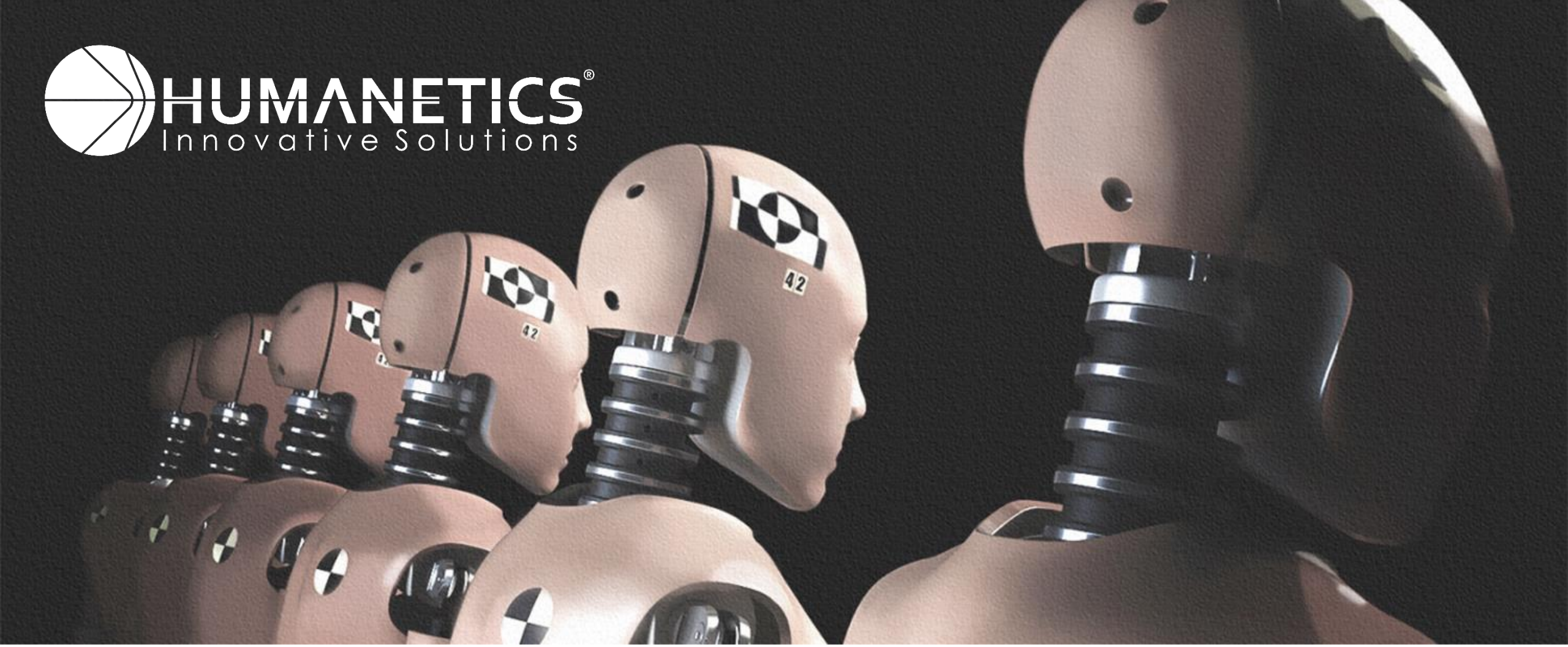
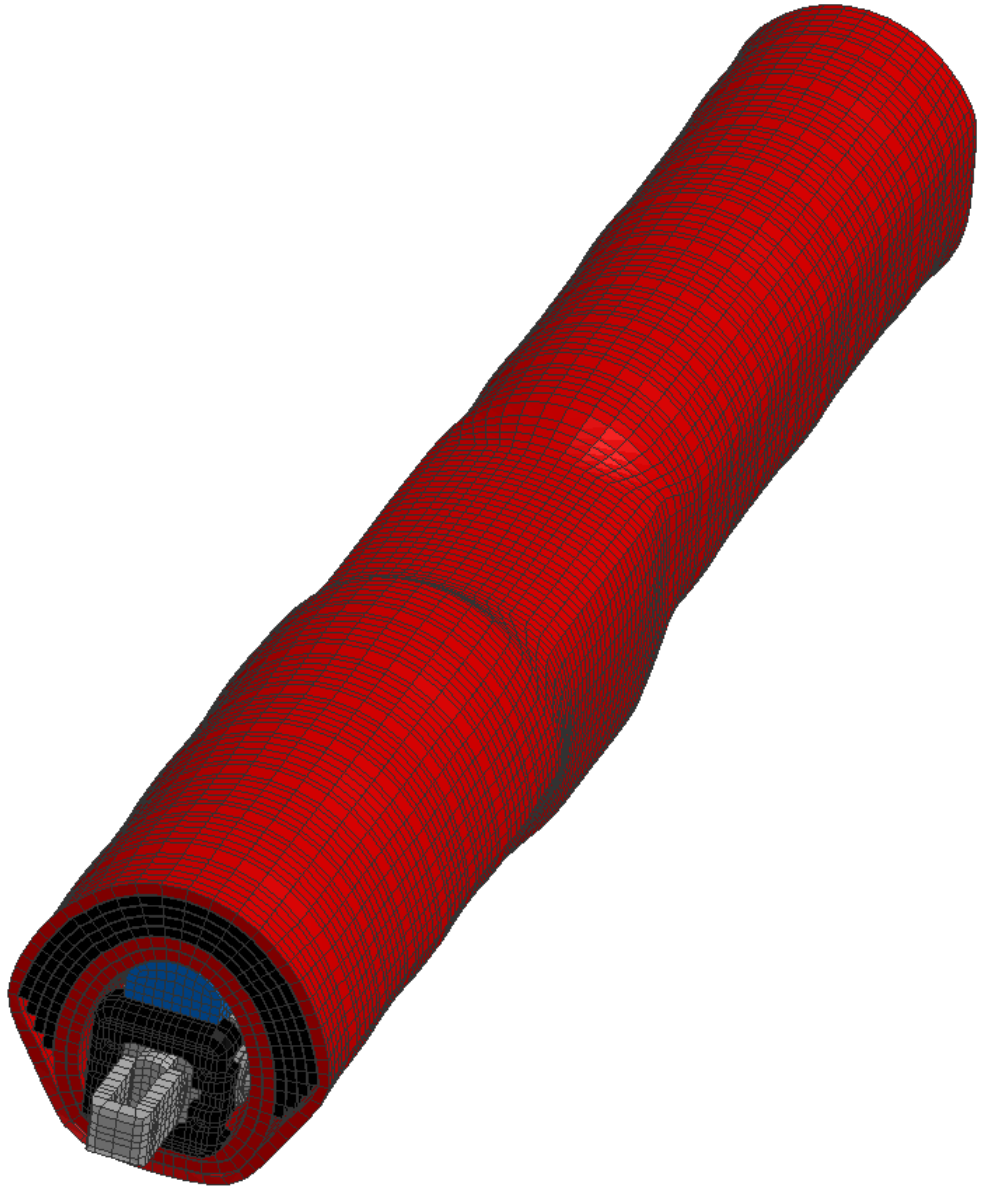


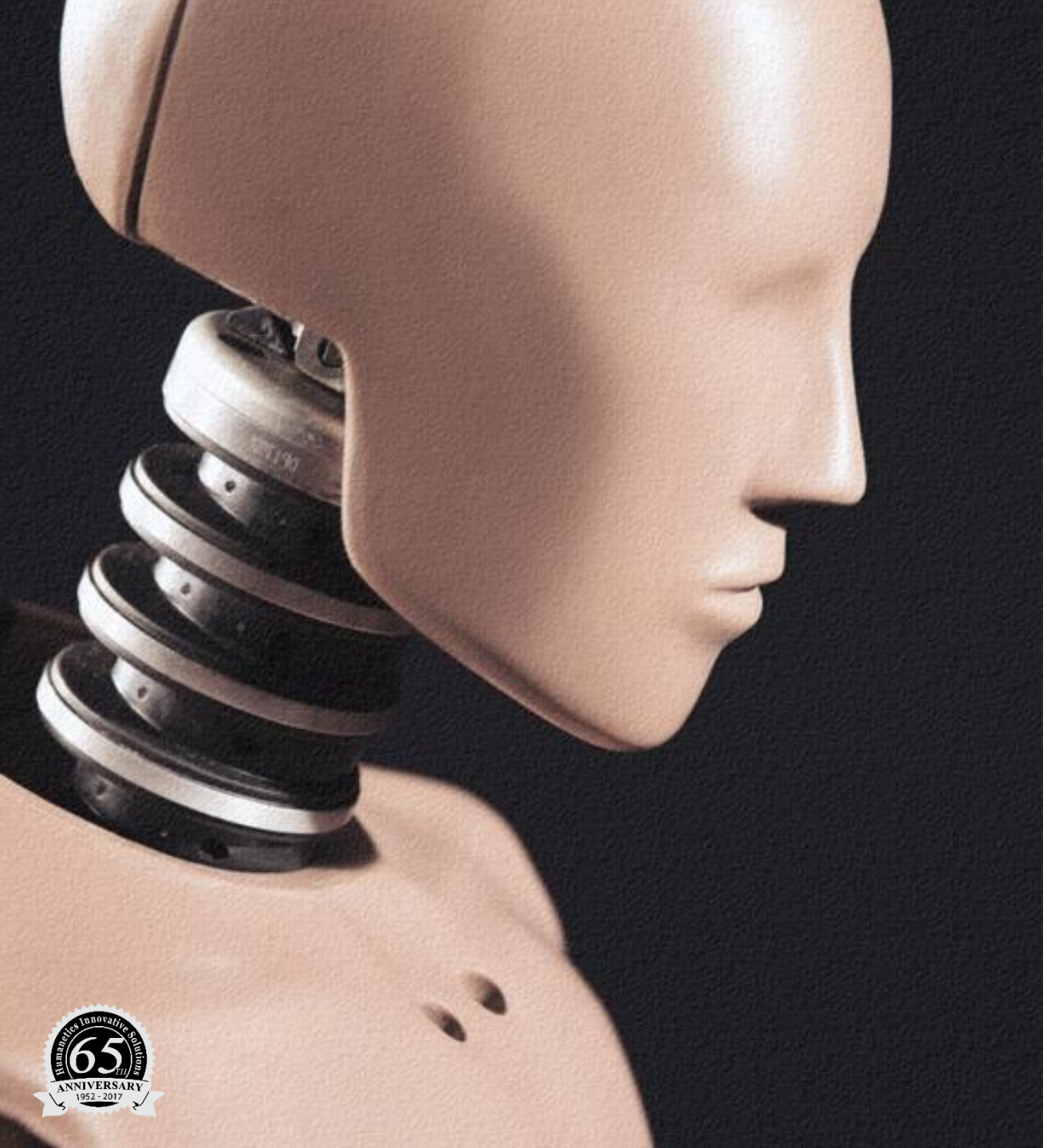
FlexPLI GTR Regulated Borderline© Model

AUTHORS: Chirag Shah, Christian Hach, Christian Brockhusen, Fuchun Zhu,

Agenda

- Motivation
- Borderline© Feature
  - How it works?
  - Validation
  - Verification
- Summary
- Models with Borderline© Features





Motivation

MOTIVATION

FlexPLI Consortium Project

Phase 1: Nov 2008 – Jan 2012

- *Initiator:* *FTSS (First Technology Safety Systems, Inc.)*
- *Project lead: Robert Kant*
- *OEMs:* *Audi, BMW, Daimler, Ford, Honda, Hyundai, JLR, Opel, Porsche, VW*
- *Chairman: Bastian Keding (Porsche)*
- *Associates:* *BASt, BGS*
- *Solvers:* *Abaqus, LS-Dyna, Pam-CRASH, Radioss*

