HBM4VT – WG 2
Sled simulation setup

Uriot et al. 2015

SCIENCE
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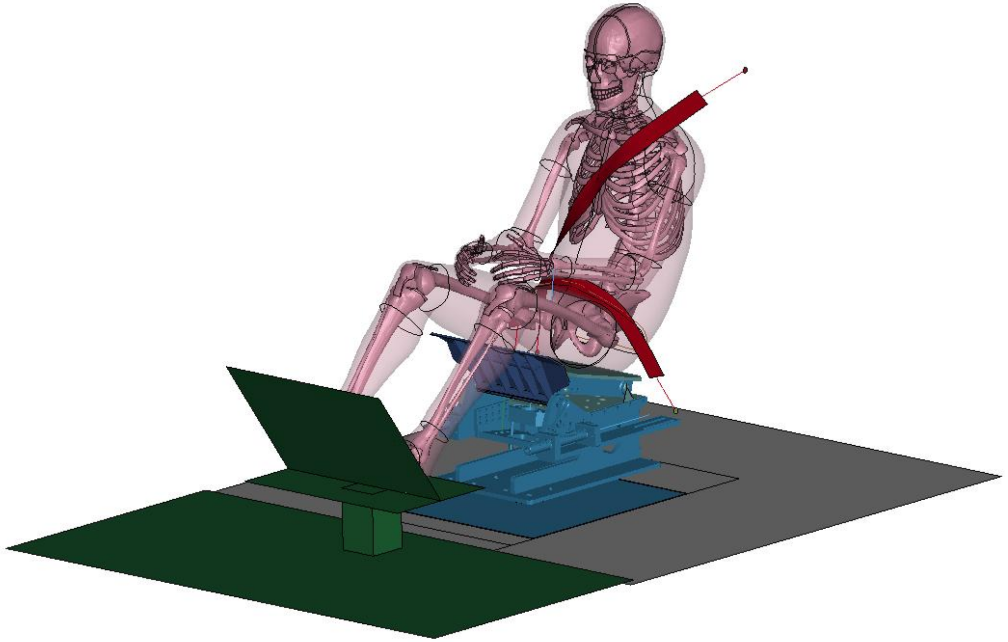
General Overview

Model Setup

Far side sled tests by Uriot et al. 2015



Key factors to replicate from PMHS tests:

- HBM seated on semi rigid seat
  - Seat belt fitted
  - Hands on thighs
  - Feet on footrest
- Sled velocity in x direction
- Forces in seat and seat pan rotation measured
- Belt forces in shoulder and lap belt measured

Development notes

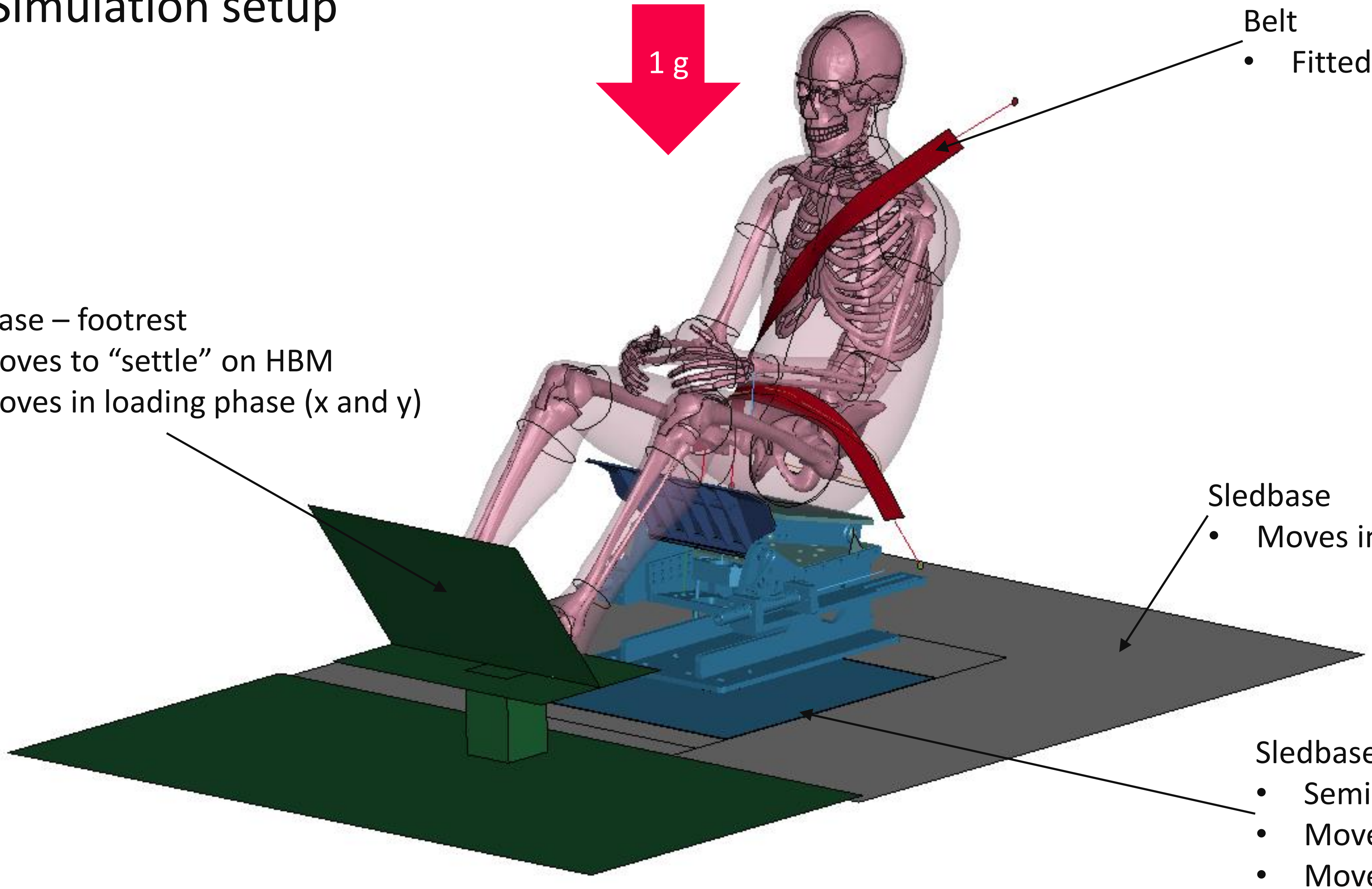
LS-Dyna version used for development:

- R12.2_217 mpp single precision (R12.2-217-gfcd6dde0c9)
- Time step: dt2ms = -4.44E-4 ms (tssfac = 0.9)

HBMs used in testing:

- THUMS v4.1 50th percentile male
- THUMS v4.1 95th percentile male
- VIVA+ v1.0.0 50th percentile female

Simulation setup



Belt
- Fitted via beams

Sledbase – footrest
- Moves to “settle” on HBM
- Moves in loading phase (x and y)

Sledbase
- Moves in loading phase (x and y)

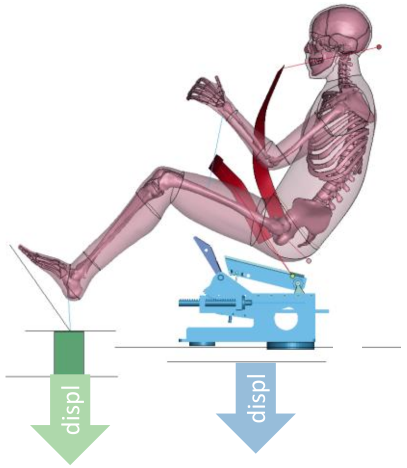
Sledbase – seat
- Semi rigid seat
- Moves to “settle” on HBM
- Moves in loading phase (x and y)

Simulation phases

Initial model

HBM positioning
- HBM in standard driver posture
- Two positioning methods

Seat and footrest transformation

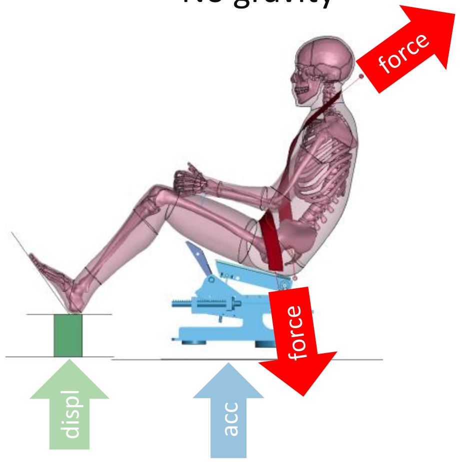


Seat
- Seat is moved downwards

Footrest
- Footrest is moved downwards

Settling phase

Testbed settling and belt fit
- HBM pelvis and spine constraint
- No gravity



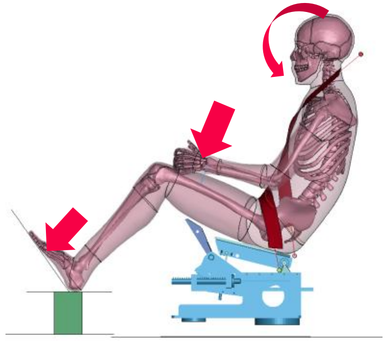
Seat
- Seat is accelerated upwards in z with 1g

Footrest
- Footrest is moved to target position

Belt fit
- Pretension is applied to fit belt to

HBM
- Anchorage points move to target position

Head rotation and extremities positioning
- HBM pelvis and spine constraint
- No gravity



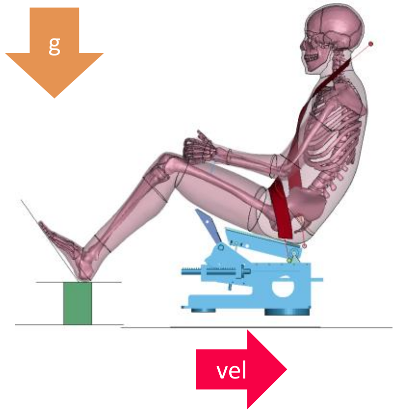
Head
- Head is rotated to reach a horizontal Frankfort plane

Feet
- Feet are moved to lie on footrest edge

Hands
- Hands are moved to target position

Loading phase

Load application
- HBM constraints released
- Gravity applied
- Sled loading applied



Load
- Sled velocity applied in x direction
- Gravity applied
- Belt load limiter

