

Latest Development of the **a**dvanced **P**edestrian **L**egform **I**mpactor CAE Model

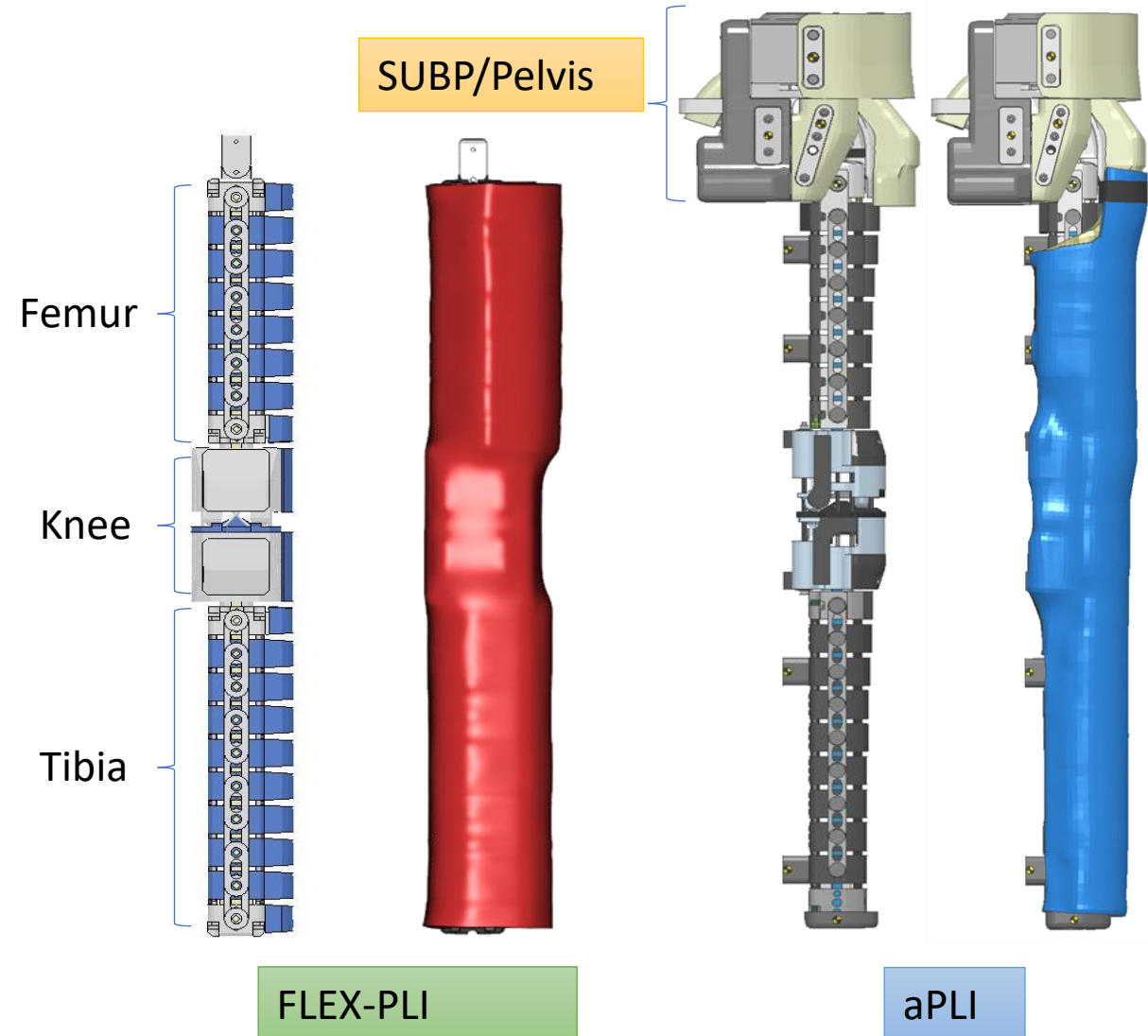
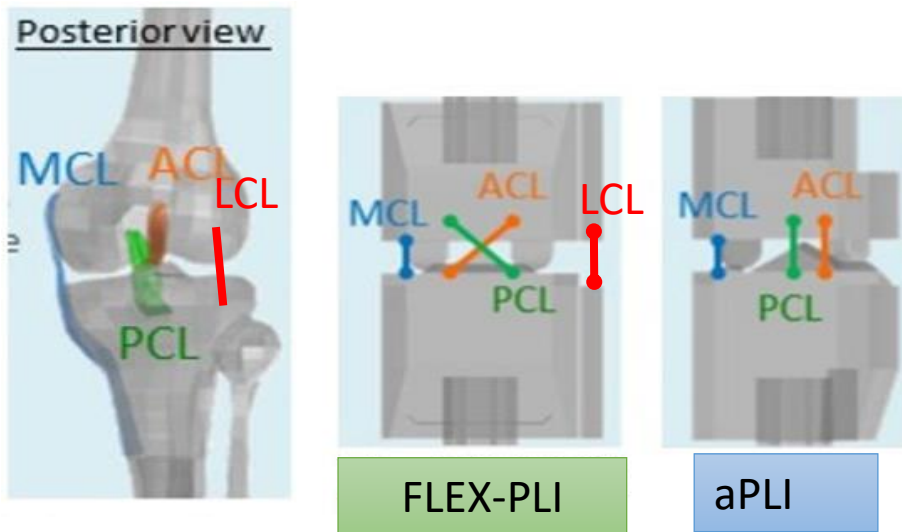
13th Europe LS-DYNA Conference 2021, Ulm, Germany

Christian Kleessen Humanetics Europe GmbH

Chirag Shah Humanetics Innovative Solutions Inc.

Introduction - aPLI

- Added upper body mass of 11.5 kg in aPLI (**Total mass aPLI 25 kg vs. FLEX-PLI 13 kg**)
- **Contoured** femur and tibia in aPLI to represent **more human like geometry**
- **Improved mass distribution** in aPLI
- **Hip joint** representation in aPLI
- Elimination of LCL and re-arrangement of knee ligaments



Introduction - aPLI

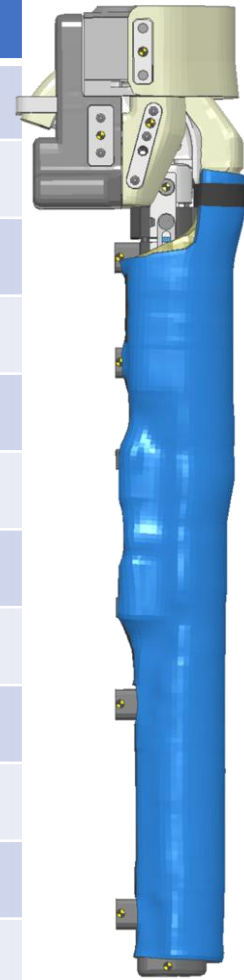
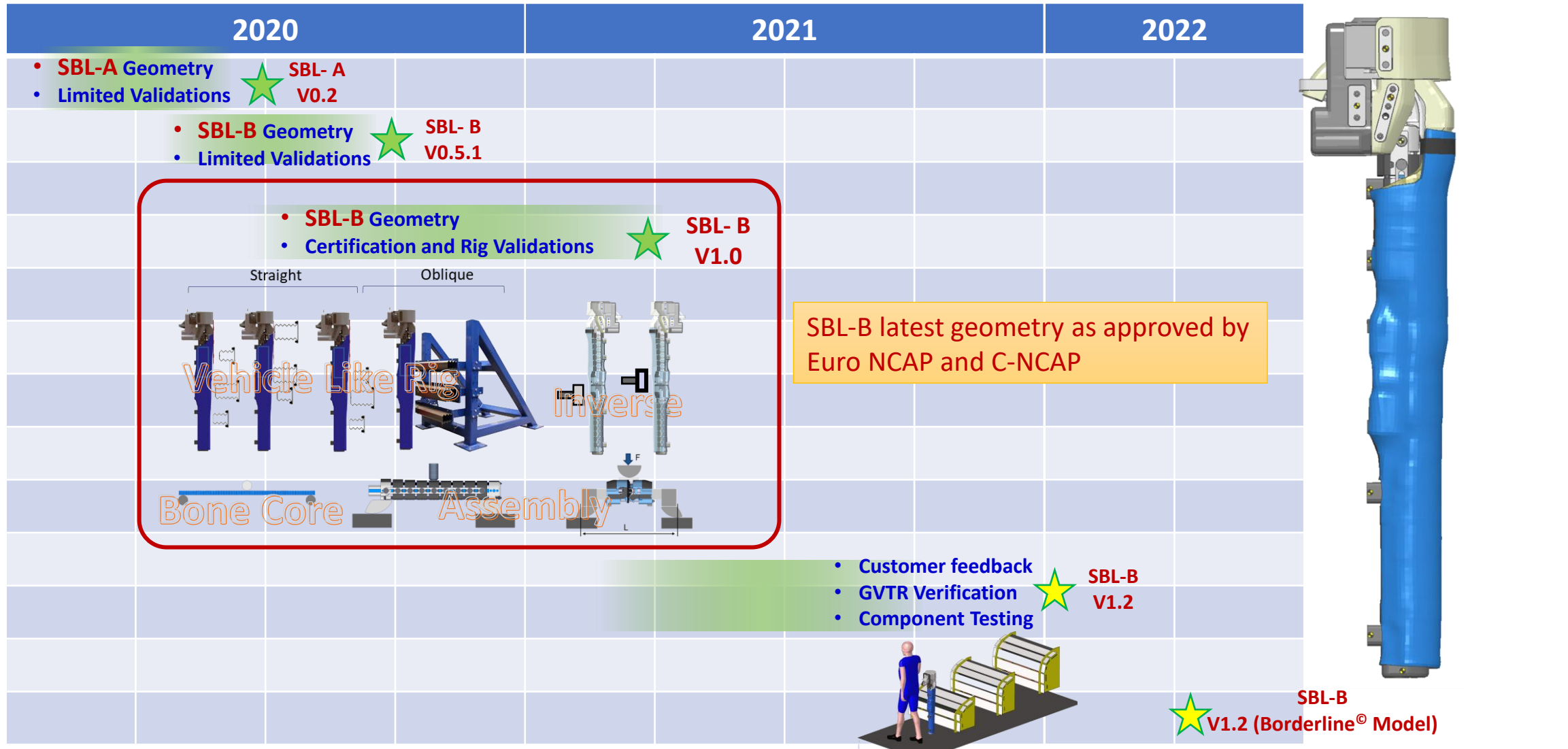
aPLI – advanced Pedestrian Leg-form Impactor

- Consumer Agencies
 - C-NCAP in early 2022 [SBL-B]
 - Euro NCAP and KNCAP in early 2023 [SBL-B]
- ISO Working Group
 - Design and improvements [SBL-B]
 - Injury risk assessment values
 - Certification procedures and corridors
- Industries, Consumer Agencies and ISO Group
 - Round robin tests
 - Performance and robustness
 - Repeatability and reproducibility

