SAE 2015 Government/Industry Meeting

Washington, DC
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Advanced Adaptive Restraints Program

Individualization of Occupant Safety Systems

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AGENDA

- INTRODUCTION
- SENSING – PROCESSING - ACTING
- CHALLENGES
- TEST MATRIX
- BASELINE TEST RESULTS
- CONTRIBUTION OF BRIC TO THE INJURY RISK ASSESSMENT
- TRADE-OFF BETWEEN BRIC AND CHEST OPTIMIZATION
- DISCUSSION

ADVANCED ADAPTIVE RESTRAINT PROGRAM
INTRODUCTION

The ***Advanced Adaptive Restraint Program (AARP)*** was initiated and partially funded by the ***National Highway Traffic Safety Administration (NHTSA)***.

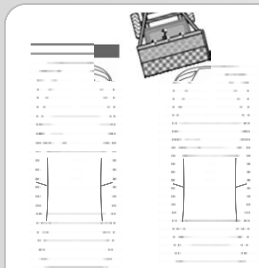
Starting in ***November 2012***, this multi-year study will be completed in ***June 2015***

Motivation

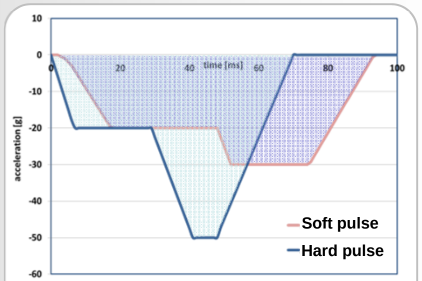
In real-world crashes, the exact location and posture of the occupant is unknown before and during the collision, which may influence the injury outcome.

Objective

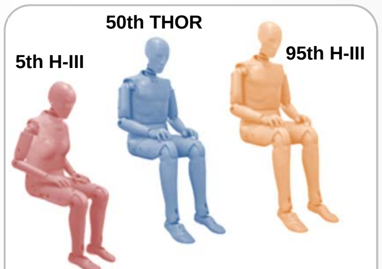
Improve occupant safety for the driver and front right passenger by enabling individualization of restraint system performance, taking into account:



