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SMT® MAGAZINE

APRIL 2016

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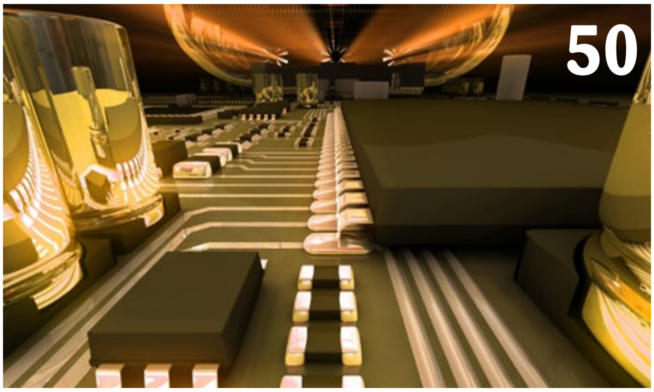
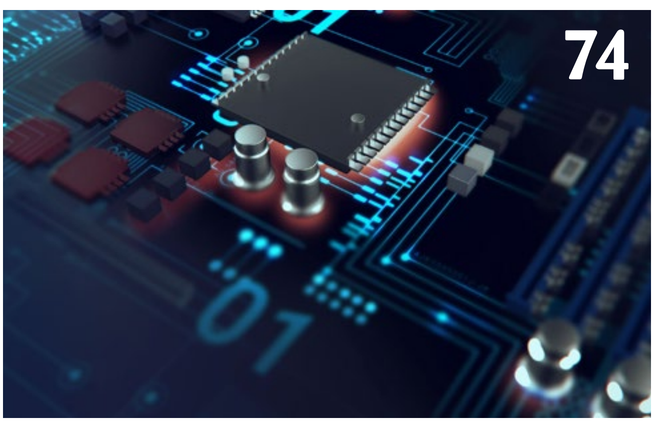
SMT MAGAZINE

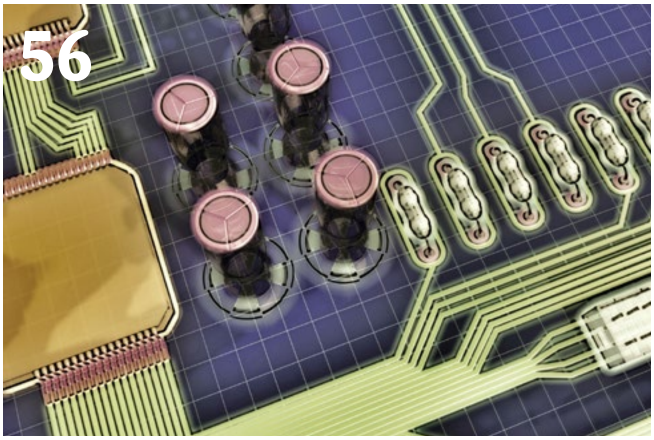
April 2016 • Featured Content





Process Engineering

This month, *SMT Magazine* features strategies for improving process engineering to achieve efficient, reliable, and reproducible assembly and manufacturing processes.



More Content:

Taking the Gremlins out of Your Process

by Stephen Las Marias
I-CONNECT007

Every step in your assembly line—bareboard loading, solder paste printing and inspection, pick and place, reflow, optical inspection, testing, unloading the assembly, and panelization—is supposed to be designed to perform optimally for you to have an efficient, reliable, robust and reproducible process.

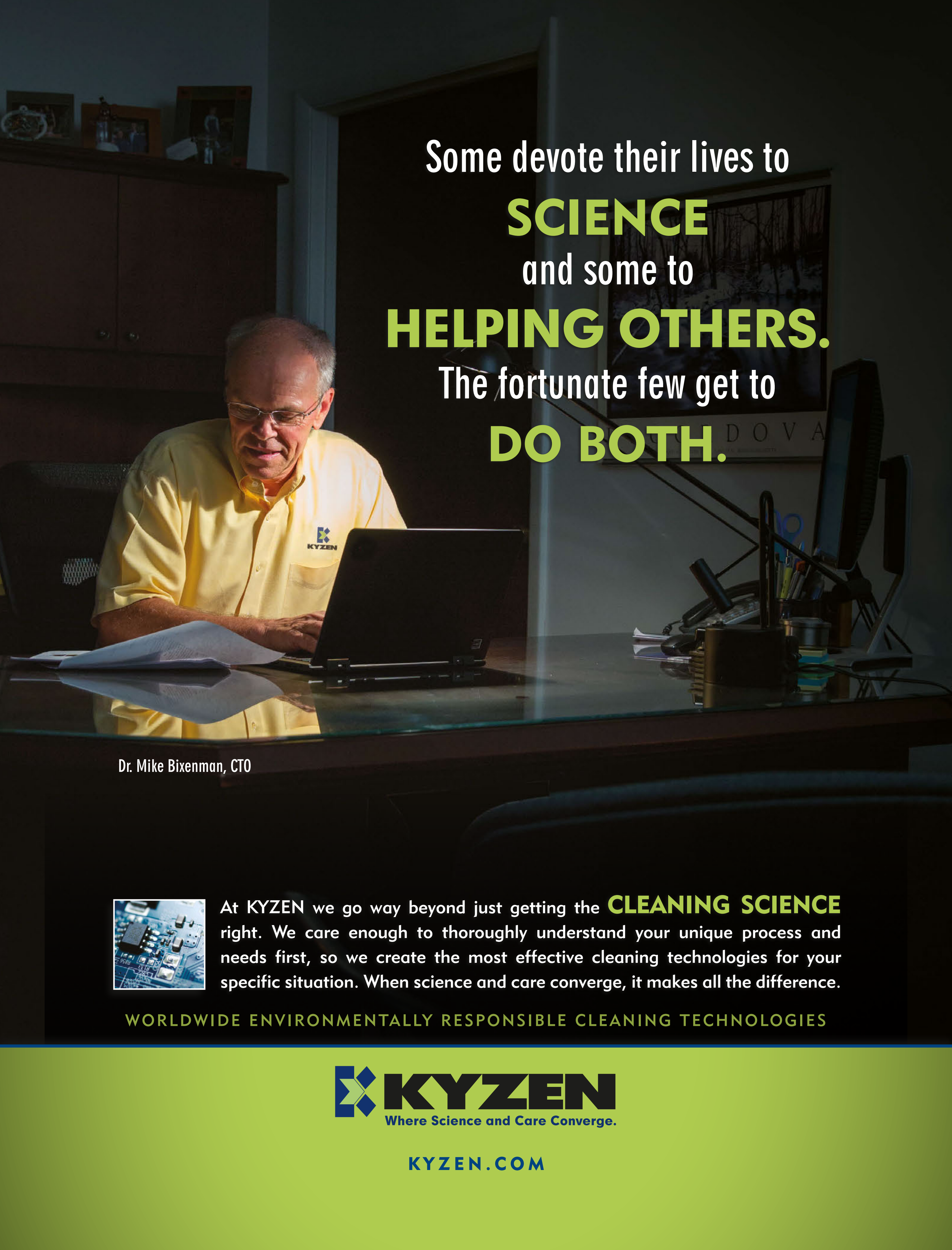
However, and as isolated as they may seem, "gremlins" sometimes appear and mess up the results of a batch, keeping operators and line engineers figuring out what seems to be wrong in their process.

In our recent survey, we asked our subscribers about their pain points when it comes to their processes, whether they need further automation for more control, and what they would like to know more about with regard to improving their process engineering.

Among the greatest challenges cited were equipment issues, materials, soldering and rework, changeovers, quality, and last but not least, management.

When it comes to equipment, some of our respondents consider the never-ending introduction of new machines as a challenge—despite these machines being designed to streamline the production. Perhaps one reason for this is the lack of time for thorough testing of a new process or machine prior to releasing to production. Respondents also said there is a lack of data acquisition systems with appropriate sensors for data logging over periods of time, and a need for systems to analyze big data to help their process innovation.

For soldering and rework, the pain points include ensuring a robust soldering and rework process for assembly,



Some devote their lives to
SCIENCE
and some to
HELPING OTHERS.
The fortunate few get to
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Dr. Mike Bixenman, CTO
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soldering BGA components, and solder printing.

The frequent production switches among different products are also among the biggest challenges. This leads to quality issues such as time-to-market pressures, respondents say, which cause them to hurry and possibly overlook key process parameters. Still on quality, the respondents say there is also a need to identify all critical-to-function parameters without having to resort to very high sample sizes.

Interestingly, 44.7% of our survey respondents are relying on their suppliers when it comes to their process engineering. Overall, most manufacturers say there is a lack of supplier support across the board. Key issues here include failure by the supplier to deliver to schedule, meet product requirements, and have adequate material on hand to recover from a yield failure.

Management buy-in also plays a key role, as according to our survey, there a lack of cooperation between management and production to ensure proper process engineering. From an administrative standpoint, respondents pointed out the lack of budget and the need for experienced and skillful staff as key issues when it comes to improving their manufacturing processes.

The trend in the electronics assembly industry is toward more automation, and our survey reflects this, as more than 60% of our respondents consider further automating the control of their processes. Also, more than a third, or 34.5% of the surveyed companies also consider the Internet of Things (IoT) or Industry 4.0 to have a huge impact in their production line.

Even though survey respondents consider the never-ending introduction of new equipment as a challenge (as mentioned above), they did point out their wish list when it comes to technology improvements in equipment or tools to help improve their engineering. Among these are the need for real-time, anytime/anywhere data assimilation from their shop floor equipment; machine diagnostic software; better linkages into tracking systems for all operations; automated data gathering; improvement in AOI speed; SPC capability; and better IR oven for soldering, to name just a few.

In line with our process engineering survey, this issue of *SMT Magazine* features articles and insights that aim to help electronics assemblers and manufacturers address the issues described above and help improve their processes.

For starters, Mike Renneboog and Robert Clarke of EMS firm Etratech detail how they were able to address their inefficient processes—in particular, solder paste mis-registration—to minimize defects and improve their PCB assembly and SMT line quality and productivity.

Michael Ford of Mentor Graphics, meanwhile, writes about the need for process preparation systems to be able to cope with every aspect and production without mistakes and confusion, in order to scale the flexibility and responsiveness of the production operation in line with customer and market expectations.

Bjorn Dahle of KIC Thermal writes that defects are simply too expensive and "doing it right the first time" is the new strategy in this high-pressure environment. In his article, he explains the benefits of improving the reflow and screen printing processes through a case study of one of his company's EMS customers.

I interviewed Matej Kranjc of National Instruments, a test and measurement equipment provider, to get an insight on data acquisition systems and big data analysis—which are among the key challenges highlighted above in our survey. In our interview, Kranjc talks about how big data analysis is enabling process innovation.

In his technical article, Gerjan Diepstraten of Vitronics Soltec writes about critical process parameters to improve and achieve a repeatable, consistent control of the selective soldering process.

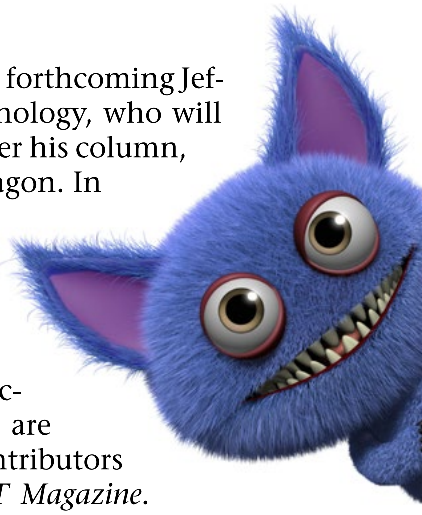
Inside these pages is also a case study regarding why TeligentEMS took a systems strategy approach wherein instead of buying off-the-shelf IT systems and dealing with support gaps if the systems don't provide all the tools needed to manage their business, they created a highly customized solution to address any support gaps. Chris Eldred writes about the benefits of this approach and how it was able to improve their information analysis and collation, and ultimately their production processes.

As always, *SMT Magazine* is not complete without our expert columnists to provide their insights on electronics assembly technology issues and challenges. In his column, Mitch Holtzer of Alpha Assembly Solutions explains why solder paste printing process capability is critical to EMS profitability.

Bob Wettermann of BEST Inc., meanwhile, justifies the need for outsourcing certain PCB rework projects. However, he also points out about the need for careful review of the suppliers' knowledge of standards and adherence to processes prior to making the outsourcing call.

After covering stencil printers, pick and place machines, reflow ovens and multiple types of through-hole soldering, Robert Voigt of DDM Novastar is starting a new series for his column on the topic of selective soldering machines.

Finally, I am happy to announce our new expert columnist, Tom Borkes, the founder of The Jefferson Project and the forthcoming Jefferson Institute of Technology, who will be writing regularly under his column, Jumping off the Bandwagon. In his inaugural piece, Borkes discusses the importance of being earnest or educated when it comes to high-tech electronics manufacturing. (By the way, we are always looking for contributors and columnists for *SMT Magazine.* Please feel free to send us a note if you are interested.)



I hope you enjoy this issue of *SMT Magazine.* Next month, we will discuss the need for automation and other strategies to reduce handling errors. Stay tuned! 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.

Are You Considering Further Automating the Control of Your Processes?

Source: I-Connect007

In our recent survey on process engineering, one of the questions asked was whether companies are considering further automating the control of their processes.

Majority of the respondents, or 58.6%, said they are willing to implement automation in certain processes in their line for reasons such as quality monitoring and preventive maintenance, and also because automation takes the human variable out of the equation.

However, the lack of management buy-in and production volume are among main reasons other respondents are not willing to implement automation in their process lines.

FEATURE

In a Culture of Continuous Improvement, *Processes Continually Improve*

by Stephen Las Marias
I-CONNECT007

Defects in the manufacturing process are part of the price of doing business, most especially in the electronics assembly industry. However, not dealing with these issues head-on and right at the root cause puts productivity and quality at risk.

In an interview with *SMT Magazine,* Etratech's Mike Renneboog, manufacturing manager, and Robert Clarke, process manufacturing engineer, discussed their most significant challenge to improving printed circuit board SMT line productivity and quality, and the lessons they learned along the way.

Canada-based Etratech designs develops and manufactures advanced electronic controls and control systems for OEMs. The company specializes in all aspects of electronic controls design and manufacturing for industries including automotive electronics, HVAC, medical devices, appliances, security systems and more. The company has been in operation for almost 30 years. Like many companies in its space, Etratech is very process-driven. It is a Six Sigma company with five resident Black Belts in its main facility, and bound by stringent ISO/TS regulations for which it is routinely audited.


Mike Renneboog


Robert Clarke

"We take quality very seriously. But, sometimes you need to stop, step back and re-assess the situation, and the challenges that have compounded in the manufacturing process," says Renneboog. The company prides itself on a culture that strives for continuous improvement, and has multiple quality programs in place.

For Renneboog and Clarke, the main challenge of that manufacturing process was the struggle with solder paste mis-registration. "And we're talking about the whole gamut of defects," says Renneboog. "We're talking about bridging, insufficient solder, and open solder connections. Those were our three major detractors."

Clarke emphasized that it is critical that you get your printing correct. "If your printing is good, chances are you will be producing quality parts on your line. If your printing is bad, you'll be creating defects, and defects just open you up to doing costly rework."

If you want zero defects further down the line, you have to make sure that your solder paste screening process is as close to perfect as possible.

The way Etratech traditionally determined printing quality was to have the operators audit the boards coming out of the printer. But, that is a subjective process, because while one operator may believe quality is good, another may think otherwise.

"You're using a certain amount of time to conduct an inspection, and it's not really effective," Clarke says. "Beyond that, our existing practice was to wait until the product came out of our inline AOI (automated optical inspection) machine. But by the time the product comes out of our AOI machine, we're looking at about 20–30 panels in process on the line, which is typically a little bit too late for us to really start making corrections."

That, he says, was the impetus to move to a new process. "It's all to do with having the inspection early, so we're getting the information in real-time as opposed to 30 panels later," Clarke says.

The basic culture at Etratech is one that strives for zero defects, which in SMT all starts at the solder paste screening operation. "If you want zero defects further down the line, you have to make sure that your solder paste screening process is as close to perfect as possible," says Renneboog.

Of course, no process is ever perfect. The team became very adept at chasing defects down the line. The process allowed them to do a good job of catching defects, but at the cost of downtime, lost productivity and wasted labor.

"Once we realized the process was inefficient and that we needed to catch these defects immediately so they didn't cascade down the line causing a knock-on effect of other issues—then we were on the road to a new way of looking at the process, a better, more efficient way," notes Renneboog. "A process can work, and still be inefficient, but an inefficient process will get the job done at a premium. We got to the point where we didn't want to pay that premium anymore."

The Importance of Process and End Quality

"If the process is right—and when I speak of process I'm speaking specifically about screen printing—if that is right, it just means that we're looking at zero defects or ppm levels that are very low," says Clarke. "We would do rework on the boards which were coming off the line, so we were basically saying 'we know we're not going to build it right' even though our philosophy should have been build it right the first time."

Clarke and his team knew that the process wasn't perfect, so to combat the problem they had rework stations set up that could handle the defects that had been seen. However, with the new process, the company has seen its ppm levels literally slashed in half.

According to Renneboog, once the SJ Inno Tech screen printer was introduced into the mix, Etratech's manufacturing team went from receiving process indicators at the end of the line—which the team would then use to adjust the printer—to the new printer actually being able to make adjustments on-the-fly in real-time. There is feedback from the internal solder paste inspection (SPI) to the screen printer, so it can fine-tune the appropriate parameters while it's running, which everyone agrees is a big improvement.

That greatly improved both the quality and the cycle time of the process. "In terms of how it improves what we do, it's the difference between having to call over a maintenance technician, who might take anywhere from ten to 30 minutes to get the issue resolved on the line versus the line running continuously without interruption with the new printer," says Renneboog. "Right now the system is self-correcting,

With the new screen printer, Etratech's manufacturing team went from receiving process indicators at the end of the line to the new printer actually being able to make adjustments on-the-fly in real-time.

so we don't see that unscheduled downtime anymore. Quite frankly, the difference is night and day between our old process and the new process."

Prior to the change, the team had been eager to make improvements. While the previous process was certainly acceptable by most standards, the team wanted to strive for zero defects while at the same time improve cycle times.

"We needed to conduct real-time inspections," says Clarke. "The yardstick we use to measure the effectiveness of the 3D on-board SPI with Closed Loop Control incorporated in the new machine is from the reduction in defects that we see coming off the line. In terms of true defects, we would typically see around 68 ppm with the old screen printing technology. It was untenable. However, with the new screen printer in place, our defects dropped from 68 ppm down to 11 ppm. The change was quite dramatic."

Also, economically, the pair were challenged to achieve a cycle time of 15 seconds in order to meet the demands of a new high-volume product being introduced. "Typically your screen printer would at best be able to give you a 30-second cycle time while conducting a limited amount of 2D inspection in select areas. But because we wanted to do a 100% 3D inspection of our solder paste—and not just a 2D inspection that you would get from most printers—this was the road to go down. It would take minutes to really do a complete 2D inspection using our existing screen printer technology. A full-scale inspection would just be prohibitive," notes Clarke. With this new system, Etratech gets all the benefits that the company needs within the 15-second cycle time.

In terms of the improvement, Etratech's utilization of the SMT line on which this piece of equipment has been installed is significantly higher. "If we go back and compare downtime that we would have seen on a printer a year or two ago, we're talking about tens of hours of downtime," notes Clarke. "Today, we're looking at uptime on this equipment of around 96%. The metric would be your overall equipment effectiveness (OEE). In terms of a world class manufacturing facility, you want to have utilization of upwards of 85%, and with this piece of equipment we're boasting an uptime of 96% today. Basically with the greatly improved ppm levels, the repairs are down to next to nothing after Etratech's AOI machine is factored into the process."

Previously, Etratech dealt with more misprints because the system wasn't capable of self-correction and was prone to washing panels or boards. With this new piece of equipment, the team never has to wash a panel. "Our system is so repeatable that we do not need to clean boards, but simply pass them back through the system, and that is one of the benefits that we get to enjoy today," says Clarke.

Lessons Learned

Etratech became very efficient at supporting an inefficient process. "We actually disguised the inefficiencies in the process by expecting them, and dealing with them so well," admits Renneboog. By re-evaluating the process and the way defects are perceived, Etratech has seen a remarkable improvement in downtime, and a streamlining of its whole production process. **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.

Cost vs. Cause: What is More Critical to EMS Profitability?

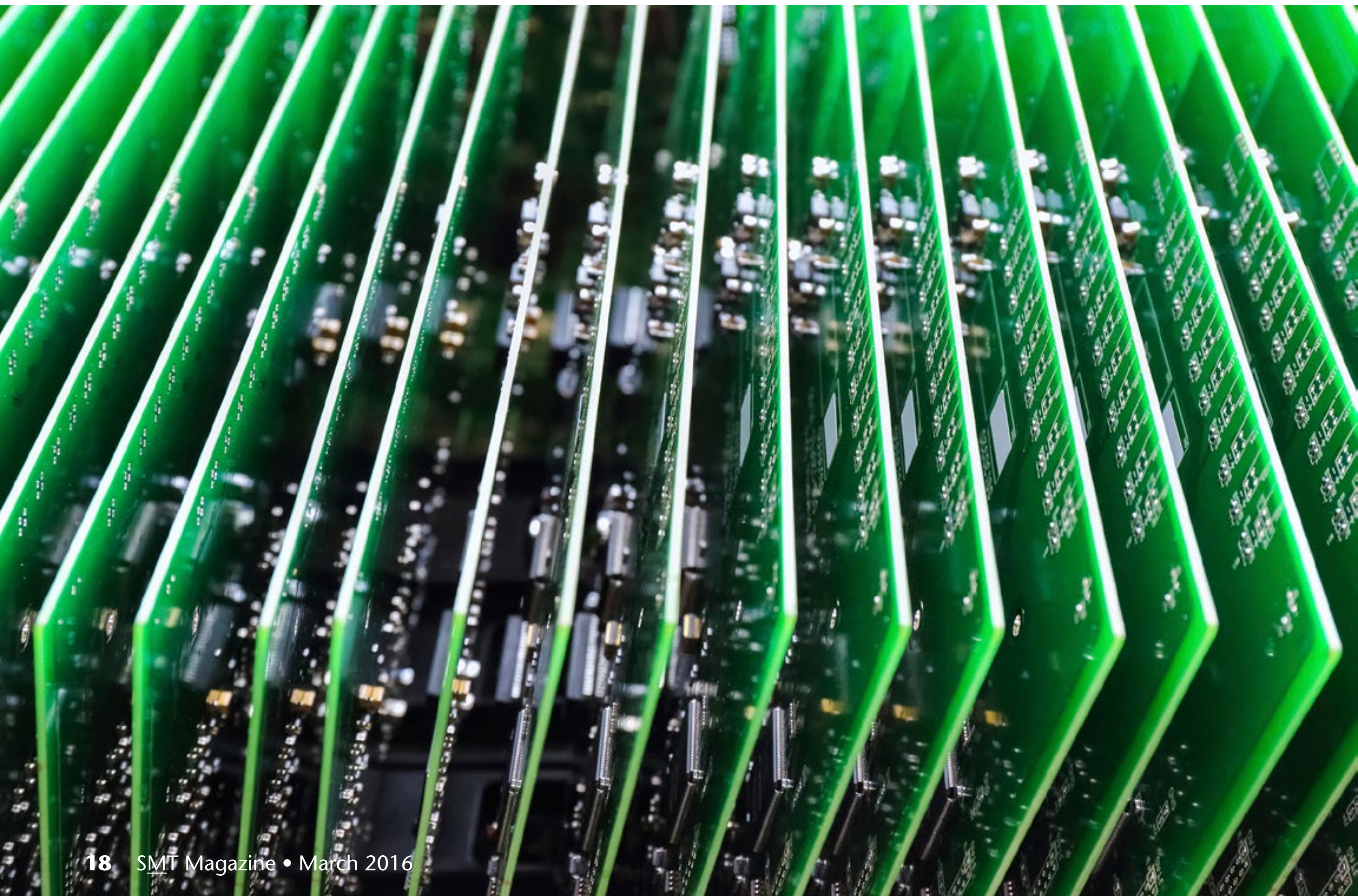
by Mitch Holtzer
ALPHA ASSEMBLY SOLUTIONS

Solder paste printing process capability is critical to EMS profitability. In more than 20 years, no one has ever been able to make me believe this hypothesis is untrue.

The reality of the market is that each major global EMS will ask solder paste manufacturers to reduce price, rather than improving first pass yield. The economics of this market trend are unsustainable. Solder paste is already the lowest cost item on every electronic assembly bill of materials, but can have the most impact of any material used in the surface mount technology process.

Numerous EMS and OEM firms have driven their companies to oblivion by determining that the unit cost of the least expensive material on their consumable list was the best choice. Looking at a list of well known, global companies who no longer assemble electronics confirms this point. Cheap solder paste has never been a driver for success. Let me show you why.

First-pass yield, determined by the number of circuits successfully produced per attempt, without requiring wasteful re-work, is a critical milestone. Profitability is the difference between



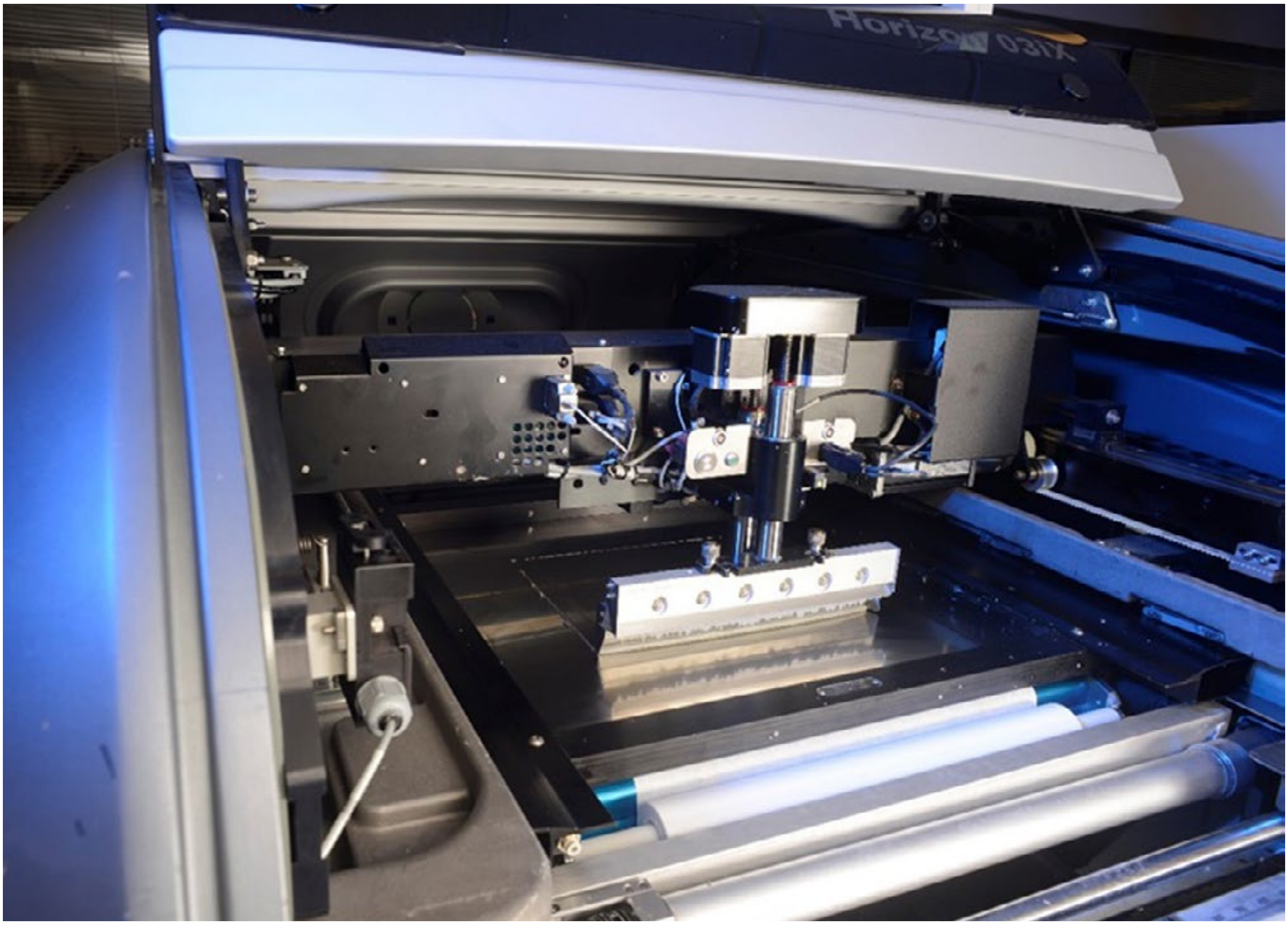


Figure 1: The solder paste printing process capability is critical to EMS profitability.

revenue and the sum of fixed and variable costs. If you have $750,000 in fixed assets (a printer, an SPI device, two or three chip shooters and a reflow oven) per SMT process line, and a rapid depreciation schedule (five years), your fixed costs would be $150,000/year.

Next, you should factor in costs for manufacturing space. Let's assume a low-cost location of 1,000 square feet and use a conservative estimate of $1/ft^2 of floor space. Manufacturing overhead is a common term for the labor required to manufacture assemblies. This is a more difficult cost to estimate, as different companies have varying head count per SMT line and wage rates determined by the local market.

