PHOENIX LIDAR SYSTEMS

Excellence in UAV integration

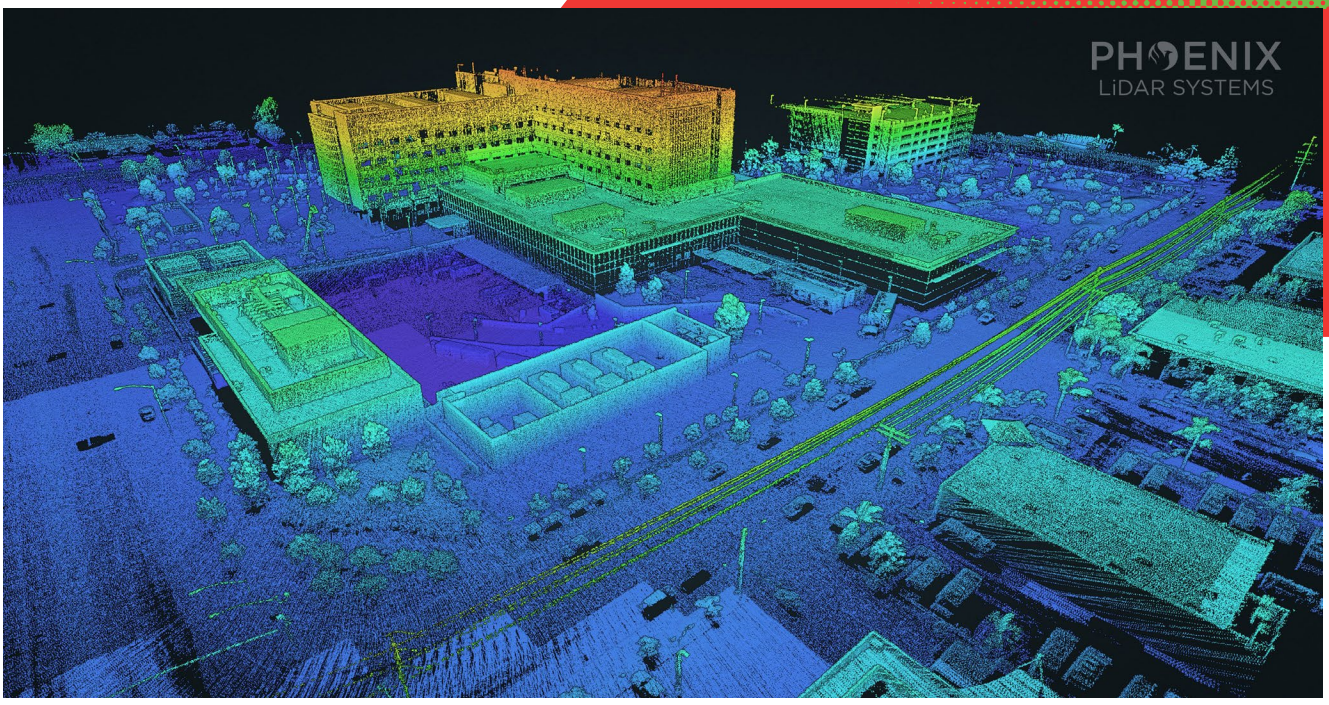
Managing Editor Stewart Walker met with Phoenix LiDAR in their Los Angeles office, profiling a young company that leads the market in the integration of LiDAR sensors with UAVs

Grayson Omans founded Phoenix LiDAR in 2012 and built a team that would develop the industry's first commercial UAV LiDAR system.

Amidst the excitement of UAVs and their rapid development as a disruptive technology in our geospatial world, *LIDAR Magazine* is pleased to take a closer look at a team driving such innovation. Phoenix LiDAR Systems, the first to offer commercial UAV LiDAR, hails from the Palms neighborhood in Los Angeles. Located just a stone's throw from big names such as Sony Pictures, NPR, and the NFL, Phoenix's roots indeed echo the entertainment ideals of its neighbors: CEO Grayson Omans started his UAV flying days hovering cameras over actors on film sets, and as UAV and LiDAR technology became more affordable for commercial use, he saw an opportunity and shifted his UAV payload from imagery to lasers.

