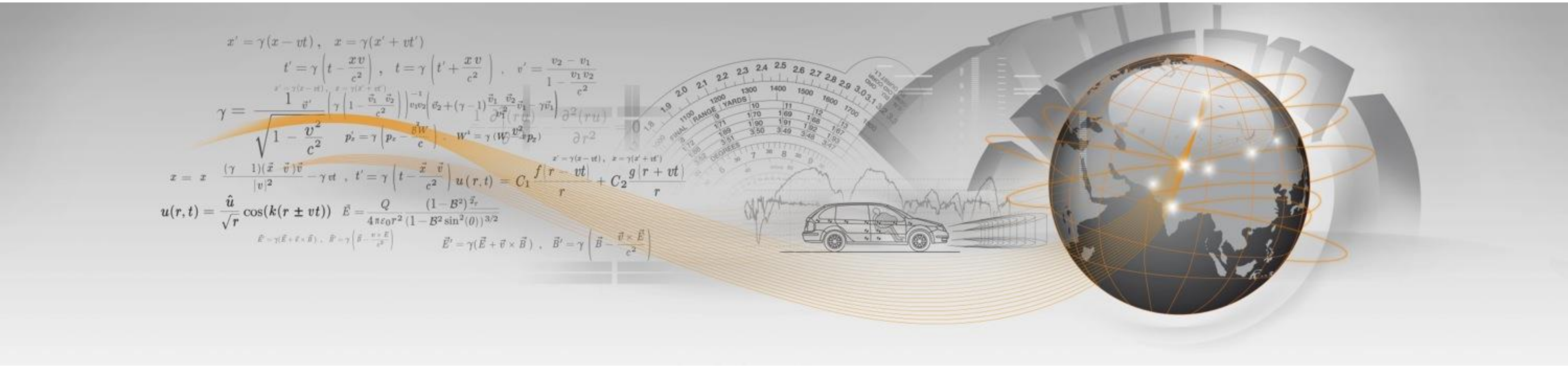

A METHODOLOGY AND TOOL CHAIN TO DESIGN INTEGRATED SAFETY SYSTEMS

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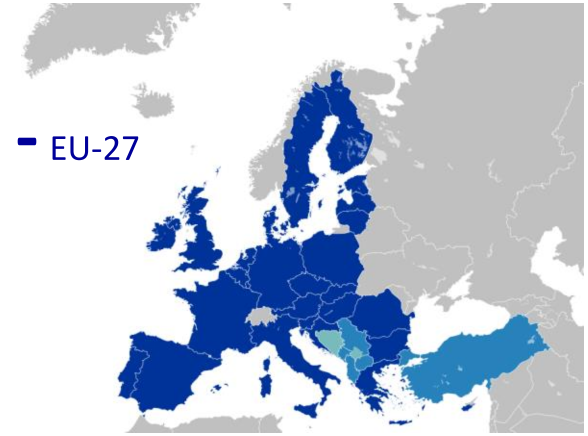
TASS International

June 15, 2017

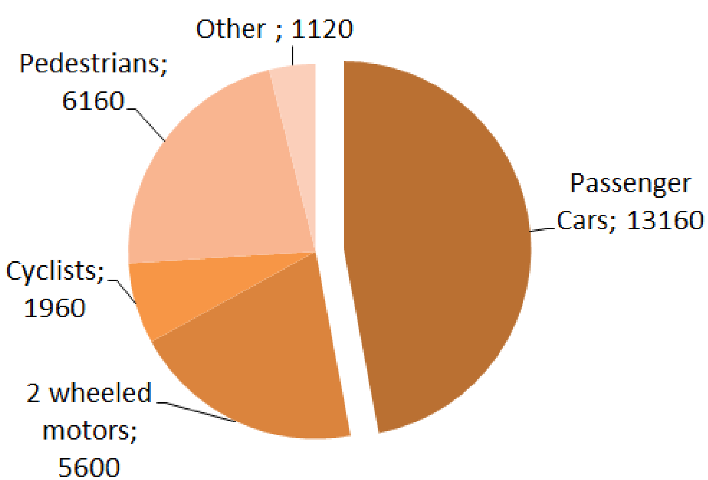
Accident Statistics

- Europe (EU-27) 2012**
  - 250.000 people seriously injured in road accidents
    - 28000 fatalities
    - Death : permanent disabled : serious injuries : minor injuries
      1 : 4 : 8 : 50
    - Cost for society: 130.000.000.000 Eur (2009)

