

Group Technology Through “People Modules”: A Case History



Jody Turner, (M), Rick Wharton (M) and Christopher D. Barry (M)

ABSTRACT

Group technology, advanced outfit and worker incentivization are commonly regarded as critical to improved productivity in shipbuilding. The authors present a case history that clearly demonstrates the importance of these techniques. The authors discuss the initial problems encountered during production of the 49 BUSL, development of the solutions, their detailed implementation, their effects in productivity improvements and suggest how these techniques can be implemented and improved in other applications, including those involving more conventional modular construction.

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INTRODUCTION

Group technology is a key to modern manufacturing productivity. The most common use of group technology in shipbuilding is modular construction; where in the dominant common aspect of grouping tasks is by location. Modular construction is generally thought to imply construction of a ship in blocks, which are subsequently joined together. This provides substantial increases in productivity, quality and safety due to improved working conditions, improved access and so on.

However, advanced outfitting techniques frequently are not used for small vessels. They are often “stick built” as one single block or module, or at most two, the hull and deckhouse, and are generally structurally complete prior to any outfitting, or perhaps even any painting. This, unfortunately, costs a great deal in extra labor.

Though Leake and Calkins (1996) and others have advocated more extensive use of block construction for small ships, it is still relatively rare, especially for vessels under about 30 meters or so.

The arguments against block construction and advanced outfitting of such small boats and ships include:

- The resulting blocks would be too small, and would be almost as difficult to access as the complete vessel, so that the additional effort in joining the blocks would not pay off in reduced labor to build them.
- Advanced outfitting requires too much engineering effort, especially up front. This is costly and a schedule problem. (Piping and wiring is often field run in these ships, usually to schematics rather than piping and cable arrangement drawings.)
- Small ships are often built very fast and machinery and components are often available too late.
- Manloading concerns can conflict with block outfitting.

Gribskov (2002) also notes that distributed systems, such as piping and cable, end up spanning conventional ship type modules in small vessels and create substantial rework to either connect or install subsequent to block joining.

However, it is important to realize that conventional modular construction is just one technique of the application of group technology and probably not the most important one. Group technology is any means of common classification of tasks that improves productivity. Even modular construction does not necessarily imply disconnected modules, but rather just the grouping of tasks by location.

In the recent construction of a small buoy tender, the Coast Guard YARD used this wider definition of group technology and modular construction to improve productivity. This technique followed the principles of group technology and modular construction, grouping tasks by location and process, and breaking them up into small limited conceptual “pallets”, but to overcome the difficulties of building small vessels in separate blocks, the boat was modularized in “people modules” not physical ones.

In addition, this people modularization allowed the workforce to be incentivized financially.

The combination of these two techniques produced substantial gains.

HISTORY

In the late 80’s the Coast Guard identified a need to replace the aging 46-foot Boat, Utility, Stern Loading, (BUSL). This steel boat entered service in 1966 and had a single engine running a azimuthing drive, a buoy handling deck roughly half the boat’s length aft ending in a notch and an A-frame at the stern. The A-frame was pivoted fore and aft by hydraulic cylinders and had a pair of winches on the crossbeam. The boat also had a pair of cross deck winches on the forward end of the buoy deck to bring aid and sinkers forward. It’s mission was servicing floating aids to navigation up to 5 x 11 buoys in estuaries, harbors and limited coastal waters, including many areas constrained by depth or fixed bridges. In operation, the boat would back up to an aid and lift it and its sinker on deck through the notch to either service them or replace them. Often this operation had to be carried out in a current. In order to service relatively distant aids, the boats frequently needed to overnight away from their homeport to accomplish relatively distant missions.

The boats were becoming increasingly difficult to maintain due to age and obsolescence of the parts of the drive. The hydraulics servicing the A-frame and its winches were operated off the single propulsion engine, so that some operations requiring both propulsion power and use of the A-frame were cumbersome. The habitability of the boat was poor so overnight stays were limited.

The 49 BUSL was designed to address these deficiencies. The initial requirements documents were developed in the late 80’s after a survey of field units and various task analyses. The Boat Engineering Branch of the Coast Guard Naval Engineering developed a conceptual and contract design by about 1991.

