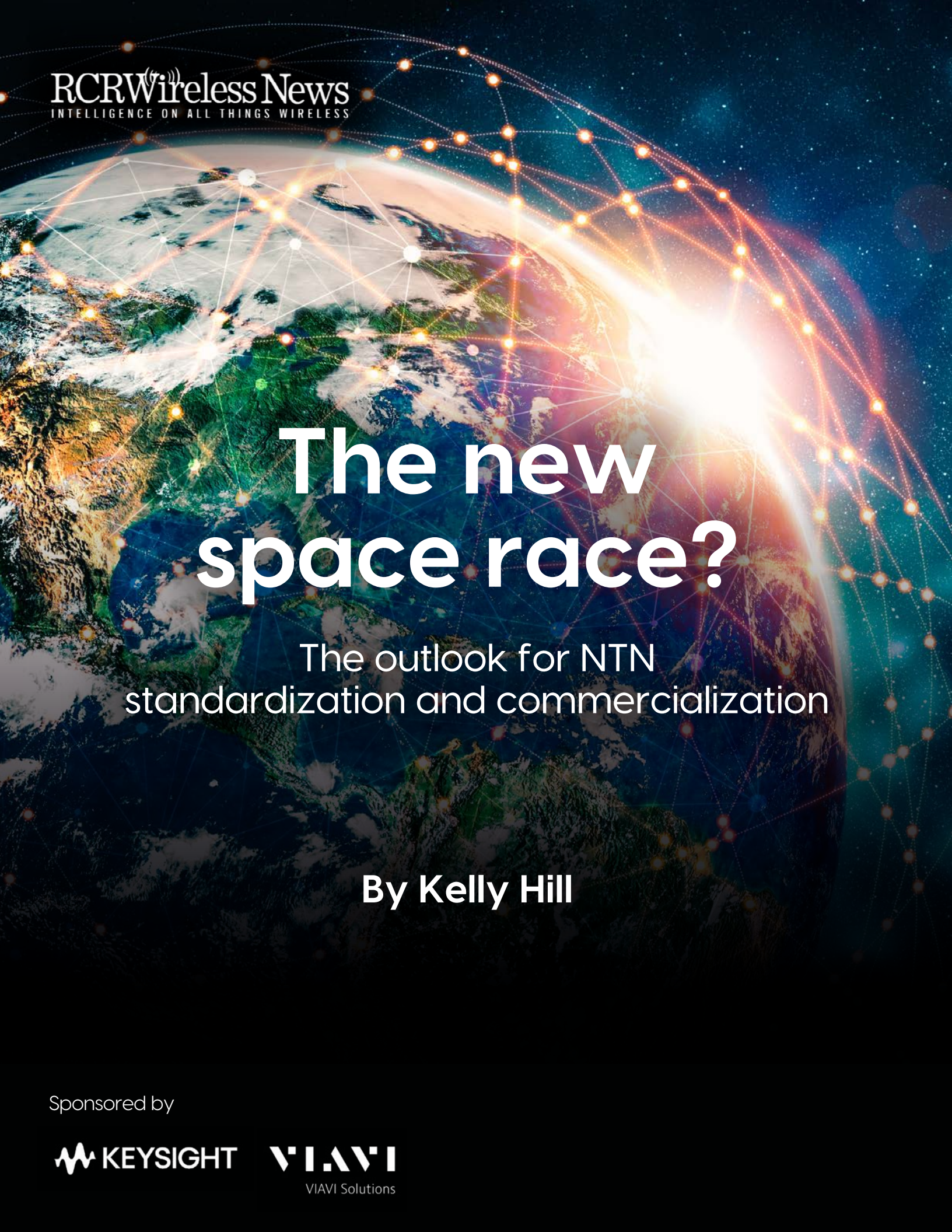

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INTELLIGENCE ON ALL THINGS WIRELESS

The new space race?

The outlook for NTN standardization and commercialization

By Kelly Hill

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INTRODUCTION

Precision agriculture that harvests as much data as food, with machinery processing large amounts of detailed video from cameras on all sides. Remote connected sensors that alert people to earthquakes or wildfires. Park rangers with seamless communication capabilities as they work on backcountry trail maintenance. First responders who can carry cell phones without fear that they will lose voice and data service when they are called into holes in cellular coverage in rural, suburban or urban areas of their county. Boaters and marine patrol units which can maintain data links as they venture far out into large lakes or the ocean.

(Images courtesy of 123RF)

These are some of the promises of ubiquitous cellular coverage. Some of them are already reality, through a combination of either cellular or satellite-based capabilities. But terrestrial cellular coverage is far from ubiquitous and never will be, because towers either cannot or are unlikely to ever be built that will cover the vast areas of the Earth which include water or ultra-remote terrain. In pursuit of cellular ubiquity, 5G standards have begun to look beyond Earth-based base stations, to rely on space-based sites: Non-Terrestrial Networks, in the parlance of the standards.

NTN brings 3GPP standardization to the satellite realm for the first time, and puts cellular and satellite on a path of technical convergence. Early services have already begun to be rolled out, with more expected to emerge over the next two years. Carriers and satellite providers are striking partnerships, business models are being hashed out and new players are hoping to grab a piece of the pie.

But space is still expensive, despite substantial reductions in launch costs and innovations from LEO companies like Starlink and SpaceX. It is also an incredibly technically challenging environment in which to initiate, maintain and handover wireless links, particularly links of any substantial capacity. New launches of satellites are being delayed and in the hands of start-ups with unproven track records. And what is the realistic market potential of NTN, anyway?

This report looks at the status of NTN standardization and commercialization, as well as the related technical and business challenges.

NTN STANDARDS: TWO WORLDS CONVERGE

Cellular and satellite have operated side-by-side for decades. What is different now?

It comes down to one word: Standardization. The inclusion of NTN in 5G standards brings the promise of actual integration of satellite-based connectivity with terrestrial networks, a single technology that offers the potential for satellite to have scale and substantially lower component costs than it has been able to achieve with existing proprietary systems. While 3GPP's view of non-terrestrial networks includes stratospheric drones (high-altitude platform systems or HAPS), air-to-ground networks and other mechanisms, the primary focus thus far has been on satellite systems, using either terrestrial or mobile satellite system (MSS) spectrum to connect smartphone or IoT devices.

"I typically refer to this like a meeting of both worlds, that were very separate before," reflects Obilor Nwamadi, senior product manager at Viavi Solutions. "Bringing these two together means we are trying to learn about satellite tech as quickly as we can, and the satellite people are trying to learn about terrestrial and 3GPP as quickly as they can as well. So most discussions are this kind of sharing of ideas. … [for] the terrestrial guys, it's about figuring out, okay, I have a terrestrial network already. What modifications do I need to make to it, to support non-terrestrial 5G over satellites? And the same exact questions is being asked by the satellite guys: I have my satellites already, what changes do I need to make to it to support 3GPP-based 5G connectivity as well?"

(Images courtesy of 123RF)

Direct-to-device is the form of NTN that is the current subject of most interest, particularly on the satellite side, Nwamadi said, because it is the "path of least resistance to support NTN." It relies on existing terrestrial spectrum and can connect existing devices—no need to wait for new chipsets, handsets or infrastructure, or a new 3GPP release. You don't even need 5G, as NTN-IoT applies narrowband IoT/4G systems to NTN. However, pre-Rel.17 approaches, Nwamadi explained, "have not necessarily always promised broadband connectivity." Neither, necessarily, are the early direct-to-device offerings that are emerging. In an August 2022 post on X, formerly known as Twitter, Elon Musk indicated that for Starlink's service with T-Mobile US, "connectivity will be 2 to 4 Mbits per cell zone, so will work great for texting & voice calls, but not high bandwidth." "So you can see that it's not promising everybody to be able to watch Netflix HD videos with that type of connection," Nwamadi added. "It's providing connectivity where in other cases, there would be no connectivity."

The Third Generation Partnership Project's (3GPP) work on 5G New Radio Non-Terrestrial Networks began with a study item back in Rel. 15 in 2017. The work falls into two broad categories: IoT-NTN, which began with an initial focus on narrowband IoT in an NTN context; and NR-NTN, or 5G New Radio in non-terrestrial networks.

3GPP has outlined three main categories of use cases for 5G NTN: 1) Service continuity, for instances when terrestrial networks alone are not sufficient, such as connecting airborne or maritime vessels; 2) Service ubiquity for areas unreached by terrestrial cellular networks, for serving asset tracking or agricultural IoT connectivity needs, public safety emergency networks or home internet access; and 3) Service scalability, to leverage the large coverage area of satellites for multicasting or broadcasting content. (1)

As work on NTN has progressed, 3GPP has established two basic architectures: Transparent and Non-Transparent, or Regenerative.

The Transparent payload or "bent-pipe" architecture relies on the satellite to basically play a very limited role of a signal repeater in space, with the waveform signal being unchanged. The 5G signal more or less bounces off the satellite and returns to Earth.

The Regenerative payload, however, requires the satellite to provide some or all of the base station/gNodeB functions, which means the satellite has to be capable of more, 5G-specific processing capabilities and active enhancement of the 5G signal, including frequency conversion and amplification as well as demodulation/decoding, coding/modulation and switching and/or routing.

In addition, the Regenerative model accounts for the option of inter-satellite links (ISL) used by a constellation of satellites. Regenerative payloads are required in order to use ISL.

