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Foreword

This report was produced by the Office of Naval Research's Best Manufacturing Practices (BMP) Program, a unique industry and government cooperative technology transfer effort that improves the competitiveness of America's industrial base both here and abroad. Our main goal at BMP is to increase the quality, reliability, and maintainability of goods produced by American firms. The primary objective toward this goal is simple—to identify best practices, document them, and then encourage industry and government to share information about them.

The BMP Program set out in 1985 to help businesses by identifying, researching, and promoting exceptional manufacturing practices, methods, and procedures in design, test, production, facilities, logistics, and management – all areas that are highlighted in the Department of Defense's 4245.7-M, *Transition from Development to Production* manual. By fostering the sharing of information across industry lines, BMP has become a resource in helping companies identify their weak areas and examine how other companies have improved similar situations. This sharing of ideas allows companies to learn from others' attempts and to avoid costly and time-consuming duplication.

BMP identifies and documents best practices by conducting in-depth, voluntary surveys such as this at the University of New Orleans, College of Engineering. Teams of BMP experts work hand-in-hand on-site with the company to examine existing practices, uncover best practices, and identify areas for even better practices.

The final survey report, which details the findings, is distributed electronically and in hard copy to thousands of representatives from industry, government, and academia throughout the U.S. and Canada *so the knowledge can be shared*. BMP also distributes this information through several interactive services that include CD-ROMs and a World Wide Web Home Page located on the Internet at http://www.bmpcoe.org. The actual exchange of detailed data is between companies at their discretion.

The University of New Orleans, College of Engineering (UNO COE) has formed impressive partnerships with the U.S. Navy, the Department of Defense, the National Aeronautics and Space Administration, the state of Louisiana, the maritime industry, and other countries and universities. Through these partnerships, the UNO COE has developed innovative technologies that are unique to the Best Manufacturing Practices (BMP) Program and national shipbuilding. The BMP resurvey of the UNO COE was conducted during the week of April 23, 2007.

The BMP Program is committed to strengthening the U.S. industrial base. Survey findings in reports such as this at the UNO COE expand BMP's contribution toward its goal of a stronger, more competitive, globally minded and environmentally conscious American industrial program.

I encourage your participation and use of this unique resource.

Rebecca Clayton
Director
Best Manufacturing Practices Program and
Center of Excellence

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Section 1

Report Summary

Background

The University of New Orleans, College of Engineering (UNO COE) has formed impressive partnerships with the U.S. Navy, the Department of Defense, the National Aeronautics and Space Administration, the state of Louisiana, the maritime industry, and other countries and universities. Through these partnerships, the UNO COE has developed innovative technologies that are unique to the Best Manufacturing Practices (BMP) Program and national shipbuilding. The BMP resurvey of the UNO COE was conducted during the week of April 23, 2007.

Since 1978, the UNO COE has continually improved its quality of instruction and is making steady progress in all its research endeavors. The tallest building at the UNO Lakefront Campus proudly belongs to the COE, offering Accreditation Board for Engineering and Technology undergraduate programs in civil and environmental engineering, mechanical engineering, electrical engineering, and naval architecture and marine engineering (NAME). The UNO COE also provides graduate programs in civil engineering, mechanical engineering, electrical engineering, NAME, and engineering management. A doctorate program in engineering and applied sciences is also offered. The UNO COE's success throughout the years has made it the largest undergraduate NAME program in the nation.

The UNO COE staffs 45 full-time faculty and has enrolled 1,134 undergraduate and 238 graduate students. The UNO COE is among the top ten universities for research dollars for faculty in the United States. The college focuses on many opportunities for students to improve their education and advance their career skills as well as 13 professional societies and five honor societies for students that include the Society for Advanced Graduate Engineering Studies, the National Society of Black Engineers, the Society of Women Engineers, and Tau Beta Pi. With 85% of the UNO students working their way through school, the COE developed an exceptional cooperative education program that includes a plan that enables students to alternate periods of school attendance with study-related work experience and a Parallel Plan, which allows students to work part-time each semester while being enrolled in a degree-granting program as a full-time student. The Engineering Placement Officer makes every attempt to place students in local or regional industries related to the student's designated area of specialization. Along with focusing on programs for students, the UNO COE continues to expand its industry partnerships and increase the scope of funding of its sponsored research programs.

The UNO COE operates four Research Centers of Excellence that collectively generate well over half the sponsored research of the university on an annual basis. These include the Schlieder Urban Environmental Systems Center (SUESC) that supports scientific and technical research activities in the management of solid waste, water and wastewater, water resources, and air quality; the Gulf Coast Region Maritime Technology Center (GCRMTC), whose mission is to help the U.S. maritime industry become more competitive on an international scale through sponsored research while striving for recognition as the best source for technology by the maritime community; the Energy Conversion and Conservation Center that conducts clean-energy research and development, catalyzes interaction among government, industry, and academia, and provides services to advocate clean energy and energy conservation; and the National Center for Advanced Manufacturing (NCAM) that promotes advanced manufacturing technologies in both aerospace and commercial markets through research, design, manufacturing, and testing activities. The researchers in all of these facilities are working to solve problems that promise to have a significant impact on regional and national industries.

Through its primary focus on research and development efforts, the UNO COE has developed many technological practices to meet the challenges and demands of today's changing world. The BMP survey team considers the practices in this report to be among the best in industry and government.

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Section 2

Best Practices

Design

Decision Support System Through Modeling and Simulation

Modeling and simulation, when combined with a Decision Support System, can provide an organization the tools necessary to make good business-case decisions. The tools enable non-specialists to more effectively and efficiently plan and control key resources by considering system-wide behavior of lower-level models, such as a representation of unit flows within a shop or work cell or high-level models of the entire enterprise.

Recent shipbuilding and automotive experience indicates that modeling and simulation technologies can provide substantial benefits, especially when these tools are embedded within Decision Support Systems (DSS). A DSS integrates models, the data that drive the simulations, and user interfaces to the data and models—placing engineering tools into the hands of decision makers and providing managers and planners with key information that enables them to make better decisions. To be effective, however, it is imperative that these models are incorporated into a support system that provides easy and meaningful access to sophisticated models by users who are not experts in modeling, analysis, and data management. The system must also facilitate the use of a variety of models that are needed to adequately perform shipyard-wide analyses and manage the data that drive the models and the results generated by the simulation.

An example of how the University of New Orleans (UNO) Gulf Coast Region Maritime Technology Center (GCRMTC) has been able to apply modeling and simulation into a DSS lies in the work that was done at the Northrop Grumman Ship Systems (NGSS) facilities in Pascagoula, Mississippi and in New Orleans in the aftermath of Hurricane Katrina in 2005. This effort originally began as a project to effectively support shipyard improvement efforts. After Katrina the project became one in which the UNO, College of Engineering (COE) was asked to support the specification and procurement processes of the shipyard recovery efforts. Prior to Hurricane Katrina, NGSS facilities in the Gulf Coast region consisted of three distinct machine shops, each manufacturing discrete components and assemblies for the shipbuilding industry. The new task for the COE's Simulation Based Design Center (SBDC) was to determine the sector-wide capacity of the NGSS machine shops, determine which product groups for the current ship construction forecasts could be produced by which shop, and specify the required equipment to be purchased for Pascagoula to meet planned production capacity.

The COE's SBDC modeling team worked very closely with NGSS personnel to gather and validate the data drivers for the simulations and to develop preliminary models of the existing equipment. Due to variances in the level of detail and quantity of data provided for each machine shop, independent models were created for each shop. The output from each model was then combined to give an overall prediction of sector capacity and verification of how many pieces of equipment in each fabrication group were required. Further refinements were made to the models and simulations to create a combined model of the three shops, allowing for a more detailed analysis of machining capacity.

The modeling and simulation effort tied into the DSS has given NGSS the tools needed to make enterprisewide decisions that optimize cost and the type of equipment necessary for establishing a regional facility. Through the modeling and simulation efforts, redundancy and overcapacity issues were avoided. To date, three other shops (pipe, blast and paint, and panel line) have been modeled and simulations of alternatives for best business-case analysis have been performed.

Environmental Engineering

The Schlieder Urban Environmental Systems Center (formerly the Urban Waste Management and Research Center), in connection with the University of New Orleans, College of Engineering, performed many studies related to wastewater treatment, which extends to urban run-off. Many new design processes for dealing with pollution content in an efficient and cost-saving manner have emerged from these studies.

The Schlieder Urban Environmental Systems Center (SUESC), formerly the Urban Waste Management and Research Center at the University of New Orleans, College of Engineering (UNO COE), supports research on solid-waste management, water and wastewater quality control, water resources, and air quality research. The SUESC also promotes activities dealing with environmental policy and transfers the technology obtained in the research to industry. The University's Urban Waste Management Resource Center was established in May 1990 and obtained a cooperative agreement with the Environmental Protection Agency (EPA) in July of that same year, which was extended to 1995. This agreement contains research, education, and outreach programs with an integrated waste management/pollution prevention emphasis. Financial support for the Center extends from the EPA, government, private industry, and the international community. A sewerage system design was performed for the country of Ecuador from 1993 to 1995, which continued to aid that country in additional city planning by providing a digital' map of the city used for sewerage design.

In one study, SUESC evaluated wastewater treatment at three different treatment plants. Results of this study led to modifications at one of the plants to improve treatment performance. Plant operators were trained to maintain the improvements. Factors affecting process performance were identified and are being retained for future studies. New factors affecting process design were developed for the trickling-filter solids contact process (a wastewater treatment process). These studies have led to graduate-level training programs and publications in journals. SUESC developed a better understanding of the role of biological flocculation in the activated sludge process. The kinetics of biological flocculation of particulate organics was included in activated sludge modeling, and a new activated sludge model was prepared linking the aerator and the settling tank. This model was tested at the pilot-plant level and the results of that testing have been published. The new design criteria have emerged and are identified as best design practices for process optimization. With new technology being developed by SUESC, anaerobic/aerobic wastewater treatment should realize a substantial reduction in sludge generation, eliminating the need for a separate anaerobic sludge digestion.

The UNO COE's SUESC is on the leading edge of technology for environmental engineering in dealing with wastewater treatment. It has performed many studies that have resulted in new design processes for treating wastewater. It has also studied many other aspects of dealing with wastewater, from sewer design optimization for solid flows to characterization of moisture content within landfills. The recycling of leachate from landfills has been found to be advantageous in SUESC's preliminary studies. Urban run-off is another study that is being conducted due to the increasing pollution caused by city draining of rainwater running into local lakes. Stochastic models for managing urban run-off are being developed to deal with managing the pollutants draining into Lake Pontchartrain.

Expert System for Shipyard Environmental Management

The University of New Orleans, College of Engineering has developed an expert system for shipyard environmental management that helps shipyards easily manage their use of materials and the associated environmental impacts. Reports, trends, and analyses can be performed with minimal effort and provided to the necessary authorities.

Most shipyards maintain records for management of its processes in the form of spreadsheets, charts, data sheets, and various other documentation. There is rarely one source that contains all the necessary information for managing the processes needed to build, refurbish, and overhaul a ship. Once a ship's needs are established, the shipyard determines what has to be performed. This requires the management to review the processes needed to perform the required task. Based on this, shipyard processes, environmental engineering and science, and environmental regulations must be determined and made accountable. Presently, this is performed by reviewing hardcopy documentation, Material Safety Data Sheets (MSDS), environmental regulations, and permit requirements.

The University of New Orleans, College of Engineering (UNO COE) has developed an expert environmental management system for shipyards—a software application that combines shipyard processes, environmental engineering and science principles, environmental regulations, and information technology skills. The application can be used to help shipyards prevent noncompliance and fines, minimize waste, reduce public health risks, provide cost savings, improve public image, and increase productivity. This is accomplished by the shipyard populating the database with information about the facility, sources, stacks, national pollution discharge elimination system permit limits, air permit limits, outfalls and watershed, air pollution control devices, and wastewater treatment facility data. With this data incorporated into the software program, material usage, MSDS information, abrasives, paints, solvents, filler/weld rods, rainfall data, ambient air quality data, and fuel are included to manage the shipyard's processes and environmental impact. This software can also be uniquely configured to a shipyard's specifications. As a result, routine reports can easily be produced, such as discharge monitoring reports (storm and process water), hazardous waste, Tier II, emission inventories, and toxic release inventory. Analyses and decisions can also be performed using data already contained in the database. Some of this data may include historical trends, planning and pollution prevention implementation, troubleshooting, emission calculations, and comparisons (e.g., year-to- year, source-to-source, material-to-material, job-to-job, and limits versus actual).

The UNO COE's customizable expert system for shipyard environmental management allows a shipyard to easily manage its usage of materials and environmental impacts. Reports to environmental authorities are easily produced and made available, and changes in regulations and limits can be easily incorporated and updated with little or no effort.

Efforts are being made to secure private and government funds so that the application can be improved with additional features that will address changes in regulatory requirements and the environmental management practices.

Load and Resistance Factor Design Rules

The University of New Orleans, College of Engineering teamed with the University of Maryland, College Park to develop new design rules utilizing probabilistic methods to reduce weight in future commercial and naval vessel structures.

The University of New Orleans, College of Engineering (UNO COE) saw a need for weight reduction in today's shipbuilding market. The U.S. Navy is now requiring the use of light-gage plate in nonstructural and structural bulkheads on their LPD-17 and DDG-21 next-generation warships. Ongoing committee studies were considered by the team in the development of these new procedures for the design of ship structures. The Load and Resistance Factor Design (LRFD) criteria were initially envisioned to be used in parallel with currently used procedures. The applications and limitations of this procedure are currently limited to the design of fine-bow, bow-with-flare, or flat-bottomed vessels and conventional displacement-type monohull surface vessels made of metallic materials, and those with a length of 300' to1000' between perpendiculars.

