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MANUFACTURING PROCESS MODELING OF BOEING 747 MOVING LINE CONCEPTS

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ABSTRACT

There are thousands of jobs performed on the Queen of the Sky, the Boeing 747, final assembly line for each airplane. When the decision was made to implement a moving line for the final assembly of the 747 it was absolutely necessary to evaluate many aspects of these jobs. Discrete event simulation models were constructed to analyze numerous 747 final assembly moving line scenarios throughout several phases. These models not only presented a visual understanding of different concepts, but also provided quantitative analysis of suggested scenarios to the moving line team. The results presented highly optimized production flows and processes, reducing cost and flow time from the traditionally 24 days to the targeted possible 18 days. This work outlined some of the moving line concepts, modeling objectives, and simulation analysis. Utilizations of different assembly positions were yielded as the result of discrete simulation modeling of many bundled jobs and stands of the 747 final assembly operation.

1 INTRODUCTION

Boeing Commercial Airplanes group identified the 747 final assembly processes as a good candidate for implementation of the moving line technology and requested the use of discrete event simulation to model this monumental change in manufacturing. The goal of the project is to complete the final assembly stages of the 747 manufacturing process while the plane is on a continuous moving line. During the next two years, the moving line will achieve four major milestones, the first of which was completed on December 10, 2001 when the plane moved for the final 64 feet of assembly. At the conclusion of the project the 747 will be on a moving line from the time of final body join (the joining of the three major sections of the plane) until the plane exits the factory.

1.1 Background of Moving Line Concept

"The moving assembly line is considered Henry Ford's greatest contribution to manufacturing." (Pope 2001) "In 1914 the benefits of a moving assembly line and subsequent mass production for both consumers and car makers have become well established in the 85 years since Henry Ford created the moving assembly process and launched the simple, efficient and cheap Ford Model T." (M2 Presswire 2000) Initial moving line models for the Model T were very rudimentary compared to where the process is today. "When test day came, they mounted the frame on skids. Two assistants pulled it along with a tow rope until they had the axles and wheels fitted, then rolled it along while Sorensen and Lewis moved with it and added parts." (Vance, 2001) The process was soon updated and many of the parts as well as the frame were moved mechanically, producing outstanding results. "The moving assembly line reduced assembly time for a Model T from 12.5 hours in August, 1913, to 1.5 hours a year later." (Vance 2001) Today, Ford is still one of the leaders in finding ways to manufacture using the moving assembly line concept. "The marvel about it is it's on a moving line," Estes said. "It puts up software barriers that help the operator guide the panel into the vehicle without hitting anything." (Spencer 2001) Although The Ford Motor Company pioneered the moving line, since then this form of manufacturing has become the norm in the automobile industry. "In a traditional auto plant – even at Nissan's 20-year-old plant in Smyrna, Tenn. – most of the assembly is done on the vehicle as it moves through the factory. Instrument panels, air conditioning ducts and electronic equipment are installed piecemeal on a moving assembly line." (Chappell 2001) 'Harbour and Associates' annual survey, "The Harbour Report" has repeatedly cited Nissan's Smyrna operation as the most productive auto plant in North America." (Chappell 2001)

For more than three decades mechanics at the Boeing Everett facility worked at stations along the walls of the factory, their work areas set at a mezzanine level. When work was done at one station, the plane would be moved to the next. With the implementation of the moving line, mechanics will be able to stay with the plane and not worry about finding tools, parts, stands, or engineers. The moving line, which is lean manufacturing directive, will promote more kitting of parts and tools as well as point of use inventory.

