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FALL 2022

SPECIAL ISSUE

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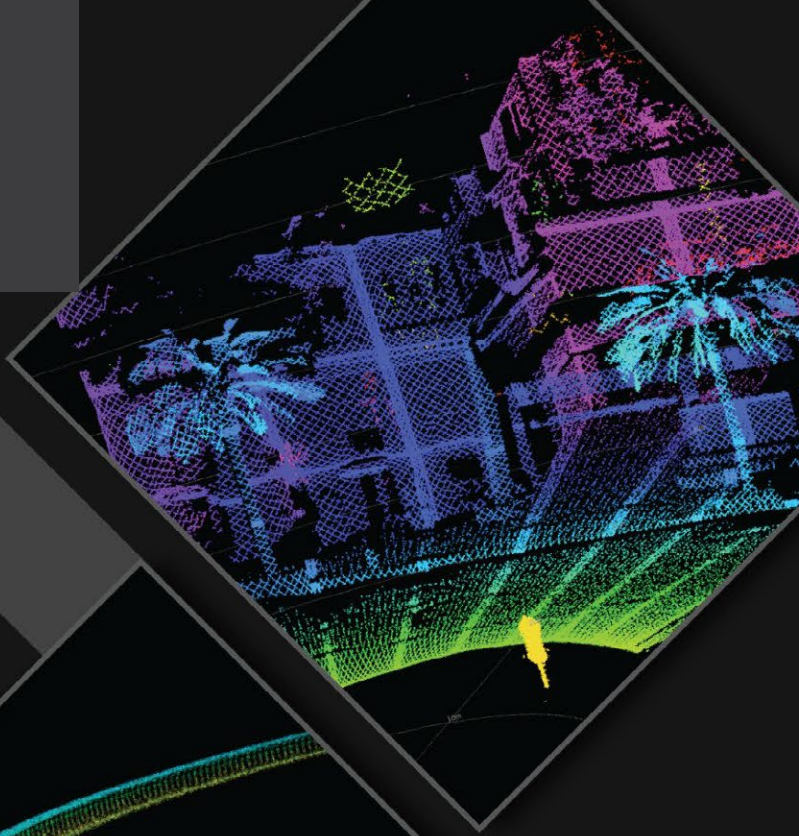

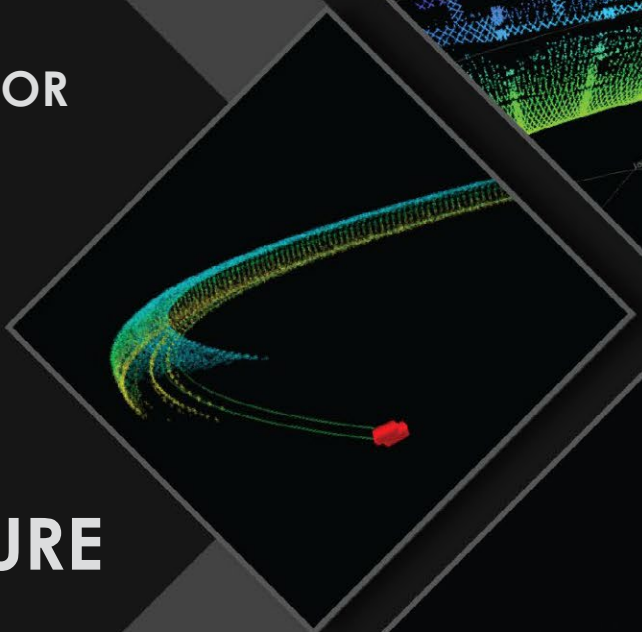

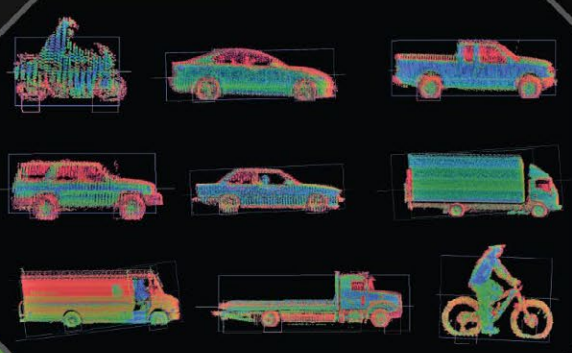

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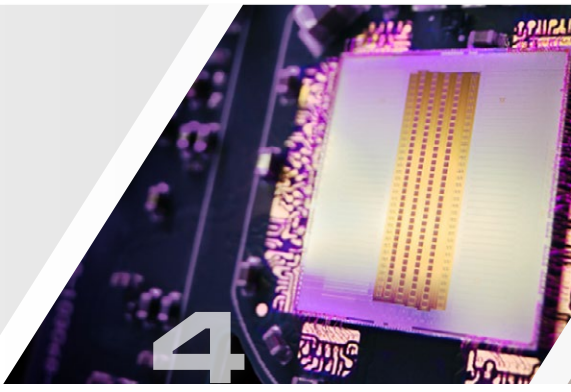

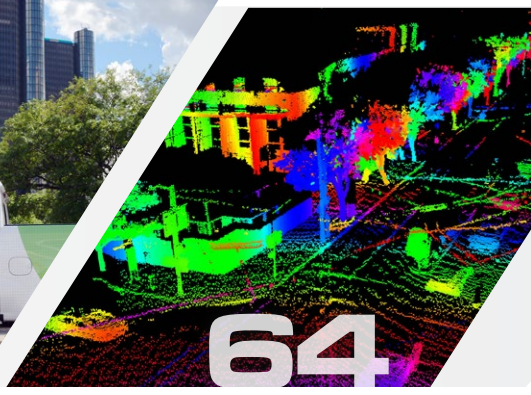

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COLUMNS

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Artist rendition of ADAS (advanced driver assistance system) and other sensor technologies in use.

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DR. A. STEWART WALKER

A look on the bright side...

Two years ago at this time I was enthusiastically rambling about mists and mellow fruitfulness, Keats's nod to fall unforgotten since I first encountered it in high school. Unfortunately, the failure of our planet defeats pleasures like seasons—every day here in southern California tops 100°F and the few wildfires being fought are surely a harbinger of impending, massive area conflagrations.

Let's look on the bright side. This year's Commercial UAV Expo opens a busy autumn. Events such as Photogrammetric Week in Stuttgart, INTERGEO in Essen and Trimble Dimensions+ in Las Vegas follow in short order. If you find yourself at any of these events, be sure to look us up!

This year's "Sensor Integration Spotlight" includes interviews with three big players in the automotive lidar world—AEye, Cepton and Ouster. All three are in the Bay Area, have completed their special-purpose acquisition company (SPAC) funding activities and are listed on the Nasdaq. All have intriguing technologies invented, nurtured and sold by supremely talented teams. And all have deals signed with car companies and/or their tier 1 suppliers. Their sensors impact the geospatial world through their integration into systems borne on UAVs or vehicles. The consensus at present is that, thanks to economies of scale and deep R&D pockets, these are cheaper and lighter than specialist lidar units, but the output is noisier. Read what their leaders say. I challenge you not to be excited!

Considerate of these goings-on, we're continually fine-tuning our coverage strategy here at the magazine. In 2023, we plan to publish more "web exclusives", meaning articles that don't appear in print, with continued emphasis on theme editions such as the one you're holding. When all is said and done, special quarterly publications allow us to focus our energies on the most exciting people, events and things. We remain devoted to geospatial technology, first and foremost, but there's simply too much going on within the larger sensor development and integration realm(s) to avoid reporting on the things you'll encounter over the coming pages. Some of Silicon Valley's brightest minds are now in pursuit of ubiquitous, digital lidar; with that said, I believe we've only scratched the proverbial surface as it relates to the impact this technology will ultimately make. Rest assured we'll cover key happenings along the way.

A. Stewart Walker // Managing Editor

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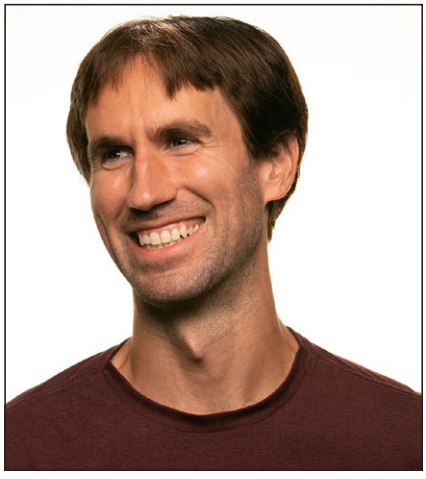
Digital Lidar for Everything

Ouster's 2021 results reflect innovative technology, SPAC completion, and charismatic leadership

An informal take on Angus Pacala, co-founder and CEO of Ouster, Inc.



Mark Fricht, Ouster co-founder.

LIDAR Magazine was fortunate to be invited to the facility of Ouster, Inc., in downtown San Francisco, for a factory tour and an interview with co-founder and CEO Angus Pacala. The visit was organized by Heather Shapiro, director of communications, and my host Tom Grey, director of product marketing. The premises were a contrast to the modern, rectangular, one- or two-floor buildings of, for example, Cepton Technologies and Quanergy Systems, which the magazine has also visited. Formerly used as a tee-shirt factory, the facility seemed labyrinthine, with multiple large and small spaces, numerous staircases and the need to cross a courtyard to walk from one part of the facility to another. Yet it seemed a captivating home for Ouster, a vivid contrast of the old and the new. I met Angus at his desk, in an open plan area. He seemed to have the same desk and floor space as any other employee, with one exception. Behind his chair was a cuboid structure, like a closet or telephone booth, to which he retreated when he needed quiet or to make important calls. We did not attempt to share it for the interview but went to a conference room.

LM: Thank you so much, Angus, for agreeing to talk to the magazine. You're another Stanford guy! You began with four people in 2015? I've visited Quanergy Systems as well, and your name is on one of the patents on their wall.

AP: Yes, I was a co-founder of Quanergy. I was director of engineering there for two and a half years, all the way back to 2012. So I co-founded Quanergy in November 2012 with Louay[1] and Tianyue[2]. Mark Frichtl, my co-founder here, is a Stanford classmate. Mark and I were friends back in 2012 and he was the

BY STEWART WALKER

1 Dr. Louay Eldade, co-founder and former CEO of Quanergy Systems; now CEO of Scidatek, Austin, Texas.
2 Dr. Tianyue Yu, co-founder and chief development officer of Quanergy Systems.

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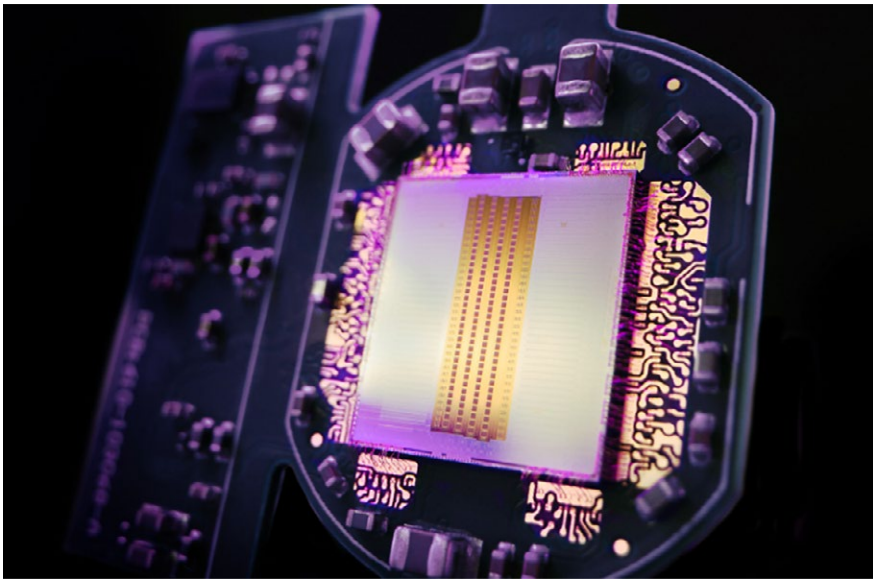
first or second employee at Quanergy. We worked on their early M8 system.

LM: But you must have left Quanergy when you and Mark said, "We have an idea. It's really special. And it's better than what we're working on here."
AP: We disagreed with Quanergy's business strategy and technology approach. A number of employees left around that time. Mark took a job with Apple and I took some time off. Eventually, we both naturally gravitated back towards discussions around lidar. What could we do next? That was where, when we were able to step back clear-eyed, we asked, how can we align? How can we apply digital technology to lidar for the very first time, truly apply it, not in some small form, but do what Silicon Valley has done for 60 years, put lidar on a chip? It truly had to be digital. That seemed like the obvious way to win the industry long-term. We had some breakthroughs in ideas and decided midway through 2015 to found the company around them.

LM: Congratulations. Look what you've done.
AP: Yes, it was the right decision.

LM: You have 200 people now?
AP: I think we have 200 or 210 people[3].

LM: That's huge. I think probably only Velodyne Lidar is in that ballpark.
AP: Of the public companies, Velodyne is maybe double us. It's interesting, because, of the companies that have reached any kind of commercial scale, we're the smallest by far. Velodyne is almost double the people. I think Hesai out of China is almost double the people. Actually, Luminar is around 500 people, so they're way bigger. And yet, we're doing a lot with a little.



Ouster released the L2X digital lidar chip in October 2021, the most powerful, highest performing chip Ouster has ever designed and it powers all of Ouster's latest Rev 06 OS series scanning sensors. Capable of counting up to 1 trillion photons per second, and outputting up to 5.2 million points per second, the L2X system-on-chip (SoC) continues Ouster's journey along the Moore's Law curve by doubling the maximum data rate of its sensors. The L2X handles all the logic and signal processing on the sensor and can process both the strongest and second strongest returns of light for each pixel.

Ouster optics module, the tiny assembly at the heart of its sensors and one of the firm's key differentiators.

LM: A more whimsical question. You've got a couple of dictionary-like definitions of Ouster on your website[4]—are they real?
AP: Yes. The Ousters are from the sci-fi book *Hyperion* by Dan Simmons. They're humans who have embraced technology for the betterment of humanity.

3 By September 2022, Ouster had grown to more than 300 people.

4 ouster.com/company

LM: It's quite hard to understand the differences between lidar companies because they've all got hardware, they've all got firmware, they've all got some software. But how far do you go? And there are other companies like DeepRoute that don't make sensors at all—they integrate other people's.
AP: It's really hard to make sense of this industry! I think of it as three pillars. We have our digital lidar technology, which is really, really different than the rest of the pack. We're putting lidar on to a silicon chip, as a digital lidar module. And it's a super simple device. Compared to the analog or complex lidar sensors, this is simple. It's a silicon chip on one side, if you look through the lens, and all these arrays on the other. That's it.

Ouster OS sensor portfolio: from left to right, OS0 ultra-wide view, OS1 mid-range, and OS2 long-range.

Ouster OS sensor portfolio rear view: from left to right, OS2, OS1 and OS0.

LM: Whereas the M8 is still a spinning device?
AP: Not just that, there's hundreds of components in the domain, for the receiver, for the laser side. And so we're replacing all that with a single custom chip.

LM: The top end of your range is 240 meters—you get 240 meters from that?
AP: You can get kind of an arbitrary range from the digital technology: it's just how much power you want to pump into the system. It's super performant, cost-reduced and small. That's the benefit of digital technology. It's the same, you know, with the cameras in the iPhone. It's the march of CMOS technology.

LM: When I was getting into land surveying, electronic distance measuring had just been invented. So you had a big box of tricks on a tripod and, at the end of the 70s, a device like that would measure about three kilometers to an array of glass prisms at the other end of the line on another tripod. All to measure one point!
AP: These devices do 2.6 million points per second. That's just amazing.

LM: I liked the Founders' Vision video on YouTube[5] that you did, "to make lidar affordable and ubiquitous". And obviously, I agree with that and admire it. But aren't your competitors all trying to do exactly the same?
AP: I don't think so, for maybe a couple of reasons. The first is, I just don't think they have the technology to do it. The ubiquitous technology is digital technology: you pull apart a phone, you pull apart a car, the technology inside is CMOS digital semiconductors, it's not anything else. It's really remarkable that it's only CMOS digital semiconductors. And it's single-chip solutions. Everything gets condensed on to a chip, whether it's a camera, whether it's an inertial measurement unit or a cell modem, it goes from discrete components to single chips. Lidar is going in that direction. In order to make things ubiquitous, you really have to go towards these hyper-affordable, hyper-performance, small-form-factor devices. You can make one-off analog devices that work great for a single application,

5 youtube.com/watch?v=9HObyY_7Kmk

like a car. But you can't make something that's a platform of products that goes on a rover on Mars and goes in your cell phone and goes on a car. That's what we're trying to do. In combination with that, our strategy has always been a diversification across industries. That's the real thing—like the rubber meets the road. Everything we communicate about our company is about ubiquity across verticals, smart infrastructure, industrials, robotics and automotive. That's not something that our competitors are doing. That's why I think we can do the ubiquity side and no-one else.

LM: There's a good quote from you, in an interview with IPO Edge on 16 March 2021[6], about the total addressable market being $8.6 billion by 2025 and $48 billion by 2030. But isn't it more difficult to address than the automotive market in terms of your sales structure, expertise and so on?

AP: What's so funny about technologists is that they only want to solve the hard technical problem. Isn't it hard to build lidar technology? Why are they okay with solving the hard technical problem, but not the hard business problem? So yes, it's hard to build a company that serves four different markets with different needs and different customer purchasing cycles and requirements. But if you do that, then you become an Nvidia or a Cisco or a Qualcomm or a Broadcom, that's the whole point. I really care that execution, proof through execution, across the business is not about being a great technologist, it's about trusting people who are good at things other than technology. I put a lot of trust in our VP of operations, Darien Spencer, and our president of field operations, Nathan Dickerman, basically our sales lead, and all these other people who know something fundamentally different than me with a Stanford engineering degree. And the proof is in the fact that we ship more sensors and have a higher revenue than the majority of public lidar companies combined. And we do it with industry-leading positive gross margins. We have a dual manufacturing strategy, so we also produce here. We build and ship from a facility in Thailand. I'll get off my soapbox!

LM: Yes, but your soapbox is interesting, because nobody else is saying exactly that. I looked at an interview on Seeking Alpha with Kevin Kennedy, the CEO of Quanergy[7]. He was basically saying, automotive is great, but we have to look at other verticals, because autonomous vehicles aren't here yet. We need revenue. Right?

AP: Yes, he's right, and then some. We're diversified because I don't want to be an oracle who has to perfectly anticipate how all these cutting-edge technologies are going to come to market. I don't want to be betting our company on autonomous vehicles or autonomous drones or what have you. I want to be diversified and allow the winners to win. I have no capacity to affect when autonomous vehicles arrive. I want to be in a position to serve as many markets as possible simultaneously. So he's right. That's the difference with Ouster: we have doubled down on all four of those verticals. We have product market fit across all of them.

Anna Brunelle, Ouster's CFO.

We're not saying, we're not interested in a market, because it's not ready now. All the markets have good potential.

LM: You've probably found the small geospatial market hard work for the number of units you've sold, because people like Jeff Fagerman at LiDAR USA are picky.

AP: An interesting thing about digital products is that when they enter a market, there's always a set of power users who have mature analog products that they want to keep using. Photography is a great example – film: professionals are the last to adopt digital. And that's true of digital lidar. There's always going to be someone who thinks, I can get better data quality, or whatever, and I'm willing to pay a tax. But digital technology, the exponential improvement rate, eventually becomes visible.

LM: If he's happy, then it probably means he's put the product through its paces on several drones. Probably he's also got a system that you can take off the drone and put on the roof of a vehicle. That's an interesting and very rapid transition.

6 ipo-edge.com/ouster-ceo-angus-pacala-on-bringing-lidar-into-everyday-life/

7 seekingalpha.com/article/4444246-quanergy-ceo-kevin-kennedy-lidar-of-the-spac-video

Ouster product line on exhibit. In the foreground is the OS2 lidar sensor, which delivers long-range, high-resolution 3D sensing for commercial deployment.

AP: That goes to product flexibility: being best in class in size, weight, power, resolution, range, field of view, allows you to be flexible across many different use cases, because there are so many.

LM: You've also come up with the phrase, "At Ouster we're building the eyes of autonomy". On your LinkedIn page, you say, "Digital lidar for everything." That's great. As we say, in Scotland, you've "got the gift of the gab." These excellent phrases make the point. It's not that easy to divide the non-automotive market into clear verticals, different people probably do it in different ways. There are smart cities. There's robotics. But you feel that you've got clarity on that, and are designing your sales structure to address it?

AP: We have internal clarity. I am very public about industrials, smart infrastructure, robotics, and automotive. But we don't provide the itemized sub-verticals within each one of those four. You're right, it's hard, there are thousands of sub-verticals. And robotics, for instance, is a total catch-all. What does robotics even mean? So we put researchers and universities, legged robotics, 3D surveying and mapping into robotics, we even put defense into robotics for now, but that may change over time. Going back to the question, do we have a map internally, do we understand what we're doing, yes, we look more for things like product certifications. If there are large customer sets that require a certain certification, they should be all lumped in together, for example with some sort of smart infrastructure, municipal certification. Those use cases, those customers, that smart infrastructure—there are ways to map it, and have strategies for the major sub-verticals.