Euro NCAP and C-NCAP Limits		
	Higher Performance Limit	Lower Performance Limit
Femur (Nm)	390	440
Tibia (Nm)	275	320
MCL (mm)	27	32



aPLI Model Development Roadmap

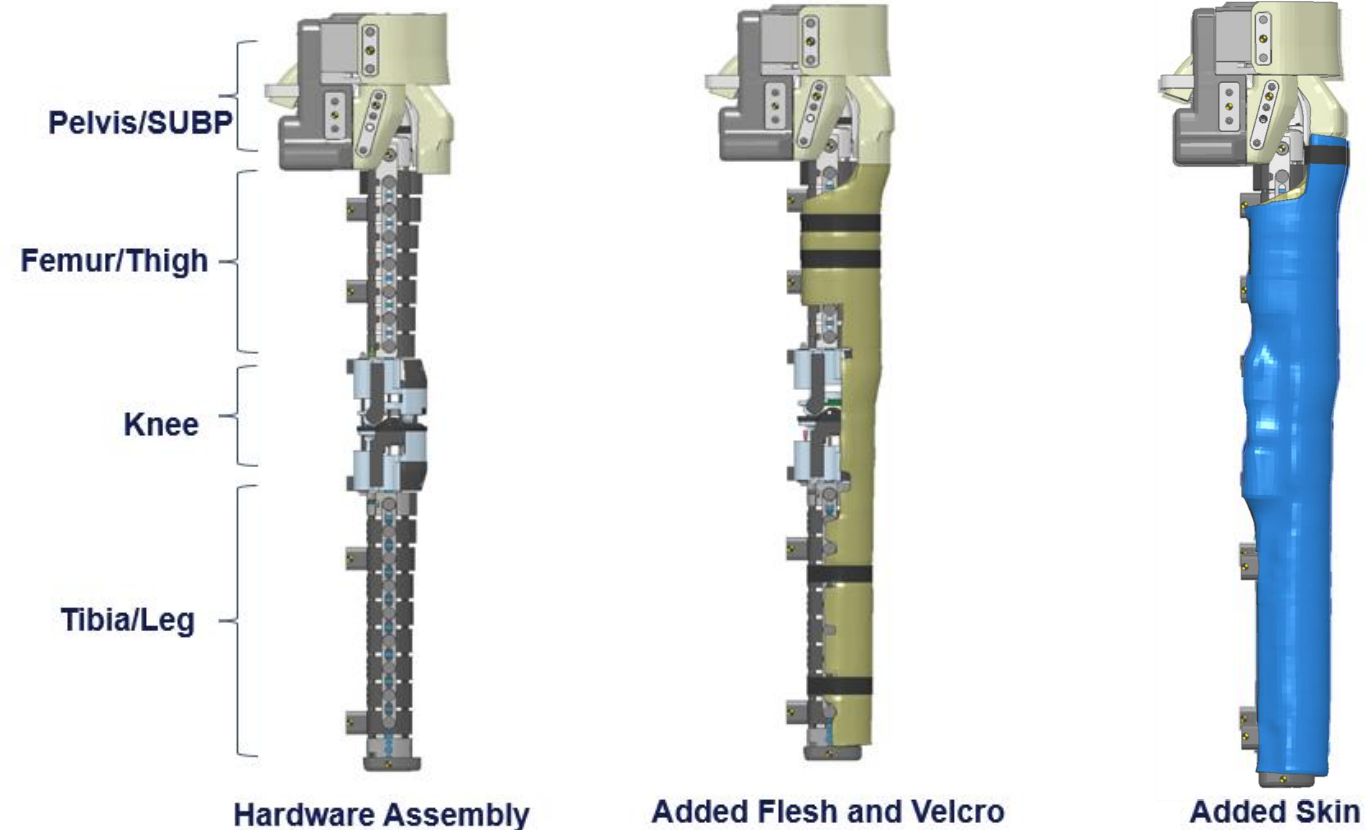


aPLI Model Development [SBL-B]

- Detailed geometric representation
- High meshing standards
- Assembly structure as in hardware
- Presimulated velcros and neoprene skin with prestress

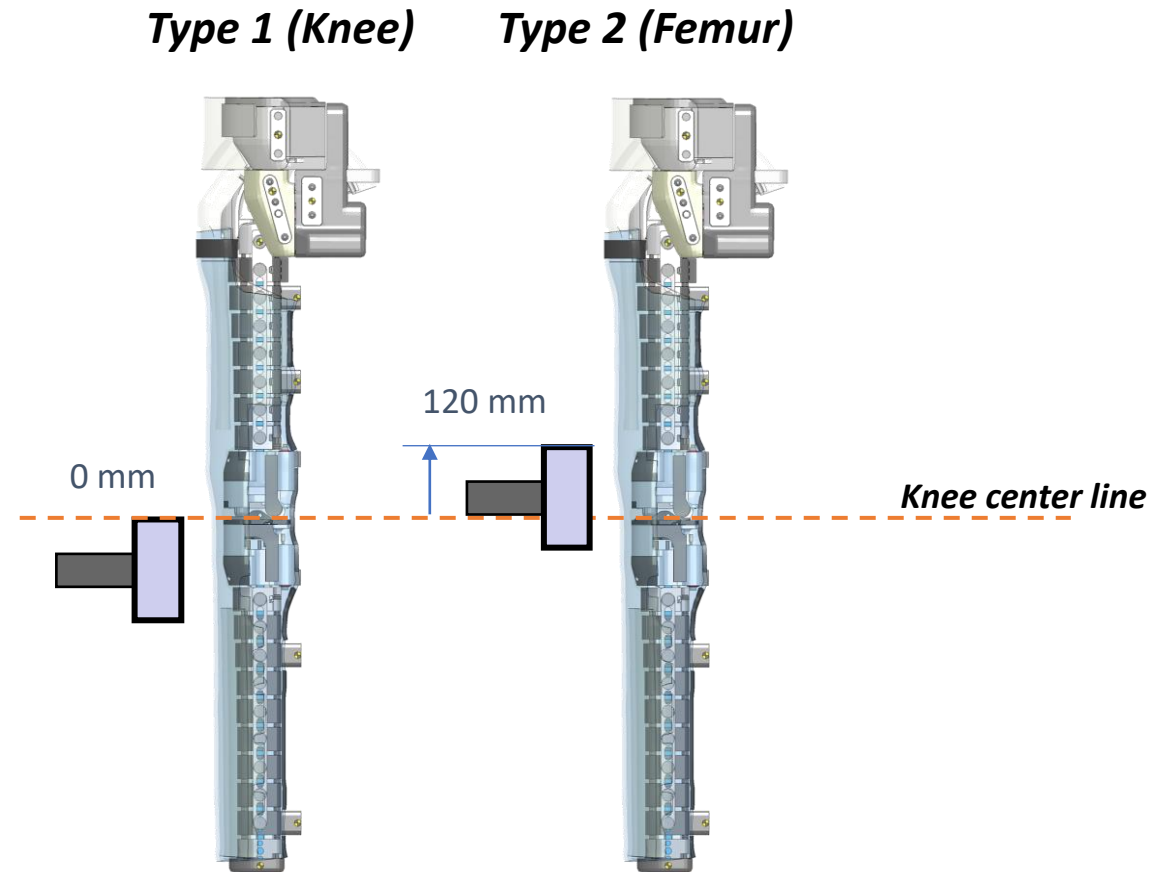
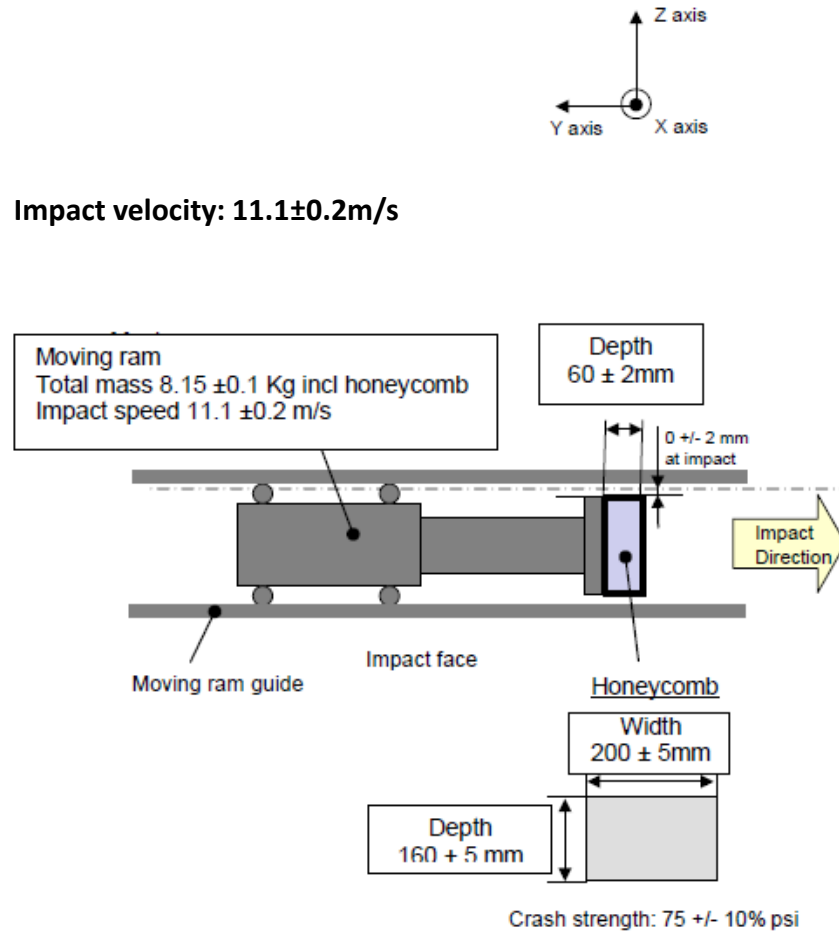
HUM aPLI v1.0	
No. of Nodes	280.000
No. of Elements	374.000
No. of Parts	800
Time-step [microseconds]	0.5
LS-Dyna Development Version	*R9.3 (rev. 131707)

* Compatibility with R7.1.2, R10 and R11



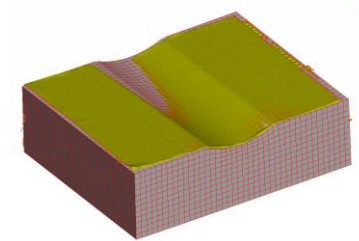
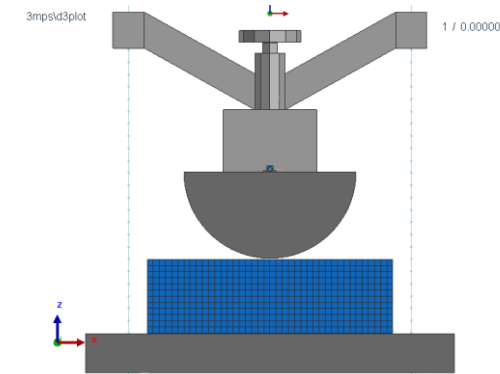
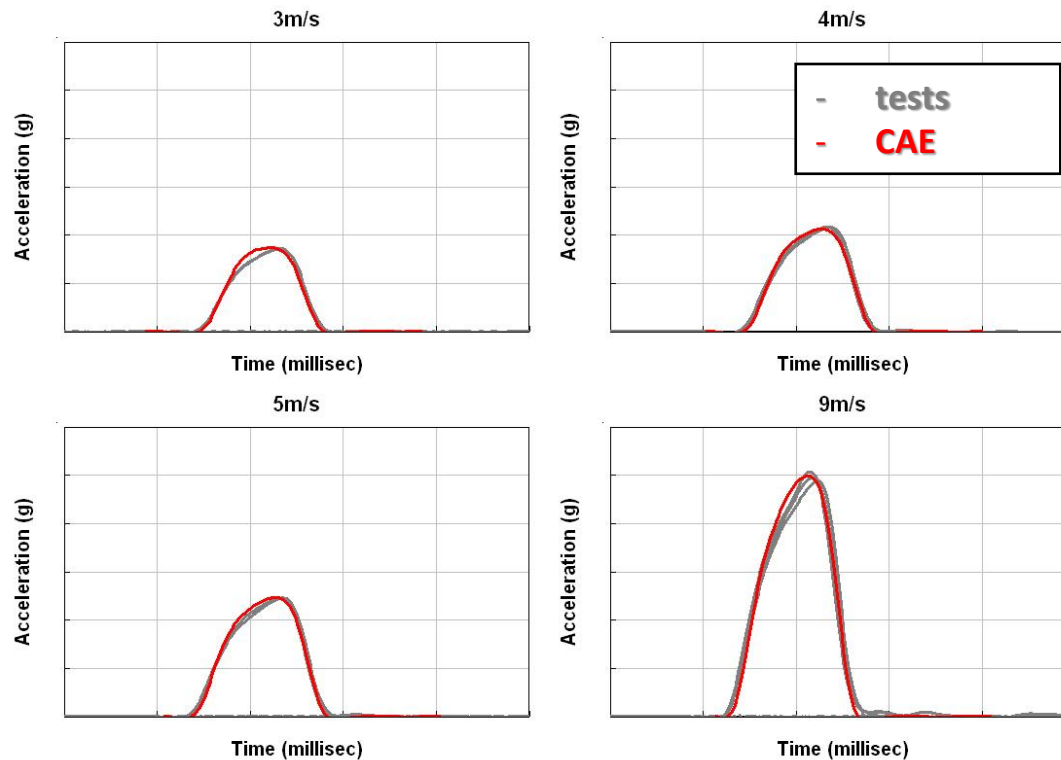
Inverse Certification

