Industry & Government Roles in the Development of CAD/CAM Tools for Navy Shipbuilding

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SUMMARY

This paper will explore the role of industry, navies, and government in implementing industry-wide changes to shipbuilding software tools in an effort to reduce fleet acquisition costs. The results achieved through a series of collaborative US Navy National Shipbuilding Research Program (NSRP) projects involving many US shipbuilders will be highlighted.

1. INTRODUCTION

Costs for building naval ships have been increasing significantly over the last decade despite successful attempts by individual shipbuilders to improve practices. Naval shipbuilding, even more so than commercial shipbuilding, consists of a community of organizations which regularly design and build for a single customer. This offers significant opportunities for improvement and cost savings if research and development (R&D) efforts across the entire group of organizations can be centrally directed.

Many of these organizations, especially those building lighter naval vessels, or those building non-combatant or support vessels, are also involved in commercial shipbuilding. In addition the engineering and trades workforces within a shipbuilding community are often extremely migratory, resulting in a significant number of workers moving from naval to commercial shipyards and back again. Finally, to create sufficient demand to allow shipbuilding support services and the supply chain to be self sustaining, the adoption of new techniques, materials or technology must involve the commercial industry as well. In the best interests of naval shipbuilding, commercial shipbuilders should be involved in any centralized R&D efforts.

Organizing and managing a major effort involving naval shipbuilders, commercial shipbuilders, industry suppliers, technology vendors, government organizations, and the navy, is rife with many seemingly insurmountable challenges.

Despite these challenges, this paper will discuss the history of a number of successful programs which have significantly improved the state of the US shipbuilding industry under the auspices of the National Shipbuilding Research Program (NSRP).

2. NATIONAL SHIPBUILDING RESEARCH PROGRAM

In 1993 President Clinton established the Defense Advanced Research Projects Agency (DARPA) MARITECH program. The MARITECH initiative was tasked with transitioning the major shipyards in the US shipbuilding industry from a pure military focus to a combined commercial and naval shipbuilding capacity. The end goal was to establish an internationally competitive shipbuilding industry in the US. The initiatives funded as part of this program were largely initiated, led, and managed by DARPA. While the MARITECH program had resulted in a number of successful projects, it was only been intended to have a 5 year life.

In 1998 the National Shipbuilding Research Program (NSRP) was created as a successor to the DARPA MARITECH program. The new program was established with one key difference. The NSRP was to be led by industry shipyards and all funded projects were to be cooperative, collaborative efforts that impacted and benefited multiple shipyards. The US shipyards were encouraged to no longer consider processes as a major competitive differentiator.

An NSRP Executive Control Board (ECB) was established to oversee NSRP activities. This board contains executives from each of the major naval and commercial shipyards in the US. These shipyards include Northrop Grumman Shipbuilding - Gulf Coast - Avondale Operations, Northrop Grumman Shipbuilding - Gulf Coast - Pascagoula, Northrop Grumman Shipbuilding - Newport News, General Dynamics - Electric Boat, General Dynamics - Bath Iron Works, General Dynamics - NASSCO, Todd Pacific Shipyards, Marinette Marine Corporation, VT Halter, Bollinger Shipyards, Bender Shipbuilding, and Atlantic Marine. As the members of the board include representation from commercial and naval shipyards of varying sizes it was ensured that projects which are funded benefited a wider cross section of the industry.

3. INDUSTRY WIDE IMPROVEMENTS

3.1 THE EARLY YEARS

Despite the establishment of the NSRP a few years prior and the completion of a number of successful projects, a 2001 study conducted by First Marine International (FMI) painted a dismal picture of US shipbuilding. The FMI system, which measures the current competitive situation of a shipyard and compares those findings to international best practices, found that the US industry was on average significantly behind their international counterparts. While it found that the US shipyards surveyed had improved since the establishment of the NSRP program, it was noted that the international shipyards had also improved, and at a faster rate.

The study specifically found that, “Some U.S. shipyards are best in the world in isolated factors surveyed. However the broad spread of Best Practice Ratings in the industry-wide report shows the need to improve the industry as a whole to bring the lower performing yards up closer to the higher rated yards. Collaboration is needed to narrow the band near the top performer.” (FMI 2001)

While many areas of potential improvement were discussed, the study noted that one of the weakest areas for many of the shipyards was design and production engineering.

