Brighter Signals

The Future of Automotive Occupancy Safety and Comfort

Automotive White Paper

September 2025

Contents

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Executive Summary

This white paper, "The Future of Automotive Occupancy Safety and Comfort," explores the evolving landscape of automotive sensor technology, emphasizing the progression from basic safety measures to advanced comfort features and, ultimately, the enablement of autonomous driving. With 1.19 million annual global road traffic deaths and escalating safety regulations, automotive manufacturers face increasing pressure to improve occupant protection.

The paper underscores the need for precise, reliable, and cost-effective Occupant Classification Systems (OCS) to support critical functions including airbag deployment and child seat detection. While regulatory bodies such as NHTSA, Euro-NCAP, and C-NCAP continuously raise the bar on these safety standards, consumer expectations are also prioritising personalized and comfortable in-cabin experiences.

As the industry moves towards improving occupant centred cabin design and higher levels of autonomous driving, advanced sensing systems become even more critical. In addition to function and cost of sensors, reliability of data and integration of data are important considerations when determining the right solution architecture. Intelligent software systems are replacing hardware as the most important system. Thus, the quality of data input is more imperative than ever.

Cameras and radar are seen by the industry as the new solutions. However, radar has limitations when classifying micro-movements and positions that are non-standard. Safety requirements require sensors to remain active after engine shutdown, so children left unattended in vehicles can be reliably detected. Solutions such as mmWave radar and cabin cameras introduce new challenges: higher power draw, continuous thermal exposure, wake-up latency, and shortened sensor lifespans. Hoping that the technology improves before NCAP requirements go up is not a good strategy for those OEMs wanting to maintain 4 and 5 star safety ratings.

Brighter Signals offers a new solution through its innovative high-depth tactile sensors made wholly from fabrics. This uniquely flexible technology goes beyond traditional binary pressure sensors by accurately measuring the sensitivity and depth of touch as well as position, movement and even proximity, and all in realtime without the need for any post-measurement computations. The sensors are also reliable, durable and affordable and easily integrated into seats and car interior. Thus, they provide a wealth of data for superior occupant classification, enhanced safety capabilities and occupant centred design.

Brighter Signals' technology not only addresses immediate safety needs and regulatory requirements. It also paves the way for future innovations in safety, monitoring and comfort offering a scalable, affordable and sustainable approach that improves the occupant experience though out the lifetime of the car.

AUTOMOTIVE

Save Lives & Increase Comfort

"Brighter Signals is set to revolutionize the automotive sensory experience."

Andrew Klein, CEO & Co-Founder

1. Introduction

Touch is one of our most important senses. It helps us feel and can have a profound effect on our emotional reactions. Unfortunately, traditional sensing technologies cannot accurately replicate what humans feel. As we move towards more software defined vehicles the intelligence of the systems is defined by the quality of data that it can use. This means there is a growing opportunity for a new generation of sensors that operate in realtime with a high degree of accuracy, reliability and durability.

The number of sensors in cars is expected to increase from 5.4 billion sensors today to 8.3 billion by 2028 (Yole Group 2024). Moreover, who is supplying sensors is also set to change, with new sensor technologies taking a growing share. However, more data often means complex integration, and additional processing costs. Determining the optimal sensor architecture is critical for all automotive OEMs.

See also Brighter Signals "Technology White Paper" for more information on our core context-aware sensing technology

In this white paper, we explore the role of high quality, real-time sensory inputs in the future of automotive occupancy safety and comfort. We analyse the future technology direction regarding safety, comfort, driver assist, and autonomous driving features. We also consider additional change drivers such as sustainability, transition to electric vehicles and occupant centred experience.

Brighter Signals' proprietary high-depth tactile sensors made wholly from fabrics are a ground-breaking innovation offering unprecedented advantages compared to existing technologies. This white paper explores the potential role this technology could play in automotive occupancy safety and comfort.