The move from aerial filming to aerial mapping was a daunting task, the first requirement being reliable control and tracking of the UAV. Enter Dr. Benjamin Adler, co-founder and researcher who wrote his Ph.D. thesis on autonomous

BY STEWART WALKER

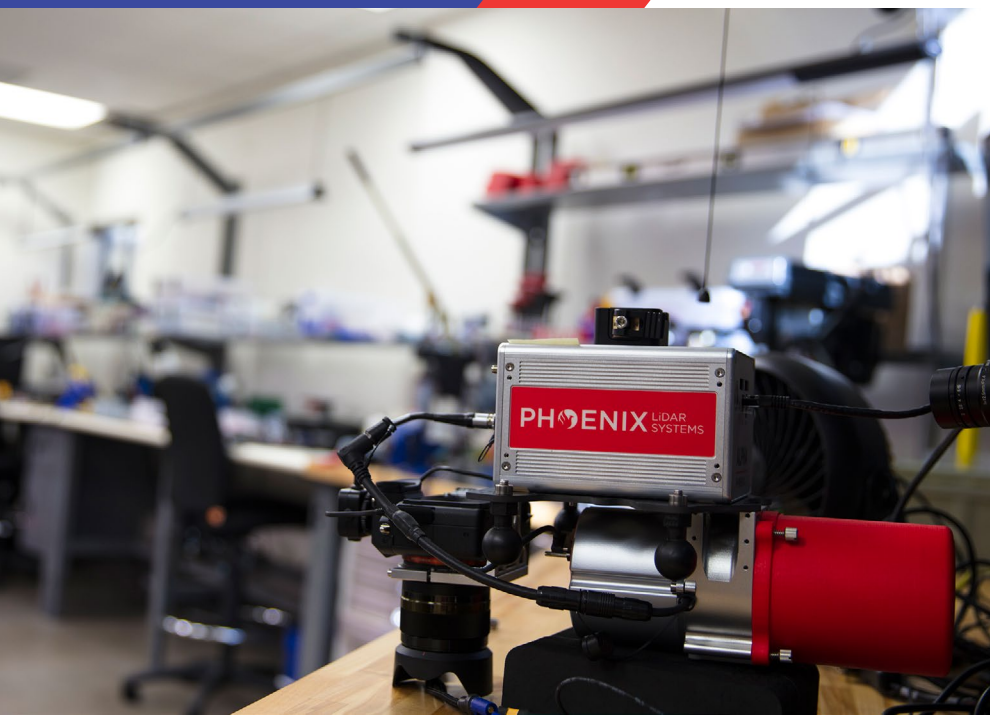


This point cloud capturing a rural hospital and nearby utility power lines was generated in LiDARMill, Phoenix's post-processing automation platform.

Phoenix LiDAR began in Los Angeles with two people and has expanded to 26 team members around the world.

UAV mapping. Working with a lot of fishing wire, Grayson and Ben developed a reliable method of controlling the UAV without risk of it flying away with their equipment. They then sought to borrow $52,000 of LiDAR equipment from none other than Velodyne LiDAR, a big request coming from a tech startup comprised of two people. To its credit, Velodyne agreed, sending Dr. Wolfgang Juchmann to Southern California to witness the test flight. A week after his wedding, and to his young wife's eternal chagrin, Grayson postponed his honeymoon and worked with Ben to prototype what would become the industry's first commercial UAV LiDAR system—needless to say, it featured a Velodyne sensor. Business ensued and the rest is history. Grayson's candor and humor on this topic characterized our discussions and the insights into the UAV LiDAR world that emerged.

