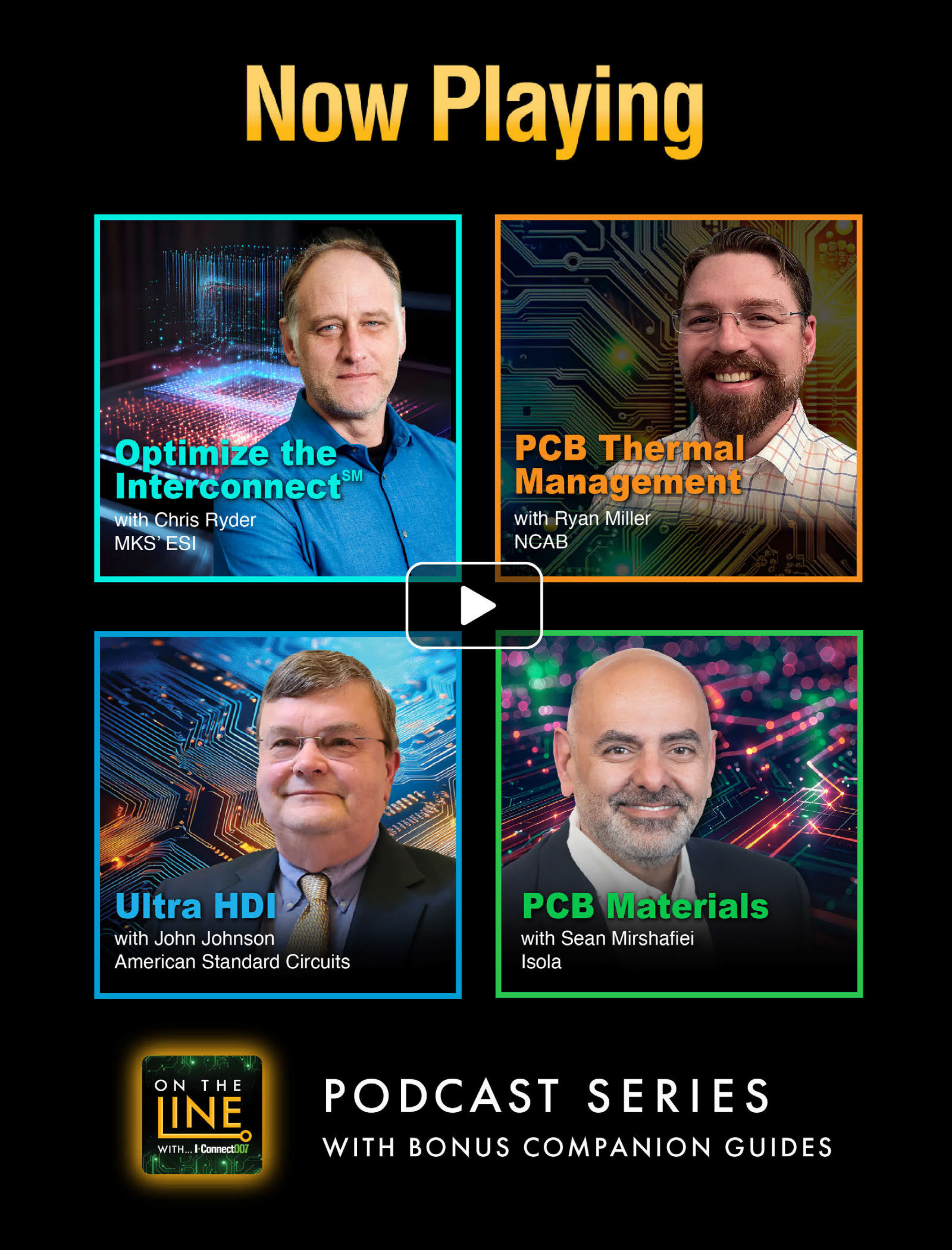
JULY 2026

SMT007 MAGAZINE

FASTER CHANGEOVER TIMES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Setup Optimization

The fastest way to improve your uptime is by reducing setup time. That means transforming setup from a machine-centered activity into a logistics-centered process where materials, feeders, programs, and tooling arrive at the line fully validated before the previous job ends. The result is faster changeovers, less labor waste, and greater efficiency through single-minute exchange of die (SMED).

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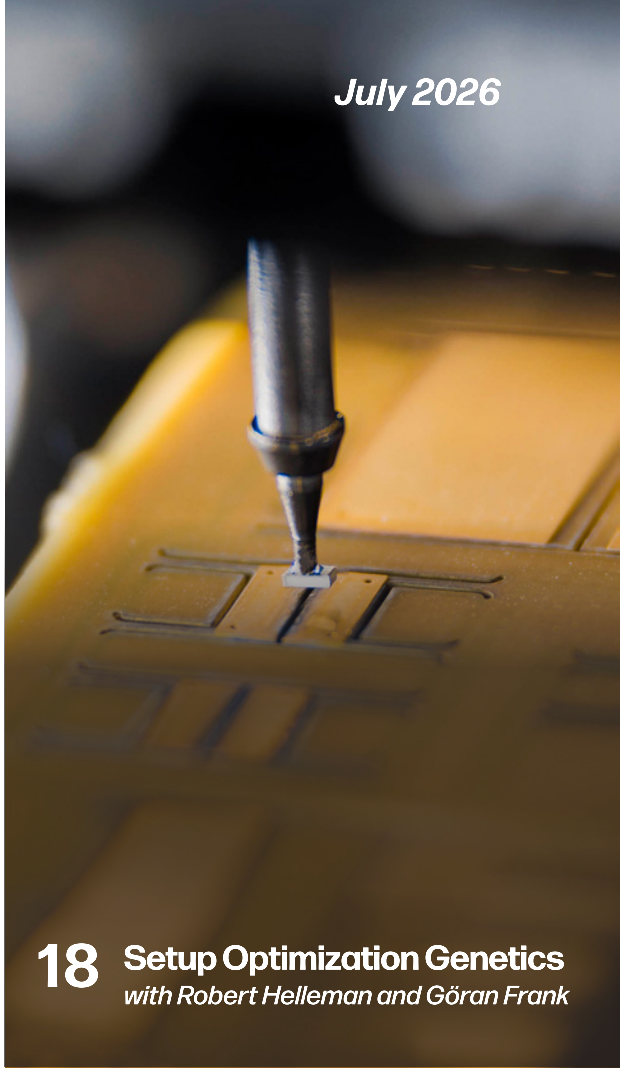

In Every Issue

SMT007 MAGAZINE


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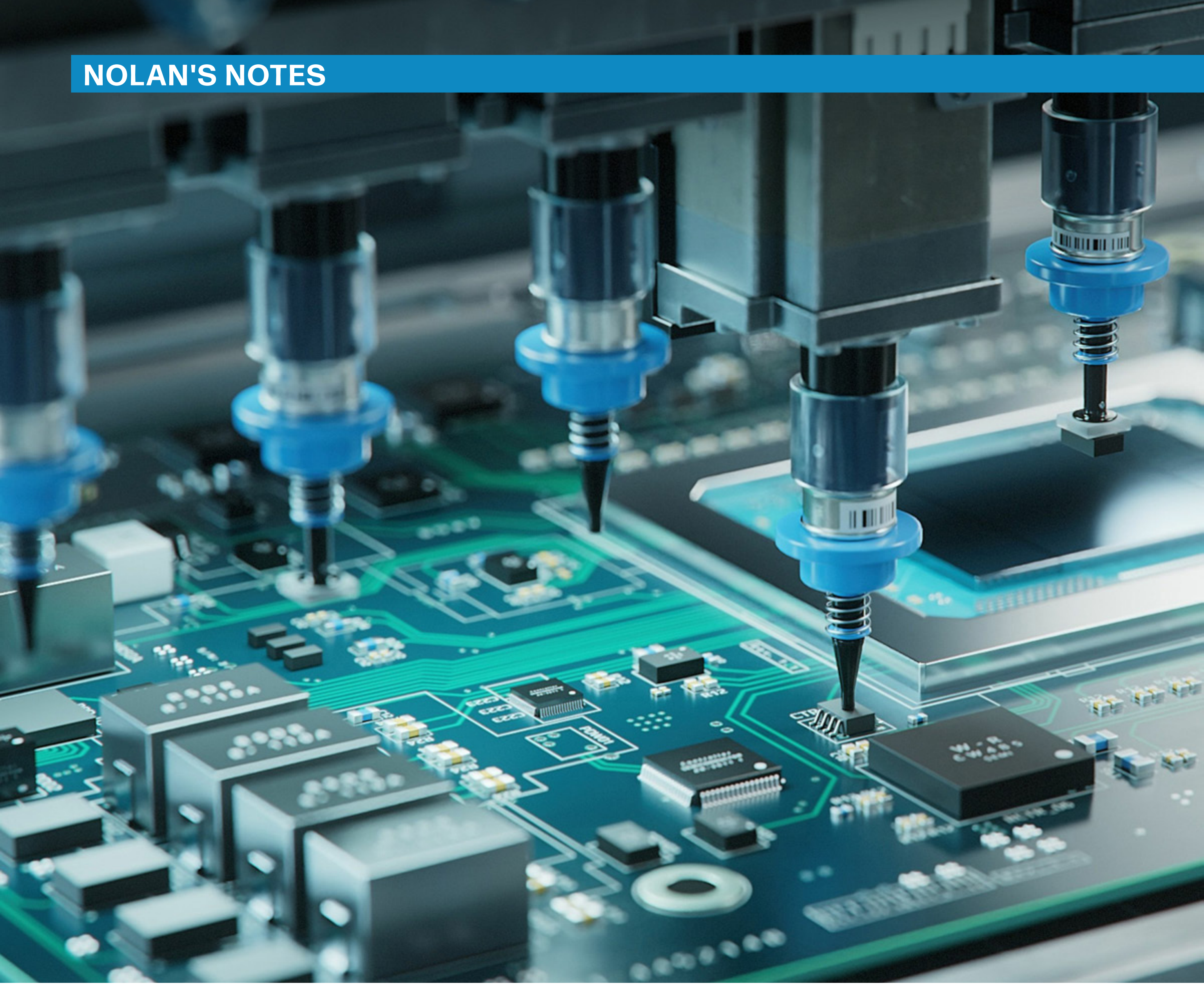

The ROI of **Setup Optimization**

BY NOLAN JOHNSON, I-CONNECT007

It was a comment from a guest at APEX EXPO last March that hit me. We were walking the show floor together and I was describing the major pieces of equipment, their functions, and the order of operation. When we stopped at a booth with robotic component towers, my guest commented, “So, everyone has one of these, right?” “Umm, no,” I said. “This is considered pretty sophisticated equipment. A lot of companies pick these parts from inventory by hand.”

My guest, an industry outsider, said, “How do they tolerate all the time and human error?” That response, frankly, was rather devastating. She may have been new to the industry, but she sure knew a thing or two about manufacturing. I said to myself, “Is it really that obvious?”

Well, if it wasn’t that obvious in years past, it is now. Reducing setup time is a key area for improving uptime and reducing labor waste. The biggest opportunity for EMS providers is not faster machine

operation; it is transforming setup from a machine-centered activity into a logistics-centered process where materials, feeders, programs, and tooling arrive at the line fully validated before the previous job ends. This shifts the setup from reactive execution to planned exchange, which is the essence of single-minute die exchange (SMED). This was a new term for me, and if it's for you as well, we explore it together in this issue.

As production volumes become more fragmented and product complexity increases, the ability to execute fast, predictable, and error-free changeovers will become a defining characteristic of world-class EMS providers. The companies that master setup optimization will not simply reduce downtime. They will gain additional capacity, improve responsiveness, strengthen customer relationships, and create a sustainable competitive advantage in an increasingly demanding manufacturing environment.

In this issue, therefore, we explore the topic with Mycronic's Robert Helleman and Göran Frank, who discuss how every minute of downtime is revenue lost. Then, I explore the SMED continuous improvement technique. After providing some details about the process, I sharpened a pencil, picked a reasonable hypothetical scenario, and did some ROI math on setup time improvement. The outcome was rather insightful as to where the biggest gains come from.

As much as the manufacturers of robotic component storage towers would like everyone to listen to my APEX EXPO guest and buy a tower or two, the truth is that a thorough and thoughtful implementation of a component-tracking system is a key yet often under-implemented process for shop-floor optimization. If floor tracking isn't correctly implemented, the fancy equipment is likely to simply automate a bad process.

Outside our chosen topic, this issue explores the leadership of Winston Churchill through the eyes of columnist Jennie Hwang, and Nash Bell writes in his column about "X-ray Inspection of Ball Grid Array Solder Joints."

Rob Ronan from Retronix concludes his three-part series on the intersection of parts reclamation and supply chain resilience. Dr. Stanton Rak concludes his series as well, wrapping up what we've learned about EV technology. Leo Lambert, technical director at EPTAC, answers common questions on soldering technology, which is well worth a read.

Dropping in from Global Electronics Association's Mexico offices, Filiberto Severiano, CEO and founder of SMTLINK Systems, explains the surge in Mexico's exports and how companies like his are finding their niche.

Finally, I want to tell you about a new column I'm writing for the I-Connect007 Substack page. This is my chance to tell the industry's story from a slightly different perspective. I'm not just talking about surface mount technology in this column. Instead, I'll be taking a much broader view of the industry and the external forces that continue to impact what we do.

I recommend you visit and subscribe to our Substack channel. I-Connect007 is a trailblazer for creating and distributing content about the electronics industry. We were the first to add multimedia, back when that meant a shoulder-carried camcorder. We led the way with books and on-the-floor interviews. We were the first publication to commit to digital distribution, and we grew because of all these channels.

Over the past two years, we've built out several alternative channels for our content, including LinkedIn and now Substack, where we are engaging with you in unique, interactive ways. Substack also gives us more space to conduct industry analysis alongside our reporting, allowing us to tell our stories from a higher vantage point. The party's just gotten started; come on over and join the conversation.

As always, if you have an idea or a question you'd like to see addressed in *SMT007 Magazine*, we're listening.

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**.

The Architecture of Winston Churchill's Leadership

BY DR. JENNIE S. HWANG, H-TECHNOLOGIES GROUP

I was recently invited to visit the U.S. Embassy and the Churchill War Rooms in London, where I met Warren Stephens, U.S. ambassador to the UK, and Bank of England Gov. Andrew Bailey. From those modern diplomatic corridors to the stark resolve of a wartime bunker, the experience reminded me that leadership in this ever-shifting global landscape is, at its best, about bridging the wisdom of the past with the realities of the present.

The atmosphere in the War Rooms is not merely one of preserved history but of palpable, high-stakes decision-making that still seems to hum within the reinforced walls. Standing in the very space where Winston Churchill orchestrated the defense of the free world, followed by my conversation with Stephens at the new U.S. Embassy in the Nine Elms district, brought the sheer weight of leadership into sharp focus. It was a reminder that true leadership is rarely about the comfort of the present but rather the courage to navigate the unknown with a clear-eyed vision and an unwavering commitment to your strategic pillars.

Churchill's philosophy turned daunting obstacles into a definitive path forward, ensuring that even in the fog of uncertainty, the direction remained true. He believed that success is never final, and failure is

never fatal. He transformed endurance into a virtue, teaching us that the only thing that truly counts is the will to continue.

Churchill's life was like a map in grit, reminding us that even the best maps have some "rugged terrain." He was famously stubborn and had a few detours in his career. Perhaps the most humanizing aspect of the Churchill museum is how it chronicles his Wilderness Years in the 1930s, when he was a political outcast, dismissed as a warmonger and a relic of a bygone era. Churchill's life reminds us that life can be a series of peaks and deep, lonely valleys. He struggled with depression and faced the stinging silence of a public that had tuned him out. Perhaps his stubbornness was a liability in peace, but it was the world's greatest asset in 1940.

I walked through the museum's corridors to the Map Room, where the pins haven't moved since 1945 (Figures 1, 2, and 3). While the tools of leadership have evolved from the telephones and telegrams of his day to the encrypted satellite and AI feeds of ours, the soul of his leadership remains exactly as Churchill defined it. In the Bunker (Figure 4), the low ceilings and smell of aged paper provide a visceral sense of the pressure he faced (Figure 5). As I stood in front of his office (Figure 6), I imagined how he worked there.

Churchill had a habit of working from his bed

Figure 1: Map in the Churchill War Rooms, located beneath the streets of Westminster in London.

Figure 2: The Cabinet War Room, where Winston Churchill and his ministers met to make critical wartime decisions.