As Dr. Juan Deaton, the chief alignment officer at Alignment Consulting and Engineering (ACE), put it in a blog post on 5G NTN, transparent vs. regenerative systems are basically the difference between racquetball and tennis. He also notes that in the transparent architecture, the 5G waveform is used in both the feeder and the service links, while in a regenerative architecture, satellite's own proprietary waveforms can be used to transmit signals to the gNodeB, which then transforms them to 5G NR for the service link to the Earth-based end user device. (The regeneration of the 5G NR signal in a regenerative architecture also results in better signal strength in the service link, Deaton wrote.)

3GPP is addressing the use of 5G in Low Earth Orbit (LEO), Middle Earth Orbit (MEO) and Geostationary Orbit (GEO) satellites, and has established standards for both narrowband IoT in the sub-6 GHz spectrum range for both LEO and GEO, with a transparent payload assumed.

In a mid-2023 white paper on the standardization of 5G NTN (2), 5G Americas said that with a Rel. 17-based NTN solution that uses sub-2 GHz FDD terrestrial spectrum, it is possible to achieve tens of megabits per second speed in the downlink, which would be shared across all users in a cell, and round-trip delay "in the range of a few tens of milliseconds." Nwamadi of Viavi Solutions said that his company has seen this born out in the lab. Release 17, he explains, is where 3GPP begins to require that handsets take on some of the support work for NTN connectivity. In Rel. 17 and in work on Releases 18 and 19, the processing work that goes into correcting for things like delay and other characteristics of a satellite-based link, shifts to the user equipment. At that point, Nwamadi said, Viavi has seen in lab tests that a single connection can achieve around 20 Mbps. "That's still not broadband, but you are looking at considerably higher than what was announced with the direct-to-cell-type approaches," he added.

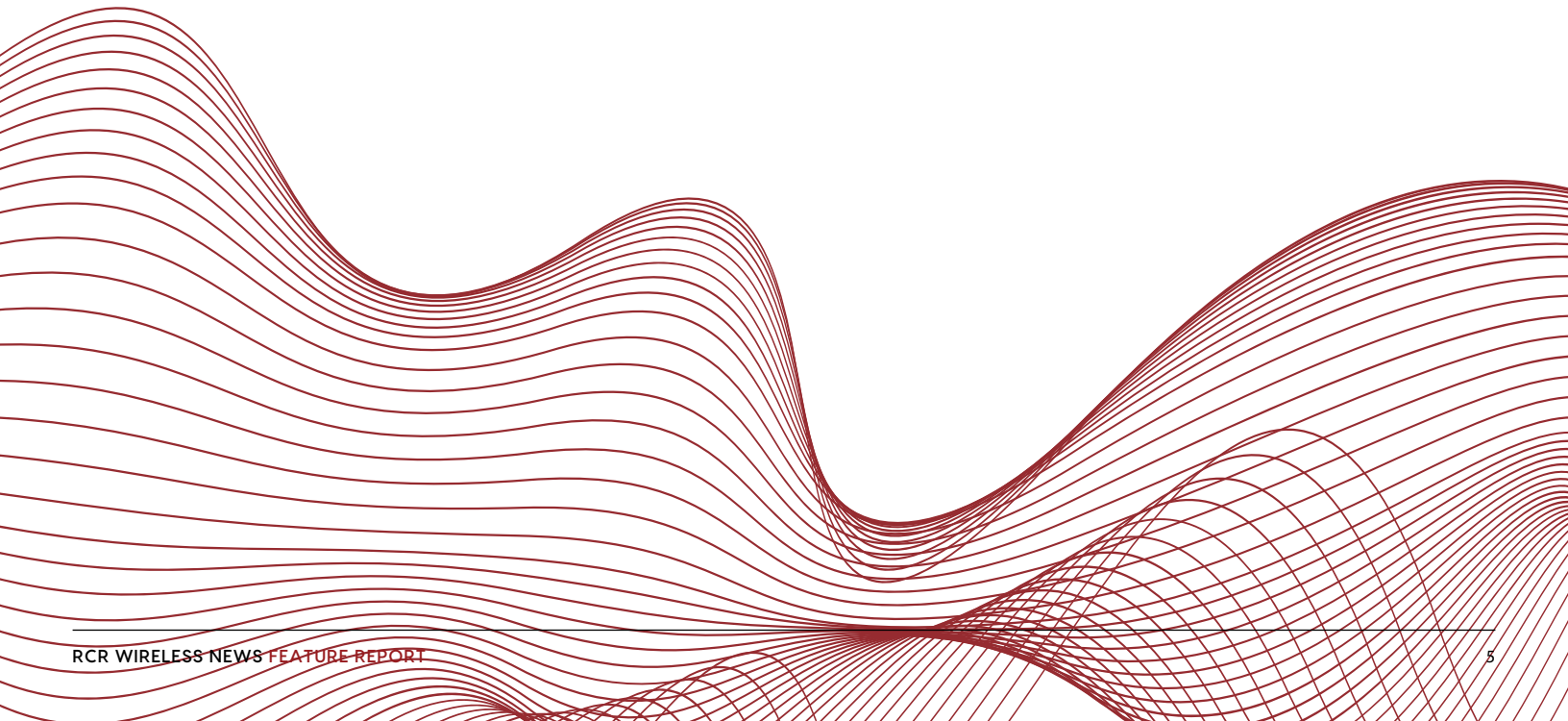
Other Rel. 17 aspects include UEs compensating for delay, in part by using their own GNSS position to determine the timing for uplink transmissions; the Doppler shift on the feeder link is compensated for at either the gateway or the NTN payload, but the UE also has to do some calculation based, again, on its own position and the satellite's velocity information. There's additional mobility support to improve handover mechanisms, plus two NTN bands under 6 GHz specified (1.6 GHz or L-band and 2 GHz or S-band, both FDD and existing satellite service bands; this constitutes NTN FR1.).

In Rel. 18, the combination of spectrum in the Ka band (27.5-30 GHz, or NTN FR2) and non-handheld devices (VSAT terminals, or small dishes similar to those deployed by Starlink as customer CPE) is expected to offer speeds on the order of hundreds of Mbps. Other work items include improving uplink coverage, consideration of bands above 10 GHz for NTN support and improving mobility and service continuity in NTN/terrestrial network and NTN-NTN scenarios.

According to 3GPP, Release 19 work related to NTN focuses on the regenerative payload and supporting 5G system functions on the space-based platform; optimized performance for terminals; capacity performance in the uplink; the use of 5G Reduced Capability (RedCap) devices within Frequency Range 1 NTN; and notifying devices of a broadcast service within a service area

Optimization and refinement will be particularly important for overall system efficiency and capacity. Paul Jacobs, CEO of satellite company Globalstar and former CEO of Qualcomm, has a unique perspective on both the cellular and satellite worlds, including the standardization process. As Jacobs sees it, the NTN standards as they stand, are very much an exercise in bringing cellular technology into space, with cellular's needs, language and engineering as the focus. "If you look at some of the things that have been done in the standards on the cellular side, there's a lot of complexity that has to do with compatibility with the [terrestrial] cellular systems—which adds a lot of overhead, which you probably don't really want in a satellite system," Jacobs explained. "There hasn't been a lot of work on optimizing that, to this point—that's one of the things that we're looking for. From a Globalstar standpoint, we're really looking at the NTN specs and trying to really understand the design decisions that were made, because a lot of it has to do with the compatibility with the cellular networks and the chipsets and the protocol stacks and a lot of the plumbing, which may not be right on the [satellite] side." More optimal design for 5G NTN will hopefully come as the standards are refined, but also in the ways that individual companies implement the standards in real networks.

(1) 5G & Non-Terrestrial Networks, 5G Americas white paper, February 2022
(2) Update on 5G Non-Terrestrial Networks, July 2023



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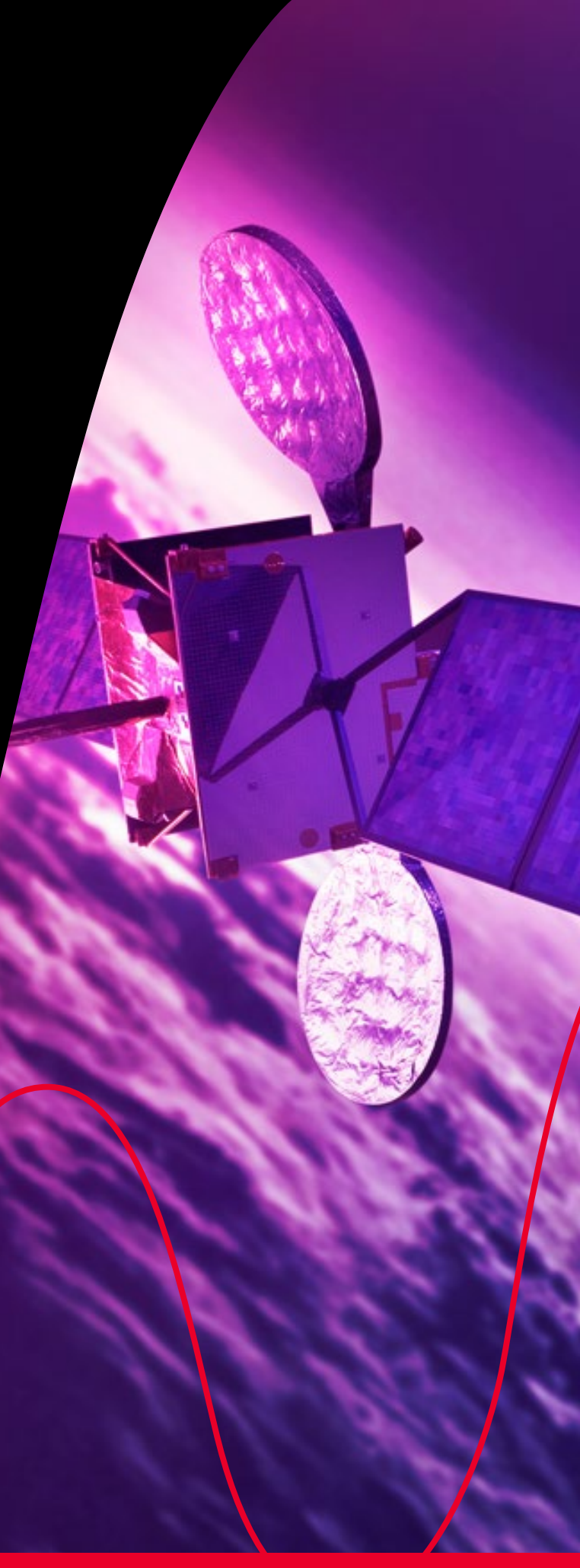

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DEALS, DEMOS, DELAYS AND DISAPPOINTMENTS IN 5G NTN

The interest in cellular non-terrestrial network technology and the business opportunity is reflected in the amount of activity in the space in recent years, as 3GPP 5G standards work has built momentum toward convergence of satellite and cellular networks and raised the possibility of true, ubiquitous (and maybe eventually, high-speed) connectivity.

