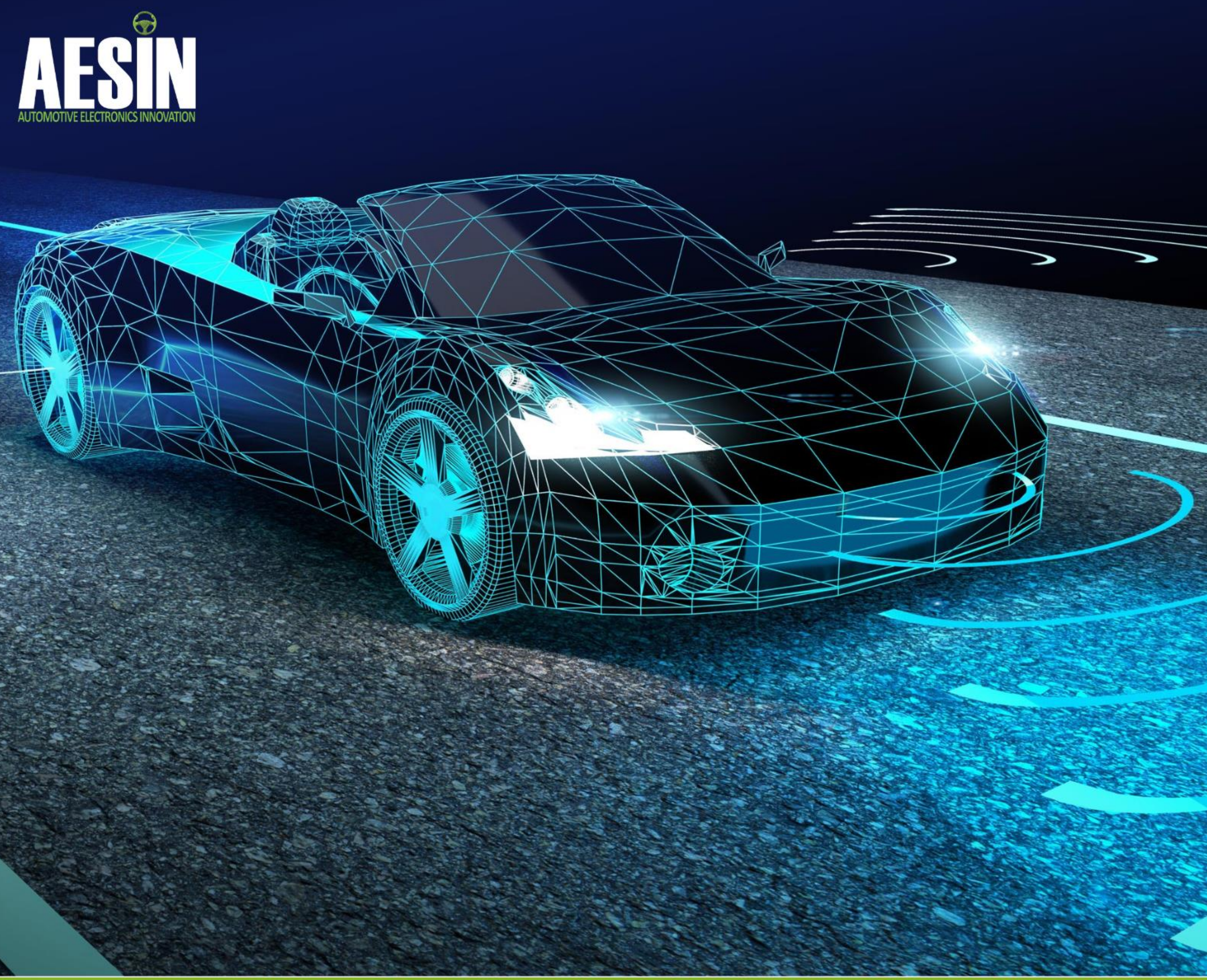

AESIN Special Interest Group Perception Sensors for CAM

Insights into the future needs for perception sensors for Connected and Automated Mobility (CAM)

TechWorks

AESIN
AUTOMOTIVE ELECTRONICS INNOVATION

AESIN SPECIAL INTEREST GROUP

PERCEPTION SENSORS FOR CAM

White paper: Workshop* outcomes, Insights into the future needs for perception sensors for Connected and Automated Mobility (CAM)

*The workshop was held on 1 December 2022 at The National Physics Laboratory (NPL), Teddington. 18 participants attended representing academia, industry, and research & technology organisations.