- Type 1 and Type 2



Honeycomb Modeling

- Well correlated honeycomb model for inverse certification
 - Material testing and validation
 - Component testing and validation

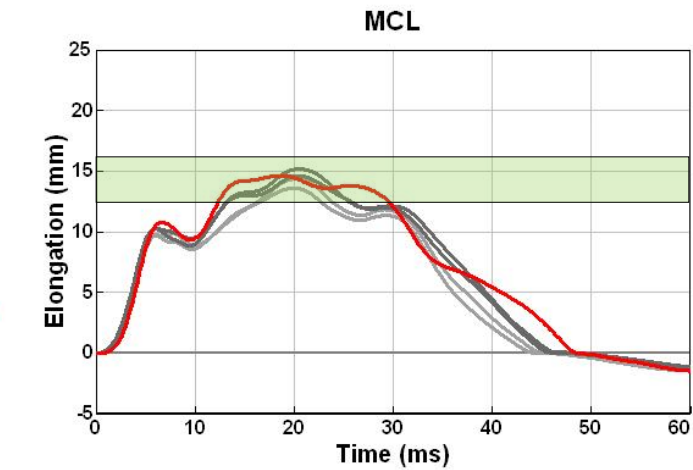
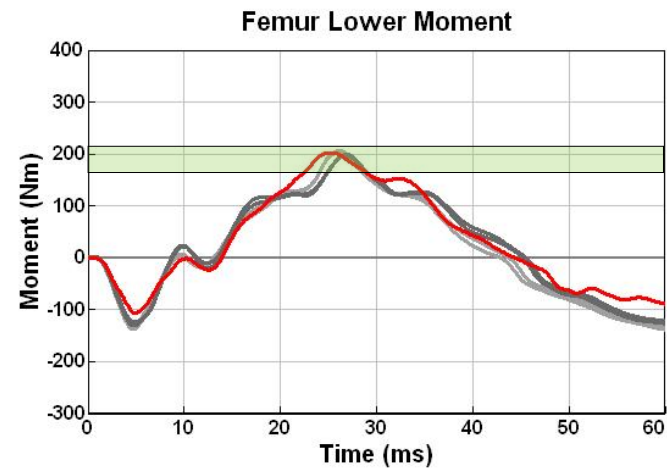
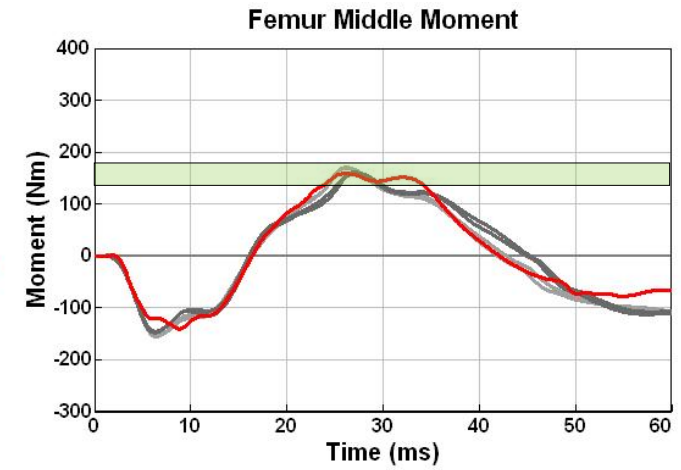
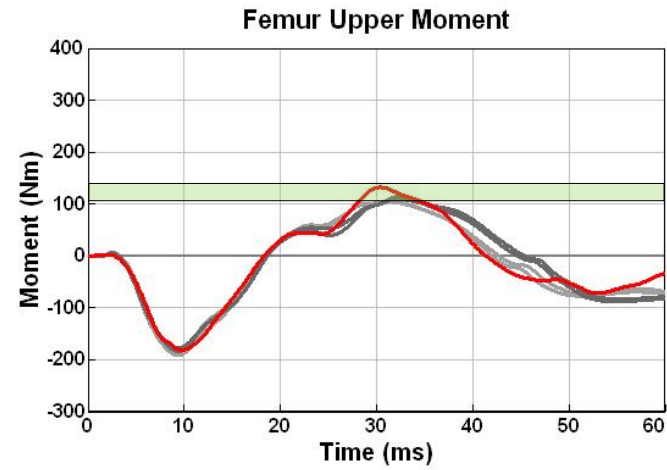
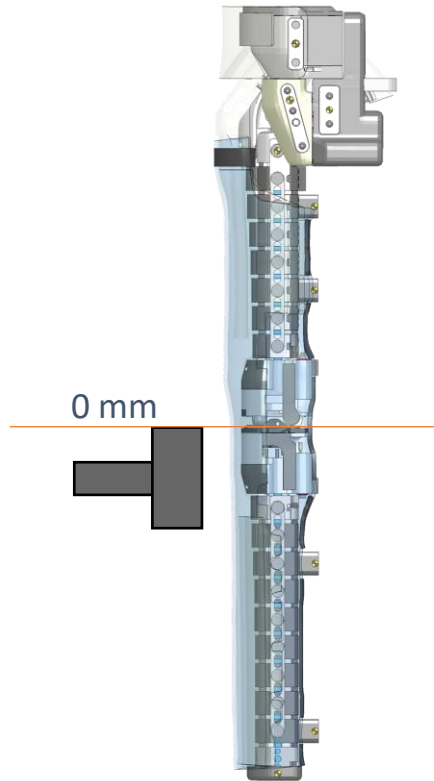


Confirmation of deformed honeycomb based on scanning



Inverse Certification

- Type 1

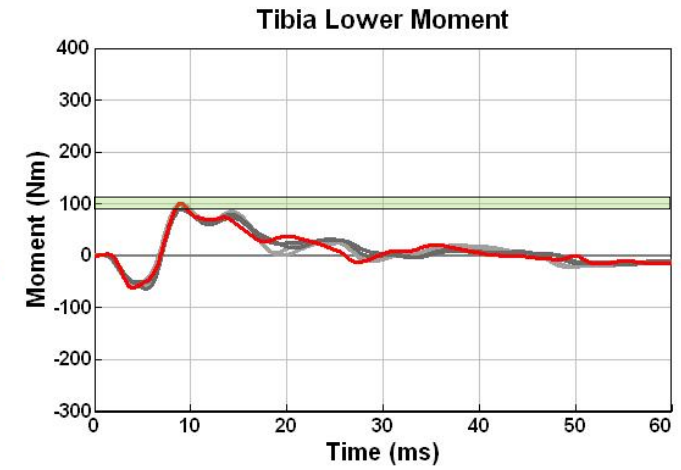
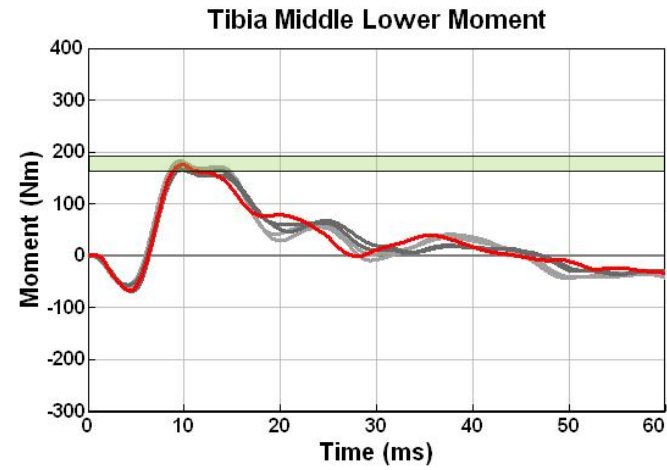
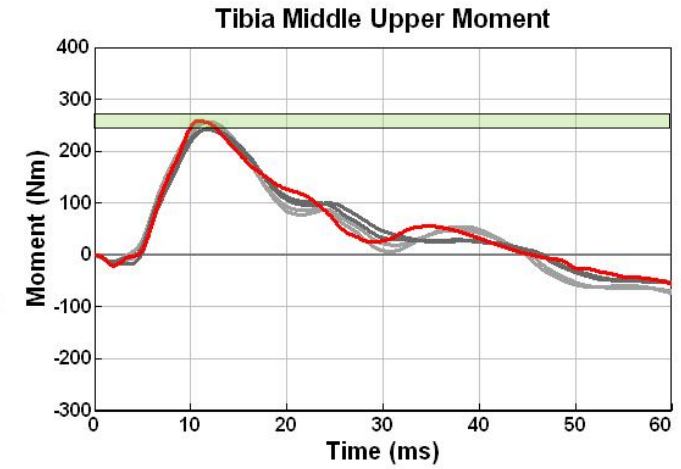
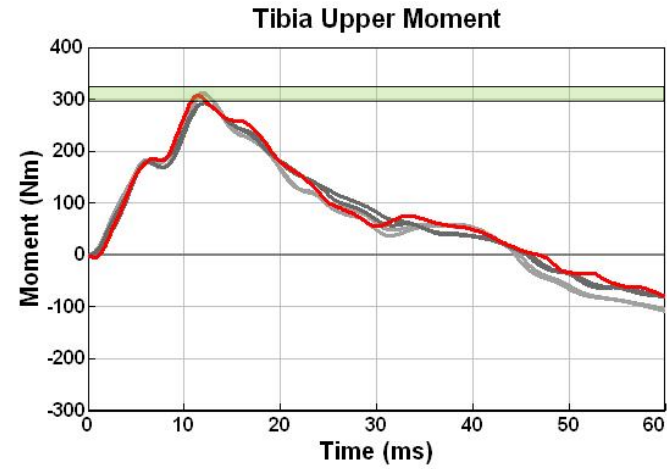
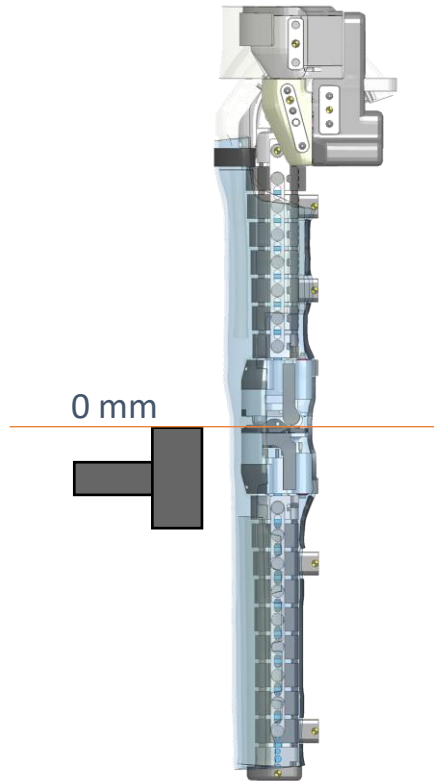


