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TEST AND MEASUREMENT MARKET PULSE REPORT

Trends, Innovations and New Challenges in Test and Measurement
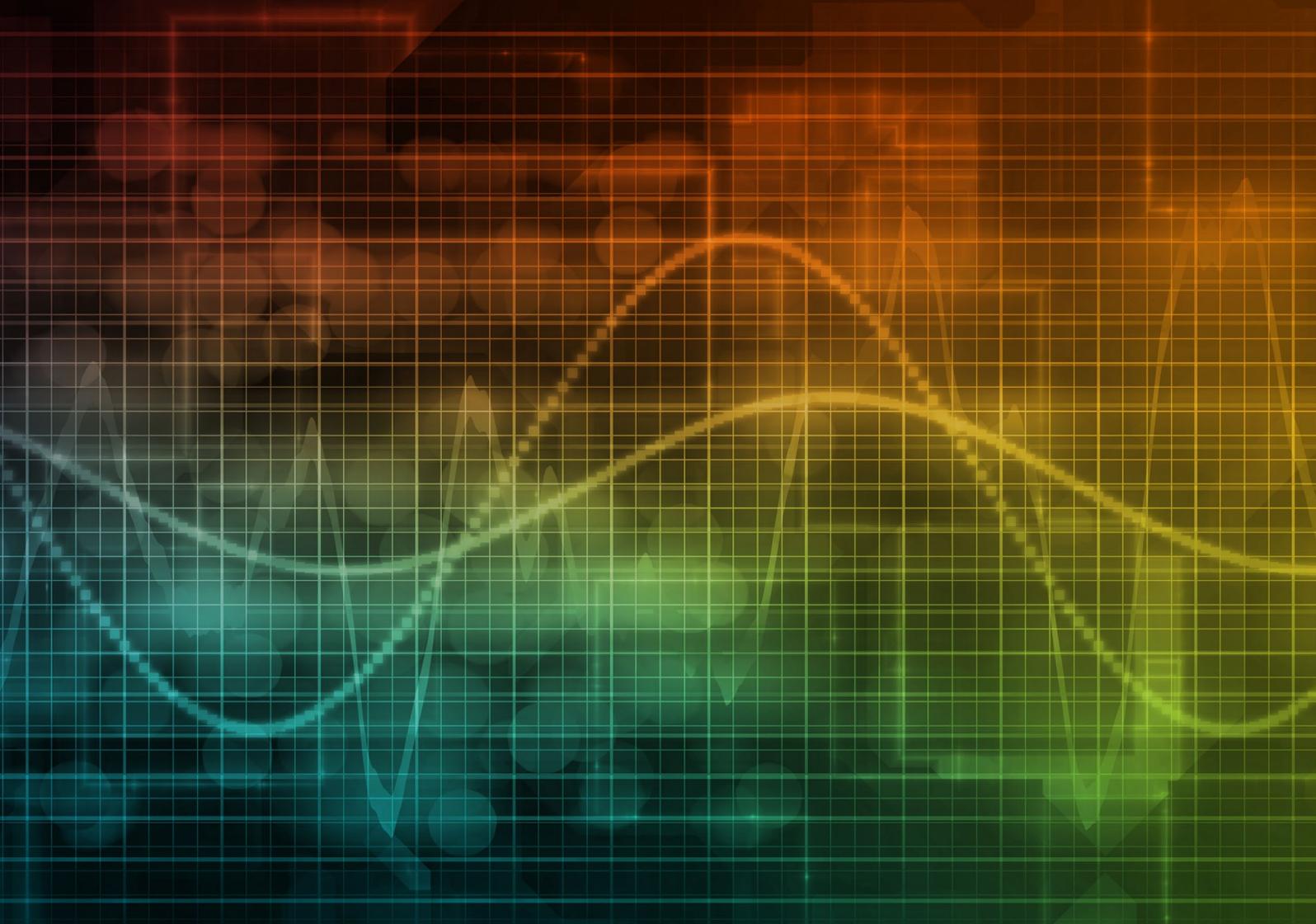
BY KELLY HILL

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Image Source: 123RF

Introduction

Testing is the foundation of ensuring that technology works seamlessly—a seemingly simple concept that, in practice, presents some of the most complex challenges in the telecom industry. From enabling new spectrum to be integrated into devices and networks, resolving bugs in cutting-edge chips and smartphones or validating revolutionary technologies like Open RAN, testing is central to technological progress. It is also how ambitious innovations, such as Non-Terrestrial Networks—where regular smartphones communicate directly with satellites in space—become reality. Whether in the lab, the field, or through continuous monitoring and troubleshooting, testing ensures that networks and services operate reliably, underpinning the profitability of devices, networks, and services.

Although testing often involves intricate technical processes, its true significance lies beyond the technicalities. Testing is not performed for its own sake but as the cornerstone of monetization. It enables the industry to deliver reliable solutions that drive revenue, because users trust their availability and performance.

This report delves into the latest advancements in telecom testing, exploring ongoing developments such as the transition to 5G Standalone, new features and services. It examines the challenges these trends bring to testing and the strategies being deployed to address them. Moreover, the report highlights how test vendors are leveraging automation, artificial intelligence, digital twins and other innovative tools to simplify testing in a telecom landscape that only ever seems to get more complicated.

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Image Source: 123RF

How the test market stands: Trends and major transactions, 2023-2025

Top *RCR* takeaways

T&M companies have weathered the 5G network investment pause due to diversification across verticals.

> Recent T&M acquisitions have focused on edging out portfolio capabilities in telecom as well as semiconductor and industrial/IoT system testing and control.

> While the T&M market has some very large players and has a track record of consolidation, it still contains many small and mid-sized companies that are innovators—and potential acquisition targets.

Slow-downs in 5G network upgrades have generally had muted effects in the T&M space, with most companies cushioned by diversification across wireline, aerospace and defense, security and other markets—and in some cases, the fact that 6G R&D is already well underway.

Several T&M CEOs have also recently indicated that they see a recovery in the works in terms of telecom investment in test. Those who have revamped their supply chains post-Covid-19 are feeling cautiously optimistic about their ability to weather tariffs as well.

"At the beginning of the year, we said we thought this year would be a slow gradual recovery in our markets. And we feel like that is exactly the trajectory we're on," Keysight Technologies President and CEO Satish Dhanasekaran told analysts on the company's most recent quarterly call, adding, "But like everybody else, we continue to monitor the risk due to tariffs and the geopolitical environment."

