Operator Touch Time Analysis at

Skyworks Solutions Inc.

Major Qualifying Project Submitted to the Faculty of

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Submitted by:

Marissa San Andres

Jose Spiegel

Luis Vargas

Andrés Vega

Sponsor:

Skyworks Solutions Inc.

Advisors:

Walter T. Towner, Jr. Ph.D.

Helen G. Vassallo, Ph.D.

Abstract

The main objective of this Major Qualifying Project was to minimize the non-value added time of operators inside the metals area of the fab at our sponsor, Skyworks Solutions Inc. The methods used to achieve our goal were axiomatic design, time studies, labor studies, and an engineering financial analysis. Through these methods we identified non-value added steps in current procedures inside the fab that could be minimized. We recommended possible alternatives for saving time in the fab and its feasibility was studied through an engineering economic analysis that showed the possible savings that will yield more productivity inside the fab.

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Next we would like to thank the entire Industrial Engineering team at Skyworks Solutions Inc., for answering our questions and working with our team to the completion of this project. A special thanks to David DeRoche, the team leader at Skyworks.

Lastly, we express our gratitude to the operators at Skyworks for their patience and for teaching us their knowledge of the processes we were observing.

Executive Summary

The purpose of this project was to analyze the current state of Skyworks Solutions Inc. metals area of the fab, find areas of improvement for reducing the operator touch time and reduce non-value added time. To achieve this, we defined the following objectives:

- Capture and record the current touch time of operators in the metals area
- Define what were value-added and non-value added steps and times
- Minimize what were non-value added steps

The first objective required time and labor studies of the current operation of the fab. Time studies were our primary source of information of this objective. This consisted in timing operators whenever they were handling the tool. To better organize what was being done, we split the operators' activity into six sections to be timed separately:

- Get WIP
- Update PROMIS
- Place WIP
- Remove WIP
- Update PROMIS
- Store WIP

By doing this for each tool, we could see if the problem resided in a specific tool or in a specific task.

As a result we found that the total number of operators per shift to run the total number of tools for the AMR, ALLOY, MEI, and SPUTTER is 0.11, 0.03, 1.39, and 0.18 respectively. We noticed that in the MEI area only one operator was working on the metals WIP for that tool. Our results show that 1.4 operators are needed, therefore we recommend that there be another

operator using a little less than half of their time to help run the MEI tools in order to avoid bottlenecking.

Analysis of these times became the principal window of information to complete the second objective and determine where there was room for improvement. We identified non-value added time for two steps: transportation of wafers, and using the PROMIS program. The key difference between what was value added and non-value added consisted of what could and could not be changed without risking heavy costs such as operator safety or breaking wafers. For the transportation of wafers, improving would mean changing the layout of the fab, and our time frame did not allow it. We developed a spaghetti diagram of the fab where we noticed the inefficiencies. After producing several layers we found the lack of efficiency in the fab ergonomics. Operators move around the wafers through great distances from step to step. We mainly focused on PROMIS, their tracking software, which we noticed was taking up a significant amount of the operator's touch time. Instead of manually entering the username and password into PROMIS we recommend the implementation a scanner system with barcodes. The operator will only need to scan a barcode on his ID badge. We also reviewed the work instructions and found out that operators were not fully following the written procedures for operating the tools. This doesn't affect the operator touch time immediately but it does long term with regard to wasted material and safety due to human error. We recommend a reevaluation of the protocols.

We concluded that a suitable solution for PROMIS time improvement was a barcode system for operator badges and lot IDs. We studied the possibility of implementing the scanners for our objective 3: minimize non-value added steps. We agreed that the battery must be cordless and the battery rechargeable. Considering these two aspects the best option we found was the

Motorola Symbol LI4278. Since Skyworks facility for the metals area counts with 16

workstations in the metals area; therefore 16 scanners will be needed. Each scanner cost about

$239, so the total cost of getting the scanners is about $3,824. Consequently, Skyworks will need

to assign a barcode to each employee and their id badges reprinted with their respective barcode.

Its cost will be insignificant because Skyworks count with their own printing facilities. To

estimate how much time Skyworks would save, we conducted a mock trial and timed how long it

would take to sign into the system through the current method and with a mock scanner. The

comparison was noticeable and we were able to use this to make a financial analysis, if the

system were to be implemented. Given that the results were positive for the company,

we included it as a recommendation.

Due to the time frame of this project, we were not able to expand on some other ideas we

deemed valuable for the project. Constructing a spaghetti diagram of all layers of the fab, and

getting the true present value of the scanner system were two of our ideas that did not come into

fruition. However, after looking into the uses of these two ideas, we determined that they can be

used for similar projects in the future, and further research can help analyze them to further

improve the workflow of the fab.

1   Introduction

Skyworks Solutions Inc. is a premier provider for analog semiconductors in the technology industry. Their most important products are diodes assembled on silicon wafers, power amplifiers, and switches which are made in Woburn, Massachusetts. Skyworks is proud to say that they are at top of their industry in terms of sales and also the quality of their product. However, they are prone to erosion of average selling price in their industry. They must constantly mitigate the effects of declining prices in their industry by increasing unit volume, reduce manufacturing costs, reduce waste at all levels of existing production, and improve overall manufacturing efficiency by becoming leaner in their production.

Wafer production at their factory in Woburn has experienced noticeable inefficiencies, most notably in lead times and cycle times of production. Through extensive observations, Skyworks concluded that the inefficiencies were caused mostly by bottlenecks in the metals area of the process, specifically focused on operator touch time. To help solve this problem Skyworks connected with WPI's Business School and the Industrial Engineering Department in order for WPI students, through their MQP, to help improve production performance of their factory's metals area.

The overall goal of this project is to decrease the time the operator is handling the product, in order to improve their production. Using axiomatic design in order to break down the problem and successfully identify the customer needs, functional requirements, and design parameters is necessary to accomplish this goal. Gathering data on the operator touch time for the metals area and creating a labor study that is useful for us and for Skyworks will help to identify the non-value added time and the areas of improvement. The team also developed a spaghetti diagram of the metals area of the plant that represents the flow of wafers carried by the

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employees. With the labor studies, and the spaghetti diagram we are able to identify the non-value added steps, and recommend the use of scanners in order to decrease the operator touch time. Our final objective is to develop a cost and benefit analysis of utilizing scanners in the handling process.

2   Background and Literature Review

2.1   Skyworks

Skyworks Solutions Inc. was founded in 2002 as a result of a merger between Alpha Industries and the wireless communications division of Conexant. Alpha Industries was a wireless chip business that acquired Conexant Systems Inc., another wireless chip business to create the analog semiconductor company, Skyworks Solutions Inc. Skyworks' headquarters are located in Woburn, Massachusetts where our project took place. Skyworks have manufacturing facilities in Woburn, MA, Newbury Park, CA, Osaka, Japan, and Mexicali, Mexico and design centers in California, Massachusetts, North Carolina, and Iowa. There are also engineering, marketing, sales, and service facilities throughout Europe and Asia. As of 2016, the company has about six thousand employees combined (Skyworks Solutions, 2016). Skyworks has many products that fall under the umbrella of analog semiconductors including, but not limited to diodes, switches, and amplifiers. The company's slogan is "Connecting Everyone and Everything, All the Time" (Skyworks Solutions, 2016).

2.1.1   Semiconductors

Skyworks Solutions Inc. manufactures analog semiconductors. Under this umbrella of technology there are many aspects. The fab in Woburn where we were focused, makes millions of devices a week. These small diodes are made on four inch or six inch wafers with anywhere from twenty thousand to forty thousand individual diodes on each wafer. The size of the wafer depends on the process. The company mostly focus on PHEMPT and BiFet, but have other products going through the fab as well. In Figure 1, a semiconductor wafer is pictured. This is the main product of the fab and thousands are shipped out every week.
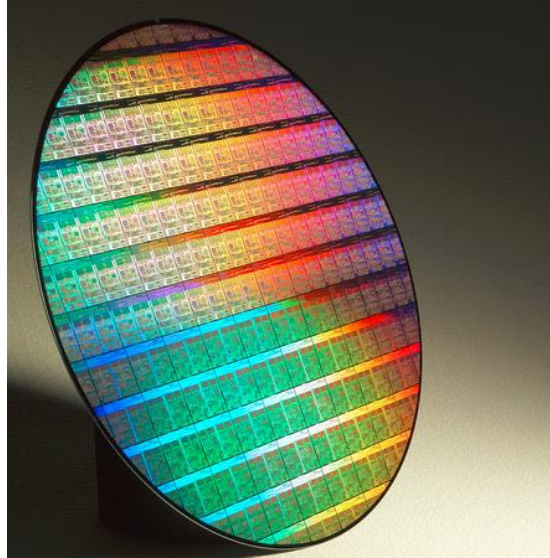
Figure 1: Semiconductor Wafer

(Gerasimas, 2015)

2.2 Lean Manufacturing

There are many different procedures and tools used for semiconductor wafer handling in a clean room facility. The procedures fall into two categories: operator handling of wafers and machine handling. Operator handling of wafers is when the operator has to interact closely with the wafers. Only at some stages is it acceptable to touch the wafers by hand. In most stages, the operator has to use tools such as a vacuum wand or tweezers. Machine handling is done by the CNC tools themselves: Each tool has to be precisely calibrated to pick up each wafer from its respective lots, move it around the tool without breaking the wafer, and do this as fast as possible. Each of these categories can be optimized through the use of time studies. Our project focused on the operator "touch time", which are the steps of when operator interacts closely with the wafers.

2.2.1   Time Studies

In most complex systems, timing the process as a whole often leads to misleading or inaccurate perceptions about the state of the system. Therefore, splitting the system into several steps is an accepted method of conducting time studies. Time and motion studies is a "method for establishing employee productivity standards in which a complex task is broken into small, simpler steps, and the sequence of movements taken by the employee in performing those steps is carefully observed and timed" (BusinessDictionary, 2016). These measurements are used to detect and eliminate redundant or wasteful motion.

One such example of time and motion studies is at a joint venture between GM and Toyota where they took the "worst operating plant in the world" and turned it into an efficient and effective plant (Adler, 1993). GM at Freemont, California during the 1980s had "low productivity, abysmal quality, drug and alcohol abuse, and absenteeism over 20%" (Adler, 1993). After becoming a joint venture with Toyota, Industrial Engineers conducted time studies up close with stop watches, where they were able to learn what was not shown on a spaghetti diagram or on a spreadsheet of numbers. This allowed them to make decisions that would not only improve performance in terms of quality and time, but also for employee morale and mutually help each other find the most efficient way to do a particular task (Adler, 1993).

Furthermore, time and motion studies can be used to assess efficiency everywhere. In 2008, a time and motion study was recorded for nurses in about 36 hospitals, where a total of 767 nurses participated. (Hendrich, Chow, Skierczynski, Lu, 2008). The goal of this study was to really understand how nurses spend their time, since they are the primary hospital caregivers (Hendrich, Chow, Skierczynski, Lu, 2008). After the study the people who conducted it were able to conclude that the time and motion study identified three main areas of improvement in

order to make the process more efficient. One such recommendation was to make changes to work processes, and unit organization and design (Hendrich, Chow, Skierczynski, Lu, 2008). This example demonstrates that time and motion studies are useful in all industries and processes, not only in a manufacturing environment.

2.2.2 Operator Touch Time

The operator touch time is focused on the operator, it doesn't account for the time the machine takes to complete a certain task. Therefore, the operator touch time scope includes manual work, walking and waiting of the operator. If the operator is idle while a machine is processing a unit, that time it takes the machine to process the unit will be recorded as waiting time (Lean Glossary of Terms, 2016). This is because it is adding non-value added time to the process since the operator could have been doing something else while a machine is processing a tool.

Companies record their operator touch time by physically observing the operators and timing them with stopwatches or recording them while handling the unit being processed (Lean Glossary of Terms, 2016). Companies conduct this type of study because they want to maximize the value-added time that the operators add to the process. Therefore, the company must identify the non-value added times in order to eliminate or improve them so the operators can be allocated efficiently within their tasks. Companies shouldn't expect operators to maximize the efficiency of their operations to 100% because operators are human and interruptions, fatigue and delay are inevitable (Lean Glossary of Terms, 2016).

2.2.3 Lead Time/Cycle Time

Lead times and cycle times are used to determine the overall productivity of the process. While Lead time is the time between the initiation of the process and its completion

(Investopedia, 2016) cycle time is the average time between successive deliveries (Cycle Time, 2015). In order to reduce cycle time, lead time must be reduced by reducing inefficiencies such as bottlenecks and starvation at every point of the production process.