2. The Evolving Relationship with our Cars

One of the machines we most interact with are our cars (Urry, 2004). Sometimes our choices are intentional, and at other times they are based on our habits (Hoffmaan et al., 2017) (Lanzini et al., 2017). In the United States alone there are 255 million drivers that in 2022 made a total of 227 billion driving trips, spending 93 billion hours driving (AAAFTS, 2022).

Not only do we use cars to transport us from one place to the next. Our relationship with them can be practical, symbolic and even emotional. Many of us have a dynamic relationship that evolves over time depending on needs, values and circumstances (Hunecke et al., 2021) (Senqi Tian et al., 2025).

Whatever this relationship is it is always personal, created through our own cultural associations and sensorial experiences. We all have our own requirements when it comes to function, safety, efficiency and comfort.

The sensorial experience we have links our bodies to the car. We feel the acceleration and deceleration. We feel safe. We feel the thrill of the ride. As cars become more intelligent and more autonomous our relationship with them will change (Okamura et al., 2020) (O'Neill et al,. 2022), shifting from one of direct control, to one of shared responsibility and partnership. We will interact with and trust cars in new ways, altering the very nature of our driving and travelling experience (Yueng et al., 2020) (Kyriakidis et al., 2015).

8.3 Billion
Sensors in cars by 2028

3. Ensuring Occupant Safety

3.1 Global Regulatory Focus

Annually approximately 1.19 million people die globally as a result of a road traffic crash. However, an additional 20 to 50 million people suffer non-fatal injuries, with many incurring a disability (WHO, 2023). These road traffic injuries not only have a large impact on the individuals and families involved. These incidents occur at such a scale that they cost most countries 3% of their GDP annually.

In the United States the National Highway Traffic Safety Administration (NHTSA) sets specific regulations for Occupant Classification Systems (OCS) as part of vehicle safety standards, especially under the Federal Motor Vehicle Safety Standard (FMVSS) No. 208, which deals with Occupant Crash Protection. (FMVSS, 2024).

Equivalent bodies regulate other areas such as New Car Assessment Programme (Euro NCAP 2022) for Europe and China's C-NCAP. Euro-NCAP has the ambitious goal to eliminate all road traffic deaths by 2050. This means that there are aggressive new safety standards continuously being set which automotive OEMs and their supply chain need to deliver against. Gaining a 5-star NCAP rating is highly desirable and will get tougher year on year.

3.2 Occupant Classification Systems

Car safety regulations aim to protect the occupants of vehicles and prevent accidents. Passive safety measures include seat belts, airbags, crumple zones and child seats. Their purpose is to minimise the effects of a collision. There are also active safety features that aim to enhance drivers' response and awareness. Examples include collision warning systems, breaking assist and blind spot monitoring.

In order for automotive OEMs to meet these occupancy safety requirements they require precise, reliable, and cost-effective methods for determining occupant presence, classification (adult, child, object), and position within the vehicle cabin. These inputs are used to support airbag deployment logic, seatbelt reminders and child detection. Knowing what is happening in the cabin can determine what action to take in the case of a collision, saving lives and reducing injuries in the process.

The global automotive Occupancy Classification System (OCS) market is projected to reach €3.1 Billion by 2033. The growth comes from increasingly stringent safety regulations and advancements in technology. There is a drive for richer data, and enhanced accuracy and reliability (Strategic Revenue Insights Report, 2025).

With increased accuracy and reliability of sensory inputs, systems can classify the type, size, weight and position of the occupants more effectively. This in turn enables optimisation of the airbag deployment, thus reducing the risk of injury during collision and aligning with the strict regulatory requirements.

In 2024 one in five cars sold globally was an Electric or Hybrid vehicle (IEA, 2024). The increasing number of EVs provides new opportunities as they have new requirements around light-weight components, eco-friendly solutions and simpler integration. The entrance of EVs into the global market is also disrupting the traditional automotive brands and their market shares, with Chinese car makers producing over 50% of the EVs sold. As a result, Chinese suppliers are putting cost pressures on the incumbent OEMs and challenging the status quo.