Some special features of the mission and thereby the design solution are worth noting:

The boat has a limit on both navigational and air

draft. Thus the mast and the A-frame must fold in certain circumstances to clear low bridges.

The 49 BUSL has twin engines, a substantially larger habitable space and a hydraulic plant independent of the main engine. The habitability flat comprises a four-man stateroom forward, a small galley to starboard and a head with a shower to port. Aft of the galley is a settee that converts to a fifth berth. A space on centerline holds electrical panels, and a small entertainment center (facing the settee). Portside of this space is a buoy workshop, considerably larger than the one on the 46 BUSL. Off centerline to starboard is the stair to the buoy deck and to port the watertight door to the engine room.

The hydraulic system had to be independent of the main engines, so it was driven off the generator prime mover, which required a relatively large generator engine compared to the electrical power load. This resulted in a relatively long engine room. The requirement to have low freeboard on the working deck (to be able to reach down to an aid), combined with the deck load (16,000 of aids and their sinkers), and the requirement to be able to survive engine room flooding, in turn produced a weight limit. The BUSL, though not a high-speed boat, was relatively limited in weight and weight had to be controlled with some care.

The boat also has to be operated in completely closed (with respect to discharges) waters, so it has a large sewage tank in the lazarette and a large gray water tank under the habitability flat.

In 1992, the construction of two prototype boats was contracted with Maritime Contractors Inc., (MCI) Bellingham WA, under an 8(a) minority disadvantaged small business set aside. The detail design of the boats was developed by MCI's contractor, Art Andersen Assoc. of Seattle and Bremerton WA.

The two boats were delivered in 1995 and entered Operational Testing and Evaluation. The results of OT&E showed that the boats were basically well suited to the mission with a few minor changes proposed.

The changes included raising the flat under the habitability area to obtain more tankage and a wider habitability flat. The prototypes had wet exhaust, but one was modified to have dry exhaust, out the side, in order to eliminate the need to have a suction sea chest serving the mufflers (the engines were keel cooled). This allows more reliable operation in waters with slush ice or other debris. Tests showed that the dry exhaust did not increase either noise or noxious gases on deck, so this system was chosen for the production boats.

Other minor structural and outfit changes were developed to improve producibility or supportability. For example, the number of production boats planned made a customized FRP sewage tank, that would fit the lazarette well, feasible.

A more detailed contract design and specification

was developed and the Coast Guard prepared to obtain bids. Due to workload in the CG Yard, the decision was made to construct the 49 BUSL in the YARD. The contract was awarded in 1996 and detailed design and was begun.

By January 1998, the U.S. Coast Guard Yard had just delivered the second of a planned total of thirty-two 49-foot stern-loading buoy boats. The second boat had completed nearly 53 percent over the budgeted man-hours. Worse, the third and fourth boats were on track to complete 64 percent and 62 percent over budgeted man-hours, respectively. Clearly, the trend had to be reversed.

Construction halted long enough to completely reorganize the production process in accordance with group technology implemented in terms of "people modules" and limited advanced outfitting rather than conventional physical modular construction. Several significant changes were made to the management of the project; all geared toward better controlling cost and schedule performance. Specific steps included:

- Increasing the number of defined discrete tasks in construction of each boat from twenty-three to over 800. This greatly increased the accuracy with which work, both estimated and completed, could be calculated.

- Establishing discrete modules of work, with a dedicated team assigned to each module and specific man-hour targets defined for completion of the module.

- Shifting approximately one-third of total production labor to prefabrication of components to be installed by the module-specific teams. This realized the economies of mass-production for these components.

Finally, a gainsharing program was implemented to establish targets for completion of the remaining boats. This returned a portion of the savings from completion of a boat below targeted cost to the production workers. The result of this effort was that, for boats five and beyond, all were delivered at or below targeted cost, including a 2% per hull learning curve.

BACKGROUND

The Yard established the production process with costs and production hour targets and scheduled delivery dates for each of the 26 BUSL boats under construction. Each successive boat was scheduled to cost less than the previous boat due to improving the production tasks. Actual savings resulted, along with decreased production time, for successive boats. The Yard met the delivery schedule in all BUSL boats delivered since the March 1998 restructuring. These boats have been on time and under budget. Smaller dedicated teams of workers also permitted fewer people to accomplish the work.

