Breakout Group B

Notes/Feedback

Key Ideas:

- A consensus effort is required
- **Help** establish a safety methodology that the standards bodies can translate into standards and other stakeholders can use to advantage:
  - **We can help move things along in the short term. It is not reasonable to expect us to develop the gold standard in methodologies up front - it will be a long iterative process. We need to enable this process**
    - What is the lowest common denominator that we all agree on and begin from this
    - Need to define roles and responsibilities for the process we will embark upon
  - How far do we have to drive things over the next 6 months to a year
    - We can use what exists today and drive towards an agile framework for testing
    - Establish metrics - we can do this in the short term
    - A mix of metrics e.g.: collisions, rules of road violations, etc
    - Bring human driver and law enforcement, first responders, school bus drivers etc. into the discussion
    - Get candidate methodology(s) out to the public and media for feedback - get public into the loop ASAP

Key Ideas (cont.)

- **Next steps for what? Widely adoptable safety methodology**
  - **Assemble team of knowledgeable experts to start drafting framework**
  - **Need to begin capturing in documents**
  - **Need to evaluate what we have and roll into frameworks**
  - **Identify core scenarios that equate to basic driving skills and methods of testing capabilities in those scenarios**
  - **Use risk analysis to identify representative set of edge cases outside of core scenarios to ensure capabilities beyond core in most important edge cases**
  - **Develop objective test methods for core and edge scenarios**
  - **How do we select amongst the infinite number of edge cases which ones are really important that we need to focus on**

1. What are appropriate definitions of ‘safety’ in a measurement context, including whether it may be a system measure, a component measure (hardware, software, etc.), a behavior/performance measure, or some combination of these?

Safety Definition:

- Don’t kill, damage or hurt anything or anyone including property damage
- No fatalities
- Is safety equivalent to current defs/standards or does it have to be better?
- What benchmark should we use? Fatality, injury rates, protect life.
- Need to evaluate system safety as well as performance requirements - need to eval unintended consequences
- How far out are we looking to define safety - today’s requirements are different than what will be implemented in the future
  - Assume 20 years out:
- Need to use probability as the basis for safety definition - need to use probabilistic math to assess system safety - need to assign risk to all ADS activities and use math to assess system level risk
- Will humans accept machine error - will ADS equipped vehicles have to act flawlessly

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Metrics/Measures

- Have to define metrics and use them to calculate if ADS performance is within acceptable levels of safety
  - System level safety metrics/measurements are required
  - Foreseeable and unforeseeable, preventable and unpreventable – need metrics and methods in each category
  - Qualitative versus quantitative metrics: needs to address needs of policy makers and testing community
  - Number of handoffs back to human for L3
  - Metrics apply to all SAE levels - we will consider L4
  - Thermal, G levels, Psychological effects - need to address all of these We need to drive towards consensus around metrics
  - Comfort is a business issue more than a safety issue. Need to focus on actual physical harm
  - Is a near collision a safety issue – is it a metric that should be measured?
  - Need to address probability of safety measures – how to measure this probability is a key challenge
  - Behavioral measures may be more important than component safety measures - need to establish system level safety evaluation capability
  - Behavior of ADS vehicles needs to be assessed with respect to other ADS vehicles and human driven vehicles
  - Need to be careful with metric definition as may enhance tech development but could impede ADS deployment
  - Measures need to take risk reward into account - perspective and outcome based evaluation
  - Need to develop measures in advance of deployment that will give user community confidence. We will have to adapt safety measures as technology is deployed
    - We need to define a minimum bar - maybe 10 fold improvement in current safety
  - Need to define mathematically so machines can implement/understand
  - Evaluation by third party is important need
  - If your insurance company is willing to insure a vehicle - this will be a critical quantitative measure - and liability will define what levels of safety are required
  - Actuarial assessment needs years and years of data - how do we get this data given pace of technology implementation
    - Frequency and severity of damage will define insurance acceptability
  - Transparency of the system is critical - needs to be able to tell us what and why it is making decisions
  - Need to understand how ADS systems interact with other ADS systems and human drivers – and why
  - Need to enable VtV communication collaboration
  - Pedestrian avoidance - can we define a three strikes and your out measure - can we accept that pedestrians can be at fault or do we need to be 100 percent protective of pedestrians

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Other thoughts:

- There needs to be congruency between public expectations and real word performance
  - One is an objective measure and the other depends on the individual
  - Public perception is a key concern - need to define safety with this in mind
  - Have to be careful given human issues with assessing risk
  - Perception is important as humans will not accept tech if perception is negative
- At certain point will get herd immunity from the number of vehicles deployed and from the duration of deployment
  - Percent of ADS in a ODD impacts the safety performance in the ODD - need to take this into account
- Need to account for how ADS was driving at time of accident - need to be able to collect this data
  - Sharing data and keeping it over time may be problematic - as tech will change and data will not be compatible
  - Insurance companies will have to figure out how to massage data

2. Is there a need for widely-adoptable measurement methods for ADS-equipped vehicle safety? Are there risks in not pursuing such methods? If so, what are some examples?