NTN was one of the major topics at this year's Mobile World Congress Barcelona, and dominated discussions at the Satellite Show 2024 in Washington, D.C. a few weeks later. Mobile network operators, handset makers and chipset companies are striking partnerships, developing products and in some cases have already begun to provide services, with more expected to emerge this year.

However, space is still expensive and technically challenging, and while there are plenty of incumbents on both sides, many of the players pushing the NTN-velope are start-ups or relatively young or small companies—and even among established corporate denizens, there have already been NTN missteps.

Here is a run-down of major publicly known partnerships and services, deals and recent development progress—plus a few duds.

• In one of the best-known deals and one that has already resulted in a consumer smartphone-based service, Apple announced back in late 2022 that it was investing $450 million from its Advanced Manufacturing Fund in satellites and ground stations to support its Emergency SOS service on iPhone 14 models (and subsequently, iPhone 15 models) for customers in the United State and Canada.

The majority of that funding went to Globalstar to provide "critical enhancements" to the company's 24-satellite LEO network and ground stations. Apple's Emergency SOS via satellite service utilizes the spectrum in L and S bands. As Apple describes it, "When an iPhone user makes an Emergency SOS via satellite request, the message is received by one of Globalstar's 24 satellites in low-earth orbit traveling at speeds of approximately 16,000 mph.The ground stations use new high-power antennas designed and manufactured specifically for Apple by Cobham Satcom in Concord, California. Cobham's employees engineer and manufacture the high-powered antennas, which will receive signals transmitted by the satellite constellation." Globalstar has said that Apple is allocated 85% of the capacity on its satellite constellation, with the satellite operator continuing to offer legacy services, including IoT connectivity, with the remaining 15%.

Apple has been offering the Emergency SOS service for free for two years after the activation of an iPhone 14 or 15 model. In fact, in November 2023, the company extended the free period for an additional year for existing iPhone 14 users, and also added a Roadside Assistance via satellite service to connect users to AAA — also free for two years. Apple iPhone users are also able to share their location via satellite to "reassure friends and family of their whereabouts while traveling off the grid." as the company puts it.

Apple has invested in bolstering Globalstar's satellite constellation and ground stations for its Emergency SOS service. Image source: Apple

"Emergency SOS via satellite has helped save lives around the world. From a man who was rescued after his car plummeted over a 400-foot cliff in Los Angeles, to lost hikers found in the Apennine Mountains in Italy, we continue to hear stories of our customers being able to connect with emergency responders when they otherwise wouldn't have been able to," said Kaiann Drance, Apple's vice president of worldwide iPhone product marketing in late 2023 when the extension of free service was announced.

In February 2023, Globalstar said that Apple was lending the company $252 million to help cover upfront costs for replenishing its LEO constellation.

-Starlink has inked multiple agreements for providing direct-to-cellular service with mobile network operators, including T-Mobile US, Rogers in Canada, Japan's KDDI, Optus in Australia and One NZ in New Zealand, Salt in Switzerland and Entel in Chile and Peru.

The satellite provider is getting closer to service launches. Starlink launched its first D2C-capable, or Starlink 2.0, satellites in January of this year, and the company said that within a few days of launch, it successfully sent and received the first text messages, using T-Mobile US' terrestrial spectrum. Text service is set to begin this year, Starlink said, to be followed by voice, data and IoT services in 2025. The service is LTE-based; Starlink already has FCC permission to test direct-to-cellular capabilities in the field using T-Mo's 1.9 GHz FDD spectrum. As Starlink describes it, its operator partners around the world "provide critical LTE spectrum in the 1.6-2.7 GHz range that we use to transmit our satellite signals. This allows Starlink to integrate like a standard roaming partner with operators, and together we provide services directly and seamlessly to their customers. Operators in our network have access to reciprocal global access that allows their users to access the service when they travel to one of our partner countries. There is incredible demand and high interest in this program, and handset providers and mobile operators alike are eager to test and participate in a successful rollout."

-Direct-to-device service provider Skylo launched its service in January of this year, and also raised $37 million in a funding round in February, co-led by Intel Capital and Innovation Endeavors and joined by investors that included BMW i Ventures and then Samsung Catalyst Fund. The funding "expands Skylo's scale and business operations to better support smartphones, wearable OEMs, IoT devices, and mobile network operator customers," according to Skylo, which called it a "major step in Skylo's commitment to making standards based non-terrestrial networks (NTN) more accessible and efficient for numerous sectors, including consumer, automotive, agriculture, energy, transportation, and beyond."

"We were impressed with Skylo's global connectivity solution that enables 'always-on, always-connected' communication for the automotive industry," said Kasper Sage, managing partner at BMW i Ventures, in a statement. "Skylo has a proven solution and team that is going to make satellite connectivity a new standard for the next generation of vehicles while keeping people safe and making their experiences seamless wherever they may go."

Tami Erwin, former CEO of Verizon Business, recently joined Skylo's board of directors; in early April, IoT module maker Semtech announced that it had integrated Skylo NTN access into two of Semtech's HL78 modules, which also support terrestrial LPWA using Cat-M and NB-IoT. Semtech said that the NTN access can be enabled with a software update which is expected to be commercially released this quarter, pending testing and certification with Skylo's network. "Giving customers the option to connect using NB-IoT over a satellite network when traditional terrestrial coverage is not available is a major advantage," Semtech said.

"By incorporating NTN support into our HL78 modules via a straightforward software update, we are enhancing the capabilities of our existing products, providing our customers with a substantial competitive edge," said Larry Zibrik, VP and GM of modules at Semtech.

-Satellite direct-to-cellular company AST SpaceMobile announced in January that it had gained two new major financial backers: AT&T and Google came on as strategic investors, and AST received additional funding from existing partner Vodafone to support commercial roll-out of its technology.

The company announced that it gained aggregate new financing of up to $206.5 million from the investments of AT&T, Google and new capital from Vodafone, and that it plans to draw on an additional sum up to $51.5 million from a credit line. Those investments encompass $20 million in revenue commitments from AT&T that are predicated on the successful launch and operation of AST SpaceMobile's first five commercial satellites and a minimum $25 million in revenue commitments from Vodafone. Both carriers have placed purchase orders in undisclosed amounts for AST SpaceMobile network equipment that will support planned commercial services. Google and AST SpaceMobile agreed to joint work on product development, testing and implementation of AST SpaceMobile's tech on Android devices.

AST SpaceMobile's BlueWalker 3 test satellite is 693 square feet in size. Image source: AST SpaceMobile

AST SpaceMobile said that its BlueWalker 3 satellite currently in orbit is the largest-ever commercial communications array in low Earth orbit. It also has satellites in the works with beams designed to support the use of up to 40 megahertz of spectrum, which AST SpaceMobile says could enable data speeds of up to 120 Mbps.

However, even as AT&T and AST conduct additional direct-to-cellular testing using 10-megahertz blocks of FirstNet and 800 MHz spectrum in Texas and Hawaii, ASTSpaceMobile said during its most recent quarterly call that the first five Bluebird satellites of its anticipated constellation have been delayed again due to supplier issues. The company had first planned to launch them before the end of 2023, then expected to launch in the first or second quarter of 2024; Chairman and CEO Abel Avellan said that the satellites are now expected to be transported to the launch site between July and August 2024.

AST SpaceMobile already has agreements and deals in place with 40 mobile network operators around the world that service around 2 billion customers, and that it anticipates that the direct-to-cellular technology could offer connectivity to 5.5 billion cellular devices in use today.

- In November 2023, Qualcomm ended a partnership with Iridium that centered on pushing NTN development forward with a chipset that utilized Iridium's proprietary satellite network. Despite having successfully developed and demonstrated the technology, smartphone makers weren't opting to include Snapdragon Satellite in their devices, so Qualcomm terminated the deal. "While I'm disappointed that this partnership didn't bear immediate fruit, we believe the direction of the industry is clear toward increased satellite connectivity in consumer devices," said Iridium CEO Matt Desch in a statement last November, when the partnership ended. "Led by Apple today, MNOs and device manufacturers still plan, over time, to provide their customers with expanded coverage and new satellite-based features, and our global coverage and regulatory certainty make us well suited to be a key player in this emerging market. User experience will be critical to their success, and we've proven that we can provide a reliable, global capability to mobile users."

