Foreign Shipyard Coatings Benchmarking Study

NSRP Surface Preparation and Coatings Panel Project Report

MAY, 2013

Foreign Shipyard Coatings Benchmarking Study

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2 INTRODUCTION

2.1 Background

1. Over a number of years the major US shipyards, through the NSRP, have undertaken benchmarking studies against major competitors. The results of these studies have been used to develop a longer term strategy to improve the productivity and performance of US yards and to establish their competitiveness against other major shipbuilding nations.
2. During the last 10-15 years, coatings have increasingly become a bottleneck in the ship production process, as steelwork and other outfit technologies have improved making the coating work more critical to the process and resulting in more complex interactions with steel and outfit work. However the Benchmark reports issued through the NSRP programme have lacked any detailed assessment of coating activities. The work undertaken by this project sets out to correct that oversight.

3 EXECUTIVE SUMMARY

3. This report sets out the findings of the benchmarking project conducted by the SPC panel during 2012 and 2013.
4. It describes the process by which the shipyard to be visited in Europe and the Far East were chosen and the team that conducted the assessment of these foreign new build yards.
5. The yards selected were a mix of commercial yards, dedicated naval yards and mixed yards handling both commercial and naval vessels.
6. The team visiting the yards prepared a questionnaire and presentations for the target yards to enable focus on the key areas of interest which were defined as:
    a. Pre-production
    b. Ship design
    c. Facilities and production technology
    d. Coating activities
    e. Coating materials
    f. Coating specification and product selection
    g. Management systems
    h. QA/QC
    i. Miscellaneous (catch all category for anything else that arose).
    j. Environmental
    k. Human Factors
7. From within the team, individuals were selected to focus on those areas and where appropriate background information was supplied by Safinah with regards to the yards to be visited.
8. The benchmark process attempted to emulate as far as possible the approach used by the ECB on the broader benchmarking work carried out previously.
9. Representatives from each US yard was asked to assess themselves against each of the key areas of interest and an average US yard score was developed. It could be argued that this may result in an over optimistic view of the US yards as the assessment was not made by an independent third party. However it is thought that for the purposes of this exercise the approach is robust enough.
10. Each yard visited was then assessed in a similar format and the results showed remarkable similarity between US warship builders and foreign warship builders, while commercial shipbuilders showed opportunities where improvements could be made,
11. The benefits were divided into 3 categories:
    a. Immediate take-aways (section 11 of this report). These were things that were already in use in foreign yards that individual US yards could adopt as appropriate almost immediately at little or no cost and with little or no additional research.

b. Short-term opportunities; these are projects that are possibly well suited to the White paper projects approach adopted by NSRP and generally fell under the following headings:

   i. Flow charting of the coating process

   ii. Functional specifications and coating strategy integration

   iii. Planning and scheduling

   iv. QA/QC

   These are reported on in section 12 of the report and one good thing was that many short term possible project ideas reinforced work already being carried out by the SPC panel under auspices of white paper projects.

c. Medium/longer term projects are also reported on in section 12 of the report and focus mainly on:

   i. Improved design

   ii. Improved production technologies and facilities

   These longer term projects would by and large involve work across department boundaries and with suppliers of equipment/enabling technologies. They would tend to require greater time and resources and some a suited to academic research. Opportunities for collaboration and funding were also identified that may reduce the overall cost and effort the US yards would need to undertake to carry out these projects.

12. From some of these there are real benefits that can be gleaned, for example the implementation of functional paint specifications and an integrated coating strategy saved the UK Navy 30% of the coating budget initially estimated for the coating works on their new carrier project.

13. The benchmark approach has afforded some areas of focus for the US yards and should enable SPC to drive projects through for a short to medium term. There is likely a need for the cost saving justification of each project to be undertaken as is currently done under the normal NSRP process, but the fact that other yards face similar challenges or have demonstrated areas that can be improved has provided a good opportunity for targeted improvement projects.

4 SCOPE

4.1 Broad Aims

14. The broad aims of the work was to:
    a. Identify suitable candidate shipyards to benchmark against in Europe and the Far East.
    b. To conduct visits to those yards and view the production process and hold discussions/interviews with relevant parties to better understand coatings issues
    c. To assess the feedback and present the results in a meaningful manner
    d. To determine what short and medium term projects could be undertaken by US yards to improve their productivity/performance in relation to coating activities
    e. To determine what lessons could be learned from commercial shipbuilders
    f. To determine what lessons could be learned from other Naval shipbuilders.

4.2 Scope

15. The scope of the work was as follows:
    a. To set up of visits to at least 3 European based yards.
    b. To provide assistance with the set-up of visits to at least 3 Far East Yards.
        i. It is possible that one alternative yard in either China or Japan may be considered.
    c. Develop a guide for the visits.
    d. Develop key questions that should be considered and assist with appropriate logistics.
    e. Arrange and make suitable contacts for all visits
    f. Produce interim feedback reports to the ECB
    g. Produce a final report
    h. Disseminate results through subsequent seminars/presentations to be held in the USA to provide a broader feedback.

4.3 Project Goals

16. Previous US shipyard international benchmarking studies provided insight into a variety of shipbuilding activities but excluded coatings.
17. This project aimed at assembling a team of coatings specialists to conduct visits to leading European and Far Eastern yards to gain a better understanding of the coating process and benchmark key aspects of it.
18. Once done the aim is to transfer lessons learned to NSRP shipyards and NSRP- Navy initiatives for implementation.

19. The aim of the project is to enable the US yards taking part to obtain lessons learned by understanding coating activity practices in foreign shipyards at pre-production and during production. Transfer appropriate lessons learned to NSRP shipyards for implementation. Where appropriate, use the lessons learned in the current “future state” project that was funded for the 2012 NSRP SPC budget.

5 PARTICIPANTS

5.1 National Shipbuilding Research Programme

20. There are a total of 12 participants active in the NSRP as follows:
    a. Austal
    b. BAE Systems
    c. Bollinger shipyards Inc.
    d. Marinette Marine Corp (Fincantieiri) (MMC)
    e. GD Bath Iron Works Corp
    f. GD Electric Boat
    g. GD NASSCO
    h. HII Newport News Shipbuilding
    i. HII Ingalls Shipbuilding
    j. Vigor Industries
    k. VT halter marine Inc.
21. In addition the NSRP involves its key customer, namely NAVSEA.

5.2 SPC – Surface Preparation and Coatings Panel

22. The work carried out in this project is one behalf of the SPC panel and the following companies participated in the benchmarking activity:
    a. BAE Systems
    b. GD Bath Iron Works Corp
    c. GD NASSCO
    d. HII Newport News Shipbuilding
    e. Marinette Marine Corp (Fincantieiri)
    f. Vigor Industries
    g. NAVSEA 05 (customer)
23. In addition the yards were supported by two consultants
    a. Elzly Technology Corp of the USA
    b. Safinah Ltd of the UK
24. Elzly has a well-established work base on coating and corrosion issues working for the US shipbuilding and general defence sector and regularly provides resources to the SPC panel to action projects and co-ordinate the strategic effort of the SPC panel.
25. Safinah Ltd is recognised internationally as a leading consulting company specialising in marine coating issues with considerable experience of the integration of coating activities with the shipbuilding process.

6 PROJECT OVERVIEW

6.1 Yard Selection

26. The first step was to consider two key factors:
    a. Which yards were to be visited in Europe and the Far East and why particular yards were selected?
    b. What format the visits would take to maximise the information obtained.
27. In addition of course a means of summarising the findings in a suitable format to allow some benchmarking assessment to be made and to allow the identification of short and medium term projects to drive performance and productivity improvement in US yards.
28. In addition, the visits should also create:
    a. A relaxed and informal environment for coating professionals to share their experiences
    b. Foster longer term relationships between US yards and foreign yards to aid future initiative.
29. The work was based on two visits:
    a. Northern Europe
    b. Far East
30. In deciding the yards to visit the following factors were taken into consideration and /or had an impact on the selection of the final yards.
    a. The yards would be building naval ships
    b. Commercial yards would be building complex ships
    c. Ideally the ships being built would be for owners who have a reputation for holding onto their ships for a long period of time
    d. The economic environment and the order books of the yards
    e. The willingness of the yards to entertain a visit from a US delegation
    f. The travel and logistics issues to keep both time and costs of each visit manageable.
    g. The availability of suitable contacts in the yards.

6.2 European Visit

31. Safinah Ltd was tasked to identify suitable yards in Europe for the visits. A quick review showed that the only significant naval new building programme was taking place in Europe.
32. After considerable effort a visit was planned as follows:
    a. Europe 1 Warship builder
    b. Europe 2 Small complex vessel builder
    c. Europe 3 Cruise ship builder

d. Europe 4 Cruiseship builder

33. These yards are all based in Northern Europe and therefore generally suffer from adverse weather conditions in particular during the winter season.

