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I-Connect007

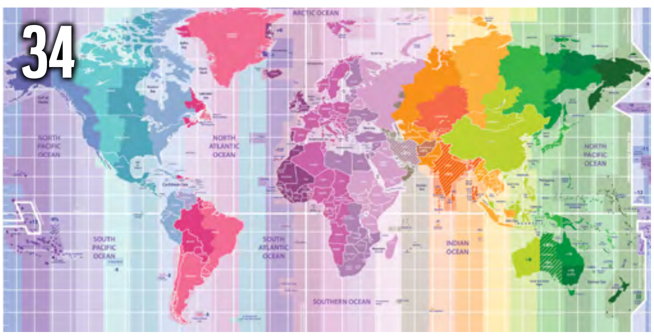
SMT007 MAGAZINE

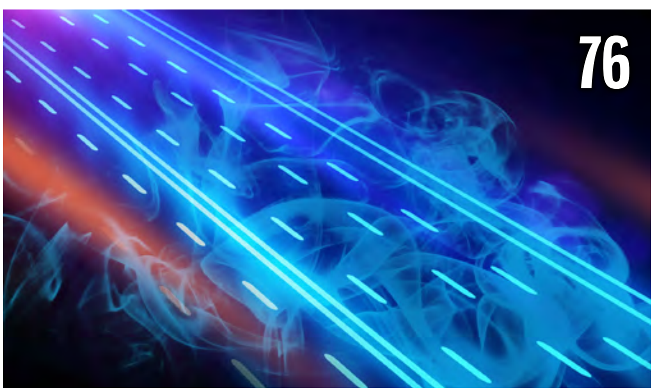
Better Living Through Industry Standards

SMT007 MAGAZINE

Industry Standards

There are rules, and then there are recommendations; one person's rule might be another person's recommendation and vice versa. That is where standards come into play. What are they? What do they mean? How do they get specified? And what are the impacts on our industry?





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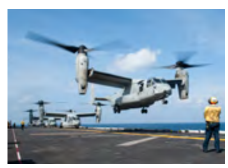


DEPARTMENTS:

SHORTS:

Rules or Recommendations?

Nolan's Notes

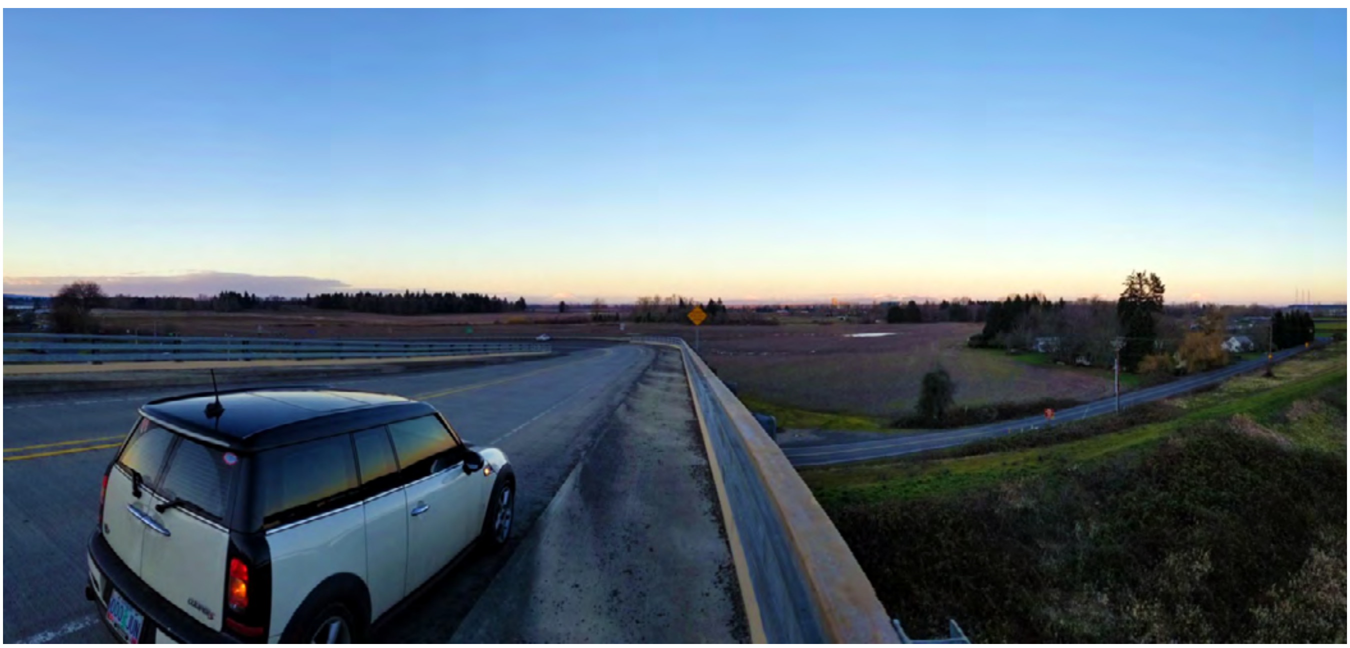
by Nolan Johnson, I-CONNECT007

Recently, I made a 150-mile trip with Junebug, my Mini Cooper. The route took me over the Cascade Mountains of Oregon and into the high desert that runs from southeast Washington State to northern Arizona. I'd just recently installed brand new run-flat tires, and this was my first long-haul drive on the new shoes. It did not go well.

Driving down the interstate just a bit faster than prevailing traffic (in this case, 75–80 mph), I felt every single rut and wrinkle in the road surface. Slowly, and inevitably, as I drove the mountain passes into the interior of Oregon, the handling worsened by a lot. When I rolled into my destination city, the steering was uncontrollable. I was convinced that I'd broken the steering rack; my car was all over the road no matter how I steered her. Thankfully, there was a store nearby for the retail outfit that sold me the tires, so I hobbled my way into their service bay.

"That was the most life-threatening ride I've ever had," I confessed to the service manager, "either I blew up my steering rack, or these are absolutely the WRONG tires for my car." The technicians were already pulling the tires and wheels off of Junebug even as I described the issue.

Thirty seconds later, a technician waved me over for the root-cause analysis. The driver's rear tire had a seven-inch split in it—not a cut, not a slash, but what looked like a manufacturing failure. However, the flat run-flat didn't look flat; it looked as normal as the other three tires. The technician said, "Well, sir, there's the problem. We'll get a new one mounted on your car. How long had you been driving on it that way?" I replied, "Oh, I don't know... 150 miles



give-or-take." He concluded, "That explains why it was getting sloppy; the standard says '50 miles at 50 miles an hour.'" Chuckling, I added, "I guess I took that as more like a recommendation." An hour later, I was on my way with four good tires and a car that went where I pointed her.

While it wasn't pretty, that tire did its job and got me where I needed to go even while going well beyond what it was specified to deliver. The point is that there are rules, and then there are recommendations. One person's rule might be another person's recommendation and vice versa. That is where standards come into play. What are they? What do they mean? How do they get specified? And what are the impacts on our industry? Sometimes, the way you treat them is situational.

We begin with an interview titled "To Improve the Standards Process, Get Involved" with Jan Pedersen and Ray Prasad—both I-Connect007 columnists. Next is a conversation on "The Convergence: IPC Merging CFX With IPC-2581" with Gary Carter and Michael Ford. Then, Barry Matties speaks with Graham Naisbitt about "The Long Road to a New Standard." Following that, I examine the history of standards in "Standards Through Time: Changing to Stay the Same" and am reminded how familiar the standards definition and ratification processes are, regardless of the standard under development.

Eric Camden's column, "Reliability by the Book" discusses definitions and specifications for IPC Class I, II and III products. Then, we feature perspectives from three organizations in "The Ecosystem of Industry Standards." Next, Michael Ford's column delves into the skill for "Recognizing the Need for Change," and Ray Prasad discusses "How Standards Impact You and Your Company."

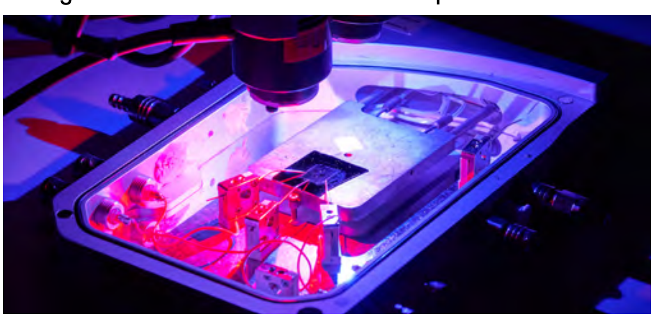
Scott Sommers, Molex's director of industry standards, provides a piece on "Explaining the QSFP-DD Data Center Interconnect Standard." Then, Alfred Macha's column outlines how to "Transform your Operations with Nadcap." And our technical paper this month comes from Jon Bengston and Richard DePoto from Uyemura titled "Comparing Soldering Results of ENIG and EIPG Post-steam Exposure." Bob Wettermann's column closes us out with "Process Methods for Reworking High Lead Count SMT Parts." **SMT007**

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

Electronic Chip Mimics the Brain to Make Memories in a Flash

Researchers from the Functional Materials and Microsystems Research Group at RMIT University drew inspiration from optogenetics to develop a device that replicates the way the brain stores and loses information.

The new chip is based on an ultra-thin material that changes electrical resistance in response to different wavelengths of light, enabling it to mimic the way that neurons work to store and delete information in the brain.



Research team leader Dr. Sumeet Walia said the technology moves us closer towards artificial intelligence (AI) that can harness the brain's full sophisticated functionality. Dr. Taimur Ahmed, the lead author of the study published in Advanced Functional Materials, said being able to replicate neural behavior on an artificial chip offered exciting avenues for research across sectors.

Developed at RMIT's MicroNano Research Facility, the technology is compatible with existing electronics and has also been demonstrated on a flexible platform for integration into wearable electronics.

(Source: RMIT University)

To Improve the Standards Process, Get Involved

Feature Interview by the I-Connect007 Editorial Team

Jan Pedersen, senior technical advisor at Elmatica, and Ray Prasad, president of Ray Prasad Consultancy Group, spoke with the I-Connect007 team about the current state of PCB standards and where the process might need improvements, including the many difficulties around transparency, slow updates, limitless numbers of variations, and a variety of other topics.

Nolan Johnson: Jan Pedersen and Ray Prasad are two of our columnists, and they are also very well-versed in standards and the standards process. Can you start by talking about why standards are important?

Jan Pedersen: Yes, standards are important for the customer and supplier to be able to communicate requirements and be clear about what they need. You need standards. Instead of all of these corporate requirements that make everything blurry, it's much easier if you have a clear standard and everyone knows what you mean by defined terms.

Ray Prasad: I agree with Jan. In addition, when you standardize something, it becomes a lot cheaper. For example, think of different kinds of sockets. If you are traveling around the world, you would need all kinds of sockets. The same thing goes for all of the chargers we have to carry around. When we standardize something, it makes it cheaper and sets expectations for the customers and manufacturers about what requirements they have to meet.

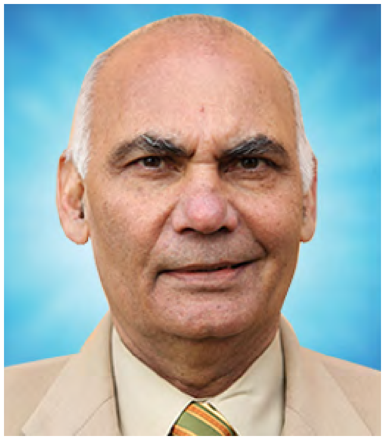
Barry Matties: Right now, I'm traveling with a bundle of power converters. Are the standards global, or are we also seeing regional standards?

Prasad: Yes, that's one of the things IPC can do that other people will have a harder time doing. Anybody can start a standard, but you need followers. Some of what we call "standards" a lot of people think are specifications, which they're not. Many people end up using standards as specifications.

Matties: How would you define the difference?

Prasad: There's a huge difference. Standards are requirements that IPC sets up for every-

body to follow. But with a specification, for example, the customer says, "It has to meet the IPC-610 standard that has 25% void. But I want a 5% void, not 25%." Then, the supplier will say, "If you're not following the standard, I will have to charge you more. I can do a 5% void, but it will be more expensive." IPC has Class 1, 2, and 3. Some people can say, "That's fine with me." Others might say, "I want something different." That's the difference between a specification and a standard. The specification is only set by the person who writes the check.



Ray Prasad

Pedersen: Having a clear language to communicate is important. That's also why I'm into IPC-2581 and dealing with how we can communicate the specification between the designer and the manufacturer. The goal is to be 100% clear on what the designer wants.

Prasad: The other thing worth noting is that the standards are global, but the specifications can be for a specific company and different.

Happy Holden: For 30 years, I was never allowed to use or even look at any IPC standards because the Hewlett-Packard specifications were better than anything IPC had. They were more correct, supplied by data, and the standards are a place where you start. And for people who have no data, that's better than nothing.

Prasad: It starts with the committee, and then it goes to China, India, and everywhere else. We want the membership of all of these companies so that they get to have their input. You have to compromise not to get too many negative votes. For example, in my standards, I tried not to get even one negative vote if I could, but there are times that you can't compromise.

Pedersen: When you say that IPC's standard is not good enough, Happy, it's still like that. It is not easy to keep up to date. They're coming after the technology continuously. I have some good examples, especially when I'm working with medical. You cannot follow the current design standard because this is much denser. Then, we introduce a new design level, but it's only for medical right now, and it should be for all standards.

Prasad: Even for medical, some companies could go looser or tighter than that. And remember that the standards are a slower process; think of it as dictatorship versus democracy. Democracy is messy and slow, but it works because other people buy in; that's part of the idea behind the standards process. We keep changing it. We release it, and then next month, we start this process of updating, which takes a year or two. It depends on how many dedicated volunteers we get; nobody is getting paid.

Johnson: There are some people in our industry who are critical of standards because they are behind the time. A few people also suggest that standards should be pointing toward the future. Is that even possible?

Pedersen: I think it's possible to become better than we are today, and for me, transparency is vital. As an example, with 6012, where are they going? What kind of level are they heading to? There is a big discussion going on about microvia reliability, for instance.

Prasad: You're right. I'm not here to defend IPC, but transparency is the main thing. It must be open to anybody and everybody. Everybody is welcome to make a contribution, but for voting, you have to be a member. In the five or six committees that I have chaired, it has been a very open, transparent process.

Pedersen: It's more the feeling that people around the globe feel that IPC is somebody in the U.S. where they decide what the standard will be.

Prasad: That hasn't been my experience. For example, in all of the committees that I have chaired, these things go through, and sometimes, I'm surprised that we have to make so many changes. So, it goes to China, India, and Europe.

Jan Pedersen

Pedersen: But I think that is the impression. I'm coming from a small company of 40 people in Norway, and I have been able to make contributions and be heard. That is something that IPC should be communicating better.

Prasad: Right. Somehow, we need to figure out how to communicate better. I've been involved for 40 years, and whenever I hear that somebody wants to make a contribution, we say, "Yes, please." If you can't attend the meeting, send the comment.

Holden: It's kind of like a representative democracy. It may not be, but at least IPC is open, and anybody can go there to a meeting and open up a new topic, saying, "We have this problem. We need this consensus." As long as people will volunteer, IPC will create a standard or update the standard. It may not be the best process, but nobody has come up with a more successful process.

Prasad: I agree, and let me give an example. It was 1987, and SMT was taking off. I used to work at Intel, and we discovered that moisture-sensitive packages were a problem. Big packages were cracking because of the moisture. We had all of the data. There was a group called the SMT Council, which was set up by EIA and IPC. This group consisted of chairmen of various IPC and EIA committees and some other people. I said, "There's a problem with SMT packages that crack if there's moisture because moisture may become steam in the reflow oven. The same package doesn't have the same problem with the same plastic in the wave soldering process because the package itself never saw the heat." All of these accomplished people there working with these things said that it couldn't be true because they had not seen the problem yet.

But, as I mentioned, I had the data. I persisted, and they said, "Okay, go ahead; you start the committee." That's how IPC-7086 started, and then it became J standard 20 and 30 these days. Any standard cannot be any better than the input that they get. Anything is possible, but we need enough supporters.

Pedersen: Exactly. You need somebody to start and somebody that has the right voice for it.

Johnson: No disrespect, but for standards development today, are the right people involved? Are designers sufficiently involved in the process? Does IPC need a different sort of mix of skillsets and professions to make for better standards?

Pedersen: What I see from my groups is that we do have participation. We seek participation from designers, EMS assembly people, etc., from the complete value chain.

Prasad: There is deep involvement of the IPC Designers Council that does a lot for the designers. They offer designers certification, education, and training. Designers are very involved.

Pedersen: They could be more involved in other standards.

Prasad: Designers won't be involved in trying to do the reflow profile, so they're involved in the things that they know about and are of interest to them.

Andy Shaughnessy: Designers tell me that they feel as if IPC doesn't get them, and there's some truth to that, but it does seem like IPC is trying.

Prasad: Keep in mind that when we say “standards,” there are so many different kinds. There are many that I’m not involved in. People only get involved in standards they and their companies are interested in.

Holden: We’re talking about IPC standards, but what about IEEE, electrical standards, government organization standards, and UL? UL is kind of related standards because UL reassures to fire and insurability, which means you don’t have to design to UL standards, but there are consequences if you don’t meet UL.

Prasad: Good point. RoHS is a standard, so then the Chinese have their own as well as Europe, and everybody is following that, so that’s the standard.

Pedersen: Compliance with ITAR, DFARS, RoHS, rules of different countries, etc. is one thing that continues to come up more and more. It is something that we have to follow.

Johnson: Jan, a question for you with regard to compliance and traceability. What do you see the role of the CAD tool software manufacturers to be?

Pedersen: I think that what we see is, or what we need is, CAD tool manufacturers and suppliers. It is important that they are able to import and export the files needed as well as communicate, like what we were talking about earlier, regarding the article specification. This includes not only exporting a file but also describing what they want and what the requirements are. There is a mismatch today and some missing language on how to communicate specification. We all use Gerbers, ODB++, and some of us even use IPC-2581, but whatever tool we use, you need to communicate the article specification. That’s where I see the biggest missing link today.

Four years ago, if you were a designer inside Ericsson, you could go three floors down into the PCB shop and test out your designs. Today, you cannot. Thus, OEMs and designers have less and less knowledge about how you produce a PCB. I tell them that they can use me as a voice or that they can meet up themselves, but they are probably not allowed to travel much because of costs. They need somebody to speak for them, and I’m one of those people.

Holden: One of the biggest problems with Industry 4.0 and the people involved in the manufacturing side of implementing Industry 4.0 is the fact that IPC standards are not electronic. But CFX is a start as IPC realizes that CFX is going to have to be electronic as part of the data stream.

Pedersen: And when you’re talking about Industry 4.0, then you also need a specification that can be transferred digitally. Today, we are losing requirements down the value chain. You could end up with a Class 2 PCB delivered to somebody that has a Class 3+ requirement. But I think that we are going in that direction in the complete value chain; we can exchange digitally all of the needs and files we have as well as control processes better.

Johnson: How do you see the younger members of our industry engaging in the standards process?

Prasad: It's a big effort to get younger people involved in the leadership of the committees. I am getting some newer, younger people involved so that they can be the next chairman of these committees one day.

Pedersen: It's difficult to get the younger generation interested in manufacturing. They are much more interested in developing other things, like IT.

Prasad: And it's a global problem because manufacturing is not as glamorous as those other things, especially because a lot of the manufacturing is getting outsourced to low-cost countries.

Holden: On a side topic, how do leading research organizations select projects? In many ways, they're one of the institutions that takes what OEMs and young designers want to design for next-generation products and relate it back to what are the gaps that we need to build it and have it reliable and survive for its intended use.

Pedersen: When you talk about NASA or ESA in Europe, the big difference is that they are conservative; they're not tuned for new technologies and exceeding standards. I had some designs yesterday that had 30–50 layers and a 2.5–3-mm board with a 0.2-mm hole. You can't call it even Class 2 because there's almost nothing left. These boards should work, but they were not made to standards, so what do we do? Should we rewrite the standards so these people can have the standard to follow? Yes, we should.

Prasad: I disagree. Part of the reason is that there are all of these requirements, and if there are some unique people who need to do that, they will have to take the risk and design it. Not everybody has the capability to do that, and by definition, it is not going to become a standard because not everybody cares about that.

Pedersen: But you can still produce reliably while violating standards.

Prasad: I don't think they are violating standards; they're creating a unique product for that segment of the market at a high cost where cost is not an issue. So, you have to keep that separate; it's not a standard. If the standard is something the majority of the people are using, they will all buy into this as a global thing. But on the other hand, for somebody who doesn't care about the yield of the board and 10% yield is okay, whether the cost is $10 or $1,000 is also fine. I have worked on a board with BGAs, and each one was $25,000.

Pedersen: Sure, if you're in that kind of segment. But we have a lot of electronics that cannot follow IPC Class 2 or 3, for example, because the designs are too tight, but they are produced globally every day. I think we need to revisit the standard and update it more frequently than we are doing today.

Matties: Have either one of you worked with the laminate standards?

Pedersen: No.

Prasad: No, I have not.

Matties: We were talking to a laminate vendor about this topic, and they were saying that the way the standard is being written is not practical and the approach to laminate should be changed to a functional standard rather than a composite standard of materials. What's the process for creating that sort of change if it makes sense, and why hasn't it already been done?

Pedersen: I understand that they are revisiting the standard for all this—the 4101 for base material laminate. But some of them are made because some laminate suppliers said, "I have a laminate here that doesn't fit into any of them, so let's make a new one for this."

Prasad: There are numerous slash sheets in 4101 for laminate, which is the strangest of all, because anybody that has a new laminate can create a new sheet in 4101. Again, remember that there is a basic requirement that all of the sheets have to meet. Various laminate suppliers from different countries—such as China, Korea, Japan, or any IPC member company—test their laminates to meet basic Tg, Td, CTE, and other requirements set by IPC. When those laminates meet those requirements, they ask IPC to add their laminate to 4101 sheet. However, it is the user's responsibility to determine the suitability of those laminates based on their own tests or test results from the supplier of that laminate.

Pedersen: Correct. That's where we should come from—which laminates can be used for which environment?

Matties: It seems to me that things need to be simplified, as you're saying. We need to look at standards more often and update them accordingly.

Patty Goldman: Everybody who has a suggestion ought to join IPC meetings. However, and I think Ray and Jan will agree with me, it's always the ones who don't participate who have all of the complaints.

Matties: And the people who are talking about it are participating, but what they're keying in on is how long it takes for change in this process. And it's all volunteers, so I understand that.

Goldman: Again, it's a democracy; everybody has to agree there is a reason to change.

Prasad: I would love it if I wrote something and everybody agreed, and it would get done in a month, but usually, not everyone agrees with it; that's the problem.

Matties: In the meantime, if everybody doesn't agree with it, then we get stuck with what we already have, which may not be the most practical or the best solution. So, how does an organization come in and facilitate this? And if you have to leave it up to the users, so be it, but is there a better way?

Prasad: The better way is participation and democracy because they have to meet these requirements that people have to buy into. There is a process of waiting if this goes out for ballot. So, there are people that think three years is too short, and people like me who think we can get it done in a year or a year and a half; we were able to do some standards that fast, but that's about the timeframe.

Pedersen: I'm all for speeding it up, but then there are people on the other side of the table who ask, "Should I buy this standard again every year?" For me, you're going need to make IPC more dynamic and up to date. Maybe we should have a subscription instead of buying a new book every year.

Prasad: The publisher of my book said IPC has this unfair advantage because they don't have to pay royalties and they get these books for free by volunteers. But IPC is able to sell these

standards to their members at very low cost because they are not paying royalties to the people who created them.

