



Prof. Philip Koopman

Automated Vehicle Safety Update for 2021

February 2, 2021

**Carnegie
Mellon
University**



@PhilKoopman



**EDGE CASE
RESEARCH**

- Where is the industry in general as of early 2021?
- Beyond the SAE Levels
 - Role of human vs. technology
- Industry trends for 2021
 - Role of standards
 - Technical challenges
 - Organizational challenges



■ Low speed shuttles

- Up to 15 passengers
- Fixed route at perhaps 5-10 mph
- Demonstrations in cities worldwide

■ Safety approach

- Slow speed limits kinetic energy
- Often a non-driver safety conductor

■ Example Mishaps

- Shuttle hit by backing truck (Las Vegas, 2017)
- False alarm emergency stop with passenger injury (Ohio 2020)

NHTSA lifts suspension of EasyMile vehicles



Smart Columbus

<https://bit.ly/39ki41t>

By [Cailin Crowe](#)

Updated May 19 2020, 10:30 a.m. EDT • Published Feb. 27, 2020

- **Parcels to stores, houses**
 - Short range delivery
 - Roads, bike lanes, sidewalks
 - Demonstrations in several cities
- **Safety approach**
 - Early: trailing vehicle
 - Later: remote human
- **Example Incidents**
 - Sidewalk bot blocks wheelchair ramp (Pittsburgh, 2019)
 - Tension over use of sidewalk space

Nuro Gets First Commercial Autonomous Vehicle Permit in California

Prepare yourself mentally to see a Prius driving itself if you live in the Bay Area.

 BY JAY RAMEY ♦ DEC 31, 2020



■ Automated driving of car or truck

- Continuous driver supervision
- OEMs in production already

■ Safety approach

- Human driver monitors automation
- Human driver responsible for safety

■ Example Mishaps

- Multiple fatal Tesla crashes
 - Issue: driver complacency
 - Issue: under 10 seconds from OK to fatal crash
- Tempe Arizona fatality in testing (Tempe, 2018)

NTSB: Tesla Autopilot, distracted driver caused fatal crash

By TOM KRISHER February 25, 2020

<https://bit.ly/3bnk3EZ>



■ Fleet vehicles

- Waymo robotaxis deployed a limited scale
- Middle-mile trucks gained interest in 2020
- Many players pushing hard in this area

■ Safety approach

- Early: Human safety driver
- Later: Human on-call if car asks for help

■ Example incidents

- California reports indicate minor incidents in testing

Waymo's robo-taxi service opens to the public in Phoenix

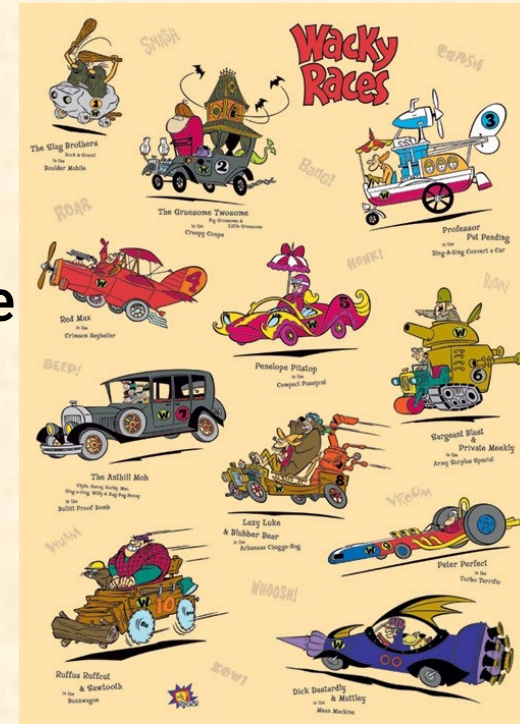
Reuters October 8, 2020 9:15 AM AI f t in



