AST SpaceMobile, Inc. (ASTS)

Unconnected from Reality

We are short shares of AST SpaceMobile, a $1.8bn satellite company trying to sell the dream of connecting billions of people with mobile broadband directly to their phones from space, but without a credible ability to bring that dream to reality. A 2021 SPAC, AST features a satellite design that is destined to fail, unsurprising given management's uninspiring backgrounds, and a business case that makes little sense in nearly all respects, whether one scrutinizes the end markets it's trying to monetize, its brutal competitive landscape or how it can ever justify its massive initial capital costs. Naturally, given how daunting the company's end goal is – operating a constellation of hundreds of giant, complex satellites that will provide fast, reliable mobile internet globally – management keeps pushing out the projected timeline of when it could conceivably provide any sort of viable service. Yet the stock has nearly doubled in the past few months, due to the launch of a test satellite that hopes to merely demonstrate that a simplified version of the ultimate theoretical satellite can provide internet connectivity. AST is an ambitious, wildly risky science project that has no business (literally) being public – only the SPAC bubble of 2021 could have managed to change its destiny from being a forgotten zero tucked away in a few venture capital funds into what is rapidly becoming a classic stock promote.

AST's vision is to be the first space-based cellular broadband network that connects directly to any mobile phone, providing service to people when out of the range of terrestrial networks. To pull off this feat and test its technology, AST recently launched a prototype, BlueWalker-3 (BW3), into orbit. In the next 2 weeks, BW3 will begin a critical step in its mission: delicately unfurling its massive, 64 square meter phased antenna and solar array, the largest ever commercial communications array in space. Few entities beside NASA have attempted to deploy anything similar. Despite being larger than a 3-car garage, BW3 is only a few inches thick – a design which alarmed multiple experts we spoke with owing not only to its "terrifying" size, but also its "infantile" demonstration of structural and thermal engineering soundness. AST will be operating BW3 without the benefit of reliable testing of full deployment of the array beforehand. Unfolding far simpler arrays by organizations with significantly more funding, preparation, engineering firepower, and space heritage than AST have still resulted in mission failure.

Even if AST passes this critical test, the obstacles to establishing a viable business model are massive. BW3 is an experiment. The production version of what AST needs to fulfill its vision, a satellite class named BlueBird-1, is anticipated to be a staggering *8x larger* than BW3. BlueBird-1's capabilities are what underpins street models, what management promotes on calls, and what retail investors have pinned their hopes on. The unsettling reality, however, is BlueBird-1 has fallen two years behind initial promises, with management recently pulling guidance on when this much-hyped satellite will launch. Our checks strongly suggest the constellation will continue to see further rising costs and launch schedule delays – setbacks that AST can ill afford given the entrance of fast-moving competitors in SpaceX and Apple. The backdrop for all this is a TAM we believe is overstated and difficult to penetrate, with niche use cases that are hard to monetize for populations currently covered by terrestrial cellular networks and an underserved population that while large is nearly impossible to monetize for a host of entrenched, socioeconomic reasons.

Investors were initially told that proceeds from the SPAC meant financing risk would be "substantially eliminated." A year and half later, the company needs additional funding just to get commercial operations off the ground. The company's ridiculously optimistic financial forecast called for $1bn in EBITDA in 2024; in reality, P&L will likely be deeply negative. *Billions* must be spent to achieve full global coverage and the company will likely continue issuing dilutive equity (it sold stock at an implied ~$6.50 earlier this quarter and announced a new $150m at-the-market equity facility on September 8). A successful demonstration of a singular prototype will not magically transform technology cooperation agreements with mobile operators into contracted revenue. Retail investors who busy themselves poring over the technical specifications of a long-delayed test satellite, without verifying management's claims with independent experts on satellite technology, are unconnected from AST's financial reality.

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Executive Summary

Fundamental design and engineering concerns surround AST's spacecraft. Interviews with a wide range of experts in satellite design, supply chain management, and manufacturing yielded overwhelming skepticism regarding key aspects of BW3. A massive antenna is needed to establish a link between space and a consumer device, but the satellite appears to have focused on this requirement at the expense of sound structural dynamics and thermal engineering. AST is about to deploy an extremely complex, unusually designed array – all without prior experience and accurate testing of the fully deployed structure beforehand.

AST will likely struggle to provide reliable service. According to analyses performed by a leading expert and author of textbooks on RF engineering and satellite communications, BW3 may be able to connect to a cellphone when conditions are perfect, i.e., in a field without any nearby tree trunks or buildings or while stationary in a car, but fail to deliver reliable service indoors and in other real-world environments – and that's assuming the satellite works perfectly. Dropped calls and interrupted streaming would lead to frustrated users, undermining a business built around delivering broadband and being "connected everywhere."

Expect BlueBird-1 program to witness further rising costs and delay. BlueBird-1, the satellite which underpins AST's planned global constellation, is running 2 years behind schedule and checks indicate that challenges continue to mount. According to a supply chain consultant who reviewed an AST bid package for parts critical to unfolding the array, AST's engineering was so "immature" that his highly qualified client no-bid the business. A former AST employee informed us the company's forecasts for projected constellation costs assumes cheap launches using SpaceX's Starship. With Starship's launch date still uncertain and SpaceX's recent announcement that it will pursue its own competing direct-to-device ("D2D") offering, we expect the BlueBird-1 program to suffer further setbacks.

SpaceX and Apple pose growing competitive threat. Having two of the most innovative, resource-rich companies on the planet offer D2D solutions within the U.S. for free – even if those initial services are very basic in nature – should be viewed as a worrisome development for shareholders. Whatever technological and competitive positioning AST perceives itself to have can be quickly eliminated by both.

Confidence in MOUs as a competitive moat is misplaced. Most Memoranda of Understanding (or MOUs) promoted by the company, and cited inaccurately as securing an unassailable competitive moat by retail investors, are little more than non-exclusive, non-binding, non-financial technology and regulatory cooperation agreements. According to someone familiar with one of the largest signed MOUs, the agreement was simply about keeping abreast of emerging technologies, with expectations of actual success being nil.

