

Engineering Management  
Field Project

# **Process Development Plan for the In-line Inspection and Rework of Printed Circuit Boards**

By

Anthony Bill Lee

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Herbert Tuttle                      Date  
Committee Chairperson

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Linda Miller                      Date  
Committee Member

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Tom Bowlin                      Date  
Committee Member

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## **Executive Summary**

PCBnation is a leader in GPS-based navigational devices for the aviation industry. The company is vertically integrated and thus assembles all of its products internally from the individual piece parts to the final product. PCBnation's Printed Circuit Board (PCB) assembly department is responsible for manufacturing all of PCBnation's printed circuit boards. Process engineers within this department have made significant strides in updating equipment to the latest technology and thus improving efficiency, quality and capacity at the same time. However, now that the PCBs are being assembled much faster, the PCB quality inspection and rework process has become the bottleneck within the assembly process.

This process development plan was created to solve the manufacturing throughput issue within PCBnation's Surface Mount Technology (SMT) Total Quality Assurance (TQA) process. The new "inline" SMT TQA inspection and rework process proposed in this document is designed to eliminate the throughput issue by targeting and eliminating the weaknesses of the current process. Some of these weaknesses include database transaction errors, unplanned rework from damaged components, undetectable supplier defects and excessive Non-Value Added work.

# Chapter 1

## Introduction

Since the release of PCBnation's new M1 avionics suite in 2002, PCBnation's Operations group has been challenged with significantly more orders than originally forecasted. This situation has challenged process engineers to increase capacity and efficiency within manufacturing. The picture below shows PCBnation's M1 avionics suite installed inside the cockpit of a five passenger business jet.



One area of manufacturing that has received significant attention from process engineers is the surface mount technology (SMT) area where the printed circuit boards (PCBs) are produced on three separate assembly lines. This area is the beginning of the final unit assembly and drives the factory's overall throughput. In September 2005, process engineers implemented the third high-speed assembly line in anticipation of the M1 release. Despite this addition, the SMT area was still struggling to keep up with demand and was forced to work weekends to keep the factory from shutting down.

Most recently in July of 2007, process engineers replaced the two remaining SMT assembly lines with the most recent high-speed technology. This upgrade has given the SMT area the breathing room they need to complete their demand without any overtime required.

Unfortunately, this increased speed and capacity has created another throughput issue in the factory. The SMT Total Quality Assurance (TQA) inspection and rework process is now a bottle neck for moving product to THT, the second and final area of circuit board production.

## **Background**

PCBnation's circuit board assembly consists of two major processes; surface mount technology (SMT) and through hole technology (THT).

The SMT circuit board assembly is the first major step in the assembly process. This area consists of three assembly lines that produce close to 100 different circuit boards. However, it takes about four to five weeks to build all of the different circuit boards. Within a given day, the SMT area may complete four to eight different circuit boards.

Printed circuit boards (PCBs) are built in large quantities at SMT ranging from 30 to 1000. This quantity is determined by how long the setup time is for each job. Each line needs to produce a large enough quantity to help recover the setup time, which can last anywhere from 15 minutes to 3 hours.

The next major step in the PCB assembly process is THT. The THT area works completely different than SMT and builds to a "daily rate". This rate comes from the final unit assembly. So, if the final unit assembly cells build 20 audio panels on one day,

the THT area will backfill that assembly cell with 20 more circuit boards. The THT area will complete 30-40 different boards in a given day.

Between the SMT and THT processes, however, there is a SMT TQA inspection and rework process where each board is manually inspected for defects. This step is required before the PCBs can be transferred from SMT to the THT area. Currently, the SMT TQA process has been unable to keep up with the demand from THT. To overcome this, associates are required to work excessive amounts of overtime to catch up.

This “off-line” inspection and rework process is the focus of this process development plan.

### **Current Process Challenges**

There are several aspects of the current SMT TQA inspection and rework process that reduce efficiency through this area. First, there is an extremely high amount of Non-Value Added (NVA) work associated with the process that prevents the required amount of work from being completed. Second, there is potential for massive amounts of rework due to supplier related defects. Third, the process requires more handling of the PCBs which increases the opportunity of broken components on the circuit board. Fourth, the process presents numerous opportunities for Oracle transaction errors. Finally, there are times when THT can not assemble any boards because SMT TQA hasn't completed their inspection process for a particular PCB.

The excessive amount of NVA work is the main contributor to the inefficiencies in the current process. The current SMT TQA process operates on a “daily rate” basis similar to THT. THT works as the signal for the SMT TQA operators to perform their

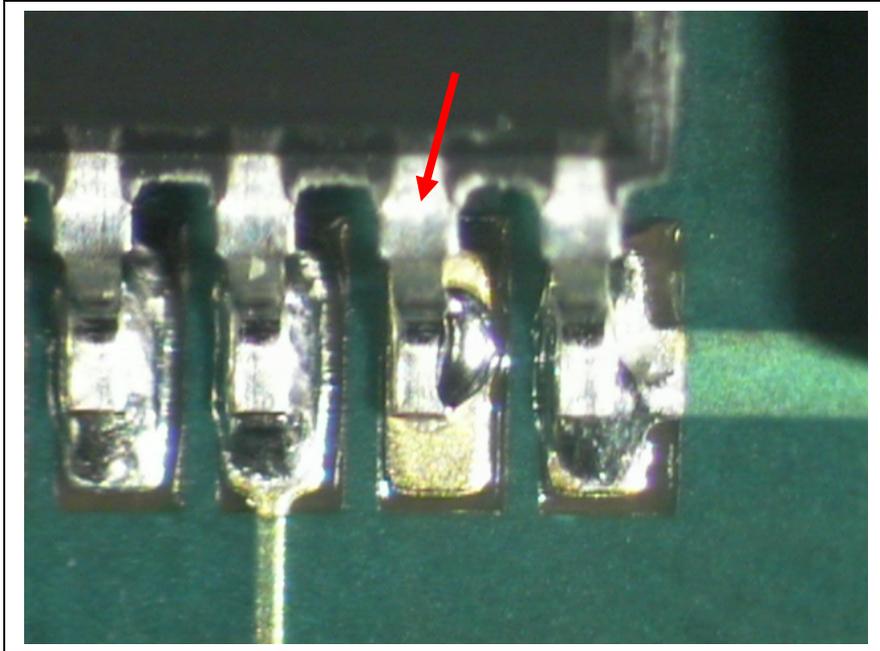
inspection process. If THT consumes 20 audio panel main PCBs, SMT TQA backfills THT with 20 more.