Mechanics will arrive at work to find the tools and parts they need waiting for them alongside the plane. Engineers are stationed closer to the floor, and can be reached by radio. "It is hoped that the moving assembly line will free up valuable factory floor space, dramatically reduce inventory and shave days off the flow time to assemble a jetliner, which means significant cost savings and more competitive aircraft pricing." (http://www.boeing.com)

1.2 Simulation Objectives and Direction

Delmia's Quest simulation software, which is part of the Dassault CATIA suite, is a 3-dimensional discrete event simulation tool that was used to model various aspects of the 747 moving line. The positioning, sequencing, and logistical usage of all tools and stands involved with the final assembly of the 747 comprised the first major simulation model for the project. This simulation depicted the last position of final assembly and established the use of all stands and fixtures that meet the airplane for component installations, power for system checkout, and mechanic access etc. The next step was to explore the effect that moving the plane would have on head counts as well as labor hours per team. This was accomplished through the modeling of labor in each slant position followed by level loading, or line balancing/positioning activities. It was imperative to identify high failure rate jobs and their affect on the line balancing of labor. Questions regarding carry over of work when not completed on time and the total number of people who should go to the next position without effecting workers in the current position will be addressed in the scenario analysis portion of the model. Multiple scenarios were modeled for each situation to provide the moving line team with various ideas and options for this state of the art change in manufacturing philosophy. The team was able to identify an optimum solution from the various scenarios, which were presented. This is an advantage that simulation or virtual prototyping can provide. "Virtual prototyping, developed at the University of Michigan nearly a decade ago, uses computer programs to create design iterations for prototype without the need to build a physical model." (Strong 2001) "Virtual Prototyping is the primary factor in cutting the time needed to produce a new car or truck from five years to 18 months, It lowers costs, improves efficiency and raises quality." says Mike Kidder. (Strong 2001)

2 INITIAL MODELING OBJECTIVES

In order to produce a value adding simulation model it was necessary to be as realistic and accurate as possible. Before starting any actual modeling, the overall benefits of the project were determined. These benefits served as the modeling objectives throughout the modeling course.

2.1 Benefits

- Providing multiple scenarios to aid in the decision making process
- Minimizing materials
- Minimizing flow times
- Minimizing resource costs
- Maximizing efficiency

3 LOGISTICAL DETAILS

The first major obstacle was outlining the logistical details regarding the stands and their movement along with the plane. The following steps were taken to achieve this goal.

3.1 Analyzation of stand logistics

- Work with Industrial Engineering and Process Engineering
- Identify specified stand locations to reduce constant clutter
- Moving stands vs. Use-and-Remove stands
- Larger and more frequently used stands should move simultaneously with the plane
- Other stands should be used and then removed from the area
- Identify & analyze stand usage
- Study redundancy of usage for each individual stand
- More frequently used stands should be more accessible

3.2 Stand Logistical Effect on Manufacturing Process

- Identify stand usage for each specific job
- Separate groups of jobs that require similar stands
- Consider possible grouping or bundling of jobs based on similarities in stand logistics

After analyzing the logistical details and labor information for each stand as illustrated in Figures 1 to 4, utilization

