Continuous Improvement Strategies for Automated X-ray Inspection

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Summary

Automated X-ray inspection (AXI) is more often a part of an effective test strategy for today's PCBAs[1] because of the benefits it provides manufacturers in meeting challenges resulting from[2]:

- Continued product miniaturization amid increased product functionality
- Increased time to market and time to volume pressures
- Growth in outsourcing and contract manufacturing

The structural defect coverage provided by AXI is complementary to electrical test; AXI helps to increase overall fault coverage when used in combination with flying probe, in-circuit and functional test methods.[3,4]

Despite the benefits offered by AXI, new users sometimes struggle with its implementation due to a lack of experience and procedures on how to optimize the inspection process to achieve stated performance targets. Common concerns among this user group include high false failure rates and defect escape rates. Because AXI is a relatively new test technology, many users are unaware of best practice use-models and continuous improvement methodologies that can be used to stabilize the inspection process and attain targeted performance goals for both defect detection and false failure rates. This paper will demonstrate procedures, use-models and continuous improvement methodologies that AXI users should consider when establishing norms for their own operational practices. Like any manufacturing process, appropriate procedures and metrics must be put in place to attain performance goals. Once suitable operational procedures are in place, even new manufacturing technologies like AXI will perform within predictable and acceptable performance limits.

The recommendations and best practices discussed in this paper are derived from the practical experiences of the authors in their direct work with AXI processes in volume production environments.

Two Categories of Continuous Improvement Methods

Continuous improvement methods involving AXI can be divided into two broad categories:

1. *Assembly process improvement* - uses AXI variable measurement data to reduce the incidence of structural defects in the manufacturing assembly process. The objective of these improvement efforts is to reduce the propensity of manufacturing stages prior to AXI, like screen print, placement, reflow or wavesolder to create defects through the application of process control or design of experiments methodologies using AXI measurement data.
2. *AXI process improvement* - focuses <u>not</u> on improving the quality of previous assembly stages, but instead on improving the quality of the x-ray inspection process <u>itself.</u> These efforts focus on achieving better performance on key AXI process metrics like false failure rates, escape rates (false accept), system uptime, program delivery time and equipment support/staffing costs.

   This paper is focused solely on AXI process improvement methods and not assembly process improvement.

Summary of Key AXI Process Metrics

Any manufacturing assembly stage will have certain quantitative metrics that can be used to accurately characterize its performance. In order to improve the performance of a manufacturing stage, these metrics must be measured then benchmarked against performance goals or industry best practice and corrective action taken where necessary. For example, we commonly understand that screen printing processes can be measured by their ability to deposit consistent volumes of solder paste with accurate registration and we know that placement machines can be measured by their placement accuracy and placements per hour; but it is sometimes counter-intuitive to some that we should measure the performance of a test or inspection stage. Since the inspection machine is a process measurement tool in and of itself, *"to measure the measurement system"* can be considered a conundrum, but this is precisely the objective within this continuous improvement plan.

At a minimum, the following AXI process metrics should be measured on a regular basis:

- False Failure Rate[5]
  $FalseFailRate = F \div J \times 100\%$
  Where F is the number of incorrectly rejected joints
  J is the total number of good joints inspected

- Escape Rate[6]
  $EscapeRate = E \div D \times 100\%$
  Where E is the number of falsely accepted joints (missed defects)
  D is the total number of defective joints inspected; note that only defects for which AXI has fault coverage are generally included within D.

- Training
  Personnel supporting the AXI process should have adequate training. Skill levels should be measured and continually improved.

- Program Development
  The time required to create a new program with a specific false failure tolerance. A release process should be in place before the program is considered completed. Specific tools and techniques are recommended to shorten development time and improve delivered quality.

- Uptime
  MTBF[7] or downtime per month should be measured as well as execution of preventive maintenance & calibration tasks. All daily, weekly, monthly, semi-annual and annual activities should be listed and signed off on log sheets for each machine. A "gold board" process should be used.

