

GYROSCOPE ASSEMBLY PROCESS IMPROVEMENT ANALYSIS

COMPANY S

A Senior Project submitted  
In Partial Fulfillment  
of the Requirements for the Degree of  
Bachelor of Science in Industrial Engineering

the Faculty of California Polytechnic State University,  
San Luis Obispo

by

Ian Douglass

Juan Saucedo

March 2013

Graded by: \_\_\_\_\_ Date of Submission \_\_\_\_\_

Checked by: \_\_\_\_\_ Approved by: \_\_\_\_\_

## ABSTRACT

### GYROSCOPE ASSEMBLY PROCESS IMPROVEMENT ANALYSIS

Ian Douglass

Juan Saucedo

The gyro is a fundamental portion of many assemblies that Company S, a directional drilling company, manufactures. The gyro assembly is a highly sensitive and complex process, and it was paramount to establish efficiency and quality guidelines to base management decisions. The first guideline succeeded by increasing throughput by means of a simulation using ProModel. Next, non-value and value added activities were identified through a value stream map. Lastly, a database was developed in order to capture high integrity quality control data, or key performance indicators, such as, throughput, first-pass inspection yields at every test performed, and defects found. This work increases the assembly management team's understanding of the gyro assembly and serves as the foundation for future six sigma process improvements.

## ACKNOWLEDGMENTS

Special thanks to:

Dr. Sema Alptekin

Company S

Cal Poly IME Faculty

## Table of Contents

List of Tables .....	v
List of Figures .....	vi
Introduction.....	1
Background.....	4
Literature Review.....	6
Design .....	13
Method and Experimentation.....	21
Results and Discussion .....	28
Conclusion and Experience.....	36
Bibliography .....	38
Appendix.....	39

## List of Tables

Table L-1: A Variety of Computer Simulation Environments.....	12
Table D-2: Gyro Assembly Phases and Activity Breakdown.....	18
Table D-3: Value Added Results Summary.....	19
Table M-1: Summary of Gyro Tracker Database Data Tables .....	26
Table RD-1: Defects per Assembly.....	33

## List of Figures

Figure B-1: Directional Drilling.....	5
Figure B-2: Gyro Inside an Assembly.....	5
Figure L-1: Value Stream Map .....	7
Figure L-2: Muri, Mura, and Muda.....	11
Figure D-1: Gyro Assembly Phase Breakdown.....	13
Figure D-2: Simulation Layout.....	16
Figure M-1: Location Usage Summary.....	21
Figure M-2: Personnel Usage Summary.....	22
Figure M-3: Location Usage Summary for Increased Arrivals.....	23
Figure M-4: Personnel Usage Summary for Increased Arrivals.....	24
Figure M-5: Floor Layout of Gyro Assembly Process.....	25
Figure M-6: Floor Layout of Recommended Gyro Assembly Process.....	25
Figure RD-1: Floor Layout of Recommended Gyro Assembly Process .....	28
Figure RD-2: Main Menu of Database.....	29
Figure RD-3: New Data Form of Database.....	30
Figure RD-4: View Data Form of Database.....	31
Figure RD-5: Update Data Form of Database.....	31
Figure RD-6: Throughput Analysis by Month.....	32
Figure RD-7: First-Pass Inspection Yield.....	33
Figure RD-8: Current State Value Stream Map.....	35



## **I. Introduction**

### **Purpose**

Company S manufactures a crucial component called a gyroscope (gyro) that is used in nearly 90% of all tools in their product lines. Although Company S has over 15 years of experience manufacturing a highly sensitive and technically complex component; Company S management still has a limited understanding the assembly process. There is no specific understanding of value added and non-value added activities, lead times are variable and unjustified, and there is very limited visibility to quality documentation. Without conclusive analysis, process recommendations cannot be validated, which leads to the content of this project: providing management with analytic tools and an established baseline of current operations to aid operational decision making.

### **Approach**

The project has three major elements, which in combination, provide management with a comprehensive analysis tool they can use to confidently and effectively base decisions.

- **Simulation:** Simulate manufacturing facility process flow
- **Value Stream Mapping:** Confirm value added and non value added work elements
- **Database:** Gather manufacturing quality data

To further define the purpose of the simulation study, multiple established objectives will be the main criteria for this simulation project. At a high level, the following general objectives need to be addressed:



## **General Objectives:**

- Analyze Current Assembly Process
- Analyze Current Assembly Constraints or Bottlenecks
- Compare Alternative Assembly Process Configurations
- Maximize Assembly Process Throughput

Developing the simulation is the first crucial step to delivering a practical tool for testing alternative solutions. In order to keep the simulation tailored to Company S's gyro operation, ideally allowing for a modular architecture (plug and play) later on, the following specific design, operation, and economic questions were approached.

## **Specific Objectives:**

- Answer Design Questions:
  - How can the assembly process be optimized to develop a higher throughput?
  - What are the bottlenecks in the process, and how can they be eliminated?
  - How many staff personnel are needed for the current process?
  - How many shifts are needed for the current process?
  - How many entities (materials) are routed throughout the process?
- Answer Operational Questions:
  - What is the optimal way to assign staff to different tasks?
  - How many staff personnel and shifts should be scheduled?
- Answer Economical Questions:
  - How much does it cost to produce one part with the current process?

- How much does it cost to produce one part with the new process?

## **Workflow**

Due to the robust scope of the project, it was imperative that proper preparation and a comprehensive understanding of the assembly process were attained before proceeding. With that in mind, the following workflow and verification loop was followed during the course of the project.

- Assess Current Gyro Process
  - What does the current process consist of?
- Analysis of Current Gyro Process
  - How does the current process function, what are the inputs and outputs, how is data managed?
- In process review with Company S key players
- In process review with Technical Advisor
- Draw conclusions, develop deliverables

Now that the scope and approach of the project is established, it is necessary to understand the background of Company S and some of the operational environments both in the field and in the manufacturing process.

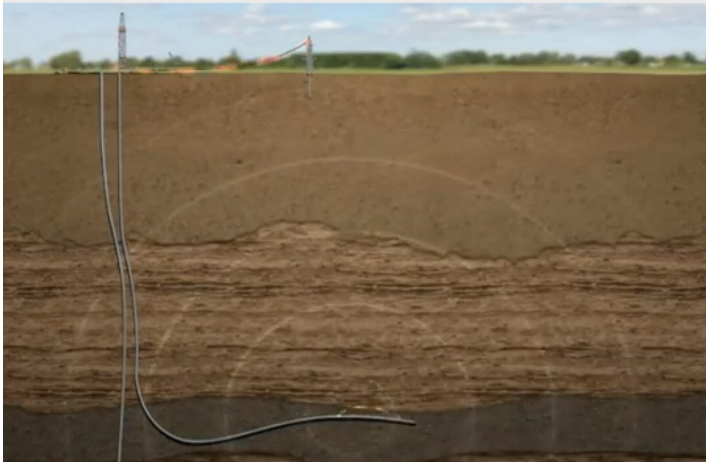
## **II. Background**

Company S, has a long and successful history of designing, engineering, building, and manufacturing directional drilling technology products. These technologies include state-of-the-art electronic sensors for downhole measurement in such applications as borehole surveying, wireline steering, MWD / LWD production logging, directional drilling and more.

Borehole surveying instruments (both gyroscopic and magnetic), MWD (measurement while drilling) / LWD (logging while drilling) systems, rotary steerable technologies, innovative drill motor designs and production logging systems comprise the bulk of their products.

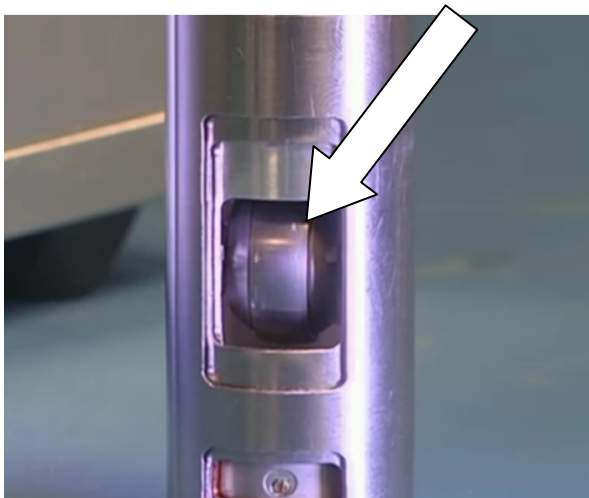
Company S has many locations in the USA, with their headquarters residing in Houston, Texas. We had the privilege of working in Company S's main manufacturing facility in Paso Robles, CA. We looked at a specific portion of their massive Gyroscope, or Gyro for short, assembly process. The Gyro is an instrumental piece of equipment within other assemblies, such as the ones aforementioned. The Gyro aids an assembly in determining its position in three coordinates (azimuthal, radial, and gain). Furthermore, the Gyro assists in sensing the rotation of the earth underneath us. Figure B-1, shows directional drilling with the assistance of a Gyro. These coordinates assist the drill operators in determining which direction to drill in order tap into the richest hydrocarbon pockets available.

**Figure B-1: Directional Drilling**



The Gyro is an innovative piece of equipment that has the capability of reaching speeds up to 48,000 RPM, and an image of the Gyro can be seen in Figure B-2 with the white arrow pointing to it.