<https://bit.ly/39j4yeC>













Waymo's fully self-driving Jaguar I-PACE electric SUV
Image Credit: Waymo

- Consolidation in the “race” to autonomy
 - It takes huge resources to succeed
 - Trend to OEM + ADS supplier teaming
 - Smaller players fail, team, or acquired over time
- Fully autonomous pivot toward freight
 - Low kinetic energy for last mile service
 - Middle mile highways less chaotic than urban
- Shift of “SAE Level 3” vehicles to L3+
 - Strict L3 means human driver supervision
 - OEMs shifting to L3+ with car safe stopping on its own



<https://bit.ly/3s9ZzW9>

A User-Centric Classification

Operating Mode	Human Role	Driving	Driving Safety	Other Safety
Assistive	Driving			
Supervised	Eyes ON the road			
Automated	Eyes OFF the road			
Autonomous	No human driver			

Vehicle Automation Modes

Standards-Based Engineering Approach

SYSTEM SAFETY	UL 4600		Safety Beyond Dynamic Driving	HIGHLY AUTOMATED VEHICLE SAFETY CASE UL 4600
DYNAMIC DRIVING FUNCTION	ISO/PAS 21448	SaFAD/ISO TR 4804	Environment & Edge Cases	
FUNCTIONAL SAFETY	ISO 26262		Equipment Faults	
CYBER-SECURITY	SAE J3061	SAE 21434	Computer Security	
VEHICLE SAFETY	FMVSS	NCAP	Basic Vehicle Functions	

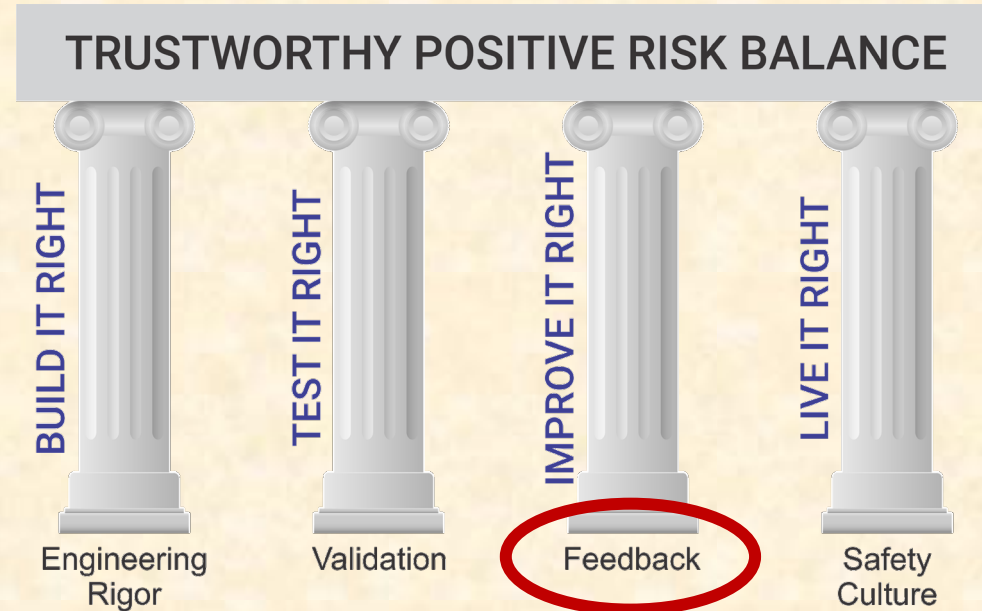


- Perception & prediction
 - Safety of machine learning-based functions
 - Need more than object motion tracking
- Safety of Intended Function (SOTIF)
 - Drive/Fix/Drive iteration with lots of testing
 - Waymo: 6M test miles; 65K deployed miles
 - How will safety be argued for larger fleets?
 - Likely will involve UL 4600 concepts and safety cases
- Getting from “works OK” to “safe”
 - You can brute force the first few “nines” ... but not all of them.
 - Field feedback into safety cases

- Still an open world with unknowns & changes
 - Want “Positive Risk Balance” (safer than human driver)
 - But ... *no human driver responsible*

