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HATS² Technology and Its Impact on Reliability Testing

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An Exclusive Interview with Andrew Naisbitt and Bob Neves

Innovative Technology Advancements in Test:

HATS² Technology and Its Impact on Reliability Testing

Interview by Barry Matties

Ensuring the reliability of printed circuit boards (PCBs) has become increasingly difficult and critical, yet the development of advanced testing methodologies is essential to meeting industry demands and addressing persistent challenges. One significant innovation is the High Acceleration Thermal Shock (HATS²) test system, which transforms how reliability testing is conducted.

After 40 years in the testing business at Microtek, Bob Neves is beginning a new journey with his company, Reliability Assessment Solutions Inc. (RAS). He has been instrumental in developing the HATS² test system, channeling his decades of expertise into what could be considered the perfect machine. Bob is working with Andrew Naisbitt, CEO of GEN3, to bring this powerful tool to market.

In this interview, Bob and Andrew share the origin of this technology, its impact on the reliability testing landscape, and how it better addresses specific failures encountered with microvia structures during component attachment. They acknowledge that after testing the same way for 50 years, change in this industry is hard. But they believe the time for change is now. You'll find out why in this compelling conversation.

Barry Matties: Bob, it's always good to see you. You are a recipient of IPC's Hall of Fame Award for your contributions to the industry over the years and have been involved in the test and measurement area for a long time. Now you have been essential in the development of some new technology. How did the development of the HATS² test system come about?

Bob Neves: In 2001, a need arose for a faster reliability test that cycled from cold to hot and would speed up the one-hour dual chamber run cycle. I received a patent and developed the first HATS tester, which cycled PCB board coupons from -55°C to +160°C.

Twenty-four years ago, that was pretty novel because people were doing one-hour cycles in a dual chamber, and it took 42 days to do a thousand cycles. We were successful at compressing that down to about a week. Then some military projects went away, and it never really took off because it was a bit ahead of its time.

A few years ago, the industry had a problem: Microvias failing during exposure to the high temperatures were associated with the components being attached to and

replaced on the boards, but when they cooled down, they made a mechanical connection again. Even if you cycled at lower temperatures, they would always pass testing, get into the field, and have early-life failures.

During failure analysis, we would find out that the micro-via was separated. Good micro-vias don't do that, so what happened? We explored how we might detect this, and concluded that the easiest way was to run coupons through multiple simulated reflows and monitor the resistance of a daisy-chain of via structures. Do they break during the simulated reflow cycles? In coming up with this, we observed that assemblers would attach components to side one first, then to side two. They might put some connectors on it. They might have a bad component or two and remove the component and then replace the component back onto the board. We could have as many as six solder processes prior to the PCBA being completed. So, how do we simulate that entire component attachment process cycle and be believable?

We created IPC test method 2.6.27 and said, "We can do six simulated reflow cycles, which will somewhat represent what you do when you attach a component to a board. That should allow us to find these types of failures."

In the Method, we created profiles at 230°C for the leaded solders, at 245°C for the in-between solders, and 260°C for lead-free solders. The response was, "That's great, but I would also like to know what's going on after I put the components on. Do I have a little bit of life left after the component attachment process?" We then decided to perform this multiple reflow assembly simulation first, followed by 100 thermal shock cycles, ensuring they are conducted below the glass transition temperature Tg of the base material. This approach prevents overstressing the material and avoids introducing acceleration factors that do not occur in real life. That way, we gain a little bit of life information as well. That's how the current requirement came forward: six cycles of reflow simulation followed by 100 cycles of thermal shock.

I set out to make a single piece

Bob Neves

of equipment that would do all of that in a reasonable amount of time with the ability to handle a lot of capacity. Doing hot and cold in the same unit is quite challenging. We were close to that with the original HATS Tester at -55°C to +160°C. Then, we decided to decrease the lower end to -65°C and the upper end to +265°C. We went through the development process with new materials, a new higher power heater, new chiller system, and other things that we needed to do to make that happen. This entire Reflow Attachment Process Simulation and Thermal Shock Cycling can now be done in a HATS² test system in less than a day.

We placed the HATS² test system in independent test laboratories for more than four years to ensure the software was stable and usable before releasing a retail version. We have now put the system on the market for sale to the industry. It's a mature product that solves an industry problem that several large OEMs, as well as many military and aerospace companies, now require for their boards.

The ultimate goal of this test methodology is to provide an alternative to the microsection, where we dip coupons into the solder pot, cut three via structures in half, and look for pretty plating. We've held on to that for so long, and it's so ingrained in our industry. But as the industry is moving into substrates, embedded components and ultra HDI, the via structures are so small and difficult to find that it becomes economically unfeasible to microsection these at any sort of speed.

You get a lot more information about performance and reliability from the HATS² test system than from the microsection. In the end, it's just a change from a visual- to a performance-based evaluation. When you've done something for around 60 years, it's hard to let go. We are focused on moving this via structure reliability technology toward the mainstream where OEMs see the value and say, "I've saved this much money by using this method rather than microsections." That's what's pushing them.