Acknowledgements

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Glossary of terms

Sensor	Relates to perception sensors for assisted and automated driving functions for vehicles such as Camera, RADAR, LiDAR, Infrared Camera, Thermal Camera, Ultrasonic Sensor
Supply Chain	Relates to the process of production from component level to a system level of a realised product, often via multiple organisations with specific expertise
Sensor Suite	Relates to the collection of perception sensors equipped to vehicles with assisted and automated driving functions and their interconnections
Sensor Fusion	The process of combining data from sensors within the sensor suite for use in perception
Operational Design Domain (ODD)	"Operating conditions under which a given driving automation system or feature thereof is specifically designed to function." [1].
AAD	Assisted and Automated Driving
Modelling & Simulation	The use of software and/or virtual environments to create a "virtual" version of a real product or environment. In the case of CAM this can be the vehicle technology or the environment the vehicle is operating in, or a combination of the two.
TRL	Technology Readiness Level [2].
DDT	Dynamic Driving Task. "Real-time operational and tactical functions required to operate a vehicle safely in on-road traffic, including longitudinal and lateral control, object and event detection and response, prediction of other road users' actions and manoeuvring." [3].

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Introduction

Current vehicles' automation systems for assisted and automated driving (AAD) mostly focus on the need to aid the driver to improve safety. In the future, there is the desire to replace the driver moving to level 3, level 4 and eventually level 5 automation, as described in the SAE J3016 standard, see Fig. 1 [4]. This process means that some of the Dynamic Driving Task (DDT) will be taken over by the automated system. It is therefore necessary to define the conditions that need to be met to ensure the automated system can take over part of the DDT.

Automation is a difficult challenge and sensors (and the data they provide) will be a key component of automated system for assisted and automated driving. Therefore, the workshop aimed to explore current expertise in sensor capability in the UK, and how to support the development of a sustainable design, test and manufacturing supply chain.

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	*Monitoring* of Driving Environment	Fallback Performance of *Dynamic Driving Task*	System Capability *(Driving Modes)*
Human driver **monitors the driving environment**						
0	No Automation	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	Driver Assistance	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial Automation	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes
Automated driving system **("system") monitors the driving environment**						
3	Conditional Automation	the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes
4	High Automation	the *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes
5	Full Automation	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**

FIGURE 1 DESCRIPTION OF THE LEVELS OF DRIVING AUTOMATION AS PER SAE J3016 STANDARD, TAKEN FROM [4].

To investigate the current state of sensors expertise in the UK, it was deemed useful to gather the thoughts and opinions of those working within the industry in the UK. Hence, this workshop was designed by WMG, AESIN and National Physics Laboratory (NPL), who hosted the event. The event was an open invitation and the participants consisted of AESIN members and industry and academic experts. Topics covered included the current state of UK expertise in sensors and sensor related activities, the relationship between ODD and sensors design and testing, and data (what is needed and how do we get it).

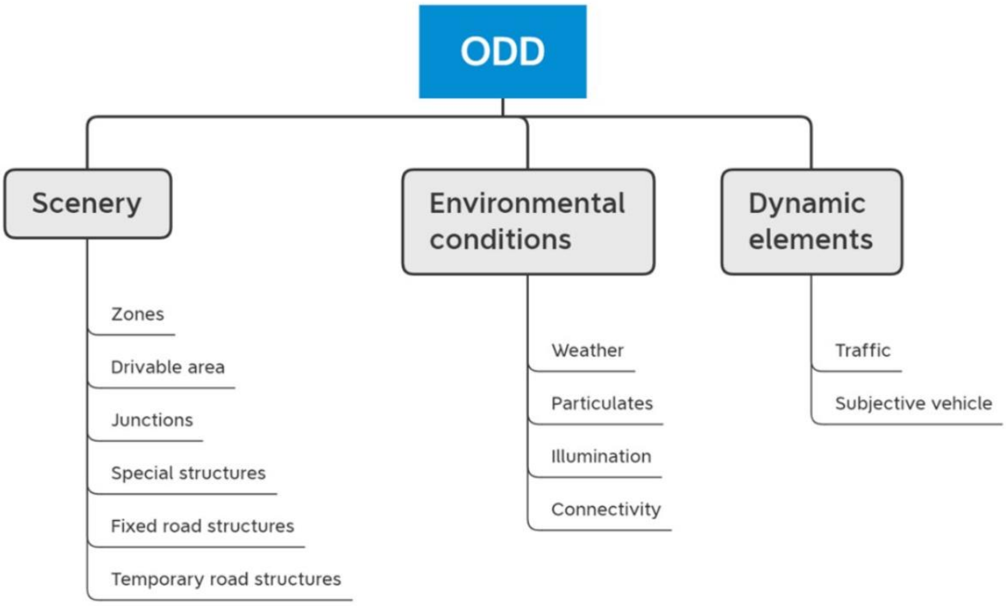

FIGURE 2 REPRESENTATION OF ODD AS DEFINED BY THE BSI IN THE UK, TAKEN FROM [5]