■ Use Positive Trust Balance

- Engineering rigor
- Practicable validation
- Strong safety culture
.... and ...
- **Field feedback
to handle surprises**



- UL 4600 ties feedback to Safety Case

Safety Arguments (Safety Case)

- **Claim** – a property of the system

- “System avoids pedestrians”

- **Argument** – why this is true

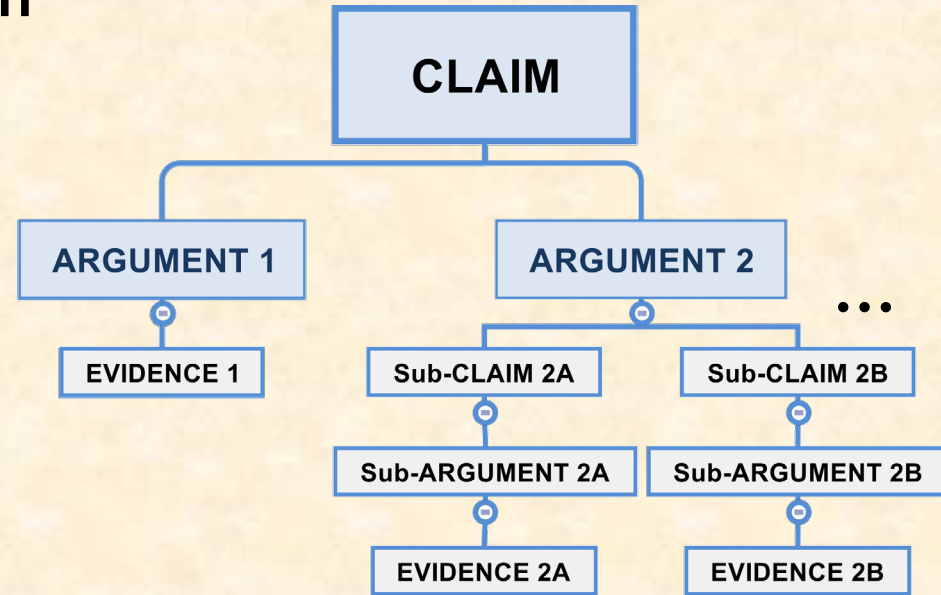
- “Detect & maneuver to avoid”

