NHTSA
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

Vulnerable Road Users

NHTSA Safety Research Portfolio Public Meeting: Fall 2021

October 20, 2021

Introduction

- This session provides an overview of NHTSA's current research efforts related to vulnerable road users (VRU)
- Vehicle Safety Research, Behavioral Safety Research, and the National Center for Statistics and Analysis have been executing projects aimed at developing new knowledge and tools to address a variety of VRU issues
- These efforts include collection of data from real-world VRU crashes, testing of passive and active safety countermeasures, and evaluation of safety regulations
- The projects covered in this session pertain to pedestrians, pedalcyclists, and school bus riders

Panel Presentations

1. **CIREN Pedestrian Study** - Rodney Rudd
2. **Crash Investigation Division Pedestrian/Pedalcyclist Special Study** – John Brophy
3. **Pedestrian Automatic Emergency Braking Night Testing Method Research** - Heath Albrecht
4. **Outside and Inside the School Bus** – Kristie Johnson
5. **Pedestrian Crashworthiness Research Update - Vehicle Testing & Injury Analysis** – Jason Stammen
6. **Pedestrian Crashworthiness - Modeling and Predicting Head Impact Time** – Whitney Tatem

Crash Injury Research and Engineering Network (CIREN)
Pedestrian Study

Rodney Rudd

CIREN Pedestrian Study Objectives and Goals

- Revisit prior NHTSA investigative protocols (PCDS) and update for current and future research needs
- Assess different case initiation/investigation approaches
- Adapt injury causation coding (BioTab) for pedestrian crashes
- Develop data collection guidelines
- Acquire data for nine (9) pilot cases

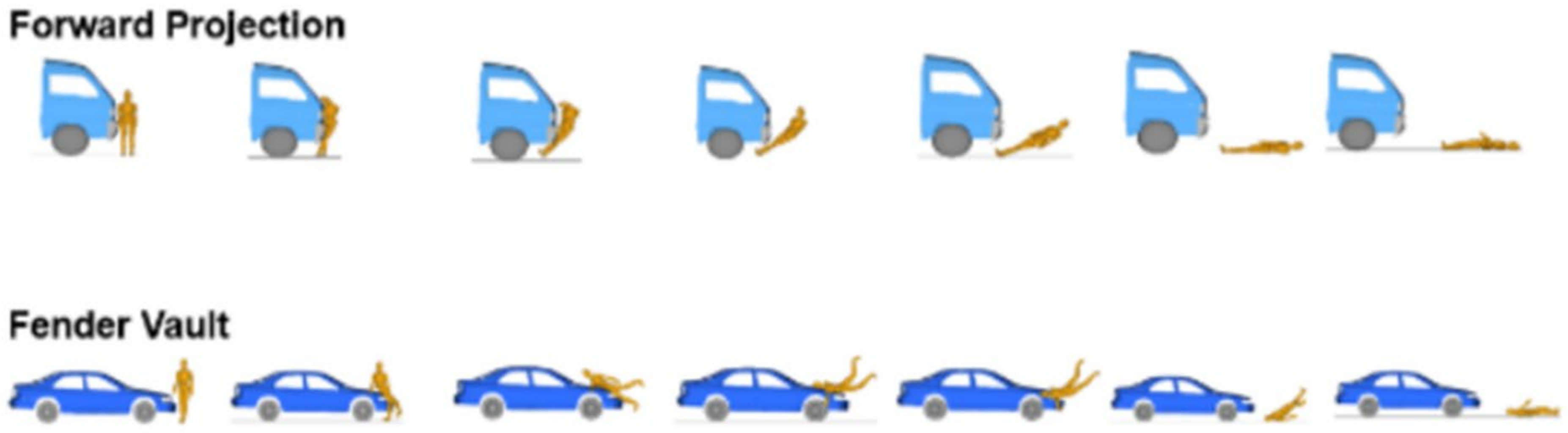
CIREN Pedestrian Study Overview

- Task Orders awarded 2018
- Pedestrian study contractors
  - Emory University (enrolling at Grady Memorial Hospital in Atlanta, GA)
  - Wake Forest/Virginia Tech (enrolling at Wake Forest Baptist Medical Center in Winston-Salem, NC)
  - Additional engineering support from Medical College of Wisconsin

Highlights

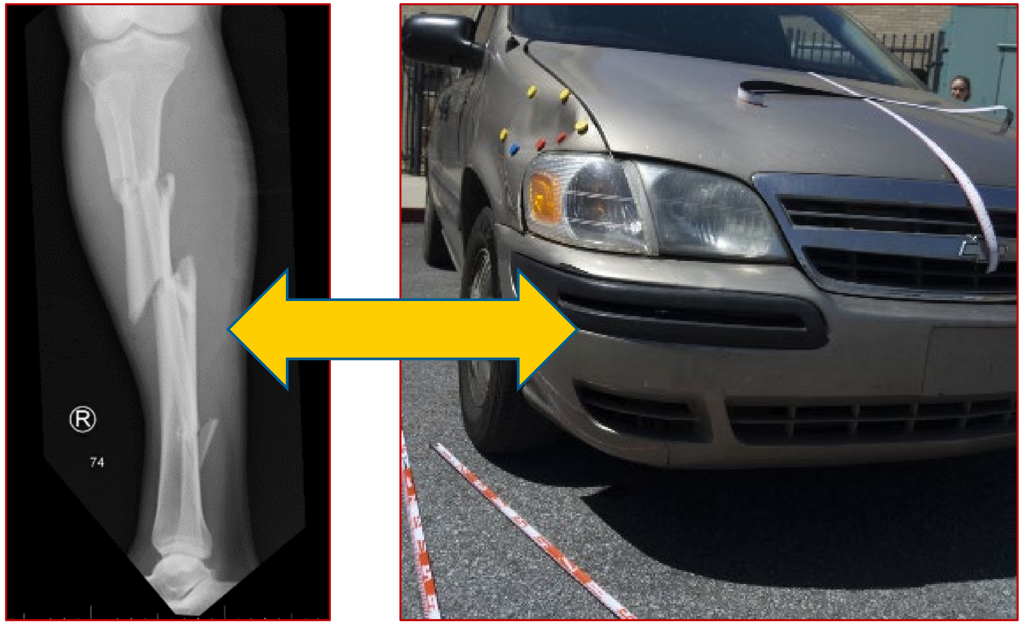
- Crash characterization
  - Conflicts
  - Kinematic Trajectory
- Crash avoidance
- Behavioral

Crash Characterization: Kinematic Trajectory



Han, Yong, et al. "Analysis of vulnerable road user kinematics before/during/after vehicle collisions based on video records." IRCOBI Conference, Antwerp, Belgium. 2017.

Kinematic Trajectory and Injury Causation



Conflict 1

- Front plane
- Contact evidence: damaged bumper
- Leg fracture

Kinematic Trajectory and Injury Causation

Conflict 2

- Side plane
- Contact evidence: damaged mirror
- Facial fractures

Crash Avoidance Elements

- Data collection includes Solar Elevation and Solar Azimuth to assess glare
- Detailed street lighting characterization

Case example

- Crash time: 0700
- Solar Elevation: 10°; Solar Azimuth: 90°
- Vehicle traveling east at impact location

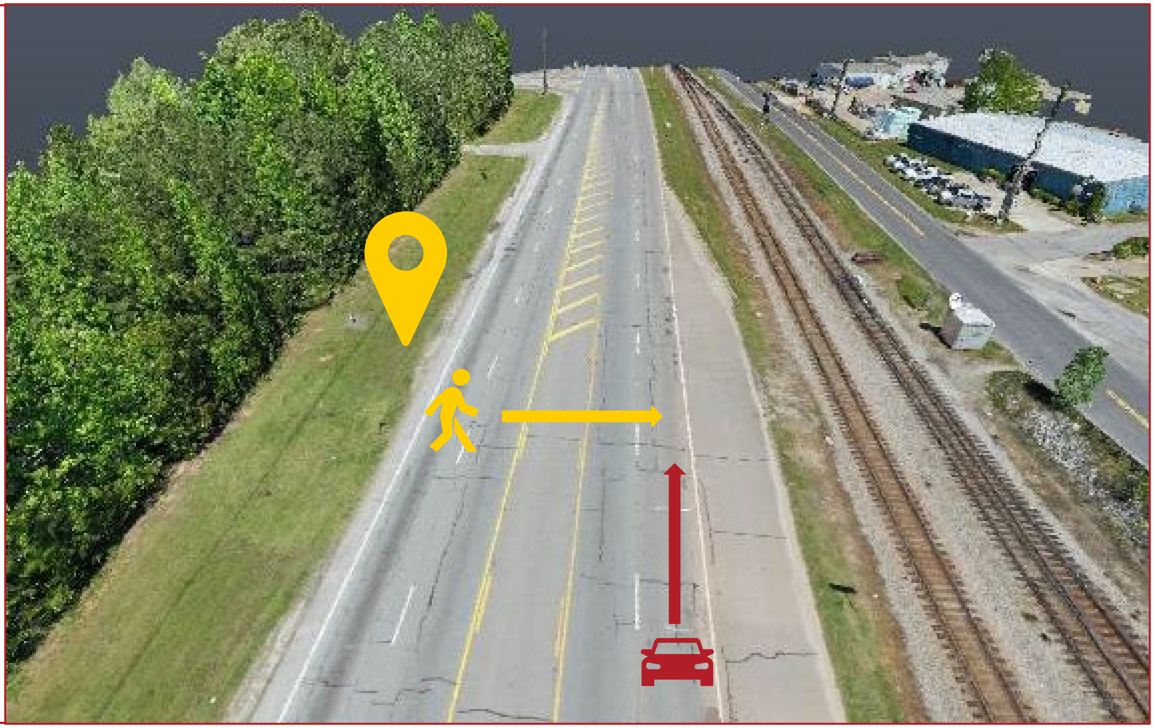
Behavioral Research Considerations

EVERYONE IS A PEDESTRIAN

- Trip purpose and routing choices
- Distractions
- General pedestrian behavior

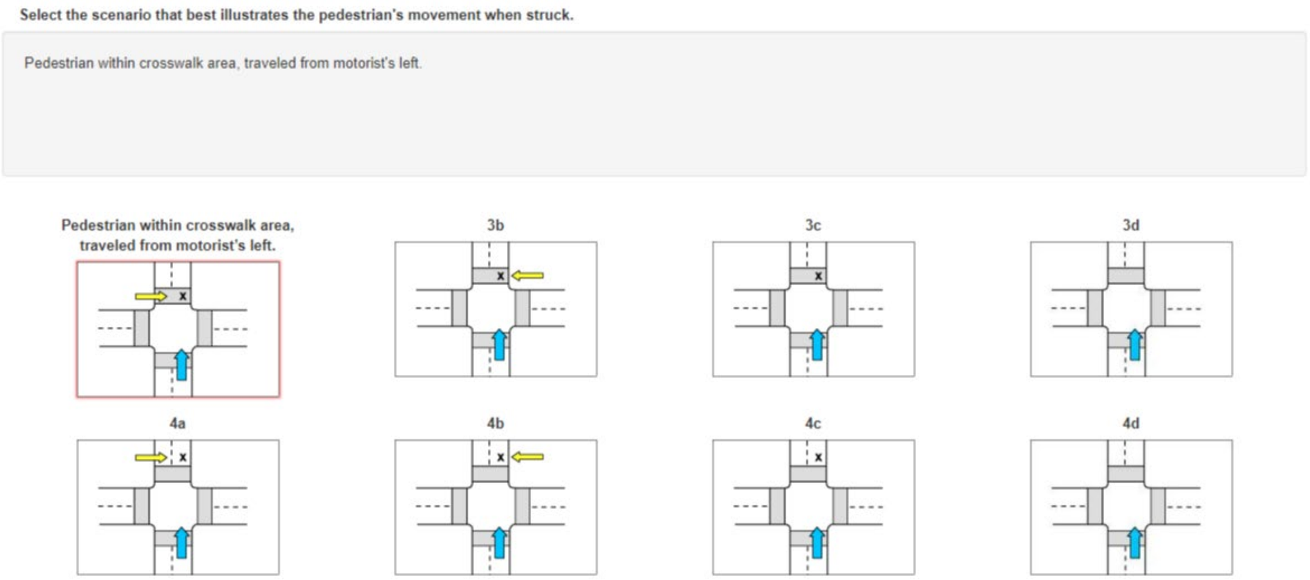
Case example

- Mid-block bus stop west roadside
- Workplace east, across tracks
- Clear; dry; dark, not lighted
- Last individual in group to cross

