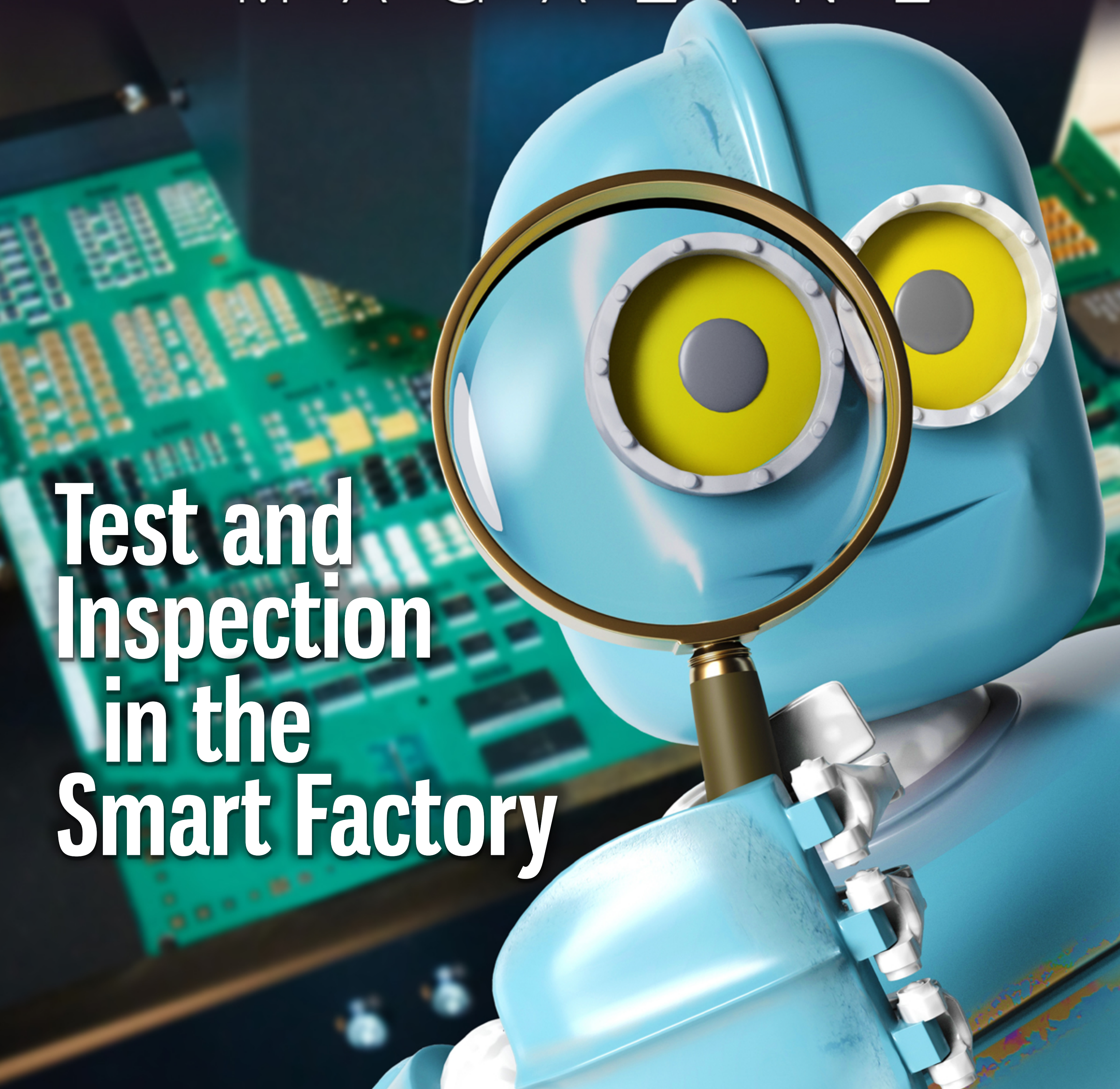
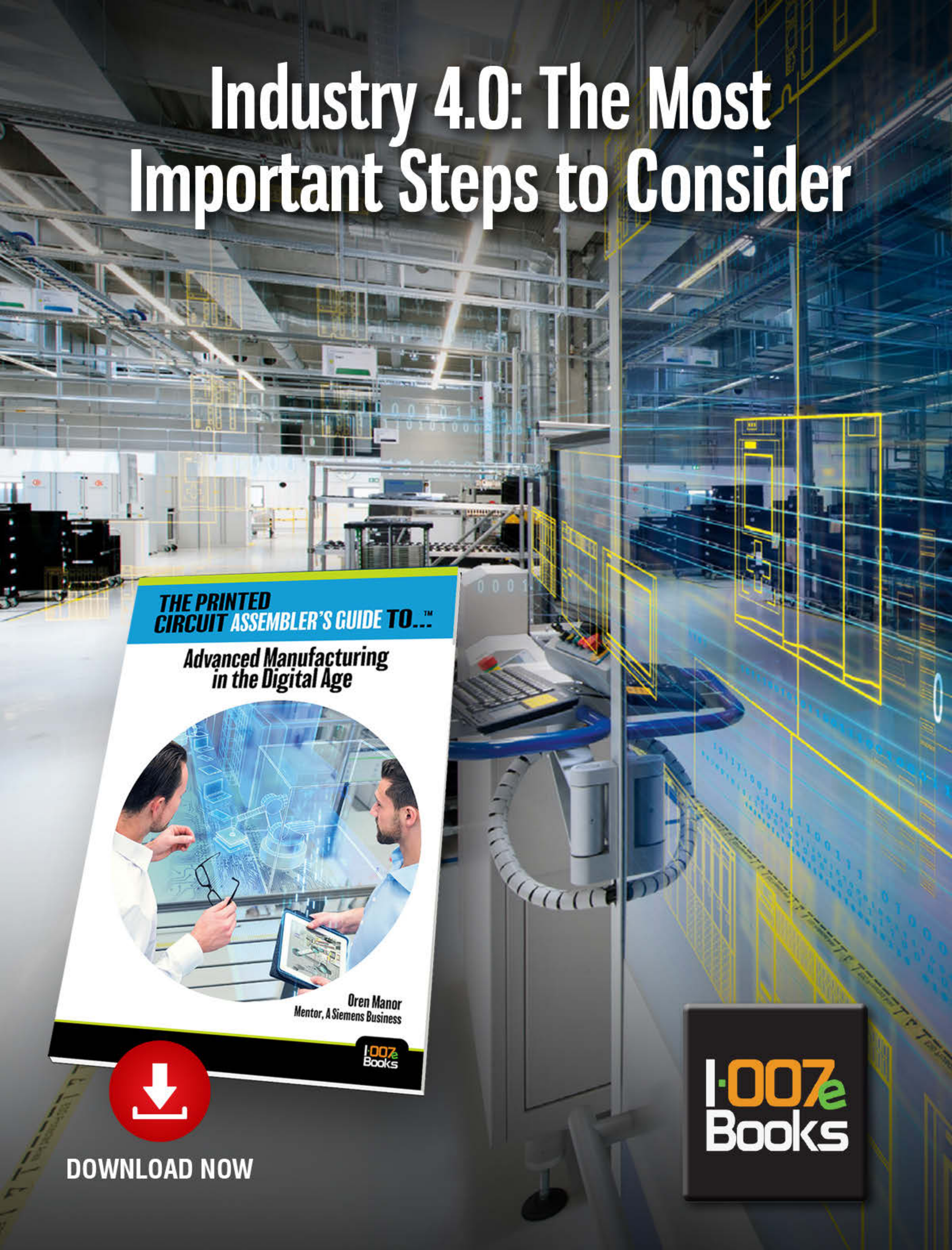
I-Connect007

NOVEMBER 2020

SMT007 MAGAZINE



Test and Inspection in the Smart Factory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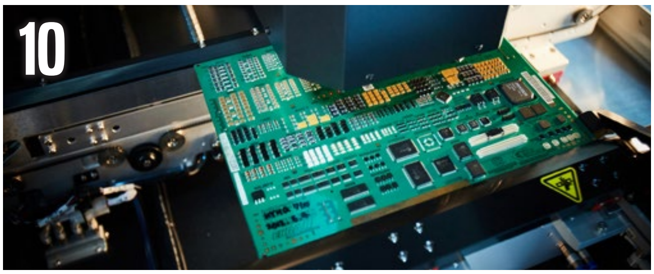
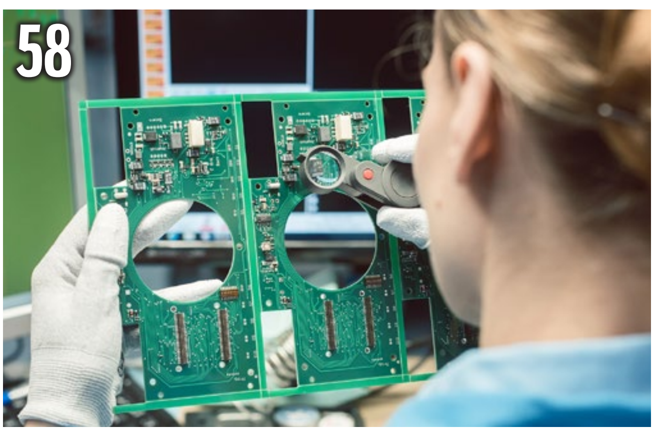
Test & Inspection in the Smart factory

The role of test and inspection is shifting. But how does the role of test and inspection change? What are manufacturers asking of their inspection equipment? What are manufacturers supplying in response? Who's leading the changeover—equipment manufacturers or their customers?





ROW6 Raves About Manncorp Training

★★★★★

"Customer Service was *OUTSTANDING*"

"The Manncorp team [was] ***PARAMOUNT*** in our success."

"The training was ***VERY THOROUGH***."

- John Kerr, CEO of ROW6, on their experience with the Manncorp service team

ROW6 uses Manncorp equipment to manufacture components for their JBOX edge-computation system.

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From manual to automatic - ROW6 made the leap to a fully-automated assembly line with the help of Manncorp's customer training services. Manncorp techs trained the ROW6 production team on how to efficiently run their entire equipment line-up.

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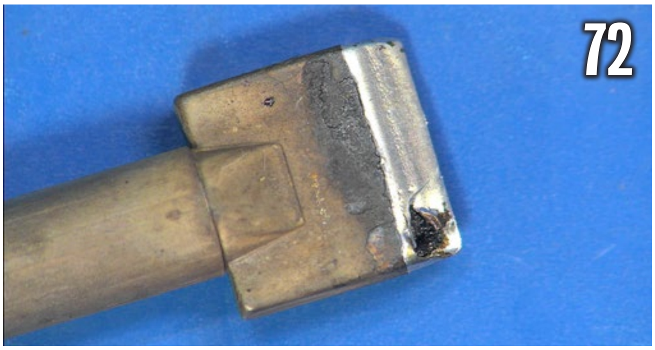

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Test and Inspection in the Kitchen

Nolan's Notes

by Nolan Johnson, I-CONNECT007

I enjoy cooking. Not everybody does, but I do. For me, kitchen time is most enjoyable when it's a social event, like making a meal with friends or family together. I took teaching my children how to cook and feed themselves pretty seriously. Both of them know their way around the kitchen and can follow a recipe.

What I am not, however, is a gifted baker. After a few spectacular failures that went undetected until they tried to actually eat what I'd baked, my children became my inspectors. They would monitor my endeavors with extra care, including recipe checks and taste tests. They saw too many handmade loaves of bread come out of the oven inedible. In particular, one bread loaf was so hard that I dared them to use it as a door stop; it lasted a good three months in that role!

With their help to keep my baking on track, many of my baking projects were edible, though maybe I wouldn't call them delicious. Eventually, I gave up on hand-making bread loaves and started using a bread machine. For me, automation was the answer to the skill and talent shortage from which I clearly suffered.

The use of test and inspection on the manufacturing floor isn't all that different. Traditionally viewed as a final step with a pass/fail result, test and inspection have grown in

importance and sophistication, especially with the advent of the digital factory concept.

Now, test and inspection can—and should—play a role all along the line, verifying correctness mid-process as well as at the finished product stage. Big data, AI knowledge bases, and processing equipment that can adjust based on software commands mean that intermediate test steps are not only verifying products but also serving as key process control devices, keeping the line solidly within the process window.

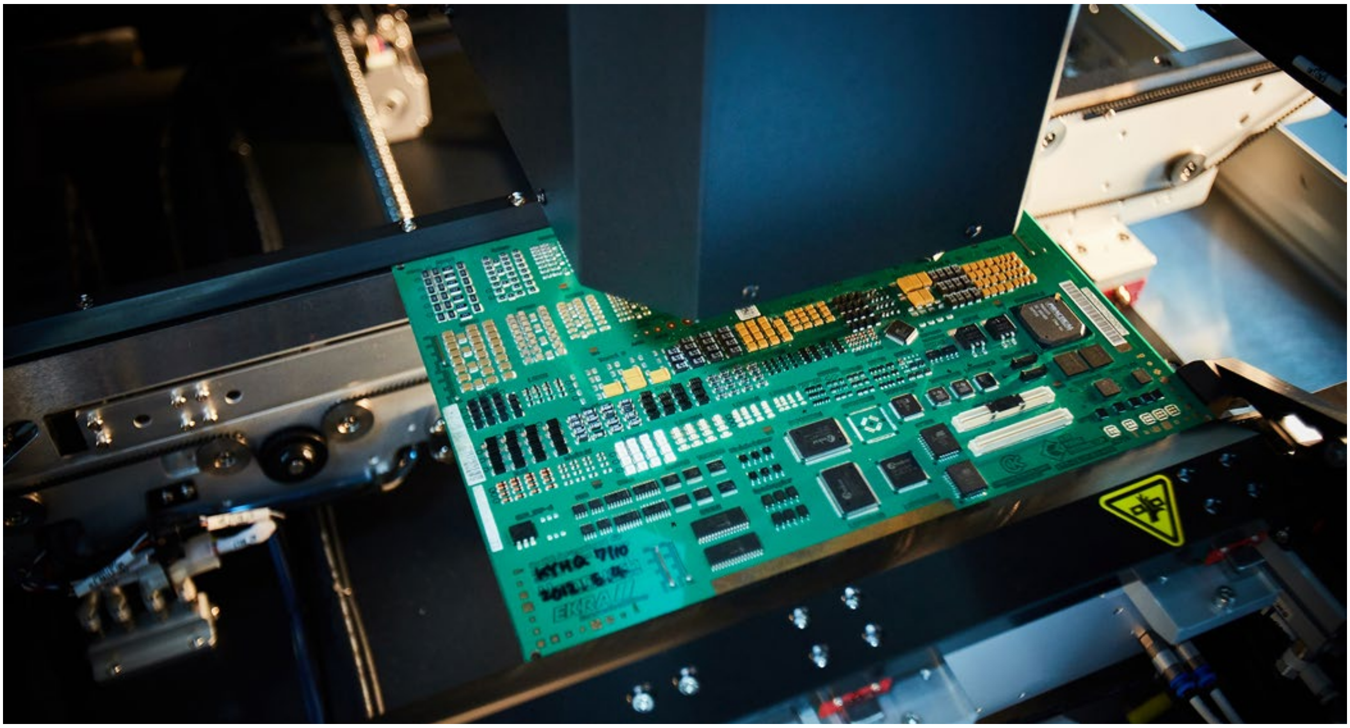
In his column this month, Michael Ford starts with a passage so spot-on that I simply had to repeat it here:

> *"…test and inspection have no place in the smart factory if it is there simply to detect defects…In the smart factory, test and inspection are reinvented, contributing direct added value, playing a new and critically important role where defects are avoided through the use of data and create a completely different value proposition."*

It's this shifting role for test and inspection that we set out to study in this issue. How does the role of test and inspection change? What are manufacturers asking of their inspection equipment? What are equipment manufacturers supplying in response? Who's leading the changeover—equipment manufacturers or their customers? Is test data actually being incorporated into the smart factory process control flow, and, if so, how? Can a manufacturer extend the useful life of the inspection machinery already on their line, or will they need to buy all new?

These questions—and this shift in role for inspection—is the natural result of digital factory infrastructure development in the form of AI, interoperability protocols, and big data. In the long term, expect a lot of development attention to shift from collecting data to analyzing and using that data. As you read the articles and interviews in this issue, it should become clear that this shift is already well underway. **SMT007**

Nolan Johnson is managing editor of *SMT007 Magazine*. Nolan brings 30 years of career experience focused almost entirely on electronics design and manufacturing. To contact Johnson, click here.



Using True 3D Inspection Data as a Process Control Tool in the Smart Factory

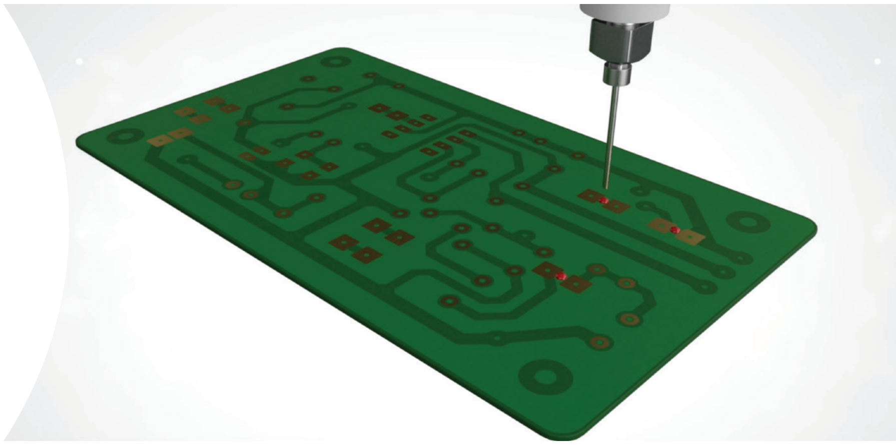
Feature by Joel Scutchfield and Brent Fischthal
KOH YOUNG AMERICA

Automated 3D solder paste inspection (SPI) and automated optical inspection (AOI) systems have become an integral part of the printed circuit board assembly (PCBA) process. These systems are increasingly important for electronics manufacturers because they help ensure high-quality production results. With board complexity increasing, inspection technology becomes even more critical. While most manufacturers base quality decisions on a "good-bad" comparison of reference images, variables like surface finish, board condition, and component proximity can easily influence these image-based decisions.

Data generated from 3D measurement systems, however, supplies meaningful insights about the process and can help manufacturers eliminate the root cause of a defect. As such, manufacturers must trust the data from the system and use that data to help transform, monitor, and control the PCBA process. Yet, for these systems to make the leap from inspection to process control—and ultimately to automated process optimization—the data must be reliable, repeatable, and relatable.

In this competitive world, manufacturers place challenging demands on process solutions. They want to monitor and adapt the process to achieve zero defects by accessing all the data anytime, anywhere. What's more, manufacturers want process optimization. However, this has been difficult to achieve for 2D, 2.5D, and quasi "true 3D" systems that cannot reliably offer accurate information by providing real true 3D data. It is also impossible for these systems to accurately measure and quantify shape, coplanarity, solder amount.

To overcome these deficiencies and challenges, a true 3D system measures every aspect of the component and solder joint per the IPC-610 standard, while generating a signif-



icant set of reliable and accurate measurement data. True 3D utilizes all measurement data, but not all 2.5D and 3D systems work this way. The 2.5D and most 3D systems rely on non-measurement-based 2D technology while incorporating a small amount of 3D capability to simply provide 3D images and—in some cases—basic measured values.

The Smart Factory

Data—especially from inspection and test systems—is the foundation for Industry 4.0 and smart factories, so advanced systems must evolve from simply judging pass/fail situations into highly intuitive, dynamic decision-making systems. This emphasizes the need for reliable, repeatable, and relatable data.

Artificial intelligence (AI) engines can empower systems to help manufacturers analyze and optimize the PCBA process by managing process data from connected SPI, pre-reflow AOI, and post-reflow AOI systems. Ideally, the AI system collects all inspection and measurement data from equipment in the line and then delivers information anywhere within the network with an intuitive, web-based user interface.

Communications

The machine-to-machine (M2M) communication standards—guided in part by Industry 4.0—are altering the manufacturing process by improving metrics like first-pass yield and throughput with autonomous process adjustments that increase board quality and reduce production costs. As part of this path, certain process control software suites like KSMART can revolutionize data collection and analysis and—more importantly—PCBA process optimization.

Of course, simply collecting reliable and repeatable measurement data is not enough on its own to realize a smart factory. The system must also instantly analyze the data with relevant indicators like yield rate, no-good (NG) analysis, parts per million (PPM) analysis, Gage R&R (repeatability and reproducibility), offset analysis, and other key metrics. When combined, these metrics allow manufacturers to compare board performance and identify process deviations from critical process steps like printing with an SPI, placement with a pre-reflow AOI, and reflow with a post-reflow AOI (Figure 1).

Measurement-Based Inspection

Process optimization is desired by every manufacturer, as well as equipment suppliers, including automated inspection providers. However, it has been difficult to realize due to the limitation of two-dimensional (2D) imaging, which was the de facto standard for the past 25 years. It is difficult for 2D AOI systems to identify defects on a curved and reflective solder joint, and 2D and 2.5D AOI systems do not generate reliable measurement-based data.

Every aspect of the 2D/2.5D inspection process relies on contrast, not quantitative measurement. As such, 2D/2.5D AOI users must either scrap or repair defective boards, which increases costs and eliminates process improvement opportunities. At the same time, the results from these non-measurement-based systems limit the application of AI to improve all aspects of the inspection environment.

The introduction of 3D imaging to the inspection market solved many of the problems. By measuring components and solder joints, and then offering critical height information to the

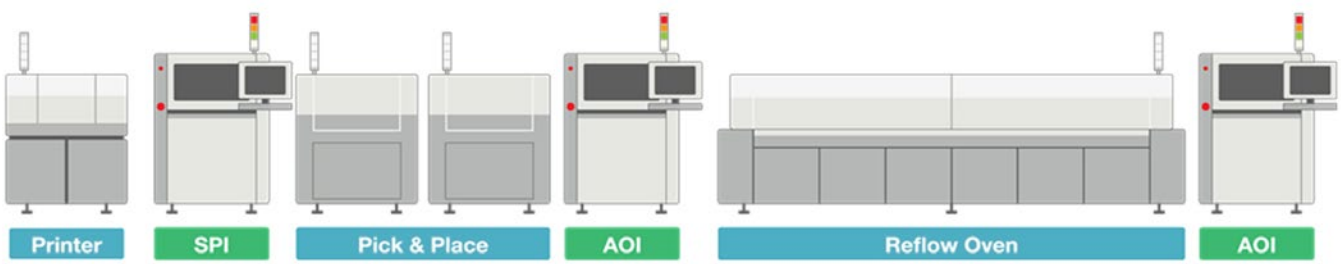


Figure 1: An example of a line configuration to improve yield with multipoint data correlation.

