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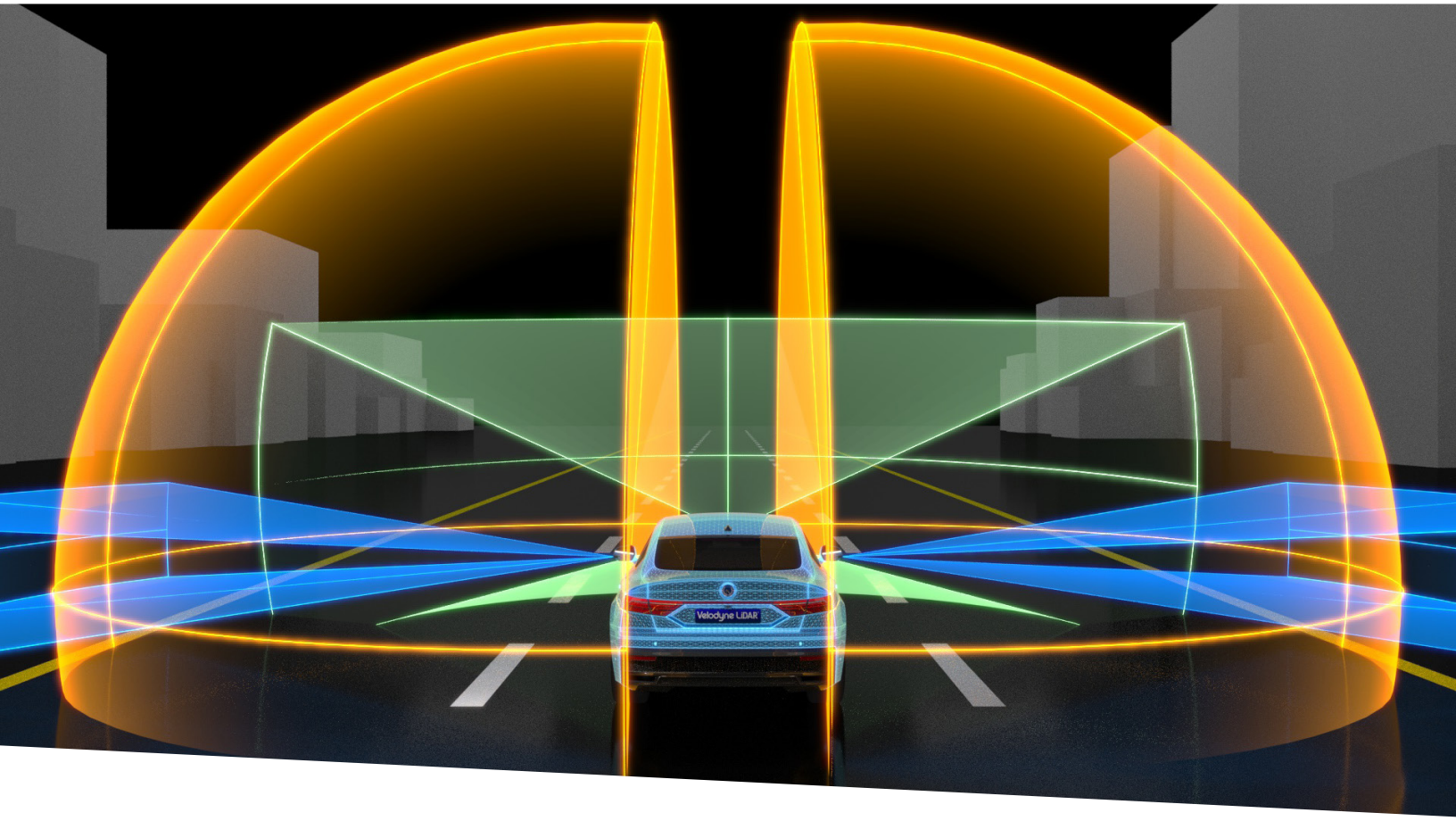

