SCIENCE
PASSION
TECHNOLOGY

HBM4VT – WG 2

Impactor simulation setup

Shaw et al. 2007

General Overview

Model Setup

Impactor tests by Shaw et al. 2007

Key factors to replicate from PMHS tests:

- Denuded thorax
  - Simulation to be performed with the entire HBM → thorax skin and flesh removed from contact
- HBM thorax in a supine position
  - Occupant HBM model is used → HBM rotated to reach a supine position
  - Repositioning of upper and lower extremities

Development notes

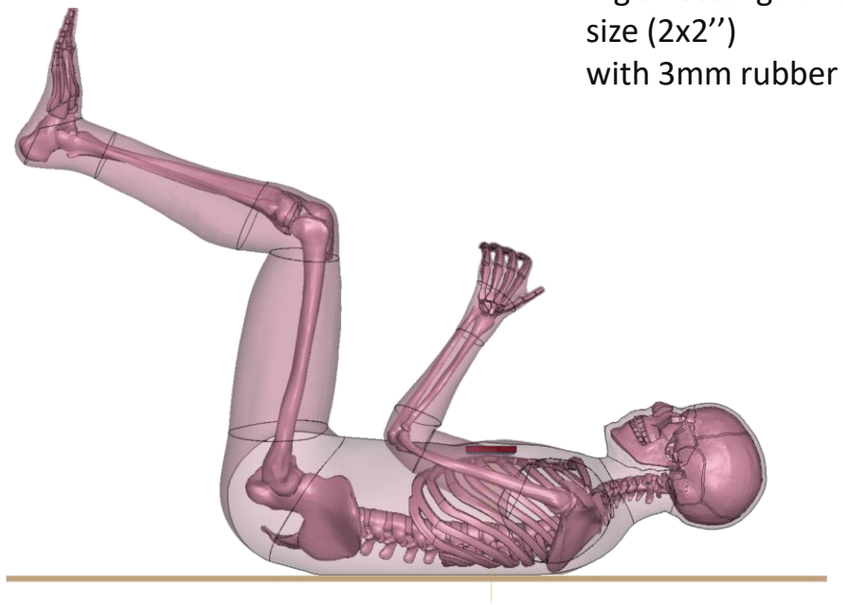
LS-Dyna version used for development:

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

HBMs used in testing:

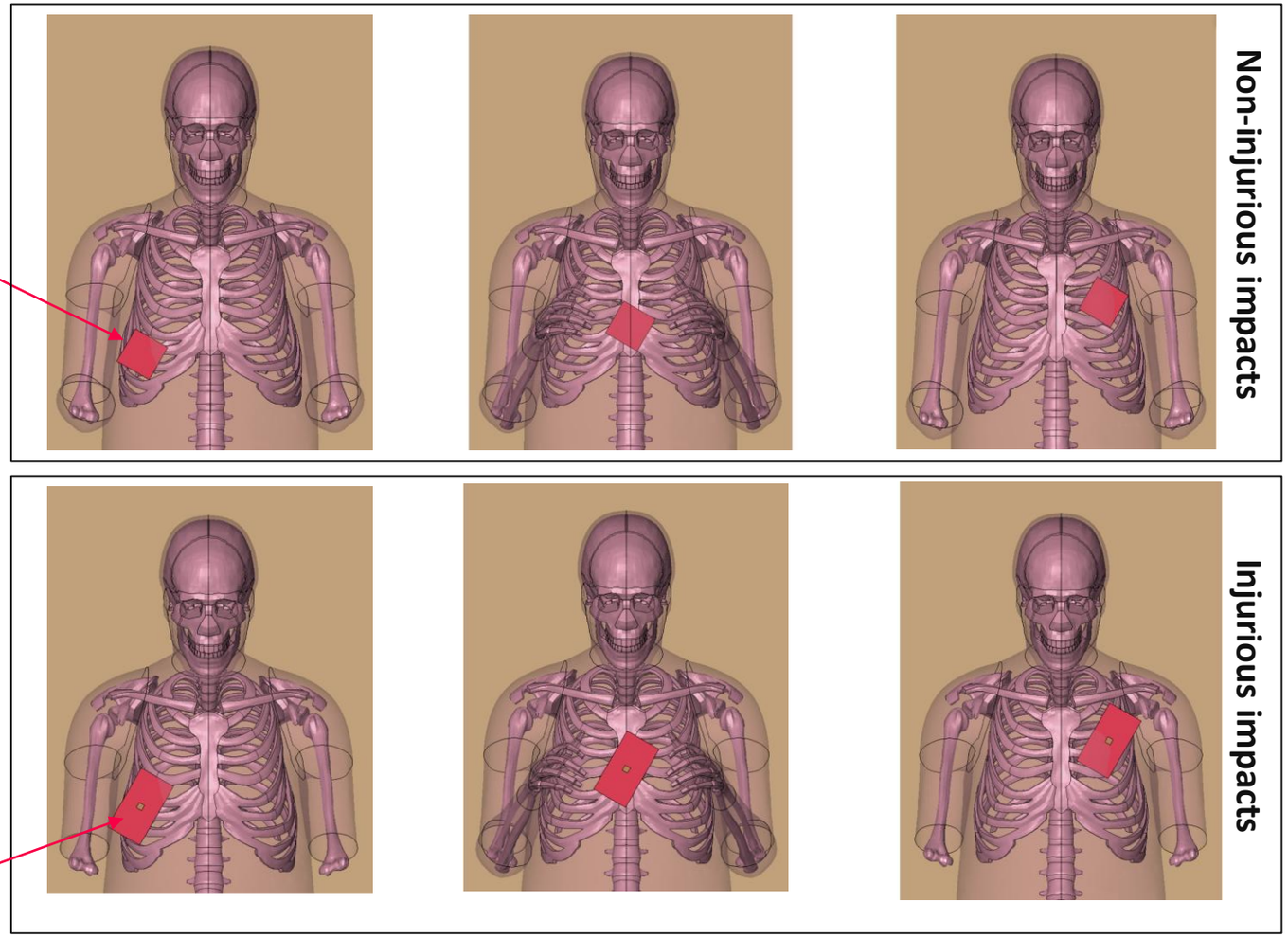
- THUMS v4.1 50th percentile male

Simulation setup



Rigid rectangular indentor of size (2x2'')
with 3mm rubber pad

Rigid rectangular indentor of size (2x4'')
with 3mm rubber pad



Impact at lower thorax

on the 6th right rib at the costal cartilage junction

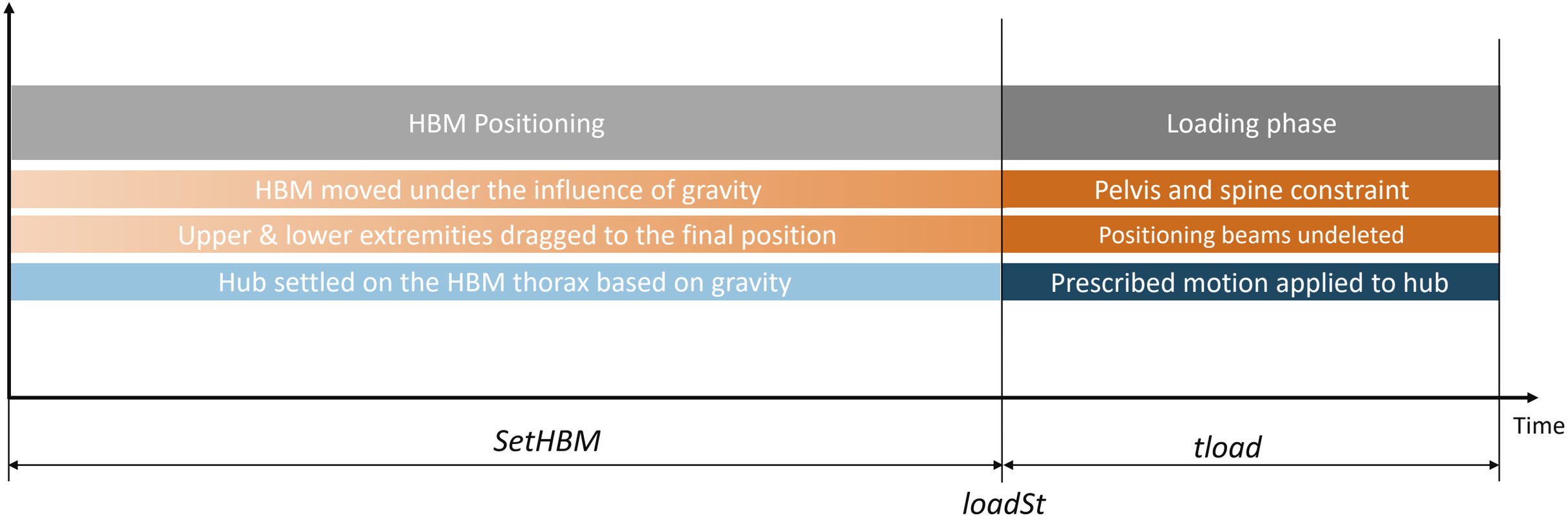
Impact at mid thorax

on the mid sternum of the 5th rib

Impact at upper thorax

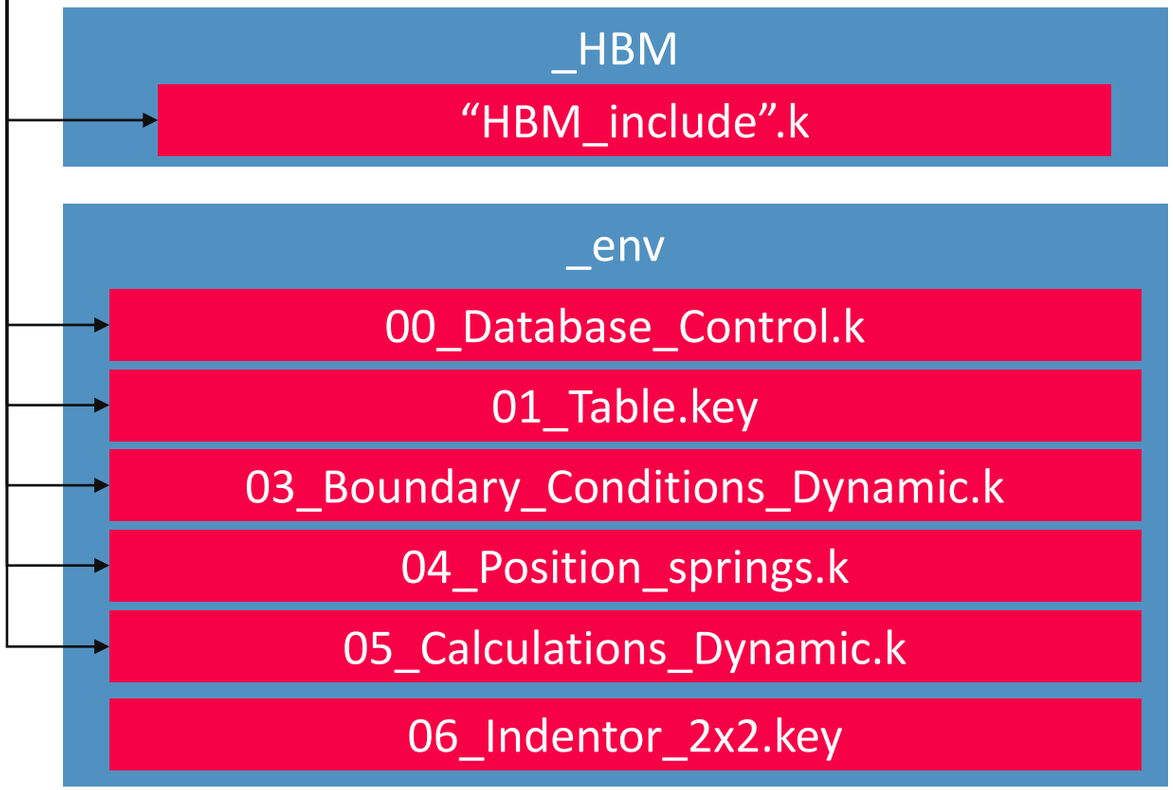
on the 3rd left rib at the costal cartilage junction