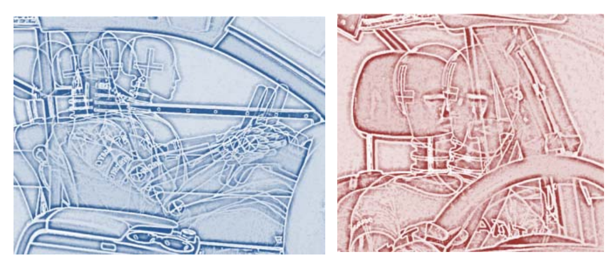
Crash type



Crash severity

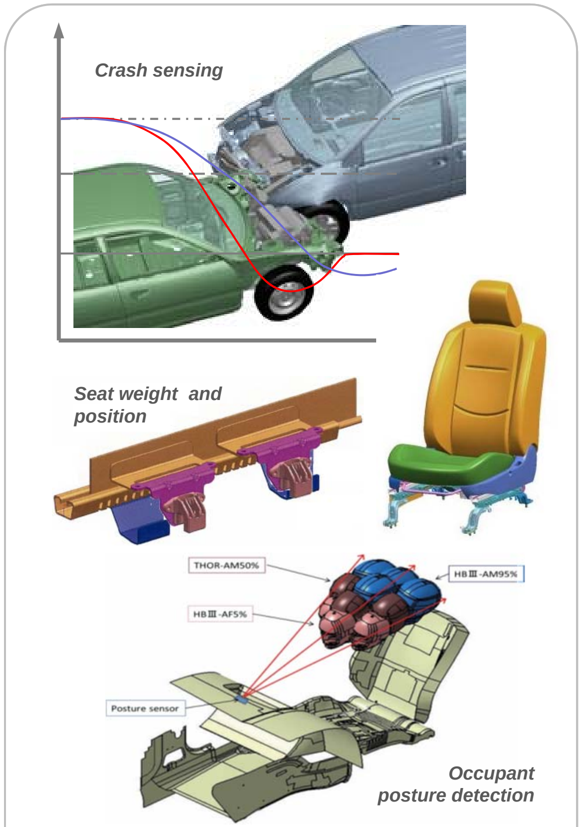


Dummy size & weight

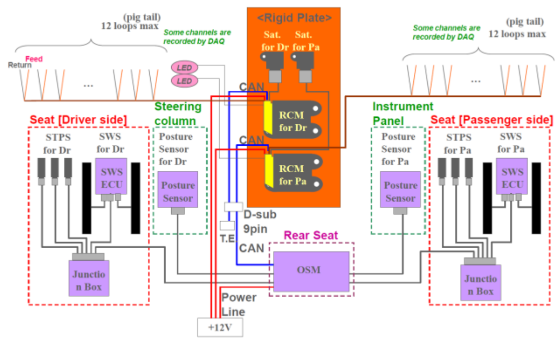


Seating position & posture

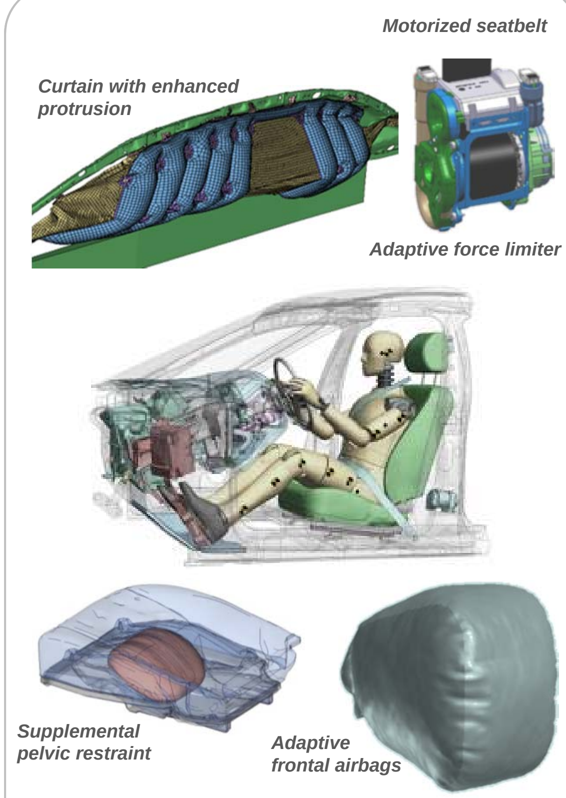
Advanced Adaptive Restraint Program
Sensing – Processing – Acting



Gathering of required system input parameters



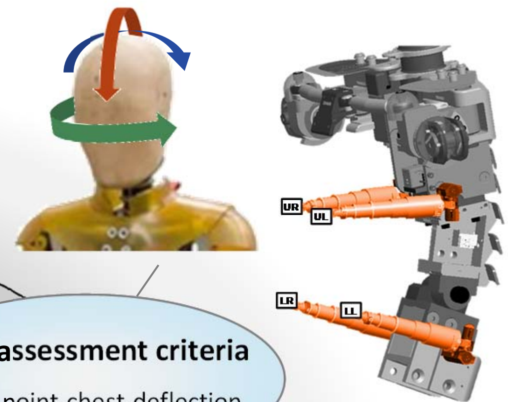
Calculation of optimum firing strategy based on underlying algorithm

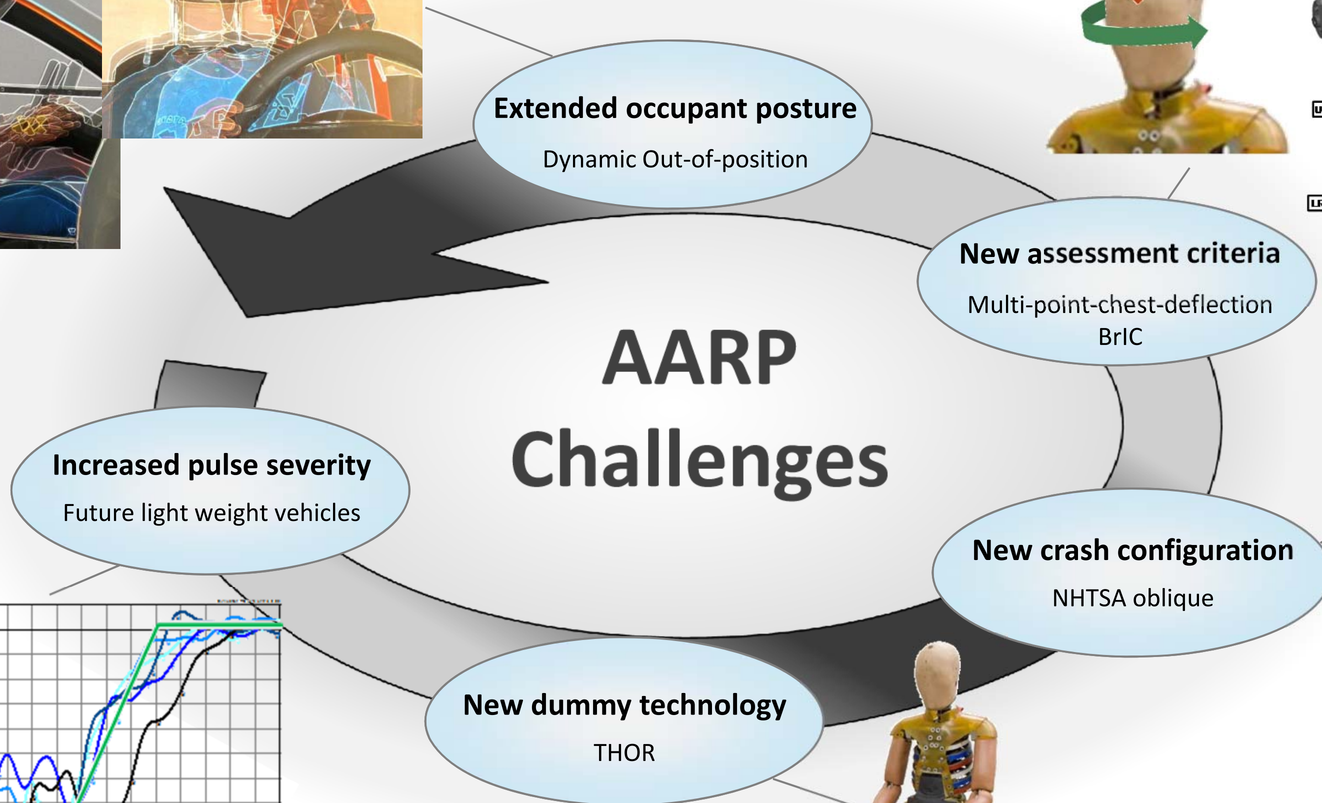


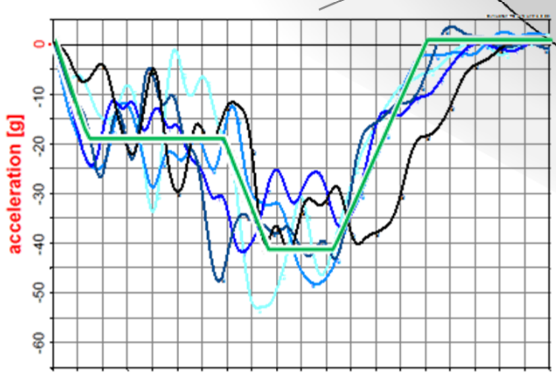
Individual setting of Advanced Adaptive Restraint Components

