National Transportation Safety Board

Pathway to Automation: Transition from CAS

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Overview

- Investigate the NTSB … Investigate them … follow-up on the implementation
- Path to Autonomous Vehicles

Perspective

Crash Investigation

- Level 2 AV (Williston, FL)
- Testing of AV (Tempe, AZ)

Public

Path to Autonomous Vehicles

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	*Monitoring* of Driving Environment	Fallback Performance of *Dynamic Driving Task*	System Capability *(Driving Modes)*
***Human driver* monitors the driving environment**						
0	**No Automation**	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	**Driver Assistance**	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes
2	**Partial Automation**	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes
***Automated driving system* ("system") monitors the driving environment**						
3	**Conditional Automation**	the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes
4	**High Automation**	the *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes
5	**Full Automation**	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**

Path to AV: Where We Were

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		the *driving mode*-specific performance by an automated				

Collision Avoidance Systems (CAS)

- **1995** - Examining the effectiveness of collision warning (CW) in heavy vehicles
- **2001** - Development of performance standards for CW and adaptive cruise control (ACC) in passenger and heavy vehicles
- **2008** - Examining the effectiveness of automatic emergency braking (AEB) in heavy vehicles
- **2015** - Installing CW and AEB as standard equipment in all vehicles; expanding NCAP to rate CAS

Today: Path Toward Automation

- CAS *assist* a driver in the performance of a driving task
  - Safety benefits by overcoming environmental factors
  - Safety benefits by reducing deficits in driver performance
- Level 2 automated vehicle systems
  - Possible additional safety benefits, but also
  - Potential cost due to reliance on driver monitoring
  - Retaining the safety benefits of CAS

Path to AV: Public View

Autonomous features we have today

- Automatic Emergency Braking
- Adaptive Cruise Control
- Auto Steering
- …

Path to AV: Public View

What is arriving tomorrow

US DOT image

Path to AV: Public View

Today (level 0 – 2)

Tomorrow (level 4 – 5)

Data availability

Takeover time

Maximum hands off time

Operational domain

Disengagement frequency

Driver engagement

Defining disengagement

Bullying of an AV system

Phased testing: roadways

Testing of AV systems

Phased testing: human operator

Enforcing driver engagement

Enforcement: who is at fault

Recording AV-related data

Path to AV: Public View

Today (level 0 – 2)

