Whelen Engineering Reduces Cycle Time by Building a New Automated PCB Factory

by Barry Matties and Bryan Bernas
I-CONNECT007

With the Chinese stock market in turmoil and China's wage scales still rising, one might think this would fuel new hope for U.S. PCB manufacturers trying to gain traction in a marketplace that's been dominated by their Asian counterparts for the better part of two decades. But despite chatter about reshoring of late, the general consensus in the industry doesn't seem overly optimistic that substantial change will occur.

While some business is certainly making its way back to the U.S., most people expect the bulk of it to relocate to the next-best location with low-cost wages, like Vietnam, Mexico, etc. To remain competitive, China's government and manufacturers didn't hesitate to call for more automation from its factories once it lost its cost advantage. It begs the question: If China is turning to automation to retain business, what might the same type of automation do for America's reshoring effort? In the case of one such North American company, the results have been breathtaking.

The future of American manufacturing might be found in the small community of Charlestown, New Hampshire, at Whelen Engineering. A company founded and headquartered in Connecticut in the 1950s, Whelen is a leading manufacturer of all things relating to emergency lights and sirens for the automobile and aviation industries. For years, Whelen had been spending about $7 million annually on PCBs from China, but being a strong advocate for bringing jobs and dollars back to the U.S., two years ago they decided to purchase their PCBs in America.

Who did they choose as their new supplier? Well, that's where it gets interesting. Whelen chose to be their own PCB supplier. Where does a company specializing in audio and visual warning equipment get off making their own PCBs?

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mutracx
THE BETTER WAY

Aerial view of one automated process.

Enter Alex Stepinski, a long-time PCB industry veteran hired by Whelen to design and oversee the building of the first captive PCB manufacturing facility in North America in years.

Alex has been in the industry for many years, working at iconic factories like TTM and Sanmina. When Whelen contacted him to lead the effort, he was excited, and rightfully so. Imagine being given a $12M budget with an empty 45,000 square-foot blank canvas to design a PCB line of your choosing, from the ground up. Whelen didn't micromanage or overburden Alex with requirements either—they gave him complete freedom to design the factory as he saw fit as long as there was a reasonable ROI and the line could handle their typical work of single- and double-sided boards, with a few multilayers mixed in. The company manages about 2,500 different part numbers in their product lineup. These were their basic requirements, and what they got in return was so much more.

When it's all said and done, Whelen will have the world's first fully automated in-line, lights out, zero-liquid discharge, 100% digital PCB factory. Alex saw this as a great opportunity to not just build a PCB manufacturing process, but a completely automated PCB manufacturing process. The interesting thing to note is that Alex chose the automation route primarily because it offered him the quickest ROI over every other option available. It's an extremely impressive setup, and unlike any other PCB fab facility you've likely ever seen. The whole line is rectangular, with a control tower-type building in the middle, allowing you to follow a board through the entire cycle. It's a conveyor belt process where you load a drilled board on one end and about 4.5 hours later a completed PCB emerges at the other. Forget having to send boards across the ocean; Whelen reduced their cycle times from days to hours. Whelen designers can have their test and prototype boards in hand by the end of the day. At first glance, what is most noticeably lacking is manpower. The open-space layout makes it easy to look down the length of the line and see two operators where you would normally expect 8–10 people in a typical board shop.

To cut down cycle time, the new facility features a substantial amount of innovation—much of which is new and unproven and comes with considerable risk. Alex did not take the safe approach when doing this; he wanted to not only automate, but also reduce the overall cycle time by bringing in new technology like Mutracx's Lunaris primary imaging equipment, an impressive piece of technology that prints the primary image on the board in about two minutes—prior to plating. The machine plays a key role in the process, printing around 50 double-sided panels an hour, as well as having a built-in AOI.

From there, the board goes into an automated plating line provided by Integrated Process Systems (IPS), who not only built the plating line, but were selected by Alex to be the primary equipment partner, supplying over a third of all of the equipment installed there. The factory

IPS fully automated plating line.

features an impressive line-up of equipment and technology supplied by 39 different companies, almost all of which was purchased from U.S. suppliers. Not only did IPS build much of the equipment, they also played a key role its integration, engineering the software that connects and controls the manufacturing process and helping design and implement all the overhead utilities.

And they are gorgeous overhead utilities, all clearly labeled, color-coded and snugly attached with U brackets. Our PCB007 team gets to visit factories all over the world and let's just say it's not commonplace to leave a shop saying, "Yeah, but those utilities, though!" In a factory like this, with so much to take in, something like the choice for overhead utilities almost gets forgotten among other notable takeaways, like the waste treatment system that allows the factory to have no permits, or the Whelen-made alarms that sound when a certain part of the line has an issue, featuring a custom alarm for each process that enables the operators to easily pinpoint the problem.

Things are done differently there, and with this kind of new technology and integration comes trial and error, as we saw firsthand with the soldermask portion of the line. But from the top down, Whelen seems like a company willing to take certain risks in order to bring manufacturing back to America and no longer be reliant on China. By taking a chance and giving Alex the go-ahead, they took that $7 million a year going to China and invested it back into American manufacturing and American jobs.

The Whelen model gives fabricators plenty to consider for cycle time reduction through automation, and it might even persuade some OEMs to contemplate the possibility of a captive shop. But what makes the Whelen factory a true triumph in American manufacturing is their willingness to share innovative solutions with other North American PCB fabs for the good of the industry and our country as a whole. Being a captive facility, Whelen isn't worried about competition stealing business or certain processes, and this makes it an extremely valuable resource for other fabricators wanting to see new equipment like the Lunaris in a working manufacturing environment before considering it themselves. There's so much to be learned from a factory like this as management continues to prove these solutions are viable. Alex Stepinski and Whelen have set the standard for automated PCB manufacturing in North America; perhaps others will be inspired to innovate similarly through automation and further strengthen the reshoring movement.

Following is the full interview with Alex, who gives a rundown of the Whelen factory, including which processes he thinks every fab shop should automate first.

***Barry Matties:** Alex, we're sitting here, in a building that was empty not too long ago, with a completely automated circuit board fabrication line. Please walk us through how this came about.*

Alex Stepinski: Well, I was hired a little over two years ago to develop a plan to see if it made sense for Whelen to make their own circuit boards in-house. After about six weeks of investigation, I drafted a business plan as well as a drawing and met with the management

Circuit Automation's silkscreening process.

here. I had design work done, and I had selected all the long-term lead time items in case the decision was made to go forward. They wanted to get the capital in here before the end of the year so they could get the appropriate tax breaks for 2013. Six weeks later we had a meeting and the decision was made to go forward.

