5G

2021: Market Drivers, Insights And Considerations

A Spirent Report

spirent™

In It, Together

We will remember 2020 as the year of the unexpected. A year of personal and professional growth. And a reminder that no moment or outcome is ever promised.

In many ways, I'll forever be inspired by how admirably our industry rose to the challenge of collaboration in the face of unprecedented physical limitations. Behind every accomplishment and breakthrough were teams that worked nonstop and found a way forward despite the difficulties. As a direct result of these efforts, 5G is better positioned than ever.

Today, there continues to be an industry-wide race to be first, to take market share, and enter new markets. We see a persistent pressure to minimize costs and, with that, an emerging interest in the power of automation to take services to new heights.

Spirent has spent years preparing for this very moment. While our heritage is in the lab, our place today is by our customers' side, supporting their entire product lifecycle as a trusted partner. Easing the burden of relentless testing demands and new network dynamics. Protecting user experiences and assuring service delivery to expand addressable markets. At every turn, we seek to introduce simplicity and help customers plot the best way forward.

"5G's future has never been brighter."

This vision has proved to be in high demand as uncertainty looms in so many aspects of telecom. Every day, we strive to help our customers cut through complexity as they pursue promising new opportunities. It just so happens that this year, the need for these capabilities accelerated even faster than we anticipated. We saw the birth of new trends we expect to be enduring, even in a post-pandemic world. Chief among them, a surge in virtual and managed services that see us take on a broader role with our customers.

We have reached a point along the 5G journey where paths are beginning to diverge. Next-gen networks bring boundless opportunity, especially as new enterprise and vertical industry plays are pursued. While the paths to 5G may differ, we are all on the journey together.

As we grow increasingly comfortable with the unexpected, we believe 5G's future has never been brighter. Spirent is pleased to once again share our latest insights from a privileged view at the forefront of 5G progress, innovation, and success.

We'll see you on the road...

Eric

ERIC UPDYKE
CEO, Executive Director

What's inside.

01

Finding The Way To 5G's Future

Every day, more of 5G's long-term vision is achieved. No matter how fast we move, there remains significant progress to make.

After a year to remember, telecom is keeping its sights focused on 5G's future. By all counts, 2020 proved to be a year of rapid evolution. Not in spite of delays and new challenges, but because of them. In our close, collaborative work with operators, network vendors and device vendors, we continue to uncover trends and market realities fueling 5G's furious pace forward.

Our second annual 5G report summarizes insights from Spirent's global 5G deals, providing an updated, behind-the-scenes view of what's gone right so far, where challenges persist and how what we learned during the year will impact priorities for 2021 and beyond.

We are proud to share our experiences gleaned from more than 600 5G deals and our view of what's in store for what is shaping up to be 5G's biggest year yet.

02

It's Up, Up And Away For 5G

Behind the surge in deals dominating next-gen network activity with Manuel Zepeda, EVP, Global Sales and Services

Manuel Zepeda
EVP, Global Sales and Services

It's Up, Up And Away For 5G

WHAT WE'LL COVER

- A Closer Look At Spirent's 5G Customer Engagements
- Market Segments
- Geography
- Network Domains
- 5G Core

INTRODUCTION

There was no stopping 5G in 2020, COVID notwithstanding. Once the dust settled, we closed the year with more than 600 new 5G engagements under our belt - a 140% increase from the year prior. Despite industry delays imposed by an unexpected move to virtual work environments, and uncertainty introduced globally by heightened regulatory scrutiny, 5G stakeholders largely kept all eyes on the prize.

The industry ended 2020[1] with over 140 5G networks launched, more than 300 devices commercially available, and above all, an ambitious sense of urgency driving progress. 2020 is the year we truly learned what is making the 5G market tick.

Most significantly, networks finally went live with real customers in a meaningful way. This meant experiences to protect, driving demand in our service assurance business. Operators are integrating assurance into networks from the start to ensure they'll be able to deliver on the lofty promises they are making about 5G.

To that end, our work with operators expanded nearly 50% in 2020. After years in the lab with network and device vendors, the rubber was finally ready to meet the next-gen road on deployments. This meant an unprecedented level of pre- and post-launch testing.

Over the past years, Spirent has diligently and deliberately evolved how it works with and serves customers. This saw our managed solutions come to the forefront as we delivered test and assurance functions as a service. That, in turn, allowed our customers to focus on innovation as we helped guide them through what has been no shortage of complexity at every turn in the 5G journey.

5G engagements increased 140%

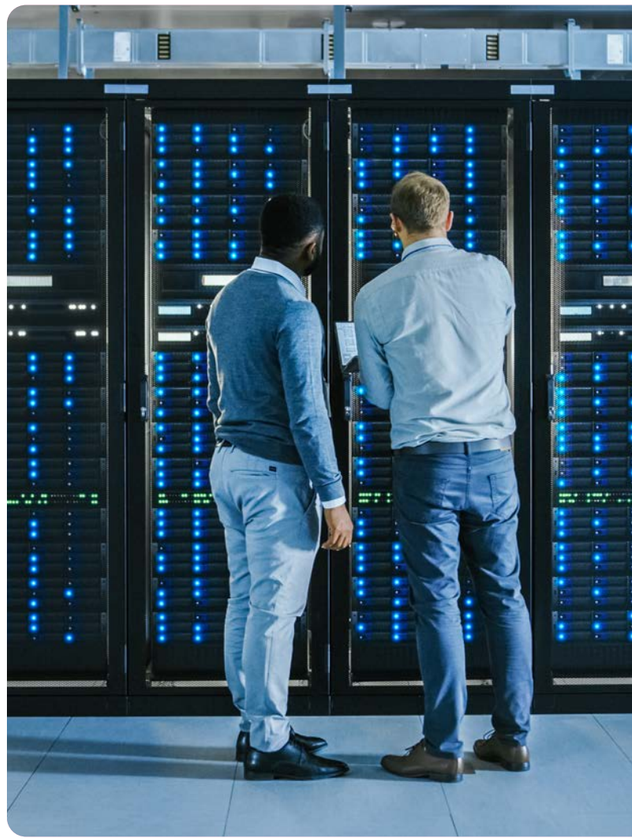
One noteworthy manifestation of Spirent's evolution is the popularity of our Test-as-a-Service capabilities among operators. A combination of challenging virtual work environments and a realization that the sheer complexity, volume and velocity of software coming into networks necessitates outside expertise, resulted in swift adoption of this new approach. With it comes a new way of working that is powered by agility and speed - two ultra-precious commodities in fiercely competitive markets.

Make no mistake. These markets have yet to reveal the killer, revenue-generating 5G app. Faith abounds that it will come. And with so many billions spent so far, finding what works fast and being willing to fail even faster demands operators move at a pace that has not previously been required of them.

1. https://gsacom.com/technology/5g/

As we look at the road ahead, there is a concerted, global focus on getting the 5G core into play to finally begin realizing the expanding enterprise opportunity, differentiate services to pursue this market and control costs along the way. We are proud to support our customers as they transform to meet this new moment.

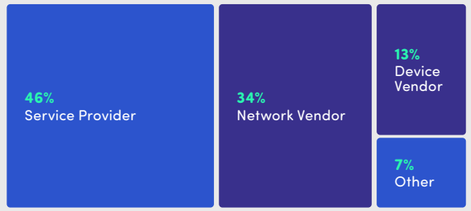
To offer a better picture of what our ongoing work in 5G looks like and highlight some of the key stories coming out of this work, we've developed several insightful snapshots of our 2020 activity and noteworthy takeaways to consider as telecom tirelessly pursues the road ahead.