Qualcomm has indicated in published reports that the lack of interest was due to smartphone OEMs preferring a standards-based approach—not a lack of interest in satellite connectivity per se. In a session at Satellite 2024 in Washington, D.C., Francesco Grilli, VP of product management at Qualcomm, said that within the Android ecosystem, there was "initially very high concern" that Apple's emergency messaging capability would have a "devastating effect" on Android's market share, which is already a minority of the U.S. smartphone market, although the Galaxy smartphone dominates in other geographies. "It had an impact, but it was not devastating," Grilli said.

"In the end, the ecosystem decided that they didn't want to start on a proprietary track if they could just wait an extra year or two and get on the standard track." Two things to note here: 1) It's not out of character for the cellular industry to jumpstart time-to-market with a proprietary solution that outpaces the standards and then scrap it once the standardized version is available; 5G TF, anyone? and 2) Apple smartphones sales did surpass Samsung devices during 2023 on a global basis, marking the first time since 2010 that Samsung hasn't been at the top of the smartphone market; however, IDC at least credits that both to Apple's ascendency and diverse offerings from other Android players.

• In early 2024, the Bullitt Group, which licensed its technology to players including Motorola for its Defy 2 rugged smartphone with satellite messaging capabilities supported by a MediaTek chipset, disintegrated. The company, founded in 2009, appeared to be on the rise for years and reported profits of more than a million dollars in 2017, upon which it sold a majority stake to a private equity firm. In its financial filings, Bullitt blamed the Covid-19 pandemic disruptions to its business as well as the war in Ukraine reducing its sales in Eastern Europe; the company lost $10 million each year in 2020 and 2021, with its losses ballooning to $22 million in 2022. Bullitt launched its Defy satellite link dongle and smartphone in 2023 and won a "best in show" device Global Mobile (GLOMO) award at MWC Barcelona 2023 for the dongle— but the company didn't have the working capital to fund its hardware sales, according to the filing, and by September 2023 it was seeking a buyer. By December 2023, Bullitt was in dire financial straits and although it tried to find additional financing, it was unable to do so and entered an administrative state and fired its 70 employees in February 2024. Bullitt had about $253 in its bank account when it entered insolvency, and more than two billion dollars in secured and unsecured debt. The company's founders bought its IP for about $265,000.

According to the Bullitt website, the company offered a 12-month free trial of its SOS service and plans that started at $4.99 a month.

• On the regulatory front, the Federal Communications Commission last month unanimously approved a new rules framework for satellite-based, cellular communications directly to end-user devices"or supplemental coverage from space (SCS), using terrestrial spectrum. The SCS framework enables satellite operators who are working with terrestrial service providers to ask for FCC authorization to operate space stations in spectrum that is currently allocated for wireless services, as long as they meet conditions like having a spectrum lease in place. Once they get authorization, the satellite operator can then serve that MNO's customers within the specific geographic area, if they are out of terrestrial network coverage. However, there are some issues around 911 emergency calling that need to be addressed. For now, the FCC established that terrestrial MNOs have to route all 911 calls made through SCS to a public safety answering point (PSAP) using either location-based routing or an emergency call center, and the agency put out a further rulemaking asking for input on making sure that SCS calls get routed correctly.

• Lynk Global, in February finalized a merger with a special-purpose acquisition company (SPAC) that is expected to help the company raise additional funds. As of January 3rd, the company had commercial cell towers in space including the world's first 5G enabled payload, according to Congressional testimony from Margo Deckard, a co-founder and COO of Lynk. Deckard told a U.S. House subcommittee that Lynk has signed 26 commercial contracts to date, valued at over $2.5 billion, to provide coverage in 41 countries and that the company plan to begin international commercial service this month. "Our initial service will be text messaging, but as we build out our constellation, we will support broadband services everywhere directly to standard phones," she said. Lynk expects the merger with the SPAC to close in the second half of 2024.

• Satellite company Omnispace has struck a deal with MTN, which provides service in 19 African countries, under which Omnispace will develop a "next-generation standards-based mobile and IoT network designed to serve MTN markets." In the meantime, MTN will test and prove out capabilities and use cases using Omnispace's current In the interim, the companies will partner to test existing technology, prove capabilities, and use cases using Omnispace's on-orbit satellites. Omnispace said in February that it now has market access to reach more than 735 million people across Latin America, Asia, Africa and the Middle East. "Together with partners that have spectrum access in 3GPP 5G NTN bands, Omnispace is poised to deliver access in all major international markets as part of a next generation global 5G NGSO system," the company said.

• In conjunction with the Satellite 2024 show, Gatehouse Satcom and cellular private network technology provider Druid Software signed a memorandum of understanding aimed at jointly developing a "fully integrated, out-of-the-box" NTN solution for satellite providers by combining Gatehouse Satcom's satellite Radio Access Network with Druid's core network platform, with the two "tailored to enable robust NTN services in line with the latest 3GPP Release 17 standards."

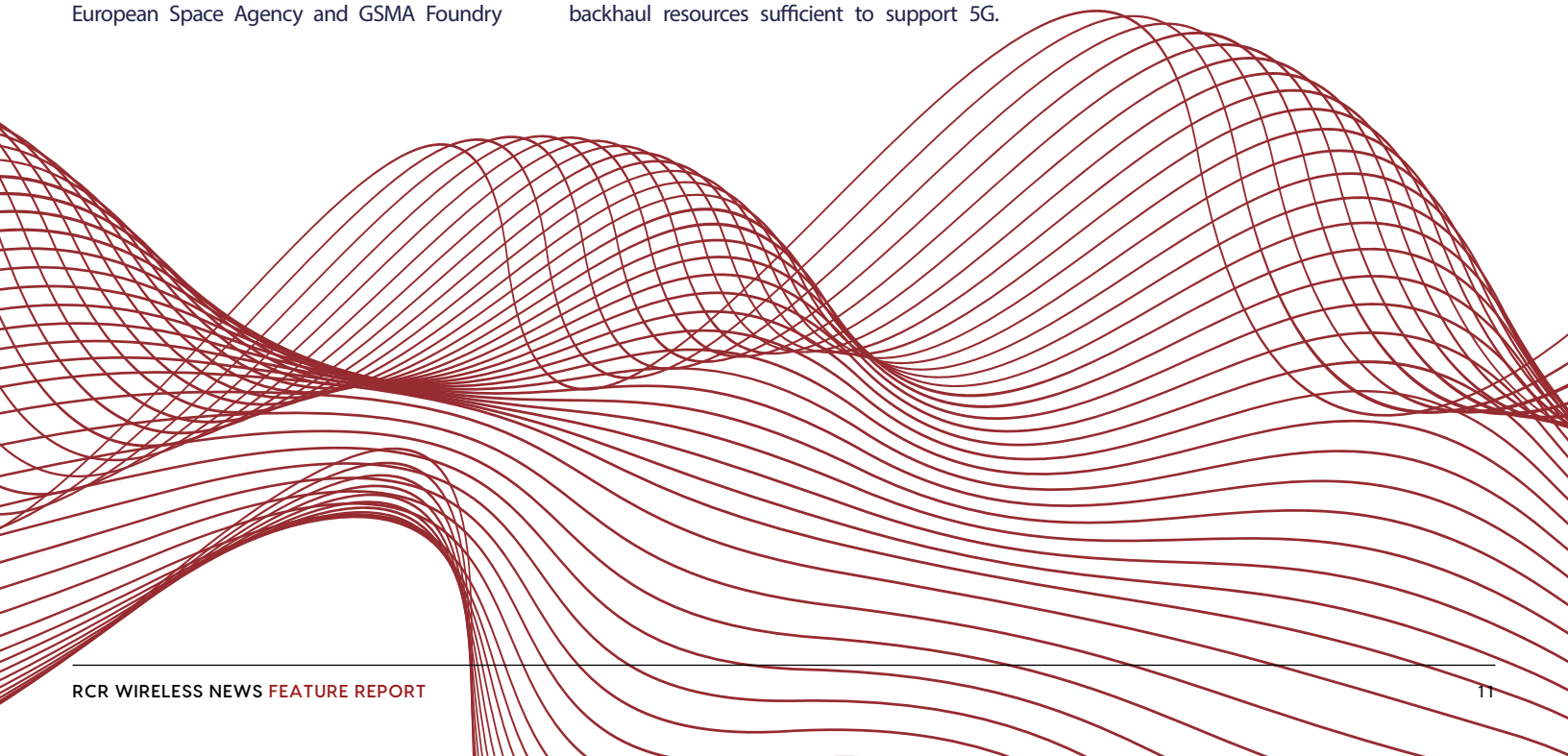
Druid also recently joined the Mobile Satellite Services Association, or MSSA, launched in February 2024; the group, consisting mostly of Mobile Satellite Service (MSS) spectrum holders, wants to facilitate development of direct-to-device connectivity via that L- and S-band spectrum, which is already allocated and licensed for MSS.

• There was no shortage of NTN demonstration at this year's Mobile World Congress Barcelona. At various booths on the show floor, Qualcomm and MediaTek chipsets were on display, enabling 5G Non-Terrestrial Networks demonstrations of both the NB-IoT, 5G and 5G-Advanced variety, with additional news on 5G NTN chip development acceleration from the likes of Ceva and Arm. Meanwhile, the European Space Agency and GSMA Foundry announced a partnership that includes up to 15 million euros in funding for tech challenges related to NTN, lab access and a GSMA training course to familiarize people with both terrestrial and non-terrestrial networks and work around "ecosystem unification." The show's Satellite and NTN Summit was standing-room only.

