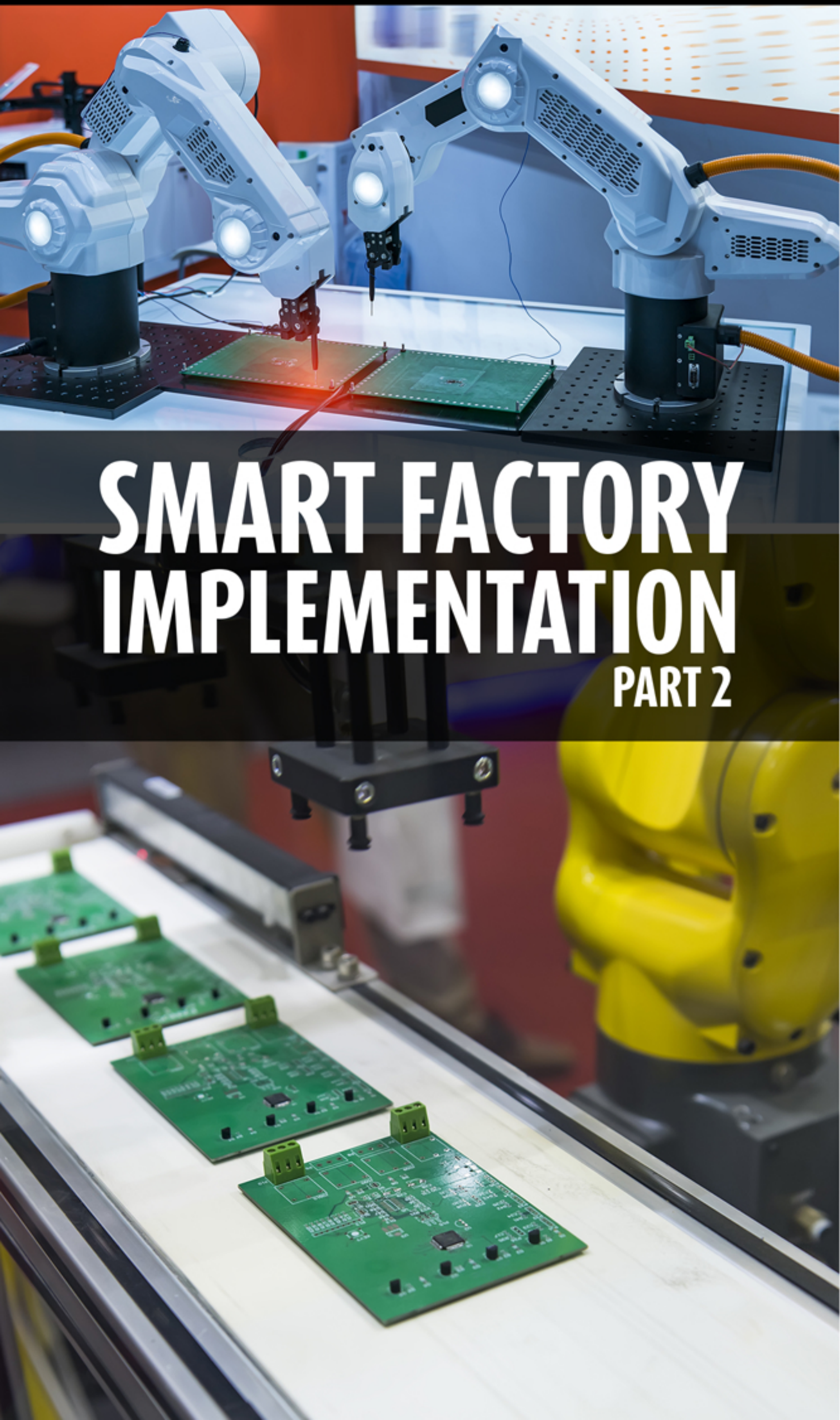
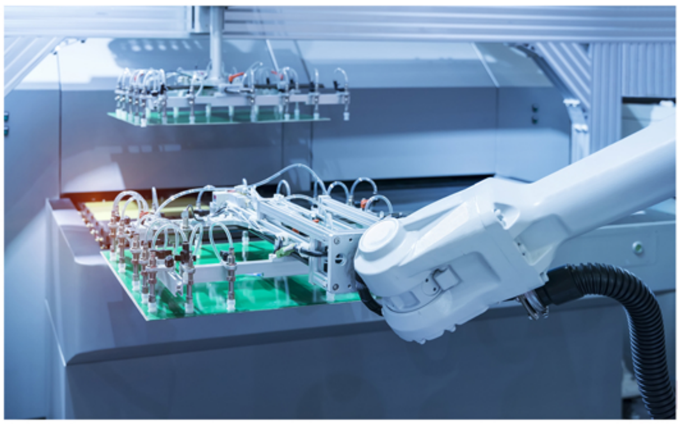
I-Connect007

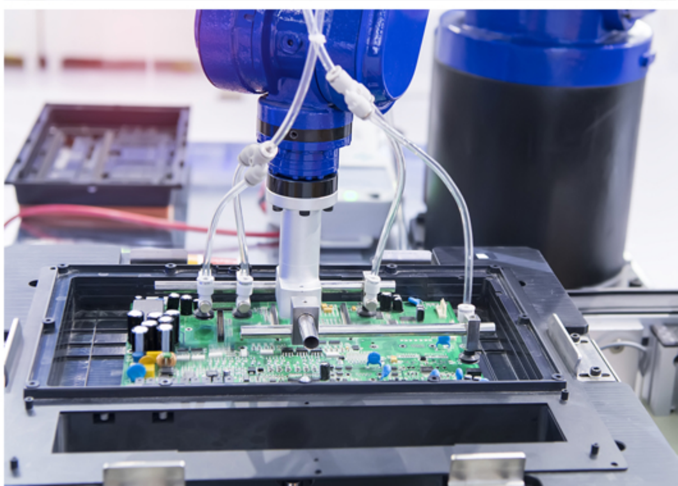
APRIL 2020

SMT007 MAGAZINE



SMART FACTORY IMPLEMENTATION PART 2



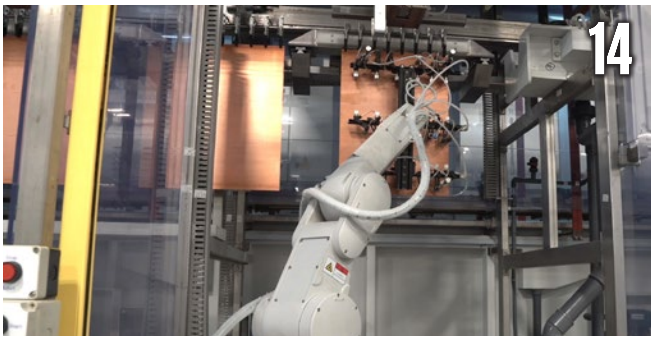



Mitigate the Effects of Tin Whiskers
Expert Phil Kinner explains how conformal coating and cleaning can protect your boards from corrosion and mitigate against the effects of tin whiskers!
LEARN HOW
I-007e Micro Webinars
ELECTROLUBE
THE SOLUTIONS PEOPLE

SMT007 MAGAZINE

Smart Factory Implementation, Part 2

We continue our exploration of implementation details for smart factories with resources and ongoing examples demonstrating that the real innovation in a smart factory comes from your business practices.



SMT007 MAGAZINE


LEAVING THE OTHERS
IN OUR DUST BY INVESTING
IN SPEED & TECHNOLOGY

Smart Factory Implementation, Part 2

Nolan's Notes

by Nolan Johnson, I-CONNECT007

As we put together this issue of *SMT007 Magazine,* the entire world has been responding to the COVID-19 outbreak, adjusting to ever-changing challenges. I-Connect007 has always been a virtual company, so working from home has been the norm. Although I'm still a relative newcomer to the team, I had worked remotely before, so it was an easy transition for me. Thus, our team had one less variable of disruption to our work life than most since we were already home.

But for many families across the industrialized parts of the globe, the home has suddenly become the office, gym, classroom, etc., as well. While we may have done all of these things within the walls of our home before the outbreak, it's different when the whole family is present and must perform all of these roles in the same space, often simultaneously.

During one of our recent interviews, conducted as government leaders around the globe were issuing lockdowns, an industry expert had to pause and whisper some gentle and loving "goodnight and sleep well" words to a small child who was headed off to bed. Under these conditions, we're working with our families and loved ones gathered close. It reminds me that we all have people for whom we do our work, strive to build successful businesses, and make the world a better place.

Making things work while under a COVID-19 sequester can be challenging. The situation requires new thinking and new solutions to long-standing obstacles. The stay-at-home orders have forced the hand for many companies, governments, and institutions to find new ways of doing things, sometimes in as little as 24 hours. Adaptability, along with nim-

ble and quick responses, is the key to success in these times, as well as with digital factory implementations—this month's theme.

During our interview with Andy Kadah and Kevin Jobsky from ICM Controls in Syracuse, New York, about their factory automation work, the COVID-19 stay-at-home orders across the nation were being announced. The situation for ICM was fluid indeed. The company's recent factory automation upgrades put them in place to have many more options with which to respond to changing conditions—an unexpected consequence of their automation upgrades.

Then, we bring you Part 2 of Sagi Reuven's interview on "Business Practices Drive the Smart Factory, Not the Other Way Around," as well as a paper from Ranjan Chatterjee and Dan Gamota, discussing the convergence of standards across the industry. Happy Holden also shares Part 1 of his series on "The Journey to an eSmart Factory."

In this issue, we look at the idea of implementing smart changes from some unexpected angles. John Watson talks with Barry Matties, Andy Shaughnessy, and Happy Holden about "When Your Fabricator Is Late." This conversation proposes some creative and out-of-the-box ways of looking at pricing models for the PCB fabrication portion of the supply chain.

We proudly bring you an extended interview with an engineering superhero: Burt Rutan. This year's IPC APEX EXPO keynote speaker, Rutan graciously sat down with the I-Connect007 team after his presentation. What emerged—in addition to some great insights for airplane geeks like me—was a philosophy of keeping it simple. Rutan's career hinged on finding simple solutions to complex engineering challenges.

Rutan's keynote (summarized by Pete Starkey) stressed solutions that were daring precisely for being so simple, and his conversation with us continued to drive that point home. After all, Rutan envisioned—and then realized—an amazingly simple system to put humans into suborbital space and bring them home again with a fully reusable vehicle in the form of SpaceShipOne. The lesson for our current set of challenges is this: When faced with an onslaught of constraints, tend toward simple-but-daring solutions, and don't be afraid to fail, learn, and revise rapidly. I found inspiration and solace in Rutan's interview; I hope you do as well.

In the meantime, stay safe, healthy, and above all, nimble. Electronics manufacturing is widely considered an essential industry during these times, and we'll continue to be here, bringing you the latest on all of us engaged in this pursuit. There is much to report on these days; we'll keep you informed, and we hope you do the same. **SMT007**

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

Smart Factory Implementation: How Smart Is Smart Enough?

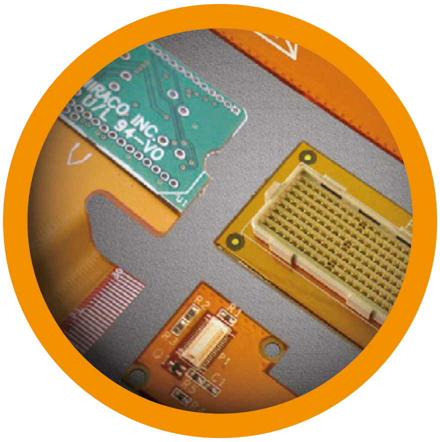
SMT Prospects & Perspectives
Feature Column by Dr. Jennie S. Hwang, CEO, H-TECHNOLOGIES GROUP

As we are moving further into the Industry 4.0 era, rigidity is out, and flexibility is in; stiffness is out, and agility is in; sluggishness is out, and swiftness is in. Responding to the evolving new industrial enterprise—delivering customized products with flexible, modular production flow at optimal economics—becomes necessary. Manufacturing companies need to develop a thorough understanding of the available technologies that can be utilized to translate business objectives into business roadmaps targeting operational excellence to produce competitive, reliable, and economical products that perform in a timely fashion in the marketplace.

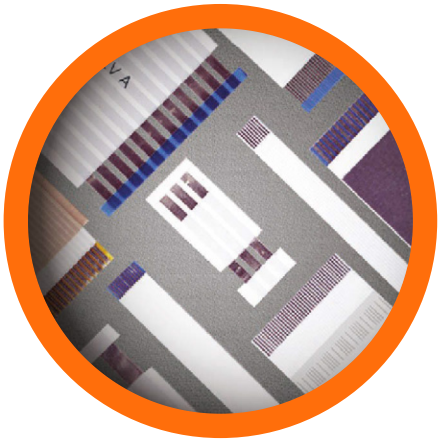
One of the beautiful fruits that Industry 4.0 bears is intelligent manufacturing, which, in turn, is manifested in smart factories. It was reported that about half the activities people are paid to do globally could potentially be automated using technologies that exist today [1]. Yes, we need automation, yet the smart factory is not merely an automation system nor robotic operation. "Smart" comes from the utilization of technologies that are available at our disposal; this includes artificial intelligence (AI), robotics, analytics, big data, the internet of things (IoT), and the advanced network technology (5G and higher).

As the factory of the future, a smart factory is expected not only to run essentially autonomously without human intervention, but also to learn and adapt in real-time with self-correcting and self-optimizing ability. Smart factories lead to a production environment in which production facilities and logistics systems are

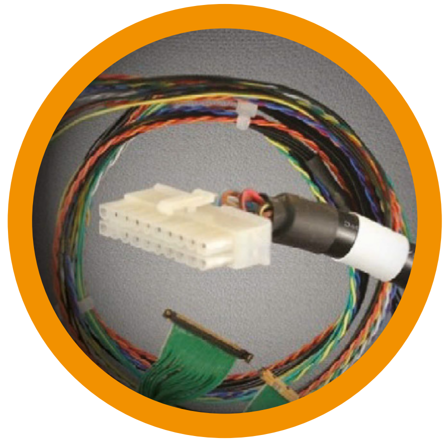
30+ YEARS EXPERIENCE. MORE THAN 30 PATENTS. JUST ONE GOAL.



Flexible
Printed Circuits



Flat Flexible
Cable



Wire
Harnesses

Providing a quality, cost-effective solution on time has been our goal since day one. We achieve this through unparalleled customer service and by designing, sourcing and finishing interconnection systems for our customers worldwide.

Miraco, Inc.
Manchester, NH
miracoinc.com
603-665-9449

MIRACO

synchronized without the need for human tasks. Accordingly, visibility, traceability, predictability, and sophisticated simulations—coupled with speed, agility, and flexibility—are the underlying characteristics of intelligent manufacturing.

In practice, the ultimate manufacturing merits—faster delivery, customized products, less waste, higher yield, lower cost, and on-demand production—can be achieved by a smart factory. As a result, production defects are prevented; preventive maintenance can be pre-scheduled; supply-chain efficiency is optimized; and new product innovation is facilitated.

In practice, the ultimate manufacturing merits—faster delivery, customized products, less waste, higher yield, lower cost, and on-demand production—can be achieved by a smart factory.

This on-demand production can only be accomplished by seamlessly leveraging the powerful tools of a cyber-physical system—namely, AI, IoT, and data analytics. Cyber-physical systems communicate with each other using IoT enabled machine-to-machine communication, machine-to-human interaction. With connected IoT devices, factories can gather data in real-time. AI capable of collecting and processing a colossally large volume of data can analyze the data to provide intelligence based on analytical algorithms. With the convergence of AI and IoT, an intelligent network of devices can be created, capable of gathering and analyzing data remotely and translating that data into intelligence and actionable steps locally.

For example, AI can identify quality problems, such as detecting missing circuit board components and making necessary remediations. It can also analyze data from raw materials, production lines, finished products, maintenance records, and customer complaints. IoT can capture data on workers' safety, energy usage, temperature, and output. IoT devices can also be outfitted on checkpoints in the distribution process, where they can keep track of parts and products as they are shipped from factory to warehouse and beyond. This also enables the formulation of reliable inventory forecasts, the avoidance of unscheduled downtimes, and the timely reaction to unexpected changes in the production line.

Factories' ability to keep track and control of inventory in the actual dollar value of inventory and days of inventory is crucial to the bottom line of a company. Doing well in this area mitigates the mishap of production outpacing demand as well as eschews cash flow traps. Using cyber-physical systems, supply chains will be fully integrated and automated. Cyber-physical systems deployed throughout the value chain generate the linkage between data and material flows, creating the complete visibility of the supply chain, in stationary or in transit state. In maintenance, the connected, intelligent machines can trigger maintenance processes autonomously. Data analytics aids the detection of process inefficiencies, thus reducing production costs. IoT sensors embedded within the products and machines provide information about actual product performance during their service life through data exchange between the production line and the product. Combining data generated and analytics employed offers the capability in predictive maintenance and quality. Additionally, how customers use the products can be monitored, which helps companies in customer services, warranty management, as well as product design.

Cellular technology (5G or more advanced) and augmented vision play a key role as well. The network enables a large number of machines and robots (when applicable) to be connected to the local boutique networks at higher speeds, using smaller antennas. Advanced sensor technology and other embedded technology aid the materialization of unmanned operation in pertinent functions, offering flexibility of on-demand production throughput.

Benefits are evidently abundant, yet challenges tenaciously remain.

With the massive amounts of data from different checkpoints, the challenge in data management takes the front and center seat, including ensuring the quality of data, classifying the data, cleaning the data, interpreting the data, and analyzing the data. The ready availability of workers who have suitable skill sets is another challenge. Although AI serves as the eyes and ears of factory operation and can learn quickly to alert irregularities and to initiate remedial actions, it has to be "trained" and to gain "experiences" to do the job well, such as recognizing production defects without misses and with required accuracy to gain the ability to know when and how to alert humans for necessary intervention.

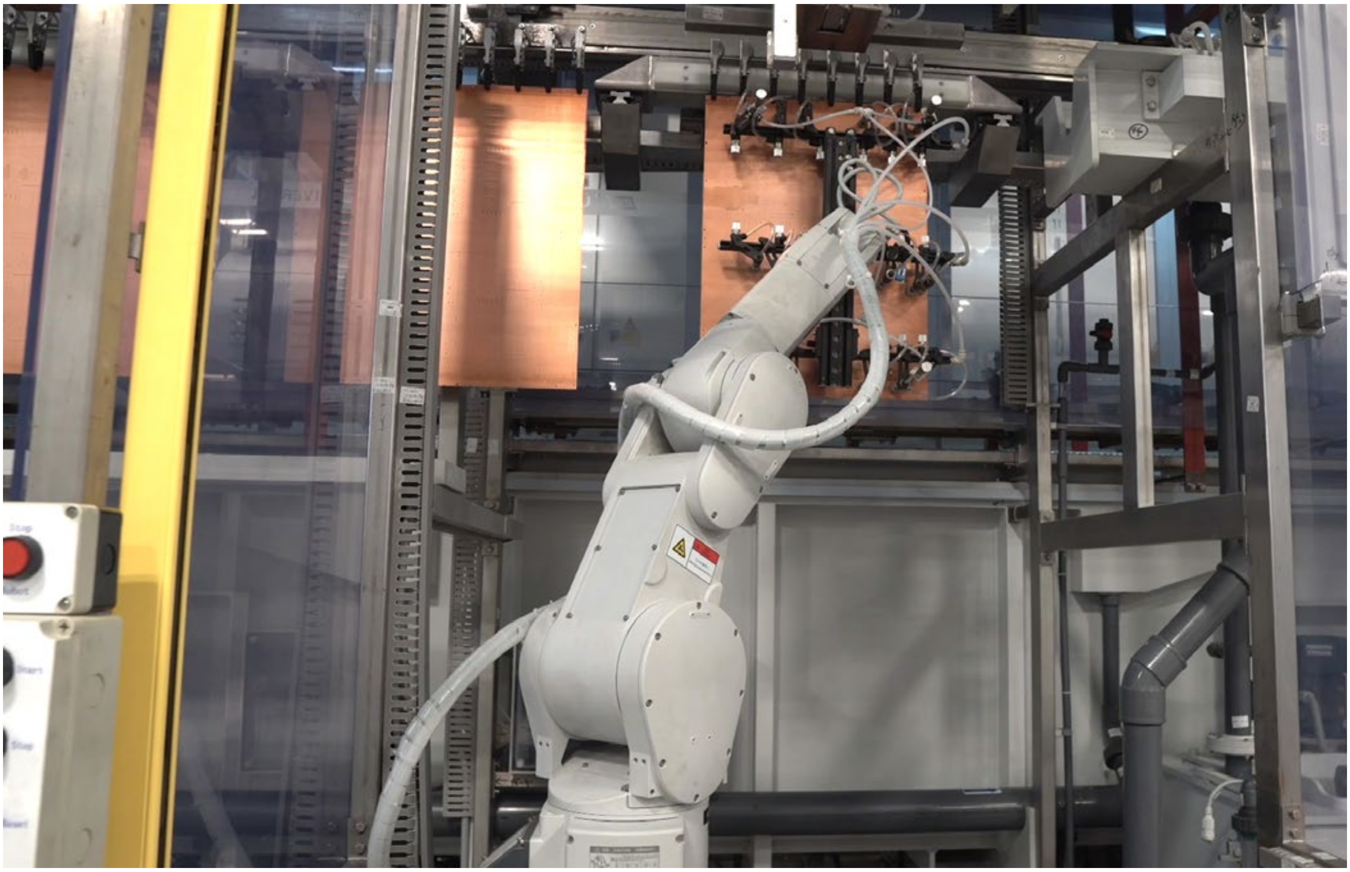
To put a business case forward, a smart factory will be able to be smart enough to deliver intended beneficial results. Then, the question becomes, "How smart is smart enough to a specific operation?"

Each company (or operation) needs to formulate its plan to garner the merits of intelligent manufacturing in establishing a smart factory. As AI and sensor technology continue to evolve, staying in sync with the technologies demands systematic, deliberate, and prudent endeavors. SMT007

Reference

1. J. Manyika, M. Chui, M. Miremadi, J. Bughin, K. George, P. Willmott, & M. Dewhurst, "Harnessing Automation for a Future That Works," McKinsey Global Institute, January 2017.

Dr. Jennie S. Hwang—an international businesswoman and speaker, and a business and technology advisor—is a pioneer and long-standing contributor to electronics hardware manufacturing as well as to the environment-friendly lead-free electronics implementation. Among her many awards and honors, she was inducted to the International Hall of Fame–Women in Technology, elected to the National Academy of Engineering, an R&D-Stars-to-Watch, and YWCA Achievement Award. Having held senior executive positions with Lockheed Martin Corp., Sherwin Williams Co., SCM Corp, and CEO of International Electronic Materials Corp., she is currently CEO of H-Technologies Group, providing business, technology, and manufacturing solutions. She is the Chairman of the Assessment Board of the DoD Army Research Laboratory, serving on Commerce Department's Export Council, National Materials and Manufacturing Board, NIST Assessment Board, Army Science and Technology Board, various national panels/committees, international leadership positions, and the board of Fortune-500 NYSE companies and civic and university boards. She is the author of 500+ publications and several books, and a speaker and author on trade, business, education, and social issues. Her formal education includes four academic degrees as well as the Harvard Business School Executive Program and Columbia University Corporate Governance Program. For more information, please visit www.JennieHwang.com. To read past columns or contact Hwang, click here.



Automation War Stories From ICM Controls

Feature Interview by the I-Connect007 Editorial Team

Members of the I-Connect007 editorial team met with Andy Kadah, president of ICM Controls, and Kevin Jobsky, senior marketing manager, via teleconference on March 20, 2020. Originally, the purpose of our conversation was to discuss factory automation implementation details. Yet, we conducted the interview in the midst of a rapid-fire and wide-ranging onslaught of executive orders from the federal level on down to the local level meant to curb the spread of the coronavirus.

As we navigated the setup and capture of this interview, New York State-level mandates were being announced, shifting the target for the ICM Controls management team on an hour-by-hour basis. One can sense the can-do attitude and urgency to respond to these shifting requirements in the interview transcript.

Although it was impossible not to intermingle the two topics—automation and responses to the COVID-19 outbreak—as a whole, this discussion sheds light on the qualitative changes that factory automation can bring to one's business methods. We pick up the interview a few minutes in.

Nolan Johnson: Let me introduce you to Happy Holden, who is one of our consulting technical editors. He is an industry luminary and a pioneer of HDI manufacturing techniques. Happy spearheaded much of the industry, including a lot of techniques related to smart or automated factories. Happy, before this interview started, we talked about roll-your-own equipment.

Andy Kadah: It's great to meet you. We're crazy engineers here, who also happen to build what we design. We built all the production bench-

BLACKFOX
Premier Training & Certification
Online IPC Training & Certification Now Available
MORE INFO
Experience the Blackfox Difference!
Premier IPC Training & Certification
• High quality training and customer service
• Offering 6 certification programs at 6 locations and online
- Colorado, Arizona, Guadalajara & Queretaro, Mexico, Malaysia and Singapore
• Military Veterans Advanced Manufacturing Program
• IPC/WHMA-A-620 Space Addendum for trainers and specialists
• Online store supporting the training industry
CLICK FOR COURSE SCHEDULE
For more information contact us at 888.837.9959 or sharonm@blackfox.com
www.blackfox.com

es and a lot of our conveyor systems. We build all of our own test equipment, and we're about to go on a little robotics binge because I have some ideas on how we can build some robotic test benches. You would be amused. This facility is an engineer's toyshop. You can dream something up and have it in your hand in a very short period of time around here. We have the electrical hardware design capabilities and embedded software development, along with product design and the capability of 3D modeling the captive circuit board. We also have the contract manufacturing assembly equipment, in addition to the machine shop for building fixtures automation and benches, molding equipment, surface-mount equipment, and test equipment that's all automated.