I spent several hours with Grayson, learning the Phoenix story first hand from him and his sales and marketing directors, Eric Agnello and Vu Nguyen. Grayson has a business degree from Cornell, though his father was a mechanical engineer, and the yen to take things apart and reassemble them rubbed off. Grayson began to build UAVs as a hobby and developed experience that would later inform his business decisions, including the opportunity created by combining an aircraft with sensors and software. He and Ben, who built their software development



This Phoenix Alpha system captures both LiDAR and photogrammetry data, and was customized to include an integrated high-definition DSLR camera.

team in Hamburg, Germany, concluded that UAV autonomy is the holy grail for their fledgling industry, and proceeded accordingly. Combining autonomous UAVs with mapping necessities such as LiDAR sensors, high-definition cameras for photogrammetry, and a host of other equipment, appeared to Grayson as a powerful business case.

The Business

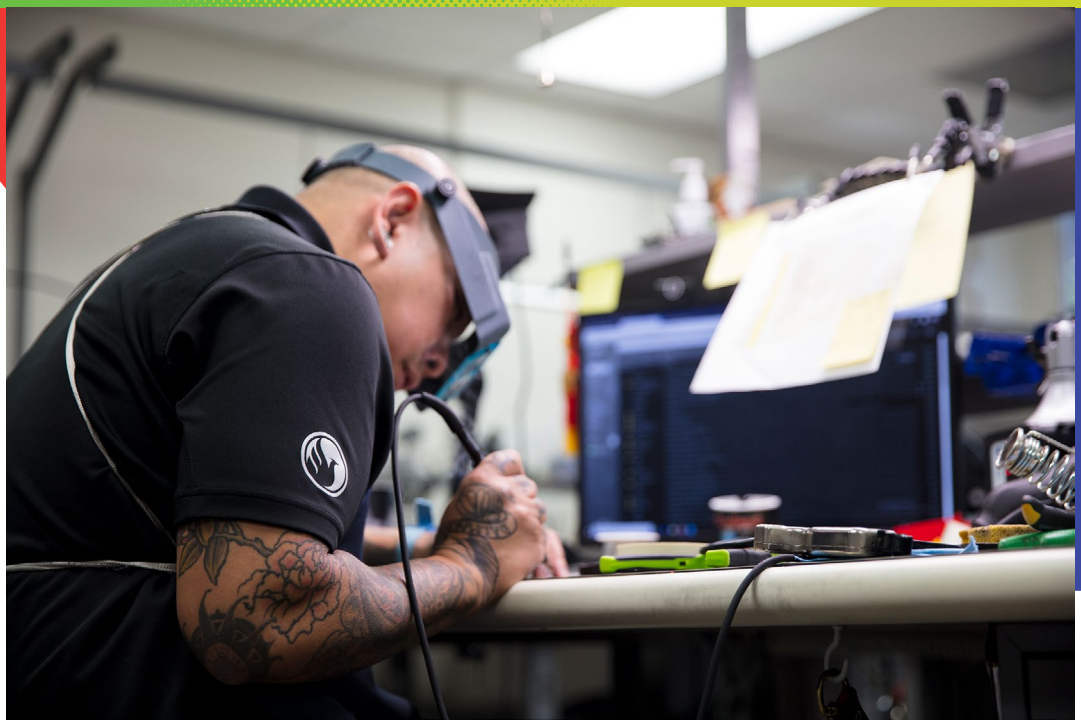
The company was founded as Phoenix Aerial Systems in 2012, in recognition of the mythical bird, but was renamed as Phoenix LiDAR Systems in 2016 to reflect more accurately its focus on LiDAR. Expanding to its current location in 2017, the team is already outgrowing its new space. Phoenix has 26 full-time employees, including some in Hamburg and around the world, and 10 consultants. Its team boasts many accomplished people with years of experience in their respective, and sometimes very specialized, fields and it has sold hundreds of systems to more than 100 customers in many countries, ranging in size from private surveyors to national governments. Phoenix's clients work in many industries, including power and utilities, forestry, mining, oil and gas, urban development, and more. Phoenix has established a worldwide distributor network and is engaged on expanding it—the knack of channel management is a subtle one when products are complex and require skills such as piloting and data processing.

