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IMPLEMENTATION OF CELLULAR MANUFACTURING FOR PRODUCTION PERFORMANCE IMPROVEMENT

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ABSTRACT

The environment in which the Defense and Space product operates now day is very different from the one in which it has historically succeeded. The decline in defense spending has increasing the importance of cost or affordability in a decision process which previously emphasized the incorporation of state-of-the-art technology into new military products. Therefore, Product of Defense and Space success depends on its ability to exceed customers' expectations through superior performance, by delivering high quality products in a timely manner, with shorter lead-times and lower costs. The present paper explores how the cellular manufacturing can help in Machining Center, a highly flexible shop with many different customers and products, achieve improved performance and customer satisfaction.

Key words: Cellular manufacturing, capacity Planning, QA, Cells

I. INTRODUCTION

Cellular manufacturing is an application of Group Technology (GT) to the manufacturing world. In a cellular manufacturing system (CMS), similar products are grouped into product families and the required machines are assigned to manufacturing cells to produce the corresponding product families. In this respect, a cell is a small manufacturing unit designed to have people, dissimilar equipment and machines together to produce like products resulting in lower lead times, work-in-process inventory (WIP), setup times and workforce [1]. See Burbidge and Wei [2] for more detailed explanation of the benefits of implementing CMS. Although there are significant benefits that can be achieved when CMS is employed, there are some disadvantages of CMS implementation such as being less flexible to rapid changes in product mix and demand [3]. In addition to these pros & cons, the major concern about Cellular Manufacturing (CM) is the reduced machine utilization due to the dedication of machines and cells to certain product families [4]. Moreover, overutilization or underutilization of cells can be another complicated issue when demand of each product is uncertain. Due to such difficulties as inefficient cell and machine utilization and poor production control associated with highly probabilistic demand [5], stochastic behavior of demand should be taken into consideration prior to CMS design.

This present paper has dual purposes: learning and improvement. The CMS are implemented in a selected company. The situation of the Machining Center in the Dec of 2015 called for action towards improvement. Any avenue leading toward increasing throughput, lowering costs and improving delivery was welcome. Cellular manufacturing was seen not only as a way to increase the efficiency of the Center, but also as a potential new way to "do business." However, before considering cellular manufacturing for the Machining Center, it was necessary to answer several questions: are the desired conditions for justifying cellular manufacturing present? What would be the performance requirements of a cell in the Center? How could cellular manufacturing be implemented successfully?

II. CURRENT SITUATION

In the summer of 2015, the Machining Center was experiencing difficulties with delivering on schedule. The F-22 contract contributed in part to this problem because of the many engineering changes that were submitted. Further, delivery performance for commercial customers was deteriorating. This increased the quantity of orders reflected in the 10 day to load lists. These lists were being used more and more to plan daily production; in other words, hot jobs were prioritized. Most of the focus and energy were being spent in the 10 manufacturing days prior to delivering parts. To alleviate the load in the Center, work was off-loaded to other suppliers. Hence, the Center is producing less and therefore earning less than expected. At a time when growth of the customer base is increasingly important, the Center actually had to turn away work that it had committed to do in the past, as well as potential customers. Thus, there

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was a sense of urgency about taking steps to correct this situation.

Machines are grouped by function, which provides the shop a great deal of flexibility. There are 50 numerically controlled (NC) machines with 3, 4 and 5 axis capabilities. There are also manually operated mills, drills, lathes, as well as precision machines and deburring stations. Presently, the shop runs a 5 days/3 shifts operation, fully manned on first shift with manpower decreasing approximately by half in each consecutive shift. All the personnel involved in actual production reports through supervisors to the Center Leader. The functions supporting production such as Inventory Management, Manufacturing, Industrial, and Process Engineering have representatives in the shop but report to their respective functional managers.

The process flow for a typical part is presented in Figure 1. As shown, after the machining operations and the first (Quality Assessment) QA step, which verifies the accuracy of the machining, parts go through a Chemical Processing step. Approximately 70% of the parts return to the Machining Center or go to another manufacturing center after Chemical Processing for further precision machining and/or subassembly work before completion. Therefore, at least two centers are involved in the production of a finished product.