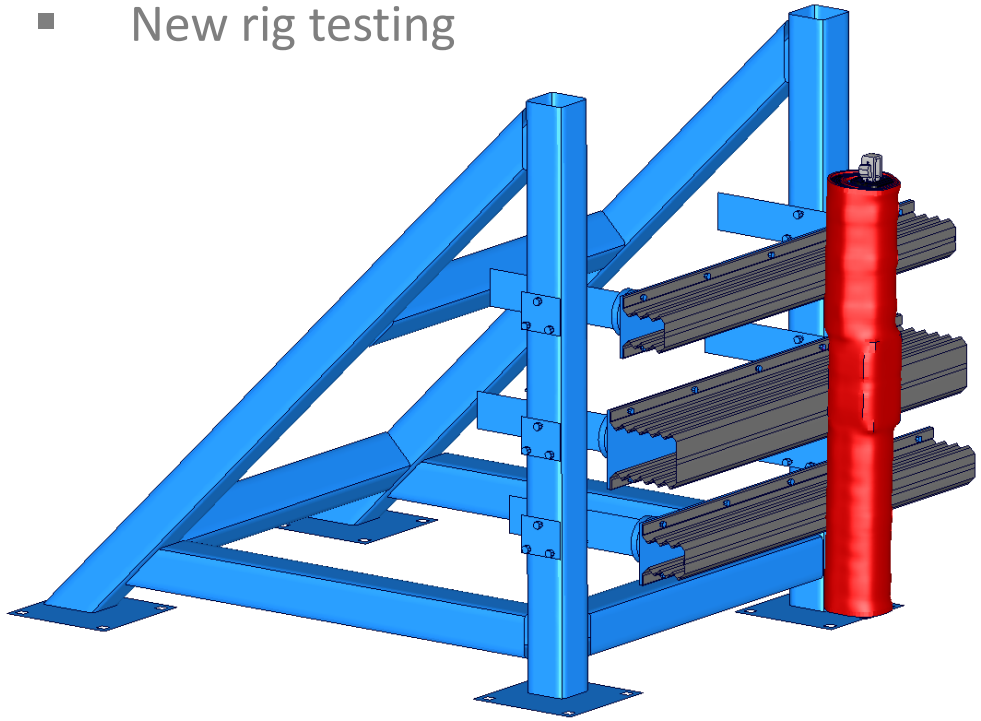
Phase 2: May 2014 – Sep 2016

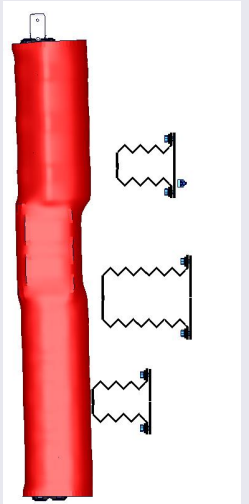
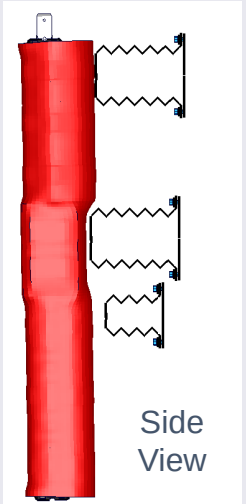
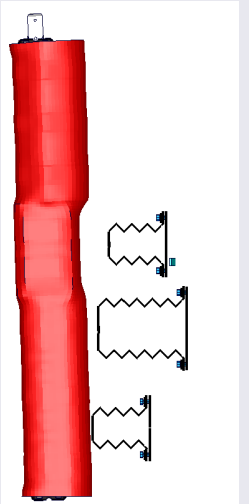
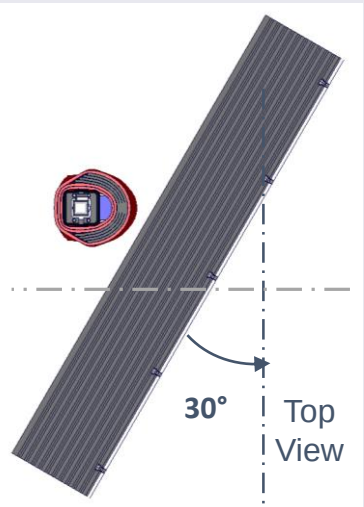
- *Initiator:* *Humanetics (resulted from fusion between FTSS & Denton, Inc.)*
- *Project lead & Co-chairman: Dr. Chirag Shah*
- *OEMs:* *Daimler, Hyundai, Jaguar Land Rover, Opel, Porsche*
- *Chairman: Victor Pardede (Hyundai)*
- *Associates:* *BASt, BGS*
- *Solver:* *LS-Dyna*

MOTIVATION

FlexPLI Consortium

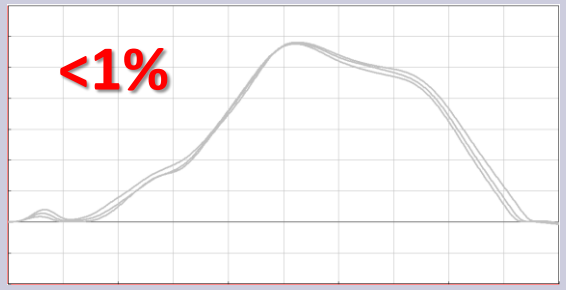
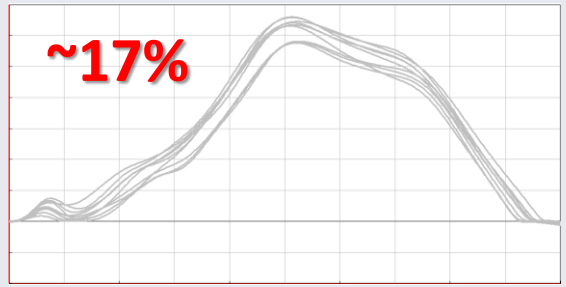
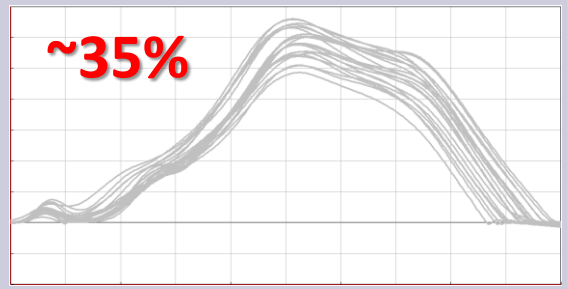
- New pendulum and inverse certification corridors
- Variability – 3 labs, 3 hardware (Phase 1: One lab, 1 hardware)
- New rig testing



STRAIGHT			OBLIQUE
Sedan 0deg	SUV 0deg	Sports Car 0deg	Sedan +/- 30deg
			

HUMANETICS® Innovative Solutions

MOTIVATION

FlexPLI (Hardware)	Test labs	Number of tests	MCL Test Data
1	1	3	
3	1	9	
3	3	27	

Variability

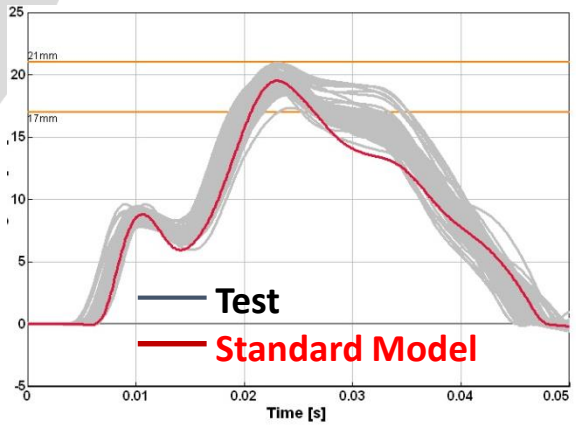
- → *Raw material batch*
- → *Design tolerance*
- → *Production process*
- → *Assembling process*
- → *Aging*
- → *Test conditions*
- → *Test environment*
- → *…*

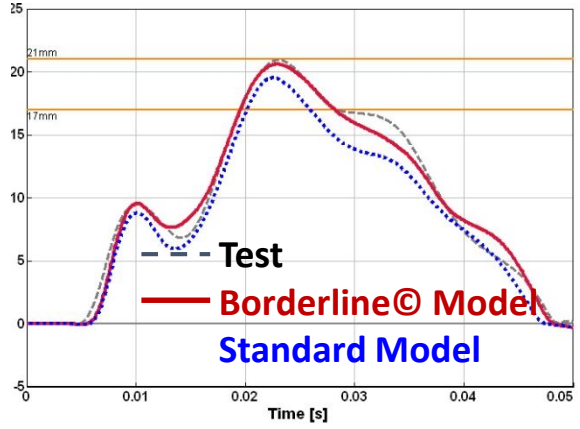
MOTIVATION

OBJECTIVES of the Borderline© Model

➔ *based on findings of the FlexPLI consortium project + customer requests*

APPLICATION	Traditional Model	Borderline© Model
PREDICTION of customer specific nominal response	✘ Not Possible	✓ Possible
ANALYSIS of certain effects due to hardware variability	✘ Not Possible	✓ Possible
QUANTIFICATION of robustness margin	✘ Not Possible	✓ Possible





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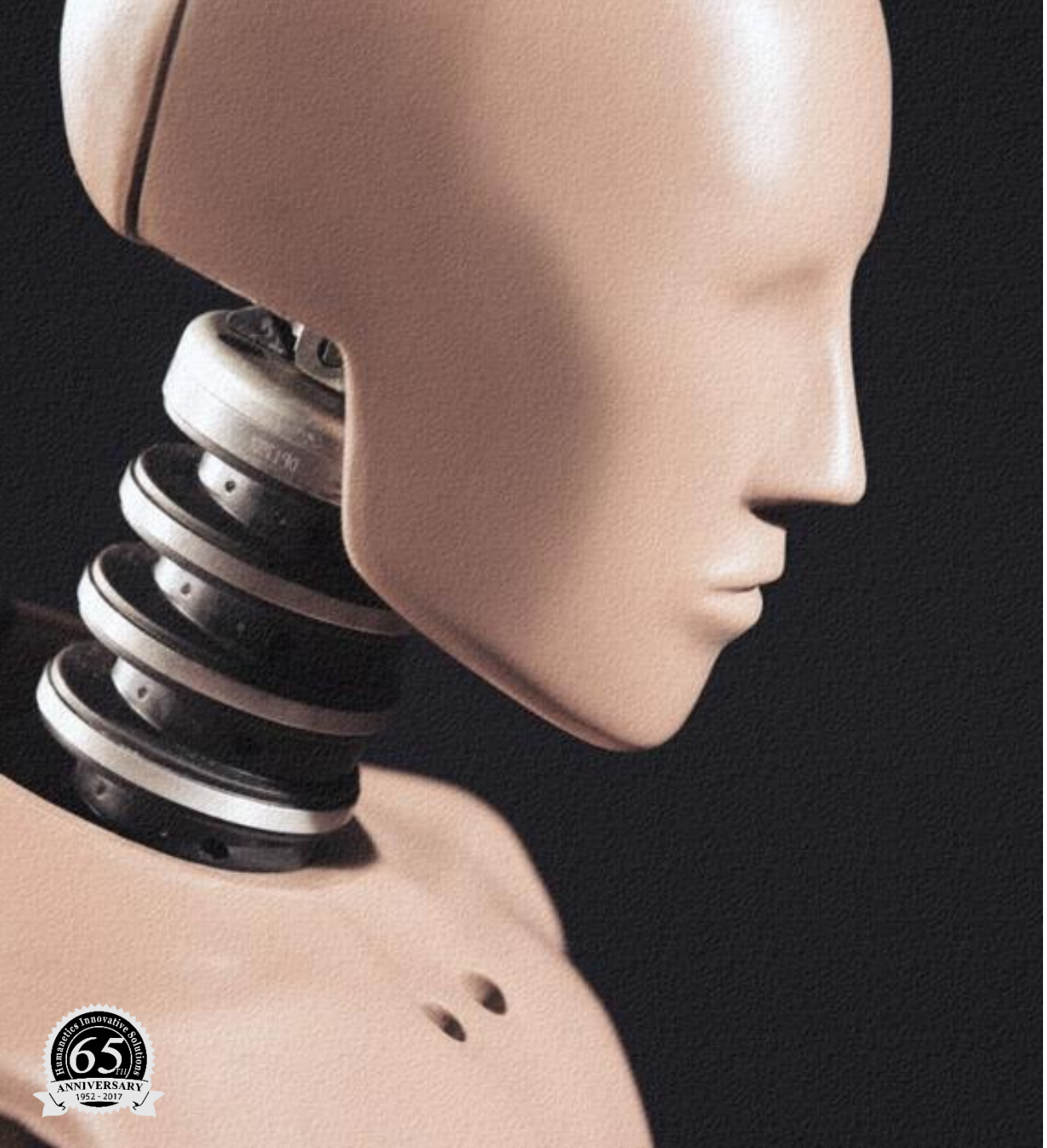

Humanetics Innovative Solutions
65TH
ANNIVERSARY
1952 - 2017

How it works?

How it works?

FlexPLI Hardware Test

- **Inverse Certification test**
- maximum value of ligaments → MCL, ACL, PCL
- maximum value of tibia moments → T1, T2, T3, T4

CALCULATION of PARAMETER

- Excel sheet
- Part of the release package
- 5 Parameters

MODEL SETTING FlexPLI Borderline©

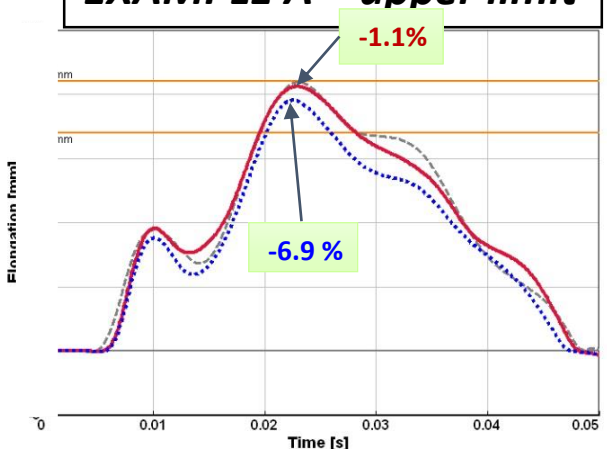
- Update the 5 Parameters according to the CALCULATION

