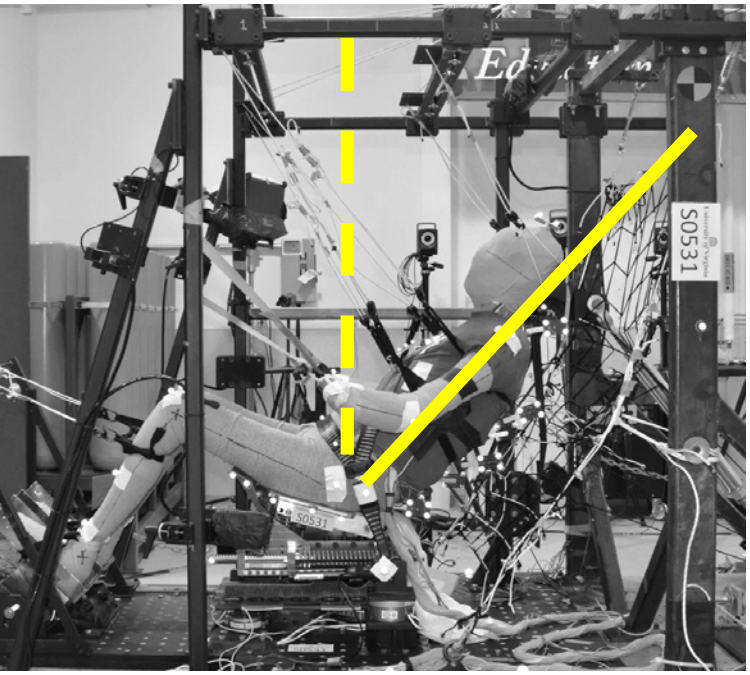
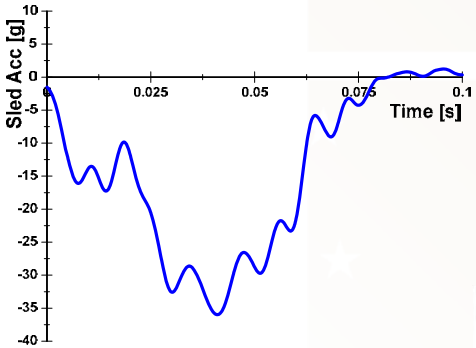
A Methodology to Replicate Lap Belt Loading Conditions from a Sled Test

David Moreau, John Paul Donlon, Aida Chebbi, Mohan Jayathirtha, Rachel Richardson, Bronislaw Gepner, Jason Forman, Jason Kerrigan

Reclined Sled Tests (Richardson et al 2019-2020)



50° recline with the vertical



30 g pulse (50 km/h ΔV)

- Restraint System with:
  - Shoulder Belt In-Seat
  - Shoulder Belt Pretensioner
    - Load Limited to 4 kN
  - Dual Lap Belt Pretensioners
- Pelvis and Vertebrae tracking

Lighter Mass

Young

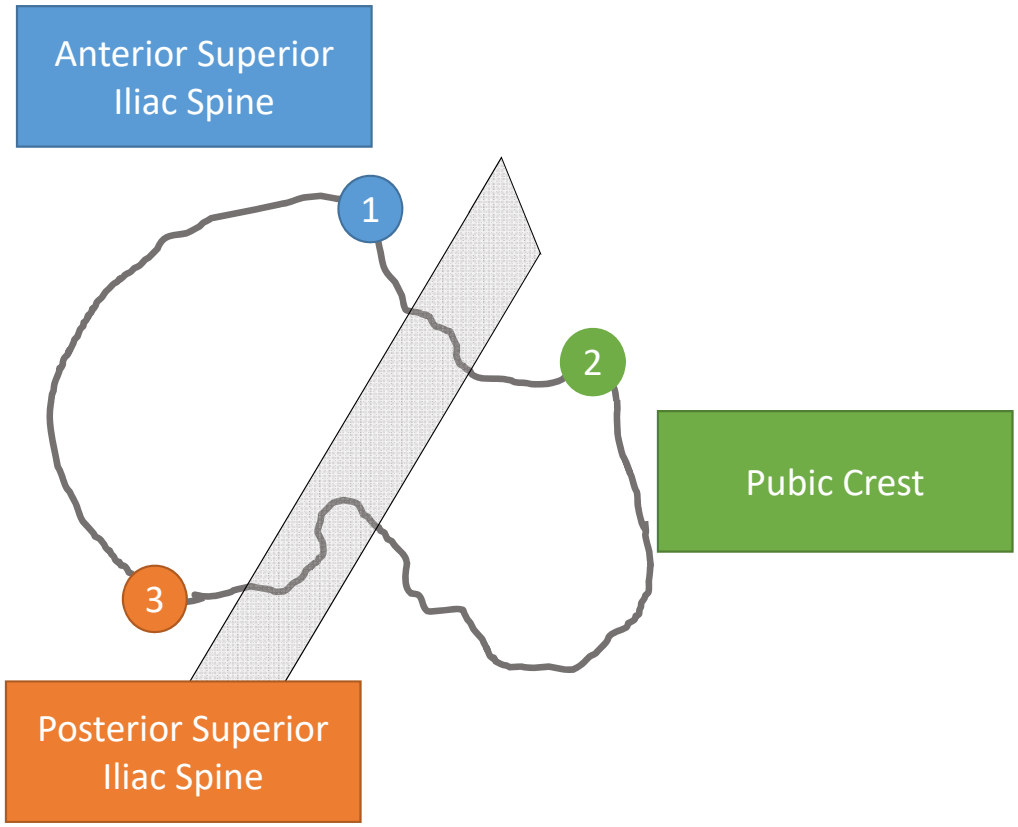
Submarined

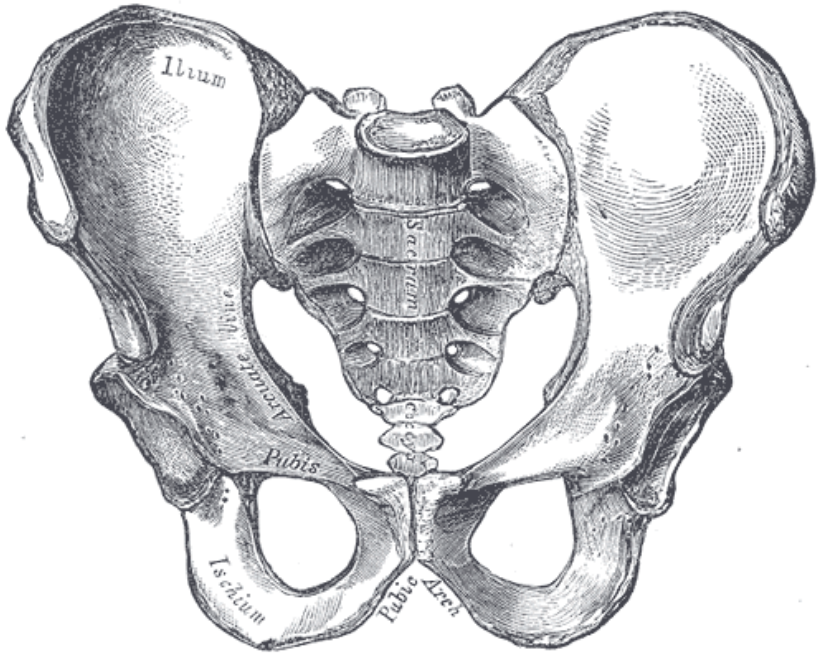
Test	S0529	S0530	S0531	S0532	S0533
Subject Number					5
Age					55
Height (cm)	177.8	173	177.8	173	177.8
Weight (kg)	74.4	56.7	73.9	75	74.4
Peak Lap Belt Force (kN)	7.8	4.6	6.6	8.3	7.6

Why do we have differing responses, given similar lap belt forces?

