SCIENCE
PASSION
TECHNOLOGY

HBM4VT – WG 2

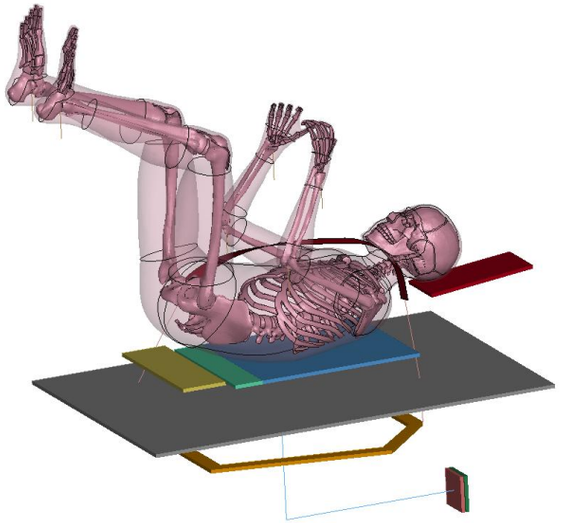
Table top simulation setup

Cesari & Bouquet 1990

General Overview

Model Setup

Tabletop tests by Cesari & Bouquet 1990



Key factors to replicate from PMHS tests:

- HBM in supine position*, settled on tabletop
- Extremities fixed in space (without affecting settling of HBM)
- Load applied via impactor
- Measure thoracic reaction force
  - Measured only in thoracic region (head and pelvis supported separately, in a way mimicking a typical occupant position)

*i.e. lying horizontally with the face and torso facing up

Development notes

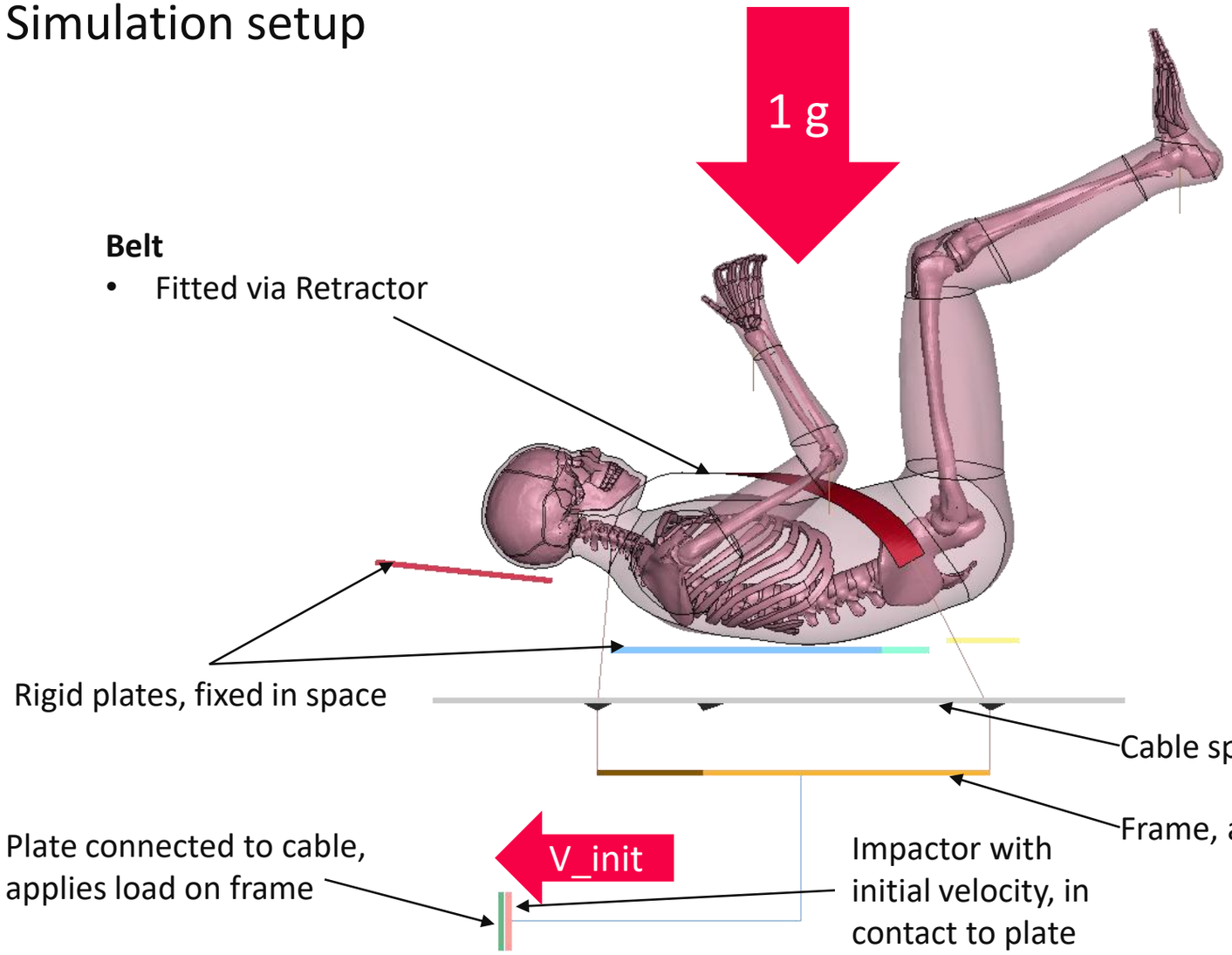
LS-Dyna version used for development:

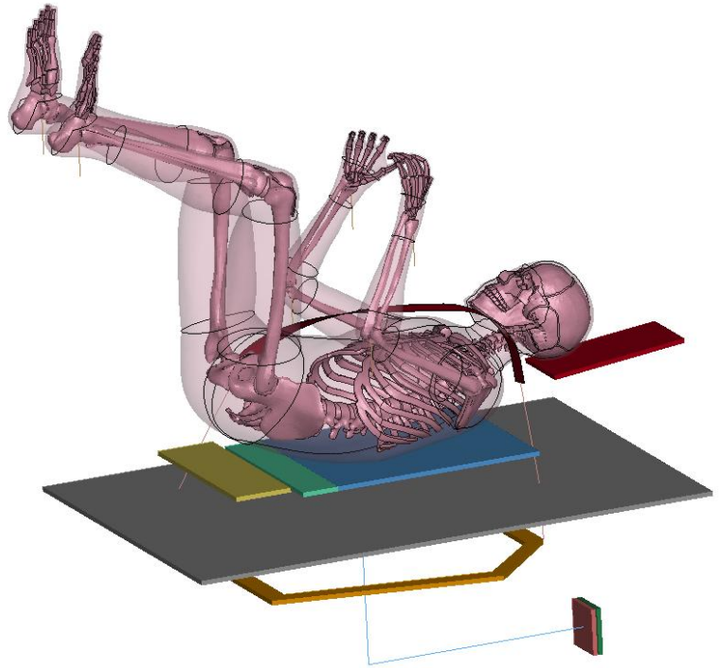
- R12.2_217 mpp single precision (R12.2-217-gfcd6dde0c9)
- Time step: dt2ms = -4.44E-4 ms (tssfac = 0.9)

HBMs used in testing:

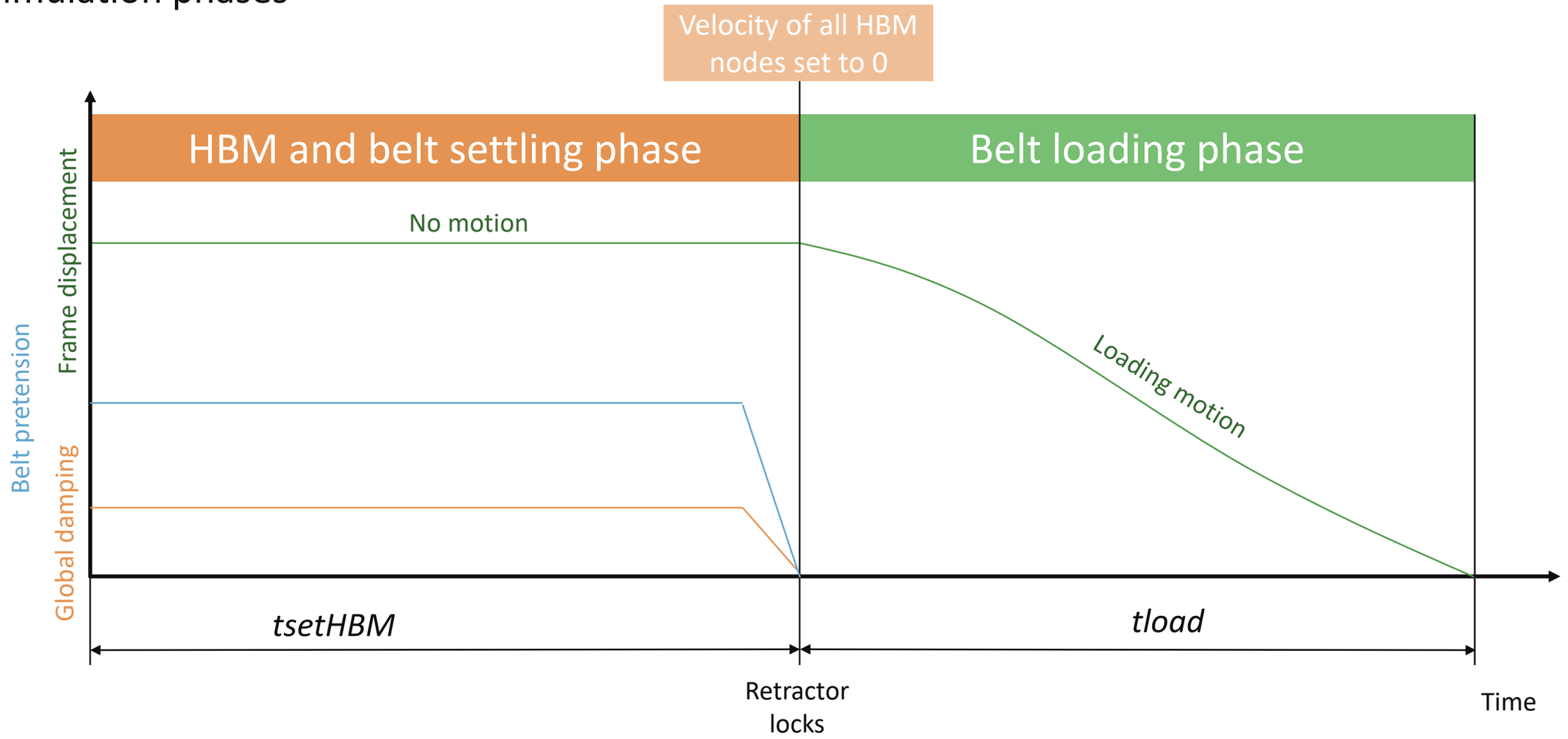
- THUMS v4.1 50th percentile male
- THUMS v4.1 95th percentile male
- VIVA+ v1.0.0 50th percentile female

