Foreign Shipyard Visits

Final Report

Singapore and South Korea – April, 2011

Italy and Spain – May, 2011

July 2011

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FOREWORD

At the direction of the NSRP Executive Control Board, two teams of shipyard and Navy representatives were formed for the purpose of gaining insight to efficiencies associated with products and practices of shipyards in Asia and Europe. Through discussions with key foreign shipyard managers and tours of their shipyards, the U.S. teams were tasked to observe and record processes, practices and technologies employed in shipbuilding. To improve foreign shipyard access opportunity and visibility of the shipyard practices, shipyards with relationships with NSRP shipyards were targeted with special emphasis on shipyards building/repairing naval vessels. In order to maximize the benefit of the time available within the shipyards, four main focus areas were targeted. In advance of the visits the four areas were provided to the shipyards along with related questions to help guide the discussions and maximize the benefit of the visits. These focus areas and sub-areas were developed from the 2005 benchmarking of the U.S. first-tier and mid-tier shipyards and were the areas that provided the greatest opportunity for improvement in U.S. shipbuilding efficiency. The focus areas targeted included:

- Ship Design and Design for Production
- Production Engineering and Planning
- Purchasing and Material Management
- Organization and Structure

The focus areas and their sub-areas are included in Appendix 7.4. The questions provided to the shipyards are also included in this appendix.

The teams for both the Asian and European shipyard visits were made up of members with expertise in the four focus areas from both mid- and first-tier shipyards, and Navy personnel with responsibility in ship acquisition and R&D management. A listing of the team members for both the Asian and European shipyard visits is included in the Acknowledgements.

The Asian shipyard visits took place during the week of April 18, 2011, and included Sembcorp (Jurong Shipyard) and ST Marine (Tuas and Benoi shipyards) in Singapore, and DSME (Okpo Shipyard) in Busan, South Korea. The European shipyard visits took place during the week of May 9, 2011, and included Fincantieri (Muggiano and Riva Trigoso Shipyards) in Italy, and Navantia Fene-Ferrol (Ferrol Shipyard) in Spain.

In the view of team members, the shipyards visited went out of their way to provide the right level of senior management and support managers to address the focus areas and questions provided by the NSRP team in advance of the visits, as well as questions asked at the time of the visits. The tour of ST Marine Benoi shipyard was reduced to a bus tour because of inclement weather; however, the tours of DSME, the two Fincantieri shipyards and Navantia Fene-Ferrol were in-depth and very informative.

ACKNOWLEDGEMENTS

The following U.S. shipbuilding industry and Navy individuals participated in the Asian and European shipyard visits. The industry participants were assigned to focus areas corresponding to their responsibilities within their shipyard. The Navy team members also participated within the four focus areas.

ASIAN SHIPYARD TEAM

Production Engineering/Planning

John Sedor	Director of Planning	General Dynamics Electric Boat
Carl Perry	Director, Administration, Labor Resources and Planning	Huntington Ingalls Industries

Ship Design/Design for Production

Chris Waaler	Director of Engineering	General Dynamics Bath Iron Works
Lee Duneclift	Manager, Production Engineering	General Dynamics NASSCO
Jeff O'Day	New Construction Ship Manager	Todd Pacific Shipyards

Organization & Structure

Bryan Ruiz	New Construction Program	General Dynamics NASSCO
Pat Burlison	Director of Operations	Ingalls Shipbuilding

Purchasing & Material Management

Eric Meulemans	Director of Purchasing	Marinette Marine Corporation
Alma Martinez Fallon	Director, Supply Chain Procurement	Newport News Shipbuilding
Russell Clark	Logistics Manager	Austal USA

Navy Team members

Gary Humes	Director, Strategic Operations	PEO Ships
Philip Koenig	Director, Industrial and Economic Analysis Division	Naval Sea Systems Command
Timothy Roberts	Principal APM T-AKE & T-AO(X)	PEO Ships
Nidak Sumrean	Director, Cost Estimating & Industrial Analyses Division	Naval Sea Systems Command

EUROPEAN SHIPYARD TEAM

Production Engineering/Planning

Scott Theriot	Vice President/General Manager Lockport New Construction	Bollinger Shipyards
Mike Butler	Director, Navy Program Operations	Newport News Shipbuilding
John Sedor	Director of Planning	General Dynamics Electric Boat

Ship Design/Design for Production

Wallace Goodloe	Director, Detail Design	Ingalls Shipbuilding
Josh Horst	Project Engineer	Todd Pacific Shipyards

Organization & Structure

Bob Watkins	Engineering Hull Manager	Marinette Marine Corporation
Zach McWaters	Deputy Program Manager	General Dynamics NASSCO

Purchasing & Material Management

Scott Mullen	Supervisor Procurement	General Dynamics Bath Iron Works
Lori Okrasinski	Purchasing Manager	Marinette Marine Corporation

Navy Team members

Connie Bowling	Program Manager	NAVSEA NSRP Program Office
Art Divens	Executive Director	PEO Ships
Gary Humes	Director, Strategic Operations	PEO Ships

The following representatives were also involved as team members, coordinators and contributors to the report:

ASIA AND EUROPE TEAM LEADS

Ron Glover	Vice President	NSRP/ATI
Bob Schaffran	Principal	NSRP/Schaffran, Inc.

ASIA AND EUROPE LOGISTICS

Frances Pearce	Administrator, Maritime Division	NSRP/ATI

Many individuals from the shipyards visited participated in NSRP Team briefings and tours. The following Asian and European shipyard representatives were the lead participants in the visits.

ASIAN SHIPYARDS

Mr. Sing Chan Ng	President	ST Marine
Mr. Wee Keng Hwee	Senior Vice President – Corporate Development	Sembcorp Marine, Ltd.
Mr. In-Sang Yoo	Senior Executive Vice President/Chief Technology Officer	DSEC
Mr. Du-Seon Park	Director of Production	Daewoo Shipbuilding & Marine Engineering Co., Ltd.

EUROPEAN SHIPYARDS

Mr. Roberto Olivari	Muggiano Shipyard Planning and Repair Director	Fincantieri – Cantieri Navali
Mr. Ferdinando Tognini	Riva Trigoso Shipyard Director	Fincantieri – Cantieri Navali
Mr. Esteban Garcia Vilasanchez	Managing Director	Navantia Fene-Ferrol Shipyard

EXECUTIVE SUMMARY

At the direction of the NSRP Executive Control Board, two teams of shipyard and Navy representatives were formed for the purpose of visiting shipyards in Asia and Europe to gain insight into efficiencies associated with products and practices that may help U.S. yards. Through discussions with key foreign shipyard managers and tours of their shipyards, the U.S. teams were tasked to observe and record processes, practices and technologies employed in shipbuilding.

In advance of the visits four focus areas were provided to the shipyards along with related questions to help guide the discussions and maximize the benefit of the visits. These focus areas along with sub-areas were developed from the 2005 benchmarking of the U.S. first-tier and mid-tier shipyards and were the areas that provided the greatest opportunity for improvement in U.S. shipbuilding efficiency. The focus areas targeted included:

- Ship Design and Design for Production
- Production Engineering and Planning
- Purchasing and Material Management
- Organization and Structure

The Asian shipyard visits took place during the week of April 18, 2011, and included Sembcorp (Jurong Shipyard) and ST Marine (Tuas and Benoi shipyards) in Singapore, and DSME (Okpo Shipyard) in Busan, South Korea. The European shipyard visits took place during the week of May 9, 2011, and included Fincantieri (Muggiano and Riva Trigoso Shipyards) in Italy, and Navantia Fene-Ferrol (Ferrol Shipyard) in Spain.

In the view of team members, the shipyards visited went out of their way to provide the right level of senior management and support managers to address the focus areas and questions provided by the NSRP team in advance of the visits as well as questions asked at the time of the visits. The tour of ST Marine Benoi shipyard was reduced to a bus tour because of inclement weather; however, the tours of DSME, the two Fincantieri shipyards and Navantia Fene-Ferrol shipyard were in-depth and very informative.

The following are the general observations from all the shipyards visited:

- The Fincantieri Riva Trigoso and Navantia Fene-Ferrol shipyards both have significant machinery manufacturing facilities within their shipyards. These facilities provide shipboard as well as other industry products. Some examples include: diesel engines, reduction gears, shafting, turbine generators, thrusters, fin stabilizers and wind mill blades.
- Personnel safety was very strongly stressed and enforced in the Asian shipyards to the point where annual bonuses would be lost for a significant safety violation even though other factors were also considered in determining the bonus. The European shipyards did not appear to stress or enforce strict safety standards (e.g., hard hats in shops and in the shipyard).

- All the Asian and European shipyards visited maintain a small core workforce and use substantial percentages of contracted labor, in some cases up to 60 - 70% contracted labor.
- All of the surface warships observed being built used bulb flats for stiffeners that met the government/international build specifications directed and some also used corrugated bulkheads
- The Navantia Fene-Ferrol shipyard visited is owned by the Spanish Government as are all of Navantia shipyards. Of interest the Ferrol shipyard was started in 1726 and delivered its first ship in 1740.
- The European shipyards visited have several multi-trade labor unions all affiliated with political parties. This provides for more flexibility in the use of the workforce.
- The market downturn has impacted many of the shipyards visited, but more so in Europe to the point where reorganization was mentioned as a possibility by one shipyard.
- The two Fincantieri shipyards visited work together to build ships greater than 100 meters. The Riva Trigoso shipyard builds the ship with all blocks from its shipyard or with some blocks provided by Muggiano shipyard. The ship is then transported via barge to the floating dry dock at the Muggiano shipyard where the ship is launched and final outfitting and testing completed.
- DSME shipyard workers start each day by cleaning the shipyard and conducting stretching exercises. It was obvious from the appearance of the shipyard that the cleaning was effective.
- Navantia Fene-Ferrol shipyard effectively used natural light through skylights in its shops to brighten the work environment. This was very noticeable.
- Navantia Ferrol shipyard pipe shop uses a Bose noise cancellation system to reduce the noise level in the shop.
- Rotating flanges (Van Stone flanges) were used to ease alignment and connection of pipes on blocks and on board.
- The Fincantieri shipyards visited seem to be moving to modular weapons and sensor installation more so than the U.S.
- All steel is bought pre-blasted and primed. There is typically only 3-4 months supply of steel in the shipyard. The 3-4 month buffer seems to be tied to the life of the primer.

The following are the key observations relating to the four focus areas:

Asian Shipyards

1) **Ship Design and Design for Production:**
    a. The extensive use of standard components and interim products used across platforms.
    b. A part numbering system that reflects a standard build strategy for all ship types. Most U.S. shipyards already have an established numbering system which would be hard to change.
    c. Detailed design phase (our contract design phase) is completed prior to start of construction. This locks in all technical requirements before work begins.
    d. The ratio of Engineers to Production workers varies by ship type. It is very low for Very Large Crude Carriers (VLCCs) and very high for Floating Production Storage and Offloading Ships (FPSOs). Further investigation is warranted on the different ratios by ship type and the rationale behind the ratios.

