DVN
Lidar

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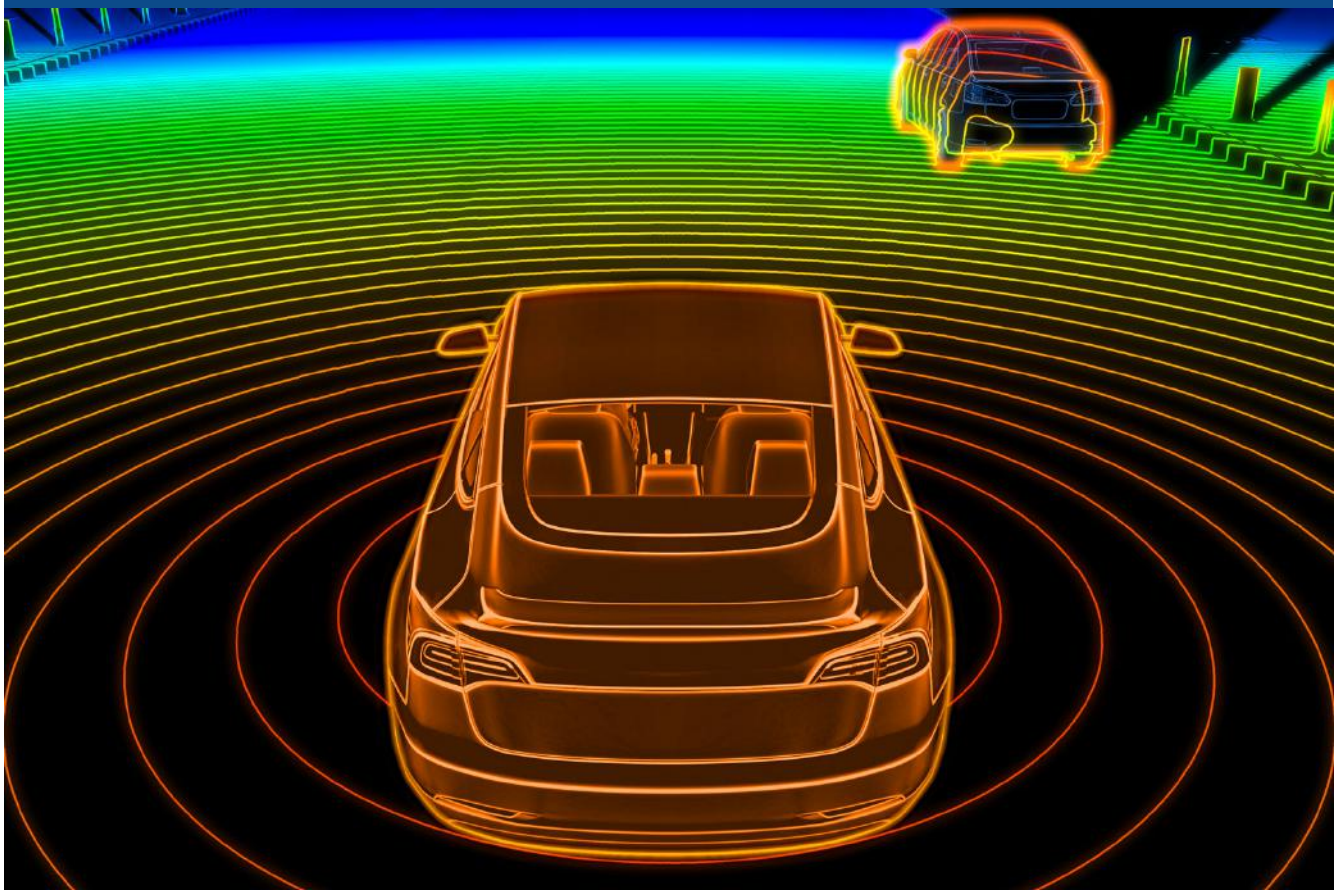


EDITORIAL

Is '23 the Year Lidar Breaks Out or Breaks Down?

