ESTABLISHING AND COMMUNICATING RULES FOR AUTOMATED DRIVING VEHICLES

Matthew Avery, Dave Baldwin, Colin Grover
Thatcham Research
United Kingdom

Paper Number 19-0328

ABSTRACT

There has been considerable confusion in the interpretation of the SAE Levels of Automation J3016, in particular when defining whether a vehicle can be classed as automated. This is particularly relevant for insurers where there is a question of liability over who was in control of a vehicle when an accident has occurred. To clarify this a set of Requirements for Automated Vehicles has been developed to give a common benchmark for consumers, manufacturers, insurers and regulators.

The approach to developing the rules has been iterative. Initially they were formulated from an insurer paper focussed on the emerging Regulation 79 UNECE steering function rules and the requirements for partial automation. The challenge of driver disengagement and driver as back-up from Level 3 automation highlighted the issue of classifying these vehicles as automated.

To address this, Thatcham Research defined vehicles as Automated or Assisted based on whether they can meet ten specific criteria for automation. The criteria are based on road safety experience, anticipated vehicle capability, consideration of other road users and the fundamental requirement that these vehicles will generate less accidents. Experience using ADAS and Assisted Vehicles helped to give practical experience of some of the challenges that needed to be addressed.

These ten requirements have now been through insurer, regulator and manufacturer challenge and review in a number of different international territories. The rules have been strongly welcomed by manufacturers and regulators who had not seen any clear guidance when the rules were first issued. They have been used in a number of European countries for insurers to lobby government for safe and insurable vehicles. At the same time the marketing and communication of the rules combined with differentiating Assisted and Automated Driving have been key to disseminating the message to the wider public. Campaigns promoted wider understanding of the differences between the new technologies and the driver's responsibility in Assisted Vehicles.

The Classification of Automated Vehicles will be a key challenge for international regulators over the next five years making the development of the rules and framework essential at this time.

BACKGROUND

The SAE J3016 Taxonomy for Automated Vehicles introduced five levels of Automated Driving Systems (ADS) which are frequently referred to in media and consumer communications. Whilst the levels allow for an evolution of automation up to fully autonomous systems, there is also a need for more clarity on when an ADS can be classified as safe to drive in an automated mode.

The levels of automation transition from Assisted Driving, where the driver is in control, through to Automated Driving where, for specific conditions, the ADS can drive without human intervention. A clear area of concern is Level 3, Conditional Automation, where the ADS is capable of driving but requires the human driver to act as a monitor and intervene as a back up.

Highly capable automated driving systems (Level 4+) will reduce the risk of accidents and present a significant future societal benefit both in terms of safety and mobility. Thatcham Research and the UK's Automated Driving Insurer Group (ADIG) recognized that an approach was needed to address the lack of clarity over safe automation to

reduce the risk of an ADS being misused or misunderstood resulting in potentially catastrophic incidents. Such an incident would not only reduce the attractiveness of these vehicles for insurers but also impact the adoption and acceptance of ADS by consumers and regulators.

At the time of developing this work, no clear guidelines on the requirements for safe automated driving systems were available to regulators or OEMs. The communications developed an evolving framework for safe Automated and Assisted driving systems.

METHOD AND DEVELOPMENT

The UNECE WP29 ACSF sub-group was developing changes to Regulation 79 to address increasingly automated steering regulations. This work formed the basis of an initial technical paper 'Regulating Automated Driving' to highlight the issues of safe automation.

Starting from the assumption that a driver will want to undertake secondary tasks while the ADS is activated, it was necessary to consider under what circumstances the system could become unsafe and where clear rules and guidelines would be needed to ensure that the system would remain safe.

The adoption and influence of these rules and guidelines could only be effective if widely shared during their development - thus open sharing with OEM safety teams, regulators, insurance bodies and insurers allowed suitable challenge to the approach, framework and recommendations presented. The 'Regulating Automated Driving' document provided a technical baseline to the market on the issues recognized at that time.

