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Roundtable Discussion

Achieving Operational Excellence in Electronics Manufacturing

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Siemens and Computrol:
Achieving Operational Excellence in Electronics Manufacturing

Moderated by Nolan Johnson and Happy Holden

I-Connect007.com

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Meet the Participants

Zac Elliott is a technical marketing engineer with Siemens Digital Industries Software. Working directly with electronic manufacturing service providers in the medical, aerospace, automotive, and public-safety markets, Zac ensures that key requirements for the smart factory are fulfilled using software and automation.

Farid Anani currently serves as the vice president of operations at Computrol Inc., headquartered in Meridian, Idaho, where he leads engineering, production, procurement, and materials teams.

Introduction

I-Connect007's Happy Holden and Nolan Johnson speak with Zac Elliott, technical marketing engineer at Siemens Digital Industries Software, and Farid Anani, VP of operations at Computrol, about how to achieve operational excellence in electronics manufacturing. They start by discussing the dynamic wherein automation projects may initially create islands of automation and the need to eventually connect those islands to achieve even greater operational efficiencies. The discussion then moves to how to make the data smarter and more useful for analysis and optimization.

Throughout the conversation, Anani shares his first-hand experience implementing automated processes at Computrol, and Elliott wraps up with an example in which data collected for one manufacturing step can actually be leveraged to achieve a completely unrelated quality check once both process steps can access the same data.

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ROUNDTABLE DISCUSSION FEATURING:

Zac Elliott
Siemens Digital Industries Software

Farid Anani
Computrol

Happy Holden
I-Connect007

Nolan Johnson
I-Connect007

Achieving Operational Excellence in Electronics Manufacturing

Nolan Johnson: Hi. Nolan Johnson with I-Connect007. Thanks for joining us. We're having a panel discussion today on achieving operational excellence in electronics manufacturing, and I'm here with Zac Elliott, technical marketing engineering team with Siemens, and Farid Anani, vice president of operations at Computrol, an electronics contract manufacturer; and, of course, my esteemed co-host Happy Holden, the PCB fabrication pioneer and my colleague here at I-Connect007.

Gentlemen, thanks for joining me. There's quite a lot of ongoing discussion about the development of new products and new solutions in the digital factory marketplace. Could you quickly acquaint our viewers with what you're doing currently with digital factory? Let's start with use, Zac.

Zac Elliott: Of course. Coming from Siemens, we're leveraging our digital twin strategy and digital thread strategy to really try to connect the different business domains that go into manufacturing these electronic products, and then to also connect internally inside the factory, connecting different processes together, in order to really streamline and improve the manufacturing processes.

Farid Anani: Yes. Over time, we have always invested in systems and the business process improvement initiatives, and we feel that in certain areas we excel and have been able to bring in leading edge technology to address certain situations and business challenges. However, we realize there's much more that can be done if the systems were somehow connected and could leverage information from one another. So that's where we're at today.

Johnson: Starting to tie pieces of that together?

Anani: Yes, yes.

Johnson: Zac, from the Siemens perspective, what does that look like?

Elliott: I think something Farid is probably dealing with is these kinds of islands of excellence, or maybe as Happy calls them islands of automation, where we have very good processes, we have the best equipment, we have the best ERP systems and the best operators and engineers, but we find that as we pull everything together into the big production lines and factories, we lose efficiencies, and we need to really look at process-to-process, and holistic views of things, in order to connect these islands into maybe more of a continent and something that you can really work together to provide the full value or the full capabilities or the full possibilities.

Johnson: Zac, that's interesting to note as we talk about digital factories, and as the industry talks about how we put this together for Industry 4.0, bringing together all of the data across the manufacturing flow, making that available. It doesn't sound like islands of automation, as far as an overall vision and yet, in the implementation process, you're talking a little bit about islands of integration there. Explain that a little bit more.

Elliott: Right. I think what we really end up with is that we need some way to connect these islands of excellence, and to connect them in such a way that they really feed into each other so we can feed data back, and we can feed data forward into the process and improve process-to-process. You could think of rolled throughput yield as an example, where we're manufacturing something through several processes and maybe each process has a certain level of yield, so we have 90% yield here and we have 90% yield there, and at the end of that we've got 81%. If we go on and we improve one of these processes upstream, and we bring it up to 100% yield, at the end we still only have 90% yield because we're limited by that one operation.