A Closer Look At Spirent's 5G Customer Engagements

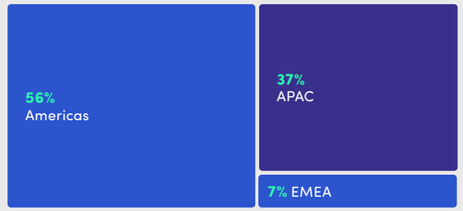
How 2020 shaped our global work.

Market Segments



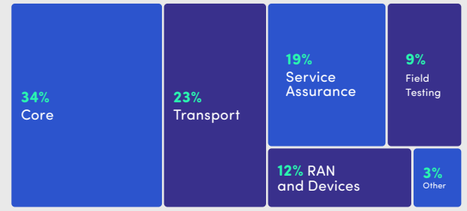
- **Service Provider** engagement increased nearly 50% as service assurance integration ramped up, and leading operators set 5G Standalone (SA) network strategies and new 5G core deployment plans. Together, they accounted for 75% of operator activity.
- Engagements with **Network Vendors** focused heavily on 5G SA, 3GPP Release 16 and transport network capabilities like 400G, slicing, FlexE, and timing and synchronization.
- **Device Vendor** work was primarily around operator acceptance and location accuracy.
- **Other**: Spirent also saw notable growth in engagements with government and military around 5G experimentation, cloud hyperscalers around operator edge partnerships, Open RAN in support of supply chain diversity initiatives, academia as future use cases are explored, and MVPDs as 5G plans accelerate.

Geography



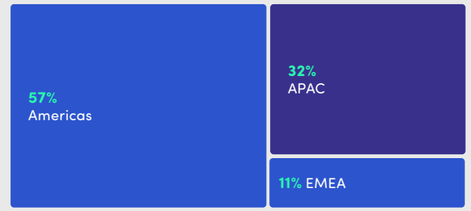
- Engagements in the **Americas** grew most substantially during 2020 as service provider rollouts increased 30% over 2019, driven by a dominant focus on network performance and end user experiences. **APAC** national coverage progress continues to accelerate with almost half of engagements in the region focused on testing of the underpinning transport networks required for cell site deployments and densifications.
- **EMEA** saw arguably the largest COVID-related impacts, with initial setbacks due to delays in spectrum auctions and global supply chain security decisions. There remains a region-wide push toward 5G SA with target use cases focused on private networks and industry.
- Across regions, we see a dedicated push to charm consumers with nationwide 5G coverage and an awareness that it is crucial to live up to the marketing hype when it comes to new experiences.

Network Domains



- **5G core** testing continued unabated as market leaders prepped 5G SA rollouts and new open networking vendors challenged incumbents.
- **Transport** testing remained of high importance as markets positioned for explosive data demands, cell site densification, edge clouds and more stringent timing and synchronization requirements.
- Our work in **assurance** and **field testing** increased considerably in 2020 as more operators launched commercial networks and began focusing more intently on guaranteeing performance, reducing customer-impacting issues and accelerating resolutions.
- As 5G device availability expanded, **device testing** focused on location accuracy while **RAN testing** was geared toward new radio capabilities (M-MIMO), new frequency ranges (mmWave) and Open RAN.

5G Core



- A deeper dive on 5G core work highlights an accelerated focus in APAC and North America to move quickly to the new 5G core and SA.
- Spirent supported a North American operator as it became the first in the world to launch 5G SA nationwide.
- Every major and significant emerging 5G core vendor uses Spirent's core test and emulation solution to support this work.
- The primary focus of 5G core test has been validating functionality, performance, scalability, disaggregation and robustness for commercial deployment, with emerging needs spanning cloud edge, enhanced security and network slicing.
- A common 5G core challenge facing operators is deploying on containers. Many vendors that began the journey with virtual network functions are still evolving toward a hybrid environment to support containerized network functions.

03

Top 10 Trends Shaping 5G's Future

Spirent's Head of 5G Strategy, Stephen Douglas, breaks down the most critical developments guiding testing work.

Stephen Douglas
Spirent, Head of 5G Strategy

Top 10 Trends Shaping 5G's Future

INTRODUCTION

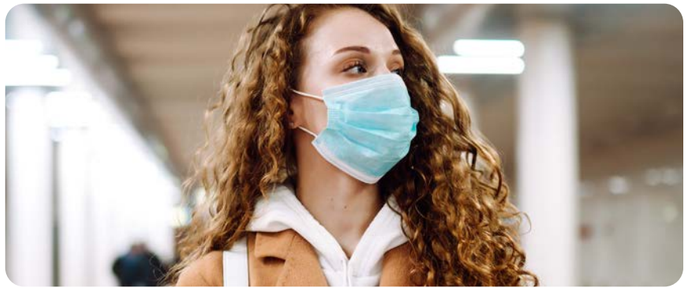
By the time the pandemic ground the world to a halt, 5G had too much momentum behind it to be stopped. Too much investment and innovation. Too much at stake. Indeed, there was a path forward and the telecom industry found it. Of course, not without quite a bit of ingenuity, compromise and a willingness to get things done.

WHAT WE'LL COVER

Truth is, much of the development work done up until the start of 2020 was almost tailor-made for the very circumstances we all found ourselves grappling with during the year. Especially as it relates to the flexibility unleashed by the cloud, and virtual infrastructures and processes.

In many ways, the pandemic accelerated trends we hadn't anticipated gaining steam for at least another couple of years – whether fixed wireless access driven by working from home or automation required to safely conduct field testing with limited personnel.

Sure, there were delays, especially around some exciting proofs of concept that have been put on hold until next year. But by and large, 5G powered ahead and remained in control of its destiny. As Spirent continues to look at the road ahead for next-gen networks, these are the ten key considerations guiding our thinking and planning.



1 The Coming Wave Of Construction

Build it and they will come! The extensive transport network and field testing work we've been conducting tells us that operators will spend this year and those ahead aggressively expanding coverage footprints. 2020 showed us glimpses of what 5G could be. 2021 will start to reveal the much bigger picture. In some APAC countries, this work has already begun with hundreds of thousands of 5G base stations deployed, greatly exceeding initial targets. 2021 will see more of the world aggressively catch up in pursuit of national 5G coverage. This work will continue for many years as tens of millions of base stations are commissioned globally.