This twelfth issue marks the first anniversary of the DVN-Lidar Newsletter. We're happy and grateful for all of you reading this, whether you've been with us from the start or you joined in along the way. It's a fine occasion to take a look at the topography of today's lidar world and see what we might forecast. Fully *nine* lidar startups have recently announced the final closing of their C-series financing rounds—such as Israeli lidar supplier **Opsys Tech**, who finalised their series-C financing rounds to the tune of about USD $50m last January, just seven years after founding. This issue of the DVN-L Newsletter brings you our exclusive interview with Rafi Arel, CEO of Opsys Technologies Ltd.

We've got a bunch of new features for you, as well: capsule summaries of lidar business news—recent fusions between Ouster and Velodyne and between Ibeo and Microvision; and Quanergy's bankruptcy filing only 10 months after going public, together show consolidations will be necessary in this phase of slow market ramp-up. And you'll find coverage of the introduction and user experience of autonomous-drive systems, which are entering the market in earnest.

Also this week: your first report on our first DVN-L Deep Dive in Wiesbaden on 28 February, dedicated to the challenging ODD issue for lidar technology in autonomous-drive systems. Particular issues discussed by the 32 live and online participants included lidar contamination and cleaning, and lidar system performance in foul weather.

Be sure and **save the dates** for these forthcoming high-content, high-value DVN-Lidar events:

- Deep Dive II (Europe): early June; date TBD, at Dorint Pallas Wiesbaden
- DVN-L Deep Dive III (USA) : 29-30 August in Redwood (San Francisco Bay area)
- DVN-L Conference (Europe): 29-30 November at Dorint Pallas Wiesbaden

We're ever so glad you're here with us in the DVN-Lidar community; enjoy this twelfth newsletter!

All best,

Alain Servel

DVN LIDAR SENIOR ADVISOR

DVN-LIDAR DEEP DIVE

DVN-Lidar 2023 / Deep Dive I · Report

The DVN-Lidar 2023 Deep Dive I, held at Wiesbaden at the end of February, was dedicated to the challenging ODD (operational design domain) issue for lidar technology in autonomous-drive systems, including sensor dirt and bad weather conditions.

With 32 participants, we had a large group of experts from automakers; lidar tier-1s; optics and coating specialists; simulation tool providers, and testing services. All had the opportunity to discuss technical issues in three working groups.

We had four speakers from Volvo Cars; Valeo; Persival (simulation tools), and FKA (testing and standards).

Speaker 1 Paul-Henri Matha

“ Contamination & Cleaning ”

Paul-Henri Matha (Volvo Cars' Exterior Lighting Technical Leader) presented the integration of lidar on the Volvo EX90, including:

- simulations related to aerodynamics; thermics; self-contamination (e.g., from wipers), and foreign contamination
- benefits from heating and air or water cleaning technologies
- benefits from coating technologies

"roof integration constraints are related to aerodynamics and temperature—it requires a cooling system".

"It is still challenging to design an efficient cleaning system, but it is improving with the new coating technologies".

"GTB has a group working on lighting cleaning systems which was extended to sensor cleaning systems".

Speaker 2 Clément Nouvel

” Scala2 - securing performance and safety in adverse weather conditions "

Clement (Valeo Lidar CTO) described the effect of contamination and bad weather conditions on lidar performance, and some cleaning solutions proposed by Valeo Lighting Systems.

"The 905nm technology has no big issue with contamination (droplets) or heavy rain, the remaing issue is the fog or smog".

"It is important to get information from the lidar about the environmental conditions to take actions, such as max range measurement, spray classification, blockage detection...".

"There is a need of standards to measure the impact of contamination and bad weather conditions on lidar performance".

Speakers 3 Philipp Rosenberger & Clemens Linnhoff

" Weather conditions and Lidar Perception "

Persival is a startup working on sensor models and simulations, created by two Darmstadt University PhDs, Philipp Rosenberg and Clemens Linnhoff.

Persival can also provide services to implement and interface the simulation tools with other design systems used inside a company. BMW is one customer of Persival.

"Persival's scope is perception sensor models and simulations, mainly for radar and lidar. Persival has done verifications of its tools with real tests. These models can be used as a starting point for interference studies".