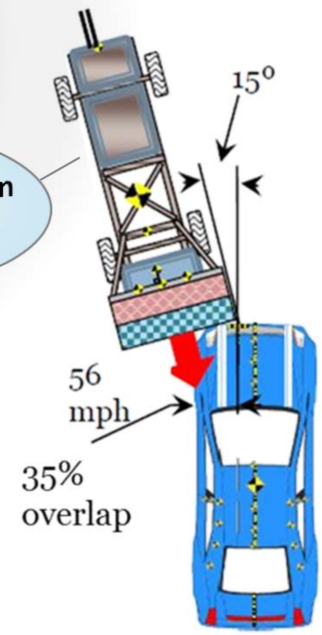
Sensing → **Processing** → **Acting**

ADVANCED ADAPTIVE RESTRAINT PROGRAM
CHALLENGES









Advanced Adaptive Restraint Program
Test Matrix

	Test configuration			Driver				Front right passenger			
	Test	Angle	Pulse	Dummy	Seat position	Posture (Fore/Back)	Posture (Lateral)	Dummy	Seat position	Posture (Fore/Back)	Posture (Lateral)
In-position	1	0deg	Soft	5th	Full fwd	Nom	Nom	50th	Mid track	Nom	Nom
	2	0deg	Soft	50th	Mid track	Nom	Nom	95th	Rear	Nom	Nom
	3	0deg	Soft	95th	Rear	Nom	Nom	5th	Full fwd	Nom	Nom
	4	0deg	Hard	5th	Full fwd	Nom	Nom	95th	Rear	Nom	Nom
	5	0deg	Hard	50th	Mid track	Nom	Nom	5th	Full fwd	Nom	Nom
	6	0deg	Hard	95th	Rear	Nom	Nom	50th	Mid track	Nom	Nom
	7	LT-15 deg	Soft	5th	Full fwd	Nom	Nom	50th	Mid track	Nom	Nom
	8	LT-15 deg	Soft	50th	Mid track	Nom	Nom	95th	Rear	Nom	Nom
	9	LT-15 deg	Soft	95th	Rear	Nom	Nom	5th	Full fwd	Nom	Nom
	10	LT-15 deg	Hard	5th	Full fwd	Nom	Nom	95th	Rear	Nom	Nom
	11	LT-15 deg	Hard	50th	Mid track	Nom	Nom	5th	Full fwd	Nom	Nom
	12	LT-15 deg	Hard	95th	Rear	Nom	Nom	50th	Mid track	Nom	Nom
	13	RT-15 deg	Hard	50th	Mid track	Nom	Nom	5th	Full fwd	Nom	Nom
Extended occupant position	14	0deg	Soft	5th	Full fwd	Fwd	Nom	50th	Mid track	Fwd	Nom
	15	0deg	Soft	50th	Mid track	Fwd	Nom	95th	Mid track	Fwd	Nom
	16	0deg	Soft	95th	Rear	Fwd	Nom	5th	Full fwd	Fwd	Nom
	17	0deg	Hard	5th	Full fwd	Fwd	Nom	50th	Full rear	Nom	Nom
	18	0deg	Hard	5th	Full fwd	Nom	I/B	95th	Full rear	Nom	I/B
	19	0deg	Hard	50th	Mid track	Nom	I/B	5th	Full rear	Nom	Nom
	20	0deg	Hard	95th	Rear	Nom	I/B	5th	Full rear	Nom	O/B
	21	LT-15 deg	Hard	5th	Full fwd	Nom	I/B	50th	Full rear	Nom	O/B
	22	LT-15 deg	Hard	5th	Full fwd	Nom	O/B	50th	Mid track	Nom	I/B
	23	LT-15 deg	Hard	50th	Mid track	Nom	O/B	5th	Mid track	Nom	I/B
	24	RT-15 deg	Hard	50th	Mid track	Nom	I/B	5th	Full fwd	Nom	O/B

Parameter

Sled buck angle
- 0deg - Full frontal
- LT-15 deg - Oblique left
- RT-15 deg - Oblique right

