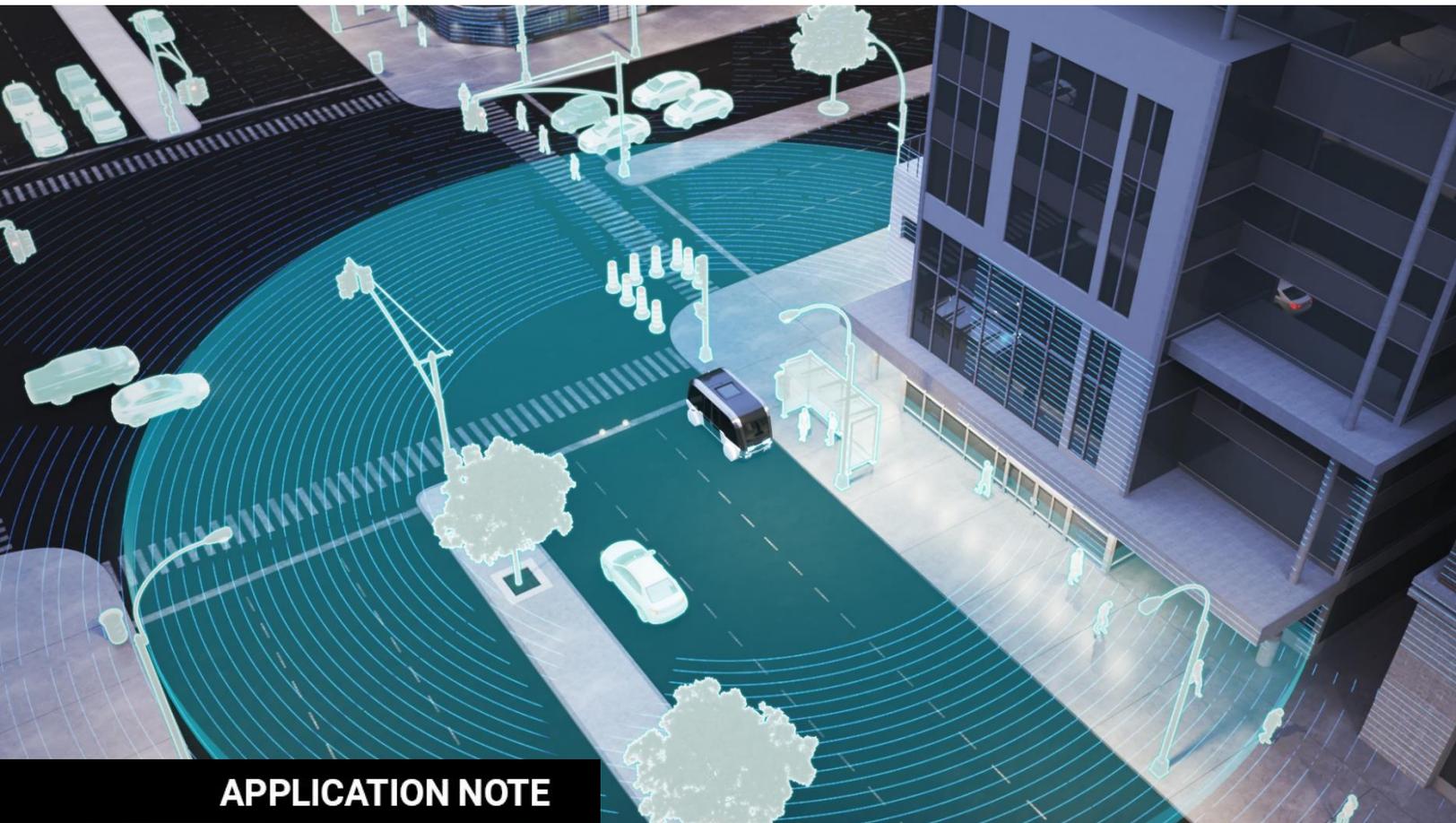


Autonomous Shuttles Turn Towards Flash LiDAR Technology to Provide Reliable and Robust Collision Avoidance Detection Cocoon