Simulation phases

Velocity of all HBM nodes set to 0

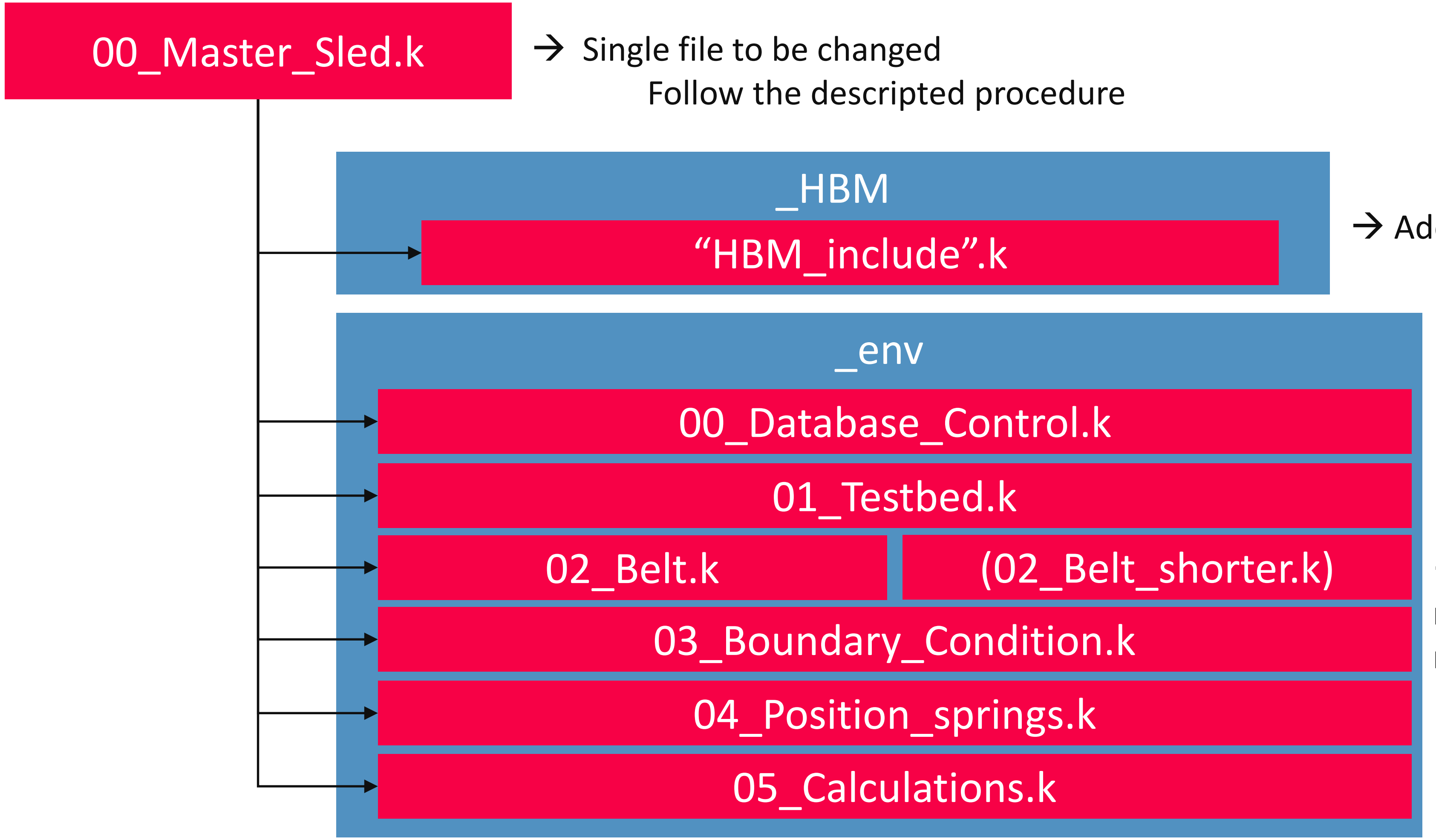
Settling phase	Loading phase
Pelvis and thorax of HBM constraint	No constraint
Heels move to target position on footrest	Positioning beams deleted
Hands move target position on thigh	Positioning beams deleted
Head is rotated to target orientation	Positioning beams deleted
Footrest moves to initial position	Load movement applied
1g applied on seat to “settle” on HBM	Load movement applied
200N pretension force applied	Load limiter in both belts
No gravity active	Gravity applied

Time

SetHBM *tload*

loadSt

Overview – belt load case



→ Single file to be changed
Follow the descripted procedure

→ Add your HBM-include in the folder „_HBM“

→ Shorter belt model provided in case of too much pull in in settling phase. Use only if necessary.

Procedure

Setting the parameters

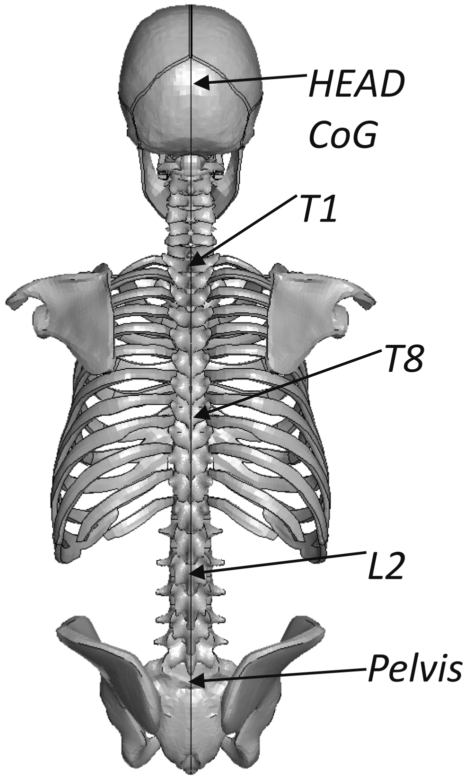
Set the include file

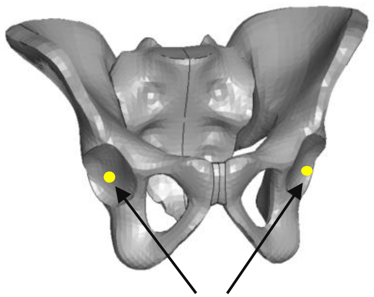
1) Put the main HBM file in the folder directory "_HBM"
2) Open the main HBM file in a pre-processor
3) Open the file 00_Master_Sled.k in a text editor
4) Define the main HBM file in the I N C L U D E S section
5) Follow the instructions from STEP 1 to STEP 6

- Note: If you need to change previously defined parameters, walk through the subsequent steps again and check if parameters need to be updated. E.g. the coordinates of the landmarks need to be updated, if the position of the HBM changes.