Strong consensus for the development of widely supported measurement methods

- There is a need for the stakeholders to take what already has been specified and expand on it . Need to address long term efficiency
- Concern - there is no silver bullet - measures will be applicable in some domains but not in others or for specific operations
  - Delivery systems vs passenger carriers as an example - they have very different requirements

- Can we use the existing standards/measures for vehicles as the baseline for ADS enabled vehicles?
- Big question is how to develop the methodology - who takes responsibility for developing them - how can this be done
- We need to develop common set of higher level scenarios and ODDs and then can develop specific measures from these - keep the common methodology general and then allow community to differentiate on them basic scenarios my form an entry level path to an ODD
- Example - can you negotiate a cloverleaf - this is an example of a test - that will define what ODDs a particular ads VEHICLE CAN OPPERATE IN
- Pursuit a measurement approach - need to make sure that measurement methods defined cannot be gamed
- Is there value in having a basic set of tests - at least this establishes a baseline even if they can be gamed
- Introducing a variability methodology will prevent gaming

2. Is there a need for widely-adoptable measurement methods for ADS-equipped vehicle safety? Are there risks in not pursuing such methods? If so, what are some examples?

- We can think about gaming potential and make sure we develop methods to minimize potential
- Companies that self evaluate their approaches - this is a good thing - companies will be cpompelled to effectively address safety
- Standard methodology can help inform the public
  - Stars on cars for automation - can define methods in ways that are understandable to the public
- Let states dictate safety testing requirements - define a program and evaluate performance of car against it
- Feds would define a menu of safety requirements/tests and each state would chose the applicable tests from this menu
  - This allows ads to be certified for entire country and yet be certified for individual states
- Each state can define the ODDs that you have to comply with in their state and your ADS vehicle needs to prove compliance
- Question how do you prevent ADS from entering a state's roads for which it is not certified
- Each state needs a working group for AV safety requirements
- We could look at the emissions as a model for how to establish requirements - vary from state to state
- Can we use geofencing to address vehicles entering ODDs that are outside their certified capabilities

3. What are possible safety measurement methods (simulation, test track, on-road, etc.)? What are possible safety metrics (miles driven, pass/fail vs. formal model, etc.)?

Measurement Methods:

- Develop approach that deploys simulation, off road and on road testing appropriately - optimal combination of all three approaches
- Sim vs on track - model based assessment - need to be able to evaluate the validity of the modeling
- Derive synergies from the learning from local, state, national stakeholders, regulators, overseers, etc from feedback from first responders
- Metrics should guide tech development but may inhibit deployment
  - Flagging is an issue - different approaches in different localities

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Possible Safety Metrics:

- Statistical:
  - Outcome measure - harm to external things
- Behavioral: Have list of scenarios and have performance requirements assigned to each
- Testability & trust: Need to be cognizant that developers can fudge results associated with scenarios
  - Need live assessment of performance to scenarios by testing agencies
  - Need to assign probabilistic requirements to performance against scenarios
- What activities are correlated with accident causation - may need to use these as measures in many cases
- Process measures - did you complete a certain safety process or not
- Reliability and availability of a system
- Safe Distance / TTC & acceleration
  - should not be a metric but rather a programmable variable
- RSS - very mathematical - also need to define safety using human concepts - safe distance, etc - so can easily explain approach to safety to humans
- Amount of redundancy is important - look to aircraft industry
- Should be able to predict where a vehicle should be accurately for short time intervals - can use this to advantage

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Issues:

- Leading and lagging indicators - need to take into account when developing metrics/measures
- Metrics should not inhibit technology development
- How do ADS systems safely extract themselves from safety challenges - learn this from human approaches
- Need to make sure that psychological impact on passengers in acceptable - cannot cause heart attacks, etc.
    - Need to monitor stress levels on passengers
    - This will vary based on ODD
- Different metrics required for different stakeholders
- Need to be able to communicate needed updates to full community of ADSs - to implement corrections rapidly
- Update process need to be compatible with realtime processing in the ADS vehicles
- Metrics need to be ODD sensitive
- We need to work as a community and take the best existing ideas and integrate them and continue to refine and broaden them
- There are safety tests that are too expensive - need to have approaches to test these scenarios
- Need to implement (use existing proven approaches where applicable) diligent S/W validation procedures - regression, etc
- We need to have an adaptive approach to safety that learns from what we learn as the deployment process proceeds
- Safety metrics have to be reevaluated and refined as deployment proceeds.

4. Are there emerging best-practices around pre-deployment safety measurement methods? Around post-deployment measurement methods? (including the methods and metrics described above).