And that's in maybe the best case. If we think about the worst case, we improve this process, and we actually push a bottleneck downstream or move a problem somewhere else, it could actually be detrimental to this other process. We really have to think about how things are working together, and we need some way to work within that. This is where Siemens is bringing together the digital twin strategy and the digital thread, so that it's really able to prototype each of these processes, and then feed data back and forth. I really think these feed-back-feed-forward loops are what takes us to that next level. Because we can make a single process work fantastically, but as I mentioned, when we start tying them together and going process-to-process, we start losing efficiencies; as we roll through the factory, those small efficiency losses compound to some difficult things to deal with.

Johnson: Part of our discussion today really zeroes in not on the finished product but on doing your step-by-step transition to get there.

Elliott: Right. And one key thing we see there is working with analytics, getting information to people so that they can use that. One of the key things we do there is we talk about transforming raw data into smart data, meaning that someone can take it, and they can use it and they can make some decision from it. Maybe if we dive down into one of these processes, we could talk about material management,

and maybe a scenario where we try to get smart data from the information that's coming from the SMT machines. We have these SMT machines, they have these large complex setups, and they have good setup verification systems that run them, they collect all the data from the machine, and we can use that information to drive, just-in-time material delivery to the machine, for instance.

But it takes a lot of information. It's not just the data from the machine, it's not just the data about what parts are loaded and what's running and how fast it's running; it's also information about the schedule. How long is this product going to be running? How many fulfillment components or replenishment components are in stock? Which reel do we want to send into the line? Do we want to send a FIFO or do we want to look at the MSD? There's a lot of information that gets pulled in from a lot of different places, in order to enrich the basic information that's coming from the line, in order to make a smart bit of data that we can make a decision on, that the person can use to guide their job.

Johnson: You're pulling what would be considered granular data around how manufacturing is done, at least the data you're pulling from the line, and then trying to use that to drive business of operations outside of the manufacturing board to support it. That's a level of application or abstraction from the data?

That seems to really be what people are paying attention to right now. So turning that raw data into something smart and analytical is the magic step right now. Are you doing work with customers in that area? Are there some applications you can share with us?

Elliott: Yes. There's a few there, of course I mentioned the material management and delivering materials to the line, so that's a big place where we're working right now. A lot of times what we see is that we work, we optimize the SMT line, and we get it running well, and then all of a sudden, we push the problems back into the stockroom, and then we have to optimize there. We've made a big investment to make sure that our lines are running perfectly, but then all of a sudden, they can't run because we've got some bottleneck now and materials are having a problem. So, what we're seeing now is that a lot of work has been done to make sure the SMT lines run well, and now we have to start looking at these business processes that feed the lines, and we have to look at the downstream process that are receiving product from the lines, and look at how we optimize those, so we don't just push the bottleneck around and have more problems than we started with.

Johnson: How do you turn that raw data into something smart—or at least smartish—to start moving in that direction?

Elliott: You need someplace that can take all the data. You need to have systems that are able to connect to the different business processes in our environment, they're able to have a prototype of what this information should look like, so they need to be able to connect, they need to be able to store the data, the data needs to be normalized. We don't have very many factories that all have one piece of equip-

ment, or one type of process they're doing, so a way to normalize the information, so that we can compare disparate datasets and make some analytics from that.

Johnson: Now, Farid jumping over to you, you've been working in this space as a vice president of operations with Computrol and having some firsthand experience with this. You are a representative of what it's like to be on the front line, really. What are you seeing in your experience in trying to set up these operations of excellence?

Anani: Sure. Let me make a step back and say this: For electronics manufacturers like Computrol, on the shop floor, there are two things that we are constantly trying to improve in order to remain competitive and grow our business. And those two things revolve around increasing product quality and yield, and at the same time increasing our throughput. Which means, building more product with the same assets we currently have today. Sure, if you want to increase your throughput, you can go out and buy another machine and finance it, spend $3 million on it, and you can increase your throughput, but that's not always the answer. For us, to focus on material management, because Zac led the way into what that means to the shop floor, let me walk you through a scenario here, and I always like to simplify things to what happens on the shop floor.

We have an ERP system that's the state of the art. It looks at our material requirements, it looks at what we have available for materials, what orders we bring in, what additional material those orders require, and it tells us what we need and when we need it, so that our buyers can go out and bring the material here in time for production to have it. That is one function of the ERP system, and it does a very great job on that, but ERP system looks holistically at your material situation. It says, "Okay, for this part, you need 20,000. You only have five, go out and buy 15, and I need them here by this date." So you do that, and it's great, and when it comes to the back receiving door, the operator says, "Okay, we did buy this from Digi-Key, we are expecting 15,000, so I will receive them, it's the right part." It goes to the inspection, boom, it goes to the warehouse. The ERP function ends there. Now the parts go to storage, namely the storage towers. Now you're dealing with a different system.