Simulation phases



Overview – hub load case (non-injurious 2x2)

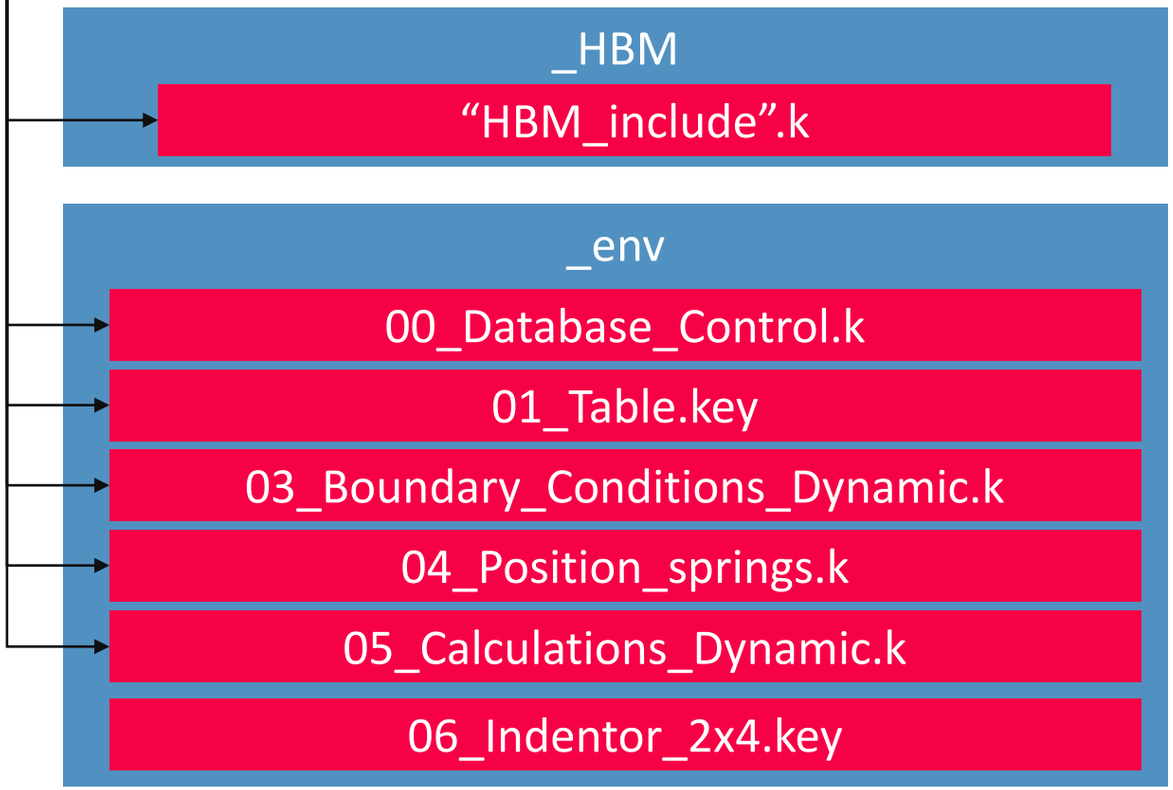
00_Master_Hub_Dynamic_2x2.k → Single file to be changed
Follow the descripted procedure



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

Overview – hub load case (injurious 2x4)

00_Master_Hub_Dynamic_2x4.k → Single file to be changed
Follow the descripted procedure



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

Procedure

Setting the parameters

Set up the include files

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_Hub.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 8 (following slides)

Instrumentation requirements

- Equip your HBM with the required output
  - Strains in cortical bones of 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)

Overview on stepwise simulation setup (see following slides)

1) Definition of the load case
2) Definition of global parameter
3) Define ID for contact sets and ID offset if necessary
4) Definition of the HBM rotations in order to reach target orientation
5) Definition of the posterior distance and location where the hub contacts HBM
6) Define attachment nodes for positioning beams and define Nodouts
7) Check for intersections of the HBM to the table and indentor
8) Run simulation and check results

Overview on stepwise simulation setup (see following slides)

1) Definition of the load case

Goal:

- Define the impact location

Overview on stepwise simulation setup (see following slides)