AN ADAS FEATURE RATING SYSTEM: PROPOSING A NEW INDUSTRY STANDARD

White Paper

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ABSTRACT

More than 90% of new vehicles include Advanced Driving Assistance Systems that offer features such as Lane Keep Assist and Adaptive Cruise Control[1]. These ever-improving vehicle systems present a great opportunity to increase driving safety and reduce the number of roadway deaths and injuries. Indeed, they are already having a positive effect. However, the wide variety of features offered in the marketplace can be confusing to consumers, who may not clearly understand their vehicles' true capabilities and limitations, or have an easy way of comparing system performance between vehicle models. This lack of information has the potential to reduce the safety gains of ADAS features by increasing the risk of improper use. To encourage transparency in the marketplace and thus engender the maximum positive effect of ADAS technologies, this paper proposes a five-level rating system, which utilizes diamonds to denote significant milestone achievements in vehicle system performance. The rating charts resulting from this system describe gradients of performance within criteria addressed by certain foundational ADAS features. Presented here in its initial stage of development, this rating system will require continued refinement. We therefore encourage the community of automotive safety organizations to take up the mantle by establishing and performing test protocols for assigning standardized ADAS feature performance ratings. We believe that the result of this effort, a common method for understanding and comparing ADAS performance, promises to deliver a beneficial level of clarity to the industry and consumers.

INTRODUCTION

The technology inside consumer vehicles is developing at a rate the market has never seen. Rapid advancements in sensor, software, and processing components are converging within the automotive sector to unlock intelligent performance capabilities that promise to greatly increase drivers' comfort and safety. Advanced Driving Assistance Systems (ADAS) include features such as Lane Keep Assistance (LKA), Automatic Emergency Braking (AEB), Automatic Emergency Steering (AES), Adaptive Cruise Control (ACC), and Blind Spot Monitoring (BSM), which are already common options, and increasingly come standard, on new vehicles. In 2018, 92.7% of new vehicles sold in the U.S. offered at least one ADAS feature, with the average ADAS package costing consumers about $1,950 [1]. These features are already yielding positive results; for example, one automaker's vehicles equipped with AEB and forward collision warning are reportedly involved in 43% fewer front-to-rear crashes [2]. And the potential benefit of further advancements is astounding. Reducing the number of front-facing crashes by 90% would prevent about 27,000 deaths and $635 billion dollars in total societal harm, annually [3].

However, rapid changes in automotive technology can also be disorienting for consumers. Even more, if marketing materials are misleading or do not align with guidelines for safe operation, drivers might overestimate their vehicle's capabilities. The proliferation of ADAS features and the marketing terminology being attached to them inspired the American Automobile Association (AAA) to recently propose "a set of standardized technology names for use in describing advanced safety systems." For example, AAA identified 20 different names automakers currently utilize to describe features that could all be subsumed under the category of "Adaptive Cruise Control." [1]

Advancing AAA's efforts to generate clarity in this rapidly changing and often perplexing arena, this paper proposes a standardized rating system for assessing the performance characteristics of foundational ADAS features -- LKA, AEB/AES, ACC, and BSM.

The notion that a spectrum of performance levels exists for ADAS features is supported by Euro NCAP's "2025 Roadmap." Importantly, this report also highlights that automakers are introducing new sensors to vehicles in order to improve performance in a broader range of conditions. Discussing AEB features specifically, the report reads, "The performance of an AEB system is dependent on the type and complexity of the sensors used. More and more manufacturers are adding additional sensors and combining multiple sensor types together in 'fusion' to offer the potential to address new and more complex crash scenarios." [4]

This project extends the call, recently articulated in an SAE Edge Research Report, for an increasingly taxonomical approach to understanding differences in sensor technologies utilized in automated and advanced driving systems. The charts that follow represent a draft framework to facilitate an understanding of ADAS feature performance levels that can be shared between component suppliers, automakers, dealerships, and consumers. We hope this project offers an immediate contribution to the field by identifying the key criteria upon which these features can be evaluated.