Euro-NCAP Corridors

-	tests
-	CAE

Inverse Certification

- Type 1

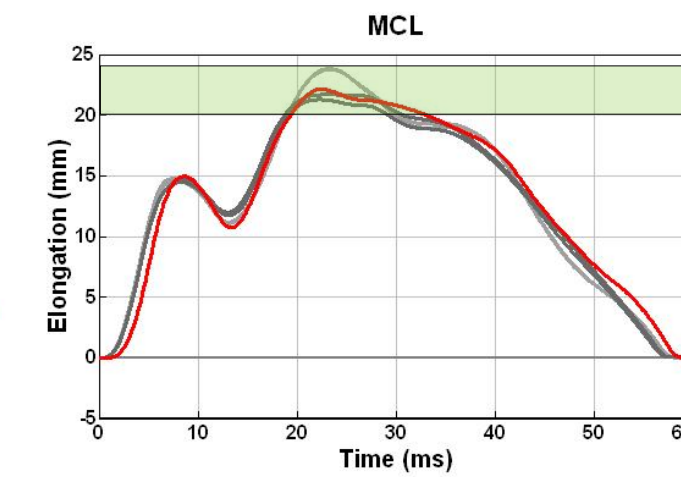
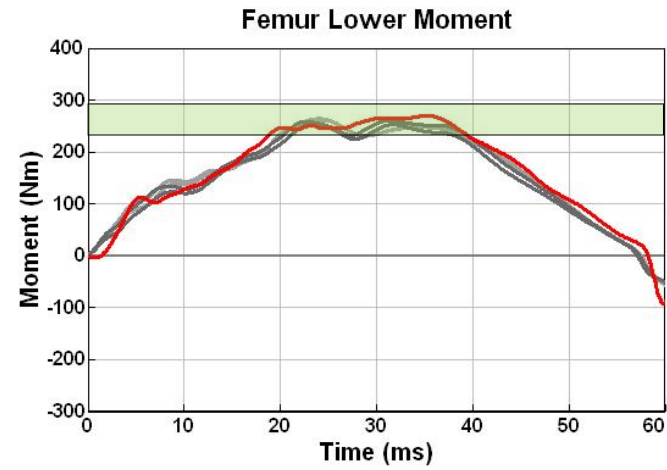
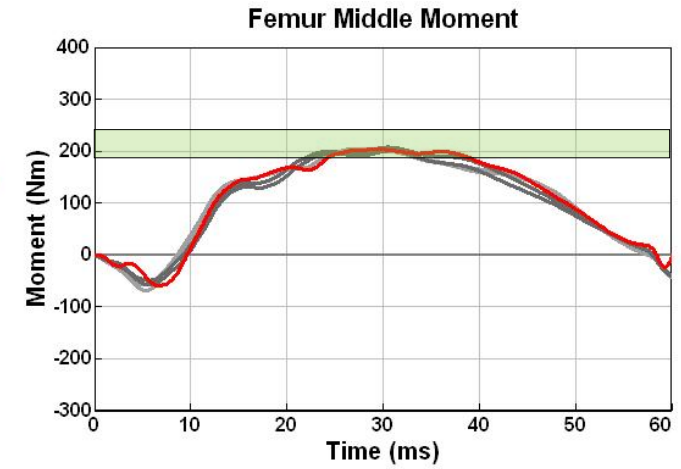
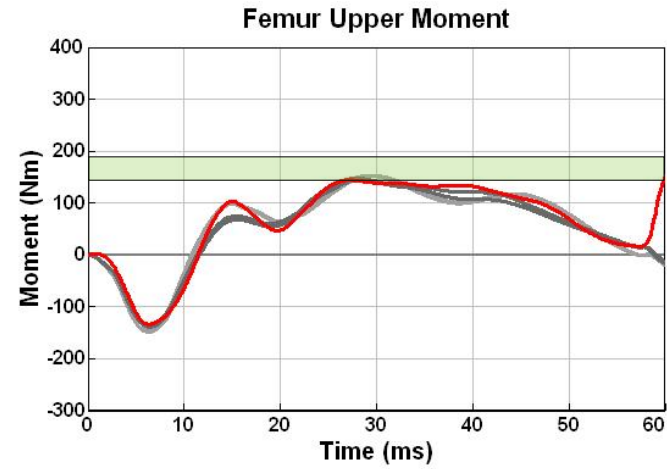
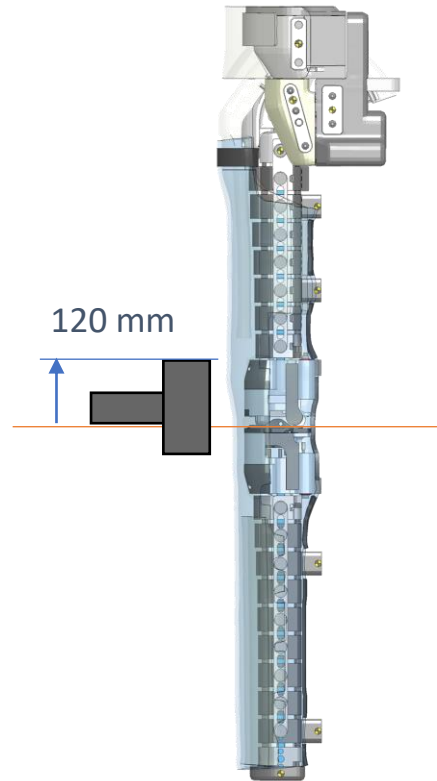


Euro-NCAP Corridors

-	tests
-	CAE

Inverse Certification

- Type 2

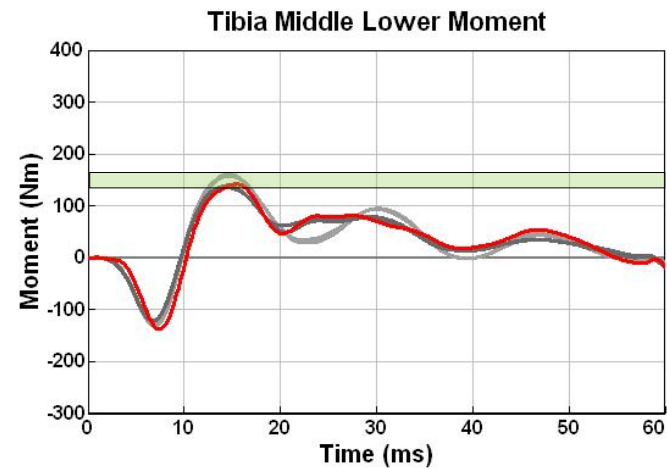
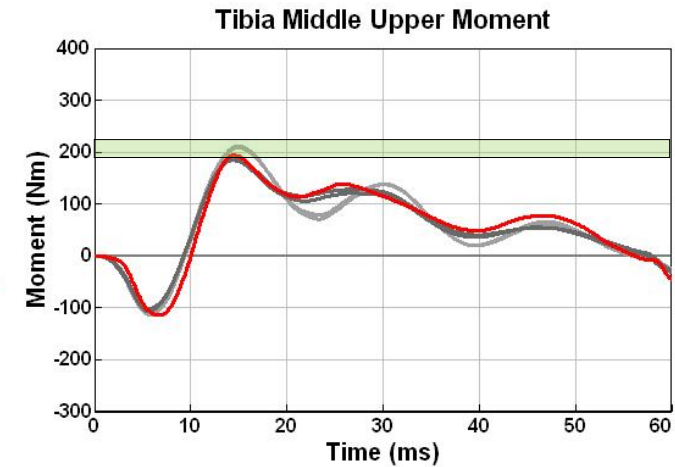
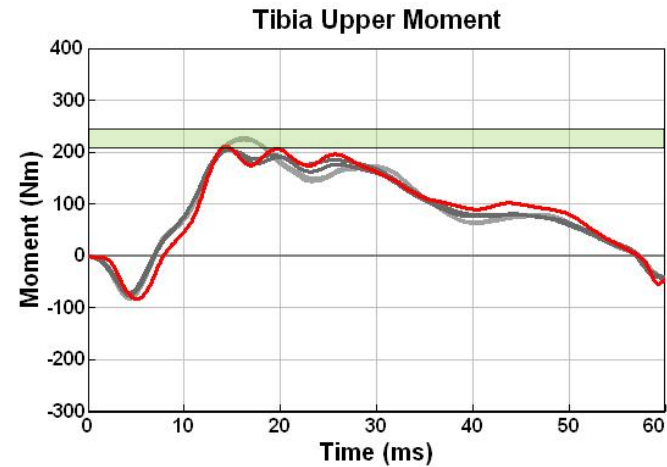
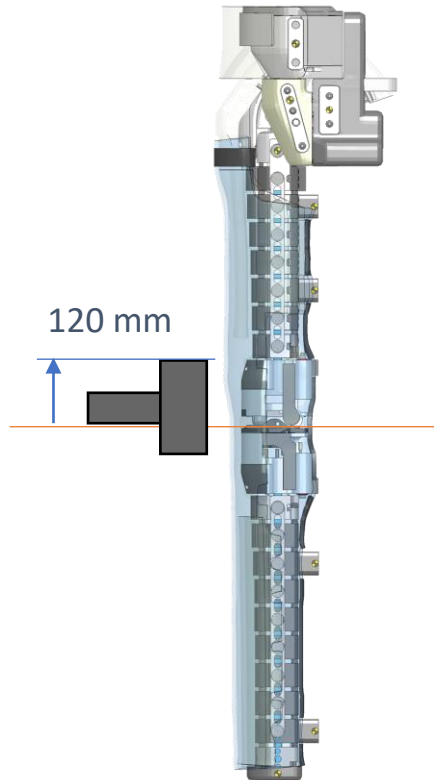


Euro-NCAP Corridors

-	tests
-	CAE

Inverse Certification

- Type 2



Euro-NCAP Corridors

- tests
- CAE

Inverse Certification

C-NCAP

INVERSE-1 (KNEE)

Signal	Lower Limit	Upper Limit	FEA Model
Femur Top	94	135	132.3
Femur Mid	125	179	158.4
Femur Low	160	204	202.5
MCL	11.4	16.7	14.6
Tibia Top	297	328	307.3
Tibia Mid High	245	267	258.4
Tibia Mid Low	161	193	175.7
Tibia Low	88	117	100.7

INVERSE-2 (FEMUR)

Signal	Lower Limit	Upper Limit	FEA Model
Femur Top	131	197	144.6
Femur Mid	183	237	203.8
Femur Low	226	289	269.6
MCL	20	24	22.1
Tibia Top	208	245	211.5
Tibia Mid High	186	226	193.8
Tibia Mid Low	131	162	142.3
Tibia Low	63	82	72.6

Euro-NCAP

INVERSE-1 (KNEE)