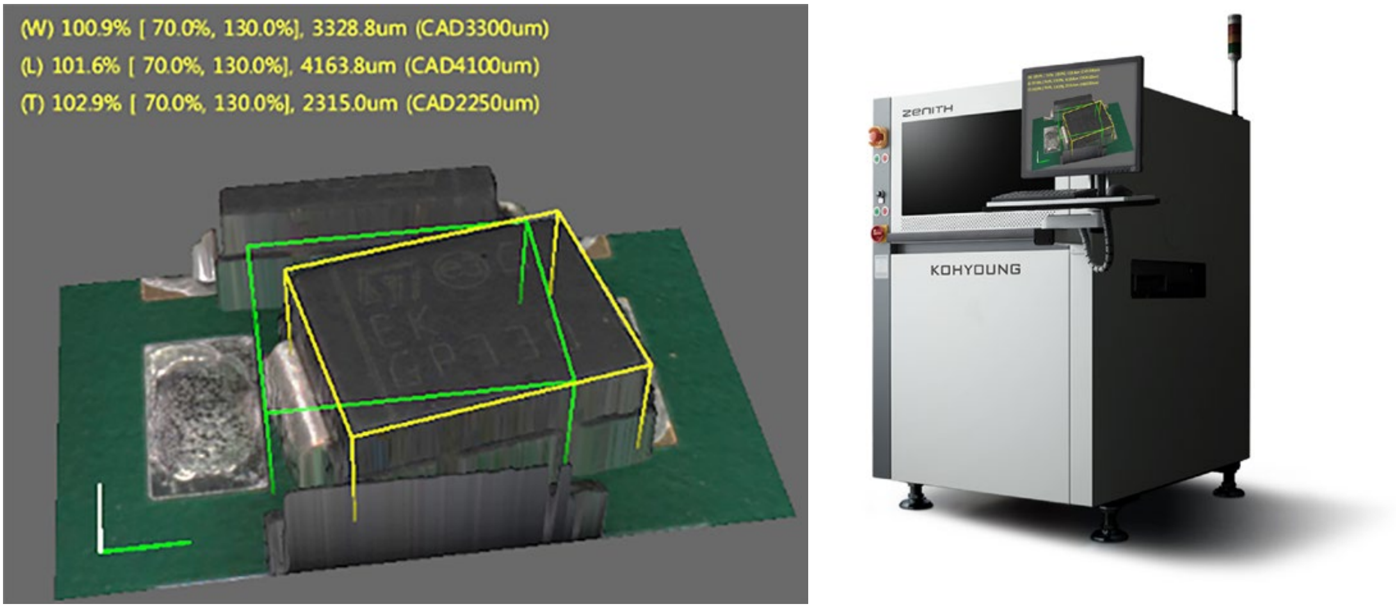


Figure 2: A practical approach to mapping the component body by using measurement technology to deliver reliable, repeatable, and relatable data.

inspection algorithms, manufacturers could locate errors like pad overhang and insufficient solder. However, the validity of the measurement data remained questionable as most of the 2.5 and 3D AOI systems still use 2D-based "blob detection" to find the component body and lead tip—a technique that is susceptible to external factors like board warpage and component proximity, etc. Since finding the component body and lead tip is the critical first step in the inspection process, if done poorly or inaccurately, it negatively affects the whole inspection sequence and contributes significantly to false calls.

True 3D inspection systems can overcome this challenge for all component types by extracting their exact body dimensions and location (Figure 2). For example, the Zenith AOI series uses a parallel computing engine to process true 3D measurements. While 2D, 2.5D, and even some 3D inspection systems combine basic 2D data with limited height and width data to offer inspection data, it is not reliable, repeatable, or relatable.

Using patented shadow-free 3D technology, the Zenith series provides superior results by measuring every aspect of the component and solder joint in accordance with the IPC-A-610 standard. It generates a significant and statistically relevant set of reliable, repeatable, and relatable measurement data. This data gives rise to industry-leading measurement-based analysis and optimization solutions like the KSMART process control software. Adept equipment suppliers can apply the data set to proprietary AI engines for continuous performance improvement.

The analysis solution collects all inspection and measurement data from all equipment with its hub and then provides the data anywhere within the network with an intuitive user interface on a web-based application. The beauty of this powerful analytical tool is traceability. Big data is the foundation for Industry 4.0, so KSMART helps advanced inspection systems evolve from pass/fail tools into highly intuitive, dynamic decision-making systems. As the gateway to the smart factory, it also ensures the highest levels of transparency by showing all conditions of the lines while providing the required documentation for changes to the job file, package, part, and more.

The Value of Accurate 3D Data

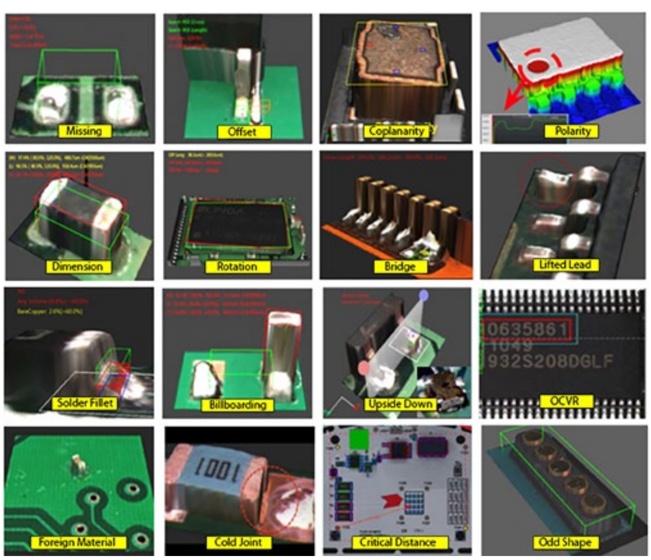
Manufacturers should not settle for anything less than reliable, repeatable, and relatable measurement data in the PCBA process. Data is the most crucial element for success and

Figure 3: The inspection machines can be the sensors.

improvement, especially when leveraging AI solutions. Experts link the effectivity of deep learning to the quality and quantity of the data used to address many different requirements from many fields. Most advanced inspection system providers want to use AI to deliver smarter inspection systems.

However, it has been difficult to realize due to the limitations of 2D and 2.5D imaging. Not only is it difficult for 2D/2.5D AOI systems to identify solder and dimensional-related defects, but these systems cannot also generate reliable measurement-based data. Every aspect of 2D inspection relies on 2D features like contrast, binarization, and reflection; thus, it is extremely challenging to correlate to the quantitative measurement of 3D objects.

Suppliers must measure the true 3D information of components and solder joints. If properly accomplished, the AOI can offer very valuable data, thus becoming the most reliable "sensor" on the line (Figure 3). Companies can only guarantee the validity of 3D data if the system uses true 3D technology to extract the exact body dimensions for all components types. "Blob detection" is simply not reliable and compromises the data; it also contributes significantly to false calls.



Accurate full 3D AOI data-based inspection.

The combination of multipoint measurement and process data collected from SPI, pre-reflow AOI, and post-reflow AOI systems, combined with data from printers, mounters, and reflow ovens will allow manufacturers to deliver an AI-powered, zero defect, self-healing line. Indeed, the quality of data is more important than the quantity of data to create effective and reliable solutions with high value proposition. Yet, it is the combination of reliable data, along with a statistically relevant quantity of data, that delivers the next level of relatable results.

Connect the Data

A single inspection system has limits and cannot manage and optimize a complete line while in isolation. Knowing this limitation, advanced companies have been working with the industry to connect its inspection systems with other process equipment like printers and mounters to streamline total communication and realize a zero-defect future. Looking inward, companies must design and deliver suitable process controls for seamless communication across their own core set of equipment, consolidating the individual machines to deliver a synergistic effect.

Realizing a smart factory means taking a practical approach to processes and systems while examining areas to improve productiv-

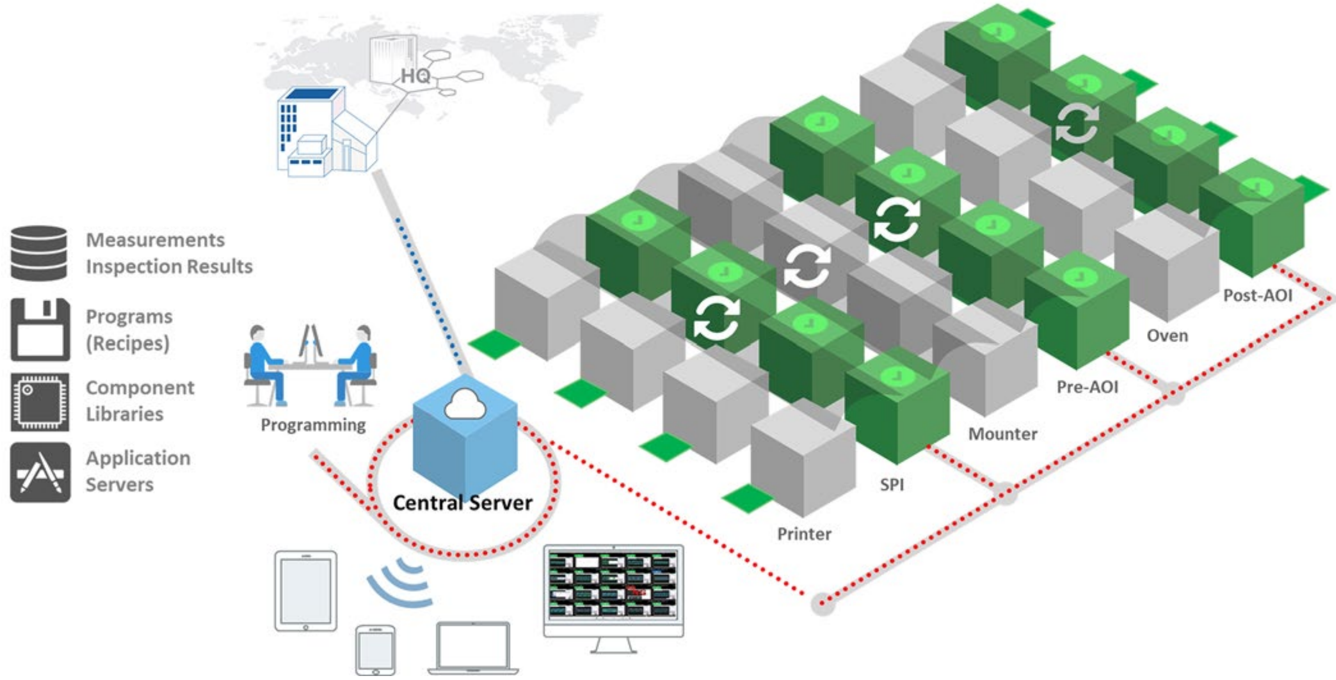


Figure 4: Factory connectivity example using KSMART.

ity. Using true 3D measurement data generated during multipoint inspection helps manufacturers define the source of inefficiencies and boost line efficiency. We use a software module called LINK@KSMART to deliver multipoint data correlation and images from SPI, pre-reflow AOI, and post-reflow AOI. The tool then uses real data management and monitoring, so operators can determine actionable insights to optimize processes in real-time.

The multipoint solution connects all systems within a line to consolidate all the inspection results, which helps correlate data between the processes and detect the source of any process anomalies. This effort streamlines production with a regular data-based review, diagnosis and optimization of printing, and pick-and-place and reflow processes via linked inspection results. Finally, it provides multipoint review images, trend charts, and inspection results to correlate results from printing, placement, and reflow process steps. The connectivity of all systems within a line help define correlations between the distinct circuit board assembly processes (Figure 4).

Working with other suppliers in the SMT line, true 3D inspection systems provide the data to unleash the true power of connectivity. With M2M connectivity, the line can optimize the PCBA process by exchanging real-time measurement data from SPI, pre-reflow AOI, and post-reflow AOI systems with other machines in the production line. The inspection machines can feed real measurement data like offset, volume, height, area, and warnings to other systems, while analyzing trends for process optimization and tolerance deviations.

Using this advanced communication, for example, the inspection systems can feed correct placement position values to mounters, which ensures components are in the targeted position. This improves process repeatability by automatically adjusting component placements and catching the shifting trend to make further position corrections. Manufacturers need to aggressively empower M2M connectivity to realize a smart factory.

Industry Communication Standards

These days, companies have a strategic focus on the smart factory concept. Its inherent ability to transform massive amounts of data into actionable information that manufacturers can use to transform their production floor is paramount to process improvement. With its open standards and broad industry collaboration, the IPC Connected Factory Exchange (CFX) initiative helps suppliers and manufacturers alike effortlessly exchange data between production equipment and systems, like the 8030 SPI Series and Zenith AOI Series. This connectivity benefits manufacturers with a straightforward approach to collect and feed information to systems for analysis that will increase process efficiencies.

Equipment suppliers must leverage developments and relationships with other leading equipment suppliers to advance plug-and-play, future-proof connectivity options for its customers. Working together will harness the true power of connectivity and optimize the process by exchanging real-time SPI and AOI measurement data with other machines in the production line. For instance, our systems feed real measurement data such as offset, volume, height, area, and warnings to other systems, while analyzing trends to optimize the process and identify trends. There must be a focus on IPC-CFX and IPC-Hermes-9852 initiatives to advance the electronics manufacturing industry.

Conclusion

Industry 4.0 is altering the manufacturing process by improving metrics like first-pass yield and throughput by applying autonomous process adjustments that enable self-correcting and self- healing production lines. Far beyond an automatic line changeover, this communication is allowing the equipment to automatically adjust production parameters to improve board quality and lower costs by eliminating rework and scrap.

More importantly, when manufacturers integrate multipoint inspection like SPI, pre-reflow AOI, and post-reflow AOI, they can optimize the assembly process to improve quality, reduce defects, and minimize costs. These inspection solutions are laying the foundation for a smart factory while revolutionizing process optimization. **SMT007**

Joel Scutchfield is the director of sales for the Americas at Koh Young America.

Brent Fischthal is the senior manager of Americas marketing and regional sales at Koh Young America.

Brian Smith

Quality Starts With the Design

Feature by Kevin Jobsky
ICM CONTROLS CORPORATION

"Quality starts with the design." That is one of the favorite sayings of Brian Smith, a quality manager at ICM Controls. Truth be told, it is the mantra of many quality managers from every industry throughout the world. Still, Smith and his peers would all be out of jobs if all product designs proved flawless right out of the gate and moved smoothly throughout the entire manufacturing process.

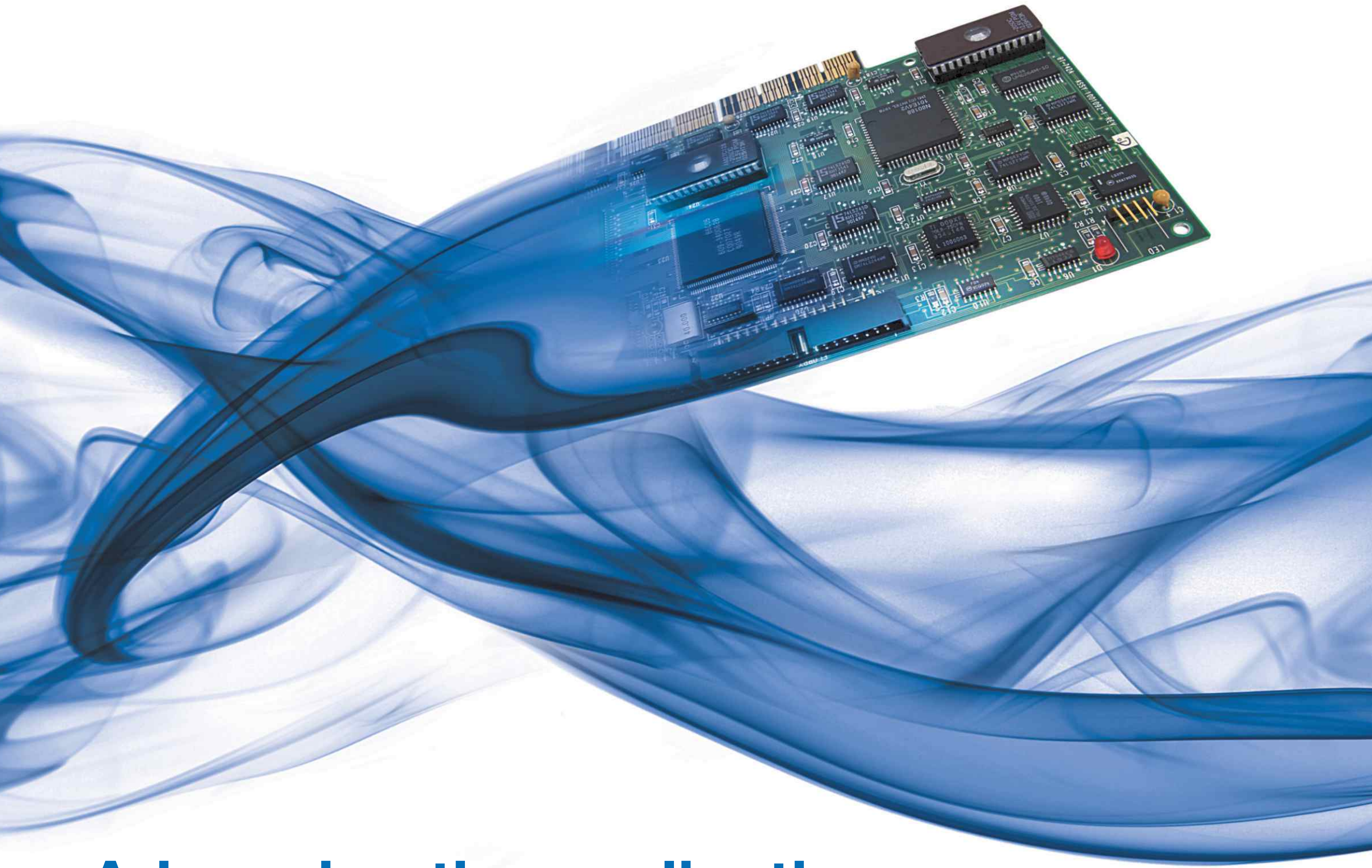
Quality control has an additional set of challenges. Previously a "captive shop" only, where its primary customer was itself or involved the manufacturing of custom turn-key OEM products that were designed in-house, we opened our doors earlier this year to contract manufacturing work in an effort to help other manufacturers struggling with disruptions caused by the COVID-19 pandemic.

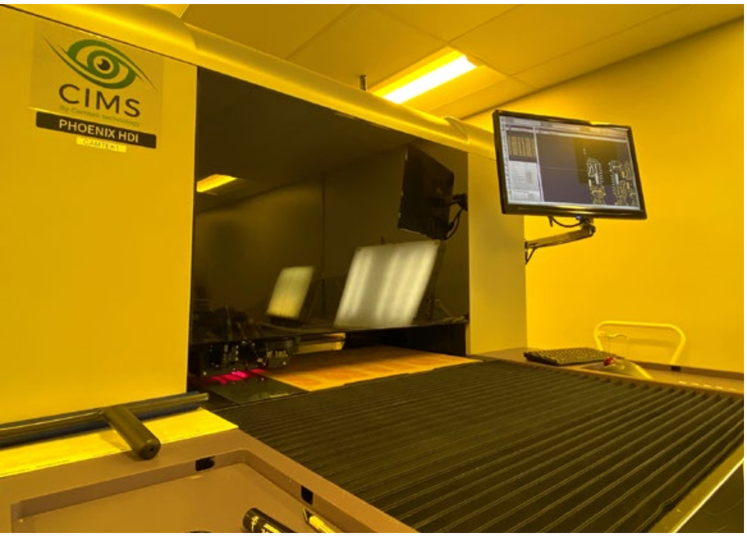
We are a U.S.-based, ISO-certified manufacturer of electronic controls. In committing to CM work, we knew that we would need to rely heavily on tight statistical process control (SPC) up front to help make the transition and overcome some CM shortfalls, knowing there is room for improvement.

A member of IPC, we adhere to IPC standard protocols for bare board fabrication but rely on AOI technology and light table visuals vs. electrical testing to inspect for indents, opens, trace shorts, and other potential board defects before the board moves on to assembly. For bare-board-only customers requiring higher levels of inspection, we currently use a third-party service to validate the work until we have our own internal electrical testing process in place.

Where we might lag in some areas, however, we make up for in others by adhering to tight tolerances, to ensure the highest quality standards are maintained. We have been in the business of fabricating and assembling PCBs for over 36 years, and we leverage statistical data to be proactive in areas like equipment maintenance to help it maintain a nearly 99% overall (entire production) first-pass yield.

Quoting W. Edwards Deming, Smith notes that "without data, you're just another person with an opinion." It's through the application of data compiled that we strive to achieve the





ICM runs each board through an AOI system, resulting in higher first-pass yields.

Operator Dan Kranze conducting a highly accelerated life test (HALT).

Six-Sigma goal for a first-pass yield of 99.99966%—a mark that Smith admits is "tight but doable."

By continually measuring with precision laser guidance the lengths and widths of drill bits and other tooling involved in the board manufacturing process and changing them out on a rigid "preemptive" schedule, we mitigate the risk of producing inferior quality boards.

Overall, we spend millions of dollars annually in our CapEx budget to follow an aggressive preventative maintenance schedule. As a true vertically integrated company, we need to continuously reinvest in the company to stay globally competitive, where quality and efficiencies are concerned.

Quality Assurance, Dock to Dock

To get a genuine sense of the quality assurance program and process controls that are in place, one need only to venture to the company's receiving docks. When materials are first received in, we perform inspections and tests on the raw laminate, including a series of measurements that check each panel for its copper and laminate thickness, rigidity, and more. These pre-board inspection measurements are essential as they are later compared to each plated panel using coating measurement instrumentation (CMI) to ensure there is even plating on both sides of a board.

Overall, just in the manufacture of a bare board, there is a myriad of process controls in place to ensure the highest results. Everything from custom jigs that hold the panels in place during the drilling and routing stages, to the constant testing and analysis of wet chemicals, all the way through to the scoring of the board itself—every operation is controlled by processes that have served the company well for more than three decades. As the old saying goes, "If it ain't broke, don't fix it."

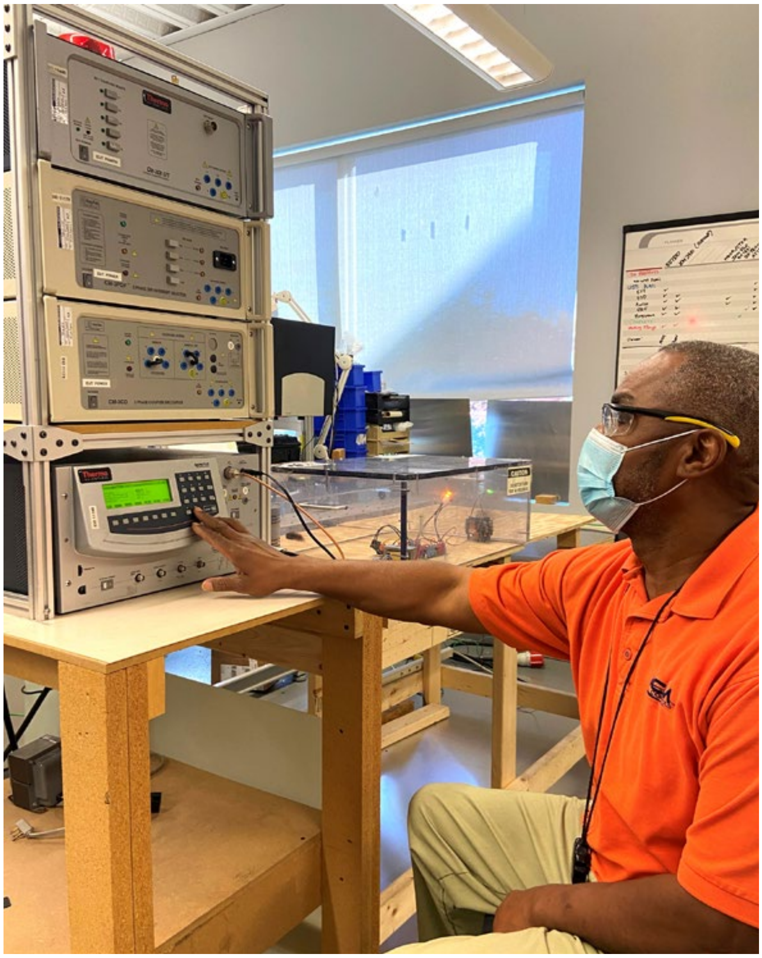
As boards move into the auto assembly area, the processes controlling quality are even more apparent and more abundant. Redundant first-piece inspections are the norm throughout the assembly area for each of the 1,000+ active part numbers that flow through the shop. With multiple mixed-technology lines (surface-mount and through-hole components) running three shifts per day, process controls and regularly scheduled equipment maintenance are critical to maintaining the high quality standards that customers have come to expect.

One of the biggest challenges in a busy shop is finding the time to perform maintenance on machines. Specialty equipment like

reflow ovens and wave solder machines have to be inspected and cleaned daily to ensure consistency in quality. Each piece of equipment has its own temperature profile, which is verified weekly to make sure it remains in compliance.

As all boards begin their journey through the assembly process, they are lasered with a barcode for tracking purposes. As the boards make their way down the lines, cameras and vision systems capture each pick and/or placement of each component. Dashboards are located throughout each assembly line that monitor missed insertions, missed picks, etc., and tabulate an overall reject rate.