Each of these fixed costs needs to be amortized over the number of good assemblies produced. Because there are so many variables in the fixed cost allocation, I won't attempt to quantify them in general, but they must be considered as a significant part of the total cost of manufacturing.

Variable costs are subject to several variations, but a little easier to analyze. Board substrate and components are obvious examples of variable costs. Although there are numerous types of substrate materials ranging from PET flexible to multi-layered FR-4, the value of the substrates range from $20 to $90/meter^2 according to a December 2015 Prismark report. A typical solder paste test vehicle used to evaluate new pastes is 65 in^2 or 0.042 meters^2 on each side of the board. Approximately five grams of solder paste are used when printing on both sides of this densely populated test vehicle. Thus one data point indicates that five grams may be used per 0.084 meters^2 of substrate or 59 grams/

meter^2. At \$0.10/gram, the cost of solder paste used converts to \$0.059/meter^2. This converts to 1/1000 of a typical substrate cost.

Components represent an even larger proportion of the bill of materials cost. Even the least expensive passive components may cost \$0.01 each. Sophisticated processors used in smart phones, tablets, PCs and other common devices can easily cost tens of dollars each. It is therefore easy to show that even high silver alloy solder paste is the least expensive material placed on a circuit board.

Eliminating rework, contributing to low cycle times, high in-circuit pin test yield, PPM levels of print volume transfer issues are all key success factors in a solder paste. Any shortfall in performance in any of these areas translates to a cost many times the cost of a solder paste.

One real world example occurred as a large consumer of solder paste converted from tin-lead to a lead-free alloy. As this happened, the price of both tin and lead escalated, essentially doubling the unit price of the solder paste. The paste consumer performed in-circuit pin testing to assure that shipped assemblies were in working order. Because the new lead-free solder paste reduced the number of false negative results in the testing procedure, a value in use calculation showed that the tin-lead solder paste manufacturer should have been paying the customer to use their paste. This was an extreme example of the value that high yielding solder paste can offer, but if any of the key success factors is lacking, the price of the solder paste does not matter.

Another example would be the economics of producing a smart hand held device. If even as much as 0.5g of solder paste is used per assembly, at \$100/kg, \$0.05 worth of paste is consumed per assembly. If the price is decreased by 25%, the savings potential would be \$0.0125/assembly.

Let's look at the cost of one defective assembly per day. One scrapped assembly per day, even with a \$50 bill of materials, outweighs the cost savings on lower priced solder paste by a factor of 4,000:1. (\$50/\$.0125). How many times do you think opting for a risk to reward ratio of 4:000:1 helps the long term profitability of your manufacturing business?

In conclusion, solder paste first pass yield is a tremendous driver for maximizing the profitability of an EMS provider. The price of solder paste multiplied by the volume used per assembly usually proves to be the lowest cost material on a bill of materials. Therefore, using lower priced solder paste while reducing first past yield may be the costliest mistake that can be made. Consider paying a fraction of a cent more per assembly while getting higher yields, it might be the best fiscal decision you make. **SMT**

Mitch Holtzer is global director of customer technical service (CTS) for Alpha Assembly Solutions. To reach Holtzer, click here.

Producing Electronics without Semiconductors is Now a Reality

A new study by an international team of researchers affiliated with UNIST has found a new way to produce electronic devices, such as diodes and logic gates without the need for semiconductors.

In their study, published in Nano Technology, the team used metal nanoparticles coated with charged organic ligands to create versatile electronic circuits, which they have named "chemoelectronic" circuits. Each ligand produces a different, charge-related effect when put in water or a humid environment. This newly developed nanoparticle diodes and devices are durable enough to withstand salty, aqueous environments, and flexible enough to be operated even under significant bending, thereby overcoming the limitations of the present semiconductor technology.

This study was jointly conducted by Prof. Bartosz Grzybowski (School of Natural Science) of UNIST, Prof. Yong Yan of the National Center for Nanoscience and Technology in Beijing, Prof. Scott C. Warren of the University of North Carolina at Chapel Hill, and Patrick Fuller from NuMat Technologies.

Supply Lines Highlights

ESI Launches Newest Addition to Laser Micromachining Portfolio

Electro Scientific Industries, Inc., an innovator of laser-based manufacturing solutions for the micromachining industry, today introduced the Garnet adaptable laser micromachining platform for high-volume cutting, marking, drilling or engraving applications.

Inovaxe Appoints Yankee Soldering as Its New England Rep

Inovaxe has appointed Yankee Soldering as its manufacturers' representative for New England. Based in Rhode Island, Yankee soldering will represent Inovaxe in Rhode Island, Connecticut, Massachusetts, Maine, Vermont and New Hampshire.

Technica USA to Expand Role with ASM Americas

Technica USA has been appointed by ASM as the exclusive U.S. distributor for the new E by SIPLACE placement equipment.

Mycronic Receives Order for a Replacement Mask Writer

Mycronic AB has received another order for a mask writer, built on the Prexision platform, replacing an older system for manufacturing of display photomasks.

Rehm Delivers 4,000th Reflow Soldering System

Rehm's VisionXP+ was delievered to Diehl Controls, a manufacturer of electronic components for the household appliance industry, for hardware and software solutions for central control units in buildings, and for products for energy management systems.

GOEPEL Test Strategy for IoT Devices Honored at Embedded World 2016

GOEPEL electronics was awarded by an international jury of experts at the Embedded World 2016 exhibition in Nuremberg for JEDOS (JTAG Embedded Diagnostics OS), GOEPEL's test and diagnostics tool for electronic assemblies.

Manncorp Celebrates 50 Years of Service to the Electronics Industry

From advancements in technology and production methods, to global shifts in markets and manufacturing economies, Manncorp founder and CEO Henry Mann has seen it all. The company he started in 1966 is among a select few that not only have survived but also continues to flourish as the electronics assembly industry has undergone the dramatic changes of the last half century.

Henkel Liqui-Form 3500 One-Part Gel a Breakthrough for Thermal Interface Materials

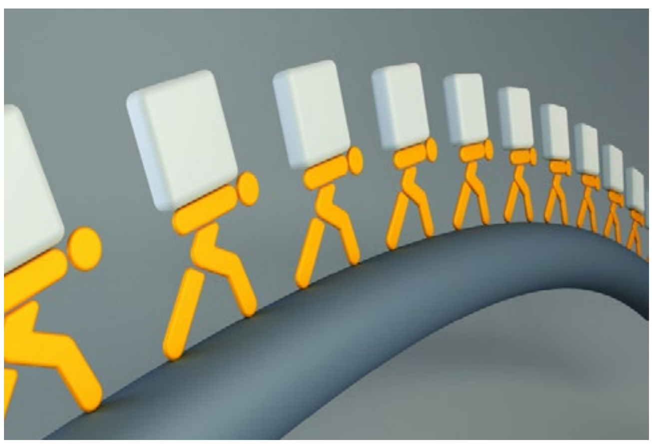
Henkel Adhesive Technologies has expanded its line of Bergquist Liqui-Form TIMs with the release of Liqui-Form 3500, a one-part, thermally conductive, liquid formable gel that combines high thermal conductivity with process flexibility and excellent reliability.

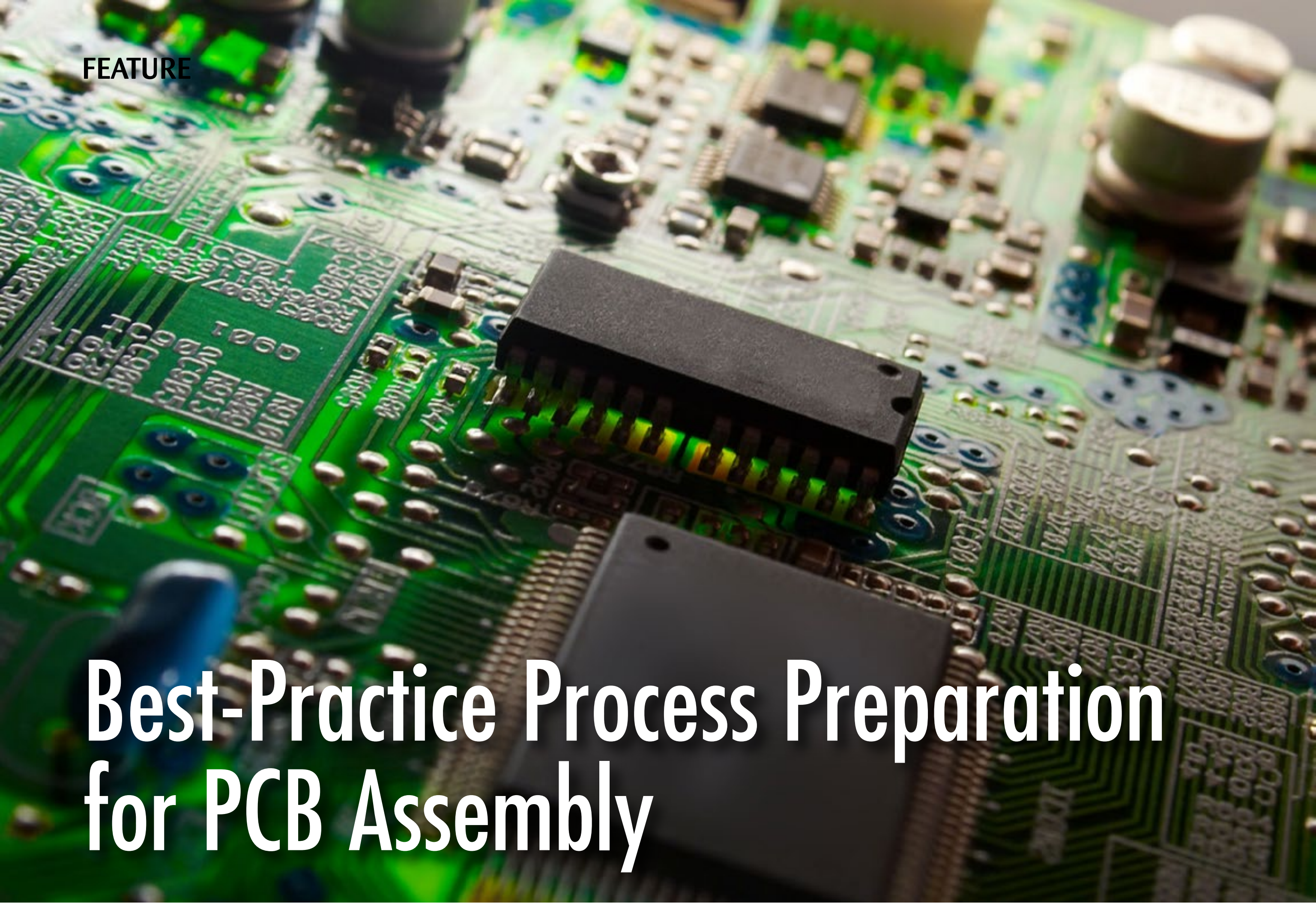
Etek Europe Appointed Distributor of CheckSum

Etek Europe has been appointed distributor for CheckSum in the United Kingdom, Bulgaria and Romania.

Count On Tools Launches StripFeeder Lightweight Kit

Count On Tools Inc. has released a new version in its line of StripFeeder products – the StripFeeder Lightweight, a low-mass version of its StripFeeder platform to accommodate machine weight limits on tray capacity.





Best-Practice Process Preparation for PCB Assembly

by Michael Ford
MENTOR GRAPHICS

Electronic product manufacturers are providing their customers with greater varieties of more complex products, all of which have to be delivered with perfect quality, on time, and at a low price to be competitive. In this high-pressure environment, process preparation systems need to be able to cope with every aspect and production, all machines and processes, without mistakes and without confusion, to scale the flexibility and responsiveness of the production operation in line with customer and market expectations.

Process preparation is mandatory and critical for high-quality production of printed circuit board (PCB) assemblies, profitably. The tools and methods used in process preparation ultimately determine if the goal for introducing a new product to the production line will be successful. Process preparation is the critical link between the completion of the design and the start of physical product realization. The gap between these two processes can be quite wide, geographically and organizationally, especially where external contract manufacturing is used.

One of the biggest challenges in process preparation is to understand the actual product that will be built, to know the processes that will be needed, to assess and understand the cost of making the product. This requires communication, project skills, process and resource information, and a lot of product information.

Information created by process preparation defines and governs every action needed to make sure that the product is built according to the desired specification. Work-orders are created for execution. Engineering information in the form of machine programs, work instructions, and test parameters can be attached to each work-order at each process to describe the specific work to be done for the specific version and instance of the product. Having this information enables the enforcement of each operation against what is required. This is the origin of compliance and conformance.

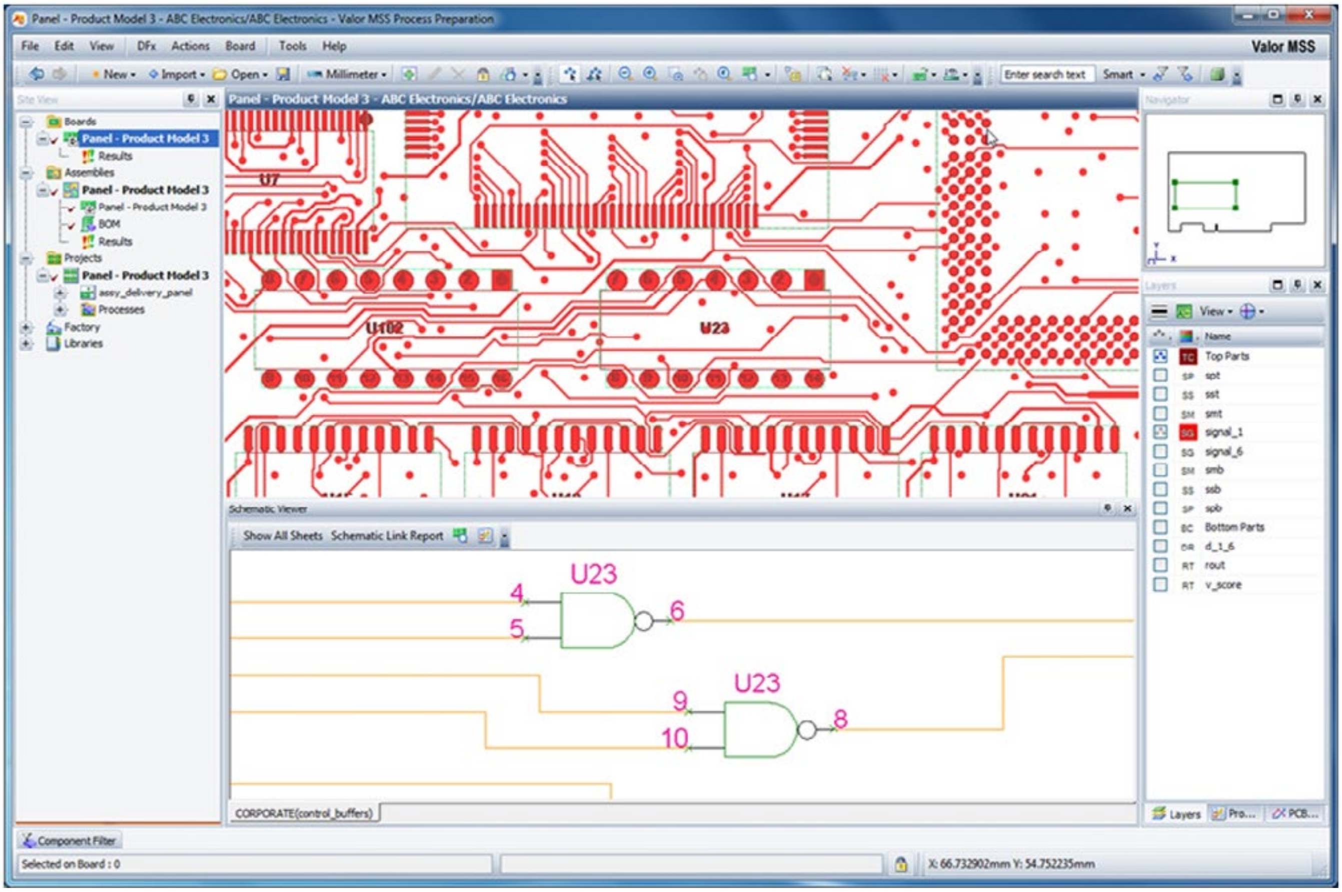


Figure 1: Complete process preparation covers layout, BOM, and schematic information.

Process preparation as a whole is actually made up of numerous processes. This is the nature of electronics PCB assembly. Each is quite different, and within each process, there can be many variations depending on which vendor of surface mount technology (SMT) machines is used. In most companies today, the process preparation for each of these is done separately.

In many cases, introducing a new product is like the Olympics but unlike the Olympics, in manufacturing it is not the first one past the post that is the winner, it is the last one to the post that defines the preparation time. Although the processes are all different, the baseline engineering data about the product is the same. So it's logical for the teams to work together on a single product data model. Different groups of people using different tools can severely limit the ability to collaborate. The end result is many people doing the same thing in slightly different ways in a parallel fashion, with the likelihood of getting slightly different results.

However, using the Mentor Graphics Valor manufacturing management software suite, and in particular the Valor Process Preparation software, to perform all of these individual process preparation tasks based on a single common data-set means that, instead of everyone taking in raw data about the product and processing it separately, the data can be processed one time correctly and then used across the various processes. This reduces engineering effort because the common part of process preparation, the data preparation, is done just one time instead of many.

Creating a Data Product Model for Assembly

The most important engineering work as part of process preparation is to create the single data model—data preparation. Best practices in the steps taken to prepare the data model reduce time and effort as well as eliminating potential mistakes.

The first step is to obtain the available product data from design. This can be challenging because of the many variations of native CAD data formats. Many process preparation tools in use today are unable to use the native ECAD formats, which has led to alternative data formats: so-called CAM data exports, such as Gerber files. These unintelligent formats, however, are not designed to hold anything other than very simple information about the product design. Using these formats with limited information then requires an extensive reverse engineering of a sample product to gather enough useful data to be able to complete the process preparation stages. This is a significant bottleneck to the process and inevitably results in frequent mistakes being made.

A better alternative is to use the standard industry format ODB++, which can be easily exported from almost any CAD system and contains all of the required information for assembly process preparation. It is a quick and easy transfer completed in a few minutes compared to days of needless engineering work recreating what was already known to the designer. However, a complete process preparation system will also need to cope with the CAM formats of information such as Gerber files, should these be the only ones that are made available to the manufacturing operation. Tools that can assist with the reverse engineering process can make a significant difference in the time needed with the minimum number of mistakes. Using the reverse engineering method should only ever be the last resort.

Qualifying the Product Data Model against the BOM

Once the product model information has been derived from the design tools, it needs to be qualified against the manufacturing bill of materials (BOM). One PCB design can service many products and variations, so it's important to be able to differentiate between these variants to ensure that the product is built correctly. The BOM needs to be used to define which placements and other components should exist for any particular variant, and what the actual materials used will be.

The BOM is based on the PCB design data,

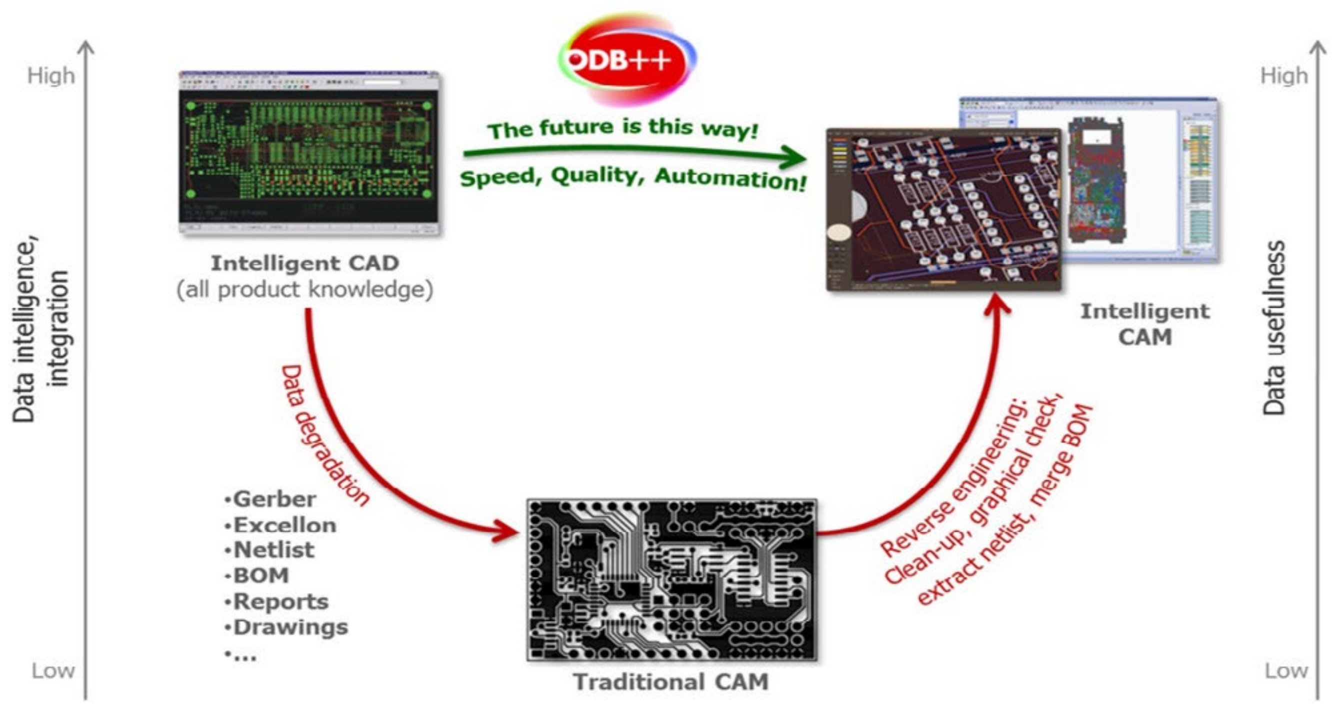


Figure 2: Data preparation using industry standard ODB++ transfer from ECAD creates a more streamlined and error-free process.

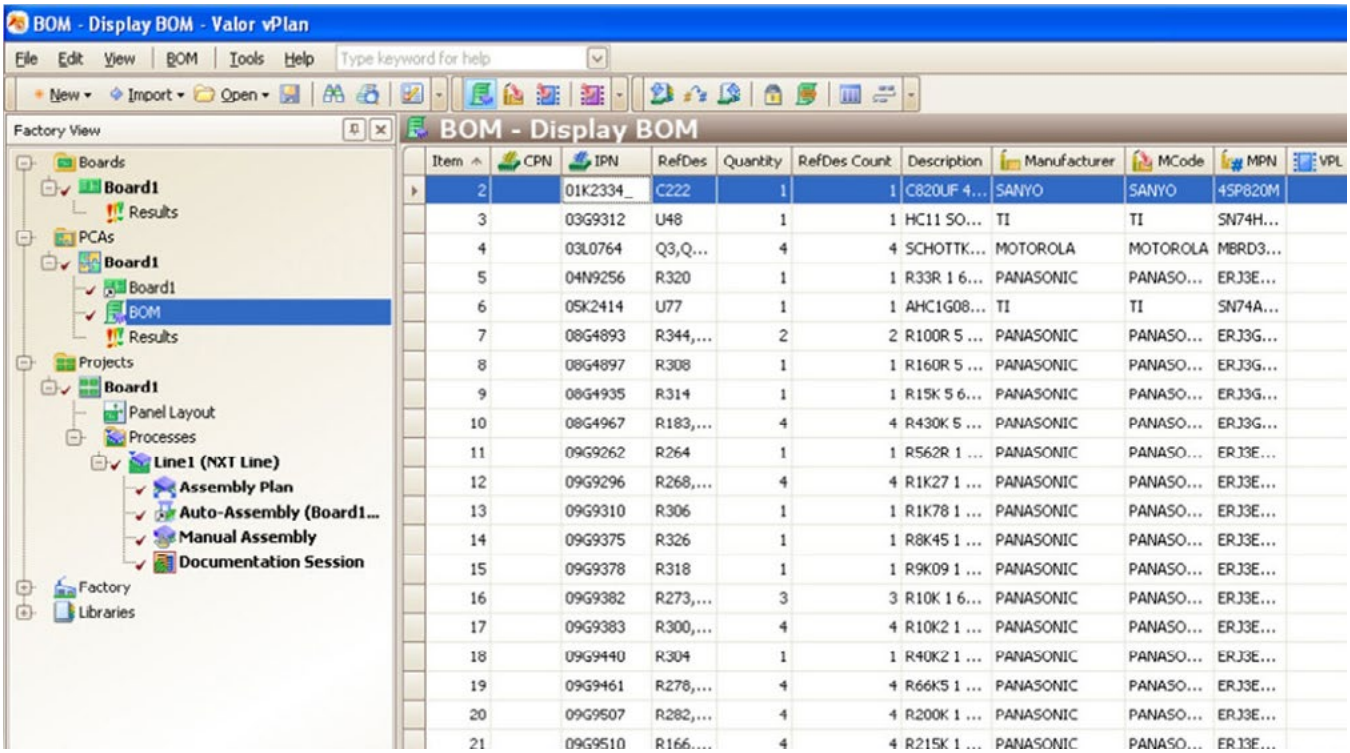


Figure 3: BOM Merge is a powerful feature of Valor Process Preparation.

with each part number linked to the location on the board by a reference designator. However, there are often discrepancies in the naming conventions and content of the BOM. This can happen because the BOM is managed in the ERP system. ERP systems are driven by materials represented by part numbers and quantities. The individual component references are often represented only as comments, all references sometimes listed squeezed together into a single field, which leads to significant corruption potential of the reference designators. This is a critical issue because the reference designator is the key piece of information to identify which component positions need to be placed and which precise component part number is location on each and every reference designator.

Merging of the ERP-based BOM with the original design data can be quite a challenge. It requires a tool such as Valor Process Preparation that is able to make decisions about matching and exposing any discrepancies, which often happen. For example, reference designators in the ERP BOM that do not appear in the design or quantities of components used of a specific part number in the ERP BOM may not match the count of references listed in the design data. These are all things that must be resolved with 100% certainty before moving forward. This process is still done manually in many cases, perhaps with the aid of a spreadsheet, and consumes significant time and resources, as well as carrying a high risk of errors.

Simulating the PCB Assembly

The next step is simulation of the as-built product model as defined in the BOM. Using the manufacturer-specific part numbers defined in the BOM, corresponding physical package definitions for all parts can be merged with the PCB data and overlaid on to the PCB. Incorrect part assignment issues can now be highlighted as well as ensuring that alternative components are also viable with respect to the PCB pads. These manufacturer-specific packages are then used to automatically create data for SMT programming, test programming, DFA analysis, stencil design, documentation, and

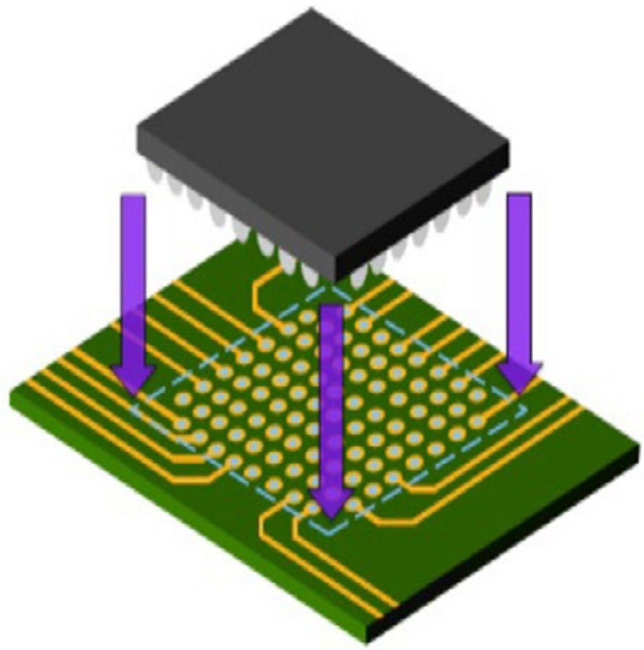


Figure 4: The Valor Parts Library is a key element to the accuracy of the product data model used in Valor Process Preparation solution.

even inspection programming for AOI and AXI machines.

The Valor Parts Library central shape-management library tool provides a significant and reliable database of shape information. It can be an important asset in the race to reduce the lead-time of process preparation. It means that accurate verified information is available for all areas of process preparation at any time.

Creating and maintaining shape libraries has two major challenges. Any new part numbers that are added to the design need to be identified.

The shape of a new part number could be the same as an existing part number and so it can be mapped, or it may be a completely new and unknown shape. The limitation of not knowing the actual shape is critical for new products using materials that are new and may not yet be physically on site. These shapes are required for the engineering process, for SMT, test, and inspection as well as confirmation of things in the basic data such as rotations. Not being able to know the shape data can delay many of the process preparation stages.

Designing for Assembly and Manufacturing

Once a complete and accurate data model of the product is created for production, some automated tests can be run to find any areas of interest in the design itself. Issues in manufacturing may crop up as a result of a design that may not have a good understanding of the needs and limitations of the manufacturing processes. It can be as simple as the actual materials being larger than expected, the leads being different shapes than expected, or the test points being in inaccessible places, etc. There are literally hundreds of categories where compromises may have been made.