The storage towers not only indicate, "Oh, you're bringing in 15,000 more parts." You are bringing in 15,000 more parts, but they are on three different reels. And those three different reels each have 5,000 on them, and they may be from different manufacturing lots. So now you have more granularity in data about not just how many you have, but what you have. Now, when the time comes to build the product, some system has to tell the tower what to issue on the line. Now there's a disconnect. How do you tell the tower, "Now I'm ready to build this?" You need an ERP to tower integration, because the ERP has the bill of materials for the product, and it needs to tell the tower, "I'm going to build 1,000 of this product and therefore I need you to dispense the material I need." Well, that's great.

Now, the stuff goes to the line, the machines will start crunching, so the ERP knows how many you need to process the order, and the tower knows how many parts it gave you, because if you need a partial quantity, the tower isn't going to cut the reel and give you a partial reel, it's going to give you a full reel. You could need 10,000, and it could give you 12,000 or whatever because of how many reels. Now that material is unaccounted for, the tower knows where it's at, but the ERP system doesn't, because the ERP thinks, "You need 10,000 for this order." So now you have another disconnect.

The product goes and gets loaded on the machine and the machine starts to place parts—machines aren't perfect, the nozzles that pick up and place the parts aren't perfect, the fitters aren't perfect—so there will be some losses. Well, you can't just carte blanche tell the ERP system, "Oh, I'm going to lose 3% of everything." That's not practical. The machine knows what it loses, but the tower doesn't know that, and neither does the ERP system.

Now you have another connection point, because if you think you're going to use 10,000, and ERP thinks you are going to use 10,000 of this part, but the machine loses 20 or 30, nobody knows that except the machine. I'm trying to make the case here for why small data gathering in real time needs to happen between all three systems, in order for it to be efficient. So now we address the material situation and how it can be handled accurately. Why is that important for someone like me? Why not just go out and buy extra material all the time? That's not practical. My CFO tells me, "Money does not grow on trees. So I can't go out and buy you 3% of everything and stock it here. This is not a high-margin business, so you can't spend 3% more on material." And I get that. But if we don't have accurate visibility of what material status we have, we run the risk of a product stopping midway, because we unexpectedly run out of a part.

That leads directly to inefficiency. When the machine's idle, that's when you begin to lose money. And if you run out of a part midway through a run because you didn't know, that is very detrimental to the factory. The other thing that drives productivity is machine operational time. When the machine is idling for changeover, it's not doing anything. The machine makes you money only when it's placing parts on boards. The beauty of the system that Zac was beginning to describe is it actually helps minimize your changeover time by doing forward-looking and backward-looking, at what material you need for the next run, versus what you were using on the previous run, then only bridges the gap and issues the information to the tower only enough material to get the line going. As the material begins to get consumed, more orders are sent from the machines to the tower, to bring more material to the line in real time. So instead of having a one-hour or two-hour changeover time, we have been able to reduce our changeover time to 30 minutes or less by following this scenario and that technology.

So I hope that by giving you a real-life example of what happens on the shop floor, and the three different silos where each one of these silos is excellent on its own but

the assistant ties them together and enables them to speak intelligently in real time together, the sum is more than the parts in this case.

Johnson: Farid, at Computrol, how long have you been working on setting up this integration?

Anani: It's been a long journey, of course for us, but to implement this material management system is something we started only in the last couple of years, and there's a lot of work in progress still. This is not something that anybody can deploy overnight across two the buildings and the seven production lines. But we're making good, steady, methodical progress, and we are seeing the benefits in what we have done so far.

Johnson: Just as Zac was mentioning a few moments ago, maybe if you fix the line, or suddenly what you've done is push part of your operational issues into another department, like material management or somewhere else, or receiving, it sounds like there's some of that going on for you, too. As you smarten an area, then you realize or find new issues somewhere else, and you are hopping around from place to place, moving everything up in a spiral. Is that a fair statement?