False Failure Rate
High false failure rates are the most aggravating and chronic problem facing new users of AXI. False failures are caused by any combination of the following issues:

1. Lack of sufficient measurement repeatability or lack of discrimination of a defective signature from a nominally good condition
2. Sub-optimal threshold limits - the upper or lower limits are not optimally defined and are failing more good solder joints than necessary.

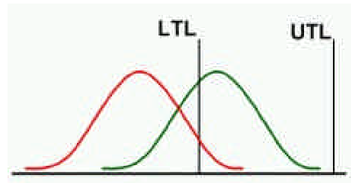


Figure 1 - The Green (right) and Red (left) Curves Represent the Measurement Distributions of Good and Bad Solder Joints Respectively

Notice that the tolerance limits cannot be defined in such a way that they eliminate false failures and find defective instances at the same time.

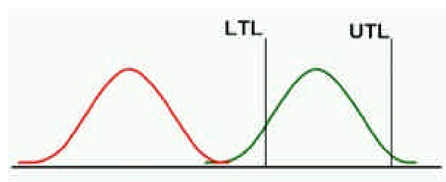


Figure 2 - The Tolerance Limits can be Defined More Optimally to Fail Fewer Good Solder Joints (green=good}right : red=bad}left)

Item 1 is a function of equipment capability and is not relevant to this continuous improvement discussion (possible solutions might include using alternate measurements, combining multiple measurements to create a unique fault signature or using distributed test strategies). Item 2 however is the most common cause of false failures for new users and the positive aspect of this problem is that all the information required for corrective action is readily available to the user. The AXI verification data can be interpreted and summarized by a software application for easy identification of root cause.

Appendix 1 shows a sample AXI verification file for one board serial number. A software application can read this type of file for every board tested and summarize the false call information into 'action-able' line items. Figure 3 shows a summary report of false calls generated from a series of verification data files. The AXI programmer can use this type of summary report to take corrective actions on a regular basis to continually reduce the false failure rate.

False fail rates should be measured on each board type independently using automated software techniques. In order for the information to be "action-able" (i.e. such that specific corrective actions can be taken), a breakdown or pareto-chart (by quantity or percentage) of both package types and reference designators causing the false failures is required. Corrective actions should be taken following each production run (at a minimum) for the first 3 runs then changing to an appropriate time based interval for data analysis and corrective action.

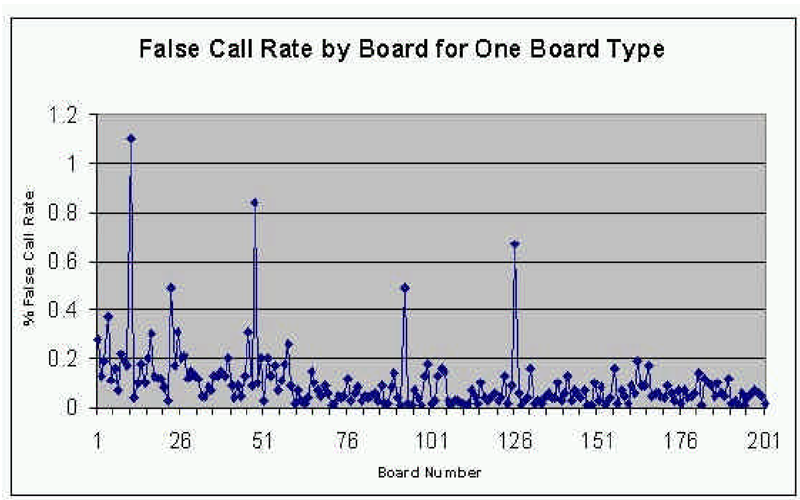
Algorithm - Subtype	False Call	Count
BGA - 2	Excess	5
BGA - 2	Missing	5
PCAP - 4	Missing	4
BGA - 3	Excess	3
FPGULLWING - 26	Open	3
BGA - 2	Insufficient	2
CHIP - 15	Insufficient	1
BGA - 4	Excess	1

Figure 3 – A summary Report Constructed from 10 Individual Verification Data Files for One Board Type (see Appendix 1)

The report summarizes quantity of false failures from highest to lowest by package type. The AXI programmer uses this type of report to continually reduce the false failure rate at a defined schedule. A similar report indexed by reference designator should also be used.