Simulation setup

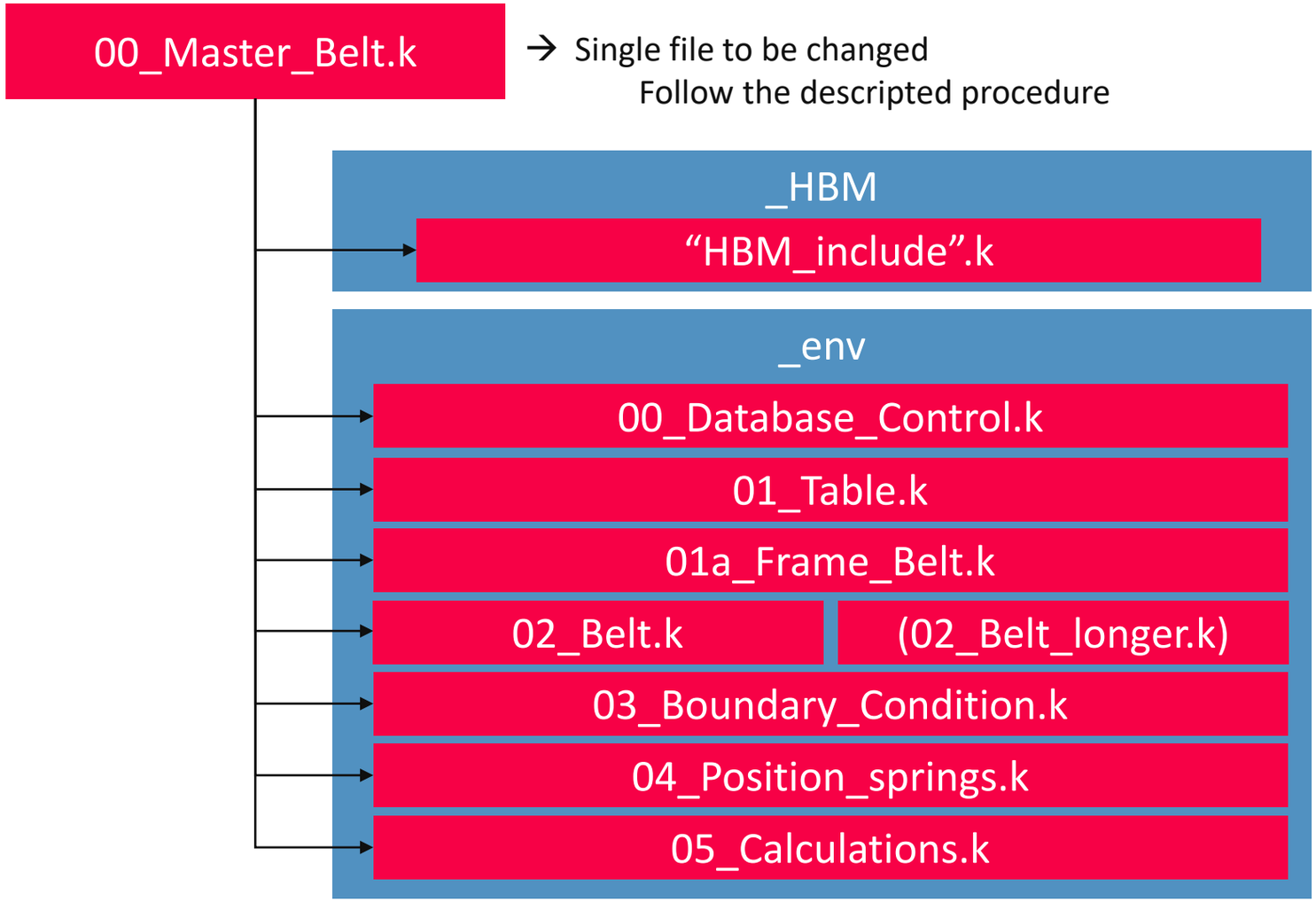




Simulation phases



Overview – belt load case



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_Belt.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 7