**Figure B-2: Gyro Inside an Assembly**



## **Literature Review**

This literature review seeks to bolster our understanding of value stream mapping, which is validated and defined by elements of lean manufacturing, as well as simulation. By examining professionally referenced examples, the quality and effectiveness of our process analysis can only improve.

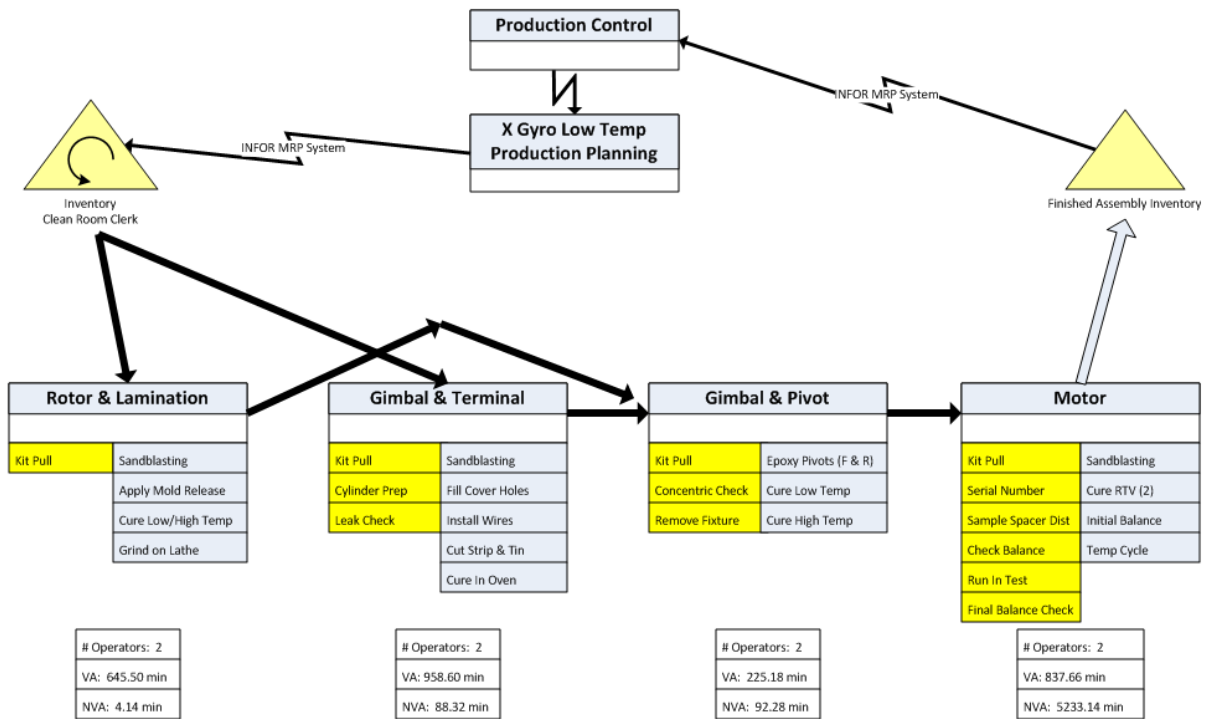
Volatile markets as seen in today's economy have lead to an environment of ultra-competitive business strategies. In order to sustain such aggressive models, companies are looking within to maximize the amount of a dollar, especially in manufacturing processes. The concept of "lean manufacturing", as made famous by the Toyota Production System, is a long standing template of successful applications of several lean manufacturing techniques such as Just-in-Time (JIT), "jidoka", 5S, cellular manufacturing, poka-yoke, and value stream mapping (VSM) <sup>[2]</sup>. These tools, coupled with quality and service management principles such as key performance indicators (KPI) allow for "value" gains, or in other words "obtaining the maximum production with minimum resources, less time, less inventory, less space, etc." <sup>[2]</sup>.

## **Value Steam Mapping**

In many industries, specific improvement areas are often delineated into special projects where a product's manufacturing process is analyzed in detail and optimized. Projects typically have stages dealing with planning, testing, solution development, and implementation with further status testing or maintenance scheduled for the future. Unfortunately, many of these process improvement projects may seem valid at the surface level, but without understanding the "root

cause” or true origin of the problem, its constituents and relationships, project improvements can be mere fixes for a reoccurring problem <sup>[10]</sup>. Therefore, a value stream map (VSM) is a technique used to “indicate what generates value and create a continuous flow through the manufacturing pull system” <sup>[2]</sup>. Understanding what specific activities contribute to value aggregation (value added, VA) as well as understanding both necessary and unnecessary non-value added (NVA) activities are essential to forming a basis for alternative solutions. Figure L-1 below shows an example of a VSM, as well as distinct value type characteristics.

**Figure L-1: Value Stream Map**



A value stream map, similar to a system model, can be defined in its scope and boundaries, which allows it to be a practical tool in actual application. According to Irani and Zhou, VSM

projects need to have two or more specific maps: a current state value stream map (CSVSM), and at least one future state value stream map (FSVSM) <sup>[4]</sup>. These maps need to be collectively developed by a cross functional team that has a focus on improving the overall process, not just optimizing individual parts. An example of an effective and balanced team might be <sup>[2]</sup>:

- **Production manager** – defines product family to analyze, specify scope requirements
- **Manufacturing employee** – provides shop floor and operator knowledge
- **Manufacturing Coordinator (Data Administrator)** – maintains KPIs, provides quantifiable analysis data
- **Lean manufacturing specialist** – knowledge of industrial engineering skills and tools

Depending on the scope of the value stream map, potential issues with suppliers, business areas, and any other entities that contribute to the end product would be easily visualized <sup>[4]</sup>. Once these issues can be successfully identified and the root cause established, solutions can start to be modeled for implementation and incorporation in the future state value map (FSVSM). Rother and Shook explain that a properly generated FSVSM carefully considers seven different “Lean Thinking” elements <sup>[8]</sup>:

1. Produce takt time
2. Develop continuous flow
3. Use supermarkets to control production where continuous flow does not extend upstream
4. Schedule based on the pacemaker operation
5. Produce different products at a uniform rate (level the production mix)
6. Level the production load on the pacemaker operation (Level the production volume)
7. Develop the capability to make “every part every (EVE) <time>” statement(s)

Ultimately, the VSM aspect of the process improvement project needs to serve as a blueprint or template for future strategic planning. Without an effective VSM, corresponding simulation models and alternative solutions cannot be validated.

## **Lean Manufacturing**

As previously mentioned, the concept of lean manufacturing is now being considered with increasing fervor based on its demonstrated cost saving and value adding abilities. Lean manufacturing is not just a tool or practice, but more of a “state of mind” or culture that still remains to be fully embraced by American manufacturing companies. There are many subtopics within the greater concept of lean manufacturing which typically need to be implemented on a large scale in order to yield positive results. However, the idea of “muda, muri, mura”, which are Japanese terms for waste, is a specific and integral part of the Toyota Production System, TPS, than can be effectively applied to nearly any process or problem. According to Liker’s *The Toyota Way*, there are actually eight “muda” wastes, rather than the original seven <sup>[5]</sup>:

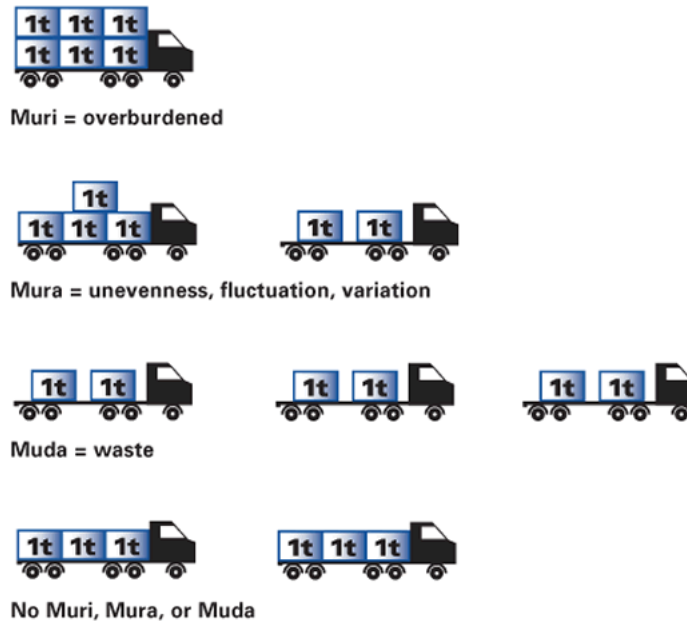
- **Transportation** – very rarely value added activity, possibility of in transit damage
- **Inventory** – in the form of raw materials or work in progress (WIP), requires additional resources to manage and control, additional holding costs
- **Motion** – similar to transportation, considers accidents and harm to both employees and products during assembly tasks
- **Waiting** – non-value added, idle time is typically an obvious waste
- **Over processing** – over fulfilling customer or quality specifications



- **Overproduction** – considered the worst of the mudas, producing more than the demand requires leads to excess inventory and encourages other muda
- **Defects**- requires additional rework to salvage effort and material value
- **Wasted worker knowledge\***- eighth waste, operators have a breadth of practical knowledge that must be considered in any type of process improvement

Manufacturing operations are especially notorious for having such muda issues which must be resolved before a definite root cause can be identified and a process improvement project can be completed. Additionally, other waste types as defined by “muri” and “mura” exist in a capacity that may not be as plainly evident as basic “muda”. Muri and mura, in relation to muda, can be defined in figure L-2 below<sup>[10]</sup>:

**Figure L-2: Muri, Mura, and Muda**



## Simulation & Environments

The term simulation can have several meanings depending on its application. However, regardless of the application, the purpose and concept are consistent: system or model testing, pseudo data generation, resulting in the ability to make theoretical conclusions<sup>[3]</sup>. Consider well known applications such as flight simulators and printed circuit board functionality simulation programs for example. Critical performance data generated by the simulation allows for designs to be validated as well as allowing projects/processing to move forward without incurring the high cost and inconvenience of a direct system study<sup>[6]</sup>.