AST is bleeding cash and execution has been absurdly poor, even for a SPAC. AST originally claimed cash proceeds from the SPAC transaction would be sufficient to fund operations through the launch of 20 Phase 1 satellites. AST told investors financing risk was "substantially eliminated." Incredibly, only 18 months later the company no longer has enough cash to fully begin commercial operation. Two years ago, AST management felt it was acceptable to issue projections that called for $1bn in EBITDA and zero capex in 2024, while we estimate EBITDA and FCF will be deeply negative for years. AST needs to spend billions to reach full global coverage and has little choice but to issue highly dilutive equity at every chance it gets. Early in the current quarter it sold shares at implied ~$6.50 (~35% below current), which has been followed up with a $150m at-the-market equity facility earlier this month.

Company Overview

AST SpaceMobile Capitalization and Summary Forecast

$ Millions except per share data	
ASTS Share Price	$9.85
Class A Common Shares	53
Class B Common Shares	52
Class C Common Shares	78
Total Shares Outstanding	183
Total Equity Value	$1,802
Long-term Debt	$5
Less: Cash	(229)
Net Debt	(224)
Enterprise Value	$1,577

Financial Summary ($ mm)

	2022E	2023E	2024E
Total Revenue	$10	$0	$14
Total Opex	(133)	(140)	(125)
Total EBITDA	(123)	(140)	(111)
Total Capex	(100)	(112)	(305)
FCF	(223)	(252)	(416)

Source: AST SEC Form 10-Q, Kerrisdale analysis. Cash pro form net proceeds from of sale of Nanoavioncs and sale of sale of 1.16m Class A shares after 2Q22.

Founded in 2017 by Chairman and CEO, Abel Avellan, AST SpaceMobile is a satellite designer and manufacturer headquartered in Midland, Texas. AST aims to deploy a first of its kind constellation of 168+ high-powered, large phased-array LEO satellites that will provide voice and high-speed data directly from space to standard mobile handsets (“D2D” or Direct-to-Device). AST’s “super wholesale” business model involves partnering with mobile network operators (MNOs) to gain access to local terrestrial markets and spectrum, while avoiding the burden of substantial customer acquisition, marketing, and other infrastructure costs. Once its network is fully deployed, AST hopes to earn high-margin revenue through 50/50 revenue-sharing arrangements with its MNO partners. To date, AST has executed commercial agreements with Vodafone (610m subs) and AT&T (200m subs) that are conditioned upon buildout of network coverage. AST also has non-exclusive, non-binding memoranda of understanding (MOUs) with roughly a dozen large MNOs (e.g., MTN Group, Telefonica), predominantly in developing markets, to collaborate on technology and regulatory efforts.

AST’s service is intended to be seamless and transparent to the end-user and their devices (see Appendix I for depictions of the network and mockups of how it may interact with customers). Users will be able to access the SpaceMobile service when prompted on their mobile device that they are no longer within range of land-based facilities or will be able to purchase a plan directly with their existing mobile provider. Though the range of plans and price points will vary by partner / country / region, AST contemplates offering service for already-connected populations on an ad hoc / one-off basis as well as on an ongoing basis for a recurring monthly charge. In addition, AST hopes to provide service to populations completely uncovered by terrestrial.

On September 10, AST launched its 1,500kg BW3 test satellite. Over the next 2 weeks it will undergo in-orbit testing and begin unfurling a 64 square meter phased array antenna. If successful, it will be the largest commercially deployed array in space. The production version of BW3, BlueBird-1, is expected to be twice as heavy and have a ~400 square meter aperture. Phase 1 of AST's global constellation originally involved 20 BlueBird-1 class satellites placed into equatorial orbit to begin generating revenue in 2023. The initial 5 Bluebird-1 satellites (Block 1) were to be similar in size as BW3 but built with enhanced BlueBird-1 technology. After a series of delays blamed on supply chain woes, AST's revised plan now calls for Block 1 to be modified versions of BW3, with BlueBird-1 satellites to follow at an unspecified later date.

AST was taken public via a SPAC merger with New Providence Acquisition in August 2021 at a pro forma equity valuation of $1.8bn. Like other NewSpace SPACs, AST has massively underperformed projections and timelines provided when coming public (See Appendix II). AST has not generated any revenue from SpaceMobile to date. In the highly unlikely scenario where AST can stick to its latest launch schedule, the Company believes it would begin generating revenue with intermittent service in 2024. Its SPAC forecast originally called for $1bn in revenue in 2024.

AST has burned through shareholder capital at an alarming rate since coming public. Despite originally claiming that its $400m+ in cash proceeds from the SPAC transaction would be sufficient to fund operations through the launch of Phase 1 commercial operations, on its last earnings call AST confirmed it would need to raise additional capital *prior* to entering Phase 1 service and is exploring a range of funding options. In June 2022, the company filed a mixed shelf for $500m of debt, equity and preferred securities. The company has a $75m committed equity facility in place with B. Riley Principal Capital, LLC. From June 30 to August 5, 2022, AST sold 1.16m shares under this facility at roughly $6.50 per share (~35% below current prices).[1] On September 8, this was supplemented with a separate at-the-market Equity Distribution Agreement with B. Riley Securities and Evercore to sell up to $150m in common stock. Given the company's ongoing cash needs, any near-term capital raises would likely be a piecemeal approach to funding operations. To achieve AST's goal of 168 satellites with full global MIMO, we estimate it will need to spend well over $3bn in satellite related manufacturing and launch capex alone.