Matties: What if we changed the model and hired a team to create standards rather than relying on volunteers?

Prasad: I'll give you a reason not to do it. Then, we have only certain people who are interested and will set the standards; everybody else would be cheated. Nobody gets cheated as long as everybody has a voting right, and it's not like our election where 50.1% is okay.

Matties: I understand your point that you need to have the voices represented, but as you're pointing out, the only voices represented are the ones participating.

Prasad: It's like an election; the people who vote decide who gets elected.

Matties: All of us that have to make it work, not just IPC.

Prasad: I agree. They have staff to facilitate, but they aren't always technical people. They conduct the meetings, but the content comes from people like you and me.

Matties: When somebody wants to change a standard, they need to start marketing, writing a column, or taking out ads and talking about the need for changing a standard.

Prasad: Yes, all those methods.

Matties: Do you all have any final recommendations you would make to the industry regarding standards?

Prasad: Based on the conversation we've had today, IPC is a good place to start, and if you have some unique requirements or new data and you are willing to provide it, share it.

Pedersen: I agree. I always support getting involved. Participate and raise your voice; that's the only way to gain attention and get something done.

Matties: Great advice.

Johnson: Valuable session, gentlemen. Thank you.

Prasad: Thank you.

Pedersen: Thanks, everyone. **SMT007**

The Convergence: IPC Merging CFX With IPC-2581

Feature Interview by Andy Shaughnessy
I-CONNECT007

Gary Carter of XPLM and Michael Ford of Aegis Software are heading a group tasked with combining the IPC-2581 standard, now referred to as Digital Product Model Exchange (DPMX), with IPC's Connected Factory Exchange (CFX). During the IPC Summer Meetings, they sat down with me to discuss the benefits that can be expected when these standards are fully merged for both PCB designers and process engineers on the manufacturing floor, especially when it comes to satisfying compliance and traceability requirements.

Andy Shaughnessy: Nice to see you both again. And I understand the two of you are co-chairs on the committee that's working on combining DPMX and CFX. Tell me about that.

Gary Carter: Sure. The 2-10 Committee is looking to leverage the synergy between a number of IPC standards to describe now digital best practices that IPC owns, from beginning to end of design and manufacturing of PCB-based products.

Michael Ford: The strength of IPC standards is that each of them satisfies a particular need in the industry. DPMX is a great example where we needed to get an extremely complicated set of information from design to manufacturing in a single file. Why do we need to understand so many different files and try to put them together and cross-reference everything? It's the kind of role people would have had 20 years ago. Now, it's sent through in one digital format that has always been your digital product model for exchanging the data from design through manufacturing.

Another digital standard—the Connected Factory Exchange (CFX)—allows data to be exchanged between machines and factory systems. Put the two together, and you start to think, "Well, I have my digital product model exchange coming in, together with that from CFX, so I know what to do and how to do it. I can measure what I'm doing. Let's put those two things together. What benefit is that going to make? Couldn't I feed that information back through to design to make a complete digital loop for manufacturing?"

But this is not something that you have to buy. This is something that is a digitally created

Gary Carter

technology IPC standard so that everybody can use it. There's no real cost to ownership. You can choose your favorite engineering, design, or manufacturing tools. The nice thing is that digital best practices are now defined by IPC through DPMX, CFX, and even our traceability standard, IPC-1782, which defines the type of information that needs to be retained by manufacturing to satisfy compliance and traceability requirements.

Shaughnessy: How long have you all been working on this?

Carter: The last year and a half. We've been talking and co-presenting in some venues and brainstorming on other IPC standards that add to this value proposition and need to be a part of this story.

Shaughnessy: It seems like there would be some natural hurdles; design data is one type of data, but CFX is a different animal. How do you blend the two?

Ford: It is, though DPMX consists of many different kinds of data, and that data is exactly what is needed in manufacturing, by machines, for example. Even before we started this project, there were cases where DPMX data was used by particular machine vendors because they needed access to the design information to understand where the components were supposed to go, what measurements they were supposed to take, and what they should expect to see in visual inspection.

As far as translating the standard design format into a standard manufacturing format, it's the same data source, but sections of the data are being used for the different manufacturing processes. So, CFX already carries the ability to take the data derived from the design and out to the machines. We're improving on that as time goes on. We're collaborating in terms of the definitions of the standard so that we can be more specific and make it easier for machine vendors, for instance, to understand the layout of this board in terms of X, Y, and Z, and know how to get that data through CFX, which is derived from DPMX.

This flow, which would have taken an engineer hours if not days to achieve, can be done with the hit of a button because the information is now standard. It doesn't matter where it came from or where it's going in terms of engineering tools because it's the same format.

Shaughnessy: Gary, you mentioned how traceability was a big part of this. How is that working?

Carter: Traceability has become a big concern, especially with counterfeit components and knowing the provenance of the materials that you are using. CFX is able to close the loop with what occurred on a line during manufacturing assembly and test. Now, you're able to have a complete record of what your product was made of, where it was operated on, how that material moved or didn't move properly through the process, and identify where your problem areas are. Further, you can do a full Six Sigma analysis that tells you what happened, why it happened, and what you need to do to eliminate it from happening again if it's not the desired outcome.

Ford: Think of the sheer power this brings back to people. Let's take your phone, for instance. There's going to be a design for that. And do you think you make it according to the design? No. People will come along and say, "Making one phone is not going to be very practical. We're going to put it on a board and make 16 of them at the same time. And we can't buy the material that you specified in the design in China, so we're going to buy something else." Does that mean it's the same size, footprint, or quality? Not necessarily. Then, you end up with phones in the market that have issues. Nobody knows if it was due to the design, materials, the change in manufacturing, etc. Now, you could find out.

With traceability data, in the past, you didn't want to capture anything beyond what was immediately specified for a specific need, because it cost you money; now, it's free because you're getting the data through CFX. The IPC-1782 traceability standard lays out where all of the data will come from, which can then even go back into your design tool to statistically analyze opportunities to improve the decisions you make for manufacturing.

Shaughnessy: Are you in beta with this?

Ford: Many companies are starting to work with this idea, but we're in the early stages of putting this together. We want to be sure that the standard itself is clearly defined because IPC is consensus-based. Many companies in the industry are already interested in this and want to make sure that we satisfy everybody's needs, so that's step one.

Shaughnessy: Are there any other hurdles you see ahead? Just organizing it seems like the biggest thing.

Carter: There are a few standards we would like to create a schema structure around so that we can eliminate that last group of notes that requires some sort of human interpretation and re-entry downstream. But beyond that, I don't think we have any big challenges from a technical perspective.

Ford: All of the standards have been developed using IPC guidelines, so they are quite compatible with each other. The terms and definitions are pretty close. And the people who we've presented this to understand it. They think it's amazing and should be pursued. In one year's time, we're going to be doing this.


Michael Ford

Shaughnessy: Do you think it will take off?

Ford: The benefits are there. We see the kind of turmoil going on in the world now where people need to do local, flexible manufacturing. They're losing sight and control of what they need to make day by day. They need digital solutions to be able to do that, but you can't afford to buy those solutions from 20 different vendors, and they're all incompatible. People are realizing that it's standards first, but don't take five years on it. Do it within the next few months. Let's get a handle on what we need to do because we need to get this value into manufacturing that's going to seize the maximum opportunity and get the most profit from all of the necessary relocations or reconfigurations of what they are going to go through.

Shaughnessy: This won't change the way a designer does their job, right?

Carter: It will give them a lot more visibility about what is going on with their product when it hits the factory floor.

Shaughnessy: It will create more communication between the designer and fabricator, which is almost nonexistent sometimes because designers often don't know where it's going to be fabricated. But this way, it will be bidirectional.

Ford: Yes. You can imagine the kind of frustration from a designer's point of view. They make the design that they think is absolutely perfect, and they review it with their peers. Six months later, they hear that there are problems in manufacturing and in the market. "You didn't do a very good job on that design." They might say, "It's not my fault. You're using materials that are completely different from what we specified. You're using machines that are incapable of producing that kind of board."

For the first time, the clarity is there. And it's presented to the designer in a way that they understand. Statistics tell the designer that this is something that needs to be changed to accommodate the use of different materials or processes; they don't need to understand materials or processes themselves, but they will understand the need, and that's what we bring back in terms of statistics so that their world is the same. But it's so much more valuable to have all of the information that designers need to make design decisions.

Shaughnessy: So, if the designer needs to look downstream and see what kind of material they switched to in Shenzhen, all of that will be brought back.

Carter: With the digital product model exchange, they should be able to model that upfront. The stackup exchange is one of the features we added to DPMX some time back. You'll be able to have that upfront negotiation and say, "These are my impedance requirements and edge rates, and this is the kind of product it is. What materials do you have in Shenzhen?" In the case of the actual materials that your contract manufacturer might be doing substitutes on, now, you have a way to collect the as-built conditions. For example, you could say, "Wait a minute; that one's not equivalent. It may have saved you a dime, but there's the root of the problem."

Shaughnessy: What are you going to call the combination? Is it going to have a name?

Ford: It's going to have an X in it. That's all we know at the moment (laughs)! We have CFX and DPMX, and we're putting together this as a whole digital manufacturing engine exchange. "X" means excellent and exchange.

Shaughnessy: And they'll be communicating whether they want to or not.

Ford: They're going to have to because manufacturing is changing. Instead of being six months of planning, it's six days. Getting information digitally and being able to snap your fingers and make things happen on different production lines and configurations and materials is the future; as a matter of fact, that's what's happening now. People can't click their fingers; they have to do it manually, which is a real cost for them. But this is essential for modern manufacturing. If people want to continue making progress with their customers and expanding their business, this is a necessity. You can't do it with human beings alone.

Shaughnessy: And it will bring designers into smart manufacturing. If you ask most designers what they think about smart manufacturing, they'll say that they don't have any thoughts on it. But if they start using this combination, that should change.

Ford: Yes. They're going to get a lot more enjoyment out of not having problems with any design, especially ones that are not their fault. And it will let them see any opportunities to improve.

Shaughnessy: It has been great talking to you. Thank you.

Carter: It's our pleasure.

Ford: Thank you for your time. **SMT007**

The Long Road to a New Standard

Feature Interview by Barry Matties
I-CONNECT007

Graham Naisbitt, chairman and CEO of Gen3 Systems, has spent decades leading cleanliness testing standards in a number of different standards organizations like IPC, IEC, and ISO around an assortment of testing methods, such as CAF, SIR, and even introducing a new standard this year for his own testing method—process ionic contamination testing (PICT). Naisbitt breaks down his long involvement with standards and where they stand currently.

Barry Matties: Please start by telling us about your company, Gen3 Systems.

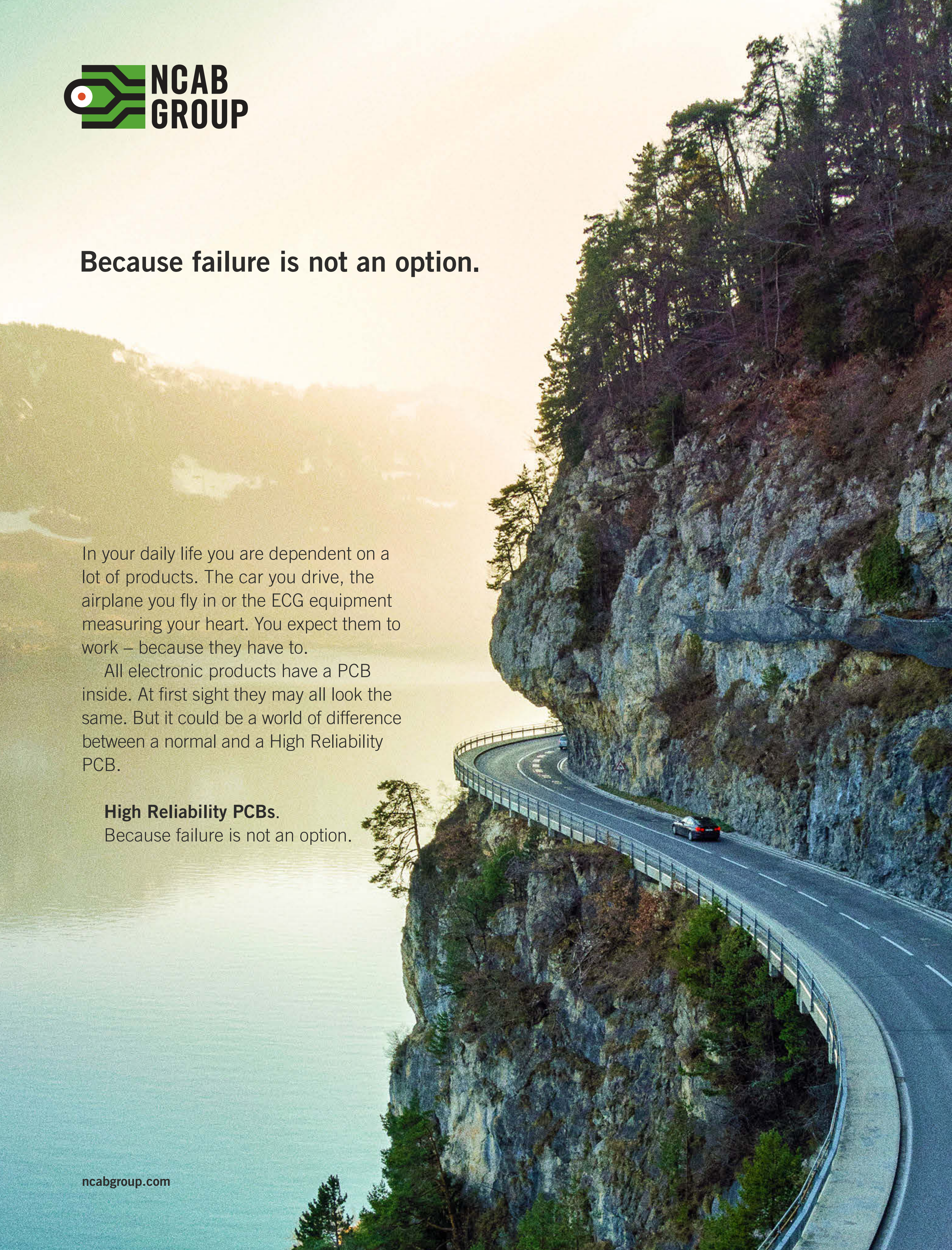
Graham Naisbitt: For nearly 40 years, we have designed, engineered, manufactured, and distributed our test and measurement equipment into the electronics industry. Back in 2009–2010, we lost 50% revenue overnight in the downturn. It was as though somebody flicked a switch. To bolster what we're doing in the U.K., looking for distribution of other people's products was a natural extension, so we lined up with two or three key players. Peter Marshall, who was the chairman of the SMART Group (a trade association in the U.K.), was at a crossroads. He had his own distribution business and wanted to retire. Peter and I came to an agreement, and I took over that business, which brought in additional distribution points.

Matties: As you told me earlier, there was one event that changed the course of your work.

Naisbitt: An important point for the industry was when Dr. Wally Rubin, who was then the technical director of a company called Multicore Solders, invented no-clean flux. Wow, that was a success. But how much longer that can continue has now come into question.

Matties: Are there some practical applications that need to be addressed?

Naisbitt: Absolutely. And it's fair to say that the vast majority of the industry is running successful no-clean processes, but it doesn't avoid the risks associated with electrochemi-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cal migration notably, which takes so many different forms.

Matties: And with HDI coming into a stronger play in the market, are we seeing more failures?

Naisbitt: Yes. That was why we became involved with the conformal coating because it helped to protect the circuitry. That was the first introduction I had into what makes electronic circuits reliable. That was the key feature of our business.

I became more involved at that point to figure out how to control the production process. One of the main elements of this is that all fluxes leave residues. Surface insulation resistance (SIR) testing was developed and used to try to evaluate whether it was acceptable or not when you were using a no-clean process. With a new process and test, then you need to develop the standards. In 2007, I finally managed to publish the first meaningful documents, which was the IPC test method, and coincidentally, the IEC standard. From there, we have developed even further. The issue came into play around 2010–2012 as the industry was migrating more into increased packaging density and insulation resistance testing became a necessity if you needed to establish product reliability.

But the question that kept coming back to me is how do you control a process? You can't use SIR testing because it takes too long and it's too cumbersome and complex. But what you can do is use that to establish a reliable production process, and then take it from there. You need to be able to measure any mobile ionic species left on the surface that can compromise performance because if you put electricity through a product in a damp environment—and you have ionics present as well as the perfect electrolytic cell—funny stuff happens.

During this time, there was some research into this subject, and a stake was stuck in the ground that said anything above 1.56 micrograms per centimeter squared of sodium chloride equivalent is bad and below is good. Now, unfortunately, the industry started without any hesitation to adopt the term "cleanliness testing," and it isn't. It never was.

Gen3's CM+ Series, the worlds first combined ROSE and PICT Ionic Contamination Tester.

The challenge is the simplified ion chromatograph test, aka ROSE testing, doesn't differentiate species; it simply looks at a value of conductivity of the solution as to whether or not it falls within acceptable limits. I have spent 25 years of my life trying to explain this to people. You have to stop thinking of it as a cleanliness test because it isn't, but it's an excellent method to control a process.

Around 2013, we received a call from Robert Bosch. They require Six Sigma for their production process. It's automotive electronics that are ultra-high reliability and safety-critical. We took on the project, and in five years of work, we achieved Six Sigma verification uniquely for the first time in the history of this entire subject. To do this, the instrument needs to be sufficiently capable of detecting changes in the process as fast as possible. We use a merit-to-fit algorithm. It means that we were able to give an accurate go/no-go answer within typically three to five minutes. What we're looking for are only those mobilizable ionic species. Cleanliness is something entirely different.

Matties: After your five years of work, the current pass-fail approach doesn't make sense as a standard. What was the response, and how do you carry that change in the standard process to the industry and get support?

Naisbitt: There are two answers to that. One, I'm silly.

Matties: That was a short answer (laughs).

Naisbitt: And the other reason is I'm stubborn. People ask, "Why are you recognized as world leaders in what you do at Gen3 Systems, which is just a small business located in Farnborough, England?" If I knock on a door as Graham with Gen3 Systems, I am turned away. But if I knock on that same door and say I'm the vice-chair or chair of the committee involved with this number, it opens doors. But who am I to change an industry standard that's been around since the 1970s? Especially when you have the entire industry saying to leave it alone until a company called Robert Bosch says, "Take that number out." After five years of effort, that's resulted in a fundamental change, the number has gone, and it was finally released to the industry in September/October of 2018.

Graham Naisbitt

Matties: One of the points that came from one of our recent expert meetings is the standards should be reviewed on a calendar basis.

Naisbitt: That's an interesting point.

Matties: These standards committees are all volunteer as well.

Naisbitt: They are all volunteered from companies concerned to be involved by topic. Trying to seek harmonization is a key factor, and that has been my endeavor over the last 20 years.

Matties: To that point, anybody with a horse in the race might have a different view and agenda, which could make finding the consensus amazingly challenging.

Naisbitt: At the end of last year, I was appointed the new vice-chair of the IPC 5-30 Clean Coating Subcommittee. Now, I have 15 different working groups reporting on those two topics, and SIR, CAF, and subsurface electric chemical migration are part of that portfolio. Therefore, we have a far better opportunity for harmonization to take out the disparities that may exist, and making sure that they do meet everybody's interests is a key part of that. Candidly, that's where IPC does a far better job.

Matties: When you brought the volumes of documentation from your Bosch work after those five years and said that the standard needed to be reconsidered and retooled, what was the process like?

Naisbitt: It was a fairly difficult environment to navigate through, but we've done so satisfactorily.

Matties: Was it because it was your organization saying, "Here's what we've done. We want a standard to benefit us." Is that how it was viewed?

Naisbitt: No, it was, "Here's what should be done if you're going to do this type of test and do it properly. This is what we recommend." Robert Bosch picked up on that and went through that five-year program to prove it. We did a joint publication at IPC APEX EXPO 2017. It's all public domain, so I'm perfectly at liberty to disclose stuff, but the barrier is trying to break down that understanding. Cleanliness is not a meaningful term.

Matties: That's not the measure that we should look at it.

Naisbitt: Correct. There have been instances when people have said the cleanliness test is superior and has to be superior to a cleaning process. That is never going to happen. It's simply a chemical mechanism that can determine whether or not there's been a change in your manufacturing process.

Matties: And it's an end-of-the-line test, and what you're talking about is process-step testing.

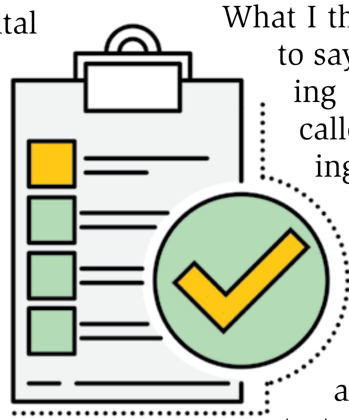
Naisbitt: It should be used correctly as a process, step by step; it shouldn't be done just at the end of the line.

Matties: As the cleanliness test is currently.

Naisbitt: Bingo. And that's where there are some problems that need to be addressed.

Matties: By the time you're at the end of the line, it's too late.

Naisbitt: Exactly. If you're making 1,500–2,000 circuits that go into a particular aircraft or spacecraft every year, it's easier, in some respects. But if you're producing that number every hour, that's a fundamental change of concept. We need to have a go/no-go answer as fast as possible.



Matties: At the earliest possible point.

Naisbitt: Right. So, the primary driver now is what else we could do that can determine acceptable conditions for a product to ship. All of the other techniques—such as ion chromatography, ROSE (resistivity of solvent extract) testing, which I hesitate to use that term, maybe even FTIR—are not able to evaluate the influence of non-ionic matter, which is a problem.

All of the research that we've been involved with for the last 25 years shows that modern-day chemistries include additives regarded in the broadest possible sense as surfactant additives. They're non-ionic, so they're not measurable nor detectable, and these additives are used for wetting or de-wetting depending on their application. To ensure that you can lower the surface energy of the material—such as solder fluxes as the primary objective at this stage—how do you get it to stick on the underside of a board if you don't have solids? You use these additives as wetting agents and have an excessive amount of liquid stuck on the ceiling above you. How does it stay there? Amazing! But then the problem is that all of this liquid has to be neutralized or dealt with.

And to that extent, it's not unusual to find the operator turning up the temperature to drive off these residues. However, with anything that gets hot tends to expand, the surface of a circuit board resembles a sponge. Now, you have trapped residue subsurface, which is an entirely separate issue. Insulation resistance testing on the subsurface was first conducted—based on my knowledge and all of the research that I've been involved with—by Laura Turbini, originally of the old AT&T Bell Labs.

The other task techniques then come into their own to identify what is there that's causing the problem. The two go hand in hand. What I then have to try and do—and I'd like to say that I've been successful in achieving it—is initiate a new test method called process ionic contamination testing (PICT). I've done it for one simple reason. ROSE testing has been around since the '70s and the industry is totally entrenched with it. I won't live long enough to see necessary changes, improvements, and enhancements made to the ROSE test and have it be acceptable to everybody. So, let's start again.

And as I said at a conference in Chicago in 2016, is a ROSE still a ROSE when it's PICT? That's what's happening. Now, our new CTO Emma Hudson is the vice-chair of the 5-32a (Ion Chromatography/Ionic Conductivity TG and 5-32c Bare Board Cleanliness Assessment TG). PICT displacing ROSE seems to be the logical development.

Matties: So, the standard for the chemical clean, like with Bosch, is there a new standard now? Is this being approved and adopted, or where is it in that process?