Figures 4 and 5 illustrate how a continuous improvement plan that involves corrective actions based upon summarized false failure data can quickly reduce the incidence of false failures on the production floor.

The data shows a reduction in false failure rate over time using continuous improvement methods that employ the false call summaries shown in figure 3. AXI programmers took corrective actions on the program at a regular interval. The false call rate for the first and last 50 boards tested was 1800pmmJ (0.18%) and 600ppmJ (0.06%) respectively. The board type referenced by this chart contained 20744 joints and measured 17"x19" in dimension.



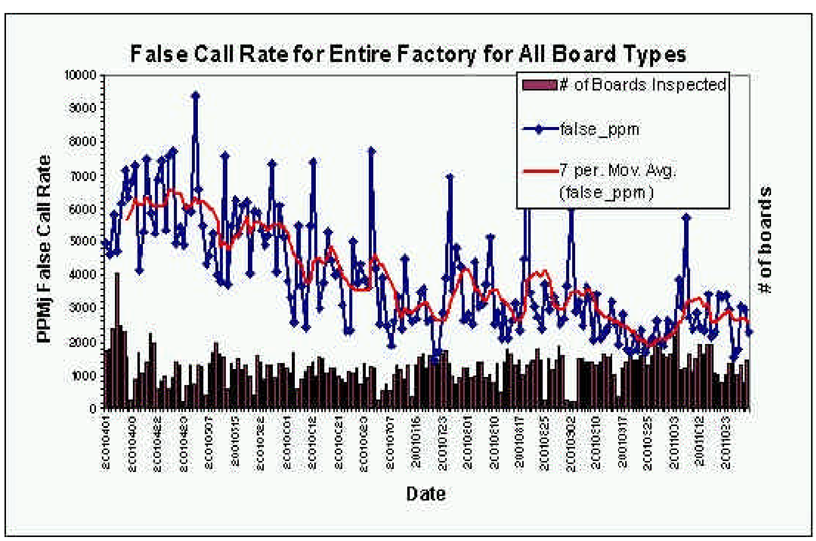


Figure 5 – This Data Shows the False Call Rate for a High Mix, High Volume Contract-Manufacturing Facility Running Multiple Laminography AXI Systems

The data shows the aggregate false call reduction over time for all board types together, from an average near 6000ppmj to 2500ppmj over a 6 month time period. The data represents a total of over 225000 boards tested. Regularly scheduled corrective actions were taken by AXI programmers based on summary reports like the one shown in Figure 3.

Other summaries of false fail data may be useful for the measurement of related processes as follows:

- False failures summarized by application developer can be a useful metric in evaluating the skill level of AXI programming personnel.
- False failures summarized by verification operator can be a useful metric in evaluating the skill level of the verification operators (i.e. operator is not recognizing true failures and diagnosing them as such).
- False failures summarized by machine can be a useful metric in evaluating machines that are operating outside of acceptable tolerance and have some inherent mechanical or calibration problem.

Proficiency[8]	Description of Practice/Methodology	Performance Level
Best of Breed	·False failure rates are continually measured automatically by software and frequent corrective actions are taken on a defined schedule. ·If the false failure rate exceeds a cut-off limit over a specific number of boards, a software lockout disables the system until corrective actions are taken.	Less than 1000 ppmJ[9] Less than 500 ppmJ on high volume products
Good Practice	·False failure rates are not continually measured automatically with software but are rigorously observed by programmers and corrective actions are taken frequently on a defined schedule.	Between 1500-2000 ppmJ
Entry Level	·False failure rates are not measured but are observed from time to time. Corrective actions are taken when resources are available.	Greater than 4000 ppmJ