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 unit system of the HBM
2) Definition of the location where belt contacts HBM
3) Definition of the HBM rotations to reach target orientation
4) Check for intersections of HBM to table or to belt
5) Define set IDs for contact sets and database for nodal output
6) Define attachment nodes for positioning beams
7) Run simulation and check results

Overview on stepwise simulation setup (see following slides)

1) Definition of the unit system of the HBM
2) Definition of the location where belt contacts HBM
3) Definition of the HBM rotations to reach target orientation

Goal:

- Set factor to scale environment to the unit system of the HBM
- Locate point were belt should impact HBM in default HBM position
- Use this point as origin and rotate HBM to bring it in supine position
- Fine-tune rotation to provide good basis for settling

Overview on stepwise simulation setup (see following slides)

1) Definition of the unit system of the HBM
2) Definition of the location where belt contacts HBM
3) Definition of the HBM rotations to reach target orientation
4) **Check for intersections of HBM to table or to belt**

Goal:

- Move environment (tabletop, head support, pelvis support) and belt to remove any initial intersections via pre-defined model parameters

Overview on stepwise simulation setup (see following slides)

1) Definition of the unit system of the HBM
2) Definition of the location where belt contacts HBM
3) Definition of the HBM rotations to reach target orientation
4) Check for intersections of HBM to table or to belt
5) **Define set IDs for contact sets and database for nodal output**

Goal:

- Define sensible HBM contact set
- Define node for chest deflection measurement at HBM

Overview on stepwise simulation setup (see following slides)

1) Definition of the unit system of the HBM
2) Definition of the location where belt contacts HBM
3) Definition of the HBM rotations to reach target orientation
4) Check for intersections of HBM to table or to belt
5) Define set IDs for contact sets and database for nodal output

6) Define attachment nodes for positioning beams

Goal:

- Define how extremities are moved during settling and fixed during loading

Overview on stepwise simulation setup (see following slides)

1) Definition of the unit system of the HBM
2) Definition of the location where belt contacts HBM
3) Definition of the HBM rotations to reach target orientation
4) Check for intersections of HBM to table or to belt
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7) Run simulation and check results

S T E P 1
Definition of the unit system of the HBM

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

- *UScal*: 0.001 for unit system t-mm-s
- *UScal*: 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 2

Definition of the location where the belt crosses the sternum

Define the coordinates of the location of the center of the 4th intercostal space in midsagittal plane and on the front point of the sternum: "4th IS"

- *x_4IS*: x-coordinate of "4th IS" in the default HBM position in respect to the global coordinate system
- *y_4IS*: y-coordinate of "4th IS" in the default HBM position in respect to the global coordinate system
- *z_4IS*: z-coordinate of "4th IS" in the default HBM position in respect to the global coordinate system

→ The HBM will be transferred so that the node "4th IS" is at 0/0/0

Define the distance between "4th IS" and the most anterior point on the chest

- *Chdist*: distance in anterior direction

→ The belt (default positioned at 0/0/0) will be moved in anterior direction to avoid intersections to the HBM

Define the thickness of HBM chest

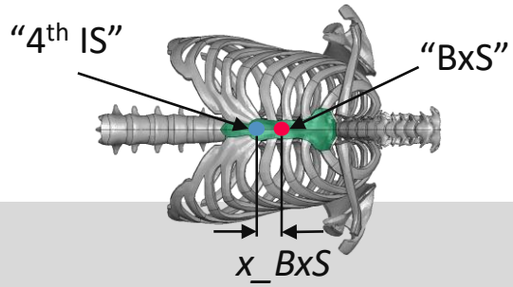
- *Thick*: distance in anterior direction

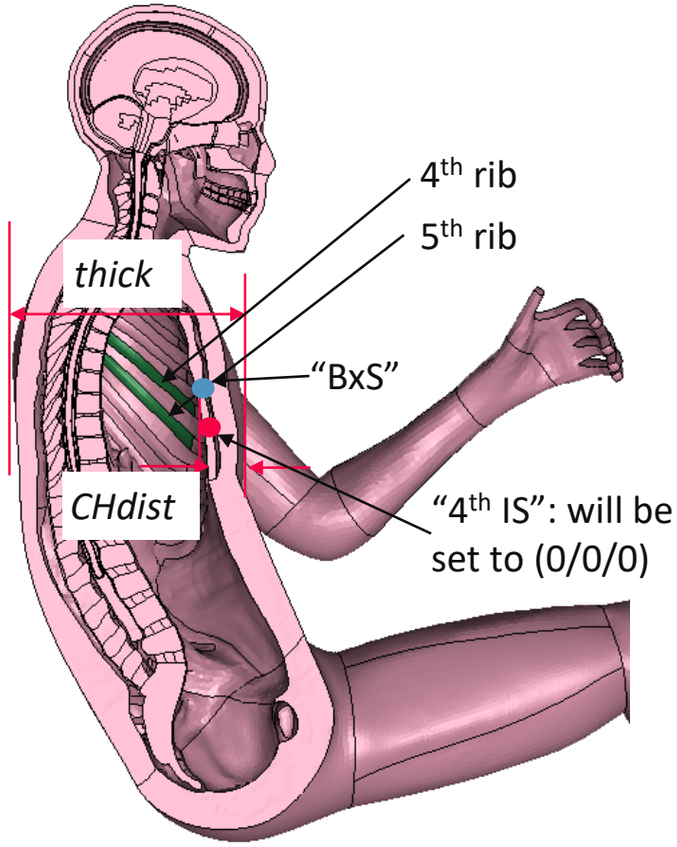
→ The table (default positioned at 0/0/0) will be moved in posterior direction to avoid intersections to the HBM

