

Date: 31st March 2021

Dear Jessica,

The Met Office welcomes the launch of your consultation on Automated Vehicles and we are responding in our role as the UK's National Meteorological Service and the organisation responsible for the delivery of services to mitigate against space weather impacts. As our interest in this consultation is specific to certain key areas, we are responding in the form of a letter to provide an overarching summary of our interest and to draw your attention to issues which you may wish to consider further. Our evidence builds on submissions to your previous consultations and complements discussions held in a meeting between yourself and my colleagues on Wednesday 3 March.

As a Public Sector Research Establishment and an Executive Agency of the Department for Business, Energy and Industrial Strategy (BEIS), we are responsible for monitoring and forecasting the weather and run the Met Office Hadley Centre, which provides climate science and services to help people and organisations understand and prepare for climate change. We are also responsible for providing the UK's space weather monitoring and forecasting service through the Met Office Space Weather Operations Centre (MOSWOC). This provides 24/7 forecasts and warnings for Government, responders, critical national infrastructure providers and the public.

Delivering meteorological services for Automated Vehicles and supporting infrastructure:

A jointly developed understanding of meteorology, measurability, Operational Design Domain (ODD) of Automated Vehicles (AVs) and dynamic weather geofences should be published and maintained by a regulator, infrastructure providers and/or a weather service provider, enabling a National AV Weather Capability. Such a capability has a degree of transferability beyond the AV sector: Unmanned Aerial Vehicles as well as Marine Autonomous Surface Ships have similar (yet not identical) weather challenges in terms of their safety assurance requirements.

Whilst the Met Office possess the capabilities to provide such a service, so long as all provision of road weather, atmospheric weather and space weather data is from a reliable source, the safety assurance objectives should be met. In addition, the consideration of AV network-specific weather warnings are highly applicable to assuring safety in use as it is likely that weather conditions will affect AVs and their infrastructure in ways that would not necessarily meet the threshold for warnings issued by the Met Office National Severe Weather Warning Service. It would therefore be more appropriate for such vehicles to make use of weather information more generally rather than limiting their use just to weather warnings.

Furthermore, whether investigation into high profile accidents involving automated vehicles is done by a specialist branch or by the police, we believe the role of weather conditions and the response of sensors and systems to these conditions should be considered as part of the process from the start. Our experience of working with the aviation industry has shown that they have a great deal of experience in considering the role of meteorology in accidents, which could provide a useful precedent to accident investigation involving automated vehicles. For example, Meteorology is one of the main factors considered by the Air Accident Investigation Board (AAIB) when investigating accidents. However, it is worth noting that any specialist meteorological service (whether that is sourced from the private or public sectors) would require appropriate resources to ensure its long-term viability.

Impact of meteorological factors on AVs and the wider AV Ecosystem

Current vehicle regulations mean that all elements of roadworthy vehicles are type approved to operate within a range of environmental conditions (e.g. temperature). The dependence of AVs on perception systems that rely heavily on electromagnetic sensors to replace humans will significantly increase the sensitivity to weather. We would therefore support a mechanism which either mandates (by the appropriate authority as part of the pre-deployment safety assurance process) the systems required or sets out a minimum list of weather conditions that a sensor, system or feature is able to operate in.

As automated road vehicles will have multiple weather-sensitive systems, we believe it will be necessary to define any weather-related Operational Design Domain in terms of the suite of sensors and Automated Driving System (ADS) capability, not any individual component. This would necessitate regulation of the performance of weather sensitive sensors and associated systems to set out clear circumstances under which human intervention (remote or in-vehicle) would be required or not.

The current generation of automated road vehicles rely upon lidar, radar, ultrasonic and camera type sensors for various aspects of their operation. It is our experience that all can suffer either degraded performance or misleading output in certain weather conditions. We believe Automated Driving System Entities (ADSE), fleet operators, private owners and network operators should maintain regulated and approved mechanisms to ensure the ODD (on the basis of weather) is defined, measured and not exceeded. In addition, this mechanism must be dynamic to reflect swiftly changing weather patterns as well as forecasting timeframes covering the potential duration of a journey.

By extending the current approach of vehicle regulation to the function of an automated vehicle, we believe this means these vehicles should:

1. evidence and be equipped with appropriate instrumentation and systems to effectively measure or confidently determine that they can competently function within the atmospheric, road surface and space weather conditions in which they are operating
2. demonstrate confidence when embarking on a journey that the ODD weather criteria are not expected to be exceeded while driving under ADS
3. demonstrate capability to review and assess competence with respect to weather throughout a journey, demonstrating safety-based redundancy on the basis of encountered or expected weather
4. transmit similar information, especially exceedances, to local and central infrastructure to allow safety measures (e.g. geofencing) around hazards in support of a safer transport network

Consideration of space weather impacts:

From our position as the UK's Space Weather Operations Centre and space weather risk owner, we feel it is also important to consider the risk posed to automated vehicle systems by space weather events. Major space weather events can particularly disrupt or damage electrical equipment, including high frequency radio communication and satellite systems. For example, it is assumed that automated road vehicles will have a reliance on Global Navigation Satellite Systems (GNSS), such as GPS. During a plausible worst-case scenario event, GNSS signal may be degraded or completely lost for around 1-3 days. It is not possible to improve upon the GNSS technology to mitigate this risk as it is changes to the atmosphere which cause the degradation. However, we would support a mechanism to provide governance and guidance relating to possible impact from space weather events, including the requirement for back-up systems that do not share the same susceptibility to space weather. We believe the governance should cover, at minimum, the use of GNSS, communications systems and any safety-critical equipment.