Anani: That is a fair, accurate description, yes. It used to depend on what material came in, if we were receiving big shipments, it could take a little bit longer to get the material through the back door and into the proper storage location; but now we're able to have the material, through the incoming material registration, which basically facilitates getting all the information in the system as soon as the material shows up at the receiving dock. As soon as it's scanned back there, all the systems know that this material is here, what it is, what the quantity is, what the lot is, and we have a lot more visibility in real time than having to wait a day or two for the manual receiving process to happen, and for the manual material transfer to take place.

So, as your lines start running more efficiently, that material flow from the backend to the floor needs to happen faster. And so that's one issue we were able to see move upstream, and luckily with the material incoming registration, it helps us realize that. Now the purchasing folks have to get more active with the purchasing in order to bring stuff in faster as we're increasing our throughput.

Johnson: Where are you seeing the benefits so far? Would you say it fits in the throughput on the factory floor?

Anani: Yes. Throughput on the factory floor, because we're getting more utilization out of our equipment due to the reduced setup time, we are seeing more machine utilization because we are less and less often running out of material unexpectedly in the middle of run. I think those are challenges that every manufacturer does face from time to time. Those are the two key areas: changeover time and machine utilization time.

Johnson: Are you seeing improvements in your labor?

Anani: Yes, of course. We're able to get more production per employee basically now with this system. Because a lot of the time that used to be allocated to indirect labor, which is support functions, is now going into actual direct labor which is producing product.

Johnson: How about in procurement and purchasing. Improvements and efficiencies there?

Anani: We haven't really done a lot of work there, so that's one area that is to be worked on in the future. The focus is mostly shop floor performance right now, but I see it moving upstream already. Absolutely.

Johnson: You can definitely see benefits that are then percolating down to the bottom line in the operational margin for Computrol.

Anani: Yes. In the future I look forward to the material scheduling aspect of this smart system, to augment what ERP is telling us, and enhance it.

Johnson: Zac, I'm curious about other ways of doing automation. There are plenty of other conversations going on where automation includes things like robot handling. Are you working with customers that are doing that sort of thing?

Elliott: Yes, and lot of times that's the next logical step. When you've connected the towers to the SMT line, and we're automatically triggering the unloads from the towers, now you have to think, "Okay, how did these materials get to the line?" And of course, the logical thing there is to start thinking about these autonomous robots. We're working with manufacturers now that are using them to transfer the raw materials to the floor, and then the next step is to start assemblies that are moving around the floor. Once you've built a PCB on the SMT line, those could go to a robot that would take it to the test area. We've always had, I think, these test cells that are separate and they're product-focused, but the SMT line has really been a dedicated SMT line used across products. But what we're seeing is that manufacturers are going to the cellular approach where the SMT line is a cell and the test area is a cell, and the depaneling is a cell, and then we're able to have the robots take the materials around the floor.

So you can have robots bring bare PCBs to the front of the line, they can deliver the components to the SMT machine, they can take the partially built sub-assemblies from the end of the line, and then take them to the test area or take them to be depaneled. This is the way things are going in what we're trying to work with, in making the whole shop floor flexible, based on this automation that we can drive.

Johnson: Good. As we sit here and talk about this toward the end of 2020, it's hard not to have a conversation about automation or what's happening on the factory floor without at least touching on the impact that COVID and the coronavirus is having on how we do our business. To Farid at Computrol, you're moving to a more automated integrated digital factory approach. Is that something that the COVID experience is driving, or helping to drive? How does that fit for you?

Anani: I think it can, based on what Zac described in terms of using robotics machinery and technology to deliver and transfer material from warehouse to shop floor, or between the different shop floor cells, that will definitely minimize human interaction. It will minimize the number of people you have here working closer to each other. We are not in a position today to benefit from that, but I can see how what Zac just described would help reduce the risk in a given community, and hopefully reduce the spread. From our end, we have started to work from home as much as possible, and the people who use a lot of the Siemens Suite or products that are currently deployed here, are able to work from home by logging in remotely and doing what they need to do that, especially the front end, the process preparation and whatnot.

All this technology is beneficial in allowing people to work from home or to work remotely, or have the functions be done by robotics in the similar material transfer technology.

Johnson: Right. I think that does seem to be something that's coming out of this naturally. The next step, Zac, is further work with the data, as you're making it smarter, and starting to get more integrated across disciplines, if you will, tying business operations together with manufacturing floor details, and real time information about what's happening with the product being manufactured, procurement, all of these, at some point you start looking at analytic aspects. It would seem like this moves more from tracking and then optimizing to do something more predictive?