2) **Production Engineering and Planning**
    a. The importance of driving down the size of work packages and sizing them according to time to perform rather than number of man-hours
    b. The importance of continuous measurement of assemblies, analysis of the data and feedback to design and/or production planning to continually improve designs and procedures to minimize distortion
    c. The establishment of multi-disciplinary teams to develop detailed assembly and outfitting procedures.

3) **Organization and Structure**
    a. The commitment to quality fostered throughout the yard resulting in a much smaller Q/A department while still achieving required quality.

4) **Purchasing and Material Management**
    a. The formation of a separate division for planning, procuring and managing all major equipment to provide better support for production.

European Shipyards

1) **Ship Design and Design for Production:**
    a. Fincantieri's use of Tecnomatics software for over-all planning of the build strategy and for shipyard resource planning.
    b. Navantia Fene-Ferrol's use of FORAN v70 which is a totally integrated design system linked to Windchill PLM system.
    c. Navantia Fene-Ferrol's many standards that are used across ship designs. These include standard structural details, outfit steel standards, standard pipe hangers, wireways, HVAC hangers and numerous standard components like communication panels and sprinkler actuation panels and where possible standard outfit modules and accommodation modules.
    d. Using the best people on the functional design team and making sure that the functional design is as complete as possible prior to starting production design.
    e. Ensuring that ship designs are producible because all designs are based on a build strategy that is developed prior to beginning of design.

2) **Production Engineering and Planning**
    a. Fincantieri's standard, best practice procedures for minimizing distortion in typical structural assemblies. The procedures provide the recommended weld procedures and the best weld sequences.
    b. Fincantieri's and Navantia Fene-Ferrol's company standards which document acceptable tolerance levels for all phases of steel fabrication and assembly.
    c. Navantia Fene-Ferrol's book of standard tolerances for all steelwork including deformation standards

d. Navantia Fene-Ferrol's robust, block-centric planning strategy.
e. The significant role that Production Planning and Production Engineering play in defining production requirements to engineering for production drawings.

3) Organization and Structure

a. Navantia Fene-Ferrol's subcontracting of their engineering by design zone, (e.g. engine room, bow, stern, superstructure, etc).
b. The role of Production Planning and Production Engineering at Navantia Fene-Ferrol and how they work together and with engineering.
c. Navantia Fene-Ferrol's Module Shop organization into three product areas; multi system pipe racks, multi system equipment modules and accommodation modules.

4) Purchasing and Material Management

a. A Central Procurement Department in Trieste, Italy that is responsible for ordering all common material and equipment, such as steel, pipe, valves, cable, etc. for all the Fincantieri shipyards.
b. Fincantieri's supplier evaluation process.
c. Navantia Fene-Ferrol's scheduling for receipt of VFI in stages, as needed, to support the detailed design and construction process. VFI schedule stages include: Foundations and mechanical information, electrical information, automation and control information, factory acceptance testing (FAT), logistics.
d. Initial procurement of material and components based on estimates during the functional design phase. As detail design progresses and material and equipment by zone are developed the procurement schedule and material requirements are refined and submitted to procurement.

Recommendations

It was recognized by the various team members on both the Asian and European NSRP teams that not all observations captured by the teams would necessarily provide improvement opportunities for every U.S. shipyard. However, some opportunities did present themselves for individual shipyard improvement while others seem appropriate for broader application across the U.S. Naval shipbuilding and repair industry. The following, for consideration, is a listing of recommendations, broken down by: Potential Opportunities for Near-Term Adoption, NSRP Investment Opportunities and Areas for Further Investigation.

Potential Opportunities for Near-term Adoption

- Use of shipside material and personnel elevators-- (Riva Trigoso)
- Non-painted cables for Navy ships (Navantia)
- Shrink-wrapped stainless steel pipe (Navantia)
- Numbered and color-coded cable ways for cable installation (Navantia)
- Peel-off paint protection used on Mega-yacht (Muggiano)
- Holding unit for neat storage of used weld wire reels (Navantia)

- Covered, painted, and organized 5S shadow boards for select working locations (Navantia)
- Use of black zip ties on temporary services to decrease cycle time for installation and cleanliness (Muggiano)
- Metal vs. Wood Scaffolding applications (All)
- Detail design drawings for structure and outfitting are scheduled to support block erection sequence. Total system arrangement plans do not have to be completed first; rather they are completed block by block.
- High level of influence that production planning and production engineering have over engineering.
- Development of build strategy prior to design. Build strategy drives design and procurement schedule.

NSRP Investment Opportunities

- Use of bulb-flats in lieu of built-up T's for U.S. Navy ships -- (all 3 yards)
- Compare U.S. Military Standards (ABS Navy Vessel Rules) to Lloyds military standards, / RINA (Italian Navy standards, DNV military standards, ROK (Korean) etc.) to identify opportunities for reducing some of the current U.S. Navy specifications to the more commercial-like requirements now used by foreign Navies.
- Use of slip flanges on U.S. Navy ships – (all 3 yards)
- Use of corrugated bulkheads on Naval Ships? (Navantia?)
- Tank coating system? They do not use high solids (Navantia)
- Modular weapons systems

Areas for Further Investigation

- ROI for covered facilities?
- Use of "labor standards" for creating Work package budgets?
- Meeting/Reviews/Collaboration structure (Duration limits? Ad-hoc? Re-occurring or standard meetings, both internally and w/ the customer?)
- Use of standardized weld procedures including weld sequences for reducing weld distortion on all typical structural sub-assemblies and assemblies (all 3 yards)
- Comparison of Navantia's company dimensional tolerance standards, including deformation standards vs. customer required standards.

APPROACH AND FOCUS AREAS

The Navy and the U.S. shipbuilding industry through NSRP have invested in numerous R&D projects focused on improving U.S. shipbuilding affordability. A majority of these projects have focused on the areas identified during the 2005 U.S. shipbuilding benchmarking effort as areas for improvement. During the 2005 benchmarking, which included both the U.S. first- and mid-tier shipyards and foreign shipyards, it was reported that, in many areas benchmarked, the U.S. shipyards lagged the foreign shipyards in efficiency. Because of the time elapsed since the benchmarking took place and realizing both the U.S. and foreign shipyards have pursued improvements, the NSRP Executive Control Board (ECB) established a team of U.S. shipyard managers to conduct foreign shipyard visits to observe their processes and practices. The purpose was to identify those processes and practices that, if adopted by U.S. shipyards, would foster naval shipbuilding efficiency and subsequent affordability gains for the Navy. To maximize the benefit of the visits to both the customer and client, personnel from NAVSEA and its affiliated shipbuilding Program Executive Offices participated as members of the visit teams.

To facilitate access to the foreign shipyards, those shipyards with ties to NSRP member shipyards through ownership or previous working arrangements were selected. Additionally, it was desired to focus most of the visits on shipyards building naval vessels. The following shipyards were therefore chosen for the visits: ST Marine and Jurong Shipyards in Singapore, DSME in South Korea, Fincantieri shipyards in Italy and the Navantia Fene-Ferrol shipyard in Spain. In addition to naval surface ship and submarine construction, this selection of shipyards also provided process and practice review of naval ship repair, commercial shipbuilding and conversion, and oil rig and mega yacht construction.

To maximize the benefit of the foreign shipyard visits, the shipyard team members were recommended by Executive Control Board members and selected based on providing the expertise in the four focus areas, and ensuring representation from both first- and mid-tier shipyards. Navy officials designated representatives from NAVSEA and its affiliated Program Executive Offices. Two teams were established, one for Asian and one for European shipyard visits. Two individuals, one from a shipyard and one from PEO Ships, participated in both teams. The team members and their organizational information are listed in the Acknowledgements.

Because the visit duration to each shipyard was limited to one day or a part of a day, advance preparation by the shipyards being visited was desired. To facilitate obtaining the most out of the visits, a draft agenda, a list of focus areas and sub-areas, and questions related to each focus area were provided well in advance of the visits. The draft agenda provided for overview presentations by the NSRP team and the shipyard being visited, a walking tour of the shipyard including the shops and break out discussions between the team members and the shipyard managers in the four focus areas. The shipyards visited adjusted the agenda to suit their desires and time allocation for the visits. Most of the shipyards visited did provide shipyard-specific responses to the questions.

The four focus areas were developed after reviewing the 2005 U.S. shipyard benchmarking report which provided a listing of the top ten recommended areas for improvement. The ten areas were further developed into four major focus areas with additional sub-areas. The advance questions provided to the foreign shipyards incorporated input from the ECB, and served to steer the discussions toward key aspects within each focus area. A listing of the focus areas and the associated questions is provided in Appendix 7.4.

KEY OBSERVATIONS

The general observations for all the shipyards visited as well as the key observations in each of the four focus areas for the shipyards are provided in this section. Appendices 7.1 and 7.2 provide a more detailed listing of the teams' observations for the Asian and European shipyards respectively.

General Observations Not Directly Related to Focus Areas:

- The Fincantieri Riva Trigoso and Navantia Fene-Ferrol shipyards both have significant machinery manufacturing facilities within their shipyards. These facilities provide shipboard as well as other industry products. Some examples include: diesel engines, reduction gears, shafting, turbine generators, thrusters, fin stabilizers and wind mill blades.
- Personnel safety was very strongly stressed and enforced in the Asian shipyards to the point where annual bonuses would be lost for a significant safety violation even though other factors were also considered in determining the bonus. The European shipyards did not appear to stress or enforce strict safety standards (e.g., hard hats in shops and in the shipyard).
- All the Asian and European shipyards visited maintain a small core workforce and use substantial percentages of contracted labor, in some cases up to 60 - 70% contracted labor.
- All of the surface warships observed being built used bulb flats for stiffeners that met the government/international build specifications directed and some also used corrugated bulkheads
- The Navantia Fene-Ferrol shipyard visited is owned by the Spanish Government as are all of Navantia shipyards. Of interest the Ferrol shipyard was started in 1726 and delivered its first ship in 1740.
- The European shipyards visited have several multi-trade labor unions all affiliated with political parties. This provides for more flexibility in the use of the workforce.
- The market downturn has impacted many of the shipyards visited, but more so in Europe to the point where reorganization was mentioned as a possibility by one shipyard.
- The two Fincantieri shipyards visited work together to build ships greater than 100 meters. The Riva Trigoso shipyard builds the ship with all blocks from its shipyard or with some blocks provided by Muggiano shipyard. The ship is then transported via barge to the floating dry dock at the Muggiano shipyard where the ship is launched and final outfitting and testing completed.
- DSME shipyard workers start each day by cleaning the shipyard and conducting stretching exercises. It was obvious from the appearance of the shipyard that the cleaning was effective.
- Navantia Fene-Ferrol shipyard effectively used natural light through skylights in its shops to brighten the work environment. This was very noticeable.
- Navantia Ferrol shipyard pipe shop uses a Bose noise cancellation system to reduce the noise level in the shop.
- Rotating flanges (Van Stone flanges) were used to ease alignment and connection of pipes on blocks and on board.
- The Fincantieri shipyards visited seem to be moving to modular weapons and sensor installation more so than the U.S.
- All steel bought in European yards visited was pre-blasted and primed. There is typically only 3-4 months' supply of steel in the shipyard. The 3-4 month buffer seems to be tied to the life of the primer.