6.3 Far East Visit

34. The end the following visits were arranged for Japan
    a. Class NK
    b. Japan 1 – Builder of Naval and commercial vessels
    c. Japan 2 – Builder of commercial vessels
    d. Japan 3 – Repairs Naval vessels

35. The commercial yards visited are amongst the most efficient in the world with the ability to deliver 9 commercial vessels from a semi-tandem dock in each year. They have therefore optimised their coating processes and specification to best fit the coating process into their build strategy and facility capability.

36. As a result of the introduction of the IMO PSPC both Japan 1 and Japan 2 had recently built paint/blast workshops to enable them to better control the coating process in ballast tanks in particular.

7 PROCESS AND SURVEY STRUCTURE

7.1 Key Steps

37. The key steps in setting up the work scope and method were:
    a. Identify key topics and questions of interest to US yards
    b. Select suitable yards and arrange visits
    c. Plan logistics
    d. Fix agenda with each yard broadly as follows:
        i. Introductions
        ii. Overview of each NSRP yard
        iii. Discussion of key topics
        iv. Review of NSRP panel projects
        v. Interactive session to understand current work practices at the yard
        vi. Discussion regarding common issues/challenges
        vii. Tour of facilities
        viii. Wrap up session

7.2 Source of Coating Issues

38. All coating issues can be categorised under the following key subjects:
    a. Pre-production
    b. Ship design
    c. Facilities and production technology
    d. Coating activities
    e. Coating materials
    f. Coating specification and product selection
    g. Management systems
    h. QA/QC
    i. Miscellaneous
    j. Environmental
    k. Human Factors
39. To ensure that all these aspects were covered a survey questionnaire was prepared before the visits and individuals assigned to ensure that the items were covered adequately during the visits.
40. These were sent out in advance to the shipyards to ensure that the yards could prepare adequately. It is fair to say that this approach seemed to work better during the European

visit rather than the Far East visit (language difficulty was the main reason for poorer communications in Japan).

7.3 Survey Questionnaire

Questions/Topic Assignments during European Benchmarking

Responsibilities
Each topical area has a lead team of two participants. The topic area leads will be asked to provide their observations during our out-brief meetings AND will be responsible for preparing a brief write up on the topic. The write up should address the specific questions asked but ALSO go beyond those questions into a general discussion of the following:

- What are the significant differences between the US practices and European/Far East practices in this area? What seems to drive those differences?
- What challenges and solutions in this area are common to US and European/Far East shipyards?
- Based on the observations, what technologies/processes should we be looking to improve or adopt?

Everyone is invited to comment on any topical area during our meetings and may also provide the leads with information to include in their write up. Everyone will also have an opportunity to edit the final report, so do not feel that you have to limit your observations to the assigned areas.

Pre-production (Lead - KATTAN/BRODERICK)

- If you have built Naval vessels, what differences do you see in the contracting process compared to a commercial vessel?
- Do you see the contracting process changing over the next 5 years?
- What problems are experienced with owners when agreeing contracts?
- What are the typical guarantees that your company requires from the paint company to cover paint between yourself and the owner?
- Are there particular guarantees required for specific areas e.g Ballast tanks, potable water, cargo tanks, under water hull?
  - What guarantees are you aware of that owners require from the paint supplier and do you see this changing in the future?
- At what points in the ship building contract process are the coating Types, specifications and suppliers agreed?
- How does a contract differ for a vessel which is to have a foul release anti fouling compared to a vessel with a standard biocidal antifouling?
- How much variation on the agreed coating specification is allowed once the build contract is signed?
  - E.g. can the supplier or paint type be altered?
- How detailed is the coating tender that is sent to the paint companies?

- E.g. does it cover all areas of the ship, or only major areas, or external areas only?
- Can you describe your QC procedure for inspection of coatings during new build?
- What aspects of the coating process do you allow
  a. The owners site team to inspect
  b. The coating suppliers site team to inspect?

Ship design (Lead – AULT & LOCKWOOD)

- What steps does the yard take to improve vessel design to make them easier to coat?
- To what extent does your yard use aluminium in shipbuilding? Titanium? Stainless steels?
  - How/why is the materials decision made (e.g., directed by owner, recommended by yard)
- How do you consider reductions in life cycle maintenance costs when making decisions during new build?
  - Are cost savings measures effectively translated to life-cycle costs?
  - Are initial costs the only measure of savings considered?
- Does the shipyard use smooth tank interiors? If so, where or when? If not, have they been considered?

Facilities and Production Technology (Lead – AULT & LOCKWOOD)

- What are the key pre-production steps for coating activities (e.g. estimating, planning, specification, purchasing)?
- What methods or processes are used to prevent heat damage to internal tank coatings when brackets or lugs are removed from the hull just prior to launch?
- What degree of automation has been attempted or is in regular use for coating activities?
  - Share experiences identifying, justifying and implementing the automation.
  - Share experiences with automation which was been considered and/or evaluated but is not in use.

Coating Activities (Lead – ZEPEDA & COGSWELL)

- What are the top 3 things the shipyard has done in recent years to improve throughput in coating activities?
- What are the top three present major challenges regarding coatings activities?
- What are the major challenges they will face in 5 years regarding coating activities?
- What surface treatment is used on disturbed areas (e.g., areas to be, or that recently were, welded)
- How is edge radiusing being achieved where required? What tools and techniques/media are being used?

- When and where do you touch up damaged coatings in particular weld/hot work damaged areas?

Coating specification/product selection (Lead – ZEPEDA & COGSWELL)

- What are typical specifications and when and where are coating schemes applied for the major vessel areas:
  - Outside hull
  - Tanks
  - Internal Ship Structure
  - Decks
  - External Ship Structure
  - Cargo holds/tanks
  - Others?
- What has been the impact of the IMO PSPC on product selection?
- What guarantees does the yard offer and what is done to manage claims?
- How do you consider reductions in life cycle maintenance costs when specifying coatings during new build?
- What is the typical number of coats applied and why?
- What is the typical coating thickness for tanks?
- What are typical re-coat windows? What challenges to re-coat windows pose?
- What is the overall timing of coating system application?
- What are the paint schemes for areas behind joiners bulkheads, insulated bulkheads. Do you spend time removing BB's, spatter and weld scars in these types of areas?
- Can you paint over electrical cables? If not how do you deal with the coating process around them?

Management systems (Lead – BLAKEY & CASTLE)

Planning/Scheduling

- How does planning attempt to minimize re-work of applied coatings?
- How is re-work managed?
  - What incentives do other trades have to minimize coating damage?
- What percentage of man-hours are typically coatings-related?
  - New construction
  - Repair/maintenance
- What percentage of coatings work man-hours are re-work?
  - New construction
  - Repair/maintenance
- How much coatings work is done in assembly vs. erection (i.e., what stages of construction contain the majority of coatings work)
  - Is the timing of coating activities within the production cycle appreciably different to US Yards?
- What has been the impact of the IMO PSPC on planning/scheduling?

QA/QC

- What is the typical inspection process for coatings?
- Who is in an inspection team? What tools do they use?
- How is the inspection process documented?
  - How do you manage documentation?
  - How much documentation is required?
  - How is the final acceptance of the quality paint product documented?
- What percentage of the ship QA costs/people is related to coatings?
- How much QA is in-process vs. inspection after the fact?
- What has been the impact of the IMO PSPC on QA/QC?

Miscellaneous (Lead – BLAKEY & CASTLE)

- What is the impact of PSPC and what lessons have you learned through its implementation?
- Are warranties typically offered?
  - What are the performance criteria?
  - What are the remedies if a coating does not meet the criteria?
- To what extent does your shipyard use subcontractor for painting activities?
  - What criteria are used to determine what work is done by subcontractors versus in-house?
  - How are subcontractors selected and managed?

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Coating Materials (Lead – QUIERO & SAGASER)

- Please share your experiences with the following coatings:
    - Retention of pre-construction primer
    - Foul-release coatings
    - Polysiloxanes
    - Hot metal spray
    - Rapid cure, high build coatings (“single coat”)
    - Other new or innovative materials
- How much do you use high solids and ultrahigh solids coatings? Elaborate on advantages/challenges

Environmental & Human factors (Lead – QUIERO & SAGASER)

<u>Environmental</u>

- What are the major environmental challenges the yards are facing and how are they being dealt with?
- What environmental compliance constraints do you have?
    - VOC emissions
    - Material restrictions
    - Other issues

<u>Human Factors</u>

- Workforce development
    - How does the shipyard train personnel in the protective coatings value chain (painters, blasters, QA/QC, planners, etc)?
    - Is an aging workforce a problem in your shipyard? If so, what strategies are used to mitigate the issues?

8 NAVAL AND COMMERICAL SHIP COATING ACTIVITIES

8.1 Overview

41. Considering the benchmarking results there is merit in summarising the key differences between the coating activities as carried out on commercial ships as opposed to naval vessels. These observations are based on information gleaned during the visits.