When setting out to simulate a manufacturing environment, there are several approaches to consider. Most importantly, the level of programming competency among the simulation

designer(s) must be understood. Additionally, the computer simulation interface should be selected based on specific results requirements. The following table, Table L-1, was developed with Bronislav Chramcov’s article on computer simulation in manufacturing systems <sup>[1]</sup>.

**Table L-1:** A Variety of Computer Simulation Environments

Computer Simulation Environments	Simulation Interface	Pros	Cons
<ul style="list-style-type: none"> <li>• Simula</li> <li>• C++SIM</li> <li>• GPSS/H</li> <li>• AweSim</li> <li>• Simscript</li> <li>• BaseSim</li> <li>• CSIM 19</li> <li>• JavaSIM</li> </ul>	Inputs and outputs are in the form of textual data.	Great degree of flexibility when it comes to how one wants to structure the model and resolving variable tasks and roles.	Expert skill level required especially with modeling and programming techniques.
<ul style="list-style-type: none"> <li>• MapleSim 4</li> <li>• AutoMod</li> <li>• Quest</li> <li>• Arena</li> </ul>	One can develop a model either in a graphical way, or with code.	One can actually visually see more of the simulation than that of the prior category.	It would be better if one still possessed some programming background.
<ul style="list-style-type: none"> <li>• Renque</li> <li>• ProModel</li> <li>• Tailor II</li> <li>• FACTOR/AIM</li> <li>• ExtendSim</li> <li>• WITNESS</li> </ul>	Fully graphical interface.	One with an average knowledge of programming can easily develop simulation models.	Not as flexible as that of the 1 <sup>st</sup> category.

ProModel provides a balanced approach especially for a defined process improvement simulation project. Its simulations are objective, scientific, quantitative, and can serve as a reliable tool for decision making based on its “What-if” capability. Furthermore, ProModel is currently the only available simulation software package at Cal Poly, and this was a primary reason for using it.

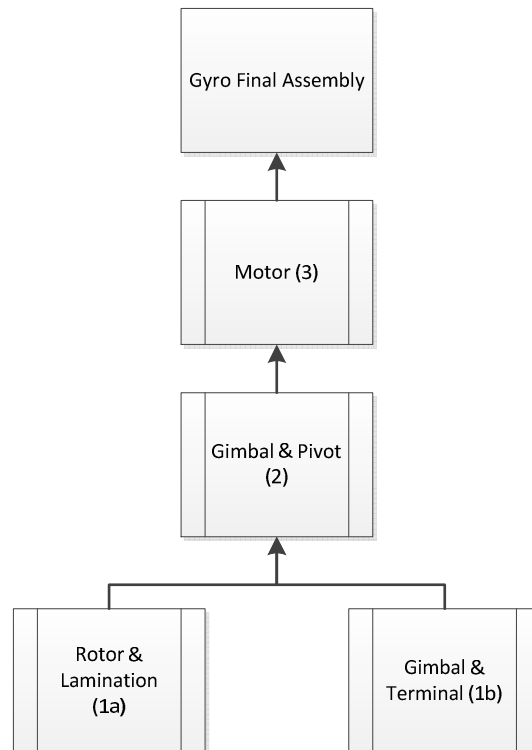
### III. Design

This section focuses specifically on the gyro assembly process, starting with a brief assembly breakdown, and then expanding to the project concept, with our three avenue approach: simulation, value stream mapping, and quality data management (database).

#### Assembly Process Overview

The Gyro assembly process is broken down into four phases: Rotor & Lamination, Gimbal & Terminal, Gimbal & Pivot, and Motor. The Rotor & Lamination as well as the Gimbal and Terminal (phases 1a, and 1b, respectively) must be completed before the Gimbal & Pivot (phase 2) phase can begin. Similarly, the Motor assembly (phase 3) phase is contingent upon the Gimbal & Pivot completion. This procedure is illustrated in the Figure D-1 below:

**Figure D-1:** Gyro Assembly Phase Breakdown



## **Project Constraints**

The overall goal of the project is to provide a “tool” for sustaining analysis and process improvement for the gyro assembly. Although there are alternative “solutions” or recommendations, special consideration was given to the following constraints:

- ***Equipment has limited capacity to move and/or change.*** Due to specific, highly sensitive equipment and corresponding clean room requirements, most equipment changes would be challenging
- ***Limited facility redesign.*** Company S is currently undergoing renovation and construction to its facilities, none of which includes changing the gyro assembly process. Workstations and basic equipment can move and change, however, no walls may be broken down or any labs remodeled.

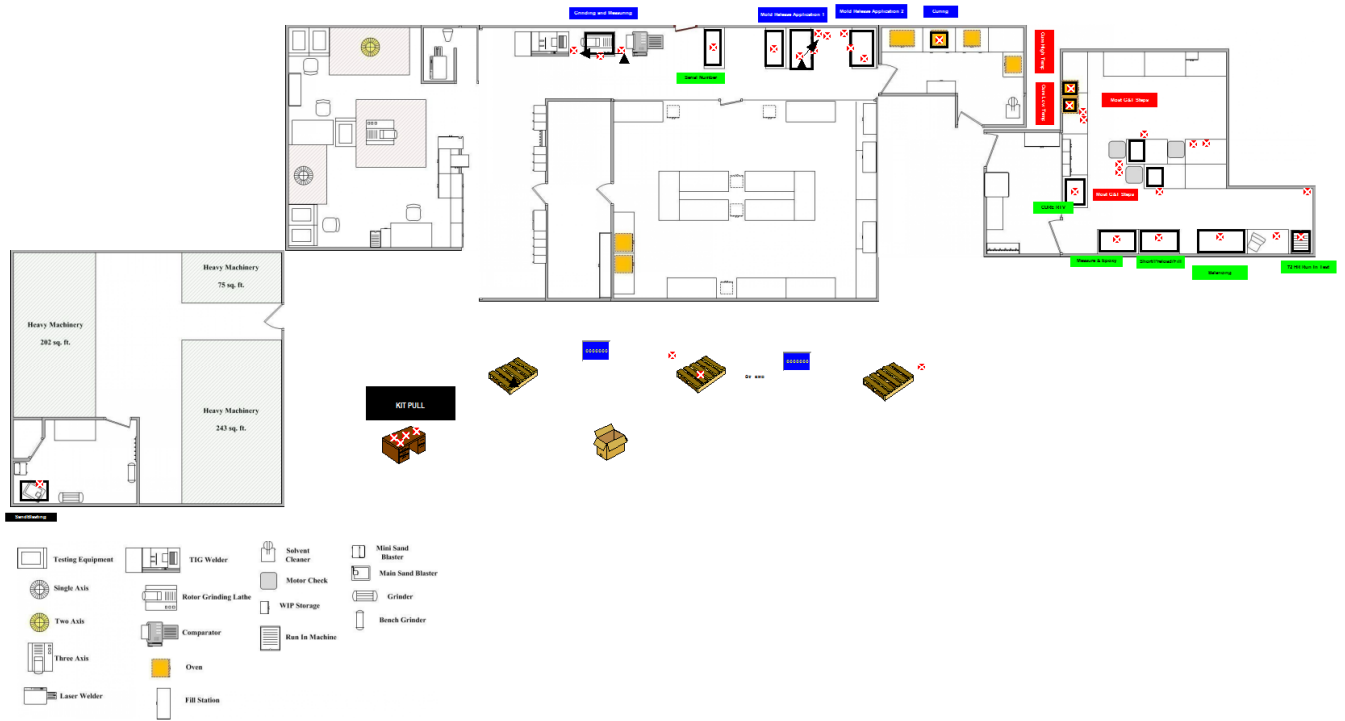
## **Current Simulation**

Taking into account the project constraints as well as the specific design, operation, and economic objectives mentioned in the “Approach” section above, the design of the current assembly process simulation seeks to “test the waters” in terms of possibilities for process improvement. The simulation serves two essential purposes, first as a template for alternative solutions, and second and primary gateway to further analysis or value stream mapping (seen in sections below).

There are many capable software packages that could be used to perform the complex simulation required for this project, however, ProModel was the ultimate selection because of its availability here at Cal Poly. With ProModel, the current process can be graphically modeled, and an alternative design can be developed and compared. One key benefit of using ProModel is that several different scenarios can be concurrently modeled without having to alter the current process. ProModel also delivers quantitative analysis that can aid in selecting an alternative solution.