"The simulations can treat object dependent conditions (i.e. road spray, exhaust gas) and non object dependent influences (i.e. rain)".

Speaker 4 Amogh Sakpal

“Lidar performance in bad weather”

FKA has recently led a consortium project dedicated to lidar performance specification and testing standardization, which will lead to a DIN-SAE spec whose publication is expected in March 2023. Several lidar tier-1s were part of the consortium: Luminar; Valeo; Innoviz, and Microvision.

FKA proposed to continue the project in 2023 including the effects of bad weather; sunlight; contamination, and interference.

DVN will contribute to recruit consortium members; provide expertise regarding traffic scenarios for interference (experience with the radar technology), and organize the presentation of conclusions and final report in a forthcoming Workshop

More details will be available in the DVN-Lidar Deep Dive I meeting minutes sent to all DVN members.

INTERVIEW

DVN-L Interview: Rafi Harel, Opsys Technologies CEO

Rafi Harel is an experienced senior executive with over 30 years in the hi-tech industry in R&D; engineering, and product-delivery C-level positions in leading worldwide global teams:

- GM Finisar Israel, 2010-2016
- VP R&D Orckit-Corrignet, 2001-2010
- IDF Intelligence Elite Technology unit, 1992-1999

DVN: Opsys, founded in 2016, are still perceived as new. Tell us about your company, won't you please?

R.H: We knew the automotive market needed an innovative lidar solution. Our goal was to solve problems, such as moving parts in lidar. We wanted to solve all known issues by enabling a no-moving-parts (pure solid-state) scanning lidar with high resolution. We wanted it to be fast-scanning and ultra-small to deliver a full performance across all operating conditions and range.

By 2018, we had already introduced our first-generation solution to the automotive market. It was based on full semiconductor technology with 2D addressable VCSEL array; SPAD detector array, and our ASIC chip which controls the lidar operation and the VCSEL array.

Opsys' newly-developed technology also enables a fully automated production line with minimal touch-labour. In addition, our solution benefits from a software-based, fully automated calibration process which looks more like a camera production line.

Our initial version proved to our customers that our pure solid-state scanning lidar technology achieves their target specifications, such as 200m with POD > 90 per cent for a 10 per cent reflectivity target at
0.1 × 0.1 angular resolution, as well as delivering the best flexibility and value.

By next summer, our SP3.0 platform will move to mass production. It will meet all automotive standards with full DV so it can be delivered to our customers.

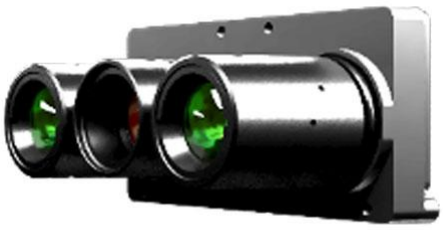
DVN: You're marketing solid-state lidars with no moving parts. What makes them better?

R.H.: Our unique implementation of electrically-scanning lidar without any moving parts enables us to design and manufacture highly reliable and best performing scanning lidars, while delivering best value to customers. Opsys scanning lidar delivers 300 metres of detection range with ultra-fast scanning and high resolution under all conditions. Our sensor can be installed behind the windshield; in the headlamps and/or taillights, and delivers a contiguous point cloud of the FOV. Currently the packaging size is 7 × 4 × 5 cm, and the next generations will be even smaller.

DVN: What wavelength do you use, and why?

R.H.: Opsys lidar is operating within the 900-nm window on several wavelengths, to optimise the performance of the lidar while enabling a scanning lidar with no moving parts, using material systems produced widely and efficiently around the world. In addition, this wavelength range minimises the impact of rain and fog; it delivers best performance under all environmental conditions, without any active temperature control.

DVN: How come your transmitting structure is based on a VECSEL array?



R.H.: Opsys' patented use of a fully-addressable VCSEL array allows us to deliver the highest power density while also operating under the FDA class-1 eye safety limit in all conditions, to achieve best-in-class performance and value for customers. That's well beyond any flash lidar capabilities. The Opsys lidar structure, which does not have any moving parts, allows for a highly automated manufacturing process while significantly reducing any touch labour requirements. It also allows for a scalable cost model for large quantities.