Instrumentation requirements

- Equip your HBM with the required output
  - Head CoG
    - *ELEMENT_SEATBELT_ACCELEROMETER required to provide local output
  - T1, T8, L2, Acetabulum centres (left and right), and Pelvis
    - *DATABASE_HISTORY_NODE_ID
    - Refer to following public documents:
      - Vertebrae, Acetabulum centres (left & right): TB024 Pedestrian Human Model Certification, Annex B
      - Pelvis: Report on PMHS 494, 492. ATD Thoracic response test development, NHTSA, 2011
  - Strains in cortical bones of pelvis and ribs
- Note: The required output rate is defined in the file “00_Database_Control.k”
  - 10kHz for contact and nodal outputs since CFC filtering is applied in Jupyter notebook
  - The output rate for strain output is defined via a curve to only generate data in the crash phase
- Update all NODE and OBJECT IDs in the HBM ID-file in “...\data\metadata” accordingly (see THUMS file for example)





Acetabulum centres (left & right)

Overview on stepwise simulation setup (see following slides)

1) Definition of the seat configuration
2) Definition of global HBM parameters
3) Definition of the HBM position and orientation
4) Define ID for contact sets and constraints
5) Check for intersections of HBM to testbed
6) Define node for pelvic angle measurement
7) Define attachment nodes for positioning beams
8) Run simulation and check results

Overview on stepwise simulation setup (see following slides)

1) Definition of the seat configuration

Goal:

- Define the desired seat configuration

Overview on stepwise simulation setup (see following slides)

1) Definition of the seat configuration
2) Definition of global HBM parameters
3) Definition of the HBM position and orientation

Goal:

- Set factor to scale environment to the unit system of the HBM
- Define the position and orientation of the HBM
- Use this point as origin and rotate HBM to bring it in supine position

Overview on stepwise simulation setup (see following slides)

1) Definition of the seat configuration
2) Definition of global HBM parameters
3) Definition of the HBM position and orientation
4) Define ID for contact sets and constraints
5) Check for intersections of HBM to testbed

Goal:
- Define sensible HBM contact set
- Move footrest, seat and backrest to avoid intersections to HBM

Overview on stepwise simulation setup (see following slides)

1) Definition of the seat configuration
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6) Define node for pelvic angle measurement

Goal:

- Define the nodes for time history output

Overview on stepwise simulation setup (see following slides)

1) Definition of the seat configuration
2) Definition of global HBM parameters
3) Definition of the HBM position and orientation
4) Define ID for contact sets and constraints
5) Check for intersections of HBM to testbed
6) Define node for pelvic angle measurement
7) Define attachment nodes for positioning beams

Goal: Define how extremities are moved during settling

Overview on stepwise simulation setup (see following slides)

1) Definition of the seat configuration
2) Definition of global HBM parameters
3) Definition of the HBM position and orientation
4) Define ID for contact sets and constraints
5) Check for intersections of HBM to testbed
6) Define node for pelvic angle measurement
7) Define attachment nodes for positioning beams
8) Run simulation and check results

Goal: Adapt settling or load time if necessary

STEP 1

Definition of the seat configuration

Define the desired seat configuration (set only one flag to 1)

- *SCfr* = 1: front seat configuration (Uriot et al. 2015)
- *SCre* = 1: rear seat configuration (Uriot et al. 2015)
- *SC1* = 1: Seat configuration 1 (Uriot et al. 2018)
- *SC1* = 2: Seat configuration 2 (Uriot et al. 2018)
- *SC1* = 3: Seat configuration 3 (Uriot et al. 2018)

Locations given in the local coordinate system of the simulation model, where the origin is at the mid of the rear edge of the seat pan

	front seat configuration	rear seat configuration	Seat configuration 1	Seat configuration 2	Seat configuration 3
Anti-submarining ramp rotation [°]	32	12	12	12	12
Seat pan side springs stiffness [N/mm]	128	37	37	19	19
Sub pan spring stiffness [N/mm]	123	36.7	36.7	18	18
Sub pan initial vertical position [mm]	0	-30	-30	-30	-30
Location of upper shoulder belt attachment point x/z [mm]	252/725	232/700	232/700	232/700	232/700
Location of lower shoulder belt attachment point x/z [mm]	14/-1	114/19	114/19*	59/20*	59/20*
Location of lap belt attachment points x/z [mm]	-41/-53	59/-33	59/-33*	109/-13*	109/-13*
Location of H-point x/z [mm]	-65/104	-74/106	-93/100	-129/97	-72/97

* algebraic sign switched based on Uriot 2015

STEP 2

Definition of global HBM parameters

Define the scale factors depending on the unit system of the HBM

- *U_Scal*: 0.001 for unit system t-mm-s
- *U_Scal*: 1 for unit system kg-mm-ms

→ The testbed environment will be scaled by *U_Scal* to the preferred unit system

