Newport News Shipbuilding
A Division of Huntington Ingalls Industries

Identify Opportunities to Reduce Grinding Labor

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Table of Contents

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Executive Summary

Manual grinding and other surface smoothing or cleaning techniques are employed throughout the structural fabrication, assembly, and erection of naval vessels. Shipyards spend a large amount of labor grinding to remove mill scale, paint, rust, burning slag, weld spatter, and scars from steel surfaces.

This NSRP contract was awarded to identify opportunities for shipyards to reduce labor by using more efficient grinding methods and/or reducing the total amount of grinding that must be done. Newport News Shipbuilding (NNS) was the project lead. Bollinger Shipyards and Ingalls Shipbuilding participated as subcontractors. The contract specifically focused on grinding that is performed to support hull assembly. Grinding that is performed to support manufacturing/installation of outfitting components and to support painting operations was excluded from the project. The project's high level plan is provided below:

Task 1 - Newport News Shipbuilding (NNS) developed current state documentation
Task 2 - NNS current state documentation was reviewed with participating shipyards
Task 3 - Participating shipyards documented their current states.
Task 4 – Shipyards compared/contrasted current state documentation, identified improvement opportunities, and created the final report outline.
Task 5 – Completed final report and presentation.

The three shipyards individually documented their grinding current states including reasons for grinding, tools and consumables used, past grinding improvement initiatives, and improvement opportunities. Shipyard representatives met to review their current states and to identify improvement opportunities. The three shipyards agreed on nineteen industry opportunities but placed significantly different priorities on the improvement opportunities due to the types of ships constructed at each shipyard and the processes emphasized in past improvement initiatives. The nineteen improvement opportunities fall into the three broad categories summarized below:

- Reduce Grinding by Eliminating Non-Value Added Activities – These improvement opportunities focus on eliminating unnecessary grinding not required by ship specifications or internal customers. The opportunities involve methods for identifying job-specific surface smoothness requirements, craftsmen training, and use of temporary attachments that do not required grinding.
- Perform Work in Optimal Stages of Construction with Optimal Tools and Equipment – Includes installation of components when accessibility is greatest to eliminate grinding or make it easier. Also, includes increased use of modern welding equipment and automated welding/burning equipment that can produce weld beads or part edges that do not require grinding.

- Reduce Grinding Associated with Paint Removal during Weld Joint Preparation – These opportunities include use of weld-through primers and/or a reduction in cleaning requirements prior to hot work.

This report focused on reducing grinding labor but the shipyards share an even more important goal of maintaining our craftsmen's health and safety by reducing eye injuries. In one of our final discussions, it was noted that eye injuries are the most frequent injury in each shipyard and that grinding results in more eye injuries than any other shipyard process. This fact only adds urgency and importance to the improvement opportunities identified in this report.

Each shipyard is deciding how they will pursue the improvement opportunities identified in this report. Since the three shipyards prioritized the improvements opportunities differently, each must develop an implementation plan that fits their business and circumstances. At a very high level, shipyards must begin to think of grinding as a process anomaly or form of rework that can be eliminated if preceding processes are in control and correctly performed. In general and as a result of participating in this project, each shipyard has identified new opportunities that they intend to pursue. In other cases, emphasis will be increased on opportunities that are well known and for which they already have implementation initiatives. In some cases, a shipyard will not place any near-term emphasis on an opportunity because it has a low priority at this time. In all cases, the shipyards agreed this project has been a valuable effort that will facilitate efforts to reduce shipbuilding cost and improve safety of the work force.

List of Figures

List of Acronyms

Acronym	Description
ABS	American Bureau of Shipping
AWS	American Welding Society
COP	Community of Practice
CVN	Carrier Vessel Nuclear (Aircraft Carrier)
ET	Eddy Current Testing
FAP	Final Assembly Platen
ILO	In Lieu Of
IWO	In Way Of
ManTech	Manufacturing Technology Program (Office of Naval Research)
MOF	Modular Outfitting Facility
MT	Magnetic Particle Testing
NC	Numerical Controlled
NAVSEA	Naval Sea Systems Command
NDT	Non-destructive Testing
NNS	Newport News Shipbuilding
NSRP	National Shipbuilding Research Program
OSHA	Occupational Safety & Health Administration
PT	Liquid Penetrant Testing
RMS	Root Mean Square (Roughness measure for machined surfaces)
SFA	Structural Fabrication and Assembly
SWSS	Shipyard Work Status System
UT	Ultrasonic Testing
VCS	Virginia Class Submarine
VT	Visual Inspection

1 Project Scope of Work / Grinding Definition

Manual grinding and other surface cleaning techniques are employed throughout the structural fabrication, assembly, and erection of naval vessels. Shipyards spend a large amount of labor grinding to remove mill scale, burning slag, paint, weld spatter, and weld scars from steel surfaces. Formal and informal inspections throughout the shipbuilding process determine when the cleaning work is performed.

This evaluation was performed to identify opportunities for shipyards to reduce labor by using more efficient grinding methods and/or reducing the total amount of grinding that must be done. Newport News Shipbuilding, Bollinger Shipyards, and Ingalls Shipbuilding collaborated on the project. Newport News Shipbuilding was the project lead. Bollinger Shipyards and Ingalls Shipbuilding participated as subcontractors. The bullets below describe the high level tasks that were performed to complete the project.

- Task 1 - Newport News Shipbuilding (NNS) developed current state documentation
- Task 2 - Reached Project Execution Agreement. NNS met with participating shipyards to kick off their portions of the project. The NNS current state documentation was reviewed and participating shipyards were tasked to develop their current states using similar methodology.
- Task 3 - Completed Project Execution Agreement. Participating shipyards documented their current states.
- Task 4 – Compared/contrasted current state documentation, identified improvement opportunities, and created final report outline
- Task 5 – Completed final report and presentation

Grinding is performed throughout the shipbuilding process and by nearly all shipbuilding departments that perform assembly work. This project focused only on grinding for structural welding processes because it was recognized that a comprehensive review of all grinding could not be adequately performed within the funding and time constraints specified by NSRP. When most people think of grinding, they picture a craftsman using a spinning, abrasive pad to remove undesired material, but the fact is that the undesired material can be removed using non-grinding techniques such as sandblasting or with solvents. A grinding definition was written to avoid scope creep and ensure that “non-grinding” techniques for removing undesired material could be considered in the baseline and as opportunities for improvement. This definition was reviewed with participating shipyards and all personnel that were involved in the project. The definition is provided below:

> *Grinding: The process of removing undesired material in the vicinity of a weld joint prior to, during, or after welding. Undesired material includes burning slag, rust, coatings, dirt, grease, or weld surface imperfections. Removal can be performed via grinding wheels, abrasive pads, shot blast, wire brushing, rotary files, needle guns, or machining. Also, includes removal of surface imperfections*

in the base material that were introduced in order to perform the welding or as a result of the welding (ie. weld spatter, temporary attachments).

We also found it necessary to create project boundaries to supplement the definition. These boundaries were developed in the form of "What's In or Out" and are provided below.

What's In	What's Out
Grinding IWO weld joints	Grinding for installation of outfitting items (pipe hangers, ventilation clips, etc…)
Materials (Carbon, HSLA, & HY Steels, NiCu, CRES & Inconel)	Removal of primer or rust for application of coating systems.
Prepping for NDT	Breaking of edges for coating system adhesion
Removal of NDT imperfections	Aluminum
Assembly through ship erection	Outfitting Shop processes

2 NNS Current State Documentation

This project focused on structural grinding which begins with the fabrication (burning) of piece parts and ends with the joining of the steel units, super lifts, or modules into a structurally complete ship. A large percentage of this grinding is performed in the Structural Fabrication and Assembly (SFA) Division where piece parts are burned, pre/sub-assemblies are manufactured, and the resulting assemblies and parts are joined into aircraft carrier units, submarine modules, or miscellaneous components (ie. equipment foundations, submarine appendages, etc…). The units or modules vary widely in weight and size but it is not uncommon to produce units or modules that are the size of a suburban house and weigh up to 300 tons.

The other major area of structural grinding is performed when the units and modules are joined into even larger sections and erected to form the completed ship. This work takes place in different locations for each program. For new construction aircraft carriers, units are joined into super lifts on the Final Assembly Platen (FAP) and then erected in dry dock 12. New structural sections for aircraft carriers being overhauled are joined to the ship in dry dock 11. Submarine module joining is performed in the Modular Outfitting Facility (MOF).

Several NNS internal meetings were held to develop a plan for documenting the current state of grinding at NNS. Any experienced shipbuilder can state some reasons why grinding is performed, offer an opinion about how much grinding is performed, and offer ideas for improvement, but the NNS project team wanted a fact-based approach that would involve personnel that actually perform the grinding. Various data collection techniques such as time studies were discussed, but a time study effort on each grinding process would have been costly and would not have provided objective data about how often the process was employed. The team also wanted a process that could be repeated at participating shipyards so that "apples and apples" comparisons could be made. The major elements of our current state documentation that emerged out of these meetings are listed below:

- Collect/Review all known grinding studies
- Document ship specifications and procedures that create need for grinding
- Document tools and consumables used to perform grinding
- Quantify time required to perform grinding
- Identify opportunities for improvement

2.1 Collect/Review all Known Grinding Studies

Reviewing all previous grinding studies provided a solid foundation for moving forward by ensuring team members were aware of all previous efforts and did not waste time on research that had previously been performed. Possible information sources that were examined include previous NSRP projects, previous and on-going ManTech projects, equipment/tool manufacturer studies and documentation, and internal NNS studies. A master spreadsheet was created that list the studies, summarizes the outcome, and provides a

hyperlink to the actual document. The master spreadsheet that was developed is provided in Appendix A.

2.2 Document Specification/Procedure Requirements that Create Need for Grinding

The need to perform most grinding originates with Navy ship specifications and Occupational Safety & Health Administration (OSHA) requirements. Navy specifications control the requirements for fabrication, welding, and inspection of Navy ships. The specifications do not usually say grinding must be performed, but do specify the surface smoothness, surface transition, non-destructive testing, and structural alignment requirements that make grinding necessary. They sometimes invoke Military Standards (Mil-Stds) and American Welding Society (AWS) standards that list specific requirements. NNS shipyard craftsmen do not look at Navy ship specifications or OSHA documents in most cases. Shipyard procedures are commonly used to communicate requirements from these documents down to the craftsmen that actually perform the work.

Joint Cleanliness

NNS welding procedures define how much paint or rust must be removed from a joint to ensure proper joint quality. These procedures instruct the craftsman to "clean and dry all weld joint surfaces and the adjacent base metal for at least ½" on each side of the expected weld toe." The procedures also direct the user to the company's health and safety manual that has additional paint removal requirements. The health and safety manual essentially overrides the ½" requirement by requiring that paint be stripped back 2 inches whenever hot work is to be performed. The 2 inch paint removal requirement is actually derived from an even more stringent OSHA standard. OSHA standard **1915.53** is worded as follows: "In enclosed spaces, all surfaces covered with toxic preservatives shall be stripped of all toxic coatings for a distance of at least 4 inches from the area of heat application or the employees shall be protected by air line respirators meeting the requirements of § 1915.1544 of paint be removed." The OSHA statement does not specify that paint must be removed by grinding, but grinding is the method that is most often used.

Flame or Arc Cut Surface Finish Requirements

An NNS procedure provides finish requirements for flame or arc cut surfaces. The procedure requires flame and arc cut surfaces to be visually inspected by the operator soon after the cutting and cleaning operations have been completed. Figure 1 below is an AWS gauge that is referenced in the procedure and used in the shop to define burned surface acceptance criteria. Flame cut surfaces similar to Sample 1 are to be rejected and those similar to Samples 2, 3, and 4 are acceptable. Rejected surfaces are to be corrected by grinding or machining and then re-inspected.

Figure 1 – Flame Roughness Guide for Oxygen Cutting

Preparing for Ultrasonic Inspection (UT)

Several NNS non-destructive test (NDT) procedures specify surface preparation requirements for the performance of UT testing. The procedures govern use of UT for butt welds, tee welds, corner welds, and various specific components. All procedures provide similar instructions for surface preparation. For example, a procedure may state that "a scanning area on each side of the weld, wide enough to allow search of the entire weld volume and heat affected zone shall be prepared for the test. The surface of this area shall be free of loose scale, loose paint, weld spatter, grease, dirt, and any other foreign matter that might interfere with the scanning procedure. It must also have a surface finish of 250 Root Mean Square (RMS) or better, and be flat enough to allow adequate coupling between the transducer and the scanning surface. The test surface may have one coat of primer."