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APPLICATION NOTE

The gradual shift towards autonomous vehicles is causing a ripple effect throughout the automotive industry as key vehicle manufacturers implement ADAS and autonomous driving capabilities into their vehicles at an accelerated pace. A growing number of test drives and pilot projects for fully autonomous passenger vehicles are underway in various metropolitan areas worldwide. This application note explores the LiDAR technologies behind autonomous shuttles and presents cost-effective detection cocoon solutions that surround the vehicle to provide blind spot coverage without dead zone in the illuminated field of view to detect and track vulnerable road users as well as unforeseen obstacles in the vehicle's vicinity.

The Challenge

At the core of a typical, fully autonomous shuttle lies two essential central processing units (CPUs) that work in tandem to prevent collisions: the main navigation system CPU and the secondary CPU.

The main navigation system CPU interfaces with one or a few LiDAR sensors that offer high ranges and high resolutions for localization, mapping, and collision avoidance. Many autonomous shuttles today rely on a mechanical-scanning LiDAR sensor that is placed on top of the shuttle, which provides long-range detection and 360 degrees of coverage around the vehicle as illustrated in Figure 1.

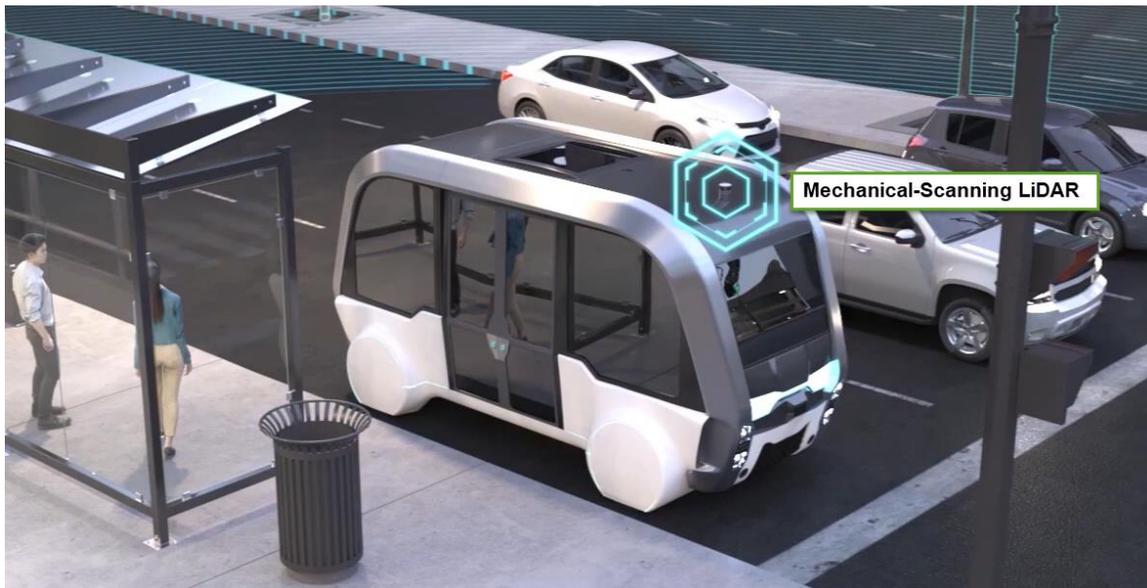


Figure 1- A mechanical-scanning LiDAR sensor mounted on the top of an autonomous shuttle.

However, the position of this mechanical-scanning LiDAR sensor on the shuttle creates an area, or dead zone, around the entire vehicle where objects cannot be detected, as illustrated in Figure 2. The radius of the dead zone varies in size depending on several factors, including the vertical field of view (FoV) of the mechanical-scanning LiDAR sensor, the sensor's mounting position on the shuttle and the size and shape of the shuttle.