LM: One of the things that I tend to ask—you've already touched on this—is that all these companies like yours seem to be blessed with a really talented leadership team. It's completely obvious that you and your competitors all worked like dogs to get here. There's no question about it. One of the interesting things—and it applies to yourself, and I think other members of your leadership team—is that there's a certain amount of jumping, I use the term bed-hopping, I wish I hadn't, going from one company to another. Do you feel that's healthy? Is there any risk to IP? Is there any bitterness in the companies that you leave behind?

AP: I guess Mark and I are the canonical examples of that, given that we left Quanergy. But if you look at Ouster in general, one of the things I'm really proud of is that we've created a community of people here who, I think, are motivated to stay and like working here. We pulled almost nobody from competitors and we've lost almost no-one to competitors. If you look at the make-up of our team, there are people that have been here five or six years, a large fraction of our team. It's really cool. We have a kind of a humble roll-up-your-sleeves attitude around here that people like.

LM: We can get on to the SPAC[8]. There have been so many SPACs in the lidar world. Cepton is in the middle of theirs, Quanergy's in the middle of theirs. Velodyne was a while back, then AEye and Innoviz. Everyone's doing it. I'm not a financial guy, but I do understand that it gives you easier access to capital, it's

8 Special-purpose acquisition company: Ouster completed its business combination with Colonnade Acquisition Corp. (NYSE: CLA) and the combined company's common stock began trading on the NYSE under the ticker symbol "OUST" on March 12, 2021: https://investors.ouster.com/news/news-details/2021/Ouster-Completes-Business-Combination-to-Accelerate-Digital-Lidar-Adoption-in-Industrial-Smart-Infrastructure-Robotics-and-Automotive-Markets/default.aspx

Angus and co-workers discuss procedures in front of a Thermotron environmental test chamber.

probably easier to get there than chasing venture capital. My question is, if all the competitors are getting SPACs, isn't it like all the boats bobbing in a rising tide? You'll compete with each other on a higher plane, you'll have hundreds of millions of spend instead of tens of millions?

AP: Is it bobbing on a higher plane? You're right about why companies are going SPACwards because it's an easier route to capital. It's not because they are necessarily ready to be public companies. This is something that I get passionate about, because of all the companies that have gone public, I really think Ouster tops the list in credible business metrics. We are the only company that makes money when we sell a product. We have a positive gross margin. Actually most companies, when they go public, have a positive gross margin. They might not be EBITDA[9] positive, they might not be profitable, but at least when they sell more of their product, they make more money. That's true for Ouster and not true for most other public lidar companies, which is insane to me. We have 600 customers now. When you look at some of these other companies, they might count the number of customers on one hand. We have the second most revenue in the industry behind Velodyne. We've actually shipped thousands and thousands of units, which is something no other company but Velodyne has done. Last quarter, we shipped almost 1500 units. So I care about distinguishing ourselves from the rest of the pack through metrics that don't require a PhD to understand, because the reality is, all these companies went public, and some of them maybe weren't ready to be public, but it was just a really convenient route to equity.

LM: It makes sense, because otherwise you're lining up on Sand Hill Road[10] for 10 or 50 million at a time. Now, a more personal question. Do you spend your time at home at night worrying about the stock price? Has it changed your life?

AP: Do I think about the stock price? Yes. Do I worry about the stock price? No. In that the stock price is divorced from reality and will be for some time. I care about communicating the long-term, real business that we have built and are continuing to scale. But I spend my time talking to investors and analysts who care about the stock price. So I do have to care about the stock. That's why you also have great people on the executive team, like our CFO. Her job is to spend a lot of time with investors. And she was a public CFO at TiVo before. I don't know how many other lidar companies have CFOs with public company experience.

LM: There are lidar companies still without SPAC. There's somewhere in the double digits of lidar companies around. The market is not going to support them all forever, there's going to be shaking out. How will that be affected by SPACs? Also, I don't know if it's an internet rumor or fact about you acquiring Sense Photonics. Is that part of a shaking out or a consolidation in this case?

AP: On that I can't comment. But on how this shakes out? You talked about boats rising and bobbing. I don't know, I think a lot of them are going to capsize, but they're going to keep floating and just kind of exist for a long period of time. They may become almost like zombie shells of companies. There's not room for seven, or however many public companies there are today. There's room for two, three, maybe five. But everyone's raised a huge amount of money. Some companies will just exist in five years with ample cash and no customers, no revenue. There's a number of private companies still, tens of them. Maybe some more will go public. I think a lot will get acquired, because it's very difficult to raise money from a VC that sees seven or more public lidar companies with ten times the cash. So I feel for the smaller companies, it's difficult.

9 Earnings before interest, taxation, depreciation and amortization.

10 The street in Palo Alto and Menlo Park where many venture capitalists have their offices.

LM: The last question is an obvious one. You have a tremendous amount going on. You closed the SPAC in March, it's all go, what are your plans for the rest of 2022 and 2023?
AP: Digital lidar for everything! We have this great silicon roadmap. You know, the way we build the products is the way that all silicon companies do. You develop a new chip, you put it into your product lineup, and it gets 2x better. And then you do that again and again and again. And that's the core of what we're doing here while we're expanding our manufacturing capacity, or quality or reliability of our products and scaling—again, the more we sell, the more money we make, which is not true of anyone else in the industry. Our goal is to expand sales and make more money and become a profitable business.

LM: There's scaling, and there's reliability and manufacturability, if that's a word.
AP: Reliability and quality. We want to have high yields and high-quality product. That's really important for safety-critical applications.

LM: Angus, I've taken enough of your time. It's a pleasure to talk to you. Thanks for seeing me. I really appreciate it.
AP: Great, appreciate it. Enjoy the tour with Tom—another Stanford alumnus!

Factory tour

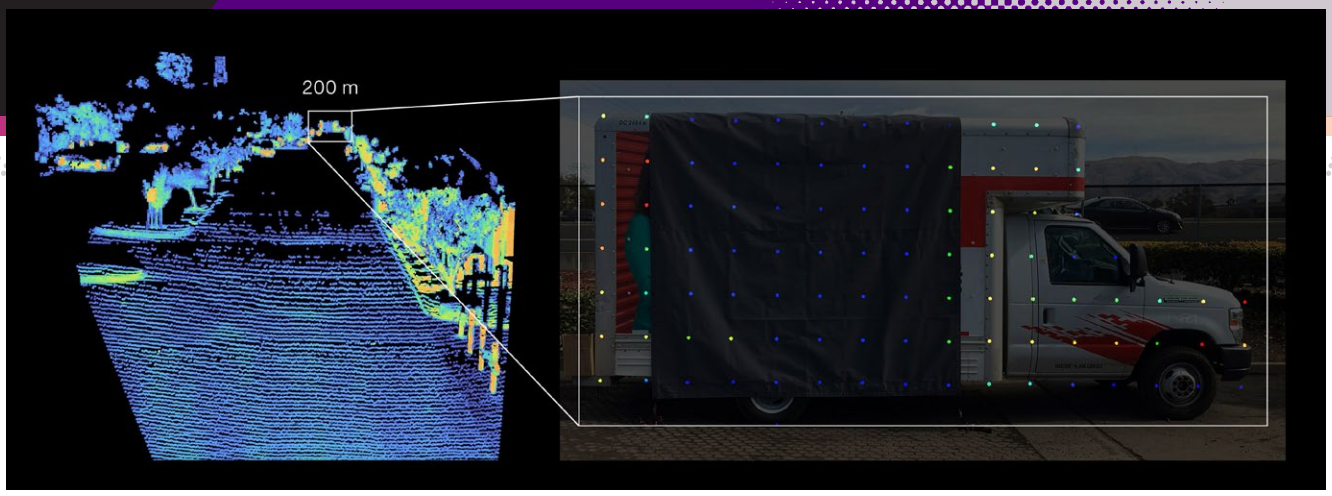
Tom explained that we had come through the main building to the area containing Angus's desk and the conference room. He described the building as the company's dedicated engineering R&D building. Angus and Mark were there, along with product management, finance and legal. On the floor below was "the hangar", an R&D control facility with limited access, compulsory wearing of safety goggles etc. We saw multiple test stations and Tom explained that as a result of covid there had been some reallocation of space, a process not yet complete. There was a half-floor, an eccentricity of the older building. We saw picnic tables, barbecue and ping pong, the accoutrements perceived as necessary to attract top talent. Tom revealed that these were in fact most popular with the manufacturing team, some of whom had worked with each other for 30 years. Moreover, Darien Spencer was a dab hand at karaoke! He's a low-key individual but had been head of manufacturing at Seagate.

Angus in Ouster's facility, reminding us that it was once a tee-shirt factory.

We mused on why lidar attracts such remarkable people. Is it about company technology and culture combined? Whether it's the technology itself measuring point clouds, or whether it's the applications, lidar does attract people. Tom couldn't quite identify the key. He ventured, "It's a little different for everybody. On the engineering side, it's a fun problem for a lot of engineers, because it's rare that you find a company where the hardware and the low-level electrical engineering, the optics and the computer science all play together. There aren't too many places where you get to do true R&D to that degree. A lot of engineers like the multidisciplinary piece of it."

We also discussed the change from two or three years ago, when lidar suppliers offered a sensor, and maybe some kind of SDK that would let people get raw data off it and start doing things, but now they have to offer considerable software as well, sometimes called the perception layer. Tom emphasized that Ouster is investing very heavily in software, with numerous software engineers on its staff.

Just a step further Tom pointed out another differentiator. "These are manufacturing stations that do optical alignment, for sensors. But these are all custom-built in-house, and all the software inside and the mechanical



Ouster flash lidar produces high-resolution 3D data and delivers rich point density on a low-reflectivity target at 300 m.

six-axis motion is done in-house. So the software to run these is also custom-developed from scratch." He perceived it as Ouster's participation in traditional, craft aspects of manufacturing, "… designing these automated machines and writing the software to automate the mechanical alignment." Some of the machines are shipped to the production facility in Thailand.

Tom showed me the break area where copies of *LIDAR Magazine* had been located, but, alas, these had perished amidst covid precautions. We had come into another building, which contains the business functions.

I was still struggling with why I had not met Ouster before, except once when I was visiting LiDAR USA in Alabama[11], but Tom was reassuring, "It doesn't surprise me. The approach to our sensors is pretty anathema to classic lidar beliefs. It requires advanced algorithms to clean [our data] up into a good map. Mapping customers are not necessarily the best fit for our sensors unless they're looking for something that's local, basically a quick and dirty map." Tom readily acknowledged the noise characteristics of the Ouster sensors, but nailed the situation perspicaciously: "It's basically due to the types of lasers we use. They're weaker, but compact, cheaper and getting better. Our approach is making something that we know is shorter range and lower performance today, but playing into a rising tide." While certainly interested in the geospatial world, Tom also pointed out that a better application for Ouster sensors at present is the autonomous robotic sector. We agreed that the geospatial market is small compared to Ouster's other segments and Tom felt that it would be subject to consolidation in the same way as lidar system suppliers.

Tom shared Angus's delight at the SPAC and felt that the process had perhaps run more smoothly for Ouster than some of its competitors.

We ended in the manufacturing facility, a room called "new product introduction", where Ouster irons out the whole process and which Tom described as a "…fast iteration by having the engineering team just in the building next door. If there's any problem, they can just call them over and work it out. The engineering team next door is designing the machines and the process, whereas the [manufacturing] team is implementing and scaling it. The capacity is about 2000 units a month, though it's not yet fully scaled." The Thailand facility, of course, has an enormously greater capacity and will be key to Ouster's growth.

As we ended the tour, Tom was quick to reemphasize the contributions of Angus and Mark, their technical and even financial risk-taking and their sheer hard work.

Just as we parted, Tom explained that, like most companies, Ouster has more remote employees than pre-pandemic, so it will take some time to sort this out in terms of expectations, office layout and work patterns. For the moment, for example, pets are allowed!

Ouster's 2021 results

Since the interview, Ouster has published its 2021 Q4 results. The raw numbers, staccato, italicized on the website[12], were impressive, "$11.9 million in revenue in Q4, up 53% sequentially, with industry-leading 30% gross margins; record shipments of over 2400 sensors in Q4, nearly tripling year-over-year; delivers on full year 2021 guidance with $34 million of revenue and 27% gross margins". 6475 sensors were shipped in 2021, totaling over 10,000 sensors shipped to date. The firm's net loss decreased to $94 million, compared to $107 million in 2020, though its adjusted EBITDA loss was $67 million, compared to $36 million in 2020. To many of us, these red figures

11 lidarmag.com/2020/01/14/lidar-usa-buzzes-with-success-and-innovation/

12 investors.ouster.com/financials/quarterly-results/

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The Ouster Automotive DF series solid-state digital lidar suite.

are scary, but remember that Ouster is a high-tech start-up, for which they are by no means unusual.

Angus was effusive in his formal briefing to investors, "This year was a turning point for Ouster as we scaled up our commercial engine, proved our high-volume manufacturing capabilities, accelerated our automotive roadmap, and won key customers across each of our target vertical markets. We expect 2022 to be even stronger, with important product and customer milestones that we are excited to share throughout the year. Ouster's diversified, digital lidar strategy has taken stride. We have a clear plan to grow our business, further differentiate our product offerings, capture market share and extend our market leadership."[13]

We took the opportunity, therefore, to pose a handful of additional questions to Angus. These were submitted and answered in writing. Here are his replies.

LM: Congratulations on your Q4 and full-year 2021 results. I've included in the article the key statistics and your words from the press release, but could you please highlight for us what gives you the greatest pleasure? Did you feel that the company fared as well as you expected in 2021, or better? Could you please explain for our readers that, despite the tremendous progress, the company has been making losses, yet these are entirely normal for a high-tech start-up at Ouster's stage in its development? You already touched on this during the main interview, so it seems that the financial progress you are making towards profitability, however it is measured, is going according to plan.
AP: 2021 was a fantastic year for Ouster. We nearly doubled revenue with positive gross margins, built world-class commercial and auto teams, accelerated our hardware and software roadmaps, tripled our unit shipments with no breakage in supply, grew to over 600 customers, and delivered on our full-year 2021 guidance. And we accomplished all of this in the midst of a global pandemic and an unprecedented disruption in the semiconductor supply chain.

Ouster is a high-growth technology company and hardware development requires capital investment. This is completely normal in our industry, and we have a clear path to profitability. Our digital lidar technology results in a simplified architecture that makes our products inherently suited to volume manufacturing, allowing us to scale rapidly while driving down the cost of goods sold faster than our average selling price. This is why Ouster has the highest gross margin profile of our public lidar peer group, validating our company's leading cost structure.

LM: I'm asking these questions a year after Ouster was listed on the NYSE. Are you happy with how the stock has performed in the first year? Does it feel good to be in the public eye in this way?
AP: In high-growth industries like ours, it takes significant capital to bring products to market and scale. Becoming a publicly-traded company is a great opportunity for companies like Ouster that have strong fundamentals such as product-market-fit, a growing customer base, growing revenue, positive gross margins, outsourced manufacturing, and an executable go-to-market strategy.

In the first quarter of 2020, Ouster had about a10% share of product revenue generated by our public lidar peers. By the end of 2021, Ouster's share of product revenue had grown to nearly 40%. Over the same time period, we have closed the market share gap with the incumbent lidar company from over 60% to under 10%.

We can't control the market trends or macroeconomic factors that impact share price. Ouster is focused on executing against our plan. We remain as confident as ever in our roadmap and market opportunity. We project to generate the highest revenue for 2022 of all public lidar companies due to ongoing and significant market share gains, along with the company's diversification strategy, where automotive, a market not slated to ramp until 2025, is only one piece of a multi-faceted business.

13 investors.ouster.com/news/news-details/2022/Ouster-Delivers-on-2021-Guidance-with-34-Million-in-Revenue-and-27-Gross-Margins-Q4-Revenue-Up-53-Aims-to-Double-Revenue-for-2022/default.aspx

LM: As we discussed before, a handful of lidar suppliers has gone through the SPAC process and as a result has been able to fund more initiatives than otherwise would have been possible. Would you say that the race to the top will be won by the contender that most effectively uses the easier access to capital? I don't mean spend the most money most quickly, but rapidly deploy the new funds in well-designed initiatives not only in R&D but also in sales and manufacturing – or perhaps in developing foci in particular markets, whether verticals or geographies. I'm sure you wish to be discreet, but is there anything you can say about Ouster's strategy in this respect?

AP: Not all SPACs are created equal, regardless of how much capital they raised. Some of these companies are only a few customers away from zero revenue. There are SPACs which will likely be able to exist for years as zombie companies on the cash they raised when they listed. Some of these companies are still trying to figure out how to bring their prototypes to market with volume production. Even lidar companies that have been around for over a decade haven't realized positive gross margins yet. The right technology approach, ability to scale, and go-to-market strategy is what will determine the winners and losers in lidar.

This is where Ouster stands apart. We have a highly differentiated technology along with a diversified market strategy and proven ability to execute. We are strategically investing in areas of the business that will enable us to scale rapidly across our target verticals, deliver even more performant sensors, and add new high-margin revenue streams to our business, such as software.

LM: You quite rightly demurred when I asked you during the interview about rumors regarding the possible acquisition of Sense Photonics, but this actually happened, and the deal was closed on 25 October 2021. Would you please explain what Sense Photonics brings to the table for Ouster? Also, do you see this as part of the consolidation that we all think is likely to take place in the industry, which we discussed during the interview, or is it more of a vertical integration along the supply chain?

AP: At the time I couldn't comment on the rumor as there was no deal signed. Of course, since then we announced the acquisition of Sense Photonics, which accelerated Ouster's automotive strategy by over a year and solidified our position as a frontrunner in the automotive market. We brought on a strategic development deal with a global automotive company and a pipeline of potential high-volume production deals under negotiation, along with really great automotive and engineering talent from the Sense team.

This is typical of maturing industries, and the winners in the space will likely be the consolidators. That being said, we're not interested in analog lidar technologies. Sense was developing a VCSEL/SPAD[14] digital lidar architecture similar to Ouster's solid-state sensor, so there were synergies to benefit from.

We have seen some lidar companies vertically integrate along their supply chain, which I suspect is because their input costs for things like lasers were too high. Ouster has a fundamentally different approach which allows us to dual-source components, leverage economies of scale, and benefit from technology advancements across our supply chain, such as with VCSELs and SPADs.

LM: Among the benefits of the Sense Photonics acquisition is progress towards "a flagship development deal with a major global automotive OEM". Would you like to comment on that? We've noticed during interviews with your competitors that the signing of a deal with a car manufacturer or tier 1 supplier seems to be critical to any lidar player that goes through a SPAC. So far, you have had deals with many companies, though I don't think these include household names of cars, and in your comments on the 2021 results you highlighted your 68 Strategic Customer Agreements, "collectively representing approximately $500 million in contracted revenue opportunity through 2025." Could you comment, therefore, on the importance of the "big deal"?

AP: While many of our peers have squarely focused on automotive, Ouster has focused on a multi-market strategy that enables us to generate near-term revenue through our 600+ customers, including 68 strategic customer agreements, until the automotive ADAS market begins to ramp in 2025. While there has been some noise from other lidar companies about brand-name partnerships, the automotive market is wide-open. Development deals are really great, but what really matters are high-volume production deals, which very few lidar companies have announced. Ouster is in a number of advanced negotiations for high-volume automotive programs with a start of production in 2025 and 2026. We feel confident about our ability to win automotive deals, which will drive scale

14 Vertical-cavity surface-emitting laser/single-photon avalanche diode.

to further reduce our costs across our entire suite of products.

LM: Between Ouster's own heavy investment in R&D and the acquisition of Sense Photonics, is it fair to say that Ouster will launch multiple new products in 2022?

AP: Ouster announced its Digital Flash (DF) series solid-state lidar sensors for automotive late last year[15] and we are focused on executing against that product roadmap. We expect to announce our new L3 chip later this year, which will power all of Ouster's OS sensors, and represents our single biggest performance jump to date. We have also discussed our plans to introduce software later this year. Aside from that, we are not pre-announcing any other products we plan to bring to market.

Endnote

The two memories of the Ouster visit were enduring: older premises atypical of the automotive lidar world; and a brilliant, sincere, self-effacing CEO who has hand-picked a superb leadership team that includes several fellow alumni. "SPAC to the future" witticisms have run their course, but surely the proof of the pudding will be in the eating. The world is crowded with lidar suppliers, both public and those that can't or don't wish to take the SPAC step. The winners will be the ones that can use the SPAC funding effectively and rapidly. To do so will depend on sound technological undergirding, a deep appreciation of markets, and a talented, motivated team. Ouster seems well placed in all these respects and its 2021 results suggest that the company is on course.

15 ouster.com/blog/ouster-automotive-df-series/

Stewart Walker is the Managing Editor of the magazine. He holds MA, MScE and PhD degrees in geography and geomatics from the universities of Glasgow, New Brunswick and Bristol, and an MBA from Heriot-Watt. He is an ASPRS-certified photogrammetrist.

SPONSORED LISTING INDEX

The following pages provide an overview of key service provider, sensor hardware, software and component part manufacturers, in addition to system integrators. Visit the online directory at *www.lidarmag.com* for additional listings.