Matties: ***What was their mandate? Did they come to you and put forward any requirements?***

Stepinski: They wanted to know what it would take to build their own boards, and I had to come up with a plan in my mind that had an ROI that would make them interested in the investment. That's how this came about. This was the only solution I could arrive at that had an ROI that was within a reasonable range.

Matties: ***When you came up with the solution, it wasn't because they said, "We want a fully automated system." They just wanted something that would give them payback.***

Stepinski: Yes, and this was the only solution I could arrive that would give a payback.

Matties: ***Is this something that you had been thinking of previously?***

Stepinski: No, this was a new problem. I had never worked in low-tech circuit board manufacturing before.

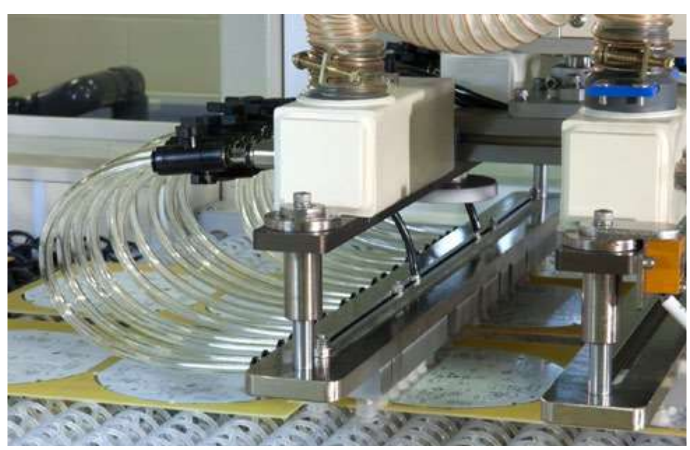
Matties: ***Tell us about the product that's being built here.***

Stepinski: It's primarily double-sided as well as single-sided metal core. A few percent are rigid-flex, and a few percent are multilayer rigid, but in general the technology is quite simple.

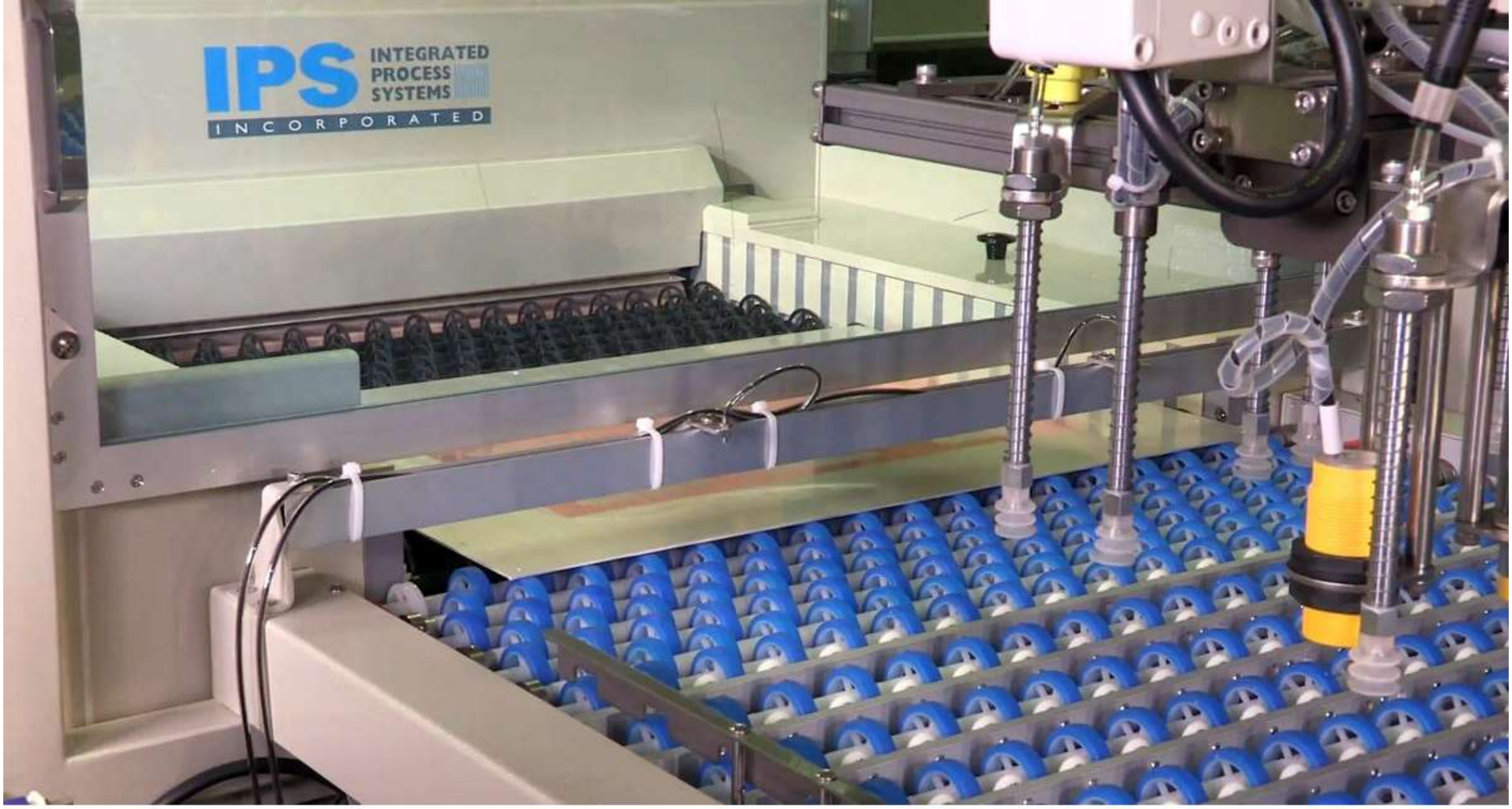
Matties: ***You were saying you have about 2,500 different part numbers that you run through.***

Stepinski: Yes. It's a lot of different part numbers and it's difficult to get economies of scale on that over in the Far East. One of the challenges was to create a process that eliminated the setup cost associated with all those part numbers. To do that I made a totally digital continuous factory that basically saw every part number as a widget and we eliminated all the setup costs associated with it, aside from initial tooling.

Matties: ***You had to build something that was extremely flexible, because you can't stop for tooling changes and such. What was the greatest obstacle in your design when you first set out?***



Handling PCBs.