Base Metal Defect Repair

An NNS procedure defines the requirements for base metal repair and associated grinding. Defects can be introduced as result of welding and other construction processes. These defects may be corrected by grinding or by welding and grinding. The final repaired surface is to be faired smoothly into the surrounding metal and the material cannot be reduced below the

specified minimum thickness. The bullets below paraphrase the defects and limits imposed in the procedure:

- The **maximum depth** of arc strikes and other fabrication scars (e.g., scars, nicks, gouges, etc.) is 1/32 inch if the material is less than ½ inch thick and 1/16 inch if the material is ½ inch thick or greater for a length of up to 12 inches. Measure depth of grinding from the unground surface next to the ground area. These defects shall be repaired by grinding to the bottom of the groove and fairing smoothly into the base material. Any defects that exceed the depths described above shall be weld repaired.
- The final weld repairs made to correct temporary attachment removal sites, arc strikes, nicks, gouges, and other fabrication scars are to have a **maximum weld repair height** of 1/8 inch except in areas that are specifically identified for more stringent requirements such as submarine hydrodynamic surfaces. Aircraft carriers are required to have maximum reinforcements of 1/16 inch above and 1/32 inch below adjacent surfaces on hull exterior surfaces, top side of decks/platforms, and un-insulated interior living spaces where paneling, Formica, or floor tiles will be installed.
- **Maximum diameter and length of tightly adhering spatter** is 1/8 inch except that no spatter is allowed on certain designated surfaces or spaces.

Repairs of Visual Inspection (VT) and Magnetic Particle Testing (MT) or Liquid Penetrant Testing (PT) Indications

An NNS procedure governs VT of welds. VT is usually performed by the welding foreman. Communication of acceptance criteria is further facilitated by the Welder's Visual Inspection Handbook and VT Job Cards but the acceptance criteria are derived from the procedure. Additional NDT procedures identify defects that must be repaired when welds are required to undergo MT testing or PT testing.

The specifications do not specifically require grinding, but grinding is used in some cases. In general, defects must be corrected according to the applicable welding procedure. The specification states that "When defects are corrected by mechanical means (i.e. grinding or machining), assure the repaired surface blends smoothly into the surrounding surface and that the minimum design (drawing) thickness requirements have not been violated. There must be no visible evidence of an abrupt change on the repaired surface." For some weld processes MT/PT drives significant grinding due to linear indications caused by adjacent beads that have angles that are less than 90 degrees.

Contour Grinding

Weld contour is the surface profile of a weld in the as-deposited condition or after preparation to meet workmanship or NDT requirements. Contour grinding is deliberate shaping of weld surfaces to achieve workmanship, hydrodynamic or fatigue requirements. Contour grinding is not required on aircraft carrier welds.

On Virginia Class Submarines (VCS), contour grinding of some welds is required. Grinding is not required when as deposited undercut is not present and the weld edges blend smoothly into

the base material. Weld contouring by grinding may be done on any groove butt weld, groove tee weld, or groove corner weld, but shall be done to the welds listed below.

- Groove tee or corner joint connection of the pressure hull envelope to penetrations.
- Bulkhead and bulkhead stiffener connections to the pressure hull envelope.
- Hard tank groove tee or corner welds.
- All full penetration welds to the pressure hull envelope in the reactor compartment. In addition, when the primary shield tank is attached to the pressure hull envelope, all primary shield tank groove tee welds in or to HY or HSLA material subjected to submergence loads.
- All full penetration welds of the shielded passageway to bulkheads in the reactor compartment.
- Reactor compartment frame to pressure hull envelope welds.
- All groove and corner boundary welds in sea chests and trunks which are attached to the pressure hull envelope.
- Flange connections of pressure hull frames to tank tops (except web side of flange)
- For HY-130 only, all weld repair areas in groove tee and corner welds in pressure hull structure.

Fatigue Adequacy

Fatigue adequacy welds always require grinding. There are no welds that require fatigue adequacy grinding on aircraft carriers. VCS welds that require fatigue adequacy grinding are identified with notes on the drawing and the Shipyard Work Status System (SWSS) ticket. Generally, the locations that require fatigue adequacy grinding are where the weld leg transitions to the pressure hull.

Correct Misalignment at Fit-up

Grinding is allowed to correct misaligned plate butts. Grinding is not specifically required but grinding is often used. In most cases, required alignment is communicated with sketches in the procedure. The tolerance for alignment is typically proportional meaning that thinner structure has a smaller tolerance and thicker structure has a higher tolerance. In some cases, the requirements are put into words. A typical paraphrased example of required alignment frame butt alignment calls for “the transverse and vertical offset of abutting surfaces at weld joints in webs and flanges shall not exceed 1/8 inch, unless so designated. If any point across the flange face exceeds 1/8 inch, but does not exceed 1/4 inch, it shall be faired by grinding to a four to one taper. These limits are applicable after completion of welding and cool down.”

Removal of Temporary Attachments

An NNS procedure governs use and removal of temporary attachments. In general, temporary attachments are burned off slightly more than 1/16 inch from the permanent member. The surface is then ground smooth to a maximum of 1/16 inch above or 1/32 inch below the adjacent surface. VT of the removal site is required along with MT in specific areas.

Aircraft carrier requirements allow leaving an entire attachment in place with engineering approval on a case-by-case basis. In these cases, weld sizes must meet procedure requirements and the attachment must be welded all around to ensure it is sealed. In certain spaces, it is technically acceptable to arc or burn the attachment off but leave a stub about ½ inch high that will be ground just to remove the sharp edges and dross.

2.3 Document Tools and Consumables Used to Perform Grinding

The NNS project team decided to document all equipment, tools, and consumables used to perform grinding with photographs and manufacturer specifications. The natural place to start was the tool room. The tool room issues nearly all the hand held grinding tools and associated consumables that are used by NNS craftsmen. The photographs of the tools and consumables that the tool room stocks along with the tool specifications are provided in Appendix B.

Sandblasting equipment is often used to remove paint on small parts. Although most personnel would not consider sandblasting to be grinding, it was identified as a grinding process for this project since grinding would be used if these sandblasting processes were not available. The two types of equipment used for small parts are known as "Glove Boxes" and "In Line T-Bar Blasters". This equipment is permanently installed in several SFA work centers where many small parts are processed. This sandblasting is performed by the fitters in the work centers where it is available. The decision to use this equipment or use other grinding tools is made by the fitter and/or the supervisor. The equipment and the locations where it has been installed are provided in Figure 2 below.

Figure 2 – Sandblasting Equipment used in Lieu of Grinding for Small Parts

Glove Boxes

Manufacturer: Empire Abrasive Equipment
Model Numbers: 4848, 3642

Building	Work Center	Asset Number	Model Number	Interior Dimensions (D x W x H)	Door Width	Door Height
1745	8C1	42390	4848	50" x 54" x 72"	41"	32"
1745	8F	42389	4848	50" x 54" x 72"	41"	32"
1745	8G	92480	3642	36" x 42" x 48"	29"	32"
276	7A	????	4848	50" x 54" x 72"	41"	32"
250	EG	????	4848	50" x 54" x 72"	41"	32"

Manufacturer: Abrasive Blast Systems

Building	Work Center	Asset Number	Door Width	Door Height
256	BG	43388	58"	40"
1865	AP	92595	58"	40"

In-Line T-bar Blasters

Manufacturer: Empire Abrasive Equipment
Model Numbers: IL-885
Other Features: 4 or 6 blast guns
Inlet and Exit Size: 8-1/2" x 8"

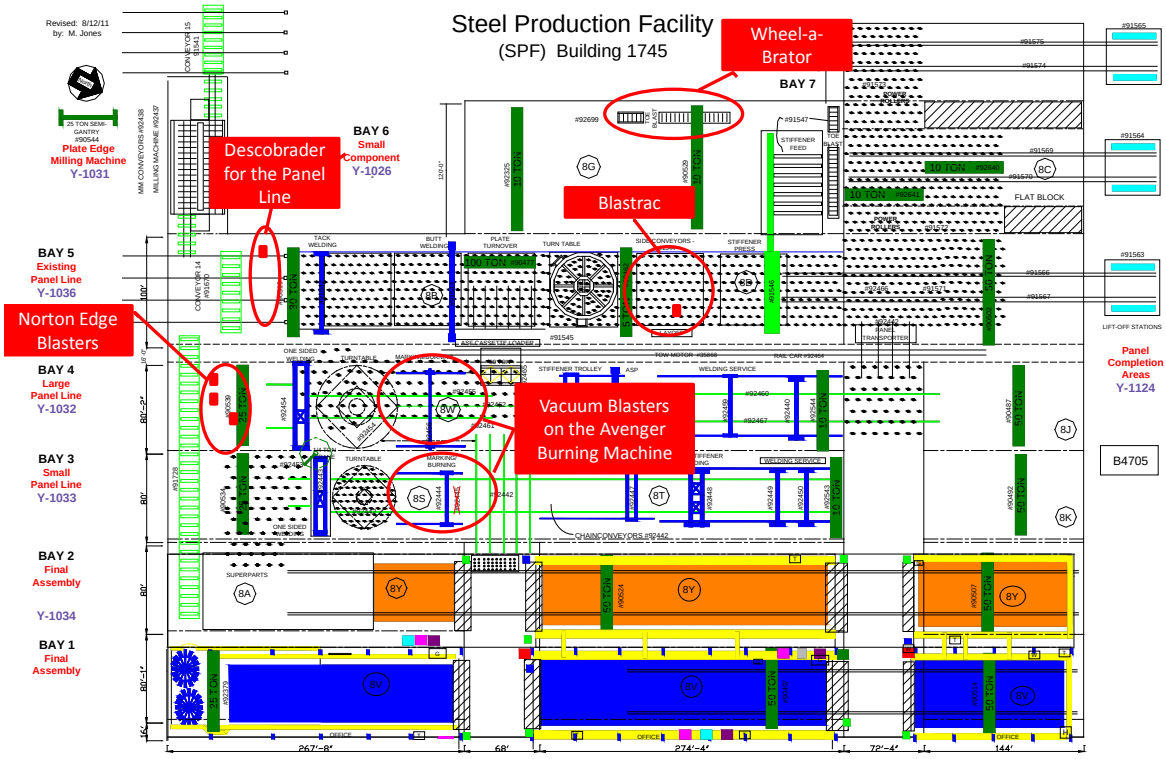
Building	Work Center	Asset Number
1745	8T	92472
276	7A	42381
256	BE	42382

NNS relies on panel line construction for a large portion of the bulkheads and decks that must be produced. NNS has three panel lines that are all in the Steel Production Facility (SPF). They are named the existing panel line (Bay 5), small panel line (Bay 3), and the large panel line (Bay 4). The panel lines produce decks and bulkheads for all contracts, but most are for aircraft carriers. The specialized work areas that make up the panel lines and the types of parts that are assembled into panels (flat plates and straight stiffeners) make this work very conducive to

mechanized sandblasting processes for removing paint in way of weld joints. NNS has implemented several specialized machines in various locations supporting the panel lines to remove paint. The use of these machines is described in the bullets below. The location of these machines is provided in Figure 3. Photographs and key specifications for the sandblasting equipment are provided in Appendix C.