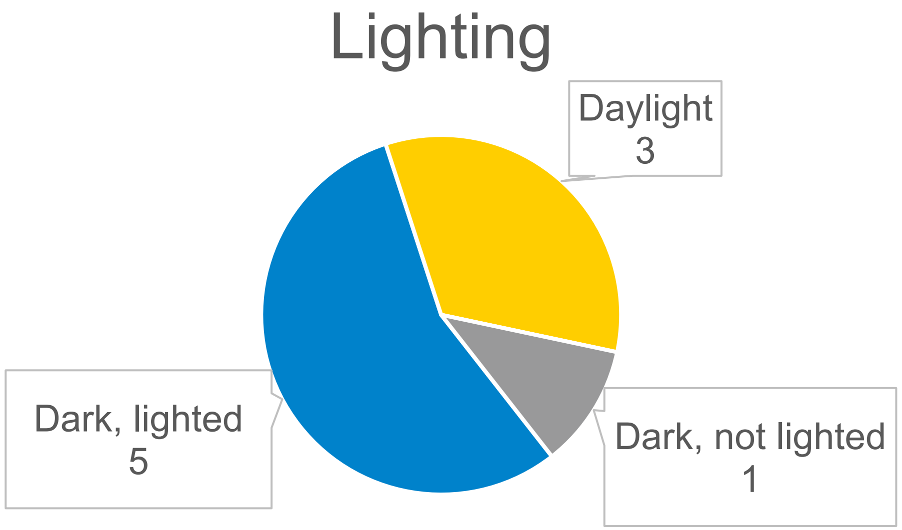


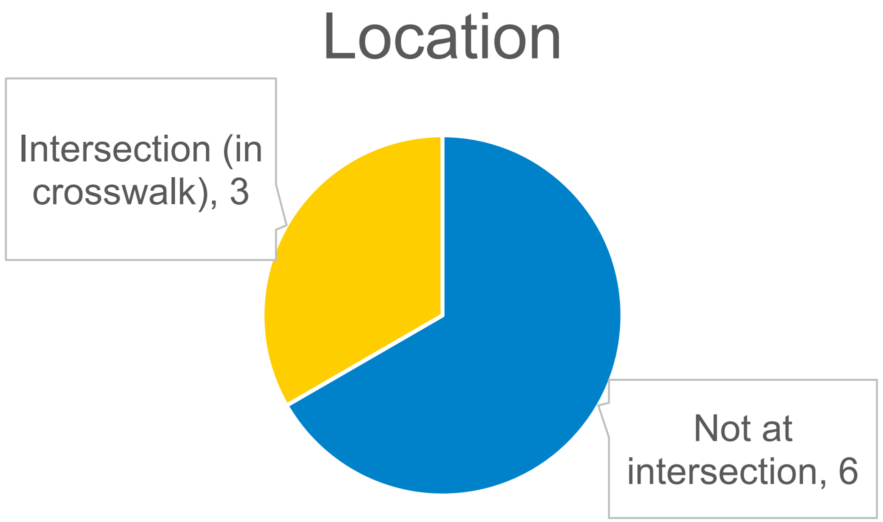
Data System Development

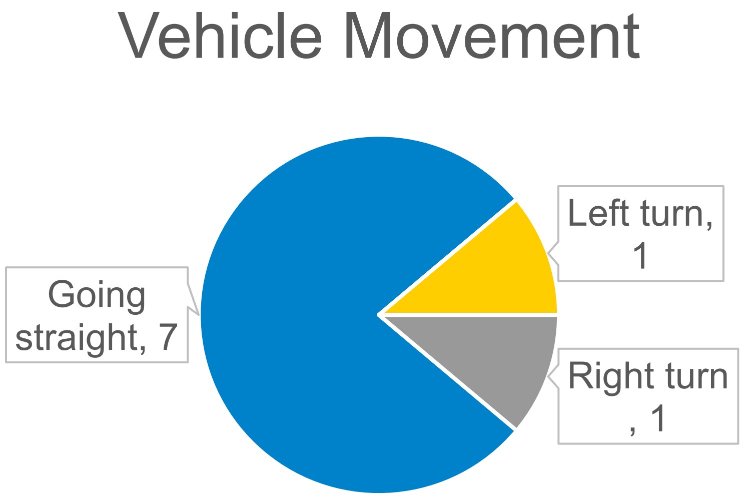
- Pedestrian-specific variable and attribute definitions
- Developed data collection application and public case viewer
- Built on existing NHTSA crash data systems
  - Utilized existing coding standards where possible (e.g., crash typing)



Overview of Pilot Cases







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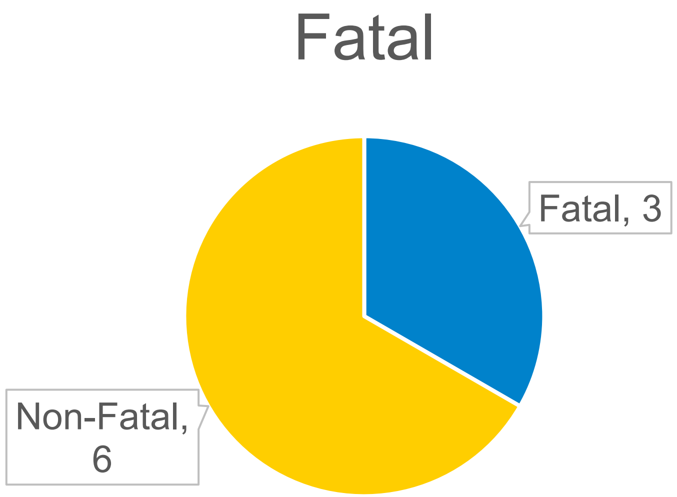
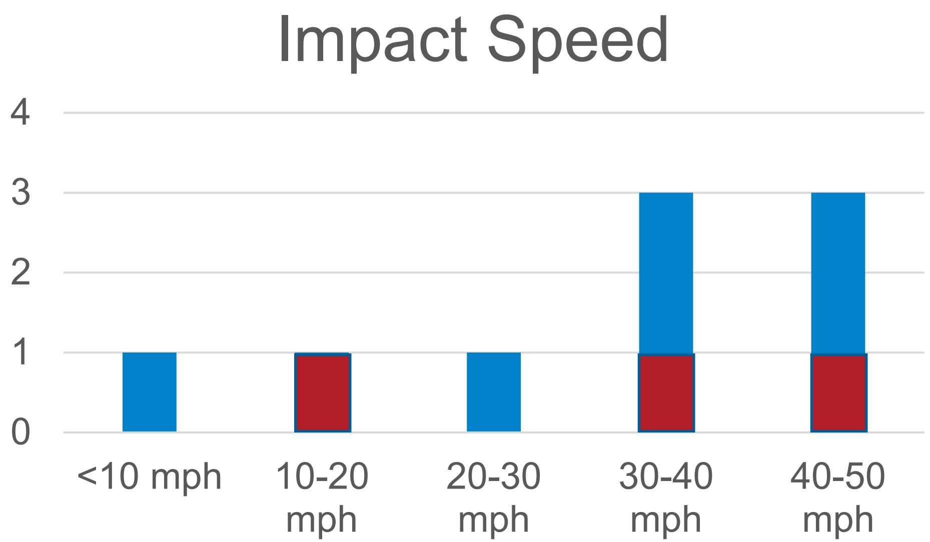


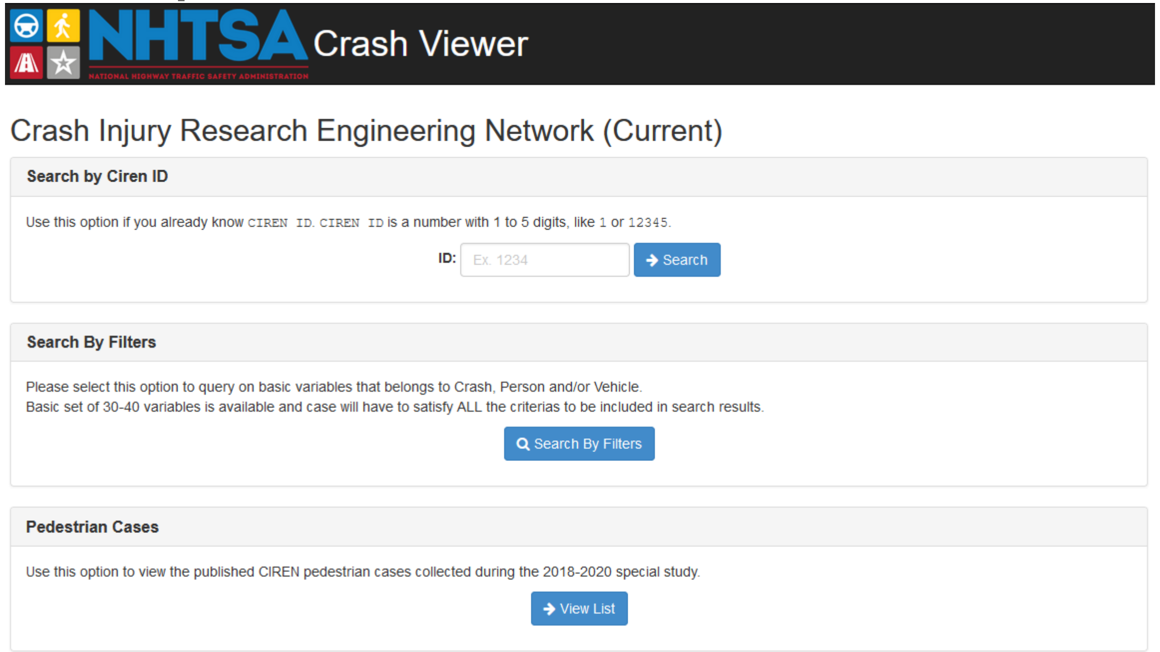


Identification and Initiation of Cases

- Pilot study considered two primary methods of case initiation
    - Consent First, Investigate Later (CFIL)
    - Fast Response On-Scene (FROS)
- Both have limitations
- Law enforcement cooperation will be necessary for both
    - Access to on-scene photos invaluable
    - Access to striking vehicle/driver
- Detailed medical documentation required for in-depth injury causation and kinematics assessment

What's Next?

- Technical report on CIREN efforts
- Pilot cases published to NHTSA crash viewer website



https://crashviewer.nhtsa.dot.gov

- Consideration for future data collection

Crash Investigation Division Pedestrian / Pedalcyclist Special Study (PPSS)

John Brophy

Objective

The objective of this project was to provide NHTSA with detailed crash reconstruction data based on police crash reports and supplemental information that can be used to:

- Identify causal factors in fatal crashes involving pedestrians and pedalcyclists to better align research programs and focus efforts on appropriate countermeasures, research and/or behavioral programs
- Identify if crash avoidance technologies could have impacted the crash and injury severity of crashes

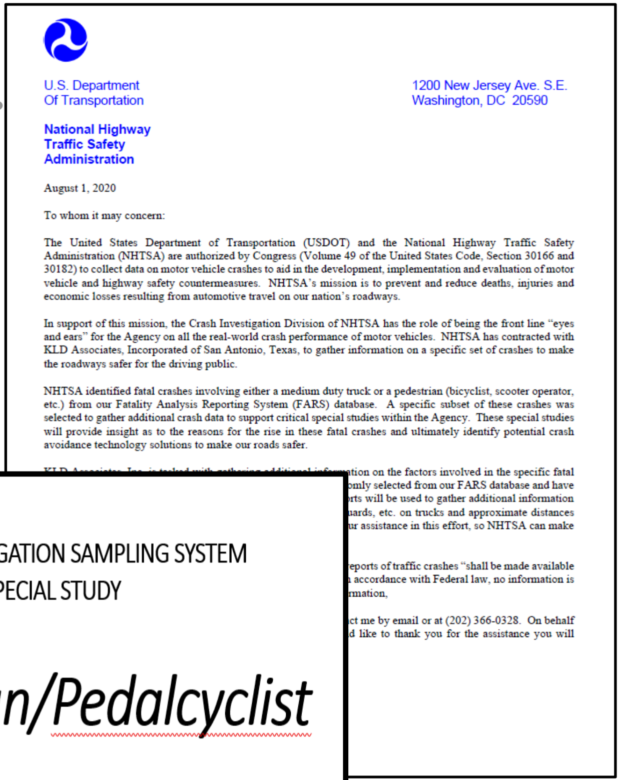
Special Study Parameters

Pedestrian Pedalcyclist Special Study (PPSS)

- NCSA Mathematical Analysis Division selected representative sample of 400 cases from 2018 FARS
- Goal of coding 200 cases
  - Fatality to any person in the crash
  - Crash had to have images for inclusion
  - Project used follow-on investigation procedures
    - Trained Crash Investigators coded data from source documents
  - Only KABCO injury levels – no injury documentation
  - Included all crash modes

PPSS Setup

- PPSS case lists provided to contractor
- CID, with assistance of Research Office, developed additional data elements
  - Used CIREN Ped study for guidance
- CID produced PPSS Coding Manual
- CID provided introduction letter
- Investigating agency determined for all PARS
- Local case number tracked down for each case
- Modified the Records Based Information System (RBIS) data entry system



U.S. Department
Of Transportation

1200 New Jersey Ave. S.E.
Washington, DC 20590

National Highway
Traffic Safety
Administration

August 1, 2020

To whom it may concern:

The United States Department of Transportation (USDOT) and the National Highway Traffic Safety Administration (NHTSA) are authorized by Congress (Volume 49 of the United States Code, Section 30166 and 30182) to collect data on motor vehicle crashes to aid in the development, implementation and evaluation of motor vehicle and highway safety countermeasures. NHTSA's mission is to prevent and reduce deaths, injuries and economic losses resulting from automotive travel on our nation's roadways.