IPS
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Stepinski: Initially, the greatest obstacle was just to get to the cost points. That was step one. I looked at various alternative technologies and no technology on its own got us there. It was through the integration of everything where we gained the cost benefits. One of the biggest initial challenges was the soldermask process, which is very manual—it's much more manual than many other things out there. To get that to the automated stage, which we're still developing, took considerable effort in the beginning. During the installation phase, the tweaking and experimentation with the inkjet processing was also a significant engineering investment, as was the etch recycling.

***Matties:* Previously, how long did it take for Whelen to get a circuit board?**

Stepinski: Six weeks on average.

***Matties:* And now, start to finish?**

Stepinski: Our cycle time from deburr through final finish is four and a half hours for a panel, and we produce a panel every minute and 15 seconds in fully automated mode. With drilling, routing, and testing, on average, we're going to add another two hours for that.

***Matties:* For your drilling you have Schmoll machines, all single heads. You have eight of**

Schmoll Maschinen Moduls—Single-head drill machines.

Auto loaders for Schmoll Moduls.

them sitting out there and they're auto load and unload?

Stepinski: Correct.

***Matties:* I see a stack of drilled boards, ready to go to the process. It looks like you queue up the drilled panels.**

Stepinski: We designed the drill area to be the bottleneck for the factory, and we designed the wet process area to be scalable for the next 10 years, so the limiting factor is the addition of drills and drill machines and drill heads as demand increases. And that is because having the addition of wet process equipment as your constraint when you initially build the factory is a very poor idea. That's not very scalable. But independent drill machines are very scalable. Our central system for vacuum power can handle up to 28 drill machines. Right now, we have eight on-site.

***Matties:* After they are drilled, the boards go into the process and then for primary imaging you're using the Mutracx Lunaris process. That's a new process—the first of its kind and unproven. You're bringing in really new technology, which seems kind of risky for a startup. What was your thinking there?**

Stepinski: The traditional process was not that amenable to the cost points. This was by far the most amenable. When we look at cost, we look at total cost as well. We look at the waste treatment impact, all of the environmental impacts. This factory is the first green circuit board factory in the world. We only use 500 gallons of water a day. We don't have a wastewater permit, and we don't have any air toxics. We don't even generate hazardous waste. We have designed all those issues out.

***Matties:** Something is being generated. How are you handling that?*

Stepinski: Every process has its own engineering controls to eliminate the waste to the greatest level possible—waste minimization. Some processes have no waste at all and some do, and we deal with that in a very non-hazardous way. The solids at the end come out non-hazardous and they are recyclable.

***Matties:** No permits are required. You already had a building. They had an empty shell here that they gave you to work with, so you had some design constraints but you built a nice, rectangular flow.*

Detail of custom piping.

Stepinski: We did that to fit inside the walls, and the idea was that deburr through final finish would be run by four people at any one time.

***Matties:** Let's talk about the labor. I think a shop like this, producing this level of product, would typically take something like a 75–100 people. Labor is not really a factor in this equation.*

Stepinski: We have 17 people inclusive of all overhead, including myself. One of the things that clearly needed to be done was we needed to minimize the labor in order to get to that cost point. The labor we have is primarily focused on maintaining these systems in place. We have a very minimal amount of manual transactions and we have a very skilled labor force here.

***Matties:** When did Whelen start?*

Stepinski: We started in the 1950s, in Connecticut.

***Matties:** That's great. There's longevity here and it looks like they're willing to take some risks in their business.*

Stepinski: Yes, all of the processes that we ended up procuring and installing, all the feasibility testing for those processes was completed in that first six-week time period. We validated that every individual step would do what it needed to do as a portion of the whole project. The details and the alpha and beta testing were worked out later, but the feasibility testing was fit in up front to minimize the risk and to make sure that when I took the business plan to the CEO, we had enough confidence in that plan.

***Matties:** Right, and when I say it was an empty shell, you had nothing in here.*

Stepinski: It was dirt.

***Matties:** You guys put in all the plumbing, electrical, every component that you needed. Integrated Process Systems came in and it sounds like they were an important partner in this.*

Stepinski: Yes, they got about a third of the project and they contributed the in-line auto-

Atotech Uniplate Integrated Horizontal System.

mation and a substantial portion of the wet-process equipment.

Matties: ***In terms of the way you're managing all of your utilities, they're all overhead: It's concrete floor, well-polished, no trenches, and everything's dry and contained. What was your thinking there?***

Stepinski: Having worked in a lot of different shops, I saw the trench as a liability. If you have a trench then it's going to get filled with solution and leaks will not be addressed when they happen. That's number one. Number two, when you have a trench you tend to collect all your waste into central pipes, so if you're actually running the waste treatment system and have a problem, troubleshooting is extremely difficult. You end up having to go to every single process step in a lot of cases to try to find the source of the problem.

When you have everything in separate lift stations, segregated, you can immediately find which lift station it's coming from and address that process. The troubleshooting time is vastly reduced. That's the justification for that system. Without a trench you're eliminating that potential for having a crack down there that goes unnoticed for a long time, because it's not easy to inspect some trenches.

Matties: ***Right. So you have only 17 staff members, and this is a captive facility. I think this is the first captive facility coming to America in many years. Do you think this is going to become a trend now that there's a model like this in place?***

Stepinski: I hope that what we've done here at Whelen, as the proof of concept, can be done in other factories at different levels. I think what we've proven here is that you can compete with the Asian Pacific region on price and you can do it in a very responsible way. I hope it's a model for continuing to reshore business here in America.

Matties: ***You guys have been very welcoming. You've opened your doors, let us look under the hood and shoot video, ask questions, talk to your people, etc. Why are you so forthcoming with that? What's the motivation to share this?***

Stepinski: We actually do want to share the technology so that other factories and companies in the Western world can learn from us and continue that trend of bringing manufacturing back. Our CEO is a tremendous advocate of manufacturing in America and he's really into promoting reshoring.

Matties: ***I see a lot of American equipment here. I do see some international equipment like Atotech and Schmoll and such, but it's mostly American. Did you go to look for American companies first?***

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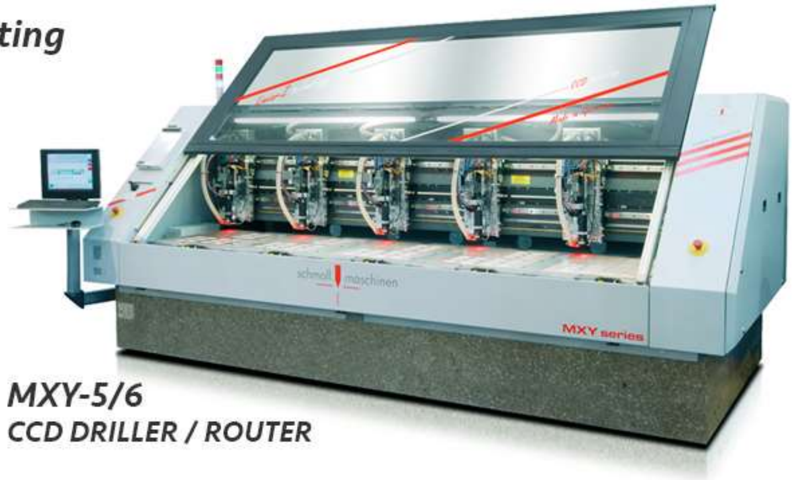

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Stepinski: Our first choice was always to go with American companies if we felt the capability was there to meet our requirements, so we chose American suppliers wherever that situation existed, but we went overseas if we needed a capability that was not here. There are 39 different suppliers contributing to the factory equipment set.