DVN: You've recently announced coöperation with Chinese supplier Hasco. Tell us more, will you?

R.H.: Opsys' unique true solid-state scanning lidar delivers high performance and reliability in a small size, providing a cost-effective solution which can be efficiently scaled up to large production capacities while realising significant economies of scale. This type of value, coupled with the ability to integrate our lidar behind the windshield and/or within the head- and taillights with no performance penalty, delivers the differentiated value our customers were looking for.

DVN: What happens to Opsys lidar in bad weather?

R.H.: Not only does Opsys lidar deliver superior performance, but the system is designed to operate under bad weather conditions! The lidar performance is optimised for ranges up to 300 metres, with a possible use for a radar system which has a range beyond that. We see the two technologies as complimentary and both can be used in an ADAS system, although the lidar delivers the best performance up to 300 meters.

DVN: How do you prioritise between short- and long-range applications? How do you see the market dividing up in terms of lidar range?

R.H.: Our lidars are designed to deliver best value and performance for short and long distances, as well as delivering a one-stop shop for our customers for their lidar needs, which will address all levels of autonomous vehicle and ADAS requirements depending on specific implementation.

DVN: Are lidar and imaging radar competing or complementary? And do you foresee the radar-lidar performance gap narrowing?

R.H.: At the moment a lot of use cases we are getting can only be solved by lidar technology. We believe, however, that the definition of our customers' architechture will be used in a way that combines lidar and radar technology, with both solutions being integrated into the ADAS system to maximize the system's reliability.

DVN: How does the automotive lidar market differ in various markets?

R.H.: We see a massive global opportunity for lidar addressing numerous applications with significant CAGR. The automotive demand for lidar is ramping up now more aggressively in Asia, and is projected to ramp at similar rates in the EU and US markets, but with a probable 1.5 to 2.5 years' lag behind China's market.

DVN: It all sounds terrific! Thanks so much for talking with us. Finally, when do you expect to start mass production?

R.H.: We plan mass production for mid-2024, based on our SP3.0 product line production release and our customer SOP date.

LIDAR BUSINESS

Lidar Business News summary

Here's our new section where you get quick, efficient news as the industry works to find the balance between cost and revenue to achieve a profitable growth.

Luminar Announce Big Mercedes-Benz Deal

Mercedes-Benz have signed an agreement with **Luminar** to supply lidar sensors into multiple vehicle models by mid-decade as part of a push to support and proliferate new automated-driving features. The two companies are calling the pact a "multibillion-dollar deal". This comes as the first time Mercedes-Benz have scheduled production of lidar-equipped cars, following a protracted development partnership with Luminar.

Ouster, Velodyne Complete Merger

Ouster and **Velodyne** have announced successful completion of their 'merger of equals', as of 10 February. The combined company will keep the name Ouster and continue to trade on New York Stock Exchange under the OUST symbol.

Cepton Win Lidar Contract from US Highway Toll Operator

Cepton have won a multimillion-dollar sales contract from one of the largest highway tolling system operators in the U.S. Cepton's Sora lidar sensors will be deployed in the U.S. on several major tollways located in multiple states. This is expected to be the tolling sector's largest commercial lidar deployment to date, with potential to scale outside of the U.S. for future projects.

Toyota Cars Will Have RoboSense Lidar

Toyota will be installing **RoboSense** RS-lidar-M equipment on a number of top-selling vehicle models. RoboSense say the M-series is the only solid-state lidar of its type designed for automotive series production, and they have already received orders for more than 50 models from 20 different car companies.

Hesai IPO Goes Large

Chinese lidar maker Hesai have raised USD $190m from their public offering on Nasdaq. Multiple Chinese tech companies have delisted from the U.S. or sought secondary listings in Hong Kong amidst rising tensions between the two major economies, and Hesai aren't immune to geopolitics.

LIDAR NEWS

Polestar, Luminar Expand Partnership

Pol

Polestar and Luminar will deepen their partnership by putting Luminar's technology on the Polestar 5, an electric 4-door GT expected to launch next year, based on the Polestar Precept concept. This expanded partnership provides a foundation to further collaborate on lidar integration and design on Polestar's future vehicles.