- Simulation approaches and the off road and on road testing are a good start
  - Number of miles driven
  - Scenarios
  - ODD specific scenarios
  - # of Disengagements
- For post deployment
  - Crash reporting data
  - Comparative measure against human drivers
- Need to develop safety matrices out of the shared DATA being collected
  - VSSA process is a good start for this
- From aviation sector mops minimal operational performance standards - we need to develop these for ADS
  - How do the various players in our highway environments interact with each others
- Common approach is good - provides basis for establishing that have performed your due diligence
- Need to make sure that safety requirements address needs and concerns of the breadth of public groups - need to be inclusive of the target groups in the design process
- Manufacturers need to test against their competitors vehicles and the breadth of other vehicles
- Resilience - ability of ADS systems to recover when faced with anomalies
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- For human drivers in the future - need to test abilities against and ADS equivalent
  - This has been used to establish requirements for ADS - use humans as the standard
  - Needs to be an excellent human driver - we need to define what this is - will help us establish ADS requirements/benchmarks
  - RSS is a start
- What is the coupling between pre and post deployment measures - need to establish this
- Third party certification - how does this play
  - What would we certify against?
- Need to build dynamic test tracks –
- Go/nogo concept - simulation on board of vehicle can help establish the health of an ADS both pre and post
- Need to compare human perception against capabilities of sensors - can break down to different components of the driving task
- For crowd sourcing input - participants need to have skin in the game to give valid input
- Look at each of the elements of the ISPO standards and apply to ADS needs
- Even though 262 is a process defined standard there are inputs we can provide along the way to augment it
- MUTCD as a reference
- Post deployment - CA DMV
- Run time verification is important

5. Should measurement of human response to ADS-equipped vehicle safety be a part of the calculation and, if so, in what way?

We will evaluate at L4

- Humans outside the vehicle? What response do we need to account for from them?
  - so inattentive pedestrians need to be accounted for
- Needs to be consistency of intent communication - cars need to communicate effectively with all road users - predictable and consistant
- Difficult to establish measurement of how pedestrians, etc are responding to ADS vehicles
- Vehicles need to be predictable in their behavior - well above human driver
- Can you measure the consistency of the prediction of other road users
- Measure - throughput and efficiency of an ADS system - how efficiently are the systems achieving their transportation goals
- TTC as a measure is good.
- Need to investigate/study how people interact with ADS - this will inform how we develop standards/measures
- How well does a pedestrian understand the intent of ADS vehicles
- How do you allow rules to be violated to allow an ADS to move forward and not create gridlock, inefficiency, etc.
  - What does this mean for enforcement ?

5. Should measurement of human response to ADS-equipped vehicle safety be a part of the calculation and, if so, in what way?

- Need to separate perception of safety to what is actually safe
- How will pedestrians, etc adapt to the realities of ADS behavior. And accommodation to pedestrians by ADS.
  - A lot of the development of the behavior of a vehicle will establish non verbal communication norms
- From inside the vehicle: can the driver make executive decisions and take over as required. And visa versa
  - Varies depending on level of automation
- More likely that ADS vehicles will have conventional seating layouts and with traditional controls. Need to think through how these controls can be deployed unintentionally
- Need to understand how the behavior of the ego vehicle impacts the other players in the environment
- Need protocol that ADS vehicle can use to communicate what its intention is to the passengers - needs to be adaptable to the individual
- We need to be very careful about human intervention - may do things that are less safe
- Collision avoidance - Predictability - comfort and accessibility of the passengers these are the key measures that oems need to address

6. What are possible next steps?

- Look at exiting data, what are the high level ODDs that need to be addressed and develop high level requirements from these
  - Scenarios involving crashes
  - Scenarios that capture the needs of various ODDs
    - Use these as the basis for establishing a methodology
- Think outside of the automotive domain - how can we bring in BKMs from other industries
- Need to develop an organization approach to developing the needed methodology
  - Engineering and risk frameworks
- Outreach to state and local orgs to get input
- Need to establish a risk register - need to establish what is the min operational performance
- Best practices should be shared with State DOTs
- **Next steps for what? Widely adoptable safety methodology**
  - **Assemble team of knowledgeable experts to start drafting framework**
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- For each safety issue, who is responsible for implementing/ handling who has the burden of proof for establishing compliance and approach
  - Need a repository for the community
- We need to have basic goals that are acceptable to regulators and the public - and establish methodology/metrics based on these. May be a chicken and egg issue
- End goal is to establish a methodology that is understandable/explainable to the public
- Build trust in systems - need to communicate that we have full coverage - how do you exploit simulation and on and off road testing to achieve this
- What is the scope of the community wide work and who is going to execute it and who is going to lead it
- Need to build on what already exists and drive things to next level - take systems engineering approach
- Need to gather the key scenarios that are essential to establish reasonable safety
- Need to agree on a standard set of tests
- What is needed to execute the tests - what infrastructure and funding is required
- Certification authority needs to be identified who can certify that a particular ADS vehicle is safe to deploy

6. What are possible next steps?

- We need to establish a methodology for safety that standards can be derived from by the standard bodies
- We need to establish metrics that we can use to drive the definition of a methodology - how do other industries establish metrics - what can we adopt
- Compare standards to legal requirements- what is the legal high bar - what are the needed liability standards
- How do we get more objective about establishing a methodology in a broadly community supported way
- Engage public to ask them what would make them feel safe - a contest
- How far do we have to drive things over the next 6 months to a year
  - We can use what exists today and drive towards an agile framework for testing
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