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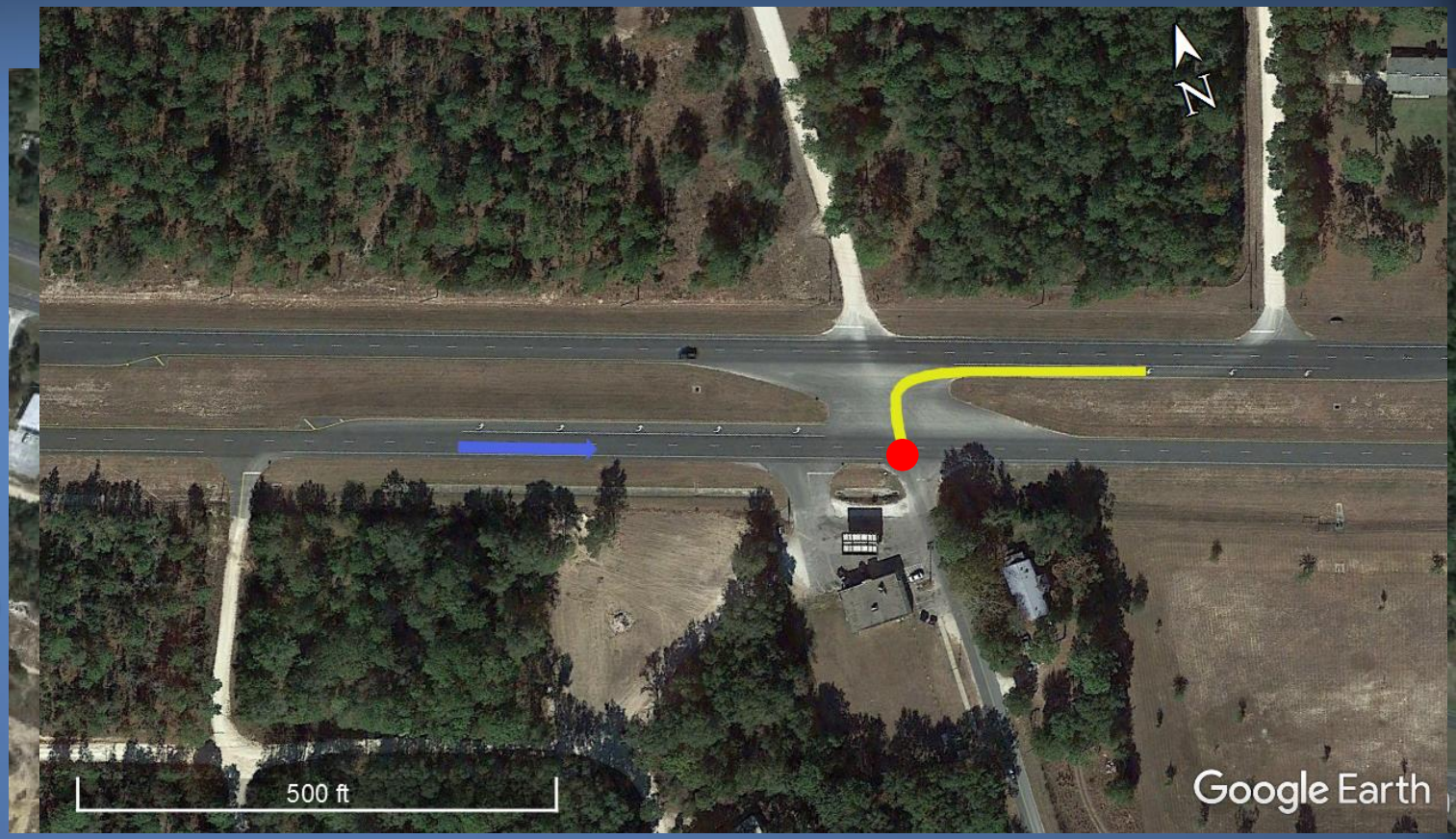
Tomorrow (level 4 – 5)

Williston, FL – Crash Overview

- May 7, 2016 ~4:36 p.m.
- 2014 Truck-tractor combination vehicle
- 2015 Tesla, Model S
  - Level 2 automation
- Daytime, dry roadway, no sun glare