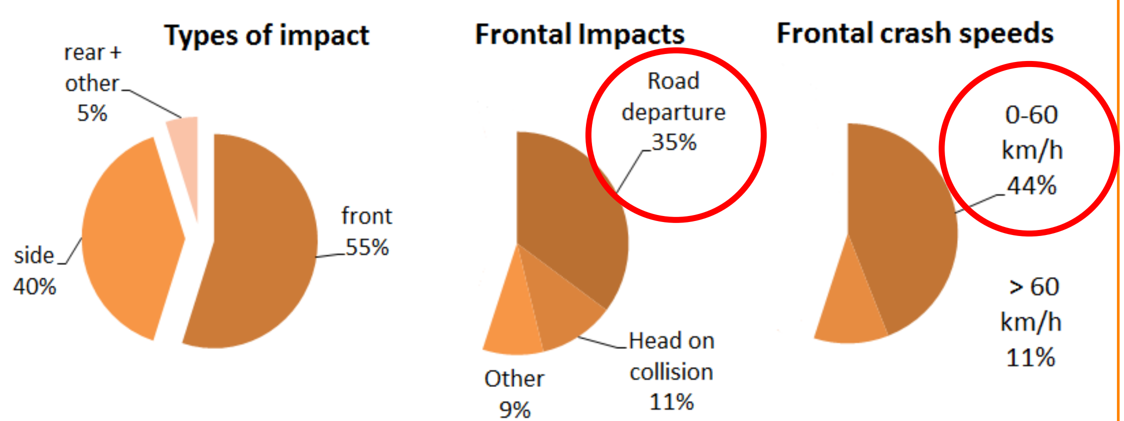


Almost ¾ of all traffic fatalities in EU are caused by passenger cars

Fatalities



Passenger cars

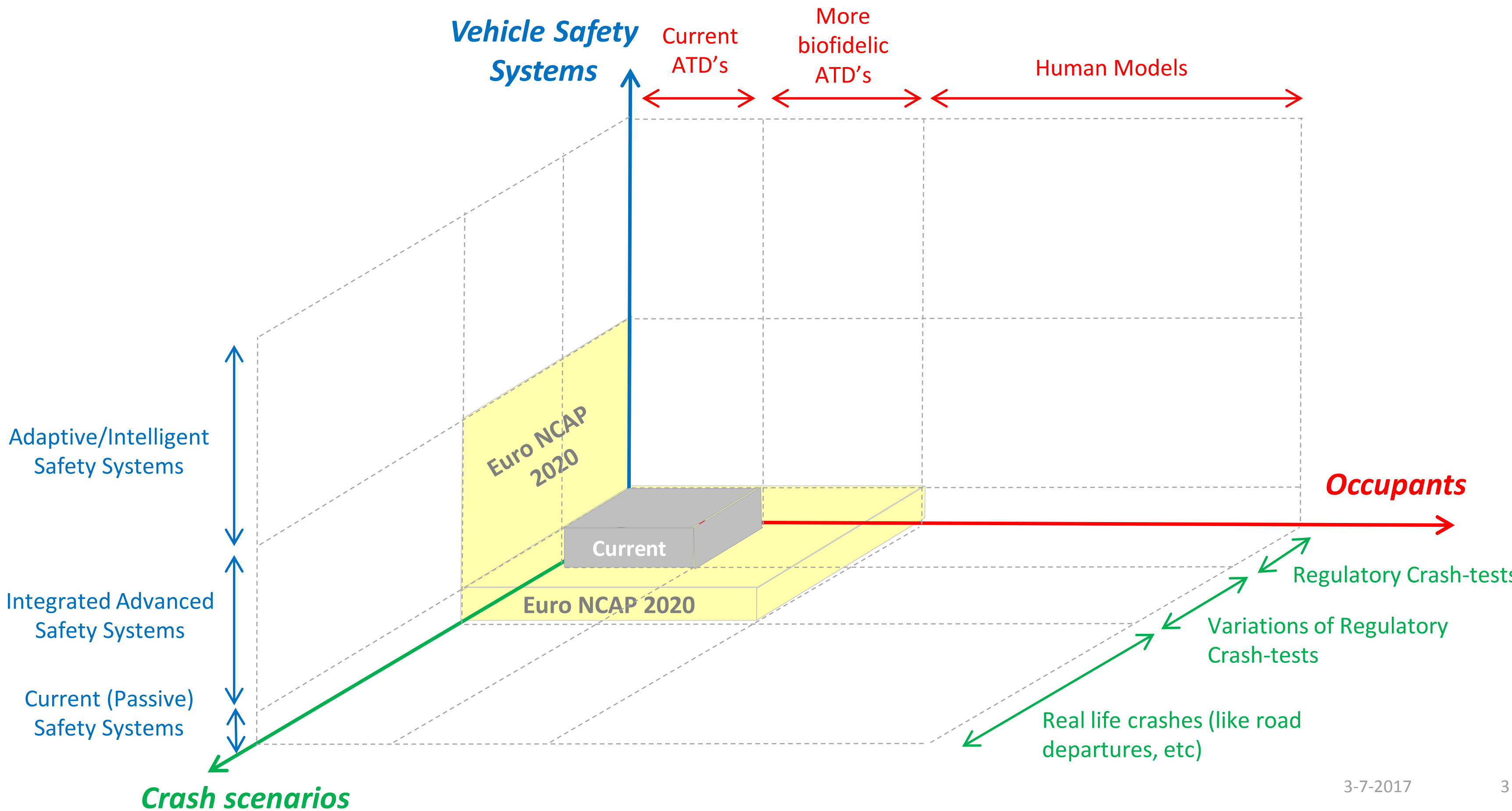


*** Source: Euro NCAP 2020 Roadmap*

Occupant safety now and in the future

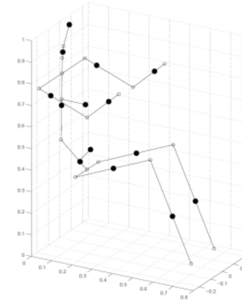
- Citation from the Euro NCAP 2020 Roadmap (concerning occupant safety):

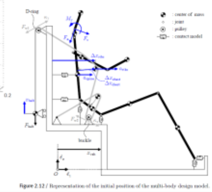
  “While **most occupant safety measures** can be considered **mature**, more should and can be done to **improve** their **robustness** for the general **diversity of occupants** and **other crash scenarios**.”



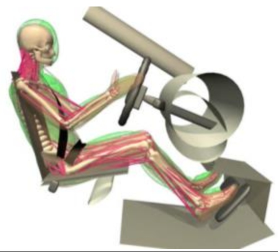
Challenges

- Accuracy: MAIS n+ or injuries (HIC, ...)
- Human: Age, gender, BMI, size, stature dependence?
- Crash: ΔV, crash direction, … dependence?

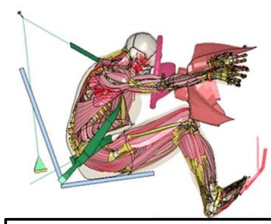




1,000,000’s scenarios
(TASS Real-time Active Humans)



10,000’s scenarios
(MB models like TASS Active Humans)



100’s scenarios
(FE models like THUMS, GHMB)