The daily rate concept requires the SMT TQA associates to perform several NVA tasks in order to complete the process. First, they have to leave their workstation and walk to the copy machine to make a copy of the shop order (the shop order is a paper document that accompanies the product through the assembly process and instructs the associates to perform work). This copy is required because the signal from THT is only a fraction of the overall quantity on the shop order. Next, the SMT TQA associates have to locate their specific product within the SMT PCB stocking area and bring the boards to their workbench. Once the boards are inspected, the associates have to leave their workbench yet again to deliver the inspected product to the THT PCB Stocking Area. Once the delivery is made, the associate must return to the Oracle Station to clock out of the shop order and claim the quantity that was inspected. The next page shows a layout of the factory with the items mentioned above highlighted.



A study was recently conducted within the SMT TQA area to better understand the actual NVA time that was involved. This study involved placing a camera over the top of the inspection area so both inspection operators were in view. The camera simply recorded the actions of the associates for two full days. On average, associates were away from their workstation 2.53 hours during their shift. Because of this, inspection associates are required to work overtime to keep up with the demand. This also creates a situation where more defects escape the inspection area. During the last three months, defect levels have increased 15%. This is unacceptable and needs to be addressed.

The next challenge PCBnation faces within the SMT TQA area is the potential for large amounts of rework due to “hidden” defects from the supplier. On occasion (two or three times per year), the bare circuit boards that PCBnation purchases from outside vendors have defective plating. This type of defect is undetectable until the boards are actually assembled and completed at SMT. Therefore, the current process prevents the inspection associates from finding the defects until the entire run is complete. So, depending on which specific circuit boards are defective, manufacturing may end up with over 1000 different boards to rework. The photo below is an example of a plating defect and how it will prevent SMT from achieving acceptable solder joints. On any given board, there will be 20 to 30 of these defective locations scattered throughout the board.



The second lead from the right has an “unwetted” defect condition due to supplier contamination on the gold plated pad.

Not only is unwanted rework generated by outside suppliers, but it is also generated internally as well. One of the main contributors to rework is damaged components from reckless handling of the circuit board. The current process requires a large amount of handling.

First, the boards are collected into “magazines”, which are glorified racks that stack the boards automatically as they come off the assembly line. Next, the boards are automatically forced out of the magazine and into an automated optical inspection machine. Once through that machine, the boards are loaded into another magazine. Once the magazine fills, the SMT operators manually transfer the PCBs to board racks. The PCBs are spaced very tightly on these racks thus creating another opportunity for damage when sliding the boards in and out of the rack. Next, the boards are removed

from the racks at the time of inspection. Once inspected, the boards are re-racked onto another rack and transferred to the THT assembly area. All of this handling creates opportunities for damage. Currently, 20% of all PCB defects are related to handling damage.

The fourth major challenge the current inspection process presents is the opportunity for transaction errors within Oracle. When PCBs are inspected and ready to move to the next process, the exact quantity has to be entered into Oracle. Since the process operates at a daily rate, each inspection associate may load 20-30 transactions into Oracle per shift. This also creates a huge opportunity for error. Not only do the erroneous transactions create inventory discrepancies, but they also force management to spend at least one hour fixing the problem per transaction. This takes away from their ability to consistently manage their areas. Without continuous supervision, many people are unmotivated and won't perform their tasks efficiently.

Finally, the current process has been known to completely shut down the assembly of certain products due to PCB unavailability from the SMT TQA area. Granted, this only happens 1.7 times per month on average, but if several SMT TQA inspection associates are absent on the same day, it is a challenge for that area to keep pace with the normal demand from THT.

# Chapter 2

## Literature Review

A literature review was conducted to research the topic of inline inspection and rework of printed circuit boards. There was a great deal of general information regarding manufacturing and inline approaches to fabrication of numerous products. Included with all of that information were the numerous references to the Toyota Production System (TPS) and Six Sigma. Because there were thousands of books and articles on these topics, the search was narrowed down to the manufacturing of printed circuit boards specifically.

When researching topics on inline rework of printed circuit boards, it was important to find books, journals and articles that were written within the last 4-5 years. The printed circuit board industry has changed almost as fast as the computer industry. Each year, the technology gets faster and more reliable. Companies in the PCB fabrication industry are coming out with new equipment each year that essentially trumps their previous version.

An extensive search was performed for information regarding in-line rework of printed circuit boards after the reflow process (post-reflow). Surprisingly, there was no information available that supported an inline process for post-reflow rework. **This lack of information supported the need for this paper and the process development plan it contains.**

Despite the absence of information about post-reflow rework, there were several journal entries and articles supporting pre-reflow rework. Here is how the pre-reflow

rework process works. After the SMT placement machines populate the individual components on the PCB, the fully populated assembly is conveyed into an automated optical inspection (AOI) machine that inspects the circuit board using a camera. The machine takes several pictures of the PCB and processes the information within approximately 20 seconds. The machine verifies that all the correct parts are placed and also ensures the parts have the correct position and orientation. If there are any errors on the PCB, the board moves into an inline rework station where the defect is corrected by the SMT operator within 60 seconds. Each PCB has a different number of placements on it. Therefore, the PCBs with the most placements have a higher opportunity for defects. PCBnation's most difficult PCBs have a first pass yield rate of approximately 88%.

The following literature references discuss different aspects of inline inspection and rework of PCBs. Included with the summary of each reference is PCBnation's position on the topic.

**“Using in-line inspection to improve PCB assembly yields”, Harikrishna Bhat and David Clark, Electronics Engineer, December 1999**

The authors of this article fully support the implementation of an inline pre-reflow inspection and rework process. In their experience, over one-half of all SMT defects are related to misaligned or missing components. Therefore, having an inline rework process allows the PCBs to be corrected before moving into the reflow oven. The reflow process is where the solder joints are formed between the PCB and the individual components. Therefore, correcting the defects on the PCB prior to the reflow process saves significant

amounts of time and labor for rework. PCBnation currently has this process in place and estimates that 40% of all defects are able to be corrected before the reflow oven.