Cycle time has more to do with the plant's ability to produce enough product to fulfill demand. Reducing this index would mean increasing the plant's capacity and improving the plant's efficiency. Lead time has more to do with each step of the process. Therefore, in order to improve the process as a whole, each segment must be improved first.

2.2.4   Flow Diagrams

Flow diagrams are defined as models of separate steps of a process in sequential order (AQS, 2016). This allows us to better understand the functions of each step of the process and the dependence they have on each other. This also makes it easier to map out "choke points" where there are bottlenecks or processes that were starved and address them in an organized fashion.

A spaghetti diagram is designed to let certain problems or symptoms of problems, which are not always clearly visible, stand out and become easily visualized. By tracing movement of materials and people through the floor layout, it not only allows us to measure overall distances traveled, but also detect possible congestions or starvation situations within the process. Opportunities for improvement that might not have been considered before become clearly visible, and having this information allows for better decision making given the diagram allows for a more detailed understanding of the process. (Figure 2)

Floor Layout Analysis (Spaghetti Diagram)
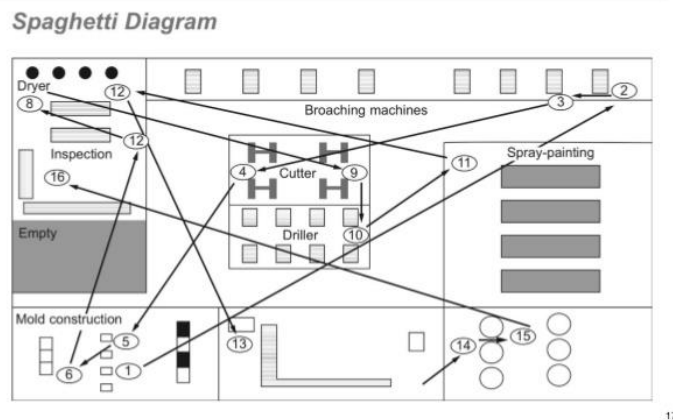
Figure 2: Spaghetti Diagram

(Jeremy Jay V. Lim, 2013)

2.3 Axiomatic Design

Nam P. Suh, a mechanical engineer professor from MIT, discovered a new way of solving problems by identifying a set of laws and principles for engineering design. The goal of Axiomatic Design is to establish a scientific basis for design by providing the designer with logic and rational thought processing tools (Suh, 1990). In the attempt of making design processes more "scientific", Suh discovered the design axioms. The axiomatic design approach provides one with axioms, which are the means for arriving to the optimal design solution when given a set of constraints or functional requirements (Towner, 2016).

Axiomatic design is composed of three main components: axioms, structure, and process. The axioms must be able to maximize independence, and minimize information. The structure is formed by the vertical and horizontal decomposition. Finally the process involves the zigzagging decomposition and the physical integration (Towner, 2016).

Furthermore, the structure of the axiomatic design can be view as domains. The horizontal decomposition is formed by the customer needs (CNs), followed by the functional

requirements (FRs), followed by the design parameters (DPs), and followed by the process

variables (PVs). Figure 3 shows a simplified version of this process.
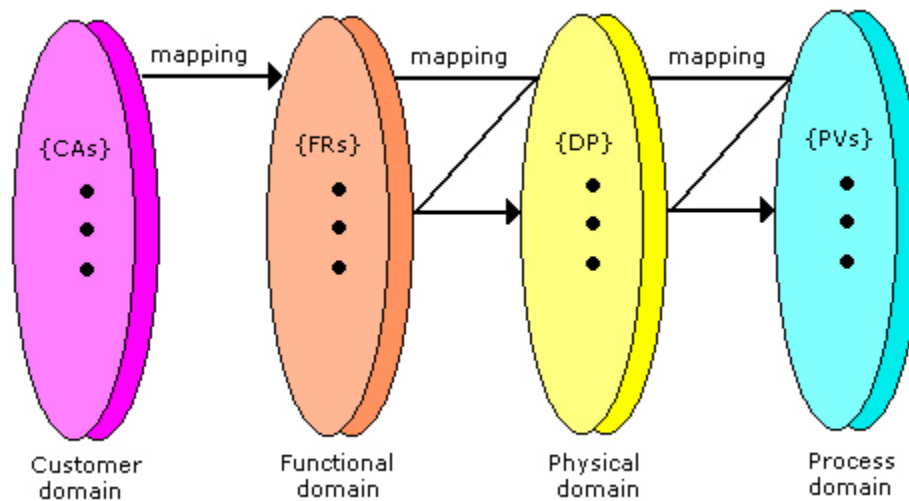
Figure 3: Axiomatic Design Domains

(Axiomatic Design Technology, 2016)

Axiomatic design models have been used to model many types of design challenges.

Examples include, software, hardware, materials, manufacturing, and organizations (Suh, 2001).

Applying axiomatic design to process design challenge will help the company make the right

decision, shorten lead time, improve the quality of a product, enhance creativity, and simplify the

complexity of a problem (Suh, 2001).

3   Methodology

3.1   Axiomatic Design

In order to understand what we needed to solve, we spent much of our time learning from

the company and the way that they work. We used axiomatic design in order to figure out our

main problem, and make a hierarchy of our objectives.

3.2   Objective 1: Capture and record current touch time on metals tools.

In order to identify the current process of the fab, we decided to gather data by capturing and recording the current operator touch time in the metals area. We did this by conducting time studies and creating labor studies.

3.2.1   Time Studies

Time studies were conducted by each member of the team on each of the tools. The team used stopwatches and timers on phones to time the touch time performed by each operator. Whenever the operator was doing a task that took up their time, it was recorded in our data findings. We shadowed operators to figure out where the WIP was coming from and going to. We often talked to the operators asking them to explain the process for each tool they were operating at the time.

The set of tools that we focused on at Skyworks were primarily in the metals area. The production plant is broken down into a few different areas, metals being where the most bottleneck was. During the summer Marissa completed time studies on Temescals, Novellus, and Matrix systems. The group mainly focused on time studies for operators operating AMR02, AMR03, SPUT03, SPUT04, ALLOY03, ALLOY04, MEI01T3, MEI03T2, MEI03T3, and MEI03T4.

In order to develop a good study of the operator touch time we decided to develop time studies with multiple rounds to validate our data collected. Each individual tool was recorded three separate times in our model. This information allowed us to view which steps were value added and non-value added in the process which ultimately led to areas of improvement.

3.2.2 Labor Studies

The industrial engineering team at Skyworks Solutions Inc. in Woburn, expressed the importance of labor studies. These would be a vital element in reducing non-value added time as well as improving the plant's general competitiveness. Through literature review and speaking with employees of Skyworks, we decided to focus on one main aspect while conducting our studies. These studies were not only time related, but also included the quality of the time that the employees experienced in their daily routine.

The main aspect of the studies concerned the time that an employee would take to complete each task. This, combined with the logic of the process that employees must follow, would clarify any problems (such as starvation or bottlenecks) that employees may experience while doing their jobs. These time studies include timing individual tasks (such as handling a machine and transporting utilities), and interactions with other employees.

3.3 Objective 2: Define value/non-value added time from processes

In order to differentiate what adds value to the system and what doesn't, we decided to use Skyworks's work instructions and procedures, and an Excel spreadsheet analysis that we created.

3.3.1 Work Instructions

In order to understand the process flow of the fab, we searched for the work instruction manuals in Skyworks database. We went over them as a team to get a better understanding of how the tools were operated inside the fab. This helped us understand what to expect inside the fab and to determine whether or not the tools being studied were functioning well and being used correctly. This set of instructions helped us figure out if the operators were following the right procedures or not. The work instruction manuals were saved in the MQP one drive for further reference if needed. An example of the work instructions is found in the Appendix.

3.3.2 Excel Sheets

In order to calculate the operator touch time for each tool throughout the entire shift based off our time studies, we inputted the data into an Excel document. Each type of tool had its own document and each tool in the metals area had its own sheet. The times were inputted into their respective places. On each sheet were the flow mixes of each type of tool. The total number of wafers for each tool was multiplied by the week starts and the total was then divided by how many tools these layers do. Also, on each sheet was the operator productivity time. The operator's shifts are 12 hours long with a total of two hours of break. The 10 hours of productivity was multiplied by 75%, which indicates that the operators work 75% of their capability. These numbers were calculated by the Skyworks team, and given to us. Based on the week starts, productivity and a 24/7 schedule, a number is calculated and the operator touch time is the result. On the summary page each tool is listed and shows the average time study data, which includes the total amount of operators needed for those tool sets and the percentages of the total time each step takes. This was so we were able to see what steps took up most of the operator's time. These Excel sheets can be found in the appendix.

3.3.3 Spaghetti Diagram

One of the most important things we needed to get from the flow diagrams were how employees handled the product around the fab. To achieve this, we used a spaghetti diagram. Using the floor layout of the fab with AutoCAD, the operator's walking path was traced based on several layers of the process. An advantage of AutoCAD is its ability to measure the distance traveled by operators. We were able to complete this by sitting down with the industrial engineering team at Skyworks as they explained the flow process to us around the fab.

3.4 Objective 3: Minimize non-value added steps

3.4.1 Barcodes/ID Badges

In order to minimize non-value steps we decided to evaluate the possibility of implementing barcodes and scanners in the fab for ID badges and Lot IDs. We researched scanners to fit the criteria set by Skyworks and looked for the most inexpensive version. We conducted a time and benefit analysis based on the number of scanners needed in accordance with the workstations in the metals area. We met with G.S., an IT consultant for the company to discuss the possibilities of implementation.

3.4.2 Mock Trial

After realizing the non-value added steps, we focused efforts on to PROMIS. To alleviate non-value added time we proposed a scanning option for entering the program. In order to get information to prove how much time would be saved we made mock trials of logging into PROMIS and scanning the operator's ID Badge. We had six different trials of students signing into a mock log in as well as scanning an ID badge. By doing this we were able to see the difference in times between the two actions.

4 Results

4.1 Objective 1: Capture and record current touch time on metals tools

4.1.1 Time Studies/Labor Studies

After timing the operators for an entire term we were able to record three loads and unloads of each tool. These were inputted in our Excel documents and calculated the total operators needed for the tools in the scope of our project.

4.1.2 AMR

AMR02 and AMR03 were part of the tools in the metals area that we focused on. These tools are located by the Temescals. Their WIP rack is about six feet from the tools and the workstation was right next to AMR03 and 6 feet from AMR02. After shadowing an operator we were able to calculate the total touch time and how many operators were needed for each tool. The results are shown in Table 1.

Table 1: AMR Time Study Results

	AMR02	AMR03
Total Time	2.2	2.0
Operators Needed	.06	.05

The total Operators needed to run both AMR tools for the metals area is 0.11 operators per shift. In other words, an eleventh of an operator's time is needed to run the amount of wafers going through the fab per shift.

4.1.3 ALLOY

ALLOY03 and ALLOY04 were tools in the photo area that we focused on because they are part of the metals process. Their WIP rack is set in between both tools so the WIP time was minimal. We waited until an operator appeared to work on the tools and then we were able to gather the data. The results are shown in Table 2.

Table 2: ALLOY Time Study Results

	ALLOY03	ALLOY04
Total Time	2.21	1.7
Operators Needed	.02	.01

The total operators needed to run the ALLOY tools during a shift is 0.03 operators. This number is low because there is generally not a lot of WIP going through the ALLOY tools.

4.1.4 MEI

We focused on four hoods of the MEI tools: MEI01T3, MEI03T2, MEI03T3, and MEI03T4. These are the only hoods we focused on because they are the pre-clean step to the Temescals which is part of the metals process. The other hoods focus on photo processes. This area has a lot going through it as it is based in the center of the fab. We found that there are multiple WIP racks for the MEI tools. One was in the same area, staged across from the tools next to the workstation and the other was in the metals area, in a different room about 30 feet away from the MEI tools. The results are shown in Table 3.

Table 3: MEI Time Study Results

	MEI01T3	MEI03T2	MEI03T3	MEI03T4
Total Time	3.4	3.1	2.9	2.9
Operators Needed	0.46	0.42	0.26	0.25

The total operators needed per shift to run the MEI tools needed for the metals area is 1.39 operators.

4.1.5 SPUTTER

There are two SPUTTER tools in the fab: SPUT03 and SPUT04. SPUT03 was located in the wetpro area far from the metals area and SPUT04 was located in the photo area. The WIP came from the MEI hoods in the front of the fab which was about a minute walk from each tool. After shadowing the operator running the SPUTTER tools, we calculated the results which are shown in Table 4.