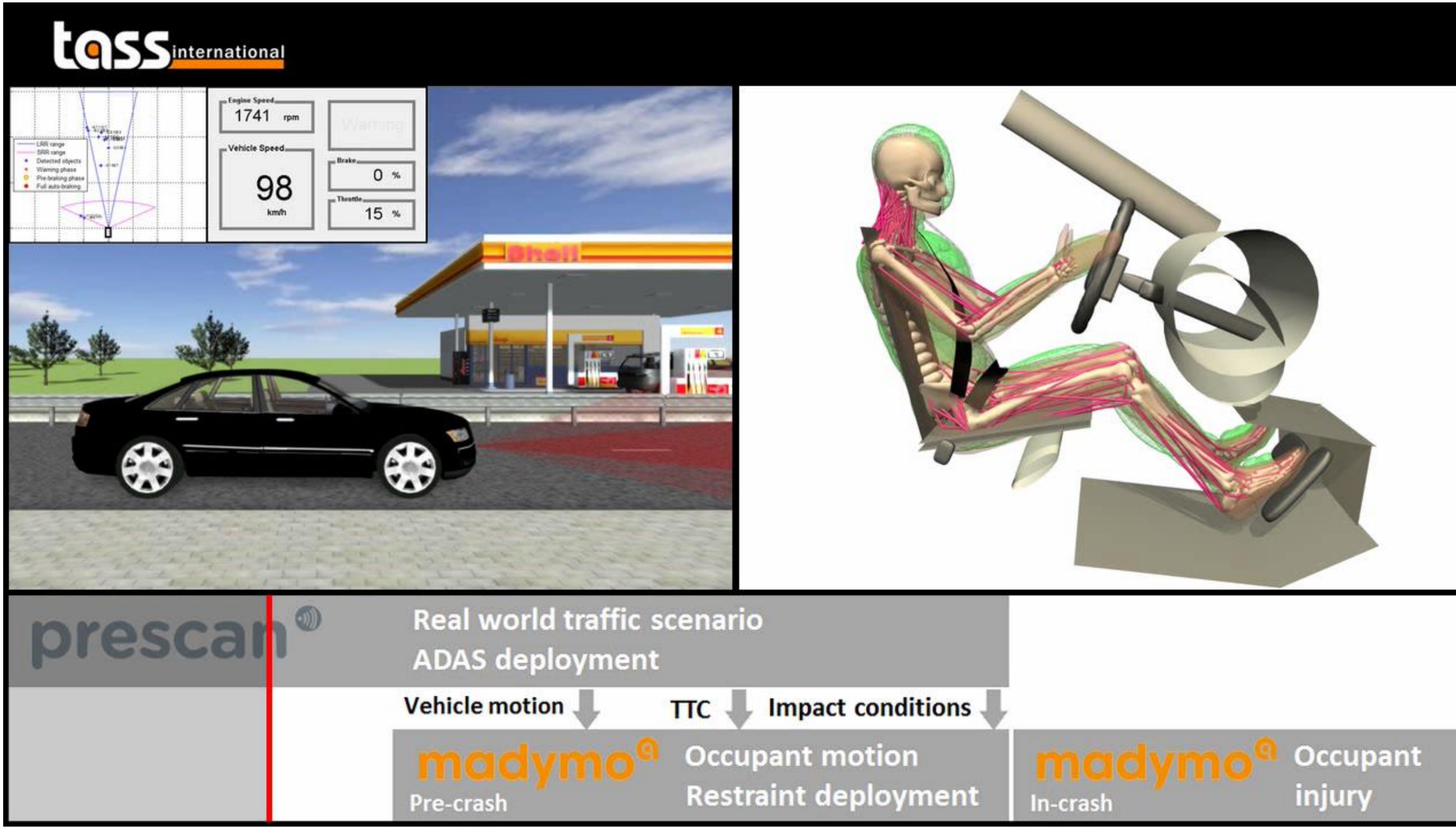
Real World Test Driving

10’s scenarios

Performance

Scenario coverage

AEB Braking load case followed by frontal crash

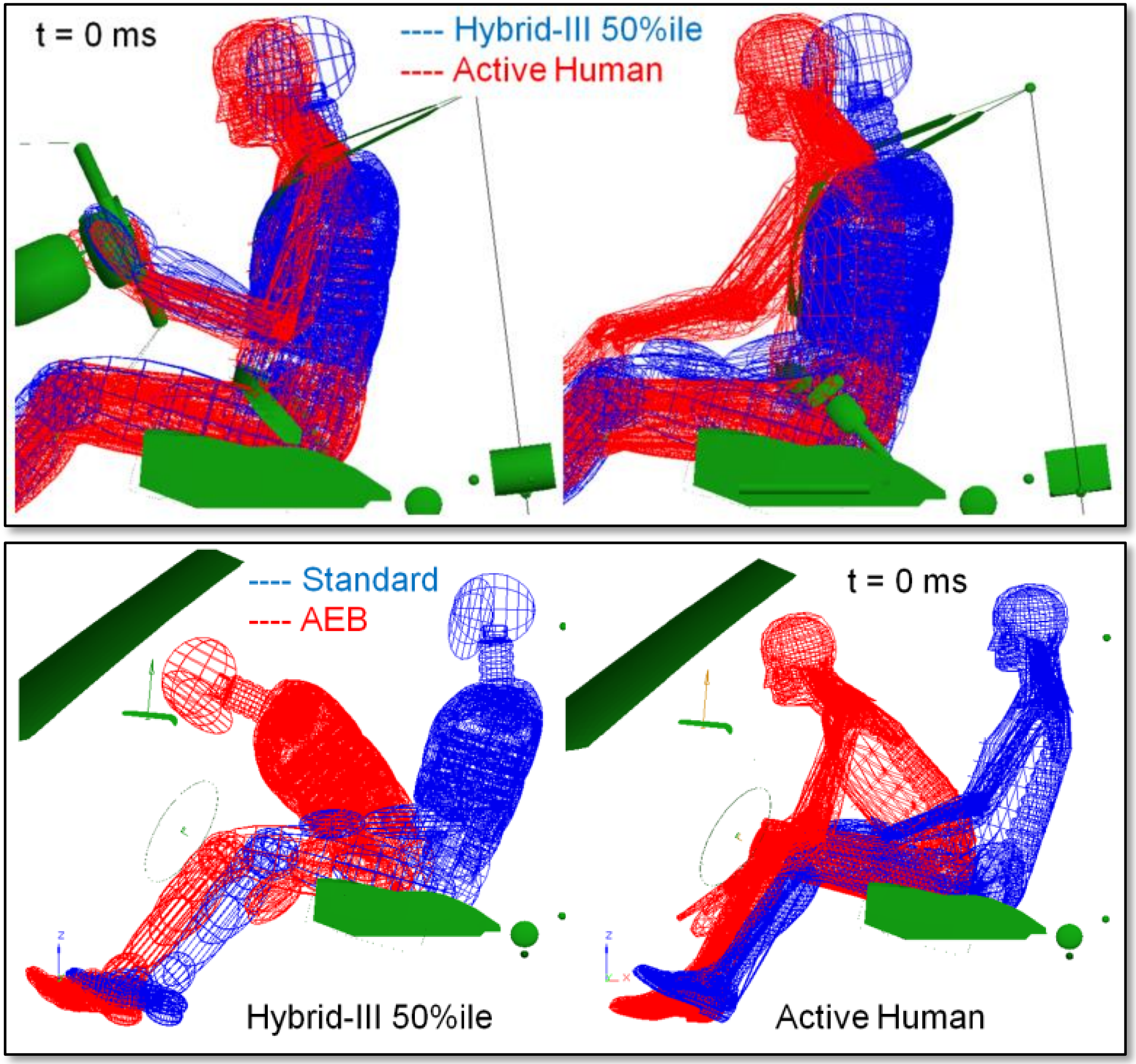


Initial test matrix

			Impact speeds [km/h]					
			RW -B		RW - UB		ODB	
			std	AEB	std	AEB	std	AEB
Driver	5 % Hybrid-III	Vehicle 01	56	56	40	40	*na*	*na*
		Vehicle 04	56	56	40	40	64	64
		Vehicle 05	56	56	40	40	64	64
	50 % Hybrid-III	Vehicle 01	56	56	40	40	*na*	*na*
		Vehicle 04	56	56	40	40	64	64
		Vehicle 05	56	56	40	40	64	64
	50 % AHM	Vehicle 01	56	56	40	40	*na*	*na*
		Vehicle 04	56	56	40	40	64	64
		Vehicle 05	56	56	40	40	64	64
Passenger	5 % Hybrid-III	Vehicle 01	56	56	40	40	*na*	*na*
		Vehicle 04	56	56	40	40	64	64
		Vehicle 05	56	56	40	40	64	64
	50 % Hybrid-III	Vehicle 01	56	56	40	40	*na*	*na*
		Vehicle 04	56	56	40	40	64	64
		Vehicle 05	56	56	40	40	64	64
	50 % AHM	Vehicle 01	56	56	40	40	*na*	*na*
		Vehicle 04	56	56	40	40	64	64
		Vehicle 05	56	56	40	40	64	64

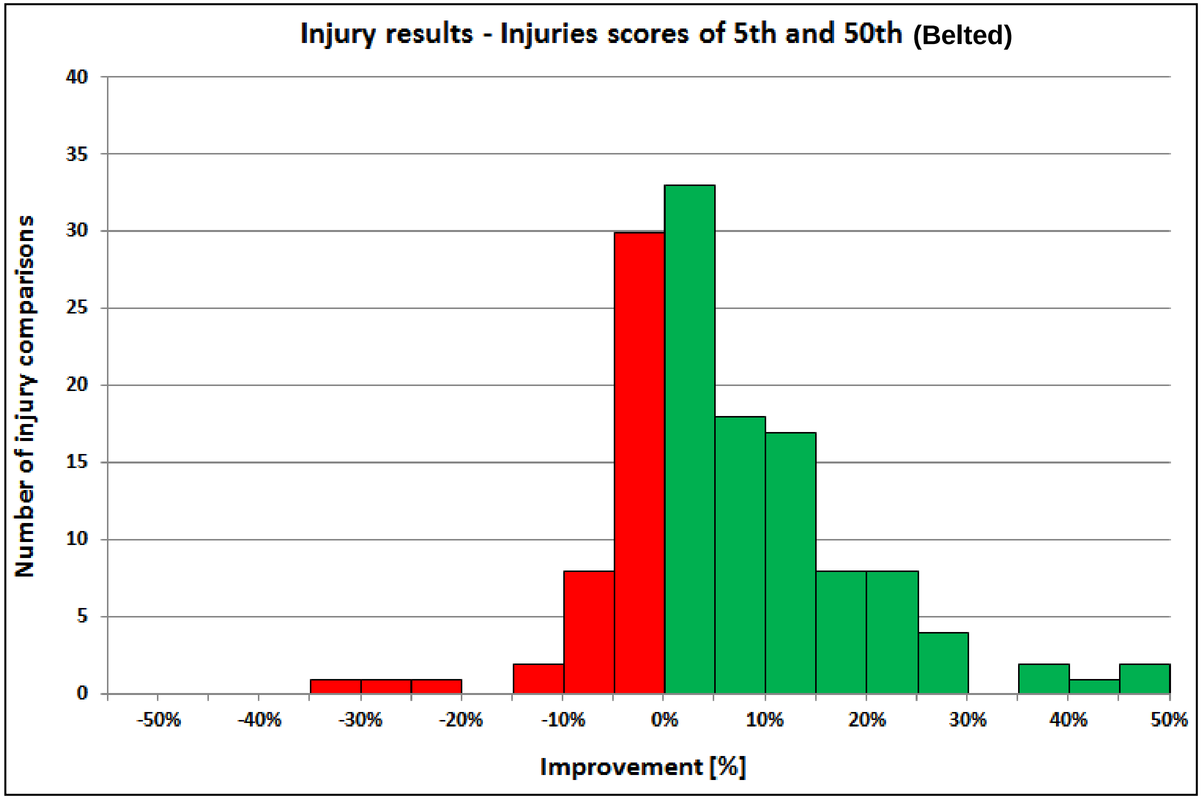
64	Impact speed of model used for study [km/h]
na	No material available for study
std	Standard Loadcase as defined per protocol
AEB	With braking, scenario (impact speed = protocol impact speed)
RW - B	Rigid Wall Belted - FMVSS208/USNCAP 35 mph test
RW - UB	Rigid Wall Un-Belted - USNCAP 25 mph test
ODB	Offset Deformable Barrier - EuroNCAP 64 km/h