Prior to the restructuring and the teaming production line process on the BUSL, the product was increasing in

cost with each successive boat delivered. The restructuring resulted in reduced hours and costs targeted for each successive BUSL. To date since restructuring, the Yard has delivered each of the BUSL's below the target hours and costs. The restructuring also established a detailed schedule, which identified where each BUSL would be in the production cycle at any given time. This allows the acquisition team to plan the delivery of each BUSL to correspond to conditions at the various receiving units. For example, all of the Great Lakes BUSL's were delivered in the summer, so they could make the long transit home before the waterways closed for the winter ice season. All of the Florida BUSL's were scheduled to avoid transits during the hurricane season.

PROCESS

CG Yard developed production drawings and started construction based on the first two prototypes BUSL's. There were some problems with accuracy of the detailed drawings provided for follow on construction. In an attempt to meet the originally agreed on delivery dates, CG Yard started material ordering and construction prior to completion of the detailed design. The First CG Yard BUSL 49403 was targeted to be delivered in May 97 with targeted 15000 hours. 49403 was launched in August 97 and delivered in September 1997 at 22,694 hours. 49404 delivered in November 1997 at 27,588 hours. The list of discrepancies from the Preliminary Acceptance trials for the first two BUSL's was longer than then was anticipated. The number of items on the first two discrepancy lists was increasing vice decreasing as was expected. In Jan 1998, 49405 was not accepted at Preliminary Acceptance Trials. A discrepancy list of 293 items was identified and the construction hours charged to the project was already at 27,000 hours. The final production hours for the delivery of 49405 was 28,355 hours.

In January 1998, CG Yard Management decided to start a restructuring of the production process. The intent was to complete the remaining hulls (49406 through 49412) under construction on the existing production scheme. Revised production plans would be started fresh on 49413, which had not yet started production. During the last week of January 1998, Hull 49406 had over 25 people per day charge to the BUSL. 49406 was scheduled to be placed in the water during the first week in Jan 98. Inspection of boat indicated that significant work was required prior to 49406 being ready to be placed in the water. Final delivery for BUSL 49406 was 29,297 hours.

To facilitate the correction of this problem earlier in the cycle, CG Yard worked with the customer

(Acquisition) to stop all work for 6 weeks starting with hull 49408. This hiatus would allow for the restructuring of the production process. It was decided that the anticipated restructuring would have little benefit on hulls 49406 and 49407. Both of these BUSL's were far enough along in the production process that the savings to be experienced as a result of the restructuring would be relatively small.

The restructuring process was multifaceted. The Production Manager, the General Foreman and foreman that had been involved with the BUSL production developed a list of all of the necessary tasks. They identified the shop that would be required to perform the task and number of man-hours to perform each task. At the same time, a group of yard workers representing all of the shops involved with the BUSL production, was assembled to identify production sequencing issues and areas that could be simplified.

The senior production management group developed a list with approximately 900 tasks. Each of these tasks identified what type of skilled production worker would be necessary to perform this work and the number of hours necessary to perform the task. The total number of hours identified to build a BUSL was determined to be 21,000 hours. Approximately 1/3 of the hours needed to produce a BUSL, were identified as being tasks that could be performed as prefabrication. By being able to perform this work in the shop on a bench, it removed personnel from the platform and allowed for work to be performed in a controlled environment. Of the approximately 8000 hours established as prefabrication work, half were determined to be able to have some economies of scale if they were fabricated in multiples. This allowed the production worker to minimize the time associated with set up of tasks thus reducing the overall cost and time to build a BUSL.

The team of yard workers identified 170 areas in which the manufacturing process could be modified or simplified. Approximately 50% did not impact on the final product and were implemented with Engineering Change Notices drafted by the production employee and the BUSL Ship Superintendent. Approximately 45 changes, which would simplify the production process but also impact the final product, were proposed to the customer (Acquisition team and to the sponsor). The only changes proposed were those identified as improving the safety or habitability of the BUSL's or those that would result in a cost savings within 10 boats. If savings could not be experienced in that time frame they were not considered.

The list of tasks developed by the Production Manager and General Foremen was assembled in to sequenced order of events. Many of the tasks were not on the critical path and could be moved in the assembly process but did have to be sequenced with other tasks.