	SPUT03	SPUT04
Total Time	5.5	4.3
Operators Needed	0.10	0.08

The total amount of operators needed to run the SPUTTER tools during a shift is 0.18 operators.

4.2 Objective 2: Define value/non-value added time from processes

4.2.1 Spaghetti Diagram

After producing diagrams of just a few layers of the fab's workflow, it became evident that it lacked efficiency in a number of areas. The most noticeable aspect was the distances traveled between tools for each step of the process. Due to the location of the tools in the fab, wafers would often have to be carried for great distances. Figure 4 below is the Emitter Contact (EC) that shows the extensive distances the must be traveled by operators between tools. This is one of the layers that goes through the metals area. This leads us to believe the layout of the fab is not designed for operators or wafers to move around in an efficient manner.
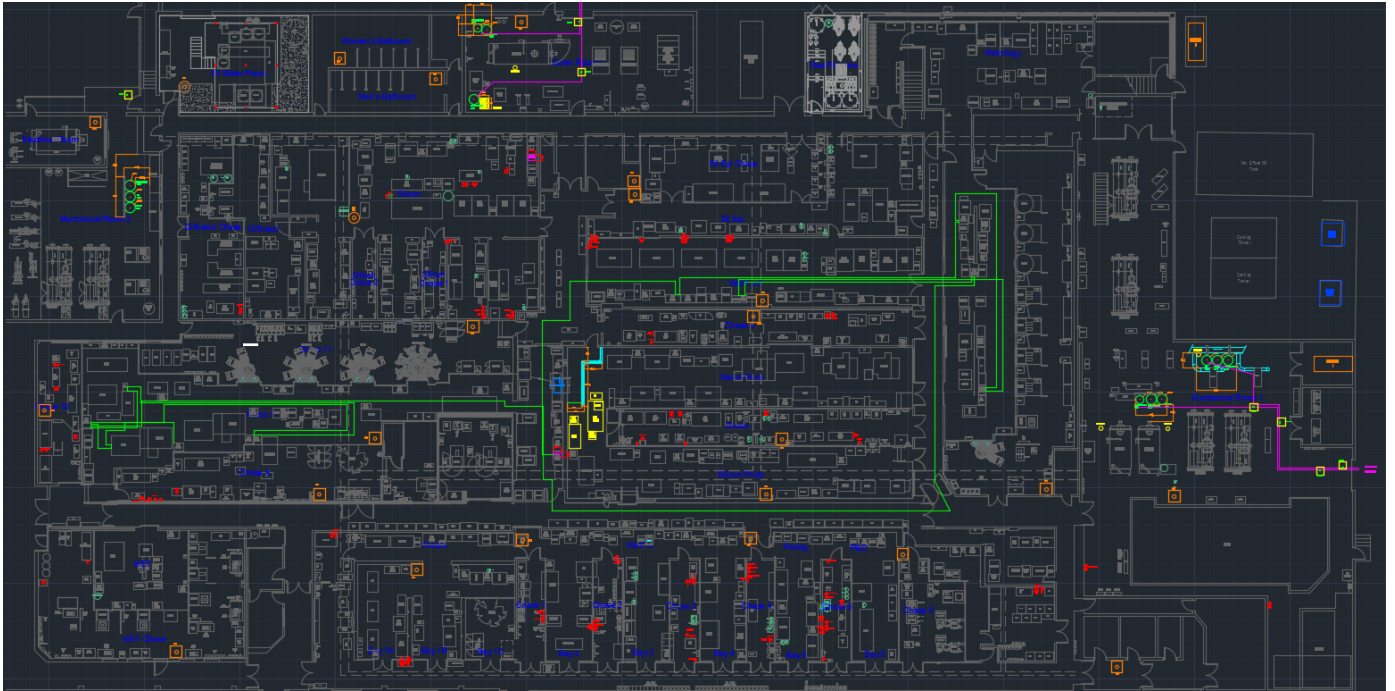
Figure 4: EC Layer Spaghetti Diagram

We found through the spaghetti diagram that there are multiple layers that go through the metals area but don't use every tool in the metals area.

4.2.2   Work Instructions

Once work instructions to handle each tool were given to us, we realized that operators were not fully following the written procedures operating the tools. An example was the buddy check, where the operator was required to wait for a fellow operator to check the setup of the tool and that the correct recipe was given before starting the tool's cycle. Though this step is designed to minimize possible human error, it was ignored by the operators for the sake of short term efficiency.

Though the effects of skipping protocol are not immediately noticeable in this project, they will be on the long term of the fab's production with wasted material or even safety due to

human error. We believe that the time it would take for an operator to perform a simple step is not time wasted but invested time for the long term performance of the fab.

4.2.3 Non-value added time

When looking at the difference between what is value added and what is non-value added time, it comes down to what can and cannot be reduced while maintaining the fab's overall productivity and standards of quality. In the case of the fab, value added steps include the loading and unloading of material, as well as the time it takes the machine to finish its run. This is because by rushing these steps, the likelihood for something failing, such as breaking wafers, rises. Therefore, it is invested time that need to happen for the process to produce optimally.

Non-value added time exists in two steps of the process: transportation of wafers, and using the PROMIS program. Due to the inefficient layout of the fab, we found that transportation time would be hard to reduce. As for PROMIS, we were able to find alternatives to the operator's current way of inputting information into the computer. By introducing a scanner system, we believe that the log in time could be reduced.

4.3   Objective 3: Minimize non-value added steps

4.3.1   Barcodes/ID Badges

After an extensive research for scanners and how we could implement this idea into the fab, we came with a possible result by analyzing each of our possibilities. The first part that we analyzed was that the scanners needed to be cordless. Since the handling of wafers must be very cautious, having a wired scanner was not feasible because it could drop cassettes to the floor if an operator gets distracted and pulls the cord. We then figure out that the scanners can't be in a cradle all the time, since operators would start to tilt the cassette lots and could potentially

damage the wafers due to excessive movement. Therefore, we came to the conclusion that the scanner must be cordless, and the battery must be rechargeable.

With this information we started searching for scanners that would have all these requirements. The best option we found was from Amazon.com for the Motorola Symbol LI4278 barcode scanner wireless with cradle and USB cable, as referred to in Figure 5. This scanner complies with all the requirements from Skyworks, and it can be used for scanning the operator's badge and the lot IDs.

Figure 5: Motorola Symbol LI4278

Furthermore, with the floor layout we were able find out that there are about 16 workstations in the metals area; hence we would need to get 16 scanners. Each scanner is about $239, so the total cost of getting the scanners is about $3,824.

In regards to the implementation of barcodes to the employee ID badges, we discussed with C.G., who is in charge of the badges at Skyworks, assigning a barcode to each operator and reprinting the badge and found that it would not be an issue. Skyworks has their own printing

capabilities which makes attaching a barcode to the ID badge a simple step that wouldn't take much time. There are approximately 100 operators in the metals area, and it takes approximate one minute per badge to print the barcode. Therefore, the printing of badges won't take time and Skyworks believes they can do an entire shift in a single hour. The cost of reprinting the ID badges is insignificant. When we discussed the idea with C.G. he said that there is no cost associated with reprinting the badges. The only thing to consider is the labor cost, but Security will be doing this during their normal hours; therefore, there is no extra labor cost associated.

4.3.2   Mock Trial

We decided to run a mock trial and measure the time Skyworks would save. After doing six different trials of first entering the credentials, i.e. username and password, and then scanning the ID badge, we were able to calculate the time they would save in the log in section of PROMIS.

We decided to record three different times out of each of the six subjects, and get the average. The average for entering the operator's username and password was 8.1 seconds. Figure 6 shows the six different subjects' times for getting into PROMIS without the scanner.
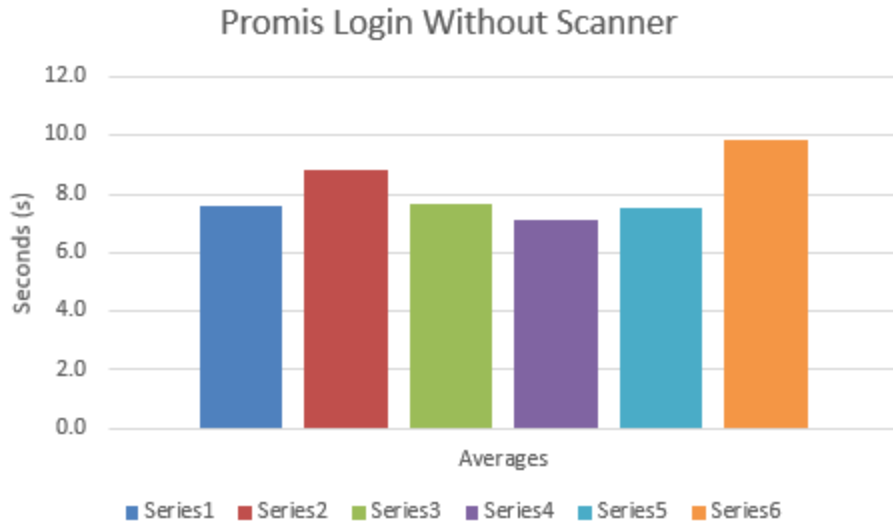
Figure 6: Mock PROMIS Login Without Scanner

After doing the same process, we calculated that the average time it takes to scan the ID badge is about 2.5 seconds. There is a 224% time improvement with the scanners. Although saving 5.6 seconds is not much, this process is done every time an operator tracks in and out the lot. Figure 7 shows the six different subjects' times for getting into PROMIS while using the scanner.
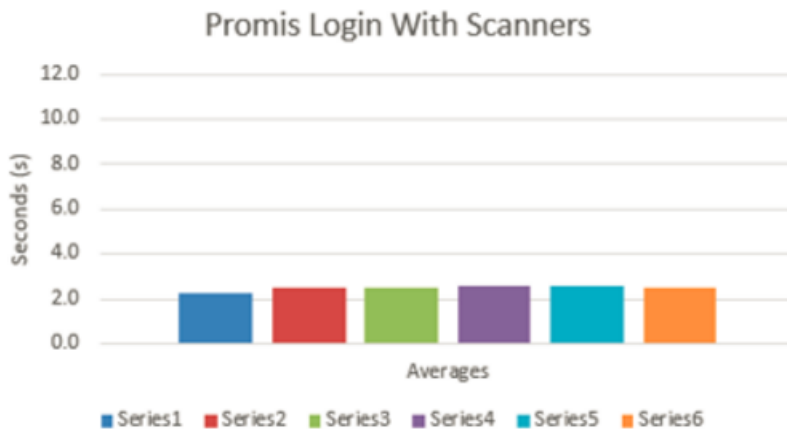
Figure 7: Mock PROMIS Login With Scanners

We acknowledge that these calculations are based on averages with no variation. In the industry there are many variations in the distribution that need to be accounted for, this in turn would change our results. Due to the time scope of this project we used averages.

4.4 Axiomatic Design

Figure 8 shows our axiomatic design decomposition and matrix.

	DP0: System to Reduce Operator Touch Time	DP1: System to capture/record current touch time	DP2: System to Differentiate value added/non value added	DP2.1: System to understand each process	DP2.2: System to validate each process	DP3: System to minimize non value added steps
FR0: Reduce Operator Touch Time for Metals Area	X					
FR1: Capture/Record current touch time on _____ tools		X	O	O	O	O
FR2: Differentiate value added/non value added from process		X	X			O
FR2.1: Understand each process		O		X	O	O
FR2.2: Validate each process		O		X	X	O
FR3: Minimize non value added steps		X	X	X	X	X

Figure 8: Axiomatic Design

We have three functional requirements under our main functional requirement. FR0 was our main objective, which is to reduce the operators touch time for the metals area. In order to

reduce the operators touch time we first needed to complete FR1, which was to capture and record the current touch time on tools. We were able to accomplish this requirement by doing a time and motion study which developed a labor study, and making a spaghetti diagram of the fab layout. After accomplishing FR1, we then worked on FR2, which was to differentiate the value added and the non-value added steps from the process. We accomplished this by using the work instruction and comparing the instructions with our observations of how they were doing the process. Lastly, FR3 was to minimize the non-value added steps, which we are recommending the use of scanners for the PROMIS login, since this takes most of the operator's time. By accomplishing the three Functional Requirements, we are able to accomplish our FR0 and eventually reduce the operator touch time for the metals area of the fab.