Detecting the obstacles within the dead zone is critical to ensure safe and successful autonomous driving. As a matter of fact, the autonomous shuttle cannot move if it has not first analyzed its surroundings to confirm that there are no obstacles nearby and that it is safe to proceed. Furthermore, throughout the shuttle's run, in stop-and-go situations, the system needs to validate whether a person, vehicle or any other object is close before moving forward. For example, when picking up passengers, the system needs to assess if people have successfully boarded the shuttle or if they are still in the shuttle's trajectory or its immediate proximity.

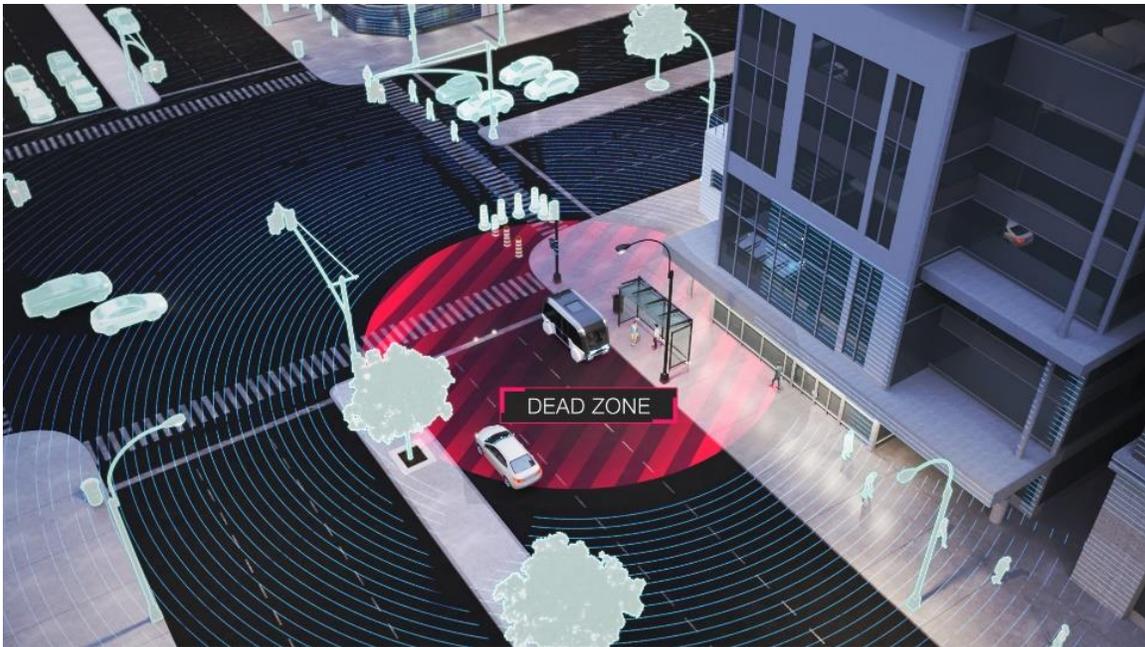


Figure 2- A mechanical-scanning LiDAR creates a dead zone that can reach several meters around the vehicle.

The same detection process is required for other unexpected objects such as open car doors, garbage cans, temporary signage, vehicles parked in an unorthodox manner or illegally, etc.

This is where the secondary CPU plays a key role in preventing the shuttle from moving or bringing it to a complete stop should a hazardous situation be detected. An integral part of the most recent autonomous shuttle designs, the secondary CPU requires short- to mid-range collision-avoidance detection to bring the vehicle to a complete stop when the main navigation system is unable to identify an obstacle or if this main system fails.

The secondary CPU is a low-power, redundant and cost-effective system that requires low data rates—but must nevertheless ensure complete coverage of its surroundings (360 degrees with full horizontal and vertical surface coverage). This poses a significant challenge as the need itself goes against the basic concepts of scanning in which more coverage by default means more data. For example, scanning LiDAR devices return anywhere from 600,000 to 2.2 million points per second, depending on the resolution and the number of vertical lines (16 to 64) that the selected sensor offers.