The old process to design vessels followed the rules of the Navy or the American Bureau of Shipping. New designs do not have historical information to use as a basis. The team's objective in the first year was to develop LRFD criteria for hull girder bending of surface ship structures for both commercial and naval vessels. In the second year, the team developed LRFD criteria for unstiffened panels of surface ship structures; in the third year of the project, the team developed LRFD criteria for fatigue of surface ship structures.

The development of this new method for the structural design of conventional displacement-type surface monohull ships is based on a structural reliability theory in an LRFD format. The LRFD rules can be used for early design of ship structures to check adequacy in the detailed design stage. For marine applications, LRFD development is based on special and extreme analysis of wave loads with a combination of partially correlated loads. Nominal strength and load values, along with achieving target reliability levels, are also considered. The LRFD method builds on conventional marine and structural codes. The design philosophy must provide for ship structural designs that have adequate safety and allow for the proper functioning of each component. The Allowable Stress Design (ASD) and the LRFD design philosophies for designing structures are currently in use. The LRFD philosophy utilizes probabilistic methods versus the pure-static and dynamic formulas used in the ASD philosophy.

Advantages of the LRFD philosophy include a more rational approach for new designs and configurations, consistency in reliability with the potential for a more economical use of material, calibration of building codes that allows for future changes from information acquired from predicted models, and material and load characterization.

Production

Advanced Composites Manufacturing Technology

The University of New Orleans, College of Engineering participates in the development of a highly capable fiber composite system and contributes to a collaborative manufacturing environment that provides considerable economic and educational opportunities.

The University of New Orleans, College of Engineering (UNO COE), in partnership with the state of Louisiana, the National Aeronautics and Space Administration (NASA), and Lockheed Martin Corporation at the Michoud Assembly Facility in New Orleans, is directly involved in the provision of research, development, and education for manufacturing the next-generation launch vehicle systems. State funding and NASA facilities have been combined to provide the UNO COE with an opportunity to participate directly to effect an intelligent collaborative manufacturing environment, strengthen national competitiveness in aerospace/commercial markets, develop and manufacture composite materials, and expand regional economic development and advanced manufacturing technology education opportunities.

Operating under the auspices of the National Center for Advanced Manufacturing (NCAM), the UNO COE established significant cooperation with federal agencies, universities, the state, and industry. NCAM currently possesses and operates a highly capable fiber composites installation and is in the process of developing and obtaining a state-of-the-art system to advance this manufacturing technology. With the capability for seven axes and 24 tow-fiber placements, the current composite fabrication equipment has successfully supported a number of NASA and aircraft applications. The current NCAM fiber placement machine has a working area that measures 5 x 12 meters (Figure 2-1). NCAM personnel have participated in research and technology development while effecting a collaborative manufacturing environment. The facility also provides both economic and educational opportunities from the added technical capabilities and work brought to the region, increased use of the UNO COE educational offerings by NASA and NCAM members and employees, and expanded research opportunities for graduate students and faculty. Of equal importance are the improved product offerings and quality that have been delivered to NASA and aircraft applications. Considerable expansion of all these opportunities is anticipated when the additional state-of-the-art system is added.

Figure 2-1. Ingersoll Fiber Placement Machine

Automatic Generation for Robotic Welding

AutoGen is a software tool that automates the planning and execution of control programs for robotic welding of ship structures. This capability will dramatically improve the ability of welding robots to play a major role in ship construction, improving quality and productivity.

One of the challenges facing the U.S. Navy is achieving desired fleet size and readiness, which is partially due to the high cost of manufacturing warships required for today's complex designs. The most common process in shipbuilding is welding. Stiffeners are welded to plate steel to form panels. Panels are assembled into subunits; and subunits are combined into larger units to form a complete ship. Welding is important at every step. Mechanized systems play a role in the panel phase, but robots are required beyond that. Few robots are used in U.S. shipbuilding because of accuracy requirements, installation cost, and personnel training. The major obstacle, however, is robotic programming. Almost every subunit is different and must be programmed individually; therefore, programming time is a key factor for the success of welding robots in shipbuilding.

In the automotive industry, the amount of time to program a robot is about twenty times the amount of time to perform the weld; however, the programming cost is spread over millions of identical welds using the same program. In military shipbuilding where every unit is different, programming cost is not afforded the large duplicate volumes but must be spread over one unit or only several at most. Therefore, the human time to program must be less than the human time to weld for the robot to be cost-effective. One of the major initiatives by the National Shipbuilding Research Program and the Office of Naval Research Manufacturing Technology Centers of Excellence is to utilize robotics to reduce the cost and improve the reliability of welding. Since 2000 the University of New Orleans, College of Engineering (UNO COE) has participated in the Automatic Generation (AutoGen) project. AutoGen is a software tool that automates the planning and execution of control programs for robotic welding of ship structures. The software works by a process-centered evaluation of the geometric context of computer representations of ship designs, including component part juxtapositions and manufacturing plans for the work piece. AutoGen identifies each weld and appropriately characterizes it, assigning suitable procedures using the same decision processes as skilled craft and welding engineers. It constructs the robot motions necessary to accomplish welds and determines the correct process control values for each path.

When provided with valid data, AutoGen generates robot control programs completely without manual intervention or edits. Foundational concepts defining AutoGen provide for a general solution not limited by product scale or geometric complexity and bounded only by the accuracy and the dexterity of the combined robot and torch. AutoGen can handle compound curved surfaces and compute collision-free and singularity-free trajectories for the torch manipulator. AutoGen understands the geometry of the part and can plan welds on work pieces presented before the robot in different orientations. Weld planning proceeds according to local process conditions and requirements computed by direct reasoning from the geometric contents of the work piece design information and the context defined by the manufacturing plan. AutoGen completes construction of robot control programs by applying computed local conditions to weld process response surfaces and the kinematics and control language specifications of the available robot. The solution is a direct consequence of the requirement. AutoGen casts all of its entities as computational geometries. All of the core issues of joint design, torch motion, and weld process and placement are expressly and directly coupled to each other through the method of geometric reasoning.

The logical object design of AutoGen provides for ready expansion and affordable modification, including incorporation of equipment from different manufacturers and possibly different kinds or types than in the original. The input data required can be electronically extracted from currently available shipyard sources, although some internal consistency of information representation and completeness issues may emerge with testing. The architecture of the software is intentionally open to modification of most of the performance rules. The software has open, well-defined hardware and software interfaces. These are readily adapted and configured for implementation by individual shipyards and to robots from different manufacturers. The AutoGen planning capability can be applied to a wide range of process problems. This provides opportunity for a large domain of potential applications in a variety of industries.

Initial work from 2000 through 2003 achieved much of the anticipated AutoGen functionality as running code. In November 2003 an AutoGen demonstration was carried out for several shipbuilding personnel at the UNO ShipWorks Robotics Laboratory (SWRL) located within the Northrop Grumman Ship Systems Avondale Operations facilities. AutoGen automatically generated control programs and welding operation on shipyard work pieces appropriately scaled for the available ABB/IRB/1400 robot.

Work in 2005 ported AutoGen to automatically compute control programs for the SWRL ISU/Motoman UP6 gantry robot. Work under this funding also ported AutoGen to produce control programs coupled with the PAWS offline system for the General Dynamics Electric Boat gantry mounted with a semi-independent pair of Staubli manipulators. This work encompassed careful calibration of the coupled motions of two significantly differing machines and addressed the particulars of the separate controllers. A preliminary version of combined robot and gantry motion (i.e., greater than six degrees of freedom) was demonstrated at Electric Boat.

AutoGen development introduced computation of directives for multi-degree-of-freedom coordinated motion, enhancements in algorithms for selecting manipulator-base placement, torch motions, and weave functions. AutoGen development realized new functionalities using electrical ground-seeking touch sensing for measurement with the robot to determine the actual lay down of work pieces and the positions of components within the assemblages. The UNO demonstrated welds through a three-plane corner, joints with continuously varying welding positions around a ring onto a canted plate, and reflexive presentation connections on a collard Tee-section standing on plate and intersecting coped transverse structure. At Sandia National Laboratories (SNL), the free-space motion planner was recast for parallel computation.

Through these developments, UNO and its partners identified further work necessary to the approaching commercialization of the software and its production implementation in ship manufacture. Experience operating AutoGen defined the need for extensions in robot motion design and planning. Robot welding through continuously varying torch positions showed the necessity for refinement, including subordinate process domains and handed-weave patterns. The current software must be restructured from a laboratory experiment to industrial architectural standards. Finally, the UNO experience showed the need for memory management to handle larger work-piece models for a graphical user interface and utilities to handle common tasks.

The goal of 2007 research is to commercialize AutoGen for shipyard robotic welding applications. The automatic planning capabilities of AutoGen are required because manual robotic planning of the thousands of subassemblies is not feasible. This capability will dramatically improve the ability of welding robots to play a major role in ship construction, improving quality and productivity. The focus of the research is in two major areas:

- Continue to enhance the current level of functionality of the code to assure robust performance with nonexpert operators
- Restructure the code to meet industrial architectural standards in such areas as user interface, error handling, and modularization

While past research emphasized extensive development followed by a major demonstration, this year's work will be a more continuous "develop-and-test" program, with successive releases undergoing a validation program. A quarterly formal test program and report are planned. The functionality enhancement will increase the length of welds that can be completed by improving the existing capabilities beyond the six degrees associated with a stationary robot. The UNO will also improve the capability on short welds, assuring the welded length matches the design. The restructuring will allow more use of AutoGen by nonexperts. This is required to attract world-case candidates for the ongoing commercial application of AutoGen in shipyards. Automated planning applied to three-dimensional models has value in a wide range of applications, with shipyard welding being the first. Others in the manufacturing areas include painting, blasting, sanding, shaping, and forming. Through automated planning, the design model programs the CNC machine or robot. Beyond manufacturing, this technology may have applications in medicine of pharmaceuticals. SNL reserves all rights to the AutoGen program. Spatial Corporation reserves all rights to the ACIS, HOOPS and InterOp programs. This capability will dramatically improve the ability of welding robots to play a major role in ship construction, improving quality and productivity.

Corrosion Inhibitors

The University of New Orleans, College of Engineering has obtained patents on the use of lithium as a corrosion inhibitor. It developed aluminum-lithium alloys that have improved corrosion resistance without the use of a coating or chemical treatment. The University of New Orleans, College of Engineering also developed a paintable chemical film treatment for aluminum alloys and is researching the use of scandium as a corrosion-resistant alloy (with aluminum) with exceptional weight and strength advantages.

Corrosion affects a metal's strength, conductivity, durability, and resistance to external influences. Several different technologies have been used to combat this problem. Chromium, copper, lead, cadmium, and zinc metals are among the materials used as corrosion inhibitors. However, each of these has health issues associated with them. For a corrosion inhibitor to be effective, the surface of the metal being protected may have galvanic and passivity properties. Lithium can provide both of these properties.

The University of New Orleans, College of Engineering (UNO COE) developed the use of lithium with aluminum for a corrosion inhibitor. The UNO COE's patented coating proved to make an aluminum alloy less reactive, less prone to corrosion, and with improved electrical conductivity. Also, using an aluminum-lithium (Al-Li) alloy allows for a lighter-weight aluminum alloy to provide the same structural properties as that of heavier aluminum alloys. With lithium alloyed into the aluminum creating an Al-Li alloy, it is determined that this alloy has all the properties of having the Al-Li coating provided on top of the metal. Heating this alloy also provides other properties due to the lithium migrating to the surface. Heating the Al-Li alloy to 350°C provides the best results; however, heating it over 600°C will vaporize the lithium and reduce corrosion advantages. In accelerated testing, a two-mil (thousandths of an inch) coating of Al-Li pigmented paint provided corrosion resistance that lasted up to 10 years. A chemical film-treated surface of aluminum is not as corrosion-resistant as a painted surface; however, it can be painted later to improve on the intermediate surface protection. Since aluminum is especially susceptible to saltwater corrosion, the Al-Li may provide substantial protection for aircraft. The UNO COE is studying this now.

The UNO COE is also studying methods that will prevent the effects a copper or copper-oxide-coated ship has on plants and wildlife. Copper-hull ships kill the surrounding plant life, causing the wildlife that feed on plants either die or leave. International researchers have developed Seal Coat™, an epoxy with embedded Teflon fibers. This method of antifouling and several others show promise. The UNO COE is studying whether this epoxy can be used in place of copper on ships to prevent the damage these ships have on their surrounding environment. The UNO COE is also studying the use of scandium, which acts as a natural corrosion-inhibitor for aluminum. This would mean aluminum-scandium-based alloys generally will not need paint or chemical film to resist corrosion. The alloy is strong, lightweight, and corrosion-resistant, making it ideal for maritime and aerospace applications.

Fiber Optic Technology

The University of New Orleans, College of Engineering developed a strong and cooperative partnership with the private sector whose function was to demonstrate, refine, prototype, and implement fiber optic components and systems in Navy ships and other government and industry operations.

Most application of fiber optics research supported by the University of New Orleans, College of Engineering (UNO COE) is handled by a small business contractor. Funds awarded through small business technology transfer research and small business innovation research programs have been instrumental in starting the process of transferring sensing and illumination technology to the Navy.