Happy Holden: One of the sets of blueprints I have is a build-it-yourself hoist handling system for panels that maintenance men can build out of one-inch tubular steel welded. You put it behind the line and load up your batches and hit the run switch, and it runs along the back, dipping the panels—plus, you can still dip by hand from the front, and it uses electromechanical timers.

Kadah: I have the welding facility right here in my tool shop, so if you share it, we'll take a look. As I said, we're crazy; we'll build anything. My dad started the electrical timer industry in 1961 here in Syracuse, New York, with his first company. It was called Syracuse Electronics, and we still make timers today. I can make any kind of timer.

Johnson: Can you walk us through what you have in your products, and what you've been building with your captive facility until now?

Kadah: A lot of our embedded systems controllers contain multiple timers and application-specific logic for the appliance that it is applied to; oftentimes, this means one control board monitors and controls all the appliances that are for heating, ventilating, air conditioning, and/or heat pumps equipment. A compressor will draw a lot of current if you attempt to start it against high head pressure, so we tend to sell hundreds of thousands—if not millions—of what we call anti-short cycle timers that protect vapor compression systems. We make voltage monitors, so if the voltage is outside of your operating range—like a hot day in New York City—three-phase and single-phase voltage monitors take your equipment offline so that it doesn't burn up the system if bad power is applied. We also manufacture surge suppressors for an additional level of system protection.

We make all kinds of thermostats. We make head pressure controls that vary the speed of a fan for maintaining high head pressure in a vapor compression system under low ambient conditions, where cooling is still required even though it's cold outside. We also make heat pump defrost controls, ignition systems for furnaces—including the controls for residential and commercial boilers—oil burner controls, and pool and spa heater controls. We have 1,600 different part numbers we produce in this facility. The facility is 83,000 square feet. We employ 271 people, and we ship about three million controls a year presently. We hope to expand that number going forward, and we don't want to shrink because of the coronavirus.

Johnson: You recently had a fire in your facility, but there was a silver lining because it allowed you to make some changes to some equipment and to automate.

Kadah: Correct. We had a fire on May 30 of 2017 in our circuit board shop. It was on the preclean line that fed the film laminator. This was about a 60-foot-long piece of equipment in modular form, and it was a plastic fire. There were chemicals in the machine, and it was a disaster. About 7,000 pounds of plastic burned, and when the plastic burned, the soot and the chemical vapor went throughout the facility. It cost us over $1 million to clean the soot out of the facility.

As a result, we lost a lot of our wet process production equipment, so we bought all new equipment. We make safety controls for fuel-fired equipment; I was not going to produce

The newly upgraded manufacturing floor in the IMS facility.

those safety controls on fire-damaged equipment. We spent about $7 million in new equipment for our circuit board shop. We ended up selecting UCE out of China because we understood they had the best value. That's how we came to have the first vertical continuous plater in North America installed in our facility. Happy said he knows of or built one earlier!

Johnson: Is that installation working well?

Kadah: It is. I understand UCE sold four or five more lines after we let them do a promotional video, and they brought a couple of their new prospective customers in to look at our shop. We have some robotics in the VCP that load and unload the panels. We have robotics that load and unload the conveyor lines. It's a pretty fancy new shop. It's 18,000 or 19,000 square feet, so it's small, but it has $7 million worth of new equipment in it.

Johnson: You also do some ongoing process monitoring and adjustment. You're gathering data along the line and doing much of what we've come to expect from a smart factory. Yet, at the same time, you're not using any of the new industry protocols to implement that setup.

Kadah: That's true. We didn't recognize that industry protocol. We just developed our own test equipment because fuel-fired equipment requires some attributes to be recorded on those circuit boards at manufacturing. We laser mark all those circuit boards for traceability, and then we developed the testers for them that record the timing attributes, like how long do you open a gas valve before you sense flame, how many seconds do you interpurge the burner before you open the gas valve, and how long it takes for you to recognize the flame was lost. Those are all ANSI requirements.

We developed the test equipment in-house and then made it. Right now, I have around 150 of these testers we built ourselves. We used a Dell computer frame with a power supply. We made all the circuit boards that went in it. For the communications with those circuit boards, we interfaced with our mainframe computer and can now record every serialized circuit board, all the critical attributes, and so on.

If there's ever an issue down the road, where that board was involved in a fire or incident, we have documented evidence to prove that it left our factory in perfect condition. That's how we have maintained our competitive edge. Even though labor costs are less outside of the United States, we have been able to survive because we simply outdesign our competitors. We file the IP. Then, we have a competitive edge that has allowed us to survive when everyone else went off to Mexico, China, Vietnam, Korea, and everywhere else, where the labor was cheap.

Johnson: One of the things you shared as we were preparing for this conversation is that there is a company culture of being nimble and responsive, as well as automated.

Kadah: It's the only way we survive, you know. For example, our competitors are Honeywell, Emerson, and United Technologies. They are very big, and we are very small. We have to float like a butterfly and sting like a bee. We must move around quickly, or we'll get squished. We had a competitor who designed a surge protector built in a plastic box. Surge protectors die for a living, and when the competitor's surge protector units started to die, they tended to catch houses on fire because they were plastic.

Even though labor costs are less outside of the United States, we have been able to survive because we simply outdesign our competitors.

We were asked to enter the market about a year before their product recall. When the MOV goes short, it gets very hot and glows red. I put our surge protector in a metal box. I also did something a little different; I found a source of MOVs that had built-in intrinsic fuses. Right around the time we entered the market with our metal box solution and intrinsically fused thermal MOVs, their recall happened, and we had a field day capturing the market share because their recall corresponded with our release.

Kevin Jobsky: The speed in which we got to market with that product was phenomenal. Outside of UL, we had that design in a week or so, with prototypes and everything else. It was fast.

Kadah: We have to be fast and nimble to survive. It's one of our greatest attributes, in addition to our engineering talent.

Johnson: You mentioned that you have 271 employees on staff. That's a nice size for being nimble, especially with all of the various manufacturing you do. And as we're talking right now, there are a lot of changes going on. We're all in the middle of a bunch of shifts regarding the supply chain and other government-mandated changes intended to respond to the COVID-19 outbreak. How has that affected you in the past few days?

Kadah: We are now rearranging all of our production shifts to maintain compliance with the executive order of Governor Cuomo, which—as of 24 hours ago—was to cut the number of people in your building at any given time in half. As of six hours ago, we got notice that he wants it down to a quarter.

We already have a fairly wide open facility. When we're done rearranging the staff, we're going to have 83,000 square feet, and probably less than 80 people in it at any given time. They said, "Try to maintain a distance of six feet between people." We're going to have 1,000 square feet per person shortly, so we're going to have a very low-density population. This was to responsibly comply with the social distancing requirement and be able to support other essential businesses with the product they need to support the infrastructure during this challenging time.

We'll take every measure that we can, but eventually, they might come back and say, "You have to shut your facility down." Until that point, we're going to comply with every rule they throw at us to keep our facility open. If we go down, then some of our supply chain partners—our customers—go down, and that ripples through this economy. The more companies that go down, the more difficult it will be to recover long-term. We're fighting hard to stay open.

Johnson: You have this ability to adjust your staffing and your operations. It sounds to me like you might be adding additional shifts to spread out your employees and keep as many of them employed as possible.

Kadah: Absolutely. We're going to four shifts. And people will still get weekends, but their weekend might be a Monday and Tuesday instead of a Saturday and Sunday. I've figured out that with 168 hours in the week, I can run four 40 hour shifts and have the extra eight hours as separation time for when people come and go so that I don't have too many people in the building at any given time, even at shift change. We're going to see how it works.

Johnson: It's interesting that you're able to adjust your resources and spread them out thanks to how your facility is set up and still comply with a government mandate to reduce your staff to 25% of normal while keeping everybody employed.

Kadah: We're very open with our people, telling them, "If we don't supply to our customers, and they don't order anything from us as a result of that, then the next choice is layoffs or furloughs or cutting the staff." When we had the fire, no one could enter the building for 18 days due to the air contamination in the building. I had people working all the way through the Fourth of July holiday, and I was flipping burgers outside, cooking them lunch. We went into 24/7 operations at that point. Our employees were interested in maintaining their jobs. We have a tight enough group where we all pull together. We can roll over and lose our jobs, or we can all pull together and make the exceptional effort we need to make to survive. We did it three years ago, and we're going to have to do it again.

Johnson: What's your take on how much your recent factory automation work enabled this nimbleness for you? You're responding to the market and government orders on staffing, keeping your manufacturing up near capacity for your customers. Do you see opportunities for growth based on the automation?

Kadah: For circuit board rebuilds, we replaced the equipment we had and spent an additional $2 million to upgrade what we lost in the fire. We now have additional robot stations that load and unload conveyor systems, including the vertical continuous plating unit that we bought from UCE. The robots came standard on that piece of equipment. We also moved to direct imaging as opposed to film imaging on our circuit boards. We still ended up with a screen printing operation for our solder mask and legend because most of our boards didn't require anything more than that. We were considering going for inkjet printing on the circuit board, but none of the companies could convince us that it was mature enough that we wanted to risk it.

In the wet process equipment, my circuit board manager, Scott Dixon, who has been running that shop for 25 years, realized that he now had the opportunity to do bath monitoring, dosing, and chemistry rebalancing through the control system as opposed to manually checking things with the PLCs built into the equipment. We still manually check the chemistries, but the machines autodose the baths to bring them back into appropriate pH, for instance. And they monitor the turbidity of something and then adjust water accordingly. Our automation will allow for a lower skill level operator, which also enables running multiple shifts.

Here we are now, faced with that challenge. I can't have my top employee work 24 hours a day, so I'm going to have a variety of staffers and rely on the closed-loop feedback systems that we have built into this equipment. I don't think the chemistry is going to get out of whack every 16 hours. There will be a little bit of risk, but we're going to be fine because the frequency at which we have to do a manual intervention right now is weeks—not hours or days.

Johnson: Will this increase your capacity?

Kadah: It will increase the capacity, but not because of the panels per hour. It will be due to the number of hours I can run by allowing us to expand the number of hours per week without having to have the chemist right there babysitting the equipment on the second and third shifts.

The ICM Controls facility in Syracuse, New York.

Johnson: What are you going to do with the extra capacity?

Kadah: The goal is to sell that extra capacity for the support of other essential businesses and, hopefully, capture domestic market share as a result and employ more people here in Upstate New York.

Johnson: In this current environment, you have not only the ability to deliver on all of your in-house manufacturing requirements, but you have the capacity that you can make available to other design teams who may find themselves frozen out from their usual supply chain.

Kadah: That's the whole idea behind pushing this into motion as fast as possible: to help out other companies. Certainly, it will be helping us because we think that the existing business will slow with the economy as a result of the pandemic. However, if we add new things to build and find new customers, we think we can grow through the worst of times. Almost always in a recession, our company grows, and I'm going to give you my take on that.

When everyone's booming, it's difficult to get time out of a purchasing agent or an engineer in a big company. The lines are full, their customer backlog is huge, and they're shipping like crazy. They're complacent and happy. It's during the tough times that those engineers and purchasing agents are being challenged by their managers to reduce cost and or design something new. That's typically when we grow, in recession, which is counterintuitive. That has been true for the last 35 years.

Johnson: If ever there's a case study for taking difficult and challenging times and working it to advantage, there it is.

Kadah: Again, it's because a lot of big companies tend to be so departmentalized; they have to have a big board of directors meeting, and they'll debate it for three months before they move on something. Around here, we'll debate it for three hours, and then we'll go because we have no choice. Similar to shifting all of these people's work times, I have no choice. Within 35 hours or something like that, I have to be compliant with the law. We have to maneuver, or we all have to go home.

Johnson: Andy, thanks for taking the time, amidst all this chaos, to talk with us. It's like you let us into your war room with you during this interview. We'll let you get back to solving these challenges.

Kadah: Thanks, everyone! SMT007

Editor's note: Shortly after this interview concluded, Governor Andrew Cuomo ordered all non-essential businesses to close throughout the state of New York. However, ICM Controls received authorization as an exempt and essential business; read more on that here. As of this writing, the company is staffed and in production.

Seeing Around Corners

Smart Factory Insights

Feature Column by Michael Ford, AEGIS SOFTWARE

Each of us has limitations, strengths, and weaknesses. Our associations with social groups—including our friends, family, teams, schools, companies, towns, counties, countries, etc.—enable us to combine our strengths into a collective, such that we all contribute to an overall measure of excellence. There is strength in numbers. This most human of principles needs to apply to IIoT, smart manufacturing, and AI if we are to reach the next step of smart manufacturing achievement.

There are a lot of very clever software engineers working to develop AI software; though, in all cases seen so far, the intelligence continues to be static algorithm-based, rather than true intelligence that would fundamentally adapt by itself. Perhaps the most common example of such software is emerging from the automotive industry, where many carmakers have established teams of engineers, combining sensors and cameras together with their smart software and striving to make the leap toward completely autonomous driving. Based on this level of engagement, forget it. No matter how clever any individual car becomes, working alone, they will always have to tiptoe around, needing the support of humans, just in case; significant risk of blindness will endure, and no potential risk of an accident will ever be acceptable.

To make a step-change that will attain a higher level of intelligence requires autono-

Relying on only their onboard sensors, automated vehicles are limited by what they can see.

mous cars to simply talk to each other. This can let cars know what is around the next corner and then be able to coordinate actions such that cars as a group decide what to do together, safely. There may even be input from fixed stations, such as at intersections so that there is less dependency on live traffic at critical points. The dependency on having faultless internal sensors is then avoided, as confirmation of observations and events can be confirmed, taking data from multiple sources and immediately exposing any inconsistent or erroneous input.

The technology to do this is relatively simple, especially with advances such as 5G and Wi-Fi 6 that support improved speed and latency. In addition to how data is moved around the network, there is also the need for a common language to be developed and adopted through which each car speaks to any other, which—of course—must be carmaker agnostic. Research and development of vehicle-to-vehicle (V2V) communication are ongoing, although the common language remains to be defined with a focus so far on describing what cars are doing rather than what they "see."

Without such standardization, it is not likely that there will be enough of any one type of car on the road to provide a good service. Enhancing competition through the restriction of communication would likely destroy the ability to progress and be sustainable. Such a lesson has already been learned in assembly manufacturing. For those familiar with the IPC-CFX (Connected Factory Exchange) IIoT standard, every topic, message, dataset, and content is determined by the standard itself such that there is never any translation or conversion of CFX data by any form of middleware required.

The exact facts related to any situation can be received and acted upon immediately. For autonomous driving to become a practical reality, a CFX-type language definition is required, with carmakers working together to create an interoperable solution. Every other aspect of driving has almost always been standardized—such as pedal positions, the steering wheel, and road signs and markings—so this should not be a surprise. The human element of the design has always been there.

The IPC-CFX standard has achieved a great deal, breaking down barriers of data exchange, eliminating the massive waste of time and money across the industry related to bespoke, customized machine interface connections, which collectively would have led to costs to the industry of many billions of dollars. With any and all machine vendors and software solution providers now, in principle, only having to develop and support one interface natively—and with the removal of the need for middleware—CFX demonstrates the advantages of collaboration in key areas of technology, building the mechanism on which to effectively offer competitive solutions, which can all share and exchange data appropriately and securely.

In manufacturing, we now look toward the next phase of standardization. The challenge is for us to extend interoperability and dataflow beyond simple shop-floor communication. We know that a single company—no matter how large they may be—will never be able to bring a single solution for Industry 4.0 or smart manufacturing. From some vendors, however, we see demonstrations of amazing, Hollywood-inspired 3D user-interface graphics, which—in many cases—are simply gimmicks intended to distract customers from the short-comings of the solution, hiding the lack of depth of scope and support, as well as the need, almost always, for extremely expensive bespoke customization.

It is an unfortunate practice of many companies in the industry to reveal the true cost of setting up and using solutions only after an initial purchase order has been given and an irreversible commitment made. This is not a sustainable business model and is regarded by many as being akin to "poison" in the market in that those taken in by such promises no longer trust anyone's solutions and are, therefore, hesitant to move forward. In the real world, there are simply too many distinct areas within overall assembly manufacturing, each of which needs to be understood at a detailed level—such as comparing the processing of real-time X-ray image-based defect detection—with the need to manage moisture-sensitive materials. As with our human social groups, the focused skills and strengths of different companies need to be combined for the best results.

The new IPC-2551 digital twin standard currently in development seeks to create an environment of interoperability that allows solution and technology providers to collaborate, exchanging information, together bringing an order of magnitude greater value than could be achieved through any single disconnected source. The IPC digital twin standard sets out the top-down hierarchical structure, through which applications can identify and communicate active and useful elements of digital twin data, in any depth of detail, using standard formats.

The intention is to utilize existing open standards throughout the various levels of detail needed, with references—for example—to existing related IPC standards, such as IPC-2581 (Digital Product Model Exchange DPMX), IPC-2591 (IPC-CFX) and IPC-1782 (traceability). Non-IPC standards, such as JEDEC JEP-30 3D component data standards, are also being considered. This is expected to fast-track adoption of the IPC digital twin standard, without having to reinvent current standards and radically change data flow practices.

Though the development of the IPC digital twin standard is still ongoing and, therefore, subject to change, the organization of the digital twin infrastructure is currently as follows. The root level of the cellular IPC digital twin standard is referred to as the "global" cell, comprising three hierarchical root structures, each of which represents key areas as follows.

1. Product

The IPC digital twin represents either a single product design instance or a range of closely related product variants and revisions. Information includes:

a. The design intent, including specification, requirements, use-case metrics, environmental limitations, etc.
b. The mechanical and electronic design, including 3D representations.
c. The intended bill of materials, including vendor selection, engineering change history, variant definition, etc.

2. Manufacturing

Includes the complete hierarchy of assembly manufacturing facilities, starting at the enterprise level, breaking down into sites, discrete configurations, lines, cells, machines, and beyond, each modelled in terms of their specification, capabilities, performance, and yield based on design features.

3. Lifecycle

Includes details of the product shipping, application, and usage, comprising market data, such as repair, all the way to ultimately recycling. Information is included to connect products should they be combined with others, such as in the case that a product becomes a sub-assembly of a larger product.

Each cell within the IPC digital twin is identified by a unique name and has an indexed table of contents that declares the data content and the degree to which the data has been populated and confirmed. Each application using data from the IPC digital twin will know exactly what data is available, how reliable it is, and any gaps that may need to be populated before any processing of the data can be done.

There are literally hundreds of different use cases of digital twins throughout the holistic manufacturing process to which the IPC digital twin standard will be applied. With known and established standards utilized where possible, new open formats will be created where necessary to fill in gaps. Data structures are likely to be encoded using XML or JSON. There may be multiple choices of data formats in certain cells if there are multiple standards suitable and applicable, including in the area of 3D visual model representation, for example.

A typical use-case example that illustrates the true power of the digital twin at the highest level might be as follows:

1. An EMS company receives an IPC digital twin from a customer as part of a request for quotation, representing a range of products. The customer requires information about the unit cost of manufacturing versus quantity, leadtime, choice of manufacturing locations, a commitment to quality, and information about materials.
2. The EMS company has an IPC digital twin of its manufacturing organization that includes several sites. Each site has many production lines and cells.
3. The EMS quotation team has an application that takes the product digital twin from the customer and processes it against their internal manufacturing digital twin.
4. Questions and responses are triggered from this application to multiple sub-applications, that may, for example, go into the different associated areas of manufacturing, down to increasing levels of detail. External systems such as MES and software associated with specific equipment may also be automatically contacted digitally as part of the process. Sub-applications work together to provide the data that contribute to the analysis. Some will assess which production configurations

Made in USA

Your American-Made Partner For

BARE BOARDS • ASSEMBLY • TURN-KEY BOX SOLUTIONS

Experienced, Dependable, Affordable and Local.

Check out our Manufacturing Videos and Request a Quote Online at www.icmcontrols.com

36-Years of Printed Circuit Board Production, Assembly and Manufacturing Expertise

Offering Bare Board, Assembled and Complete Turn-Key Box Solutions

84,000 Sq./Ft, Vertically Integrated World Class Facility

Millions of Controls Produced Annually

$7-Million Dollars in New Automated Equipment in Last 12-Months

High-Volume Surface Mount and Through Hole Production Lines

Adherence to IPC Class 2 Standards or Higher

100% Optically Inspected; First Pass Yield Rate of 99.7%

RoHS & REACH Compliant

Globally Competitive Pricing

Quick Turn-Around Times Available

In-house Plastic Injection Molding Capabilities Available

In-House Hardware, Software and Product Design Engineering Services Available

Extensive Component Library for Maximum Design Flexibility

Contact Us Today for Full Specs and Capabilities!

ICM® CONTROLS

Follow Us:

Intertek

7313 William Barry Blvd., North Syracuse, NY 13212 • 800-365-5525 • www.icmcontrols.com

are capable of making the product, and, if so, what would be the expected line rate and yield, etc. At the same time, other applications will confirm the material and availability of capacity.
5. All of the data is collated and fed back automatically upstream to the quotation application, which then offers the choices for the quotation team, including costs.

Another example could be where a manufacturing site has the allocation made of products to a specific configuration, which includes the setup of robots, requiring both optimization and simulation. Taking the applicable cells from the product digital twin—together with the manufacturing digital twin cells that represent the robots—the appropriate analysis takes place using an application that is dedicated to a deep knowledge of robot operations, including the robot arms, conveyors, associated tools, etc., such that the exact operation of the line can be assessed. This application can run as a result of many cases. Some examples include:

1. Needing to know the processing time of a potential new product, as seen in the previous example.
2. Determining the features of the line to support near-term manufacturing expectations in a way that is specifically optimized in terms of tooling and flow, choosing from a selection of potential configuration changes.
3. Finding the best sequence of events needed to run the line, including the prediction of maintenance events.

Each of the hundreds of applications of the IPC digital twin is interoperable with each other through the data definitions defined. Applications are developed, provided, and executed without the need for customization and middleware, interoperable with other applications from different vendors.

As the development of the IPC digital twin is ongoing, successive layers are likely to be added over the coming months, until every aspect of product design, manufacturing, and lifecycle are included. The speed with which this is done very much depends on interest and participation from the industry. As there are many products available on the market which are based on proprietary digital twins, there are many opportunities on the horizon to evolve them into being aligned with this industry standard.

As seen with the revolution in shop-floor communication using IPC-CFX, the design through manufacturing flow using IPC-DPMX has seen barriers between companies in terms of data exchange come down when it is realized that there is a true mutual and business need to share and utilize big data from multiple sources to effectively achieve a desired goal. The interoperability that the IPC digital twin provides enables companies to provide their specific value to customers in a way that does not require specific collaboration using proprietary data formats between companies, supporting the protection of intellectual property, whilst also having increased functionality and capability.

As with the autonomous car, having access to data from outside of a specific sphere of visibility enables applications to "see around the corner" to be able to build value that is far greater than had they been limited by data obtained only from within their own domain, or through expensive middleware and customization.

In the future, software with futuristic 3D interfaces, and amazing graphics will have substance behind them, as is normally experienced when working with companies that are instrumental in creating and utilizing IPC standards. Ultimately, the awareness of the business differentiation that this kind of technology brings—in terms of costs, return on investment, quality, and dependability—will drive the IPC digital twin forward, benefiting the whole industry. **SMT007**

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

Business Practices Drive the Smart Factory, Not the Other Way Around (Part 2)

Feature Interview by the I-Connect007 Editorial Team

In Part 2 of this conversation, Sagi Reuven—business development manager at Mentor a Siemens Business—continues his discussion on how smart factory implementations must start with traditional process analysis and improvement before the data capture process is useful. Read Part 1 of this interview in the March 2020 issue of *SMT007 Magazine* here.

Johnson: Sagi, we started out this conversation with the proposition, "How do you transform your brownfield site—your existing facility—into a smart factory?" So far, we've learned that converting to a smart factory is not necessarily about the equipment; it's centered around business practices, and manufacturers don't necessarily need to go build a brand-new greenfield facility to implement a smart factory. What you need to do is be "greenfield" about how you think about the operation of your business. We left off with materials as the first place your customers usually start their smart factory transition. If the compelling event to get them off the dime and moving is material handling, where do they tend to go next?

Reuven: Usually, they start with the basics of data acquisition, including IIoT. This will be the first step if they don't want to do it all at once. They will do basic data acquisition and look into some dashboards and analytics; one example could be around optimizing the changeover. Then, the second step would be advanced material management like ERP visibility, such as just-in-time delivery, including AGVs and material towers. If the material is about to be fully consumed on the machine, it will send a notification to the storage tower or the operator in the storage that you need to put a new reel in the machine so that it will keep on working. Again, when you look at the numbers, it saves 3–4 minutes, but I want to go back to the numbers.

The margins in electronics are very small. You have a 7–8% margin because the material is super expensive. If you save three minutes on one machine, there are three machines per line, and the line is working 20 hours for six days a week, you can multiply the three minutes that the machine stops because you need to bring a new reel and change it since it didn't bring it on time. When you're thinking about it from the basic level, you would say, "I don't need to invest $100,000 in a software piece that will save me three minutes." However, there is no problem here.

Johnson: That three minutes of time, accumulated, can double your margin.

Reuven: Exactly. You should not think, "I don't have a real problem because three minutes is not a big deal. I will get the reel and replace it. No problem. It's fine."

We had one customer who had three SMT lines in their factory. They didn't have enough capacity, and they were considering the purchase of another line. The people who usually buy the machines said, "We just need to buy another line. Let's do it," but someone at the operator level that was not fully convinced.

The operator did some drill-down to analyze the situation, including finding out what the real usage and availability were and where the bottleneck was in the manufacturing process. The operator made some calculations using very simple analytics. I'm not talking about machine learning or artificial intelligence—just basic analytics, asking some questions and looking into the data. They concluded that, on average, they wait 60 hours a month for the reflow oven. With that, they went back to the department that was pushing to buy another line and said, "We can just buy another oven and move the PCBs that are stuck over to the other oven." I think it was a difference of $1.5 million in purchasing the new equipment.