Elliott: Yes. That's really what we're driving to, that's the next step. If you make the data smart, you make it something that people can make decisions on, and then you use that to drive improvements. And maybe keeping with this material management topic, an example of taking this data from the lining, using it to drive, some business process could be purchasing. We're collecting all of this data from the SMT machine, we're using the data from the SMT machine, and the data from the ERP to drive the stock movements on the floor. If we think about also taking some additional information from the inspection machines, and we can start to think about the yield and the defects per component and tying that back to ERP and the source of those materials, then we can start to look at maybe a costed price for a component.

So when you're ordering materials and you have several different vendors to choose from, you could look in your database and see, for this vendor, how many defects have I had? And what's the cost of fixing those defects and then aggregating it by that vendor, and seeing that potentially, you could have a vendor that's more expensive, but has lower defects, defects that are easier to repair, so even though it's a more expensive component, the factored cost of that, using it in production is less for you, and then you can use that to drive your purchasing and improvements that will flow down into your profitability.

Maybe another example we talked about was the just-in-time scheduling, or if we want to take it to the next level using this data with artificial intelligence or machine

learning, that's the next place we want to go with that, I think.

Johnson: I've heard some reports about using some of this information to do things like counterfeits.

Elliott: Yes. We actually work with a partner of ours called Cybord, and they're doing something really interesting. They're using machine learning and artificial intelligence, along with the images that come from the inspection camera on the SMT machine, to detect counterfeit components. We know today, the counterfeit components are very, very good, but they're not quite good enough to escape the artificial intelligence. This is what Cybord does. They take all the images that are coming from the inspection camera, that are looking at the adjustment and rotation of a part, and they use that to build what they call a fingerprint, a digital fingerprint of each picture's part, and then as the images are coming from the machine, they can basically score each one, and detect if something is wrong, and maybe you've got a counterfeit component.

And this is really interesting because the counterfeiters are becoming more sophisticated. It used to be that there would be a reel, the first 100 parts were good, and then after that they would disperse every 10 parts, they'd put a bad one in there, or something like that. But as we've improved at capturing those, they've moved to maybe statistically uncatchable ways of doing things. So they'll just randomly stick them in there. Maybe seven good parts, two bad parts, 15 good parts... a bad part, and they do it in a way that you can't really detect it with statistical methods. This is an example of really taking this data we're collecting and taking it to a problem that we can't really solve today.

Johnson: Yes. That ties back to Farid's original point, doesn't it, Farid? As far as being able to tie together your ERP, your tower, the information you're getting on manufacturing forwarding you to give you a better sense for what's happening, even as you're tracking reel by reel.

Anani: Yes. I actually had a chance to look at what Cybord was doing today, I was quite intrigued by the methodology, and the artificial intelligence they are deploying to solve the counterfeit parts problem. I think it's something that I intend to look into further. I'm quite interested in what Cybord can bring to the table because the problem, as Zac described it, is becoming more and more difficult to detect through classical statistical methods, as we know. Here we have a situation where you have a machine that's already taken pictures of our parts for the purpose of aligning them, and making sure the part is dimensionally correct, and will be oriented correctly on the board, and someone is saying, "Oh, there's so much information available here. We can use it for other means." So that's really where this AI and Industry 4.0 is going–leveraging the huge amount of data that is already available, to better improve efficiencies and quality.

Zac also mentioned feedback mechanisms probably coming from testers and inspection equipment, and that's where this industry is headed–having a completely

autonomous or almost completely autonomous decision-making process on the floor. We already see some systems where they have continuous feedback connected from the solder paste inspection system that feeds directly into the printer and tells the printer what parameters need to be adjusted without human intervention. Similarly, the same can be done from AOI, and there's no reason why the same technology can't happen to capture information from test and repair data, because that information, it's available. There's plenty of information out on the shop floor. Making actionable intelligence decisions out of that data is where this industry is going, and that's the meaning of Industry 4.0.

Johnson: I think you're right. Happy, you've been watching this industry, and you've been a part of it. What's your opinion on operational excellence in manufacturing, as we bring all these pieces together and take this approach to implementing something better? Are we on the right track as an industry?