Prior to AST, Avellan was the founder and CEO of Emerging Markets Communications, a non-facilities-based reseller of satellite communications services to maritime and other mobility markets – not a company that built and launched constellations of satellites. CFO Sean Wallace joined AST 5 months ago, prior to which he was CFO of Cogent Communications, a large internet backbone and collocation services provider. Chief Strategy Officer Scott Wisniewski was a former TMT banker at Barclays. CTO Dr. Huiwen Yao was previously the Senior Director of Commercial Payload/RF Engineering for Northrop Grumman, working primarily on GEO satellites. None of the members of senior management have sufficient experience in the design, construction, operation, financing and large-scale manufacturing of phased-array LEO satellites. Neither do any members of the company's Board of Directors.

[1] *SEC Form 10-Q, page 16.*

Design and Deployment Challenges Pose Existential Risk

> *"The problem with AST SpaceMobile is the structural dynamics of their spacecraft – the way they intend to build a giant phased array antenna is really poorly thought out…their knowledge of structural dynamics is so positively infantile; I don't know how they got as far as they did.* ***I think their approach to making a giant antenna just won't work. I think even if you could talk directly to a handset from space, they wouldn't be able to do it.****"*
>
> — *Physicist and Former Senior Engineer, NASA's Jet Propulsion Laboratory*

> *"The size of the antenna is terrifying…there's only a handful of entities that have deployed a foldable thing in space that big and they're NASA and intelligence entities…****it's an extremely difficult thing to do and it's also more or less impossible to accurately test on the ground.****"*
>
> — *Former Director of Engineering at SpaceX, led team of 150 engineers across multiple disciplines*

> *"****Some of the preliminary engineering that I've seen did not have the same tolerances I would expect in a zero gravity deployment space environment*** *and the number of single point failures in the articulation on deployment; all of those factors…talking about risk to the company, you're betting everything on that one demonstration…all of that is riding on a hundred different opportunities for the phased array to not deploy."*
>
> — *Former Director of Supply Chain for leading defense prime who reviewed engineering designs for the phased arrays of BW3 and BlueBird-1*

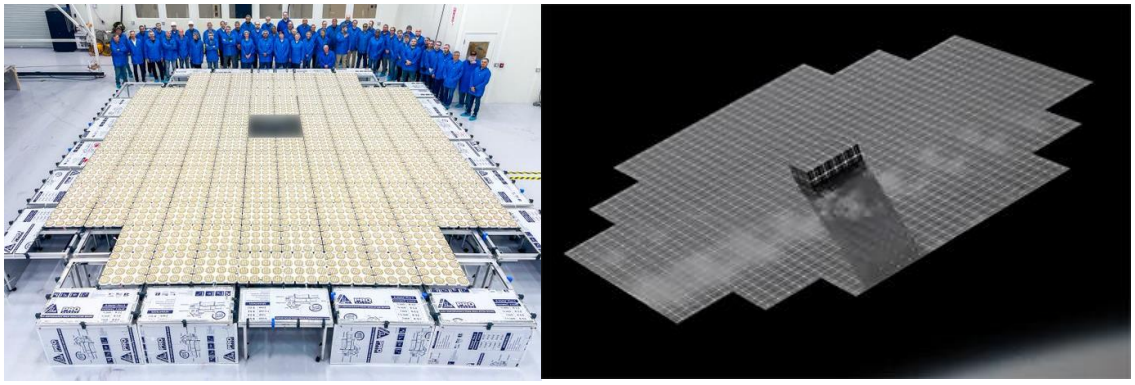
Much of the technical due diligence we have come across on investor blogs and social media has focused on the ability of BW3 and BlueBird-1 to establish a communications link with a mobile phone from space. Unsurprisingly, taking technical specifications from AST at face value and running it through formulas found in any RF engineering textbook confirms that, indeed, no laws of physics have been broken, and a connection can be established (though later in the report we question how reliably). What these analyses generally overlook is whether a satellite design that by necessity must solve for producing enough power and gain to connect to a handset, has done so at the sacrifice of other equally important engineering disciplines as it hurtles at 17,000 mph through the harshness of space.

During interviews conducted with a range of experts in spacecraft design and manufacturing, we encountered a wall of skepticism regarding numerous aspects of AST's unusual satellite design, chief of which are its structural dynamics and thermal management.

Bigger Is Not Always Better in Space

To overcome the challenge of communicating with a small antenna in a standard consumer mobile phone on the ground, AST built a massive 64 square meter antenna in space. While AST supporters on Twitter crack jokes about the impressive size of this satellite, the truth is the extremely large, but only inches thick, planar nature of BW3 and BlueBird-1 has raised serious engineering concerns within the space community.

AST SpaceMobile – BW3



Source: AST SpaceMobile

According to a former JPL physicist with specific expertise in the structural dynamics of large spacecraft, AST's spacecraft possesses neither the rigidity nor the active controls needed to avoid positive feedback and uncontrolled oscillations as the satellite rotates and orbits the earth every 90 minutes. A magnetorquer or torque rod is a device that interacts with Earth's magnetic field to provide the satellite attitude control and stabilization without having to use fuel. Based on descriptions of BW3 filed with the FCC and management comments, each element of AST's array is more or less identical, and individually controlled torque rods are distributed across the entire array service. Rather than working to keep the mosaic stable and flat, however, as the filing states, in the opinion of the physicist AST's configuration will result in hundreds of independent torque rods constantly firing, causing a magnetic tug of war as panels push and pull against one another. In that situation, BW3's lack of a large backing truss to provide tension and balance would cause the contiguous, hinged array panels to "flap." If the whole antenna structure cannot stay rigid, the ability to form a consistent beam on its target becomes compromised. Even more ominously, as described by the expert, "I'm worried that [the satellite] will shake itself apart and create a giant cloud of debris that will last for 10-15 years and I'm not usually a big space junk worrier."