To fund Phoenix's research without the venture capital investment that is so common for tech startups, Grayson founded a second company, BrushlessGimbals.com, which profited by building components for stabilizing cameras in flight, as an alternative to legacy servo-based systems. The support it provided was especially important, since Phoenix's systems were not yet legal in the US: this was well before the Section 333 waivers that the FAA began granting in 2014, and even further before the current Part 107 regulations that opened up much of the drone market in the country. Grayson sees these changes as key to his business and that of many others in the UAV space.

Despite the fact that expensive components strain margins, Phoenix continued to grow organically and now offers a spectrum of systems, each tailored for a different set of specifications, ranges, densities, etc. The automotive market is enormously bigger than the airborne, and is the leading driver in LiDAR sensor development. Sensors suitable for UAV flights are expensive, though systems are expected to become lighter, more accurate, and less costly, due to R&D for the automotive segment. Though he's gone to great lengths to minimize weight, Grayson thinks his systems are still heavy and labors on further reductions while also increasing power.

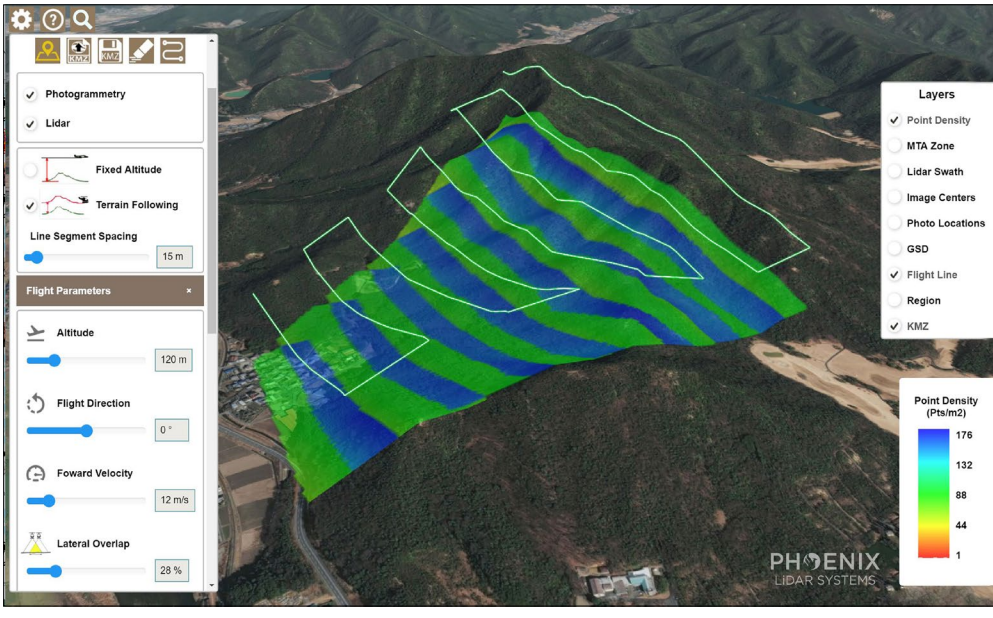
Innovative "Firsts"

Phoenix has used its head start in UAV LiDAR to its advantage, developing a number of other industry "firsts." In 2013, it launched a feature to enable clients to view their LiDAR data in 3D while the system was airborne, reducing acquisition errors such as flying too high—or, more embarrassingly, forgetting to turn on the LiDAR sensor. In 2015, it launched the industry's first fixed-wing UAV LiDAR system and,



The Phoenix team builds every LiDAR system in the United States.

in 2016, the first dual fixed-wing and VTOL system. Both took advantage of the speed and stability of a fixed-wing aircraft and the latter also enabled vertical take-off and landing for runway-deprived surveying environments. In 2017, Phoenix announced the industry's first cloud LiDAR post-processing platform, which they call LiDARMill, and the first UAV LiDAR flight planner, a free tool which helps users plan terrain-following autonomous flights that optimize LiDAR data quality. Users can then upload that data directly to the UAV.