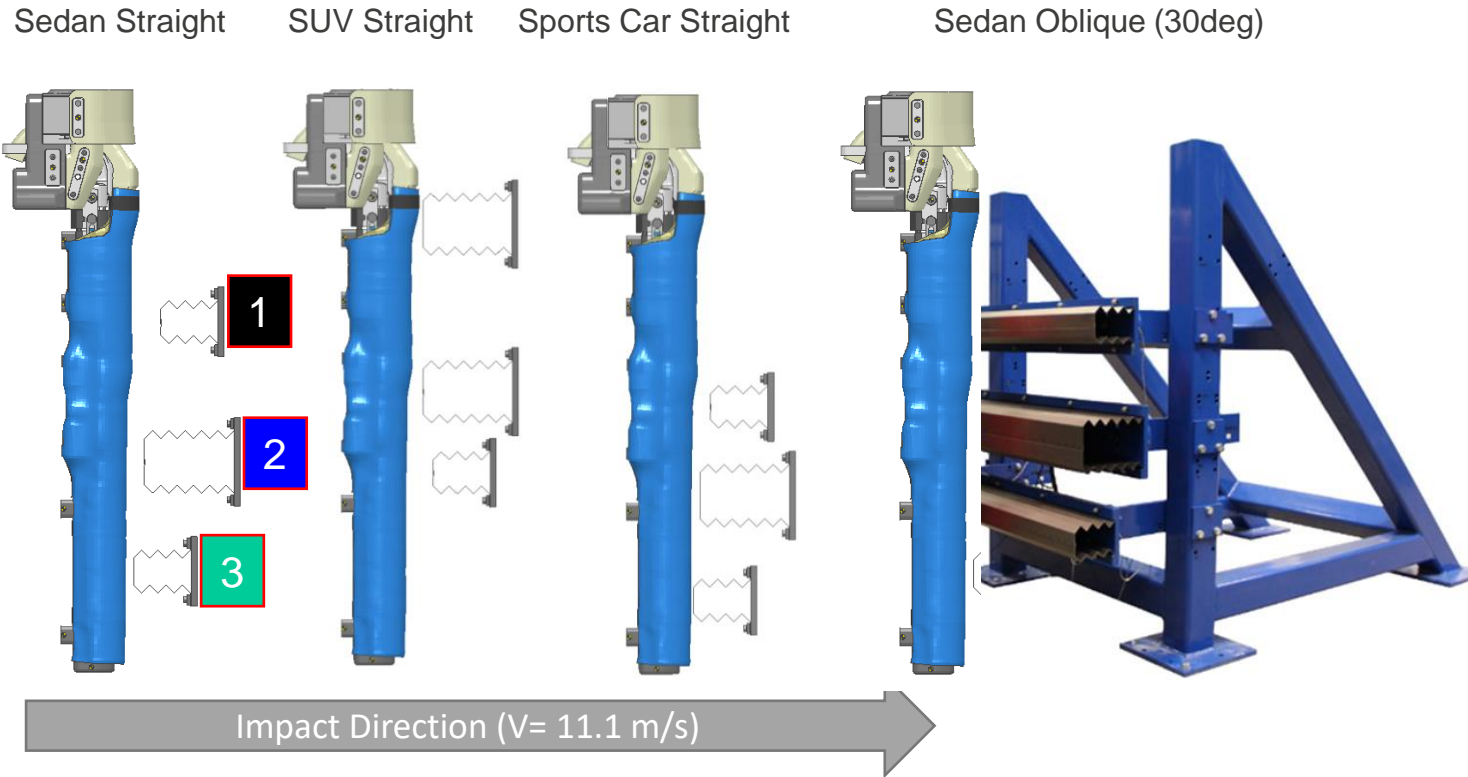
Signal	Lower Limit	Upper Limit	FEA Model
Femur Top	101	134	132.3
Femur Mid	133	178	158.4
Femur Low	162	208	202.5
ACL	3	4	3.4
PCL	6	8	6.5
MCL	12	16	14.6
Tibia Top	291	334	307.3
Tibia Mid High	238	272	258.4
Tibia Mid Low	160	193	175.7
Tibia Low	92	116	100.7

INVERSE-2 (FEMUR)

Signal	Lower Limit	Upper Limit	FEA Model
Femur Top	147	190	144.6
Femur Mid	189	238	203.8
Femur Low	233	293	269.6
ACL	3	4	3.4
PCL	8	10	8.9
MCL	20	24	22.1
Tibia Top	206	251	211.5
Tibia Mid High	182	228	193.8
Tibia Mid Low	132	164	142.3
Tibia Low	63	83	72.6

All signals are within certification corridors. C-NCAP is planning to adopt Euro-NCAP corridors.

Rig Testing and Validation



Vehicle Like Response:

- Configuration (Stiffness)
 - Sheet Metal Thickness **1** **2** **3**
 - Geometry
- Position
 - Input from industry partners

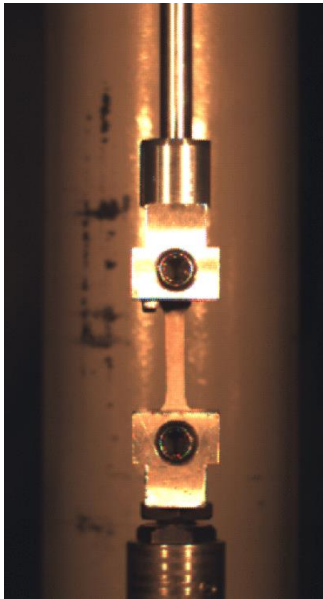
PLUS

Corrugated Load-path (CRS) Performance

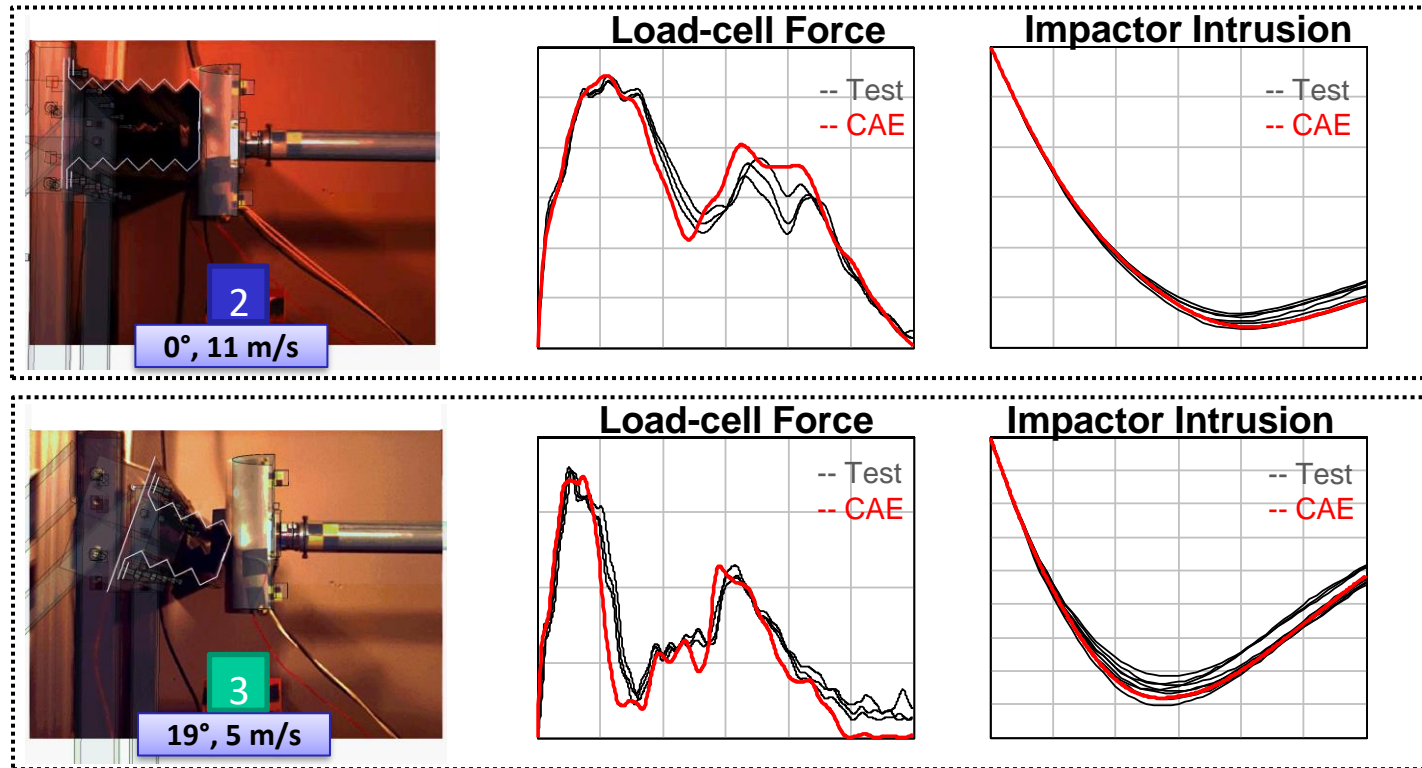
- Well-defined boundary conditions
 - High Repeatability and reproducibility
- Better FE modeling capabilities
- Acceptance by industry partners

Rig Testing and Validation

- Well validated corrugated bumpers for rig load cases
 - Material level validation
 - Component level validation

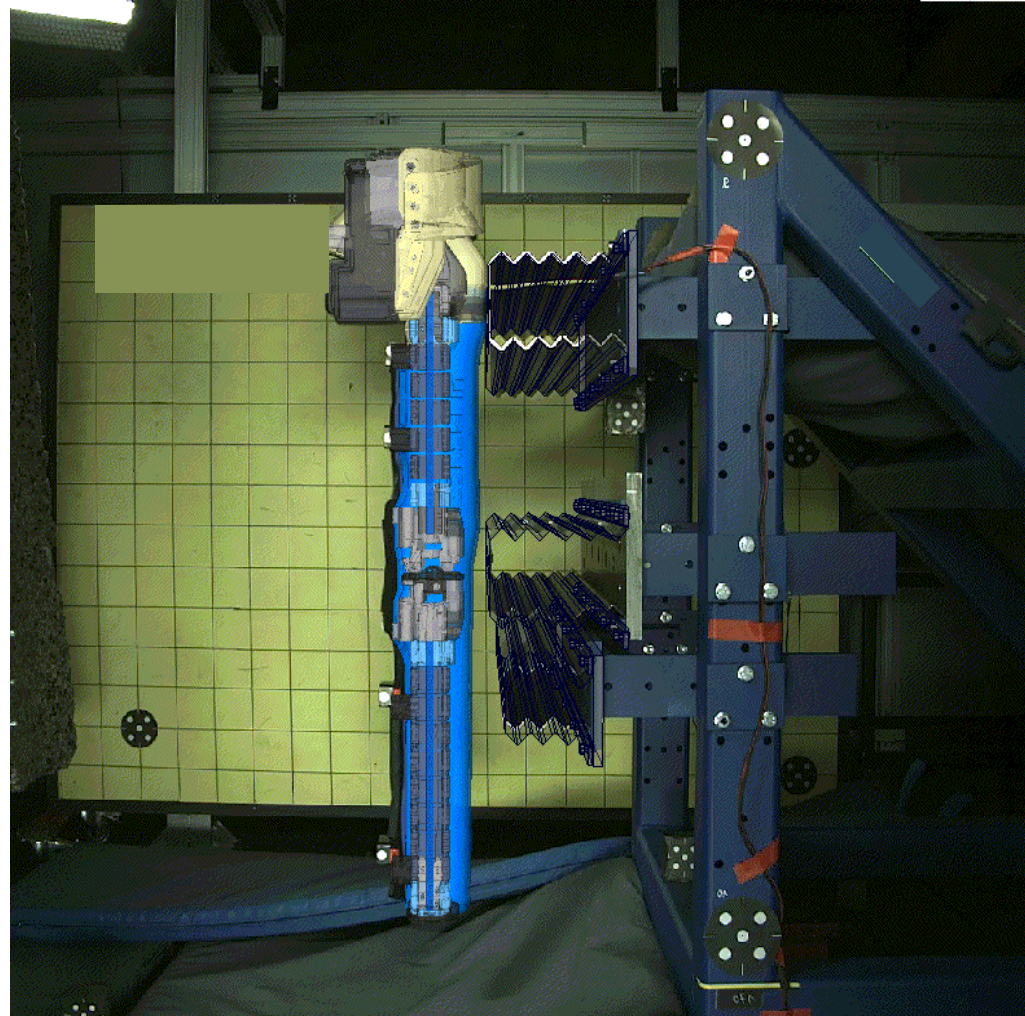
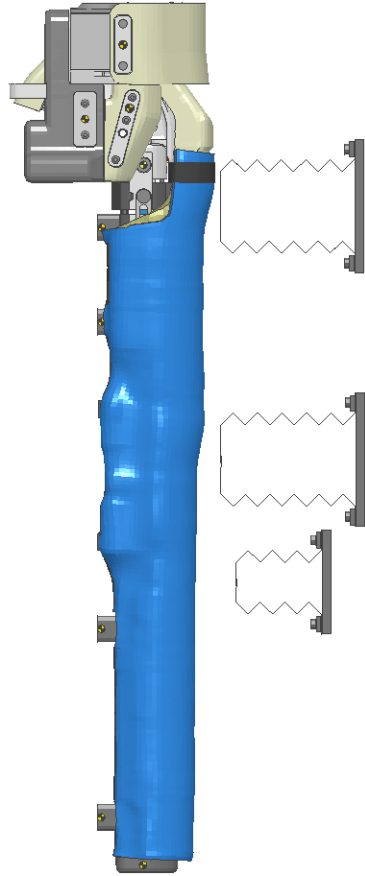