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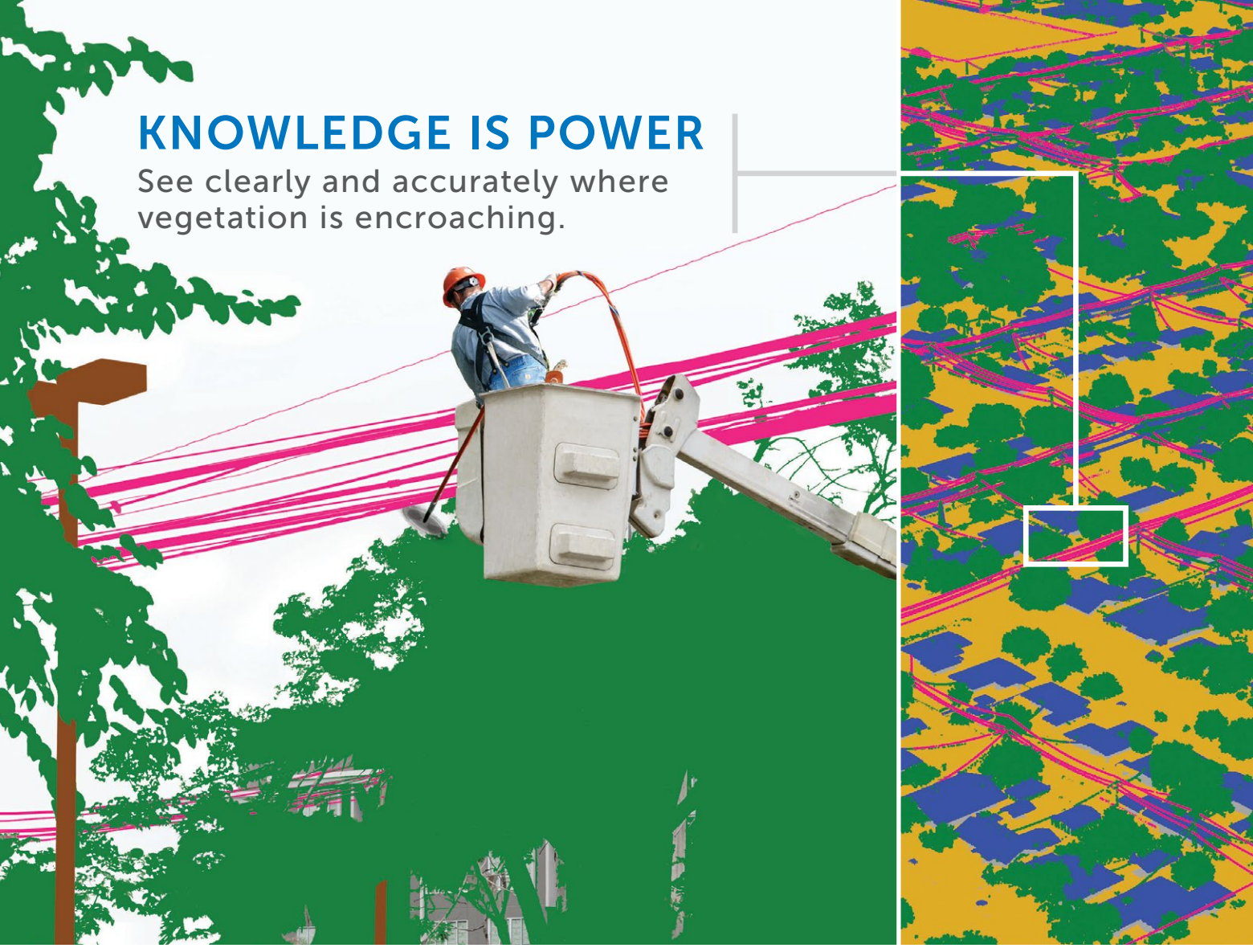

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- SMART INDUSTRIALS
- AGV

COMPANY PROFILE

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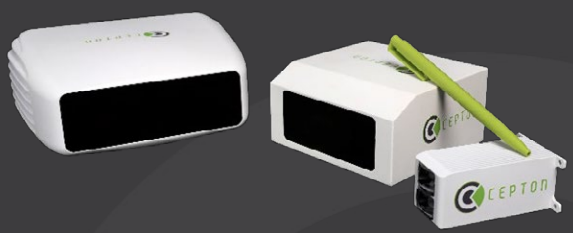

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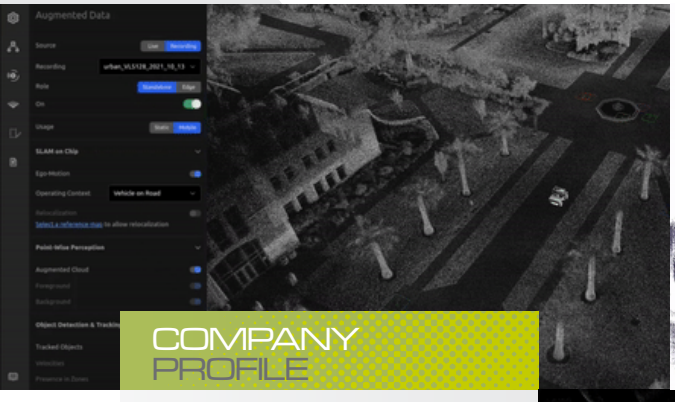

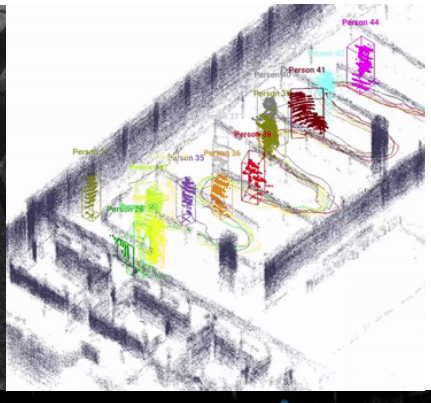

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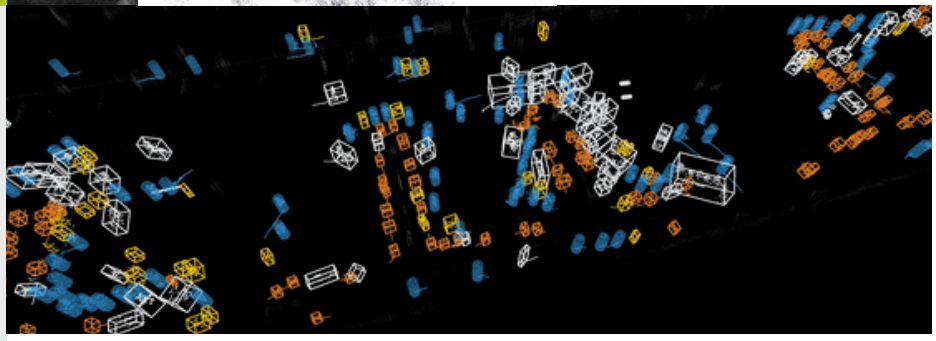

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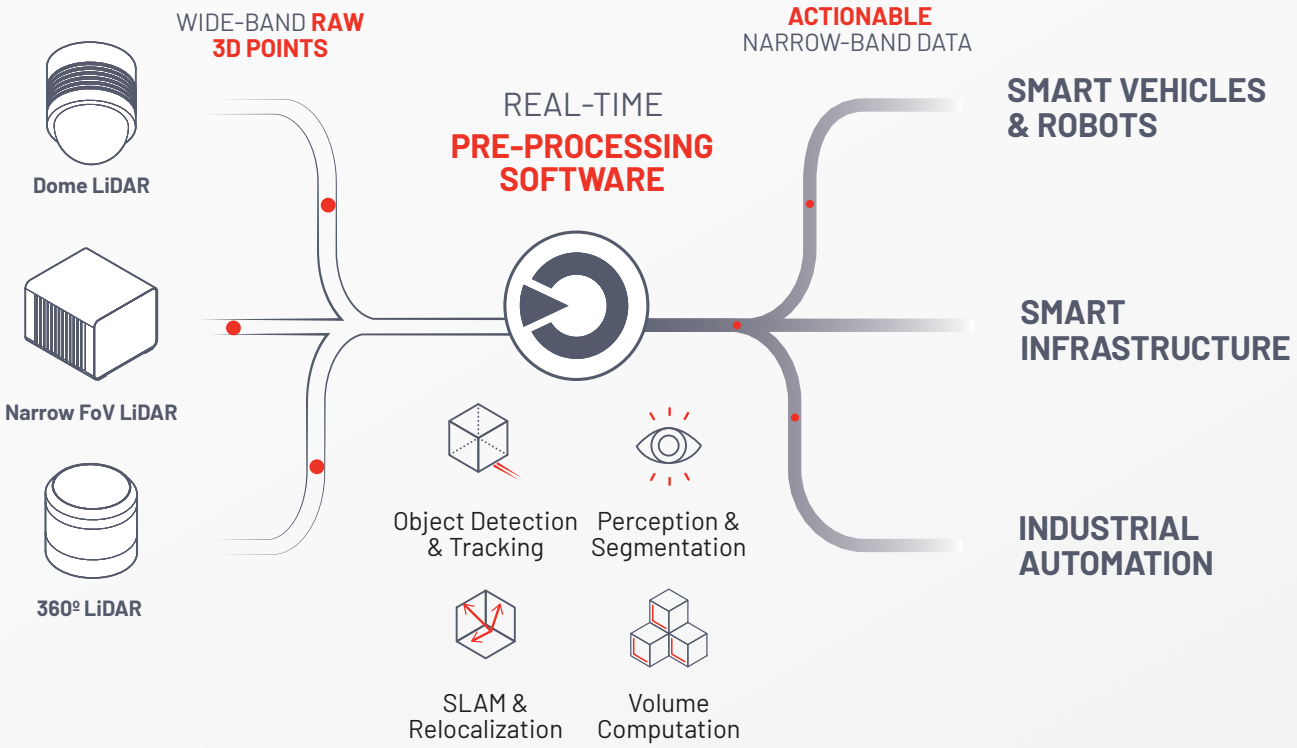

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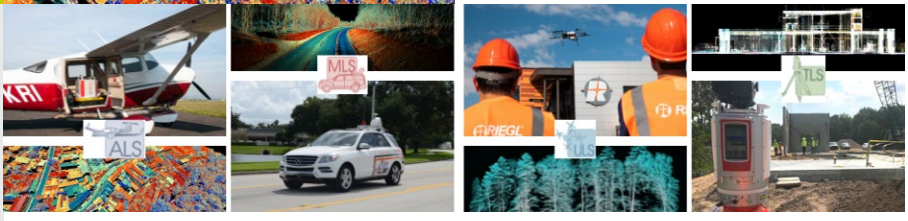

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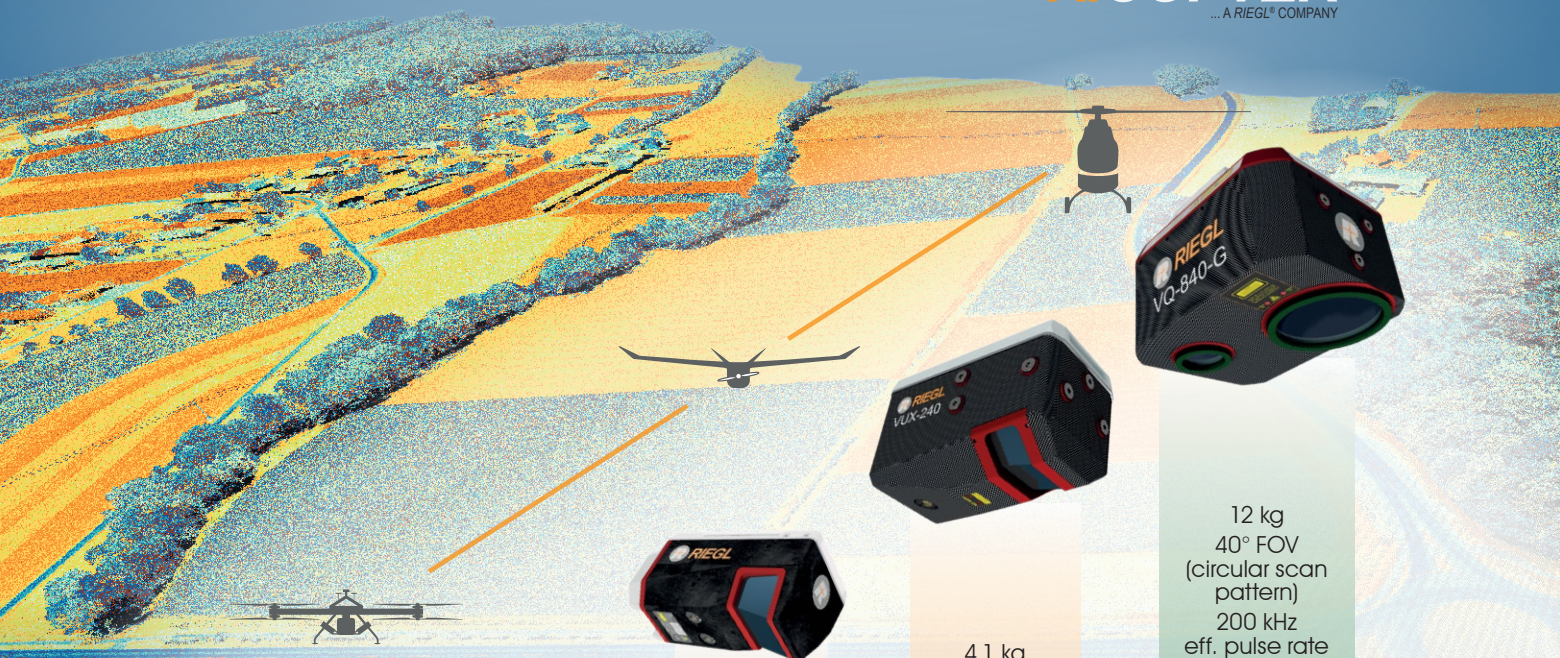

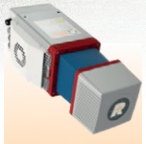

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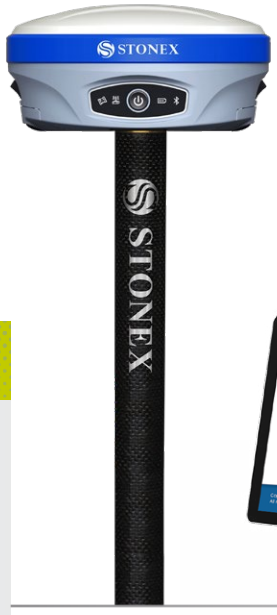

APPLICATIONS

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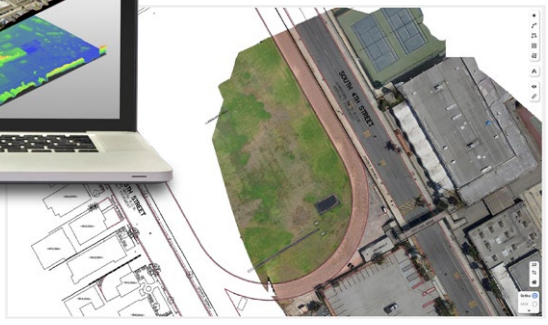


COMPANY PROFILE

Carlson Software has innovated for the land development and mining industries with software and hardware solutions built to work for the clients that depend on them every day. As a one-source solution, we provide CAD design software, field data collection, and laser measurement products for the surveying, civil engineering, GIS, and construction industries.

We have a large user base, and an exceptional rate of customer retention over our 37-year history, and we are the only company with free tech support since the day of our founding.

Our wide product range includes Carlson PhotoCapture for photogrammetry and UAV mapping, Carlson Precision 3D for engineering design in 3D, and solutions that include SurvPC data collection software, data collectors, GNSS receivers, robotic total stations, and laser scanners.

Carlson

33 East 2nd Street
Maysville, KY 41056
606 564 5028
info@carlsonsw.com

carlsonsw.com

Integrated Photo-grammetry Solutions

Carlson's photogrammetry solutions take you from flight planning, through image processing, to point clouds, to surfaces, elevation models, and CAD deliverables.

Pre-flight, Carlson's CAD office software provides flight planning. Post-flight, Carlson PhotoCapture provides powerful, versatile, scalable photogrammetry processing. It is available in two versions:

Carlson PhotoCapture Online may be used on any device with access to the internet. All that's required is a yearly membership and the purchase of processing capacity as needed. No minimum monthly fees, and projects may be shared for collaboration with coworkers and clients.

Carlson PhotoCapture Standalone is for customers who need Carlson's photogrammetry solution but want to process locally. Now anyone lacking high speed internet, working in remote locations, or requiring enhanced security now has the option of bringing the ease and power of PhotoCapture to their own computers.

Carlson Point Cloud provides powerful tools for processing of point cloud files from aerial or surface sources, whether of laser or photogrammetric origin. Employ the bare earth filters to create surfaces, or use the identified above-ground cloud for feature extraction of point clusters. Use point cloud files to create profiles, sections, contours, breaklines, and finished plats, or export surface models, points, etc. to CAD.

Whether you're working with free LIDAR data, fly your own UAV, or work with terrestrial scanner files, Carlson's industry-proven solutions provide the workflow options to produce the deliverables you need for your clients.

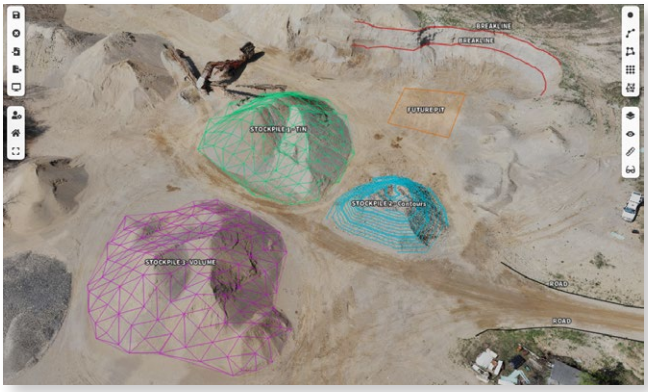
Carlson Software for Photogrammetry

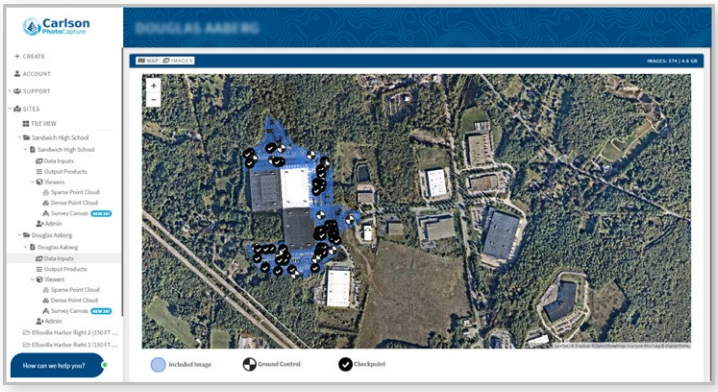
Bridging the Gap Between UAVs and CAD

Carlson PhotoCapture

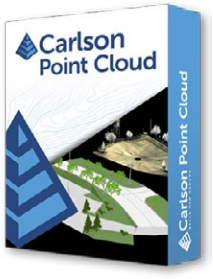
- Choose a perpetual license or cloud-based pay-as-you-go model
- Accuracy through control points and full RTK UAV support
- Output point clouds, volumes, surfaces, elevations, and more
- 30-day free trial

Powerful, versatile, scalable photogrammetry processing. **Online or standalone.**

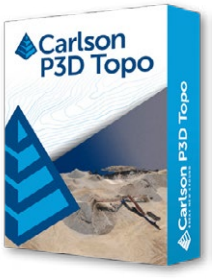




- Sparse or Dense point clouds
- Orthoimages
- Digital Elevation Models
- Project Quality Reports
- Survey Canvas – Virtual Drafting
- Calculate distances, areas, and volumes
- Create points, linework, grids, TINs, and contour lines
- Export in a wide variety of file formats



- Powerful tools such as bare earth and feature extraction
- Point clouds to finished plats
- Point clouds to profiles & sections
- Polylines to CAD



- Powerful point cloud editing in a 3D environment
- Pit/pile volumes
- Surfaces to CAD

Learn more at carlsonsw.com/photogrammetry
33 East 2nd Street ■ Maysville, KY 41056, USA
800-989-5028 ■ 606-564-5028 ■ www.carlsonsw.com

Carlson
BREAK NEW GROUND

GreenValley International

COMPANY PROFILE

Headquartered in Berkeley, California, GreenValley International is a leading innovator of 3D mapping technologies. We provide a wide range of advanced aerial, terrestrial, and mobile LiDAR surveying and mapping hardware systems, as well as cutting-edge software and service solutions. we strive to bring to our customers the most effective products that will get the job done.

