First Marine International

a company of

Royal HaskoningDHV

Enhancing Society Together

2014 US Naval Shipbuilding and Repair Industry Benchmarking

Part 2: Ship repair

DISTRIBUTION A
Approved for public release: distribution unlimited

Assistant Secretary of the Navy
Research, Development & Acquisition

9Y1755

10 April 2017

First Marine International

2014 US Naval Shipbuilding and Repair Industry Benchmarking

Part 2: Ship repair

CONTENTS

First Marine International

SUMMARY AND PRINCIPAL CONCLUSIONS

This report presents the findings of the ship repair aspects of the 2014 US Naval Shipbuilding and Repair Industry Benchmarking study carried out by First Marine International (FMI). The shipbuilding aspects are presented in the Part 1 report. The study is sponsored by the Assistant Secretary of the Navy for Research, Development and Acquisition (ASN (RDA)). The overall objectives are to understand the use of best practice in the US naval repair industry and identify actionable items to help improve its performance. The findings are presented in individual shipyard reports, in this report, and in a separate customer factor report. The proprietary FMI shipyard benchmarking system, which has been used in previous US shipyard benchmarking studies, has been used as the basis for this study.

The four private shipyards included in this study perform the full range of US Navy surface ship non-nuclear availabilities. The shipyards are successful in satisfying the stringent naval requirements and have competent, experienced management teams and workforces. Some repair facilities are dated and, although many facilities are being upgraded, they would benefit from further investment. The shipyards operate in a commercial and technical environment that is heavily regulated by the Navy and this limits their opportunities to improve performance independently. That said, there are improvements that can be made in each shipyard. As a group, the yards have a similar technology profile to an international sample of yards working in the same sector. Although the US yards have higher scores in some areas, such as purchasing and logistics, in general, they lag slightly behind the international yards. This is due in part to the influence of US Navy processes and practices.

The industry currently faces a changing commercial environment that includes the transition from cost-plus to fixed-price contracting, a shift of workload from the East to West Coast and the possible introduction of out-of-port competition.

Collectively, the Navy and the industry appear to understand the key issues relating to improving the performance of the enterprise. However, even though there have been many initiatives over the years, it has been extremely difficult to achieve change. The most significant recent change is the introduction of fixed-price contracting, which could help to provide the impetus necessary to bring about change in both the shipyards and the Navy. However, it may also result in varying shipyard workloads, make it more difficult for the shipyards to justify investment, and potentially reduce levels of cooperation between all parties. All of these impacts are detrimental. The Navy and the industry need to work in partnership to achieve significant improvement; therefore, establishing an effective Navy-industry performance improvement forum should take priority.

This study has determined that the top five industry performance improvement areas are:

- Approach to performance improvement
- Organization and approach to work
- Support for work
- Planning, scheduling and control
- Commercial relationships

There is sufficient commonality for some improvement opportunities to be developed collaboratively between the shipyards.

FMI suggestions regarding specific investments in facilities and equipment have been included in each shipyard benchmarking report. Some of these require high levels of capital expenditure and will have long payback periods. Some common, generally lower value, items are listed below.

- Rationalization of workshops
- Information and communications technology
- Long-range facilities planning

First Marine International

1 INTRODUCTION

1.1 Background

This report is Part 2 of the 2014 US Naval Shipbuilding and Repair Industry Benchmarking study carried out by First Marine International (FMI). It presents the overall industry-level findings of the ship repair aspects of the study. The shipbuilding aspects are presented in Part 1. The study is sponsored by the Assistant Secretary of the Navy for Research, Development and Acquisition (ASN (RDA)). The overall objectives are to understand the use of best practices in the naval repair industry and to identify actionable items to help improve its performance. The shipyards are part of the wider US Navy ship repair enterprise, which requires the shipyards to adopt some processes and practices that impact their performance. The enterprise includes the Navy, the shipyards and all other participants such as the planning yards, subcontractors, OEMs, and other government organizations. The findings are presented in individual shipyard reports, in this report, and in a separate customer factor report. The FMI shipyard benchmarking system, which is briefly described in Section 1.3, has been used as the basis for this study.

1.2 First Marine International

First Marine International Limited was formed in 1991 to provide specialist consultancy services to the marine industry. Principal clients include shipbuilders and ship repairers, UK and overseas government departments and agencies, and national and international maritime organizations. Members of the FMI team have worked on projects in over 50 countries and first collaborated in the 1970s with the design and engineering of some of the largest and most successful shipyards in the world. The company's expertise includes market research and forecasting; marine industry studies; benchmarking; competitiveness; technology development; upgrading of existing shipyards; design and engineering of greenfield shipyards; and development, implementation and management of shipyard performance improvement programs.

In February 2008, FMI was acquired by Royal Haskoning, an independent international engineering and project management consultancy. In July 2012, Royal Haskoning merged with another international engineering company, DHV, to form Royal HaskoningDHV. FMI is the shipyard technology and marine market research advisory group within the Maritime and Aviation business line of Royal HaskoningDHV.

1.3 The FMI benchmarking system

The FMI shipyard benchmarking system allows the processes and practices applied in individual shipyards to be compared to others and to international best practice. The system has a number of uses but is most commonly applied in assisting shipyards to develop performance improvement programs. It was first used to support the nationalization of the British shipbuilding industry in the mid-1970s. It has since been applied in over 150 shipyards worldwide and has been used as the basis for the following industry studies:

1978:	US shipyard technology survey
1985:	US shipyard technology survey
1992:	EC shipbuilding competitiveness study
1993:	EC Eastern European shipyard study
1995:	NSRP study (system derivative)
1998:	Portuguese shipyard benchmarking
1999:	UK shipyard benchmarking study
2000:	US, Asian and European shipyard benchmarking study
2004/2006:	US ODUSD(IP) GSIBBS
2008/2009:	UK MoD dockyard benchmarking study
2010/2011:	Benchmarking in support of the Canadian NSPS

The full system contains 157 elements of shipbuilding, ship repair and ship conversion technology grouped into 20 functional areas. The nine functional areas of ship repair practice included in this study are:

B	Commercial
C	Purchasing and the supply chain
D	Production infrastructure and equipment
E	Production methods
F	Production support
G	Human resources
H	Technical support
I	Organization and operating systems
J	Performance improvement

The benchmarking system describes five levels of use of best practice in each element of each group. In broad terms, these levels correspond to the state of development of leading shipyards at different times over the last 40 years, with Level 5 being state of the art. On the basis of interviews and inspections carried out during the survey, a 'level of technology' rating is assigned to each element. Elements that are subcontracted are noted and if sufficient information is available to evaluate subcontractor performance the element is rated. The ratings are aggregated; first, for the functional areas, and second, for the whole shipyard. The results are presented graphically in the individual shipyard-specific reports and clearly show the strengths and weaknesses. Due to the small sample of participating US Navy repair yards and the need to ensure that shipyard confidentiality is maintained, aggregated benchmarking scores for the four shipyards are not included in this report.

Further details of the benchmarking system are available in the FMI shipyard benchmarking system description, a copy of which can be supplied on request.

1.4 General approach

The overall approach for the ship repair industry benchmarking phase of the study was as follows:

1. Carry out a benchmarking survey of 68 processes and practices in the four participating US ship repair yards.
2. Interview shipyard personnel to gather opinions on changes the Government could make to help improve shipyard productivity.
3. Review international best practices, consider US ship repair circumstances, and suggest target technologies and hence target benchmarking scores for the US yards.
4. Compare the technology applied in each yard to the suggested targets to identify technology gaps that represent opportunities for making improvements.
5. Write shipyard-specific reports on the findings in each yard that include a prioritized list of action areas and suggested actions.
6. Aggregate the findings to an industry level to identify opportunities for industry-wide actions to improve performance.
7. Combine industry opinion with FMI's study findings to suggest government actions to improve performance.
8. Present the general industry findings and suggestions for government actions in two separate reports.