Define the correct unit system in the assessment Jupyter notebook

- ms_mm_kg
- s_mm_ton

Attention: all parameters in the **main key file** need to be defined in the unit system **kg-mm-ms**

Define if the used HBM wears shoes or not

- *Shoes:* set to 0 if HBM wears shoes
- *Shoes:* set to 10 if HBM wears NO shoes

→ Footrest is positioned +10mm in x and z direction if HBM doesn‘t wear shoes (represents thickness of sole)

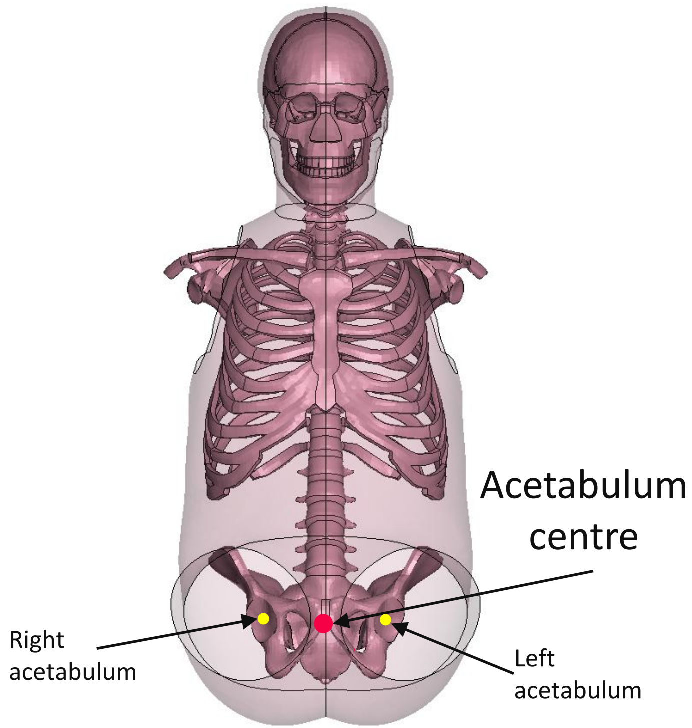
STEP 3

Definition of the HBM position and orientation

Define the coordinates of the location of the acetabulum centre point (AC) between the left and right acetabulum (in midsagittal plane):

- *x_AC*: x-coordinate of AC in the default HBM position with respect to the global coordinate system
- *y_AC*: y-coordinate of AC in the default HBM position with respect to the global coordinate system
- *z_AC*: z-coordinate of AC in the default HBM position with respect to the global coordinate system

→ The HBM will be transferred to the H-point of the seat



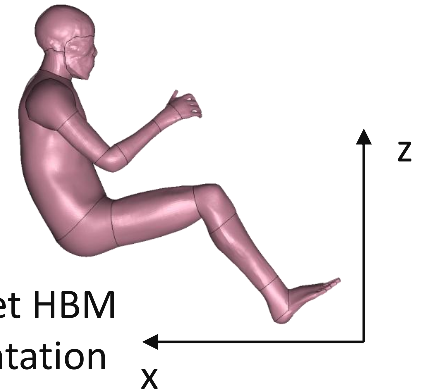
Default HBM position

Check the actual HBM orientation and compare to the target orientation as illustrated

Define the flag to 1 or -1 for all axes:

- *x_rt*: "1" for correct axis orientation and "-1" to rotate the model 180deg about the x axis
- *y_rt*: "1" for correct axis orientation and "-1" to rotate the model 180deg about the y axis
- *z_rt*: "1" for correct axis orientation and "-1" to rotate the model 180deg about the z axis

→ HBM will be rotated to reach target orientation



Target HBM orientation

STEP 4
Define ID for contact sets and ID offset if necessary

Define the part set of the HBM
- *P_hbm*: ID of the set including all HBM parts

→ This part set will be damped

Define the part set of all skin parts of the HBM
- *P_ski*: ID of the set including all skin parts of the HBM

→ This part set will be in contact to the testbed

Define the part set of the HBM body without arms and lower legs
- *P_bdy*: ID of the set including the HBM body without arms and lower legs

→ This part set will be in contact to the belt in the settling phase

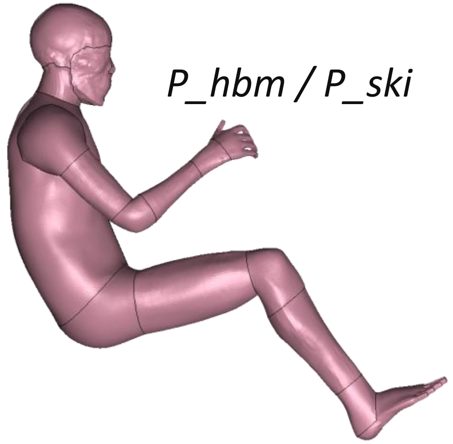
Define the mass of the HBM without legs
- *M_HBMt*: Mass of the HBM without legs in [kg]

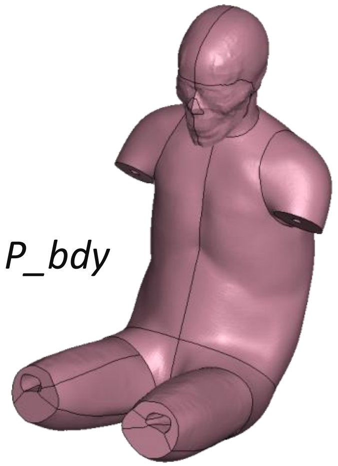
→ The mass of the seat will matched to the mass of the HBM without legs to reproduce a realistic settling behaviour