However, we anticipate the need for further refinement and quantification of particular performance descriptors. For example, the industry will surely demand more precision in defining the difference between roads that are "flat and straight" versus "hilly and curvy." Performance testing parameters should also include a broad range of carefully defined lighting and weather conditions. Also, within the lidar industry, we realize that detection ranges cannot be compared in isolation from other factors, such as object reflectivity and the sensor's field of view. Further, a sensor's placement within the vehicle, for example behind the windshield or in the bumper, has a critical effect on the sensor's practical field of view. Therefore, in testing and attributing ratings to vehicles' ADAS performance, considerations of sensor placement and the system's resulting coverage of the surrounding 3D space will need to be accounted for, beyond the specifications provided by component suppliers.

Beyond performance, we anticipate that future ADAS rating frameworks will address vehicle systems' functional safety achievements, including considerations of their reliability, failure monitoring, and self-diagnosis functions. Further variation between ADAS systems can be described with regards to their relative abilities to self-clean their sensor components, their immunity to cyber threats, and whether they incorporate redundant, overlapping fields of view. Certainly, organizations such as Euro NCAP are experts in developing rigorous and regimented testing protocols and can help strengthen and implement this aspect of the proposed rating system.

Movement towards a standardized framework for understanding vehicle systems' capabilities would have far-reaching effects in the industry. The Boston Consulting Group states:

> Systematizing a rating system for ADAS features and factoring that into overall vehicle ratings would signal recognition of the importance of ADAS features and influence consumer choices. Like Euro NCAP, [market research and rating agencies such as J.D. Power and publications such as Consumer Reports] could require the inclusion of ADAS technologies and features in any vehicle aspiring to their top safety rating. [5]

We build on this vision by advocating that safety ratings should consider not only the presence of certain ADAS features but also their level of performance. Our main goal in proposing a method for systematically rating ADAS features is the very same reason these features are included on

vehicles in the first place: to improve roadway safety. With this rating system, automakers will have a better understanding of the performance levels they are working to achieve and will be able to intentionally aim for higher ratings. Marketing practices will gain an added level of transparency and utilize common terminology. Providing consumers access to clear descriptions of what their vehicles can and cannot do will encourage responsible implementation. Finally, this rating system enables consumers to make comparisons across common criteria and promotes competition between automakers to develop and deliver increasingly better-performing ADAS features.

DISSECTING THE DIAMOND RATING SYSTEM

The proposed rating system utilizes diamonds to grade a vehicle system's ADAS feature performance from one to five. Importantly, a one diamond rating should not be interpreted as a demerit to the system or to the automaker who developed it, but marks achievement of the baseline criteria that must be met for automakers to advertise that a vehicle is equipped with that feature. Whereas we designed the one diamond rating to capture the minimum performance required to offer that feature, our three-diamond rating is designed to describe the current market-leading level of performance. Thus, the two-diamond rating signals a level of performance that falls between the minimum required capability of that feature and the current state-of-the-art. To date, vehicle systems that perform at the level of one, two, or three diamonds utilize cameras and radar as their main sensor components.