Pulse characteristic
- Soft - Soft pulse
- Hard - Severe pulse

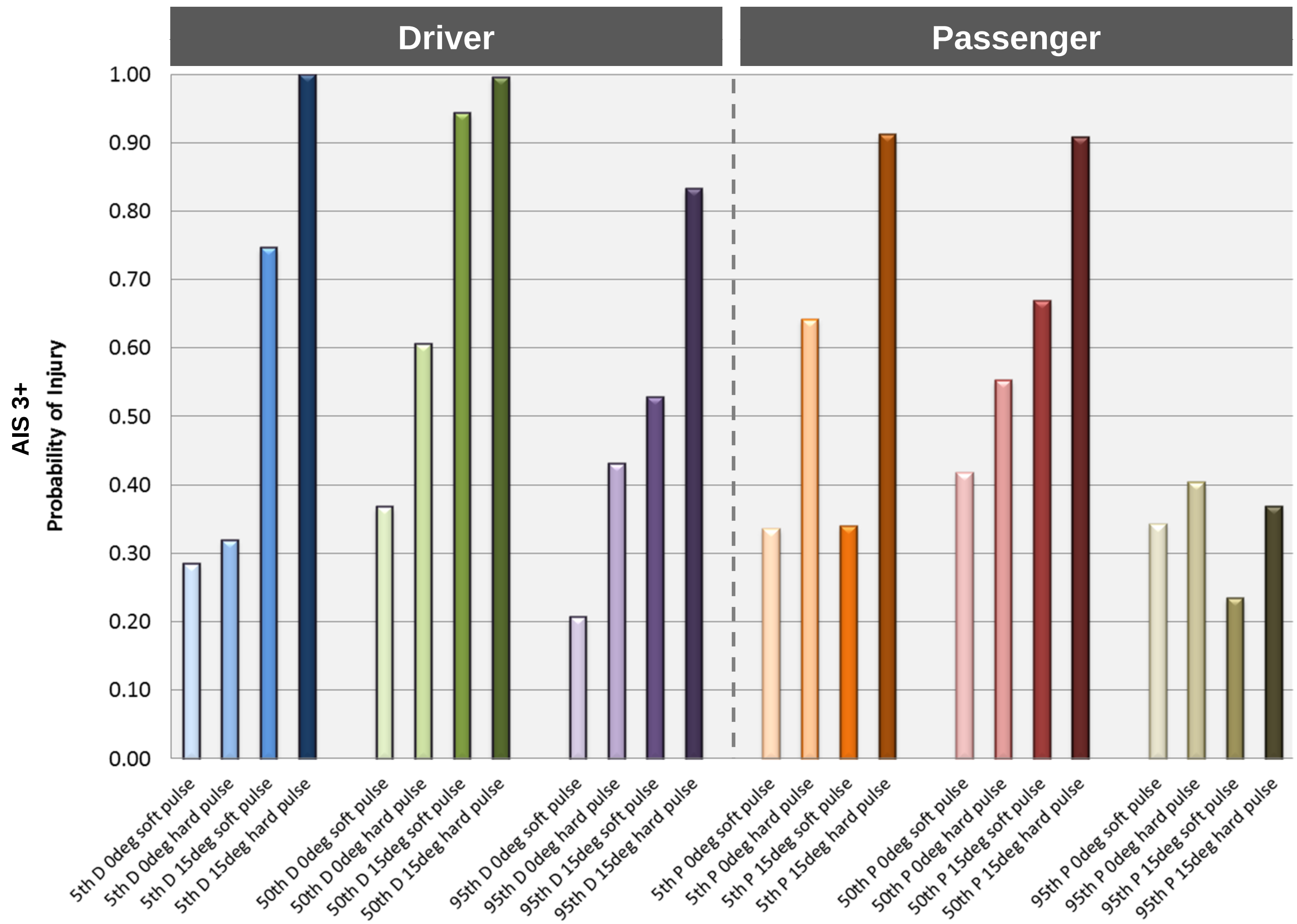
Dummy size
- 5th - AF05 dummy
- 50th - AM50 dummy
- 95th - AM95 dummy

Seat position
- Full fwd - Full forward
- Mid track - Mid track
- Full rear - Full rear

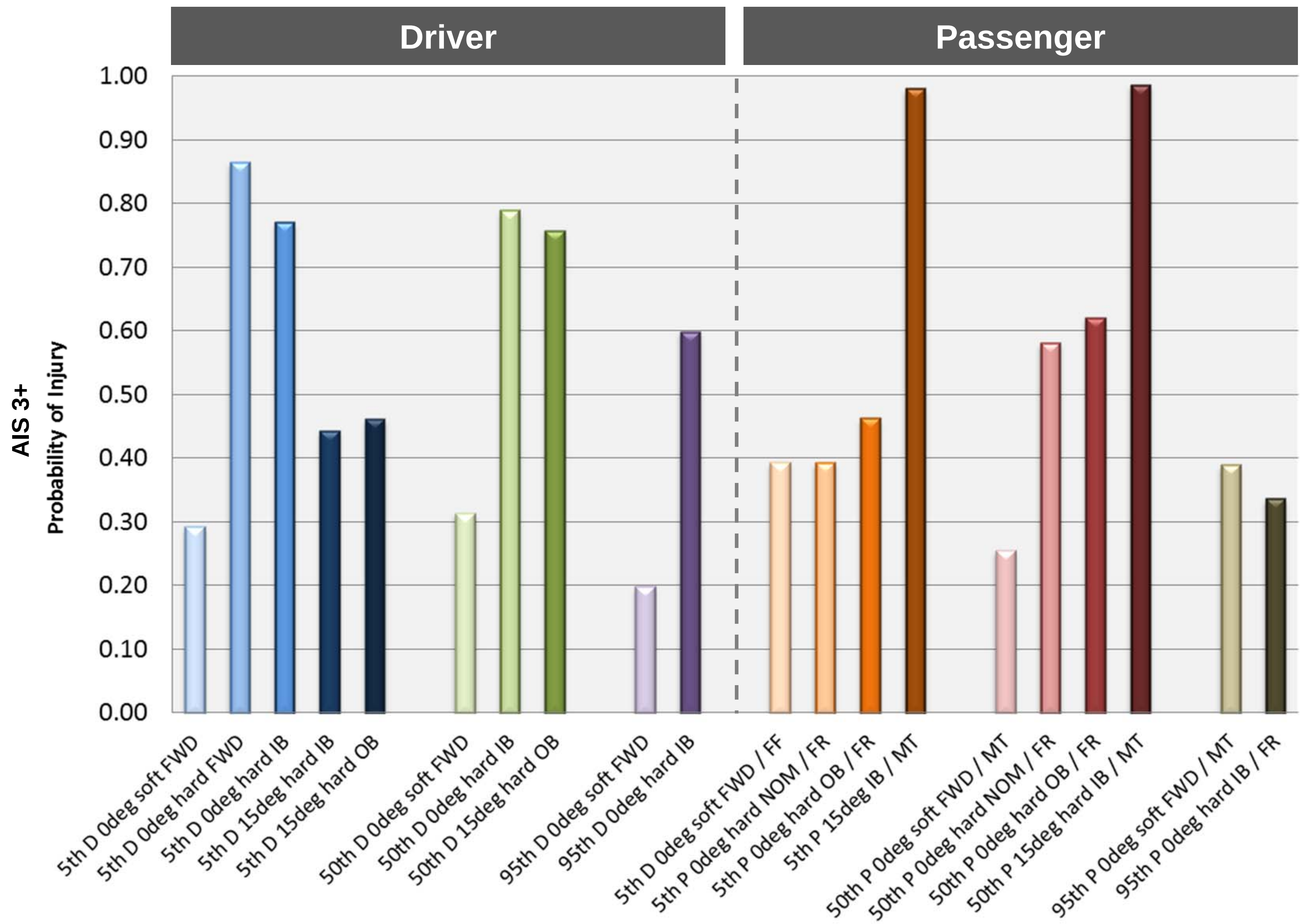
Occupant posture
- Nom - Nominal
- Fwd - Forward
- O/B - Outboard
- I/B - Inboard