Looking for the Right Technology

To cover the dead zones that surround the shuttle, different detection technologies have been considered and tested by AV developers, yet each of these technologies presents considerable limitations:

- Sonar: Limited range and low resolution;
- Radar: Permeable surface and static object detection issues;
- Camera: Lack of range information and important weather degradation.

Other solution criteria are equally as important. For one, since the solution will play a fundamental role in the secondary CPU, it cannot send too much data to the system to avoid interfacing issues that may occur with data overload. The optimal data input for secondary CPUs is estimated to be between 3,000 to 60,000 points per second for 360 degrees of coverage.

The technology must also offer a resolution that is high enough to detect small objects, enable precise trajectories and speeds by the implementation of tracking algorithms and provide precise object positioning for effective avoidance decision-making.

Another important factor to consider is that the selected solution must have complete coverage of the field of view and offer a very high detection rate on all type of surfaces, which is critical in a security system that will be used to detect objects that may otherwise be missed by a low-resolution sensor.

Finally, data from the secondary CPU will then be fed into the navigation CPU for redundancy purposes. Redundant sensors increase system performance levels, detection rates, and robustness. An event that could potentially be missed by one sensor will be captured by another, thereby significantly increasing the system's performance and ensure a safe operation, which is of paramount importance in fully autonomous applications involving multiple passengers.

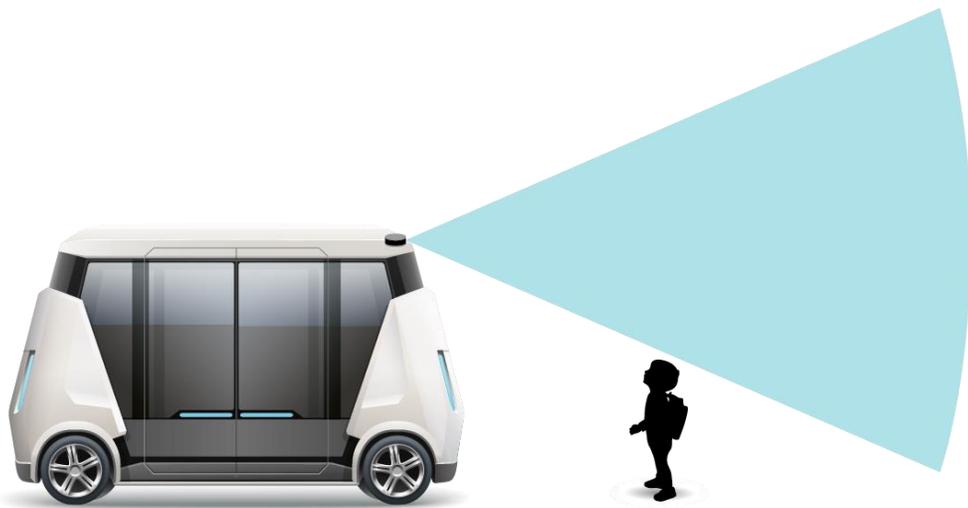


Figure 3- Having a blind spot zone could have disastrous consequences, as illustrated with an undetected child close to the vehicle.

A Solution with the Right Performance-to-cost Ratio

Based on these requirements and inherent sensor technology limitations, many shuttle developers turn to solid-state Flash LiDARs to cover the detection dead zone around the shuttle. Flash LiDARs provide highly reliable detection at a much higher mean-time-between-failures (MTBFs) than mechanical scanning LiDARs as well as offer 100% light density and complete coverage of the field of view.

When the main long-range detection system is unable to detect an object because of a failure or a false negative, the flash LiDAR solution offers the range required to be a redundant proximity detection and

collision avoidance system that respects maximum deceleration rate, especially at the maximum cruising speeds of many typical shuttles.