42. Perhaps the most salient observation can be summarised as follows:

“The commercial owner inspects the ship before he takes delivery. The Naval owner inspects the paperwork after the ship has gone”

43. Whereas this may not be a true reflection of the physical process, it perhaps does reflect the perception that naval vessels in general generate more documentation than their commercial equivalents to arrive at the same outcome. It may also reflect that the commercial owner has less power over the shipyard and therefore uses physical inspection to mitigate risk while work is in progress, while the Navy owner focuses on document review post vessel delivery, because the documentation is available.

44. Coating activities on vessels generally take place in 4 locations:
    a. Prime line
    b. On block
    c. Post erection
    d. Post launch.

45. For the purposes of this work the pre-construction primer line has been ignored as it is an automated process with very mature technology.

46. The remaining 3 locations are simply split into two:
    a. At assembly (on block)
    b. Post erection

47. Based on Japanese yard data, for a typical commercial ship the breakdown of man-hours expended on surface preparation and coating work would fall into the following ratio
    a. At assembly – 40-45%
    b. Post erection – 55%-60%

48. While for a Naval ship the figures would be
    a. At assembly – 10% - 15%
    b. Post erection – 85% - 90%

49. Whereas the exact figures of man-hours used are not relevant and would generally be commercially confidential, it is clear that for both commercial and naval vessels, whereas the greater surface areas treated are usually at assembly the smaller areas post erection

and the resultant hot-work damages and repair can consume significantly more man-hours.

50. Based on European yard data the cost ratio of carrying out work at assembly when compared to Post erection is a 12 fold increase in the price per square foot i.e. if it costs $1 at assembly it will cost $12 post launch per square foot.
51. A study carried out by Safinah Ltd in the mid-1990's showed that in a commercial yard carrying out first time coating activities in at Assembly was typically 2.5 times cheaper than carrying them out Post-erection.
52. While a Benchmark study carried out by Safinah of the US yards under a previous NSRP study gave the following values:

Unit of measure	USA yards	Asia	Europe
Man-hours per GT for coating activities (primer line, assembly and post-erection)	100	6	12
Cost per GT for coating activities (primer line, assembly and post-erection)	100	11	81

53. On the face of it one could wrongly conclude that the US yards lag considerably behind their international rivals. However this would not be entirely true. The reasons are as follows:
    a. Naval vessels tend to be relatively smaller and more consistently complex vessels. In a paper published in 2007 (Warship Design Complexity – Measurement and Valuation by Noel-Johnson and Kattan, RINA Warship 2007 – The affordable Warship Conference, Bath, UK) considered a measure of complexity as a relationship between the total enclosed volume of the hull and superstructure against the lightship mass. On that basis Naval ships were on average significantly more complex than even quite complex commercial vessels such as RoPax ferries. Other studies carried out by Kattan at Newcastle University in the early 90's (unpublished) confirmed this by assessing CGT relationships for Naval and commercial vessels.
    b. It is a fact that naval vessels in general incur a far greater number of design and engineering changes through their construction period. This can be a function of many factors:
        i. Relatively low level of design maturity at start of build
        ii. Required upgrades and design changes resulting from the relatively long build period and the desire to ensure the adoption of latest technologies.

iii. A difference in the coating strategy adopted with a greater acceptance of Pos-erection coating work by Naval Builders (accepting that there will be hot work damage resulting from design and engineering changes).

iv. The relative inability to close off spaces and not need to re-enter them once completed, resulting in damage to coated surfaces.

v. The painting specification is generally more onerous than commercial ships in the following key areas:

- Documentation requirements (as also evidenced by a pervious NSRP SPC project).
- Surface preparation requirements
- Total coats of paint applied in the chosen schemes.
- Increased inspection burden

54. In addition it should be noted that within the US the behaviour of private yards and commercial yards can vary significantly.

55. For these reasons it should come as no surprise that the US yards direct productivity measures are likely to appear worse. In fact from the trip and in discussions with Japan 1, which builds both Naval and Commercial vessels, then their productivity for commercial ships was about 3 times better in sqm per man-hour than their own productivity on naval ships.

56. All these factors reinforce the need for finding better engineering solutions to the coating of Naval vessels and the removal of any extra work and effort (in particular documentation and audit oversight) to allow increased focus on the practical process that really matters.

57. It would be wrong to conclude that commercial shipyards have solved the problems of coating ships. They have not. However they have better optimised their processes and aligned them with their build strategy.

58. One of the common themes that came to light in the discussions with the yards visited is that all the yards are pretty much using the same technologies for surface preparation and coating application (no one had some magic tool or equipment that others had not considered or seen equivalent of). However the availability of some small tools (e.g. Perago wheel for mechanical surface preparation) may offer some benefits to some of the US yards.

59. The main differences would seem to have stemmed from:

a. Integration of coating work with other activities

b. Improved design o assist coating work

c. Allocation of man-hours for hot-work damage and repair to the departments who cause them to be incurred (let the extra work be reflected in the man-hours/cost of other trades).

The simplicity of the commercial approach can be summarised by the flow chart in Figure 7.1 from one of the Japanese yards (this is in small scale to fit in the report, but can be enlarged by copying to powerpoint).

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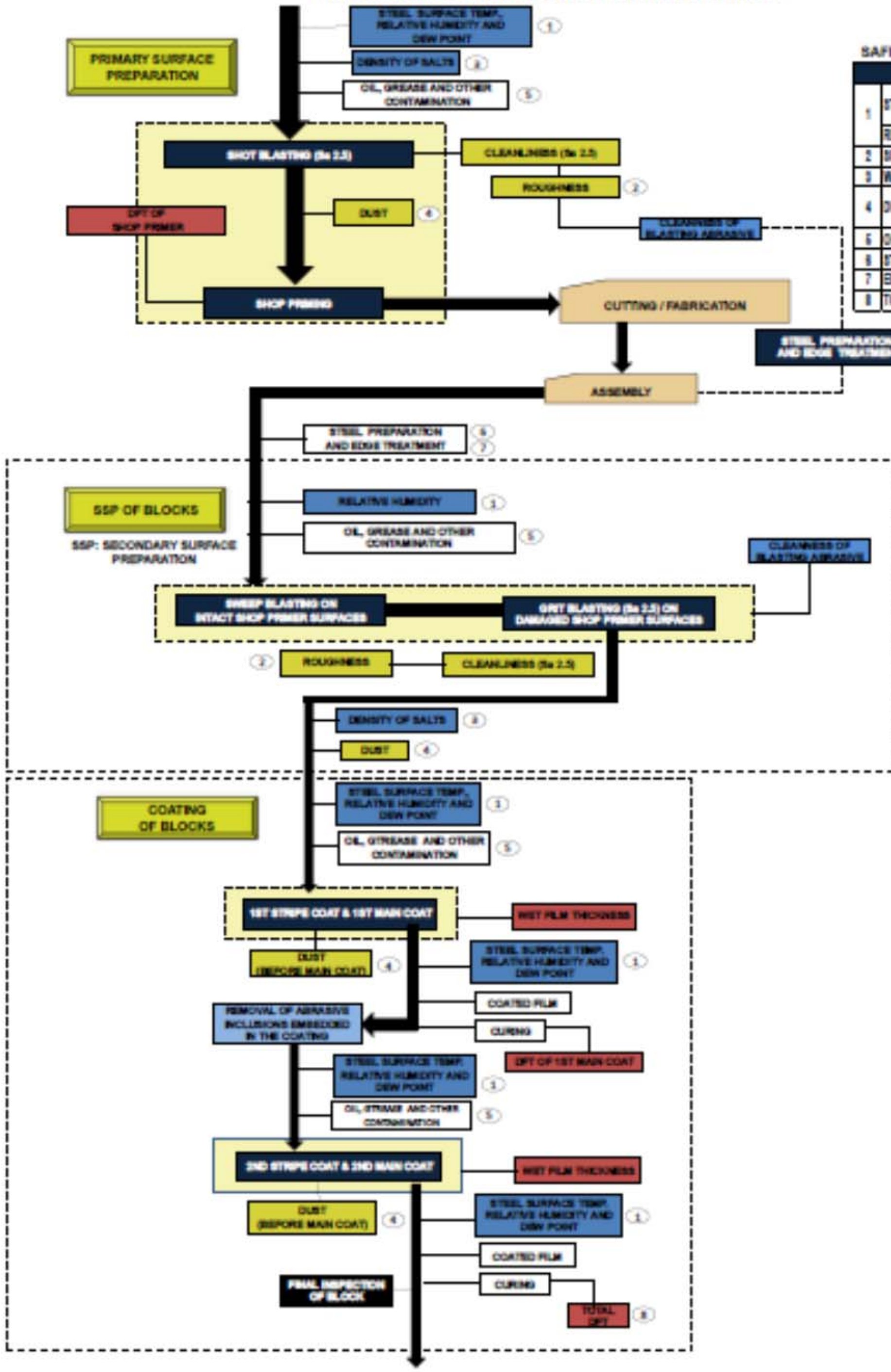
PROCEDURES FOR INSPECTION AND MEASUREMENT