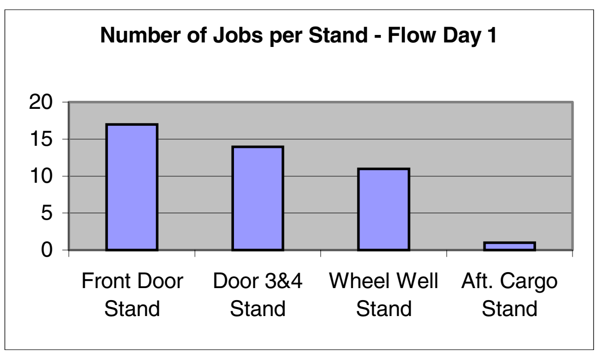

Figure 1: Stand Analysis Flow Day 1

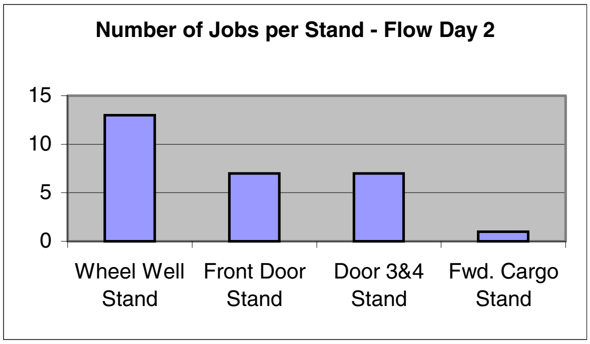

Figure 2: Stand Analysis Flow Day 2

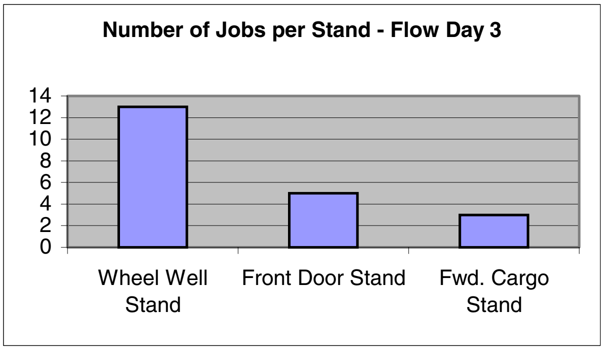

Figure 3: Stand Analysis Flow Day 3

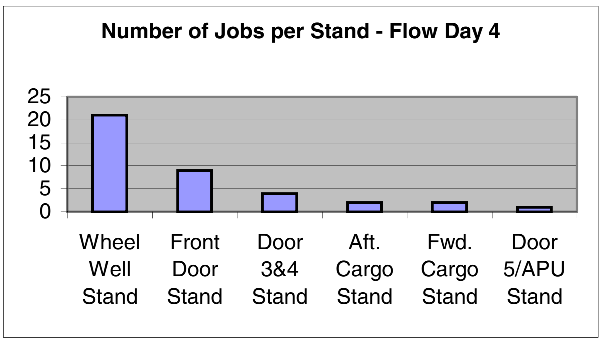

Figure 4: Stand Analysis Flow Day 4

could then be determined. The utilization is extremely important due to high inventory costs for each stand as well as difficulty in moving all of these stands along with the plane in the moving line. The objective was to include only the stands, which are used for high numbers of jobs and are absolutely necessary.

3.3 Stand Utilization Information

Figure 5 was a screen copy of a simulation model that yielded the following stand utilization information.

Wheel Well Stand:	29% of total jobs use stand
Front Door Stand:	24% of total jobs use stand
Door 3 & 4 Stand:	18% of total jobs use stand
Forward Cargo Stand:	4% of total jobs use stand
Aft. Cargo Stand:	2% of total jobs use stand
Door 5/APU Stand:	1% of total jobs use stand

Figure 5: Stand Logistic Model 1

4 SIMULATION SCENARIO ANALYSIS

Phase 2 of the moving line project has been focused on many lean-manufacturing initiatives. Simulation modeling was identified as a key tool to help with the level load positioning activities (line balancing) of labor in each slant position. With the addition of the moving line there will be a reduction of 2 days from the slant 1 position. Because of this it will be beneficial to model different scenarios with regards to each one of the moving line related jobs, and associated labor to different positions in the factory. In order to achieve this it was necessary to analyze the various jobs that were being affected, and their respective head counts and total times. The plane currently spends a total of 8 days in the slant 1 position and the following data represents the job, time, and head count information.

Simulation modeling yielded utilizations of the final body join position, the first slant position, and the moving line of the 747 final assembly as illustrated in Figures 6 and 7.