FINAL CUSTOMIZED FlexPLI Borderline©

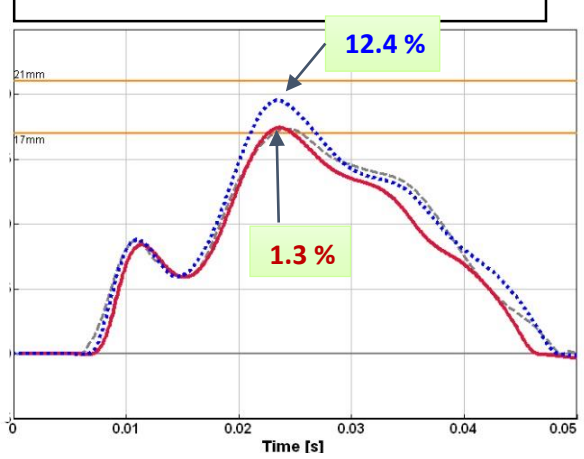
- Hardware specific configuration

MCL

EXAMPLE A – upper limit



EXAMPLE B – lower limit

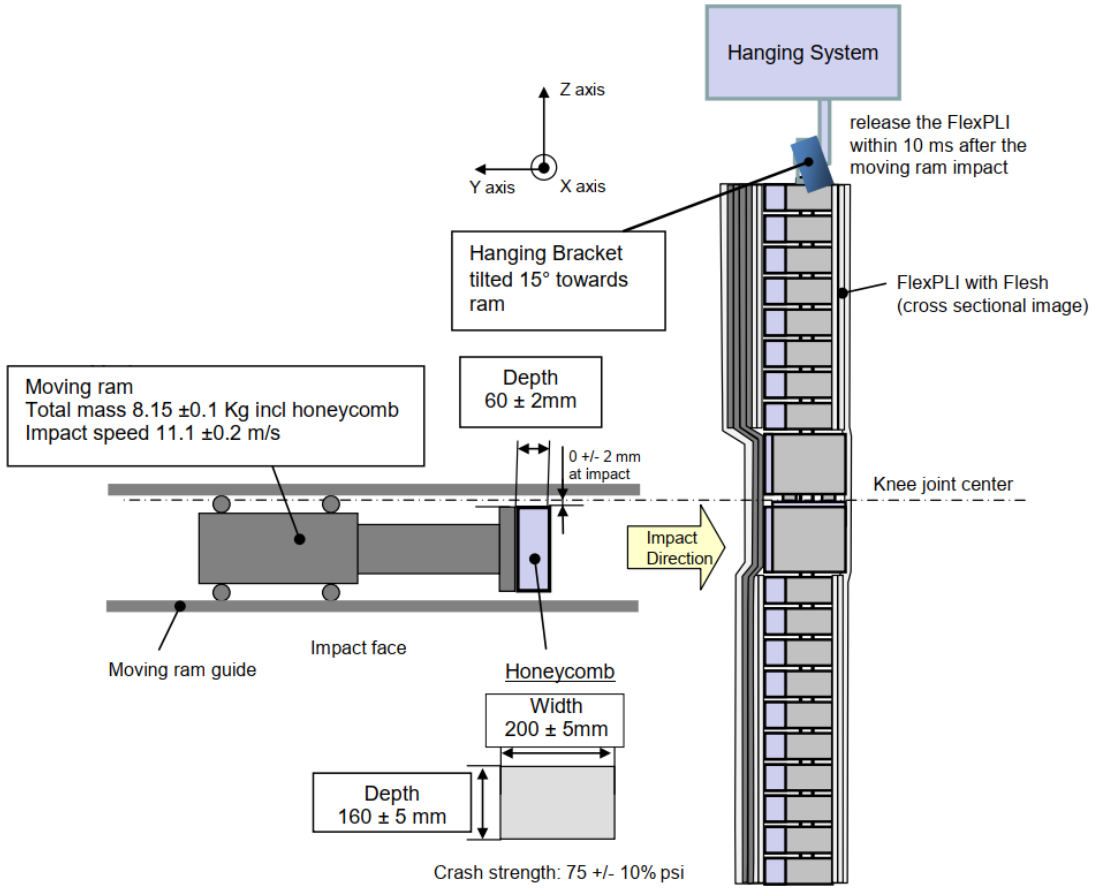


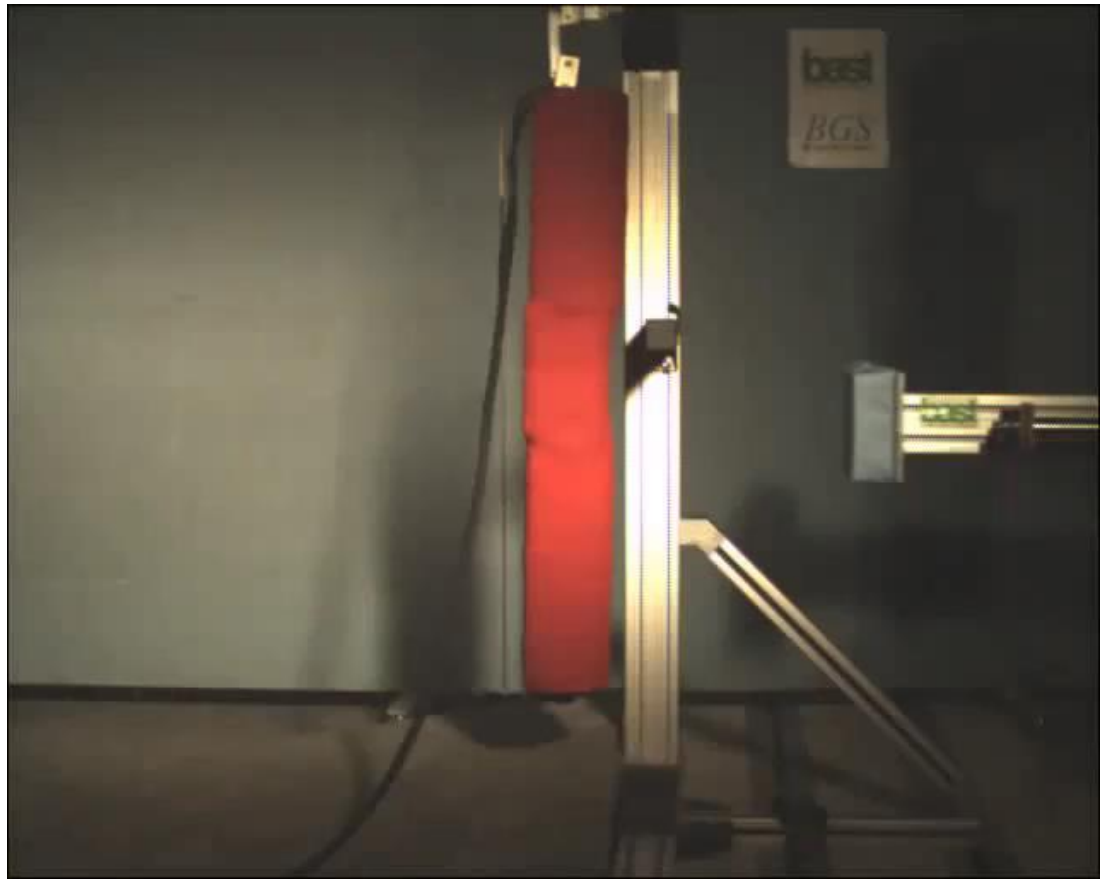
Corridor
Test
Borderline© Model
Standard Model

HUMANETICS® Innovative Solutions

How it works?

FlexPLI – inverse Hardware Certification Test





How it works?

CALCULATION of PARAMETER

2.

A	B	C	D	E
0.6647	0.1272	0.8788	0.9372	-0.1359

BORDERLINE MODEL USING INVERSE CERTIFICATION

	Optimized Values	Upper Limit	Lower Limit	Value from User's Hardware Inverse Certification	Squared Difference
T1 [Nm]	249.88	272.0	230.0	251.00	1.25
T2 [Nm]	232.92	252.0	210.0	231.00	3.70
T3 [Nm]	178.24	192.0	166.0	179.00	0.58
T4 [Nm]	99.36	108.0	93.0	100.50	1.30
ACL [mm]	8.81	10.0	8.0	9.00	0.04
PCL [mm]	4.84	6.0	4.0	5.00	0.02
MCL [mm]	18.99	21.0	17.0	19.00	0.03

Sum of Squared Difference
6.92

DO NOT ENTER OR CHANGE IN GREY COLORED CELLS

1.

Excel sheet is part of the release package

How to use:

1. Enable the Add-Inn Solver option.

a) Go to: FILE>Options>Add-Ins
b) Select from drop menu: Excel Add-Inn and click Go...
c) Check the box for Add-Ins and click OK.

2. Set up values for Optimization.

a) Input Tibia moments, Knee elongations from hardware's Inverse Certification Test.
b) Use cells in column E, from E4 to E10.
c) Do not change anything other than cells E4 to E10.

3. Variables Optimization using Solver.

a) Change cells values, from A1 to E1, equal to zero.
b) Go to: DATA and click Solver from top menu.
c) On Solver Parameter box click Solve.
d) On Solver Results box, be sure that Keep Solver Solution option is selected.
e) Click OK.

4. Copy optimal values from cells A1 to E1 in your lsdyna FlexPLI main file.

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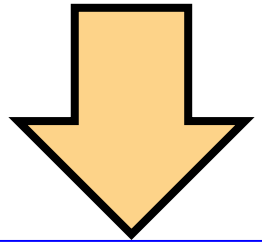
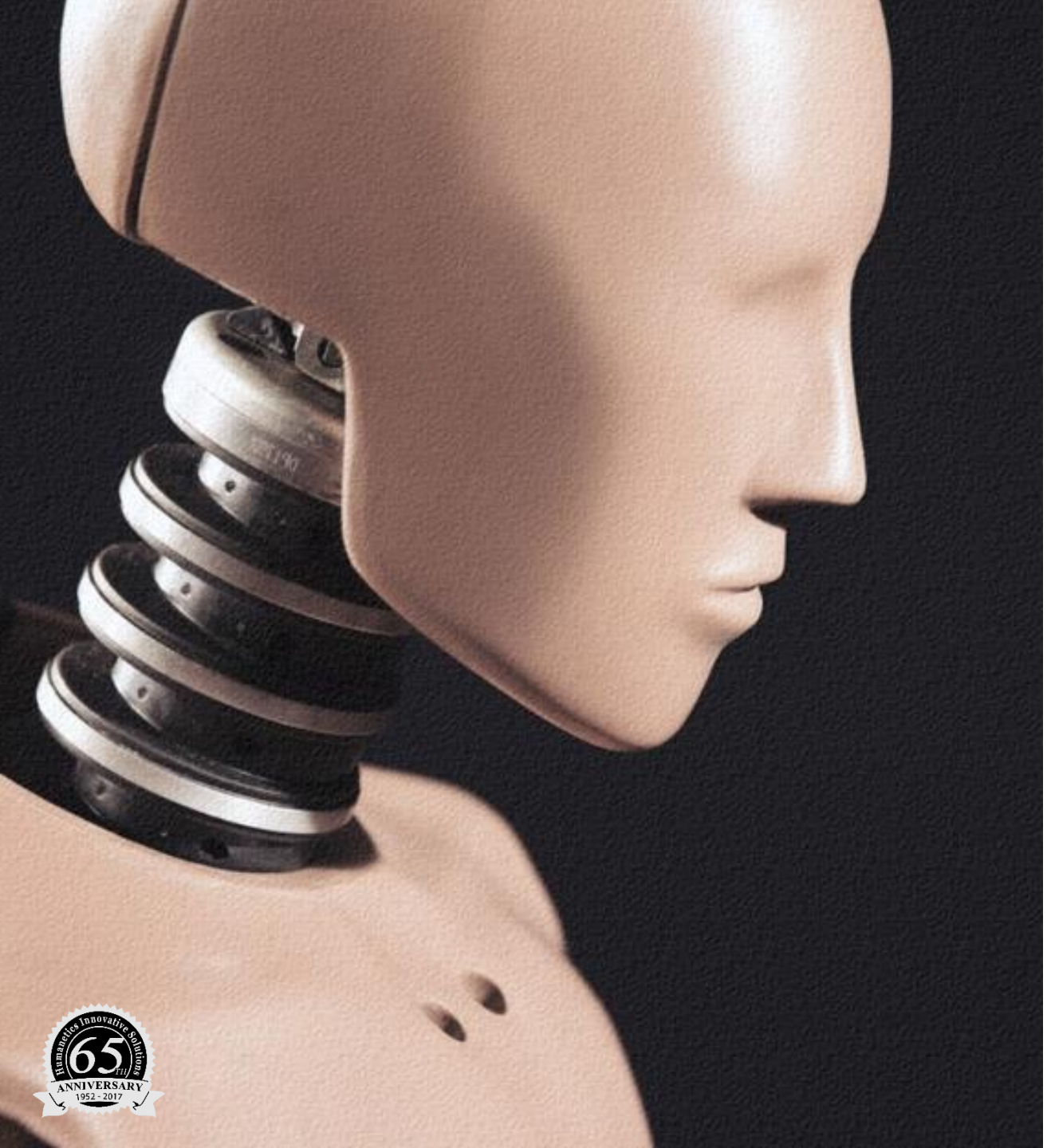
How it works?

MODEL SETTING FlexPLI Borderline©

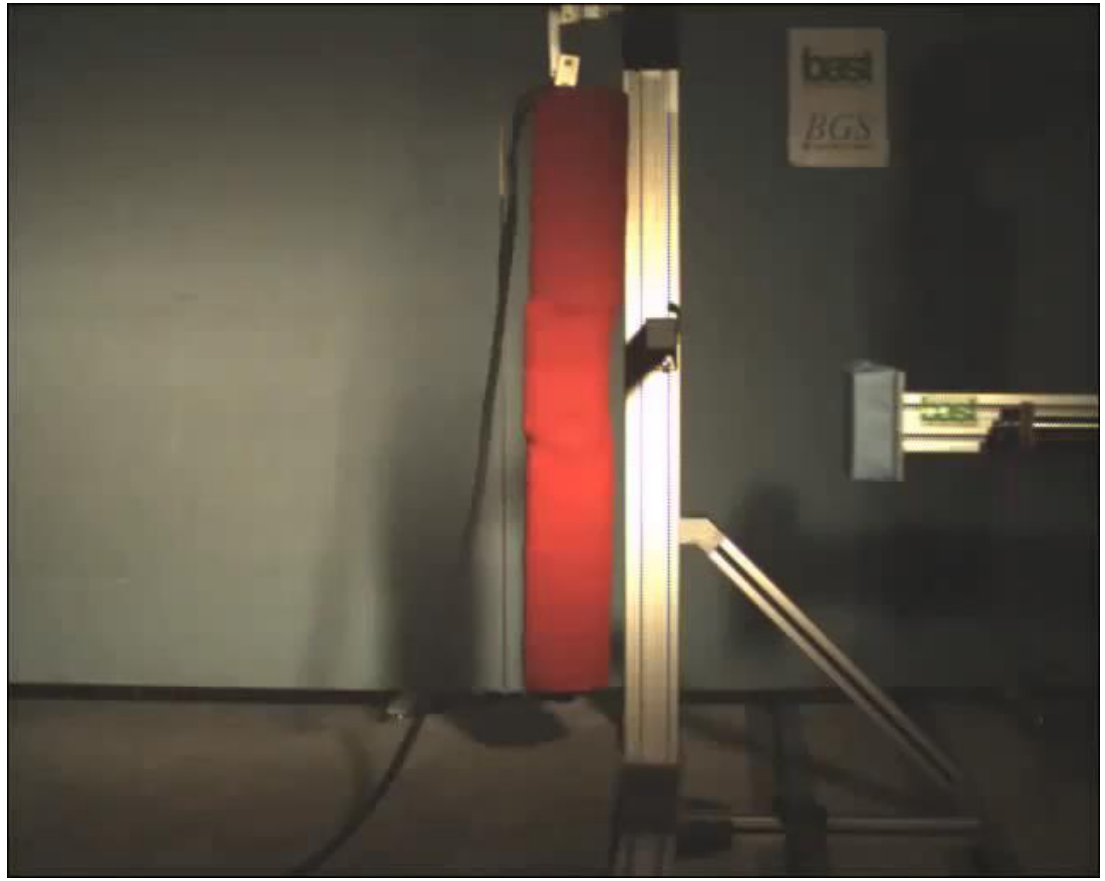


Header of the input deck

```
$-------------------------------------------------------------------------
$               ADDED PARAMETERS FOR VARIABILITY
$-------------------------------------------------------------------------
$ Purpose: These parameters are needed to have the borderline model. These
$          parameters will customize the response to match to the specific
$          hardware. User has to copy each of these five parameters from
$          the provided excel file making sure that proper cells are copied to
$          to proper parameter. Ex. A1 cell from excel must be copied to A1
$          parameter in the *PARAMETER section below and so on.
$-------------------------------------------------------------------------
$
*PARAMETER
$USER CUSTOMIZED INPUT VALUES FROM EXCEL SPREADSHEET
R A1           0.0130
R B1           0.3452
R C1           0.3301
R D1           1.0000
R E1          -0.0619
```