Occupant position after the automonous braking

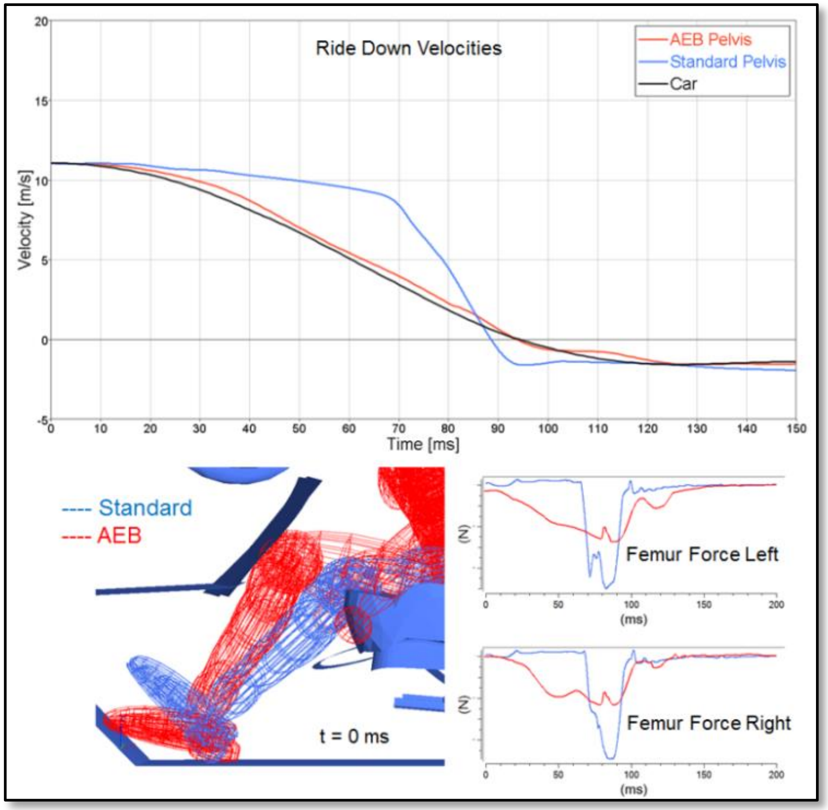


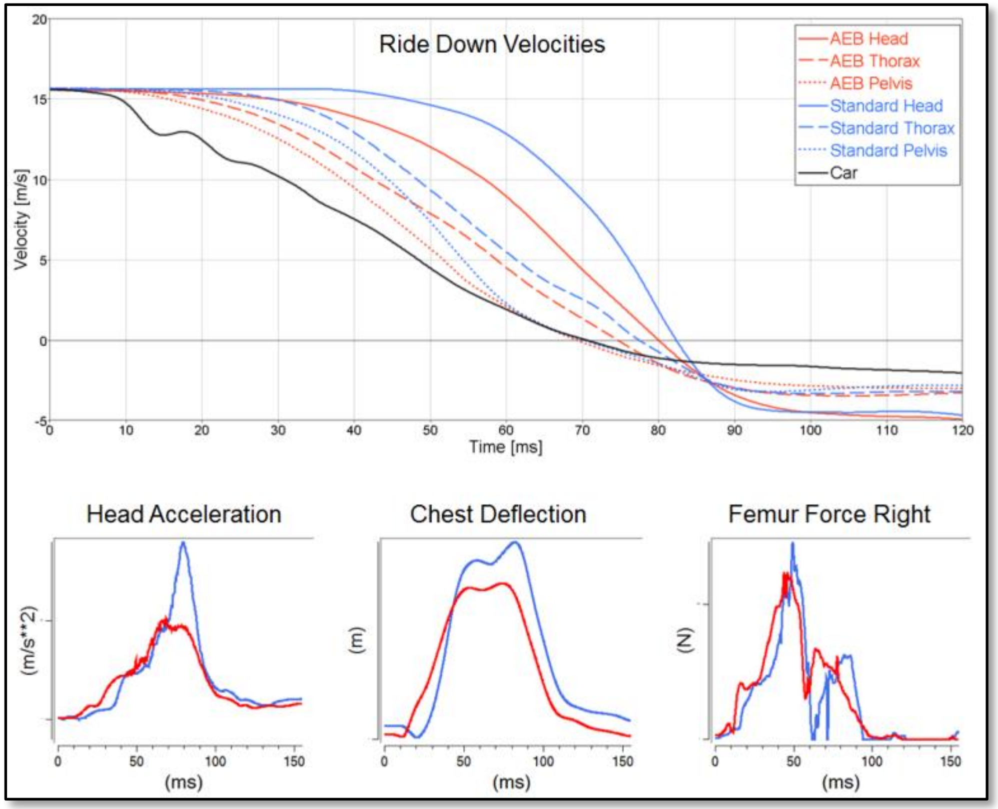
Occupant injury values summary

- Most injuries improve with addition of AEB pre-crash braking system
- A few injuries become worse