3.2 A COMMON SHIPBUILDING TOOL

While the NSRP was in its formative years and the FMI study was being created a new factor was being introduced into the US shipbuilding industry. The ShipConstructor software package was being adopted by a significant number of US shipbuilders. By 2003 ShipConstructor was in use by the majority of the US commercial industry and was being implemented on several upcoming US Navy and Coast Guard vessels. Of those shipyards with representation on the NSRP ECB, 7 out of 12 had begun to rely on ShipConstructor as their primary engineering and production software.

3.2 (a) The Appearance of Collaborative Projects

The emergence of a common tool removed one of the more significant barriers to industry wide improvement in the area of Design and Production Engineering, as well as in peripheral activities including business processes, and production capabilities. Despite the findings of the 2001 FMI study regarding the potential opportunities for improvement to be found in the areas of design and production engineering, few projects had successfully been implemented over a wide cross section of the industry. Without a common platform, changes to production engineering and design, whether these were improvements to processes or software tools, rarely could be applied to more than a small handful of shipyards.

Once a common platform was introduced many new collaborative projects were proposed, a significant number of which were successfully funded and implemented.

Project	**Participants (NSRP ECB Members)**
Shipyard Design Tool Enhancement I	17 (6)
Shipyard Design Tool Enhancement III	17 (8)
Smart “As-Built” Models	7 (4)
Modern Shipbuilding Design Course	10 (3)
Practical Applications of Design for Production	7 (4)

Table 1 Major successful NSRP projects involving ShipConstructor

3.2 (b) Industry Impact

As a direct result of the implemented NSRP projects, the ShipConstructor software tools have been greatly enhanced, as has the way in which they are implemented by US shipyards. These enhancements to ShipConstructor have been at least partially responsible for the significant improvements in the production engineering capabilities of the US shipbuilding industry.

At the time of writing, more than 150 US shipyards and design agents of various sizes use ShipConstructor in some fashion. This includes 9 of the 12 NSRP ECB members, and many of the US shipyards responsible for US Navy shipbuilding.

3.2 (c) Navy Shipbuilding Programs

Since the beginning of the NSRP projects involving ShipConstructor, many US Navy shipbuilding programs have benefited from the increased Design and Production Engineering capabilities which have been created. The affected US Navy and Coast Guard shipbuilding programs include both of the Littoral Combat Ships (LCS), the National Security Cutters (NSC), the LHA-6, the Improved Navy Lighterage System (INLS), the DDG-113 Arleigh Burke-class destroyer, the TAG-M(R) missile ranging vessel, the Joint High Speed Vessel (JHSV), and many others. While it is difficult to determine the direct fiscal benefit that resulted from these improvements on the specific shipbuilding programs, it is not much of a stretch to infer that such a benefit does exist and that it is likely significant.

3.2 (d) Direct Return on Investment (ROI)

Since the inception of the NSRP in 1998 over $74m USD in total project funding has been provided to the industry. In return these projects have been estimated to have had a direct return (not including secondary or tertiary ROI to the Navy or other owner operators) of more than $373m USD.

1998 - 2009	Savings	125,099,547
	Avoidance	248,446,720
	Subtotal	**373,546,267**
Funds Received by Industry (FY99 - Feb 09)		**74,111,137**

Table 2 ROI on NSRP projects 1998 – 2009

3.3 RESULTING IMPROVEMENTS

In 2007 FMI released a second study, largely focused on mid-tier shipyards, which evaluated the progress that had been made by the US industry since the original study. In some areas the US shipyards which were studied had made significant improvements however overall they still lagged behind the international yards included in the benchmark that year.

Category	US 2001	US 2007	Intl 2007
Steelwork Production	2.2	2.4	2.9
Outfit Manufacturing and Storage	2.5	2.6	3.4
Pre-erection Activities	2.4	2.5	2.8
Ship Construction and Outfitting	2.7	3.1	3.5
Yard Layout and Environment	2.5	2.6	3.6
Design and Production Engineering	2.7	3.2	3.4
Organization and Operating Systems	3.2	3.4	3.8
Overall Industry Rating	**2.6**	**2.9**	**3.3**

Table 3 Best practice rating in key areas for US shipyards

Overall the industry saw an 11% improvement in Best Practice Rating. While significant this was only half of the improvement required to gain parity with the international yards. In areas like Outfit Manufacturing and Storage and Steelwork Production the actual improvements made were insignificant, reducing the overall score.

