Safety Always Matters: How the Need for Occupant Protection Will Influence Vehicle Design with Increasing Vehicle Automation

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The Current Crash Injury Problem in the U.S.

- Motor-vehicle crashes:
  - –account for 40% of trauma admission to US hospitals,
  - –are the fourth most common cause of non-fatal injuries treated in EDs, and
  - –are one of the leading causes of death for people age 3 to 30 years.
- 35,000 fatalities and ~2.4 million injured road users each year
- Annual economic costs estimated at $277 billion (in 2010), harm associated with lost productivity estimated at $581 billion.

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Sources: CDC (2011), NHTSA (2014), Blincoe et al. (2014)

Important Points of Reference

- NHTSA's Federal Automated Vehicles Policy
- SAE J3016

Absurd Interiors

SAE INTERNATIONAL

SURFACE VEHICLE RECOMMENDED PRACTICE	J3016™	SEP2016
	Issued 2014-01 Revised 2016-09 Superseding J3016 JAN2014	
(R) Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles		

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Important Points of Reference

NHTSA's Federal Automated Vehicles Policy

"Regardless of whether the ADS* is operating the vehicle or the vehicle is being driven by a human driver, the occupant protection system should maintain its intended performance level in the event of a crash."

* Automated Driving System

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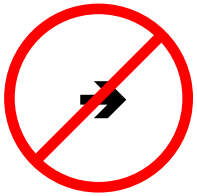
Spot the Fallacy

Drivers cause 95% of crashes

+

Driverless cars don’t have drivers



With driverless cars we will have 95% fewer crashes?

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Don’t Believe (most of) the Hype

- Driving is exceptionally complex. Going from easy driving to difficult driving is much easier for humans than for computers.
- The infrastructure is not designed for automation.
- AI systems do not respond well to unusual or highly variable events (police officer directing traffic after a crash or sporting event, many weather conditions)
- Current US risk is ~1 fatality/100 million miles (includes weather, drunk, no belts…); how much safer does automation need to be to be acceptable?

Automation in other fields suggests some cautions: **de-skilling**, mode confusion, humans called upon only in extreme conditions that lead to automation failure, and low acceptance of machine failure

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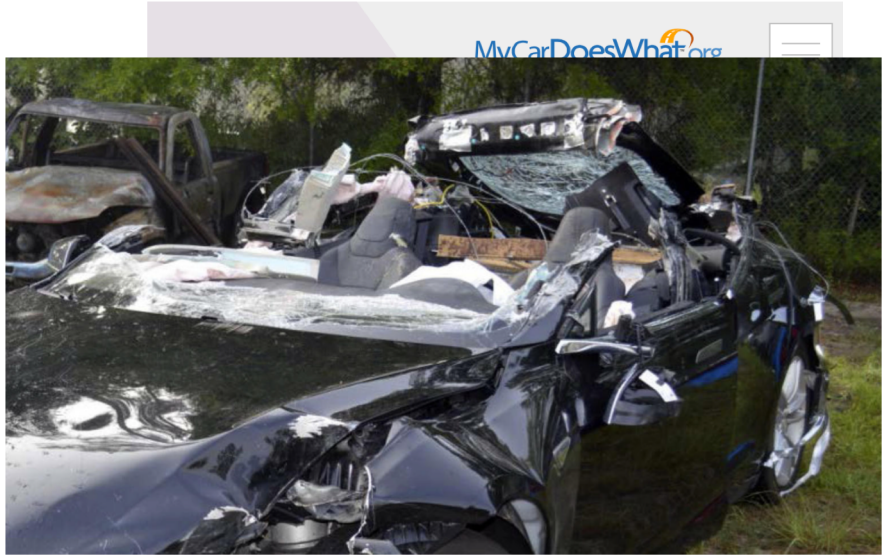
Near-Term Technology (5 years)

Crash Avoidance:

- lane-departure warning, lane-keeping assist
- forward collision warning, automatic emergency braking
- adaptive cruise control (ACC)
- ACC with lane-keeping (“autopilot”)
- low-speed “traffic-jam assist”
- blind spot warning
- adaptive headlighting