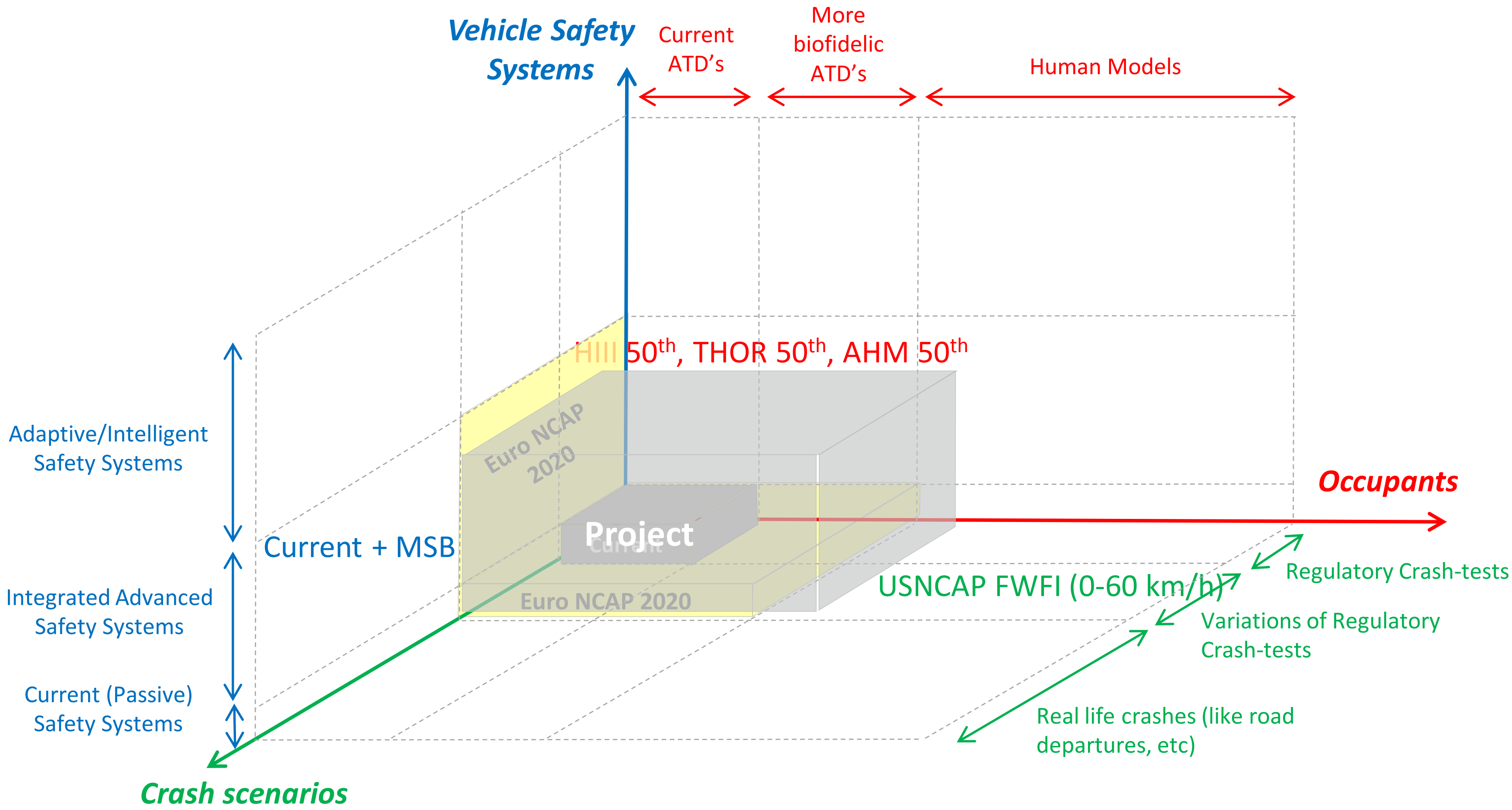


Ride down effect





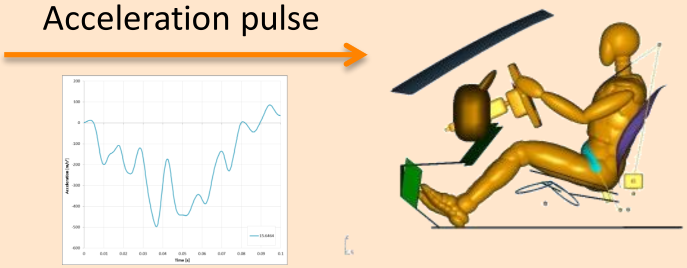
Embrace variability



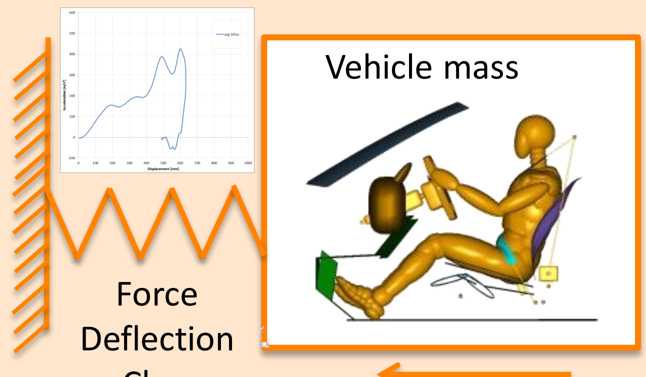
Model set-up

Traditional Method

Acceleration pulse



Proposed Method



Initial Velocity

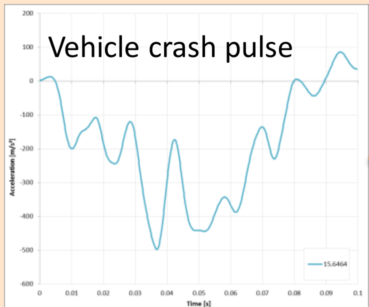
$$(1)\quad F = ma$$

$$(2)\quad E_{Absorbed} = \int F ds$$

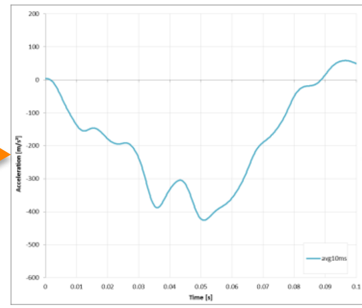
$$(3)\quad E_{Kinetic} = \frac{1}{2} m {v_0}^2$$

Pulse Scaling Method

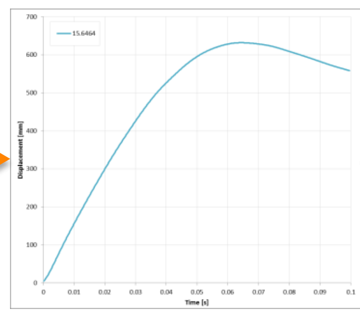
Traditional Method



Vehicle crash pulse with a 10 ms running average
(Described in section 3.3)



Double Integration

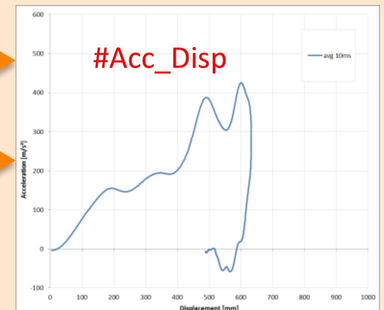


Cross Plot

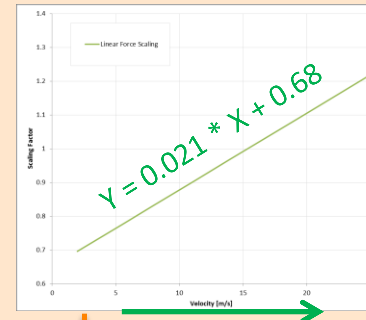
Additional required input:
- Vehicle weight
- Inertia estimation

Proposed Method

Acceleration vs deflection



Generic Force displacement multiplier (Y-SCALE) as a function of Impact Speed
(Determined based on full vehicle FE simulations)



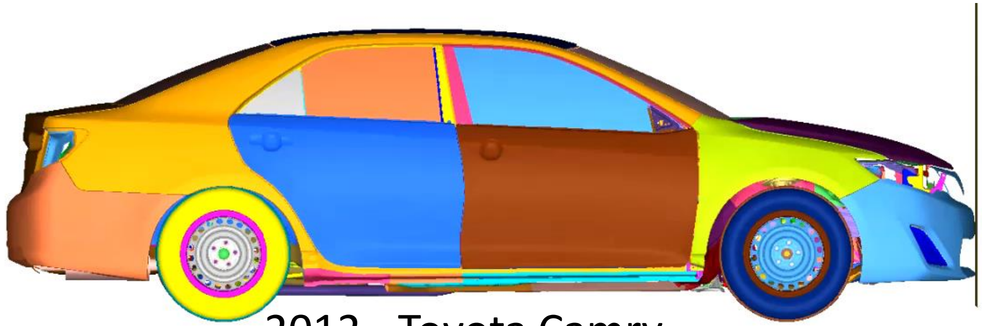
#Impact_Speed

These curves are used in the MADYMO inputdeck.