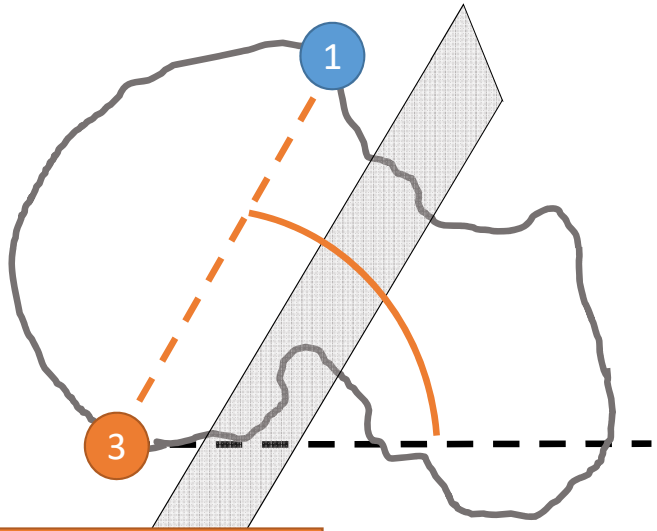
Fracture

Pelvis Anatomy



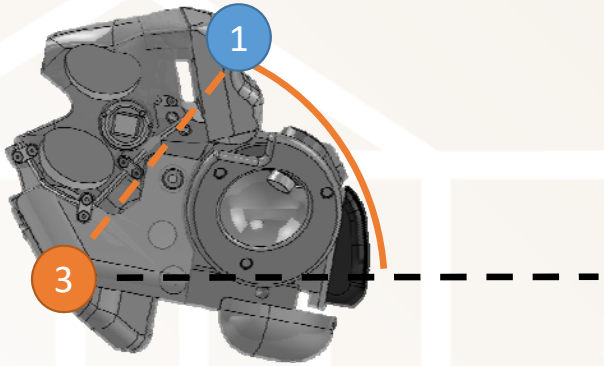


Anterior Superior Iliac Spine



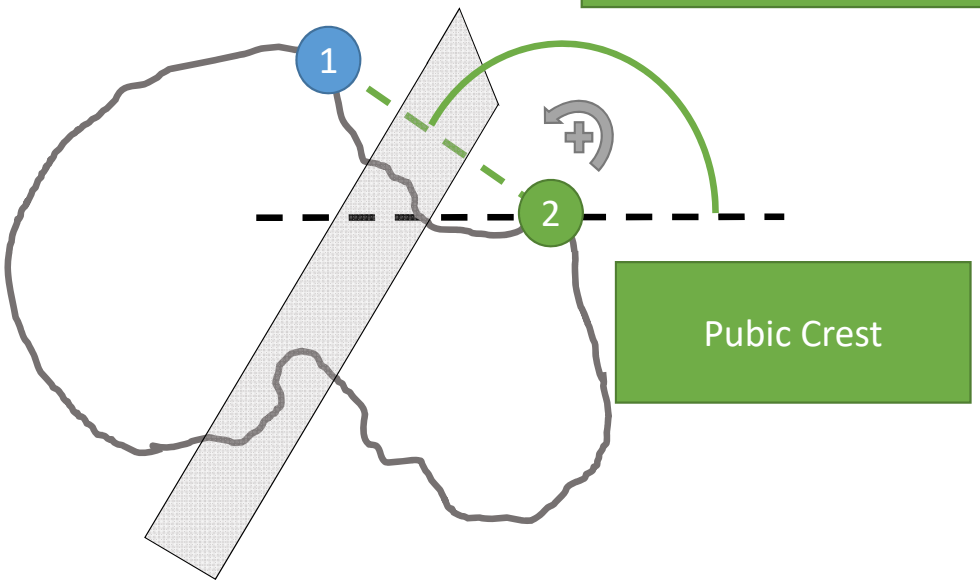
Posterior Superior Iliac Spine

ASIS-PSIS Angle



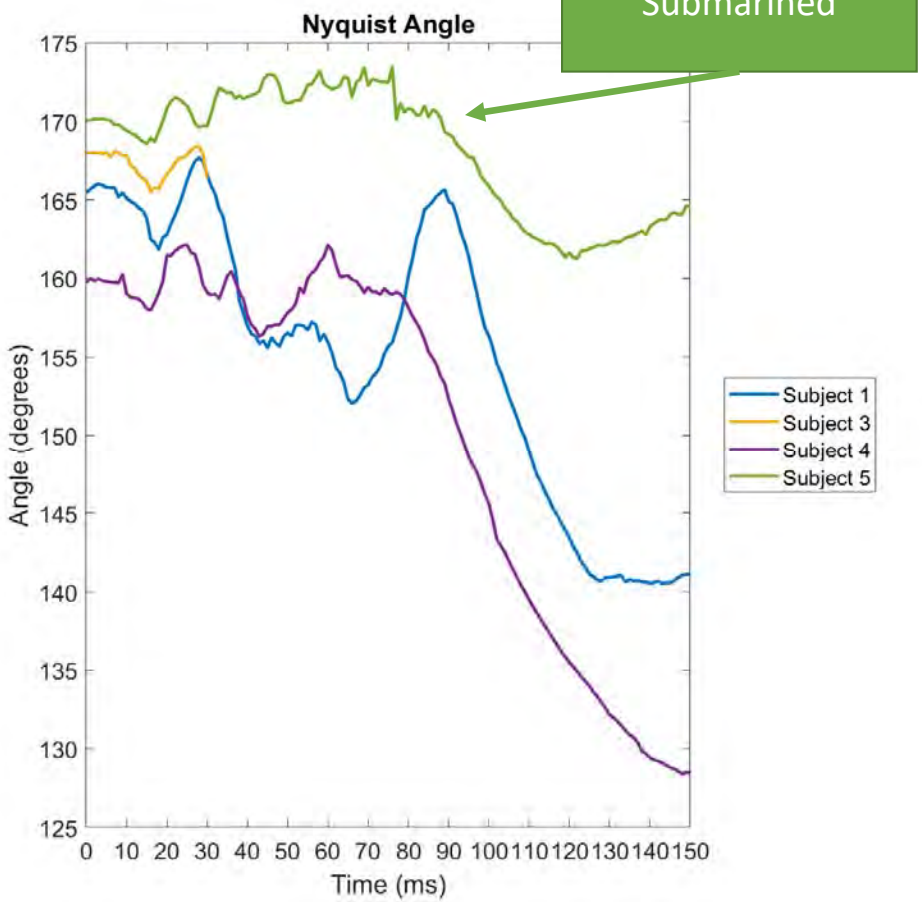
Anterior Superior Iliac Spine

Nyquist Angle (Nyquist and Patrick 1976)



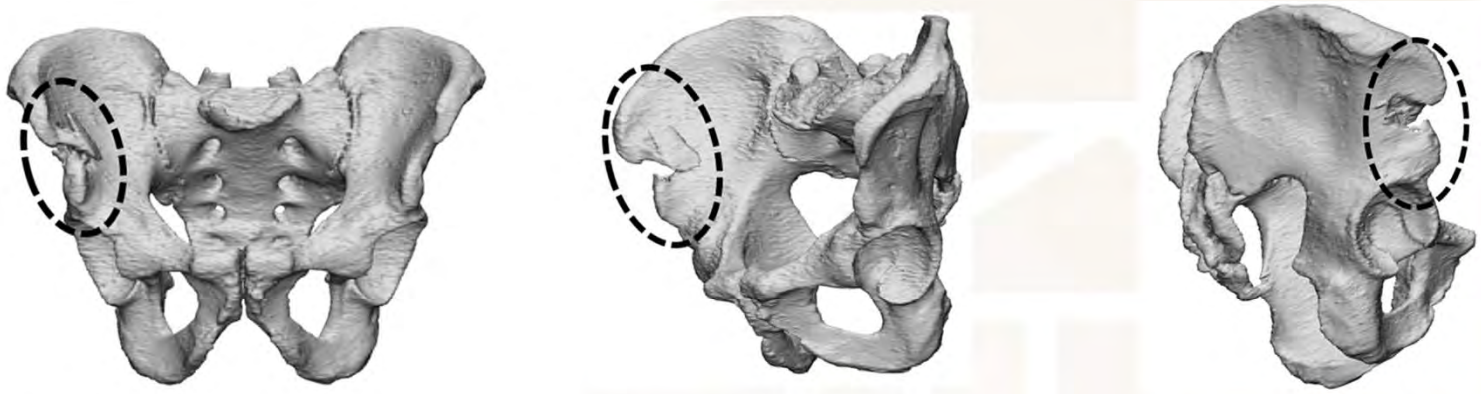
Pubic Crest

Submarined

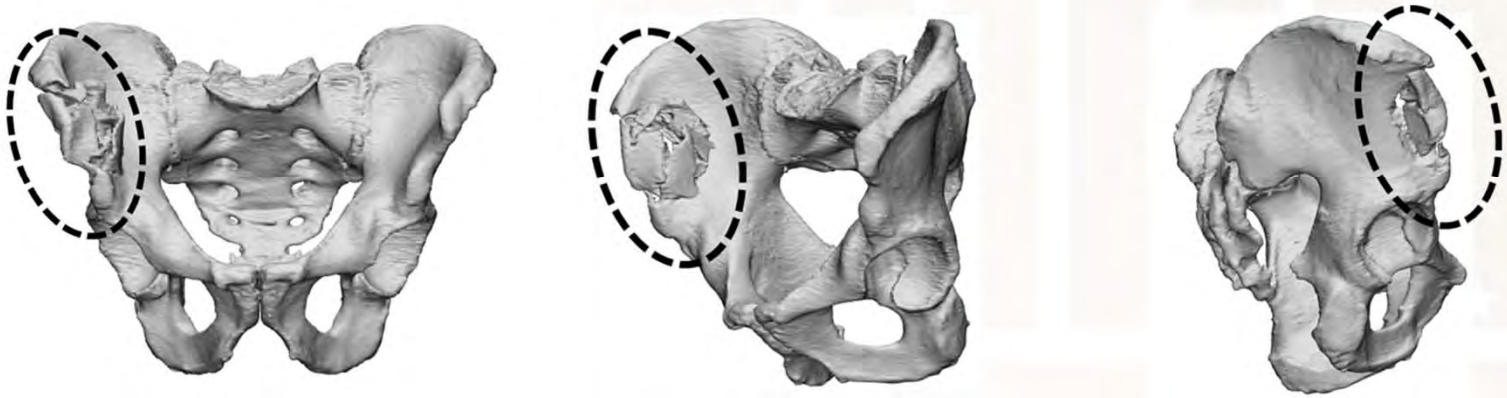


Iliac Wing Fractures

Subject 1



Subject 3



Richardson et al 2020

1970s

Schmidt 1974

Fayon 1975

Kent 2001

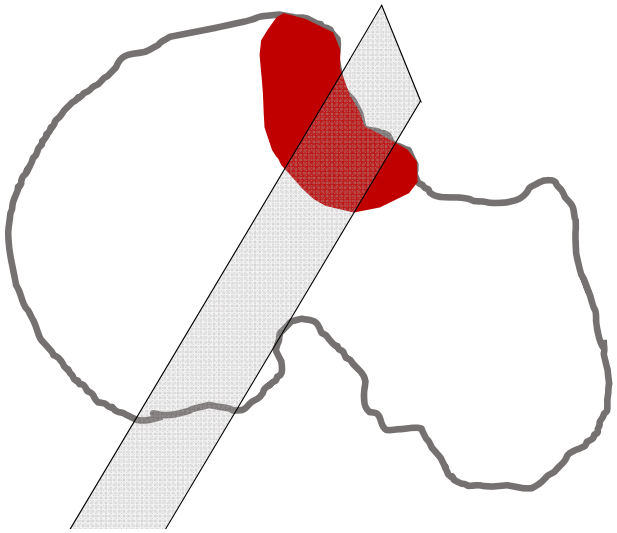
Kent 2011

Luet 2012

Uriot 2015

Shaw 2018

Trosseille 2018



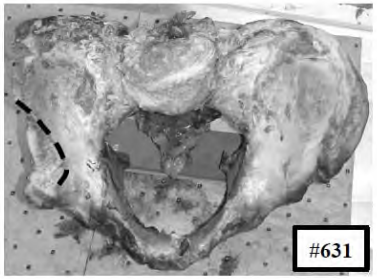


FIGURE 13. Pelvic bone fracture of specimen #631.

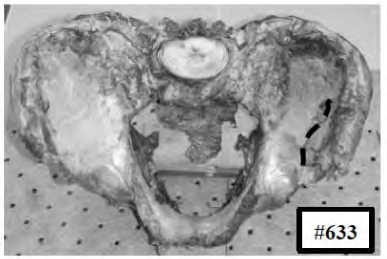


FIGURE 14. Pelvic bone fracture of specimen #633.

Luet 2012

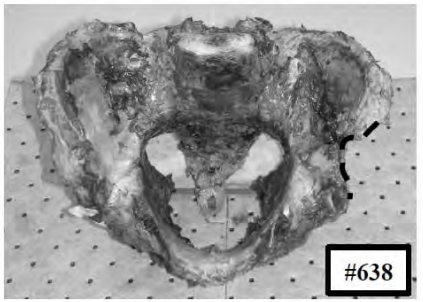


FIGURE 15. Pelvic bone fracture of specimen #638.

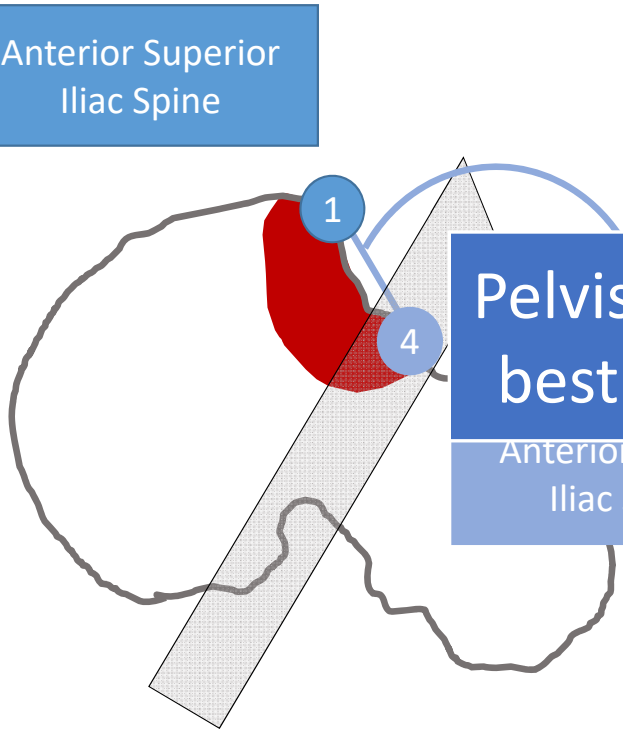
Uriot 2015

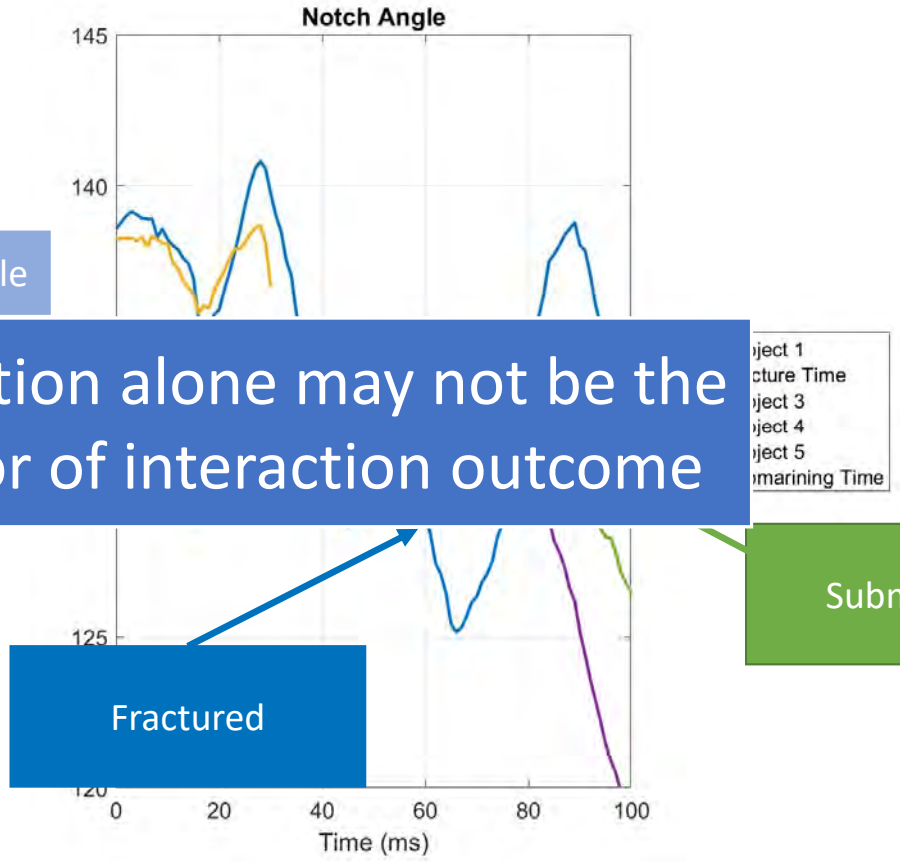
Fracture of the anterior part of the right ilium wing (AIS2)