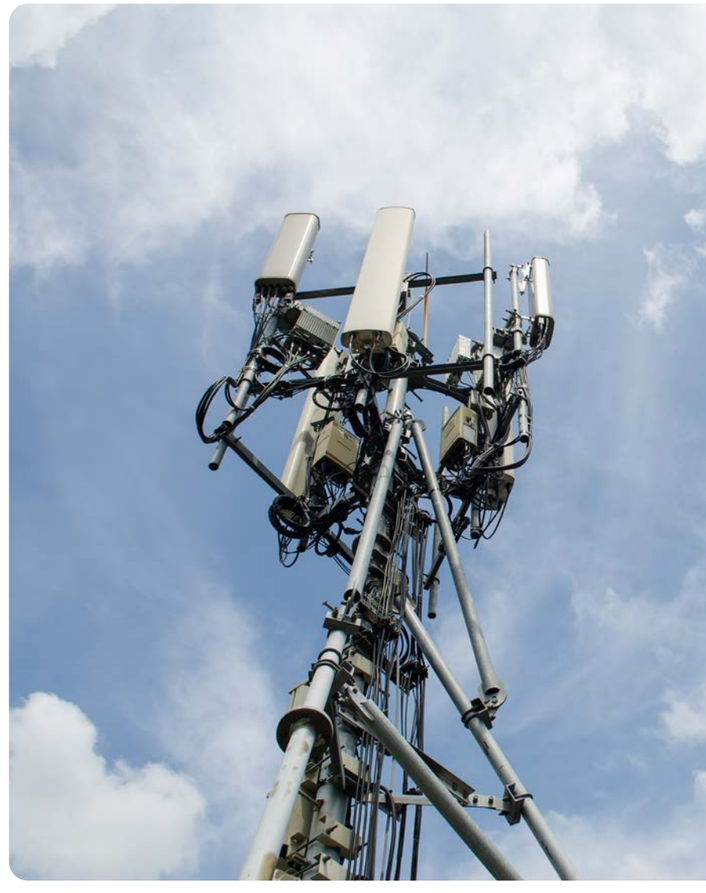
By Q4 2020, China had built nearly 700,000 5G sites (GSMA Intelligence).

2 5G Standalone Accelerating, But With Training Wheels

The volume and type of 5G core testing Spirent conducted during 2020 indicates a continued acceleration toward Standalone (SA) 5G in North America and China, as we identified in our last report. These networks will launch alongside Non-Standalone (NSA) networks, but expect limited access until operators grow more comfortable managing and supporting the new core.

Europe will see its first SA networks in 2021, though they will be primarily limited to campus, private network and enterprise deployments. Globally, the cautious start for SA is not unlike the migration to a virtual EPC we witnessed as 4G matured. However, operators are already moving some traffic onto SA just eighteen months since 3GPP R15 standards were published.

As of December 2020, more than 60 CSPs had invested in 5G Standalone (GSA).



3 Spectrum In High Demand, And Non-Traditional Stakeholders Want A Piece

We won't have a true picture of how the 5G market will shake out until the dust settles on the flurry of spectrum auctions taking place globally. Low-band, mid-band, high-band, c-band – you name it, it's all in high demand. The volume of testing we're seeing across multiple frequency ranges and validation of new RAN capabilities like Dynamic Spectrum Sharing in a range of geographies suggests high interest in spectrum auctions and availability to support geographic coverage.

Notably, private industry is eager to carve out a piece of its own 5G spectrum, with national regulators beginning to dedicate spectrum exclusively for this purpose. 4G LTE will remain mainstream for private networks in 2021, but enhanced trials of 5G and early adoption by leading innovators is anticipated, with mmWave tech in APAC likely to see commercial deployments in late 2021. This provides a glimpse of 5G's expanded potential as enterprise adoption drives new revenue opportunities.

Germany has awarded nearly 100 licenses for private 5G networks (BNetzA – German Telecom Regulator).

4 O-RAN Just The TIP Of The Open Networking Iceberg

Open RAN shows potential to become telecom's low-cost, vendor-neutral future. It can serve as an efficient architecture for 2G and 4G deployments. The foundation of novel Network-as-a-Service plays. A safe approach for private networks. All use cases are on the table as more and more muscle is put behind this effort with the goal of rapidly proving Open RAN's robustness. This initiative will grow unabated as testing focuses on interoperability, performance, robustness and operational costs. But first, expect to see a focus on legacy network densification for rural coverage with 5G Open RAN deployments still years off.

The market for Open RAN solutions will grow to more than $11B by 2026 (Appledore Research).

5 Automation Advancing Agility

Operators got an unexpected taste of automation's power during 2020 and they're hooked. With the pandemic throwing up one roadblock after another, it was automation that came to the rescue. Field testing with scaled back, socially distanced crews? Complex lab environments for testing and service turn-ups? The deluge of software from multiple 5G new core and SA vendors creating process challenges, overhead and performance risks? 2020 demonstrated there was no task that automation couldn't handle effectively and efficiently – from the lab to the field.

This begs the question: once operators have seen for themselves that automation works and alleviates a range of headaches, why would they ever go back? During 2021, we anticipate tier-one operators will focus on vendor-neutral, continuous testing environments that provide an automated CI/CD pipeline process to manage multi-vendor ecosystems and continuous releases. Expect this to eventually become the norm for agile management of developing initiatives, like Open RAN.

6 No End In Sight For Edge Exploration

If there's one thing everyone can agree on, it's that the combination of lower latency, reduced backhaul and security promised by edge computing are worth the pursuit. How to get there? That's another matter entirely as experimentation and a search for killer use cases continues. The cloud hyperscalers want in on this potentially game-changing tech that could position mobile operators to deliver incredible next-gen app experiences. Cloud companies can bring developers into the fold and seamlessly hand off sessions to the telco edge, while mobile and cable operators have access to subscribers, location, billing profiles and more. A joint effort makes sense, helping ease the associated complexity and cost burdens for both players.

Ultimately, operators will need thousands upon thousands of edge locations across national footprints over the next three years. A hybrid model that combines a range of technical and business approaches will be required for operators to get edge off the ground. With this in mind, figuring out how to test and assure hybrid infrastructures consisting of self-build, hyperscaler-hosted and neutral host environments from new entrants will be a priority.

7 Fixed Wireless Access Will Let Us Work From Anywhere

At the start of 2020, Fixed Wireless Access (FWA) took a back seat as most of the industry focused its attention on smartphones. It only took a pandemic resulting in an overnight societal shift toward what will be enduring work-from-home lifestyles to shake things up. As more businesses adopt permanent WFH policies over the next decade, 5G FWA will see a surge in demand on the back of robust, ubiquitous and secure 5G coverage.

Look for FWA to ultimately power unprecedented remote work environments that demand automation, augmented reality and telepresence. To that end, in the latter half of 2020, we saw a renewed focus by chipset and device manufacturers on CPE devices for whole-home broadband. In 2021, expect FWA business case exploration, meaningful test work and growth milestones in North America and Western Europe. And don't underestimate the significance of Wi-Fi 6 (and Wi-Fi 6E), which also stands to play a major role in in-home connectivity.

8 Defense Departments Cozy Up To Commercial Tech

4G LTE wasn't quite robust enough for a serious look from defense departments with mission critical demands. Not so with 5G, where investment is pouring in as governments scrutinize capabilities in support of future defense modernization. Because 5G could be as flexible and evolutionary as the challenge of emerging threats themselves, it has the potential to power rapid responses in a range of situations and environments, transforming the way the military operates and enabling a new generation of the knowledge economy.

The U.S. Department of Defense has been one of the most advanced in its investments, committing hundreds of millions of dollars toward 5G experimentation across AR/VR for mission planning and training, smart warehousing, distributed command and control, and dynamic spectrum utilization. This work will expand throughout 2021 and we expect to see more defense departments globally increase investments to evaluate and test solutions that can help accelerate defense capabilities, simplify partner engagement, reduce costs and secure tactical communications.

US DoD has announced $600 million in awards for 5G experimentation (US DoD).

9 Driving In 5G's Fastlane

More auto manufacturers are planning the future integration of 5G chipsets into vehicles. This speaks to anticipation of national coverage over the next three to four years and confidence that connectivity will be robust enough to support emergency and maintenance features. China, especially, is seeing acceleration toward 5G connected vehicles for a range of use cases, with preparation for commercial availability by major car manufacturers as soon as early 2022.