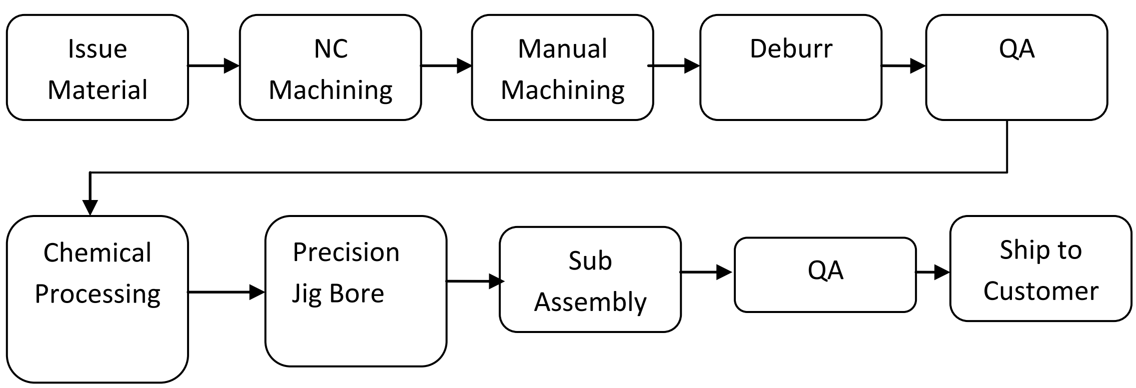

Figure 1: Typical process flow diagram

III. CAPACITY PLANNING SYSTEMS

It is important to understand the underlying assumptions driving the case capacity decisions. The system currently being used has no capacity planning capability; it assumes that capacity is infinite [6]. Since this is not the case, capacity charts are developed to avoid accepting work in excess of the capacity of the shop, and Puget Sound Flows are used to plan this work. Puget Sound Flows are basically planned lead times. In other words, there are methods in place to accommodate long and short term capacity planning decisions.

The ratio between actual machining time and Puget Sound Flow time, if we allow a variance to standard of 2 for each of the FWC's associated with the manufacturing step, is approximately 1%. This means that of the 40 days that the part spends in the shop, 99% of the time the part will be in queue waiting to be processed, and only during 1% of the time there is actual value added to the part. In general, the simpler parts which require shorter machining times exhibit ratios between 1 and 3%, for the more complex ratios are in the 5 to 7% range. As an average, a ratio of 5% is used when estimating the queuing vs. machining time ratio.

Table 1: Standard and Puget Sound Flow Times for a Fictitious Part

Manufacturing Step	**Puget Sound Flow**	**Standard Set-Up Time**	**Standard Run Time**
3 Axis Machining	9 days	44 minutes	30 minutes
Manual Saw	2 days	10 minutes	4 minutes
Manual Drill	2 days	39 minutes	9 minutes
5 Axis Machining	10 days	40 minutes	33 minutes
Manual Deburr and Blending	2 days	14 minutes	40 minutes
QA Inspection	5 days	N/A	N/A
Total	*40 days*	*147 minutes*	*116 minutes*

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IV. ASSESSMENT OF CELLULAR MANUFACTURING

In the assessment stage, the primary goal is to gather accurate data on lead-times, costs, quality, and other important metrics to obtain a true picture of the way in which the production environment functions. Then using analysis of this data is converted into information which in turn is used to support the decision of moving on to the cell design step [7]. The assessment stage is the foundation of the whole process. This stage has a different focus if the cell is introduced in a new facility where the main manufacturing process/layout is not yet defined. In this case, the main objective of this stage is to determine whether or not the purpose of the facility and the expected product stream match the conditions which make cellular manufacturing a beneficial production method. However, this present thesis will limit its scope to developing an approach to cellular manufacturing in already existing production environments.

When introducing cellular manufacturing in a shop like the Machining Center, which has been operating as a job shop for many years, the assessment stage not only must answer the matching question. It must also explain why cellular manufacturing has the potential to yield improvements over the existing manufacturing process, and create support from management to proceed with the design stage. The following list presents a short summary of the main activities to be accomplished during the assessment step:

1. Answer the match question
2. Gather accurate data on present situation
3. Make the case for cellular manufacturing

The assessment findings were presented to the Machining Center Leader and a group of production and functional managers, who agreed that “something had to be done.” The author urged this group of managers to support the possibility of introducing cellular manufacturing as a way to increase throughput while reducing total costs and satisfying the customer quality and schedule requirements. For instance, by reducing set-up times and utilizing smaller lot sizes, cell capacity would increase and the Center would have the ability to “do more work,” and eliminate any off-loading of cell parts. The scheduling complexity would also be considerably reduced by dedicating machines to parts with a stable and known demand, which facilitates the Center's ability to forecast, capacity plan and respond to schedule changes or emergencies. The collocation of the manufacturing process steps would result in reduction of part travel distance and queuing time, which in turn would decrease costs because of less WIP and shorter flow-times. In addition, by having cell operators working in close proximity quality problems would be identified and corrected much faster than before. By being responsible for several operations in the production of a part, cell operators not only are more aware of the root causes of defects, they also develop a sense of ownership facilitating quality improvements, self-discipline and trust in the process.