Naisbitt: With the input from a huge number of people, I've put together a document that has now been accepted by IEC. It has gone through all of the necessary approvals. Hopefully, it will be scheduled for publication at the end of this year.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Matties: It sounds like that standard will be adopted. How long was that process? Because you worked with Bosch for five years and tried to change that.

Naisbitt: Effectively, it was a three-year program to develop the test method following the five years taken to produce the required data.

Effectively, it was a three-year program to develop the test method following the five years taken to produce the required data.

Matties: If somebody is looking to drive a new standard, should they expect a three- to five-year window?

Naisbitt: Definitely.

Matties: That is not an easy task. What was the greatest challenge for you in that process?

Naisbitt: Making sure that the document was prepared correctly, accurately, and accepted and signed off by an international group representing every country that's a member of the World Trade Organization. Their national committee can shadow this. Each national committee may be many people strong. Then, they read through the document and proffer comments, which are different stages in the document development. The maintenance leader, which was me, has to address every single comment, recirculate it, and get approval and authorization to move it to the next stage. Only at that point can people say, "We have it correct now."

Once it gets to committee draft for voting, the only changes that can be then made to a document would be of an editorial nature, not technical. To get to that point, you have several iterations, and you have to know what you're doing. There was a huge learning curve for me and everyone involved.

Matties: You have to have a vested interest to begin a standard process. Otherwise, what's the point? But it should be met with some scrutiny because we need to be certain that this is purely technical and not just marketing.

Naisbitt: That's absolutely essential. Differentiating between the two is key.

Matties: The fact that you're driving technology testing and rethinking standards is great; it's a 25-year commitment to this process. What advice would you give to somebody who's starting on a mission to create a new standard?

Naisbitt: Take plenty of provisions with you (laughs). The best possible way is to identify the group most accessible to you, which in my experience, will be the trade associations that help support all of this work on an international level. I've been a member of IPC since 1988. They are incredibly approachable and each of us, in terms of the Technical Advisory Executive Committee (TAEC), have had a mandate from the board of directors to focus on encouraging young people to get involved in our industry and try and take on mentoring as far as we can. I have strongly pursued and supported that throughout most of my career.

We've engaged students from local colleges and universities. For example, our chief engineer, Bob Smith, is the best electronics engineer I've ever worked with; he's quite extraordinary. His depth of knowledge and understanding is immense. Bob is around 60, and the young man that's working alongside him is learning a ton. Share your enthusiasm with somebody. Get them involved and excited, and give them something to think about.

Matties: I appreciate you sharing your knowledge with us.

Naisbitt: Thank you. SMT007


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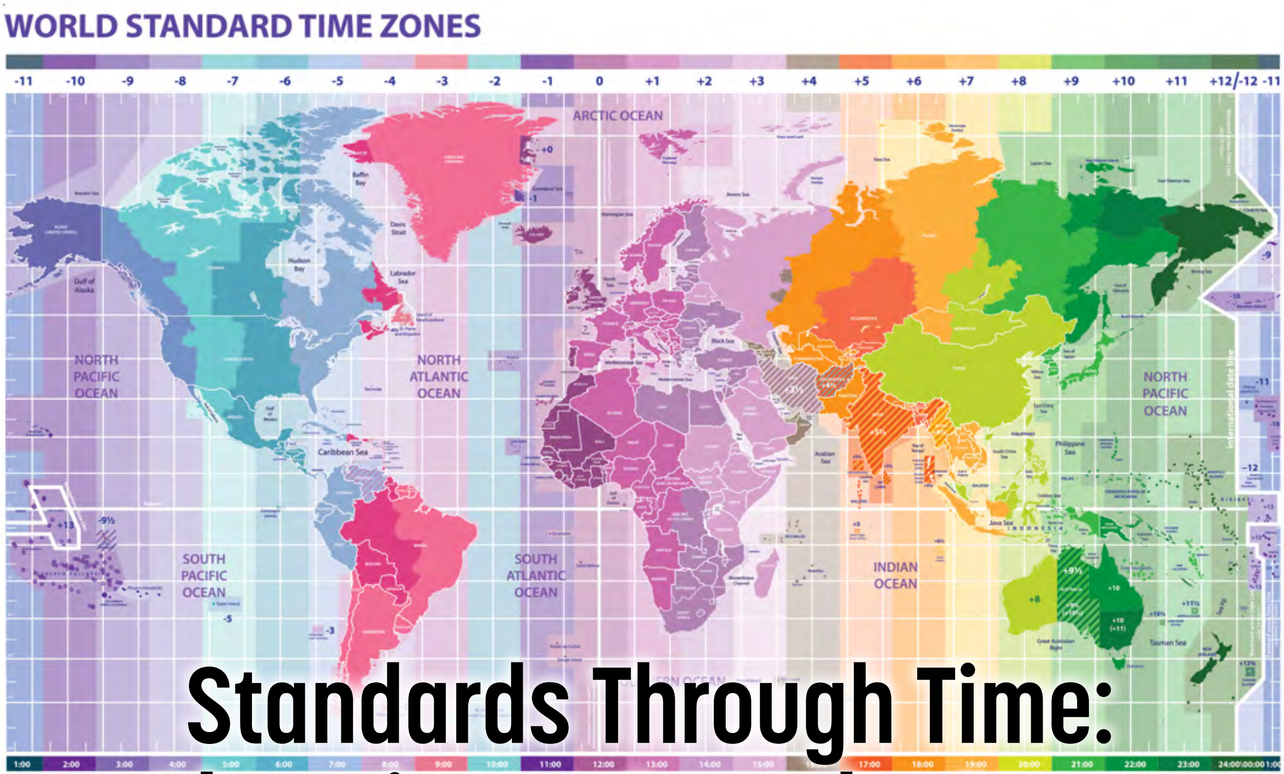

Standards Through Time: Changing to Stay the Same

Feature by Nolan Johnson
I-CONNECT007

The use of standards has, ultimately, propelled civilization forward. As the electronics manufacturing industry works to create, revise, update, and restructure standards, it helps to take a moment to review how standards, and the process of creating them, have occurred throughout history.

One dictionary [1] defines a standard as:

- Something considered by an authority or by general consent as a basis of comparison; an approved model
- An object that is regarded as the usual or most common size or form of its kind
- A rule or principle that is used as a basis of judgment
- An average or normal requirement, quality, level, grade, etc.

Time Is the Beginning

Humans kept time by the Moon and the seasons for many millennia. The Egyptians are credited with developing the first solar calendar in about 3000 B.C. [2]. Coincidentally, at about the same time, the Mayan long-count calendar begins. However, it is unclear whether the long-count calendar starts with the first day of the calendar or the beginning of the world in Mayan mythology [3]. Interestingly, Chinese legend suggests that Emperor Huangdi invented the Chinese solar calendar in 2637 B.C., which is also around the same time. Overall, humans began keeping solar calendars simultaneously on widely separated parts of the globe.

In general, solar calendars are based on precise astronomical observations and indicate the emergence both of mathematics, and of some form of record-keeping, whether written or otherwise. This is because a solar calendar fits almost, but not exactly, into the Earth's rotational timing. The Earth's spin is slightly faster than the orbital rotation (known as the tropical year) so that a solar orbit completes in 365 days, 5 hours, 48 minutes, and 46 seconds [4]. It's these fractional days that must be accounted for with leap days and other similar calendar adjustments.

Units of Measurement

Naturally, as humankind transitioned to agricultural societies, and trade routes were established, standards for measurement became important in wider and wider circles [5].

> "The earliest recorded systems of weights and measures originate in the third or fourth millennium B.C. Even the very earliest civilizations needed measurement for purposes of agriculture, construction, and trade. Early standard units might only have applied to a single community or small region with every area developing its own standards for lengths, areas, volumes, and masses. Often, such systems were closely tied to one field of use so that volume measures used, such as for dry grains, were unrelated to those for liquids with neither bearing any particular relationship to units of length used for measuring cloth or land. With the development of manufacturing technologies, and the growing importance of trade between communities and ultimately across the Earth, standardized weights and measures became critical. Starting in the 18th century, modernized, simplified, and uniform systems of weights and measures were developed with the fundamental units defined by ever more precise methods in the science of metrology. The discovery and application of electricity was one factor motivating the development of standardized internationally applicable units."

This trend to have local "flavors" of units of measurement is a common theme throughout history. For example, the yard (the introduction of which is unclear) was localized throughout Britain until it was standardized sometime after 1100 A.D. to be the distance from King Henry I's nose to the end of his thumb (or so the story goes). Other sources (from the reign of Edward I or II, around 1300 A.D.) suggest that "three grains of barley dry and round do make an inch," and that all other measurements of length build up from this reference length [6]. The imperial yard, however, goes on to play a key role in standards for length measurement.

In 1758, the legislature required the construction of a standard yard, which was made from the Royal Society's standard and was deposited with the clerk of the House of Commons; it was divided into feet, including one of the feet into inches, and one of the inches into tenths. A copy of it, but with upright cheeks between which other measuring rods could be placed, was made for the Exchequer for commercial use [7].

In 1760, this standard yard was certified as the "imperial standard yard" from which all other imperial units of measurement then were derived. Of note is the exacting specification applied to the definition of this yard standard [7]:

> "…the straight line or distance between the centres of the two points in the gold studs of the straight brass rod now in the custody of the Clerk of the House of Commons whereon the words and figures 'Standard Yard 1760' are engraved shall be and the same is hereby declared to be the original and genuine standard of that measure of length or lineal extension called a yard; and that the same straight line or distance between the centres of the said two points in the said gold studs in the said brass rod—the brass being at the temperature of 62 degrees by Fahrenheit's thermometer—shall be and is hereby denominated the imperial standard yard and shall be and is hereby declared to be the unit or only standard measure of extension, wherefrom or

whereby all other measures of extension whatsoever, whether the same be lineal, superficial or solid, shall be derived, computed and ascertained…"

Change and Constance, Simultaneously

In 1834, the primary imperial yard standard was partially destroyed by a fire in the British Parliament building. In 1838, a commission began the reconstruction of all the standards lost in the burning of Parliament. In 1845, using three previously existing secondary standards ("R.S. 46," which was kept by the Royal Astronomical Society, and "A1" and "A2," which had been made for the Ordnance Survey), a new primary yard standard was constructed [7]. Thankfully, all three secondary standards had recently been compared to the primary standard, making the process somewhat easier.

The commission's recommendation was that the new standard was to be "made of Baily's metal No. 4 consisting of 16 parts copper, 2.5 parts tin, and one part zinc. It was 38 inches long and one-inch square." Between 1845 and 1855, 40 different yard standard candidates were fabricated—one of which was ultimately selected as the new imperial standard. The Weights and Measures Act of 1855 granted official recognition to the new yard, amongst other reconstructed standards [7].

Four of the candidate standards—the Parliamentary Copies—were distributed to the Royal Mint, the Royal Observatory, the Houses of Parliament, and the Royal Society of London. The cities of London, Edinburgh, and Dublin each received a standard example, as did a number of foreign countries. However, the foreign copies are no longer considered full standards [7]; for example, the imperial standard received by the United States is known as "Bronze Yard No. 11." Further, "The Weights and Measures Act 1878 confirmed the status of the existing yard standard, mandated regular intercomparisons between the several yard standards and authorized the construction of one additional Parliamentary Copy (made in 1879 and known as Parliamentary Copy VI)."

Running Down the Rails

The almost-but-not-quite-true story persists that standard gauge railroad tracks have a direct lineage to Roman chariots. The story goes that railroad tracks were gauged to match existing horse wagon spacing, which then traces all the way back to the original wheel ruts cut by Roman chariots [8]. While not strictly true, myth does point out that similarities arise in part from sharing equipment between horse-drawn vehicles and the newly developed railroads. It should be noted, however, that a variety of track gauges have been, and continue to be, in existence.

Looking to American history, for example, one reason often cited for the ultimate failure of the Confederate cause was that the Confederate States had not been successful in standardizing the railroad gauge throughout the region. With 113 different railroad companies and three different track gauges, the South was hampered in setting up workable supply lines. The Union States in the north, however, had already reached a standard agreement, allowing rail cars to travel easily anywhere on the rail network. This standard helped win the U.S. Civil War [8].

Time Zones

The concept of noon is entirely local to the place where you are. Solar noon, it can be argued, is the source idea for midday. Solar noon is the moment in time when the sun reaches its highest point (celestial meridian) in the sky. Naturally, solar noon is a function of one's longitude and the time of year. When travel meant moving no faster than a horse could run, time could be localized from

The Prague Astronomicol Clock is a medieval clock built in 1410 in the Czech Republic.

town to town without consequence. Advances in transportation, however, created a need for time standards [9].

> "Prior to the late 19th century, timekeeping was a purely local phenomenon. Each town would set their clocks to noon when the sun reached its zenith each day. A clockmaker or town clock would be the 'official' time, and the citizens would set their pocket watches and clocks to the time of the town. Enterprising citizens would offer their services as mobile clock setters, carrying a watch with the accurate time to adjust the clocks in customer's homes on a weekly basis. Travel between cities meant having to change one's pocket watch upon arrival."

With the advent of the railroads, in particular, standard time became crucial to the efficient and safe operation of the railroads from station to station. In 1878, Canadian Sir Sandford Fleming introduced the global time zone system we use today. As Rosenberg writes [9], "Sir Fleming's time zones were heralded as a brilliant solution to a chaotic problem worldwide." Of course, the maritime trades had been using longitude-by-Chronometer techniques since the early 1700s when John Harrison developed the H-4 chronometer as the first marine timekeeping device accurate enough to use for navigation.

While standard time noon might be perceived as a relaxing of the standard for actual solar noon, the overall benefits of consistency are generally much more useful than a strict astronomical interpretation of noon, which leads us to standards that shift over time.

Standards That Drift

Even the greatest attempts at creating stable, consistent standards can face challenges with change over time. For example, recall that the British Weights and Measures Act of 1878 required periodic checks of all copies against the standard. It's a good thing too, as those mandated regular intercomparisons revealed that the yard standard and its copies were shrinking "at the rate of one part per million every twenty years due to the gradual release of strain incurred during the fabrication process [9]."

The international prototype meter was comparatively stable, however. A great deal of preventative work had been done before the Metre Convention (1875) to ensure a standard as consistent at possible at the time [10].

> "The bars were to be made of a special alloy—90% platinum and 10% iridium—which is significantly harder than pure platinum, and have a special X-shaped Tresca-style cross to minimise the effects of torsional strain during length comparisons. The first castings proved unsatisfactory, and the job was given to the London firm of Johnson Matthey who succeeded in producing 30 bars to the required specification. One of these—No. 6—was determined to be identical in length to the Mètre des Archives and was consecrated as the international prototype metre at the first meeting of the CGPM in 1889. The other bars, duly calibrated against the international prototype, were distributed to the signatory nations of the Metre Convention for use as national standards. For example, the United States received No. 27 with a calibrated length of 0.9999984 m ±0.2 µm (1.6 µm short of the international prototype)."

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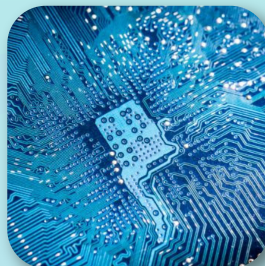

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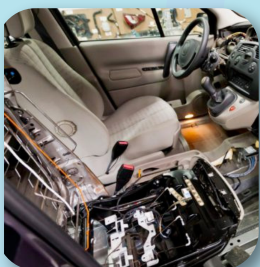

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A measurement made in 1895 determined the length of the meter at 39.370113 inches relative to the imperial standard yard. The Weights and Measures (Metric) Act of 1897 in conjunction with Order in Council 411 (1898) made this relationship official. After 1898, the de facto legal definition of the yard came to be accepted as 36/39.370113 of a meter [7].

The yard (known as the "international yard" in the United States) was legally defined to be exactly 0.9144 meters in 1959 under an agreement in 1959 between Australia, Canada, New Zealand, South Africa, the United Kingdom, and the United States. In the U.K., the provisions of the treaty were ratified by the Weights and Measures Act of 1963. The Imperial Standard Yard of 1855 was renamed the United Kingdom Primary Standard Yard and retained its official status as the national prototype yard [7].

Standardization Resistance

Of course, changes to standards can be the subject of resistance too. Spelling reform for the English language, for example, has been proposed multiple times over the past few centuries. But even though spelling reform could bring "quicker, cheaper learning, thus making English more useful [internationally]," spelling reform has only "rarely attracted widespread public support, and has sometimes met organized resistance" [11].

American Noah Webster is widely considered to be the publisher of the first English language dictionary, and it's worth noting that his first edition (1806) included an essay which proposed spelling reform. By the 1828 edition, Webster's proposed spelling reforms were slowly becoming the American standard [12].

Of course, there are also a few countries that have yet to officially transition to the metric system—the United States being perhaps the most stalwart and complete it its resistance. It has been pointed out the irony that the imperial system the U.S. continues to maintain is now officially defined in relation to the metric system standards.

Conclusion

Unless a standard is defined by royal or government edict, standards are generally best when reached through meticulous consensus. Loosening local time constraints to allow for standardized time zones improve transportation, saved lives, and simplified communication and measurement. Creating physical reference standards regularly pushed manufacturing skills forward. That pre-existing processes and de facto standards can be preserved in later iterations of a standard. And the fact that measurement standards continue to evolve with changes and technological advances being instituted to—quite paradoxically—keep things the same.

For all of the imperfections we may see in the process of reaching consensus and defining and implementing a method and enforcing a standard, the standards process has worked in similar ways throughout history. **SMT007**

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Reliability by the Book

Quest for Reliability

Feature Column by Eric Camden, FORESITE INC.

Standards have been around in the industry as long as the industry itself. But if they are followed, does that mean that you'll have improved reliability? The answer is a famous one in certain circles; it depends on a few things, such as the product's intended use and warranty. If you are building something that must work only as it leaves the facility and is considered a Class I product, then reliability isn't something you need to worry about. But having been in electronics for just shy of 20 years, I can say that the next time we work on a Class I failure analysis project, it will pretty much be the first. Class I electronics serve a different purpose in life, and if they fail, it's normally not a big deal; instead, it's mainly a minor inconvenience. In this month's column, I'll speak to specifications for Class I, II, and III products per IPC definitions as well as the IPC standards process.

Class I, II, and III

The low-cost materials and disposable nature of Class I products basically preclude them from ever being labeled as high-reliability. Within IPC guidelines for Class I, the assembly guidelines are very different than Class II or Class III. This isn't necessarily a knock on Class I products by any means. IPC's definition for Class I is "includes products suitable for applications where the major requirement is the function of the completed assembly." There's not a single word about reliability or critical nature of their intended use.

	IPC Class I	IPC Class II	IPC Class III
Category:	General electronics	Dedicated service electronics	High-reliability electronics
Life cycle:	Short	Long	Extended
Quality:	Low	Good	Dependable
Product examples:	Toys	Laptops	Medical devices

This simplified chart outlines the three IPC product classifications.

Class II is defined as dedicated service electronic products, which "includes products where continued performance and extended life is required, and for which uninterrupted service is desired but not critical. Typically, the end-use environment would not cause failures." Class II products would be found in a lot of automotive electronics, not related to safety, as well as harsh environment electronics that may not necessarily be life-critical but are expected to operate for 20+ years.

Class III is defined as "products where continued high performance or performance-on-demand is critical, equipment downtime cannot be tolerated, the end-use environment may be uncommonly harsh, and the equipment must function when required, such as life support or other critical systems." These electronics are most commonly found in industries like healthcare and aerospace. When your life, or the life of others, is on the line, Class I simply won't do.

These electronics are most commonly found in industries like healthcare and aerospace. When your life, or the life of others, is on the line, Class I simply won't do.

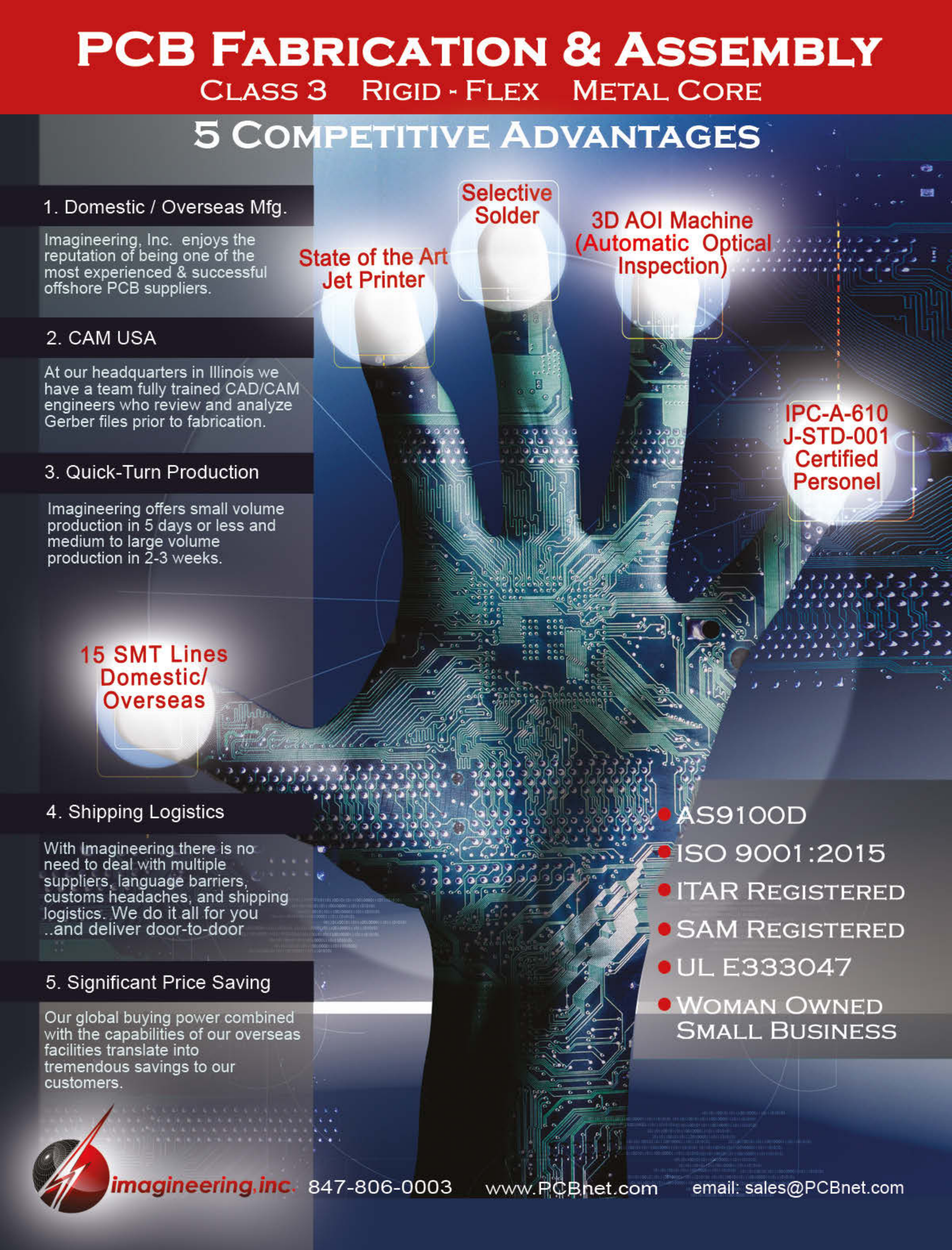
The standards for assembling Class II and III are well known with IPC J-STD-001 being the cornerstone of the J-STD series of standards. J-STD-001 is titled "Requirements for Soldered Electrical and Electronic Assemblies," which covers a lot of ground. The Technical Activities Executive Committee (TAEC) says, among other things, that standards should focus on the end-use environment, not tell you how to make something. That last part is very important to remember because standards aren't the full recipe necessary to build electronics; they should be considered a guideline to reference when there is uncertainty on how to do some part of the process. The order of precedent on any drawing should be as agreed between the user and the supplier and standards like J-STD. This helps to drive home the point that IPC standards are not necessarily the final word on how to build a PCBA, but should be used as a companion to the demands of the customers.