GreenValley International

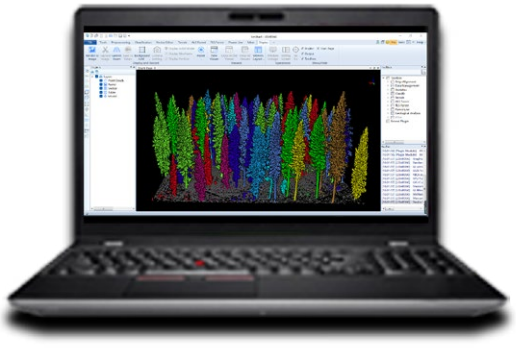
+1(510)345-2899
info@greenvalleyintl.com
2120 University Ave
Berkeley, California 94704

greenvalleyintl.com

APPLICATIONS

- GIS
- SURVEYING & MAPPING
- FORESTRY & FARMING
- POWER SYSTEM
- MINING
- BIM & AEC
- INFRASTRUCTURE
- CONSERVATION

Accelerate Your Surveying



Our high-precision lidar scanning systems, such as LiAir (UAV/Fixed-Wing), LiMobile (vehicle-mounted), LiBackpack, and LiPod (terrestrial), help create smart cities and provide intelligent solutions in energy, agriculture, forestry, roadwork, mining, and more. GreenValley International's LiDAR360, LiPowerline, LiStreet, and other software solutions provide core processing and analysis for accurate point cloud editing and visualization.

While expanding, our primary business efforts focus on innovation and producing breakthrough technology to help create a sustainable future.

GREENVALLEYINTL.

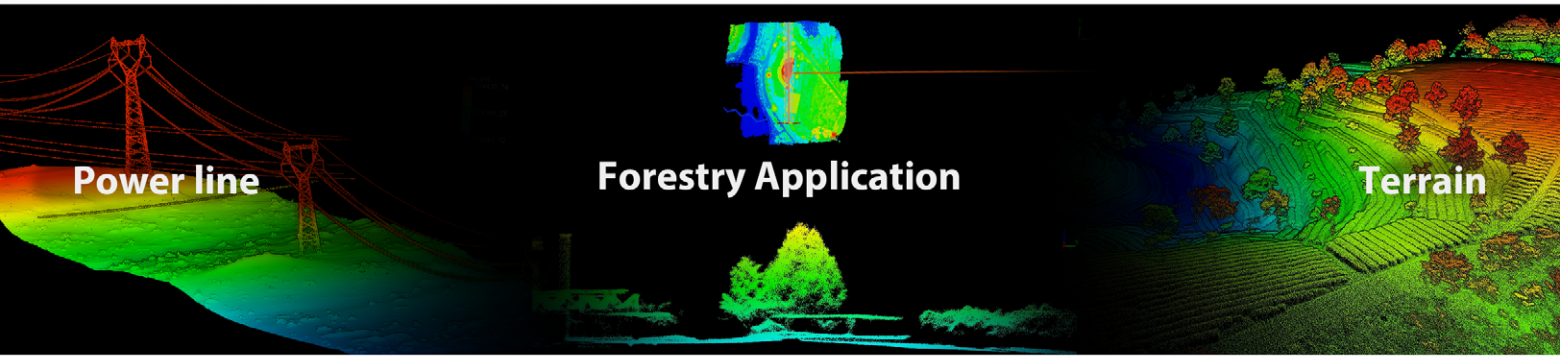
LiAir X3

Enhanced Lightweight UAV LiDAR System

Highly Accurate IMU & GNSS
For the Best Positioning & Details

Upgraded RGB Camera - 26MP -
Providing Ultra-Clear Resolution

LiPlan Flight Assistance Software
Making Field Work Easy



Scan here to learn more about LiAIR X3
or explore GVI's full array of products at greenvalleyintl.com

@GreenValleyINTL

+1 (510) 345 - 2899
info@greenvalleyintl.com
2120 University Ave. Berkeley, CA 94704

SBG SYSTEMS

APPLICATIONS

- AIRBORME
- AUTOMOTIVE
- DEFENSE
- INERTIAL
- MAPPING
- MARINE
- SURVEYING
- UNMANNED

COMPANY PROFILE

SBG Systems is a fast-growing supplier of miniature, high performance, and innovative motion sensing solutions. SBG Systems is headquartered in Carrières-sur-Seine, France and operates in North America from its subsidiary in Santa Anna, CA, and in Asia with its subsidiary in Singapore. SBG Systems offers a complete line of inertial sensors, such as Attitude and Heading Reference System (AHRS) or Inertial Measurement Unit (IMU), based on the state-of-the-art MEMS technology. This technology combined with advanced calibration techniques offers miniature and low-cost solutions while maintaining a very high performance at every level. Our sensors are ideal for industrial, defense & research projects such as unmanned vehicle control, antenna tracking, camera stabilization, and surveying applications. From hydrography to mobile mapping and aerial cartography, SBG Systems offers a complete solution including the IMU, PPK software and services.

SBG SYSTEMS

Founded 2007
11–50 Employees
Carrières-sur-Seine, France
Santa Ana, CA

sbg-systems.com

New Quanta Micro

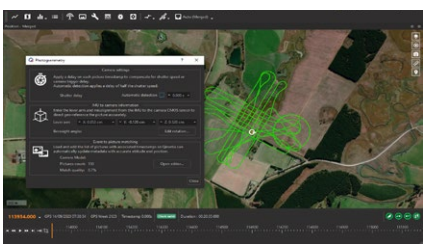
GNSS-aided INS for Pure Performance in the Palm of your Hand

SBG Systems announced its new Inertial Navigation System named Quanta Micro, completing the Quanta product line. This new GNSS aided INS offers a unique combination of navigation performance and SWAP-C. It leverages on a survey grade IMU for optimal heading performance in single and dual antenna operations. Highly versatile, Quanta Micro suits all applications: Land, Air, or Marine.

New Quanta Micro: Outstanding Navigation Performance with Incredible SWaP-C

Quanta Micro integrates a survey grade IMU featuring temperature compensation (0.8°/h class) and is calibrated from -40 to +85°C.

The INS/GNSS embeds a cutting-edge multi-frequency, multi-constellation GNSS receiver and delivers outstanding accuracy (0.02° roll/pitch, 0.05° heading, 1cm positioning in RTK) in the smallest package in all conditions, even in vibrating environments. It is also compatible with SBG Systems' in-house post-processing software: Qinertia for even higher accuracy after data collection.



INS/GNSS Post-Processing for all Applications with Qinertia

This full-featured software gives access to offline RTK corrections and processes inertial and GNSS raw data to further enhance accuracy and secures the survey, thus enhancing SBG Inertial Navigation Systems' performance.

Qinertia now supports third-party IMUs and all GNSS receivers and covers all surveyors' projects with its new GNSS license to post-process both static and kinematic GNSS data.

It now includes a brand-new Virtual Base Stations (VBS) feature to ensure a maximized, homogeneous, and robust position accuracy. With its new features for UAV Photogrammetry, such as image geotagging and specific outputs, Qinertia can dramatically reduce the need of GCP and maximize ROI with an optimal workflow.

SBG SYSTEMS

0.02° RTK Roll/Pitch | **0.06°** RTK Heading | **1 cm** RTK/PPK Position

QUANTA MICRO

Outstanding Performance/ SWaP-C

- Tactical grade IMU: 0.8°/h Gyro Bias Instability
- Robust to Vibrating Environments
- Post-processing with Qinertia PPK Software
- Quad-Constellation Multi-Band RTK GNSS receiver

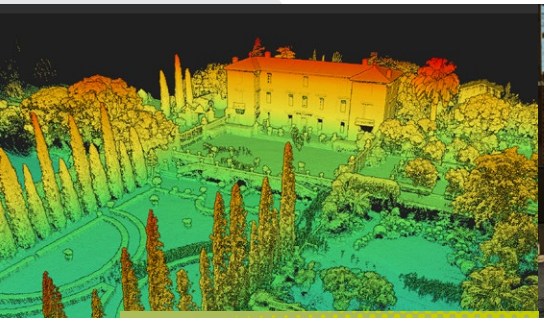
Single or Dual Antenna

Highly Tested and Calibrated

Qinertia PPK Software

www.sbg-systems.com **JOIN US** at Intergeo • Hall 3, Stand E3.024

Yellowscan



COMPANY PROFILE

APPLICATIONS:

- AIRBORNE
- CONSTRUCTION
- MAPPING
- MOBILE
- SURVEYING
- INSPECTION
- TRANSPORT
- UNMANNED

YellowScan lidar products are fully-integrated systems designed for commercial UAV applications. Our lidar solutions include the laser scanner, IMU, GPS, embedded computer and batteries. The processing software provided enables the generation of a georeferenced point cloud in the projection of your choice. Output format is .LAS (lidar industry standard) or .TXT. YellowScan is committed to provide users with the most reliable fully-integrated lidar imaging systems and customer support for demanding UAV applications. Since 2012, the team's dedication to fulfill high resolution and high-quality survey requirements has fueled research and development. Our next generation of fully-integrated lidars are ergonomic, robust and easy-to-use, designed by surveyors to serve surveyors, civil engineers, archeologists and other professional users with a turn-key solution that can be mounted on most commercial-scale drones. The Mapper II, Ultra and YellowScan Vx models complete the "Just press the Yellow Button" product line, complementing the original YellowScan Surveyor, the successful world lightest fully integrated lidar for UAV.

YellowScan

Founded 2005
25-50 Employees
Montferrier su lez, France
Utah, USA + Tokyo, Japan

Yellowscan-lidar.com

Fly & Drive

YellowScan Fly & Drive is a combo that can-do mobile mapping & aerial survey using the same lidar (Surveyor or Surveyor Ultra). It combines high resolution laser scanning and precise positioning to collect georeferenced point clouds for a wide range of applications. This will move the user into another level of possibilities and productivity. The swap can be done in less than 5 minutes. It reduces project duration through fast implementation, collection and data analysis.

Fly & Drive can be rapidly deployed on road vehicles as well as on any types of UAVs (multirotor, helicopter, VTOL or traditional fixed-wing), expanding the range of applications and thereby hastening your return on investment.

Fly & Drive is an extension of our Surveyor and Surveyor Ultra, consisting in set of mobile mapping gear: a pod, an adaptable bracket and a GNSS antenna.

The possibility to switch the lidar system from UAVs to land vehicles and vice versa, allows the user to perfectly complement a top view acquisition of building roofs with a detailed façade survey. Or, in a light forest, a canopy and tree trunks survey.

It also allows to survey flight restricted zones, such as urban areas, power plant, refineries and more. The main purpose of the point clouds you acquire with Fly & Drive are road, pipeline, renewable energy construction pre-survey or quarries in presence of vegetation.

As the swap is easy and fast to operate, both acquisitions can be done in 1 day.

APPLANIX

APPLICATIONS:

- AIRBORNE
- MAPPING
- MOBILE
- OEM
- SURVEYING
- INERTIAL/IMU
- GNSS
- UNMANNED/UNCREWED

COMPANY PROFILE

Position and Orientation Solutions
For nearly 30 years Applanix, A Trimble company, has offered complete and customized mobile mapping solutions while championing the technology revolution that allows pinpoint positioning in any condition. Applanix is the standard for organizations that depend on accuracy and quality and who value experienced partners.

Our turnkey and OEM GNSS-Inertial solutions are designed for pinpoint accuracy, efficiency and ease of use, supporting applications for aerial survey and remote sensing, land-based mobile mapping, and autonomous vehicles. Whether you require a complete airborne mapping solution for generating directly georeferenced lidar data or guidance and Advanced Driver Assistance Solutions for vehicles, Applanix has your solution.

applanix™
A TRIMBLE COMPANY

Founded 1991
51-200 Employees
Ontario, Canada

applanix.com

APX-18 UAV

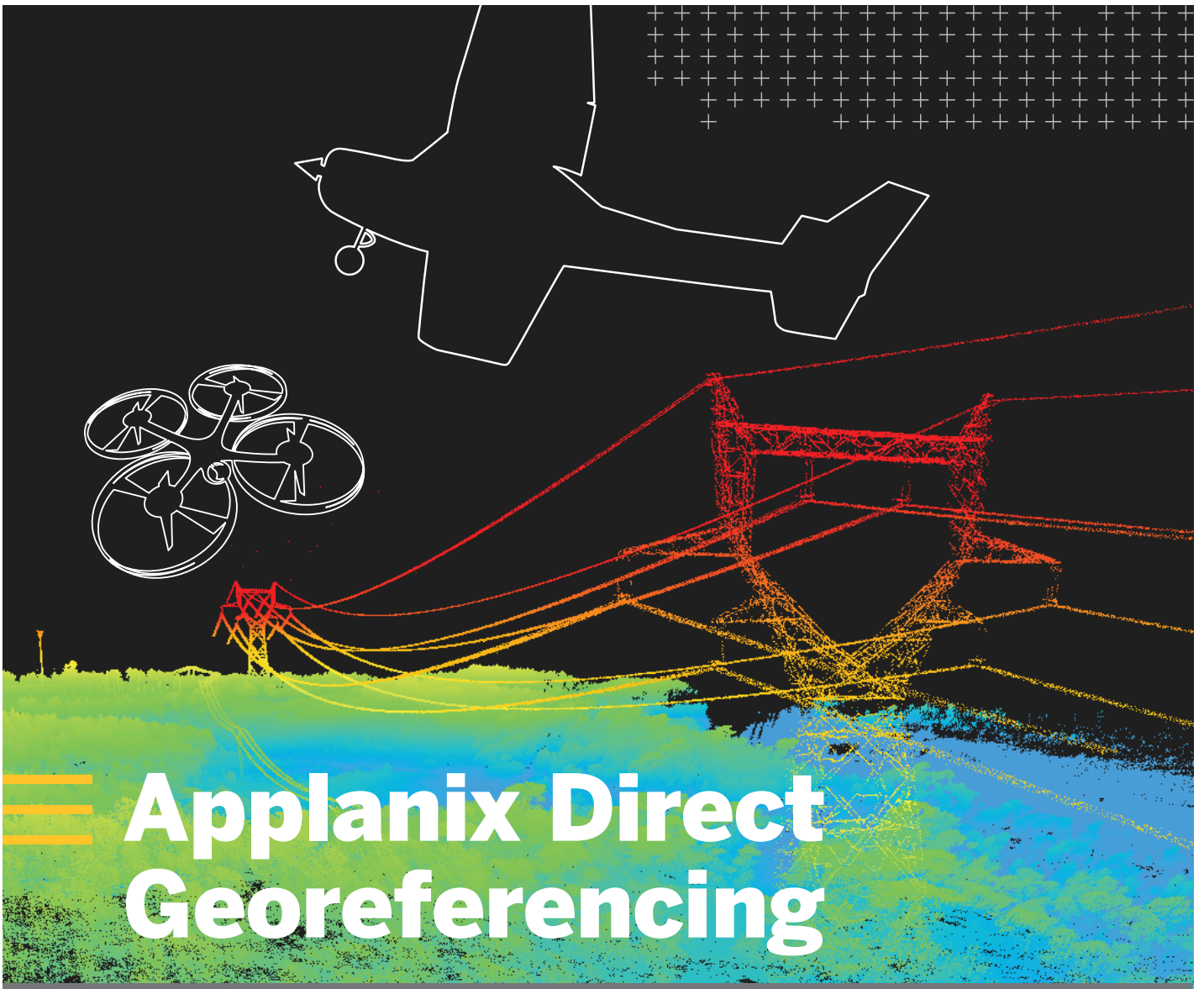
The Trimble APX-18 UAV is an OEM GNSS Inertial solution with dual GNSS antenna input, designed to georeference lidar and other imaging data when collected from Unmanned Aerial Vehicles (UAV) at low speeds or when hovering. Comprised of a small single OEM board containing a precision GNSS receiver with two antenna heading and inertial sensor components plus POSPac UAV Differential GNSS-Inertial office software, the Trimble APX-18 UAV produces a highly accurate position and orientation solution for directly georeferencing lidar point clouds and imagery.

High accuracy, extremely small package

Measuring just 100 x 60 mm and weighing only 62 grams, the APX-18 UAV provides unparalleled performance in an extremely small package. With the included POSPac UAV postmission software, it produces a highly accurate position and orientation solution for direct georeferencing of cameras, lidars and other UAS sensors.

Key features:

- High-performance Direct Georeferencing solution for improved efficiency and accuracy of mapping from small Unmanned Aerial Vehicles
  - Reduce/eliminate GCP's
  - Reduce sidelap
  - Accurate lidar georeferencing
  - Instant alignment through dual GNSS antenna heading
- Compact single-board OEM module complete with survey-grade multifrequency GNSS receiver and MEMS inertial components
- Applanix IN-Fusion™ GNSS-Inertial and SmartCal™ compensation technology for superior position and orientation performance
- POSPac UAV Differential GNSS Inertial post-processing software for highest accuracy
- RTK real-time position for precision landing applications
- Supports all common RTK corrections such as CMR, CMR+, RTCM



Applanix Direct Georeferencing

Turn your aerial vehicle into a professional mapping solution, no matter what you fly!

- GNSS-inertial technology specifically designed for Direct Georeferencing airborne sensor data without base stations.
- Applanix DG™ is used with cameras, LiDAR, and hyperspectral sensors for highly-efficient, automated mapping and surveying.
- Experience the accuracy of POSPac MMS/POSPac UAV with Trimble CenterPoint® RTX™.
- Discover Applanix IN-Fusion™ GNSS-Inertial and SmartCal™ compensation technology for superior position and orientation performance.

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85 Leek Crescent, Richmond Hill, ON L4B 3B3 Canada
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airborne@applanix.com

applanix™ DG™

Jun Pei in front of Cepton's new headquarters.

Cepton Technologies Grows with a Vengeance

San Jose lidar supplier celebrates huge auto win

Cepton Technologies is one of many vibrant start-ups leading the way in automotive lidar. Located like many of its competitors in Silicon Valley, it has recently enjoyed a boost in financing through a SPAC[1,2].

LIDAR Magazine has twice reported on Cepton[3,4], firstly when it was about to move into new premises, the interior of which had been carefully designed by CEO Dr. Jun Pei. The company has moved again, forced by rapid growth. The latest facility stands at 399 West Trimble Road, San Jose, California[5]. The street name may occasion gasps from many readers, but in fact is named after John Trimble, a stockman born in

1 Special Purpose Acquisition Company. *LIDAR Magazine* attempted to explain the SPAC process in an article about Velodyne Lidar:lidarmag.com/wp-content/uploads/PDF/LIDARMagazine_Walker-Velodyne_Vol10No4.pdf.

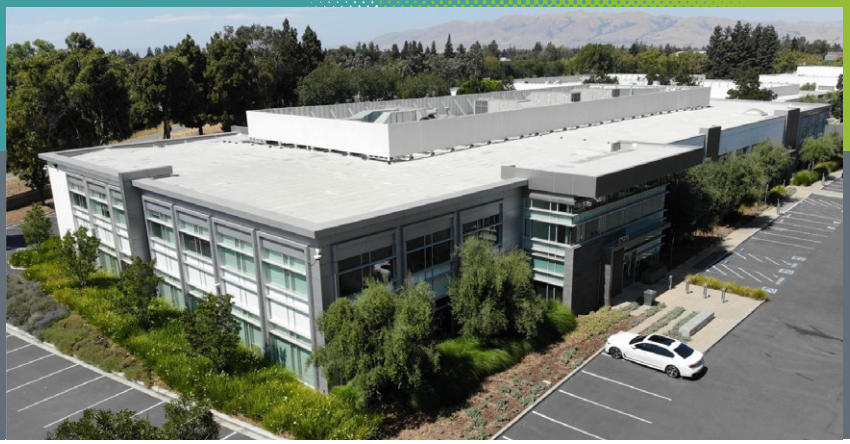
2 cepton.com/announcements/cepton-technologies-and-growth-capital-acquisition-corp-announce-closing-of-business-combination

3 lidarmag.com/2018/04/27/cepton-technologies

4 lidarmag.com/2020/09/05/intelligence-at-the-speed-of-light/

5 news.theregistrysf.com/cepton-takes-92000-sqft-in-san-jose-for-new-headquarters/

BY STEWART WALKER



UAV view of Cepton's new headquarters in San Jose, Silicon Valley, California.

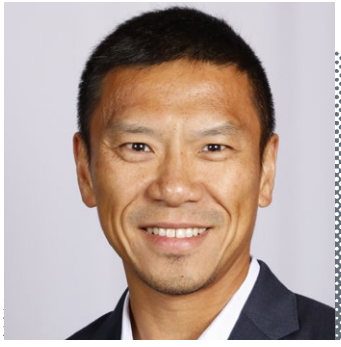
External and internal views of Cepton's new headquarters.

Missouri, who traveled to California in 1849 and settled in the area now known as Silicon Valley in 1853.

I was keen to take the opportunity to obtain an update on Cepton. My visit was once again hosted by marketing and communications manager Faithy Li and I was privileged to have two brilliant interlocutors, Dr. Pei himself and his new VP of finance and strategy, Hull Xu.

Before the formal interview, however, Faithy and Jun accompanied me on a tour of their imposing premises. Cepton moved in after the building had been vacated by AMSL, a leading supplier to semiconductor manufacturers. "They moved to a bigger campus and we captured all their good stuff," enthused Jun. Certainly, the building was beautifully appointed and pleasing to the eye—the Cepton team has a fine base to work from and won't grudge the fact that they had only four years in their previous home. On the upper floor, we traversed the software department, the electrical, mechanical and systems labs, and a plethora of conference rooms that was an insight into the company's culture.