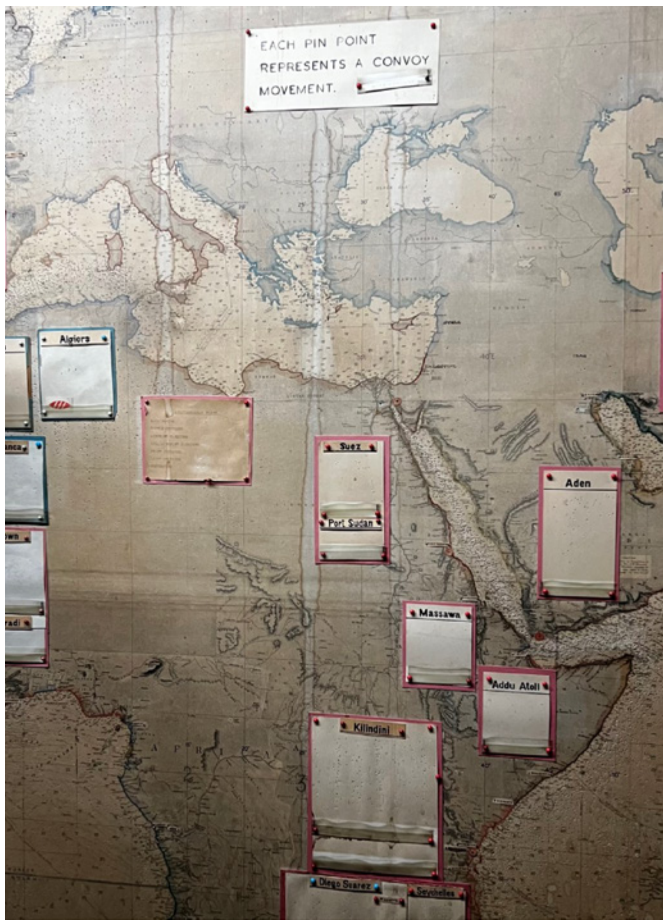

Figure 3: The Map Room, preserved exactly as it was left in 1945, with maps and position markers unchanged since the end of World War II.

(Figure 7). His eccentricities weren't just quirks; they were his way of managing the immense mental load of the war. Perhaps his cigar box or a marked-up draft of a speech illustrates his hands-on approach to communication and his curiosity and interest in technology (e.g., tanks and aviation).

His leadership was built on a foundation of radical, often brutal, transparency. His "Action This Day" philosophy demanded brevity and truth. He had an "allergic reaction" to bureaucracy and procrastination. He famously asked his ministers to provide reports on a single sheet of paper.

The Power of Language and Communication

Churchill's eloquence was not accidental; it was the product of preparation, reflection, and an acute understanding of human psychology. He knew when to inspire, to warn, and to unite.

I learned that he possessed an extraordinary ability to distill complexity into clarity. However, this is not a mere simplification. It is disciplined thinking that requires the leader to absorb complexity, filter it through principles, and communicate a path forward that others can trust. He believed that the

Figure 4: The underground bunker that housed Britain's wartime command center during the Blitz and throughout World War II.

Figure 6: The War Office, from which military operations and wartime administration were coordinated.

Figure 5: The Telegraph Room, where communications and military messages were transmitted and received around the clock.

Figure 7: Winston Churchill's bedroom, a small private space within the underground complex reserved for his occasional overnight stays.

most profound truths should be expressed in the simplest language. He implemented his Rule of Three, which was three ideas grouped together for greater effect, as in his quote, "A riddle, wrapped in a mystery, inside an enigma." This powerful practice was used to build momentum and maximize cognitive impact. By using common language, he ensured his message reached a broad audience, from factory workers to aristocrats alike. This created a sense of national unity.

Reportedly, his speech preparation time was 60:1: one hour of preparation for every one minute of delivery. He practiced in front of a mirror and, to test the "mouthfeel" of the words, he hummed his speeches while bathing, dressing, or walking. If the sentence was difficult to say, he assumed it would be difficult to hear, and he would rewrite it until it flowed perfectly. He broke sentences into short, jagged phrases with staggered indentations. This acted as a musical score, telling him exactly when to pause and breathe, and which words to emphasize.

The Importance of Perspective

Churchill's leadership was deeply informed by history. He understood not only the immediate stakes but the broader context within which those stakes existed. This perspective enabled him to make decisions that were not merely reactive but strategic.

In the modern context, where immediacy often dominates, maintaining perspective is increasingly challenging. Leaders are pulled

Lessons Learned From Churchill

I walked through the old Museum and the new Embassy, examining and reflecting on Churchill's leadership. These are the lessons I learned from that experience:

1. Leadership goes hand-in-hand with mental capacity.
2. Leadership isn't a title; it's a temperament.
3. The leader must speak with remarkable clarity.
4. Leadership requires the practical execution of vision under pressure.
5. Authenticity isn't a branding buzzword; it is a strategic asset.
6. Churchillian leadership is about conviction.
7. Architecture of communication and mastery of language are pivotal. Churchill didn't just give "updates"; he painted a vision.
8. Resilience isn't just about winning; it's about surviving the periods when you are unpopular or "wrong" in the eyes of the majority.
9. True leadership is about building alliances when you don't yet need them, so they are ready when you do.
10. Curiosity as a tool: A leader must remain a lifelong student of innovation to stay ahead of the curve.
11. For the modern leader, the lesson is that influence is not a constant. There will be seasons when your ideas are unpopular, and your voice feels small.
12. The mark of a leader is what they do in the "wilderness." Do you change your tune to fit the fashion of the day, or do you continue to sharpen your axe for the moment the forest needs clearing?
13. Great leaders aren't great because they lack flaws; they are great because their virtues are so massive they outweigh their vices.
14. Effective leadership does not require perfection; it requires authenticity, self-awareness, and the ability to act decisively despite imperfection.
15. Leaders must possess the ability to surround themselves with people who could say "no."
16. Great leadership doesn't require a lack of ego, but rather an ego that is entirely harnessed toward a singular, noble purpose.
17. At the intersection of historical legacy and modern diplomacy, the essence of influence remains unchanged. Leaders have the ability to project stability in an unpredictable environment.
18. The tools of leadership change, from telegrams to AI, but the requirement for courage remains constant.
19. Leadership, after all, is not tested in moments of ease.
20. A leader's courage should be grounded in realism.

toward short-term metrics, rapid responses, and continuous adjustment. Churchill's example reminds us that perspective is a competitive advantage. It allows leaders to prioritize effectively, resist distractions, and align actions with long-term objectives.

Resilience

Churchill demonstrated that resilience is built through consistent habits, decision-making, and communication, and through the capacity to recover quickly from setbacks. It's adaptive endurance, and for him, it was sustained. His resilience required emotional stamina, intellectual rigor, and an ability to persist under relentless pressure.

Courage Beyond Optimism

In contemporary leadership, there is often pressure to appear positive at all costs. Yet forced optimism can erode credibility. Churchill's approach reminds us that courage is about acknowledging difficulty while committing fully to the path forward.

Churchill embodied communication, clarity, courage, resilience, perspective, partnership, and humanity. He put them into operation when failure was not an option.

In reflecting on his legacy, today's leaders should not ask whether they will face comparable crises, but whether they are cultivating the qualities required to lead when it matters most. Churchill didn't try to be perfect. He sought moral clarity, infectious courage, and the power of the word.

He is my strategic compass and intellectual anchor. I am moved by his words, "It is no use saying, 'We are doing our best.' You have got to succeed in doing what is necessary."

Contexts and tools change. Challenges evolve. But the foundational principles of greatness endure. Winston Churchill is not a historical figure, but a blueprint for resilience and true leadership. **SMT007**

Upcoming Appearances

Dr. Jennie Hwang will present a lecture on "Artificial Intelligence and AI-powered Future Manufacturing," Oct. 26, at SMTAI, in Chicago. She will also present two virtual lectures on "Reliability of Electronics: Tin Whisker," Aug. 18 and 20, for the Global Electronics Association.

Dr. Jennie S. Hwang, an international businesswoman, speaker, and business and technology advisor, is a pioneer and longstanding leader in SMT manufacturing since its inception, and in developing and implementing lead-free electronics technology and manufacturing.

She has served as chair of Artificial Intelligence-Justified Confidence for DoD Command and Control study, chair of AI Committee of the National Academies, and Review Panels of NSF National AI Institutes and Committee of Strategic Thinking for Engineering Research. An International Hall of Famer (Women in Technology), she has been inducted into the National Academy of Engineering, named an R&D-Stars-to-Watch, and received the YWCA Achievement Award. She has held senior executive positions with Lockheed Martin Corp., and was CEO of International Electronic Materials Corp. She is currently CEO of H-Technologies Group, providing business, technology, and manufacturing solutions.

She has served as chair of the Laboratory Assessment Board, the DoD Army Research Laboratory Assessment Board, and the Assessment Board of Army Engineering Centers. She is on the board of Fortune-500 NYSE companies and civic and university boards, Commerce Department's Export Council, National Materials and Manufacturing Board, NIST Assessment Board, various national panels/committees, and international leadership positions.

She is the author of 10 books (four as co-author) and 750+ technical/editorial publications. She is a speaker and author on trade, business, and education issues. Her formal education includes four academic degrees (Ph.D., M.S., M.A., B.S.), as well as Harvard Business School Executive Program and Columbia University Corporate Governance Program. To read previous columns, click here.

Setup Optimization Genetics

When it's time to switch jobs, pre-kitted feeders are loaded in seconds—keeping downtime to a minimum, while also enabling on-the-fly replenishment without interrupting production.

At Mycronic, Robert Helleday, head of R&D, and Göran Frank, head of product management, are quick to clarify that setup optimization is "in our DNA at Mycronic." That's important because, in electronics manufacturing, every minute of machine downtime directly impacts productivity, profitability, and responsiveness to customer demand. As product lifecycles shorten and high-mix, low-volume production becomes the norm, manufacturers are under increasing pressure to reduce setup times, accelerate changeovers, and improve material flow without sacrificing quality or traceability.

In this interview, Robert and Göran discuss why setup optimization has long been a core focus of the company. That philosophy influences everything from machine design to software development. For manufacturers looking to increase flexibility and throughput in a high-mix environment, this interview offers valuable insights into the future of factory optimization.

Nolan Johnson: Much of the research on EMS processes points to setup and changeover as a significant contributor to system downtime on the factory floor. How does Mycronic best address that situation, and what are you seeing with your customers?

Robert Helleday: For changeover, there's a big difference between unidirectional and bidirectional material flow in factories. In unidirectional flow, components come from storage, go onto the machines, then the boards, and that's it. But our

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whole concept is specializing in bidirectional material flow: You put some of your components on the board, and some go back. It's everything from the software and hardware to accessories, feeders, storage, and so on. That's what we have built everything around.

I was just at a customer here in Europe, and they do 100 NPIs per day. I've been in the business for 30 years, and I've never seen anything like it. That is a good example: If you work the process from A to Z and use our equipment, you can do some great stuff.

You have to know what you're doing, though—everything from the data flow from their customers, the whole Agilis feeder system, the material handling system, and the software. This customer shows you can get those results without investing crazy amounts of money.

When we start talking about changeover optimization, industry insiders understand there's significant potential for human optimization. There are many manual operations that need improvement. That involves adjusting the timing of your processes and equipment to optimize them. How is Mycronic helping with bidirectional flow?

Helleday: Our feeders are quite small, and you can have hundreds of them at your kitting area. You can unload them in a couple of seconds, and they don't weigh anything. Because they are quite easy to handle, you can really do so efficiently. But the feeders don't go into our magazines straight away. Depending on the size of our bin, you can easily carry, say, 16 eight-millimeter components. If you have a station near the machine, that's where you can put components into the reusable magazines.

If you place the components in the wrong place in the machine, it won't matter because the machine will self-optimize. Of course, you want to do it right so you get better performance. We also electrically verify the components before they're placed. You can choose to verify every component, or perhaps the first one in the reel. This minimizes the room for error in the changeover process.

So, you're doing a verification on the line to make sure that there is no human error in the setup. Do you remove the previous job the same way?

Helleday: Yes, you put the bins in the magazine, then you connect the feeders to the end of the magazine facing the machine. To remove it, do the reverse: you can quickly load and unload. It's the flow in the factory, the flow of material, the flow of data. Those are the big things.

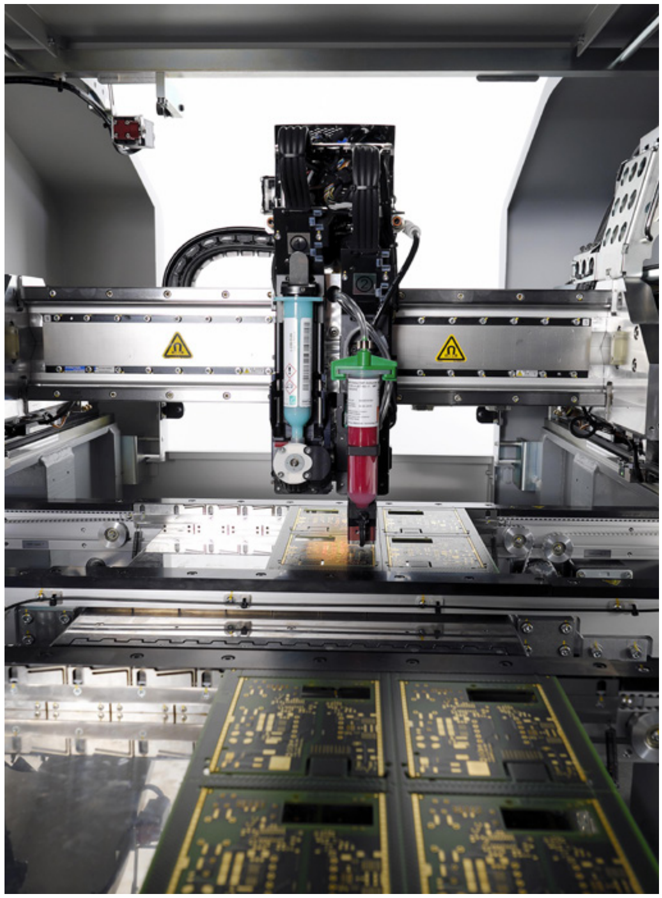
In a traditional manual flow, the machine is stopped for the duration, up to many minutes. The process you're describing sounds like just a few seconds at the machine. Are operators doing prep away from the machine while it's running a different work order?

Helleday: Yeah, for sure. Our machines are quite big; you can load a lot of components on them. If you need to change out everything, then we're talking maybe a few minutes. But for each, it's both quick and ergonomic.

You must support that with software, programming component placement, or connecting to software that tracks your inventory. Tell me about that.

Göran Frank: An optimal process requires more than just the machine; it relies heavily on how the customer works with the machine. We guide customers based on our extensive experience in running high-mix production. That's the core of each software component we offer. We help with best practices for running high-mix production. On the software side, the focus is on preparation and planning. It's prepar-

With lightweight, easy-to-handle feeders, operators can move quickly, preparing and exchanging components in seconds.



Jet printing removes the need for stencils and allows instant adjustments during production.

ing the job, but it's also planning the next job and the sequence of jobs. We are really good, together with the material management process, in supporting this.

Our core competency is the frequent changeover. That's what's triggering the bidirectional material flow Robert described. We got into this space very early; material flow has always been where we excel. We've been first with Agilis feeders, which are super easy to use with our MYTower solution for automated component storage and a bidirectional material flow. Supporting the different aspects of changeover is done with our software.

I assume traceability is a key feature, certainly for the EMS companies. How do you assist there?

Frank: Of course, traceability is very important. Many of our customers that work in sectors such as defense, space, med tech, and similar areas have high demands for both traceability and process optimization. The tools in our software portfolio run the process as efficiently as possible.

We see APIs and factory integration becoming even more important, and a need for both horizontal integration with other machines in the line and vertical integration with enterprise systems such as MES or ERP systems. APIs are part of our core DNA, and that's even more important now as people focus on collecting data and building AI tools to draw conclusions from it.

Doesn't setup optimization and horizontal integration work together here by tracking component status and location from the receiving dock, through verification and stocking, to the factory floor?

Helleday: Yes. Most of our customers build high-value electronics. They need to be very concerned about what goes on the boards and so on, so that it's the exact parts that their customers specified. I think most of our customers do that to a high degree.

Before placement, components can be electrically verified, adding an extra layer of control and reducing the risk of setup errors.

How does Mycronic support that kind of tracking?

Frank: We need to make all relevant data accessible and provide good APIs for customers so we can provide them with data. Customers would like to find as many data points as possible so they can optimize for more NPIs in the long run and improve profitability.

