National Transportation Safety Board

Multi-Vehicle Crash in Mountain View California (March 28, 2018)

Talking TIM Webinar (May 2020)

Robert J. Molloy, PhD.

Presentation Overview

- Automation in theory
- Vehicle automation
- The crashes
- The safety areas
- Actions needed

The Theory

Automation can eliminate
human error
by eliminating the human
from the loop

Crashes Involving Driver Error >90%

The Reality

Automation can significantly increase productivity, efficiency, reliability, throughput, and safety

but the downside . . .

The Downsides

"In their efforts to compensate for the unreliability of human performance, the designers of automated control systems have unwittingly created opportunities for new error types that can be even more serious than those they were seeking to avoid."

Prof. James Reason, University of Manchester (UK)

Vehicle Automation

Levels of Automation

No Automation

Driver Assistance

Partial Automation

- Supervise automation
- Maintain awareness
- Understand limitations
- Intervene when needed

Conditional Automation

High Automation

Full Automation

NTSB

Autopilot Description

- Monitors travel path
- Maintains set cruise speed
- Maintains vehicle's position in travel lane
- Brakes when detecting slower-moving vehicles ahead
- Decelerates and follows vehicles ahead at a predetermined following interval

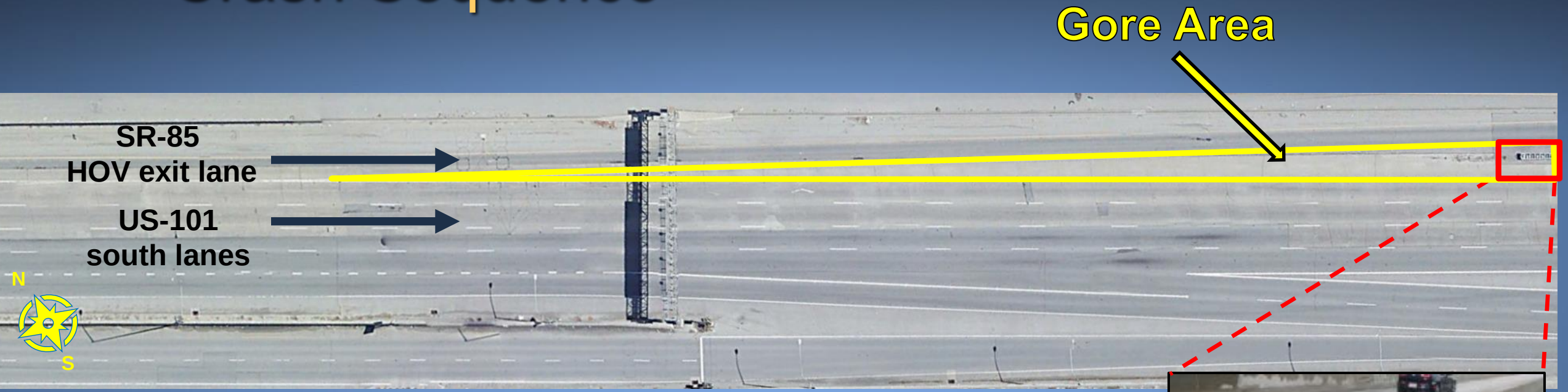
The Crashes

Mountain View

- Friday, March 23, 2018
- 9:27 a.m.
- Mountain View, California
- US-101 / SR-85 interchange
- 2017 Tesla Model X SUV
- 38-year-old driver
- Partial automation “Autopilot” engaged