Here is where CM work can sometimes present a challenge to long-time captive shops that have traditionally standardized the component library to strategically leverage specific equipment to maximize shop efficiencies and control costs. As we migrate toward becoming a true CM, however, the company will undoubtedly be forced to expand its component library, thereby requiring additional layers of scrutiny as boards move between operations.



Operator Walter Hudson conducts an electromagnetic compatibility (EMC) test.

The Human Element

While modern technology is relied on heavily throughout the shop to maintain quality, there is still a human element that also comes into play, particularly in the assembly area. Each time we change out a component reel, we mandate that two operators inspect and verify that the component being selected is correct.

This same multiple inspection requirement carries over to several other areas on the assembly floor—including at the end of the flex line, as well as the solder wave—and requires an operator and supervisor sign-off. Holding multiple people accountable for the quality of a process and product has proven to be an extremely effective and reliable deterrent to making mistakes.

While everyone on the shop floor has some responsibility for the quality of the products that leave the factory, the quality team is often placed under a customer's microscope and held accountable to the outside world. For this reason, we invest heavily in personnel to support our quality efforts.

We employ more than 20 full-time employees on the quality team, which represents more than 10% of overall first-shift production personnel. From QA auditors and engineers to test technicians and document control, the quality team is a highly visible force throughout the company's shop floor.

We typically test products to a Level 3 Production Part Approval Process (PPAP) standard, which is a modified version of the Automotive Industry Action Group (AIAG) format. It conducts and reviews the tests in parallel with all necessary agency approvals, with most products subjected to a minimum of 18 elements.


KOH YOUNG AMERICA
Those who demand more, demand Koh Young.
KSMART
The True Smart Factory Solution
True 3D
You can't deliver quality products if you don't excel at ordinary operations. With best-in-class inspection, Koh Young's advanced 3D inspection technology and solutions optimize your PCBA manufacturing process. We ensure that you can improve your productivity and quality, while sustaining the flexibility to overcome current and future challenges.
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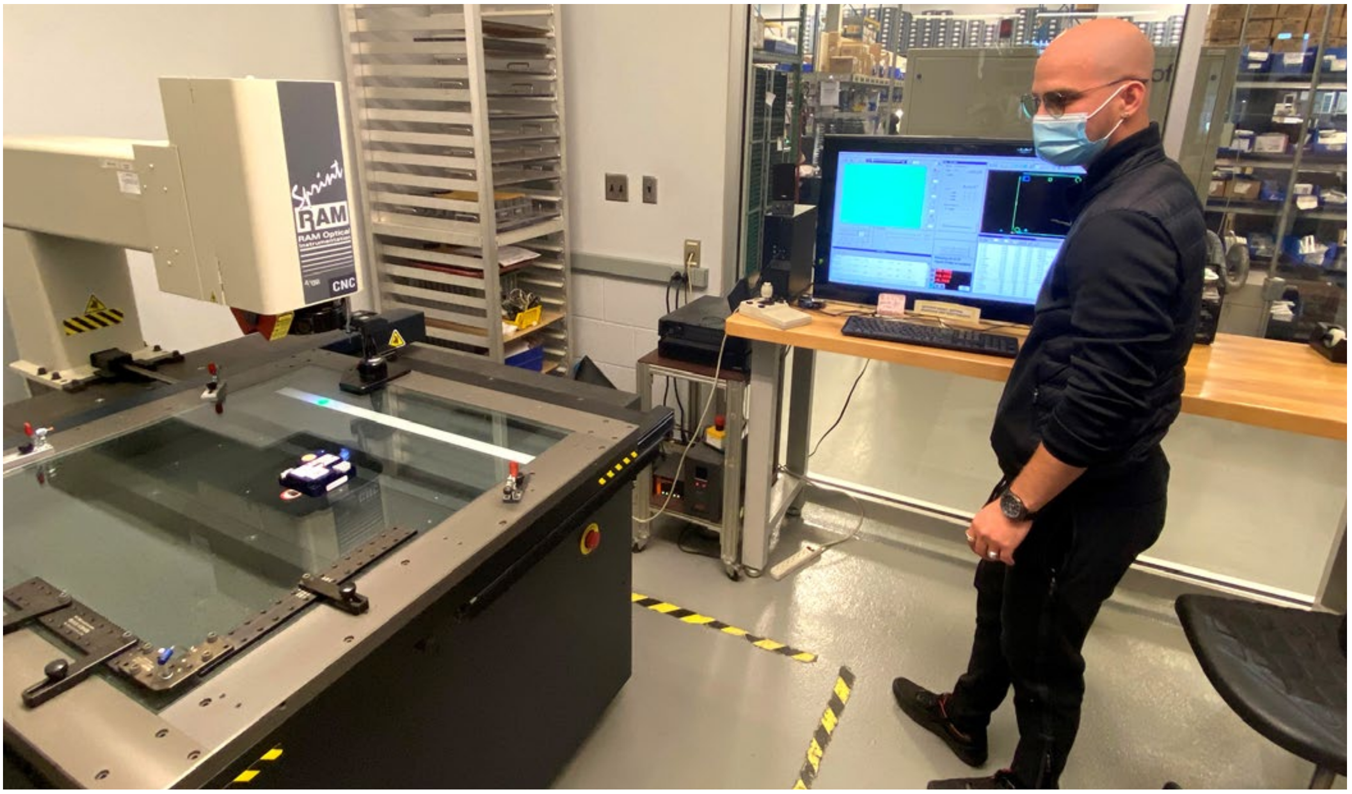


With the optical video probe (OVP), Operator Julio Placeres gathers detailed full-color images.

To this end, the company's Pre-Production Engineering and Reliability Department is one of the busiest and most important in the building. From conducting simple temperature and pressure tests to using its HALT chambers to perform highly accelerated life testing, the quality team is deliberate in its attempt to find manufacturing flaws that could ultimately compromise a product.

While several test technicians enjoy the practice of "blowing things up," they do so for much more than their own enjoyment. We want to ensure that controls "fail safely" when under duress. The company uses the internal data it collects to improve upon product designs that can help its branded products gain a competitive edge in the marketplace. It's all part of its Six-Sigma "lessons learned" approach.

Additionally, the team performs load testing and has an EMC chamber with a capacitive clamp, and even a salt spray chamber to replicate environmental extremes. Quality uses a standard design, validation, plan, and report (DVP&R) method for selecting the appropriate tests for each of our products. Only when reliability and quality sign off on a product is it released into production.

The quality team has already undergone Six Sigma training with several members holding Black or Green Belts, and it is Smith's goal to have everyone at ICM Controls trained to at least a Yellow Belt level. Additionally, Smith invokes the Japanese term "Gemba" (meaning "the actual place") and encourages his peers and colleagues to join him on a "Gemba walk" of the production floor to see and learn firsthand where quality begins.

We continue to grow. As the company becomes more entrenched in the world of contract manufacturing, we will continue to invest in the tools and personnel that will cement our reputation as a manufacturer of products that are backed by American-made quality and reliability. **SMT007**

Kevin Jobsky is a senior marketing manager at ICM Controls Corporation.

Test and Measurement in a Smart Factory

Feature Interview by Nolan Johnson
I-CONNECT007

I spoke with MIRTEC President Brian D'Amico about how the role of test and measurement equipment is changing in the smart factory and how shops can adjust to make use of the new technology. D'Amico shares this insight: "While approximately 90% of U.S. electronics manufacturers recognize the potential of Industry 4.0 to improve productivity, many are slow to adopt smart factory solutions within the manufacturing process."

Nolan Johnson: What are the changes to test and inspection's role in the factory? Does it differ depending on whether you're in the U.S., Europe, or Asia?

Brian D'Amico: Industry 4.0 is a topic of much discussion within the electronics manufacturing industry. Manufacturers and vendors are trying to come to terms with what that means. In the most simplistic of terms, Industry 4.0 is a trend toward automation and data exchange within the manufacturing process. This basically requires connectivity and communication from machine to machine within the manufacturing line. The challenge is to collect data from each of the systems within the line and make that data available to the rest of the machines.

Without test and inspection, there is no Industry 4.0. The whole purpose of test and inspection is to collect actionable data that may be used to reduce defects and maximize efficiency within the manufacturing line. The goal is to minimize scrap and get a really good handle on those process parameters that need to be put in place to manufacture products the right way the first time.

For maximum efficiency, three inspection systems are required within the production line. These are solder paste inspection (SPI) post-solder deposition, automated optical inspection (AOI) post-placement, and AOI post-reflow. This requires a substantial investment; however, the combination of all three inspection machines is really the only true way to provide feedback for each stage of the manufacturing process.

Johnson: You mentioned three places to put test and inspection. In a more traditional "red

light, green light" approach, test and inspection is an end-of-the-line process.

D'Amico: While I understand and agree that most manufacturers rely on a single post-reflow AOI system, the problem is that it becomes more difficult to diagnose and resolve where an issue may have occurred within the manufacturing line because you're only looking at a snapshot of the final result of all the other assembly equipment within the line. From there, you're kind of guessing where the issue occurred.

An SPI system, for example, would provide immediate feedback on issues such as insufficient or excessive solder, solder bridging, or solder offset directly after solder deposition. These issues are typically related to process parameters, such as stroke speed for a screen printer, squeegee pressure, under-stencil cleaning, etc. The bottom line is that it is more difficult to diagnose screen printing issues based on data collected by post-reflow AOI.

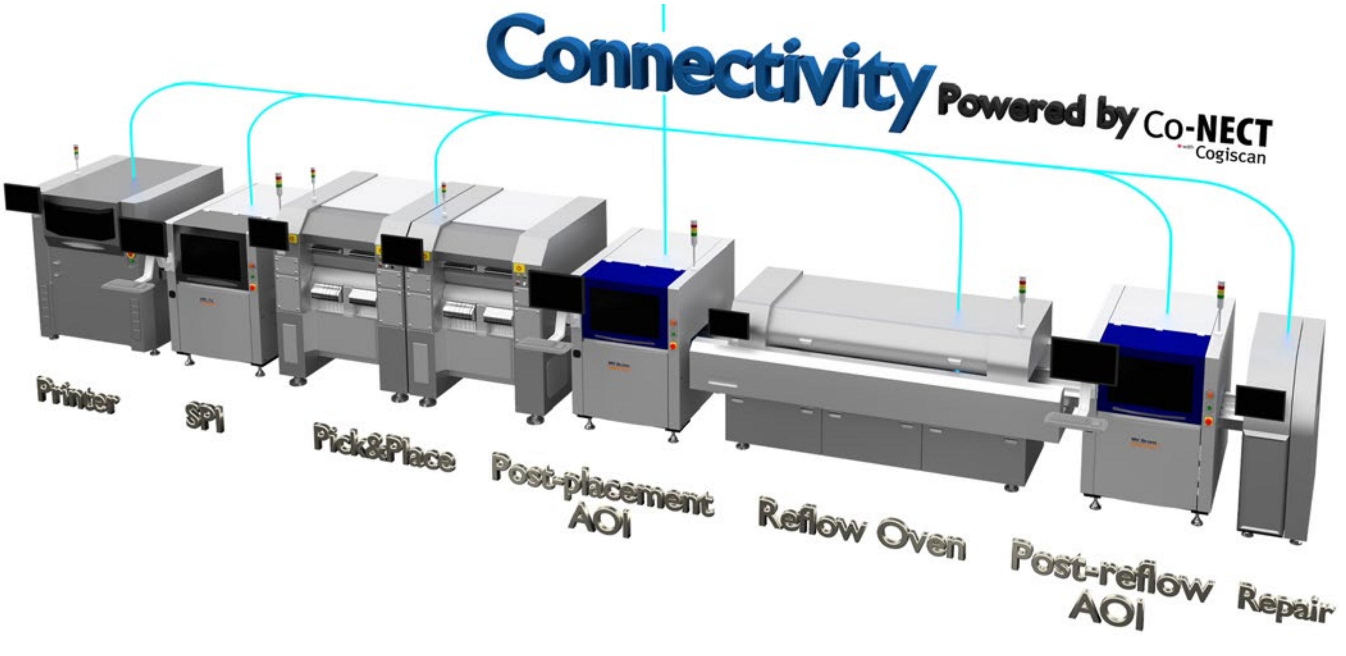
Johnson: For somebody who's a more traditional thinker in this industry, then the one test at the end of the line is how they think about test and inspection. The more factory automation you put into place, the more places you'll need measurement—mini feedback loops.

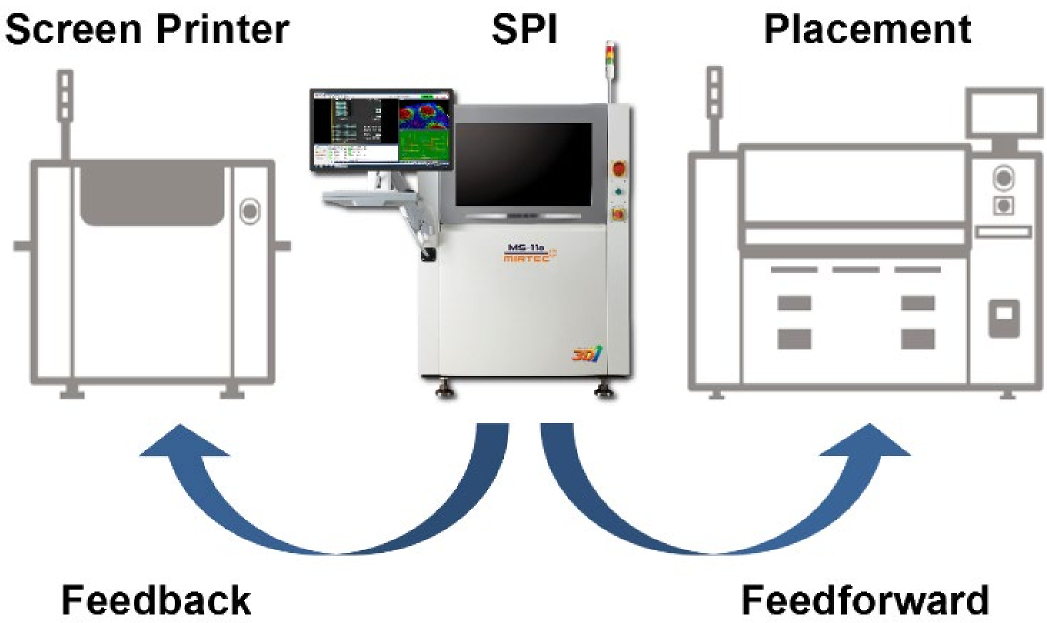
With the measurement data captured, it becomes a case of how sophisticated the machinery is that you're feeding test data back to. Can the machinery self-adjust, for example, or does it need a human operator to make the fix?

Brian D'Amico

D'Amico: Adjustments are typically made based on trends within the inspection data. For example, let's say that the SPI machine detects an offset trend in solder deposition with regard to pad location. Under these circumstances, the SPI machine would report the trend to the screen printer.

The screen printer, in turn, may then use this data to adjust the location of the stencil with respect to the pads to eliminate the offset. As you stated, however, this really does depend on the level of sophistication of the screen printer to accept this data and then make the necessary changes to the specified parameters to resolve the issue. Please keep in mind that the goal is not to control the screen printer but to provide actionable data which may be used to eliminate the offset trend and potential





defects. It's really up to each vendor to determine whether adjustments are to be made manually or autonomously. Most vendors will provide a means of selecting between manual and automatic mode.

As I mentioned earlier, it is very difficult to determine which adjustments need to occur throughout the line based on the post-reflow analysis of defect data. You can certainly make assumptions, but those assumptions are so far down the line that it becomes increasingly difficult to determine exactly where the defect occurred.

From the customer's perspective, I completely understand that we are suggesting a substantial investment in test equipment; however, the absolute best way to get a handle on the entire production line is to have testing at each interval within the line, including post-solder deposition, post-placement, and post-reflow. That is really what industry 4.0 is all about.

Johnson: Based on this trend of moving toward inserting inspection functions throughout the, does that cause test and inspection equipment manufacturers like you to specialize a feature set for a particular spot in the line?

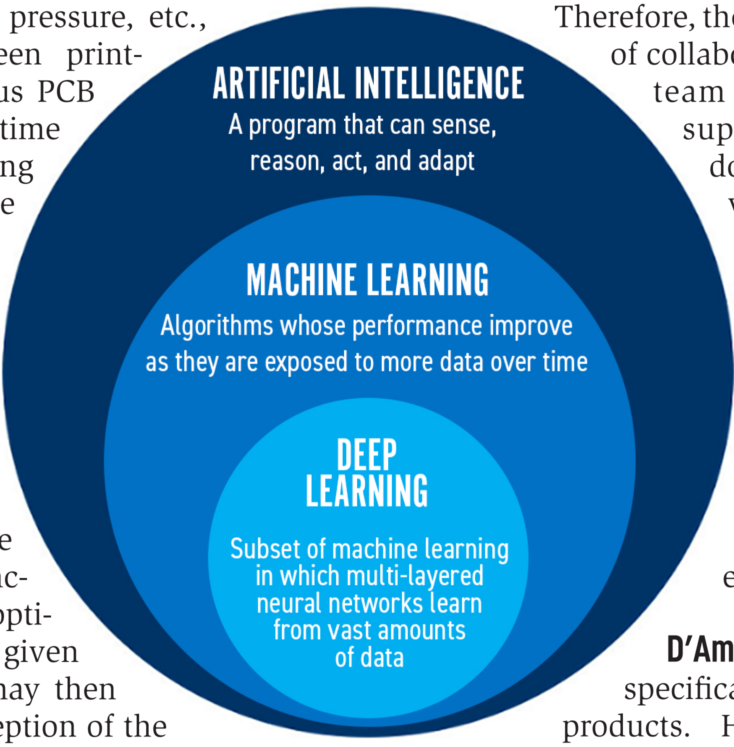
D'Amico: Absolutely. An SPI system is specifically designed to test for defects related to solder paste deposition such as excessive or insufficient solder, X-Y offset with respect to pad location, solder bridging, shape deformity, etc. A post-placement AOI system would be programmed to test for component presence or absence, part markings, proper rotation, offset, etc. And a post-reflow 3D AOI system would be programmed to test for all of the same parameters as a post-placement AOI system, as well as co-planarity, for each device, solder joint integrity, and solder bridging.

Johnson: Talking about getting information from this equipment and feeding the trending data back, and performing the analysis, is that analysis taking place on your system or is that happening in the database?

D'Amico: The answer is basically yes. Under some circumstances, data may be available through direct machine-to-machine communication. This machine data, however, is also collected within the inspection database for analysis. This is commonly referred to as big data. By applying a subset of artificial intelligence (AI) called deep learning to this big data, we can determine the optimal process parameters for maximum quality and efficiency.

When setting up a new PCB, an SMT engineer will program the process parameters for each system within the manufacturing line based on the respective experience of the engineer. Deep learning methodology is designed to assist with this daunting task of process optimization by predicting optimal parameters based on historical data. The goal is to achieve the highest production quality regardless of the capability or experience of the engineer. The performance of the line must then be monitored in real-time through continuous collection and analysis of production data.

The concept is as follows. Let's say we have collected historical big data for squeegee speed, squeegee pressure, etc., across multiple screen printers and across various PCB models. At the same time that we are collecting this process data, we are also collecting inspection results data from the SPI machines. By analyzing and correlating the inspection results with the various squeegee speed and squeegee pressure settings, we can proactively determine the optimal parameters for a given application, which may then be applied at the inception of the SMT manufacturing process to ensure optimal performance. Keep in mind that this is just one of the machines within the line. The same methodology is applied to the entire SMT manufacturing line.



Johnson: That process optimization, real-time adjustment is happening in the database with the AI engine, and that AI expertise is someone else's core competency. Is there a lot of collaboration with the companies specializing in that work?

D'Amico: Absolutely. AI is a very large and comprehensive term. The AI that I am referring to is, of course, specialized toward the SMT manufacturing process. But AI and big data are used worldwide for many different applications. As an example, many of us have visited websites online only to be greeted with a test to see if we are robots. These tests typically direct you to "click on all the images that show a bus, bridge, bicycle, pedestrian, etc." Few people realize, however, that this test is part of an AI engine collecting big data that is then provided to assist in the programming of autonomous vehicles.

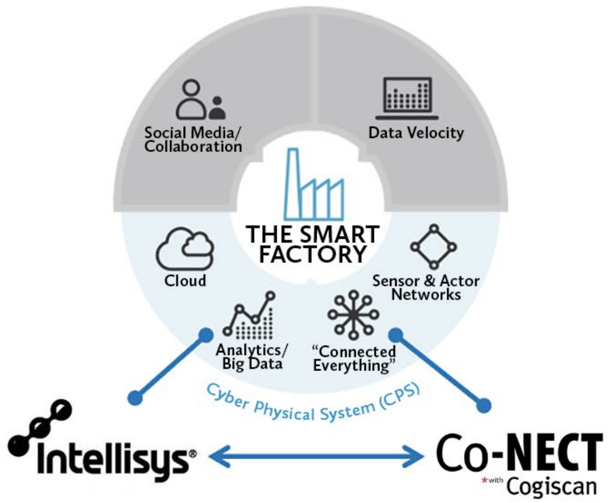
The bottom line is that an AI engine is highly specialized for any given application. Therefore, there must be a great deal of collaboration between the AI team and SMT equipment suppliers, as what we're doing in our industry is very specialized versus other industries.

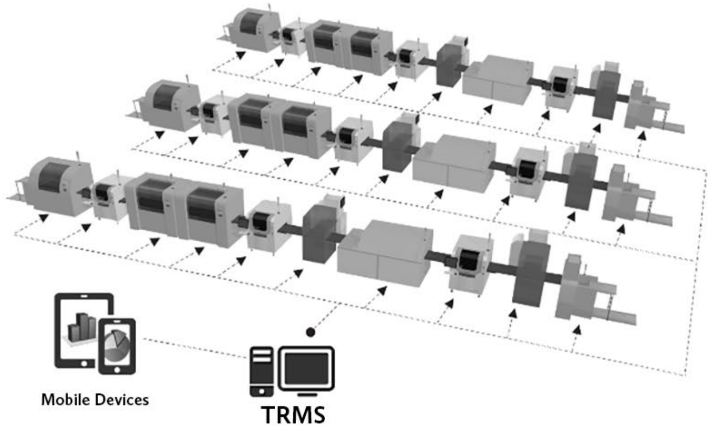
Johnson: How does MIRTEC connect with the AI engine? Do you leverage a third-party tool or a group of approved AI suppliers, for example?

D'Amico: Our AI engine is specifically designed for our products. However, the system must be flexible enough to be able to process data from multiple pieces of production equipment, including competitive inspection systems.

With this in mind, MIRTEC has made a strategic decision to partner with companies like Cogiscan that specialize in machine-to-machine communication, allowing us to connect to virtually any machine within the manufacturing line.

Machine data is then collected, formatted, and entered into a repository from which it is made available to other systems within the line. This also overcomes the hurdle of working with some competitive systems. Together, MIRTEC and Cogiscan have collaborated on a fully integrated Industry 4.0 solution, which is





our Total Remote Management System (TRMS). This application displays data collected from MIRTEC's AOI and SPI systems, as well as all other equipment in the SMT manufacturing line, giving our customers a clear view of the manufacturing process, and thereby helping them achieve higher operating efficiencies and improved quality.

Johnson: Not everybody can install new equipment to make a digital factory. To retrofit the equipment you have and bring it up to speed, and at least keep moving forward step by step is a valuable thing to do. As we started this interview, you shared that the adoption rates for the digital factory are geographically influenced. Where do you see more adoption?

D'Amico: Asia is where we see the most traction. But that is really something that I would fully anticipate as we typically see that Asia is at the forefront of adopting new technology. That includes Industry 4.0.