As with the shipbuilding benchmarking phase of the study, to provide continuity the same team of four FMI consultants carried out the surveys of all four ship repair yards. Each consultant is a specialist in the areas they surveyed. Several members of the FMI team were also involved in the GSIBBS and earlier US and international studies. The NAVSEA NSRP program manager accompanied the team on the surveys of all four shipyards but did not influence the benchmarking scores assigned. It is assumed that the industry, for example through the NSRP, will use this report as the basis for an action plan to further improve performance.

1.5 Participating shipyards

The four ship repair yards surveyed during this study predominantly repair Navy surface ships. In addition to working in their own facilities, the shipyards undertake repairs in the naval bases and other facilities in their local area. They are also subcontractors to other shipyards in their local area. Until recently, the shipyards carried out the majority of US Navy work under multi-ship multi-option (MSMO) time and materials contracts. The recent transition to predominantly fixed-price Navy contracts will require substantial changes in shipyard roles and business processes. While no international ship repair yards were

benchmarked as part of this phase of the study, some international comparisons are provided based on FMI's findings from previous studies.

1.6 Proposed best practice targets

Lowest cost is achieved by having a best practice rating appropriate to the product mix, throughput and cost base of the shipyard. The most appropriate score in each element is therefore not necessarily 5.0 (Level 5). It is possible to calculate the most appropriate target best practice ratings from an analysis of productivity and the structure of project cost. These analyses have not been included in FMI's scope of work for this study. Therefore, a realistic target has been proposed for each element on the basis of FMI's international experience applied to each US shipyard's current product mix and throughput.

The relatively low manufacturing throughput means that it may not be possible to justify high levels of technology in all areas. Thus, the targets proposed for some elements are lower than might be expected. The complexity of Navy vessels and the nature of the work mean that most of the pre-production functions need to be strong. This includes Technical support, Organization and operating systems, as well as most of the Commercial elements. Some of these functions may be provided by third parties, such as the planning yards.

The targets for each element are directed at achieving the appropriate balance of applied technology for the circumstances in each shipyard. The technology gap is the difference between the current score and the proposed target. Where a shipyard's current score for an element is higher than the proposed target, the target score has been increased to match the current score.

While the aggregated current scores and proposed targets for the shipyards are not included in this report, FMI has analyzed the industry-wide findings to identify common technology gaps that represent opportunities for improvement for the industry as a whole. It will be necessary for the Navy to facilitate some of the changes required to close the technology gaps.

First Marine International

2 BUSINESS ENVIRONMENT

2.1 Context

The shipyards surveyed work in a complex, challenging and highly regulated business environment, which limits the overall performance that the shipyards can achieve and restricts their ability to independently make changes to improve performance. This section summarizes aspects of the business environment that are relevant to the survey results and recommendations.

2.2 Shipyard activities

About half of the Navy repair work carried out by the shipyards is routine cleaning and painting, general repairs and maintenance. The remainder is often complex work such as the incorporation of alterations and additions. Shipyards are required to be agile and flexible enough to respond to a range of work types and a variable workload. For all availabilities, a large number of different organizations need to be coordinated and a great deal of procedural documentation needs to be managed.

Some availabilities require the use of a dry-dock (an expensive capital investment), while other availabilities do not and can be executed by shipyards with limited facilities. Work may be carried out within a shipyard's own facilities, in other yards or at naval bases. The manufacturing work involved has reasonably low throughput and low repeatability, which makes it difficult to justify automation.

Shipyards may be the prime contractor on certain availabilities and a subcontractor to another shipyard on others. As prime contractors, yards work with original equipment manufacturers (OEMs), subcontractors and Navy-designated participants. These include the ships' crews, the planning yards, alteration installation teams (AITs), and providers of government-furnished equipment and information (GFE and GFI). With the exception of their own subcontractors, the shipyards have limited influence over these groups.

2.3 Customer factor

In the US and some other nations, government projects require shipyards to commit proportionately more management, technical and administrative resources than would be the norm on a commercial vessel. This is because the customer requires the shipyard to adopt practices that are not normally necessary on commercial projects and there is simply more work involved in dealing with, and responding to, the customer. This effect is referred to as the customer factor.

The US Navy repair sector is subject to high levels of business process regulation such as the Federal Acquisition Regulations (FAR) and Defense Federal Acquisition Regulations supplement (DFARS), as well as extensive oversight from the Navy, the Defense Contract Audit Agency (DCAA) and others. The execution of a large proportion of the work is

governed by an abundance of Navy repair standard items and procedures, contract requirements and government processes.

There are numerous interfaces with the Navy, including several regional maintenance center departments, the ships' crews and the fleet. The ships' crews remain in command during all availabilities and participate in numerous aspects of ship operation and control. The result is that daily progress of repairs is often dependent on crew cooperation – something which varies from ship to ship. The crews also have non-availability-related priorities and are not directly accountable for availability cost or schedule performance. The various Navy representatives are essentially multiple customers who have competing and sometimes conflicting goals.

The effect of customer factor on US Navy ship repair productivity and cost has not been quantified in this study. Previous FMI studies have found that the customer factor in shipbuilding caused an increase in overall work content of about 10% for the construction of US naval auxiliaries and about 15% for surface combatants. The customer-driven processes in repair suggest that the US Navy repair customer factor is likely to be higher than the levels in new construction.

2.4 Commercial tensions

The US Navy repair market operates as an oligopoly. The Navy has limited options for fulfilling its repair and maintenance requirements and it is the predominant or only customer for the repair yards. This interdependency, together with an inherent misalignment of goals, can result in tension on both sides, as well as strategies that may not be in the best interests of the enterprise as a whole.

A high level of contract growth and emergent work is typical during an availability and can be a major source of tension between all involved. The complex processes for dealing with growth work, the accompanying slow response times, or lack of funding, can result in inefficient working. A high volume of growth work can occur relatively late in an availability. This is especially problematic as the work is likely to be performed in less-than-optimum conditions, potentially disrupting previously completed work and testing.

2.5 Contract types and the changing environment

Contracting approaches and incentives are used to motivate outcomes desired by the Navy. While these may motivate short-term program-based behaviors, they can also limit long-term continuous improvement and, in some cases, have negative unintended consequences.

Until recently, all availabilities were carried out under MSMO contracts, which are essentially cost-plus framework agreements that incorporate incentives. The incentives are set by an award fee plan and include a range of elements of performance such as schedule adherence, financial performance and responsiveness. From time to time the Navy modifies the incentives based on its view of the current issues.

MSMO contracts were introduced in the late 1990s. When compared to competitive fixed-price contracting, they made it easier for shipyards to respond to Navy needs and to collaborate with the Navy in maintenance and availability planning. These contracts also reduced administrative costs. Each MSMO contract involved work on multiple ships over several years, giving the shipyards foresight of their workloads and making it easier for companies to justify investment. However, MSMO contracts tended to obscure the fact that the availability scope of work was not always well defined at the outset. With shipyards responding to multiple customers within the Navy, the resulting difficulties in controlling the scope of work gave rise to significant growth and emergent work. The nature of the contracts also meant that cost reduction and performance improvement initiatives could potentially become a low priority.

A number of initiatives have been undertaken in the last few years to improve MSMO contracting and these have affected the shipyards' business environments. MSMO Spiral 2 was introduced in 2009 to enhance cost-control mechanisms. In 2010, the Navy implemented the NAVSEA 02 contracts discipline initiative, which centralized change order approval authority. Along with increased control, recent initiatives appear to have made the change approval process more complex and less responsive to the schedule demands of the availabilities.

There have also been increased procedural requirements and the number of standard items has continued to grow. Work certification requirements were added in 2011, along with an increase in the number of checkpoints and reports. Expanded process control procedures (EPCPs) were added in 2012 and, more recently, the number of critical system process control procedures (PCPs) has been increased. The trend to increase procedural requirements and control may or may not reduce program risk appreciably, but it has increased the shipyards' ratio of administrative-to-production effort and the durations of repair tasks. This has added costs and reduced responsiveness.