Oleg Khaykin, president and CEO of Viavi Solutions, said on Viavi's most recent quarterly call that Viavi saw strong growth in fiber monitoring demand from service providers and hyperscalers and a gradual recovery taking shape in demand for the field instruments used in wireless network testing. "We believe the demand for wireless field instruments is a leading indicator for the resumption of 5G network buildout, leading to gradual recovery for the overall wireless segment," Khaykin added.

The test and measurement space has also seen bursts of testing M&A activity over the past couple of years. The acquisitions or divestments signal where companies see demand, as well as where their portfolios could edge out into new, tangential growth areas.

Additionally, while there are high cost-of-entry barriers to some parts of the test ecosystem, other areas have plenty of competition and smaller players. For example, Zuercher Kantonalbank analyst Daniel Buerki told *Reuters* earlier this year that the four biggest players in the testing, inspection and certification market (which includes, but extends well beyond, wireless or wired tech testing) only have a combined market share of 20-25%. So in addition to test businesses which are part of, and sometimes traded among, large global conglomerates, there are also plenty of small-to-midsized companies to acquire.

"We believe the demand for wireless field instruments is a leading indicator for the resumption of 5G network buildout, leading to gradual recovery for the overall wireless segment."

- Oleg Khaykin, President and CEO, Viavi Solutions

What transactions have shaped the T&M space over the past two years? Here are some of the notable acquisitions and transactions in the testing market since 2023.

- **Synopsys** announced a deal to acquire competitor **Ansys** in early 2024 for about $35 billion to create a company with deep expertise across electronic design for semiconductors combined with system simulation

Image Source: 123RF

and analysis. That deal is expected to close in the June 2025 timeframe, pending final regulatory approvals.

- In terms of pure testing, inspection and certification (TIC), perhaps the highest-profile recent testing M&A movement was the possible combination of TIC giants **SGS** and **Bureau Veritas**, valued at an estimated $30 billion. Those discussions were first reported in early January 2025, but the merger talks eventually fell apart.

  However, even with that particular transaction off the table, it isn't necessarily the end of related M&A. Because when Bureau Veritas reported its Q1 2025 results, the company said that it was still looking for other acquisitions and would "focus on small bolt-on acquisitions and will very selectively consider medium-sized bolt-on deals with revenue in the range of EUR 100 million to EUR 500 million."

- **Keysight Technologies** outbid **Viavi Solutions** in 2024 for ownership of **Spirent Communications** at a price of about $1.5 billion. That deal had been expected to close by April 2025, but has now been pushed out to July 2025 as it continues to work through regulatory approvals.

  But Viavi isn't coming away empty-handed. Keysight was required to divest Spirent's high-speed Ethernet and network security business as part of the regulatory approval process, and Viavi is buying those assets for $425 million once Keysight officially takes ownership of Spirent. Most recently, the U.S. Department of Justice added a requirement that Keysight divest Spirent's channel emulation capabilities to Viavi as well.

- **Viavi Solutions** also recently acquired positioning, navigation and timing (PNT) company **Inertial Labs** for $150 million, which was a complementary acquisition to Viavi's existing portfolio in the PNT space and expanded its autonomous system capabilities.

- Testing and tech conglomerate **Teradyne** expects to close on its purchase of privately held photonic integrated circuit (IC) testing company **Quantifi** by the end of Q2 2025. Teradyne expects the acquisition to position it for growth in high-volume manufacturing of silicon photonics, in support of advanced optical interconnects for high-performance cloud and AI networking.

- **Rohde & Schwarz**, which operates in the broadcasting business as well as in cellular technology testing, transferred its dedicated DOCSIS test solutions portfolio to longtime partner **Calian** in mid-2024. Financial details of the transaction were not disclosed.

- **Keysight Technologies** acquired **ESI Group**, known for its advanced simulation software for automotive and aerospace, for 913 million euros (about $1 billion). That transaction was finalized in early 2024.

- Looking a bit further back, the biggest telecom-related testing M&A transaction during 2023 was **Emerson**'s acquisition of **National Instruments (NI)** in a transaction that valued the test stalwart at $8.2 billion. The buy bolstered Emerson's position in the test markets for semiconductors and electronics, transportation and aerospace/defense as well as digital transformation, software, control and industrial markets.

- Global interconnect, sensor and antenna company **Amphenol** picked up test and antenna specialist **PCTel** for about $140 million in late 2023.

- Privately held international test house **Dekra** acquired Taiwan-based **Onward Security** in 2023, as part of its goal to expand its portfolio in cybersecurity product testing and certification. Onward Security focused on cybersecurity compliance solutions for companies in IoT and industrial IoT device manufacturing, as well as automotive, industrial and medical industries, among others.

- Global conglomerate **Fortive** acquired **EA Elektro-Automatik**, a German specialist in energy-related electronic test equipment, in 2023 for $1.45 billion.

  On a related note, Fortive also announced plans in 2024 to split into two public companies. One of them, to be known as **Ralliant**, will include Fortive's assets in test and measurement, specialty sensors and aerospace and defense subsystems. (Fortive itself was formed when test and comms assets were spun off from Danaher in 2016.) The company is targeting June 2025 for the split—meaning, there will be a new T&M player in the market soon.

  Fortive's telecom test brands include **Tektronix** and **Fluke**.

Final thought: What do these transactions tell us about areas of focus for testing M&A? Test and measurement companies are seeking to build more comprehensive portfolios in addition to their traditional telecom and tech positions, extending their capabilities in semiconductor testing, automotive and support for industrial markets in particular.

Image credit: 123RF stock photo

What are the new 5G challenges for T&M?

Top *RCR* takeaways

Halfway through the 5G era, 5G NSA has spread prolifically—but 5G SA deployments have been slower than expected.

New features are emerging as 5G continued to mature, including NTN and RedCap as a path for 5G IoT.

Fixed wireless access has put new demands on networks and testing.

5G is roughly halfway through the typical 10-year generational cycle for cellular technologies. 5G poses a unique evolutionary challenge, however, due to the way it was standardized. Most operators initially moved from 4G to 5G-NonStandalone, which relied on 4G as an anchoring control. The next point of evolution has been to institute a cloud-based 5G core, which marks the point of 5G Standalone: a true, end-to-end 5G system. From 5G SA, the next step in evolution is 5G-Advanced, implementing features from 3GPP Rel. 18 and onward.

Each of those phases of 5G development must be tested, and poses its own unique testing and service challenges. So where is the industry on that evolution path, and how does that impact testing?