Define the distance between "4th IS" and "BxS" (BxS is in the mid of sternum)

- *x_*BxS: x-distance between "4th IS" and "BxS" (positive: cranial direction)

→ The belt will cross the sternum at this point





Default HBM position

STEP 3
Definition of the HBM rotations to reach target orientation

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

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

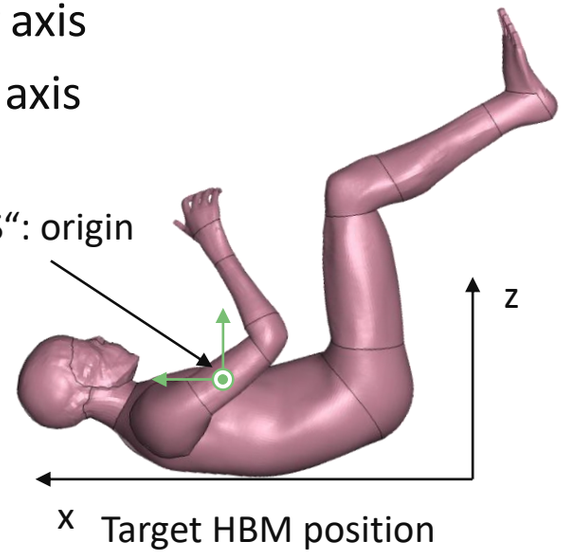
- *x_rt*: “1” for correct axis orientation and “-1” to rotate the model 180deg about the x axis
- *y_rt*: “1” for correct axis orientation and “-1” to rotate the model 180deg about the y axis
- *z_rt*: “1” for correct axis orientation and “-1” to rotate the model 180deg about the z axis

→ HBM will be rotated to reach target orientation

Define the rotation angle of the HBM about the y-axis to achieve a horizontal back angle

- *HBMrot*: set angle (positive = leaning forward)

→ HBM will be rotated about the y-axis



STEP 4

Check for intersections of HBM to table or to belt

Save the file “00_Master_Belt.k” and open it in a pre-processor
Check for intersections and set values if needed:

IF the test bed share node IDs with HBM, set an ID offset for the HBM
- *IDoff*: default: 0.

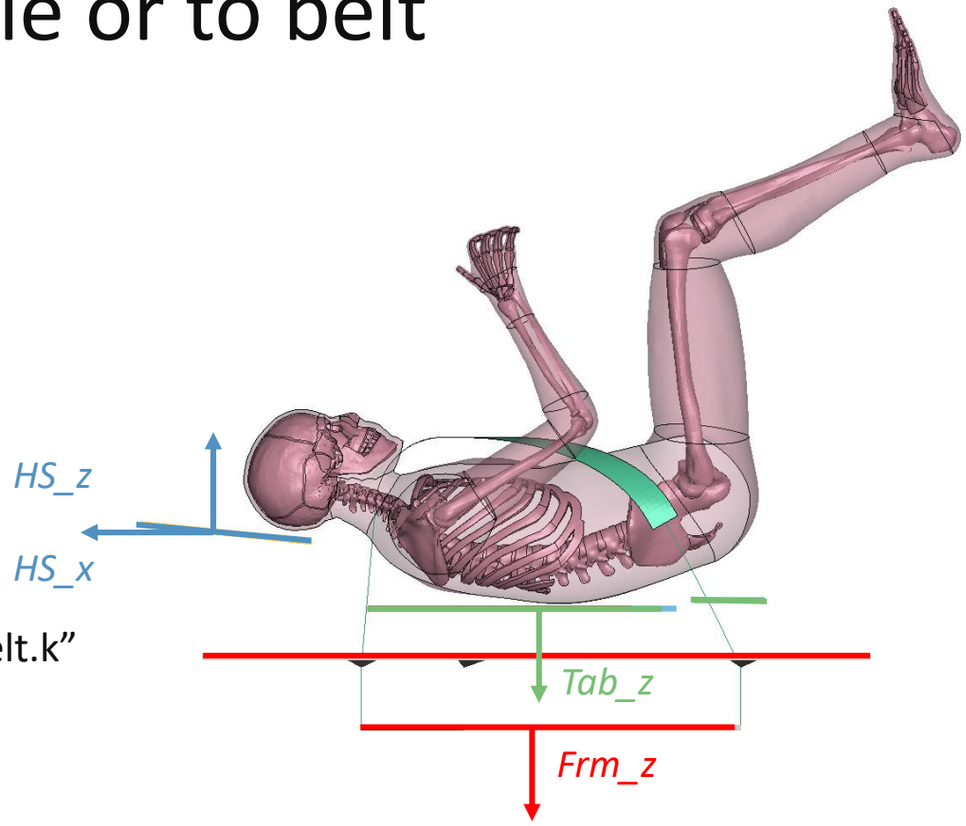
If the table has intersections to HBM, translate the table in z
- *Tab_z*: positive value: table is moved downwards