MSMO contracts are currently being phased out and replaced primarily by competed, single-availability, fixed-price contracts. Some of these may be competed coast-wide rather than restricted to home port shipyards. The Navy considers that fixed-price contracting will enable the better definition of requirements at the outset, better control during an availability, and hence reduced growth. Another positive aspect is increasing the motivation for the shipyards to control cost and improve performance in a competitive environment. A negative aspect of competition is its increased restrictions on shipyard collaboration with the Navy and other shipyards. Additionally, with availabilities competed individually, workload instability is likely to increase in some shipyards, particularly on the East Coast where the diminishing overall workload will exacerbate the effect. This will cause fluctuations in employment and negatively impact the shipyards' ability to retain and motivate experienced employees and effectively maintain succession plans. It will also make it more difficult to justify long-term investment in shipyard facilities.

The evolution to fixed-price contracts has numerous other impacts on the business environment, particularly in the roles and relationships of the repair participants. In the critical pre-arrival period, the Navy and the third-party planner will now perform a majority of the planning functions that the shipyards performed in partnership with the Navy on MSMO contracts. This means that the shipyards will have less knowledge of the material state of the

ships than they did previously. There are also likely to be Navy expectations that positive MSMO behaviors will continue in fixed-price contracts and some stress will result when they are not. Pre-contract teaming between the shipyards will also be greatly diminished or even eliminated in a competitive environment. As a result of changing shipyard roles and incentives, internal shipyard processes will be changing and maturing over multiple availabilities.

Announced in 2012, the US military's Pivot West affected the shipyards' business environment. Home ports for a number of vessels have been moved from the Atlantic Fleet to the Pacific Fleet, which has increased the repair workload on the West Coast and reduced it on the East Coast. This has affected workload planning, facility and tooling investments, and human resources activities on both coasts. In addition, the East Coast reductions combined with the shift to single-availability competition, some of which may be coast-wide, have resulted in workload instability in the Norfolk Navy repair community.

Finally, indefinite delivery/indefinite quantity (IDIQ) contracting has been introduced for some Navy repair work. This approach involves shipyards bidding labor rates that would be in force for a period of time with the scope of work to be defined later. IDIQ contracts motivate very different shipyard behaviors than either MSMO or fixed-price contracts. Given that a shipyard may concurrently have contracts of two or three very different types, the business environment is further complicated.

2.6 Government-sponsored performance improvement initiatives

A number of government-sponsored programs have been providing industry with information and financial assistance to support performance improvement efforts for some time. At a national level, these include the National Shipbuilding Research Program (NSRP), the Navy Manufacturing Technology (ManTech) Program, and its centers of excellence, particularly its shipbuilding center of excellence, the Naval Shipbuilding and Advanced Manufacturing Center (formerly known as the Center for Naval Shipbuilding Technology). There are also several local initiatives dealing with specialist areas. NSRP has been the cornerstone for industry performance improvement efforts for a number of years. The program has provided necessary research and development (R&D) and a unique forum for discussion. However, since 2011 only 3% of NSRP projects have been specific to ship repair, although about a third of the remainder were common to both shipbuilding and repair.

In addition to R&D, there have been numerous Navy-industry performance improvement initiatives. Examples over the last few years include:

- Joint Industry Navy Improvement Initiative (1995)/Industry Navy Discussion Panel (2014): presentations by Navy with opportunities for discussion
- National Ship Repair Industry Conference (2008): presentations by Navy with opportunities for discussion
- Maintenance and modernization performance review (2011): an annual review on each coast. Navy-invited industry participation has been greatly reduced in the most recent meetings

- MSMO summits (2011): core issue problem-solving sessions, which ended after a few meetings
- VADM McCoy Industry Day meetings (2013)
- "Challenge Every Requirement" initiative (2013): study results not communicated to industry
- CNSF Maintenance Summit (2014)
- Knowledge sharing networks (KSNs) and rapid improvement events (RIEs): some beneficial changes adopted
- Monthly CNRMC teleconference: industry feedback to Navy on specific issues

Collectively, the Navy and the shipyards understand the key issues relating to improving performance, and so it would be reasonable to expect the efforts made to have resulted in significant change. Although there appear to have been some successes, the industry view is that most of the efforts have resulted in little positive change. The level of change achieved has not been reviewed, but some of this study's findings are similar to issues raised in GAO reports and other studies dating back to the 1970s. Clearly, it is not easy to make changes in this complex environment.

The strategic shift to fixed-price contracting is presumably motivated by the desire to improve the performance of both the shipyards and the Navy. However, the changing balance between workload and capacity on the two coasts will vary the effectiveness of this approach.

First Marine International

3 SUMMARY OF USE OF BEST PRACTICE

3.1 Overall findings

The four private US shipyards that represent the industry in this study perform the full range of Navy surface ship non-nuclear availabilities. The shipyards are successful in satisfying the stringent naval requirements and they have competent, experienced management teams and workforces. The repair facilities tend to be located on older sites with good navigational access, a mix of old and new buildings and varying levels of investment in new technology and capability. The shipyards are near Navy facilities and infrastructure, and some availabilities are undertaken with the ship at a naval base. At the time of the survey, the industry was beginning to undertake single-ship fixed-price availabilities after nearly two decades of MSMO contracting. As such, the ship repair processes and practices observed during the survey are largely those that have been in place over the long period of MSMO contracting, with some modifications for the fixed-price environment being implemented.

While there is a range of best practice ratings across the shipyards, the overall profile of the use of technology is similar. This stems from the fact that the companies are working in the same commercial environment and for a prescriptive customer. The highest ratings are in some of the so-called 'soft' areas, for instance the Commercial, and the Purchasing and supply chain groups of elements. However, there are some substantial technology gaps in low-scoring soft areas such as the Technical support and Organization and operating systems groups. The latter includes planning and the organization of work. Other generally low-rating groups are Human resources and Performance improvement, where there are also some large technology gaps. The overall average ratings in the Production infrastructure and equipment group and the Production methods group were moderate, but the suggested targets for some elements in these groups are also relatively low. This is because the variety and low volume of some types of work can make it difficult to justify high levels of investment.

As explained in Section 1.6, the targets suggested for the US shipyards are based on FMI's international experience; therefore, these provide a form of international comparison. In order to make a more direct comparison, the average benchmarking ratings for the shipyards surveyed have also been compared to those of a relevant sample of other shipyards. While the technology profiles of the two sets of shipyards are similar, the overall average best practice rating for the US yards is a little lower than comparable international shipyards. The US yards are more highly rated in some specific elements and, in terms of group averages, the Purchasing and supply chain group has a higher average score. In most of the other benchmarking groups, the average for the US yards was either the same as or a little below the international average. However, there are much larger gaps in the Performance improvement, Human resources and Technical support groups. Some of these gaps are due to shipyard processes and practices, but others are influenced by Navy processes and practices that the shipyards are required to follow.

The individual shipyard reports have commented on the processes and practices in each shipyard and suggested shipyard actions where relevant. The following sections summarize the benchmarking findings by benchmarking element group, and identify common areas for improvement. The highest priority actions are discussed in Section 4.

3.2 Commercial

Six elements from the Commercial group were benchmarked, which include aspects of commercial responses, specifications, change orders, contracts, invoicing, and competitor analysis. Estimating and after-sales activities were not included in the scope of the study. Navy rules and procedures influence many parts of the shipyards' commercial approaches. While there are opportunities for improvement across the group in each individual shipyard, the areas identified for potential improvement at industry level are: understanding the material state of vessels, repair specifications and the change order process.

Positive, close working relationships have developed between the shipyards and the customer through regular communication before, during and after availabilities. This is helpful but the relationships appear to be changing within the fixed-price contracting environment, where there are strong drivers for a greater distance between parties. Competition rules mean that a higher degree of separation is required prior to contracting. At the outset, a Navy request for proposal (RFP) is posted on an automated system. Contrary to commercial norms, there is no requirement for shipyards to acknowledge receipt of the RFP or specify how it will be handled. However, the shipyards' response protocols and turnaround times meet with Navy requirements; otherwise, they would be excluded from the bidding process. Naval RFPs are far more complex than is the norm in US commercial ship repair. This adds shipyard costs, and increases the handling time and requirement for specialist knowledge to prepare the response.