5   Recommendations

5.1   Objective 1: Capture and record current touch time on metals tools

5.1.1   Time Studies/Labor Studies

After conducting our time studies and looking at our results we compared them to the actual staffing in the metals area of the fab.

When we were in the fab we noticed that one operator was working on multiple tools. This operator was running SPUTTER, ALLOY, and AMR all at once. According to our results this is possible for one operator to do all those tasks; however, the issue with one operator working on all these tools is that they are not located in close proximity to each other.

We noticed that in the MEI area only one operator was working on the metals WIP for that tool. Our results show that 1.4 operators are needed, therefore we recommend that there be

another operator using a little less than half of their time to help run the MEI tools in order to avoid bottlenecking.

Through our time studies we were also able to focus on steps that were non-value added. This led to us researching and recommending improvements that would alleviate or speed up these processes.

5.1.2   Limitations

We ran into a few limitations when conducting our time studies. In A term we were only able to visit three times a week which was all during one shift. We were not able to conduct time studies/labor studies on any other shift because of this reason. Other limitations were that there was not always WIP for the tools we were studying. This led to us waiting around for WIP to appear and not being able to move forward with our time studies for that specific tool. We were able to get the missing information from the IE team at Skyworks.

5.2   Objective 2: Define value/non-value added time from processes

5.2.1   Spaghetti Diagram

With the two layers in the spaghetti diagram that we were able to accomplish, we recommend that Skyworks continue to produce these for every layer of the process. This diagram will help Skyworks quickly identify potential problems and areas of improvement in regards to the layout of the fab. We would recommend a facility layout analysis resulting in a new layout but Skyworks believes that this option is too expensive and would stop production for too long when they would not be able to get any product out to their customers. As for benefits, it is impossible for us to measure any savings due to the time frame of this project. Instead, we recommend that Skyworks looks at the spaghetti diagram to reduce non-value added time.

5.2.2 Work Instructions

There are two main things we recommend for work instructions. The first is to reevaluate the established protocols in order to make sure operators are performing in the most efficient way while keeping losses at a minimum. This recommendation comes from the idea that operators are the ones that know how to move lots as efficiently as the fab layout will allow. However, we cannot always assume that their methods will be safe. Due to this element of the problem, the second recommendation is that protocol be enforced in a better manner in order to minimize potential costs of damaged wafers and guarantee safety for all operators at every level of the production line. In other words, design protocol to ensure that long term costs of breaking protocol do not outweigh short term benefits, and enforce it accordingly.

5.2.3 Limitations

Given that out project's scope was limited to the metal's area, we were not able to identify inefficiencies outside this area that could be affecting the performance of the metals area. For instance, in spaghetti diagrams, we could not see things that were happening independently from the metals area and therefore, possible traffic that increased non-value added time of metals area was not identified.

Several of the layers involving the metals process were shown in our spaghetti diagram, but because of the time frame of this project, not all layers were modeled in the AutoCAD file. However, our example portrays how the operators move around the fab per layer. Our model excludes walking to and from the WIP racks because they are not accurately depicted in the fab layout that was used. A drawback from using the spaghetti diagram was that the scope of this project was limited to the metals area but because the flow was done by layer, we had to look at the fab in its entirety.

5.3 Objective 3: Minimize non-value added steps

5.3.1 Scanner Implementation

In order to minimize the non-value added steps found, such as the PROMIS login time, we recommend implementing a bar code and scanner procedure as mentioned above. The operator will no longer need to manually input his username and password through the keyboard. Now he will only need to scan a barcode that will be located on his ID badge.

There will need to be some trainings for the operators in order to understand how to use the scanners to login to PROMIS and to scan lot IDs, if implemented.

5.3.2 Next Steps

The first step to implement the bar code and scanner login will be to buy one Motorola Symbol LI4278 Scanner per station. This idea was discussed with G.S., in order to get an IT perspective and to confirm its feasibility with the current system in the fab.

Simultaneously, C.G. will need the specifications of the barcodes in order to print a barcode for each operator's badge.

Subsequently Skyworks Solutions Inc. will need to instruct the operators on how the improved PROMIS login procedures will be executed. Operators will need to understand the benefits of change so they are accepting of new practices.

5.3.3 Limitations

One of the main limitations was that we recommended to use scanners for lot ID's but being that the Lot Id's change so often a printer would be needed at all work stations. Often operators need to split the lot into new cassettes and generate a new lot ID for each cassette. Operators change the lot ID by handwriting new number on a piece of paper which is placed on the front side of the box. We recommend that Skyworks looks more into the details to implement barcodes

for Lot ID's because writing the Lot ID by hand on pieces of paper are prone to human error and takes longer. We encourage Skyworks Solutions Inc. to confer with G.S. and the IT team to discuss the possibilities of a tool that generates a barcode for the lot numbers. These bar codes will be printed at the workstations and placed on the front side of the box as they normally do. Skyworks Solutions Inc. will need to buy a printer for each workstation. By doing this, the operator won't need to input the lot number manually into PROMIS. This will lead to a reduction of the operator touch time while reducing the room for human error.

5.4   Financial Analysis

After calculating the time saved by using scanners, we were able to do a financial analysis by assuming some of the given data. The first assumption that we made was that a single operator logs into PROMIS around 100 times per shift. Since each shifts is of 12 hours per day, we were able to calculate that a single operator logs in 8.3 times per hour. With 100 operators in each shift, there is a total 833.3 logins per shift.

Once we had this information, we were able to use the mock trials in order to calculate the number of hours the use of scanners would save the company. Without scanners, operators spend a total of 1.9 hours per shift logging into PROMIS, and with scanners they would spend a total of 0.6 hours per shift. This makes up to a difference of 1.3 hours per shift of time that is being wasted. Because the fab runs 24 hours a day, they have two shifts. Therefore, there is total of 2.6 hours of non-value time in regards to logging into PROMIS every day for all operators.

The second assumption we made was that the fab runs 50 weeks out of the 52 weeks in a year. The reason behind this is that we are taking into consideration time the fab is not running due to vacations, shut downs, etc. With this assumption we were able to calculate that there is 907.4 hours per year lost due to the non-value added time from having to log in to PROMIS.

With the amount of hours Skyworks is losing, and the wage per hour of a full time employee at Skyworks, we were able to make a financial analysis of the scanners investment. We decided to analyze the investment for five years, and with a 5% interest rate for the annuities of the savings. With an investment cost of $3,823.4 and an estimated saving of $23,592.59 per year, we calculated the net present worth of the investment to be $102,143.58. Figure 9 shows a cash flow diagram of the investment.

Figure 9: Cash Flow

(San Andres and Vargas, 2016)

With this assumption, we were able to calculate the present value of the amount of money Skyworks would be saving during these 5 years. Not only is money being lost presently, but also there is the opportunity cost of having this non-value added time. Since we are not sure of the interest rate we decided to do a sensitivity analysis with different interest rates. Table 5 shows the present worth of the investment with different interest rates.

Table 5: Sensitivity Analysis

Sensitivity Analysis	
Interest Cost	**Net PW of Investment**
3%	$108,047.17
4%	$105,030.03
5%	$102,143.58
6%	$99,380.58
7%	$96,734.29
8%	$94,198.38
9%	$91,766.96
10%	$89,434.49

For further details on the cost and benefit analysis, please refer to the appendix.

6   Conclusion

Through this project our team learned that we could frame a problem using axiomatic design. We were able to collect data, in a real world environment, through time studies which led to analyzing labor studies and non-value added time. We proposed solutions through discrepancies in their work instructions as well as researching the possibility of implementing scanners and a barcode system through the fab. We conducted a mock trial and a financial analysis to suggest how our proposed solutions will benefit the company. If Skyworks was to implement the scanner and barcode system they would save approximately 907 hours per year resulting in a new present worth of $102,143.58 for a five year period.

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8 Appendices

8.1 Excel Sheets

ALLOY Labor Study - Q3 FY16

Photo Process	Avg Load Labor Req / Shift	Full Load Labor Req / Shift	..	Get WIP	Update Promis	Place WIP	Other 1	Remove WIP	Update Promis	Store WIP	Other 2	Total Time	Note
ALLOY03	0.02	0.02		0.04	0.54	0.32	-	0.31	0.52	0.48	-	2.21	
ALLOY04	0.01	0.01		0.03	0.38	0.53	-	0.22	0.18	0.31	-	1.65	
Total	0.03	0.03		0.08	0.92	0.85	0.00	0.52	0.70	0.79	0.00	3.86	
				2.0%	23.9%	22.0%	0.0%	13.5%	18.2%	20.4%	0.0%	100.0%	

Variables	
Item	
Available time per operator per shift (hr)	12.0
Lunch time (hr)	2.0
Productivity factor %	75%
Productive hours by operator by shift (hr)	7.5

	WSPW	1850

Process	HBT5 M2	HBT5 M3	HBT6 M3	BI-FET5 M3	BI-FET5 M3 MC	BI-FET5 M2	BI-FET6 M3	BI-FET6 M3 MC	BI-HEMPT 4/5	SUM
Collector Contact (CC) Alloy	22.8%	32.1%	9.0%	3.4%	3.7%	14.9%	8.2%	6.0%	0.0%	100.0%
Metal 1 (M1) Alloy	X	X	X	X	X	X	8.2%	6.0%	X	14.2%

FLOW MIX BIFET	OVERALL MIX		MIX WITHIN M3/M2/BIHEMT	
M3	95.00%	HBT5 M3	0.00%	32.1%
		HBT6 M3	10.00%	9.0%
		Bi-FET5 M3	0.00%	3.4%
		Bi-FET5 M3 MC	0.00%	3.7%
		Bi-FET6 M3	90.00%	8.2%
		Bi-FET6 M3 MC	0.00%	6.0%
M2	5.00%	HBT5 M2	50.00%	22.8%
		Bi-FET5 M2	50.00%	14.9%
Bi-HEMT	0.00%	Bi-HEMT 4/5	0.00%	0.0%
TOTAL	100.00%			100.0%

Item	Category	Description
1	Get WIP	Check WIP profile, retrieve WIP, return to workstation, validate wafer ID match to cassette box label
2	Update Promis	Log into Promis, select tool, select lot, validate wafer ID to screen, track in lot
3	Place WIP	Notch finder, slide transfer, load lot into tool, enter lot ID into tool, select recipe for tool, start tool
4	Other 1	All other tasks before tool runs not included in the 1,2,3 above. Place operator manual process for running tool here.
6	Remove WIP	Remove lot from tool, macro inspect wafers, place cassette into its box
7	Update Promis	Log into Promis, select tool, select lot, enter process data, comments, track out of Promis
8	Store WIP	Deliver WIP to next step
9	Other 2	All other tasks after tool runs not included in 6,7,8 above

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HOME — **ALLOY03**

Task	Time	Time	Time		Task	Time	Time	Time	Avg Time
Get WIP	0.08	0.02	0.03		Get WIP	0.08	0.02	0.03	0.04
PrePromis work	0.42	0.53	0.67		Update Promis	0.42	0.53	0.67	0.54
Load tool	0.25	0.30	0.42		Place WIP	0.25	0.30	0.42	0.32
Other 1					Other 1	0.00	0.00	0.00	0.00
Unload tool	0.35	0.37	0.20		Remove WIP	0.35	0.37	0.20	0.31
Post Promis work	0.55	0.50	0.50		Update Promis	0.55	0.50	0.50	0.52
Store WIP	0.27	0.25	0.92		Store WIP	0.27	0.25	0.92	0.48
Other 2					Other 2	0.00	0.00	0.00	0.00
					Total	1.92	1.97	2.73	
TOTAL Time/Run (min)	1.92	1.97	2.73		Average		2.21		2.21
Avg. TOTAL Time/Run (min)		2.21							

Variables	
Item	
Available time per operator per shift (hr)	12.0
Lunch time (hr)	2.0
Productivity factor %	75%
Productive hours by operator by shift (hr)	7.5

	WSPW BIFET
	1850

			Goal/day	Runs/day	Total touch time Per day (hr)
		Avg. Lot size	24	150.8	6.3	0.23
		Full Lot	24	150.8	6.3	0.23

	Avg. Load	Full Load
Total touch time Per day **(hours)**	0.23	0.23
Touch time per day per shift **(hours)**	0.12	0.12
Available time per operator **(hours)**	7.5	7.5
Operators required/shift	0.02	0.02

