for developing countries' low-cost manufacturing. At the same time, these very advances can accelerate the growth of higher value added manufacturing in emerging markets by lowering the advantage of economies of scale and making smaller factories more competitive. This could strengthen regional supply chains, bolstering the trend towards intra-regional trade, but it will also lead to greater specialization and global integration of supply chains, with a positive impact on trade overall. Increased use of renewable sources of energy and dematerialization could reduce the demand for the at-present highly traded primary commodities, but new manufacturing techniques will require new materials, for which trade will increase.

*Improvements in physical and digital technologies have tremendously increased the potential for specialization and trade and defined our era of globalization. Overall, we think that this trend is likely to continue, but a combination of the right skills, institutions and infrastructure will be necessary for users to benefit from the opportunities offered by new technologies.*

[12]See Vaclav Smil (2010) "Prime Movers of Globalization," MIT Press.

# Enabling conditions

The new wave of digital innovations of the Future of Work brings tremendous opportunities to the Marine industry: it can allow industry participants to address the challenges that characterize this pivotal phase for the industry and turn them into substantial gains in efficiency, sustainability and profitability.

Achieving this will require a strong and coordinated effort on the part of all industry participants: ship owners, builders and operators; providers of services and technology solutions; policymakers and regulatory agencies. In this section we will briefly discuss the key enabling conditions that will need to be put in place in order to realize the full potential of the digital revolution in Marine.

## Investment in digital solutions and capabilities.

Just as in other industries, all participants in the Marine sector need to develop stronger digital capabilities. Over time, all industrial companies will need to transform themselves into digital-industrial companies, and the Marine sector is no exception. **There are four drivers behind this massive opportunity—software and analytics, intelligent machines, big data, and people,** and it will involve a series of steps: retrofitting some of the existing equipment with sensors and digital controls; investing in new, state-of-the-art digitally enabled equipment, but also incorporating data and digital systems into all aspects of activities, from vessel design to route planning to the management of on-board energy systems; and investing in advanced technologies for both onshore and offshore data analysis, monitoring and control, as well as for data transmission.

## New business models.

Fully exploiting the potential of new technologies often requires a change in the way that operations are planned and managed. Decisions on investment, procurement, capacity expansion, and market growth and positioning will have to be more data driven. Operations will need to be structured so as to allow users to leverage available analytical insights at different steps in the process, and they will also need to find the right combination of automated responses and human interventions, and of on-shore and off-shore data analysis and decision-making, whether human or automated. Business models will also need to evolve towards greater collaboration across a range of different actors. We have highlighted above how the cooperation of shipbuilders, vessel owners, operators and third-party providers can enable optimization in vessel design and yield major efficiency gains in operations. This is only one example. The new generation of digital innovation is based on open collaboration, and all players will have to be open to the possibility of new alliances and cooperations in order to maximize potential value.

## Interoperability.

The benefits of big data, analytics and collaboration can be maximized only by ensuring a high degree of openness and interoperability. Common platforms like Predix are especially powerful exactly because they can foster interoperability, allowing applications developed in one area to be quickly adapted and ported to a different sector or industry, fostering cross-fertilization of ideas and accelerating app development.

Interoperability and openness also allow analytics to be performed on larger amounts of data, yielding better insights. Compatibility of on-board systems allows the maximization of efficiency benefits through digital solutions that can "talk to" all assets on the individual vessel, guiding coordinated responses to changing conditions. Industry bodies and regulatory organizations can play an important role in fostering the development of common standards to maximize interoperability.

## Cybersecurity.

The need for openness and interoperability must be matched by the imperative of ensuring data protection and overall cybersecurity. Data generated by on-board and onshore systems should be secure, to guarantee the confidentiality of company information, and should be shared in a controlled way aimed at maximizing efficiency benefits. Digital systems should be made secure against the risk of industrial espionage, terrorism, electronic warfare, piracy or sabotage—risks that will naturally increase as the digital dimension of the marine industry becomes more important, both in naval and commercial systems. Companies like GE are already making important investments in cybersecurity, and cybersecurity is one of the key characteristics of the Predix platform. Policymakers will naturally play an important role in this area, but it is incumbent upon the developers and providers of digital solutions to ensure the highest degree of cyber security in their offerings. Industry players should be as mindful of cyber risks as they are of all other operational, regulatory and environmental risks.

## New talent.

None of the above conditions can be ensured without developing the right talent for the digital age of the industry. The new innovations of the Industrial Internet are quickly creating the need for new professional categories: digital-mechanical engineers (i.e., technical experts who combine proficiency in traditional engineering with strong knowledge of data and analytics); and a new generation of managers who can naturally incorporate analytics and data-driven insights in their approach. Creating and maintaining this talent pipeline will require changes in the education systems, with greater emphasis on STEM (science, technology, engineering and mathematics), and also on problem-solving, creativity and flexibility. It will require a closer coordination between schools and industry, to keep talent supply aligned to the changing demands of a fast-innovating industrial system, and it will require companies to invest more in on-the-job training, life-long learning and continuous skills upgrading. It will benefit from investment in new labor-augmenting digital technologies, and it will benefit from open and flexible labor markets at a global level, so that scarce talent can be most effectively deployed. These new technologies will create opportunities for new high-reward and high-remuneration jobs at different levels of the skills distribution, but a joint effort to guarantee alignment of skills demand and supply will be essential.

# Conclusions

The convergence of digital and physical technologies is beginning to transform the global economy—and it offers tremendous potential benefits to the Marine industry. Digital solutions can enable greater efficiency starting from the vessel design stage: they can improve asset performance and reduce nonproductive time, and enhance routing, and the speed and efficiency of maintenance and repairs; they can improve fuel efficiency and environmental sustainability; and they can help cope with the shortage of skills caused by the aging of the workforce.

Securing these benefits will require substantial investment in digital capabilities, high levels of interoperability and cyber security, and the development of a new pool of talent, and industry participants will also have to be ready to embrace new business models.

The effort required is substantial, but so are the benefits at hand. Thanks to the digital-industrial revolution, the Marine industry is in a position to experience a rapid pace of sophisticated innovation that can lay the basis for renewed sustainable growth and profitability for the next several decades.