Many customers in the U.S. and in Europe are still in the process of "kicking the tires." They recognize that there will definitely be value added by embracing Industry 4.0, but there does not seem to be a sense of urgency. Having said that, I find that a lot of customers are asking the same question. Are these machines Industry 4.0 capable? This means that they are definitely considering this as a future requirement, which makes perfectly good sense. When a manufacturer invests in a new piece of assembly equipment, they expect to use the equipment for a period of 5–10 years or more. It stands to reason that any new piece of assembly equipment must provide the required process data, as well as the ability to communicate with other machines within the line. These are the basic requirements for Industry 4.0 capability.

Johnson: It makes sense that smart factory and automation would be a priority when you're working in high volume production. You want to keep the line running; as much as possible, you'd like for the line to do its own adjustment, keep itself optimized, or to quickly throw up an alert to keep it moving.

But it seems to me that, when you get into the U.S. and Europe, the manufacturing is more specialized—lower volume, higher mix, and perhaps more esoteric—in terms of what's being built, higher layer counts, and other constraints that will require precise adjustments to the process windows. That process window feedback seems even more important in that environment than ever.

D'Amico: I fully agree. In Asia, manufacturers are typically geared toward high-volume production. The same is true in Mexico. Keep in mind that these higher volume markets are very cost-competitive with very slim margins, so there is a special emphasis on fully automatic SMT manufacturing lines. In the U.S. and Europe, however, we specialize in high-

mix, low-to-medium volume manufacturing with a separate subset of challenges. Lot sizes may range from 1–100 PCBs, so there is a sense of urgency to quickly dial in the manufacturing process and eliminate defects. Furthermore, products manufactured in the U.S. and in Europe are typically higher dollar value, which makes rework an extremely costly endeavor.

Considering the fact that the cost of rework increases dramatically as the product advances through the manufacturing line, it becomes clear that high-mix, low-to-medium volume manufacturing is the ideal environment for inspection at each phase of production. For example, let's say we have an SPI system that detects an insufficient solder defect. Since the defect has been flagged post-solder deposition, we can either add solder to the pad or simply clean the PCB off and start over again. This is a relatively low-cost solution.

A post-placement AOI system may perhaps flag a polarity issue with a certain device. Under these circumstances, the operator can simply use a tweezer to rotate the device and resolve the issue. This is also a fairly low-cost solution. Any defects that are caught by the post-reflow AOI, however, will most likely require rework, which may either damage the component or the PCB. The bottom line is that it simply makes sense to catch the defect before reflow to avoid costly rework.

Johnson: Smart factory implementation helps relieve the pressures faced by large-volume production facilities because they can keep the line running, teach it to self-adjust to maintain process windows as much as possible, and keep product flowing. But those same features also work well for a higher-mix, lower-volume, more technical line by providing more accuracy in the retooling process during the setup for the next job.

D'Amico: Exactly. In Asia, you're talking about high-volume applications and a very low mixture of products. Once the line is set up, it may produce tens of thousands of PCBs or more. In this environment, it is very important to monitor each phase of the production line in real-time so as to maintain maximum quality and efficiency. When dealing with high-mix, low-to-medium manufacturing, it becomes even more important to have the proper setup parameters at the inception of production as there is little time to dial in the line for maximum quality and efficiency.

Johnson: What's the key to making this all work?

D'Amico: There is really no substitute for a good process engineer as they have the experience and know-how to make a production line "sing." In setting up the screen printer, a good engineer may recognize that a step-down stencil may require a certain squeegee speed and pressure for optimal solder deposition. He or she may also know how to tune the pick-and-place machine for optimal performance as well. For example, there may be certain devices which require a bit more pressure or dwell time during placement. The same is true for the optimal reflow profile as well. The key here is that this requires a level of expertise as a result of having spent a lot of time working with a given production line and knowing the nuances of each machine.

The whole purpose of having machine-to-machine connectivity and communication is to collect and analyze process data and provide optimal parameters for each machine within the line, thereby removing some of the "art" in the manufacturing process. Furthermore, a complete Industry 4.0 solution will monitor each phase of the production line in real-time so as to maintain maximum quality and efficiency throughout the manufacturing process.

Johnson: That's a great point that it's a little bit more science and a little bit less art.

D'Amico: Exactly.

Johnson: Great. Brian, thank you for the time.

D'Amico: My pleasure Nolan. Thank you for the opportunity! **SMT007**

Test and Inspection With Industry 4.0

Feature Interview by Nolan Johnson
I-CONNECT007

Historically, test and inspection has been a pass/fail point part of the overall process. Now, it's in a place to feed information back to the rest of the factory and even help contribute to process optimization. That requires some more sophisticated integration with software tools and databases, which is where Bert Horner of The Test Connection and William Webb of Aster fit into the conversation.

Nolan Johnson: Let's start with a quick introduction to you both.

William Webb: I'm the technical director at Aster Technologies in the U.S. The company is based in France, and I'm head of the U.S. operation. I come from a test engineering background. I worked as an ICT development engineer and then in managing development and deployment overseas with previous companies. About five and a half years ago, I moved to Aster. My previous company bought the Aster TestWay tool, so we used the tool and liked it. That's how that connection was made in going to Aster.

Bert Horner: I'm the president of The Test Connection, an applications group in Maryland. Our services include in-circuit, boundary scan, flying probe, functional, and DFT. At our location, our engineers work on development as well as testing, so we can do contract testing for folks who do not have their own equipment. Our main business started out as only ICT and test development, but we've expanded our services and moved into flying probe, boundary scan test, and other applications.

We have been in business since 1980 and are proud to say we are the oldest test development house in the world. We are 100% family-owned—one group. We're also an Aster customer and partner. We bought the TestWay software after evaluating a couple other CAD transition tools. We've been working with Will for about two years, and our partnership is growing stronger.

Johnson: Will, how does your software solution fit into a test environment? And does it differ whether it's a company specializing in test, like Test Connection, or in a traditional contract manufacturing house?

Webb: That's a good question. The TestWay software can allow you to do a number of things around optimizing your test. After it started 25 years ago, the objective was a tool to do advanced electrical DFT. A lot of times, when people talk about DFT today, they focus strictly on the mechanical side accessibility from a flying probe or ICT viewpoint. But it actually goes a lot deeper than that. If you can start early at the time of schematic capture, even pre-layout, you have the chance of looking at the design from an electrical viewpoint, making sure the board has been designed to be testable. You're looking at things like boundary scan chains, looking at disables, you're looking at anything that would keep you from being able to fully test the board.

William Webb

That's one thing the tool does, and that's how the tool got started. The other equally important thing is we can analyze test coverage. We can do test coverage simulation early on, so if you know that you have a circuit board that's coming to you and you need to have some tests, the tool allows you to simulate different test strategies.

For example, you can look at boundary scan, AOI, AXI, or ICT, and you can see what types of coverage each of those would bring to the table and decide on what your best strategy would be. You could also use the tool to eliminate redundancies because you might be over testing the board. You can use the tool to identify places where you're testing in more than one strategy, and you might choose to eliminate one of those. You can also identify gaps in the test coverage, and maybe you need to think about adding another strategy to make up for some gap that you haven't thought of. The software will point all of that out.

Those are the two primary things that you can use the tool for initially. We also do CAD/CAM output processing. For example, you can use the tool to create beginning development files for a large number of machines—AOI, ICT, flying probe, boundary scan, and all of that. The neat and unique thing about that is if you've done simulation, identified redundancies, and use our output processing, you're going to already create a lean test program.

A classic is somebody who is doing a boundary scan and flying probe, for example. Flying probe, as we know, has a long test time in comparison to ICT. But if you can identify the parts that are being very well tested with boundary scan, you can create a flying probe program that has now removed that redundancy that was tested with the boundary scan. You can get a cheaper test, less engineering time to develop the flying probe, and a faster execution time, saving you engineering hours.

Johnson: You're creating quite a database for coverage.

Webb: Yes. Let's extend this a little bit more into coverage and measurement. I talked to you about coverage estimation or simulation and the after processing stage. The third part is, once you have tests developed and running on the production floor, we can bring in those programs or the test coverage reports that are produced by the machine, and we can measure how good the test coverage actually is. Does it meet your expectations? Does it match what you simulated them to be? Are there gaps that didn't get debugged correctly? It gives you a lot of visibility as to how the test program actually turned out.

That completes the loop. You can estimate in the beginning, do the CAD-to-CAM conversion, and then do the measurement. We refer to that whole process as the digital twin, which is an Industry 4.0 term. You're replicating your manufacturing test line inside your computer. You're modeling that and measuring the results, so you're using data to make better decisions about your test that, otherwise, you might be guessing about.

Johnson: As test and inspection become more of a part of the feedback loop for the digital twin, what are the challenges? Now that you have results, how do you integrate your results with a digital twin?

Horner: When you're measuring the results, it is based on the metric. A lot of times, the quality reports that come off a test or inspection system are not based on a metric. What can be accomplished with TestWay is a comparison of theoretical coverage versus measured coverage. When you're looking at test coverage, somebody says, "I have 90% coverage, and that's all very subjective. But if you base it on a metric that says, "I have a PPVS metric," then we have something that's based on presence, polarity, value, and solder.


Bert Horner

The PPVS is a metric that is a subset of PCOLA/SOQ, an industry standard that is loosely adopted. I think Keysight and other ATE suppliers are embracing this type of metric, but not everyone. But if you have a baseline that you could take to management and say, "I have 90% coverage," then you would have a better idea of what that 90% coverage entails.

Webb: It relays it back to a metric. The problem that you have is if you start looking at coverage from different types of machines, you have a particular AOI machine and a particular flying probe. Those all produce a coverage report like Bert says, but they may use different metrics to evaluate the coverage. The good thing about bringing in a tool like TestWay is that it resolves everything back to the PPVS or PCOLA/SOQ and easily creates a combined coverage report for you from any of the tests that you're going through—something that would be very difficult to do manually with a spreadsheet. With TestWay, it is done instantly by resolving all that back to the metric that Bert says.

Johnson: You could use multiple test styles, flying probe, optical, and bring all of that information together into one place for one cohesive set of results.

Webb: Exactly. There's no one strategy in our industry that would cover all your potential defects. You need to look at multiple strategies to come up with decent test coverage. With ICT, certain faults can be caught with AOI, and others can be caught with X-ray. You need to be able to look at what each one of those is bringing to the table and make sure that the sum total of all your strategies is giving you good coverage.

When you do that, you're going to wind up with the overlap, as we said. Not only will each strategy be testing something uniquely, but you'll wind up with overlap. The tool will identify that for you. Then, the user can make the decision about whether they want to reduce that overlap and have a leaner test and more cost savings in your test department. The tool will help you find the right amount of tests and keep the cost low.

Johnson: That's great. For somebody like Bert, in your facility, there's a lot of tooling, setup, and optimizing. You are living and dying profitability-wise in the effectiveness of your test coverage tool. Of course, there are other production facilities with fewer products but longer lead times. It would seem to me that the value in your product to a more production-oriented assembly house would still be there, but it would be a different set of returns on investment.

Webb: It's very interesting that you asked that question. We deal with both OEM, CM, and EMS companies. They can both be customers of our tool, and they are. As you say, the ROI calculation can be a little bit different. An OEM can look at what the DFT can do for them. In fact, coming from my previous employment, we were an OEM using the tool. With DFT, we could reduce our board spin. And we had some costs associated with every time a board spin happened, and it doesn't take too many board spins to pay for the tool since you have already paid for it.

Coming from the CM side, they're not always engaged early enough to have a real impact in a timely matter on the DFT side. The OEM might have already completed its design, gone through layout, and thrown it over the wall to the CM, and say, "Build and test this for me."

A CM will have a more difficult time identifying how to pay for the tool. But if you start looking at reducing the gaps in coverage, you reduce your faults going out the door that are going to come back. You look at eliminating the redundancies and can calculate your ROI right there. The tool still pays for itself. There are two different ways of looking at it, but it has been done by both. We've had a lot of customers of both variants.

Johnson: That sets up the next step, which is once you have that kind of information and a facility using your tool to set that up and getting the test results back with great coverage, that is just waiting to be used upstream in real-time as process optimization.

Webb: Correct. We have another part of our toolset called our QUAD tool. The easiest way to understand what it can do for you is automation of the repair loop. As your boards are flowing through your production test, all of the defect information and everything is being collected in a centralized database. When a board fails ICT, for instance, the troubleshooter can pull up that failure ticket from the database. They can click on the failure, and that failure information will be shown visually to them on our viewer so that they can see on the layout where the part is and where it is on the schematics. They can also access any prior failure information.

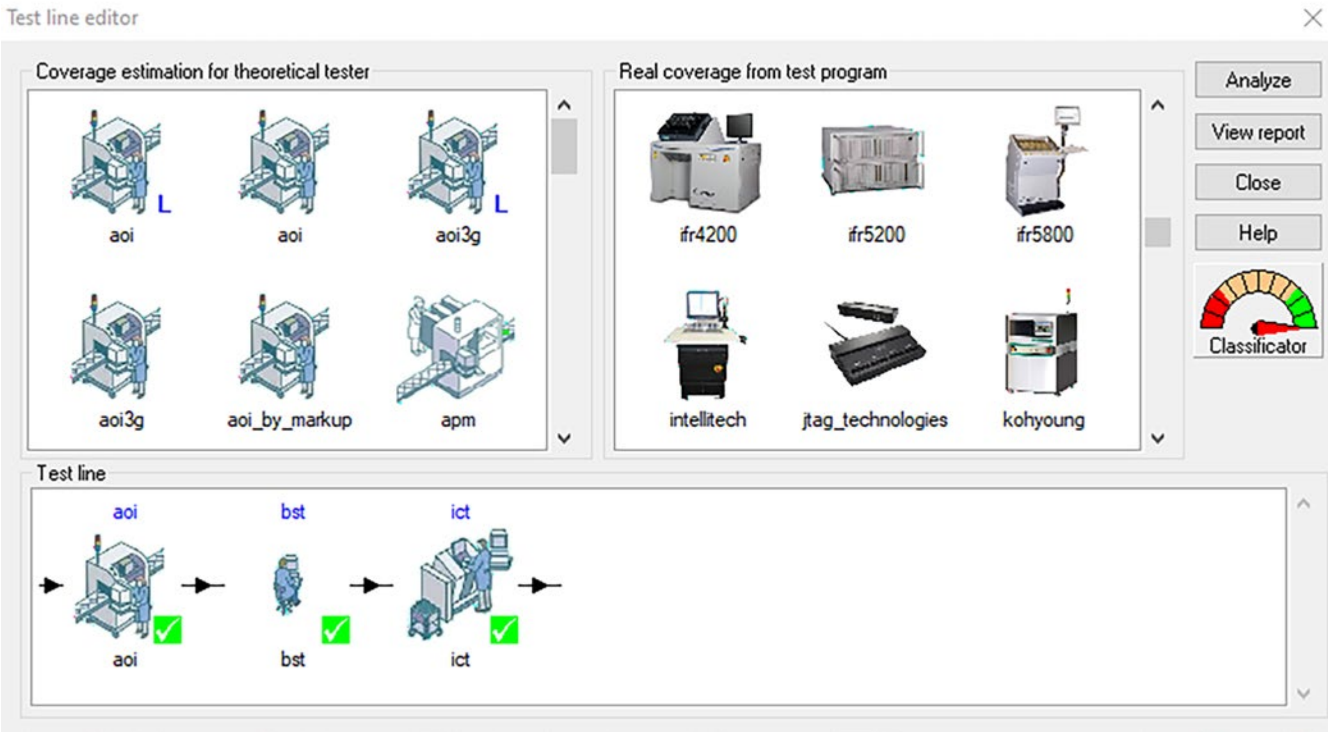
If the past five times that C10 has failed, it has been the result of another component on the board U5, they'll instantly see that information brought up in front of them. And you can see how that would help the troubleshooting loop and the repair loop and help the technician achieve a much quicker result in figuring out failures.

Johnson: A number of companies are using CFX, pulling the big data, looking to bring AI, automated problem solving, or issue response to the process. Now that you have statistical data, that begs for some change in the manufacturing process to be identified and steps to be taken. Are you starting to see that sort of interaction show up in customer installations?

Webb: Yes. We have employed something along those lines for some time with our Sherlock algorithm. What the Sherlock algorithm does is analyze what has been tested so far. If you're troubleshooting ICT failures, for example, and the board has gone through AOI and ICT, but hasn't yet gone through functional test, if there are unknown failures that are encountered, the Sherlock algorithm will give you likely places to look based on what has been tested and what hasn't been tested yet. That's a little bit about what you mentioned about using AI. It's using some information that you know to make some educated guesses about what the failure could be. If there isn't already something in the database that says, "This particular problem is fixed by this," it can lead the technician in the right direction based on what has not been tested yet.

Horner: There are actually two challenges. One, if you don't have any homogeneous equipment in your line, where they're communicating to each other, a seamless flow might not always happen as we would like because there are variances in the protocols talking to each other and might not be fluent. Each of them is going to have their own neutral talking languages. Two, if you have two pieces of equipment that are different makes or one is very old, you would still have the same communication issues.

When you start looking at the tools like Aster, Will is going to be looking at it from a point of view of test. TestWay and QUAD are going to be giving feedback to the manufacturing line. The value of this software is that you don't have to have a homogeneous line or have that synergy in your manufacturing line. You can now say, "I have a Keysight 3070 and a Goepel boundary scan giving us feedback on the line," and they can give that feedback to the command tower or the process people, which will allow them to tweak as they go along. I think that's a hidden value we see as a contract engineering service. The contract manu-



facturer will see the value and not have to say, "I have to scrub my whole line because I want to do this Industry 4.0."

Johnson: That's a valid point. That's one of the things that CFX, as a protocol, is attempting to accomplish: the ability to communicate seamlessly and clearly across multiple vendors using a common language.

Webb: As you may know, we are involved with CFX. But to take what Bert said just a little bit further, we don't actually require a machine to be CFX compliant to extract data from it. Not to take anything away from CFX at all because it's a good deal. It will make life easier. But we've been able to interface for many years with any number of machines because we have custom parts and everything that can identify the information that we need to get out of a particular machine. Once the CFX standard is in place, that makes our job even easier to get the data and information coming from these machines.

Johnson: It sounds like you have a library of an old-fashioned middleware as well.

Webb: That's correct.

Johnson: Let's say that at final inspection, you're looking at the board. It has been assembled, the components have been placed on it, and now inspection sees on this particular job a statistical bump for a handful of passives over on this one corner of the board, where they're starting to tombstone a bit more than normal. That indicates that something needs to adjust upstream to ensure a better solder paste application. Is that something that you can be a part of today?

Webb: Absolutely. If you start to see process shifts or process deviations that are happening, then flags are going to be set up to identify that within the QUAD tool. Not only does it automate the repair loop as we talked about, but it also produces all of your usual process-related charts and graphs and all that—any sort of alarms and stops that you want if things start to drift and go haywire. You can do that today, and we have customers doing exactly that.

Johnson: Is that implemented in the form of flags to operators?

Webb: Yes. It can be set up as flags to operators and send an email to production people to say this is what's now going on in real-time. It could be either one or both. I also want to cover defect parts per million opportunities (DPMO). We were talking about the coverage calculations earlier. We use the PPVS metric, but we also balance that by the DPMO. The value of doing that is you really want to have a good test coverage where you have the opportunity for defects, and if you have great test coverage on something that never fails, it doesn't really help you.

Having an understanding on where your defects are is very important to the whole process of making sure your coverage is in the right place. Part of the database we talked about is collecting DPMO information. And because for a lot of people these days, even a lot of our sophisticated customers, you start introducing this concept to them and they don't have a good way to get their own DPMO. Now, in our tool, there are some built-in models you can use for people who don't have their own DPMO.

We suspect as people shift more to Industry 4.0 concepts and collect big data, then they should be able to collect and make better use of those DPMO figures. You can feed that back into the tool now, and you get more accurate coverage results because now you know where your defects actually lie.

Johnson: That gives you better results to pass upstream for better process optimization to begin with. Fewer errors escape down-process, and everything starts to cycle upward with increased yields.

Webb: Yes, in an upward direction.

Johnson: Will, in this environment, what are some of your customer's biggest challenges? What are some of the key issues pushing them to decide that this is a solution they need?

Webb: There can be a couple of ways they decide that they need to have some sort of a tool like ours. One is, as I mentioned before, identifying that they're going through board spins. They're not identifying the key items in a timely manner. That can be a flag that, "We need some sort of a tool to automate this process so that we can do it every time the same way. If somebody is gone or somebody's left the company, we still have our built-in rule set that we can run in an automated fashion that's going to look at the things that we should be looking at for testability."

Equally as important, they need to have a way to produce test coverage numbers. A lot of times, we find that some customers of ours—and I'm sure Bert can identify with this—operate a little bit in silos. You might have the ICT department, but they don't talk to the AOI engineers or X-ray people at all. Everybody is focused very much on what they're doing, so trying to pull together two different teams to look at the combined coverage or looking at reducing overlap, etc., becomes very challenging from a management perspective.

The tool can really help that happen and start pulling in data from all the various teams. Somebody then becomes a coverage engineer or DFT engineer who has good visibility to the whole manufacturing test process and can start to understand what we've been saying. They can look at gaps that are missing and see what must be covered at functional coverage because we're not able to cover it with structural tests up until that point. They can also look at the redundancies that could be eliminated as a cost-saving.

It really ties together the manufacturing floor, and it can tie in design with test very nicely, which sometimes doesn't take this either, so the tool can really help bring those two groups to a place where they're talking more.

Johnson: Bert, as you're building your business and serving your customers, providing tests and services, you're not on the manufacturing floor. What are some of the challenges that this software solution has helped you with? I'm thinking mostly about feedback rather than test optimization.

Horner: We do not know what is upstream as far as inspection, but there is a lot of redundancy. When a contract manufacturer looks at us and says they have multiple inspections like SPI, solder paste, and they have different inspection processes. When it comes down to electrical intermediate test or some assembly test, there is a lot of redundancy. They're looking at their cost on the line, and they are getting shocked by the amount of cost that is just in test. Honestly, this tool has helped us QC the test process even better. When we are deploying a test set, we don't test a revised product.

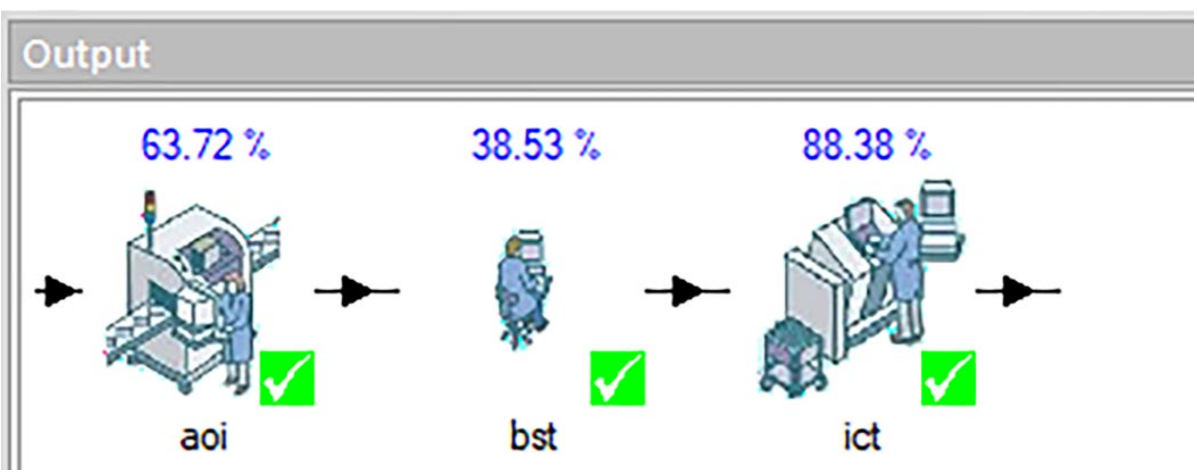
Most times, it's developed and deployed. And when we deploy a test set anywhere in the world, it is a lot easier to know that you have a stable, robust, test solution going out into the field before the manufacturer inherits it and then finds problems. When you try and deploy something to fix it in the field, let's face it, it is really difficult. We do a lot of work with a customer down in Texas, a military-aerospace group, and they live and die by the feedback we can give them and share. We are able to use some of Aster's tools as an intermediate process. Before we go and fix their build, we ask the customer what is their predicted coverage? By adding this model, could we get better coverage? The answer is either, yes, we did or find out that there's no value added, so you do not.