- **Evidence** – supports argument

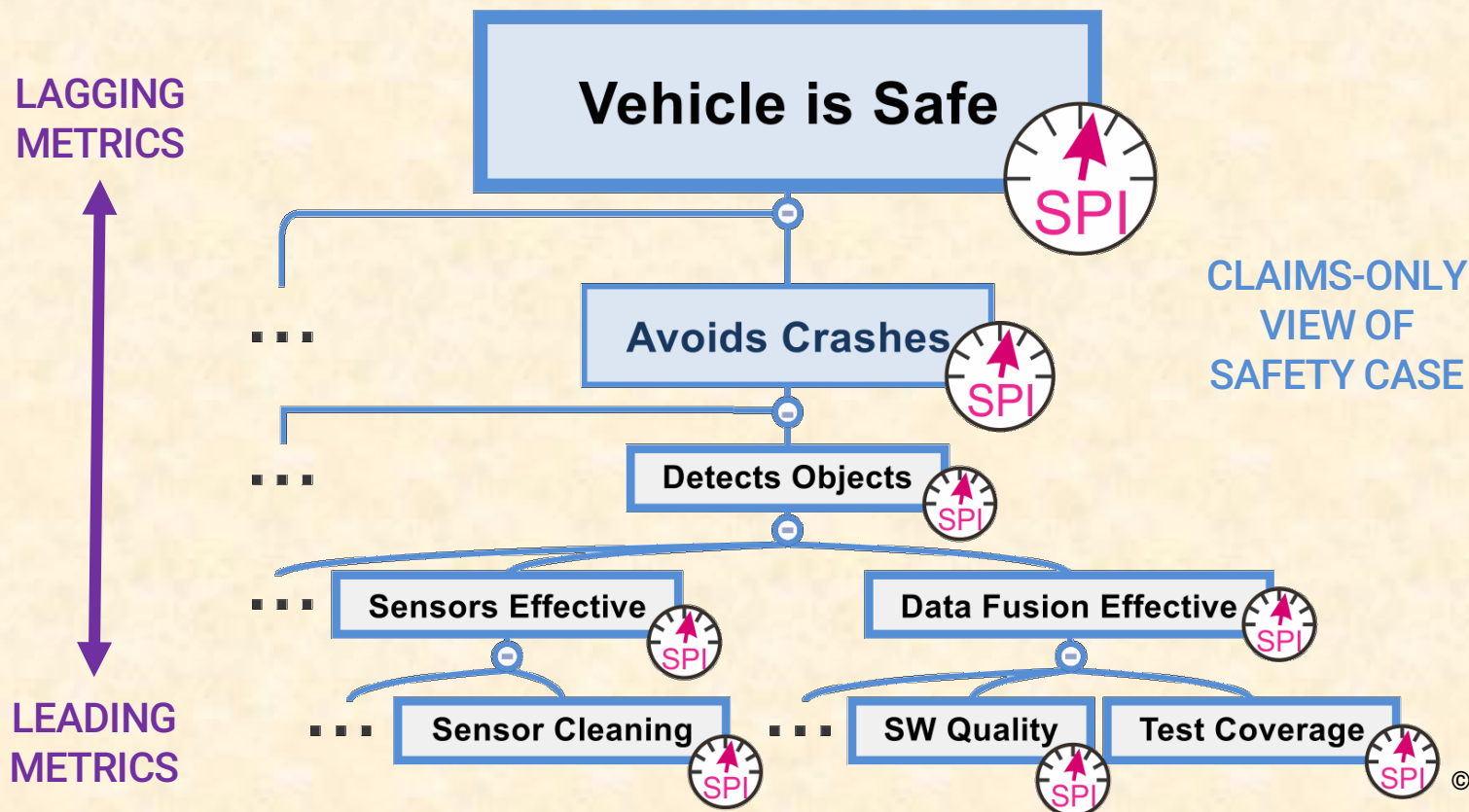
- Tests, analysis, simulations, ...

- **Sub-claims/arguments address complexity**

- “Detects pedestrians” // evidence
- “Maneuvers around detected pedestrians” // evidence
- “Stops if can’t maneuver” // evidence



- SPIs monitor the validity of safety case claims (UL 4600)



Examples of SPIs

- “Acts dangerously” is only one dimension of SPIs
 - Violation rate of pedestrian buffer zones
 - Time spent too close per following distance math
- Components meet safety related requirements
 - False negative/positive detection rates
 - Correlated multi-sensor failure rates
- Design & Lifecycle considerations
 - Design process quality defect rates
 - Maintenance & inspection defect rates
- Is it relevant to safety? → Safety Case → SPIs



- **Positive Trust Balance:**
 - Engineering Rigor, Validation, Feedback, Safety Culture
 - Standards-driven safety
 - Transparency
- **Safety Performance Indicators (SPIs)**
 - Continual improvement & updates
 - Field feedback: development; deployed
- **Scalability past pilot vehicles**
 - Accurate perception/prediction is still work in progress
 - Transition from brute force data to safety case approach





<https://youtu.be/nhqyrze30bk>
Yandex demo video,
Ann Arbor MI, Aug 2020

- **Significant pressure to deploy**
 - Flurry of empty driver seat demos in late 2020
 - Can teams take the time needed for safety?
- **Industry transparency needed**
 - Safety collaboration rather than competition
 - Public trust in face of an adverse news event
- **Ensuring robust safety cultures**
 - Silicon Valley culture + automotive culture + no human driver
 - We need to get this right to succeed!



EDGE CASE RESEARCH
WE DELIVER THE PROMISE OF AUTONOMY