5G digital twins are playing a starring role in some global automotive testing efforts, replicating complex 5G networks in lifelike lab environments. These efforts are helping to expedite millions of hours of testing that would otherwise require stakeholders to jump through a series of network and transportation authority hoops in the real world.

By 2022, General Motors plans to launch vehicles capable of 5G connectivity for Chinese consumers (GM).

10 5G Only Getting Better

When you're in the thick of it, daydreaming about the future is inevitable. Such is the case for a vocal cohort already looking to 6G to solve some of 5G's initial shortcomings. 2020 certainly saw some grumbling related to 5G's inability to deliver in certain key areas. But it's far too early to count 5G out – not with so many features and capabilities set to be added over the next decade as up to four more 3GPP industry standards releases introduce even more functionality.

Putting too much stock in 6G now, while it remains about a decade away, risks 5G becoming politicized. Plus, 5G is directionally well understood today while 6G could eventually take an entirely different direction by the time we actually get there. Focusing on 5G's ability to deliver capacity and coverage while accelerating innovation is Spirent's near-term focus in its work with customers. 6G will come and Spirent will be there to lead and support, but 5G has a lot of promises still to be delivered.

04

Device And Radio Testing

An update from James Kimery, Vice President, Product Management, Connected Devices

James Kimery
VP, Product Management, Connected Devices

Device And Radio Testing

WHAT WE'LL COVER

- The Latest Insights From Our Connected Devices Work
- 2021 Perspectives
- Dispatches From The Field

INTRODUCTION

Perhaps the biggest takeaway from 2020 is that there is almost no limit to what can be accomplished remotely if you're clever, methodical and determined.

In our Connected Devices group, we primarily serve chipset and device vendors through the development lifecycle. For operators, we help ensure devices meet user expectations in terms of functionality and performance. This past year certainly saw its share of delays and derailed some next-gen lab testing initiatives in the wake of the pandemic. But by and large, our team will remember 2020 as a year of resourcefulness. A year that we hunkered down with our customers against the odds to pursue a shared goal of keeping major 5G initiatives on track. Most importantly, we will remember it as a year that we overcame the odds to push the limits of testing.

Our customers know that even in the face of uncertainty, they cannot sit still. Overwhelmingly, they have been open to new approaches, new technologies and more support than ever before. This has been a key driver of Spirent's significantly expanded field testing business this year. We had already made considerable investments in our 5G network digital twin capabilities which provide an emulated replica of the 5G network for advanced prototyping and to accelerate innovation. This market is now accelerating and we believe this trend is here to stay.

From a user experience perspective, we're still not convinced consumers understand whether or not they're accessing 5G. Mixed marketing messages are part of this equation. 5G network claims run the gamut and with some 5G networks not yet able to surpass 4G speeds, confusion abounds. Pair this reality with extended device upgrade cycles driven by tighter budgets and slowing innovation, and it's clear operators must look beyond the consumer market to drive 5G revenue.

In our view, the enterprise market for 5G is still early in its development. Some of the research and experimentation on this front was hampered by COVID-19 this year. Globally, early testing of private networks is starting to take off so we do anticipate a market with considerable opportunity once it hits its stride.

Above all, 5G network development is dynamic. We expect to see a strong beating pulse that continues over time versus ramp-up, adoption and ramp-down phases that were the norm for previous generations. We are still early in the first major pulse of what promises to be a long and strong beating heart of 5G moments. If the opportunity ahead is as promising as what the market has delivered so far, there will be no shortage of milestones to celebrate in the future.

Whatever the near-term brings, we are optimistic that, globally, the telecom industry has shown unprecedented willingness to explore new paths to common goals and experiment more than ever before. This will have a lasting impact on all of the breakthrough work that is still to come.

The Latest Insights From Our Connected Devices Work

Teaching 5G Testing New Tricks

As we covered in last year's report, connected device testing is as much about testing radios as the devices themselves. Spirent spent 2020 helping its customers work through difficult 5G network technology challenges against a COVID-19 backdrop that limited lab interactions and put countless hurdles in the way of field tests. Adapting on the fly was the name of the game for every operator eager to keep pace with global advancement.

We saw radio testing processes evolve rapidly on the heels of three key trends:

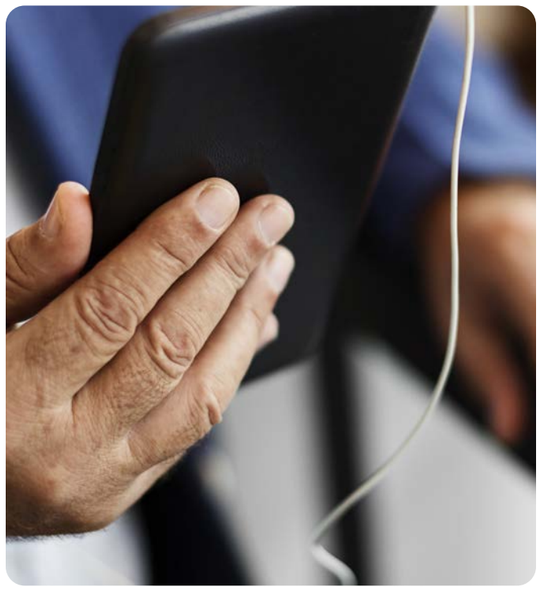
- **Testing, at your service.** More than any other year, our operator customers were eager to turn over testing duties they traditionally handled in-house. The catalyst was one-part COVID-19 limitations that kept workforces at home and one-part 5G complexity that has muddied traditional workflows. In 2020, Test-as-a-Service took off in a real way and we expect it to be a major driver of testing revenue in the years to come.
- **Automation for the win.** Sending crews of field testers to travel the country together was a tried and true approach made suddenly obsolete as safety and efficiency took precedence and gave way to new methodologies and processes. The star of this

advancement was automation that enabled remote capabilities and drove down testing costs, ultimately resulting in field testing that has become less labor dependent and can be conducted more quickly.

- **Getting the full picture on video benchmarking.** Spirent's early and advanced work in 5G has resulted in the company being sought out for expansive benchmarking projects. In particular, as video remains the bandwidth hogger of choice for mobile subscribers, more of our customers have demonstrated interest in measuring how video performance on their networks stacks up against the competition.

Device Narratives Focus On 5G

For the first time in the smart device evolution journey, the network has become the star of new devices. As features and specs of the latest crop of smartphones struggle to differentiate and entice upgraders, device vendors are shifting the spotlight to the 5G networks that support them. In last year's report, we signaled that the 5G experience wasn't yet living up to the hype for consumers. Devices overheated, signals dropped, built-in antennas weren't supporting all 5G flavors.



One year on and device vendors have begun to address these issues in a meaningful way. Yet, while 5G networks are more available, the blazing fast speeds that have been promised have yet to materialize. Still, the current crop of devices hitting shelves, purses and pockets are well-positioned to eventually deliver for businesses and consumers alike as networks rapidly improve.

2021 Perspectives

While 2020 was slogged by pandemic-induced delays, the acceleration of network deployment trends have positioned the industry at large for meaningful progress in 2021.