The UNO COE and the contractor demonstrated capabilities in packaging a variety of complex sensing components and illumination systems for prototype application on Navy ships. Extensive work in temperature, flame, and level-sensing devices were designed into damage control prototype systems installed on the USS Ross DDG-71. This installation demonstrated its effectiveness and value over competitive devices and systems. The UNO COE developed a fiber optics based torque and thrust measurement device for propulsion monitoring. UNO COE also sponsored Bragg temperature sensor development whereby the physics of a single fiber demonstrated the capacity to detect stresses and translate these into a simple and inexpensive temperature detector. Application possibilities are present in sensing and monitoring critical processing parameters required for high- quality composite material fabrication. The UNO COE continues to sponsor remote-source lighting development as an alternate lighting source for ships and commercial use. Remote-source lighting uses high-energy fiber bundles to illuminate areas where electrical lighting systems pose a safety threat and require cool lighting and color sequencing. The UNO COE also developed machine vision systems based on unique fiber optic bundle technology that was employed in experimental robotic welding systems.

Fiber optic sensing and illumination technology go beyond Navy ships. Homeland Security can benefit through optical spectroscopy of chemical and biological dangers. Condition-based maintenance of enterprise operations can be greatly improved through employment of fiber optic sensor and systems technology. Commercial manufacturers can also benefit from this research.

Life Cycle Costing and Assessment

The University of New Orleans, College of Engineering developed a computer model for life cycle costing and assessment of shipyard blasting and painting. The model will reduce total life cycle costs and increase environmental compliance.

The University of New Orleans, College of Engineering's (UNO COE's) Gulf Coast Region Maritime Technology Center (GCRMTC) developed a computer model for life cycle costing and assessment of shipyard blasting and painting. The model will result in minimizing wastes and natural resource utilization, reducing production and societal costs, and increasing compliance with the Environmental Protection Agency and Occupational Safety and Health Administration.

The computer model has a graphical interface that allows the user to select costs and parts of equipment, and entry of materials and process parameters. Total life cycle costs (e.g., direct, indirect, and societal) for all levels of painting and blasting operations will be calculated based on the user's input. By changing process parameters (e.g., nozzle, pressure, abrasive type, paint application equipment, type of paint, etc.), new models can be generated for comparison to optimize the process for both cost and environmental compliance.

Alternate blasting materials and paint application methods will be identified that minimize costs to the shipyard and society. The computer model can be used with about 80% of the shipbuilding industry.

As a followup to this project, the UNO completed a project titled "Environmentally Friendly Abrasives" that provided information on various mathematical models, namely emission factors for particulates, abrasive consumption, and solid-waste generation. Efforts are being made to secure funding so the new knowledge can be incorporated into the UNO's life cycle costing and assessment model.

Plasma Cleaning Process

The University of New Orleans, College of Engineering evaluated Cathodic Atmospheric Plasma using foam plasma processes for cleaning rust, scale, hydrocarbon, and other forms of contaminants from conductive metal surfaces, allowing them to accept paint or coatings. The technology is ready for commercialization, with its first full-scale application in the cleaning and preparing of wire, rods, and tubing.

The University of New Orleans, College of Engineering (UNO COE) is developing and evaluating electro-plasma technology as a source for cleaning and coating metal surfaces for maritime applications. The scope of its work involves the study and comparison of flow-through electro-plasma processes with Cathodic Atmospheric Plasma (CAP) using foam plasma processes for cleaning rust, scale, hydrocarbon, and other forms of contaminants from conductive metal surfaces, allowing them to accept paint or coatings. The technology is ready for transfer to industry, with its first full-scale application in the cleaning and preparation of wire, rods, and tubing. The development and evaluation work was accomplished in partnership with CAP Technologies, LLC. Commercialization of the technology is being pursued to meet the needs of shipbuilding and other industrial markets.

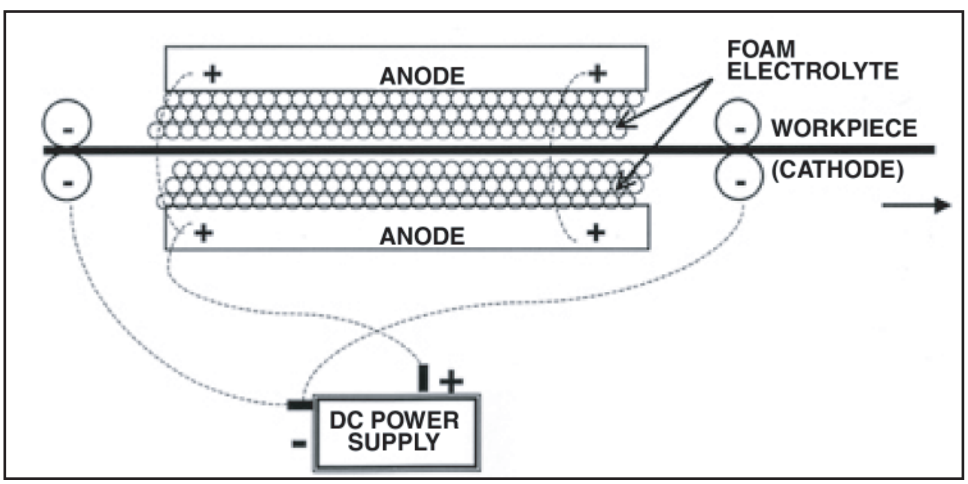


Figure 2-2. CAP Foam Process Chamber

Existing processes for removing rust and scales from steel and other conductive metals include grit or shot blasting, acid pickling, electrolytic cleaning, electroplating, and plasma processing in a high vacuum. The UNO COE's original study evaluated the cost effectiveness, long-term performance, and environmental considerations of each process compared to the flow-through electro-plasma process. This first-generation technology was soon superceded by the CAP foam process, which has fewer critical parameters and achieves more reliable results without the use of a vacuum system. The CAP foam process consists of a foam-aqueous electrolyte comprised of at least 30% gas/vapor. The workpiece is then positioned in a sealed chamber and filled with foam (Figure 2-2). A pad of discrete hydrogen bubbles form within the liquid layer on the surface of the workpiece. The conductive path becomes the walls of the foam bubble. The key to this process is that the distance between the anode and the workpiece is less critical than the flow-through process. Tap water and baking soda can be used to create a denser foam material to remove stubborn materials from surfaces.

The UNO COE and its partner CAP Technologies, LLC, built prototype equipment and evaluated the cleaning of carbon, stainless, duplex, silicon steels, copper, titanium, and aluminum. Zinc, copper, lead, nickel, copper/nickel, copper/zinc, and zinc/aluminum were deposited using the process. Evaluations of cleanliness, corrosion resistance, and adhesion properties were based on data accumulated from polarization resistance tests, ultraviolet weathering tests, surface profiling, and others. Analysis shows that CAP plasma cleaning provides superior cleaning and corrosion resistance and offers good adhesion properties at a fraction of the cost of traditional cleaning and coating methods. As a result, the CAP plasma cleaning system is being repackaged for use on a production scale to clean metal pipes, rods, and tubes for sale to shipyards and commercial markets. Future plans call for broader commercial applications on metal surfaces and conductive metal coatings.

Shipboard Application of Lightweight Steel Structures

The University of New Orleans, College of Engineering, in conjunction with Northrop Grumman Ship Systems, the Edison Welding Institute, and the Battelle Memorial Institute, has developed a process that mitigates buckling and distortion issues associated with thin steel panel fabrication. The process has identified new cutting patterns, improved handling, and modified construction sequencing for fabricating thin steel structures used in low-weight ship structures. When implemented, the new manufacturing plan produced thin conventional panels with no buckling distortion and complex panels with some buckling near manually welded inserts. The successful implementation of the process techniques recommended from this program will lead to higher-quality ships for the U.S. Navy while realizing savings from reduced rework.

Reduction of topside weight is imperative for shipbuilders, providing improved ship stability by increasing both metacentric height and ship range. In addition to topside weight reduction, both commercial and military ship acquisition officials have increased strength and stiffness requirements for these same topside structures to improve performance. Buckling distortion of complex lightweight panels has historically had a significant negative effect on manufacturing cost and production throughput. This multiyear project was a collaboration between the University of New Orleans, College of Engineering (UNO COE), the Northrop Grumman Ship Systems (NGSS) Avondale Shipyard, the Edison Welding Institute, and the Battelle Memorial Institute. NGSS has increased the use of thin steel structures from less than 10% to more than 90% per vessel during the past two decades. With the increased use of thin steel, it has become evident that current infrastructure, design methodologies, and construction techniques are inadequate. Radar cross-section minimizing hull designs cannot accept distortion or deformation that often results. Structural distortion of thin- steel superstructure assemblies and its associated rework costs have emerged as a significant problem in ship construction. In response to this issue, a series of initiatives has been accomplished to understand the engineering issues and control production in thin-steel structural construction, with a goal to reduce overall cost. The objectives focus on detailed solutions for numerical finite element modeling, preferred cutting, welding and fabrication processes, and optimal assembly methods for distortion control.

The use of Light Detection and Ranging (LIDAR) mapping was developed as a technique to produce three-dimensional scans of shipboard assemblies for the purpose of quantifying the distortion phenomenon. The UNO COE investigated this problem by exploring all potential sources, from mill processes to assembly and rework. Sources of distortion include residual stress and condition of the incoming material, material-handling damage, cutting accuracy, intrinsic deflection in tool and foundations, fit-up accuracy, overwelding, assembly sequence, panel design complexity, and excessive rework.

An experiment was designed and carried out to investigate fabrication issues for lightweight test panel designs. Each panel was unique and incorporated different characteristics of this type of structure and used different techniques and processes during its fabrication. Out-of-plane dimensional variations were tracked during fabrication using LIDAR techniques previously developed in this program. Panel buckling, distortions, and anomalies discovered during this experiment were analyzed and characterized.

The work of the UNO COE resulted in the development of a preferred manufacturing plan for thin plate steel. The recommendations developed by the UNO COE were designed to mitigate the forces that cause the distortions and buckling inherent in thin steel fabrications. Recommendations of the preferred manufacturing plan include:

- Modify incoming material-handling and storage processes to prevent permanent deformation
- Precision mill or laser cut panel pieces to control accuracy and distortion before assembly
- Design and deploy an effective panel-handling and processing system
- Build a hard deck foundation and provide a material-clamping capability for panel fabrication
- Develop narrow-grove SAW or hybrid seam-welding procedures for panel blanket assembly
- Prefit and tack all stiffeners before panel fillet welding to improve restraint and fit-up
- Optimize tack weld size or grind to ensure blending into stiffener fillet welds
- Deploy precision high-speed fillet-welding parameters and procedures with through-the-arc or laser seam tracking
- Develop and deploy Transient Thermal Tensioning (TTT) distortion-prediction computer-aided engineering tools and production hardware for panel-welding systems
- Develop best practices for manual welding of inserts and transverse stiffeners to minimize overwelding

Work is in progress to deploy this technology on full-size production panels. When implemented, the new manufacturing plan produced thin conventional panels with no buckling distortion and complex panels with some buckling near manually welded inserts. New panel manufacturing lines are being procured to replace the current production lines at NGSS. Downstream operations receiving flatter material should see a reduction in the number of hours needed for fitting and welding assembly of panel structures. Ship-fitting costs for unit assembly should also see a significant improvement.

Solid-State Friction Stir Welding

Solid-State Friction Stir Welding produces a stronger and more reliable weld than other types of welding operations. This welding operation also reduces and eliminates the need for consumable welding materials and reduces hazardous fumes.

The National Center for Advanced Manufacturing, in a joint venture with the state of Louisiana, the National Aeronautics and Space Administration, the University of New Orleans, and Lockheed Martin Space Systems Company - Michoud Operations, researched the application of the Universal Friction Stir Welding System (UFSWS). The system eliminates the need for consumable welding products and increases the strength of the welded surfaces. Present technology allows only the welding of one side of two metal items at a time. For both sides to be welded, two passes must be performed. An external material must also be used to join the two items (i.e., welding rods). When joining two metal surfaces, gases are expended.

UFSWS is performed by the use of a pin-tool that rotates at a speed causing the metal to plasticize. Two types of pin-tools are used. First, a retractable pin-tool that is the approximate thickness of the material being welded rotates at a speed that allows the pin-tool to penetrate the two units to be welded. The tool is pressed down into the two units until the pin-tool's shoulder impacts the two surfaces. Once the shoulder contacts the surfaces, the rotating pin-tool will generate enough frictional heat to plasticize the metal edges. When this occurs, the pin-tool traverses along the weld seam and plasticizes the metal, generating a combination of extrusion and forging. After the tool moves away from the plasticized metal, it solidifies to become solidly welded, yielding a ductile, high-strength, solid-state weld. The second pin-tool is self-reacting where a hole is drilled between the two items to be welded. The self-reacting pin-tool has two shoulders that impact the front and back of the items being welded and a pin that goes through them. In a similar process, as is performed with the retractable pin-tool, the metal edges are plasticine, mixed together, and resolidified. This operation allows the pin-tool to weld the full thickness of the metal being welded, which ensures welding on both faces at the same time. At the end of this process, only a hole is left to plug. A special plug has been manufactured that allows the plug material and previously welded materials to fuse together. With this process, no external materials are used.

UFSWS also allows welding of diverse material, increases fatigue resistance by up to 30%, improves ductility, prevents fumes, ensures safe operation, reduces weld defects, welds tapered thickness joints, and reduces and eliminates the need for external materials. UFSWS also eliminates porosity and solidification cracking.

Use of Light Detection and Ranging for Ship Production

The University of New Orleans, College of Engineering has been conducting research on the use of Light Detection and Ranging for ship production.