If the belt has intersections to HBM, translate the frame in z
- *Frm_z*: positive value: frame and belt is moved upwards

IF the belt has intersections to the HBM (e.g. AM95), use the longer belt model
- update the name of the belt include “02_Belt.k” in the file “00_Master_Belt.k” to “02_Belt_longer.k”

If the head support has intersections to HBM, translate the head support in z
- *HS_z*: positive value: head support is moved upwards

If the position of the head support is not satisfying, translate the head support in x
- *HS_x*: positive value: head support is moved in superior direction



S T E P 5

Set IDs for contact sets and database NODOUT

Define the part set of the HBM
→ This part set will be damped
- *P_hbm*: Set ID of the set including all parts of the HBM

Define the part set of the HBM skin
→ This part set will be in contact to the table
- *P_ski*: Set ID of the set including all skin parts of the HBM

Define the part set of the thorax skin
→ This part set will be in contact to the belt
- *P_tho*: Set ID of the set including all thorax skin parts with shoulders

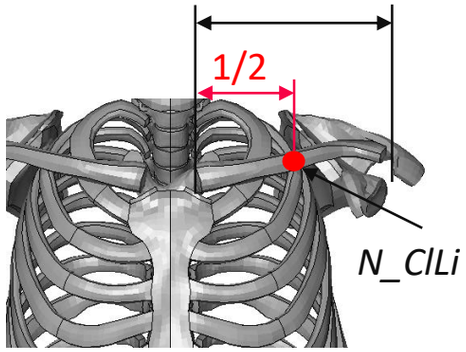
Define the node ID on the anterior surface of the sternum on height of “BxS”
- *N_BxSi:* Node ID on the anterior surface of the sternum at “BxS”

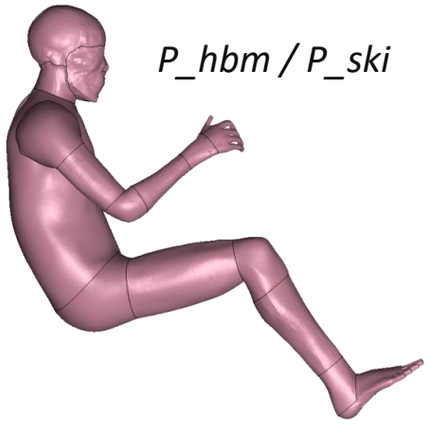
Define the node ID on the most anterior point on the chest on height of “BxS”
- *N_BxS:* Node ID on the anterior thorax at “BxS”

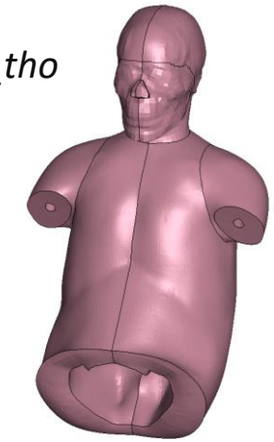
Define the node ID on the anterior skin projected in anterior direction from to the 3D midpoint between most medial and lateral nodes of the left clavicle
- *N_ClL*: Node ID on the mid of left clavicle

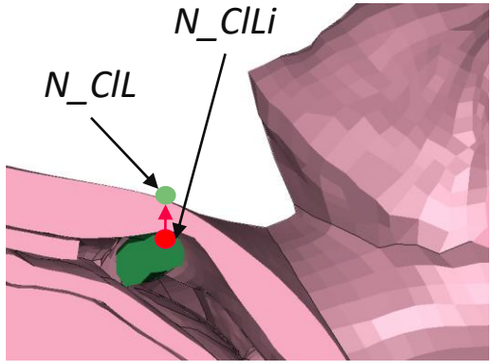
Define the node ID on anterior surface of clavicle bone closest to the 3D midpoint between most medial and lateral nodes of the left clavicle
- *N_ClLi*: Node ID on anterior thorax on height of mid of left clavicle

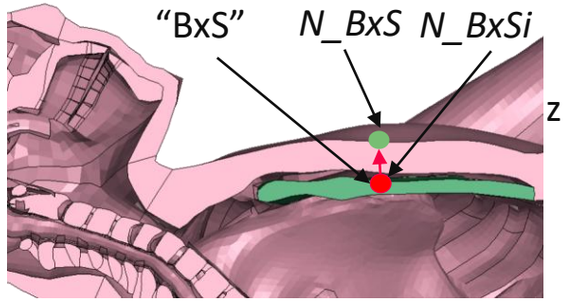
→ *DATABASE_HISTORY_NODE will be generated for this nodes
  - Update node IDs in the HBM ID-file in “…\data\metadata” accordingly (see THUMS/VIVA+ files for examples)