Addressing Autonomous Ambiguity

A core challenge for the approach was that the SAE Levels, OEM marketing of systems and lack of consumer and media understanding created **Autonomous Ambiguity** leading to driver confusion as to the vehicle's capability and the driver's responsibility. This was summarised as vehicles needing to be either classed as **Assisted**, where the driver is always responsible, or **Automated**, where the vehicle can take over the driving task for some or all of a journey. In the UK, personal vehicle insurance policies make this critical since until a vehicle is classed as automated, traditional vehicle insurance policies apply. At the time there was no provision for insuring vehicles when driving in an automated mode.

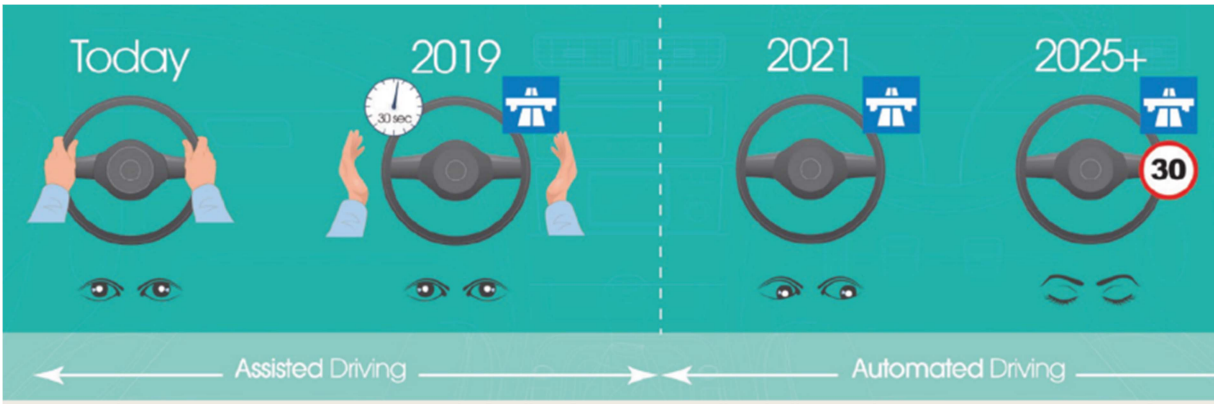

Figure 1. Assisted vs Automated Vehicles

Communication of this concept needed a simple infographic (See Figure 1) demonstrating Assisted driving with eyes on the road ahead, systems operating in a highway environment with limited hands off wheel time. Level 4 shows a disengaged driver in a single domain for level 4 awake to come back into the loop at the end of the ODD whereas Level 5 allows the driver to switch off entirely in all ODDs.

At this time international media reports of highly assisted Level 2 vehicles being misused as 'self-driving' demonstrated the combination of over-reliance on the system and confusion over the system capabilities reinforcing the need for clarity.

Establishing and Communicating Rules for Automation

Having established a clear break between Assisted and Automated vehicles, it was necessary to determine the criteria for what constituted an Automated vehicle. 'Clarity in an Uncertain World – A Model for Automated Driving' brought together the main elements of automated driving to allow common understanding of the issues positioned at a level which could be more widely used beyond regulatory and technical audiences.

The framework rules were built around the assumption that an Automated Vehicle will allow the driver to disengage and do secondary tasks.

If the driver can disengage from the driving task then the vehicle must be capable of driving safely in its operational design domain (ODD), a basic requirement. The system should similarly not be able to operate outside its operational design domain – so it must be geo-fenced. If it is to drive safely, it must be law abiding. Allowing a vehicle to break the law makes little sense in promoting safe automation. To ensure no confusion, the system should be named and marketed appropriately when describing its functionality. Thus Auto Pilot may be fine for Automated Vehicles but not for an Assisted Vehicle as this is misleading.