**“Realizing the Expectations of AOI”, Matthew Holzmann, SMT Magazine White Paper, 2006**

In this white paper written by the CEO of Christopher Associates, an AOI company, the author finds that the article written by Bhat and Clark isn't true for every PCB manufacturer.

In a recent visit to a European automotive supplier, Holzmann found that the company had moved all of its inspection and rework off-line. They were forced to do this because of the high number of false calls generated by the AOI equipment and the constant requirement for an operator to be present to confirm the false calls. The AOI only slowed the assembly line down and didn't produce the quality improvement the engineers had hoped.

The movement of inspection and rework off-line isn't the answer. The engineers responsible for the AOI systems need to create a much more robust inspection library to eliminate the false calls. By eliminating the false calls, the process will not slow the assembly line and will catch legitimate defects as they arrive. Another benefit that inline inspection and rework has is the ability to track defect trends and correct these defects as the line is running.

**“Inspection Yesterday and Tomorrow – In Japan”, Sakie Akiyama, SMT Magazine, February 2001**

The author of this article supports the use of an inline inspection and rework process, especially for high-volume production of PCBs. However, the author says that an inline process is conditional. In order for a company to successfully implement an inline system, their process has to meet the following conditions: the inspection process must not be the bottleneck within the line and off-line programming must be available to create and debug programs without stopping the assembly line. PCBnation currently has these options available, so the in-line system currently at PCBnation is justifiable.

Ms. Akiyama also mentions that inline inspection and rework is beneficial since it gives the SMT operators and engineers instant feedback about defects that are being found on the current production run. PCBnation has been able to realize this benefit and have lowered their defects per million opportunities by 78% since installing its solder paste and pre-reflow inspection equipment. In an effort to reduce these defect levels even further, PCBnation needs to implement an inline post-reflow inspection and rework process.

***Inline Component Placement Inspection: Lowering PCB Assembly Costs with Continuous Quality Improvement, Bob Kelley and John Weisgerber, December 2006***

Kelley and Weisgerber support the notion of inline inspection at SMT because it provides the data and knowledge needed for continuous quality improvement (CQI). Implementing CQI will allow companies to produce PCBs at a lower cost with a much higher level of quality.

Another reason the authors support the inline process is due to its powerful information that is provided by statistical process control (SPC) tools. These tools allow engineers to study the information in-depth and provide them a roadmap for what defects need to be eliminated next. If the inline inspection is positioned as close to the source as possible, it will allow the defect source to be eliminated almost immediately after a defect trend starts. This prevents the entire run of boards from having the same defects.

**“Anorexic Manufacturing: When it Banishes In-line Inspection, Lean has Gone Too Far”, Phil Zarrow, ITM Consulting, Circuits Assembly, October 2006**

The author of this article has seen numerous companies adopt the Lean Manufacturing concept and take it too far when they eliminate inline inspection within their SMT lines. Lean Manufacturing concepts target activities that don't add any value to the product and waste time and labor. When companies remove inline inspection from their SMT process because there is no perceived value being added or that it slows down the process, that company is taking an extreme risk of having significant amounts of labor for reworking defects. Removing important parts of the process due to Lean Manufacturing is what the author calls “anorexic manufacturing”.

Again, this author argues the inline inspection is essential in SMT assembly and it allows manufacturers the ability to immediately target the source of the problem. On numerous occasions (way too many to count), PCBnation's inline AOI equipment has identified defects at the beginning of a production run that would have resulted in significant rework. However, because the defect was captured on the first PCB of the

production run, the error was able to be fixed and the remaining PCB assembled correctly.

### **Literature Review Summary**

The support for inline inspection by these industry experts further justifies the need for inline post-reflow inspection at PCBnation. PCBnation currently has the inline inspection of solder paste and component placement, the two processes that create the most opportunity for defects. To take the next step towards eliminating defects, PCBnation needs to implement inline inspection and rework after the reflow process. This will complete the full range of quality inspection possible with the SMT assembly process.

# Chapter 3

## **The New Process**

The new process involves transforming the current “off-line” post-reflow inspection process into an “inline” process. Therefore, once the boards are fully assembled, they will be immediately inspected as they come off the end of the line. This post-reflow inline inspection idea was a result of many things. First, the group of four process engineers that work on PCBnation’s SMT process have 35+ years of manufacturing experience. This experience includes aerospace and automotive production where 100% of the assembly was done using an inline process. Next, as previously stated, PCBnation process engineers have witnessed the significant quality improvements from the other inline inspection equipment currently in place. Finally, it has been recognized that all of the challenges within the current process can be eliminated by making this one simple change.

Process engineers estimate that the current non-value added work will be reduced by 60%. There are several reasons for this. First, the inline process significantly reduces the need for the inspection associates to leave their workbench to enter the 20 to 30 different Oracle transactions per shift. Since the assembly lines only average 4 to 5 different boards per shift, the same number of transactions would be required by the TQA associates. Second, process engineering plans to install Oracle on all the inspection computers so the transactions can be completed at their workbench. Finally, the time required to find boards to inspect and then deliver the boards to the THT area is will no longer be required. The boards will be delivered automatically by conveyors to the

inspection associates. Once the boards are inspected, they will be placed in a stocking location adjacent to the inspection area. The THT area will be required to locate the PCBs they are planning to build.

The next challenge the new process engulfs is the large amounts of rework due to hidden supplier defects. Since the boards will now be inspected immediately after they are built, these defects will be detected very early in the production run and the problem can be addressed before the entire shop order quantity is complete. Reworking 10 to 15 boards versus 500 to 600 is very manageable. Process Engineering estimates that 95% of our supplier related rework will be eliminated.

The other contributor to rework, handling, will also be greatly reduced. The handling steps that currently position and remove the boards from the racks will no longer be required. Therefore, process engineers estimate that a 75% reduction in rework due to damaged components can be realized. This prediction is based on the fact that PCBs will be handled less frequently than before, thus reducing the overall opportunity for damage.