Spirent is tracking several key developments on this front:

- **Standalone 5G networks ready to take hold**. We are actively conducting comprehensive testing on the 5G Standalone networks that began rolling out in the past year. Iterations are happening on the fly as a hyper-optimized feedback loop quickly identifies bugs so that patches can be rapidly developed and deployed. We noted in last year's report that 5G SA holds the key to truly unlocking some of 5G's greatest potential. 2021 will be the year we finally see the fruits of these diligent efforts.
- **Disaggregation will trigger more proactive testing.** Open RAN initiatives continue to gain steam among vendors and operators alike. Sizable bets are being placed and newsworthy commitments made, with multi-vendor environments poised to occupy an outsized role in 5G footprints of the future. The dizzying array of network configurations will require intense, rapid, end-to-end and nodal testing both before launch and proactively in the live network. Testing processes will need to continue to scale, which will ultimately drive further uptake of Test-as-a-Service solutions.
- **Government 5G initiatives accelerate.** We had multiple government-related proofs of concept initiatives during 2020 as defense departments started to experiment with 5G, security agencies looked to better understand risks and commerce departments looked to accelerate national innovation. All signs point to government initiatives accelerating this year. For example, the U.S. Defense Department's investment in 5G will continue to ramp up,[2] building on five existing installations with seven additional testbeds exploring opportunities for military applications.
- **mmWave interest growing globally.** Initially confined to some North American deployments, mmWave opportunities appear set to expand as the technology takes on a larger role in China. But contrary to what we see in the U.S., deployments in China aren't being driven by consumer applications. Rather, vertical and enterprise applications appear poised to benefit. mmWave's mobility challenges aren't going away but operators are beginning to zero in on how to best exploit the tech. This development could have ripples in other regions where mmWave has yet to see traction but where similar promising use cases may exist. Spirent's focus will be on continued optimization of antenna designs and receiver algorithms for further performance improvements.

2. https://www.defense.gov/Explore/News/Article/Article/2207390/dod-announces-new-locations-for-additional-5g-testing-experimentation/

Dispatches From The Field

Fine-Tuning One Of 5G's Biggest Moments Yet

With the world watching, a top smartphone maker was getting set to launch a high-profile lineup of 5G devices. But not before validating complex multiband RF performance to support the market's broadest range of 5G bands across Frequency Range 1 (sub 8GHz) and Range 2 (mmWave). Spirent's device test solutions were put to work to test 5G RF applications spanning M-MIMO and beamforming for multiple frequency ranges. By accurately emulating the complex effects of wireless transmissions, the smartphone leader was able to safely launch the world's most advanced 5G handset to date.

Plotting Security Strategies In A 5G Sandbox

A European governmental national security organization needed 5G testing flexibility to conduct security research and set a strategy for protecting future national communications networks. The plan? Safely conduct wargames in a digital sandbox. Spirent's digital twin solution is providing a replica of the 5G network for extensive testing towards mitigation of future risks. This is just the tip of the iceberg, with researchers working to understand the broader risk landscape as 5G becomes an enabling technology for many critical national industries.

05

Test, Assurance And Automation

An update from Doug Roberts, GM, Lifecycle Service Assurance

Doug Roberts
GM, Lifecycle Service Assurance

Test, Assurance And Automation

WHAT WE'LL COVER

- The Latest Insights From Our Assurance And Automation Work
- 2021 Perspectives
- Dispatches From The Field

INTRODUCTION

In a year when uncertainty ruled supreme, we found more customers than ever were looking for a sure thing. As 5G networks finally went live with meaningful deployments, operators rushed to make sure they could guarantee performance for subscribers. This drove a significant increase in our assurance business, with 80% of it focused on 5G work.

Whether it was a core network buildout, lab certification, or new service delivered, 5G plus automated assurance were the dynamic duo that customers turned to as they sought to continue pushing forward.

Remember, prep and deployment of 5G Standalone (SA) rollouts has accelerated following Non-Standalone's (NSA's) inability to really wow consumers and deliver a solid new revenue proposition. But this means our customers are finding themselves struggling with the complexities and relative lack of maturity of the 5G SA ecosystem. This is not surprising since the 5G core is cloud-native right from the start and introduces a radically different stack. And, by the way, operators haven't even gotten cloud-native core networks working for 4G yet.

Now, add in network slicing, Open RAN and a disaggregated core network, plus a big push by hyperscalers toward hybrid cloud deployments for edge applications. All told, there remain considerable operational challenges to sort before 5G can be deployed – and enjoyed – at scale. We expect this to be an active focus for at least the next 12-18 months with our priority being to help customers successfully come out the other side of this important and consequential initiative.

Operators are asking for help navigating the complexity from lab testing to successful deployment and operationalization, and leaning more than ever on our expanding resources and experience. Not just our products, but most importantly, our people and our expertise in automation. These services-based engagements and the use of our automation environments are redefining the way we work.

It became clear during the year how vital our role will be in helping our customers successfully deploy 5G. Not just get it into the market quickly, but safely. Operators and vendors alike are having a wake-up call: 5G is moving faster with a higher volume of moving pieces than expected, posing a major challenge to profitable, timely rollouts of a proven portfolio of services at scale. Automated assurance is a hedge against the inherent risks of moving fast along a path that has yet to fully reveal itself.

The Latest Insights From Our Test, Assurance And Automation Work

Keeping 5G Testing And Performance On Track, From Afar

As we discussed in last year's report, the unpredictability introduced by 5G's many dynamic components has dictated that automation and assurance be built into the network from the start.

These tools are now the foundation of a proactive and healthy service lifecycle, not just a way to react to problems.

The journey to 5G continues to live up to its name with a myriad of challenges emerging along the way. While these next-gen networks have yet to enchant mass audiences or sufficiently impress early adopters, we are seeing more examples where promises are finally beginning to be realized. It's assurance's job to protect the emerging experiences that will be accessed by increasingly discerning users, including within the enterprise, where 5G providers are placing sizable bets.

As telecom considers its near-term assurance rollouts, we identified several key trends during 2020 that we believe should guide future strategies:

- **Low latency is 5G's future, eventually.** Early 5G deployments have yet to demonstrate significantly lower latency than LTE across broad footprints. This isn't surprising given edge and SA core deployments and general network optimization are still in early stages. However, we see a widespread desire to quantify end-to-end latency from the gNB to the core, broken down by each "hop" from cell site routers to backhaul and aggregation, and ultimately, core networks. We uncovered transient network connectivity issues at the cloud fabric layer up to 40% of the time in one network, significantly impacting latency. We believe these to be expected growing pains for early-stage networks that will require focus, effort and the right solutions if low latency performance is to become a significant differentiator for 5G this year.