It is unlikely that the ODD will apply for every part of a journey, so there needs to be a controlled and managed timely hand-over and hand-back process between human driver and ADS. It is essential that the driver is clear whether or not they are in control of the driving task. At the same time, if the driver is needed to re-engage then the system cannot simply hand back control without warning. The vehicle needs to be capable of identifying when the ODD is coming to an end. This may happen based on location, but also where weather or road conditions end the ODD. The ADS will therefore need to manage a controlled hand-over even when the situation could not be anticipated at the start of the journey. If the driver does not take control back from the ADS, the ADS will need continue and stop safely (Safe Harbour), not presenting a hazard to other traffic, and without relying on the driver.

The need for the vehicle to be highly capable, manage handovers and be able to find safe harbour requires a sufficient level of system redundancy to be built in.

Not every event can be anticipated within systems testing. Some events will require emergency intervention. In this case the ADS should be able to carry out a minimal risk manoeuvre to attempt to mitigate or avoid a crash (in the same manner a human driver may do).

In addition to the above requirements, insurers identified the need to have sufficient data in the event of a crash to establish who was driving. Availability of near real time incident event information will be more widely needed. For example, a fault introduced through an over the air (OTA) software update could potentially affect all ADS operating the software and may need an immediate response.

The rules for automation were summarized in an infographic (See Figure 2) for easier communication to non-experts and wider dissemination to media, safety and consumer groups as well as regulatory and industry stakeholders.

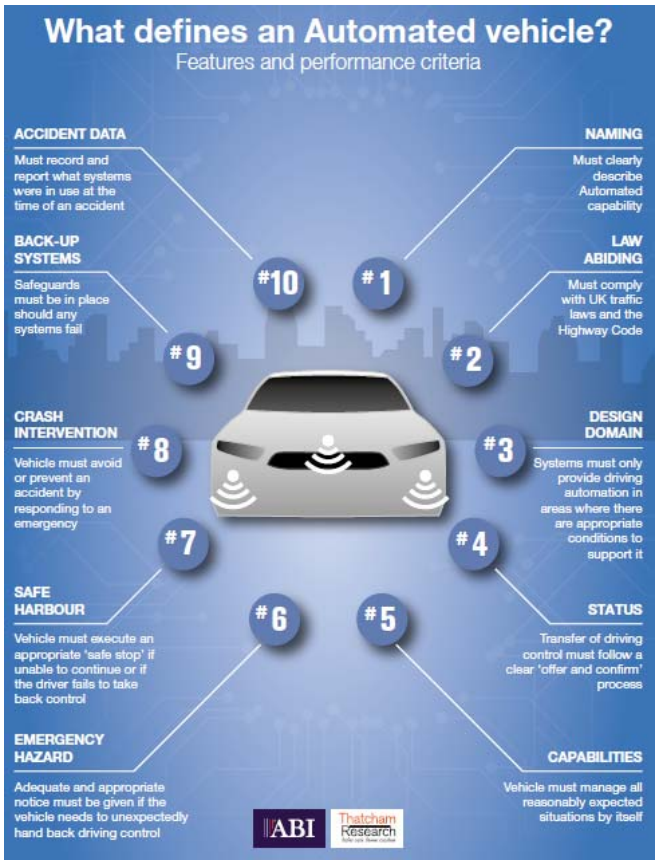

Figure 2. What defines an Automated Vehicle

Whilst the rules are useful in building a high-level framework, more detailed technical descriptions of the ten requirements outlined above were needed to support technical users. These descriptions were initially developed in a series of brainstorming sessions followed by a number of external stakeholder review iterations to ensure broad agreement with the concepts (See Table 1).

Table 1.
Detailed Criteria for Automated Vehicles

	Automated Vehicle Criteria
Naming	*The naming of the system must clearly specify automated driving.* The description of the system must be unambiguous and clearly describe the automated system functionality, limitations and driver responsibility.
Law Abiding	*Systems must abide by local traffic law including seat belt use, speed and driving behaviour. The system must abide by Road Traffic Laws and follow the Highway code including limiting speed to posted speed limits.* Some exceptions may be permissible to avoid a collision or to deal with a developing emergency situation. Such exceptions and anticipated vehicle behaviour must be recorded in manufacturer documentation.