Key Observations Relating to Focus Areas:

Asian Shipyards

1) **Ship Design and Design for Production:**
   a. The extensive use of standard components and interim products that are used across platforms. It would be good to get a clear understanding of the standards that DSME uses across ship types.
   b. A part numbering system that reflects a standard build strategy for all ship types. Most U.S. shipyards already have an established numbering system which would be hard to change. But is everybody using an intelligent numbering system for easy tracking and monitoring of all parts across different ship types and hulls within the ship type? Does this need further investigation?
   c. Detailed design phase (our contract design phase) is completed prior to start of construction. This locks in all technical requirements before work begins.
   d. The ratio of Engineers to Production workers. The ratio varies by ship type. It is very low for VLCCs and very high for FPSOs. Further investigation is warranted on the different ratios by ship type and the rationale behind the ratios.

2) **Production Engineering and Planning**
   a. The importance of driving the size of work packages down and to size them according to time to perform rather than number of man-hours.
   b. The importance of continuous measurement of assemblies, analysis of the data and feedback to design and/or production planning to continually improve designs and procedures to minimize distortion.
   c. The establishment of multi- disciplinary teams to develop detailed assembly and outfitting procedures.

3) **Organization and Structure**
   a. The commitment to quality fostered throughout the yard resulting in a much smaller Q/A department while still achieving required quality.

4) **Purchasing and Material Management**
   a. The formation of a separate division for planning, procuring and managing all major equipment to provide better support for production.

European Shipyards

1) **Ship Design and Design for Production:**
   a. Fincantieri's use of Tecnomatics software for over-all planning of the build strategy and for shipyard resource planning.
   b. Navantia Fene-Ferrol's use of FORAN v70 which is a totally integrated design system which is linked to Windchill PLM system.

c. Navantia Fene-Ferrol's many standards that are used across ship designs. These include standard structural details, outfit steel standards, standard pipe hangers, wireways, HVAC hangers and numerous standard components like communication panels and sprinkler actuation panels and where possible standard outfit modules and accommodation modules.
d. Using the best people on the functional design team and making sure that the functional design is as complete as possible prior to starting production design.
e. Ensuring that ship designs are producible because all designs are based on a build strategy that is developed prior to beginning of design.

2) Production Engineering and Planning

a. Fincantieri's standard, best practice procedures, for minimizing distortion in typical structural assemblies. The procedures provide the recommended weld procedures and the best weld sequences.
b. Fincantieri's and Navantia Fene-Ferrol's company standards which document acceptable tolerance levels for all phases of steel fabrication and assembly.
c. Navantia Fene-Ferrol's book of standard tolerances for all steelwork including deformation standards.
d. Navantia Fene-Ferrol's robust, block-centric planning strategy.
e. The significant role that Production Planning and Production Engineering play in defining production requirements to engineering for production drawings.

3) Organization and Structure

a. Navantia Fene-Ferrol's subcontracting of their engineering by design zone, (e.g. engine room, bow, stern, superstructure, etc).
b. The role of Production Planning and Production Engineering at Navantia Fene-Ferrol and how they work together and with engineering.
c. Navantia Fene-Ferrol's Module Shop organization into three product areas; multi system pipe racks, multi system equipment modules and accommodation modules.

4) Purchasing and Material Management

a. A Central Procurement Department in Trieste, Italy that is responsible for ordering all common material and equipment, such as steel, pipe, valves, cable, etc. for all the Fincantieri shipyards.
b. Fincantieri has a robust supplier evaluation process.
c. Navantia Fene-Ferrol's scheduling for receipt of VFI in stages, as needed, to support the detailed design and construction process. VFI schedule stages include: Foundations and mechanical information, electrical information, automation and control information, Factory Acceptance Testing (FAT), logistics.
d. Initial procurement of material and components based on estimates during the functional design phase. As detail design progresses and material and equipment by zone are developed, the procurement schedule and material requirements are refined and submitted to procurement.

PROPOSED ACTIONS / RECOMMENDATIONS

Potential Opportunities for Near-Term Adoption

- Use of shipside material and personnel elevators-- (Riva Trigoso)
- Minimizing the use of scaffolding (DSME)
- Non painted cables for Navy ships (Navantia)
- Shrink wrapped stainless steel pipe (Navantia)
- Numbered and color coded cable ways for cable installation (Navantia)
- Peel-off paint protection used on Mega-yacht (Muggiano)
- Holding unit for neat storage of used weld wire reels (Navantia)
- Covered, painted, and organized 5S shadow boards for select working locations (Navantia)
- Use of black zip ties on temporary services to decrease cycle time for installation and cleanliness (Muggiano)
- Metal vs. Wood Scaffolding applications (All)
- Detail design drawings for structure and outfitting are scheduled to support block erection sequence. Total system arrangement plans do not have to be completed first; rather they are completed block by block.
- High level of influence that Production Planning and Production Engineering have over engineering.
- Development of build strategy prior to design. Build strategy drives design and procurement schedule.

NSRP Investment Opportunities

- Use of bulb-flats in lieu of built-up T's for U.S. Navy ships
- Compare U.S. Mil Standards (ABS Navy Vessel Rules) to Lloyds military standards, / RINA (Italian Navy standards), DNV Military Standards, ROK (Korean) etc. to identify opportunities for reducing some of the Navy specs to more commercial-like requirements used by foreign Navies.
- Use of slip flanges on U.S. Navy ships
- Use of corrugated bulkheads on Naval Ships (Navantia)
- Tank coating system? They do not use high solids (Navantia)
- Modular weapons systems (Fincantieri)

Areas for Further Investigation

- ROI for covered facilities?
- Use of "labor standards" for creating Work package budgets?
- Use of standardized weld procedures including weld sequences for reducing weld distortion on all typical structural sub-assemblies and assemblies (all 3 yards)
- Comparison of Navantia's company dimensional tolerance standards, including deformation standards vs. customer required standards.

APPENDICES

7.1 Report of Team Observations – Asian Shipyard Visit

The following pages contain the team observations from the visits to ST Marine in Singapore and DSME in Korea. (Jurong Shipyard in Singapore was also visited but the visit was so short that nothing unique was observed) The team observations are broken down into the four major focus areas, 1) Ship Design and Design for Production, 2) Production Engineering and Planning, 3) Organization and Structure and 4) Purchasing and Materials Management.

Ship Design and Design for Production

ST Marine Ship

- ST Marine currently uses Tribon as their CAD tool, Microsoft project as their scheduling tool and MARS as their material management and resource planning tool. It is unclear how well these tools are integrated but the impression of the team is that there is minimal integration of the tools.

- It appears that they have a very competent design department. In the past ST Marine developed 4-6 designs per year based on their marketing studies. However, for the past 4-5 years they have concentrated solely on military work because they do not think that they can compete in commercial markets anymore. They have developed a Patrol Vessel that is configurable for multiple roles (e.g. ASW, patrol, Special Ops, etc). They have also applied a bulbous bow to patrol vessels with a resultant 30% reduction in fuel consumption at cruising speed. They are now concentrating on building proven, foreign designs.

- ST Marine recently completed a 5 ship production run of a French design for the Singapore Navy. The first ship in the series was built in France with several ST Marine representatives participating and observing the processes. The design was then modified to suit the ST Marine facilities and apparently the ships were completed within schedule and cost targets.

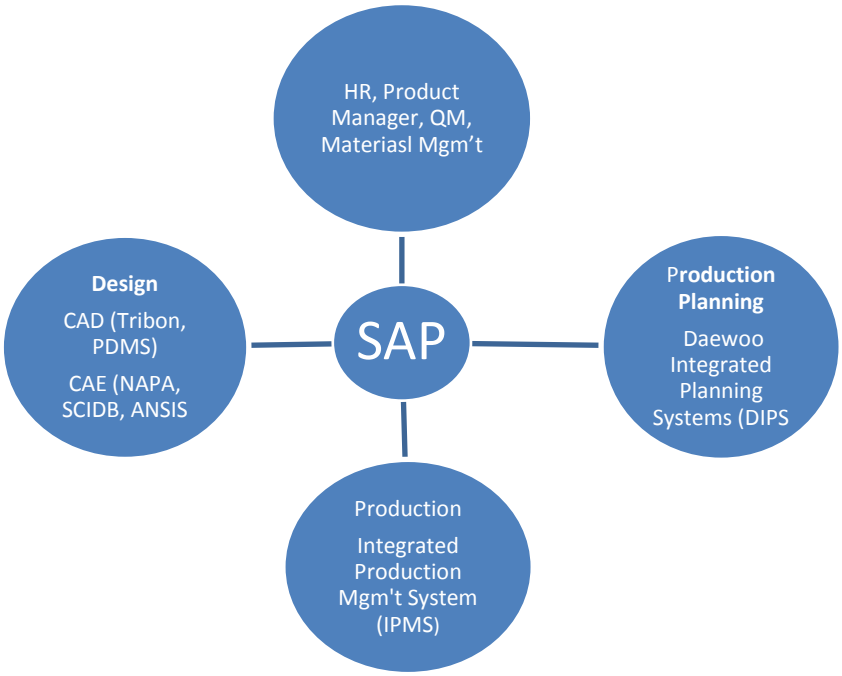
- Standard components are used when possible. They are now standardizing on cable and pipe fittings across ship types as well as standard steel outfit components. Use of standard water tight doors was mentioned. It does not appear that they use standard structural assemblies, outfit modules, arrangement plans, etc. however they did mention that they have variants of the same design so possibly for the variants they do use standard arrangements, etc. They indicated that they are using German Military standards for military combatants.

- The team was unable to get information about their steel and outfit coding systems.

- ST Marine indicated that they had 4 criteria they had to meet prior to start of production: 1) arrangements complete, 2) equipment identified, 3) steel work identified and 4) cable ways identified. They reported a time of 6-9 months for commercial design and 9-12 months for Naval ship design but the team could not pin down what this included.