1) Definition of the load case

2) Definition of global parameter

Goal:

- Set factor to scale environment to the unit system of the HBM

Overview on stepwise simulation setup (see following slides)

1) Definition of the load case
2) Definition of global parameter
3) Define ID for contact sets and ID offset if necessary

Goal:

- Define sensible HBM contact set

Overview on stepwise simulation setup (see following slides)

1) Definition of the load case
2) Definition of global parameter
3) Define ID for contact sets and ID offset if necessary
4) **Definition of the HBM rotations in order to reach target orientation**

Goal:

- Determine the target orientation of the HBM

Overview on stepwise simulation setup (see following slides)

1) Definition of the load case
2) Definition of global parameter
3) Define ID for contact sets and ID offset if necessary
4) Definition of the HBM landmarks & rotations in order to reach target orientation
5) Definition of the posterior distance and location where hub contacts HBM

Goal:

- Table transformation
- Define the impact location landmarks

Overview on stepwise simulation setup (see following slides)

1) Definition of the load case
2) Definition of global parameter
3) Define ID for contact sets and ID offset if necessary
4) Definition of the HBM landmarks & rotations in order to reach target orientation
5) Definition of the location where hub contacts HBM
6) Define nodouts and check for intersection

- Define nodouts to determine chest depth
- Check for intersections pf the HBM to the table and the indentor

Overview on stepwise simulation setup (see following slides)

1) Definition of the load case
2) Definition of global parameter
3) Define ID for contact sets and ID offset if necessary
4) Definition of the HBM landmarks & rotations in order to reach target orientation
5) Definition of the location where hub contacts HBM
6) Define Nodouts and check for intersections of the HBM to the hub
7) Define attachment nodes for positioning beams

- Define how extremities are moved during positioning

Overview on stepwise simulation setup (see following slides)

1) Definition of the load case
2) Definition of global parameter
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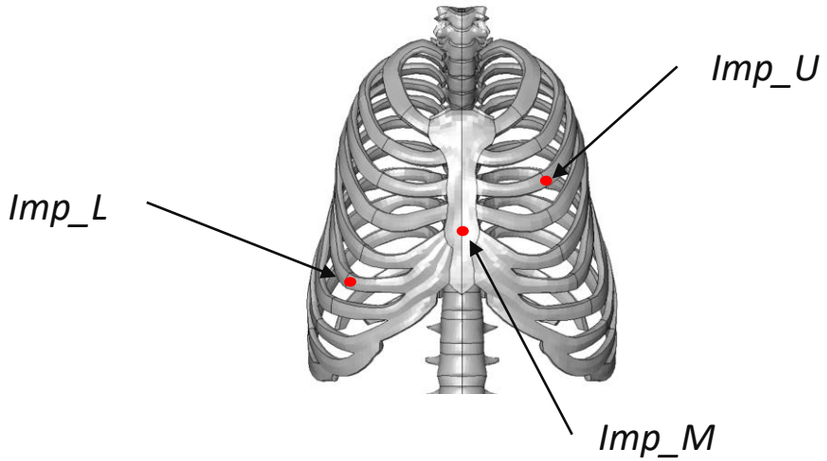
5) Definition of the location where hub contacts HBM
6) Define Nodouts and check for intersections of the HBM to the hub
7) Define attachment nodes for positioning beams
8) Run simulation and check results

S T E P 1
Definition of the load case

Define impact location

- *Imp_M*: set to 1 for impact on the mid sternum at rib 5 (set other parameter to 0)
- *Imp_U*: set to 1 for impact on the costal cartilage junction at the 3rd upper left rib (set other parameter to 0)
- *Imp_L:* set to 1 for impact on the costal cartilage junction at the 6th lower right rib (set other parameter to 0)



STEP 2
Definition of global HBM parameter

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 *UScal* to the preferred unit system

Define the correct unit system in the 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**

STEP 3

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_skin*: ID of the set including all skin parts

→ This part set will be in contact to the table

Define the part set of the HBM thorax without thorax skin, flesh and muscles

- *P_thx:* ID of the set with HBM thorax excluding the thoracic skin, flesh and muscles

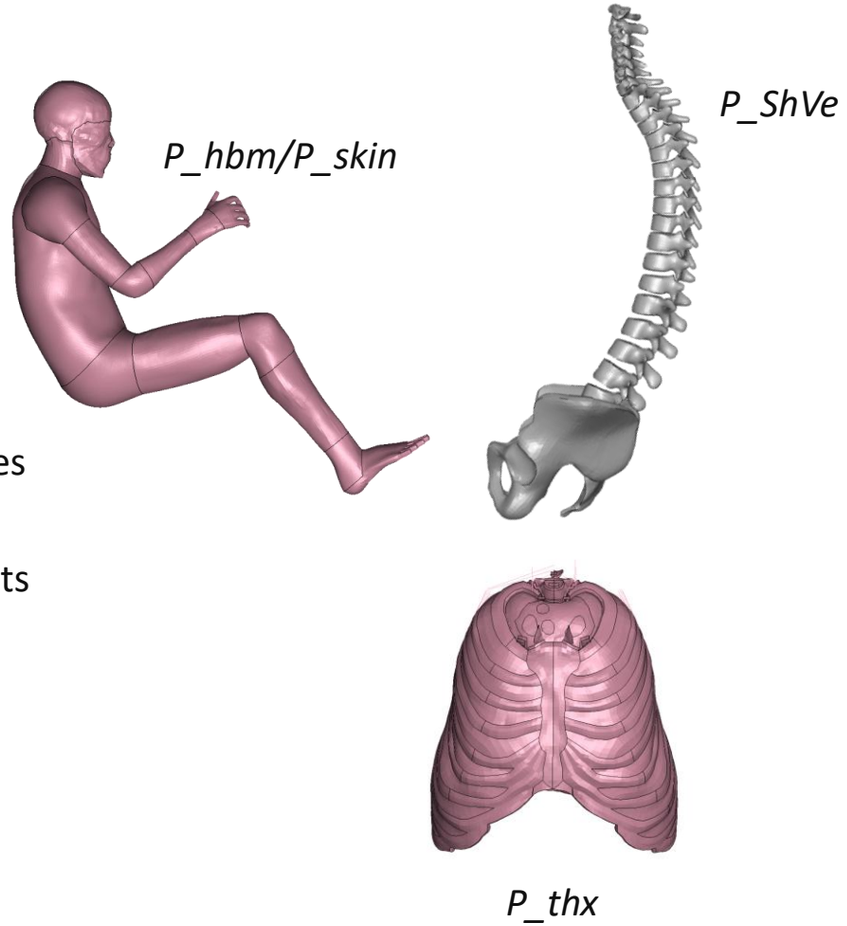
→ This part set will be in contact to the indentor