Task	Time	Time	Time
Get WIP	0.03	0.02	0.03
PrePromis work	0.25	0.60	0.52
Load tool	0.58	0.38	0.47
Other 1			
Unload tool	0.22	0.22	0.22
Post Promis work	0.25	0.55	0.12
Store WIP	0.32	0.67	0.30
Other 2			
TOTAL Time/Run (min)	1.65	2.43	1.65
Avg. TOTAL Time/Run (min)		1.7	

Task	Time	Time	Time	Avg Time
Get WIP	0.03	0.02	0.03	0.03
Update Promis	0.25	0.60	0.52	0.38
Place WIP	0.58	0.38	0.47	0.53
Other 1	0.00	0.00	0.00	0.00
Remove WIP	0.22	0.22	0.22	0.22
Update Promis	0.25	0.55	0.12	0.18
Store WIP	0.32	0.67	0.30	0.31
Other 2	0.00	0.00	0.00	0.00
Total	1.65	2.43	1.65	
Average		1.7		1.7

Variables	
Item	
Available time per operator per shift (hr)	12.0
Lunch time (hr)	2.0
Productivity factor %	75%
Productive hours by operator by shift (hr)	7.5

	WSPW BIFET		
	1850		
	Goal/day	Runs/day	Total touch time Per day (hr)
Avg. Lot size	24	150.8	6.3	0.17
Full Lot	24	150.8	6.3	0.17

	Avg. Load	Full Load
Total touch time Per day (hours)	0.17	0.17
Touch time per day per shift (hours)	0.09	0.09
Available time per operator (hours)	7.5	7.5
Operators required/shift	0.01	0.01

Photo Process	Avg Load Labor Req / Shift	Full Load Labor Req / Shift	..	Get WIP	Update Promis	Place WIP	Other 1	Remove WIP	Update Promis	Store WIP	Other 2	Total Time
AMR02	0.06	0.06		0.12	0.55	0.38	-	0.33	0.33	0.46	-	2.18
AMR03	0.05	0.05		0.21	0.40	0.38	-	0.19	0.29	0.48	-	1.95
Total	0.11	0.11		0.33	0.95	0.77	0.00	0.52	0.62	0.94	0.00	4.13
				7.9%	23.1%	18.5%	0.0%	12.6%	15.0%	22.8%	0.0%	100.0%

Variables	
Item	
Available time per operator per shift (hr)	12.0
Lunch time (hr)	2.0
Productivity factor %	75%
Productive hours by operator by shift (hr)	7.5

		WSPW	1850

Process	HBT5 M2	HBT5 M3	HBT6 M3	BI-FET5 M3	BI-FET5 M3 MC	BI-FET5 M2	BI-FET6 M3	BI-FET6 M3 MC	BI-HEMPT 4/5	SUM
Emitter Contact (EC) Liftoff- Tape	22.8%	32.1%	X	3.4%	3.7%	14.9%	X	X	0.0%	76.9%
Gate (GL) Tape Liftoff			X			X				0.0%
Collector Contact (CC) Tape Liftoff	22.8%	32.1%	9.0%	3.4%	3.7%	14.9%	8.2%	6.0%	0.0%	100.0%
Metal 1 (M1) Tape Liftoff	22.8%	32.1%	9.0%	3.4%	3.7%	14.9%	8.2%	6.0%	0.0%	100.0%
MIMCAP (MC) Metal Tape Liftoff			X		3.7%			6.0%		9.7%
Metal 2 (M2) Tape Liftoff	22.8%	32.1%	9.0%	3.4%	3.7%	14.9%	8.2%	6.0%	0.0%	100.0%
Metal 3 (M3) Tape Liftoff	X	32.1%	9.0%	3.4%	3.7%	X	8.2%	6.0%	0.0%	62.2%

FLOW MIX BIFET	OVERALL MIX	MIX WITHIN M3/M2/BIHEMT		
M3	95.00%	HBT5 M3	0.00%	32.1%
		HBT6 M3	10.00%	9.0%
		Bi-FET5 M3	0.00%	3.4%
		Bi-FET5 M3 MC	0.00%	3.7%
		Bi-FET6 M3	90.00%	8.2%
		Bi-FET6 M3 MC	0.00%	6.0%
M2	5.00%	HBT5 M2	50.00%	22.8%
		Bi-FET5 M2	50.00%	14.9%
Bi-HEMT	0.00%	Bi-HEMT 4/5	0.00%	0.0%
TOTAL	100.00%			100.0%

Item	Category	Description
1	Get WIP	Check WIP profile, retrieve WIP, return to workstation, validate wafer ID match to cassette box label
2	Update Promis	Log into Promis, select tool, select lots, validate wafer ID to screen, track in lot
3	Place WIP	Notch finder, slide transfer, load lot into tool, enter lot ID into tool, select recipe for tool, start tool
4	Other 1	All other tasks before tool runs not included in the 1,2,3 above. Place operator manual process for running tool here.
6	Remove WIP	Remove lot from tool, macro inspect wafers, place cassette into its box
7	Update Promis	Log into Promis, select tool, select lot, enter process data, comments, track out of Promis
8	Store WIP	Deliver WIP to next step
9	Other 2	All other tasks after tool runs not included in 6,7,8 above

AMR02

Task	Time	Time	Time
Get WIP	0.08	0.12	0.17
PrePromis work	1.00	0.35	0.31
Load tool	0.33	0.33	0.48
Other 1			
Unload tool	0.20	0.37	0.43
Post Promis work	0.50	0.18	0.31
Store WIP	0.50	0.45	0.43
Other 2			
TOTAL Time/Run (min)	2.62	1.80	2.13
Avg. TOTAL Time/Run (min)		2.2	

Task	Time	Time	Time	Avg Time
Get WIP	0.08	0.12	0.17	0.12
Update Promis	1.00	0.35	0.31	0.55
Place WIP	0.33	0.33	0.48	0.38
Other 1	0.00	0.00	0.00	0.00
Remove WIP	0.20	0.37	0.43	0.33
Update Promis	0.50	0.18	0.31	0.33
Store WIP	0.50	0.45	0.43	0.46
Other 2	0.00	0.00	0.00	0.00
Total	2.62	1.80	2.13	
Average		2.2		2.2

Variables	
Item	
Available time per operator per shift (hr)	12.0
Lunch time (hr)	2.0
Productivity factor %	75%
Productive hours by operator by shift (hr)	7.5

WSPW BIFET			
1850			
	Goal/day	Runs/day	Total touch time Per day (hr)
Avg. Lot size	24	593.1	24.7	0.90
Full Lot	24	593.1	24.7	0.90

	Avg. Load	Full Load
Total touch time Per day (hours)	0.90	0.90
Touch time per day per shift (hours)	0.45	0.45
Available time per operator (hours)	7.5	7.5
Operators required/shift	0.06	0.06

AMR03

Task	Time	Time	Time
Get WIP	0.20	0.33	0.08
PrePromis work	0.23	0.35	0.62
Load tool	0.53	0.25	0.37
Other 1			
Unload tool	0.22	0.18	0.17
Post Promis work	0.35	0.35	0.17
Store WIP	0.62	0.42	0.42
Other 2			
TOTAL Time/Run (min)	2.15	1.88	1.82
Avg. TOTAL Time/Run (min)		2.0	

Task	Time	Time	Time	Avg Time
Get WIP	0.20	0.33	0.08	0.21
Update Promis	0.23	0.35	0.62	0.40
Place WIP	0.53	0.25	0.37	0.38
Other 1	0.00	0.00	0.00	0.00
Remove WIP	0.22	0.18	0.17	0.19
Update Promis	0.35	0.35	0.17	0.29
Store WIP	0.62	0.42	0.42	0.48
Other 2	0.00	0.00	0.00	0.00
Total	2.15	1.88	1.82	
Average		2.0		2.0

Variables	
Item	
Available time per operator per shift (hr)	12.0
Lunch time (hr)	2.0
Productivity factor %	75%
Productive hours by operator by shift (hr)	7.5

WSPW BIFET			
1850			
	Goal/day	Runs/day	Total touch time Per day (hr)
Avg. Lot size	24	593.1	24.7	0.80
Full Lot	24	593.1	24.7	0.80

	Avg. Load	Full Load
Total touch time Per day (hours)	0.80	0.80
Touch time per day per shift (hours)	0.40	0.40
Available time per operator (hours)	7.5	7.5
Operators required/shift	0.05	0.05

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MEI Labor Study - Q3 FY16

Photo Process	Avg Load Labor Req / Shift	Full Load Labor Req / Shift	..	Get WIP	Update Promis	Place WIP	Other 1	Remove WIP	Update Promis	Store WIP	Other 2	Total Time	Note
MEI01T3	0.46	0.46		0.12	0.47	0.88	-	0.79	0.48	0.66	-	3.40	
MEI03T2	0.42	0.42		0.22	0.47	0.67	-	0.66	0.68	0.38	-	3.09	
MEI03T3	0.26	0.26		0.22	0.51	0.76	-	0.83	0.31	0.08	-	2.70	
MEI03T4	0.25	0.25		0.15	0.48	0.60	-	0.87	0.51	0.07	-	2.67	
Total	**1.39**	**1.39**		**0.70**	**1.92**	**2.92**	**0.00**	**3.16**	**1.97**	**1.19**	**0.00**	**11.86**	
				5.9%	16.2%	24.6%	0.0%	26.6%	16.6%	10.0%	0.0%	100.0%	

Variables	
Item	
Available time per operator per shift (hr)	12.0
Lunch time (hr)	2.0
Productivity factor %	75%
Productive hours by operator by shift (hr)	7.5

WSPW	1850

FLOW MIX BIFET	OVERALL MIX		MIX WITHIN M3/M2/BIHEMT	
M3	95.00%	HBT5 M3	0.00%	32.1%
		HBT6 M3	10.00%	9.0%
		Bi-FET5 M3	0.00%	3.4%
		Bi-FET5 M3 MC	0.00%	3.7%
		Bi-FET6 M3	90.00%	8.2%
		Bi-FET6 M3 MC	0.00%	6.0%
M2	5.00%	HBT5 M2	50.00%	22.8%
		Bi-FET5 M2	50.00%	14.9%
Bi-HEMT	**0.00%**	Bi-HEMT 4/5	0.00%	0.0%
TOTAL	100.00%			100.0%