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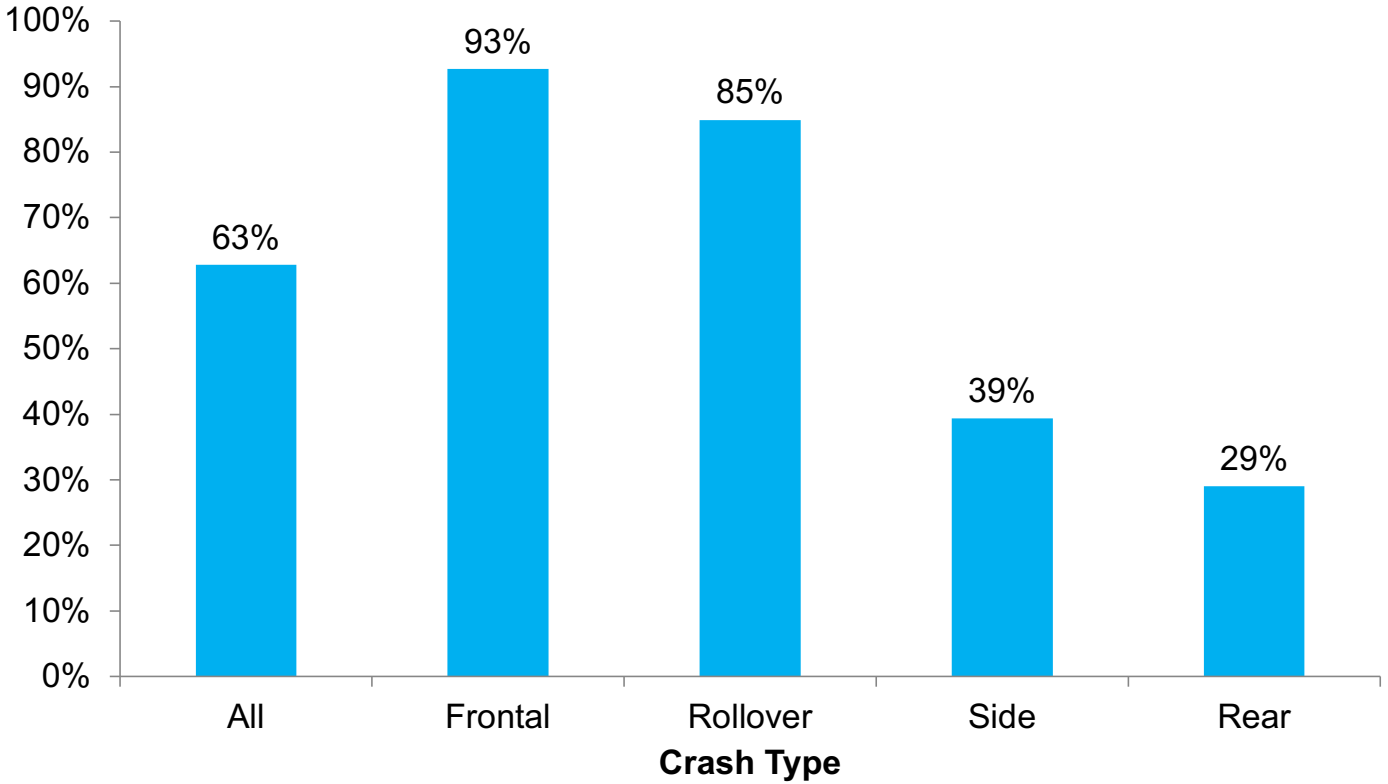
Mythical Vehicles

What if my vehicle can’t cause a crash?

(But still might get hit by other cars…)

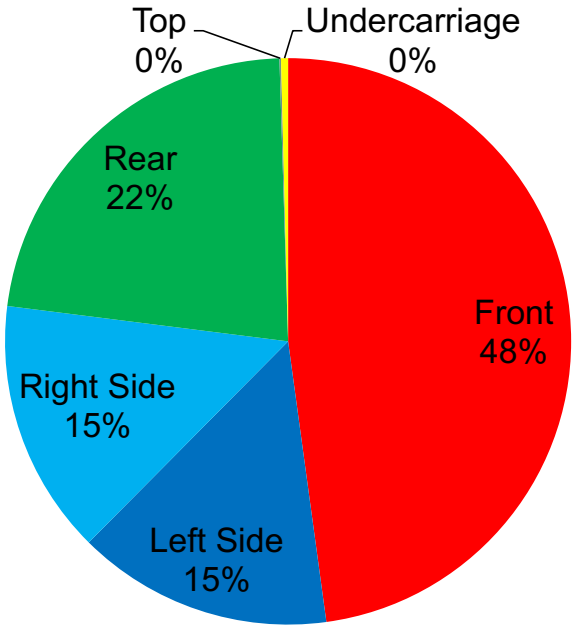
Crashes Avoided by a Vehicle that Doesn't Cause Any Crashes

Percentage of crashes prevented with ideal crash avoidance

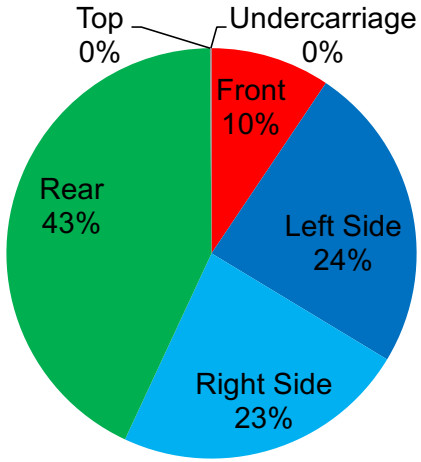


Klinich et al. 2016 IRCOBI

Crash Type Distribution



Current



With Ideal Crash Avoidance

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Near-Term Technology (5 years)

Crashworthiness and Occupant Protection:

- improved adaptive restraint systems (weight and seat position)
- improved vehicle structures for reduced intrusion
- expanded airbag coverage in the front seat
- more advanced restraint technology in rear seats
- “active-passive integration”: restraints adapting to real-time crash information from crash avoidance sensors
- improved protection for people who don’t look like crash test dummies.

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Phase-In Timelines

- 50% of registered vehicles in the US are more than 12 years old (but people drive their newer cars more miles)
- Technologies take many years to penetrate the fleet because of relatively slow turnover of vehicles
- **Increasing vehicle cost slows turnover**
- People at higher crash risk tend to drive older vehicles: the average age of a **new car buyer** is 52 years

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Phase-In: Electronic Stability Control