ADVANCED ADAPTIVE RESTRAINT PROGRAM

BASELINE TEST RESULTS – IN-POSITION



Advanced Adaptive Restraint Program
Baseline test results – Extended occupant position



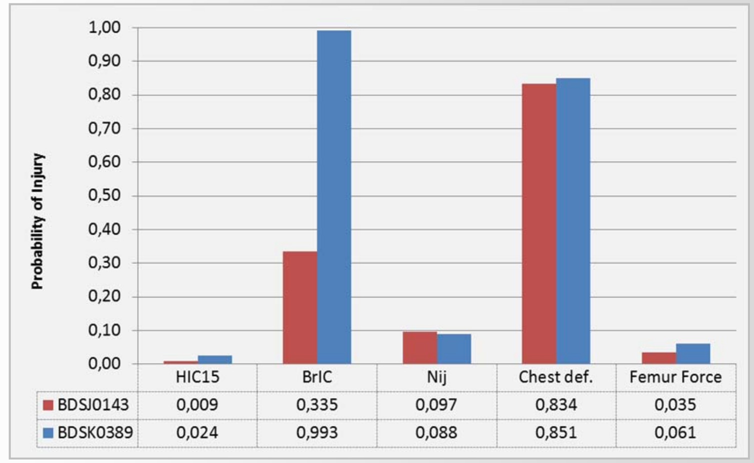
Test results

Test configuration

Load case
- 0 degree full frontal hard pulse
- 15 degree oblique hard pulse

Dummy
- THOR NT mod kit

Posture
- In-position (according to FMVSS 208)



	HIC15	BrIC	Nij	Chest def.	Femur Force	Chest acc. a3ms
0 deg full frontal hard pulse	**301,00**	**0,72**	**0,50**	**59,93**	**5,14**	60,95
15 deg oblique hard pulse	**400,00**	**1,73**	**0,45**	**60,61**	**6,87**	61,67

Kinematic

0 deg full frontal hard pulse

15 deg oblique hard pulse

0 msec | 20 msec | 40 msec | 60 msec | 80 msec | 100 msec

CONTRIBUTION OF BRIC TO THE INJURY RISK ASSESSMENT

Formula

$$BrIC = \sqrt{\left(\frac{\max(|\omega_x|)}{\omega_{xC}}\right)^2 + \left(\frac{\max(|\omega_y|)}{\omega_{yC}}\right)^2 + \left(\frac{\max(|\omega_z|)}{\omega_{zC}}\right)^2}$$

$\max(\lvert\omega_{[x,y,z]}\rvert)$	=	Maximum of the absolute value of the angular velocity time-history of the head about the local [x, y, or z] axis. Note that the peak angular velocities about the local x, y, and z axes may occur at different times.
$\omega_{[x,y,z]C}$	=	Critical values for the angular velocity of the head about the local [x, y, or z] axis (from Takhounts et al, 2013; Table 3, last column).
ω_{xC}	=	66.25 rad/s
ω_{yC}	=	56.45 rad/s
ω_{zC}	=	42.87 rad/s

Risk curves

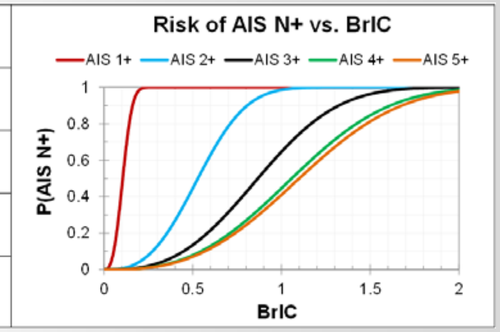
$$P(AIS\ 1+) = 1 - e^{-\left(\frac{BrIC}{0.120}\right)^{2.84}}$$

$$P(AIS\ 2+) = 1 - e^{-\left(\frac{BrIC}{0.602}\right)^{2.84}}$$

$$P(AIS\ 3+) = 1 - e^{-\left(\frac{BrIC}{0.987}\right)^{2.84}}$$

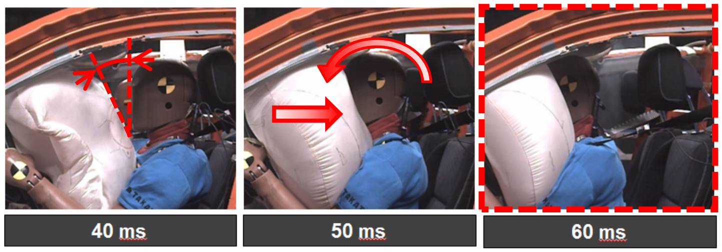
$$P(AIS\ 4+) = 1 - e^{-\left(\frac{BrIC}{1.204}\right)^{2.84}}$$