	Automated Vehicle Criteria
Design Domain	*Systems must only provide driving automation in areas where there are appropriate conditions to support driving automation. Systems must indicate to the driver where automation is available.* The system must be able to determine in what circumstances it is able to offer its driver an Automated Mode of operation taking into account, for example: the environment in which it is operating (type of road, car park, private drive etc); Traffic conditions, road pavement conditions etc.; weather; connectivity; and speed limit and/or average traffic speed
Status	*Hand over and hand back must follow a clear 'offer and confirm' process between driver and vehicle with appropriate notice.* The Automated Mode is only engaged after the vehicle has understood the planned journey and/or parking manoeuvre and confirmed it is safe to operate in the Automated Mode for all or part of that journey. When Automated mode becomes available there must be a clear offer and confirm process from vehicle to driver. Similarly, the reverse must be true when the vehicle hands control back to the driver. Hand back from Automated Mode to manual driving must take place at a predetermined point in the journey (e.g. motorway off-ramp) with warnings given to the driver and a countdown timer from a minimum of 60 seconds. Driver monitoring must be in place to establish the level of driver engagement to ensure and appropriate hand over is achieved. Should the driver fail to respond to a hand back request the vehicle must execute a '**safe harbour**' manoeuvre, as described below
Capabilities	*The system must provide driving automation which safely controls the vehicle in all reasonably foreseeable driving situations within the design domain environment.* The vehicle must be able to deal with any obstruction or incident that may appear in its path and not require involvement from, or monitoring by, the driver for any part of the journey where it is in an Automated Mode.
Emerging Hazard	*If the Automated Vehicle becomes aware of a situation which was unknown at the start of automation (e.g. poor weather) and which requires a hand over to the driver earlier than planned, adequate and appropriate notice must be given.* Where such a situation arises, the vehicle must provide at a minimum a 60 second warning to the driver. The procedure must then follow that outlined for hand back under **Status** above, with the vehicle performing a '**safe harbour**' manoeuvre should the driver fail to respond.
Safe Harbour	*If the driver fails to respond to a hand back request, the vehicle must execute a 'safe harbour' manoeuvre and navigate to a safe harbour appropriate to the design domain and traffic conditions* Safe Harbour will generally be in a position away from the main carriageways In heavy traffic. In certain circumstances Safe Harbour may be to stop in lane but this will vary depending on Design Domain, traffic conditions and road speed.
Crash Intervention	*If the vehicle senses an immediate unforeseen dangerous situation the system must initiate the minimum risk manoeuvre to avoid or mitigate a collision* The vehicle must be able to use its available functionality to avoid or mitigate any collision to the best of its ability. Decisioning should be based on 'doing least harm'. It should not be expected to make ethical choices in life threatening circumstances

	Automated Vehicle Criteria
Back-Up Systems	*The system must be fault tolerant so that in the event of a fault the vehicle can continue in its Automated Mode or provide a planned system hand over to the driver.* Sufficient redundancy must be included within the vehicle systems to allow the Automated Mode to 'fail operational', that is to continue normally and safely with its journey whilst notifying the driver that an issue exists and its nature. As a minimum there must be sufficient redundancy for the vehicle to complete the planned journey in a reduced speed 'limp home' mode or to complete a controlled Offer and Confirm hand back to the driver**.** The system must have a self-diagnostic capability to detect faults and the functionality to communicate these to the driver. The system must also be capable of over the air (OTA) updates to its software or firmware and any such update deemed safety-critical must be applied automatically without any requirement for intervention or interference by the vehicle owner, operator or user.
Accident Data	*Data must be recorded in the event of a collision and made available to both manufacturer and insurer to quickly and impartially assess the status of automated systems and extent of driver input leading up to the accident.* In the event of a collision, the vehicle must be able to record, and preferably transmit the minimum dataset, described in the Clarity on Driver Status: Shared Accident Data section below, via a suitable intermediary (or 'neutral server'). For the UK it is also proposed that the that most suitable intermediary would be the Motor Insurers Bureau.