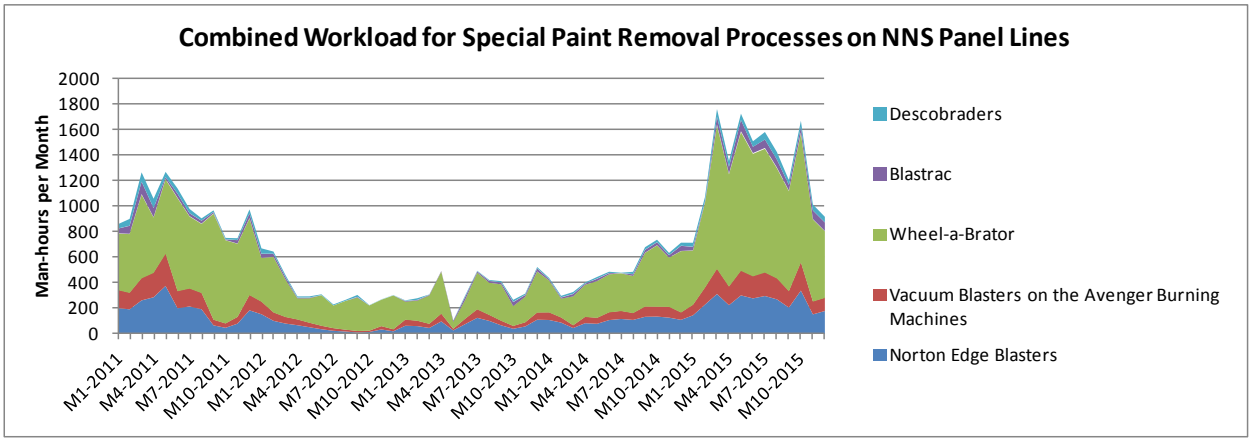
- Norton Edge Blaster- These machines remove paint from the edges of flat plates that are routed to either the small or large panel lines. The machines are located at the south end of Bay 4 in the SPF. A crane operator sets the plates on large wood blocks to make the edges accessible. An operator positions the blasting head with vacuum on the edge of the plate and then pushes and pulls the head along the plate to clean the edges. Once the top side is done, the blast head is turned upside down and the process is repeated for the bottom edge. The overhead crane is used to remove the plate from the wood blocks once the edges are clean.
- Vacuum Blasters on the Avenger Burning Machines – These machines are used after the plates are joined into a plate blanket to remove paint in way of (iwo) where stiffeners will be installed. The small and large panel lines each have a burning machine. The vacuum blast equipment is built into the burning machines and is controlled by the numerical control (NC) program. The machines automatically blast where the stiffener line will be to remove the paint and then mark the stiffener lines. Multiple blasting passes are required to remove the required width.
- Wheel-a-Brator – This machine is used to remove paint from the bottom of stiffeners that will be installed on the existing, large, or small panel lines. The machine is located in Bay 7 of the SPF. All the stiffeners for a panel are delivered to the machine in a large pallet where they are typically processed at one time. The stiffeners are removed from the pallet and placed on the Wheel-a-brator's in-feed conveyor with the overhead crane. The operator runs the stiffeners through the blast cabinet which removes all paint from a T-bar's web and the bottom side of the flange. After the bars are blasted, they are moved to the Wheel-a-brator's out-feed conveyor to be removed with the overhead crane and put back in the pallet.
- Blastrac – This blasting unit with vacuum is used to remove paint from plate blanket lines on the existing panel line. The operator moves the equipment from an adjacent cart to the plate blanket surface. The operator then uses the equipment to blast lines on the plate blanket that were previously installed by a lines crew.
- Descobraders – SFA has three of these portable machines. For the panel lines, one is normally used to clean the top edges of plates on the existing panel line before the plates are joined into a plate blanket. Another unit is permanently assigned to the Web Line in the Fabrication Shop where it is used to remove paint in way of stiffener locations.

Figure 3 – Location of Panel Line Paint Removal Equipment



Panel line utilization at NNS has a cyclical pattern due to the aircraft carrier construction schedules. New aircraft carrier construction contracts have been received at about 5 year intervals in recent years, but most panels are produced during a three-year time period. Also, the units that have the most decks and bulkheads and therefore require panel line assembly are produced relatively late in SFA unit production schedule for the aircraft carrier. This scheduling reality means that the NNS panel lines are loaded to near-maximum capacity during the three year period and at a much lower level the rest of the time. A strategy of this project was to document the amount of grinding that takes place. To make sure the cyclical nature of the panel line workload was considered, it was decided to estimate the grinding (mostly sandblasting in this case) over a 5 year period (From January 2011 to December 2015). A summary of the labor over time that is spent removing primer on using these processes is provided in Figure 4. Labor timelines for each piece of equipment is provided in Appendix C.

Figure 4 - Combined Workload for Panel Line Paint Removal Equipment



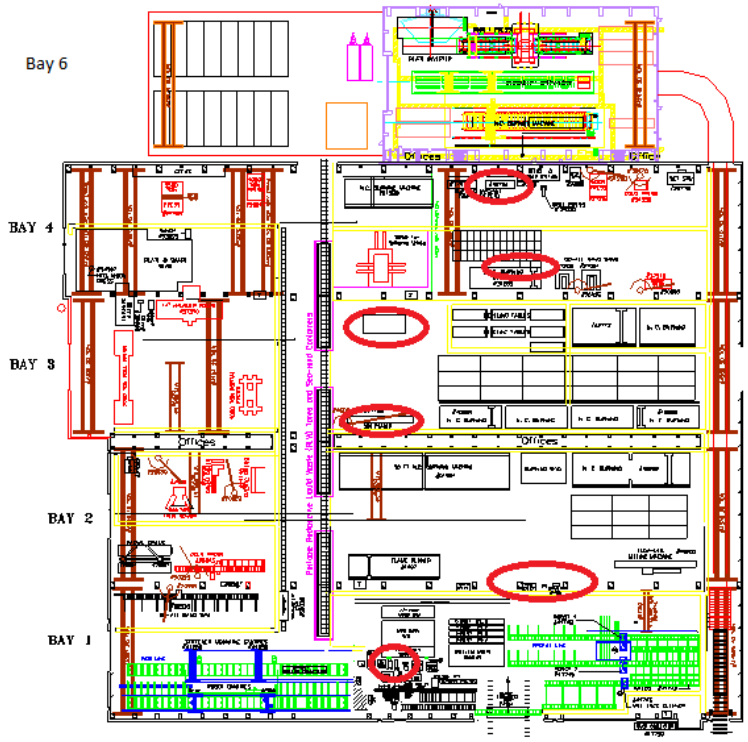
The Fitters sometimes request the Paint department to use sandblasting to remove paint on large parts that would be very time consuming to remove with manual grinding tools. Typically, all pre-construction primer is removed from the entire part by blasting down to bare metal. This process is widely used on many submarine parts that are curved in shape. Due to their large size and curved shape, these parts cannot be cleaned with the type of mechanized processes that are used on the panel lines. The decision to remove paint via blasting is made tactically by production management and is not specified or scheduled in the work package by the planning department. The Paint Department blasters charge on-loan to the Fitters ticket to perform this work. In 2012, 1570 man-hours were charged to the Fitter ticket to perform this work. Examples of the types of parts that that this process is used on include cylinder plates and frames, appendage skin plates, primary shield tank vessel plates, and fairing covers.

2.4 Deckplate Data Collection Processes

Structural grinding is performed by four different departments at NNS: 1) Fabrication Shop, 2) Fitters, 3) Welders, and 4) Non-destructive Test. Primary goals of the data collection process were to determine how much grinding is being performed, what tools are being used to perform the grinding, when is grinding being performed, and to obtain the craftsman's perspective on improvement opportunities.

Collecting data for the Fabrication Shop was relatively easy because most grinding is performed in designated locations and the same personnel grind all day long. Most grinding is performed on the edges of the parts after they have been burned out of raw plates or shapes. Grinding is performed to remove burning slag, correct surface defects, or to break free edges so that paint will adhere better. Most shapes are processed and then ground in Bay 1. Bays 2, 3, 4, and 5 handle the plates with each bay specializing in types of plates according to material type, plate thickness, or processing requirements. A Fabrication Shop layout showing grinding locations is provided in Figure 5.

Figure 5 – Fabrication Shop Grinding Locations



•Areas circled in red are where the full time grinding is performed.

•Other grinding is done around the shop on a case by case basis

•Bay 1 handles the shape process

•Bays 2, 3, 4 and 5 handle the plate process

How to collect the data for Fitters and Welders was a significant topic early in the project. The NNS project team discussed two options: time studies or craftsman interviews. Time studies offered the advantage of being the most accurate way to quantify grinding process speeds and compare grinding process efficiencies, but they would require a large amount of time and resources to perform the studies. The NNS project team decided the most practical way to collect the information was to perform interviews with randomly selected craftsmen.

The NNS project team developed a questionnaire for use in the interviews (See Appendix D). The goal for the questionnaire and interviews was to provide data to quantify how much grinding is being performed, why it is being performed, the tools and consumables that are being used, and to obtain craftsmen's input on improvement opportunities. The questions and interview process was structured to ensure the most accurate grinding time estimates could be obtained. The following process was used to conduct the interviews. First, the interviewer read the grinding definition to the craftsman so that the scope of the questions was clearly understood. Second, the interviewer asked the craftsman to talk about the grinding he performed on his most recent job. Generally, this was the job he worked on the day before. The interviewer asked for the total time the craftsman worked on the job so that percent of time spent grinding could be calculated. Third, interviews were never performed on a Monday to make sure the job and associated grinding activities were fresh in the craftsman's mind. Fourth, the interviews were always conducted at the job site. This allowed the craftsman to show the interviewer the areas he had ground, rather than just trying to describe them. If a craftsman was working on a different job, the interviewer asked him to take us to the job he

worked on the previous day. Fifth, the interviewer asked the craftsman to provide the specific reason for grinding and tool/consumable combination he was using before asking how much time was spent grinding. If a person performed grinding for more than one reason or used various tools and consumables, then each combination was considered a specific grinding activity and separate time estimates were collected on each activity. Occasionally, the interviewer talked to craftsmen who had not performed any grinding the day before. In these cases, the craftsmen would still answer all the general questions but would just end up with no grinding activities and zero grinding time. The NNS project team believed this approach of starting broadly and then narrowing down to an individual grinding activity provided a frame of reference that allowed us to obtain the most accurate estimates that could be achieved with interviews.

The question of "when grinding is being performed" was addressed by putting all grinding activities into the "construction stages" listed in Figure 6 below. The construction stages were assigned to each grinding activity during the interviews.

Figure 6 – Construction Stages for When Grinding is being Performed

Construction Stage	Purpose of Grinding
After burning (fabrication)	To remove slag/sharp edges and correct surface imperfections.
Before fitting	To remove rust and paint
After fitting but before welding	Includes cleaning slag from tacks, installing heater bars, and burning/grinding to remove temporary attachments.
During welding	Includes grinding between passes.
After welding	Scrap-up and dressing of welds
Repair Grinding	Includes grinding whether caused internal rework or identified by NDT.

The opportunities for improvement were addressed in the final part of the interview. The interviewer told the craftsman to put aside the specific job that was discussed and to answer the next questions using all of his shipbuilding knowledge and experiences. The craftsman was asked the two questions listed below.

1. What is the main thing that affects your grinding efficiency using the present tools/processes?
2. What could your department or the shipyard do to reduce grinding time or improve process effectiveness?

Normally, the craftsman had to stop and think about his answer, but the interviewer had already told the person that the next questions were harder and seeing the craftsman think about it was good. Often the answers to the two questions were very similar because a problem and its solution were often discussed in a single statement. The interviewer was careful not to influence the craftsman's ideas. Whatever improvement was mentioned was recorded. The interviewer did ask clarifying questions so that ideas could accurately be

recorded. If the interviewer did not like an idea, he did not tell the craftsman. If the craftsman did not have any ideas, none were recorded. If the craftsman had more than one idea, all were recorded.

A spreadsheet was created to be loaded with data from the interviews. Interviewers were asked to load the data as soon as possible after an interview so that information was most accurate and details were not lost.

The process described above was used to interview 138 personnel working in the structural trades. These craftsmen were employed within the SFA division, the aircraft carrier assembly area and the submarine assembly area. The NNS project team obtained at least two interviews from each work center in SFA since this division has many specialized work centers that assemble large variety of aircraft carrier and submarine components. The number of personnel that were interviewed in each department is provided in Figure 7 below, along with notes about the extent of their grinding and other data that was used to quantify grinding. *Note: All interviews enumerated below were not completed before the NNS current state was presented to Ingalls and Bollinger.*

Figure 7 – Number of Craftsmen that were Interviewed

Trade	Number of Interviews	Notes
Fabrication Shop	5	All grinding is assigned to a small number of personnel that work in designated grinding cells
Fitters	56	Most personnel except linesmen perform grinding
Welders	65	Nearly all welders perform grinding
Non-Destructive Test	12	About 40 personnel perform grinding as part of their jobs in this department. The department maintains other grinding time records that were used to estimate the time and tools used to perform grinding.
Total	**138**	

Non-Destructive Test department grinding data was initially collected from existing departmental records that they maintain. This department grinds to remove rust or surface imperfections in preparation for weld surface inspections MT or Eddy Current (ET) testing. It is preferred that the welds are ready for inspection with no grinding necessary, but in practice it is much easier for the inspector to have a grinder so that minor issues can be corrected.

2.5 Quantify Grinding Time

Once the interviews were completed, the NNS project team decided to quantify the data by the construction stage and by tool/consumable used. The calculations described in this section are primarily for the use of manual grinding tools since panel line and Paint Department blasting activities were excluded from the questionnaires.

The data and percent values presented are very dependent on the progress of new aircraft carrier construction. The submarine work is relatively stable because NNS is in a consistent two hull per year pace. The aircraft carrier workload is much more variable because SFA typically has a gap between carriers. SFA had several CVN 79 units that were being assembled when the interviews were performed, but had much less work in progress than in recent years. For aircraft carrier erection, the team was able to perform a small number of interviews of personnel that were erecting the last structural assembly in the dock.