Approved methodology:

We support the need to regulate standards or specifications of sensors, sensor systems and ADSs in their entirety, via a meteorologically and metrologically approved and led mechanism. Such a mechanism should complement any planned type approval via the CAV PASS safety regime (or similar). This would be required to happen in the pre-deployment approval phase as well as throughout the continuous operation of vehicles.

We also believe that as part of this, the parameters describing ‘typical weather’ must be fully and unambiguously defined (a starting point was made in the publication of BSI’s PAS 1883 but is by no means complete) to ensure there is a shared understanding when designing and operating automated vehicles and the infrastructure within which they operate. There are examples of other sectors following similar protocols where comparisons can be drawn, for example, the accreditation of instruments and systems used by air traffic control in the aviation industry.

Further, there are several key points relating to weather which should be considered as part of the evidence base when training ADSs. We believe it would be useful to document these considerations, in order to make an audit trail possible. For example, when testing automated vehicle sensor systems the data used should include a traceable standard of meteorological “edge cases” covering a range of extreme conditions where sensor performance is likely to be compromised in order to fully characterise sensors and systems. This needs to capture sensor and system degradation in a traceable and quantitative sense is currently being articulated by CCAV and Innovate UK funded joint work with the National Physical Laboratory (NPL) as a Sensor Assurance Framework (SAF). The SAF will be designed in consultation with government, regulators, academia and industry. At the heart of such a SAF is the explicit treatment of measurement uncertainty. We recommend that, while there must be commercial freedom to use different testing environments, any testing approaches must be relatable (traceable) to such a SAF, and indeed one that covers all aspects of AV operation.

In addition to a traceable and quantitative measure of performance with respect to the weather, we believe that any safety case must include how the AV will acquire the necessary situational awareness with an acceptable level of uncertainty in order to confirm it is within its ODD. This is often described as the measurability of the ODD. The following three examples illustrate the range of scenarios that may need to be accommodated:

- i. Prior to being put into service, the AV is demonstrated to perform safely (including performing a Minimum Risk Manoeuvre (MRM)) in all weather conditions that it will encounter without the need for externally supplied data. In addition, demonstration that the need to perform a weather-related MRM will only happen an acceptable number of times, from a climatological perspective.
- ii. The AV is able to use accredited external weather data in order to ensure it can stay within its ODD. Due to the challenges around measurability of the weather aspects of the ODD, this requires that such use explicitly incorporates uncertainties in the relevant ODD parameters, including demonstrating that AV is able to adapt to varying levels of meteorological data quality. (Meteorological data quality will be highly dependent on its original source, e.g. whether this is derived from other vehicles, reference weather measurements, or a combination of both).
- iii. The AV is able to combine both its own and external weather data to remain in its ODD.

Data sharing and use of approved data sources:

Consideration should also be given to how safety-critical information can be shared to ensure that all automated vehicles are able to benefit in real-time from knowledge gained during an incident involving an individual vehicle. We believe a minimum baseline of information should be defined and shared across platforms in an interoperable way and should include consideration of both mobility infrastructure

and relevant data provision services. This means that the data could be exchanged in a useable and agreed way whilst also ensuring that any additional data input, such as that from forecast providers, can be assessed against pre-agreed standards to ensure levels of reliability. A practical illustration of this principle which could be investigated for synergies and best practice is the way the International Civil Aviation Organisation (ICAO) regulate the aviation industry to ensure that observations of weather and/or environmental conditions that pose a threat to safe operations are shared across the network. This is done both routinely for general weather and specifically for conditions which pose a threat to safe operations.

From a weather perspective, there is an opportunity through the regulation and mandatory requirement to share observation data, for the UK to promote symbiosis between the mobility sector and weather forecasting capability. For example, the output from AV and supporting infrastructure sensors is likely to contain some (indirect) information about the prevailing weather conditions which are potentially a valuable source of information to meteorological forecasting agencies. This information could be used to improve our understanding of dynamically changing weather, at a resolution beyond that of the present, which ultimately will have a benefit to all weather forecast users, including automated vehicles and their supporting infrastructure. We would therefore suggest exploring whether the safety critical regulation could be designed at outset to incorporate this, even if the facility is not used initially.

The Met Office is willing to further engage with and support the Law Commission with this work and explore potential scenarios and mitigation procedures to provide assurances for future regulation.

Yours sincerely,

Ian Cameron

Met Office Markets Director