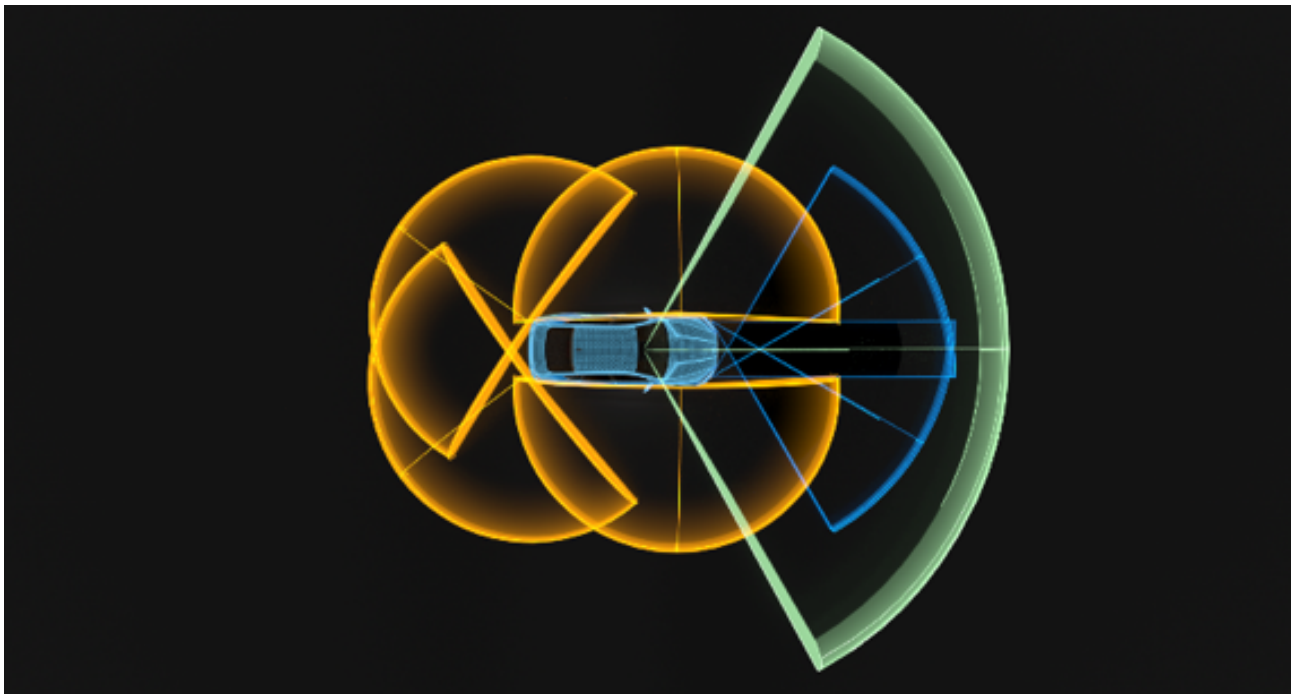

Figure 1. One example of possible lidar sensor coverage to achieve five diamond level ADAS performance (top down view).

The top two levels of performance for each ADAS feature under consideration have not yet been offered on consumer vehicles. To better understand how we designed the top level of our system, consider this statement from the Boston Consulting Group: "As valuable as ADAS features are in and of themselves, they also serve a vital function as a bridge to autonomous vehicle operation, which will rely on much of the same technology as ADAS" [5]. Recognizing that ADAS features are

the building blocks of fully driverless vehicle capability, the five diamond ratings in the following charts are therefore designed to capture the level of performance that a vehicle system must achieve to reach Level 4 automation, as described by SAE. [6] However, an important caveat applies when considering this level of performance within the context of ADAS: because the vehicle is not truly autonomous, the driver is still fully responsible for monitoring the vehicle's environment and maintaining its safe operation. As a result, the proposed rating system encourages a responsible transition from ADAS to full autonomy, with incremental advancements towards L4 becoming available and extensively vetted in real world roadway scenarios as ADAS features.