The number of employees had increased beyond 120, though Jun described this as "slow growth", noting that the company had celebrated its fifth anniversary in July 2021. We passed a row of executive offices, then went



Hull Xu, Cepton's VP of finance and strategy. Hull was appointed chief financial officer in April 2022.

Jun Pei at work in the garage area of Cepton's new headquarters.

downstairs to see more conference rooms, a manufacturing area and the machine shop. We visited a testing area and Jun explained that it was more structured than testing areas upstairs, because it serves production rather than engineering. There was a production line in operation – this activity, obviously, is not suited to working from home during the pandemic – and a validation lab. Jun said, proudly, "It's a 90-000-square-foot building, around four times the size of our previous one. It's a very notable place now." The calibration area has grown in both size and status as the company has evolved. We saw production managers' cubicles, a materials storage area, another testing area, with a range of targets, which would be not unfamiliar to a college student in land surveying, for long-range calibration, and a second production area. Having visited Cepton's previous two facilities, I could not hide my astonishment at the spaciousness of the new one. Jun responded, "After all, we are becoming a public company—that also astonishes you, probably!"

We spoke briefly about the SPAC. Jun was at liberty to furnish details based on publicly available information, though the formalities were not yet complete at the time of the interview. We inspected the "patent wall", which Jun anticipated would become more heavily populated as the company had around two dozen patents in the pipeline. The final phase of the tour seemed to fill Jun with the greatest pride—a cafeteria, the first Cepton had had, with both indoor and outdoor spaces, in which all-hands meetings were held; and the backyard, complete with barbecues, bocce ball and a fountain that can be used when city regulations permit. Jun is conscious of employee contentment.

We passed test vehicles, including a Chevrolet Tahoe with Michigan plates[6]. There was the machine shop, of course, complete with Jun's personal equipment on which he had rhapsodized on an earlier visit, then yet more manufacturing and testing areas, in this case testing sensors against targets of different reflectivities. There is an outdoor testing area too, ensuring that lidar is fully assessed in bright sunlight. Jun pointed out that the company's processes were much more mature than on my earlier visits.

The layout seemed logical, everything was carefully laid out and labelled, as well as attractive, giving Cepton whatever advantages could be derived from a building and its fixtures and fittings. The spaciousness and the growth of the company it housed, however, held a downside for Jun too: "I start to not know everybody's name." I reminded him of his comment in a previous interview that he liked to take a prospective employee for coffee to explore whether the relationship would work. "I think I pretty much lost that," he lamented. Indeed, HR people and facility managers have joined Cepton. "When you first visited, I used to be the engineer, the machinist, everything," Jun quipped as we rejoined Hull in the interview room. He had expressed the wish then that the business would run automatically, so he wouldn't have to come to the office every day. "That remains a desire, not a reality," he admitted. Jun's office was much the same as before, still with the piano, but the conference table was larger. "It's been quite a run in the last five years." He was clearly delighted that Cepton was becoming a public company.

LM: Let's talk about the SPAC. It will be lovely in terms of access to capital, but I hope you don't feel restricted. My understanding is you have to have more members on your board to meet SEC requirements. So there'll be more people controlling you than before.

HX: One more, from the SPAC entity, and possibly another one, just to meet the various committee requirements.

JP: If you're doing a good job, smart bosses will not bother you. That's been true in my entire past career. If you're not doing a good job, then you have to

6 One week after this interview, the news came out that Cepton's big contract is with General Motors: forbes.com/sites/samabuelsamid/2021/09/09/general-motors-selects-cepton-to-supply-lidar-for-2023-production/?sh=31520f9e701e. This article also confirmed the SEC filing to which Hull referred in the interview. In its S-4 filing (SEC Form S-4 is filed by a publicly traded company with the Securities and Exchange Commission and is required to register any material information related to a merger or acquisition), Cepton had revealed that it had been, *"awarded a significant ADAS lidar series production award with Koito on the General Motors business."*

Lidar sensors mounted on one of Cepton's Chevrolet demonstration vehicles: Vista-X90 can be seen mounted between the internal rear-view mirror and the windshield and Nova units on the front grille (under the Chevrolet logo), in the rear fender, in the handle of the tailgate, and on the external rear-view mirror.

be supervised. I hope I will continue to do a good job in this place. So the board members are not going to be an issue. Yes, there will be more board members coming my way. And perhaps they can give me even more help.

LM: Presumably you have some influence over the choice of board members?
HX: As we grow as a public company, the corporate governance part, with the right board member choices, will help us solidify some aspects of the business.
JP: Hull is a Stanford guy in electrical engineering, but prior to joining to Cepton, can you imagine, he was an investment banker for a dozen years? One of the very fortunate things for this company is that we can continue to attract talent like this, and we get to work together. Now we actually have professional professionals. Last time you were here, Bob Brown had just joined us—he moved on to some other opportunity.

LM: He had come from one of your competitors. He was very highly rated in this kind of company.
JP: Absolutely. Our current CFO, Winston Fu[7], is our series A investor. He's, what else, a Stanford guy, a physics PhD with an investment background. Stanford is just a cult here. Faithy is from Stanford —East Asian studies. But there's always a balance. I graduated from Brandeis in the Boston area. In that area the culture in the academic world is rather different—it's very pure academic—none of this capitalism! Yes, entrepreneurship is great. But sometimes I long for the pure academics.

LM: The last time I was here, in February 2020, you had had the injection of capital from Koito, you had fitted out the office, you had about 100 employees. On the product side, the Vista X-120 and the Helius software. You've grown to over 120, you've got a fantastic new building, you've got some great new people. What happened on the product side?
JP: There was something that I alluded to in February 2020, by far the biggest news in this industry! In December 2019, just a couple of months prior to our meeting, we captured the largest lidar design win from a top-five, Detroit-based OEM[8]. It ranks as one of the top five in the world by volume. This is by far the largest design win for lidar for any company. It's a good validation for Cepton and the entire industry. In comparison, you're aware of Innoviz's design win with BMW and Luminar's with Volvo. By the same ranking[9], BMW ranks number 13 worldwide in sales volume, Volvo ranks 28. If you combine all the ADAS design wins out there by volume, it's only a fraction of what we have won. It is a 2023 program for production cars, not demonstration vehicles but everyday consumer cars. In a couple of years, you'll be able to buy a car, from a dealership near you, with lidar inside. This is a huge milestone for Cepton. We buried our heads—to answer your question—for the last 18 months, we embarked on the journey to execute

7 With Hull being appointed to CFO, Winston remains a board member and is now Advisor on Strategic Projects

8 cepton.com/announcements/cepton-secures-industrys-largest-adas-lidar-series-production-win-with-leading-detroit-based-global-automotive-oem

9 IHS light vehicle production volume rankings for 2019

this largest design win for the industry. We've delivered A samples, B samples, C samples[10], if you're familiar with all those terms associated with automotive programs, and, so far the execution, even under the very difficult circumstances of covid, has been carried out pretty nicely.

Cepton lidar sensors for the ADAS market. Vista-X90 (left) and Nova (right).

LM: That explains what you've been doing! Innoviz has lots of very able people as well[11], although they're different in the sense that the top management all met each other in the Israeli military.
JP: Absolutely. Especially when you start companies like this, in this risky, competitive environment, having buddies with the same cultural and educational background is one of the key elements to success.

LM: On the product side, I think since we last spoke, Nova is new. And Vista has several variants.
JP: The major design win is still based on the MMT[12] that we have developed in this company. We've talked about it a couple of times in the past and it hasn't really changed. The win is very much a Vista-derivation. It's another slight change of the Vista design that will fit into the vehicle, but it's based on the same technology. So there's the Vista variation and there's Nova, which is meant for near range and smaller distance. For the automobile industry, we see, in the not too far future, these high-performing, near-range lidars have a chance to replace ultrasonic sensors to provide an even higher level of safety, as the car starts from zero speed. If you count all the accidents for cars, one of the most dangerous occasions is actually when the car starts from zero, for example in the garage, when you have stuff or people around you.

We've always had a focus on the ADAS industry, promoting additional safety for cars, before autonomy. Even in 2016, there was a bandwagon of autonomous vehicles on level four, so you saw many companies trying to aim high for the big pie, which never came. We aimed at everyday consumer cars and this enabled us to get this largest design win. Looking back, I think it really is the correct direction. First and foremost, lidar will be in the consumer cars marketplace, to promote additional safety, not just autonomy. Of course, a benefit is additional automation that brings us from level two to level two plus and towards level three, which is how you can reduce the accident rate by 30%, 50%, or even 90%. That's where lidar brings tremendous value to consumers.

LM: You won a couple of 2021 Tech AD Europe awards[13]. Congratulations.
JP: Thank you. We're starting to make a name for ourselves out there, slowly, gradually. Cepton has been an understated company. Until today, not many people knew that this is the place with the largest ADAS win and it's a dominant force—MMT is going to be the future, at least for the next decade. That will be the technology in cars.

LM: One of the things that must be remarkable to people outside the industry is how many SPACs are lidar companies. There's you; Velodyne was one of the first ones; then Quanergy, AEye, Aeva, Innoviz and Ouster. A SPAC gives you quicker, better access to capital than the traditional VC route. Is that right?
JP: To me, yes, absolutely!
HX: There are a couple of factors. For a traditional IPO, investors typically don't look beyond two years, in terms of revenue visibility, but lidar companies' value is in the more distant future, especially in the automotive market. For a SPAC transaction, the company is allowed to communicate its future prospects directly to the investor, whereas in a regular IPO, it's not. That's a key factor why lidar companies have chosen the SPAC route to communicate their stories.

LM: The other things I don't quite understand are, how do you decide the timing, and how do you choose your SPAC company? In your case, it was Growth Capital Acquisition Corporation. Did they choose you? Or did you choose them? And when?

10 According to Cepton's Q2 2022 earnings call, the company had been delivering D-samples by Q2 2022. https://investors.cepton.com/static-files/c9fc0d37-5e01-427b-af73-de8911ed7994
11 lidarmag.com/2021/08/18/israeli-automotive-lidar-supplier-leapfrogs-into-sight/
12 Cepton's patented Micro Motion Technology.
13 businesswire.com/news/home/20210819005247/en/Cepton-Lidar-Innovations-Score-Twice-at-the-2021-Tech.AD-Europe-Awards

HX: It's a mutual process. We did talk to a number of interested parties and we did receive a number of interesting term sheets. We chose Growth because they have quite a bit of experience in SPACs. This is not their first, or their second, but their fourth SPAC. They've been doing SPACs for over 10 years now. And they also are operators. We saw these two benefits, so we decided to go.

LM: This is a question because my readers are not fintech people. Koito is providing another $50 million through a PIPE[14]. If they're doing that, why do you need a SPAC?
HX: Koito, as you know, is our long-term partner, our tier-one partner, so they know more about us than most any other investor. They have confidence in us, so we asked them to come into the PIPE as a way of supporting us. And they've agreed.
JP: There's always more than just the financial stuff for going public. There's marketing: if you're a public company, you're better known, better recognized and the operations are more transparent. That promotes credibility as we do further engagements with future partners and consumers. So it's not just, Koito gives you $50m and you hide away. We can no longer afford to be a closet operation. Now we're coming out of the closet, we are an important lidar company, we're the dominant force in the ADAS industry. We're going for public, we're going to establish ourselves in this open market.

LM: Koito is going to manufacture for you as well?
JP: For this specific ADAS win. Koito is the tier one, we're the tier two and they will be the manufacturer and the product will come out of Japan. Yes.

LM: So they're called a tier one and you're called a tier two?
JP: The tier-two-tier-one OEM structure is a very well-established, structured supply chain for automotive manufacturing. In this case, we're adopting that same methodology. Just to clarify, Koito and Cepton are not exclusive to each other. We have additional partners and supply chains to work with. But for this specific project, yes, we are together.
HX: Technically, we're a tier two, but we're almost like tier 1.5, because lidar is such a new technology and we are leading the discussion directly. Also, we're leading some of the manufacturing—calibration and other steps—in conjunction with Koito. With some more mature technology, you have tier one, tier two, where the tier two doesn't really speak to the OEM. That's not the case here.

LM: Many lidar companies have SPACs. Is this like all boats bobbing up on a rising tide? Can you say that your SPAC is better than someone else's? What's happening?
JP: A SPAC is a SPAC, just like an IPO is an IPO. That's what I call a process, a capital-raising process. Ultimately what matters is whether the company can do what it promised to do and can deliver what it promises to deliver. I keep coming back to the largest design win we have, these are solid contracts with solid revenue that's going to come in, starting from 2023. These are huge numbers, just from the beginning of this program. And for companies just going public, just going through the SPAC process, having or not having solid automobile contracts is going to be the speaking power.

LM: Having access to capital means that you can do what you have to do to get there, in the sense that you need to organize manufacturing, you need to optimize the manufacturability of the product. And now you have the flexibility, the means to do that.
JP: All these elements—manufacturability, supply chain management, scalability, reliability, and quality of your product—all of these things associated with volume production come with a prerequisite that you must have a design win. If you don't have a design win, you don't even get to work on these things. There are not many people, maybe you can count them on one hand, who actually have a meaningful design win. So that's how selective the lidar company landscape is. You can say, I don't work on ADAS, I work on some niche markets. But if you look at the total addressable market in the next decade, ADAS occupies more than 80% of the entire lidar market. So it's a matter of choice whether you compete in this 80%. It's almost winner takes all, given the size and the spread being so heavily concentrated on ADAS.

LM: We had a chat last time about how extremely talented people move around in the industry and in the Valley and, of course, Cepton is an example of this now: you have a new CFO, replacing Bob Brown. As you said, most of that movement is inward.
JP: A few people have moved out to other lidar companies, but the inbound is a lot more. And as we announced our SPAC, you can imagine there are even more. I'm a bit surprised and proud to hear that last time you were here we were about 100 people. Now we're a little over 120—it's very slow growth. We're so selective in hiring people with top talent—it's a hard process.

14 Private investment in public equity. See the article cited in footnote 1.

Bell ringing as Cepton (CPTN) is listed on the Nasdaq on 17 February 2022. Front row of podium party, from left to right, includes George Syllantavos (chartreuse tie), co-CEO of GCAC; Akis Tsirigakis, co-CEO of GCAC; Dr. Jun Pei, co-founder and CEO of Cepton; and Dr. Mark McCord, co-founder and CTO of Cepton.

LM: There are probably somewhere between 10 and 30 lidar manufacturers. They're not all going to survive. There will be consolidation and shaking out.? What do you think's going to happen?
JP: I'm not a prophet with a crystal ball. I always come down to fundamentals. Whether it's consolidation or otherwise, it has to make business sense, which comes from winning contracts and having solid revenue paths. Do I see consolidations leading to that? I'm not so sure. Some shape and form may be helpful.
HX: When I was at RBC Capital Markets, I covered auto tech and over 60 lidar companies. Automotive is the largest chunk of the total addressable market. The space outside automotive has a very different dynamic in terms of projects being a lot smaller. In order to achieve the same revenue, you have to get a ton more customers. It's a much more fragmented market. The total addressable market does not really support 60 lidar companies. Inevitably, there's going to be some consolidation and some are just not going to make it. Jun talked about the fundamentals in terms of commercial traction. My view is that the ones with the largest commercial traction by definition are going to be the players with the biggest market share. Those are going to survive and thrive. In the early stages, companies which don't have as much commercial traction but do have some kind of technology that could be beneficial to others will be consolidated into others, but some are just not going to survive.

LM: We have an article in the magazine by a company called Lumotive[15]. They're into very small sensors, physically small, and therefore they're interested in the very close-range market. There's a market there. I'm sure Jun has explained to you that the magazine come from a geospatial background. When I got into lidar, systems flew up to 5000 meters and there are really only three companies do that, one Swiss, one Canadian, and one Austrian. It's been like that for decades. And they only overlap with you in the tiniest possible way. They make sensors that fly on UAVs at 100 meters, but they cost 10 times as much. Their performance is better in terms of noise level, but you could put three or four of your sensors on the UAV and maybe with some math get to the same answer. It could be that there's not just niche markets with niche technologies, but also some of these companies may have a better market understanding—they may be focusing their sales efforts in particular areas.
HX: Everything could be a balancing act, whether it's focusing the sales effort or focusing R&D efforts on niche markets. That's obviously the choices of those companies. Some lidar companies, maybe because of their addressing that niche market, are going to be smaller. They'll be around.

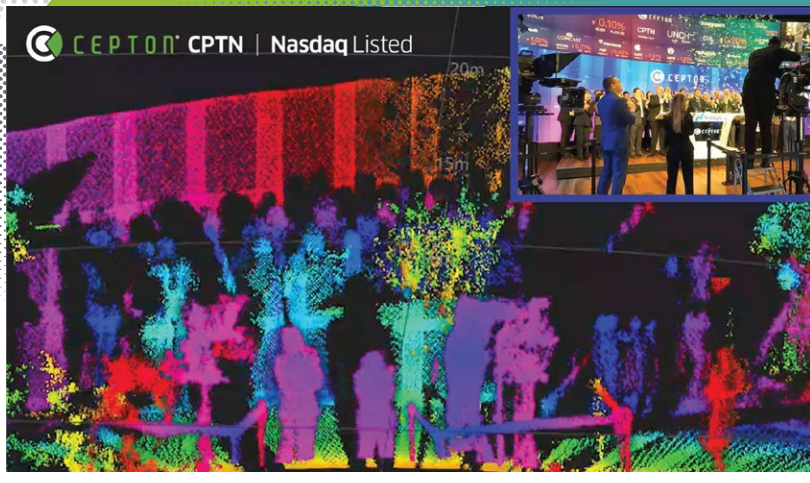
LM: These other markets are much more difficult to understand. I think that, after ADAS and AVs, you've talked about smart infrastructure, then you divide that into smart cities, smart spaces and smart industrials. That's a good classification. Other people might classify it slightly differently. But I think it's just harder to do than automotive.
HX: I think in automotive we get the best return from our efforts. For example, the, design network, the series production network that we have, is one thing. With customers outside automotive, you might have some customization with each deployment—imagine the amount of engineering resources and application support that has to go on for each of these customers. It's just a different game. We cater to those applications as well. We utilize our partners and production partners in those spaces to help with the customization, but we supply the core technology.
HX: On the SPAC process, there is another filing with SEC that we will need to do next week. It's a very thick disclosure, much more information will be contained in that disclosure than our announcement investor deck. So there's a lot of good information if you have the time to read through some of it[16].

LM: And when do you think you'll finally be listed? What will be your ticker?
HX: Our ticker is CPTN. In terms of exactly when the transaction will close, we anticipate Q4 of this year, but it really

15 lidarmag.com/2021/08/18/short-range-lidar-opportunities-and-challenges/

16 This was the S-4 filing referred to in footnote 6.

Cepton features on the Nasdaq tower, Times Square, New York, on the day of the bell-ringing, 17 February 2022.



Cepton took its Vista-X90 lidar sensor to New York to record the Nasdaq bell-ringing ceremony on 17 February 2022.

depends on how fast the regulatory bodies get back to us[17].

LM: Will there be enough work for you and the CFO to do once this happens?
HX: There's definitely plenty of work. My role here is finance *and* strategy. As a public company, we have many things to work on. On the strategy side, as you mentioned earlier, it's a crowded lidar space. There may be other things that will happen. Obviously once we're public, there is going to be a lot of investor interaction. Part of my job is also to handle that piece of the work and we may need to have additional help on that. We also have an IR[18] advisor, just to focus on investors. But it's an ongoing effort.
JP: As part of the company growth now, we have really talented people with professional backgrounds in this organization.

LM: To me as an outsider, I think it's important that you and Mark[19] can remain focused on the technology because after all, that's your expertise. That's where you came from. You've got some of the patents.
JP: If you always consider me as the technical guru in the company, then we're going to be falling behind. New people bring a fresh breath of air and new blood infusion. There are plenty of technical people here better than I. I lost a lot of jobs in this place!

LM: I'm grateful to you for having me in at such short notice and making me so welcome. Because I saw the SPAC announcement, I knew that I needed to talk to you again! And thank you, Hull, for joining the meeting.
JP: We're very thankful that you can come here and I get to show off the new building.

On the way out, I encountered Cepton's then CFO[20], Dr. Winston Fu. His PhD, of course, is from Stanford, in applied physics, but is preceded by an MBA from the Kellogg School at Northwestern University and a BS from MIT in applied physics. While I had never doubted Cepton's strength in depth on the technology side or its entrepreneurial spirit, I left San Jose equally impressed with its freshly hired expertise in financial engineering. Cepton's design win with its Detroit-based client is the sort of success expected from an automotive lidar player, especially after a SPAC. Cepton has the technology and the acumen to justify its place in the premier league.

Cepton announced the expansion of its Detroit office in June 2022.

17 Cepton was listed on the Nasdaq on 11 February 2022, some weeks after the interview. Photographs of the events are included here to underlines the celebratory nature of the occasion.
18 Investor relations.
19 Dr. Mark McCord, Cepton's CTO.
20 cepton.com/about-team/winston-fu

Stewart Walker is the Managing Editor of the magazine. He holds MA, MScE and PhD degrees in geography and geomatics from the universities of Glasgow, New Brunswick and Bristol, and an MBA from Heriot-Watt. He is an ASPRS-certified photogrammetrist.