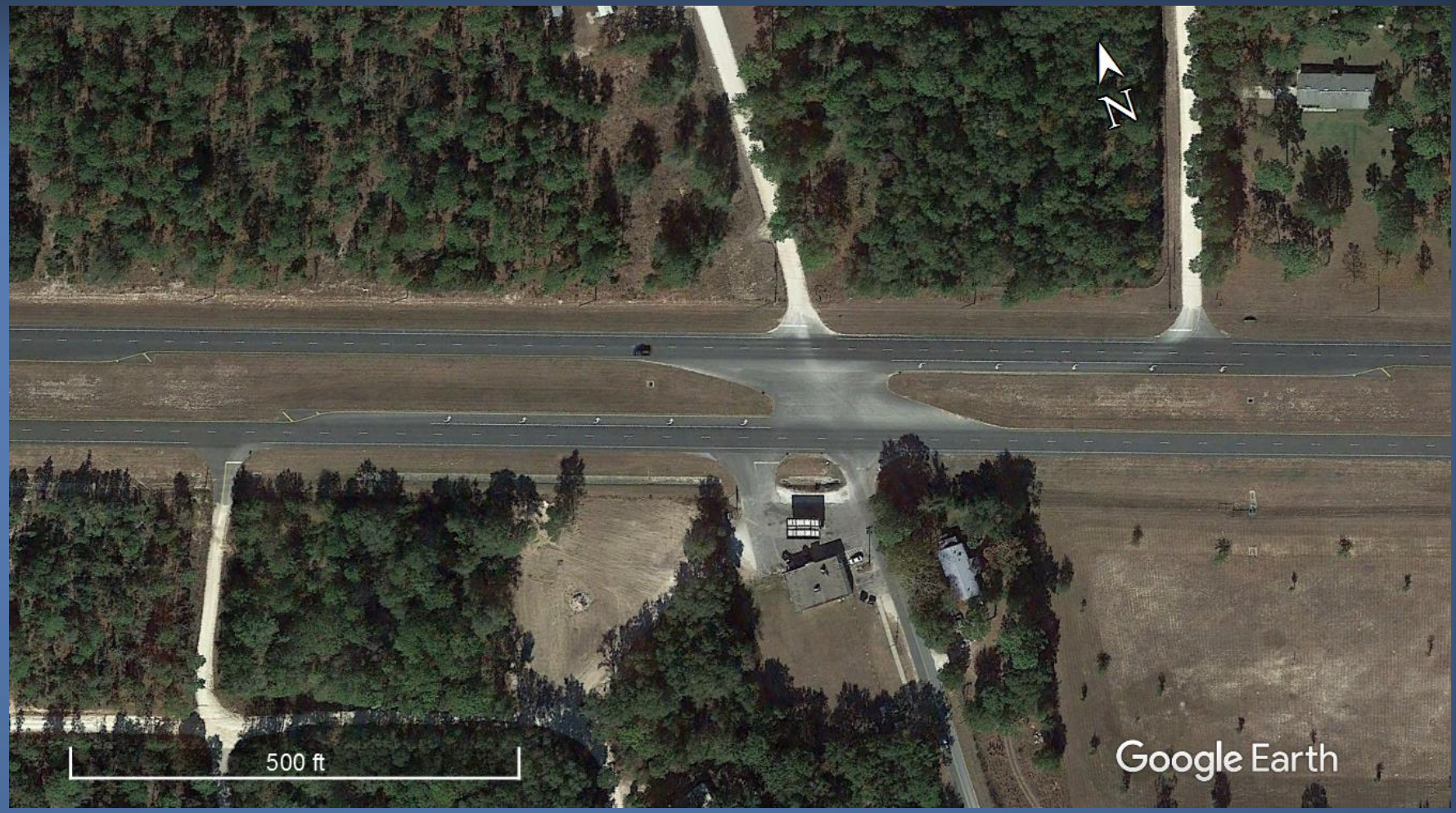


NTSB

Operational Domain: Roadway

US-27A

- 4-lane roadway
- With central median divider
- Not limited access
- Cruise speed limited to 90 mph



NTSB

Operational Domain: Roadway

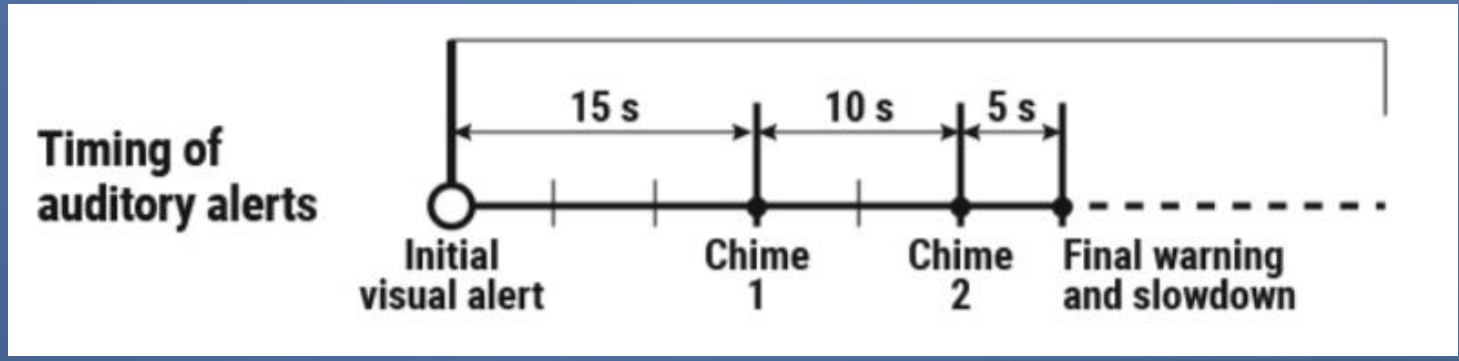
SR-24

- 2-lane roadway
- No central median divider
- Not limited access
- Cruise speed limited to 5 mph over the speed limit