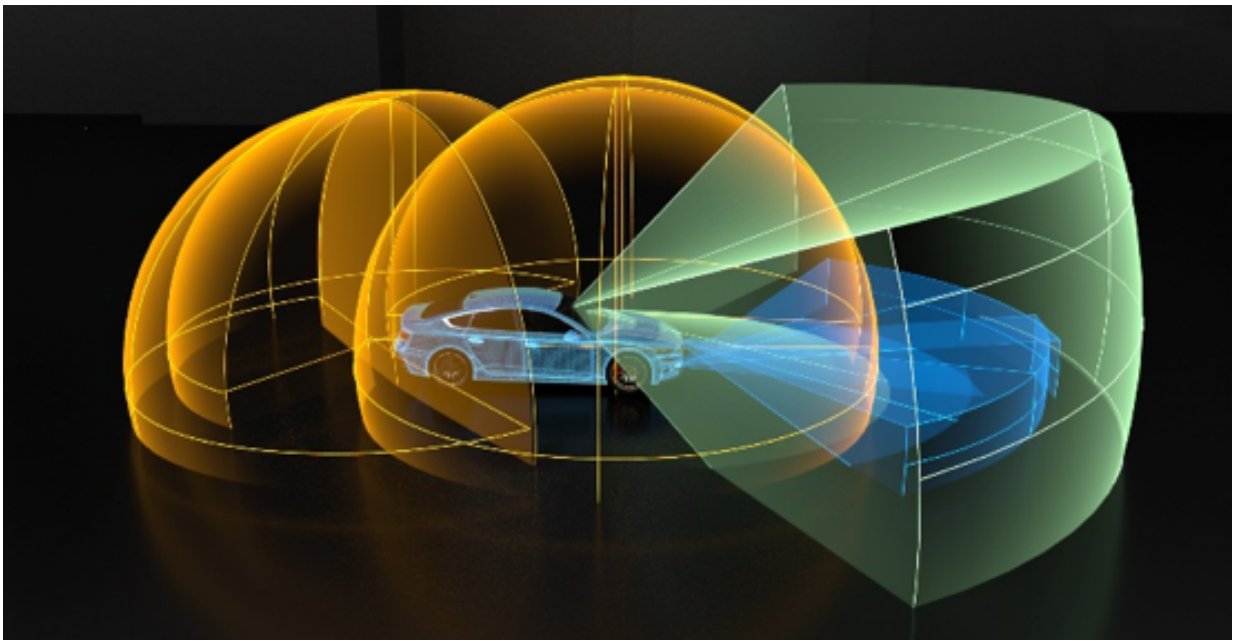

Figure 2. One example of possible lidar sensor coverage to achieve five diamond level ADAS performance (side view).

The four-diamond level within each feature is therefore best understood as being better than any current camera and radar-based vehicle system capabilities, but not yet at the level that would be required for that feature to function as it will need to in fully autonomous vehicles. We believe that four and five diamond level performance is not attainable without the integration of lidar sensors as a key perception component. Figures 1 and 2 illustrate examples of lidar placement that would support five diamond level performance. Before moving to an examination of the performance criteria upon which ADAS features shall be evaluated, it is important to recognize that there will exist a gradient of performance within each diamond level. That is, there will likely be permutations of performance characteristics within any given level that exceed the minimum criteria attributed to that rating but that do not quite reach the next level ahead.

IDENTIFYING THE PERFORMANCE CRITERIA OF EACH FEATURE

Lane Keep Assistance, Automatic Emergency Braking, Automatic Emergency Steering, Adaptive Cruise Control, and Blind Spot Monitoring are the foundational features of Level 2+ ADAS (as well as Level 4+ autonomy). For each of these features, this section will review the minimum performance requirements for vehicle systems to satisfy the baseline definitions proposed by AAA. We will also outline several of the key criteria and the variation of vehicle system performance within these criteria, which creates the framework of our rating system for each feature. For example, for each of

the following features, one measure of a system's capability is its Light and Weather Performance, which ranges from suffering in low light or inclement weather at lower levels to performing well in all light and most weather conditions at the four and five diamond levels.

AAA defines Lane Keep Assistance as a feature that "Controls steering to maintain vehicle within driving lane. May prevent vehicle from departing lane or continually center vehicle"[1]. The performance criteria we identify for this feature include Lane Positioning, or the system's ability to keep the vehicle within the lane, which directly correlates with the number of required driver interventions. Whereas lower levels of LKA experience considerable drift within the lane, requiring the driver to frequently take over the steering task, a five diamond rating denotes that the system steers the vehicle along an optimized driving trajectory, which may not always be simply centered within the lane depending on the scenario, and does not require the driver to take the wheel. A second performance indicator within LKA is Lane Line Dependence, which ranges from the requirement of clear lane lines in the lowest level to the ability to navigate roadways without needing to detect lane lines at the five-diamond level. Further, within LKA there is a broad range of performance capability related to Roadway Functionality, with lower rated systems requiring flat and straight roads, and five diamond systems excelling on all types of roadways

Table 1. Proposed guidelines for standardized five diamond rating system for Lane Keep Assistance.

