Evaluating Safety of Automated Driving Systems (ADS)

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Need for Robust Evaluations of ADS Safety

- **To satisfy needs of multiple stakeholders:**
  - **Internal ADS company risk managers**
  - **Government regulators**
  - **Insurance industry risk underwriters**
  - **Potential ADS fleet operators**
  - **General public and media**
- **To demonstrate that ADS can improve traffic safety**
- **To earn trust of people so they will be willing to use ADS and share road space with them**

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Most Difficult Impact to Evaluate

- **Safety-critical events are rare, on extreme tails of statistical distributions**
- **Hard to test, for technical and ethical reasons**
- **Very hard to simulate extreme conditions**
- **Very little real-world test data available in public**
- **Results need to be explainable to non-technical audiences**
  - **public and officials have poor understanding of risks**

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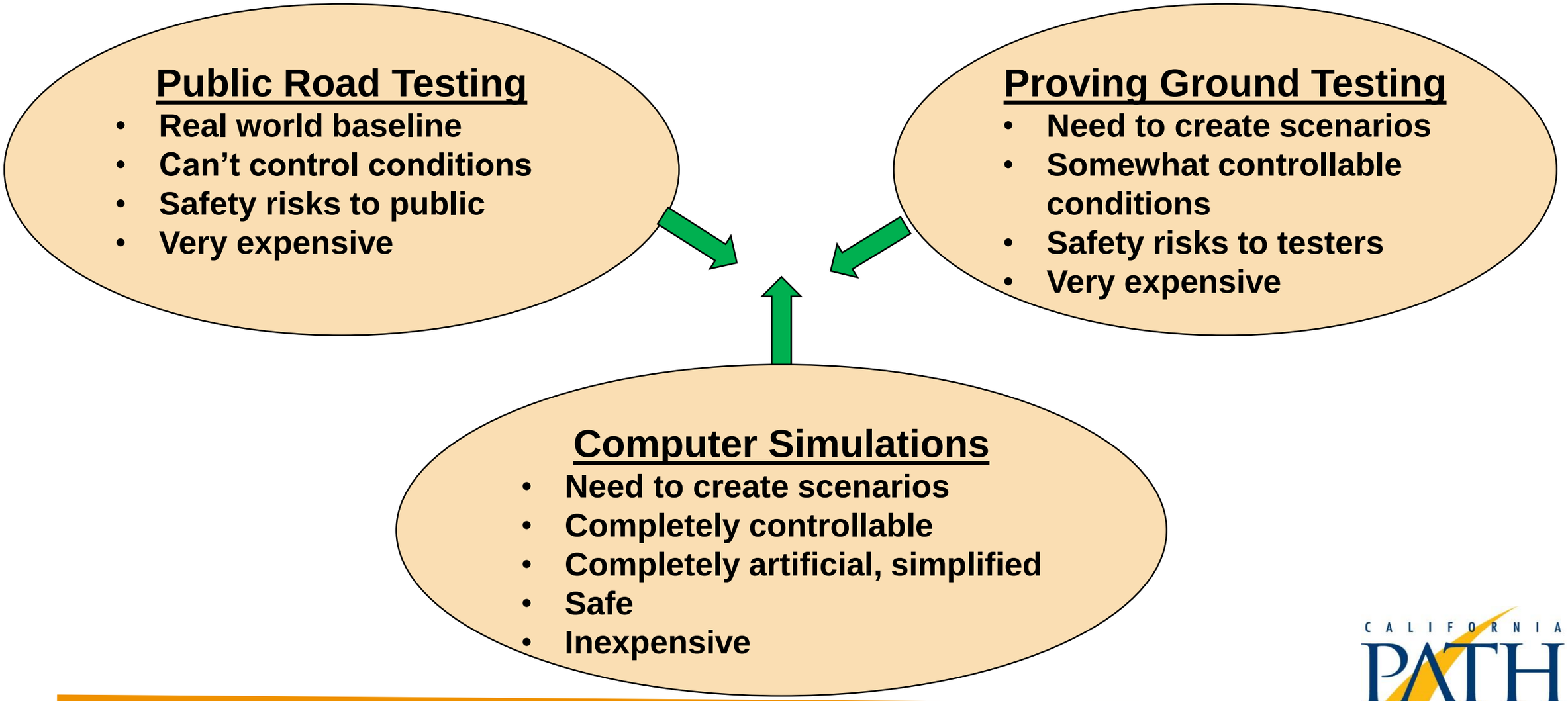
Integration of Results from Multiple Methods



Challenges in Defining Scenarios

- **Real-world hazard scenarios are near-infinite in number, and frequency of occurrence of each is unknown**
- **Each real-world hazard scenario has many dimensions – motion vectors of all vehicles and VRUs, road geometry and surface, traffic controls, weather, lighting, vehicle condition,…**
- **Crash data reports don’t provide sufficient detail**
- **How to prioritize estimated frequency of occurrence and severity in selecting scenarios to test or simulate?**
- **How to determine the sufficient set of scenarios to “prove” safety of each ADS?**

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Challenges in Validating Simulations

- **Pre-crash and crash behaviors of drivers and vehicles are the most difficult to model and validate**
  - **Extreme conditions (tails of distributions)**
  - **Limits of performance of all technologies**
  - **Very hard to perform tests for these conditions**
- **Unavailability of validation test data sets**
- **How to define validation criteria? (How closely do simulation and test results need to match?)**
- **What happens when simulation runs outside the range of validation data?**