Comminuted fracture of the ilium wing with involvement of the posterior ilium (AIS2)

Fracture of the ilium wing (anterior part) (AIS2)

Fracture of the anterior part of the left ilium wing (AIS2)

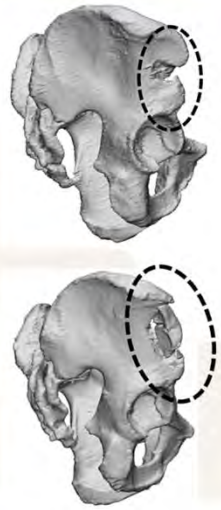




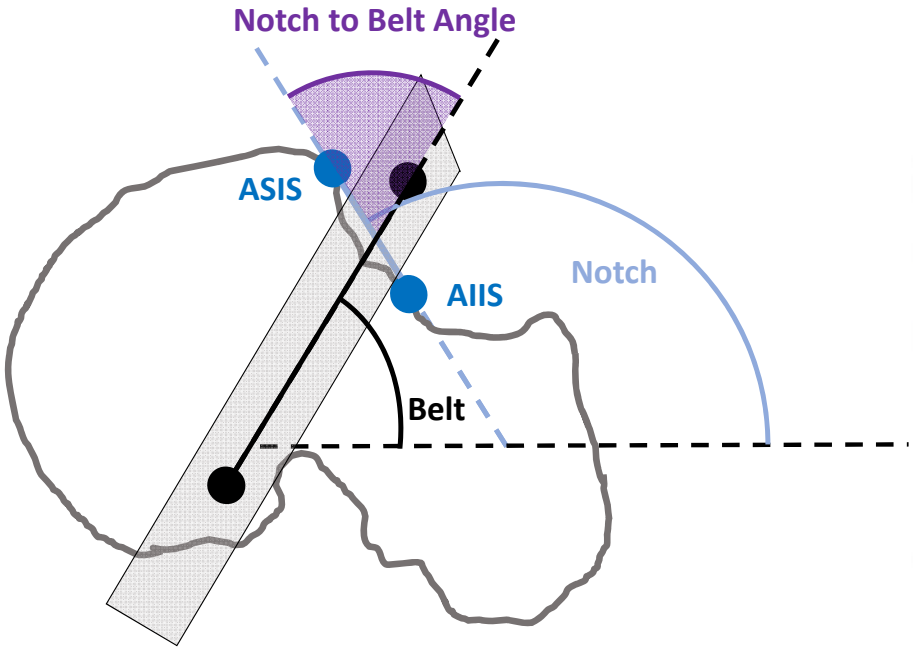
Pelvis orientation alone may not be the best predictor of interaction outcome

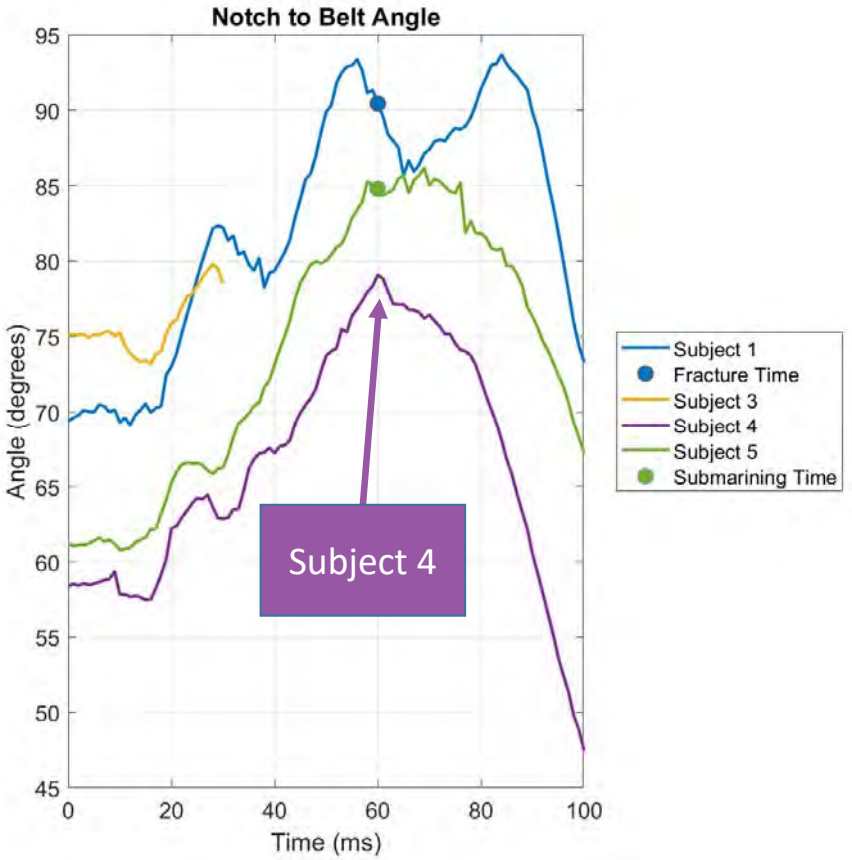
Fractured

Submarined

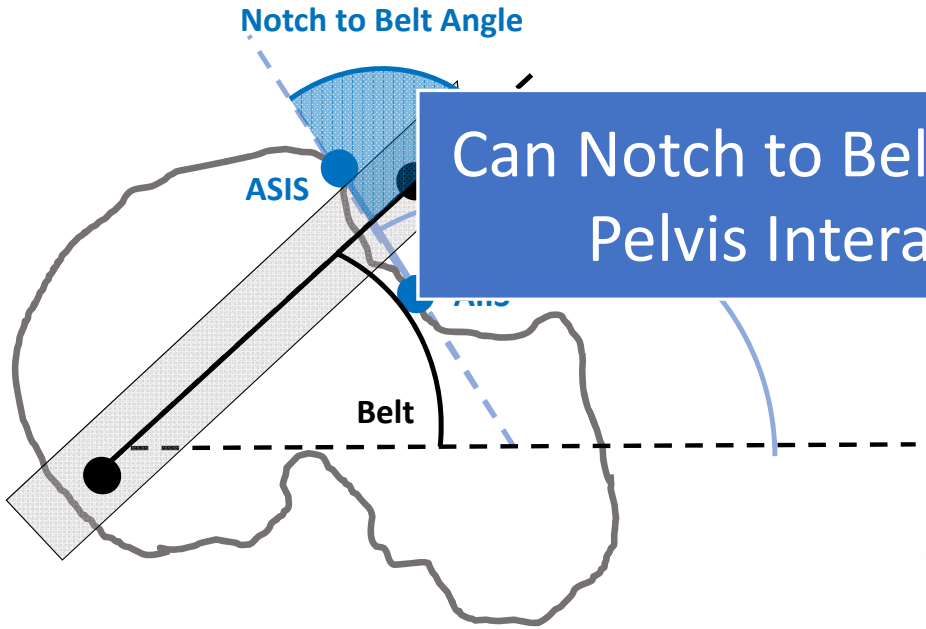


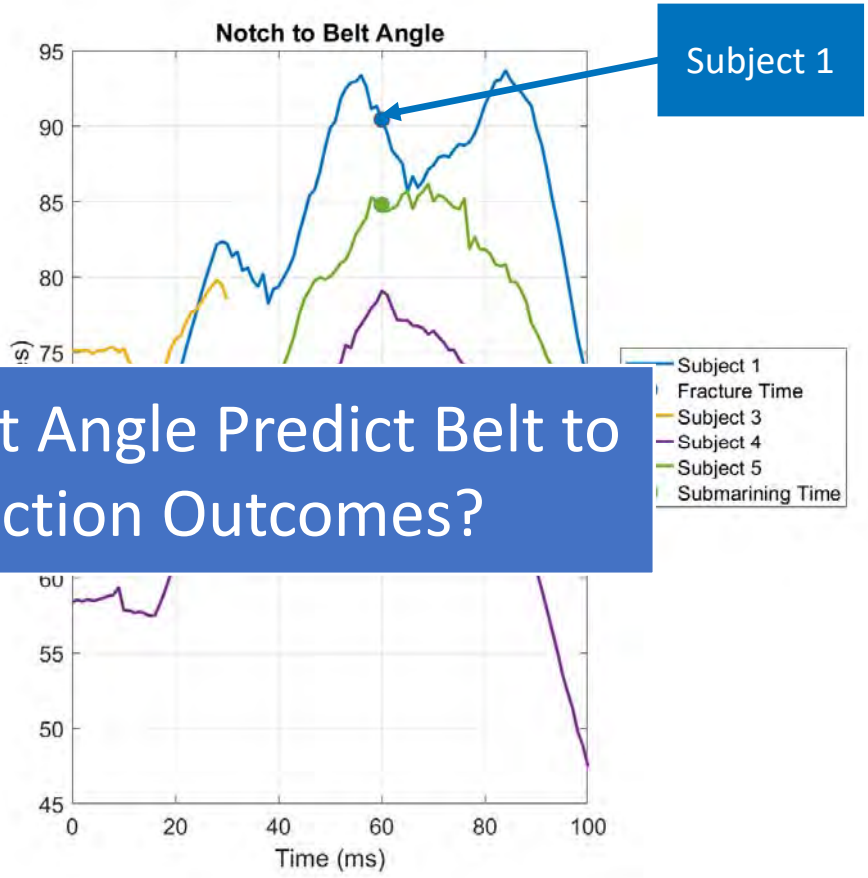
Richardson et al 2020





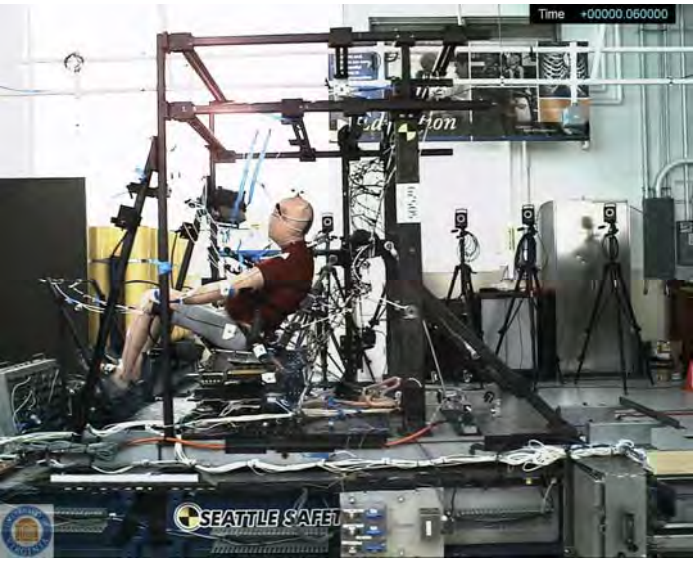
Richardson et al 2020

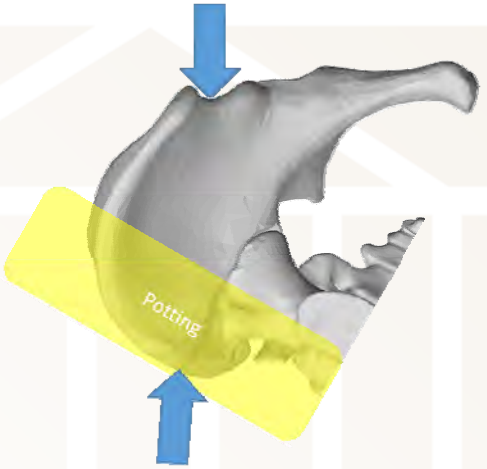




Subject 1

Can Notch to Belt Angle Predict Belt to Pelvis Interaction Outcomes?