The requirements for accident data are already being progressed through the DSSAv event data proposed by UNECE. The communication documents propose that insurers have access to sufficient data to establish whether the ADS or the human driver was in control leading up to the crash. This data will only be used to confirm who or what was in control of the Automated Vehicle and not the liability between different vehicles.

The limited data request is:

- GPS-event time stamp
- GPS-event location
- Automated Status – on or off
- Automated Mode - Parking or Driving
- Automated Transition time stamp
- Record of Driver Intervention of steering or braking, throttle or indicator
- Time since last driver interaction
- Driver Seat Occupancy
- Driver Belt Latch

It is recognized that there will also be a challenge in determining accident trigger rules to generate a data event which is not currently captured in the evolving communications to date.

Extending the Framework for Assisted Vehicles

Whilst the framework rules developed had provided rules to define safe automation and a simple message for all stakeholders, requests were received to extend these to lower level Assistance, specifically Level 2 vehicles. These requests came from industry bodies seeking to bridge the gap between today's production vehicles and the future Automated systems. Since the rules for automation defined a set of features to determine whether a vehicle is automated, the assisted features allowed the team to start establishing a framework for the features of good assistance systems.

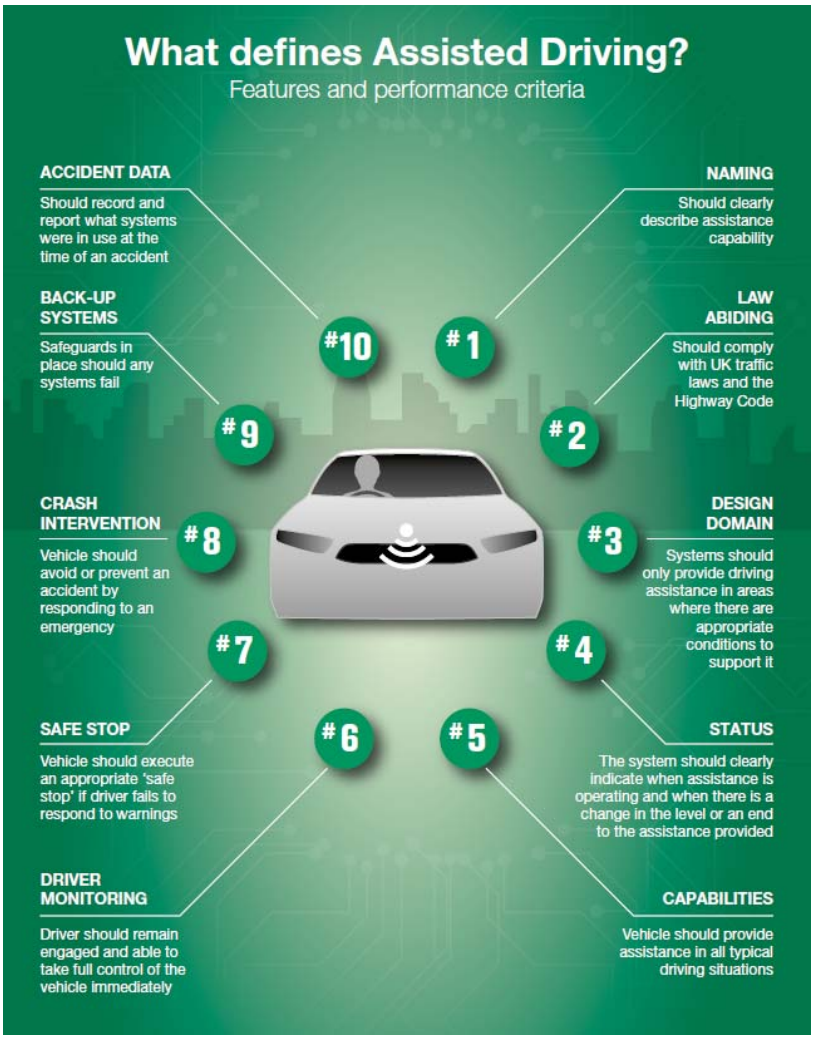

Figure 3. Features and Performance Criteria for Assisted Driving

Once again ten features were selected (See Figure 3). There were two subtle differences to reflect the lower level of capability in these systems. Firstly, the change from Safe Harbour to Safe Stop reflects the need for the system to be able to execute a safe stop if the driver does not respond to 'hands on wheel' warnings but also that the ADS may not have lane change capability. Secondly, the replacement of Emerging Hazard (for managed Hand-Back) by Driver Monitoring where drivers' engagement levels can be monitored and action taken if a driver starts to disengage. Driver monitoring is of value for all systems providing increasing levels of driver support whether assisted or automated – as the driver's workload decreases they are more likely to start disengaging from the driving task creating a less safe system overall.

Once again the Technical Assessment document gave lower level detail for specialists and provided contrast to the automated rules. Note the language is framed as systems 'should' rather than the 'will' language used in the Automated rules. (See Table 2)

Table 2.
Detailed Criteria for Assisted Vehicles

	Assisted Driving Criteria
Naming	*The naming of the system should not specify, suggest or indicate automation.* The description of the system should be unambiguous and clearly describe the assistance system functionality, limitations and driver responsibility.