Quantification of the Total Amount of Time Spent Grinding

The Fabrication Shop typically has 170-225 working within the shop. Between 10 and 15 craftsmen grind full time. This means the department spends about 4 to 9 percent of the total departmental time grinding. The grinding is performed mostly to remove burning slag (80%), but is also used to break sharp edges for paint adherence (12%) and to correct surface defects (8%). The specific percent is dependent on many factors including the shop's workload and the types of parts being produced.

The percent of time that Fitters and Welders at NNS spend grinding has been speculated for many years. Almost all Fitters and Welders grind as part of their jobs, but the nature of their work in the many specialized work centers and diverse construction environments of structural shipbuilding makes estimating the average amount of grinding time very difficult.

The interview results allowed us to specify an average grinding percent of time for Fitters and Welders that was based on data. The team simply took the total grinding times from the interviews and divided it by the total job times that came from the interviews. The percentages for aircraft carrier and submarine work were calculated separately because the type of work is so different. This information is presented in Figure 8.

Figure 8 – Percent of Time Spent Grinding for Fitters and Welders

- All Ships

Dept.	Total Minutes Worked	Total Minutes Grinding	Percent
Fitters	20610	7686.5	37%
Welders	22260	3613	16%

- By Ship Type

Dept - Ship Type	Total Minutes Worked	Total Minutes Grinding	Percent
Fitters-VCS	8340	2561	31%
Welders-VCS	14880	2614	18%
Fitters-CVN	12270	5125.5	42%
Welders-CVN	7380	999	14%

The percents were reviewed with Fitting and Welding process leaders to make sure they made sense. It was noted that the significant difference between the Fitters' aircraft carrier and submarine grinding percents (42% vs. 31%) are logical because a significant number of large parts used to build submarine ring assemblies are blasted to white metal by the Paint department before assembly begins. This practice eliminates a great deal of time of grinding time that would be necessary to remove paint. The difference between Welders' aircraft carrier and submarine grinding percent (18% vs. 14%) was also noted and was logical because the submarine welds typically have more non-destructive testing requirements and specific requirements for fatigue adequacy and contour grinding.

The Non-Destructive Test department has 58 employees. Currently, about 40 of these 58 employees perform grinding. Grinding is typically needed to remove paint for MT testing, to create a smooth surface for ET testing, or to remove minor surface indications that are within the VT limits when found by MT testing. Departmental records indicate a typical inspector who grinds spends about 44% of their time grinding for submarine work or 37% of their time grinding for aircraft carrier work. The removal of surface indications identified by MT was a recent cost reduction improvement. Previously, the inspector notified the Welders of the indication. The Welders corrected the surface indications by grinding if possible and then notified the MT inspector so that the joint could be re-inspected. Having the Non-Destructive Test department remove the indications when possible eliminated the delays associated with contacting the welders.

Quantification By Construction Stage

All jobs and grinding activities discussed during the interviews were assigned to one of the stages of construction identified in Figure 6 during the interview process. For each stage of construction, the grinding activity times were summed and then divided by the total grinding time. These calculations were performed for all the data and then repeated for the two types of ships that NNS is building (aircraft carriers and submarines). Please note that since the percentages only reflect grinding time, then the values in the Percent of Grinding Time columns always add up to 100%. The resulting percentages are presented in Figure 9.

Figure 9 –Grinding Time by Trade, Ship Type, and Construction Stage

- Fitters

	All Ships		CVN Fitter Grinding		VCS Fitter Grinding	
Dept - Grinding Category	Total Minutes Grinding	Percent of Department's Grinding	Total Minutes Grinding	Percent of Department's Grinding	Total Minutes Grinding	Percent of Department's Grinding
Before fitting to remove paint and rust	3759.5	49%	2667.5	52%	1092	43%
After fitting but before welding	2380	31%	2008	39%	372	15%
After Welding	1170	15%	450	9%	720	28%
Repair Grinding	377	5%	0	0%	377	15%

- Welders

			CVN Welders Grinding		VCS Welders Grinding	
Dept - Grinding Category	Total Minutes Grinding	Percent of Department's Grinding	Total Minutes Grinding	Percent of Department's Grinding	Total Minutes Grinding	Percent of Department's Grinding
After fitting but before welding	216	6%	171	17%	45	2%
During Welding	2014	56%	603	60%	1411	54%
After Welding	1037	29%	45	5%	992	38%
Repair Grinding	346	10%	180	18%	166	6%

The data indicates that Fitters spend the most time grinding before fitting which is primarily to remove paint and rust. The grinding before fitting percent is less on submarines which is no surprise due to the Paint Department blasting submarine parts as was discussed earlier. The data shows that Fitters spend more time grinding after welding on submarine than on aircraft carrier jobs. Once again this is logical due to the need to flush more hull and control surface welds along with the increased NDT and contour/fatigue adequacy grinding that is required on submarines.

The majority of the Welders' grinding time is either spent between welding passes or after welding – No surprise there. The biggest difference between aircraft carrier and submarine percents is the grinding that is performed after welding. Once again, it is only logical that the submarine percent would be higher than aircraft carrier percent (38% vs. 29%) due to additional NDT and fatigue adequacy/contour grinding requirements.

Quantification By Tool/Consumable

A tool and consumable was assigned to each grinding activity during the interviews. The NNS interviewers found that different craftsmen often had different names for tools. For instance, some craftsmen called the 7" Vertical Grinder a Surface Sander. To avoid confusion, the interviewer carried photographs and standard names of all tools and consumables very similar to the information presented in Appendix B. If there was any question on the specific tool or consumable used, these pictures would be pulled out and used to make the determination. The information was then loaded into the interview database using the standard names.

The Fabrication shop uses a relatively small of tools and consumables that are presented in Figure 10. The same consumables are often used on the same tools. The 6" angle grinder that is used 39% of the time is always equipped with a 7" Fiber Disc. The protective guard must be removed from the 6" angle grinder to accommodate the 7" Fiber Disc, but all grinders are required to wear triple eye protection to ensure safety (safety glasses, goggles, and face shield with shroud). The 4" angle grinder is used 37% of the time - mostly equipped with the 4" grinding wheel (32%), but occasionally with a 4" cutoff wheel (5%). The 7" Surface Sander is used 18% of the time and is always used with the 7" grinding stone. The Small Straight Grinder and Small Angle Grinder are always used with the Rotary File and account for 6% of total grinding. The Rotary File is almost always used to remove burning gouges.

Figure 10 – Tools and Consumables used in the Fabrication Shop

Tool	Consumable	Percent of Department's Grinding
7" Surface Sander	7" Grinding Stone	18%
6" Angle Grinder	7" Fiber Disc	39%
4" 31A Angle Grinder	4" Grinding Wheel	32%
	4" Cutoff Wheel	5%
Small Straight Grinder	Rotary File	4%
Small Angle Grinder	Rotary File	2%

The percent of grinding time using each tool and consumable was calculated for the Fitters and Welders and is presented in Figures 11 and 12. Please note that since the percentages only reflect grinding time, then the values in the Percent of Grinding Time columns always add up to 100%.

Figure 11 – Tools Used by the Fitters and Welders

	Fitters		Welders	
	Total Minutes Grinding	Percent of Department's Grinding	Total Minutes Grinding	Percent of Department's Grinding
7" Surface Sander	3162	41%	130	4%
6" Angle Grinder	189.5	2%	10	0%
4" 31A Angle Grinder	2634.5	34%	1132	31%
Large Straight Grinder	198	3%	286	8%
Small Straight Grinder	185	2%	437	12%
Small Angle Grinder	380	5%	527	15%
Small Needle Gun	567.5	7%	1091	30%
Large Needle Gun	0	0%	0	0%
Belt Sander	100	1%	0	0%
Descobrader	0	0%	0	0%
Glove Box	120	2%	0	0%
In-line T-bar Blaster	0	0%	0	0%
Dynafile	0	0%	0	0%
Stand-up Grinder made from 7" Vertical Grinder	0	0%	0	0%
Cleco Prototype 6" Angle Grinder	90	1%	0	0%
IR 4" tester grinder	60	1%	0	0%

The tools that were used for grinding more than 10% of the time are highlighted yellow. The Fitters primary tools are the 7" Surface Sander and the 4" Angle Grinder. Once again, the majority of their grinding was to remove paint. The small needle gun was a distant third place – It was used almost exclusively to clean tack welds.

The welders typically used many more grinding tools. They relied primarily on the 4" Angle Grinder for post-weld grinding but they were often challenged to perform this grinding in small spaces and with obstructions that limited the size of the tools they could use. This fact accounts for the large usage of the Small Angle and Small Straight Grinders that were used. Another primary tool is the Needle Gun which is used primarily to clean welds between passes and remove loosely adhering spatter.

The data shows that some tools were rarely used by Fitters and Welders and there are several explanations. Some tools are only available in a limited number of work centers and since only a few interviews were conducted in each work center their usage percents are therefore low when divided by the total amount of grinding performed in the shipyard. This equipment includes the belt sanders, Descobraders, Glove Boxes, In-Line T-bar Blasters, and the Stand-Up Grinder). These tools are not used everywhere, but they are usually very effective in the places they are used. Other tools like the Cleco Prototype and IR 4" Grinders are being evaluated by the Tool Room department and would therefore only be available to a few employees. Another tool, the Dynafile, was not purchased by the tool room and is therefore not supported by them. It is a good example of a department going around the official system for procuring tools to get a tool they feel is needed.

The consumables used by Fitters and Welders are provided in Figure 12. The consumables with grinding percentages greater than 10% are highlighted yellow. For the Fitters, it should be no surprise that the primary consumables are those that are used on their primary grinding tools (7" Surface Sander and 4" Angle Grinder). The Welders percentages show a high reliance on the Rotary File. These bits are effective at removing metal which is what the welders need to do correct many surface defects. These bits are very versatile because they come in several shapes and can be used on several tools like the Large Straight Grinder, Small Straight Grinder, and Small Angle Grinder (See Appendix B). Several consumables have percentages of "0" indicating they are rarely used in the structural trades. These items are available in the tool room when needed, but probably have much greater usage requirements in non-structural trades.

Figure 12 – Consumables Used by the Fitters and Welders

	Fitters		Welders	
	Total Minutes Grinding	Percent of Department's Grinding	Total Minutes Grinding	Percent of Department's Grinding
7" Grinding Stone	785	10%	0	0%
7" Fiber Disc	2377	31%	130	4%
7" Tiger Paw	0	0%	0	0%
6" Grinding Wheel	90	1%	30	1%
6" Cutoff Wheel	99.5	1%	0	0%
4" Grinding Wheel	1332	17%	852	24%
4" Cutoff Wheel	820	11%	45	1%
4" Fiber Disc (Tiger Paw)	2.5	0%	0	0%
3" Wire Brush	260	3%	190	5%
1", 2", or 3" Sanding Discs	660	9%	0	0%
Spiral Point Abrasives	0	0%	0	0%
Pencil Point Abrasives	0	0%	0	0%
2" Grinding Wheel/Stone	0	0%	0	0%
1", 2", or 3" Flap Wheels	0	0%	0	0%
1" or 2" Buffing Bands	0	0%	0	0%
1/2", 3/4", or 1" Wire Brushes	0	0%	36	1%
Rotary File	383	5%	1194	33%
Small Needle Bundle	567.5	7%	1091	30%
Large Needle Bundle	0	0%	0	0%
Fiber Wheel	0	0%	0	0%
Grit	120	2%	0	0%

The Non-Destructive Test department's tool and consumable usage is presented in Figure 13. The percentages are broken down by ship because, as noted earlier, the Non-Destructive Test department performs more grinding on submarine than on aircraft carrier jobs. This is a breakdown of total grinding time so the percentages for each hull will add up to 100%. On the aircraft carrier side, note that more grinding is performed to remove paint as indicated by the 53% of the time that either a 3" Wire Wheel and Wire Brush is used. These consumables are only used 29% of the time on submarines which is most likely due to the fact that submarine

ring units are blasted to white metal before assembly, which eliminates the need to use manual grinding tools for paint removal.

Figure 13 – Tools and Consumables used by the Non-Destructive Testing Department

	4" Angle Grinder		Small Angle Grinder			Small Straight Grinder		
	3" Wire Wheel	4" Grinding Wheel	Wire Brush	Rotary File	Sanding Disk	Wire Brush	Rotary File	Sanding Disk
Submarine	12%	29%	17%	18%	1%		11%	12%
Aircraft Carrier	39%	35%	11%	4%		4%	6%	

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3 Bollinger and Ingalls Current State Documentation

Bollinger Shipbuilding and Ingalls Shipbuilding were hired as subcontractors for this project to provide an industry perspective. Representatives from both shipyards were invited to Newport News in July 2013 to review the NNS current state documentation that was described in the previous section. Each shipyard was then asked to perform a similar, but less extensive evaluation of their grinding current states. Each shipyard agreed to consider the items listed below in their evaluations.