DSME

- DSME installed SAP in 2002 as their integrated Resource Planning tool. All departments, including design, production, production planning, material management and finance are totally integrated through SAP and all departments have access to the SAP data. See diagram below: They use Tribon as their CAD tool for commercial and specialty ships and PDMS as their CAD tool for all offshore work. The DSME Integrated Production Planning System (DIPS), which apparently is a very detailed planning system, was developed in-house by DSME.



- DSME uses a unique steel and outfit coding system. It consists of 16 numbers which clearly identifies each part by Ship Type, Hull Number, Item, and the zone, area and stage of construction that the item is installed. The number system is used on all ship types and reflects a common build strategy for all ships. Below is an example of the coding system:

    - 16 Number Part Code: (1, 2, 3, 4) - (5) - (6) - (7, 8) - (9, 10, 11) - (12, 13) - (14, 15, 16)
    - 1, 2, 3, 4- The first number identifies the ship type (1 = bulk carrier, 4 = container ship, 5 = tanker, etc) and the next three numbers are the hull number
    - 5 – Identifies who supplied the material (owner, yard or maker)
    - 6 – The Item number (structure, steel outfit, accommodation outfit, piping, etc)
    - 7, 8 – The serial number
    - 9, 10, 11 – Work stage when it will be installed (Shop, dock, wet slip)
    - 12, 13, 14 – Block number

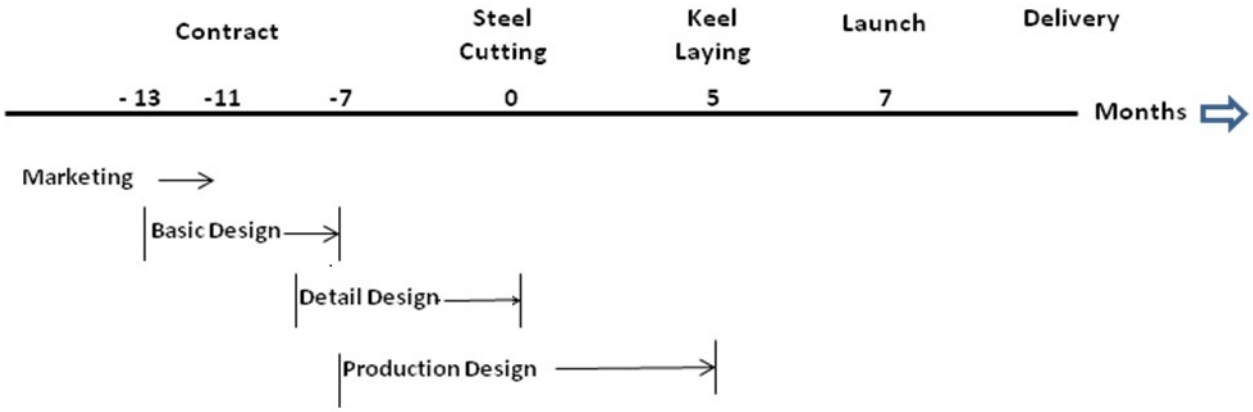
- 15, 16 - Ship Zone (area within the block)

- DSME has a range of ship designs that it offers its customers. They also design and build ships to any classification rules that a customer requests. All the major classification organizations have representatives in the yard.

- Wherever possible, DSME uses standard components as well as standard steel sub-assemblies and assemblies across designs. They have books of DSME Standard Engineering (DSE) design standards. They showed the team their DSE book for piping which was very comprehensive. Apparently they have DSE's for most components. All standards are pre-approved by class societies. DSME has also developed standard arrangement plans; however, they let the customer modify the arrangement to meet their specific needs.

- DSME has 3 distinct design phases, Basic Design (developing initial design to meet the customer's requirements, Detailed Design (locking in all technical requirements and developing detailed specifications) and Production Design (developing the working drawings). It appears that these correlate to U.S. shipyards' Preliminary Design, Contract Design and Detailed Design.

  About 13 months before start of construction, DSME holds a meeting with the prospective buyer to fully understand the owner's requirements after which they begin their Basic Design (U.S. yards would probably call this their Preliminary Design phase). At 11 months prior to start of construction they sign the contract. At 9 months prior to start of construction, DSME begins development of their Detail Design (U.S. yards would probably call this their contract design phase.) At approximately 7 months prior to start of construction they begin their Production Design phase (U.S. yards would probably call this their detailed design phase) and it goes on for about 12 months until keel laying at which time the production design should be complete.



(Notes: Production design is released on a block by block basis and delivery is longer for specialty ships)

All steel foundations are identified 4 months prior to start of construction and all steel outfit items are identified about 1 month prior to start of construction. Keel laying is typically scheduled for 5 months after start of construction.

The lessons learned from DSME are: 1) the extensive use of standard components and interim products that are used across platforms, 2) A numbering system that reflects a standard build strategy, and 3) Their detailed design phase (our contract design phase) is completed prior to start of construction. This locks in all technical requirements before work begins.

Production Engineering and Planning

ST Marine

- The team did not receive detailed answers for our questions in this area, but we did come away with some general impressions about ST Marine's capabilities. The yard recently completed a 5-ship Combatant program using a French Design. The first ship was built in France with members of ST Marine observing, so it appears that much of the production planning came from the French which ST Marine then modified for their facility.

- ST Marine has a Production Planning Department that is under the Production Department. The group has lots of experience. They use production planning tools typically associated with small, low volume yards. Production does have limited access to the CAD model in the field with computer workstations located in several areas around the yard. It is probably because of the experience of the production planners at ST Marine that they perform well with the lower levels of technology used.

- Visualization tools are not used to create easy to understand work packages. We were unable to see exactly what is provided to the shop but we suspect that the work packages are typical, old school, 2D drawings and work instructions. There is no standard for the size of a work package. They vary in size based on the situation and stage of construction but typically the maximum size does not exceed 500manhours.

- There is a build strategy developed that does a typical block break down and erection sequence but it is not clear how they schedule and sequence the steel work through the shops. The steel work erection plan does include an "Embarkation Plan" for "blue sky" loading of major machinery and equipment.

- They do try to do as much pre-outfitting as possible but the sequencing and planning process was not described. They are assembling single system outfit modules however they do not pre-test these modules prior to installation. It was not clear if the "Embarkation Plan" also included loading of the outfit modules at different stages of the steel assembly process.

- We questioned how they control distortion and they simply stated that it is an issue that continually needs to be addressed. ST Marine prefers to use decks of one thickness to minimize the problem but stated that customers are starting to demand lighter weight structures. This requires the use of different thickness deck inserts which exacerbates the distortion problem.

- It was not clear how dimensional accuracy is controlled but it was stated that they do use lasers to check dimensions of the steel assemblies.

- Painting is done after pipe installation is complete. All pipe joints are taped so that they can be inspected during the subsequent testing phase. Because of the high heat and humidity in Singapore, all painting is done in environmentally controlled buildings.

- Very little, if any, testing is done prior to launch.

- In the final analysis, the team did not think that there was much the U.S. could directly apply from what was shared in the production planning area from ST Marine. Using foreign designs for naval combatants and having the first ship in a series built at a foreign yard is not an option for U.S. yards.

- One thing that the team particularly liked was that the Production Planning Department was under the Production Department.

DSME

- DSME has a very sophisticated and detailed production engineering and planning process. They have teams that develop Detailed Assembly Procedures (DAP) for Steel, Detailed Outfitting Procedures (DOP) and Detailed Erection Procedures (DEP). The procedures stress three things: 1) Workability, which includes optimizing processes and sequences 2) Cost minimization, which includes reducing the volume of work and the number of parts and 3) Improved Safety which includes maximizing down-hand work and minimizing the use of staging.

- The typical size of a work package varies from 50 hrs to 1200 man-hours depending on the situation but DSME is now striving to go to smaller and smaller work packages. They are now tending to think in terms of time to complete a work package rather than number of man-hours. They like work packages that can be performed in 4 hrs to 8 hrs so that they can be managed from start to completion on a daily basis. The steel assembly work packages are developed by a production member of the DAP team. Outfitting work packages are developed by a production member of the DOP team.

- DSME has developed an in-house Production Information System which uses the ISO STEP standard for data exchange to convert Tribon CAD data into production friendly information including visualization to support work package information. A paper prepared by Mr. Lee titled “A STEP-based Production Information System for Block Assembly” was published in the SNAME Ship Production Journal in 2007.

- For the outfitting process, the information is broken down by outfit unit (stand alone outfit packages), on Block (outfitting installed on steel sub-assemblies), On-Module (outfitting installed on structural modules), Module outfitting (outfitting done after erection) and Off-shore outfitting (outfitting done after launch). A work package observed for the On-module outfitting stage consisted of one drawing for all pipe in one section of a zone. All of the required pipe spools were marshaled in a bin next to the job site. The work package drawing showed all the pipe spools to be installed, the area, within the zone, where the pipes were to be installed, and a plan view and an elevation view of the installed pipes. The entire drawing was laminated in clear plastic to prevent damage in the shop.

- Multi-system, pre-assembled and painted piping outfit units were observed however we were told they were not pre-tested. All piping systems are tested after the entire system is installed.

- Percent outfitting completed at different stages of construction varies by ship type. For VLCCs approximately 40% of the outfitting is completed prior to erection, 50% after erection and 10% after launch. For more complex ships, like LNGs (Liquefied Natural Gas Ships), only 70% of the outfitting is completed at launch.

- Distortion mitigation is addressed by the R&D department. They spend a lot of time studying and optimizing welding sequences to minimize distortion. They track measurement of steel units after each stage of assembly to analyze results of the processes. Measurement targets are installed on units as they are assembled and lasers are used to take measurements. Measurements are analyzed and processes are modified as necessary to improve results. All distortion is corrected with line heating methods before moving units to the next stage. The typical hang time to align erection units for welding is 60 – 90 minutes which means the units are very accurate.

- The lessons learned from this visit are 1) the importance of driving the size of work packages down in size and to size them according to time to perform rather than number of man-hours 2) the importance of continuous measurement of assemblies, analysis of the data and feedback to design and/or production planning to continually improve designs and procedures to minimize distortion and 3) the establishment of multi- disciplinary teams to develop detailed assembly and outfitting procedures.

Organization and Structure

ST Marine

- ST Marine has about 150 engineers against a workforce of about 2,800. The breakdown is as follows:
  - Management 68
  - Engineering 148
  - Administration 70
  - Production (core labor) 810
  - Sub-contracted labor 1,752
  - Total 2,848

- In the past, ST Marine developed 4-6 designs per year based on their marketing studies. However, for the last 4-5 years they have concentrated solely on military work. Currently, the typical process at ST Marine is to build foreign designed combatants so it does not appear that they are developing many in-house military designs any more. Instead, foreign designs are modified to suit ST Marine's facilities and processes.

