



# How A 34-Year-Old Audio Equipment Company Is Leading The Self-Driving Car Revolution



Alan Ohnsman, FORBES STAFF

[FULL BIO](#)

*This story appears in the September 5, 2017 issue of Forbes. [Subscribe](#)*



Timothy Archibald for Forbes

*Inventor Dave Hall, founder and CEO of Velodyne, has positioned his company to be the leading supplier of LiDAR sensors that allow autonomous vehicles to see.*

Seconds after David Hall punches in a code, the electronic gate to his waterfront residence swings open. It's a large compound but not the kind you'd expect from a tech entrepreneur who is as responsible as anyone for ushering in the self-driving-car revolution. Hall, 66, is CEO of [Velodyne](#), the leading maker of LiDAR sensors, the "eyes" that allow autonomous vehicles to see what's around them. He lives among a ramshackle collection of low-slung, shingled and metal structures built around a concrete plot on the Bay Area island town of Alameda, California. It's his

favorite refuge, equal parts living quarters and workshop, where this inveterate tinkerer and serial inventor can work on his pet projects.

---

 [Gallery](#)

## Top 10 Most Innovative Companies 2017

[Launch Gallery](#)  
11 images



---

At one end there's a barn-size industrial shed where Hall and a team of engineers are perfecting one of his latest obsessions: a patented technology that keeps boats steady in the roughest waters. Marta, his wife and the head of business development at Velodyne, paints and sculpts in an art studio nestled inside another building. A couple of his Ford F-150 pickups are parked near a hulking crane that hauls boats in and out of the water. Hall's home itself is a houseboat, or rather a roomy prefab structure bolted onto a barge. From the living room you can hear small waves lapping at the shores of the sleepy canal that separates Alameda from Oakland. It's a world away from the bustle and glitz of Silicon Valley, where Velodyne has its headquarters, and that's the point. "I'm an engineer," the reclusive Hall says, referring to both profession and persona. "I'm basically an introvert, a nerd ahead of my time."

About a decade ahead of his time. In 2006, Hall patented one of his inventions--a multi-beam spinning LiDAR sensor--that put Velodyne, albeit almost accidentally, at the center of a revolution that's disrupting the auto and tech industries. Hall built the LiDAR sensor on a whim. Velodyne, which he had founded in 1983, was a successful business known for specialized audio equipment. But always itching to keep inventing, in the early aughts Hall became obsessed with a seemingly fantastical contest: a Defense Department-sponsored race for autonomous vehicles. It promised to be both fun and an excellent proving ground for his engineering chops. Over a couple of years, Hall refined a roof-mounted LiDAR (for "light distance and ranging") unit consisting of 64 lasers spun by a small electric motor;

the device became a favorite of the race's winning teams. "It was revolutionary," says William "Red" Whittaker, a roboticist at Carnegie Mellon University and a father of the autonomous-vehicle movement.

The races, known as the DARPA Challenges, became the Big Bang event for self-driving cars, and Hall's LiDAR forever changed Velodyne from a modest family-run business into a hot commodity: a 34-year-old startup whose technology is remaking transportation and robotics. Today Velodyne is the top supplier of advanced automotive LiDAR and sells its sensors to virtually every auto and tech company that's building or testing autonomous vehicles. GM, Ford, Uber and China's Baidu are big buyers, and even Caterpillar uses Velodyne's tech for gargantuan robotic mining trucks. Google has been a major customer for years, though it's also making its own sensors. No company other than Velodyne produces comparable units in sufficient quantities to meet the growing demand.

NOVA "The Great Robot Race" | DAD's Big Day | PBS



Being the pick-and-shovel seller in the gold rush to a self-driving future is proving to be lucrative. Velodyne, which remains private, says revenue is expected to be about \$200 million this year, and the company is profitable. It has set its sights on the billion-dollar sales mark, says Mike Jellen, Velodyne's president, though he won't say when it will reach that milestone. The company is ramping up production quickly, following a \$150 million investment from Baidu and Ford last year. It was the first outside money into the company since Hall raised \$200,000, mostly from his parents and his grandfather, to start the business. Velodyne won't disclose its valuation, but an estimate by Forbes, based on expected revenue, suggests a market value of about \$2 billion. Hall is said to own more than 50%, giving him an

estimated net worth of more than \$1 billion. Jellen says an IPO is likely in "the 2018-19 time period."