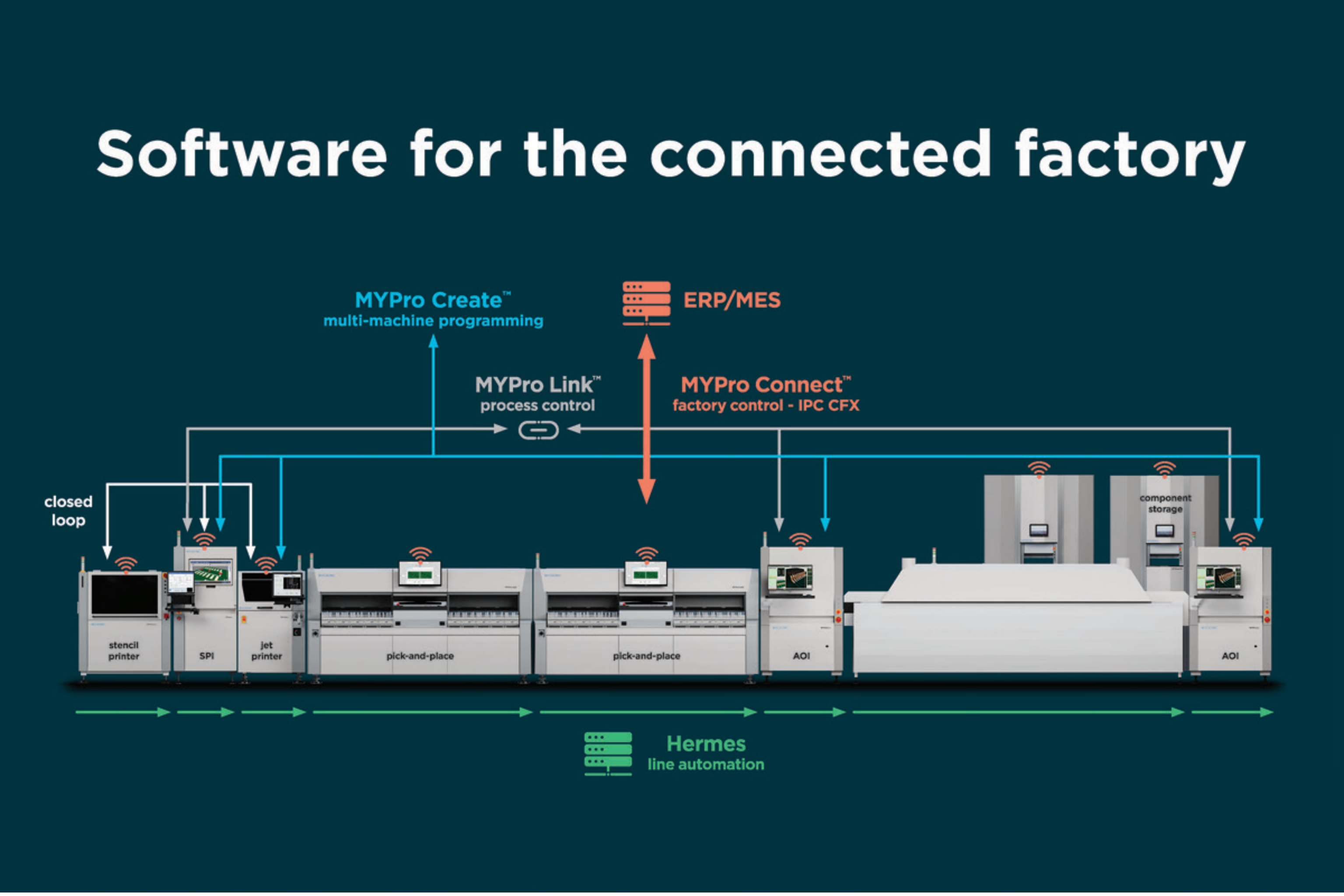
We need good APIs to interact in real time on the line. Material management has always been a bottleneck: How do we accomplish changeovers in a smart way? Using AI will help to complete this process.

Each component is part of a structured flow across machine, feeders, and material storage, all coordinated by software.

Helleday: We should also mention that we have, for instance, not only the pick-and-place, but the jet printer and so on. The jet printer fits very well with the customer segments we're in.

Right. It's not just the pick-and-place machine where optimization can take place.

Helleday: You can do more than you can with a screen printer. Programming all the jet printer functions in one go makes everything much smoother.



Across the line, machines, software, and material handling work together in a closed loop—optimizing flow, uptime, and performance.

Frank: Our jet printer really tells the story of Mycronic's work with optimization. To make a change, you don't need to order a new stencil and wait for delivery. You just make the change in the program. Iterating in the NPI environment is much easier.

Helleday: For example, if you want to write an article, you use Word, and it's easy to make changes to your text. It's the same with our jet printer. Instead of making a stencil, where you have to order another one to make a change, now you just adjust it in the file when you make an error. We're talking about days saved, not minutes.

There is a lot happening in the optimization space. Even with data integration, there is still a process to ensure that the programming is both efficient to use and produces optimal output. What has Mycronic done recently to improve the programming process?

Frank: Programming, along with material management, is probably the most important process when running high-mix production. We are investing heavily in this area to be even better.

With automatic optical inspection (AOI) systems, for example, we have shown that with GenI™, where we step away from the traditional AOI library into an AI-based approach, drastically cuts programming time. That approach is unique on the market so far.

Helleday: That development is on all levels. GenI is revolutionary. It's a whole new concept in that we don't make it easier to program libraries; we do away with libraries altogether.

But on the other end of the spectrum, we want to make the jet printer, AOI, and pick-and-place work well together, even down to details like tracking which pin is labeled pin number one. Pin number one is here in this system, but pin number one is there in that system. That's just work, it's not a revolution. But customers need to think about these

Bidirectional material flow is part of Mycronic's DNA—and a cornerstone for enabling efficient high-mix production.

things, especially when you have different systems from different vendors, people name things differently. If you have a lot to do, then it's easy to miss these details, only to see that the part is twisted 180 degrees in the first article. That's why we need to appreciate both the big things and the small details for the people on the factory floor. They have a lot to think about, and our job is to take away these unnecessary things.

When you can take the setup, consider all the actions, and remove every one that can be done while the machine is doing some other job, make them asynchronous to the operation of the machine, if you will, then you're keeping the machine busy printing money. We've talked mostly about placing, inspecting, and jet printing so far. Tell me more about Mycronic's complete line.

Frank: Overall, it's the combination of machines, software, feeders, and storage working together that turns this into a complete line offering, not just a set of individual products.

We track performance across the key machines—pick-and-place, jet printing, and AOI—to keep the process stable and continuously improve it. Material handling is fully integrated into this setup, with towers, feeders, and magazines working as one system rather than separate elements.

Components can be prepared offline, stored in the tower, and loaded as pre-kitted feeders. This enables fast, automatic changeovers and helps minimize downtime. At the same time, the system supports on-the-fly replenishment—when a component runs low, the tower supplies the right material without interrupting production.

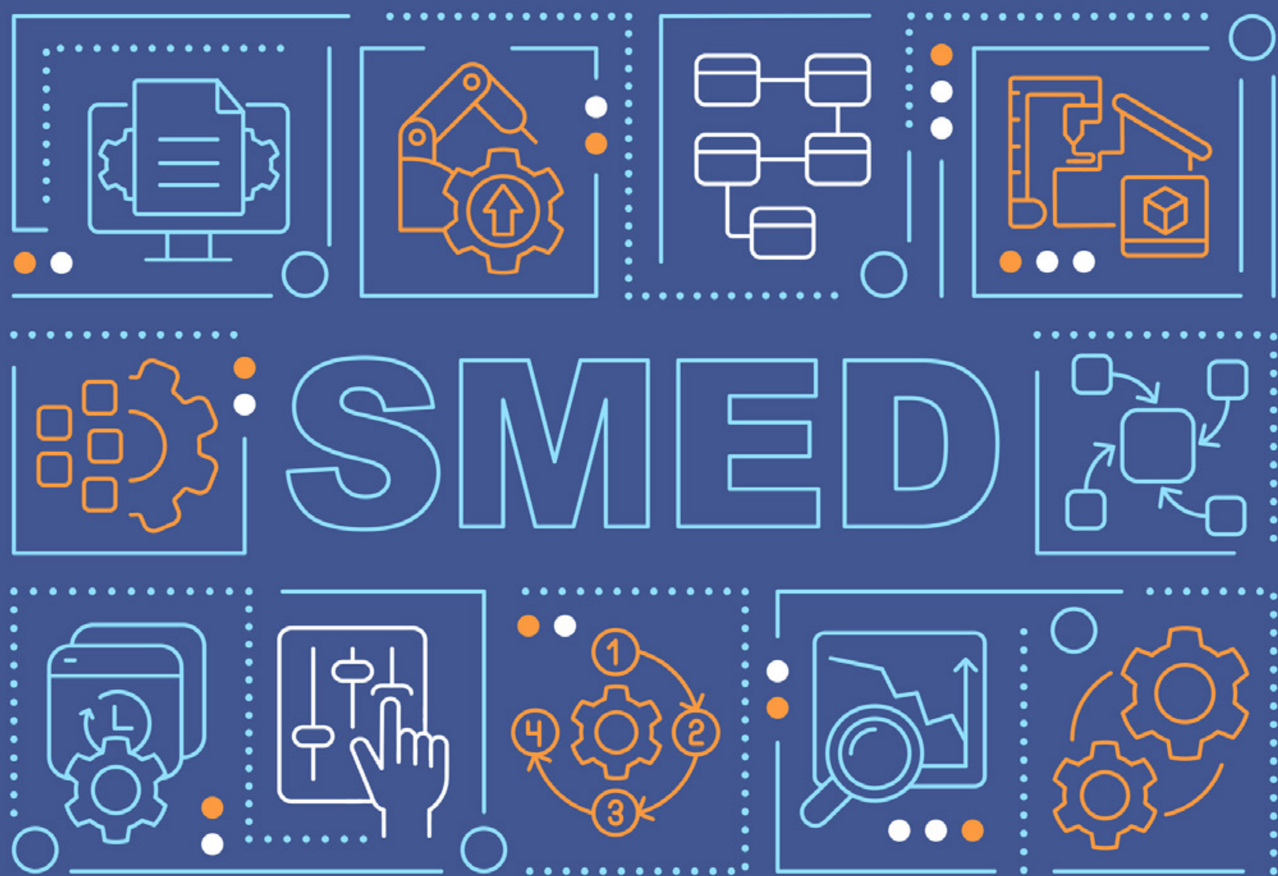
Gentlemen, clearly Mycronic is innovating in this space. Thank you for taking the time to talk with me. **SMT007**

Sponsored Link: Mycronic.com

FEATURE ARTICLE

BY NOLAN JOHNSON, I-CONNECT007

How Faster Changeovers **Unlock Production Capacity**



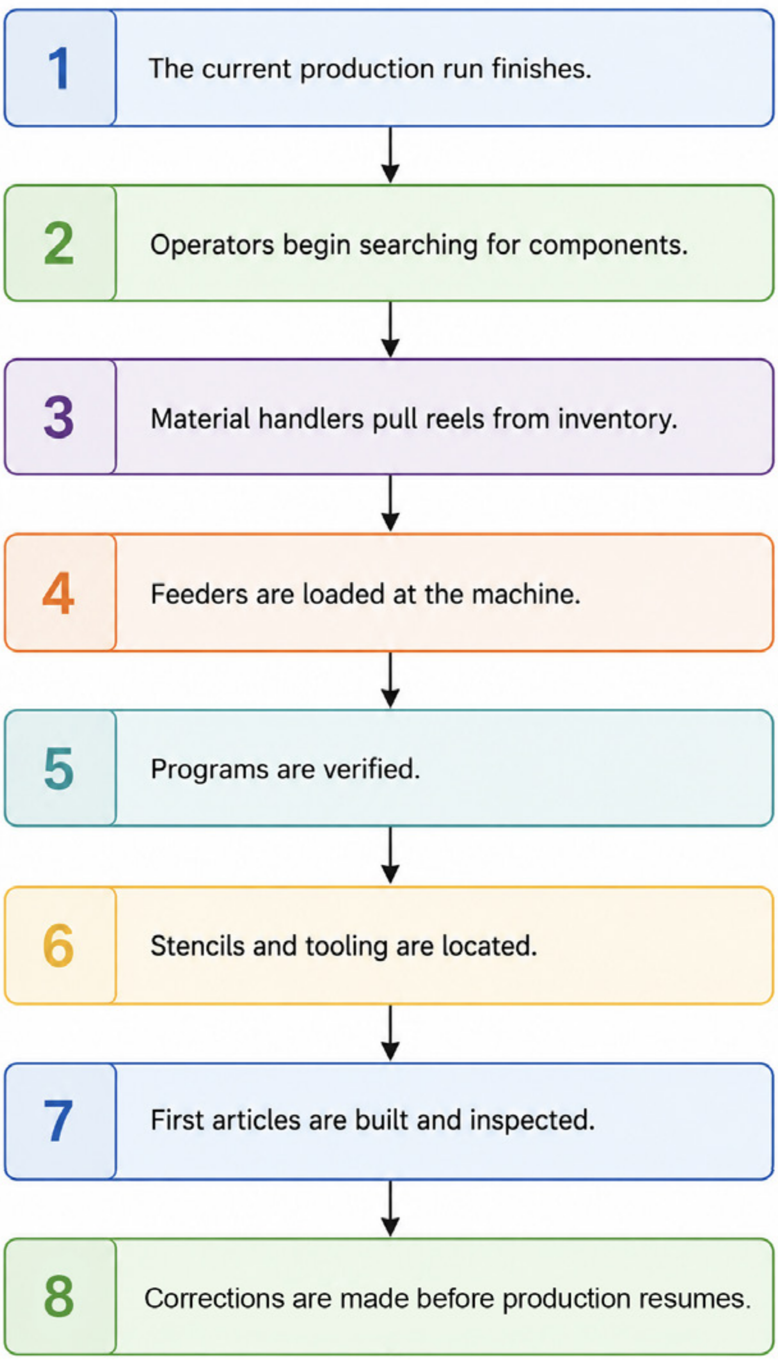
Traditionally, EMS companies have focused their continuous improvement efforts on machine speeds, placement accuracy, yield enhancement, and labor productivity. Yet across much of the industry, one of the largest contributors to lost capacity remains largely hidden in plain sight. We're talking, of course, about setup time optimization.

High-mix production is increasing even as product lifecycles shrink, meaning changeovers occur more frequently than ever, resulting in a proportionally larger amount of time lost to setup activities. Inefficient setup processes cost hundreds of hours of annual production capacity, and this lost time can mean the difference between a modest profit and self-funded company expansion.

The good news is that setup optimization follows the proverbial 80/20 rule: a 20% effort well targeted can create an 80% return in overall equipment effectiveness (OEE). The key is applying the Lean manufacturing principle of single-minute exchange of die (SMED) to modern SMT manufacturing.

What Is SMED?

If you're like me, SMED is a new term. Even though I've been around Lean manufacturing principles, I hadn't encountered the SMED idea. The idea is to find ways to optimize changeovers that take under 10 minutes to complete. The term emerged from the development of TPS at Toyota. Shigeo Shingo wrote the authoritative book on the subject, *A Revolution in Manufacturing: The SMED System*. James Womack also developed a SMED summary, published by the Lean Enterprise Institute.



The Hidden Cost of Setup Time

At a typical high-mix EMS facility operating multiple SMT lines, a standard changeover often includes material preparation, feeder loading, machine setup, program verification, tooling changes, first article inspection, and process validation. While these activities are necessary, the way they are carried out often results in significant downtime.

In many facilities, this process consumes between 60–120 minutes per changeover. For a line performing four changeovers per day, that can translate into more than seven hours of downtime every day on a single line. Across multiple lines and multiple shifts, the lost capacity becomes enormous. The challenge is that many organizations view setup time as an unavoidable cost of doing business. In reality, much of that downtime can be eliminated.

Understanding SMED in Electronics Manufacturing

The foundation of setup reduction comes from SMED. The core principle is simple. First, separate setup activities into two categories:

- **Internal setup:** Tasks that can only be performed when the machine is stopped
- **External setup:** Tasks that can be completed while the machine is still running

The objective is to move as much work as possible from internal to external setup.

In an EMS environment, this distinction becomes extremely powerful. Material pulling, feeder preparation, tooling staging, program validation, and setup verification can often be

completed before the previous production run finishes. Many facilities, however, perform these activities only after the line has stopped. Every minute spent searching for components or loading feeders while a machine sits idle represents lost revenue-generating capacity.

Historically, EMS providers could rely on long production runs to absorb setup costs. That assumption is becoming outdated as customers increasingly demand smaller batch sizes, faster delivery, more product variants, frequent engineering changes, and greater responsiveness. Manufacturers, consequently, may perform several changeovers during a single shift.

That's where the challenge lies. In a high-volume environment, setup represents a small percentage of available production time. In a high-mix environment, setup can become one of the most significant causes of lost capacity. Suddenly, changeovers start to eat away at operating margins, and this changes the calculus for improving processes.

For example, a manufacturer that reduces placement cycle time by 5% may see modest gains. But a manufacturer that cuts setup time by 50% may unlock hours of additional production capacity every day.

Where Most Setup Time Is Lost

The largest contributors to downtime are rarely machine related. Instead, the most significant losses usually occur in four areas:

1. **Feeder and material preparation:** This is often the largest source of delay. Operators may spend valuable time searching for components, verifying part numbers, loading reels into feeders, resolving shortages, and correcting material discrepancies. Because these tasks are frequently performed only after production stops, they directly extend downtime.
2. **Changeover execution:** Each feeder movement consumes time and increases the risk of error. Yet, many facilities still replace feeders individually rather than utilizing preconfigured feeder carts or modular setup systems.
3. **Setup verification:** Manual verification processes often create bottlenecks. Incorrect feeder assignments, outdated setup sheets, and program mismatches can generate rework and delay production release.
4. **First article approval:** Engineering reviews, inspection delays, and process corrections frequently extend changeover duration beyond the physical setup itself. While these challenges are common across the industry, they can be improved.

> **"The organizations achieving the strongest results are those that view setup time reduction as a strategic initiative rather than a tactical project."**

The Most Effective Improvement Strategies

Consistent with the 80/20 rule, organizations pursuing setup reduction initiatives often discover that a relatively small number of improvements generate most results.

Offline feeder preparation: One of the most impactful changes is moving feeder preparation away from the production line. Instead of building feeder setups after a machine stops, dedicated setup personnel prepare feeder carts while production continues. When the current job finishes, the new setup is already waiting. This single improvement can dramatically reduce downtime while improving setup consistency.

Standardized feeder cart systems: World-class EMS providers increasingly use feeder carts that can be exchanged as complete assemblies. Rather than replacing dozens of individual feeders, operators swap entire carts in minutes, and the resulting reduction in setup time can be substantial. Furthermore, standardized feeder positions reduce operator variability and simplify training.