The timely and accurate definition of the scope of work is a fundamental pre-requisite to accurately planning an availability, avoiding contract growth and achieving good levels of shipyard productivity. Accurate knowledge of vessel material state is central to this. Under MSMO contracts, the shipyards are normally involved early in an availability's planning and specification writing phases. This and the continuity the shipyards have with the vessels concerned gives them a good understanding of each vessel's material state. This is highly advantageous but is difficult to achieve under the competition rules associated with fixed price.

Under fixed-price contracts a third party, as opposed to the shipyard, works with the Navy to produce the repair specifications. Also, a particular vessel may be worked on by a number of different shipyards so continuity at shipyard level can be lost. Therefore, the first-hand knowledge of material state is removed from the shipyard and there is increased emphasis on the specification writers to properly reflect the material state in the scope of work. The shipyards then have a relatively short time to assimilate the scope of the work and plan for the availability.

Although the shipyards are involved in the specification writing earlier under MSMO contracts than fixed price, some specifications for MSMO availabilities are not finalized until very late in the planning cycle or even early in the availability itself. This has a detrimental effect on shipyard productivity and is presumably due in part to a reduced contractual pressure to finalize the scope of work when compared to a fixed-price contract. The requirement to accurately define the scope of work to support a fixed-price contracting approach should be a driver to improve its timeliness and accuracy. However, since the move to fixed price, there are instances where repair specifications are also delivered late. Specifications are complex

and contain multiple hierarchical embedded references to standards, procedures and regulations, which need to be individually referenced and conflicts between them resolved.

Ship checks carried out by the shipyards, which assist with the understanding of material state, are less common under fixed price than they were under MSMO. A ship check can be costly so the shipyards are relying on the third-party planners to accurately represent the work to be done in the repair specification. If it is not accurately represented, the additional work will become the subject of a change order. There are no shipyard personnel or third-party planners embedded within ships' crews to help gather the information required for an availability. This is left to the port engineers who work for the regional maintenance centers.

Under MSMO, some availabilities experienced very high growth due to emergent work. The reasons for this include inaccurate repair specifications and regulations that constrain the use of contingencies in government contracts. Therefore, inspection work that uncovers defects will almost always result in some unplanned contract growth even though in the majority of instances it was highly likely that the work would be required. Contract growth appears to be lower for fixed-price contracts, where there is a greater need to properly define the scope of work prior to contract award. On these contracts, growth levels appear to be closer to 20%, which is more the norm for naval maintenance and repair. Overall growth of more than about 20% will usually affect the overall schedule in availabilities such as those carried out by the shipyards. Opportunities to incorporate growth allowances into schedules are often limited by Navy requirements, so growth can result in time consuming re-planning and a lack of resources to execute the work. Similarly, pressure to limit the level of growth on an availability can result in the deferral of work that should otherwise be performed.

The change order process, internally and externally to the shipyards, is complex. Even though the shipyards report that they meet their obligations regarding the processing time for change orders, the time taken by the Navy appears extremely variable. This can have a significantly detrimental effect on shipyard productivity. A collaborative Navy-industry review of the change order process is recommended to minimize the change order turnaround time and so reduce possible rework and impact to availability schedules.

For Navy work, the shipyards accept the Government's terms and conditions of contract. The shipyards' collective view is that these terms are clear and generally fair, but that they favor the Government. However, the terms are non-negotiable if the shipyards wish to remain compliant. In addition to MSMO and fixed price, the Navy uses a range of other contract types including level-of-effort-based arrangements that are effectively another form of cost-plus contract.

In the main, the shipyards' bid review processes are well established. However, their competitor analyses are predominantly price focused. Key competitors' strengths and weaknesses are well known due to the close working relationships established between shipyards through teaming arrangements under MSMO. While this information remains valid at present, the source is likely to become restricted under fixed-price contracting. Therefore, the shipyards will need to carry out more in-depth competitor analyses in the future to maintain an understanding of their competitive position. They should also actively gather structured information on international yards that are not direct competitors.

The invoicing regime during an availability is every two weeks, with a final invoice (excluding the 'recommended final rates' invoice) usually being prepared within two or three months of completing the availability. While there appears to be no customer-driven requirement or need to shorten this period, commercial best practice is to be able to produce an up-to-date invoice at any time with the final invoice being issued before a vessel leaves the shipyard. For MSMO contracts, closure of shipyards' open commitments with suppliers and agreement of the 'recommended final rates' invoice can lead to long periods of delay before the total cost commitment of an availability is finalized. This can potentially impact the Government's budget allocations for future availabilities. Moving forward into a fixed-price contracting environment, this will be less of a concern. Even so, shortening the invoice submission time must be in the interests of both the shipyards and the Navy.

3.3 Purchasing and the supply chain

The Purchasing and the supply chain group comprises eight elements, all of which were benchmarked. These cover the full life cycle of the procurement process from the identification and recruitment of suppliers and subcontractors, through to the management and delivery/distribution of the goods and services. Development of supplier relationships and performance monitoring are also reviewed. While there are opportunities for improvement across the group for each shipyard, on the whole the purchasing functions are well resourced, with good working procedures and integrated systems. Areas identified for review and potential development at industry level include benchmarking the US supply base against the international market, clarifying the requirements for demonstrating value for money, and understanding the true cost of procurement (including non-value-added activities).

A reliable and responsive supply chain is fundamental for efficient repair operations. For US Navy repair, equipment and materials are supplied through three channels: the Government, the planning yards and the repair yard. Equipment supplied by the Government (naval stores) and the planning yards is considered as GFE by the repair yards. While GFE is available from naval stores, it was often reported that the process for drawing it was cumbersome and unreliable. Thus, there is a tendency for the yards to source equipment directly from suppliers and use the naval stores for specialist equipment or as a last resort only. The planning yards are a major source of GFE. The shipyards acknowledged that it was appropriate for some equipment to be supplied by the planning yards, particularly long-lead items. However, they also identified items of equipment commonly supplied by the planning yards that could be sourced directly from suppliers more cost effectively. It appears that cost savings can be made through better understanding, communication and coordination between the three supply channels.

In general, shipyards have identified that supply chain issues are core to the well-being of their Navy repair business, reflecting the fact that procurement activities (equipment, materials and subcontractors) account for approximately 55% to 60% of the total yard repair cost. The purchasing departments are well resourced, if a little oversized in places, and are usually responsible for delivering materials and equipment to production. This is a good arrangement as it minimizes the number of handovers and increases the probability of delivering the right materials to production at the right time. While day-to-day working

procedures are generally well documented, there appears to be a lack of clearly documented long-term strategic visions that would be beneficial to develop.

Government requirements, and the need to maintain equipment already installed on vessels, mean that many aspects of the supply chain are inflexible. The requirements include compliance with FAR, DFARS and the Buy American Act, but there are many more. On the whole, the processes for identifying and recruiting suppliers and subcontractors are sound. That said, a collaborative Navy-industry review of supply sources outside the US supply base would show whether the prices and technology offered by US companies are competitive and leading-edge.

There have been clear moves by the shipyards toward identifying key activities that they routinely subcontract. However, more can be done in developing shipyard-wide approaches to subcontracting and rationalizing in-house work. The variable workload that could result from fixed-price contracting is likely to increase the use of subcontractors and agency labor, so the way they are managed is likely to become more important.