Despite marginal improvements in some areas, in the areas which were the focus of the majority of the outlined collaborative NSRP projects, namely Design and Production Engineering, the yards saw an 18% improvement, bringing them to within 95% of their international counterparts in this key area.

4. PRACTICAL APPLICATIONS OF DESIGN FOR PRODUCTION

One of the most recent examples of a successful collaborative NSRP project was called 'Practical Applications of Design for Production (DFP)'. The participants on this project included Bollinger Shipyards, Inc., VT Halter Marine, Marinette Marine Corporation, Atlantic Marine, Todd Pacific Shipyards, Northrop Grumman Ship Systems, ShipConstructor Software USA Inc., ShipConstructor Software Inc., and Genoa Design International Ltd.

The first phase of this NSRP project focused on the creation of a complete set of DFP guidelines, shipyard standards, and DFP manuals. The introduction of documented shipyard standards and preferences, along with a set of DFP manuals, was intended to provide a set of tools which allow junior or inexperienced designers to apply DFP principles to their work. As the workforce available in the US, as in many countries, is an aging workforce these tools were essential to ensure correct implementation of DFP principles.

It was noted that the tools created in the first phase of the project still required designers to interpret and apply these principles manually based on their own understanding of the guidelines. The second phase of the project was intended to strengthen the DFP specific capabilities of ShipConstructor.

4.1 TARGET AREAS

The areas where the shipyards felt that they could benefit the most from DFP principles introduced into the software involved three of the guiding principles identified in the first phase of the project: Minimization of Total Piece Parts and Welding, Minimization of Fabrication/Assembly Complexity, and the Standardization of Parts.

The most significant challenge these shipyards face when trying to implement this type of cost saving measure is in ensuring that less-experienced designers can identify these opportunities and create solutions that take advantage of them. As a result two new modules were identified that, when added to the ShipConstructor software, would provide the largest return.

4.1 (a) Standard Assemblies

The first software deliverable created as part of this project was a new software module called 'Standard Assemblies'. A Standard Assembly is defined as a part, or set of parts, including Structure, Pipe, HVAC and Equipment components that can be defined once and used repeatedly throughout the detail design of a vessel. The definition of a Standard Assembly includes both the 3D model of the assembly as well as the specific assembly sequence to be used each time the assembly is used in the 3D product model.

This module allowed experienced designers to build a library of commonly used parts, assemblies, and components that can be consumed by less experience designers. These assemblies can be moved between one vessel and the next, allowing for significant reuse of this captured knowledge. Reusing portions of the detail design across shipbuilding programs increases the degree of repeatability during the build process of vessels. Increased repeatability reduces the amount of training required across vessels and once again reduces the number of hours spent in production.

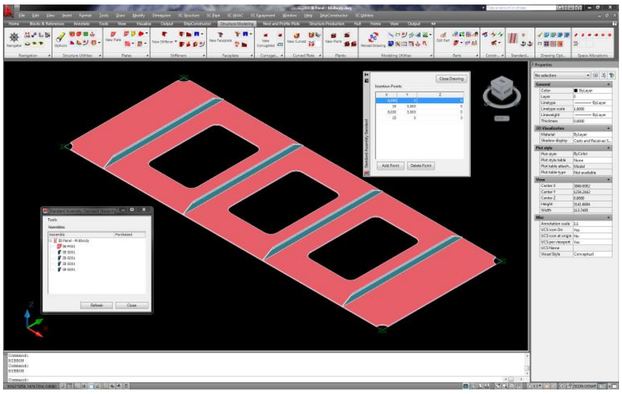

Figure 1 An Inner Bottom panel defined as a Standard Assembly

The effort by experienced designers to introduce DFP principles into a detail design, thereby reducing the number of parts or complexity of a given assembly, can be used over and over by less experienced designers. When used correctly this process creates significant cost savings due to reduced production labor, but also significantly reduces the time required to model the portions of the vessel where these Standard Assemblies are used.

In addition, a Standard Assembly does not only consist of the 3D product model for the assembly. The assembly sequence required to correctly fabricate the assembly is maintained along with the 3D model information. This ensures that the knowledge capture from the experienced designer, when utilized by a less experienced designer in a vessel, includes both the model and the intended assembly sequence for the piece parts.