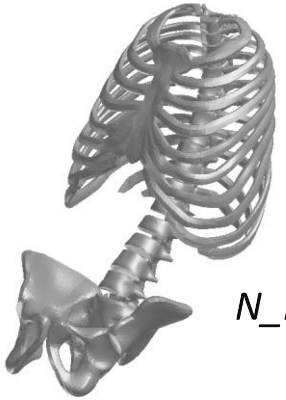
Define the node set including several nodes on the bones of the pelvis and the thorax (e.g. choose three nodes per bone, not all nodes of a bone are required to be constrained)
- *N_bone*: ID of the set including nodes on bones of pelvis, spine and ribs

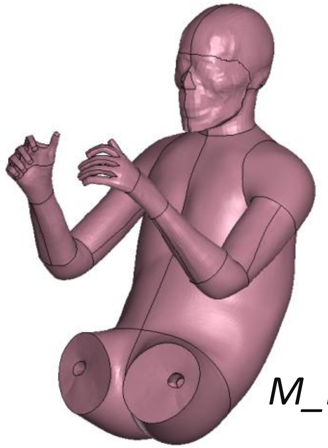
→ This node set will be constrained in the settling phase (do not choose nodes belonging to rigid materials or rigid bodies)

IF the testbed shares node IDs with HBM, define an ID offset for the HBM
- *IDoff*: default: 0.


P_hbm / P_ski


P_bdy


N_bone


M_HBMt

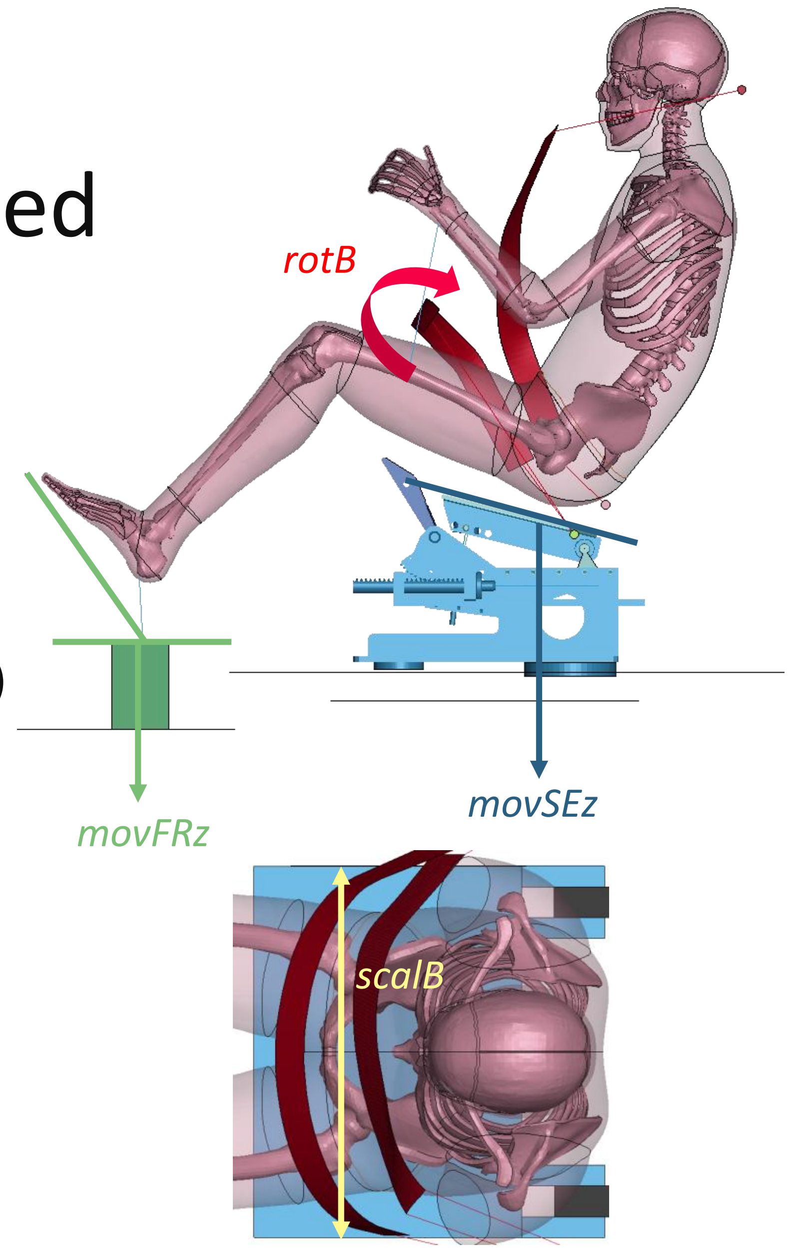
STEP 5
Check for intersections between HBM and sled

Save the file “00_Master_Sled.k” and open it in a pre-processor

IF the seat has intersections to the feet, move the seat in z direction
- *movSEz*: moving distance of the seat in z direction (positive value = downwards)

IF the footrest has intersections to the feet, move the footrest in z direction
- *movFRz*: moving distance of the footrest in z direction (positive value = downwards)

IF the lap belt has intersections to the HBM:
- rotate the lap belt about the y-axis
    - *rotB*: rotation angle in degrees about y axis (positive value = rotation upwards)
- scale the lap belt in y-axis
    - *scalB*: scale factor of lap belt in y-axis (positive value = lap belt extends to the side)