There is a clear understanding of the benefits of developing long-term relationships with key suppliers and subcontractors, monitoring and assessing their performance and creating open two-way communication. Framework agreements with key suppliers are common, although not always effectively used. In the interest of demonstrating value for money, as required by the Navy, a large percentage of the supplied equipment and material cost is competitively sourced on a project-by-project basis. It has been shown that the use of supplier long-term agreements is an excellent approach to securing and ensuring value for money, while also reducing the workload for procurement, administration and materials handling. A common understanding of the requirements for demonstrating value for money should be established between the Navy and industry, which would hopefully allow for better and more effective use of framework agreements. If possible, there would also likely be benefits from the Government entering into framework agreements with some critical sole-source suppliers on behalf of the industry. These would focus on service levels, pricing, quality, stock holding and performance/cost improvement initiatives.

While low levels of inventory are difficult to sustain given the nature of the repair work, greater effort to reduce inventory levels can be made. Just-in-time deliveries and deliveries direct to the point-of-use are rare, as are line-side stores that are restocked by suppliers. An industry-wide coordinated strategic approach to retaining critical, long-lead remanufactured parts should also be considered to relieve schedule pressures. Some initiatives have been implemented to reduce non-value-added procurement costs such as multiple handling and storage. However, across the industry there is a lack of understanding of the true cost of procurement. Without a comprehensive knowledge of these costs, it is difficult to reliably assess the benefits of process changes.

3.4 Production infrastructure and equipment

This group includes facilities and equipment that require substantial capital expenditure to improve. Shipyards therefore tend to focus on making improvements in less expensive areas before making investments in infrastructure and equipment. This trend is reflected in the shipyards reviewed in this study. With regard to performance improvement, prioritizing

investment toward process improvement is a good approach but there is a point where infrastructure and equipment improvements become necessary. While many of the infrastructure improvements are desirable, the high cost of improvement has resulted in the average target score for this group being the lowest of the group targets. Uncertainty regarding the volume of future work in some yards also makes it difficult to plan and justify high levels of investment.

The shipyards are engaged in making investments to improve the general environment and working conditions. Workshops and offices tend to be in old buildings that have been or are being refurbished. The benefits of this approach rather than constructing new buildings may be questioned in some cases. Although there are no covered docking facilities, most of the work ashore is done under cover in workshops configured to carry out specific tasks. Temporary covers are used on floating docks to provide environmental protection as required. The methods used to provide protection could be improved in some yards.

Housekeeping is generally good but there are some congested areas where it is poor. The layout of the facilities is reasonably good in some yards, although improvements could be made in all. The benefit that these improvements would bring varies. Generally, more attention needs to be paid to reducing distances between work centers, reducing travelling times, providing support facilities closer to the work fronts, and improving lay-down areas. The development of a long-range facilities plan would be beneficial in those yards that do not currently have such a plan. The industry carries out much of its work in external locations such as naval bases. Naval rules and requirements relating to the use of mobile workshops and stores can make it difficult to support remote working and attention should be given to improving these facilities.

All of the shipyards visited operate floating docks that are certified by the Navy. They have different control systems that affect efficiency of the docking and undocking process. In general, the time taken to set a dock can be lengthy. This is largely due to the blocking arrangements, and research focused on improving the efficiency of this process and block design would be helpful. All docks have good vehicular access, but crane coverage is variable and personnel access to wing walls and high up on large vessels is not mechanized. Although difficult to achieve, investment in improving access would be beneficial. Most docks are equipped with some form of hauling-in and -out equipment. High maintenance costs and poor reliability have resulted in dock arms being removed, so there are none currently in use.

Quays and piers are typically well serviced with gases, fluids and power, but crane coverage can be patchy and some have limited room to support afloat operations. There has been some recent investment in this area but more is required.

Warehousing is provided by a mix of buildings equipped with pallet racking and Conex boxes, which – in addition to occasionally being used as local stores – are assigned to ships' crews and subcontractors. Warehousing is not particularly high density and there is no automation. Some warehousing is off site. The approach to storing new and set-aside equipment is relatively conventional. Some improvements could be made to reduce non-value-added activities and make more effective use of floor area. That said, the approach taken to managing set-aside equipment appears efficient and is lean. However, it may be worthwhile improving the level of computer-based control of this equipment.

The majority of materials are handled using forklifts, cranes and trailers. Although pallets are common, few are purpose-designed or stackable. Major moves tend to be coordinated but, in general, material is handled on an as-required basis either by a project team, trade group or the warehousing/logistics operation. This approach is not unusual in ship repair. In addition to supporting materials handling, the wide range of mobile equipment in the industry is used to provide efficient human access that does not rely on staging. Some of the equipment is dated and there does not appear to be much evidence of the use of modern equipment such as telehandlers. It would be worthwhile reviewing the applicability of these.

Small tools and equipment appear to be widely available. They are managed and maintained using different approaches that tend to be computer-based and well organized. However, the industry is in general agreement that a more robust digitally-based tool tagging system would be helpful. The kitting of small tools and equipment required to execute a particular task is not common and the acquisition, from the shipyard's store or otherwise, of appropriate tools for the job is usually left to the supervisors and the workforce. Some specialist tools are made available by equipment manufacturers, but there is no central Navy facility that carries specialist equipment that can be used by the industry. Most shipyards have a maintenance organization and operate a computer-based planned maintenance regime. Condition-based maintenance, which tends to be more cost-effective, is not common. The use of production labor to carry out maintenance tasks in downturns is also not a common practice.

3.5 Production methods

The Production methods group comprises the activities of ship repair that involve work in the shops and on board, including diagnostics, manufacturing and installation processes, surface preparation and coating, rigging, and testing. The industry's use of technology in this group is in the mid-range of all groups surveyed and there are opportunities for improvement in the individual shipyards. However, this group of elements as a whole is not among the highest priorities for industry action.

The shop work required for weapons systems and associated electronics tends to be subcontracted. This is a sensible choice as the shipyards are located in areas with large Navy infrastructures and qualified subcontractors are therefore often close at hand. Weapons installation work is typically led by government-contracted AITs, with the shipyards providing foundations and mechanical support. Similarly, joiner furniture is typically purchased rather than manufactured by the shipyards – which is also sensible.

The processes applied to work on shafting, propellers and rudders are generally good. Experience and skill levels required for this work tend to be well-defined and available. The work is adequately planned and the required tools and materials are preloaded to the dock floor to avoid unnecessary lost time. The skill levels and technology for repair of machinery is generally good for a wide range of ships' equipment. The technology applied to rigging operations also tends to be good, although in some cases the development of additional written procedures is recommended. The approach for sheet metal work is not particularly sophisticated but, in general, is adequate considering the throughput and complexity required for Navy repair work.

Each shipyard maintains a surface preparation and coatings capability. This may be comprehensive, but more often it is limited and supplemented by subcontractors responsible for major areas such as tanks and the underwater hull. The technology applied in the major areas is generally good with an appropriate range of blasting and coating processes and equipment. Where the in-house capability is limited, however, the technology tends to be basic and more could be done to investigate the use of semi-automatic and automatic methods.

Shipyard test teams are experienced and well integrated with the numerous government and contractor groups involved in the availabilities. The procedures are well documented and standardized in a majority of cases. The test schedules strongly influence the priorities of the project schedules, and opportunities to accelerate progressive acceptance of systems and compartments are often sought by the shipyards. That said, the current customer-driven process is highly constrained with organizational and procedural interactions that make schedule reduction difficult. More could be done to implement test-focused continuous improvement initiatives.

There is a wide range of technology applied to in-house machine shops. Accordingly, the shipyards apply a good mix of in-house and subcontracted resources to accomplish the required work. There are good examples of cellular arrangements to repair and test common items such as pumps, valves and manifolds. Increased attention to such approaches is recommended.

There are ample opportunities to improve structural and pipe work. A family-based approach to classifying onboard tasks and shop-manufactured interim products is suggested to promote the application of group technology techniques. Defining structural product families may identify sufficient product volume to introduce family-based shop flow with workstation or cellular arrangements. It would also increase justification for the use of simple mechanization such as submerged arc welding tractors. A family-based approach is also recommended for the pipe shops to justify development of a workstation or cellular approach for pipe-piece fitting and welding, and possibly some basic welding automation.