Matties: How do we get more people excited? We've talked a lot about what the barriers are, whether it's labor, skill, expertise, or finances, but it's going to be the leaders that have the greatest opportunity to gain from this situation.

Reuven: In all my sessions, I'm trying to continuously explain to them that the three things are combined: digitalization, innovation, and excellence. Again, I go back to my startup mentality. Innovation doesn't have to be to the extreme. You don't have to change the entire length of the line with robots or AGVs. Innovation can start with something very basic. You can innovate by improving your changeover by 20%. If you improve the changeover in your factory even by 10%, you reduce the time by two or three minutes and will be the employee of the month.

Again, I go back to my startup mentality. Innovation doesn't have to be to the extreme.

Johnson: Your point is contained in your earlier anecdote. Basic shop floor utilization brought a different conclusion. "We need to buy another oven." That's innovative.

Reuven: Yes, but it's a mindset. This person that was skeptical about buying an entire line and said, "I want to find out what's going on here. I want to look at the numbers. I want to see how we are using the equipment." It's okay if you don't have this ability, a floor manager, or any kind of basic dashboard of analytics that you can drill down because you don't need to be a data scientist. You don't have to do machine-learning algorithms or predictive maintenance to find out the solution, but you must be open to the fact that there may be a better way to do it.

Once, our business consultant visited a customer to look at how many lines, etc. He sat there for about a week with a stopwatch, measuring various things, and came back and said, "They're only using 40% of the machine capacity they have." Again, every line in this business costs $1–2 million dollars. From their perspective, they are at full capacity of production compared to planning. They're not taking new jobs.

Sagi Reuven

Matties: Part of the problem is there's no clear roadmap for people. There's a lot of confusion about "Beta vs. VHS" and whether various formats will be compatible down the road. There's a lot of uncertainty.

Happy Holden: This same question has been asked for the last 40 years once we started buying automatic machinery instead of using people to put parts into holes on circuit boards. It comes back to the fundamental business basics, like Sagi was saying, in terms of a person sitting there with a stopwatch. How much of the time is that machine being used? How much is set up? How much time are you losing if you're looking for the part that we need? A lot of times, that basic information isn't available. You buy the line, do some kind of scheduling, and it looks like everybody's busy, but when you use a stopwatch and characterize it, there's a lot of room for improvement.

Matties: It still comes down to logistics. It reminds me of an interview I recently did with Frank Lorentz, who is the operations manager for Ventec International Group, a laminate supplier out of Germany. Frank came from the newspaper business, and his background was logistics. He has been doing what you've been saying factories need to do: benchmarking. He reconfigured their factory, and the results have been amazing. Frank had no knowledge of laminates, but he understood business processes and made a huge difference. He brought a paradigm shift. It seems like that's what you're talking about; you have to change your thinking first before any of this is going to make sense.

Johnson: That seems to be the theme of the conversation. It's easy to buy equipment, but it's harder to change your thinking.

Matties: Perhaps the people you already have in place aren't the people that you need to have thought about the solution. You may need a fresh set of eyes to come in.

Reuven: I can give you another example from a telecommunications company. They wanted to measure the operator efficiency, and the only thing that they did was develop a dashboard on a big-screen TV. The dashboard data was coming from a shop floor management system showing how many boards and panels were produced, how many components were placed, as well as yields and recipe changes. It was all very basic information. There was no machine learning, algorithms, or buzzwords, basic stuff—just equipment utilization, OEE, inventory turnover, and waste.

They put a big-screen TV on every line in the canteen, so the data was visible to everyone all the time. They increased the units that they were shipping by 25%. They had the same people and resources, but it was all about visibility. Seeing it was impactful.

It's like having a Fitbit. A couple of people in the office have Fitbits, and they look at them all the time. They say, "I've only walked 2,000 steps. I'm going to take the stairs," and then they do it. It only counts your steps, but the fact that you have it in front of you all the time changes something. They walk more as a result.

Matties: We feel the same way. Especially in a virtual company like I-Connect007, we have to make our systems and work visible to each other. The more we do so, the more understanding we have for how one process connects to the other and the impact that we have upstream and downstream, and with internal

The best way to get a return on investment is to collect and leverage the data.

and external customers. That visibility changes the way people work. You're absolutely right.

We've covered a lot in this conversation, and we appreciate your insights. If you were to summarize for our readers what this boils down to, what would that be?

Reuven: The best way to get a return on investment from one of the Industry 4.0 pillars is to focus on collecting and leveraging the data in the best way you can.

Matties: In today's world, data is everywhere; there's an overload of data. What recommendations would you have for prioritizing the data that you collect?

Reuven: Start with the very basic information, not only knowing your OEE but also knowing what lies behind it: utilization, availability, things about your material like your inventory turnover, waste costs, etc. You need to know your DPMO. Are you close to the industry standard or not? Do you use the maximum capacity of the machines you spent millions of dollars on or not?

Matties: You're talking about performance characteristics.

Reuven: Yes. You can become excellent and improve your profit by asking the right questions and looking at your data.

Matties: Once you have this snapshot, then it becomes pretty easy to decide where you need to start making the digital factory investment initially; then, you can either step into it or go all in. At that point, you're going to be doing it with some real intelligence.

Reuven: Right. You are going to make smart decisions and put the robot that you need in the right place.

Matties: Smart decisions for a smart factory. It makes sense. Let's assume that they have done this thinking and have their snapshot. The other concern is financing. This is an expensive proposition. What sort of investment by a relative index, percentage of revenue, or whatever the gauge is, should they be thinking about to convert to a smart factory?

Reuven: It depends on to what extent, but if you go step by step, the basic investment is not that high. It's very cheap compared to any piece of equipment that you buy. For instance, to connect four SMT lines to get analytics and maybe do very basic material management is about half of the cost of one pick-and-place machine. You can return the investment in 6–9 months.

Matties: That's pretty substantial in savings or costs, depending on how they look at it. When we talk about a digital factory, we have the idea that it's almost a lights-out factory, and that a board comes in and has a barcode. That barcode automatically adjusts the machine to whatever settings it needs for that particular job. That job runs through, and then the next board comes with the barcode, and it's automatically adjusting the equipment. There are two parts to automation: one is mechanizing, moving the boards around, and the other is process control automation where you're recipe-driven. When you talk about 4.0, are you talking to that level, or are you talking data acquisition?

Reuven: We also talk to that level, not just the data acquisition.

Matties: When you look at that lights-out level of automation, there is a lot of front-end input and engineering before the job even hits the factory floor because you're going to have to set all those parameters up front. When the barcode hits, the machine understands what it needs to do. What sort of investment are people putting in the front end of their factories for a digital manufacturing environment?

Reuven: It varies a lot. As I mentioned earlier, we have different types of customers. Some of them have global IT and innovation groups, and they take it in this direction, while some of them want you to do everything.

Matties: But do you see an increasing emphasis in the digital factory on hiring the front-end workers to interpret the data coming in and making sure that it fits into their manufacturing ecosystem?

Reuven: We see that more and more, slowly. I think it's because it's hard to find or train them, not because they don't want to.

Matties: Is that the employee of the future?

Reuven: You could say that. The employee of the future will know how to maximize equipment usage with simulation, planning, scheduling, and analytics.

Johnson: There's yet another silo that's outside the scope of this conversation: the front end and the business practices.

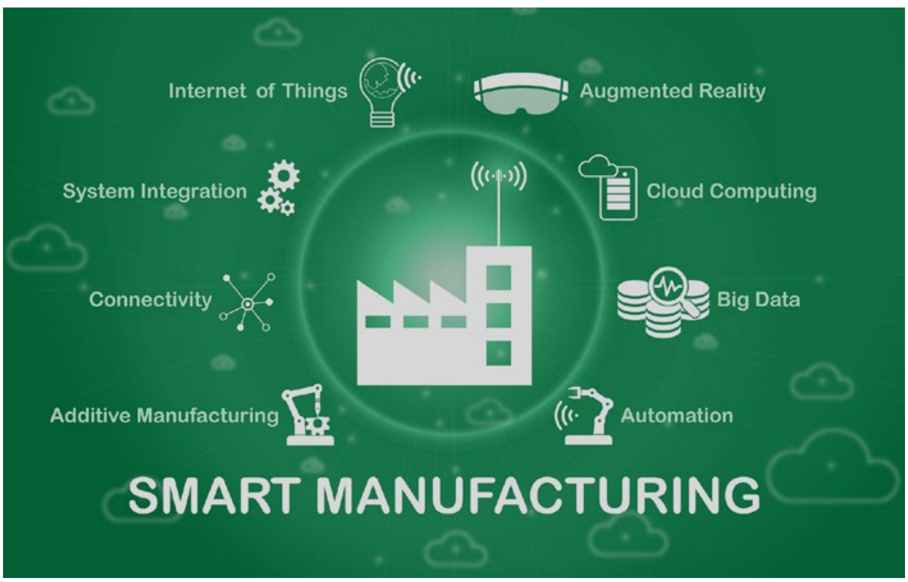
Matties: Because it's all going to start with the way that the job enters into the factory.

Reuven: Yes.

Matties: What questions do you get about front-end work in your workshops?

Reuven: It's connected to the end-to-end vision, which is the reason why Siemens acquired Mentor. The first thing is that they understand that now electronics are in almost every product. You cannot say this is electronics, and this is a mechanical product. Siemens had a lot on the mechanical side, and Mentor Graphics has all expertise and solutions together with what we do at our division at Valor because we cover everything. We now have new partners in Siemens and two new products; the first one is the MES for electronics, and the second one is the integration between engineering to PLM. We have the design tool, and then it goes to design for manufacturing. This is the part where you process everything, simulate it, and check if it can be manufactured in the way that it was designed; then, you go to the process engineering part.

This is the part where you take it, start to crunch it, and check if you can do it with this machine or another one. You also run a virtual simulation. You manufacture it, identify some issues in advance, and say if it's not testable. "I thought that I would be able to easily test it." Only then, assuming you use this end-to-end approach, can you publish all your plans, including everything that you did, and



simulate it after you fixed it a little bit. You can publish it to the next step, which is in the manufacturing area.

Matties: Is this where the phrase "digital twin" comes into play?

Reuven: Exactly. It is the digital twin. The idea from Siemens is that now you're able to have it on both sides—from the mechanical side and the electronics side.

Matties: If you build it on the digital side first, then it becomes predictive, and you are predicting the output.

Reuven: Yes. Again, it can be very simple things. Can I test the board in an effective way? We found out that some of our users even use the DFM/process engineering tool; they use it for quotation purposes. Even before they get the job, they simulate it and say, "I want to charge you X plus 10% because your design is going to cost me with some challenges."

Johnson: Sagi, thank you very much for the information. This has been very helpful. The big takeaway for me is in changing management's thinking much more than changing the equipment or the processes. You need to look at your business to make Industry 4.0 happen; it doesn't happen just by buying sensors and collecting data.

Reuven: Exactly. I'm happy that I managed to express my mindset.

Matties: Thank you very much.

Reuven: Thank you. SMT007

Showing Robots How to Do Your Chores

Roboticists are developing automated robots that can learn new tasks solely by observing humans. In the workplace, you could train robots like new employees, showing them how to perform many duties.

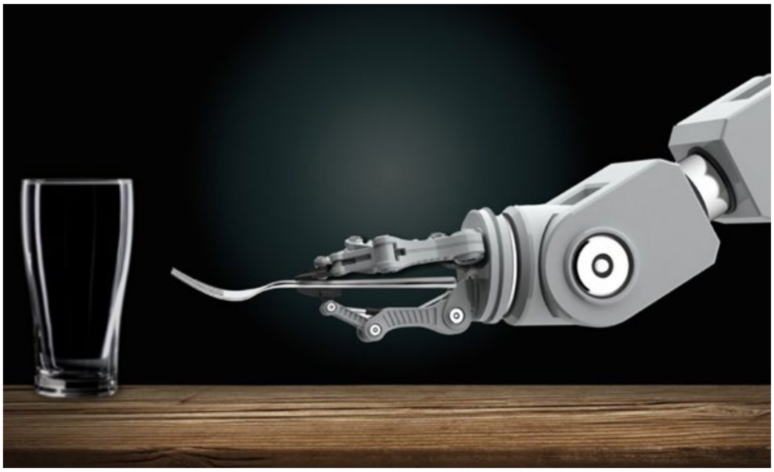
Making progress on that vision, MIT researchers have designed a system that lets these types of robots learn complicated tasks that would otherwise stymie them with too many confusing rules. One such task is setting a dinner table under certain conditions.

At its core, the researchers' "Planning with Uncertain Specifications" (PUnS) system gives robots the humanlike planning ability to simultaneously weigh many ambiguous—and potentially contradictory—requirements to reach an end goal. In doing so, the system always chooses the most likely action to take, based on a "belief" about some probable specifications for the task it is supposed to perform.

The researchers compiled a dataset with information about how eight objects—a mug, glass, spoon, fork, knife, dinner plate, small plate, and bowl—could be placed on a table in various configurations. A robotic arm first observed randomly selected human demonstrations of setting the table with the objects. Then, the researchers tasked the arm with automatically setting a table in a specific configuration, in real-world experiments and in simulation, based on what it had seen.

To succeed, the robot had to weigh many possible placement orderings, even when items were purposely removed, stacked, or hidden. The researchers' robot made no mistakes over several real-world experiments, and only a handful of mistakes over tens of thousands of simulated test runs.

(Source: MIT News Office)



SMT007 Supplier Highlights

ACDi's North Carolina Manufacturing Plant Installs New Koh Young 3D SPI and AOI Equipment

ACDi, a leading electronics manufacturing services provider, announced the most recent capital investment in PCB inspection technology and equipment at its Nashville, North Carolina, factory.

Rehm Redesigns ViCON Protecto System Software to Improve Dispensing and Coating Systems

ViCON has now been redesigned for the special requirements of the dispensing and coating systems of the Protecto series (ViCON Protecto).

Z-AXIS Invests $1 Million in PCB Assembly Equipment at Its Rochester Contract Manufacturing Center

New SMT lines double the company's capacity for surface-mount technology PCB assembly and address the growing demand for electronics manufacturing services in the USA.

Mycronic Receives Order for a Prexision 800 Evo

Mycronic AB has received an order for a Prexision 800 Evo mask writer for display applications for deployment in Asia. The order is valued at USD 35–40 million. The delivery of the Prexision 800 Evo is scheduled for the first quarter of 2021.

Electrolube's New Thermal Gap Fillers Prove a Success for Multiple Applications

Electrolube has launched a new range of thermal gap fillers that provide a highly effective heat transfer solution for many different applications. The new gap filler range includes the GF300 and GF400 products. Both of these thermal interface materials are two-part, liquid silicone-based fillers, which provide excellent thermal performance of 3.0 W/m.K (GF300) and 4.0 W/m.K (GF400).

Weller's Dyan Reagan to Lead West Region's Field Sales Team

Weller Tools, the world's No.1 brand in hand soldering solutions, announced that Dyan Reagan's role within the company expanded to include the duties of the West Regional manager.

Restronics to Represent All KIC Products

KIC announced the appointment of Restronics Co. Inc. David Leventhal, Steve Clair, Jarred Mandel, and Teddy Skechus would cover New York, New Jersey, and East Pennsylvania for all KIC products. Restronics is an established manufacturers' representative in the electronics OEM industry.

Data I/O Announces New Distribution Partnership With NOA Leading Co. Ltd. in Japan

Data I/O Corporation, a leading provider of manual and automated device programming solutions, announced the company completed a distribution agreement with NOA Leading Company Ltd. for representation and sale of Data I/O products in Japan.

MIRTEC Presents Murray Percival Company With Award for 60th Year in Business

Murray Percival Company, supplying the Midwest's electronics industry, was pleased to accept an award from MIRTEC during IPC APEX EXPO 2020 in honor of the company's 60th year in business.

The Convergence of Technologies and Standards in Smart Manufacturing

Feature by Ranjan Chatterjee, CIMETRIX,
and Daniel Gamota, JABIL

Editor's note: Originally titled, "The Convergence of Technologies and Standards Across the Electronic Products Manufacturing Industry (SEMI, OSAT, and PCBA) to Realize Smart Manufacturing" this article was published as a paper in the Proceedings of the SMTA Pan Pacific Microelectronics Symposium and is pending publication in the IEEE Xplore Digital Library.

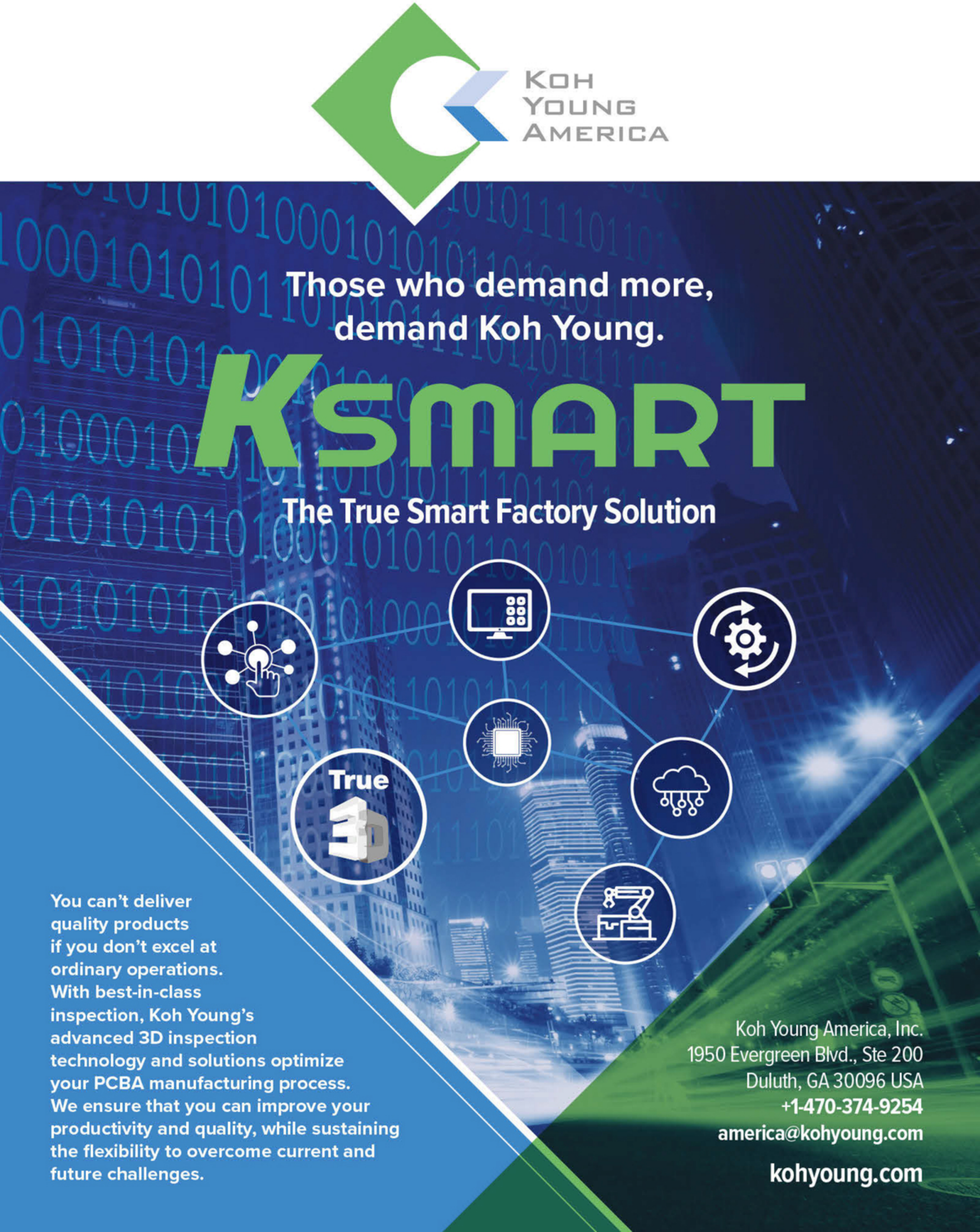
Abstract

The vertical segments of the electronic products manufacturing industry (semiconductor, outsourced system assembly, and test, and PCB assembly) are converging, and service offerings are consolidating due to advanced technology adoption and market dynamics. The convergence will cause shifts in the flow of materials across the supply chain, as well as the introduction of equipment and processes across the segments. The ability to develop smart manufacturing and Industry 4.0 enabling technologies (e.g., big data analytics, artificial intelligence (AI), cloud/edge computing, robotics, automation, IoT) that can be deployed within and between the vertical segments is critical. The International Electronics Manufacturing Initiative (iNEMI) formed a Smart Manufacturing Technology Working Group (TWG) that included thought leaders from across the electronic products manufacturing industry. The TWG published a roadmap that included the situation analysis, critical gaps, and key needs to realize smart manufacturing.

Introduction

The future of manufacturing in the electronics industry is dependent on the ability to develop and deploy suites of technology platforms to realize smart manufacturing and Industry 4.0. Smart manufacturing technologies will improve efficiency, safety, and productivity by incorporating more data collection and analysis systems to create a virtual business model covering all aspects from supply chain to manufacturing to customer experience. The increased use of big data analytics and AI enables the collection of large volumes of data and the subsequent analysis more efficient.

By integrating a portfolio of technologies, it has become possible to transition the complete product life cycle from supplier to customer into a virtual business model or cyber-physical model. Several industry reports project manufacturers


KOH YOUNG AMERICA
Those who demand more, demand Koh Young.
KSMART
The True Smart Factory Solution
True 3D
You can't deliver quality products if you don't excel at ordinary operations. With best-in-class inspection, Koh Young's advanced 3D inspection technology and solutions optimize your PCBA manufacturing process. We ensure that you can improve your productivity and quality, while sustaining the flexibility to overcome current and future challenges.
Koh Young America, Inc.
1950 Evergreen Blvd., Ste 200
Duluth, GA 30096 USA
+1-470-374-9254
america@kohyoung.com
kohyoung.com

will realize tens of billions of dollars in gains by 2022 after deploying smart manufacturing solutions. In an effort to facilitate the development and commercialization of the critical smart manufacturing building blocks (e.g., automation, machine learning, or ML, data communications, digital thread), several countries established innovation institutes and large R&D programs. These collaborative activities seek to develop technologies that will improve traceability and visualization, to enable real-time analytics for predictive process and machine control, and to build flexible, modular manufacturing equipment platforms for high-mix, low-volume product assembly.

The vertical segments of the electronic products manufacturing industry (semiconductor (SEMI), outsourced system assembly, and test (OSAT), and printed circuit board assembly (PCBA) are converging, and service offerings are being consolidated. This occurrence is due to the acceleration of technology development and the market dynamics, providing industry members in specific vertical segments an opportunity to capture a greater percentage of the electronics industry's total profit pool.

The convergence of the SEMI, OSAT, and PCBA segments will cause shifts in the flow of materials across the supply chain, as well as the introduction of equipment and processes across the segments (e.g., back-end OSAT services offered by PCBA segment). OSAT services providers are using equipment and platforms typically found in semiconductor back-end manufacturing, and PCBA services providers are installing equipment and developing processes similar to those used by OSAT.

The ability to develop smart manufacturing technologies (e.g., big data analytics, AI, cloud/edge computing, robotics, automation, IoT) that can be deployed within the vertical segments as well as between the vertical segments is critical. In addition, the ability to enable the technologies to evolve unhindered is imperative to establish a robust integrated digital thread.

As the electronic products manufacturing supply chain continues to evolve and experience consolidation, shifts in the traditional flow of materials (e.g., sand to systems) will drive the need to adopt technologies that seamlessly interconnect all facets of manufacturing operations. The iNEMI Smart Manufacturing TWG published a roadmap that would provide insight into the situation analysis and key needs for the vertical segments and horizontal topics (Figure 1) [1].

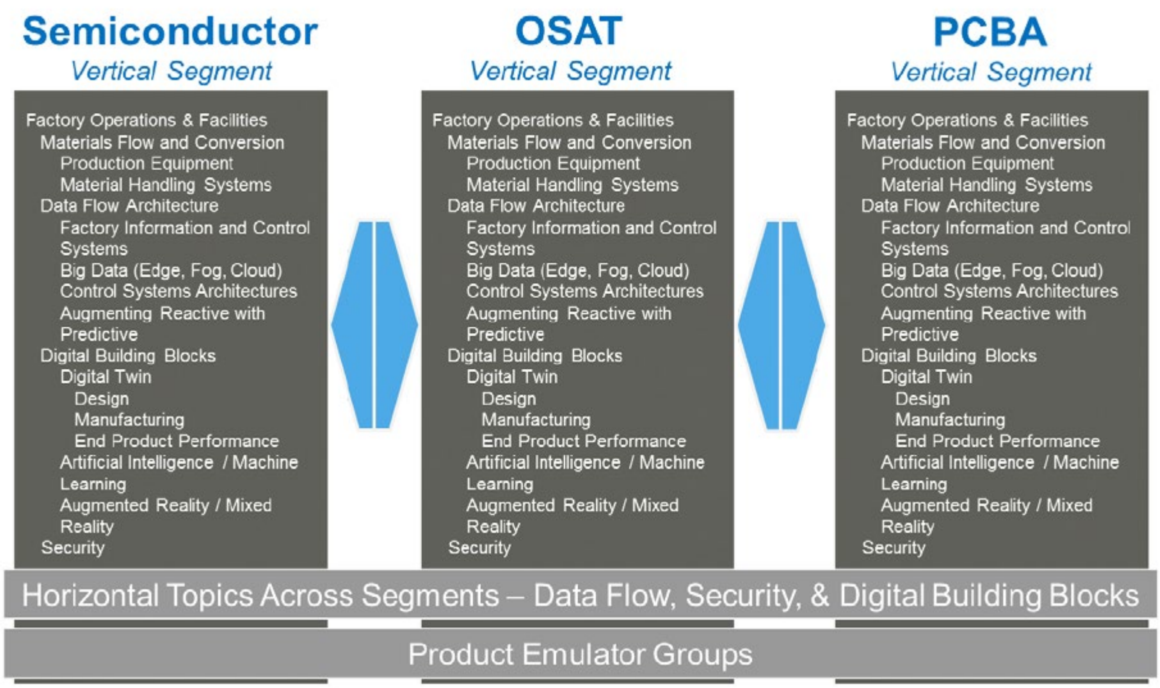


Figure 1: Horizontal topics across vertical segments.