5G Standalone deployments have moved slower than expected, in part due to less monetization of services than the industry had hoped. According to Global mobile Suppliers Association (GSA) figures from spring 2025, there have been 354 commercial 5G network launches around the world, but just 73 operators in 39 countries have either launched or soft-launched 5G SA services. Meanwhile, GSA has identified just 26 operators in 15 countries who are investing in 5G-Advanced, mostly in the form of tests, trials and evaluations as they wait for the device ecosystem to mature.

However, a report from Spirent Communications earlier this year concluded that the "lack of visible commercial deployments in the field doesn't tell the whole story" of 5G SA. Progress toward large-scale SA rollouts took place largely behind the scenes during 2024, the test company said, and set the stage for more "strategic" 5G moves this year. The company said that during 2024, it engaged with more than 50 CSPs, hyperscalers and NEMs on 5G SA testing; more than 30 of those engagements were with network operators.

"The big takeaway is the momentum around 5G Standalone and early Advanced," said Stephen Douglas, head of market strategy for Spirent Communications.

Given the context of the 5G evolution, let's now look at some of the major emerging features and associated services that operators expect to help them further monetize their networks. Smartphone-based enhanced mobile broadband (eMBB) services were, of course, the first 5G services to emerge and are now well-established. Beyond that, the current areas of development include:

Fixed Wireless Access. One clear success for 5G thus far has been the emergence of 5G Fixed Wireless Access broadband services, providing new revenues and a basis for converged service offerings in areas where wireless network operators do not have a wireline footprint. The GSA said that more than half of existing 5G deployments including FWA service launches. Based on targets from U.S. wireless carriers, the domestic FWA subscriber base could reach more than 20 million by 2028.

However, as Sylwia Kechiche, senior director of industry analysis at Opensignal, pointed out, there's a catch with FWA. "A Fixed Wireless Access user consumes around 15 to 20 times more network capacity than a typical mobile smartphone user," she explained, adding that "typically, at least in the U.S., [they] generate around the same revenue."

Kechiche continues: "This actually creates a very delicate balance. So there's a need for very careful network planning, and making sure there's enough spectrum capacity—because Fixed Wireless can cannibalize some of mobile performance, especially when you think about peak times."

She added that key testing questions include capacity and performance, because "poor backhaul equals poor user experience." Joey Villamil, market development manager for wireless—America at EXFO, confirmed that issues in the transport network can have a major impact on end-user experience, particularly for FWA. "If you just deploy cell sites and you don't improve the transport network, you're going to end in a situation where even though people might have service, they might not have the level of service that they're expecting," Villamil said. "They might not be able to do their jobs or they might not be able to do homework, something as simple as that." Carriers are upgrading transport networks from 10 Gbps backhaul to 100G and even 400G at

Image source: 123RF

the moment, he added, in order to met anticipated capacity needs for both current 5G use cases like FWA, and anticipated future needs. "If you're going to really get to the next level and improve coverage and hits on some of the … 5G advancements, you're probably going to have to continue to increase the transport networks," Villamil said.

FWA also behaves more like home broadband than a mobile cellular service, which means that network traffic tends to be highest in the evenings. Understanding how performance differs at the cell-edge is particularly important to the customer experience, Kechiche added. Also, router quality and antenna set-up are key, but installation—particularly self-installations by customers—may mean that devices are not positioned optimally. "Customer experience became a very hot topic last year in many of our markets, but North America and Asia Pacific especially, around Fixed Wireless Access," Spirent's Douglas confirmed in an interview earlier this year. He added that operators wanted to test end-user experience where shared spectrum was being used with mobility subscribers and how the networks were performing at peak hours in the evenings.

Overall, Kechiche said, testing needs to focus on real-world customer experience and be dynamic in order to understand the shifting balance between mobile and FWA customers utilizing the same network and resources. But she also made the point that FWA can be designed and tested for "good enough" service.

"As Fixed Wireless Access is expanding, it is clear it cannot offer the same speeds as fiber—and it's not attempting to," she said during Test and Measurement Forum. "Quite often when we think about what end users really want, they want a 'good-enough' connectivity." When Opensignal analyzed FWA through the lens of its "constant quality" metric, it scored about 15 percentage points lower than fiber connectivity. That's still good enough for stable network performance and satisfactory responsiveness for most applications, she said.

"Quite often when we think about what end users really want, they want a 'good-enough' connectivity."

- Sylwia Kechiche, Senior Director, Industry Analysis at Opensignal

5G Reduced Capability. Also known as RedCap, this is seen as the primary evolution path for IoT devices to be deployed in 5G. RedCap is meant to offer less performance than full-featured 5G, but also a less expensive price tag.

GSA expects RedCap to "dominate the mid-tier" IoT applications in the near-term and provide an IoT bridge between LTE and 5G, followed by broad adoption of enhanced RedCap—which is expected to offer a wider range of low-power/low-cost options—from 2026 onward.

According to Spirent's report, the company has seen significant ramping up of RedCap testing, with a focus on network readiness to be able to cope with large numbers of RedCap devices. But simply expanding 5G IoT isn't the only driver for MNOs' eagerness to deploy RedCap—they also want to deploy it quickly quickly in order to clear existing spectrum and re-farm it. GSA reports that 30 operators in 21 countries and territories are investing in RedCap, with early commercial launches by T-Mobile US and China's major operators.

As Middle Wen, senior product manager for LitePoint, explained, the purpose of RedCap is to support IoT and expand the use cases for, and adoption of, 5G by leveraging lower-cost devices.

Wen described three areas of testing challenges for RedCap: Testing compliance with 3GPP standards; operational testing, or ensuring that RedCap device can operate on a specific carrier network and also that they can talk to other devices; and performance testing.

"The mission of the RedCap device is [to] provide a lower cost 5G device," he said. "But still, you need to keep the good performance with this lower cost device … even with the lower power use." He added: "You need to test under the different conditions to ensure [those] qualities."

RedCap is meant to be use less bandwidth and less power, achieve lower data rates and rely on a simpler design. "We need to ensure the device[s] work well, despite being simpler," Wen said. Because one of the primary goals with RedCap is also to mass-produce the devices at lower cost, that also has implications for device design in terms of materials, and for manufacturing test to optimize production.

5G Non-Terrestrial Networks. Early forays into 5G NTN have garnered high-profile partnerships, investments and launches of the first satellites that have standards-based 5G connectivity—for the most part, beginning with narrowband IoT for NTN, or NB-NTN.

Extending 5G to space and connecting with unmodified smartphones poses some extensive challenges. Those include the round-trip latency, link variability and channel changes due to both the satellite and the end-user device moving, channel fading and handovers, according to Randhir Choony, lead engineer and NTN solution architect at Viavi Solutions. In the current direct-to-device context, "the UE itself can't deal with these different challenges on the channel," he said, so all of the necessary intelligence needs to happen on the network side for now.