The next challenge that is addressed by the new process is Oracle transaction errors. As stated before, TQA associates will only be required to enter 4 to 5 transactions per shift instead of the current 20 or 30 transactions. These few transactions will be for the entire quantity on the shop order. There is no subtraction involved that is currently required with the daily rate process. This will make the transactions less complicated and very straight forward. Process engineering is predicting a 99% reduction of all transaction errors at SMT TQA.

Finally, the situation where THT assembly is unable to build because of shortages from SMT TQA will no longer exist. Since all boards will now be fully inspected immediately after assembly at SMT, the THT associates are able to retrieve the PCBs they need from the stocking location. They no longer have to wait for SMT TQA to complete their inspection process before they can obtain the necessary PCBs.

### **Work Breakdown Structure**

In order for the new inspection process to become a reality, there are several action items that need to occur. These action items are listed below in the order in which they must occur.

- *Capacity Planning*

Capacity planning will be conducted by the Production Manager in conjunction with process engineering. Their job is to determine whether our current staff will be able to handle the process change based on the time standards developed by process engineering. They must also consider planning's current product forecast and any new products that will be starting production in the next year. This capacity planning is scheduled for a two-week period.

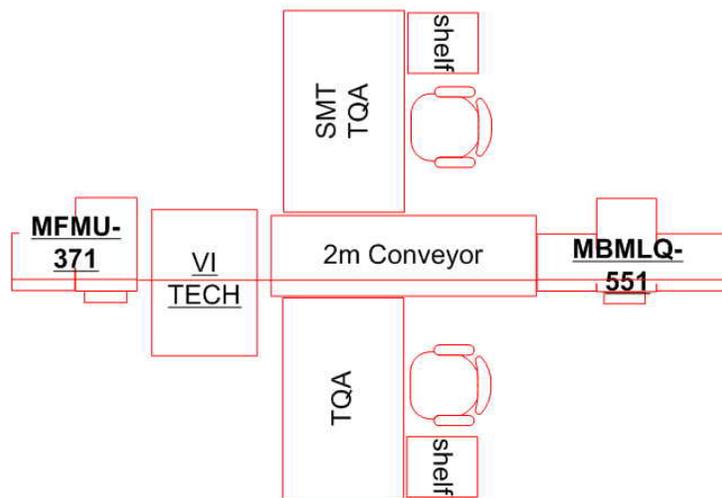
- *Hire New Employees (if required)*

The hiring of new employees will also be conducted by the Production Manager in conjunction with Human Resources. Interviews, reference calls and paper work can take at least 10 business days, so this section is scheduled for a two-week period and starts after the first interview. If the hiring of new

employees is not needed based on the capacity results, process engineering can immediately start with the relocation of equipment.

- *Relocation of Equipment*

In order for the process to flow properly, process engineering, along with the maintenance technicians, will have to implement a two-stage conveyor between the two inspection work benches. This conveyor will deliver boards to the inspection associates on one stage and then deliver the inspected boards to a magazine unit on the second stage. All the equipment will have to be properly aligned and leveled to ensure proper transferring of the PCBs. This task can easily be completed in one week. The figure below shows the new layout of the inspection area.



- PCBs waiting to be inspected are inserted into the multi-functional magazine unloader (MFMU).
- The MFMU transfers the PCBs into the VI-Tech automated optical inspection machine where the PCBs are inspected for defects.
- Once the PCBs have been inspected by the VI-Tech, they will transfer onto the 2 meter conveyor and wait for an inspection associate to obtain the PCB.
- After the inspection associates have verified all of the defects, they will place the PCB on the 2<sup>nd</sup> half of the conveyor. The conveyor will then transfer the PCBs into the magazine loading unit (MBMLQ).

- *Creation of Automated Oracle Report*

An Oracle Master Planner will be responsible for creating an automated report that will replace the current “dual card kanban” process. This process is currently used to release new work orders when the current orders reach a specific minimum balance while being stored within the SMT PCB stocking area. The SMT TQA associates are currently responsible for releasing the new work orders. This new Oracle report will take that responsibility away from production associates and turn it over to the planning group.

The report will query several different fields in Oracle to determine whether the inventory in AWIP (work in process) has reached the minimum inventory level. Once a particular PCB has reached the minimum balance, that part number will show up on the report notifying planning that a new work order needs to be generated. Due to a back order of report requests, it will take at least two weeks for this report to become a reality.

- *Operator Training*

Process Engineering will be responsible for training the inspection associates. The new process only requires a few minor changes, but it will be a challenge to receive the approval from the inspection associates in regards to the new process. The most important portion of the training will be the operation of the new conveyor and prioritizing the circuit boards that need to be inspected. Operation of the AOI equipment will also be essential for the project to run efficiently. Process engineering is confident this training can be completed in 1 week.

- *Pilot Run and Implementation*

The process's pilot run is very critical. This is the opportunity for process engineering to see the weaknesses of the process first hand and realize any problems that were overlooked during the planning process. The pilot run period will also be the time when the new Oracle report is tested and validated. The pilot run is scheduled for a two-week period.

- *Collection of Feedback and Process Tweaking*

During the pilot run, process engineering will be collecting feedback from the inspection associates regarding problems and potential improvements to the process. The inspection associates are the best resources for information, so this information needs to be taken seriously. This will occur simultaneously with the pilot run and extend one additional week so nothing is missed.

- *Update Documentation and Work Instructions*

Once the process is fully implemented and de-bugged, process engineering will be responsible for updating all documentation and work instructions that affect the SMT TQA inspection area. All of this needs to be done rather quickly to minimize confusion, but there are quite a few items that need to be updated and approved. Therefore, two weeks has been allotted for this task.