Barcode and MES verification: Digital verification systems eliminate many of the errors associated with manual setup validation. Digital solutions can be as simple as barcode scanners, or as sophisticated as a robotic inventory management system. No matter the specific solution, scanning work orders, feeders, reels, and machine locations, manufacturers can automatically verify:

- Correct components
- Correct feeder assignments
- Correct machine positions
- Correct lot traceability

This not only reduces setup time but also improves quality and compliance.

Parallel setup activities: Many changeovers are performed sequentially when they could be executed simultaneously. A more effective approach assigns responsibilities across multiple personnel. This particular optimization step can be facility- and staff-dependent, however, a typical set of assignments may include:

- Material handlers staging components
- Technicians validating programs
- Operators preparing machine tooling
- Setup specialists preparing feeder carts

The key metric for parallel execution is to reduce elapsed time without necessarily increasing labor requirements.

The Impact on OEE and Capacity

One of the most compelling aspects of setup reduction is its direct impact on capacity.

Imagine an SMT line performing four changeovers per day at 100 minutes per changeover. That equals 400 minutes of downtime daily. If a SMED initiative reduces changeovers to 25 minutes, downtime falls to 100 minutes, and the organization recovers 300 minutes of productive capacity every day. In many facilities, this additional capacity can eliminate the need for overtime, postpone capital equipment purchases, or create room for new customer programs.

Unlike many capital investments, setup optimization often requires relatively modest expenditure while generating significant returns.

Beyond Productivity: Strategic Benefits

The advantages of setup optimization extend well beyond efficiency metrics. In an era where responsiveness increasingly influences supplier selection, these capabilities create meaningful competitive advantages. Faster changeovers enable greater production flexibility. Manufacturers can accommodate smaller lot sizes without sacrificing profitability. Customer lead times can be reduced, and schedule changes become easier to absorb. Engineering change orders can be implemented more rapidly. Moreover, standardized setup processes improve training effectiveness and reduce dependence on tribal knowledge.

As experienced operators retire and labor shortages persist, process consistency becomes increasingly valuable.

The Future of EMS Setup Optimization

Emerging technologies will continue to transform setup management. New packages, new solder formulations, and the ever-increasing customer demand for higher reliability while simultaneously designing more densely will only increase the complexity of setup.

The greatest improvements still come from applying Lean principles to eliminate non-value-added activities and redesigning workflows around efficiency. The organizations achieving the strongest results are those that view setup time reduction as a strategic initiative rather than a tactical project.

Advanced MES platforms, feeder intelligence systems, digital work instructions, automated material handling, and predictive scheduling tools are already helping manufacturers reduce setup complexity, but technology alone is not the answer. The more we develop technology and automation, the more we need human insight to make it work at its best. **SMT007**

BY GLOBAL ELECTRONICS ASSOCIATION

IPC Standards Released for Q2 2026

Each quarter, the Global Electronics Association releases a list of standards that are new or have been updated. To view a complete list of newly-published standards and standards revisions, translations, proposed standards for ballot, final drafts for industry review, working drafts, and project approvals, visit www.electronics.org/ipc-standards.

These are the latest releases for Q2 2026.

IPC-1401B, *Environmental, Social Governance (ESG) Management System Standard*

IPC-4101B specifies the requirements and best practice guidelines for an effective environmental, social, and governance (ESG) management system to help an enterprise integrate ESG as a customer requirement into products and value chain activities, as well as to identify and manage ESG risks and opportunities through cooperation with customers and suppliers, so as to enhance the competitive advantages of the enterprise and its supply chain.

IPC-2223F, *Sectional Design Standard for Flexible/Rigid-Flexible Printed Boards*

IPC-2223F establishes the specific requirements for the design of flexible and rigid-flexible printed board applications and their forms of component mounting and interconnecting structures. The flexible materials used in the structures are comprised of insulating films, reinforced and/or non-reinforced, dielectric in combination with metallic materials. These interconnecting boards may contain single, double, multilayer, or multiple conductive layers and can be wholly flex, or a combination of flex and rigid.

IPC-4202C, Specification for Flexible Base Dielectrics for use in Flexible Printed Boards

The IPC-4202C standard establishes the classification system, qualification, and quality conformance requirements for flexible metal-clad dielectric materials to be used for the fabrication of flexible printed boards. The purpose of IPC-4202C is to classify and characterize base materials for use in flex and rigid-flex boards for electronic applications. It is to be used for procurement and quality assurance activities.

IPC-6921, *Requirements and Acceptance for Organic IC Substrates*

IPC-6921 establishes and defines the qualification, performance requirements, and acceptance requirements for organic IC substrates, including wire bonding and flip-chip IC substrate products. The purpose of IPC-6921 is to provide requirements for the qualification and performance of rigid organic substrates based on the following constructions and/or technologies. These requirements apply to the finished products unless otherwise specified:

- Double-sided organic IC substrates with or without plated through-holes (PTHs)
- Multilayer organic IC substrates with or without PTHs or buried/blind vias/microvias
- Passive embedded circuitry on organic IC substrates with capacitive planes or resistive planes

IPC-9711, *Generic Requirements for Automated Inspection Process Control*

IPC-9711 provides generic requirements for automated inspection systems to define, set up, establish, and apply process controls. Requirements include inspection parameters, calibration, detectability, resolution, threshold limits, and program setups, measurement system analysis (MSA), maintenance, and verification protocols. The standard establishes generic requirements applicable to automated inspection systems and is intended to be used in conjunction with product/process-specific standards of the IPC-971X series.

IPC-9712, *Requirements for Automated Inspection Process Control for IC Substrates*

The IPC-9712 standard provides requirements for automated inspection systems—automated optical inspection (AOI), automated visual inspection (AVI), and metrology—to define, set up, establish, and apply process control for manufacturing integrated chip substrates, including general and specific process and equipment conditions. Requirements include those for operating and inspection parameters, vision systems, lighting conditions, calibration, detectability, resolution, threshold limits, process windows, program setups, measurement system analysis (MSA), maintenance, and verification protocols, in addition to the generic requirements of IPC-9711.

IPC-9716A, *Requirements for Automated Inspection Process Control for Printed Board Assembly Processes*

IPC-9716A provides specific requirements for automated inspection for printed board assembly processes in addition to the generic requirements of IPC-9711. Requirements are based on the use of inspection systems such as solder paste inspection (SPI), automatic optical inspection (AOI), and automatic X-ray inspection (AXI).

The purpose of IPC-9716A is to set industry-defined requirements for inspection systems to reduce false calls, ensuring quality and reliability while improving throughput and shortening cycle times. This standard also supports electronics manufacturers to enable advanced manufacturing, real-time data analytics, and control capabilities. **SMT007**

BY NOLAN JOHNSON, I-CONNECT007

A Roadmap to Faster SMT Changeovers

The top-performing EMS providers—Jabil, Flex, Sanmina, Benchmark, Zollner, and Asteelflash—consistently focus on a foundational Lean manufacturing methodology known as SMED (single-minute exchange of die) to reduce equipment setup and changeover times to under 10 minutes. The four SMED pillars:

1. Offline feeder preparation
2. Feeder cart exchange systems
3. Barcode/MES verification
4. Dedicated setup technicians

These four changes alone typically deliver 60–80% of total achievable setup time reduction before more advanced automation is even considered. The biggest opportunity in EMS setup reduction is transforming setup from a machine-centered activity into a logistics-centered process where materials, feeders, programs, and tooling arrive at the line fully validated before the previous job ends. This shifts the setup from reactive execution to planned exchange, which is the essence of SMED.

How does a smaller EMS company develop a SMED profile similar to the big guys? Let's explore some specific ways to reduce changeover time.

Reducing SMT Changeovers From 60–120 to 15–40 Minutes

This example roadmap is based on a hypothetical high-mix EMS operation running multiple SMT lines with frequent product changeovers. Beginning with a rather typical baseline for changeovers, let's outline how a six-phase, six-month optimization process, following SMED, might roll out.

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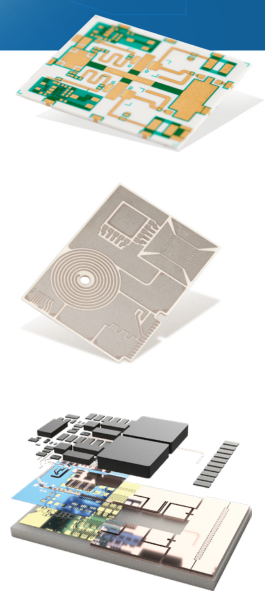

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Table 1: Typical changeover timeline

ACTIVITY	DURATION (IN MINUTES)
Wait for production completion	5
Search for feeders/ components	10
Pull and verify material	15
Load feeders	20
Remove old setup	10
Install new feeders	15
Load programs	5
Verify setup	10
First article corrections	15
Total	**105**

Common places for changeover improvements uncovered in this phase often include:

- Operators waiting for material to arrive
- Feeders built only after the machine stops
- Setup sheets printed manually
- Wrong reels discovered at machine
- Feeder slot changes every job
- First article failures
- Setup performance varies by operator

The effect on overall equipment effectiveness (OEE) can be staggering. For one line running four changeovers per day, that amounts to 420 minutes (seven hours). In a two-shift 16-hour operation, that line is unavailable 44% of the day. In a $10 million business, 44% downtime equates to $4.4 million in lost potential revenue.

Phase 1: Baseline and Measure

The first objective is to understand exactly where time is being lost. Spend about two weeks video recording 20–30 changeovers. Categorize every minute of each changeover into either internal or external setups.

- **Internal setup (machine stopped):** Internal setup might include feeder installation, program loading, and verification steps
- **External setup (machine still running):** Some examples might include material pulling, feeder loading, and cart preparation

After all the videos have been analyzed and broken down into categorized tasks, create a Pareto chart of all the activities.

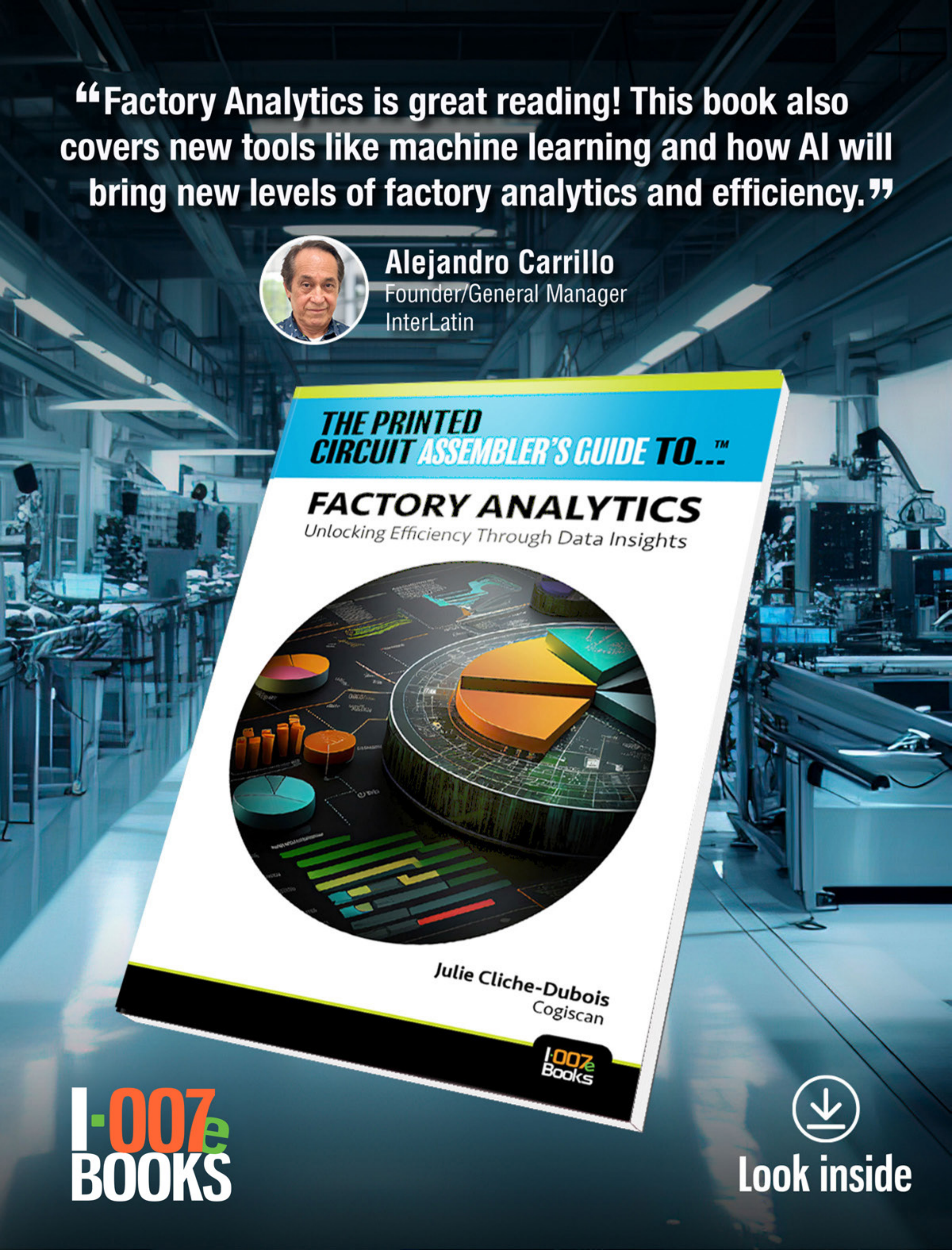
Table 2: Typical findings in setup (your specific values may vary)

ACTIVITY	% OF SETUP TIME
Feeder preparation	35%
Material search	20%
Verification	15%
Program issues	10%
Mechanical setup	10%
Other	10%

Phase 2: Convert Internal to External

For the next three weeks, the focus is to move as much work as possible into an offline process. Previously, the machine would run the job to completion before the operator started pulling old reels, building new feeder configurations, and locating the needed tooling. Now, the goal is to restructure so that, while the previous job is still running, operators:

- Stage material
- Load feeders
- Validate programs
- Prepare stencils
- Get the cart ready



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Ideally, everything for the next job is on hand when the machine stops. The only delay occurs for a physical swap between jobs. This change in process may require creating a dedicated preparation cell on the shop floor for feeder loading, material verification, and cart staging.

Based on expert opinion, a preparation cell can shorten the changeover time by about 33% or, in this example, from 105 to 70 minutes. That amounts to saving $1.45 million. Not bad for a three-week analysis.

Phase 3: Feeder Cart Standardization

Over the next two months, the next steps are to eliminate individual feeder handling. If the operators are still swapping feeders one at a time on an idle machine, that can take 20 minutes (±5 minutes) for a job needing 80 feeders, at an average of 15 seconds per feeder to swap.

By setting up a cart with all the feeders ahead of time, the operator can swap the entire feeder cart at the machine in 3–5 minutes. That represents a 14% time savings, or a bit more than $700,000.

Astute readers will be pointing out (correctly) that the cart still needs to be loaded with feeders; that is not a zero-time activity now. Process optimization means keeping the line running as close to 100% as possible. While it may be an equivalent activity with respect to labor charges, removing 15 minutes per cart from the changeover time brings significant revenue that can be considered entirely margin: more capacity for the same price.

At this point, you're down to 50 minutes per changeover.

Standardization Rules

Assign Cart A to High-run products and Cart B to Medium-run products. Then use a Universal Cart for Mixed production.

Table 3: Example of a slot strategy

SLOT	COMPONENT
F1	10k resistor
F2	100nF capacitor
F3	1k resistor
F4	10uF capacitor

Use a slot strategy in which carts store common components in a fixed location. Figure 3 gives an example.

Phase 4: Barcode and Digital Verification

Our next objective is to spend two months removing setup mistakes. At the completion of this phase, we will have spent approximately four months on this initiative. At the start of this phase, operators are visually inspecting reels, feeders, and slots. This process can be error prone. Familiarity can breed complacency, as well. Once an operator has looked at, touched, and loaded 80 feeders, they are inclined to believe they'd have caught any errors already.

What is needed is a single-check procedure in which automation handles verification. This is exactly the sort of function that compute power is good for.

With a new scanning system (presumably barcode), operators scan the work order, reel, feeder, and slot. The system confirms the component is correct, is from the correct lot, loaded into the correct feeder, and in the correct position. Not only does this help reduce redundant checks, but it also reduces setup time. In this case, the estimate is 10 minutes out of the original 105 minutes, about 9%, amounting to about $400,000.

After Phase 4, setup times are now in the 40-minute range, resulting in an annual capacity increase of a bit more than $2.5 million.

Phase 5: Parallel Setup Teams

For process improvement folks, the highly linear nature of traditional setup processes has obvious limitations. Not only should as many things be done externally as possible, but as many things as possible should be done in parallel. This brings us, in Phase 5, to the consideration of elapsed setup time. Traditionally, one operator performs each setup step in sequence:

1. Material
2. Machine
3. Tooling
4. Verification

But once these activities have been moved into their own work cell, as they were in Phase 2, sequence is not as crucial as before. Reorganizing roles to create specialists for a specific part of the setup process means that each specialist can prepare multiple jobs ahead of time. It's a bit of Henry Ford's assembly line thinking applied to the EMS environment. For example, a team might be assembled as:

TEAM MEMBER	RESPONSIBILITY
Operator A	Machine prep
Operator B	Feeder carts
Material Handler	Component staging
Technician	Program verification

This creates a parallel workflow even if each individual job must be run in a specific sequence. Each team member is working on one of the jobs in the queue; up to four jobs are being prepared simultaneously under this structure.