A key requirement of the Standard Assemblies module, and all ShipConstructor software, is the ability to associatively update all instances of the Standard Assembly when the standard itself changes. This requirement was set to allow the shipyards to respond to changes in applied DFP principles, in shipyard constraints and capabilities, and as the designers improve on the overall design of the vessels.

4.1 (b) Improved Pipe Supports

Another area was identified where an extremely low degree of standardization, little use of documented shipyard preferences, and a high degree of assembly complexity was causing a significantly higher than necessary amount of production work. The culprit was complex supports for piping systems throughout the vessel.

Each situation where a support is required, for one or many pipes, is slightly different. This often results in a completely different support arrangement for each situation. Different material types are used for the doublers, legs and cross tiers for each support. Different endcut and cutout standards are applied to each of the elements in the support depending on the preferences of the designer. A different configuration is created for each support with insufficient thought to the variety that production will see.

However, because every situation is different, a system was required that would allow for standardization on configurations, material types, and production standards without imposing too many constraints on the resulting supports. As a result the project team proposed the creation of a DFP-based Pipe Supports module.

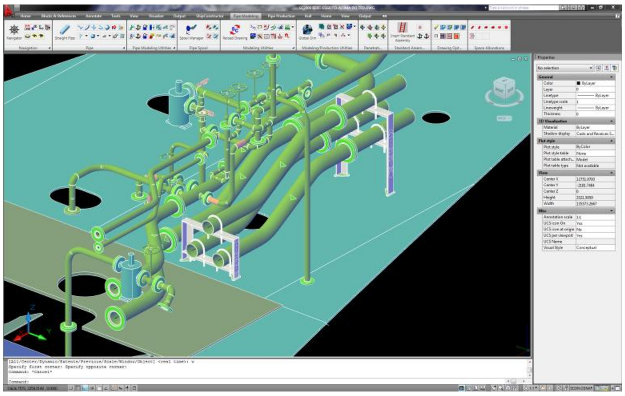

Figure 2 Improved Pipe Supports in a ShipConstructor model

The requirement to improve the use of shipyard standards, and material types across various situations where pipe supports are required led to the creation of Pipe Support Templates. A Pipe Support Template is the definition of the required elements, including endcuts, doubler plates, and material types to be used, to build a support when it is applied in a specific situation. 5 different categories of templates were identified to ensure that the software being developed handled the majority of cases required by the shipyards.

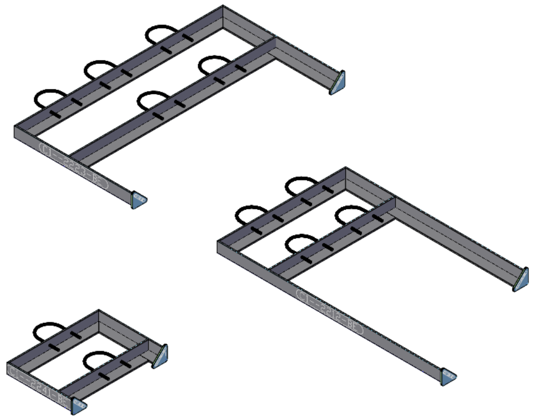

Figure 3 Several Pipe Supports derived from the same Support Template

Upon insertion into the 3D model the pipe support, derived from the selected template, has the required cutouts, endcuts, trims and materials required to produce each of the components required. In addition each of the components can be included in ShipConstructor's usual array of production output including plate and profile nesting, profile plots, assembly drawings and more.

To ensure that the standardization added to the design of pipe supports was correctly leveraged by the shipyard, a final requirement of the new software was the addition of functionality to generate template driven, construction drawings for the supports. The drawings needed to be automatically dimensioned, and annotated based on the shipyards requirements. Complete bills of materials on each drawing were required that would facilitate the fabrication of the support.