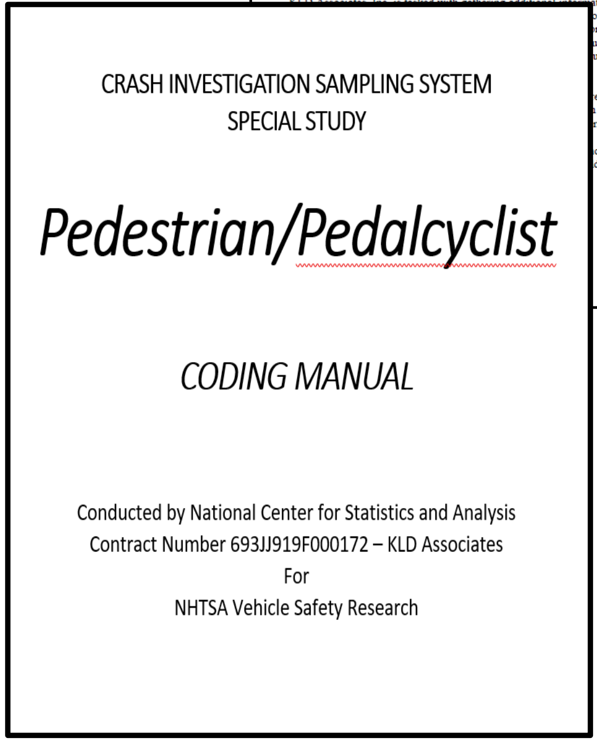
In support of this mission, the Crash Investigation Division of NHTSA has the role of being the front line "eyes and ears" for the Agency on all the real-world crash performance of motor vehicles. NHTSA has contracted with KLD Associates, Incorporated of San Antonio, Texas, to gather information on a specific set of crashes to make the roadways safer for the driving public.

NHTSA identified fatal crashes involving either a medium duty truck or a pedestrian (bicyclist, scooter operator, etc.) from our Fatality Analysis Reporting System (FARS) database. A specific subset of these crashes was selected to gather additional crash data to support critical special studies within the Agency. These special studies will provide insight as to the reasons for the rise in these fatal crashes and ultimately identify potential crash avoidance technology solutions to make our roads safer.

…tion on the factors involved in the specific fatal
…omly selected from our FARS database and have
…rts will be used to gather additional information
…uards, etc. on trucks and approximate distances
…ur assistance in this effort, so NHTSA can make

…reports of traffic crashes "shall be made available
…accordance with Federal law, no information is
…rmation,

…ct me by email or at (202) 366-0328. On behalf
…d like to thank you for the assistance you will



CRASH INVESTIGATION SAMPLING SYSTEM
SPECIAL STUDY

Pedestrian/Pedalcyclist

CODING MANUAL

Conducted by National Center for Statistics and Analysis
Contract Number 693JJ919F000172 – KLD Associates
For
NHTSA Vehicle Safety Research

PPSS Process

- Trained Crash Investigators requested information from investigating law enforcement agency
- All case materials received / processed at one location for consistency
- Assembled and coded additional data to pedestrian / pedalcylist crashes
- Determined presence of crash avoidance equipment
- Assessed if crash avoidance equipment could have mitigated the crash or injury outcome

PPSS Process

- Substantial effort went into determining the presence of advanced safety features:
  - Forward Collision Warning (FCW)
  - Crash Imminent Braking (CIB)
  - Lane Departure Warning (LDW)
  - Lane Keeping Support (LKS)
  - Blind Spot Detection (BSD)
  - Adaptive Cruise Control (ACC)
  - Pedestrian Automatic Emergency Braking (PAEB)
  - Dynamic Brake Support (DBS)
  - Daytime Running Lights (DRL)
  - Advanced Lighting, and
  - Automatic Crash Notification (ACN)

Note: ADAS equipment, PAEB in particular, were not common in 2018 and prior year vehicles

PPSS Response Rates

Documents and images were requested for 400 cases

- Response rates :
  - Received complete documentation for 233 of the 400 requested cases 58%
  - Received partial data - not enough detail to code a case on 14%
  - No data or response 19%
  - Refused 9%

Total – 233 cases for PPSS

PPSS Status

- Data received for cases was robust
- Data was received slowly
- Follow up with many agencies was required

PPSS – Issues Identified

- For some cases, NHTSA was required to make the official request … not the contractor
- Agencies were operating in a COVID atmosphere
  - Skeleton crews
  - Curtailed workweeks
  - Delays in processing requests
- Some agencies supplied crash report … but required a subpoena / FOIA to send any images
- Quality / subject of images provided were not always useful for NHTSA needs
  - Law enforcement involvement for a different reason

PPSS Status

- Much of the PPSS data received was robust due to nature of ped crashes

- Many graphic images were received but filtered out if not useful for NHTSA needs

PPSS Status

- Some agencies included EDR data, however most of the modules did not record an event
  - Expected, due to lack of safety system deployment

- Some data / image files were huge
  - Videos / body cam
  - Drone images
  - Law Enforcement body cam images

Next Steps

PPSS

- Complete quality control of the 233 cases by early October
- SAS file will be produced by IT contractor
- Deliver to Math Analysis Division (MAD)
- MAD will produce a report based on the data
- Await PRA clearance to publish any data

Summary

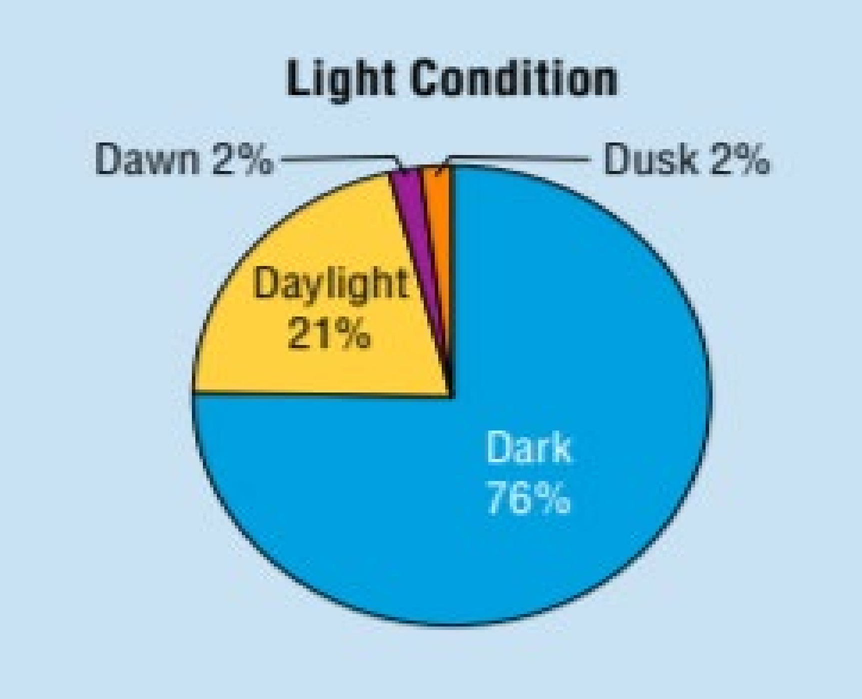
- Targeted special studies can provide very specific data to NHTSA
- Issues with some law enforcement agencies requiring additional documentation, authorization, FOIA, etc.
- Typically, more detailed data was available at the investigating Agency than what was available for coding on crash report
- PPSS blended crash investigators experience with detailed law enforcement data to provide much more detail regarding a FARS pedestrian crash

Pedestrian Automatic Emergency Braking Night Testing Method Research

Heath Albrecht

PAEB Night Testing Research

- More pedestrian fatalities occur at night in the U.S.[1]
- Low light conditions are challenging for PAEB system performance[2]
- Other sensing technologies could aid nighttime PAEB performance



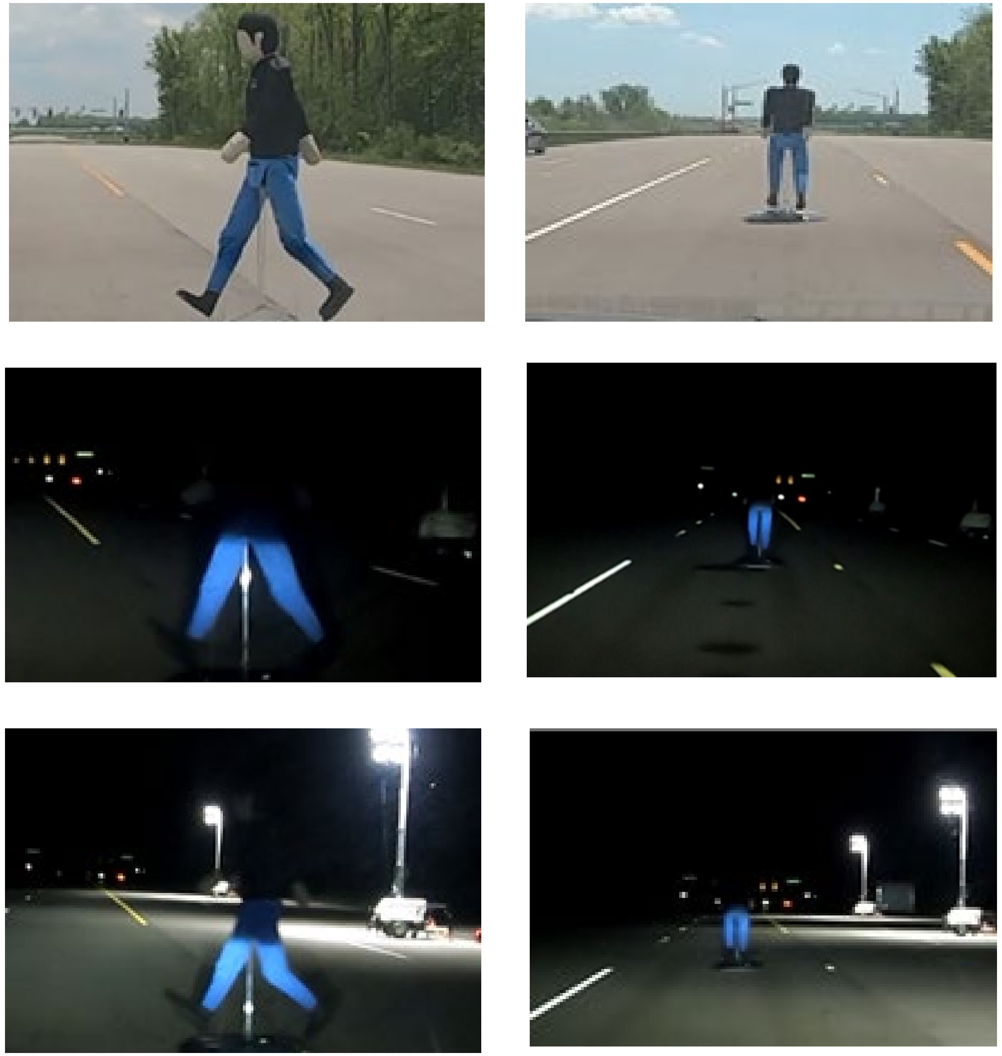
https://www.foresightauto.com/autonomous-vehicles-need-thermal-cameras/

[1]2019 NHTSA traffic safety facts
[2]https://www.aaa.com/AAA/common/aar/files/Research-Report-Pedestrian-Detection.pdf

Research Objectives

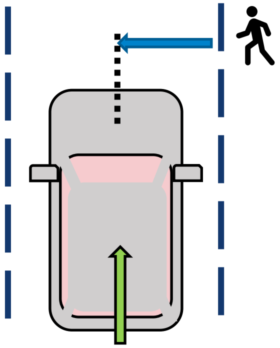
Perform PAEB testing under different lighting conditions

- Daylight (baseline)
- Dark – lower/upper beam headlights only
- Dark – streetlights and lower/upper beam headlights

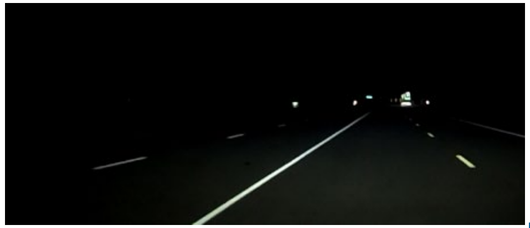


Test Method

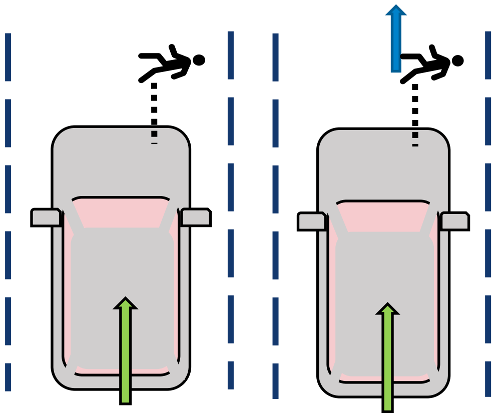
Vehicle	Technology
Vehicle 1	Camera
Vehicle 2	Camera and radar
Vehicle 3	Camera and radar



https://gmundcars.com/low-beam-vs-high-beam/



https://www.dekalbcountyga.gov/transportation/street-lighting



- NHTSAs draft PAEB test procedures were followed for testing[1].