Target HBM position

STEP 6
Define attachment nodes for positioning beams

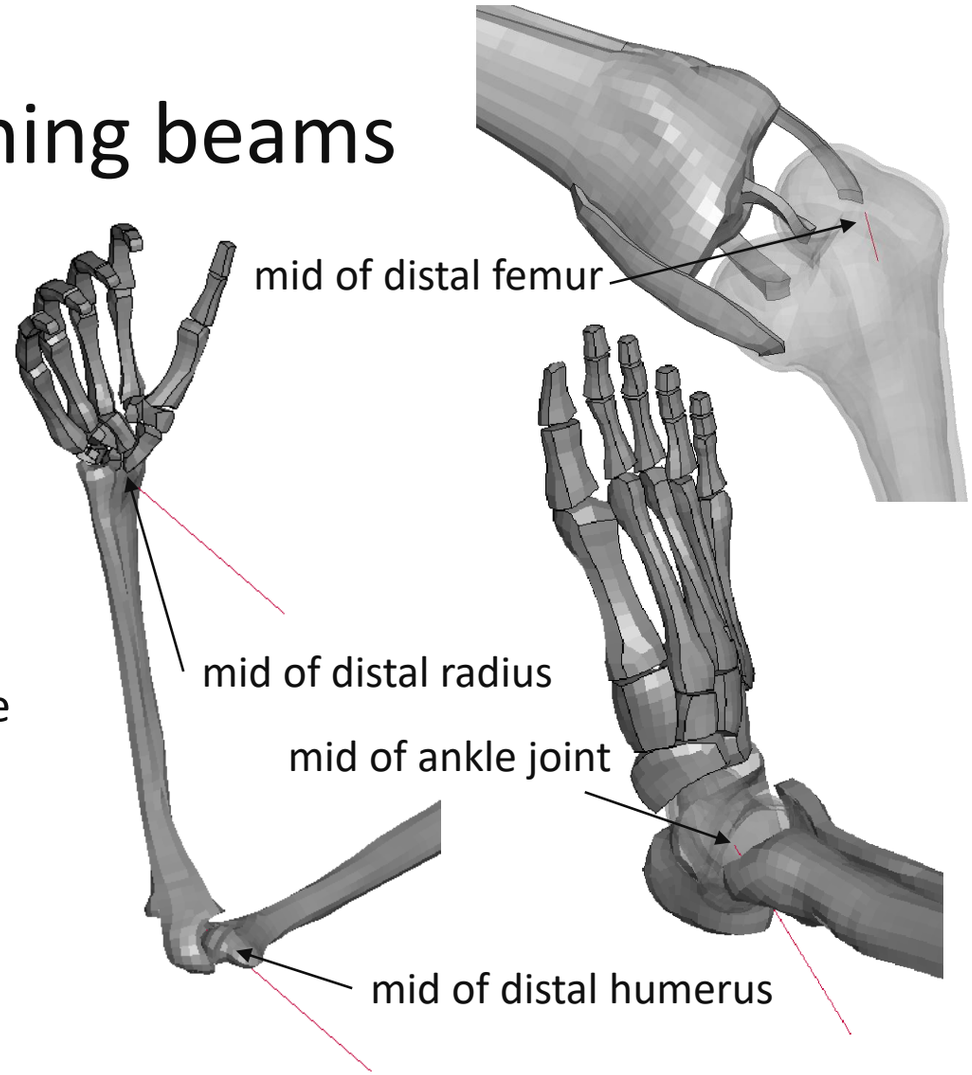
Define the Node IDs for the landmarks to be positioned

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_Belt.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 7
Run simulation and check results

Check the d3plot and adapt the parameter if needed:

If position of center of “BxS” moved in x-direction during HBM settling phase more than 10mm, translate the frame accordingly