Knowing these issues in advance provides the opportunity to plan countermeasures into the operation, reducing the risk of quality issues. An undetected quality issue that makes its way into the market can have fatal consequences for the product life and business returns. For the contract manufacturer, this provides the opportunity to use the best information about the product and production processes and to be able to more accurately make the quotation for producing the product to the customer. For the OEM manufacturer, the same principle of design for assembly is an opportunity to feed issues back to the design team with a view of improvement for the next generation of design, based on actual manufacturing capabilities and limitations.

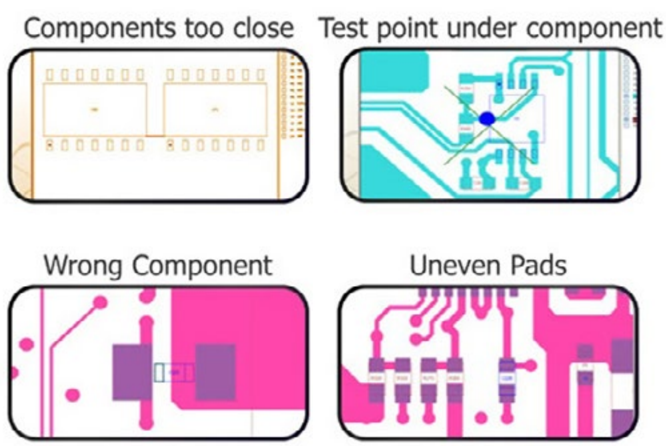


Figure 5: DFM analysis is crucial to protect product quality and the cost of manufacturing.

Managing Component Rotation

After merging the accurate shapes of the components into the data model, still one more crucial issue for SMT placement needs to be addressed—component rotation. Component rotation is challenging because it's a relative measurement, relative to the original design footprint rotation of 0°. As a result, a standard definition of rotation in design is rarely achieved successfully, and even more rarely communicated. Even within the same design team and within the same shape of components, there can be cases where the rotation of zero degrees of one part number is different to that of another. Just looking at the rotation, it is often impossible to know the actual correct orientation of the component. Correct orientation is achieved on the board when pin 1 of the component is actually located on the designed pin 1 of the pad stack or component footprint.

At the time of importing the design data, automated adjustments can be made. For example, as a first step, a rule can be applied based on the quadrant that pin 1 or the first electrode of a device appears in. This rule will set consistent normalized rotations. Once normalized in this way, the rotations can then be adjusted to a defined standard for that shape using a simple look-up table. Very quickly then all the correct rotations can be neutralized in the product data model.

An error in rotation or offset is serious enough, however, that positions and rotations must always be 100% checked for new products. The standard approach in the industry for a new product introduction to SMT is to run a special board covered in a film of sticky tape in lieu of solder paste, through the SMT placement machine. People will then study this board through a magnifying glass to see whether in fact all of the rotations and positions of all of the components are correct. Corrections can be made to the program and the process repeated until perfect. This can go on for awhile, consuming a lot of line time and materials which cannot then be reused. The result of this even cannot be fully trusted because having gone through the machine programming software to make program "tweaks" on the shop floor, compensating errors may have been introduced, potentially causing serious quality issues later on.

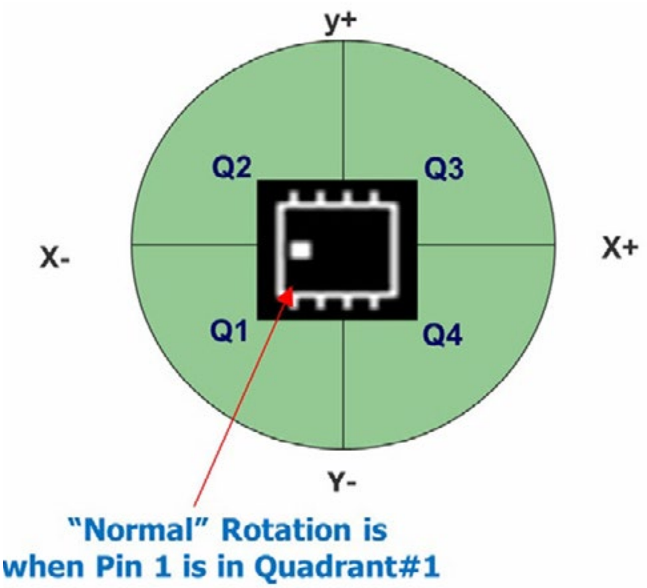


Figure 6: Automatic rotation normalization is used to account for inconsistencies in design data.

Alternatively, the Mentor Graphics Valor Data Preparation has a built-in simulator known as "virtual sticky tape," which shows exactly how each component will look when placed on the surface of the PCB. This is possible only because the actual design and shape data are available. When overlaying these two data layers for each component position, the result is a significant reduction of time and cost. Quality can also further be improved. Often 180° errors on symmetrical polarized parts are missed in visual checks of the physical board because polarity marks are sometimes obscured.

Stencil Design

Stencil design traditionally involves sending out a stencil guidelines document to the stencil vendor and a Gerber layer that instructs the stencil vendor how to define the various apertures needed for the stencil. They make these changes, typically contacting the manufacturer a number of times, to create a complete stencil. This is then sent for final confirmation to the manufacturer who can approve it before getting the stencil and a Gerber file that describes the stencil. This whole process takes time. It is also very manual as each stencil does not learn

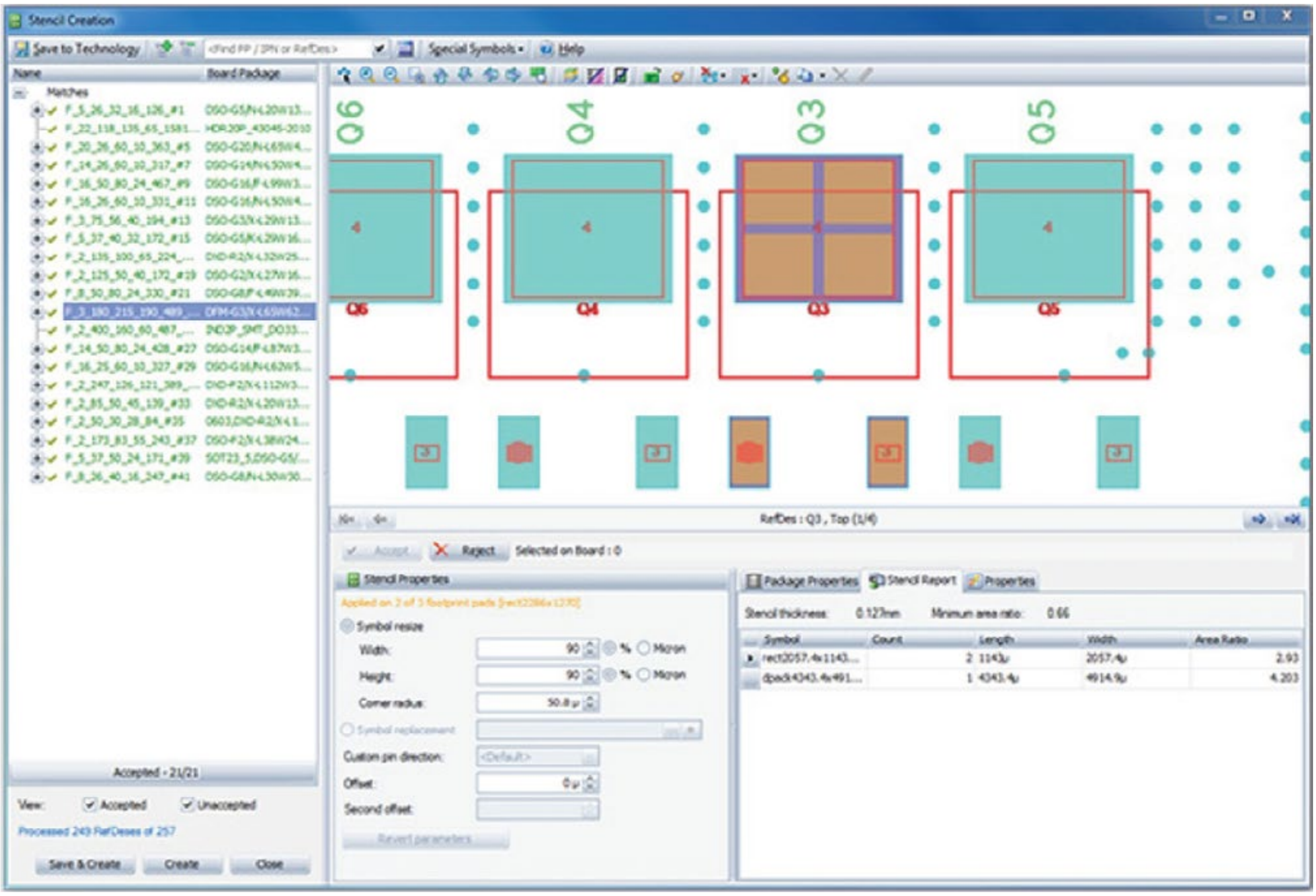


Figure 7: Valor Process Preparation can quickly and easily create stencils using the same product data set.

from the previous one because the nature of the source Gerber file.

With Valor Stencil Design, the intelligent design data set assigns each component with a repeatable footprint name that can be used on future stencil designs, even from different design centers. Resizing algorithms can be applied to existing shapes, new apertures can be built with standard symbols, or complex apertures can be created to assign the correct aperture for each location that needs paste. Rules are added for each footprint, or if necessary for each unique part number that is placed on each footprint, which can be reused on future designs and are then applied to all occurrences across both sides of the board. As complete intelligent design data is being used for the stencil design, the engineer can see how the copper pad, VPL pin, and stencil aperture will all align in a virtual world before committing to the stencil. When the stencil is complete, it is output for delivery to the stencil vendor who creates and delivers the final screen.

SMT Process Definition

In the process preparation work flow, each of these processes is now founded on a central consistent known good product data model. This common data model can be used in many different ways. The first key challenge of SMT programming is to understand the capability of the machines. There are so many different machine platforms, types, models and variants from many different suppliers, each designed to bring slightly different advantages. These machines operate also use many different software platforms. It can be quite a challenge to effectively distribute the placement workload over the different machines in a line. Often compromises and assumptions are made to make the

job manageable, for example, a preset decision of which line is to be used for each product.

With today's modern process preparation system, however, the capabilities of all machines are modeled in software. This enables the software to automatically and accurately distribute the placement workload over any line configuration made up of any machines from any vendor. Whether a product is run on line A or line B should be based on using the best machine for the job, not limited to which machines include required library data or not. With the Valor Process Preparation software, several line configurations can be modeled to find the best machines for the job. The engineering time required to perform mindless repetitive duplicated manual operations can now be refocused to make real improvements in shop-floor productivity.

There is always a large overlap in SMT machine capabilities, meaning that most parts can be placed on a choice of machines in the line. This is where program optimization and line balancing come in. Of course, within a single machine vendor's platform, there will be software provided with the machine to do this. In these cases, it can be just a matter of sending the fully prepared data to the machine vendor's software, including the details of the shape library.

One key element to do this is the automated rule-based generation of what would normally be handmade settings for the components to run on the machines. These settings are the personal parts settings, for example, lighting, camera, nozzle, things which are related to the treatment of specific types and shapes of material on the specific machines. These can be worked out automatically by the Valor unique automated-generation function that generates these parameters based on defined engineering rules. This leads to consistency and accuracy, even taking care of new parts automatically as they are introduced.

When there are mixed platforms in the line, including the case of different platforms from the same vendor, some very significant engineering work is required for line balancing. First, the data has to be prepared into multiple formats. After each piece of the vendor's software has done its work, the estimated working times of each machine may be quite different. Parts assignment will need to be moved manually from machine to machine and the optimization repeated, often several times, until a good balance is achieved.

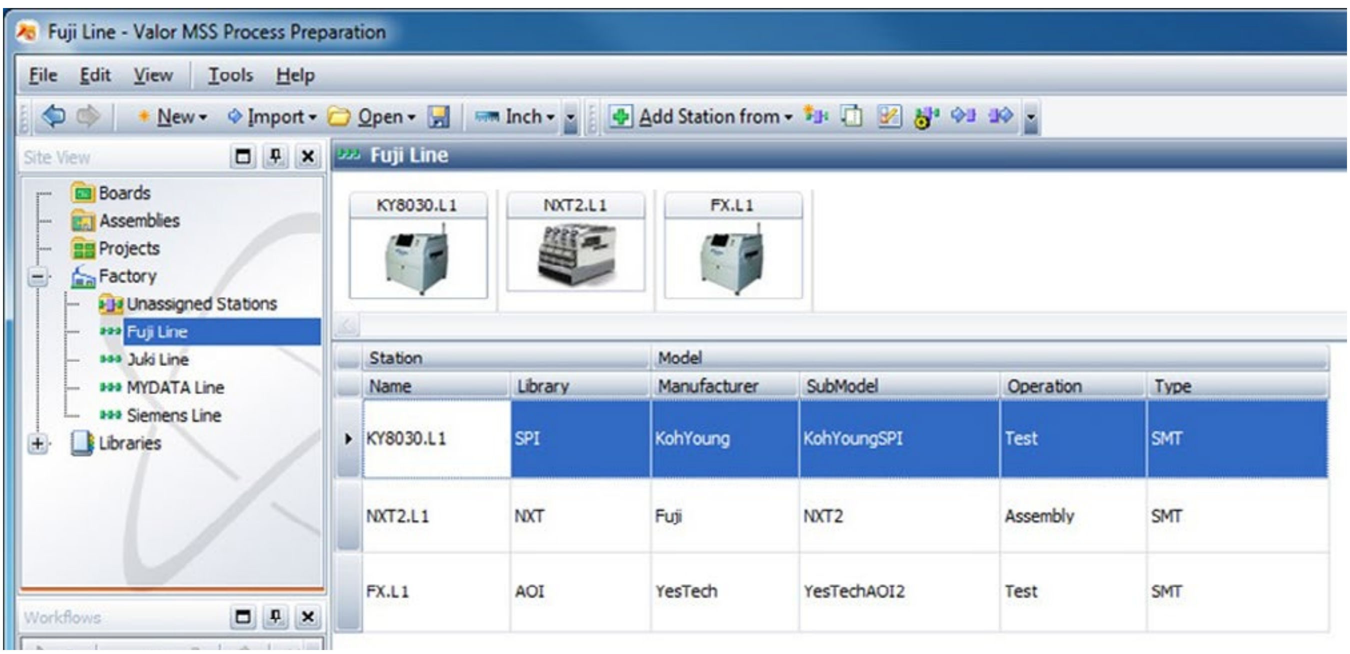


Figure 8: The ability for a process preparation solution to facilitate easy line or site transfer is key to efficiency and productivity.

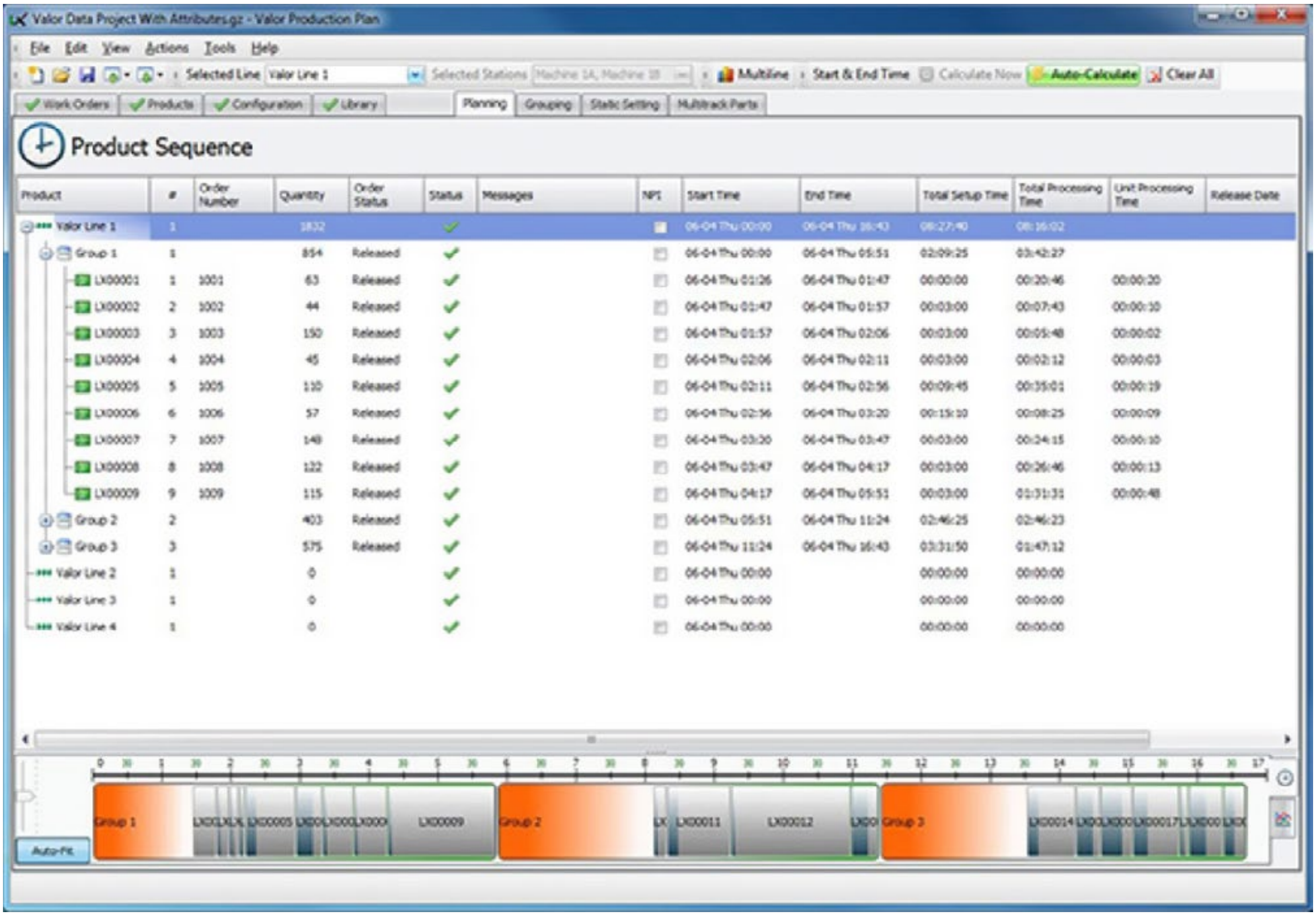


Figure 9: Valor Production Plan works in concert with Valor Process Preparation for setup and change-over optimization across the factory.

In a best-practice process preparation system, however, the machine optimization and line balancing is done centrally and automatically. Just press a button and a week's worth of work is performed as you drink a cup of coffee. In an increasing number of cases, the Valor program optimization uses the machine vendors own software to provide the most accurate and consistent performance. Others are optimized using Valor advanced optimization algorithms. Many iterative line balance cycles are performed automatically until the line is as perfect as it can be.

SMT Setup/Change-over Optimization

Much of the time lost in SMT production is changing-over the machines from one model to another. This is becoming an everyday occurrence on every line in higher product mix environments. The major contributor to this changeover loss is the time that it takes to set up the materials. Clearly, reducing the number of material changes will reduce the changeover time. Making some or all of the feeder positions common between products can reduce the changeover time to almost zero. The trade-off, however, is that for each individual product, it will not be possible to optimize the feeders as well as if any choice was available. The best optimization of several products together is the goal. The Valor Process Preparation tool can consider the optimization of many products run in any combination to find the best possible result in even the highest product mix scenarios.

When used in combination with the Valor Production Plan tool, which uniquely allows schedule optimization at the same time as creating common feeder setups.

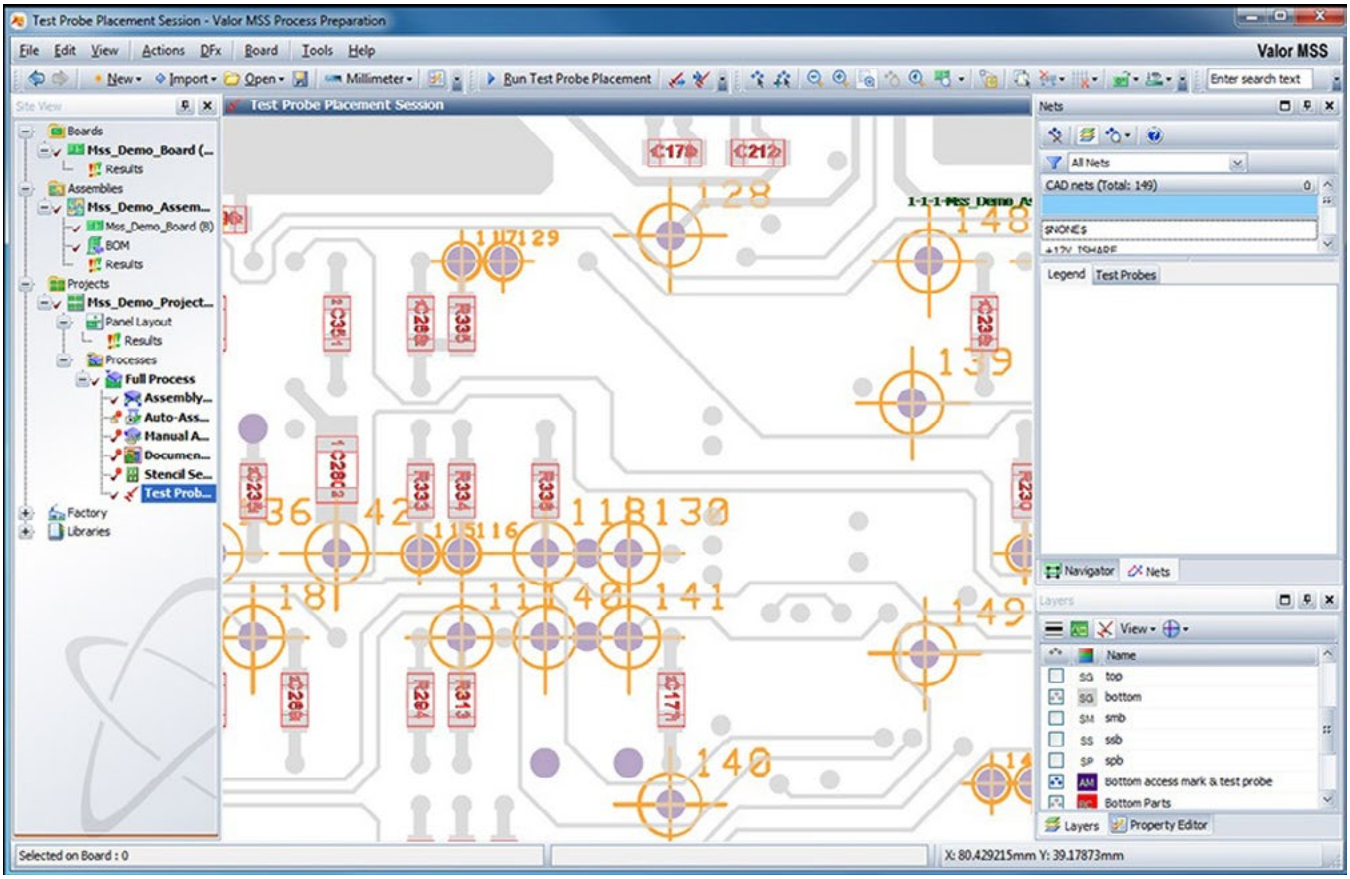


Figure 10: Test engineering and testability analysis are always based the common product data model.

Test and Inspection Engineering

Parallel to SMT process preparation, the test processes can also be prepared from the central product data. For electrical testing, the essential issue is finding the best ways possible to access all circuit nodes using test points or other exposed contacts on the PCB. This heavily draws from the design data to understand the position and nature of every feature of the circuit. Once the best accessibility has been found, the process preparation system chooses the most appropriate probe or pin to be used with respect to the particular tester and fixture parameters.

The logic for flying probe is similar to in-circuit test except that accessibility has to be calculated in 3D as the probes go around the product. In each case, the process preparation system creates the necessary output data formats to completely describe the test process to the respective machines. Again, many days of work has been replaced with a few minutes.

A similar process is provided for optical inspection machines. Depending on where a machine is placed in the line, the system knows which components are placed on the PCB at that point, or none in the case of solder paste inspection. Again, using the design data, being able to simulate the optical views of the PCB based on each machine's inspection parameters and knowing the physical shape attributes of the parts themselves, process preparation can calculate the required inspection program parameters.

In the process of creating all of the various forms of test programs, a good measure of the testability of the PCB can be obtained. It's possible to check whether every element of the PCB can be tested, or whether there are untestable risks. If any of the risks are deemed critical, for example, important areas or features of the PCB cannot be tested, then processes in production can be made or adjusted to compensate. This

information is also one example of data that can be fed back to design so that with the next iteration of this PCB, or the next product, the testability risks can be designed out.

Process Documentation

Shop floor documentation can be created from the prepared single engineering product data model. Documentation, whether delivered electronically through a web-browser or on paper is an essential part of any operation where a manual "touch" will be required. Some documentation is static, that is, a fixed image provided as a reference for any particular operation. More interesting is the dynamic documentation that follows the working process, which can zoom in to features of interest providing a much larger and contextual amount of value. Documentation that dynamically highlights recent changes in the operation is critical to avoiding mistakes and can greatly improve the level of quality of manual operations.

The major use for documentation is work instructions. For assembly workstations, preparation of work instructions involves the assignment and sequencing of manual operations to ensure that all placements are visible and accessible for the human hand at the time of execution. The order in which components can be placed is driven from this logic, and work instructions are created. The work instructions need to show precisely yet simply the method for correct assembly. These can be used for PCB assembly as well as final product assembly.

For repair stations, the documentation is triggered dynamically by a test failure report. In this case, the appropriate area of the product needs to be highlighted quickly and automatically so that the suspected failure can quickly be found and compared to what it should be. Digging deeper dynamically in to the product information is essential for accurate and timely repair.

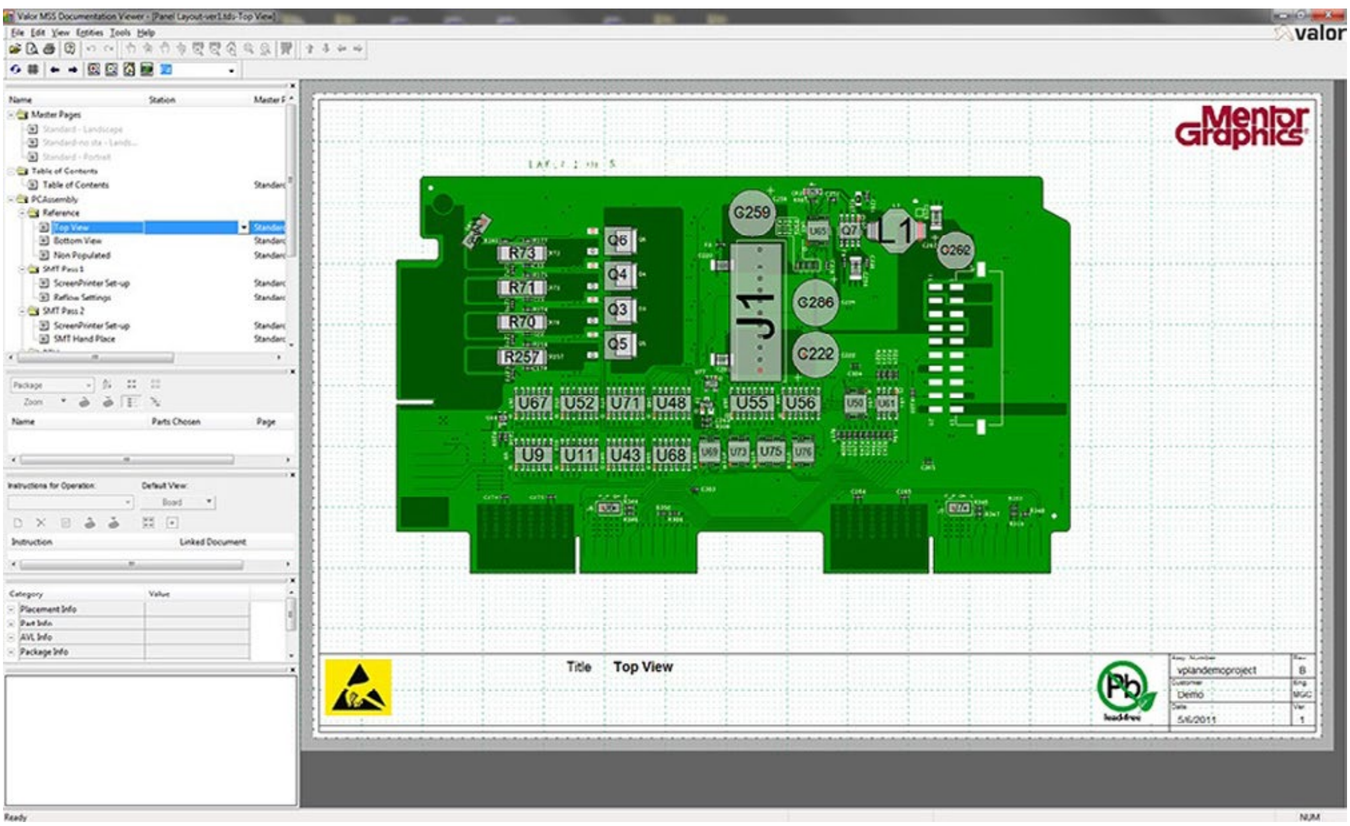


Figure 11: Automatic rotation normalization is used to account for inconsistencies in design data.