[1]NHTSA research draft test procedure https://www.regulations.gov/docket/NHTSA-2019-0102/document

Test Equipment

Lighting

- Portable light towers (5) were used for providing lighting
- Lighting height, angle, and intensity are adjustable

Articulated Mannequin

- Legs were activated (arms posable) at beginning of path to simulate walking
- For stationary testing, legs were not activated

Platform

- Mobile platform was used to move the mannequin along its path

- https://www.generacmobileproducts.com/products/light-towers/products/plt240-linktower

- https://www.abdynamics.com/en/products/track-testing/adas-targets/launch-pad
- https://www.4activesystems.at/

Lighting Setup

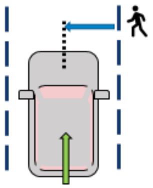
- Documented test methods for lighting setup and measurements were used as a guide for this research.[1]
- Light measurements on the test surface were taken to adjust light patterns and intensity.
- Light measurements of the mannequin and vehicle path were recorded

[1]https://cdn.euroncap.com/media/62795/euro-ncap-aeb-vru-test-protocol-v304.pdf

Pedestrian Crossing in Front of Approaching Vehicle

Dark – Vehicle headlights

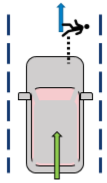
Dark – Street lights and vehicle headlights



Pedestrian Walking with Approaching Vehicle

Dark – Vehicle headlights

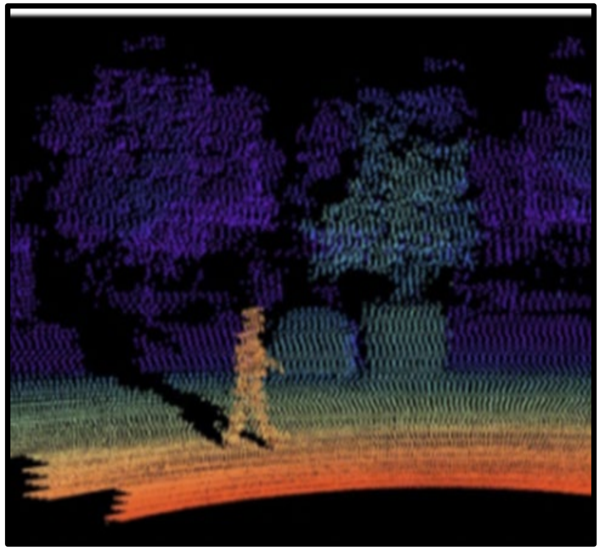
Dark – Street lights and vehicle headlights



Perception Research

- Investigate other sensing technologies, test methods, to better understand if PAEB performance in the dark can be improved.
  - Thermal Imaging
  - Light Detection and Ranging (LIDAR)

https://www.flir.com/oem/adas/



https://velodynelidar.com/press-release/velodyne-lidar-technology-can-improve-pedestrian-safety/

https://www.4activesystems.at/

https://velodynelidar.com/

https://www.flir.com/browse/camera-cores-amp-components/automotive/

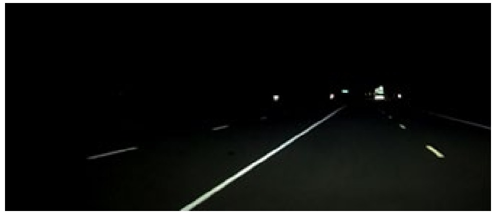
Research Timeline

Nov 2019 | July 2020 – October 2021 | July 2021 – August 2022

Draft Research Test Procedures

- Published - Nov. 2019 ADAS RFC

Night Test Development



https://www.dekalbcountyga.gov/transportation/street-lighting

Perception Research

- Review technologies (thermal imaging, lidar, other)
- Investigate testing/characterization methods

- https://www.4activesystems.at/
- https://www.flir.com/browse/camera-cores-amp-components/automotive/
- https://velodynelidar.com/

Outside and Inside the School Bus

Kristie Johnson

School Bus Safety

- ~26 million children ride school buses to school each day
- School buses are the safest mode for transporting students to school
- On average each year 120 people are killed in school-transportation-related crashes
  - 7 fatalities are passengers of school transportation vehicles
  - 6 fatalities are pedestrians stuck by other vehicles (not the school bus)
- NASDPTS reported 95,319 illegal passes of school buses during a single day count

Current and Recent School Bus Research Projects

- Examination of Three Districts Implementing Stop-Arm Camera Programs to Enforce Laws Against Illegal Passing of Stopped School Buses
- Indirect Effects of School Bus Seat Belt Installation
- Securing Safe Passage when Crossing a Roadway to Board School Buses (SBIR)

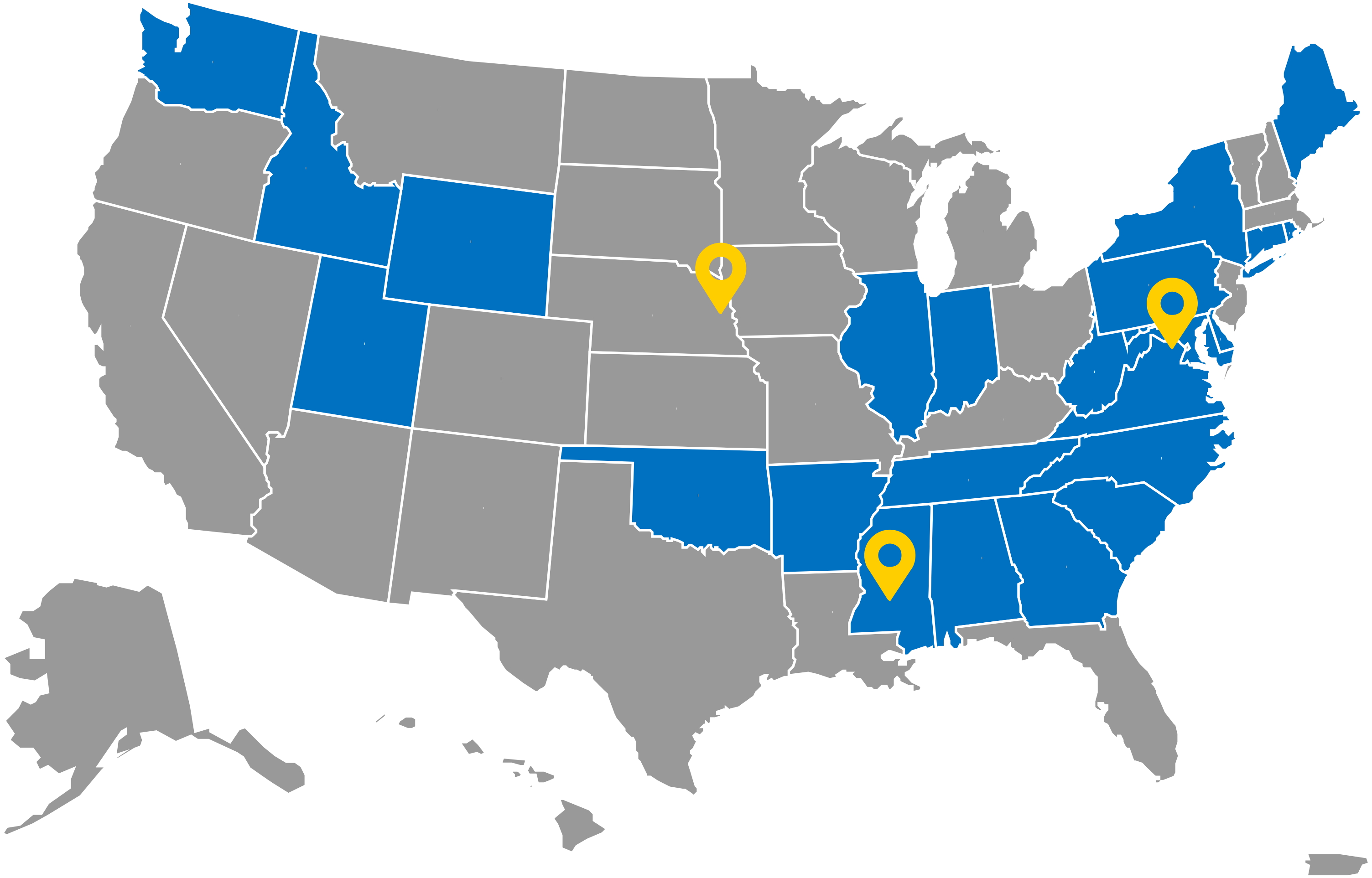
School Bus Stop-Arm Camera Study

Study Components (DOT HS 813 102)

- Literature review of implementations around the United States
- Detailed examination of stop-arm camera implementation in three school districts
- Analysis of previously collected camera-enforcement data from an additional 33 districts

Stop-Arm Camera Legislation | *Study Sites*

- As of July 2021, at least 23 States have explicit legislation relating to the use of automated school bus stop-arm enforcement (NCSL, 2021).
- State legislation varies but tends to have similar elements.

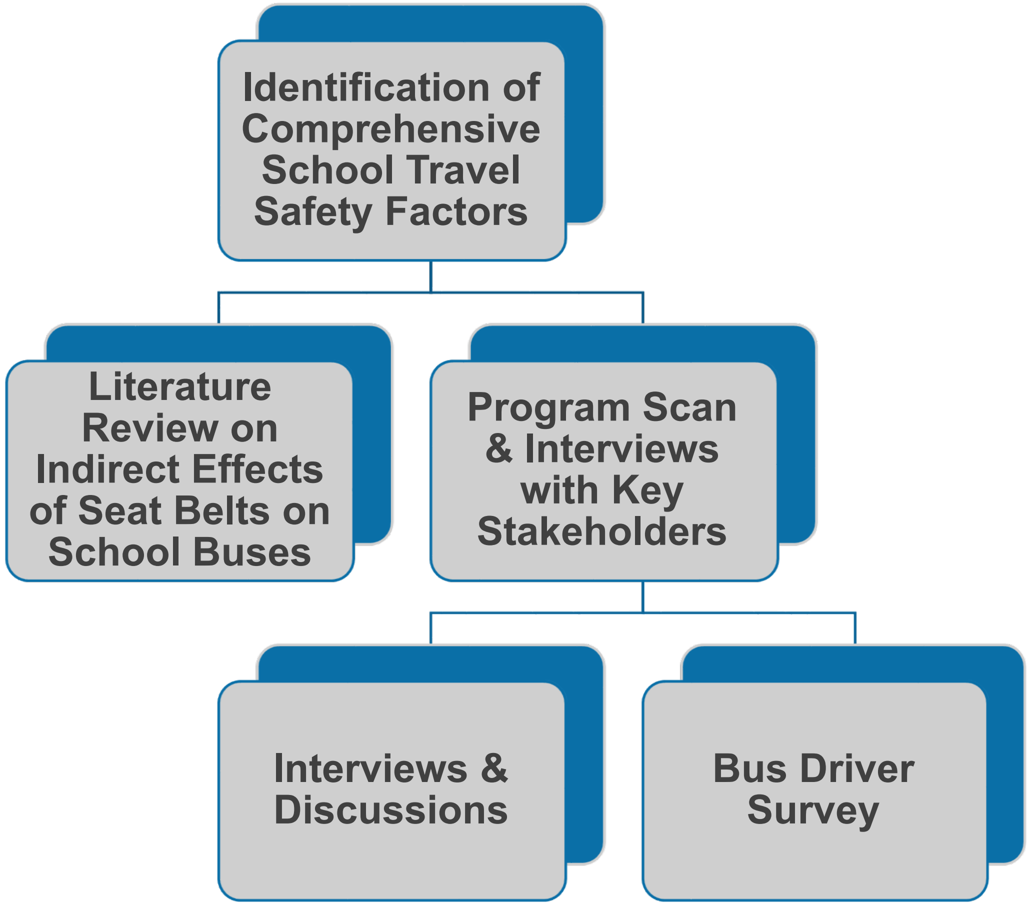


Indirect Effects of School Bus Seat Belt Installation

Primary Literature Review Topics
General Indirect Effects of Seat Belts on School Buses
Student Behavior Management
Bus Driver Stress and Distraction
Bus Driver Satisfaction and Retention
Loading and Unloading Times of Buses
Decreased Space Inside Buses
Effects on Route Times
Transfer of Effects to Passenger Vehicles

General/Support Topics
Changes In/Effects of Sound Level on Buses
Distracted Driving
Distraction in the Car with Children
Children Arriving to School Ready to Learn (Effects of Commute)

DOT HS 813 049



Safe Roadway Crossing for School Bus Boarding

- 2 SBIRs (Small Business Innovation Research) awarded
- Testing various methods to increase student safety
    - Digital alert for driver notification
    - Preemptive driver notification of bus routes and stops
    - Communication with surrounding vehicles
    - Illumination of the crossing area
    - Illuminated virtual crosswalk projection

Pedestrian Crashworthiness Research Update – Vehicle Testing & Injury Analysis

Jason Stammen

Integrated CA/CW Study

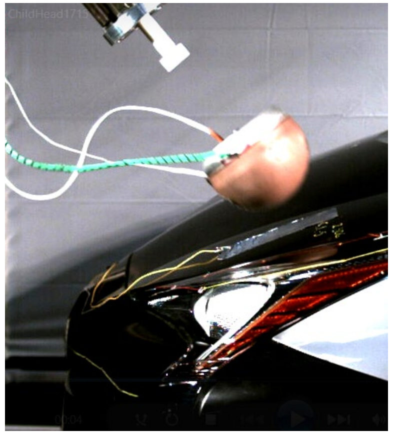
- How do crash avoidance technologies (pre-crash systems) and crashworthiness countermeasures work together in a given vehicle to reduce injury severity?