IPC Standards Process

IPC standards are nearly ubiquitous these days on most all assemblies, which is a good thing. IPC standards are written, and constantly rewritten, by some of the best minds in the industry, and me. Seriously, they will let literally anyone come to the task group meetings and have some input on what the next revision should look like. 5-22A J-STD-001 is one of the largest task groups of the many focused ones, such as the 7-31B IPC-A-610 Task Group; it's one of the few meetings that lasts all day, including a review of how it plays with other standards on a different day. It's tied to training, and there is another task group for J-STD on how to teach the class and what updates within J-STD-001 will impact that training. What I am getting at is that it's a big undertaking.

One of the things I appreciate about the standards process within IPC is the fact that most are constantly being reviewed to react to changes within the electronics industry. This is of the utmost importance when you think about changes spurred by things like the required implementation of lead-free solder or trying to keep up with miniaturization. This requires reviewing and updating the assembly process that needs to be reflected in the standards, which is why it's so necessary to meet face-to-face during the year to make sure everything is being covered.

The latest update to J-STD is a great example of how the standards are ever-evolving for the betterment of the industry. A cleanliness standard that was initially a military standard in the 1970s and then adopted by IPC was written into a lot of product drawing requirements. This is the resistivity of solvent extract



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CLASS 3 RIGID - FLEX METAL CORE
5 COMPETITIVE ADVANTAGES
1. Domestic / Overseas Mfg.
Imagineering, Inc. enjoys the reputation of being one of the most experienced & successful offshore PCB suppliers.
2. CAM USA
At our headquarters in Illinois we have a team fully trained CAD/CAM engineers who review and analyze Gerber files prior to fabrication.
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Imagineering offers small volume production in 5 days or less and medium to large volume production in 2-3 weeks.
4. Shipping Logistics
With Imagineering there is no need to deal with multiple suppliers, language barriers, customs headaches, and shipping logistics. We do it all for you ..and deliver door-to-door
5. Significant Price Saving
Our global buying power combined with the capabilities of our overseas facilities translate into tremendous savings to our customers.
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3D AOI Machine (Automatic Optical Inspection)
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test that at one point was a good test for monitoring for gross changes in the process. The test was used, and abused, over time for process qualification when that was never the intent.

Recently, J-STD was updated to include better analysis recommendations for process qualification while leaving the option to continue using the ROSE test if you have historical data showing that it is effective for the purpose for which you are using it. Basically, if it ain't broke, don't fix it. But the fact the industry recognized that the test was no longer enough for qualifying today's materials and component styles is proof that people within the industry are taking ownership of their processes and not simply relying on historical testing protocols that worked 20 years ago.

Conclusion

The best thing about standards is the fact that they will always be second to what is agreed upon between the user and the supplier. Nobody knows more about your product than you do, but in lieu of internal specifications, industry standards are a great option. They are all written by companies that require reliability as part of their standard, so you can expect the same. SMT007

Eric Camden is a lead investigator at Foresite Inc. To read past columns or contact Camden, click here.

Photovoltaic Technology to Power Synaptic- and Neuronal-like Devices

Neuromorphic engineering—developing devices that mimic the brain structures' functioning—is an emerging field of research that has the potential to produce a change of paradigm in computing, signal processing, and artificial neuroscience. Since energy efficiency and autonomy are critical aspects of the development of these systems, the implementation of self-powering through sunlight is being explored.

A review of the latest progress in photo-neuromorphic electronics by Dr. Amador Pérez-Tomás of the Catalan Institute of Nanoscience and Nanotechnology (ICN2) Oxide Nanophysics Group has been published in *Advanced Materials Interfaces*. The report focuses on the application of a specific category of materials—functional oxide thin films—for photovoltaic neuromorphic systems production.

The development of more powerful computers and artificial intelligence systems is facing an important limitation given by their energy consumption. The diffusion of these technologies, which have great potential for better internet of things (IoT) implementation, requires the devices of the future to be self-powered and able to harvest light, kinetic, electromagnetic, or thermal energy.

The inspiration for new research lines comes more and more from the human brain, which is able to process many data in parallel at very low cost. Implementing the computing capability of a human brain with an artificial neural network built with silicon CMOS technology is evidently not viable; thus, new neuromorphic or synaptic electronic structures are being developed with the aim to design devices having the learning and adaptive capabilities of biological brains.

According to the review, photovoltaic technology could be employed in these systems to make them self-powered and energetically efficient. Oxide thin films are good candidates for neuromorphic devices self-sustainment. The paper provides a thorough overview of some of the recent functional oxide-based advances for these applications, envisioning the future design of self-powered photo-neuromorphic systems. However, extensive R&D is needed to reach this objective.

(Source: ICN2)

Feature Interview by the I-Connect007 Editorial Team

Standards are a community and governmental process, if you will, formalizing methods and techniques to allow for consistency and repeatability across the industry. Thus, there are many participants in the standards definition processes from individual volunteers to corporations to industry organizations—all participate in the standards processes in some way.

I-Connect007 reached out to representatives from several organizations and talked with them about how they participate in the standards process. Along the way, these conversations clarify which group does what, how they all work together as well as clarify and dispel a couple of industry myths.

Join us for some interview excerpts from IPC's Dave Bergman, iNEMI's Marc Benowitz, and NextFlex executives Scott Miller and Wilfried Bair.

IPC Continues Global Standards Initiatives

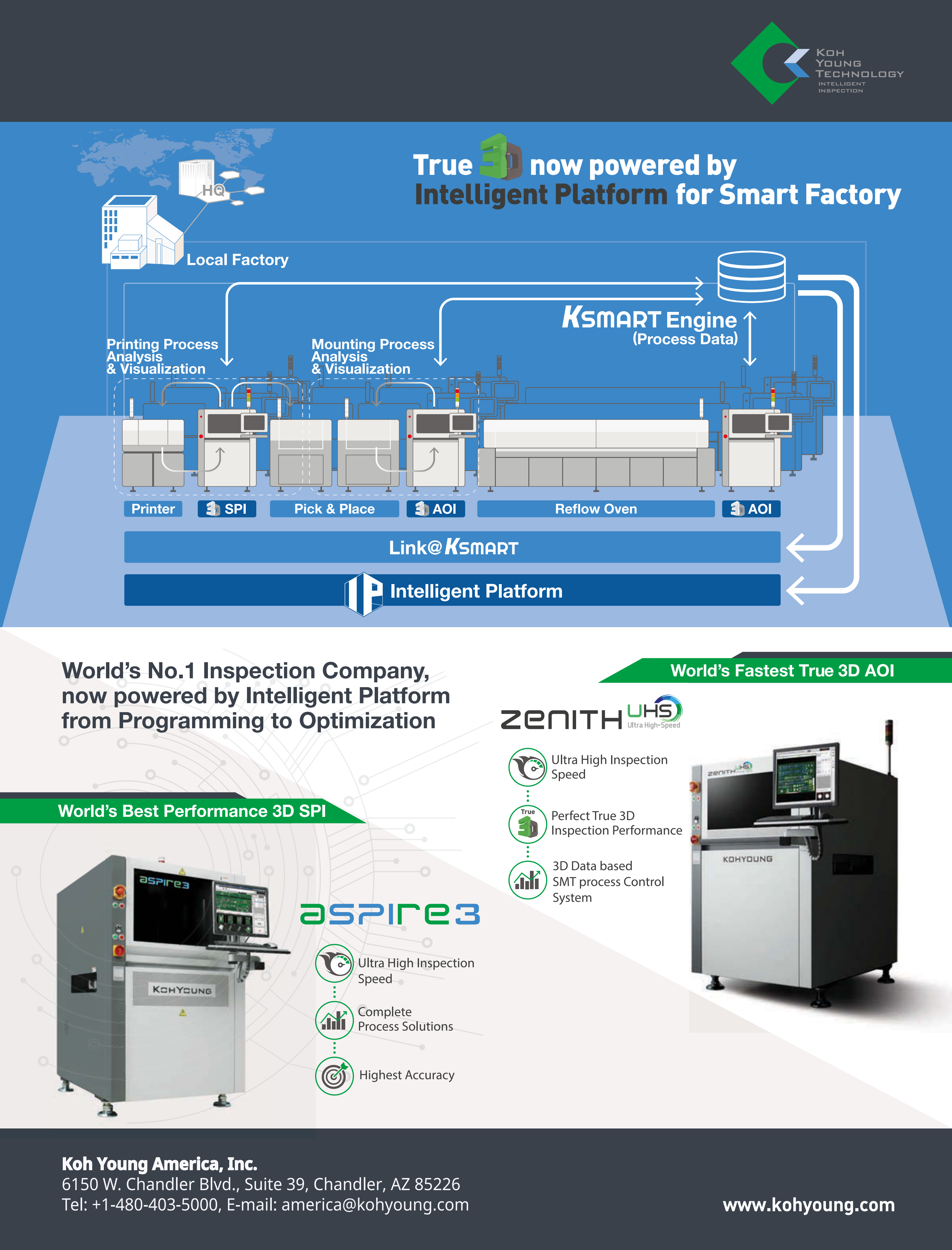
Dave Bergman, IPC VP of standards and technology, gives an update on the current state of IPC's global development standards activity with new standards growth in industries—such as printed electronics for e-textiles and wire harnesses—as well as continued growth for IPC's connected factory exchange and automotive standards.

Nolan Johnson: Dave, what's your role with IPC?

Dave Bergman: I've been with IPC for 39 years. Currently, I am responsible for our global standards activity, our events at IPC APEX EXPO, and our IPC India office. I'm also involved with some co-team European activity with Sanjay Huprikar, IPC VP of solutions.

Johnson: Let's start out with an overview of IPC and standards. What's the mission?

Bergman: IPC has been involved in standardization since 1959, and we have continued to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Dave Bergman

develop from that. At our core, we focus on four areas encompassing electronics manufacturing and a little bit in general electronics. We start out at the design of the PCB, then move to the materials and fabrication—including the acceptance of PCB materials—as well as the assembly area—such as the materials, equipment involved, workmanship of the assembly product, and associated rework and modification of both board and assemblies.

As of January of this year, we have a tighter affiliation agreement with the Wire Harness Manufacturers Association (WHMA), and I also serve as executive director of WHMA. That is a reflection of a long collaboration between the two associations in the wire harness arena. We have a workmanship standard on wire harness as well as some design documents. We were looking to expand that in support of some of the automotive efforts we're pursuing.

We develop standards for enclosure work and the component area, particularly as it supports electronics assembly manufacturing. And we have become involved in some corporate social responsibility, particularly with our standardization in China. We have a series of data standards that support companies if they have to report either conflict minerals or material safety concerns, such as Restriction of Hazardous Substances (RoHS) and Registration, Evaluation, Authorization, and Restriction of Chemicals (REACH).

Johnson: With such a long history in standards with IPC, a lot of things have evolved and changed over the years. Right now, what does IPC see as the most strategic places to be doing standards work right now?

Bergman: We have a core of standards, and the industry expects our core to be well-supported. I would consider our core activities to be the long-time offering and most popular standards. We have IPC-A-600 for printed board acceptability and the specification for PCBs (IPC-6012). For electronics assembly, we have IPC-A-610 for assembly workmanship, J-STD-001 for soldering, and IPC/WHMA-A-620 for wire harness workmanship in addition to IPC-7711/21 for rework and repair of PCBs and PCBAs. We continue to support those with training and certification programs, and they are heavily used globally by the industry.

If you look to the ones we are working on, they're not closer to leading-edge but are strategic in supporting the industry and fall into a few categories. For Industry 4.0, we are putting significant effort toward supporting companies assembling in smart manufacturing modes. The standard that we have for that is the IPC-2591, Connected Factory Exchange (CFX), which was released in the spring.

IPC-2591/CFX is intended to be a common set of messages that will allow plug-and-play for manufacturing lines. We figured that IPC-2591, v. 1.0, would get the industry to 85% usefulness, and then we could start adding to the standard from there once companies started working on the implementation of v. 1.0. We expect v. 1.1 to come out Q4 of this year. The industry is currently in the process of implementing it; equipment manufacturers are committing to their roadmaps for implementation, and we are actively updating the standard with various versions.

We also cooperate with an industry consortium called The Hermes Standard Initiative, which is a group of companies that developed a digital machine-to-machine interface standard. Their intent was to replace some of the hard wire standardization that was called the IPC-9851 SMEMA standards. The Hermes Initiative document, which we designated IPC-HERMES-9852, is what some have called "digital SMEMA." Hermes is mostly line control; it's not going to get you to Industry 4.0 smart factory, but it has some unique features that we felt were important to support as an industry association.

For the PCB side, we have IPC-2581. Essentially, it's a data file that completely identifies the assembly. If you're sending this file, there shouldn't be a lot of back-and-forth communication between you and your supplier. We've had some demonstrations with complex assemblies showing that you can manufacture a complex multilayer board with a single IPC-2581-format data file.

From the technology side, e-textiles is a hot topic we have been working for a few years. IPC will release the first standard for e-textiles—IPC-8921—in Q4. IPC-8921 covers woven and knitted e-textiles materials. We are also working on a guideline for connections for e-textiles—a design standard for printed electronics e-textiles and standards for e-textiles for wearable applications (e.g., medical, sports, health monitoring, personal protective equipment). This is an active area for IPC, and we are engaging the e-textiles industry to continue progress.

For the automotive area, we have a couple of different efforts that support market segments. We've done a number of activities in support of space and aerospace for some of our standards. We've been active in supporting the automotive industry—initially their needs for high-reliability, low-cost products in the PCB area. We started out with an addendum to IPC-6012. We then moved into a draft document, which we hope will be released by the end of this year for press-fit pins in press-fit pin applications for use in printing circuit boards. We have an active group in that area.

In assembly and soldering, by IPC APEX EXPO 2020, we expect to release an addendum document that will customize two of our most popular standards—IPC-A-610 and J-STD-001—for the automotive industry. We've had some influential automotive companies, such as Bosch and Continental, participating, and I'm looking forward to seeing that release next year. And because of our collaboration in the wire harness area and WHMA, we are looking at wire harness standards that support electric mobility and electric vehicles. We have an initial effort being kicked off that's intended for wire harness for high-voltage applications, so that's another new activity.

The last activity to mention is that for data transfer, materials declaration, REACH, and conflict minerals, we have a series of standards for in the IPC-175X series that address companies' needs for data transfer in the electronics manufacturing space. We have an active group of companies helping to make it easier to collect and report on the information that the supply chain is requesting. There's no lack of activity. And by the way, most of these efforts are European-led global efforts with the chairs and leadership mostly from Europe.

Johnson: That's a large list. I was going to ask you how active the standards definition process currently is at IPC, and after going through that list with you, it has to be incredibly active.

Bergman: Yes, we have an active group. We've been challenged for years to find a way to become relevant to the automotive industry; it's not from lack of trying. Right now, we have a stable staff with 11 technical department employees at headquarters in the Chicago area. We also have more than 200 committees and task groups. We currently have 41 standards projects in the pipeline as well as 44 translation projects that are being worked on. All of that is supported by our standards team based out of Chicago.

Yes, we have an active group. We struggled for years to find a way to become relevant to the automotive industry; it's not from lack of trying.

In Europe, we have one staff member supporting some of the European-led efforts, and he's based in Estonia. That works very effectively for us. As we have more European-led committees, we will add additional staff there. In China, we have three staff members located in different cities. They currently have almost 30 active projects and 350 volunteers. If we count up the volunteers that are on IPC committees globally, there are about 2,800 active participants.

And in China, we've had continued growth. Companies have been more actively engaged in global standards efforts, and I have been spending time encouraging local participation. We have six standards that were brought up by, approved, and are being actively led by IPC member companies in China. And that runs anywhere from the corporate social responsibility where they already published to active standards currently under consideration for high-speed rail. There are some fascinating and exciting standards being actively worked on by our members in China.

It has been IPC's goal to be a global standards organization. It doesn't matter to me one bit where standards are developed, only that we have a global consensus when they're finished. Most of our standards, because of our committee structure in history, have been U.S.-initiated, but that's changing as we've grown in other areas and have continued to encourage and cultivate standards development in other areas.

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Johnson: It's interesting to imagine how wiring harness standards connect up with technologies like e-textiles. Some of these products start to touch each other developing into a larger, system-based environment.

Bergman: Right. I attended the last WHMA meeting and met an exhibitor. I asked what his company did, and he said, "We make fine wires, and we're looking for applications for these fine wires." I asked if he would look into our e-textiles efforts, so we matched him up with a couple of the committee activities. There are technologies and standards activities that complement each other.

Johnson: CFX is not only a powerful standard for our industry at this time, but its development and release was particularly fast compared to what people typically think with respect to standards. It made a great case for companies collaborating rather than protecting in an otherwise competitive environment. Do you see more of that going on with standards?

Bergman: As fast as it was, it took longer than anticipated because we had some early missteps. The process could have been faster, but we encountered a dead end and had to redirect. We also spent a lot of time debating the right solution and future-proofing the solution.

CFX is not Industry 4.0, but it is the foundation of Industry 4.0. Once you know your machines can all speak the same language, then the magic can happen. What can your AOI solder paste inspection machine communicate back to your solder paste printer? What can then be changed based on what feedback it's getting? You have to be able to pass the messages if you're trying to connect machines from different suppliers. That's simply where the marketplace had to go.

At first, I never expected the equipment manufacturers would have such a high level of interest in collaborating, but that's what the customer wants. The customer has stated pretty clearly that they want a line that can be made from different vendors' machines, and they'd like it to be plug-and-play. So, that's the message that was delivered.

When we had our meeting in Las Vegas, I walked into a cramped meeting room, and everybody was in business suits. I saw the chairman of IPC's board along with senior management from about 80% of the equipment manufacturers in the world. My response was, "Wow. This is serious."

The group debated a series of formats and spent at least a year talking about a format. When your machines can all talk to each other, the next concern is going to be, "What about security? I don't want my line hacked, or my information shared over the internet." So, we picked a protocol that's one of the most secure available—the same format that the banking industry used. Still, there was a lot of debate because this would be a series of choices that we would make in support of electronics manufacturing. We chose the most secure one in the end.

We wanted to choose methods that could go machine-to-machine and yet weren't completely tied to a single broker so that it was flexible. We had a significant donation from one of the industry software providers who created a software developer kit (SDK) that lowered the barrier of effort for companies to get the messages from their machines into CFX. That SDK was probably one of the most significant efforts in reducing the amount of time needed to get CFX to market. The IPC CFX SDK is available for free on Github.

Our intent for this was to look at the surface-mount manufacturing process; it's what we had in mind when we were working on CFX. But as other industries have seen our approach, they have reached out, commenting, "I could use CFX for metals forming. And you could find a way of creating messages to build automobiles with CFX given the right set of time and messages." What I'm looking forward to is seeing the implementation of how the smart factory comes to life on the foundation that CFX forms. I can tell you that there are several active implementations happening.

Johnson: That's exactly why it seems to be a model. I'm picking up from you that there's similar momentum going on with automotive?

Bergman: With the automotive side, there are multiple efforts and different technology segments with three or four committees. CFX is a single committee with subcommittees and task groups. In the automotive efforts, though, we have a PCB group, press-fit pins group, an assembly group, and a wire harness group, reaching across all of IPC's manufacturing areas. There's some commonality of leadership, but it's not a single committee driving it. Certainly, the energy is there, and seeing the success has led to additional successes. There is interest in supporting electric vehicles. There's also interest in pushing more data, particularly within the trucking and agriculture industries. They have to know where the trucks are at all times, so the data requirements are increasing.

Johnson: What's clear is that CFX is an infrastructure project—a conduit for communication to enable facilities to improve their capabilities, consistency, throughput, and yields. Meanwhile, the challenge from automotive for our industry is an application project. The need is to improve our yields by orders of magnitude to deliver the kind of reliability that automotive requires for electric vehicles and autonomous cars. I'm getting the feeling from you that there is that same sort of interest and momentum—a "let's get this done" attitude—in automotive.

In some of our existing standards, we've had active participation from the aerospace industry.

Bergman: In some of our existing standards, we've had active participation from the aerospace industry. The automotive industry is looking for the same amount of reliability, but with less cost. They want to reduce the testing and still maintain the quality requirements and expectations. And for the assembly side, automotive wants to allow for components that may not be ready for acceptance by the aerospace industry. There are some process validation requirements in the assembly addendum to address that.

Johnson: Do you feel like the standards environment has changed?

Bergman: There have always been ebbs and flows. Often, standards have been a reaction to industry problems; you see a failure, so you go back in time. We became involved in measles—thermally-related voids being seen in PCBs—back when the industry was having trouble with them. We did round-robin testing in PCB manufacturing that drove requirements on inner plane separation, barrel cracking, and resin recession, which still exist today. Those actions came out of some of IPC round-robin testing that took place in the '80s. We also did round-robin testing small-diameter plated through-hole (PTH) reliability and aspect ratios that support PCB activity.

We've attempted to support other markets too. We did one guideline standard for optoelectronics, and then that industry crashed and disappeared. It's not to say that optoelectronics is not still important, but it's not what it was. We also did some things in fiber, and we respond as the industry has an interest. With automotive and e-textiles, the growth has been more of an active staff initiative to pull together audiences,

With automotive and e-textiles, the growth has been more of an active staff initiative to pull together audiences, which has been successful.

which has been successful. And CFX would be an example of an industry pull. Typically, you gather a group of people together and provide some oil to the gears to make sure everything moves smoothly, but it depends. I don't see that the process has changed, necessarily.

At IPC, we are engaging the global industry so that standards are not perceived as a U.S. push. I'm happy to be a U.S.-based association, but we're a global standards development organization. I don't want to hear somebody saying, "IPC standards are all U.S. standards," because they aren't. Becoming more global is a continuing effort, and each new standard that was not initiated by the U.S. helps the cause.

People have less time to participate in standards development, and we also have an aging workforce in the U.S., which is reflected in our committees. So, we're trying to capture that and maintain their resources and experience while investing in the next generation through our Emerging Engineer Program and engaging future leaders.

Further, we implemented a series of programs to improve the overall standards effort. The goal is to both accelerate and reduce the overall time required to create an IPC standard. We worked on a series of initiatives or techniques that reduced wasted time and effort. I don't want to create a process so that someone can't participate. I want to preserve openness and due process, but I also want to create a process where people feel that their time is respected and valued.

We have A-teams in place that do triage on comments, make recommendations to the committee, and facilitate tasks. As a result, I can have a dedicated group of 6–10 people invest more of their hours, which then saves the time of 180 other people. Overall, IPC's impact on the industry time is significantly less even though IPC is leaning on a smaller group of individuals. There's a continuing effort to maximize the end result and impact from fewer people in less time while ensuring that people are not cut out of the process. The IPC/WHMA-A-620 group, which is the collaboration between IPC and WHMA on wire harness, is one of our most shining examples of how the A-team can be used effectively to help achieve updates to standards in a shortened timeframe where everybody is able to have their voice heard.

iNEMI Plays a Supporting Role in Standards Creation

iNEMI CEO Marc Benowitz draws a clear line on iNEMI's involvement with standards—they

are not a standards organization. They do, however, work closely with many electronics standards organizations and provide input to help create standards.

Nolan Johnson: How does iNEMI view standards, and what's strategically important?

Marc Benowitz: To be clear and avoid any misinterpretation, iNEMI is not a standards organization. We don't publish standards, though our projects and activities connect to standards in a number of ways. We complement and have a good partnership with standards organizations and often get involved on the front end of standards development.