But what of AST management's exhaustive testing claims? Surely during the "over 800" tests the company performed, it was able to fully test the structural integrity of a fully deployed satellite? As captured in the quote at the start of this section from a former SpaceX engineer (and echoed in multiple other interviews), accurate environmental testing of a fully deployed satellite as large as BW3 (let alone a satellite 8x bigger in BlueBird-1) is virtually impossible on the ground. AST may have laid out the panels (as depicted above) and suspended the satellite, but it would not have been able to test the deployment of the panels while the satellite was

moving in a simulated zero G environment. BW3's panels and the componentry used to unfurl them are designed to fold out origami-style in space, not against whole earth gravity. According to the former SpaceX engineer, AST may have conducted tests by using wires and counterweights to unfold panels but even if these rigs were cleverly devised, this form of testing is never particularly accurate in recreating the conditions of deployment in space. In summary, a 2021 vintage SPAC that has failed every deadline and financial forecast will attempt to deploy and operate an array very few entities have ever even attempted, with little directly applicable experience, and without accurate testing of the structure beforehand. Good luck.

Thermal Management Concerns

> *"When I look at this AST spacecraft [BW3], I don't see this as a spacecraft that is going to function well because it's going to start overheating…so you can't have it on for very long and so at that point, what are you proving?"*
>
> — *Former Senior Spacecraft Systems Engineer, OneWeb. 16 years of professional experience in the design and development of spacecraft and space flight hardware.*

Based on input from engineering consultants, BW3 has a ~20 kW solar array on the back (non-Earth facing) side of its phased array – a massive amount of power for a relatively small satellite bus. To place this figure in context, 20 kW is the same level of power as a 6,400kg GEO satellite like ViaSat-3. Why this poses a problem for BW3 is because large amounts of electrical power in space generates heat. A spacecraft on orbit is essentially a toaster that must dissipate heat or risk melting components, hardware, and breaking down. GEO communications satellites operate their payloads 24/7 and employ large 4-6m radiator panels to manage this thermal load. To our knowledge, no description of any such panels exist for BW3. For a spacecraft like BW3, industry consultants we spoke with expressed doubt over whether it could dissipate enough heat unless it operated its payload for only brief periods, perhaps as low as 5-10% of its orbit before shutting down. But this raises other additional questions. Beyond quickly operating the satellite as it passes over a ground station to see if it connects, how useful are test results from a satellite that must be operated in such a manner? If BW3 has this level of engineering concern for something as fundamental and critical as heat dissipation, what does it imply for potential design changes to a 2x as heavy and 8x larger BlueBird-1? Starlink can afford to be thermally inefficient – its constellation blankets the sky with satellites, if a few fail it hardly matters. AST does not have that luxury in its constellation plans. It has effectively put all its eggs in one untested, questionably designed (and apparently liable to melt) basket – meaning early failures could be devastating.

SpaceMobile Service Will Not Work as Hyped

To answer the question of what kind of signal quality BW3 and the 1st block of Phase 1 can be expected to provide, we solicited the expertise of a highly regarded satellite communications expert who has literally written the book on radio frequency interference and satellite communications (technically, 8 books). The reliability of a signal in RF telemetry is a function of the level of power in excess of that required for a specified minimum level of system performance, referred to as fade margin. Think of it as a margin of safety or buffer that guards against signal loss in the event of a temporary attenuation (i.e., walking inside a building) or fading of the received signal power caused by the surrounding environment.

Based on a detailed analysis of the technical specifications BW3 and the testing AST intends to conduct filed with the FCC, along with certain assumptions needed to complete the exercise made by the expert who has run analyses such as this for the better part of 30 years, the D2D link between an iPhone and the satellite using ~850 MHz spectrum would have a fade margin of 19.1 dB (derived from: received carrier power from the satellite antenna of -113.5 dB and receiver sensitivity of -132.6 dB).

For the non-RF engineers that have made it this far in the report, a fade margin of 19 dB is respectable. It's enough to penetrate glass, brick, even concrete if not too thick. Assuming BW3 doesn't experience immediate failure, we wouldn't be surprised that one day there will be a picture of Avellan, probably outdoors, holding his iPhone just-so on an open expanse of land in Texas, giving the thumbs up as his device connects to a satellite in space. The problem with this level of fade margin however is that unless one is standing outside on flat land positioned under the broadside of the satellite and not at the edge of coverage, and without any nearby tree trunks, hills, or buildings, or in a car that's stationary, or even if one's head is positioned the wrong way – that margin of safety can get chewed up in a hurry. Translation: reception will be highly dependent on where you are and what you're doing – which is problematic because isn't AST supposed to be "connected everywhere"? If one wants to send a non-urgent text message, drops and interruptions are probably fine. If one wants real-time communication (the vast majority of cell phone usage in developing markets is voice calls) or to download/stream video, that will frustrate users. Lastly, 19 dB makes the critical assumption that the satellite works flawlessly which, as we have argued, is far from likely. So, can AST physically connect to users in the various ways it has said? Technically, yes. Can AST do it in a way that people expect their cellphones to work and how AST itself promotes its technology solution? Not according to the guy who wrote a textbook on it.

BlueBird-1 Delays and Phase 1 Changes Raise Red Flags

BlueBird-1 Development Likely to Fall Further Behind

In December 2020, AST stated its goal was to have 20 BlueBird-1s in orbit by the end of 2022. This would then be followed by 90 more by the end of 2023 to begin generating meaningful EBITDA ($130m according to the original SPAC presentation). In the very first earnings call after closing the SPAC, those ambitions were scrapped. In August 2021, Avellan lowered the target to launching only "a handful" of BlueBird-1s by year end 2022. More recently, in May of this year, Avellan stated, "We anticipate that our next launch after BlueWalker 3 would be a BlueBird satellite…" That guidance was also short lived. On last month's earnings call, AST made yet another significant change to Phase 1. In addition to raising the cost projections for

the Phase 1 constellation by 14%, AST announced the first five satellites would no longer be BlueBird-1s, but rather upgraded versions of the BW3 test satellite – a satellite bus that AST had stated in the past was not intended for commercial service.