The report is designed to summarise key points raised by the participants of the workshop. Therefore, text often contains personal and collective opinions of those who attended. By gathering stakeholders from across the AESIN sensor network and affiliated organisations, a picture of the perception of the sensors industry within the UK can be developed, to highlight any perceived strengths or weaknesses. This report is designed to guide decision-making over where focus can be targeted and improvements can be made for the UK sensors industry.

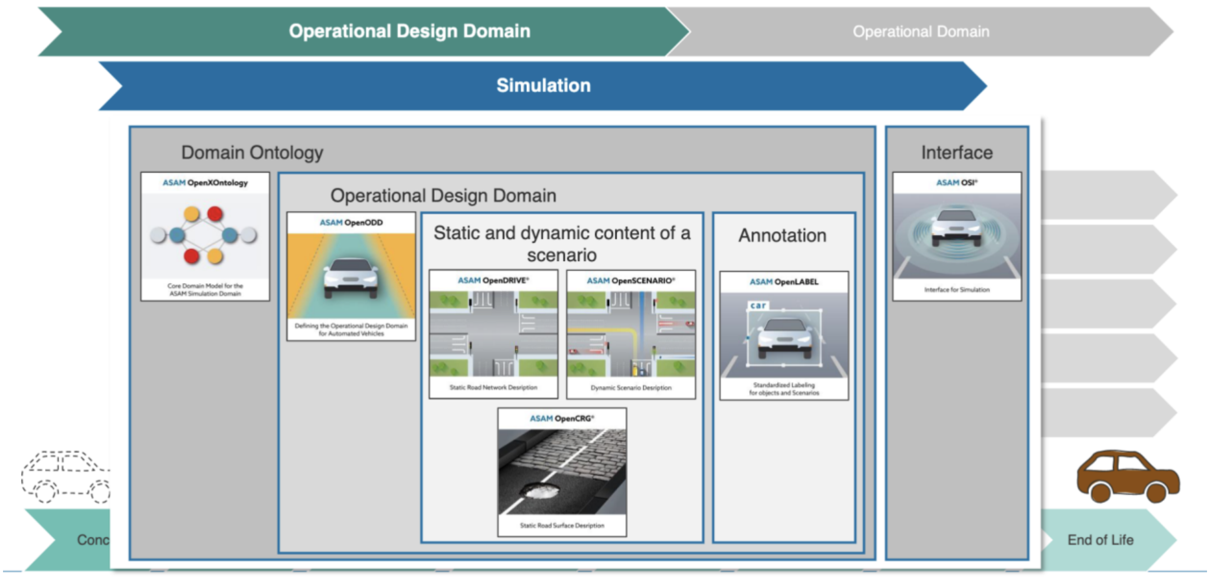

FIGURE 3 DIAGRAM SHOWING HOW ODD FITS WITHIN ASAM STANDARDS, TAKEN FROM [6]

Perception exercise: strengths and weaknesses of supply chain in the UK

This activity was designed to capture the views of the participants on the current state of sensor related expertise in the UK.

Workshop Design

The first activity involved posing 9 topics (listed in Table 1) and asking participants to rate the expertise in the UK on that topic. This activity was completed by writing the reasoning on a post-it note, assigning a score (between 1 and 10) and placing it on a chart. Participants were not required to respond to every topic, giving freedom for them to choose those which they felt more comfortable with. There were 18 participants in total.

Summary of discussion

The design of this activity means that there is valuable information to be obtained from both the topics that were talked about most and the least. Table 1 shows the number of responses for each topic along with the cumulative score and average score. The three topics most discussed were '*Sensor Design*', *'Modelling and Simulation'* and *'Manufacturing and Supply Chain'*. *'Sensor Design'* and *'Modelling and Simulation'* were also given two of the highest average scores. Comments attached to scores suggest that sensor design at low TRL is excellent, but this does not always translate into realised products. These numbers suggest that the participants viewed these two topics as the UK's strengths.