- Assess CW countermeasure performance at various levels of CA effectiveness to estimate real-world performance

Vehicle	CA	CW
2017 Chevrolet Malibu	PAEB	Passive hood
2018 Buick Regal	PAEB	Active hood
2020 Subaru Outback	PAEB	Passive hood
2021 Volkwagen Arteon	PAEB	Active hood

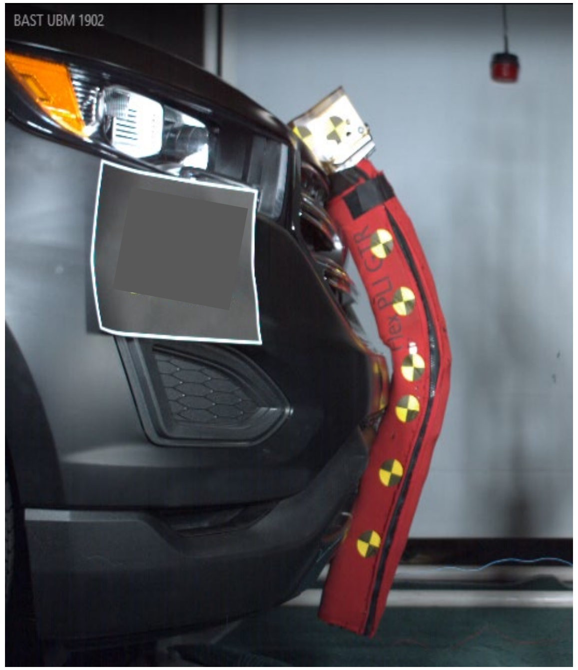
PAEB tests provide reduced speed at 25%, 50% overlap

FlexPLI, upper leg, and head impacts
- 40 kph & reduced speed
- 25%, 50% overlap



Advanced Legform Evaluation

- Two benefits of using a legform with upper body mass:
  - (1) Addition of upper body mass provides more accurate femur injury measurement
  - (2) Replaces two tests with one
- Evaluated two candidate legforms (aPLI, Flex-UBM) that do this[1]
- Currently testing an updated version of aPLI



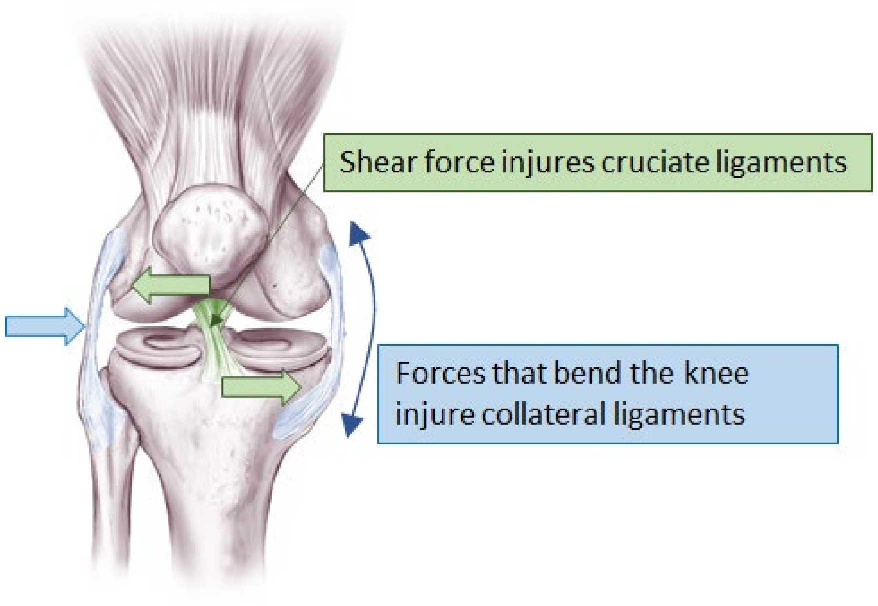
[1]Suntay et al. "Comparison of the aPLI, FlexPLI With Upper Body Mass, and FlexPLI Pedestrian Legforms in Matched-Pair Vehicle Tests" DOT HS 813 086.

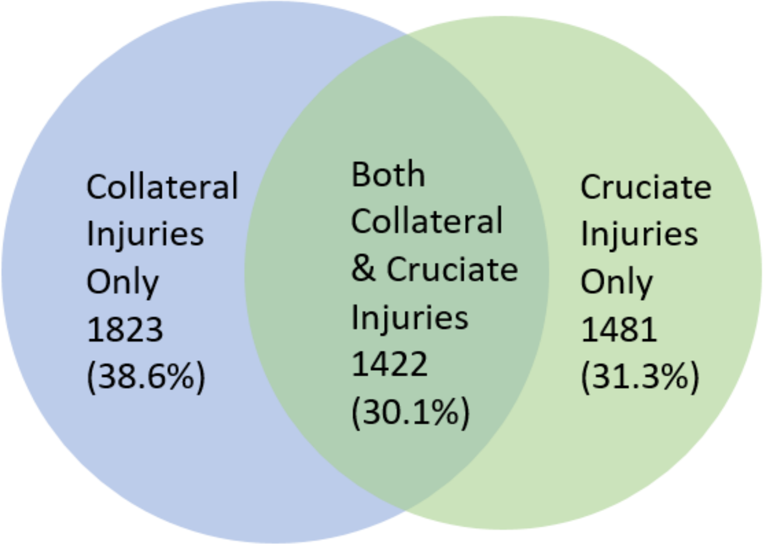
Pedestrian Knee Ligament Injuries

- **Knee cruciate/collateral ligament injury patterns:** is there a need for a cruciate injury metric in the FlexPLI or does a collateral injury metric alone adequately protect the cruciate ligaments?

- NTDB data says yes – more than 60% of pedestrian knee ligament injury cases involve cruciate injuries that could be predicted with a shear/cruciate metric

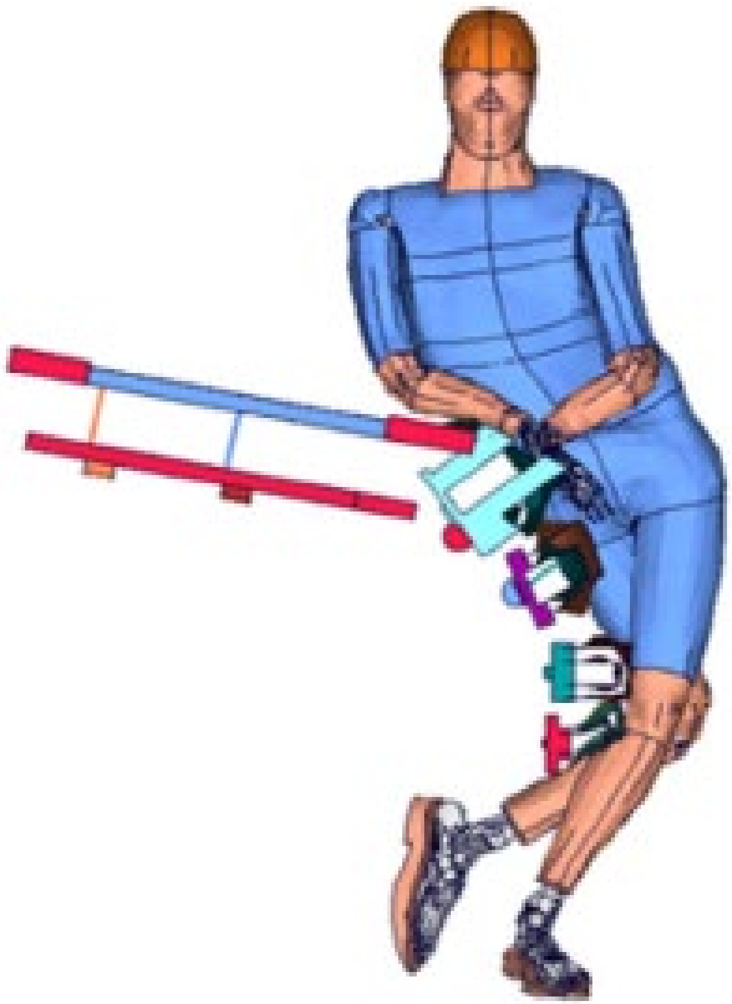
- Technical paper under review





Pedestrian Thorax Injury Assessment

- Thorax injuries from hood contact among most frequent serious pedestrian injuries
- Objective: use trauma center data (NTDB) to determine if reductions in thorax injuries are keeping pace with expected reductions in head, leg, and pelvis injury
- Preliminary results based on ~100K pedestrian cases since 2007 show an increasing proportion of cases with thorax injuries



Technical Support

- An NPRM on head-to-hood impact is included in the Unified Agenda at
  https://www.reginfo.gov/public/do/eAgendaViewRule?pubId=202104&RIN=2127-AK98

- We are providing technical support to other NHTSA offices:
  - Cost-benefit calculations, including test data, field injury data for target population, and vehicle dimensions
  - GTR No. 9
  - Method to find head impact times (HITs) for pop-up hood systems

Summary

For more information see Docket ID NHTSA-2019-0112 NHTSA Crashworthiness Research – Pedestrian Protection Documentation

Pedestrian Crashworthiness – Modeling and Predicting Head Impact Time

Whitney Tatem

Pedestrian Crashworthiness

Modeling and Predicting Pedestrian Head Impact Time (HIT)

Purpose:

The purpose of this research effort is to define an objective process to calculate a representative HIT time for use in standardized testing of vehicles both with and without active hood systems.

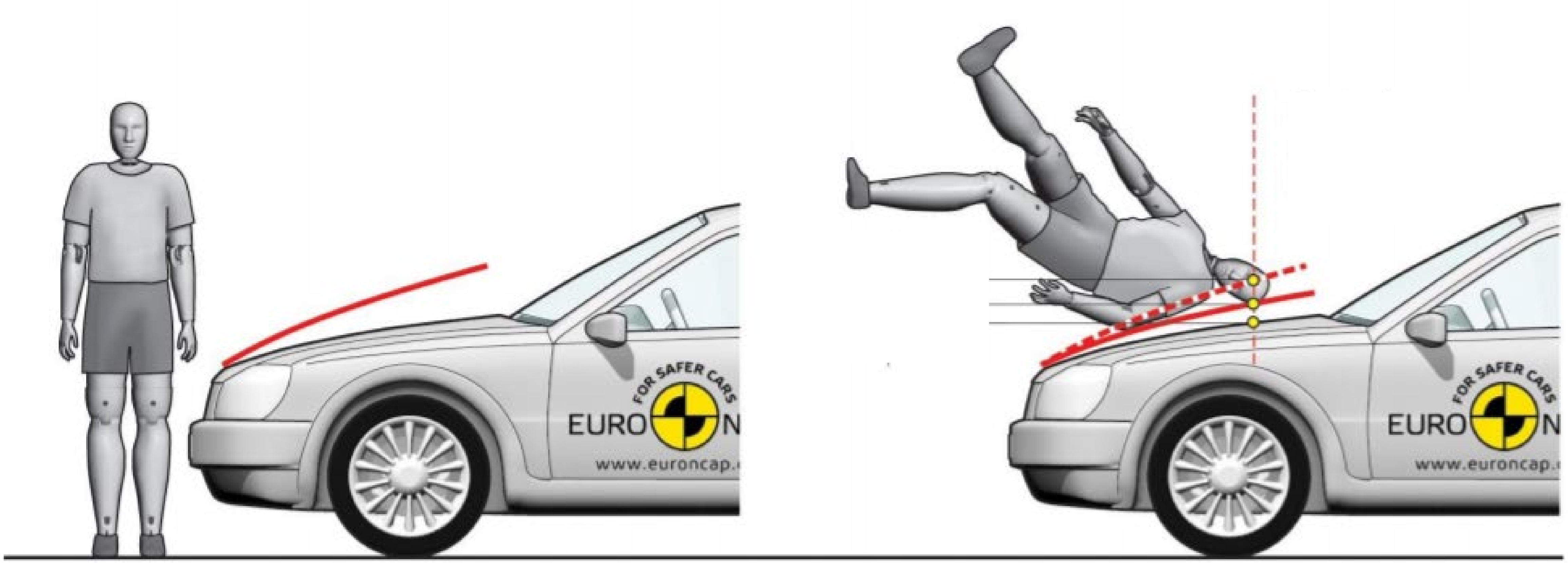
Tasks:

Establish a virtual dataset of HITs for various vehicles sold in the U.S. via FE modeling.

Based on the HIT dataset, develop a general algorithm to predict a HIT based on crash, pedestrian, and vehicle characteristics.