- There does not appear to be strong participation by production in the design process. They try to get some production input and want to increase it in the future but for the most part,

production critiques the design after construction so that improvement can be made in future designs.

- ST Marine currently uses Tribon as their CAD tool, so any foreign designs that they may build will be designed in Tribon. They use Microsoft Project as their scheduling tool and MARS as their material management and resource planning tool. It is unclear how well these tools are integrated but the impression of the team is that there is minimal integration.

- One interesting aspect of the organization is that it includes a stand-alone Production Planning department that is separate and distinct from the Engineering department. There is also a small Q/A department consisting of about 10 people and the head of the Q/A reports directly to the President so it is considered very important. The Q/A department is able to remain small because ST Marine has fostered a culture of quality throughout production where workers keep other workers accountable for quality. Inspections are typically done by production with random inspections performed by Q/A.

- ST Marine likes to do as much as possible in-house, therefore very little is outsourced. They do place a heavy reliance on sub-contracted labor. There are two tiers of subcontractors: project related which sign 2-3 year contracts and surge related with short term contracts. All subcontractors are pre-certified but all also receive ST Marine training.

- The workforce is organized around trades and there was little cross crafting therefore there is also little if any cross training provided. The supervisor to worker ratio was around 1-20.

- Probably the major take-away from organizational structure of ST Marine that could and should be applied in all U.S. yards is the commitment to quality fostered throughout the yard resulting in a much smaller Q/A department while still achieving required quality.

DSME

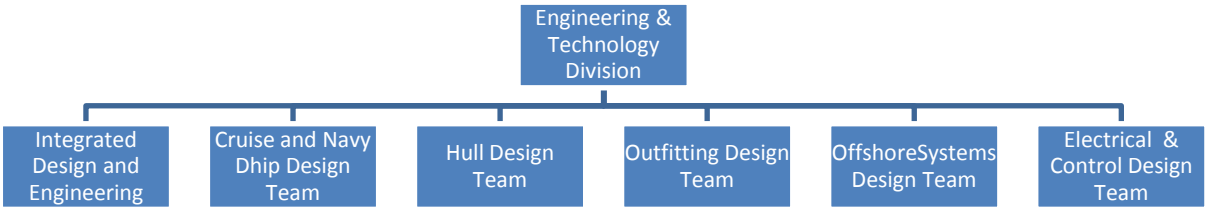
- DSME consists of approximately 30,000 people including 18,000 sub-contracted labor, organized around three different product mixes: 1)Commercial ships (VLCC, Container Ships, LNG, LPG), 2)Offshore (jack-ups, Semi submersibles, FPSOs, Drill ships) and 3)Specialty Ships (Naval vessels, Car Passenger ferries(ROPAX)) . There are specific docks and steel fabrication and assembly shops for each area; however, there is only one large steel storage yard and one cutting facility that feed all three areas. Most of the details provided addressed the Commercial ships area. Below is the workforce breakdown for the commercial ships area (including sub-contracted labor):

o Fabrication	740
o Assembly	4,000
o Pre-Outfit	1,200
o Pre-Painting	830
o Pre-Erection and Erection	2,200
o Outfitting	6,100
o Painting	2,100

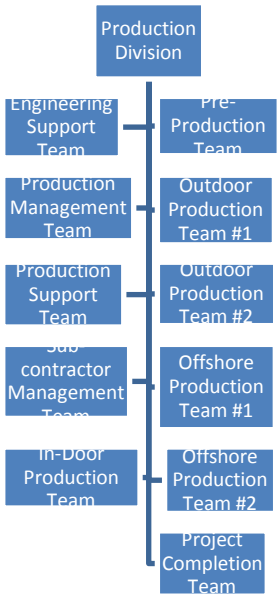
- Total 17,170

- It was mentioned that the ratio of direct to indirect labor was 10 -1.

- The organization of their Engineering and Technology Division has a dedicated design team for each of the two non-commercial ship areas, Cruise/Navy Ships and Offshore Systems. There are also design teams for Hull, Outfitting and Electrical/Controls which are probably associated with the Commercial Shipbuilding area. There is also an Integrated Design and Engineering Administration Team whose function is unclear. See abbreviated Organizational Chart below:



- The Production Department has eleven different teams and appears to be different than typical production organizations in U.S. shipyards. An abbreviated Organization Chart is below.



- It was very apparent that there is close integration between all teams and between the engineering and production divisions.

- The information flow between all organizations is coordinated via their ERP system SAP. Design, Engineering, Production, Production Planning, Quality, Material management, HR and Finance

are totally integrated. They have also developed their own in-house Production Information Management system that is linked through SAP and Tribon.

- There are approximately 200 people in the QA department with 2-3 QA inspectors assigned to each ship. QA inspectors appeared to be involved in production and their presence is known on the work floor.

- Because DSME is building so many ships and space is limited, they are required to do a lot of outsourcing. They have recently built a facility in China that builds 2500Ton ring units for VLCCs. They are barged in to support the production schedule. They also outsource a lot of pipe fabrication including assembly of piping modules. In addition to outsourcing they also employ 18,000 subcontracted laborers.

- Overall planning is done through SAP, their ERP system. The planning process is totally integrated and quite detailed. Central planning controls scheduling and it is also very detailed. They are trying to get their work package sizes down to hours so that from start to completion they can be easily tracked and managed on a daily basis.

- There is clear trade demarcation with little cross crafting. The labor union is very strong and DSME honors and supports the trade demarcation.

- The take away from this visit is that these guys are good and it would take a long time to really understand their planning and scheduling processes. The other take away is that it appears that they spend more time than we do reading and studying all of our NSRP publications going back to the early 1980's. They could be learning more from the NSRP publications than we are. They are now interested in learning the lean processes that were funded and published under the NSRP.

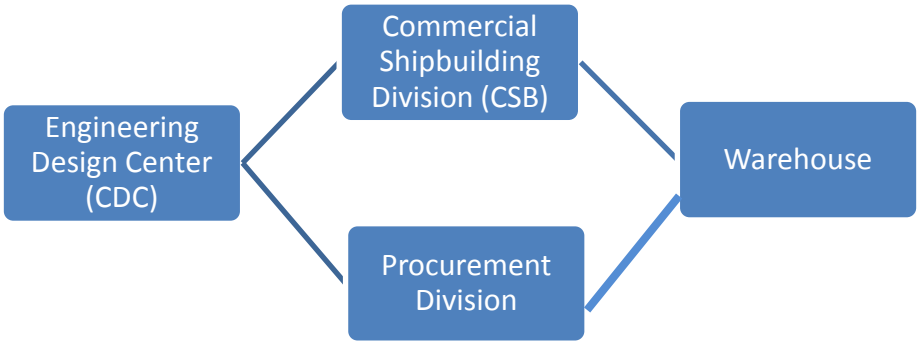
Purchasing and Material Management

ST Marine

- Supply Chain Management at ST Marine is coordinated with Engineering and Production via their ERP system MARS. ST Marine typically procures material and equipment from a list of pre-approved vendors with which they maintain a close relationship. The shipyard indicated that they prefer to spend a little more on these suppliers because they receive a lot of intangible benefits from the close relationships. The approved vendors are responsible for their own QA checks. The supplier base consists of between 500 and 1,000 suppliers.

- ST Marine tries to collaborate with their customers to maximize the use of standard parts while still meeting the customer's requirements and expectations. ST Marine is currently using standard cable and pipe fittings on all ships so they can buy in bulk and not order specifically for each ship.

- The major difference in Purchasing and Material management at ST Marine is the recently established Commercial Shipbuilding Division (CSB) as part of the procurement chain of command (see abbreviated organizational chart below).



- Responsibilities:

- Engineering Design Center (EDC)
  - Prepare specifications, evaluate proposals and makes final selection of all minor parts and equipment
  - Vendor liaison

- The Procurement Division
  - Purchase non-major equipment
  - Oversee the ordering process and delivery management for these items

- Commercial Shipbuilding Division (CSB)
  - Develop the procurement plan for all major equipment
  - Develop budget and cost estimates for major equipment
  - Procure all major equipment
  - Ensure timely execution of the production plan
  - Review budget vs. actual costs for all major equipment

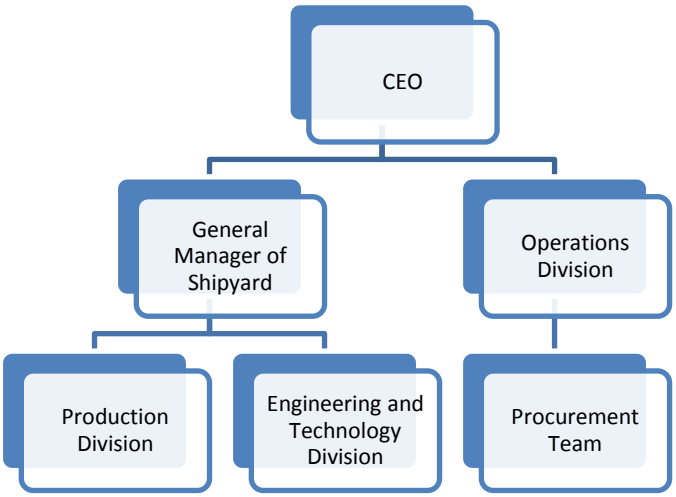
- It is not clear what people make up the newly formed CSB. The team suspects that it could be a combination of engineering and production people but it is clear that this division is directly tied to the production process to ensure timely delivery of the major equipment to support the production schedule.

- The team did not get a chance to witness the warehousing processes but would not expect any modern operations at ST Marine. The team was told that the warehouse issues materials based on production requisitions. Materials are palletized to work orders and delivered to the appropriate work shop however, the size of the work orders varies and some could be as high as 500 hrs and require lots of parts and materials to be palletized.

- The major take away from ST Marine has to be the formation of the CSB division. It would be good to get more information on the make-up of the department and the impact that it is having on production.

DSME

- DSME's Procurement Team is functional and supports all Programs/Contracts at DSME. The Procurement Team reports to the Operation Division which appears to be a centralized corporate organization that also includes Corporate Management and HR/Administrative Team. The General Manager of the Shipyard, who controls Engineering, Production and Quality Management, is considered a separate division from Operations and therefore does not control procurement (see abbreviated Organization Chart below). Interestingly, when the Shipyard Manager was asked what one thing he would fix if he could, he said, "procurement". So it appeared that he was not too happy with a separate Procurement Team.



- Supply Chain Management at DSME is coordinated and integrated with Engineering (EBOM) and Production Planning via their ERP system SAP/R3 System which was implemented in September 2004.