Most Complex
Most Realistic

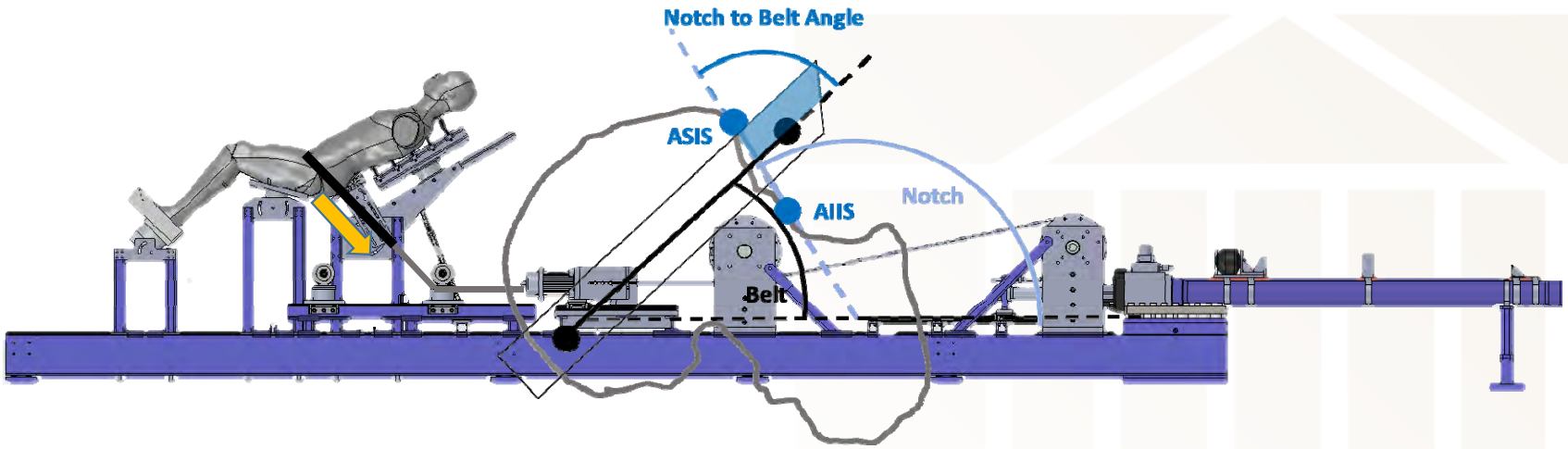
Less Complex,
More Controllable

Most
Controllable

Goal 1: Replicate pelvis fractures

Goal 2: Evaluate the tools available (ATDs)

Goal 3: Understand why/when submarining occurs



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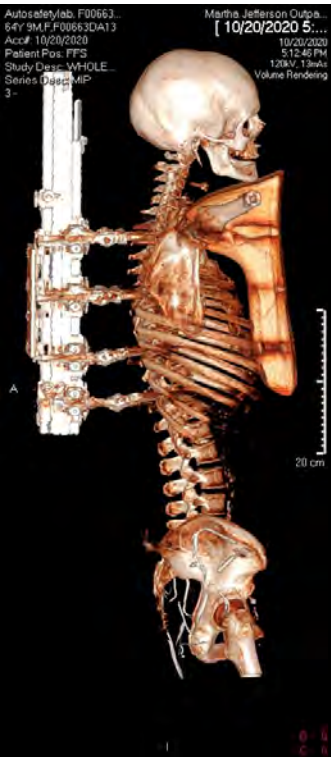
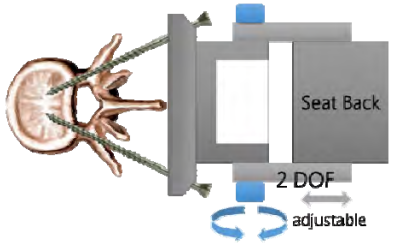
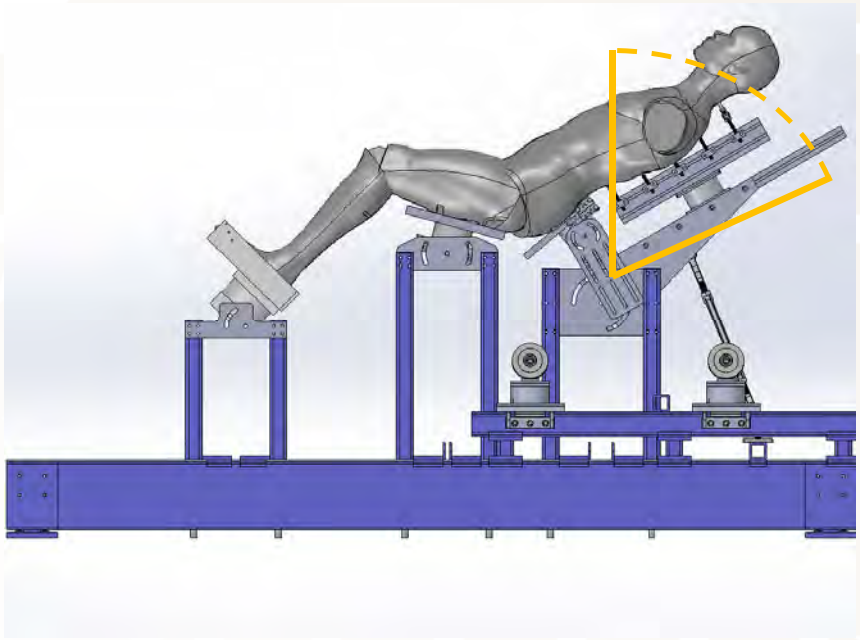
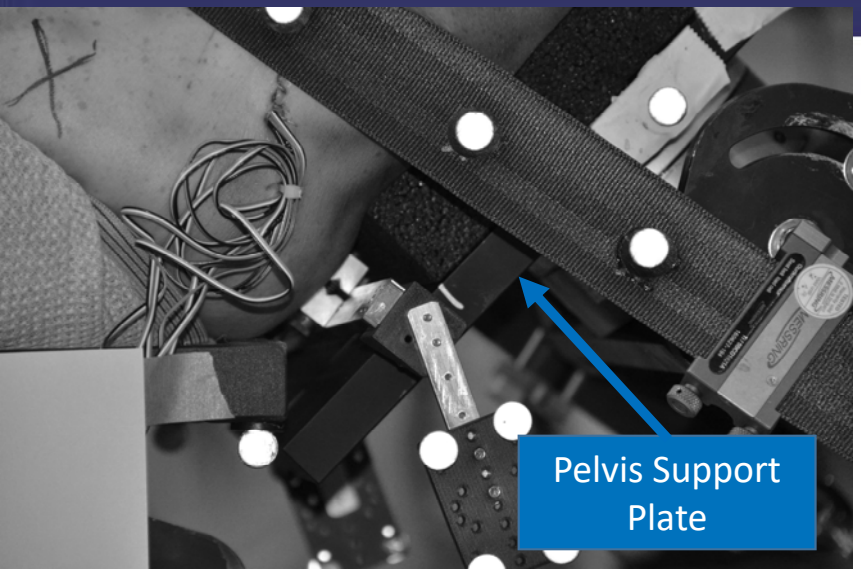
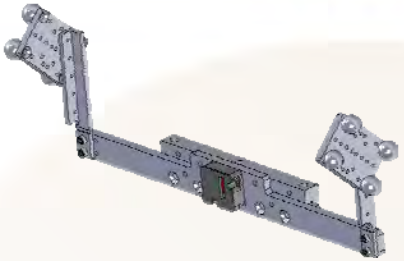
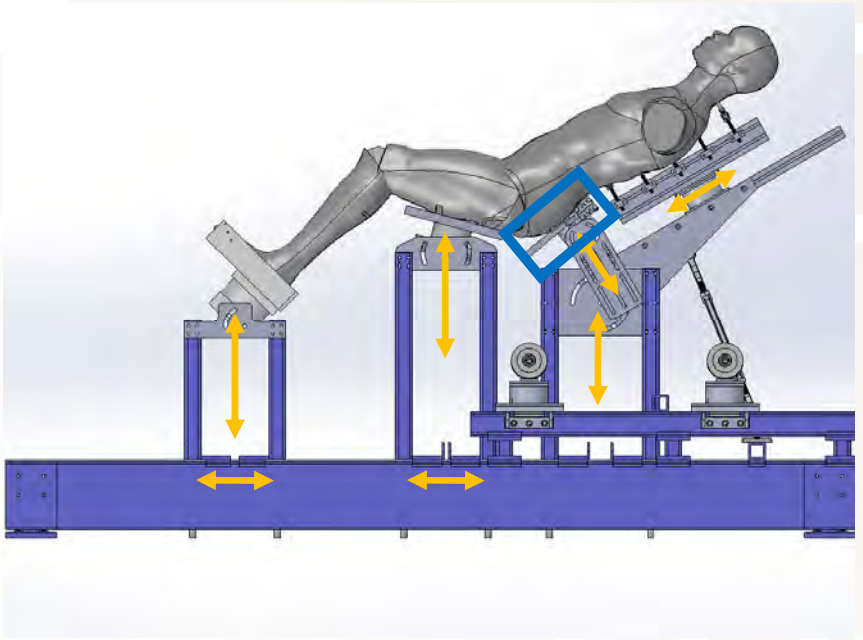

Autosafetylab, F00663...
64Y,9M,F,F00663DA13
Acc#: 10/20/2020
Patient Pos: FFS
Study Desc: WHOLE...
Series Desc: MIP
3 -
Martha Jefferson Outpa...
[10/20/2020 5:...
10/20/2020
5:12:46 PM
120kV, 13mAs
Volume Rendering
A
20 cm