Process	HBT5 M3	HBT5 M2	HBT6 M3	BI-FET5 M3	BI-FET5 M3 MC	BI-FET5 M2	BI-FET6 M3	BI-FET6 M3 MC	BI-HEMPT 4/5	SUM
StressReliefEtch-Sapphire	32.1%	22.8%	9.0%	3.4%	3.7%	14.9%	8.2%	6.0%	0.0%	100.0%
1:1 HCl Dip- Through-Wafer Via (TWV) Pre-Clean	32.1%	22.8%	9.0%	3.4%	3.7%	14.9%	8.2%	6.0%	0.0%	100.0%
HCl Dip- 1:1 Seed (SE) Pre-Metal Clean	32.1%	22.8%	9.0%	3.4%	3.7%	14.9%	8.2%	6.0%	0.0%	100.0%
HCl Dip- 1:1 Pre-AU Plating Clean	32.1%	22.8%	9.0%	3.4%	3.7%	14.9%	8.2%	6.0%	0.0%	100.0%
HCl Dip- 1:1 Pre-CU Plating Clean	32.1%	22.8%	9.0%	3.4%	3.7%	14.9%	8.2%	6.0%	0.0%	100.0%
CU Flash HNO3 Pre-Clean	32.1%	22.8%	9.0%	3.4%	3.7%	14.9%	8.2%	6.0%	0.0%	100.0%
HCl Dip- 5:1 Polyimide V1 w/MIMC2 Post-Etch Strip	X	X	X	X	3.7%	X	X	6.0%	X	9.7%
HCl Dip- 5:1 Polyimide Via 1 (V1) Post-Etch Strip	32.1%	22.8%	9.0%	3.4%	3.7%	14.9%	8.2%	6.0%	0.0%	100.0%
Wet Etch - Zero	32.1%	22.8%	9.0%	3.4%	3.7%	14.9%	8.2%	6.0%	0.0%	100.0%
5:1 HCl Dip- Emitter Contact (EC) Pre-Clean	32.1%	22.8%	X	3.4%	3.7%	14.9%	X	X	0.0%	76.9%
Channel (CH) Etch (BFREC)	X	X	X	3.4%	3.7%	14.9%	8.2%	6.0%	X	36.1%
BHF Dip- Emitter Mesa (EM) Post-Etch Clean	32.1%	22.8%	9.0%	3.4%	3.7%	14.9%	8.2%	6.0%	0.0%	100.0%
BHF Dip- Base Pedestal (BP) Post-Etch Clean	32.1%	22.8%	9.0%	3.4%	3.7%	14.9%	8.2%	6.0%	0.0%	100.0%
BiFET Base Overlay (BO) 2% NH4Oh Pre-Clean	X	X	X	X	X	X	X	X	0.0%	0.0%
BHF Dip- Base Overlay (BO) Post-Etch Clean	X	X	X	X	X	X	X	X	0.0%	0.0%
HCl Dip- 5:1 Collector Protection (CP) HCl Clean	X	X	X	X	X	X	X	X	0.0%	0.0%
Photo NH4Oh Pre-Adhesion Dip	X	X	X	X	X	X	X	X	0.0%	0.0%
Wet Etch - Collector Protection (CP) Main Etch	X	X	X	X	X	X	X	X	0.0%	0.0%
BHF Dip- Collector Protection (CP) Post-Etch Clean	X	X	X	X	X	X	X	X	0.0%	0.0%
Wet Etch - Collector Protection (CP) Post Etch	X	X	X	X	X	X	X	X	0.0%	0.0%
II Protection (AA) 2% NH40h Pre-Clean	32.1%	22.8%	9.0%	3.4%	3.7%	14.9%	8.2%	6.0%	0.0%	100.0%
BHF Dip- Base Contact (BC) Post-Etch Clean	32.1%	22.8%	9.0%	3.4%	3.7%	14.9%	8.2%	6.0%	0.0%	100.0%
HCl Dip- 5:1 Base Contact (BC) Pre-Clean	32.1%	22.8%	9.0%	3.4%	3.7%	14.9%	8.2%	6.0%	0.0%	100.0%
EBC Via (CV) Passivation 2% NH40h Pre-Clean	32.1%	22.8%	X	3.4%	3.7%	14.9%	X	X	0.0%	76.9%
HCl Dip- 5:1 EBC Via (CV) Post-Nitride Etch Clean	32.1%	22.8%	9.0%	3.4%	3.7%	14.9%	8.2%	6.0%	0.0%	100.0%
HCl Dip- 5:1 Gate (GL) Pre-Clean	X	X	X	3.4%	3.7%	14.9%	X	X	0.0%	22.0%
Wet Etch - Collector Contact (CC)	32.1%	22.8%	9.0%	3.4%	3.7%	14.9%	8.2%	6.0%	0.0%	100.0%
Collector Contact (CC) 2% NH40h Pre-Clean	32.1%	22.8%	9.0%	3.4%	3.7%	14.9%	8.2%	6.0%	0.0%	100.0%
BiFET6 TaN (RL) Passivation 2% NH40h Pre-Clean	X	X	9.0%	X	X	X	8.2%	X	X	17.1%
HCl Dip- 5:1 Resistor Layer (RL) Pre-Clean	32.1%	22.8%	9.0%	3.4%	3.7%	14.9%	8.2%	6.0%	0.0%	100.0%
Metal 1 Layer (M1) 2% NH40h Pre-Clean	32.1%	22.8%	9.0%	3.4%	3.7%	14.9%	8.2%	6.0%	0.0%	100.0%
BiFET6 Metal 1 (M1) Layer 2% NH40h Pre-Clean	X	X	9.0%	X	X	X	8.2%	X	X	17.1%
MIMCAP (MC) 2% NH40h Pre-Clean	X	X	X	X	3.7%	X	X	6.0%	X	9.7%
5:1 HCl Dip- MIMCAP (MC) Pre-Clean	X	X	X	X	3.7%	X	X	6.0%	X	9.7%
MIMCAP (MC) 2% NH40h Pre-Clean	X	X	X	X	3.7%	X	X	6.0%	X	9.7%
Nit Via (NV) 2% NH40h Pre-Clean	32.1%	22.8%	X	3.4%	X	14.9%	X	X	0.0%	73.2%
HCl Dip- 5:1 Nit Via (NV) Post-Etch Clean	32.1%	22.8%	9.0%	3.4%	X	14.9%	8.2%	X	0.0%	90.3%
Polyimide Via 1 (V1) 2% NH40h Pre-Clean	32.1%	22.8%	9.0%	3.4%	3.7%	14.9%	8.2%	6.0%	0.0%	100.0%
1:1 HCl Dip- Metal 2 (M2) Layer Pre-Clean	32.1%	22.8%	9.0%	3.4%	3.7%	14.9%	8.2%	6.0%	0.0%	100.0%
Polyimide Via 2 (V2) 2% NH40h Pre-Clean	X	22.8%	9.0%	3.4%	3.7%	X	8.2%	6.0%	0.0%	53.0%
HCl Dip- 5:1 Polyimide Via 2 (V2) Post-Etch Strip	X	22.8%	9.0%	3.4%	3.7%	X	8.2%	6.0%	0.0%	53.0%
1:1 HCl Dip- Metal 3 (M3) Layer Pre-Clean	X	22.8%	9.0%	3.4%	3.7%	X	8.2%	6.0%	0.0%	53.0%
1:1 HCl Dip- Scratch Pro (SP) Pre-Clean	32.1%	22.8%	9.0%	3.4%	3.7%	14.9%	8.2%	6.0%	0.0%	100.0%
HCl Dip- 5:1 Scratch Pro (SP) Post-Etch Strip	32.1%	22.8%	9.0%	3.4%	3.7%	14.9%	8.2%	6.0%	0.0%	100.0%
HCl Dip- 5:1 Polyimide V1 w/MIMC2 Post-Etch Strip	X	X	X	X	X	X	X	6.0%	X	6.0%

Item	Category	Description
1	Get WIP	Check WIP profile, retrieve WIP, return to workstation, validate wafer ID match to cassette box label
2	Update Promis	Log into Promis, select tool, select lots, validate wafer ID to screen, track in lot
3	Place WIP	Notch finder, slide transfer, load lot into tool, enter lot ID into tool, select recipe for tool, start tool
4	Other 1	All other tasks before tool runs not included in the 1,2,3 above. Place operator manual process for running tool here.
6	Remove WIP	Remove lot from tool, macro inspect wafers, place cassette into its box
7	Update Promis	Log into Promis, select tool, select lot, enter process data, comments, track out of Promis
8	Store WIP	Deliver WIP to next step
9	Other 2	All other tasks after tool runs not included in 6,7,8 above

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MEI01T3

Task	Time	Time	Time
Get WIP	0.05	0.13	0.17
PrePromis work	0.50	0.53	0.37
Load tool	0.97	0.97	0.72
Other 1			
Unload tool	0.78	0.62	0.98
Post Promis work	0.28	0.48	0.67
Store WIP	0.72	0.98	0.28
Other 2			
TOTAL Time/Run (min)	3.30	3.72	3.18
Avg. TOTAL Time/Run (min)		3.4	

Task	Time	Time	Time	Avg Time
Get WIP	0.05	0.13	0.17	0.12
Update Promis	0.50	0.53	0.37	0.47
Place WIP	0.97	0.97	0.72	0.88
Other 1	0.00	0.00	0.00	0.00
Remove WIP	0.78	0.62	0.98	0.79
Update Promis	0.28	0.48	0.67	0.48
Store WIP	0.72	0.98	0.28	0.66
Other 2	0.00	0.00	0.00	0.00
Total	3.30	3.72	3.18	
Average		3.4		3.4

Variables	
Item	
Available time per operator per shift (hr)	12.0
Lunch time (hr)	2.0
Productivity factor %	75%
Productive hours by operator by shift (hr)	7.5

T3
BC-ME
CV-ET
EC-ME
GL-ME
M1-ME
M2-ME
M3-ME
MC-ME
NV-ET
RL-ME
SP-ET
SP-ME
V1-ET
V2-ET

WSPW BIFET			
1850			
	Goal/day	Runs/day	Total touch time Per day (hr)
Avg. Lot size	24	2935.6	122.3	6.93
Full Lot	24	2935.6	122.3	6.93

	Avg. Load	Full Load
Total touch time Per day (hours)	6.93	6.93
Touch time per day per shift (hours)	3.47	3.47
Available time per operator (hours)	7.5	7.5
Operators required/shift	0.46	0.46

MEI03T2

Task	Time	Time	Time
Get WIP	0.08	0.17	0.42
PrePromis work	0.42	0.45	0.55
Load tool	0.70	0.93	0.38
Other 1			
Unload tool	0.45	0.85	0.68
Post Promis work	0.42	1.03	0.58
Store WIP	0.32	0.40	0.43
Other 2			
TOTAL Time/Run (min)	2.38	3.83	3.05
Avg. TOTAL Time/Run (min)		3.1	

Task	Time	Time	Time	Avg Time
Get WIP	0.08	0.17	0.42	0.22
Update Promis	0.42	0.45	0.55	0.47
Place WIP	0.70	0.93	0.38	0.67
Other 1	0.00	0.00	0.00	0.00
Remove WIP	0.45	0.85	0.68	0.66
Update Promis	0.42	1.03	0.58	0.68
Store WIP	0.32	0.40	0.43	0.38
Other 2	0.00	0.00	0.00	0.00
Total	2.38	3.83	3.05	
Average		3.1		3.1

Variables	
Item	
Available time per operator per shift (hr)	12.0
Lunch time (hr)	2.0
Productivity factor %	75%
Productive hours by operator by shift (hr)	7.5

WSPW BIFET			
1850			
	Goal/day	Runs/day	Total touch time Per day (hr)
Avg. Lot size	24	2935.6	122.3	6.30
Full Lot	24	2935.6	122.3	6.30

	Avg. Load	Full Load
Total touch time Per day (hours)	6.30	6.30
Touch time per day per shift (hours)	3.15	3.15
Available time per operator (hours)	7.5	7.5
Operators required/shift	0.42	0.42

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HOME_____ MEI03T3

Task	Time	Time	Time
Get WIP	0.33	0.50	0.10
PrePromis work	0.35	0.79	0.67
Load tool	0.79	1.02	0.73
Other 1			
Unload tool	0.85	0.48	0.82
Post Promis work	0.27	0.53	0.35
Store WIP	0.08	0.07	0.07
Other 2			
TOTAL Time/Run (min)	2.67	3.39	2.73
Avg. TOTAL Time/Run (min)	2.9		

Task	Time	Time	Time	Avg Time
Get WIP	0.33	0.50	0.10	0.22
Update Promis	0.35	0.79	0.67	0.51
Place WIP	0.79	1.02	0.73	0.76
Other 1	0.00	0.00	0.00	0.00
Remove WIP	0.85	0.48	0.82	0.83
Update Promis	0.27	0.53	0.35	0.31
Store WIP	0.08	0.07	0.07	0.08
Other 2	0.00	0.00	0.00	0.00
Total	2.67	3.39	2.73	
Average	2.9			2.7

Variables	
Item	
Available time per operator per shift (hr)	12.0
Lunch time (hr)	2.0
Productivity factor %	75%
Productive hours by operator by shift (hr)	7.5

WSPW BIFET
1850

			Goal/day	Runs/day	Total touch time Per day (hr)
		Avg. Lot size	24	1883.7	78.5	3.84
		Full Lot	24	1883.7	78.5	3.84

	Avg. Load	Full Load
Total touch time Per day (hours)	3.84	3.84
Touch time per day per shift (hours)	1.92	1.92
Available time per operator (hours)	7.5	7.5
Operators required/shift	0.26	0.26

MEI03T4

Task	Time	Time	Time
Get WIP	0.20	0.50	0.10
PrePromis work	0.28	0.79	0.67
Load tool	0.47	1.02	0.73
Other 1			
Unload tool	0.92	0.43	0.82
Post Promis work	0.33	0.15	0.68
Store WIP	0.05	0.38	0.08
Other 2			
TOTAL Time/Run (min)	2.25	3.28	3.08
Avg. TOTAL Time/Run (min)		2.9	

Task	Time	Time	Time	Avg Time
Get WIP	0.20	0.50	0.10	0.15
Update Promis	0.28	0.79	0.67	0.48
Place WIP	0.47	1.02	0.73	0.60
Other 1	0.00	0.00	0.00	0.00
Remove WIP	0.92	0.43	0.82	0.87
Update Promis	0.33	0.15	0.68	0.51
Store WIP	0.05	0.38	0.08	0.07
Other 2	0.00	0.00	0.00	0.00
Total	2.25	3.28	3.08	
Average		2.7		2.7

Variables	
Item	
Available time per operator per shift (hr)	12.0
Lunch time (hr)	2.0
Productivity factor %	75%
Productive hours by operator by shift (hr)	7.5