SAFIANH LIMITED, FEBRUARY 2013

CRITERIA		
1	STEEL SURFACE TEMPER	MORE THAN 3 DEGREES C ABOVE DEW POINT
	RELATIVE HUMIDITY	NOT EXCEEDING 85 %
2	SURFACE ROUGHNESS	BETWEEN 30 - 75 µm
3	WATER-SOLUBLE SALTS	LESS THAN 50 mg/m2
4	DUST	NO VISIBLE DUST TO THE NAKED EYE
5	OIL CONTAMINATION	NO OIL CONTAMINATION
6	STEEL PREPARATION	AS PER TABLES 1,2
7	EDGE TREATMENT	THREE (3) - PASS GRINDINGS
8	TOTAL DFT	320 µm (BASED ON 90/10 RULE)

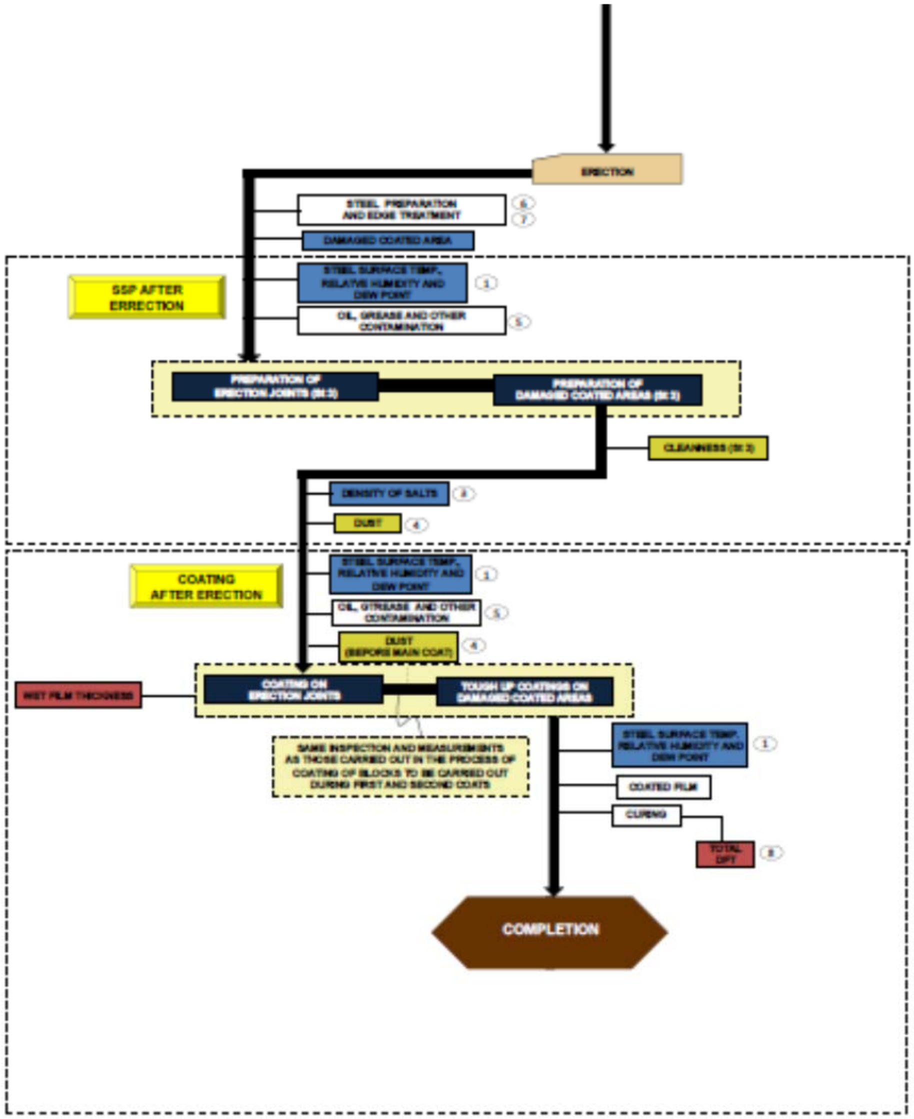


Figure 7.1 Japanese yard flow chart.

60. Simple Key to above:

Yellow and white boxes - surface inspection
Red boxes - paint inspection
Light Blue - environmental records

61. The flow chart reflects the current state of commercial shipbuilding procedures during production process of commercial ships. One new feature that has emerged for commercial ships is the need to create an "as built" record of how ballast tanks are coated (The Coating Technical File as required by the IMO Performance Standard for Protective Coatings). This has resulted in a number of the yards developing some form of computerised record keeping system (Prime ship by Class NK and Europe 2 internal system). These have a similar target to the Paperless QA project that NSRP SPC is already undertaking.
62. There may be merit to simply flow chart the current US shipyard required procedures to understand where they deviate from the above commercial ship yard flow chart and to determine the reasons/background to any deviations and to collate the justification for those deviation and re-assess the rational of all of them with a view to streamlining the current process.

9 WEIGHTINGS AND ASSEMENTS

9.1 Qualitative Approach

63. Given the breadth of the work undertaken and the experience of the various team members then a simple assessment method was developed. The approach took into account two key factors:
   a. Other benchmarking work already carried out by NSRP and the way the data was presented
   b. Other work done on benchmarking the US yards coating process as carried out by the SPC panel in the early 2000's.
64. Based on these then the following approach was adopted:
   a. For each category as follows
      i. Ship design
      ii. Facilities and production technology
      iii. Coating activities
      iv. Coating specification/product selection
      v. Management systems (planning/QA etc.)
      vi. Coating materials
      vii. Environmental
      viii. Human factors
      ix. Other/Misc issues
   b. A scoring system of 1 – 5 was devised, whereby 5 meant state of the art while 1 meant a basic level of technology.
65. In all such activities it does not mean that a yard with level 5 across the board is more efficient or productive. The key is to be at a balanced level of technology across all the aspects and to pick the level of technology that best suits the particular yards cost structure (i.e. do not overspend on technology but do not underinvest).

9.2 Scoring Method

66. At the end of the European visit the US yards were asked to go back and consider the weightings they would give their own facilities across these elements and the results were collated by Elzly Corp and averaged giving the US yards the following average scores:

Item	Score 1 – 5
Ship design	3.75
Facilities and production technology	3.50
Coating activities	3.30
Coating specification and product selection	3.30

Planning and scheduling	3.25
QA/QC management systems	3.25
Coating materials	3.40
Environmental	3.75
Human factors	3.50
Other	3.25
Overall average	***3.43***

67. The European yards scores were similarly collated and averaged as follows:

Item	Score 1 – 5
Ship design	4.00
Facilities and production technology	4.00
Coating activities	3.50
Coating specification and product selection	4.00
Planning and scheduling	3.60
QA/QC management systems	3.80
Coating materials	3.60
Environmental	3.60
Human factors	3.50
Other	3.40
Overall average	***3.70***

68. The Japanese yards scores were similarly collated and averaged as follows

Item	Score 1 – 5 Inc Japan 3	Score 1 – 5 Ex Japan 3
Ship design	3.0	3.6
Facilities and production technology	3.2	3.9
Coating activities	3.3	3.4
Coating specification and product selection	3.4	3.5
Planning and scheduling	3.7	3.95
QA/QC management systems	3.7	3.75
Coating materials	3.2	3.25
Environmental	3.4	3.2
Human factors	3.0	3.0
Other	2.9	3.0
Overall average	***3.3***	***3.46***

69. Thus on average the results can be summarised as follows

Item	Score 1 – 5 USA	Score 1 – 5 Europe	Score 1 – 5 Japan inc Japan 3	Score 1 – 5 Japan ex Japan 3
Ship design	3.75	4.00	3.0	3.6
Facilities and production technology	3.50	4.00	3.2	3.9
Coating activities	3.30	3.50	3.3	3.4
Coating specification and product selection	3.30	4.00	3.4	3.5
Planning and scheduling	3.25	3.60	3.7	3.95
QA/QC management systems	3.25	3.80	3.7	3.75
Coating materials	3.40	3.60	3.2	3.25
Environmental	3.75	3.60	3.4	3.2
Human factors	3.50	3.50	3.0	3.0
Other	3.25	3.40	2.9	3.0
Overall average	***3.43***	***3.70***	***3.3***	***3.46***

70. Thus it can be seen that coating vessels employs quite mature technology with the results across the yards visited very similar on average. This can be considered both positive and negative.

71. The positive aspects are:

   a. All yards building warships are almost identical in the abilities (Japan ex Japan 3 and the USA yards).

   b. It is likely that the US yards are on a level footing with other yards in terms of technology employed.