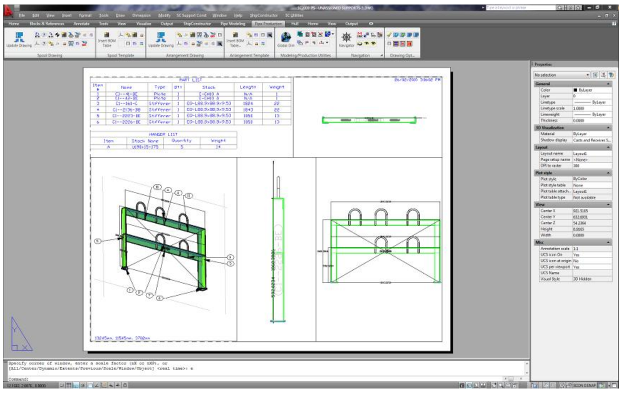

Figure 4 A generated Pipe Support construction drawing

4.2 IMPLEMENTATION EXAMPLES

As part of this project the shipyards implemented a few of the DFP principles into existing shipbuilding programs. These examples show the efficacy of DFP principles applied in engineering at the participating shipyards. Each of these examples and the results of implementation were summarized in a paper (Fanguy, Dlugokecki, Hepinstall, 2008) to SNAME after the project was completed and are shared here.

4.2 (a) Grid-Cooler Arrangement and Build Strategy

Before: In their initial arrangement, grid cooler location was such that the coolers crossed a master erection butt. Therefore, the grid coolers could not be installed until after the two adjacent units were erected. Because the grid coolers are generally situated on the bottom shell, this meant that the coolers had to be installed in an overhead position, using pad-eyes and chain-falls for the lifting arrangement. In addition, because the shipyard uses stock at the ends of units, and trims to suit during final fit-up of the units, the piping penetration locations for the grid coolers could not be finalized until after the two blocks were joined. The penetrations then had to be manually cut.

Figure 5 Before: Grid cooler crossed master butt

After: Implementing DFP methodologies, the arrangement was optimized for build strategy considerations. The grid cooler location was revised so that it only spanned one unit. The result was that the grid coolers could be installed at the subassembly stage of construction, while the unit was in the shop, and was accessible by an overhead crane. In addition, because the piping penetration locations were firm, the penetrations could be cut with the plate, using the CNC plate cutting machine.

Figure 6 After: Grid cooler included on one module

Cost Avoidance: The shipyard estimated a projected savings of approximately 1,050 man hours per boat. There was a minimal cost for engineering and drawing changes required to implement this change.

4.2 (b) Minimizing Total Piece Parts and Welding

Before: The steel functional design of the deckhouse structure had already included some instances of using flanged plate parts for some minor bulkheads in lieu of welding plate parts to create small subassemblies. For example, as shown in Figure 7, the design shows the three minor bulkheads around an outfitting trunk being created from one flanged plate part. This type of arrangement, while viewed as a cost saving opportunity, was not fully implemented in the existing functional design.

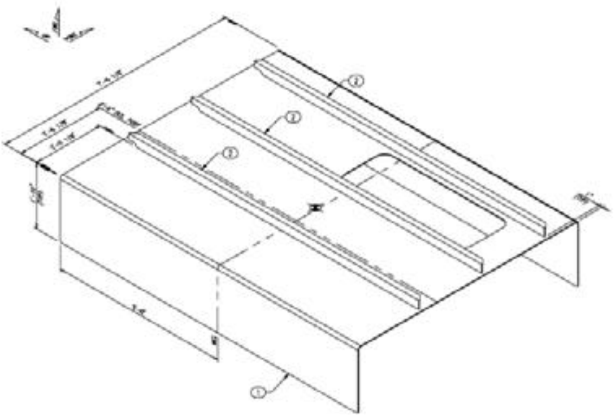

Figure 7 Example of Minor Bulkhead using Flanged Plate

After: Lessons-learned held with production and engineering personnel after construction of the first in a series of vessels, indicated that there were numerous other instances in the deckhouse design where they could take advantage of using flanged parts in lieu of welding for minor bulkhead subassemblies. One example is shown below. It shows a recessed bulkhead with a door opening. The first boat sub-assembly had four plate parts that were welded together, with an angle backing bar used to facilitate welding of the part in place. Subsequent vessels used a flanged part in lieu of 3 of the 4 parts, and simplified the backing bar arrangement. Cost Avoidance: A total of 12 sub-assemblies were eliminated in the deckhouse design. It is estimated that a savings of 120 man-hours per boat was achieved, with a minimal design change cost.