Was cycle time the primary driver for this development?

Neves: Initially, yes, because nobody wanted to wait 42 days for dual-chamber reliability results. Reliability is about stressing the product without overstressing it. It is the nature of reliability that this process takes time. But even with that, nobody wants to wait so they come up with ways to accelerate failures using robustness

testing rather than true reliability testing.

Systems that use current-induced heating to stress a coupon (like IST) are a good example of that. They are typically used as a robustness tester that goes from a bit above room temperature to infinity really quickly by heating traces on a coupon. It puts a lot of thermal stress on the board, but it gives you information quickly. It doesn't tell you anything specific about field reliability, but it tells you A is better than B, which is important to some people. Reliability and robustness testing is like religion; you have to believe in it. I wanted to make a test system that would do any of the Reliability or Robustness tests out there. If you believe in a particular cycle or temperature range for testing, my HATS^2 test system will do that. If you believe that super high-temperature cycling is your path, then you can do that with this system, too.

For any systems that have been around for a while, including dual chamber, the HATS^2 test system will cover all their temperature ranges, cycling profiles, rise times—really anything that has been published before. I believe that, moving forward, this one test system will address it all.

As you were developing the machine, did you have a list of features and capabilities that you knew you wanted in your machine?

Neves: The driving factor was my spending 40 years running an independent laboratory. It was a passion for me. I wanted to build a test system that would meet everyone's needs for reliability or robustness testing of via structures, a unit that I would be proud of and that I would want in my laboratory. It has been a joy.

You're probably the only person with 40 years of lab experience to build a piece of equipment in this space.

Neves: I think so. I've helped develop many test methods and worked with the companies making reliability test equipment over the past 40 years. I have an intimate knowledge of this type of testing. My lab had 14 big, dual-chamber test systems where we were doing this kind of reliability testing. We had other types of reliability equipment. So, I had everything to play with. I was able to see what worked and what didn't work. The HATS^2 test system is the culmination of putting all the things that worked together into one machine.

Andrew Naisbitt

Bob, didn't you partner with GEN3 for distribution and technical input?

Neves: Yes, I've used GEN3 equipment in my laboratory to test the reliability of the insulation systems of printed circuit boards for many years. We have

a long history together. GEN3 is well recognized as a leader in the reliability of insulation systems. Now, adding the reliability of PCB via structures brings the value proposition full circle. They're now supplying anything you need to look at the reliability of a printed circuit board. Their customer base is the same as mine. The shops that would think about buying reliability for insulation systems are also always looking at the reliability of via structures. It was a very good fit as far as having a complete package to go into a board shop or an OEM.

GEN3 can now supply you with everything you need to ensure reliable printed circuit boards. That's where our partnership came in. I didn't want to develop a distributor network all over the world, and the GEN3 team already knew about reliability and PCBs. They're in the facilities that need it. My job now is supporting them to make sure they fully understand the capabilities of the HATS^2 test system and how to help customers obtain reliability or robustness of via structures from the system.

"GEN3 can now supply you with everything you need to ensure reliable printed circuit boards."

Andrew Naisbitt: This is such an exciting opportunity for us. We've worked with Bob for many years with our AutoSIR and AutoCAF systems. There is a lot happening at GEN3 right now. We've just completed a nine-month refurb expansion of our whole factory and facility, with a brand-new technical center, something we identified as a real need.

It encompasses many things, including a test service lab, showroom, and training area. It's a place that enables us to support our customers and distributors in new and exciting ways we've not done before. The HATS^2 test system will be a key part of that.

We've also relaunched a new website focusing on clear messaging as to who we are and what we want to be doing as GEN3. We've released our vision and mission statements and our core values, which is to be the leading provider of reliability and assurance equipment and solutions to the electronics industry. Within that is our contribution to make sure the devices people make today will work in the field for the end consumers. Really, it's about critical reliability, like making sure airplanes stay in the sky and autonomous vehicles don't crash into each other on the roads. We knew this was an opportunity we did not want to pass up. Our offerings for HATS^2 technology are twofold in the fact that we will be both selling the equipment and offering the test services. We have the machine in our test lab fully up and running.

Andy, we've spoken in the past about your work surrounding Objective Evidence. What's the latest on that from GEN3?