The growing demands for both safer and more intelligent cockpits means some of the traditional technologies used for OCS are no longer viable. They do not supply rich enough data to satisfy these growing demands.

3.3 How Brighter Signals Enhances Safety

Brighter Signals addresses this technology gap, offering a more precise and responsive sensor capability. Unlike traditional pressure, weight and human presence detection sensors that each require separate and disparate set-ups and integrations, the sensors of Brighter Signals can measure all of those things, and more, in a single seat sensor array.

By integrating the flexible sensors into the seats, we create advanced seating systems. For example, with just one array per seat you have occupancy presence and classification, and the ability to measure occupancy position and micro-movements. The technology is so sensitive and accurate it can determine between different percentile sizes of adults and children and detect and classify specific objects such as child seats. All of this can be done in real-time and without the need for post processing of the data stream.

The ability to detect micro-movements means that, unlike radar or vision based systems, our tactile sensors can uniquely identify and respond to individual users' bodies in real time, enabling more inclusive and human-centred machine interactions. These micro-measurements mean we can track movement and seating positions which is critical information when determining how to deploy airbags. See Figure 1 for the benefits of the Brighter Signals sensors.

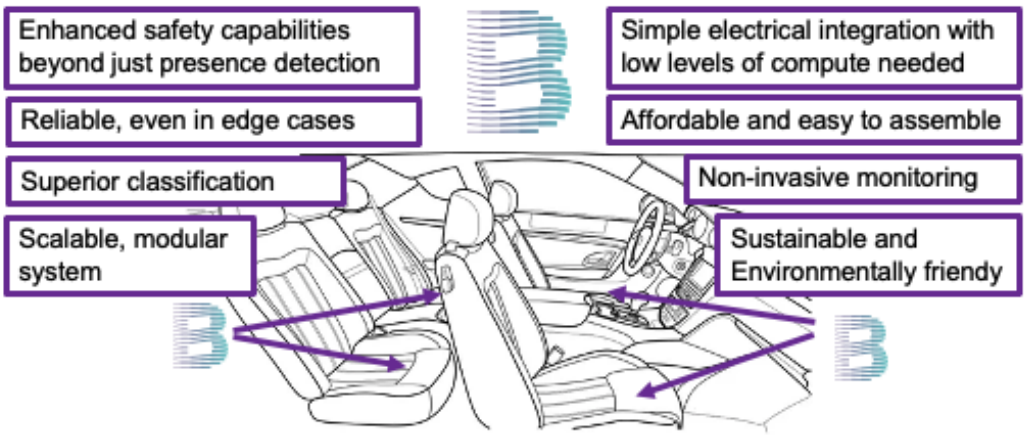


Figure 1: Brighter Signals Seat Sensor Location and Features

However, the benefits of the technology are not limited to the lower cushion of the seats. Once the sensor system is part of the architecture, it is easy to upgrade the features to include more functionalities. For example, see Figure 2 below. By adding sensors to the back of the seats or lower feet rests the occupancy classification can be used to detect even more movements and detect finer positions of legs and arms.