Summary

A single automated data preparation stage creates a single product data model for all process preparation stages within minutes, instead of days, which means that time to market can be faster. Features dedicated to each task then work together on the product data model to complete the preparation. All in a fraction of the time compared with using separate software pieces, even those provided by the machine vendors, in isolation.

Built into all of these tools is the highest degree of error checking, ensuring that nothing is left out, that every element of the production process can be simulated in the software tools. If errors are eliminated, expensive line time is not wasted. New products are introduced right the first time without significant cost and resource overhead. For the contract manufacturers, the surprises have been removed, risk is lowered, and pricing can be made more accurate and competitive.

For existing products, the software reduces the time and cost to move products between line configurations to the point that it is insignificant, even if the target site is on the other side of the planet. This reduces the product movement barrier enabling agility throughout the operation, allowing it to scale much more effectively and efficiently in response to changing demand patterns.

Asset utilization is increased as a result of more efficient line configurations, balancing, and machine programs. The cost of work to perform process preparation has also been significantly reduced, with process preparation engineers now free to focus on actual engineering issues and improved planning technologies rather than manual and duplicate data processing.

When engineering product data is used as part of the integrated factory, scheduling is far more effective when the accurate execution times of each process are known. Planning can be much more flexible when given several line configuration options to choose from, together with the ability to dynamically create common feeder layouts. It is practical and cost-effective to prepare each product for multiple different lines, bringing real value to schedule optimization.

For assembly and quality, each process has complete and accurate information, highlights of changes, and qualified documentation. Knowing that the product is being built correctly, to the correct revision, with each process knowing exactly what is expected, providing the benchmark against which to measure the actual execution of each piece of product at each process. **SMT**

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

Manufacturing Method for Batteries with Organic Electrode Materials

Researchers of Aalto University in Finland have demonstrated the fabrication of electrochemically active organic lithium electrode thin films, which help make microbatteries more efficient than before. Researchers used a combined atomic/molecular layer deposition (ALD/MLD) technique to prepare lithium terephthalate, a recently found anode material for a lithium-ion battery.

"ALD is a great method for making battery materials fit for 3D microstructured architectures. Our method shows it is possible to even produce organic electrode materials by using ALD, which increases the opportunities to manufacture efficient microbatteries," says doctoral candidate Mikko Nisula from Aalto University.

The researchers' deposition process for Li-terephthalate is shown to comply well with the basic principles of ALD-type growth, including the sequential self-saturated surface reactions, which is a necessity when aiming at micro-lithium-ion devices with three-dimensional architectures. The as-deposited films are found to be crystalline across the deposition temperature range of 200-280°C, which is a trait that is highly desired for an electrode material.

To Outsource or Not to Outsource PCB Rework

by Bob Wettermann
BEST INC.

When a task is outside a company's core competency, it's time to outsource in order to save time and money while reducing the risk. This core competency is a deep proficiency that enables a company to deliver unique value to customers. According to business texts[1], such a core competency creates sustainable competitive advantage for a company and helps it branch into a wide variety of related markets.

Typically, the litmus test for a core competency is that it's hard for competitors to copy or procure. Wait... isn't this the value proposition of EMS companies when selling the advantages of outsourcing to the OEM? Isn't the OEM better off designing, testing and supporting their customer base rather than being process geeks and "making" their widgets? Well, there is a case to be made that outsourcing certain rework projects makes a lot of sense.

Costs to Consider for a Rework Technician

Several factors need to be considered as part of PCB rework and repair costs when looking at the "total costs." These costs include the labor rate of the rework technician performing the rework and repair operations, their training program costs as well as costs associated with supervising the individual.

Hourly labor costs for soldering technicians performing rework operations drives a significant portion of the marginal cost of rework. The mean salary for associates skilled in the art of rework is $14.23 in the United States[2]. The national average for the overhead burden which

	Hourly Rate($US)
Soldering technician wages (fully burdened @ 2015 rates)	$20.20
Training of soldering technician	$ 6.00
Supervision/technical (oversight of rework project)	$ 2.02
TOTAL, per hour soldering technician effective wages	**$28.22**

Table 1: Effective U.S. rework technician cost, lower/mid-tier EMS provider[1].

Effective cost of rework technician	$ 28.22
# of QFPs technician can replace per hour	3
Cost per component reworked	$ 9.59
Average costed BOM of PCB assembly	$250.00
Number of PCB assemblies in rework project	150
Yield of rework technician	95%
Total Cost per component reworked incl scrap	$ 22.92

Table 2: Example removal and replacement cost, 0.5 mm QFP100.

needs to be added this hourly rate is 42% for manufacturers with less than 500 employees[3]. This consists of both voluntary (medical, dental and life insurance, etc.) and involuntary (i.e., social security, unemployment insurance, etc.). This puts the loaded cost at $20/21 per hour.

There are numerous indirect costs associated with the cost of having a skilled soldering technician on hand including their ongoing training overhead. The technicians responsible for the rework process have a real cost of training associated with their expertise, certification and ongoing training. Numerous costs are associated with training. Included in this list are the fully loaded cost of the trainer spread over the number of associates being trained, the lost pay linked to the time when the soldering technician was not providing manufacturing support to output, the equipment used for training purposes, as well as any training space costs. By taking in to account a trainer's base salary, the number of employees that they support for training, how often the recertification training takes place, the training equipment and the floor space costs dedicated towards training, these indirect costs can be calculated. These indirect costs for a $20–30M EMS company operating the Midwest in the neighborhood of $6.00 per hour [4].

Supervisory labor is also a part of the indirect portion of a rework technician's labor costs. Whether it be a dedicated supervisor responsible only for the rework area, a floor supervisor who spends some of their time in the area or a process engineer supervising temporary help for a given rework job, supervision of rework personnel is part of the cost of rework. If temporary associates are brought in for large rework projects, the cost of their supervision needs to be considered. In this rework cost model it adds another 10%[5] to the cost of the rework technicians effective hourly wages.

Rework yield and the associated cost of the circuit board assembly is a major cost driver associated with the cost of reworking an assembly. Effectively, this means at very low board value that outsourcing makes less and less sense. Conversely, for complicated repairs where the yield is going to be suspect, outsourcing becomes the better option assuming the board value is several hundred dollars or more. PCB rework studies have placed the rework yield in the 92–96% range[6]. Since this is a manual process and is a function of the skill level of the operators, their training and experience this is to be expected given the much higher yields in the original assembly process area.

In order to see how this cost model plays

Figure 1: QFP100, 0.5 mm pitch inside of shield—difficult rework project example.

out, the replacement of a fine pitch 0.5 mm pitch QFP100 will be used as a test case. A skilled operator should be able to remove and replace this device per IPC 7711 guidelines within 20 minutes[4]. If this operator yields 95% in the rework operation when working on a PCB with a costed BOM value of $250.00 assuming a 150-piece board rework job is at hand, the cost model calculates a $21.30 cost per component rework cost. The summary calculation is below:

As this example illustrates, the major cost drivers in this cost model include the skill level of the rework technician in terms of their throughput and yield (i.e., both fast and accurate), the complexity of the assembly as well as the cost of the rework technician's time.

Assuring a High Level of Quality When Outsourcing Rework

Outside of the cost question in this make or buy decision other factors should be taken in to consideration when considering whether or not to outsource this kind of work. The quality systems of the provider, the training of the contractor's staff as well as a deep-rooted understanding of processes and applicable soldering standards should apply. For example, the contractor should understand the practices of the most recent applicable industry assembly (IPC J-STD-001), rework (IPC-7711), repair (IPC-7721), parts MSD handling (JEDEC-033) and inspection criteria (IPC-A-610) standards. Each of the rework technicians should, for the standard repair and rework operations such as repairing a lifted pad, removing and replacing an SOIC, be able to perform them per the IPC guidelines. Not only should the rework personnel be trained in the proper rework, repair and workmanship guidelines but they should also have demonstrated the ability to properly handle electronic assemblies while insuring that ESD (using EOS/ESD 2020 as the standard) and MSD (IPC/JEDEC J-STD-033) guidelines are maintained.

In addition to having the properly trained personnel, the contract rework and repair facility should have leading edge equipment including X-ray inspection, cross sectioning capability and high magnification digital photo documentation.

When to Outsource Rework

When does it make sense to consider using an outside contract services provider for rework and repair services? There are several instances when it makes sense to outsource this work.

The first justification for outsourcing PCB rework is when the PCB rework or repair operation is beyond the skill level of your rework technicians. Examples of such work may include: repairs of traces or pads that are smaller than 5 mils on a given side; replacement of 0.4 mm pitch or less QFPs; and micro QFN or 0201 replacement.

The second instance in which the outsourcing of rework should be considered is when the amount of rework is beyond the capacity of your company to handle the rework in the time frame under which the contract calls for the rework to be completed.

The final case where it makes sense to consider outsourced PCB rework is where there is a one of a kind project such as a marketing or investor sample or a priceless developer's PCB

Figure 2: X-ray capability is something to look for in a higher-end rework/repair facility.

and only an expert in the field can be trusted to touch such a project.

Conclusion

The cost of rework indicates that the major cost drivers for rework include: the fully burdened hand soldering technician costs, the equipment and its support and most importantly the rework process yield. The use of contract rework providers is prudent in the cases of large, complex or highly time-sensitive rework projects. However, careful review of the suppliers' knowledge of standards and adherence to processes needs to be taken in to consideration prior to making the outsourcing call.

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MilAero007 Highlights

API Technologies to be Acquired by PE Firm
API Technologies Corp. has inked a definitive agreement providing for the company to be acquired by an affiliate of private equity firm J. F. Lehman & Co., which specializes in the aerospace, maritime and defense industries.

Benchmark Electronics Appoints Paul Tufano to Board
Benchmark Electronics has appointed Paul J. Tufano, who most recently served as CFO of the Alcatel-Lucent Group, as an independent director to the company's board of directors.

NextFlex Names Founding Members
The 30 founding members represent a diverse group of leaders in flexible hybrid electronics manufacturing and education that will each bring unique manufacturing capabilities and needs to NextFlex.

Stadium Sets Up New High-tech Manufacturing Facility in China
Stadium's new manufacturing and electronics assembly facility in Dongkeng, China, offers upgraded operations that boast leading-edge infrastructure and technology.

Sparton Explores Strategic Alternatives
Sparton Corp.'s board of directors has been exploring a range of strategic alternatives. This process, which commenced several months ago, has the goal of identifying the best way to enhance shareholder value.

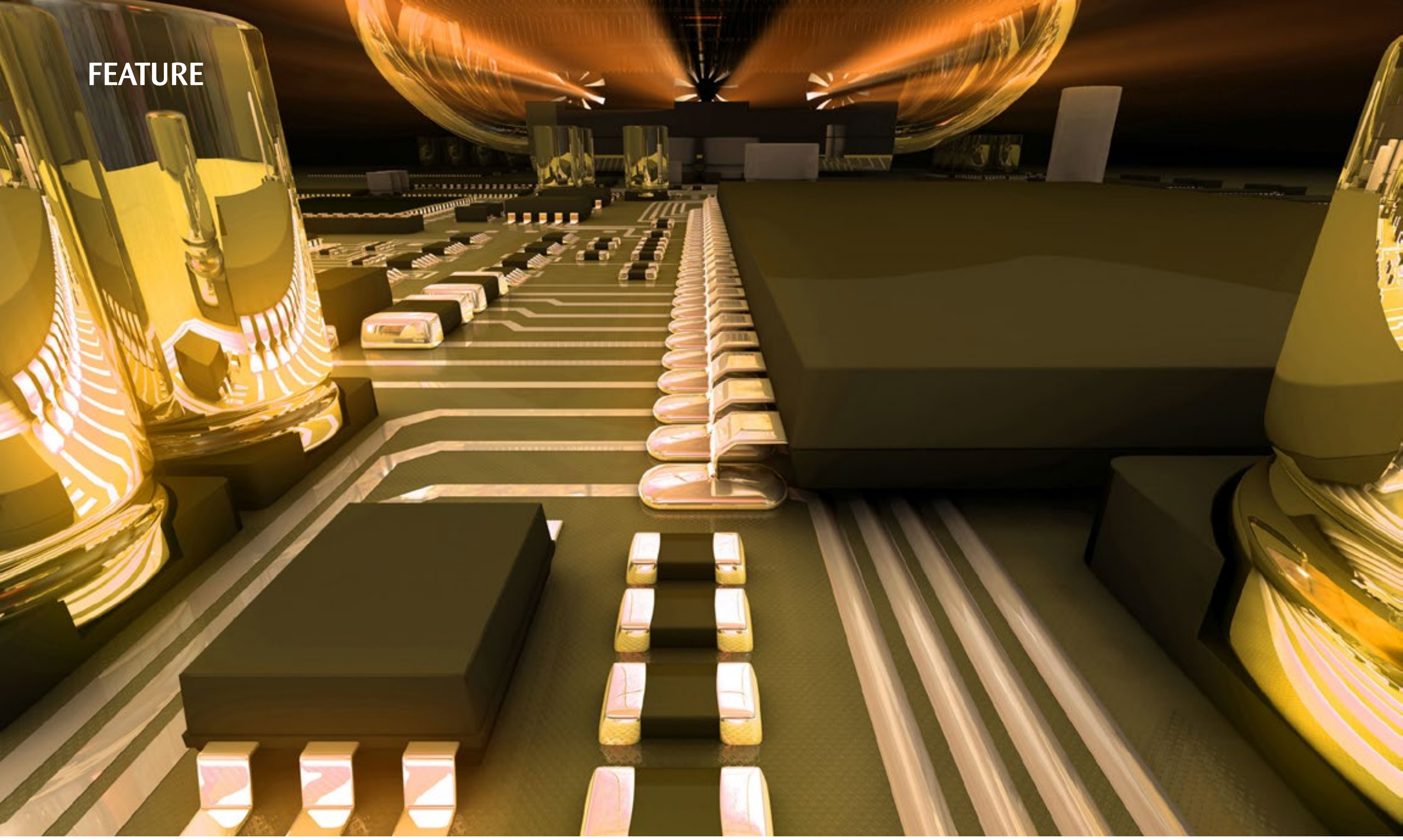
Nortech Reports Higher Q4 Sales, Operating Profits
Nortech Systems Inc. has reported net sales of $31.4 million for the fourth quarter ended 31 December 2015, a 3% increase over net sales of $30.4 million for the fourth quarter of 2014.

Joel Wolnik Returns to Libra Industries as Production Manager
EMS firm Libra Industries has announced that Joel Wolnik has returned to the company for the position production manager.

MC Assembly Names Jose Sierra VP of Quality and Engineering
In his new position, Jose Sierra will lead MC Assembly's technical initiatives across the company's sites in the United States and Mexico, supporting the operations strategy and market growth of the company.

CTS Acquires CTG Advanced Materials
CTS Corp. has acquired CTG Advanced Materials LLC, a designer and manufacturer of single crystal piezoelectric materials serving major OEMs throughout the medical and defense technologies, for $73 million in cash.

Product Compliance Requires Supply Chain Transparency
Changes to the RoHS, REACH, and conflict minerals regulations make the need for supply chain transparency more crucial than ever. In line with this, full material declaration (FMD) is quickly becoming the "gold standard" data requirement for an OEM to accurately assess the risk of restricted materials in a product.



FEATURE

Benefits of Improving Reflow and Screen Printing Processes

by Bjorn Dahle
KIC THERMAL

With a level playing field in terms of access to talent, technology, knowhow, infrastructure, and financial resources, how can an EMS company build a successful business year after year, decade after decade? There may not be a magic formula that works for everybody in this fiercely competitive business. As a matter of fact, having a differentiated strategy relative to the competitors is one opportunity for success. With the ever-growing pricing pressure is there any alternative to penny pinching? In my opinion, not only do successful alternatives to penny pinching exist, but they are necessary for long-term success. The teachings of a competitive strategy led by Michael Porter states that in a commodity market there is only one long-term winner, which is the lowest cost leader because he can lower the price until everybody else leaves the business. So unless you are the Walmart or Amazon of the EMS business, you may want to consider a differentiation strategy.

One EMS company in the St. Louis area has used a number of successful strategies, some of which are counterintuitive, that have led to a successful business since 1963. There may be lessons to learn when dissecting Siemens Manufacturing Co. Inc.'s strategies. (No relation to Siemens AG, the multinational conglomerate.)

The first striking revelation about this manufacturer is that it does not specialize in any specific industry segments or applications. As illustrated in Figure 1, the company serves numerous industries.

According to Mike Siemens, director of business development, a diverse spectrum of clients provides less volatility in demand since various industry's segments tend to be countercyclical to others. A growth in some industry sectors often compensates for downturn in other segments.

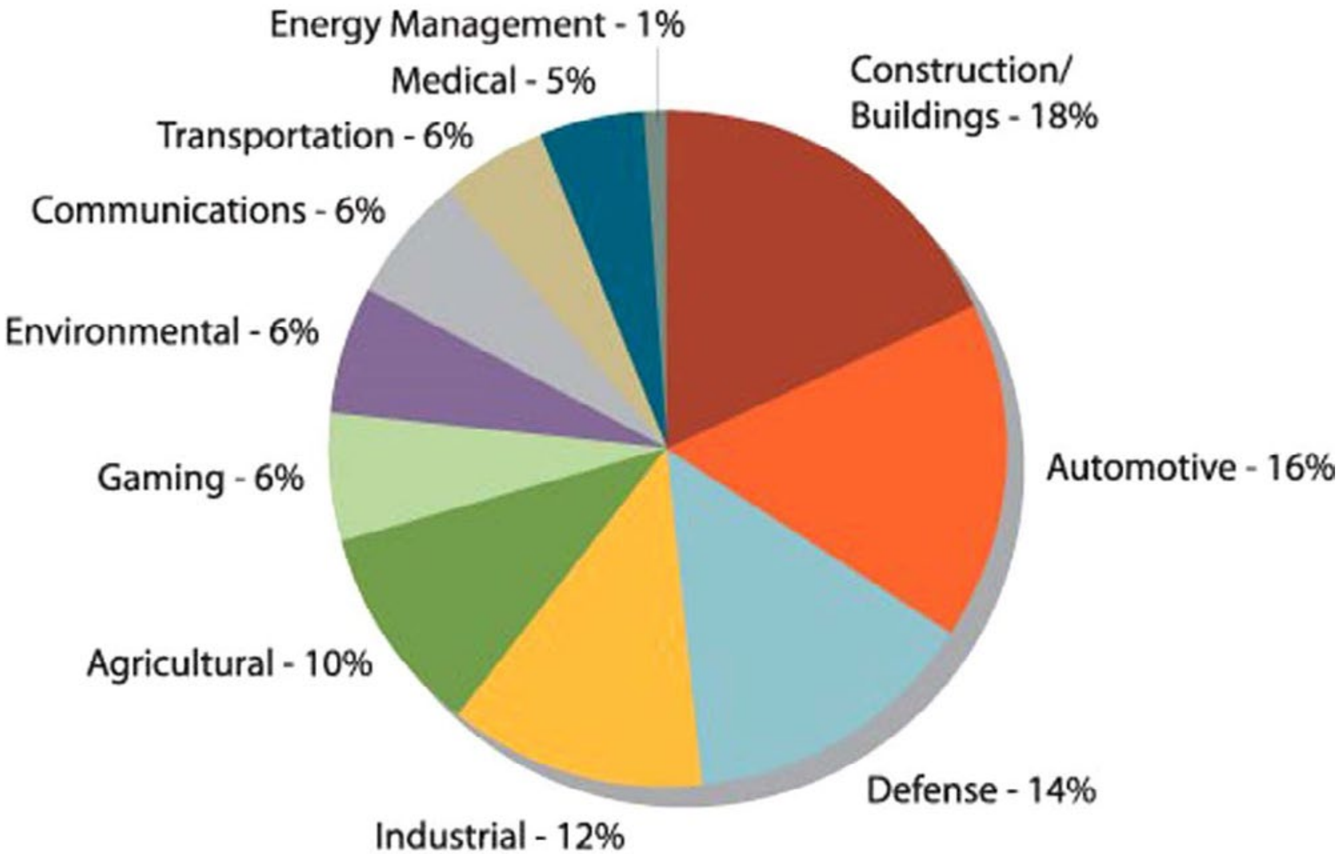


Figure 1: Siemens Manufacturing Co. Inc.'s client industry composition.

There is always a risk of being everything to everybody, which usually leads to being nothing to anybody. There is also a concern that by gearing up the factory to satisfy the most demanding customers, such as the automotive sector, expensive solutions go unappreciated by the less demanding clients.

But what if we could look at this strategy in a different light? Are there best manufacturing practices valued by a wide variety of industry segments that also reduce production costs?

Before the 2008 industry downturn, the company implemented a Lean manufacturing practice to run its operation more efficiently at a lower cost. This was a company-wide initiative that proved hugely beneficial over time. Let's drill down to a specific process and analyze how the company operates.

President John Siemens III states that because the pick-and-place machines do a great job, the company focuses more on the reflow and screen printing processes where there is room for improvement. Kelli Lubenkov, operational excellence manager at the company, believes that the RoHS thermal process is critical due to the narrow process window brought on by the heat tolerances of some of the components. The company has established the practice of profiling every new, unique PCB assembly before starting production. Additionally, previously run PCB assemblies are profiled after production line changeover to verify that the oven is ready to process the assembly in spec. This is an expensive practice because it leads to additional production downtime as well as an extra labor cost associated with technicians performing such a time-consuming manual task numerous times daily.

EMS companies in North America tend to produce a large variety of assemblies in a high-mix/low-to medium-volume production environment. Siemens is no different, with up to half a dozen changeovers per line per day. Client benefit is obvious in terms of better quality products that carry its name and reputation. However, such an expensive practice contradicts the trend towards lower cost.

The company takes a holistic view to running their factories efficiently. Verifying that the reflow oven is ready for an in-spec reflow reduces cost associated with rework and scrap. The company recently was reminded of the cost of poor solderability when it acquired another EMS company. Before implementing the best manufacturing practices at this facility, $7,000 worth of assemblies were scrapped due to incorrect reflow.

All this profiling downtime is costly, and part of Lean manufacturing is to seek out opportunities for improvements. The company wanted to significantly improve the time it takes to dial in an oven for a new assembly, as well as to speed up profiling after oven changeover. The first step was to acquire prediction software that would identify the most appropriate oven recipe for a new assembly. With literally billions of possible oven recipes, the old-fashioned, manual trial and error approach was wasting time. Also, the manual tweaking of the oven recipe depends on operator skill, and it tends to lead to oven recipes that are not optimized for quick oven changeover. While the new oven setup software eliminated the trial and error approach, it still relied on running manual profiles.

The company's second step was to invest in a KIC automatic profiling system (Figure 2). Once the automatic system has been programmed, oven changeover is a simple matter of loading the product file, and the automatic system will notify the operator the instant the reflow oven is ready to run the next assembly in spec. Not a moment of unnecessary downtime is sustained. The 2-6 manual profile runs per oven per day for existing assemblies, along with the associated production downtime, are now a thing of the past. Mike Siemens estimates that with seven lines, their factory now saves a total of five hours and 15 minutes downtime per day, which represents a daily saving of $1,000. The

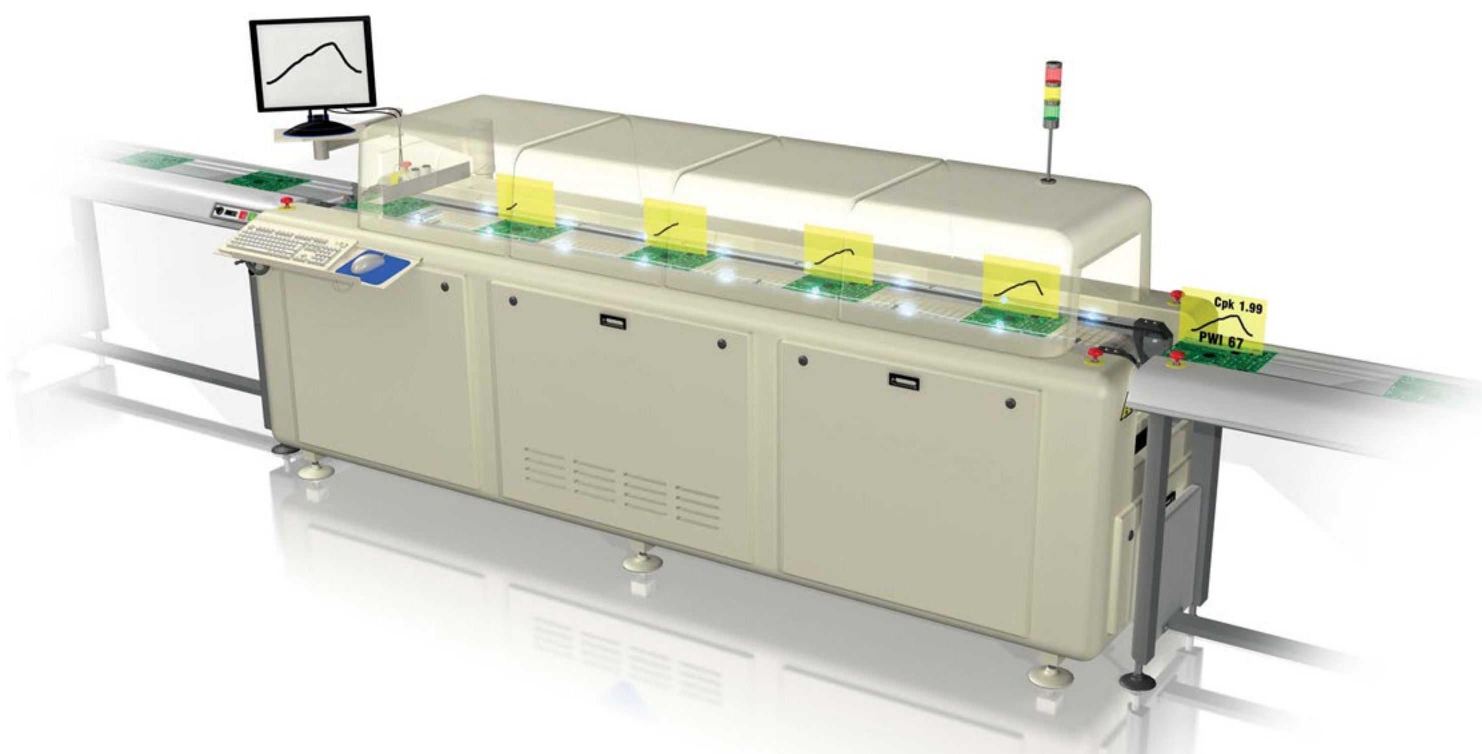


Figure 2: An automatic profiling system, which increases production line utilization, saving both time and money.

Figure 3: Smart reflow oven.

calculations are based on the following representative numbers:

- Automatic profiling is saving at least 15 minutes per changeover
- $190 per hour cost of downtime ($90 labor, $100 machine time)
- Average three changeovers per day on seven lines.
- 10x3x7= 315 minutes per day
- 315/60*$190= $997.50 per day savings

Another benefit is that during the production run, every PCB is profiled automatically, and adherence to the relevant process window is verified. John Siemens stated that there are opportunities for the oven to drift out of spec during a given production run. One example may be an upstream stoppage that leads to a temporary empty oven followed by a wave of tightly spaced PCBs. Such thermal loading may lead to changes in the PCB profile. Other opportunities for profile variations during production may include facility exhaust system changes, human error and more. Now, the reflow quality becomes consistent and free of operator influence.

This is an example of a win-win situation where the client is ensured a high-quality product (from the thermal process perspective) and full thermal process traceability, while the new reflow technology reduces cost in scrap, rework, production downtime and even electricity use. (Case studies indicate a 15% electricity use reduction opportunity for each reflow oven with the use of oven setup software.)

The same investment in Lean manufacturing and smart oven technology also supports Siemens' other core strategy characterized by an intense focus on customer support. Clients appreciate flexibility, quick response time and fast time to market. The reflow oven prediction software enables a faster NPI and the automatic system offers process documentation, traceability and peace of mind. The company is even setting up a factory in Mexico, not motivated by reducing production cost, but by being able to better serve its many clients who now are located in Mexico.

Running a Lean and flexible factory offers an opportunity to accept projects that few other contract manufacturers can handle. According to Sales Manager Lisa Boland, the flexibility allows the company to react faster and to take on different sized projects, all the way down to small client. As a result, Siemens has won several contracts over the years with little to no competition due to the difficulty in accommodating clients' requirements while staying profitable.

Conclusion

The intensely competitive EMS industry makes the following adage unacceptable: "There is never enough time to do it right, but there is always enough time to do it twice." Defects are simply too expensive and "doing it right the first time" is the new strategy. Investing in the right technology and strategy can lead to the best of both worlds: happy customers and higher profits. **SMT**

Bjorn Dahle is the president of KIC Thermal.

The Importance of Being Earnest (Educated)

by Tom Borkes
THE JEFFERSON PROJECT

This is the inaugural offering of a new monthly column in *SMT Magazine*. We call this cozy corner of the e-zine "Jumping off the Bandwagon." It is meant to be a safe place for the soft landing of provocative ideas and challenges to the status quo—both for you and for me. It is dedicated to the continued development and improvement of the high-tech electronic product assembly industry, and to you, the human component of that industry.