- Documentation of tools and consumables used
- Summaries of previously completed grinding studies
- Opportunities for improvement

Newport News Shipbuilding representatives traveled to Ingalls Shipbuilding in September 2013 to review the Bollinger and Ingalls current states. While at Ingalls, the NNS group toured their structural shops to see the tools in use. After the Ingalls visit, the NNS group drove to Bollinger's Lockpoint facility to tour that shipyard and see their grinding tools and processes. A summary of the each shipyard's current state is provided in the sections below.

3.1 Bollinger Current State

Dennis Fanguy of Bollinger presented their current state. The complete presentation is provided in Appendix E. The presentation began with an overview of Bollinger Shipbuilding including their history, facilities, capabilities, and product lines. Photographs and descriptions of Bollinger's primary grinding tools and consumables were presented. The primary tools included a DeWalt electric grinder and a smaller right angle grinder that used 4" consumables. Primary consumables are Brilliant grinding discs and Walter flap discs to be used as a finishing disc. A list of the consumables purchased during 2012 and 2013 was provided to provide an indication of usage.

Bollinger provided a summary of the grinding tool and consumable testing that was performed during 2009 and 2010. A 2009 study of alternative consumables found very little performance differences between different brands. A 2009 study of DeWalt and Bosch grinders found that both brands were acceptable, but craftsmen had a slight preference for the DeWalt grinders and it was felt the Bosch grinders may not hold up in the Bollinger environment. In 2010, Bollinger compared Brilliant discs against 3M's Cubitron II discs. The Brilliant brand was retained as the standard, primarily because the Cubitron discs cost more. Later in 2010, Brilliant and Walter flap discs were compared. The Brilliant flap disc cost more and was selected, but employees rebelled against the decision. Bollinger reversed the decision and decided to keep Walter as the standard flap disc.

Bollinger interviewed five craftsmen from various trades using the questionnaire developed by NNS. Improvement opportunities from these interviews included the following:

- Tackers could use smaller tacks

- Greater use of corner joints
- Put less paint in area to be tacked

3.2 Ingalls Current State

Jeffrey Cook and Ken Miller of Ingalls presented their current state for Ingalls Shipbuilding. The complete presentation is provided in Appendix F. Ingalls provided photographs with specifications and usage information for their grinding tools and consumables. Their primary tools are the Cleco 7" vertical grinder, Buckeye 4" angle grinder, and the 3M Burr Motor/Die grinders. Tool specifications included brands, model numbers, performance specifications, size/weight details, and the number of tools in stock. Photographs of the consumables for each tool were provided including the grinding application for each consumable. A list of consumables usage from January to August 2013 was provided.

Ingalls presented a summary of their evaluations comparing "legacy" to "preferred" tools and consumables. Most evaluations concluded that the 3M consumables were superior because they cut faster, had a longer life, and had less vibration. Ingalls did most of the research in 2011 and made a significant switch to 3M Cubitron II products in 2012. Note: Appendix A – Project number 10, provides another detailed summary of the evaluations Ingalls performed in 2011.

Ingalls presented a list of 12 requirements from the ship specification document titled "Welding and Workmanship requirements for Naval Surface Ship Hull Construction (SSG-M5350) that list the reasons grinding is performed (See Appendix F - Slide 15). The data indicated their top two reasons accounted for 40% of their grinding - Remove paint/primer (20% of grinding time) and to clean back gouged welds (20% of grinding time).

Ingalls had discussions with about seven craftsmen to identify their opportunities for improvement. These suggestions included "continue process improvements", "more application of tape in the paint department to reduce the amount of paint removal", and "have welders perform some of the grinding."

Ingalls summarized all of the above and presented their perspective on improvement opportunities as listed below:

- Stop the use of inefficient abrasives
- Use weld-through primer
- Stop polishing welds
- Eliminate the requirement for grinding temporary attachments

4 Identify Best Practices and Opportunities to Reduce Grinding Labor

A primary goal of identifying improvement opportunities was to make sure they were based on our current state analyses. The NNS Technical Lead took the following approach to achieve that goal. NNS identified an initial set of opportunities while Bollinger and Ingalls were still documenting their current states. Then, the three shipyards met at Ingalls to review the Bollinger and Ingalls current states. Following the current state review, the overall project team reviewed the improvement opportunities developed by NNS and determined if they were NNS-specific or industry opportunities. A more thorough discussion of this process and the opportunities that were identified is included in the following sections.

4.1 NNS Initial Identification of Opportunities

The following sections describe how NNS developed the initial set of improvement opportunities. The NNS team decided the best way to identify improvement opportunities would be to assemble subject matter experts and systematically discuss the reasons they grind and the strategies that could be implemented to eliminate or reduce grinding for that reason. This approach required preparation to make sure the improvement opportunities selected were based on all the facts that had been collected. First, the NNS project team wanted to understand the craftsmen's comments that were collected during the interviews. Second, a list of reasons that each department had for grinding was needed and the relative weight for each grinding reason. Once these two sets of information were available, the NNS team sat down with the subject matter experts to identify the opportunities. Further information about this process is described in the sections below:

Summarization of Craftsmen Comments

The first task was to make sure that the craftsmen's comments and ideas about improvement opportunities collected during the interviews were understood and summarized. As discussed earlier, the craftsman was asked two questions about improvement opportunities during the interviews. The first question was "What is the main thing that affects your grinding efficiency using the present tools/processes?" The second question was "What could your department or the shipyard do to reduce grinding time or improve process effectiveness?"

The NNS team reviewed and categorized all the resulting comments. Then Pareto charts were developed for the Fabrication, Fitters, and Welders departments. Common categories were developed for the Fitters and Welders so that each department's ideas could be better compared. Figures 14 through 16 provide the Pareto charts that were developed for these three departments. The actual text of the Fitter and Welder comments that support Figures 15 and 16 are provided in Appendix G.

Figure 14 – Fabrication Department Opportunities for Improvement from Interviews

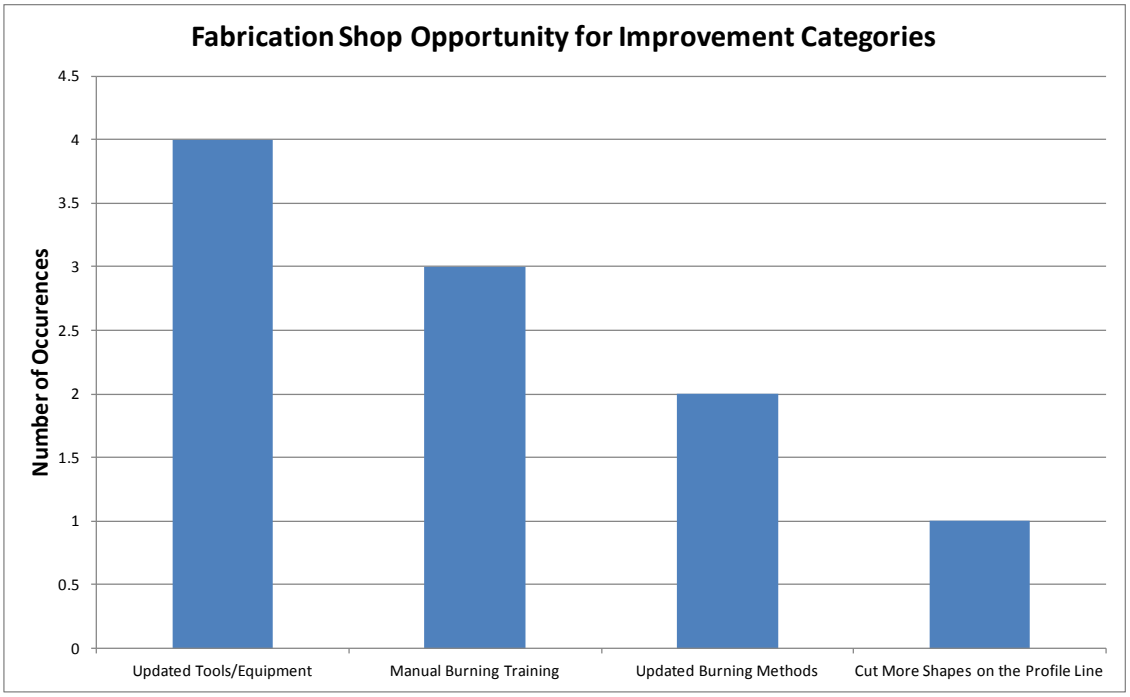


Figure 15 – Fitters Department Opportunities for Improvement from Interviews

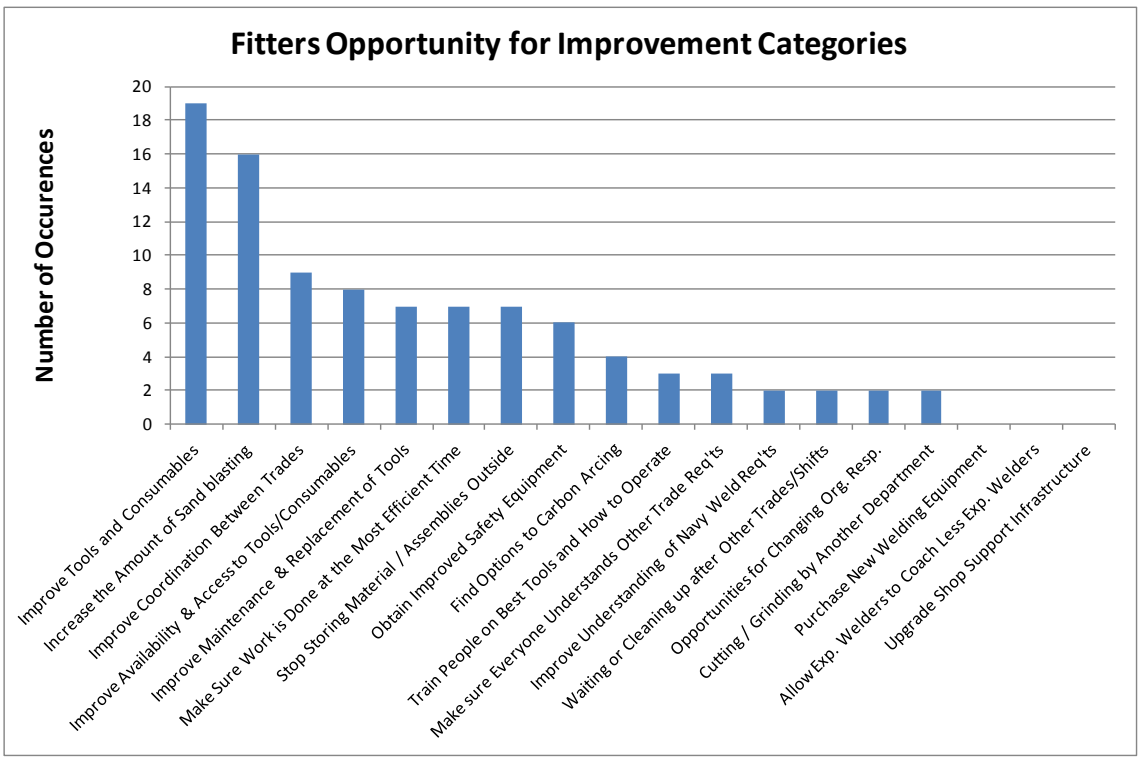
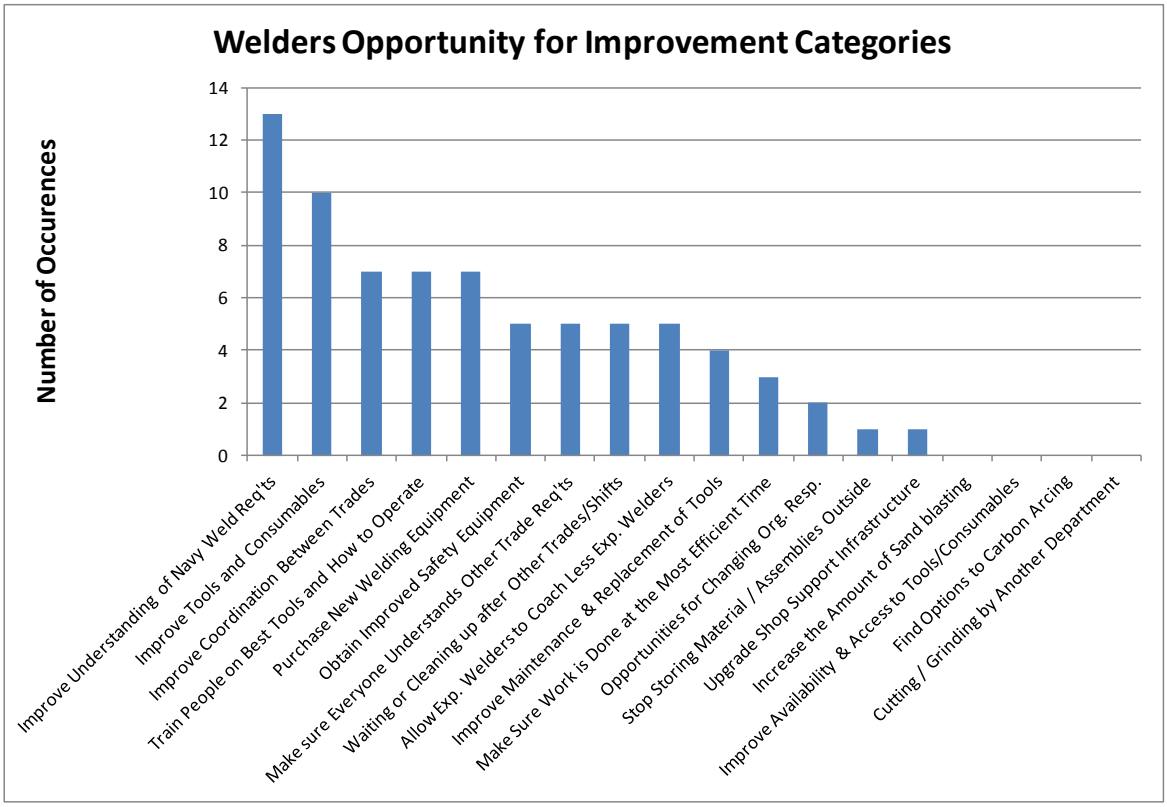