These first five upgraded BW3s are now scheduled for launch in late 2023 when it will begin intermittent service. When asked about the timing of satellites beyond this first block, satellites that investors should rightly expect to be the long-awaited BlueBird-1s, Chief Strategy Officer Scott Wisniewski declined to give any guidance whatsoever. Furthermore, according to a report published after 2Q earnings by space industry analyst, Chris Quilty, management's plans to launch the Phase 1 into equatorial orbit are also "now in question."

So, to summarize: BlueBird-1, the foundational satellite for AST's planned global constellation which underpins every analyst model, is roughly 2 years delayed, with the company providing limited transparency on quantity, timing, cost, or even eventual orbital location. Given the changes to the composition of Phase 1, it was reasonable for an analyst on the last earnings call to inquire about satellite capacity and what affect these changes may have on performance. However, when Avellan responded, he only gave details for the "production satellite" i.e., the drawing board version of BlueBird-1. When asked point blank to provide a ratio of throughput between BlueBird-1 and BW3 – in other words, to compare what AST has set a launch date for with the satellite actually needed to close its business case – Avellan dodged the question. The stonewalling, evasion and general lack of transparency simply speaks to how poorly the program is developing, and the company's growing difficulties in bringing Bluebird-1 to fruition.

Based on conversations with consultants in the space supply chain, we believe BlueBird-1 development will continue to incur higher costs and lengthy delays, all while a spacecraft with BW3's inferior capabilities, initially meant to conduct a trial run, replaces the original dream sold to investors.

(Im)maturity of Engineering

Our research into BlueBird-1's development uncovered three areas of concern: the maturity of BlueBird-1's engineering design plans, the cost and availability of solar panels, and the cost and timing of launch services.

As far back as last November, AST described ramping the procurement process for BlueBird-1. Indeed, our checks confirm that Requests for Information (RFIs) went out in the first quarter of this year for key components in BlueBird-1s phased array. The components encompassed a variety of small, high precision, but not mechanically complex, parts made from 7075 aluminum (an aluminum alloy commonly used in aerospace engineering) needed to articulate the array from folded to a straight position.

According to a former Director of Supply Chain for a leading defense prime who evaluated AST's RFI and provided consulting services on them to a pre-eminent precision component manufacturer, AST's request and mechanical drawings for the parts and array were woefully "immature." According to the consultant, with experience overseeing all supply chain aspects for multi-billion space programs, concern over the "maturity of engineering" from AST was a key reason as to why his client, a highly qualified and well-resourced machine shop, declined to bid on the project. Worrisome engineering for a critical piece of AST's array that was bound to encounter problems was simply not worth the hassle. We believe that when AST cites "supply chain disruptions" as a contributing factor to delays there is a tendency among investors to assume these are temporary factors entirely outside of AST's control, such as shipping delays

or raw material availability. Our diligence suggests a contributing reason for repeated delays and cost overruns is fundamental engineering and design issues, which any veteran aerospace defense investor knows typically take much longer and cost more to resolve.

Launch Costs and Availability Are Not Going According to Plan

> *"What AST is banking on now is SpaceX is building this new launch vehicle called Starship… it's going to be this huge launch vehicle that can launch up to 14 or 16 of the designed AST satellites…the cost of that launch vehicle is going to be in the hundreds of millions of dollars each too, but somehow Abel and AST think they can get the price down, that SpaceX and Elon Musk are going to negotiate with them when they are actually a competitor.*
>
> — *Former AST SpaceMobile employee*

While AST bulls rushed to applaud SpaceX's recent announcement of a D2D service as a sign of validation for AST's technology, it seems few, if any, are aware of just how reliant AST's cost projections may be on cheap launch services from its new competitor. Each BlueBird-1 has an estimated mass of roughly 3,000kg (twice that of BW3), meaning at most ~7 can be transported on a dedicated Falcon 9 to LEO. Even at $50m per launch (well below recent list prices of $67m), this would imply over $1.2bn in launch costs alone ($2,400/kg) to place the 168 BlueBird-1s needed for global coverage in obit (this math doesn't change materially if assuming a Falcon Heavy for $90m). Going back to the time of the SPAC, AST has insisted that initial costs of $14m per satellite (inclusive of launch) would decline materially to below $10m per satellite as manufacturing and launch costs come down. But none of that is currently happening. Both costs are rising. As the quote from the former AST SpaceMobile employee describes, the only way AST can dramatically lower launch costs to the levels embedded in financial forecasts is with a massive launch vehicle like SpaceX's planned Starship. With a payload 2x that of a Falcon Heavy, Starship has the potential to drive launch costs well below $1,000/kg, perhaps even as low as $100/kg (depending on how much stock one puts in comments from Elon Musk, who has never delivered on charging lower prices for Falcon 9).

There's only two problems: 1) Starship has encountered repeated setbacks and delays, and 2) SpaceX is a competitor which has no real incentive to be all that cooperative with AST. Starship was initially scheduled to begin orbital flight testing in 2020. In a tweet last month, the notoriously overly optimistic Musk implied a "successful" first orbital flight might yet still be 12 months from now. All this adds up to a highly uncertain path for AST to launch its constellation of BlueBird-1s in a cost-efficient manner.

Solar Panels Are Prohibitively Expensive

BlueBird-1 is envisioned to be a ~400 sq meter phased array with a solar panel power generation north of 100 kW. Gallium arsenide (GaAs) solar cells are commonly used in satellite construction because of their exceptional light absorption and low weight. Given the boom in mega-constellations and smallsats, demand for high-quality, radiation hardened GaAs solar cells has tightened availability and elevated price. Our checks returned a wide range of $200-$500/W for gallium arsenide (GaAs) radiation-hardened solar cells. Even at the low end of the price range above, this would imply over $20m in solar panel costs alone for each BlueBird-1, far above the $15m all-in cost per satellite (inclusive of launch) that AST has claimed its Phase 1 constellation will incur. Even if these panels were available in the quantities AST requires

(which we were advised is not the case), this would not appear to be an affordable option for AST.