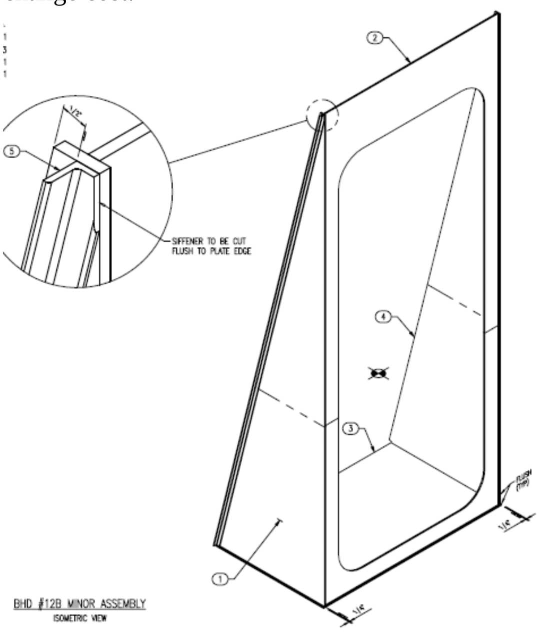

Figure 8 Before: 5 parts total, welded.

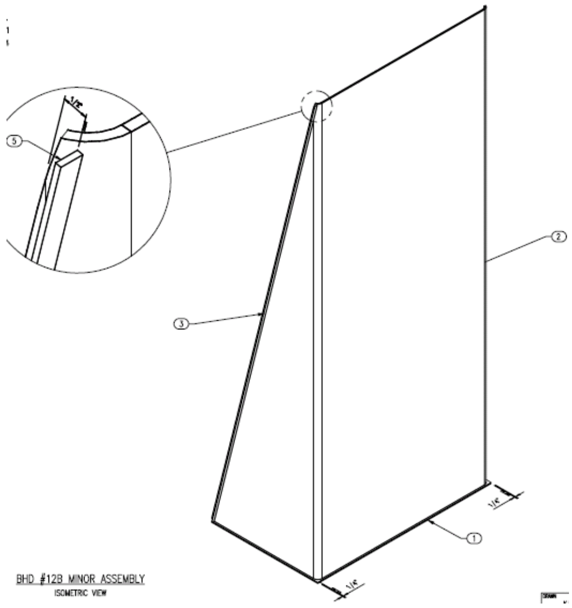

Figure 9 After: 3 parts total, flanged

5. CONCLUSIONS

Costs for naval shipbuilding are often significantly higher than commercial shipbuilding. Due to the complexity of naval vessels and the adoption of newer technology, driven by the requirement for additional capability in future vessels, some of this cost disparity is unavoidable. However, naval shipbuilding does provide a captive audience for change, driven by a single customer that is motivated to drive that change. This should provide a mechanism for avoiding cost on future naval shipbuilding programs.

The adoption of a common tool and technologies, combined with an industry led program tasked with improving the entire industry, has been proven to elevate the state of both commercial and naval shipbuilding in the US. The US Navy, via the NSRP, has funded a significant number of projects that have seen direct returns on Navy shipbuilding programs.

A key factor in the success of these programs, and the resulting improvements, is the emergence of a collaborative spirit in the industry and a willingness by participants to look past process as a major competitive differentiator. The adoption of a common platform for design and production engineering was the catalyst that led to this degree of collaboration.

6. REFERENCES

1. First Marine International, '*Benchmarking of U.S. Shipyards Industry Report',* January 2001.

2. First Marine International, 'F*indings for the global shipbuilding industrial base benchmarking study',* February 2007

3. Fanguy, D. Dlugokecki, V. Hepinstall, L., *'Leading the Way for Mid-Tier Shipyards to Implement Design for Production Methodologies'*, 2008

7. AUTHORS BIOGRAPHY

Mr. Darren Larkins is currently the Deputy CEO at ShipConstructor Software Inc. (SSI). He has at some point been responsible for all aspects of product management, product development, IT, client implementation, technical sales, marketing, and client training at ShipConstructor.

Mr. Larkins combines over 10 years experience in the development, marketing, sales and implementation of marine systems with the knowledge gained from onsite visits to more than 50 of the world's leading shipbuilders and offshore experts. This experience is applied to the implementation and development of marine specific Integrated Shipbuilding Environments (ISE).