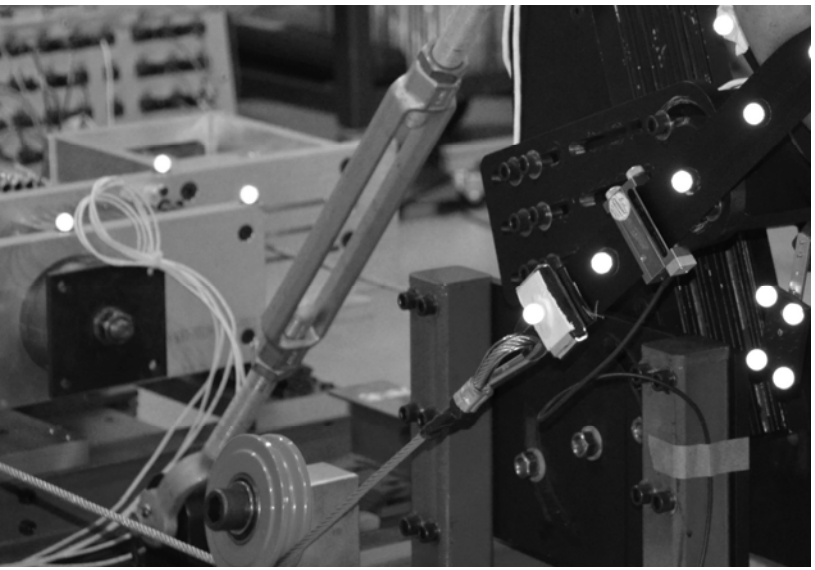

Seat Back
2 DOF
adjustable

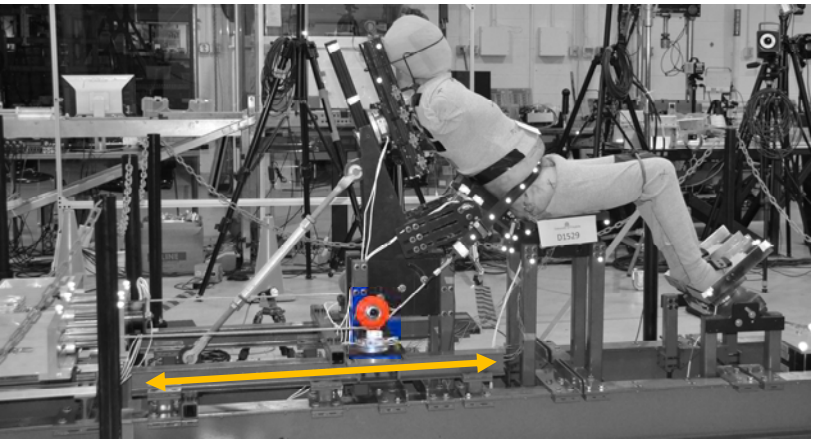


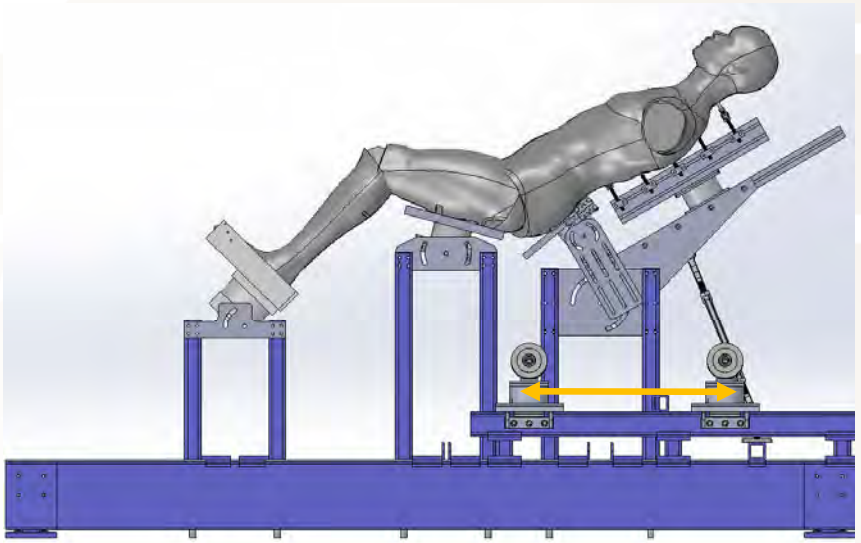

Pelvis Support
Plate











Goal 1: Replicate pelvis fractures

Goal 2: Evaluate the tools available (ATDs)

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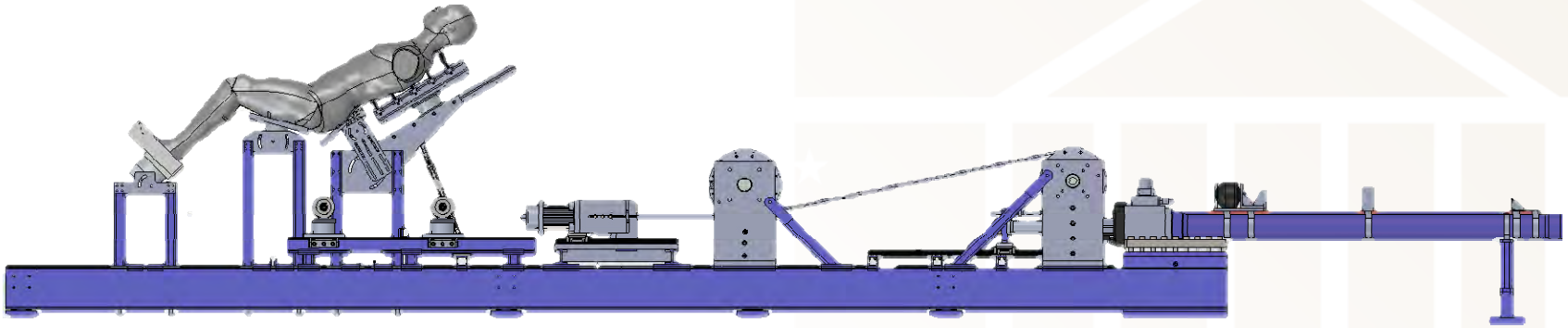

Most Complex Most Realistic

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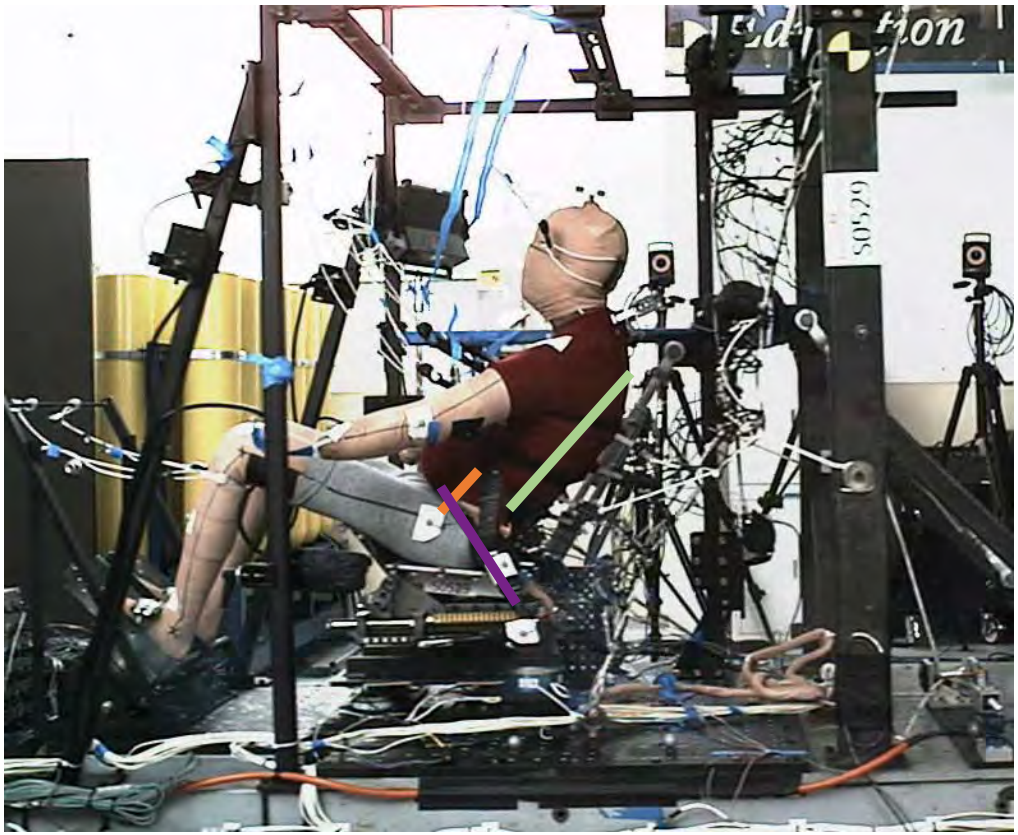
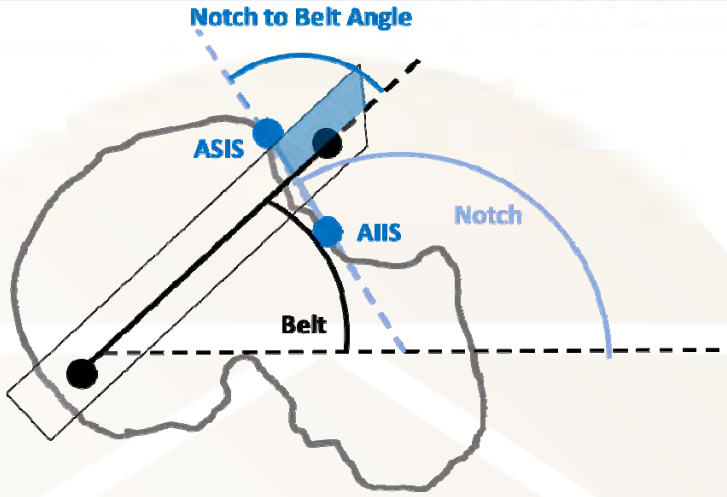
Most Controllable