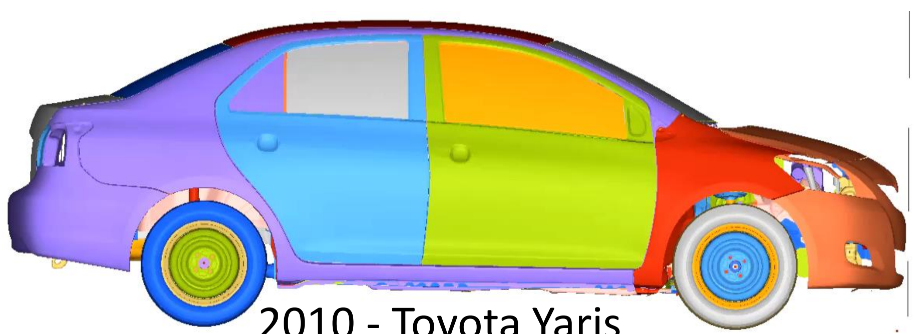
Using DEFINES and math-operators makes it possible to just vary the Impact Speed to create new simulations

Generic vehicle stiffening

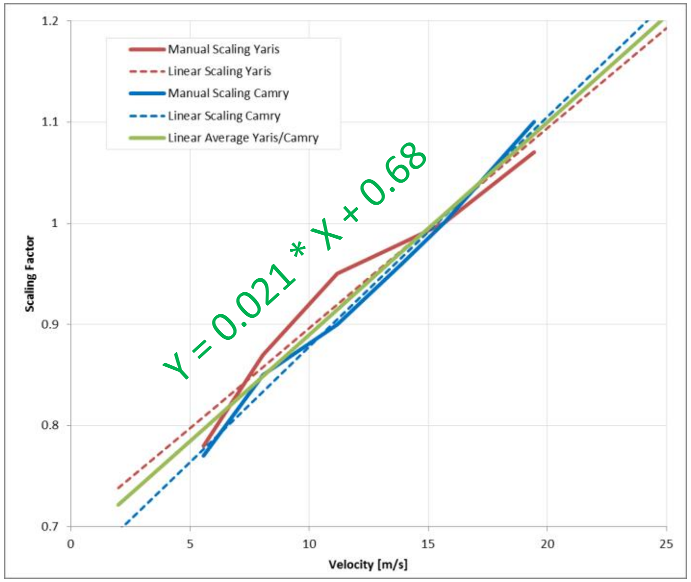
	FFW 12.42 mph **FFW 20 kph** [m/s]	**FFW 18mph** *FFW 28.96 kph* [m/s]	**FFW 25mph** *FFW 40.2 kph* [m/s]	*FFW 31.07 mph* **FFW 50 kph** [m/s]	**FFW 35mph** *FFW 56.3 kph* [m/s]	*FFW 43.49 mph* **FFW 70 kph** [m/s]
Toyota Camry	5.5555	8.04672	11.176	13.8889	15.6464	19.4444
Toyota Yaris	5.5555	8.04672	11.176	13.8889	15.6464	19.4444