Multiple Rate Material Testing

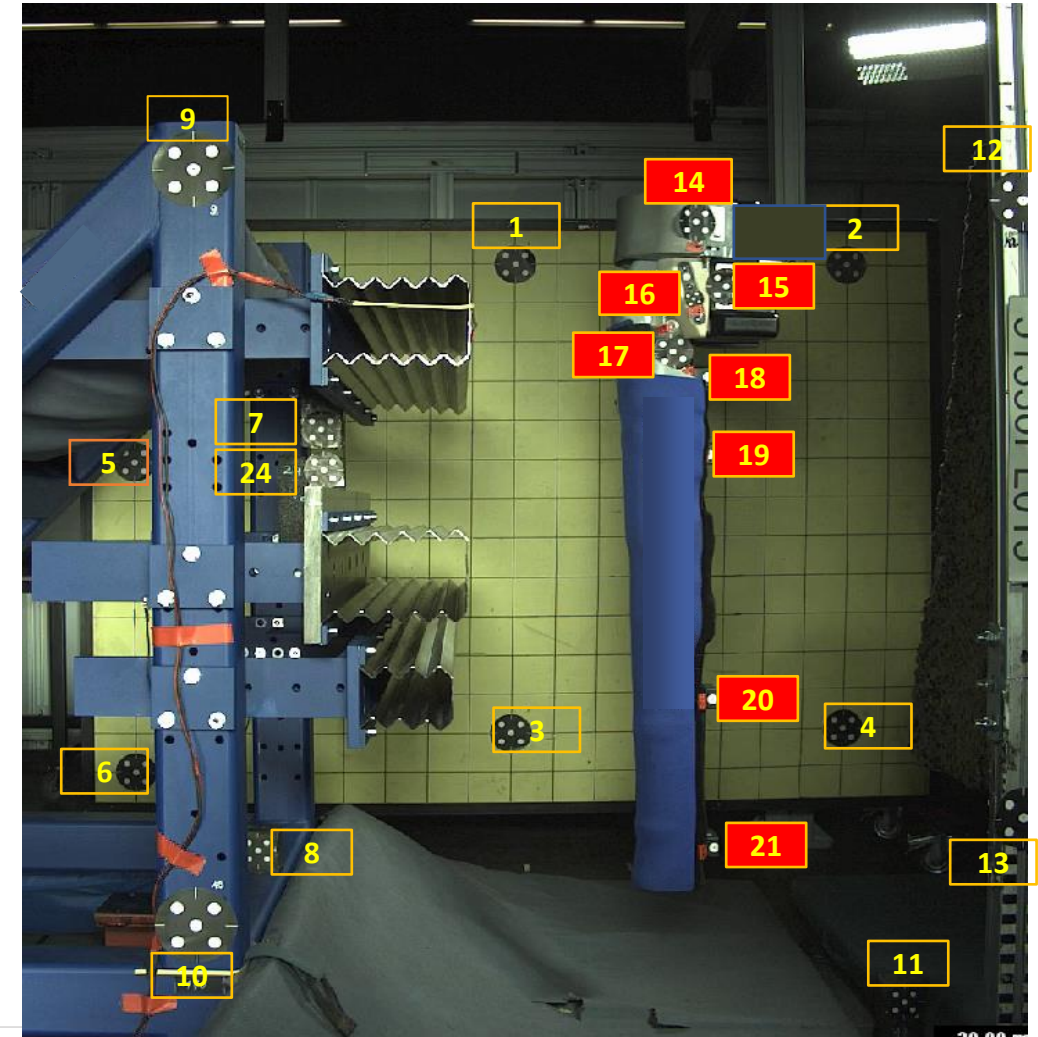
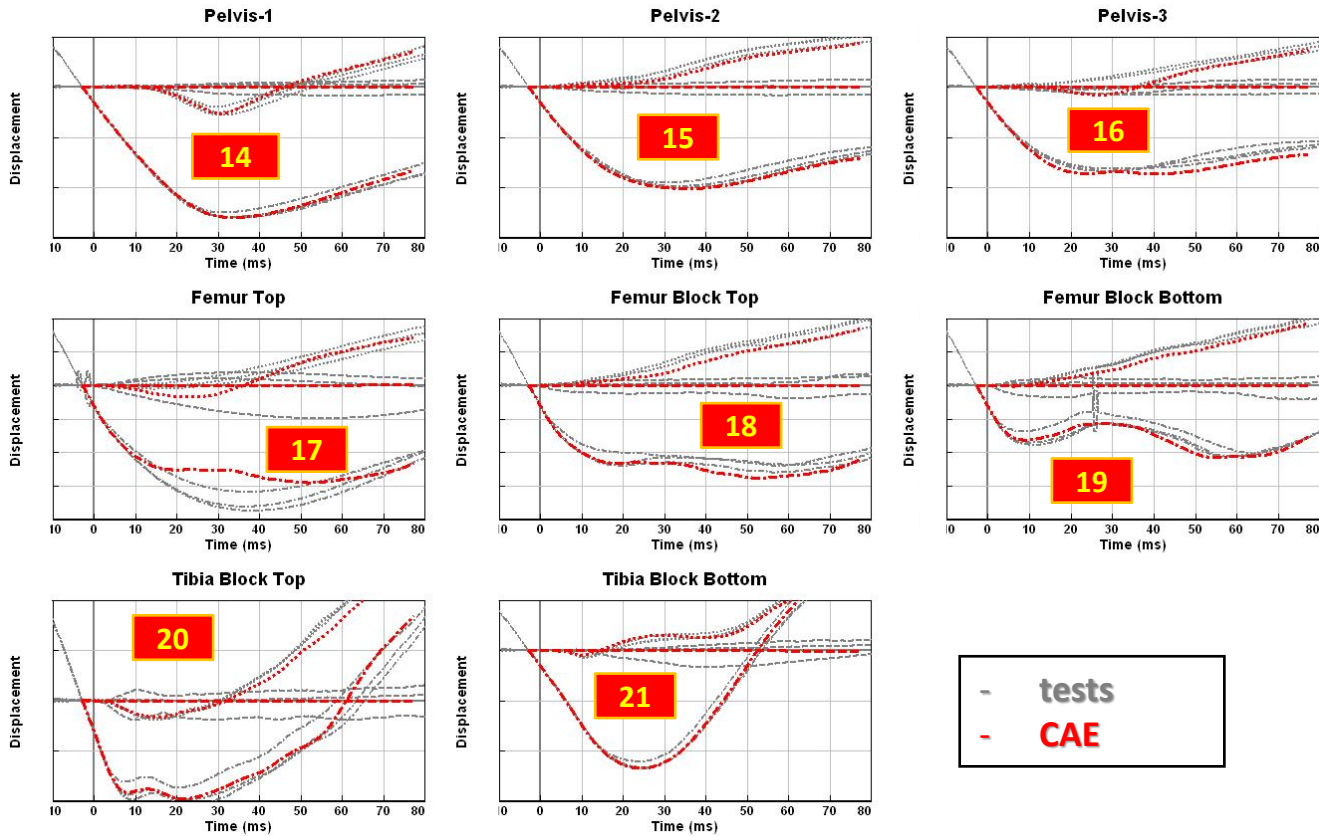


CRS Configuration	No.	Impact Speed, V (m/s)	Orientation
1	1, 2	5.0 ~ 11.0	0° 19°
2	3, 4, 5		
3	6, 7		

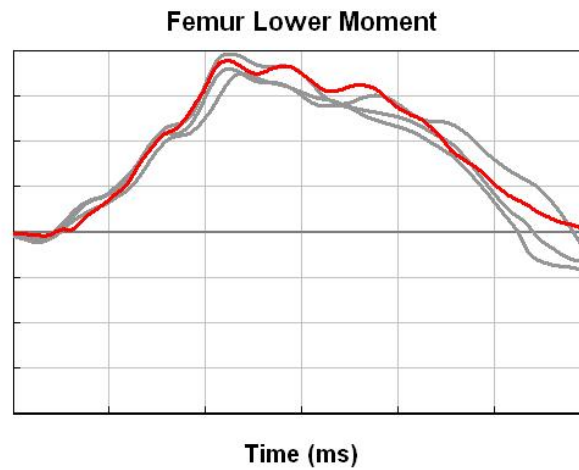
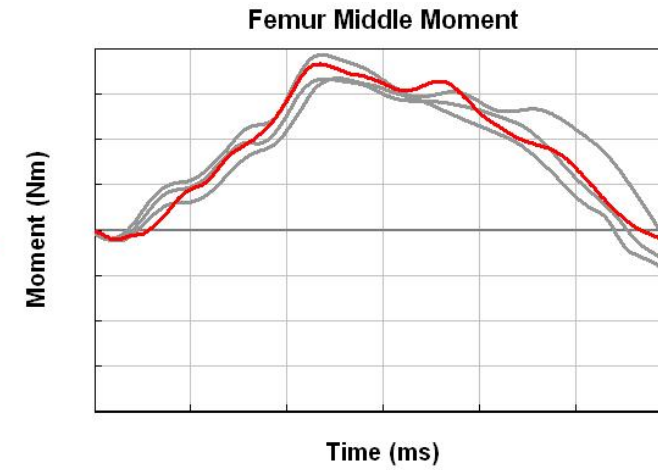
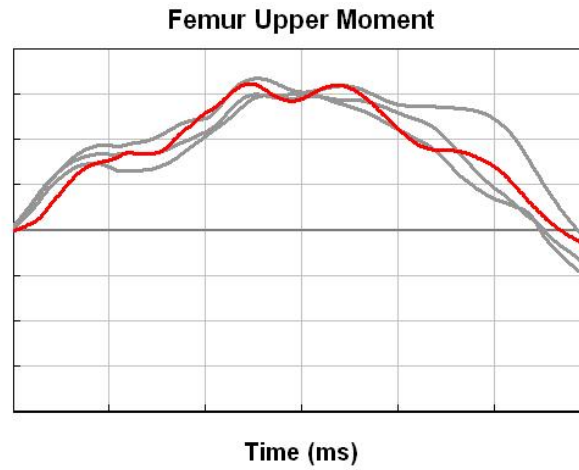
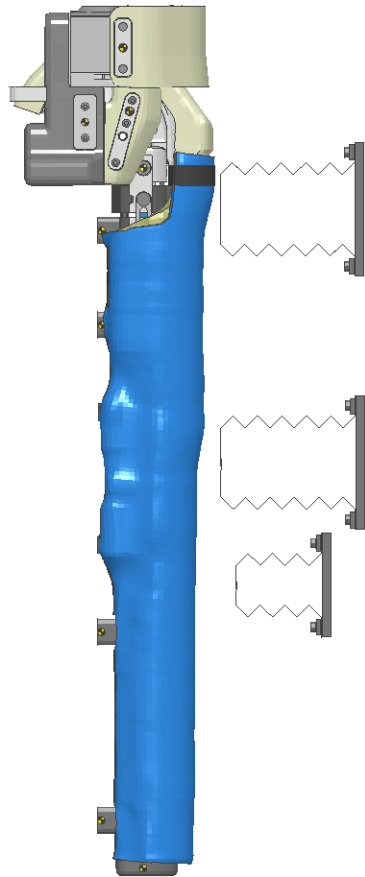
Rig Validation - SUV