- *Monitor the Process*

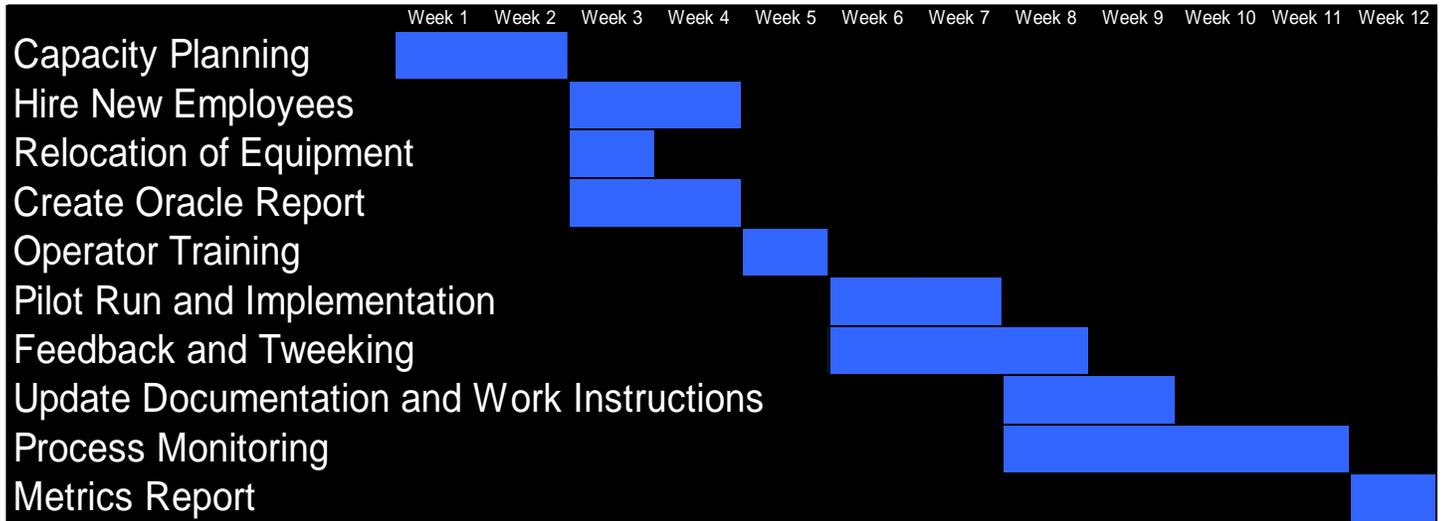
Constant monitoring of the process will be conducted by process engineering for one month after the pilot run is complete. During this time, statistics will be gathered from the time before the process change and compared to the results that come in during this period.

- *Create Metrics Report*

Once all of the data has been collected during the monitoring task, a final report will be submitted to upper management showing the improvements the process change has had on the SMT TQA process. Process engineering should be able to complete the report in one week's time.

## Project Shedule

All of these action items will be completed using the following 12-week schedule.

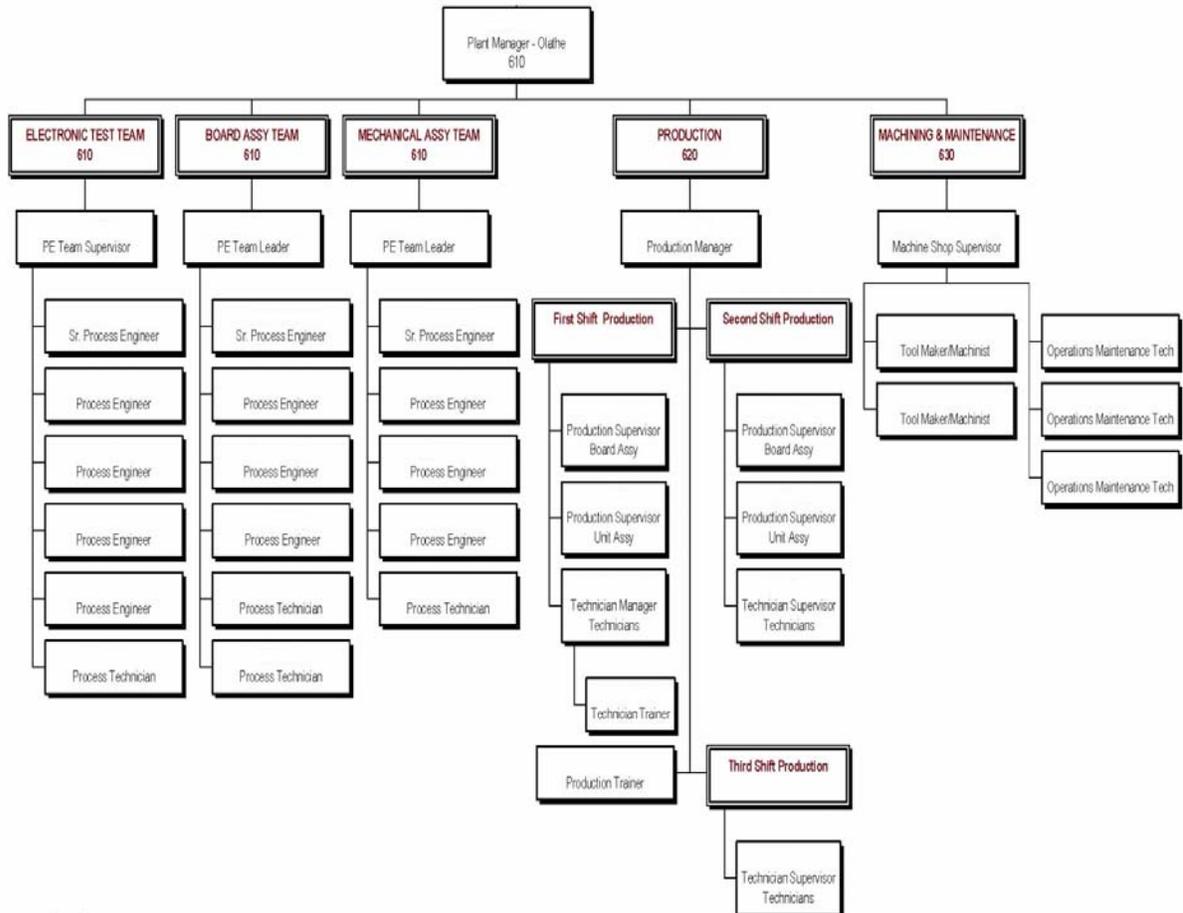


## Organizational Chart

The following organizational chart shows the relationship between all of the parties responsible for the tasks. Human Resources and the Oracle Master Planning team are not shown since their groups are completely separate from the manufacturing group.

# Olathe – Manufacturing & Repair

Dept. 610, 620, 630



5/11/2007

## Project Risks

The risks involved with this project are very minimal. Some of the major risks are listed below.