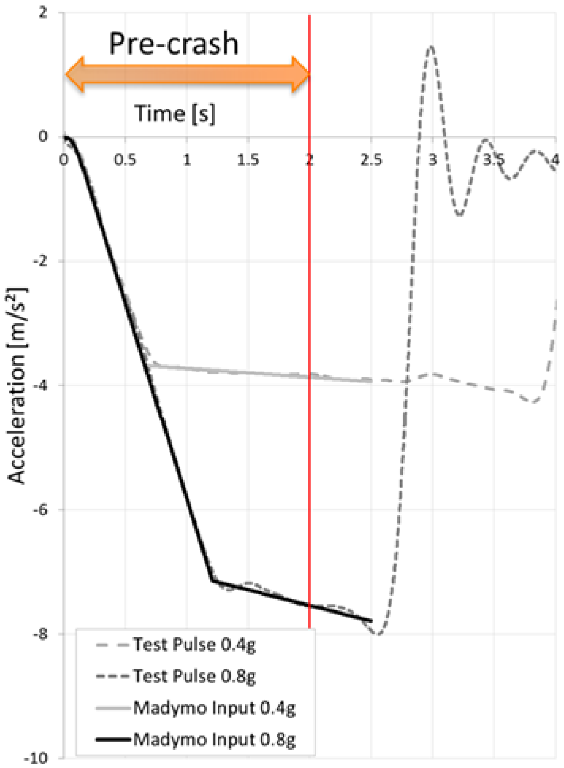
2012 - Toyota Camry



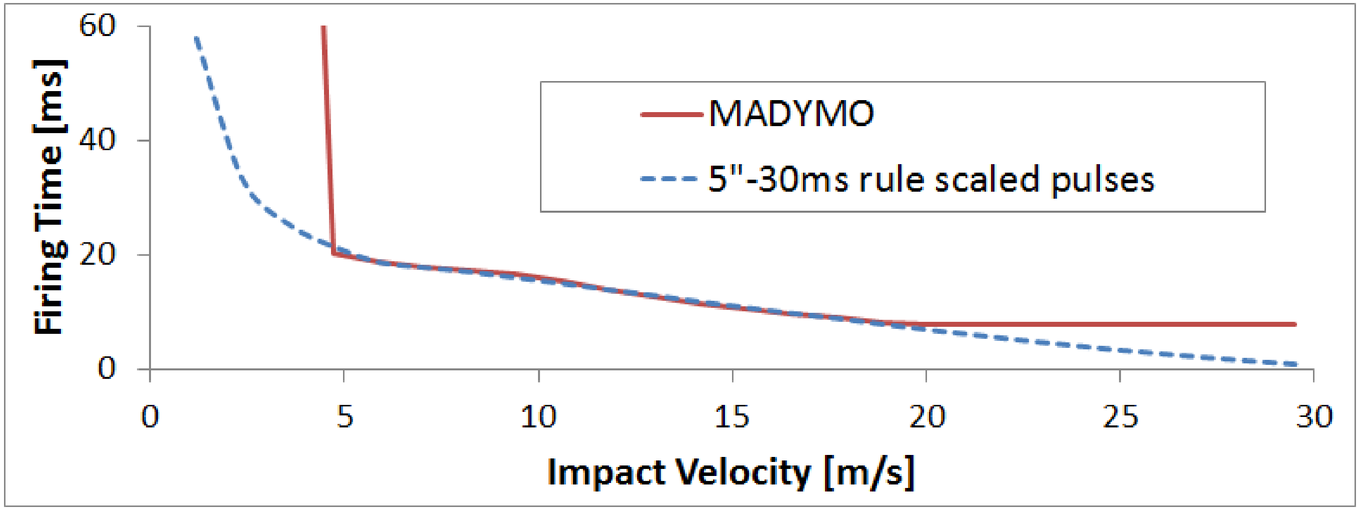
2010 - Toyota Yaris



Pre-crash braking from volunteer tests



Airbag trigger time scaling 5''-30ms rule



Airbag not fired below lower threshold

Constant airbag fire time above upper threshold

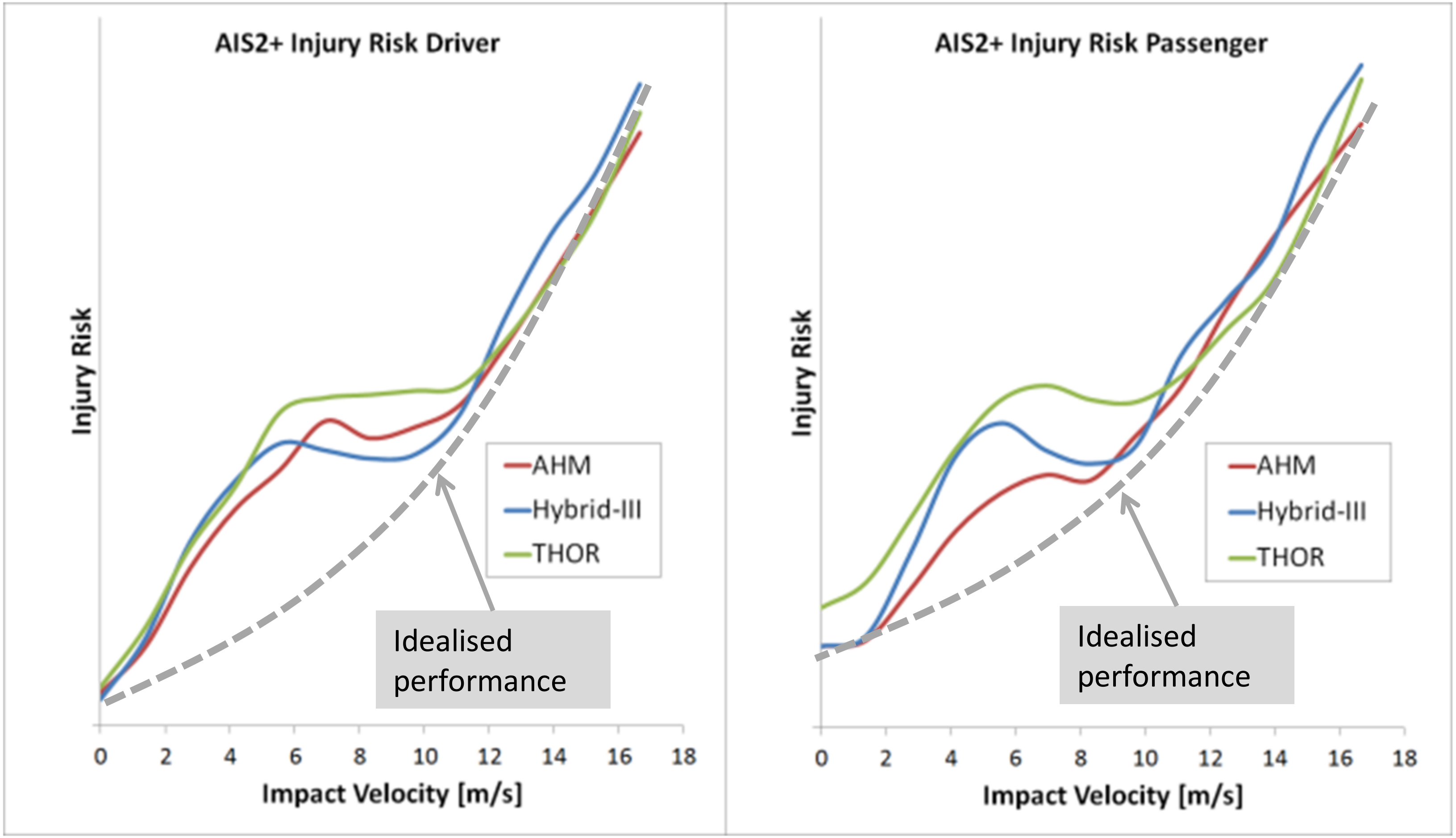
Injury Risk curves for AIS2+

- Relative benefit of speed reduction is estimated with AIS2+ injury risk
- AIS3+ injuries aim to reduce fatalities
- AIS2+ includes injuries with severe loss of body function
  - Cost to society
  - Long term health and trauma impact

Body Region	Hybrid-III, THOR, AHM
Head (13) *HIC15*	MAIS 2: $[1 + \exp((2.49 + 200/HIC) - 0.00483 \times HIC)]^{-1}$
Neck (14) *Nij*	$p(AIS \geq 2) = \frac{1}{1 + e^{2.054 - 1.195Nij}}$
Chest (14) *Defl. [mm]* *Chest3ms [g]* *CTI*	$p(AIS \geq 2) = \frac{1}{1 + e^{(1.8706 - 0.04439Dmax)}}$ $p(AIS \geq 2) = \frac{1}{1 + e^{(1.2324 - 0.0576Ac)}}$ $p(AIS \geq 2) = \frac{1}{1 + e^{(4.847 - 6.036CTI)}}$ $P_{chest}(AIS \geq 2) = \max(P_{Dmax}, P_{Ac}, P_{CTI})$
Femur (14) *Force [kN]*	$P(AIS \geq 2) = \frac{1}{1 + e^{(5.795 - 0.5196*F)}}$
All (15)	$P_{joint} = 1 - (1 - P_{head}) \times (1 - P_{neck}) \times (1 - P_{chest}) \times (1 - P_{femur})$

AIS2+ Injury Risk

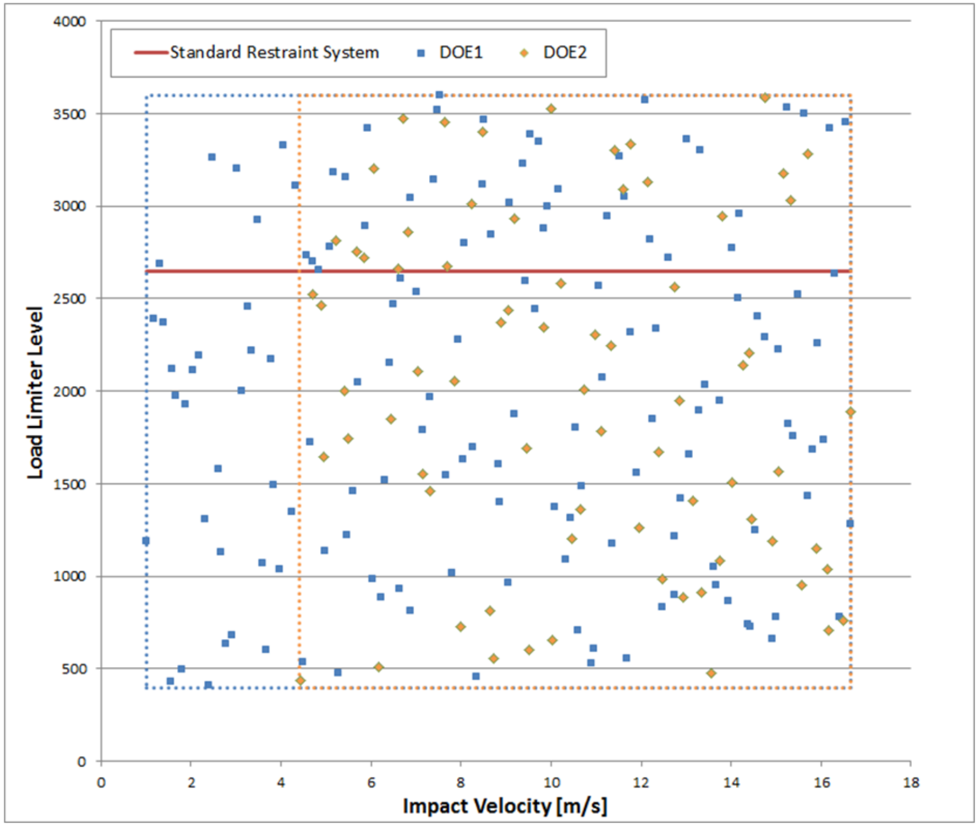
Driver (left) and passenger (right) with standard restraint system