In this example, two months are set aside for a deep dive into creating and training parallel workflows. A typical performance gain might be 10 minutes, representing about 9% of the original 105 minutes, and bringing the optimized setup time after five phases down to 30 minutes, which translates to about $400,000 in annualized additional capacity.

Phase 6: First Article Optimization

Finally, spend about two months tackling engineering bottlenecks. If your first article process looks like this:

1. Build first board
2. Wait
3. Engineer arrives
4. Inspection begins
5. Corrections made

Then it's time to shake up the first article procedures. While this hurry-up-and-wait methodology only costs about 15 minutes of time, to optimize, move as much as possible into a pre-verification methodology of program simulation, feeder validation, and AOI recipe verification.

Ultimately, evolve your physical first article acceptance process into a digital first article checklist, and first article moves from 15 to five minutes. The return on investment here is about 4%, representing approximately $175,000 in added capacity.

Setup's New Normal

Every EMS company is its own unique microcosm. You might find your specific optimization results to be different, or perhaps you identify other optimizations not mentioned here in this example. Still, using the reasonable estimations in the six phases, the newly optimized setup flow looks like Table 4.

Table 4: Typical changeover timeline

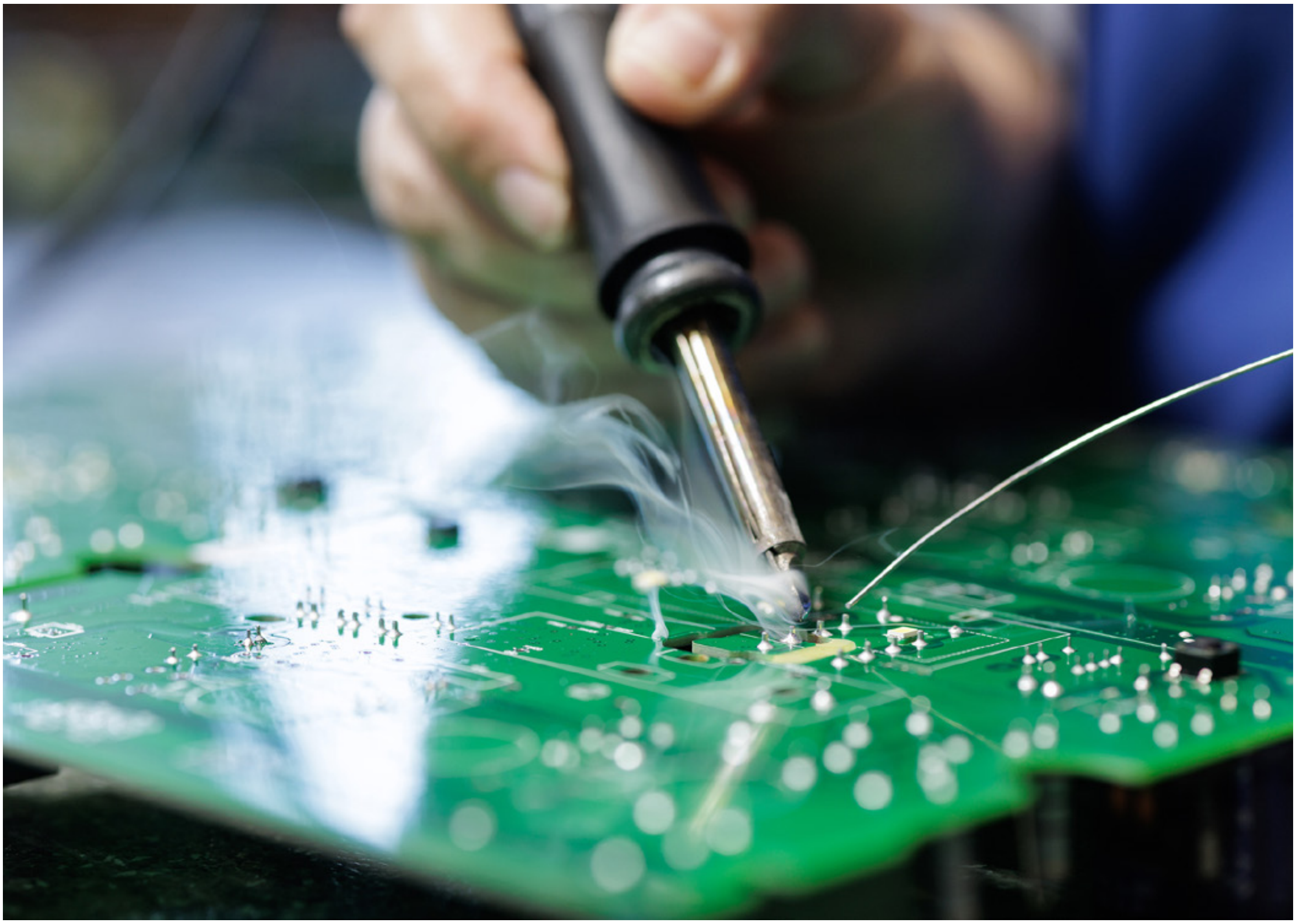
ACTIVITY	DURATION (IN MINUTES)
Cart swap	5
Program load	2
Validation scan	3
Tooling change	5
First article	5
Buffer	5
Total	**25**

The Net Return

By recovering 320 minutes per day for use in revenue generation, this EMS company likely added more customers without requiring additional capital outlay. Perhaps this extra capacity allowed for equipment upgrades and/or employee compensation that extend capabilities and improve experienced employee retention.

Of course, every company is unique. Your specific challenges may be somewhat different than this hypothetical example. Nevertheless, using this thought experiment as inspiration, chances are good you can find new areas for improvement. After all, even the top EMS companies are still optimizing. That's why it's called "continuous improvement." **SMT007**

BY LEO LAMBERT, EPTAC



Answering the Most Recurring Questions *on Soldering*

This article analyzes a collection of recurring customer questions identified through technical support, training activity, and consulting engagements, and examines their relationship to assembly reliability, manufacturing process control, and overall operational performance.

Technical inquiries received from electronics manufacturers often reveal underlying challenges associated with standards interpretation, process control, and product reliability. While many questions concern specific soldering or inspection issues, they often expose broader reliability risks that affect manufacturing quality and long-term field performance. This discussion is framed within the requirements of IPC-A-610, IPC-J-STD-001, and IPC-7721 and supported by published reliability studies. The findings suggest that many manufacturing defects arise not from deficiencies in standards but from misunderstandings of the engineering intent behind those standards. Recommendations are provided for improving process control, training, and reliability assurance.

Introduction

The electronics manufacturing industry relies heavily on consensus standards to show workmanship requirements and product acceptance criteria. Standards such as IPC-A-610 and J-STD-001 provide

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> **"The word 'solder' is very confusing to many people. It is used as a noun, an adjective, and a verb, and they can all be included in one sentence: Solder is used for soldering solder joints."**

a common framework for manufacturing, inspection, and quality assurance of electronic assemblies designed by the IPC documentation. However, the interpretation of these requirements often generates questions from engineers, operators, inspectors, and quality personnel.

Many customer inquiries concern simple issues such as the requirements or the allowance for toe fillets, rework limitations, or plated through-hole dimensions. Yet these questions often expose deeper concerns involving reliability, process capability, and design-for-manufacturing considerations. As electronic assemblies become more complex and component dimensions shrink, understanding the engineering basis of these requirements becomes increasingly important.

Electronic clearances consist of a mixture of different elements, such as component lead materials, various laminate materials, manufactured stress relief, flux composition and selection, clearance, and entrapment areas impacting cleaning efficiency, cleaning processes, defining contaminants and their impact on the functional product, component mass weight and size impacting thermal profiles, lead trimmings, etc. Each of these example items is brought to a soldering process with the expectation that the mass solder process will create acceptable, reliable solder joints for all these components and joint configurations.

Electronics assembly reliability is influenced by a variety of interacting variables, including product design, component materials, thermal profiles, mechanical stress, and workmanship quality, and soldering processes, to name a few.[1]

According to IPC-A-610, acceptability criteria are intended to ensure adequate electrical and mechanical performance while recognizing normal process variation.[1] Similarly, IPC-J-STD-001 defines the process requirements designed to achieve reliable soldered interconnections.[2]

Research by Maxwell[3] demonstrated that multilayer ceramic capacitors are particularly susceptible to thermal and mechanical stress during assembly operations. Excessive thermal gradients and board flexure can initiate cracks that later develop into field failures.

Studies of plated finishes have also shown that excessive gold thickness can contribute to solder joint embrittlement by forming brittle intermetallic compounds within the solder matrix.[4]

Different lead materials and the configuration of the leads impact stress relief of the resultant solder joints, and this must be considered in the design phase when selecting components and understanding the need to properly characterize the base lead materials that will be soldered.

These findings support the importance of understanding not only what the standards require but also why those requirements exist.

Here are examples of conditions that are or should be addressed by manufacturing engineers when preparing to submit the assemblies for the manual, semi-automatic, or automatic soldering process.

Many of these component lead materials are intentionally hardened to achieve specific thermal expansion characteristics or mechanical properties. The reduced ductility of hardened materials increases their susceptibility to cracking during forming or clinching operations. Manufacturing procedures must therefore account for the mechanical characteristics of the lead material to prevent reliability and quality issues during the product lifecycle.

Questions have arisen regarding the meaning of the term "tempered component leads," as these leads are much harder and stiffer than copper leads and should not be clinched during manufacturing. Component lead materials may include the following:


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- Copper alloys
- Kovar: Nickel/iron and cobalt alloy
- Alloy 42: Nickel (42%) and iron (58%)
- Alloy 52: Nickel (52%) and iron (48%)
- Phosphor bronze: Copper alloy containing tin/phosphorus
- Beryllium copper: Copper with beryllium alloys

Gold Coatings

Understanding and distinguishing between gold flash and gold electroplate when evaluating compliance with J-STD-001 gold removal requirements is important for addressing gold intermetallic conditions. The concern with excessive gold thickness is the formation of brittle gold-tin intermetallic compounds, reducing solder joint ductility and reliability.[5] Historically, connector contacts are plated with gold thicknesses ranging from 50–100 µins. However, increasing precious metal costs resulted in widespread adoption of thinner deposits commonly referred to as gold flash. Gold flash thickness is typically below 10 µins, whereas functional gold plating typically exceeds 25 µins.[4] Consequently, manufacturers should obtain plating thickness data directly from component manufacturers and suppliers to minimize or eliminate gold embrittlement conditions rather than relying solely on descriptive terminology.

Toe Fillets

One common inspection-related question is whether a visible toe fillet is required for gull-wing solder joints. IPC-A-610 establishes requirements for side joint length, heel fillet height, end joint width, and solder thickness. There is no minimum requirement for toe fillet.[1] If the toe of the lead does not violate the minimum electrical clearance requirement, it is acceptable. The confusion arises because illustrations depict solder extending to the toe of the lead. From a structural perspective, the primary load-bearing region of the solder joint is the heel fillet, not the toe fillet. Therefore, the absence of a visible toe fillet does not impact solder joint reliability.

However, IPC specifically states that written requirements take precedence over illustrations.

Soldering all these dissimilar materials is a general process that raises the recurring question of whether Class 3 products may be reworked. Does IPC-J-STD-001 explicitly permit rework provided that the assembly is restored to full compliance with applicable requirements?[2] Yes, rework is allowed, but the defect must be dispositioned and documented as not meeting the requirements of the contract and/or the specification. For Class 3 products, the repair process must be defined, documented, and approved by the regulating agency, and the acceptable conditions must be approved by the customer. The IPC standards recognize that manufacturing defects can occur and provide mechanisms for restoring compliance without compromising reliability.

These provisions demonstrate that reliability depends on process control and verification rather than an absolute prohibition of corrective actions.

Solder Joint: Metallurgical Evaluation of the Solder Joints

Microsection analysis remains one of the most valuable tools for evaluating soldering process quality, whether for process qualification or continuous monitoring of either raw boards or the final process. The testing would consist of assessment of solder wetting, verification of plated through-hole fill, evaluation of intermetallic layer formation, or, on raw boards, the detection of voids and barrel cracks.

Optical microscopy at magnifications between 200x and 300x is sufficient for evaluating solder joint quality. More detailed metallurgical investigations may require scanning electron microscopy (SEM). Microsection analysis provides direct evidence of process performance and is particularly valuable when confirming soldering profiles or investigating field failures.

Flux

Flux is used to prepare surfaces for soldering. It is acidic in nature, and its function is to remove the metallic oxides present on the metallic surfaces to be soldered. This is why the discussion of the various alloys was pertinent for highlighting the unique variability of different metals that will be soldered in a single process. Fluxes must be qualified for the soldering process to determine their impact on the materials being soldered, as well as on the laminate and solder mask materials previously applied to the raw boards. IPC-J-STD-004 is used to develop the qualification program for selecting the proper flux material. Proper flux penetration is essential to achieving complete wetting within plated through-holes, as insufficient flux penetration will prevent the solder from adequately wetting barrel surfaces, resulting in incomplete hole-fill and reduced mechanical strength.

Process verification methods for verifying flux penetration include glass plate testing, absorbent paper penetration testing, and microsection evaluation. The effectiveness of flux application is particularly critical for high-reliability products where through-hole integrity contributes directly to long-term performance.

Capacitor Cracking and Reliability

Failure analysis studies consistently identify multilayer ceramic capacitors (MLCCs) as a major source of assembly failures.[3]

Mechanical Cracking

Mechanical cracks can and will occur from stresses applied from PCB flexure, improper handling, excessive placement forces, or design-induced fabrication. These cracks may initially remain undetected but can propagate over time, allowing moisture penetration and eventual dielectric failure.

Thermal Cracking

Thermal cracks result from differential expansion between ceramic materials and metallic terminations.

Research by Maxwell[3] demonstrated that excessive heating rates and thermal shock significantly increase susceptibility to cracking. Wave soldering produces the highest thermal stress, while controlled reflow profiles produce lower thermal gradients. The results emphasize the importance of profile development and process validation for reliability-critical assemblies.

Conclusions

The customer inquiries analyzed in this study reveal several recurring themes:

- Misinterpretation of visual illustrations
- Incomplete understanding of reliability mechanisms
- Insufficient knowledge of material properties
- Lack of process verification data
- Inadequate linkage between standards requirements and engineering intent

These observations suggest that technical training should focus not only on acceptance criteria but also on the underlying reliability principles that drive those criteria. Organizations that integrate standards knowledge with materials science and reliability engineering are more likely to achieve consistent manufacturing outcomes.

Hence, the customer questions reviewed here provide valuable insight into the usual challenges facing electronics manufacturers.

The analysis demonstrates that many manufacturing concerns stem not from deficiencies within IPC standards but from misunderstandings regarding their application and intent. Topics such as gold plating, toe fillets, rework practices, microsectioning, flux penetration, lead materials, and capacitor cracking all illustrate the importance of linking standards requirements to reliability objectives.

Future efforts should emphasize education, process validation, and continuous improvement to ensure that manufacturing personnel understand both the requirements and the engineering principles behind them. **SMT007**

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Leo Lambert is the VP/technical director at EPTAC Corporation, and an I-Connect007 columnist. To read past columns, click here.