- *Frm_x*: positive value: belt is moved in cranial direction

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

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

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

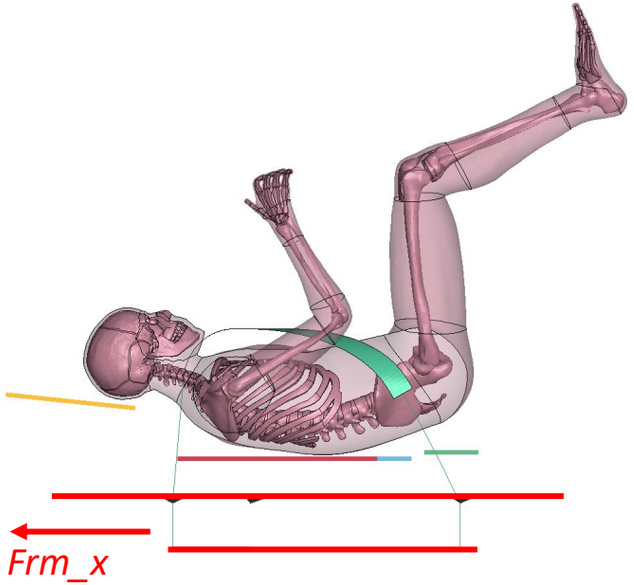
- *Depth*: default: 25

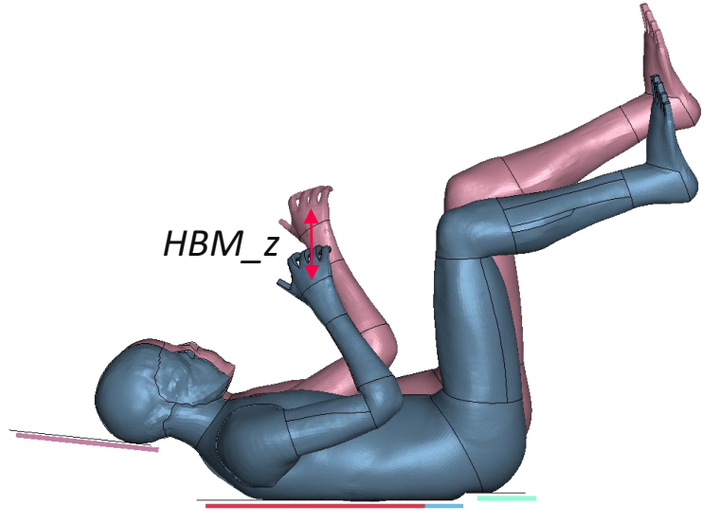
IF belt fitting is not satisfying, change belt force parameter:

- *f_belt*: force in retractor in kN (default 0.015kN)

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

- *tload*: duration of loading curve (default 100ms)

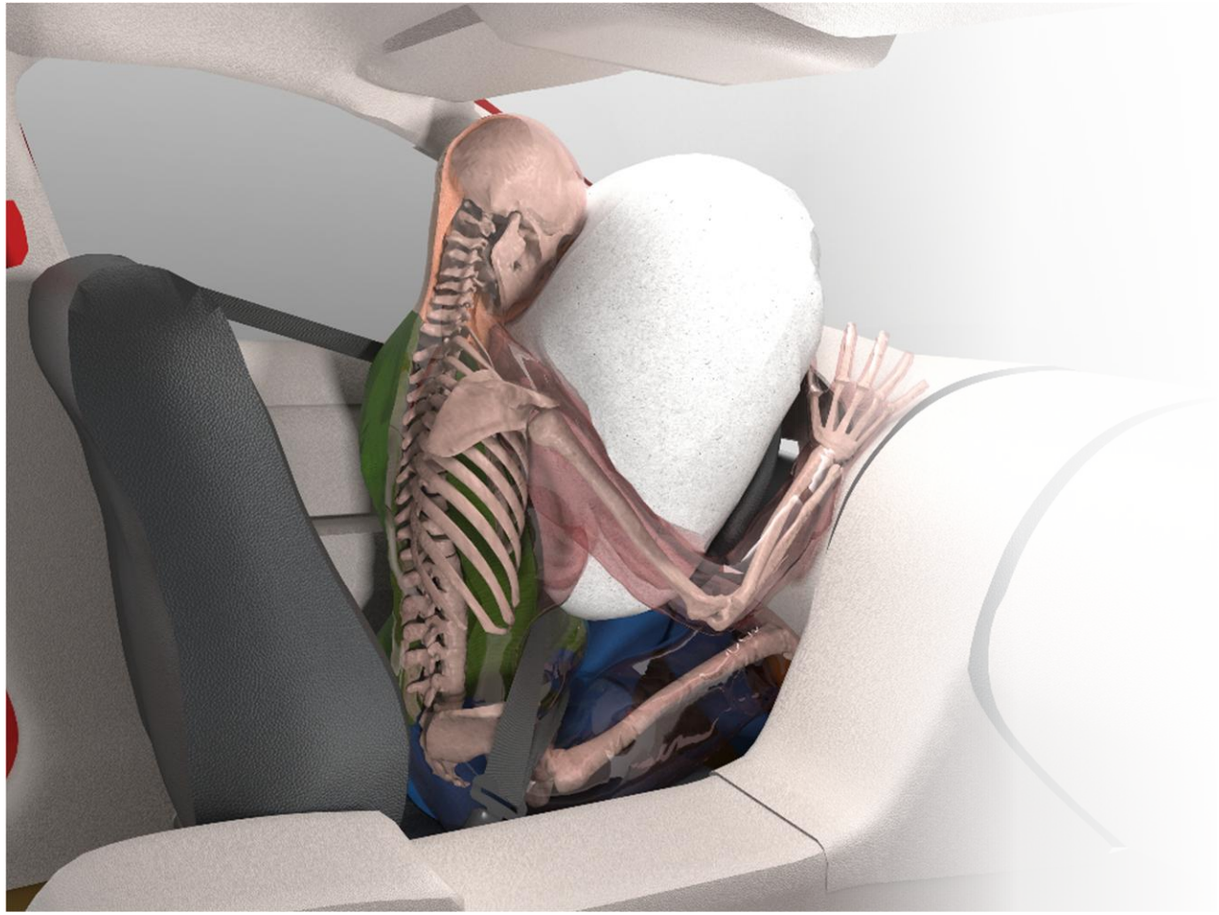




Final checks

Check the following in the settled model (@ tSetHBM)

- Position of center of “BxS” (Step 7)
- Movement of Extremities (Step 7)
- Belt path (Step 7)



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