NTSB

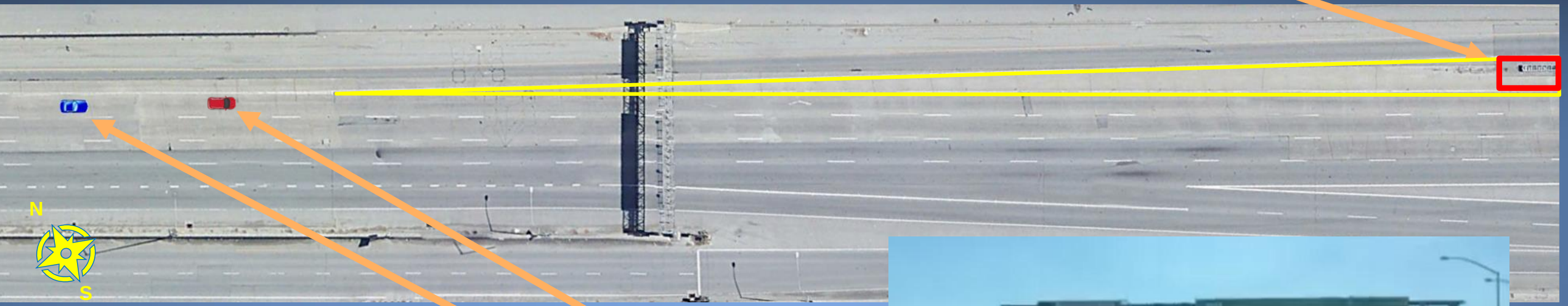
Crash Sequence



Crash attenuator was collapsed and nonoperational prior to the crash

NTSB

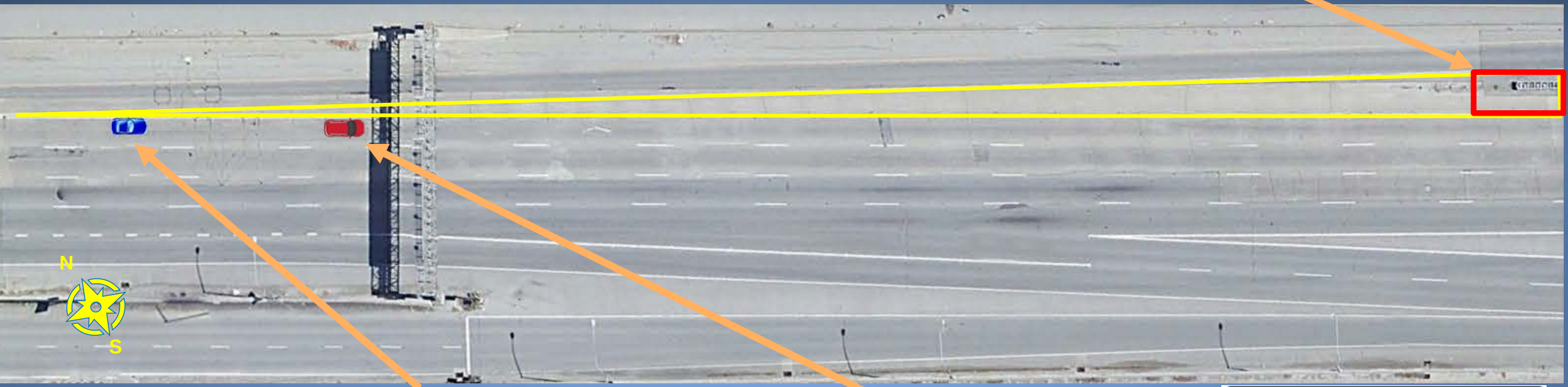
Crash Sequence



Time to crash:	7.9 seconds
Speed:	64.3 mph
Lead vehicle:	83.7 feet
Distance to crash:	748 feet

NTSB

Crash Sequence



Time to crash:	**5.9 seconds**
Steering:	**5.6 degrees left**
Speed:	**64.1 mph**
Lead vehicle:	**82 feet**
Distance to crash:	**560 feet**
Indication:	**Hands-off steering wheel**

Crash Sequence

Time to crash:	3.9 seconds
Speed:	61.9 mph
Lead vehicle:	None detected
Distance to crash:	375 feet