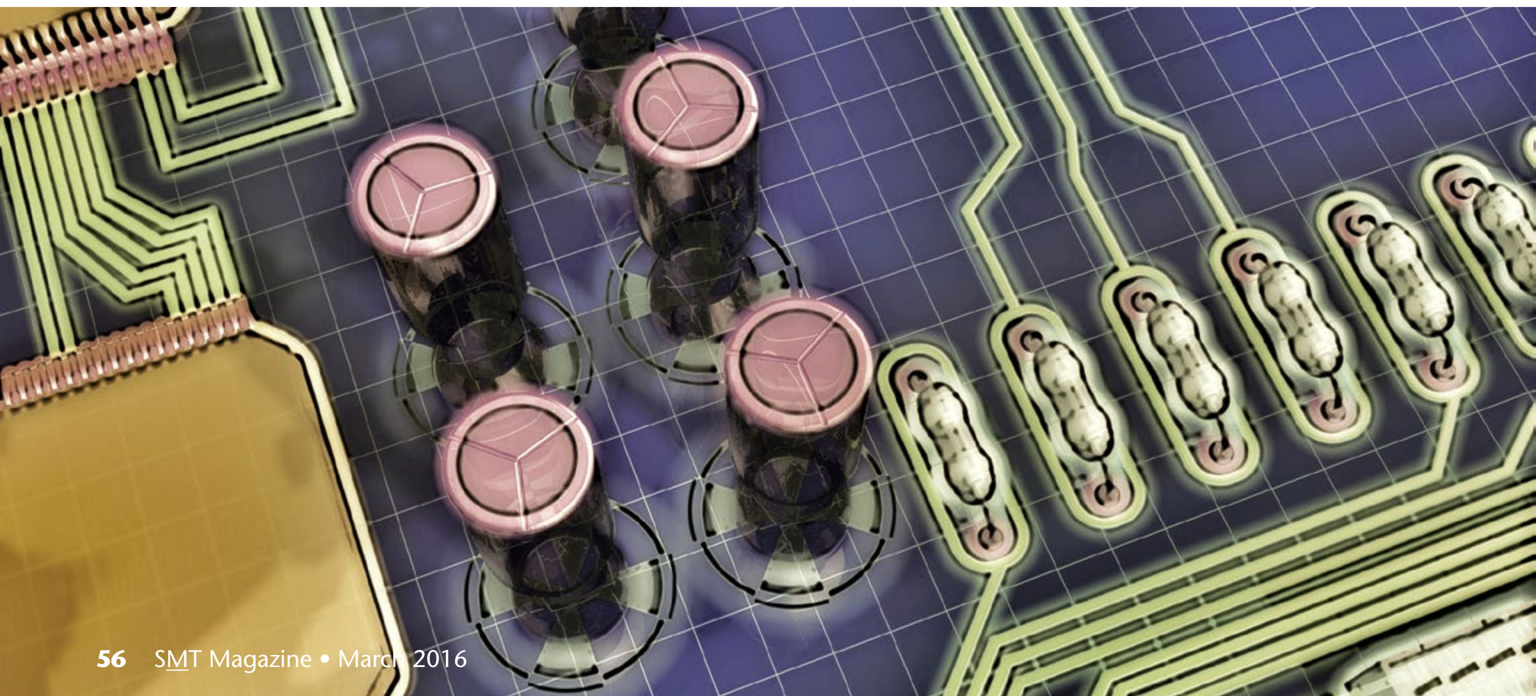
It is not popular to be provocative and challenge what we have grown accustomed to in our industry as axiomatic. Insecure, myopic management teams in the real world who are dedicated to making this month's numbers don't like having their worldview shaken. Faculties and school administrators are upset when they are told that the emperor is wearing no clothes, which is to say that the content and delivery systems of what they are teaching have little relevance to the skills that their customers, the students, will need to lead the companies effectively that employ them in the real world. Moreover, that world is not only real, but also global.

Some of you will embrace the ideas and positions found here and in the columns to follow; some of you will disagree with them, and you may even feel uncomfortable with them. Just remember: These concepts are meant to be disruptive. We have nibbled around the edges of these industry problems for too long.

So here we go. Hold your breath and get ready to make the leap OFF the bandwagon.

The title of Oscar Wilde's 1895 stage production plays with the word *earnest,* referring to both the fictional protagonist, Ernest, and the quality of being *earnest*—a sincere and serious behavior toward a subject.

In the play, Ernest leads a double life. While in his rural countryside home he maintains his true identity as John Worthing, a proper Englishman who provides a good example for a young girl, his ward. A willing Jekyll and Hyde of sorts, he fabricates a fictional brother, Ernest, whom he must occasionally visit in London—



where he becomes that brother, allowing Ernest to act out a much more wild and libertine existence.

The character's attempt to deceive provides Oscar Wilde with a vehicle to comment on some serious, hypocritical aspects of Victorian English life, using Wilde's ability for double meaning word play to address serious societal issues. Throughout history, whether in newspapers or works of fiction or non-fiction, writers have been able to promote certain positions and persuade their readership around to their way of thinking. Oscar Wilde does this in a subtler way than the biting satire of Voltaire in *Candide* and the irreverent poking at the hypocrisy done by Moliere in *Tartuffe*.

These techniques were once taught in schools as a formal class called *Rhetoric,* which relates to the skills of debate, argument and persuasion. Today, the word rhetoric is mostly used in a pejorative sense, meaning language that is meant to persuade, but lacks sincerity and meaningful content.

"Today, the word rhetoric is mostly used in a pejorative sense, meaning language that is meant to persuade, but lacks sincerity and meaningful content."

What does all this have to do with high-tech electronic product manufacturing in 2016? In 1895, Wilde, who had a reputation for his clever word play, used a pun (Ernest and earnest), to make a larger social comment. For decades, members of the academic world have played with the word *education*. They decided what should be taught in the primary and secondary parts of a student's educational pipeline. They designed the metrics used to evaluate the students' success in learning. If the student proceeds to the post-secondary (college) level, he again encounters a traditional university curriculum, with perhaps some minimal input from the real world.

In any case, the course content, which Mortimer Adler would call academic "learning for learning," needs to be balanced with what he terms academic learning for *earning*. While rich in what academia feels is significant to the student and is quite important, traditional content is light on the elements that students require to optimize their contribution to the success of the companies that ultimately employ them. Unfortunately, it takes two to three years to change a college curriculum for an industry that itself changes at light speed.

Currently, the task of closing the skill gap between academic preparation and industry need has been left to the company that hires the graduate. Besides, how dare we challenge the man in the high castle[1]—I mean the man in the ivory tower—who, by the way, most probably has never set foot in a high-volume electronic product assembly factory. And, of course, there is little push back from the students who certainly don't know the value of the education they are receiving and the way they receive it. It's the man behind the curtain, the great and powerful Oz, who decades ago made these decisions. There has been little push back from industry, since they are reconciled to continue the way it always has been.

Unlike Wilde, however, who wrote and played with *Earnest* over a period of about a year, we in product assembly have played with the word "education" for more than 50 years. Henry Ford tapped into the growing wealth of a growing middle class and met them half way by reducing the cost of automobiles through the economies of scale for the material and by assembly line cost reductions for the labor. The post-WWII consumer electronics world exploded with new products that had electronics circuit boards at their core. *Education* went from teaching how to put wheels on axles, to putting components on circuit boards.

In our world today we use the term *education* to suggest a process leading to excellence and success in high-tech product manufacturing. While not consciously attempting to deceive, haven't the results of our efforts exposed the shortcomings of our misguided efforts? We continue to hold our intentions to solve the problems as more important than achieving the results.

I would submit that in the U.S. we have never really taken electronic manufacturing seriously. Since low labor rate, global manufacturing, competitive forces emerged about 25 years ago, it has worsened.

Now, at this point, you might be thinking, "How could you say that, Tom? Look at the attention that is being paid with programs like STEM (science, technology, engineering and math). However, do you see the words *manufacturing, production, assembly,* or *automation* in there? Politicians, academics and consultants quickly got the religion and had the term STEM embroidered on their shirt pockets. Oh yeah, a few more government grants and you'll see. We are on the yellow brick road to our manufacturing Oz—our manufacturing Legoland.

Since valuable real world skills such as critical thinking, root cause analysis, proactive process control, and continuous flow assembly are difficult to teach and test in the Ivory Tower, academics always fall back on assigning and testing the students' ability to "solve the odd numbered problems at the end of the chapter." In fact, the educational experience of Nobel Prize-winning particle physicist, Dr. Murray Gell-Mann, is a great example of this mentality. Dr. Gell-Mann, the co-proposer of the existence of the sub-atomic particle he named the quark, said upon receiving his Ph.D. in Physics from MIT, the reason for his success in school was largely due to his ability to memorize, *regurgitate and forget*[2]. Many of his classmates did not do as well—not because they were less intelligent, but because they weren't as proficient in taking tests.

However, we do not work in the academics' world of the Ivory Tower—we work in the real world. Time and technology continue to pass by academia. Before microprocessor-controlled machines and automated product assembly and test, the required skills for a process engineer were very different. Back then, the ability to conduct a time and motion study, calculate a learning curve and methodize a product design into an efficient series of labor steps, was significant. Having a copy of *Motion Study: A Method for Increasing the Efficiency of the Workman* by Frank B. Gilbreth was helpful as well (read or see the Hollywood treatment of this man's life: Cheaper by the Dozen).

The young people drawn into our industry are those who are successful in school; however, is academic achievement the sole critical success factor in predicting who will be achievers in the real world of high-tech product assembly? Does using this criterion actually cause potentially valuable members of our industry to avoid this as a career choice? Does the fault lie with an outdated and ill-structured curriculum, and a delivery and measurement system that is established by people who have little experience in the electronic product production industry?

> "The young people drawn into our industry are those who are successful in school; however, is academic achievement the sole critical success factor in predicting who will be achievers in the real world of high-tech product assembly?"

Following are the issues that, unless addressed, will continue to put product assembly at a disadvantage in high labor rate areas of the world. I'll list those issues I've observed plaguing the U.S., but would welcome feedback from those of you in other areas of the world:

1. The continued use of time-worn excuses as a pretext for failure to successfully compete in high-tech electronic product assembly (e.g., low labor rate competition, an uneven playing field, unfair monetary policy [exchange rates], and the regulatory climate).

• Although all of these have had an effect on the exodus of production-related activity from high labor rate markets, the root causes need to be addressed as well (e.g., education).

• Labor cost can be reduced by reducing labor content as well as finding sources of low labor rates. However, it requires a workforce that can automate the process.

2. Looking upon the manufacturing, assembly (production) industries and industrial engineering as subservient to the product design and engineering professions.

• This is a perception that has evolved over the years as those students who could solve differential equations majored in mechanical and electrical engineering and those who couldn't built things in shop class. This mentality led to the fact that the VCR was invented in the U.S., but few were ever built here.

• Today's challenges presented by the need for sophisticated automation on the production floor requires a level of math and engineering education that rivals the other engineering disciplines. The technology demands a workforce that can exploit the ever-increasing complexity of the automation (i.e., an engineering workforce).

• The expectations of the academic community as to what is needed in the real world has driven many potentially valuable candidates away from this profession. This is largely a consequence of educating in one community (the Ivory Tower) for employment in another community (the real world).

3. The value of segmenting engineering into specialized areas is over.

• In industry, we continue to group employees into departments of common skills (e.g., mechanical engineering, electrical engineering, test engineering, process engineering, etc.).

• During their academic experience, engineering students are forced into silos (e.g., electrical, mechanical, industrial, computer, etc.), that ultimately support this industrial organizational structure. This is largely a function of the arrogance of the academic community and who makes the rules that define academic success.

• The *engineering* part of mechanical, electrical and industrial engineering is the same. What differs is the part of the physics that each address.

• Today, software exists to cover the physics.

• Students need to develop a solid understanding of the physics across all sciences, and develop the engineering skills that cut across all the areas of the physics.

• An Engineering Science degree that is built upon these principles is more valuable to the students and to the company that ultimately employs them. Schools have offered Engineering Science programs for years. Restructuring the curriculum that leads to this degree to provide a balance between learning for learning AND learning for earning should be the goal. Yes, we need to teach Wilde, Voltaire and Moliere, but we also need to teach continuous flow manufacturing, the potential that the Occam™ process offers by eliminating the need for soldering in product assembly, and the principles of motion control that are at the heart of automation.

4. Our industry, consciously or subconsciously, has become resigned to the fact that they must be prepared to tolerate two- or three-year learning curves for recent graduates to become productive.

• Few schools employ professors or instructors with real world experience; academically, they are at the top, but they are not well-versed at hands-on manufacturing and assembly. Unfortunately, those with real world experience are out of industry and in the schools, quite frankly because many do not do very well in the real world. School provides them a comfort zone. So relying on people to prepare students for success in the real world of high-tech product assembly is inconsistent.

Future columns will address these and other topics. Your comments and suggestions are welcome. We want to create a forum for people who want to *Jump off the Bandwagon!*

Summary

The workforce that a company needs to compete successfully in the global electronic product assembly marketplace will never be established by educating in one community (academia's Ivory Tower), and then sending graduates to work in another community (the real world) without the skills they need to succeed. This strategy will continue to result in an ever-widening gap between academic preparation and industry need. The industrial sector will always bear the cost of closing this gap, putting companies at a competitive disadvantage.

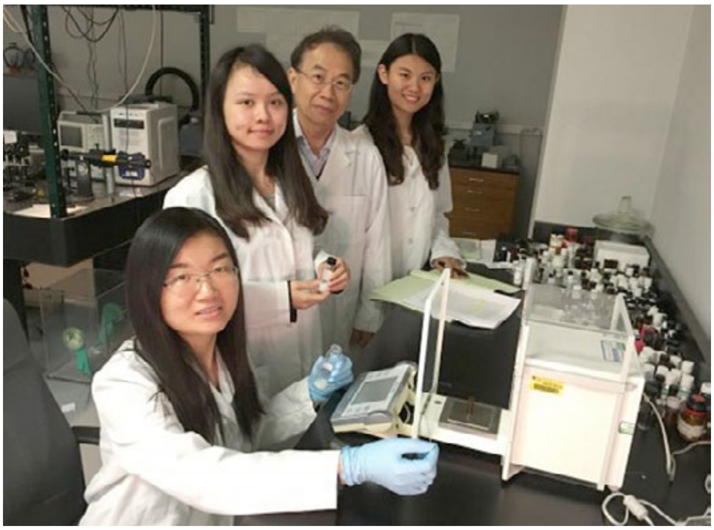
Yes, the importance of being educated cannot be underestimated as a critical success factor in the high-tech electronic product assembly industry. But, like Ernest in Oscar Wilde's play, is what we call *educated* a deception, or is it a process that leads to a world class electronic assembly workforce? **SMT**

References

1. The Man in the High Castle is an Amazon original series (2015) that delves into the question of what life would have been like in North America if the Nazis had won WWII.
2. The Quark and the Jaguar.

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

New Research Ensures Car LCDs Work in Extreme Cold, Heat



One of University of Central Florida's (UCF) most prolific inventors has solved a stubborn problem: How to keep the electronic displays in your car working, whether you're driving in the frigid depths of winter or under the broiling desert sun.

"Liquid crystals exist only in a certain temperature range. In order to work in extreme environments, we need to widen that temperature range," said researcher Shin-Tson Wu of the UCF. That's what Wu and his team have done in his lab in UCF's College of Optics & Photonics.

As reported Optical Materials Express, Wu and his collaborators formulated several new liquid crystal mixtures that don't have the temperature limitations of those now in use. The liquid crystals should maintain their speed and viscosity in temperatures as high as 212°F and as low as -40°F.

In addition, the pixels are able to change their brightness level about 20 times faster than required by European automotive standards.

The breakthrough has applications in the automotive industry and with any other manufacturer of devices with LCD screens.

Wu, who holds UCF's highest faculty honor as a Pegasus Professor, is no stranger to new discoveries with practical uses in the real world. He previously played a key role in developing LCDs for smartphones and other devices that are readable in sunlight.

Through his work with advanced LCDs, adaptive optics, laser- beam steering, biophotonics and new materials, Wu has registered about 84 patents. In 2014, he was one of the first inductees to the Florida Inventors Hall of Fame.

Wu worked with a team of doctoral students from his research group-Fenglin Peng, Yuge "Esther" Huang and Fangwang "Grace" Gou—as well as collaborators from Xi'an Modern Chemistry Research Institute in Xi'an, China, and DIC Corp. in Japan.

Wu is currently working on a smart brightness control film that has applications for automobiles, planes, eyewear, windows and more.

Electronics Industry News
Market Highlights

Flourishing Chinese NAND Flash Industry to Spur the Growth of Domestic Controller Chip Manufacturing
Chinese semiconductor companies building up their memory manufacturing capabilities at the wafer level are also beginning to pay greater attention to the production of controller chips for memory products.

Flexible AMOLED Display Production to Increase in 2016
With the growing popularity of the Samsung Galaxy Edge series and the Apple Watch, display manufacturers are expanding their production capacity of flexible AMOLED displays.

Top 10 IoT Technologies for 2017 and 2018
Gartner Inc. lists the top 10 Internet of Things (IoT) technologies that should be on every organization's radar through the next two years.

Emergence of 5G and Industry 4.0 to Ignite the Global Test and Measurement Market
The ubiquity of connected devices and the rising relevance of the Internet of Things will provide a huge boost to the test and measurement market, specifically, the communication testing segment.

Semiconductor Unit Shipments to Exceed One Trillion Devices in 2018
Semiconductor unit shipments are forecast to climb to 1,022.5 billion devices in 2018 from 32.6 billion in 1978, reflecting an average annual growth of 9% over the 40-year period.

Steady Smartphone Shipments Limit Global Mobile DRAM Revenue Slide to 1%
DRAMeXchange reports that the decline in mobile DRAM prices eased in the fourth quarter of 2015 amid steady smartphone shipment.

Automotive Lighting System Market to See 8% CAGR from 2015-2021
The global automotive lighting system market is predicted to progress from $19.9 billion in 2014 to $34.1 billion by 2021, according to a new report by market research firm Transparency Market Research.

Worldwide Wearables Market Leaps 126.9% in Q4 and 171.6% in 2015
The worldwide wearable device market took a big step forward in the fourth quarter of 2015, fueled by the growing popularity of fitness trackers and the Apple Watch.

Over 1.5 Billion Smartphones to Ship Worldwide in 2016
Despite turbulence for certain vendors and countries, the global smartphone industry will still grow by over 10% this year thanks to new opportunities, according to a new report by Canalys.

Semiconductor Capital Spending Rebound Fails to Materialize in 2015
Total worldwide semiconductor industry capital spending is forecast to show low single-digit growth in 2016 after registering a 1% decline in 2015, according to IC Insights.

Enabling Process Innovation through Test and Measurement Solutions

by Stephen Las Marias
I-CONNECT007

Industry experts predict that by 2020, more than 50 billion devices will be digitally connected, representing $19 trillion in business opportunity. At the forefront of this growing trend is National Instruments (NI), which, for nearly 40 years, has been providing automated test equipment and virtual instrumentation software to engineers and scientists to help accelerate productivity, innovation, and discovery.

I caught up with NI Managing Director Matej Kranjc, to talk about the company, how their platforms are enabling the development of intelligent systems of systems that help users make smarter business decisions, and how big data analysis is enabling process innovation.

***Stephen Las Marias:** What continues to be the unique value proposition of NI and what are its key competitive differentiators in the global T&M industry?*

Matej Kranjc: Our value proposition is that we offer reconfigurable hardware and customizable software for test, measurement and embedded control solutions, empower our customers to use the same development from designing, all the way through prototyping, deployment, and monitoring and control. Using our approach, users can then develop much more cost-effective solutions. Instead of having embedded intelligence that you cannot customize, we offer an open "canvas", all the building blocks required for our customers' unique requirements, and the ability to add your intelligence, IP and

customization, and get solutions faster to the market at a much lower cost.

One of our key platforms is our PXI platform, a rugged PC-based platform which is highly modular with a large number of different I/O capabilities, so that modules that can handle signals from DC up to 26.5GHz signals. Many of these I/Os harness the power of our RIO architecture, which, using FPGAs, gives capabilities that can change the personality of the hardware. And that's something unique on the market. These are supported by our LabVIEW graphical system design software environment, which abstracts all these complexities that are normally associated with FPGA technologies.

> **Many of these I/Os harness the power of our RIO architecture, which, using FPGAs, gives capabilities that can change the personality of the hardware.**

Las Marias: ***From a test and measurement standpoint, how does NI ensure the robustness of your solutions to accommodate the increasing complexity in newer technologies?***

Kranjc: I look at robustness from two sides: one is from a hardware point of view, and the other is from the software side. From the hardware side, all the products and all the technologies are designed for 24/7 operations. We understand fully what the conditions are in those applications, and we put a lot of effort to engineer our products and put all measures in place in our manufacturing and final inspection so that products end up at the shelves delivering, I would say, 24/7 operations.

When we are talking about complexity, devices now—like mobile phones, for instance—contain lots of different applications and functionalities, such as GPS, wireless communications, audio and video. That's the beauty: Simply by changing software, we can easily accommodate all these new tools. If there's a new communications standard, it's more or less software-based. So software has to be designed in a way that is reliable and robust. That's where LabVIEW comes in.

Las Marias: ***In our recent survey about improving process capabilities, one of the key issues pointed out by the respondents is the lack of data acquisition with appropriate sensors for data logging over periods of time in an electronics assembly line. What is NI's view on this?***

Kranjc: When it comes to manufacturing equipment and electronic assembly lines, and as products and applications become more sophisticated and complex, engineers are faced with the same challenges as many other industries, which is, an explosion in the amount of available data and the need to optimize based on their application and project needs.

The trend towards smart, connected devices is driving technology such as processors and FPGAs, wireless connectivity, low-cost sensing, and software. Our goal at NI is to build our platform on top of these technologies so that the quarter billion dollars we spend each year on R&D is heavily leveraged.

NI provides a common platform to add intelligence and control to these measurement systems, along with a rich set of I/O for interacting with the physical world, embedded computation, and open data connectivity, for any sensor or bus type. This allows these systems to be a lot more selective about what data to store, and where to store it, and makes retrieving and analyzing the specific data of interest easy so engineers can focus on the task at hand.

Las Marias: ***One of the big themes from NI is "big analog data." How can NI help improve the manufacturing process through big data analysis?***

Kranjc: It is actually estimated that NI data acquisition devices have collected an estimated 22 Exabytes of data over the past few decades. An exabyte is really a large number. To put this into perspective, this is equivalent to the data from high-definition video playing continuously…for 1 million years.

NI describes big analog data solutions using a three-tier solution architecture, meaning solutions are made up of solution elements that fit into three distinct tiers. These come together to create a single, integrated solution that can be used from the point when data is initially acquired (from a sensor) to ultimately the decision that is made based on this data to help customers make better decisions for their assembly and manufacturing processes.

The first step in making a decision based on data comes from accurately acquiring it. Analog data comes from acquiring natural phenomena such as temperature, strain, pressure, and so on. Because the varied sources of analog data are so great, each system requires specific sensors and actuators (if used in a controls application) to meet the needs of the type and magnitude of natural phenomena being measured.

The second tier looks at the data acquisition systems and analysis itself. This is a valuable piece of an end-to-end Big Data solution because these systems, such as NI CompactRIO, PXI, and NI CompactDAQ help connect the benefits of precise data acquired from a sensor to the benefits of in-depth data analysis, usually while the data is real time or early life. The system nodes are network-connected hardware (with associated software) that perform A/D conversion, conditioning, and early analysis of the data acquired and help it move past “the edge” to the switch and server where it is stored and will likely undergo further analysis.

This is the point at which customers can realize a great value from the data they’ve acquired and where many engineering, scientific, and business decisions are made. This tier also includes the cloud, a growing and appealing IT infrastructure for NI customers.

Las Marias: Can you give some examples as to how NI is showing value to customers who are still under pressure to cut cost?

Kranjc: We see this every single day. Today, we saw a few examples of how much we reduced testing time. And that’s what I would say the main benefit that customers are getting from us: Instead of getting ten test systems for a manufacturing floor—which could mean millions of dollars of investment—they can have one or two systems, and have less staff at the end. At the same time, they can test even more.

And it’s all about really driving the cost down so that companies have lower CapEx and lower operating cost. And the products can go to the market faster.

Las Marias: What are the key trends shaping the future of the T&M industry?

Kranjc: Devices before are very simple. Now, whatever we use is becoming quite complex. It is forecast that there will be 50 billion devices becoming connected by 2020. So first, you know, the volume is there—every single device will contain quite a high degree of intelligence and connectivity. Then, every single device has to be tested. That volume and that huge diversity of all these devices will probably be the biggest challenge when it comes to really building test systems faster, so that everyone can test at the end. And that I would say is a fantastic opportunity for us.

> **“It is forecast that there will be 50 billion devices becoming connected by 2020.”**

Las Marias: How important is the industrial Internet of Things (IIoT) trend for NI?

Kranjc: It impacts everyone. Let’s say around 10 years ago, we didn’t have, I would say, apps—so productivity is pretty limited. Now, the mobile phone has a lot of intelligence, a lot of sensors. We have wearables now. Just walk around and you will see that everyone has at least one wearable device that provides connectivity and computation. It’s the same in the industrial space.

In the industry, there have been a lot of control, a lot of measurement, but there were limited level of connectivity in between these systems. So now, everybody wants to extract maximum output. The more data you get, the better decisions you can make with your processes and systems in the future.

But in order to do so, you really have to architect everything in a way that, first, you do a certain level of processing. And then that level of processing, analytics is found at the enterprise. And then there is that connectivity between machines or devices.

> The more data you get, the better decisions you can make with your processes and systems in the future.

It's important for everyone to invest into technologies that contain local and distributed computation, local intelligence and control, and connectivity, and we see this as a big opportunity because we are already are in this space; our customers are designing, testing, monitoring, controlling and measuring the things and the systems of the IoT.

***Las Marias:* With industrial IoT, definitely huge amount of data will be generated in one production line in just a day. I think one of the challenges here will be the analysis of that data, and getting the correct, accurate data.**

Kranjc: I've been talking to a couple of large companies who manage huge machineries. We are talking about hundreds of millions of dollars of investment. For them, it is critical that every single machine runs continuously. If they are shut down for an hour, it cost millions. Now, they have all the intelligence, they have sensors, measurement units, and they all feed this into a corporate enterprise level system.

But the problem that they have now, since it is so large, is struggling to extract those bits and pieces of information that are really essential for them because they see so much, and they don't know really what the problem may be. How can they come up with a next generation solution that would provide a lot of local intelligence and really publish what is essential?

Now, we have a capability that helps acquire and generate data at extreme speeds. But the key is how much we can process. Because if we don't process and analyze that huge amount of data, then what is the point?

We have tools that help engineers get incredible insights and make predictive decisions out of that huge amount of data; in applications such as machine condition monitoring for energy and infrastructure.

***Las Marias:* In the smart factory, how can NI help usher the evolution, the convergence of the factory plant and the enterprise?**

Kranjc: One of our key advantages is the ability to scale to multiple deployment targets and a wide variety of applications, from small embedded wearable devices to autonomous robotics or monitoring and controlling the entire operation, with the same platform and development environment. Like in the example of Airbus, where they used our board-level products so that they can process images locally and communicate with their corporate systems and feedback information to the engineer about what to do, what tool to be used. We provide that high-level access point, so that they can really start working and focus on a problem, and not think about how to architect from a component point of view. That's a huge time savings.

***Las Marias:* What role can we expect NI to play in the future of the T&M market, and what does the future hold for the company?**

Kranjc: I believe the future indicates growth for us because we are fortunate to have such a good staff and really smart people who are motivated. We have very capable management, and I believe that we are in the frontline of innovations in this industry. **SMT**

Selecting a Selective Soldering System, Part 1

by Robert Voigt
DDM NOVASTAR

So far in this series, we've covered stencil printers, pick and place machines, reflow ovens and multiple types of through-hole soldering. In this and the next couple of chapters, we'll discuss selective soldering machines.

It's useful to start by understanding why and when selective soldering is used. There's a misconception that it is a newer, better way to go than wave soldering, and nothing could be further from reality. They are two entirely different types of solder techniques for very different kinds of applications.

Whereas wave soldering is used extensively for economical and secure soldering of boards with only through-hole components, selective is used on boards with a mix of surface mount and through-hole populations. Wave is still the fastest, most effective method for processing through-hole components because it comes in contact with the whole surface of the board at once; selective tends to be considerably slower because it's soldering individual leads or closely spaced components one joint—or set of joints—at a time.

Hybrid boards exist for a number of reasons. In spite of the proliferation of surface mount components which are perfect for high density functions on smaller and smaller footprints, through-hole devices are still preferred for high power applications and those with connectors which require a very strong, stable joint.