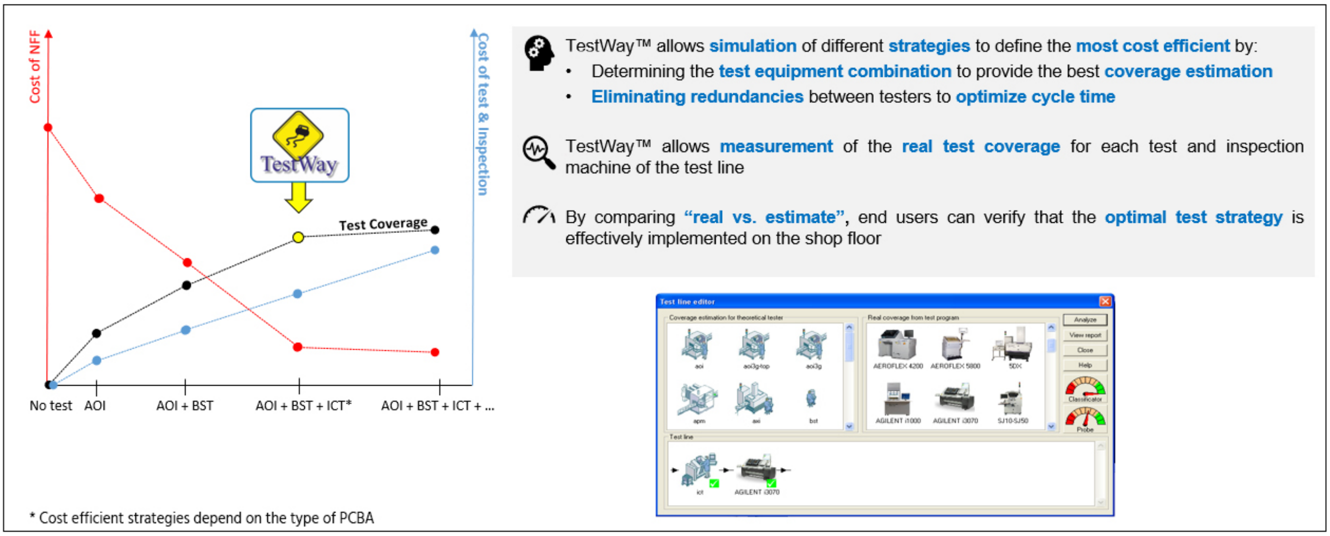
There are some intermediate steps. If you embrace the technology for what it's meant to be, there can be a huge value. And what we saw with this tool is a lot of the manufacturing tools that play in the same arena as our partner are similar. But they're looking at it from a production point of view, not a test point of view. What master do you serve? The production or the test? Test is where I put my head down at night. That's who we want to embrace, so we're going to be very test-centric versus some of the other tools out there that are more about production. And it's not going to give us the same value for test people.

It's not to say that the tools are inferior, it's just they have a different spectrum that they're servicing, and we distinctly feel that the other tools wouldn't give us the same value. This has given us value with some reporting mechanism. And let's face it, when you catch an issue earlier, not only on your production line, but in the test development or design world, the value is to go back and say, "You have a problem." You can have a report say, "Fix this."

Johnson: Will, who's your ideal customer?

Webb: Our ideal customers could be different. As I said, we can have CMs. They can be an ideal customer, where they're just looking to reduce their slip rate out the door and need a way to do that, so they come to us looking for a solution. On the other hand, it could be an OEM design house or group that's doing designs, and they just want to get better at their testability. They recognize that they're not able to fully test the board, and they're looking at solutions that would help them get to a better testable product. They equally could come





to us, looking for a solution, and we can provide it. The perfect customer can vary, but we can support customers with a little bit different needs and ultimately find them a solution to get a better product at less cost.

Johnson: Bert, any parting words from you?

Horner: A customer who doesn't play well with our service is one who does not have the ability to change. We deal with some of those folks too. They buy the tool and the reporting and put it on the shelf. They're not able to utilize the feedback to go to process. They'll say, "Lesson learned," but it needs to be a constant level of tweaking.

With Will's discussion about the DPMO, that's something that's an art, and I don't think a lot of production groups have the ability to grasp that number, and that modeling has to have a level of intensity. It's one thing to program an in-circuit tester and one thing to program SMD equipment; it's another to really understand the manufacturing process and being able to get that understanding where your possible faults could occur.

As you move toward higher volume, you're going to be dealing with something a lot different than building up 20 boards of this type and building 20 of that. It's a high mix of volume versus high volume and no mix or low mix. Those are two different spectrums. If they don't have an understanding of that, this tool could fall flat on its face. And I don't care what tool you have, you must have that champion, or you have to have a management champion for something like this.

Johnson: The success depends on the attitude brought by management.

Horner: In some, it can be done by management, but it could be the customer too. If I say, "Company X's prices are really good at building these assemblies," I'm not pushing you to do it better, quicker, faster, and smarter. They might respond, "I'll just keep slapping these boards up, and if one out of 20 fails, that's what it is. C'est la vie! I'm always going to have 1 out of 20 that fails." That would be versus somebody that's building a thousand of them because OEMs have their name on the product.

How many times have you said, "I'm never going to buy from Company X again because that tool I bought constantly dies, has no battery life, or whatever the problem is?" That company has the bad name now, not the CM. The OEM at that level has to embrace their name and the CM because if they lose their customer—whether they go out of business, etc.—they shoot themselves in the foot. You must have that champion.

Johnson: Thank you, gentlemen.

Webb: Thanks for having us. **SMT007**

MilAero007 Highlights

Standard of Excellence: Five Ways to Ensure You Have the Right Military PCB Supplier ▶

With the current shortage of qualified and certified military PCB suppliers, finding one has become more challenging than ever, and the trend toward consolidation over the past few years has only added to the shortage. Anaya Vardya shares five guidelines to consider when developing a bilateral relationship with your military PCB supplier.

Fresh PCB Concepts: Advantages of Application-Engineered PCBs ▶

When working with your PCB supplier, do you have a dedicated engineering resource to help with the design of your PCB before fabrication? How about a resource that has experience and knowledge about the different applications for PCBs? Jeffrey Beauchamp explains how this is one of the most important and valuable factors when producing high-reliability PCBs, as well as what—or who—this resource could be.

Defense Speak Interpreted: The Defense Innovation Unit ▶

Many of Denny Fritz's columns are about new defense technologies and innovations, but what about an organization with "innovation" in its name? Here, he describes the history and purpose of the Defense Innovation Unit (DIU), as well as some of its programs.

Mr. Laminate Tells All: Is Your Laminate and Prepreg Supplier Cheating? Only One Way to Find Out ▶

According to Doug Sober, a huge void now exists in the base materials specifications for PCBs and PCB assemblies with the inactivation of MIL-S-13949 for base materials and the loss of the military's oversight function. IPC-4101 replaced the specification for MIL-S-13949, but there was no mechanism established for an oversight function.

Just Ask John Mitchell: The Exclusive Compilation ▶

We asked you to send in your questions for IPC President and CEO John Mitchell, and you took us up on it! We know you all enjoyed reading these questions and answers, so we've compiled all of them into one article for easy reference. We hope you enjoy having another bite at the apple. And if you'd like to hear more from John Mitchell, view his column series "One World, One Industry."

Microchip Expands Solutions With New High-Speed Analog-to-Digital Converter Family ▶

Microchip Technology Inc. announced it filled this gap with its MCP37Dx1-80 family—the company's second pipelined ADC offering and first to combine 80 MSPS in a choice of 12-, 14- and 16-bit resolutions, integrated digital features, and qualification to a higher temperature range, including Automotive Electronics Council Q100.

Ventec Launches High-Speed Material Option Cladded With Thin-Film Resistor Foil ▶

For enhanced high-speed signal-handling performance required by the world's most demanding high-frequency PCB applications, Ventec International Group has launched a laminate option to its tec-speed 20.0 glass-reinforced hydrocarbon and ceramic laminate cladded with thin-film resistor material from Ticer.

Smart Factories: Indirectly the Death of Test and Inspection

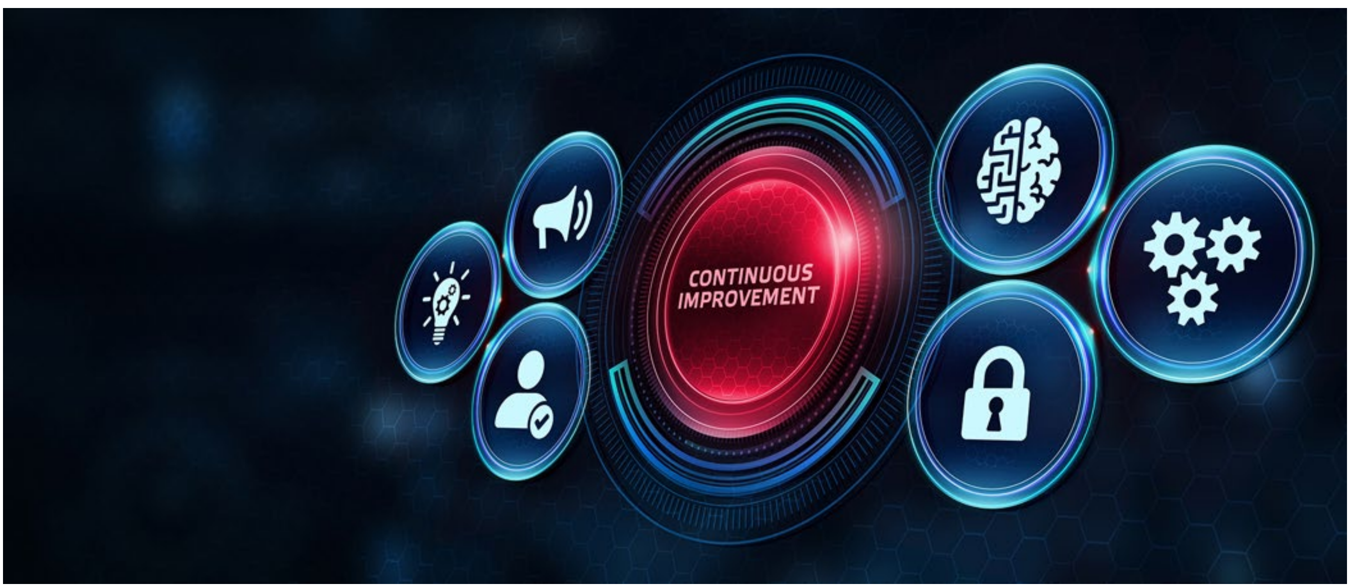
Smart Factory Insights

Feature Column by Michael Ford, AEGIS SOFTWARE

The indirect role played by test and inspection has no place in the smart factory if it is there simply to detect defects, providing a filter, at best, and acting for the improvement of product reliability in the market—a response to mistakes and weaknesses within manufacturing, effectively, or a tax on inadequacy. In the smart factory, test and inspection are reinvented, contributing direct added value, playing a new and critically important role where defects are avoided through the use of data and create a completely different value proposition. How can the digitalized Deming Theory be explained to those managing budgets and investments to ensure that we move our operations forward digitally in the best way possible?

Going back to basics, the concept of "direct" vs. "indirect" value to manufacturing is a fundamental measurement of the core business performance of any manufacturing operation. The value of the metric is the measurement of efficiency of any expense or cost related to manufacturing support, including non-added-value processes, in comparison to resources that are performing added-value manufacturing. Most other metrics focus on breaking down production activities, allowing inefficiencies in support, and enabling activities to go unchallenged. These include the operational costs of test and inspection, as well as physical activities orchestrated, managed, and monitored by MES, such as supply-chain logistics and quality management.

The origin of this metric predates automation and is associated with the work of W. Edwards Deming, though his dream had to be fulfilled with armies of staff, paperwork, and processes. Now, we have digitized it. As production operators represent the major operational fixed cost, those who perform assembly are seen as direct added-value, whereas other



activities—including repair and re-work—are seen as being indirect.

Applying the same principle to test and inspection, imagine a set of production processes where there is one machine, such as a pick-and-place, and a reflow oven both involved in the making of the product, and then an SPI, AOI, and ICT machine. Applying the direct/indirect rule, the direct ratio of this line is just 40%. In a perfect world, we would only need the two direct machines making the product. It means that considerable investment has been made, together with a high proportion of the operational cost, which is—in a sense—waste.

Applying the direct/indirect rule, the direct ratio of this line is just 40%. In a perfect world, we would only need the two direct machines making the product.

However, few would be bold enough to do without the test and inspection machines, as quality performance would no doubt suffer, bringing potentially more substantial costs associated with poor quality later. The reluctance to invest in equipment and software solutions that are regarded as being indirect is understandable. But as this and other similar business-level metrics are adversely affected, this leads to concerns with business sponsors.

How poor is the actual team at the site that they need so much more indirect support than others? Why should we invest in their inadequacy? These are old-school questions that the smart factory still has to answer if investment in smart technology associated with test and inspection, as well as software solutions, are to be readily accepted, as opposed to being a continuous battle for funding.

The fact that the smart factory is run on the contextualization of data provided by the IIoT-driven MES solution's built-in defined ontology is very fortunate for vendors of test and inspection equipment. These processes actually provide a large part of the required data for smart decision-making. Can we finally put aside the stigma that these machines and solutions are indirect costs, and position them as adding direct value to the production operation? We need to bear in mind that the key people we need to convince are not technically minded. The engineering-orientated explanation of how the role of these machines has changed is not going to be easy.

Let's first take a look at where we are in terms of maturity with the use of test and inspection data, as the technology is not yet at the point where it can be regarded as mature. Many years ago, the application of Six Sigma showed that defect occurrence is not required and is avoided by understanding the variations in processes and how to control them. Analysis of the data statistically as machine learning, closed-loop solutions, or as MES-level quality analysis exposes trends that risk defects, communicating the issue—and even executing the appropriate corrective action—before any defect occurs.

Whilst this is simple in theory, the practice itself is multi-dimensional, as there are so many complex and interacting factors. Machine-learning and closed-loop algorithms are yet to be perfected to the point where the root cause of variation can be correctly identified and appropriate action taken. A simple example of this is the analysis of the deviation of placement coordinates, comparing positions as specified in the machine program against those inspected after placement.

Simply put, too much deviation raises the alarm before the risk of making a poor joint or an unwanted short. However, how much is too much depends on many factors, such as the size, shape, and orientation of the pads on the PCB. Consider the size, shape, pitch, and contact profile of component leads, as well as the location, size, shape, and thickness of the solder paste.

Then, there is the need to understand the nature of the patterns of deviation, especially with respect to adjacent parts. Patterns in the data may suggest a PCB condition—for example, stretch or twist, which is an issue around a specific nozzle that has been used—or be related to the specific part itself. Each of these factors comes with its own set of rules as to what can or cannot be tolerated, as well as what potential adjustments in any preceding processes may be applied.

In reality, all of these effects happen concurrently with different levels of contribution. With all the analysis done, that is not the end of it, as certain aspects of trend calculations need to be reset when, for example, PCB packs change, nozzles are cleaned or replaced, materials replenished, machine parameters adjusted, etc. A truly challenging AI application running within a truly big data environment, with data from design, the supply chain, machine programs, MES, and other sources all needed to provide a holistic machine-learning or closed-loop solution. And this was a "simple" example. It is not quite a done deal as to whether we can say that "defects are history" already, though a lot of people are working hard on these algorithms from many directions, so we get closer and closer.

Business-wise, to get the buy-in to invest in smart factory inspection and test machines—as well as IIoT-based MES solutions—we need to create a convincing argument that shows that they are an essential and intrinsic part of the value-added process. Direct machines today already include operations that are not strictly of direct added value. Reading fiducial locations on the PCB increases the accuracy of placement, as does the taking of the picked-up component to a camera for recognition and alignment before placement. A significant amount of machine run-time can be dedicated to these tasks, which are in addition to the basic pickup and placement.

As a whole, the industry sees these functions as being essential to the SMT placement operation, and that it is only through the use of these technologies that the machines have become capable of placing the newer, smaller, or higher pitch components successfully. The addition of post-placement inspection and test could be positioned as being an evolution of this. The only difference is that it takes a separate machine to perform the test and inspection, as well as external software for the machine-learning, line-learning closed-loop, or factory-learning at the MES level. However, they are all essentially the same in that they facilitate increased direct performance of the line itself.

As we have seen with the state of the technology as it evolves, the transition of test and inspection to become a zero-defect driver as opposed to being a filter of defects may not yet be black and white. For some time, there will be an element of both happening. As line and factory layers evolve, the expectation is that defects will be reduced and eliminated over time, as the data captured from test and inspection is improved, linked with increasing sources of data—such as that from MES—and algorithms at the machine.

As we have seen with the state of the technology as it evolves, the transition of test and inspection to become a zero-defect driver as opposed to being a filter of defects may not yet be black and white.

The process has to start somewhere, though. Smart factory management must invest in initiatives that strive to make the transition from defect-based quality management to zero-defect quality management through the use of test and inspection data. I have seen yield losses reduce by an order of magnitude already through the use of software that utilizes test and inspection data to improve placement accuracies—a benefit that simply cannot be ignored.

Test, inspection, and IIoT-based MES software that support machine, line, and factory-learning belong in the must column of any smart factory shopping budget, justified as being of direct contribution to manufacturing, with an expectation that actual defect rates become very close to zero over a reasonable period.

If we are to truly embrace the potential of smart factories, we need to be able to utilize the latest revolutionary steps forward in technology that the industry has seen with standards-driven IIoT data exchange in the form of CFX, for instance, which virtually eliminate the costs of data acquisition. The use of IIoT-based machine-learning, closed-loop line learning—as well as contextualization of big data at the factory layer through the use of IIoT-driven MES solutions based on built-in ontology—are all things that are available now.

Significant benefits are already achievable, with the risk of non-added value investment eliminated—for example, in middleware and locked proprietary solutions. It is altogether great support for a manufacturing business strategy for success as we come to terms with increased global challenges, promoting flexible, sustainable, environmentally responsible, and profitable local manufacturing. **SMT007**

Michael Ford is the senior director of emerging industry strategy for Aegis Software. To read past columns or contact Ford, click here.

Lean Digital Thread: Accelerating Global NPI

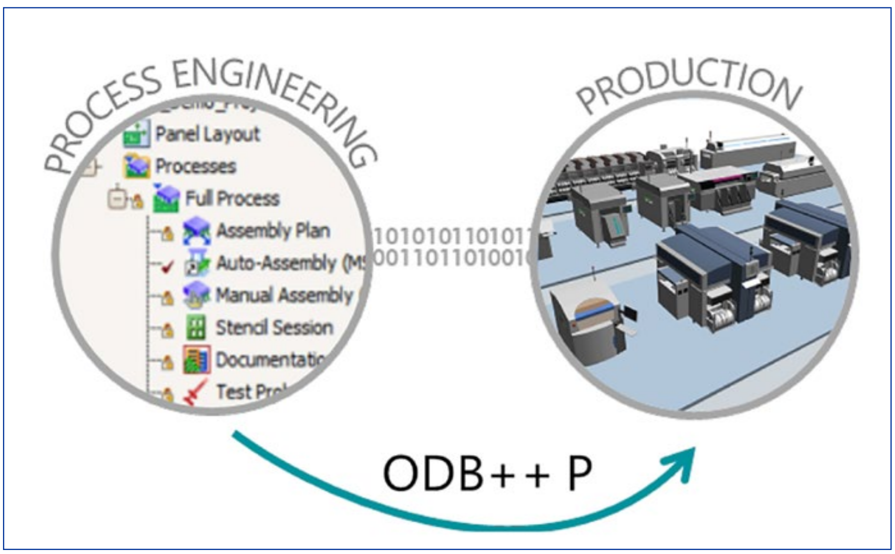
by Sagi Reuven
SIEMENS DIGITAL INDUSTRIES

I have previously written about topics related mostly to the shop floor, but my last column swam upstream and covered design for manufacturing. To make this list whole, I need to cover the phase between design to manufacturing: process engineering or simply new product introduction (NPI).

In this column, I will describe why this is an important phase and how process engineers can make a big difference. In my view, both terms are too simple to describe this phase. I would also like to focus on the dollar sign–the bill of materials (BOM). Approximately 75% of the product cost is just the parts on the BOM.

To read the full column, click here.

Sagi Reuven is a business development manager for the electronics industry, Siemens Digital Industries. Download your free copy of the book *The Printed Circuit Assembler's Guide to... Advanced Manufacturing in the Digital Age* from Mentor, a Siemens Business, and visit I-007eBooks.com for other free, educational titles. You can also view Siemens' free, 12-part, on-demand webinar series "Implementing Digital Twin Best Practices From Design Through Manufacturing."



Electronics Industry News and Market Highlights

Mitsubishi Chemical Develops Electrolyte for Tesla ▸

A Mitsubishi Chemical technical expert revealed that the important innovations of Tesla's new battery are the positive and negative electrodes and the new electrolyte.

NVIDIA, Oracle Advance AI in Cloud for Enterprises Globally ▸

Accelerating innovation for enterprises around the world, Oracle announced the general availability of bare-metal Oracle Cloud Infrastructure instances featuring the NVIDIA A100 Tensor Core GPU.

Twenty Companies Join New Industrial Digital Twin Association ▸

VDMA and ZVEI have founded the "Industrial Digital Twin Association" as a user organization for Industrie 4.0 together with Bitkom and 20 companies from the mechanical and electrical engineering industries.

GlobalFoundries, Mentor Launch Semiconductor Verification Solution ▸

GlobalFoundries, a leading specialty foundry, announced at its annual Global Technology Conference a significantly enhanced design for manufacturability kit embedded with advanced machine learning capabilities.

Hitachi ABB Power Grids Launches Ecosystem for Digitalization of Transformers ▸

Hitachi ABB Power Grids is delighted to launch the TXpertTM Ecosystem for the digitalization of transformers. The ecosystem is designed to drive data-driven intelligence and decision making in the operations and maintenance of transformers and power grids.

Keysight Technologies Makes Two Key Leadership Appointments ▸

Keysight Technologies Inc. announced that Ee Huei Sin, head of Keysight's General Electronics Measurement business, was promoted to lead the Electronic Industrial Solutions Group, effective immediately.

Ford Breaks Ground on New Electric F-150 Plant at Historic Rouge Center ▸

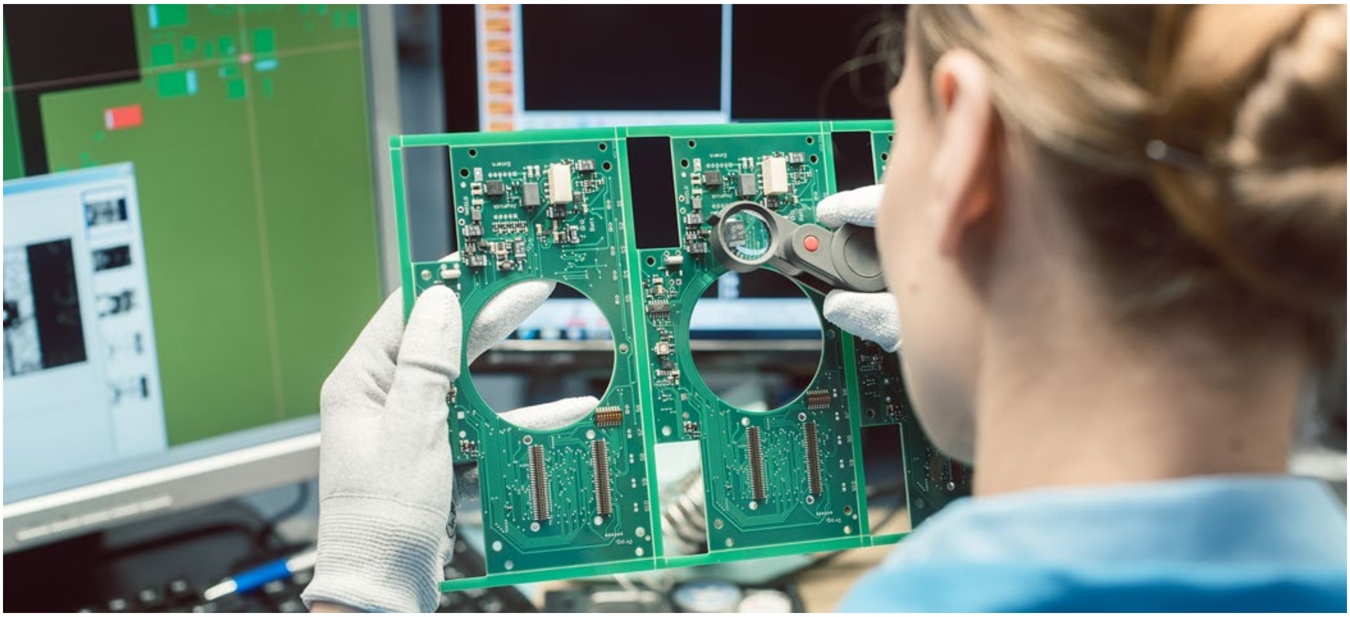
Ford announced an even deeper commitment to American manufacturing, celebrating the production start of the all-new F-150 at the storied Ford Rouge Center and confirming the construction of the new Rouge Electric Vehicle Center where it will build the all-electric F-150 by mid-2022.