Terrestrial crystal silicon (C-Si) can be purchased for as low as $1/W but would require additional processes to make them suitable for the harsh temperatures and radiation levels of space. At an estimated $20/W this would bring solar panel costs down to a more manageable ~$2m per satellite but C-Si has much lower cell efficiency and much higher mass, perhaps triggering the need for a range of design and operational changes.

Either AST has "cracked the code" and a firm that failed to submit mature drawings for aluminum parts has made a breakthrough in solar panel technology, or more likely, one of two things will eventually happen: management cost estimates for BlueBird-1 will rise much higher and/or plans for BlueBird-1 will continue to be delayed and scaled back.

Addressable Markets Will Prove Difficult to Penetrate

The notion that AST has a financial opportunity remotely related to "$1.1 trillion" in global wireless service revenue as included in AST investor decks, or that 5.3 billion unique cellular subscribers on the planet is an appropriate figure to applying penetration rates to, is complete nonsense. The mere presence of these statistics in a SPAC deck should be red flags to investors. A more realistic view of AST's addressable markets should be derived (at a minimum) from two distinct populations: those with existing cellular coverage from traditional terrestrial networks and those who live in remote and rural areas without any access. These two segments differ greatly in terms of market opportunity for a satellite-based D2D network. In markets where there is terrestrial coverage, AST has a business opportunity built on only niche uses; and in markets where there is no coverage, AST has a broad potential but no business case.

Niche Use Cases for Covered Populations

The majority of the world's 5.3 billion existing cellular users spend nearly all their time living, working and traveling entirely within the ever-expanding reach of traditional, terrestrial networks. According to Opensignal, the proportion of time spent without a mobile signal in the U.S. is just 1% on a nationwide basis (Alaska and Wyoming were around 4%) . According to GSMA, on a global basis, the coverage gap for mobile broadband networks has declined in the last ten years from a third of the world's population to just 6% as of 2021. Even in a country as geographically and demographically diverse as India, for example, a key market for AST's partner, Vodafone, 98% of its population is now covered by 4G LTE.

Given the pervasiveness of modern cellular networks, mobile subscribers don't usually find themselves beyond the reach of terrestrial systems for extended periods of time. Only in relatively episodic cases, such as remote travel and outdoor recreational activities (camping is a frequently mentioned use case[2]), is this not true. These subscribers may have an interest in supplementing a core monthly cellular plan with a space-based add-on when they are off-the-grid (particularly in an emergency), but this is not a mass market offering sufficient to justify the spending of billions in new satellites. This use case does not support taking monthly ARPU and multiplying by 12 like a traditional telecom model. This is an irregular, seasonal / high churn,

[2] *Ironically, one of the most commonly cited reasons to go camping is to "Digital Detox" and not be in touch. For these individuals, a free basic emergency service as Apple recently announced, would probably be attractive.*

niche use case. The fact that in one of the highest ARPU markets globally, the United States, SpaceX / TMUS and Apple iPhone14 recently announced plans to give away basic messaging for free, and Apple's relatively modest annual payment to Globalstar (we estimate ~$70m-$100m) supports that thesis.

In instances where terrestrial networks have been incapacitated due to natural or man-made disasters, AST may have utility as a redundancy service, but even here the value is questionable. If an earthquake hit a population center knocking out the terrestrial cellular network, thousands of simultaneous calls and messages to an AST satellite would likely result in the same network congestion that overwhelms even robust cellular networks during a disaster.

In our view, even achieving a fraction of the modest sounding 10-11% terminal penetration rates of the entire cellular subscriber base as implied in AST's SPAC financial projections vastly overstates the addressable market for anyone with even poor access to a terrestrial network.

By AST's own admission, where it may have its most powerful use cases are areas where there is little-to-no terrestrial coverage, particularly in the developing world. But here too are massive challenges which have stymied penetration attempts by tech companies for years.

Underserved Populations Are Underserved For a Reason

Space is hard. Selling telecom services to the underserved in sub-Saharan Africa and Asia might be harder. Western-centric telecom investors tend to overweight their own interest in being in constant touch, as well as their own inclination and ability to pay for services, when considering how technology could unlock market potential in these regions without paying close enough attention to *why* these people are underserved in the first place. The issue is not any technology pain point that AST (or any other company) can alleviate, but rather fundamental socioeconomic obstacles that render building a business case around these populations virtually impossible.

Let's use Nigeria as an example. In the relatively affluent cities like Lagos, 5G has just been rolled out. In many of the country's northern states, however, where terrestrial networks are the least penetrated and many tens of millions lack cell coverage, the poverty rate is nearly *90%*, defined as living on ~$1/day or less. In many rural towns and villages there is literally zero economic activity, where residents rely on government subsidies and family remittances. Illiteracy rates are as high as 80%. Rural populations skew heavily toward the young and elderly as those of working age gravitate to cities for better job prospects. Those within terrestrial coverage do not regularly travel or migrate to rural areas because it's dangerous, particularly in the war-torn parts of the country.

None of this means rural villages are completely cut off, however. People may not be in constant contact, but they still find ways to stay in touch. They schedule times to speak to loved ones from the landline in town, they walk to hills where they know there is cell service. Sometimes they do what's called "flashing," where someone calls from a landline and immediately hangs up, signaling to the recipient (the more well off relative in a city) to call back. In rural Nigeria they are resourceful and make do with little.

Does any of the foregoing sound like a truly penetrable market for space-based roaming??

Will anything significant be unlocked simply because a connection can be made directly to a handset instead of a specialized device? What good is roaming when people can't afford a phone? How successful will selling text messaging be in places where well over half the population can't read? Does a 5% penetration rate sound realistic? It sure isn't if you talk to an executive in the Nigerian telecom industry. One executive we spoke with thinks even 1% would be heroic. And if one think Nigeria is a cherry-picked example, one would be correct – we picked Nigeria because it is the most populous and wealthiest nation in sub-Saharan Africa, meaning in many other countries with large underserved populations in sub-Saharan Africa, the market opportunity is probably worse.