$$P(AIS\ 5+) = 1 - e^{-\left(\frac{BrIC}{1.252}\right)^{2.84}}$$

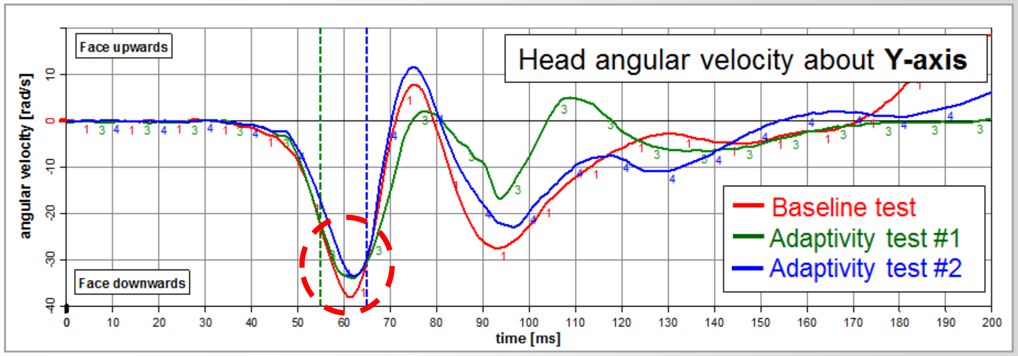


A **BrIC** value of **0.87** corresponds to a **50% risk** of **AIS 3+** brain injury

BrIC Level



max.angular velocity about Y-axis

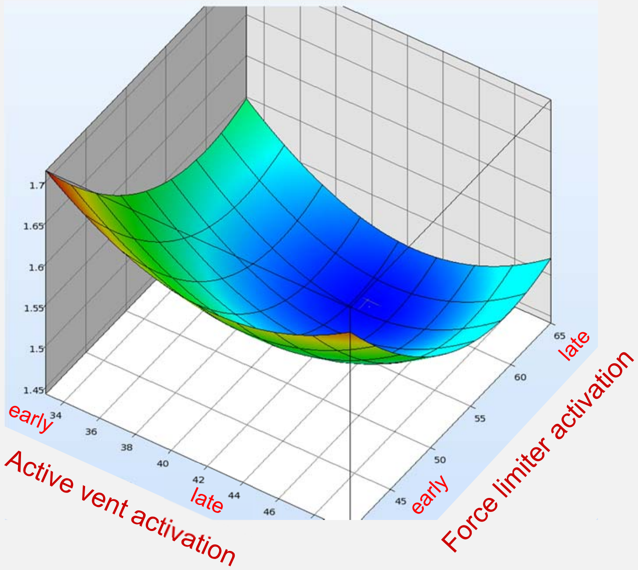


BrIC level in AARP **Full frontal load cases** between **0.6-0.8** during the coupling phase to the Airbag

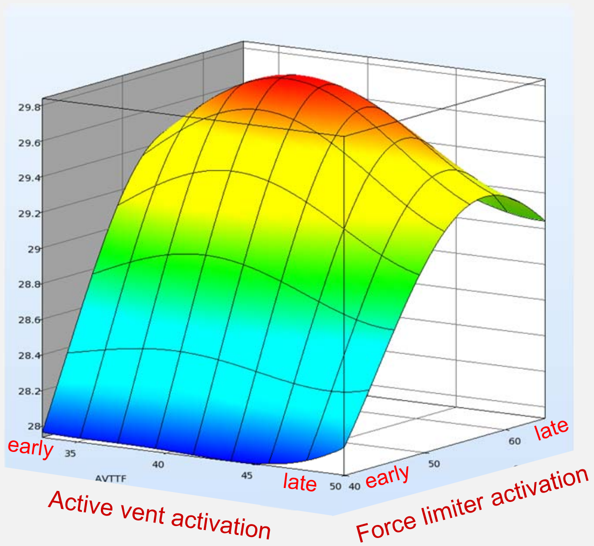
Advanced Adaptive Restraint Program
Balancing restraint system performance

Optimization of Seatbelt and Airbag performance required to define a Balance between both body regions (Head / Chest)

BrIC



Chest deflection



Correlation between Bric and chest deflection in hard pulse load cases

Load case:

- Passenger 5th percentile H-III dummy
- In-board leaning position
- Hard pulse 15 deg

Baseline Test

AARS Test
TTF setting #1

Advanced Adaptive Restraint System

Firing strategy
of Advanced Adaptive Components
optimized to all body regions

AARS Test
TTF setting #2

Advanced Adaptive Restraint System

Firing strategy
of Advanced Adaptive Components
optimized to BrIC solely

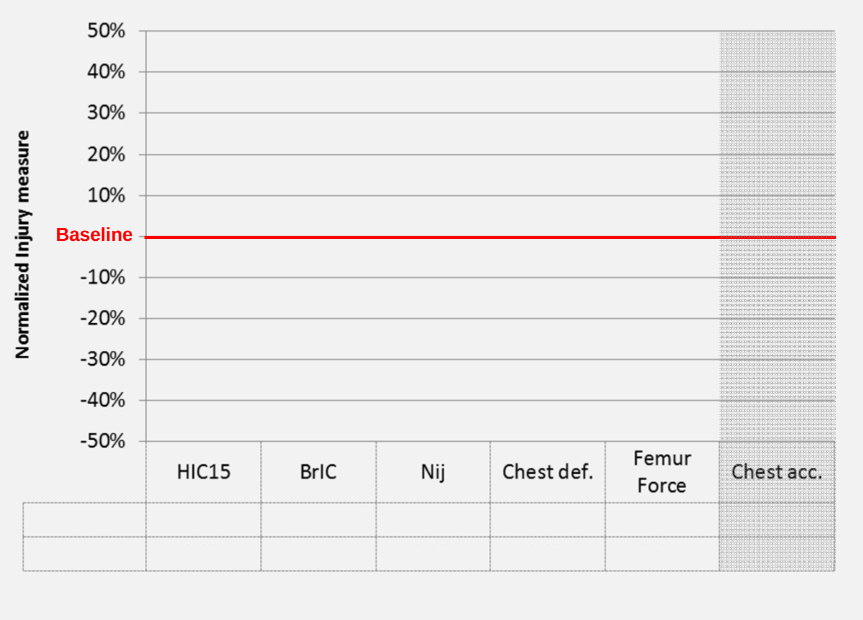
		Test #	Passenger airbag	Cushion adaptivity	Seatbelt	TTF AV	TTF FL
Baseline		BDSJ0154	conventional symmetric 3D shape	---	Single stage load limiter	---	---
AARS	**optimized to all body regions**	BDSK0306	modified asymmetric 3D shape with extende volume to the left hand side and the upper portion of the airbag	Active vent	Dual stage load limiter	**50 ms**	**50 ms**
	optimized to BrIC solely	BDSK0341		Active vent	Dual stage load limiter	**45 ms**	**no fire**