While current services are starting with NB-NTN; services such as best-effort emergency texting, there is a roadmap for voice services as well—something that Jason Trombley, VP commercial for Terrestar, expects to see emerge in the next couple of years. That's particularly tricky with the NB-NTN protocol, he added, which "requires a bit of bending beyond what it was originally meant to do" in order to support voice.

Image source: 123RF

"It's not easy to do it, and we're testing a lot of voice compression technology to get it to [a] reasonable [signal strength] level," Trombley said.

However, both Trombley and Choony agreed that in an IoT context, there is significant variance over the amount of data transmissions that actually need to be supported. "You've got use cases where you only need a ping or two a day, and there's others where you need that constant stream. … but typically you're dealing with varied limited bandwidth requirements on IoT," Trombley said.

"Most of the use cases … you don't need to have streaming data, you just need to have a burst of data," Choony said. If NTN connectivity catches on in the consumer smartphone space, however, those services will most likely need the higher data rates supported by LEO satellites—a space that is also going to be seeing more change in the near-term, as additional satellite constellations from the likes of Amazon's Project Kuiper and AST SpaceMobile are launched.

At this point, however, there is more posturing than progress for many NTN announcements. For example, Trombley said that testing may occur in satellites that are in a lower orbit position than is actually authorized for commercial operations—leading to a splashy press release, but not much real progress toward a service.

Private networks. While 5G was fundamentally designed with enterprise uses in mind, that aspect of the technology is only starting to take off. According to Dell'Oro Group, private wireless RAN revenues grew more than 40% last year.

"Private wireless is currently one of the more exciting RAN segments, partly because of the more favorable growth trajectory compared to the broader RAN market," said Stefan Pongratz, VP for RAN market research

"At the end of the day, the enterprise doesn't want to have to deal with the complexities of a typical telecom or a 3GPP-style network deployment."

- Shirish Nagaraj, SVP of Global R&D, Airspan Networks

at Dell'Oro Group. "While it is still early in the private 5G journey, and it will take some time before enterprise spending will move the larger RAN needle, initial readings suggest private wireless moved above the noise in 2024, representing around 3 to 5 percent of total RAN."

Omdia recently called private networks the "key enterprise 5G monetization opportunity and identified Nokia, ZTE, and Ericsson as the top three leaders in the market. "Vendors now recognize that private networks are highly specialized and require a few focused partners – not a wide distribution channel – to drive market growth," Omdia concluded.

Verizon CEO Hans Vestberg said during a recent JP Morgan investor conference that Verizon was seeing "way better" demand for private networks. Verizon, he continued, has seen an increasing funnel of private networks for several years now, across various industries and use cases, from capacity and security to low-latency. "As soon as you get in a private 5G network, then usually, the CIO or the head of IT of the company starts seeing a lot of new opportunities [on] how to use it," Vestberg said. "They are fairly small, the first private 5G networks that you sell. It's like a Wi-Fi network. But over time, they are growing." Customers usually start with one site and if it is successful, take it to all their sites. "We are in that scaling right now," he concluded.

Saurav Jah, president and CEO of Simnovus, said that as 5G private network demand picks up, there is growing demand for multi-tenant, neutral-host-based private networks—which bring some additional complexity in terms of integration and validation. "We need to ensure that there are no traffic leakages across tenants, and also at the same time, ensure that there is a fair allocation and distribution of resources, radio resources or compute resources across each tenant," he said. Those networks typically have to be integrated on one side with an external carrier network, and internally with a company's IT infrastructure, he explained. "The complexity mainly comes from the fact that there are external networks involved, which needs a smooth integration with the private network setup that you're creating, as well as the integration with the IT network of that enterprise."

"As you go towards private networks, being enterprise friendly is kind of really critical," said Shirish Nagaraj, SVP of global R&D for Airspan Networks. He said that means having easy deployment mechanisms, providing data localization and security, and guarantees around performance metrics like coverage, mobility and latency.

"At the end of the day, the enterprise doesn't want to have to deal with the complexities of a typical telecom or a 3GPP-style network deployment," Nagaraj said. "We truly believe that if we can tie this all together with a very simplified managed service with a management plane and offering the right levels of visibility and controllability of the network, that I think is really the key as you go towards managing these hybrid networks of the future."

Final thought: Monetization of 5G has been slower than expected, particularly in terms of enterprise. FWA has been bridging the revenue gap, but emerging strategies in NTN, RedCap at scale and private networks are beginning to pick up. There are significant technical challenges. But testing is fundamental to making sure that new services work, and ultimately, fundamental to monetization.

Image credit: 123RF stock photo

# Open RAN picks up– but it's 'not there yet'

Top *RCR* takeaways

Open RAN is expected to see modest growth this year after plummeting in 2023-24.

Some early Open RAN adopters are beginning to talk about the technology not only in terms of flexibility, but performance.

Testing and system integration is still a heavy lift, made more complicated by inconsistent test approaches even across authorized labs.

It has been nearly a decade since the telecom industry began its concerted push toward Open Radio Access Networks (Open RAN). Open RAN appeared to be hitting its stride as revenues accelerated between 2019-2022, but then a RAN market slowdown starting in 2023 interrupted its momentum. During 2024, the overall RAN market recorded what Stefan Pongratz, VP for RAN market research at Dell'Oro Group, called the "steepest full-year decline in more than 20 years," and Open RAN revenues fell 30% year-over-year during the first three quarters of the year.

However, Pongratz has indicated cautious optimism for the RAN market this year, and forecasts that Open RAN revenues will grow and account for 5-10% of the total RAN market. The "when" of Open RAN may be pushed out, but it's still a "when" rather than an "if."
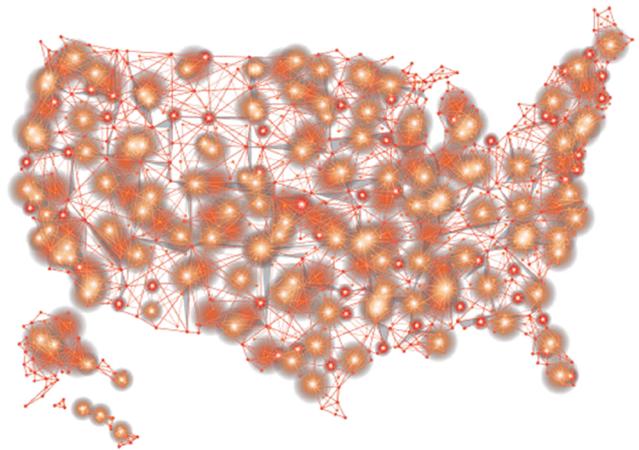
Boost Mobile, part of EchoStar, is operating a greenfield Open RAN network.
Image: Boost Mobile

Establishing interoperability and consistent, repeatable ways to test and measure the behavior and performance of O-RAN elements and systems has been one of the major challenges for the technology. While revenues and deployments may not have moved as quickly as hoped, there are other signs of technology maturity. O-RAN Alliance's spring plugfest for 2025 ran through mid-May, and its six themes have shifted away from basic conformance testing and toward use cases and applications of O-RAN to achieve things like energy savings, system testing with Layer 1 acceleration and open fronthaul transport testing with multiple open radio units.