Active Hoods/Bonnets and Global Technical Regulation (GTR) No. 9, ‘Pedestrian Safety’

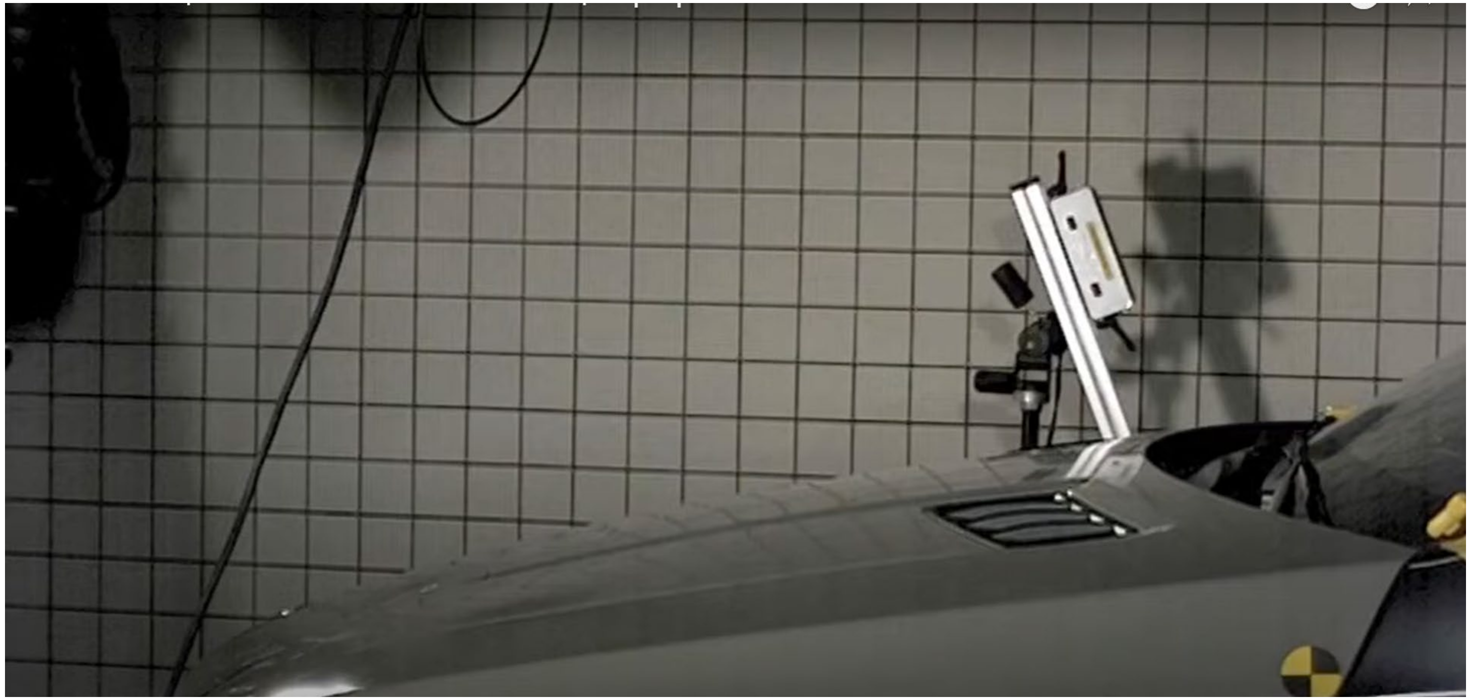
Headform impacts are used to assess pedestrian head injury risk and can be conducted on both standard and active hoods/bonnets.

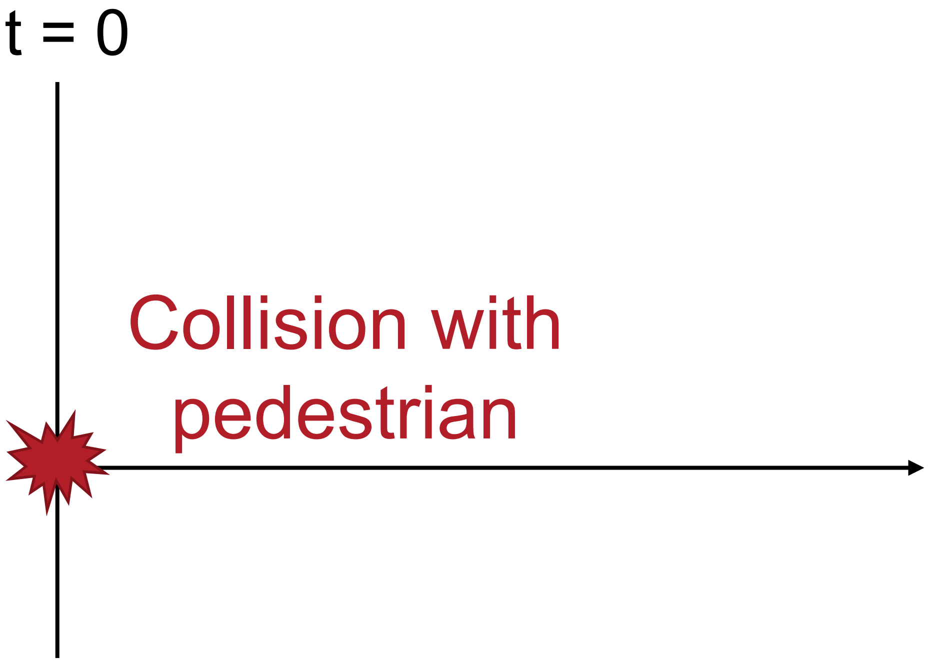


Source: EuroNCAP Pedestrian Testing Protocol, Version 8.4, Nov 2017

Draft GTR No. 9 Test Procedure

Example Headform Impact Test with an Active Hood





Source: EuroNCAP, Pedestrian Headform Test with a Pop-up Bonnet

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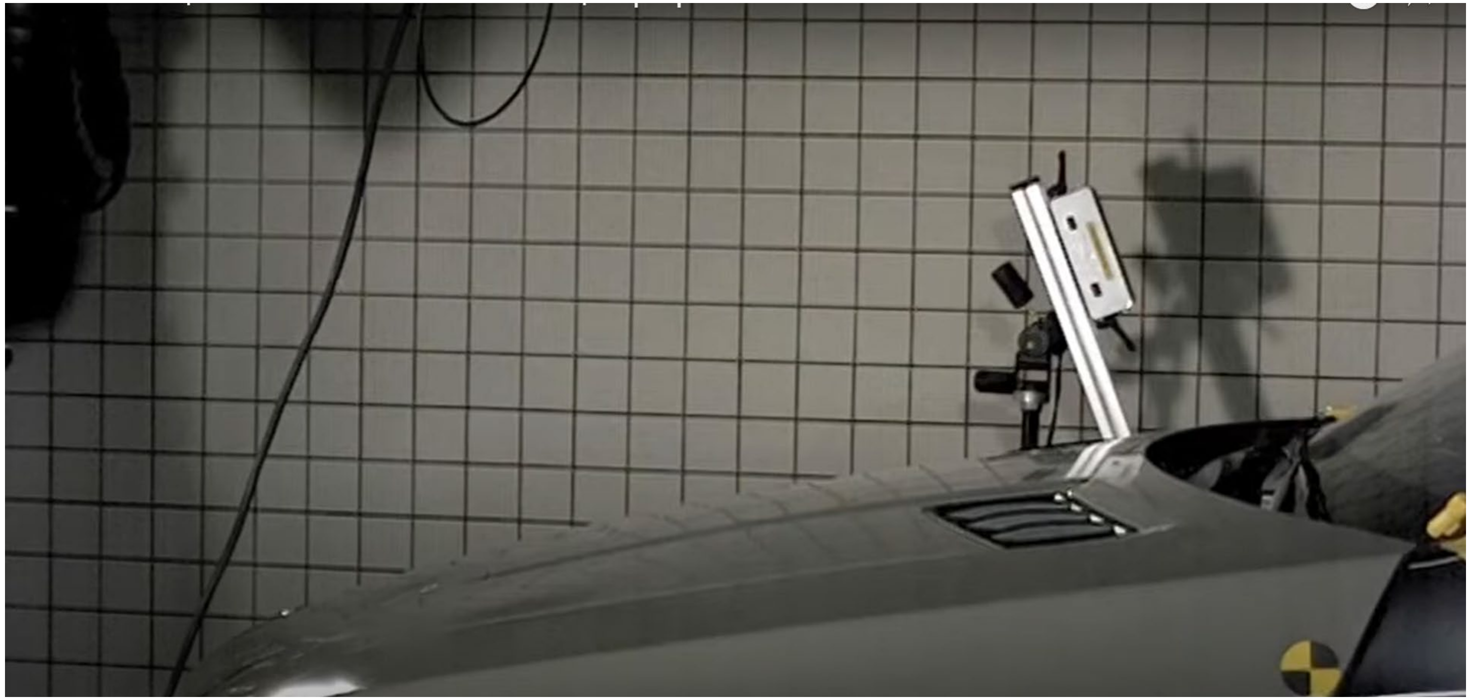

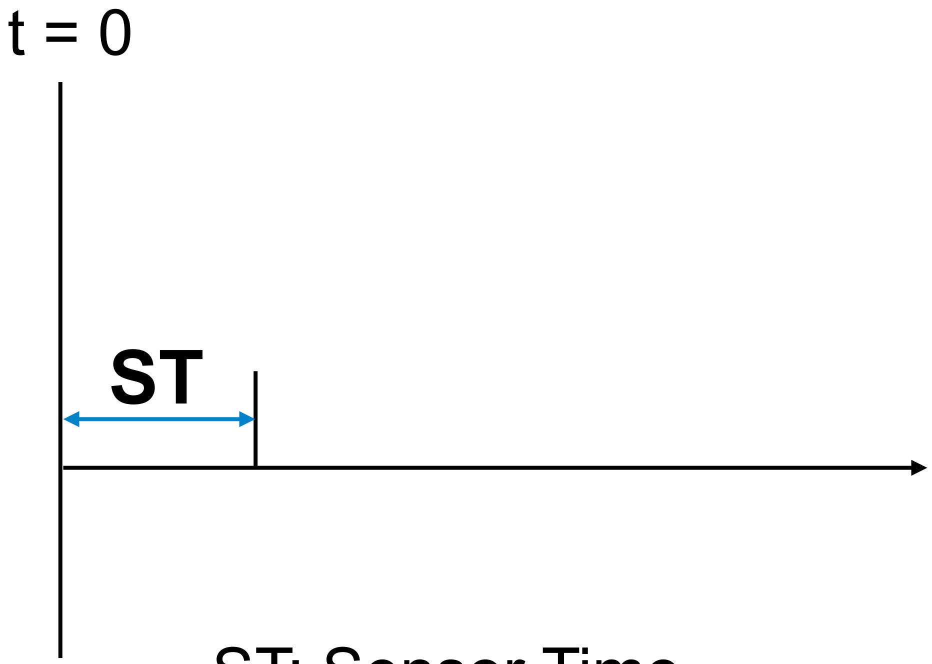

ST: Sensor Time

Time between pedestrian detection and hood activation.

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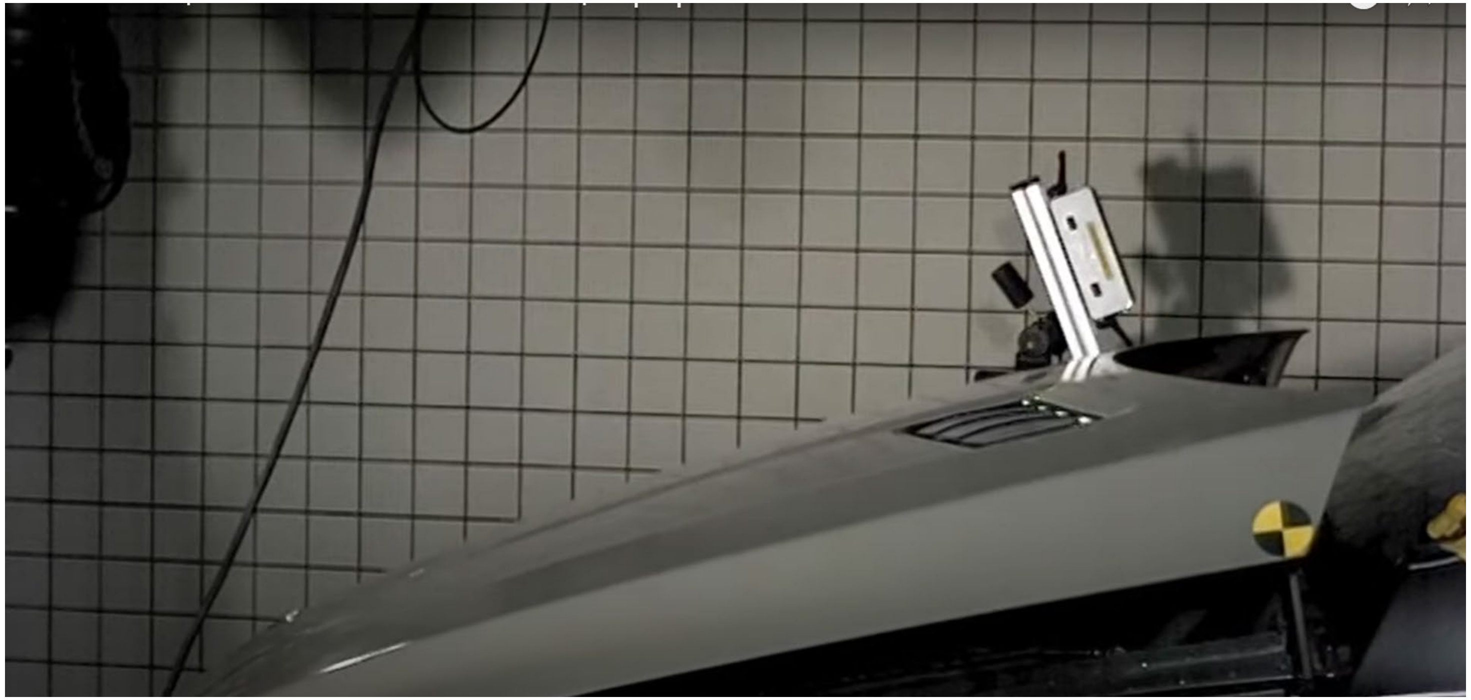