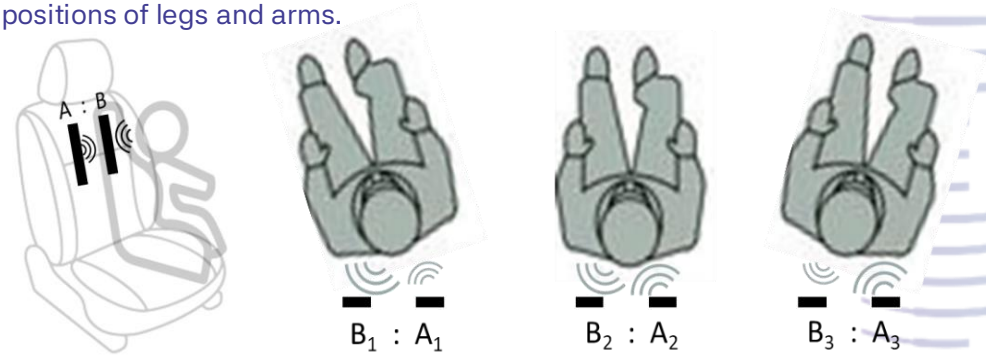


Figure 2: Location and Measurement Using Sensors in the Seat Backs

The technology has even been proven to be able to detect movement in different sizes of adults while also monitoring their breathing and respiratory function (Nicholson, Lim and Shim 2018).

Detecting micro motions in actions such as steering correction and pedal usage can be used to extract movements that correlate to neurological impairments. These non-invasive measurements are fundamentally a different way of detecting driver states compared to camera-based monitoring alone and can enable more precise detection of fatigue, impairment and even cognitive distraction (InCabin Report, 2025).

The sensors can be used to measure proximity to objects as well as touch. Thy can classify if the object that is close is human or not, moving or stationary. Imagine being able to transform all the traditional car interior surfaces into intelligent proximity and touch sensors. These matter detection sensors can, for example, be fitted into car interior pillars for directional interior sensing, see Figure 3. The benefit of this method over conventional radar is that radar could pick up noise and other artefacts including from outside the vehicle, whereas Brighter Signals' technology uses "directional" method, thus concentrating the focus of the sensing parameters within the conductors inside the pillars.

In other words, the technology understands what is occupying each seat, where they are positioned and if they are moving. The proximity measurements mean we will know the position of all arms and legs, even if they are not touching the seats. These measurements are continuous and non-invasive, providing real-time data to any safety systems.

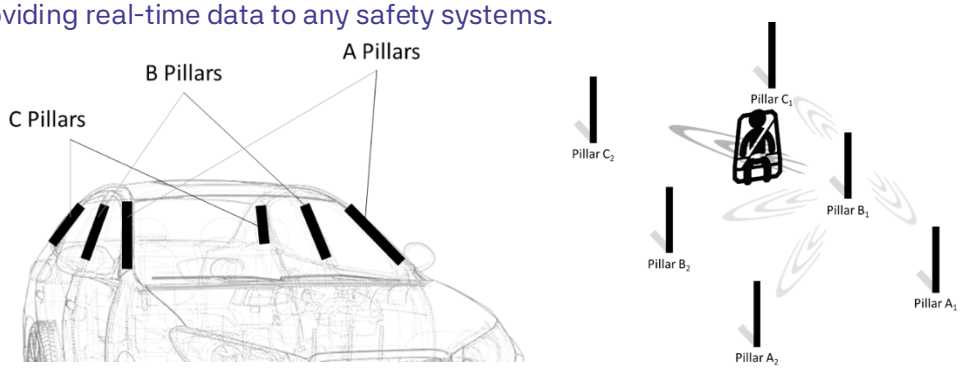


Figure 3: Non-Invasive Measuring of the Entire Cabin Using Sensors in the Pillars

Improving occupancy safety, saving lives and reducing injuries is paramount. Affordable and effective solutions mean that all car models can have the highest levels of safety, not just those who can afford the luxury models.

4. Occupant Centred Design

As cars become safer, and we begin to trust our cars more, occupants will look to automotive manufacturers to also improve our comfort and user experiences.

As stated in section two, the sensorial experience we have links our bodies to the car. At Brighter Signals we believe the future of automotive occupancy safety, health and comfort will be Occupant Centred Design where car manufacturers will aim to create intelligent cabin environments that are safe, integrated, personalised and adaptive. These technically advanced environments will anticipate the needs of the occupants and adjust safety and comfort features based on the seating positions and body types. The systems need to be deeply personal and engaging, with different occupants preferring different levels of comfort, sportiness and efficiency.