Considering the level of technology in the shipyards and the high volume and schedule implications of electrical work in Navy repair contracts, this area offers perhaps the greatest opportunity for improvement within the Production methods group. Electrical work tends to be accomplished in situ. Further consideration should be given to undertaking more work in shops or in mobile workshops on or near the ship. Analysis of the work is recommended to maximize opportunities to gain shop-like efficiencies in electrical repair, prefabrication, assembly, test and kitting work. For example, a high percentage of cable can be pre-cut with a maximum of cable connectors and terminations installed and tested in a shop or mobile workshop. Consideration should also be given to increasing multi-skill capabilities in the electrical departments to install cable trays, penetrations and foundations without assistance from other trades.

3.6 Production support

The Production support group of elements covers the activities that support production by providing access to each of the work fronts and ensuring there is sufficient light, power,

services and waste removal available for the work to be undertaken. This group also covers the supporting systems to ensure adequate quality control, health and safety, and environmental control procedures are in place, and that the parts of the ships not being worked on are not damaged. Individual shipyards differed widely in their use of technology within the group and there are some technology gaps that should be addressed.

The processes of preparing vessels prior to arrival at the shipyards were generally good. A mutual understanding of the requirements for this appears to have developed between the yards and the ships' crews over the period of MSMO contracting. The proximity of naval bases is also beneficial, as many of the de-storing and tank emptying activities are done at these facilities prior to the arrival of ships at the yards. To enable a quick start to the work, the opening and venting of tanks prior to vessel arrival is also commonplace. However, more could be done to increase the levels of advanced preparation work carried out. The transition to fixed-price contracting will shorten the lead times available to prepare the vessels. It also appeared that some crew/shipyard relationships are becoming more strained under the revised contracting arrangements. Thus, there is a chance that the current good levels of preparation will deteriorate in the short or medium term.

A strong emphasis is generally placed on shipyard processes relating to health, safety and the environment and this appears to have paid dividends. This is unsurprising given the spotlight these areas have been under in many businesses in recent years. More efforts could be made, however, to improve housekeeping in areas across the industry and to increase the proportions of waste that are recycled.

The care and protection regimes surveyed were generally sound. Ships tend to remain under the control of the ships' crews, so the protection and care programs undergo high levels of customer liaison and scrutiny. Security is commonly maintained by the crews, including verifying identity and access authorization.

Temporary services are well planned initially but tend to become increasingly responsive to changing needs. Use of the ships' systems to augment the supply of temporary services appears limited when compared to best practice elsewhere. This is largely due to Navy concerns regarding the risks of running yard tools on ships' power, although the shipyards also do not want to be liable for any problems that might arise as a result of such use. Opportunities are also limited by the need for clear separations between yard and crew activities, as the relationships are not strong enough to avoid disputes when something goes wrong. As costs were recouped under MSMO, the necessity of the full provision of temporary services was not questioned by the shipyards. This may change under fixed price.

Areas of good opportunity in this group were those covering the staging and access activities, and the levels of remote support provided for onboard work. As with many other non-value-added processes, it is common for yards to regard staging and access as inevitable requirements to support production. In fact, it is likely that these are areas where significant savings can be made – through better planning, for example, or the increased use of modular staging solutions and mobile access equipment.

There were few instances of remote support being provided close to the place of work. Reasons for this appear to be a mix of crew reluctance to allow converted Conex boxes to be

placed on the decks of ships and shipyard policies of doing all work in the permanent, fixed workshops. While it is important to maximize the proportion of work undertaken in the shops for major or repetitive refurbishment and for prefabricating parts and assemblies, it is not always efficient to remove items of equipment for shop work and subsequent refitting. In these instances, the use of dedicated support facilities either on board or on the wharf near the gangways can be a more effective approach.

One advantage of the crew retaining control of the ships is that it facilitates the progressive hand-back of systems and compartments from the shipyard on completion of the work. However, this is unlikely to be outweighed by the additional costs created when the crews and shipyards do not share the same goals and priorities. This is discussed further in the Customer factor report. For long availabilities, it may be more efficient for the crew to hand over the vessel to the shipyard or for the crew to be brought into the shipyard's management structure. It is recommended that these options be investigated.

Quality control processes were reasonable. The procedures and systems are detailed and highly influenced by Navy requirements. However, more could be done in many yards to better identify rework and trend-analyze the root causes. While this may not have been a high priority under MSMO contracts, increased commercial pressures under fixed price may bring it under more scrutiny. Levels of formal self-checking by production were relatively low, although this is influenced by Navy resistance to the practice.

3.7 Human resources

The Human resources group comprises eight elements, of which four were benchmarked during this study. These elements cover the flexibility of the workforce and how it is used to improve productivity; the extent of training carried out and the methods used; the education and skills levels available; and the age profile of the workforce. Overall, the Human resources group had one of the lowest average group scores. The need for flexibility within the workforce, and for conducting an industry-wide skills requirements and gap analysis are areas identified for improvement/investigation that are common across the industry.

The industry does not appear to have many formal workforce-imposed demarcation lines between the trades or restrictive practices. This provides a good opportunity for establishing flexible, multi-skilled workforces to meet the varying demands of the repair industry. Yet, the production workforces are generally managed within a trade-oriented structure, with little or no multi-skill training or cross-trade flexible working. There appears to be an unwillingness to challenge the current working practices, possibly in fear of disrupting the good working relationships between management and the trades. Historically, negotiations around these topics can be confrontational, cumbersome and time-consuming. However, it is recommended that the shipyards advance to a more flexible, multi-skilled production operation to meet the changeable repair workload and create a more stable workforce environment. An industry initiative to demonstrate the commercial and employee benefits of multi-skilling would assist with this change in operational behavior.

Skill levels across the industry have been mainly built up from experience rather than formal education. While employees complete relevant introductory and trade-related training prior to commencing their roles, training thereafter is often limited – particularly for the production

workers. Although experience is invaluable, the benefits of formal role-related education and development should not be overlooked in terms of broadening an individual's outlook, enabling them to operate more effectively, and enhancing their ability to introduce new ideas and up-to-date processes and practices.

There appears to be a trend of apprenticeship schemes being replaced by more short-term alternatives. Both have their place, but an apprenticeship scheme is also a positive and proactive way of recruiting personnel while sustaining the future skill levels of the industry workforce. There is recognition of the need for formal, structured supervisor training, with a number of training courses having recently been established. However, the courses are usually a one-off session and limited in scope and duration. This type of training would benefit from further development, influenced by an industry-wide study into the ideal form and content. Although training procedures are largely well defined and training requirements for each trade/discipline are often identified, shipyards do not appear to have integrated plans for developing the skills of their workforces to meet the requirements of their overall strategic business plans.

During the last few years the average age of workforces has generally fallen, although it remains slightly over the optimum age. This is not unusual in an international context. The trend is impressive given that workforce numbers are reducing and seniority often plays a part in the lay-off process. However, there is a significant increase in the number of personnel over the age of 50, suggesting the industry may lose a disproportional number of skilled personnel through retirements over the next ten years. This could lead to skill shortages and gaps, not only within the shipyards but also regionally or industry-wide. Undertaking an industry-wide workforce skills analysis would assist in identifying current and potential skill shortages and gaps.

3.8 Technical support

The Technical support group comprises five elements, of which four were benchmarked during this study. These elements cover the arrangement and capability of the design and technical support function, along with the form, content and management of technical information provided to production and supplied by the Government and suppliers. While there are opportunities for small improvements in each individual shipyard, overall, the technical support functions are appropriately resourced and capable. One area identified for review and potential development is the form and content of the technical information supplied to production. However, improvements in this area will require collaboration between industry, the Navy and the planning yards.