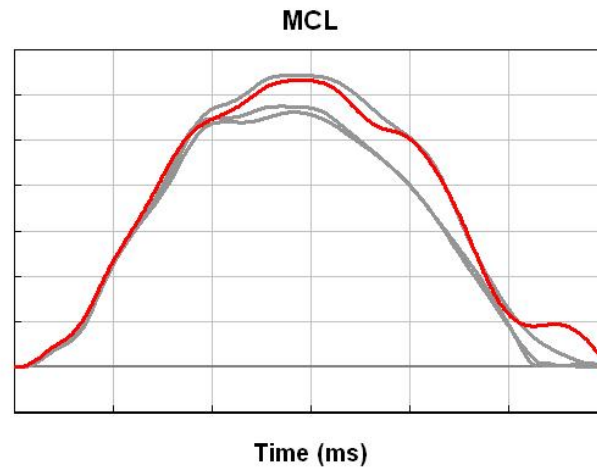
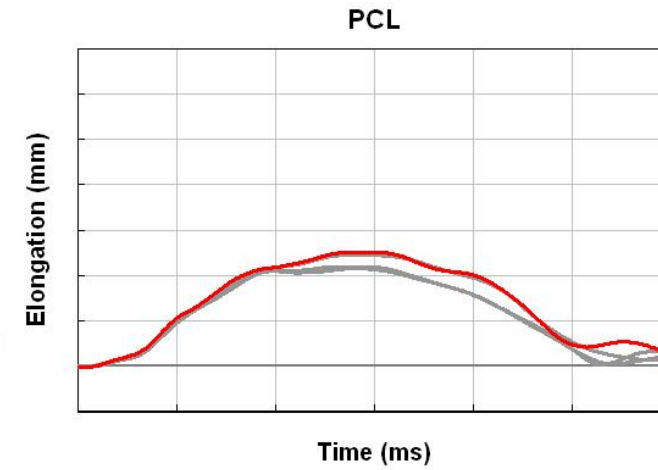
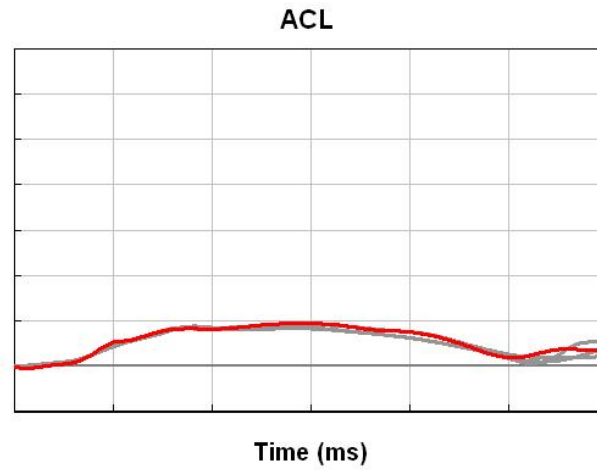
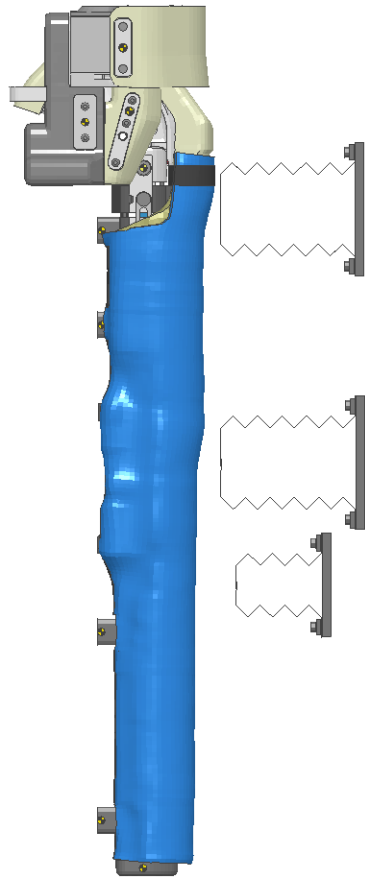
Rig Validation - Kinematics



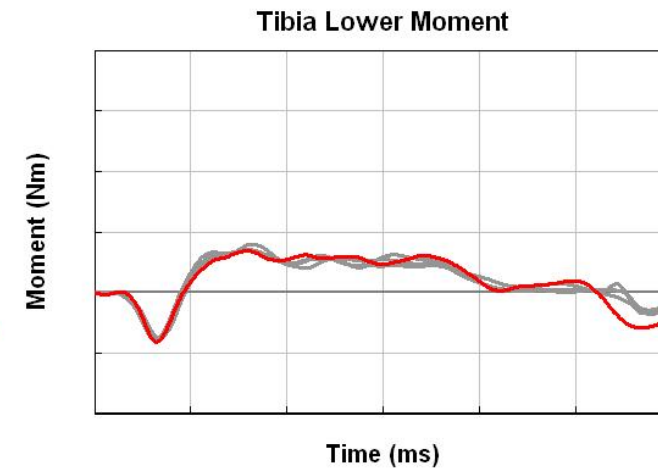
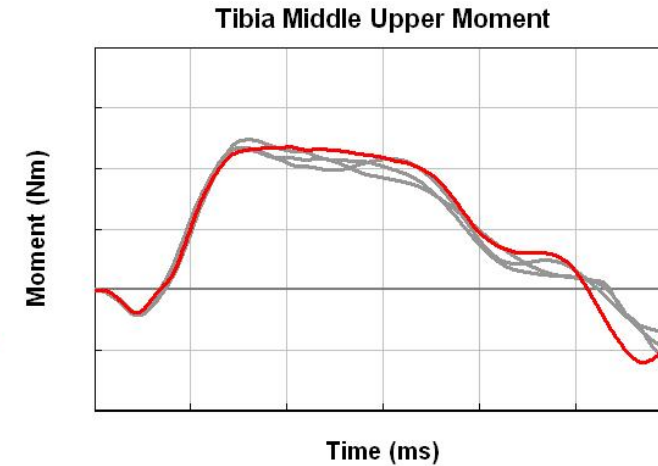
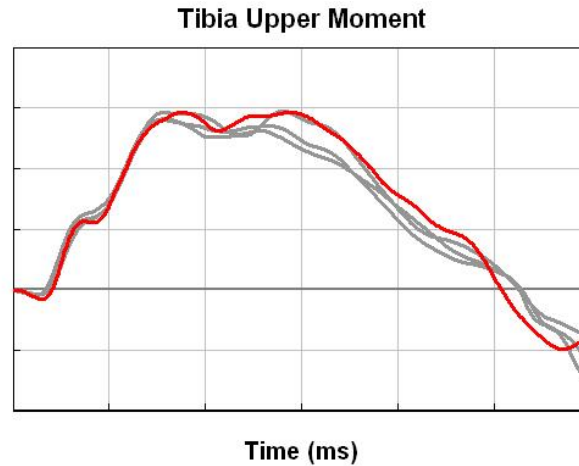
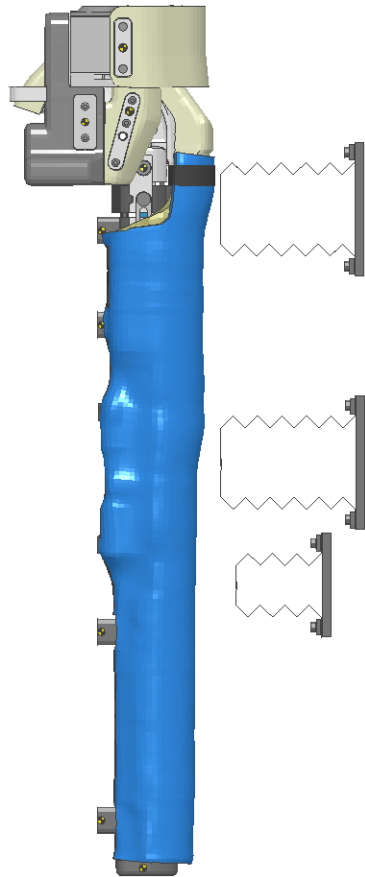
Rig Validation - SUV



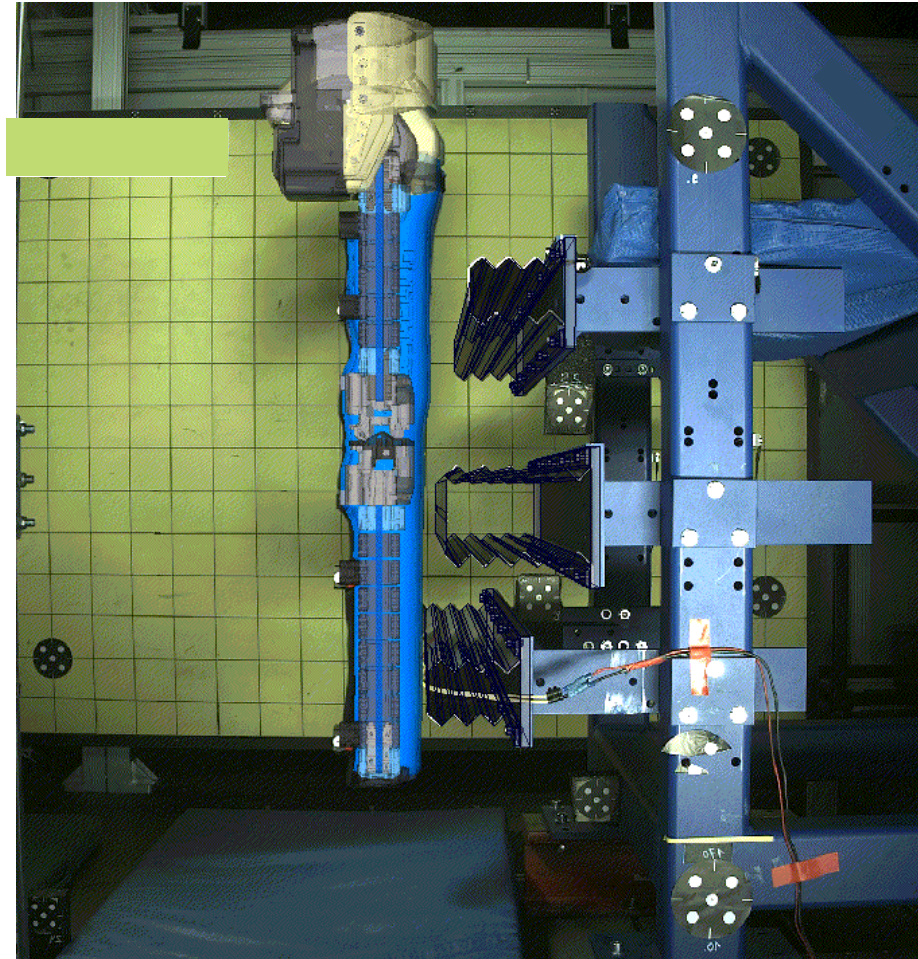
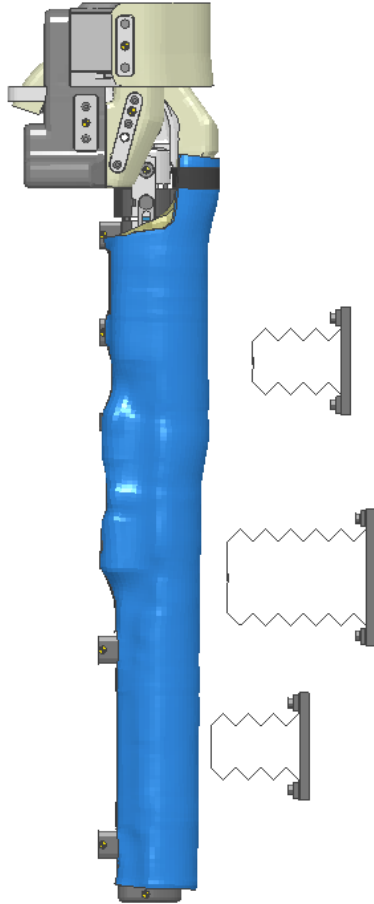
Rig Validation - SUV



