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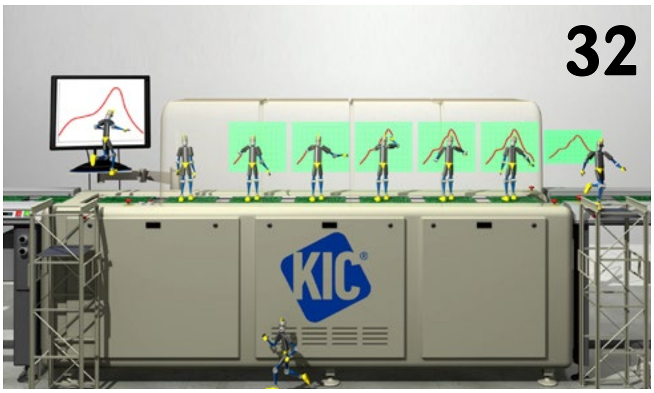
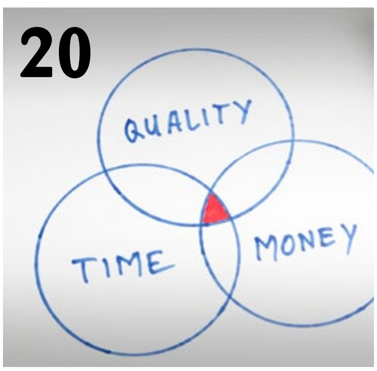
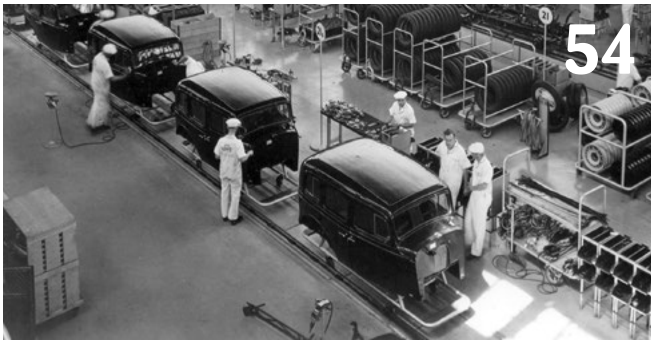
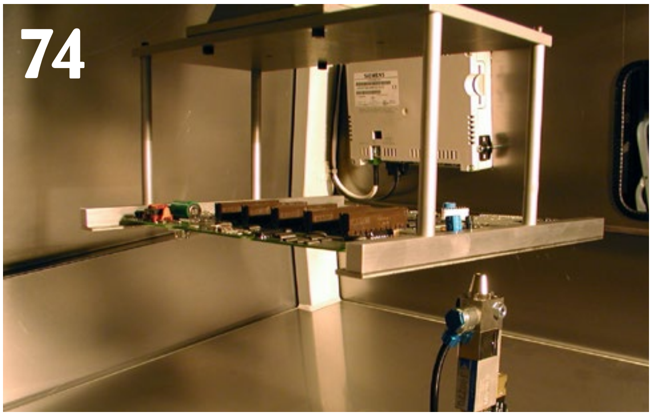




Reducing Handling Errors

This month, *SMT Magazine* features strategies to help reduce handling errors and improve efficiencies in your assembly lines.





More Content:

Strategies to Reduce Handling Errors

by Stephen Las Marias
I-CONNECT007

Despite the advancement in manufacturing technologies, processes in assembly lines continue to involve multiple opportunities for errors or defects to happen. Sometimes, these processes involve factory workers doing repetitive, dull tasks that do not add much value into the overall productivity of the company. More often than not, such causes of errors also involve out-of-date or legacy equipment that electronics manufacturers are hesitant to replace, as doing so entails a significant investment.

Nowadays, the electronics assembly industry is looking more and more into automating their production lines as automation offers several benefits, including a return on investment in the long run; reduced variation; and higher reliability. In our recent survey, the majority of respondents said automation helps them reduce handling errors—or operator errors—in their processes. It also enables faster throughput, as well as reduces the number of processing steps.

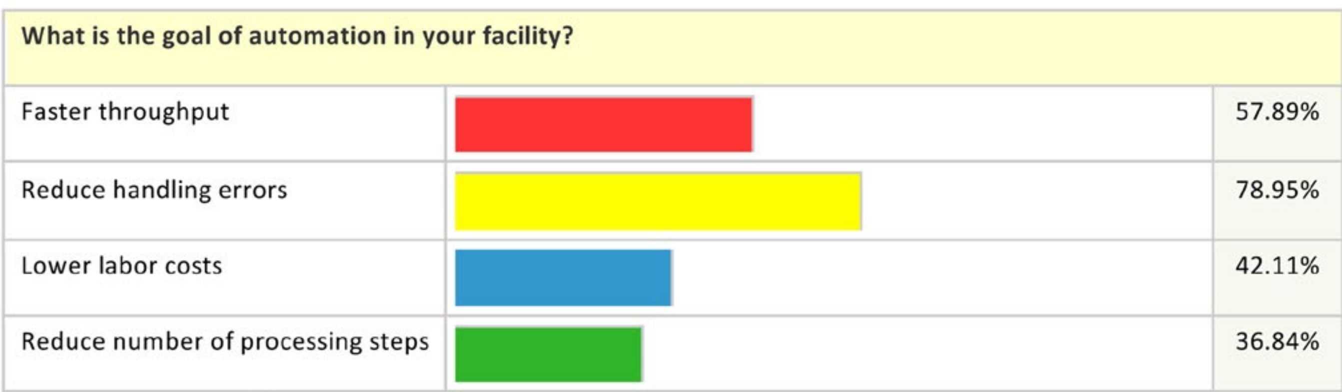
During my visit to the IPC APEX EXPO in March, I witnessed one demonstration that can be related to our topic for this issue of *SMT Magazine*—strategies for reducing handling errors. It was Sawyer, a collaborative robot by Rethink Robotics. (You can watch my interview with Rethink Robotics' Carl Palme here.)

In Rethink Robotics' demonstration, Sawyer was integrated into a legacy testing equipment. What the robot does is open the tester, put the board assembly to be tested into the proper testing area, and then close the equipment. After testing, the robot will open the tester, take the board out (and probably place it on a conveyor or somewhere for the next process—the demo didn't show this), and then take the next board due for testing. And on and on it goes.

"One of the nice things about a robot is that it can do the same thing over and over every single time. Robots are very good at repetitive, dull tasks, while humans can actually add a lot of value in many different tasks. I think what is going to happen is robots will take over jobs that are very low value-add—where operators don't feel fulfilled; and humans are going to be promoted to jobs where they can add more value to a product, where they get more satisfaction out of their jobs," said Palme.

I think what's even better here is that the robot was integrated into legacy equipment, and it was able to offer some level of automation into that process, without having a significant amount of investment into new equipment. Moreover, it reduced the opportunity for handling error, as it made sure that the boards were placed accurately and precisely into the fixture, before testing. Sure, a person can do that over and over again. But as Palme said, that person can add more value somewhere else.

Going back to our survey, one of the comments made was that some smaller-volume



Source: I-Connect007 Survey

companies cannot justify the ROI on automation. And that is true. In his column for the March 2016 issue of *SMT Magazine,* Michael Ford of Mentor Graphics wrote that in the 1990s, when high-volume production was still enjoyed by most operations, the idea of replacing remaining manual operations with automated processes seemed like a great idea, although the technology at the time did not quite deliver on expectations. Today, the same ideas and goals for automation are once again in play, but this time, although technical capabilities have vastly improved, little high-volume is left. Ford added that automation now has to be part of a high-mix production environment, with flexibility as factories are called on to be more responsive to shorter term changes in demand.

Of course, the trend is toward automation, especially if you aim to reduce the handling errors in your production lines and improve the overall efficiency of your facility.

However, many companies cannot afford to acquire new and more advanced equipment just to say they are automated. There are many alternative strategies to help assemblers improve their process and reduce errors along the way.

This idea leads me to this month's issue of SMT Magazine, which features other aspects of the assembly line where improvements can be made to increase the efficiency of the process. For starters, Donald Naugler, president and general manager of Massachusetts-based VJ Electronix, discusses in an interview the strategies to help customers reduce handling errors in their rework processes as well as material handling.

I also interviewed Bjorn Dahle, president of KIC, during IPC APEX EXPO, to discover more about the technology improvements being made in reflow ovens that ensure visibility, traceability, and reduce handling errors in the process.

Handling errors can also be reduced through shortening the time it takes to set up a system. So from his perspective, Bob Bouchard, corporate marketing manager at BTU, explains how advances in thermal processing systems for reflow ovens can help users reduce their setup times, handling errors, and total cost of ownership.

While automation is arguably the popular answer to really eliminating the handling errors in a process, justifying investments in automation is getting more difficult, as the stakes are higher now for introducing automation.

Circling back to Michael Ford, he writes about understanding the cost of automation when it comes to the EMS industry, the flexibility it can offer, and deciding how much to invest in automation.

Michael Hansson, director for global automation at EMS firm Integrated Micro-Electronics Inc., writes that for an EMS provider, it is a given that the front-end board assembly process needs to be automated. For the back-end final assembly process, however, the situation is often less clear. In his article, he explains how far it makes sense to automate, and what type of automation—full, semi or partial—is better.

Following up on his article last February, our technical editor Pete Starkey interviews Ron Jakeman, group managing director of Electrolube, during the recent productronica China in Shanghai to discuss the company's activities in the region.

Dave Becker of All Flex Flexible Circuits LLC—who is also our expert columnist for *The PCB Magazine*—explains how coordination between flexible circuit makers and the electronics assemblers can have a significant effect on costs based on material/panel utilization.

Finally, *SMT Magazine* is not complete without our columnists. For this issue, Robert Voigt of DDM Novastar continues his discussion on selecting a selective soldering system.

Tom Borkes of The Jefferson Institute, meanwhile, writes about the production model based on Henry Ford and his assembly line idea.

That's it for this month. Next issue, we will talk about the challenges surrounding solder paste printing amid the tighter tolerances and finer lines and spacing due to the continuing miniaturization trend in the electronics industry.

Enjoy! **SMT**

Stephen Las Marias is managing editor of *SMT Magazine.* He has been a technology editor for more than 12 years covering electronics, components, and industrial automation systems.

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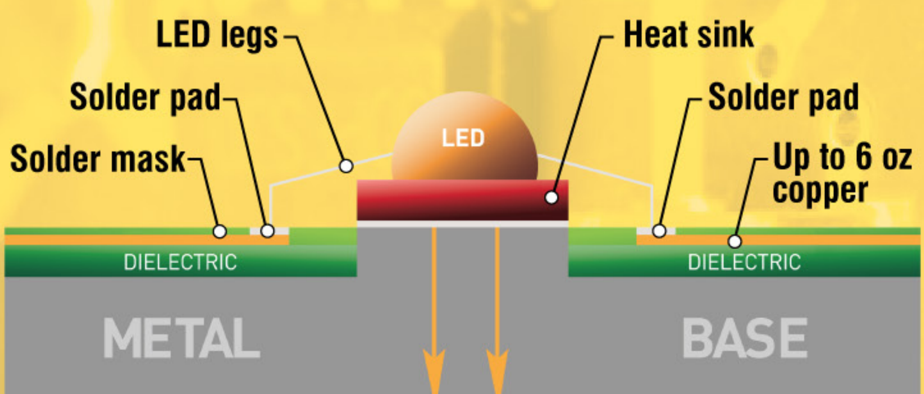

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Strategies to Reduce Handling Errors in Your Rework Process

by Stephen Las Marias
I-CONNECT007

Massachusetts-based VJ Electronix provides SMT rework systems and X-ray inspection solutions for the electronics assembly industry. Their systems are suitable for applications ranging from high-volume consumer products such as mobile phones, netbooks, set-top boxes, game consoles to ultra-precision, challenging applications found in aerospace, medical devices, and automotive electronics.

In this interview during the recent IPC APEX EXPO in Las Vegas, Donald Naugler, president and general manager of VJ Electronix, discusses rework challenges and strategies to help customers reduce handling errors in their processes. He also talks about automation, and the impact of Industry 4.0 in the electronics assembly industry.

***Stephen Las Marias:** Don, what are some of the challenges that your customers are experiencing in this industry?*

Donald Naugler: It all comes down to productivity. It always is productivity and price, and you've got to perform in both areas. But we see a growing need, or a growing desire I should say, to start being more automated. We have a lot of our customers saying, "What do you have in the field of automation? How can I reduce the number of touches or even eliminate the touches by the operator?" So, we are working with a couple of the large companies both EMS as well as OEMs to adapt our equipment and take what has been kind of a minimal level of automation to the next level and try to, if not totally, eliminate the operator, minimize the number of touches.


Donald Naugler

Our history really goes back to something we used to call semi-automation. We focused hard on taking out any variability that an operator could

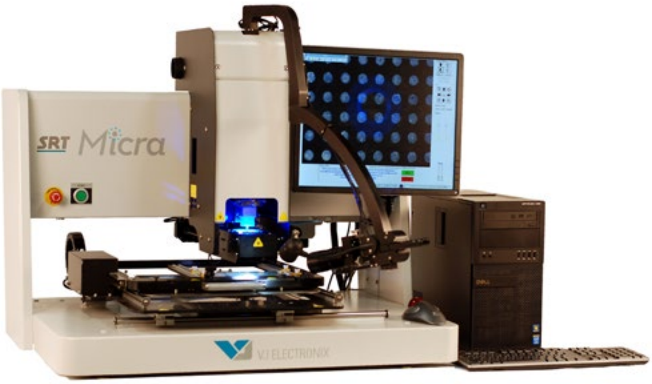


Figure 1: Most manufacturers still rely on operators to do material handling and some of the more basic functions—such as interfacing with the job tickets or whatever the customer may have to track the rework or the inspection process.

have. So we still relied on operators to do material handling and some of the more basic functions—interface with the job tickets or travelers or whatever the customer may have to track the rework or the inspection process, and then automate the areas where the operator has influence. We have been doing that for a number of years, now it is just a matter of taking the next step and trying to do some of the material handling using conveyors or robots and take a step up in eliminating some of the other operator interventions, such as manual alignments and placing the boards onto the system itself. So that is something that you will see coming down the road from us as well as suppliers across the industry.

***Las Marias:** What strategies can you think of that will help OEMs and EMS reduce handling errors in their process?*

Naugler: I think there are a couple different approaches that are required actually on the equipment side for both rework and inspection. We have to make sure we put in some form of validation to make sure that if an operator loads a printed circuit board, that it is what the system expects it to be. We can do that with anything from operator aids to what we call interlocks, in a way. It actually is a method of using bar codes or other methods to make sure that it is the correct product put on in the right orientation and so on.

The other thing that we have is actually fairly new and kind of exciting for us on the material handling side. On the production lines when people do changeovers or introduce new kits to the floor, they are moving a lot of material, components and whatnot. Obviously, they have to make sure they get the right components to the pick-and-place machine. But the other factor that has been very difficult is to make sure that they have an adequate supply as well. The last thing you want is to set up a line and have the line go down because you thought you had 10,000 of a certain component, but you only had 2,000. We have a new product called the XQuik with AccuCount. It's an automated way using X-ray technology to look at the reels, and do a very accurate count of those reels.

You can connect the XQuik with AccuCount directly to the MES system for inventory management or we can have it print labels. In that regard we are taking the variability of manual counting that these components can add. In the manual counting, you can have an error in the actual count, you could have an error when the operator either puts a tag on it, or a lot of times they are manually entering this inventory update into the MES system, and they could transpose some numbers or use the wrong reel ID. So we are taking that aspect completely out of the operator's hands.

***Las Marias:** So does it really make sense to take the operators out of the process?*

Naugler: Well, they won't be totally removed. Again, there is a reduction in the number of operators required, because it is much faster and much more efficient. But what it does is takes away the possibility for errors in this process. So, we use a barcode scanner to scan and identify a reel by its ID number, by its part number, however the customer has it set up. Then in turn, we either print the label which gets applied right away, or in many cases we can talk directly to the inventory management system and make that update right then and there, and that eliminates a couple of possibilities for error in the counting.

***Las Marias:** One of the issues that we just published is about increasing profits, and one of the factors is materials management. From your per-*

spective, what can you say about managing the material components?

Naugler: We have large users that have installed our XQuik with AccuCount system in multiple locations that tell us that they see a return on investment from the reduction in actual handling and requirement for a number of operators, and their return on investment is between three and five months, which is very fast. But the other part that is a little more qualitative and hard to track is how does it help them on the production line? But what we see, using the older methods is these reels that need to be counted will sit on the production floor for days, sometimes a week, waiting to go back in inventory. And if that is not going back to inventory, that is inventory that they can't use. With this new technology, they turn this around much faster. It is turned around in hours, not days. So now, they are maximizing utilization of their inventory as well.