Human interaction with the systems will also evolve. To enhance occupant experience it is essential to minimise cognitive load. Increased mental workload can result in stress, fatigue and changes in behaviour. For example, drivers have been known to avoid night driving or urban driving. High mental workload can make trips more exhausting and less enjoyable thus reducing the overall driving experience.

Improvements will include advanced seating systems, advanced assist and gesture control. For example, following Formula 1 trends, controls will be added into the steering wheel to empower the driver to make intuitive adjustments while paying maximum attention to the road.

Systems will become more dynamic, continuously evolving and improving throughout the vehicle's lifetime. This ongoing development will enhance performance, safety, and comfort through over-the-air software updates and upgrades.

Broader wellness features, such as health monitoring, will become possible, alongside a focus on sustainable design that leverages circular economy principles.

Brighter Signals sensors have the potential to serve as the foundational sensing technology in all occupant-centred automotive interiors. Used primarily and initially for safety, the sensors can also be used to empower all other areas of Occupant Centred Design.

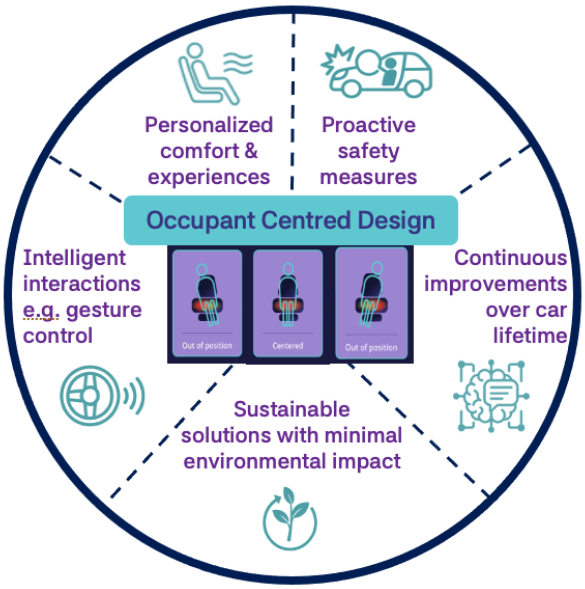


Figure 4: Occupant Centred Design

Whether embedded in seats to enable personalized comfort adjustments or in pillars to monitor movements and positions, this data will empower interior design teams to create more personalized and engaging environments. The smarter these sensory inputs become, the more occupant-centric the environment can be. This will lead to safer, more comfortable, and highly personalized vehicle interiors, delivering a richer user experience and supporting sustainability throughout the vehicle's lifecycle.

5. The Demand for More Intelligent Systems

To obtain a 5 star NCAP rating systems will need to perform better year on year, scoring 60, 70 and 80 out of 100 in 2026, 2027 and 2028, respectively. These requirements create a growing need for more intelligent safety systems which then demand more accurate and reliable sensor inputs. Considering safe driving, crash avoidance, crash protection and post-crash safety means thinking beyond just OCS, but also towards Advanced Driver-Assistance Systems (ADAS), In-Cabin experience and Autonomous Driving capabilities.

ADAS systems use a high-resolution camera to monitor the driver as well as the outside of the vehicle and its environment. They aim to assist the driver with the safe operation of a vehicle. Vision technologies are becoming more advanced with higher resolution imaging.

As the camera is already in the cabin it can be used to assist the OCS. However, the camera is positioned to focus on the driver rather than being optimised to monitor all occupants. The camera, for example, cannot reliably see the lower leg position of the passenger, or all the positions of the rear occupants. However, the biggest limitation of the camera is its lack of ability to monitor in the dark, when driving at night.

"We're bringing human touch perception to tactile sensing. Our sensors have the intelligence to differentiate objects from human contact (capacitive method), and feel even slight delicate-to-rough touch (dynamic resistive method), in a single sensor."