In this roadmap, the enabling smart manufacturing technologies are referred to as horizontal topics that span across the electronics industry manufacturing segments: security, data flow architecture, and digital building blocks (AI, ML, and digital twin).

The three electronics manufacturing industry segments SEMI, OSAT, and PCBA share some common challenges:

- Responding to rapidly changing, complex business requirements
- Managing increasing factory complexity
- Achieving financial growth targets while margins are declining
- Meeting factory and equipment reliability, capability, productivity, and cost requirements
- Leveraging factory integration technologies across industry segment boundaries
- Meeting the flexibility, extendibility, and scalability needs of a leading-edge factory
- Increasing global restrictions on environmental issues

These challenges are increasing the demand to deploy, enabling smart manufacturing solutions that can be leveraged across the verticals.

Enabling Smart Manufacturing Technologies (Horizontal Topics): Situation Analysis

Many of the challenges may be addressed by several enabling smart manufacturing technologies (horizontal topics) that span across the electronics industry manufacturing segments: security, data flow, and digital building blocks. The key needs for these are discussed as related to the different vertical segments (SEMI, OSAT, and PCBA) and the intersection between the vertical segments.

Members of the smart manufacturing TWG presented the attribute needs for the following: security, data flow, digital building blocks, and digital twin. Common across the vertical segments is the ability to develop and deploy the appropriate solutions that allow the ability to manufacture products at low cost and high volume. Smart manufacturing is considered a journey that will require hyper-focus to ensure the appropriate technology foundation is established. The enabling horizontal topics are the ones that are considered the most important to build a strong, agile, and scalable foundation.

Security

Security is discussed in terms of two classes: physical and digital. The tools and protocols deployed for security is an increasingly important topic that spans across many industries and is not specific only to the electronics manufacturing industry. Security is meant to protect a number of important assets and system attributes that may vary according to the process (novel and strong competitive advantage) and perceived intrinsic value of the intellectual property (IP).

In some instances, it directly addresses the safety of workers, equipment, and the manufacturing process. In other cases, it transitions toward the protection of electronic asset forms, such as design documents, bill of materials, process, business data, and others. A few key considerations for security are access control [2], data control [3], input validation, process confidentiality, and system integrity [2].

At the moment in manufacturing, in general, IT security issues are often only raised reactively once the development process is over and specific security-related problems have already occurred. However, such belated implementation of security solutions is both costly and also often fails to deliver a reliable solution to the relevant problem. Consequently, it is deemed necessary to take a comprehensive approach as a process, including implementation of security threat identification and risk analysis and mitigation cycles on security challenges.

Data Flow

General factory operations and manufacturing technologies (i.e., process, test, and inspection) and the supporting hardware and software are evolving quickly; the ability to transmit and store increasing volume of data for analytics (AI, ML, predictive) is accelerating. Also, the advent and subsequent growth of big data are occurring faster than originally anticipated. This trend will continue highlighting existing challenges and introducing new gaps that were not considered previously (Figure 2).

As an example, data retention practices must quickly evolve; it has been determined that limitations on data transmission volume and length of data storage archives will disappear (e.g., historical data retention of "all" will become standard practice). Examples of data flow key considerations are data pipes, machine-to-machine (M2M) communication, and synchronous/asynchronous data transmission.

A flexible, secure, and redundant architecture for data flow and the option considerations (e.g., cloud, fog, versus edge) must be articulated. The benefits and risks must be identified and discussed. Data flow and its ability to accelerate the evolution of big data technologies will enable the deployment of solutions to realize benefits from increases in data generation, storage, and usage. These capabilities delivering higher data volumes at real-time and near-real-time rates will increase the availability of equipment parameter data to positively impact yield and quality. There are several challenges and potential solutions associated with the increases in data generation, storage, and usage; capabilities for higher data rates; and additional equipment parameter data availability.

The primary topics to address are data quality and incorporating subject-matter expertise in analytics to realizing effective on-line manufacturing solutions. The emergence of big data in electronics manufacturing operations should be discussed in terms of the "5 Vs Framework":

1. Volume
2. Velocity
3. Variety (or data merging)
4. Veracity (or data quality)
5. Value (or application of analytics)

The "5 Vs" are foundational to appreciate the widespread adoption of big data analytics in the electronics industry. It is critical to address the identified gaps—such as accuracy, completeness, context richness, availability, and archival length—to improve data quality to support the electronics manufacturing industry advanced analytics [4].

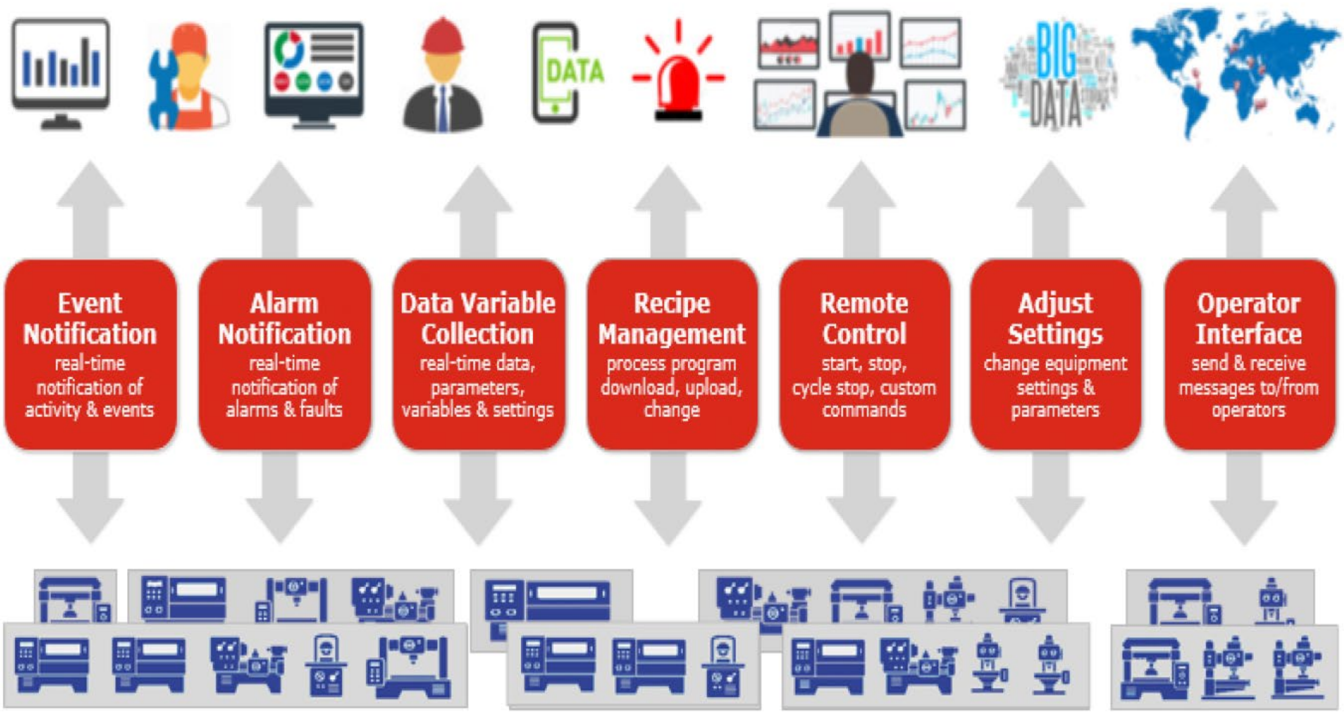


Figure 2: Example of a connectivity architecture providing smart manufacturing functionality. (Source: Cimetrix)

Digital Building Blocks

The advancements in the development of digital building blocks (interconnected digital technologies) are providing digitization, integration, and automation opportunities to realize smart manufacturing benefits. These technologies will enable electronics manufacturing companies to stay relevant as the era of the digitally-connected smart infrastructure is developed and deployed. Several technologies considered fundamental digital building blocks are receiving increased attention in the electronics manufacturing industry (e.g., AI, ML, augmented reality, virtual reality, and digital twin).

AI and ML

AI and ML tools and algorithms can provide improvements in production yields and quality. These tools and algorithms will enable the transformation of traditional processes and manufacturing platforms (processes, equipment, and tools). The situation analysis for AI and ML, as well as their enablers, typically consider the following features and operational specifications: communications at fixed frequency, commonality analysis, material and shipment history and traceability, models for predicting yield and performance, predefined image processing algorithms, secure gateway, warehouse management systems.

AI and ML present several opportunities to aggregate data for the purpose of generating actionable insights into standard processes. These include, but are not limited to, the following:

1. Preventive maintenance: Collecting historical data on machine performance to develop a baseline set of characteristics on optimal machine performance, and to identify anomalies as they occur.
2. Production forecasting: Leveraging trends over time on production output versus customer demand, to more accurately plan production cycles.
3. Quality control: Inspection applications can leverage many variants of ML to fine-tune ideal inspection criteria. Leveraging deep learning, convolutional neural networks, and other methods can generate reliable inspection results, with little to no human intervention.
4. Communication: It is important for members of the electronics manufacturing industry to adopt open communication protocols and standards [5–8].

Digital Twin Technology

The concept of real-time simulation is often referred to as the digital twin. Its full implementation is expected to become a requirement to remain cost-competitive in legacy and new facility types. Digital twin will initially be used to enable prediction capabilities for tools and process platforms that historically cause the largest and most impactful bottlenecks. The ultimate value of the digital twin will depend on its ability to continue to evolve by ingesting data and the availability of data with the "5 Vs": veracity, variety, volume, velocity, and value. The situation analysis of the digital twin within and between electronics industry manufacturing segments highlight the following data considerations: historical, periodic, and reactive.

The concept of a digital twin lends itself to on-demand access, monitoring and end-to-end visualization of production, and the product lifecycle. By simulating production floors, a factory will be able to assess attainable projected KPIs (and what changes are required to attain them), forecast production outputs, and throughputs through a mix of cyber-physical realities (the physical world to the virtual world, and back to the physical world), and expedite the deployment of personnel and equipment to manufacturing floors worldwide.

Enabling Smart Manufacturing Technologies (Horizontal Topics): Key Attribute Needs

Security

Security will continue to be a primary concern as the electronics manufacturing industry adopts technologies and tools that rely on ingested data to improve manufacturing quality and yield and offer differentiated products at a lower cost and higher performance. SEMI members generated a survey to appreciate the needs, challenges, and potential solutions for security in the industry and its supply chain and gather more comprehensive input from the industry in terms of users, equipment and system suppliers, security experts, and security solution providers [9]. It is a topic that permeates many facets of manufacturing: equipment, tools, designs, process guidelines, materials, etc. Processes continue to demand a significant level of security to minimize valuable know-how IP loss; this requirement will generate the greatest amount of discussion such as data partitioning, production recipes, equipment, and tool layout. A few key attribute needs for security are network segmentation [10], physical access, and vulnerability mitigation.

These security issues are not unique to microelectronics manufacturing, and many of the issues go beyond manufacturing in general. The topic of security should reference the challenges and potential solutions across the manufacturing space. As an example, the IEC established an Advisory Committee on Information Security and Data Privacy [11]. It is suggested to collaborate with other standards and industry organizations that are developing general manufacturing security roadmaps by delineating specific microelectronics manufacturing issues and focusing on common needs.

Data Flow

The development of a scalable architecture that provides flexibility to expand; connect across the edge, the fog, and the cloud; and integrate a variety of devices and systems generating data flow streams is critical. A smart factory architecture may, for example, accommodate the different verticals in the electronics manufacturing industry as well as companies in non-electronics manufacturing industries.

As mentioned previously, different industries seeking to deploy smart manufacturing technologies should leverage architectures that

Dan Beaulieu: Adapting to New Methods at D.B. Management

In this audio interview, Nolan Johnson gets an update from Dan Beaulieu, president of D.B. Management Group. Dan is a 40+ year veteran of the electronics manufacturing industry and has been an industry consultant for 25+ years.

Dan shares an update on current business operations for D.B. Management, including how—like his clients—he may be at home, but it's still business as usual. Dan also offers his perspective on how our industry will weather and emerge from this challenging time.

provide the desired attributes; data flow architecture is considered a prime candidate for leveraging and cross-industry collaboration to identify optimum solutions (i.e., data synchronizers, execution clients).

The development and deployment of technologies for data flow are accelerating. Focus on data analytics, and data retention protocols are increasing at a faster rate than first anticipated. It is imperative to collect the critical data as well as to establish guidelines to perform intelligent analysis and to exercise the appropriate algorithms to specify data-driven decisions. Several topics related to data are under consideration, such as general protocols:

- "All" versus "anomaly" data retention practices
- Optimization of data storage volumes
- Data format guidelines for analytics to drive reactive and predictive technologies
- Data quality protocols enabling improvements in time synchronization, compression/uncompression, and blending/merging
- Guidelines to optimize data collecting, transferring, storing, and analyzing

Data considerations for equipment are:

- Defining context data sets for equipment visibility
- Improving data accessibility to support functions
- Data-enabled transition from reactive to predictive functionality
- Data visibility of equipment information (state, health, etc.)

Digital Building Blocks

The ability to deploy the necessary digital building blocks to realize smart manufacturing is at different stages of maturity.

AI and ML

A few key attribute needs for AI and ML are data communication standards, data formatting standards, and 3PL tracking solutions. Technologies, such as AI and ML, are seen as enablers to transition to a predictive mode of operation: predictive maintenance, equipment health monitoring, fault prediction, predictive scheduling, and yield prediction and feedback. This paradigm in AI-enhanced control systems architectures will enable the systems to "learn" from their environment by ingesting and analyzing large data sets. Advanced learning techniques will be developed that improve adaptive model-based control systems and predictive control systems. The continued development and assessment of AI and ML technologies is critical to establish the most robust and well-tuned prediction engines that are required to support emerging production equipment.

Digital Twin Technology

Advances in digital twin technologies are accelerating as the potential benefits are communicated to end-users. Also, the costs for enabling technologies (hardware and software platforms) are becoming less expensive. The following are considered key attribute needs that will increase adoption and broad-based deployment of the digital twin (product design, product manufacturing, and product performance: digital thread, predictive, prescriptive, and systemwide continuous data access.

Digital twin is a long-term vision that will depend on the implementation of discrete prediction capabilities (devices, tools, and algorithms) that are subsequently integrated on a common prediction platform. It is generally considered that the digital twin will provide a real-time simulation of facility operations as an extension of the facility operations system.

The successful deployment of digital twin in a facility environment will require high-quality data (e.g., accuracy, velocity, dynamic updating) to ensure the digital twin is an accurate representation of the real-time state of the fab. Also, the realization of this vision will depend on the ability to design an architecture that provides the key technologies to operate collaboratively by sharing data and capabilities. Ultimately, the success of the digital twin will depend on the ability to develop a path for implementation that provides redundancy and several risk assessment gates.

Prioritized Research, Development, and Implementation Needs

The topic of collaboration is often mentioned in industry-led initiatives as a key element to realize the benefits attributed to smart manufacturing. There is a strong drive by members of the electronics manufacturing industry to engage in activities that foster collaboration. Participants in these activities recognize that solutions must be consensus-based and adopted by many vendors. Equipment suppliers appreciate that deep domain knowledge combined with data analysis contributes to only a fraction of the potential value that can be captured. The optimal value will be realized when data is shared across manufacturing lines in facilities, with vertical segment industry supply chain members and across vertical segments.

Example prioritized research, development, and implementation needs topics are as follows:

- Define data flow standard interfaces and data formats for all equipment and tools
- Investigate if data flow continuity between vertical segments should be mandatory or optional
- Determine optimal operation window for the latency of data versus process flow and quantify permissible latency for data flow when used to determine process go/no-go
- Investigate data security and encryption requirements when sharing common process tools versus isolating process equipment between vertical segments
- Develop open and common cross-vertical-segments communication standards and protocols for equipment

Gaps and Showstoppers

There is universal agreement that digitization will drive huge growth in data volumes. Many predict that cloud and hybrid cloud solutions are critical to enable the storage and subsequent manipulation of data by AI algorithms to derive value. However, industry members must adopt consensus-based standards and guidelines for connectivity protocols and data structures (Figure 4). Smart manufacturing is a journey, and a robust and scalable connectivity architecture must be established on which to deploy digital building blocks (e.g., AI, ML to extract the optimal value from the data).

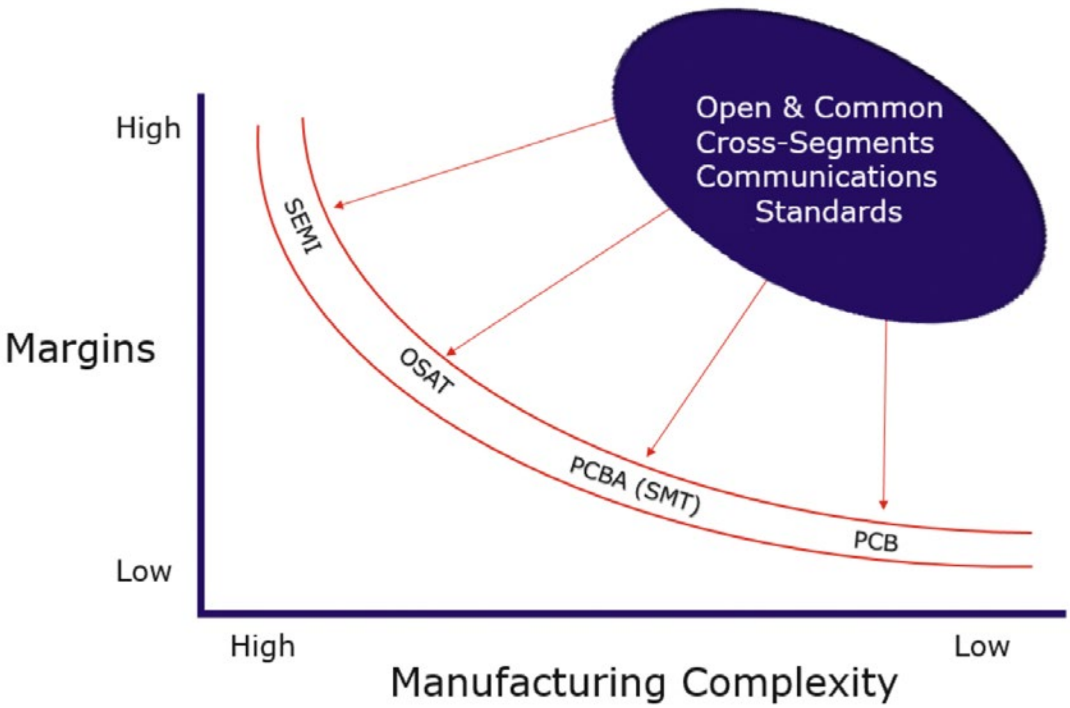


Figure 4: Cross-segments standard for equipment connectivity enabling smart manufacturing.

Example critical gaps that could significantly impact the progress of the deployment and adoption of smart manufacturing are:

- Undefined data security between vertical segments
- Lack of machine interface standardization for data flow
- Undefined data formats for data flow
- Data vulnerability when security is breached
- Robust and scalable connectivity architecture across electronics vertical segments to enabling smart manufacturing functionality (event and alarm notification, data variable collection, recipe management, remote control, adjustment of settings, interfacing with operators, etc.)

Summary

The iNEMI Smart Manufacturing Roadmap Chapter provides the situation analysis and key attribute needs for the horizontal topics within the vertical segments as well as between the vertical segments. Also, the chapter identifies the primary gaps and needs for the horizontal topics that must be addressed to enable the realization of smart manufacturing:

- Definitions: Smart manufacturing, smart factory, Industry 4.0, AI, ML, etc.
- Audits for smart manufacturing readiness: Develop consensus-based documentation, leverage published documents (e.g., Singapore Readiness Index [12])
- Security: Best practices, physical, digital, local and remote access, etc.
- Equipment diversity and data flow communications: Old, new, and mixture
- Data attribute categorization and prioritization: Volume, velocity, variety, veracity, and value
- Cost versus risk profile versus ROI
- Talent pool (subject-matter experts): Data and computer scientists, manufacturing engineers, and automation
- Standards and guidelines: Data formats and structures, communication protocols, and data retention
- Open collaboration: SEMATECH 2.0

The gaps and needs that were identified for addressing require additional detail for the status of the different vertical segments to appropriately structure the initiatives. It was suggested to circulate surveys to gather the information to appreciate the issue. One survey format was suggested as an example template: Manufacturing Data Security Survey for IRDS FI Roadmap [13].

iNEMI, together with other organizations, such as SEMI, can organize workshops to facilitate collaboration between the electronics manufacturing industry stakeholders. In addition, iNEMI can establish cross-industry collaborative projects that can develop the enabling technologies to address the roadmap identified needs and gaps to realize smart manufacturing.

iNEMI, together with other organizations, such as SEMI, can organize workshops to facilitate collaboration between the electronics manufacturing industry stakeholders.

Further, organizations, such as iNEMI and SEMI, can collaborate to establish guidelines and standards (e.g., data flow interfaces and data formats) as well as lead groups to develop standards for equipment and tool hardware to reduce complexity during manufacturing. Also, iNEMI can engage other industry groups to foster the exchange of best practices and key knowledge from smart manufacturing initiatives.

The members of the roadmap TWG are committed to provide guidance during the smart manufacturing journey—people, processes, and technologies. Members of the TWG also suggested engaging microelectronics groups as well as non-microelectronics groups to assess opportunities to leverage existing smart manufacturing guidelines and standards.

Acknowledgments

Thank you to the members of the iNEMI Smart Manufacturing TWG. Their dedication, thought leadership, and deep appreciation for SMT enabling technologies was critical to preparing the roadmap chapter.

In addition, we would like to thank the participants and facilitators of the SEMI Smart Manufacturing Workshop—Practical Implementations and Applications of Smart Manufacturing (Milpitas, California, on November 27, 2018). SMT007

References

1. 2019 iNEMI Roadmap.
2. U.S. National Institute Standard and Technology's Special Publication 800-82.
3. U.S. National Institute Standard and Technology's Special Publication 800-171.
4. IEEE International Roadmap for Devices and Systems, Factory Integration.
5. Japan Robot Association's Standard No. 1014.
6. SEMI E30-0418, Generic Model for Communications and Control of Manufacturing Equipment (GEM); SEMI A1-0918 Horizontal Communication Between Equipment; SEMI E5-1217, Communications Standard 2 Message Content (SECS-II); SEMI E4-0418, Equipment Communications Standard 1 Message Transfer (SECS-I).
7. Hermes Standard.
8. IPC-CFX Standard.
9. J. Moyne, S. Mashiro, and D. Gross, "Determining a Security Roadmap for the Microelectronics Industry," 29th Annual SEMI Advanced Semiconductor Manufacturing Conference (ASMC), pp. 291-294, 2018.
10. IEC 62443 3-2.
11. www.iec.ch/acsec.
12. EDB Singapore, "The Singapore Smart Industry Readiness Index," October 22, 2019.
13. www.surveymonkey.com/r/ZXLS6LH.

Ranjan Chatterjee is vice president and general manager, smart factory business, at Cimetrix.

Dan Gamota is vice president, manufacturing technology and innovation, at Jabil.

Electric Cars Better for Climate in 95% of the World

Reports have questioned whether electric cars really are "greener" once emissions from production and generating their electricity are taken into account.

But a new study by the universities of Exeter, Nijmegen, and Cambridge has concluded that electric cars lead to lower carbon emissions overall, even if electricity generation still relies on fossil fuels. The results are reported in the journal *Nature Sustainability*.

Under current conditions, driving an electric car is better for the climate than conventional petrol cars in 95% of the world, the study finds.

Average lifetime emissions from electric cars are up to 70% lower than petrol cars in countries like Sweden and France (which get most of their electricity from renewables and nuclear), and around 30% lower in the U.K.

The study projects that by 2050, every other car on the streets could be electric. This would reduce global CO_2 emissions by up to 1.5 gigatons per year, which is equivalent to the total current CO_2 emissions of Russia.

(Source: University of Exeter)

The Journey to an eSmart Factory, Part 1

Feature by Happy Holden
I-CONNECT007

Editor's Note: The following is the first of a five-part series, originally published in PCB007 Magazine, February 2020.

"Smart factory" is another phrase that describes Industry 4.0 programs. These programs seem to have replaced CIM and CAM, but it did not make them obsolete. While these topics are getting a lot of press, there is nothing new about them. We have been on a journey to automate manufacturing since the mid-'70s. What has evolved are faster and cheaper computers and more complex and integrated networking. Meanwhile, the cost of wireless communications has dropped dramatically, and labor and materials costs have gone up. These conditions all foster a greater return for automation, with the possibility of lights-out factories with no environmental impact, leading to "lean and green" implementation.

Strategy and Planning

What hasn't changed over all these years is the need for a strategic plan to achieve a smart factory. While the investment in automation may be straightforward, the investment in integrating all these islands of automation clearly is not. The strategic planning for this integration is the major topic in the smart factory. Networking has advanced so much in the intervening years that it has now become an over-riding element of the new smart factory. These elements were introduced in the free I-Connect007 eBook *Automation and Advanced Procedures in PCB Fabrication.*

Now, the elements are the islands of automation. This important third axis involves material handling degree and network communication extent between cells and work centers. Figure 1 shows the six stages of planning a smart factory. Most of the elements will be your current equipment and any new islands

SIEMENS

Ingenuity for life

Smart Manufacturing for Electronics

Where manufacturing meets tomorrow

siemens.com/software

The inherent complexity of the surface mount technology (SMT) process operation makes meeting High-Mix, Low-Volume demands extremely complicated for Electronics manufacturers. With Siemens digital solutions you can digitalize your electronics manufacturing process.