Understanding the nature of the product life cycle is very useful in determining the appropriate production strategy. This present chapter discusses this concept in greater length by introducing the product-process matrix [8]. Then, it discusses the benefits and limitations of the different processes structures, making it easier to appreciate the advantages of cellular manufacturing and the situations in which its implementation is desirable. Next, it explains the reasons that justified pursuing the design and implementation of a manufacturing cell in the Machining Center. Finally, the process used to introduce the cell is outlined.

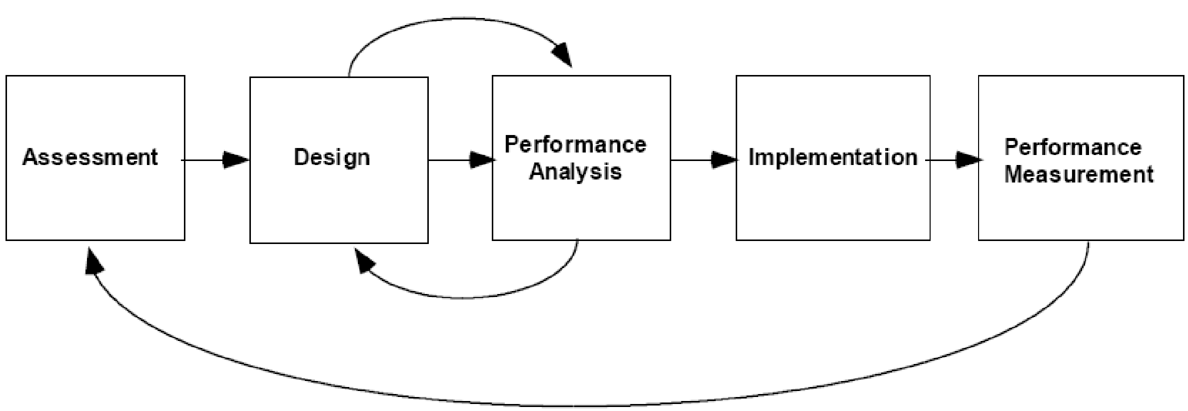

Figure 2: Cell Design and Implementation Process

In the Assessment stage it is very important to obtain an in-depth understanding of current process and metrics. This assessment should be thorough in covering the different aspects that affect the process,

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including but not limited to personnel alignment and incentives, manufacturing process, driving metrics, etc. By doing so a baseline can be established this clearly defines "where we are today" and thus facilitates defining "where we want to be tomorrow" and how to get there. In this way, identifying the cell requirements and expectations is a more rational and realistic exercise.

V. PERFORMANCE ANALYSIS STEPS

The Implementation step requires mobilizing the people that "do the work" to implement the changes. Many companies that have tried to implement continuous improvement programs have their own recipe for "kaizen events" that lend themselves to mobilizing people and resources to make changes [9]. The author suggests that these kinds of activities that are already in place may offer the vehicle to mobilize the resources. Whereas the previous steps required support from management, the Implementation step requires commitment from management, as implementation requires having those involved in the process take time from production to participate in changing the process. Therefore, there are costs attached to the training and mobilization of employees as well as costs for not producing during that time. Preparation, identification of key players and clear goals will go a long way to ensure the success of the implementation.