Las Marias: You mentioned one of the trends now is automation and Industry 4.0. What can you say about that? Is there hype there?

Naugler: There is a lot of excitement; I don't know if hype is the right word, but yes I think it is going to be important that people do address this requirement coming down the road. For us, we've never been mainline. We are not in the production stream per se, we are always on the side—doing repair, doing inspection—so you won't see us the same way that you would see a screen printer or a pick-and-place in-line. But, they are looking for us to do the same sort of thing with automation just to streamline that process as well. I think it gives us a little bit more time to get it done, but it is going to have to happen.

Las Marias: So what can you say about the future of your industry?

Naugler: That is the $64,000 question, isn't it? It's really interesting. You see the technology being driven down in terms of component size, and you see people now talking about the 03015 passive components, where just a year or two ago, they were questioning the viability of the 01005s. Now, that has become common-

Figure 2: Installing advanced systems can help companies achieve ROI from the reduction in actual handling and requirement for a number of operators.

place and they are looking to go smaller and smaller. And the level of integration on some of the active components is going up. So it is really pushing the demand on the equipment supplier to be able to do exactly what's needed to make a reliable product and not even have a small hiccup in the production.

It all comes down to accuracy and repeatability. I think that is going to be the key to coming up with a successful process, but I think that the automation is going to lend itself in there, too. When you expect an operator to handle some of these smaller components and smaller assemblies and so on, it becomes even more difficult, so we really are going to have to start relying on that automation and inline conveyor and simple motion solutions as well.

Las Marias: Don, do you have anything that we haven't talked about that you think we should be talking about?

Naugler: Well, I do just want to kind of reiterate where we started, and I want to thank you, I want to thank the IPC for another great year. As I said earlier, I think that everything seems to be in a positive direction now. I hope that is kind of an indicator that is going to tell us that we are all looking forward to a very good year.

Las Marias: Great, thank you very much.

Naugler: All right, thank you. **SMT**

Supply Lines Highlights

RTW IPC APEX EXPO: Blackfox Celebrating 20 Years of Providing Quality Training

Sharon Montana-Beard, vice president of sales and operations at Blackfox, talks with I-Connect007's Andy Shaughnessy about the company's 20th year in business, their recent partnership with Pace, as well as their latest developments and activities.

RTW IPC APEX EXPO: Technica USA and ASM Americas Highlight Expanded Partnership

In this interview with I-Connect007's Andy Shaughnessy, Jeff Timms, managing director, ASM Assembly Systems Americas, and Frank Medina, president of Technica, discuss their expanded cooperation.

RTW IPC APEX EXPO: Cogiscan Explains Benefits of Having Real-Time Factory Intelligence

Francois Monette, VP of sales and marketing at Cogiscan, speaks to I-Connect007 Guest Editor Mark Thompson about modern factory intelligence, and the benefits of having this capability in assembly lines.

RTW IPC APEX EXPO: AIM's O'Neill Highlights M8 Solder Paste

Timothy O'Neill, technical marketing manager at AIM Solder, updates I-Connect007 Guest Editor Mark Thompson about the company's M8 solder paste, which they launched at last year's APEX.

RTW IPC APEX EXPO: Mentor Graphics Makes Internet of Manufacturing Affordable

Michael Ford, marketing development manager at Mentor Graphics, and I-Connect007 editor Andy Shaughnessy discuss the Open Manufacturing Language (OML), the challenges in supporting the hundreds of thousands of machines that are out there at shopfloors already, and how Mentor is making the Internet of Manufacturing affordable for everyone in the PCB assembly supply chain.

RTW IPC APEX EXPO: Alpha Explains Approach to Address Miniaturization Challenges

Jason Fullerton of Alpha Assembly Solutions discusses with Dr. Jennie Hwang the company's approach to helping customers address product reliability issues amid the continuing miniaturization trend in electronics.

Rogers' PES Introduces New curamik CoolPerformance Plus Coolers

Rogers Corporation's Power Electronics Solutions group's latest high-performance cooling material, the curamik CoolPerformance Plus, is designed to dissipate large amounts of heat and provide reliable thermal management of high-power laser diodes and other heat-generating optical devices.

IPC Crowns Winner of Hand Soldering World Championship

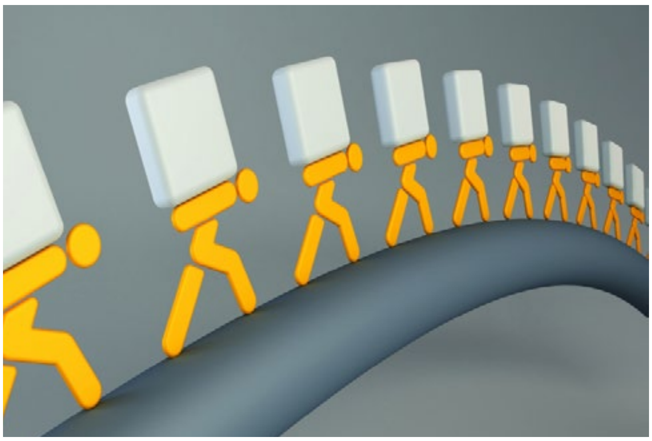
Completing the championship round with a score of 534 points out of 550, Vu Thi Xuan, UMC Electronics Vietnam Ltd., was crowned champion, earning her a $1,000 cash prize, a new America Hakko Products, Inc. soldering station and bragging rights as the world's best hand solderer.

Indium Addresses ICT Challenges with New Indium10.2HF Solder Paste

Indium Corporation has launched Indium10.2HF, a halogen- and Pb-free, no-clean solder paste that is specifically formulated to address in-circuit testing challenges.

Mycronic Launches Mask Writer for Top Critical Display Photomasks

Mycronic AB's latest display mask writer defines a new resolution standard for top critical display photomasks.



EMS Rules of Automation & ROI

by Michael Ford
MENTOR GRAPHICS

Unlike OEM companies that can spread the cost, risk, and allocation of production jobs across multiple lines, EMS companies are often forced to focus customer's products on individual dedicated lines and small groups of resources. As EMS companies typically have to deal with significant variation in demand from their customers, automation could be significantly under-utilized, which makes the justification of automation much more difficult. Are smaller EMS companies effectively dependent on manual labor and excluded from the innovation that automation and the computerization of the factory operation can bring? The answer is no because IoT is coming to the rescue.

Comparisons are often made between OEM and EMS models of production. The perception of the OEM model is that products can be allocated freely across the entire factory to best meet individual product delivery requirements. The advantage that the vertical organization brings is often not fully embraced because most OEM operations still lack the engineering tools that provide the product portability or finite planning solutions. Some, normally larger, EMS companies are in a similar position, where a bulk of products from a specific customer will be made together in the same factory. In these cases, the EMS factory is almost like a replacement or extension of the OEM factory, with the same opportunity for product allocation.

In the majority of cases, typically more in the smaller EMS companies, a wide range of products for different customers are made simultaneously, often across different sectors of the market. This is a smart approach that considers customer dependency and load balancing because different sectors have peaks and troughs in production as they are affected by seasonality, product cycles, marketing campaigns, and competition.

Understanding the Costs of Automation

All of these factory models suffer from the same issues of efficiency and productivity, but in cases where single lines are effectively dedicated to a customer's production, certain issues

are brought into clear focus. There is a lot of waste in these lines, especially for major assets such as SMT machines, in-circuit test, reflow ovens, because of variation in customer demand. The manual labor on such lines can be redeployed, but very rarely the machines. This situation gets worse as the level of automation increases, resulting in a law of diminishing returns for investment in automation; even though, in principle, the use of automation should provide lower fixed costs.

We need to understand the context of the costs on both sides of the equation to address this conundrum. The investment cost of automation and the fixed labor costs that it replaces is relatively easy to calculate in a well-defined way. The more difficult element to calculate is the effect of introducing automation where the equipment will not be fully used.

> "We need to understand the context of the costs on both sides of the equation to address this conundrum."

Consider a simple, dedicated, end-to-end production line that an EMS company may typically operate. They will have negotiated with the customer the quantities of the product and schedule needed for delivery, process requirements that match the product technology, as well as conformance and compliance, including testing, quality control, management, and traceability.

The EMS company will have made calculations to decide on the specific SMT and related equipment for the line to ensure that it can satisfy the peak production requirement for the customer, given target yields and productivity levels. For example, the customer requires 2,500 units per week of a certain product. Looking at the production calendar, they may decide that this requires an all-inclusive production cycle time of 120 seconds. An allowance must then be included for productivity and unavoidable losses, so perhaps a line with a cycle time of about 100 seconds per product is specified. In peak-time scenarios, the line is then capable of building to the customer's order without significant risk of missed delivery.

Built into this model is the reality that the line will never exactly meet the demand from the customer. Even at peak times, the line is expected to run with 20% overhead. These example numbers will vary, of course, as more or less risk is deemed acceptable. Throughout the life-time of a product, however, the production demand will fluctuate significantly. This condition will be reflected in the contract between the EMS company and its customer, which also often specifies a minimum production quantity.

However, if the delivery demand were to reduce by 30%, then unless it is acceptable to stockpile products, the line either has to slow down by 30% or stop working 30% of the time. Factoring in the original 20% overhead, the whole line operation is now only working at around half its expected capacity. The human element in the line operations can be easily reallocated to other customers' production lines, so balancing of human resource requirements over the entire operation is possible. The SMT and related machines are stationary, however, and thus underutilized.

Replacing the human operations with further automation now seems like a bad idea because the return on investment has to be calculated on the basis of the average workload, not the rated workload. This can effectively double the expected time required for the return on investment to be achieved, which can then extend toward or even beyond the agreed contract with the customer. The dedication of production automation in the simple EMS environment is an effective barrier to innovation and performance improvements, handling, and quality.

Flexibility with Industry 4.0

This inability to provide flexibility in manufacturing, especially at the small and medium enterprise level, is exactly what Industry 4.0 is aimed at resolving. Flexibility can be achieved in different ways. Moving SMT machines from

line to line is actually done by a few companies as they try to alter line capabilities and performance, but this creates associated problems with power, air, conveyors, positioning, setup, and operational changes, not to mention space allocation. Some SMT machines are more modular and allow additional units or heads to be added to a standard base to adjust the throughput. Considering all of the other resources on the line, however, the effectiveness overall is limited.

Instead of moving the equipment, how about moving the products through the reallocation to different lines, much like the flexibility that the larger EMS and OEM companies enjoy? The issue is that the equipment and operation has been linked to the product by contract so that moving the production to another line configuration requires a revised agreement and recertification of the operation because the processes, such as SMT machines, are likely to be different models with different capabilities and even may be sourced from different vendors.

Application of the principles of Industry 4.0 are designed to avoid all of these issues. One way in which the approach could be made with Industry 4.0 could be:

1. The PCB production areas would be split to separate the common process area, such as the SMT placement machines, from the product-dependent process areas, such as functional test.

2. Each of the common process production lines in the factory would have similar capabilities that provide different levels of performance, which could include a selection of machines from different platforms or vendors.

3. An automated transport system would connect the output of every common line to a "bus" so that any PCB can be automatically routed to the corresponding dedicated product processing line.

This raises some interesting questions about how the operation would work. First, with all of the lines possessing similar capabilities, any product for any customer could be built on any line at any time. The technical requirements for this to happen is to have an engineering process preparation system that can quickly create qualified machine programs for any specific product on any capable line, with the minimum of lead-time. Because lines may consist of machines from different platforms or even vendors, third-party tools that work around a common qualified product model and parts shapes library, with simulation of machine operation and the ability to output complete machine programs including materials libraries, are best suited to this task.

This introduces a high degree of product portability that allows products to be assigned as required to any capable line configuration. The production plan tool can then take the engineering information, including the line options and delivery requirements, the machine timing simulations, and materials information to allocate the overall production to the lines in the most efficient way that meets the various delivery requirements.

"The use of Lean material logistics enables rapid changes in plan to be executed without the need to return large amounts of excess materials to the warehouse."

The use of Lean material logistics enables rapid changes in plan to be executed without the need to return large amounts of excess materials to the warehouse. The advantage with this approach is that, rather than having the 20% line overhead on each individual line basis, the overhead can be shared and smoothed over all lines. In a similar way, rather than facing the reduction in the production rate as delivery demand varies, the product can be moved to a line that more closely matches the delivery requirement while allowing it to work at higher productivity levels.

The overall efficiency of production as a whole managed in this way can improve from around 50% loss to less than 20% loss, increasing production capacity by almost a third. On the commercial side, agreement has to be made that any of the line configurations can be used. The machines are not the most major issue, because even though they have different internal technologies and methodologies, the basic input and output condition of the PCBs is the same.

More importantly, the machines' setup, operation, product flow, handling, and exception management have to be managed to ensure compliance to the customer's specific needs. The simplest solution for this is to connect all of the machines and processes together with an Internet of Manufacturing connection, so that engineering data flow, management control, material logistics, setup including material verification, traceability data collection, and product flow management are all managed in the exact same way on the exact same platform. All of these key management functions applied equally to all production lines, no matter what machine and processes are used, assures customers that there are no significant issues related to the move of product. In effect, the whole factory becomes qualified against each product, rather than the individual line.

Connecting All the Automation with One Language

The use of the open manufacturing language (OML) is a perfect backbone for this, because it includes not only the normalization of raw machine command processing, but also supports essential management operations such as material verification material and process traceability, inspection, test, and quality management.

The routing of products from the common process lines to the product-specific lines would best be achieved using automation, again managed and controlled by OML. Because of the difference in sizes and other physical characteristics, PCBs would likely require transport in standard trays, carriers, or magazines so that transportation is not product-specific. The product-dependent lines will always be less flexible in terms of equipment, but they can be arranged in Lean cell formation to make best use of the flexibility of labor.

OML also can be used to control the flow of each PCB throughout the inspection, test, and repair environment, ensuring that no mistakes are made, such as PCBs with defects that are allowed to progress in the operation or out to the customer. Using OML from end-to-end in the operation enables a single, clear, controllable environment where all information can be used easily by IT systems that control product flow and material logistics, active quality management, while providing finite planning.

The smart application of automation initially in the EMS factory has less to do with process automation and is more related to operational automation. Qualified factory processes that allow the sharing of SMT lines with different speeds across products, with a common infrastructure for data flow, compliance, and conformance, allows the effective capacity of the factory to increase by as much as 30%.

Deciding How Much to Invest in Automation

This concept can be proven by analyzing the current performance of dedicated lines over a reasonable period of time to see how much absolute productivity is actually being lost, measured by the absolute machine working time over the working calendar. Once the number of hours of loss on each line is known, it can be multiplied by the amount of added value that each line is expected to create per hour. Then, extrapolating over a year can provide the appropriate budget for the investment in automation.

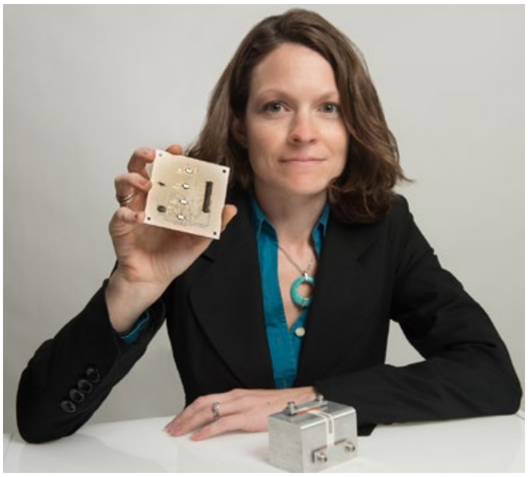
A useful first step in being able to assess and measure this correctly is to introduce the Internet of Manufacturing (IoM) to the existing operation, such as with OML. IoT solutions are

available today that can extract OML data from any machine or process on the market. Having real-time, accurate, and normalized data from all processes allows the detailed analysis of machine utilization, especially the scheduled downtime periods.

Not only does the OML IoM data provide the information necessary to assess how automation may be used to improve processes, but it is also a key backbone for the control, management, and monitoring of Industry 4.0 or other smart factory solutions. In any case, even when measurements who it is not prudent to go ahead with automation, an installed OML backbone would provide critical information for process management and operational improvement. The specification of OML, which is available to everyone, free of charge, can be found at www.omlcommunity.com. SMT

Michael Ford is senior marketing development manager with Mentor Graphics Corporation's Valor division. To read past columns, or to contact the author, click here.

NASA Investigates 3-D Printing for Building Densely Populated Electronic Assemblies



As detector assemblies get smaller and denser — packed with electronic components that all must be electrically connected to sense and read out signals — it's becoming increasingly more challenging to design and manufacture these all-important instrument devices.

A team of NASA technologists at the Goddard Space Flight Center in Greenbelt, Maryland, however, has begun investigating the use of a technique called aerosol jet printing or direct-write manufacturing to produce new detector assemblies that are not possible with traditional assembly processes.