Valor Process Preparation

- Increase engineering efficiency by using a single tool for all process engineering tasks: stencil, SMT, inspection, test and EWI
- Eliminate redundant preparation work with Learning Libraries (VPL)
- Increase documentation efficiency through automation and use of templates
- Increase quality by preserving manufacturing knowhow, including manufacturing best practices, libraries, and customer data preparation flows

> Like the conductor conducting an orchestra, Valor Process Preparation is a single tool which addresses all manufacturing process decisions

Visit website

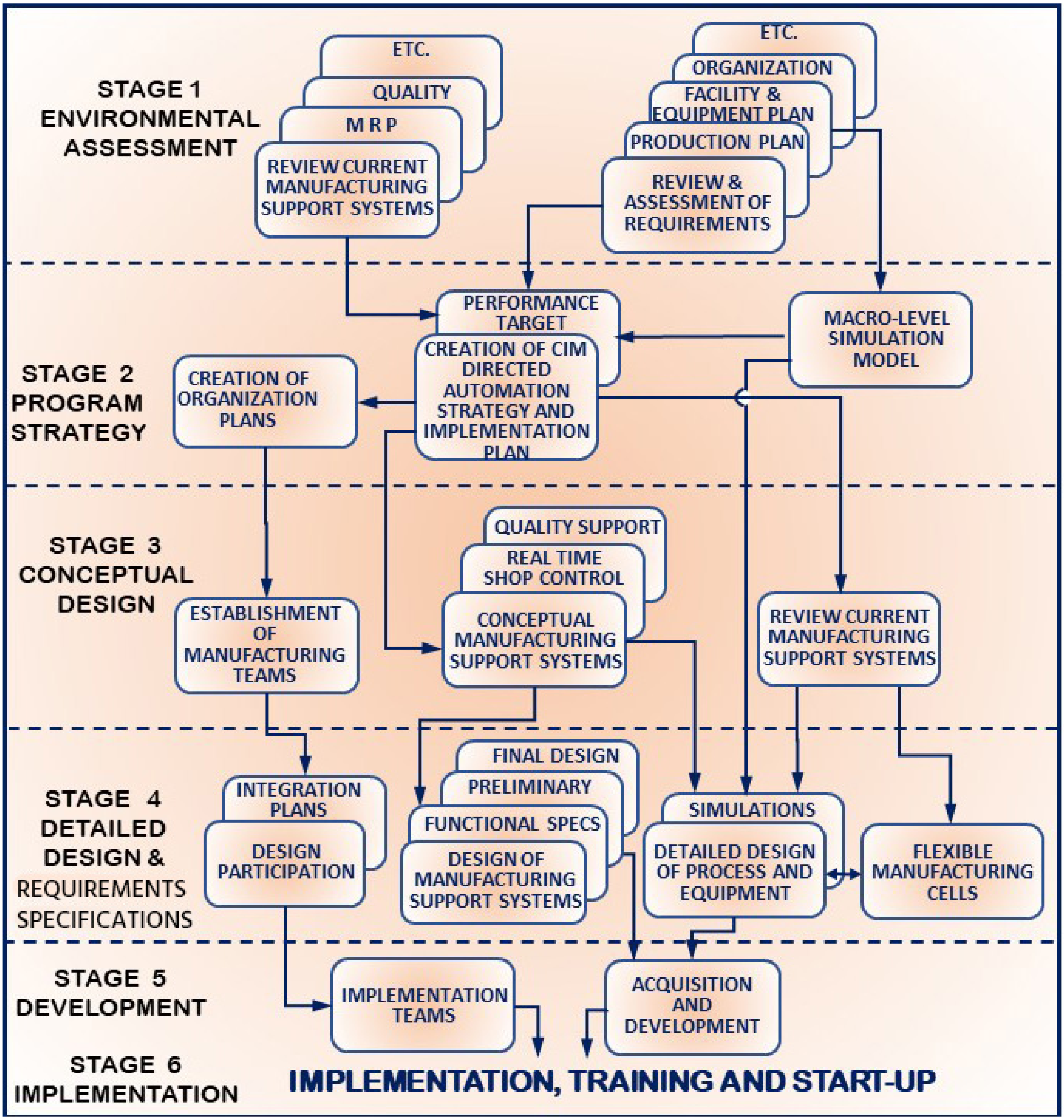


Figure 1: The first priority is to establish a strategy for what your smart factory will look like and how it will operate.

of automation. The arrows are of significance, as they outline the flow of information that will be an important new part of your smart factory.

Table 1 provides more details on creating your smart factory strategy. The timing is approximate, based on how many resources are assigned to the job.

The Computer Architecture

The computer architecture for the smart factory is the familiar four-level hierarchy (Figure 2). This particular one is the European ISA-95 architecture defined in 1995. The only difference between the earlier architectures is that Level 4 will probably be the cloud.

Another essential feature of the smart factory is the interactive use of data from the many sensors and IoT devices. The data ownership and data structures for both the management environment and the technical environment compose many elements (Figure 3). The activ-

PHASES	ACTIVITIES	DELIVERABLES
1 ENVIRONMENTAL ASSESSMENT (4-8 weeks)	• Conduct Systemization Review (flow, quality, etc) • Conduct "The CAD/CAM Audit" • Perform "The Process Scan" • Perform organization review • Analyze business forecast	• Profile of systemization / mechanization opportunities • CAD/CAM systems specification input • Assessment of organizational impact • Rationale for cost / benefits analysis model
2 PROGRAM STRATEGY (6-10 weeks)	• Perform macro-level stimulation for CBA • Establish performance targets • Create CIM strategy & automation plan • Develop documentation methodology for CIM system	• Documented CIM strategy and implementation plan • CIM architecture • Organization and staffing plan • Database mapping of functional processes
3 CONCEPTUAL DESIGN (6-10 weeks)	• Exploration of preliminary process equipment and automation alternatives • Initiation of requests for information (RFI) • Develop conceptual specs for MFG support systems • Organize manufacturing technology teams	• Budget profiles on equipment / software development created • Documented conceptual specifications for functional approvals
4 DETAILED DESIGN AND REQUIREMENTS SPECS (13-26 weeks)	• Generation of detailed process/equipment designs • Generation of detailed manufacturing support sizing of system specs • Involvement with technology suppliers • Creation of integration plans • Execution of simulation model on automation alternatives • Creation of RFP specs for supplies	• Transaction (I/O level) design document for manufacturing system • REF Specification with functional sizing of system • Detailed cost / benefits model document • Implementation plan
5 DEVELOPMENT (Cycle depends on Phase 4 scope)	• Selection of equipment, hardware and software suppliers • Implementation of development hardware and software • Software programming • Debug and test subsystems	• Completed system software • Installed, operational equipment
6 IMPLEMENTATION (Cycle depends on Phase 4 scope)	• Construct ATP • Execution of system test • Construct system and user documentation • Execute ATP • Trainer of end-users	• Acceptance of test procedures • Operational CIM systems • Technical and user documentation

Table 1: Details for creating the six-stage smart factory strategy.

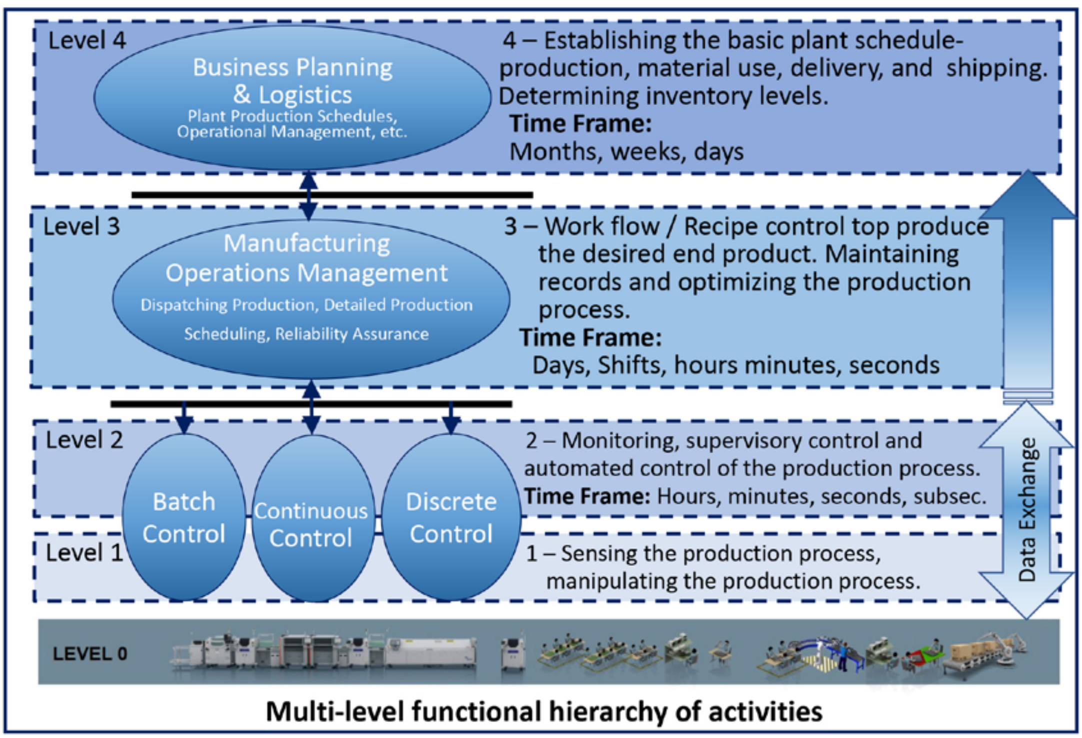


Figure 2: The ISA-95 architecture is still the preferred hierarchy for implementing automation for Industry 4.0.

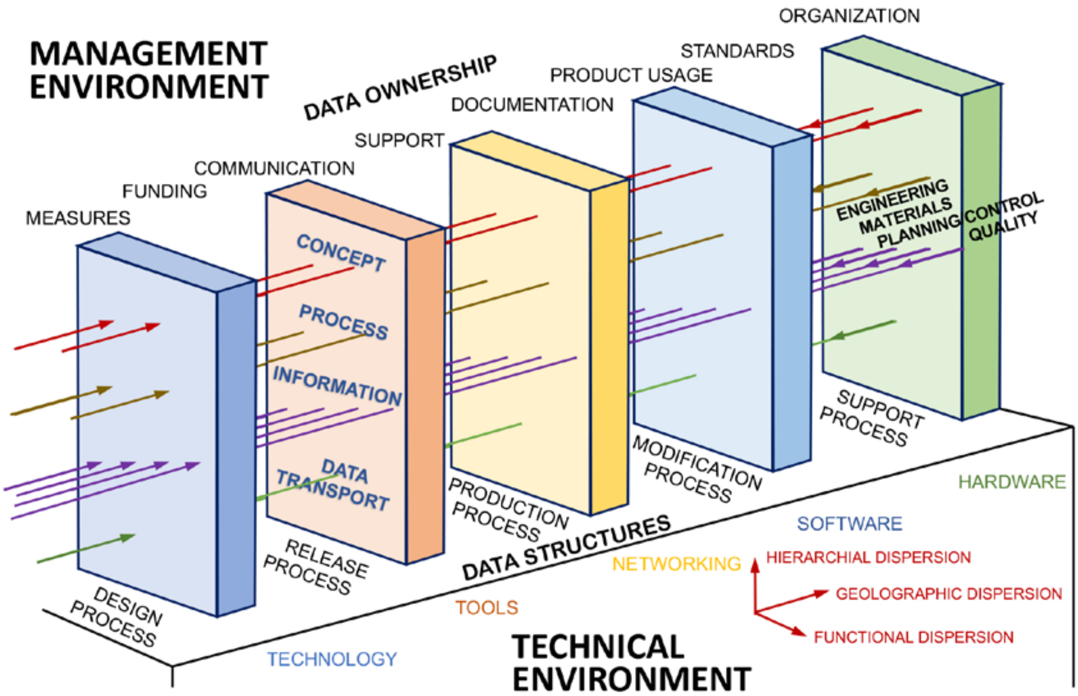


Figure 3: The data ownership and structures for the eSmart factory have a management environment and a technical environment dissected into a hierarchical, geometric, and functional dispersion.

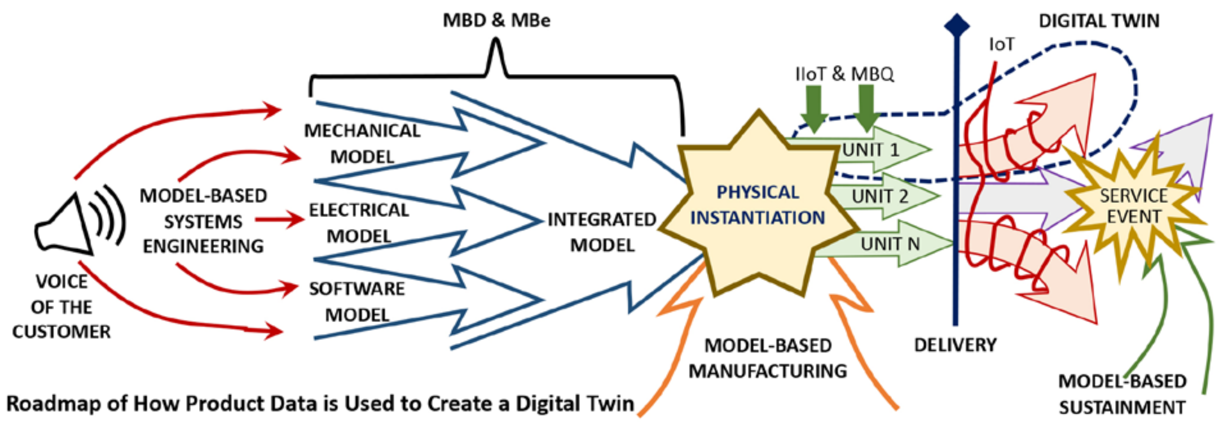


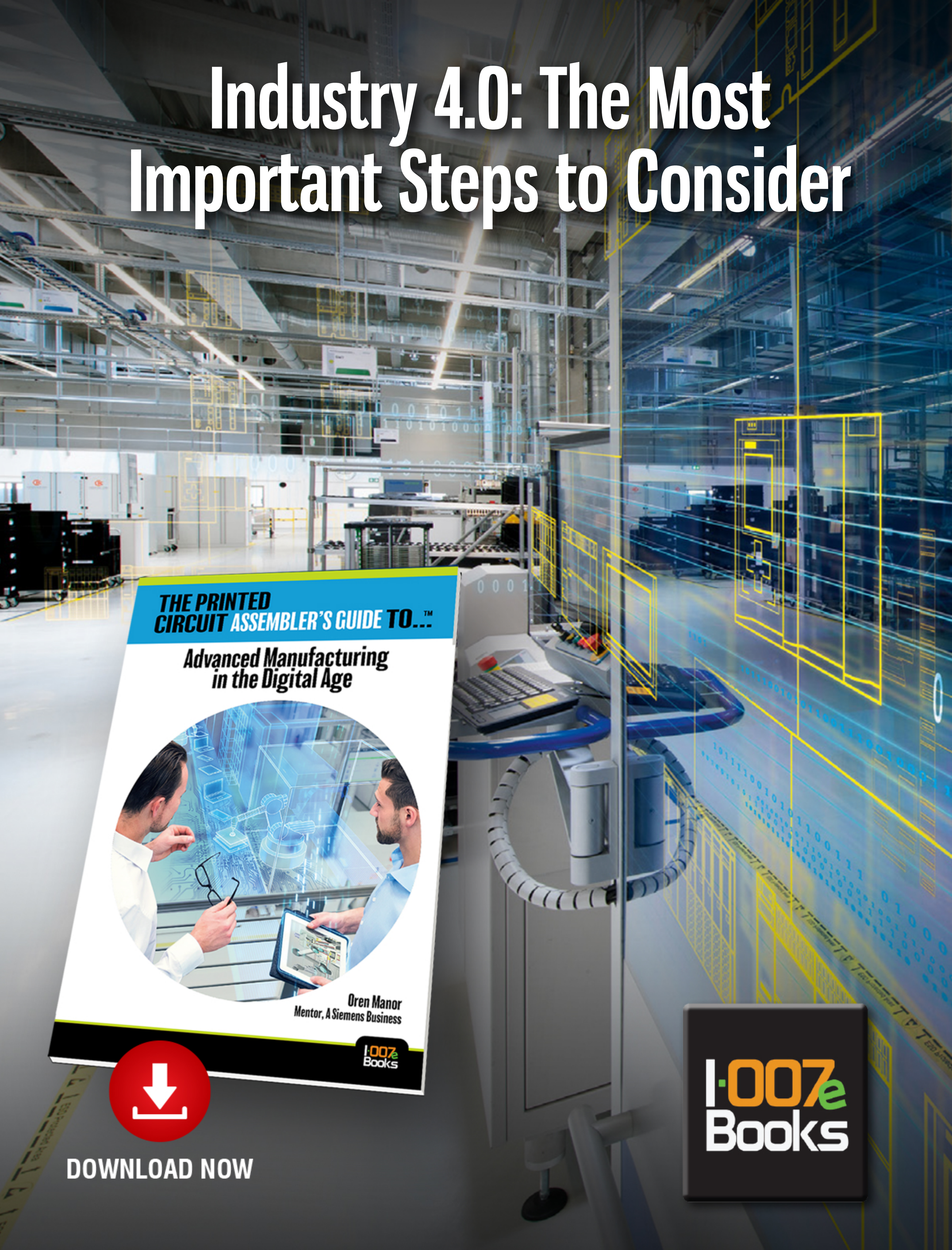
Figure 4: The digital twin model is used increasingly in the smart factory for predictive results. (Source: Machine Design, March 2019)

ities are straightforward, but the deliverables are essential to having a successful project.

The Digital Twin Model

Increasingly common for Industry 4.0 implementation is the use of the digital twin models. These virtual predictive models for a product, process, or service contribute a predictive model for engineering, manufacturing, delivery, and sustainment (Figure 4).

The pairing of the virtual and physical worlds allows analysis of data and monitoring of systems to head off problems before they occur. This allows for the prevention of downtime, presenting new opportunities, and the ability to plan the future by using simulations. The models and simulations are fed by IoT and the internet of systems (IoS) following the data structures and data ownership defined for the planned future networking system (Figure 3). **SMT007**


Industry 4.0: The Most Important Steps to Consider
THE PRINTED CIRCUIT ASSEMBLER'S GUIDE TO...™
Advanced Manufacturing in the Digital Age
Oren Manor
Mentor, A Siemens Business
I-007e Books
DOWNLOAD NOW
I-007e Books

Burt Rutan

Exclusive Interview With Burt Rutan, Aerospace Legend

Interview by the I-Connect007 Editorial Team

If you follow advancements in aerospace technologies and expeditions, then you know the name "Burt Rutan." Described by *Newsweek* as "the man responsible for more innovations in modern aviation than any living engineer," Rutan is a bold visionary with a passion for the advancement of technology, who has designed 46 aircraft throughout his career.

Rutan designed the legendary Voyager—the first aircraft to circle the world nonstop without refueling. He also created SpaceShipOne—the world's first privately-built manned spacecraft to reach space—which won the $10 million Ansari X Prize offered in an effort to spur the development of affordable space tourism.

In addition, Rutan was named one of "the world's 100 most influential people" by *TIME* in 2005 and has received over 100 awards for aerospace design and development, including the Presidential Citizen's Medal, the Charles A. Lindbergh Award, and two Collier Trophies. He also founded the aerospace research company Scaled Composites and retired on March 31, 2011.

Rutan is currently working on two projects: the Stratolaunch—part airplane, part spaceship—and the SkiGull—an amphibious aircraft that runs on the same gas we use for cars and boats. In business, Rutan believes that the best ideas come from the collaborative efforts of small, closely-knit project teams, and an environment not limited by adversity to risk.

In his IPC APEX EXPO 2020 keynote titled "SpaceShipOne: A New Era in Commercial Space Travel and Inspiration for Innovation and the New Race for Space," Rutan inspired attendees with his vision on creativity, innovation, and managers' tasks to motivate a creative team.

Following his presentation, Rutan stopped by the I-Connect007 booth and shared his thoughts on a wide variety of topics, from early fixed-wing flight through Mars expeditions to his love of long sideburns as a tribute to Elvis Presley. I-Connect007 is pleased to share this exclusive interview.


APCT
Passion | Commitment | Trust
Where Advanced Technology,
Highest Quality & Fastest Delivery Are Standard
APCT Offers Printed Circuit Board Solutions from NPI to Mass Production
• Standard to Advanced HDI Technology
• Flex and Rigid Flex Technology
• Complete DFM Support
• Cycle Times Faster Than Industry Standards
• Defense & Aerospace Certifications
• Global Offshore Solutions
Advantages Include:
— Ease of Use
— Seamless Recipe Transfer
— Inventory Management
— Risk Mitigation
Contact APCT Today 408.727.6442 | APCT.com
Printed Circuit Board Solutions
APCT.com
APCT Santa Clara HQ 408.727.6442
APCT Anaheim 714.921.0860
APCT Orange County 714.993.0270
APCT Wallingford 203.269.3311
APCT Global 203.284.1215

SpaceShipOne, Rutan's sub-orbital vehicle, and winner of the Ansari X-Prize.

Barry Matties: Burt, thank you for the IPC APEX EXPO 2020 keynote. That was fantastic.

Burt Rutan: You're welcome. It was a great audience.

Dan Feinberg: The American space effort, as you mentioned today in your keynote, seems to have slowed down over the last decades, but it seems to be gaining a little momentum again. Is that what you see?

Rutan: It's gaining momentum primarily due to what Elon Musk and Jeff Bezos are doing.

Feinberg: Do you feel we're going to land a person on Mars? If so, when do you predict that could happen?

Rutan: I'd like it to happen before I die. That would be cool. Although, it's not as exciting of a place to visit as when we were kids. I have a college textbook from the '50s that debated what kind of animals would be on Mars. The author's conclusion was that scientists saw changing colors through telescopes and knew there were plants there, but they didn't know what kind of animals. We still don't know whether there's intelligent life on Mars.

I pointed out a long time ago that the delta-*v* for a one-way trip to Mars is the same as the delta-*v* for a round trip to the Moon. If you take something and change its velocity by so much, you have to do that several times when going to the Moon before decelerating and landing. You have to do it again to get into orbit and do it again to come back. Add all that up, and it defines how big your rocket needs to be to start because you throw away pieces of it. Delta-*v* is the key to what chemical propulsion can do. Clearly, we proved that a 6-million-pound Saturn 5 could do the job of getting two people to the surface of the Moon and back, but delta-*v* is not different than what it takes to land

Rutan poses with SpaceShipOne on the tarmac in Mojave, California.

somebody on Mars. The bottom line is we could use technology from the 1960s to take people to Mars; we just cannot bring them back.

Now, I should point out that when people took that much more dangerous trip to California in covered wagons, many died on the way. It begs the question, "Why aren't we sending people one way to Mars?" I didn't ask this to the audience because I didn't have time, but let's assume that you could live for six months. There may be a possibility of getting supplies to you to live beyond that, but that's not guaranteed. Who would go? Who would be the Buzz Aldrin and Neil Armstrong of Mars? Usually, a lot of attendees raise their hands. People want to volunteer. Look at the percentage of people who die climbing Everest, but people still want to do it.

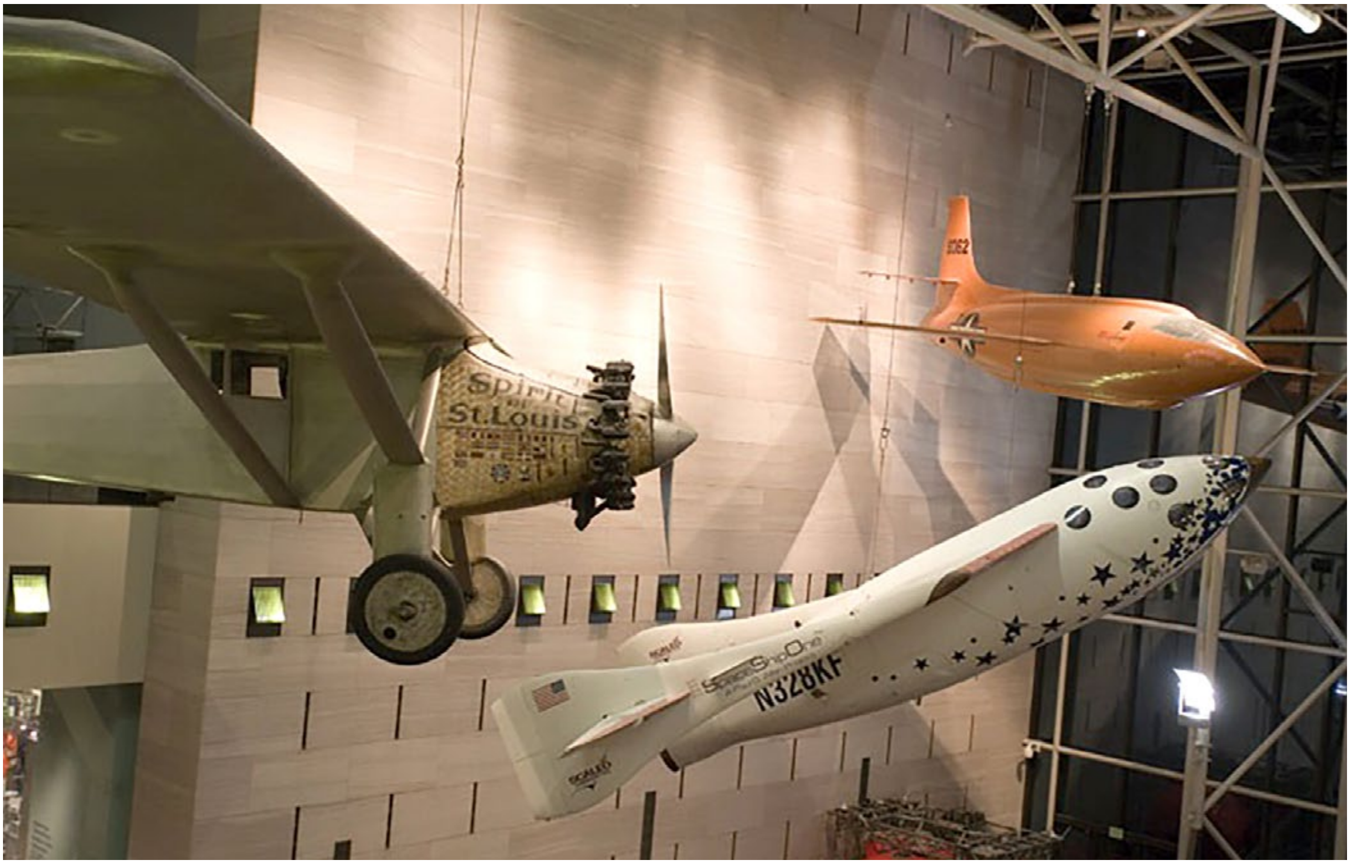
The only reason not to go in the '70s and '80s was if you built the vehicles to go one way, if nobody showed up and volunteered, it would be judged as unethical to put someone to sleep and let them wake up inside after the door was locked, especially if they didn't want to go. That's the only reason not to do it. I initially proposed that we send lawyers, but I quickly was told that it wouldn't work because they would lie about what they saw.