VI. DESIGNS AT THE MACHINING CENTER

Cell Vision Team: -A cell vision team was formed at the Machining Center to involve representatives from production and supporting functions in the design of the cell. The cell vision team was led by the author and met twice a week for six weeks. Its members included both managers and staff from different functions to ensure that both knowledge and authority were being tapped and engaged. It included:

- Machining Center Leader
- Shop Floor Supervisor
- Shop Floor Area Lead
- Machinist
- Facilities Manager
- Machining Center Business Manager
- Process Engineering Manager
- Process Engineer
- Manufacturing Engineering Manager
- Inventory Management Manager
- Inventory Management Representative
- NC Programming Manager

- Machining Center Industrial Engineer
- NC Programmer
- Quality Assurance Manager
- AIW Representatives

Early in the assessment stage it was decided that an Accelerated Improvement Workshop (AIW) would be the vehicle for cell implementation. Therefore, the two AIW leaders and their coach were invited to join the cell vision team; in this way they would have firsthand knowledge and understanding of the cell planning phase to facilitate the implementation workshop.

The cell vision team's mission was to provide direction, support and "data package" to the floor team to give them clear boundaries, expectations, schedule, deliverables and empowerment to create and sustain the production machining cell. The team worked to accomplish this vision by adhering to a demanding schedule and working in sub-teams on areas such as definition of Statement of Work (part family) and Load Procedures. There was a general concern among the cell vision team about controlling the costs of implementing cellular manufacturing in the Center. Therefore, one of the first tasks of the team was to decide the boundaries of the improvement. The team agreed that no equipment requiring new foundations would be moved and that no new NC equipment would be purchased to implement the cell. In addition, to keep costs down, non-recurring costs such as NC programming of parts, changes to manufacturing plans, etc. would be minimized, and the cell would work within existing business systems. The cell vision team expected to get much of the benefit by producing mature parts in a disciplined, work-to-schedule environment where the disruptions from "priority" work would be minimized.

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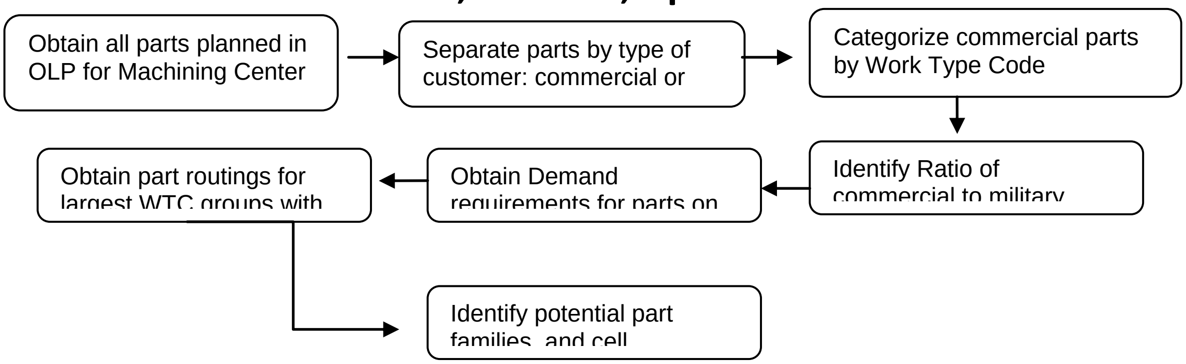

Figure 3: Part Family definition process in the Machining Center

VII. ACCELERATED IMPROVEMENT WORKSHOP AT MACHINING CENTER

In its effort to improve efficiencies and reduce costs, the selected case company has introduced Accelerated Improvement Workshops (AIW's) as a way to effect change. The AIW's are five-day "kaizen" type events. During the first two days, the employees and first line managers involved in the area or process where the improvement is sought learn the basic Just-In-Time principles, such as identifying waste, pull systems and visual controls, continuous flow and small lot sizes, and set-up reduction, and mistake proofing. In the next three days, the workshop participants apply what they have learned to improve their work area as much as possible. At the end of the AIW the results are presented to management. The Center Leader, the Manufacturing Director and other functional managers at the division level usually attend the presentation. The AIW's are facilitated by a team of leaders and facilitators, who have received more in depth training in the above mentioned subjects. Generally, the AIW's have two leaders that work with the management of the area prior to the event to identify the theme of the AIW, i.e. the specific purpose of the workshop. On the final day of the AIW, the employees participating in the event make a presentation to management on the improvements expected/accomplished, other benefits obtained, and further potential areas for improvement or required resources.

The main goal of the cell layout team was to identify the equipment arrangement within the cell to

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facilitate part flow and decrease travel distance. The team used the cell process and part routings to arrive at the final layout as shown in Figure 3. According to this figure, the area just below the 3 Axis FMS was used to accommodate two 4 Axis Machines and the rest of the conventional equipment and QA bench. The two 4 Axis Machines were placed on the foundations of the NC machines that were previously installed there, and moved to accommodate the cell. The fourth NC Factory Work Code was not moved to the cell area because moving the equipment was considered too risky, due to the age and reliability history of the Machine. Although not collocated, this machine was tied to the cell and dedicated solely to the production of cell parts.