Figure 16 - Welders Department Opportunities for Improvement from Interviews



Quantification By Reason for Grinding

The four departments that perform structural grinding at NNS were asked to develop a list of the reasons that grinding is performed. Interviewers had asked the craftsmen why each grinding activity was performed during the interviews, but the official departmental lists provided a way to classify the varied wording of the craftsmen's answers into one of the official reasons for grinding. The time each department spent grinding for each reason was calculated from the interview data. The grinding time for each reason was then divided by the total grinding from all the interviews for that department to develop a percentage of total grinding time for each reason. This approach means that the percentages for each department reasons add up to 100% for each department

The NNS project team established a "priority ranking" for each departments' reasons for grinding based on the percentage of times calculations described above and the number of personnel in the department that perform grinding. The priority ranking simply illustrates how much time the department spends on each reason for grinding. A large ranking means the department spends a large amount of time grinding for that reason. The rankings are proportional both within and across departments – For instance, comparing a priority ranking of 1000 with 500 means that twice as much time is spent grinding for the reason with a ranking of 1000 versus the grinding reason that has a ranking of 500. Obviously, when the NNS project

team began identifying opportunities for reducing grinding labor, more effort was focused on the grinding reasons that have a high priority ranking. The reasons for grinding and associated priority ranking are presented for each department in Figures 17 through 20.

Note: The "percent of grinding time" numbers that are presented in this section are slightly different than those presented in Figures 9-12. For instance, the percentage of time fitters spend removing paint and rust is indicated as 49% in Figure 9 and 42% in Figure 18. The reason is that additional interviews were conducted between when the Figure 9 and 18 tables were developed. The figure 9 table was developed for the Task 1 presentation to Bollinger and Ingalls. Additional craftsmen interviews were conducted after their visit to improve accuracy of the data. This also highlights the fact that all the grinding time estimates are approximations based on craftsman interviews about specific jobs. They are valuable for establishing priorities, but should not be used to estimate how much total time the shipyard spends grinding.

Figure 17 – Fabrication Department's Reasons for Grinding

Reasons for Grinding	Percent of Department's Grinding Time Performed for this Reason	Priority Ranking
Remove burning slag	80%	51
Break sharp edges	12%	8
Correct Surface Defects	8%	5

The Fitters Department's reasons for grinding are listed and quantified in Figure 18. Note that several reasons for grinding have a priority ranking of zero. This is because the department provided this reason for grinding, but no instances of grinding for this reason were collected during the craftsmen interviews. This happened for several reasons. First, some reasons for grinding are component-specific and the component was never the topic of an interview. Second, the grinding may only be performed during a specific stage of construction and the interviews did not take place during the stage. And third, the craftsmen may rarely have to grind for that reason and, by chance, craftsmen had not performed that type of grinding on the job that was discussed during the interview.

Figure 18 – Fitters Department Reasons for Grinding

Reasons for Grinding	Percent of Department's Grinding Time Performed for this Reason	Priority Ranking
Remove paint and rust to prep weld joints for weld	42%	1116
To remove temporary attachments	14%	374
Cleaning Tacks	11%	288
To cut material ilo saws and torches	10%	277
Grind rough welds to prep for NDT	10%	266
Smooth rough cut plate edges to prep for welding	7%	173
Flush plug welds	3%	80
Remove spatter from welds and base material	2%	46
Flush cured PR944 (LWWAA, Chin Array, and FLTA)	1%	18
Break square edges of plates for paint prep.	0%	7
Fatigue Adequacy Grinding	0%	0
Contour Grinding	0%	0
Grinding welds flush iwo deck coverings	0%	0
Grinding welds on decks to meet a required height.	0%	0
Grinding welds flush on appendages	0%	0
Grind wide welds flush to prepare them for UT inspection	0%	0
Flush weld repairs to base material	0%	0

The Welders Department reasons for grinding are listed and quantified in Figure 19. The welders also had some reasons for grinding that were never captured during the interview process. The reasons are the same as were previously discussed for the Fitters Department.

Figure 19 – Welders Department Reasons for Grinding

Reasons for Grinding	Percent of Department's Grinding Time Performed for this Reason	Priority Ranking
Cleaning between passes	30%	454
To make welds acceptable to weld visual inspection requirements	26%	391
Cleaning weld repairs	18%	270
Prepping for MT	11%	174
Removing weld spatter above weld visual inspection requirements	8%	115
Cleaning backside of back gouged welds	2%	29
Contour	2%	27
Prepping for Painting	2%	26
To remove temporary attachments	2%	26
Prepping for UT	0%	6
Fatigue Adequacy	0%	0
To meet height requirements on flight deck and main deck	0%	0
To flush welds IWO Appendages	0%	0
To flush welded scars in base material	0%	0

The Non-Destructive Test Department's reasons for grinding are listed and quantified in Figure 20. Once again, the "remove rust" reason for grinding occurs, but was not captured on a job discussed during the craftsman interview.

Figure 20 – Non-Destructive Test Department Reasons for Grinding

Reasons for Grinding	Percent of Department's Grinding Time Performed for this Reason	Priority Ranking
Removing spatter & roughness	55%	142
Remove Indications	45%	114
Remove Rust	0%	0

Meetings to Identify Improvement Strategies

Meetings were held with subject matter experts from each of the four structural trades to identify opportunities to reduce grinding labor. These were essentially brainstorming meetings. An agenda was prepared for each meeting that included the department's reasons for grinding table, Pareto charts for grinding improvement opportunities if available (See figures 14-16), and/or the list of improvement opportunities that were identified by craftsmen during the interviews (See Appendix G).

During the meetings, the NNS project team took each reason for grinding (See Figures 17-20) and asked the participants to identify the strategies and supporting actions that their department or the company could take to eliminate the grinding that was performed for that reason. Occasionally, the NNS team found that some "Reasons for Grinding" had the same solutions and the strategies/actions therefore were combined. Meeting minutes were written after the meeting and sent to the participants to ensure the ideas were recorded correctly. The strategies and actions identified during these meeting are presented in Appendix H.

4.2 Compare / Contrast Current States from Participating Shipyards

After Bollinger and Ingalls developed their current states, the overall project team discussed notable similarities and differences. The similarities and differences discussed are described in more detail below:

- All three shipyards agree that grinding has a significant negative impact on injuries and steps to eliminate or reduce grinding will reduce eye injuries in particular. Grinding particles can get into eyes despite the shipyard's best attempts to make sure personnel are wearing proper safety glass, hoods, with shrouds, and or goggles. A foreign particle in the eye is the most common reason for personnel to visit the clinic at all three shipyards. Grinding operations are the underlying cause for a large percentage of these clinic visits.
- All three shipyards use different tools and consumables. All three shipyards have performed comparisons of alternative products but the comparisons resulted in different conclusions. For example, all shipyards agreed that Cubitron II sanding discs removed material faster, but only Ingalls concluded that the labor savings outweighed the additional cost of the Cubitron products.
- Tool and consumable decisions are heavily influenced by craftsmen preference. This was clearly illustrated when Bollinger said they tried to switch from the Walter flap disc to a less expensive consumable but the craftsmen "rebelled" and the decision to switch was rescinded.
- The shipyards had very different policies for issuing consumables. Bollinger requires that a craftsman bring back the old consumable before a new one is issued. Ingalls used to have a similar policy, but began recently began stocking consumables on the shop floor. The Ingalls Tool Room manager said he had seen usage increase significantly due to the change in policy and would like to see it changed back. NNS allows up to five consumables to be issued by the tool room to the craftsman at one time.

- All three shipyards have records of consumable usage or purchases. The overall project team agreed that consumable usage may be a good way to measure the effectiveness of grinding improvements over time. The baseline and routine measurements would need to be adjusted for workload to be an effective measure. Consumable usage information is readily available as opposed to the difficulty of collecting man-hour spending for grinding.
- NNS relies extensively on grit blasting to remove primer in way of welds. Bollinger and Ingalls both rely more heavily on grinding techniques to remove primer. Ingalls does use a toe blaster to remove primer from the toe of webs for stiffeners being installed on the panel line. NNS heavy reliance on grit blasting is probably due to their much more extensive paint removal requirements iwo welds. These requirements have forced NNS to develop expensive but effective grit blasting processes over the past several years. Bollinger did express interest in obtaining a glove box for removing paint from small parts.
- All three shipyards agreed they were grinding too much for cosmetics (to make the welds pretty). Each shipyard had challenges making the craftsmen understand the true requirements and that they should perform only the work needed to make those requirements. Each yard had an issue with personnel smoothing and polishing weld surfaces because of the perception that it resulted in a better quality job.
- The improvement opportunities for all three shipyards were very similar, but the labor reduction offered for each opportunity was different. For example, NNS' biggest labor reduction opportunity is for removing primer iwo welds. Ingalls and Bollinger both had the same opportunity, but the potential savings was much lower because they perform less primer removal and Bollinger is welding through primer in some cases. Ingalls said they were spending about 20% of their grinding time for removing primer whereas the figure for NNS is about 25%. By contrast, Bollinger said much of their grinding is performed to break free edges for coating adhesions and they viewed that as their greatest opportunity. NNS and Ingalls saw an opportunity, but a much less significant than others. The Ingalls analysis says 5% of their grinding cost was for breaking free edges.

4.3 NNS Engineering Initiatives to Eliminate Grinding Temporary Attachments

After Bollinger and Ingalls presented their current states during our Ingalls visit, NNS presented two relatively new initiatives that NNS Engineering had taken to reduce grinding. Brief summaries of the two initiatives are provided below:

- Unnecessary grinding is done on aircraft carriers because there was not an effective way to communicate compartment-specific surface smoothness requirements to the trades. Ship specifications have less stringent temporary attachment removal requirements in certain space, such as those to be insulated, but the fitters and welders assembling the ship do not have any way of knowing what steel surfaces and welds fall in the spaces with reduced requirements. To alleviate this situation, on CVN 78 Newport News

engineering piloted a process where supplemental data sheets that identify temporary attachment removal requirements for each unit. These packages identify surfaces where standard temporary attachment removal processes are not required and eliminate the grinding that would otherwise be required.