Law Abiding	*Systems should only provide driving assistance when driving in accordance with local traffic laws relevant to seat belt use, speed and driving behaviour.* The system should default to the speed limit on activation or current speed if lower, provide Intelligent Speed Adaptation (ISA) and overspeed warnings. A clear warning should be displayed to the driver if driving with Assistance while contravening local traffic law.
Design Domain	*Systems should only provide driving assistance in areas where there are appropriate conditions to support driving assistance.* The vehicle should not operate in areas determined as inappropriate by the manufacturer. This will be supported by clear and robust manufacturer documentation. The system should be geo-fenced to those roads and/or locations where it is deemed safe to operate.
Status	*The system should clearly indicate when assistance is operating and when there is a change in the level or an end to the assistance provided.* There should be a clear, commonly used display of Continuous Assistance statuses. Required statuses include: Enabled, Available, Engaged, Disengaged, Driver Intervention Required
Capabilities	*The system should provide driving assistance which assists with the safe control of the vehicle in all typical driving situations within each Design Domain* The system should provide driving assistance that delivers safe lateral and longitudinal support to guide the vehicle along the road taking into account other road users. If a situation is encountered that it is unable to cope with, then a clear and timely warning should be given and ideally the hand over completed in a controlled manner.
Driver Monitoring	*Driver monitoring should ensure that the driver remains engaged in the driving task and able to take full control of the vehicle immediately. Ignoring warnings should lead to system deactivation.* While system is engaged the driver should be monitored to ensure that they remain present and able to control the vehicle. Driver inactivity or inattention should require an escalating cascade of warnings to re-engage the driver
Safe Stop	*If the driver fails to respond to the escalating cascade of engagement warnings, the vehicle should execute a safe stop.* Safe stop should vary with the design domain and traffic conditions. The system should provide appropriate warnings to other drivers to minimize the risk of stopping (e.g. hazard warning lights). An eCall event must be triggered
Crash Intervention	*The vehicle should be equipped with collision avoidance systems capable of preventing or mitigating an emergency situation likely to result in a crash.* The vehicle should be able to react to any such situation, using its available functionality to avoid or mitigate a collision to the best of its ability. Technology to address collisions with other vehicles and vulnerable road users includes, for example, AEB and lane support systems for lateral control.
Back-Up Systems	*The assistance system should clearly indicate to the driver a reduction in assistance as a result of vehicle sensor or system failure.* System should provide sufficient warnings if the system becomes unavailable and should be capable of a controlled hand back to the driver
Accident Data	*Limited data set should be provided in the event of an accident.* Where data can be made available, this should be provided in line with DSSAV specifications.