AMD EPYC Processors Deployed With Over Two Petaflops of Computing Power ▸

AMD and Okinawa Institute of Science and Technology Graduate University announced the deployment of AMD EPYC™ 7702 processors for use in a new, high-performance computing system. The EPYC processor-based supercomputer will deliver the 2.36 petaflops of computing power OIST plans to use for scientific research at the University.

Kinestral Technologies Joins Siemens Connect Ecosystem ▸

Siemens and Kinestral Technologies Inc. announced that Kinestral, developer and manufacturer of Halio® smart-tinting glass, joined the growing Siemens Connect Ecosystem—a network that brings together experts in software development, IT, cybersecurity, remote and digital services, and business intelligence.



Passing the Test

Feature by Happy Holden
I-CONNECT007

Editor's Note: This article was originally published in *CircuiTree Magazine* in June 2006. Happy Holden has made some minor updates, but the foundations of test and inspection in electronics manufacturing are essentially unchanged. This article serves as a solid introduction and an effective refresher on the tenets of test and inspection.

Ever wonder how you are going to improve profits? One way is to understand your processes, what causes your yield losses, and how your boards perform. The best tools I know for doing this are the many parametric analysis and characterization coupons that are available. These are part of the quality assessment process. These processes cover reliability evaluations, end-product evaluation, work-in-process product evaluations, and process parameter evaluations.

Here are the six coupon systems I will explain in more detail:

1. Parametric test system (PTS)
2. Conductor analysis technology (CAT)
3. Printed circuit quality and relative reliability ($PCQR^2$)
4. Highly accelerated thermal shock (HATS)
5. Interconnect stress test (IST)
6. PerfectTest

Why Is This Important?

With so many different part numbers running through your production, it is difficult to know how well your process is running. This finds its most extreme challenge in integrated circuit (IC) production. One way that IC manufacturers know their process is running correctly is to measure specific coupons on a parametric die that is placed on each wafer and to have specific parametric wafers.

Probe stations can be set up at specific process steps to probe these parametric dies to provide feedback as to whether the process is running in control bounds. Having a specific coupon that is sensitive to a specific process is like the proverbial canary in a coal mine. It signals a problem with the process before it hurts the product. The accumulation of these process effects, as well as the design, will be demonstrated at final test with the characteristic first-pass yield (FPY).

Parametric Test System

The PTS was created by Hewlett Packard's Printed Circuit Division in 1987, based on early HP coupons used in production from 1972 onward. Those early coupons focused on inner layer shifting by using the copper on I/Ls shorting to a plated through-hole (PTH), moiré patterns, and hole quality cross-sections. Additional influence came from parametric PCBs used as a training and process vehicle for the first NanYa PCB Facility in Taiwan (~1983). This PCB had various design-rule technologies on it and provided feedback on how the process was improving.

The HP PTS was a group of seven coupons that could be placed on production panels or used on a parametric panel to provide a snapshot of the capability of the process. The initial seven coupons (Figure 1) were designed to test:

1. Outer layer registration
2. Inner layer registration and shifting
3. Conductor/pad opens and shorts
4. Continuity of PTH and I/L conductors
5. Artwork defects
6. Solder mask registration
7. Etch factors

The coupons were all designed to be tested by a facility's continuity testers using the bed-of-nails open-short testing machines. In this case, the tester was an ATG2000 grid tester. The tester's fault-file was captured by an HP workstation and stored. Each coupon had a stored perfect response or netlist that was compared to the fault file, and the opens and shorts were translated to dimensional shifts or other parametric data. The RS/1 statistics program was used to produce control charts and statistical reports, as well as historic data. This system is shown in Figure 2a.

Figure 2 (b and c) also demonstrates the small standalone coupon testers that operators had to check the process immediately as a confidence indicator. These home-built milliohm meters worked with a simple 1-ampere power brick, a 4-digit digital panel meter, and a machined-Plexiglas coupon holder with eight spring-loaded gold pins wired to a 4-position rotary switch in a four-wire Kelvin measurement scheme (Figure 3j).

Conductor Analysis Technology

CAT is the longest-running commercially available parametric coupon system. Born out

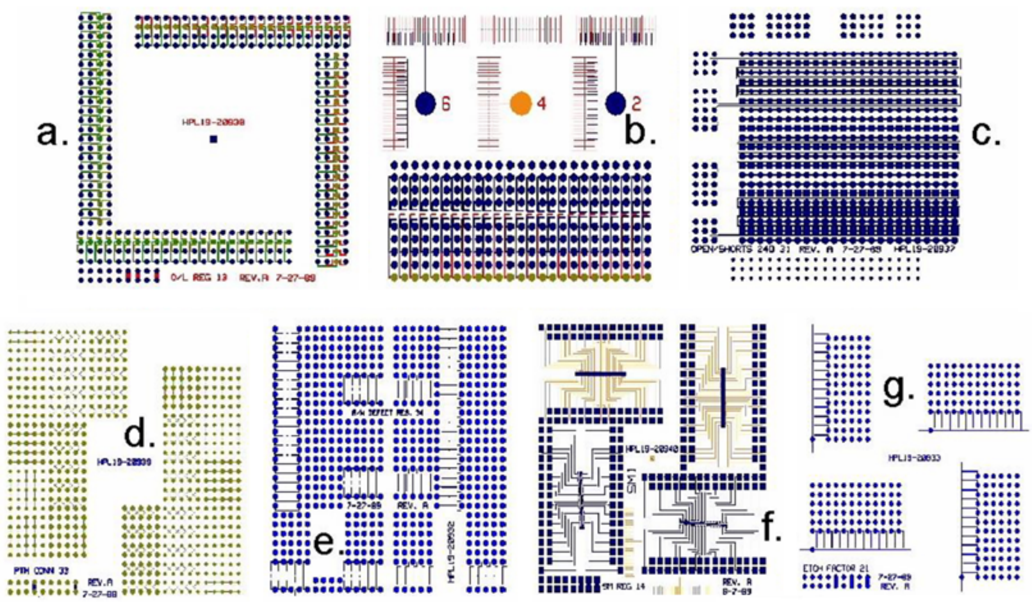


Figure 1: The seven coupons designed by HP; (a) Outer layer registration in 0.00025" increments, (b) inner layer registration and shifting in 0.00025" increments, including 0.1-mil X-ray vernier, (c) trace/trace/pad open and short circuit on multiple layers, (d) PTH continuity patterns, including I/L connections at various angles to the PTH, (e) artwork defects analysis in 0.00025" increments, and (f) etch factor analysis in 0.00025" increments.

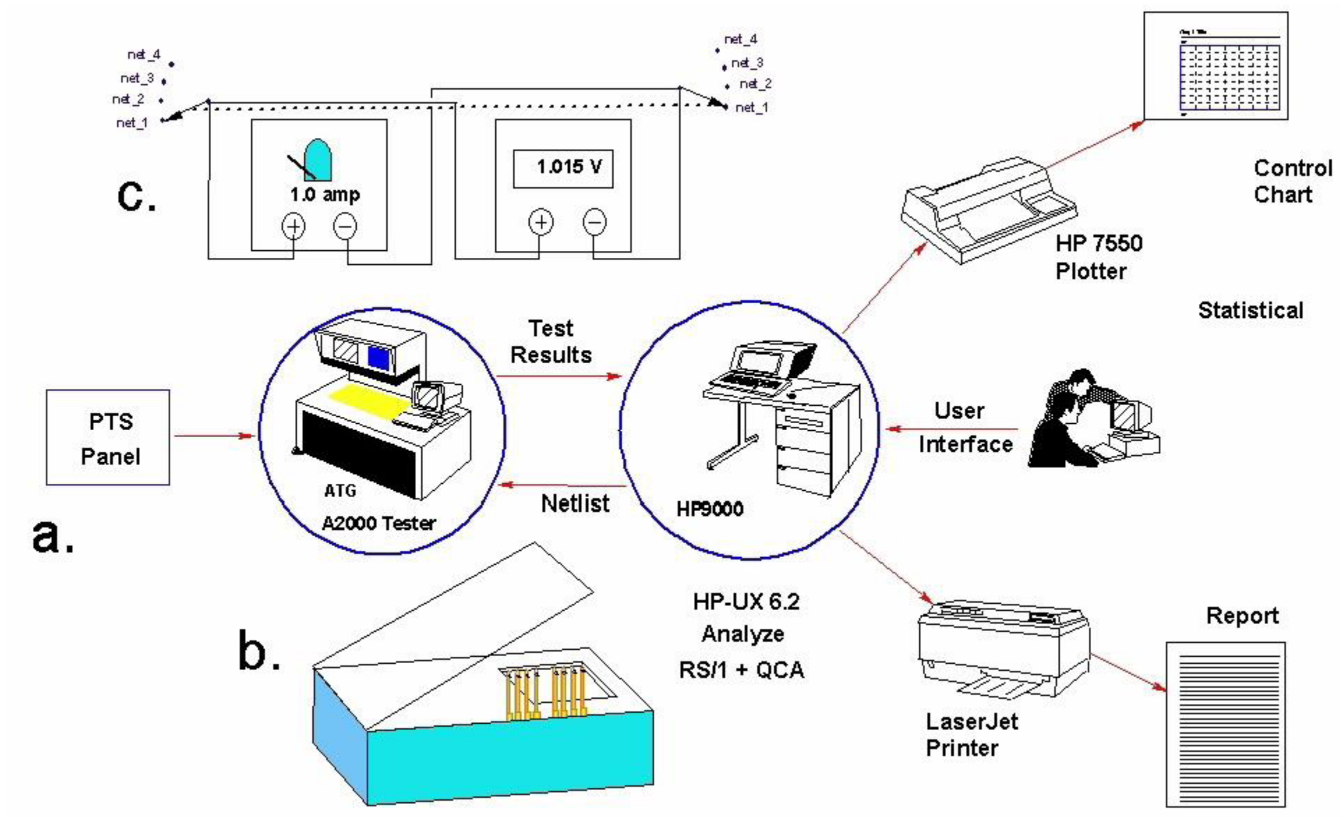


Figure 2: (a) HP's PTS arrangement with a continuity tester, (b) coupon test fixture for individual coupons, (c) milliohm measurement using a 1-amp power supply and digital panel meter in a Kelvin four-wire test configuration.

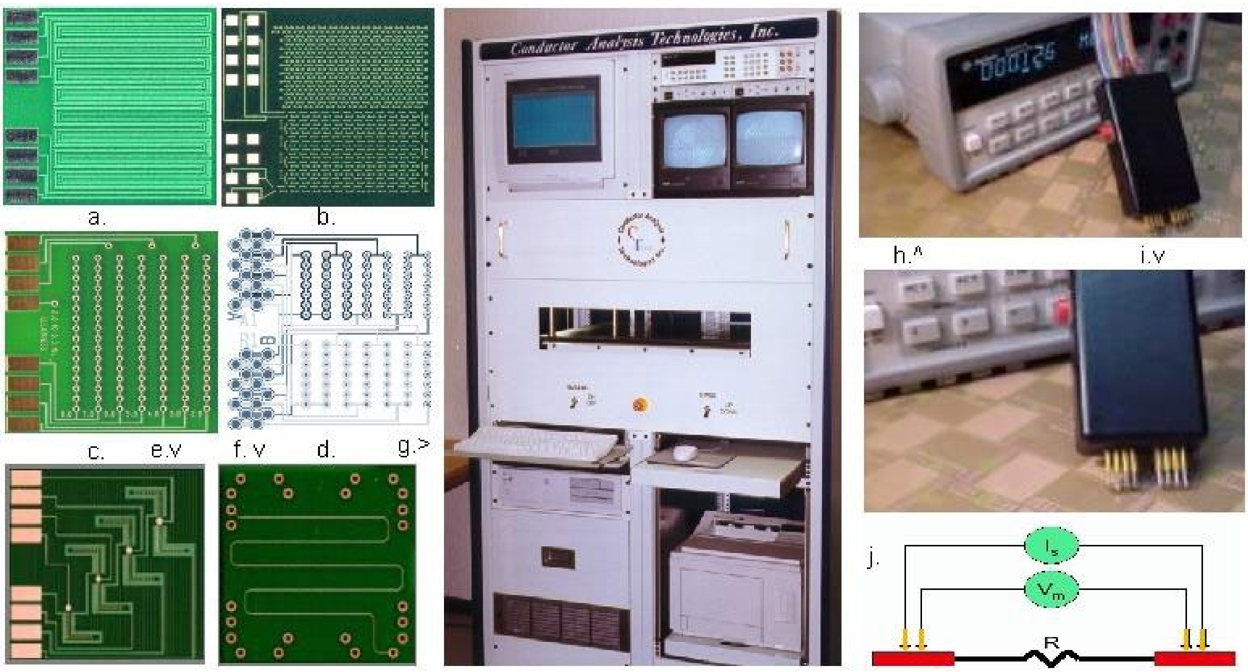


Figure 3: CAT (a) drill overshoot coupon, (b) conductor/spacing coupon, (c) solder mask registration coupon (d) four via nets daisy-chain coupon, (e) impedance coupon, (f) registration coupon, (g) sensitive AC chopped four-wire micro-ohm test system, (h) portable coupon test system using Agilent 34401A meter, (i) close-up of coupon probes, and (j) current and voltage arrangement of the four-wire Kelvin measurement configuration (cat-test.info)[2].

of an NCMS program with Scandia National Laboratory, founders Tim Estes and Ron Rhodes licensed the testing machine from Scandia and started CAT in 1994. The test equipment and test methodology are patented under U.S. Patent No. 5,659,483. Because of the length of availability, its thoroughness, and the wealth of publications, the CAT coupons are the most used and benchmarked.

Six coupons, all 25.4 mm by 25.4 mm (1.0" x 1.0"), make up the primary sensors for CAT (Figure 3):

1. Conductor (spacing)
2. Via formation (nets daisy chain)
3. Registration (I/L and O/L)
4. New registration (I/L and O/L)
5. Solder mask registration
6. Impedance

The value of a parametric system like CAT is its ability to capture the true capability of a process, procedure, machine, or materials. There are numerous features on each coupon such that they can be tailored to capture current capability. Complex as these are, they cannot be inspected or sorted, so they truly represent what is going on. For novice users, the temptation is to inspect them to get perfect samples. This usually proves to be a futile activity, as some features are beyond the current capability by design.

These coupons are all customizable by CAT: conductor spacing (1–20 mils), via diameter, via land, daisy-chain sequence, number of layers, registration sensitivity and layers, via structure (through, blind, buried, skip vias, stacked, sequentially laminated, etc.), impedance type (single-ended, differential, edge-coupled, broadside, coplanar, etc.), overall thickness, placement, and panel size. Some coupons were designed to be removed and put in small testers. The ones shown have been redesigned, and you can see the new ones under test patterns at cat-test.info.

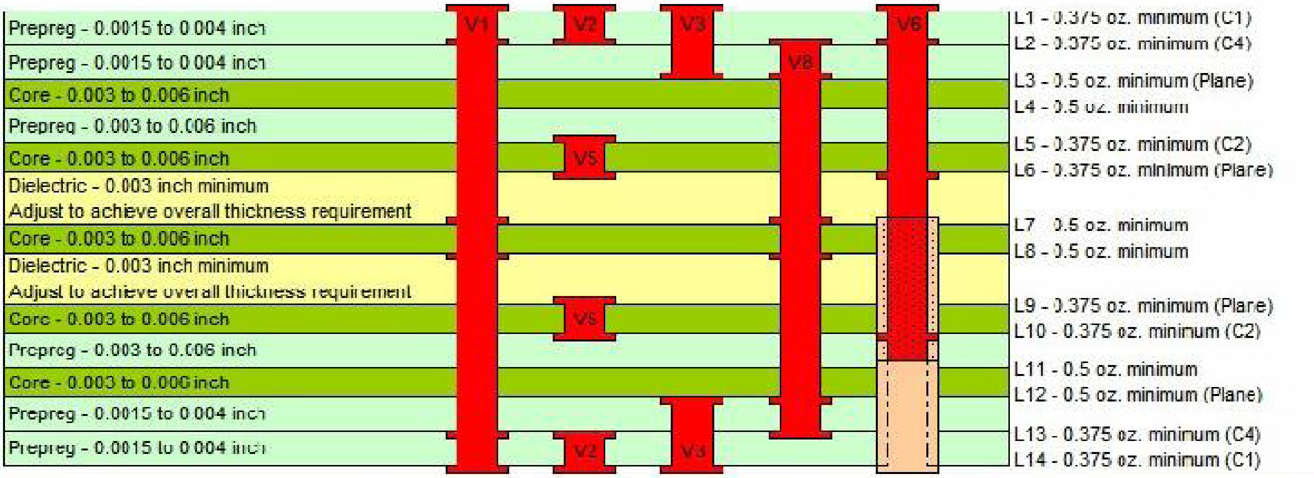
The primary equipment is shown in Figure 3g. This was designed by Scandia and consisted of an alignment system, fixtures, and a bed-of-nails connected to a sensitive AC-chopped, four-wire Kelvin resistance measurement system (Figure 3j) feeding a PC. In 1999, a portable system was also designed so that readings could be made in production using an Agilent 34401A voltmeter shown in Figure 3 (h and i). The portable system has additional coupons from 0.33"x 3.0" to 0.5" x 2.0" to facilitate placing on production panels, as well as software, to automatically calculate responses. To improve the impedance measurements, the Polar RITS-510 robotic probe and measuring unit were added in 2003. The Hong Kong Productivity Council erected a second testing facility using this equipment in Hong Kong in 2004 [1].

Printed Circuit Process Capability, Quality, and Relative Reliability

The popularity of the CAT panels eventually led to its standardization in 2000 by IPC. The D-36 Subcommittee created standard parametric panels and a test standard that became known as IPC-9151 PCQR². The data from these benchmarking panels is kept in a database available by subscription from IPC. Over 89 PCB fabricators worldwide have built PCQR² panels for testing. Artwork and specifications for these benchmarking panels are available to the industry for free at pcbquality.com. Figure 4 shows a typical PCQR² panel, which is a 14-layer (IPC-14VB-D) via rigid board design (18" x 24") utilizing through, blind, buried, and sub-composite vias with two laminations. Figure 4 shows the complete list of available PCQR² panels.

Highly Accelerated Thermal Shock

One of the results of the D-36 Subcommittee's work on relative reliability was the creation of a highly accelerated thermal shock procedure. Developed by CAT and Microtek Labs, HATS™ runs the PCQR² coupons through an air-to-air thermal cycle from -45°C to 145°C (-60°C to 160°C available) in a 30-second cycle (Figure 5a). The coupons are continuously monitored by a four-wire data acquisition system connected to the test fixture (Figure 5b) to detect a 10% change in the resistance of the via daisy chains, or 500 cycles. The coupons can be various sizes from 0.5"x 1.0" to 1.0" x 2.0"



Layer Count	TYPE	Size	Laminations	Conductors mils	Via Structure min. via/pad (mils)	Zo
2	Rigid Board	18" x 24"	1	3 - 6	TH, 8/18	--
4	Rigid Board	18" x 24"	1	3 - 6	TH,8/18;BI,3/11	2
6	Rigid Board	18" x 24"	1	2 - 5	TH,8/18;BI,3/11	2
10	Rigid Board	18" x 24"	1	2 - 5	TH,8/18;BI,3/11	4
14	Rigid Board	18" x 24"	1	2 - 5	TH,8/18;BI,3/11	4
18	Rigid Board	18" x 24"	1	2 - 5	TH,8/18;BI,3/11	4
10	Via Rigid Board	18" x 24"	1	5 - 8	TH,8/18;BI,3/11;Bu,7/15;skip,16/26	--
10	Via Rigid Board	18" x 24"	2	5 - 8	TH,8/18;BI,3/11;Bu,7/15;sub,8/18	--
14*	Via Rigid Board	18" x 24"	1-2	5 - 8	TH,8/18;BI,3/11;Bu,7/15;skip;sub	--
24	Via Rigid Board	18" x 24"	1-3	5 - 8	TH,10/20;BI,3/11;Bu,6/16;skip;sub	--
12	Rigid-Flex Design	12" x 18"	1	3 - 6	TH,8/18	3
4	Pkg. Substrate	16" x 18"	1	2 - 5	TH,6/16;BI,2/10;Bu,4/12	2
6	Pkg. Substrate	16" x 18"	2	2 - 5	TH,6/16;BI,2/10;Bu,4/12;sub,6/16	2

Figure 4: PCQR^2 artwork available, 14-layer via rigid board illustrated by cross-section showing thickness ranges and various through-hole, blind, buried, sub-composite, and back-drilled vias (pcbquality.com) [3].

(Figure 5—c, d, and e). These are available for free from the coupon generator software at hats-tester.com. Many companies are purchasing the unit due to the speed and efficiency of this system.

Interconnect Stress Test

The IST is the oldest and most used accelerated thermal via reliability system in the industry. Developed in 1989 by Digital Equipment of Canada, patented in 1994, and commercialized by PWB Interconnect Solutions in 1995, over 120 systems have been installed worldwide. Used by over 120 OEMs, EMSs, and PCB fabricators, it has six licensed service centers around the world and is standardized by the IPC-TM-650 Test Method 2.6.26, the DC current induced thermal cycling test.

A typical coupon is shown in Figure 6a. This is one that the OEM supplies for an IPC Class 3 board. This one has through-holes, blind microvias, and buried vias using a high-Tg, low-loss laminate. Two of these coupons are built with every board, and until an approved number of IST cycles are passed, it is not assembled. Failure means a return to the fabricator for analysis.