72. The negative aspects are in effect opportunities and these will be discussed in section 12 of this report. However in simple terms:

   a. The US yards lag behind the European builders of complex ships, indicating that there are opportunities for productivity improvements

   b. There are opportunities for reducing in service operational costs.

   c. It is unlikely that there is a miracle panacea that would solve all the coating issues being faced by US yards, instead there is a need for a methodical and systematic approach to ensure that the best solutions available are adopted.

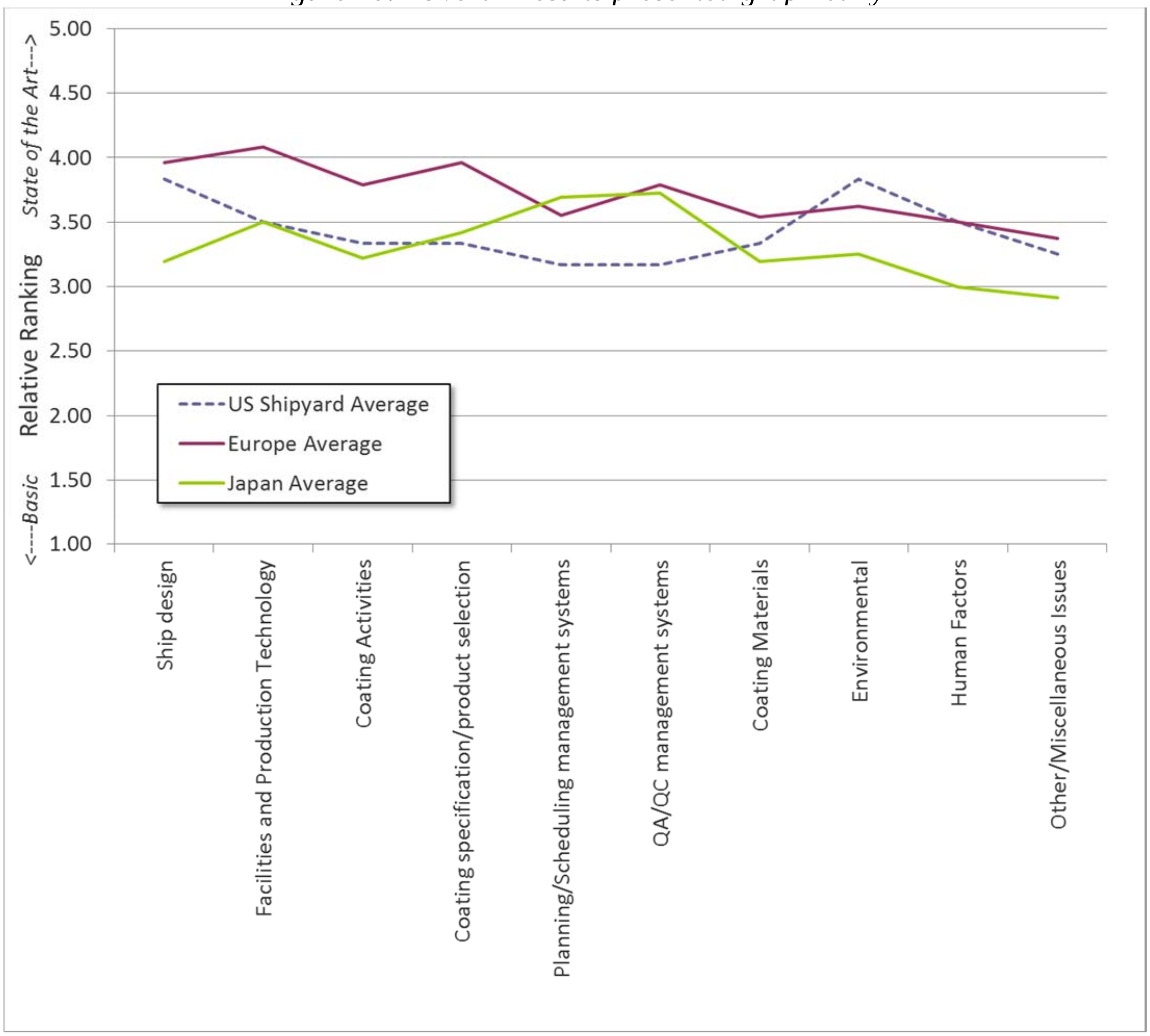
   d. The current technology employed is quite mature and hence there is little opportunity at present to make a step change in productivity based on technology improvement, without significant investment in Research to drive future technology development. This may present a key role for academia in the USA and elsewhere.

10 RESULTS

10.1 Overall Findings

73. The results are best presented in a graphical format for each key activity area as shown in Figure 10.1.

Figure 10.1 Overall results presented graphically



74. The graphic representation demonstrates a saw tooth effect indicating that all yards are good at some things and not so good at others. Keeping in mind that the ideal yard would

have a horizontal line across an appropriate technology level that is it has a balanced process performing at an acceptable level.

75. Some activities show a wide spread of competence (e.g. ship design, while others show a narrow range of capabilities e.g. planning and scheduling.