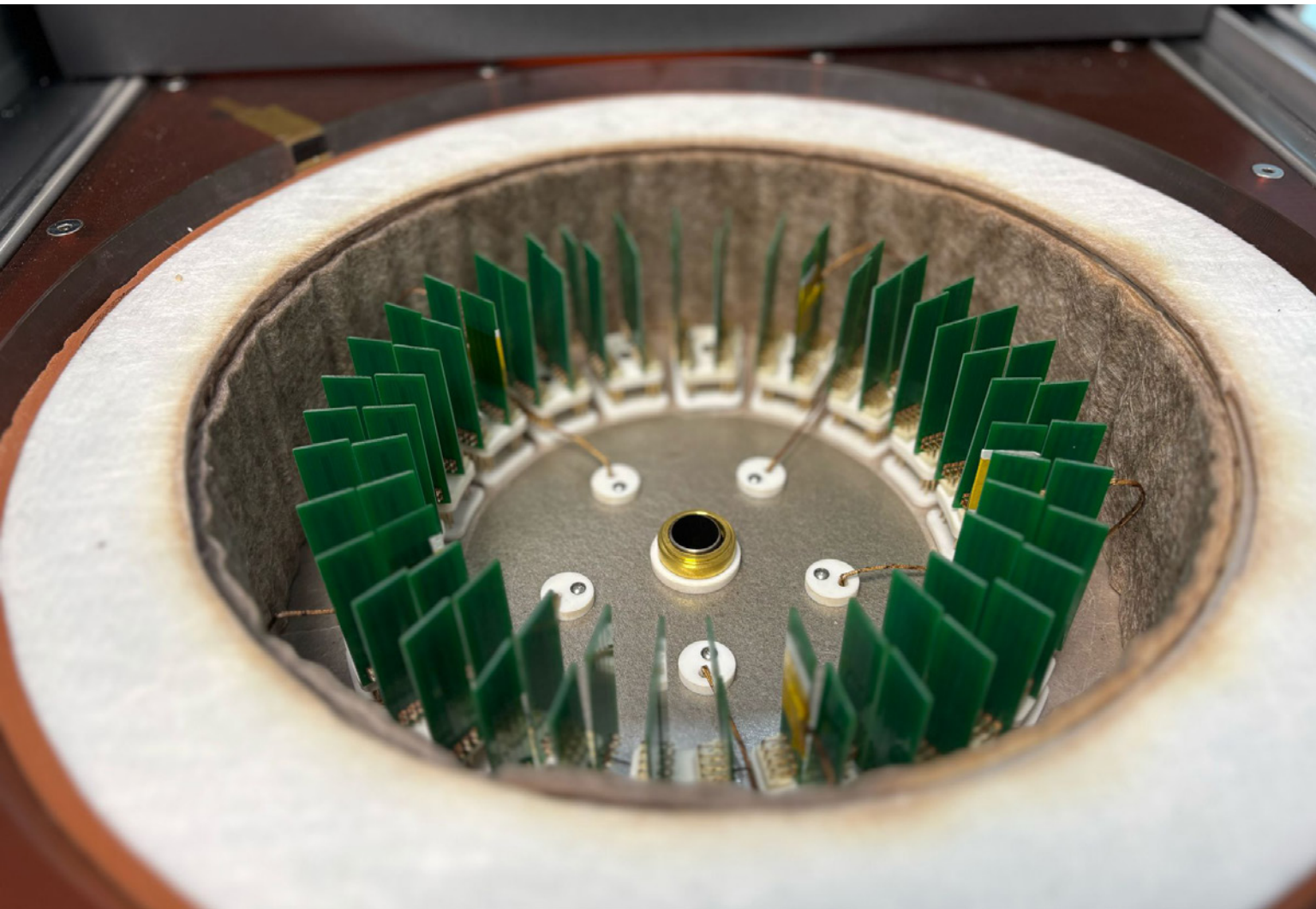
Naisbitt: So, this is all about the changes to the standards, where there has been a lot of talk about how we can update testing so that it reflects the needs of modern electronic builds. That's where Objective Evidence comes in and the removal of this 1.56µg NaCL number. You now need to gather objective evidence to prove and validate your manufacturing process.

There are three simple ways to do this. The first is to characterize your material set using SIR. Next, if there's a problem, you can do ion chromatography to find out what has caused the issue, but only if there's a problem with your SIR results. Finally, you can then use the ionic contamination tester (or ROSE test, as it's better known) as the process control tool.

That's a big thing we are trying to help people understand about the ROSE tester. It is not a cleanliness tester; it's a process control tool.

When you get a golden board and put it in the ionic contamination tester, that will give you a new number. That number could be 1µg, 3µg, or 4µg, it doesn't matter. As long as it's proven and it works in SIR, then you've got the number that you can use on the shop floor. The quick test on the shop floor—pass, fail requires a number, your objective data—that is born out of doing the SIR work to characterize your material set.

Neves: A lot of the tests that are out there have been just window dressings, check-the-box, plausible deniability should something go wrong. Of course, my lab did a lot of that because the industry demanded it. But I remember thinking that people were throwing away their money in terms of what was meaningful. I don't know that there was another choice at that time, but now there is. This process of finding Objective Evidence gives you the ability to watch and control your process and prevent things from happening. If you failed the old



ROSE test, things were really bad. So, we are evolving and looking at these tests more carefully. In cross-section evaluation, I'm looking at six points on three via structures of 20,000 via structures on my circuit board. Is that giving me what I want? Does that represent anything meaningful? People are questioning all of this now because things are getting smaller and more complex. Technology is changing very rapidly. We just can't rely on what we have always done in the past. We are making these tests valuable. So, yes, this testing technology is excellent because it offers significantly more value.