- No Qualified Candidates to Hire – There is a slight chance that no one will be available to hire if the capacity planning indicates new associates are needed. Currently, the company has people lined up at the front doors waiting for an opportunity.
- Oracle Problems – There is the possibility that Oracle could crash and the automated report for releasing work orders will not be available. However, if Oracle did ever crash, this report would be the last concern on IT's mind since the entire operations of the company would also be down.
- Unpredictable Product Demand – There is a possibility that our product demand could increase to a point where the new process would not be able to keep up with the assembly lines. If this ever occurs, overtime will be needed until new inspection equipment can be purchased and new inspection associates hired.
- The New Process Doesn't Work – If the project is implemented and just doesn't make sense, then there's always the opportunity to go back to the original process.

## **Budget**

At PCBnation, process engineering groups have the luxury of not having to worry about budgets. Within the process engineering group, if money is needed for a capital expenditure, a justification is written and presented to management for review. If the expenditure can pay itself off in less than one year, the expenditure is approved with little or no questions asked.

For this project, there are no major expenditures. Time and resources are the only items needed for this project. Thus, no budget was needed.

# Chapter 4

## Conclusion

PCBnation currently has a process limitation within their SMT TQA area. The inspection and rework process that occurs in the area has become a bottleneck for the SMT assembly process. With three high-volume assembly lines feeding into the SMT TQA area and THT demanding a large quantity of PCBs each day, associates are no longer able to keep up with demand. Therefore, a new process has to be implemented to ensure on-time delivery to downstream processes within the factory.

A new inline inspection and rework process within the SMT TQA area will eliminate the weaknesses of the current process. First, non-value added activities will be reduced by approximately 60% through several avenues. Implementation of Oracle software at the associate's workstations will eliminate their need to leave the area to enter quantities into Oracle. The associates will no longer need to leave the area to make 20 to 30 copies of shop orders per shift since they will only be inspecting 4 to 5 different PCBs per shift as they come off the assembly lines. The last non-value activity that will be eliminated is the retrieval and delivery time of PCBs. The PCBs waiting to be inspected will be delivered to the associates by conveyor. Once the PCBs are inspected, they will be stored in the SMT PCB storage area adjacent to the inspection work stations.

Next, the new process will eliminate the potential for massive rework due to supplier related defects. Since the PCBs will be inspected immediately after assembly, defects can be realized quickly and communicated upstream to prevent any further defects. Because of this, process engineers estimate that rework from supplier related defects will be reduced by approximately 95%.

Third, the opportunity of handling damage will be reduced by approximately 75%. This will be achieved through the elimination of additional handling steps that are required with the current process.

Finally, the new process will eliminate the possibility of the THT area not having inspected boards to assemble. Since the boards will be inspected immediately, THT associates will have the entire PCB storage area to obtain PCBs for assembly. Although the PCB shortage at THT happens only 1.7 times per month on average, it creates a ripple effect downstream and ultimately costs PCBnation anywhere from \$5,000 to \$12,000 depending on the shortage.

The new inline process will provide numerous benefits to PCBnation's PCB assembly process for a very small cost. The new process does not require the purchase of any capital equipment and only requires the occasional resources of process engineering, manufacturing supervision and planning for a 12-week period. This is a very small price to pay when the potential yearly savings of this new process is approximately \$115,000.

### **Future Considerations**

As demand increases for PCBnation, process engineers have a plan to purchase two additional post-reflow AOI machines and install the machines inline with each SMT assembly lines. Currently, the single post-reflow machine is able to handle the volume of PCBs coming off the three assembly lines.

## **Bibliography**

**“Using in-line inspection to improve PCB assembly yields”, Harikrishna Bhat and David Clark, Electronics Engineer, December 1999**

**“Realizing the Expectations of AOF”, Matthew Holzmann, SMT Magazine White Paper, 2006**

**“Inspection Yesterday and Tomorrow – In Japan”, Sakie Akiyama, SMT Magazine, February 2001**

***Inline Component Placement Inspection: Lowering PCB Assembly Costs with Continuous Quality Improvement*, Bob Kelley and John Weisgerber, December 2006**

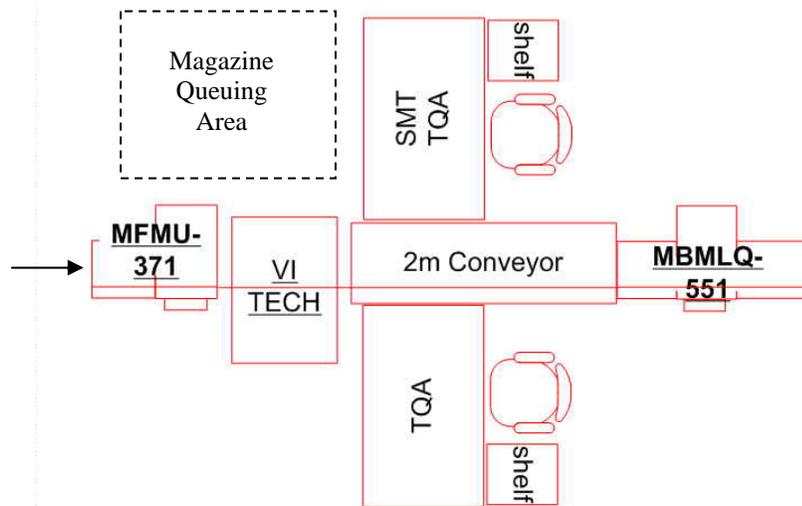
**“Anorexic Manufacturing: When it Banishes In-line Inspection, Lean has Gone Too Far”, Phil Zarrow, ITM Consulting, Circuits Assembly, October 2006**

# Appendix

**SMT TQA Inline Savings**

<b>Issue</b>	<b>Offline Labor per day (Hrs)</b>	<b>Est. Inline Labor per day (Hrs)</b>	<b>Hourly Rate</b>	<b>Savings per day</b>	<b>Yearly Savings</b>
<b>Non-Value Added Work</b>	5.06	3.04	\$121.25	\$245.41	\$64,788.24
<b>Supplier-Related Defects</b>	0.34	0.02	\$121.25	\$39.27	\$10,366.88
<b>Handling Damage</b>	1.42	0.36	\$121.25	\$129.13	\$34,090.65
<b>Oracle Transaction Errors</b>	N/A	N/A	N/A	N/A	\$1,000.00
<b>THT PCB Shortage</b>	N/A	N/A	N/A	N/A	\$5,000.00
				<b>Savings Grand Total</b>	<b>\$115,245.77</b>