Johnson: I am intrigued by how iNEMI functions in the support role.

Benowitz: That's probably the way we most often act in standards. iNEMI operates through our membership and the industry at large to identify some of the key gaps and needs that are candidates for collaborative work. We do this partly through our roadmap, which looks out 10 years in the electronics manufacturing arena across multiple technologies, ranging from board assembly to electronics packaging, sustainability, etc. The roadmap then identifies gaps, which often lead to iNEMI projects. Again, the members determine which projects we will pursue, and some of them end up having a standards component.

iNEMI operates through our membership and the industry at large to identify some of the key gaps and needs that are candidates for collaborative work.

As an example, go back a few years to the implementation of RoHS. There was a lot of angst over the issue of tin whiskers. iNEMI had a tin whiskers task force that developed mitigation techniques that were eventually integrated into standards related to tin whiskers.


Marc Benowitz

Right now, there's a project in the early stages of development that's getting a good amount of industry support around back-end packaging. If you look at electronics manufacturing processes, you have wafer fabrication upfront, packaging, board assembly, system-level assembly, etc. The front-end is a structured, well-aligned process.

Moving to back-end packaging, there's a lot more uniqueness in what's done. But do we need all that uniqueness? Is there a level of commonality that would benefit everyone? We have about eight participants who are developing the initial project proposal and planning a call for participation in the next couple of weeks to a broader range of participants, looking specifically at back-end packaging commonality. The intent here is to take the project outputs to the relevant standards organization(s).

That gives you a sense of where we come in. Primarily, we do initial technical work that supports the argument that something is feasible, demonstrated, and works. It's feasible. Then, the standards teams—whether at IPC, SEMI, JEDEC, etc.—create the standard.

Johnson: What sorts of standards work does iNEMI see as strategically important for the industry?

Benowitz: I'll try to answer that in terms of some examples from the perspective of our current activities. Recall, iNEMI exists through our membership. The question is, "Where does membership want to put their resources and time on projects?" Smart manufacturing is clearly one. We're seeing a lot of interest in terms of demonstrating the interconnection and benefits of smart manufacturing, such as closed-loop inspection, working with the existing standards and helping to identify where further work may be needed. The example of back-end packaging commonality I mentioned before also came out of our smart manufacturing efforts.

Other areas where we currently have, or are developing, projects with linkages to standards include optical interconnect cleanliness, connector reliability, new package technology qualification, and solder voiding. In electronics manufacturing, there is such a breadth of activities that I can't say one is more important or more focused than the other.

Andy Shaughnessy: How big of a role do standards play in your roadmaps? A lot of people think of iNEMI for the roadmaps, which would be a reflection of what the standards are at the time.

Benowitz: My impression is the standards aren't influencing the roadmap in the beginning, but the output of the roadmap could identify the need for standards—or updates to standards—in some areas. As you said, the landscape is defined by standards and other elements, technology capabilities, etc., which are inputs to the roadmap. The outputs of the roadmap would be the gaps to meet those technology needs, and/or, in this case, the landscape that includes standards.

Shaughnessy: It seems that it's kind of a bi-directional thing. You come out with roadmaps that state, for example, that we'll see lines and spaces of two and two in 2024. That triggers the people at the appropriate community at IPC to ask, "How do we accomplish that?" Then, back-and-forth communication begins.

Benowitz: That's true. What a great example. As you said, if the standards currently don't address that, then we need to do something. We might have enough information to update the standard, or we don't have enough information, and we need to support it, which would manifest as a project.

Shaughnessy: Like Nolan, I associated iNEMI with standards. iNEMI doesn't, but you're working with the people who do.

Benowitz: Yes. There are relationships there, but it's not like anyone calls each other every day and says, "Help. I need this." Action comes-from the members and naturally occurs as opposed to a strategic occurrence, but maybe that's something for us to consider. We don't have regular meetings with the standards organizations saying, "What are you working on?" Like us, the standards organizations provide a framework. The standards themselves are done by representatives of the industry.

Action comes from the members and naturally occurs as opposed to a strategic occurrence, but maybe that's something for us to consider.

Shaughnessy: It's interesting that the standards are kind of a snapshot in time. Some people would say, "Well, they're kind of behind the times because we can do much more than this." But at least we know right now, with IPC standards, that you can build a product pretty much anywhere, theoretically, by following standards. With the iNEMI roadmaps, you're looking way down the road.

Benowitz: That's a good point. Like our projects, the ones we're working on represent a point in time. What comes in next is the next-gen stuff. Standards show a point in time, too, with some outward look, but as long as technology changes, this will all evolve following some sort of natural drumbeat.

Johnson: There is, and at the risk of overusing the word, an ecosystem of participation amongst the different organizations.

Benowitz: That's a fair representation. There is an ecosystem of these organizations, whether it be standards bodies, entities for collaboration and roadmaps, etc. It does everyone good. Our key message is advancing the technology through collaborative work, the keyword being "collaborative." How can we collaboratively accelerate the closing of these gaps? There is a healthy slice of challenges and opportunities that the industry can address most efficiently through collaboration.

NextFlex's Perspective on Trending Standards Topics

I-Connect007 also discussed standards with NextFlex—a consortium of companies, academic institutions, non-profits, and state, local, and federal governments with a shared goal of advancing U.S. manufacturing of FHE. While NextFlex did not have an opportunity to sit down for a full interview, we did discuss standards with Scott Miller, director of strategic programs, and Wilfried Bair, VP of engineering, both with NextFlex.

Scott Miller

Wilfried Bair

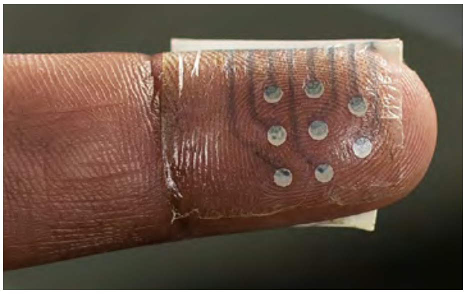
On the topic of standards, Miller said, "Standards for manufacturing, testing, and reliability are increasingly important in flexible hybrid electronics, and while some initial work on testing as part of an early project call was completed at NextFlex, the community has looked to standards developing organizations (SDOs) like IPC to apply the rigor around standards development that the industry requires." He continued, "In the future, standards for design and test will absolutely be necessary to facilitate the wide adoption of FHE technology."

And while discussing some specific standards, Wilfried Bair stated, "While we can apply the majority of test methods and standards used for standard copper flex PCBs for flexible hybrid PCBs, currently, we see a gap in reliability standards for two important areas for FHE: stretchable or skin-/body-worn electronics." He added, "We encourage standards development organizations to focus on standards for these emerging wearable applications." **SMT007**

How Electronic Skin Could Help People With Disabilities

Anusha Withana, a researcher from the University of Sydney's School of Computer Science, is developing wearable technology that could be used to control devices, receive information, and even register sensation through cellphone-like vibrations. This could have benefits in robotics, education, game-playing, and for people with disabilities.

Withana is working with a team in Germany to develop what is effectively a printable electronic fake tattoo called the Tacttoo that can be personalized to specific needs. Tacttoo is screen-printed with a circuit made from polymer-based conductive inks, which can stretch and move with the skin, while all connections between the skin and the electronics are printed in skin-safe silver ink.



The "feel through interface," as in the sticky tape element, is only half the thickness of a human hair, making it the thinnest wearable tactile device to date, and so thin that it doesn't interfere with the normal sense of touch. Tacttoos are also inexpensive; mass-produced, the material content would cost less than one cent each.

"We want people to be able to wear it today and remove it tomorrow—and we want people to be able to create it themselves," Withana says.

(Source: University of Sydney)

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ACCEPTING APPLICATIONS

Electronics Industry News and Market Highlights

India PC Market Registers Strong Growth in 2Q19 ▶

The India traditional PC market—inclusive of desktop, notebook, and workstation—shipped 3.4 million units in the second quarter of 2019, recording a solid 49.2% year-on-year growth, according to IDC's Asia/Pacific Quarterly Personal Computing Device Tracker.

Hosting Infrastructure Services Market Revenues to Reflect at 8% CAGR During 2019-2029 ▶

The global hosting infrastructure services market is estimated to reach a value of $12 billion in 2019, up from $11 billion in 2018, according to a recently published report by Future Market Insights (FMI).

Active Electronic Components Market to Witness Growth at 10% CAGR by 2022 ▶

The global active electronic components market is projected to touch $330 billion by 2023. These components are the heart as well as the soul of electronics and are vital aspects of electronics.

Global Artificial Intelligence Market in Retail Sector 2019-2023 ▶

The global artificial intelligence (AI) market in the retail sector is expected to post a CAGR of more than 35% during 2019–2023, according to the latest market research report by Technavio.

Smartphone Shipments Decline 2.3% in Q2 ▶

Worldwide smartphones shipments declined 2.3% year-over-year in the second quarter of 2019 (2Q19) for the strongest quarterly performance since 2Q18, according to preliminary data from the International Data Corporation (IDC) Worldwide Quarterly Mobile Phone Tracker. Smartphone vendors shipped a total of 333.2 million phones in 2Q19, which was up 6.5% over the previous quarter.

Cable Assemblies Market to Be Worth $220.7B by 2025 ▶

The global cable assemblies market will increase at a CAGR of 6.7% from 2019 to reach $220.7 billion by 2025, driven by the increasing number of electric vehicles, increasing demand from the aerospace industry, growing internet penetration across the globe, and the high growth of the automotive industry.

Cellphone 3D Sensing Market Enters Growth Stage ▶

As smartphone shipments are predicted to decline in 2019, cellphone brands are expected to be engaging in a "specs-contest" with their flagship devices for the second half-year, and 3D sensing modules will become an important component in that race, according to LEDinside.

5G Core Platforms Set to Generate $8B ▶

An increased emphasis on software-centric networks like 5G, which favor services, is expected to usher in the next wave of growth in telecommunications, finds global tech market advisory firm ABI Research.

2Q19 Revenues of NAND Flash Brands Trending Flat From 1Q19 ▶

The end-demand in smartphone, notebook PC, and server markets for NAND flash have recovered from the traditional offseason in the first quarter of 2019, bringing total bit consumption growth to 15% in the second quarter of the year.

Recognizing the Need For Change

Smart Factory Insights
by Michael Ford, AEGIS SOFTWARE

As you are reading this, there is something significant in your eyeline, that you are not actually seeing—your nose. The human brain is programmed to ignore things that it already recognizes to reduce the load on the analytical side of the brain responsible for visual recognition of objects and events. Only if you really try to focus on your nose, perhaps open one eye at a time, will it come into view. This example of optimization of processing resource is not unique to humans; to some extent, it applies to everything that we do, especially when we grow tired. What are people working every day for many years in manufacturing not seeing?

We Are Only Human, Mostly

We are reminded many times in manufacturing, that "you cannot fix what you cannot see" and "you cannot improve what you cannot measure." These annoying aphorisms are all very well as a motivational quip for gaining better visibility of the operation. However, the reality is that there is a lot going on that no-one is seeing. Many operations and practices have become a part of the background—the canvas on which we perform our daily tasks.

Proof of this has been painful for some when dealing with challenges. Consultants come in from outside to help identify and resolve problems. The frustration is the thought that people within the factory should know what is going on and how to improve. To many, it seems quite unrealistic that external people, who know a great deal less than incumbent factory members about their specific operation, are able to come in and genuinely add considerable value. Consultants see things with "fresh eyes." In other words, their brains are

not blocking out the familiar. They raise questions about everything, including practices, processes, and flows, and challenge every assumption. However, consultants can eventually suffer the same issues as the factory members when they start to believe that they have seen everything.

The same is true for software systems. When evaluating different solutions, each will provide a different set of functions and features that need to be mapped into the process flows and practices of the factory. Any change to the status quo will be met with resistance, even if the change suggested is potentially very valuable. People will immediately try to mold the software to support existing operations that they are comfortable with rather than moving forward. The best software will bring innovative opportunity to break established paradigms and evolve new best practices.

The best software will bring innovative opportunity to break established paradigms and evolve new best practices.

One simple example is the replacement of the push-driven material kitting system with a Lean material management pull-system. Looking honestly and openly at both practices, the difference is enough to clearly differentiate it as a step-change improvement to any factory operation. Yet to date, Lean material management remains a niche technology. As with consultants who have seen everything, most of the old MES software solutions have also become less effective and compelling as time goes on. Most have not been keeping up with the ever-evolving market trends, software architecture, and machine connection technologies, such as IIoT. Thus, their messages become jaded and limited. The "nose effect" is everywhere.

However, there are other surprises in store when humans in the manufacturing operation begin to utilize a modern IIoT-based MES solution and see real data coming from the operation as a whole. The IPC Connected Factory Exchange (CFX) has now become established as the favored method to extract high-quality, detailed, and timely data, natively from machines, all adhering to a single common standard content definition—a true plug-and-play environment. But the limitation of any form of communication from single-machine entities is the need for the derivation of context from all of the many sources of information. Approximately 80% of the data from each individual machine only has significant meaning when set into the context of, for example, the line configuration, the product profile, material logistics, and most of all, the history of what has already happened. Only the latest IIoT-driven MES solution specifically intended to work in this environment with CFX IIoT technology is able to take, format, and present genuine information of value, and then utilize such information for critical decision-making support.

Shock to the System

The challenge within production operations is how to deal with the truth that the solution exposes. For many years, the nose has been invisible, but in terms of the digital world, it is there, front and center. IIoT data and managing IIoT-driven MES software are poised to bring a wealth of benefits, and yet the most common question raised right now relates to how the data should be used. Sometimes, it is better just to let the data do the talking and allow the system to do its job. Take the opportunities that appear as a result of implementation—win after win—for the streamlining and reinvention of legacy production practices as the digital factory evolves.

Lean material management, though just one of a great many, is an excellent example for those who need to understand that the benefits are tangible. For those who are still using legacy push systems, consider these questions:

- Why does each kit contain a great deal more materials than will be needed?

- Why are several kits of materials being prepared in advance?
- Why is there a huge build-up of materials on the shop floor, where few people, if any, know where anything is?
- Why do materials get "stolen" from kit to kit?
- Why do I get so many MSD violations and related defects?
- Why do I experience many unexpected internal material shortages?
- Why do I spend so much time and effort counting materials?
- Why does my ERP inventory level still not match my physical stock?
- Why do I need to waste about 2% overall productivity doing a stock-check twice a year?
- Why do I get material-related quality problems coming and then going?
- Why do I need so many material logistics personnel, when most of the time, they are grossly under-utilized?
- Why are there so many questions?

If you are not confident in answering any of the above questions or are happy to justify the associated losses in your own mind, then you need to see me after class. This is Lean Material Management 101. Though the majority of people in production must surely have the answers to these questions right in front of them, in most cases, they are blind to the consequences because the losses have always been there—they have long become invisible. Digital manufacturing with IIoT-driven MES with CFX data is going to put the untainted answers to all these questions on your dashboard and into your reports. There is no hiding anymore; there is only opportunity. This particular shock to the system is just one of many happening across many areas, including production engineering, routing control, quality management, test and inspection, and warehouse control.

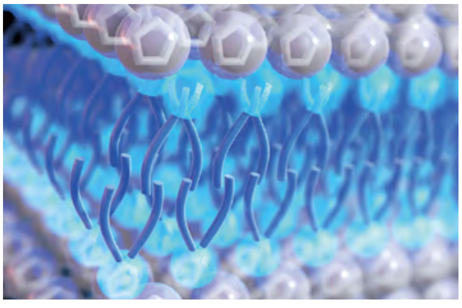
Going Digital

The question is not so much related to what can be done with the data in a digital factory, but how best to engage to gain the most opportunity and benefit. For many, and what is very much acceptable, starts with getting the real data. Include the true digital MES layer and start truly opening your eyes. Let your head get around to see your day with a fresh perspective. Then, let's talk about all of the many ways your investment has paid off. It is also fine to pick up on a specific need, such as material management, to justify the initial investment. But know that open eyes and an open mind to change are really all you need. **SMT007**

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

New Type of Electrolyte Could Enhance Supercapacitor Performance

Researchers at the Massachusetts Institute of Technology (MIT) and several other institutions have developed a novel class of liquids that may open up new possibilities for improving the efficiency and stability of supercapacitors while reducing their flammability.



The new class of materials called surface-active ionic liquids (SAILs) could have a variety of applications for high-temperature energy storage, including for use in hot environments, such as oil drilling or in chemical plants.

According to the researchers, the proof-of-concept work represents a new paradigm for electrochemical energy storage. The study was published in *Nature Materials*. (Source: MIT)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How Standards Impact You and Your Company

SMT Solver

Feature Column by Ray Prasad, RAY PRASAD CONSULTANCY GROUP

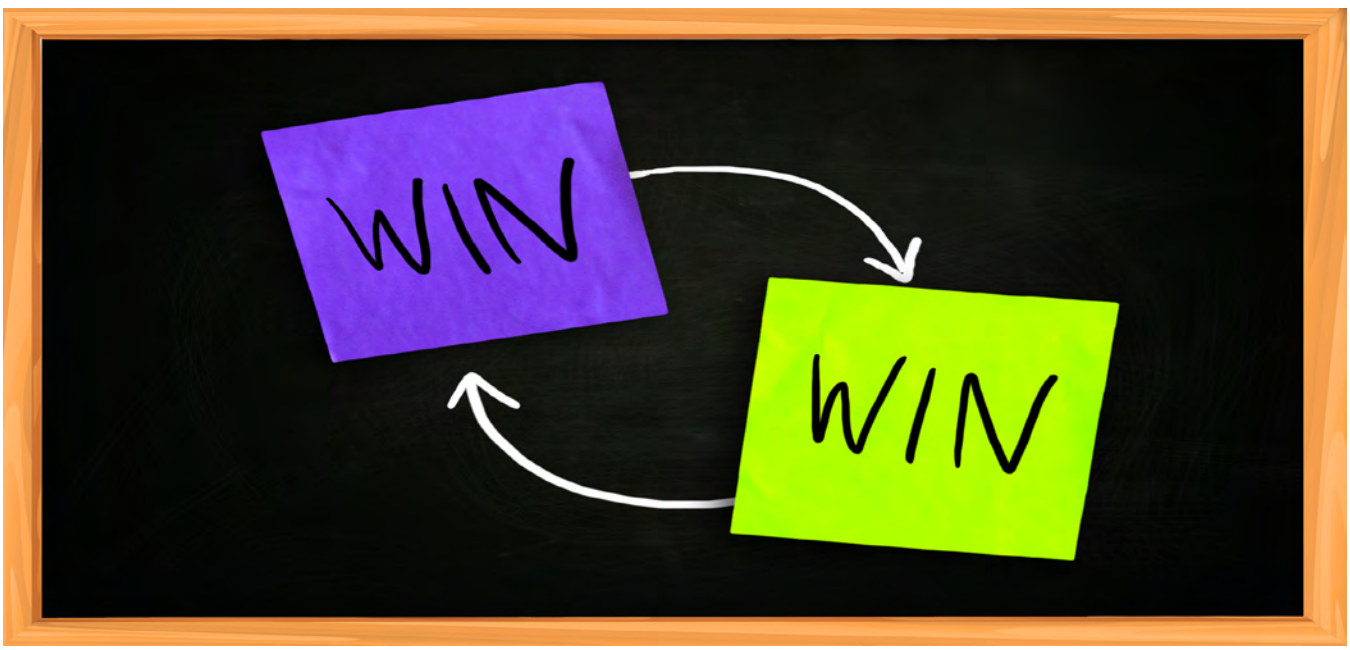
Standardization is one of the key issues in promoting any new technology, but it is almost mandatory for SMT because of the need for automation to promote consistency in quality. Standards make the market grow faster than it would without them. A good standard benefits both users and suppliers. For example, if the package size tolerances are tightly controlled (within the requirement of the standard), the user can properly design the land pattern and use the same design for all suppliers of that package. The supplier also benefits because as long as the packages meet the standard, they can meet the needs of all their customers.

Use of standards also sets the quality expectations for both the suppliers and users. An industry standard creates a win-win situation for everyone. Following standards ensures that suppliers and OEMs are on the same page to ensure superior quality and reliability and lower cost.

However, standards have a couple of downsides. They take time to develop and release because there are established guidelines and rules, which are critical for their acceptance and need to be followed. They are also not good for lawyers because they reduce conflicts and legal disputes; on second thought, this is an upside.

Standard Vs. Specification

A standard is not the same as a specification. Standards are set by industry organizations, such as IPC and EIA, in their areas of interest to their industry in general and their members in particular. Specifications, on the other hand, are established by users to meet their own unique requirements. However, if a particular company wishes to use a given standard as their specification, they certainly can do that, and many just do that.



There is another option for a company if you want to use a standard as a specification. You can use industry standards as specifications for most of your requirements to keep your costs down and use your custom specifications to meet requirements for your specific applications. IPC makes this easier for having the standards meet three classes of requirements: Class 1, 2, and 3. Class 1 is for non-critical consumer applications. Class 2 is recommended for industrial and office applications and is the most common class used. Class 3 is for very critical applications such as military and space. Again, you can add custom requirements to any of these classes if you want to use them as a specification for your company, but it is important to remember that industry organizations do not develop specifications; the user develops their own specification for use by them and their suppliers.

As noted earlier, since it is required to get the input from IPC members across the globe, standards take time; they can take two to three years.

As noted earlier, since it is required to get the input from IPC members across the globe, standards take time; they can take two to three years. By the time they are released, the technology may have changed. To address those changes, it is not uncommon to proceed with the next revision of that standard. Some of the most common standards are now in their ninth and tenth revisions; IPC-610 is a good example.

Meanwhile, specifications can be released very quickly. They are developed by a single company to meet and address their particular requirements but not to solve world hunger or fit the entire industry, as is the case for a standard. However, if your specification strays away too far from the standards, you better be prepared to pay for it. And you will have fewer and fewer suppliers who may be able to meet your unique requirements.

Common Standards in the SMT Industry: IPC, EIA, and J-STD

There are various types of standards in the SMT industry, but the most commonly used are IPC, EIA, and JEDEC standards. IPC, with membership from users across the globe, sets standards for PCBs, assemblies, interconnect designs, and manufacturing processes as well as acceptability and process control. There are over 300 active IPC standards covering almost every stage of electronics product manufacturing from PCB laminate materials to assembled printed circuit board assemblies (PCBA). IPC standards are accepted worldwide since they are created by participants across the globe.

EIA is a trade organization of electronic component manufacturers. Various committees of EIA establish outlines for passive and electromechanical components. JC-11 committee of the Joint Electronic Device Engineering Council (JEDEC)—part of EIA—is chartered to establish a mechanical outline for packages of active devices. Similarly, various "P" or parts committees of EIA are responsible for setting standards for the mechanical outlines of passive devices.

One of the main complaints about EIA and JEDEC standards by user groups tend to be loose tolerances of packages. This makes land pattern design by the users very difficult. However, it is worth noting that to address these and many other issues to promote SMT, both IPC and EIA, to their credit, formed a Surface Mount Council in the mid-1980s. As one of the members of Surface Mount Council, I can say with certainty that the component tolerances today, which are not perfect by any means, are way better than what was the case then.

You probably also know about some very popular standards known as J-STDs. In the early days of SMT, both IPC and EIA used to develop some overlapping standards with conflicting requirements for acceptability, solderability, and baking and handling of moisture sensitive components. Conflicting requirements only confuse users and suppliers and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are not good for anyone. Joint standards, or J-STD, are the joint effort of both IPC and EIA to develop common and very popular standards, such as J-STD-001 (acceptability requirements), J-STD-002 and 003 (solderability requirements of component and PCBs), and J-STD 20/33 (moisture-sensitive packages).