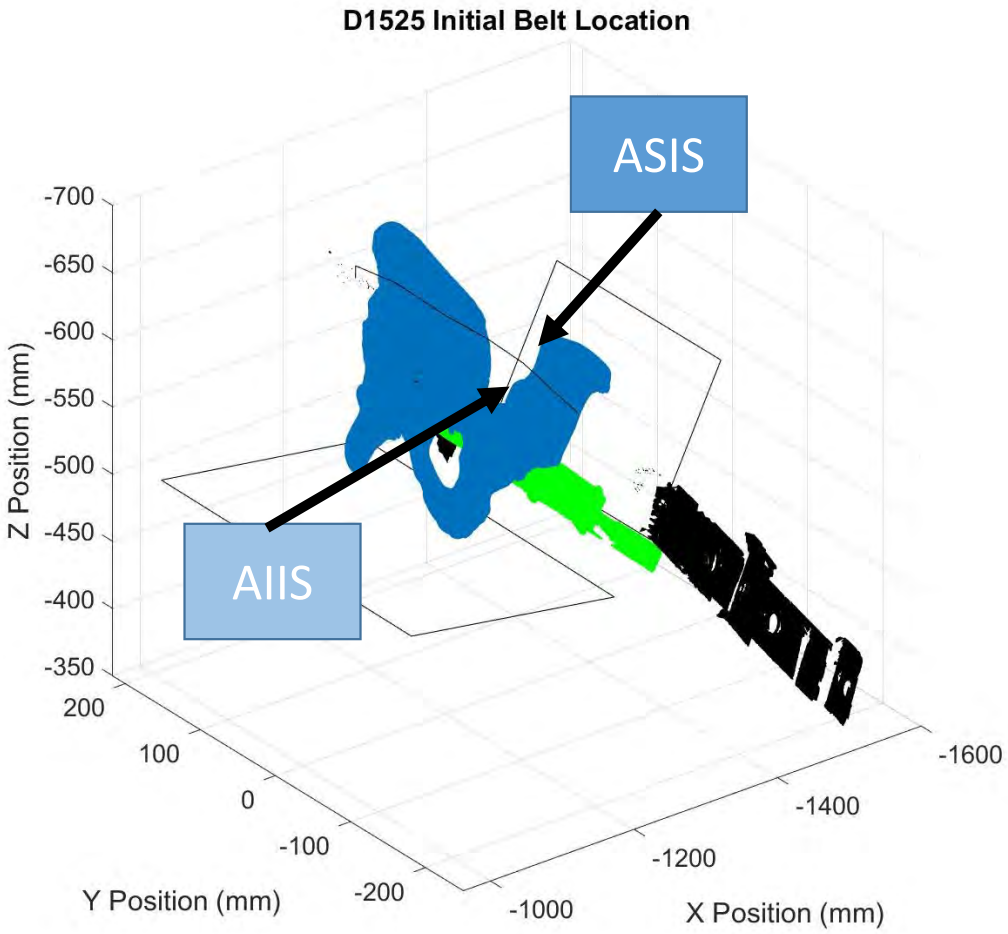
Spine Angle: 45 Degrees

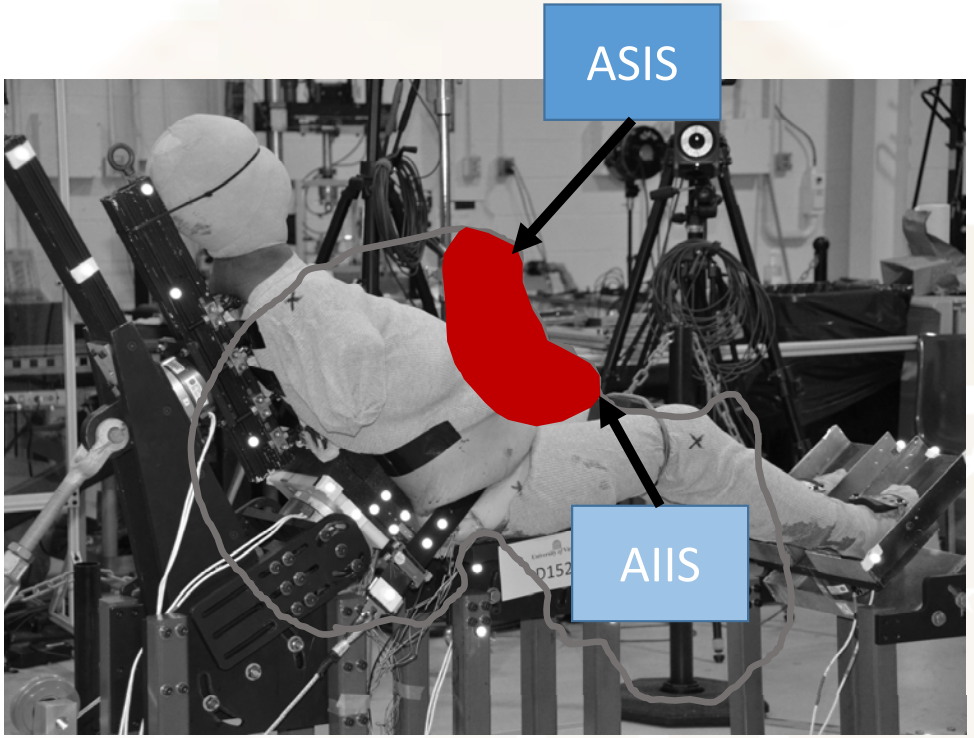
Notch Angle: 130 Degrees

Belt Angle: 40 Degrees

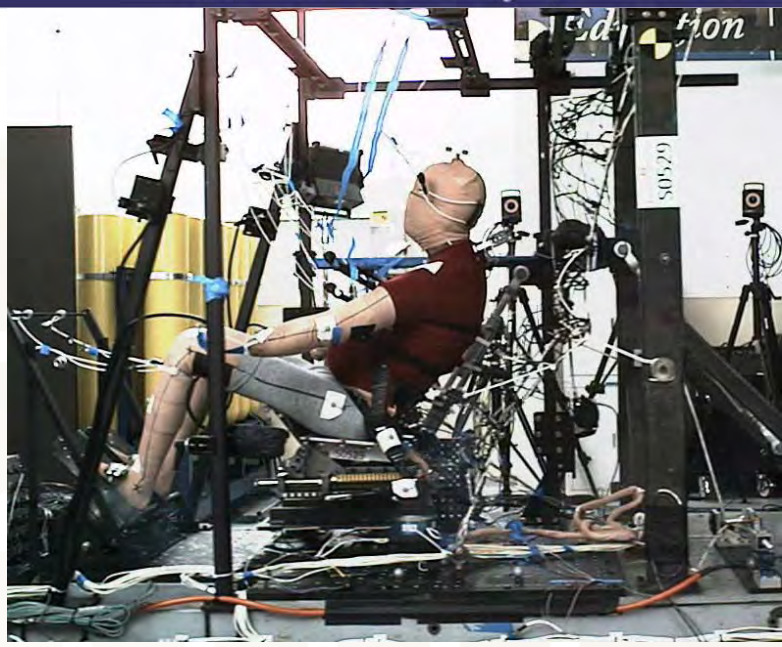
Notch to Belt Angle: 90 Degrees

Richardson et al 2020

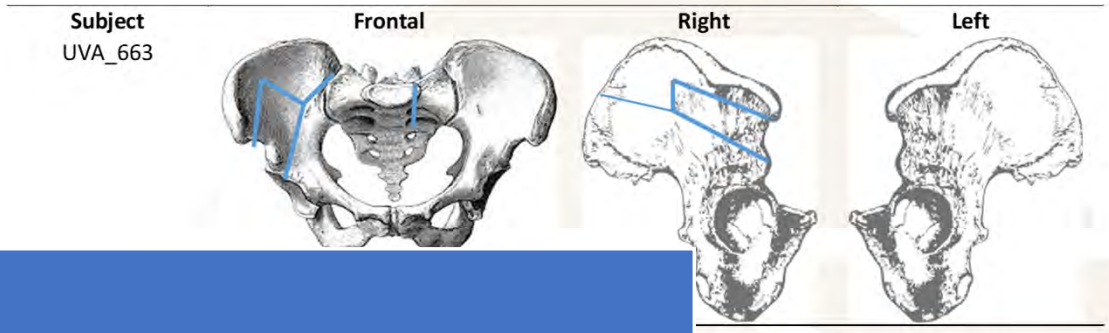

D1525 Initial Belt Location
ASIS
AIIS
Z Position (mm)
-700
-650
-600
-550
-500
-450
-400
-350
200
100
0
-100
-200
Y Position (mm)
-1000
-1200
-1400
-1600
X Position (mm)


ASIS
AIIS


University of Virginia
D1525

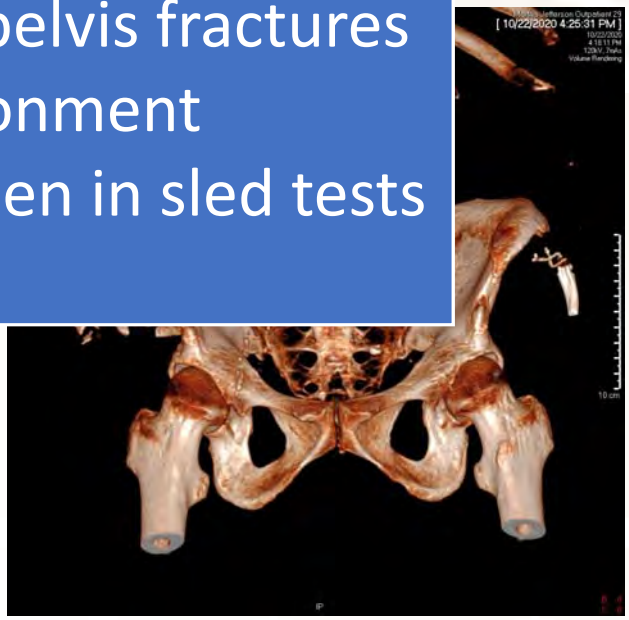


PMHS Results



Environment
Sled Test Maximum
Sled Test Minimum
Non-Impact Dynami

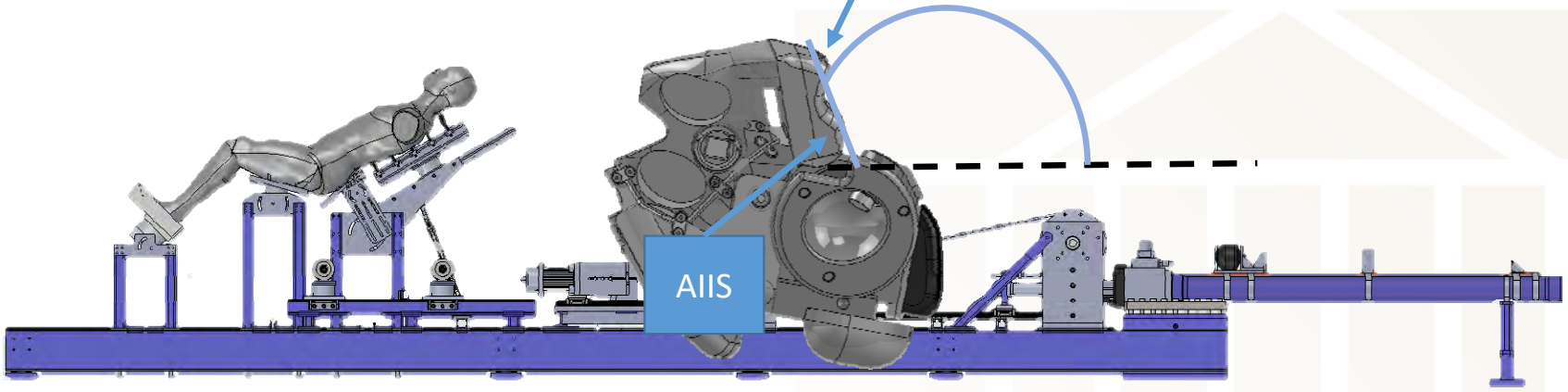
Successfully recreated pelvis fractures in simpler environment
Matched loading rate seen in sled tests



Goal 1: Replicate pelvis fractures

Goal 2: Ev[illegible]he tools avail[illegible]Ds)

Goal 3: Understand why/when submarining occurs



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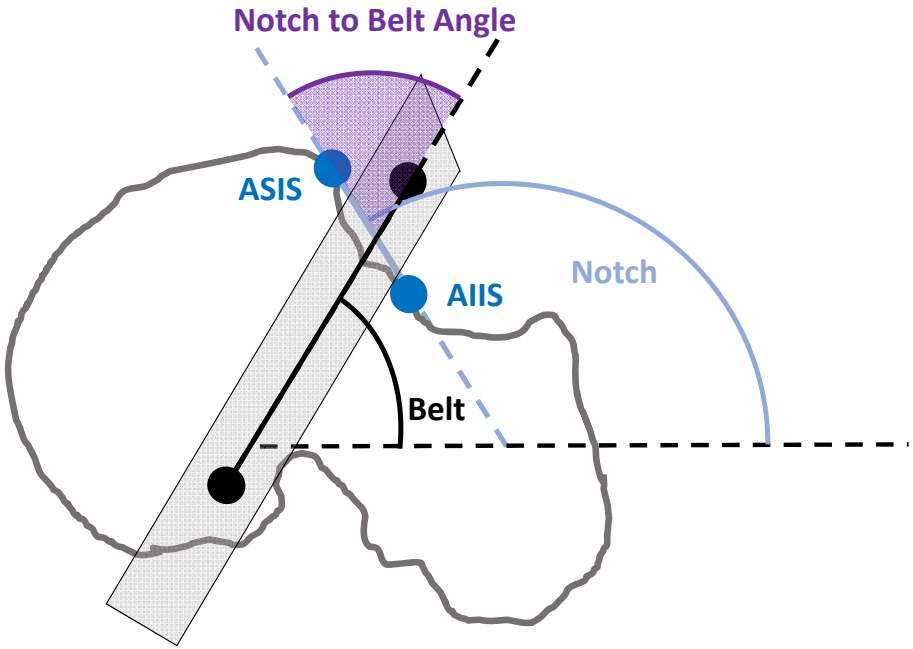
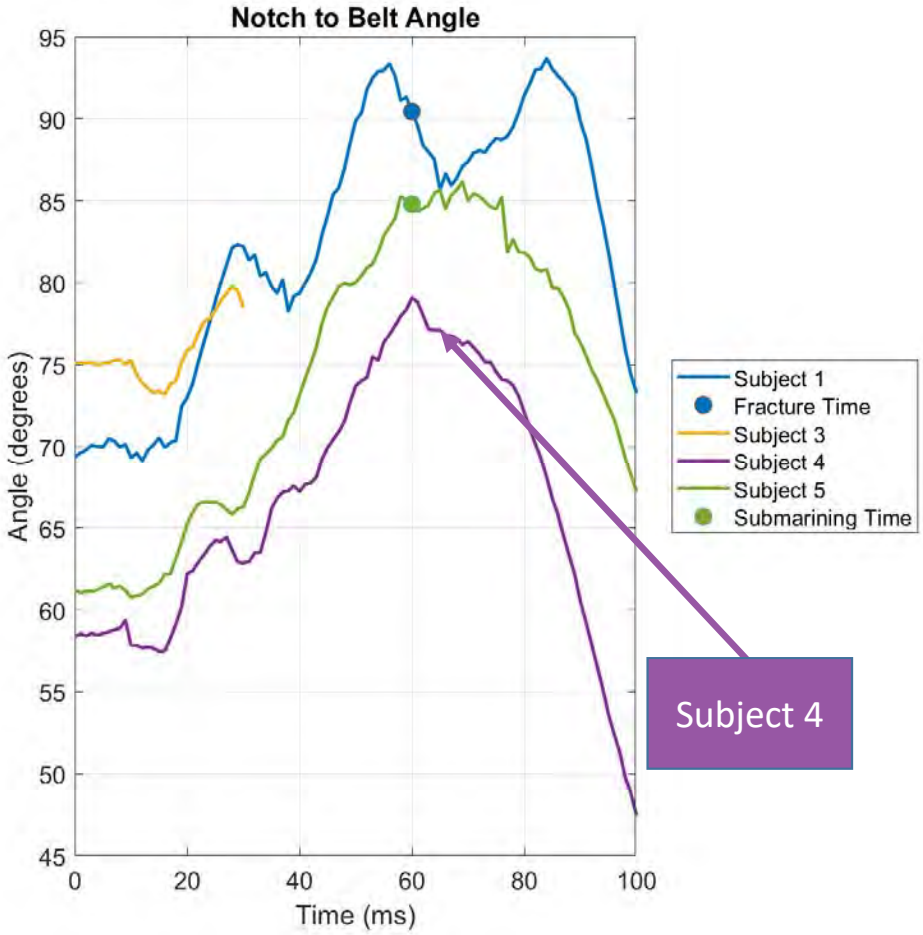
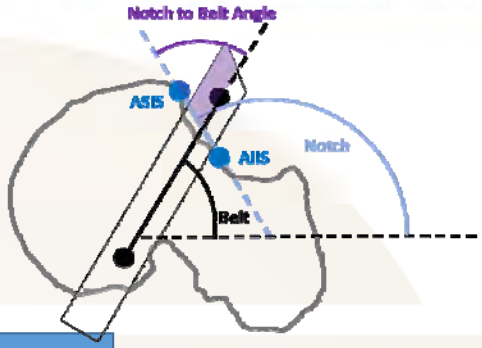
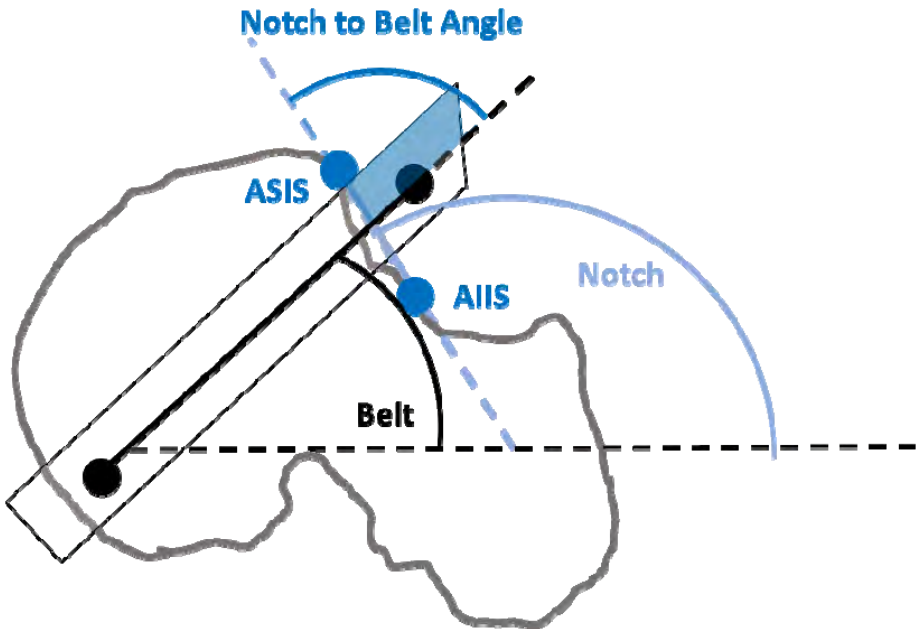