The current simulation has 45 locations, which includes queues, 12 entities, and 5 different resource types. The background image is a floor layout of the current production floor, which was made in Microsoft Visio. The process for this simulation is depicted in Table D-2 above. The simulation makes use of various ProModel Process commands such as, UNGROUP, GROUP, USE CREW, and JOIN. It also contains path networks for the resources to depict animation on the production floor. An image of the current simulation is seen below in Figure D-2.

**Figure D-2: Simulation Layout**



## Material Flow Diagramming

As the simulation mainly serves to animate and analyze bottlenecks within the gyro assembly process, the “spaghetti” diagrams shown in appendix A specifically trace material movement throughout each phase.

## **Assembly Activities and Distribution**

The results of the current simulation provided enough evidence to move forward with value stream mapping which would provide a balanced explanation of bottlenecks from a physical or location standpoint as well as a “value effectiveness” standpoint.

In Table D-2 below, each of the four phases are broken down. The nomenclature reflects each assembly activity as its real entity within the ERP system INFOR. Additionally, a triangular distribution for assembly activity times was used. Due to Company S’s recent implementation of INFOR, the historical data totaled less than 30 gyro assembly batches. With that in mind, the central limit theorem (CLT,  $n > 30$ ) was not fulfilled and we could not outright assume the normality of our data set. Instead, the triangular distribution explains the low, mean, and high values for each activity.

For the “Low” element of the distribution, the generated values come from a calculation within INFOR (ERP system), based on the collection of employee’s “log in” times on a kiosk at their workstation. Many of values have a relatively inconceivable completion time, however, the main concern of the analysis falls on reducing the “Mean” and “High” values for both value added and non-value added work activities.



**Table D-2: Gyro Assembly Phases and Activity Breakdown**

<b>Main Phase</b>	<b>Step</b>	<b>Value Added</b>	<b>Low</b>	<b>Mean</b>	<b>High</b>
<b>Rotor &amp; Lamination</b> (51.76, 54.81, 67.18) hrs - 1a	10 KTP - KIT PULL	N	0.01	0.069	0.25
	15 - Sandblast lamination rings	Y	0.01	2.214	6.07
	20 - Apply mold release to rotor fixtures	Y	0.01	2.942	10.45
	30 - Cure in low and high	Y	2	2	2
	40 - Grind on lathe/measure both	Y	0.01	3.619	10.46
<b>Gimbal &amp; Terminal</b> (64.05, 82.01, 96.27) hrs-1b	10 KTP - KIT PULL	N	0.01	0.336	1.63
	20 - Cylinder Prep	N	0.01	0.25	0.5
	25 - Sandblasting	Y	0.01	2.523	22.76
	30 - Cure low temp	Y	1	1	1
	35 - Fill Term/Coverholes	Y	0.01	2.283	9.87
	36 - Cure for 1 hour	Y	1	1	1
	37 - Cover FA8 with LCA4	Y	0.01	0.915	5.01
	38 - Cure at low temp for 1 hour	Y	1	1	1
	40 - Install wires	Y	0.01	3.204	10.89
	50 - Epoxy corner of wires	Y	0.01	0.02	0.025
	60 - Cut strip and tin/check for shorts	Y	0.01	2.031	6.86
	70 - Cure low/cure high	Y	2	2	2
	80 - leak check	N	0.01	0.886	4.52
<b>Gimbal &amp; Pivot</b> (25.60, 39.36, 42.19) hrs-2	10 KTP - KIT PULL (HERE)	N	0.01	0.151	0.91
	20 - Set front and rear pivot/epoxy in p...	Y	0.01	1.753	8.64
	30 - Cure low temp oven	Y	1	1	1
	40 - Check front and rear concentrici...	N	0.01	0.401	1.83
	50 - Cure in high temp oven	Y	1	1	1
	60 - Take fixture off/check again/clear	N	0.01	0.986	3.51
<b>Motor</b> (145.31, 174.63, 188.45) hrs-3	10 - 050-400319-002 KTP PULL	N	0.01	0.16	0.42
	20 - Sandblast	Y	0.01	4.399	9.46
	25 - Sonic Cleaner	Y	0.01	0.01	0.01
	30 - Serial number	N	0.01	2.861	10.41
	35 - Measure & Epoxy	Y	0.01	0.01	0.01
	40 - CURE RTV	Y	0.01	0.01	0.01
	50 - Sample Spacer/Check Distance	N	0.01	5.08	10.2
	60 - CURE RTV	Y	2.8	2.8	2.8
	65 - Initial Balance	Y	0.01	3.44	9.44
	70 - Short/Preload/Fill	Y	0.01	0.01	0.01
	80 - Temp Cycle	Y	0.01	3.282	8.92
	85 - Check Balance	N	0.02	3.484	9.16
	90 - 72 Hour Bearing Run In Test	N	72	72	72
	100 - Final Balance	N	0.01	3.634	9.89

## Value Added Analysis

Table D-2 above also segregates value added and non-value added activities, with non-value activities shaded in gray. Each activity was evaluated for its value added characteristics in collaboration with key SDI personnel involved in each assembly phase. The definition of value added used was influenced by Literature Review research and asked the ultimate set of questions: “Would the customer pay for this activity? Is this activity associated with testing or inspection? If perfect components could be attained, would this activity still be required?”

With that in mind, the follow Table D-3 summarizes value added analysis results as well as identifying specific labor and machine hour totals.

**Table D-3:** Value Added Results Summary

Distribution	NVA (hours)	VA (hours)	Labor (hours)	Machine (hours)
Low	72.13	11.97	0.28	83.82
Mean	90.298	44.465	71.43	83.82
Hi	125.23	130.695	172.105	83.82

## **Gyro Tracker Database**

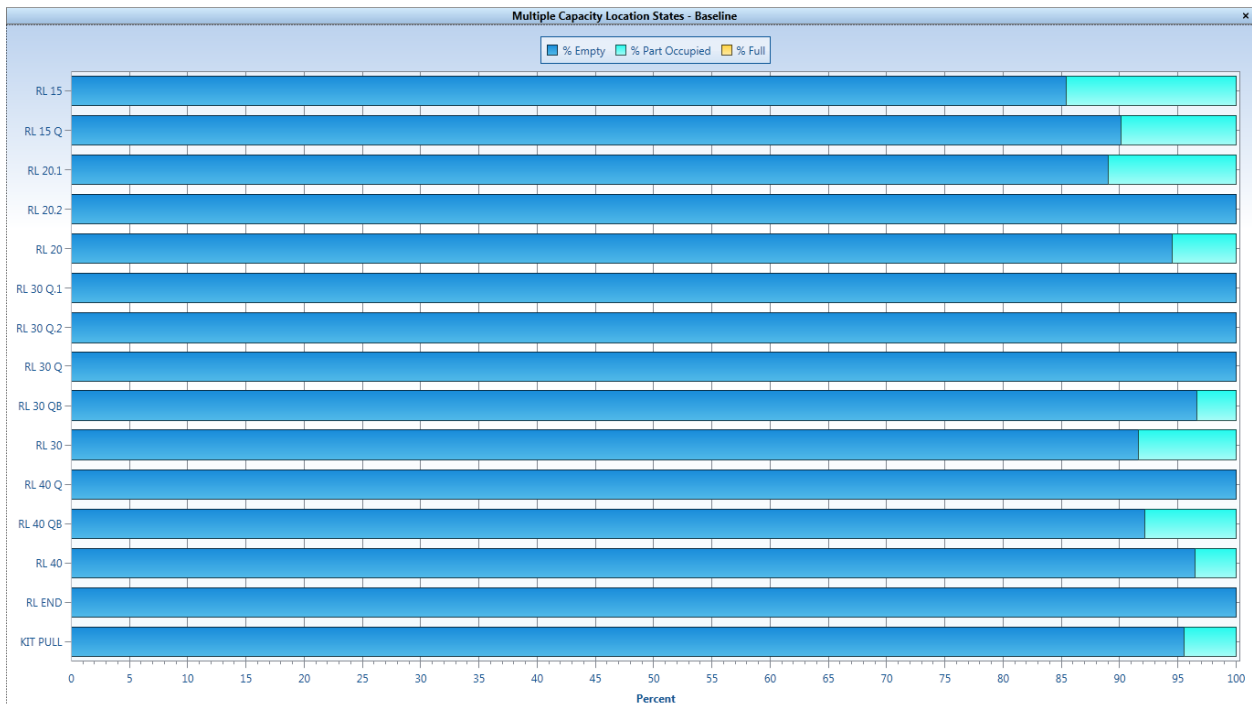
Company S came under new ownership within the past 2 years. The company used to be run as a ‘Mom & Pop shop’, so there was little to no documentation. Furthermore, because documentation was scarce, product quality was poor and production endured low yield rates. The “Gyro Tracker” database will assist Company S to capture throughput, first-pass inspection yields, and defects found on the products. The data captured in this Microsoft Access database will connect to a pivot table in Excel in order to allow the user to manipulate desired trends, for example, throughput for a given week, month, or quarter. By implementing these key performance indicators, this will assist Company S in their efforts to become ISO 9001 certified.

## V. Methods & Experimentation

### Simulation

The simulation was originally going to be for 50% of the Gyro X Low Temperature assembly process, but it was decided to focus on one of the more crucial aspects of the process, and see what kind of output data would be produced. The following charts were produced by the simulation of the Rotor & Lamination phase.