When industry looks at creating a test strategy, what considerations should they be looking at?

Neves: If you look at all standards and testing, they're almost 100% driven by failures experienced. They are driven by the fact that someone has had a very expensive failure somewhere, and someone else high up at the company has said, "This will never ever happen again." Therefore, a lot of effort goes into trying to prevent that from happening, whether it's standards, creating new tests, or increasing sampling. You will see that in industry documents too. Learning from bad experiences or outcomes is, maybe, a better way to say it.

As these issues become a widespread industry concern, you ultimately bring together a group of individuals from various fields or companies to develop a solution, whether it's a specification, a testing method, or something else. Unfortunately, it follows a backward-looking approach, but that's the reality. Few have the time or resources to invest significantly in the forward-looking aspect, aside from those who are designing and striving to create smaller, faster, and better products.

So, if someone were forward-facing, what advice would you give? Obviously, you will focus on the issues that cost the most, but what should their strategy be to remove that pain point?

Neves: First, it's a philosophy of managing your supply chain and understanding that building a board or building certain things within that supply chain is very complex.

It is also important to understand that expecting the supply chain to be great all the time is just not reality. At some point someone in your supply chain will fail. How do you manage that? Do you test the heck out of everything, or do you

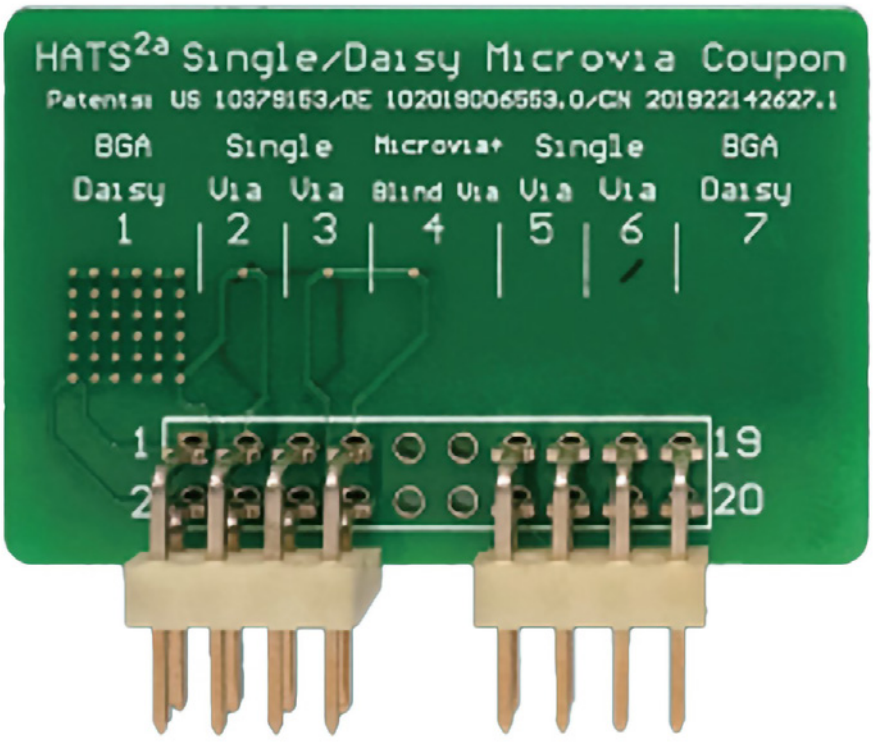
manage it by having multiple suppliers or a bit of both? You have to come up with a strategy that creates financial success for you.

Accept the fact that your suppliers won't be perfect, but you can help them be better. That's where these requirements come in—going to audit and making sure they have process control. But then, with good process control of core processes, a circuit board with 400 steps or processes will not be able to do 100% process control of every process. Things will fall out of control every once in a while, so you must be able to manage that. The scary part is when people put all their proverbial eggs in one basket, and then the bottom falls out of the basket.

If you've been around awhile, you don't do that. You have multiple material suppliers, as an example, and can switch relatively quickly.

I could sit here for hours and talk to you about how you do that, but it really is a thought process that you have to go through. GEN3 and I are providing the tools to allow you to do this and get information that brings value back to your company as far as making decisions on your suppliers and your supply chain, so that you can better manage it, making sure that once your products get into the field, they are reliable and working soundly. Ultimately, this is about keeping your customers satisfied.

You mentioned your software iterations and that you are many versions from your starting point. AI is a big topic right now.



How will AI come into the world of test, or has it already?

Neves: It's on its way in because tests generate lots of data. The HATS^2 test system will generate tens of thousands of resistance data points. The system goes through and highlights the worst and the best ones. But it's not necessarily looking at all the trends and everything else that may be in all that data. I can't do that without something like AI.