The University of New Orleans, College of Engineering's (UNO COE's) Gulf Coast Region Maritime Technology Center (GCRMTC) conducted research on the use of Light Detection and Ranging (LIDAR) for ship production. The LIDAR system is a unique technology that can take a three-dimensional (3-D) scan of an object through multiple scans. This system can be used to determine the accuracy and quality of as-built modules and complete vessels to greatly speed and improve the manufacturing process. It can also be used to obtain as-built drawings and perform reverse engineering on as-built subsystems.

The GCRMTC determined the Riegl LPM-25HA-C LIDAR as one system that is suitable to the shipyard production environment based on range, data collection rate, accuracy, and eye safety. Acquiring multiple scans of an object from different views is needed because LIDAR scanners can only capture data from one perspective. PolyWorks and MENSI 3Dipsos 2.4c software is being used to combine scans to form one-point cloud and produce 3-D models and conventional 2-D drawings. The accuracy of two mating assemblies that are to be fitted can be determined using PolyWorks IMAlign software. The alignment error as a function of position is graphically represented, and the alignment error can then be corrected.

Interior and exterior measurements of a ship or building and numerous other shipyard applications can be easily acquired through LIDAR. The GCRMTC plans to introduce and train the shipbuilding industry on the use of LIDAR.

Facilities

Clean Technologies Evaluation and Emissions Test Facility

A clean technologies evaluation and emissions testing facility was erected and is available on the University of New Orleans campus for use by the maritime industry. Abrasive blasting, painting, welding, and metal-cutting processes can be studied with regard to their impact on emissions, waste minimization, regulatory compliance, and cost optimization.

The University of New Orleans, College of Engineering (UNO COE) designed and installed a clean technologies evaluation and emissions testing facility. This facility aids in the research of the optimization of maritime industrial processes (e.g., abrasive blasting, welding, painting, and metal cutting) and in the study of its impact on the environment, which is important to productivity and emission potential for airborne pollutants. Emission factors that include mass of pollutant/unit amount of work done or unit amount of product produced, are not readily available for all the processes—at least to the extent that it includes life cycle costing and life cycle assessment. Therefore, with the help of the maritime industry, regulatory agencies, equipment vendors, and materials suppliers, the facility and research provide a test and evaluation capability to promote the development of emission factors.

The clean technologies evaluation and emissions testing facility is located on the UNO campus, with partial funding received through a research project funded by the Environmental Protection Agency (EPA) Region IV. The 12' x 10' x 8' test facility is equipped with a fume extraction system and a two-

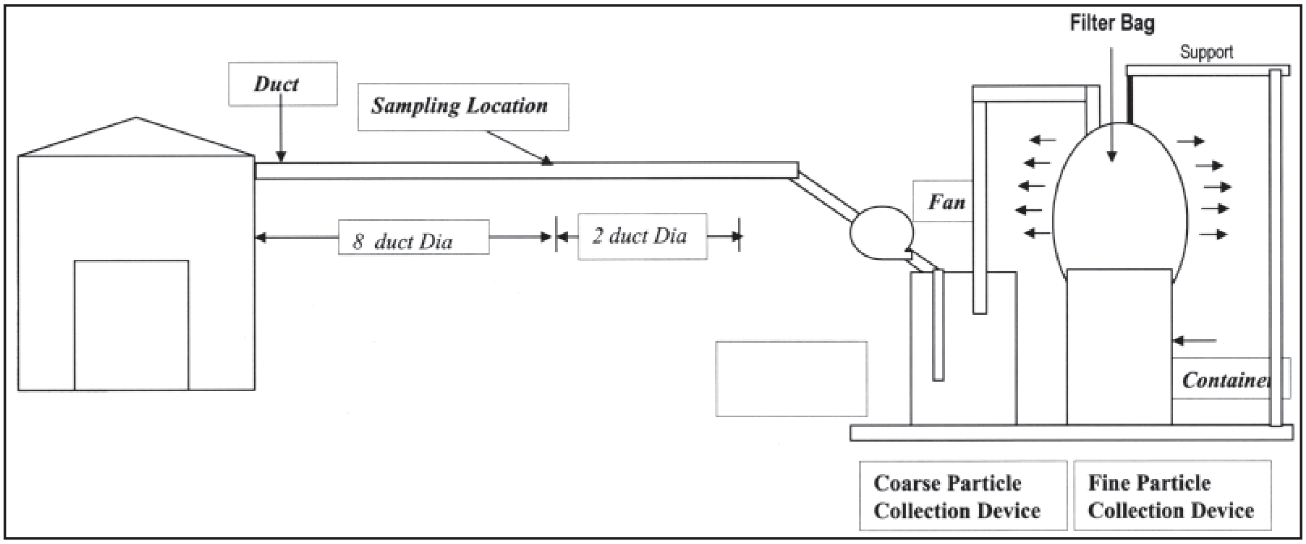


Figure 2-3. Clean Technologies Evaluation and Emissions Test Facility

stage particle-collection system (Figure 2-3). Fumes from the emissions test facility are extracted with a variable ventilation rate up to 5400 cubic feet per minute, allowing capture of the various size particles generated during blasting, welding, metal cutting, etc. The two-stage particle-collection system includes an inertial separator for coarse particles followed by a bag house for fine particles. The facility is equipped with a long, 12-inch-diameter duct to allow the measurement of particles under isokinetic conditions as recommended by the EPA for particle collection from stationary sources.

Research projects are underway to establish relationships among process conditions/materials and the cost/environmental parameters by measuring productivity and waste quantities (solids/hazardous wastes and air emissions) in conjunction with process parameters to develop necessary mathematical relationships and models to minimize costs and waste quantities. Process parameters and types of abrasives being evaluated include abrasive feed rates (lb/hr), blast pressures (psi), types of abrasives (coal slag, copper slag, steel shot, garnet, sand, and specular hematite), and gradations of abrasives (course, medium, and fine). Environmental/cost parameters include solid-waste generation potential (lb/square ft), atmospheric emissions (lb/1000 square ft), and productivity (square ft/hr). With this capability, the UNO COE expects to improve maritime industry productivity, environmental performance, and worker health as well as reduce abrasive consumption, energy, labor, atmospheric emissions, and overall costs.

Hurricane Katrina damaged this facility in August 2005. The facility will be repaired and/or refurbished after securing insurance and FEMA proceeds, both of which are still being processed.

ShipWorks Robotics Laboratory

Although automation has been the norm in the automotive industry for many years, it is not adequate for the U.S. shipbuilding industry. Typical automation requires high volume and high precision, neither of which is characteristic of shipbuilding. The ShipWorks Robotic Laboratory was developed by the Gulf Coast Region Maritime Technology Center to demonstrate to shipbuilders how robotics and process simulation can be incorporated into shipbuilding processes.

The Gulf Coast Region Maritime Technology Center (GCRMTC) at the University of New Orleans, College of Engineering (UNO COE) undertook a research program that greatly assists the shipbuilding industry to incorporate robotics in its processes. The GCRMTC has developed the ShipWorks Robotics Laboratory (SWRL) with a goal to develop methodologies that provide rapid robotic programming, increase the tolerance of the robot to handle shipyard accuracy levels (which may require some type of vision system), provide a baseline for shipyards to estimate return on investment, seek other process applications beyond welding, and establish a training program to support shipyard applications.

Figure 2-4. ShipWorks Robotics Laboratory

This research and demonstration project is a joint effort among GCRMTC, ManTech, the Naval Surface Warfare Center - Carderock, and the Navy Joining Center. Industrial collaborators include Northrop Grumman Ship Systems, Atlantic Marine, Bender Shipyards, Bollinger Shipyards, Electric Boat, Jeffboat, NASSCO, and the Northrop Grumman Newport News shipyard.

The GCRMTC-built SWRL (Figure 2-4) has two industrial welding robots with simulation software such as Delmia or vendor-proprietary tools incorporated. The facility provides the capability to model various robots, positioning devices such as gantries, and welding guns. During the planning phase, SWRL allows the designer to investigate various robots and positioners and to consider the range of parts to be welded. Part models can be loaded directly from computer-aided design models. After the welding system has been chosen, SWRL technologies can be used to simulate the specific welding process and prepare the off-line program (OLP) to actually weld a part. The OLP is loaded into the robot, and the welding is then carried out.

One industrial collaborator performed a complete study of the application of robotic welding to its processes and conducted a system study of alternative layouts and work flow. The simulation was provided to company executives, allowing them to see robotics in their facility. Following the simulation review, actual product testing was performed. The shipyard provided material cut with its standard processes, welding tack in the robotic cell; the robotic welding was then carried out by shipyard personnel. The results showed that one robot was adequate to meet the shipyard's production needs.

Another study considered the application of robotics to the end cuts of structural members. The ends of a structural member must often be cut in a complex shape to fit up with other parts. The system study considered the workflow and throughput to determine the equipment needed to automate the process. Various cutting devices including oxy-gas, plasma, and laser were considered to attach to the robot arm. A simulation of the system allowed the shipbuilders to see how the new system would fit and to compare costs.

A key area where existing technology is not adequate to support robotic welding in shipyards is vision systems for welding. These systems allow the robot to locate the part and confirm its size. During welding the seam track for in-process changes can be modified and torch movement can be slowed to accommodate gaps. Unfortunately, few welding vision systems exist, while those that are available are bulky and designed for straight welds.

The GCRMTC engineers designed, built, and tested a welding vision system designed for shipbuilding with key detection and agility capabilities that include:

- Detection: Seam position, end of material, bead connection, root gap, molten pool, and bead appearance
- Agility: Does not obstruct the torch, works around corners

The system consists of four small lenses mounted around the welding torch. Images are fed to a common screen via fiber optics. The image is captured by a high-performance camera that can accommodate a range of brightness from arc welding to natural light. Image processing is conducted real time to locate the seam and calculate the root gap. The system has been patented, and commercialization discussions are ongoing.

Another key area where current robotic welding technology is not adequate for shipbuilding is in the preparation of OLPs. In the automotive industry, the same weld is carried out thousands of times. As a result, workers will spend many hours developing the best OLP for welding. Shipbuilding, conversely, requires the welding of thousands of parts that are, for the most part, all different. Therefore, the time to program the part should be less than the time to weld the part.

GCRMTC engineers have developed technology based on Delmia UltraArc software, which substantially shortens the time to develop an OLP. The underlying concept is a "path macro" in which frequently recurring seam sequences (e.g., a watertight clip) are saved and reused on various subassemblies. The macro contains not only the path motion but all the process parameters, which are then combined with air moves to build the complete welding program.

GCRMTC engineers are also working with Sandia National Laboratories to enhance an automated path planning called AutoGen. The tool, originally developed under the National Shipbuilding Research Program, automatically prepares the complete OLP using the three-dimensional product model and relevant weld procedures.

Management

Technology Transfer

The University of New Orleans, College of Engineering created proven processes and methodologies to transfer technology developed from research projects to private entities and industries.

The University of New Orleans, College of Engineering (UNO COE) and its centers, such as the Gulf Coast Region Maritime Technology Center (GCRMTC), are not manufacturing facilities. The centers educate, research, and develop products and processes to be used in manufacturing facilities. The UNO COE, like most universities, is engaged in many research projects. These projects lead to the development of innovative and cutting-edge technologies and processes, which must be transferred to industry in the form of technology transfer to become effective tools that industry can use. The UNO COE developed methodologies and processes to effect the transfer of these research findings to the U.S. industrial base. The research conducted at the UNO COE and the GCRMTC is applied research, which from its incipience has an intended application, market, and customer base.

The GCRMTC was recently involved with three major technology transfer projects. The first was the Innovative Quotient (IQ) project. This project involved getting the U.S. shipbuilding industry to conduct a self-assessment of how it compared to truly innovative companies with regard to its ability to change. The IQ self-assessment tool was based on parameters known to be important to innovation. A meta analysis of existing literature on technology transfer and innovation developed the IQ model. This model was used to determine specific areas that needed to be assessed to measure the innovative abilities of an organization. IQ was linked to GCRMTC-developed software that was user-friendly and produced easily understandable outputs. After the group being evaluated answered the questions in the software package on innovation, the results were produced in a radar plot and used as a point of discussion with the group. The UNO COE found this dialogue to be the most informative step in the use of the IQ project. The software is now licensed to Managing Change Associates in Houston, Texas, and the UNO COE is in discussion with Top Tier, Inc., a gas and oil consulting company in Slidell, Louisiana.

The second successful technology transfer project completed by the GCRMTC was a productivity project that identified areas of improvement in the shipyard. The main result of the project was the development of a template for introducing new technologies into the shipyard through actual cases. This template consists of the three phases of adoption of new technology that include initiating, implementing, and institutionalizing. Within this context, the concept of the importance of knowing the difference between major and minor change was introduced. Handy worksheets were developed for each phase of adoption, and training was given to shipbuilders on the use of the worksheets. Through the understanding of how to implement technology and handle the related change, the reluctance to learning from others has decreased.

The third recent technology transfer project completed by the GCRMTC was the successful commercialization of the UNO COE-developed software. The significance of this project is that after all of the research, product development, beta testing and final development, the GCRMTC was able to find a viable commercial entity to take over the marketing, installation, upgrading, and support of the software. By having someone independent of the University market, install, and maintain the software, ship owners and operators have accepted the new technology that enables them to operate in a more efficient and cost-effective manner.

These examples show how the UNO COE undertakes research projects with the goal of transferring the technology to industry upon completion of the research and development of the product. By doing this, the UNO COE assists industry to become more competitive by incorporating state-of-the-art processes, materials, and technologies.