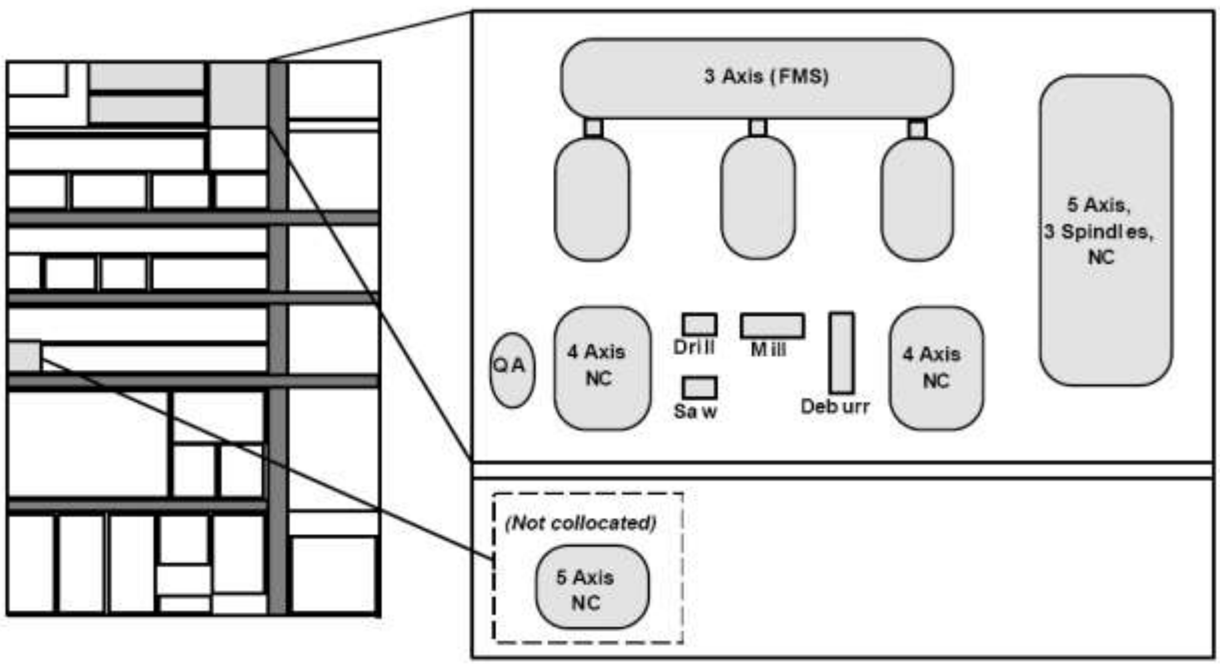

Figure 3: Cell Layout

VIII. CONCLUSIONS

The goal of the present research work was twofold: learning and improvement. The author feels that these objectives have been accomplished. The cell design and implementation process proposed in this present paper was used to implement the cell at the Machining Center, and the Machining Center has begun to realize the benefits expected from the cell. The author offers the following paragraphs as key lessons learned from the internship at the selected company and thesis.

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- *Do not underestimate the importance of analysis*. A successful implementation requires thorough analysis. When introducing a cell in an already existing job shop, managers may decide to rely on their own knowledge and experience rather than on data and analysis to determine part families and cell capacity. While knowledge and experience are extremely important, without analysis it is impossible to synthesize the data into useful information to support decisions. Furthermore, analysis encourages the exploration of different scenarios, and these iterations yield a more robust design.
- *People make it happen*. Analysis is necessary but not sufficient. Participation from people across the organization facilitates and enhances the design; and it is people that implement the design! Ensure that input from as many of those who will “work and live within the cell” is obtained prior to implementation; it will make the implementation process much smoother.
- *Break down the functional barriers*. Cellular manufacturing requires communication amongst and between the operators and the functional support personnel to support rapid problem solving and results. The culture of an already existing shop may not support the kinds of interactions and relationships that support cellular manufacturing. Managers should be aware that the introduction of cellular manufacturing can potentially require changes to the organizational culture.

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