All of the prefabrication tasks were placed in two groups, one which was an individual task for each BUSL and the other which there would be a man hours saving by manufacturing multiples. From past experience it was known that more than 10 people on a BUSL was inefficient. It was determined that six weeks for a group (Module team) to perform a set of tasks was appropriate. The tasks were grouped into Modules of no more than 2000 hours worth of tasks that could be performed at the same time with a mix of trades. This targeted 8 people per module team.

Previous work on the BUSL and at CG Yard had not required significant interaction between the various shops. By sequencing the work by trades, it appeared that there had been out of sequence work and unnecessary rework. The tasks in the modules were grouped by sequence and would require a cross section of trades to be working during a module. To ensure ownership by the Module team it was decided to have one shift working on each boat.

This would minimize the possibility of the team not developing a sense of ownership and responsibility for the condition of the boat. If there was more than one shift working on the boat at a time there was always the possibility that the finger pointing for cleanliness and materials issues could occur.

For each 240-hour (6 weeks by 40 hours a week) group of tasks a person was assigned to the team. The teams were made up of production works from various shops. Attempts were made to group tasks from a

specific trade into groups of 240 hour, so that the assignment of personnel from the various trades would be clearly defined. Each module team consisted of the various shop members required to perform the assign tasks. A leader was assigned to each module. The leader was from the shop that had the most hours for that module. He was full time on the BUSL project and counted as part of the total production hours in the module.

Each module was also assigned a Foreman. This foreman was from the same shop as the leader and he was assigned to the project 30% of the time. His responsibility was to track down the necessary materials, prefabrication parts and intercede on the behalf of the leader when there were problems with work on the modules from other shops. The foremen positions at CG Yard are overhead positions and are not charged out as production hours.

The final schedule resulted in the establishment of nine teams. The second module had two separate teams – 4 weeks for the structural team to complete the hull on the mock and two weeks for the paint team to blast and prime. All of the other teams started with a duration of 6 weeks. The requirement to build a BUSL was 48 weeks from start of production to ready for PAT. There was 8 weeks of prefabrication prior to the start of production and 12 weeks prior to start of prefabrication for materials to be ordered. Thus the entire process started at 68 weeks.

Table 1 - People Modules

Mod	Description	Duration	Approximate hours	Number on Team
Mod 0	Pre-fabrication	8 weeks	8200	
Mod 1	Build Shell	6 weeks	1700	6
Mod 2	Structural Outfit	4 weeks	900	4
Mod 3	Blast, Prime and Set Upright	2 weeks	400	6
Mod 4	Rough Outs	6 weeks	2100	9
Mod 5	Install Machinery	6 weeks	1800	8
Mod 6	Machinery Connections	6 weeks	1700	8
Mod 7	Electrical / Electronics Installations	6 weeks	2000	8
Mod 8	Final Paint	6 weeks	500	4
Mod 9	Launch BDT, BST, PAT	6 weeks	1300	5

Each module was assigned a multi-disciplined, self-directed team of production workers led by a

dedicated work leader. The trades and experience levels of the individuals assigned to the modules was

determined by the tasks to be performed in that module. To ensure the success of the multi-discipline teams, the union was brought onboard early to minimize the concerns of personnel being supervised by individuals from other areas.

Once the multi-disciplined teams were set up for each module, the learning curve was looked at. It was difficult to apply a traditional reduction of work force when in many modules there was only one individual from a particular trade. The first approach was to remove the various individuals from the modules for a short period of time for each subsequent hull thus allowing the reduction of hours. This would result in maintaining the 6-week cycle for each of the modules but would interrupt the teaming efforts that would occur with people coming and going during the module. Also there was the concern that individuals would be moved off the module for a couple of days get involve in a new project and a new individual would be assigned to the module. It was decided that an aggressive 2% reduction on hours would be targeted for each follow on hull built. To minimize the disruption, it was decided that every fifth module cycle the total time for the module would be reduced by 10%. Thus the total hours that each team member would have would be reduced by 10% thus the targeted hours for these shorter modules would be reduced by 10%. This would result in a 2% savings per subsequent hull. After five cycles at 6 weeks or 240 hours per man per module, the modules would be reduced to 5 weeks and 2 days or 216 hours per man per module. After an addition five cycles at 5 1/2 weeks the module duration would be reduced to 5 weeks per module or 200 hours per man per module. Because the construction process on BUSL's 49408 through 49412 was interrupted and these BUSL's had various tasks completed that did not clearly place them in a module it was decided to start the production line with 49408 in module 4. The hours targeted for this modified module 4 were determined by surveying the hull using the tasking list and determining what was completed and what in module 4 was remaining. After a 3 week modified module 4 on 49408, it was moved to module 5. The Module 4 team moved to 49409 and the module 2 / 3 teams were started up on 49410. Hulls 49410 through 49412 had not completed all of the structural work associated with tasks to be performed while the hulls were inverted. 49413 was the first hull started with all of the prefab performed in accordance with the task list and started module 1 on the revised production process. The first five modules performed on 49413 had a duration of 6 weeks each. The start of module 7 on 49413 and the start of module 1 on 49418, the module duration was reduced to 5 1/2 weeks.