The IST method measures changes in resistance of vias and internal layer connections as the holes are subjected to thermal cycling. The thermal cycling is produced by the application of a high current through the resistive

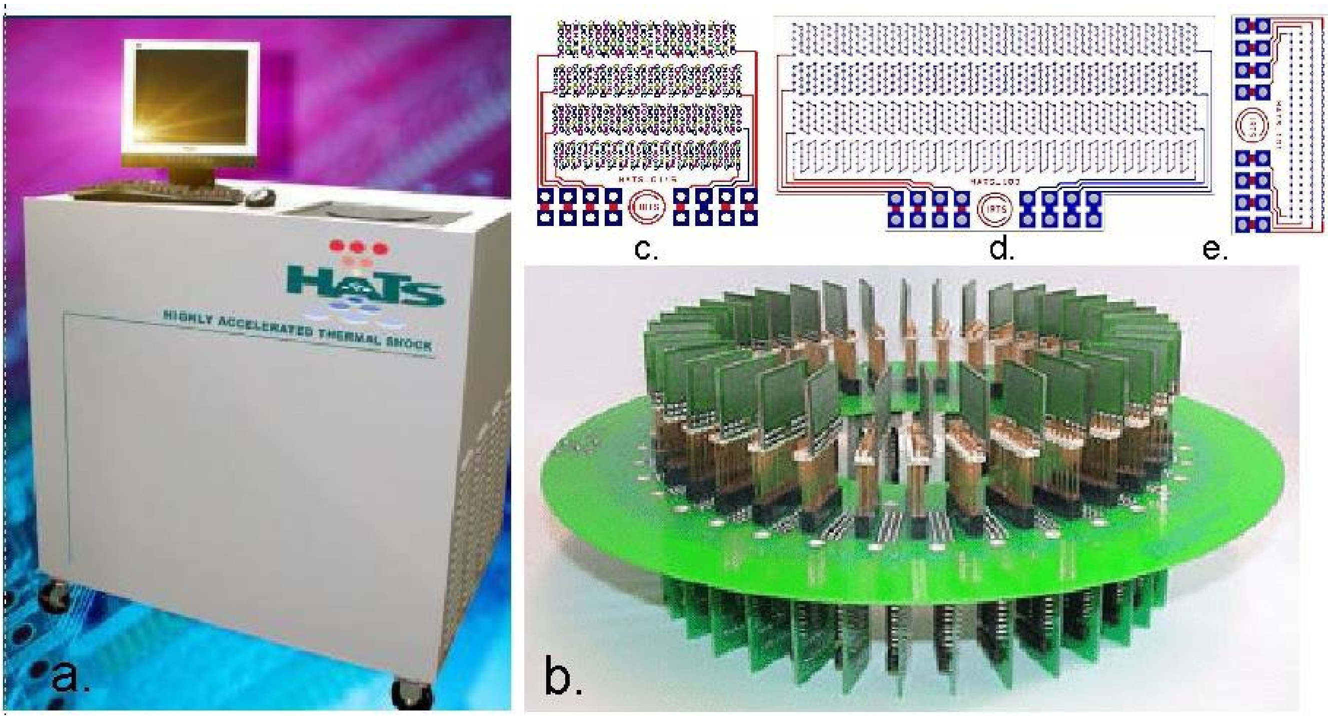


Figure 5: HATS is accomplished by the unit in (a) generating refrigerated and heated air passing over the test fixture (b) that contains 36 test coupons as shown in (c) the 1.0″ x 1.0″ or (d) the 2.0″ x 1.0″ or (e) the 0.5″ x 1.0″ coupons (hats-tester.com) [4].

internal layer connections of a specific group of holes—usually, 200 daisy-chained vias—interconnecting through two adjacent layers, called the power circuit (Figure 6c). Switching the current on for three minutes creates heat to take the connections from room temperature to a designated higher temperature. Stopping the current and with forced-air cooling, the connections cool in two to three minutes (Figure 6f).

Another group of interconnects involves two independent daisy chains interconnecting 500 vias through any two inner layers at various levels. The ones under test are the sense circuits (Figure 6b). An isometric view of the two sets of interconnects running parallel to and sequentially overlapping is shown in Figure 6d. The equipment providing the coupon fixturing, current, cooling, and resistance measurement is shown in Figure 6e.

An accelerated failure will occur because of the differential thermal expansion of the interconnect structure. Failure can occur in a number of locations (Figure 6g)—either a via crack, post separation, connection crack, or material delamination in a specific region within one or multiple areas. Cycling continues until the specific rejection criterion is achieved or the required numbers of cycles are passed.

The IST site (pwbcorp.com), or its European licensee Polar Instruments (polarinstruments.com), has extensive application data available, including standard designs of 5- and 6-inch coupons for any number of layers covering these structures:

- GB400000A: Any two-layer sequentially laminated blind vias
- GB400000B: Any two-layer drilled blind vias
- GC400000B: Any layer sequentially laminated buried vias
- GM400000B: Any two-layer blind microvia
- GP400000A: Any-layer through-hole on a PCB > 0.125 inches

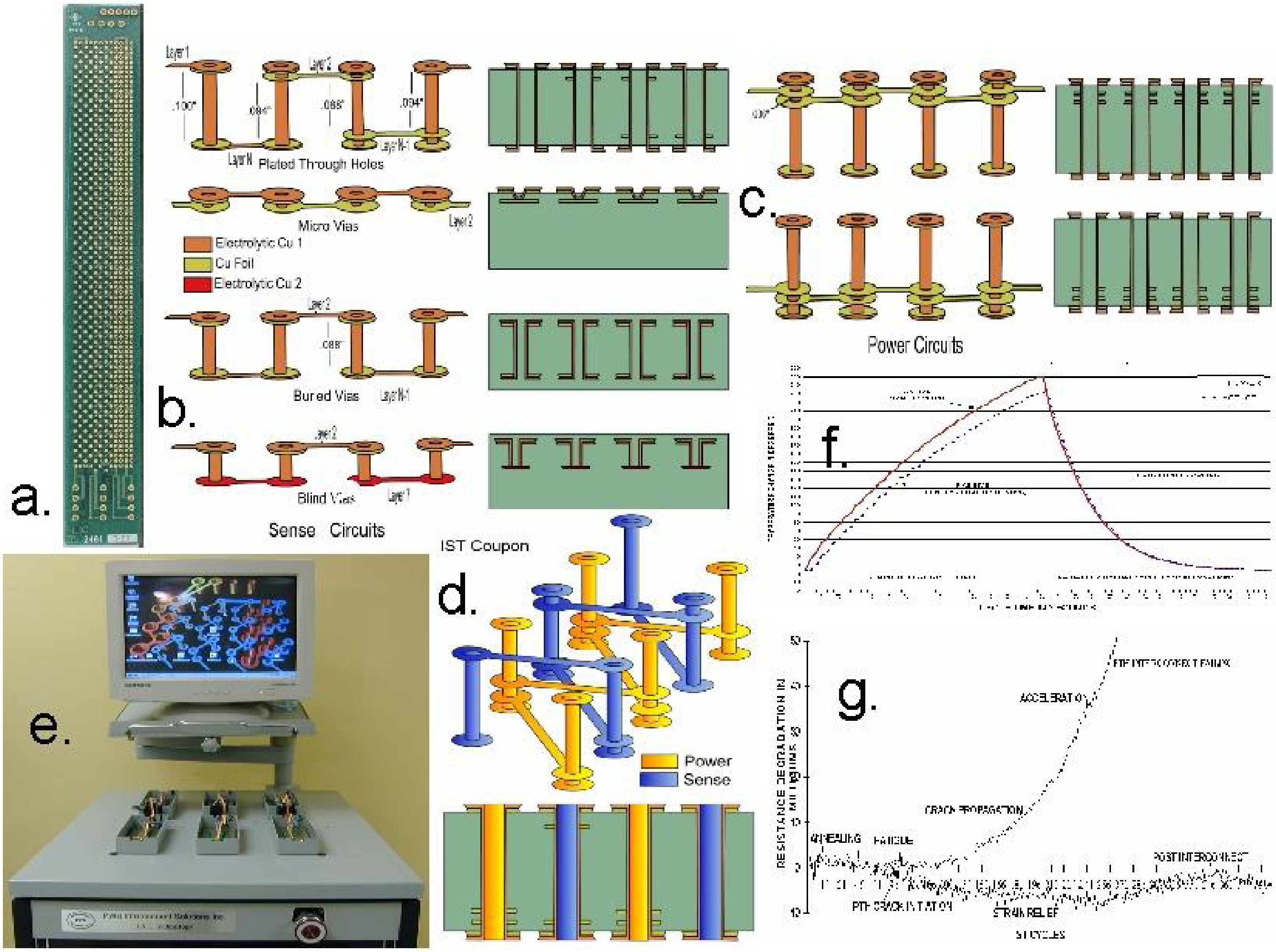


Figure 6: IST is a DC current-induced thermal cycling test; (a) a typical 6" coupon, (b) a sense circuit daisy chain, (c) a power circuit daisy chain, (d) an isometric view of parallel and overlapping power and sense circuits, (e) IST power, data acquisition, and fixturing test equipment, (f) typical heating-cooling cycle, (g) and failure modes of thermally stressed interconnects (PWB Interconnect Solutions Inc., pwbcorp.com) [5].

- GS400000A: TH and blind vias > four layers sequentially laminated on a PCB ≤0.125 inches
- GT408000B: Any-layer through-hole on a PCB ≥0.125 inches on a 5" coupon
- GT501000A: Any-layer through-hole on a PCB ≥0.125 inches on a 6" coupon

PerfectTest

PerfectTest came along in 1989 to address the problems in multilayer material movement and drill registration. Unfortunately, they are no longer in business, but their idea is one that should be explained. The coupons (Figure 7a) were placed at the outer edges of the multilayer panel. The coupons worked by detecting which PTHs detected the movement of a particular I/L copper wedge. Figure 7b illustrates the 0.002" increments from 1 mil to 9 mils in the X- and Y-axis that the coupon detected.

Coupons could be placed on every layer or just specific ones. Although no specific testing equipment was required, Figure 6C shows the PerfectTest unit equipped with analysis and data storage software. Figure 7d is a summary of 250,000 coupon readings collected in manufacturing over a six-month period. At the time, there were over 185 users of this coupon in 22 countries.

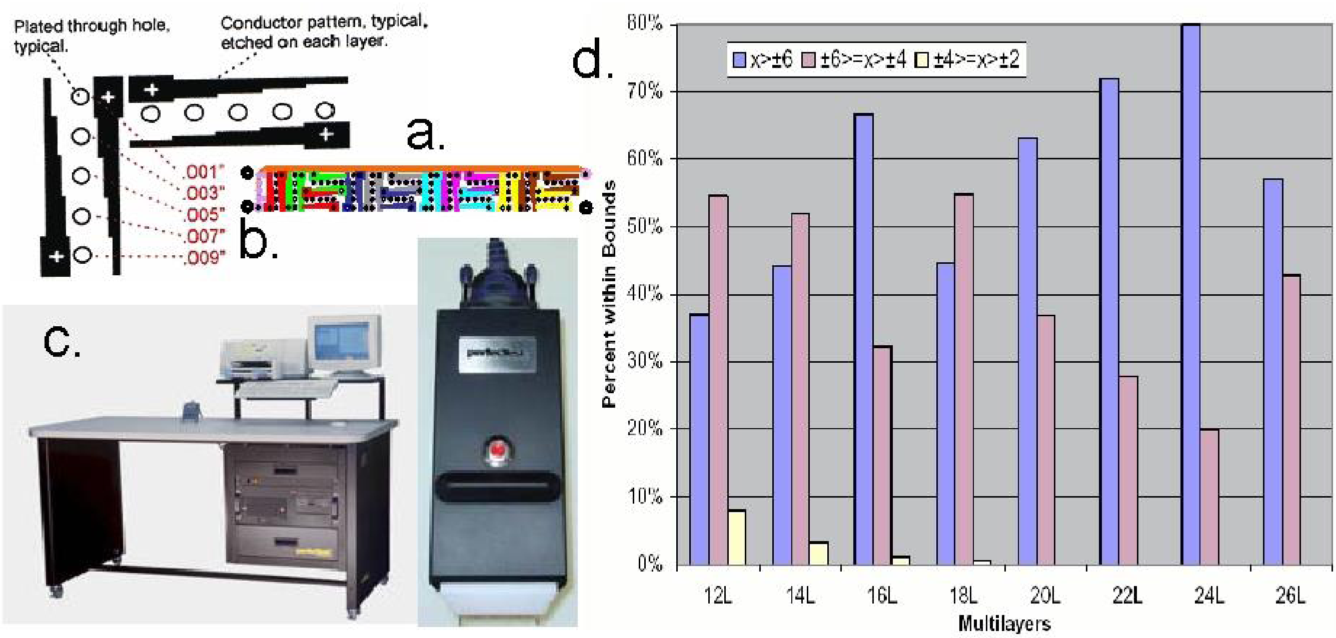


Figure 7: PerfectTest was a material movement and registration coupon system; (a) the coupons were 0.2" x 1.73" and placed at the edges of production multilayer panels, (b) it worked by measuring the continuity of PTH versus the metal foil of specific layers, (c) the testing equipment included a close-up of the probe head, and (d) data from one user in production of nearly 250,000 readings for 12-layer to 26-layer multilayers [6].

While the PerfecTest coupon system is not available today, the idea can still be incorporated into any CAM system if an AOI system is not available to measure inner layer shifting.

Conclusions

For as long as there has been printed circuit production, there have been coupons to test every factor. Many excellent coupons have been designed over the years—too many for me to address here. The choices now are greater than ever. Hopefully, you use one of these systems. You can buy it, rent it, or develop it yourself. The economic pressures of competition makes that an imperative. A statistical software package and training are available for free at NIST/SEMATECH [7]. But without something, you are going to find it increasingly difficult to stay in business either because of profitability or reliability. **SMT007**

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Happy Holden has worked in printed circuit technology since 1970 with Hewlett-Packard, NanYa/Westwood, Merix, Foxconn and Gentex. He is currently a contributing technical editor with I-Connect007.

5 Habits to Make Your Soldering Iron Tips Last Longer

Knocking Down the Bone Pile

by Bob Wettermann, BEST INC.

Poorly maintained soldering iron tips have real costs associated with their lack of care. The replacement costs associated with failing soldering tips, as well as the negative impact on outgoing quality levels, are the two greatest costs related to poor tip management practices. A poorly maintained soldering tip can result in ineffective heat transfer, which means that a reliable intermetallic interconnection is difficult to ensure. To maintain the integrity of the soldering joints and prevent the tips from becoming a runaway consumable expense, there are several areas of tip care that can prolong their life.

When to Replace the Tip

There are signals to the rework technician that a soldering tip is beginning to fail. If solder on the tip tends to "pool up" rather than flow across the tip, then surface oxidation may be going on in the tip. This will lead to a poor heat bridge and limited heat transfer. Another sign of oxidation buildup will be a drop in soldering performance. If it seems like the iron is just not getting hot enough, it could be that a thermal barrier of oxidation is preventing the tip from doing its job.

Another telltale sign is in the visual appearance of the surface of the tip, which should have a luster and shininess to its visual appearance. The soldering iron tip plating material should show that it is intact by not displaying any signs of pitting, holes, or cracks in the tip plating. All of these are signs that the tip needs a replacement.

Keeping the Tip Clean

One of the habits that rework technicians need to nurture is keeping the soldering tip clean. Clean tips will help ensure that they last longer and work most efficiently during their lifetime. Ideally, the tip should be cleaned frequently during use and after every shift. There are multiple methods for cleaning the soldering iron tip.

One technique is wiping the tip on a damp sponge wetted via distilled or DI water (to reduce any mineral buildup on the tip). Be sure to let the tip return to the set temperature between each of the wipes as the sponge will cool the tip. Change these sponges periodically so as not to re-contaminate the tip. As an alternative, brass wool can be used to gently scrub the iron plating on the tip without damaging it. Sandpaper and files should never be used to clean the tip of a soldering iron as this will damage the plating material and cause premature tip failure.

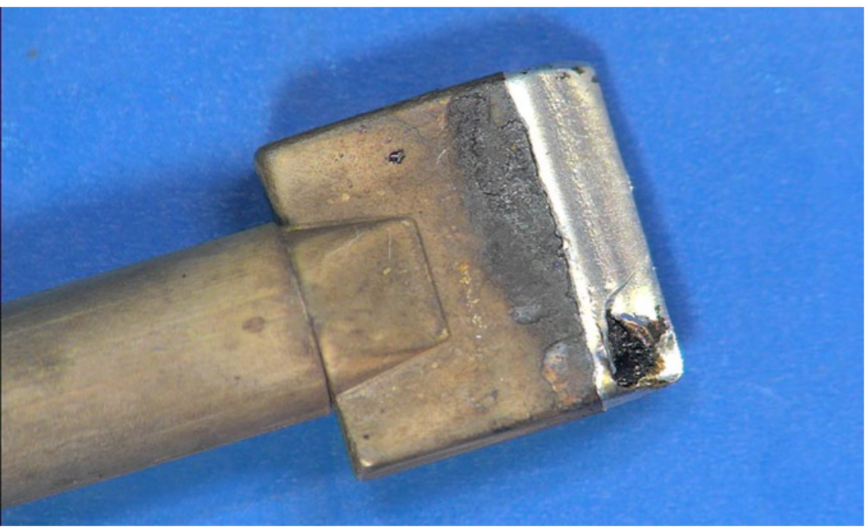

Figure 1: An example of a degraded blade tip.

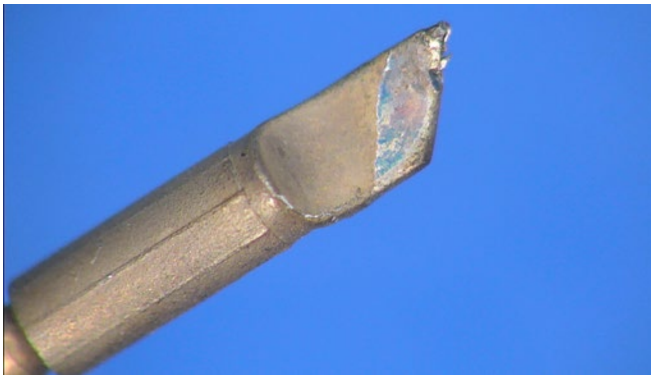

Figure 2: Chisel tip plating erosion.

Most tip cleaners contain highly aggressive chemicals and should be avoided, as buildup can lead to blackening of the tips and oxidation of the plating. Due to the numerous heat cycles and the many different coatings, fluxes, epoxies, and other materials found in the rework area, cleaning may need to be on a more frequent basis compared to other areas of the manufacturing floor; thismaintains tip life and ensures solder joint integrity.

Tip Tinning

Once cleaned, one of the best ways to extend the life of your soldering iron tip is to apply solder so as to protect it from oxidation and premature failure. Tip tinning helps prevent oxidation, which hinders the tip from transferring heat effectively. Simply flood the tip with solder before putting it into the holder. This layer of solder works to protect and seal the iron plating from the air, thereby inhibiting oxidation. The other benefit to tip tinning is that it creates a heat bridge, which can effectively transfer the heat from the soldering iron to the pad as well as the component leads.

Storage and Handling

In addition to cleaning and tinning of the tip, their life can be extended through proper handling and storage. It is recommended that tips be stored in a container to limit the effects of oxidation, corrosion, and debris accumulation. Never bang or drop the tip, as this can cause damage to the plating or heating cartridge. Through proper storage and handling, tip life can be extended.

Understanding the Role of Flux

Tip plating can be eroded and altered by flux as activators found therein can damage the plating of the tip through a chemical reaction. More aggressive fluxes such as rosin-based or water-soluble fluxes can act more aggressively in wearing the tip plating away. It is not advised to dip your soldering iron tip into the flux as it could prematurely damage the plating. Instead, flux should be applied at the interconnection point of where the solder is applied at the pad/lead interface and never directly to the tip itself to protect tip life.

Maintaining the Right Tip Temperature

Tip temperature has a big impact on the expected life of the soldering iron tip for a number of reasons. Fluxes and cleaning agents coming into contact with the soldering iron tip under increased temperature can accelerate the degradation of the tip coating. Oxidation of the tip increases under higher temperatures. Finally, the thermal stress on the tip increases with increased temperature, thereby inducing a greater rate of tip degradation.

In some soldering stations, the soldering iron can go into a "sleep" mode to increase tip life, which greatly reduces the temperature of the tip while it is not in use. By understanding the impact of temperature on tip life, rework technicians can prolong the life of their soldering iron tips.

Conclusion

By following these guidelines for soldering tip maintenance, more consistent and reliable hand soldering rework results can be obtained while reducing the consumable costs associated with the purchasing of many tips. **SMT007**

Bob Wettermann is the principal of BEST Inc., a contract rework and repair facility in Chicago. For more information, contact info@solder.net. To read past columns or contact Wettermann, click here.

Supplier Highlights

Real Time with...SMTAI 2020: MacDermid Alpha's Single-Step Metalization Paper ▶

Nolan Johnson talks with MacDermid Alpha Electronics Solutions about a new process for filling through-holes with copper in a single step. Carmichael Gugliotti, the primary author and an applications specialist, and Richard Bellemare, director of electrolytic metalization, address why this new process matters.

Real Time with... SMTAI 2020: Full List of Interviews With Industry Leaders ▶

The virtual SMTA International Electronics Exhibition took place on September 28–30, and I-Connect007 is here to provide you with comprehensive coverage of the event. We've assembled the full list of show-related interviews from before, during, and after SMTAI 2020 with the industry's top executives, engineers, and managers—all without leaving your office. To view our video series, photo gallery, and more, be sure to stop by Real Time with… SMTAI 2020.

Electrolube Introduces AF International's Anti-bac+ Range ▶

2020 has been a year of contradiction and uncertainty; with safety advice surrounding COVID-19 changing practically daily, it is increasingly common to feel that much of life is beyond our control. One element is of vital importance, however: the safety and well-being of our staff and colleagues.

C.R. International Inc. Expands Capability With ASM's E by SIPLACE Platform ▶

ASM's E by SIPLACE was again selected over competitive systems for its flexibility and expansive range of high-performance features. C.R. International Inc., a long-time SIPLACE customer and trusted mil/aero EMS provider, cited the platform's 01005 component placement capability, changeover simplicity, and real-time component teach function as top factors in its E by SIPLACE investment decision.

STI Accomplished AS9100D Certification ▶

STI Electronics Inc.—a full-service organization that provides training services, training materials, analytical/failure analysis, prototyping, and contract PCB assembly—announced it received AS9100D recertification for manufacturing/engineering services and initial certification for its Training Resources Division.

Siborg Offers New Bluetooth Data Acquisition Tool for Surface-Mount Technology ▶

A new model of the LCR-Reader-MPA offers Bluetooth connection enabling remote test data recording. The main feature of the tool is its LCR-MPA-BT Logger program that allows users to set specific test parameters for each component in the predefined list and then to automatically grant pass/fail status to the tested component.

Indium Corporation Announces New High-Reliability Alloy ▶

Indium Corporation released a new high-reliability alloy with enhanced thermal cycling performance specially formulated for harsh environments.

Rehm Invests in Seven New Apprentices for Various Roles ▶

The beginning of September signaled a new phase in the lives of many junior staff—the start of their apprenticeships. Seven young people have started their apprenticeships in various professions at Rehm Thermal Systems in Blaubeuren-Seißen.

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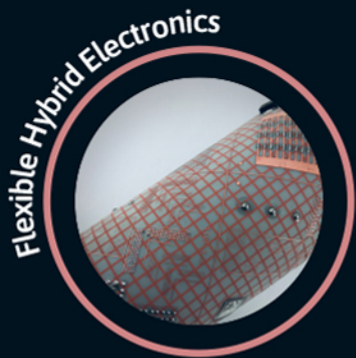

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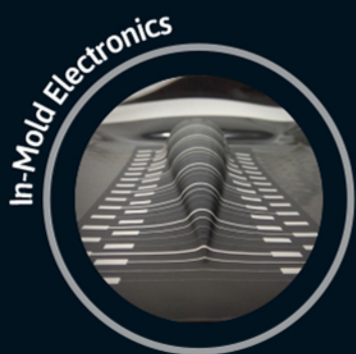

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How to Audit OEM-EMS Assembly Capability, Part 2

SMT Solver

by Ray Prasad, RAY PRASAD CONSULTANCY GROUP

As I mentioned in Part 1 of this column series, during the past two decades, there has been a tremendous increase in outsourcing by OEMs to EMS companies, which also results in a decrease in yield. I further discussed the overview of an audit process to assess the manufacturing capability of OEMs or EMS companies. In this column, I will focus on the technology and manufacturing capabilities of the supplier.

Even though I am dividing the questions into various areas—namely technology, manufacturing, quality, and RoHS compliance—there are going to be overlaps. However, it is not important which category these questions fall into, but they should be asked. They are intended to help generate questions that are relevant to your product and the manufacturing site you plan to audit.

Manufacturing Questions

There are some business-related questions aimed at determining the supplier's financial stability, long-term viability as a business, pricing policy, and quality standard to be used. They should be asked. You should also ask about the production capacity of the line and the percentage of that capacity available for your products to see if there is a match. I am not covering these business areas in this series of columns; instead, I'll focus only on the technical areas.