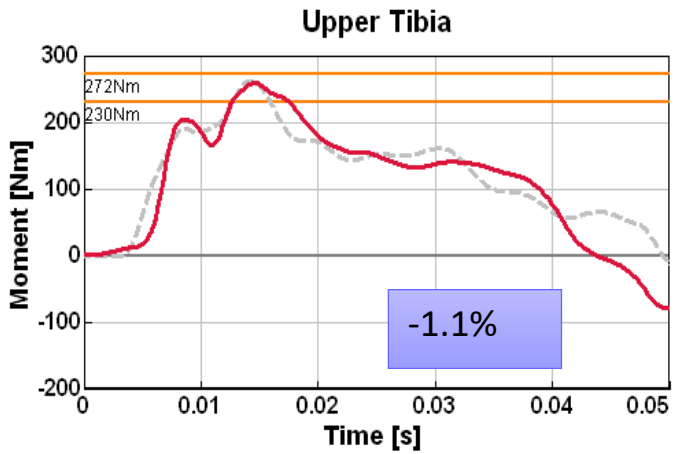


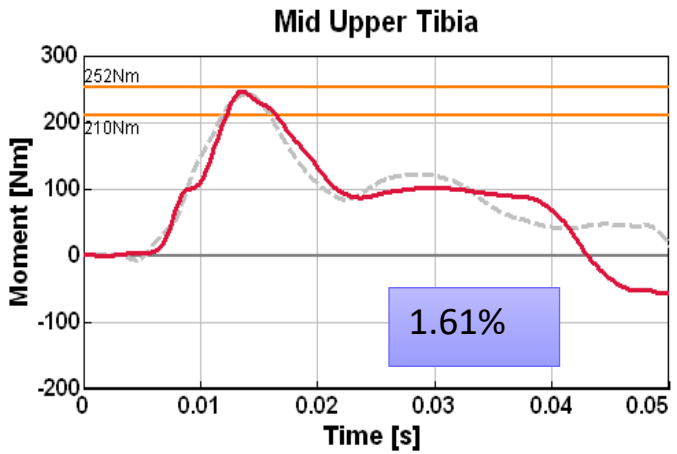
Validation



Validation

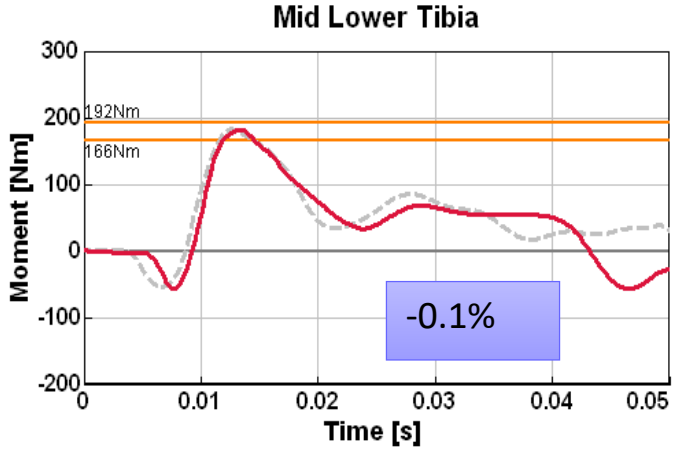
Example A: Certification with High Tibia Moments

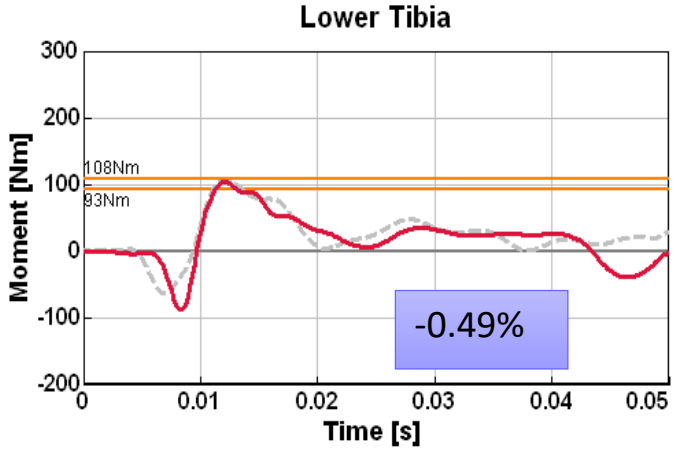


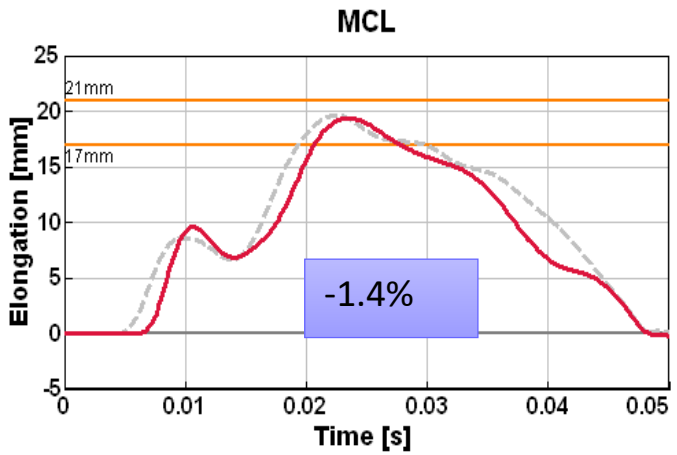


Corridor
Test High Tibia Moment
CAE Borderline© Model

% Difference between Hardware and Model







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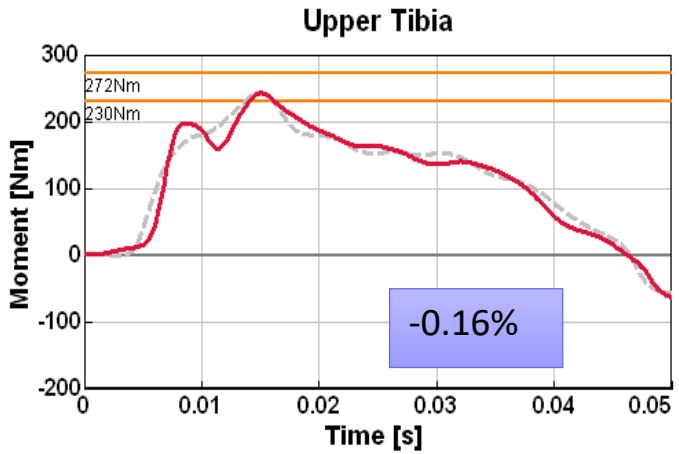
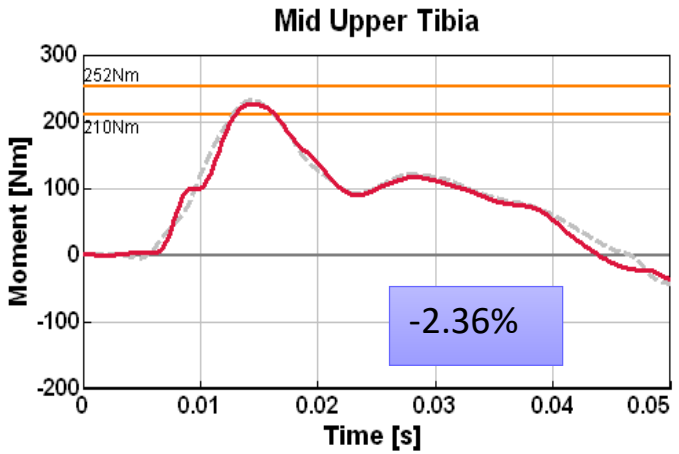
Validation

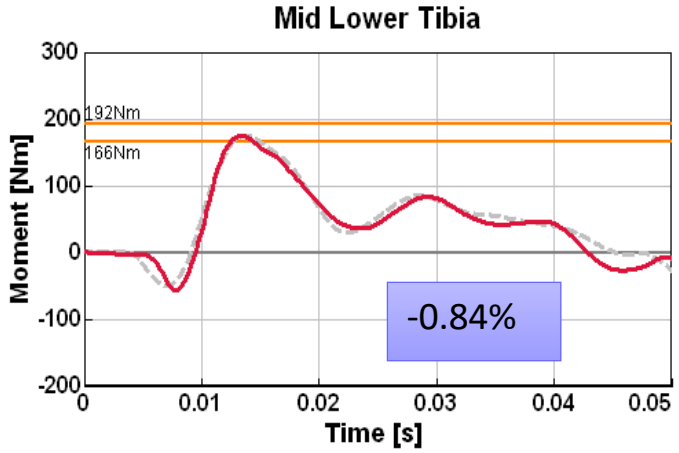
Example B: Certification with Low Tibia Moments