**Figure M-1:** Location Usage Summary



As one can see from Figure M-1, all the locations are, for the most part, empty. This means there are not enough arrivals coming into the process. The arrivals for the simulation are something that is based on customer orders. If customers do not place an order for one of the kits that contain the Gyro, the Gyros do not get made.

**Figure M-2: Personnel Usage Summary**

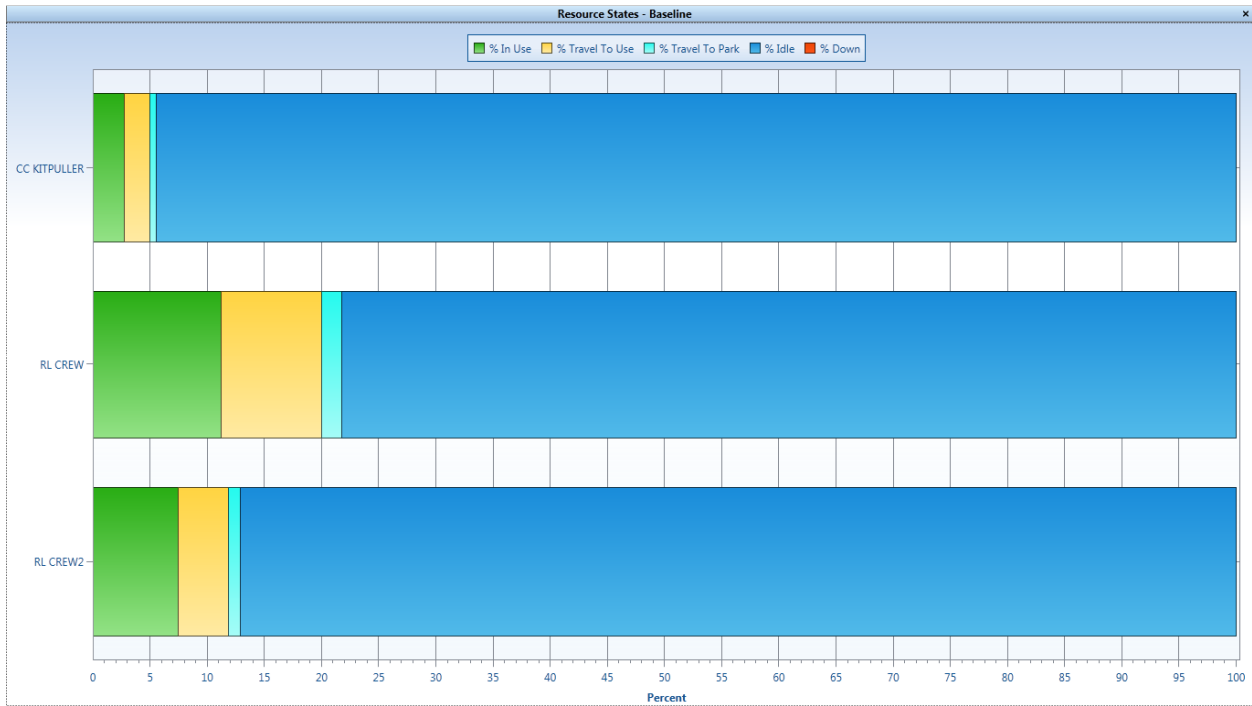
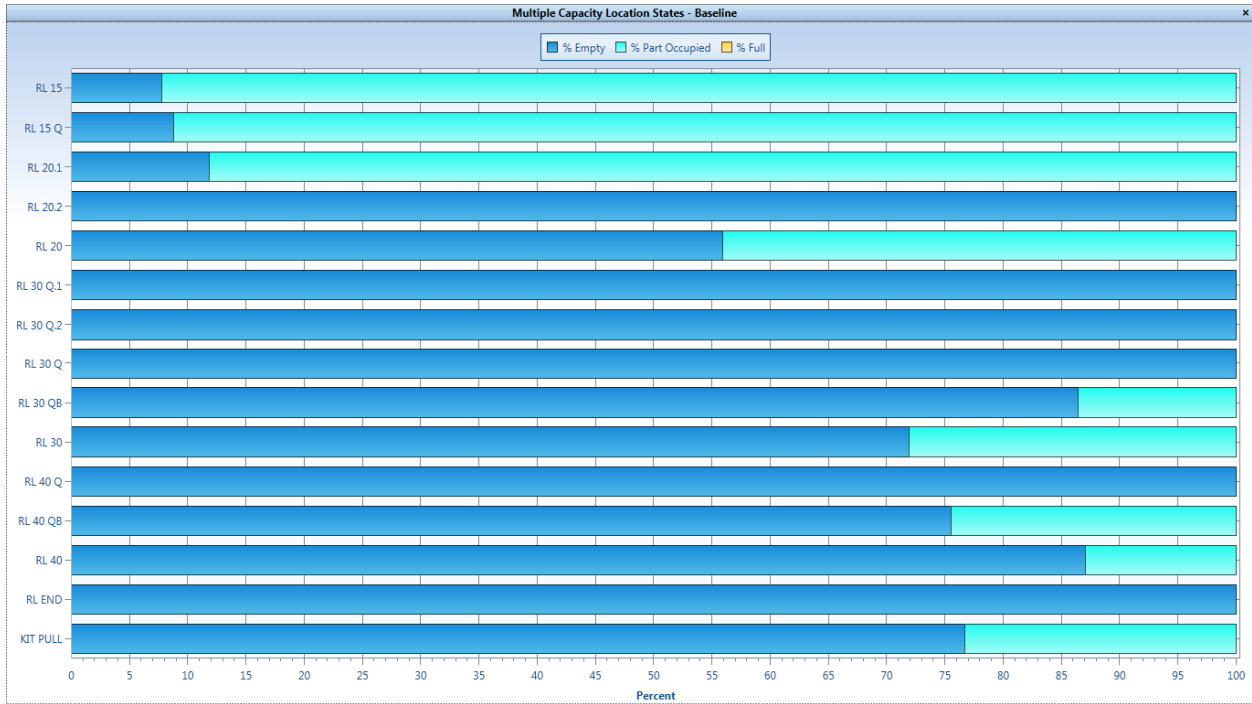


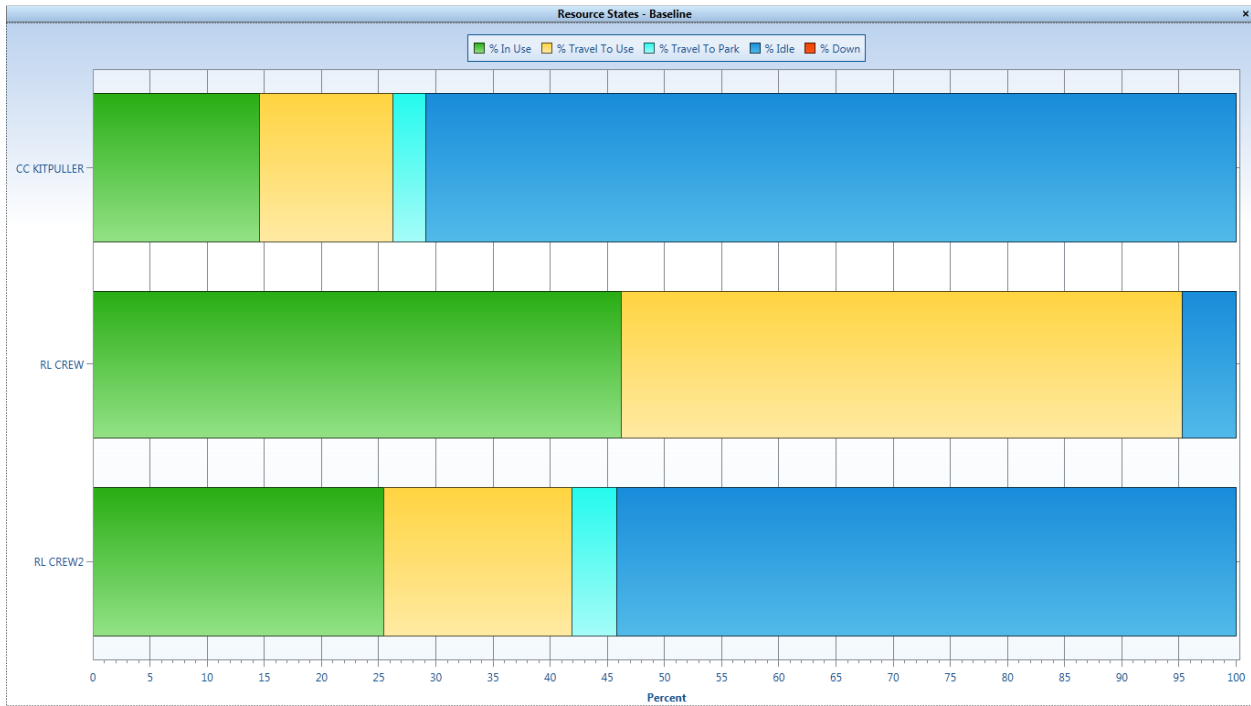
Figure M-2 reiterates the fact that there are not enough arrivals coming into the system. As one can see in the bars above, all of the personnel are idle. This is not to imply that they are not working on other items, they in fact are. The personnel are also working on field return items (a field return is when a piece of equipment malfunctions in the field and are returned for repairing) which has a more complex flow than that of the new build Gyros. In essence, the major bottleneck in this simulation process is the number of arrivals, which is a variable that is difficult to change. Nonetheless, we increased arrival times by a factor of 5, this was verified by past throughput orders.