But Hall is already thinking bigger. He wants to increase LiDAR production capacity from thousands of sensors a year to at least a million by next year. To do that, he's busy transforming Velodyne's new San Jose factory into a giant robot itself: a fully automated megafactory that speeds up production while reducing the cost of his complex devices to a level competitors can't match. Think of it as a scaled-down version of Elon Musk's "machine that makes the machine," as the Tesla founder has described his famed Gigafactory and next-generation plants. While an automated facility won't be making Teslas until at least 2019 or 2020, Hall wants his to be fully robotic by next year. If he pulls it off, Velodyne will be at the forefront of two seismic shifts in tech: cars that drive themselves and factories that need human technicians and programmers but no assembly workers. "Here's the goal," Hall says. "Can you run your factory with the lights off? If you can do that, then you can actually make this stuff in the United States."



*Velodyne's "Megafactory" in San Jose, California, is being designed to produce 1 million LiDAR sensors a year on a fully automated assembly line.*

**HALL MAY BE A TECH MOGUL** in the making, but he remains the quintessential engineer, someone who is most at home tinkering in a lab and

typically dressed in a faded blue Oxford shirt, chinos and running shoes. He's often terse when the subject turns to himself, but his eyes light up when he discusses things like his 1970s Boston machine shop, which made specialty parts for clients such as Raytheon and Harvard Medical School.

Hall grew up in Connecticut, the son of an engineer who built nuclear power plants and the grandson of a physicist who in the 1930s invented a scanning process to make color photographs. It was his grandfather who had helped Hall, as a teenager, set up his own workshop, where, among other things, he made a motorized bicycle and a "really loud" guitar amplifier.

He studied mechanical engineering at Cleveland's Case Western Reserve University during the tumultuous early 1970s. After college he moved to Boston to open a shop to build parts for tech, medical and industrial companies. The projects were interesting and required creativity, but the anonymity of the work was frustrating. He decided he needed to move into consumer products. "If I walk down the street sometime in the future and yell out my brand name, every now and then I'll find somebody that has heard of me," he recalls thinking.



In the early 1980s, Hall moved to the Bay Area with a plan to get into the audio business, which was booming. "You could go to a stereo store, and they were always looking for something new," he says. With backing from his family, he started making premium sub-woofers with a design (which he patented) that reduced distortion. He named the company Velodyne, in a nod to his passion for cycling. His speakers, which cost between \$2,000 and \$5,000 a pop, caught on. "I was able to make it louder and deeper than anybody had ever done before without it sounding like the speakers were going to fall apart," he says.

His brother Bruce joined to handle sales. Business grew, and customers included Bay Area sports stars and the late Robin Williams. But competition in the audio business, particularly on price, became increasingly cutthroat, and by the late 1990s Hall was again looking for something new.

As a diversion, he started making fighting robots for the cable show Robot Wars, and one of his creations finished second in a 2001 world championship. But it was the annual series of DARPA Challenges--races for autonomous vehicles that were

first held in the California desert and later moved to urban environments--that offered a more serious test for his ingenuity. Starting in 2002, Hall experimented with a number of technologies, including cameras and lasers, and entered a vehicle in the 2004 and 2005 races. After recognizing the limitations of cameras, Hall and others turned their attention to LiDAR, a technology used for mapping and surveying that took individual pictures and stitched them together into detailed maps.