STEP 6

Define node for pelvic angle measurement

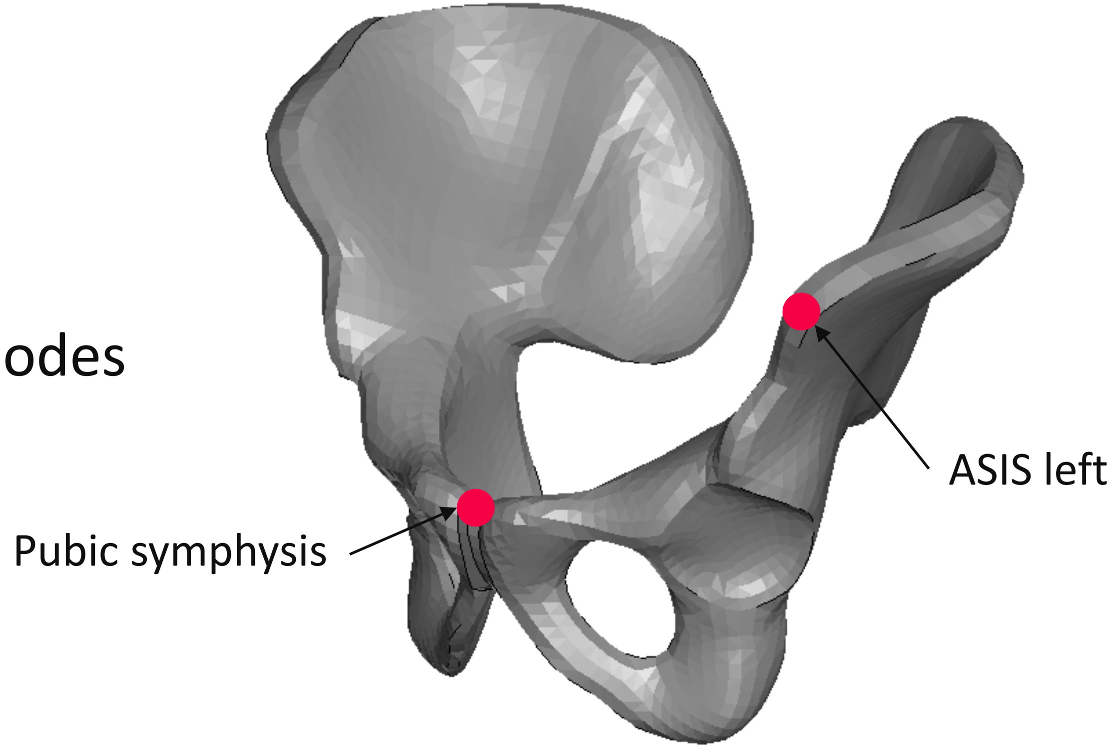
Define the node ID on the left ASIS

- N_ASIS: Node on left ASIS

Define the node ID on the pubic symphysis

- N_PS: Node on pubic symphysis

→ A nodal history output will be defined for this nodes



STEP 7

Define attachment nodes for positioning beams

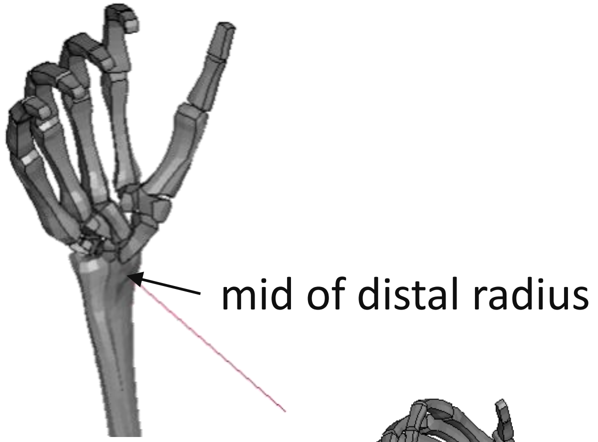
Define the node IDs for the landmarks to be positioned

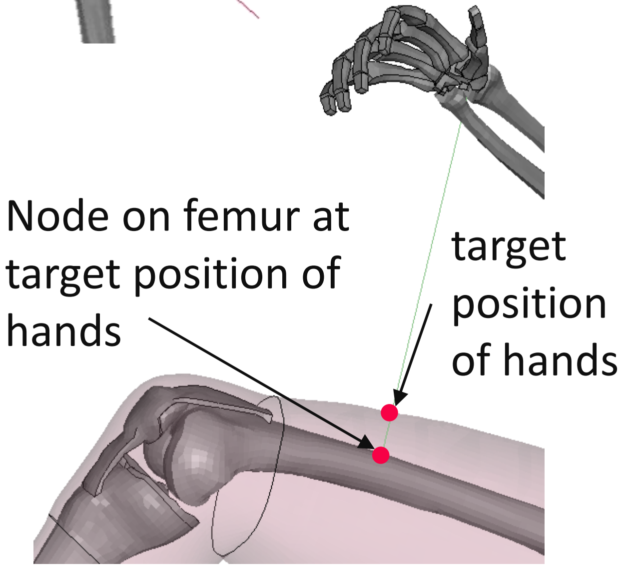
ri = right, le = left

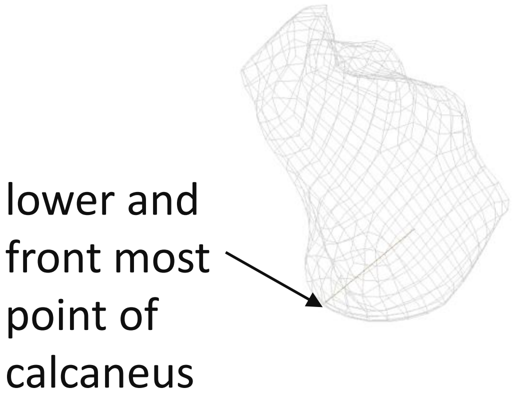
- *N_rari/N_rale*: Node at mid of distal radius
- *N_tari/N_tale*: Node on femur at target position of hands
- *N_heri/N_hele*: Node at lower and front most point of calcaneus
- *N_orri/N_orle*: Node at inferior margin of orbit
- *N_acri/N_acle*: Node at superior margin of external auditory canal