- DSME is in the enviable position of procuring material and equipment in such high volume that it generally can, and does, command on-time and quality performance of its suppliers. And naturally, DSME enjoys relatively high leverage in negotiations with most equipment suppliers owing to its high volume production. Therefore, inherent competition via market supply and demand provides a healthy source of cost control for materials and equipment. Additionally, because on-time and quality supply chain is so critical to sustaining its high production rate, DSME also indicated an emphasis on establishing standing and mature purchase agreements with pre-agreed-upon terms (pricing, lead times, data, services, warranties) , thus favoring supply chain stability even if it means not necessarily competing for the absolute lowest price.

- The key focus of procurement is delivery and quality. A preferred/pre-approved supplier list is maintained and managed by the Procurement Team. The clients/ship owners also provide their preferred supplier list of all major components so in essence the major components may be considered Sole Source.

- There appears to be a procurement part standardization strategy for commodities (steel, cable, electrical, valves, fittings, hardware, motors, pumps etc.) and it is standardized across

designs/programs. During the shipyard tour (shops and ship), there was evidence of part standardization.

- In general, all dates (including VFI need dates) for a given project are derived from an integrated planning tool, "DiPS" (Daewoo Integrated Planning System) based on engineering and production inputs; in turn, these dates are linked across all schedules and departments via the ERP system, "SAP". The dates generally are based on standard offsets that are built into the DiPS model.

- As noted above, DSME uses its integrated planning tool, DiPS, combined with its ERP tool, SAP, to schedule all items including long lead and bulk items. However, it is also noted that DSME buys material in significant bulk quantities, and on a "rolling basis", because of high sustained production volume. For example, bulk steel plate shipments arrive every ten days like clockwork. For DSME, this certainly provides some economies of scale, but, perhaps more importantly, provides assured supply that is critical to sustaining its production rate.

- High volume commodities are purchased as bulk (ship set(s)) with forecast required in-yard dates. Actual required delivery dates are then refined in SAP as the production detailed schedules are developed.

- The team was unable to discuss make/buy items, however, based on observations, make/buy decisions are based on the lowest cost solution and maintaining only production core competencies in the shipyard.

- From a Logistics perspective, it appears that DSME's material is stored mostly outside the Shipyard. The team did not get a chance to see the warehouses and how they were operated. There is very little material storage in the shipyard with the exception of steel plates and work in process. Even the work in process flow appears to be at a very high "speed" because there was little evidence of material stops having a high volume of kitted material.

- In the Steel Fabrication area, there appears to be a bay set-up for plate Kanbans by structural unit assembly. The plates go directly to the burning machines and after that to the secondary operations if required. There appears to be very little WIP, back to rack and scrap material. Fabricated material kits are completed at the other side of the fabrication shop so it appeared that material flow in one direction.

- Kitted outfit materials are delivered directly to the structural unit outfitting area. In addition to having the planned material near the units, the consumable material was closely stationed to the workcenters. All material was labeled with DSME's 16 digit coding system which clearly details all the required information associated with the part, including what it is and where it goes. The 16 digit coding system is explained in the Ship Design and Design for Production section of this report.

- The major take away from DSME is how well they control the enormous amount of material and equipment necessary to support the many different projects within the yard and how they do it with a Procurement Team that is not controlled by the Shipyard Manager.

APPENDICES

7.2 Report of Team Observations – European Shipyard Visit

The following pages contain the team observations from the visits to Fincantieri's Muggiano and Riva Trigoso shipyards in Italy and Navantia's Ferrol Shipyard in Spain. The team observations are broken down into the four major focus areas, 1) Ship Design and Design for Production, 2) Production Engineering and Planning, 3) Organization and Structure and 4) Purchasing and Materials Management.

Ship Design and Design for Production

Fincantieri's Muggiano Shipyard and Riva Trigoso Shipyard

- The ship design and design for production processes are very similar in both the Muggiano Shipyard and the Riva Trigoso Shipyard.

- Both Fincantieri shipyards visited use a mix of tools for their design, scheduling and resource planning. Tribon is used for steel design and Micro-station for outfitting. For engineering and outfit scheduling they use Microsoft project. For steelwork scheduling Excel spreadsheets are used. SAP is the ERP system used throughout Fincantieri. It was also mentioned that Siemens Tecnomatics software is used for over-all planning of the build strategy and for shipyard resource planning. It is unclear how well these tools are integrated but we were given the impression that everything is integrated through SAP.

- Fincantieri has a central design office in Genoa that is responsible for initial ship design which includes the general arrangement plans, system diagrams and ship specifications. The central design group works closely with each shipyard's production planning and production engineering departments to develop a high level block breakdown and erection sequence and an initial schedule for all major milestones. Once all these documents are accepted by the shipyard, the shipyard takes ownership and has full responsibility for the detailed design phase.

- In the area of design standards, the central design office in Genoa does have some standards. It is not clear how many and what kind of standards are used by central design. They did mention that they had standard arrangement plans for different propulsion systems but these are modified per customer requirements. Fincantieri also has a central procurement office in Trieste that buys common materials and equipment in bulk for all their yards. This includes steel, pipe, pipe fittings, cable, etc. This indicates that there must be company-wide standards for these items. Both shipyards also have in-house standards for steel outfit and steel details but it was not clear if these were shared between the yards. Neither shipyard uses outfit modules.

- It was not clear how much engineering is done prior to contract award for new designs. Riva Trigoso, which only builds Navy surface vessels, seems to use a lot of design information from previous vessels that they have built so they may have a lot of the engineering complete prior to contract award. On the other hand, Muggiano builds a variety of products, many of which are one of a kind, and it is not clear how much pre-contract engineering is done for these vessels.

- Both yards typically take between 6-8 months to go from functional design to detailed design. Detailed design is scheduled by block in accordance with the erection sequence, so start of construction can begin when the design for the first block to be erected is complete. Outfit fabrication and installation drawings are issued by block, location, system and stage of installation to support the erection sequence. The entire system arrangement plans do not have to be complete at this stage, only the portion of the system(s) that will be installed in the block to be erected. Foundation design is also scheduled to support the erection sequence .

- Riva Trigoso builds to the military standards that are required by the country for which the ship is being built. These include Lloyd's military standards, Australian mil specs and RINA (the Spanish Mil Specs). They have not built anything to ABS Naval Vessel Rules. The Muggiano yard builds to whatever class the customer wants, both military and commercial.

- Both yards use a part numbering system for steel fabrications and assemblies that identifies the ship, block, sub-block and area. Each assembly would have an identifier as shown below:

    - C6218 = the ship number
    - Lotto 33 = the number of the Main Block
    - Blocco A2 = the Sub-Block/Unit within the Main Block (A always indicates the engine room block, A2 always indicates the machinery space)
    - #3 = the sub-assembly within the sub-block (#3 indicated a deck)
    - Outfit parts have a slightly different numbering system. Example: 6218 03 A2 256 T1
    - 6218 = the ship number
    - 03 = the phase of construction/work station
    - A2 = the block # (A2 always indicates the machinery space.)
    - 256 = the system (SWBS #)
    - T = piping
    - 1, 2, 3 etc. = is a consecutive number assigned to each pipe spool in that space

Navantia Fene-Ferrol

- Navantia Fene-Ferrol uses a mixture of design tools. Prior to 2005, FORAN was used for basic design and structural design, Intergraph's PDS system was used for piping and HVAC design, and Microstation was used for general arrangements and equipment and for electrical, electronics and Combat Systems.

- The data was managed through oracle® databases and linked to the Navantia Fene-Ferrol's in-house developed ERP system (NECORA).

- All new designs developed after 2005 are using FORAN v70 which is a totally integrated design system. This is linked to Windchill, a product data modeling system and both are integrated with Navantia Fene-Ferrol's ERP system, NECORA.

- Navantia Fene-Ferrol builds many similar ships and as such has developed many standards that are used across ship designs. These include standard structural details, outfit steel standards,

standard pipe hangers, wireways, HVAC hangers and numerous standard components like communication panels and sprinkler actuation panels.

- It was not clear if they have standardized arrangement plans or standardized structural assemblies. They do build outfit modules that are broken down into 3 categories; 1) Multi-system pipe racks up to 15 meters in length including pipe supports. 2) Multi-system equipment modules up to 6 m X 3 m, which include piping, structure, equipment, gratings etc. and 3) Accommodation modules, 5 m x 2.5 m which include everything but the floor. Where possible they try to use similar outfit modules across ship platforms.

- Navantia Fene-Ferrol has a standard numbering system for steel work which does identify the zone, area and stage of construction.

    - Example: 13 110 505 4 104
    - 13 is the ship number
    - 110 is the block number
    - 505 is the work category (400s are cutting and bending operations, 500s are steel fabrication and assembly operations and 600s are erection operations)
    - 4 is the location within the block
    - 104 is a consecutive number assigned to the part/assembly

- The coding system for outfit was not described.

- Navantia Fene-Ferrol ensures that ship designs are producible because all Navantia Fene-Ferrol designs are based on a build strategy that is developed prior to beginning of design.

- Very little pre-engineering is done prior to contract signing. Functional design, which starts at contract award, takes approximately 12 months. They put their best people on the functional design team and make sure that it is as complete as possible prior to starting production design.

- Production design which starts about 10 months after contract award, takes 18 to 24 months to complete however, work goes on concurrently. If possible, foundations are included with the structural drawings.

- There is a Preliminary Design Review (PDR) at the end of Functional design (CA+12mo): a Hull Critical Design Review (HCDR): (CA+18mo) after which steel cutting starts and a final Critical Design Review (CDR): (CA +24 mo).

Production Engineering and Planning

Muggiano Shipyard

- Muggiano is currently building and repairing an interesting mix of ships. Two patrol crafts are being totally over-hauled, a Navy frigate that was built at Fincantieri's Riva Trigoso Shipyard is in the final outfitting stages, two mega-yachts are under construction and a submarine is also being constructed. We were told that the planning department at Muggiano was broken down

by product area, Navy, Commercial and yacht and there were approximately 6 planners per area. The number of planners must vary based on workload.

- The information provided to the production workforce varies by area and stage of construction. At the plate fabrication and sub-assembly phase, 2D drawings of the completed panels and sub-assemblies are provided, which includes identification of the all piece parts and the piece part numbers. There are frame lines put on the plates at the NC burning tables to show where each stiffener/frame should be landed but there are no instructions provided as to the sequence of assembly. This is controlled by the shop superintendent.
- For larger steel assemblies, isometric drawings are provided that show each of the sub-assemblies and how they are assembled to form the completed unit. Again, the sequence of installing the various sub-assemblies was left to the discretion of the shop superintendent.