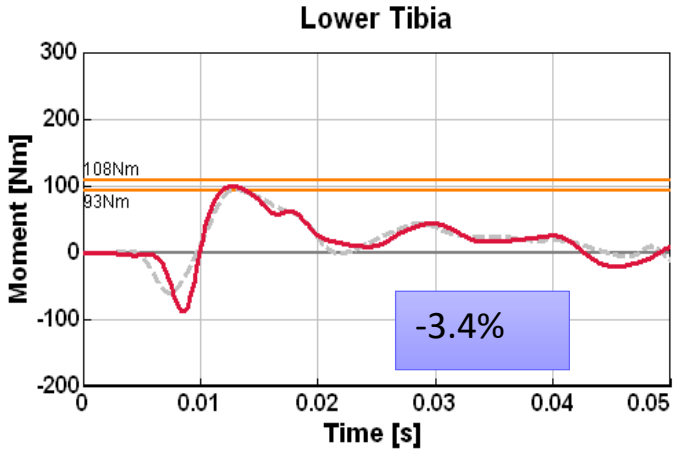


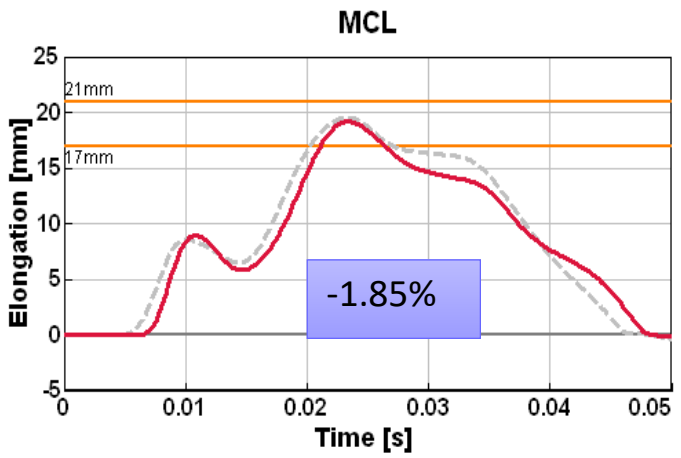


Corridor
Test Low Tibia Moment
CAE Borderline© Model

% Difference between Hardware and Model







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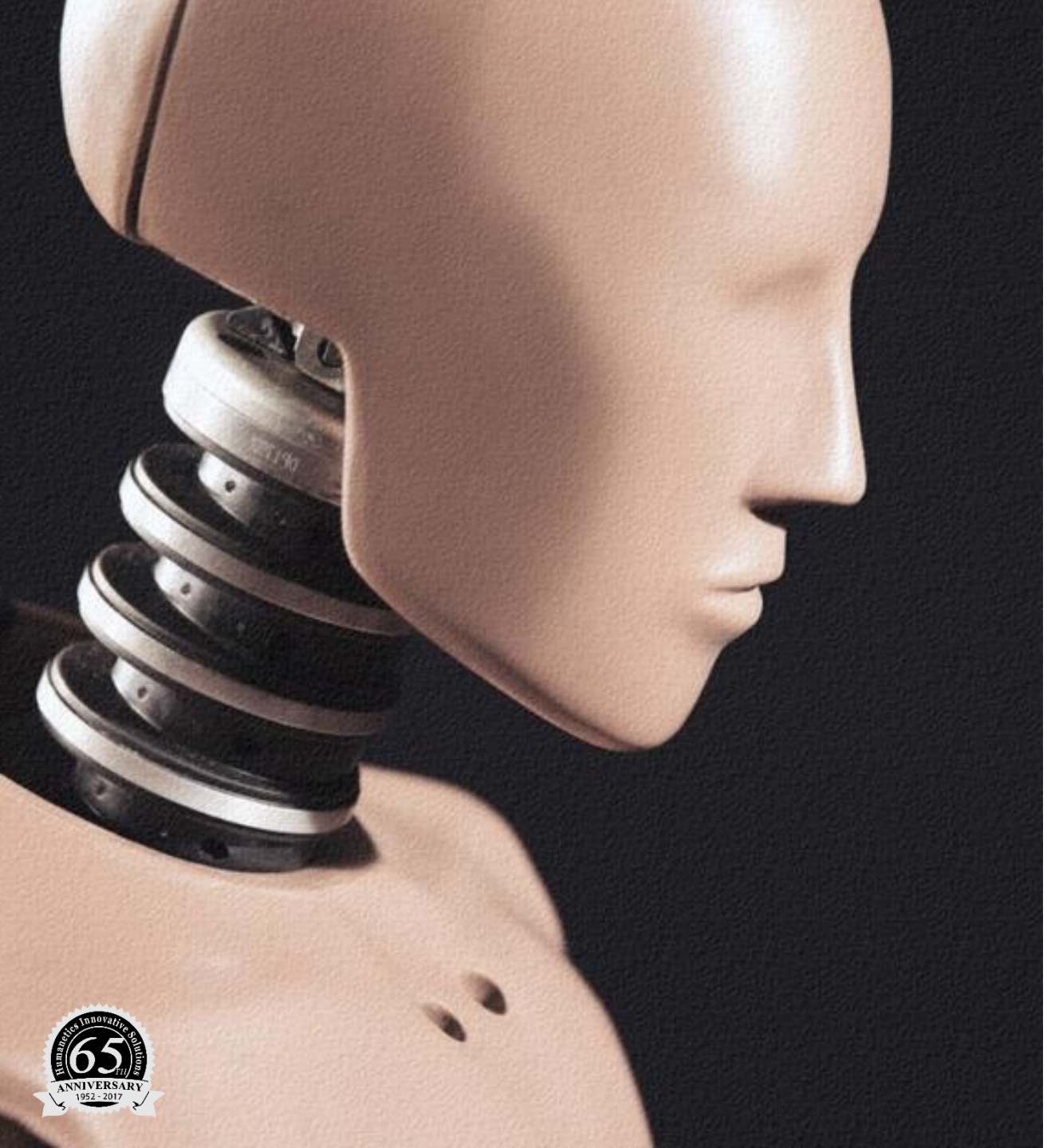
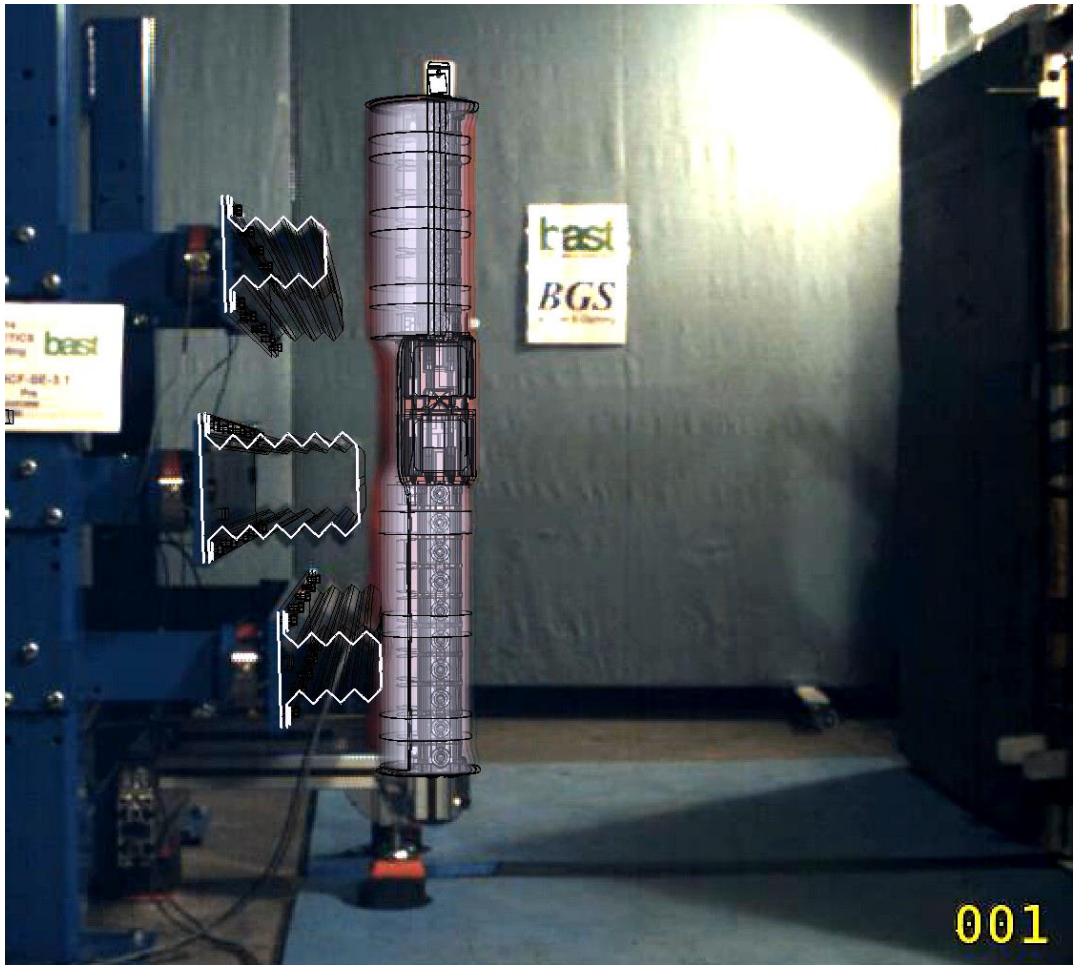
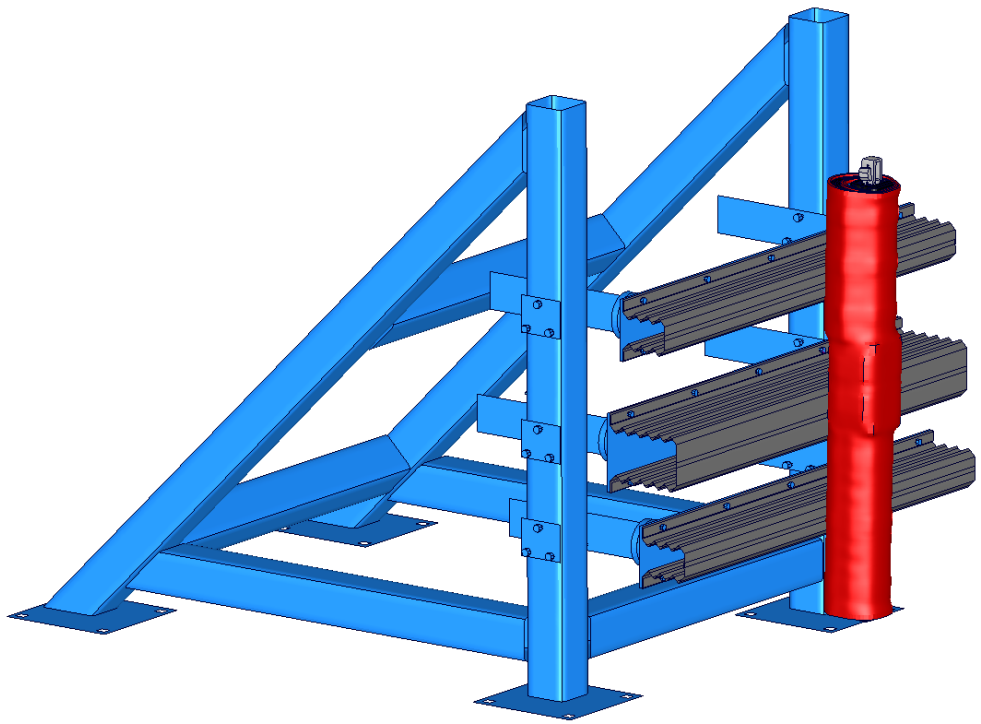
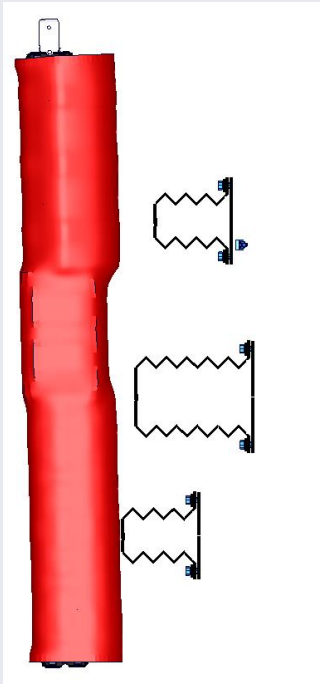
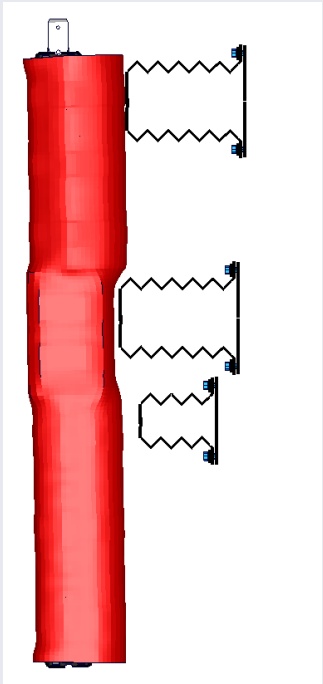
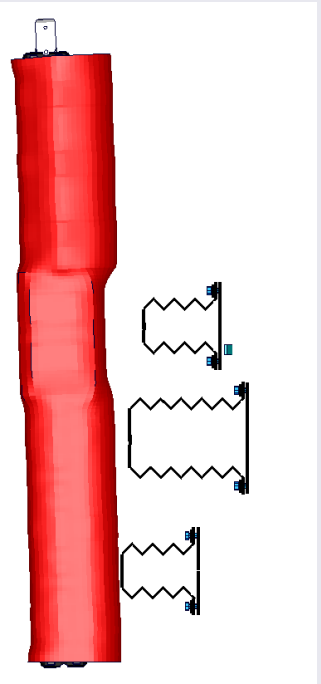


Verification



Verification – Test Rig Configuration



STRAIGHT		
Sedan 0deg	SUV 0deg	Sports Car 0deg
		

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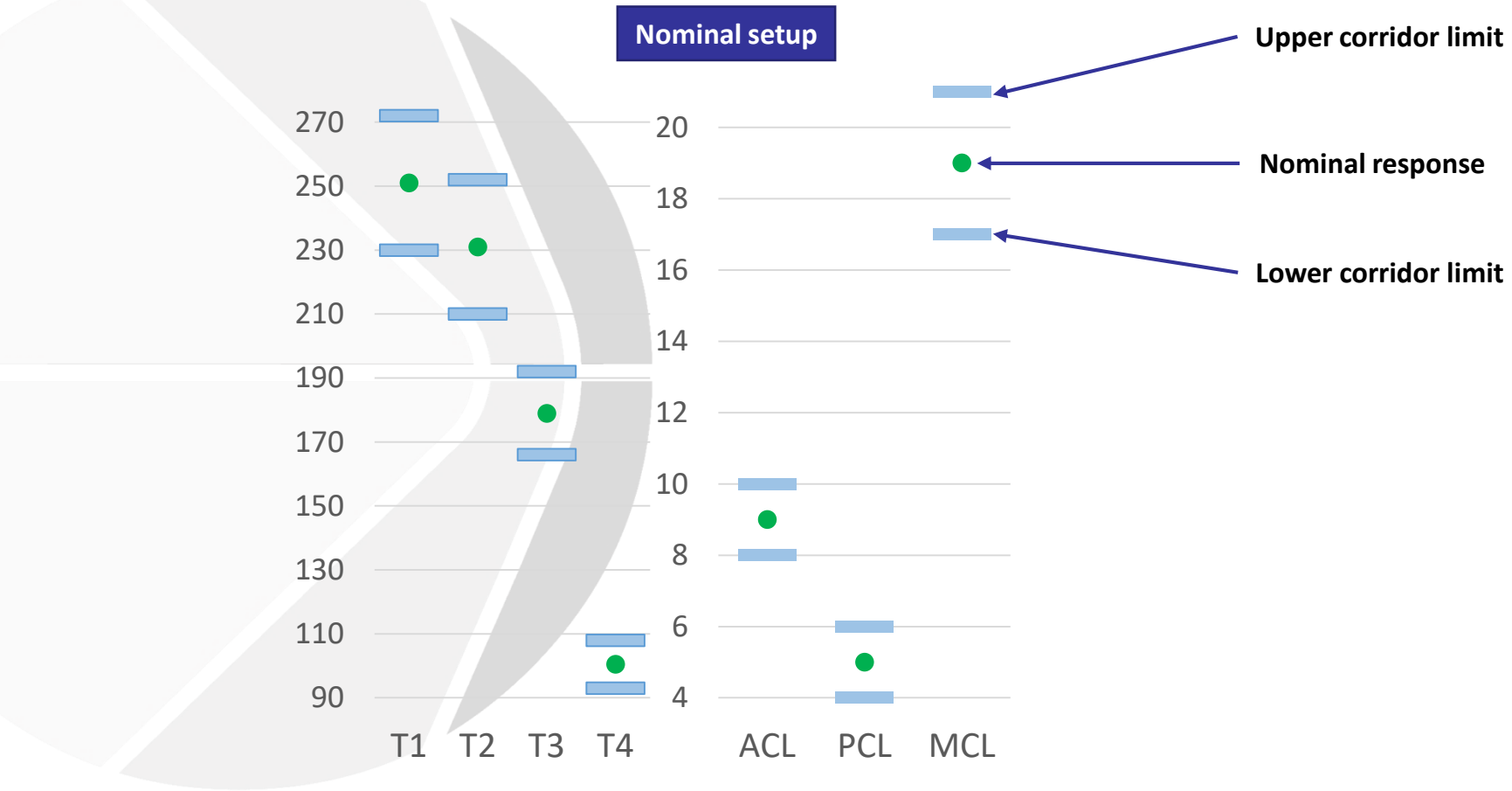
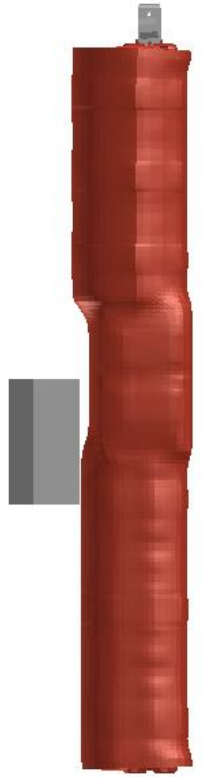
Verification – Inverse Certification (Nominal response)