• In a slightly tangential recent development, the government of Canada announced in early April that it was increasing its investment in a previously announced deal with Telesat to support Telesat's LightSpeed LEO constellation, which is anticipated to provide broadband access to Canadians. While satellite has long provided mobile backhaul for cellular sites either in remote locations or as part of additional event capacity or disaster recovery, the supported bandwidth has also been limited. However, LEO constellations that can support higher speeds also offer new possibilities for extending 5G mobile or fixed broadband (Verizon mentioned interest in such an arrangement with Amazon's Project Kuiper for high-speed cellular backhaul, back in 2021.)

In the case of LightSpeed, the LEO constellation may end up extending the reach of 5G by providing backhaul and trunking services in rural areas which are not served by fiber or backhaul resources sufficient to support 5G. Brazilian operator TIM tested LightSpeed for its suitability for 5G backhaul last year and concluded that the service levels provided by LightSpeed would be acceptable, in terms of latency and reliability, to support terrestrial 5G service.

• A satellite with a regenerative payload (one of the two NTN architectures laid out by 3GPP) is set to be launched this year by Lockheed Martin, as part of its 5G.MIL network solutions for the U.S. Department of Defense. In its final lab demonstration in October 2023, Lockheed showcased what it says is the "industry's first fully regenerative Advanced 5G Non-Terrestrial Network (NTN) Satellite Base Station." In a live hardware-in-the-loop test environment, the NTN base station "performed high-speed data transfers connecting with prototype NTN user equipment," according to Lockheed, which said that the satellite is "compliant with 3GPP Release 17 and was developed in anticipation of pre-Release 18 and 19 regenerative specifications." The defense vendor added: "During a simulated satellite orbital pass, the Satellite Base Station, running on space-hardened flight hardware and the user equipment on the ground, successfully connected and transferred data, including live video streaming."



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5G NTN and direct-to-device connectivity and business models were a major point of discussion during the Satellite 2024 show in Washington D.C. Image source: K. Hill/RCR Wireless News

Lockheed used Accelercom's 5G NTN Layer 1 PHY solution and 5G NTN Layer 2/3 and 5G Standalone core software from Radisys. The company says that its Advanced 5G Satellite Base Station "is the lynch pin in Lockheed Martin's vision to provide global 5G connectivity." It has been investing in hybrid base stations for three years, and says that the satellite uses a full 5G NR RAN software stack, a RAN Intelligent Controller (RIC) and 5G SA Core that run on space-qualified flight hardware that will fly on the TacSat; that it is reprogrammable on orbit using a software-defined satellite architecture; and that it can be structured with a split architecture with a Control Unit (CU) on the ground and Distributed Unit (DU) on the satellite.

"Our Satellite Base Station is real, operational hardware and we're excited for the next step," said Joe Rickers, Lockheed Martin's vice president for Connectivity, Transport and Access. Lockheed is self-funding the launch of the regenerative payload to orbit during 2024 to bring "5G's capabilities to the final frontier to prove its capability to connect the globe."

(Images courtesy of 123RF)

FOUR MARKET PREDICTIONS FOR 5G NTN

With both the satellite industry and the cellular industry very clearly trying to figure out which use cases, services and business models should shape their approach to converged 5G Non-Terrestrial Networks (NTN), what do analysts have to say about the market opportunity?

Here are four takes from analyst firms on the 5G NTN market, and one that looks specifically at the direct-to-device opportunity and how it is likely to evolve.

• ABI Research has predicted that there will be $124.6 billion worth of annual service revenues from satellites by 2030 and that the specific NTN-Mobile segment "has the potential to reach a market value of around $18 billion with up to 200 million connections by 2031."

"The emergence of satellite-enabled mobile devices from major consumer smartphone manufacturers and chipset makers like Apple, Qualcomm, Motorola, MediaTek, Huawei, and ZTE indicates satellite communications services breaking into the mainstream consumer market," said Andrew Cavalier, satellite communications industry analyst at ABI Research, who also added that "The possibilities for global IoT connectivity have expanded, driving further innovation in the satellite industry."

"We are seeing that the market is evolving quickly, and many services are finding enhanced deployment through strategic alliances and from increased bandwidth supply in LEO," added Jake Saunders, VP of Asia Pacific at ABI Research. "With satellites becoming smaller, more affordable, and reaching closer orbits, the barriers to entry have been lowered, fostering innovation and expanding the scope of satellite-based services and applications. The market is revealing new development paths that will influence the Terrestrial and Non-terrestrial connectivity markets and shape enterprise opportunities throughout the telecommunications value chain."

• Market analysis firm Lucintel released a report in January 2024 on its forecasts for the 5G NTN market, saying that the future of the market "looks promising" with opportunities anticipated in the maritime, aerospace, defense, government and mining markets. The firm predicts that the 5G NTN market will reach $27.7 billion by 2030, with a compound annual growth rate of more than 33% from 2024 to 2030.

Lucintel expects the maritime market to have the highest rate of growth the "multitude of applications and services" which are possible on board yachts and the seamless connectivity and high data rates that are expected from 5G NTN. In terms of regions, North America is expected to see the highest growth rate.

• Global Market Insights pegs the 5G NTN market at about $4.2 billion as of 2023 and expects a CAGR of 35% through 2032, with the market reaching nearly $80 billion at the end of the forecast period. The firm cites "increasing demand for ubiquitous and high speed connectivity worldwide" as the driving factor for the market. Aerospace and defense uses account for an estimated 35% of the market, with maritime, government and mining constituting the other major market segments. 5G NTN will be "a crucial enabler for innovation and efficiency in the aerospace and defense domain," the firm concludes, with 5G NTN offering "enhanced data transmission, improved reliability and extended coverage" that align with aerospace and defense operational needs and the ability to support autonomous systems including UAVs, remote sensing and mission-critical communications. GMI also sees North America as the dominant region for the 5G NTN market at this time.

• NSR (which is part of Analysys Mason and focuses on the satellite market) expects that NTN revenue for telcos is set to grow by USD32.5 billion between 2022 and 2027.

However, in a March 2024 blog post on the direct-to-device opportunity, NSR Principal Analyst Lluc Palerm laid out four distinct phases for the D2D market—and not all of them are particularly profitable, especially in the near-term. Palerm says that "the direct revenue opportunity in the early years [of NTN D2C] is low," and notes that currently available systems limit offerings to basic emergency alerts and messaging.

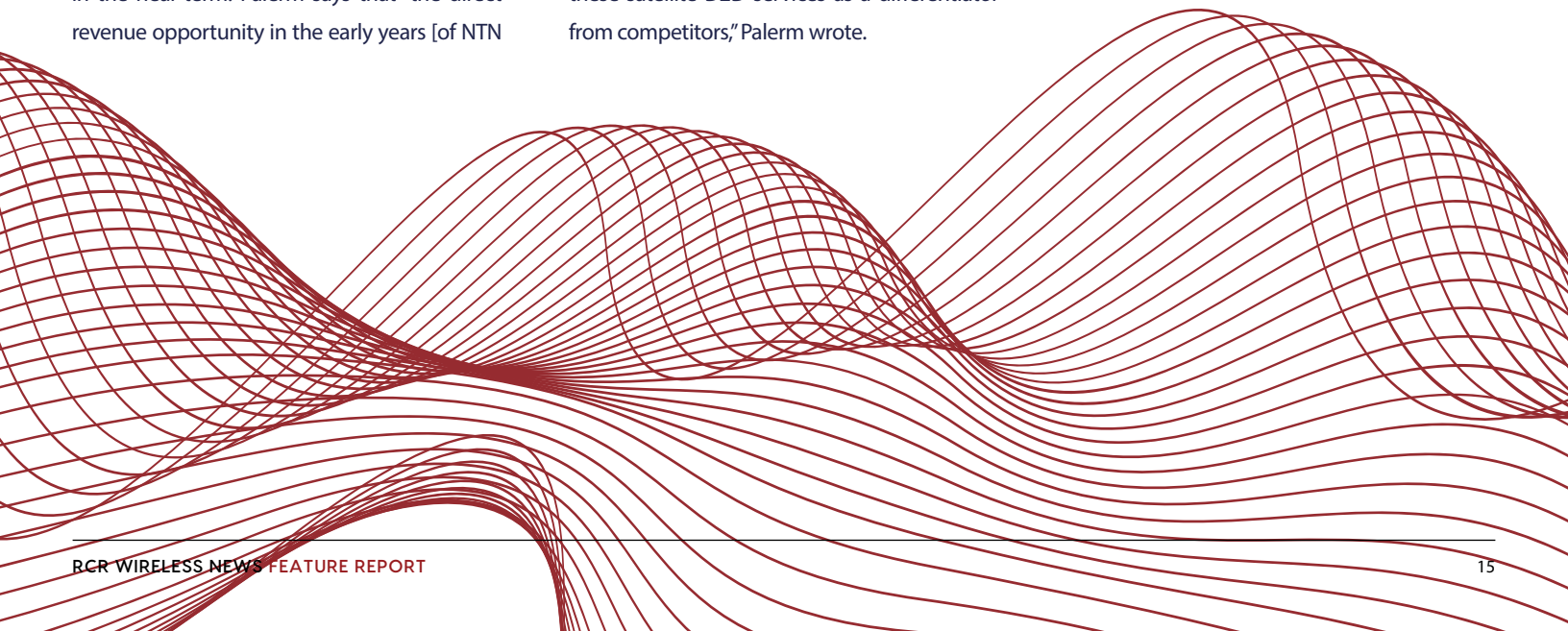
For systems that use pre-Rel. 17 technology, "the amount of bandwidth available is not big enough to support advanced voice and data services direct to unmodified phones at scale," he concludes—and adds that even for companies that plan to use terrestrial spectrum from space for direct-to-device offerings that are compatible with existing phones, "the early offerings of these constellations will also be limited to emergency alerts and messaging."