Matties: How much did it cost to put this factory together?

Stepinski: The cost of all the equipment in the factory was around $12 million.

Matties: What sort of timeframe did it take from breaking ground to running your first board?

Stepinski: Approximately 15 months.

Matties: Is that because a lot of engineering was happening as you were building or was it just cycle time for getting equipment?

Stepinski: It was limited primarily by equipment cycle time, the arrival time for equipment.

Matties: The other thing that you've done here is factory software integration from process to process. When we talk about the automated process, what you built is a conveyor belt. These boards aren't queuing up necessarily, they're going through one at a time into the plating and they just conveyor around—you're not storing them. How did you manage that and plan it all?

Stepinski: If you look at a conventional board shop, in my opinion, the majority of the cost is associated with all the non-value-added steps that are between processes, whether it's inspection, handling, putting cleaners and micro-etchers at the beginning of the next process to compensate for the handling in-between, or anti-tarnishes at the end of the preceding process.

If you design all that out, your line is a lot shorter and you need a lot less equipment—there's cost savings there. Things like the sizing and determination of speed-matching and recipe-matching were all planned up front. We worked with our suppliers to develop the chemical parameters and the mechanical parameters, so we would have a continuous half a meter a minute line. That's what we have here is half a meter a minute line. Approximately 50 panels an hour, with the space to add pieces to the line and increase that, if needed.

Matties: All right, so it's not really capable of going higher than that without additional equipment.

Stepinski: Yes, but we are only planning a 50-hour work week with the current demands. We have tons of upside for expansion without adding equipment to the wet process line. The wet process line was specifically oversized knowing that we have a pretty strong growth curve here.

Conveyorized oven.

Boards in transit.

Matties: ***Alex, what's your background? How did you get to be so qualified to do this?***

Stepinski: I've worked for quite a few different board shops. I've worked in many different positions in those board shops, from working waste treatment, working in the lab where I started, to running engineering for companies, from being the general manager of a company to working in quality, running manufacturing, doing purchasing, etc. By working in many different shops and in many different functions, I was able to compound all the experience to somehow be qualified, I guess.

Matties: ***How many years have you been in the industry?***

Stepinski: It will be 18 years this year.

Matties: ***What other issues should fabricators take into account?***

Stepinski: I would think the green side of things must be taken into account. A lot of people miss how cost-effectively they can improve their lot in life from an environmental health and safety perspective. Our capital cost was less than what an average facility pays for a conventional waste treatment system that has significant waste water discharge and air toxics. I think that's something that a lot of people can look at and improve. If they looked at how we did it over here, with a lot of point source solutions with recycling the etch and recovering all the copper, not having any waste is significant.

I think we really put a stake in the ground here that the industry needs to look at, in terms of how to be totally clean, keep operating costs far below a standard factory for wastewater treatment and environmental control in general, and spend less money on it, just by looking at how waste integrates with the process. When you engineer a process, look at the waste. That's my message. I don't think anybody really does it very much.

Matties: ***Talk about your process. I notice that you're using the DIS pinless lamination system. How's that working out?***

Stepinski: We've only used it a few times because we're focusing on ramping up the double-sided before we move to multilayer, but initially all the results passed. Eliminating pins in our system and using vision-based alignment for everything is a key point of the factory. Every stage in this factory is vision-aligned, whether it is layup, drill, rout, score, imaging with inkjets, legend, or soldermask—everything is vision aligned. Where the image can be scaled, we scale it sometimes to meet the final print. We may add some for manufacturing tolerances, but everything, if it's not scaled, is still rotated and shifted, zero-corrected to the optimal alignment to the image that it needs to align to, preceding.

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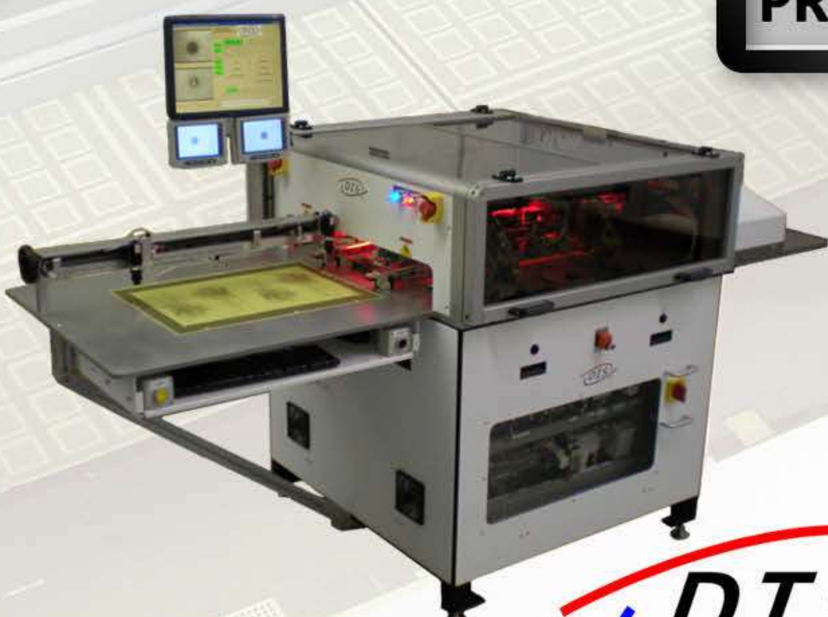

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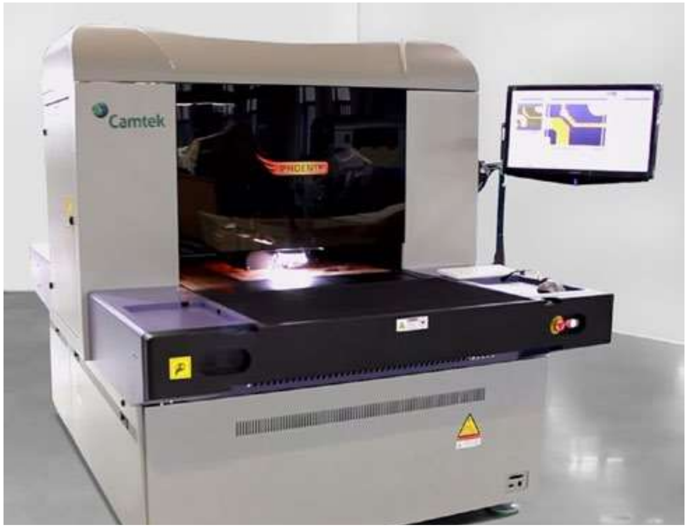


Camtek AOI machine.