- *P_ShVe:* ID of the set including **shell parts** of all vertebrae and the pelvic iliac crests

→ This part set will be in constrained after settling

If the test setup shares node IDs with HBM, define an ID offset for the HBM

- *IDoff*: default: 0.



STEP 4

Definition of the HBM landmarks and rotations to reach target orientation

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

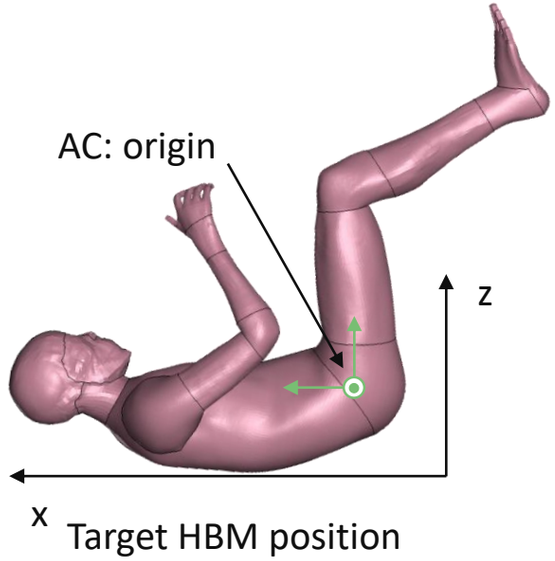
- *x_AC*: x-coordinate of AC in the default HBM position with respect to the global coordinate system
- *y_AC*: y-coordinate of AC in the default HBM position with respect to the global coordinate system
- *z_AC*: z-coordinate of AC in the default HBM position with respect to the global coordinate system

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

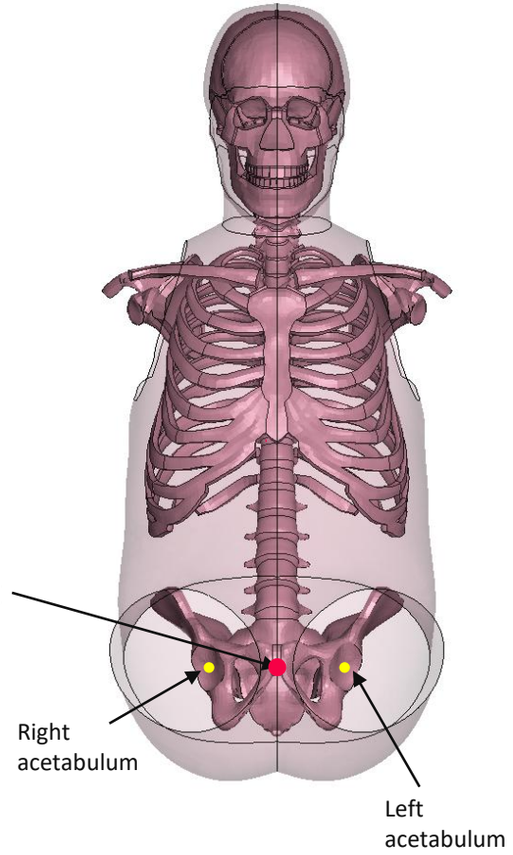
Define the flag for all axes:

- *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



Default HBM position

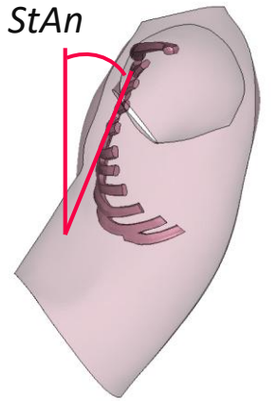


STEP 4
Definition of the HBM landmarks and rotations to reach target orientation

Measure the sternum angle between the center of attachment of 4th to 2nd rib relative to frontal plane