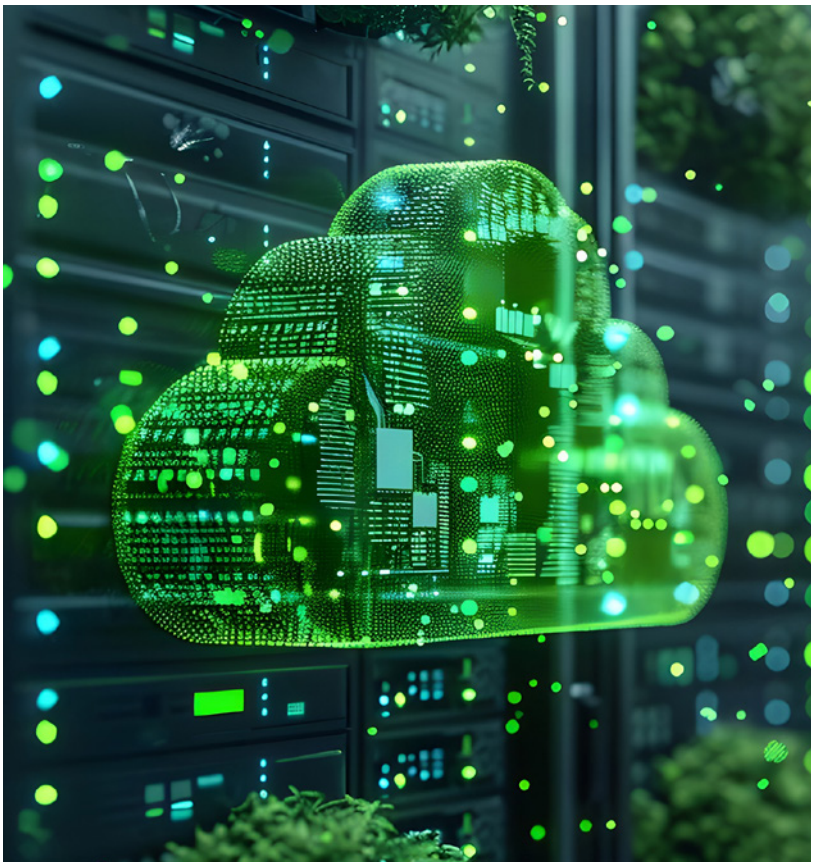
The benefit of AI in testing is its ability to analyze not just the individual test, but also all the parameters: board thickness, via structure sizes, the number of via structures, and various other attributes across multiple jobs. AI can interpret all of this to identify, "This now points to X issue," which is something I have never been able to do in all my years of experience. There are great possibilities for AI taking the data that's produced by all the tests that we do and pointing back to process changes, process control, and really high-value feedback to help the manufacturer make better decisions.

When all this data is captured, where is it being stored? Is it localized or is it in the cloud?

Naisbitt: Data storage has always been a significant challenge because test equipment, especially with SIR, generates a lot of data. We have the capability to run 4,000-hour tests at 1-minute intervals which take 18 different measurements every minute. As you can imagine, that amounts to millions and millions of lines of data. If the PCs in use are not up to spec or are older, it can be a struggle to keep up, which may result in lost data or cause issues with the test itself. Then you have the famous Microsoft updates. We advise our customers not to connect to the

internet because Microsoft updates happen automatically, and they can interrupt the test being conducted. With AI, once you've got the data churning and looking at trends, it will likely need to go into the cloud. I don't see, at present, how it will work otherwise.

Neves: As I look forward to developing new tests or improving existing ones, I consider the possibility that AI might say, "You're doing a lot of unnecessary work. Your left hand is performing well, so just focus on the right hand, where you see an issue." It will help with the allocation of resources contributing to the smart use of time and money. AI will likely analyze a vast dataset over an extended period and suggest, "Invest here and examine this aspect of your manufacturing process. You don't need to spend or concern yourself with this other area because nothing is going wrong there."



Naisbitt: There's risk with that as well. Even if that is working well, for how long? Equipment can break down and materials can change. I believe some risk mitigation will be needed there.

With AI, theoretically, it can analyze your database of manufacturers and determine which one has the best performance and process control. This data exists because you are engaged in testing.

Neves: If Company A spends $3 million to learn something about its product and supply chain, it typically does not want to share that information with the rest of the world.

Unless it makes them more sales.

Neves: Yes, but that's been a hard sell at this point. I have knowledge about materials and processes that work much better than others. But companies have spent a lot of money to understand those things, and they don't want their competitors to gain that knowledge from their work so it's not published. It is a drawback and something that will hold some of this back, but the way that information is moving now, it will be harder to control.

They won't hold it back because it will come from many sources.

Neves: It's like holding water: Eventually, it leaks out. Historically, we have faced a strong sentiment of protectionism, as people have made significant investments to understand their processes or suppliers in order to gain a competitive advantage. This is understandable.

I have a file cabinet containing confidentiality agreements I've signed over the years to ensure that the companies I work with feel secure knowing their information will only be seen by themselves, my staff, or me.

Are you taking the new HATS² system out to market?