As an example, if an object is detected in the proximity of the vehicle, an emergency braking procedure will be activated. Since a certain braking distance is required in order to keep deceleration at a safe level for shuttle passengers, who oftentimes do not wear safety belts and often stand, the sensor solution must provide enough detection range to allow the vehicle to come to a complete stop safely. For example, considering a 3.5 m/s^2 deceleration rate, a shuttle moving at the speed of 40 km/h would take 23 meters to stop, including a 0.5 second reaction time. Therefore, it is important that the sensor solution enables pedestrian detection at more than 23 m.

To provide enough range, many LiDAR solutions will require more powerful, expensive optics and laser sources. By optimizing signal processing on the software side through patented methods, LeddarTech's flash LiDAR technology is able to deliver the range and performance required at costs that make them highly attractive for commercial deployments in shuttle applications, such as proximity detection, blind spot coverage, and collision avoidance.

Flash LiDAR configuration examples for shuttles

To ensure that all dead zones are covered, various combinations of flash LiDARs can be implemented. 2D Flash LiDAR modules from LeddarTech are offered in various fields of view (FoV) configurations and are ideal when the objective is to cover smaller or specific zones around the shuttle. Recently introduced on the market, LeddarTech's 3D Flash sensors providing a 180° horizontal FoV are favored when the objective is to cover a more significant area or to create a complete detection cocoon around the shuttle.

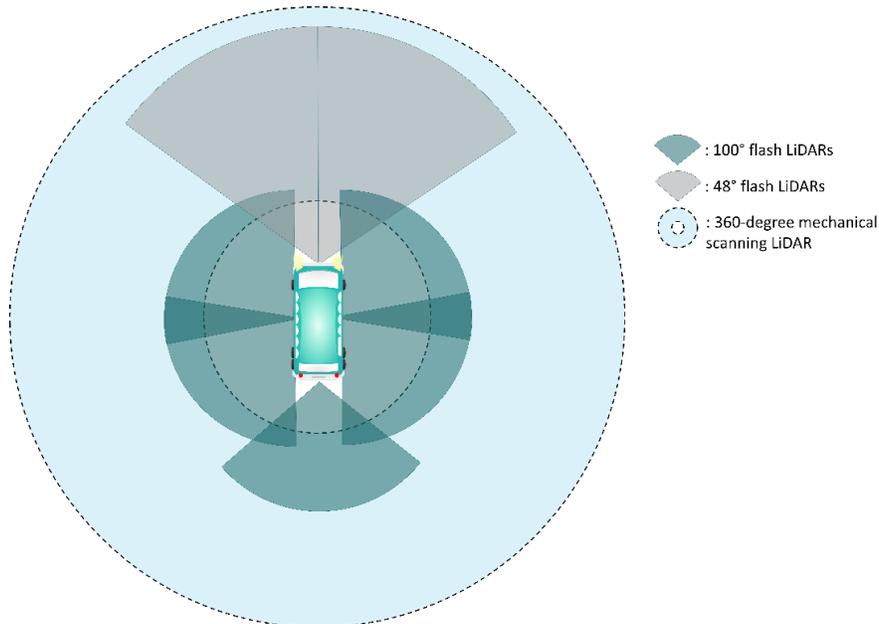


Figure 4- Example of 2D LiDAR sensor coverage using various FoV configurations (top view).

2D Flash LiDAR configuration example

Figure 4 above illustrates various positions where the 2D sensors could be integrated to cover specific areas around the shuttle. The presented architecture uses short-range coverage on the sides and in the back of the shuttle with extended range in the front for a redundant collision avoidance system using 2D Flash LiDARs. To achieve this, two Leddar M16-LSR modules with 100-degree FOV are placed on each side and one is placed on the back of the shuttle. At the front of the shuttle two LiDAR sensors that provide higher range and higher resolution are recommended such as the Leddar M16-LSR module with 48-degree FOV which provides 30 m range on pedestrians.

3D Flash LiDAR configuration example

The following architecture type using 3D Flash LiDARs enables 100% scene coverage and improves detection capability in the entire vehicle surroundings. Each LiDAR sensor provides a 180-degree field of view allowing to cover the 360-degree cocoon around the vehicle using four sensors whilst minimizing integration complexity. This architecture also provides redundancy on the four corners, which enhances the perception robustness.