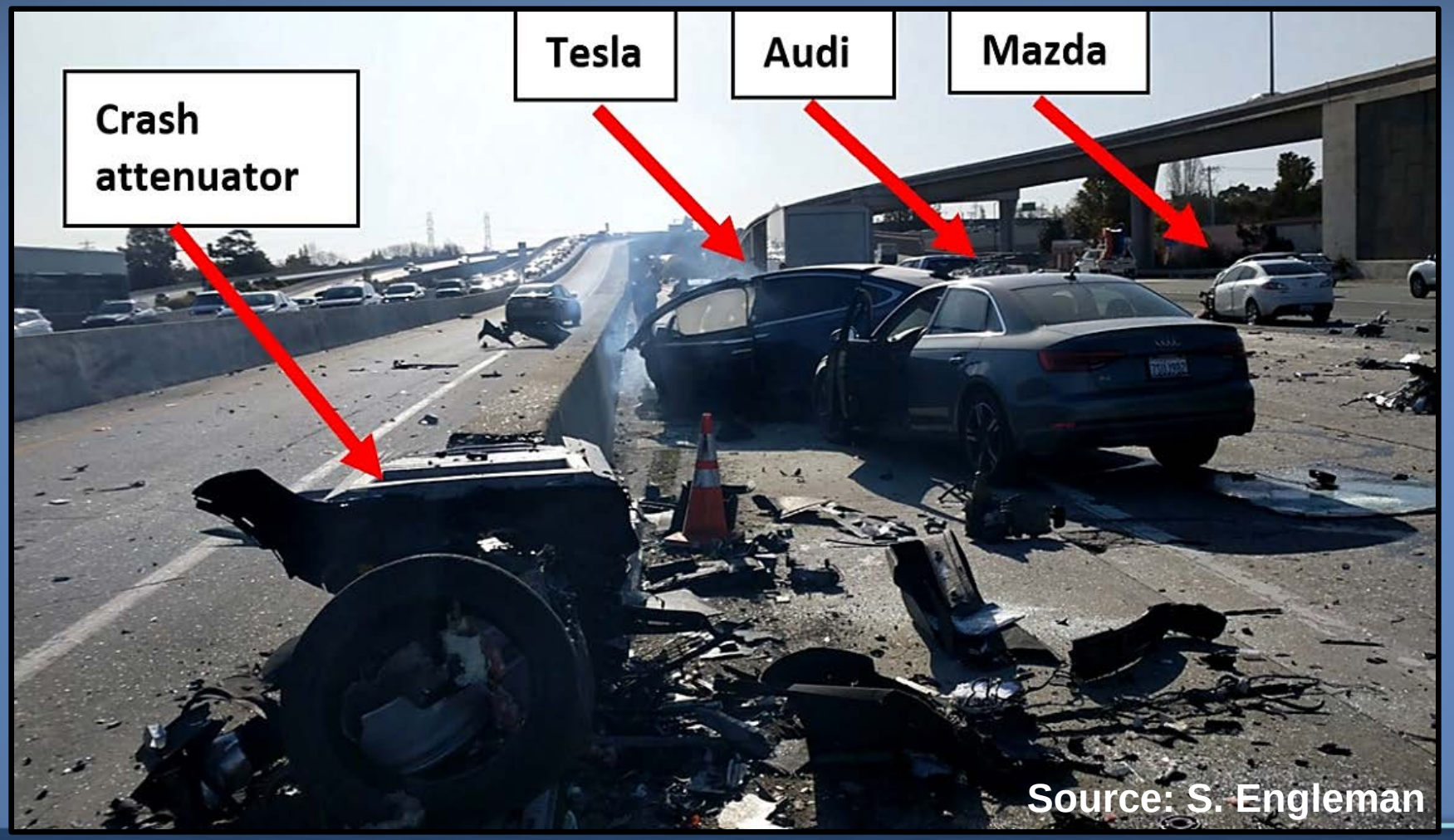
Vehicle begins to accelerate
Hands-off steering wheel indicated

Lead vehicle
(no longer followed)