Naisbitt: Yes, and it's brand new. As Bob said earlier, it's been in development for a long time. The product is actually very mature in terms of development. Now it's been launched and released. We received our first unit two weeks ago and Bob has now visited us to install it and train our team.

Do you have hands-on experience with it yet?

Naisbitt: Not quite yet. This is all brand new. I want to make sure our team is up to speed with the knowledge and has a full understanding of HATS² technology so that we are in the best position possible to sell and support the machine going forward. It's a vital part of who we are that we can support the equipment, just as much as we supply it.

As Bob said, it's a real passion for him. We saw that and, frankly, jumped through hoops to become a part of this. I've got my own passion for honoring the legacy of my own family and the length of time that we've been around. I want to drive the business forward with new ways of doing things with new partners. This is a really exciting opportunity for us, and for where we will go from here. As far as communicating with the market to address interest, we have some webinars lined up with customers and our distribution network to get the discussion and education started.

Neves: We've been doing a lot of work with industry consortia and some of the government and space entities in various countries. They recognize the importance of reliability and are eager to use the latest available tools. The buzz is very good. I just didn't want to release an unfinished product. So many people I know put an idea on the market and allow customers to buy an early revision that is still in the idea phase and being developed. They have their customers developing their product. That's just not a good way to do business.

Let's talk a little bit about the process itself. Are you still using coupons to go through the tester?

Neves: Yes, historically people have put IPC-2221 coupons on the edges of their production panels. Sometimes it's just the AB/R coupons for microsectioning, but there are other coupons that serve different purposes as well.

The D coupon is one that can be automatically generated by most of the design programs out there. That's just two daisy chains of via structures that represent what's on your production panel. D coupons are the primary coupon being tested right now for via structure reliability, and those just plug right into the HATS² test system.

I made the system very configurable, so you can reconfigure the unit very easily to test any kind of coupon you want to design, up to seven 4-wire resistance nets per coupon. We're also using the system for solder joint reliability. We're cycling daisy chains that go through the solder joints, looking at their reliability, and speeding up that process a lot. Because now, with seven nets, we can regionalize testing on large I/O components rather than just having one net for the entire component. We can look at the corners, the center, and at other areas separately and give you information

"This is a really exciting opportunity for us, and for where we will go from here."

without you having to figure out where the failure happened on a very large set of solder joints.

We also have a much more sensitive capability of measuring resistance than the other testers out there. For a long time, the automotive business realized that testing daisy chains only really allows you to see the end of the via structure's failure. There's so much resistance of the circuits that connect the via structures together that when a single or a few via structures start to fail, they don't change the resistance enough for you to see it. It's just noise. You only see it when one or more pop open.

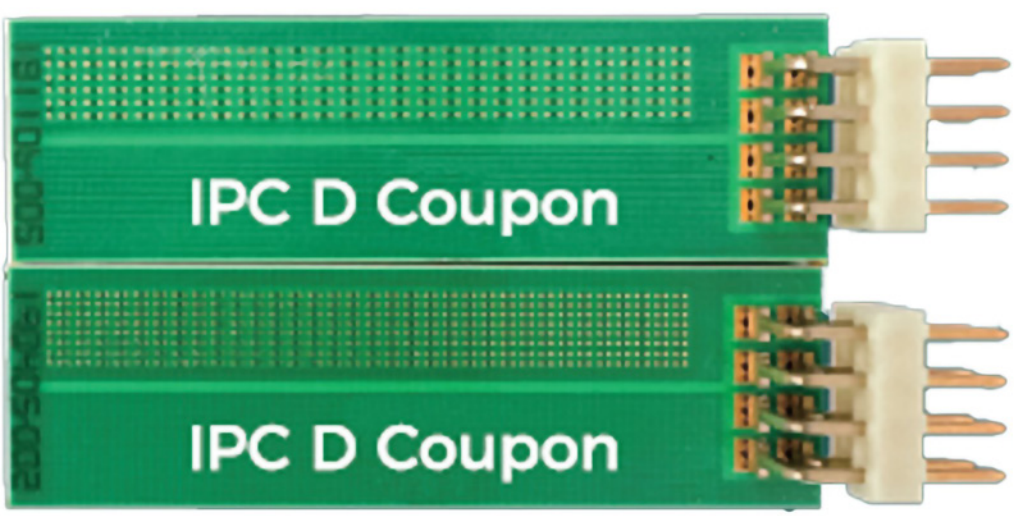
That's a good set of information, but a lot of people want to see how it fails, and the only way to do that is to measure one via structure, which is typically less than a milliohm of resistance. It's a really tough measurement to make, so there are a lot of innovations that we did with the HATS[2] test system to be able to measure below a milliohm and to increase measurement precision and minimize drift. All our measurement and switching equipment is climate-controlled and kept at a very constant temperature so we minimize the drift during the test and measurement. We use mechanical wetted relays that allow a higher current to go through, assuring more accurate measurement than any other tester that's out there today.

Those little things increase the quality of the data that's coming back so you can make better decisions.