Both the Polestar 3 and Polestar 5 will seamlessly integrate Luminar's long-range Iris lidar and software into the roofline. Coinciding with the announcement, sales of Polestar 3 with lidar have been brought forward so that customers in initial markets can now place orders for Polestar 3 with lidar, with deliveries expected next year.

Luminar CEO and founder Austin Russell says, "As we successfully execute together, Polestar's conviction in Luminar and the value of our technology has continued to accelerate. With this new expanded partnership and our shared pioneering spirit, we will push the boundaries of automotive technology and design into new territories for the next generations".

DVN comment

Luminar's Iris lidar has been adopted by Volvo for the SPA2 platform. Polestar's solution is similar to integrate this discreet, slim Iris lidar just above the windscreen, at the junction with the edge of the roof. This sensor location benefits from the car's windscreen cleaning system and from airflow continuously sweeping away raindrops and snowflakes as the car moves.

LIDAR NEWS

AMD Adaptive Computing for Denso Lidar

AMD's adaptive computing technology is powering Denso's next-generation lidar platform to deliver a more-than-twentyfold improvement in resolution with extremely low latency, for increased precision in detecting pedestrians, vehicles, free space and more—and to enable ISO 26262 ASIL-B certification.

Denso's SPAD (single-photon avalanche diode) lidar system, powered by AMD's XA Zynq UltraScale+ multi-processor system-on-a-chip (MPSoC) platform, is slated to begin shipping in 2025. AMD say it generates the highest point-cloud density level of any lidar system on the market today, and enables smaller packaging for Denso's lidar systems, in turn allowing multiple lidars to work in tandem for forward view and side views of a vehicle. One device can be used for multiple Denso lidar systems, including future generations, which drives down system costs and helps designs to be future-ready.

Eiichi Kurokawa, head of Denso's sensing system business unit, says his company "are excited to expand our collaboration with AMD as we introduce our next-generation lidar system. AMD high-performance, highly scalable, programmable silicon offers distinct benefits for the extremely complex image processing requirements of our lidar sensor architecture. The flexibility and capabilities of the Zynq UltraScale+ MPSoC platform and its ability to meet stringent functional safety requirements led us to work with AMD".

And AMD SVP and general manager of the core markets group Mark Wadlington said, "Denso has developed an exceptionally precise lidar system. With lidar continuing to evolve, there are new technology requirements, driving the need for improvements in sensitivity, density and performance. Through AMD adaptive computing technology, we're helping to enable a reduction in system size and space, while also improving resolution for increased precision in object detection, all at very low latency".

DVN comment

Component suppliers like AMD; Infineon; Intel; NXP, and Texas Instruments are proposing radar-on-chip structures wherein ultra-high frequency stages (LNA; mixers, VCOs) coexist on the same chip as digital signal processing structures. This mono-chip integration is possible because radar's architectures are more and more standardised; their specificities come only from antennas. We foresee lidars proceeding along similar evolutionary lines.

LIDAR NEWS

Lumotive-Lumentum M30: Reference Design for Next-Gen Lidar Sensors

Lumotive and Lumentum Holdings have announced availability of the M30 Reference Design, a complete sensor implementation of their software-defined lidar solution. The design integrates Lumotive's Light Control Metasurface (LCM) beam steering chips and Lumentum's M52-100 multi-junction VCSEL array. Lumotive demonstrated the LCM beam steering technology at SPIE Photonics West 2023 in San Francisco.

Lumotive's VP of Strategy and Partnership Rakinder Grover says the M30 Reference Design offers a software-definable lidar solution that meets the low power and small footprint requirements of short to long-range mobility and industrial applications. lidar sensors based on LCM electronic beam steering have several advantages over traditional flash illumination solutions, including improved outdoor range performance, software-defined scan modes, reduced multipath effects, and high power density in a small package.

Matt Everett, Senior Director of Product Line Management at Lumentum's Imaging and Sensing Business Unit, says the M30 Reference Design provides outstanding performance and the ability to adjust the field-of-view and region of interest. The design is currently being evaluated by several leading lidar developers; tier-1 automotive suppliers, and industrial OEMs. The solution with enhanced performance optimized for volume manufacturing is expected to be available by mid-2023.