**Figure M-3: Location Usage Summary for Increased Arrivals**



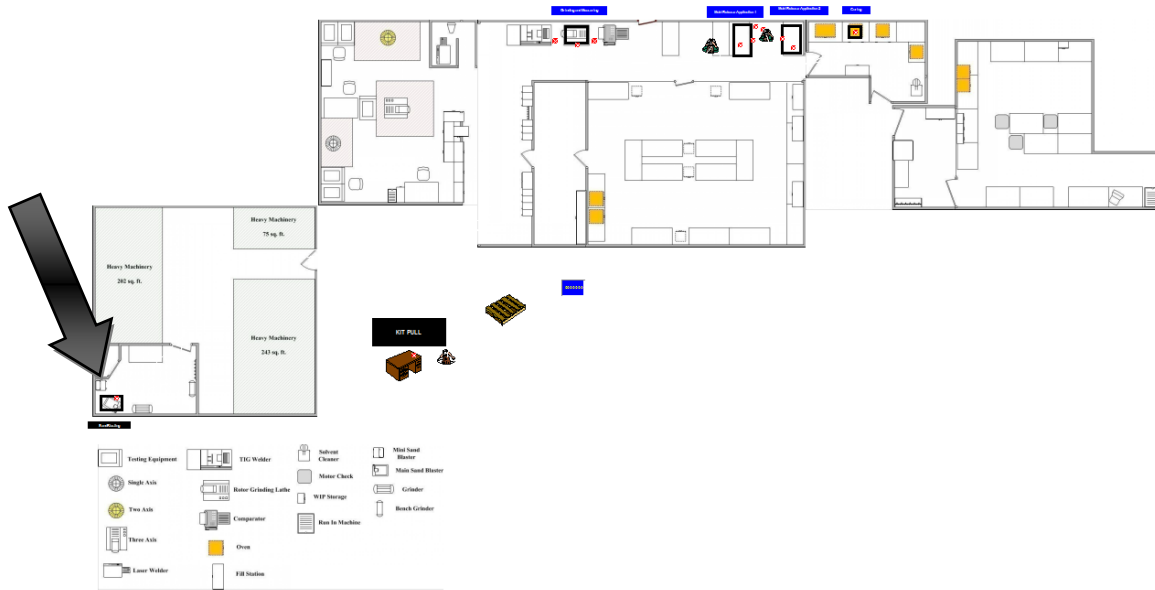
Increasing the arrivals does not have an effect on the locations because none of them are full as seen in Figure M-3. This is not the same story with the personnel.

**Figure M-4: Personnel Usage Summary for Increased Arrivals**



RL CREW has a major percentage of traveling. This is because RL\_15 or the sandblasting machine is far from the other aspects in the process. RL\_15 is identified by a black arrow in Figure M-5.

**Figure M-5: Floor Layout of Gyro Assembly Process**



**Figure M-6: Floor Layout of Recommended Gyro Assembly Process**

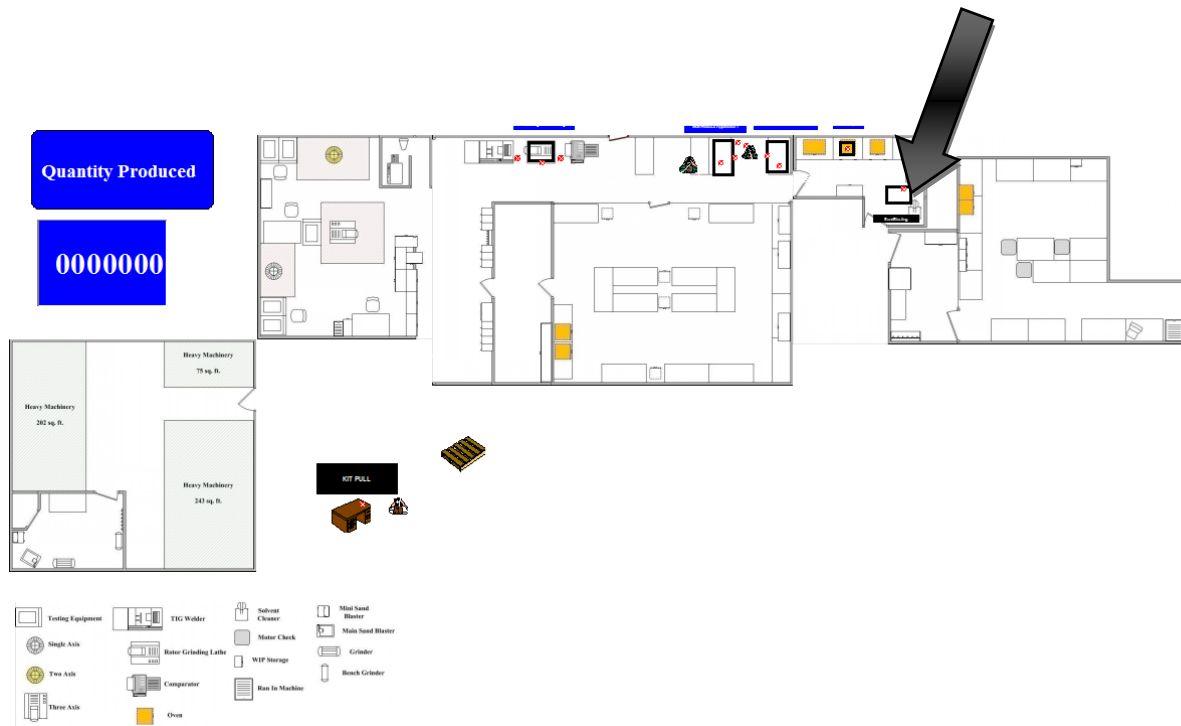




Figure M-6 has an arrow pointing to the new location of the machine. The machine is now much closer to the operator, and this means less non-value added time wasted by walking a far distance in order to perform value-added work. Note, this simulation was done as an introduction of a simulation package to Company S. The main point of this simulation exercise was to implement minimal changes to yield a major impact in the assembly process.

### Gyro Tracker Database

The purpose of the Gyro Tracker Database is to measure three key aspects of the assembly process: Throughput, First-Pass Inspection Yield, and Defects found. The following table, Table M-1, summarizes the methodology for inputting data into the tables.

**Table M-1:** Summary of Gyro Tracker Database Data Tables

<b>Table</b>	<b>Columns</b>	<b>Key</b>	<b>Purpose</b>
<b>Throughput</b>	<ul style="list-style-type: none"> <li>• Order Number</li> <li>• Date Inspected</li> <li>• Assembly Number</li> <li>• Assembly Description</li> <li>• Serial Number</li> <li>• New or Field Return</li> </ul>	Order Number	The Order Number is the unique identifier for each part coming into the assembly process.
<b>First Pass Inspection Yield</b>	<ul style="list-style-type: none"> <li>• Order Number</li> <li>• Date Inspected</li> <li>• Assembly Number</li> <li>• Assembly Description</li> </ul>	Order Number & Test	The Order Number and Test are unique Identifiers because each tool is identified by the Order Number, but multiple tests are performed on a single test. Having these two

	<ul style="list-style-type: none"> <li>• Serial Number</li> <li>• New or Field Return</li> <li>• Inspector</li> <li>• Main Test</li> <li>• Test</li> <li>• Tested</li> <li>• Passed</li> </ul>		as the key will prevent duplicates in the database.
<b>Defects</b>	<ul style="list-style-type: none"> <li>• Order Number</li> <li>• Date Inspected</li> <li>• Assembly Number</li> <li>• Assembly Description</li> <li>• Serial Number</li> <li>• New or Field Return</li> <li>• Inspector</li> <li>• Main Test</li> <li>• Test</li> <li>• Parameter</li> <li>• Defect</li> <li>• Frequency</li> <li>• Defect Value</li> <li>• Comments</li> </ul>	Order Number, Defect, Defect Value, and Defect Value Units.	Each tool is identified by the Order Number. Furthermore, each tool can have the same defect with differing defect values and units.

The main issue with the database was that Company S did not want to have a Microsoft Access format, so our database would serve as the framework for Company S to transition it into a Web-Application and SQL server.

## V. Results and Discussion

### Simulation

Figure RD-1: Floor Layout of Recommended Gyro Assembly Process

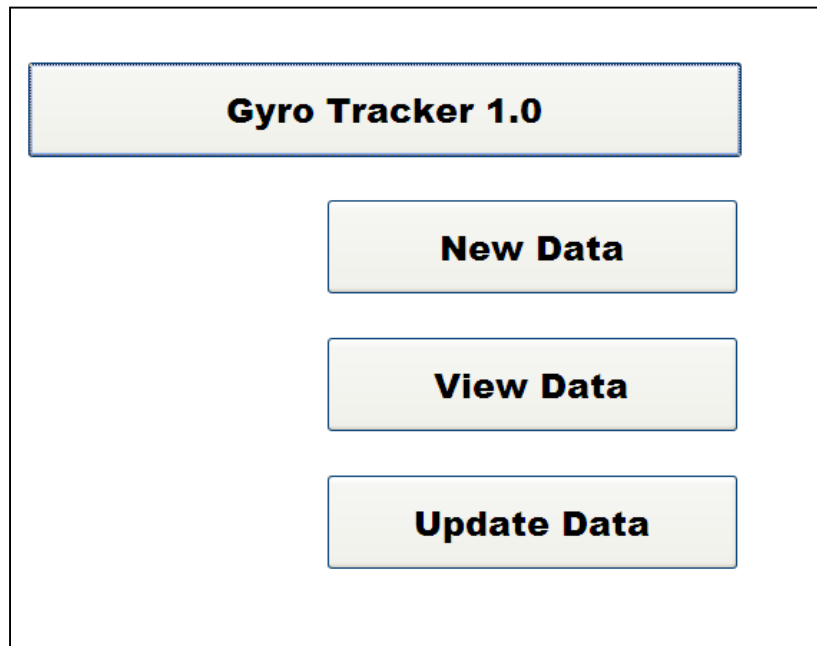


Figure RD-1 shows the recommended layout of the assembly process. The recommended layout of this current assembly produces a throughput of 1480. This means an increase of 680 rotor laminations produced! Overall, the recommended layout met the requirements of implementing minimal changes to yield a major impact on the process.