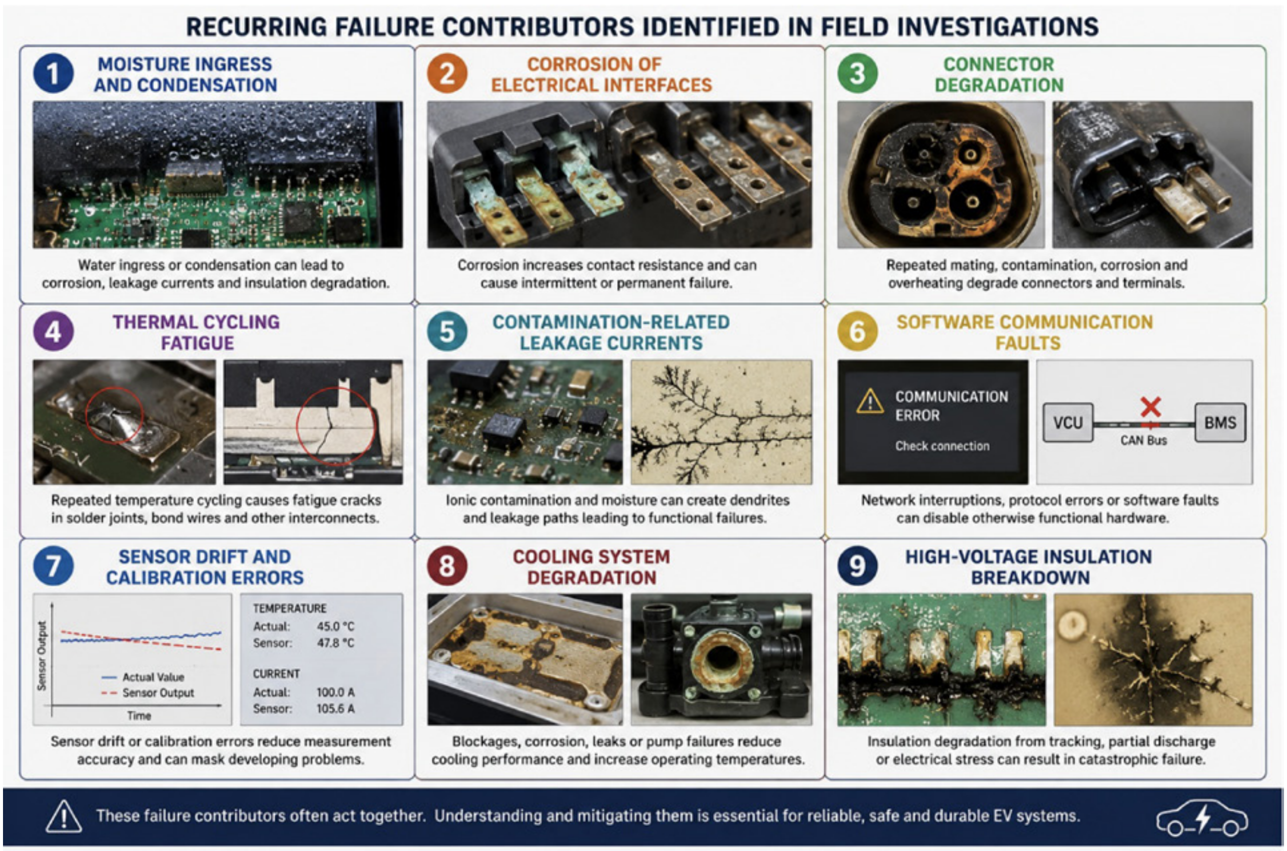
BY STANTON RAK, SF RAK COMPANY

Failures, Monitoring, and Standards on the Path to EV Reliability

Throughout this series, we have examined the technologies, materials, architectures, and environmental challenges that influence the reliability of EV electronics. Yet reliability is ultimately judged in only one place: the field. Customers do not experience qualification reports, design reviews, or accelerated test results. They experience vehicles that either perform as expected or do not.

As EV adoption expands globally, the industry has accumulated a growing body of field experience. These lessons reveal both the strengths of current designs and the areas where improvement remains necessary. They also reinforce an enduring reality of electronics engineering that failures are often the result of multiple contributing factors rather than a single root cause. Design decisions, manufacturing variation, environmental exposure, software behavior, and operational stresses can interact over time to produce outcomes that were not fully anticipated during development.[1,2]

The good news is that the industry is gaining access to tools, data, and standards that can help identify emerging issues before they become widespread field failures. The challenge is learning how to use them effectively.



What the Field Has Taught Us

Many of the most visible EV reliability events during the past decade have involved battery systems. While public attention frequently focuses on the battery cells themselves, investigations often reveal contributions from electronic controls, sensors, connectors, thermal management systems, contactors, and software.

Several major recalls have highlighted the importance of system-level reliability management. The Chevrolet Bolt EV battery recall demonstrated how manufacturing variation, when combined with specific operating conditions, can create conditions that lead to thermal events.[3] Hyundai and Kia conducted extensive recall campaigns involving battery systems and charging-related concerns.[4] Jaguar's I-PACE experienced battery-related recalls and software updates intended to reduce risk while long-term corrective actions were developed.[5]

These examples should not be interpreted as evidence that EV technology is inherently unreliable. Rather, they demonstrate that reliability is a system property. Individual components may meet their requirements while interactions between components create unexpected outcomes. Similar lessons have been observed throughout the history of aerospace, telecommunications, industrial automation, and conventional automotive electronics.[6]

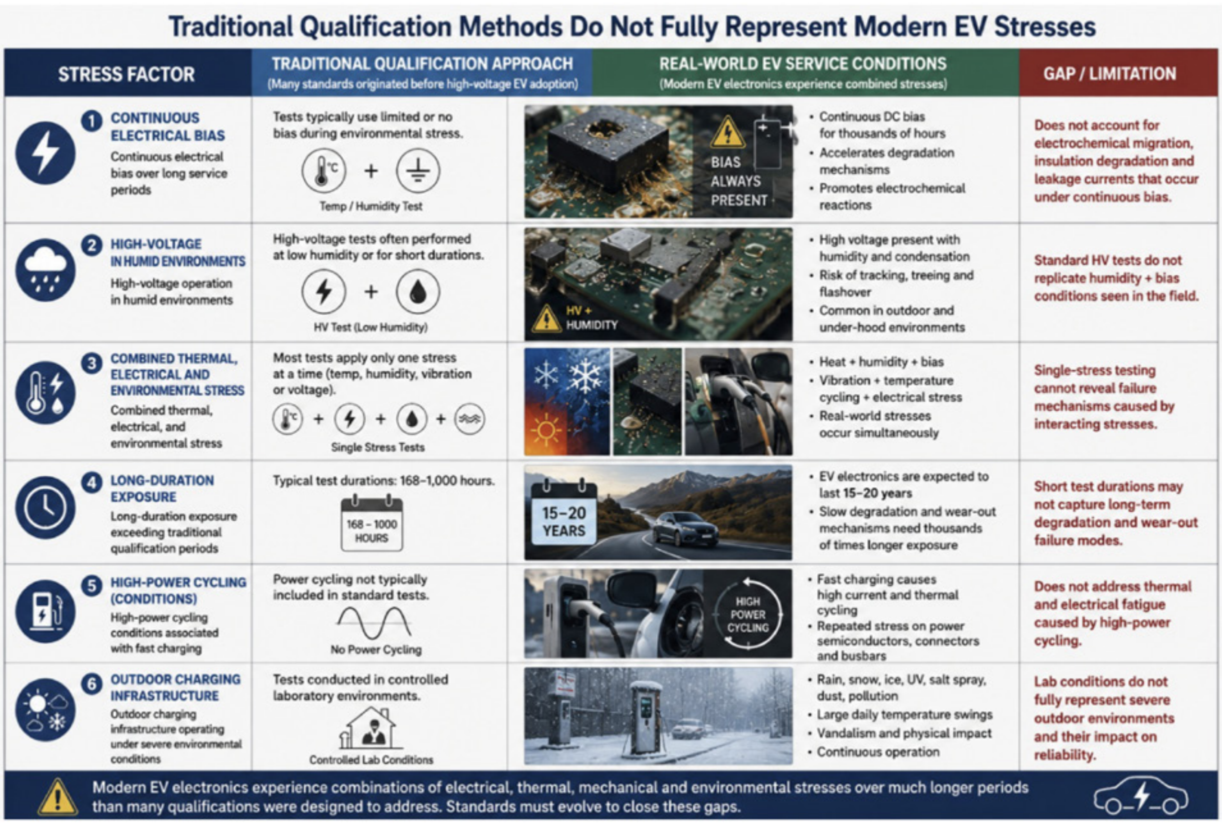
Field investigations also identify recurring failure contributors that are familiar to reliability engineers:

- Moisture ingress and condensation
- Corrosion of electrical interfaces
- Connector degradation
- Thermal cycling fatigue
- Contamination-related leakage currents
- Software communication faults
- Sensor drift and calibration errors
- Cooling system degradation
- High-voltage insulation breakdown

Many of these failure mechanisms develop gradually and may remain undetected for extended periods before producing observable symptoms.[7-12]

The Rise of Predictive Maintenance

Historically, maintenance occurred after a failure was observed. EV architectures are increasingly adopting predictive approaches to identify degradation before functional failure occurs. Battery management systems already monitor voltage,


Traditional Qualification Methods Do Not Fully Represent Modern EV Stresses

STRESS FACTOR	TRADITIONAL QUALIFICATION APPROACH (Many standards originated before high-voltage EV adoption)	REAL-WORLD EV SERVICE CONDITIONS (Modern EV electronics experience combined stresses)	GAP / LIMITATION
1 CONTINUOUS ELECTRICAL BIAS Continuous electrical bias over long service periods	Tests typically use limited or no bias during environmental stress. Temp / Humidity Test	BIAS ALWAYS PRESENT • Continuous DC bias for thousands of hours • Accelerates degradation mechanisms • Promotes electrochemical reactions	Does not account for electrochemical migration, insulation degradation and leakage currents that occur under continuous bias.
2 HIGH-VOLTAGE IN HUMID ENVIRONMENTS High-voltage operation in humid environments	High-voltage tests often performed at low humidity or for short durations. HV Test (Low Humidity)	HV + HUMIDITY • High voltage present with humidity and condensation • Risk of tracking, treeing and flashover • Common in outdoor and under-hood environments	Standard HV tests do not replicate humidity + bias conditions seen in the field.
3 COMBINED THERMAL, ELECTRICAL AND ENVIRONMENTAL STRESS Combined thermal, electrical, and environmental stress	Most tests apply only one stress at a time (temp, humidity, vibration or voltage). Single Stress Tests	• Heat + humidity + bias • Vibration + temperature cycling + electrical stress • Real-world stresses occur simultaneously	Single-stress testing cannot reveal failure mechanisms caused by interacting stresses.
4 LONG-DURATION EXPOSURE Long-duration exposure exceeding traditional qualification periods	Typical test durations: 168–1,000 hours. 168 – 1000 HOURS	15–20 YEARS • EV electronics are expected to last 15–20 years • Slow degradation and wear-out mechanisms need thousands of times longer exposure	Short test durations may not capture long-term degradation and wear-out failure modes.
5 HIGH-POWER CYCLING (CONDITIONS) High-power cycling conditions associated with fast charging	Power cycling not typically included in standard tests. No Power Cycling	HIGH POWER CYCLING • Fast charging causes high current and thermal cycling • Repeated stress on power semiconductors, connectors and busbars	Does not address thermal and electrical fatigue caused by high-power cycling.
6 OUTDOOR CHARGING INFRASTRUCTURE Outdoor charging infrastructure operating under severe environmental conditions	Tests conducted in controlled laboratory environments. Controlled Lab Conditions	• Rain, snow, ice, UV, salt spray, dust, pollution • Large daily temperature swings • Vandalism and physical impact • Continuous operation	Lab conditions do not fully represent severe outdoor environments and their impact on reliability.

Modern EV electronics experience combinations of electrical, thermal, mechanical and environmental stresses over much longer periods than many qualifications were designed to address. Standards must evolve to close these gaps.

current, temperature, state of charge, and state of health. Advanced analytics now extend these capabilities by evaluating trends over time and identifying abnormal behavior patterns.[13-15]

Machine learning and cloud-connected diagnostic systems are becoming important tools in this effort. By analyzing fleet-level data, engineers can identify subtle changes that would be difficult to detect at the individual vehicle level. Changes in charging behavior, thermal performance, isolation resistance, contact resistance, or sensor output may provide early indicators of future problems.[14-16]

This approach offers several advantages:

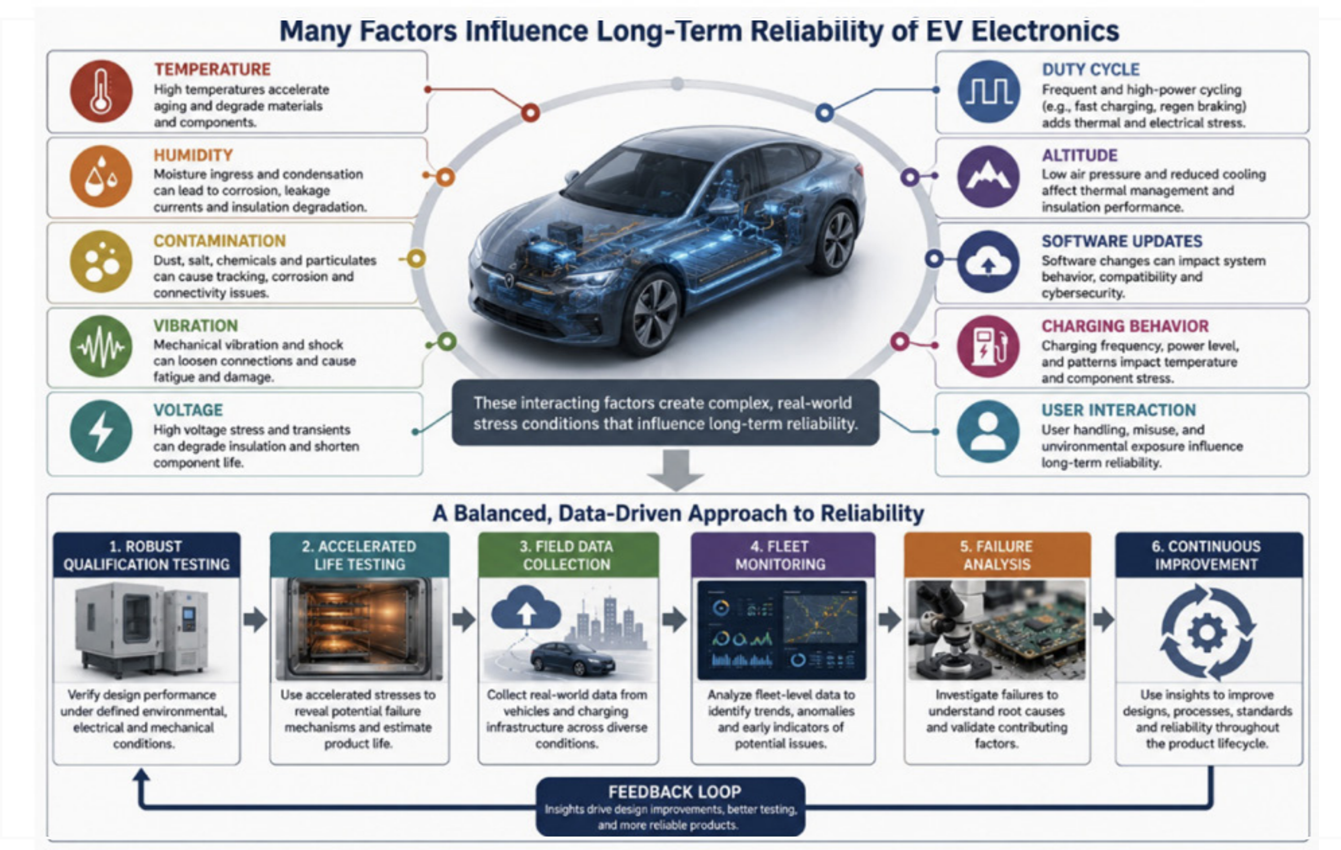
- Reduced unexpected downtime
- Improved warranty management
- Better service planning
- Earlier detection of emerging reliability concerns
- More efficient use of replacement parts
- Improved customer experience

Predictive maintenance does not eliminate failures. It provides an opportunity to intervene before degradation progresses to a level that affects vehicle operation.

Digital Monitoring Extends Beyond the Vehicle

Monitoring is not limited to onboard systems. Charging infrastructure increasingly employs remote diagnostics, cloud-based analytics, and network-level performance monitoring. Recent ChargerHelp reliability studies found that reported charger availability often differs significantly from actual charging success experienced by drivers[17-18] A charger may report itself as available while communications faults, connector damage, payment-system issues, or software errors prevent successful charging sessions.

This distinction highlights an important evolution in reliability thinking. Availability metrics remain valuable, but successful mission completion is often a better indicator of real-world performance. For the charging infrastructure, the mission is not simply to remain powered. The mission is to successfully initiate, sustain, and complete a charging session. The same principle applies to vehicle electronics. Reliability is not measured solely by component survival. It is measured by successful completion of the intended function under expected operating conditions.



Standards Continue to Evolve

As EV technology matures, standards need to keep up. Existing standards from organizations such as IPC, IEC, ISO, SAE, UL, and AEC provide important foundations for design, qualification, manufacturing, and validation.[19-24] Many of these standards originated before the widespread adoption of high-voltage EV architectures. As a result, some qualification methods do not fully represent the combined stresses experienced by modern EV electronics.

Examples include:

- Continuous electrical bias over long service periods
- High-voltage operation in humid environments
- Combined thermal, electrical, and environmental stress
- Long-duration exposure exceeding traditional qualification periods
- High-power cycling conditions associated with fast charging
- Outdoor charging infrastructure operating under severe environmental conditions

Recognizing these challenges, industry groups have begun developing new guidance and test methods that better reflect current operating conditions. High-voltage temperature-humidity-bias testing, insulation performance assessment, contamination control methodologies, and advanced power electronics qualification approaches are receiving increasing attention.[25,26] The objective is for qualification testing to replicate the stresses that products are likely to encounter during actual service.

Closing the Gap Between Qualification and Reality

One of the recurring themes throughout this series has been the difference between laboratory qualification and real-world operation. Laboratory testing remains essential. It provides repeatability, controlled conditions, and a basis for comparison. At the same time, field environments often introduce combinations of stressors that are difficult to reproduce completely in any single test. Temperature, humidity, contamination, vibration, voltage, duty cycle, altitude, software updates, charging behavior, and user interaction may all influence long-term reliability.[27,28]

This reality argues for a balanced approach that combines:

- Robust qualification testing
- Accelerated life testing
- Field data collection
- Fleet monitoring
- Failure analysis
- Continuous improvement processes

Organizations that successfully connect these activities create feedback loops that improve future designs and reduce field risk.

Lessons for the Road Ahead

The transition to electrified transportation is one of the largest engineering efforts in automotive history. Significant progress has already been achieved. Vehicle range is increasing, charging times are decreasing, and reliability is improving.