	WSPW BIFET		
	1850		
	Goal/day	Runs/day	Total touch time Per day (hr)
Avg. Lot size 24	1883.7	78.5	3.75
Full Lot 24	1883.7	78.5	3.75

	Avg. Load	Full Load
Total touch time Per day (hours)	3.75	3.75
Touch time per day per shift (hours)	1.88	1.88
Available time per operator (hours)	7.5	7.5
Operators required/shift	0.25	0.25

SPUTTER Labor Study - Q3 FY16

Photo Process	Avg Load Labor Req / Shift	Full Load Labor Req / Shift	--	Get WIP	Update Promis	Place WIP	Other 1	Remove WIP	Update Promis	Store WIP	Other 2	Total Time
SPUT03	0.10	0.10		0.80	0.97	0.92	-	0.77	1.32	0.71	-	5.48
SPUT04	0.08	0.08		0.51	0.63	1.10	-	0.58	0.57	0.28	0.61	4.28
Total	0.18	0.18		1.31	1.59	2.02	0.00	1.35	1.89	0.99	0.61	9.76
				13.4%	16.3%	20.7%	0.0%	13.8%	19.4%	10.1%	6.3%	100.0%

Variables	
Item	
Available time per operator per shift (hr)	12.0
Lunch time (hr)	2.0
Productivity factor %	75%
Productive hours by operator by shift (hr)	7.5

WSPW 1850

Process	HBT5 M3	HBT5 M2	HBT6 M3	BI-FET5 M3	BI-FET5 M3 MC	BI-FET5 M2	BI-FET6 M3	BI-FET6 M3 MC	BI-HEMPT 4/5	SUM
Seed Metal (SE) Deposition- Sputter	32.1%	22.8%	9.0%	3.4%	3.7%	14.9%	8.2%	6.0%	0.0%	100.0%
Street (ST) "Flash Passivation"- Sputter	32.1%	22.8%	9.0%	3.4%	3.7%	14.9%	8.2%	6.0%	0.0%	100.0%
Reistor Layer (RL) TaN Deposition- Sputtered	32.1%	22.8%	9.0%	3.4%	3.7%	14.9%	8.2%	6.0%	0.0%	100.0%

FLOW MIX BIFET	OVERALL MIX		MIX WITHIN M3/M2/BIHEMT	
M3	95.00%	HBT5 M3	0.00%	32.1%
		HBT6 M3	10.00%	9.0%
		Bi-FET5 M3	0.00%	3.4%
		Bi-FET5 M3 MC	0.00%	3.7%
		Bi-FET6 M3	90.00%	8.2%
		Bi-FET6 M3 MC	0.00%	6.0%
M2	5.00%	HBT5 M2	50.00%	22.8%
		Bi-FET5 M2	50.00%	14.9%
Bi-HEMT	0.00%	Bi-HEMT 4/5	0.00%	0.0%
TOTAL	100.00%			100.0%

Item	Category	Description
1	Get WIP	Check WIP profile, retrieve WIP, return to workstation, validate wafer ID match to cassette box label
2	Update Promis	Log into Promis, select tool, select lots, validate wafer ID to screen, track in lot
3	Place WIP	Notch finder, slide transfer, load lot into tool, enter lot ID into tool, select recipe for tool, start tool
4	Other 1	All other tasks before tool runs not included in the 1,2,3 above. Place operator manual process for running tool here.
6	Remove WIP	Remove lot from tool, macro inspect wafers, place cassette into its box
7	Update Promis	Log into Promis, select tool, select lot, enter process data, comments, track out of Promis
8	Store WIP	Deliver WIP to next step
9	Other 2	All other tasks after tool runs not included in 6,7,8 above

SPUT03

Task	Time	Time	Time
Get WIP	0.98	0.58	0.83
PrePromis work	0.77	1.57	0.57
Load tool	0.65	1.27	0.85
Other 1			
Unload tool	0.63	0.58	1.08
Post Promis work	2.42	0.83	0.70
Store WIP	0.47	0.98	0.67
Other 2	2.00	1.73	1.95
TOTAL Time/Run (min)	5.92	5.82	4.70
Avg. TOTAL Time/Run (min)		5.5	

Task	Time	Time	Time	Avg Time
Get WIP	0.98	0.58	0.83	0.80
Update Promis	0.77	1.57	0.57	0.97
Place WIP	0.65	1.27	0.85	0.92
Other 1	0.00	0.00	0.00	0.00
Remove WIP	0.63	0.58	1.08	0.77
Update Promis	2.42	0.83	0.70	1.32
Store WIP	0.47	0.98	0.67	0.71
Other 2	2.00	1.73	1.95	1.89
Total	5.92	5.82	4.70	
Average		5.5		5.5

TAPING DUMMY WAFER

Variables	
Item	
Available time per operator per shift (hr)	12.0
Lunch time (hr)	2.0
Productivity factor %	75%
Productive hours by operator by shift (hr)	7.5

		WSPW BIFET		
		1850		
		Goal/day	Runs/day	Total touch time Per day (hr)
Avg. Lot size	24	396.4	16.5	1.51
Full Lot	24	396.4	16.5	1.51

	Avg. Load	Full Load
Total touch time Per day (hours)	1.51	1.51
Touch time per day per shift (hours)	0.75	0.75
Available time per operator (hours)	7.5	7.5
Operators required/shift	0.10	0.10

SPUT04

Task	Time	Time	Time
Get WIP	0.25	0.25	1.02
PrePromis work	0.75	0.50	0.63
Load tool	1.05	0.92	1.33
Other 1			
Unload tool	0.50	0.92	0.33
Post Promis work	0.53	0.75	0.43
Store WIP	0.25	0.27	0.33
Other 2	1.03	0.43	0.37
TOTAL Time/Run (min)	4.37	4.03	4.45
Avg. TOTAL Time/Run (min)		4.3	

Task	Time	Time	Time	Avg Time
Get WIP	0.25	0.25	1.02	0.51
Update Promis	0.75	0.50	0.63	0.63
Place WIP	1.05	0.92	1.33	1.10
Other 1	0.00	0.00	0.00	0.00
Remove WIP	0.50	0.92	0.33	0.58
Update Promis	0.53	0.75	0.43	0.57
Store WIP	0.25	0.27	0.33	0.28
Other 2	1.03	0.43	0.37	0.61
Total	4.37	4.03	4.45	
Average		4.3		4.3

TAPING DUMMY WAFER

Variables	
Item	
Available time per operator per shift (hr)	12.0
Lunch time (hr)	2.0
Productivity factor %	75%
Productive hours by operator by shift (hr)	7.5

		WSPW BIFET		
		1850		
		Goal/day	Runs/day	Total touch time Per day (hr)
Avg. Lot size	24	396.4	16.5	1.18
Full Lot	24	396.4	16.5	1.18

	Avg. Load	Full Load
Total touch time Per day (hours)	1.18	1.18
Touch time per day per shift (hours)	0.59	0.59
Available time per operator (hours)	7.5	7.5
Operators required/shift	0.08	0.08

8.2 Work Instructions

SPUTTER

Operating Instructions

1. If computer screen is dark, touch the screen to wake up

2. Check bottom right of screen, it should be logged in as OPERATOR

3. If not, press the key symbol in the upper right to log in.

   - User name is operator

   - Password is operator

4. If the Cassette 1 platform is not ejected, press VCH1 – Eject – OK

5. Tape a glass monitor to a dummy sapphire mounted wafer

6. Load the monitor wafer into slot 1 (Seed and Flash only)

7. Load up to 24 product wafers into remaining slots

8. Place cassette onto platform being careful that it is fully seated into the slots. If wafers slide forward during placement of the cassette, push the wafers back to the bottom of the cassette.

9. Press the select recipe button for VCH1

10. Select the recipe "specified in Promis"

11. Press OK

12. Press the play button

13. Enter the LOT Id(s)

14. Press OK

15. Verify the information

16. Press Start

17. When the cassette platform is fully in the loadlock, close the door

18. Tool will process all wafers

19. Completed wafers will be displayed as green in the cassette picture

    - Unprocessed wafers will appear grey

    - Wafers with Errors will appear red. – Notify engineering before unloading if any wafers are red.

20. When complete the message "Waiting for VCH Door to be Opened" appears

21. Open the Cassette 1 door

22. Wait for the platform to fully extend before removing cassette.

23. Remove cassette.

24. Place an empty TWV Cassette on the platform – the tool will alarm if you do not.

25. Pump down the loadlock by pressing VCH1 – Load – OK

26. When the cassette platform is fully in the loadlock, close the door

27. The glass monitor thickness will be measured on a KLA-Tencor Profilometer (Seed and Flash only)

28. The glass monitor resistivity will be measured on a Lehighton resistivity measurement system. (Seed and Flash only)

29. If chart is out of control follow OCAP WB-PC0933.

ALLOY

Running Product Wafers:

1. Cassette requirements:

- Send Cassette- Standard Black Cassette

- Receive Cassette- Standard Black Cassette

2. One CLEAN bare GaAs mechanical wafer must be loaded into the first slot before the first product wafer in the lot. An MBE reject is acceptable. Do NOT use Silicon dummies. Load wafers so that the flats or notches are down. Handle the mechanical wafer with wands. Do NOT handle mechanical wafer with hands.

3. Load the send and receive cassettes on each elevator, making sure to turn the mounting lever/knob towards you so that the cassette sits firmly on the platform. Release the mounting lever/knob so that it is holding the cassette in place. Verify that each cassette is mounted correctly by making sure that the white LED light is on. Place wafers to be processed on the elevator on the right side of the system.

4. Press the RUN button on the Main Menu Screen.

5. The recipe list will appear on top of the system diagram.

6. Select the correct Recipe according to Promis instructions.

7. Then press the DOWNLOAD button.

8. Press the START button.

9. At this point a window will appear asking "Enter Wafer Count to Search". Touch the box (it will always have a 3 in it by default) and enter the number 25.

- **Note: It will always start counting from slot 1, regardless of whether or not you have a wafer in it.**

10. At this time it will start processing the wafers.

- STOP: This will stop the recipe/wafer processes immediately.

- ALARM: Will let you view the alarms.

- PRINT: N/A

- EXIT: Allowing the user to exit the run display.

11. While the clean GaAs dummy is running, the following should be monitored and recorded during the STEADY step.

12. Record the Pyrometer Temperature of the GaAs dummy, 30 seconds into the STEADY step of the process recipe and enter into Promis.

13. When the wafers have finished processing, the system will give an audible alarm. Pressing the OK button displayed on the AG touch screen can silence it.

14. Unload the cassette in the same fashion by turning the lever/knob mounting bar releasing the cassette.

15. Remove the GaAs dummy by placing the vacuum wand on the top of the wafer.

- Do not attempt to place the vacuum wand between the GaAs dummy and the first product wafer.

- **Note: If resist coated wafers are accidentally ran the operator must place the tool UNSCHEDULED in Promis and notify cell lead, supervisor and process engineer. System needs to be cleaned prior to running product.**

MEI

Lot Procedure:

MEI03T2 or MEI01T3 1:5 HCl:DIW

1. Select Recipe:

2. "HCL TEN"

3. "HCL TWENTY"

4. "HCL THIRTY"

5. OK

6. YES

7. START

8. Enter Lot ID

9. OK

10. Verify Lot ID

11. Verify Recipe

12. OK

System will alarm when done and wafers will stay in QDR until alarm is acknowledged.
OK to acknowledge Wafers will come to Load position Once the etch/dip has
completed, place several cleanroom wipes under the cassette to prevent DI water "drips"
while transferring from MEI to SRD. **DO NOT** place the wipes in the SRD. Wipes may
be re-used if clean. Once transferred to the SRD, Press Start

Lot Procedure:

MEI03T4 or MEI03T3 2% NH4OH

1. Select Recipe:
2. "NH4OH PRECLEAN"
3. "NH4OH SHORT"
4. "CC_PRECLEAN"

5. OK

6. YES

7. START

8. Enter Lot ID

9. OK

10. Verify Lot ID

11. Verify Recipe

12. OK

System will alarm when done and wafers will stay in QDR until alarm is acknowledged. OK to acknowledge Wafers will come to Load position Once the etch/dip has completed, place several cleanroom wipes under the cassette to prevent DI water "drips" while transferring from MEI to SRD. **DO NOT** place the wipes in the SRD. Wipes may be re-used if clean. Once transferred to the SRD, Press Start

Lot Procedure:

MEI03T2 or MEI01T3 1:5 HCl:DIW

1. Select Recipe:

2. "HCL TEN"

3. "HCL TWENTY"

4. "HCL THIRTY"

5. OK

6. YES

7. START

8. Enter Lot ID

9. OK

10. Verify Lot ID

11. Verify Recipe

12. OK

System will alarm when done and wafers will stay in QDR until alarm is acknowledged. OK to acknowledge Wafers will come to Load position Once the etch/dip has completed, place several cleanroom wipes under the cassette to prevent DI water "drips" while transferring from MEI to SRD. **DO NOT** place the wipes in the SRD. Wipes may be re-used if clean. Once transferred to the SRD, Press Start

AMR

AMR02 - 6" system

Pre-Process checks

- Wafers for metal lift off process **require** the use of a **dedicated** output cassette on the Takatori AMR02. The dedicated cassette is used to ensure that no pieces of tape and / or tape adhesives are transferred to the original lot cassette. There are two types of dedicated cassettes: most are **light blue** in color to differentiate them from the standard black cassettes and there are also black cassettes with a blue plastic label "Tape Liftoff" adhered to the front. Only these two types of cassettes should be used for the output cassette on the AMR tools.