Notch to Belt Angle
ASIS
AIIS
Notch
Belt

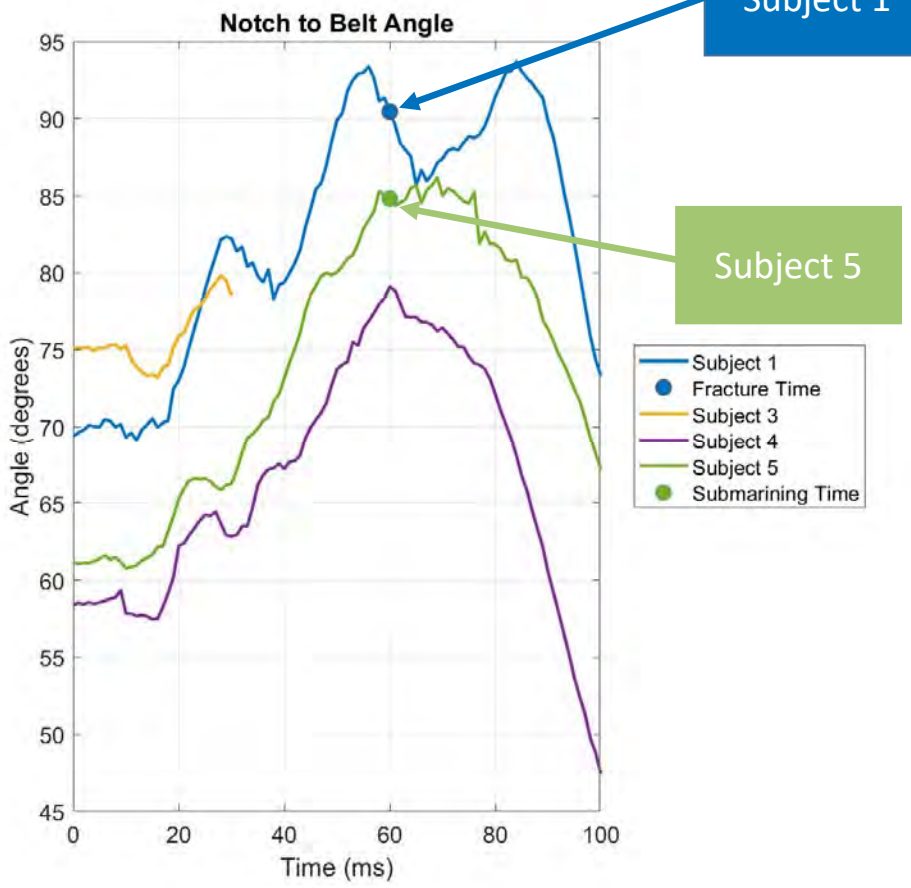

Notch to Belt Angle
Angle (degrees)
Time (ms)
95
90
85
80
75
70
65
60
55
50
45
0
20
40
60
80
100
Subject 1
Fracture Time
Subject 3
Subject 4
Subject 5
Submarining Time
Subject 4