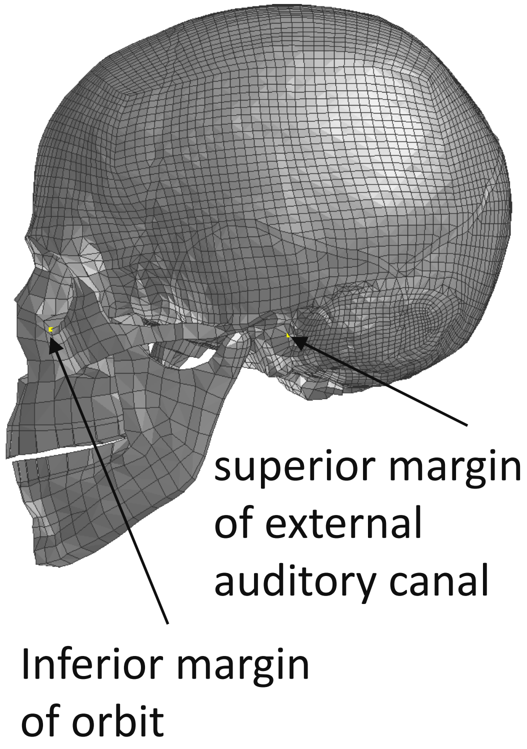
Coordinates of landmark nodes in updated “00_Master_Sled.k” file

- X...: x-coordinates of chosen landmarks in positioned model
- Y…: y-coordinates of chosen landmarks in positioned model
- Z…: z-coordinates of chosen landmarks in positioned model









STEP 8

Run simulation and check results

Check the d3plot and adapt the parameter if needed:

Measure the distance between the seat base and the sled base in the settled model

- Distance < 5mm: neither a change of z_set nor a rerun of the simulation is required.
- Distance > 5mm: insert the measured value for z_set, update the z-coordinates of the nodes in step 7 and rerun the simulation.
    - *z_set*: distance in z (insert a positive value, if the seat base is below the sled base)

→ After the settling phase, the seat will be at the same height as is the PMHS tests

IF settling phase is not long enough, change duration

- *SetHBM*: duration of settling phase (default: 400ms)

IF positioning beams do not fully compress, increase tension force (insert value in kN)

- *Fbeam*: default: 0.2 kN

Duration of testbed movement in ms. Change only IF load curve duration changes

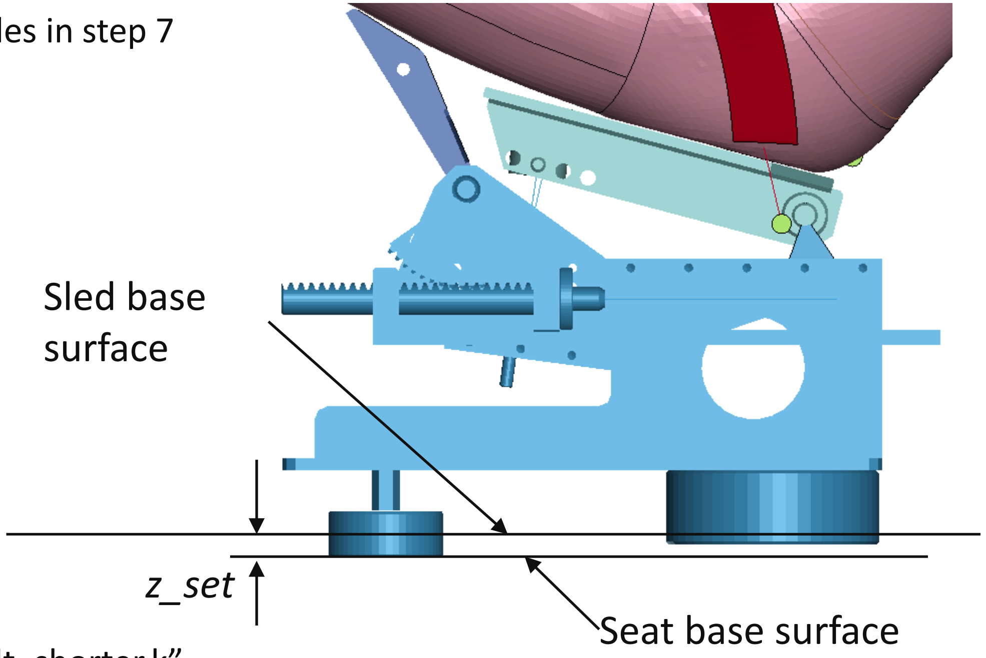
- *tload*: duration of loading curve (default 300ms)

IF contact issues occur, modify DEPTH flag for contact HBM to environment

- *Depth*: default: 23

IF the simulation terminated due to too much pull in of the lap, use the shorter belt model

- update the name of the belt include “02_Belt.k” in the file “00_Master_Belt.k” to “02_Belt_shorter.k”



Final checks

Check following values in the settled model (@ tSetHBM)

- Distance between seat base and sled base: ± 5 mm

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