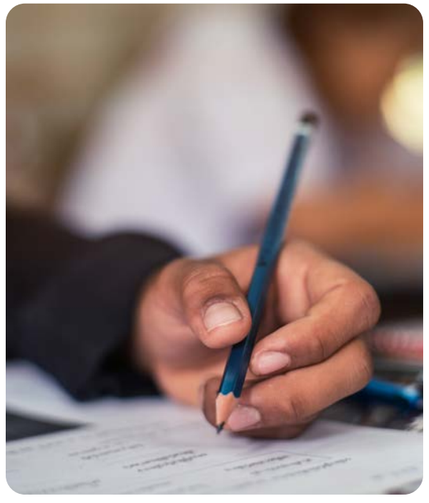
- **Fast, asynchronous vendor releases drive automation.** Operators recognize automated validation of the 5G core is ultimately a must-have. 5G core networks consist of multiple layers spanning cloud infrastructure, mesh networks, container managers, cloud-native 5G network functions, and applications and services. There are multiple vendors conducting rapid releases at each layer on varying timetables. As operators awaken to this challenge, we expect a rapid pivot to fully-automated validation. As each new component is released, a full suite of realistic validation tests will be performed, problems isolated and dev systems updated. Collaborative development systems shared by providers and all vendors alike will become a standard. Many providers don't have the time, skills or budget to take a DIY approach in this area, creating increased interest in managed services offerings for a smooth evolution to CI/CD environments.
- **Active assurance is now table stakes.** It has become clear to us that passive monitoring cannot hold up in a 5G world that may see core network infrastructure exist simultaneously in three physical locations and sliced multiple different ways for various service delivery models. Rather, proactive, automated, active testing generating synthetic traffic and utilizing software agents that are as dynamic as the 5G networks they support, will eventually be the heartbeat of the live 5G network.
- **Protect edge experiences to win market share early.** As we predicted in last year's report, 2020 saw growth in cloud edge assurance by incumbents as well as new entrants like cloud hyperscalers eager to partner with operators. We expect to see wider-scale edge deployments begin in earnest during 2021, but telecom will not have this market to itself. Moving swiftly now to establish a meaningful footprint, supported by protected experiences should be an imperative for industry stakeholders.

2021 Perspectives

If 2019's focus was on proving the feasibility of new 5G assurance tools and 2020 was about rushing them into real deployments, 2021 will be spent ramping for scale. This will also require a substantial investment in service assurance for troubleshooting and performance monitoring.

As we look to the year ahead, key developments we are tracking on this front include:

- **Migrating 5G Standalone from the lab to the live network.** We anticipate significant 2021 assurance activity driven by the move of 5G SA from the lab to the field. It will require a wealth of basic testing and monitoring, including for the cloud-based core, latency testing for every hop in the network, basic endpoint connectivity validation, as well as speed tests. Performance testing will follow to assess the ability to scale.
- **Cloud edge solutions will become real.** After several years of dreaming about game-changing edge-based apps, activity at the cloud edge is set to intensify with key players beginning to commit to strategies and defining first-gen experiences. Early testing has shown us proximity of edge locations alone won't be enough to guarantee performance. Assurance will play an integral role in determining the impact of cloud edge on application performance and the user experience.
- **Active assurance will start to pay off.** If our extensive 5G field testing revealed anything this year, it's that many early networks weren't delivering experiences fit to assure. As a laundry list of trouble issues are rapidly addressed, we will begin seeing the real payoff of active, automated service assurance that adapts to dynamic network configurations, the implementation of new network elements, such as 5G NR, and the first virtualized services.
- **Partnering to meet business goals.** With our Test-as-a-Service offering, we are partnering with tier-one operators to deliver outcomes that meet larger service delivery business goals across the entire lifecycle. This end-to-end consultative approach is poised to result in faster deployments that free operators to focus on other critical elements of service design and delivery. We are seeing a considerable uptick in interest in this model from other customers in the market, even ahead of what we had initially anticipated.



Dispatches From The Field

Putting A 5G Deployment On The Path To Success

A major North American mobile operator was getting ready to launch network-wide 5G and needed to ensure rollouts were ready for consumer uptake. Being able to seamlessly upgrade to new 5G releases and provide service differentiation in a crowded marketplace was a critical need. Spirent's automated assurance solution supported pre-launch validation across new 5G cell paths, continuous post-launch performance monitoring, rapid fault isolation and ongoing troubleshooting. Today, the solution proactively assures live network performance and user experiences, helping to set the bar for 5G delivery.

Transforming The Lab As 5G Sets A New Pace

A global top-five operator faced challenges collaborating efficiently with multiple network vendors in its quest to rapidly deploy the new cloud-native 5G core and ongoing releases in the face of unprecedented pace and complexity. Despite considerable experience and capabilities, the operator simply lacked the time, resources and tools to move as fast as it needed to hit ambitious goals. Spirent's Test-as-a-Service offering powered the operator's collaboration with vendors via an automated and continuous test environment. The result is multi-vendor 5G core features being released three times faster than on 4G – all without significant upfront operator investments in test infrastructure. This signals the dawn of a pervasive testing trend.

06

Cloud And Transport Testing

An update from Abhitesh Kastuar, GM, Cloud and IP

Abhitesh Kastuar
GM, Cloud and IP

Cloud And Transport Testing

WHAT WE'LL COVER

- The Latest Insights From Our Cloud And Transport Testing Work
- 2021 Perspectives
- Dispatches From The Field

INTRODUCTION

I haven't spoken with one other business leader who didn't have to contend with a fair share of 2020 curveballs. In the Cloud and IP group, we certainly had some obstacles to overcome to keep network testing on track for our customers. When you suddenly can't get into the lab to test, what do you do? Innovate with your customers and find a better way.

In the end, 2020 saw us accelerate our strategy to automate labs and integrate remote functionality that made it easier to do work from anywhere. There is still more progress to make, but physical limitations in lab testing are quickly becoming a thing of the past.

We are focused on making lab test capabilities more portable with smaller hardware form factors and more software, effectively minimizing lab and testbed footprints. We are also making our test capabilities more accessible by introducing an entirely new SaaS platform. With a simple login, our customers can benefit from zero-touch installs, remotely test and troubleshoot virtual machines, cloud tools and more with ease, and they will also be able to purchase capabilities online. All this without needing a demo or truck roll, or being in the lab to troubleshoot. In short, we are building the foundation to enable software to be migrated to the live network.

Transport testing remained of high importance around the world. This was driven largely by 5G networks rolling out at a much more aggressive pace than 2019 and markets preparing for new data demands, cell site densification, edge clouds and more stringent timing and synchronization requirements.

In 2020, most operators were still testing the Non-Standalone (NSA) architecture and deciding how to best deploy and test Standalone (SA) networks. Most of the core network will be virtualized with SA and become more containerized. This means new releases will be rolling out at least every four to six weeks and sometimes sooner – a rapid cycle we've never seen before in the network. We know the ramifications of such a dynamic network are significant and require equally dynamic test procedures that continuously validate the changing live network.

We have moved rapidly to retool many of our core lab technologies to meet these emerging needs and the opportunities that arise with them. In an industry first, our cloud test agents bring realism to lab validation by creating synthetic traffic that emulates real-world loads. Using agent-based analytics in live networks, operators can automatically verify end user service quality and isolate problems to a specific network layer or segment – all critical elements of 5G operational success. These capabilities have also found a home in the production networks of large enterprises.

In many respects, 2020 felt a lot like trying to change the tires on a car while going 100 mph. Yet COVID proved a positive stimulus for us to double down on ambitious progress we'd already made in remote and automated technology, and accelerate further along the 5G journey. We are better positioned for the months ahead as a result.

The Latest Insights From Our Cloud And Transport Testing Work

Transport Testing Goes The Distance

In last year's report, we noted 5G discussions often focus on what's happening over the air, but it's the transport networks that will ultimately bear the heaviest burden of new 5G services. Of course, those services won't work as expected if the underlying transport network can't provide the required connectivity and performance. Transport infrastructure testing activity held steady during 2020 as it continued to evolve with open and virtual infrastructures, as well as new interfaces and protocols such as eCPRI.