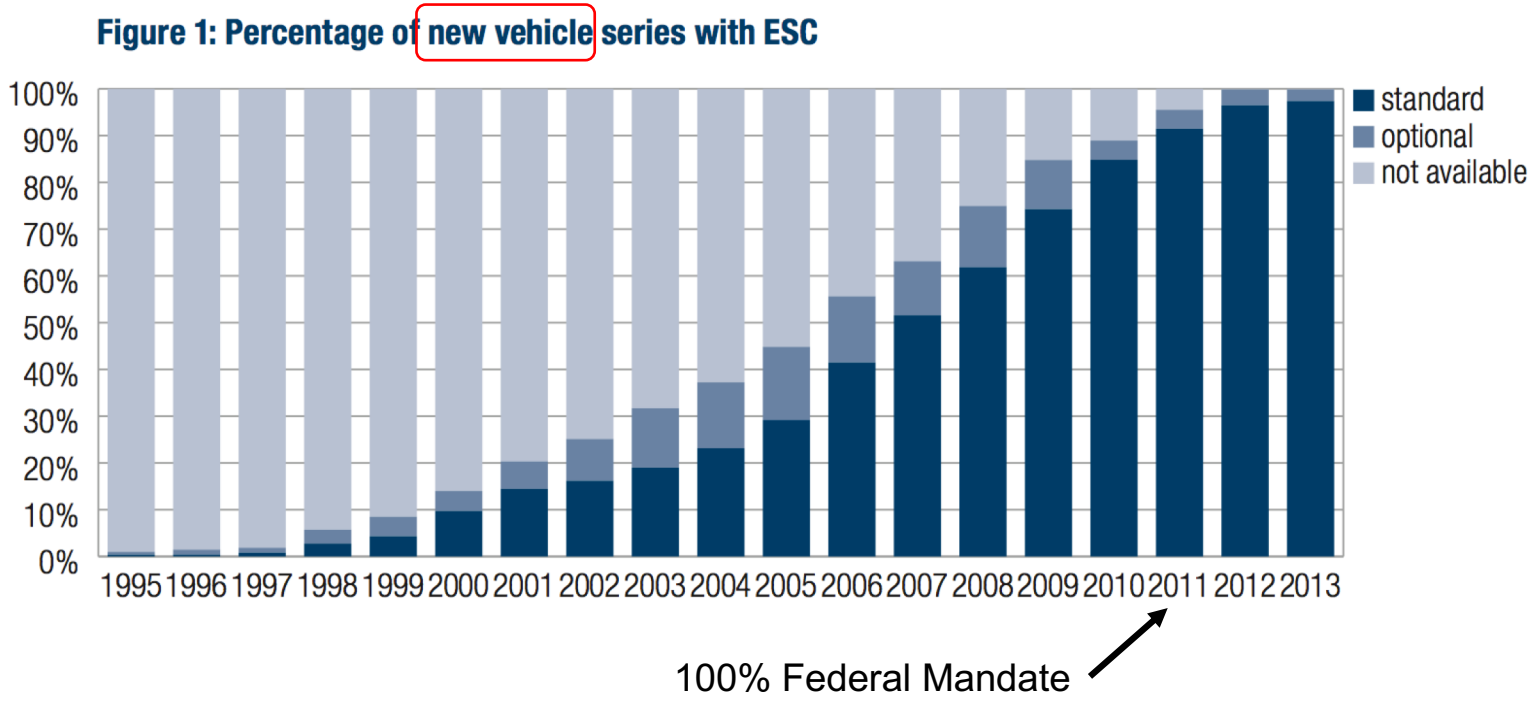
Blue: No ESC

Red: ESC

ESC prevents about 40% of all crashes involving loss of control. The greatest reductions were found for rollover crashes (−50%), followed by run-off-road (−40%) and single vehicle crashes (−25%).

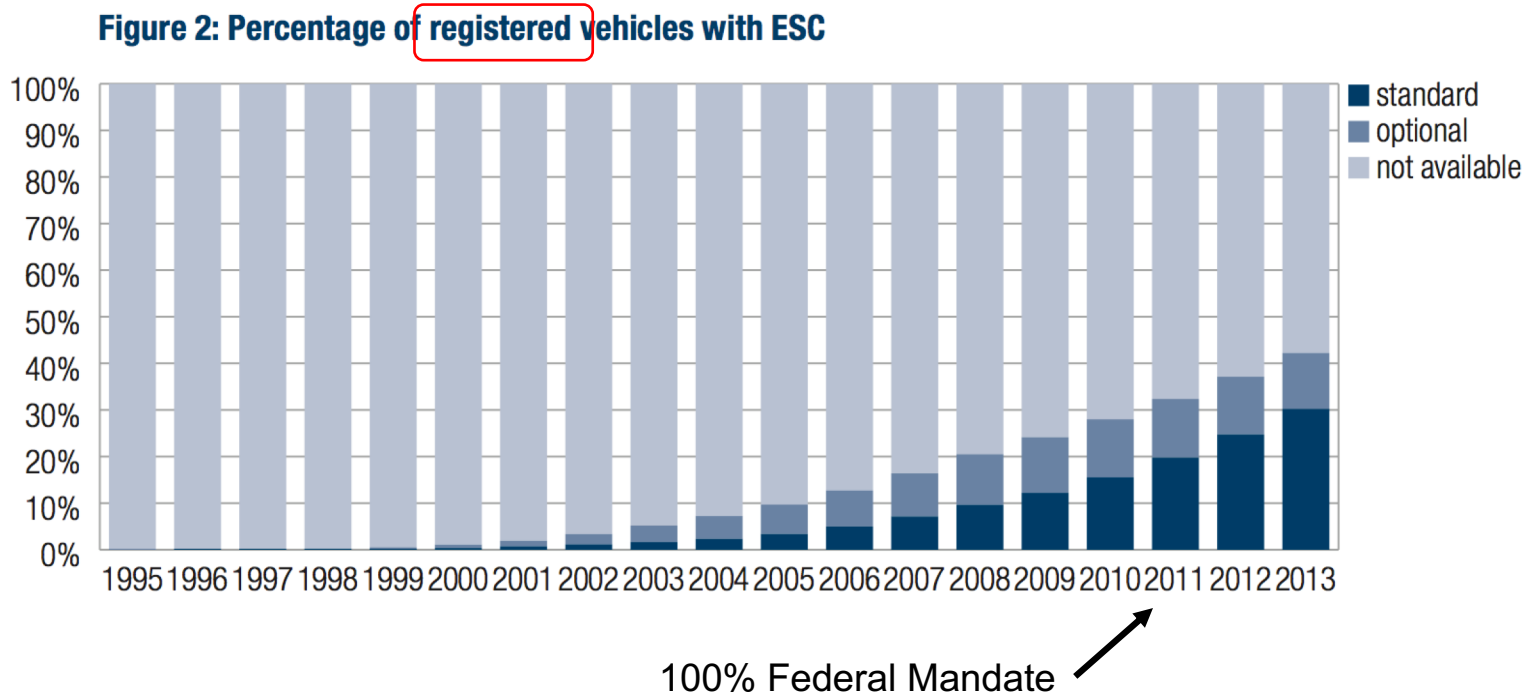
Source: Høye (2011). Accident Analysis and Prevention