LiDAR USA

COMPANY PROFILE

We are an aggressive team of pioneers in geomatics searching for new, innovative, and affordable solutions. We build economical UAV & mobile mapping systems, that push technology to the edge using the latest tools for scanning, imaging, and navigation.

The idea to develop the Snoopy and ScanLook LiDAR systems came out of our need to find an affordable light weight solution that was easy to use and operate. We have developed solutions for indoors and outdoors. The key technologist and principal investigators are Daniel and Jeff Fagerman. We are experienced in photo control work with conventional total stations, levels, etc., and also with the latest GPS technology. We consider software development a particular interest and hardware integration something we excel at. We seek out ways to improve workflows using existing technology in an unconventional way.

20 YEARS ANNIVERSARY CELEBRATION
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Founded 1999
20+ Employees
Alabama, USA

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APPLICATIONS

- AIRBORNE
- EDUCATION
- MAPPING
- MOBILE
- INDUSTRIAL
- MILITARY
- UNMANNED

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Snoopy A-Series HiWay Mapper HD + UAV Package

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M200 Series Snoopy LiDAR Package

The M200 Snoopy Series LiDAR Package is designed specifically for the ever-popular DJI M200/M210 UAV. Custom designed for the Velodyne A-Series Scanner and weighing only 1.63kg, the M200 Snoopy Series is light, fast and easy to use. With deployment from an easy to carry case and just a click of a button on your smartphone, you are ready to scan. The M200 Snoopy Series is a smaller, evolved version of our Snoopy system. This unit is designed to be an affordable yet extremely accurate solution.

Revolution 60, 120 and HD

Ready-To-Fly-Ready-to-Scan package. Endless coordinate systems; LAS/LAZ, etc., formats; Control point registration; Point Cloud filtering; Coordinate measurement update tool.

We also offer the Snoopy Mini-VUX and VUX (RIEGL); Snoopy Dual-VUX (Riegl); SCANLOOK TreX, for Trimble shops; our PhaseOne Photogrammetry Package, a host of supporting products and more! Sensors we integrate and resell include the Velodyne Puck Hi-Res,Velodyne Puck LITE, Velodyne HDL-32E, Velodyne Puck. Sensors we inegrate include the FARO FOCUS 3D, Quanergy M8 and the Z+F Profiler.

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20 YEARS ANNIVERSARY CELEBRATION

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RIEGL inside

Phoenix LiDAR Systems

APPLICATIONS

- MAPPING
- SURVEYING
- UAV
- GIS
- MODELING
- IMAGING
- SCANNING

COMPANY PROFILE

Phoenix LiDAR Systems was the first to introduce commercial drone LiDAR to the market, in what is now a global industry. When organizations seek to digitize the physical world, whether for surveying, archeology, film, or more, Phoenix LiDAR builds them a fully integrated UAV LiDAR system, combining our hardware and software with an assortment of sensors to create a customized system that is ready to fly. Phoenix LiDAR Systems builds custom, survey-grade laser mapping systems, and automation software for flight planning, acquisition, and post-processing, enabling clients to collect detailed, 3D topographic information for a wide range of commercial and research applications, including engineering, construction, mining, and more.

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Phoenix LiDAR System's MiniRANGER-3 LITE + DJI Matrice 300 UAV

The MiniRANGER-3 LITE is an upgrade to the renowned miniRANGER-LITE—boasting a 3X increase in point density. This solution is designed to provide survey-grade LiDAR data and imagery (optional) on an ultra-lightweight platform. Packed with options, the miniRANGER-3 LITE leverages Phoenix's years of experience and industry leading LiDARMill software platform to provide a seamless user experience. Optional mobile and backpack mounting options along with several imaging sensor options provide the adaptability required to address any mapping application. With the photogrammetry package, operators of mid-size multirotors can now simultaneously acquire survey-grade LiDAR data and high resolution 61 MP photogrammetry at up to 100 m operating flight altitude.

The MiniRANGER-3LITE is a dependable, lightweight system designed to be a cost-effective tool for meeting federal USGS Quality level 0 project standards, and is the only DJI Matric 300 mountable system capable of meeting these strict specifications. This unstoppable combination reliably achieves sub 2cm precision on hard surfaces with up to 5 returns per laser pulse. The added benefit of Phoenix LiDAR System's real time data visualization empowers user confidence and offers peace of mind on high-value projects.

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We combined RIEGL® industry leading laser precision with the ubiquitous M300 airframe, and topped the solution off with **Phoenix LiDAR Systems**' renowned real-time 3D data visualization software.

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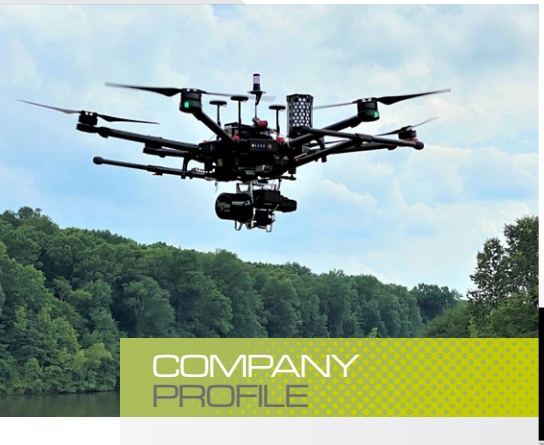


COMPANY PROFILE

GeoCue is the largest supplier of kinematic lidar processing tools in North America and LP360 is one of the world's most widely used tool for exploiting point cloud data. In 2014, GeoCue Group started a division focused on using small Unmanned Aerial Systems for high accuracy mapping. Leveraging our expertise in production, risk reduction, and point cloud processing tools, we are continuing to bring new services and products to market to provide surveyors and other geomatics professionals exciting tools for geospatial data extraction using low cost drones including Loki, our plug-and-play PPK direct positioning system, and now our new True View® Drone LIDAR/Imagery fusion sensors.

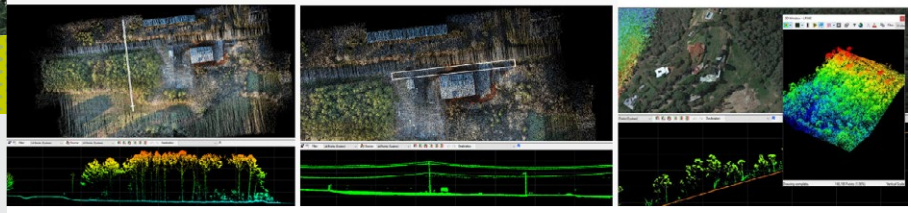
GeoCue Group

Founded 2003
11-50 Employees
520 6th Street Madison, AL 35756

geocue.com

APPLICATIONS

- MAPPING
- PROCESSING
- SURVEYING
- UNMANNED
- AERIAL
- CONSULTING



True View 3D Imaging Sensors

Powerful LIDAR + Dual Camera Sensor integrations, post processing software and data management for high accuracy drone mapping applications.

Fly, Process, Deliver— All in One Solution

GeoCue's True View 3D Imaging Sensors offer an innovative drone mapping solution supporting LIDAR, photogrammetry, and direction geo-referencing solutions integrated in lightweight payloads. GeoCue focuses on offering full solutions rather than individual parts. Unlike other drone LIDAR providers, GeoCue includes post-processing software and a data management portal to provide users with a complete solution from flight to post-processing and data delivery.

Utility-Grade to Survey-Grade 3D Imaging

GeoCue offers a series of True View 3DIS systems ranging from utility grade to survey grade ensuring successful drone mapping projects no matter the application. The True View 3DIS includes all the components and software necessary to collect LIDAR and RGB image data and process these data to a 3D colorized point cloud in LAS format. True View systems use Applanix POS for best-in-class position and orientation accuracy.

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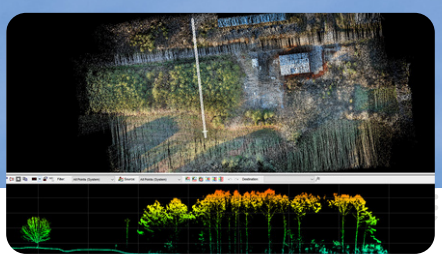

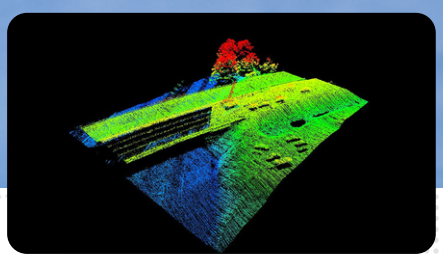

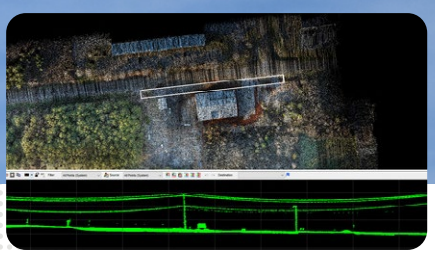

3D IMAGING SENSORS

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True View EVO software is bundled with every 3DIS. EVO generates a 3D LIDAR point cloud in LAS format, colorizes the point cloud and geotags the collected images.

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Manage True View Points and sensor calibration files along with hosting your True View Data in our Reckon Portal.

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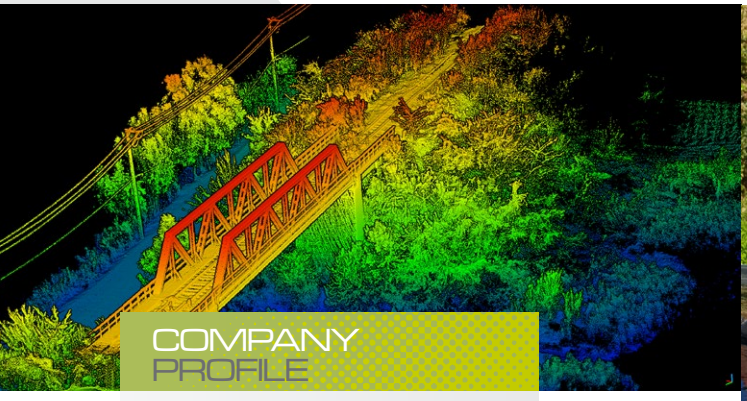
GeoCue Group

Oxford Technical Solutions (OxTS)



APPLICATIONS

- NAVIGATION
- GEOREFERENCING
- AUTONOMY
- MAPPING
- SURVEYING
- LOCALISATION & GROUNDTRUTH

COMPANY PROFILE

At OxTS we're passionate about inertial navigation and how we can help our customers with our technology. Our hardware and software solutions are used across the world for a range of applications including mobile mapping, LiDAR survey and more.

With over two decades of experience in combining the best of high precision GNSS receivers with inertial navigation expertise, OxTS' products have become the go-to inertial navigation systems (INS) in a wide and varied range of industries—particularly those where LiDAR is prominent.

If there is LiDAR-based project or application you're working on that requires highly accurate position and inertial measurements, speak with OxTS—we have the experience needed to help.

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OxTS hardware devices and software applications have been developed with the user in mind. They are suitable for many data collection methods whether that be on land or in the air.

Our flagship INS, the Survey+, is our most accurate INS used primarily for land-based mobile and manned aircraft mapping. It's more cost-effective counterpart, the xNAV650, is our smallest and lightest INS to date making it ideal for LiDAR surveying with a UAV or drone. However, despite its small size and light weight, the xNAV650 is equally suitable for mobile mapping applications owing to the accuracy of the data it creates.

Other software solutions within the OxTS product portfolio serve to provide users additional benefits. NAVsuite, OxTS' complimentary software suite, gives users the ability to configure, monitor, post-process and analyse their INS data. The step-by-step configuration wizard is particularly useful when setting up your INS for a LiDAR survey.

For areas where GNSS signal is intermittent such as under tree canopies and in urban canyons, gx/ix tight-coupling software ensures OxTS INS data is the best it can be.

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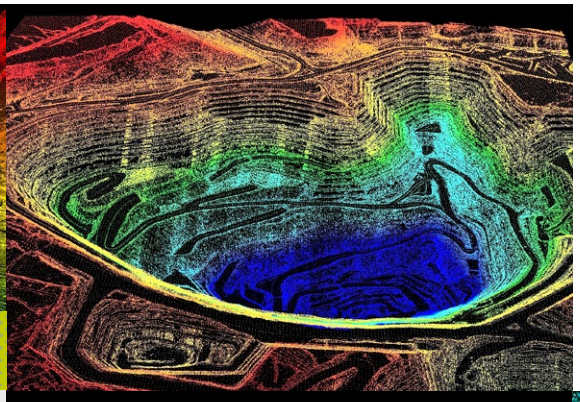
Create clear and accurate pointclouds by fusing OxTS INS data with raw LiDAR data...

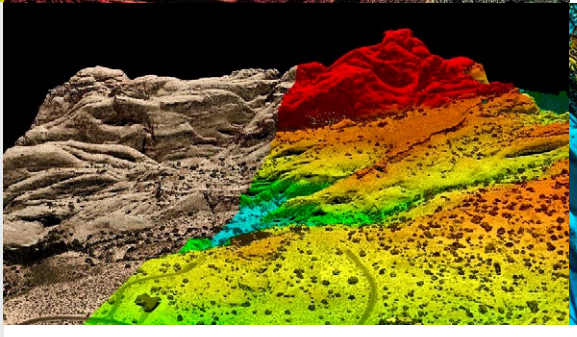
...and find out how.

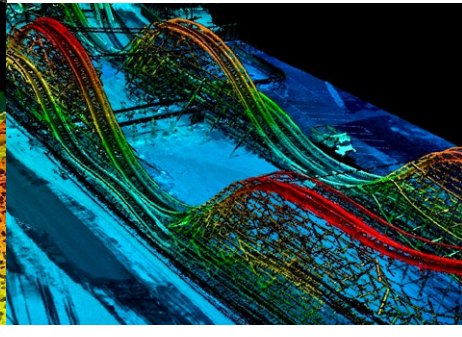
Aero-Graphics Inc

APPLICATIONS

- MAPPING
- SURVEYING
- PHOTOGRAMMETRY
- LIDAR
- INFRASTRUCTURE
- ENERGY
- AEC
- TRANSPORTATION







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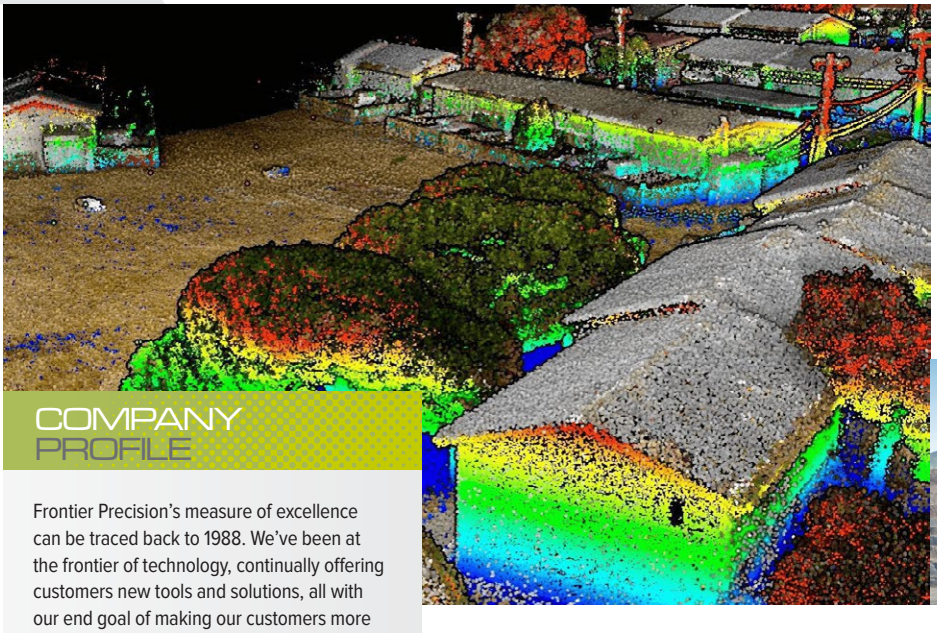

APPLICATIONS

- SURVEY
- MGIS
- UNMANNED
- SCANNING
- MONITORING
- CONSTRUCTION
- MOSQUITO & VECTOR CONTROL

COMPANY PROFILE

Frontier Precision's measure of excellence can be traced back to 1988. We've been at the frontier of technology, continually offering customers new tools and solutions, all with our end goal of making our customers more efficient, productive, and profitable with today and tomorrow's technology. Frontier Precision is an employee-owned company—offering solutions in Survey, Mapping & GIS, Drones/UAS/Unmanned, Construction, Scanning/Imaging, Mosquito & Vector Control, Water Resources, Invasive Plant Control. We became one of Trimble's largest geospatial dealers worldwide by offering our customers the solutions they need. Every day, we bring it to life by seamlessly connecting our physical and digital worlds to use technology to improve how we all interact better with the earth—in all kinds of meaningful ways.

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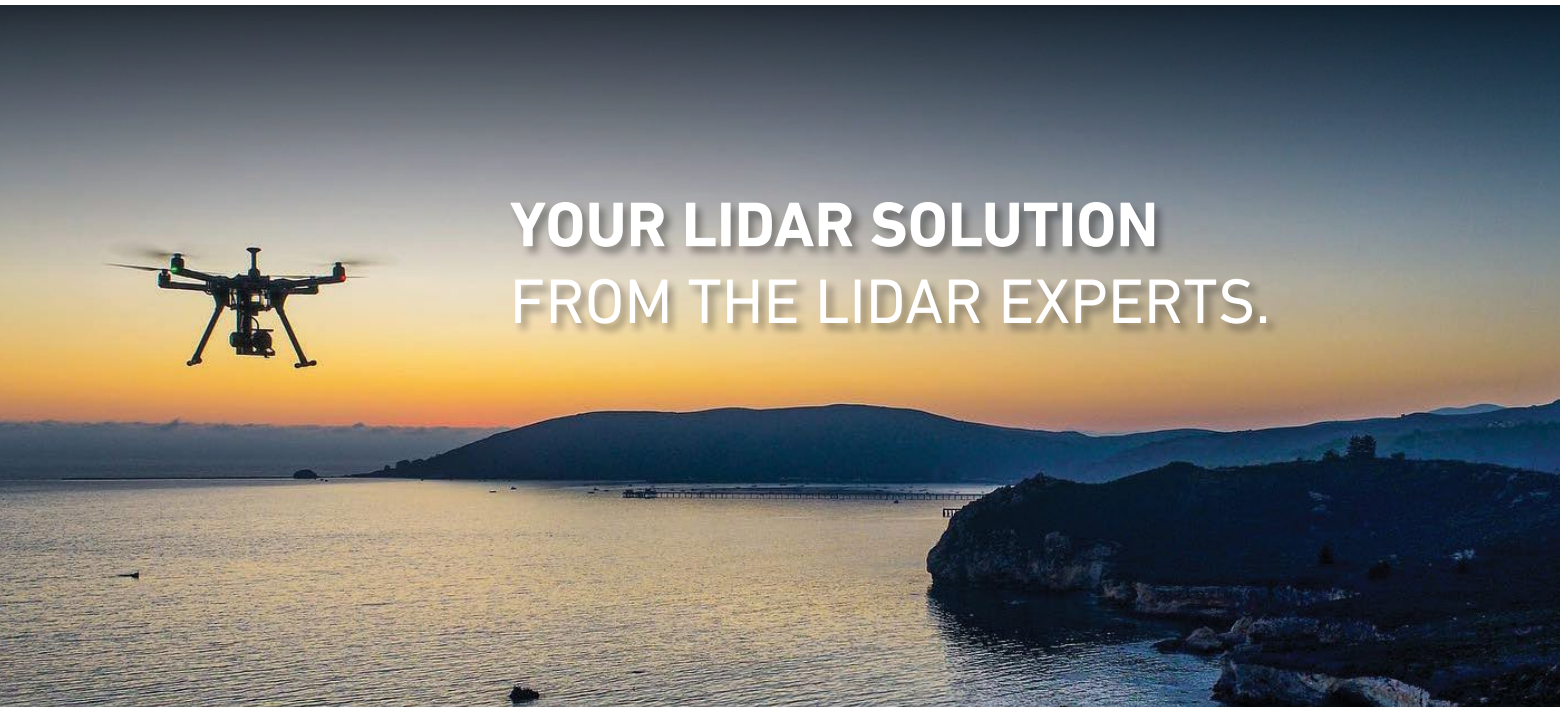

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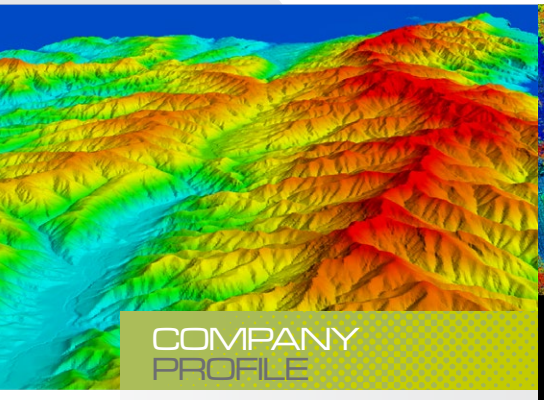

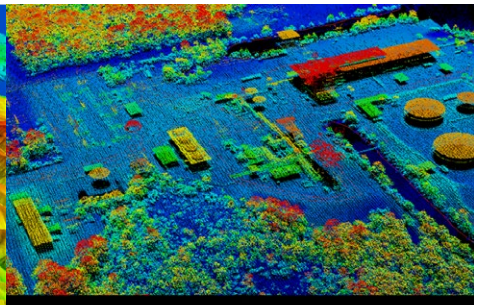

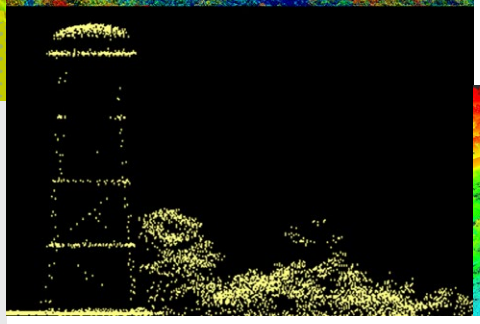

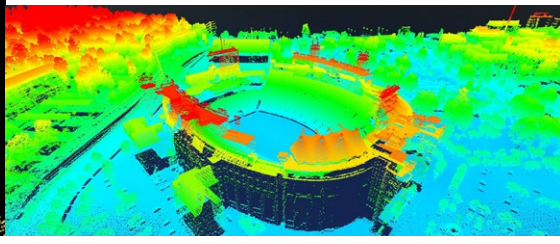

APPLICATIONS

- REMOTE SENSING
- TOPOGRAPHIC LIDAR
- TOPOBATHYMETRIC LIDAR
- GIS
- APPLICATION DEVELOPMENT
- MODELING
- ASSET MANAGEMENT
- ANALYTICS

COMPANY PROFILE

Dewberry is a leading, market-facing firm with a proven history of providing professional services to public- and private-sector clients. Established in 1956 and headquartered in Fairfax, Virginia, our professionals are dedicated to solving clients' most complex challenges and transforming their communities. The firm harnesses the power of geospatial science to offer complete end-to-end remote sensing and mapping services starting with state-of-the-art airborne lidar sensors to automated processing, surveying, web/mobile GIS, and advanced data analytics. Dewberry creates, analyzes, and builds geospatial data and tools, to help clients integrate, share, and simplify the use of information allowing for more effective and efficient decision making. To learn more, visit www.dewberry.com.