- NNS Welding Engineering performed extensive testing and submitted a proposal to NAVSEA to allow temporary attachments to be removed by mechanical means (ie. Hammer strikes). The testing showed that base material was not damaged by removing attachments with hammer strikes when the base material was above 5/16" thick and the attachment was welded only on one side. NAVSEA agreed with the proposal and the aircraft carrier ship specification and applicable procedures are now being revised. *Note: Other restrictions besides material thickness also apply.*

4.4 Industry Identification of Opportunities for Improvement

NNS, Bollinger, and Ingalls reviewed the grinding reasons, improvement strategies, and supporting actions that were developed by NNS and previously presented in Appendix H. Nineteen shipyard industry improvement opportunities were agreed to as a result of this discussion. In a subsequent session, each shipyard ranked the improvement opportunities in terms of importance to their yard. It was clear from the discussion and rankings that one yard's high priority opportunities were sometimes another yard's low priority opportunities due to the type of work performed by the yard and other circumstances. *Note: Readers should realize that a low priority ranking does not necessarily mean it is not a good opportunity – In many cases it means that the shipyard has already made significant improvements in this area and it makes more sense for them to focus on other opportunities that have "lower hanging fruit".*

The improvement opportunities were assigned to one of the construction stages identified earlier in Figure 6 so that readers could easily understand the processes that would benefit from the improvement opportunity. Improvement opportunities that are applicable to more than one construction stage were assigned a value of "Multiple" to designate multiple construction stages. Finally, the improvement opportunities were ranked within the construction stages according to the average overall ranking of each shipyard.

The results of the categorization and ranking efforts described above are presented in Figure 21. The subsections following Figure 21 provide descriptions of each opportunity in the order of the construction stage to which it is assigned.

Figure 21 – Shipyard Industry Grinding Improvement Opportunities

Construction Stage	Improvement Opportunity Description	Ingalls Overall Ranking	NNS Overall Ranking	Bollinger Overall Ranking	Ranking within Construction Stage
After Burning	Standard burning recipes for manual burning	10	8	7	1
	Maximize cutting/beveling on numerical controlled (NC) burning machines	18	4	15	2
	Routinely clean burning machine water tanks	13	16	11	3
	Change perception of acceptable burned edge surface smoothness	17	10	17	4
Before Fitting	Weld-through pre-construction primer	1	1	19	1
	Use grit blasting in lieu of grinding	4	19	18	2
After Fitting but Before Welding	Non-welded temporary attachments	2	6	4	1
	Removal of temporary attachments with hammer strikes	3	12	8	2
During Welding	Use needle guns to remove silicate and lightly adhering spatter	12	18	5	1
After Welding	Implementation of modern welding equipment	15	3	2	1
	Change perception of acceptable weld surface smoothness	7	2	16	2
	Documents that define temporary attachment removal and scrap-up requirements	5	7	14	3
	Use Eddy Current (ET) in lieu of Magnetic Particle (MT) testing	9	13	9	4
	Implement *Rust-Off* for cleaning flash rust from welds prior to non-destructive testing	11	17	6	5
	Non-destructive testing (NDT) department to perform grinding on joints requiring NDT	19	9	12	6
Multiple	Plan assembly so that grinding is performed at the most accessible stage of construction	6	5	3	1
	Identify non-grinding tools to break free edges and shave weld reinforcements	16	14	1	2
	Testing and comparisons to find the most effective tools and abrasives	8	15	10	3
	Resolve conflicts between ship specifications and procedures	14	11	13	4

Construction Stage: After Burning

1. **Standard burning recipes for manual burning** – All shipyards should maximize burning on NC burning machines, but it is simply not always possible. When manual burning is required, grinding to remove surface imperfections is costly. For NNS contracts, flame or arc cut burned surfaces must adhere to the smoothness requirements pictured in Figure 1. All shipyards should maintain work standards that define gas pressures at the tip, burning tip sizes, and other parameters so that craftsmen can burn surfaces that do not require grinding. Ingalls has worked with torch vendors to establish standards for

torch tips relative to material grades and thicknesses and will continue to identify the most desirable permutation.

2. **Maximize Cutting/Beveling on NC Burning Machines** - This is a significant industry opportunity for NNS, but a much lower priority for Ingalls and Bollinger. NNS priority is probably higher to the higher usage of thick plate on VCS and CVN contracts that require beveling. Flame or arc cut burned surfaces have smoothness requirements similar to those pictured in Figure 1. To achieve optimum edge quality, burning equipment parameters must be tightly controlled. The most practical way to achieve the needed control is to have burning performed on NC burning machines with operators who perform burning daily. Manual or portable burning equipment is often used by personnel that do not perform burning everyday and do not fully understand or have all the elements needed to achieve a high quality burn. Often, Fitters actually use grinding tools and cutting wheels to cut material. NNS has significant opportunities to gradually reduce the cutting that is being performed with manual tools. The technology to cut square tubes is being developed on the NNS Profile Line. New NC burning machine that are being installed at NNS have the ability to cut bevels. However, the NC burning machines cannot be used for beveling until data tables that are needed by the NC cutting programs are populated with data that can only be obtained through extensive burning testing. NNS must also emphasize to craftsmen to continuously report when they are performing cutting that can be performed on NC burning machines so that these operations can be eliminated on future ships. Bollinger has purchased a NC pipe cutting machine in 2013 and will further invest in this technology over the next couple of years. Ingalls will continue to look for opportunity to further utilize their burning machines and insure the accuracy of their performance.
3. **Routinely Clean Burning Machine Water Tanks** - This is an industry opportunity. NC plasma burning machines capture slag below their burning table surfaces that can eventually build up so that it touches the bottom of the plate being burned. The slag will then stick to the bottom of the plate during the burning process. This slag must be removed by grinding and often requires the plates to be flipped with a crane. All shipyards should have a process that requires routine slag removal from burning machines and replacement of burning skids before slag gets to the top of the burning skids. Ingalls changes the burning skids in sections to minimally impact production when the burning tables require slag removal.
4. **Change Perception of Acceptable Burned Edge Surface Smoothness** - This is an industry opportunity. All three shipyards perform grinding to make burned edges of piece parts smooth. Sometimes this is done excess of ship specifications and procedures. The excessive grinding can be linked to expectations of some customers (Fitters). Some customers' expectations for burned edge smoothness are greater than the specification/procedure. The customer's expectations become complaints and the Fabrication shop craftsmen often grind the edges smoother to promote customer satisfaction. Fabrication shop personnel gradually adopt more stringent customer expectations as perceived quality requirements and perform grinding that "makes surfaces pretty". Fabrication Shop management needs to clearly identify grinding as a non-value added activity and a form of rework. The emphasis should be on performing

burning processes with such precision that grinding is not necessary. If customers are requesting edges be ground in excess of requirements the customer needs to be informed about the true requirements. The need to grind should be viewed as an anomaly. When grinding is performed, people should ask, "What went wrong with the NC burning process to make this grinding necessary?" A possible method for shop management to focus changing the perception of grinding may be to measure and communicate grinding man-hours per part to shop leadership and workers so that everyone can see the cost of grinding and the data can be used to set improvement goals. Continuous improvement training and coaching can be implemented. Burning layoff personnel actually decide when grinding is necessary. These craftsmen can be trained and coached not to send parts to the grinding skids unless absolutely necessary. Grinders should be empowered to call timeout with burning machine operators when they start seeing parts with excessive grinding requirements. Ingalls plans to eliminate excessive grinding by conducting training on application-specific requirements.

Construction Stage – Before Fitting

1. **Weld-Through Pre-construction Primer** - This is the number one priority for NNS and Ingalls. Conversely, it is Bollinger's lowest priority because they have been successfully welding through primer on some welding processes for many years. NNS is initiating a new investigation of weld-through primer as a result of this project. NNS currently uses an organic epoxy primer that cannot be welded through. NNS fitters must remove all visible paint 2" from the weld before welding or any hot work can be performed. A near-term opportunity for switching to an inorganic zinc (weld-through) primer may be reduced paint removal requirements iwo hot work. For NNS, this opportunity must also be tempered with caution because of our previous experiences. Successfully implementing weld-through primer at NNS will require much effort and research. Significant obstacles must be overcome including current OSHA interpretations. The new investigation will focus on fundamental questions about removal requirements and the benefits of making the switch. In the late 1990's, NNS was unable to adequately control primer thickness with their existing plate blasting equipment when using weld-through primer on commercial ships. A recent, 2011 IR&D project welded through primer with poor results due to issues with application thickness. When this report was reviewed with key NNS vice-presidents, it was made clear that the impact on weld quality and welding speed would need to be clearly understood before NNS begins welding through primer. Ingalls also has a significant opportunity with weld-through primer with 20% of their overall grinding time being used to remove primer and paint. Ingalls already uses an inorganic zinc (weld-through) primer so this is mainly a matter of them developing the capabilities of welding through the primer. Ingalls has been pursuing this opportunity aggressively over the past year. They reported during our meeting that they now have the ability to control primer application thickness on both plates and shapes. They have developed some welding processes for welding through primer that have been successfully demonstrated in their welding laboratory. At the

time of this report's issue, they are preparing to test the first weld processes on the shop floor.

2. **Use Grit Blasting in lieu of Grinding** - This is an industry opportunity, but not one that is significant at this time. NNS uses grit blasting extensively to remove primer prior to welding. These processes and the specialized machines NNS has implemented have been shown to be very effective and fast at removing all primer, including the primer that is in the pores of the plate. Another benefit of grit blasting over mechanical grinding is that grit blasting does not reduce material thickness (remove stock material) in normal usage. Ingalls and Bollinger do not use very much grit blasting. This is probably due to the fact that their less extensive primer removal requirements described in the previous section make the higher investment that is needed for grit blasting impractical. Bollinger did see an opportunity to obtain a glove box to perform grit blasting on small parts (See photograph of this equipment in Figure 2). NNS should place its primary focus on implementation of weld-through primer rather than grit blasting at this time. Implementing a weld-through primer could reduce primer removal requirements and affect the business case for procuring additional equipment. NNS should however, to continue using the equipment it has since it is much more efficient than alternative methods of removing primer. Ingalls also recognizes value in this and will be looking into applications where this could be implemented.

<u>Construction Stage – After Fitting but Before Welding</u>

1. **Non-Welded Temporary Attachments** - This opportunity had a high priority for all three shipyards. The process for removing welded temporary attachments often requires base metal repairs and associated grinding. Non-welded temporary attachments require no such repairs. There are many types of non-welded temporary attachments. Some industry suppliers such as *Fit Up Gear* specialize in providing families of non-welded temporary attachments. Other creative devices are being developed by shipyards as opportunities are identified. All shipyards should exploit or continue to exploit this opportunity to eliminate the grinding that must be performed when welded temporary attachments are removed. NNS has an ongoing process to develop non-welded temporary attachments. A device known as a "Pac-man" collar was recently developed that holds bulkheads upright during erection. NNS is also investigating the use of vacuum pads that can be used to eliminate lifting pads. Bollinger has implemented <u>permanent</u> attachments and will continue to work with their customers to address this improvement opportunity (Note: The customer has agreed these attachments will be useful later in the ship's lift and has agreed that they will stay with the ship). Ingalls uses high strength rare earth magnets for fitting and moving material in lieu of temporary attachments in applications that they are suitable.
2. **Removal of Temporary Attachments with Hammer Strikes** - This is a good opportunity for NNS and Ingalls, but lower for Bollinger because their current Coast Guard Cutter product requires relatively thin steel. This technique can only be used on steel greater than 3/8" thick and on certain steel types. The proposal presented to NAVSEA demonstrated that a temporary attachment could be knocked off with a hammer strike

without any damage to the base metal if the attachment was welded on one side only. NNS won approval for the process from NAVSEA for the Ford Class of aircraft carriers, but implementation is still in progress. NNS still has to modify appropriate procedures and perform training. NNS Welding Engineers are considering whether this opportunity should be pursued for the VCS program. Ingalls is currently pursuing permission from NAVSEA for mechanical removal of temporary attachments. Bollinger has already started to develop standard work instructions to address a more consistent methodology to address this issue.

Construction Stage: During Welding

1. **Use Needle Guns to Remove Silicate and Lightly Adhering Spatter** - This is a significant industry opportunity for Bollinger and Ingalls. NNS placed a lower priority on this opportunity because it already uses needle guns extensively. NNS second biggest reason for grinding is remove silicate between weld passes. NNS views use of needle guns as a safe and effective way of removing silicate and lightly adhering spatter. Ingalls and Bollinger are using scaling guns. See Figure 22 for photographs of the two tools. The recommendation for NNS is to continue using needle guns. Bollinger and Ingalls do not use needle guns. Bollinger is not using needle guns because their local American Bureau of Shipping office (ABS) views needle guns as a "Peening" process that is used to remove stresses from welds. Ingalls could allow use needle guns but chooses to use a scaling gun instead that employs a chisel-like tool. NNS feels that needle guns would be a much more effective tool for Ingalls and Bollinger. NNS recommends that Bollinger pursue discussions with their local ABS office to resolve the issues that prevent use of needle guns. Bollinger has already started the dialogue with our customer and the regulatory agencies to readdress the use of needle guns. NNS recommends that Ingalls initiate an internal investigation to compare efficiency of scaling and needle guns.