Throughout the year we tracked these key industry trends and imperatives:

- **Reducing latency for network slices**. The industry placed a major focus on testing transport networks to support network slices through capabilities such as FlexE, Slicing Packet Network (SPN) and Segment Routing (SR) that provide differentiated levels of service quality. This is an important initiative as the latency generated by the transport network will have a major impact on quality of service.
- **Interoperability of distributed fronthaul**. 5G is bringing major changes to fronthaul transport networks, such as new air interfaces, virtualized and distributed cloud RAN, and the use of shared Ethernet and fiber transport. The industry is performing critical testing of these

new elements and validating interoperability. In addition, Open RAN is now being strongly considered. This fledgling technology that introduces the most dynamic network vendor ecosystem telecom has seen to date will need to be tested.

- **Transport enables the edge**. High hopes are being placed on edge clouds to enable new types of services that capitalize on speed and low latency. Cloud got a lot of the attention this year for some breakthrough deals around the world, but it's still transport networks that will need to do much of the heavy lifting to move data around rapidly and support ubiquitous experiences.

- **400G waiting in the wings for some**. As expected, Japan, China and parts of Korea are ahead of the curve, investing in 400G uplinks to the core in anticipation of future needs. China is taking 400G all the way to the edge. North America remains slightly behind with a 100G focus and is in a wait-and-see mode until 400G applications are identified. Europe is also lagging in the battle of the Gs.

However, we do expect a gradual evolution toward 400G for each of these regions in the near future as 5G coverage and data consumption increases. As for 800G, trials are still in early stages at just a few chipset manufacturers and leading edge network vendors.

2021 Perspectives

What is the biggest imperative for 2021? Making 5G real for more consumers, as well as the enterprise. The industry is currently grappling with the nitty gritty details of getting the infrastructure to work, which means certifying and deploying equipment and software at scale and at speed. Operators won't be able to monetize investments with value-added applications unless the infrastructure works.

With that in mind, Spirent is anticipating the following key developments throughout the year:

- **Testing amid rapid obsolescence**. As we move toward a more containerized world, new solution set releases are being introduced every month and going out-of-support every two to three months. It is no longer a question of testing releases in the lab for a year or more. Testing will need to move to near real time. We will need to continuously test and certify every change, which is an unprecedented development. In 2021 we will see more automated lab-to-live testing, which takes lab testing capabilities into live run-time environments, to support this paradigm shift. Many operators are eager for Spirent to provide this capability as a service.
- **Pre-integrating agents into hardware**. Beyond the traditional network vendors, cloud assurance agents are starting to be pre-integrated into OEM equipment. By using SaaS to unlock the agents, it will be much faster and easier to continuously certify and troubleshoot all layers of the live network. This also opens a window to using the same approach with large enterprise production networks that face similar CI/CD change management challenges.
- **Transport timing and synchronization challenges**. One of the biggest challenges for 5G networks with disparate access mechanisms is network timing for mmWave. Another question is how 5G network slicing will work. In China, the focus has been on both Flex Ethernet (FlexE) and SRv6, whereas there is active debate In the U.S. on FlexE versus SRv6. Whichever way it goes, network transport will be greatly enhanced.
- **Building out the network**. As the SA network gets deployed and early 5G private networks are stood up, there will be new challenges in connecting and deploying the edge and core. This includes certifying all layers, assuring edge latency, and making sure that accurate and deterministic network timing and synchronization work throughout. For Private Networks and operator B2B engagements, the integration of Time Sensitive Networking (TSN) will be critical for 5G networks to deliver reliable, low-latency connectivity across time-critical Industrial IoT applications.

Dispatches From The Field

Serving Up A Slice Of Differentiated 5G

An APAC fiber provider was ready to help fortify 5G's slicing future. First order of business was making sure Slicing Packet Network tech was ready for prime time. This was a principal step toward prepping 5G's integrated service transport network and future differentiated services that relied on network slicing. Spirent's transport test solutions were used to validate the functional, performance and specification aspects of the 5G transport slice packet network. This work laid the groundwork for enabling commercial availability and ensuring the diverse bandwidth, latency, security and time synchronization demanded by emerging 5G applications.

Testing 400GE At World Record Capacity

5G and the emerging apps it brings with it are driving substantial internet capacity demands that necessitate 400G interconnection technology in data centers. The S12500 Data Center Switch from leading Chinese network equipment vendor H3C is set to support these demands and integration requirements between 5G and cloud network services. H3C worked with Spirent to test the company's switch with up to 72 400G ports for 400GE full-connection line-rate forwarding and SRv6 (Segment Routing over IPv6 dataplane) performance. The testing resulted in record core switch forwarding performance providing a reliable foundation for 5G's underlying network infrastructure to meet future data requirements.

07

5G's Journey To Maturity

5G's Journey To Maturity

Is there anything 5G can't do? Yes, in fact. Early, expected challenges and progress that hasn't advanced quickly enough for some stakeholders has put a spotlight on certain shortcomings over the past 12-18 months. That's why it's worth taking a step back and looking at the big picture to remind ourselves exactly where we are along the long and interconnected road to 5G.

Truthfully, we are still very much at the beginning of this journey. We're seeking to move on from a 4G world while considerable LTE demands persist. We're laying the groundwork for future services capabilities before demand and business models have been fully-realized.

There are several major standards releases to come over the next decade. Various industries are developing complex use cases that capitalize on next-gen connectivity - 5G functionality that remains years off but is being diligently worked against today. Eventually, all of these initiatives begin to impact each other.

The full picture tells us that the 5G journey is multifaceted and multidimensional. It will require patience and perseverance. Above all, it will demand persistence and commitment. We see this every day from industry participants around the world. Today, our belief in 5G's promise and the ability to realize it has never been greater.

	2020	2021	2022	2023	2024	2025 »	2030
	5G 3GPP R16 Initial "full" 3GPP 5G System	**5G Build Outs** Coverage, Densification & Stand Alone	**5G 3GPP R17** 5G System Enhancements and New Capabilities	**5G Industry** Mainstream adoption	**5G 3GPP R18** 5G System Enhancements and New Capabilities	**5G Evolution** Support for up to 500GHz Radio, AI Cognitive Networks, 3GPP Rel-19 & 20	**6G 3GPP R21** 6G Holographic Communications
5G	5G R15 + DSS (ongoing deployments)	5G SA + R16 Upgrades	R17 Upgrades	R18/19 + 20 Upgrades			
	5G Distributed Cloud (Edge) Deployments		5G Neutral Host Environments				
	2G-4G Open RAN	Early 5G Open RAN	Mainstream 5G Open RAN				
	Basic Automation	CICD Automation (5G Core then Open RAN)	Extreme (AI) Network Automation	Cognitive Networks			
	LTE Private Networks	Early 5G Private Networks + Slicing	Mainstream 5G Private Networks + Network Slicing				
	LTE C-V2X In-Vehicle Deployments	Early 5G C-V2X (China)	5G C-V2X In-Vehicle Deployments (Mainstream)				
	5G Military Experimentation	5G Military Operational Network					
	LEO Constellations	5G Non-Terrestrial Networks					
6G	6G Early Research	6G Study Items + Specification Development					

3GPP Release 16/Second 5G Standard
This is the initial "full" 3GPP 5G system to meet the IMT-2020 requirements for 5G networks. It also includes support for Industrial IoT, 5G C-V2X, Integrated Access Backhaul, 3 meter positioning accuracy and spectrum to 52.6GHz.

3GPP Release 17/Third 5G Standard
Release 17 will see more 5G system enhancements advancing 5G's potential beyond consumers to include enterprises and new delivery mechanisms. Support for non-terrestrial networks, RAN slicing, New Radio Light for mMTC, 30 centimeter positioning and spectrum to 71GHz.