"If we succeed, aerosol jet technology could define a whole new way to create dense electronic board assemblies and potentially improve the performance and consistency of electronic assemblies," explained Goddard technologist Beth Paquette, who is leading the R&D effort that began last fiscal year. Furthermore, aerosol jet printing promises to slash the time it takes to manufacture circuit boards, from a month to a day or two, she added.

Aerosol jet manufacturing builds components by depositing materials layer-by-layer following a computer-aided design, or CAD, drawing. The difference is that instead of melting and fusing plastic powder or some other material in precise locations, as in the case of many 3-D printers, aerosol jet printing uses a carrier gas and printer heads to deposit a fine aerosol of metal particles, including silver, gold, platinum, or aluminum, onto a surface. Aerosol jet printers also can deposit polymers or other insulators and can even print carbon nanotubes.

These attributes make the technology ideal for detector assemblies, particularly those that need to be shaped differently or are very small, yet dense because of the large number of tiny components that must be electrically wired or linked together on a circuit board.

The technique's use isn't limited to detector electronics. Technologist Wes Powell, who specializes in electronics at Goddard, envisions a time where instrument developers could use aerosol jet technology to print antennas, wiring harnesses, and other hardware directly onto a spacecraft.

SMTA
Surface Mount Technology Association

Certification Program

April 26-28 - Shanghai, China
May 9-11 - Toronto, Canada
May 24-26 - Querétaro, Mexico
Aug 30-Sept 1 - Shenzhen, China
Sept 27-29 - Rosemont, Illinois
Oct 3-5 - Guadalajara, Mexico
Nov 29-Dec 1 - Atlanta, Georgia

*SMTA reserves the right to cancel any class offering with less than 10 registrants.

About SMT Certification

Each SMTA Certification program is a three day workshop on topics in SMT Processes or Six Sigma/Green Belt. The program concludes with an open and closed book examination. This challenging examination requires both written answers and calculations with the intent to enable the attendee to establish competitive credentials as "Certified" by the SMTA in SMT Processes or Six Sigma/Green Belt.

Certification Curriculum

All applicants must pass a combined open and closed book exam focusing onthe following curriculum for SMT Processes or Six Sigma/Green Belt:

- SMT Materials
- SMT Components
- Stencil Printing
- Dispensing
- Line Balancing (Downtime, Line Design)
- Component Placement
- Reflow Soldering
- Wave Soldering
- Test and Inspection

Who Should Attend?

SMTA Certification is intended for those trying to prove competence of process technology at a fundamental level.

IDEAL FOR:

- Experienced Manufacturing and Process Engineers
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- SMT Assembly Managers

Prerequisite

- Two years of college (or equivalent)
- Minimum two years of experience in all aspects of SMT, including process optimization
- Knowledge of all process and systems steps, including calculations from screen printing and dispensing through test and inspection

Jenny@smta.org www.smta.org/certification/ 952-920-7682

MilAero007 Highlights

[BAE Systems, Shengyi Receive IPC Corporate Recognition Awards]
During the recent IPC APEX EXPO, IPC bestowed its highest corporate honors—the IPC Stan Plzak Corporate Recognition Award and the IPC Peter Sarmanian Corporate Recognition Award—to BAE Systems and Shengyi Technology Co. Ltd, respectively.

[Northrop Grumman Awards Radar Contracts to Kitron]
Kitron has been selected as an international source for manufacturing of a sub-assembly related to the JSF Radar system developed by Northrop Grumman Corp. for the F-35 Lightning II.

[FTG Completes Acquisition of all Photoetch Assets]
Firan Technology Group Corp.'s US subsidiary FTG Aerospace Inc. has acquired substantially all of the assets of Airco Industries LLC, a Texas based designer and manufacturer of a full portfolio of cockpit products, electronic assemblies and simulator solutions.

[Sparton Explores Strategic Alternatives]
Sparton Corp. has been exploring a range of strategic alternatives aimed at identifying the best way to enhance shareholder value.

[Valtronic Expands Sales Department throughout the U.S.]
Valtronic Technologies USA Inc. announces the addition of Charles Connell as sales engineer – East Coast, and Jennifer Aldridge as sales engineer – West Coast.

[Asteelflash Moves Up in MMI's Top 50 Ranking of EMS Providers Worldwide]
From 20th place in the 2014 ranking, French EMS firm Asteelflash has moved up three notches to take the 17th spot in MMI's ranking of EMS providers worldwide.

[Sypris Reports $27M Net Loss for 2015]
For the full year ended December 31, 2015, Sypris reported revenue of $145.3 million compared to $354.8 million for the prior year and a net loss of $27.2 million, compared to a net loss of $1.2 million for the prior year.

[Kingfield Boosts Capabilities with Fourth ESS Chamber]
Contract electronics manufacturer Kingfield Electronics has added a fourth environmental test chamber to further increase its existing ESS test capabilities.

[CTS Acquires CTG Advanced Materials]
CTS Corp. has announced the acquisition of CTG Advanced Materials LLC for $73 million in cash.

[ERAPSCO/SonobuoyTech Systems Wins $17.5M in Foreign Contracts]
Ultra Electronics USSI, a subsidiary of Ultra Electronics Holdings, and Sparton Corp. have received subcontracts valued at $17.5 million from their ERAPSCO/SonobuoyTech Systems joint venture.

Making Systems Smarter to Gain Visibility, Traceability, and Reduce Handling Errors

by Stephen Las Marias
I-CONNECT007

Based in California, KIC is focused on the thermal process—basically making reflow ovens smarter through profiling, automation, data analytics and sharing, and optimization solutions. The company essentially has three product categories. The first is a manual profiler. If you look at a reflow oven and ask yourself, "What is the job that the reflow oven is supposed to do?" It is to process an assembly within the specifications set by the solder paste components and so forth. That's matched up with a profile—KIC's system measures that profile manually and can compare that to the required process window.

The company also has software that can optimize the oven setup. Last, but not least, KIC offers automation solutions. The company integrates sensors into the oven to enable on-the-fly measurement of the profile for every assembly going through and checking to see if it's in spec.

At the recent IPC APEX EXPO event in Las Vegas, I interviewed Bjorn Dahle, president of KIC, to learn more about his views on automation, the technology improvements being made in reflow ovens, and strategies to reduce handling errors in assembly lines.

***Stephen Las Marias:** How is your technology improving the reflow process?*

Bjorn Dahle: The thermal process has kind of been seen as the black box process in a production line. You don't really know what's going on inside there. You hope for the best, and traditionally you check that once a day or once a month, and hope that in between your spot checks that everything is doing okay. More and more now, customers want more transparency; they want to know what's going on, not once a day or once a month, every single board. Is it being processed in spec? They want to have access to that information so there's process traceability available later on. Transparency and

Bjorn Dahle

traceability are very big. There is now a number of new needs developing as people are getting into more smart machines and smart factories.

When we install sensors in the oven, it's almost like installing a video camera. We film, if you will, the thermal process and, in real time, we can then make sure that no boards are being processed out of spec. You get an instant alarm, and we can provide SPC charting and CPK numbers, so you also get an early warning when your process is out of control. Historically this information has been contained at the oven, on the oven PC.

More and more now, you want that transparency to go beyond just the operator or the process engineer on the line, so we can send this information on to, let's say, an MES system where now the information is shared with up and downstream the production line, and with all the other production lines. Clients now have access to this for their own products if they use an MES, and you get full traceability and transparency.

Las Marias: What is the benefit of having that full traceability and visibility across the line?

Dahle: There are several. One is that, in the early days of this industry factories often had an engineer on the floor that had sort of the Midas touch. If there was a problem, call Joe and he would come over and tweak the oven and then everything would work great again. But if he was on vacation or if he wasn't on that shift, then the consistency of the production and the quality would not be there. Now we can provide that consistency, essentially, regardless of the skillset of the people on the line. We make sure that each and every PCB is being processed in spec. That's one part of it.

There is another element of this that is becoming very intriguing, and as the variety of products being produced grows, whether it's consumer electronics or others, what you will see—and you already see that in your Europe and the United States, but there's a growing market for this in Asia as well—is that the production runs get shorter and they'll be more and more production line change over. The slowest machine sometimes to change over from one product type to the next is the oven. You may have a multimillion dollar production line sitting still, waiting for a $50,000 oven to stabilize on the new recipe. What we do is we can basically do an exhaustive search on all the alternative set ups for the oven, and we can identify one recipe that can handle a wide range of products. There is essentially no change over time at all, because you've used the same recipe.

If that's not possible, we can also search on literally billions of alternative set ups of an oven. We can search all of them in a few seconds, and we can tell the system to not change the temperature and just look at different conveyor speeds and see if you can find a profile in spec. If we do, then the conveyor speed can be changed in a second, versus temperature which can take 20–25 minutes and more.

Las Marias: With the system providing more data and a more efficient production line, does that mean companies can cut down on their workforce for that particular line?

Dahle: That might be the case, or it might be that you free up the people you have to do more high-value-added work. I was also fascinated when I recently visited Jabil's facility in Silicon Valley called Blue Sky, which is their sort of future technology area. One of the things they have there are robots. I always thought of robots replacing human labor, but these robots are designed to actually work side-by-side with humans. They're soft and they are covered with sensors, so if you touch them or if you get in their way, they stop so they don't harm the workers. There was an article recently by Mercedes Benz in Germany that actually found that

WITH COMPONENTS
GETTING SMALLER AND SMALLER

THE NEED FOR SAFE HANDLING IS
GETTING BIGGER AND BIGGER

With today's high value components, cobbling together a makeshift ESD solution from multiple vendors is no longer a sustainable solution. You need a partner with the experience, materials and production to deliver complete ESD solutions with just one call. You need CCI. We design and develop sustainable shipping and handling products that are more cost effective and deliver the static protection high value components demand.

due to their variety and constant change of products, they actually had to dial back some of their robot investment and use humans instead because they're much more flexible. It took too long to program the robots.

I think that it's not a matter of having factories with no people, but that some of the repetitive tasks that have to be precise every single time will be taken over by machines, and that frees humans up to do, hopefully, something that provides higher value.

***Las Marias:** Do you agree that the reflow and the screen printing process have a lot of room for improvement?*

Dahle: Yes, and I think early on in this industry, it was recognized that 60% of the defects were in the screen printing process. Since then, there's been a tremendous improvement in screen printers and they do a fantastic job. Reflow ovens have also, of course, become a lot more stable, a lot better controlled, with better flux management systems and so forth. But now, we're sort of in a revolution where we are looking at the utilization of the equipment. As I said, if the equipment is standing still because of change over or troubleshooting or whatever, it doesn't help that it's the best on the market. Now we need to use information and process information to help these production lines run more efficiently, which means more up-time and find all the areas of downtime so we can influence and eliminate that.

***Las Marias:** Does that mean you can also upgrade a legacy reflow oven with your technology?*

Dahle: Correct. It's almost limitless. We will retrofit on virtually every oven make, model and age. If you have a really old computer, pre-Windows XP, there might be need for a separate computer. I think you raise an interesting question, because as companies are looking to have a smarter factory, it's important that you can retrofit.

To ask them to just throw away all their existing equipment and buy all brand new is going to be cost-prohibitive for most companies. We go in and make old ovens intelligent.

***Las Marias:** Yes, I think this is also related to IoT. You mentioned that having all the equipment, it's going to be difficult to justify getting new ones just to have that smart factory.*

Dahle: Exactly. Obviously the new machines are better and they become more and more intelligent every year, so if you can afford it that would be fantastic. We work with a lot of oven manufacturers, so our technology can be integrated into

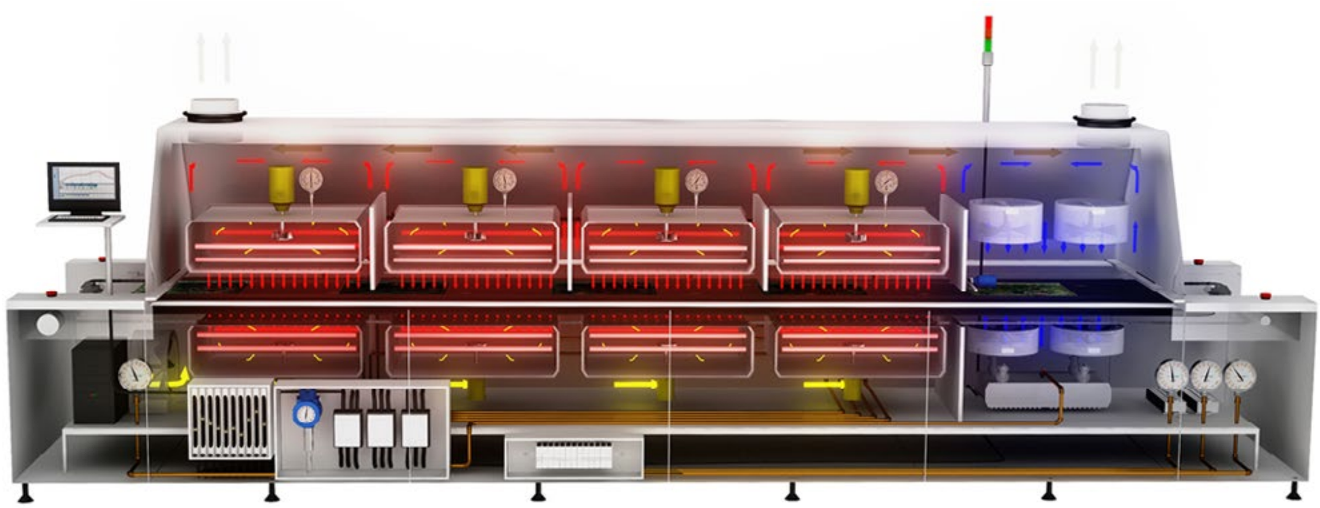


Figure 1: More and more companies now want transparency in their equipment processes.

a brand new oven as well. If you look at the trillions of dollars invested in factories around the world, I think it's a requirement that most of this new intelligence and the value it drives to customers can be retrofitted on existing equipment.

Las Marias:* *One of our surveys for the upcoming issue of our magazine is about reducing handling errors. From your perspective, what strategies can you think of to help assembly companies deal with this issue?

Dahle: The way I look at it, human beings are wonderful things. We have many talents, but one of them is not consistency, right? We're not a robot; we don't do the same thing over and over again. We forget things. One of the elements in reducing operator error or human error is to make the product basically tell the machines what to do. An incoming product has a barcode that's being scanned, and we can verify that the right program in the oven matches that barcode. If not, we stop the product from entering the machine and we can download, automatically, the correct program. If we do detect some issue in the oven, we can also alert the MES system or they can alert the AOI machine to stop their machine because we've just identified some suspect boards that need special attention.

All of this is done by sensors being read without the human intervention. We don't require them to remember to take corrective actions; it's done for them in all these cases.

Las Marias:* *Can you talk about the future technology trends that you expect to see in reflow ovens?

Dahle: I think that historically, the focus has been on the oven, the machine. More and more now, if you want progress, you need to not just sub-optimize on the oven, you need to optimize the whole production line. Then you need to go beyond that and optimize all of the production lines. For example, scheduling. Typically, what happens in a factory today is that they decide one day to build a family of boards, which is dependent on how the pick-and-place machine operates. But if they were running, let's say, three boards in a day, the pick-and-place machine says this is board A, B, and C, but we may say if you run it in a sequence and you start with C, then A and then B, you're going to minimize the changeover time in the oven. You start having communication between individual ovens in terms of optimizing an entire production line.

Then, you can now do that same thing across different production lines. I think most manufacturers now have developed their own MES systems, and the rest purchase excellent MEs systems from companies such as Aegis, Mentor Graphics and Itac. I think they are serving an increasingly important role, where we not only get machine data from the various ovens, but also provide the process data.

Las Marias:* *For smaller assemblers, it's going to be a big investment on their part. Do you see any challenges on this?

Dahle: Yes, there's always competition on price. We have tens of thousands of automatic systems out there. Most of them are sort of the full-scale products, but there are some companies that want a more limited functionality and at a lower budget. We have a more modular product where you can just pick and choose the capabilities you're interested in at a much lower price point.

> “We can make some significant improvements in a couple of areas.”

There are a couple areas where we can make some significant improvements. One is, as I mentioned, basically all but eliminating change over time. The other one is troubleshooting. If a production line is running day in and day out, and then all of a sudden one day there's a yield issue identified. The last four boards are all defective, for example. They shut down the whole line, and now they try to identify the cause of the problem and fix it. Of course, every second of downtime is very expensive. It's not uncommon for them to run a profile manually, because the oven is the black box process. They don't know exactly what's going on in there. Then after 15–20 minutes, they see there's nothing wrong with that. They have wasted 15–20 minutes looking for a problem where it did not exist.

> "They have wasted 15–20 minutes looking for a problem where it did not exist."