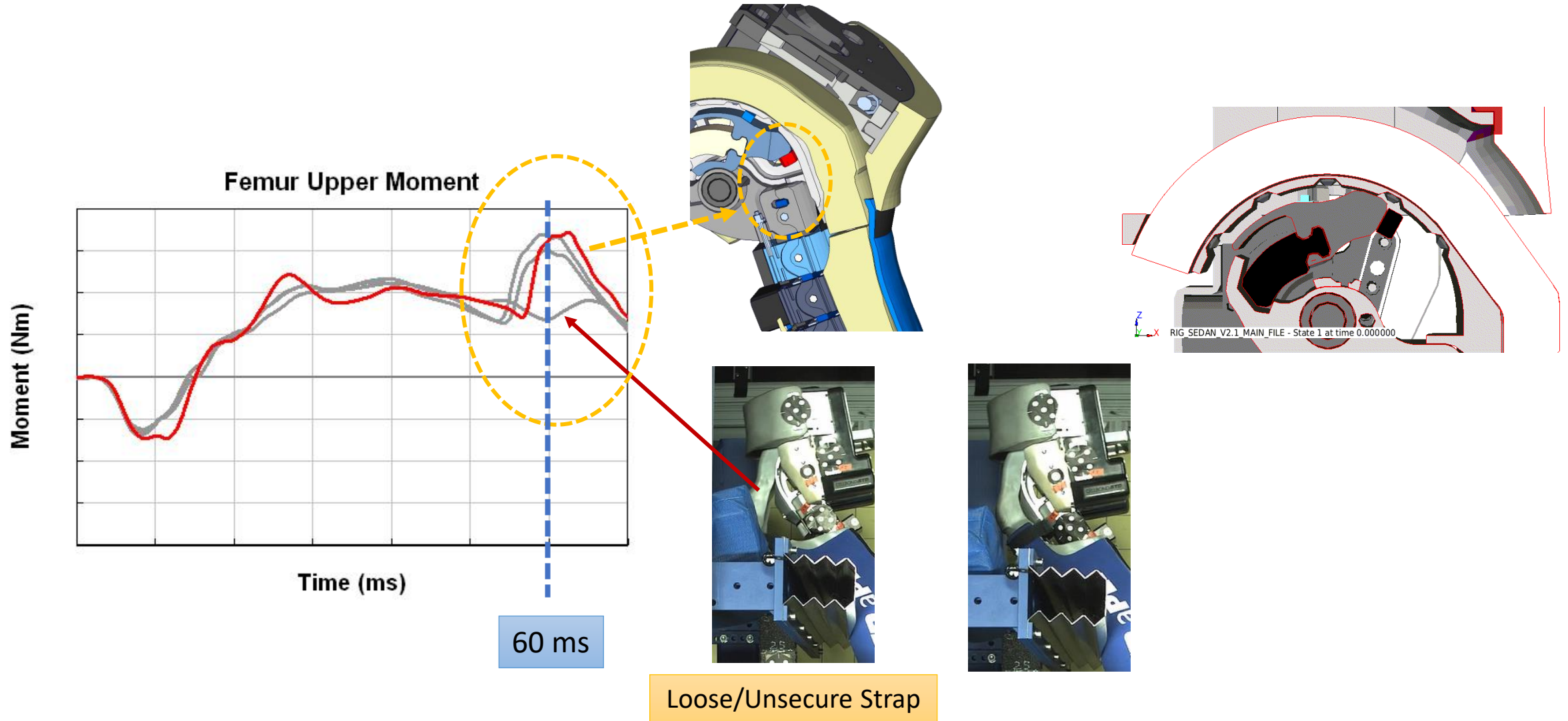
Rig Validation - SUV



Rig Validation - Sedan



Rig Validation - Sedan

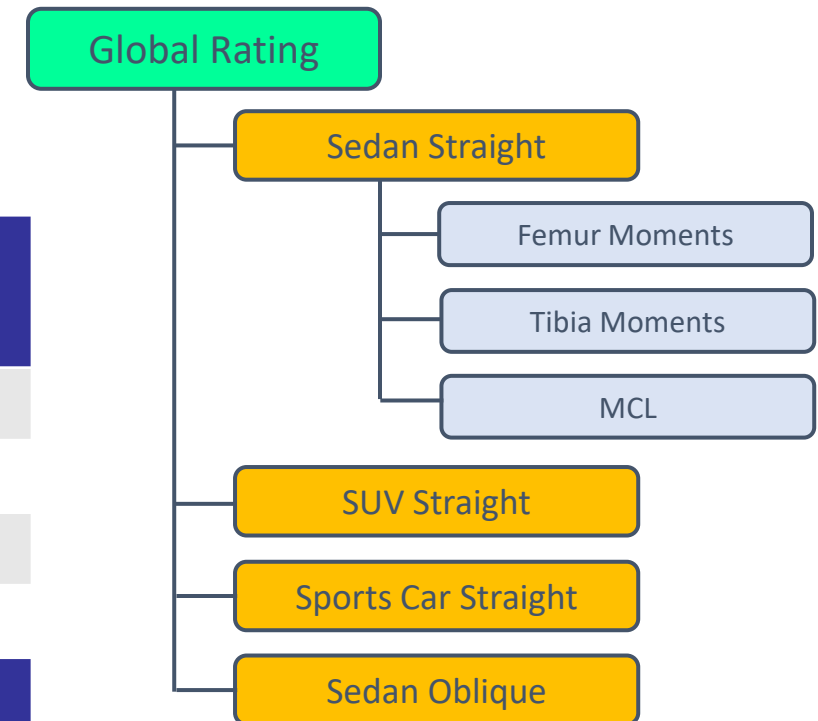


Rig Validation - CORA Rating

● Parameters:

- Corridor (50%) and cross correlation (50%)
- Corridor Method
 - » Inner half width of corridor: 5%
 - » Outer half width of corridors: 25%
- Evaluation Interval: 0 ~ 60 milliseconds

Load-case	CORA aPLI v1.0
Rig Impact: Sedan Straight	0.861
Rig Impact: SUV	0.856
Rig Impact: Sports car	0.814
Rig Impact: Sedan Oblique	0.864
Global Rating	0.849



Summary

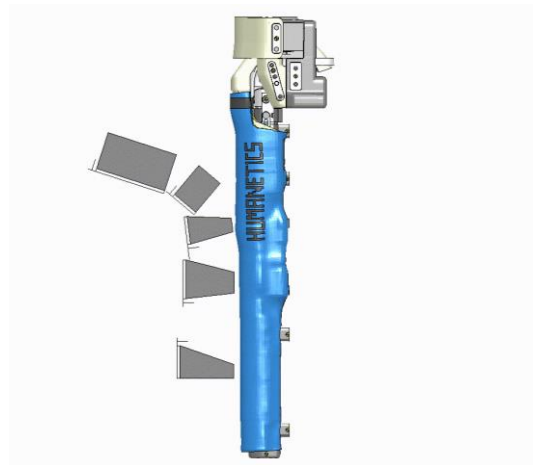
- aPLI model developed based on the latest approved hardware design from Euro NCAP and C-NCAP
- Certification
 - Fully validated honeycomb modeling for inverse certification
 - Models can meet the current certification requirements
- Vehicle like rig cases
 - The validated rig model with corrugated load-paths for superior repeatability and reproducibility as compared to foam
 - Models predict reasonably well in vehicle like rig cases [kinematics + signals]

Outlook

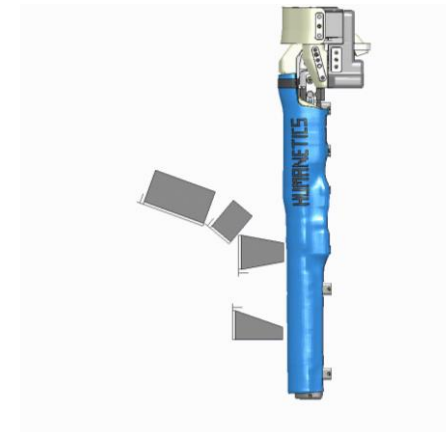
- V1.2 is planned in Q1 2022
 - Additional SBL-B Rearward and forward bumper dynamic validation tests
 - Verification aPLI on another vehicle like rig test (GVTR)



GVTR - SUV



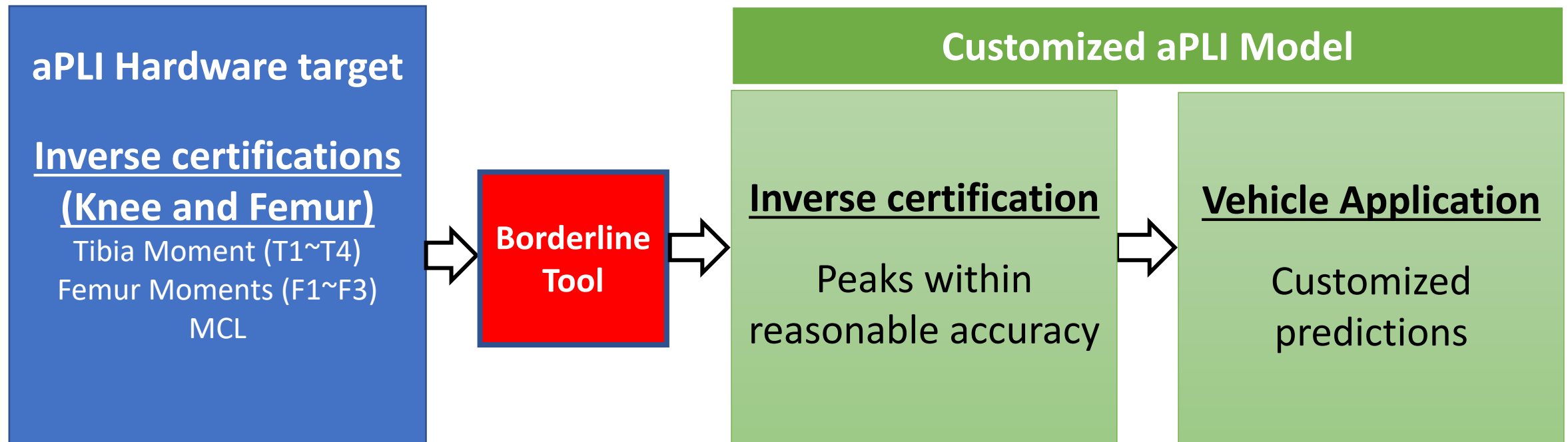
GVTR - Sedan



GVTR – Sports car

Outlook – aPLI Borderline[©] Model

- Work in progress – Q2 of 2022
- Benefits:
 - Captures hardware variability
 - Adjust the nominal model response at user discretion
 - Robustness evaluation of safety system (Example: worst case scenario)



Thank you for your attention!

Christian Kleeßen

Phone: +49 162 1687815

Email: ckleessen@humanetics.eu