You can begin by asking about the types of components used in various products being built by the company today and the level of defects (PPMO and first-pass % yield) in those products. The answer to this one question will give a good general overview of the assembler's capability.

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Material Management is now one of the biggest challenges of Electronics manufacturers. This is due to the ongoing shift to high-mix, low/mid volume manufacturing with smaller lot-sizes batches and the significant cost of materials in PCB assembly.

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You can ask the supplier to check the types of packages and their pitch being used in the products they are currently building. Here are some examples, but the basic idea is to know the capability of the supplier to handle the largest and smallest I/O counts and lowest pitch to make sure types of components you have in your products are being built by the supplier:

- Types of through-hole components being used
- Smallest components (0402, 0201, and 1005)
- Resistor networks with fine-pitch pads (0.4-mm pitch)
- BTCs, such as QFN, DFN, LGA
- QFP with 0.4-mm and 0.3-mm pitches
- CSP/BGA with 0.5-mm pitch
- CSP/BGA/fine-pitch with lower than 0.5-mm pitch
- Maximum BGA I/O count
- Package-on-package (PoP)
- Others (please list)

The types of packages and their pitches play a key role in the level of defects. For example, as I have discussed in my previous columns, here is a brief summary of defects you can expect for different types of packages:

- Plated through-hole (PTH): 4,000 PPM
- Gull-wing: 1,400 PPM
- Chips, BGA, J-lead: Around 600 PPM
- Average of all types: 1,079 PPM

What is noteworthy in this study is that through-hole components cause the highest level of defects. It should not be a surprise since the most common process for soldering through-hole components is wave soldering, which has too many variables to control. Since through-hole is not going away for some time to come, even though their number has dwindled drastically, you or your supplier may want to consider automated selective soldering for PTH to reduce PTH defects.

In the same study, the author found that the type of lead and its pitch plays an important role in defects:

- 16-mil pitch (0.4 mm): 13,088 PPM
- 20-mil pitch (0.5 mm): 1,878 PPM
- 25-mil pitch: 950 PPM
- 50-mil pitch: 650 PPM

When the pitches get below 0.5 mm, the defect level really skyrockets. If you cannot avoid 0.4-mm pitch, you really need to focus on the manufacturing capability of your supplier to successfully deal with fragile leads of ultrafine-pitch packages. Put another way, if your product contains pitches below 0.5 mm, there are very few companies that can build them with good quality on a consistent basis. Thus, your audit process must be a lot more rigorous if you need to assemble ultrafine-pitch components.

There is no such thing as a perfect PCB surface finish. All surface finishes—such as HASL, OSP, ENIG, immersion silver, and immersion tin—have their pros and cons. In most cases, the assembler does not make their own PCBs; they order them from a PCB supplier. An assembler who is a turnkey supplier is responsible for selecting their own PCB supplier. On the other hand, if you specify the surface finish, you should ask the same questions from the PCB supplier.

Here are four examples of questions that should be asked about different surface finishes being used on your product:

1. ENIG surface finish: Did you ever have black pad incidence? How was it resolved? Very few suppliers are willing to admit the problem, but black pad is a potential problem with ENIG, and you should ask about it.

2. Immersion silver: Have you ever had champagne micro-void incidence? If so, how was that resolved?

3. OSP: Have you ever had BGA ball drop incidence or any issues with via fill during wave soldering of mixed assembly? Did you have to use a more active flux or nitrogen to achieve 100% via fill? Even though only 75% via fill is required, if you always get that 75% minimum, it is not acceptable quality.

4. HASL: Since the inherent problem with this finish is an uneven surface finish, it is

really worth asking whether the supplier has successfully used HASL for BTC, BGA, or fine-pitch packages. Very few people can make that claim, and that was the reason for moving away from HASL in the first place. It was not too long ago that the predominant surface finish was HASL. In addition to getting uniform solder coating with HASL, board warpage may also be an issue with HASL. For most companies using finer pitches, BGAs, and BTCs, HASL is really not an option.

Because of availability constraints, many companies end up using both tin-lead and lead-free components on the same board. Such assemblies fall into what is commonly known as forward or backward compatibility scenarios. The key concern is the selection of the right peak reflow temperature since the tin-lead and lead-free components require very different peak reflow temperatures for proper reflow.

Key questions to ask are as follows:

- How does the assembler deal with tin-lead and lead-free BGAs on the same board?
- What peak temperature is used to prevent overheating of tin-lead BGAs/QFPs without compromising the proper reflow of lead-free BGAs?
- What reflow peak and TAL do you use when most of your components are tin-lead, but the BGAs are lead-free?
- Does the supplier know the difference between TAL and true TAL? (TAL is time above liquids even if only one component sees that temperature. True TAL, on the other hand, is time that all components being monitored see that temperature. It makes a big difference when you measure the temperature of BGAs—especially the temperatures of inner and outer BGA balls.)

Handling and control of moisture-sensitive components and tracking of their exposure times is another issue that is worth digging into since very few companies do it correctly:

- What is the handling procedure to prevent baking (when exposure time has expired) of moisture-sensitive BGAs?
- How many times do you bake moisture-sensitive components (only once is allowed for some MSL levels)?

It is not easy to detect the seriousness of the defect in a company during the course of a short audit. But finding the ratio of bridging to opens over the last six months can give you a good idea about the extent of field failures you may see. About six times more shorts than opens are a good sign since there is practically zero chance that shorts would escape any inspection or test. Opens, on the other hand, can easily escape inspection and test and will come back to haunt you after a relatively short time in the field. Don't be surprised at all if you have a very difficult time finding any supplier that can meet these criteria, but be surprised (and happy) if you find one with more shorts than opens in their products.

It is also important to ask about the test strategy (ICT, flying probe, functional, etc.) used on the product—especially when you see a large bone pile on the shop floor. A large bone pile is common in companies that do not use ICT and have high defect rates.

Technology Questions

The types of machines used by a company are important. However, the existence of detailed and formal design and process documents and extensive training programs for operators, technicians, and engineers are the key elements of a strong SMT infrastructure of a company. You should ask about the number of engineers working on manufacturing process development and on the production floor, and their qualifications. And the questions should be intended to assess their understanding of the technology.

For example, you should ask about the properties of solder paste (compositions, metal content, particle size range, etc.) to see if they have been selected for a reason:

- What is the solder application method (stencil or screen)?
- Why was this method chosen?
- What is the paste deposit thickness?
- Does this thickness requirement change if fine-pitch is used on the same board?
- What is the approach (differential stencil thickness versus micro-modification of stencil aperture) for applying the paste on a board with standard surface mount and fine-pitch?
- Have they looked into the implications of each approach?
- Do they get heel fillet in fine-pitch without getting insufficient fillets in standard components?
- What is the reflow soldering method used (vapor phase, infrared, convection, or combinations thereof)?
- What are typical thermal profiles on the board surface and at a solder joint?
- Do they develop a unique profile for each board?
- How and where are the thermocouples attached?
- Are they attached on the surface or on the solder joints?
- Is the board drilled to attach thermocouples to the BGA balls on the outer and inner layers?
- If not, how do they know if the BGA balls really reflow?
- Have the reflow processes been compared for manufacturing yields?

In developing a profile, there is an inherent conflict between the type of profile you need for a BGA (shorter soak time) and what you need for BTC (longer soak time). What does the supplier do when both are on the same board, which is a very likely scenario? Developing a reflow profile for electronic assemblies is like trying to figure out the time and temperature (bake profile) to bake turkey, chicken, and shrimp for the same length of time at the same temperature in the same oven without undercooking the turkey or overcooking the shrimp.

Your questions should focus on assessing the inherent technical capability of personnel to resolve complicated technical issues that they need to deal with all the time in a complicated assembly:

- What cleaning method and solvents are used?
- How is the cleanliness of product boards monitored?
- What sort of repair/rework equipment is used?
- What are the thermal profiles for repairing each surface mount device type?

To determine whether the company has any experience or plans to develop capabilities for newer technologies such as BTC, BGA, and ultrafine-pitch packages (if your product requires them now or in the future), you should ask detailed questions related to that technology. For example:

- Are you planning to achieve toe/side fillets in BTCs, and if so, how?

- How do you ensure you get sufficient paste thickness to prevent potential opens without getting too many voids?
- How do you prevent paste dripping into via holes in thermal pads?
- What do you see as the major concerns in PBGA, and how do they compare to PQFP?
- What is their experience with head-in-pillow (HIP)?
- If you are doing all you can about paste height, reflow profile, do you think the component supplier is responsible for HIP?
- Do you prefer copper-defined pad or solder mask-defined pad, and if so, why?
- What do you think of the approach used by some companies where solder mask is sprayed up to the edge of the pad with zero clearance?
- Do you prefer via in pad or tear-drop design, and if so, why?
- Did you conduct any evaluation on PCB routing for different pitch, pad sizes, line width/space, etc., and their impact on layer count?
- Did you experiment with different pad sizes and their impact on process yield?

Conclusion

The idea behind the questions in this column is to establish whether the company has done extensive process evaluation and whether they understand the importance of critical materials and process variables on product quality and reliability. It will be obvious within a very short time during the visit if there is someone in the company who understands these issues or if they are just following the recommendations of component and material suppliers. How many component or material suppliers do you know who build PCBAs? How useful would their recommendations be?

I should also note that the intent of these questions is not to dictate the process to the company but to assess their understanding and capability. You should focus mainly on the end requirements. Let the assembler worry about how best to meet those requirements. You are simply trying to establish whether they can meet your requirements.

In my next column, I will conclude this series with questions on quality and RoHS compliance. **SMT007**

Ray Prasad is the president of Ray Prasad Consultancy Group and author of the textbook Surface Mount Technology: Principles and Practice. Prasad is also an inductee to the IPC Hall of Fame—the highest honor in the electronics industry—and has decades of experience in all areas of SMT, including his leadership roles implementing SMT at Boeing and Intel; helping OEM and EMS clients across the globe set up strong, internal, self-sustaining SMT infrastructure; and teaching on-site, in-depth SMT classes. He can be reached at smtsolver@rayprasasd.com and regularly offers in-depth SMT classes. Details about classes can be found at rayprasad.com. To read past columns or contact Prasad, click here.


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IPC Standards Development: Business Challenges and an Inside View

Article by Graham Naisbitt
GEN3 SYSTEMS

The rapid pace of technology development, miniaturisation, and high-density packaging is presenting new opportunities, but with them come challenges involving traceability and quality control—both of which heavily rely upon control standards.

One of the best forums for evolving such documents is IPC, which is headquartered in the U.S. and has historically been heavily influenced by the demands of the U.S. aerospace and defence sector since the removal of "MIL" standards during the Reagan administration back in the '80s. However, a major criticism is the pace by which standards are developed and for which five-year timescales are a problem. This time lag with the actual technology used in high-volume products is problematic. Moreover, the military and high-reliability industries are late adopters, further delaying the start of work on standards for current products. Another, and perhaps more significant, problem is that the development work has been done by volunteers, albeit on behalf of their employers.

With increasing frequency, standardising the standards, such as ISO 9201, imposes certain rules that must be met to ensure "fair play" amongst the supply chain. There will be those familiar with hearing about "false positives/negatives" and "never trust the salesman," so mitigating these is no easy task. However, there is the chance for each 5-30 Task Group to review industry requirements and set out the work program for the ensuing period.

With that in mind, much of what follows is based on comments we learn about from our industry around the world, many of whom are not yet IPC members. Yes, this is a membership recruitment drive, unashamedly, as well as a search for volunteers willing to help create the standards of tomorrow.

IPC Task Group 5-32b SIR and ECM: Structured Development Programme

Background

The current IPC SIR 2.6.3.7 test is targeted at typical applications, which is where the minimum PCB feature is separated by more than 200 µm and the voltage is within the approximate range of 10–100 V. The test duration

states not less than 72 hours by committee agreement. This was to revert to 168 hours, but evidence is now available that flux residues may lie dormant for beyond 500 hours in service, and hence there is a need for a three-week or four-week test.

Today, there are two different developing technology regimes: (1) high voltage (~1,000 V) electronics for electric vehicles and (2) low voltages and fine-pitch devices (~2 V and <100-µm feature size) in the medical and space industries. The existing test 2.6.3.7 is not appropriate for these technologies. For example, in the high-voltage testing standard ISO PAS 19295:2016(E), electric components or circuits are required to operate with a maximum working voltage between 30 V AC (rms) and 1,000 V AC (rms) or between 60 V DC and 1,500 V DC.

An impetus for a new test has been created by the removal of the ROSE test from Rev G of J-STD-001. There is a desire to qualify cleaning efficacy underneath bottom terminated components (BTC), using a modified SIR test, along with a new test vehicle, that can take advantage of low-cost test vehicles and use SIR patterns underneath the BTC to evaluate cleaning efficacy.

Following on from a current HDPUG project on corrosion, a method will be produced to look at pitting and crevice corrosion through solder mask. Here a modification of the SIR technique is proposed to evaluate solder mask integrity and use a new test vehicle.

Aim

The aim here is to develop new SIR standards to cover the low and very high voltages, and validate the developed approach with a Gauge R&R study, all under the auspices of IPC. The work will build on the approach in 2.6.3.7 but will tailor the approach appropriately for the two technology areas. 2.6.3.7 will also be updated from the current 2007 version, and incorporation of the new IPC B53 test pattern, which incorporates a 200-µm SIR pitch pattern. The new standard will also look at test duration, which will include a minimum of one option to test for at least 500 hours and possibly beyond 1,000 hours.

The cleaning efficacy SIR evaluation, and the corrosion of solder masks, will follow a similar path, with the development of test vehicles, dummy components, and a test protocol. The IPC SIR committee 5-32b will lead the development of the documents and organise a round robin trial with Gauge R&R validation.

Funding

The standards will be written as now within 5-32b by voluntary work. Production of the samples might be funded by IPC, and then the intercomparison work by the collaborators will take place at their expense.

Methodology

For these, we need a consensus on the track and gap for the patterns. Our current point is 25 V/mm, with the 200-µm (B53) and 500-µm (B24) patterns. For low-voltage applications, it is envisaged that the test voltage of 2V and ~50-µm track spacing, and this will lead to 40 V/mm. With high-voltage testing, an anticipated field strength of 500 V/mm is expected, hence with a 1,000 V test, the feature spacing will be 1 mm.

It has been demonstrated that electrochemical processes will not always scale with feature size, or SIR pattern pitch, and the applied voltage. Thus, careful consideration must be given to the applied test, and the conditions of the test must be applicable to the use case. If not, the produced data can be valueless. Therefore, new test coupons will be required, and the input from the wider industry is essential to define the requirements.

New material systems are known to have a long incubation period before the onset of corrosion; periods of up to 500 hours have been noted. Testing at >1,000 V may generate failure modes that occur over relatively long distances and hence may take even longer times, and test durations of over 1,000 hours may be required. Proposals for the cleaning efficacy SIR evaluation and the corrosion of solder masks will be brought forward.

Validation

When the committee has agreed on the test methodology, the method and chosen test


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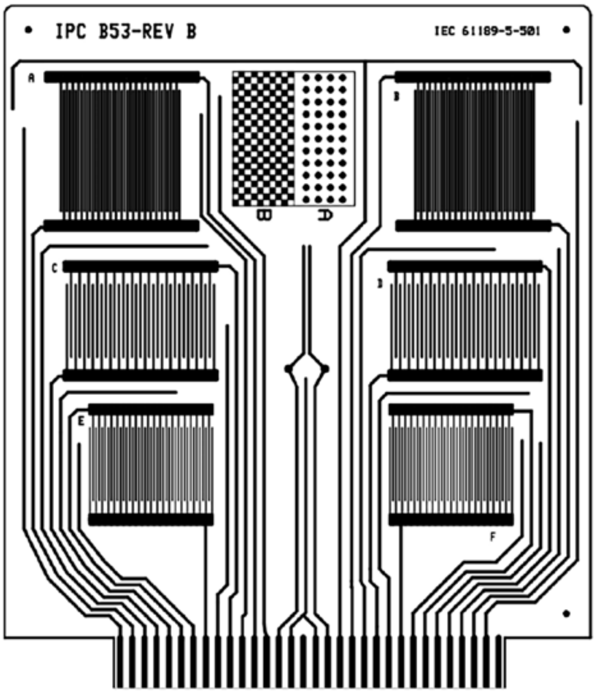


Figure 1: IPC B53 Rev B.

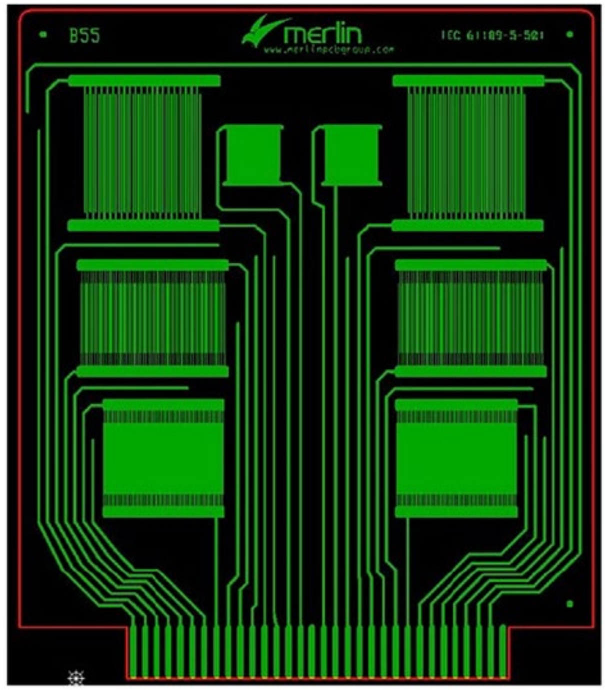


Figure 2: Proposed IPC B55.

vehicles need to be validated. Previously an intercomparison was organised jointly by IPC and the IEC, and the results were reported and published as IEC TR 61189-5-506. This report compared the response using SIR patterns with 500-µm, 318-µm, and 200-µm conductor separation. The test coupon used for this was IPC B53 Rev A. These results are now an important part of the updating of 2.6.3.7. The development work described here plans a similar exercise with the to-be-developed standards and test vehicles.

Work has already started, and there is a Rev B to IPC B53—the development of which was intended as a potential replacement for IPC B24, B25, and B25A coupons. A further refinement of the B53 to the B55 has also been designed, which contains an extra pair of patterns with 50-µm spacing. Both of these new boards are shown in Figures 1 and 2.

The plan is to start this work soon and produce the necessary draft standards and test vehicles.

We feel that the broader industry needs to be aware of this work and help in the development of the next revision of the SIR/ECM standard that includes:

- IPC-TM-650 Method 2.6.3.7
- IPC 9201 Surface Insulation Resistance Handbook
- IPC 9202 Material and Process Characterization/Qualification Test Protocol for Assessing Electrochemical Performance
- IPC 9203 Users Guide to IPC-9202 and the IPC-B-52 Standard Test Vehicle

A new test method for process characterisation and a toolbox of other test methods can assist in evaluating and resolving test failures. **SMT007**

Editor's note: This article originally appeared in the October 2020 issue of PCB007 Magazine.

Graham Naisbitt is the chairman and CEO of Gen3 Systems, as well as the chair of IPC 5-32b SIR/ECM, vice-chair of the IPC 5-30 Cleaning and Coating Committee, and vice-chair of 5-32e CAF. He is also the author of *The Printed Circuit Assembler's Guide to…Process Validation*. Visit I-007eBooks.com to download this book and other free, educational titles.

Editor's Picks from SMT007.com

1 Lean Digital Thread: DFM Is Now as Easy as Spellcheck ▶


Sagi Reuven

In past columns, Sagi Reuven has written about topics mostly related to the shop floor. In this column, he talks about design for manufacturing. It is clear to everyone in the Industry 4.0 era that the holy grail is to close the loop between design and manufacturing.

2 Real Time with...SMTAI 2020: Seika's Preparation Pays Off ▶


Michelle Ogihara

Nolan Johnson and Seika Machinery's Michelle Ogihara, senior sales and marketing manager, catch up on SMTAI 2020. Michelle shares her team's generally positive experience in preparing for the exhibition, details the new products on display in the Seika virtual booth, and describes an experience from SMTAI that could have only happened at a virtual event like this.

3 Sensible Design: Key Benefits of Resins and Differences From Coatings ▶


Alistair Little

Alistair Little focuses on the benefits of using a thermally conductive encapsulation resin and compare the difference between using a resin and a conformal coating. He also looks more closely at the best way to mix a resin pack and what to be wary of if air bubbles get trapped in the cured resin.

4 Real Time with... SMTAI 2020: Technical Conference Review ▶

SMTAI 2020, which was converted to a virtual event, took place from September 28–30. This event covered a broad range of topics related to everything in assembly. Over 90 technical presentations are available, but this report covers just some of the sessions I attended.

5 Real Time with...SMTAI 2020: Creative Electron Moves Toward Autonomous Systems ▶

Dr. Bill Cardoso

Andy Shaughnessy recently spoke with Dr. Bill Cardoso, CEO of Creative Electron, a provider of advanced X-ray inspection systems. Bill discusses some of the new technologies the company will demonstrate in their virtual booth at SMTAI, including a next-generation X-ray parts counter and a new software platform that offers better automation than ever.

6 Part 5 of Siemens' Digital Twin Webinar Series: Managing the Digital Thread ▶

Jay Gorajia

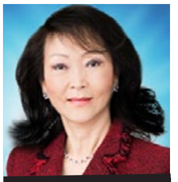
I-007e Micro Webinars recently released a free, on-demand series titled "Implementing Digital Twin Best Practices From Design Through Manufacturing" with Siemens' Jay Gorajia. In part 5, Gorajia discusses "Managing the Digital Thread From Design to PCB Assembly Engineering."

7 Catching up With Cabletree's Thomas Chang ▶

Thomas Chang

Dan Beaulieu has always been interested in exploring the wire harness and cable areas business, so he jumped at the chance to talk with Thomas Chang, the president and owner of Cabletree. Here, they discuss the cable assembly segment and how Cabletree serves EMS companies.

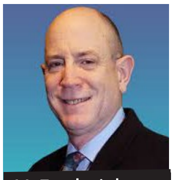
8 SMT Perspectives and Prospects: Joint Industry Standard IPC J-STD-00-Electronic Solder Alloys, Part 2 ▶



Jennie Hwang

In Part 2 of her column series on requirements for electronic-grade solder alloys and fluxed and non-fluxed solid solders for electronic soldering applications, Jennie Hwang addresses questions raised regarding the subject industry standard IPC J-STD-006.

9 Real Time with... SMTAI 2020: Insituware Offers Handheld Process Controls for the Smart Factory ▶



M. Frederickson

Nolan Johnson speaks with Insituware CEO and Chief Engineer Michael Frederickson. Mike and Nolan discuss how these new devices contribute to accuracy, compliance, and real-time process optimization—all key factors in the smart factory environment.

10 Real Time with... SMTAI 2020: Cimetrix's Universal Translator–Sapience for Industry 4.0 ▶

R. Chatterjee

Ranjan Chatterjee—vice president of smart factory solutions for Cimetrix teases some of the new features in Sapience for Industry 4.0 and shares that smart factory implementation is becoming increasingly quick and straightforward with Cimetrix's approach to automation.

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  - Develop long-term customer strategies to increase business

Qualifications

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- Engage suppliers in quality improvements and process control issues as required.
- Generate process control plan for manufacturing processes, and identify opportunities for capability or process improvement.
- Participate in FMEA activities as required.
- Create detailed plans for IQ, OQ, PQ and maintain validated status as required.
- Participate in existing change control mechanisms such as ECOs and PCRs.
- Perform defect reduction analysis and activities.

Qualifications

- BS degree in engineering
- 5-10 years of proven work experience
- Excellent technical skills

Salary negotiable and dependent on experience. Full range of benefits.

Lenthor Engineering, Inc. is the leader in Flex and Rigid-Flex PWB design, fabrication and assembly with over 30 years of experience meeting and exceeding our customers' expectations.

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- Build and maintain positive relationships with customers
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