Communication Timeline and Media Coverage

The communication timeline for publications and associated media activity to date is summarized below .

July 2017 – **Regulating Automated Driving** [1] - R79 Strategy Document – laying out issues – fed into the UK Automated and Electric Vehicle Bill (AEVB) to ensure Insurance needs addressed.

November 2017 – **Clarity in an Uncertain World** [2]– first iteration of 10 Rules of Automation Framework

May 2018 - Publication of **Assisted and Automated Definition** [3] – Framework doc defining both insurance issues and ten criteria for Automated and Assisted vehicles. This formed the basis of defining a test procedure for Insurers and Euro NCAP as well as wider adoption by International Insurers – GDV FFA IBC

June 2018 – Presentation '**Assisted and Automated Driving – International Insurance Views**' by Matthew Avery to UN ECE WP29[4]

The Assisted and Automated Definition launch attracted significant media attention worldwide with 250 pieces of coverage in the week following launch with a reach of more than 550 million. Pre-launch interviews/demos were conducted with BBC News[5], WIRED, The Guardian, Insurance Times and Press Association. Key broadcast coverage included BBC Breakfast, Radio 4 Today programme, BBC national and regional news updates, plus BBC Online. Worldwide the launch was covered in more than 20 countries, across national and technology media, especially within US. Social media generated over 320k video views on YouTube and social channel plus tens of thousands of social posts/commentary. Overarching sentiment across all media was that terminology used needed to change.

DISCUSSION AND LIMITATIONS:

The development and communication of the Assisted and Automated Driving rules has been very successful in breaking some of the public misunderstanding of both the vehicles and the media messaging. The rules are intended to be a benchmark which will continue to grow and evolve as the technologies come closer to publicly available vehicles and approval standards.

There is an ongoing challenge to build consumer understanding that will need to be reinforced as we move towards the first Automated Vehicles in particular providing sufficient education and support in promoting safe system usage.

This work continues to be built on. The next iteration will be a further level of technical detail to produce a Definition of Safe Automated Vehicles with a more regulatory level of detail. It is likely that this document will lay out detailed criteria to establish what threshold a Level 3 vehicle would need to reach to be classed as Safely Automated.

CONCLUSION

Although the communications outlined in this paper have evolved with the fast pace of technology, there is still considerable work to do to ensure the development and adoption of safe automation is achieved. The 10 rules of automation have provided the basis for a framework for regulators, OEMs and safety test development. This will need to continually evolve as AD systems come closer to market and regulation of ADS moves forward.

We recognize that there is also considerable work to do to build understanding within the general population who do not have a sufficient understanding of the likely benefits and limitations of Automated Vehicles. However, we also need to recognize that the work already undertaken has helped to build a common baseline for regulators, OEMS insurers and other stakeholders to work from.

REFERENCES

[1] Thatcham Research, ABI : Regulating Automated Driving https://www.abi.org.uk/globalassets/files/publications/public/motor/2017/07/regulating-automated-driving/

[2] Thatcham Research, ABI : Clarity in an Uncertain World https://www.abi.org.uk/globalassets/files/publications/public/motor/2017/11/clarity-in-an-uncertain-world---final-version.pdf

[3] Thatcham Research, ABI : Assisted and Automated Definition Summary https://news.thatcham.org/documents/assisted-and-automated-definition-and-assessment-summary-79399

[4] Matthew Avery : Assisted and. Automated Driving –. International Insurance Views https://wiki.unece.org/download/attachments/60364189/%28ITS_AD-15-05b%29%20UN%20Deck%20June.pdf?api=v2

[5] BBC Technology : Car insurers warn on 'autonomous' vehicles https://www.bbc.co.uk/news/technology-44439523