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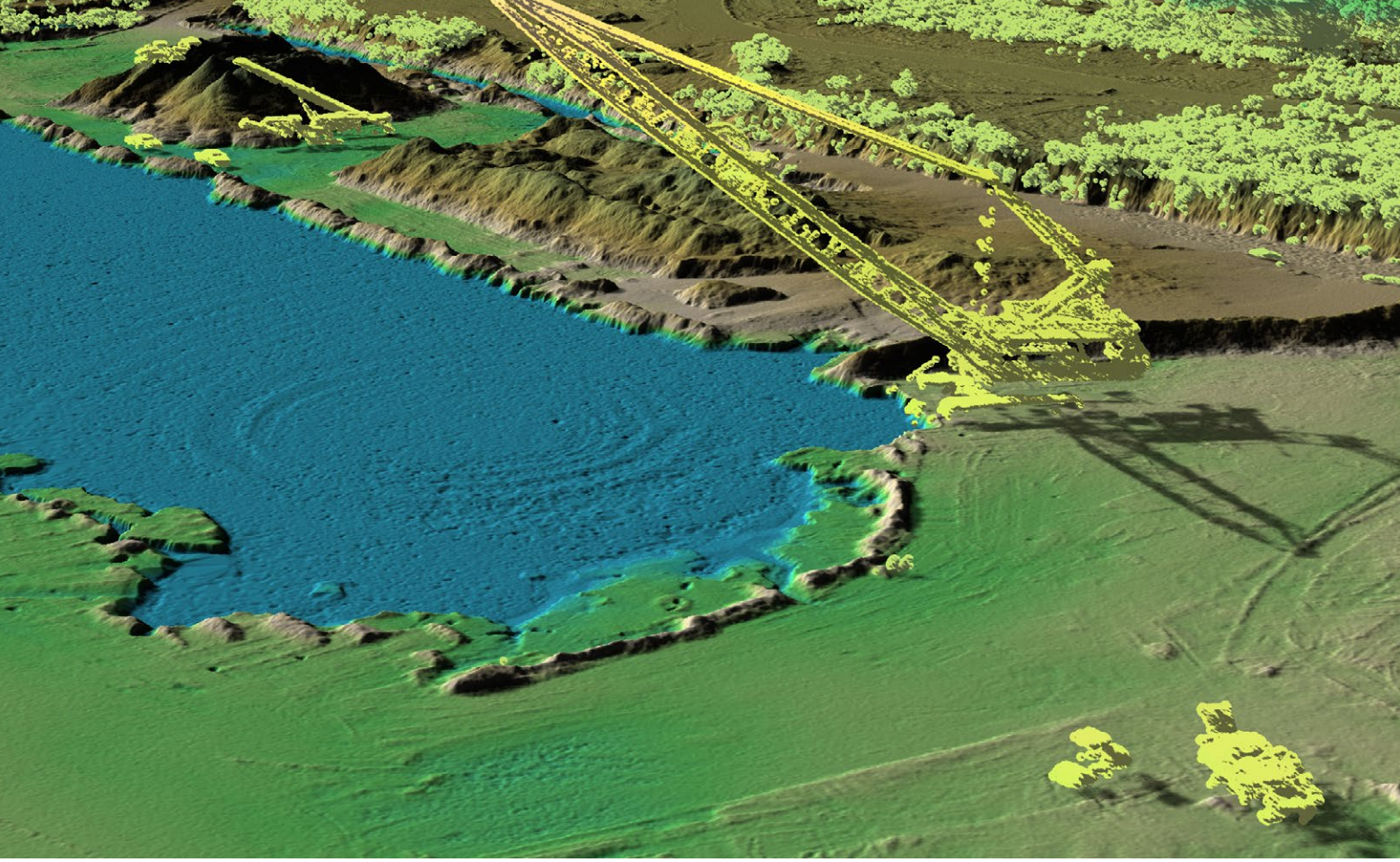
Dewberry's Geospatial and Technology Services

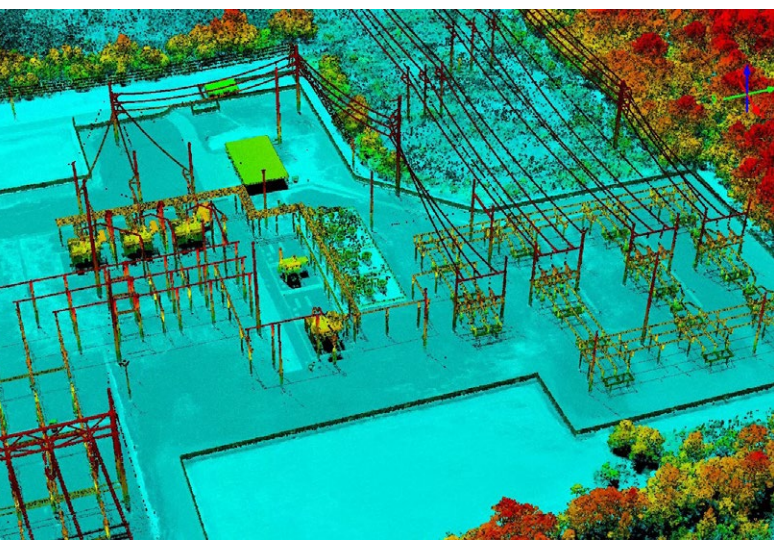
Dewberry's geospatial and technology services team creates, analyzes, and builds tools to share geospatial data, and helps clients integrate these tools into their daily lives. By fusing multiple data sets together, Dewberry provides clients with easy-to-use tools that simplify the use of information to allow for more effective and efficient decision making.

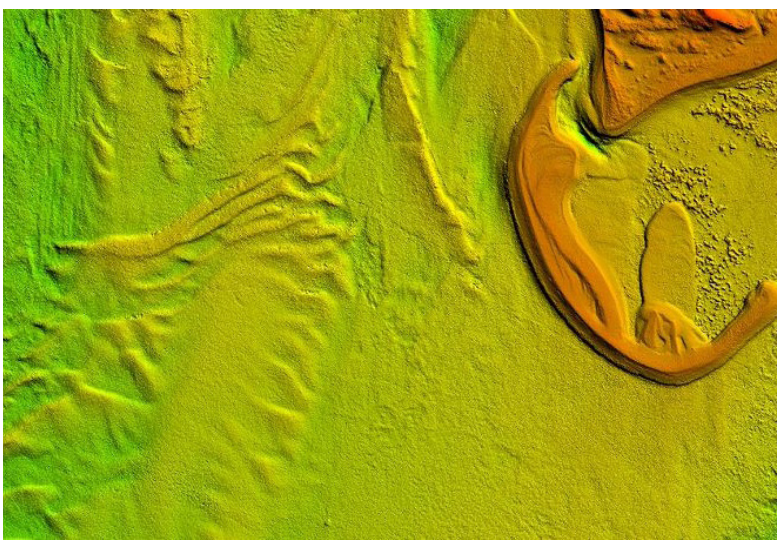
Dewberry recently purchased two sensors—the RIEGL VQ-1560 IIS topographic airborne lidar sensor and the CZMIL SuperNova, a powerful topobathymetric mapping sensor. This investment allows Dewberry to expand its mapping capabilities with current clients, keep the entire acquisition lifecycle in-house, and monitor the quality of its products. The firm is excited to empower their clients with access to the most innovative technology to meet their topographic/lidar needs, delivering hi-definition lidar datasets quickly and efficiently.

The firm's solid performance processes in geospatial technologies and corporate IT services led to it being appraised at Level 3 of the CMMI Institute's Capability Maturity Model Integration (CMMI) in Services and Development Models. In 2020, Dewberry also received the International Lidar Mapping Forum (ILMF) and Lidar Magazine's 2020 Outstanding Enterprise Achievement in Lidar award.

Dewberry works seamlessly to provide geospatial mapping and technology services across various market segments. With more than 30 years' experience, the firm is dedicated to understanding and applying the latest tools, trends, and technologies. Dewberry employs the latest GIS software and database platforms, including the full suite of ESRI products. The firm's products and services include application, web, and cloud-based development; system integration; database design mapping; data fusion; and mobile solutions.







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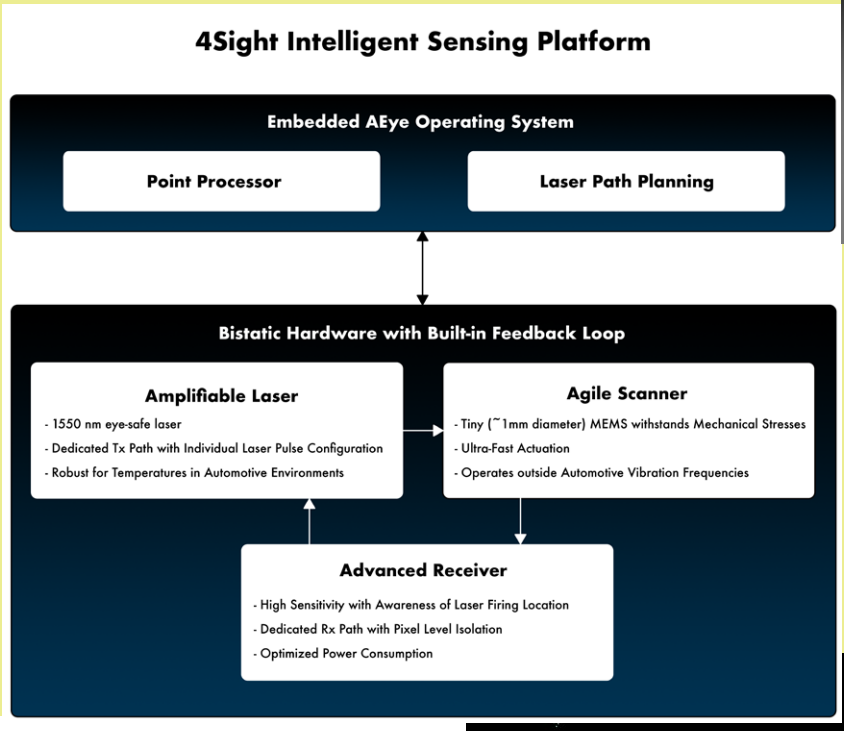
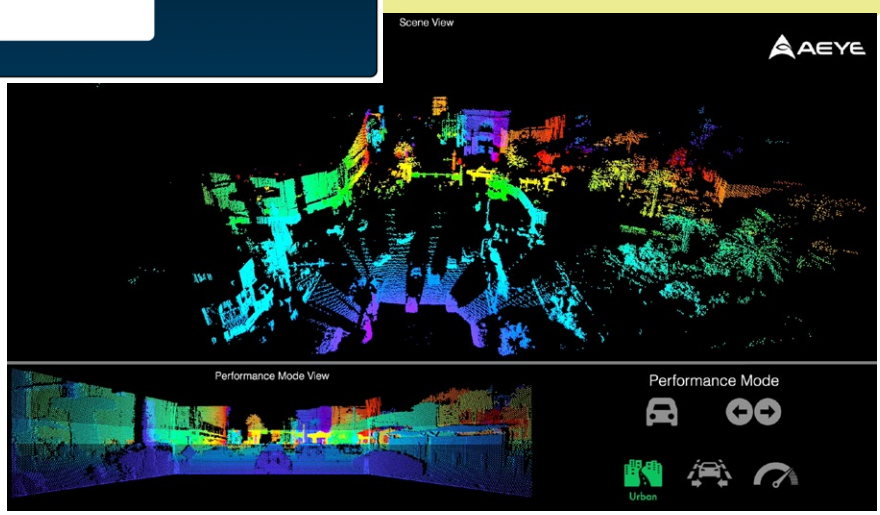


Above: 4SightM—A software-configurable MEMS lidar designed to adapt for intersection management, automated tolling, improving highway incident detection, and optimizing other industrial applications.

Left: Core building blocks of AEye's software-definable bistatic design

Below: High-fidelity point-cloud display of AEye's 4Sight platform captured while driving in dense urban environments.



AEYE, continued from page 64

and special ops units that searched for, identified and tracked incoming threats. I realized that a self-driving vehicle faces a similar challenge: it must be able to see, classify, and respond to an object—whether it's a parked car or a child crossing the street—in real time and before it's too late.

What intrigued me most was artificial intelligence, and the possibilities of software to calculate complex things like intent. Before AEye, software and hardware were siloed and AI was really an afterthought. That is a big part of the AEye difference: we combine hardware and software to create a robust solution that powers the future of safe autonomy.

LM: Our magazine comes from the geospatial side, where lidar is a tool that has transformed the world of surveying and mapping over the last 25 years. More recently, this world, particularly the application of UAVs for data collection, has been further transformed by the arrival of economical, reliable sensors from the automotive world. But there's more to it than just sensors—there's the computer hardware and firmware, the communications and, importantly, the perception engine. Could you please give an overview of AEye's product range and how your company fits on the spectrum that is perhaps a way of defining the supplier side of the market: companies that offer (i) sensors only; (ii) sensors, SDKs and development tools; (iii) sensors and software that runs all the way to the perception engine; (iv) systems that include not only lidar but other sensors too, such as cameras and radar; and (v) software only?

LD: We are on the higher end of the spectrum: we offer sensors, like a mechanically fused camera and

adaptive lidar and a development kit. We have automotive ADAS, mobility, and industrial solutions. Our industrial and mobility solutions include cameras with multiple sensors, and that includes software and SDKs that we provide. AEye's advanced technology can be used in multiple applications, not just automotive: our sensors can be used in rail, trucking and smart city applications—we like to say it's next generation perception for everything that moves.

LM: Your offering includes 4Sight A and 4Sight M, one based and the other built on AEye's 4Sight Platform. Could you please describe this architecture, product, and the underlying technology? In particular, could you explain, for those of us who don't enjoy a physics or EE background, how your bi-static approach differs from—or has similarities to—the "multiple pulses in the air" technology employed by the purveyors of lidar sensors for data acquisition from manned aircraft?

LD: Sure. We offer a customizable lidar product for industrial and mobility markets, the 4Sight M, and a software-configurable reference architecture for ADAS, the 4Sight A. With 4Sight M, we sell directly and through systems integrators to the industrial and mobility markets for applications ranging from trucking and rail to intelligent transportation systems, and aerospace and defense. With 4Sight A, we license our reference architecture to AEye's Tier 1 partners like Continental, who manufacture their own custom products and sell these solutions to their automotive OEM customers.

The 4Sight M and 4Sight A are based on our 4Sight™ Intelligent Sensing Platform, an adaptive lidar platform which employs principles from automated targeting systems to scan the environment, intelligently focusing on what matters most. What is truly revolutionary about AEye's system is our bi-static, agile design, where we separate the transmit path from the receiver. Other lidars typically have the transmit and receiver use the same aperture and path—which is called co-axial. At AEye, we keep them separate. This enables the system to be independently software configurable so that we can optimize both the transmission of each laser pulse—and the receiver that is going to capture the returned data. This lets us create an adaptive, weather-robust, intelligent system that captures higher quality data. It also allows us to put the complexity of the system in the software—where it is easier and faster to incrementally innovate and optimize. This approach enables us to deliver world-leading performance in range, speed, and high-density resolution, on-demand.

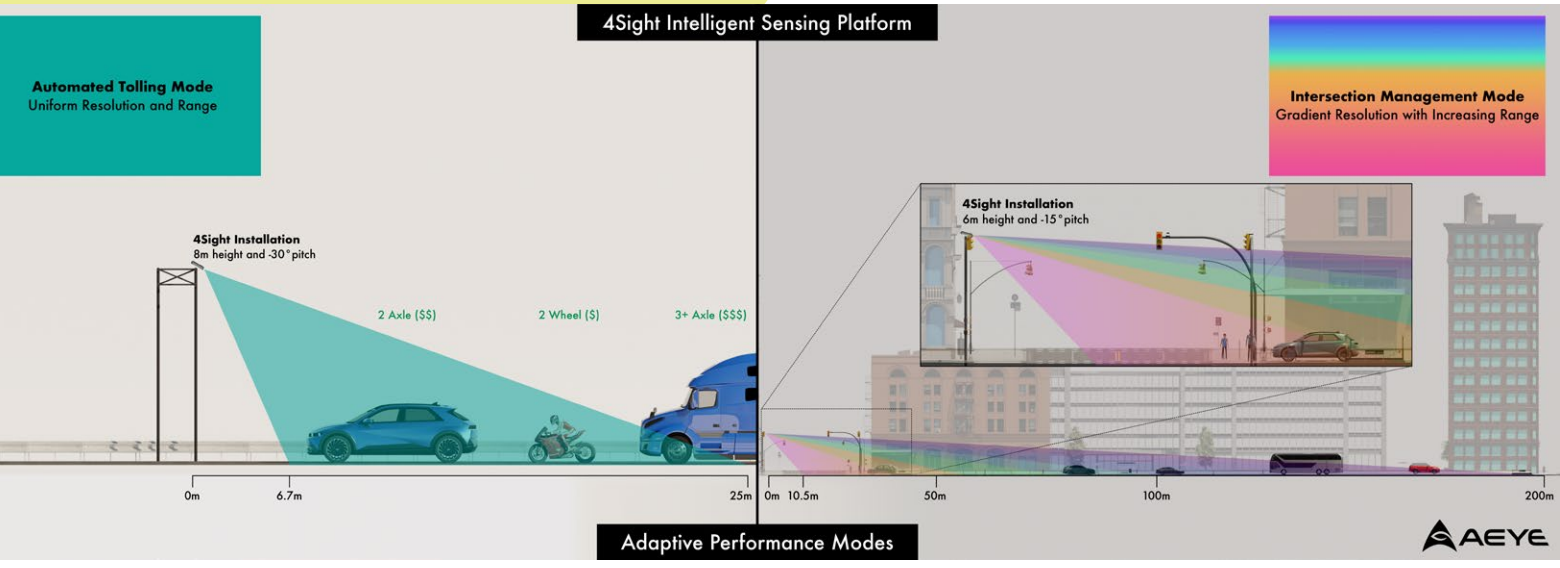
Our bi-static, agile architecture with programmable receiver can look at different areas, similar to "multiple pulses in the air" technology, but in many ways better than what the military employed in the past. Our product is automotive-grade with a high-precision, software-definable, adaptive lidar. This approach enables us to deliver higher quality, more accurate information faster to the perception system to improve the safety and efficiency of automated and autonomous vehicles and machines.

LM: Can you please give an indication of the price points of your products?

LD: The price points of our products depend on the volume. In general, we are significantly below the average market price.

> "Before AEye, software and hardware were siloed and AI was really an afterthought. That is a big part of the AEye difference: we combine hardware and software to create a robust solution that powers the future of safe autonomy."

LM: There seems to be an emerging consensus that lidar is critical to autonomous vehicles, ideally complementing cameras and radar into powerful solutions that maximize safety. But there's more to automotive lidar than simply sensors that provide strong performance at ranges of up to, say, 300 m, with appropriately high resolution and scan rate. They have to be solid-state, MEMS-based and capable of some element of software control. They have to be very robust and must operate in a broad range of weather conditions, including rain, snow, and bright sunlight. And, above all, they have to be manufactured at scale, in such a way that the units display an amazingly high degree of reliability. Is this a fair summary of the situation? Please explain how the AEye product range fits into this model.