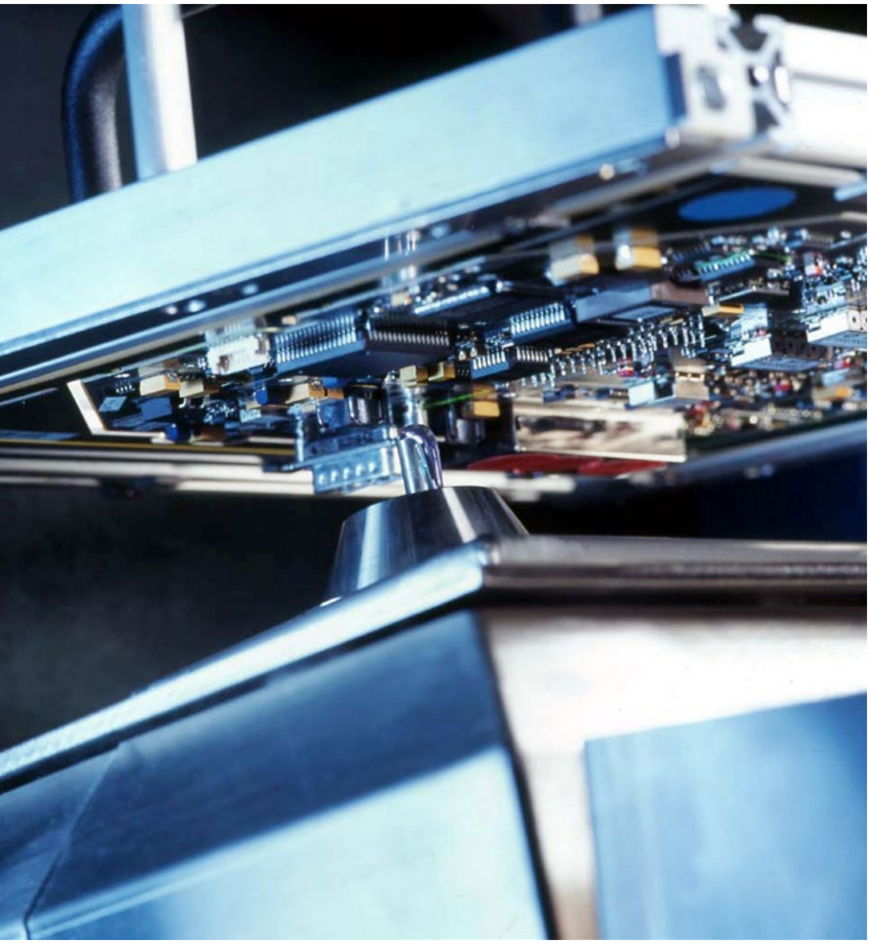


Figure 1: Selective soldering leads on a hybrid PCB both through hole and surface mount components.

How Selective Soldering Works

Selective soldering acts on the underside of the board without affecting anything on the top. A board is positioned in a frame, and all subsequent operations occur automatically according to the process control system programmed in advance for that board.

For each solder point, the machine operator controls the flux, preheat dwell time, and solder position, reducing any side effect of other joints on the board, unlike a wave process, which swipes the entire board without discrimina-

tion. All process steps are independently done, one at a time, over the entire board population:

1. All selective areas are fluxed first
2. All areas are then preheated to activate the flux
3. Each joint is soldered one at a time according to the program

In addition to a single point, selective can be designed to perform "dips" and "drags." These are closely spaced joints that can be handled by the same soldering operation either by covering multiple points in a single dip, or by swiping a row of joints in a long connector, for instance, by dragging the solder tip across them.

Pros and Cons of Selective Soldering

While there is often no other practical way to handle boards with hybrid components except manual soldering, selective soldering has the usual set of advantages and disadvantages.

Pros: Near-perfect joints, lower labor and rework costs than manual, reduced training and staffing costs for skilled hand labor, excellent joint consistency, high production efficiency

Cons: Generally more expensive than wave, although their costs have been coming done recently as they've become more popular; speed is relatively slow compared with wave, but considerably faster than manual soldering in a production environment

Options with Selective

As with all other types of machine soldering, there are multiple types of fluxing, preheating and soldering methods, which we'll dig into in later chapters. For now, here are some things to be aware of:

Fluxing Technology

Two types are available: spray and microdrop.

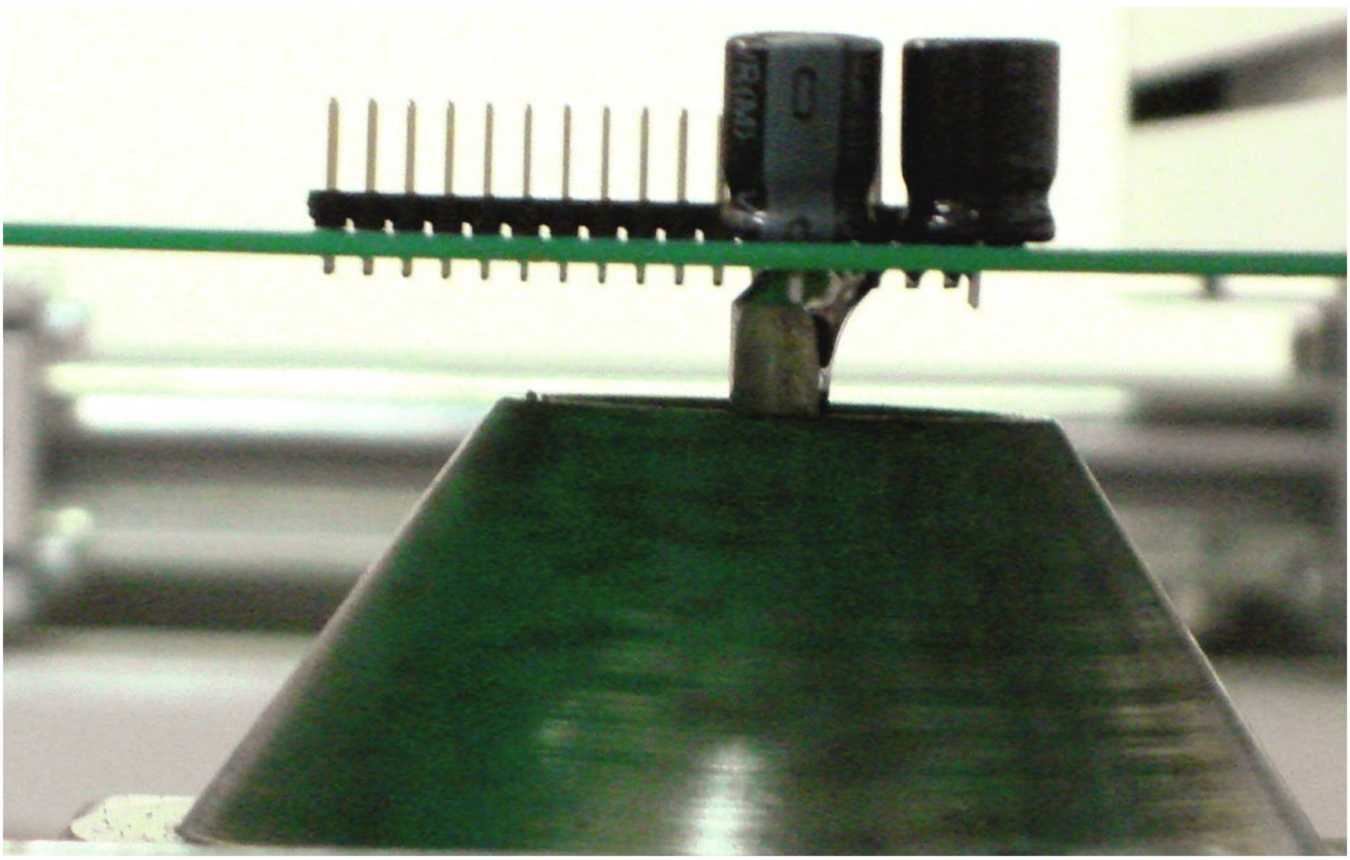


Figure 2: Selective soldering leads on a through-hole circuit board.

The spray type is generally faster, has been time-tested over many years of service, and has higher solids flux capability. Downsides to spray are: more flux residue, more maintenance and more wear parts may need replacing.

Microdrop fluxing is more accurate, provides better hole filling, leaves little residue and is generally maintenance free. However, it costs more, runs a bit slower and is more complicated to program.

Figure 3: Some of the soldering nozzles that are typically used in the selective soldering process.

Preheating Technology

Preheating minimizes thermal shock before soldering. Preheat systems can be integral with the selective soldering machine or offered as an optional module.

Quick IR, area IR, and area quartz techniques are available, and can be employed on both the bottom and the top of the board. Area quartz is usually specified for thick boards.

IR provides quick response and is gradient controllable, whereas some form of convection delivers a lower gradient but a more uniform heat transfer quality. A combination of the two may be used for high thermal mass applications.

Soldering Technology

There are three common types of soldering technologies available: jet wave, wettable nozzles, and hybrid (mini-wave and dip combination).

Jet wave is similar to wave soldering in that it's directional and has the same benefits as wave. Its smallest solder diameter is 4 mm, it requires minimal maintenance, and it is fairly low cost.

Wettable nozzles solder in every direction, 360°, or in either the x or y direction. It is easy to control the wave height, and its smallest diameter is 3 mm. It costs more than jet wave and requires daily maintenance.

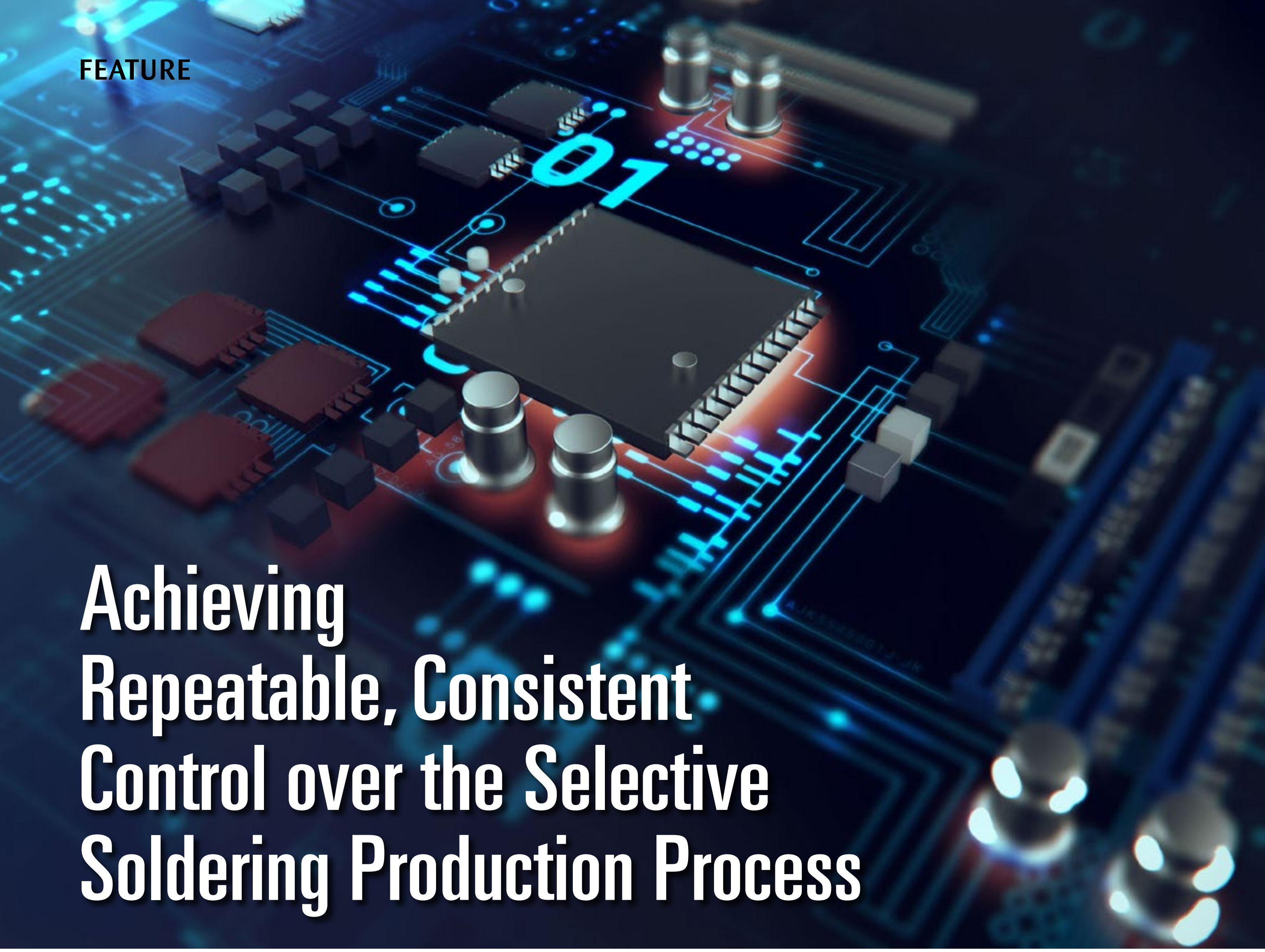
Check References

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.

Next chapter: Selective Solder Fluxing Technologies. **SMT**

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

FEATURE



Achieving Repeatable, Consistent Control over the Selective Soldering Production Process

by Gerjan Diepstraten
VITRONICS SOLTEC B.V.

Abstract

Selective soldering is a process with more than 100 different parameters that may impact soldering performance. Some conditions change over time (e.g., machine temperature, humidity, contamination, wear of parts or settings after maintenance). Other factors in the process include the materials used, component wettability, solder mask surface energy, board material Tg and Td values, solder oxidation and composition.

During production, conditions may begin to drift. In order to avoid solder defects, statistical process control or SPC is the best method of identifying unexpected changes in the process. When using this statistical technique, however, it is important that the machine has the tools to measure these essential process parameters and if necessary control them to maintain a robust soldering process. Apart from machine parameters, the materials have a big impact. A robust selective soldering process should have a wide process window that is able to handle variations in material quality. In this paper, critical process parameters are discussed as well as methods that can be used to widen the process window. Additionally, process robustness is evaluated.

Introduction

Selective soldering machines are available in many different configurations, primarily because the assemblies are very different, not only in design, width and mass, but also in volume and in the number of solder joints.

Nevertheless, they all require the same three sub-processes of fluxing, preheating and soldering. These processes can have different methods, but in the end all main parameters are identical to create a solder connection: the

amount of flux per area, preheat temperature, solder temperature, and contact time.

Machine and Process Capability

A machine capability analysis may be applied to a selective soldering machine to ascertain its suitability to flux, preheat and solder a circuit assembly. It is a short-term study with the sole aim of discovering the machine-specific effects on the soldering process.

Process capability is more of a long-term study. In addition to variations arising from the machine, all other external factors that influence the soldering process over a longer operating period must be taken into account.

Process capability can only be performed directly on the production line. Parameters tested may include topside board temperature and solder contact time. Parameters that influence the process and are related to the materials that are used include the printed circuit board itself.

Selective soldering is a method often used in the automotive industry. Machine capability is part of the quality program that ISO-certificated companies ascribe to. The ISO auditor may want to see how the company assures the assembly process. Quality tools including process FMEA, machine capability analysis, process capability and statistical process control are part of their daily business.

A machine capability analysis (MCA) is typically done before the acceptance of the machine, when the machine is installed in the production line and/or when the machine is moved to another place in the manufacturing facility to ensure that the performance of the machine is not affected. Some automotive customers require a MCA before a new production line starts up that is dedicated to a specific (new) product/model.

Fluxing Process

The majority of flux application systems in selective soldering are dropjet devices. In the flux process there are some very important parameters that may affect reliability. The most critical is when flux penetrates into a SMD or other area where it is not activated, due to lower process temperatures. Non-activated flux in combination with humidity can cause electro-migration when the product is used in the field. Therefore, the spreading of the flux is the most critical parameter in this process, although it may have no impact on the final soldering result. This is a problem because engineers focus on soldering results and not on flux residues that are very hard to identify. To avoid reliability risk, it is the best to choose a selective soldering flux that is inert even when it isn't activated[2].

Today many engineers are struggling to control the applied flux amounts. For good soldering, more flux is sometimes needed. Applying more flux creates, however, the potential risk that flux may penetrate into SMD areas.

To avoid this, it is important to understand properties of flux and the printed circuit board.

The solder mask on the PCB is an important component that significantly impacts the spreading of the flux. The flux spread depends on several factors, including the following:

- Flux surface tension (flux type)
- Surface energy of the board (solder mask)
- Temperature of the flux
- Temperature of the board
- Flux amount

As one may notice, none of these are machine parameters expect for the flux amount that can be controlled by adjusting flux machine parameters.

The situation is even more complex. Flux spreading is critical for reliability, but the amount of dry solids of flux per square inch affects soldering quality. Thus, a trend in new fluxes for selective soldering is to increase flux solid content, which allows minor flux (less spreading) and yet retains a high concentration of solids in the soldering area.

A typical soldering process requires 500–2000 µg/in^2 solids.

Figure 1 shows the impact of the flux surface tension and the surface energy of the solder mask on flux spreading. Printed circuit boards made for the wave soldering process may fail in selective soldering due to the higher surface energy of the solder mask that makes the flux spread away from the soldering area.

All of these different parameters affecting the spreading (and thus also the amount of flux per

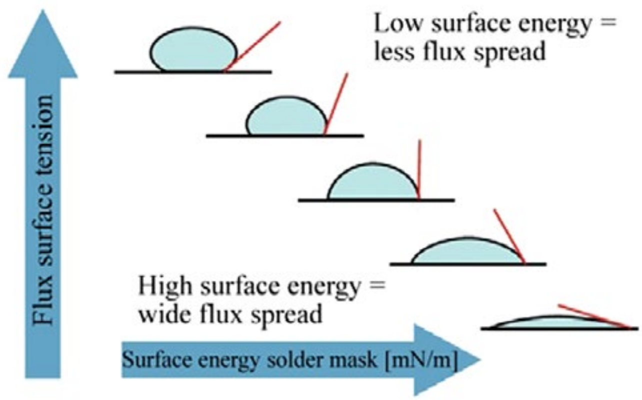


Figure 1: Higher surface energy of solder mask makes flux flow.

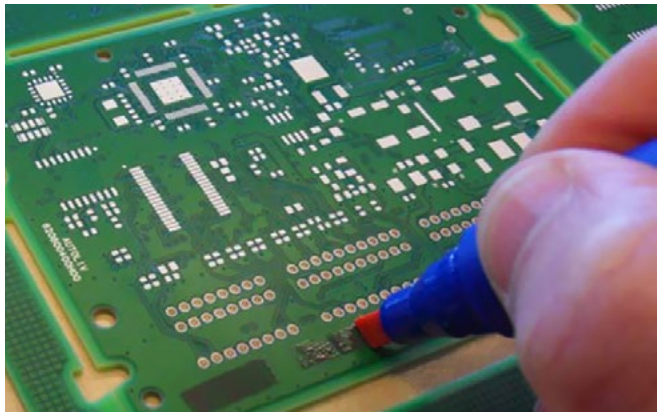


Figure 2: Ink pencils to help define surface energy of a PCB.

square inch) makes it complicated to effect a process control on this critical process parameter. The surface tension of a flux (influenced by surfactants in flux) isn't even defined in the datasheet. The surface energy of the solder mask can be measured using simple ink pencils with different inks.

The line of ink should remain unchanged for two seconds without turning into droplets; this indicates that the surface energy of the board is the same or higher than the surface tension of the ink. A typical value for selective soldering is 35 mN/m.

This parameter will not change from board to board, but requires verification when a different batch of bare boards are used.

In a previous study on a selective soldering application with respect to flux spreading, the data is converted into a Pareto chart:

When monitoring these two parameters (surface energy of solder mask and flux amount), 99% of the influence on flux spreading is covered.

Some selective soldering machines utilize a laser to measure flux flow. However, a laser system can only measure the time that a flux flows, and then uses an algorithm to convert this into a flux amount more accurate method is to use a thermal micro sensor. This sensor technology measures these very small amounts of flux. The short response time and high precision allows accurate monitoring of high dynamic fluxing processes. Sample times of 10 ms are achievable. The flow of the flux is very small 0.25–1.25 g/min (wet flux).

Flux spreading			
Process parameter	**Method**	**Interval**	**Recording**
Surface energy solder mask	Pencil test	New batch or random	Visual approval
Flux amount	Flow meter	Each board	SPC-chart
Flux spreading	Sensitive paper	New batch or random	Visual approval

Table 1: Recommended methods to control flux spreading.

For machine capability analysis, the flux amount was also measured manually by spraying on a coupon and weighting the amount on a balance.

Process engineers use sensitive paper to verify flux spreading. What type of paper used depends on the flux. A water-based flux requires a different type of paper than an alcohol-based one. For reliability reasons a selective soldering flux will be alcohol-based (rosins don't dissolve in water).

Dropjet calibration is required to achieve a machine-to-machine consistency. Some applications may have a dual dropjet to reduce the flux cycle. In these circumstances it's required that both machines dropjet spray the same

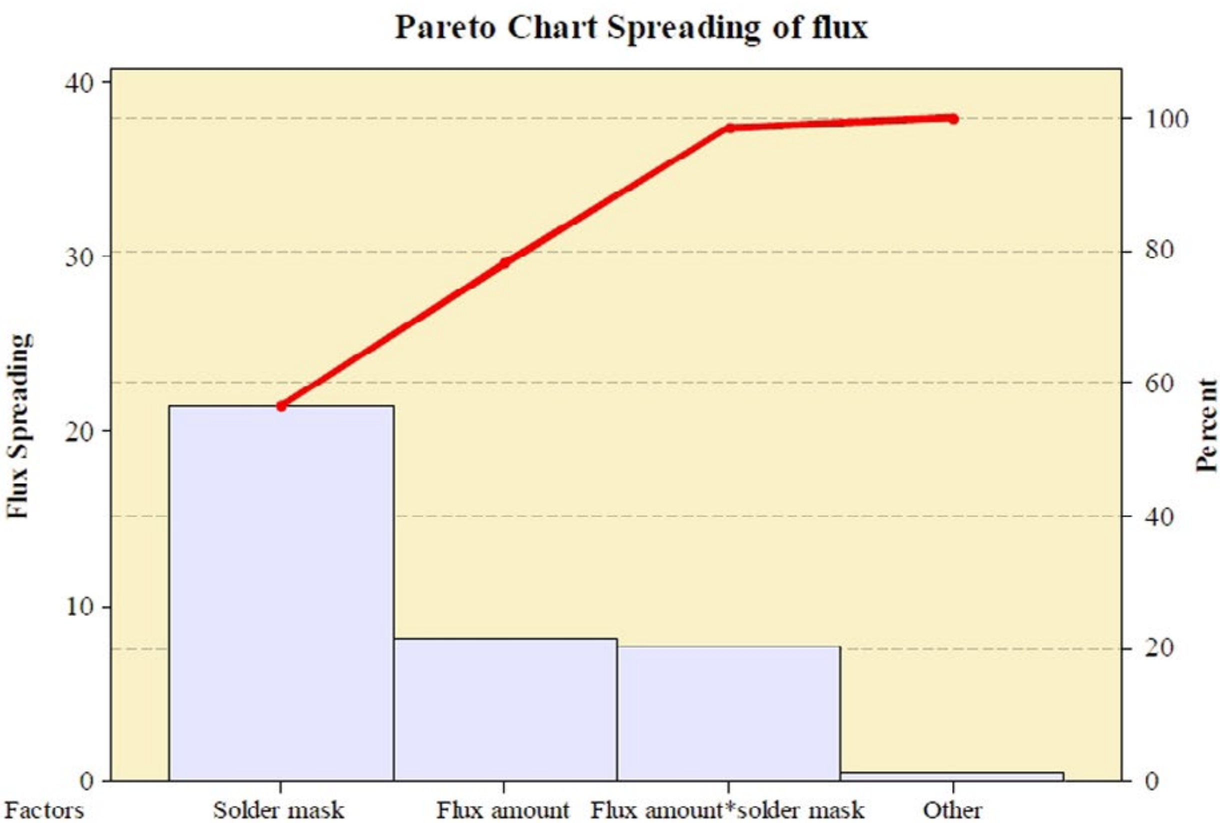


Figure 3: The Pareto chart shows that there are two main factors affecting flux spreading.

amount at the same setting. Calibration is necessary to guarantee this.

Flux should be applied to the right spot. Placement accuracy of the robot and spray direction of the dropjet should ensure this. Robot accuracy is measured during a machine capability analysis by dedicated laser sensors. The x and y positions are logged.

The speed of the robot is controlled by the PLC. The software detects if the speed is not following the setting or if the acceleration or deceleration are out of bounds. The machine will generate an alarm. The robots have an accuracy that is significantly higher than the flux spreading. The dropjet mounted on the robot should spray the droplets straight to the bottom side of the assembly. This can be checked by spraying the flux through a device whereby a laser sensor verifies the straight flux flow (which can be influenced by contamination). Frequency of this confirmation can be set into the software.

Position and spreading are controlled; the next and most complex process parameter is the amount of flux per area measured in dry solids per inch.

This parameter can be calculated since the spreading is known as well as the solids content of the flux. There are only two critical issues to be defined:

1. What is the solids content of the flux and is it homogenous in the flux solution?
2. When applied to the board, is the solids content on all areas identical?

The solids content of a batch flux can be verified by taking a defined amount out of the barrel, evaporating the solvents and then measuring the mass of the solids remaining. The % of solids can then be calculated.

This image shows the solids of an organic no-clean flux as applied to the test board. The spreading of this flux is clearly visible as well as the concentration of solids. Obviously, the solids

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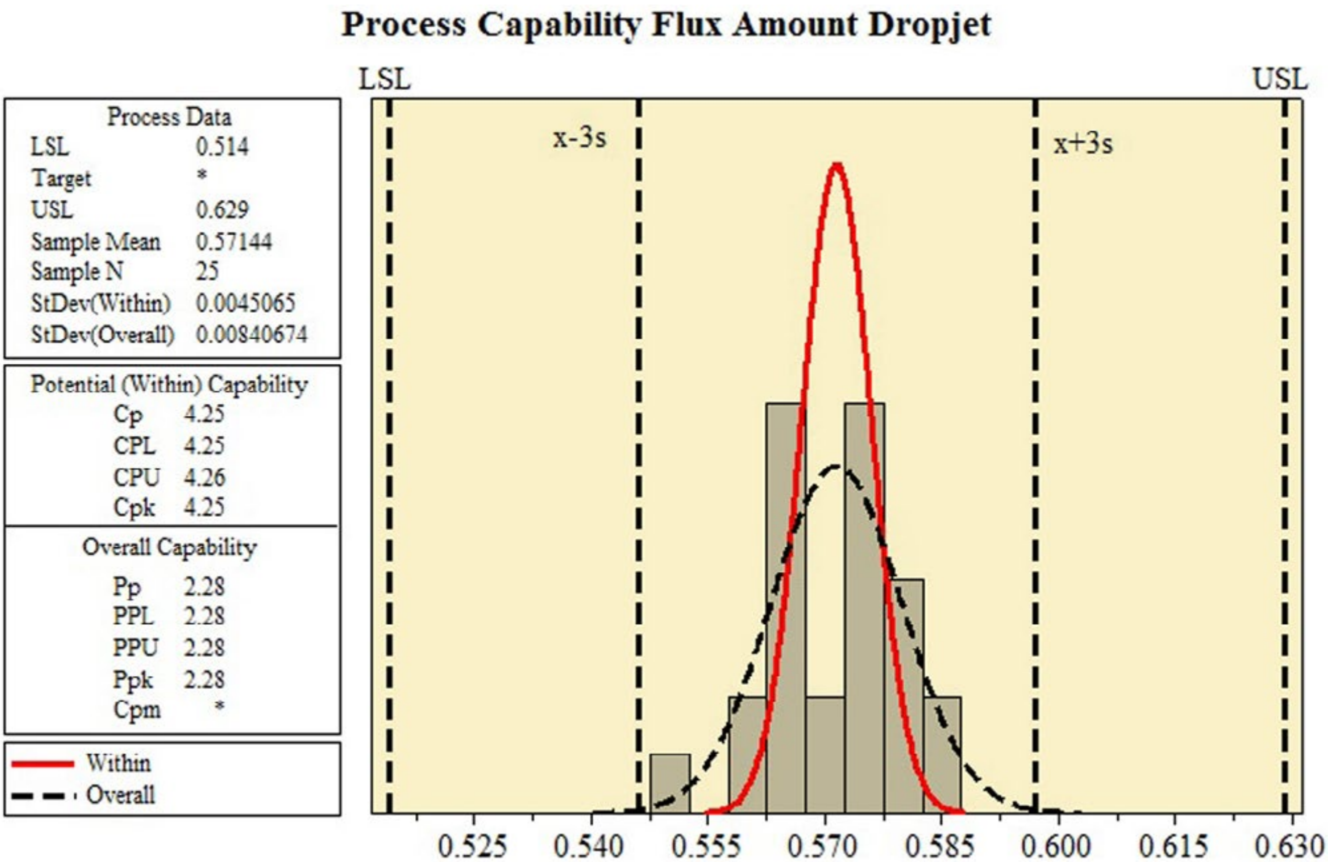

Figure 4: Histogram of the wet flux amount measured during a machine capability analysis. Process capability Cp=2.28 is acceptable.

concentration is higher at the edges of the flux deposit and less so in the center. Distribution seems to be non-homogeneous on the board.