Various factors will affect the false failure rate performance level (and the performance level for other key metrics like escape rates, development time etc.) that is achievable within a particular manufacturing environment. Although "best of breed" practices and methodologies may be in place at a particular manufacturing facility, not all AXI programs will operate at best of breed performance levels; some programs will operate at "good practice" and "entry level" performance levels. The following issues will have a negative impact on the performance level of AXI programs and will cause some programs to perform below the tolerance defined by the applied methodology/practice:

- High mix, low volume environments versus dedicated high volume lines
- Small batch size and infrequent production runs
- NPI[10] grams that have not experienced a significant population of boards
- Contract manufacturing environments that experience high mix and high process variability instead of an OEM environment where design parameters, product mix and process parameters are more narrowly distributed
- Multi-system environments where machines are not fully compatible with one another due to calibration problems
- Use of 3D AXI versus 2D AXI (2D AXI will deliver better false fail performance[11,12])
- Limited resources

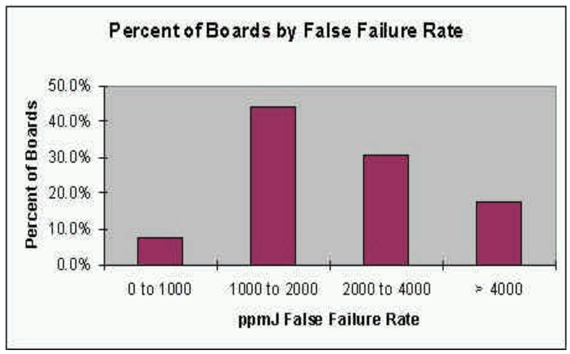


Figure 6 – This Data Shows the Distribution of False Failure Rates on Programs at a High Volume, High Mix, Contract-Manufacturing Facility Using Multiple 3D Laminography AXI Systems, Employing "Best of Breed" Methodologies

This data represents measured false call rates for over 67,000 boards; the majority of boards in the ">4000 " category are NPI or low volume boards with infrequent production runs.

Escape Rate

The root causes of defect escapes are identical to the root causes of false failures described above in figures 1 and 2. Unlike false failure rates however, defect escape rates are inherently very difficult to measure. In order to measure the AXI escape rate, one must rely upon feedback from downstream test/inspection stages. This poses the following challenges:

1. Downstream test or inspection stages are unlikely to have sufficient overlapping fault coverage to detect all AXI escapes; furthermore, these downstream test stages have their own inherent escape rates. Therefore once an escape

occurs at AXI, it may not be detected downstream - this is especially true of solder quality defects like insufficient solder or poor solder wetting since these do not cause open conditions at downstream electrical test stages.

2. Production floors often operate as "cells" and the AXI process may be part of different cell than downstream in-circuit or functional test cells where AXI escapes are detected. A training gap often exists between personnel from different cells that further compounds the problem - operators do not know what types of defects constitute AXI escapes vs. defects that AXI cannot detect.
3. There are often numerous assembly process steps between AXI and any downstream test or inspection, some defects that appear to be AXI escapes may not be, the defect may have been caused by one of the intermediate stages or by improper board handling.
4. Additional parts (wave solder or press fit connectors, heat-sinks etc.) are often added at intermediate assembly stages between AXI and downstream test/inspection. These additional parts may render the board physically out of bounds for testing at AXI due to lack of handling edges or exceeding component height limitations. Even if the board is not physically out of bounds, it can be rendered unusable for feedback purposes if components were added near/above/below the affected solder joint. X-ray signatures from these new parts can cause sufficient noise in the region of interest such that corrective action cannot be taken.
5. There are numerous logistical difficulties in the feedback of AXI escapes from downstream test or inspection stages:
   - Identifying contact personnel between cells on each manufacturing shift
   - Identifying a physical location to temporarily stock cards that have defect escapes
   - Ensuring AXI programming personnel are available to disposition escapes promptly
   - Urgency to repair cards and ship them to the end customer ("no time to wait")

Despite these many challenges, the recommended best practice for the feedback of AXI escapes is to identify a kanban at downstream test where boards with AXI defect escapes can be temporarily held (without undergoing repair) so that x-ray programmers can take the necessary corrective actions. A log sheet should be used at the kanban so that the frequency and types of corrective actions can be monitored.