NTSB

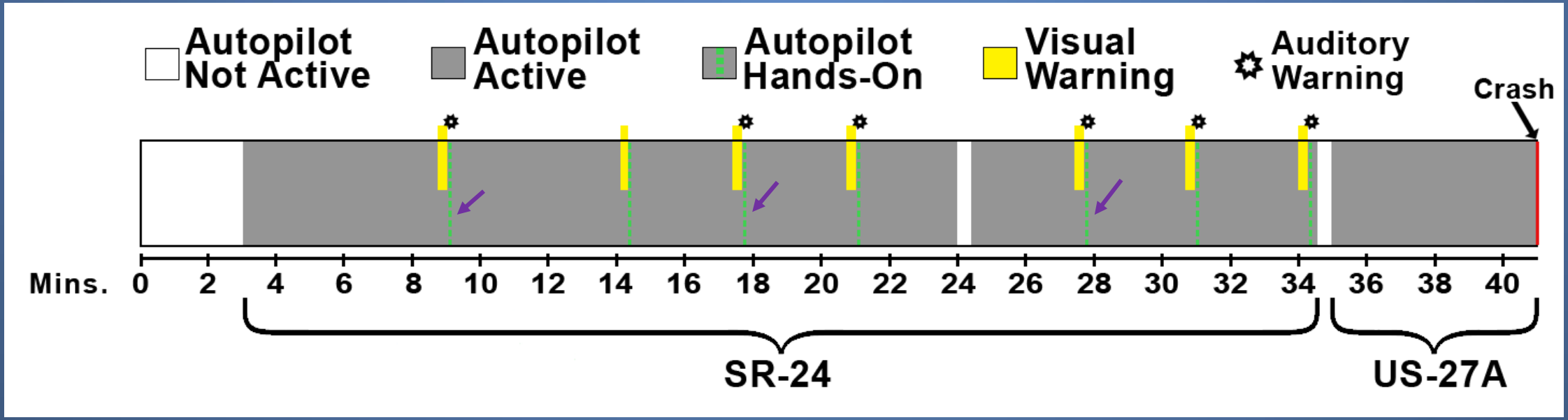
Driver Engagement

- Tesla monitored driver engagement through driver-applied changes to steering wheel torque
- Timing of the alerts after hands-free operation in Autopilot mode
  - Initial visual alert after 3-5 minutes when traveling above 45 mph
  - Additional 2 auditory alerts and a final auditory alert with a slowdown
  - No alert when traveling less than 45 mph



Driver Engagement During the Crash Trip

- Crash trip lasted 41 minutes
  - Hands on the steering wheel for 25 seconds
  - Autopilot was engaged for 37 minutes



NTSB

Conclusions and Recommendations

Autopilot operated within its limited functional capabilities, but outside its operational domain

- Driver-based adherence or system-based implementation
  - Recommendation: System-based restriction to its operational domain

Driver's lack of responsiveness indicated overreliance on automation

- Steering wheel torque a poor surrogate measure
  - Recommendation: Improved means of monitoring driver engagement

Other recommendations: AV data parameters and availability

Path to AV: Safety Issues

Today (level 0 – 2)