3GPP Release 18/Fourth 5G Standard
While priorities for inclusion are still being determined, this release will see even more 5G system enhancements as it evolves to enable a connected and immersive world. Candidate study items include 5G smart energy, personal IoT networks and 5G glass-type AR/MR devices.

Open RAN And Open Networking
2020 highlighted the desire for greater diversity in the RAN supply chain, and the need for open and interoperable systems. Open RAN for 5G remains a few years from prime time but with support and momentum across operators, governments and OEMs, it is anticipated to begin capturing RAN spending in the next three to five years. Eventually, it could become the foundation for 6G radio.

5G C-V2X
4G tech is supporting vehicle-to-everything communications and establishing the foundational applications for basic safety. But it is 5G capabilities like ultra-low latency and higher throughput that will power use cases required for advanced driver-assistance systems to progress functionality beyond level-three vehicle autonomy, eventually achieving full-autonomy.

5G For The Military
National defense organizations are starting to experiment with 5G in pursuit of military and security leadership. This experimentation will lead to increasing investment as future military use cases are proven across smart bases and supply chains, AR/VR training for troops, survivable command and control systems, cellular drone delivery and unmanned aerial systems, tactical edge communication systems, battlefield telemedicine and secure interoperable emergency communications.

08

Safely Accelerate The Journey To 5G

Progress rapidly to 5G victory with virtual and cloud native test solutions for open architectures.

Safely Accelerate The Journey To 5G

While wireless networks are opening supply chains by moving to software, network software itself is also becoming more open to innovation. Not only will 5G network software often run on cloud-based servers, but in many cases, it will expose APIs to developers from outside the traditional telecom ecosystem for added value via new applications.

These moves to open 5G architectures won't just transform core network functions and APIs: new standards such as Open RAN are poised to further virtualize and commoditize 5G radio functions, beginning with fronthaul. Spirent is leading the way in virtual and cloud native test solutions for new open architectures and integrating assurance throughout our customers' complete lifecycle.

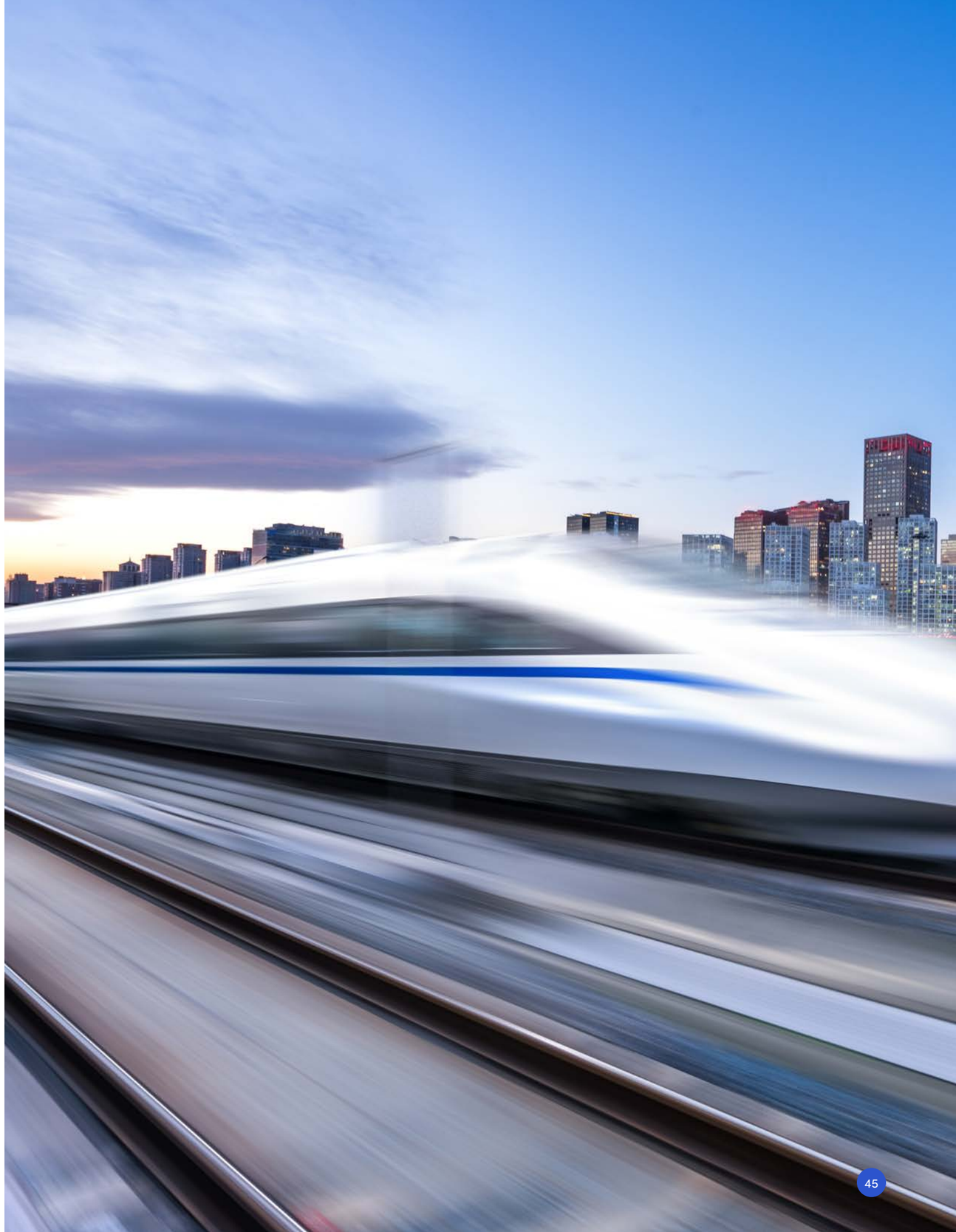
We're here to help you accelerate 5G from initial deployments to ongoing rollouts and operation of networks. Incorporating the latest open standards and innovations, our:

- Continuous test and assurance solutions, integrated into DevOps pipeline processes, achieve agility and address the continuous release nature of software from multiple vendors.
- Automation framework provides a holistic capability consumed across the 5G lifecycle to simplify labs, tests and operational processes such as fulfillment.
- Emulation, and transport and security test solutions have evolved to become digital twins, accelerating research and fostering innovation within adjacent industries.
- Active testing and assurance using synthetic traffic injected into an operational environment proactively monitors, isolates and revalidates performance and security in elastic 5G networks.

"While our heritage is in the lab, our place today is by our customers' side, supporting their entire product lifecycle as a trusted partner."

ERIC UPDYKE
CEO, Executive Director

- Testing as a service offers a new engagement model as the industry seeks cross-domain subject matter experts and partners to support the complexity of testing as a managed service.



Americas 1-800-SPIRENT
+1-800-774-7368 | sales@spirent.com

Europe and the Middle East
+44 (0) 1293 767979 | emeainfo@spirent.com

Asia and the Pacific
+86-10-8518-2539 | salesasia@spirent.com

About Spirent Communications
Spirent Communications (LSE: SPT) is a global leader with deep expertise and decades of experience in testing, assurance, analytics and security, serving developers, service providers, and enterprise networks.

We help bring clarity to increasingly complex technological and business challenges. Spirent's customers have made a promise to their customers to deliver superior performance. Spirent assures that those promises are fulfilled.

For more information, visit: www.spirent.com

Rev A | 01/21