Proficiency	**Description of Practice/Methodology**	**Performance Level**[13]
Best of Breed	·Escapes are measured automatically via data collection software. ·The root cause of the escape can be traced to be verification error or programming error[14] ·If a valid escape is found, boards are held at a downstream kanban (via software lock) until dispositioned by a programmer and signed off on the log sheet. ·Personnel at downstream test cells are knowledgeable of what constitutes an AXI escape and the importance of feedback.	Less than 5%
Good Practice	·A kanban and log sheet is used at downstream test for AXI escapes. ·Corrective actions are frequent and the log is analyzed on a regular basis to ensure continuous improvement. ·Personnel at downstream test cells are knowledgeable of what constitutes an AXI escape and the importance of feedback.	5% to 10%
Entry Level	·A kanban is used at downstream test and corrective actions taken by programmers on an irregular basis. ·Personnel at downstream test cells are not very knowledgeable of what constitutes an AXI escape and the importance of feedback.	10% or greater

The Relationship Between False Failure Rates and Escape Rates

The reality of all inspection systems is that a balance between false calls and escapes must be reached that is suitable to the user and end customer.[15] Increasing the sensitivity of the inspection will drastically reduce, or can eliminate all escapes but can also greatly increase the number of false calls if the inspection system lacks sufficient discrimination as per Figure 1. An excessive false call rate significantly complicates the task of defect image verification.

If for every real defect there are upwards of 10 false defects that must be screened through, an operator may quickly lose confidence in the inspection system and assume that most images presented for review are false defects - this will lead to verification error escapes (not programming escapes, see footnote 15); thereby demonstrating the inter-relationship between false failure rates and escape rates and that a high false call rate can also cause a high escape rate. Figure 7 below shows the percentage of boards inspected with at least one real defect called false by the verification operator (thereby causing an escape) when a simulated very high false call rate is prevalent; ninety-five verification operators were involved in study.

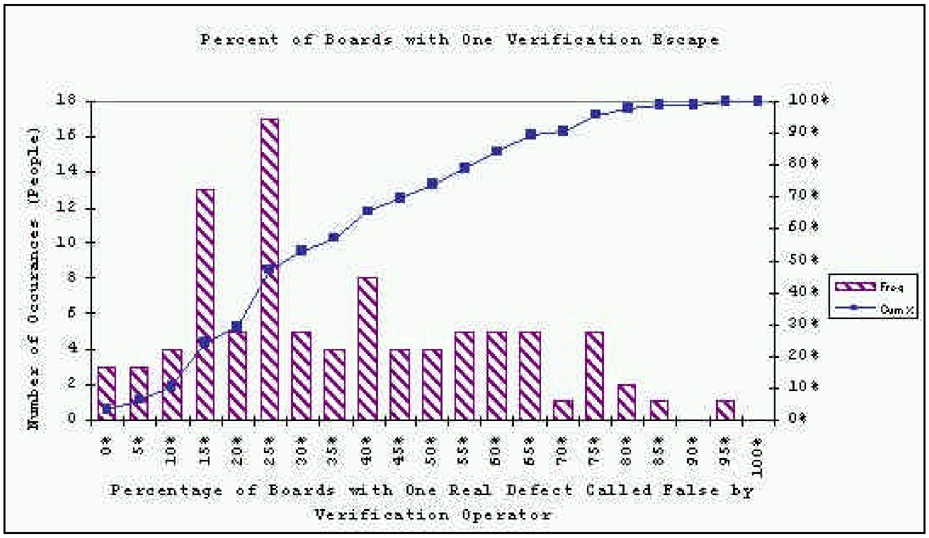


Figure 7 - Percentage of Boards with One Real Defect Called False

95 operators inspected 28 boards. Each operator reviewed a total of 6000 images with 1423 true defects amongst them (note that the total number of images and the number of true defects included was deliberately inflated for the sake of the experiment to simulate a high false failure rate and high number of true calls). The chart shows what percentage of the boards inspected by the operators had at least one true defect called false by the verification operator

The chart shows that 80% of operators called a true defect as a false call on at least 50% of the boards they inspected. The results show that when high false call rates are prevalent in the process (exceeding 5000ppmJ), high escape rates will also result. Escapes through AXI are as inevitable as with any test or inspection system, understanding that false calls and escapes are part of the process, and working to minimize both will ensure that confidence in the x-ray inspection process remains high.