TABLE 1 COMPILED RATINGS GIVEN BY PARTICIPANTS FOR EACH CATEGORY

Topic	Number of Responses	Score	Average
Sensor Design	8	46	5.75
Sensor Fusion	3	19	6.33
Perception Algorithm Development	4	22	5.50
Modelling and Simulation	7	52	7.43
Sensor Testing Facilities and Equipment	5	24	4.80
Sensor Testing Methodology	6	19	3.17
Sensor Data Gathering, Curation and Availability	5	17.5	3.50
Manufacturing and Supply Chain	7	17	2.43
Sensor Packaging	1	3	3.00

'Manufacturing and Supply Chain' was given the lowest average score demonstrating that the participants believe this to be one of the UK's main weaknesses. In the comments attached to these scores it was mentioned that there are very few sensor companies in the UK and that the supply chain is inadequately developed in the country. However, one participant brought up that there are some centres of excellence in the UK, e.g. related to laser diode design and manufacturing but they are not well known. This comment

suggests that the developments and manufacturing of UK companies are not known well within the UK, and more UK capabilities awareness can be raised. This would be worth investigating further to explore where UK manufacturing capabilities lie and integrated in the discussion further.

The topics least discussed were *'Sensor Packaging'* and *'Sensor Fusion'*. This lack of discussion could be representative of the technical background of the participants since *'Sensor Fusion'* scored high and *'Sensor Packaging'* scored low. *'Sensor Testing Methodology'* and *'Sensor Data Gathering, Curation and Availability'* also had reasonable response rate and low scores, showing that these were also viewed as areas where the UK is weak. Comments seem to suggest that it is the availability of data (getting access) that is the biggest issue preventing one obtaining useful sensor data and that testing methodologies often involve self-certification with no available industry standards.

ODD for Perception Sensors

The objective of this activity was to understand, in the view of the participants, what parameters need to be specified in the ODD, to enable both sensor design and sensor testing.

Workshop Design

This activity encourages a discussion around how Operation Design Domain (ODD) can and will inform choices for sensor design and testing. Participants were encouraged to participate in the area where they had expertise and knowhow focusing on one of the following questions:

> Q1) *What are the parameters that we need to define in the ODD to* ***design and develop*** *a robust perception sensors/sensor suite?*
> *Q2) What are the parameters that we need to define in the ODD to* ***test and/or validate*** *a sensor suite?*

Workshop Outcomes

ODD for Design

In this workshop, the participants raised several questions around the ODD (presented in section 3.2.1) before discussing specific points in more detail.

The most significant discussion point was around understanding what the system is going to encounter, which therefore will inform the design and development of the sensors and sensor suite. The following areas and points were raised by the participants in this group:

- Objects – specifically characterisation and sensor behaviour prediction as they can inform the suitable sensor choice and development of technology to handle the object encountered. For example, understanding different material responses to different wavelengths is an important characteristic. This knowledge allows the optimal selection of sensors which operate at difference wavelengths. The behaviour of the sensors under different conditions such as rain or fog is important as they degrade the data and reduce the sensor coverage.

- Noise Factors – There are many noise factors that can affect the sensor data. These noise factors can range from internal sensor noise to dirt on sensors and cross-talk/interference with active sensors. An understanding into which noise factors the sensor will need to handle is desired. Moreover, it was agreed that some noise factors may require further work to allow the definition of severity. For example, rain is generally measured through rain rate, with the MetOffice providing different scales [7]. For dirt on lens, there is no range of measure. There was a comment around the possibility of using thickness of dirt and coverage of sensor to measure the severity of dirt.

ODD for Testing

What is immediately clear from the responses to Q2 is that a broad range of parameters need to be defined in the ODD to test and/or validate a perception sensor suite, ensuring robustness. Discussions covered:

- environmental parameters such as rain and fog including the effect these have on the road surface;
- scenery parameters such as traffic signs;
- congestion from other road users;
- vehicle related parameters such as speed and position;
- lighting, colour, and material properties were also mentioned;
- latency and requirements of the computational stack.

In conclusion, if something will have an effect on the output of the sensors then the consensus seems to be that it should be considered in the ODD for testing.

Note on other points

- A question raised within the design and development group was whether the sensor suite should be capable of detecting whether the vehicle is operating within it's ODD. This is a wider topic that does not involve just the sensor system, but the wider assisted and automated system.
- Another interesting topic that was brought up, but was out of scope, related to the potential need to include infrastructure in the ODD and which type of infrastructure.
- Finally, a short discussion took place around the need for sensor diagnostics, particularly related to detecting noise factors which may bring the system out of the ODD.

Data: What do we need and how do we get it?

The objective of this exercise was to understand what data is needed and what is needed to obtain it. The scope encapsulated everything related to sensor development and testing, up to including the creation of a realised product.