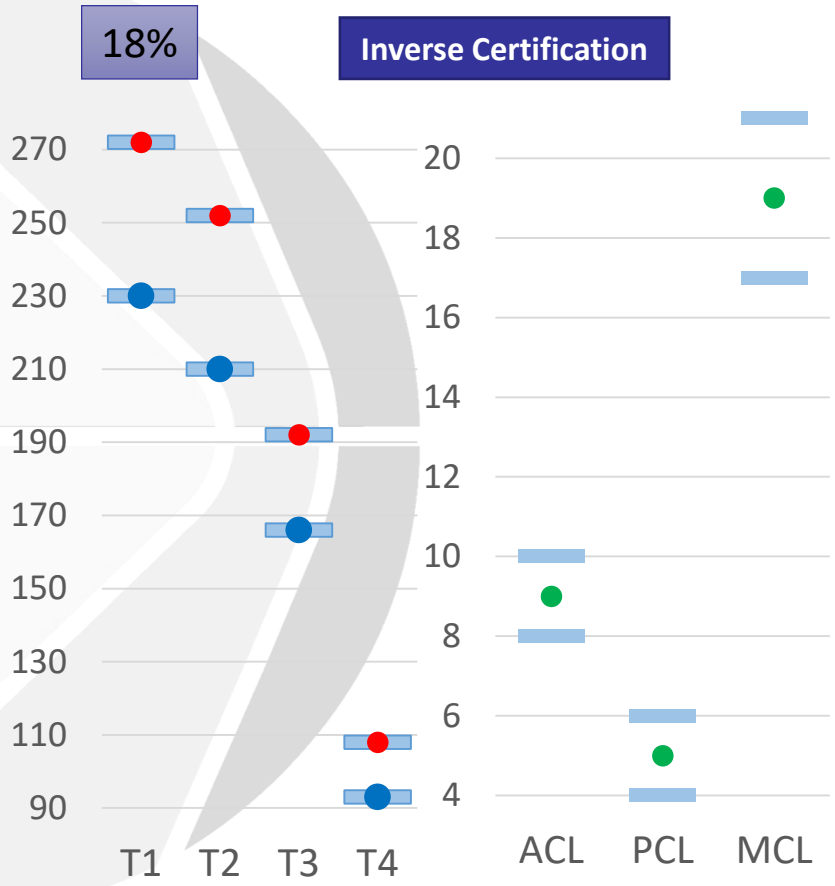
Flex-PLI Borderline© Model Patent Pending

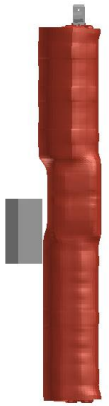
Verification – Sports Car (Tibia Moment variation)

19

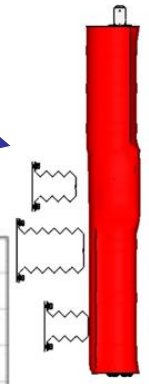
18%

Inverse Certification

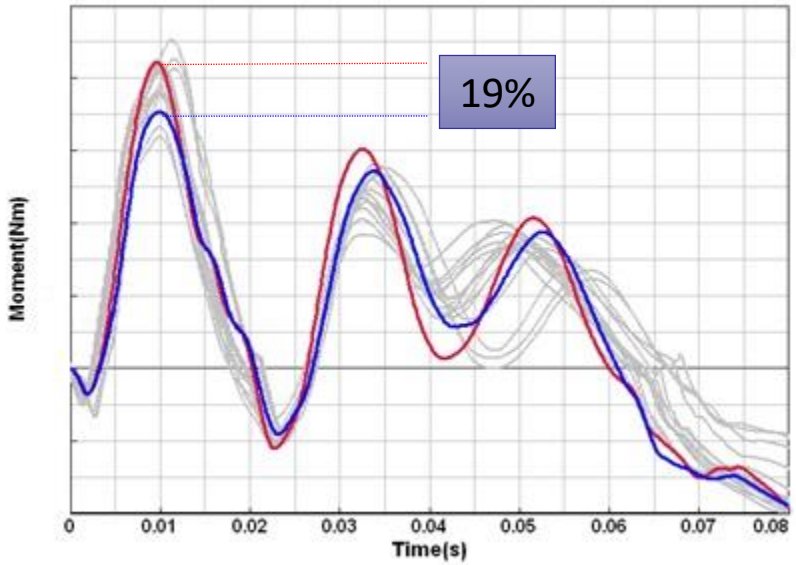




Sports Car Rig



Highest Tibia Moment

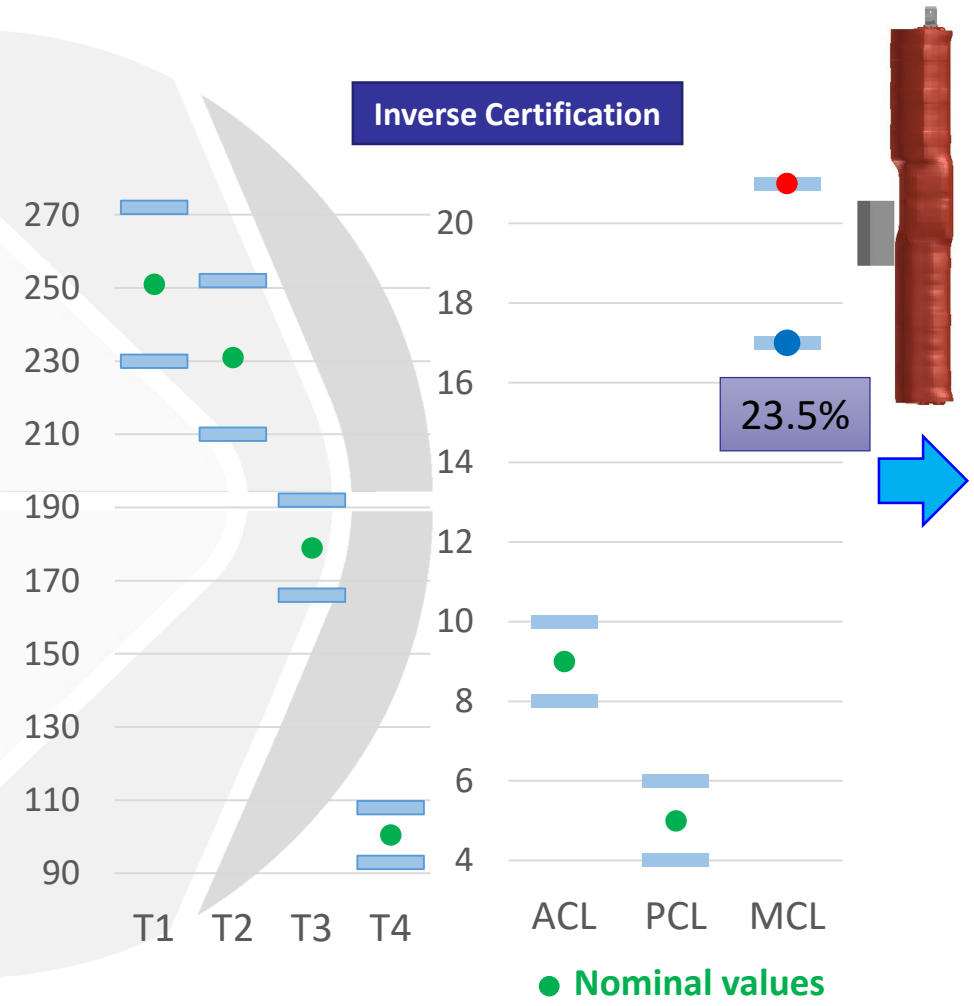


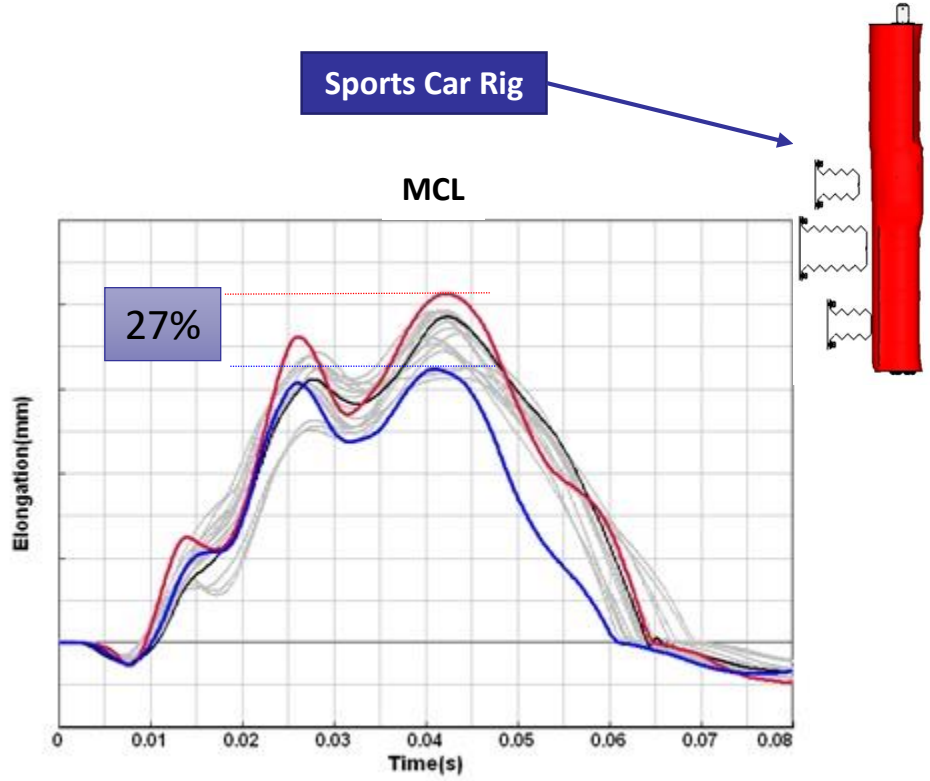
Maximized Tibia Moment

Minimized Tibia Moment

Flex-PLI Borderline© Model Patent Pending

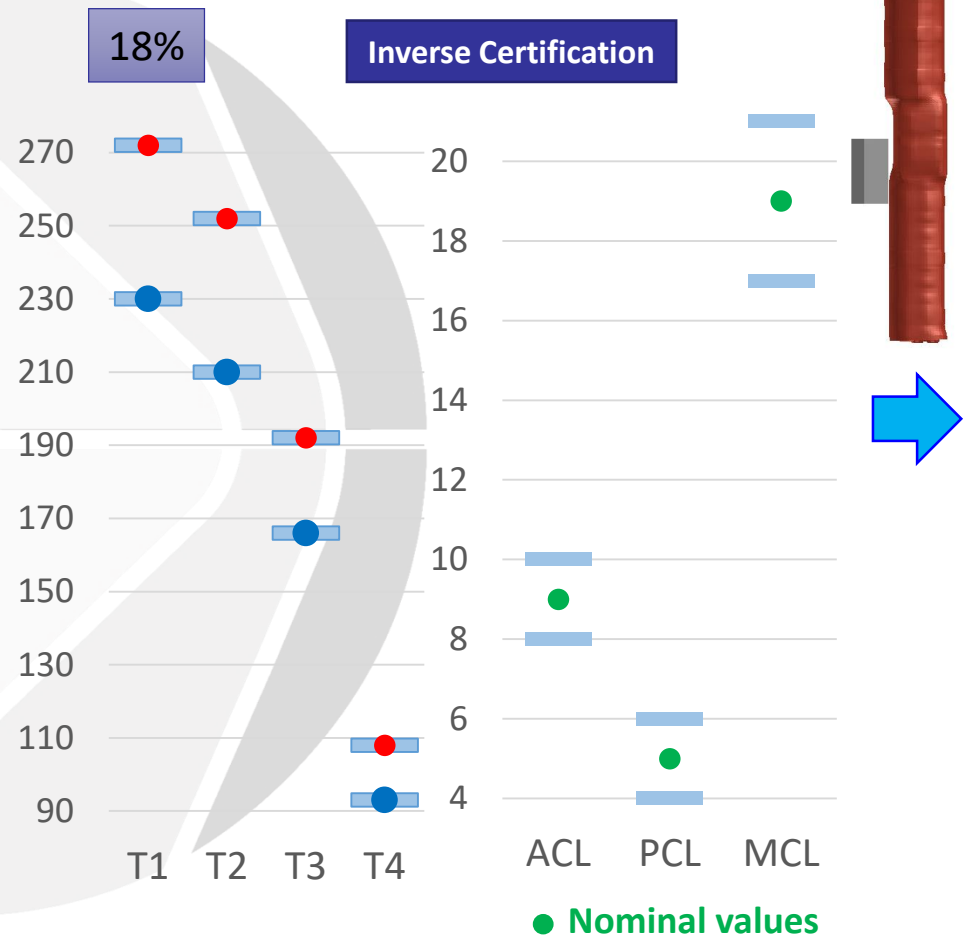
Verification – Sports Car (MCL variation)