With our system, we can know instantly whether it's a problem in the oven or not. If it's not, don't waste your time there. Go and check the other areas. If it is in the oven, we can typically point out which zone. Is it the conveyor speed? So the maintenance people or the process engineer will get very good information that helps him identify and correct a problem quickly. There are other areas where we can help them save cost. For example, we can optimize the oven set-up based on electricity use. We have four case studies out there where customers save 15% electricity in all their ovens.

***Las Marias:** That's a big change.*

Dahle: Yes. When you look at the cost of the system versus the cost savings, it's very big.

***Las Marias:** How would you compare the acceptance of your technology in Asia to that in the U.S. or Europe?*

Dahle: That's one of the biggest surprises of my career here. Until recently, in countries like China where the labor rate was relatively low, which has since grown much higher and actually is higher than Mexico, one would think that they would be less interested in the kind of sophisticated automation that we're offering. The exact opposite has been the case. We are seeing, if anything, a higher interest in Asia than we're seeing in the rest of the world.

That may change now with the Industry 4.0 or the Chinese "Made in China 2025" and so forth. It's really surprising, because I think Asia doesn't want to only compete on price. Asia actually has the ambition and I think are proving themselves more and more that they can compete with the best manufacturers in the world, not only on cost but on quality as well.

***Las Marias:** Bjorn, can you briefly talk about the benefits of having a fully-automated line when it comes to your reflows or operating processes?*

Dahle: One benefit is transparency. This black box, you know what's going on continuously. You're not dependent on certain operators or engineers. Another is process traceability, which is very big in the high reliability segments like automotive. If a product fails in the field two years later, you want to find a root cause to prevent that ever happening again. Now, I can take that product PCB that was produced two years ago, I can scan the barcode and I can see on the screen the profile that board had when it was produced, if that profile was in spec, and all that information. Traceability is very big. Also, lowering electricity use, as I mentioned.

I was fascinated last time I was in Asia, where companies now have budgets for automation. They are trying to make sure that they make it right the first time. There's now a growing list of clients, especially the high reliability clients, but going beyond that, automotive, medical, telecommunications, so forth, where they simply refuse to accept any assembly that has undergone rework.

If you have to rework it, just scrap it. It's expensive, and so being able to make it right the first time is important and automation can help you do that, particularly the kind of systems that I explained that we have. I think that the ability to retrofit this technology on older ovens is very attractive to people. There are a number of other benefits, but if you're looking at the financial benefits, the biggest is to reduce the unproductive time and the downtime—whether it's troubleshooting, NPI, change-over time and

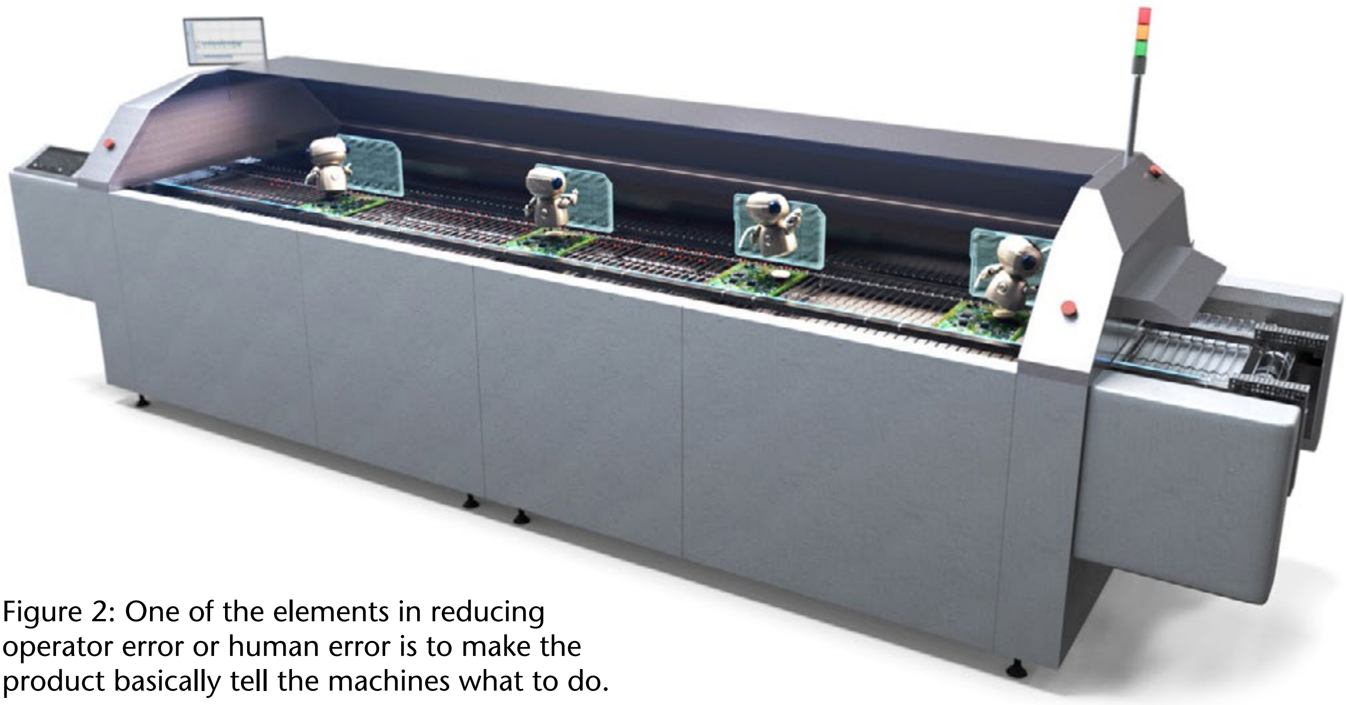


Figure 2: One of the elements in reducing operator error or human error is to make the product basically tell the machines what to do.

so forth. That's really where you get the most bang for your money.

***Las Marias:** Yes, it definitely impacts the bottom line. Bjorn, what can we expect next from KIC Thermal?*

Dahle: We actually doubled our R&D budget a year and a half ago, so we have a lot in the pipeline. Of course, I can't easily share that with you, but I think that a lot of value for customers will be driven through better use of data. The ability to extract that data, analyze it and share it. The ability, through MES, to look at the oven just not as an isolated case, but how it fits into your whole production line in the whole factory.

One of the benefits is that we have customers that purchase this as a sales tool because their clients want transparency. They want to know that it's not checked once a day or once a month, but every single product is verified to be in spec. Having this technology can help a manufacturer get a competitive advantage to get that next client. I think you're going to see maybe a closer relationship between companies out there, things like MES and us, for example. That's definitely an area of growth and cooperation you're going to see continue in the future.

***Las Marias:** Is there anything that we haven't talked about that you think we should be talking about?*

Dahle: The only thing I'd like to maybe mention is there's a lot of hype in the industry about Industry 4.0 and Made in China 2025, and I think there's a disconnect between that marketing hype from the vendors like us and the customer. I'm struck that going to Asia and the U.S. and even some places in Europe that there's still people who don't know what that is, but if you dig below the surface, then there's elements of that they're very much interested in investing in it. It's really not technology for its own sake, it is technology to drive value, primarily to help them save cost, help them improve quality, and give them some of these capabilities that the industry is requiring in an increasing amount, such as traceability and transparency.

***Las Marias:** Do you see the Asian market being more open to the Industry 4.0 trend than those in Western markets?*

Dahle: Asian countries are extremely pragmatic. They're saying, "We need to do this to save money." Take automation, for example. The Europeans and the Americans are more into the technology and the sophistication of it. They're sort of interested in the same thing but from two different perspectives. The Asian side is very much financial driven. If you think about it—I've been in this industry since the late 1980s—there's been a tremendous improvement in machineries. They're faster, they're more accurate, they're more reliable and they're more efficient.

I think that what we're looking at now is sort of a new revolution where it is about how you utilize that equipment to invest in. How you can run an efficient operation when they constantly have to produce new and different products. How you can ensure these automotive manufacturers that their electronics will not fail. They need to know how it was produced, and that's the transparency and traceability.

All of these new demands—we need to be able to do and in a cheaper way. By the way, this isn't going to happen overnight. This is going to take many, many years. As all that technology matures over the next few years, you're going to see a steady progress and the end result is that it's going to drive a lot of value for the manufacturers.

Las Marias:* *Bjorn, going back to providing more data in the manufacturing lines, we recently conducted a survey on data. One of the pain points was getting the right data. What's your comment on this?

Dahle: Data for the sake of data is useless. This is all a means to an end. You have to look at what it is that you're trying to achieve. That's the data you want, and being able to analyze and share that data is the key. One thing that we're focused on is you have to separate between machine data and process data. They're both very valuable. But with an oven, for example, you can get hundreds of readings a second from each zone, the temperature of the conveyors, etc. It is very valuable, but it doesn't answer the ultimate question for an oven--and that is, what is the profile that I'm creating right now on this assembly, and is that profile acceptable?

That's where we come in and we analyze that data. I even heard a comment that there's concern with some of the tier one EMS companies who are in the process of creating and collecting so much data that they foresee in the future that they won't even be able to get that through their trunk line. It could be overwhelming. You need to sort of, in my view, start at the output. What is it you're trying to achieve and then how will you achieve that? That's the data that is of interest. That perhaps will filter out lots of the data that may not be necessary.

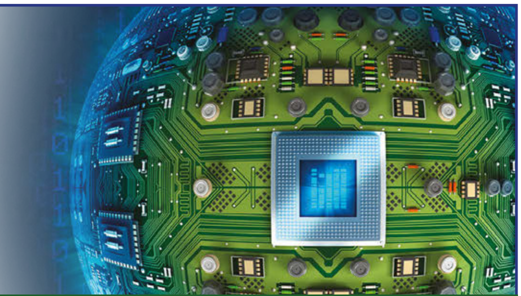
Las Marias: Thank you very much, Bjorn, for your time.

Dahle: I appreciate the opportunity. Thank you so much. SMT

Micro-sized, Liquid-metal Particles for Heat-free Soldering

Martin Thuo, an assistant professor of materials science and engineering at Iowa State University and an associate of the U.S. Department of Energy's Ames Laboratory, and a group of researchers have found a way to make micro-scale, liquid-metal particles that can be used for heat-free soldering at room temperature.

The project started as a search for a way to stop liquid metal from returning to a solid. Thuo and his research group, including Simge Cinar, a postdoctoral research associate; Ian Tevis, a former postdoctoral researcher who is now CTO at an Ames startup called SAFI-Tech; and Jiahao Chen, a doctoral student; experimented with a new technique that uses a high-speed rotary tool to sheer liquid metal into droplets within an acidic liquid. The group created liquid-metal particles containing Field's metal (an alloy of bismuth, indium and tin) and particles containing an alloy of bismuth and tin. The liquid metal particles, which are 10 micrometers in diameter, could have significant implications for manufacturing.



Electronics Industry News
Market Highlights

Optoelectronic Components Market to Touch $137.44B by 2023

The global optoelectronic components market was valued at $60.05 billion in 2014 and is anticipated to reach $137.44 billion by 2023, expanding at a CAGR of 9.7% from 2015 to 2023, according to Transparency Market Research.

Optical Sensors Market Worth $971.8M by 2020

The global market for optical sensors is projected to grow from $315.9 million in 2015 to $971.8 million in 2020, a CAGR of 25.2% from 2015 to 2020.

TV Panel Shipments Down in February

The latest large-size panel shipment report by WitsView, a division of TrendForce, says TV panel shipments for February totaled 17.88 million units, representing a monthly decline of 8.7% and a year-on-year decline of 8.3%.

The Automotive Market is Turning Electric

Electrified vehicles will be part of our future. Indeed, after many years of research and development, successes and failures, car manufacturers, their partners, governments and public are now ready.

UAV Payload and Avionics Market to Grow at a CAGR of 8.3%

The UAV payload and avionics market is expected to reach $3.93 billion by the year 2022.

Global Automotive Sensors Market to Reach $36.25B by 2021

The global automotive sensors market is expected to reach a revenue of $36.25 billion by 2021, growing at a CAGR of 9.1 from 2015-2021.

Tablet Market to Sink Below 140 Million Shipments in 2021

While the total tablet volume in 2015 was more than 207 million, ABI Research expects this to sink below 140 million global shipments in 2021.

Global Biometric Sensors Market to Reach $1.6B by 2023

The global biometric sensors market was worth $710 million in 2014 and is expected to rise at a CAGR of 9.6% from 2015 to 2023 to reach a figure of $1.6 billion by 2023, according to Transparency Market Research.

Worldwide PC Shipments Declined 9.6 Percent in Q1 of 2016

Worldwide PC shipments totaled 64.8 million units in the first quarter of 2016, a 9.6% decline from the first quarter of 2015, according to preliminary results by Gartner Inc.

Worldwide Shipments of Wearables to Surpass 200 Million in 2019

According to International Data Corp., an expanding lineup of vendors combined with fast growing consumer awareness and demand will generate double-digit growth for the wearable device market over the 2015-2020 period, culminating in shipments of 237.1 million wearables in 2020.

Reducing Setup Time to Provide More Uptime in Production

by Stephen Las Marias
I-CONNECT007

BTU International provides advanced thermal processing equipment and processes to the electronics assembly markets, focusing on SMT reflow ovens and high temperature custom-built furnaces. A wholly owned subsidiary of the Amtech Group, BTU has operations in Billerica, Massachusetts, in the United States, and in Shanghai, China.

In an interview with I-Connect007 at the recent IPC APEX EXPO event in Las Vegas, Bob Bouchard, corporate marketing manager at BTU, talks about the latest developments in their products, how their technology is helping users reduce their setup times, and the impact of Industry 4.0 in the electronics assembly industry.

***Stephen Las Marias:** Bob, tell us about your latest technologies.*

Bob Bouchard: Sure. One of the things that we've been working on with our partner, Electronic Controls Design (ECD), is RecipePro. ECD is well known for their thermal profiling and analytical software solutions. RecipePro is a recipe generator tool. The recipe generator is used to create a starting group of settings or what we call a recipe to be used in the oven. It allows a user with limited knowledge about thermal profiling an oven to enter some simple attributes about the PC board, and the recipe generator will create a starting recipe. It dramatically reduces the oven setup for a specific printed circuit. What's unique about it and how it differentiates us is we have other competitors that actually have a similar tool that they've contracted with third parties. One of the things that we found and is critical to the success of a tool like this is that it has the correct algorithms, so the background technology needs to be right. One of the things missing from the competitive solutions is the convection rate for the heat transfer is not included in competitive algorithms.

When we selected ECD to come up with a new tool to do this, we wanted to find a partner that would include the convection rate in the

Bob Bouchard

algorithm technology so that we had a more accurate prediction to provide our customers a better tool.

***Las Marias:* What is the importance of knowing that convection rate?**

Bouchard: In a reflow oven, the heat transfer is created by a handful of things. To keep it simple, we have radiation, conduction and what's called forced convection. Forced convection is the dominant heat transfer method inside the oven that is directed onto the product.

The convection rate, in particular, is one of the major heat transfer components. By not including the convection rate, the algorithm has to use a fixed heat transfer rate that doesn't reflect the convection rate that's in the oven. For example, in our systems, the convection is very tightly controlled. Changes in convection can impact a number of things—like the uniformity on the PCB—or it can impact the actual heated zone set points and conveyor speed.

All these things work together, and in particular BTU has a very precise convection control system that creates very repeatable process. From one machine to another, or one site to another, you dial in a recipe in our equipment and it can be transferred anywhere in the world. This is the importance of a convection rate. By changing the convection rate, it allows us to have a very accurate prediction of the thermal profile.

***Las Marias:* Definitely it ensures the quality of the product that goes out of the oven.**

Bouchard: It makes it repeatable. What we're focused on here is to help reduce set up time. If a customer had a new PCB that they need to setup the oven and the reflow profile for, the process has typically been trial and error. Many of the customers today don't have the same experienced staff that they might have had in the past. Someone who can look at the board and say, "Oh, this is similar to another board and I think I get in the same ball park." The recipe generator reduces the set up time; it reduces mistakes in setting this up, and it improves yield because you're not putting in a bad recipe, even a bad starting recipe. There are a number of benefits on having this capability.

***Las Marias:* It also reduces the cycle time of the process, right? According to one our surveys, reflow is one of the processes in the assembly line that is a pain point for some companies.**

Bouchard: It's certainly a step in the right direction. What this tool is intended to do is to create a starting point. By doing that, you reduce the down time associated with setting up a new PCB. That's another benefit that comes from the fact that you don't have the downtime associated with profiling. The downtime means that you're not running product with the tool. If you spend time taking your machine out of production to set up a new profile, you're losing production time. Time is money. This is a tool that's designed to reduce that set up time so you have more uptime in production.

***Las Marias:* In our recent survey on automation and reducing handling errors, one of the systems or processes in the assembly that readers said had room for improvement is reflow soldering. Definite-**

Figure 1: Reducing set-up times minimizes operator errors in setting up the oven and improves yield.

ly your technology is also addressing that particular issue.