Edward Shin, CTO & Co-Founder

One of the most recent additional safety requirements is for all European cars to have Child Presence Detection (CPD). Here sensors are needed to detect if someone accidently leaves a child in the car after they have stopped driving. Trying to fulfil this additional safety requirement using the driver focused camera system has serious limitations.

To combat these weaknesses some automotive suppliers are turning to radar to monitor the cabin and determine occupancy in combination with the camera. These radar systems measure occupancy indirectly using electromagnetic waves, resulting in general localisation. Sometimes a single radar is not enough so two are needed to measure line of sight. At other times a single, more expensive, higher specification radar can be used.

Cameras and radars have limitations. Although good at identifying adults sitting normally radar has sometimes only 70-80% accuracy when detecting rear facing infant seats or large objects. Radar signals can create a lot of false readings and require a large amount of post processing.

Radar struggles to reliably detect and adapt to the vast global diversity of human body types and physical characteristics. These vision-based systems often overlook subtle but critical variations in posture, shape, and size, resulting in limitations that directly impact safety, accessibility and inclusivity.

When implementing these new types of safety indicators, it is important that the technology is reliable. CPD systems that generate false positives, triggered by pets, hot air convection, or reflective surfaces, can frustrate users and erode trust in safety features. Once confidence is lost, drivers may disable or disregard alerts, negating the safety benefit.

Radar and camera-based CPD systems also consume significant energy. The CPD requirement means that the chosen sensors need to keep operating after the driver has turned off the engine and left the car. Even low-power radar devices that operate in the 1-3W range create significant drain on the 12V battery or traction batter in EVs. This can lead to battery depletion and have a direct effect on the distance the car can travel between charges, and the satisfaction of the user experience.

Unlike crash sensors that activate only during rare events, CPD radars operate every day for years. Continuous operation raises the probability of calibration drift, component fatigue, and premature failure well before end-of-vehicle life.

These post-shutdown sensing requirements mean that if high power consumption sensors like radar and camera are used it could lead to wasted kilowatt-hours, premature sensor failures, and sustainability setbacks at fleet scale risking reducing both EV range, system reliability and customer trust.

Brighter Signals is addressing these regulatory and sustainability pitfalls with its high-depth Sensor technology. If we take Child Presence Detection as an example it is clear that the Brighter Signals' sensors are a superior technology architecture when directly compared against mmWave radar (see Figure 5).

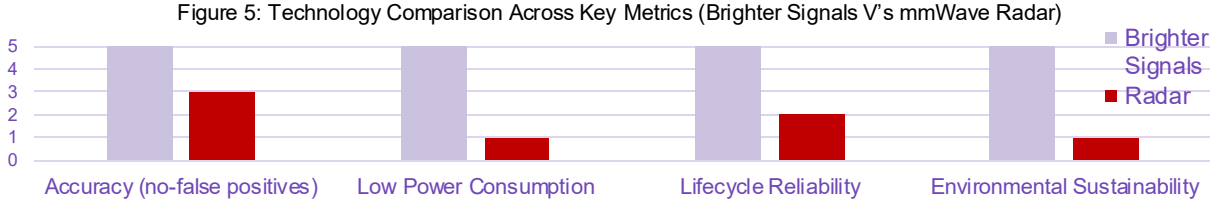
Unlike radar, which typically consumes 2-3W in post-shutdown states, the Brighter Signals' sensor operates at just 0.05–0.15 W, delivering a 27-fold reduction in power consumption.

Over the course of a vehicle's 10-year lifespan, this efficiency translates into tens of kilowatt-hours saved per car. At scale, the impact is profound where, for an electric vehicle fleet of 1 million cars, cumulative savings approach 10 TWh over 10 years, the energy equivalent of powering every smartphone in a medium-sized country for an entire year.