	Total Hours	Head Count
Day1	293	37
Day2	232	29
Day3	272	34
Day4	368	46
Day5	520	65
Day6	640	80
Day7	128	16
Day8	120	15

Figure 6: Slant 1 Job Time and Head Count info

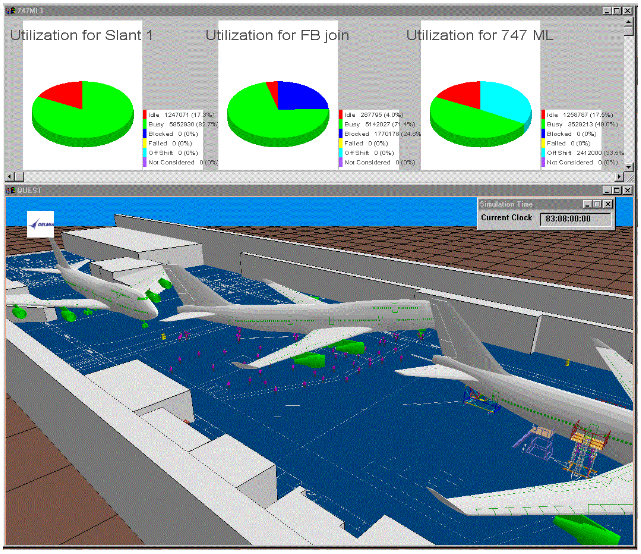

Figure 7: Job/Head Count Simulation

5 LINE BALANCING/LEVEL LOADING MODEL

One of the early findings to move the moving line concept upstream showed the necessity to move the gear swing test from the slant 1 position to an earlier Final Body Join (FBJ) location. However, the affected job codes had too many tasks in them to feasibly move the tasks back to FBJ. A simulation and work analysis showed that many jobs could be separated from the gear swing minimum required tasks and that those tasks could then be done in the moving line. This simplified the gear swing tasks to the point where they could be moved to the FBJ position allowing the moving line concept to move back a whole position in the factory and eliminate the first slant position. Models created for the gear swing issue depicts the redistribution of all gear swing labor activities from the slant 1 position to FBJ and the moving line. The associated utilizations for each FA position were also analyzed. The end goal was to move gear swing as well as all other labor activities out of slant 1 and into either the moving line or FBJ therefore using all of the positions more effectively.

5.1 Additional Line Balancing Models

In the process of moving the gear swing to FBJ, it was discovered that in order to complete the move successfully certain activities within FBJ needed to be improved. Section 44 floor wiring operations, which are conducted when the three major sections of the 747 are joined, are prone to getting delayed while going through pipes, ducts, air and hydraulic lines etc. before meeting and being connected.

Recovery from such substantial damage events would make it difficult to complete gear swing in the 6 days of FBJ and would also negate the benefit of moving the gear swing back to FBJ. An analysis task was defined to simulate and possibly improve these wiring tasks. All of the jobs in FBJ that were associated with the wire assembly were modeled as well as associated head counts and total hours related to these jobs. The final goal was to provide models of alternate ideas and approaches, which would improve the wiring, task and ultimately allow the gear swing to be moved to FBJ.

6 CONCLUSIONS

There is much more simulation modeling that can be performed to further benefit the Queen of the Sky's final assembly moving line. This work initiated the realization of the usefulness of discrete event simulation modeling and the benefits to stochastic manufacturing processes on the 747 final assembly floor. This project has given us great confidence in the use of simulation modeling as a direct support tool in an intense manufacturing/production environment. As the moving line continues to improve in the future, so will the simulation modeling practices. Findings of this work were just the tip of the iceberg. Ultimately, Boeing would like the 747 moving line process to be as standardized and flawless as the moving assembly lines being employed in the auto industry. Moving line has been illustrated beneficial and practical. "The basic method of building cars has not changed much over the past 85 years: Move the chassis slowly along an assembly line and have workers attach components as it passes. (Vance 2001) "Toyota plans to spend $120 million to construct the Lexus paint line… keep the vehicle moving." (Chappell 2001) In the future, faster simulation modeling iterations, deployable models, and real-time feedback models would further enhance the value of the manufacturing process simulation practices.

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