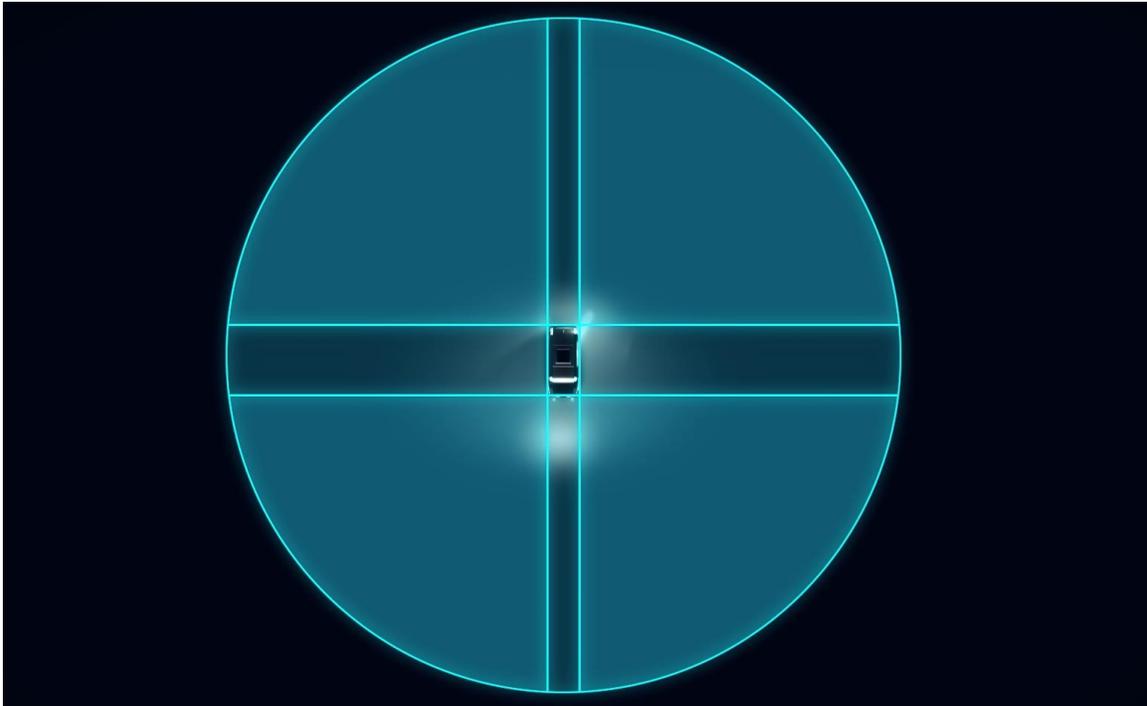


Figure 5- Example of 3D sensor coverage using four 180° horizontal FoV flash LiDAR (top view)

Enabling a Reliable, Robust detection Cocoon with LeddarTech Solid-state LiDAR Technology

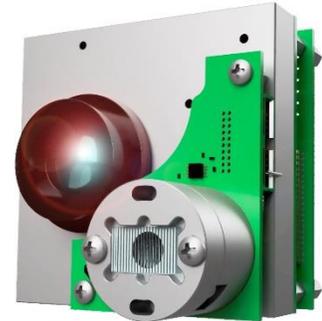
Here is an overview of 2D and 3D Flash LiDAR solutions offered by LeddarTech and used by autonomous shuttle developers for reliable and robust proximity detection, blind spot coverage and collision avoidance.

2D Flash LiDARS: Leddar M16-LED and M16-LSR Modules

Leddar M16 modules are available in two main configuration types based on the type of light source: the LED family and the Laser family.

Both M16 families are perfectly suited to outdoor operation, provided they are used within an enclosure: solid-state design with no motorized mechanisms, wide operating temperature ranges, all-weather performance and immunity to lighting variations—both day and night.