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Need to focus on “failure” rates

- Failure rates determine crash statistics
- Human drivers’ failure rates are already very low
- ADS failure rates must be demonstrably lower
  - From 1 in 100,000 miles to 1 in 1,000,000 miles is a factor of 10 (more understandable than 0.99999 versus 0.999999 success rate)
  - Each additional factor of 10 in safety gets harder (rarer and more complicated hazard scenarios)
- Remaining ADS development effort scales <u>at least</u> with needed reduction in failure rates

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Start with Disengagements in Public Road Testing

- **California requires ADS testers to report when test drivers take over control for safety reasons**
- **Dozens of companies testing hundreds of vehicles accumulated 12.5 million miles (20 million km) of automated driving in California from 2015-2021.**
  - **Some report every disengagement**
  - **Some report only disengagements that avoided a crash (based on "counter-factual" simulations)**
- **Data since 2015 show trends in frequency and causes of disengagements**

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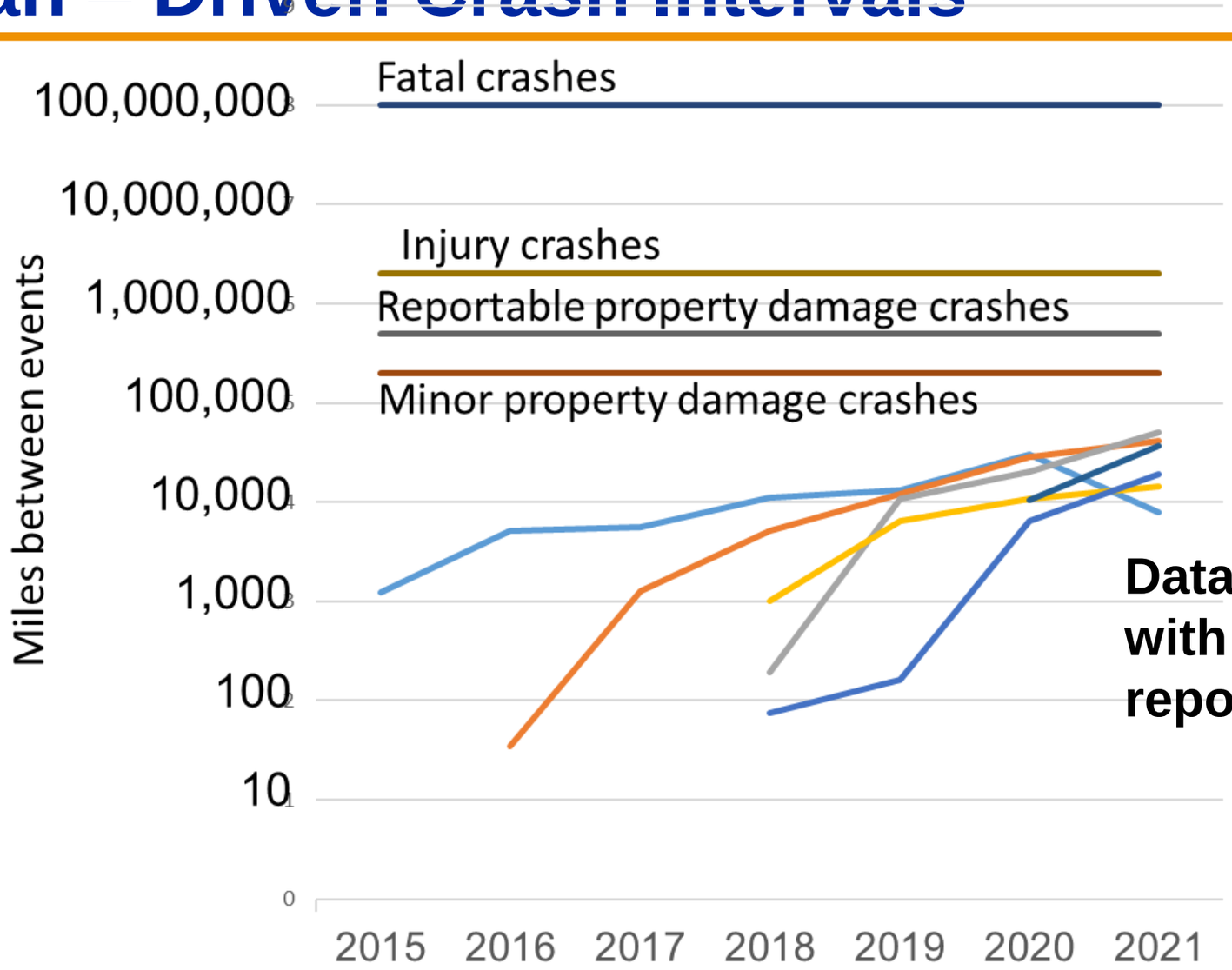
Safety-Related ADS Disengagement Intervals vs. Human – Driven Crash Intervals



Data for the 6 companies with the least-frequent reported disengagements

Much more work is needed….

- **Disengagement reporting enhancements to increase completeness and consistency**
- **Agreement on most meaningful safety measures of effectiveness to apply**
- **Methods for identifying the scenarios necessary and sufficient to prove safety of each ADS**
- **Large improvements in realism of simulations**
- **Safety simulation validation methods and testing datasets for validation versus reality**

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