NASA made a big mistake that has made Mars not as attractive as it was when we were kids. They sent all these robots out there and landed them only in the deserts; they didn't land one of them downtown (laughs). Downtown Mars, to some people, is Cydonia. It's a walkable distance from the face on Mars, but NASA has said that it isn't a face, but what if they had said, "We think that's man-made?" What would happen to the NASA budget?

Feinberg: We'd be going there, no matter the cost.

Rutan: Why would NASA kill its own budget? The bottom line is that to get people who will agree to go, you must tell them you're going to land in Cydonia where the pyramid-looking structures are. If they were pyramids, and if they did build a face so that Earth could see it someday, that might have happened millions of years ago. I think that would be interesting to find out. I'm not a believer that it was, but I'm curious. Note that I am a UFO skeptic. If you want to understand the details about what I think of UFOs, you can download the white paper on my website.

Nolan Johnson: You referenced natural selection for airplanes in your keynote as well. Are we stepping away from trying to use natural selection as a method to innovate?



SpaceShipOne is on display at the Smithsonian National Air and Space Museum's building on the National Mall in Washington, D.C. It hangs between Charles Lindberg's Spirit of St. Louis, left, and Chuck Yeager's Bell X-1, above right, in the Boeing Milestones of Flight Hall.

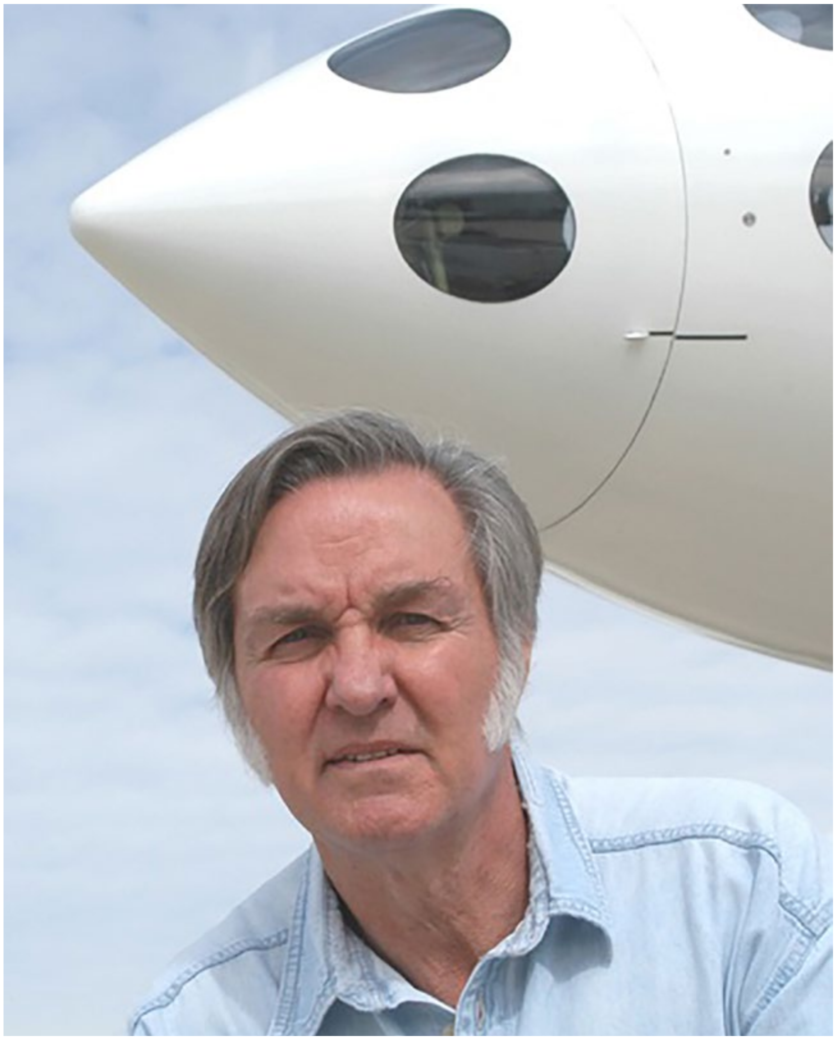
Rutan: The reason that it was natural selection is that, initially, there were tens of thousands of attempts to build airplanes. When people realized, even without the internet, that a couple of guys had flown, and their background was in repairing bicycles, everybody had to try it. There was no regulation stating that you couldn't try. Are there tens of thousands of attempts going on right now to find breakthroughs for better airplanes, business jets, or airlines? No. The reason that a 787 looks like a 707 is that Boeing bets their whole company on a new airplane's success, and they're unwilling to take a risk to try something completely new.

Matties: In your presentation, you looked at the past 40 years. You showed the Blackbird SR-71 and the B-70, which seemed like very advanced planes back then, even by today's standards.

Rutan: They were advanced. We called the B-70 "the savior." Occasionally, people would see this plane overhead, but the opportunities to look at it up close were tiny. They did do a rollout. Around 800 people showed up for the rollout. Pictures don't do justice to show you how big and beautiful it was, so few people knew.

They had to have a special hangar because of the two tails instead of one. In those days, they would build engineering offices and flight test pilot offices outside the hanger. The B-70 sat so high that you could build them inside the hangar. After walking through a large office, you opened a small door, and right in front of you was this big nose wheel. Then, you craned your neck up and saw these enormous, square, supersonic inlets. Turning, you saw the huge extended nose with a canard wing. It was so freaking beautiful that almost everybody who had that experience said, "Jesus Christ!" That's why the B-70 was called "the savior."

The same thing happens with the Stratolaunch—the huge airplane that Scaled Composites is developing. You come through a small door and look way up at the tail section. Then, turn to see a huge wing. It gives you the same feeling of, "Wow, I didn't expect it to be this big."



Matties: When we look at your contributions to society, they span a lot of different areas. In the future, how do you want people to look back and remember you?

Rutan: I'd like to be remembered the way I remember the huge progress in the 60s in manned space flight. I've done 392 preliminary designs. And 49 of them are manned airplanes that were flight-tested. It's possible that this next year, I'll be flight testing the 50th research airplane. The volume of work is a much more impressive overall accomplishment than the Voyager flight. You could even argue it's a lot more impressive than SpaceShipOne.

SpaceShipOne was easy, technically. The most difficult thing was the courage to do it. I avoided all the complexity with SpaceShipOne. I took the risk that we didn't need a yaw damper or autopilot. My pilots could fly it. Flight controls are basic: the stick has pushrods, and the pedals have cables, which is exactly the same flight control system you find on a Piper Cub.

That's the flight control system of a manned spaceship! I found a solution to avoid a lot of heating on boost and re-entry by having a very low ballistic coefficient. That means it's more like a feather than a bullet. A feather slows down at 110,000 feet, whereas the X-15 slowed down at 60,000 feet. The difference was that I get dynamic pressure, which is a force that is seen during re-entry on your ship that's only 13% of what the X-15 saw, even though it flew two miles higher than the X-15.

I figured out a way to do it simply, and I took the risk of doing it without wind tunnel testing. Keep in mind that the people flying it were my best friends. I want to be remembered for what I thought was unique about what I did and that I had the courage not to do wind tunnel testing and a lot of analysis. I had developed a lot of airplanes before SpaceShipOne, and I trusted my gut instead of spending hundreds of thousands of hours in engineering.

Johnson: I'll be an airplane geek for a minute. One of the things that shows up often in your designs is the canard. You mentioned that with the early B-70s. Why was that?

Rutan: I was enthralled by the Swedish Viggen.

Johnson: Me too.

Rutan: I thought it was a pretty airplane, and I did some calculations while I was in college that showed that that airplane would probably have natural stall limiting. It had to be stable. It had to have a higher wing loading on the front wing than the back, which means it's easy to design it so that it stalls first. If it stalls first, it won't go to a higher angle. It will limit itself. I thought that could solve a large percentage of the accidents that happen in general aviation. Trying to get back to the airport, you turn back, you turn too tight, you land upside down, and you kill everybody.

I had developed a lot of airplanes before SpaceShipOne, and I trusted my gut instead of spending hundreds of thousands of hours in engineering.

I was focused on natural stall limiting. I even did it on an attack airplane that had a 25-millimeter Gatling gun—the ARES. It was a better plane because of natural stall limiting. You can yank full stick on it, and it will make a very tight turn; you don't have to worry about it departing. I thought it was important because of the stability and control. At one point, I was chief flight test engineer on the F-4 Phantom—an airplane that had 61 accidents due to loss of control. Sixty-one airplanes without bullet holes in them are smoking wreckage on the ground, and it's based on the fact that if you pulled too much angle of attack, you're likely to begin to spin. One of those spin modes is not recoverable in the flight mode.

My experience of flight testing the F-4 made me a big fan of trying to do stall limiting in the very big VariViggen. I named it after the Saab Viggen. I could vary the trailing edge and leading edge to change the lift at a given angle of attack, which was a feature that wasn't all that useful when I looked at all the data later; that's the origin of the name, too. A buddy of mine who worked for me and was flying in the backseat of the F-4 named it. It worked out nicely.

I would do maneuvers in Oshkosh in front of hundreds of thousands of people and fly the base leg right at the numbers. There was nothing set where you turn and then fly a final approach; I pointed it right at the numbers. If I set the right speed at the right moment, I could roll it quickly 90 degrees and pull the full half-stick, and the airplane would slow down to its minimum speed. I'd touch down, and I could stop within 500 feet of the end of the runway, even though I was flying 90 degrees to the end of the runway. It was a cool maneuver, and it was safe.

If I had tried that in an airplane that would stall and depart, it would have been a fatal maneuver. I was enthralled by that. Now, of course, that was a lousy performing airplane. Its aspect ratio, which is short wings, meant that it didn't have a very good range or great performance. My next task was to see if I could attain that same safety benefit of stall limiting by having a canard on a high aspect ratio airplane. That's how the very easy research prototype was done. I did not market that. I was using a modified Volkswagen engine, and it failed twice. So, I said, "I'm not going to have people building home-builds and having accidents. I'm going to design a bigger airplane around an aircraft engine." That's why we had the ARES. I thought that the stall limiting was important on the attack airplane.

Other than that, you don't see the canards that much, except for Proteus. Proteus had a canard because I was designing an airplane that would sit in a seven-mile diameter circle over large cities with a big dish on it so that people on the ground with a six-inch dish pointed at the airplane would have broadband. This was before fiber in the ground. To do that, I had to do something special so that the wings weren't in the way. The back wing goes up and then down, and the left wing is transparent. It's quartz and fiberglass. The right wing is carbon fiber. That's the only

Rutan's safe twin-engine airplane design, the Boomerang.

thing that's sort of in view when you're in this continuous turn.

The Voyager was a canard for dynamic support of a lot of span-loaded fuel. If you put all the fuel in the middle, your wing spar is going to be heavy, but if I put it partially out here, the wing is a lot lighter. If you put it out there on that slender wing, it will twist in turbulence and come apart. The canard on the Voyager is to support the torsion of what is most of the fuel in the airplane. That's why the Voyager was a canard. After that, I got away from them. I found that I was wrong about a pusher engine being quieter. It's not because a prop sees the vibrations that are going in and out of the wing in flight. It's noisier to have the prop on the back. That's why my Catbird and Boomerang have engines on the front.

Feinberg: Of all the designs over the years that you were involved in and developed, what do you consider to not necessarily be the most advanced but the most significant?

Rutan: Boomerang, clearly. The only people that fully appreciate Boomerang are people who fly light twins. Like a Baron, it's an airplane with engines on the wings. With those airplanes, if you lose an engine and have to feather that engine and then go to full power on the other one, it will roll upside down, and everybody dies. You have to fly at a speed so that with full rudder, you can barely control that. It's called the blue line speed.

Statistically, on general aviation airplanes—everything from Piper Cubs to King Airs—your chance of having a fatal accident after the failure of a single-engine is much higher on a twin than it is on a single, even though on a single, you become a glider. The reason is controllability. It shouldn't be. If pilots keep it fast enough, they should be able to fly back on a single-engine and land. But people buy twins because they think, "I have twin engines. It will be safer, with a much smaller chance of killing my family and me." But statistically, they're twice as dangerous.

Rutan's Boomerang twin-engine design.

The Boomerang is significant because it looks asymmetric, but it is symmetric when the Baron is asymmetric due to the P-factor. You have a propeller where if the wind goes straight into it, the thrust of that propeller blade is the same as it goes around like this. But when you're slow, which is when you lose control, you're flying nose-up. The air is coming in from the bottom. When the blade is in one direction, it's going into the flow, but when it's in another, it's going with the flow. One propeller blade makes more thrust in one direction than in another.

Feinberg: There's no balance.

Rutan: The net effect of that is the thrust line is not in the crankshaft; it's about nine or so inches to the right. The Boomerang looks asymmetric. Between where the CG is and the shorter engine on one side, at your low speed where you have the P-effect, the thrust of both engines moves to the right, and the Boomerang becomes symmetrical. Not only does it become symmetrical, but your engines are blowing on your tail, which gives you more control and more stability. A Boomerang is absolutely dramatic. The minimum control speed on a light twin is defined by the fact that you have the full rudder in as you slow down, and even though you have the full rudder in and you're pushing like hell with your right foot, if you fly a little bit slower, you can no longer go straight. You'll start to turn. You go a little bit slower than that, and you could be on your back. That's the definition.

With the Boomerang, you don't even need to put your feet on the rudder pedals. You can fly it at its minimum speed with the full half-stick, which doesn't stall. It does a bucking motion, single-engine. You can turn into the dead engine as tight as you want to. It's a bizarre, extreme difference in safety. On top of that, the Boom-erang has a tremendous advantage in efficiency. I built the Defiant, which is a push-pull twin, and then the Boomerang. If you take a Boomerang with four-cylinder engines—which normally cruises at 260 knots—and slow it down to 185 knots—which is the maximum cruise speed of the Defiant—the higher altitude, you're going the same speed. The Boomerang has exactly half the fuel flow of the Defiant—twice the miles per gallon.

The bottom line, in all of my work, is the airplane that has the most dramatic benefit for safety and for efficiency and range. That's why the Boomerang is probably my best work. Yes, the Voyager flew more than twice as far as that B-52 did, and it had to be built frail, but it was pretty obvious what I had to do with the Voyager. I had to make the structure extremely light, and I had to make it stiff enough to carry a lot of fuel. With the Boomerang, it wasn't obvious what I had to do to make that safe. In fact, most people look at it and say, "I'm not riding in that. It doesn't look safe." That's why there have been three attempts to raise money to certify and build a Boomerang, and none of them have raised the money.

Matties: My question was around the light twin. When you lose one engine, the natural instinct, perhaps, is to accelerate, but wouldn't you be safer if you turned off the second engine?

Rutan: First of all, they have heavy wing loading. You're going to go right into the trees or the houses. It's better to hit the trees with the wings level than upside-down. Again, people who do that also have fatal accidents because they hit the trees. The people that do what you need to do to keep control don't always do it right. It's too complex to list all of the reasons, but I can tell you confidently that, statistically, twins are more dangerous than singles. They keep selling them with this impression that they're safe. But you cannot get in trouble with a Boomerang. You need the rudder pedal for taxiing on the ground. You don't need them at all in the air. It's by far my best work.

Matties: You talked a bit about engineering and some of the principles and rules. What advice would you give to young engineers that are coming into a new career?

Rutan: Ask them what they like to do. Are they attracted to the idea of being the inventor of a breakthrough? If they are, they have to work very differently than almost any engineer that comes in and goes to work. When someone comes in out of college, they might think, "I don't like what I see out there. There's not much going on since the '60s that is breakthrough in nature, and I want to fix that." That sort of person would get totally different advice from me than someone who says, "I'm in engineering because I heard it pays well, and I can live in San Diego, which is a nice place."

A recent graduate might also think, "I have all this cool software. I know how to run it, and maybe I'll invent some new software, but I'm going to use it to be more efficient in my work, be more productive, and therefore make more money and be able to retire." There's nothing wrong with feeling that way. I have no idea how to train someone to be innovative. My expertise has been knowing the environment to put him in, and that is to not burden him with the regulations of a company.

Let me give you an example in the computer field. Around '83, IBM finally figured out that there is money to be made in what Steve Jobs was doing at Apple, so they went out and made the right decision. They didn't try to develop one in-house; instead, they took a few smart people and put them in a hotel and didn't burden them with any of their in-house regulations. They invented the IBM PC. After it was a huge success, they thought, "We know how to do this. Let's do another one that's more affordable," and they developed the PC Junior in-house. IBM only sold a few of the PC Junior units, but they acted like entrepreneurs to do the IBM PC.

I gave a talk to General Motors, and I ended up taking them to the High Sierras above the timberline. I gave them boxes. I said, "Teams will be made up of a member of Scaled Composites and an engineer from General Motors. Here's a box for each team. Go where you can't see anybody else and figure out a solution to our problem that we're trying to solve. Don't come back until you've figured out something or it gets dark."

The next day, their management showed up. I'm talking about the people that have silk handkerchiefs in their coat jackets. I made them show and tell, and I concluded that the teams were too large by a factor of two. They spent almost all the time trying to convince my people of what they knew, and my people spent almost all the time trying to convince them what they knew. Very little time was spent discovering a breakthrough in solving the problem that was before us. That's a story that takes longer to tell, but I'm going to detail it in my biography.

Feinberg: To give you an example that what you say is so true, where are the big advances coming today in personal computers? The big advances are coming in pieces, but they're significant advances.

Rutan: Why aren't they working into more VR? I think VR is a big thing.

Feinberg: They are, but the answers are coming from the do-it-yourself builders. Then, the more advanced or premium companies copy what the DIY people are doing.

Rutan: I understand what you're saying, and I agree, but I don't follow it as much since I'm retired now.

Matties: Now that you're in retirement, what has your attention?

Rutan: I was burned out when I retired. I did a phase one of a flying car for the last five months of work before I retired, and I worked my ass off. I'm talking about long hours, and not just doing the drawings for it, but also building it in the shop.

During the last months of my work before retirement, I didn't want to be a manager. Think about it. I'm the founder. I'm the boss. Almost every time that there's a strategy decision, I didn't run it democratically all the time. I would take a vote at a management meeting, but a lot of times, I'd say, "I hear you guys, but this is the way we're going to do it." Now, visualize that position when you're in the last few months, and you know that you're going to be not only retired, but you're going to move to Idaho. You will not be there to deal with your decision.

Northrop owned the company at that time, and they won't let you consult afterward. There's some rule; you have to be retired for two years. After retirement, I did not want to consult. I was burned out big time. I didn't even look in the rear-view mirror when I drove away.

From my retirement home, I could look from my deck down at this floating green of the golf course. It's the most recognizable feature of

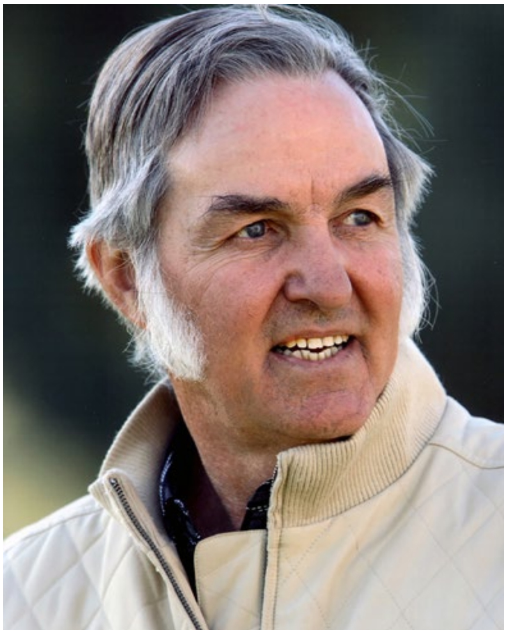
Video Clip: SpaceShipOne Keynote

Click image above to view an excerpt from Burt Rutan's keynote address at IPC APEX EXPO 2020.


We are dedicated
to excellence through
innovation,
technology
and most importantly,
service.
COMMERCIAL • MILITARY • MEDICAL • BAREBOARD
U.S.C.
U.S. CIRCUIT
www.uscircuit.com
ISO
9001 CERTIFIED
DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA
ITAR
Registered International Traffic in Arms Regulations

Idaho. But golf is a six-months-per-year activity. On the lake below, I'd see these seaplanes come in. That looked like a bunch of fun. If I had good sense, I'd have bought one, but instead, I tried to do something that was hard to do—build a much better one. So far, I have failed at that. I'm back to designing new airplanes now and working on a solution for the urban transport category.

Feinberg: I understand, not to the same degree as you , but I have failed retirement twice, and I hate golf. You have to do something. About every six months, I'll take a break and build a new computer because that's what I do instead of playing golf. I'll max it all out, benchmark it to the end, and then forget about it for six months. Then, you find out that someone beat you. I also play with a country-rock band.



Rutan: Do you ever play Elvis?

Feinberg: We do.

Rutan: I have sideburns out of respect for the king. The problem is that the people who love Elvis are dying off, but I decided to continue to wear the sideburns. When you get older than me, you might find yourself wandering around now, knowing where you are, and you get lost. My right sideburn is in the shape of Idaho. I can say, "Canada is here. I live here. Take me home." (laughs)

Matties: It has been enjoyable having you as a guest.

Rutan: I've enjoyed talking to you, as well. I wish I had time to see all the displays here. I'm surprised that I don't see much virtual reality stuff here, but if I was working on breakthrough technologies for virtual reality—such that you don't have to travel to a vacation or business meeting—I wouldn't show it. I would hide it until it's ready. When you attend a show like this, you're telling everybody else what you know. We didn't attend shows or demonstrate our composite manufacturing methods. I thought, "Why would I do that?" I sent my people to shows to learn things, but I wouldn't display myself.

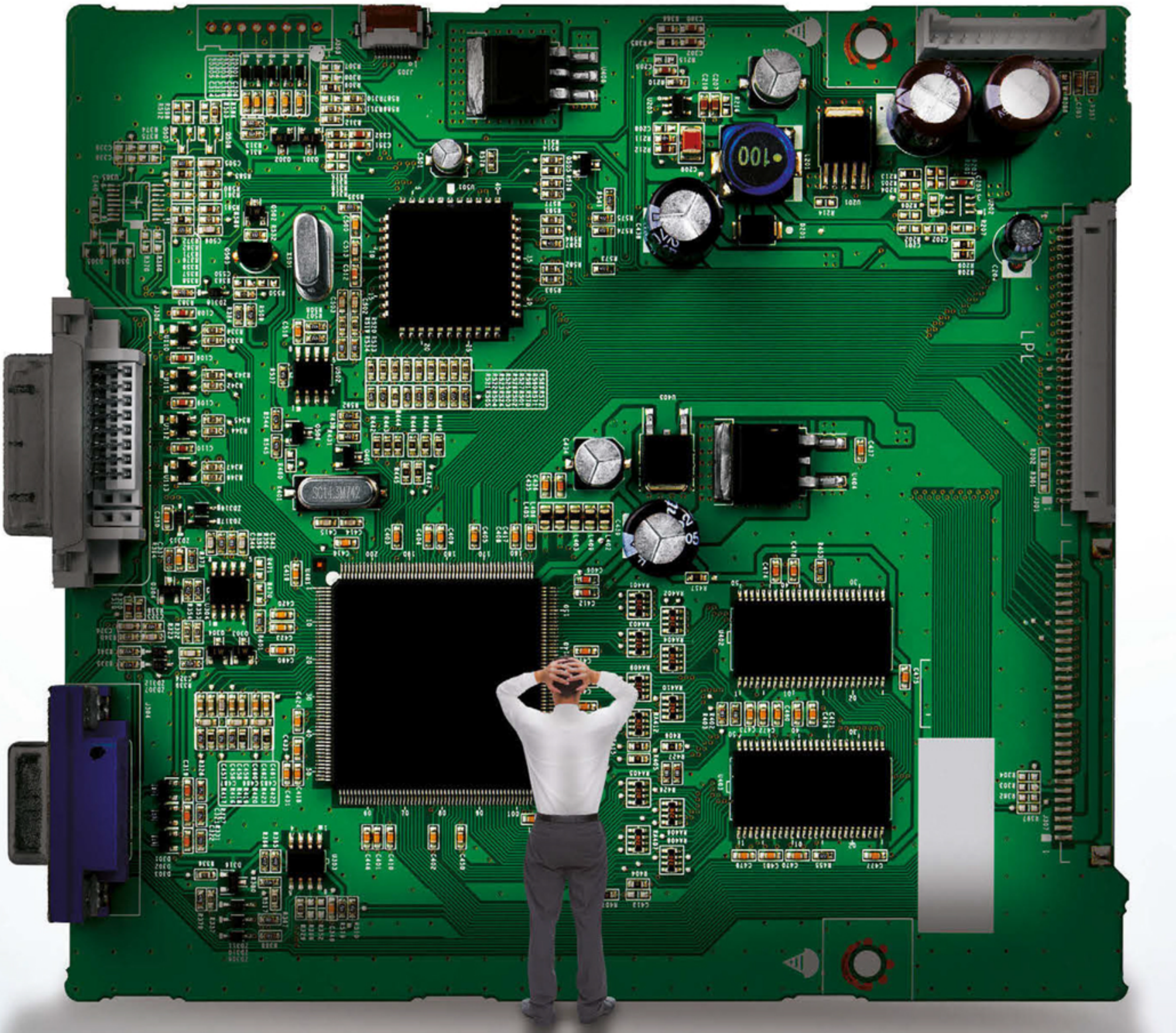
Matties: It's interesting that you say that. Happy worked for HP for 30 years, helped invent the first HP scientific calculator, and he's the father of HDI fabrication. When he talks to young engineers, they will say, "We're going to try this new thing." He'll remind them, "We did that back in the '60s, but at HP, we never got patents because once you got one, you had to share the idea." Happy always says that they were good at keeping secrets. That's exactly what you're talking about.