- At the pre-outfitting stage, the pipe outfit installation drawings provide a list of all pipe spools and accessories to be installed, an isometric view of all the pipes installed, as well as a plan and elevation view. It is not clear who controls the sequence of installation but, like the steel assembly process, it is probably the responsibility of the pipe superintendent. Pipe hangers are installed by the pipe fitter based on general instructions as to the distance between hangers. Although the installation work package contains all the systems that will be installed in a particular area, it appears that cost is tracked by system and zone. It is not clear how this is tracked.

- Production does not have access to the CAD model and visualization tools are not used to create easy to understand work packages. There is no standard for the size of a work package. We were told that they can be anywhere between 200-600 man-hours and up to 2 months long.

- There were no pipe modules or outfit modules being fabricated, rather, outfit material was installed piece by piece with in an area.

- For surface ship construction, there did not appear to be much control over distortion. Many units that we observed needed straightening. However, there did not appear to be weld sequences provided for welding submarine rings.

- It was not clear how dimensional accuracy is controlled. It was stated that measurements are taken by “specialists” using laser scanners but it did not appear that this data was fed back to production planning or design. In some of the steel structures observed, the fit up was not that good.

- All painting seems to be done in place, after erection. The paint planning process is not well defined.

- The most interesting part of the Muggiano yard was the submarine pressure hull cylinder construction process. Automatic, down-hand welding processes are used for welding the flanges to the ring stiffeners and for welding the flanged stiffeners to the hull cylinder. For both processes, the welding heads are stationary and the cylinder is rotated. It appeared to be a very

efficient process. The inside diameter of the rings frames are machined for perfect circularity prior to welding the flange to the ring frames. The external diameter of the flanged frames is also machined to achieve perfect circularity prior to welding into the hull cylinder.

Riva Trigoso Shipyard

- Unlike Fincantieri's Muggiano Shipyard, the Riva Trigoso shipyard only builds Navy vessels. They are currently building 4 French designed FREMM frigates. The first ship will be launched in July 2011. The interesting thing about the Riva Trigoso yard from a production planning perspective is that they have no outfitting piers. Therefore all ships, as they are launched, must be barged to the Muggiano yard for final outfit and testing. Apparently, Riva Trigoso remains in charge of the final outfitting even though it is done at the Muggiano Shipyard.

- Production planning at Riva Trigoso is very similar to Muggiano. Similar work instructions are provided for the steel assembly process. Like in Muggiano, the sequence of steel assembly is left to the shop foreman although Riva Trigoso does have standard documents that advise how to weld typical structural units to minimize distortion. These documents are referenced in the work order and are generally known by the shop supervisors.

- In the outfitting area, Riva Trigoso provides separate drawings for pipe installation, HVAC and electrical wireways. They try to do most of the outfitting in the overhead while the unit is in the inverted stage. Each discipline installs their components separately. There are no outfit modules. The area supervisor sequences the order for each discipline. The superintendent for each discipline sequences the installation of his components.

- Like Muggiano, the Production department at Riva Trigoso does not have access to the CAD model and visualization tools are not used to create easy to understand work packages. There is no standard for the size of a work package. They vary with the stage of construction with large work packages early in the construction phases and smaller work packages after erection.

- Painting is done in place at the unit level prior to joining the units.

- There does appear to be very close cooperation between Production, Production Planning and Engineering with weekly meetings being held to ensure that production is on track.

- There are several take–aways from Fincantieri's Riva Trigoso yard in the Production Engineering and Planning area. 1) They have standard, best practice procedures, for minimizing distortion in typical structural assemblies. The procedures provide the recommended weld procedures and the best weld sequences. 2) They have company standards which document acceptable tolerance levels for all phases of steel fabrication and assembly.

<u>Organization and Structure</u>

Muggiano Shipyard

- Muggiano has a total workforce of 661 comprised of 221 white-collar and 412 blue-collar. They supplement this with a large amount of in-house subcontractors. The supervisor to work or ratio

is one supervisor for 20 company workers and one subcontracted supervisor for 30 to 40 subcontracted workers.

- The in-house, blue collar workforce is broken down into hull and structure, outfitting, and facilities. The outfitting department is broken down into engine outfitting, outside outfitting (everything outside of the ER) and electrical. The facilities department is broken down into scaffolding, temporary facilities, cleaning and protection, and cranes. More than 50% of the work is subcontracted, including scaffold builders, machinist, pipe fitters, welders, riggers and painters. The subcontractors are broken down into departments similar to the in-house work force but they are separately managed which make coordination between the In-house workforce and the sub-contractors very important.

- Fincantieri has a central design office in Genoa that provides technical services to all of their yards. The overall planning starts in Genoa with a feasibility study to determine the amount of manpower and capacity required for a ship construction contract. The central technical group also develops the basic design, the general arrangement plan and the ship specification. They work closely with Muggiano's production planning and production engineering department to develop high-level, major milestones, including dates for start of construction, erection sequence, supplier support, launch and delivery. Once accepted, the shipyard then develops the detailed plan down to the work package level. Work packages are typically large, providing schedule, budgeted hours and material for the work package. Once the shop is provided the overall duration and scope of the work order, they then control how the work will be performed to meet the budget and schedule.

- There is a central procurement group in Trieste that does all of the purchasing for high volume material and parts used by all of Fincantieri's yards. This includes steel, pipe, valves, cable, etc.

- Feedback loops between production, engineering and purchasing is established through their SAP system however the level of integration between the design, planning and production departments was not clear. During construction, production planning and production meet weekly to check schedule adherence.

- Muggiano has a fairly large Quality Assurance department made up of 60 people. Since Muggiano typically does pilot, one-off ships, it performs detailed dimensional checks throughout the building process which probably explains why the QA department is so large. There seemed to be a submarine mentality that showed throughout.

Riva Trigoso Shipyard

- The organizational structure in Riva Trigoso is very similar to the Muggiano yard. The number of in-house people was also similar consisting of 230 white collar and 400 blue collar employees. Of the white collar employees, 65 were in the technical department. Riva Trigoso also uses a large amount of subcontractors within the shipyard which are separately managed but must be coordinated with the in-house employees. Riva Trigoso does not have as large a QA department as Muggiano.

- The major difference at the Riva Trigoso shipyard is that they only build Naval surface ships and they do not have any outfit piers. After a ship is launched it must be moved, by barge, to the Muggiano shipyard for final outfit and testing. In some cases the Muggiano yard will also build sections of the ships for Riva Trigoso yard. This requires both yards to work very closely with each other in the planning and execution of the work.

Navantia Fene-Ferrol

- Engineering at Navantia is organized by traditional functional area (Structure, Equipment and Outfitting, Mechanical, etc). Navantia Fene-Ferrol is interesting in that they sub-contract a large amount of their engineering to a variety of subcontractors. These engineering companies all have been pre-certified by Navantia and are familiar with Navantia's engineering procedures and tools. The work is subcontracted by design zone, (e.g. engine room, bow, stern, superstructure, etc).

- Planning and Production Engineering play a major role in influencing the engineering department. Planning is a separate department that is responsible for the first 3 levels of planning (levels 0, 1 and 2).

- Level 0 develops the resource planning and defines the construction period and major milestones for engineering, procurement, production, ILS, IWS, etc. Level 1 develops the high level build strategy, block breakdown, engineering plan, main equipment plan and a high level integrated schedule. Level 2 adds more detail to the build strategy and develops schedules for drawings, shop floor, testing, dry docking, Diesel Generator start, Gas turbine start, combat system load out, etc.

- Production Engineering, which is under the Production Department, receives these planning documents and develops: 1) the drawing requirements and schedule for engineering to support the build strategy; 2) the materials and equipment purchasing strategy for Procurement; and 3) the intermediate products and activities list for production. This is followed by refinement of the build strategy and interfacing with design, engineering and production to develop the work orders which provides all the information needed to purchase materials and build the ships in accordance with the build strategy. Production engineering is also responsible for materials checking associated with the work orders.

- There are formal feedback loops from production to production engineering regarding process improvements, from production to engineering regarding technical questions and from Production Engineering to engineering regarding process changes and any deviations from contractual requirements. The Planning department is responsible for monitoring progress.

- The Production Department has a typical organization, consisting of Steel, Outfitting, Testing and Logistics departments. As mentioned previously, Production Engineering is also under Production.

- The Steel Department has a Section Manager for Fabrication, Assembly and Erection and a separate Section Manager for Welding and Dimensional Control.

- The Outfitting Department has Section Managers for Piping, Accommodations, Mechanical, Electrical, and Painting and a separate Section Manager for Pre-Outfitting.

- Navantia Fene-Ferrol has a fairly large Quality Department which is comprised of managers in the following areas: Quality Assurance, Quality Systems, Project Quality and Engineering Quality. There is also a Procurement Department Quality Coordinator. Additionally, there is an overall Quality Manager for each project and a Quality Inspector on each ship.

Purchasing and Material Management

Muggiano Shipyard and Riva Trigoso Shipyard

- The purchasing and material management systems at both the Fincantieri yards are basically the same. Fincantieri have several levels of procurement. There is a central Procurement Department in Trieste, Italy that is responsible for ordering all common material and equipment, such as steel, pipe, valves, cable, etc. for all the Fincantieri shipyards. In some cases the central procurement department in Trieste will also order common long lead items for cruise and merchant ships, like shafts and propellers. There is also a purchasing function in Genoa for procurement of Naval ship equipment. Finally, within each shipyard there is a Procurement Department that coordinates shipyard requirements with the central procurement department(s) and also orders equipment and materials that are specific to a product. The shipyard procurement manager answers directly to the shipyard manager.

- All suppliers that are used company-wide are evaluated by each shipyard's procurement, finance and production departments. Each shipyard gives the supplier a score from 1-5 for quality of the product, financial stability, and ease of purchasing. All Fincantieri shipyards provide their scores to the central procurement department. If a supplier scores under 2, they cannot be used. If a score is between 2 and 4 and the price is good, Fincantieri will work with the supplier to help them improve. Fincantieri yards use SAP as their ERP system and it contains all approved suppliers. Shipyards are not allowed to use suppliers that are not in SAP.

- VFI requirements are part of the standard purchase orders and are scheduled via the master schedule. Both shipyards indicated that VFI is scheduled as needed to support engineering. The material ordering schedule is part of the Master schedule which is developed jointly with Planning, Production and Procurement. Long lead items and bulk material are included in the Master schedule.

- Actual material and equipment cost are tracked against budgeted costs. Cost estimates are based on previous BOMs and prices from similar ships.

- The Riva Trigosa yard has a mechanical department that is capable of manufacturing turbines, TG sets, shafts and props, thrusters, fin stabilizers, reduction gears and rudders and steering gears. Make or buy decisions are based on workload and yard skill level. If work is subcontracted it must take fewer hours to produce than Fincantieri and the hourly rate has to be less.