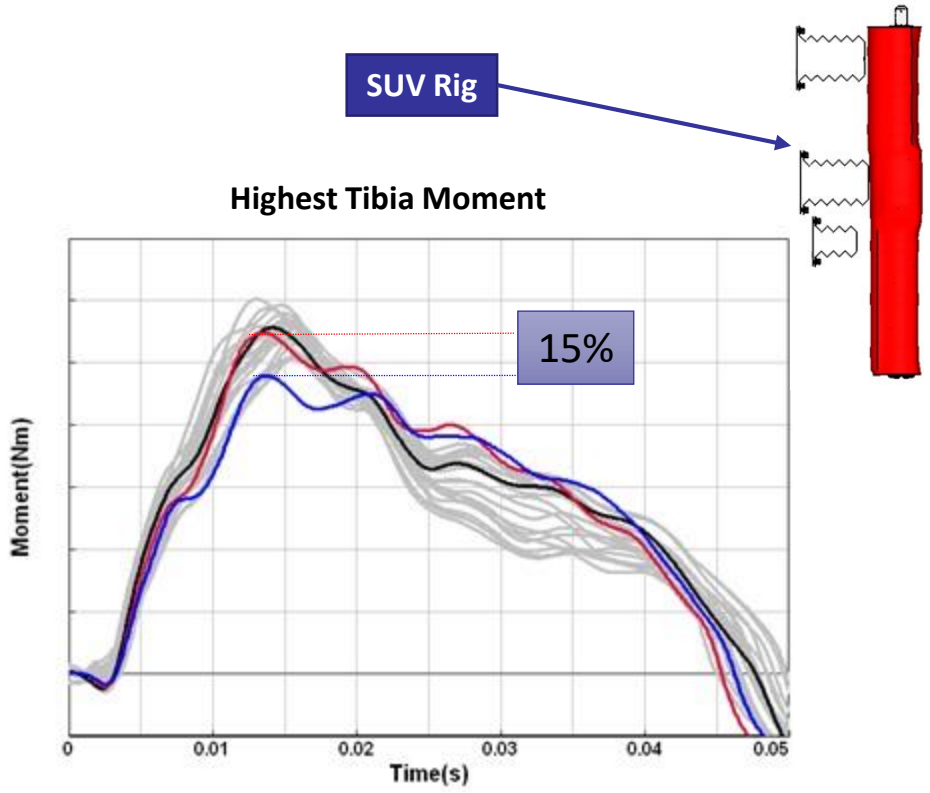




Flex-PLI Borderline© Model Patent Pending

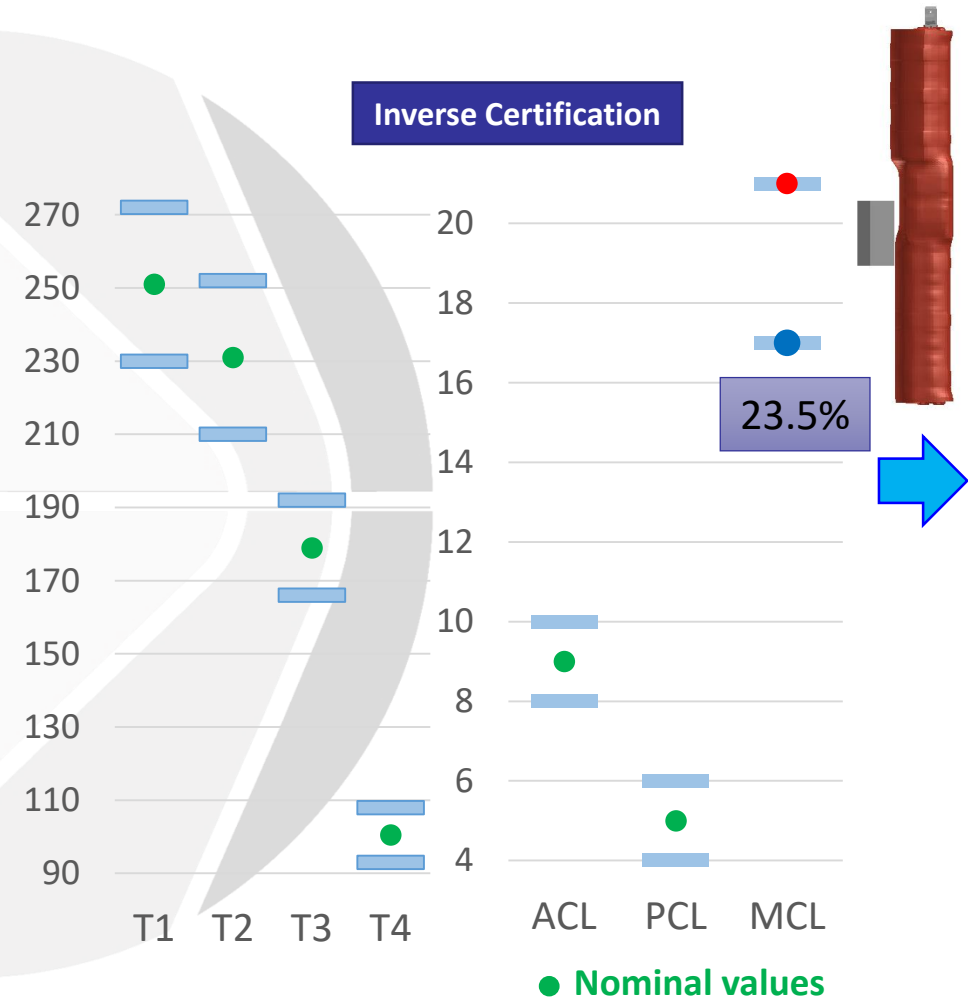
Verification – SUV (Tibia Moment variation)

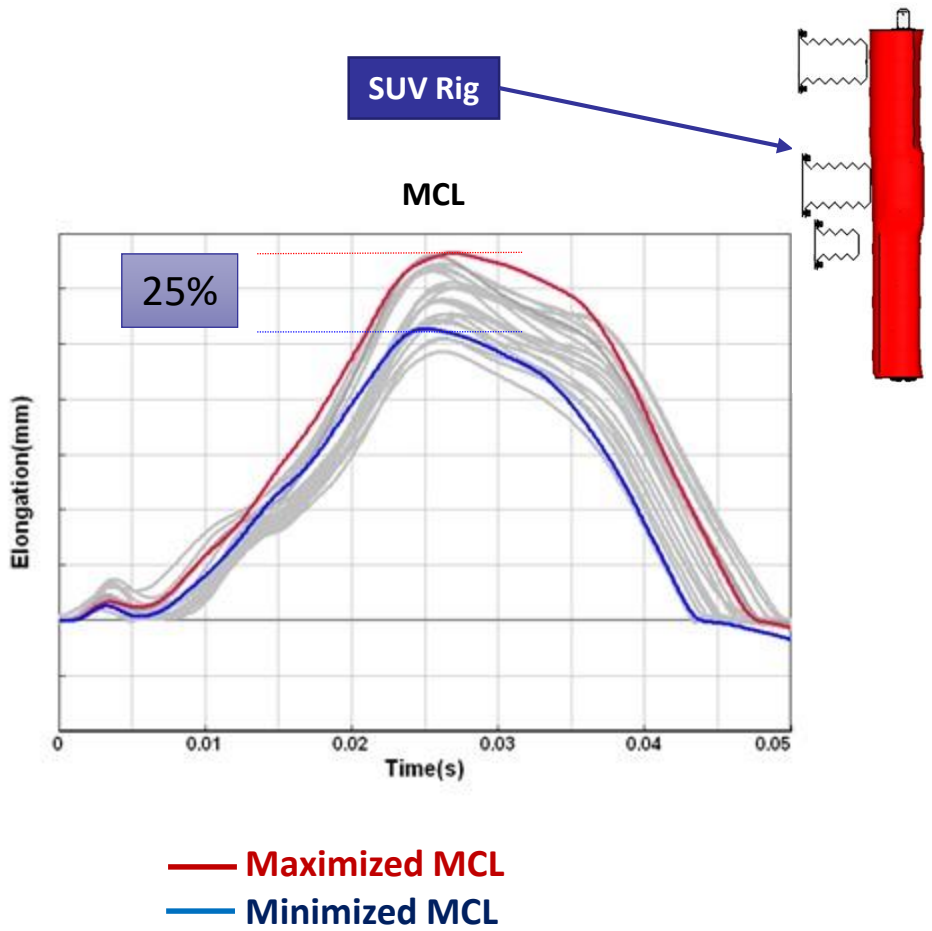




Flex-PLI Borderline© Model Patent Pending

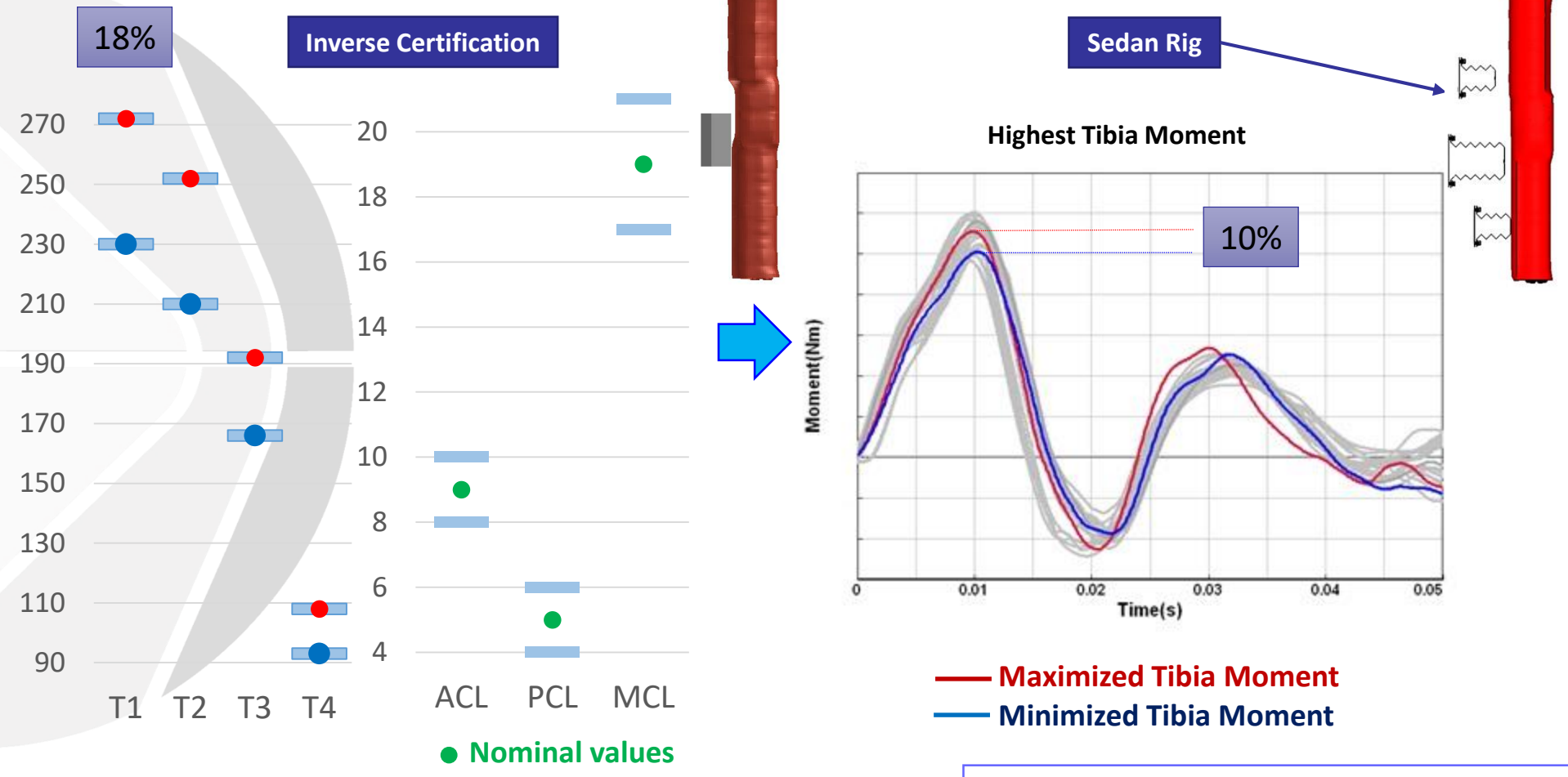
Verification – SUV (MCL variation)





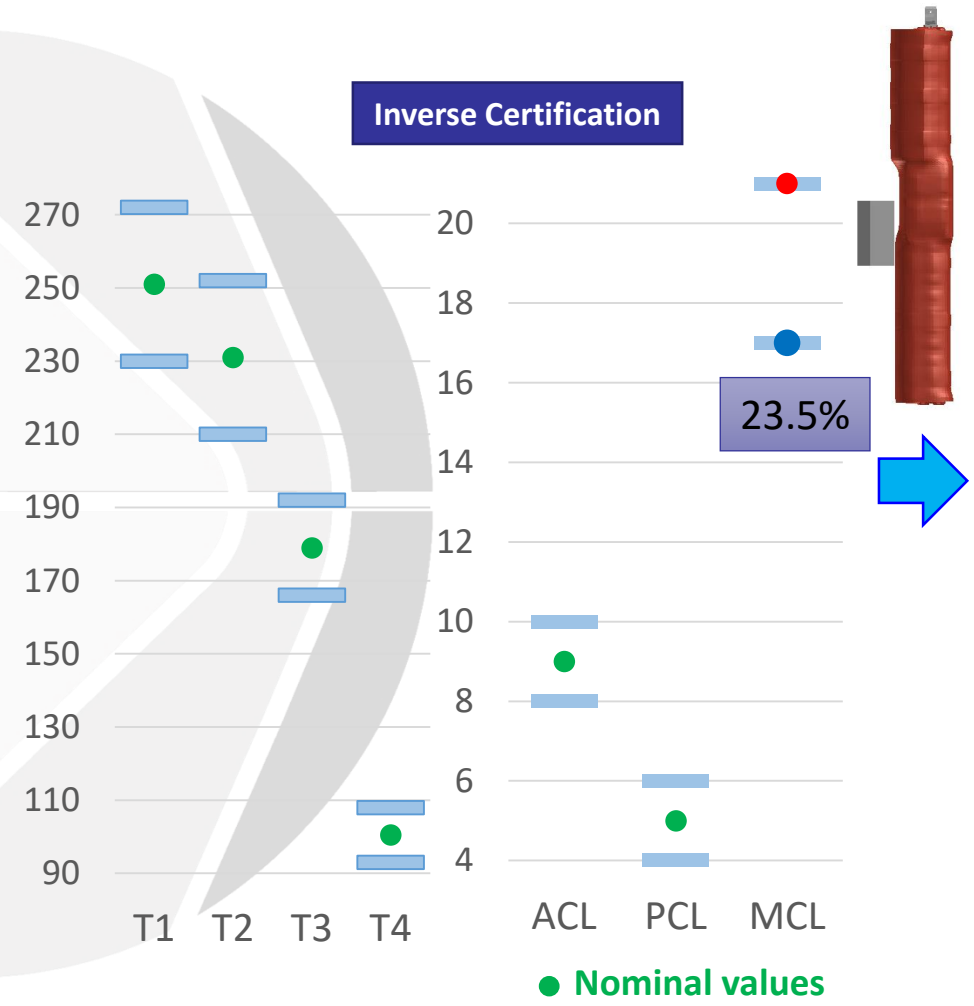
Flex-PLI Borderline© Model Patent Pending