Rutan: That's much better than a patent. Now, I have 13 patents, but I've only paid for three of them myself. It's the customers that say, "We want to protect it." I found that life is a whole lot more fun if you don't deal with lawyers. If I had more time, I would have shown my lawyer slide, which essentially says that big companies are run by the lawyers. When lawyers advise companies on risk management, executives will always follow them because they don't want to have a lawyer who comes up later and says, "I told you so." That's a huge problem.

Matties: Burt we certainly appreciate your time today.

Feinberg: Thank you so much. It was a pleasure meeting you.

Rutan: It was very nice meeting you, too. **SMT007**



Improving Reliability for Free

Quest for Reliability

by Eric Camden, FORESITE INC.

While implementing a digital factory for assembly will help predict measurables like cost and throughput, can you also rely on that data to predict your product reliability? Admittedly, I am not an expert on the implementation of a digital factory, so if you decide to move onto the next article, my feelings will not be hurt.

I know that words and phrases like 3D motion simulation, integration, and virtual models are used, but I honestly don't have a clue what the meaning of those words are in this context. Please don't hire me to help you with your digital factory implementation. I mean, it's your money, and I'll probably take the job, but I can guarantee we will both regret that decision.

The good news is that I do have quite a bit of experience with reliability, so let's stick with that for now. I have seen more than a few factories make the move to use more and more automation that has indeed improved production numbers but has done very little to address cleanliness and reliability. If you are building a thousand pieces per hour of reliable products, that is a good thing.

However, and you knew the but was coming, if you have an unknown issue in your process, and it goes undetected because you are solely relying on your system, you might be producing a thousand failures per hour. If this is the case, you might be lucky enough to catch the product while it is still in-house and direct it to quarantine for disposition—that is, if you are lucky enough to catch the problem before it heads out to its next destination.

To help reduce the risk of producing a questionably reliable product, I am going to take this opportunity to pretty much completely disregard this month's topic and offer up a few easy steps you can take to reduce that risk. Remember, what I know about implementing a digital factory

Highly Certified Premier
Mil-Aero C5ISR
Electronics Contract Manufacturing
& Engineering Design Services

DESIGN
BUILD
TEST
TRUSTED

Protect your data and choose an electronics contract manufacturer that is IPC-1791 certified.

Zentech was one of the first electronics manufacturers to earn the IPC-1791 Trusted Assembler certification and to become NIST 800-171, DFARS 252.204-7012 and FAR 502.204.21 compliant.

Zentech is considered a subject matter expert in NIST 800-171 compliance.
Cybersecurity/John Vaughan interview

NIST Compliance is just one of the many ways we take great care of our customers.
Learn more at zentech.com

ZENTECH

Baltimore, MD Fredericksburg, VA Dallas, TX

www.zentech.com • 443-348-4500 • sales@zentech.com would maybe fill a thimble, so this will be time better spent for both of us.

One thing I have learned after 20 years is that while there are endless combinations of materials that could be used for an assembly, the number of actual assembly process steps is fairly low and consistent. There are a few exotic processes that won't be covered today, but if you have one, I would love to see it. I will address the basics that seem to be consistent with 99% of all manufacturing I see on a regular basis. As with all good stories, let's start at the beginning.

Receiving materials is a step of the process that is not always thought to be directly related to reliability, but it's just as important as any other step.

Receiving materials is a step of the process that is not always thought to be directly related to reliability, but it's just as important as any other step. I was in a facility just last week that had one of the biggest issues I see with receiving where the dock doors open directly to the warehouse racks. I was in a normally arid part of the world, and the issue is if the doors are open to the outside environment, and a wind kicks up, there is a real opportunity for dust that might be laden with ionics to come right in and deposit on the racks or even to the production floor. This could pose a threat to solderability if there are any open packs of bare boards or parts.

If the process is truly no-clean, there may also be an issue with the adhesion of conformal coating if that is to be used. Further, there is an issue with spikes in the amount of available atmospheric moisture when it rains. This can cause the same issues as dust, but you can also add in problems like an under-cured solder mask absorbing moisture into the board and causing more problems down the road when that moisture comes into contact with other process residues.

The one thing that is normally covered and exempt from the dock doors being open is parts that have a moisture sensitivity level. The impact would be on the dry cabinet and how hard it works to maintain a low percentage of relative humidity. In general, you want to segregate the receiving area and the storage areas to be sure that the outside environment has as little impact as possible.

Normally, in the same part of the facility, you will find solder paste and epoxy storage. You want to be sure that your refrigerator temperature and relative humidity are being monitored with a calibrated device with alarms for exceeding the upper and lower control limits. It is always recommended to have a system for monitoring the temperature and humidity in all parts of the facility, and receiving is no exception to that.

Now, let's move on to the surface-mount solder process as it is normally next in line, and this is where the real action starts. The first part of this process is, of course, the solder paste printing process. When it comes to paste printing, I can only recommend a few tips, as we don't see a lot of problems stemming from this process. What we see on a regular basis are poorly cleaned stencils that collect paste in the corners of the apertures that can cause skips in paste deposition. A good paste process will include automated solder paste inspection (SPI) to find anomalies. If a misprint is discovered, the board should only be cleaned with an aqueous wash process of some sort if cleaning of misprints is allowed at all. The same goes for the stencils.

We now have properly pasted boards, and parts are placed properly I assume, it's time to get them into the oven for reflow. The thermal profile is pretty much the most important part of this process, so it's imperative to do it right. Doing it right includes taking a look at the paste manufacturer's recommendation, and then realizing they have no idea what you are building.

The reflow profiles on most of the tech datasheets, and the correlating analytical data, are based on bare test boards that don't represent the thermal mass or complexity of your product. When determining the profile parameters, you must use an actual assembly—most often, a first article or prototype unit. The thermocouples need to be placed at locations with the highest areas of thermal mass and areas with components that are difficult to process like QFNs and other bottom-terminated components.

Another good idea is to keep up on machine maintenance. If the exhaust ducts are clogged, the airflow will be restricted, and flux activators won't be drawn out of the machine and can collect on the inner surfaces. When enough of this material collects, it can drip back onto the surface of the board in a form that is basically pure activator and extremely conductive and corrosive.

Now, we move on to the plated through-hole process, where applicable, of course. Wave soldering can be the dirtiest of all solder processes, and this is normally because of the liquid flux application process. The standard process is an indexing spray flux at the opening of a wave solder machine. The problems we see with this process is excess flux being drawn to the top side of the assembly through the vias and up the part leads. The issue with this is that the flux may or may not reach the required temperature to render it near benign as designed by the manufacturer. This is especially a problem if a selective solder pallet is used.

When flux is drawn into areas that are designed to keep flux out, it is shielded by the pallet from the proper temperatures. The same can be said for other types of selective solder using robotics or humans. Humans are normally the worst of the worst when it comes to causing electrical leakage and electrochemical migration. This is usually associated with the use of a bottle of liquid flux for hand solder of PTH parts. Generally, extra flux will make a nice shiny solder joint, but it will also leave a lot of active flux residues causing issues.

The next assembly category is what I consider most of the miscellaneous processes that aren't standard. This is where the conformal coating, various epoxies for staking, underfill, etc., are applied. Each of these processes have their own inherent problems, and the preceding soldering processes can have a huge impact if not properly done. Excessive flux residues will impact the adhesion of any subsequent application on top of the electrical leakage issues.

Excessive flux residues will impact the adhesion of any subsequent application on top of the electrical leakage issues.

Then, the parts need to be installed into their housings in the case of facilities doing a full box build or into boxes for shipping to the next supplier. Yes, even this process can impart enough contamination and handling residues to facilitate the dreaded dendrite growth. The simple tip I have for this process is to be sure to only handle the assemblies by the edges. I assume you've always only handled them by the edges, right? RIGHT? The other thing to keep at the top of your mind is to only use new, or provably clean, ESD bags for packaging.

Those are just a few simple things that can be done to help reduce the number of detrimental residues on your assemblies, and none of them cost a dime. I do apologize if you came to my column this month, hoping to see some detailed dive on the implementation of a digital factory. I'd have been interested in reading what I had to say about that as well. Maybe next time this topic rolls around. SMT007

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

MilAero007 Highlights

Elmatica CEO Approved Member of the Swedish Cyber Defense and Export Control Groups ▸

Elmatica has announced that CEO Didrik Bech is an approved member of the Swedish Cyber Defense and Export Control Groups.

Raytheon Facility Earns First True Platinum Zero-Waste Certification in Texas ▸

Raytheon Company earned the first TRUE Platinum Zero-Waste Certification in Texas for its advanced manufacturing center in McKinney. The site earned the designation for its innovations in resource management and waste reduction.

American Standard Announces License Agreement With Averatek ▸

Anaya Vardya, president and CEO of American Standard Circuits, announced that the company signed a licensing agreement with Averatek for its A-SAP™ patented manufacturing process.

What It Takes to Be a Milaero Supplier, Part 1 ▸

The decision to pursue military and aerospace certification impacts every facet of the organization, and not every shop is prepared to make this transformation. This is the first article in a four-part series, breaking down what it takes in sales and customer service, engineering and CAM, purchasing and quality, and manufacturing. Anaya Vardya starts by exploring sales and customer service.

Burt Rutan's Keynote: SpaceShipOne ▸

In this video clip from his presentation, Burt Rutan discusses some of his aircraft's revolutionary flights that drew the most public attention, including SpaceShipOne, which flew three of the five manned space flights launched by man in 2004. He also explains the benefits of working with Microsoft's Paul Allen, who agreed to fund SpaceShipOne based on a simple handshake.

Defense Speak Interpreted: The Missile Defense Agency ▸

The Missile Defense Agency (MDA) has its roots in the Strategic Defense Initiative (SDI), known as "Star Wars" in the 1980s, as proposed by President Ronald Reagan. In this column, Denny Fritz provides an overview of how the MDA operates and describes types of missiles and phases.

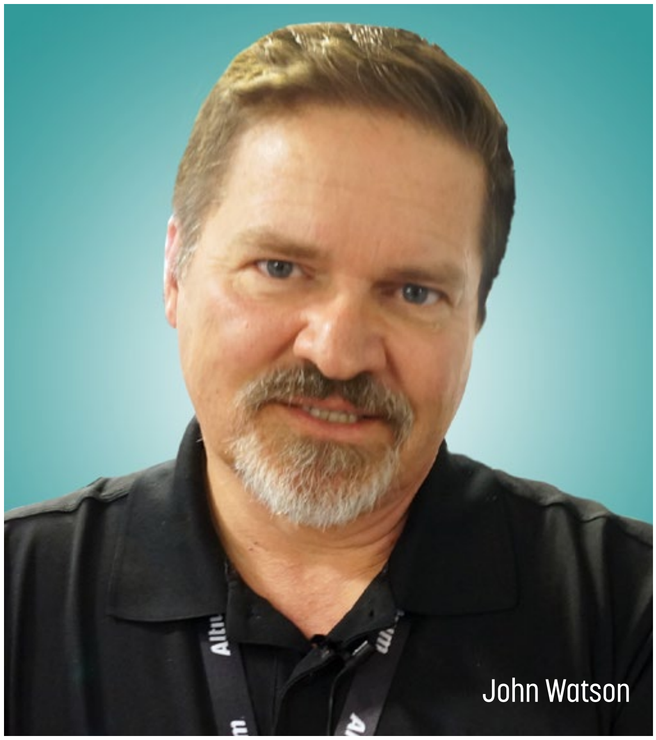
CAMtek Receives AS 9100D 2016 Certification ▸

Ms. Christine Davis, president and CEO of woman-owned CAMtek Inc., announced that her company received its AS9100D 2016 certification from registrar TUV Rheinland of North America, achieving a near-perfect audit. This will allow the company to further participate in its aerospace programs.

HSIO Technologies and Flexible Circuit Technologies Sign Comprehensive Flex and Rigid-flex Printed Circuit Production Agreement ▸

HSIO Technologies LLC—based in Brooklyn Park, Minnesota—and Flexible Circuit Technologies Inc. (FCT)—headquartered in Plymouth, Minnesota—announced a comprehensive technology agreement for the production of high-performance, high-density flexible, and rigid-flex circuits.

When Your Fabricator Is Late


John Watson

Interview by the I-Connect007 Editorial Team

The I-Connect007 Editorial Team recently had a wide-ranging discussion with John Watson, CID, of Legrand. Questions covered include, "What happens when your fabricator is late, whether it's a prototype or volume production?" and, "What are the costs and ramifications up and down the chain?"

Andy Shaughnessy: You and I have spoken before about time to market, and how we're all battling time. Let's talk about what happens when one cog in the system is late. What are the costs?

John Watson: Time is the big issue that I hear about. The VPs at my company say, "We need to decrease our time to market," because they see our competitors. The lead dog always gets that biggest piece of the pie if they can get out there with their product first.

Barry Matties: To that point, when you're working with your fabricator, you place the order, and they give you a delivery date that then goes one, two, or three days late. What happens if they miss it by one day?

Watson: That has a significant impact.

Matties: From a designer's point of view, what does that do to you?

Watson: It puts us in a place where you can't put a number on it for how much market share you've lost. We have a lot of external things involved in our design process that throw monkey wrenches into it, such as tariffs because we do work with China. One of our places is in China, so we have some outside influences on our designs, but we try to keep it to a consistent schedule. We identify what we call "blockers" in what we're trying to accomplish, meaning things that are blocking us both internally and externally. We need to identify those blockers and get them out of our way because those can constantly be problems. I would talk to the fabrication house about potential issues.

Happy Holden: The first thing you learn as a young engineer at Hewlett-Packard is breakeven time. It's like ROI, but for designers. It came about because if design managers hit obstacles and they're going to be late, they go to management and say, "I need more resources,"


PRINT ON DEMAND
ORDER NOW
Automation and Advanced Procedures in PCB Fabrication
Happy Holden
DOWNLOAD NOW
I-007eBooks
I-007eBooks.com/automation

and managers say no. Lo and behold, they are late. Hewlett-Packard made money off of being the first to market. Then, Stanford MBAs used Professor William Ireson's idea of break-even time, which the financial guys understood. Break-even time is when the profits have paid for all the R&D development money, so it's not a return on investment. After the break-even time, you're truly making a profit.

Matties: You had your schedule.

Holden: And if they were too late, they would pay us more.

Matties: Do they agree to that in advance?

Holden: Yes, before they ever took the orders. If they didn't, they didn't get any orders.

Matties: I don't know many board shops that have a money-back guarantee for on-time delivery, so to speak, because it's more than money back.

Holden: That's right, but they only gave us money, not time, so they couldn't possibly compensate us. If they were one day or two days late, they didn't get the next order because time is so valuable, especially in being first to market. We were only going to make the profits in the early six or eight months before everyone else jumped in and lowered the price.

Matties: That was your highest margin period.

Holden: Many times, we'd design the second generation at the same time as the first generation. The first generation was about time to market, and the second generation was about lowering in cost. As everybody copied our first generation, we introduced the second generation and dropped the price dramatically, so they all dropped out of the market.

Matties: Back to external blocks, if you have a fabricator that you think is going to be on time, and then they wind up being a few days late, how do you handle that?

Watson: We do our fabrication internationally, so we have less control over the fabrication processes than I would like.

Matties: But when you place an order, they give you a delivery date and miss it, there's a consequence for you.

Watson: Right. Often, we have to do a root-cause analysis to try to solve some of those issues in the future.

Matties: If the manufacturer caused you to be late, what is the ramification?

Watson: The main ramification, if they continue doing that, is I would drop them and find another fabricator that can follow the schedule. The fabrication industry is such a dog-eat-dog world. They will make any promise to get that contract.

Matties: When you place an order, do you look for some sort of guarantee?

Watson: We can't do that in our situation, but I think it's a good idea for structuring.

Holden: What if they're one day early? You have to accept that if you're going to charge them for being late, you have to give a bonus for being early.

Watson: Exactly.

Holden: The companies that do it can take advantage of it because they're giving you a conservative time. But if they get a bonus for doing it earlier, they'll carry the stick.

Watson: Right now, we are getting more and more into high speed, and that is going to require us to have specific material and control our design, especially in fabrication. The biggest problem I have in dealing with international fabrication houses is there's this "curtain" of an image that they put out. The fabrication house will say, "Yes, we can do it." Later you ask, "How did it go?" They sometimes respond, "Everything went perfectly! We'll ask our fabrication or assembly house, "How many boards fell out of the design process?" Again, they'll say, "We had 100%."

Matties: I was born at night, but not last night!

Watson: I fell off the truck, but not the turnip truck. Statistically, it is impossible that everything was perfect. That's not good information or feedback for us to operate on because we're looking to improve, and I know it's not perfect. Working with international suppliers is very difficult.

Matties: How are you handling your prototypes?

Watson: We handle our prototypes domestically, which comes with its own problems. Understand that a prototype is only the beginning process because you design, fabricate, and assemble it with more of a controlled situation. When we do things domestically, I talk to the fabrication and assembly house to find out the details because we want to make sure that we monitor everything in detail of this design; I was just on the phone this morning doing that with our fabrication and assembly house in Germany. That works well to get a high-quality board. Next, the board will be put forward in the process, and a lot of times, we look at compliance and certification.

Then, you switch everything over from domestic to international and lose control of our entire design, fabrication, and assembly. We may lose compliance. Compliance is not something you want to redo, so we have to take it down to a point before it gets into compliance and then transfer it over to the international level and get that certified. We want the certification based on what we're going to be building, not just a prototype. It's great if you have a product you can verify, but somehow, that has to be translated into the international area.

Holden: Why do you go to international companies?

Watson: Price.

Holden: If you could get the prototype for the same price as the high-volume international, would you use the same source?

Watson: I think we would.

Matties: More and more offshore fabricators offer that. We see the lot size move down to 40 in some of these big places.

Watson: These are some of the conversations that I'm going to have in a couple of weeks in China. I'll be in Shanghai to discuss it with our board house.

Matties: This is bad news for U.S. fabricators.

Watson: True, but there are so many restrictions on U.S. fabricators, especially in California. The restrictions on chemicals and processes that can be used have killed PCB fabrication in the U.S.

Shaughnessy: Of course, state regulators would say it was because they dumped everything in the river for many years.

Holden: Even the Chinese are learning that PCB fabrication has a lot of nasty chemicals. Now, the Chinese are moving to Vietnam because they can't meet their own emissions standards.

Watson: It's starting to impact China like what we have gone through here in the U.S.

Matties: When you do prototypes, this is a race for time as well. If a prototype house is late, at impact does that have on you?

Watson: It has much more of an impact on the beginning of the project than it does later on because everything is lined up waiting for this hardware and ready to move forward with that prototype. That's the reason why I was on the phone with Germany this morning: They were a day behind. I asked them some very serious questions about what was going on with the delay.

Matties: That's typically their issue, not yours.

Watson: Right. A lot of times, the biggest issue is the procurement of parts, especially when you're doing a quick prototype. When you have a fabrication that only takes a day or two, especially a simple four-layer board, you're doing a day or two of fabrication, and you have a day or two to get parts in.

A lot of times, the biggest issue is the procurement of parts, especially when you're doing a quick prototype.

Holden: When we wanted to beat everybody in time to market, one of the big problems was that the time delay in getting a solder paste stencil was two weeks. Somehow, they magically couldn't get that time down in the printed circuit, so we put the solder paste on while it was still in the board shop at the panel level. The prototypes never have any solder paste stencils; they flux, place the part, and reflow. That saves all of these days that our competitors put in that we never had. Think outside the box and consider how you can get past the bottleneck.

Watson: They have solder paste stencils now. I understand that they're 3D printed onto the board.

Holden: But they don't print it at the board level, where you have all the things already in the panel. That's a much higher resolution when it's a panel. That was one reason we were always interested in jetting solder paste rather than stencil; however, it interferes with the components, but not in the bare board state because there are no components at the bare board state. The simplest solution is right here, not fighting the powers that be.

Matties: When you have a string of vendors lined up, and you're a day late, that hurts.

Watson: For every fabrication and assembly build, we do a post-mortem analysis covering how well we did and what issues arose. We find the root cause of the problem and try not to do that again. A lot of that is done now through managing projects in Altium and the collaboration tools. Everything is documented inside the PCB design. If we have problems, then that communication about solutions happens inside.

Holden: I think the key thing is you have a post-mortem. We had a post-mortem after every design at HP. We would review the problem and write down how we could do this better and faster the next time.

Watson: Those post-mortems are fantastic because that's where you start to analyze yourself, including how well you did and what the issues were.

Matties: This is where the truth really matters, though. You have to realize you're attacking the process and not the people because when they feel so connected to their work, it's hard not to take it personally.

Watson: Right. And you constantly keep trying to improve that process.

Matties: Thank you for your time, John.

Watson: This has been great. Thank you all. SMT007

Electronics Industry News and Market Highlights

Rockwell Automation Strengthens Control and Visualization Portfolio With Acquisition of ASEM ▶

Rockwell Automation Inc. announced it signed an agreement to acquire Italy-based ASEM S.p.A., a leading provider of digital automation technologies. ASEM provides a complete range of industrial PCs, human-machine interface hardware and software, remote access capabilities, and secure industrial IoT gateway solutions.

Virginia Middle School Student Earns Honor of Naming NASA's Next Mars Rover ▶

The name was announced recently by Thomas Zurbuchen, associate administrator of the Science Mission Directorate, during a celebration at Lake Braddock Secondary School in Burke, Virginia. Zurbuchen was at the school to congratulate seventh-grader Alexander Mather, who submitted the winning entry to the agency's "Name the Rover" essay contest, which received 28,000 entries from K–12 students from every U.S. state and territory.

BAE Systems Secures $188 Million Contract for U.S. Navy's AEGIS Combat System ▶

BAE Systems Inc. was awarded a five-year $188.2 million contract to provide the U.S. Navy's AEGIS Technical Representative (AEGIS TECHREP) organization with critical large-scale system engineering, integration, and testing expertise for the AEGIS weapons and combat systems aboard U.S. Navy surface combatant ships.

Lockheed Martin's HELIOS Laser Weapon System Takes Step Toward Ship Integration ▶

Lockheed Martin and the U.S. Navy moved one step closer to integrating a laser weapon system onto an Arleigh Burke destroyer after successfully conducting a critical design review for the high-energy laser with an integrated optical-dazzler and surveillance (HELIOS) system.

Micron Partners With Seven Industrial Companies to Deliver Robust and Innovative Solutions ▶

Micron Technology Inc. reaffirmed its three-decade commitment to the industrial market with the introduction of its Industrial Quotient (IQ) Partner Program.

Boeing T-7A Crew Shuts Off, Restarts Engine in Flight to Demonstrate Reliability ▶

Restarting a military jet's engine in flight is a critical safety feature that can only be demonstrated by doing something a flight crew rarely wants to do: shutting off the engine in flight.

Silvus Technologies Radios Used by Team CoSTAR in DARPA Subterranean Challenge ▶

Silvus Technologies is proud to support Team CoSTAR in the DARPA Subterranean Challenge. The Collaborative SubTerranean Autonomous Resilient Robots (CoSTAR) team uses radios by Silvus Technologies for communication with the CoSTAR robots and sensors during the DARPA "SubT" Subterranean Challenge.

Rolls-Royce Launches New Electronics Manufacturing Capability at Purdue to Support U.S. Defense Engines ▶

Rolls-Royce created a new engine control capability near the campus of Purdue University to support its U.S. defense business, including the F130 engine competing for the U.S. Air Force B-52 program.