SpaceX and Apple are Growing Competitive Threats

On August 25th, SpaceX and T-Mobile announced plans to provide connectivity directly from Gen 2 Starlink satellites to T-Mobile handsets. AST shareholders cheered the news, believing Musk's involvement validated AST's technology, brought welcomed attention to the space, and did little to threaten AST's perceived technological and time-to-market advantage. Two weeks later, on September 7th, Apple announced the new iPhone 14 would provide a very basic "satellite SOS" D2D service. The service will be available as soon as November and offered for free to purchasers for two years. This time shareholders were unnerved, sending shares down -7% on a day when the market had its best performance in a month. Shareholders seem to be figuring out that maybe having two of the most admired, resource rich companies enter a market while AST is still pre-revenue and hemorrhaging cash isn't worth cheering about.

No Room for Further Delay

SpaceX has the proven engineering prowess, manufacturing scale, and pace of innovation to quickly eliminate AST's perceived market advantages. Just ask ULA. Or the entire GEO communications satellite industry. And nothing about AST's track record as a public company instills confidence that it wouldn't easily squander any sort of lead if one existed. SpaceX stated it will initially provide only lower bandwidth voice calls and text messages, with beta testing to begin in late 2023. AST has fallen behind schedule with BlueBird-1 and the lack of progress has forced the company to take a shortcut by launching modified test satellites just to have *something* generate revenue by a shaky sounding "very late 2023, early 2024." Whatever one thinks AST's leads are, it certainly seems like they will evaporate as Bluebird-1 continues having more and more delays.

Competing against SpaceX is an unenviable task given its structural advantages. While AST sells shares using the latest trend among struggling NewSpace companies – an equity commitment facility from B. Riley – and will need to repeatedly tap the markets to build out coverage, SpaceX enjoys the support and market access of the richest man on Earth. While AST is tasked with trying to make its giant, unfolding satellites compatible with multiple launch providers, SpaceX has the non-trivial engineering advantage of being able to maximize the design of its satellites to fit the precise dimensions of its own rocket fairings. While AST ponders how it will afford to launch hundreds of heavy, expensive satellites without the aid of Starship, SpaceX can rest easy in knowing whenever the vehicle is ready, it can prioritize the capacity for its own needs at the lowest possible cost. Note that AST's launch agreement with SpaceX only covers the launch of the first BlueBird satellite, a vague sounding "framework" for future launches, and was signed before Musk threw his hat in the D2D ring.

SpaceX and AST both require regulatory approval to access and repurpose terrestrial spectrum in every country where they intend to offer service – an arduous, frequently capricious process that can compress any market timing lead. AST only has authority from the FCC to test its satellite on an experimental basis. Apple, meanwhile, can offer service as soon as November because it is partnering with an established Mobile Satellite Services operator in Globalstar, which already has licenses with the FCC and many other jurisdictions. Through its control of the handset, Apple has embedded a chip capable of communicating with Globalstar's network (Band 53/n53) and consequently avoided regulatory red tape. The drawback is Globalstar has very limited bandwidth and is latency challenged for voice connections. While elegant in terms of timing, far more investment in satellite capacity will be necessary for Apple to offer what Starlink and AST are proposing. As part of its agreement with Globalstar, Apple has agreed to pay 95% of the cost to replace Globalstar's fleet with 17 new satellites by the end of 2025.

MOUs Are Not What Bulls Make Them Out to Be

AST management and bulls are quick to promote the 1.8bn subscribers covered under MOUs with global telecom operators as a competitive advantage which "locks up" a "captive" pool of subscribers from competitors, but this is simply not true. Among AST's existing MOUs, according to a Barclays Research initiating report, MOUs with Telefonica, Indosat Ooredoo, Millicom, Telecom Argentina, Telstra, Liberty Latin America, and Smart (Philippines) are not exclusive. Though management sometimes blurs the line between the two (evidenced by Avellan's meandering response to a straightforward question from the Scotiabank analyst on how MOUs translate into a business opportunity) MOUs are not definitive commercial agreements.

In thinking about the true value or competitive protection afforded by these MOUs, one should know *why* they were signed. We spoke to someone familiar with MTN Group's (230m+ subs and the largest MNO in Africa) decision to sign an MOU with AST SpaceMobile. Nothing about the decision was based on the perceived quality of AST's technology or likelihood of financial success. It was borne out of what any good incumbent telecom company does – hedge risk and learn about an emerging technology, even if it has zero perceived ability to put a dent in the local market. Most of these MOUs are non-binding, non-commercial agreements to conduct tests and collaborate on technology that serve primarily as marketing PR for AST. Turning these MOUs into contracts that pay AST is not in any way certain. Experienced investors in start-ups (and all SPACs) should instantly recognize that MOUs like these belong in the same mostly worthless bucket as backlog with contracts that can be cancelled out of convenience, and "sales pipelines" based on conversations with potential customers.