Section 3

Information

Design

Digital Planning for Shipyards

The University of New Orleans, College of Engineering draws upon its strong modeling and simulation expertise to design and develop a modeling and simulation capability for the shipbuilding industry. Working at the Gulf Coast Region Maritime Technology Center at the Northrop Grumman Ship Systems Avondale Operation shipyards, this project specified, designed, and demonstrated a digital planning system that will revolutionize the way shipyards are able to plan and evaluate a design for manufacturing.

The University of New Orleans, College of Engineering (UNO COE), under the auspices of the Gulf Coast Region Maritime Technology Center (GCRMTC), has led research and development of modeling and simulation (M&S) tools to benefit shipbuilding planning for manufacturing. Current shipyard practice for production planning is a labor-intensive, manual, and textual-based process usually requiring redundant work to implement change. Compounding the problem is that production planning usually occurs when the design is nearly complete; this does not readily allow for design changes to accommodate unforeseen production problems. M&S techniques have been applied to interrogate process plans and assembly sequences. However, these efforts are limited by the time and expense of collecting the appropriate data required for the model and the expense of creating the usually stand-alone models.

The objective of the Manufacturing Process Modeling Technology project was to develop a system that would store pertinent manufacturing process and planning knowledge, associate specific product data with the process information, and make both readily available to analysis tools. There were three distinct phases to this project:

- Phase I formulated a detailed modeling plan and requirements for the Manufacturing Process Planning System (MPPS) and selected a potential commercial solution to the system (Figure 3-1).
- The Phase II portion of the project performed a proof-of-concept study of Delmia Process Engineer, the selected commercial package. The goal of the Phase II effort was to determine the applicability of the selected software to the requirements specified in Phase I. Phase II determined the impact of the system to current-state business practices, areas for improvement in future-state business practices, organizational impacts, legacy system areas of impact, and capability gaps and limitations.
- The Phase III effort investigated the system in more detail in preparation for the anticipated implementation of the MPPS with the DD(X) program.

Testing was performed at two shipyards, Bath Iron Works (BIW) and North Grumman Ship Systems (NGSS). The division of research paralleled the associated efforts of each shipyard with respect to the DD(X) Destroyer Program. NGSS tested the capabilities of the tool within a new program, specifically the DD(X) program. NGSS utilized the tools for planning tasks associated with the conceptual design. BIW addressed the tail end of the production process, focusing on a Build Plan Review (BPR) process within a mature program (the DDG program). The goal was to determine if the tools could handle the quantity and type of information needed for detailed planning.

The results of the Phase II investigation demonstrated that the Delmia toolset (and the MPPS) provide rich functionality that will enable the shipyards to initiate process planning improvements during the development of a new ship program. The investigation at BIW has shown how an integrated, electronically based and three-dimensional support system can dramatically improve certain process planning tasks by as much as 90% for certain tasks within the BPR process, even under an existing infrastructure. NGSS results indicate that the benefits of implementing within a new shipbuilding program greatly outweigh the expense since the supporting infrastructure can be tailored to accommodate and support such a planning system. Using the planning test results, the shipyards propose a potential $12.8M savings on the first hull of a demonstrative destroyer program.

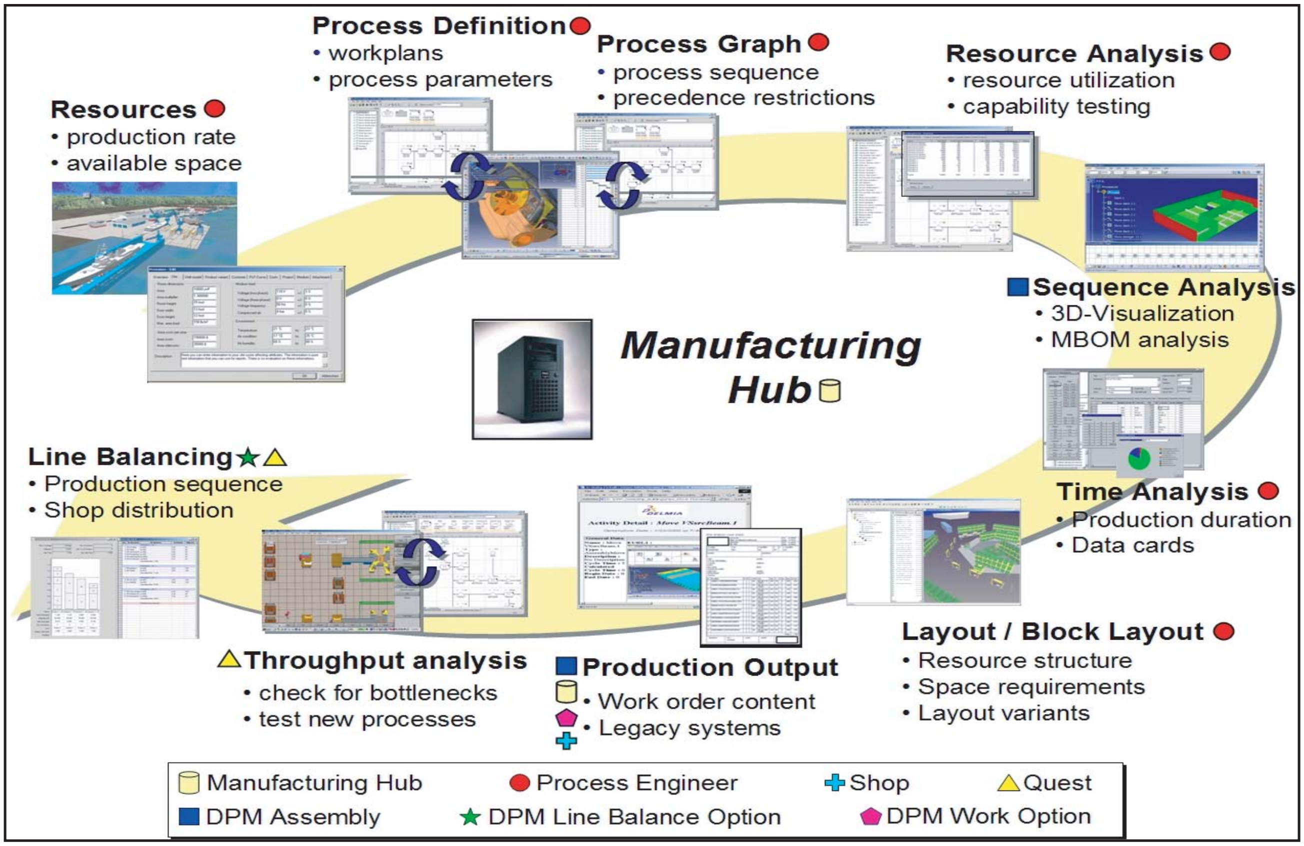


Figure 3-1. System Concept

By the end of the project, the team members were able to secure budgeting within the respective shipyard budgets for implementation of the MPPS. Since then, both shipyards have implemented some version of the system using commercial off-the-shelf components for best-of-class utilization.

Modeling Residual Stress in Steel Plate Making

Eliminating residual stress or a means to identify and predict the effects of the stress will enable shipbuilders to improve their usage of automated part nesting and cutting of steel plates while minimizing material usage. A team of researchers, including researchers from the University of New Orleans, College of Engineering, Bender Shipyards, Battelle, and Caterpillar, have undertaken a research project that will assist the shipbuilders and others.

The shipbuilding industry found that nesting several different parts within the same sheet of material and then cutting the parts to near net shape had some unexpected downfalls. Typically, cutter path movement is optimized to minimize cutter (laser or plasma) movement and maximize torch-on time. This process also ensures maximum utilization of material. Residual Stress (RS) is created within the plates of steel during the steel making process. This stress is relieved during the cutting operation, resulting in movement of the plates (e.g., walking, growth, shrinkage, and warping). This movement negates the accuracy of the cut parts as programmed and creates undue waste and scrap.

The University of New Orleans, College of Engineering (UNO COE) was asked to investigate this phenomenon and develop ways of mitigating the unwanted problems. The research began with the investigation of typical steel-making processes in major steel mills. Three steel-making processes were investigated: the reverse mill process, the steckle mill process, and the hot strip mill process. Possible sources of residual stress were thoroughly investigated, researched, and analyzed in each of these processes. Mill temperature data for each step of the steel-making process was collected, and three-dimensional models were generated to analyze the different rolling, leveling, and cooling processes—all possible sources of RS.

Since there are numerous thermal and mechanical parameters involved in steel-plate making, many of them contribute to thermal stress/strain development only at high temperatures and are washed out by subsequent process steps at lower temperatures. Leveling and cooling operational non-uniformity dominate the short-range RS distribution and do not affect long-range stress factors. Consequently, it was determined that primary leveling does not contribute to the stress development in plates. Below 1500°F, cooling mechanisms dominate the long-range RS distributions; for shipyard cutting dimensional accuracy, it is the long-range RS's that are of concern.

The research team is now conducting a systematic parametric study on long-range RS and will be developing a means to identify RS types (e.g., distribution characteristics and magnitude) for cutting optimizations. This information will assist the shipbuilders in attaining their goals of high accuracy, high- material utilization, optimized cutter-path utilization, and low material scrap. Final results and technical papers on this research project are now available.

The Wave™ Strategic Asset Management Software System

The University of New Orleans, College of Engineering collaborated with industry to transfer software technology development initially designed for naval applications. The Wave™ Strategic Asset Management software system enables industry to take advantage of research and development efforts performed for the Navy.

The University of New Orleans, College of Engineering (UNO COE) developed software that was designed to store, monitor, and investigate failures experienced from initial factory testing through ship delivery. This software was developed for Northrop Grumman Ship Systems (NGSS) in its construction of the LPD-17 (USS San Antonio class ship) for the U.S. Navy. The UNO COE saw a need in industry for this software to be used outside the military environment. The commercialized version of the software is the Wave™ Strategic Asset Management System (SAMS). Wave™ SAMS's unique features enable equipment operators to lower maintenance and repair costs, increase equipment availability, and reduce procurement costs.

Resurgence Software, headquartered in New Orleans, delivers innovative software solutions and services that help improve the bottom line for equipment owners and operators. One of their products, the Wave™ SAM, is a fully functional maintenance management and equipment and reliability analysis system that enables equipment owners and operators to improve their maintenance practices and optimize the reliability and financial performance of their organizations by maximizing equipment uptime, minimizing maintenance costs, and reducing the risk of equipment failure. Wave™ SAMS implementation by NGSS at four of its Gulf Coast shipyards (Pascagoula, Mississippi; Gulfport, Mississippi; Avondale, Louisiana; and Tallulah, Louisiana) has significantly improved maintenance management performance at each facility.

The Wave™ SAME software system (Version 4.0) offers the following enhancements:

- The ability to share aggregate data between plants and across the organization
- The addition of both predicted and required customer-defined parameters for mean time between failure and mean time to repair that allow the user to analyze actual performance versus expectations
- The creation of a failure review board module designed to formalize procedures for addressing critical failures
- The addition of "tree views" throughout the program, which allow users to easily navigate wherever there are hierarchical structures
- The ability to track equipment and failure during the construction phase, which makes Wave™ SAME a true-asset life cycle cost management package
- A management feature that enables users to keep track of warranty and asset information, even as a piece of equipment moves to different locations within an organization

World Standard Hierarchy of Equipment Boundaries

Standardization of reliability, availability, and maintainability performance data is a key element to obtain useful shareable information for use in the improvements of ship design and operation. The University of New Orleans, College of Engineering is currently attempting to establish a standard that will help plan and design teams handling reliability, availability, and maintainability objectives.

In an attempt to identify standard equipment boundaries within the maritime industry, the University of New Orleans, College of Engineering (UNO COE) investigated and performed research of existing standards and its applicability to this effort. Capturing high-quality reliability, availability, and maintainability (RAM) performance data requires careful and consistent collection of equipment failure and repair data, operating hours, and repair time. One important link that is currently lacking in the universal analysis and application of RAM equipment performance data is a well-defined standard of equipment nomenclature, boundary definition, taxonomy, and systems hierarchical data structure. Establishing this standard is the next step in ensuring that the reliability and maintainability data collected will be consistent across both commercial and military applications. Without agreed-upon boundaries and equipment identifiers, it becomes difficult—if not impossible—to share equipment data among organizations, benchmark equipment performance, perform modeling and simulation of current and proposed systems, or use performance data to improve operations of commercial and naval vessels. Creating consistency on the largest possible scale will produce accurate information for the improvement of shipbuilding and ship operations.

The objective of this effort is to propose and agree on standard equipment boundaries with the maritime industry, the U.S. Navy, and any other maritime organizations willing to participate and establish a worldwide set of standards for use by government and industry in operational data collection and reporting. Applications for this data include modeling and simulation of complex systems for new ship design, tracking of commercial and naval equipment performance, bench marking equipment performance across commercial and military applications, condition-based monitoring, overhaul planning, and preplanned product improvement using commercial-off-the-shelf and mission-specific equipment.

The following current equipment identification systems were reviewed:

- Norwegian SFI Group system
- Expanded Ship Work Breakdown Structure System of the U.S. Navy
- North Atlantic Treaty Organization codification system
- Draft Marine Safety Evaluation Program System of the U.S. Coast Guard
- ISO/Final Draft International Standard 14224 - petroleum and natural gas industries guidelines
- Draft ISO Standard for the Exchange Product (STEP) Model Data/Application Protocol (AP) 226 - Ship Breakdown Structure

The advantages and disadvantages of each system were identified. Requirements for potential compliance with ISO 13584 were also investigated. An object-oriented approach was selected since it offers higher efficiency as well as the best potential for compliance with existing standards. It was decided to use the draft ISO STEP AP 226 as the basis for the development of a generic list of objects.