- *StAn*: angle in default posture of HMB used here

→ The HBM will be rotated in a way so that the sternum is parallel to the table



STEP 5

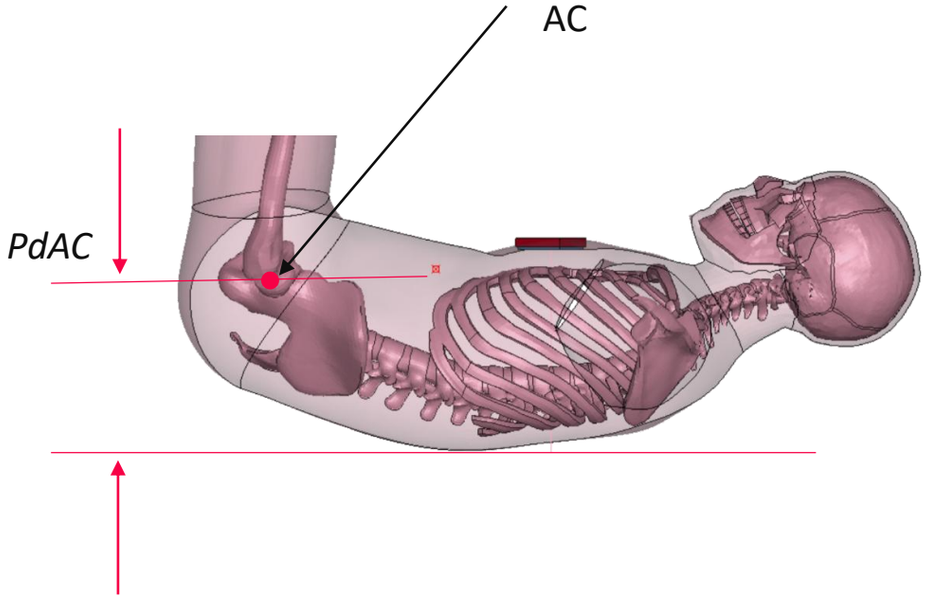
Definition of the posterior distance of the HBM

Save this file (00_Master_Hub_Dynamic.k) and open it in a pre-processor

Define the posterior distance between acetabulum center (AC) and the most posterior point of the HBM

- *PdAC:* posterior distance between AC and the most posterior point of the HBM

→ The table will be translated based on this value



STEP 5

Definition of the location where hub contacts HBM

Save this file (00_Master_Hub_Dynamic.k) and open it in a pre-processor

Define the coordinates of the mid sternum at rib 5

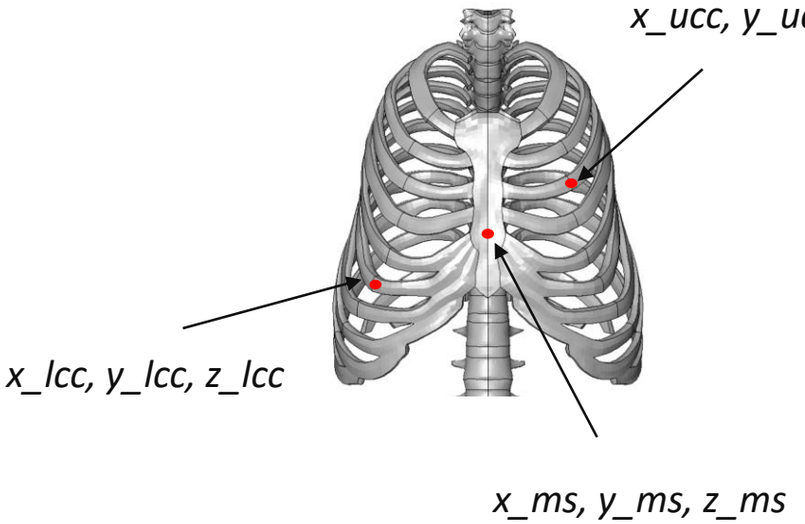
- *x_ms:* x-coordinate of the mid sternum at rib 5
- *y_ms:* y-coordinate of the mid sternum at rib 5
- *z_ms:* z-coordinate of the mid sternum at rib 5

Define the coordinates of the 3rd left rib costal cartilage (CC) junction

- *x_ucc:* x-coordinate of the 3rd left rib CC junction
- *y_ucc:* y-coordinate of the 3rd left rib CC junction
- *z_ucc: z-coordinate of the 3rd left rib CC junction*

Define the coordinates of the 6th right rib costal cartilage (CC) junction

- *x_lcc:* x-coordinate of the 6th right rib (CC) junction
- *y_lcc:* y-coordinate of the 6th right rib (CC) junction
- *z_lcc:* z-coordinate of the 6th right rib (CC) junction



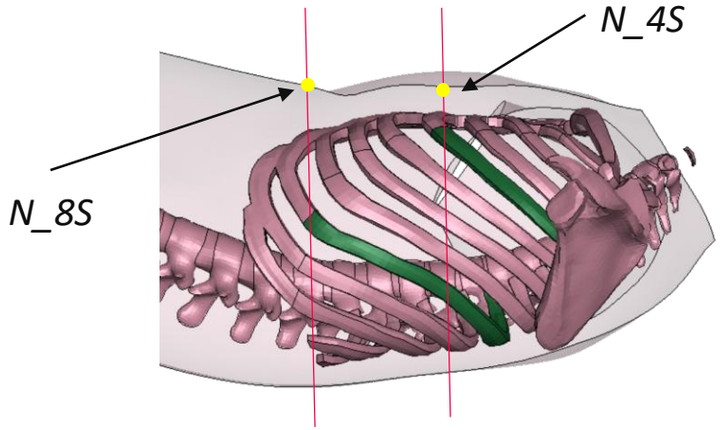
STEP 6

Define Nodouts and check for intersections of HBM to the hub and table

Define node ID on the anterior skin of the thorax on the 4th rib level on the sagittal plane