The 4Sight Intelligent Sensing Platform allows tailored performance modes to solve multiple use-cases using the same hardware.

LD: Yes, this is a fair summary. We are one of only two companies that focus on long-range, high-performance lidar and the only company with an adaptive, intelligent lidar solution. Lastly, we are likely the only system that will be reliable enough, especially at range with high performance, to be truly automotive-grade, and this comes from the tiny MEMS we are now well known for. In addition, our hardware components are completely software configurable, creating a powerful, intelligent sensor system that is both flexible and adaptable to different or changing environments and weather conditions, as well as varied markets, applications, and use cases.

We use a simple design with four core components: a 1550 nm amplifiable fiber laser, with proven superior performance in rain, snow, smoke and other visual obscurants; a proprietary tiny MEMs-based scanner, with proven durability and reliability; a receiver with a bi-static design that enables the system to be independently software-configurable so we can optimize both the transmission of each laser pulse and the receiver that is going to capture the returned data; and our SOC[4]—where the system's complexity lies—making it easier and faster to incrementally innovate and optimize. And yes, our design means AEye's sensors can be put in the roofline, behind the windshield, or in the headlight or grill—enabling automotive OEMs to make design-centric decisions without impacting lidar perception performance, which is key to widespread lidar and sensor adoption.

LM: We listened to a Reuters webinar in which Jordan Greene[5] was one of the panelists. Dr. Gunnar Juergens of Continental contrasted how far forward radar had advanced as an automotive sensor compared to lidar. For example, in the case of his company, lidar lagged radar by about 100 million delivered units! This seems strange to us in *LIDAR Magazine*, since lidar technology has been around for 50 years. Could you give a perspective on this, please? Why is radar so far ahead?

LD: The differences are in the components associated with lidar and the problems that the industry needed to solve. When first introduced, in general, nobody had thought of a reason to use lidar that radars and cameras couldn't also solve. To boot, radar was less expensive than lidar primarily because of the optics, lasers, and scanners required, so early implementations were limited to places like the military, which has used it extensively. But then a new industry problem arose. While radar could accurately measure distance with limited resolution, lidar could also accurately measure distance but with a resolution that was fundamentally three orders of magnitude better than radar; this was hard to beat. This is why lidar can see smaller objects and details further away.

4 Software on a chip.
5 AEye's co-founder and GM of Automotive.

With the development and interest in ADAS and autonomous mobility (driverless navigation), there is good reason to use lidar. It had to be given the problem to solve. That problem is deterministic or non-interpreted long-range detection at high resolution, and small-object detections at a long range—cboth of which must be solved to create safe autonomous mobility.

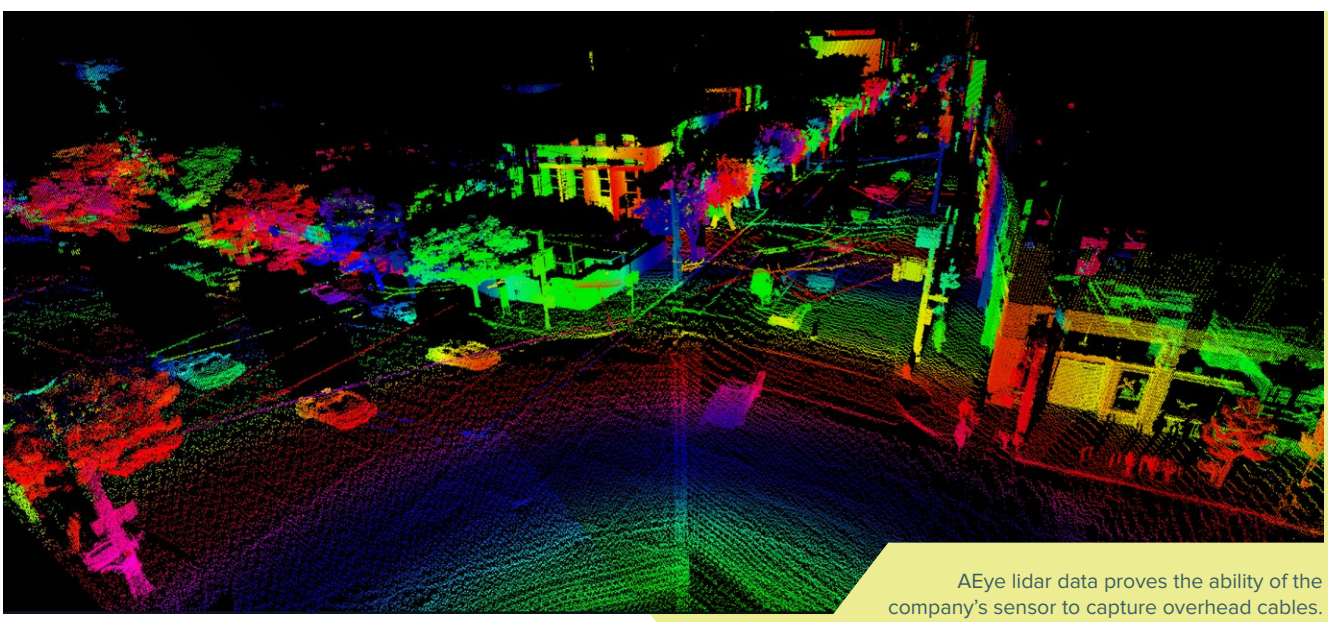
Now add to that the fact that the costs are coming down, due in no small part to the investments made by many players in the field. In just the past three years lidar has seen a massive price drop, and as we see the automotive market ramp up volume production, we'll continue to see cost-downs and economies of scale that will parallel that of radar and cameras.

LM: Turning to the business side, we notice that you went public through a merger with special purpose acquisition company (SPAC), CF Finance Acquisition Corp III (CFAC.O), in a deal valued at $1.52 billion. Our readers are becoming, rather unusually for a technical magazine in the geospatial field, familiar with SPACs and PIPEs, since Velodyne Lidar, Ouster, Luminar, Quanergy and Innoviz, to name but five, have followed the same route. Could you please explain how you came to go this way and what stage you have reached right now? Also, please say why this works better for you than either conventional IPO or VC funding rounds.

LD: We completed a successful merger and became a public company listed on Nasdaq under LIDR in August 2021. Because of the high demand for our products, the SPAC route proved a solid one for us to scale and to do so quickly, and with ample funding we are well-positioned to tackle the immense market opportunity.

LM: Companies like AEye typically start with a founder, or perhaps two or three co-founders, one of whom plays the role of CEO. But you are founder and CTO, whereas Blair LaCorte is CEO. Could you please say more about this choice of structure and about how well it works? How did you form the original leadership team to get the company started?

LD: Those two titles, CEO and CTO, are appropriate for a Silicon Valley start-up to divide and conquer the rigors of running a growing company. Both roles require creativity and vision. The CEO applies those skills to solving company-wide challenges in the areas of marketing, finance, business and corporate development, but is also involved in securing deals and understanding the market. These are among Blair's strongest areas of expertise. A Silicon Valley CTO requires creativity and vision in cutting-edge product design and development, building and leading tech teams, and carving out the best technology path for the company, but also securing deals and understanding the market. The transition in our roles makes a lot of sense at this stage of our company's growth and product development, and in preparation for the next milestones of volume production



AEye lidar data proves the ability of the company's sensor to capture overhead cables.

and our new life as a public company. Note that I said that we both take part in deal-making and understanding the market. That is an aspect of our relationship that I enjoy, where we bring different perspectives and fuse them together to get those things done. And that's just Blair and I. It is truly the combined expertise of our leadership team that makes AEye stand apart—not only in technical prowess but also in proven management experience. Jordan, Allan, Bob, John, Rick[6] and others on our leadership team really make us whole.

The Continental HRL 131—An adaptive, high-performance MEMS lidar, based on AEye's 4Sight reference architecture, designed for level 3 and level 4 applications to improve assisted and automated driving in passenger cars, robotaxis, and long-haul trucking.

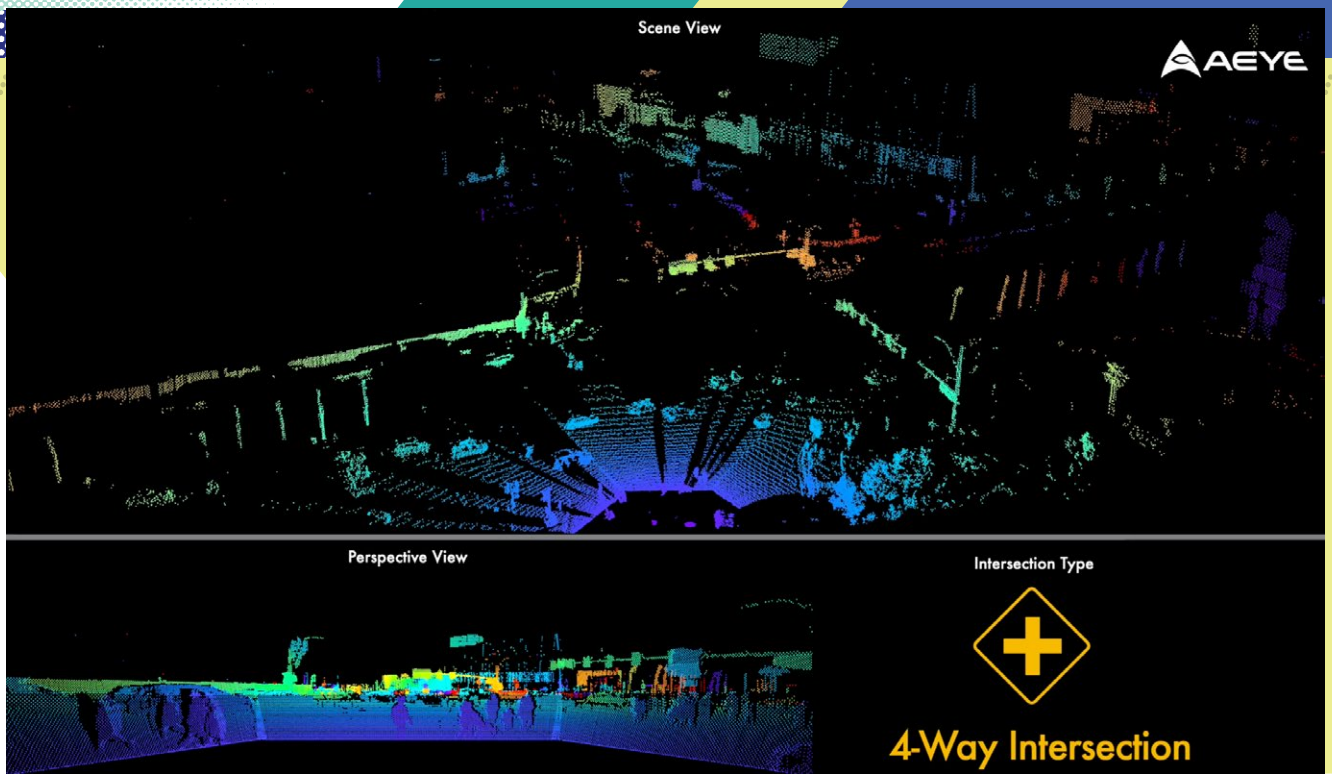
LM: We've also noticed that the consummation of a SPAC merger tends to result in the lidar company making changes to its board of directors. Is AEye doing this?
LD: Yes, AEye announced the election of our Board of Directors shortly after the closing of our merger. These new members bring extensive public governance, legal, and financial management experience, as well as deep domain expertise in automotive, aerospace, and defense markets. The new board is chaired by Carol DiBattiste, an experienced public and private company senior executive, with a background in heavily regulated markets and government agencies. Timothy J. Dunn, a veteran public company financial management executive, serves as chairman of the audit committee. Former Apple global marketing production lead Sue Zeifman chairs AEye's marketing committee, and Professor Dr. Bernd Gottschalk and Dr. Karl-Thomas Neumann, both automotive industry veterans, serve as additional independent board members, alongside current AEye board members Wen Hsieh of Kleiner Perkins, Blair and myself.

LM: We've further observed that many highly able, proven executives seem to move between different companies in or near Silicon Valley. This could be said of some of the AEye leaders. Is this a good thing, i.e. brilliant talent finds its way to where it contributes the most? Is there any danger to IP?
LD: We are thrilled with the talent in the Valley, and the executives who are choosing to bring their considerable talent to AEye. We've recently attracted several top-notch executives from within the lidar and automotive ecosystem who are drawn to our differentiated technology, appealing licensing model, and collaborative workplace. So, yes, I think they are coming to a company they believe in, with a culture they want to be a part of. In regard to IP, if you have a solid organizational structure along with a mature and talented management team to properly safeguard IP, as we do, IP should not be a concern.

LM: Critical factors for the success of a company like yours seem to include relationships with automotive manufacturers and/or with Tier 1s, whereby the latter may be your customer and/or may provide the capabilities you need to manufacture at scale. Could you explain where you are in this part of the process?
LD: We believe in working within the established automotive ecosystem, partnering with trusted suppliers who have decades—and in some cases more than a century—of experience producing automotive grade products in volume, at scale. To that end, we have partnered with a handful of best-of-breed automotive Tier 1s, including Continental, to commercialize and manufacture our lidar sensors. Continental has industrialized our long-range lidar sensor (the HRL 131), is building a manufacturing line around it, and is scheduled to begin mass production in 2024.

While other lidar players are trying to scale up organically, we've thought through our licensing so we can proliferate faster. The automotive industry knows how to produce robust components efficiently and at a low cost. Partnering with a Tier-1 supplier such as Continental enables AEye to scale, not just in the automotive industry, but in other markets as well.

6 Jordan Greene; Dr. Allan Steinhardt, chief scientist; Bob Brown, CFO; John Stockton, SVP of R&D; Rick Tewell, COO.



AEye's 4Sight platform captures pedestrians in the near-range with cross-traffic in the background at a 4-way intersection.

Along with this, Tier-1 suppliers have been and are actively looking at lidar companies and their technical approaches. Companies such as Continental and Hella performed months of due diligence before selecting AEye as a partner—a key validation of our model and our team. They chose us because of our technology, and the scalability, adaptability and robustness of our design. Tier-1 partners will work only with viable companies that have solid technology and are designed for large scale manufacturability, and we certainly fit that bill.

LM: Your primary market is, of course, AVs and ADAS. Are you doing anything in robotic vision, outside the automotive sphere? Furthermore, you have an aerospace background. Your sensing pattern can achieve a range of 1000 m, way beyond most of your competitors. Are you looking at other markets, for example, as part of payloads for UAVs or even crewed aircraft or helicopters? Or, indeed, what about applications in ground-based surveying, whether on moving vehicles or stationary?

LD: Yes, we are definitely pursuing opportunities outside of ADAS and automotive mobility. In addition to these markets, we are actively working with companies in trucking, rail, mining and ITS[7]. For example, we announced a development partnership with global self-driving technology company TuSimple and an integration with Seoul Robotics to deliver adaptive, long-range perception for ITS. As part of our plan to scale up, we are looking at markets that are relevant to our mission and business model that can benefit from AEye's lidar system, and thoughtfully entering those markets as quickly as possible.

LM: We are sure that one of your major goals for 2021 was completion of the SPAC merger. But what else would you like the company to achieve by the end of 2022? Do you also have longer-term aspirations?

LD: This year and moving forward, we're focused on scaling the company effectively, securing design/production wins with our Tier-1 go-to-market partners, and lining up development deals in the industrial and mobility markets, while continuously improving our system's performance.

LM: Luis Dussan, thank you very much indeed for answering our questions. We look forward to further articles about AEye in the future.

7 Intelligent transportation systems.

Stewart Walker is the Managing Editor of the magazine. He holds MA, MScE and PhD degrees in geography and geomatics from the universities of Glasgow, New Brunswick and Bristol, and an MBA from Heriot-Watt. He is an ASPRS-certified photogrammetrist.

AEye Finds Success through Close-Coupling of Hardware and Software

LIDAR Magazine interviews Luis Dussan, co-founder and CTO

LIDAR Magazine has reported on several lidar suppliers that focus on the automotive market and has commented on their experiences in merging with SPACs[1] to ensure deep enough pockets not only for R&D but also for productization, sales and production at scale. Further keys to success include leading-edge technology; the very best talent in terms of both technical and management skills; a superbly trained, flexible workforce; willingness to attack the ADAS[2] market while waiting for autonomous vehicles (AVs) to become widespread, yet not losing sight of other markets; and the skills required to navigate the challenging waters between an exciting, operational product and its manufacture in the quantities and quality required by the automobile market. One of these winners is AEye, Inc., which is located in Dublin, California and has offices in Germany, Japan and Korea[3]. *LIDAR Magazine* was offered the opportunity to interview Luis Dussan, AEye's co-founder and CTO.

LM: Luis, thank you very much indeed for agreeing to talk to *LIDAR Magazine*. First of all, let's get to know you a little better. After an undergraduate degree in EE and computer science, you worked with NASA, Lockheed Martin and Northrop Grumman before founding AEye in 2013. During these years you completed two master's degrees at the University of Central Florida in optics, photonics and physics. Could you please summarize your working life and explain how your ambitions grew and matured, with the result that you founded AEye? In particular, your career has perhaps more of a defense component than the founders of other lidar companies—has that made a difference?

LD: A key differentiator in my career is that, as I was studying for my post-graduate degrees, I was also working at companies such as Northrop Grumman and Lockheed Martin as a researcher and engineer. Because of this, I was able to study many concepts that I could immediately apply to my work. I was also exposed to classified programs and cutting-edge technologies.

Luis Dussan, co-founder and CTO of AEye, Inc.

Early on, I was able to understand new technology life cycles in even the most complex of applications, from initial design to the end product. This was a precursor to identifying and addressing both the challenges and opportunities in building a complete commercial-grade lidar and perception solution.

In fact, it was my defense work that inspired a robust AEye solution. While at Northrop Grumman and Lockheed Martin, I was designing mission-critical targeting systems for our fighter jets

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1 Special purpose acquisition companies.
2 Advanced driver-assistance systems.
3 www.aeye.ai

BY STEWART WALKER

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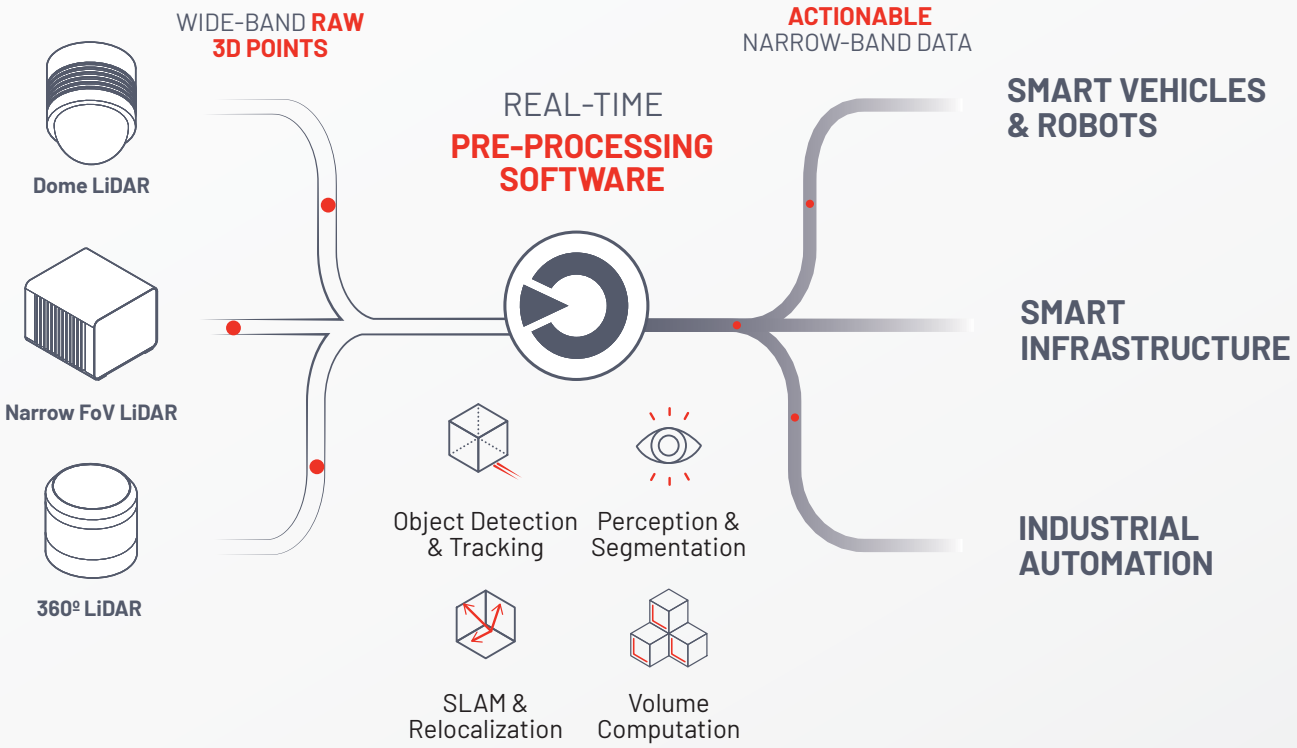

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