***Matties:** With regard to inspection, I think you only have one AOI in your system.*

Stepinski: Yes, we use a Camtek AOI to qualify individual part numbers. Once we qualify a part number, we say it's good to run in production and then we continue to do spot inspections as new parts come into the system. So we're actually sampling our production on a regular basis to know if there are any potential problems, but we do not do 100% inspection. We only sample based on our product technology and based on the robustness of the process, that's all that we need to do.

***Matties:** What sort of fails do you have or what are your yields?*

Stepinski: We continue to learn some of the design rules for our products. How we apply tooling to the products, with certain features doing things a little bit differently, seems to be the root cause of 99% of what we have for issues now. We mitigate that by running a test lap first when we get new tooling and learning from it. That's not a long-term solution. That's only for the next couple of months until we feel our design rules are robust, based on feedback from that process. Once we get 10 or 20 part numbers that are clean in a row, off we go.

***Matties:** I would think that for your circuit design and new product development team this is an amazing resource to have, because they can come and test a design and within hours have some prototypes.*

Stepinski: Before they would take days to get prototypes, and now we can do multiple iterations in the same time it took to get one prototype done.

***Matties:** That's a huge advantage.*

Stepinski: It's a huge advantage for debugging when they're doing a box build.

***Matties:** So you've done it—you did the planning, the execution, and it's running. What would you have done differently?*

Stepinski: What would I have done different? Because of the time constraints for the design phase of the project, I did a lot of concurrent engineering. I did the high-level design in a very short time, and then the details were worked out over the course of time. As the equipment was being built I'd be in regular conversations with suppliers going through a lot of details, and if I had a little bit more time to have done that all up front instead of doing it concurrently, I probably would have reduced the cost by another 10%. I probably would have been able to reduce the capital cost by 10%, and probably the operating cost by the same amount if I'd had a little more time. But that's the nature of schedules. We can't all have infinite time to do things.

***Matties:** But the next time you do this, I'm sure your knowledge and attention will be in high demand. Because a lot of people will look at this and just be blown away by what you have achieved. I've been in this industry for almost 30 years and I've talked with people about doing this, but I don't ever recall seeing anyone do it to this extent.*

Stepinski: We needed to do something different in this industry. Nobody's built low-tech boards in mass production in the U.S. this century, profitably.

***Matties:** You're profitable, you're healthy, it looks like you have a few bugs you're working*

out but you guys are really close to just turning this thing on and letting it roll. Congratulations.

Stepinski: Thanks.

Matties: In general, I see that Mutracx is really the primary imaging over there. You were saying you've already run some 14,000 panels through there?

Stepinski: We have about two-thirds of the process basically fully automated. That means one person can run from deburr all the way through soldermask pre-treatment, and we're working on finalizing the soldermask process in the short term right now.

Chemical dosing stations.

Matties: What about chemical management? I see all these dose stations.

Stepinski: After having worked in a lot of different factories, I was not excited about having drums and containers partially full and having people checking inventory on things like that, having to deal with the potential safety issues of a lot of chemical transactions. What I mean by that is in the typical industry process you do an analysis and you potentially need to make an add. So you go to the drum and you make the add, which means a person has to handle the chemistry.

I always worry that someone's going to have a bad day and put the wrong chemical in the wrong bath. I've seen it happen enough over my career that I wanted to minimize the risk of that as much as possible. We don't have any open drums here. We have day tanks for everything. They're all sized for the packages, they're all double contained, and they're all vented.

When we get a package in, like a drum, we transfer the whole drum into the day tank one time with a two-person team checking each other. We've minimized the transactions because of that and then we have metering pumps on those day tanks that go to whatever location needs the chemistry. It's all controlled by the PLC, so there's nobody pumping anything. That reduces the transactions by well over 90% and increases our safety factor and reduces risk.

Mutracx Lunaris system.

Matties: Sounds like health and safety are big issues here. You have one lab in the center of your facility and one person that just maintains your baths, but that's not automated, right?

Stepinski: We have automation in the lab itself to improve things. Most circuit board shops don't have an ICP, an inductively coupled plasma spectrophotometer. They use AA, which means you have to analyze every element individually and sit there for long periods of time to do that. We have an ICP which allows us to just put the sample in the auto sampler and walk away and do other things at the same time.

Just a couple of days ago we analyzed some samples for 32 different elements at once, and you're able to walk away. We have auto titration. We pick the program, put the sample in, and walk away. With all of that automation in there, one person is able to spend no more than six hours a day maintaining all of the chemistry in the factory as well as doing all of our cross-section work. That person still has time to do other things at the factory.

I didn't want to manage a factory where I didn't feel good about coming to work. The health and safety of the employees comes first.

***Matties:** I should note that you guys are sitting out here in the middle of nowhere, really. You're the largest employer in this area.*

Stepinski: Yes, the largest in the valley.

***Matties:** The people I've talked to here are really excited about working for this company. Many have been here for many years and it sounds like a few have moved into this new division. The other thing that I noticed is several young people here—it looks like you're really helping these people.*

Stepinski: I'm 39 and the average age here I think is about 37, according to my calculations. We have a full range and a nice bell curve of experience here.

***Matties:** Are you doing a lot of cross-training in this factory?*

Stepinski: Yes, the idea is that the people here are able to do just about every job needed to support the manufacturing operation. With so few people, you have to have that level of cross-training to tolerate a vacation (laughs).

***Matties:** Exactly! Now, in this process I know there are a lot of steps, but what was the thing that most surprised you? Was there anything that you didn't plan for and it was just like, "Wow this really worked out better than I expected"?*

Stepinski: Actually, the waste water system. When we first started, it was planned to have a waste water discharge. We were actually in the permit application process to have a waste water discharge, and the more and more I got into the details of the engineering, I actually ended up not having one and continued to realize the benefits that could be had with very minor process adjustments to eliminate waste.