76. Some elements can be picked out as shown in figures 10.2, 10.3 and 10.4

Figure 10.1 Design possibilities

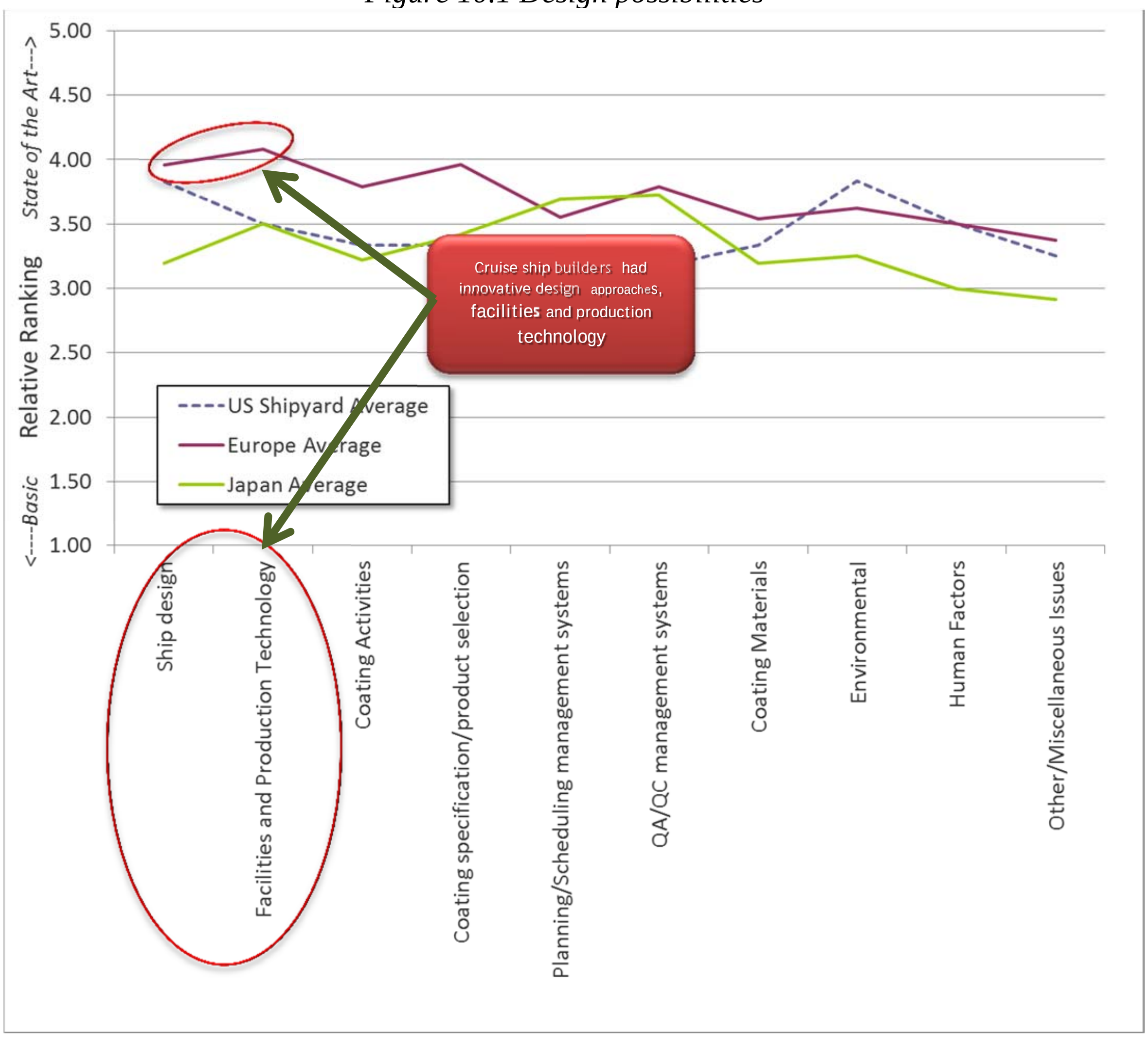


Figure 10.2 Planning and scheduling

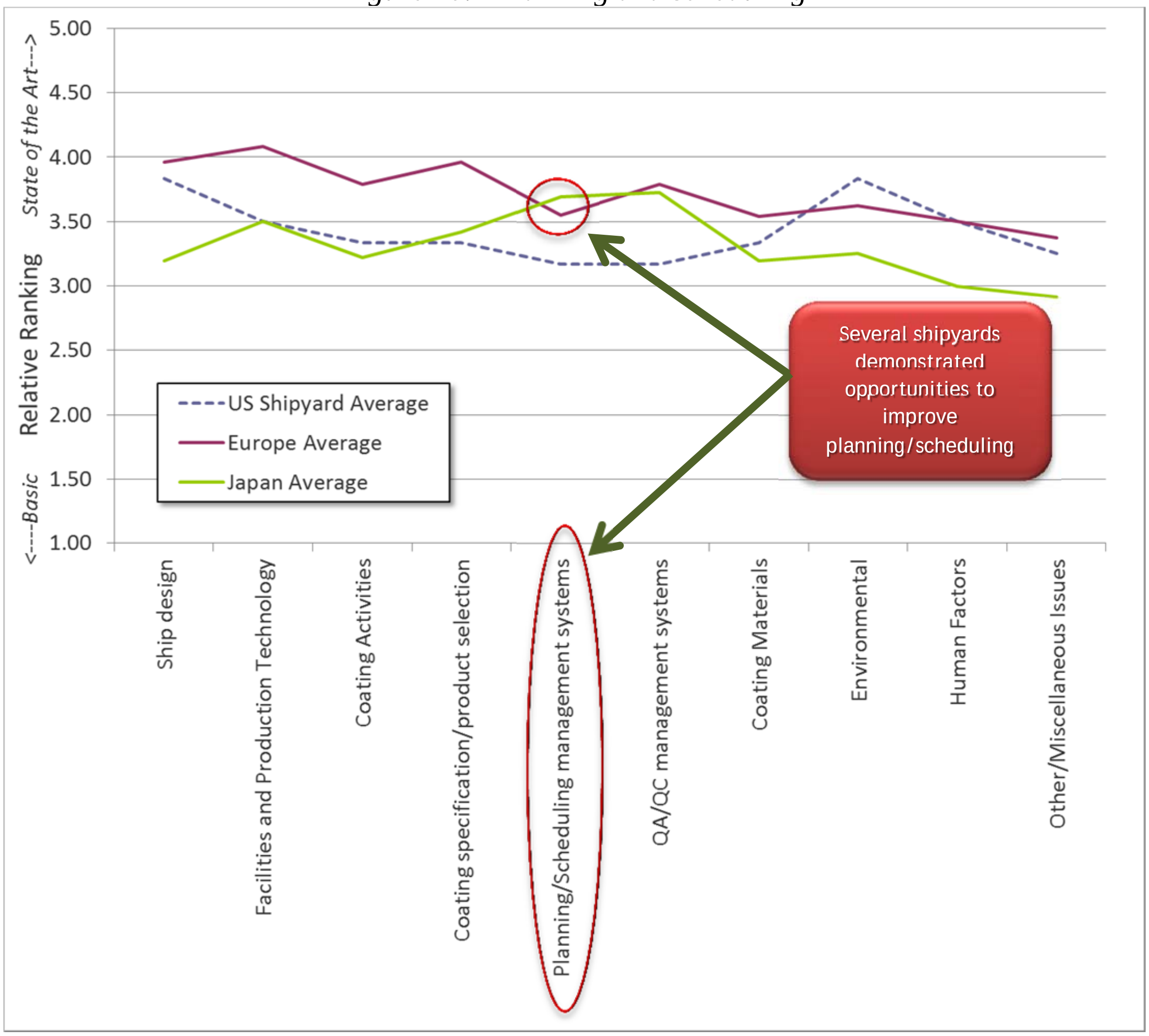


Figure 10.3 QA/QC

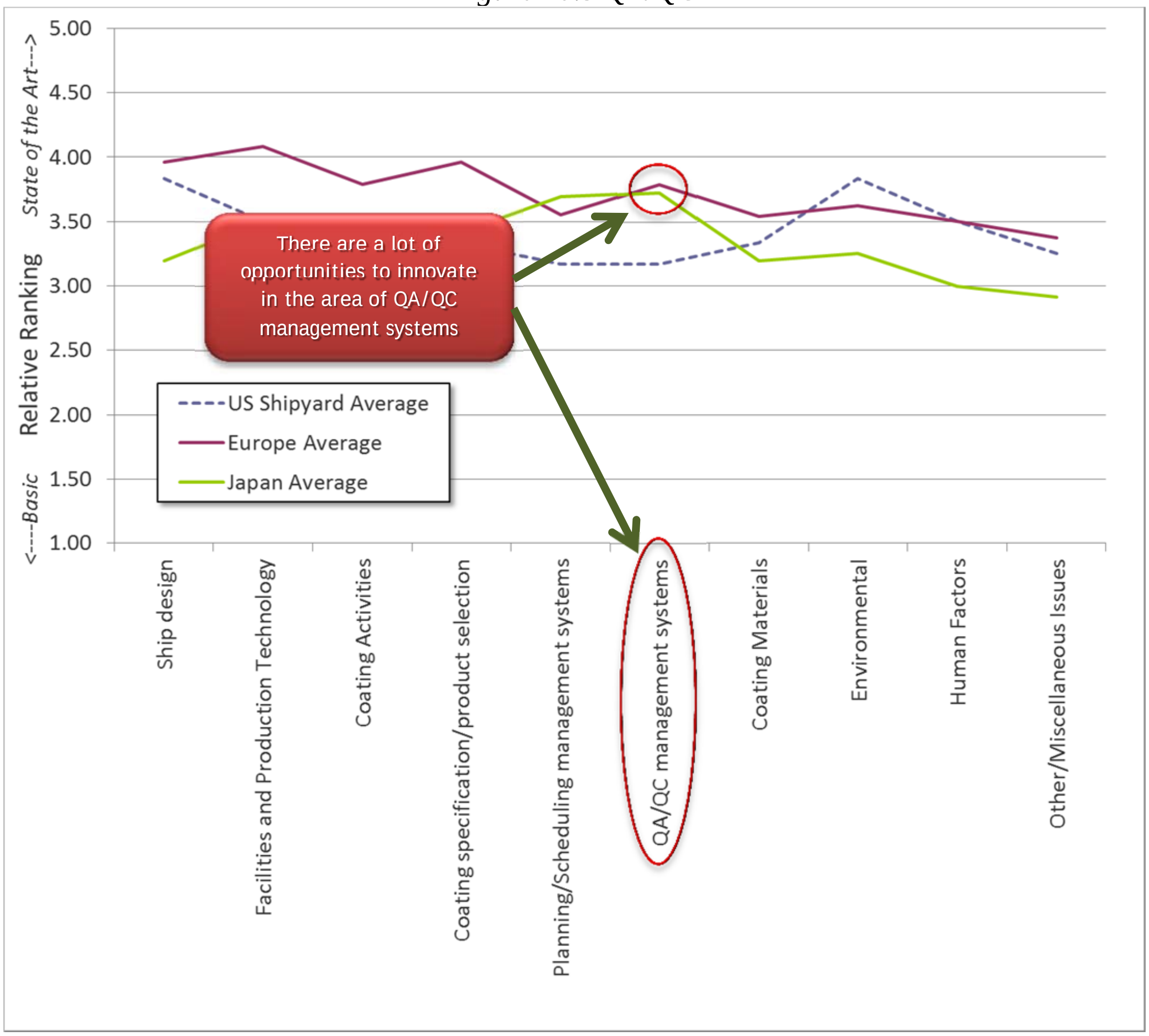
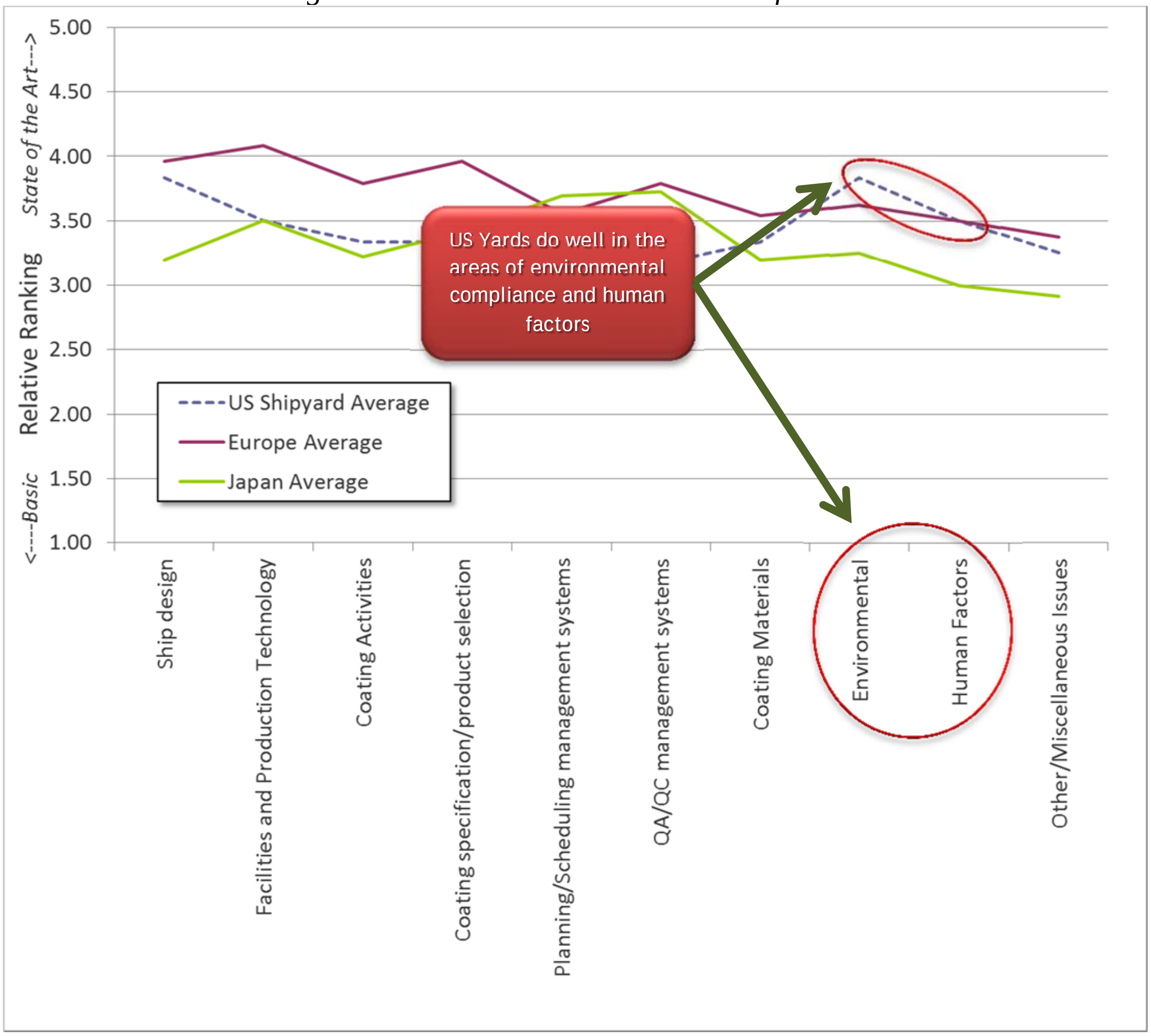