It was his adaptation of LiDAR into a roof-mounted unit with 64 spinning lasers that proved to be a breakthrough and finally gave cars vision. "It was enabling for the kind of general driving we were going for," says Whittaker, the CMU roboticist. Using Hall's LiDAR, Whittaker's Tartan Racing team won the \$2 million prize in 2007. Stanford, whose team was led by Sebastian Thrun, who later started Google's self-driving-car project, came in second. It, too, used Velodyne's LiDAR. Most of the other industry pioneers, who are now leading autonomous-vehicle programs at Google, Uber, Ford, Toyota and a host of tech startups, are also DARPA Challenge veterans. Many became Hall's customers. "Some good ideas really make it and change the world," Whittaker says.

Velodyne's headquarters are in San Jose, but Hall's efforts to keep the company at the forefront of his industry are centered some 38 miles to the north, in an Alameda R&D lab that's close to his marina compound. In a space that looks like an unusually well-funded high school maker lab, Ph.D.s in computer science, electrical engineering, physics and optics are pushing the capabilities of Hall's LiDAR.

Velodyne's devices give cars a 360-degree view that is rendered as a 3-D "cloud" of points on a map. Whether it's day or night, a vehicle can "see" everything in a 200-meter (or 650-foot) radius, allowing cars that travel at highway speed to detect distant hazards and avoid collisions. Last year, Hall sold thousands of units. This year, he plans on selling tens of thousands, with list prices ranging from about \$8,000 for a 16-laser model (which looks like a hockey puck) to as much as \$85,000 for a 64-laser unit. "There really was no other game in the market, and no one as advanced," says Jim McBride, Ford's technical leader for autonomous vehicles.

Rivals have emerged. Quanergy raised \$90 million from, among others, auto-parts supplier Delphi in 2016 to make low-cost solid-state LiDAR units, and Luminar, which got \$36 million to fund a LiDAR sensor, says it has range and image quality that top anything on the market. Velodyne is rolling out a new solid-state "Velarray" LiDAR, with no spinning parts, to go toe-to-toe with competitors at the lower end and is readying longer-range units to fend off those at the higher end. For now, Velodyne remains the undisputed leader, in part because none of the other companies are manufacturing at scale. "If you're working on self-driving, you're

trying to get your hands on Velodyne, because that's the most likely unit you can get in any quantities," says Mark Wheeler, a veteran of Google and Apple who's chief technology officer for DeepMap, a Palo Alto developer of mapping services for driverless cars. Hall dismisses his competition with a "been there, done that" wave of the hand. "Does anyone know how to mass-produce LiDAR other than me?" he asks. "It turns out I'm the critical link in this whole thing."

Not everyone in the autonomous-vehicle universe is a fan of LiDAR. The most notable holdout is none other than Musk, who committed Tesla to using a combination of cameras, radar and sonar that he says provides sufficient sensing capabilities. But even without Tesla, the market for Velodyne's gear remains huge. Today there are a few thousand prototype driverless cars being tested. While no one knows exactly when self-driving vehicles will be sold to consumers, forecaster IHS Markit expects sales will grow rapidly to 600,000 units in 2025 and at least 43% annually for a decade after that. That would imply a cumulative 76 million vehicles driving themselves through cities and highways by 2035. Velodyne's forecasts are for hockey-stick growth of at least 300% annually for the next few years, says Jellen, the company president.

That goes a long way toward explaining why Hall, whose company already employs 530 people, is so focused on his megafactory. The glass-encased manufacturing facility opened early this year in San Jose. About 200 workers are busy assembling critical microelectronics and optical components for the newest LiDAR units. But over the next 18 months, the work will be taken over by robots that are popping up within the facility. Hall and his engineers are figuring out the final form of the robotic manufacturing process in secret. He's not ready to share details, but he says the San Jose facility will soon be ready to churn out a million units a year. "It has to be automated to make these volumes," Hall says. After a brief pause, he adds: "This is far more interesting to me than all the LiDAR marketing stuff."

Radiohead - House of Cards



*Alan Ohnsman covers technology-driven changes reshaping transportation. Follow him on [Twitter](#). Have tips to share with Forbes anonymously? Click [here](#).*