Workshop Design

This activity prompted participants to discuss within their breakout groups around the data needed to support sensor activities for ADD functions deployed in vehicles. Sensor activities could include, but are not limited to: design and development, modelling and simulation, testing, validation and assurance. The groups were asked to address the same question, and note down their discussion:

Q. Data: what do we need and how do we get it?

Workshop Outcomes

The discussion was more focused towards what was needed from a data perspective. There were two key areas in which data can be critical to support sensor activities identified during the discussions: to support the development of virtual environments for testing and gathered datasets for algorithm development purposes.

Related to virtual testing, one participant discussed that it is desirable to have physics-based models that are as representative of the real-world sensors and objects as much as possible. The modelling process will often require more information than is provided by a sensor specification sheet. Additionally, different object targets under different conditions will influence the output of the sensor data, which needs to be measured, characterised and modelled correctly. The data gathered for virtual simulation and testing purposes should also be ideally in the form of raw data.

Another major use for gathered data is for development purposes such as to create perception algorithms. Moreover, the data collected will need to be properly curated: from data filtering to creating ground truth information to complement the collection. Creating metadata for ground truth was one common desire for the participants. Any processing of the data will need to be appropriately documented and published along with the dataset. The availability of datasets can become an issue due to IP issues or GDPR for camera data. Datasets must include dynamic scenes containing objects of different risk types and levels with random occurrences.

Finally, a common agreement within the two groups was the need for standards to support the datasets. For example, standards can be setup for target objects and test methodology to make sure that the measures carried out in different part of the globe are repeatable and directly comparable. With sufficient information and documentation for the data gathered, there can be a potential to use this data for certification and benchmarking in the UK.

Key takeaways

The key takeaways from the workshop are listed below and should act as a guide to where further exploration is encouraged by the UK's sensor community.

- Sensor design at low TRL the UK is excellent, but often this excellence does not translate into realised products.
- Participants believe there are no sensors available from UK suppliers and that the supply chain in the UK is fragmented and inadequate.
- UK sensors capability is not well known even in the UK.
- Availability of curated and adequately collected data is the biggest issue preventing one from obtaining useful sensor data.
- Testing methodologies often involve self-certification with no available industry standards.

The first task would be to map the UK for existing capability in perception sensors supply chain covering aspects including research, design, development, modelling, simulation and testing. Beyond this is to consider what a UK perception sensor strategy would look like and how we can continue to grow UK's opportunity in this space.

About AESIN

AESIN is an outstanding member-based community committed to create the next generation of UK-centric automotive electronics and software systems and supply chains.

Leading thought for ingenious, sustainable, efficient, safe, and resilient mobility through the innovative application of electronics and software systems.

Interested in finding out more about AESIN? Contact Gunny Dhadyalla: gunny.dhadyalla@techworks.org.uk

References

[1] BSI, “Operational design domain (ODD) v3.0,” 2020. https://www.bsigroup.com/en-GB/CAV/cav-vocabulary/operational-design-domain/ (accessed Mar. 07, 2023).

[2] UKRI, “Eligibility of technology readiness levels (TRL),” 2022. https://www.ukri.org/councils/stfc/guidance-for-applicants/check-if-youre-eligible-for-funding/eligibility-of-technology-readiness-levels-trl/ (accessed Apr. 17, 2023).

[3] BSI Group, “CAM Vocabulary (BSI Flex 1890 v5.0): Dynamic Driving Task (DDT) (updated),” 2023. https://www.bsigroup.com/en-GB/CAV/cam-vocabulary/dynamic-driving-task/ (accessed Apr. 17, 2023).

[4] J. Shuttleworth, “SAE Standards News: J3016 automated-driving graphic update,” 2019. https://www.sae.org/news/2019/01/sae-updates-j3016-automated-driving-graphic (accessed Mar. 20, 2023).

[5] BSI, “Operational Design Domain (ODD) taxonomy for an automated driving system (ADS) - Specification,” 2020. [Online]. Available: https://www.bsigroup.com/globalassets/localfiles/en-gb/cav/pas1883.pdf

[6] ASAM, “ASAM SIM : Guide Standardization For Highly Automated Driving.” [Online]. Available: https://www.asam.net/index.php?eID=dumpFile&t=f&f=4297&token=cbeec18c4770d0ff88e3d3c539c13a32abed6300%0A

[7] MetOffice, “National Meteorological Library and Archive Fact sheet 3 - Water in the atmosphere,” Exeter, UK, 2012. [Online]. Available: https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/library-and-archive/library/publications/factsheets/factsheet_3-water-in-the-atmosphere.pdf