By the way, J-STD-001 is the real standard and not IPC-610 for accept/reject criteria of solder joints. Even though IPC-610 is more popular and common than J-STD-001, is the visual and in-color representation of requirements established in J-STD-001. It is a tribute to both IPC and EIA to agree on common joint standards. It prevents confusion and helps everyone in our industry to promote higher quality and reliability by agreeing on a common set of requirements for some of the critical issues, such as accept/reject criteria, solderability, moisture sensitivity, and many others.

Standards and You

As noted earlier, the development of standards takes time, but the process for development and approval ensures all meaningful technical inputs are considered and reviewed by everyone concerned. The people who develop and publish the standards are unpaid volunteers from different companies. One of their main goals is to make sure the standard does not benefit a specific company but the entire industry.

IPC and other standards are only as good as the willingness of participants to share their expertise and time. Having been involved with IPC for decades and chairing over half dozen IPC committees, I can also say that it is very important to have a core group of dedicated volunteers who will attend almost every phone and in-person meeting and their companies encourage their participation as company policy. Only then are good and useful standards developed in less than two years.

I have been fortunate to have (and had in the past) a core group of engineers from major companies who helped to develop some very useful standards, such as IPC-7095 (BGA), IPC-7093 (BTC), IPC-7530 (reflow), IPC-782 (now IPC-7351, land pattern), and IPC-786 (now J-STD 20/33, moisture-sensitive packages). All of these standards were developed pretty quickly, and some of them within 18 months. Yes, the document is released only after everyone across the globe has a chance to review them and give their comments, but the dedication of core team members and IPC liaison staff is the key to developing a good and meaningful standard on a timely basis.

We welcome anyone and everyone to participate if you have the time and expertise in a particular standard being developed. For example, we are almost in the final stage for the release of the next revision of BTC standard IPC-7093 (Design and Assembly Guidelines for BTC). As chairman of that committee, I invite you to participate in the final review of this important industry document. Not only will the industry benefit from your input, but you and your company will also benefit from close interaction with your peers. Some of us have even become lifelong friends and attend these conferences not just for technical meetings but to renew our friendships and connections, so please join us.

And one more thing, if you are a new graduate, IPC has a deal for you—their mentoring program. IPC President Dr. John Mitchell himself would be delighted to take your call, and I would certainly be glad to hear from you as well. **SMT007**

Ray Prasad is the president of Ray Prasad Consultancy Group and author of the textbook *Surface Mount Technology: Principles and Practice.* Prasad is also an inductee to the IPC Hall of Fame—the highest honor in the electronics industry—and has decades of experience in all areas of SMT, including his leadership roles implementing SMT at Boeing and Intel; helping OEM and EMS clients across the globe set up strong, internal, self-sustaining SMT infrastructure; and teaching on-site, in-depth SMT classes. He can be reached at smtsolver@rayprasasd.com. Prasad is teaching two workshops on BGA and BTC design and assembly at SMTAI in Chicago on September 22, 2019. To sign up for either or both of these workshops, please contact Karlie@smta.org. He also has an upcoming SMT class October 21–23, 2019. More details at www.rayprasad.com. To read past columns or contact Prasad, click here.

MilAero007 Highlights

NASA Seeks Input from U.S. Industry on Artemis Lander Development ▶

In a major step toward returning astronauts to the surface of the Moon under the Artemis lunar exploration program and preparing for future missions to Mars, NASA is seeking comments from American companies interested in providing an integrated human landing system to put the first woman and next man on the Moon by 2024.

Artificial Intelligence and Space Exploration ▶

From utilizing machine learning to advancing space exploration, optics technology leads the chart toward our scientific and outer-space frontiers.

The Power of Alignment: Celebrating the 50th Anniversary of the First Moon Landing ▶

The vision of man going to the Moon united the world. And 50 years ago, this feat was proven possible when the Apollo 11 successfully landed the first humans on the Moon.

M&A in Defense and Security Market Reaches Record High of $130B in 2Q19 ▶

Mergers and acquisitions (M&A) activity in the defense and security domains was valued at $130 billion during the three months to June 30, 2019, according to Jane's by IHS Markit.

Aerospace Entrepreneur Burt Rutan to Keynote IPC APEX EXPO 2020 ▶

IPC APEX EXPO 2020 will feature aerospace entrepreneur and Virgin Galactic spacecraft designer Burt Rutan. During the opening keynote on February 4, Rutan will present "SpaceShipOne: A New Era in Commercial Space Travel and Inspiration for Innovation and the New Race for Space."

Lockheed Martin to Produce More APY-9 Radars for U.S. Navy's E-2D Program ▶

Lockheed Martin's Radar Sensor Systems market segment has been awarded a contract from Northrop Grumman worth over $600 million for multi-year production (MYP) of 24 additional APY-9 radars for the U.S. Navy's E-2D aircraft program. It's also known as the Advanced Hawkeye program.

Innovators from NASA, Lockheed Martin Space, and Lenovo to Keynote SMTA International 2019 ▶

The SMTA is pleased to announce three inspiring keynote presentations scheduled during SMTA International, September 22–26, 2019, in Rosemont, Illinois, USA.

Raytheon Upgrading Germany's Patriot Integrated Air and Missile Defense System ▶

Raytheon Company is upgrading Germany's Patriot Integrated Air and Missile Defense System to the most current configuration available under a $105.5 million direct commercial sales contract from the NATO Support and Procurement Agency.

Raytheon Reports Strong Second Quarter 2019 Results ▶

Raytheon Company has announced net sales for the second quarter of 2019 of $7.2 billion, up 8.1% compared to $6.6 billion in the second quarter of 2018.

Explaining the QSFP-DD Data Center Interconnect Standard

Feature by Scott Sommers
MOLEX

The explosion in data center activity shows no signs of abating. Cisco's latest Visual Networking Index (VNI) study projects annual global IP traffic will reach 4.8 zettabytes per year by 2022 after breaking one zettabyte just three years ago. Worldwide traffic will triple over the next five years, reaching 50 GB per capita. The VNI study anticipates 28.5 billion networked devices by 2022, up from 18 billion in 2017, with 82% of all data flow due to video viewing.

According to Cisco's report, most IP traffic either originates or terminates in data centers. Yet as massive as the flows between centers are becoming, the data managed within those same facilities is going even higher. All of this activity means that "hyperscale" is the word of the future. Roughly one-quarter of all servers installed in 2016 went to hyperscale facilities, but that number will grow to almost one-half by next year. Other advances that are heavily impacting the modern data center is the rise in 400-Gbps technology, the expansion of cloud computing, and how virtual data centers, machine learning, and AI are all driving change.

To meet the pressing need for high signal integrity, lower latency, lower insertion loss, and higher density data transmission, transceivers and modules capable of supporting 400 Gbps are quickly being developed. At the forefront is the Quad Small Form Factor Pluggable-Double Density (QSFP-DD) system—the most advanced interconnect standard yet. Defining form factors and performance specifications for this new standard is the QSFP-DD Multi-Source Agreement (MSA) comprised of leading data center equipment and component suppliers.

The QSFP-DD MSA was formed to address the speed/density requirements of 400 Gbps. Over 60 companies and organizations are currently in the QSFP-DD MSA. Promoters of the standard include Broadcom LTD, Cisco, Corning, Finisar, Foxconn Interconnect Technology, Huawei Ltd., Intel, Juniper Networks, Lumentum, Mellanox, Molex LLC, and TE Connectivity. A number of well-known organizations contribute to the MSA, such as Alibaba Group,

Celestica, Ciena, DellEMC, Fujitsu, Hewlett-Packard Enterprise, Nokia, and Sumitomo Electric.

QSFP-DD: Ultimate Performance

The QSFP-DD MSA has publicly released two specifications. The first is the QSFP-DD hardware specification, which defines the electrical connector, module cage, optical connectors, and module types. The other specification is the QSFP-DD Common Management Interface Specification (CMIS), which defines the management interface protocol between hosts and modules.

QSFP-DD is the industry's smallest 400-GbE module, providing exceptional port bandwidth density. The standard features an eight-lane electrical interface with each lane achieving up to 50-Gbps data rates and enabling at least 20 W of power dissipation. It also supports 3 m of passive copper cables, 100 m over parallel multimode fiber, 500 m over parallel single-mode fiber, and 2 km and 10 km over duplex single-mode fiber. The QSFP-DD connectors/cage are fully backward compatible with legacy QSFP modules and cables (Figure 1).

Typical older data center interconnect solutions support single- or quad-lane data transfer; moreover, the few eight-lane form factors available are not fully equipped for next-generation systems. QSFP-DD accommodates the bandwidth/channel capacity, electrical demands, and thermal requirements of high-speed networking. Importantly, QSFP-DD interconnects can also deliver 400-Gbps performance for long-reach coherent interconnects via the help of innovative heat sinks. This is critical, as advanced ASICs consume more power and dissipate more heat.

Figure 1: Molex QSFP-DD cage and cable.

The QSFP-DD standard spans both software and hardware. CMIS describes the software methodology and registers required for the host to control QSFP-DD modules based on a two-wire serial interface. CMIS is intended to cover a wide range of possible module functionalities and applications from cable assemblies to coherent dense wavelength division multiplexing (DWDM) modules. The QSFP-DD hardware specification, by contrast, defines the mechanical transceiver, connectors, and cages, including the electrical and optical interfaces. It also defines the thermal properties of the QSFP-DD module, connector, and cage system. QSFP-DD connectors accept legacy QSFP cables and transceivers.

QSFP-DD Performance Specifications

While QSFP-DD supports both line-side and client-side interfaces, it's anticipated that the dominant implementations will be for high-volume, cost-sensitive, client-side use. A wide range of media and transceiver types are supported, including direct-attached copper (DAC) cables, multi-mode fiber (MMF), single-mode fiber (SMF), wavelength division multiplexing (WDM), and coherent modules. Transceivers and active copper/active optical cable assemblies will support 100, 200, and 400 Gbps for Ethernet, fiber channel, or InfiniBand (IB) applications.

The QSFP-DD connector system is fully backward-compatible with all QSFP-based transceivers and cables from 40 to 200 Gbps, including QSFP+ and QSFP28. Backward compatibility is important, especially in this transitional era; many ASICs, for example, are designed for multiple interface rates. Having the ability to span multiple speeds allows engineers to stagger implementations across the data center and supports economies of scale in purchasing.

Thermal management is an important part of the QSFP-DD system as well. A flat-top design allows vendor- and/or application-specific riding heat sinks and/or heat pipes to accommodate a range of port inlet, port exhaust, and side-to-side cooling options. Cage-integrated heat sinks have been validated for performance, taking advantage of front-to-back airflow for module cooling. Air can be drawn from the aisle across the heat sink for additional dissipation. In addition, an innovative transceiver heat sink is optional in the QSFP-DD specification. This innovation in thermal management is a big improvement compared to other module types that use integrated heat sinks, which provide unneeded thermal management for passive copper cables and insufficient thermal management for WDM/coherent applications.

Due to its thermal management features, the single QSFP-DD SMT connector and cage support at least 12 W in its standard configuration; the heat dissipation designs required for higher-consumption classes are relaxed for the lower-power classes to avoid unnecessary cost. For thermal loads beyond 20 W, stack cages with internal riding heat sinks as well as single and belly-to-belly cages are available.

The QSFP-DD system supports a module with eight host electrical lanes. It includes a mechanical module, a single-height 1x1 surface-mount cage and connector, and a press-fit 2x1 cage with integrated connector, thermal, pinout, and the CMIS management specification.

In addition to its own interconnect standard, QSFP-DD CMIS can be applicable to Octal Small Form Factor Pluggable (OSFP) MSA and Consortium for On-Board Optics (COBO) as well as QSFP and SFP-DD. However, QSFP-DD interconnects—due to their versatility, cost-effectiveness, and future-proofing—are engineered to be the dominant pluggable transceiver for the foreseeable future. As people continue to demand more from their connected devices—in more places and for more reasons than ever—the QSFP-DD system will be there to make the world a faster, more data-friendly place. **SMT007**

Scott Sommers is the director of industry standards, Molex, and co-chair of the QSFP-DD MSA.

Development of Flexible Sensors Mimicking Human Finger Skin by DGIST

Senior Researcher Changsoon Choi's team at the Department of Smart Textile Convergence Research at Daegu Gyeongbuk Institute of Science and Technology (DGIST) and Dr. Sungwoo Chun at Sungkyunkwan University (SKKU) have developed artificial skin tactile sensors that can feel the similar pressure and vibration felt by human skin.

Unlike existing sensors—which only have pressure and temperature detection functions—the new sensors detect both pressure and vibration as well as convert the surface roughness of a matter into electrical signals to identify with more sensitive and accurate detections of physical stimulations.

The tactile sensors mimic both slow adaptive (SA) receptors that detect pressure and fast adaptive (FA) receptors that detect the vibration and roughness. The sensors are in a flexible film-form that consists of an upper panel with human fingerprint-like micro-patterns, a middle panel with vibrator sensor mimicking FA receptors, and a low panel with a pressure sensor mimicking SA receptors. The sensors open the potential of artificial skin grafting for patients who need skin graft as a result of accidents to have a real skin sensation.

Choi said, "I was inspired to develop the new sensor while watching a movie where the main character was wearing a suit to experience virtual reality and feel his pain like in real life. I hope that our research becomes the cornerstone for artificial skin-related and other researches."

This research was published in *Nano Letters*.
(Source: DGIST)

Transform Your Operations With Nadcap

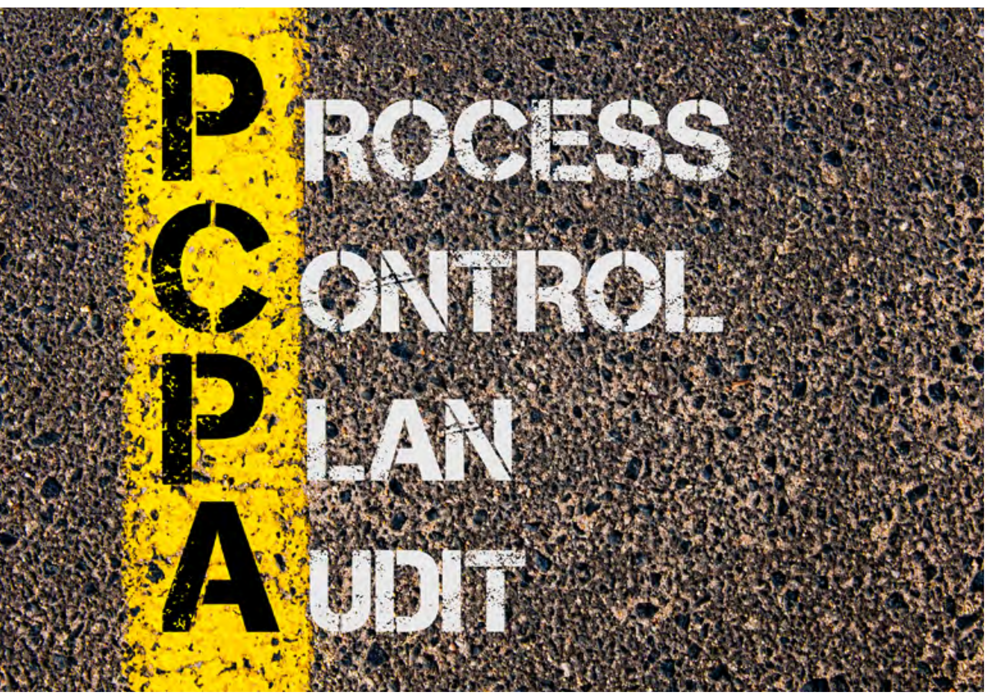
Operational Excellence
by Alfred Macha, AMT PARTNERS

Based on my experience with audits over the last 20 years—reviewing compliance to various standards and regulations, such as Nadcap (formerly known as the National Aerospace and Defense Contractors Accreditation Program), AS9100, ISO 13485, ISO 9001, Defense Logistics Agency (DLA), and U.S. Food and Drug Administration (FDA) inspections—I can confidently say that Nadcap audits are the most rigorous. Suppliers that offer services or products to the aerospace industry are familiar with Nadcap accreditation; it's the gold standard for best-in-class process compliance assessment. However, obtaining Nadcap certification can be an overwhelming endeavor for suppliers that don't have proper guidance. This column provides guidelines that companies have used in the past to successfully achieve Nadcap accreditation.

Accreditation Fundamentals

Before I outline these strategies, it's important to understand the fundamentals of the accreditation. Nadcap accreditation is an aerospace-driven program where highly qualified professionals, having experience in the aerospace industry, conduct the actual process audits, using criteria specifically developed by industry experts. The official Nadcap guidance is found in the Performance Review Institute (PRI) website.

The PRI auditor will use a product-specific checklist to evaluate compliance to processes being evaluated. Before attempting Nadcap special process accreditation, the organization must have an approved quality management system (QMS) to the following standards: aerospace quality systems (AQS) standard AS/EN/JISQ9100, AS/EN9110, or ISO 17025 recognized by the National Cooperation for Laboratory Accreditation (NACLA) and the International Laboratory Accreditation Cooperation (ILAC) accreditation body for testing laboratories, including nondestructive testing laboratories. If the organization doesn't already have an approved QMS, Nadcap can conduct an AQS audit.



Understand the Accreditation Process and Timeline Expectations

Obtaining Nadcap certification can be a lengthy process. Figure 1 shows a roadmap of the steps that are required for accreditation. The overall process typically takes 12–16 months to complete. Some organizations that take longer, depending on the complexity required to correct findings identified during the audit. The key to the qualification process is preparation. You need to do a gap assessment with an independent industry expert that can provide you with an unbiased compliance review of your process(es). The gap assessment is not required but highly recommended by PRI. The internal audit is required before the accreditation audit.

Important Steps to Take Before the PRI Audit

The internal Nadcap audit is the most important part of the preparation. Allocate the right resources and time to do a comprehensive process audit with the Nadcap checklist. The objective is to identify all possible deficiencies ahead of the accreditation audit. Assign appropriate resources to correct deficiencies identified during this internal audit.

Once you have completed the internal Nadcap audit and addressed deficiencies, prepare for the accreditation audit by reviewing the fundamentals of your quality systems with all employees before the audit. As with any audit, it is important your procedures, calibration logs, and records are in good order.

Collect and review (for compliance) copies of the objective evidence, such as calibration certificates, quality procedures, records, logs, and sample job traveler documents that the auditor will need to review beforehand. Verify that there will be a sufficient number of parts, products, and components available for demonstration of proficiency. The auditor will only review parts or services being processed for aerospace customers.

Also, advise your customers, both internal and external, of the impending Nadcap audit. They have a vested interest in your success as an accredited Nadcap supplier as well. This request will increase the confidence level of your customers that your processes are compliant, and you are not concerned for them to participate in this rigorous audit.

Assign a Technical Expert to Lead the Nadcap Certification

The audit is highly technical regarding process compliance, so it is recommended that you assign a technical expert or senior process engineer to lead the Nadcap preparation. Quality systems personnel can help to coordinate the audit schedule and ensure documentation

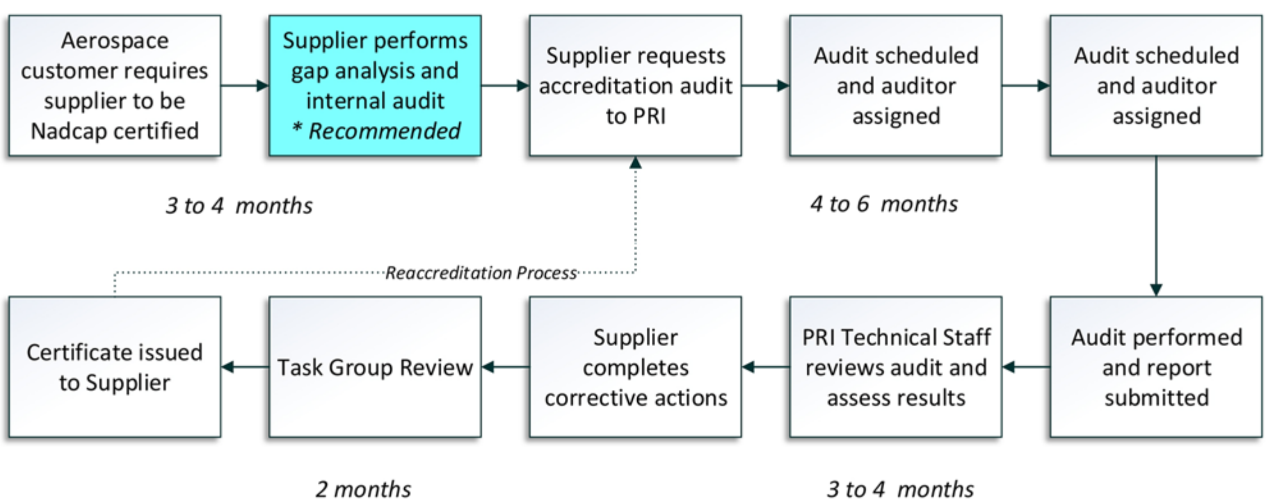


Figure 1: Roadmap of the steps required for accreditation.

is in place to support the accreditation. However, the audit itself will require your technical expert to review process capabilities, controls, and industry-specific test methods used to validate product reliability and product conformance.

Gain a Comprehensive Understanding of the Auditor Criteria Checklist

The audit criteria checklist used for the Nadcap audit is defined by the type of product or service the supplier offers to the aerospace industry. Make sure the assigned technical lead is immersed in understanding the specific requirements outlined in this checklist. You will also use this checklist for the internal process audit.

Here is a listing of the available checklists by the type of service or manufacturing offered by suppliers:

- AQS: AS/EN/JISQ9100, AS/EN9110, or ISO 17025 (it is recommended that you obtain this before the Nadcap process)
- Chemical processing: AC7108 series of checklists
- Coatings: AC7109 series of checklists
- Composites: AC7118 series of checklists
- Conventional machining as a special process: AC7126 series of checklists
- Elastomer seals: AC7115 series of checklists
- Electronics: AC7119, AC7120, and/or AC7121 series of checklists
  - AC7119: Nadcap Audit Criteria for Electronics Printed Boards
  - AC7119/2: Nadcap Audit Criteria for Electronics Flexible and Rigid-Flexible Printed Boards
  - AC7119/4: Nadcap Audit Criteria for Printed Circuit Board Personnel Qualification
  - AC7120: Nadcap Audit Criteria for Circuit Card Assemblies
  - AC7120/1: Nadcap Audit Criteria for Circuit Card Assemblies Personnel Qualification
  - AC7120/2: Nadcap Audit Criteria for General Soldering of Printed Board Assemblies
  - AC7120/3: Nadcap Audit Criteria for Plated Through-Hole Technology (PTH)
  - AC7120/4: Nadcap Audit Criteria for Surface-Mount Technology (SMT)
  - AC7120/5: Nadcap Audit Criteria for Mixed Metallurgy for Ball Grid Arrays (BGAs)
  - AC7120/6: Nadcap Audit Criteria for Lead-Free Soldering
  - AC7120/7: Nadcap Audit Criteria for Conformal Coating of Printed Board Assemblies
  - AC7120/8: Nadcap Audit Criteria for Encapsulation
  - AC7120/9: Nadcap Audit Criteria for Programming
  - AC7120/10: Nadcap Audit Criteria for Final Testing
  - AC7120/11: Nadcap Audit Criteria for Repackaging
  - AC7121: Nadcap Audit Criteria for Electronics Cable and Harness Assemblies
  - AC7121/1: Nadcap Audit Criteria for Electronics Cable and Harness Assemblies Personnel Qualification
- Fluid distribution systems: AC7112 series of checklists
- Heat treating: AC7102 series of checklists
- Materials testing laboratories: AC7101 series of checklists
- Measurement and inspection: AC7130 series of checklists
- Nondestructive testing: AC7114 series of checklists
- Nonconventional machining and surface enhancement: AC7116 checklist for nonconventional machining and the AC7117 checklist for shot peening
- Non-metallic materials manufacturing: AC7124 series of checklists
- Non-metallic materials testing: AC7122 series of checklists
- Sealants: AC7200/1 and AC7202 series of checklists
- Welding: AC7110 series of checklists

Mode "B", Task Group ETG (Electronics) NCRs Per Auditor Day						
# of NCRs Per Auditor Day (Initial Accreditation Audit)						
	1 Day	2 Days	3 Days	4 Days	5 Days	Failure Threshold % (95–98)
Major	2	4	6	8	10	89%
Total	4	8	12	16	20	72%
# of NCRs Per Auditor Day (Reaccreditation Audit)						
	1 Day	2 Days	3 Days	4 Days	5 Days	Failure Threshold % (95–98)
Major	1	2	4	6	8	92%
Total	3	6	9	12	15	95%

Table 1.