Training

All personnel involved in the support of the AXI process require sufficient training. Training recommendations for verification operators and programmers are discussed below:

Verification Operator

Because the AXI process is dependent on human verification operators to disposition real defective calls from false calls, the skill level of the verification operator plays a very important role in the delivered quality of the AXI process. If verification operators lack the ability to identify images of defective solder joints from those of good solder joints, one of two things will happen:

1. Excessive escapes will occur, thereby causing downstream and/or field failures.
2. Excessive repairs will occur (false failures are unnecessarily repaired) thereby causing downstream and/or field failures. Unnecessary repair actions should be minimized to ensure defect free product and long-term reliability. Studies have shown that repaired solder joints are often the first to fail.

Verification operators also require an understanding of false fail and escape reduction activities described above. Given this awareness, a verification operator can appreciate their role in the continuous improvement process; that a new program will exhibit a much higher false failure rate, thereby necessitating their patience and focus in identifying the true defects from the false calls during their review cycle.

Proficiency	Description of Practice/Methodology	Performance Level
Best of Breed	·An image library of both good and defective x-ray images of all solder joint types and defect types is used and continually improved. ·Verification operators are measured at least annually (via a test) on their ability to discriminate false and true calls as per a defined truth table. 100% correct disposition is required except for marginal defect cases. ·Verification operators have a very clear understanding of their role within the AXI continuous improvement process.	Lowest verification operator induced escape rate and lowest rate of unnecessary repairs
Good Practice	·An image library of defective and good x-ray images exists although it is not continually revised and improved. ·Operators are tested against a truth table at initial certification but not necessarily thereafter. ·Operators have some understanding of their role in the AXI continuous improvement process.	Low verification operator induced escape rate and low rate unnecessary repairs

Entry Level	·Verification operators are not provided any specific training apart from shadowing another operator and do not have an understanding of AXI continuous improvement processes	High verification operator induced escape rate and high rate of unnecessary repairs

Programmer

The skill level and training of AXI programmers will play a very important role in the delivered quality of the process.

Proficiency	Description of Practice/Methodology	Performance Level
Best of Breed	·Candidates have equivalency to at least 1st year college mathematics and computing skills, are familiar with concepts/analysis of statistics and have good electro-mechanical aptitude ·Programmer is first certified as verification operator ·2 weeks classroom focused training ·1 month closely monitored on the job training ·4 months monitored on the job training ·AXI continuous improvement program in place, programmer participates ·Regular meetings occur to discuss new techniques, skills, requirements review metrics and take corrective actions	Lowest false call and escape rates
Good Practice	·Candidates have equivalency to at least final year high school mathematics and computing skills, are familiar with basic concepts/analysis of statistics and have good electro-mechanical aptitude ·2 weeks classroom focused training ·1 month closely monitored on the job training ·AXI continuous improvement program in place, programmer participates ·Meetings occur to discuss new techniques, skills, requirements, review metrics and take corrective actions	Low false call and escape rates
Entry Level	·1 month monitored on the job training ·Little evidence of AXI continuous improvement program for programmer to participate within	High false call and escape rates

Program Development

Program Development Time

A key motivator in the adoption of AXI technology is that it can help to accelerate time to market by reducing the time required for test development. This is especially true for new product introductions since no fixture is required for AXI testing. Another attraction for many users is that the skill level required for AXI test development is generally less than what is required for in-circuit test or functional test methods; the relative availability of skills for AXI test development helps to improve time to market.