The Phoenix Flight Planner is the industry's first tool that helps users plan terrain-following autonomous flights that optimize LiDAR data quality. Users can then upload that data directly to the UAV.

The Technology

The Phoenix team explained that many of their clients start with photogrammetry, but eventually seek LiDAR to address some of photogrammetry's limitations. Unlike its counterpart, LiDAR is able to map the ground underneath dense vegetation and can work in situations with low or no light. Though they seemingly compete, Grayson views UAV photogrammetry as a complement to UAV LiDAR. Both are powerful tools that address different parts of the surveying and mapping process. Professionals should perceive the technologies as complementary and use them accordingly. If the full potential of LiDAR is to be reached, however, night flying and BVLOS must become possible, though they are currently prohibited by regulation.

Phoenix LiDAR team members assemble a RANGER system on a Vapor 55 UAV.

In building their first systems, Grayson and Ben's research concluded that not only is a large UAV necessary to support the weight of a LiDAR sensor, but for survey-grade reliability, each system would also need an IMU and GNSS equipment of sufficient caliber and durability to withstand the vibration and general environment of an airborne drone. Systems would also need to include electronics, data recording hardware, software, and an assortment of other sensors that clients might need for their projects. Integrating it all and keeping the weight low has been an ongoing objective of their research since 2012.

Phoenix's custom electronics box, which they call the navigation box or "navbox," serves as the system's "brain," and can be used to connect a variety of accessories, such as cameras that record RGB, multispectral, hyperspectral, and thermal imaging. These sensors and others, integrated based on client requirements, connect to the navbox, saves the data and can broadcast it for live transmission to operators or remote viewers. The resulting data comprises millions of laser points in a raw point cloud that often encompasses a 360° viewing field.

Customized LiDAR

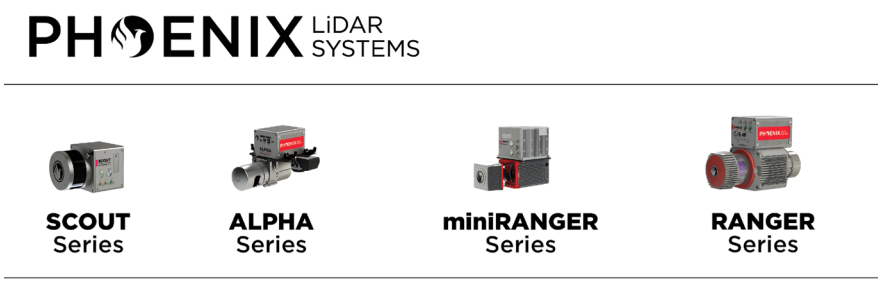
Flexibility is Phoenix's battle cry—the key, Grayson contends, to their success. They design signal routing boards from scratch and go to the very root of the GNSS cards that they build into their navboxes. This control of detail enables Phoenix to cater to almost all requests. Their boards can handle gigabit Ethernet cameras, for example global shutter, RGB, hyperspectral, plus LiDAR. Every customer is unique, so customization is worth a great deal to the team, which modifies their standard systems as needed. For example, Phoenix's miniRANGER system, which includes a LiDAR sensor, a Phoenix navbox, an IMU, and a UAV, can be upgraded to include dual RGB cameras, which expands the scan swath to a surprising 250-meter swath, all on a UAV flying within the rules.

Because the key to its success is customization, not only can these systems be integrated with a host of sensors based on client need, but most Phoenix systems are also modular and can be moved between platforms as needed: from UAV to aircraft, vehicles, or backpacks. This modularity maximizes the value of each system, which is often a major investment for clients.

Since most of their LiDAR systems feature custom integrations, Phoenix sends teams out several times a week to test every outgoing system for accuracy and calibration. Phoenix's calibration site in northern Los Angeles features a huge concrete dam with structures of varying shapes to facilitate the process.