Bouchard: Yes. Another strong industry focus right now is on cost of ownership in the process. BTU has other reflow oven suppliers that are highly focused on reducing cost of ownership. If you're affecting downtime, you're affecting your cost of ownership.

Las Marias: I read something about your systems being Industry 4.0-ready. Can you please elaborate that?

Bouchard: Sure. There isn't necessarily a standard out there for Industry 4.0, and frankly there's a lot of hype in the industry about it and for the right reasons. After studying this, we came to recognize that BTU actually has already in place a number of the elements that's required to support Industry 4.0. We have a number of interfaces that are available to communicate with host computer systems. We have a number of the data collection services that will be required for Industry 4.0 for the machine data and making that available to a host or to an Industry 4.0 compliant factory management system. We're well-positioned and have been working on things for many years that are currently available for Industry 4.0.

Las Marias: How do you see that impacting the overall manufacturing process?

Bouchard: I think it's a little different for every piece of equipment in the line. The reflow oven, I think, is a little less impactful, so to speak, in terms of the amount of data that will come from the reflow oven versus the pick and place machine or screen printer, for example. In terms of impact, I think the scale is fairly high for the more intensive processes. For the reflow process, I think there's certainly room and opportunity for moving in more automated systems, and self-correcting systems and intelligence in the reflow oven that can feed that information up into Industry 4.0 compliant systems.

Las Marias: What other technology development should we expect from BTU?

Bouchard: There is only so much that we can share at this point. We're in a mature market from the technology point of view. What we are looking at is really some opportunity that really not a lot of folks have started to explore. That

area is probably a few years away before we can actually get to those types of things. The things that we're thinking about are centered on taking the reflow oven to the next step and really creating a smart and intelligent system that becomes almost a lights-out tool.

There's very little that the operator has to do with that tool from profiling to maintenance to intervention, with the tool to change recipes and things like that. There's a whole set of things that haven't been addressed yet, that we view as problems to solve that we're looking at. I can't get into much more detail than I have already, but we have some pretty good ideas about how to take the reflow oven to the next level.

***Las Marias:** What can you say about the demand for your products in Asia as compared to the U.S. or Europe?*

Bouchard: Asia, in particular, has been soft for all equipment suppliers, not just BTU. We're not losing any market share or anything, but Asia has been soft especially over the last quarter or so. The Americas and Europe are actually very strong and that's consistent with the other companies that we've spoken with as well. The start of the year, although we're early into it, looks very good for the Americas and Europe. Parts of Asia are doing okay, but Asia in general is still a bit soft.

***Las Marias:** Which markets are driving growth for your company?*

Bouchard: One of the areas that are showing strong growth for us is automotive. We're starting to look at LEDs, which is another area that we see some challenges that need to be solved. Overall, what we're seeing are customers that require a high precision, highly uniform and repeatable process for very demanding PCBs. That's where BTU really excels, and those markets for us are in a growth phase. When those markets do well, we certainly do really well with our product line. Those are a couple of the areas that we see. Another area in our business that is very strong is semiconductor packaging, which has been soft; but that is again another area where BTU excels in performance, reliability, repeatability and process control. As we excel in those areas, those are what the customers right now in the Americas and Europe are buying.

***Las Marias:** How do you see the next 12 to 18 months developing for the company?*

Bouchard: About a year ago, we were acquired by Amtech. We're now part of the Amtech Group and that transition has gone extremely well. We've made a number of changes and improvements in our organization. We've become much more efficient, and looking ahead we're now very well positioned to grow the business. I would say at this point we're in that process. We're at the point where we are creating a new BTU moving forward. We are in the start of that process and our future is very bright.

***Las Marias:** Bob, thank you very much for your time.*

Bouchard: You're welcome. **SMT**

Engineers Fabricate Fastest Flexible Silicon Transistor

One secret to creating the world's fastest silicon-based flexible transistors: a very, very tiny knife. Working in collaboration with colleagues around the country, University of Wisconsin-Madison engineers, led by Zhenqiang (Jack) Ma, the Lynn H. Matthias Professor in Engineering and Vilas Distinguished Achievement Professor in electrical and computer engineering, and research scientist Jung-Hun Seo, used a simple, low-cost process called nanoimprint lithography to fabricate a transistor that operates at a record 38GHz.

The unique method could allow manufacturers to easily and cheaply fabricate high-performance transistors with wireless capabilities on huge rolls of flexible plastic.

The research was published in the journal Scientific Reports.

The Henry Ford Division of Labor Production Model

by Tom Borkes
THE JEFFERSON PROJECT

Last month, in my inaugural column entitled, "The Importance of Being Ernest (Educated)," I identified U.S. academia as "the emperor with no clothes" because of their self-congratulatory nature—reveling in buzz acronyms like STEM, and suggesting that decades of a continually widening gap between academic preparation and industry needs in high-tech electronic product assembly has been magically closed just by talking about the "new religion," when, in actuality, little has changed.

I went on to talk about the need to complement an undergraduate engineering curriculum of primarily "learning for learning" with a commensurate dose of "learning for earning." Our industry has failed to challenge the "emperor" since our industry's domestic competition has been faced with the same education level of employees that they hire out of school.

However, I indicated that the competitive landscape over the decades has changed in several important ways, as we have continued to tolerate the ill-prepared entry-level employee:

1. Low labor-rate global competition
2. The need for high engineering skill level employees to develop and maintain the leading-edge automation needed to reduce labor content as a way to compete with low labor-rate dollars. In other words, everything else being equal, if your direct labor rate is 10x more than your competition, but you find a way to reduce the labor content (labor hours) of a particular product by a factor of 10, you have removed the low labor rate competitive advantage—assuming that the low labor rate competition isn't able to automate as well. This rarely happens with minimum wage operators and sup port technicians (process "engineers").

Since, everything else being equal, one's labor cost is simply the number of labor hours needed to build a product multiplied by one's labor rate (or, more accurately, one's labor sell rate).

Of course, "everything else" isn't equal, and "el diablo esta en los detalles!"

I concluded the column by listing a number of "core issues" that, if not addressed, will continue to have us wallow in good intentions without ever seeing a tangible improvement:

1. Using excuses for the exodus of manufacturing jobs in the U.S.—about 6 million from early 2001 to late 2009, alone[1]. The excuses, of course, range from cheap labor global competition, to an uneven playing field, unfair monetary policy, a strangling regulatory environment, and corporate tax rates. Enough already! Finding shelter in this jungle of excuses will never permit us to gain the clarity needed to identify what high labor-rate regions of the world CAN do to successfully compete. For example, the great free market economist, Milton Friedman, once said that to impose retaliatory tariffs on countries that impose tariffs on you is like having two people in a lifeboat. When the person sitting in the other end fires a bullet through the bottom of the boat, out of spite, you do the same.

In my mind, there are only two reasons to build electronic products remotely: (1) you want to sell your products into those markets (a good reason); (2) you can't successfully compete with low labor-rate markets (a poor reason). It's usually because of the second that U.S. manufacturers and assemblers off-shore their products. And, of course, they are quick to pull out the excuse list. I'm waiting for, "the dog ate my operations sheet!" Actually, the root cause of the second is rarely raw high labor rates. It's usually:

a. High yield loss during the assembly process
b. The inability to exploit the automation to offset the labor rate disparityIndirect, overhead, G&A and non-value-added costs that have to be loaded on the raw labor rate

c. Indirect, overhead, G&A and non value-added costs that have to be loaded on the raw labor rate

Both "a" and "b" cause expending high labor rate dollars unnecessarily, both for the rework of assembly defects and for more manual labor for processes that could have been automated. Choice "c" is largely a function of a traditional organizational structure and is discussed below.

2. Looking upon product production (industrial engineering) as subservient to product design (mechanical and electrical engineering). "It's really not engineering, you know. People who are industrial engineers are engineers who couldn't do the math." If that's so, the cost-conscious operations manager thinks, "Why pay for engineers to do the relatively easy task of methodizing a product design for assembly? An 'engineer' with a technology degree should be fine. Or, why a degree at all—shouldn't someone with a mechanical aptitude work?" (e.g., someone able to rebuild the heads on his car).

3. A world-class workforce.

4. The segmentation of engineering into specialized areas. In fact, the grouping of all employees with similar skills into departments (silos). Your customers don't pay you for electrical engineering, process engineering, accounting,

Figure 1: Your customers don't pay you for electrical engineering, process engineering, accounting, procurement, etc. They pay you for products.

procurement, etc.; they pay you for products. They could care less that you have to do ICT (in-circuit test) on each circuit board you build to separate the ones assembled with manufacturing defects from the ones that are defect-free. It is the quality of the final product that they care about.

I left two critical competitive success factors out last month:

5. Material management—shop floor control and a rational just-in-time material strategy. These reduce the inventory cost that is usually absorbed in the labor sell rate. If the customer won't allow a material mark-up cost, it has to be accounted for somewhere. People who have tried to embed these carrying costs, including scrap and attrition, in the material price they charge their customer are usually met with the customer saying, "I don't want to pay for your inability to manage material." (This is often up to 75–90% of the total product cost.)

6. Not knowing how much the things we assemble cost (whether the assembly operation is part of an original product design [OPD] company, or an EMS company). In other words, having the ability to capture and analyze cost in real time. All the tools are available to do this. We used to call this measurement-to-standard. And, although we didn't have bar-coding and software to look at cost in real time, it was looked at by cost accounting. Someone (usually an industrial engineer) would do a paper time and motion study. This became the basis for the labor cost part of the quote. If the job was won it became the standard that the actual labor hours expended when building the product on the floor were measured against. Today, this doesn't happen as much. Management, in their infinite wisdom to cut cost, just wait until the end of the month and hope. If the company's direct costs (direct labor and material)—costs that could be charged to a product (or, the cost of products sold)—were less than product sales (revenue), we had a positive gross profit. If the company's total cost including some indirect costs, overhead, general and administrative, and sales costs, were less than the revenue, we had a positive net profit (also called earnings). Whew! If there were no earnings and costs were more than sales…uh-oh.

These last two are more local issues than global. Not having an infrastructure that addresses 5 and 6 is a cause for increased product assembly cost and, hence, being less competitive. However, tools have been available for a long time to address these issues. Again, there are excuses to obfuscate. It is usually management…

Item 4 leads us to this month's topic: The Henry Ford division of labor production model.

We are all aware of what the price of assembling a product is based upon:

- Material cost (assuming the assembler purchases the material);
- Number of labor hours needed for the product assembly and test; and,
- Labor sell rate in dollars per hour.

The material cost, although seemingly uncontrollable, is crucially important and will be the subject of an upcoming column in this space. However, at this time we want to drill down into the labor sell rate to see what pops up out of the ground.

> **"In the beginning, before product production for the masses, there were craftsmen. Prior to Henry Ford and his assembly line, depending on complexity, products were produced by craftsmen."**

In the beginning, before product production for the masses, there were craftsmen. Prior to Henry Ford and his assembly line, depending on complexity, products were produced by craftsmen. These craftsmen were highly skilled people who either applied those skills to one part of the product's creation or to the entire product. The important point here is that even if the craftsman was involved with only one aspect of the product's creation, he still had a thorough working knowledge of the product's entire production.

There are two very basic economic laws that are in play for our discussion:

- Supply and demand
- Economies of scale

In free markets, the price of a product is determined by what Adam Smith called the "invisible hand." In 1776, he published *An Inquiry into the Nature and Causes of the Wealth of Nations*. His timing was perfect. The Industrial Revolution was in its early stages and his book provided a blueprint for nations and individuals who were involved in mercantilism (trade). I consider these, along with Karl Marx' *Das Kapital* (first volume published in 1867) and his *Communist Manifesto* (1848), required reading for the post-secondary student who wants to build products. This meant a combination of the desirability of the product (demand) and the amount of that product I am willing to produce at a certain price (supply). That's all. The price is established naturally. If there is an incredible demand for a product and I produce 1 unit, I can set a very high price since the demand far outweighs the supply. There is a price range, however. Somewhere between what the product costs to produce and what someone is willingly to pay. As more of the product is produced, the supply goes up. When the supply goes way up as other sources begin to produce the product, pressure is put on the price. These competitive forces will drive the price down, as I will settle for less profit in order to sell the product.

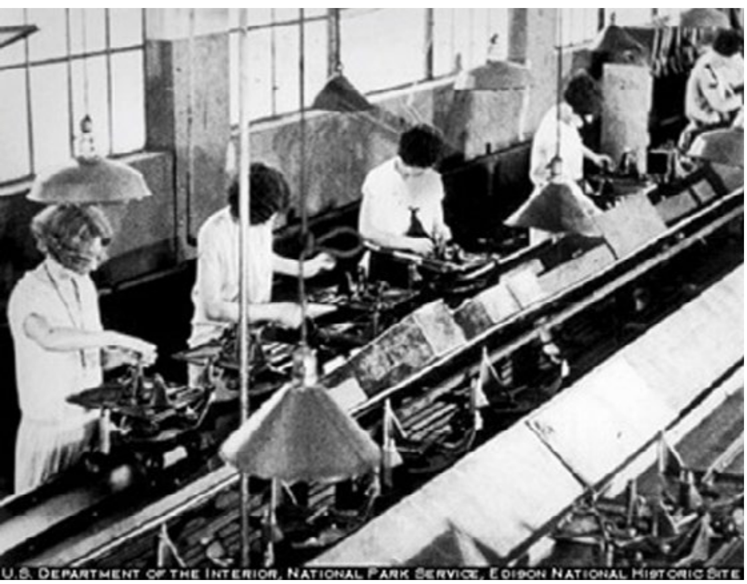


Figure 2: Assembly line development by Henry Ford after visiting Thomas Edison's mining operation in Sparta, New Jersey. (Courtesy US Department of the Interior)

You can think of a product production organization as a wagon. The wagon is pulled along (progresses) by the direct labor worker. All other employees RIDE in the wagon. As business wanes and backlog is reduced, the wagon can pull fewer riders.

So, here's the great irony: As a company automates to reduce labor content (to be more competitive with low labor rate regions of the world), the company's number of wagon pullers is reduced. However, if the company doesn't also address the riders, the wagon eventually stops—too much weight to pull and not enough pullers to pull the riders in wagon.

The point of all of this is that just automating normally doesn't cut it. There IS another way to pull more riders. It's clear a company needs direct labor hours. We've reduced the number of wagon pullers for a given product through automation. However, if we add the assembly of more products (increase assembly volume), that will restore some of the wagon pullers (direct labor hours). This will permit us to pull more riders again (absorb the cost of more wagon riders). The problem is this: the disparity in labor sell rates is still daunting. You have to do something about the wagon riders!

Where did all these wagon riders come from? And how much value do they add to the operation? How do we reduce the wagon load? To answer these questions, we need to do more than just look outside the box—we need to look outside history!

The history is this: In 1908, Henry Ford began to make cars for the masses. We've all heard the Henry Ford marketing strategy, "You can get the Model "T" in any color as long as it's black." Why was this important? Ford had to produce a car that would attract the masses by offer-

Figure 3: Magnetos and flywheels being assembled on the first moving assembly line in 1913, Highland Park, Michigan. (Courtesy US Department of the Interior)

ing it at a price that the masses could afford. This brings us to the second basic economic principle that is in play in our discussion: The economies of scale. Why is it less expensive to build a product quantity of a million than it is to build a hundred? One reason is that all the up front, non-recurring costs for engineering, set-up, tooling, fixturing, etc., are spread (amortized) over a million instead of a hundred (i.e., these costs add 10,000 times less to the cost a single unit when building a million instead of a hundred!).

Offering the car in only black cut the set up and carrying costs of producing and inventorying cars in multiple colors.