A draft ship breakdown structure was developed for mechanical products. The proposed breakdown uses an object-oriented approach similar to the approach recommended by ISO 10303. Four levels of indenture from the ship to the maintenance part are proposed. A definition is provided for each object along with a list of properties for identification and RAM data exchange. The draft breakdown structure is currently being reviewed by the project advisory board.

The immediate objective is to turn the proposed draft into an official draft with the American Society for Testing and Materials. A further objective would be to expand the scope of the standard. In particular, advisory board members expressed the need to include software applications, which are becoming a critical element in modern ship design with respect to RAM assessment. This project is sponsored by the Office of Naval Research's Navy Manufacturing Technology Program through the Gulf Coast Region Maritime Technology Center at the UNO COE.

Test

Evaluation of Hex-Chrome Exposure Levels in the Shipbuilding Industry

The University of New Orleans, College of Engineering measured hex-chrome exposure levels under actual field conditions for arc welding in the shipbuilding industry.

When the Occupational Safety and Health Administration (OSHA) proposed a 200-fold reduction in permissible exposure levels for hex-chrome (Cr)(VI) among industrial workers, considerable problems were posed for the nation's Navy and shipbuilding facilities. The University of New Orleans, College of Engineering (UNO COE), under the direction of the Navy/Industry Task Group, set out to measure Cr(VI) exposure levels under actual field conditions. Measurements were collected for actual Navy work performed by Avondale. Processes evaluated included:

- Flux-Cored Arc Welding on AH36 Base Metal
- Shielded Metal Arc Welding on AH36 and Stainless Steel
- Gas Metal Arc Welding on Stainless Steel
- Gas Tungsten Arc Welding on Stainless Steel and Nickel Copper

The data also provided the opportunity to evaluate Nederman Filterbox and Binzel Gun control equipment under actual field conditions. Data was collected for both open areas (e.g., open shop areas and outdoor locations) and confined/semienclosed areas (e.g., tanks, modular units, and exhaust stacks). While the actual data provided limited samples and confidence in open areas, model equations were developed to replicate the concentrations of total fumes (Cr(VI) and Cr) measured against arc time.

Effectiveness of the Nederman Filterbox and the Binzel Gun was also documented for these areas. As a consequence of these efforts, the Navy, the shipbuilding industry, and the Occupational Safety and Health Administration (OSHA) have a much better basis for proceeding to establish rational permissible levels for Cr(VI) exposures among industrial workers.

There is a continued interest among shipbuilders to reduce weld fume exposures to workers as well as the public due to recent and/or proposed regulations of OSHA and the Environmental Protection Agency. The report continues to be useful in many ways.

Measurement of Residual Stress in Steel Plates

Laser Holographic Hole Drilling research conducted at the University of New Orleans, College of Engineering has the potential of making residual stress analysis measurements an inexpensive, quick, and highly accurate process for industry.

The shipbuilding industry is beginning to implement new technologies such as automated welding, cutting, and material movement in shipbuilding processes. In order for these technologies to work as envisioned, the shipyards will have tighter dimensional control of parts and must develop increased control of distortion of parts. The distortion of steel plates is almost always due to the residual stress (RS) that is caused by manufacturing processes. Some of those processes are milling, drilling, cutting, grinding, and welding—all necessary steps in the manufacturing of ships. Since the elimination of RS is not possible using today's manufacturing process, an inexpensive and quick method of measuring the stress is necessary. Once the degree of stress can be identified and measured inexpensively and corrective actions can be taken to reduce the stress, distortion can be reduced before other manufacturing processes are impacted.

Traditional methods of measuring stress are Strain Gage Hole Drilling (SGHD) and X-ray Diffraction (XRD). Other methods are available, including Synchrotron and Neutron Diffraction, but neither is considered to have a high degree of reliability. The University of New Orleans, College of Engineering (UNO COE) has recently undertaken a project to assess the capabilities of a new technology for measuring residual stress in materials. This technology is called Laser Holographic Hole Drilling (LHHD). In the mid-1980s, research found that holographic hole drilling caused an interference fringe pattern related to the displacements that occurred as a result of the hole drilling to the subsurface residual stress. In-plane sensitive electronic speckle pattern interferometry with automated fringe analysis was developed in 2000 for rapid stress analysis. The attainment of real-time or near-real-time results of the tests are now available. One RS measurement typically takes only five minutes.

The research team at the UNO COE measured RS in test specimens using several techniques, including SGHD, XRD, and LHHD. SGHD and XRD were selected because they are the industry standards. Each of the three methods for measuring RS has advantages and disadvantages. LHHD may become the preferred method of measuring RS in the shipbuilding industry. The advantages of LHHD over other methods include portability and quickness, no surface preparation, no costly strain gages, automated drilling and data analysis, and only two material properties required (Young's Modulus and Poisson's Ratio). LHHD is also semidestructive and does require hole drilling. A comparison of the results of the three technologies using identical base material conditions indicated that LHHD can become the most effective test method for determination of RS. However, the vibrations always present in a production atmosphere make LHHD measures problematic. This issue must be resolved before LHHD replaces SGHD or XRD as the preferred method of residual stress measurement in an industrial setting.

Production

Integrated Environmental Management Plan

The Environmental Management Plan developed by University of New Orleans, College of Engineering researchers is an effective tool that can be used by U.S. industry for managing environmental processes, concerns, and regulatory compliance.

The University of New Orleans, College of Engineering (UNO COE) developed a comprehensive environmental management tool that is applicable to not only the shipbuilding industry, but also other manufacturing enterprises. In order to develop an effective Environmental Management Plan (EMP) for any industry, a clear understanding of several factors is required. Some of those factors include processes; materials used in products; multimedia wastes generated; emissions pathways (land, air, and water); impact on the environment and health; environmental regulations; best management practices and controls; control over compliance, costs, image, and feedback; and continuous improvement.

In developing the EMP for the shipyards, all typical major shipyard processes were identified (e.g., surface preparation, surface finishing, painting, coating, welding, cutting, etc.) and then flowcharted to identify the possible sources of environmental concerns and the environmental outfall flow. After the processes were identified and flowcharted, the process flow verified, and environmental concerns identified, the UNO COE researchers developed a comprehensive series of reports and resource books detailing the process followed for the development of an effective program. These reports and resource books also provide guidance on regulatory requirements, waste minimization equipment, waste sampling and analytical methods, employee training, best management practices, and focus areas to reduce multimedia emissions.

This approach continues to benefit shipyards and Navy yards and is scalable to other industrial sectors with some modifications.

OSHA Compliance Management System

The University of New Orleans, College of Engineering began development of a personal computer-based system to track and monitor Occupational Safety and Health Administration worker exposure and hazards in the shipbuilding industry.

Facilities faced with monitoring and reporting compliance with Occupational Safety and Health Administration (OSHA) exposure and hazards may discover that the collection, analysis, and reporting effort are quite considerable. The University of New Orleans, College of Engineering (UNO COE) began the development of a personal computer-based system to track and manage that effort from one point. The compliance management system will contain data on worker exposure, health, safety, training, and related activities. It will be developed to calculate occupational safety and health parameters to support decisions on regulatory analysis and compliance. Four tasks have been identified, with the first two completed. These include established type of work versus risks, exposures, safety and health hazards, and established OSHA compliance procedures, calculations, and requirements.

Much of the data was collected separately to measure exposure levels in the shipbuilding industry and was used to complete the first task. Similarly, compliance models developed to assess worker health and safety information were derived from data collected under actual field conditions. The Nederman Filterbox is typical of measures used to control exposure in the shipbuilding industry.

Two remaining tasks are underway, including established shipyard responsibilities to achieve OSHA compliance and established performance-tracking procedures and methods. The third task will address monitoring, prevention efforts, data analysis, and reporting. The final task will consider historical trends and desired tracking metrics. The UNO COE is conducting the collection, analysis, and reporting effort in cooperation with OSHA and members of the shipbuilding industry.

Socket Welding of Titanium Grades

Research presently underway at the University of New Orleans, College of Engineering on improved welding methods for titanium pipes shows promise for improving quality and reducing welding costs for the shipbuilding and petrochemical industry.

In cooperation with the École Centrale de Nantes, the University of New Orleans, College of Engineering (UNO COE) is investigating a new welding technique for welding the P-80 socket joint on titanium pipe. Fusion welding of titanium is particularly difficult due to its low thermal conductivity coupled with the intrinsic spreading nature of titanium melt. Atmospheric conditions surrounding the welded joint also contribute to the welding difficulty. The P-80 Socket joint, which is very common in shipbuilding and petrochemical operations, typically takes two passes to meet specification. Reducing the number of passes while attaining proper joint geometry and strength reduces time spent achieving the welding and reduces opportunities for nonconformance. Parameters being investigated by the UNO COE and the École Centrale de Nantes researchers are electrode shape, assist gas, electrode-to-work distance, weld current (steady and pulsating), travel speed, flux composition, and flux thickness. The first step of this research will be conducted on flat titanium plates. This will allow for the various parameters to be investigated while eliminating the orbital effects of pipe welding. Based on the results of this research, fabrication of socket joints on pipes will be accomplished.

To date, flat-plate welding research has resulted in significant findings. Weld depth has increased from approximately 3 mm to approximately 6 mm while significantly reducing weld bead width. Because the shielding medium of chloride flux produces the desired results, it is more effective to use than chlorides.

Appendix A

Table of Acronyms

ACRONYM	DEFINITION
Al-Li	Aluminum-Lithium
ASD	Allowable Stress Design
AutoGen	Automatic Generation
BIW	Bath Iron Works
BMP	Best Manufacturing Practices
BPR	Build Plan Review
CAP	Cathodic Atmospheric Plasma
COE	College of Engineering
CR-VI	Hex-Chrome
DSS	Decision Support System
EMP	Environmental Management Plan
EPA	Environmental Protection Agency
GCRMTC	Gulf Coast Region Maritime Technology Center
IQ	Innovative Quotient
LHHD	Laser Holographic Hole Drilling
LIDAR	Light Detection and Ranging
LRFD	Load and Resistance Factor Design
M&S	Modeling and Simulation
MPPS	Manufacturing Process Planning System
MSDS	Material Safety Data Sheets
NAME	Naval Architecture and Marine Engineering
NASA	National Aeronautics and Space Administration
NCAM	National Center for Advanced Manufacturing
NGSS	Northrop Grumman Ship Systems
OLP	Off-line Program
OSHA	Occupational Safety and Health Administration
RAM	Reliability, Availability, and Maintainability
RS	Residual Stress
SAMS	Strategic Asset Management System
SBDC	Simulation Based Design Center
SGHD	Strain Gage Hole Drilling
SNL	Sandia National Laboratories
SUESC	Schlieder Urban Environmental Systems Center
SWRL	ShipWorks Robotics Laboratory
TTT	Transient Thermal Tensioning

UFSWS	Universal Friction Stir Welding System
UNO	University of New Orleans
XRD	X-ray Diffraction

Appendix B

BMP Survey Team

Team Member	Activity	Function
Al Lang 843-818-9498	**BMP Field Office - Charleston** Charleston, SC	**Team Chairman**
Gail Lavrusky 301-405-9990	**BMP Center of Excellence** College Park, MD	**Technical Writer**
Don Hill 317-849-3202	**BMP Field Office - Indianapolis** Indianapolis, IN	
Larry Halbig 317-891-9901	**BMP Field Office - Indianapolis** Indianapolis, IN	
Mike Delaney 843-572-1028	**BMP Field Office - Charleston** Charleston, SC	