DOE settings

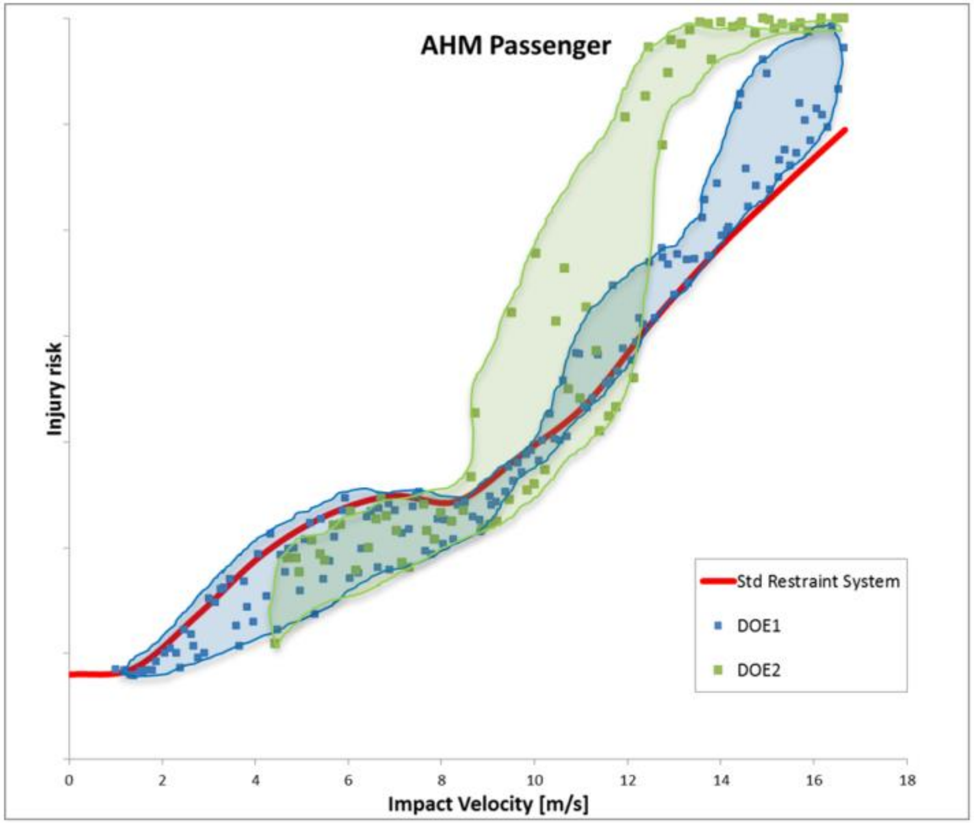
- 1296 simulations
  - Latin Hypercube
  - Simulation generator
- Simulation time: 2.13 seconds
  - 2 s pre-crash + 130 ms in-crash
- Average 4 hrs/sim on 1 CPU

Setting	DOE1	DOE2
No. of runs / occupant	144	72
Impact speed [m/s]	1 - 16.6667	4.4 - 16.6667
Load Limiter Level [N]	400 - 3600	400 – 3600
MSB	Activated	Activated
Airbag	Activated	De-activated

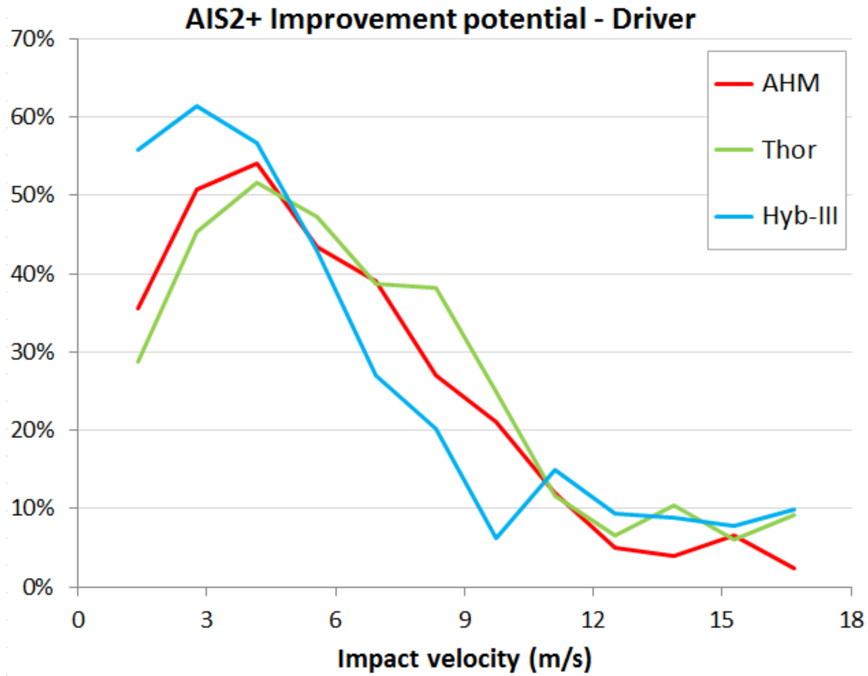


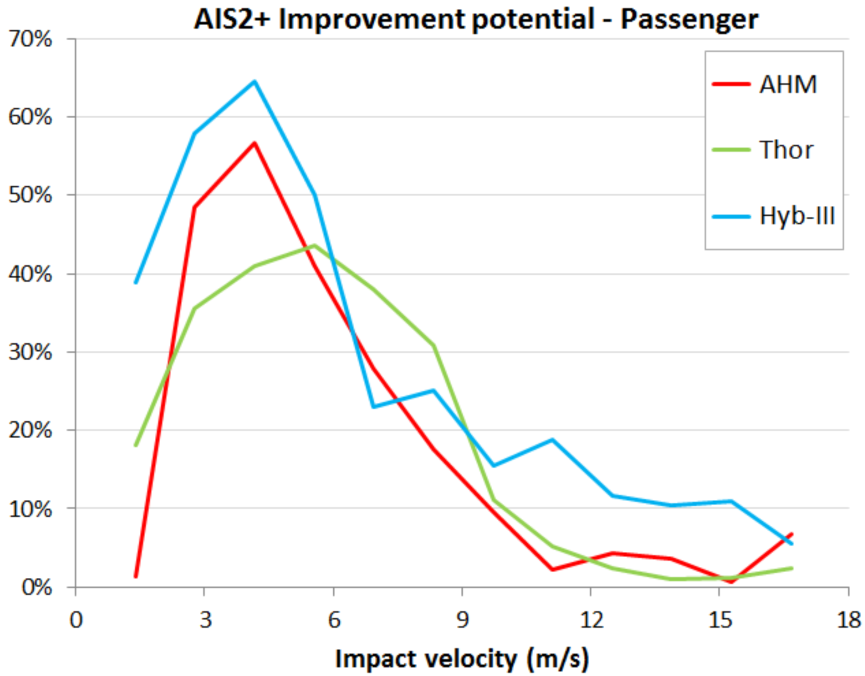
DOE AIS2+ results for AHM 50% passenger

- Optimal performance of standard restraint system near protocol speed
- Below 12 m/s significant improvements in injury risk can be achieved – also with de-activated airbag
- Above 12 m/s benefit of airbag is clearly shown especially by Active Human Model



Improvement Potential AIS2+





AIS2+ improvement potential at lower velocities approximately 50%

Implementation example

Load limiter levels adaptable to crash situation