Figure 10.4 Environmental and human factors



77. The results would indicate that US yards could improve their coating activities by investigating the following areas:

a. Facilities and production technologies
b. Coating specifications/product selection
c. Planning/Scheduling
d. QA/QC systems

78. Based on the scoring then the priority areas would be:

Item	Score 1 – 5	Other yards average Japan 3
Facilities and production technology	3.50	3.95
Coating specification and product selection	3.30	3.75
Planning and scheduling	3.25	3.80
QA/QC management systems	3.25	3.80
Overall average	***3.33***	***3.85***

79. Thus these should be the areas of initial focus for the US yards.

11 INITIAL TAKE AWAYS

11.1 Europe

11.1.1 Europe 1

80. The take-aways can be broken down into two, cost saving and improved service life.
81. Cost savings
    a. Temporary protection used to reduce re-work by 15-30%
        i. Tempro-tech rubber mats
        ii. Corrugated boxes
    b. Perago rotating blaster disk for mechanical surface preparation
    c. Spray on insulation used where possible (Temp Coat)
    d. Logistics of paint supply handled by paint supplier
    e. Undertake some design and build for coating studies (detail design)
    f. Exploring use of adhesives
        i. Good test results even under 120G shock loads
    g. Exploring laser ablation to reduce re-work on surfaces where adhesives are to be used.
    h. Minimize documentation
82. Improved service life
    a. Polysiloxane topcoats used to reduce M&R costs
    b. Life cycle maintenance plan offered by builder
    c. No liquid paint stores on board (using adhesive films as temporary repairs).
    d. Use of ZIMTECH to reduce the need for galvanizing
    e. Use of "Zinga" Zinc rich primer in key areas.

11.1.2 Europe 2

83. The take-aways can be broken down into two, cost saving and improved service life.
84. Cost savings
    a. Sweep blast of ballast tanks
    b. Design for coating improved as a result of research project
        i. Larger access holes
        ii. Leave wear areas unpainted
    c. Sell a standard specification and process and charge for changes/deviations required by owners

d. Avoid coating damages to minimise costs as the cost of repair is 12 times the cost of the original coating work.
e. Have customer check points (G-points) but minimise paperwork required.
f. VOC reporting is done by the paint supplier.
g. Make use of 3M clean and strip

85. Improved service life
    a. Testing adhesives for smaller outfit items
    b. Investigating laser ablation
    c. Training courses for CAD operators/designers to improve design for coating.
    d. Life cycle maintenance programme is offered by IHC to clients.

11.1.3 Europe 3

86. The take-aways can be broken down into two, cost saving and improved service life.
87. Cost savings
    a. Smart paper based QA system across all trades not just for coating.
    b. Laser hybrid welding in use to reduce heat damage and distortion and hence minimise coating damage.
    c. Do not paint unexposed interior structure
    d. Use Iron Oxide Epoxy see no benefit in weld through primers that are more expensive (note their facility is totally enclosed).
    e. Have homemade portable tools for spot blasting
    f. Use high solids products.
    g. Only inspect for colour on cosmetic areas
    h. Dry ice cleaning for many spaces instead of power tool cleaning
    i. Electrostatic spray for exterior topcoats (Polysiloxane)
    j. Subcontractor control is good with strong partnership/teaming arrangements.
    k. Exploring the use of robotics in coating activities.
    l. Good control of lock-out spaces to minimise coating damage
88. Improve service life
    a. Looking at the use of robotics for in service inspection of tanks
    b. Monitor their vessels with owners over their life time with regular visits.

11.1.4 Europe 4

89. The take-aways can be broken down into two, cost saving and improved service life.
90. Cost savings
    a. Estimate surface area from CAD and identify paint scheme for all areas on CAD.
    b. Do not paint unexposed interior structure
    c. Most testing is completed in the dock.

d. Pressure testing of tanks is allowed by DNV post application of coating scheme
e. Use of glass flake coatings and minimise the number of coats on the underwater hull
f. Make use of primer finish coats where they can.
g. All Ballast tanks covered by an 86 page Coating Technical file (note Cruise ships do not have many ballast tanks but are comparable to Naval Ships in this).
h. Bulk supply of coatings from single source supplier to reduce waste and increase universality of coating application.
i. VOC limits drives product selection
j. Paint supplier has customized some products to meet the local yard needs.

11.2 Japan

11.2.1 Class NK

91. The following was of interest to US yards:
    a. Konki-jet (mixed air, water, grit abrasive blasting system developed by collaborative Japanese research).
    b. The increasing use of corrosion resistant steels
    c. The development and use of Prime ship (paperless QA system).

11.2.2 Japan 1

92. The following was on interest to US yards
    a. Contract paint specification developed in collaboration with commercial owners but with yard taking the lead.
    b. The Japanese Navy generally specifies older coatings and more coats of paint
    c. Japanese Naval vessels dock every year (45 days).
    d. QA/QC oversight is left to the shipyard with documentation minimized
        i. 4 sheet coating report per area
        ii. No requirement for outside certification or auditor
        iii. Inspect the ship not the documentation
    e. Naval coating costs are significantly higher than commercial vessels
    f. Naval ships need considerably more man hours for coating work Post erection.
    g. Naval ships are more complex.

11.2.3 Japan 2

93. The following was on interest to US yards
    a. The shipyard takes a lot of responsibility at new build and can veto owners' inspectors (and have them removed from the yard).

b. Painter training for Naval work is driven by SSPC while in house training is used for commercial work.

c. Block size is optimised not only for steel work and cranes but also for access for coating activities (bigger is not always better).

d. Shop coat is applied during steel work by welders to protect new welds but has to be removed for subsequent scheme. There is a possibility of suing the first coat of the scheme here.

e. Bulk supply of coatings in 200-250 litre drums as they tend to drive toward a universal primer and a single source supplier.

f. PCP line has a morning and evening QC check

g. For non- IMO areas inspections are made but generally not recorded.

11.2.4 Japan 3

94. The following was on interest to US yards

a. The majority (80%) of coating work is carried out by in-house personnel and not contractors.

b. All work is carried out to 009-32

c. Interested in NSRP projects

i. Flash rust

ii. Cost of QA

iii. Single Coat

iv. Laser ablation

v. Zero G arm

d. Use plural component equipment only of Naval tank work

e. No real oversight by Naval personnel, the builder builds the vessel and maintains it.