Availability of AV data

Availability of AV data

Testing of AV systems

Takeover time

Maximum hands-off time

Operational domain

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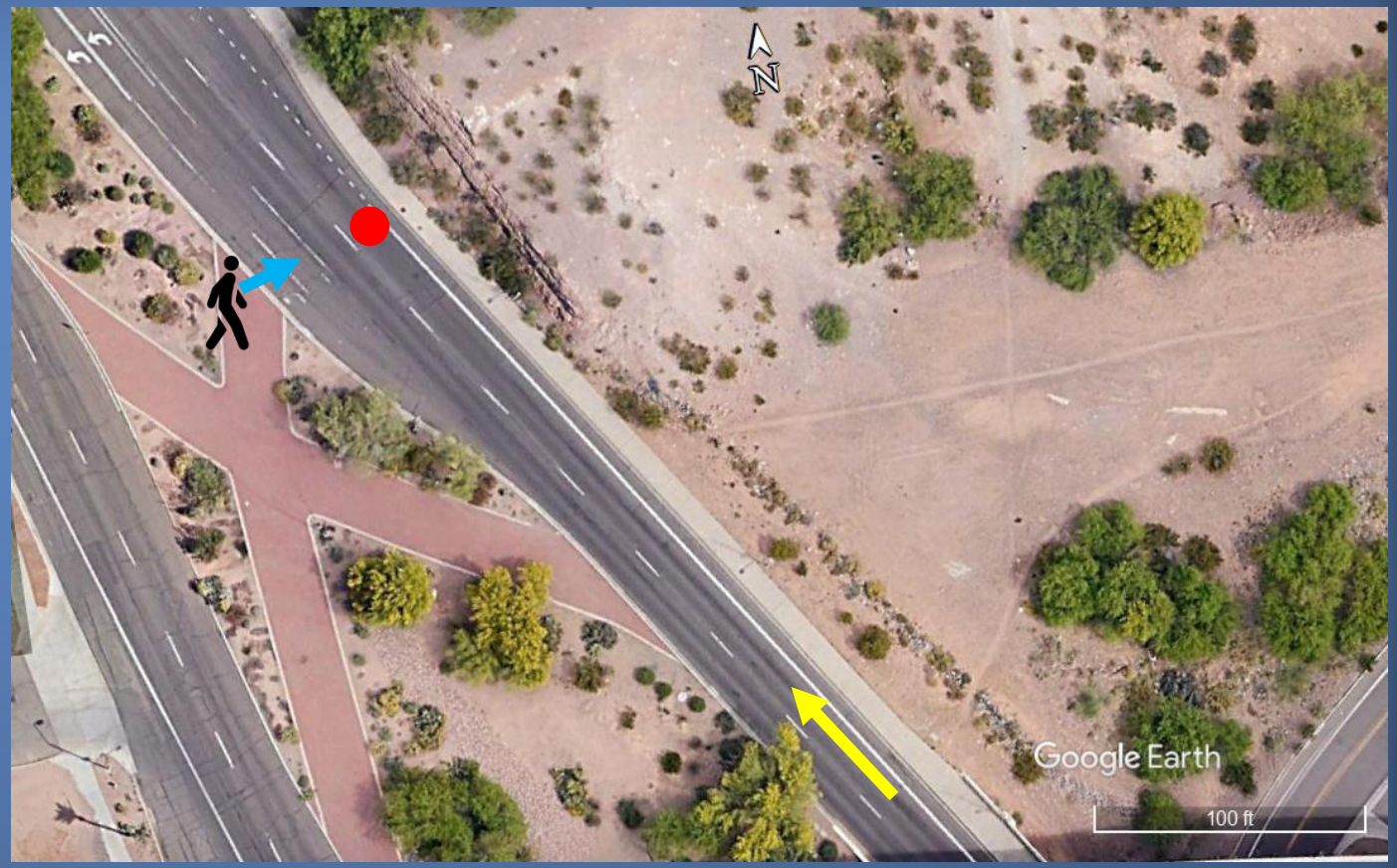
Enforcement: who is at fault

Recording AV-related data

Future (level 4 – 5)

Tempe, AZ – Crash Overview

- March 18, 2018 ~10 p.m.
- Uber test vehicle
  - Operated in autonomous mode
- Pedestrian walking a bicycle
- Nighttime conditions
- Roadside lighting present