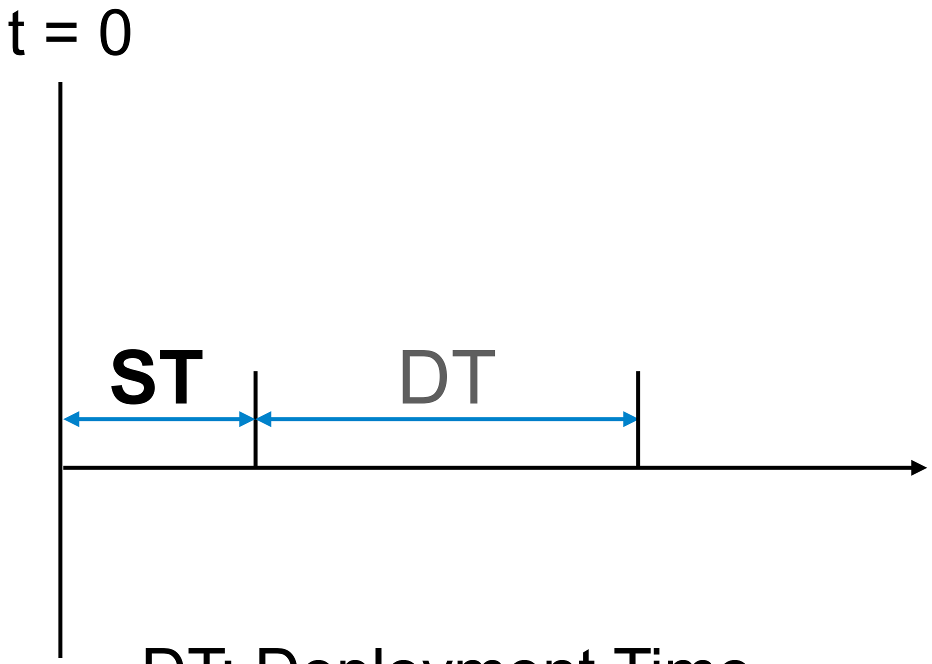

DT: Deployment Time

Time it takes for the hood to reach its fully deployed position.

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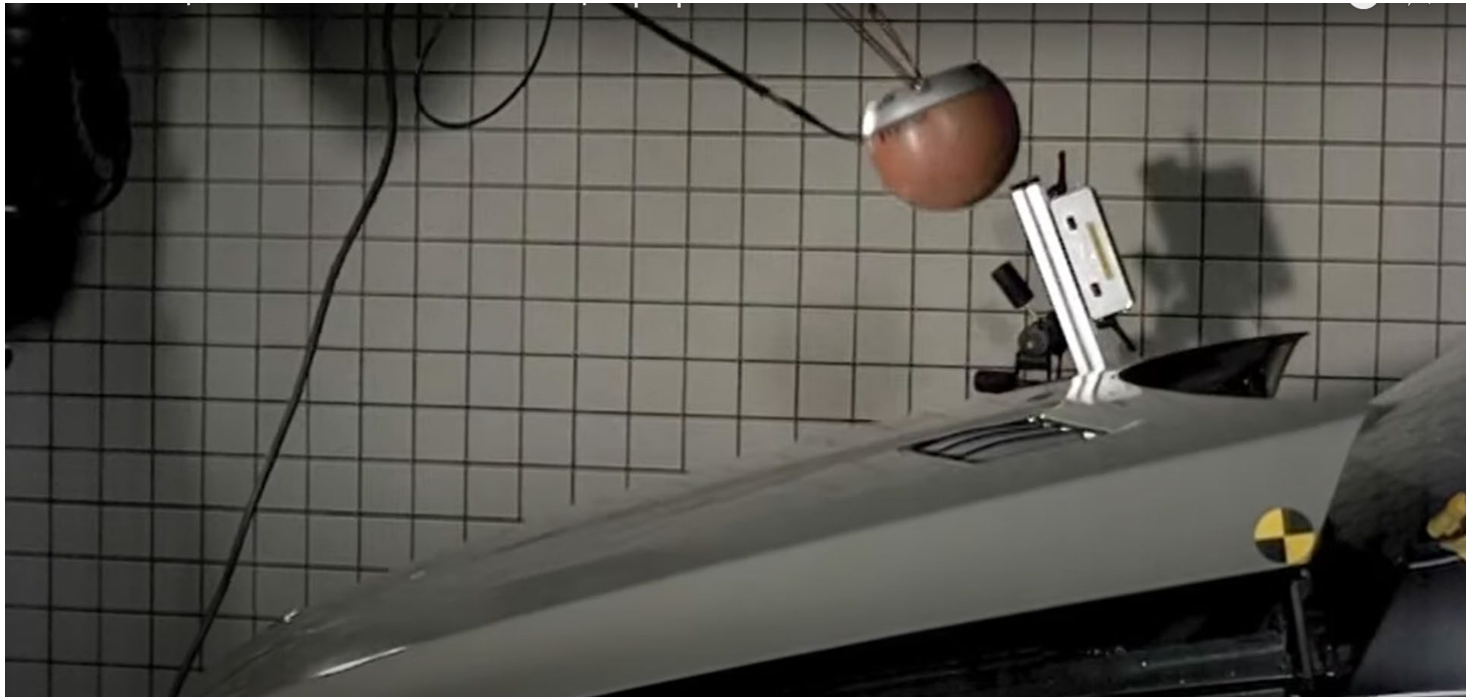

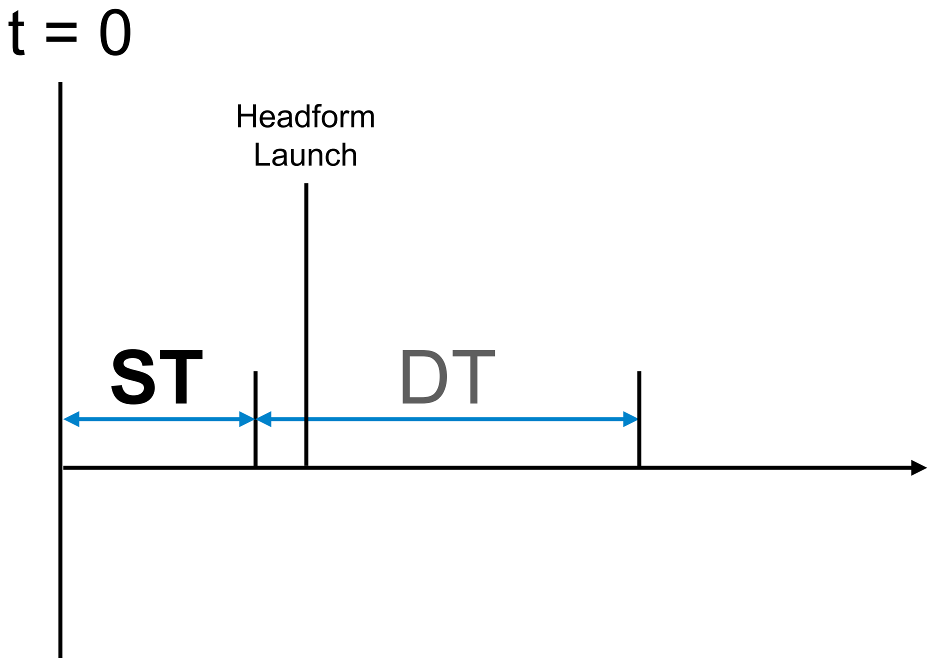

Source: EuroNCAP, Pedestrian Headform Test with a Pop-up Bonnet

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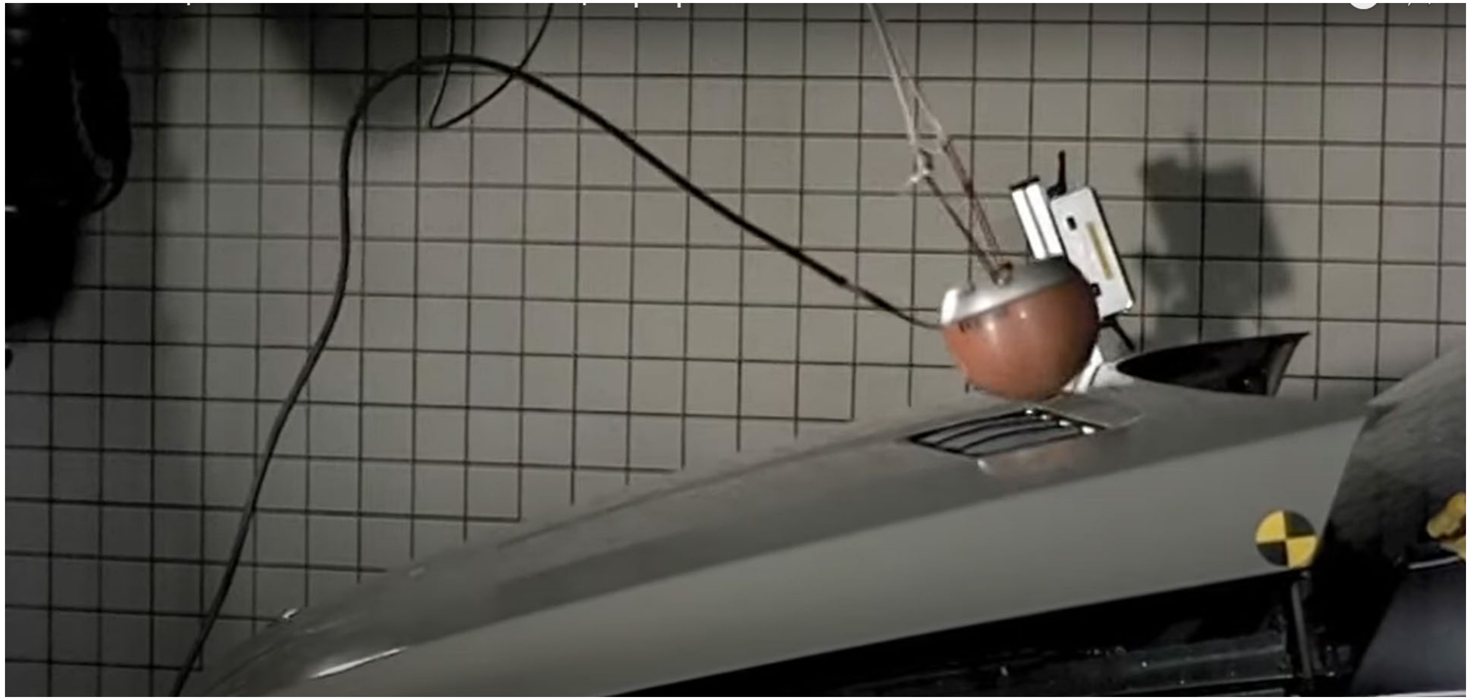

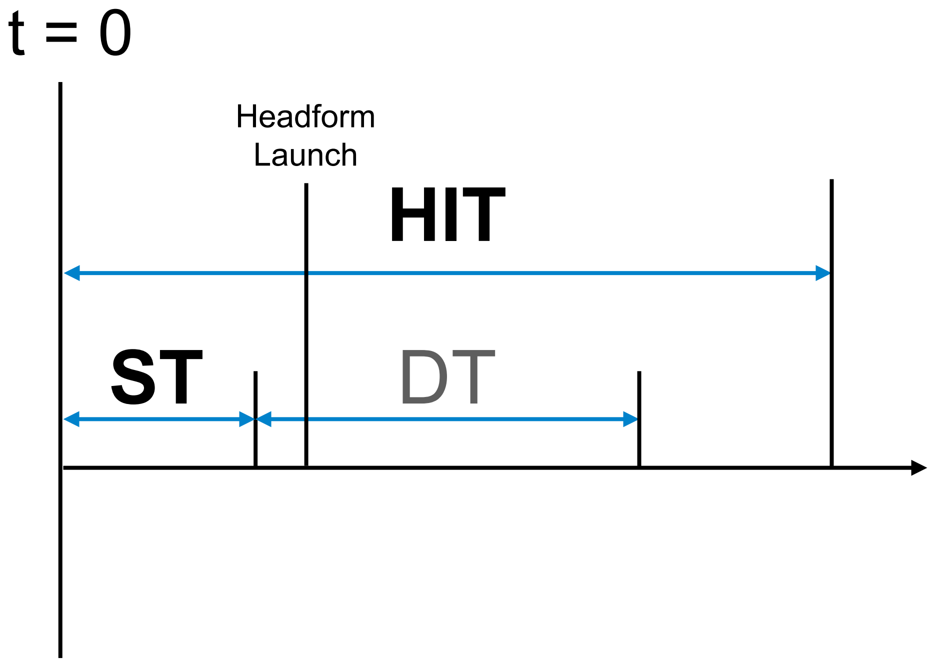

HIT: Head Impact Time

Time that the pedestrian headform makes first contact with the hood/bonnet.