But Ford went further, and here is the big thing: To cut recurring assembly costs, Ford divided the total labor needed to assemble the Model "T" into many packets of about the same size (line balancing) and assigned a wagon puller(s) to each packet. Further, each work packet was done in the same place in the factory by moving the product past the wagon pullers instead of having the wagon pullers move to the product as the "craftsmen" of pre-industrial revolution days did for the most part. The assembly line was born. The relatively small amount of the same labor each wagon puller applied over and over again was not only small, but relatively elementary (and, unexciting). Rocket scientists need not apply! Marx was dead, but communists (the Bolshevik revolution in Russia was around the corner in 1918) jumped on the class struggle between manager and worker. So here, the two great world views of free market economics and collectivism (centrally controlled economies) had real world laboratories to collide in—the United States and the new Soviet Union. The collectivists (from Marx predictions) pointed to worker unrest and alienation as greedy capitalists squeezed every ounce of la-

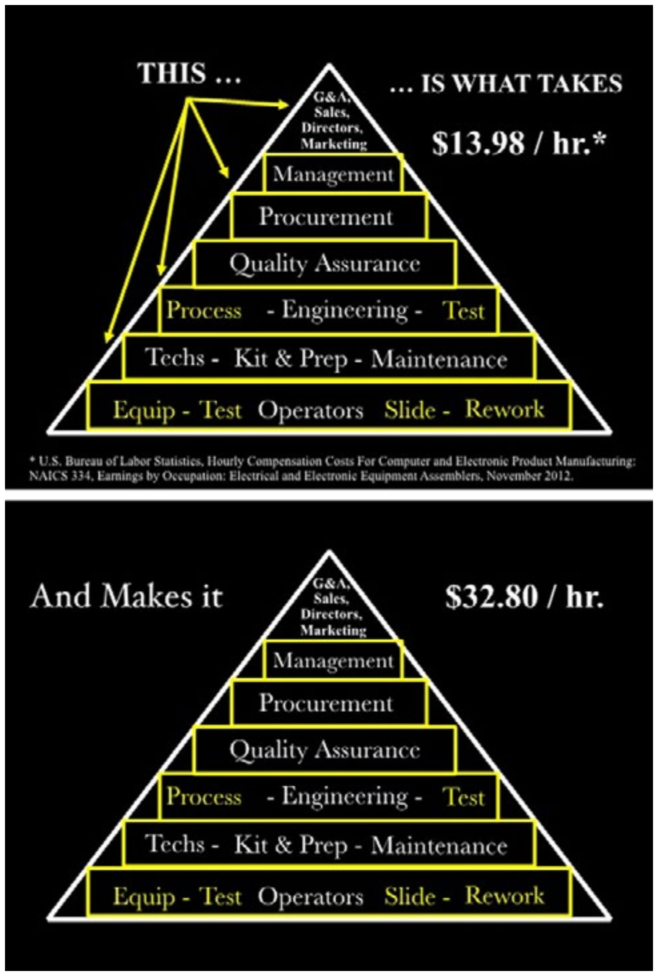


Figure 4: The ratio of the costs that the direct labor has been called on to absorb, to the direct labor itself, can become 1x, 2x and even 3x the cost of the direct labor.

bor they could from the worker, and the workers quickly tired of doing the same thing over and over again on the assembly line.

What in the world does this have to do with high tech electronic product assembly?

Our industry organization structure started to form in the 19th century and was mirrored in academia as specialization started to take root. As companies started to replace cottage industries and the factory became the industrial workplace, people like Henry Ford found it convenient to organize by common skill set: wheel assemblers, engine assemblers, body assemblers, etc. Also, managing essentially by work packet permitted upper management to set goals and hold specific managers and lead people accountable for the quality and output of each area. Organizations started to put employees with common skill sets into departments. As factories, mass production and assembly lines spread into other product areas, the hierarchal organizational pyramid grew as the economies scale and competition drove product cost and prices down. Great for the consumer whose disposable income continued to rise as the cost of products continued to sink! This process took a huge step back in 1929 as the globe sunk into a global depression. Not until 1939 when the world was thrust into WWII did the world quickly retool for existential reasons, laying the groundwork for a massive economic upturn after 1945. Housing became affordable to returning soldiers and their families. Electronic products like the transistor radio became available to the masses for the reasons similar to the exponential rise in automobile production during the early part of the century. One difference was that electronic products were yet to be automated. Sources of inexpensive labor like Japan dominated this product assembly market segment. Low labor costs and the mass production of the electronic components again made the consumer the big winner.

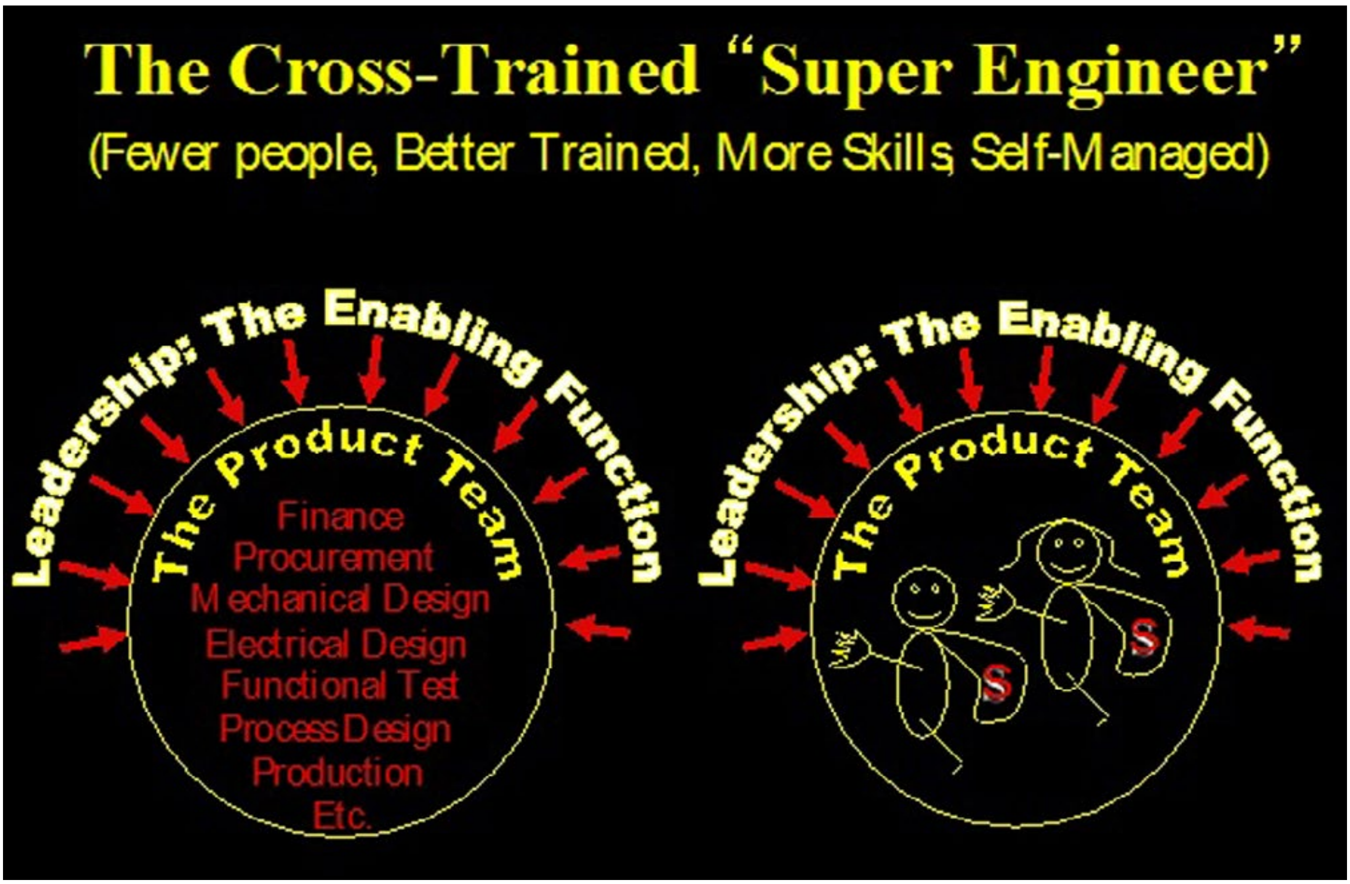


Figure 5: An alternate organization model.

The industrial hierarchal pyramid with layer upon layer of specialized labor grew with the increase in disciplines and the continued the grouping of people with similar skills into the same departments—now extending to the segmentation of engineering by creating departments for EEs, MEs, IEs, QEs, etc. Each department needed a manager. As the companies and departments grew, positions were created for section heads and group leaders within a given department, a portion of their cost adding an indirect cost to the labor sell rate.

Interestingly, the world of academia mirrored this segmentation as majors were created for MEs, EEs, etc. It was in the latter half of the 19th century that colleges and universities began to require students select a major. It appears Johns Hopkins University was the first in 1877.

Look at the ratio of the costs that direct labor has been called on to absorb, to the direct labor itself. In some cases, this bloating became 1x, 2x and even 3x the cost of the direct labor. In the U.S., it's what takes a $13.98/hr direct (raw) labor rate and makes it a $32.80 labor sell rate![2] So, how much value does this organizational model that has evolved from the Henry Ford division of labor model add? How much weight does the yoke of this division of labor model burden the wagon pullers with? Don't get me started.

Here is an alternate organizational model for your consideration, as Rod Sterling used to say:

- Dismantle the traditional industrial hierarchal organizational model.
- Replace it by just two groups. A group of product teams and a leadership group.
  - A product team consists of a small number of highly skilled, highly paid, cross-trained engineers who do everything, from ordering and managing the material, to developing capable processes, implementing the automated tools to keep those processes in control, dealing with the customer, and planning the work; there are no departments, it's totally self-managed.
  - The leadership group works for the project team and serves an enabling function providing the team with all the human skill sets and tools they need to be successful. They also act as a check and balance on team activities and serve as arbiters to resolve conflict when the team internally reaches an impasse.

So, where's the rub, as Shakespeare would say? It's academia again. Think about this: what is the difference between me, a mechanical engineer, and many of my associates, who are electrical engineers? The engineering aspect is the same. The difference is we work a different part of the physics. There is software today that addresses this. We need to teach students team dynamics and to be engineers with an underlying deep and solid understanding of all the physics—not just an area of specialization that feeds into the Henry Ford division of labor model. Isn't it time to stop measuring a student's success exclusively by their GPA? Is it effective to use this metric for 16 years and then send them into the world and expect them to be team players? It's time to break the yoke and empty most of the wagon. Just think where we could go if 90% of our high-tech electronic product assembly workforce pulled the wagon instead of riding in it.

Hey, what do you say? I'd like to get your thoughts. **SMT**

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Tom Borkes is the founder of The Jefferson Project and the forthcoming Jefferson Institute of Technology. To reach Tom, click here.

How Far Does it Make Sense to Automate?

by Michael Hansson
INTEGRATED MICRO-ELECTRONICS INC.

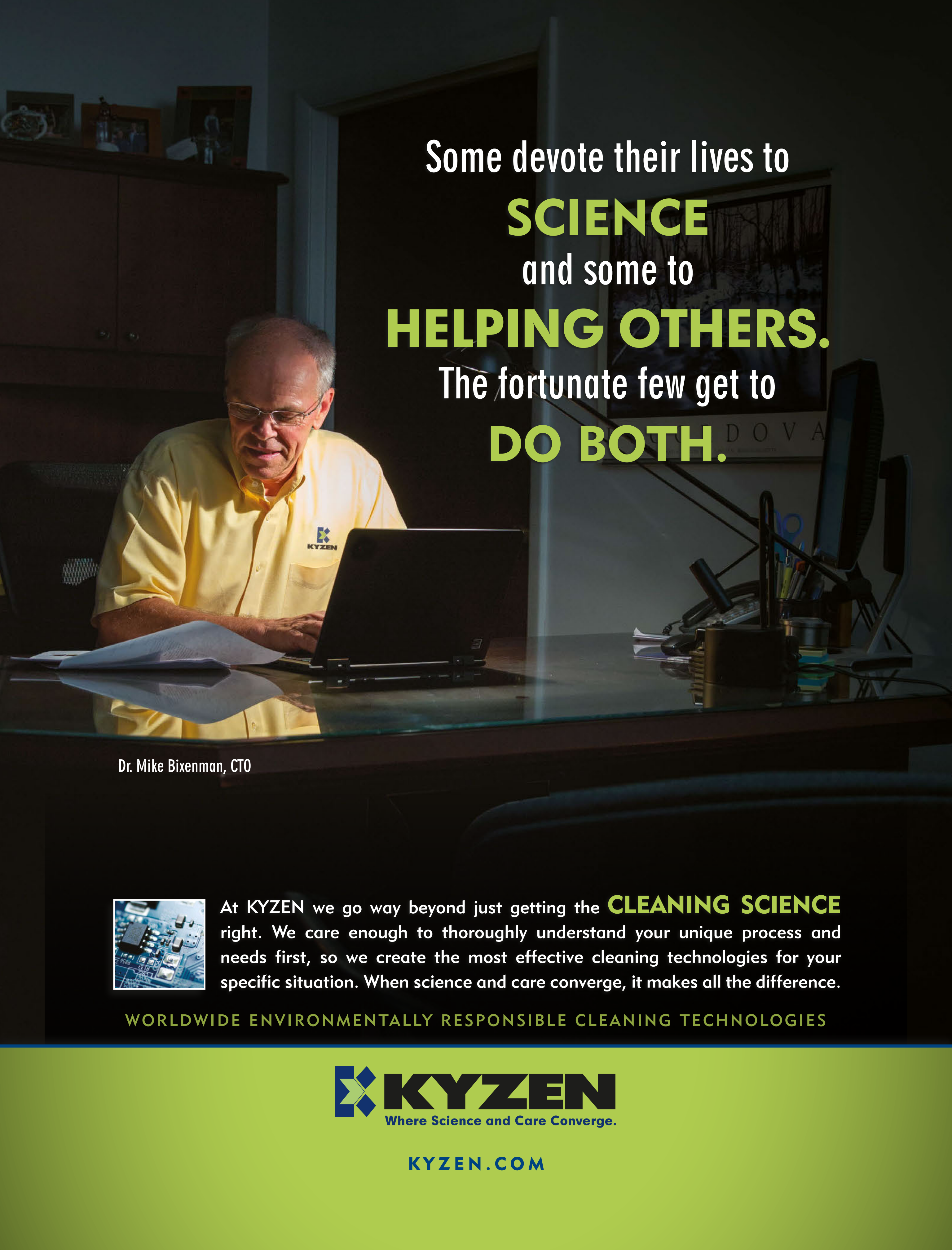
For an EMS provider, it is a given that the front-end board assembly process needs to be automated. Regarding the back-end final assembly process, however, the situation is often less clear. There are often many advantages to automating the final assembly process, but how far does it make sense to automate? Is a fully automated process better than a semi-automated, or partially manual process?

Advantages of Automation

Let's start by reviewing some of the advantages of an automated final assembly process. First of all, an automated process is much more repeatable and will thus allow a much higher quality level to be attained. Today's requirements for the assembly of automotive-grade electronics require a hands-off approach to handling, with robots and automated handling preferred by most tier 1 customers and OEMs.

In addition to improvements in quality, we can expect a reduction in the total cost of a project—assuming that the volumes are relatively high. Savings come from a reduction in the cost of non-quality, which includes the cost of analysis, inspection, scrap, education, training, field returns and loss of reputation. Furthermore, an automated solution frequently takes up less floor space than a manual process. Flexible automation can be designed to be utilized for multiple programs thus reducing the cost per individual project further. Finally, with the ability to provide an automated final assembly process, an EMS provider can typically attract higher value-add projects that it otherwise would not have been considered for.

Personally, I do not think that automation will lead to a mass displacement of human workers. There will always be new goods that need to be manufactured. The stations that will be automated first will be those where more critical process steps are executed, allowing production operators to fill in the gaps where automation


Some devote their lives to
SCIENCE
and some to
HELPING OTHERS.
The fortunate few get to
DO BOTH.
Dr. Mike Bixenman, CTO
At KYZEN we go way beyond just getting the CLEANING SCIENCE right. We care enough to thoroughly understand your unique process and needs first, so we create the most effective cleaning technologies for your specific situation. When science and care converge, it makes all the difference.
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is not needed or cannot be justified. There will always be new goods with shapes, materials, or even in quantities, where automation will not be possible nor practical. The more equipment we put in place on our production lines, the more designers, technicians, programmers and integrators will be needed.

Almost half of the world's global manufacturing output came from Asia in 2013. Somebody once asked me if I thought that Asian electronics manufacturers are heading for full automation or partial automation. I think such considerations will be made by project rather than by geography. High-volume manufacturing of high-quality products will see more automation than projects with lower volume requirements, higher mixes or lower quality requirements.

Obstacles to Full Automation

What I know for certain is that full automation is nearly impossible to achieve, and very seldom practical to implement. There are currently too many obstacles to full automation, including:

- Product designs
- Component tolerances
- Equipment availability
- Packaging design and handling

Many customer designs are variations of legacy products, or designs developed by engineers far removed from a high-volume manufacturing environment. Often, they are not designed for fully automated handling and processing. Even with a thorough design for automated assembly (DFAA) exercise executed together with their manufacturing partner, it is very difficult to capture every requirement of every piece of assembly equipment, especially since the assembly equipment may not even have been designed yet at the time the design is being finalized. In addition, once an automotive electronics product has been tested and validated, it is nearly impossible to change it without incurring lengthy delays and repeating costly product and process validations.