- *N_4S:* node ID on the anterior skin on the 4th rib level
- *N_8S:* node ID on the anterior skin on the 8th rib level

→ *DATABASE_HISTORY_NODE will be generated for these nodes



Check for intersections between HBM and the table

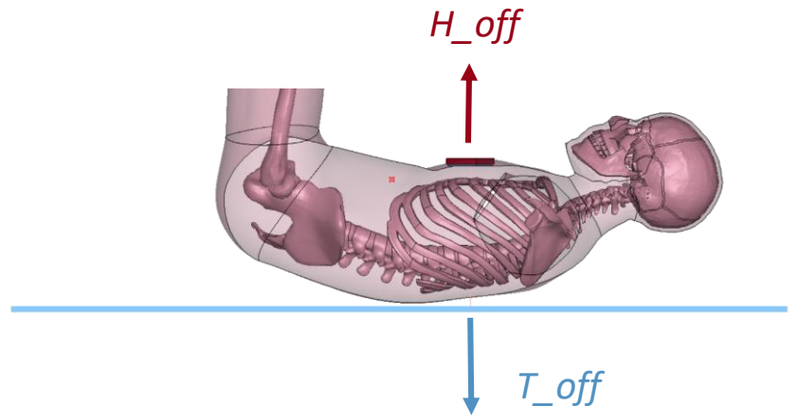
- *T_off:* offset z-value between the table and the HBM

→ Entering a positive value moves the table downwards

Check for intersections between HBM and the hub

- *H_off:* offset z-value between the hub and the HBM

→ Entering a positive value moves the hubupwards



Important!! Update these NODE IDs in the HBM_ID.def file in data\metadata accordingly

STEP 7
Define attachment nodes for positioning beams

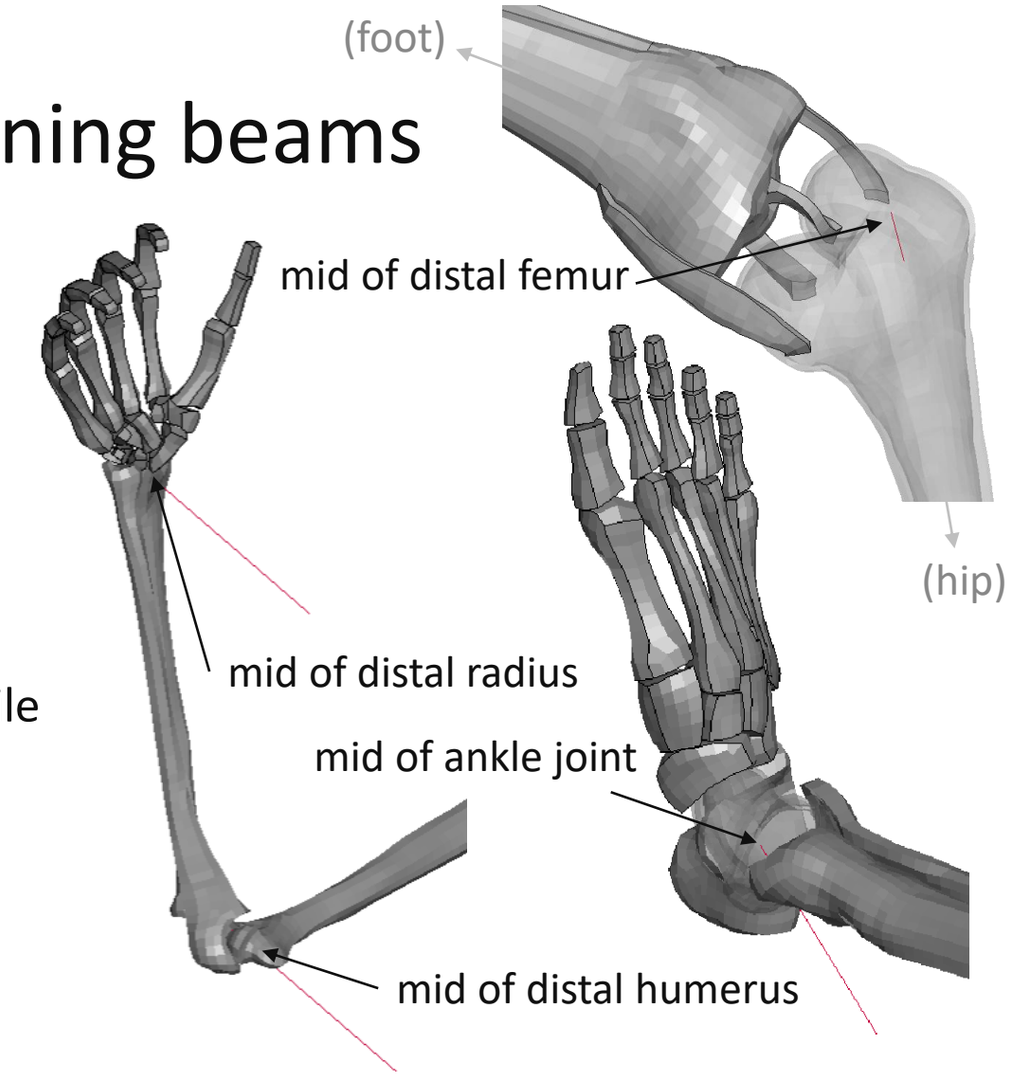
Define the Node IDs for the landmarks to be positioned

ri = right, le = left

- *N_elri/N_elle*: Node at mid of distal humerus
- *N_rari/N_rale*: Node at mid of distal radius
- *N_feri/N_fele*: Node at mid of distal femur
- *N_anri/N_anle*: Node at mid of ankle joint