ADVANCED ADAPTIVE RESTRAINT PROGRAM
BALANCING RESTRAINT SYSTEM PERFORMANCE

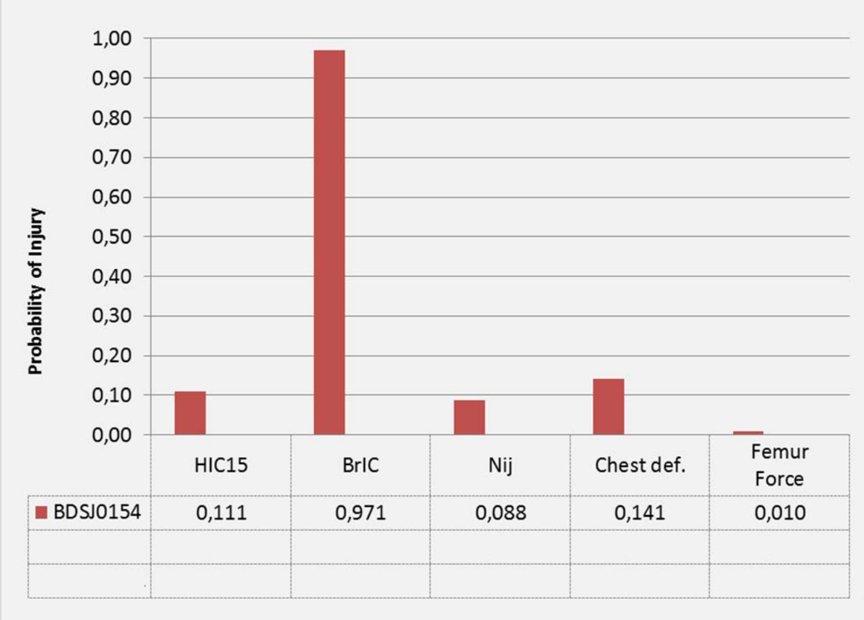
	Test #	HIC15	BrIC	Nij	Chest def.	Femur Force	Chest acc. a3ms	TTF AV	TTF FL
Baseline	BDSJ0154	**698,00**	**1,54**	**0,45**	**32,75**	**0,78**	60,68	---	---

Chest acceleration will only be considered as a constraint (< 60 g)

Normalized Injury Measure



Probability of Injury AIS 3+

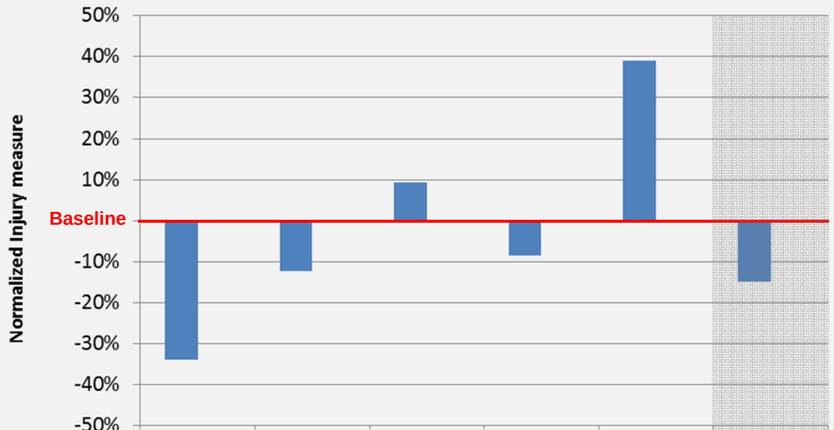


ADVANCED ADAPTIVE RESTRAINT PROGRAM
BALANCING RESTRAINT SYSTEM PERFORMANCE

	Test #	HIC15	BrIC	Nij	Chest def.	Femur Force	Chest acc. a3ms	TTF AV	TTF FL
Baseline	BDSJ0154	698,00	1,54	0,45	32,75	0,78	60,68	---	---
AARS optimized to all body regions	BDSK0306	461,00 ↓	1,35 ↓	0,49 ↑	29,98 ↓	1,09 ↑	51,68 ↓	50 ms	50 ms