That's a tough situation, because he goes on to say that "the willingness of mainstream users to pay for emergency alerts and messaging services is limited." Analysys Mason predicts that the potential revenue for NTN-based emergency alerts will be less than $100 million globally through 2032. Revenue from direct-to-device messaging is expected to be only a bit higher at $500 million globally. Instead, NTN emergency services are expected to be a service differentiator for competitive purposes (exactly the approach being taken by Apple and T-Mobile US, for example.) "The direct revenue opportunity might not be significant for mobile network operators (MNOs), but end users value these potentially lifesaving features. MNOs should focus on incorporating these satellite D2D services as a differentiator from competitors," Palerm wrote.

But the outlook isn't entirely without hope of revenue. Palerm thinks the much more substantial revenue opportunity will come with voice and broadband data. When those become available via NTN, "a vast and accessible market will emerge" consisting of "demand from recreational travellers, rural residents, IoT, first responders and many others who want to stay connected when out of the reach of the limited terrestrial network coverage will boost market penetration and adoption rates. Huge revenue opportunities await when coverage is worldwide, connections are reliable and data speeds are consistent."

However, this will mean that far more satellites will have to be launched in order to scale voice and data services. As telcos think about partnerships in this arena, Palerm points out that they have to make important decisions about spectrum strategies (terrestrial or MSS? Which frequencies and how much spectrum to dedicate, in which areas?), proprietary vs. standardized solutions and whether they will serve consumers or enterprise/industrial IoT.

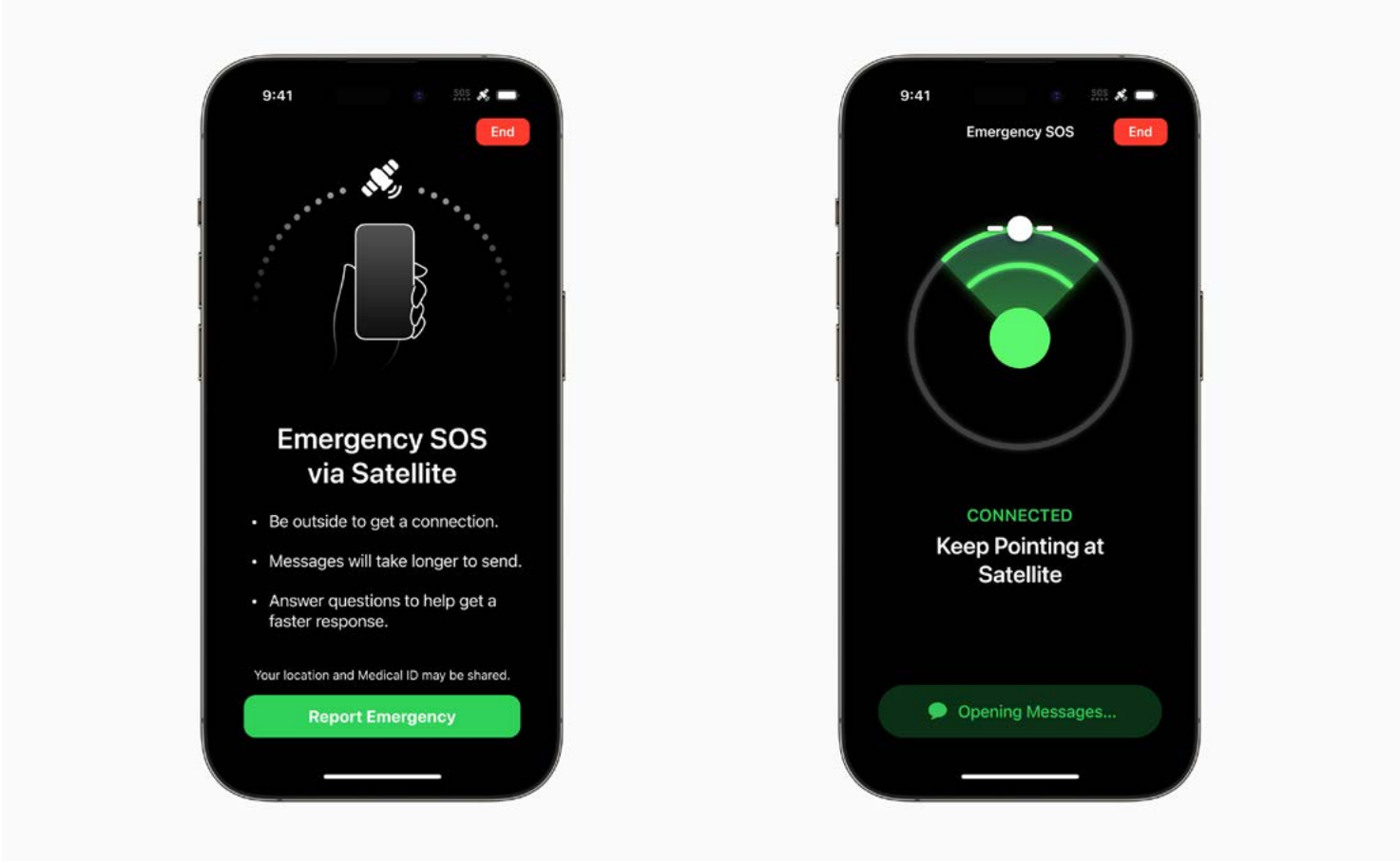
"Successful partnerships will probably be those that acknowledge the importance of the members of the value chain, and those that can coordinate and garner support from players across the value chain," he writes.



PARSING THE POTENTIAL MARKET FOR NTN SERVICES

With Palerm's reality check in mind, let's break down some of the factors that will impact the potential of the NTN market.

First of all, the technical issues are still very much being worked out. "Satellite is tough, because space is tough," said David Witkowski, founder and CEO of telecom engineering consulting company Oku Solutions. He cites two main challenges in satellite, both related to the uplink. First, "it's easy for a satellite to broadcast a ton of data down to the ground. It's a lot harder to get satellite data back to orbit," he explained. In a direct-to-device context, only having the output power of a typical smartphone to reach all the way to a fast-moving satellite in space, makes this particularly challenging. The other aspect is uplink contention. Satellites, particularly GEO satellites, cover a huge swath of the Earth at once, far more than any single terrestrial base station sector—with, potentially, the ability to "hear" hundreds of thousands or millions of devices requesting authentication and/or service. Ground terminals also need to have a clear view of the sky in order for services to work; Apple's Emergency SOS actually assists users in keeping their devices pointed at a satellite to ensure that they make and keep a connection.



(Apple's Emergency SOS guides the user in keeping the device pointed at a satellite. Image: Apple.)

Hand-in-hand with the technical issues is that putting anything into space is expensive, and you have to painstakingly get everything right before the equipment goes into space. As a result, says Jani Tolonen, product manager for Keysight Technologies, more and more of the test process is becoming digital: Using digital twins/virtual RF surroundings to work on initial integration and test relationships with virtual base stations and create virtual RF streams from virtual satellites over 400 miles up. "You can put up instances that do everything that a full-blown base station does, in real time. You can treat that like it was a real thing," Tolonen says. And as hardware gets developed, he explained, subsystems of the test scenario can be replaced with actual hardware: Devices, base stations, even satellites, to ensure that the end-to-end communications work before launch.

While costs have come down substantially with the development of smaller satellites, the emergence of LEO technology and the reduction of launch costs a la SpaceX, the expenses associated with space are still daunting.

"It takes a person to really have the sheer hubris and large amount of money to be able to throw at the problem," says Witkowski. The obvious example there is Elon Musk and the success of SpaceX and Starlink, the latter of which Jeff Bezos' Amazon hopes to replicate with its Kuiper LEO service (which Amazon expects to spend more than $10 billion on). Apple, too, has deep enough pockets to spend hundreds of millions of dollars to have Globalstar provide a network for a service that is currently offered to end-users for free. It remains to be seen whether new kids like AST SpaceMobile, Lynk and Skylo can build profitable long-term businesses.

"It really is like a gold rush, with everybody trying to figure out to to get on board, how to get the benefits of being one of the first ones," said Tolonen, in describing the state of the NTN landscape.

But is there—or will there be—enough gold to go around? Matt Desch, CEO of Iridium Communications, cautioned that the business models aren't yet clear for direct-to-device, converged services, even as they start to emerge. Is there a sharing of infrastructure and launch costs as well as service revenues? How is money being made when, for example, new satellite-based services are being offered to consumers for free? "Nobody still knows how money will be made in [direct-to-device]. That's one big question I keep asking," said Desch. He added: "Everybody wants to wait and see how good it is, because they don't know what it will be priced until they know what the user experience will be, and we can't exactly tell them because we can't exactly architect that well ahead of time. There's just a lot, a lot of questions right now. It's coming together, it's inevitable—it's just taking time more than anything else."

(Images courtesy of 123RF)

Greg Pelton, CTO of Iridium Communications, also questioned how much of a market there truly is for expanding terrestrial coverage with space-based cellular connectivity–between consumer, enterprise and government use cases, how many new market entrants can actually be sustained? Pelton expects there to be inevitable, long-term consolidation of the multiple new market entrants who are taking advantage of the new environment of lower launch costs and the ability to offer LEO satellite-based services at a relatively low cost with a relatively fast time-to-market compared to historical norms in the satellite industry.