During the recent CTIA 5G Summit in Washington, D.C., Eben Albertyn, EVP and CTO of Open RAN network operator Boost Mobile, touted not only Open RAN's flexibility, but its performance—and, amid a backdrop of increasing geopolitical tensions, emphasized that its network was built using only technology from American vendors and close allies.

In January, Accenture and its testing unit, Umlaut, released a report from drive- and walk-testing conducted in New York City which ranked Boost Mobile over all three of the other national mobile network operators on data performance scores and data reliability (Verizon edged Boost out on voice-related metrics).

"Open RAN is not a science experiment," Albertyn declared at the CTIA summit. "It really works." He went on to add: "Open RAN not only works, but it also provides absolutely fantastic quality. … You can provide the best possible quality in the most competitive and most difficult environment using these technologies."

According to Albertyn, Open RAN is also living up to promises of its flexibility. "This year we have changed two very significant portions of our architecture, without our customers being aware of it at all. And we did so in days, not months or years, like we would have if we used a different architecture," he said. "We were able to do that because we live in the cloud, and therefore we can innovate at the speed of the cloud."

However, the Open RAN discussion at Test and Measurement Forum reflected the real-world complexity that is still playing out with O-RAN testing.

"Open RAN is not a science experiment. It really works."

- Eben Albertyrn, EVO and CTO, Boost Mobile

"Keep in mind that this is not an easy task," cautioned Venkatesh "Venki" Ramaswamy, distinguished chief technologist for NextG at MITRE Labs. "That is something that we already knew from the beginning, but this is an enormously complex task, putting these things together. So, we made a lot of progress. We are not there yet." He sees a current trend toward Open-RAN-compliant solutions that come from the same vendor—which doesn't quite live up to the thesis of Open RAN as supporting a diverse set of suppliers.

Nirlay Kundu, head of technology standards at research institute IMDEA Networks and a longtime veteran of Verizon, said that he thinks success in Open RAN will come when service providers are actually able to easily mix and match radio units and distributed units from different vendors. "In my opinion, it's getting there, but it's not there yet," Kundu said. And, he added, the additional integration and testing costs make it unclear whether the total cost of ownership (TCO) for Open RAN is actually better at this point.

One of the double-edged swords for Open RAN testing is lies in the variety of configuration possibilities. "Let's say that you are getting [a radio unit] from vendor A, and they have a given configuration for testing—and that configuration is going to be quite different from a different vendor's configuration," Ramaswamy said. That not only makes it difficult for the person conducting the tests, but the configuration "is not going to provide the same set of behavior across different RU vendors." Throw in a third component, say, for scheduling, and the parameters suddenly skyrocket.

"Even when you are able to match one-on-one with those parameters, it's impossible to get the same behavior across these different components," Ramaswamy said. "So that makes [testing] very, very complicated; very, very time consuming; very, very inconsistent and not reproducible."

Even among Open Test and Integration Centers (OTICs), which are qualified by O-RAN Alliance, testing results can be inconsistent. Kundu said that OTICs are not all equal in terms of capabilities or testing resources for various layers. "If you test certain interfaces or certain layers, it has to be very, very consistent. And we are seeing that consistency is not there," he added.

Ramaswamy suggested a accreditation program for OTICs that would certify not just the labs' capabilities, but support consistent testing across labs. "Right now, there is nothing like that. So you cannot reproduce the results that you get from one of them to the other," he said.

He suggested that it would be helpful to be able to create "pre-tested versions" of Open RAN network components for specific verticals, which would support private O-RAN networks and also be a starting point, to which specific testing would be added for given use case or implementations. "Having a pre-integrated solution where you have some confidence and some trust for a given equipment ecosystem for a given vertical, I think that is going to help as well. But the first and foremost, in my opinion is to have the accreditation of the testing lab itself."

Kundu said that he also would like to see more test-result cross-checking from O-RAN Alliance, of which he is a participating member. But he noted that another gap is that service providers haven't yet jumped in to require specific parameters from the labs. Why? "Because the service provider is still not confident of the repeatability of the results," he said. "So what the Tier One service providers do is, even if it's tested by the OTICs, they will do most of the testing in their own labs themselves. That step should not be there." O-RAN will be successful, he continued, at the point at when service providers have confidence in the results coming out of OTICs and can put a list of requirements in an RFP, rather than conduct extensive additional system testing and integration themselves.

"We all know that just plugging different vendors together and standing back and turning on the on switch and hoping it's going to work, it is not the way that it works," said Simon Fletcher, chief strategy officer from Small Cell Forum. He added that product development teams should be working with test and measurement companies to create standardized profiles for testing, and that this is a gradual process.

"If you test certain interfaces or certain layers, it has to be very, very consistent. And we are seeing that consistency is not there."

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- Nirlay Kundu, Head of Technology Standards,
IMDEA Networks

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He added: "To some extent I'm hearing some frustrations that perhaps we are not making so much progress, but I was always of the thought that this was not going to be a short-term gain. You've really got to stick at this. … But hopefully we can work through that over the next couple of years."

Adam Smith, director of product marketing for testing company LitePoint, made the point that while O-RAN interfaces can be "wildly complicated," in other ways the technology has made great strides towards a standardized software test automation framework, despite disparities across vendors. "I think what we need to move towards is testing towards a collection of experience," he offered. "We're finding things that fail in the real world, that don't interoperate in the real world. And being able to feed that back into the test, I think is important, moving forward."

Final thought: Despite progress toward Open RAN ecosystem maturity, key challenges persist— particularly around interoperability and consistency of testing. Meeting the spec is only the start, and the space is likely to see more demand for holistic and streamlined approaches to integration (which, ahem, starts to sound a lot like … the purpose-built equipment/software market that Open RAN was supposed to disrupt). Open RAN's potential for flexibility and innovation is slowly being realized, but its path forward will require sustained collaboration and continued technological refinement.