The M16-LED is a proven Leddar workhorse that our clients have come to value for its versatility and reliability. This module's infrared LED light source provides wide-beam illumination at ranges up to 100 m and is offered in six different field-of-view configurations.



The new generation M16-LSR uses laser sources to achieve longer ranges, providing narrower and better-defined vertical FOV, all in a smaller form factor.

Key features of the Leddar M16 include:

- 16 independent segments with simultaneous acquisition enabling tracking capabilities
- Multitarget and lateral discrimination capabilities
- Various beam options for optimized field of view
- Wide operating temperature range

Key benefits include:

- Various beam options allow for optimizing integration and dead zone coverage
- Proven reliability, even in harsh conditions
- No moving parts, providing ultimate robustness
- Low power consumption

3D Flash LiDAR: Leddar Pixell Sensor

The Leddar Pixell is a 3D flash LiDAR with a 180-degree field of view and is specifically designed for ADAS and autonomous driving applications. Powered by the LCA2 LeddarEngine, the Leddar Pixell provides highly reliable detection of pedestrians, cyclists and other obstacles in the vehicle's vicinity and is optimized for use in perception platforms that are meant to ensure the safety and protection of vulnerable road users (VRU). The robust, solid-state Pixell compensates for the limitations of mechanical scanning LiDARs used for geopositioning which generate blind areas that can reach several meters. The Pixell enables a comprehensive detection cocoon that surrounds the vehicle to provide reliable blind spot coverage.

Key features include:

- 96 horizontal and 8 vertical segments providing 768 independent surfaces with simultaneous acquisitions
- 3D flash illumination technology providing 100% scene coverage
- Pedestrian detection range of up to 32 meters
- 100% solid-state design; vibration and shock-resistant
- IP67 enclosure with impact-resistant windows and automotive-grade connectors
- Wide operating temperature range



Key benefits include:

- Optimized for ADAS/AD detection cocoon applications, including:
 - Detection cocoon in stop-and-go situations
 - Wide turn monitoring for large vehicles
 - Emergency braking for collision avoidance in urban settings
- Blind spot coverage without dead zone in the illuminated field of view
- Provides valuable sensing redundancy and compensates for limitations of other LiDAR technologies
- Robust road-ready technology translating to higher MTBF and reduced maintenance

What Lies Ahead for Cocoon LiDARs

Flash LiDAR technology is evolving at a rapid-fire pace. Newer, more powerful solutions are becoming available, thanks to the intensive development of new cocoon LiDAR architectures and ongoing improvement in signal processing, which are driven by the requirements of mass-market, high-volume mobility applications.

Solid-state flash LiDARs provide a commercially sound detection solution for applications ranging from ADAS for large commercial vehicles to fully autonomous driving for vehicles such as shuttles or robotaxis. 2D and 3D Flash LiDARs have already been adopted by leading autonomous vehicle providers in North America and Europe and are available today for commercial deployments.

Over the coming years, flash LiDAR technology will become even more cost-effective and offer performance levels that will be the driving force in eventually replacing mechanical scanners —as anticipated by experts in the automotive industry.