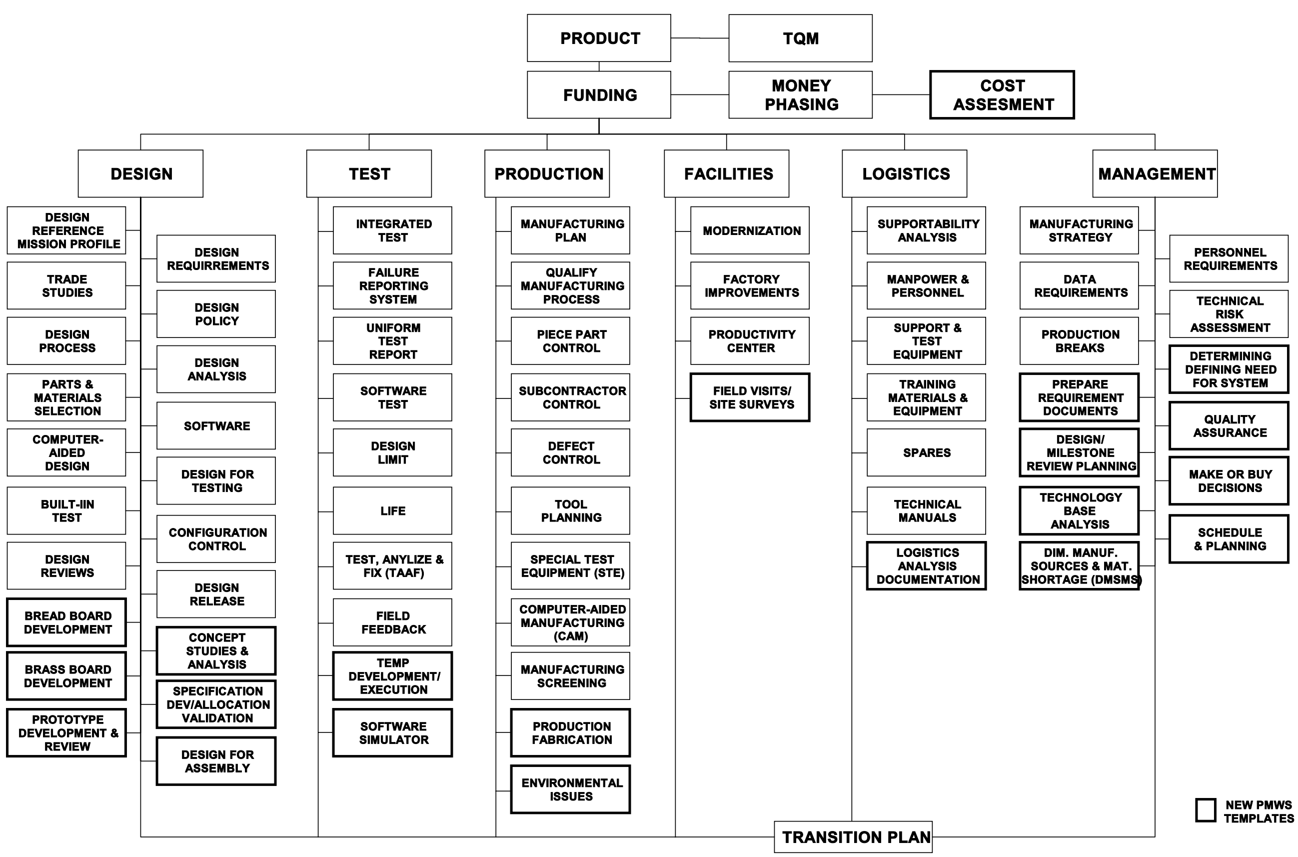
Appendix C

Critical Path Templates and BMP Templates

This survey was structured around and concentrated on the functional areas of design, test, production, facilities, logistics, and management as presented in the Department of Defense 4245.7-M, "Transition from Development to Production" document. This publication defines the proper tools-or templates-that constitute the critical path for a successful material acquisition program. It describes techniques for improving the acquisition process by addressing it as an industrial process that focuses on the product's design, test, and production phases which are interrelated and interdependent disciplines.

The BMP program has continued to build on this knowledge base by developing 17 new templates that complement the existing DOD 4245.7-M templates. These BMP templates address new or emerging technologies and processes.

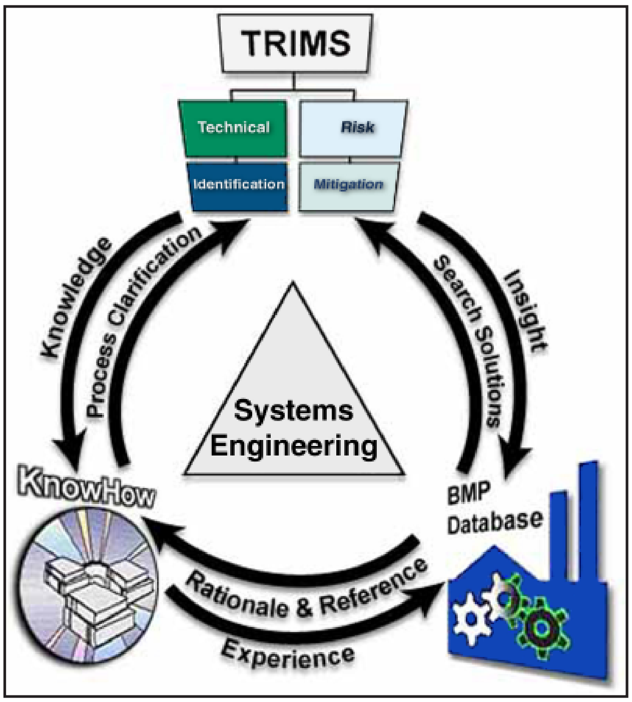
"CRITICAL PATH TEMPLATES FOR TRANSITION FROM DEVELOPMENT TO PRODUCTION"



Appendix D

The Program Manager's WorkStation

The Program Manager's WorkStation **(PMWS)** is an electronic suite of tools designed to provide timely acquisition and engineering information to the user. The main components of PMWS are KnowHow, the Technical Risk Identification and Mitigation System (TRIMS), and the BMP Database. These tools complement one another and provide users with the knowledge, insight, and experience to make informed decisions through and beyond all phases of product development and production.



KnowHow provides knowledge as an electronic library of technical reference handbooks, guidelines, and acquisition publications that cover a variety of engineering topics including the DoD 5000 series. The electronic collection consists of expert systems and simple digital books. In expert systems, KnowHow prompts the user to answer a series of questions to determine where the user is within a program's development. Recommendations are provided based on the book being used. In simple digital books, KnowHow leads the user through the process via an electronic table of contents to determine which books in the library will be the most helpful. The program also features a fuzzy logic text search capability so users can locate specific information by typing in keywords. KnowHow can reduce document search times by up to 95%.

TRIMS provides insight as a knowledge-based tool that manages technical risk rather than cost and schedule. Cost and schedule overruns are downstream indicators of technical problems. Programs generally have had process problems long before the technical problem is identified. To avoid this progression, TRIMS operates as a process-oriented tool based on a solid systems engineering approach. Process analysis and monitoring provide the earliest possible indication of potential problems. Early identification provides the time necessary to apply corrective actions, thereby preventing problems and mitigating their impact. TRIMS is extremely user-friendly and tailorable. This tool identifies areas of risk, tracks program goals and responsibilities, and can generate a variety of reports to meet the user's needs.

The **BMP Database** provides experience as a unique, one-of-a-kind resource with more than 4,000 best practices that have been verified and documented by an independent team of experts during BMP surveys. BMP publishes its findings in survey reports and provides the user with basic background, process descriptions, metrics and lessons learned, and a point of contact for further information. The BMP Database features a searching capability so users can locate specific topics by typing in keywords. Users can either view the results on screen or print them as individual abstracts, a single report, or a series of reports. The database can also be downloaded, run on-line, or purchased on CD-ROM from the BMP Center of Excellence. The BMP Database continues to grow as new surveys are completed. Additionally, the database is reviewed every other year by a BMP core team of experts to ensure the information remains current.

For additional information on PMWS, please contact the Help Desk at (301) 403-8179, or visit the BMP Web site at http://www.bmpcoe.org.

Appendix E

Best Manufacturing Practices Satellite Centers

There are currently ten Best Manufacturing Practices (BMP) satellite centers that provide representation for and awareness of the BMP Program to regional industry, government and academic institutions. The centers also promote the use of BMP with regional Manufacturing Technology Centers. Regional manufacturers can take advantage of the BMP satellite centers to help resolve problems, with the centers hosting informative, one-day regional workshops that focus on specific technical issues.

Center representatives also conduct BMP lectures at regional colleges and universities; maintain lists of experts who are potential survey team members; provide team member training; and train regional personnel in the use of BMP resources.

The nine BMP satellite centers include:

California

Izlay (Izzy) Mercankaya
BMP Satellite Center Manager
Naval Surface Warfare Center, Corona Division
Code QA-21, P.O. Box 5000
Corona, CA 92878-5000
(951) 273-5440
FAX: (951) 273-5315
izlay.mercankaya@navy.mil

District of Columbia

Brad Botwin
BMP Satellite Center Manager
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14th Street & Constitution Avenue, N.W.
H3876
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(202) 482-4060
FAX: (202) 482-5650
bbotwin@bis.doc.gov

Illinois

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BMP Satellite Center Manager
Rock Valley College
3301 North Mulford Road
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(815) 921-2073
FAX: (815) 654-4343
r.lindstrom@rvc.cc.il.us

Iowa

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BMP Satellite Center Manager
Iowa Procurement Outreach Center
2273 Howe Hall, Suite 2617
Ames, IA 50011
(515) 289-0280 or (515) 294-5240
FAX: (515) 294-4925
rcox@iastate.edu

Louisiana

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Site Director, Simulation Based Design Center
University of New Orleans, College of Engineering
Gulf Coast Region Maritime Technology Center
c/o NGSS-Avondale Operations
Station 721-1-1
5100 River Road
New Orleans, LA 70094-2706
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FAX: (504) 654-3880
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South Carolina Research Authority - Applied Research and Development Institute
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<u>**Tennessee**</u>

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biasdl@y12.doe.gov

Appendix F

Navy Manufacturing Technology Centers of Excellence

The Navy Manufacturing Technology Program has established Centers of Excellence (COEs) to provide focal points for the development and technology transfer of new manufacturing processes and equipment in a cooperative environment with industry, academia, and the Navy industrial facilities and laboratories. These consortium-structured COEs serve as corporate residences of expertise in particular technological areas. The following list provides a description and point of contact for each COE.

Best Manufacturing Practices Center of Excellence

The Best Manufacturing Practices Center of Excellence (BMPCOE) provides a national resource to identify and share best manufacturing and business practices being used throughout government, industry, and academia. The BMPCOE was established by the Office of Naval Research's BMP Program, the Department of Commerce, and the University of Maryland at College Park. By improving the use of existing technology, promoting the introduction of improved technologies, and providing non-competitive means to address common problems, the BMPCOE has become a significant factor in countering foreign competition.

Point of Contact:
Rebecca Clayton
Best Manufacturing Practices Center of Excellence
4321 Hartwick Road
Suite 400
College Park, MD 20740
Phone: (301) 405-9990
FAX: (301) 403-8180
E-mail: rebecca@bmpcoe.org

Institute for Manufacturing and Sustainment Technologies

The Institute for Manufacturing and Sustainment Technologies (iMAST) is located at the Pennsylvania State University's Applied Research Laboratory. iMAST's primary objective is to address challenges relative to Navy and Marine Corps weapon system platforms in the areas of mechanical drive transmission technologies, materials processing technologies, laser processing technologies, advanced composites technologies, and repair technologies.

Point of Contact:
Mr. Robert Cook
Institute for Manufacturing and Sustainment Technologies
ARL Penn State University
P.O. Box 30
State College, PA 16804-0030
Phone: (814) 863-3880
FAX: (814) 863-1183
E-mail: rbc5@psu.edu

Composites Manufacturing Technology Center (operated by the South Carolina Research Authority)

The Composites Manufacturing Technology Center (CMTC) is a Center of Excellence for the Navy's Composites Manufacturing Technology Program. The South Carolina Research Authority (SCRA) operates the CMTC and the Composites Consortium (TCC) serves as the technology resource. The TCC has strong, in-depth knowledge and experience in composites manufacturing technology. The SCRA/CMTC provides a national resource for the development and dissemination of composites manufacturing technology to defense contractors and subcontractors.

Point of Contact:
Mr. Henry Watson
Applied Research and Development Institute
Composites Manufacturing Technology Center
934-D Old Clemson Highway
Eagles Landing Professional Park
Seneca, SC 29672
Phone: (864) 656-6566
FAX: (864) 653-7434
E-mail: watson@scra.org

Electronics Manufacturing Productivity Facility (operated by American Competitiveness Institute)

The Electronics Manufacturing Productivity Facility (EMPF) identifies, develops, and transfers innovative electronics manufacturing processes to domestic firms in support of the manufacture of affordable military systems. The EMPF operates as a consortium comprised of government, industry, and academic participants led by the American Competitiveness Institute under a cooperative agreement with the Navy.

Point of Contact:
Mr. Michael Frederickson
Electronics Manufacturing Productivity Facility
One International Plaza, Suite 600
Philadelphia, PA 19113
Phone: (610) 362-1200, ext. 215
FAX: (610) 362-1288
E-mail: mfrederickson@aciusa.org

Electro-Optics Center (operated by the Pennsylvania State University's Applied Research Laboratory)

The Electro-Optics Center (EOC) is a national consortium of electro-optics industrial companies, universities, and government research centers that share their electro-optics expertise and capabilities through project teams focused on Navy requirements. Through its capability for national electronic communication and rapid reaction and response, the EOC can address issues of immediate concern to the Navy Systems Commands. The EOC is managed by the Pennsylvania State University's Applied Research Laboratory.

Point of Contact:
Dr. Karl Harris
Electro-Optics Center
West Hills Industrial Park
77 Glade Drive
Kittanning, PA 16201
Phone: (724) 545-9700
FAX: (724) 545-9797
E-mail: kharris@psu.edu

Navy Joining Center (operated by Edison Welding Institute)

The Navy Joining Center (NJC) provides a national resource for the development of materials joining expertise and the deployment of emerging manufacturing technologies to Navy contractors, subcontractors, and other activities. The NJC works with the Navy to determine and evaluate joining technology requirements and conduct technology development and deployment projects to address these issues. The NJC is operated by the Edison Welding Institute.

Point of Contact:
Mr. Harvey R. Castner
EWI/Navy Joining Center
1250 Arthur E. Adams Drive
Columbus, OH 43221-3585
Phone: (614) 688-5063
FAX: (614) 688-5001
E-mail: harvey_castner@ewi.org

Navy Metalworking Center (operated by Concurrent Technologies Corporation)

The Navy Metalworking Center provides a national center for the development, dissemination, and implementation of advanced technologies for metalworking products and processes. Operated by the Concurrent Technologies Corporation, the Navy Metalworking Center helps the Navy and defense contractors improve manufacturing productivity and part reliability through development, deployment, training, and education for advanced metalworking technologies.