11.3 Common Themes

95. As was expected all yards seem to face similar challenges.

a. The technology used by all yards is comparable.

b. There is an focus on efficiency and integration in commercial yards

c. The commercial shipyard community is involved with classification societies and rule/regulation making

d. Complexity of Naval ships results in increased man-hours.

e. All yards seek to minimise the degree of surface preparation required

f. All yards seek to minimise the number of coats applied and to increase the use of universal products to minimise total number of products used coating a ship.

g. Shipyard, paint supplier, owner and contractor are well integrated in the whole process

i. Assist with planning and scheduling
ii. Minimize documentation and auditing

h. QA/QC documentation minimized

i. Select the coatings to support he build process instead of forcing a fit (if needed they change the build process to fit available coating).

j. Every yard has a different strategy to reach the same goal based on facilities and local conditions.

k. Inspection team on the ground have a high degree of authority

l. ISO9000 is the only audit process.

96. These initial take-aways should offer some simple short term benefits and gains to US yards. The exact benefit or gain will vary from yard to yard depending on the suitability of its adoption by that yard.

97. The implementation of these can be left to each yard as they do not appear to need any co-ordinated development and are solutions that can be readily adopted as the solutions already exist or are in use.

12 POSSIBLE COST SAVING PROJECTS

12.1 Project Learning

98. It is clear that for complex ships the European cruise shipbuilders have most to offer the US yards, while the Japanese yards building Naval ships seem to perform overall to the same degree as US yards, lagging in some areas while leading in others.
99. Looking at the results and trying to decide what aspects should be focussed on in the short and medium term is not so straightforward and to a degree judgement must be applied. The short and medium term projects have been broken up on the basis of the time frames required to deliver benefits.
100. Whereas the short term projects may fit within a white paper programme (or a 2 year cycle) the medium term projects are more in the 3-5 year range but could offer significant long term benefits and cost savings.

12.2 Short Term

101. These are being considered as projects beyond anything that has arisen in the immediate takeaways that individual yards may pursue as required e.g. Perago wheel, rubber mats, outfit item protection and so on.
102. The aim here is to focus on projects that may offer suitable opportunities for collaborative projects (white paper or otherwise).
103. These would be:
    a. Flow charting of current yard activities
    b. Coating specifications/product selection
    c. Planning/Scheduling
    d. QA/QC systems
104. Taking each of these in turn:

12.2.1 Flow Chart Analysis

105. The aim of such a project is to go back to grass roots and understand how and why US Naval practices at new build for QA/QC differ from commercial practices and the rationale and justifications for deviations. The aim of the project is not simply to adopt commercial practices but to gain a better understanding of why what is done is done and re-evaluate it to make the current approach more robust and better understood.
106. In the commercial sector inspection times can account for up to 10-15% of total coating man-hours (they have probably increased with the introduction of the IMO PSPC, [data is based on Safinah analysis of Korean shipyards]).An analysis of inspection time for Naval vessels (including audit time of paperwork could provide useful insights into current practices and afford opportunities to make improvements.

12.2.2 Coating Specification and Product Selection

107. US yards need to consider moving to engineered paint specifications (Functional paint specifications), which would create a good fit between the proposed build strategy and the coatings to be used.
108. Experience on Naval vessels by Safinah has shown potential savings on initial budget estimates for new build work of about 20% of total coating costs.
109. It is proposed that some form of guidance is produced to assist US yards to develop function specifications and this should be backed up with suitable training of key personnel.

12.2.3 Planning and Scheduling

110. These ties in with the functional paint specification project. In effect it requires the development of a coating strategy that integrates with the overall build strategy and is thus better planned and scheduled to minimize re-work damage and optimize the timing of coating work.
111. The opportunity here is to work within key yards with a cross trade team to look at the integration of coating activities into the required build strategy to minimise planning and scheduling issues.

12.2.4 QA/QC Systems

112. There is work underway within NSRP SPC to streamline this and additional opportunities may arise as a result of the other two short term projects.
113. It is recommended that at this time the outcome of the current NSRP/SPC project on paperless QA be allowed to run its course and then a decision be made on what additional support or effort may be required.

12.2.5 Sequencing of Medium Term Projects

114. The following time line should be considered
    a. Completion of current QA/QC projects
    b. Development of a coating strategy
    c. Paint specification and product selection.

12.3 Medium Term

115. The key elements to consider here would be
    a. Ship design
    b. Facilities and production technologies
116. Taking each of these in turn:

12.3.1 Ship Design

117. Improved vessel design to make coating works easier clearly will involve the design teams, the production engineering teams and the CAD system users as well as the customer.
118. The opportunities here are to take considerable time and effort out the building process by simplifying structures to make them easier to preserve and this in turn will have knock-on effects once the vessel is in service as the benefits of improved first time application will be realised.
119. This work will require a number of key stages such as:
    a. Lessons learned from the fleet and previous new builds (i.e. where are the problem areas and how are they to be prioritised).
    b. Seek novel or better design solutions including
        i. Alternative materials
        ii. Alternative structural configurations
        iii. Better detail design
    c. Update CAD library to ensure that the improved systems are adopted as a first choice from libraries.
120. Research carried out by Safinah Ltd in partnership with ABS, Jotun and IHC yards in Holland, indicates that better design could reduce surface area of a tank by as much as 20%, reducing in turn edges and welds and hence associated labour and materials increasing productivity while reducing costs.
121. It is understood that naval vessels face different design constraints to commercial vessels and so a careful study would be needed to assess what benefits could be achieved in terms of:
    a. Improved access
    b. Reduced surface area
    c. Reduce coating time
    d. Reduced inspection time
    e. Etc.

12.3.2 Facilities and Production Technologies

122. Many of the immediate take-aways do cover production technology opportunities and a variety of projects could be set up to take advantage of these. These could be done on a yard by yard basis for some projects while others may need a more co-ordinated approach to maximize benefits and reduce overall time and cost of implementation. However projects could include:
    a. Use of the Konki-Jet
    b. Use of corrosion resistant steels
    c. Improved methods of coating protection
    d. Use of alternative technologies for

i. Surface preparation
ii. Coating application
iii. Coating systems
iv. Inspection regimes

e. Use of adhesives to reduce hot-work damage

123. These would offer opportunities to improve yard throughput and reduce costs.

13 OTHER POSSIBLE BENEFITS

13.1 Class NK

124. On unforeseen benefit of the visit to Japan was the meeting hosted by Class NK, which proved very worthwhile and introduced the team to:
    a. Classification society role and R&D in the coating areas
    b. Japanese paint suppliers
    c. Japanese paint contractors
    d. Japanese equipment manufacturers
    e. Japanese steel makers
125. Class NK also declared a strong interest to support suitable collaborative research with funding as appropriate and are keen to present their intent to the wider US Shipbuilding community.
126. It would be opportune to invite the yards visited to attend/present at SPC panel meetings on some regular basis to sustain the contact and exchange of information.

13.2 Commercial Yard Exchange

127. The contact with key personnel in some of the most efficient commercial shipyards. The fact that some of them also are involved in naval shipbuilding has already opened opportunities to continue this exchange to share the ideas and thoughts for new tools/techniques and experiences with different products. The challenge here is to ensure a continued dialogue with the yards and personnel that have been met and to possibly seek collaborative projects.
128. These initiatives may save time and money by taking advantage of research work already done elsewhere and enabling faster adoption of new ideas by US yards for a reduced investment in time and money.

14 SUMMARY AND CONCLUSIONS

14.1 The Overall Experience

129. Overall the general view of all who took part has been that the experience has been very positive on a number of levels:
   a. Increased awareness and sharing of experiences between US shipyards themselves.
   b. Increased awareness and sharing of experience with commercial shipyards
   c. Increased awareness and sharing of experience with other naval new build yards.
130. Insight has been gained into shared problems and challenges and how these have been addressed in different parts of the world and the different approaches to resolving them.

14.2 Opportunities for Cost Savings

131. The opportunities to reduce costs at US yards fall into 4 categories:
   a. The immediate take-away projects each US yard may adopt from those identified in section 11 of this report
   b. The opportunities to develop a number of short term projects that could move US yards toward the better performing yards that were benchmarked as identified in section 12 of this report
   c. The opportunity to develop a number of medium term projects that would allow US yards to focus on those areas where they lag behind some of the yards visited as identified in section 12 of this report.
132. The exact cost savings that can be made would need to be evaluated to enable the projects to be properly prioritised to ensure that the projects that offer the largest benefits are handled first. This would require NSRP to make a suitable assessment of the benefits of each project and prioritised.
133. For the medium term projects it would be appropriate for some ground work to be undertaken to determine which have the best chance of success and what options may exist for funding them and if there are opportunities to collaborate with any of the yards visited.