The lessons emerging from the field are clear: Reliability begins with sound materials selection. It depends on disciplined design practices. It requires robust manufacturing processes. It benefits from continuous monitoring. It improves through data-driven feedback. It is strengthened by standards that reflect real-world operating conditions.

Most importantly, reliability is an ongoing engineering discipline. Technologies, architectures, and operating environments will change. Engineers, manufacturers, suppliers, standards organizations, and vehicle producers all play a role in the road to reliability. The future of EV reliability will be determined not only by how vehicles are designed, but by how effectively the industry learns from experience and applies those lessons to the next generation of products. **SMT007**

Dr. Stanton Rak is principal consultant for SF Rak Company, and co-chair of the APEX EXPO Technical Program Committee.

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Rocket Lab Acquires Motiv Space Systems, Adding Mars-Proven Robotics Capabilities ▶

Motiv, now rebranded as Rocket Lab Robotics, brings mission-tested Mars heritage and is renowned for its advanced multi-degree-of-freedom robotic arms, actuators, and drive electronics that have enabled some of the most ambitious planetary exploration missions in history, including NASA's Mars Perseverance rover, the CADRE lunar rovers, and precision mechanisms supporting critical scientific instruments and spacecraft subsystems.

Lockheed Martin Delivers First Integrated Combat System Baseline for the U.S. Navy ▶

ICS-enabled baselines combine heritage combat system capability with modern infrastructure, driving rapid proliferation of capability through a singular development effort at scale.

BAE Systems Delivers Next-Generation Flight Hardware for U.S. Space Force Missile Warning Program ▶

BAE Systems has delivered the sensor subassembly and sensor system controller components for the Next Generation Overhead Persistent Infrared Polar (NGP) program. The program will provide the U.S. Space Force with advanced missile warning, technical intelligence, and battlespace characterization mission capabilities.

NASA's INCUS Mission on Road to Launch, Study Storms From Space ▶

Teams working on NASA's INCUS (Investigation of Convective Updrafts) mission, the first space-based survey of the dynamics of tropical convective storms, have completed assembly and tested two of the mission's small satellites, or SmallSats. Testing continues on the third SmallSat and is scheduled for completion no earlier than September in advance of a 2027 launch.

Northrop Grumman to Demonstrate Space-Based Interceptor Capabilities with Apex for U.S. Space Force ▶

Northrop Grumman Corporation announced one of its industry collaborators, Apex, will support Northrop Grumman's leading role in the Nation's historic drive to make space-based interceptors (SBI) a reality by the end of the decade.

Boeing Validates MQ-28 Stealth Performance ▶

The MQ-28 Ghost Bat is designed to complement existing crewed aircraft by performing a variety of roles, including surveillance, electronic warfare, and force multiplication, all while maintaining a low radar profile. This milestone further demonstrates the platform's maturity, survivability, and ability to deliver cost-effective advanced capability for modern air combat operations.

Webinar Review: Europe Moving to Strengthen Defence Industrial Base ▶

Europe is seeking to establish a more sovereign, coordinated, and resilient defence industrial base. Electronics manufacturers and PCB-related companies will have an opportunity to apply for funding through the program to support specific defence systems by supplying critical enabling components.

Teledyne Space Imaging Sensors Launch Aboard European Space Agency's SMILE Mission ▶

Teledyne Space Imaging supplied two CCD370 imaging sensors for the Soft X-ray Imager on the European Space Agency's SMILE mission (Solar wind Magnetosphere Ionosphere Link Explorer). SMILE is a scientific collaboration designed to advance understanding of space weather and the interaction between the Sun and Earth.

Intuitive Machines Expands Integrated Space-to-Ground Network with Goonhilly Acquisition ▶

Supporting long-term lunar operations requires a resilient, secure space network that keeps missions connected in real time and provides access to ultra-low-latency communications, navigation and timing, and mission data.


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BY ROB RONAN, RETRONIX

Keeping *Electronic Component Recovery and Reuse* Closer to Home

Over the past several years, electronics manufacturers have been forced to rethink what supply chain resilience really means. Shortages, extended lead times, allocation pressures, obsolescence, and price volatility have exposed the limits of a procurement strategy built on the assumption that new components will always be available when needed. However, even when parts can be sourced, they may come with unacceptable lead times, inflated spot-market pricing, or concerns around authenticity and traceability.

Component recovery and reuse are no longer viewed simply as a last-resort option for obsolete or hard-to-find parts. They are part of a broader supply chain strategy focused on control and unlocking value from assets that companies already own.

Rethinking What Resilience Looks Like

Resilience is often discussed in terms of supplier diversification, better forecasting, and stronger inventory planning. These are important, but they remain dependent on external supply. In semiconductor recovery for reuse, we use the term "internal supply creation." This could mean recovering components from surplus assemblies, decommissioned products, obsolete boards, manufacturing scrap, or excess inventory that no longer has value

in its original form. In the right circumstances, those parts can be safely removed, inspected, reconditioned, tested, and returned to stock for reuse.

In practical terms, recovery can help companies:

- Maintain production when critical parts are unavailable through traditional channels
- Reduce exposure to spot-market pricing and broker risk
- Extend the usable life of legacy platforms and long-life programs
- Create value from inventory and assemblies that might otherwise be written off
- Create a more controlled response to shortages, obsolescence, and last-time-buy pressure

For aerospace, defense, industrial, transportation, and medical electronics sectors where redesign is slow, qualification is costly, and product lifecycles are long, this matters enormously. The inability to source one specific component can stall a program, delay deliveries, and create significant financial consequences. Recovery and reuse reduce that vulnerability.

From Scrap Value to Strategic Value

One of the biggest shifts in electronics supply chains is the reclassification of what constitutes "usable inventory." Historically, failed assemblies, obsolete products, surplus boards, and aging stock have often been treated as scrap or low-value material. But in many cases, those assets contain highly valuable semiconductors and other components that remain functional, difficult to replace, or expensive to source.

That changes the economics completely. A board that appears to have little value as a finished assembly may contain several high-value components that are still critical to active production programs. Likewise, excess stock from a canceled project may represent a future buffer against obsolescence or supply disruption if those parts can be safely recovered, reconditioned, and returned to stores.

This is where the commercial value of recovery becomes especially compelling. The cost of reclaiming a component is often significantly lower than the combined cost of:

- Sourcing the same device on the open market at inflated prices
- Redesigning around an alternative component
- Holding up production while waiting for new supply
- Scrapping boards or inventory that still contain usable value

Control Matters as Much as Availability

When shortages hit, the market tends to respond in familiar ways: more broker activity, more spot buying, and more urgency. But as sourcing moves further away from authorized channels, concerns around authenticity, traceability, prior handling, and quality assurance tend to increase. In some sectors, that risk can be just as serious as the shortage itself.

Recovery and reuse offer a fundamentally different model by keeping the supply loop closer to the customer. Instead of sourcing unknown material from the market, the customer can recover components from assemblies and inventory it already knows, owns, and can document. That creates a far greater degree of control over provenance, traceability, and chain of custody.

Why Standardization Matters

If component recovery is to move to an accepted supply chain strategy, confidence in the process is essential. Electronic components are sensitive devices, and poor removal or reconditioning practices can introduce damage, alter solderability, compromise coplanarity, or create latent reliability concerns.

I'm part of a committee drafting a new IPC standard that aims to establish clearer best practices for the safe removal of components. Our committee consists of professionals with hands-on experience in real-world component recovery. We are helping bring a practical perspective to how the standard evolves. That is important because any standard in this area must reflect the realities of working with high-value, often hard-to-source devices in environments where quality and traceability are non-negotiable.

Recovery as a Service, Not Just an Engineering Exercise

Recovery is no longer viewed solely as something done ad hoc in-house. Increasingly, it is being treated as a specialist service. It's important to make that distinction because successful recovery involves much more than removing one part from a board. Depending on the component type and application, it may also involve inspection, lead straightening, retinning, alloy conversion, reballing, coplanarity checks, electrical testing, packaging, and documentation. It requires a deep understanding of package behavior, handling controls, process limits, and potential failure mechanisms that can arise if any stage is poorly managed.

It makes sense to work with specialist partners who can apply those processes in a controlled, repeatable environment. In that model, recovery becomes less of a one-time intervention and more of an extension of the supply chain itself. Companies such as Retronix have helped shape this approach by providing recovery, reconditioning, and test services that allow manufacturers to reclaim value from existing assets while maintaining the quality controls and traceability.

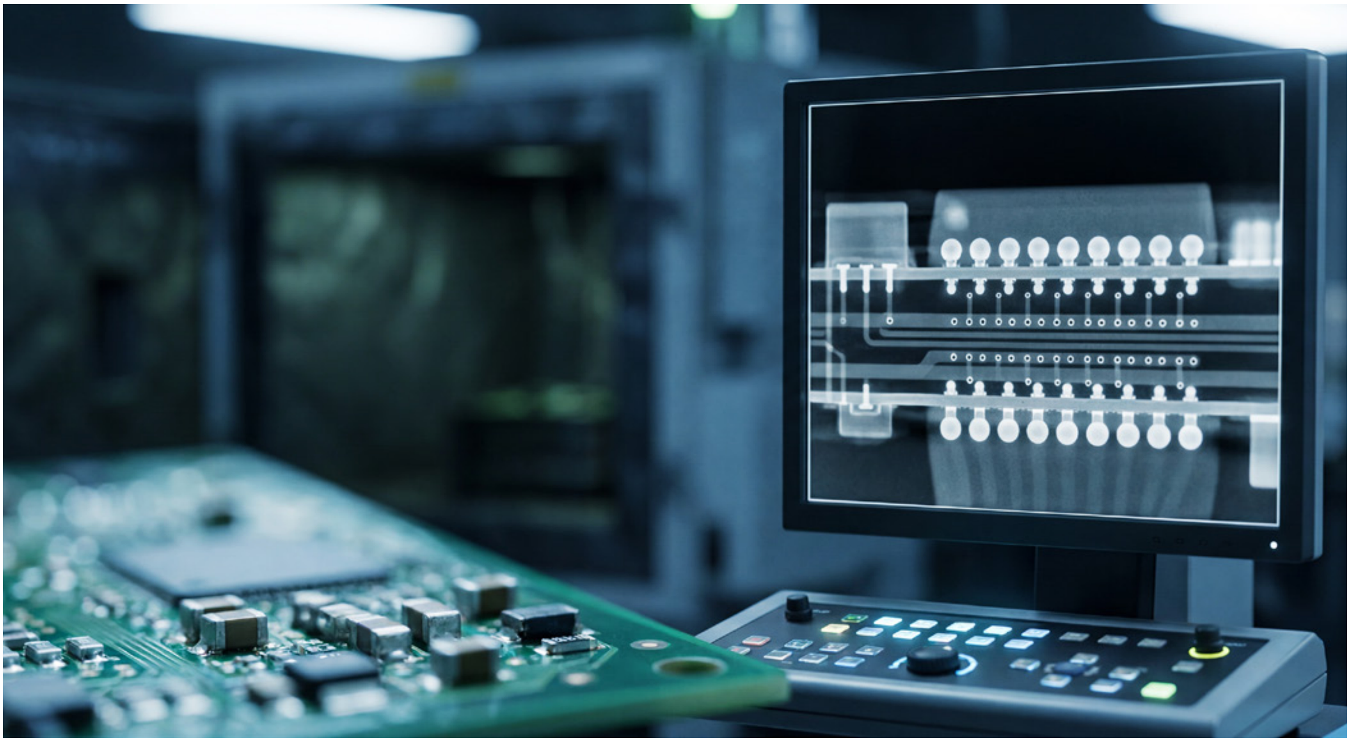
A More Mature View

The sustainability benefits of recovery are real, but this is not the only reason it matters. Recovering and reusing components can reduce electronic waste, extend the life of existing devices, and make better use of the energy and materials already embedded in semiconductors and assemblies. For most manufacturers, though, the immediate case is operational and financial. Recovery reduces dependence on volatile supply, improves control over critical components, and extracts value from assets that have already been paid for.

The companies best positioned for the next disruption will be those that broaden their definition of supply. We must look beyond what can be bought next quarter and ask what can be recovered, restored, and reused from the assets already inside the business. With uncertainty in today's markets, the greatest value often lies in the components you already own and can return to service. **SMT007**

Rob Ronan is the UK sales and support manager at Retronix Ltd.

X-RAY INSPECTION of Ball Grid Array Solder Joints



BY NASH BELL, BEST, INC.

Ball grid array (BGA) devices are ubiquitous in electronic products primarily due to their advantages, including compact packaging, greater durability than leaded devices, and improved performance from shorter signal paths.

BGAs improve electrical performance by reducing inductance and capacitance between the internal silicon die and the PCB, resulting in superior signal integrity and faster operation speeds. BGAs also offer superior thermal performance by dissipating heat more effectively, reducing the risk of overheating.

BGAs provide high density interconnection because, unlike perimeter-only packages such as quad flat pack (QFP) devices, BGAs utilize the entire bottom surface of the device, allowing for a much higher number of I/O connections in a smaller footprint. However, since the solder interconnections of a BGA are hidden beneath the device, inspecting solder joints is challenging.

Solder Joint Inspection Methods

A major advantage of BGAs in the PCB assembly process is their ability to self-align during reflow soldering, as the surface tension of molten solder balls helps position the component on the PCB pads. Several methods can be used to inspect BGAs after solder reflow on a PCB, including visual, endoscope, and X-ray inspections.

- **Visual inspection:** Used with an optical microscope to view the outer rows of a BGA for wetting and ball-to-pad alignment

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- **Endoscope inspection:** Used to view some inner rows of a BGA for wetting and alignment otherwise inaccessible by an optical microscope
- **X-ray inspection:** Used to inspect internal solder joints, detect voids within solder balls, and identify bridging between solder balls that cannot be seen visually
- **Electrical testing:** Functional testing to ensure BGA connectivity, but requires specialized equipment and skilled technicians, and is a time-consuming process

While optical microscopes and endoscopes for visual inspection are useful as an initial check of a BGA assembly, they are limited in the ability to detect other critical parameters, such as voiding and solder bridging.

Acceptance Criteria

The key acceptance criteria for BGA assembly per the IPC-A-610 and J-STD-001 standards include:

- **Alignment:** Solder balls are centered and show no offset of the ball-to-land centers or spacing violations
- **Solder ball spacing:** Solder balls do not violate the minimum electrical clearance

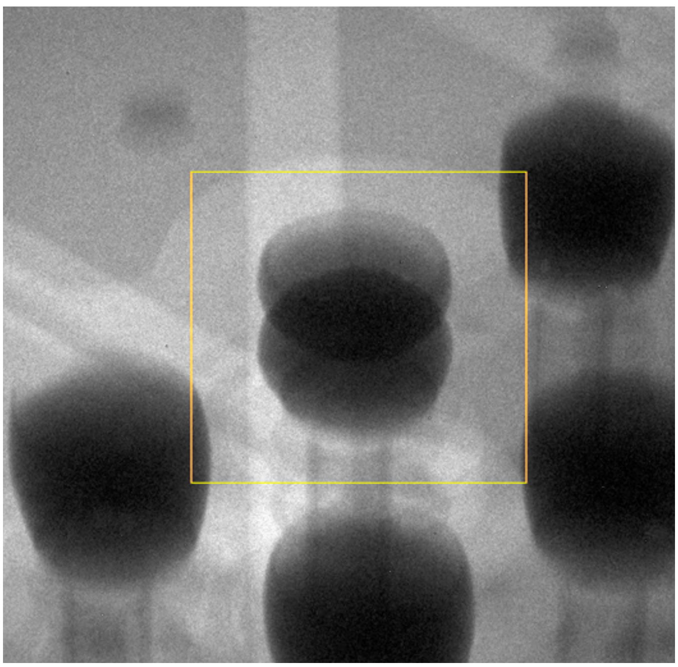

Figure 1: Head-in-pillow BGA defect as detected by X-ray inspection.

- **Solder connections:** BGA solder balls contact and wet to the land, forming a continuous elliptical round connection; no solder bridging, opens, missing balls, or unsoldered connections
- **Solder ball uniformity:** While not considered a defect, solder balls that are not uniform in size, shape, coloration, and color contrast are considered a process indicator for Class 2 and Class 3
- **Solder voids:** 30% or less of any ball in the X-ray image area
- **Solder ball appearance:** Solder balls should show evidence of proper reflow, wetting, and uniform collapse across the array
- **Head-in-pillow:** No head-in-pillow defects
- **Foreign object debris (FOD):** No signs of conductive or loose debris that violates clearance or can affect function under or around BGA

Popcorning

The term “popcorning” refers to a failure mode associated with moisture ingress into surface mount components such as BGAs. If moisture-sensitive devices, including BGAs, are not retained in a nitrogen-dry storage cabinet, they are susceptible to the popcorn phenomenon. Popcorning occurs when a small amount of moisture trapped within the polymer molding of a BGA is converted into a large volume of steam during the solder reflow process. This causes the BGA package to expand like a kernel of cooked popcorn, potentially leading to cracks and field failures.

Popcorning of BGAs can be indicated by bridging between adjacent solder balls beneath the device, since the bottom of a BGA is its thinnest point. This occurs when the package expands during solder reflow, causing it to “dish” downward; the underside of the package deforms and presses down on the solder balls. As the solder is liquid at the time, it allows solder from adjacent balls to coalesce, thereby forming a solder bridge underneath the BGA device.