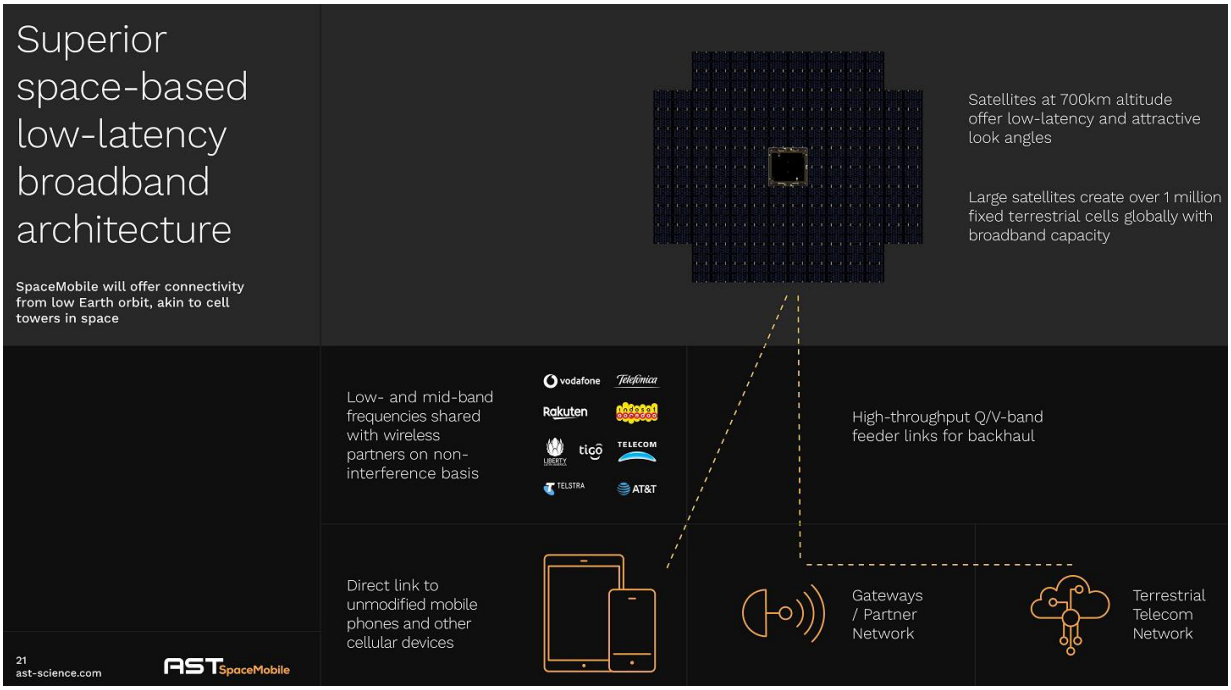
The only firm commercial agreement we are aware of with an established 50/50 revenue share is with Vodafone, but even here there is hardly anything "locked up." Per AST's 10-K, the Vodafone Commercial Agreement does not commence until the launch of commercial service in *all* Vodafone Markets – which means AST is at least 2 years, 110 satellites, and billions of dollars away from having these subs covered under a binding agreement. That doesn't sound "locked up" to us.

Conclusion

One of the touted benefits of SPACs is that they allow retail investors access to companies with exciting ideas far earlier in their development than a traditional IPO. In 2021, this clearly became abused, and SPACs increasingly became a way for truck companies without working trucks and rocket companies without working rockets to foist development risks that few institutional investors would ever underwrite onto a less sophisticated retail investor base. AST is among the most ambitious yet of its generation of zero-revenue SPACs, and we think its lofty ambitions of providing viable 4G-like mobile internet connectivity to the planet's cell phones will never come close to fruition.

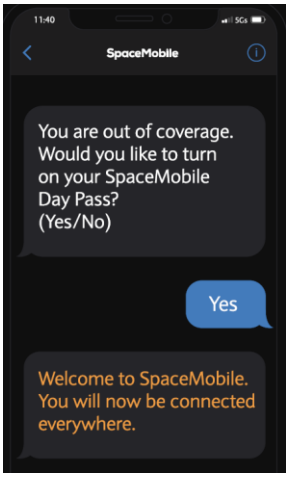
Appendix I: AST Network Architecture, User Interaction Example

AST Network Diagram



Source: AST investor presentation, December 16, 2020

AST Day Pass Example



Source: AST investor presentation, December 16, 2020

Appendix II: AST Financial Projections

AST Financial Projections

Financial Projections Summary

Phased financial plan, becoming profitable in three years and delivering significant growth and profits thereafter

Note: Please see slide 2 for more information regarding financial projections and non-GAAP measures.
1. 2021E-2023E capex shown reflects full global coverage with MIMO deployed in Japan, Europe and North America.

$ in Millions, except ARPU figures	2021E	2022E	2023E	2024E	2025E	2026E	2027E	2028E	2029E	2030E
Cumulative Satellites Deployed	-	20	110	168	168	168	233	336	336	336
Subscribers (Equatorial)	-	-	5	17	41	81	115	136	156	180
Monthly ARPU	-	-	$1.03	$1.03	$1.03	$1.03	$1.03	$1.03	$1.03	$1.03
Equatorial Revenue	-	-	$67	$208	$508	$993	$1,423	$1,670	$1,919	$2,221
Subscribers (Global)	-	-	4	27	67	153	258	332	375	440
Monthly ARPU	-	-	$2.67	$2.62	$2.62	$2.62	$2.66	$2.69	$2.71	$2.70
Global Revenue	-	-	$114	$862	$2,116	$4,819	$8,233	$10,721	$12,166	$14,225
Total Subscribers	-	-	9	44	108	234	373	467	531	620
Monthly ARPU	-	-	$1.68	$2.02	$2.02	$2.07	$2.15	$2.21	$2.21	$2.21
Total Revenue	-	-	$181	$1,070	$2,625	$5,812	$9,655	$12,391	$14,086	$16,445
% Growth	*NM*	*NM*	*NM*	*NM*	*145%*	*121%*	*66%*	*28%*	*14%*	*17%*
Less: OpEx	(36)	(47)	(51)	(56)	(65)	(81)	(102)	(116)	(125)	(138)
EBITDA	($36)	($47)	$130	$1,014	$2,560	$5,731	$9,554	$12,275	$13,960	$16,307
Less: Equatorial CapEx	(114)	(192)	(3)	-	-	(76)	(184)	(1)	-	-
Less: Global CapEx[1]	(9)	(458)	(925)	-	-	(4)	(448)	(907)	-	-
Unlevered FCF	($159)	($697)	($797)	$1,014	$2,560	$5,651	$8,922	$11,367	$13,960	$16,307

Revenue expected to begin in 2023

2024E EBITDA basis for valuation

Future CapEx spending to grow with demand

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ast-science.com

AST SpaceMobile

Source: AST investor presentation, December 16, 2020

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