- Some QA checks of equipment and material are done by the supplier and others by QA department. When material and equipment arrives it is first checked for proper quantity and

description provided against the packing slip. Some quality inspection processes can take up to 2 days prior to storage in the warehouse. The team was unable to visit the warehouses but was informed that there are 3 types of warehousing; normal, secure, and spare parts. Parts do have an identification code used for tracking. There was no bar-coding or RFID tags being used.

- Parts are retrieved from the warehouse and marshaled according to a work order pick list. There is a min/max system within SAP that is used for ordering consumables.

Navantia Fene-Ferrol

- Navantia's Procurement Department answers directly to the Shipyard's Managing Director. There is a supplier review committee, comprised of representatives from procurement, QA and Engineering that meets monthly to evaluate supplier performance and to analyze and treat any procurement issues. Vendors can be penalized and removed from the approved supplier list if they do not perform well.

- The procurement department does try to maintain Long Term Agreements with key suppliers as much as possible. They also try to have a couple of agreements in place for each commodity to mitigate risk and maintain flexibility.

- The procurement schedule is developed by production engineering to support the build strategy. The Engineering Department identifies VFI requirements and includes them as part of the purchase specification. Receipt of VFI is scheduled in stages, as needed, to support the detailed design process. VFI schedule stages include:

    1. Foundations and mechanical information
    2. Electrical information and automation and control information
    3. Factory Acceptance Testing (FAT)
    4. Logistics

- During the functional design phase, as system diagrams are developed, estimates of material, such as pipe, valves, cable, etc. are submitted to procurement for initial orders. As detail design progresses and material and equipment by zone are developed the procurement schedule and material requirements are refined and submitted to procurement.

- Material and equipment budgets are developed by the Planning Department and includes the main equipment and the rest of the material divided into different areas/groups (Steel, Electrical, Piping, Fittings, Accommodations, etc). Planning updates this monthly to track purchase orders submitted and Procurement submits a tri-monthly report which re-adjusts the budget with actual material and equipment costs.

- All plate remnants are squared and re-cataloged if larger than 2m. Smaller than 2m remnants are scrapped, resulting in a scrap rate of 20%. Cable is pre-cut prior to installation with a 15% excess of requested amount.

- Depending on the supplier, some QA inspections are done by the supplier with random checks done by the shipyard. For other suppliers the inspections are performed by QA upon receipt in the shipyard. Vendors are required to provide standard information on all packing slips.
- Warehousing and material handling reports to the Production Director. There is a seven digit location system for tracking the location of all material. Work orders are released via the SAP system and include the required material, quantity and delivery location. Based on the work order the warehouse retrieves, marshals and delivers the required material to the work site. Once delivered, materials are not tracked.

APPENDICES

7.3 Overview of the Asian and European Shipyard Visits

The following is a brief description of the shipyards visited in Asia and Europe. Much more info is available on each company's web site.

Asian Shipyards visited:

- Singapore Technologies Marine Ltd (ST Marine)
  - Tuas Shipyard
  - Benoi Shipyard
- Sembcorp Marine
  - Jurong Shipyard
- Daewoo Shipbuilding and Marine Engineering Co. (DSME)
  - Okpo Shipyard

It was planned to visit ST Marine – Tuas and Jurong Shipyards in Singapore and DSME in South Korea. The Jurong Shipyard visit was cut short a few days before the team arrived at the request of shipyard management which resulted in a 2 ½ hour presentation and bus tour. Because of this late change, and at the request of the NSRP Team, ST Marine provided an additional briefing and tour of their Tuas Shipyard which focuses on repairs and conversions.

Although ST Marine (Benoi Shipyard) completed a 5-ship class build program of Frigates for the Singapore Navy a few years earlier and currently has under construction an LPD for the Tai Navy, very little new construction was in progress in the yards visited in Singapore other than rig construction which was in the Jurong Shipyard. Jurong Shipyard also had a major FPSO conversion in progress. It was explained that since Singapore has no significant industrial capacity, almost all of the material to build ships had to be imported impacting Singapore shipyard competitiveness. However, because of the availability of less expensive labor, much of it contracted and brought over from Indonesia and Malaysia, the Singapore shipyards were very competitive in repair and conversion projects so were focused there for their main business. Both ST Marine and Jurong Shipyard's parent company Sembcorp Marine have shipyards in the USA, VT Halter, Inc. and Sembcorp-Sabine Industries, Inc. respectively.

In contrast, DSME - with significant industrial capacity in South Korea and access to China industrial capacity and reasonable labor rates - is building both military and commercial shipping. It was reported by DSME representatives that DSME will deliver 64 commercial ships in 2011, along with building Navy Aegis Class Cruisers, submarines, oil rigs and FSPOs.

European Shipyards visited:

- Fincantieri Marine Group

    - Muggiano Shipyard
    - Riva Trigoso Shipyard
- Navantia Fene-Ferrol
    - Navantia Fene-Ferrol shipyard (Note: The team visited the Ferrol facility only)

Two Fincantieri shipyards (Muggiano and Riva Trigoso) in Italy and one Navantia shipyard (Fene-Ferrol) in Spain were visited by the NSRP European visit team. All three shipyards are building naval vessels.

The Muggiano shipyard located in La Spezia and the Riva Trigoso shipyard located in Genoa actually team together to build naval surface combatants. The Muggiano shipyard has one floating dry dock and no graving docks while Riva Trigoso has no piers or wharfs or dry docks. Surface combatants are constructed in Riva Trigoso shipyard, transported by barge to the Muggiano shipyard where they are moved into the floating dock and launched. Final outfitting, testing and trials are conducted from the Muggiano shipyard. The Riva Trigoso shipyard had three FREMM class destroyers under construction during the visit. The Riva Trigoso also has a large machinery manufacturing facility on site where it manufactures many major shipboard systems including steam turbines, stabilization systems and diesel engines. The Muggiano shipyard also builds mega yachts and submarines as well as conducts repairs and conversions on other vessels.

The Fene-Ferrol shipyard located in Ferrol, Spain was visited although only Ferrol shipyard facility was visited. Both the Fene and Ferrol facilities of the shipyard produce blocks for assembly on the building ways at the Ferrol shipyard facility. The shipyard was building the fifth of five Aegis Class Frigates for the Spanish Navy and was in final outfitting on one 27,000 ton LHD for the Australian Navy with the second under construction. It was also conducting repairs and conversions on other naval vessels. The Ferrol shipyard also has a large machinery manufacturing facility at the yard where it builds turbines and wind mill blades among other major equipments. The NSRP team did not tour this portion of the shipyard.

APPENDICES

7.4 Focus Areas and Supporting Questions

Ship Design and Design for Production

1. Please explain the computer tools that are used for design, production planning, production, material management and resource planning.
    a. How are the tools integrated to work together?

2. Please explain your steelwork and outfit coding (numbering) systems.
    a. Is the coding system the same with each ship contract?
    b. Does the coding system include the zone, area and stage of construction?

3. Do you have design standards that are applied across ship types?
    a. Do they include standard components, arrangement plans, steel outfit components, steel sub-assemblies and assemblies, outfit modules, other areas?

4. Please provide answers to following questions on design phases.
    a. On a new ship design, how much pre-engineering is done prior to contract signing?
    b. How much time is typically spent between Contract design and functional design?
    c. How much time is typically spent between functional design and production design?
    d. At what stage of the design process does production work start?
    e. At what phase of design are all necessary foundations identified?
    f. At what stage of design are steel outfit items identified?

Production Engineering and Planning

1. Please explain or show the kinds of information that you provide the production workforce for steel fabrication and assembly.

2. Please explain or show the kinds of information that you provide the production workforce for outfit fabrication, assembly and installation.

3. For the two items above, please provide any information on the following items:
    a. The typical size of a work package
    b. The level of detail provided in a work package
    c. The group responsible for preparing work packages
    d. Visualization tools that are used (if any) for preparing the work packages
    e. Links to the design data base

4. Please explain how the work sequences are planned for steelwork fabrication and assembly.

5. Please explain your outfitting planning processes, including the following:
    a. The outfitting that is planned for installation at the different stages of the steel assembly process.
    b. Are pre-assembled outfit modules used? If so, who plans them; how large are they; do they include different systems; are they pre-tested; and when are they installed?
    c. How much outfitting is done after erection?

6. How is weld distortion minimized and controlled?
    a. Who establishes welding sequences and weld shrinkage allowances?
    b. What level of detail is provided to the shop regarding weld sequences and procedures?

7. How is dimensional and accuracy control of structural units controlled?
    a. What is measured and how often are measurements taken?
    b. What are acceptable tolerance levels?
    c. Who sees the measurement data and how is it used/analyzed to improve processes?

8. How are tests and trials coordinated with production? Please explain your painting planning process for both structure and outfit modules.

Purchasing and Material Management

1. Please explain how you deal with your supplier base.
    a. Do you measure supplier performance?
    b. Do you have a list of pre-approved vendors?
    c. Do you try to procure standard items for all ships?
    d. Who does QA checks? Supplier or shipyard.

2. How do you handle VFI requirements to support design?
    a. Who identifies the VFI requirements?
    b. Who schedules when they are needed?
    c. How are they scheduled? On an as needed basis or all at once?

3. How is the material ordering schedule developed?
    a. Who is responsible for scheduling material and equipment procurement to support the outfitting plan?

4. How are long lead items and bulk material scheduled to support production?

5. How are material and equipment costs controlled?

6. Please explain your process for deciding whether the shipyard will make an item or buy it

7. Please explain your general storage and warehousing practices.

    a. How are material and equipment inspected when they arrive?
    b. How are they stored?
    c. How is material retrieved from the warehouse and delivered to production?
    d. Do you use a material control and tracking system? Please describe.
    e. How do you control your consumable inventory, like welding wire, tools, etc

8. Please explain how you marshal your outfit parts prior to delivery to production?

Organization and Structure

1. Please explain how each of the following departments are organized and the level of influence has on the design process:
    a. Engineering
    b. Production Engineering
    c. Production Planning

2. Please explain the information flow between Engineering, Production Planning, and Production including feedback loops.

3. Explain how QA/QC is organized.

4. Explain your use, if any, for outsourcing work and for bringing in subcontractors
    a. How much work is typically outsourced/ subcontracted?
    b. What is the decision process for what will be outsourced/subcontracted?

5. Please explain how your overall planning is done in the shipyard from basic shipyard loading to detailed ship building programs.

6. Please explain your master planning and steel and outfit scheduling process.
    a. What is the level of detail used for scheduling?
    b. Do you use very detailed central planning or more shop controlled scheduling?

7. Please explain how your manpower is organized including the management structure, trade demarcation.