Phase-In: Electronic Stability Control



Source: IIHS

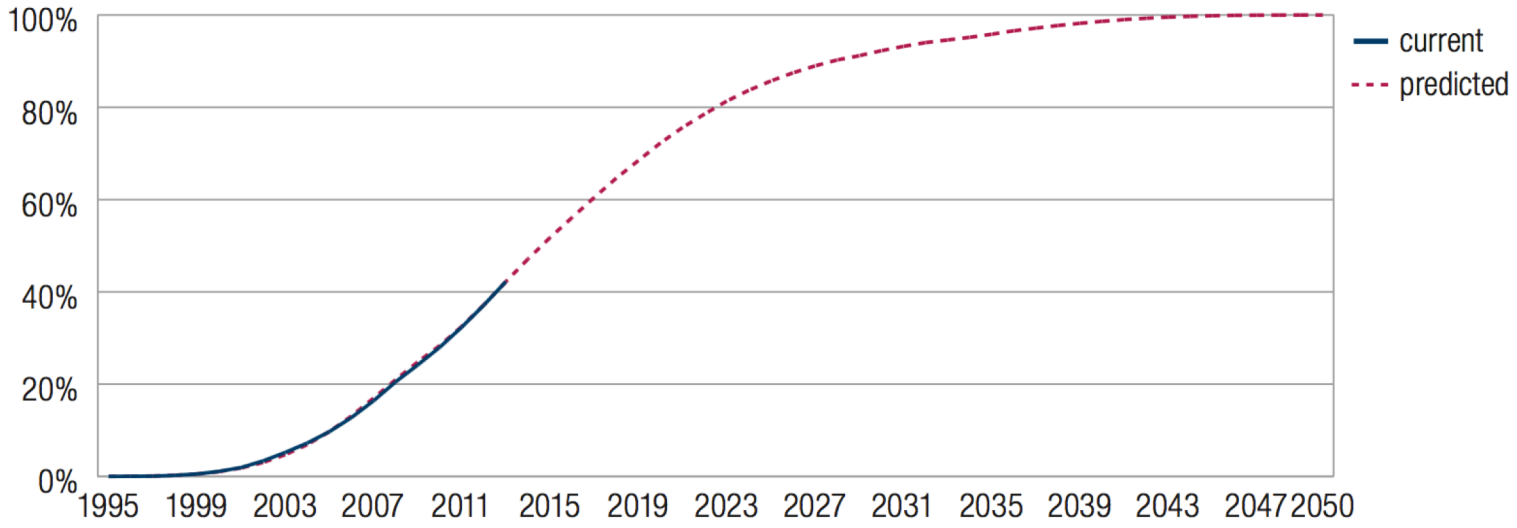
Phase-In: Electronic Stability Control



Source: IIHS

Phase-In: Electronic Stability Control

Figure 3: Predicted percentage of registered vehicles with ESC



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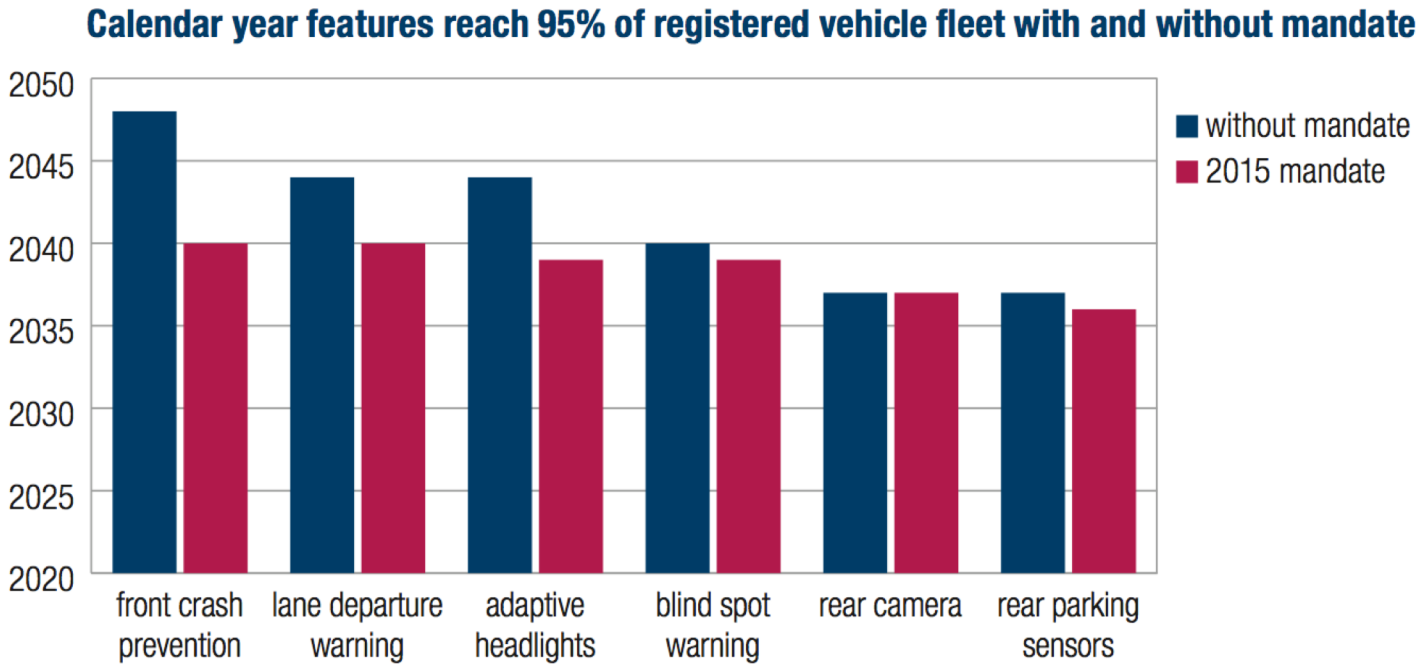
Source: IIHS