## Gyro Tracker Database

The database is composed of 4 forms, 10 tables, and 20 queries. Images of the front-end database can be seen in Figures RD 2-5.

**Figure RD-2:** Main Menu of Database



The main menu has three form controls each leading the user to a separate avenue of altering data in the database. The New Data control allows the user to input data for the very first time. The View Data control allows the user to view existing data by selecting from a date range or an order number. The Update Data allows the user to alter existing data.

**Figure RD-3: New Data Form of Database**

**Main Menu**      **Auto-Fill Past Tool**      **Clear All Fields**

**Tool General Information**

Assembly Description

Assembly Number

Order Number

Serial Number

Field or New

**Test Information**

Date Inspected

Inspector

Main Test (What Main Test are you Performing?)

Test (What Specific Test are you Performing?)

Tool Passed Test       Tool Failed Test

Quantity Tested

Quantity Passed

**Defect Information**

Parameter

Defect

How Many Times Did the Defect Occur?

Comments

Defect Value       Defect Units

Ready to Submit

The user enters assembly information such as, order number, test performed, and defect found if any in the new data form.

**Figure RD-4: View Data Form of Database**

**Order Number**

12345

**View Data**

**First Pass Information**

OrderNumber	DateInspected	AssemblyNumber	AssemblyDescription	NewOrField	Inspector	MainTest	Test	Tested	Passed
12345	2/14/2013	111-1111111-111	X GYRO	New	Employee 1	Gimbal & Terminal	Test 1	1	1
12345	2/14/2013	111-1111111-111	X GYRO	New	Employee 1	Gimbal & Terminal	Test 2	1	1
12345	2/14/2013	111-1111111-111	X GYRO	New	Employee 1	Gimbal & Terminal	Test 3	1	1
12345	2/14/2013	111-1111111-111	X GYRO	New	Employee 1	Gimbal & Pivot	Test A	1	0

Once again, the view data form shows the user what records currently exist in the database.

**Figure RD-5: Update Data Form of Database**

**Order Number**

12345

**View**

**First Pass Information (Click to Select the Record)**

OrderNumber	DateInspected	AssemblyNumber	AssemblyDescription	SerialNumber	NewOrField	Inspector	MainTest
12345	2/14/2013	111-1111111-111	X GYRO	1	New	Employee 1	Gimbal & Pivot
12345	2/14/2013	111-1111111-111	X GYRO	1	New	Employee 1	Gimbal & Terminal
12345	2/14/2013	111-1111111-111	X GYRO	1	New	Employee 1	Gimbal & Terminal

**Defects (Click to Select the Record-Double Click to Delete Single Defect)**

Parameter	Defect	Frequency	DefectValue	DefectValueUnits	Comments

**Tool General Information**      **Test Information**      **Defect Information**

Assembly Description      Date Inspected      Parameter

If the user makes an error while entering new data information, he or she can correct that error in the update form. The user can easily attach the database to a pivot table in order to analyze the data. The following graphs and table are output examples of what the database attached to a set pivot tables can produce.

**Figure RD-6: Throughput Analysis by Month**

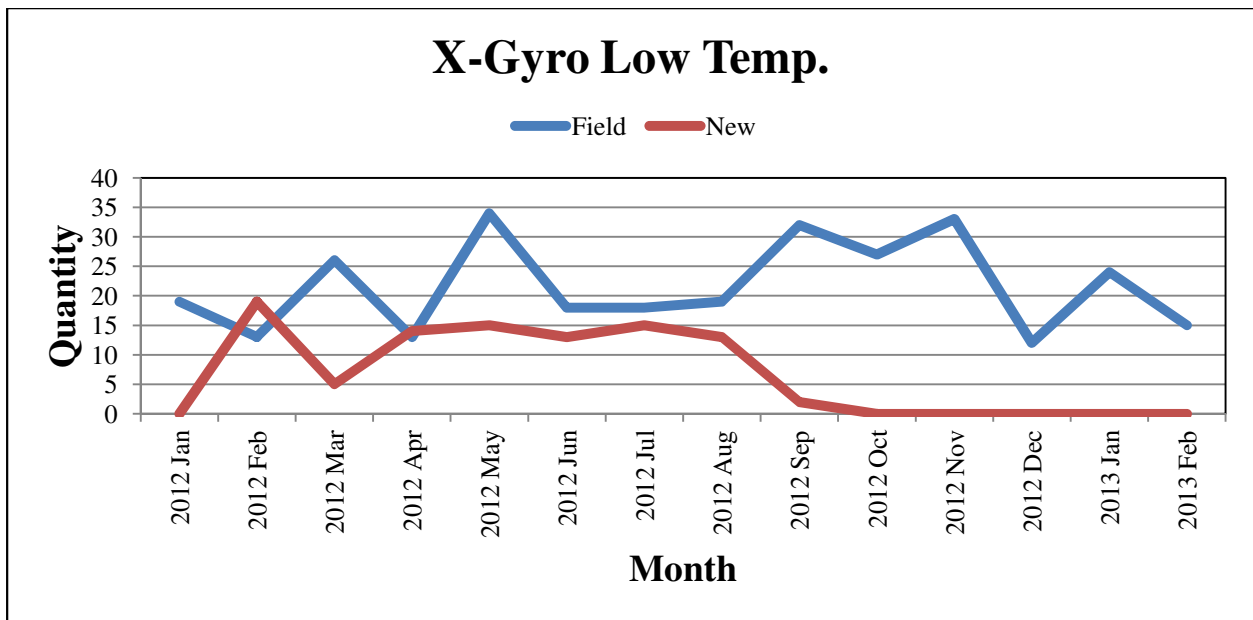
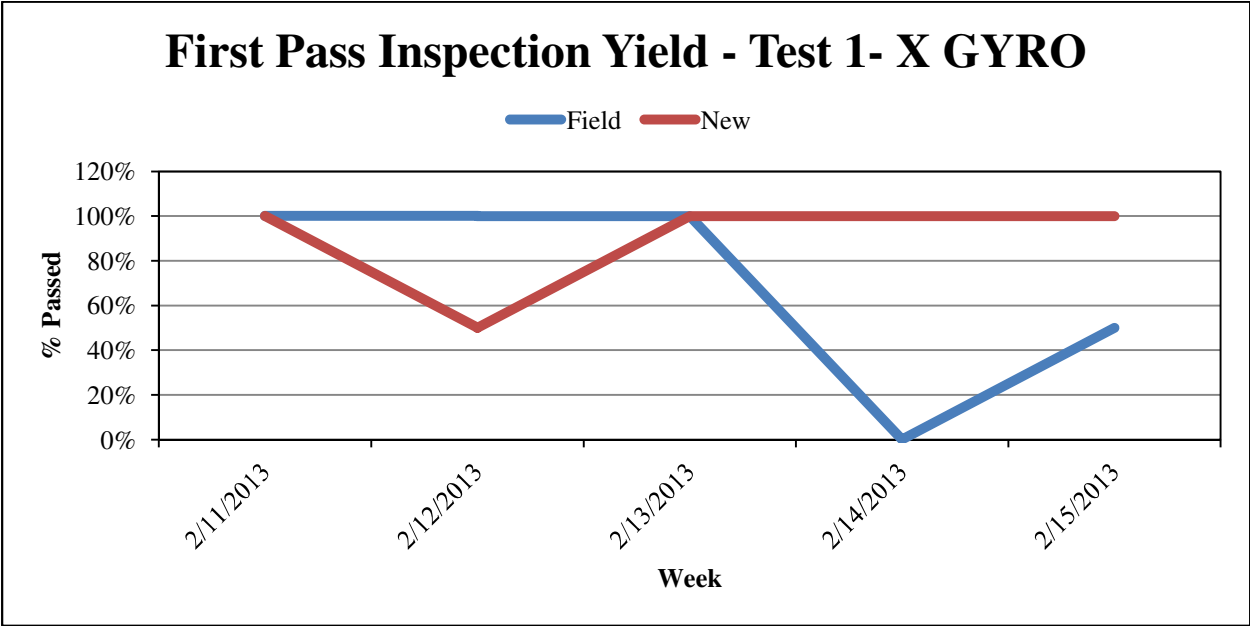


Figure RD-6, shows the throughput for an X Gyro Low Temperature in terms of months. The pivot table can easily alter the scale of time in order to see the throughput in terms of years, quarters, months, weeks, or days. First-pass inspection yield, as seen below is an example of another deliverable of the database.