Child Presence Detection Technology	Power (W)	Annual Battery Use (kWh)
mmWave Radar	2.0	4.38
Camera	1.5	3.28
Brighter Signals	0.05	0.11

In addition to the power savings the Brighter Signals' technology is also more accurate, with more stable detection, resulting in fewer false alarms. The sensors are also highly durable, drawing a less continuous load, ultimately lowering the risk of calibration drift and premature failures. These significantly higher performance features coupled with the fact that the materials used are lightweight and sustainable makes the Brighter Signals' technology the superior sensor architecture choice.

Figure 5: Technology Comparison Across Key Metrics (Brighter Signals V's mmWave Radar)



Advanced Driver Assist Systems (ADAS) are needed to effectively monitor both the outside and inside of vehicles. While cameras and radar are well-suited for monitoring the exterior of moving vehicles, the interior presents very different safety and comfort requirements that these systems are not ideally equipped to address. Figure 6 shows some of the examples where Brighter Signals' tactile sensors out-perform radar in detecting nuanced, non-standard occupant positions. They provide clear input for seatbelt logic, airbag deployment strategy, and monitoring systems where radar often struggles.

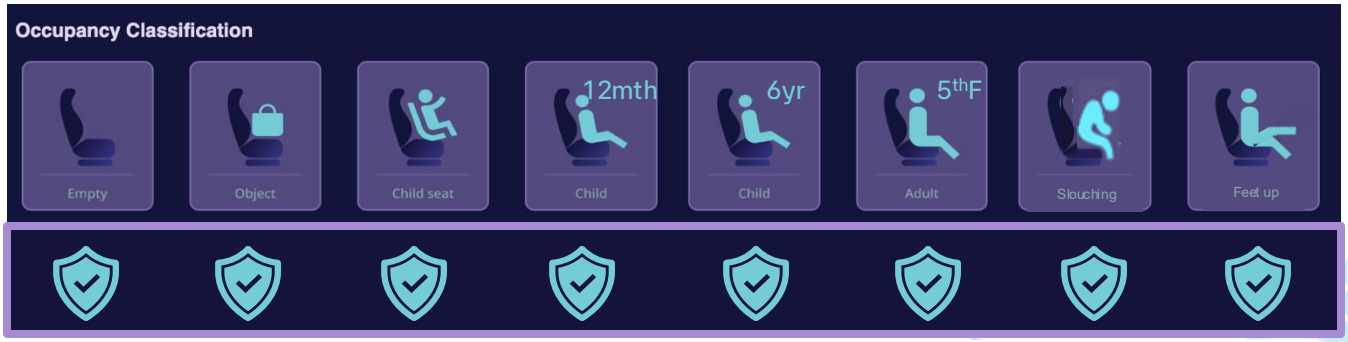


Figure 6: Brighter Signals Edge-Case Classification Examples

Brighter Signals' technology offers the precision and reliability necessary to enhance sensory inputs specifically for automotive interiors. The multi-modal nature of the Brighter Signals' sensors mean that, once installed, sensors can be upgraded with simple software updates to extract additional insights and measurements, enabling continuous improvement and adaptation throughout the vehicle's lifespan. OEMs are recognizing that cameras and radar, primarily suited for external monitoring, may not be the optimal choice for interior cabin sensing. With Brighter Signals' innovative technology, there is a better, more effective alternative for protecting and enhancing the in-cabin experience.

6. Levels of Driving Autonomy

The future of occupant safety and comfort cannot be considered without understanding the evolving role of autonomous vehicles. As autonomous driving features become more advanced and widespread, they will fundamentally redefine how occupants interact with their environment and how safety is maintained on the road.