The design and technical support functions are often small, consisting of a few key technically qualified engineers. Technical installation drawings are managed and provided by the relevant planning yard, so there is no requirement for a highly sophisticated and resourced technical department in the shipyards. The functions operate in a support-role capacity to production and, in the main, are capable of addressing the majority of queries raised. Specialist 2D and 3D CAD capabilities are available, while other technical calculations are commonly carried out using in-house developed software. Planning and control of the technical activities tends not to be integrated with production planning. While no specific

issues or delays with technical support were reported, identification and integration of key technical activities within the availability project plan, particularly for larger projects, should be considered. This would allow these activities to be more effectively managed and for critical interdependencies to be formally recognized.

Technical drawings supplied by the planning yards are generally system-based, broken down by zone and in portable document format (PDF), which does not allow the shipyards to leverage the advantages of the digital information. No dedicated workstation- or task-oriented production information is supplied. While this may not be easily arranged in a fixed-price contracting environment, collaborative Navy-industry initiatives to develop guidelines for workstation- or task-oriented production drawings and other information would help. Production information should also be issued in a format compatible with production requirements. Also, early production involvement in the planning phase of an availability will result in higher levels of productivity.

Vendor-furnished information (VFI) is generally supplied as GFI with limited VFI being supplied directly from the vendors. Although no delays with the availability of the information were reported, the supply of VFI is unplanned. Early definition of all required VFI and the identification of specific supply milestones would allow the delivery of the information to be more effectively managed.

3.9 Organization and operating systems

The Organization and operating systems group of elements covers the processes and systems that plan and implement the ship repair work, and organize the workforce and subcontractors. This includes the means by which the work is controlled, quality is assured and progress is monitored. The group also covers the way shipyards manage their customer relationships. Some elements in this group scored highly across the industry, but there is a wide range of technology employed within the group and some opportunities for improvement.

The management information systems, communications systems and underlying supporting technologies were generally found to be comprehensive and well integrated, although some systems are dated and the timeliness of the data held tends to lag behind real events by up to a week. For reference, commercial best practice is for shipyard data to reflect what is happening as closely to real time as is practical: usually less than a few hours. While paper reports are still used, there is an increased use of dashboards for accessing online management information. It is important that these are customizable by the users, with access restrictions to underlying data being driven by individuals' roles within their organization.

Use of wireless technologies in the industry has been hampered by the overriding need to maintain data security. However, as the technology has become more secure there are an increasing number of solutions in place. Navy interpretation of wireless policies appears to vary from port to port and the industry would benefit from more standardization of the acceptable security solutions. There was surprisingly little use of bar-coding or RFID technologies for material control and/or the tracking of piece-parts, assemblies and tools.

The approach to project management, including the management of subcontractors, was generally strong and has clearly benefited from Navy policies promoting and rewarding the development of competent, experienced program teams. Approaches to risk management varied but are largely a response to either Navy or corporate requirements to report high-level risks, rather than being detailed, project-oriented risk registers used as fundamental project management tools.

Repair strategies are usually developed well in advance of the start of availabilities and there were many instances where key subcontractors and suppliers were consulted over principal repair strategy choices. However, the use of documented type plans, organized by class and availability type, was not common. These present an opportunity to capture the high level of knowledge the shipyards have of the classes and, in many cases, the individual ships.

Navy pressure to develop and present detailed plans prior to the start of an availability means that the development of repair strategies into working plans at the activity level was comprehensive. However, the practice forces shipyards to create unwieldy plans early on in a program that are too highly detailed to be effective. This is evidenced by the instances of disconnects between the project plans and what actually occurs in production. Ideally, planning systems should be agile enough to respond quickly to emergent issues and change. This requires a rolling development of the detail. The high levels of change and the Navy requirement for highly detailed plans early in the programs are obstructing yards' abilities to adopt this approach. Thus, detailed planning is commonly devolved to production, leaving the formal plans inaccurate and, as a consequence, ineffective as planning tools. Increasingly detailed regulation of shipyards' planning processes by the Navy is unlikely to be beneficial as there is no 'one-size-fits-all' solution regarding the ideal timing, level of detail and department responsible for detailed planning. This is discussed in more detail in the Customer factor report.

Actual hours tend to be recorded at the work item level rather than the more detailed activity level. This lack of granularity is unusual. It may have resulted from Navy acceptance of EVMS man-hours being recorded to the work item only. Where it occurs, the lack of detail limits a shipyard's ability to accurately monitor existing work and update the metrics used to reliably estimate and plan future work.

Materials for work packages are commonly identified by supervisors and first-line managers. The source bills of materials are usually those generated by the planning yards, using their own work breakdown structures (WBS) originating from the arrangement of the specification. As Navy influence hinders yards from using their own WBS, it is difficult for the shipyards to reorganize materials according to their preferred approach or achieve repeatability where appropriate.

The difficulties associated with using their own, optimized, WBS also impacts upon the way the shipyards organize themselves. To a greater or lesser degree, workforces tend to be organized as a matrix of trade and project hierarchies. Within these, the trade groups commonly retain the most control. Some multi-disciplined, mixed-trade teams are used; however, these tend to be for small assignments that are remote from the shipyards, such as ad hoc repairs done in the naval bases. The imposed WBS can hinder the shipyard's ability to plan work using multi-disciplined teams. This means that the comprehensive planning of

larger availabilities on an area management basis – widely accepted to be the most effective approach for complex repair work – is not easy to achieve. The degree of workforce resistance to area management is mixed: while there are few active occurrences of demarcation or restrictive practices, it is generally rare for workers to operate outside their main trades. It would be advantageous if the currently limited levels of workforce flexibility were to be increased.

In general, the quality assurance systems benefit from being heavily influenced by Navy standards and are comprehensive with well-documented procedures. However, Navy influence also prevents them from becoming specific to each shipyard's processes and, therefore, being embedded into the shipyards' own performance improvement programs. More could be done to identify and trend-analyze rework, using this data to move toward a thorough 'right-first-time' approach.

3.10 Performance improvement

The Performance improvement group comprises interrelated areas that support developing and sustaining a culture of continuous performance improvement. The industry's use of technology in this group is at the low end of all groups surveyed. It is expected that this is the result of productivity improvement not being the primary goal for the shipyards due to their business environment and contract incentives. For example, as opposed to focusing on productivity, MSMO contracting motivates high levels of responsiveness to customer requirements such as collaborative pre-arrival planning and attention to schedule performance. There is ample opportunity for improvement in this highly influential group. However, the shipyard repair processes are heavily controlled or affected by Navy procedures; thus, many shipyard improvements will need to be supported by the Navy, whose own processes may also need to change.

The industry is generally open to new ideas and innovation with a positive attitude. There are often performance improvement activities in the shipyards, but they typically lack guidance from a top-level company vision defining future repair processes and priorities. There is a wide variety of approaches to providing an in-house organization for performance improvement. The use of quality and performance metrics, benchmarking and value-stream mapping to prioritize activities could be increased. As a majority of the work is driven by Navy procedures (standard items and work instructions, for instance), the shipyards do not typically have robust process and production engineering functions. In general, the yards would benefit from defining a cost-focused continuous performance improvement approach, as well as creating the organization and tools required for its implementation. More could also be done to adopt new cost-saving technologies from other shipyards and industries.

Shipyards tend to maintain a range of project-based metrics that appear to provide effective management oversight and satisfy government requirements. These could be supplemented by metrics designed to drive continuous performance improvement. Generally being pan-project, these would either support, or actually be, well-defined key performance indicators of the business, depending on the level at which they are measured. Examples might include monthly yard-wide measures of schedule adherence or the man-hours to install a standardized unit of cable. In this way, the measures would assist with setting targets in all

key aspects of white- and blue-collar operations and could be linked to the estimating database.

First Marine International

4 CONCLUSIONS AND RECOMMENDATIONS

4.1 Priority areas for improvement

The primary focus of this study is the performance of the four individual shipyards and the government actions required to help improve performance. Although some key government actions are included in this section, the full list is discussed in the separate report.