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Image source: 123RF

The A's and E's of modern test

The Open RAN testing debate raises one of the fundamental issues that the wireless industry—and the test segment in particular—has to constantly deal with: These are complex technologies. Making them work can be challenging. What does modern test need to look like, in order to bring simplicity to what is fundamentally complicated? Here are the essentials.

Adaptable. The push toward 5G Standalone is resulting in rapid change in how the networks are architected, moving from physical infrastructure to cloud infrastructure and expansion on the edge.

"Carriers are going from consumers of network infrastructure, to providers of the very fabric that these network services run on," said Ross Cassan, senior director of assurance strategy for Spirent Communications. "That comes with a lot of demand for testing and being able to support not only the infrastructure, but then the proliferation of network functions and protocols that ride on top of that." Meanwhile, legacy technologies and services still need to be supported.

UScellular has launched a 5G SA core and recently began offering network slicing. Greg Agami, the carrier's

director of network solutions, said that as the the carrier has moved to cloud-native architectures, that has meant redesigning its testing processes. The deployment of a 5G core, cloud-native development and smaller micro-services mean that the company can iterate faster—which has changed the way UScellular tests, to a continuous integration, deployment and testing (CI/CD/CT) process that has test fundamentally built into development. Validation has to cover a wide range of scenarios, Agami noted: 5G SA itself, coexistence with NSA and LTE on the network and device sides; across spectrum bands, across traffic for mobile vs. fixed wireless, and in terms of IoT, across performance across device classes.

Authentic. Sameh Yamany, CTO of Viavi Solutions, points out that optimizing the network doesn't start from a single point. Really, it starts in the lab—where a lot of network operators don't particularly want to spend a lot of time. They tend to jump straight to thinking about the upgrades they want and how to manage vendors, Yamany said. Why the avoidance of the lab? Because traditionally, it hasn't effectively or accurately mimicked what people actually saw in the field.

Chris Hristov, AVP of network engineering and automation for AT&T, confirmed this during Test and Measurement Forum, saying during a panel discussion that AT&T has been trying to minimize lab time and get into the field as quickly as possible in order to work with live network traffic. "That's been a movement: Don't get stuck in the lab, get the minimum viable product done and kind of get going," he said.

Yamany argues, however, that lab-based digital twins are increasingly capable and can be more dynamic and reflective of real-world network conditions, especially if they have access to real-time network data. But digital twins shouldn't only be used to reflect the current state of the network, Yamany said—they can also be used to create and explore new ones. What happens if you upgrade a regional or national train system with 5G? How does the network respond to a hurricane? "It's not just creating reality, it's also trying to create extra reality," he offered. "You're taking it to the next step, because we really want resiliency." Similarly, digital twins can play an important role in what-if scenarios, optimization and figuring out technically challenging new network services like NTN—but only if they sufficiently reflect real-world conditions.

Active and automated. Testing and service assurance have to keep up with fundamental changes associated with speed of change in cloud-native networks—that CI/CD/CT pipeline. This means being more proactive than testing frameworks of the past.

"We've largely relied on passive analysis in the past for things like service assurance," said Cassan. "If you just think about that term passive, it means that you've detected something after it happened, right? It's already happened to you, it's already happened to your customer. … What we're seeing is a move towards active assurance."

Cassan outlined several examples of recent case studies of active service assurance. In one case, an operator was providing a mobile slice for enterprise, but that required a huge amount of manual testing whenever a change was made, to ensure that other customers' SLAs weren't be impacted—so much testing, in fact, that they couldn't test changes across every one of the large, Fortune 500 customers which were using the service. "They really didn't have good end-to-end visibility and were often getting calls from their customers when things weren't going well—and that was the first time they would hear about an issue, when their customer called in," Cassan said. With active testing and automated fault isolation, he said, "we've been able to evolve that to the point where within a five minute window, all 5,000 of those slices are being tested."

In another instance, Spirent focused on turning routers at customer premises into test agents for a fixed line service, and using automation to be able to run tests from a central location, so that engineers were only deployed to the field for very specific needs. The changes not only reduced the time to detection and reduced operating costs by 25%.

Active assurance helps to address the gap between lab scenarios and the behavior of the real network. "There's always things that are going to be different in the live network. You just can't create that scale. You can't create the dynamicism of everything your customer is going to do," said Cassan. "So you need to be able to constantly

"We need to make the job easy for humans. So we want to do things like automating the triage procedures, and making sure that we're providing as much information as we can to the folks that are solving the problem, and also getting the right folks in the room."

<div align="right">

- Ross Cassan, Senior Director of Assurance Strategy,
Spirent Communications

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have the eyes and ears ready—whether it's closed-loop or open-loop systems—to be gathering that information and ideally, trying to get ahead of those issues before they impact customers."

Part of that means distilling data and increasing automation. "We need to make the job easy for humans," he said. "So we want to do things like automating the triage procedures, and making sure that we're providing as much information as we can to the folks that are solving the problem and also getting the right folks in the room."

Artificial intelligence-powered. AI, of course, is the technology with perhaps the biggest potential for change within the test and assurance space. While network testing, validation and assurance have used AI or machine learning for years, the capabilities of generative AI have yet to be applied at scale.

Hristov of AT&T said that AT&T has used closed-loop, rules-based, AI/ML-decision-making to predict, model and improve network performance for some time. For the newest AI capabilities, he said, "I think there's been some struggles. I think finding the right use cases, where it can bring value to the business is probably where we spend a lot of time on."

"Some of the capabilities with LLMs, of gathering … information and providing actionable insights, is definitely a path forward and has made a lot of growth just the last year or two," said UScellular's Agami. But, he continued, having a controlled environment and automation in a lab to run all sorts of tests, from modeling to stress testing, is still important. In the field, the focus is drive testing and use of network probes to gain a picture, plus anomaly detection to look at areas that need more investigation about whether features or functions aren't working, or if optimization is needed.

Hristov also pointed out that over time, the business priorities and strategy for the network have changed—and algorithms need to change to reflect that. Five or so years ago, operators were focused primarily on network speed. "It was very, very much performance driven," Hristov said. "So a lot of the automation algorithms focused on that. I would say nowadays … performance is table stakes, pretty much. Now it's about, how can I run a network at the lowest cost per gigabyte while delivering that excellent customer experience? So a lot of the automation … is changing a little bit. The use cases are changing more towards lower opex. I think that's driving also a lot of the innovation," Hristov said.