**Figure RD-7: First-Pass Inspection Yield**



Again, the scale of time can be changed in order to view the data in terms of years, quarters, months, weeks, or days. Also, the pivot table has a ‘filter’ feature which allows the user to narrow down what specific type of gyro one wants to view, as well as, how that gyro performed in any given test.

**Table RD-1: Defects per Assembly**

DateInspected (All)   
 NewOrField (All)

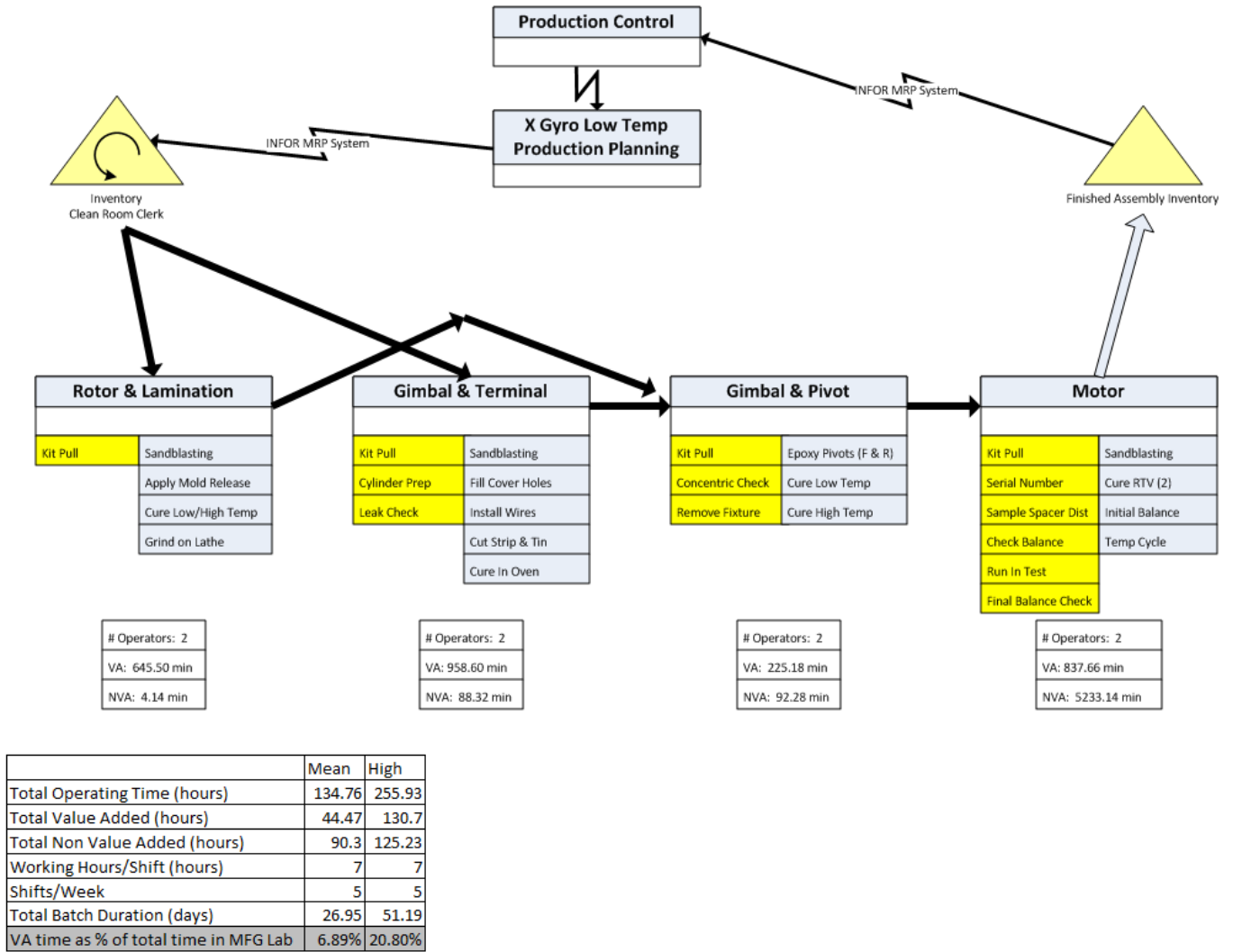
Count of Defect	X GYRO HI TEMP	Z GYRO	X GYRO	Grand Total
Defect 1			2	2
Defect 2		1		1
Defect 3			1	1
Defect 4			1	1
Defect B		1		1
Defect F	1			1
<b>Grand Total</b>	<b>1</b>	<b>2</b>	<b>4</b>	<b>7</b>



The user can also view what defects were found on what specific assembly. This will allow managers or lead supervisors to initiate design revisions in order to progress towards eliminating reoccurring defects. The 'filter' feature allows the user to view new or field returned assemblies, and also to view for a specific window of time in the date inspected filter.

### **Value Stream Mapping**

The value added analysis as described above is collectively presented on the current state value stream map seen in Figure RD-8. The four main assembly phases are detailed and the major work elements within those phases are listed. As a current state map, a baseline is established for the engineering and manufacturing to build upon. As more data is accumulated within INFOR (ERP system), further analysis can be done to identify frequencies and proportions of batch times and subsequently what work elements can be reassessed or redesigned for bottlenecking characteristics, or "problem work elements".



**Figure RD-8: Current State Value Stream Map**

Figure RD-8 above shows non-value added activities in yellow, with value added activities in white. A vast majority, almost 70% of the non-value added time, is tied up in the motor assembly phase. This clearly is cause for concern as well as further investigation into both equipment and operator's training.

## **Conclusions and Experience**

Ultimately, the three phases of the gyro assembly process analysis: simulation, value stream mapping, and quality data management (database), provide Company S management with a validated baseline to pursue further experimentation and improvement. The simulation is an effective means to rapidly test alternative solutions and from there, any ideas can be confirmed through value stream mapping. The quality data key performance indicators, KPIs, the database automatically generates will not only increase visibility to these issues across the organization but also compliment the value analysis by offering a quantitative idea of reliability and associated costs.

The next step of the project is taking the three deliverables and expanding. The simulation will be expanded to all four phases of the gyro assembly process including: the gimbal and terminal, gimbal and pivot, and motor. The Gyro Tracker database, with the assistance of Company S's software team, will transition into a fully functional and concurrent data management system by creating a Web Application based front end off our MS Access front end interface as well as creating a SQL backend server. The ability of deliverables to be sustainable and applicable for the future is a major accomplishment and will most certainly make a distinct impact on the assembly process.

From the project experience perspective, this senior project was a successful application of several years of Industrial Engineering study. Many classes were represented throughout the course of the project ranging from work measurement and design, to data systems management and more. Partnering with a high-tech company such as Company S also provided a unique and realistic experience as our work can be immediately utilized. However with the same idea of an

industry related project, the scope of the project was variable as Company S management encouraged a multitude of concepts whereas the timeframe and criteria of the project constrained our ability to deliver an even more effective analysis tool. We plan to provide senior project or class project opportunities to future generations of IME department to continue our work, and expand it to the other components manufactured by Company X.

## Bibliography

1. Chramcov, Pavel V. *Use of computer simulation with the aim of achieving more efficient production in manufacturing systems*. Recent Researches in Manufacturing Engineering. 3rd WSEAS International Conference on Manufacturing Engineering, Quality and Production Systems (MEQAPS 11) Pages: 50-55 Published: 01 2011
2. Coppini, N.L., and W.C Lucato. "Value Stream Mapping Simulation Using ProModelSoftware." . University Nove de Julho, n.d. Web. 13 Oct 2012.
3. Fishman, George S. *Discrete-Event Simulation Modeling, Programming, and Analysis*. Ed. Peter Glynn and Stephen M. Robinson. New York: Springer-Verlag, 2001. Print.
4. Irani, Shahrukh, and Jin Zhou. "Value Stream Mapping of a Complete Product." *Lean-manufacturing-japan.com*. N.p.. Web. 20 Nov 2012.
5. Lean Enterprise Institute, Inc., . *Lean Lexicon: A Graphic Glossary for Lean Thinkers*. 4th ed. Lean Enterprise Institute, 2008. Web.
6. Liker, Jeffery. *The Toyota Way*. New York: McGraw-Hill, 2004. 28-31. Print.
7. Richard D. Irwin, 1970. Print. Irwin Series in Quantitative Analysis for Business.
8. Rother, M. & Shook, J. (1999, June). *Learning to See*. Version 1.2. Brookline, MA: Lean Enterprise Institute. pg44-54
9. Sacadura, Luis, and Alexandra Tenera. "Integrating Value and Lean Management in Manufacturing Processes." . Universidade Nova de Lisboa, 06 May 2011. Web. 13 Nov 2012. Quality and service management
10. Sobek II, Duward. *Understanding A3 Thinking*. 1st ed. New York: Taylor & Francis Group, 2008. Print.

# Appendix A

## Rotor & Lamination Phase (1a) Spaghetti Diagram



## Gimbal & Terminal Phase (1b) Spaghetti Diagram



## Gimbal & Pivot Phase (2) Spaghetti Diagram



### Motor Phase (3) Spaghetti Diagram