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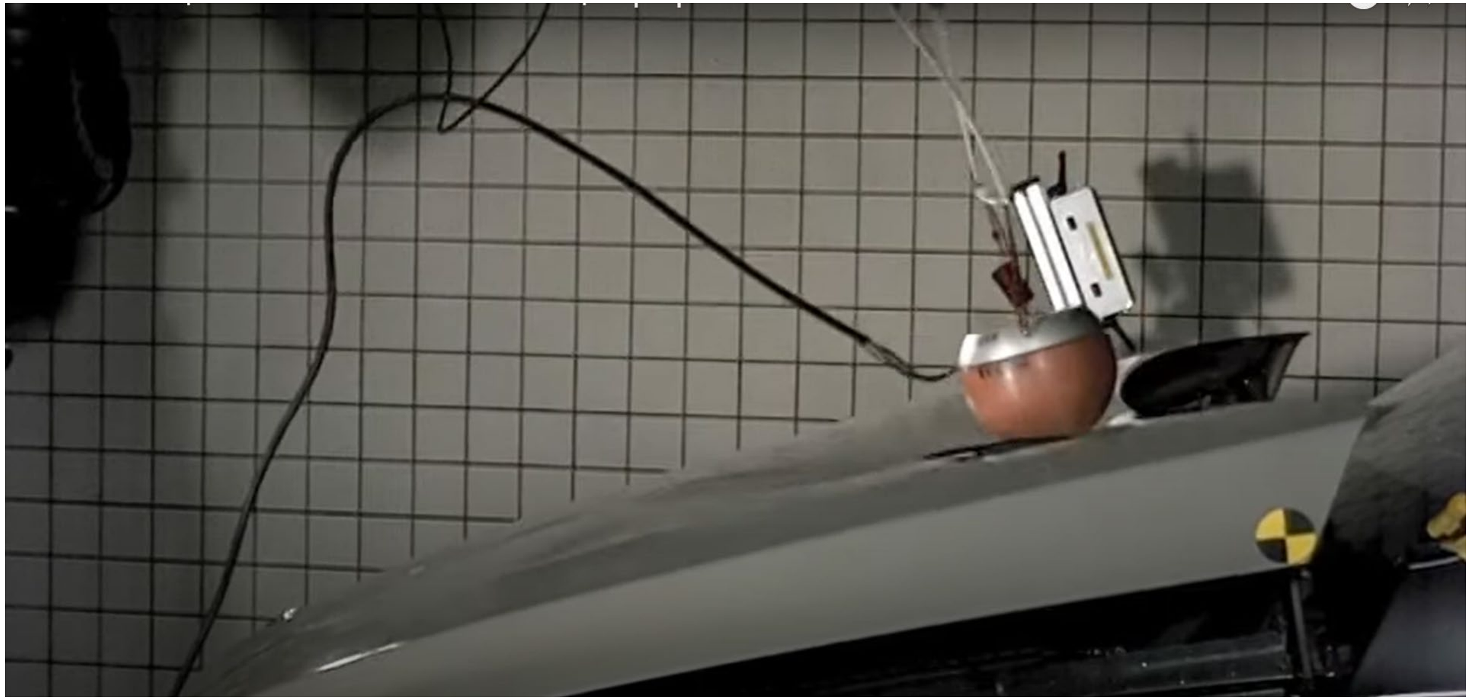
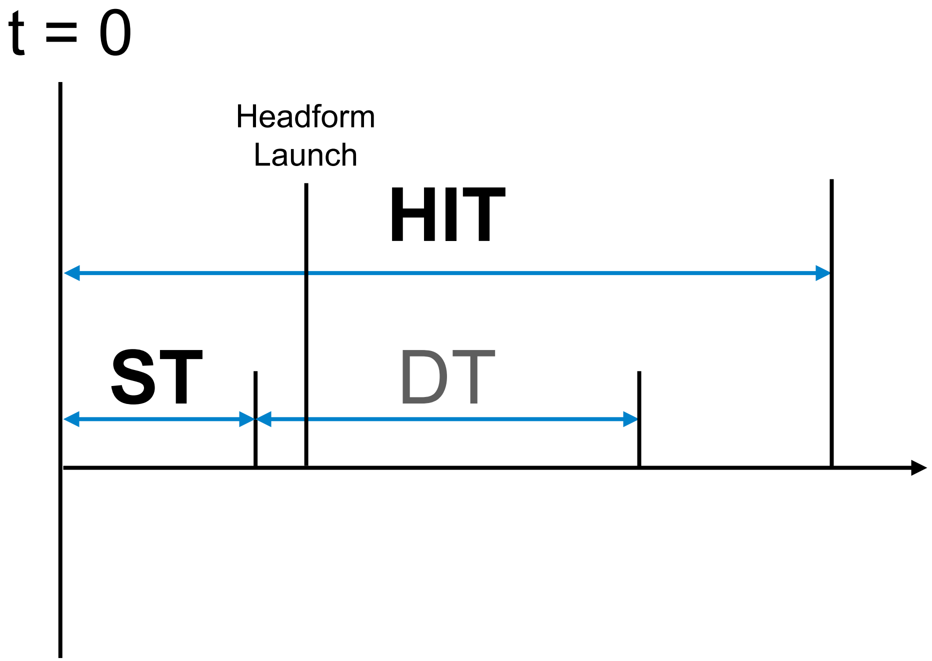
Example Headform Impact Test with an Active Hood

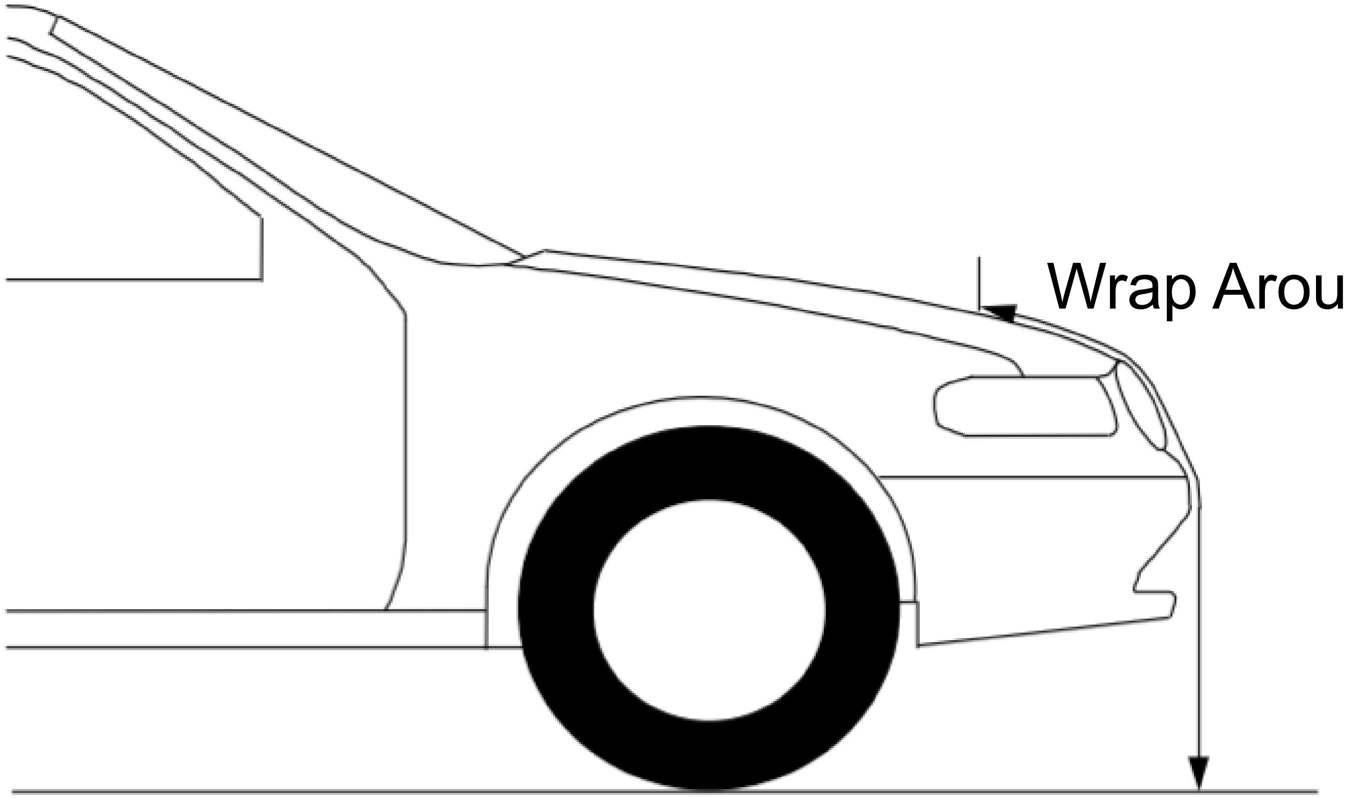




Source: EuroNCAP, Pedestrian Headform Test with a Pop-up Bonnet

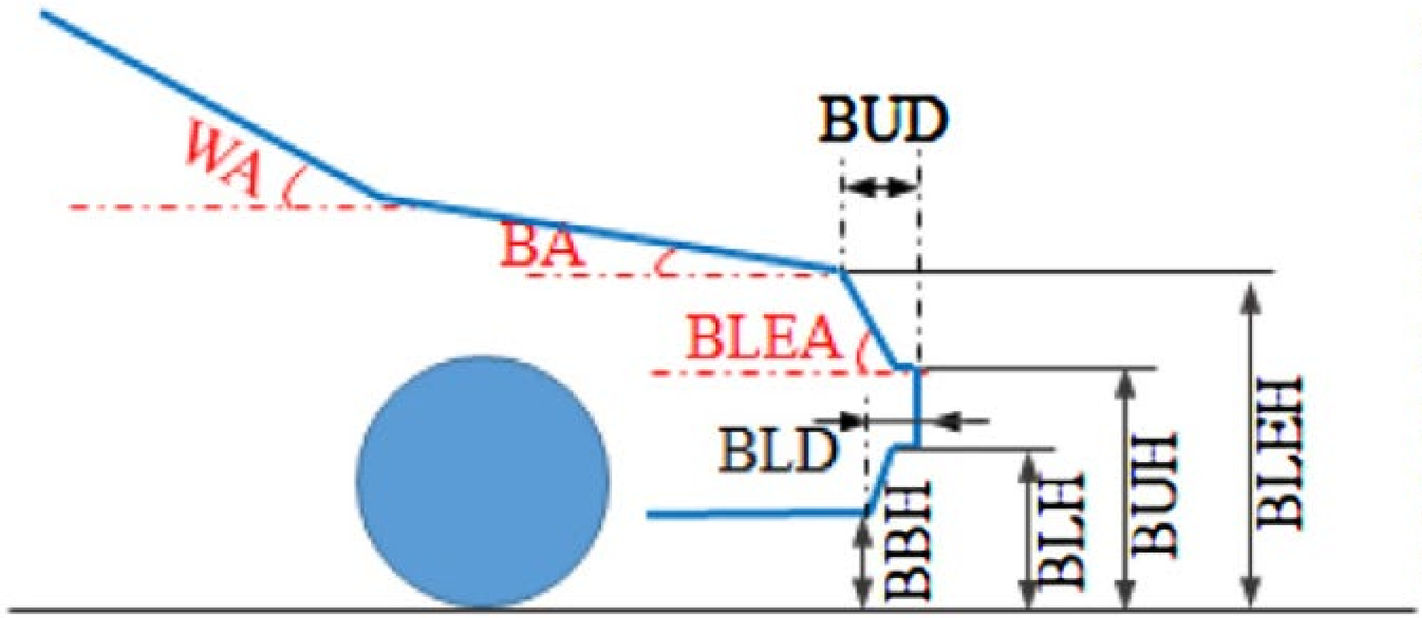
How can we determine HIT?

In literature, HIT has been shown to be affected by both pedestrian wrap around distance (WAD)…



How can we determine HIT?

In literature, HIT has been shown to be affected by both pedestrian wrap around distance (WAD) and vehicle front-end characteristics.



BBH: Bumper Bottom Height
BLH: Bumper Lower Height
BLD: Bumper Lower Depth
BUH: Bumper Upper Height
BUD: Bumper Upper Depth
BLEH: Bonnet Leading Edge Height
BLEA: Bonnet Leading Edge Angle
BA: Bonnet Angle
WA: Windscreen Angle

Goals and Outcomes of NHTSA’s Exploratory Research

- Comprehensive literature summary of variables influential to pedestrian HIT
- Fleet survey of U.S. vehicle front-end characteristics
- Development of a HIT dataset based on numerous simulations in a variety of configurations (crash, pedestrian, and vehicle)
- Algorithm to predict HIT based on selected crash, pedestrian, and vehicle characteristics

Thank you for your time and attention

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