"The business model [for satellite] is tough," said Armand Musey, president and founder of Summit Ridge Group, which focuses on financial and business valuation in both the telecom and satellite industries. "You have to cover the whole globe, which two-thirds is water, and on top of that, a big chunk of it, including China and Russia, are really tough markets to get into." He includes India and Brazil as large markets that are challenging to enter. But if a satellite-based service covers the entire world and can only draw on customers on a small percentage of the Earth's surface, can it build a viable business?

Part of the business case debate is in whether the profit more likely lies with billions of consumer users, or in the enterprise IoT space. A NTN Summit panel at MWC Barcelona concluded that enterprise is the more valuable opportunity, although it will be a balance between both markets. A variety of businesses are interested in better coverage and connectivity, panelists said, and the combination of cellular + NTN promises both the reach of satellite, with the opportunity to switch to lower-cost terrestrial cellular when and where it is available—lowering the overall cost of solutions for use cases such as asset tracking, logistics, fleet tracking and telematics, and so on. And as Comtech President and CEO Ken Peterman put it in remarks at the NTN Summit, once businesses get access to the type of data that helps them refine their operations and reduce costs, "They will want more, and they will want more."

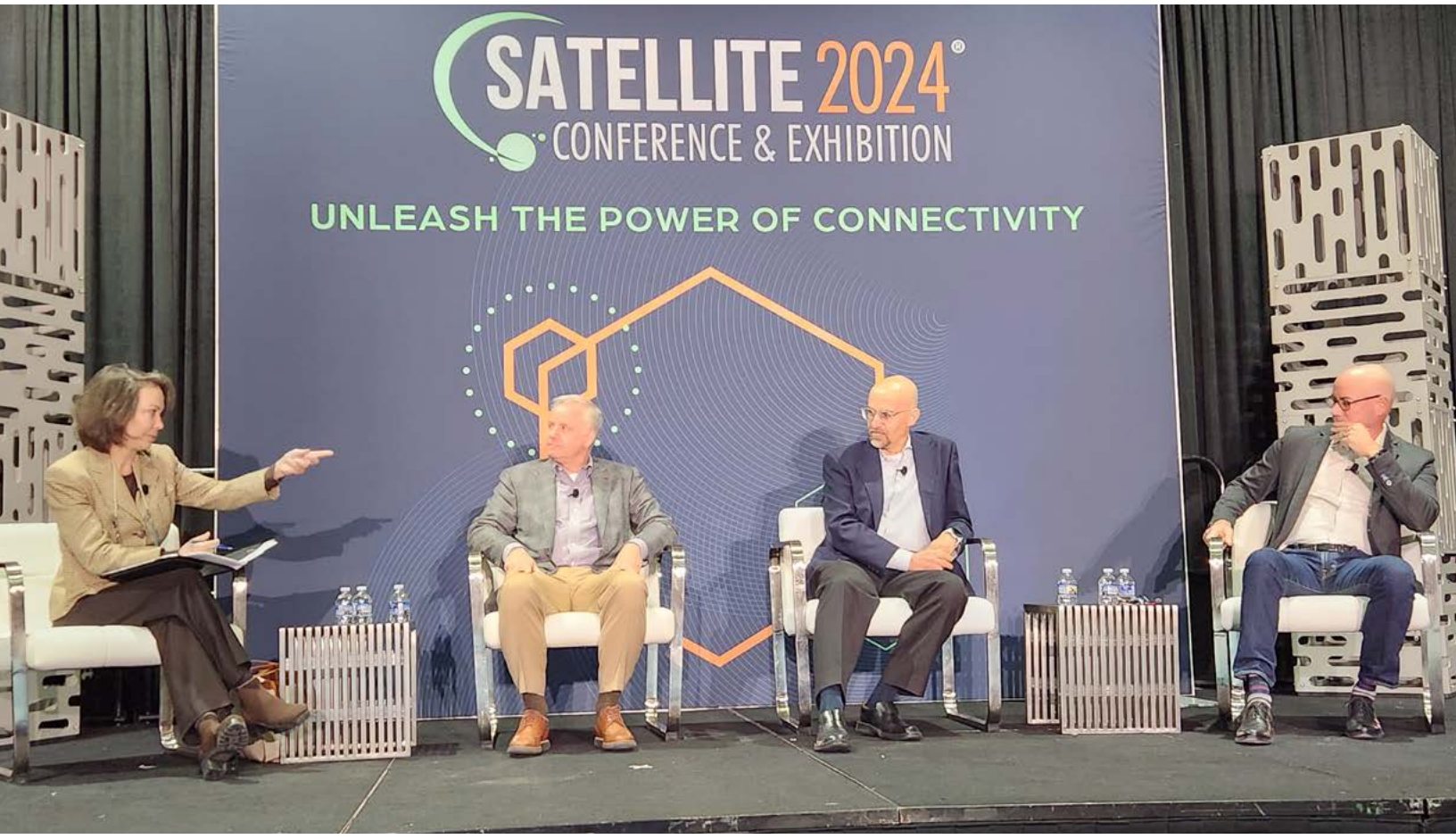
(Images courtesy of 123RF)

However, Musey cites the example of long-time cellular and satellite IoT provider Orbcomm as a rare success in the satellite IoT space that has survived in spite of a "long, hard slog"; Musey cites challenges for satellite IoT that include long sales cycles and verticals with highly specialized demands in terms of tolerance for heat, cold, water exposure, vibration and so on. "It's a very tough market, and at the end of the day, the average price is very, very low. The average monthly fee is very low," he added. If module and service prices go up with 5G NTN, it may not be able to compete—especially if the service level is on-par with current satellite capabilities.

And as much as the satellite ecosystem is interested in the potential market opened by embracing 3GPP standards, speakers at Satellite 2024 also expressed some wariness about no longer being able to compete on the basis of technology, rather than price. This is an industry used to dealing with government and defense customers around the world who are accustomed to prioritizing making something work and aren't particularly price-sensitive. Another wrinkle is that many of the potential use cases cited for 5G NTN, such as connectivity for ships and airplanes, are already provided by satellite companies. Are they going to be willing to potentially cannibalize their own enterprise businesses to partner with terrestrial service providers to get a slice of a price-sensitive consumer market?

Maybe, if the consumer market is actually big enough. If there was one thing that was clear at Satellite 2024, it was that serving even a small slice of the wireless consumer market would be a step-change in scale for the satellite industry.

"The breakthrough in the last few years has been satellite to the phone in your pocket. That's the big change," said Dan Dooley, chief commercial officer of Lynk Global, in a session at Satellite 2024. Asked about the potential size of the market, he said that 25% of the 5.5 billion phones in service experience intermittent connectivity interruptions and estimated another billion people who have no connectivity at all—which, combined, he pegged at a $300-$400 billion business of being able to serve devices that already exist and could be connected via NTN.



An NTN panel at Satellite 2024 featuring Dan Dooley of Lynk Global (center left) and Francesco Grilli of Qualcomm (center right).
Image: K. Hill/RCR Wireless News

"Direct-to-device is something that is probably more interesting to the satellite industry than the wireless industry," said Musey. "The relative size of the two groups is very different."

It's difficult to make an apples-to-apples comparison across the two sectors, but satellite operators, when they report connections, often count subscriber bases in hundreds of thousands of connections, rather than tens or hundreds of millions. Another comparative example: Viasat, one of the largest satellite operators and which recently merged with Inmarsat, reported $2.56 billion in revenue for its fiscal 2023. Comparatively, the smallest national U.S. operator, T-Mobile US, reported $78.56 billion in revenue for the full-year 2023. So capturing even a few percentage points of that revenue is an attractive opportunity for satellite—and percentages that cellular players don't want to lose to their competitors.

"I think the main business is going to be in integrating this in the mainstream chipsets for the mainstream smartphones," said Grilli of Qualcomm during Satellite 2024. He pointed out that in the cellular market, "Even a tiny change in market share for an operator or a handset manufacturer could mean hundreds of millions of dollars in difference in their revenue and profits." He sees NTN as important for competitive advantages among handset manufacturers (as indeed, Apple seems to be using it) and for carriers.

Musey agrees once one carrier in a geography has that kind of feature, competitors will feel pressure to follow suit—and he thinks that people will be willing to pay high rates for even low data-rate, on-demand emergency connectivity. Maybe they won't pay ahead of time for a monthly plan, but when they're on the roadside or in the backcountry trying to make a call that won't go through? Suddenly even basic connectivity is highly valuable.

Grilli said that he believes that once people get basic emergency messaging from anywhere, they'll want to send pictures. And make calls. And eventually, use higher-speed data services. Grilli sees a progression for satellite much like cellular connectivity evolved from 2G to 3G to 4G to 5G as consumers demanded more and more speed and capability. "We have barely scratched the surface with messaging service," he said.