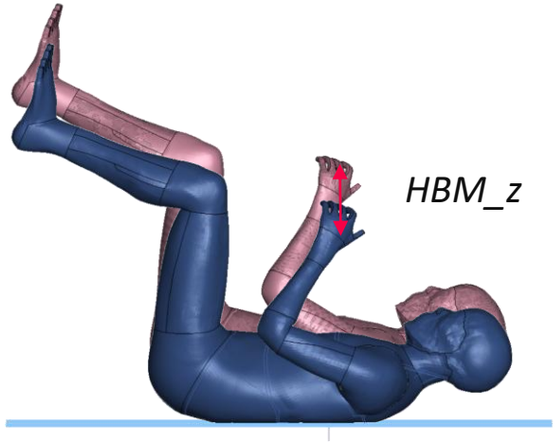
Coordinates of landmark nodes in updated “00_Master_Hub.k” file

- 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



S T E P 8

Run simulation and check results



Check the animation and adapt the following parameters if needed:

If HBM extremities move with respect to thorax, modify settling beam length

- *HBM_z*: length by which extremities are dragged down in HBM settling phase (default: 100mm)

If settling phase for HBM is not long enough, change duration

- *SetHBM*: time of HBM settling phase in ms (default: 350ms)

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

- *Fbeam*: default: 0.05 kN

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

- *Depth*: default: 25

If the impact location differs from the actual impact location after settling, go to S T E P 5 and update the new impact location coordinates after settling*

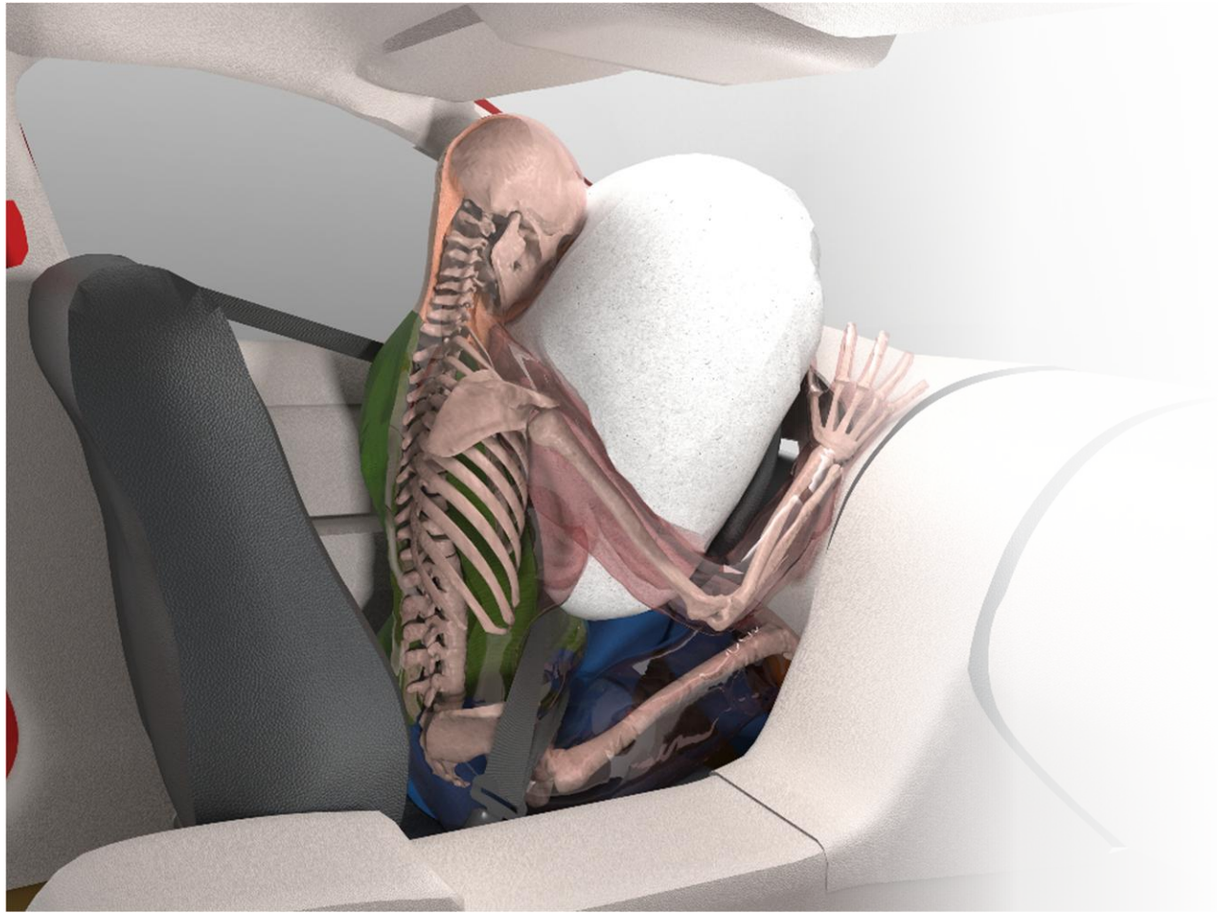
Example

If node ID 89004159 is the impact location node, with coordinates:

x_ms : 328.92
y_ms: 0
} Initial coordinates before settling

x_ms: 340.56
y_ms: -0.24
} Final coordinates after settling → Update these new coordinates in S T E P 5 and rerun the simulation

*NOTE: Only update x and y coordinates



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