Preheating Process

The flux solvents must be evaporated before the board can be soldered. The preheaters also heat up the assembly to activate the flux system and bring thermal heat into the assembly to facilitate soldering. Typically, two types of preheaters are used in a selective soldering process. These are IR lamps that respond quickly and are used in mixed production and forced convection heaters that can bring a lot of heat into a high thermal mass board.

In the machine capability tests the preheating experiments proves that selective soldering machines can guarantee a consistent temperature on the top side of the board in the short term. For process control purposes,

Figure 5: Flux spreading visual check. Solder joint positions are printed on the check paper. Visual criteria are stored at the machine.

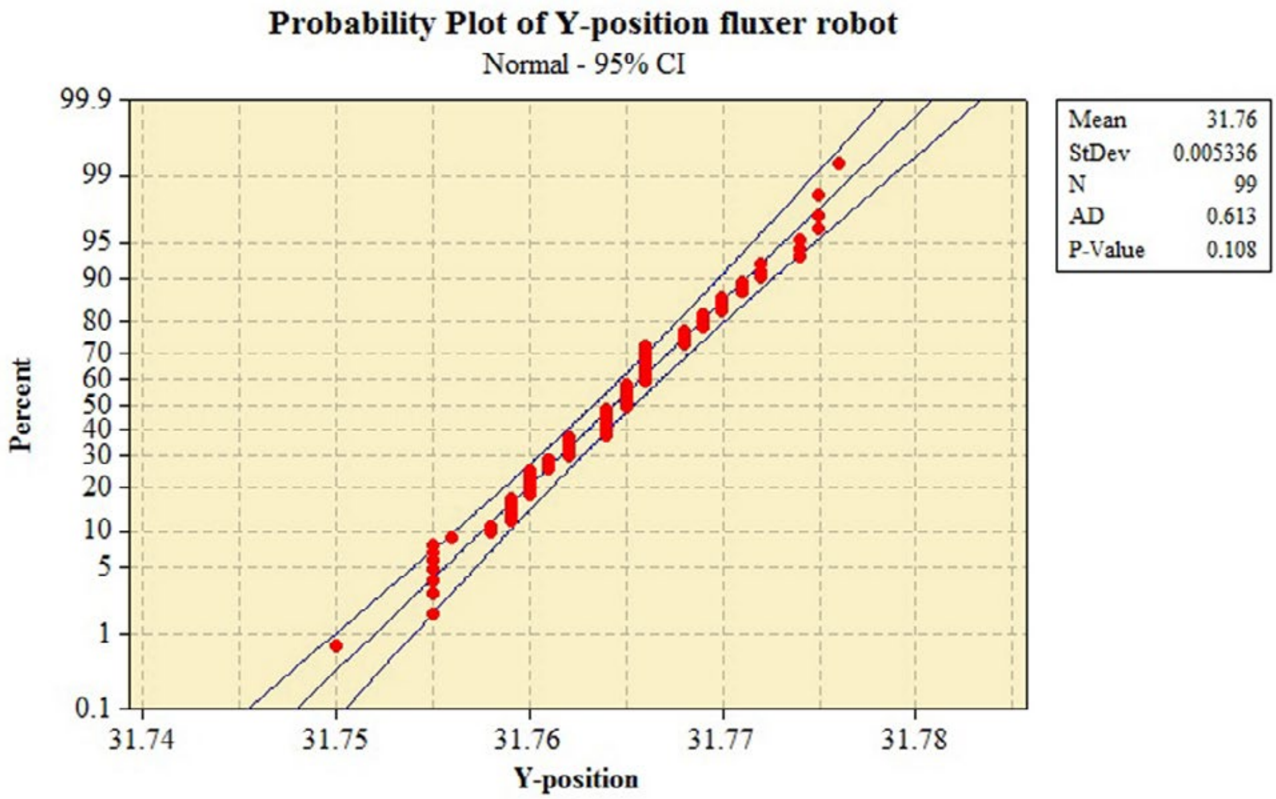

Figure 6: Accuracy of the fluxer robot in y-direction.

Flux position			
Process parameter	**Method**	**Interval**	**Recording**
Robot position	Laser	Once	MCA
Robot speed	Embedded in PLC software	Continues	Machine alarm
Flux deposition	Sensitive paper	Every batch or random	Visual approval
Flux direction guardant	Laser	Customer defined	Machine alarm

Table 2: Recommended methods to control position of flux.

many engineers run a board at the start of a new production session or at random to verify temperatures.

Similar data is shown for a forced convection preheater tested in a machine capability analysis.

This data proves the consistency of the machine. The process however is run with boards that have different thermal builds. On one board there are Cu-rich areas as well as other areas with less thermal mass. It is not only a challenge to maintain a constant temperature, but also to achieve small ΔT's across the board. Otherwise some parts may be out of the flux specification limits that define the acceptable preheating temperatures.

Many engineers run a golden board during production. This board contains thermocouples on cold and hot areas of the assembly to verify process conditions.

Some selective soldering machines are equipped with closed loop controlled systems in the last preheat zone. A pyrometer measures the topside board temperature when the board enters the IR lamp heater. The machine calculates the time before soldering and modifies the

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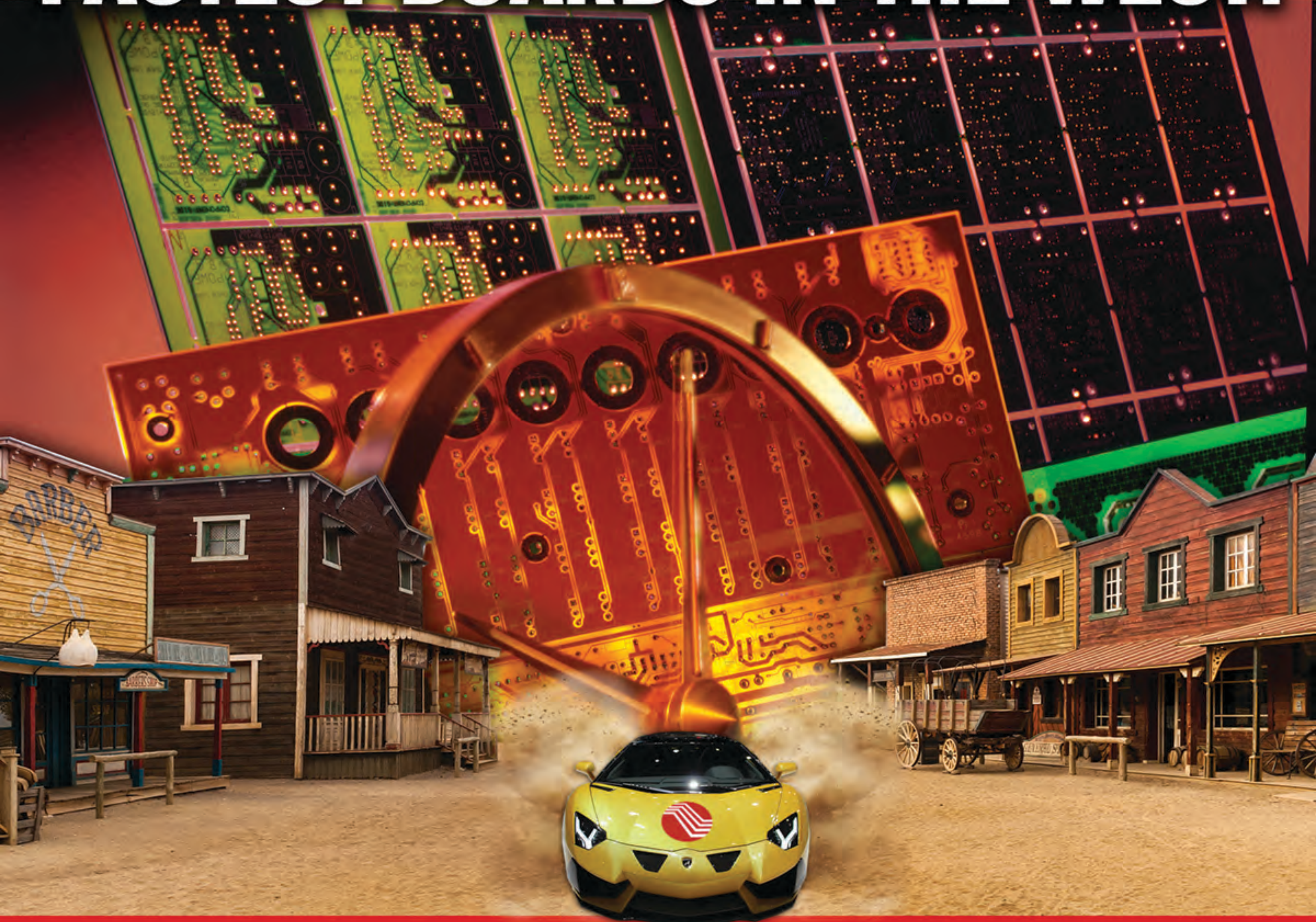

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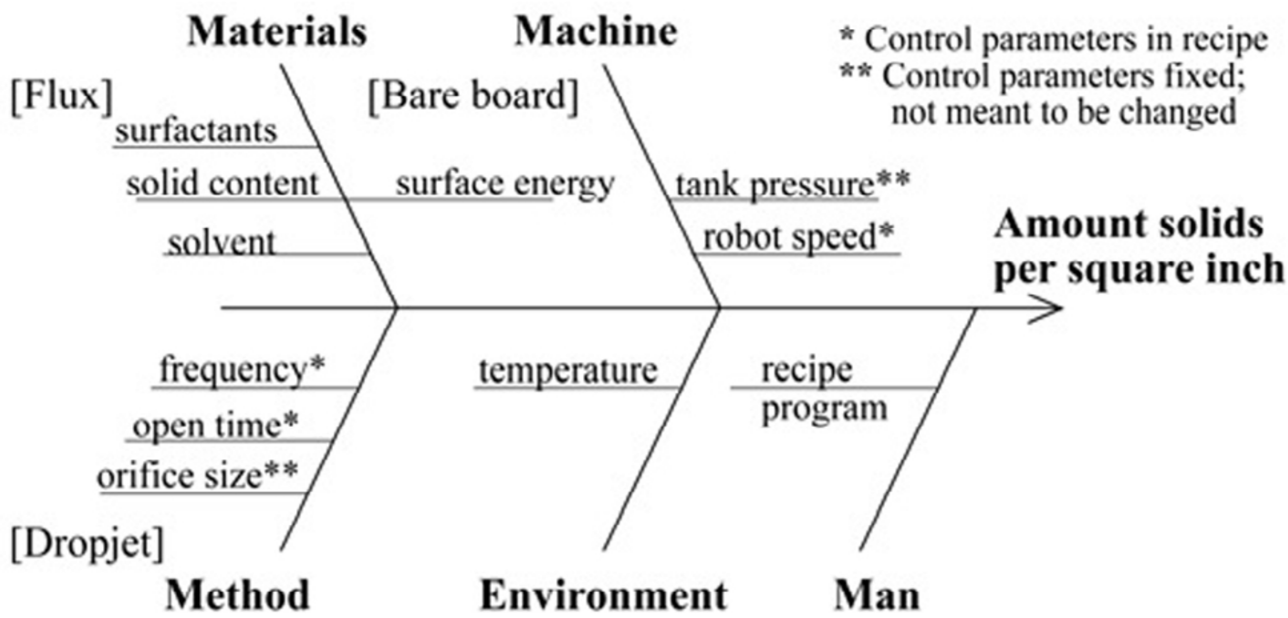

Figure 7: Ishikawa diagram of flux amount per square inch.

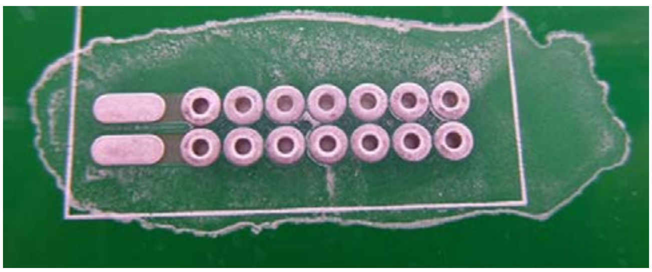

Figure 8: An organic no clean flux applied on the test board.

Preheat temperature			
Process parameter	**Method**	**Interval**	**Recording**
Topside temperature	Pyrometer	Each board	SPC, machine alarm

Table 3: Recommended board temperature control.

power of the heaters in such way that the final end temperature is always the same.

Another method to verify if the complete assembly is heated correctly is to take a thermal image with a thermal camera. The advantage of such an image is that one is able to analyze the complete assembly in detail. However, it is only one shot at the end of the preheating—a one-moment temperature picture.

Soldering Process

Just before soldering, the assembly is clamped onto the conveyor or in a robot. Then the assembly is positioned above the solder device. In the next study the accuracy of the robot, the repeatability of the clamping system, and consistency of the fiducials are monitored.

A fiducial is mounted on the robot. The robot itself including the assembly is moved to a camera that records the x, and y position of the fiducial of the robot as well as the fiducial of the assembly. The test is repeated with the same assembly and with different assemblies introducing the noise of poor fiducials.

The machine capability proofs the accuracy of the robot. All x and y position are repeatable and Cp values are well above the requirements.

The graph shows that for a process accuracy of ±0.10 mm, the data is not consistent enough. For a select wave process (point to point soldering) a fiducial recognition system corrects the

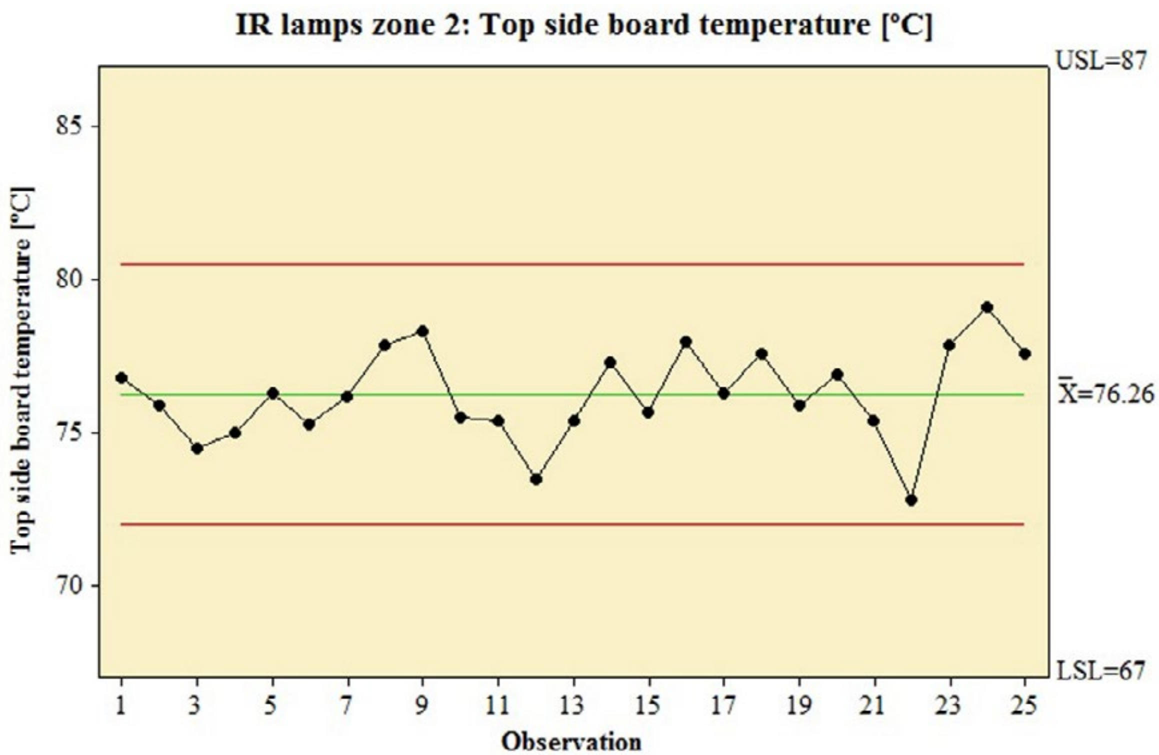

Figure 9: The end temperature measured on the top side of a bare test-board after 30 seconds at 50% power of the IR lamps.

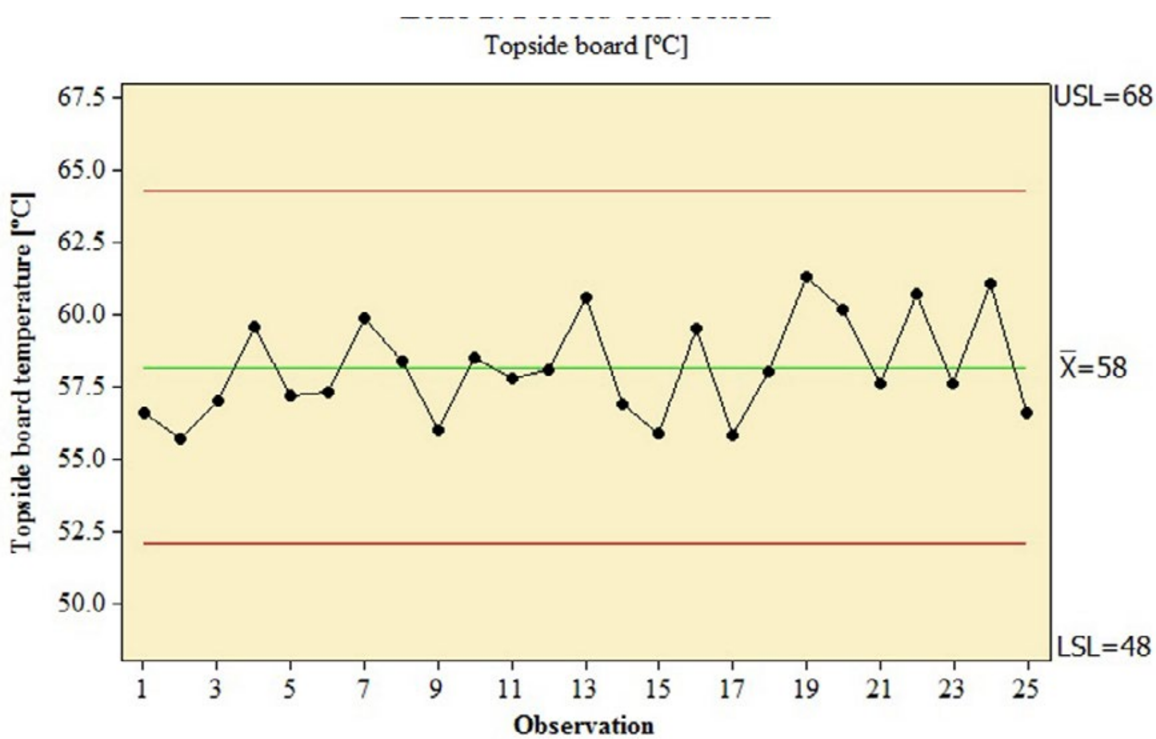

Figure 10: The end temperature measured on the top side of a bare test-board after 30 seconds at 150°C/50Hz.

offset. For a multi wave dip process, a fiducial recognition or a mechanical pin-hole device (between nozzle plate and pallet/board) are able to correct the offset.

Also, in machines where the board remains in the conveyor the clamping of the assembly may not be that consistent and a fiducial recognition system can be implemented to correct the offset.

In a multi-wave dip process, board warpage is corrected by stand-off pins in the solder point and the z-position is fixed. For select wave soldering the warpage of the board can be critical. If the board bends too much the pin connector may touch the nozzle or the solder may not touch the board when warped in the opposite direction.

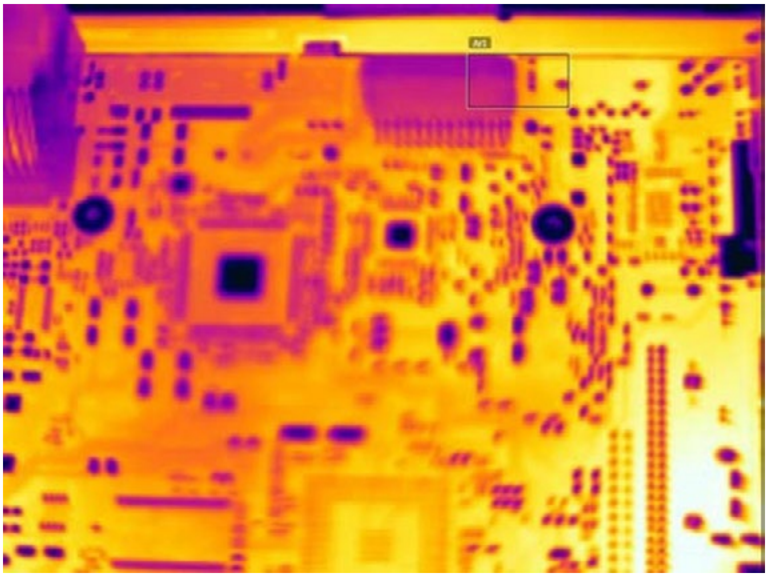

Figure 11: Camera image at end of preheat. With software it is possible to analyze the temperatures of various spots on the assembly.

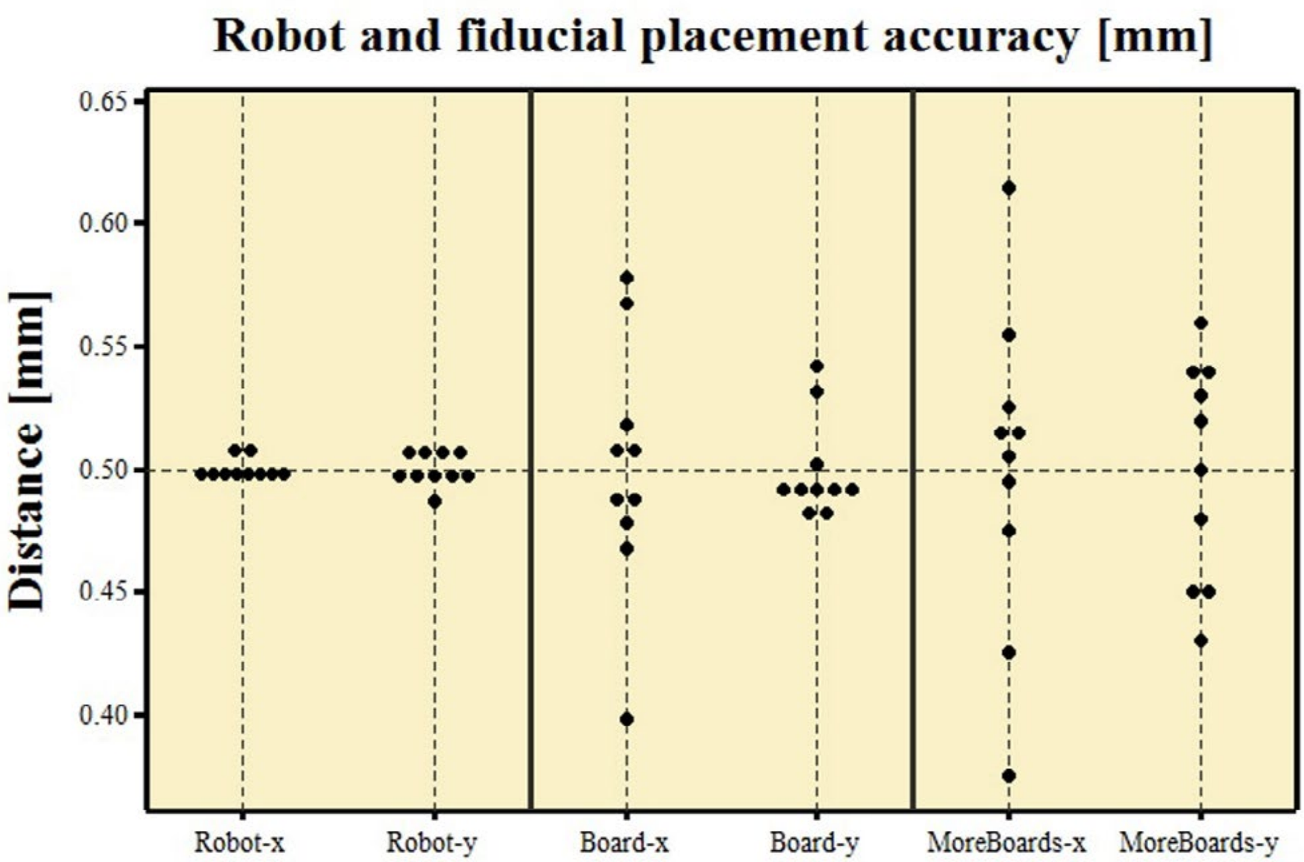

Figure 12: Dot-plot of the different measurements, robot only versus fiducials of one board and multiple boards.

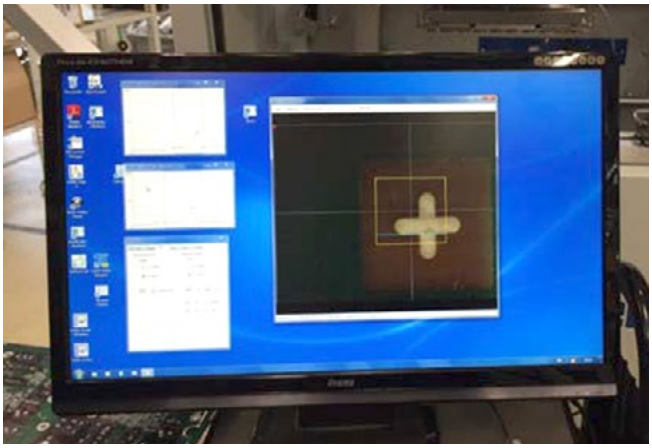

Figure 13: Camera with software to measure fiducial position.

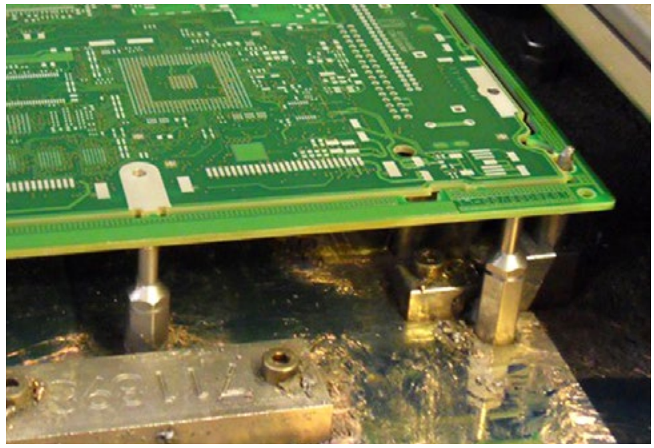

Figure 14: Pins on the multi wave plate serve to flatten the board and the slotted pin to position the assembly.

With laser sensors the warpage can be measured and corrected with the robot z-position.

Most of the assemblies have holes and slotted holes at the front and rear ends of the board; these can be used for positioning. The pictures show how pins of a multi plate fit into the holes and guarantee the position of the assembly in the hot solder pot.

Temperature is another parameter that affects soldering. Temperature is continuously monitored and logged for management information and, traceability.

The solder temperature depends on thermal heat of the assembly, hole filling issues, pin- to- hole ratio, and solder alloy. Solder temperatures in selective soldering processes are relatively high and the volume of solder is small. This makes copper dissolution and other contaminants like nickel more critical concerns.

To ensure that the composition of the solder doesn't run outside of specifications, a sample of the solder should be sent for inspection every month. Once the trends are known, the frequency of sampling can be reduced[4].

Solder temperature and contact time are the most relevant factors impacting hole filling of a solder joint. Contact time is another factor that can't be set as a machine parameter, but it is a derivative of several parameters. The solder level, pump speed, board warpage, wave height measurement and robot speed all have an impact on contact time.

Solder position			
Process parameter	**Method**	**Interval**	**Recording**
Robot accuracy	Laser sensors or camera	Once	MCA

Table 4: Solder position recommended controls.

In a dip soldering process, the solder is pumped to the solder side of the board and the pump speed is lowered before the board moves away. Contact time is programmed, but it depends on acceleration and deceleration of the solder pump. During a wave height measurement, a needle defines the height of the solder and may correct the pump speed if required. This results in a consistent contact time.

The solder level in the pot must be controlled. One bar of solder (1 kg) increases the solder level with 1.4 mm. How much this increase impacts wave height depends on the number and sizes of the nozzles. Thus, a wave height measurement with a needle is an adequate method for all different nozzle plate dimensions and designs.