- The original black cassette should be transferred with the lot to the Backside area. Once the wafers have been through Wet

- Strip in an SSEC tool they can be transferred back into the black cassette for further processing. Return the blue cassette and/or the black cassete with the blue label to the AMR tools for future lots.

Prior to running a lot

- Check the lot to be run in Promis to assure that all previous steps have been completed, that the correct wafers are present and that the lot is at the correct step. If not, return the lot to the previous workstation for corrections.

Running the AMR02 Taper / Detaper

- If the tool has been shut down or any reason ,turn the key clockwise until the POWER light on the main panel is lit. See the image below. Once the tool is active go through Step #3 in the "Pre-Process Checks" sections.

- Track the lot(s) to be run into the tool in Promis. The AMR02 system can process up to 25 wafers at a time.

  - There are three recipes on the AMR02 tool. The recipe used depends on the layer being run. Refer to the list below for selecting the correct recipe.

    Layer to be tape lifted Recipe to be used

    Emitter Contact and Collector Contact Thin Metal

Gate Gate

M1, M2 and M3 Thick Metal

- o The Thin Metal and Thick Metal recipes are very similar and use the same machine settings. The Gate metal is more difficult to lift off so the internal tool settings are different and the Gate recipe also takes longer to lift off the metal. Note: To use two different sets of machine settings the Thin and Thick Metal recipes use the 6" machine settings while the Gate recipe uses the older 4" machine settings. When the gate recipe isselected and shown on the main screen the Wafer Size will be listed as 4" because of the machine settings that are being used. Even though it uses the 4" settings only 6" wafers can be processed on AMR02.

- To select the correct recipe:

  - o Press the **RECIPE SET** button on the main screen (see the image below).

  - o The following screen will appear. Press the RECIPE LIST icon the upper right corner.
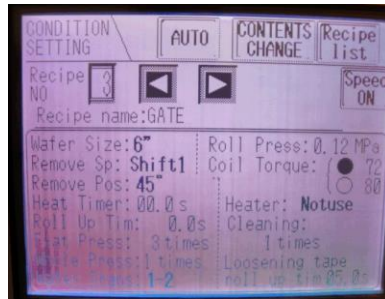
o   The following screen with the list of available recipes will appear. Press

the recipe to be run and then press END. (see the image below).
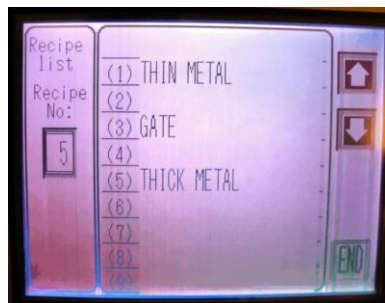
o   When you press the END button the following screen will appear. Press
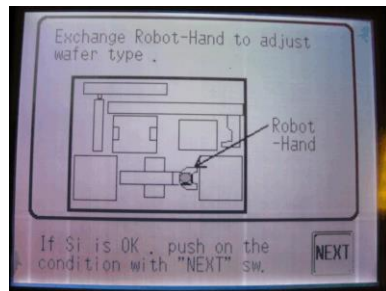
AUTO to return the main screen.

Note: If the screen doesn't change when you press the AUTO button check

to ensure that one of the 3 production recipes is listed after RECIPE

NAME. If an empty recipe number was selected the recipe name will be

blank and the tool won't allow the AUTO screen to appear.

o   Because there are two sets of internal machine settings used, additional

screens will be shown when changing from Gate to Thick or Thin Metal

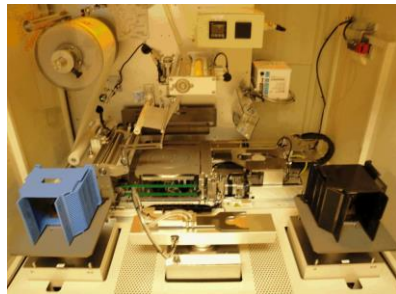and when the tool is switched from Thick or Thin Metal back to the Gate recipe.

- o The next screen to appear is shown below. Press NEXT in the lower right corner to proceed.

- o After pressing NEXT the following screen will appear. Press NEXT to proceed.
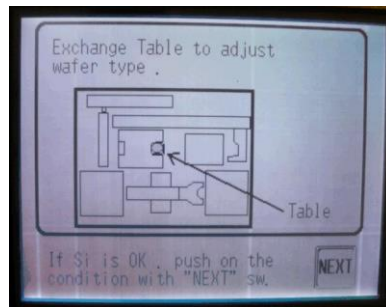
- Once the tool has returned to the main screen and the correct recipe has been verified according to the procedure above, open the two front doors.

- Place an empty blue cassette in the unload station on the left and place the lot(s) to be run in the load station on the right. (see the image below)

- Close both doors.

- Verify that the green START button is blinking. If the START button is blinking proceed to the next step. If the START button is not blinking go to the section below titled "**Re-initializing the Taper / Detaper**".

- Press the green START button once. After approximately 2-4 seconds the tool will automatically start.

- When the lot is complete an audible alarm will sound. Press the RESET button on the main panel once to silience the alarm.

- Open the two front doors. Remove the blue cassette with the processed wafers and the empty black cassette.

- Close both doors unless another lot is ready to be processed.

- Verify that all wafers are present and track the lot out in Promis.

- Bring the lot with the empty black cassette to the Backside area for Wet Strip processing.

AMR03 - 6" system

Pre-Process checks

Wafers for metal lift off process **require** the use of a **dedicated** output cassette on the Takatori AMR03. The dedicated cassette is used to ensure that no pieces of tape and / or tape adhesives are transferred to the original lot cassette. There are two types of dedicated cassettes: most are **light blue** in color to differentiate them from the standard black cassettes and there are also black cassettes with a blue plastic label "Tape Liftoff" adhered to the front. Only these two types of cassettes should be used for the output cassette on the AMR tools.

- The original black cassette should be transferred with the lot to the Backside area. Once the wafers have been through Wet

Strip in an SSEC tool they can be transferred back into the black cassette for further processing. Return the blue cassette and/or the black cassette with the blue label to the AMR tools for future lots.

Prior to running a lot

Check the lot to be run in Promis to assure that all previous steps have been completed, that the correct wafers are present and that the lot is at the correct step. If not, return the lot to the previous workstation for corrections.

Running the AMR03 Taper / Detaper

- If the tool has been shut down or any reason ,turn the key clockwise until the POWER light on the main panel is lit. See the image below. Once the tool is active go through the "Pre-Process Checks" section.

- Track the lot(s) to be run into the tool in Promis. The AMR03 system can process up to 25 wafers at a time.
    - Only M1, M2 and M3 for BiFet/HBT and ThickMetal for 6" pHEMT are qualified to be run on AMR03.
    - Prior to running a lot on AMR03 verify that the correct recipe is displayed on the main screen. M1 lots need to be processed with

Recipe #7 METAL 1. M2, M3 and ThickMetal need to be run with

Recipe #5 THICK METAL.

- o To change the recipe on AMR03 do the following:
  - ▪ The control panel on the tool is a touch screen. Use your finger
    to select CONDITION SETTING. See the image below.

  - ▪ At the next screen, use the left/right arrows to toggle through
    the recipe list. Select either Recipe #5 for THICK METAL or
    Recipe #7

    METAL 1. The image below shows the recipe for METAL1.

  - ▪ Once the correct recipe is displayed touch the AUTO button to
    return the tool to the main screen.

- o Open the two front doors.

- Place an empty blue cassette in the unload station on the left and place the lot(s) to be run in the load station on the right. (see the image below)

- Close both doors.

- Verify that the green START button is blinking. If the START button is blinking proceed to the next step. If the START button is not blinking go to the section below titled "**Re-initializing the Taper / Detaper**".

- Press the green START button once. After approximately 2-4 seconds the tool will automatically start.

- When the lot is complete an audible alarm will sound. Press the RESET button on the main panel once to silence the alarm.

- Open the two front doors. Remove the blue cassette with the processed wafers and the empty black cassette.

- Close both doors unless another lot is ready to be processed.

- Verify that all wafers are present and track the lot out in Promis.

- Bring the lot with the empty black cassette to the Backside area for Wet Strip processing.

Re-initializing the Taper / Detaper systems

- If the tool needs to be re-initialized, follow these 4 steps:

    1. Open both doors and remove all cassettes.

    2. Close both doors.

    3. Press the ORIGIN button on the main screen for approximately 1-2 seconds. A new menu screen will appear.

    4. Press the ORIGIN button on this second screen for approximately 1-2 seconds. The tool will re-initialize. Verify that the parameters on the main screen are the same as those listed in the "Pre-Process Check" section above.

Excess metal

- Excess metal may be left after tape lift off and will appear as shiny spots on the wafer. The image below shows a lot with excess metal.

- A small amount of excess metal is normal and will vary depending on the device type. Device with spiral coils in the design tend to leave more excess metal. Any wafers with excess metal similar to the image above can be sent on. The small amounts of excess metal will be removed with the wet strip that follows tape liftoff.

- Any wafers that have large areas of continuous, unlifted metal that covers more than 10% of the wafer surface should be held for Process Engineering and the tool should be put to ProEval in Promis.

8.3 Financial Analysis

<table>
<tr><td colspan="8">MQP Recommendation for Skyworks Solutions Inc.</td></tr>
<tr><td colspan="8">Auxiliary Data (assumed)</td></tr>
<tr><td></td><td></td><td>100.0</td><td>logins/hour</td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td>12.0</td><td>hour shift</td><td></td><td>8.3</td><td>login/hour</td><td></td></tr>
<tr><td></td><td></td><td>100.0</td><td>operators</td><td></td><td>833.3</td><td>login/shift for all operators</td><td></td></tr>
<tr><td colspan="8"></td></tr>
<tr><td colspan="8">Mock Trials</td></tr>
<tr><td colspan="2">Without Scanner</td><td>8.1</td><td>sec</td><td></td><td>6750.0</td><td>sec</td><td>112.5 min 1.9 hours/shift</td></tr>
<tr><td colspan="2">With Scanner</td><td>2.5</td><td>sec</td><td></td><td>2083.3</td><td>sec</td><td>34.7 min 0.6 hours/shift</td></tr>
<tr><td colspan="8"></td></tr>
<tr><td colspan="2">Savings</td><td>1.3</td><td>hours/shift</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="8"></td></tr>
<tr><td colspan="2">there are 2 shifts/day</td><td>2.6</td><td>hours/day</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2"></td><td>18.1</td><td>hours/week</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">(only 50 weeks b/c of vacations)</td><td>907.4</td><td>hours/year</td><td></td><td></td><td></td><td></td></tr>
</table>

Scanners Financial Analyis

wage/hour	$	26.00	Scanner Cost	$ 238.99
Estimated Interest Rate		5%	Workstations	16.0
Time Frame of investment		5 years		
Initial Cost	$	3,823.84		
Savings per Year	$	23,592.59		
Net Present Worth of Investment		$102,143.58		

$23,592.59 $23,592.59 $23,592.59 $23,592.59 $23,592.59

1   2   3   4   5

(years)

-$3,823.84

Sensitivty Analysis	
Interest Cost	**Net PW of Investment**
3%	$ 108,047.17
4%	$ 105,030.03
5%	$ 102,143.58
6%	$ 99,380.58
7%	$ 96,734.29
8%	$ 94,198.38
9%	$ 91,766.96
10%	$ 89,434.49