AI to watch the AI. As operators start to operationalize AI, they are also going to need tools to check up on how those AIs operate.

"If you really want to test what AI is doing, you have to use AI," Yamany said—anything else is effectively bringing a knife to a gunfight. He sees another role for digital twins here, in using AI to mimic both a real network and its built-in AI capabilities in order to see how those internal AI agents react under normal conditions, impairments, or large-scale disasters; and, to look for opportunities for upgrades and potentially, different places where AI or functions could be implemented, trained on real and real-time data from the network.

However, Yamany also says that it would be naive to think that we currently understand how AI is going to be tested, because so many things are not standardized, and because the models themselves are so dynamic. "But I will also say this: one of the fundamental thing about AI is that we know that it'll be biased. It depends on
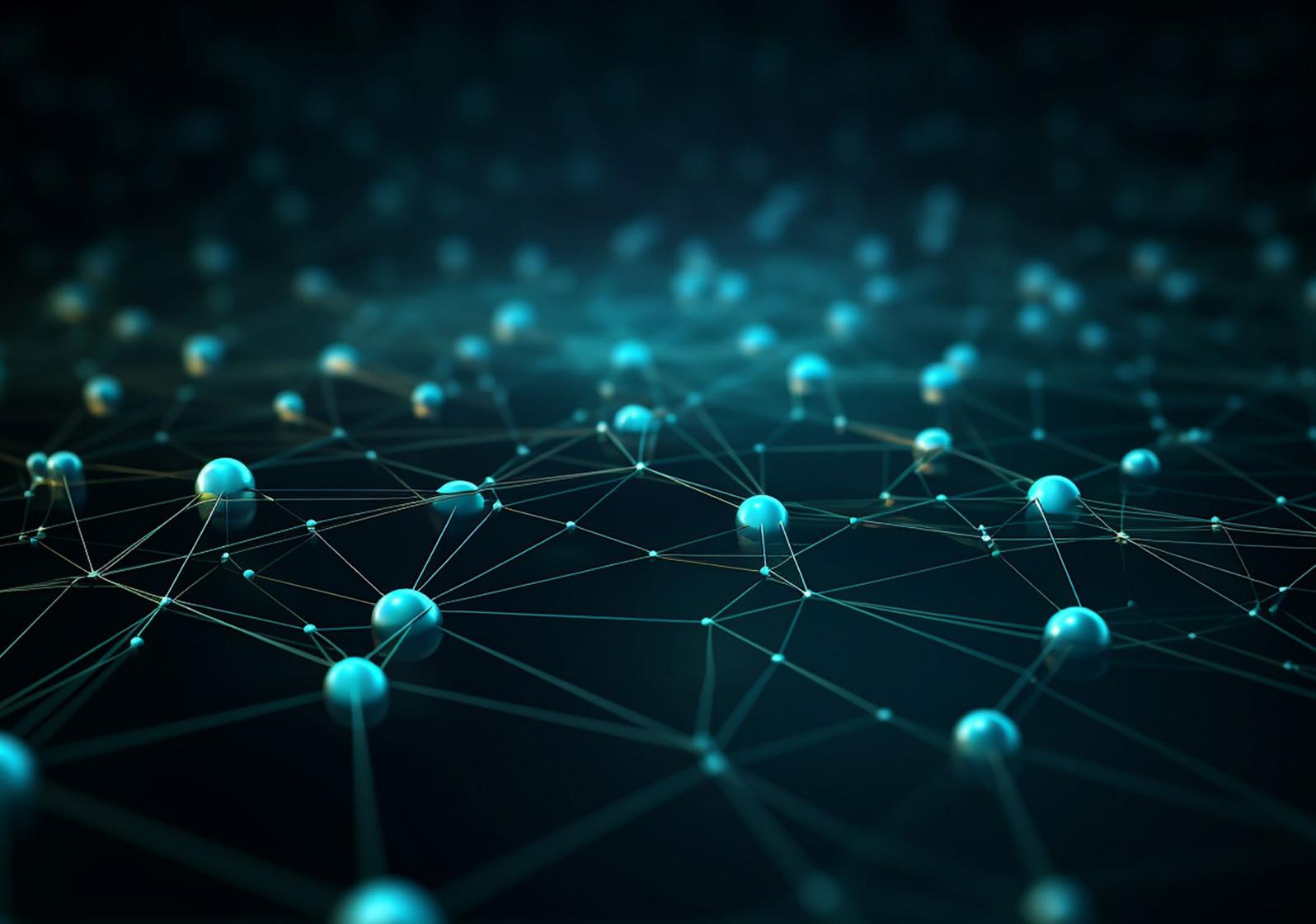
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"If you really want to test what AI is doing, you have to use AI."

- Sameh Yamany, CTO, Viavi Solutions

data. So if you don't govern what the data is that you're using to train your AI, by default, you'll be biased." That bias may not be able to be completely fixed, but it could be monitored with something like a bias meter, which compares bias and model drift over time. "I think we have a good idea how you can measure these kind of biases," he reflects. "I always say if you don't measure, you can't control it. If you don't measure, you can't optimize."

Emphasize end-user experience. So what does all this testing and optimization hopefully result in? The metric which trumps them all: A good end-user experience. Which also happens to be widely subjective, and in many cases, more difficult to pinpoint than one might think. No single data source or tool is perfect when it comes to understanding what the end-user experience is across the totality of device capabilities; why it's good, or degraded; and if it's degraded, what is causing the issue and how it can be fixed. Sometimes the available stats don't match up.

"There's so many times where—at an event, let's just say—our metrics look great," lamented Hristov. "We're maintaining calls. Throughput looks great. Quality of experience looks great. And then I get some executive that complains—they say, oh my God, it was horrible. I was at that basketball game and it was horrible."

So more, better and varied data is needed to understand the end-user experience. "The more metrics we have, the better we can do a job in terms of testing and optimizing our networks," UScellular's Agami said. Network

"The more metrics we have, the better we can do a job in terms of testing and optimizing our networks."

– Greg Agami, Director of Network Solutions, UScellular

probes are still necessary, he added, but UScellular also sees increasing value in crowd-sourced metrics, which are based on end-user experience.

In terms of data sources, Hristov said, "I think that you kind of have to take each one with its weaknesses and strengths." Crowdsourced data is likely to lean Android vs. iOS, he pointed out—a big issue for a company like AT&T, which has an iPhone-heavy device base. Granularity from some tools may be limited to 15-minute cycles and aggregated, as opposed to isolating individual user experiences.