NTSB

Crash Sequence

Crash Sequence



NTSB

Other NTSB Investigations

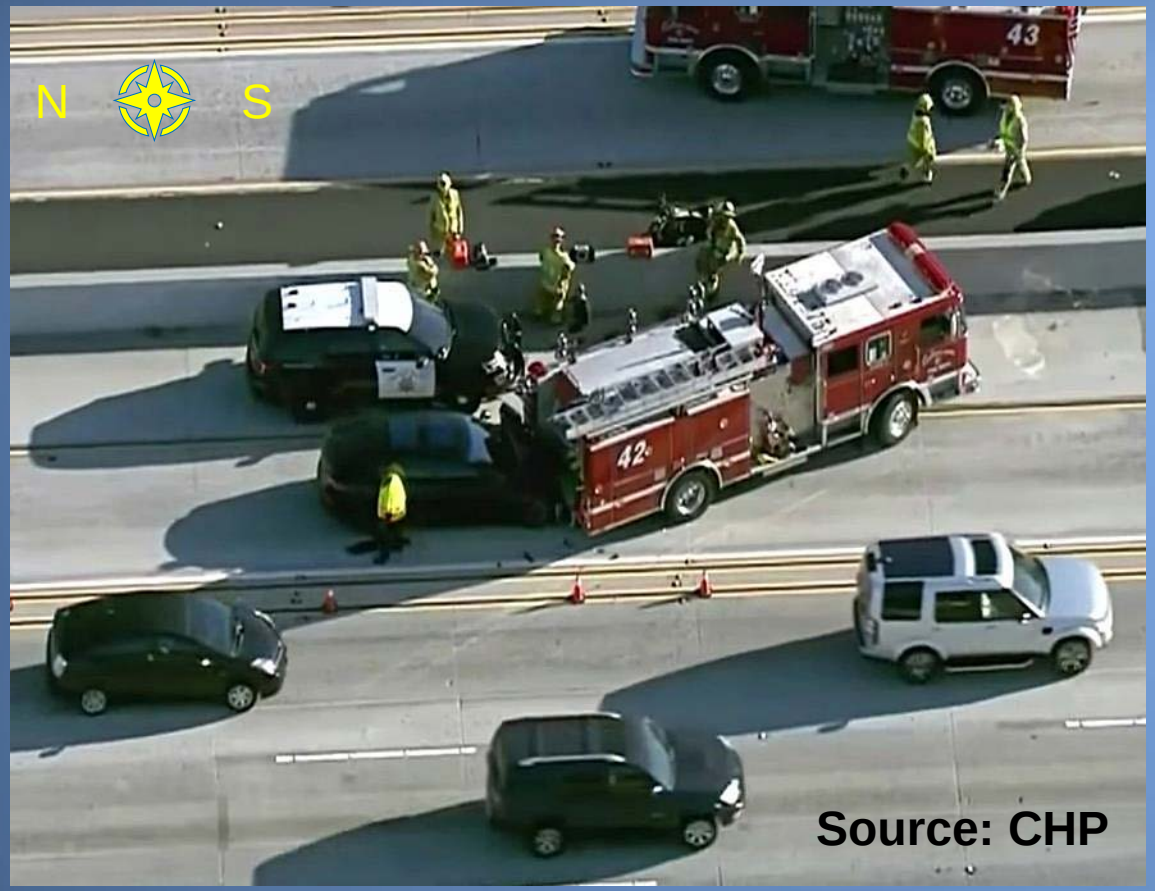
Lessons learned from three other Tesla crashes were incorporated into the Mountain View crash investigation:

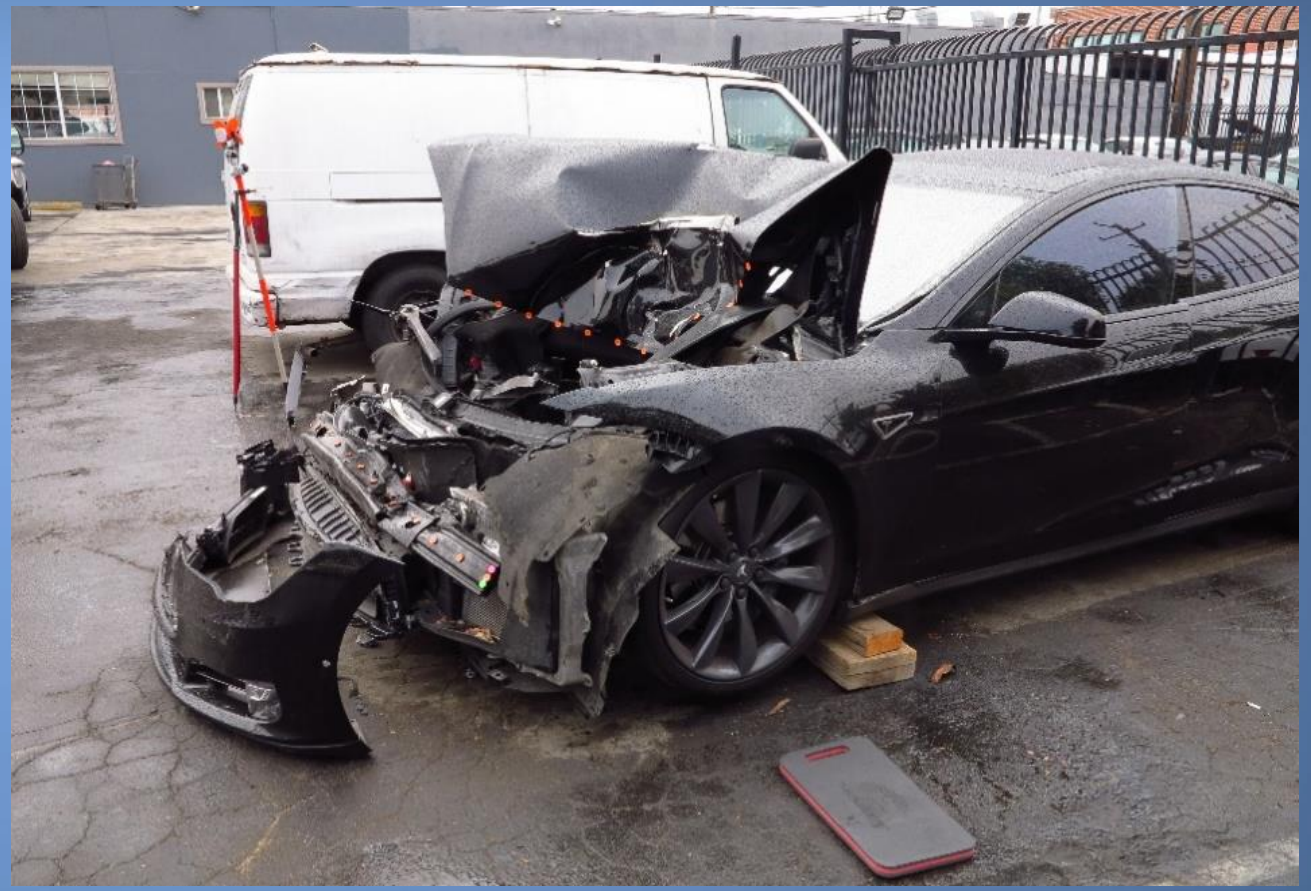
- Williston, Florida
- Delray Beach, Florida
- Culver City, California

Williston, Florida (May 7, 2016)

Delray Beach, Florida (March 1, 2019)

Culver City, California (January 22, 2018)