That was something I had never done before. I had never developed a waste water process or an environmental control process in general, along with the manufacturing process at the same time. Normally, you have something preexisting and you're adding onto it in a brownfield operation. From a greenfield perspective, doing both at the same time, the benefits were huge. After doing it, you realize that it can be applied to a brownfield as well after all the things you learn here.

***Matties:** We've been here for three days and you all have been quite accommodating and welcoming, and we greatly appreciate that. I think you may have a lot of disruptions in the future because a lot of people will want to see what you're doing here.*

Stepinski: We hope it helps the industry in the West.

***Matties:** I think it will. I can't imagine someone not being inspired by this and looking to do this else-*

Burkle WorkCell lamination system.

where. Although a lot of fabricators, as you know, are already in place, and it's hard to say "We're going to start fresh with a clean piece of paper."

Stepinski: I think in a brownfield operation it is difficult, but it's not impossible. One way to look at it from a brownfield perspective is you have process segments that you can certainly automate. If you just were to look at individual process segments like pre-clean through strip, for instance for innerlayers, that segment should always be automated. There's no good reason why it should not be automated.

A lot of people say, "Well there's product variation, or there's fine lines," and things like that. You need to just spec the equipment out appropriately so it's robust for that application. You need to do pretesting. All of that equipment is on the market now from a host of different suppliers and you can also make it so there's no waste from the system.

It's all available. Our research showed that and we've done a proof of concept here, and this is applicable to multi-layer applications. The innerlayer applications, the easiest ones, are automated. We actually automated the whole outer layer process here. People have tried to do innerlayer processing before with varying degrees of success, but outer layer is much more difficult. If you can do that, you can do an innerlayer.

Matties: What sort of line spaces are you getting down to?

Stepinski: The minimum we do here is three and three.

Matties: Can you go lower with the technology you have here if needed or is that just what you designed to?

Stepinski: That's what we designed to.

Matties: But if someone needed to go lower, they could certainly go to whatever they need to.

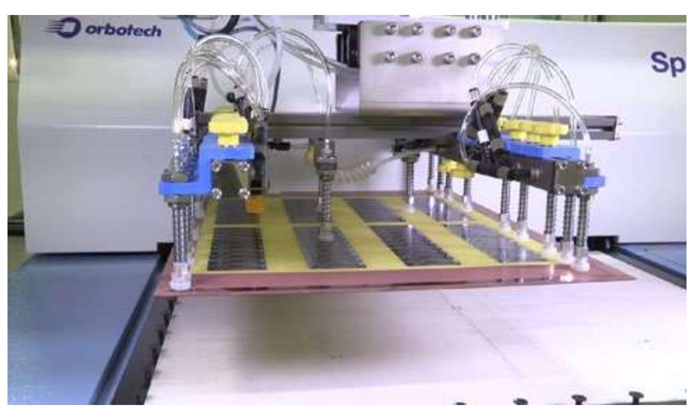
Stepinski: Yeah, and there are all different processes that can be employed to go lower and all of them are robust. A lot of this stuff is used in Asia all the time now.

Matties: You know, I'm looking at it and really, I only see a couple of really new pieces of technology in the Mutracx system, but everything else...

Stepinski: Everything else has just been integrated. We took equipment that has been around for a while as a standalone and we integrated it.

Matties: For the primary Mutracx process, what sort of reduction in cycle time did you gain there?

Stepinski: One of the challenges with a conventional photolithography process is if you're using artworks you're worried about repetitive defects and things like that. The Mutracx process



Handling system for Orbotech Sprint inkjet printer.

has a built-in AOI step and it's fully digital, so you don't have to worry about repetitive defects from a contaminated setup. Then you might say, "Well, why not LDI?" LDI is not the most cost-effective solution. The materials associated with it have a higher cost.

Then you have to really look at the indirect cost. With a dry film process in general, no matter how you image it, you have to develop the image. The developer is actually a pretty terrible limitation on the process. You'll hear from the imaging equipment suppliers, "We can hold this spot size, or we can hold this tolerance." Then when you develop it, you're putting it through a very primitive technology. With a dry film the thickness of the dry film is uniform, and if you look at an inkjet image, you'll see that it's not uniform.

Someone that's used to looking at dry film might say, "Well there's something wrong with the inkjet image." In fact, it's much better because it tapers down from the center of the line to the edge, so that where you're actually etching there is no profile—it tapers down to the copper. The actual difficulty of etching is less with inkjet versus dry film because the aspect ratio of the channel you're etching is less. What we find with inkjet technology is we can hold equivalent etched tolerances to laser direct imaging because we don't have to contend with the aspect ratio of a channel and we don't have to contend with the developer. There are a lot of benefits to that.

We also don't have to deal with thousands and thousands of liters of waste developer solution every week that needs to be treated in some way, or need a permit that's regulated and need an outfall to the river or the POTW.

Inside view of automated Orbotech inkjet legend printing line.

Matties: You said innerlayer pre-cleaning through stripping is the first line they should automate.

Stepinski: That should be automated in every factory.

Matties: What would be the second line you would go after?

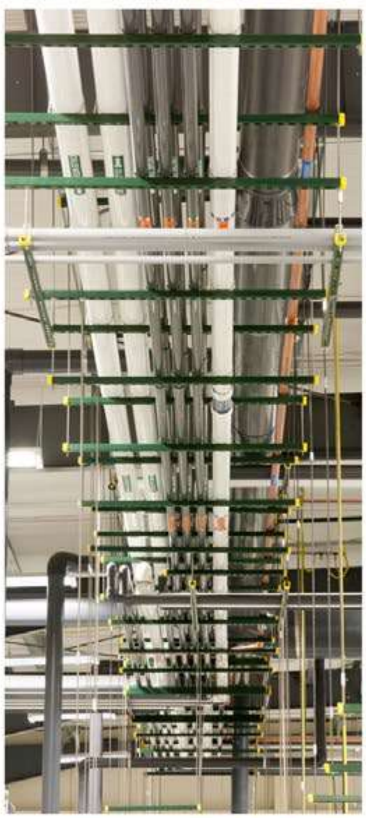
Stepinski: It depends on the factory and the space. You have to look at what the space constraints are. Typically most people have an innerlayer process pretty close to each other or somewhat in line as it is. You find that in most applications, and why it's broken up is a really good question. A lot of it's because the equipment is being bought piece by piece. It's not being looked at as a complete system to be integrated. Stepping back a little bit and pausing and looking at the big picture can save tremendous amounts of capital investment and tremendous amounts of operating cost later. I think that's what people miss.

Matties: Thank you so much for everything.