Happy Holden: I certainly hope so. I went through all of this in the '80s, you might say Industry 3.75. We didn't really have the internet, but we had intranet and things like that, and we were actually selling the application software, as well as using it in our own manufacturing. And so, one of the things we focused on is, how do you get started in the planning? Where do you start kind of thing? The software that's available, it is quite excellent, but there's enough different software and vendors out there that the job because of that in engineering of figuring out, where should we start and where do we need the greatest help and improvement? Fortunately, the Industry 4.0 and intelligent sensors makes the job a lot simpler now than when I had it. But also in the same case, the product has gotten a lot more complex now, and so the challenges never stop.

I haven't been in manufacturing for 25 years, and the last time I was in manufacturing, we were unfortunately doing 10 million a month of the devices, not 1,000 or 100. I was at the biggest surface mount manufacturer in the world, and I only had 270,000 workers, out of the two and a half million that we employed at Foxconn. These problems repeat themselves, but we're getting better and better at it. Like you and I know, we're focused on the young engineer or the engineer themselves in terms of the tools they need in order to use Industry 4.0 effectively, if somebody has to direct it and interpret it?

Johnson: With implementation on the factory floor, now you need to analyze and use that data in creative ways. Does that seem like a reasonable takeaway, gentlemen?

Holden: Like we said before, from high-volume data to smart data, how do you apply the smart?

Elliott: What's interesting when you talk about high volume is that you've got a lot of data to work with, and when you have more data it's easier to find characteristics and common things going on, but really, there's also a challenge when you're doing more low volume stuff, and you don't have a lot of data to go on, how do you make

decisions with limited data, and I think what you'll find is that, of course, a lot of these products are common, so you might have a board that's a completely unique design, but many pieces of that board are reusable blocks that are also in other designs. So now you can start looking at not just this one board, but other designs that are using common pieces, and taking the data from the manufacturing of those products, putting it together, and then making some decision, or you can maybe just look at not product quality, but board process quality.

So, you might only build 10 of this board down this production line through this particular process, but you have 50 other boards you build on this same process, so instead of looking at maybe product quality, you can look at just generic data from that process, and start trying to make some decisions about how you can make improvements. So, even if you don't have a high volume, lots of data to look at, maybe looking at the data from a different angle or a different way will still let you make improvements, make decisions, things like that.

Johnson: That's a process that's really kind of buried in the current situation. Looking at that information, there's been a lot of the stories we've talked about this morning. Once you have information, new data, you can start to look at how you can use this data in a different way. Farid's point was right on the money, I think it's to do counterfeit inspections using data you already had for another purpose, and finding a new role for that data you already have.

Farid, as part of wrapping us up here, where do you see this going? As a contract manufacturer, where do you see this going? How is your business going to be different in future?

Anani: How the business is going to be different in the future is I think we will see more and more analytics being utilized in order to drive decisions in the factory across all processes, from planning to procurement to process on the production floor. One of the things that Zac mentioned earlier is, he alluded to a low volume production, and that's the world we live in today. It is possible you might build 50 of something and you have one marginal component that affected your yield slightly, and that component could be used on another product that you build two months down the road, but now you have the data and that tells you that you had a marginal performance of this component, and it's used on this one. So, you can make a decision about whether to look for a different manufacturer, or things of that nature.

I see this industry going into a mode where Industry 4.0 will actually be with us for a long time because really nobody knows when we will say, "Okay, we have reached the end of Industry 4.0, and now we have to start working on 5.0." That's a work in progress. But to sum it up, I look for a lot more artificial intelligence and data analytics systems to become available for manufacturers like us.

Johnson: And you see that's strategically important as well?

Anani: Absolutely. Yes.

Johnson: Zac, from your chair at Siemens, where do you see this going into the future?

Elliott: I think the robots will be the ones telling us it's time to move to industry 5.0. I think when they take over that's what we're going to do, but really what we're working on with Siemens and what I'm working on is trying to take these ideas and make it something that people like Farid can deploy. We have the tools that can be used, and you don't have to be a manufacturer with a thousand sites and thousands of engineers to put together a solution. It's something that can be deployed by the average manufacturer and get value from it. So that's the direction we're going.

Johnson: Great. I think our time is just about up and we have covered a great deal of territory here this morning. This has been really informative, even for those of us who follow along with the industry, there was a lot to think about in what we talked about today. I want to thank you for your time, and for participating here, it's been fantastic, thank you so much.

Elliott: Thanks a lot, Nolan.

Anani: Happy, it has been great meeting you and Nolan. Likewise, Zac, always good to see you. I hope you all have a good day, and if I don't talk to you before then, have a Happy New Year and Merry Christmas.

Elliott: All right, thanks a lot, guys.

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