## SMT TQA “In-Line” Brainstorming Session



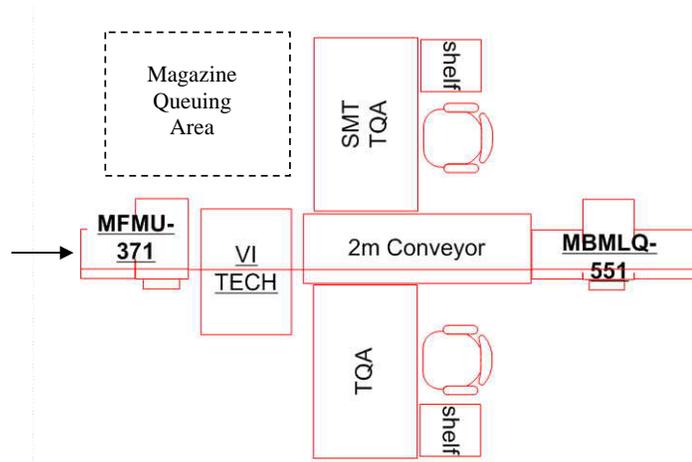
### The Process

- Full magazines of PCBs from all three SMT lines will be delivered to a queuing area in front of the Post-Reflow VI-Tech. These magazines act as a signal for SMT TQA to perform their inspection.
- A TQA associate will load the magazine into the unloader (MFMU-371) and start the VI3k2. TQA associates will then clock into the specific shop order at their workstation via TIMEKEEPER.
- Inspected boards from the VI-Tech 3K2 will exit onto the 2m conveyor and stop between the two TQA desks for an associate to grab and inspect.
- Boards will continue to be inspected by both TQA associates as they come out of the machine. Minor rework and repair will be completed during the inspection process as it is today. Major rework will require the TQA associates to split those individual boards from the shop order for a rework associate to repair offline.
- Single sided boards can be placed directly on a board rack once they are fully TQA'd. Double-sided boards will be placed on the 2<sup>nd</sup> stage of the conveyor and loaded into the magazine loader after side 1 has been TQA'd. This enables the SMT line to load a magazine that's ready for side 2 production.
- Once the entire shop order has been inspected and claimed in Timekeeper, the boards requiring an 012- level assembly at THT/Sel. Solder will be reported to KIP207.
- Boards that do not require a THT process will remain on open shop order and be located in a WIP location after TQA. Their routings will include a final step of depaneling and filling a tote.

## Advantages

- Boards are being inspected “real-time” without having to purchase additional AOI equipment. Mfg. supervision has been promoting this option.
- Board defects affecting the entire run can be realized and corrected immediately. (375-03 contamination)
- TQA associates can no longer pick and choose what they want to inspect.
- Eliminates non-value-added work for TQA associates including the splitting of shop orders.
- Reduces the overall handling of boards, thus reducing the potential of handling damage.
- Allows process engineering to debug post-reflow programs real-time. P.E. currently has to wait for the next run of boards (2+ weeks later).
- Eliminates the need to re-run large quantities of boards that were inspected while the network was down.
- THT will no longer have to wait for boards to be inspected. All boards will be ready for the THT process.
- Eliminates the manual replenishment process in the dual card kanban system. Oracle will be able to track inventories in KIP207 to automatically release SMT shop orders. (?)
- VI-Tech image database for defects will be much smaller and should improve computer processing speed.
- Eliminates daily overtime required for associates to count boards in KIP207.
- Allows SMT Line associates to spend more time on the line for feeder splicing/replenishment by eliminating them from the Post-Reflow AOI setup.

## SMT TQA “In-Line”



### The Process

- Full magazines of PCBs from all three SMT lines will be delivered to a queuing area in front of the Post-Reflow VI-Tech. These magazines act as a signal for SMT TQA to perform their inspection. This is a push system, rather than a pull system. We should always be striving for pull systems (Look to your downstream IPKs to signal which work needs to be done.) In my mind, this method of inspection will be the final part of the assembly process. It is very similar to the process at THT wave, where inspection is performed as assemblies come off the end of the line.
- A TQA associate will load the magazine into the unloader (MFMU-371) and start the VI3k2. TQA associates will then clock into the specific shop order at their workstation via TIMEKEEPER. Will all magazines from a given shop order be batched together or will it be FIFO from all three lines? If FIFO, how will TQA know the correct S/O number and Operation number to clock into? When will they report their quantity; at the end of each magazine? Does SMT report quantity at the end of each magazine? We will use a FIFO system and apply custom labels to the tops of each magazine for the SMT operators to specify the shop order number and the correct AOI program from the MPI. At this point, we have agreed that both the Line operators and TQA associates will claim the entire S/O quantity once their operation is completed. An “in-process” inspection truck (labeled as such) will be positioned next to the TQA line for boards to be stored until the entire shop order is complete. At that point, the quantity will be verified and the racks will be transferred to a truck in KIP207.
- Inspected boards from the VI-Tech 3K2 will exit onto the 2m conveyor and stop between the two TQA desks for an associate to grab and inspect.
- Boards will continue to be inspected by both TQA associates as they come out of the machine. Minor rework and repair will be completed during the inspection process as it is today. Major rework will require the TQA associates to split those

individual boards from the shop order for a rework associate to repair offline. Will major/minor be determined by MINOR<TAKT<MAJOR? Ideally, yes. However, at times it may be difficult to judge whether some rework will take longer than the TAKT time. This is something that will require some monitoring by the BAT and experience by the TQA associates to obtain a good feeling for what can be repaired and maintain pace with the SMT lines.

Major rework is still possible for TQA associates to perform during downtimes in production for setups and changeovers. According to data taken from October and November 2006, TQA should easily keep pace with the SMT lines. The capacity numbers (assuming two inspection people on two shifts) for these two months came out to be 71% and 56%, respectively. I can provide you with this data if you're interested.