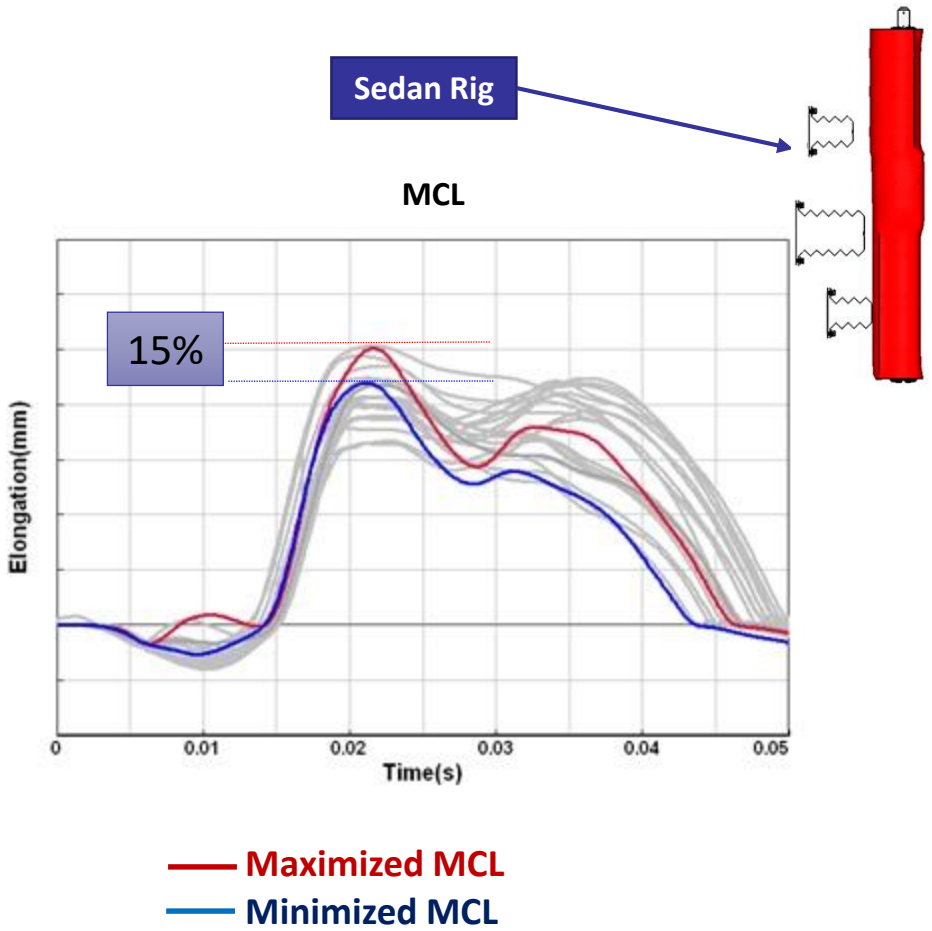
Verification – Sedan (Tibia Moment variation)



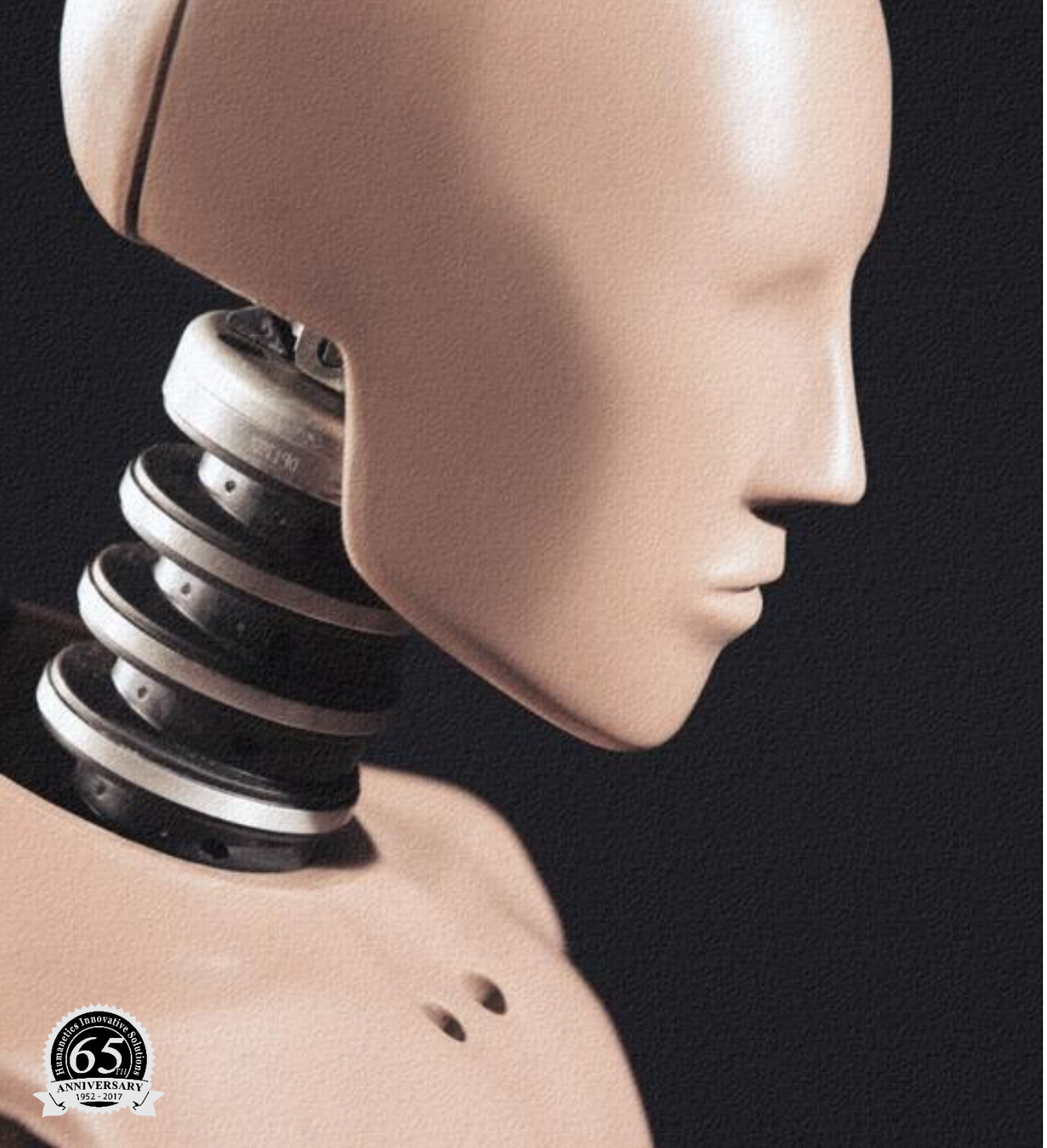
Flex-PLI Borderline© Model Patent Pending

Verification – Sedan (MCL variation)





Flex-PLI Borderline© Model Patent Pending

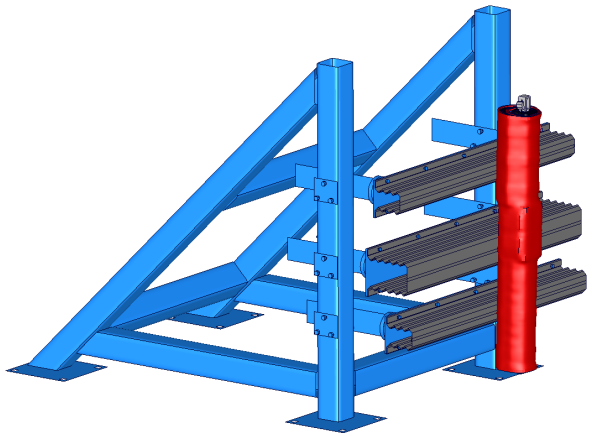

Humanetics Innovative Solutions
65TH
ANNIVERSARY
1952 - 2017

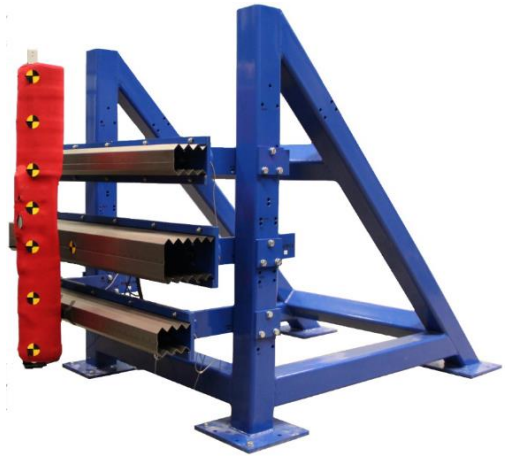
Summary

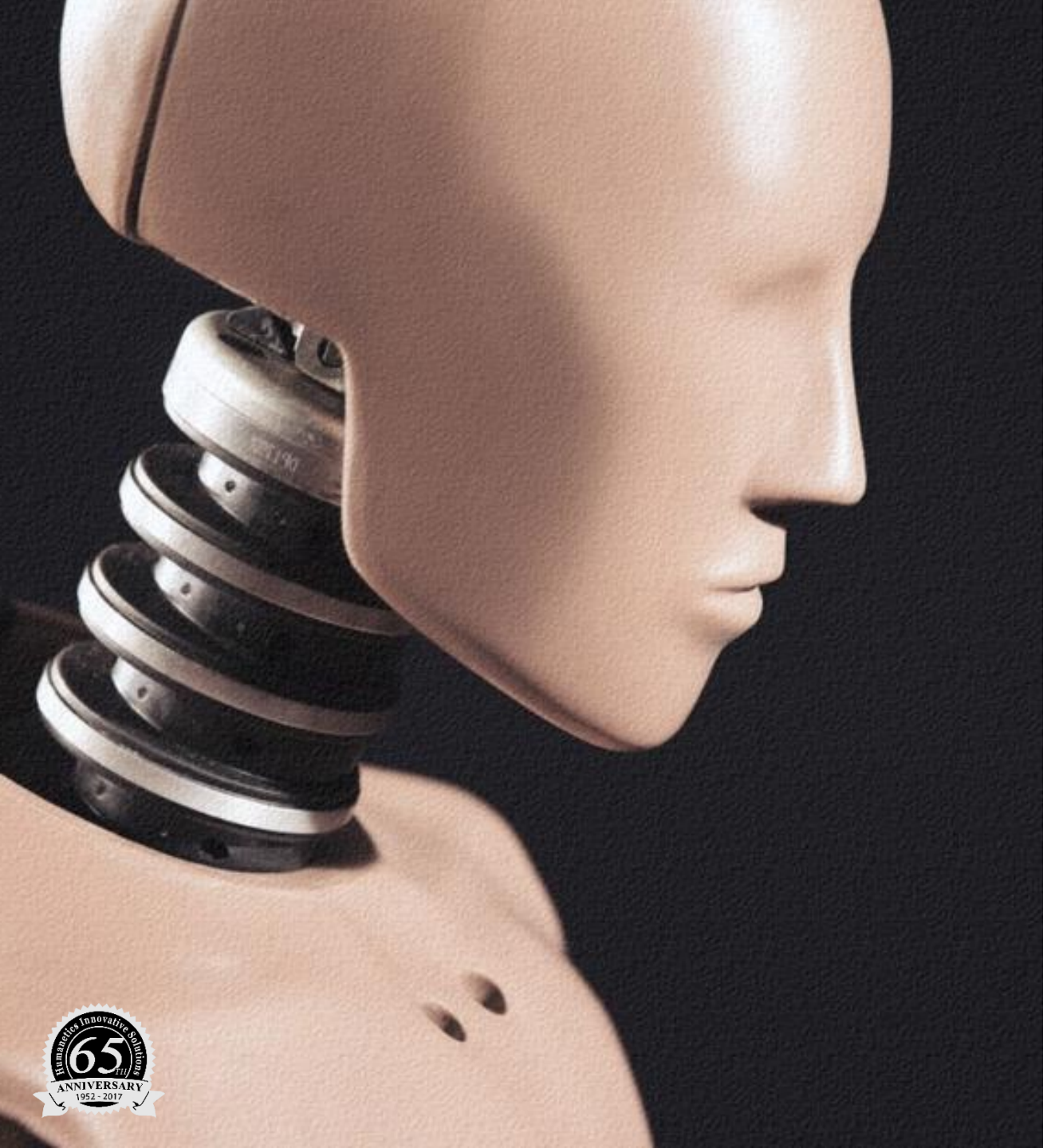
Summary

- **FlexPLI Borderline© model is capable of predicting the FlexPLI hardware variation from certification to vehicle like cases**

- **Environment variability has additional influence on the FlexPLI due to nature of application**
  - ➔ Environment variability is not within the scope of the Borderline© model





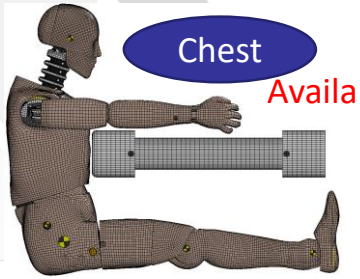


Borderline© Models

Borderline© Models

Target to predict a response of a specific hardware

HHIII-50M



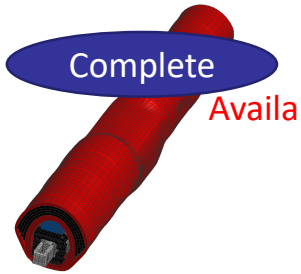
Chest
Available

HHIII-5F

Neck
Available

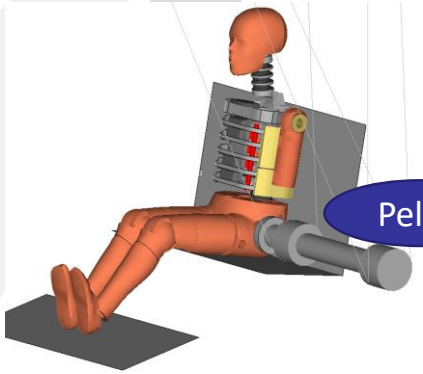
Chest
Available

FLEX PLI GTR



Complete
Available

SID-IIs



Pelvis
2019

THOR-50M

Neck
Customer requests

Chest
First Development Model available

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