Equally Important: Post-Processing

After LiDAR acquisition comes the equally important step of post-processing. While they've made great progress on the flight planning and acquisition side, Phoenix continues to build new products, most of which are the direct result of client feedback. Knowing that the barrier to UAV LiDAR entry isn't only the high upfront equipment cost, but also the expensive software and engineering work required to process the data, Phoenix launched the industry's first cloud post-processing automation platform, LiDARMill.



Phoenix offers a suite of flexible systems that can be customized to suit each client's projects.

The platform, currently in beta testing, tackles the basics of post-processing in the cloud for organizations that don't yet have their own post-processing setup. LiDARMill covers point-cloud calibration, from trajectory refinement to ICP (iterative closest point algorithm), makes flight line adjustments, and fits strips of data together. The later post-processing steps, such as denoising, filtering, and classification, are much easier with a calibrated point-cloud. As a result, companies can quickly scale, taking on more projects and growing their operations.

The Hamburg crew has created a remarkable software stack, which works with large and dense point clouds. As a result, Phoenix can deal with lower quality IMUs shored up by high quality laser shots. The company is almost there in terms of "processing the cloud in the Cloud." While it seeks to save money for its clients, Phoenix has no aspiration to take the place of specialist post-processing software, which will continue to play an important role in LiDAR mapping, but rather, to simplify and automate as much as possible.

The Standard Phoenix Systems

Phoenix offers a suite of customizable systems. The Scout is billed as an entry-level system and consists of a Velodyne puck sensor attached to a Phoenix navbox. The system is typically mounted to a UAV such as the DJI M600, and is often used to conduct research surveys and map basic infrastructure. Its older "sibling" is the Alpha Series, which is also often paired with a DJI M600 and features a mid-grade Velodyne sensor. This 32-laser sensor rotates as it captures the world in 360°.

The miniRANGER boasts a powerful Riegl sensor that can accept up to five returns per pulse. Like the others, it can be integrated with many UAVs, though the DJI M600 is a popular choice. The RANGER system features a Riegl VUX, which is designed for the most demanding mapping applications, and offers the best combination of range, density, accuracy and data quality. This 1550-nanometer sensor, when paired with the Phoenix navbox, becomes the heart of a powerful payload that has few rivals in unmanned aerial mapping. It's often flown on a Pulse Aerospace Vapor 55 UAV, but has also been modified for the TerraHawk CW-30 system and others.

Phoenix's two TerraHawk systems, CW-20 and CW-30, are the industry's first fixed-wing VTOL UAV LiDAR systems. Gas and electric hybrids, these birds are Phoenix's response to customer feedback that fixed-wing systems required belly landings that endangered costly LiDAR equipment. Phoenix built these systems to take advantage of the speed and stability of a fixed-wing, while offering the convenience and protection of VTOL, which eliminates the need for landing strips, and offers a backup landing system, if needed.

In Conclusion

I was very impressed. Phoenix's expertise and commitment are evident, and their passion for LiDAR is apparent in the frequent innovations they introduce. With new products such as the Flight Planner and LiDARMill, they also demonstrate awareness that, despite all of its development, LiDAR is still a very complex technology, and acquiring and post-processing data must be simplified if the industry is to grow fast. Through the hardware and software options they offer, Phoenix takes steps to simplify and automate both the acquisition and post-processing phases.

To those who have been in the industry for a long time, it's clear that UAV LiDAR acquisition requirements cannot be addressed by merely offering single-flavor solutions; rather, systems must adapt to meet the needs of each application. Maximizing this flexibility while maintaining survey-grade accuracy will be a particular challenge to system integrators such as Phoenix, especially if the technology continues to develop as rapidly as it has in recent years. I believe it will, and based on their work, I look forward to seeing how Phoenix will help shape the UAV LiDAR industry in the years to come.

Stewart Walker is managing editor of the magazine.