Phase-In : Electronic Stability Control



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Source: IIHS

Crashworthiness and Occupant Protection Regs (selected)

FMVSS* 201: Interior head impact **

FMVSS 202a: Rear impact neck protection **

FMVSS 203, 204: Steering wheel & column performance

FMVSS 205: Glazing

FMVSS 206: Door locks & retention

FMVSS 207: Seat back strength **

FMVSS 208: Frontal crash protection & belts **

FMVSS 209, 210: Seat belts **

Remains applicable without driver

**Implications for Seating

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* Federal Motor Vehicle Safety Standard

Crashworthiness and Occupant Protection Regs (selected)

FMVSS 212: Windshield mounting

FMVSS 213: Child restraint systems*

FMVSS 214: Side-impact protection **

FMVSS 216: Roof crush

FMVSS 225: Child restraint anchorages **

Remains applicable without driver

**Implications for Seating

* Does not apply to vehicles, but strong interactions with FMVSS 225 and vehicle seating

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Federal Policy Matters

- Airbags were effectively delayed for more than a decade by the Reagan administration [with the encouragement of much of the auto industry], costing thousands of lives
- The prohibition by Congress of **belt interlocks** in 1974 cost thousands of lives (still not permitted, though research is underway)
- Delays in primary enforcement of **belt use laws** meant the US lagged behind the rest of the developed world (yes, costing thousands of lives)
- Strong political influence from the **trucking industry** has delayed changes in hours of surface, truck underride protection, antilock brakes, and other safety improvements

What About Ride Hailing?

1. Rear seating positions are not as safe as front seating positions for many occupants, particularly older adults
2. Belt use is much lower for rear-seated ride-hailing passengers than for the same people as drivers or in the back seats of their own vehicles*
3. Ride-hailing rides may be slightly safer per mile than personally driven miles (+driver state, -congestion exposure) and may replace high-risk (e.g., drunk-driving) miles

Crash protection issues remain essentially the same whether or not a driver is present; unbelted rear-seat passengers are at much higher risk than belted front-seat passengers

* Jermakian (IIHS) 2018

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What About (Automated) Ride Hailing Interiors?

1. Plush or utilitarian? Depends on how much money the company is willing to lose per trip.

2. Benchmarks tend toward utilitarian:
   1. Public transportation
   2. Taxis
   3. Airport shuttles

Purpose-built ride-hailing vehicles will experience close scrutiny of their crash safety performance from NHTSA and consumer information groups (e.g., IIHS)

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What About Alternative Postures?

Considerable emphasis in the crash safety and interior design domains relating to automated vehicles is focused on rear-facing and reclined postures

(That belt fit… not so good)

(My favorite absurd vehicle interior pic)

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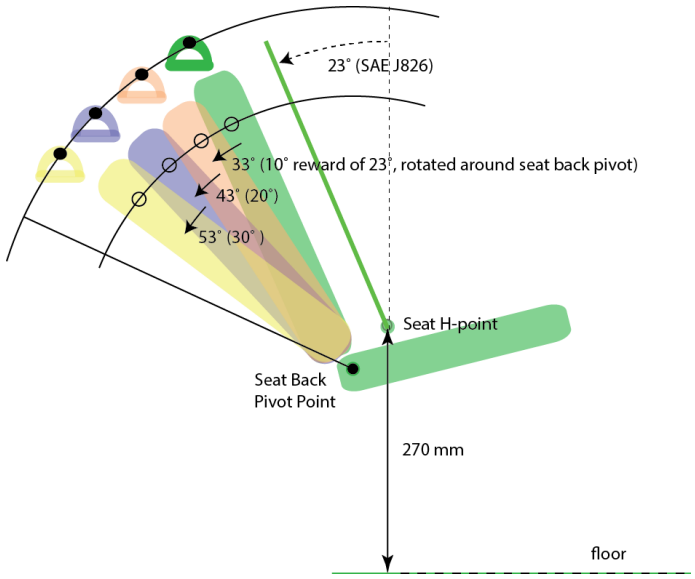
Details of Reclined Postures

Pilot lab study at UMTRI with 24 men and women



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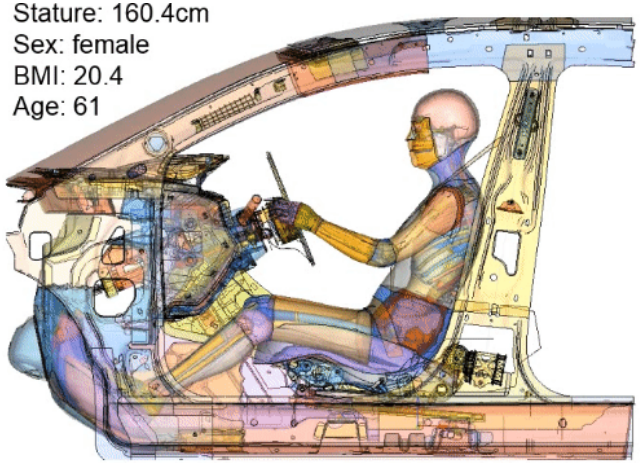
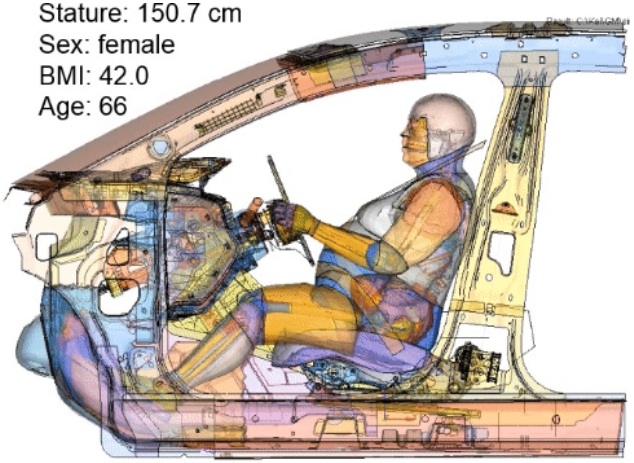
Frontal Crashes for Drivers