The most typical cause of popcorning is the hygroscopic sensitivity of the molding compound used to protect the die. Device manufacturers

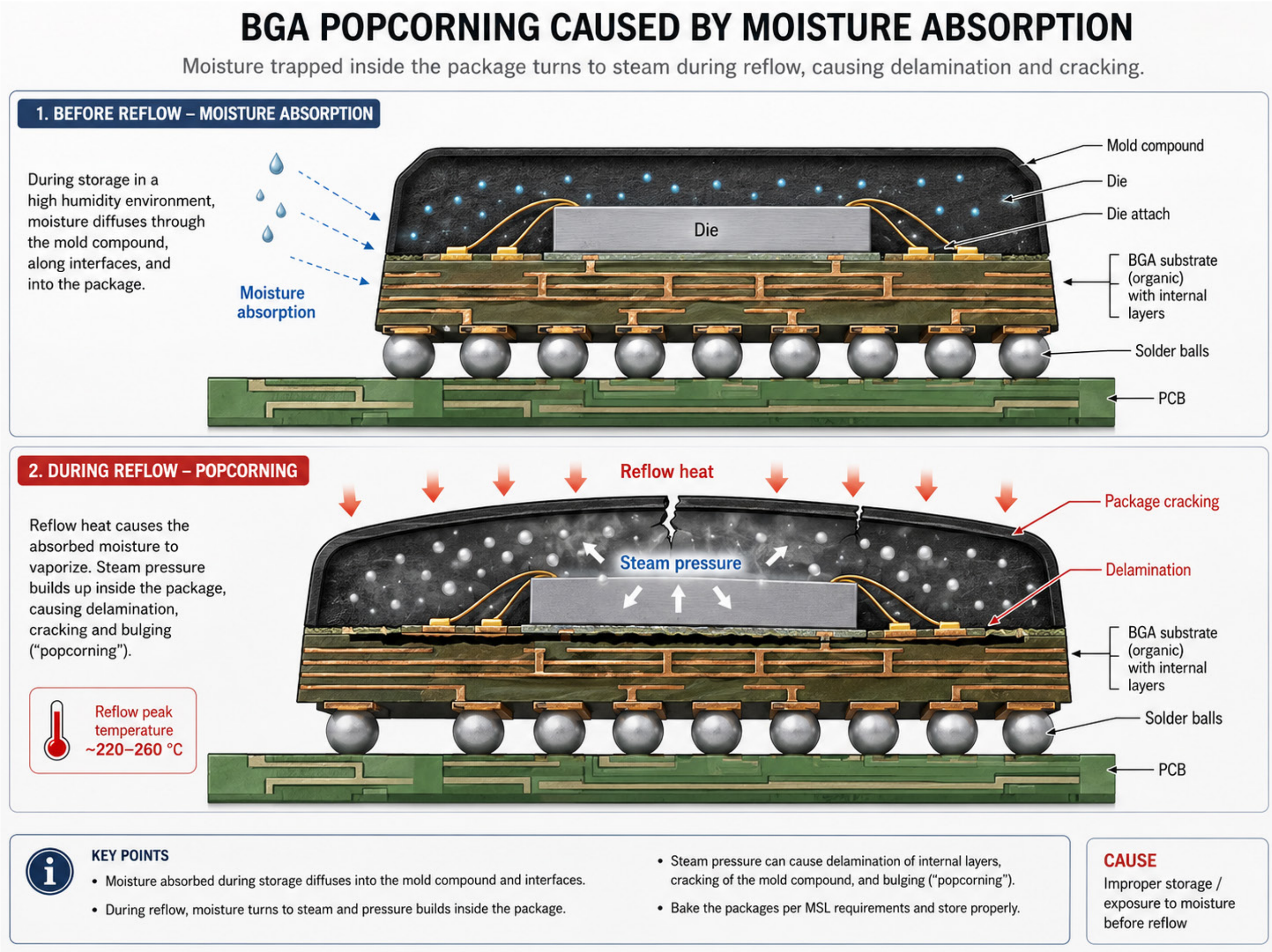

Figure 2: BGA popcorning caused by moisture absorption.

have been aware of package moisture sensitivity levels (MSL) for many years and have procedures in place to treat components prior to their use in the reflow process.

With the move to lead-free solders, which have substantially higher reflow temperatures, BGA packages are more susceptible to popcorn. This is due to the peak temperature a BGA is exposed to, with lead-free alloys approximately 20°C higher than tin-lead solders. As a result, it is suggested that a typical MSL will increase between one and three levels for the same device when used in a lead-free process.

Common Causes for Rejection

Several anomalies can occur during the assembly of a PCB containing BGA devices. The most common are incomplete solder melting, excessive voids, misalignment, or missing solder balls.

- **Partial reflow or cold solder:** Incomplete melting of solder balls during the solder reflow process, resulting from inadequate time-temperature profile or insufficient dwell time
- **Excessive voids:** Large or clustered excessive voids within solder balls, greater than 30%. Alternatively, this voiding requirement can be as low as 10% for mission-critical applications such as aerospace, defense, and medical products, etc.
- **Misaligned or shifted BGA:** Device package should be located over its intended PCB land/pad with no gross offset that risks contact with

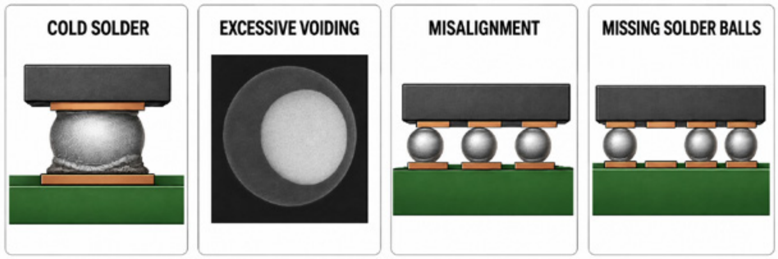

Figure 3: Common BGA defects, including cold solder, excessive voiding, misalignment, and missing solder balls.

the wrong land, insufficient connection, or reduced electrical clearance

- **Missing or broken balls:** Missing or damaged solder balls prior to placement

X-ray Inspection

Transmissive, real-time X-ray with a tilt function should be used to document several potential defects during BGA inspection. Solder bridges are the most common defect detected by this technique. Gross voids are visible at higher power and magnification levels.

Defects such as opens and voids can sometimes be difficult to discern even with high-quality X-ray equipment. Inspection technicians need adequate training to interpret X-ray images and identify all types of defects.

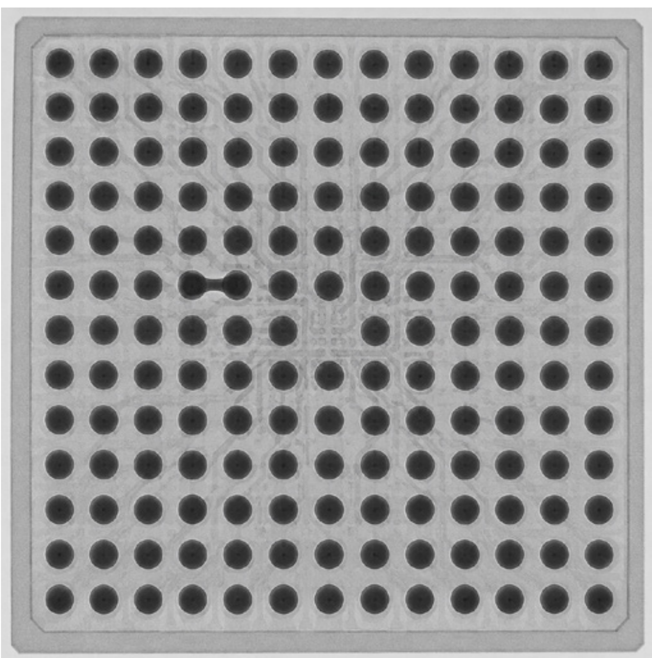

Figure 4: BGA solder bridge between adjacent balls as detected by X-ray inspection.

In addition, the concentricity, pitch, circularity, and solder ball diameter can also be measured as part of the BGA inspection process. With the proper equipment, which either tilts the sample or the detector, even head-in-pillow defects can be noted.

Endoscopic inspection is a valuable supplemental tool for BGA inspection because it allows inspectors to view beneath the BGA and assess visible solder joint surfaces that may not be fully characterized by X-ray alone. It can help determine whether reflow produced an acceptable joint condition or signs of defects by revealing surface characteristics such as texture, uniformity, smoothness, color, brightness, wetting, and possible micro-cracking. Endoscopes also provide useful documentation through captured images and video, supporting inspection findings, customer review, process improvement, and failure analysis.

Conclusion

The ability to rework and inspect hundreds of BGA types across a wide range of board designs, using both industry-standard and customer-specific acceptance criteria, is essential. A robust BGA inspection protocol should combine proven X-ray inspection expertise with the latest X-ray tools and techniques to reliably identify the full range of potential BGA defects.

It is also important to avoid excessive X-ray exposure during inspection, particularly when working with commercial off-the-shelf semiconductor devices, where radiation effects may be a concern. Methods for minimizing the impact of X-ray radiation will be discussed in a future column. **SMT007**

Nash Bell is president of BEST, Inc. To read past columns, **click here**.

BY FILIBERTO SEVERIANO, SMTLINK SOLUTIONS

SMTLINK in the Evolution of *Mexico's Electronics Industry*

For years, Mexico's competitive advantage was largely associated with manufacturing capacity, geographic proximity to the United States, and cost efficiency. While those factors remain important, success increasingly depends on a broader set of capabilities: engineering expertise, workforce development, process reliability, automation, and supply chain resilience.

This trend reflects a reality in the industry that manufacturing excellence is no longer driven by a single factor. Instead, it depends on the successful integration of technology, talent, engineering, and continuous improvement.

As global manufacturers diversify their operations and strengthen regional supply chains, Mexico is becoming more of a strategic partner within the North American electronics ecosystem.

This evolution is particularly visible in regions such as the Bajío, where a growing network of manufacturers, technology providers, educational institutions, and industry organizations is helping build a more integrated industrial environment.

These organizations are responding by expanding their capabilities in areas such as advanced manufacturing support, automation, technical training, digital process control, and reliability engineering. More than ever, companies are looking to reduce fragmentation in their operations and work with partners that understand the complexity of their challenges.

Companies such as SMTLINK Solutions reflect this trend by expanding beyond traditional technical support roles to help manufacturers address increasingly complex operational and workforce challenges.

From Technical Provider to Strategic Partner

SMTLINK Solutions is a Mexican company specializing in integrated solutions for electronics manufacturing, serving the automotive, energy, technology, and industrial sectors, with locations in Mexico, the United States, and Canada. SMTLINK's growth and expansion show a transition from independent service models to integrated platforms that support companies throughout their entire production process.

It has become an integral partner to its customers, not "just" a single supplier in a complex supply chain. To mark a new beginning where deep technical expertise transformed into a structured, integrated offering to create the highest value proposition for their customers, we re-established our identity in 2025.

Being based in the Bajío region places us at the center of Mexico's nearshoring momentum. We work closely with both local and international manufacturers to optimize processes, shorten implementation timelines, and strengthen operational reliability across the supply chain.

Competitiveness in electronics manufacturing is no longer defined only by cost. Today, it depends on the ability of companies to ensure consistent quality, regulatory compliance, operational efficiency, and technological adaptation. SMTLINK's approach reflects the reality that the combination of engineering, operations, and training is now the foundation of manufacturing excellence.

Our comprehensive business model is based on specialized business units that cover key points of the production cycle:

- Technical support for SMT and THT processes
- Maintenance and reliability strategies
- A strategic supply of machinery and consumables
- The integration of automation and robotics
- Implementation of an ESD program
- Digital solutions for process control
- Technical training for staff that is aligned with international standards

"In an environment where speed of execution must go hand in hand with technical precision, organizations that can integrate these capabilities will define the future of the industry."

Evolving, Embracing, and Thriving

SMTLINK Solutions is part of a new generation of Mexican companies that understand electronics manufacturing as a complete system, where every component—technology, processes, talent, and development—is connected.

Looking ahead, we are committed to continuous training, certification, and standardization. Developing highly skilled specialists is not just part of our growth strategy; it is essential to Mexico's increasing competitiveness in electronics manufacturing.

In an environment where speed of execution must go hand in hand with technical precision, organizations that can integrate these capabilities will define the future of the industry.

Mexico is integrating, developing, and building reliability. In this path, companies like ours are helping close the gap between operational capacity and global excellence.

Filiberto Severiano is the founder and CEO of SMTLINK Solutions.

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Associate's degree or equivalent experience; 1–3 years of relevant experience. Valid driver's license, passport, and willingness to travel frequently, including internationally.

BÜRKLE North America is the U.S. subsidiary of Robert Bürkle GmbH, a global leader in press, laminating, and coating technologies. We support manufacturers in the PCB and photovoltaic industries with precision-engineered equipment and expert field service.

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CAREER OPPORTUNITIES

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The Test Connection, Inc. is a test engineering firm. We are family owned and operated with solid growth goals and strategies. We have an established workforce with seasoned professionals who are committed to meeting the demands of high-quality, low-cost and fast delivery.

TTCI is an Equal Opportunity Employer. We offer careers that include skills-based compensation. We are always looking for talented, experienced test engineers, test technicians, quote technicians, electronics interns, and front office staff to further our customer-oriented mission.

- Candidate would specialize in the development of in-circuit test (ICT) sets for Keysight 3070 (formerly Agilent & HP), Teradyne/GenRad, and Flying Probe test systems.
- Strong candidates will have more than five years of experience with in-circuit test equipment. Some experience with flying probe test equipment is preferred. A candidate would develop, and debug on our test systems and install in-circuit test sets remotely online or at customer's manufacturing locations nationwide.
- Proficient working knowledge of Flash/ISP programming, MAC Address and Boundary Scan required. The candidate would also help support production testing implementing Engineering Change Orders and program enhancements, library model generation, perform testing and failure analysis of assembled boards, and other related tasks. An understanding of stand-alone boundary scan and flying probe desired.
- Some travel required. Positions are available in the Hunt Valley, Md., office.

Contact us today to learn about the rewarding careers we are offering. Please email resumes with a short message describing your relevant experience and any questions to careers@ttci.com. Please, no phone calls.

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The Test Connection, Inc. is a test engineering firm. We are family owned and operated with solid growth goals and strategies. We have an established workforce with seasoned professionals who are committed to meeting the demands of high-quality, low-cost and fast delivery.

TTCI is an Equal Opportunity Employer. We offer careers that include skills-based compensation. We are always looking for talented, experienced test engineers, test technicians, quote technicians, electronics interns, and front office staff to further our customer-oriented mission.

Associate Electronics Technician/ Engineer (ATE-MD)

TTCI is adding electronics technician/engineer to our team for production test support.

- Candidates would operate the test systems and inspect circuit card assemblies (CCA) and will work under the direction of engineering staff, following established procedures to accomplish assigned tasks.
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Accurate Circuit Engineering seeks an organized, technically proficient Quality Assurance Specialist dedicated to bare board PCB production. You will champion compliance with industry standards, lead internal audits, manage certifications, and drive continuous improvement based on product performance data and customer feedback.

Key Responsibilities:
- **Standards Compliance & Certification:** Enforce IPCA600, IPC6012 (CIS/CIT preferred), and ISO 9001 quality standards throughout fabrication
- **Internal Process Auditing:** Conduct scheduled and ad hoc audits of incoming materials, fabrication stages, testing protocols (etest, AOI), and documentation traceability
- **Employee Training & Development:** Create and deliver training programs for inspectors and production staff on IPC standards, quality procedures, and inspection tools to maintain certification
- **Failure Analysis & Corrective Actions:** Investigate nonconforming boards—including internal findings and customer returns/RMAs—analyze root causes, and lead corrective/preventive actions (8D/CAPA)
- **Procedure Optimization:** Analyze quality trends and RMA data to update processes, inspection checklists, and control plans

Qualifications:
- Associate degree or equivalent experience in electronics manufacturing
- 3+ years in bare board PCB QA, with IPCA600/CIS and IPC6012 certification
- Strong auditing, training, documentation, and cross-functional collaboration skills
- Proficient in rootcause failure analysis

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Contact brandon@ace-pcb.com and James@ace-pcb.com to apply.

Apply Now!

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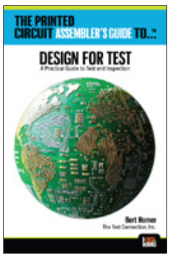
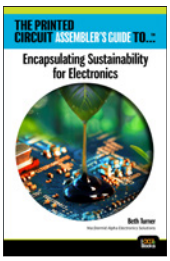


Design for Test: A Practical Guide to Test and Inspection

by Bert Horner

This book presents a practical roadmap for integrating DFT into PCB and CCA development, emphasizing early test strategy rather than adding it after design completion. The author highlights the cultural shift required to make DFT a shared responsibility across engineering, manufacturing, quality, and leadership teams. Download your copy today!



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marcy@iconnect007.com • (480) 280-5229

Managing Editor
NOLAN JOHNSON
nolan@iconnect007.com

Associate Editor
MICHELLE TE
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TOBEY MARSICOVETERE
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BRITTANY MARTIN
brittany@iconnect007.com

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