Components have to be selected for their ability to be unpacked and mounted automatically. A wide mechanical tolerance range, especially between multiple manufacturers, have to be taken into account. Assembly technologies have to be selected to balance the cost of the product with the cost and complexity of the equipment. Connection terminals have to be spaced far apart, with enough distance that allows them to be reached by automated welding or soldering equipment, and oriented in a symmetric manner to minimize handling time. Careful design techniques are necessary to avoid excessive tolerance stack-ups when multiple assemblies are connected together. Proper supports have to be provided under areas to be pressfit. Sufficient clearances have to be provided for access by pressfit and screwdriving tools. Guide pins need to be added to plastic connectors for ease of assembly. Chamfers and clips should be added to guide and hold smaller components. The use of adhesives should be minimized, and well controlled if its use is unavoidable. Gripping areas should ideally be symmetric and well balanced. Areas to be optically inspected should have a clutter-free background and easy to illuminate. The list of design guidelines goes on and on; a product design engineer would be challenged to retain the collective know-how of the equipment manufacturers, tool suppliers, component suppliers, system integrators and contract manufacturers.

Many electronic components are very challenging to pick and place automatically. Large electrolytic capacitors may have wide dimensional tolerance ranges. Small ceramic capacitors may be dip-coated and irregularly shaped, and therefore difficult and error-prone to grip. Large inductor coils may also have an irregular shape and be difficult to grip. Large variations in lead position or external dimensions greatly complicate handling. Many components may have been originally designed to be mounted in PCBs whereas many products today require them to be mounted in a lead frame of sorts; examples include power drivers and filter assemblies.

Many final assembly processes such as pick & place, printing and automated optical inspection are relatively standard. However, the majority of equipment available for standard processes are designed for front-end SMT processes,

not for back-end final assembly. As such, they often cannot be used without costly modification.

Entry/exit openings may be too small to fit a pallet sitting on a conveyor belt with a large assembly in a nest on top. The distance between the tool and the product inside the machine may be too short to accommodate a larger final assembly. A camera might be mounted too low and its lens may need to be replaced with a wider one. As an example, we recently had to order a custom modification to a standard gel printer and the custom modification cost us more than the original machine.

Standard components such as ICs and most passive components are often packaged for easy removal from tubes, trays, ammo packs or reels. However, there are no common packaging standards for odd-form or customized components. Likewise, packaging for finished goods could be difficult to fully automate in a cost-effective manner. Plastic or cardboard boxes are bulky and difficult to work with, and still need to be brought to and from the line by human material handlers or by mobile transporters. Boxes need to be sealed and opened. Labels need to be printed, applied and read. Box inserts need to be inserted and removed.

Manual or Semi-Automated Processes

I believe that some processes will remain manual or semi-automated for a long time to come, especially in Asia where labor costs are still significantly lower than in Western factories, despite the constant rise of labor cost.

The loading of very small, or very large, or odd-form, components into lead frames, plastic frames or other odd-shaped assemblies is an error-prone process that benefits from dexterity in handling and immediate visual feedback; at the same time, ideal for a trained operator and challenging to automate. As component and product designs improve and standards develop, however, I believe we will see more and more automation in this area.

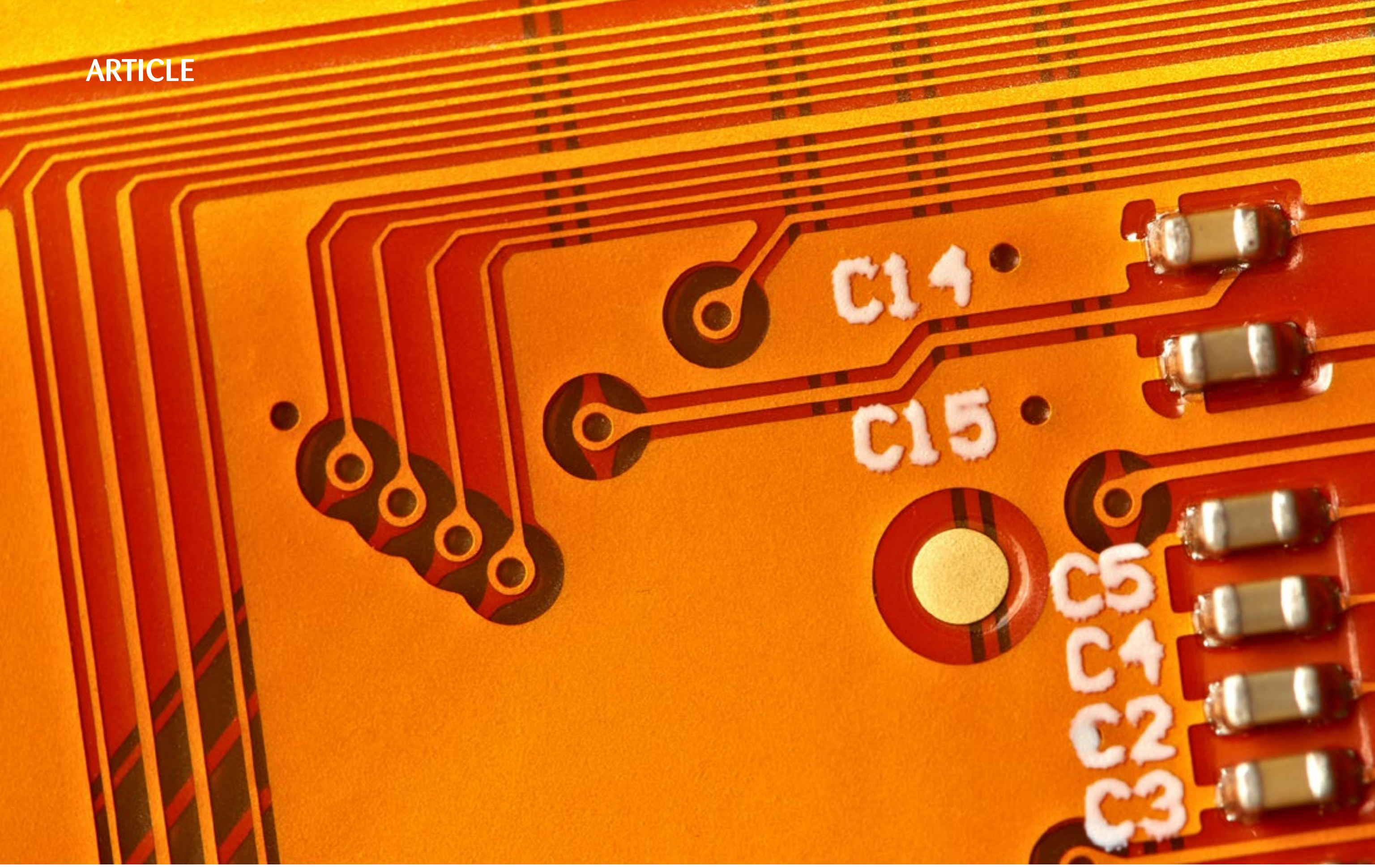
Placing finished goods in their final packaging is relatively easy to automate today. However, I believe the last step—adding any inserts, closing the box, labeling it and transporting it—will remain manual processes for some time. Likewise, unpacking direct and indirect material at the warehouse, transporting them to the production line, and loading the trays, tubes or reels to the loading stations will also remain manual processes for the time being.

Finally, visual inspection of products against scratches, dents, discolorations and other defects is something that is quite easy (albeit boring) for a human quality inspector to do, but difficult, expensive and time-consuming for an automated inspection system to execute, especially for larger and more complex products. I predict that we will continue to have manual visual inspection steps in our high-reliability manufacturing processes for a long time to come.

At Integrated Micro-Electronics Inc. (IMI), we recently developed and installed a semi-automated production line for the assembly of complex automotive ECUs for power steering at our factory in Jiaxing, China (Figure 1). This multimillion-dollar line has more than 25 machines automatically executing complex process steps such as heat staking, dispensing, mounting, resistance welding, visual inspection, electrical testing, screw driving, soldering, laser marking and cleaning. The whole line has only three manual operators performing loading and unloading operations, with additional material handlers, quality inspectors and equipment technicians to support. We are now working to develop a larger, even faster version of this line at our factory in Guadalajara, Mexico.

There are always numerous challenges to overcome when implementing such a complex line, but we believe that such semi-automated assembly is the future for high-reliability, high-quality, high-volume electronics manufacturing. **SMT**

Michael Hansson is the director for global automation at Integrated Micro-Electronics Inc.



Flexible Circuit Component Assembly… and a Math Lesson

by Dave Becker
ALL FLEX FLEXIBLE CIRCUITS LLC

The market for rigid PCBs is estimated to be about 10x the market size for flexible printed circuits (FPCs). As a result, the equipment infrastructure is driven primarily by the needs of the rigid board market. This is true of both equipment used to fabricate the circuitry (image, etch, copper plate, AOI, etc.) and equipment used for component assembly (wave solder and SMT assembly).

Flexible circuits are often sold in multiple-up panels or arrays to facilitate the assembly of SMT components. Coordination between the desires of the assembly supplier and the fabricator can have a significant effect on costs based on material/panel utilization. Fabrication panels are generally larger (12″x24″ and 18″x24″ are common sizes in the U.S.) than assembly panels. Assembly panel sizes should be efficient subsets of fabrication panel sizes to optimize material utilization. The math for determining parts per panel becomes a bit more complicated since fabrication panels will have a "keep out" border around the perimeter of the panel for tooling holes, fiducials, and test coupons.

In addition to considerations for material utilization based on circuit fabrication panel sizes, the quantity of circuits on a given panel size will be a function of several other variables. These variables include: size of the circuit, components to be populated, registration requirements, and assembly equipment capability. Multiple fiducials per panel may slow SMT placement rate, but this tradeoff is often trumped by the yield improvement and/or rework avoided.

Positioning parts accurately for SMT placement is a key to successful assembly. Custom carrier pallets are sometimes designed to hold singulated circuits. Another option is to use a

machined glass epoxy carrier that is bonded to the circuitry. This can be the same material as is used to selectively apply discrete component stiffeners, thereby integrating the carrier panel and the component stiffeners into a single drilled and routed stiffener. Breakaway features separate the carrier from the circuitry after component assembly. Both these methods mimic the handling conventions of rigid printed circuits.

Multiple-up panels inevitably result in a discussion about defective parts within the panel matrix. False economy results when the contract manufacturer (CM) specifies a "no X-out" requirement. The CM wants to operate their equipment as efficiently as possible, and intuitively this works best if they never deal with defective parts within the assembly panel. But this will often make the CM non-competitive on their bid to capture the business because of the premium paid for circuits.

The incredible yield impact on the fabrication house is best illustrated with an example. Suppose an assembly panel with eight circuits is required. If any of the circuits within the panel are defective, the entire panel is scrap. Even if the fabrication process is running at a 98% yield, the probability of all eight parts being good on a panel tumbles to 85%! As circuit density, tolerances, and layer counts increase, yields of 90–95% are not uncommon. Using the same 8-up panel and a 92% yield, the probability of a defect-free panel is a mere 51%.

These statistical calculations assume defects occur randomly on a panel, which is probably a stretch, but the illustration remains valid. Someone has to pay for all those good parts that are thrown in the trash can. The fabrication house, seeing a 'no X-out' requirement, will quote the part assuming a poor yield. The likely consequence is the CM uses an inflated circuit cost in their BOM and doesn't get the contract, especially if they are competing with assembly houses allowing defects within the panel. Today's modern SMT equipment has the ability to recognize black marked circuits and will avoid placing components on these individual circuits. Most CMs recognize this inefficiency is a legitimate cost expectation and are willing to concede some level of defective parts within a panel.

The example with defective parts in a panel is a good illustration of the need for compatibility and cooperation among the members in the supply chain. Sub-optimizing at circuit fab may make component assembly much more cost-effective. Or vice versa. Lowest cost is often achieved as a result of compromise. Understanding the big picture will win the game. **SMT**

Dave Becker is the V.P. of sales and marketing at All Flex Flexible Circuits and Heaters. To contact Becker, or read past columns, click here.

Breakthrough with New Generation Robots

A research into improving control of industrial robotic arms by doctoral candidate Maarten Essers of the University of Twente shows that the new generation of intelligently controlled robots is in fact capable of a quick and flexible performance of production tasks. In this new system, robots are not controlled in a top-down manner; instead they discuss what they are going to do next—allowing them to eventually assign and execute tasks individually (heterarchical approach).

The new design architecture results in more flexible robots that are easier to use in smaller production environments.

Essers' research is part of the SInBot project in which ten Dutch and German companies and research institutes are all working on a new robot platform.

Selecting a Selective Soldering System, Part 2

by Robert Voigt
DDM NOVASTAR

Our last chapter began a discussion of selective soldering, including how it works, some pros and cons, and several fluxing and soldering options to choose from. In this chapter, we'll dive a little deeper into the mechanics of fluxing systems.

Flux Materials

As covered in prior chapters on wave soldering, there are a variety of flux types and chemistries available, including low pH, high-solids content, and water soluble, alcohol-based, and others. Selection of a particular type of flux is frequently not an option for the contract manufacturer, since it is usually determined by the end-user's application, so they must be able to accommodate work using many types of flux.

No-clean fluxes are generally preferred because they require little to no post-solder cleaning, except for a visible residue that should be removed. If the user opts not to use a no-clean flux, it is very important to control the amount of flux applied to the board. In most cases, controlling the solder head to cover the area previously sprayed will burn off the flux and eliminate the necessity of cleaning the residue in a subsequent step.

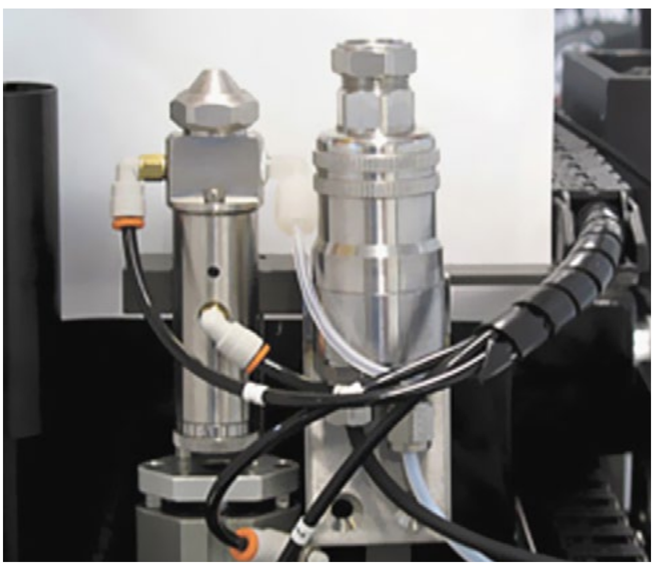


Figure 1: Drop-jet fluxer nozzle (right) and standard nozzle (left).

Remember that solder types used for selective must be compatible with solder used on the top of the board, and this will likely have a material effect on the flux type used.

Spray Fluxing

Through-hole penetration is the ultimate goal of any fluxing system, but there are a number of factors that affect the performance of a spray fluxing system. Factors to consider for spray flux deposition include:

1. Compatibility of materials of construction: Make sure the application technique is compatible with your flux chemistry.
2. Motion and speed of the spray head: The faster or slower the spray head moves, the leaner or heavier the deposition will be.
3. Flux flow rate delivered to the spray head: Will affect the quantity of flux deposited on the board.
4. Pitch pattern between spray strokes: Determines whether consistent coverage will be achieved over a wide area.
5. Spray pattern: Check for controls that will help minimize overspray and waste while targeting the critical areas to be covered.

In a spray fluxing system, flux can either be delivered by ultrasonic energy or by pumping from a canister in a housing below the machine

into a spray head where it's atomized with air. Nozzle-free spray heads are preferable because they are less likely to clog. Spray is delivered in a cone shape, in a variable band of material onto the board. The narrower the band, the more likely flux will be directed into the plated holes. While it covers a lot of real estate, a wider band doesn't necessarily penetrate deeply into the through-hole to get good flux coating in the fillet.

Another important factor for effective spray fluxing is the speed and position of the spray head. Fluxers with reciprocating heads provide a greater opportunity to direct flux to plated holes from a variety of angles, and electronically driven heads are more apt to overcome issues with sticking due to flux residue and airborne contaminants than pneumatic systems, which are more susceptible to this problem.

Figure 2: High pressure flux tank.

Finally, evaluate the fluxing system based on its construction attributes. A self-cleaning system will reduce downtime for maintenance. A robust machine will perform continuously without excessive maintenance attention.

Micro-drop Jet Fluxer

A micro-jet (or drop-jet) fluxing system sends an undiluted bead or bubble of flux directly through the fillet, the through-hole and the solder ring of the circuit board in droplet form. A micro-jet system will generally use less flux than a spray system because it's only applying flux precisely where it's needed. Most systems allow for a variety of dot patterns which are pulsed through the nozzle, ensuring accuracy.

Micro-jet technology provides very fine control of bead size and positioning, thus reducing liquid media waste and virtually eliminating post solder cleaning. An advanced micro-jet flux system is capable of depositing precise amounts of liquid flux with extremely high accuracy, achieving pinpoint through-hole penetration, with no wasted overspray.