While the adoption of autonomous driving capabilities is progressing, it is happening at a slower pace than industry initially predicted (WEF-BCG Report, 2024). The SAE International standard, J3016, outlines six levels of driving autonomy, from no automation (Level 0) to full automation (Level 5). Currently, fewer than 5% of consumers are familiar with Level 2 and 3 features, which include partial automation and driver-assist systems. Most vehicles on the road today are equipped with Level 1 features, with about a quarter offering Level 2 capabilities such as partial hands-off driving, automated lane changing, and traffic light detection.

Figure 6: Levels of Driving Autonomy

Autonomous driving is often associated with safety and convenience, yet some safety features like automatic emergency braking (AEB) and electronic stability control (ESC) are not classified as autonomous capabilities because they involve momentary interventions rather than ongoing automation. These systems are viewed as essential safety functions rather than autonomous driving features.

At a recent industry debate (IEEE RAS ICRA@40, 2024), experts highlighted the rapid progress of autonomous taxi services, such as Waymo, which conducts over 10,000 safe rides per week in select cities in the United States. However, expanding these services globally remains complex due to diverse road systems and regulatory challenges, with limited certainty for wider adoption (The Economist, 2023; Forbes, 2022). Incidents like the 2023 crash involving a driverless autonomous taxi further impact public trust (NHTSA, 2023).

Currently, many providers are shifting focus from autonomous consumer vehicles to commercial applications, such as traffic management within cities and highway driving, where conditions are more predictable. Over the next five years, consumer vehicles will likely emphasize safety, assistance, and comfort features, rather than full autonomy, focusing on higher perceived value features and meeting rising regulatory safety requirements.

7. Conclusion

For the automotive industry to hit the target of no road deaths by 2050 and NCAP 5-star safety ratings in 2028, they must invest in, and implement, new sensory technologies and solutions.

There is growing demand for more accurate data to empower safer and more intelligent car systems. With the number of sensors in cars forecast to increase, car manufacturers and suppliers need to think beyond just the cost and reliability of sensors. Reliability, accuracy and integration of data are important considerations when determining the right solution architecture.

*"Brighter Signal's **flexible high-depth tactile sensors represent a strategically superior investment for in-cabin safety and should be a core part of any automotive solution architecture"***

Christine Fraser COO & CO-Founder

Sensor systems need to be able to deliver accurate, rich real-time data. However, they also need to be able to be manufactured and assembled at the right reliability, scalability and quality. They also need to look beyond just delivering static systems and consider systems that can be continuously improved throughout the lifetime of the vehicles.

The costs to integrate and process data, and determine action, as part of the wider automotive intelligent system are also significant. Technology choices can introduce integration, processing and latency challenges. Suppliers to automotive OEMs need to look beyond the traditional boundaries of OCS, ADAS and autonomy capabilities. They need to think instead of how to add value and data for safer, more intelligent systems.

OEMs are recognising that cameras and radar, primarily suited for external monitoring, may not be the optimal choice for interior cabin sensing. With Brighter Signals' innovative technology, there is a better, more effective alternative for protecting and enhancing the in-cabin experience.

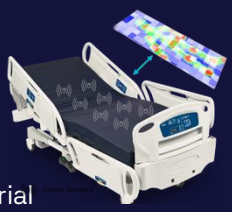
Brighter Signals' technology has the accuracy and reliability to deliver the improved sensory inputs to feed these intelligent systems. They do it in a sustainable, affordable and scalable way.

Given the regulatory trend toward more reliable and robust safety systems and the automotive industry's desire to minimize system cost and complexity, Brighter Signal's flexible high-depth tactile sensors represent a strategically superior investment for in-cabin safety. They align better with evolving safety standards, occupant wellbeing monitoring trends, and integrate easily into existing manufacturing processes.

Brighter Signals

The Future of Touch

- Patent Granted
- US10386224B2
- Link to Patent



Clinical Trial

Nicholson, Lim and Shim 2018 " *Intelligent bed sheet detects respiratory patters"* Sage journals, Volume 62, Issue 1 Sept 2018
Link to Clinical Trial Publication

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