For these reasons, we recommend that users measure and continually improve the time they require to deliver new applications to the production floor. This metric should be clearly defined to include the following items:

1. Number of solder joints on assembly
2. Number of solder joint types on assembly
3. False failure rate or delivered quality of completed program (via program release process)

Proficiency	Description of Practice/Methodology	Performance Level
Best of Breed	·Program development time is measured and defined as noted above. Corrective actions are taken as necessary.	Shortest test development time ~ hours
Good Practice	·Program development time is often measured and corrective actions are taken.	Acceptable test development time ~ a few days
Entry Level	·Program development time is rarely measured.	Long test development time ~ week(s)

Program Release Process

The delivered quality of a completed program should be measured prior to releasing a program to production. The quality is most easily measured via the false failure rate over a specified number of NPI boards. Best of breed release processes verify the false call rate to a specific level with a software lockout of the system. At the completion of the release process, the aggregate results of a specified number of boards (say 5) will not exceed a running average false call rate greater than (say 2500ppmj). If the false call rate exceeds this "clip level" a software lockout is engaged until a programmer takes corrective action.

As noted previously, the escape rate of an AXI application is very difficult to measure; however the "kanban method" noted above should be used throughout the life cycle of the program with a more focused effort in place during the early life of a new application. In addition, we recommend a "pasted board" verification step prior to program release to minimize the escape rate. This involves the screen-printing of a bare board with solder paste <u>without</u> any component mounting. The bare board with solder pasted pads is then reflowed <u>without</u> any components populated on the pads. The result is a "pasted" board with solder profiles that resemble open conditions on most types of solder joints (with the exception of BGA devices). The AXI program should be verified with this pasted board to ensure a 100% failure rate for all pads on the board prior to release. This is an effective process to help ensure confidence in the program escape rate; due to cost and availability however, it is often difficult for users to acquire a bare board for this purpose since it will be rendered unusable for assembly.

Proficiency	Description of Practice/Methodology	Performance Level
Best of Breed	·Program release process is used rigorously and includes a pasted board whenever possible. Clip Levels are used with software lockout.	Lowest false call and escape rates, lowest test development time, lowest rate of continuous programmer interventions over life of program
Good Practice	·Program release process is often used but rarely includes a pasted board	Low false call and escape rates, low test development time, acceptable rate of programmer interventions over life of program
Entry Level	·No Program release methodology is used.	High false call and escape rates, long test development time, very high rate of programmer interventions throughout life of program

Tools and Techniques

Users should employ a naming convention and library strategy when developing AXI programs. AXI program attributes will vary according to the following design related parameters:

- Package type or joint type
- Lead geometry
- Pad length and pad width
- Stencil thickness used
- Assembly process attributes

Because contract manufacturers work with so many different OEMs and design groups, it is especially important for them to communicate the importance of consistency in the above parameters across a single OEM's products. Varying design parameters will negatively impact test development time and delivered quality of AXI applications.

In order to manage these complexities effectively, users should employ an intelligent naming convention and ensure a library of program attributes is indexed according to this defined naming convention. Over time, the library should be updated with production verified, more optimal, higher performance program attributes for each component name. By employing these tools and techniques, users will be able to:

- Continually reduce program development time
- Continually increase the delivered quality of programs

Proficiency	Description of Practice/Methodology	Performance Level
Best of Breed	• Naming convention and library are used rigorously • Library is continually revised with production verified higher performance attributes	Lowest false call and escape rates, lowest test development time
Good Practice	• Naming convention and library are used • Library is sometimes revised with higher performance, production verified attributes	Low false call and escape rates, low test development time
Entry Level	• No naming convention or library is used	High false call and escape rates, long test development time

Uptime

We recommend MTBF or downtime per month should be measured as well as execution of preventive maintenance & calibration tasks. All daily, weekly, monthly, semi-annual and annual activities should be listed by line item and signed off on log sheets for each machine. The owner of the task (operator, programmer, maintenance technician, equipment supplier) should be clearly identified beside each maintenance activity line item.