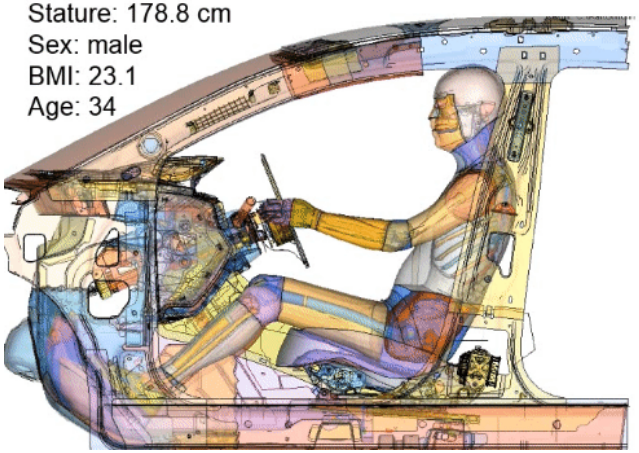
Stature: 160.4cm
Sex: female
BMI: 20.4
Age: 61



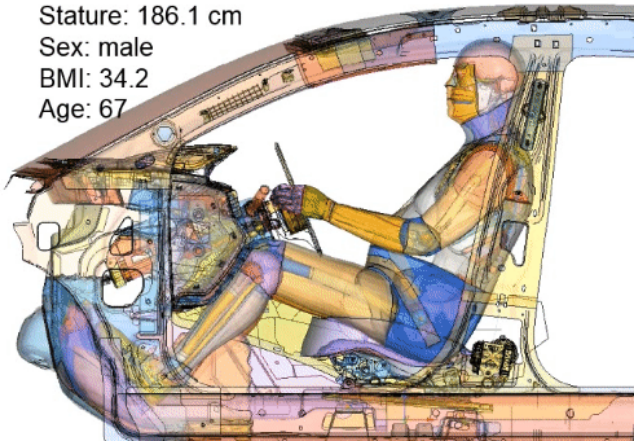
Stature: 150.7 cm
Sex: female
BMI: 42.0
Age: 66