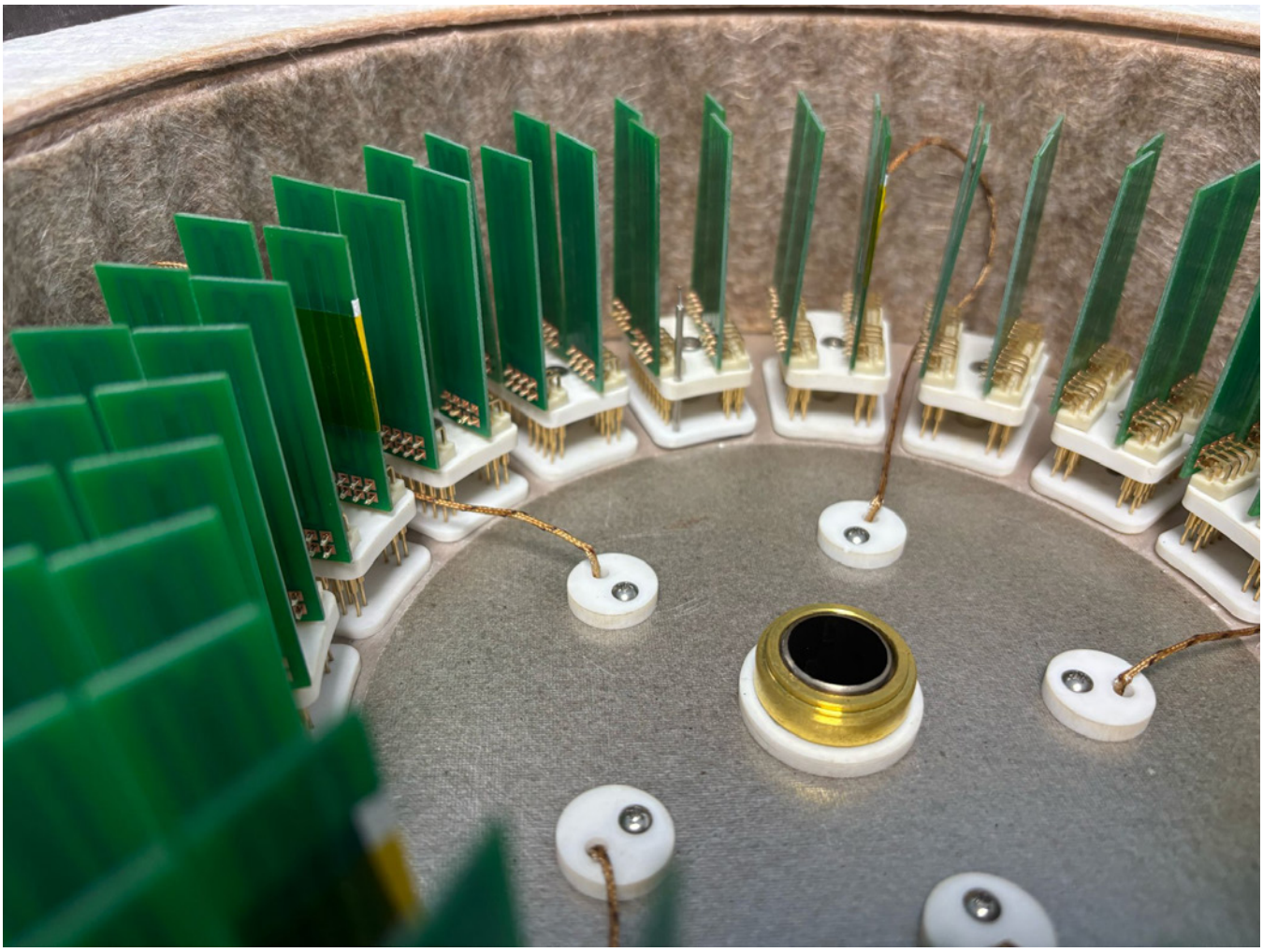
Do you already have ideas for improvements and the next generation?

Neves: Assessing via structure quality and reliability using multiple reflow simulations followed by thermal shock is the next phase. Using the microsection, nothing has really changed for the past 40 years. Some IPC documents are addressing it. With HATS[2], we can start evaluating and improving the reliability and robustness of solder joints more rapidly and economically than what is currently being done.

It will become more important and valuable because now you have other ways of making interconnections to your components that don't necessarily involve via structures and different ways that components can attach to the supporting base structure. There is the movement toward glass substrates that will create some interesting interconnection issues because they don't have any through-holes. As the industry moves, we will move with it.



I plan to attack some of the old stuff that just hasn't been fixed in a long time. If you want reliability of via structures or solder joints, you have to wait a month for traditional chamber results—and nobody waits that long. If you want it in a few days, you



need another tool to speed up your evaluation without adding failure mechanisms that do not occur in a product's life.

Does the information you're bringing out get back to the circuit designer? Is there a design for test strategy?