A "gold board" process should be run on each machine at a regular frequency to ensure confidence, peak efficiency and eliminate uncertainty in times of questionable AXI results. The gold board is a "regular" production card (preferably as high complexity as possible for the manufacturing site) that may have several naturally occurring/appearing defective solder conditions on it (defects that appear artificial should not be induced). The user should create a truth table and program for this board and verify machine measurement repeatability and call accuracy using this same board on a regular basis for all machines installed at the facility using an identical copy of the program on all AXI machines.

Proficiency	Description of Practice/Methodology	Performance Level
Best of Breed	• All maintenance tasks are signed off by line item on log sheet by the relevant owner on a strict schedule, accountability and execution is ensured • Gold board process is used and gold board results are strictly monitored and analyzed on a regular basis	Minimal downtime (24/7)
Good Practice	• Maintenance tasks are usually signed off, exact ownership and task description is not readily apparent • Some type of gold board process is in place	Downtime is less than 8 hours per month (24/7)
Entry Level	• Maintenance tasks are sometimes completed, no log sheet is used • No gold board process in place	Downtime exceeds 48 hours per month (24/7)

Conclusions

AXI technology offers users many benefits including reducing cost of test, improving time to market and helping to improve process quality. As with any new technology, best practices, use models, tools and techniques must be defined <u>and refined</u> in order for the process to operate within expected performance limits. Methodologies for the continuous improvement of key AXI metrics like false failure rates, escape rates, program development time and training have been recommended. These methods have delivered measured results in real production environments. We recommend AXI users consider these methodologies when establishing norms for their own AXI processes. Once suitable operational procedures are in place, AXI processes will perform within predictable and acceptable performance limits that align with the objectives of its users.

As AXI technology continues to mature, the definitions of practice and associated performance levels documented in this paper will change. The recommendations herein are based upon the collective experience of the authors at the time this document was written.

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Appendix 1 – Sample Verification File

- The text below is removed from a verification data file for one board tested at AXI.
- The data identifies the board serial number and other header information.
- Each defect found by the machine is listed along with the diagnosis made by the verification operator as to whether the defect found by the machine was a true call or false call.
- Both the true call and false call information can be summarized by a software application for continuous improvement of AXI processes.

"Repair Operator Name","OPERATOR"
"Machine Serial Number",
"Panel Name","abcdef"
"Board Name","PRIMARY"
"Board Number",1
"Board Serial Number","012345678"
"Total Pins Inspected ",7777
"Total Defective Pins",12
"Total Number of Defects",14
"Total Defective Components",10
"Repaired Pins",0
"Not Repaired Pins",1
"False Called Pins",11
"Repaired Defects",0
"Not Repaired Defects",1
"False Called Defects",13

"Layer","Component","Pin","Status","Comment","Defect","JointType","Subtype","XLoc","YLoc"

1,"F2",2,"F","","Misalign Across","JLEAD",3,5801,2241
1,"FB4",2,"F","","Short","PTH",7,4696,12130
1,"FB5",1,"F","","Short","PTH",7,5186,11530
1,"FB5",2,"F","","Short","PTH",7,5186,12130
1,"U7",8,"F","","Short","PTH",10,2041,12830
1,"U37",5,"F","","Short","PTH",5,4546,12740
1,"U60",7,"N","613-INSUFFICIENT SOLDER","Short","PTH",6,4786,1205
1,"Y1",1,"F","","Open","GULLWING",9,3881,10195
1,"Y1",1,"F","","Misalign Across","GULLWING",9,3881,10195
1,"Y1",2,"F","","Open","GULLWING",9,3511,10195
1,"Y1",2,"F","","Misalign Across","GULLWING",9,3511,10195
2,"C102",1,"F","","Short","CHIP",10,4941,2190
2,"C992",2,"F","","Insufficient","CHIP",15,4941,12217
2,"R147",1,"F","","Open (Clear)","CHIP",14,5346,9375