Stature: 178.8 cm
Sex: male
BMI: 23.1
Age: 34



Stature: 186.1 cm
Sex: male
BMI: 34.2
Age: 67



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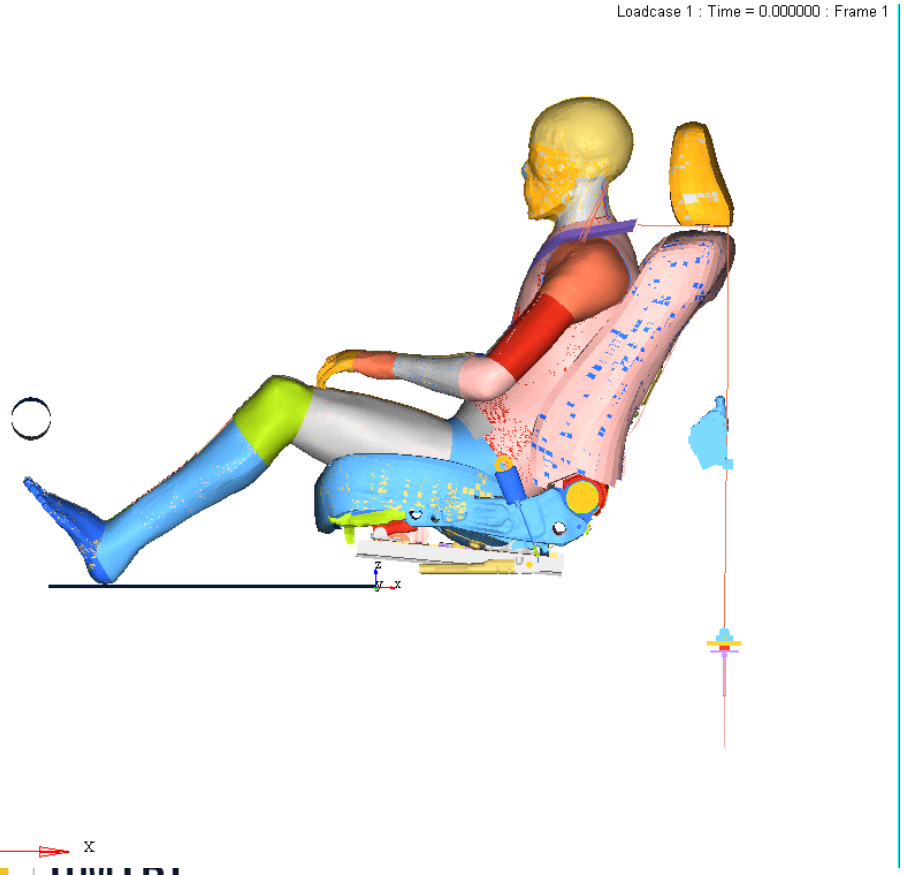
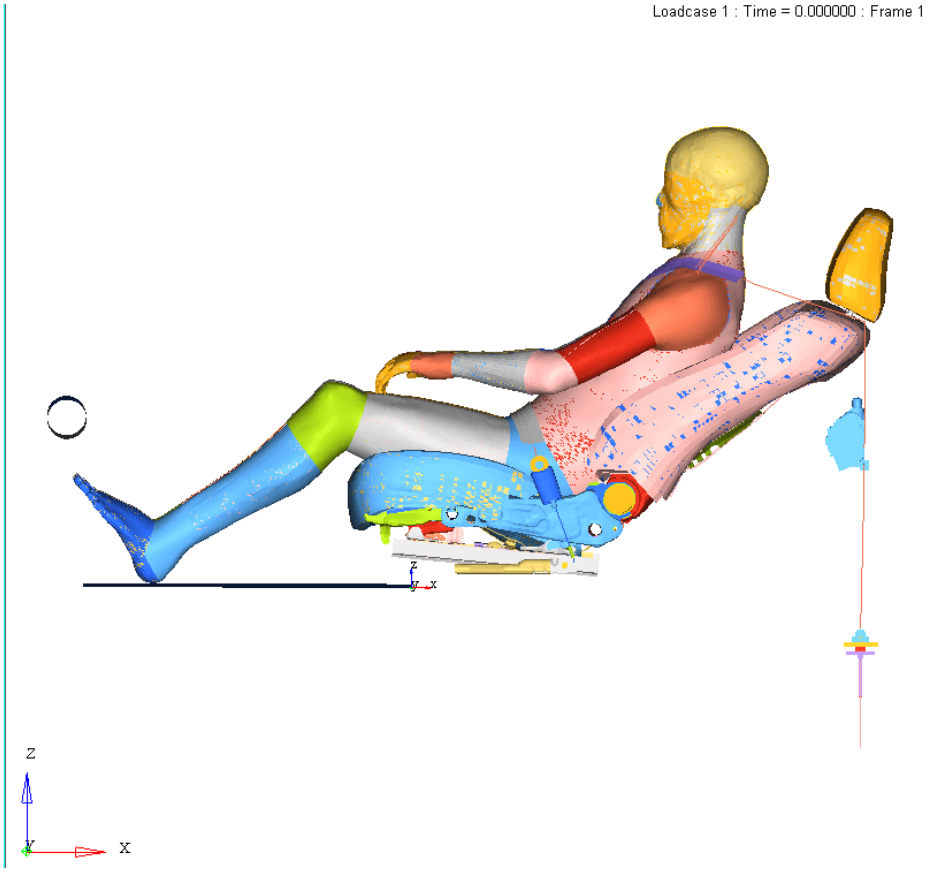
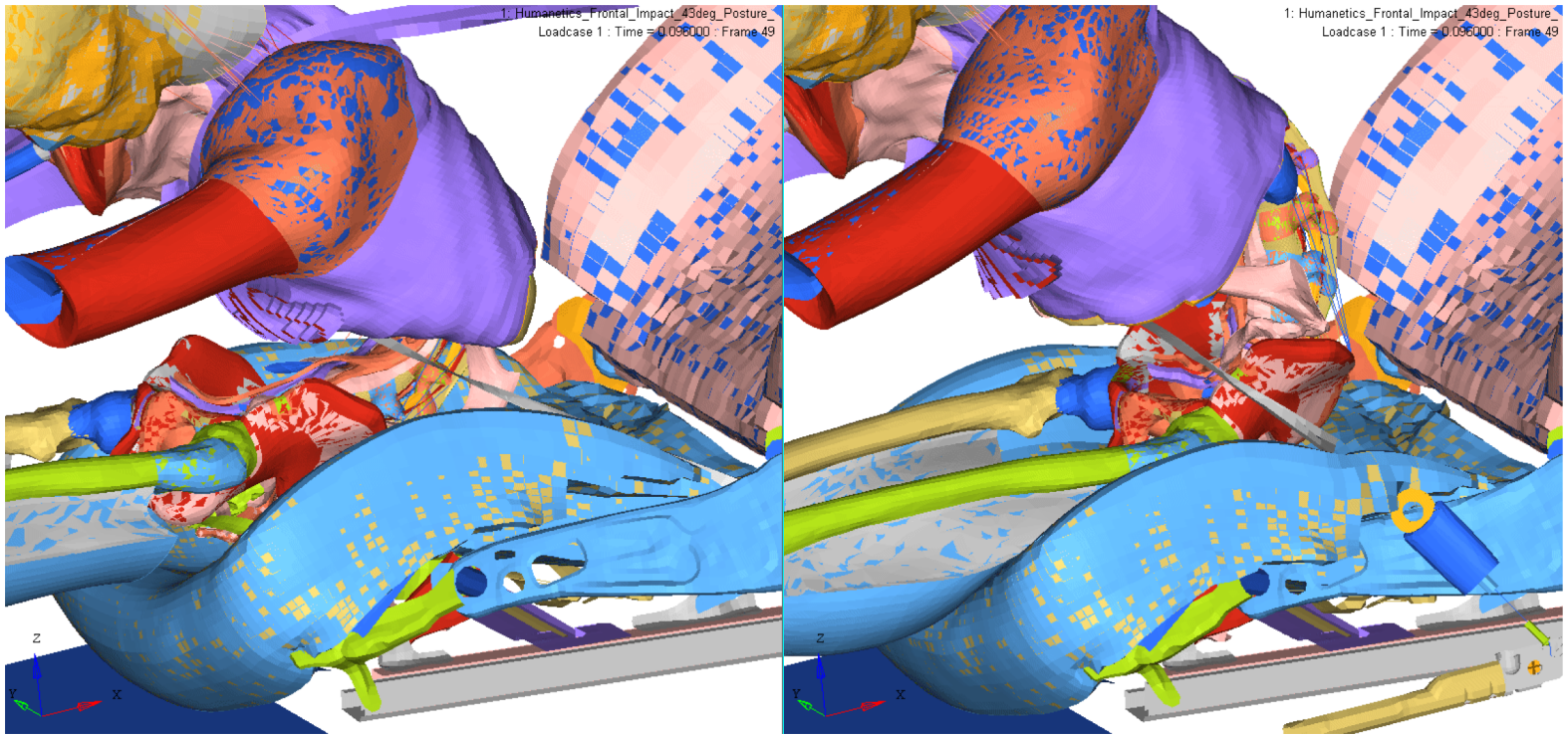
Effects of Recline On Occupant Kinematics