Figure 22 – Needle Gun versus Scaling Gun

Needle Gun

Scaling Gun

Construction Stage – After Welding

1. **Implementation of Modern Welding Equipment** - This is a high priority for NNS and Bollinger, but a lower priority for Ingalls because they have already made a significant investment. Old and poorly maintained welding equipment, gas lines, and power lines cause the welding arc to fluctuate from the prescribed parameters. Skilled welders need to carefully monitor the arc to ensure the desired weld bead is being deposited. Less skilled welders produce welds with rough surfaces that they then grind to achieve the desired surface finish. The inconsistent arc also produces weld spatter on adjacent base material that must be removed by grinding. Shipyards should recognize that having modern and well-maintained welding equipment is a pre-requisite to implementation of a no-grinding belief system. NNS recently began a major program to modernize welding equipment. A thorough comparison of the welding equipment offered by major providers was completed in 2013 and standard equipment was selected. The first new welding machines are arriving in late 2013. Bollinger has invested heavily in updating their equipment over the past few years and will add additional capital expenditures in 2014 to address this issue. Ingalls recently retooled the majority of the Hull department and as a result has modern equipment.
2. **Change Perception of Acceptable Weld Surface Smoothness** - This is a significant opportunity for the industry. Much grinding is performed in all three shipyards to make completed welds visually appealing or pretty. Many craftsmen and their foremen see this as producing a quality product. The practice of making welds pretty then gets embedded in the craftsmen's belief system and comes to be understood as the required way of doing business. Ingalls has observed that there is significant opportunity for improvement in this area by implementing requirements-based training. Trades management needs to focus on the craftsmen belief system regarding weld surface smoothness to reduce the amount of grinding that is being performed. Management needs to clearly identify grinding as a non-value-added activity and a form of rework. The emphasis should be on performing welding and burning processes with such precision that grinding is not necessary. The need to grind should be viewed as an anomaly. When grinding is performed, people should ask, "What went wrong with the previous process to make this grinding necessary?" Trades management may have different methods to approach this cultural challenge, but one option would be to create a Community of Practice (COP) team to focus on the issue. The team would be led by a general foreman or foreman, and include respected craftsmen that understand what causes the need for grinding. They would be charged to preach the message to their associates that grinding is a form of rework. If someone is seen grinding, they should ask what went wrong that required this grinding. Maybe additional training or coaching is needed. Maybe there is equipment problem. The COP team members should be tasked to get down to real reasons that grinding is being performed. Team members should take barriers to eliminating grinding back to their COP team so that common problems can be discussed and reported to management as necessary.
3. **Documents that Define Temporary Attachment Removal and Scrap-up Requirements** - This is a high priority for shipyards building larger vessels where compartment

requirements are not clear during manufacturing. Scrap-up and temporary attachment removal requirements vary due to ship type, compartment type, and coating system. By aircraft carrier ship specification, temporary attachment "stubs" less than ½" high can be left in compartment that will eventually be insulated. The problem is that craftsmen in the assembly shops do not know what portions of the decks and bulkheads they are working on will eventually become boundaries for those compartments. As a result, all temporary attachments are burned off and grinding is performed to clean up scars even though it may not be necessary per specification. The introduction of high solids paint that is used in critical coated spaces has presented another challenge. The high solids paint manufacturers disallow surface imperfections or small amount of weld spatter that are allowable with other coating systems. The craftsmen at NNS that are tasked with cleaning the imperfections may not be aware of the true requirements because they are not captured in current structural procedures and/or they do not know which compartments will be coated with high solids paint. NNS piloted a process on CVN 78 to identify specific surface smoothness requirements that was presented to Ingalls and Bollinger. However, the piloted process did not address the issue with coating systems. NNS will pursue expansion of the piloted process to provide surface smoothness requirements to trades on all ship and make sure the process includes coating system requirements. NNS also needs to investigate the best way of providing this information to the trades to ensure all craftsmen that work on surfaces throughout the build cycle are aware of the surface requirements. NNS also needs to consider whether official drawings are created that can be planned and scheduled, instead of the supplementary documents that were provided in the pilot. Ingalls issues bills that detail the scope of work for the work packages and will investigate how to incorporate the requirements for the removal of temporary attachments. Bollinger's craftsmen have a good understanding of compartment smoothness requirements due to the relatively small size and manufacturing repeatability of the ships they build.

4. **Use ET in Lieu of MT Testing** - This is a medium opportunity for all three shipyards. ET requires some surface preparation but less than MT because it is only necessary to remove large spatter (>1/16"). ET has been proven to reduce false positives of weld indications when compared to MT so repair welding is reduced. ET can also be performed on painted joints. This eliminates the grinding necessary to remove paint. All shipyards should review their current use of ET testing and develop plans to maximize usage. NNS' NDT and Welding personnel agree that use of ET will eliminate grinding. The NNS NDT department has the lead to expand use of ET throughout the shipyard. In addition, NNS plans to use ET testing on flight deck plates to check for cracks in formed dimples. MT was previously used for this testing, but it required grinding to remove paint so that MT could be performed on un-coated surface. Bollinger has been able to recently review and implement the ET process. Ingalls does not practice ET testing, however, in the wake of this project will explore feasibility of it.
5. **Implement *Rust-Off* for Cleaning Flash Rust from Welds prior to Non-destructive Testing** - NNS has already implemented use of this compound so it is now a lower opportunity. NNS Welding Engineers have tested a liquid compound called *Rust-Off* that can be used to remove flash rust on completed welds so that NDT can be performed.

The liquid can be applied with a paint brush and then wiped off with a rag. The compound is easy to use with no significant hazards that must be accommodated. NNS Welding Engineers did not approve the compound for use on un-welded surfaces because it left a residue that was shown to affect weld quality. *Note: NNS has some new concern about the Rust-Off product at the time this report was issued. It was found that the Rust-Off product leaves some residue that may need to be removed by grinding prior to painting. NNS' NDT department is investigating.* Ingalls does not currently use *Rust-Off*; although, recognizes the benefit and believes there are other applications that will benefit from it as well.

6. **Non-Destructive Testing Department to Perform Grinding on Joints Requiring NDT** - This is an industry opportunity. Often, the best organization to perform grinding is the internal customer because they have the best understanding of the requirements. NNS recently implemented a change in responsibility on jobs to require non-destructive test department personnel to perform grinding to remove surface indications that are identified during MT testing. In the past, these indications would have been turned back over to the welding foreman so that a welder could be assigned to repair the indication. Then, the welders would need to notify the non-destructive test department that the job was ready for re-inspection. This process caused a lot of human interaction and churn for what was really a simple repair. All shipyards should evaluate this opportunity and departmental responsibilities to determine if it can be implemented in their organizations.

Construction Stage: Multiple

1. **Plan Assembly so that Grinding is Performed at the Most Accessible Stage of Construction** - This opportunity had a high priority for all three shipyards. Nearly all shipbuilding professionals agree that outfitting installation work and hot work in particular should be performed at the earliest stage of construction. This allows maximum accessibility to the job and makes almost any job including grinding much easier to perform. Performing hot work prior to painting also eliminates the paint repair that will otherwise be necessary. This comment was heard often during craftsmen interviews at NNS, especially for those craftsmen working in tight submarine compartments. These areas were often so tight that small people had to be identified for certain tasks. Craftsmen often complained about the position they had to put their bodies in or that tools were too large to get in the confined spaces. All shipyards need to continue to develop planning processes, ship designs, and facilities that allow integration of outfitting work with structural assembly so that the work can easily and safely be performed at the earliest stage of construction. NNS Engineering is actively populating the CVN 78-class product model with "monuments" that define the type and location of studs that are used for wire way hangers or insulation. The monuments allow the stud locations for CVN 79 to be marked on the panel line burning machine. The paint is removed without any grinding by using the panel line's vacuum blasting capability. This opportunity to reduce grinding is well recognized by other shipyards. Bollinger continues to review the build strategy to better address this opportunity.

2. **Identify Non-Grinding Tools to Break Free Edges and Shave Weld Reinforcements -** This is Bollinger's number one opportunity, but much lower for Ingalls and NNS. All three shipyards use grinding tools to break free edges (for coating system adhesion) and to flush weld reinforcements with base material when required. All three shipyards use grinding tools to break free edges (for coating system adhesion) and to flush weld reinforcements with base material when required and development of a non-grinding tool could provide significant benefits. Also, the NNS team knows that commercially available equipment for shaving weld reinforcements has been developed that is very beneficial in the right set of circumstances. NNS will evaluate commercially available weld shaving system for potential use at NNS. Bollinger should consider submitting a ManTech project proposal for development of a small tool that can break free edges and steel components.
3. **Testing and Comparisons to Find the Most Effective Tools and Abrasives** - This is an ongoing opportunity for all three shipyards. Improved tools and consumables are constantly being developed by industry suppliers. The overall project team found that all three shipyards continuously tested and implemented new tools and consumables to improve efficiency. It was also found that different tools and consumables were used at the three shipyards and that craftsman's preferences are an important determinant of what tools and consumables were selected. The overall project team concluded that selecting an optimum set of tools and consumable that could be used for all shipyards was not a practical solution at this time due to the strong role that craftsman preference plays. All shipyards need to continue the testing and comparisons of tools and consumables that they are performing as a method of continuous improvement. However an improved method for comparing tools and consumables is desirable. An industry-standard Industrial Engineering-based comparison method should be developed to help select optimum tool and consumables. This doesn't mean craftsmen's opinions should not be considered, but a fact-based approach would promote better decision making. NNS will continue to compare grinding tools and consumables. NNS recently implemented a new 7" surface grinder that cost more but demonstrated superior performance. Bollinger will continue to review tools and consumables to address a better way to perform the processes used. Ingalls has regular meetings with tooling and abrasive vendors to remain current on the latest technology, and performs follow up activities on site to validate findings.
4. **Resolve conflicts between ship specifications and procedures** - This is an industry opportunity, but it is probably most significant for NNS. NNS trades leadership is aware of instances where procedures have requirements that are more stringent than the ship specification. One costly disconnect was recently found at NNS, when inspectors and craftsmen found arc strikes and fabrication scars with a depth of less than 1/32" were required to be repaired per procedure but repair was not required per the ship specification. This conflict had existed for several years. The procedure is now being modified, but this instance illustrates that conflicts are not easy to spot. NNS engineering has developed a spreadsheet that compares the procedure and aircraft carrier ship specification requirement for structural attributes side by side. NNS engineering is holding meetings with subject matter experts from each department to

compare the procedural attributes they work to with the specification requirement to identify any conflicts. In addition, NNS has found apparent conflicts between SWSS tickets used to identify weld processes for VCS program welding and the controlling drawings. A Rapid Improvement Workshop is being arranged to look into this issue. Bollinger and other shipyards must further investigate this opportunity to determine if this is an opportunity for them. At Ingalls requirements between contracts vary so there is opportunity for training on contract specific requirements.

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5 Conclusions and Path Forward

This study identified many opportunities to reduce grinding labor but it also made it clear that there are no quick solutions. Significantly reducing grinding will require strong consistent leadership over many years. Management must continuously promote a belief system that views grinding as a non-value-added and unnecessary process. Management and production leaders will need to focus on what is wrong with existing processes, equipment, or training that creates the need to grind. Management will need to strongly support projects that will eliminate the need for grinding like modernizing welding equipment, welding through primer, and developing methods that provide surface-specific smoothness requirement to the trades.

Each shipyard will need to develop an implementation plan that focuses on their priorities. Nearly all the improvement opportunities identified in this study applied to the three participating shipyards so it can be concluded that most of the improvement opportunities will also apply to other shipyards. Some improvement opportunities were much more significant for specific yards because of the type of work they perform or due to current processes.

Bollinger will review the priorities identified in this report and develop a plan to help reduce the grinding in our shipyards. Bollinger has identified this as a priority due to the eye injuries reflected in our 2013 statistics. The Quality team will join with the Safety team to implement a plan that will address each of the opportunities noted.

For Ingalls this project presented an opportunity to identify current abrasive tooling and processes which will suffice as a baseline to reference as improvements are developed and implemented later on.

At NNS, a shipyard-wide team was recently established at the direction of the NNS president with the goal of eliminating grinding. This “global grinding team” has members from all trades and will be involved in implementation of many of the opportunities for improvement that were identified in this report. The team’s scope of work from their charter is team is provided below:

> *The project’s goal is to eliminate grinding operations across the company and identify, evaluate, and consolidate grinding improvement efforts where grinding is the only alternative. Where grinding is necessary, opportunities will be explored to ensure that ongoing grinding operations will be performed in a manner that will incorporate new technology and processes to mitigate injuries and inefficiencies.*

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