The Gemba Transformation of Manufacturing With AI

Operational Excellence

by Alfred Macha, AMT PARTNERS

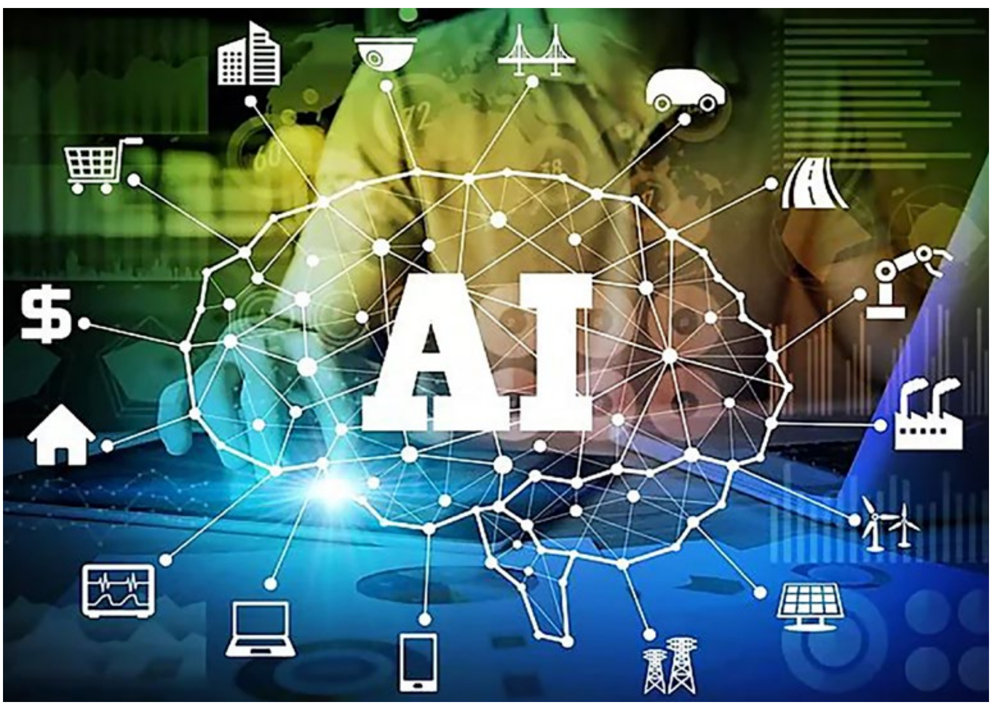
Operational excellence managers have been leading organizations' transformation with Lean Six Sigma methods for the past two decades. An effective Lean Six Sigma method often used is the gemba walk. This method can improve your operations by having managers observe and engage with manufacturing workers to collaborate where work is done. This column will look at how AI can redefine gemba to accelerate changes in your operations, including covering the fundamentals of Lean, how traditional gemba works and introducing ideas on how AI can enhance improvements.

What Is Gemba?

"The term 'gemba' comes from the Japanese word meaning 'the real place.' In Lean management, 'gemba' is the most important place for a team as it is the place where the real work happens," so you can observe and analyze it [1].

Various methods exist to implement gemba walks. There is, however, a common requirement. Gemba walks are led by senior managers by collaborating with production workers to optimize processes or to resolve operational challenges.

There is a common pitfall that some organizations fall into when implementing gemba walks. These companies schedule random walks by senior managers to observe the process and try to correct issues on the spot. This approach turns gemba into a reactive process where operators become apprehensive about engaging management for fear of making mistakes when they are observed.



Prepare a Purpose for Your Gemba Walks

Gemba walks need to be for the specific purpose of achieving gains in operational improvements. Managers should have a well-defined process for gemba walks before starting this process. Table 1 can help provide a purpose when doing gemba walks.

	Phase Description	What's the Purpose of Doing This?	Suggested Guidelines to Apply for This Phase
Phase I	Observe, but don't correct.	Conduct an objective assessment of what is working well and document opportunities for improvement.	Prepare a gemba checklist to take notes of items observed and discussed during these gemba walks.
Phase II	Seek to understand.	Get an unbiased review of the process being reviewed.	Ask the right questions, such as, "Why is it this way?" Don't make conclusions without understanding why things are done a certain way.
Phase III	Consider value-added activities.	Identify activities that are working well.	The objective is to maintain best practices and recognize workers.
Phase IV	Subtract value.	Identify non-value-added activities that create waste and burden productivity.	Engage with workers to understand the reasoning behind these activities. Challenge assumptions.
Phase V	Improve conditions, tools, and procedures.	Remove the activities that are detrimental to production.	Collaborate with production workers to find the best path to eliminate non-value-added activities and optimize the process for success.

Table 1: Gemba walk phase guidelines.

Purpose of a Gemba Walk	- Define the product line or product type that will be evaluated - Define the specific issue that needs to be reviewed		
Evaluation Sections	**Lean/Waste Element**	**AI Data Inputs Gathered Before Gemba Walk Starts**	**Gemba Walk Observations**
	Transport	- Data that shows product movement from location to location.	
	Inventory	- Data that shows WIP, production output, and material scrap.	
	Motion	- Data that shows a "time study" of operator movement during set-up or the actual assembly of a part.	
	Waiting	- Idle time data over a period of time. - Number of occurrences where there was idle time.	
	Over-production	- Parts produced versus parts required. - Analyze material variances or batch size configuration challenges.	
	Over-processing	- Data that shows process time for each step. Allows for manager to evaluate time spent in non-value-added steps.	
	Defects	- Data that shows quality data and trends.	
Report Out	- What action items were derived from the gemba walk? - Key takeaways from the gemba walk		

Table 2: Gemba checklist with AI.

Integrate AI to Gemba Walks

AI can improve the effectiveness of gemba walks. This can be done by evaluating real-time process data before gemba walks start. The objective is for manufacturing organizations to design and implement an effective AI configuration in order to gather the right process data. AI can monitor and adjust to many more variables and data points faster objectively and more consistently than people can.

The more AI learns, the more it can act and predict outcomes to subsequent changes. This rapid iteration allows people to see how something in production can be improved, forecast the effects of change, and identify where there are bottlenecks or resource constraints.

What would an enhanced gemba walk look like with AI? Table 2 shows a sample gemba checklist that integrates data evaluation from AI.

With the ease of data gathering, thanks to AI, manufacturing organizations can realize more effective continual improvement efforts and specifically have successful gemba walks wherein managers and operators can evaluate real-time data and make the necessary improvements to manufacturing process steps and work tasks accordingly. **SMT007**

Reference

1. "Gemba Walk: Where the Real Work Happens," Kanbanize.

Alfred Macha is the president of AMT Partners. He can be reached at Alfred@amt-partners.com. To read past columns or contact Macha, click here.

System Trains Driverless Cars in Simulation Before They Hit the Road

A simulation system invented at MIT to train driverless cars creates a photorealistic world with infinite steering possibilities, helping the cars learn to navigate a host of worst-case scenarios before cruising down real streets.

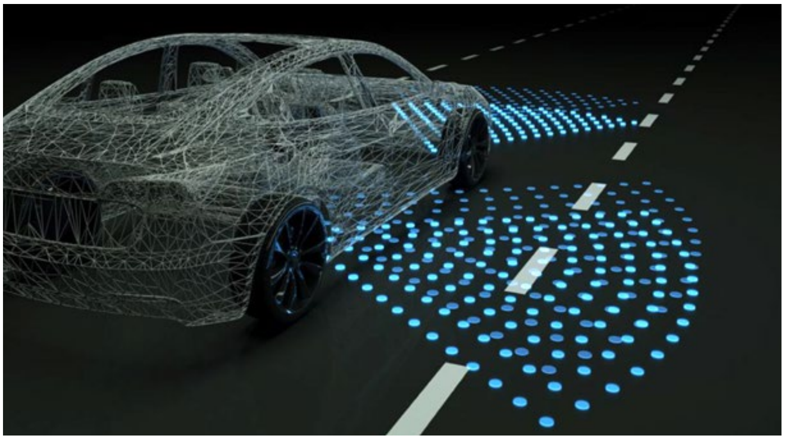
Control systems for autonomous vehicles largely rely on real-world datasets of driving trajectories from human drivers. From these data, they learn how to emulate safe steering controls in a variety of situations. But real-world data from hazardous "edge cases," such as nearly crashing or being forced off the road or into other lanes, are—fortunately—rare.

Computer programs, or "simulation engines," aim to imitate these situations by rendering detailed virtual roads to help train the controllers to recover. But the learned control from simulation has never been shown to transfer to reality on a full-scale vehicle.

The MIT researchers tackle the problem with their photorealistic simulator, called Virtual Image Synthesis and Transformation for Autonomy (VISTA). The controller is rewarded for the distance it travels without crashing, so it must learn by itself how to reach a destination safely, including regaining control after swerving between lanes or recovering from near-crashes.

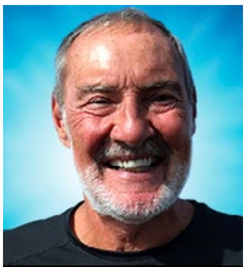
In tests, a controller trained within the VISTA simulator safely was able to safely deploy onto a full-scale driverless car and to navigate through previously unseen streets. In positioning the car at off-road orientations that mimicked various near-crash situations, the controller was also able to successfully recover the car back into a safe driving trajectory within a few seconds. A paper describing the system has been published in IEEE Robotics and Automation Letters and will be presented at the upcoming ICRA conference in May.

(Source: MIT News Office)



Editor's Picks from SMT007.com

1 Will Moisture Management Expand to the U.S. Market? ▸


Rich Heimsch

Rich Heimsch, Super Dry director, chats with Nolan Johnson about the growing demand for moisture management in North America versus its earlier adoption in Europe and how moisture management fits into Industry 4.0 and the smart factory.

2 Powerful Prototypes: An Open-source Adventure ▸


Duane Benson

Duane Benson describes the latest board design project he has been working on in his off-hours—a motion-sensitive lapel pin—including compromises, mistakes, and lessons learned.

3 Stencils: Not As Simple As They Seem ▸


Stephanie Hardin

Stephanie Hardin of Integrated Ideas and Technologies Inc. discusses her role in the supply chain as a stencil manufacturer, improvements she sees from micromachined step stencils, and why she believes trying to have standardized stencil layouts is wishful thinking due to the many fluctuating variables.

4 Solder Paste Printing From the Stencil's Perspective ▸


Jeff Schake

Jeff Schake of ASM Assembly Systems discusses the complications surrounding printing and solder paste that he sees from his perspective as a stencil expert.

5 I-007e Micro Webinar: Primary Flight Control Case Study on Condensation and Coverage ▶

The seventh episode of the popular webinar series “Coatings Uncoated!” is now available to view. Author of *The Printed Circuit Assembler’s Guide to Conformal Coatings for Harsh Environments* and topic expert Phil Kinner from Electrolube shares highly focused educational information on conformal coating and encapsulation. If you are in the assembly business, an EMS, or responsible for specifying conformal coating and/or encapsulation, then this free series is for you.

6 Congratulations to Steve Pudles! IPC Hall of Fame 2020 Inductee ▶

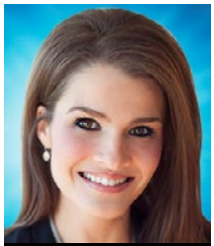

Steve Pudles

With over 32 years spent working with IPC, Steve Pudles was elected to the IPC’s Hall of Fame this year. Patty Goldman spoke with Steve about how he first became involved as well as his time in the organization, including his work with the EMS Management Council.

7 Joe Fjelstad Breaks Down His Occam Process ▶

Joe Fjelstad recently met with the I-Connect007 Editorial Team to discuss the potential benefits of his Occam process for solderless assembly. This technique allows assembly of the PCB without the risks associated with traditional surface-mount processes, such as solder joint failure. Has the time come for the industry to embrace Occam?

8 Foundations of the Future: STEM Student Outreach Program at IPC APEX EXPO 2020 ▶


Gunter du Plessis

When IPC holds an event, there is nothing more rewarding than words like these from Diego, Mount Miguel High School: “I learned many valuable pieces of information related to engineering careers. My favorite topic to learn about was PCBs.” Charlene Gunter du Plessis shares the success of the IPC STEM Student Outreach Program, as well as other updates from IPC APEX EXPO 2020.

9 Zentech Manufacturing Inc. Acquires CAMtek Inc. ▶

Zentech Manufacturing Inc. is pleased to announce the acquisition of CAMtek Inc.

10 Zulki’s PCB Nuggets: Putting the Heat on for Thermal Profiling ▶


Zulki Khan

A unique thermal profile is designed for each PCB job undergoing conventional SMT assembly, as virtually every PCB assembly professional knows. But what about a PCB assembly project involving both conventional rigid board and an extraordinarily small rigid or rigid-flex circuit undergoing microelectronics assembly? Zulki Khan covers PCB hybrid assembly, which requires two separate, unique, and distinctly different thermal profiles.

For the latest COVID-19 industry updates, click here.

Career Opportunities

Employment Opportunities

National Technology, Inc., a manufacturer of high-quality printed circuit boards, is currently looking for candidates for the following positions in our Rolling Meadows Illinois Facility:

Quality Control Manager

- Manage QMS in accordance with the ISO 9001:2015 system.
- Manage inspection departments, including final inspection, pre-mask inspection, AOI inspection and all associated quality inspections.
- Maintain continuous improvement initiatives.
- Generate and maintain monthly quality reporting.
- Manage internal and external corrective and preventive action.
- Responsible for maintaining the ISO status, including audits, training, procedures, etc.
- Maintenance and scheduling of calibrations.
- Be a liaison to our facility in India regarding customer related issues.
- Customer contact with RMA and corrective action.

Process/Quality Engineer

- Develop and document new processes and technologies.
- Review existing processes for improvement opportunities.
- Assist in identifying and addressing manufacturing issues.
- ISO internal auditing and process related audits.
- Set-up and monitor process controls through manufacturing.
- Maintain regulator compliances.

Candidates for these positions should have a solid background in printed circuit board fabrication. An in-depth knowledge of applicable IPC standards as well as ISO 9001 standard will be required.

apply now

I-Connect007
GOOD FOR THE INDUSTRY

News Editor – Full Time Position

I-Connect007 seeks a positive, independent self-starter to manage news gathering process and work closely with editorial team. Qualified candidates will demonstrate strong organizational and communication skills and be able to work full-time remotely.

New hire will start with a portion of this work and ramp up with demonstrated mastery of the processes.

Aptitudes

- Organized
- Time aware
- Team oriented
- Planning skills
- Meeting deadlines
- Good record keeping
- Problem solving skills
- Attention to details
- Strong follow-through skills
- Grammar and editing skills
- Knowledge of basic photo editing
- Knowledge of HTML a plus

Attitude

- Ability to work remotely, often with only "virtual" supervision.
- Discipline to keep regular hours, communicate with team and deliver on deadline.
- Curious, investigative nature and interest in technology.

Objective: Submit editorial proof for the newsletter daily. This task includes news gathering, posting, categorization and simple editing functions.

- Gather news items from pre-planned primary sources for publication.
- Review and post all news items to the news manager prior to deadline.

Interested candidates please submit resume by clicking below.

apply now

Career Opportunities

DB MANAGEMENT GROUP

Talent for Hire

Have a position to fill? D.B.Management has the people you're looking for. Candidates currently available include:

- **Director of Operations, PCB and CEM**
  Grew previous operations to over $100 Million.
- **Technical Field Applications Engineer**
  Over 15 years of experience working in the U.S. with offshore companies.
- **Two Highly Experienced Front End Engineers**
  Over 25 years of experience. Will work remotely.
- **Four Experienced Sales Professionals for Both PCB Fabrication and Assembly**
  All four exhibit successful growth records.

Let D.B. Management help you with your staffing needs. Contact us now by calling Dan Beaulieu at:

207-649-0879

or emailing him at:

danbbeaulieu@aol.com

more details

FREEDOM CAD SERVICES

Sr. PCB Designer–Allegro

Freedom CAD is a premier PCB design service bureau with a talented team of 30+ dedicated designers providing complex layouts for our enviable list of high-tech customers. Tired of the commute? This is a work-from-home, full-time position with an opportunity for overtime at time and a half.

Key Qualifications

- EXPERT knowledge of Allegro 16.6/17.2
- Passionate about your PCB design career
- Skilled at HDI technology
- Extensive experience with high-speed digital, RF and flex and rigid-flex designs
- Experienced with signal integrity design constraints encompassing differential pairs, impedance control, high speed, EMI, and ESD
- Experience using SKILL script automation such as dalTools
- Excellent team player that can lead projects and mentor others
- Self-motivated, with ability to work from home with minimal supervision
- Strong communication, interpersonal, analytical, and problem solving skills
- Other design tool knowledge is considered a plus (Altium, PADS, Xpedition)

Primary Responsibilities

- Design project leader
- Lead highly complex layouts while ensuring quality, efficiency and manufacturability
- Handle multiple tasks and provide work leadership to other designers through the distribution, coordination, and management of the assigned work load
- Ability to create from engineering inputs: board mechanical profiles, board fabrication stack-ups, detailed board fabrication drawings and packages, assembly drawings, assembly notes, etc.

apply now

Career Opportunities

Career Opportunities

ventec
INTERNATIONAL GROUP
騰輝電子

OEM Sales Manager

Chicago/Home-Office-Based

Want to advance your career by joining a globally successful and growing world-class CCL manufacturer and help drive that success? We are seeking to hire an OEM sales manager to grow and manage key customer accounts with OEM's and Tier 1 manufacturers in the USA, focusing on Ventec's core market segments: mil/aero, automotive, and medical, offering a full range of high-reliability materials, including polyimide, IMS, and thermal management products.

Skills and abilities required for the role:

- Non-negotiable: Drive and tenacity!

Required:

- 7 to 10 years' experience in the PCB industry in engineering and/or manufacturing
- Detail-oriented approach to tasks
- Ability to manage tasks and set goals independently as well as part of a team
- Knowledge of MS office products

Full product training will be provided.

This is a fantastic opportunity to become part of a successful brand and leading team with excellent benefits.

Please forward your resume to jpattie@ventec-usa.com and mention "Technical Sales Engineer—Chicago" in the subject line.

apply now

ROGERS
CORPORATION
Advanced Connectivity Solutions

Senior Development Engineer

Rogers Corporation is seeking a senior development engineer accountable for the development of more complex products and processes, the establishment of sound technical bases for these developments, and effective interaction with technology, process, and platform innovation; operations; sales and marketing; and process engineering personnel to commercialize these developments.

Essential Functions:

- Design and conduct experiments and interpret the results
- Report on projects in both written and verbal formats at all levels of the organization
- Perform technical troubleshooting of new products and processes; act as new product/concept incubator for new technologies and platforms, identifying opportunities for improvement and incorporation design for manufacturing requirements resulting in a viable, scalable product
- Provide ongoing process and manufacturing support to newly launched products as applicable
- Provide support in terms of analytical equipment maintenance, methods development, material analysis, and documentation of new process or products
- Manage capital projects for the purchase and installation of new process or support equipment; train employees in new processes

Required Education and Experience:
Ph.D., Ch.E., M.E., or material science, or B.S. or higher in a technical discipline with accomplishment in product development and project management.

Rogers Corporation provides equal employment opportunities to minorities, females, veterans, and disabled individuals as well as other protected groups.

apply now

Career Opportunities

Gardien Is Hiring!

The Gardien Group, a leading solutions provider in the PCB industry, is looking to fill multiple openings in their China, Japan, Taiwan, and United States service centers.

We are looking for electrical engineers, operations managers, machine operators, and sales executives. Prior experience in the PCB industry is beneficial but not essential. Training will be provided along with excellent growth opportunities, a benefits package, and periodic bonuses.

Our global teams are from diverse cultures and work cohesively as a tight-knit unit. With performance and initiative, there are plenty of opportunities for professional growth.

Gardien is an equal opportunity employer. Employment decisions are made without any regard to race, color, religion, national or ethnic origin, gender, sexual orientation, age, disability, or other characteristics.

Interested candidates, please contact us with your resume and a cover letter. Kindly note that only shortlisted candidate will be contacted.

Apply at careers@gardien.com.

apply now

eptac

TRAIN. WORK SMARTER. SUCCEED.

Become a Certified IPC Master Instructor

Opportunities are available in Canada, New England, California, and Chicago. If you love teaching people, choosing the classes and times you want to work, and basically being your own boss, this may be the career for you. EPTAC Corporation is the leading provider of electronics training and IPC certification and we are looking for instructors that have a passion for working with people to develop their skills and knowledge. If you have a background in electronics manufacturing and enthusiasm for education, drop us a line or send us your resume. We would love to chat with you. Ability to travel required. IPC-7711/7721 or IPC-A-620 CIT certification a big plus.

Qualifications and skills

- A love of teaching and enthusiasm to help others learn
- Background in electronics manufacturing
- Soldering and/or electronics/cable assembly experience
- IPC certification a plus, but will certify the right candidate

Benefits

- Ability to operate from home. No required in-office schedule
- Flexible schedule. Control your own schedule
- IRA retirement matching contributions after one year of service
- Training and certifications provided and maintained by EPTAC

apply now

Career Opportunities

Career Opportunities

TAIYO AMERICA

Development Chemist
Carson City, NV

Develop new products and modify existing products as identified by the sales staff and company management. Conduct laboratory evaluations and tests of the industry's products and processes. Prepare detailed written reports regarding chemical characteristics. The development chemist will also have supervisory responsibility for R&D technicians.

Essential Duties:

- Prepare design of experiments (DOE) to aid in the development of new products related to the solar energy industry, printed electronics, inkjet technologies, specialty coatings and additives, and nanotechnologies and applications
- Compile feasibility studies for bringing new products and emerging technologies through manufacturing to the marketplace
- Provide product and manufacturing support
- Provide product quality control and support
- Must comply with all OSHA and company workplace safety requirements at all times
- Participate in multifunctional teams

Required Education/Experience:

- Minimum 4-year college degree in engineering or chemistry
- Preferred: 5-10 years of work experience in designing 3D and inkjet materials, radiation cured chemical technologies, and polymer science
- Knowledge of advanced materials and emerging technologies, including nanotechnologies

Working Conditions:

- Chemical laboratory environment
- Occasional weekend or overtime work
- Travel may be required

apply now

INDIUM CORPORATION®

Multiple Positions Available

The Indium Corporation believes that materials science changes the world. As leaders in the electronics assembly industry we are seeking thought leaders that are well-qualified to join our dynamic global team.

Indium Corporation offers a diverse range of career opportunities, including:

- Maintenance and skilled trades
- Engineering
- Marketing and sales
- Finance and accounting
- Machine operators and production
- Research and development
- Operations

For full job description and other immediate openings in a number of departments:

www.indium.com/jobs

apply now

Career Opportunities

Manncorp

SMT Field Technician
Huntingdon Valley, PA

Manncorp, a leader in the electronics assembly industry, is looking for an additional SMT Field Technician to join our existing East Coast team and install and support our wide array of SMT equipment.

Duties and Responsibilities:

- Manage on-site equipment installation and customer training
- Provide post-installation service and support, including troubleshooting and diagnosing technical problems by phone, email, or on-site visit
- Assist with demonstrations of equipment to potential customers
- Build and maintain positive relationships with customers
- Participate in the ongoing development and improvement of both our machines and the customer experience we offer

Requirements and Qualifications:

- Prior experience with SMT equipment, or equivalent technical degree
- Proven strong mechanical and electrical troubleshooting skills
- Proficiency in reading and verifying electrical, pneumatic, and mechanical schematics/drawings
- Travel and overnight stays
- Ability to arrange and schedule service trips

We Offer:

- Health and dental insurance
- Retirement fund matching
- Continuing training as the industry develops

apply now

U.S. CIRCUIT

Sales Representatives (Specific Territories)

Escondido-based printed circuit fabricator U.S. Circuit is looking to hire sales representatives in the following territories:

- Florida
- Denver
- Washington
- Los Angeles

Experience:

- Candidates must have previous PCB sales experience.

Compensation:

- 7% commission

Contact Mike Fariba for more information.

mfariba@uscircuit.com

apply now

Career Opportunities

I-007e EDUCATIONAL RESOURCE CENTER

I-007e Micro Webinars

Learn from the Experts in Our On-demand Webinar Series

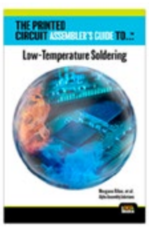
NOW AVAILABLE:
COATINGS UNCOATED from Electrolube, a 12-part webinar series.

I-007e Books

The Printed Circuit Assembler's Guide to...

Process Validation, by Graham K. Naisbitt, Chairman and CEO, Gen3
This book explores how establishing acceptable electrochemical reliability can be achieved by using both CAF and SIR testing. This is a must-read for those in the industry who are concerned about ECM and want to adopt a better and more rigorous approach to ensuring electrochemical reliability.

Advanced Manufacturing in the Digital Age, by Oren Manor, Director of Business Development, Valor Division for Mentor a Siemens Business
A must-read for anyone looking for a holistic, systematic approach to leverage new and emerging technologies. The benefits are clear: fewer machine failures, reduced scrap and downtime issues, and improved throughput and productivity.



Low-Temperature Soldering, by Morgana Ribas, Ph.D., et al., Alpha Assembly Solutions
Learn the benefits low-temperature alloys have to offer, such as reducing costs, creating more reliable solder joints, and overcoming design limitations with traditional alloys.

Conformal Coatings for Harsh Environments, by Phil Kinner, Electrolube
This handy eBook is a must-read for anyone in the electronics industry who wants a better understanding of conformal coatings. Kinner simplifies the many available material types and application methods and explains the advantages and disadvantages of each.

Our library is open 24/7/365. Visit us at: I-007eBooks.com

MANAGING EDITOR: **NOLAN JOHNSON**
(503) 597-8037; nolan@iconnect007.com

PUBLISHER: **BARRY MATTIES**
barry@iconnect007.com

SALES MANAGER: **BARB HOCKADAY**
(916) 608-0660; barb@iconnect007.com

MARKETING SERVICES: **TOBEY MARSICOVETERE**
(916) 266-9160; tobey@iconnect007.com

TECHNICAL EDITOR: **PETE STARKEY**
+44 (0) 1455 293333; pete@iconnect007.com

TECHNICAL EDITOR: **PATTY GOLDMAN**

CONTRIBUTING TECHNICAL EDITOR: **HAPPY HOLDEN**
(616) 741-9213; happy@iconnect007.com

ASSOCIATE EDITOR: **KIERSTEN ROHDE**
kiersten@iconnect007.com

PRODUCTION MANAGER: **SHELLY STEIN**
shelly@iconnect007.com

MAGAZINE LAYOUT: **RON MEOGROSSI**

AD DESIGN: **SHELLY STEIN, MIKE RADOGNA, TOBEY MARSICOVETERE**

CREATIVE TECHNOLOGIST: **BRYSON MATTIES**

COVER: **SHELLY STEIN**

COVER IMAGES: **ADOBE STOCK © XIAOLIANGGE**

SMT007 MAGAZINE

SMT007 MAGAZINE®
is published by BR Publishing, Inc.,
942 Windemere Dr. NW, Salem, OR 97304

April 2020, Volume 35, Number 4
SMT007 MAGAZINE is published monthly, by BR Publishing, Inc.

ADVERTISER INDEX