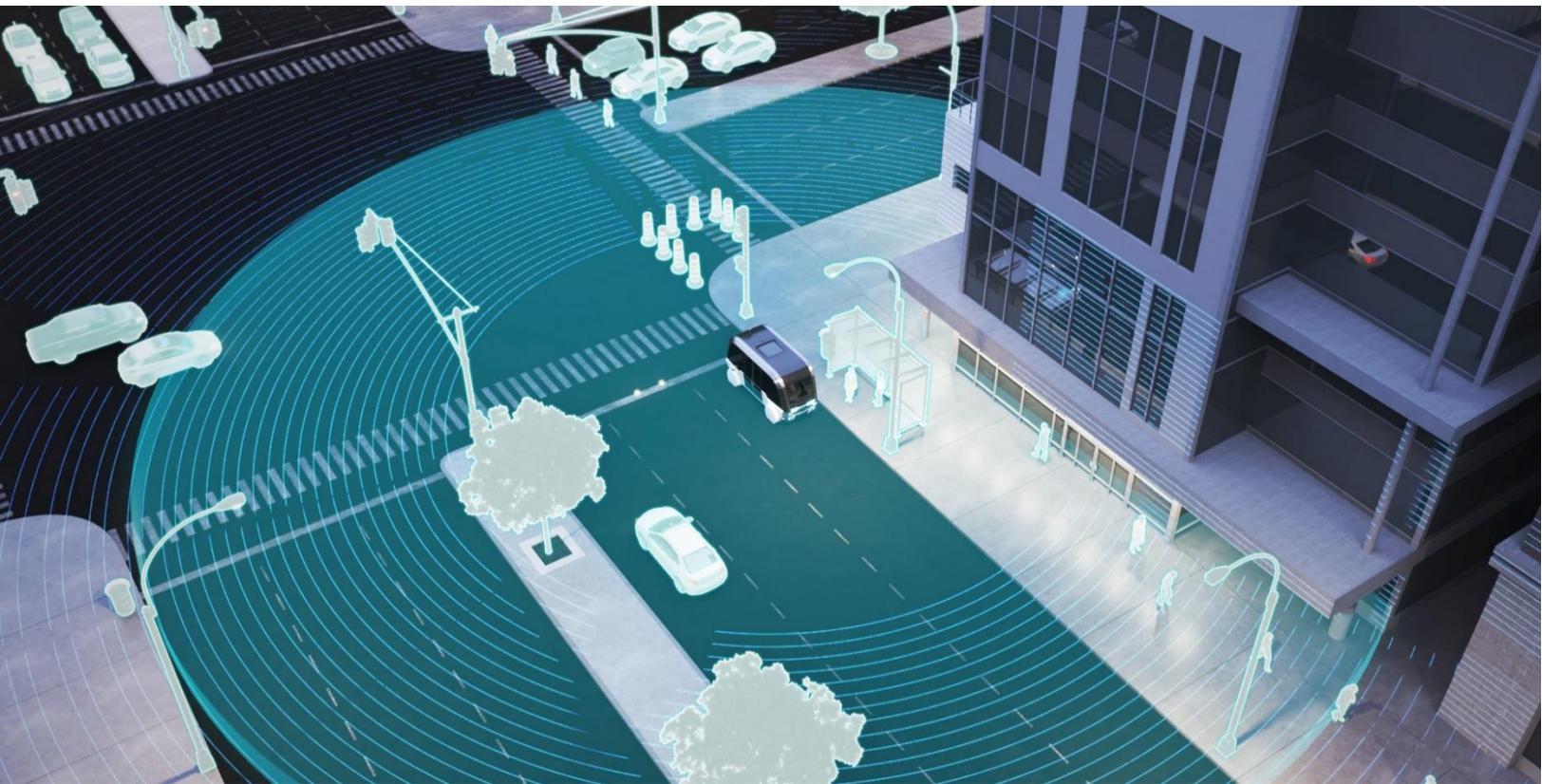


Figure 6- Representation of complete cocoon coverage around the vehicle using 3D Flash LiDAR sensors such as the Leddar Pixell Cocoon LiDAR.

For more information on 3D solid-state flash LiDARs, visit leddartech.com/pixell

About LeddarTech

LeddarTech is an industry leader providing the most versatile and scalable automotive LiDAR development platform based on the unique LeddarEngine™, which consists of a suite of automotive-grade, functional safety certified SoCs are working in tandem with LeddarSP™ signal processing software. The company is responsible for several innovations in cutting-edge mobility remote-sensing applications, with over 70 patented technologies (granted or pending) enhancing ADAS and autonomous driving capabilities for automobiles. LeddarTech also serves the mobility market with solid-state high-performance LiDAR module solutions for autonomous shuttles, trucks, buses, delivery vehicles, and robotaxis.

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