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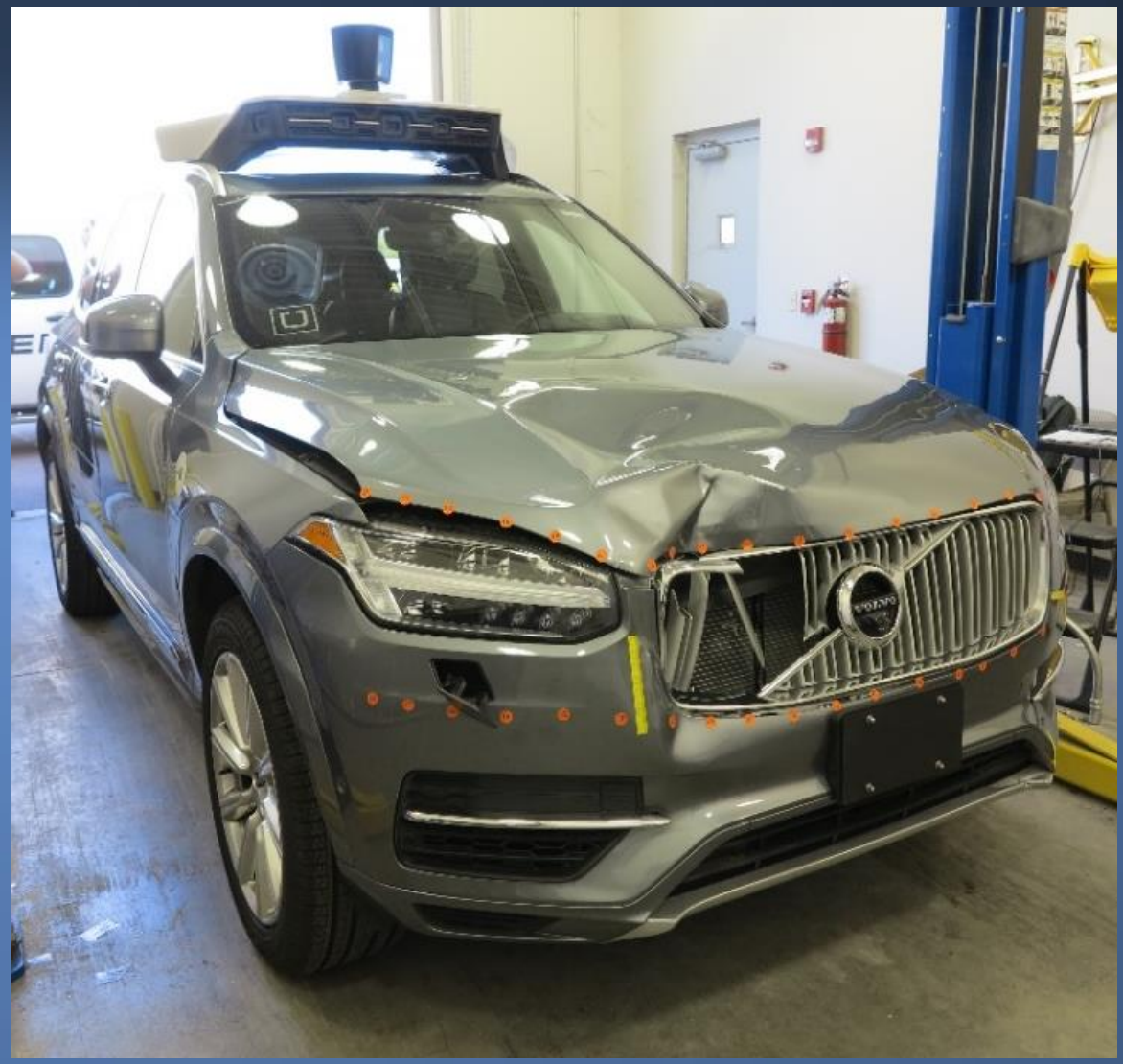
Uber Test Vehicle

- Built on Volvo XC90
  - Includes CAS with CWS and AEB
- Uber's autonomous system
  - LiDAR, radars, cameras
  - Disables Volvo's CAS



Crash Detection Sequence

- A hazard (pedestrian) detected 6 sec TTC
- The hazard changed to an unknown object, a vehicle and finally a bicycle
- Image at 1.3 s TTC
  - Speed of 43 mph
- Driver steered < 1 s

System and Driver Tasks

- AV system task
  - Follow the path; speed and lane position determined by the system
  - Does NOT engage emergency braking
- Driver task
  - Take over in case of emergency
  - Report events of interest (e.g., system disengagement)

All Issues Are Being Examined

- Highway design, pedestrian safety, …
- Testing of AV systems (not investigation-specific)
  - NHTSA and State requirements for public roads
  - Requirements dependent on an AV level
  - Phased complexity
  - Driver monitoring
    - Necessary or optional
    - In-vehicle or remote

Conclusion and Near Future

- The safety promise of AV systems
  - Retaining the safety benefits of CAS while progressing toward a fully autonomous vehicle
- Modulating public expectations
- Determining parameters or requirements for testing

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