Point of Contact:
Dr. Daniel Winterscheidt
Navy Metalworking Center
c/o Concurrent Technologies Corporation
100 CTC Drive
Johnstown, PA 15904-1935
Phone: (814) 269-6840
FAX: (814) 269-2501
E-mail: winter@ctcgsc.com

Energetics Manufacturing Technology Center

The Energetics Manufacturing Technology Center (EMTC) addresses unique manufacturing processes and problems of the energetics industrial base to ensure the availability of affordable, quality, and safe energetics. The EMTC's focus is on technologies to reduce manufacturing costs, improve product quality and reliability, and develop environmentally benign manufacturing processes. The EMTC is located at the Indian Head Division of the Naval Surface Warfare Center.

Point of Contact:
Mr. John Brough
Naval Surface Warfare Center
Indian Head Division
101 Strauss Avenue
Building D326, Room 227
Indian Head, MD 20640-5035
Phone: (301) 744-4417
DSN: 354-4417
FAX: (301) 744-4187
E-mail: broughja@ih.navy.mil

Center for Naval Shipbuilding Technology

The Center for Naval Shipbuilding Technology (CNST) supports the Navy's ongoing effort to identify, develop and deploy in U.S. shipyards, advanced manufacturing technologies that will reduce the cost and time to build and repair Navy ships. CNST provides a focal point for developing and transferring new manufacturing processes and technologiy; benefits that will accrue not only to the Navy but to industry. CNST is operated and managed by ATI in Charleston, South Carolina.

Point of Contact:
Mr. Ron Glover
Center for Naval Shipbuilding Technology
5300 International Boulevard
Charleston, SC 29418
Phone: (843) 760-4606
FAX: (843) 760-4098
E-mail: glover@aticorp.org

Gulf Coast Region Maritime Technology Center (operated by the University of New Orleans College of Engineering)

The Gulf Coast Region Maritime Technology Center (GCRMTC) fosters competition in shipbuilding technology through cooperation with the U.S. Navy, representatives of the maritime industries, and various academic and private research centers throughout the country. Located at the University of New Orleans, the GCRMTC focuses on improving design and production technologies for shipbuilding, reducing material and total ownership costs, providing education and training, and improving environmental engineering and management.

Point of Contact:
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Gulf Coast Region Maritime Technology Center
Research and Technology Park
CERM Building, Room 409
University of New Orleans
New Orleans, LA 70148-2200
Phone: (504) 280-5609
FAX: (504) 280-3898
E-mail: fbordelo@uno.edu

Appendix G

Completed Surveys

As of this publication, 152 surveys have been conducted and published by BMP at the companies listed below. Copies of older survey reports may be obtained through DTIC or by accessing the BMP Web site. Requests for copies of recent survey reports or inquiries regarding BMP may be directed to:

Best Manufacturing Practices Program
4321 Hartwick Road, Suite 400
College Park, MD 20740
Attn: Rebecca Clayton, Director
Phone: 1-800-789-4267
FAX: (301) 403-8180
rebecca@bmpcoe.org

1985	Litton Guidance & Control Systems Division - Woodland Hills, CA (now Northrop Grumman Navigation Systems)
1986	Honeywell, Incorporated Undersea Systems Division - Hopkins, MN (now Alliant TechSystems, Inc.) Texas Instruments Defense Systems & Electronics Group - Lewisville, TX General Dynamics Pomona Division - Pomona, CA Harris Corporation Government Support Systems Division - Syosset, NY IBM Corporation Federal Systems Division - Owego, NY Control Data Corporation Government Systems Division - Minneapolis, MN
1987	Hughes Aircraft Company Radar Systems Group - Los Angeles, CA ITT Avionics Division - Clifton, NJ Rockwell International Corporation Collins Defense Communications - Cedar Rapids, IA (now Rockwell Collins) UNISYS Computer Systems Division - St. Paul, MN
1988	Motorola Government Electronics Group - Scottsdale, AZ General Dynamics Fort Worth Division - Fort Worth, TX Texas Instruments Defense Systems & Electronics Group - Dallas, TX Hughes Aircraft Company Missile Systems Group - Tucson, AZ Bell Helicopter Textron, Inc. - Fort Worth, TX Litton Data Systems Division - Van Nuys, CA GTE C^3 Systems Sector - Needham Heights, MA
1989	McDonnell Douglas Corporation McDonnell Aircraft Company - St. Louis, MO Northrop Corporation Aircraft Division - Hawthorne, CA Litton Applied Technology Division - San Jose, CA Litton Amecom Division - College Park, MD (now Northrop Grumman Electronic Systems Division) Standard Industries - LaMirada, CA (now SI Manufacturing) Engineered Circuit Research, Incorporated - Milpitas, CA Teledyne Industries Incorporated Electronics Division - Newbury Park, CA Lockheed Aeronautical Systems Company - Marietta, GA Lockheed Missile Systems Division - Sunnyvale, CA (now Lockheed Martin Missiles and Space) Westinghouse Electronic Systems Group - Baltimore, MD (now Northrop Grumman Corporation) General Electric Naval & Drive Turbine Systems - Fitchburg, MA Rockwell Autonetics Electronics Systems - Anaheim, CA (now Boeing North American A&MSD) TRICOR Systems, Incorporated - Elgin, IL
1990	Hughes Aircraft Company Ground Systems Group - Fullerton, CA TRW Military Electronics and Avionics Division - San Diego, CA MechTronics of Arizona, Inc. - Phoenix, AZ Boeing Aerospace & Electronics - Corinth, TX Technology Matrix Consortium - Traverse City, MI Textron Lycoming - Stratford, CT

1991	Resurvey of Litton Guidance & Control Systems Division - Woodland Hills, CA Norden Systems, Inc. - Norwalk, CT (now Northrop Grumman Norden Systems) Naval Avionics Center - Indianapolis, IN United Electric Controls - Watertown, MA Kurt Manufacturing Company - Minneapolis, MN MagneTek Defense Systems - Anaheim, CA (now Power Paragon, Inc.) Raytheon Missile Systems Division - Andover, MA (now Raytheon Integrated Air Defense Center) AT&T Federal Systems Advanced Technologies and AT&T Bell Laboratories - Greensboro, NC and Whippany, NJ Resurvey of Texas Instruments Defense Systems & Electronics Group - Lewisville, TX
1992	Tandem Computers - Cupertino, CA Charleston Naval Shipyard - Charleston, SC Conax Florida Corporation - St. Petersburg, FL Texas Instruments Semiconductor Group Military Products - Midland, TX Hewlett-Packard Palo Alto Fabrication Center - Palo Alto, CA Watervliet U.S. Army Arsenal - Watervliet, NY Digital Equipment Company Enclosures Business - Westfield, MA and Maynard, MA Computing Devices International - Minneapolis, MN (now General Dynamics Information Systems) (Resurvey of Control Data Corporation Government Systems Division) Naval Aviation Depot Naval Air Station - Pensacola, FL
1993	NASA Marshall Space Flight Center - Huntsville, AL Naval Aviation Depot Naval Air Station - Jacksonville, FL Department of Energy Oak Ridge Facilities (Operated by Martin Marietta Energy Systems, Inc.) - Oak Ridge, TN (now National Nuclear Security Administration) McDonnell Douglas Aerospace - Huntington Beach, CA (now Boeing Space Systems) Naval Surface Warfare Center Crane Division - Crane, IN and Louisville, KY Philadelphia Naval Shipyard - Philadelphia, PA R. J. Reynolds Tobacco Company - Winston-Salem, NC Crystal Gateway Marriott Hotel - Arlington, VA Hamilton Standard Electronic Manufacturing Facility - Farmington, CT (now Hamilton Sundstrand) Alpha Industries, Inc. - Methuen, MA
1994	Harris Semiconductor - Palm Bay, FL (now Intersil Corporation) United Defense, L.P. Ground Systems Division - San Jose, CA Naval Undersea Warfare Center Division Keyport - Keyport, WA Mason & Hanger - Silas Mason Co., Inc. - Middletown, IA (now American Ordnance LLC) Kaiser Electronics - San Jose, CA U.S. Army Combat Systems Test Activity - Aberdeen, MD (now Aberdeen Test Center) Stafford County Public Schools - Stafford County, VA
1995	Sandia National Laboratories - Albuquerque, NM Rockwell Collins Avionics & Communications Division - Cedar Rapids, IA (now Rockwell Collins, Inc.) (Resurvey of Rockwell International Corporation Collins Defense Communications) Lockheed Martin Electronics & Missiles - Orlando, FL McDonnell Douglas Aerospace (St. Louis) - St. Louis, MO (now Boeing Integrated Defense Systems) (Resurvey of McDonnell Douglas Corporation - McDonnell Aircraft Company) Dayton Parts, Inc. - Harrisburg, PA Wainwright Industries - St. Peters, MO Lockheed Martin Tactical Aircraft Systems - Fort Worth, TX (now Lockheed Martin Aeronautics Company) (Resurvey of General Dynamics Fort Worth Division) Lockheed Martin Government Electronic Systems - Moorestown, NJ Sacramento Manufacturing and Services Division - Sacramento, CA JLG Industries, Inc. - McConnellsburg, PA
1996	City of Chattanooga - Chattanooga, TN Mason & Hanger Corporation - Pantex Plant - Amarillo, TX Nascote Industries, Inc. - Nashville, IL Weirton Steel Corporation - Weirton, WV NASA Kennedy Space Center - Cape Canaveral, FL Resurvey of Department of Energy, Oak Ridge Operations - Oak Ridge, TN (now National Nuclear Security Administration)

1997	Headquarters, U.S. Army Industrial Operations Command - Rock Island, IL (now Operational Support Command) SAE International and Performance Review Institute - Warrendale, PA Polaroid Corporation - Waltham, MA Cincinnati Milacron, Inc. - Cincinnati, OH (now Cincinnati Machine, LLC) Lawrence Livermore National Laboratory - Livermore, CA Sharretts Plating Company, Inc. - Emigsville, PA Thermacore, Inc. - Lancaster, PA Rock Island Arsenal - Rock Island, IL Northrop Grumman Corporation - El Segundo, CA (Resurvey of Northrop Corporation Aircraft Division) Letterkenny Army Depot - Chambersburg, PA Elizabethtown College - Elizabethtown, PA Tooele Army Depot - Tooele, UT
1998	United Electric Controls - Watertown, MA Strite Industries Limited - Cambridge, Ontario, Canada Northrop Grumman Corporation - El Segundo, CA Corpus Christi Army Depot - Corpus Christi, TX Anniston Army Depot - Anniston, AL Naval Air Warfare Center, Lakehurst - Lakehurst, NJ Sierra Army Depot - Herlong, CA ITT Industries Aerospace/Communications Division - Fort Wayne, IN Raytheon Missile Systems Company - Tucson, AZ Naval Aviation Depot North Island - San Diego, CA U.S.S. Carl Vinson (CVN-70) - Commander Naval Air Force, U.S. Pacific Fleet Tobyhanna Army Depot - Tobyhanna, PA
1999	Wilton Armetale - Mount Joy, PA Applied Research Laboratory, Pennsylvania State University - State College, PA Electric Boat Corporation, Quonset Point Facility - North Kingstown, RI Resurvey of NASA Marshall Space Flight Center - Huntsville, AL Orenda Turbines, Division of Magellan Aerospace Corporation - Mississauga, Ontario, Canada (now Orenda Turbines, Repair, Overhaul and Industrial - Division of Magellan Aerospace Corporation)
2000	Northrop Grumman, Defensive Systems Division - Rolling Meadows, IL Crane Army Ammunition Activity - Crane, IN Naval Sea Logistics Center, Detachment Portsmouth - Portsmouth, NH Stryker Howmedica Osteonics - Allendale, NJ (now Stryker Orthopaedics)
2001	The Tri-Cities Tennessee/Virginia Region - Johnson City, TN General Dynamics Armament Systems - Burlington, VT (now General Dynamics Armament and Technical Products) Lockheed Martin Naval Electronics & Surveillance Systems-Surface Systems - Moorestown, NJ (now Lockheed Martin MS-2) Frontier Electronic Systems - Stillwater, OK
2002	U.S. Coast Guard, Maintenance and Logistics Command-Atlantic - Norfolk, VA U.S. Coast Guard, Maintenance and Logistics Command-Pacific - Alameda, CA Directorate for Missiles and Surface Launchers (PEO TSC-M/L) - Arlington, VA (now Surface Ship Weapons & Launchers - PEO IWS 3.0) General Tool Company - Cincinnati, OH
2003	University of New Orleans, College of Engineering - New Orleans, LA Bender Shipbuilding and Repair Company, Inc. - Mobile, AL In Tolerance - Cedar Rapids, IA ABC Virtual Communications, Inc. - West Des Moines, IA Resurvey of Electric Boat Corporation, Quonset Point Facility - North Kingstown, RI United Defense, L.P. Ground Systems Division - Aiken, SC Auto-Valve, Inc. - Dayton, OH

2004	United Defense, L.P. Armament Systems Division - Aberdeen, SD TOMAK Precision - Lebanon, OH RB Tool & Manufacturing Company - Cincinnati, OH Forest City Gear - Roscoe, IL CALCE Electronic Products and Systems Center - College Park, MD (now Center for Advanced Life Cycle Engineering - CALCE) U.S. Army Aviation & Missile Command, Automation Division-Integrated Materiel Management Center - Redstone Arsenal, AL
2005	Northrop Grumman Electronic Systems - Baltimore, MD Raytheon Integrated Air Defense Center - Andover, MA
2006	Raytheon-Louisville - Louisville, KY Midwest Metal Products - Cedar Rapids, IA Rockwell Collins - Cedar Rapids, IA Resurvey of Tobyhanna Army Depot - Tobyhanna, PA
2007	Raytheon Network Centric Systems Manufacturing Center - Largo, FL Resurvey of University of New Orleans, College of Engineering - New Orleans, LA