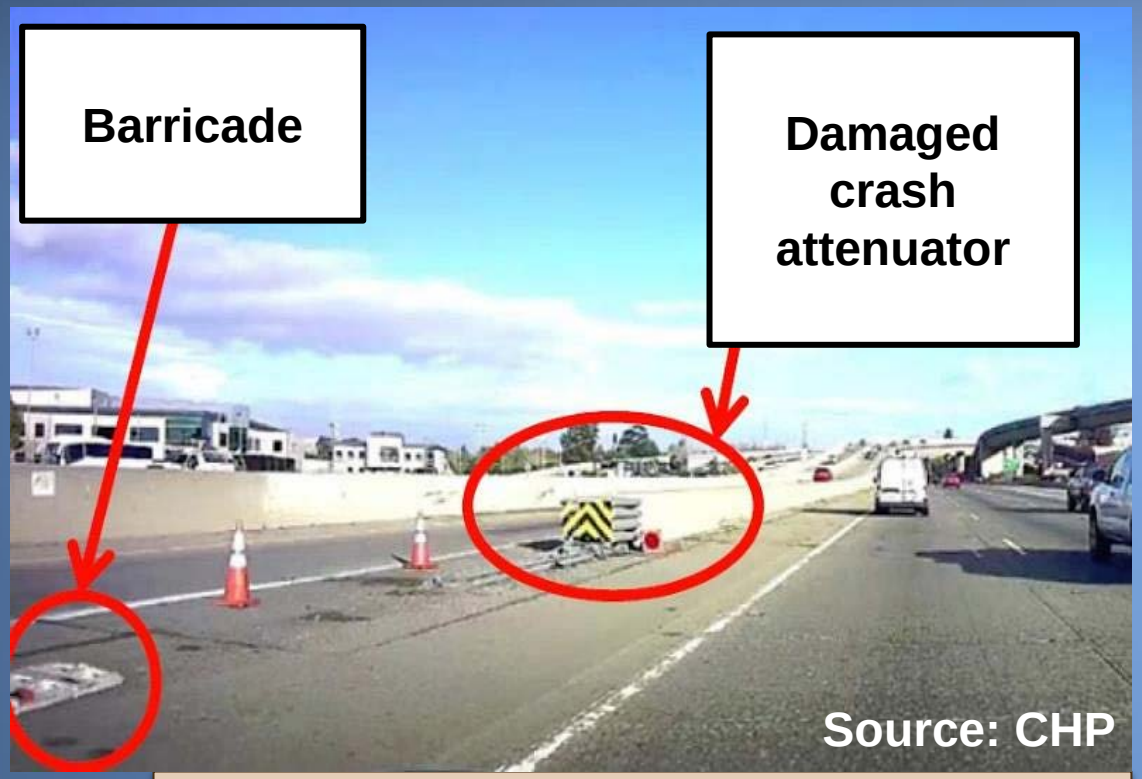
NTSB

The Safety Issues

Autopilot Performance

- Lane markings were worn
- Autosteer vision system likely lost lane line prediction
- Identified stronger lane line
- Steering movement likely due to vision system limitations

Crash Attenuator Performance



Barricade and cones placed in advance of attenuator prior to crash

- Damaged 11 days earlier
- Prius collision
- Driver survived
- CHP did not notify CalTrans
- CalTrans repair not timely

NTSB

Automation Issues

- Operational design domain (ODD)
- Monitoring driver engagement
- Collision avoidance system (CAS)

Operational Design Domain

- Conditions in which an automated system is designed to operate
  - Geographic location, roadway type and markings, speed range, weather conditions
- ODD constraints are designed to reduce the effect of Level 2 limitations

ODD Constraints

- Autopilot, stated in vehicle manual, is
  - *Not for use* on city streets, in constantly changing traffic conditions, on winding roads with sharp curves
  - *For use only* on divided highways with limited access
- The system allows a driver to use Autopilot outside its ODD
- Level 2 system limitations are industry-wide

Geographic ODD: Mountain View

- Crash location
  - Highway with center median divider
  - Limited access (no cross-traffic)
  - Major interchange (changing traffic conditions)
- Tesla stated ODD does not apply to Level 2 systems