There are opportunities for individual shipyards to improve their performance by changing some of their processes and practices, and making further investments in facilities and equipment. However, due to the prescriptive nature of Navy work, there is a limit to what the shipyards can achieve independently. The initiatives most likely to have the largest effect are those that the Navy can implement independently or those requiring shipyard-Navy collaboration. Therefore, while recognizing that individual participants in the enterprise can have differing goals, establishing a more effective Navy-industry performance improvement forum will be central to implementing change and should take priority.

The opportunities have been identified by determining technology gaps between the existing and proposed processes and practices. Priorities for the improvement areas within each shipyard have been assessed by applying a simple methodology, which gives precedence to elements with the largest technology gap and where a high-value, short-term return on investment could be expected. The results are indicative only and each yard will need to carry out further analysis to confirm the relative benefits of changes in each area. Performance improvement priorities for the industry have been assessed by merging the individual shipyard results. The resulting highest-ranked priorities are grouped into the following five focus areas:

Performance improvement, which includes:

- attitude toward change and new technology
- organization for performance improvement
- process and production engineering
- metrics and measures to support continuous improvement

Organization and approach to work, which includes:

- overall repair strategy
- organization of production work
- quality control procedures
- workforce job and skills flexibility
- workforce education and skill levels

Support for work, which includes:

- technical information provided to production
- arrangements to support work carried out on board
- management and distribution of equipment and materials

Planning, scheduling and control, which includes:

- specifications and change orders
- coordinating and planning the ship repair workload
- strategic resource planning
- day-to-day allocation and scheduling of work on the shop floor
- project management

Commercial relationships, which includes:

- optimizing stakeholder relationships
- developing contract arrangements and incentives

Details of some of the issues relating to these items are discussed in Section 3. There is further detail in each shipyard report. Many of these focus areas need to be addressed by the Navy and industry working in collaboration and should be tackled by the forum referenced above. Sections 4.2 to 4.6 below provide further discussion on each focus area and suggest shipyard collaborative actions. Section 4.6 specifically addresses collaborative actions that will need to be government led. These are included in this report, as they specifically address the commercial relationship between the Navy and the shipyards.

The scope of the suggested initiatives is generally limited to the elements of the benchmarking system included in the study. There may be other areas where collaboration is possible that are not discussed here.

4.2 Performance improvement

All the elements in the Performance improvement group are ranked highly in the prioritization analysis. Individual shipyards have responsibility for enhancing how they conduct their performance improvement activities. The Navy needs to provide a commercial environment that encourages performance improvement and be responsive to the resulting process changes developed by each shipyard. That said, the industry could collaborate on the following:

1. Develop a typical charter for a team or organization to implement and facilitate ongoing continuous performance improvement.
2. Develop a typical charter for a team or organization to implement and facilitate the process and production engineering function.
3. Develop a typical set of pan-project performance metrics.
4. Identify and agree upon Navy standard items, procedures and behaviors that would benefit from revision.

4.3 Organization and approach to work

There are several action areas in this group that will require the Navy to make changes to support the industry in closing the technology gaps. These include the introduction of self-checking, the contractual treatment of rework, and allowing the shipyards a high degree of latitude with respect to repair strategy. These and other items have been listed in the Customer factor report and will require the Navy to take the lead. In addition to the individual shipyard actions, the following industry-level collaborative actions are proposed:

1. Conduct a research project involving all stakeholders to examine the issues associated with use of multi-disciplined teams in a full area/zone management approach. Issues may include organizational structure, work breakdown structure, planning and scheduling, team leader training and others. Pilot the use of multi-disciplined teams.
2. Conduct a research project involving all stakeholders to examine the issues associated with development of a multi-skilled workforce. Issues may include union and/or human resources policy, workforce training, workforce retention during variable workloads and others. Define examples of well-matched primary and secondary skills and develop sample training outlines to suit.

4.4 Support for work

Improving production support activities either on board or in the workshops will improve productivity, especially for remote working. Proposed industry-level actions are:

1. Work with the Navy to increase the use of mobile workshops on and near ships, including ships undergoing repairs at naval bases. Define standards and typical onboard and pier-side workshop arrangements acceptable to the Navy for common ship types.
2. Develop guidelines for workstation- or task-based production drawings. Maximize areas of industry-wide agreement and develop templates for shipyards to provide yard-specific guidelines and data. Address differences by ship class and type of work.

4.5 Planning, scheduling and control

A well-defined specification of work and a responsive change order process are considered prerequisites to effective planning, scheduling and control. It is understood that issues with these continue to be major challenges to repair efficiency and there have been numerous initiatives by the Navy and industry over recent decades to improve in this area. Actions by the Navy to improve the knowledge of material state of vessels will assist with improving performance in this group. Agreeing on an optimum form, content and modus operandi for ship repair plans and schedules that will meet both Navy and industry needs will also be necessary. These are discussed in the Customer factor report. The proposed industry-level collaborative action is:

1. Conduct a research project to compare typical Navy repair shipyard planning, scheduling and control approaches with leading international commercial and naval yards. Compare system and process features and produce recommendations for an optimized approach.

4.6 Commercial relationships

Fixed-price contracting is increasing competition and motivating shipyard performance improvement initiatives from which the Government will benefit. In addition, an attractive commercial environment is needed to provide justification for performance improvement investments, most of which require a longer-term viewpoint than a single availability. A positive working relationship between all the stakeholders is also required. Changes in the commercial environment would necessarily be led by the Government, and heavy collaboration with industry is suggested to ensure the intended results are achieved. The Customer factor report addresses these issues. The recommendations set out below provide context for industry participation.

The following government-led actions are proposed:

1. Define the characteristics of the ideal customer-supplier relationship in a fixed-price Navy repair environment. Primarily, this should focus on the Navy-shipyard relationship but it could be extended to include other stakeholders such as ship's crew, suppliers and the planning yards. The characterization should include both hard and soft aspects of the relationship.
2. Having defined the relationship, undertake formal quarterly 360° reviews to measure it and discuss where performance on both sides falls short of the optimum and how it might be corrected.
3. Identify acquisition methods and contract requirements that are barriers to achieving the ideal relationship. Define strategies to reduce or eliminate the barriers while maintaining essential government requirements. Define typical contract incentives that support long-range objectives of both the Government and the industry (i.e., objectives beyond a specific availability).

First Marine International

4.7 Facilities and equipment investment priorities

For the industry as a whole, performance improvement projects that address the five focus areas listed in Section 4.1 are likely to be worthwhile investments. Closing the technology gaps in these areas will require minimal investment in hardware and facilities. Specific suggestions for investment in facilities and equipment have been included in each shipyard benchmarking report. Some of these require high levels of capital expenditure. Common items are listed below.

Rationalization of workshops: Improvements to shipyard workshops have been recommended, including:

- Developing portable workshops
- Further improving the working environment
- Further improving shop layouts

Information and communications technology (ICT): ICT improvements include investments in hardware and network infrastructure, such as:

- Wireless data improvements

Long-range facilities planning: Plans to guide specific incremental facilities improvements are yard-specific. However, some common areas that need to be addressed include:

- Improved personnel access
- Improved vehicle access
- Improved material lay-down areas

First Marine International

HASKONINGDHV UK LTD
MARITIME & AVIATION

2 Abbey Gardens
Great College Street
Westminster
London SW1P 3NL
United Kingdom

+44 (0)20 7222 2115 Telephone
info.fmi@rhdhv.com Email
www.maritime-rh.com/fmi-home-page.html Internet

Document title:	Part 2: Ship repair
Status:	Final
Date:	10 April 2017
Project name:	2014 US Naval Shipbuilding and Repair Industry Benchmarking
Project number:	9Y1755
Client:	ASN (RDA)
Revision:	Draft issued 22 September 2016 Draft rev. 1 issued 14 March 2017 Final issued 10 April 2017
Drafted by:	Damien Bloor, Steve Maguire, Gilly Fox and Adam Broughton
Checked by:	Gilly Fox
Date/initials check:	10 April 2017
Approved by:	Damien Bloor
Date/initials approval:	10 April 2017