Lane Keep Assistance

Vehicle System Performance Criteria	♦	♦♦	♦♦♦	♦♦♦♦	♦♦♦♦♦
Lane Positioning	Drifts within lane, frequent driver intervention	Reduced drift, fewer driver interventions	Excellent centering. occassional driver interventions	Excellent centering. occassional driver interventions	Optimized driving trajectory, no driver interventions
Lane Line Dependance	Requires clear lane lines	Requires lane lines	Requires lane lines	Requires lane lines	No lane lines required
Lane Line Detection Range	Near-range detection	Mid-range detection	Mid-range detection	Mid-range detection	No lane lines required
Dynamic Driving Inter-vention Capability	Minor late corrections, no response to peripheral activity	Better active assistance, some response to peripheral activity	Excellent active assistance, good response to peripheral activity, Lane Change Assist	Excellent active assistance, good response to peripheral activity, Lane Change Assist	Superior navigation, smooth and comfortable ride, excellent reponse to peripheral activity, Lane Change Assist
Roadway Functionality	Flat and straight roads	Flat and straight roads	Better on curves and hills	Better on curves and hills	Excellent on all roads
Light and Weather Performance	Suffers in low light and inclement weather	Better in low light and inclement weather	Better in low light and inclement weather	Performs well in all light and most weather	Performs well in all light and most weather

Table 2. Proposed guidelines for standardized five diamond rating system for Automatic Emergency Braking and Automatic Emergency Steering.

Automatic Emergency Braking and Automatic Emergency Steering

Vehicle System Performance Criteria	♦	♦♦	♦♦♦	♦♦♦♦	♦♦♦♦♦
Max Speed	10 mph	30 mph	50 mph	65 mph	75 mph
Detection Reliability	Frequent false negatives or positives	Fewer false negatives or positives	Occasional false negatives or positives	Extremely rare false positives or negatives	Extremely rare false positives or negatives
Pedestrian, Bicycle, Motorcycle Detection and Classification Range	Near range detection, no classification	Mid-range detection	Mid-range detection and classification	Mid-range detection and classification	Far-range detection and classification
Vehicle Detection and Classification Range	Near range detection, no classification	Mid-range detection	Mid-range detection and classification	Far-range detection and classification	Far-range detection and classification
Stationary Object Detection and Classification Range	May not detect	May not detect	Near range detection	Mid-range detection and classification	Far-range detection and classification
Peripheral Object Detection and Classification Coverage	No perception coverage	Limited perception coverage	Limited perception coverage	Improved perception coverage	Excellent perception coverage
Dynamic Driving Intervention Capability	AEB for crash mitigation	Forward collision avoidance AEB	Forward collision avoidance with steer and brake control	Forward and side collision avoidance with steer and brake control	Forward and side collision avoidance with steer and brake control
Light and Weather Performance	Suffers in low light and inclement weather	Better in low light and inclement weather	Better in low light and inclement weather	Performs well in all light and most weather	Performs well in all light and most weather

Another key performance gradient related to LKA is Dynamic Driving Intervention Capability, with baseline systems delivering steering corrections that are often late, minor, or uncomfortable. In contrast, five diamond level LKA provides a consistently smooth and comfortable ride. Additionally, higher rated levels of LKA expand on the capabilities described in AAA's baseline definition. Thus, in LKA and several of the other ADAS features under consideration, advanced performance levels build on the baseline capabilities to the extent that they enable additional features. For example, higher levels of Lane Keep Assistance include Dynamic Driving Assistance in the form of Lane Change Assist. Such a result points to the close relationship between many secondary active dynamic driving assistance capabilities that represent the logical maturation of foundational features.

Forward Automatic Emergency Braking and Automatic Emergency Steering offer another example of a close relationship between ADAS features, which we have captured in Table 2. According to AAA, Forward Automatic Emergency Braking "Detects potential collisions while traveling forward and automatically applies brakes to avoid or lessen the severity of impact" [1]. This capability marks the entry point of our rating system for these features. However, higher level systems in this category also display the ability to perceive and respond to potential side impacts while driving forward. Higher levels also avoid crashes with Automatic Emergency Steering, which "Detects potential collision and automatically controls steering to avoid or lessen the severity of impact." Other key performance criteria within these features are related to Detection Reliability, or the rate of false positive and negative readings, and perception coverage, which factors in the system's range and field view.