Neves: Over the past two years, primarily with consortia efforts, we've conducted several studies looking at how different stackups of via structures affect reliability, such as, "This one is 50% more reliable than if you do the same thing slightly differently." This type of consortia or company effort that compares designs, processes, and materials provides information that goes back to the circuit designer.

Also, we see the HATS^2 test system being very useful for changes of materials and chemicals and changing your drill or hole cleaning parameters. The system can tell you very quickly which process or product is better or worse for via structure reliability or robustness.

People have been doing that with other test technologies, but you can do the same thing with HATS^2. You have external needs for reliability, but you also have a lot of internal needs for improving your process. If we make this change, does it make your reliability better or worse? Our system allows

"The system can tell you very quickly which process or product is better or worse for via structure reliability or robustness."

> **Our system allows you to have one high-capacity unit that can provide for all your reliability and robustness testing needs for via structures or solder joints.**

you to have one high-capacity unit that can provide for all your reliability and robustness testing needs for via structures or solder joints. Prior to this, multiple units were necessary to provide both the capacity and range now delivered by the HATS² test system.

Back to your supply chain.
Neves: Correct. Because somebody comes to you and says, "I can sell you a chemical that will be three cents less a liter, a material that's two cents less a square foot." That's attractive, right? I want to look at that, but I need to look at more than just the datasheets and salesperson's promises. I can now quickly build coupons, test them in the HATS² system, and know whether or not the salesperson is right.

If I'm investing money into this new equipment, what should I expect for ROI? What's the real value proposition?
Neves: The path forward for this has typically been that a customer asks you to do this test, and you subcontract it to one of the services out there. As that gets busier, you look at the money you're spending on test services and say, "I can buy a piece of equipment and put it in my facility and save money." That's normally the progression toward investment in this type of equipment. That's what we expect. When a piece of capital-intensive test equipment is placed in a manufacturer's lab, a different value proposition is assessed. It doesn't build anything or create revenue. The lab is always viewed as a cost center. The only way to truly make it appealing for people to purchase a non-revenue-generating piece of equipment is to examine the cost center and say, "I can help you reduce expenses by placing this equipment in your facility." They can see it, feel it, and justify their budget.

Naisbitt: As Bob says, it's a high capital cost, but the value proposition of them spending so much money on test services and considering bringing it in-house is where we anticipate the model will generate lots of activity.

Will there be any special skill set required for an operator of the HATS² test system?
Neves: We've worked very hard over the past three years with technicians at two labs where we've been conducting R&D to ensure that an entry-level operator can easily run the system. The real challenge was to make the input such that an entry-level operator with just an hour or two of training could successfully run it. We have reached that level now. The retail version of the HATS² test system is no longer an engineering unit but a production unit that can be set up, trained with inputs, and operated by technicians on the floor.

Naisbitt: What about interpreting the results?

Neves: The system's results are output to several different people. We output an Excel workbook that has every piece of data we collect and give that to the engineer, who can dive through it, give it to a data specialist, or give it to AI and ask what it means.

We also have a program that does that for you and arranges the data together in a nice test report with

graphs, charts, and highlighted tables so that you can explain it to your non-technical boss or customer. You can show them the pictures. Who doesn't love pictures?

We have some tables that show, "You failed at this level, you passed at this level." Summarized, we have box plots that show the spread and distribution passes and fails. It's a very concise way of looking at the data and it can be understood by pretty much anybody.

This report can then ship with your boards and the receiving inspector can look at it and know what he is looking at. That is something we have spent a lot of time thinking about and working on.

Bob, Andrew, this is an exciting new test technology and timely for where we are today in the technology arc of PCB, PCBA, and substrates. Do either of you have any final thoughts?

Neves: It's always hard for someone to make a change when they've been doing something the same way since they started their business.

The driver right now will be customers saying, "You have to do this." I'm hoping that, as things move on, people will start seeing the value of it and it will not be the customer driving it anymore. It will be propelled forward in the market because the fabricator believes, "I can save money by running this test and understanding my materials and processes, making sure my boards will be reliable in the field, that they will survive the assembly process, that my customers will be happy." It is not just shipping them a green board but shipping them something that the manufacturer knows will get through their customer's assembly process and into the field, and they'll never hear about it again. That part of the ramp-up will take some time. But as this becomes more prominent, just like other newer processes that are starting to be widely used, it will become a normal part of the way people are doing business in the circuit board industry.

Congratulations, Bob Neves, on this equipment, 40 years in the making. Andrew, do you have any final thoughts from a GEN3 perspective?

Naisbitt: This is just a very exciting time. We have a lot going on. We had six major announcements made in the first five months of this year, HATS² technology being one of them. We're looking at a lot of areas of the business with different revenue streams and how we can grow them. For example, in the UK, we've partnered with Zestron and are positioning ourselves to be a cleaning hub in the UK, with the knowledge surrounding that and, of course, all our standards development work which ties in. For now, we have a strategy and action plan. We are kicking off HATS² with our first one and working to get the message out to the industry. It's here. The technology is like nothing before. It is needed at this time, and we can help.

Congratulations again, and good luck to you both as you go forward.

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