And at some point, even the best data becomes overwhelming in terms of volume, obscuring any insights. Once more, AI is seen as a potential solution. "I do think that's where AI can come in and help a lot in terms of anomaly detection and look at patterns, and understand why it's most likely X or Y," Hristov added.

Final thought: Modern testing strategies and tools must be adaptable, active, automated, and AI-powered—with AI to monitor other AIs at work. The most sought-after metrics are increasingly associated with end-user experience, but operators also prioritize cost-efficiency and resiliency.

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Question marks for tariffs and test equipment

Top *RCR* takeaways

Test companies are seeing millions of dollars in tariff costs and are working to reduce the impacts on their businesses through price increases and shifting of sourcing.

Most test companies have not yet seen demand slip, but they are not ruling out that it might.

Tech-related tariffs and trade restrictions are changing rapidly, and the uncertainty is leading to conservative expectations within the test market.

Amid tariff whiplash from the Trump administration and increased geopolitical and economic tensions, companies in the test equipment and services space are navigating new market uncertainties. During the recent round of first quarter calls, some of analysts' most frequent questions revolved around what impacts test companies were seeing from tariffs, and how they were dealing with them.

A few common themes from the responses of executives: They are increasing their prices due to tariffs and expect to both revenue impacts and increased costs on their supplies. They are shifting sourcing, and using other strategies to mitigate their exposure to tariffs and the associated costs. Several companies also mentioned eating initial tariff costs for orders which had already been placed, before they put price hikes in place.

Most executives said that they haven't seen changes in their customer behavior yet, but are wary and watchful—and in many cases, being conservative about their expectations for financial performance for the rest of the year, since tariff and trade restriction details are changing unpredictably, sometimes from week to week or even day to day.

Robert Mehrabian, longtime CEO and now executive chairman of Teledyne Technologies—which includes test equipment specialist Teledyne LeCroy—outlined two components of tariff impacts on the company's most recent quarterly call with analysts.

The first was supply chain impacts and increases to the cost of supplies. Mehrabian said that could result in $100 million in increased costs annually, although mitigation strategies might be able to get it down to around $18 million in additional costs per quarter. Additional costs won't fully hit its bottom line until later in the year, as it goes through existing inventory.

The second part of the tariffs would be revenue impacts. Eighty percent of what the company makes is either made in the U.S. and sold in the U.S., or made internationally and sold internationally, Mehrabian said. Another 17% of revenues involve selling U.S. products to international customers, and four percent is selling from Teledyne's international locations to the U.S. Less than 2% of its revenues come from China, but that 2% includes high-end oscilloscopes and protocol analyzers.

"Yes, the tariffs are going to affect us," Mehrabian said. But, he added, Teledyne still expects revenues to increase year-over-year, with acquisitions offsetting tariff impacts. He said later in the call: "It's going to cause a little pain, but … we'll make it up somewhere else."

Meanwhile, Viavi Solutions absorbed $3 million in tariffs on previously committed orders and imported U.S. materials during the initial period when tariffs were imposed, President and CEO Oleg Khaykin said. However, eating the tariffs was short-lived. Any orders in process or new orders now get a "universal tariff adder, and it's non-negotiable," Khaykin clarified. "There were some people who tried to play the game and said, 'hey, I'm not going to pay tariffs'. I said, well, it's kind of like if you buy a product on Amazon and you refuse to pay the tax—you don't get the product."

"What we see in the industry is universally, all of our peers, and everybody's passing it on," Khaykin said. "Even the biggest customers are saying it is what it is. It is the new normal. … So far, nobody has canceled. Nobody has reduced the size of the order, and they're accepting the tariff increases," he added. Khaykin also went on to say that service providers, rather than semiconductor companies or data centers, would be more likely to delay orders.

Keysight CFO Neil Dougherty told investors a similar scenario: that Keysight was passing tariff costs along, but not to orders that were already on its books when the tariffs were first imposed.

The most recent quarter had about $7 million in new tariff expenses in cost of sales, according to Dougherty, which reduced the quarter's earnings per share by about four cents per share. That impact is expected to more than double in the next quarter simply due to the timing of when the tariffs were imposed during the second

Image source: 123RF

quarter. Keysight estimates its annual exposure to increased tariff costs at between $75 million to $100 million, with most of the impact coming in the third quarter.

In terms of a possible silver lining, though, Dhanasekaran hinted that Keysight sees an opportunity to work with customers and partners who are looking to changing their manufacturing footprint due to the tariffs. That could mean, for example, that customers might want to upgrade production test equipment along the way.

Teradyne CEO Greg Smith that the company's customers in the mobile, automotive, and industrial segments are the ones most likely to be impacted by tariffs (Teradyne's test equipment portfolio includes semiconductor and board production test solutions; it owns wireless test specialist LitePoint as well.)

Due to the level of uncertainty, Teradyne isn't providing guidance for the second half of this year.

On test equipment specifically, Smith said was asked whether international customers were shifting toward non-U.S. test suppliers. He responded: "We have not seen any competitive impact customers that are deciding to buy from a different vendor because of the tariffs," he added. "It's a very competitive market, so we're in competition all the time. The tariffs has not been a deciding factor in any of those competitions."

Final thought: Test companies are managing tariff impacts through price increases, supply chain adjustments and short-term absorption of costs. Although test demand has not shifted appreciably, companies are cautious about future performance given the unpredictability of tariff and trade restrictions. Despite the challenges, some see opportunities for growth.

Conclusion

Testing is a technical requirement, but it is also more than that. It's a process of discovery, of getting to know and understand networks and services. It helps the industry define and develop new technologies, and eventually, deploy them. Every test poses questions whose answers are unknown until the process unfolds. Is it a pass or a fail? What insights does it reveal about the chip, the device, the radio, the spectrum, the network or the service? Is a service working, and if it isn't—why not? Some questions and answers are more urgent than others, and artificial intelligence is increasingly helping sort through and prioritize information and gather insights, to advance understanding in a telecom landscape which continues to become ever more complicated.

Throughout this report, we've explored how testing is adapting to meet the demands of groundbreaking technologies such as 5G Standalone, Open RAN, NTN and more We've also examined the innovative tools and strategies, including automation, AI and digital twins, which are helping to simplify and enhance the testing process in an increasingly complex environment.

Ultimately, testing is about asking the right questions—questions that challenge our assumptions, push the boundaries of what's possible, and lead to solutions that enable reliable, scalable and profitable networks and services. The questions won't ever all be answered. But each answer that testing provides, helps both to navigate the present and guides actions that build better networks, while also posing new ones that guide the next technology evolution.

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