In the early years of micro-jet fluxing, designs were adapted from currently available ink-jet printer technologies, and often were not as well-suited to the PCB market as needed. However, as the technology matured, dedicated designs have been developed that were (and are) better suited as integrated systems in the selective soldering machine.

Micro-jet technology, however, still comes with a couple drawbacks:

1. Programming is typically more complicated and time consuming; however, once programmed, repeatability is excellent and the recipe can be stored for producing the same boards again in the future.

2. Initial cost of a micro-jet system is higher than spray fluxing, but again, with its added efficiency, pinpoint accuracy and long-term reliability, this cost can often be made up very quickly in a production environment. The biggest advantage: less flux, less cleaning.

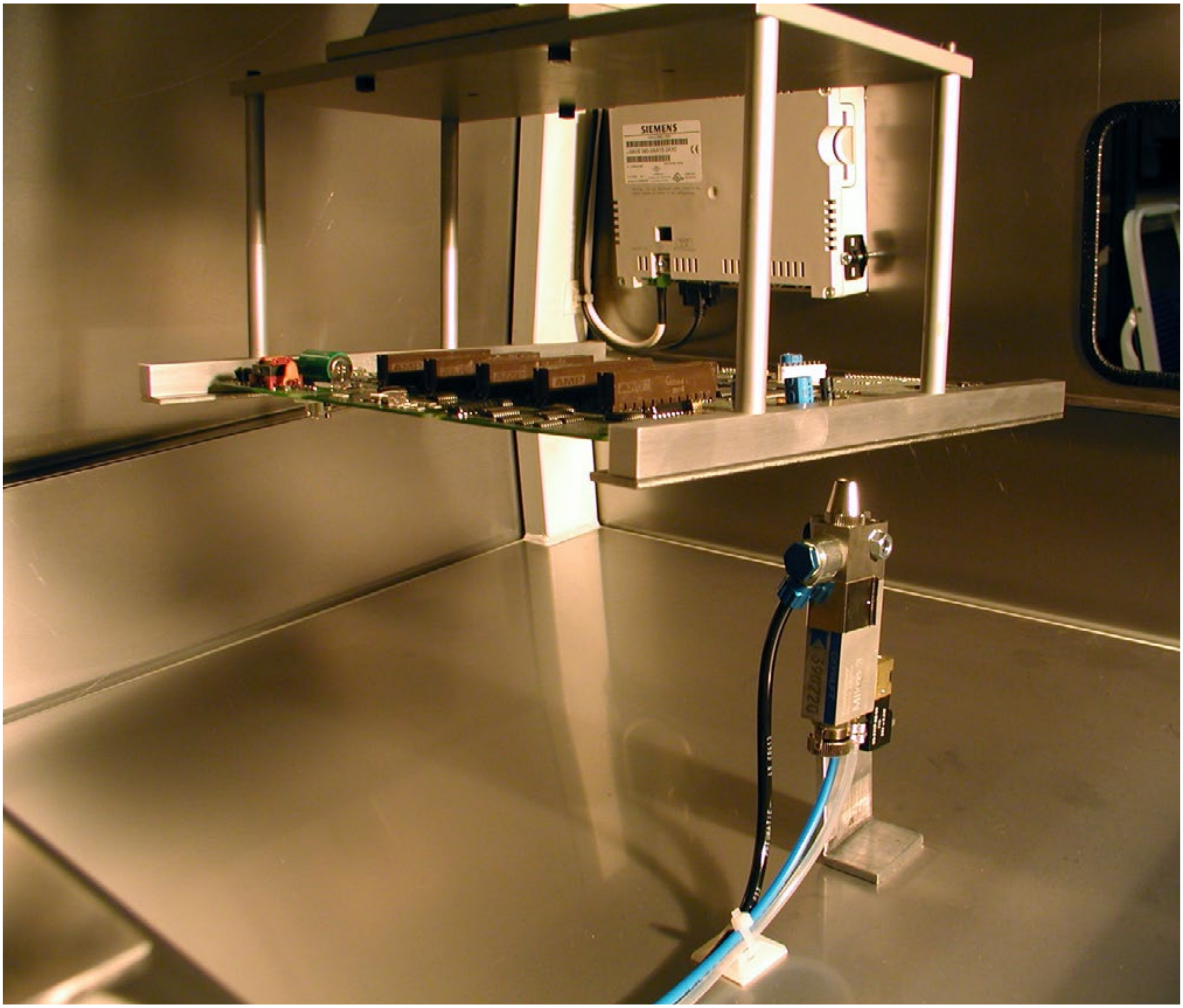


Figure 3: Spray fluxer head.

One of the most important technical considerations is the actual control software of the manufacturer, as this is more important than the control of the fluxer itself.

Both the spray fluxer body and the microdrop fluxer body can look identical—it's only the methods of dispersement that differ.

Check References

Remember to consult a variety of machine providers, talk to the manufacturers themselves if possible, and get references to contact before making a purchase. An important consideration for a complex machine such as a wave soldering system and associated options is factory support, specifically training, software, upgrades and spare parts. SMT

Robert Voigt is VP of global sales at DDM Novastar Inc. To reach Voigt, click here.

Electrolube: We Like Problems (Chinese Style)

by Pete Starkey
I-CONNECT007

I spent time with Ron Jakeman, group managing director of Electrolube, while at productronica China in Shanghai very recently. In addition to solving customer's problems and finding solutions, Electrolube has been busy preparing for the launch of two new products to complement the European range, which will have significance in thermal management.

***Pete Starkey:** Ron, it's great to see you again. The last time we met was in England, and here we are in China. What's the general state of business in China from your point of view?*

Ron Jakeman: We've actually found it's continued to be good in our particular sector. We've heard all the stories and there's a lot of factories empty down in the Shenzhen-Guangzhou area. I think there's a lot more automation going on, and I think it's really a people problem in our industry, an employment problem, rather than actually a downturn in business. There really is a lot of automation creeping in as they're joining the Western world in terms of production. Business is still strong for us and as a result of that, we've expanded our technical team and our R&D team significantly. We've doubled it in size and we've invested quite a lot of resources in it, which means we're able to more of the testing in-house and actually solve customers' problems at our premises rather than theirs. Doing so obviously shortens the time for everybody.

***Starkey:** You're still in the business of finding problems and sorting them?*

Jakeman: We love problems, as you know, Pete. Problems are always opportunities aren't they?

***Starkey:** It is great to have the opportunity and the resources to be close to your market rather than have to solve Chinese problems in your English labs; it's good to be able to approach them directly.*

Jakeman: To do it locally, yes. In terms of the time you have to solve problems, it would never work from anywhere else than here. The sort of response times that they're looking for are just

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ITI & IPC Conference on Emerging & Critical Environmental Product Requirements — Conference
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June 8
ITI & IPC Conference on Emerging & Critical Environmental Product Requirements — Conference
Chicago, IL USA

June 10
ITI & IPC Conference on Emerging & Critical Environmental Product Requirements — Conference
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August 31
IPC Education Online — Webinar
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IPC India 2016 — Conference & Exhibition
Co-located at electronica India and productronica India 2016

September 24–30
IPC Fall Committee Meetings — Meeting
Held in conjunction with SMTA International
Rosemont, IL USA

September 26
EMS Management Meeting — Meeting
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October 19
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October 25–27
IPC-SMTA Cleaning and Conformal Coating Conference — Conference
Chicago, IL USA

November
IMPACT Europe 2016 — Meeting
Brussels, Belgium

November 2
PCB Carolina: Regional Trade Show — Conference and Exhibition
Presented by the RTP Chapter of the IPC Designers Council
Raleigh, NC USA

November 2–3
IPC Technical Education — Workshop
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December
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December 7–9
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December 14
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not achievable unless you've got people on the ground, and committed people as well, who are prepared to work outside of normal hours. The key to it as always, everywhere in the world, is people. We're very pleased with the progress that they've made. We're actually coming up to our thirteenth year here now, so it feels like more like home every year.

Starkey: What proportion of your business is in this area, Ron?

Jakeman: It's significant—probably close to 50%, because we also use the Chinese operation to support Malaysia, the Philippines, Taiwan, and Korea, in shipping products from Beijing to those countries. It is the most important subsidiary we've got, currently. Also, we're using it to support our Indian operation. We've been sending products in from China to India for some time, but we're now sending equipment in to allow us to manufacture in our own factory, which we now have in India. We also have expertise from the guys in Beijing, who have been making the products, as I mentioned, for almost 12 years now. It really is the most important subsidiary we've got.

Starkey: You mentioned products Ron; are you offering new products at this show?

Jakeman: We've got three new products, two of which we think are significant on the thermal management side. They're actually non-silicone gap pads. We've had silicone pads in the range probably for about a year to complement the thermal paste. It really depends on the manufacturing operation on the product whether you want to use a paste or a pad. These are significant because a lot of people don't like silicone around electronics. Our non-silicone paste has done really well, and these are two really high-performance, non-silicone gap pads.

The other product is in our Safewash range which has been successful, as you know, for many years. We've moved into pH neutral types of cleaners for very specific operations on delicate electronics. This new one is very low foam so it can be used in all of the cleaning kit. It's pH neutral but extremely effective at removing flux residues, which a lot of the products on the market, neutral phase, don't actually do that. We think this is important, and we've sold it in quite good volumes, actually. Development has been going on for about six months.

Starkey: What sort of flux systems is this appropriate for?

Jakeman: It's really for cleaning PCBAs and very delicate electronic assemblies. Of course it's biodegradable, water-based, and it solves many of the issues.

Starkey: Ron, is there anything that we should have talked about that we haven't?

Jakeman: I don't think so. We're very busy supporting the customers with developing our new products to complement the European range. You were at productronica and you saw the new range of coatings, which is where we're expecting to get significant business this year. The coatings are in test with many of our major customers and we have secured BMW's approval on them as well. I was in Munich about three weeks ago actually going through the reports with the materials guy.

Starkey: That's excellent news.

Jakeman: That's very good news. Phil Kinner presented at APEX yesterday on the 2K range of coatings. We've done some joint work with the National Physical Lab on condensation on circuit boards, about which he presented a paper to the IPC Committee. All in all, worldwide, it's going very well and we're very busy.

Starkey: Thank you, Ron. It's been great to see you in China. I'm very grateful for your time and I wish you every success.

Jakeman: Thanks very much, Pete.

Starkey: My pleasure. **SMT**

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Recent Highlights from SMT007

1 RTW IPC APEX EXPO: IPC's Fern Abrams Provides Updates on RoHS, REACH Directives

Fern Abrams, director of regulatory affairs and government relations at IPC, discusses with I-Connect007's Stephen Las Marias the latest updates on the changes happening in the RoHS and REACH directives this year, as well as IPC's new initiatives and advocacies.

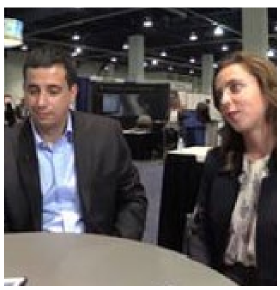
2 RTW IPC APEX EXPO: Zentech's Matt Turpin Talks Strategies for Success in CM Industry

Zentech's Matt Turpin, named as one the electronics industry's Rising Stars by the IPC, speaks with I-Connect007 guest editor Dan Beaulieu on how to become successful in the electronics contract manufacturing space.

3 RTW IPC APEX EXPO: Kimball Electronics Sees Strong Growth in Automotive Electronics Sector

Kimball Electronics' Chris Thyen discusses with I-Connect007's Stephen Las Marias the company's growth and first year as an independent, public company after its spin-off from Kimball International, as well as its new facility in Romania.

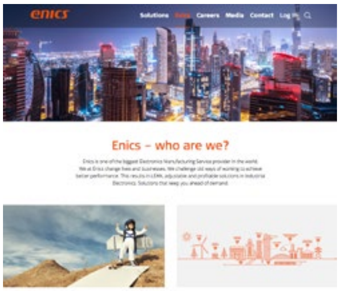
4 RTW IPC APEX EXPO: Saline Lectronics Discusses How Industry 4.0 Can Give CMs the Edge



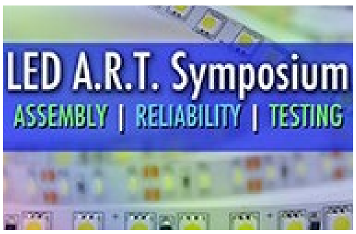
Jason Sciberras and Davina McDonnell of Saline Lectronics speak with I-Connect007 guest editor Steve Williams about how they embraced Industry 4.0 in their manufacturing line.

5 Enics Launches Redesigned Website

Enics has launched the redesign of its website, www.enics.com, to provide its stakeholders with even more relevant and easy-to-find information about the company.



6 SMTA and CALCE Seeking Abstracts for LED Symposium



The SMTA and CALCE are pleased to announce the LED Assembly, Reliability, and Test (A.R.T.) Symposium will take place November 29 - December 1, 2016 at the Crowne Plaza Midtown in Atlanta, Georgia.

7 International Conference on Soldering and Reliability Workshops Announced

The SMTA has announced three new workshops—to be presented by Martin Simard-Normandin of MuAnalysis, Dave Hillman of Rockwell Collins, and Mike Bixenman of KYZEN—for the 10th Annual International Conference on Soldering and Reliability (ICSR) being held May 9-11, 2016 in Toronto, Canada.

8 IMI CZ Collaborates with the University of West Bohemia

Integrated Micro-Electronics Czech Republic s.r.o., a subsidiary of EMS firm Integrated Micro-Electronics Inc., is collaborating with the University of West Bohemia in the field of automation.

9 Zentech CEO Matt Turpin Recognized at IPC APEX EXPO 2016

Zentech Manufacturing Inc. CEO and President Matt Turpin was named as one the electronics industry's Rising Stars by IPC at the recent IPC meeting and conference in Las Vegas.

10 Concepcion Industrial Forms IoT Strategic Alliance with Ionics

Concepcion Industrial has formalized a strategic alliance with EMS firm Ionics to develop the next generation of smart products using Internet of Things technology.

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Events

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For the iNEMI Calendar, click here.

For a complete listing, check out SMT Magazine's full events calendar here.

International Conference on Soldering and Reliability
May 9–11, 2016
Toronto, Ontario, Canada

IPC Reliability Forum
May 17–19, 2016
Dusseldorf, Germany

NEPCON West China 2016
June 21–23, 2016
Chengdu, China

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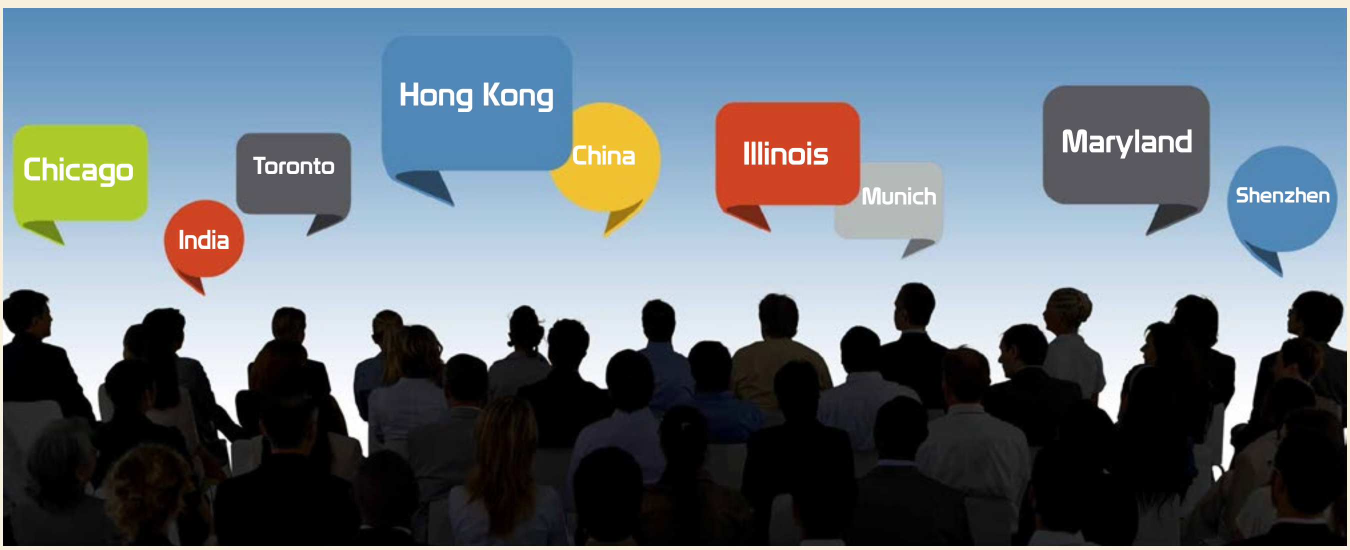
International Printed Circuit & Apex South China Fair (HKPCA)
December 7–9, 2016
Shenzhen, China



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