The schedule was built for all of the remaining

BUSL's from 49408 through 49436. The schedule had a final module duration of 4 weeks. BUSL 49436 was scheduled to be delivered 40 weeks after the start of prefabrication. This schedule established target hours per module and per boat and module and boat completion dates for all of the remaining BUSL's. From the start of the new process, the program was able to schedule Preliminary Acceptance Trials and projected delivery of all future BUSL's.

When the quantity of BUSL's to be delivered was truncated to 26 hulls the schedule was revised so that the shortest module would be 5 weeks in duration. This resulted in the learning curve (reduction in scheduled hours) in tapering off for the last 4 BUSL's. The learning curve was scheduled to level out on the last 5 BUSL's if the production line had continued to 36 boats. The reduction in quantity of BUSL's was as a result of the Coast Guard's review of their required assets and the determination that they only required 26 BUSL's.

The targeted hours for the BUSL's in the revised production line prior to 49413 were determined as a result of the remaining work to be performed as a result of the production task list. The remaining tasks and their associated scheduled hours were added to the hours charged to the hull prior to the hiatus. Starting with the delivery of 49408, the number of items on the Preliminary Acceptance Trials discrepancy list was less than the previous hulls. 49408 and subsequent BUSL's were delivered on the targeted dates and below the targeted hours.

As the modules progressed there was consistent buy-in from the dedicated teams. They made recommendations on ways to improve production and move tasks between modules to allow for a smooth assembly process. Workers and leaders identified areas of improvement, and determine a more logical sequencing of tasks. By having a single team on one shift responsible for the hull during the module ensured that the team had ownership.

The sense of buy-in and team pride became obvious from another signal; the teams engaged in occasional whimsical pranks with their module designation signs. For example, the first module involved the inverted hull, so the workers on that module put their sign upside down. This type of thing seems minor, but it is a clear indication that the workforce is taking personal responsibility and pride in their work. These small actions by the workforce are much more powerful than the signs, dodads and exhortations so beloved by some managers (and, incidentally condemned so loudly by Deming (1982).

This re-organization established clearly defined targets for production hours, costs and delivery schedules. CG Yard was a National Performance

Review Reinvention Lab designated facility and had requested and received self-directed awards. The Yard's Reinvention Lab status enabled an experiment in gain sharing, using the targeted production hours for each of the BUSL's. The gain sharing consisted of two parts. Each gain share distribution was based on the combined target hours for four BUSL's. If the target hours were met, then the CG Yard, as an industrially funded facility, would pay a fixed amount of self-directed awards for the scheduled number of employees working the BUSL project.

For BUSL 49408 through 49411, the fixed amount was \$100 per share; for BUSL 49412 through 49415, the fixed amount was \$125 per share. For every hour saved on the BUSL project, the customer agreed to pay a variable percentage of the savings. The CG Yard is a time and materials facility so hours saved results in lower costs to the customer. For BUSL 49408 through 49411, the variable amount was 5%. This 5% was returned to the employees as gain share rewards, while 95% of the gain was returned to the customer: the US Coast Guard. For BUSL's 49412 through 49415, the variable amount was 7.5%. Ultimately, the US taxpayer benefited in lower project costs. The break down for all of the BUSL's is as follows:

HULLS	Fixed Award	Variable Award
49408 to 411	\$100	5% of savings
49412 to 415	\$125	7.5% of savings
49416 to 419	\$150	10% of savings
49420 to 423	\$175	12% of savings
49424 to 427	\$200	14% of savings

Gain-sharing is the technique used to compensate workers based on improvements in their measured performance. Gain-sharing is attributed to improve overall profitability, by reducing scrap, rework and waste and increasing worker retention. This gain sharing program and the workers proved that the Coast Guard Yard could emulate the best commercial practices of private industry, where profit and gain sharing are powerful motivating tools.