Notch to Belt Angle Target: 75 degrees

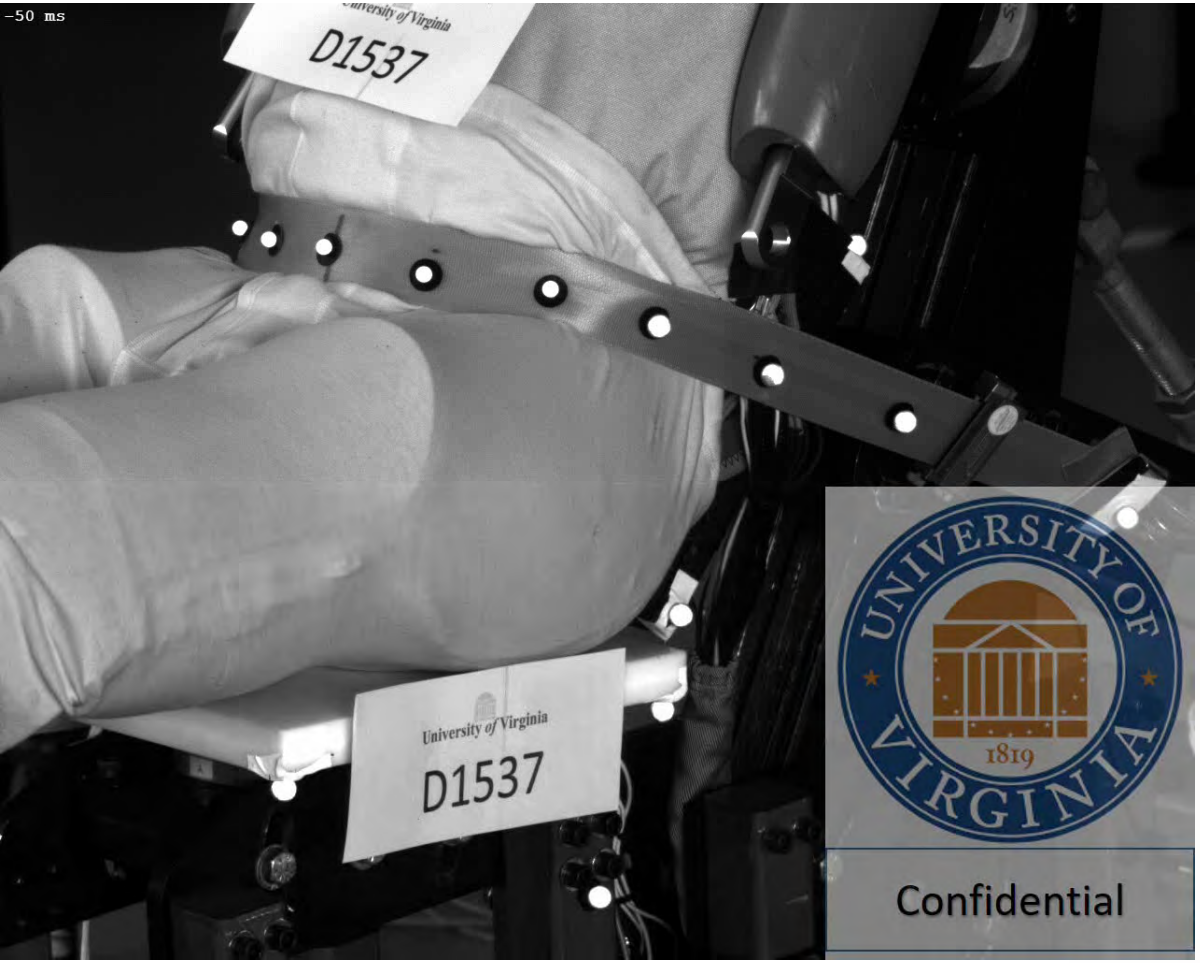
No Submarining

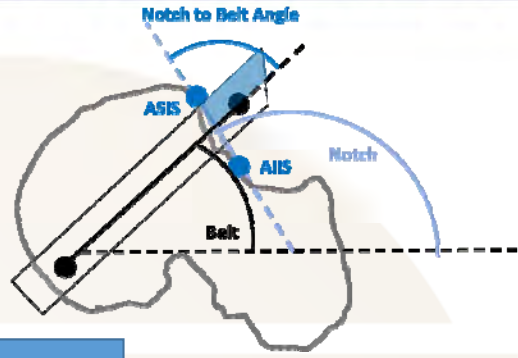




Subject 1

Subject 5



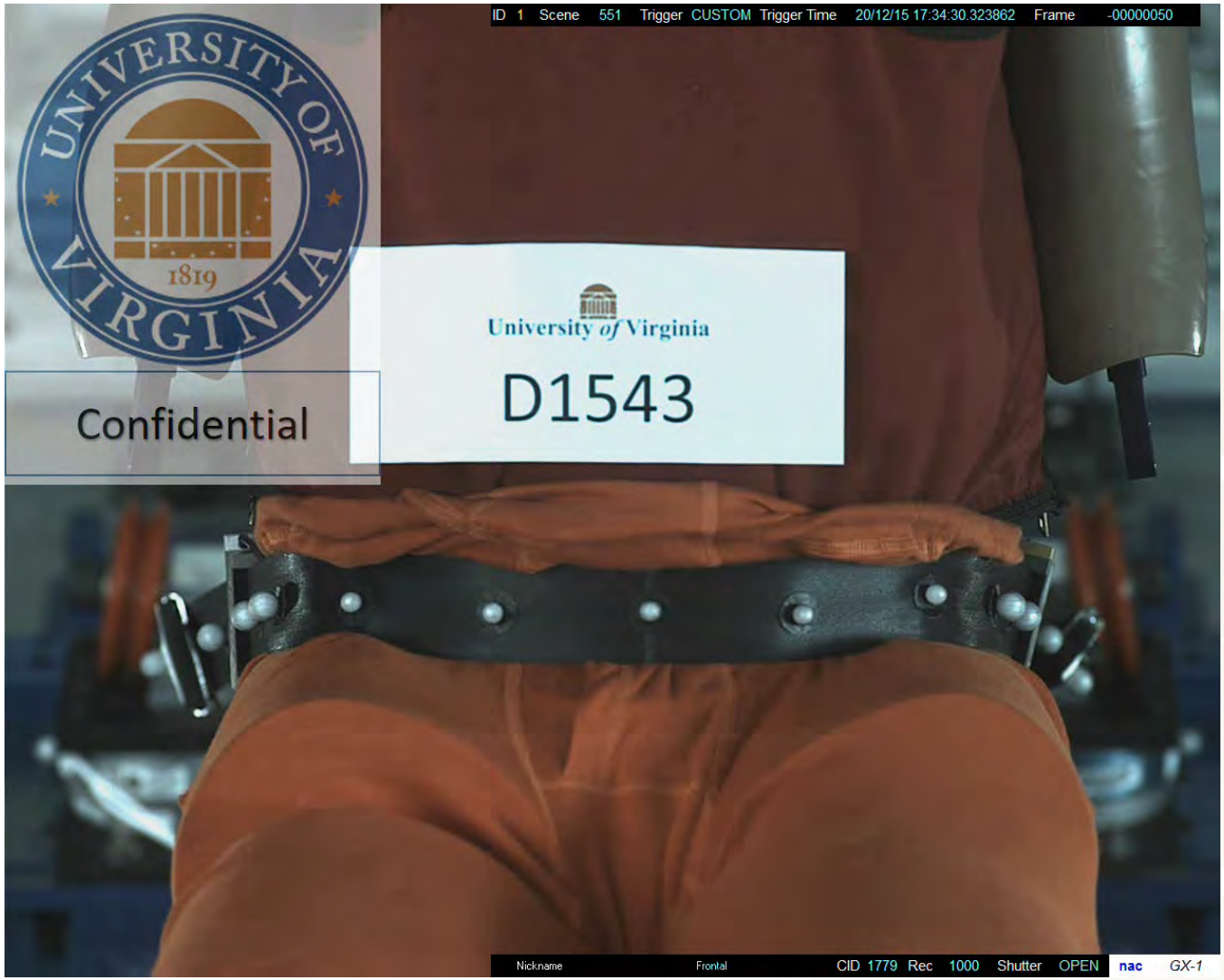


Notch to Belt Angle Target: 90 degrees

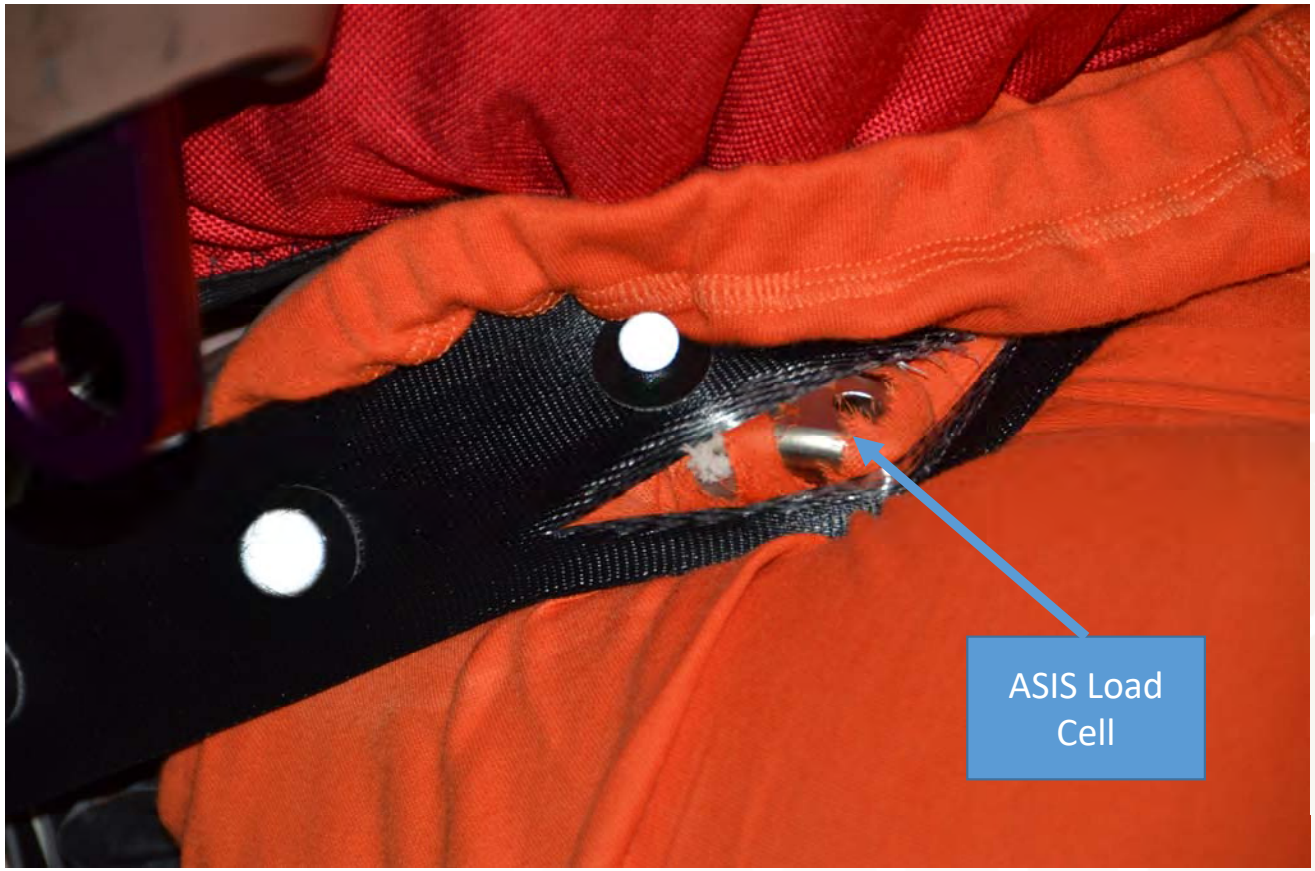
Submarining

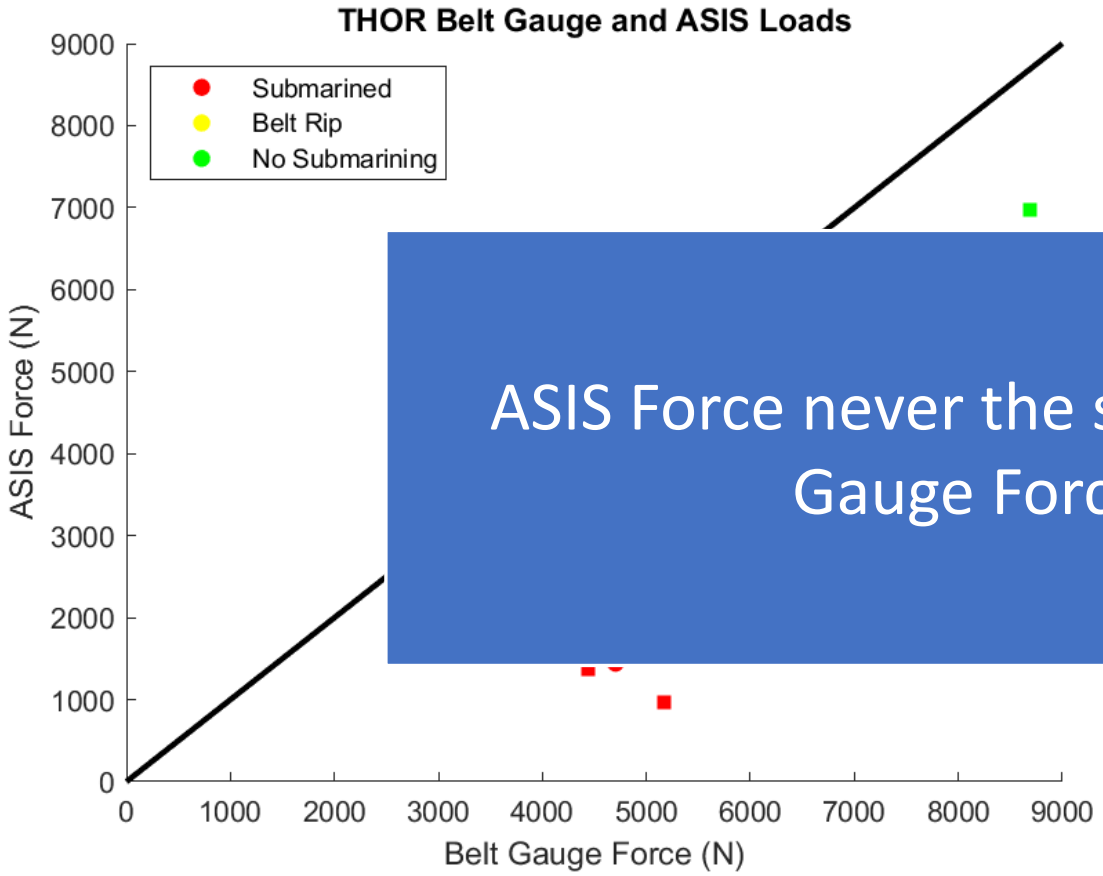
Notch to Belt Angle Target: 82 degrees

A Third Outcome?

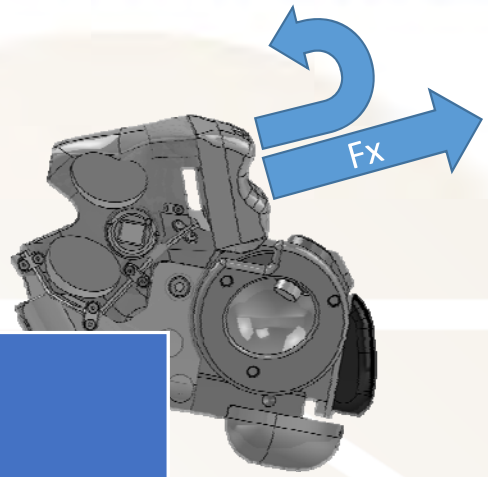


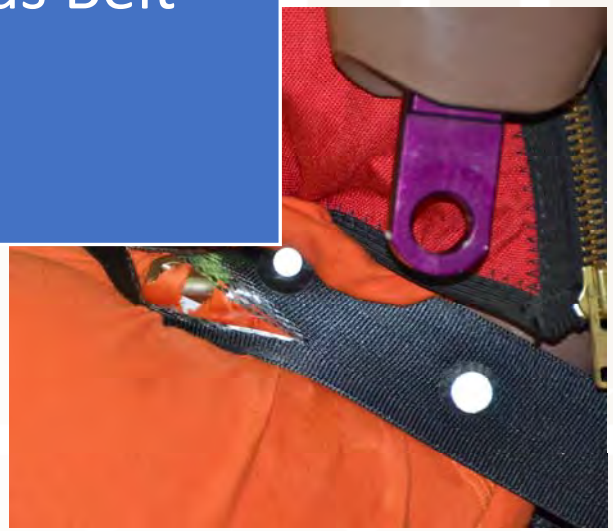
Did THOR Submarine?





ASIS Force never the same as Belt Gauge Force

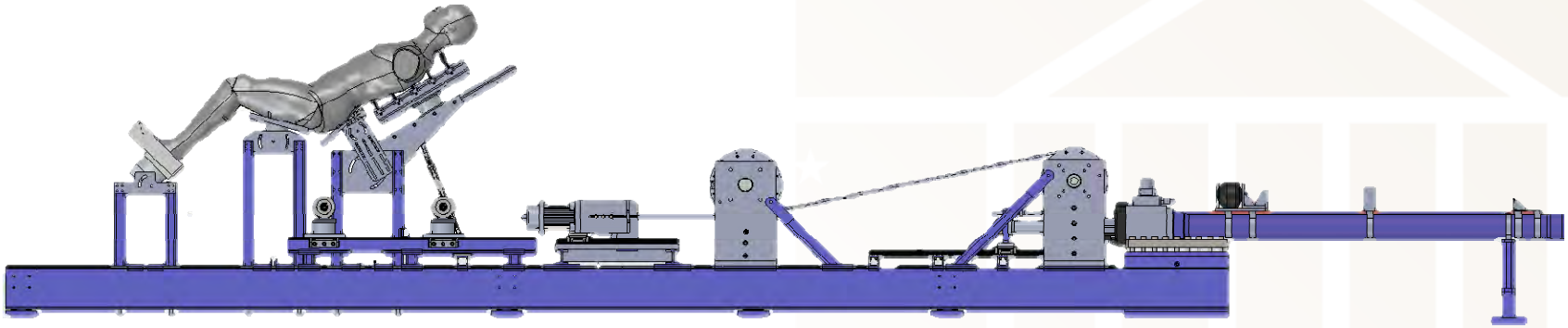




Goal 1: Replicate pelvis fractures

Goal 2: Evaluate the tools available (ATDs)

Goal 3: Understand why/when submarining occurs



Most Complex Most Realistic

Less Complex, More Controllable

Most Controllable

RCCADS | Research Consortium for Crashworthiness in Automated Driving Systems

UNIVERSITY of VIRGINIA

Thank you!

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