Table 3 addresses Adaptive Cruise Control, which, according to AAA, "Controls acceleration and/or braking to maintain a prescribed distance between it and a vehicle in front. May be able to come to a stop and continue" [1]. Key performance criteria for this feature include the comfort and responsivity of acceleration and deceleration. Other important capabilities for ACC are detection and classification ranges of moving and stationary objects both in front and peripherally. Finally, ACC features can be

compared based on the range of roadways upon which they are able to function, with lower rated systems being limited to freeway settings and higher rated systems operating well on all types of roadways.

Table 4 describes the performance gradient related to Blind Spot Monitoring, which, according to AAA, "Detects vehicles to rear in adjacent lanes while driving and alerts driver to their presence" [1]. Higher level systems build on this capability to actively avoid collisions with vehicles, pedestrians, bicycles, and motorcycles occupying drivers' blind spots. Another logical expansion of this feature in higher levels is Lane Change Assist. These advanced Dynamic Driving Assistance features require not only broad peripheral perception coverage, but also forward-facing perception.

Table 3. Proposed guidelines for standardized five diamond rating system for Adaptive Cruise Control.

Adaptive Cruise Control

Vehicle System Performance Criteria	♦	♦♦	♦♦♦	♦♦♦♦	♦♦♦♦♦
Maintains programmed following distance	Uncomfortable, late deceleration	Improved decelera-tion response	Good deceleration response	Excellent deceleration response	Excellent deceleration response
Automatic resume after slow/stop	Does not automati-cally resume	Improved accelera-tion response	Good acceleration response	Excellent acceleration response	Excellent acceleration response
Roadway Functionality	Freeway only	Freeway only	Freeway/highway	Rural and city streets and freeways/highways	Rural and city streets and freeways/highways
Stationary object detection and classification range	May not detect	May not detect	May not detect	Mid-range detection and classification	Far-range detection and classification
Peripheral object detection and classification coverage	No perception coverage	Limited perception coverage	Limited perception coverage	Good perception and classification coverage	Broad detection and classification coverage
Light and Weather Performance	Suffers in low light and inclement weather	Better in low light and inclement weather	Better in low light and inclement weather	Performs well in all light and most weather	Performs well in all light and most weather

Table 4. Proposed guidelines for standardized five diamond rating system for Blind Spot Monitoring.

Blind Spot Monitoring

Vehicle System Performance Criteria	♦	♦♦	♦♦♦	♦♦♦♦	♦♦♦♦♦
Peripheral field of view	Narrow	Wider	Wider	Broad, 180 degree field of view	Broader than 180 degree field of view
Peripheral vehicle detection and classification coverage	Near range detection	Mid-range detection	Mid-range detection	Mid-range detection and classification	Expansive mid-range detection and classification
Peripheral object detection and classification coverage	May not detect	May not detect	Mid-range detection	Mid-range detection and classification	Expansive mid-range detection and classification
Dynamic driving intervention capability	Warning only	Warning only	Active collision avoidance with vehicle in blindspot	Active avoidance of vehicles, motorcycles, bicycles, and pedestrians	Active avoidance of vehicles, motorcycles, bicycles, and pedestrians; Lane Change Assist
Light and Weather Performance	Suffers in low light and inclement weather	Better in low light and inclement weather	Better in low light and inclement weather	Performs well in all light and most weather	Performs well in all light and most weather

SUMMARY

Rapid developments within driving assistance technologies necessitate unambiguous marketing and communication from automakers and dealerships so that customers understand, in clear terms, what their vehicles can do, under what conditions, and with what limitations. It is no longer enough to simply list ADAS features such as LKA or ACC on the sticker. We also need a shared, consistent method for rating these features. To advance this project beyond the current proposal, a third-party organization will likely need to further refine the performance descriptions and adapt testing protocols to fit these use cases. We are eager to continue the conversation because the potential impact is tremendous. Improving driving safety is a paramount concern within the industry -- and advancing safety requires not only revolutionary technology, but common, transparent standards clearly conveyed to customers to allow responsible implementation.

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DEFINITIONS/ABBREVIATIONS

ACC Adaptive Cruise Control

ADAS Advanced Driving Assistance System

AEB Automatic Emergency Braking

AES Automatic Emergency Steering

BSM Blind Spot Monitoring

L**KA** Lane Keep Assist

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