The five BUSL's delivered prior to the restructuring averaged 2.2 warranty claims (casualty reports) per BUSL per month during their one year warranty period. The BUSL's delivered after the restructuring have averaged 1 warranty claim per BUSL per month. This is an exceptional improvement in performance in a quality product. The majority of the casualties (warranty items) on the BUSL's delivered after the restructuring were equipment failures and not workmanship issues. These warranty

items were passed onto the suppliers that had been contracted in the local area that the delivered BUSL was operating.

CONCLUSION

CG Yard developed a new concept of modular construction based on the fundamental principles of group technology. This approach worked exactly as the fundamentals of group technology suggested it would. We recommend not only that readers consider "people modules" where appropriate, but also at a more fundamental level, looking at the basic principles underlying modern techniques to see how they can be adapted to a unique application.

The CG Yard also implemented a process of gainsharing, one of many schemes for sharing cost reductions with some of those responsible for making them. A variety of such schemes have been used and, more often, proposed, many times throughout manufacturing history and have repeatedly been shown to be successful. In the vast majority of cases they work and work well, at least as much because of the sense of empowerment and respect that they give workers as because of the actual amount of money.

As regards people modules as well, there is an additional lesson here. Much of the power of the "people module" scheme was because of its effect in giving workers a sense of empowerment, responsibility and respect for their labor.

Perhaps a larger conclusion of this effort is what we are all taught early on but sometimes forget: Treating others with respect, and recognizing their efforts, is the right thing to do.

	Target hours	Actual Hours	Hours Saved	Target cost	Actual Cost	Savings	Distributed to workforce	Employee share
49408	25,439	22,930	2,509	\$1,759,761	\$1,683,484	\$76,277		
49409	24,570	22,533	2,037	\$1,690,624	\$1,596,163	\$94,461		
49410	23,246	20,899	2,347	\$1,626,567	\$1,531,425	\$95,142		
49411	22,072	18,743	3,329	\$1,578,361	\$1,460,375	\$117,986		
			10,222			\$383,866	\$23,505	\$539
	Target hours	Actual Hours	Hours Saved	Target cost	Actual Cost	Savings	Distributed to workforce	Employee share
49412	21,039	17,110	3,929	\$1,533,604	\$1,397,046	\$136,558		
49413	20,992	18,574	2,418	\$1,565,982	\$1,505,116	\$60,866		
49414	20,572	18,201	2,371	\$1,577,399	\$1,443,827	\$133,572		
49415	20,152	18,142	2,010	\$1,529,146	\$1,440,342	\$88,804		
			10,728			\$419,800	\$37,004	\$576
	Target hours	Actual Hours	Hours Saved	Target cost	Actual Cost	Savings	Distributed to workforce	Employee share
49416	19,733	18,172	1,561	\$1,493,137	\$1,436,634	\$57,503		
49417	19,313	17,799	1,514	\$1,477,440	\$1,434,416	\$43,024		
49418	18,893	17,837	1,056	\$1,460,862	\$1,479,539	-\$18,677		
49419	18,515	17,907	608	\$1,448,349	\$1,439,584	\$8,765		
			4,739			\$90,615	\$21,795	\$415
	Target hours	Actual Hours	Hours Saved	Target cost	Actual Cost	Savings	Distributed to workforce	Employee share
49420	18,137	17,354	783	\$1,436,870	\$1,428,896	\$7,974		
49421	17,932	16,955	977	\$1,463,514	\$1,458,319	\$5,195		
49422	17,667	16,814	853	\$1,456,914	\$1,412,150	\$44,764		
49423	17,502	16,717	785	\$1,453,747	\$1,426,319	\$27,428		
			3,398			\$85,361	\$18,753	\$400

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