DVN comment

We reported in our previous newsletter the announcement of the zero-inertia beam steering system LCM developed by Lumotive. This solution capable of arbitrary scan patterns allows a sensor to adapt to any situation. To provide a complete and efficient lidar source dedicated to long range applications, it was necessary to associate an adequate laser source. It is done through the M30 module which integrates both a LCM and a Lumentum's VECSEL array. The association of a tuneable multi-light power source (Lumentum VECSEL) and the LCM structure expands the possibilities of this agile scanning system.

LIDAR NEWS

Kyocera Ceramics and Optics at Photonics West

Kyocera, acclaimed specialists in fine ceramics, exhibited their latest optoelectronic products and technologies at SPIE Photonics West in San Francisco. Their products enable new innovations in optical communication, Laser/IR/Motion sensing, 2D/3D industrial image recognition, medical image acquisition, and smart vehicles. Of particular interest, Kyocera propose a variety of components for lidar applications, including:

- Integrated FMCW modules for L^4 and L^5 autonomous driving applications
- Custom modules used in ToF (Time of Flight)
- Lasers
- SOA (semiconductor optical amplifiers)
- Receivers and detectors
- MEMS mirrors
- Ceramic packages and submounts for VCSELs

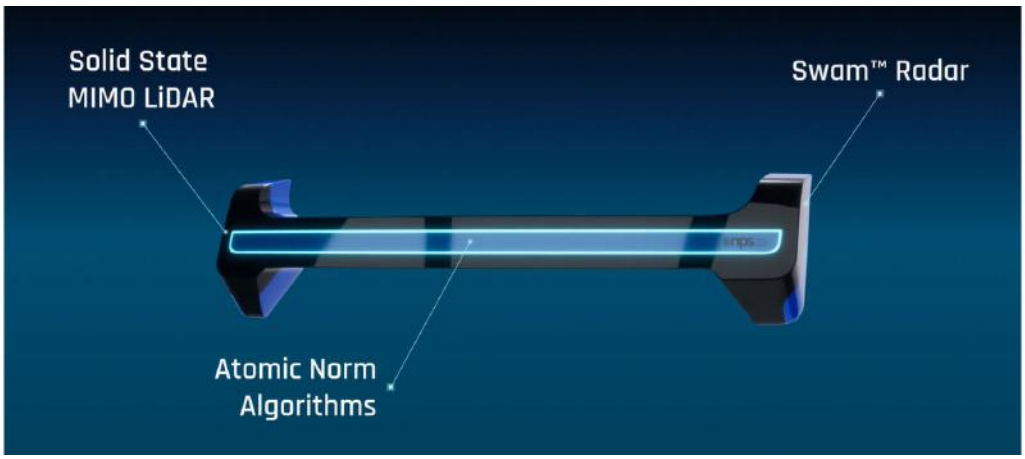
Kyocera Corporation was founded in 1959 as a producer of fine (or "advanced") ceramics. By combining these engineered materials with metals and integrating them with other technologies, Kyocera have become a leading supplier of industrial and automotive components; semiconductor packages; electronic devices; smart energy systems; printers; copiers, and mobile phones. During the year ended 31 March 2022, the company's consolidated sales revenue totalled J¥1.8tn (about USD $15.1bn).

DVN comment

Solid-state lidar's electronic structures must support arrayed transmitters and receivers, and in certain cases a specific deflecting structures made of optical wave guide and arrays or micromechanical mirrors. Due to wavelengths, such structures can be highly miniaturised, allowing very interesting solutions for a seamless integration of lidars. Kyocera are a key supplier for such components.

LIDAR NEWS

NPS' Breakthrough AtomicSense Radar Technology



Neural Propulsion Systems (NPS), founded in 2017 by Silicon Valley luminaries, specialise in hyper-resolution digital imaging radar technology. Their AtomicSense radar technology been recognised for its exceptional performance—it won a CES 2023 Innovation Award.