Effects of Recline On Occupant Kinematics

43-Degree Recline



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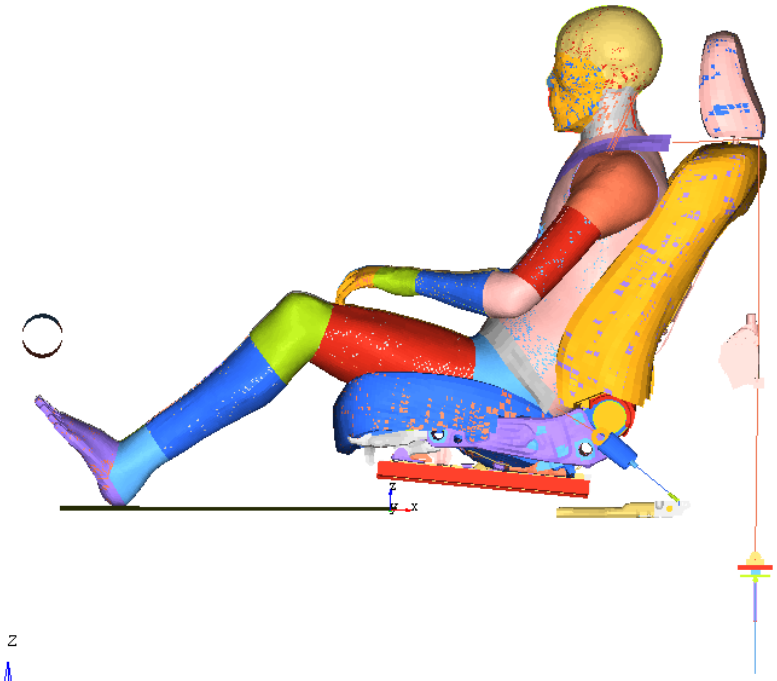
Original Anchor Locations

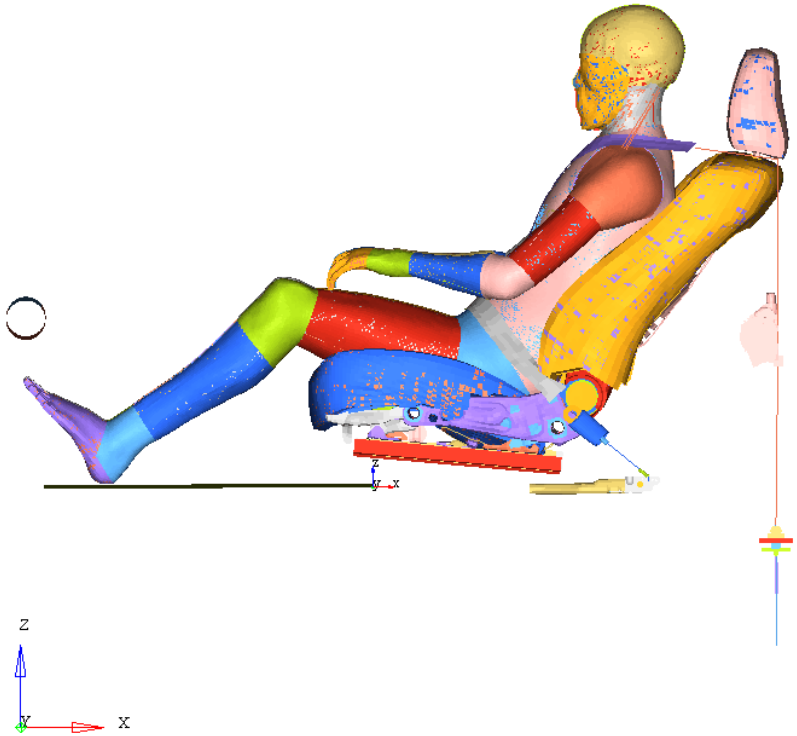
Alternative Anchor Locations

Effects of Recline on Rear Impact

23deg_Rear_Impact : Time = 0.000000 : Frame 1



33deg_Rear_Impact : Time = 0.000000 : Frame 1



What's a "Low Speed Vehicle"?

FMVSS 500 establishes a class of vehicles to which most FMVSS do not apply:

- <25 mph
- access to roads locally regulated
- seatbelts, headlights, a few other safety features are required
- many opportunities to add automation
- seating opportunities?

aka Neighborhood Electric Vehicles

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Implications for Vehicle Seating

- Current-technology seats are going to be sold for a long time
- Safety requirements on seats will continue to increase
- Opportunities to use the seat to improve safety:
  - -- improved protection in side impact
  - -- dynamic pre-crash posture adjustment
  - -- more integrated belt restraints
  - -- occupant sensing and adapting restraints
- Much greater emphasis on reclined postures and rear impact protection

Acknowledgements

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- General Motors
- Toyota
- TRW
- JCI
- Britax
- Faurecia

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- Wayne State U.
- Hunan U.
- Tsinghua U.
- Oakland U.
- UVa

U-M:
- D. of Emergency Medicine
- D. of Pediatrics
- College of Engineering

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