Don't Treat the Nadcap Audit as an ISO Audit

The Nadcap audit is an extensive process compliance review per the auditor criteria checklist. It is common for suppliers to have approximately 20 audit findings or more during their first attempt to get accreditation. During an ISO audit, a supplier may receive some minor or major findings where you need to complete corrective actions within 30 days to attain or keep your certification. A similar approach is followed by PRI when it comes to Nadcap audits. However, PRI has established strict guidelines in their operating procedures; there are thresholds of allowable findings to achieve accreditation. Also, it is important to understand that PRI notifies its subscribers—the list of aerospace companies that are signed up in their program—when a supplier has achieved Nadcap certification or failed their audit. Therefore, poor preparation may give you a bad reputation with aerospace customers if the audit results in significant findings. Table 1 shows an example of how many allowable nonconformances (NCRs) are allowed per auditor day (Source: PRI, Operating Procedure, OP 1110, Audit Failure).

Make Process Audits the Engine of Your Quality Systems

Even though Nadcap is driven by the aerospace industry, those suppliers that attain this accreditation will increase their level of process compliance, which will benefit all customers that receive parts or services from that supplier. Consider integrating your internal quality audit schedule to include the Nadcap process audit checklist associated with the process step being audited. This approach will embed this requirement into your overall operating plan, which will result in a highly effective and process-focused quality system. The business objective is to maintain Nadcap to satisfy your aerospace customers' requirements. However, the true benefit is that you will achieve higher operational performance with a constant review of your operations with best-in-class process audits. Make Nadcap the catalyst to transform your operations. **SMT007**

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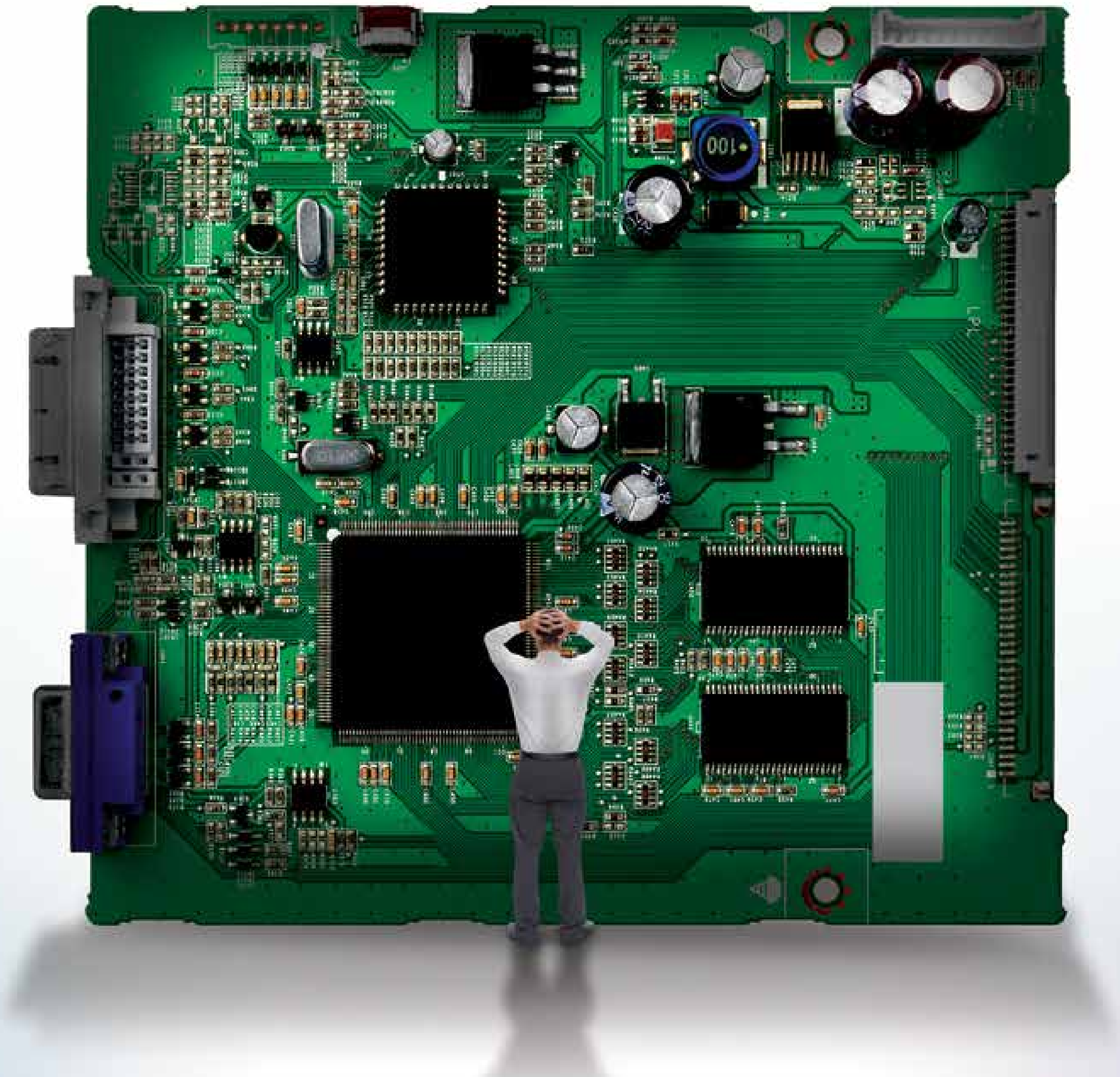


Supplier Highlights

Advancement of SPI Tools to Support Industry 4.0 and Package Scaling ▶

This paper evaluates the current state of inline SPI tools from multiple vendors for solder paste measurement accuracy and capability. It discusses a measurement capability analysis that was carried out against a golden metrology tool across a range of volume deposits and highlights the results from the study.

Operational Excellence: Becoming the Preferred Supplier, Phase 3–Re-engineer Your Quality System ▶

The final phase of becoming a preferred supplier is to apply a business process re-engineer approach to your quality system. Before you start with this phase, the company should have implemented the first two phases, which are focused on changing its leadership mentality to embrace LEAN Six Sigma and the pillars of operational excellence.

Altus' Axis: Is Your Soldering System Smart Enough for the Future? ▶

Time and time again, we read about the importance of changing processes to work with Industry 4.0, IoT, and smart manufacturing. We all know how important having the correct systems in place is, but are we implementing the necessary processes required to future-proof our factories?

Optimizing Solder Paste Volume for Low-temperature Reflow of BGA Packages ▶

This article explains how the volume of low-melting-point alloy paste—which delivers the optimum proportion of retained ball alloy for a particular reflow temperature—can be determined by reference to the phase diagrams of the ball and paste alloys.

Goepel electronic Adds Solder Paste and Placement Inspection ▶

Goepel electronic has enhanced the capabilities of its 3D AOI systems Basic Line·3D and Vario Line·3D with the addition of complete solder paste inspection function as well as placement control before the soldering process, making the system more flexible.

Recent Advances in X-ray Technology: SMTA Webinar Recap ▶

Technical Editor Pete Starkey recently attended a webinar on advances in X-ray technology and its applications in the electronics industry, as presented by Keith Bryant, Chair of SMTA Europe, on behalf of SMTA India. Here are the highlights of the webinar.

BESTProto Adds Third Proto Line With Mycronic ▶

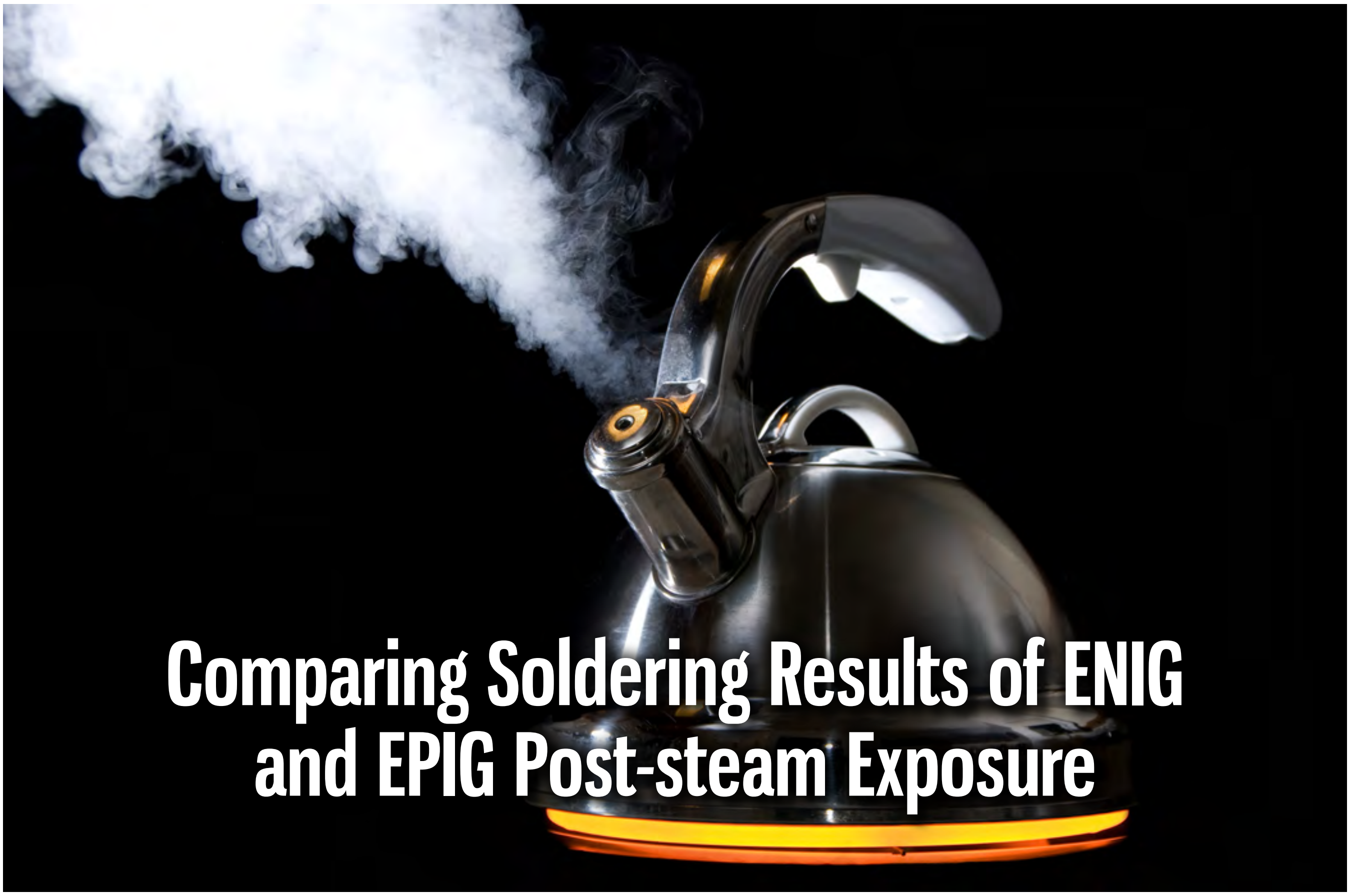
BESTProto Inc. has strengthened its assembly capability with the acquisition and installation of a new Mycronic MY-300 pick-and-place line.

New Microcare Cleaner Joins Ellsworth Adhesives Europe Portfolio ▶

The versatile Microcare General Purpose Cleaner and Adhesive Remover, which replaces the discontinued Slow Drying Flux remover (MCC-E7M), is now available to order from Ellsworth Adhesives Europe.

H K Wentworth Names New Commercial Director ▶

H K Wentworth, the parent company of Electrolube and AF International, has appointed Robert Crosby-Clarke to the board of directors as commercial director.



Comparing Soldering Results of ENIG and EPIG Post-steam Exposure

Article by Jon Bengston and Richard DePoto
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SOUTHINGTON, CONNECTICUT

Abstract

Electroless nickel immersion gold (ENIG) is now a well-regarded finish used to enhance and preserve the solderability of copper circuits. Electroless palladium immersion gold (EPIG) is a new surface finish also for enhancing and preserving solderability but with the advantage of eliminating electroless nickel from the deposit layer. This feature has become increasingly important with the increasing use of high-frequency PCB designs whereby nickel's magnetic properties are detrimental. We examine these two finishes and their respective soldering characteristics as plated and after steam aging and offer an explanation for the performance deviation.

Comparing the results of steam-age test data shows a clear benefit of EPIG over ENIG. After even a short duration exposure to steam, ENIG finishes failed to solder. Much longer steam exposures produced little to no effect on EPIG plated samples. Rapid oxidation of the electroless nickel phosphorous layer when stressed with heat and moisture explains the superior EPIG result.

The ability to demonstrate excellent solderability following steam exposure represents increased fabrication reliability under non-ideal storage conditions.

Introduction

Assessing the solderability of a given final finish can range from a simple solder dip as coated or plated to quite complicated procedures involving the final finish type, solder alloy, flux characteristics, test preconditioning, soldering apparatus (wetting balance), and part geometries. Focusing on two types of solderable finishes and one preconditioning procedure allows the clear reporting of results and expectations that those finishes afford.

Morris, Lukaszewski, and Genthe [1] describe a need for verification methods for accelerated testing of electronics. Specific to soldering


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operations, steam aging of PCBs before solder wick testing is seen as not only quick and inexpensive but also a reliable shelf-life predictor. Eight hours of steam aging is reported to be equivalent to 12 months of shelf-life exposure for tin-lead (60/40) systems only [2].

There are many solderable surface finishes used on copper printed circuit boards that range from thin organic coatings to heavy metal plates, such as 1–3 microns of gold plate. Plated tin-lead or molten tin-lead coatings (HASL) are early predecessors of the diversified finishes that are available today. These leaded alloys consistently show high resistance to steam aging and solder quality retention. Most other PCB coatings do not fare well after steam exposure. Currently, all other final surface finishes for PCBs fail to maintain acceptable solderability performance after one-hour steam exposure [2].

Of the many solderable finishes available, two are tested here. One—ENIG—has been available for over 20 years. It has a track record of robust soldering performance and is generally ascribed a 12-month shelf life before its soldering performance begins to degrade. EPIG, on the other hand, is a new finish with EPIG test results showing very good solder wetting and force values. The overall shelf life has yet to be determined. However, test results in this article comparing ENIG performance to EPIG performance under steam exposure stress will shed light on this question.

Steam exposure is not the only approach to determine how well a finish will hold up to environmental conditions. Other tests include thermal cycling, which shows the effect of multiple solder applications; real-time environmental exposure, which yields the most reliable data; and mixed flowing gas testing, a precise chamber test where gas type and concentration are stringently controlled. Meanwhile, steam exposure provides a quick, reliable, and inexpensive indicator of soldering shelf life.

Methodology

A steam-aging preconditioning or stressing procedure was exacted upon both ENIG and EPIG coupons per IPC J-STD-002 and J-STD-003. Using the stress of steam exposure helps to determine the durability and robustness of each solderable surface. Robustness is a difficult term to define and measure accurately. Here, robustness is intended to mean that a PCB's shelf life vastly exceeds the typical 12 months, can withstand more solder reflows, and holds soldering properties regardless of the normal fabrication processes employed.

Soldering test materials used include the application of a mild flux just before solder testing and the use of lead-free solder—Sn3Ag0.5Cu joining metal. These were limited to single non-variable options to simplify testing protocol. Both of these represent common commercial soldering practice.

This assessment observes the solder wicking onto a PCB test coupon plated with either ENIG or EPIG. The testing is conducted on an as-plated condition and after exposure to steam. The duration of the steam exposure is in units of hours and continues until failure or a total of eight continuous hours of exposure. It is expected that failure to solder wet will coincide with the oxidation of plated films or the base copper to an extent whereby fluxing is no longer able to clean and remove those oxides.

The PCBs plated for testing consisted of standard solder wicking coupons, as shown in Figure 1.

The ENIG film thickness used equals 3.75 microns of nickel phosphorus with 0.075 to 0.1

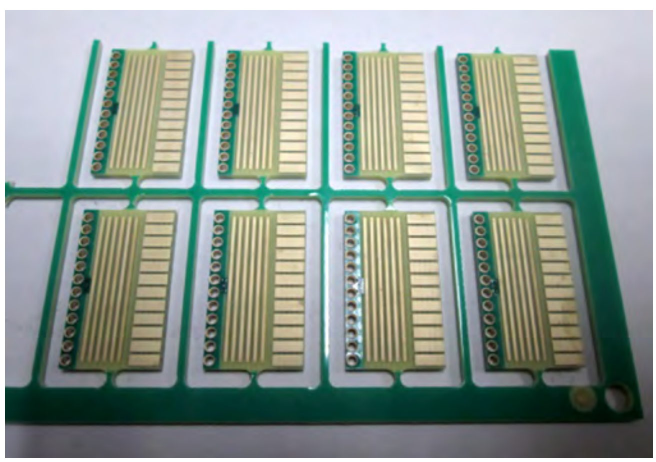

Figure 1: Solder test coupon used for solder wick testing.

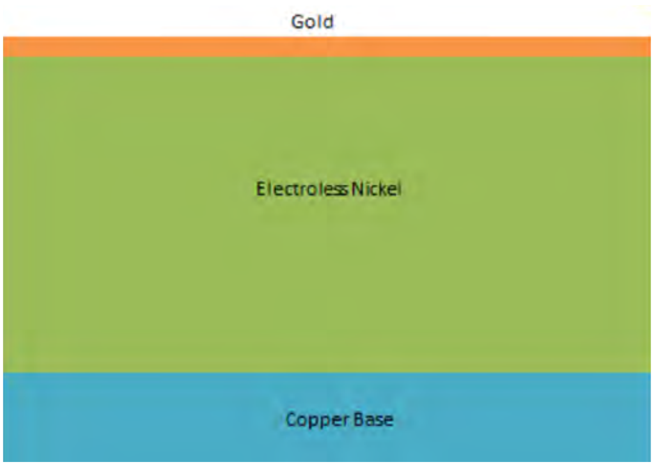

Figure 2: Diagram of ENIG plate tested.

Figure 3: Diagram of EPIG plate tested.

microns immersion gold on top. Thickness levels were not changed, so as not to be a variable (Figure 2).

The EPIG film thickness used equals 0.375 microns palladium phosphorus with 0.025 microns immersion gold on top. Again, thickness was held to one level for testing duration (Figure 3).

The solder flux used was composed of 25% ±0.5% colophony, 0.39% ±0.01% diethylammonium chloride, and the balance isopropyl alcohol. The solder alloy employed was a SAC 305 alloy consisting of 3% silver, 0.5% copper and the balance tin. The solder temperature was set at 255°C. The contact time between the solder and sample measures wetting time and soldering final force.

A production solder wetting balance was used to measure time to wet and solder force (Figure 4). A production XRF machine was used to measure plating thicknesses (Figure 5).

Steam aging apparatus used was as outlined in IPC J-STD-002/003 as shown in Figure 6.

The solderability evaluation procedure engaged was to first plate solder test coupons with ENIG and EPIG. Both of these plating processes utilized the exact same preparation

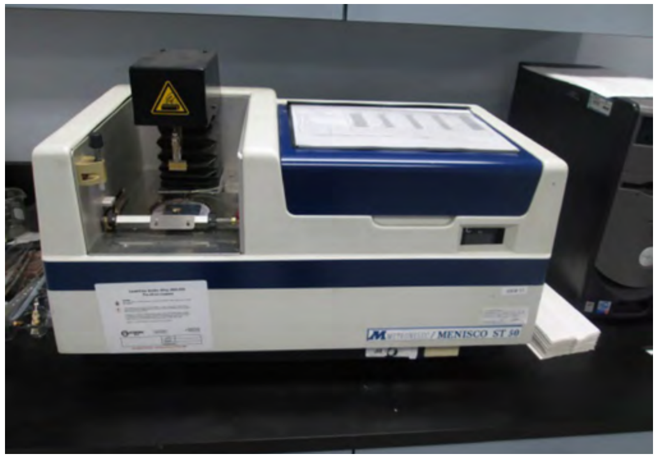

Figure 4: Wetting balance used to test solderability.

Figure 5: XRF used to measure plate thicknesses of the ENIG and EPIG test samples.

Figure 6: Steam aging apparatus used to stress ENIG and EPIG solder wicking.

Plating Step	Temperature	Time	Agitation	Type
Clean	49°C	5 minutes	Stirring	Acidic
DI water rinse	21°C	1 minute	Stirring	
Etch	27°C	1 minute	Stirring	Peroxide/sulfuric
DI water rinse	21°C	1 minute	Stirring	
Activate	27°C	2.5 minutes	Stirring	Acidic dissolved palladium
DI water rinse	21°C	1 minute	Stirring	
Electroless nickel or electroless palladium	82°C 49°C	20 minutes 15 minutes	Stirring	Nickel: 7% phosphorus Palladium: 3% phosphorus
DI water rinse	21°C	1 minute	Stirring	
Immersion gold Conditions used for EN (ENIG) Conditions used for EPd (EPIG)	 81°C 85°C	 10 minutes 20 minutes	 Stirring Stirring	Gold potassium cyanide 2g/l gold metal pH 5.2
DI water rinse	21°C	2 minute	Stirring	
Dry				Forced air

Table 1: Plating cycles used to prepare ENIG and EPIG test samples.

cycle to clean and activate the base copper. Electroless palladium was simply substituted for electroless nickel to create an EPIG finish. The singular preparation and plating sequence utilized are outlined in Table 1.

Plating times were adjusted in the immersion gold step as the deposition is more vigorous on nickel versus palladium as predicted by the relative corrosion potentials of -0.250V for nickel and +1.498V for gold, a delta of -1.748V compared to +0.987V for palladium, and +1.498V for gold a delta of -0.511V [3]. The larger delta negative potential between nickel and gold shows that, in the case of immersion plating, gold deposits more rapidly on to nickel than on to palladium.

Post plating, solder coupons were dried and stored in a sealed and desiccated environment until steam stressing and solder wick testing was performed. Coupons were steam aged, as outlined in J-STD-002/003, for one to eight continuous hours. This was conducted in one-hour increments until solder failure or until eight hours of total steam-aging time had been achieved.

Results and Discussion

Test results show that ENIG is an outstanding final finish. ENIG, however, is susceptible to rapid solder non-wetting after steam exposure. On the contrary, EPIG shows little to no susceptibility in comparison. Speculation as to why such a difference between the two finishes suggests a strong interaction of steam on exposed nickel phosphorus. The nickel phosphorus is made available to steam penetration through the thin porous gold topcoat present in the ENIG deposit.

Figures 7–12 show the results of solder wetting tests using the solder wetting balance. The X-axis measures contact time between the plated copper pads and the liquid solder. The time units are in seconds. Total contact time for each measurement is 10 or 20 seconds.