AtomicSense offers faster scanning time, 10× better resolution, and a 2.5× improvement in range compared to conventional radar offerings. This performance is made possible by NPS' innovative algorithms, based on frequency modulated continuous wave (FMCW) and array processing.

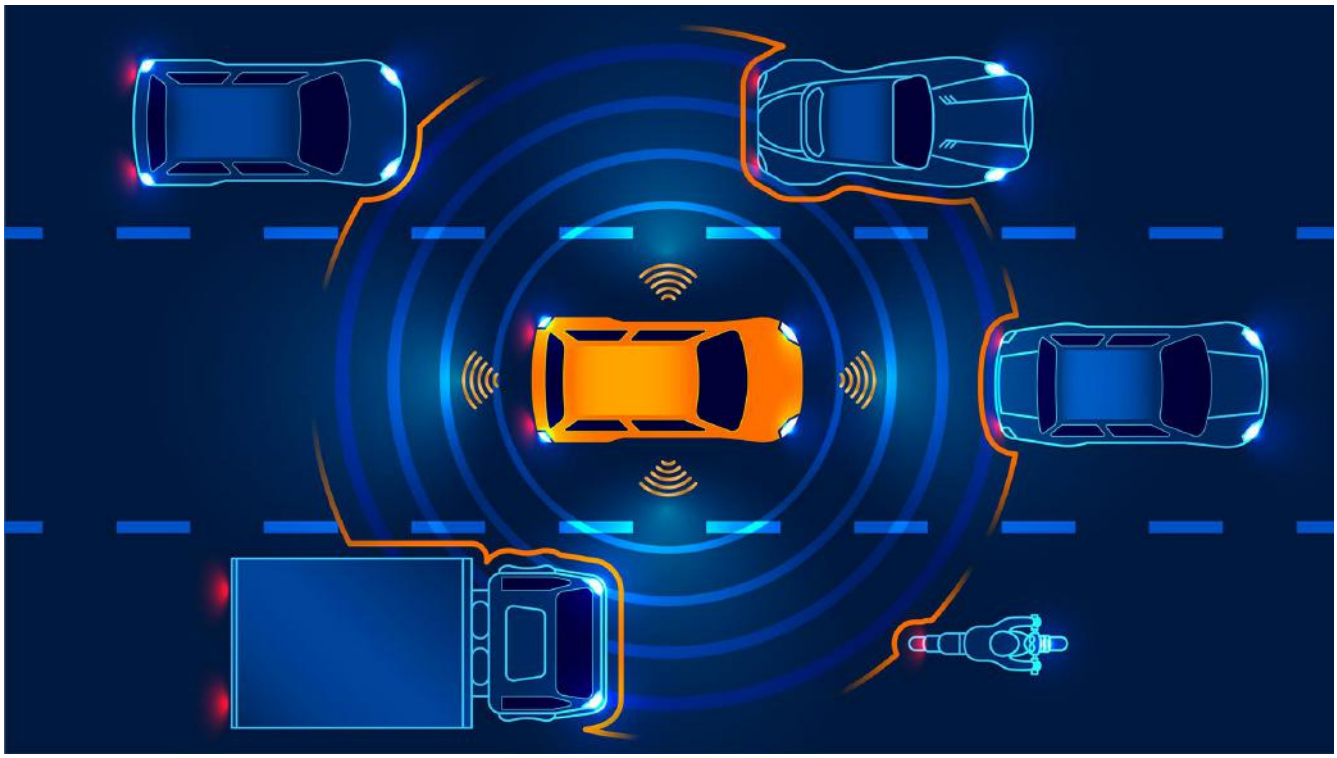
The AtomicSense platform is described by NPS as the world's first all-in-one, deeply-integrated, multimodal sensor system for ADAS and AVs at high volume and affordable cost. The AtomicSense components fuse data from the NPS solid-state MIMO lidar; super resolution SWAM radar, and cameras to deliver consistent and accurate, high-resolution, 360° data. The system is powered by a new class of estimation and detection algorithms based on the Atomic Norm, and has shown terrific performance advantages in excess of 50× over current solutions. The densely integrated deep sensor-fusion system gives vehicles the ability to see around corners and over 1,000 metres away.