(Images courtesy of 123RF)

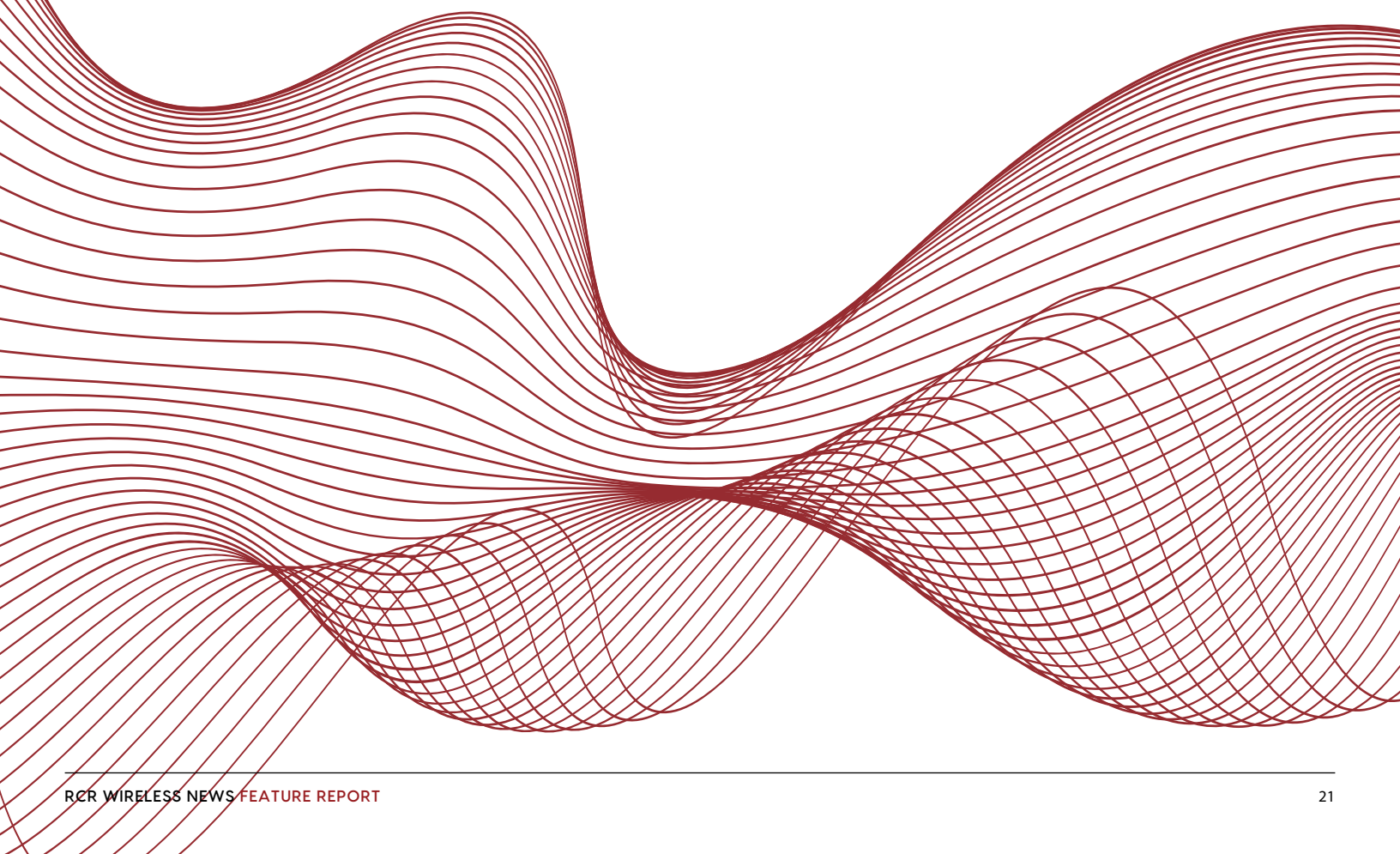
Parth Trivedi, CEO and co-founder of wholesale satellite connectivity service provider, Skylo offers up three potential options for go-to-market strategies for MNOs to build a consumer NTN business. First: A "connectivity insurance" model, where customers pay a monthly fee in exchange for a guarantee that they will always have access to at least a basic level of service. He points out that this isn't necessarily limited to people who venture into remote areas. "To me, it's not just about Death Valley, or Utah. This is about holes in coverage also in the suburban areas and in areas that you wouldn't expect, in an RF-dense environment like the Bay Area. This ensures a consistent layer of connectivity around the planet." A second option would be to bundle that service into an operator's most premium rate plans. A third way would be entirely usage-based, similar to how carriers charge a per-day rate or usage rate when a user is roaming internationally. "There's no particularly right answer," Trivedi says—or at least, not one that is obvious quite yet, in a nascent market.

Another possibility for making the numbers work on NTN involves utilizing LEO capabilities and broadband-capable dishes that don't have the limitations of smartphones, for infrastructure expansion—5G NTN used to expand 5G terrestrially, an extension of the traditional satellite backhaul paradigm. Keysight's Tolonen points out that satellite-based services offer the possibility of global networking capabilities without the enormous cost that it would take to build out a comparable terrestrial network composed of hundreds of thousands of miles of fiber and large numbers of base stations.

During a panel at Satellite 2024, Hamid Akhaven, president and CEO of EchoStar (which now is the parent company of Dish Wireless and its terrestrial 5G network) likened the current situation of satellite and cellular convergence to the early days of cellular, when only a few potential users, like Realtors, were seen as a viable target customer for the technology. "History has shown that when you give people something that they know how to use, they will find many ways to take advantage of it," he reflected.

As business models are being hashed out and partnerships are being negotiated, another observation comes from Mark Dankberg, CEO of Viasat. Dankberg said that based on his company's experience in providing Wi-Fi on planes, Viasat learned several lessons: That demand varies wildly based on price. That the usage profile is largely the same as terrestrial use. And that you have to figure out a strategy that is not only good for the end user, but other players such as the airlines who are part of providing the service or mobile network operators who may want to provide connectivity on the plane for free to their customers.

He expects that the same factors—pricing, usage and advantages for ecosystem partners—will also shape satellite/cellular convergence.

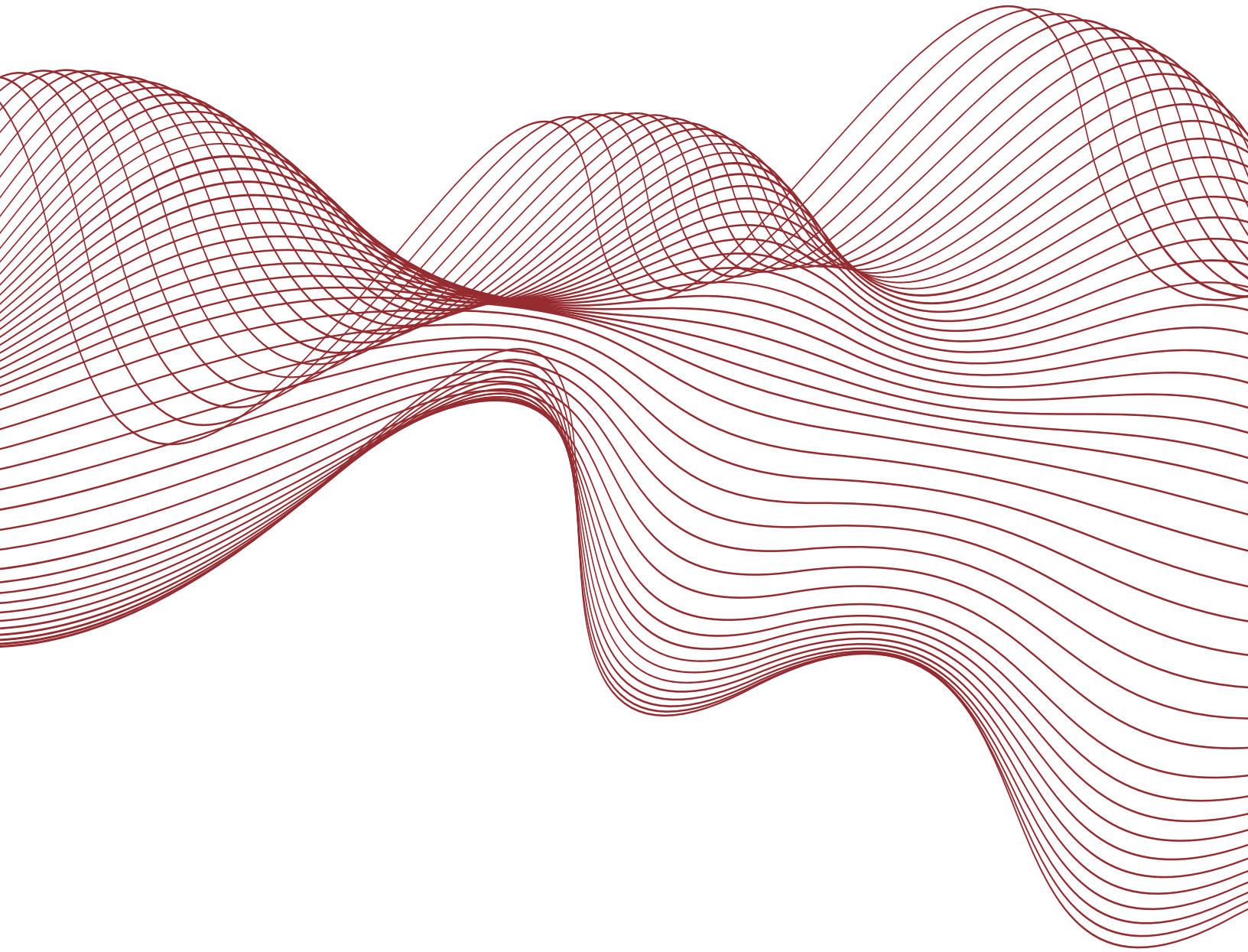


KEY TAKEAWAYS:

- Spurred by 3GPP NTN standards, new opportunities for convergence are opening up for the cellular and satellite worlds.

- There are significant technical challenges associated with NTN, and initial services serve use cases such as emergency messaging. As standards work progresses, higher performance and additional services are expected to be able to be achieved.

- Both satellite and cellular company are striking deals to position themselves in this emerging market, but business models and revenue streams are still emerging.



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