The contact time itself, the final parameter that counts, is measured in a machine capabil-

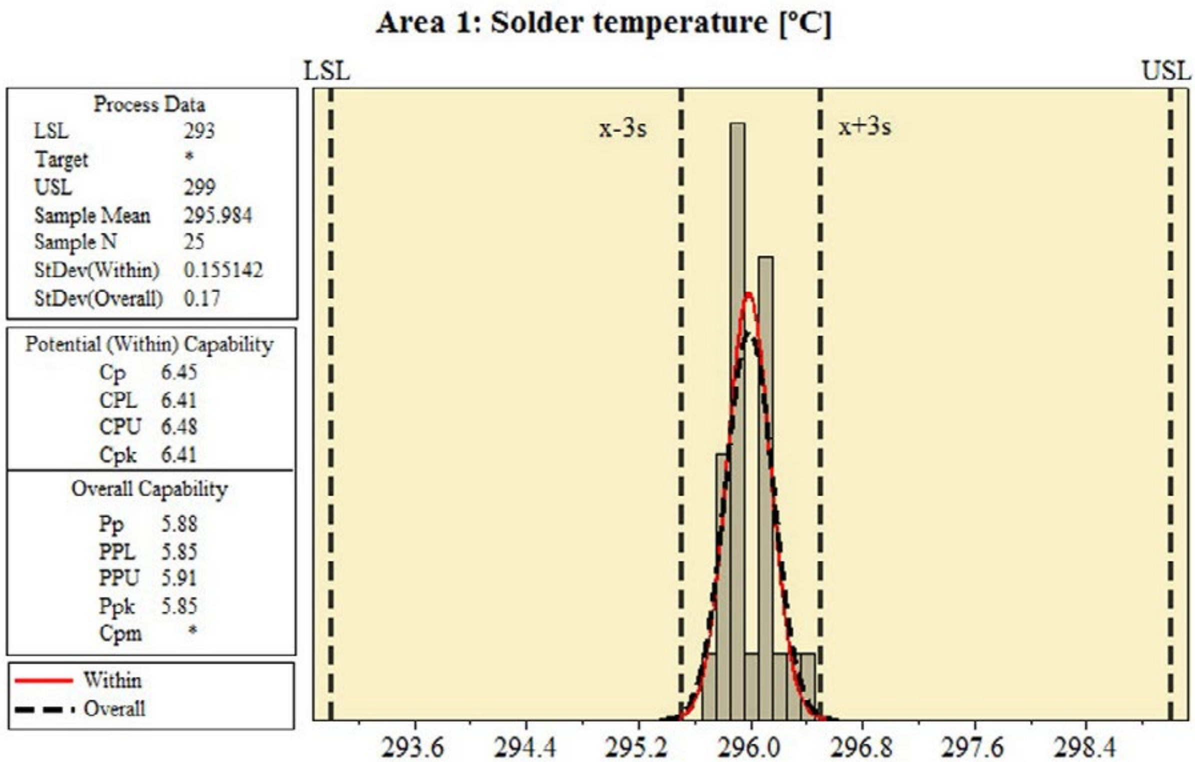

Figure 15: MCA solder pot temperature. Pp = 5.88—well above 1.66.

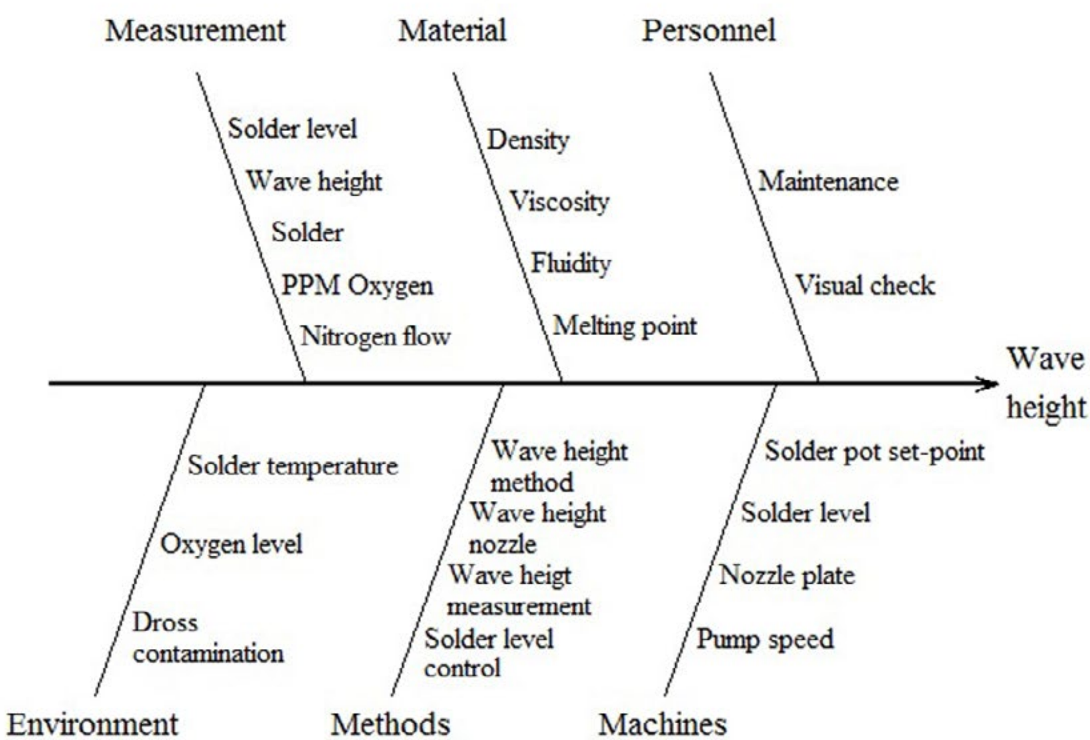

Figure 16: Ishikawa diagram for wave height.

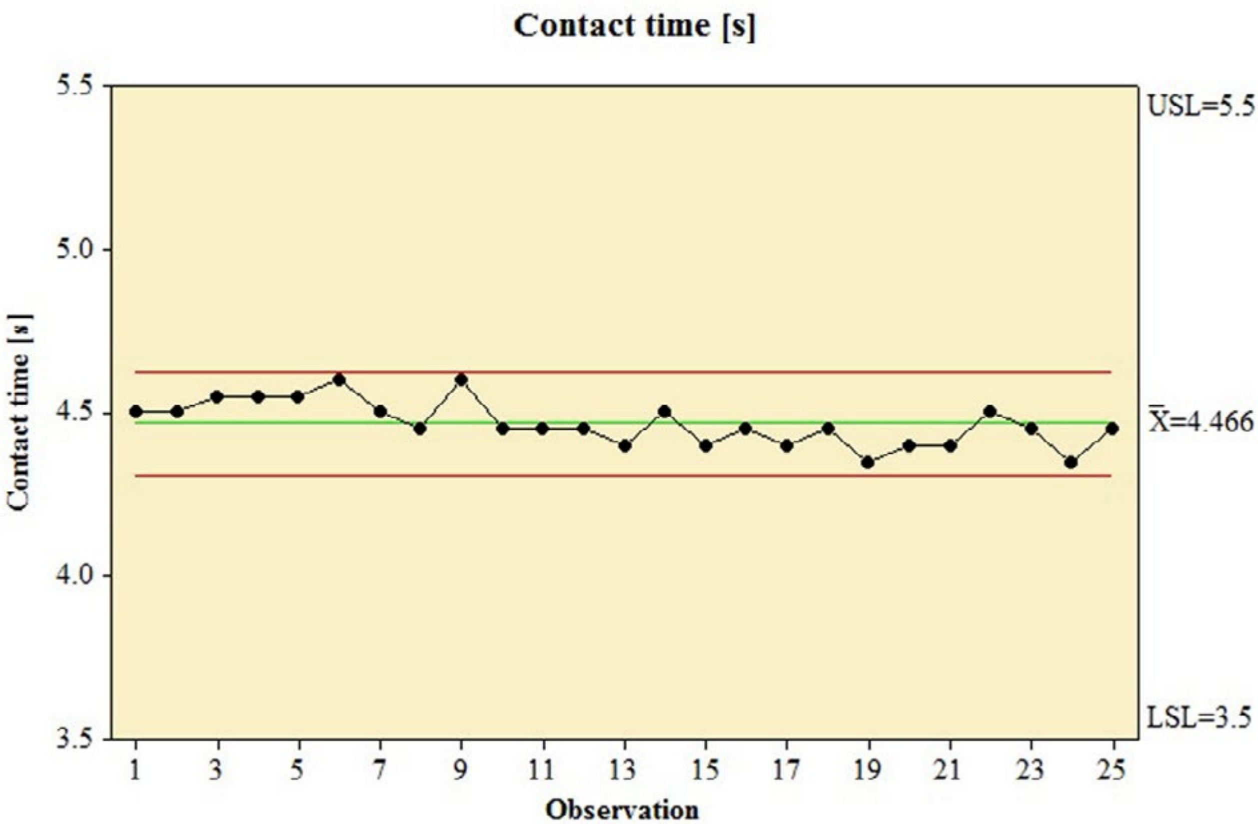

Figure 17: Contact times measured during machine capability analysis.

ity analysis using dedicated tools that are commercially available on the market.

For select wave soldering with a small nozzle, it is possible to measure the wave height continuously using a camera. For this process, a board warpage measurement might be necessary when the boards tend to warp frequently. The robot should be capable of compensating for warpage and correct the position if fiducial recognition is used.

The robot position is monitored as part of the PLC control. This is very accurate as shown in the machine capability analysis. Any exception will trigger an alarm.

Conclusion

Many parameters must be controlled to establish a robust and consistent selective soldering process. Some important process parameters (dry flux amount per square inch, top side board temperature and contact time) are hard to monitor continuously.

Modern selective soldering machines are delivered with a machine capability analysis already performed that proves that the machine is able to maintain consistency and achieve high yields.

Statistical process control can be applied on critical process parameters. Data is logged in files and traceability is part of the software.

This paper recommends how to control the process. The recommendations are only a guide to set-up a process. Also critical but not discussed in this paper are the issues of the board design and material quality.

Many soldering defects can be avoided when materials are selected that are high quality and products have designs that meet selective soldering requirements. The machine supplier is happy to support users with design guidelines to make their products even more dedicated to selective soldering. Design for manufacturing often means a better design for selective soldering. **SMT**

2016 Programs

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The Changing Landscape of REACH — **Workshop**
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Wisdom Wednesday — for IPC Members ONLY — **Webinar**

April 18–20
IMPACT Washington, D.C. 2016 — **Meeting**
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IPC Reliability Forum — **Conference**
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May 19
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Dusseldorf, Germany

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Wisdom Wednesday — for IPC Members ONLY — **Webinar**

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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**
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June 10
ITI & IPC Conference on Emerging & Critical Environmental Product Requirements — **Conference**
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September 24–30
IPC Fall Committee Meetings — **Meeting**
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Rosemont, IL USA

September 26
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October 19
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October 25–27
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November
IMPACT Europe 2016 — **Meeting**
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November 2
PCB Carolina Presented by the RTP Chapter of the IPC Designers Council — **Conference and Exhibition**
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November 2–3
IPC Technical Education (in conjunction with PCB Carolina) — **Workshop**
Raleigh, NC USA

November 7–11
IPC EMS Program Management Training and Certification — **Certification**
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November 16
Wisdom Wednesday — for IPC Members ONLY — **Webinar**

December
IPC Education Online: Winter Semester — **Webinar**

December 7–9
HKPCA International Printed Circuit & IPC APEX South China Fair — **Conference and Exhibition**
Shenzhen, China

December 14
Wisdom Wednesday — for IPC Members ONLY — **Webinar**

Contact time (multi wave)			
Process parameter	**Method**	**Interval**	**Recording**
Robot accuracy	Laser sensors or camera	Once	MCA
Solder level	Floater with sensor	Continuous	Machine alarm
Wave height	Needle with sensor	Selectable, every boards	Machine alarm
Pump speed	Sensor	Continuous	Machine alarm
Nitrogen flow	Flow sensor	Continuous	Machine alarm

Table 5: Recommended controls for the soldering area of a multi wave dip process.

Contact time (select wave)			
Process parameter	**Method**	**Interval**	**Recording**
Robot accuracy	Laser sensors or camera	Once	MCA
Solder level	Floater with sensor	Continuous	Machine alarm
Wave height	Camera	Continuous	Machine alarm
Pump speed	Sensor	Continuous	Machine alarm
Nitrogen flow	Flow sensor	Continuous	Machine alarm

Table 6: Recommended controls for the soldering area of a select wave point-to-point soldering process.

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Gerjan Diepstraten, CIT, is advanced technology manager at Vitronics Soltec.

New Terahertz Source Could Strengthen Sensing Applications

Current terahertz sources are large, multi-component systems that sometimes require complex vacuum systems, external pump lasers, and even cryogenic cooling. The unwieldy devices are heavy, expensive, and hard to transport, operate, and maintain.

Now, Manijeh Razeghi, Walter P. Murphy Professor of Electrical Engineering and Computer Science in Northwestern's McCormick School of Engineering, and also director of the Center for Quantum Devices, has developed a new type of security detection device that bypasses these issues. With the ability to detect explosives, chemical agents, and dangerous biological substances from safe distances, the device could make public spaces more secure than ever.

Razeghi and her team have demonstrated a room temperature continuous wave, highly tunable, high-power terahertz source. Based on nonlinear mixing in quantum cascade lasers, the source can emit up to multi-milliwatts of power and has a wide frequency coverage of one-to-five terahertz in pulsed mode operation.

ARTICLE

CASE STUDY: Working Smarter Through a Proprietary Systems Strategy

by Chris Eldred
TELIGENTEMS

The mantra of the electronics manufacturing services (EMS) industry has long been build products faster, better and cheaper than your customers can do it. That drives a culture of working smarter and forces multiplying resources wherever possible.

From an IT perspective, EMS companies have two choices: Select off-the-shelf systems and deal with support gaps if the systems don't provide all the tools needed to manage the business, or buy an off-the-shelf core system with the source code and create highly customized solutions to address any support gaps.

TeligentEMS chose the latter route in its systems strategy, building proprietary tools around an Epicor ERP system. The advantages of this approach are threefold. First, developing internal proprietary systems was far less costly than purchasing specialty modules, additional systems or hiring outside consultants to modify the system. Second, the internal development effort ensured that the systems were built around user input in terms of desired features and ease-of-use. Finally, the internal development effort helped ensure that systems could be easily modified as the market requirements changed.

The systems development effort had three key goals:

- Improve real-time management visibility in areas critical to the business
- Provide associates with tools that make it easy to do their jobs
- Automate data collection related to product quality and traceability to support mission critical customer needs
- Make interfaces easy-to-use and collected data easy-to-understand

To fully understand the benefits of this approach, it is important to understand some of the EMS challenges these systems are designed to eliminate. In this case, there were six main areas the company wanted to create proprietary systems to support:

- **"What if" analysis:** The largest cost in any product is raw material. In the EMS environment, raw material is typically tracked and stocked by customer number rather than manufacturer part number. An EMS provider's ability to quickly determine not only the number of parts available to that customer, but the total number of that part and similar parts on hand and in the pipeline, is critical to understanding the lead-time needed for an increase in production. Similarly, the ability to quickly look up the total demand for a particular part can be helpful in determining whether or not an engineering change order (ECO) that obsoletes a part will result in excess inventory or inventory that can be consumed by other customers' programs.

- **Supply Chain Management:** Just as materials represent the largest business cost, inefficiency in managing materials represents the largest potential hidden cost. The speed at which buyers and program managers can identify material availability issues determines whether or not they can be fixed with low or no schedule impact. Good visibility into order confirmations and inbound shipment arrival dates can reduce inventory carrying costs and optimize production scheduling, since kit shortages are visible well in advance of the kitting process. While an ERP system tracks much of this information, it doesn't typically present it in a format that is optimized for the personnel charged with monitoring material status and cost.

Figure 1: Monitors showing real-time metrics are located throughout the production areas.

- **Material Integrity and Traceability:** The EMS role in materials screening and tracking has never been greater. Since this requires some level of manual interface, systems that ensure consistency and efficiency help reduce costs in this area. Additionally, the data collected at this point can support customer information requirements related to traceability and/or mandated supplier declarations.

- **Centralized Documentation Control:** Today's product lifecycles are shorter and often include frequent ECOs. EMS providers focusing on high mix or variable demand product often need to make frequent line changeovers in as short a time period as possible and digital work instructions help speed that changeover. Requirements such as ITAR drive a need to closely control access to documentation. In short, a centralized digital documentation repository with controlled access is the best way to ensure product is built to correct revision levels and that access is limited to only the personnel who are authorized to view that information.

- **Shop Floor Control:** You can't manage what you can't measure. While analysis of historical data can result in corrective action over time, scrap and/or inefficiency accrue until the situation is corrected. Real-time tracking systems help identify inefficiencies in production processes plus support customer traceability requirements. Real-time tracking of quality data at inspection and test points provides an immediate warning of undetected quality issues. The key is making the system holistic and visible enough that the personnel who can benefit from the data have easy access to it and can identify issues as they arise.

- **Production Associate Empowerment:** The EMS production environment is dynamic and typically production associates are fully capable of problem-solving, performing multiple

Figure 2: The p-Dash system makes it easy for production associates to open a support ticket an d get immediate response when they need help with an issue in their work area.

operations and suggesting improvements. The key is providing them with the knowledge and tools needed to effectively do their jobs.

TeligentEMS' development efforts began with creation of Possible-X, a system that started out as a simple 'what if' tool designed to integrate with the ERP system and quickly assess material availability of specific parts in existing inventory. Over time, this simple tool has grown to a suite of tools accessing a central repository for information. Today, the component search tool enables users to also easily access receiving history, prior price quotes on that part, what subassemblies it is used in, information on the top level assembly and alternate components. With that information, a buyer or program manager has the tools to better understand their options in addressing production increases, ECO impact and changes in component availability. They can also monitor cost trends.

As the central repository for information, Possible-X is the access point for all production documentation and links all related information. It tracks ECOs and deviations and links them to work orders so that as documentation is pulled to build a product, production associates access the correct revision. It also contains a new production introduction (NPI) checklist and work instructions for each product. The checklist aligns with the company's focus on Lean manufacturing since a standardized setup process helps minimize variability. Access to product documentation is limited to associates working on the product and designated members of management.

Possible-X also integrates closely with the ERP system in receiving. The receiving inspection process has been designed to capture the bulk of the information required for both internal and customer requirements. Upon delivery each component is validated to the AVL. Any variance in labeling triggers additional inspection steps. Custom components go through additional inspection including measurements. Following inspection, a bar code label with purchase order receipt information is generated for each package and an ERP transaction is executed. Label data includes key information such as moisture sensitivity level (MSL), RoHS status, etc. Certificates of compliance are also validated at that point and scanned into Possible-X. The system automatically flags parts needed to fill shortages to ensure they are expedited.

Kit status is another tool in Possible-X. Kit status runs off work orders. The system also has a feature that enables program management, purchasing, production and the stockroom to have visibility into soft and hard shortages in kit status by work order. A soft shortage is a part that is scheduled to be received prior to the date the kit is scheduled to run. A hard shortage is a part that will not be available on the date the kit was initially scheduled to run. Since the system runs in real-time, the team has immediate notification if an issue such as a returned material authorization (RMA) causes an unanticipated shortage. This level of visibility into kit status, optimizes production scheduling, makes it easy to understand whether or not material availability will support production schedule changes, and highlights exactly where expediting is required.

Possible-X also includes a metrics menu that takes the visible factory into the 21st century. Defects per million opportunities (DPMO) is monitored in the SMT area in real time. Monitors showing a real-time, color coded graphical interface indicating both DPMO and production status relative to production targets are placed throughout the production floor and also accessible to management. DPMO is measured every 30 minutes and the trend for the last 24 hours is displayed. The top-ten identified defects are shown in a Pareto diagram. A test data collec-

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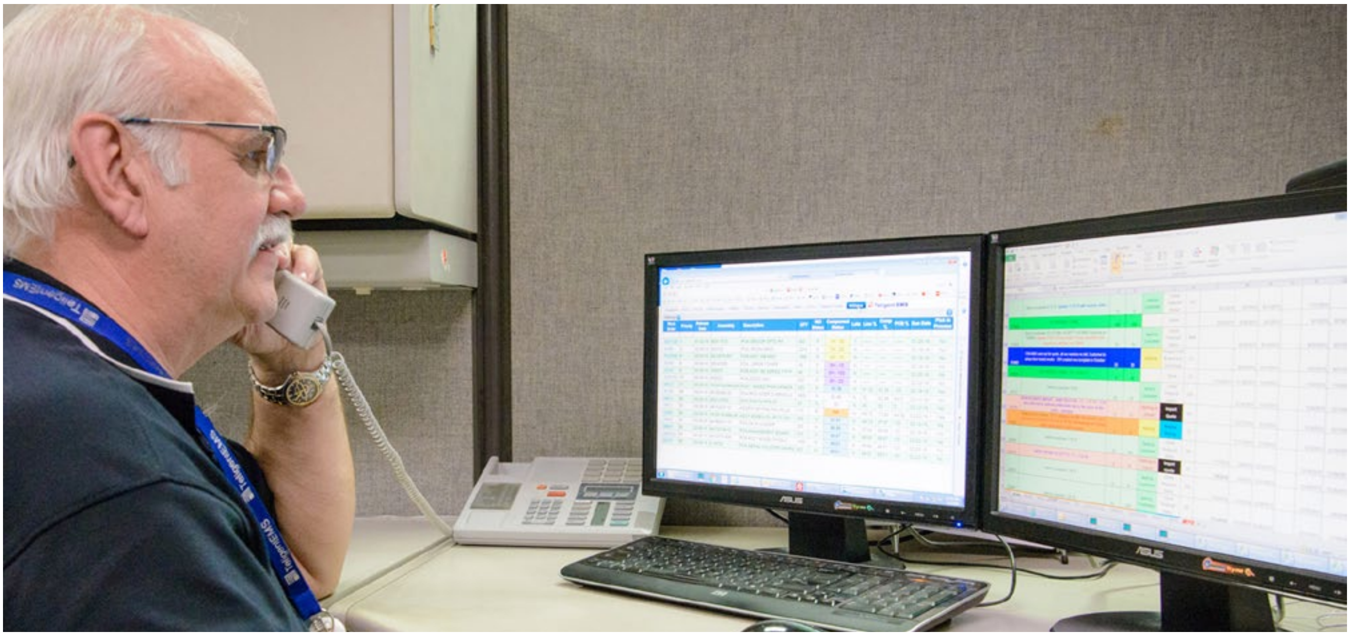

Figure 3: Program managers can easily check the real-time status of critical details of the programs they manage and are automatically notified if an exception needing program manager approval arises.

tion chart displays results from in-circuit test, functional, flying probe, RF, burn-in and hi-pot, making it easy to identify if any issues are developing in any test stage. Issues are addressed as they arise by the people closest to the issue. As with all Possible-X tools, it is possible to drill down to data related to specific work orders and serial numbers.

The production dashboard or p-Dash is a Possible-X tool designed to help empower production associates by ensuring they have the information needed to do their jobs. Associates must log in using their ID number. They utilize the system to clock in and out, plus access all documentation related to their jobs. p-Dash also facilitates movement of cross-trained associates among different work areas as demand varies, as well as lets associates open support tickets which text a message to an engineer whenever a production issue arises that the associate needs help with.

Meanwhile, supply chain management is supported by a related proprietary system known as TeligentEMS Purchase Order Tracking System (TPOTS, a dashboard designed to help buyers more easily track cost and order status). The dashboard shows quoted part, variance, buyer cost target and delivery status including tracking numbers. In the event a there is an exception, a dialogue box pops up and flags it to program management, enabling the program manager to authorize whatever action is required to address the exception. TPOTS also has a supplier portal, enabling suppliers to log on and confirm orders that aren't automatically transacted by MRPshare. Information can be filtered to focus on specific work orders, suppliers or types of exceptions.

For TeligentEMS, the end result of this proprietary systems strategy has been the ability to force multiply its staff by automating information analysis and collation. The team can easily monitor trends and act on issues early enough in the process to minimize any negative impact. Non-value added activity is eliminated. Most importantly, Possible-X, p-Dash and TPOTS will evolve as users suggest improvements or customer requirements change. **SMT**

Chris Eldred is TeligentEMS' President and CEO. He can be reached by clicking here.

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There will be a session on contamination and corrosion. RoHS initial implementation may be well behind us, but the implications are still resounding through our industry. Two sessions will focus on lead free solders, with one concentrating on bismuth-containing possibilities.

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Michael Osterman, Ph.D.
CALCE/University of Maryland

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Free Lunch
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Recent Highlights from SMT007

1 Best Technical Paper at IPC APEX EXPO 2016 Selected

The technical papers "Round Robin of High Frequency Test Methods by IPC-D24C Task Group" by Glenn Oliver of DuPont Electronics & Communications, and "Optimizing Thermo-Mechanical Reliability of Components with Flat Gull Wing Leads" by Simon Wolfangel of Robert Bosch GmbH were the considered the best papers at IPC APEX EXPO 2016.

2 ITL Upgrades UK Facility to Double PCBA Manufacturing Capacity

Innovative manufacturer ITL has launched a high volume PCB manufacturing service for medical devices, after upgrading its automated surface mount line to a Europlacer iineo II and revamping the entire PCB area at its UK facility.

3 IPC Joins NextFlex

IPC — Association Connecting Electronics Industries has become a partner of NextFlex, America's flexible hybrid electronics manufacturing institute. As part of the National Network for Manufacturing Innovation (NNMI), this new public-private partnership aims to establish America as the global leader in the flexible hybrid electronics manufacturing space.

4 Expert Assembly Launches New Quality Initiatives

Southern California EMS provider Expert Assembly Services recently enhanced that control with the addition of ultra-low RH component and PCB storage and drying by Super Dry.

5 Incap Enjoys 65% Revenue Growth in 2015

Incap Group has reported a revenue of €30.6 million in 2015, up 65% year-on-year, and operating profit of €3.7 million, more than triple that of the previous year.

6 Zentech Recognized as Top Ten EMS Provider in Northeast U.S.

Zentech Manufacturing has been recognized by Venture-Outsource as a Top Ten EMS provider in the Northeast United States.

7 IMI's ATC Lab Receives ISO/IEC 17025 Certification

Integrated Micro-Electronics Inc.'s Analytical Testing and Calibration (ATC) laboratory was granted accreditation for ISO/IEC 17025 on January 8, 2016 by the Philippine Accreditation Bureau (PAB) of the Department of Trade and Industry.

8 UEI Boosts Manufacturing Capabilities

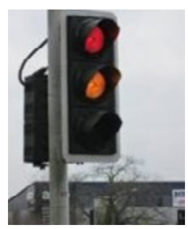
Universal Electronics Inc. has increased its PCB and higher-level assembly electronics manufacturing capabilities with the addition of new capital equipment for its manufacturing facilities in Whitewater and East Troy, Wisconsin.

9 SMTA Seeks Student Applications for the Charles Hutchins Educational Grant

SMTA is soliciting applications from full time graduate-level students pursuing a degree and working on thesis research in electronic assembly, electronics packaging, or a related field, for the $5,000 Charles Hutchins Educational Grant, which was established in memory of past SMTA president, educator, mentor, and industry colleague, Dr. Charles Hutchins.

10 Newbury Electronics Works on Traffic Light Detector System

Newbury Electronics has provided PCB development expertise using Downton Technology's designs to enable the manufacture of an LED interface for use between UK traffic signal heads and enforcement cameras.



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For the iNEMI Calendar, click here.

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

South East Asia Technical Training Conference on Electronics Assembly Technologies 2016
April 12–14, 2016
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PCB Expo Thailand
April 19–22, 2016
Bangkok, Thailand

NEPCON China
April 26–28, 2016
Shanghai, China

SMT Hybrid Packaging
April 26–28, 2016
Nuremberg, Germany

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

IPC Reliability Forum
May 17–19, 2016
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College Park, Maryland, USA

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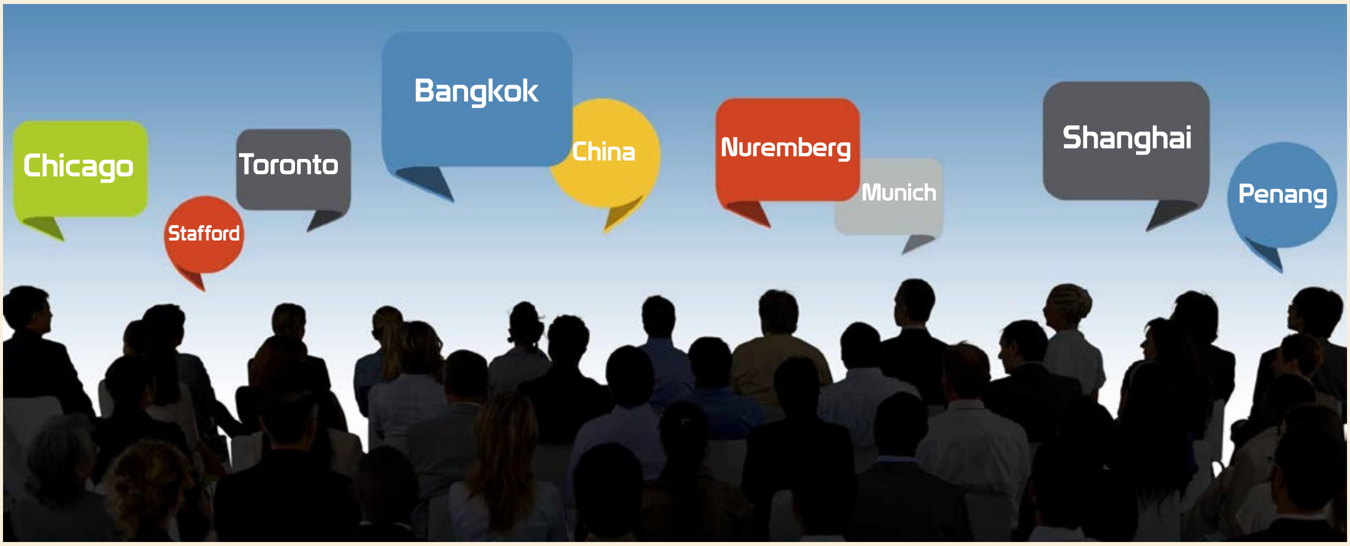

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