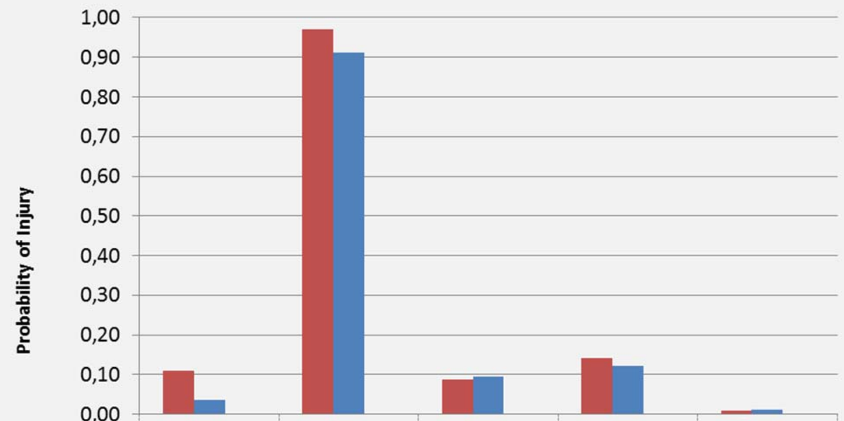
Chest acceleration will only be considered as a constraint (< 60 g)

Normalized Injury Measure



	HIC15	BrIC	Nij	Chest def.	Femur Force	Chest acc.
BDSK0306	-34,0%	-12,3%	9,4%	-8,5%	39,1%	-14,8%

Probability of Injury AIS 3+



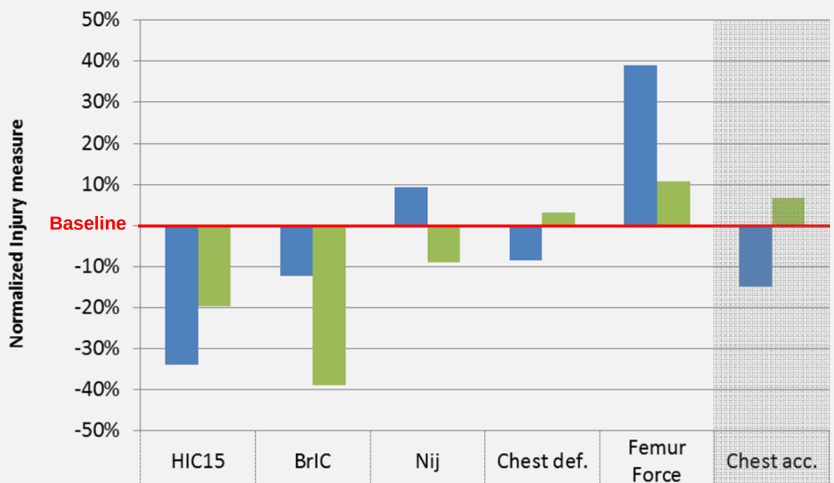
	HIC15	BrIC	Nij	Chest def.	Femur Force
BDSJ0154	0,111	0,971	0,088	0,141	0,010
BDSK0306	0,037	0,912	0,095	0,123	0,011

ADVANCED ADAPTIVE RESTRAINT PROGRAM
BALANCING RESTRAINT SYSTEM PERFORMANCE

	Test #	HIC15	BrIC	Nij	Chest def.	Femur Force	Chest acc. a3ms	TTF AV	TTF FL
Baseline	BDSJ0154	**698,00**	**1,54**	**0,45**	**32,75**	**0,78**	60,68	---	---
AARS optimized to all body regions	BDSK0306	**461,00** ↓	**1,35** ↓	**0,49** ↑	**29,98** ↓	**1,09** ↑	51,68 ↓	50 ms	50 ms
AARS optimized to BrIC solely	BDSK0341	**561,00** ↓	**0,94** ↓	**0,41** ↓	**33,79** ↑	**0,87** ↑	64,71 ↑	45 ms	no fire

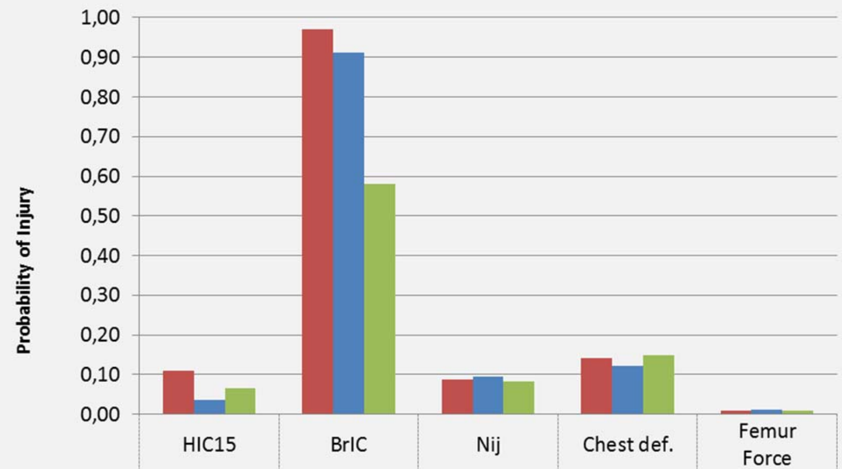
Chest acceleration will only be considered as a constraint (< 60 g)

Normalized Injury Measure



	HIC15	BrIC	Nij	Chest def.	Femur Force	Chest acc.
BDSK0306	-34,0%	-12,3%	9,4%	-8,5%	39,1%	-14,8%
BDSK0341	-19,6%	-39,0%	-9,0%	3,2%	10,9%	6,6%

Probability of Injury AIS 3+



	HIC15	BrIC	Nij	Chest def.	Femur Force
BDSJ0154	0,111	0,971	0,088	0,141	0,010
BDSK0306	0,037	0,912	0,095	0,123	0,011
BDSK0341	0,065	0,581	0,082	0,148	0,010

Advanced Adaptive Restraint Program

Individualization of restraint system performance

- High Complexity in the Advanced Adaptive Restraint Program
- Additional sensors are required to determine the occupant posture
- Reduction of brain injurys will be one of the major challenges of the near future

Questions ?

Thank you very much for your attention!