Geographic ODD: Williston and Delray Beach

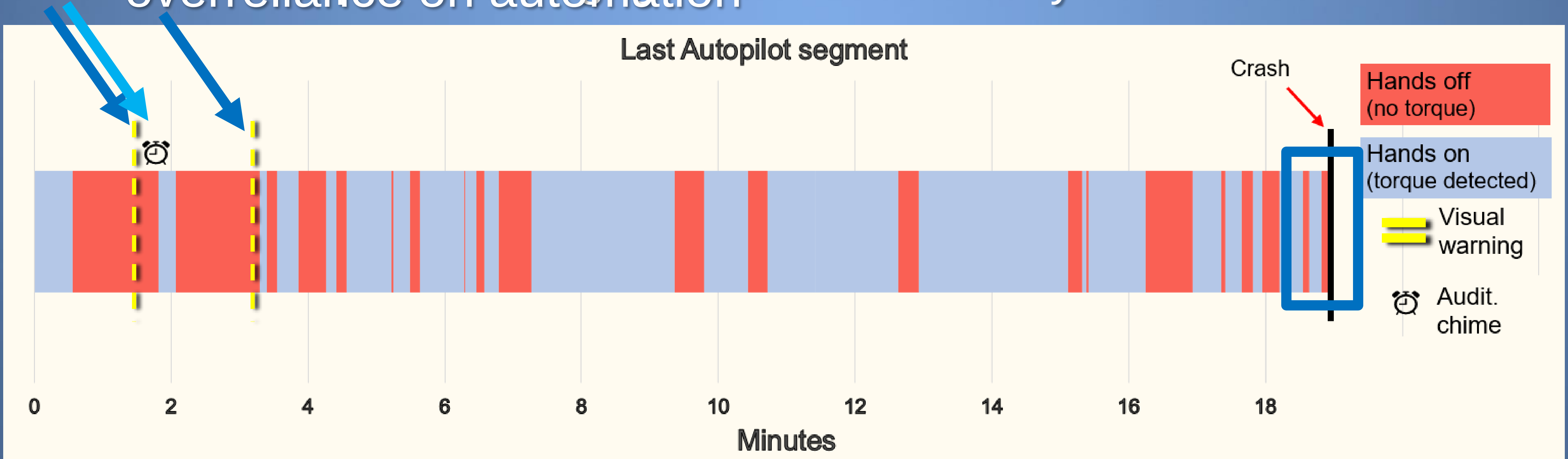
- Williston crash location
  - Outside ODD of Autopilot
- Delray Beach crash location
  - Highway with center median divider
  - Not limited access (has cross-traffic)
  - Outside ODD of Autopilot

Monitoring Driver Engagement

- Driver monitors environment in Level 2 systems
  - Tesla stated that Autopilot can be used on undivided roads with an *attentive* driver
  - Risk of automation complacency and misuse
- Tesla's method of monitoring driver engagement
  - Driver-applied steering wheel torque
  - System provides series of warnings to driver (visual, 3 stages of auditory warnings)

Driver Engagement: Mountain View

- The crash trip lasted 28.5 minutes
  - Autopilot was engaged for the last nearly 19 minutes
- Two visual warnings, one auditory warning
- Lack of responsiveness indicates distraction and overreliance on automation



Driver Engagement: Other Level 2 Crashes

- Williston and Delray Beach, Florida; Culver City, California
  - Driver-applied steering wheel torque not detected at time of impact
  - Prolonged inattentiveness by drivers
  - Drivers were ineffective monitors
- Humans are poor monitors of automation
- Monitoring of steering wheel torque is a poor surrogate measure of driver engagement

Automation: The Path Forward

Needed ODD Improvements

- Manufacturers should include system safeguards to limit the use of Level 2 systems to conditions for which they are designed (H-17-41)
- NHTSA should verify that manufacturers are incorporating the safeguards (H-17-38)
  - Lack of guidance on identifying ODD

Needed Driver Monitoring Improvements

- Manufacturers should implement more effective means of monitoring driver engagement when using Level 2
- NHTSA and SAE should develop performance standards for driver monitoring systems to address automation complacency
- An engaged driver remains a critical component even with advanced driver assistance systems

Summary

- Technology offers hope
- Automation must consider the human
- Infrastructure must support the automation

National Transportation Safety Board

Robert Molloy, PhD. Director
Cell 202-320-6294
Email molloyr@ntsb.gov