The Y-axis of the wetting chart measures the wicking force of the solder as it wets the plated copper test pads. The force units are mN/mm for these tests. The force climbs as a greater area of the test pad is covered with solder. The initial dip in force represents the initial contact between the coupon and solder. As the test area wets with solder the force climbs to a maximum. That maximum is the wetting force for that particular test. The time needed for the force to cross or intersect the zero-force line is considered to be the total wetting time for that particular test.

Results are interpreted as positive when the wetting force rapidly ascends to a maximum and holds at that level. Should the wetting force not pass through zero for the duration of the test, then a non-wetting solder failure is assigned. Likewise, solder failure is also observed when the wetting force reaches a maximum and then decreases. That type of chart represents solder de-wetting for the test.

Comparing the solderability results of ENIG (Figure 7) and EPIG (Figure 8) show that both provide excellent wetting times and soldering forces in the as-plated condition.

After just one hour of steam aging, the ENIG finished sample fails to wet solder (non-wet condition) (Figure 9). The EPIG sample continues to wet well to solder, unaffected by one-hour steam preconditioning (Figure 10).

Through eight hours of steam aging, the EPIG samples solder well with a minor reduction in wetting force as seen in Figure 11, which shows a 20-second contact duration.

These test results show that steam has a dramatic negative impact on the solderability of ENIG even after one-hour exposure. Meanwhile, EPIG remains quite solderable with almost no change in wetting times and force after eight hours of continuous steam exposure. The reason for the performance difference is thought to be a rapid formation of a nickel oxide on the electroless nickel phosphorous surface during steam stressing, inhibiting wetting and the formation of a nickel-tin intermetallic, which reduced the ability to solder well. The formation of a tin-nickel intermetallic is required for good solder wetting to occur.

K. Yokomine, et al. [4], describe results of testing the depth of oxygen found on the electroless nickel surface from an ENIG film as plated and after immersion in an aqueous cleaner at 80°C. Using electron spectroscopy for chemical analysis (ESCA) equipment, a three-to-four-

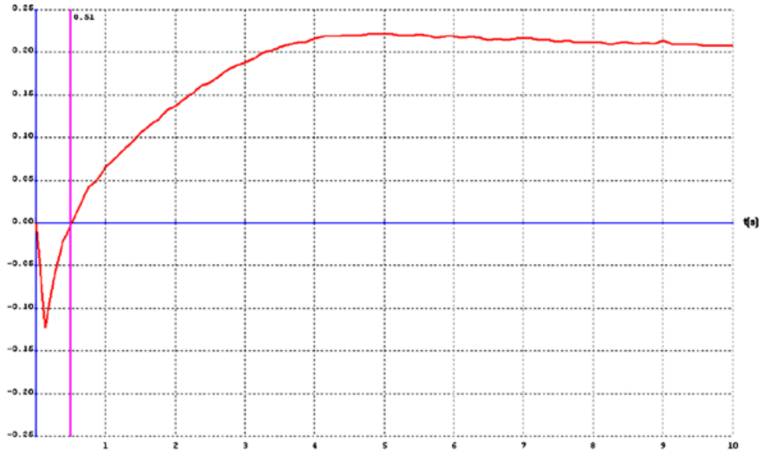

Figure 7: ENIG wetting time and force as plated.

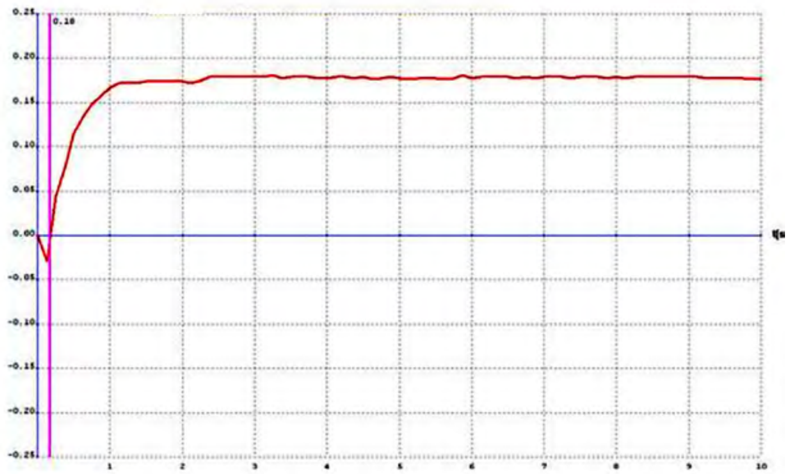

Figure 8: EPIG wetting time and force as plated.

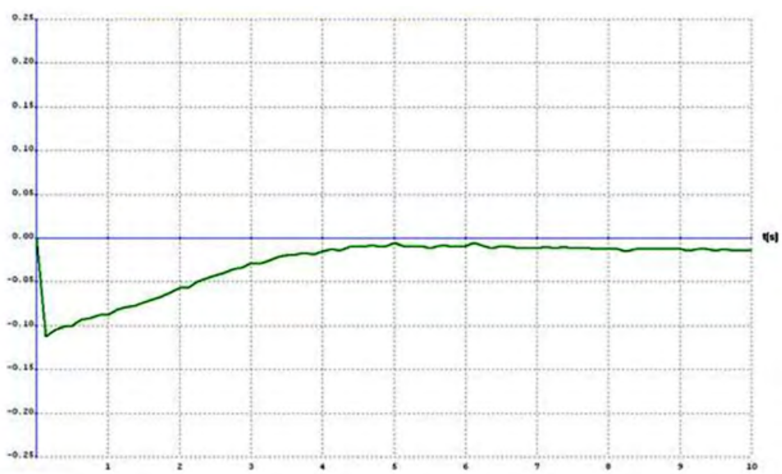

Figure 9: ENIG non-wet condition after one-hour steam exposure.

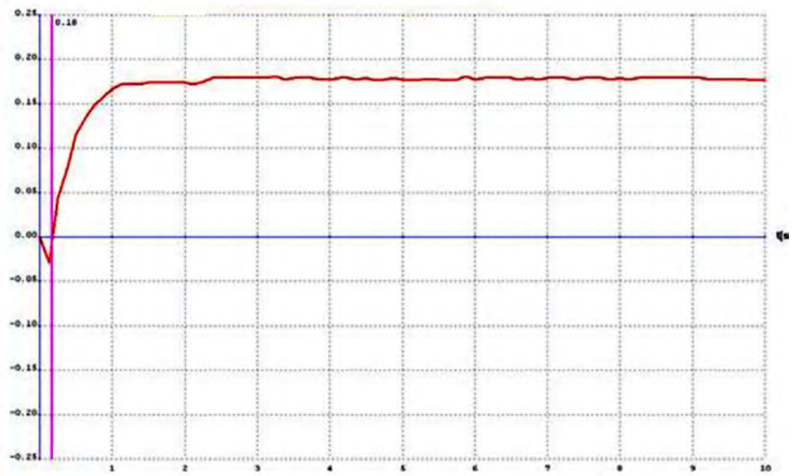

Figure 10: EPIG normal wetting after one-hour steam exposure.

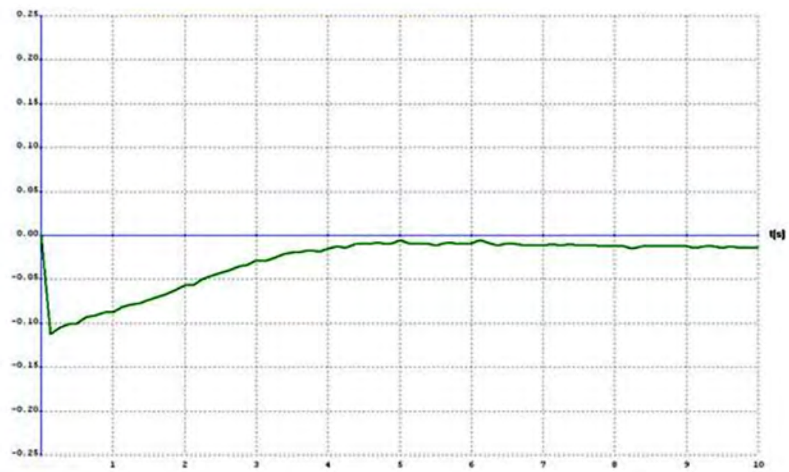

Figure 11: EPIG wetting after eight hours of steam exposure.

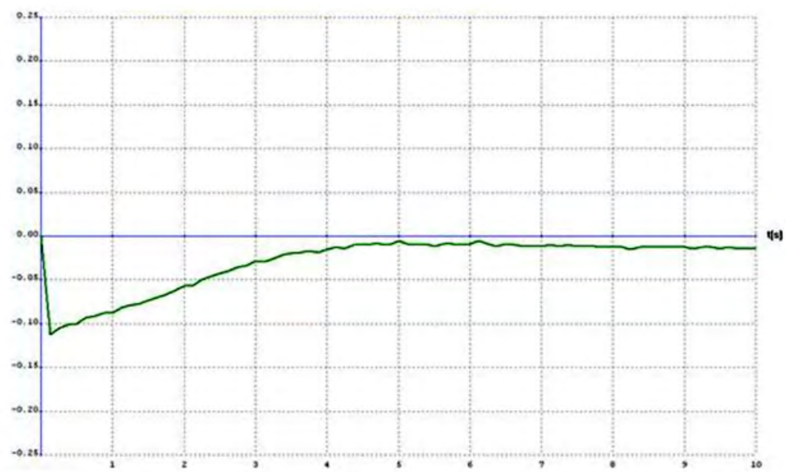

Figure 12: Organic anti-tarnish protected ENIG wetting balance after eight hours of steam stressing.

fold increase in oxygen depth post dipping ENIG at 80°C versus room temperature measurements was recorded [4].

Palladium's inherent resistance to oxidation provides a robust, oxidation-free protective layer for solder applications. Also, palladium dissolves in the molten solder allowing the formation of a copper-tin intermetallic directly with the underlying copper surface.

Another contributing reason for the soldering performance difference between ENIG and EPIG is the tin intermetallic formed. ENIG forms a nickel-tin intermetallic whereas EPIG forms a copper-tin intermetallic. The gold and palladium layers readily dissolve into solder, so the bonded interface is directly between copper and tin. Hence, any thin oxidation or other environmental contamination of the palladium layer is essentially dissolved and thus inconsequential to the copper-tin bonding interface.

A follow-up verification test was made by coating ENIG solder coupons with an organic anti-tarnish topcoat. The topcoat is a solderable organic anti-tarnish coating that is intended to be a barrier to oxygen penetration. The coating is applied on top of the immersion gold layer, essentially sealing the thin porous gold.

Solder wetting tests using the organic topcoat on ENIG substantially eliminate the adverse effects of steam conditioning. Starting at one-hour steam exposure through to eight hours limited the degradation in the ENIG's solderability, which indicates that the nickel layer remained relatively oxide-free with solder wetting occurring after eight hours of steam stressing (Figure 12).

Test Condition	Time to Positive Wetting (Seconds)	Wetting Force (mN/mm)
ENIG "as plated"	0.51	0.21
EPIG "as plated"	0.18	0.17
ENIG "after one-hour steam"	Null	-0.02
EPIG "after one-hour steam"	0.12	0.19
EPIG "after eight hours of steam"	0.20	0.16
ENIG/anti-tarnish "after eight hours steam"	2.0	0.25

Table 2: Compilation of test conditions, positive wetting time, and maximum wetting force (from Figure 7-12).

Summary/Conclusions

The successful soldering to PCBs is lessened with time and exposure to environmental conditions—most notably heat and moisture. Excessive exposure renders boards unsuitable for final fabrication/assembly based on poor solderability resulting in disposal before—or worse, after—expensive components have been mounted. Enhanced soldering reliability is achieved by rendering heat and humidity ineffectual in reducing solderability.

Steam aging per IPC J-STD-002 and J-STD-003 is a convenient and low-cost method of evaluating the shelf-life of finishes used on PCBs that takes minimal time. Two finishes—ENIG and EPIG—were tested for solder wetting pre- and post-steam stressing exposure. Test data shows that the steam stressing had little influence on the EPIG board surface finish solderability while ENIG board surface finish rapidly becomes unsolderable. The swift oxidation of the nickel layer by steam is thought to be the cause. Supporting evidence was provided by applying a secondary organic anti-tarnish coat to the ENIG samples before steam stressing. Oxidation of the nickel layer was then suppressed. The organic film reduced nickel oxidation after steam stressing with improved solder wetting. **SMT007**

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4. Yokomine, K., Shimiizu, N., Miyamoto, Y., Iwata, Y., Love, D., and Newmam, K., "Development of Electroless Ni/Au Plated Build-Up Flip Chip Package with Highly Reliable Solder Joints," IEEE, Electronic Components and Technology Conference, 2001.

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Process Methods for Reworking High Lead Count SMT Parts

Knocking Down the Bone Pile

by Bob Wettermann, BEST INC.

There are numerous methods for getting the solder onto the right pads in the right volume during SMT rework of high pin count or very small footprint SMT devices. The most common types of solder deposition include printing, dispensing, and hand soldering. Each of these methods has pros and cons, depending on a variety of factors in the rework process.

Hand Soldering Rework

Hand soldering of high lead count or very small package SMT components for rework is fast and requires a high degree of skill from the operator. The good news about using the hand soldering process for these types of SMT components is that a device during debug can be quickly reworked and passed back to test or design engineering.

However, there are some deficiencies in using a hand soldering rework process for electronic components. First, the lack of consistent solder volumes and consistent hand soldering uniformity makes this an uncontrolled process. When the process allows for adding flux, the lack of control over this flux volume means that flux residue and board cleanliness can be a potential reliability risk. For some of the fine-pitched parts in high-density areas, a high degree of rework technician skill is required, which limits the throughput (Figure 1) In addition, nearby components can become damaged if the technician is not careful when placing the soldering iron. Also, hand soldering is not a cost-effective option in some cases, as it can be very time-consuming.

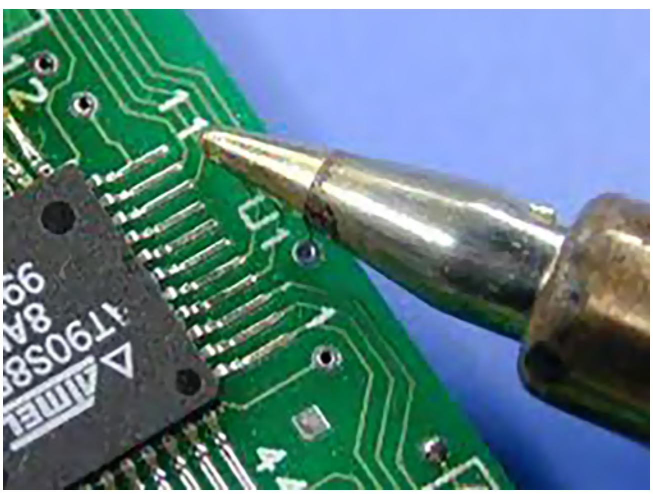

Figure 1: Hand soldering for rework of fine-pitched components.

Stencil Printing

Stencil printing for the rework of high pin count or very small package SMT components for PCB rework has some pluses and minuses. The advantages to using stencil printing for the rework of these devices are numerous and include this being a well-known technique with well-known materials, requiring a moderate degree of skill from the rework technician. The speed of the rework method is also fast compared to the other methods.

The flexible, single-use stencils (Figure 2), while still being space-constrained, allow the rework technician to get into tight spaces. These adhesive-backed stencils have overcome the limitations of the metal stencils, including board coplanarity, the bending of the stencils during handling, getting into tight spaces, the necessity to tape around the device to prevent solder paste from contaminating the area, and the necessity for a holding fixture for alignment and time it takes to clean the stencils.


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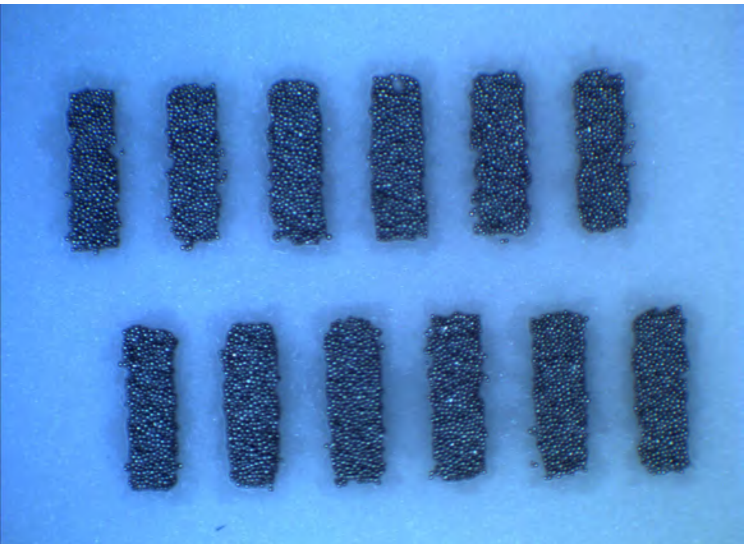

Figure 2: Flexible stencil paste print.

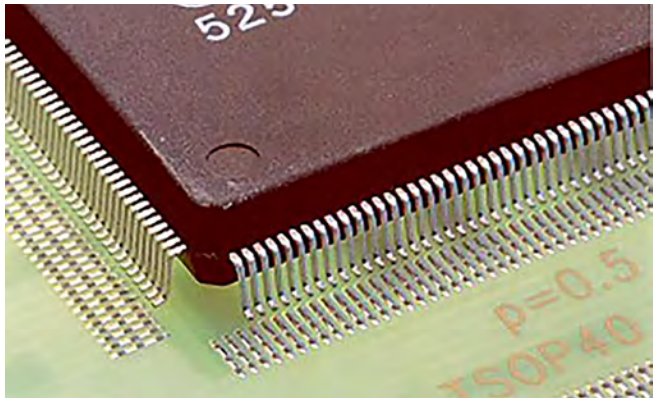

Figure 3: Dispensed solder paste on ultra-fine-pitch SMT component.

But this rework method has drawbacks, including the handling of stencils when very small packages are involved, the "messiness" related to solder paste printing, and the time it takes to have the stencils on hand (24–48 hours) all limit the usefulness of stencil printing solder paste for rework.

Dispensing

Dispensing, along with jet printing, offers an alternative to both stencil printing as well as hand soldering. There are several advantages for dispensing when it comes to the rework of high I/O count and/or very small package components (Figure 3). The biggest differentiator of this technology is the precision of the dispensing technique. Modern Archimedes screw-type dispensers can dispense 20,000 dots per hour down to 800-um sizes. A single jet printing setup can print at a constant speed of up to 300 Hz, or 1,000,000 dots per hour, with the dots getting down to 200-µm in size.

One of the other big advantages of jetting is that multilevel boards and odd-shaped lands—such as RF shields with the same deposited solder volume—offer high repeatability. In addition, this method is more automated than the stencil or hand solder rework methods. While this method offers many advantages, it is not for every scenario due to its capital-intensive nature, the programming required, and the relatively slow speed of deposition. Dispensers that can be used for solder paste deposition start at several thousand dollars and range up to over $100,000 U.S. dollars. And each of the package footprints take time and skill level to program.

This method, even when finely tuned, is very slow compared to the methods. Finally, any process that involves a liquid and dispensing like this requires expertise so that lines, nozzles, and other elements of the dispensing system are kept clean and optimized. This is rheological "tightrope to walk" with dispensing technology and the associated precision deposition upside.

Conclusion

The process engineer has to take each rework situation and consider the turn time required, the reliability of the assembly in the end-use operating environment, the skill level of the operators, the available funds, and the economics to make the right decision. **SMT007**

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

Editor's Picks from SMT007.com

1 SMT Stencils 101: What Are Industry-standard Stencil Designs? ▸


Greg Smith

If you've been in the SMT industry for any length of time and involved in ordering stencils, you may have instructed your stencil supplier to design your stencil to "industry standards" or per IPC standards. These are very loose terms and may be interpreted differently by different stencil manufacturers.

2 The Government Circuit: Trump Praises Industry on Workforce Issues, IPC Launches Grassroots Platform ▸

On the government relations front, IPC's workforce development efforts were recognized at the White House in Washington and on a factory floor in Michigan. On another front, we've launched an online platform that makes it easier for our members to contact their elected officials, and we're using it to seek more R&D funding for an important industry project.

3 Zulki's PCB Nuggets: Protect the Die and Wire Bonding for Effective PCB Microelectronics Assembly ▸

Protecting bare dies on a PCB or substrate is a major process of microelectronics assembly. As we've said before, microelectronics assembly and manufacturing work in tandem with traditional SMT manufacturing for complete PCB hybrid manufacturing of today's smaller form factor products, including IoT, wearables, and portable devices.

4 The Mannifest: Common Machine Errors and How to Avoid Them ▸


Chris Ellis

When it comes to the quality of SMT boards you produce, it can be difficult to know where to begin and what features various PCBA machines offer are most important. To avoid common errors that could compromise the boards you're looking to produce, be sure to keep an eye out on these key features before assembling your line.

5 SMT Solver: Would You Prefer Shorts or Opens in Your Products? ▶


Ray Prasad

Would you prefer shorts or opens in your products? Of course, neither. But what if you do have to choose? Ray Prasad says he would choose a more desirable defect, if there is such a thing. But what is a desirable defect? Read on.

6 Lindsay Goldberg to Acquire Creation Technologies ▶

The transaction is to be completed by way of a plan of arrangement under the Business Corporations Act of British Columbia. Completion of the transaction is subject to a number of conditions, including court, shareholder approvals, and applicable regulatory approvals.

7 The Four Things You Need to Know About Test ▶


Neil Sharp

The electronics manufacturing process can often be extremely complex, and the costs associated with product recalls can be astronomical. A robust approach to test is key to ensuring the quality of your product and the satisfaction of your end user.

8 Member Companies Visit White House to Promote IPC Skilled Workforce ▶

The Trump administration is praising IPC—Association Connecting Electronics Industries—and several of its member companies for their efforts to expand the skilled workforce.

9 Quanta Appoints Benchmark as Manufacturing Partner ▶

Quanta Dialysis Technologies Ltd.—a pioneering British medical technology company, developing a personal haemodialysis system (SC+) for patient use at home and in the clinic—has selected Benchmark Electronics Inc. as its production partner for the SC+ haemodialysis machine.

10 Powerful Prototypes: 5 Common Myths About Solder Mask ▶


Duane Benson

Before parts are added, a typical PCB has four ingredients: substrate, metal, solder mask, and silkscreen. Solder mask, in particular, seems to be looked at as a great place to cut when costs are tight, but Duane Benson disagrees. Read on as he dispels five common myths about solder mask.

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NEPCON Vietnam ▶
September 11–13, 2019
Hanoi, Vietnam

SMTA International 2019 ▶
September 22–26, 2019
Rosemont, Illinois, USA

productronica India 2019 ▶
September 25–27, 2019
Delhi NCR, India

electronica India 2019 ▶
September 25–27, 2019
Delhi NCR, India

52nd International Symposium on Microelectronics ▶
September 29–October 3, 2019
Boston, Massachusetts, USA

16th Annual International Wafer-Level Packaging Conference ▶
October 22–24, 2019
San Jose, California, USA

productronica 2019 ▶
November 12–15, 2019
Munich, Germany

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IPC | SMTA Surface Mount Technology Association | iNEMI | smt007

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OCTOBER: **The Landscape of the Industry**
In this issue, we examine the current landscape of the electronics industry and how it is changing from design tools to AI, manufacturing, and markets.

NOVEMBER: **Voices of the Industry**
Sometimes, the best view into an industry or a community is through individual voices. In this issue, we talk to members of our business community, gathering and sharing their voices and perspectives.

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