Stepinski: You're welcome, Barry. Thank you. **PCB**


CEDA PARK
WHELEN


IPS




BURKLE


IPS


PENTA
AUTOMATIC


IPS
AUTOMATION
UNIPLATE

FEATURE

WHELEN & IPS:
A Strategic Partnership—A Winning Combination

by Bryan Bernas
I-CONNECT007

Integrated Process Systems, Inc. (IPS) is a manufacturer of automated wet process equipment and material handling systems in Cedar City, Utah. IPS was formed in June of 1996 with a philosophy of being a multi-product, multi-industry company. In 1996, IPS purchased the assets of VCM for its vertical process equipment, and in 2000, purchased the assets of Western Technology Associates Inc. (WTA) for its horizontal process equipment and VRP technology. The result is the establishment of IPS as a state-of-the-art product line that offers a turnkey solution to all wet process and material handling requirements.

Of the 39 suppliers Whelen chose to use, none were as integral to the automation and overall design and layout of the line as IPS, with its team led by President Mike Brask. In February 2014, IPS approached Whelen at a very early stage, to put the required infrastructure in place before any of the equipment could be installed. This involved the design and installation of all the overhead utilities: the blower on the roof for exhaust, the process piping, as well as all the Unistrut framing (yellow and green for Mike's favorite Green Bay team—a playful jibe for a factory located in the heart of New England Patriot territory). IPS also hired local mechanical contractors to run the plumbing, which would later be connected to pump stations (also installed by IPS) scattered throughout the factory. From start to finish, the Whelen project took the IPS team approximately 18 months.

Speaking about taking on such a large project, Brask said, "From an engineering point of view, the challenge was thinking through all the process flows and automation details that needed to happen; Alex Stepinski had his flow charts and his logic worked out, but what does that tool have to look like? That's where we came in. He did a very good job spec'ing the process, which made it a lot easier, but then configuring the tools to do each one of those functions—that took some time. Another big challenge for us was that normally, equipment manufacturers in the U.S. don't get huge orders like this every day. We had to ramp up to keep up with the

IPS Conveyorized horizontal wet processing line.

IPS panel accumulator.

capacity we needed to build this along with our other projects and try to balance it all."

The IPS equipment made up about one-third of Whelen's equipment spend. Overall, IPS installed 52 machines at Whelen. One of the key technical challenges was working with other vendors to integrate their tools into the software management system. IPS had the responsibility of integrating these tools for the line to run as a turnkey solution. This involved writing software drivers to work with each supplier's unique formats and languages that, in some cases, weren't developed at the time the orders were placed with IPS. All systems needed to be programmed so the user could define the process flow of each job in a tray that could be independently routed and tracked. This software and hardware allowed the line to run as a continuous system.

All IPS equipment was manufactured in the U.S. in Cedar City, Utah, except for the handling equipment, which was made by IPS' Taiwanese partner, WorldTech. It makes up an impressive automated conveyor system that tracks very smoothly and is filled with IPS loader/unloaders, buffer systems, etching and stripping systems, and so on. But perhaps the most impressive IPS system is the vertical electrolytic plating machine. Being fully automated, this machine has the biggest cycle time gain; in 30–40 minutes Whelen is able send a panel through the entire process. After all of the equipment was installed, IPS also worked with Proface, their touchscreen provider, to develop software that coordinates all the machines and allows the system to monitor each job in real-time.

Within the budget Whelen set, Alex dreamed up a remarkable factory, but it was IPS that played a central role in making it a reality.

"We're in a redefining moment," Brask said." We had our initial business plan that we started the company with—to be multi-product, multi-industry. We've always stuck with that philosophy. That has gotten us through the downturns and the recessions. We've been fortunate enough to always be stable. Now what we're doing is we're redefining the business plan to basically bring to the table integration and automation. It's what the future market needs in the U.S. for circuit boards." **PCB**

FEATURE

MUTRACX: First Install Achieves CAM to Etch in 5 Minutes

by Barry Matties
I-CONNECT007

While visiting Whelen Engineering, which had just installed Mutracx's new Lunaris machine. I met with Mutracx Sales and Marketing Director Peter Coakley, who showed me how the new machine works and explained how it can save time and money on the shop floor.

***Barry Matties:** Why don't you just start by explaining the Lunaris imaging process?*

Peter Coakley: What you are looking at here is our digital inkjet printer, a key component of the automated process. At Whelen, it is used for etch resist (inner layers), and plating resist applications (outer layers). This process replaces many costly steps in the traditional photolithography and provides significant reductions in process time, massive cost savings in materials and labour, and is fully compatible with supporting "green" manufacturing ethics and the environmental requirements demanded here at Whelen.

In a production environment, we go from a file that the CAM operator prepares to inkjet printing and subsequent etch or plating process in five minutes. That's what we offer, the flexibility and full batch automation that lets you actually print, on the panel, the exact circuit design you need in a short time.

With the conventional process, you would have to laminate the panel with dry film, manufacture a set of artworks and then expose that dry film using these artworks on a separate process followed by a developer process to wash off the majority of that unexposed dry film.

***Matties:** And it's done inline as well?*

Coakley: It's automation that lends itself to inline volume production. Due to the flexible CAM interfacing without set up time it's perfect to manufacture in a high-mix environment, even running prototypes between the main production volume.

Using the automated line buffers, you can stop a job part way through and switch production types and lots, so it has the flexibility built in to switch jobs and print either a negative image for subsequent plating or an inner layer positive image prior to etching.

Let me just emphasise again, that the inkjet process does not require a developing process as you only use the minimum of ink resist needed to produce the circuit design, thereby again reducing processing time, materials and wastage.

Matties: ***How does it know which job? Does an operator have to come in and select?***

Coakley: In the basic manual operation mode that is possible, but the system is designed for full automation by referencing panels in barcoded trays at the very start of the manufacturing process. It uses the master database to print the right image design on the right panel with minimum intervention.

Matties: ***Can you explain the inkjet printing process in simple terms?***

Coakley: The panel, either for PTH or inner layer, enters the machine after standard pre-clean process and alignment. Once inside, the panel is picked up by a gripper bar that transports the panel into position on a vacuum table or chuck.

The table and panel are then moved to an inclined (60°) position for an alignment process using punched fiducials for inner layers or using pre-existing drilled fiducial holes in the case of PTH boards.

The panel is then transported, again with a gripper bar, onto the printing stage and aligned with the scanner prior to inkjet printing. These alignment steps ensure high front to back accuracy.