DVN comment

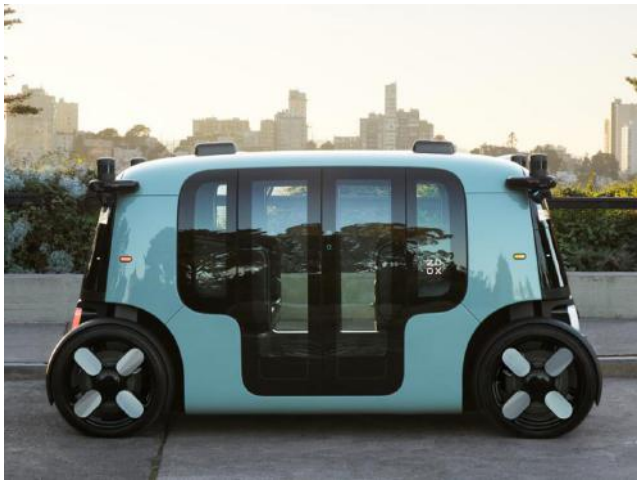
The association of a lidar and an imaging radar can improve the reliability of this global perception system, especially in adverse weather conditions. Camera perception performance in fog; spray; rain, and snow is something of a pain point or bottleneck on the way toward widespread autonomous driving, and a great deal of work is being done in this area.

LIDAR NEWS

Automated Driving is Coming. Let's Try it Now!



The future of lidar is partly linked to autonomous driving. In this chapter, you can get a bit of end-user experience to understand what autonomous driving means and where you might use it in the near future.



Autonomous-mobility-as-a-service company **Zoox** have announced a major milestone in the development of AVs: the world's first purpose-built robotaxi deployed on public roads with passengers.

On 11 February 2023, Zoox conducted their first run of their employee shuttle service in Foster City, California. This marks the first time in history that a purpose-built autonomous robotaxi without traditional driving controls has carried passengers on public roads.

Carrefour, the leader in home delivery in **Carrefour,** the leader in home delivery in France, are partnering with Goggo Network, an autonomous logistics operator, to pilot autonomous delivery of Carrefour Drive orders for residents on the Plateau de Saclay. Customers submit their orders on the Carrefour website and choose an available delivery slot to have their shopping delivered by autonomous shuttle. The shuttle then travels autonomously to the Plateau de Saclay, where customers retrieve their goods from a locker using a code sent to them via SMS. Once all orders have been distributed, the shuttle returns to its starting point in Massy.

San Francisco Transportation Authority (SFTA) officials have asked the California Public Utilities Commission to slow or stop the expansion of Cruise and Waymo robotaxi services in the city, stating that unlimited expansion would be unreasonable given recent incidents when vehicles have blocked traffic and interfered with emergency vehicles. Waymo and Cruise both operate fully autonomous vehicle services in San Francisco. In June 2022, Cruise got permission to charge for rides in specific areas of the city between 10 PM and 6 AM. Waymo have permission to offer rides, but they're waiting for another permit to charge for them.

The **Technical University of Munich** (TUM) have made a significant breakthrough in the development of autonomous driving software. The team has created an algorithm that takes into account the 20 ethics recommendations from the EU Commission expert group, allowing for fairer risk distribution on the road. The software is a major step forward in ensuring the safety of automated vehicles by evaluating the varying levels of risk to pedestrians and motorists. The algorithm was tested in over 2,000 critical scenarios on various types of streets, in Europe, the USA, and China.

In **Consumer Reports**' recent testing of 12 ADAS suites, Ford's BlueCruise ('ActiveGlide' in Lincolns) got the best grade. General Motors' similar Super Cruise took second, and Mercedes-Benz's system took third. Tesla 'Autopilot' fell to № 7 this year, from second in 2020. CR say that's because Tesla haven't made any significant upgrades to Autopilot's core functionality in years—it still doesn't allow collaborative steering, and doesn't have an effective driver monitoring system. The assessment criteria were ease of use; capability and performance; keeping the driver engaged; how they handle an unresponsive driver, and how clearly they indicate when it is safe to use them.