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- Single sided boards can be placed directly on a board rack once they are fully TQA'd. Double-sided boards will be placed on the 2<sup>nd</sup> stage of the conveyor and loaded into the magazine loader after side 1 has been TQA'd. This enables the SMT line to load a magazine that's ready for side 2 production.
- Once the entire shop order (how will they know?) The Line operators will clock out and claim the full quantity on their assembly operation and place the shop order on top of the last magazine in the queuing area. This will visually tell the TQA associates that the run as been completed at the line. has been inspected and claimed in Timekeeper, the boards requiring an 012- level assembly at THT/Sel. Solder will be reported to KIP207.
- Boards that do not require a THT process will remain on open shop order and be located in a WIP location after TQA. Their routings will include a final step of depaneling and filling a tote. Why does this have to be a separate step? Is it today? What is the signal for doing this; empty tote from workcell? For boards going directly to the workcell from SMT, there needs to be a "depaneling and tote replenishment" step on the shop order in order to maintain a process that sends the daily demand to the workcell. Without this last step, the entire shop order of boards will show in Oracle as being in the workcell. The physical totes will act as the visual signal for replenishment. We've decided to label these totes with a unique indicator and create a dedicated tote rack for the empty totes to be arranged. This will be an easy visual for replenishment.

## Advantages

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- Boards are being inspected "real-time" without having to purchase additional AOI equipment. Mfg. supervision has been promoting this option. Which option? Real time or more equipment? Ideally, the supervisors would like to have a Vi3k2 in each SMT line along with a dedicated TQA associate. However, the extremely high cost of equipment makes this option un-justifiable. This new option allows for us to TQA boards as close to "real-time" as possible with only one machine.

- Board defects affecting the entire run can be realized and corrected immediately. (375-03 contamination) Great!!!!!!!!!!
- TQA associates can no longer pick and choose what they want to inspect. This doesn't seem to be any different than the latitude that they have today to pick and choose. Within the documented procedure, we will instruct them to inspect using FIFO. Yes, there is still the possibility they can pick and choose one magazine over the other, but their options within this process are at most 3. Currently, they can pick and choose from 25-30 different boards listed on the TQA white board. The two shifts like to play games and leave each other the more time-consuming/difficult boards when they aren't getting along.
- Eliminates non-value-added work for TQA associates including the splitting of shop orders. And what other NVA? OTS (out-of-their-seat) NVA that will be eliminated: making multiple copies of shop orders, retrieving multiple TQA defect sheets from the aisle printer, moving boards to CC/3070/THT/Sub-Assy Cell, filling totes and moving boards to the workcell, clocking in and out of KRONOS, stopping to receive the daily factory gossip.
- Reduces the overall handling of boards, thus reducing the potential of handling damage. Good.
- Allows process engineering to debug post-reflow programs real-time. P.E. currently has to wait for the next run of boards (2+ weeks later).
- Eliminates the need to re-run large quantities of boards that were inspected while the network was down.
- THT will no longer have to wait for boards to be inspected. All boards will be ready for the THT process. Current process should provide this as well if properly executed. You are correct. However, on days where multiple workcells are building close to Dc, TQA gets behind and inspects more boards (and takes more time) than what KIP207 requires. This creates a domino effect over the next few days and certain boards get overlooked. When this happens, THT will be ready to build a board with nothing available in KIP207.
- Eliminates the manual replenishment process in the dual card kanban system. Oracle will be able to track inventories in KIP207 to automatically release SMT shop orders. (?) Leaving us at the mercy of inventory accuracy and with no check & balance visual process. Will we still use dual card calculations to determine lot size? If so, why not keep the final step of the process to signal replenishment? THT could perform this task when they pull from the threshold PCB rack. I have the same concerns regarding the lack of visual signals and the BAT has struggled with finding a perfect solution. However, if we can automate the tracking of inventory levels and shop order releases using Oracle, we are eliminating half of the manual process that is currently in place. Opportunities for inventory accuracies will be reduced significantly on the SMT side of KIP207. Only ONE transaction will be required to move the entire shop order into KIP207. We are

currently moving boards into KIP207 at a daily rate which equates to several more transactions into KIP207.

I will continue to determine replenishment points and lot sizes using dual card calculations.

For boards that go directly to the workcell and do not report to KIP207, we will continue to perform the manual dual card replenishment. For boards that do report to KIP207, it is possible to have the dual card replenishment as the last operation on the 019- level shop order, but it would still require a lot of NVA work by a THT associate to constantly clock in and out of shop orders to backfill KIP207.

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- VI-Tech image database for defects will be much smaller and should improve computer processing speed. How so? Will we no longer be able to look back at defects found at troubleshoot and see if they were identified at AOI? The IMAGES of each defect take up large amounts of memory and are removed once the defects are dispositioned. Large amounts of memory consumed by imagery will be freed up with the new process because defects will be dispositioned 30 seconds after they are stored. All other defect and disposition data will still be retained for future reference.
- Eliminates daily overtime required for associates to count boards in KIP207. We wouldn't be counting today if we were using visual signals. I agree, but our limited floor space at THT limits us from having totes for all the board flavors.
- Allows SMT Line associates to spend more time on the line for feeder splicing/replenishment by eliminating them from the Post-Reflow AOI setup.

## **“Inline” SMT TQA Action Items**

### **Process Engineering**

- Update conveyor with correct operating features
- Relocate equipment and workbenches
- Update routings accordingly
- Train TQA associates on proper AOI/conveyor/magazine loading operations
- Coordinate a quick informational training session between the shifts for all SMT associates
- Update MFG-102 with process change to SMT TQA
- Install KRONOS on both TQA computers
- Train new associates on dual card process
- Coordinate Oracle Inventory Tracking system with Kip Helser
- Setup additional TQA station for implementation overtime
- Create new “white board” that contains location tags for board trucks
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### **MFG Supervision**

- Coordinate overtime for transfer of boards to KIP207.
- Develop a rotation plan to ensure processes are fresh in the minds of all TQA associates
- Implement tote labels from boards coming directly from SMT TQA
- Assign responsibility for tote replenishment and train accordingly
- Train 3070/CC/Assy associates on new process of retrieving required boards
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