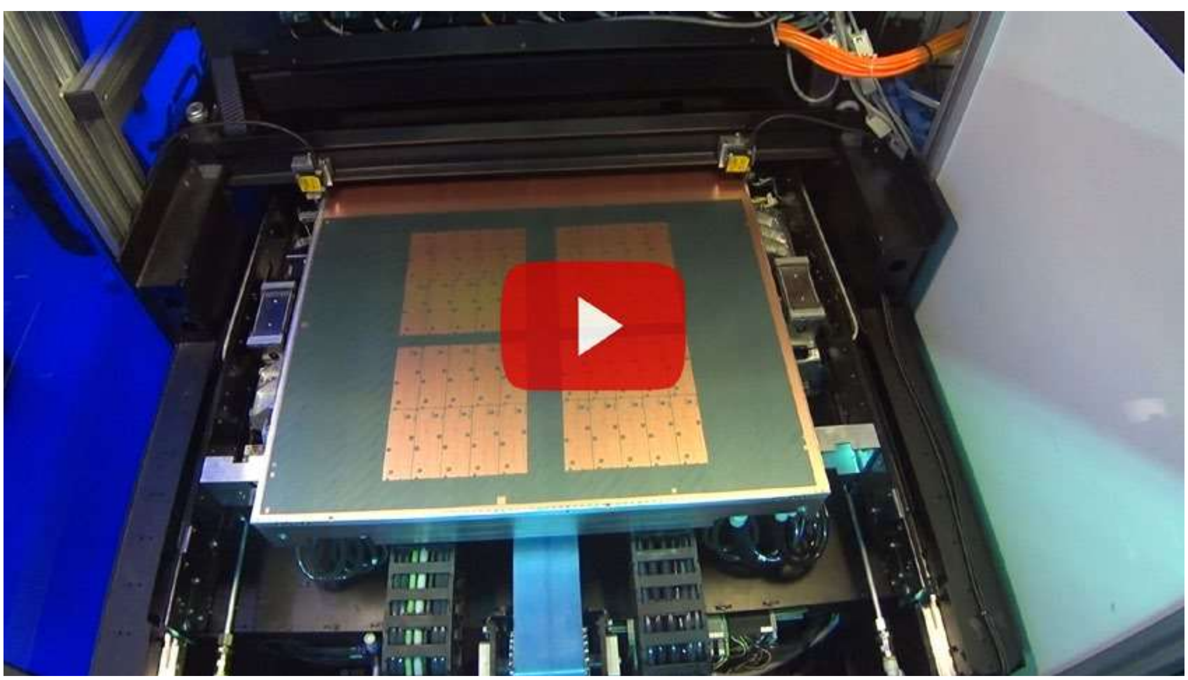
Inkjet printing takes place by moving the panel in a number of swathes under the print head assembly, containing 60 print heads, to print the image. Mutracx use a unique print strategy and algorithms, with built-in print head redundancy, to ensure quality printing with the minimum of heads.

After inkjet printing the panel goes through the internal AOI system to verify the printed pattern matches the CAM file and is free from printing defects; this automated AOI step ensures higher yields.

The panel is then transported onto a turn buffer table to rotate the panel into the vertical position for the UV cure cycle to cure the printed resist. Once cured the panel is returned to the alignment stage ready for the bottom side print cycle.

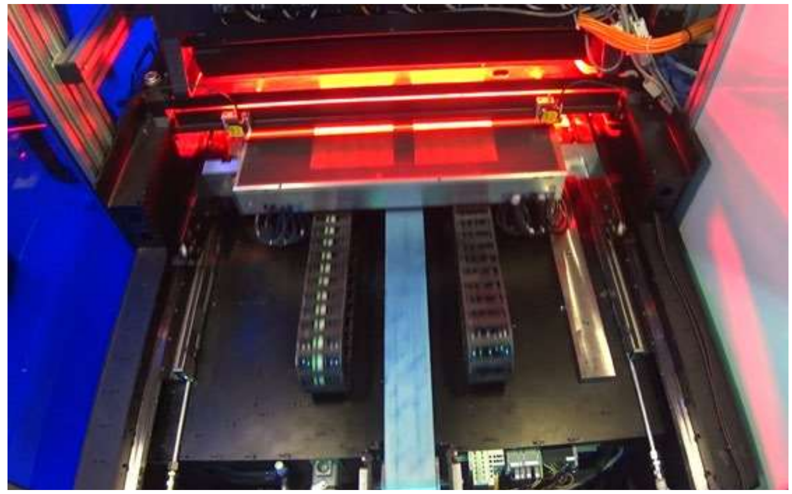
The printing swathes are repeated, along with the AOI function to check print integrity and then back into the UV cure stage to cure the bottom side.

Matties: ***How many panels are processed at any one time?***



Mutracx demonstration video. (2:31)

Vacuum chuck.



Proprietary built-in AOI system.

Coakley: The system processes a maximum of three panels at any given time in order to achieve the high productivity required for volume production.

Matties: What about the ink? Is this a proprietary ink from a single source?

Coakley: The ink resist is a hot melt wax formulation that requires UV cure and the resist is suitable for acid or alkaline etching and for tin plating as used here at Whelen.

The ink is supplied to us by our strategic partner, Dow Chemicals, based here in New England. We then supply the inkjet engine and the resist in one package to the customer.

Matties: And you resell it?

Coakley: What the customer buys is a good board and maximum potential yield into the subsequent process; this is paid for in a unique commercial model called "Pay for click," which is adapted from the graphic print industry. It ensures the customer only pays for good panels printed that have met stringent quality controls.

The click payment not only includes the resist to produce a good panel, but replacement print heads as required, all spare parts, preventative maintenance and full on-site service support and can be structured for single or double-sided printing. It keeps control of related process costs plus equipment consumable and servicing costs throughout the life of the system.

Matties: It's reliable, hands off, and it needs limited customer intervention?

Coakley: Yes, that's the design brief and the practical day-to-day experience at Whelen today. At the start, we supplied extensive engineering and operator support as you would expect in the early days, but today, Whelen has taken full responsibility for daily production with limited and sometimes only remote intervention from our Dutch team.

High-reliability has been built into the system and combined remote diagnostics and "machine-to-world control."

Matties: This is your first installation, correct? Has it gone the way you thought it would?

Coakley: Yes, Whelen is our first installation and we are honoured to be a valued supplier for such a key component in this groundbreaking project.

The concept to change the face of PCB manufacturing with inkjet technology in such a short space of time has been a challenge at times and many valuable lessons have been learnt for future installations.

We, along with our partners, plus great support from Whelen, have ensured this first project has been a resounding success and all parties can be proud of the joint achievement.

Matties: Thank you very much

Coakley: Thank you. PCB