Analysis of HS boat-impact data and modeling occupant responses

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Data provided by Vladimir Sovilj, Magnus Ullman and Johan Ullman
Sven-Åke Eriksson assisted the analysis.

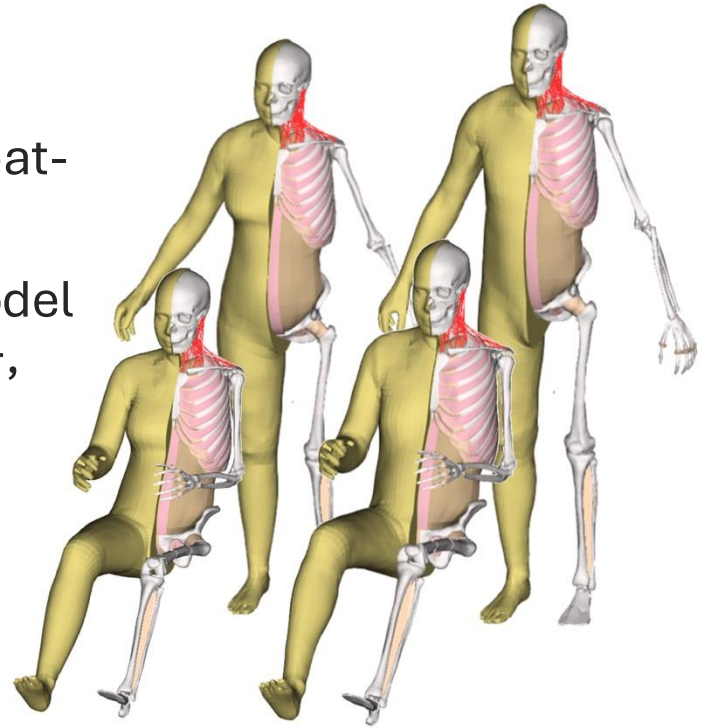
Aims

Main aims:

To develop an analysis tool for automate HS boat-impact data analysis.

To evaluate if a Finite Element Human Body Model developed for vehicle crash analysis, the VIVA+, can reproduce pilot hip accelerations.

To identify future research.



Analysis tool and analysis examples

Python code

Open access

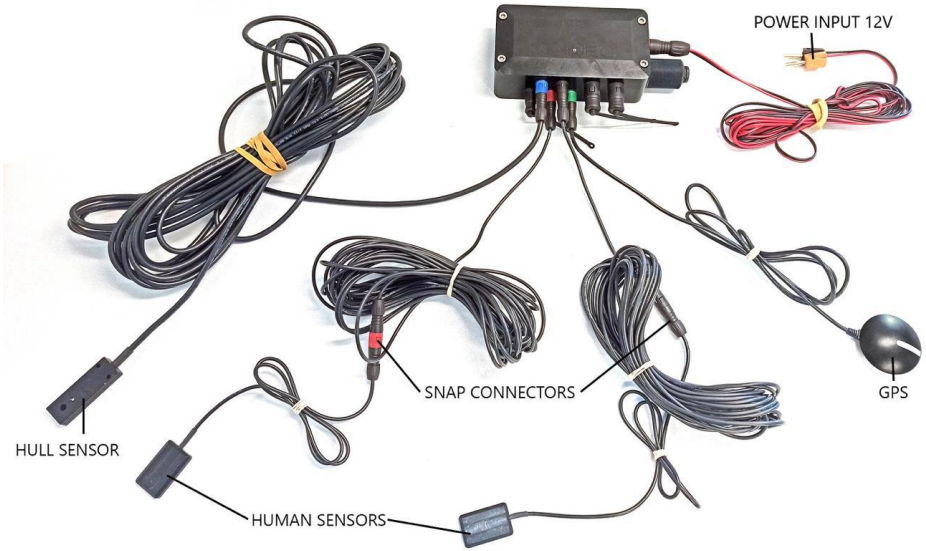
Online tool

Example analysis - Boats and seat information

- Data presented today are mainly from test with a Marathon 900 RIB-D powered by two 250 hk engines.
- Pilot seated in a Biscaya jockey standard seat

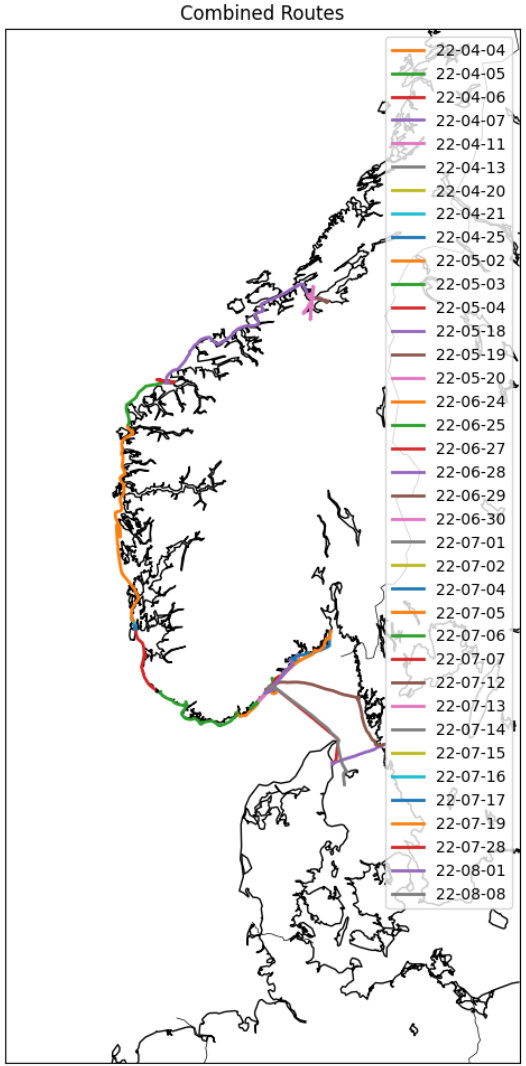
Instrumentation and data collection

- A MAREC® data collection system was used:
  - Tri-axial MEMS accelerometers with a range of ±25 g.
  - GPS antenna for tracking speed and position.
  - Data logger unit.
- Accelerometers were mounted to:
  - Hull midships and close to the seat base.
  - On pilot hips using kidney belts.

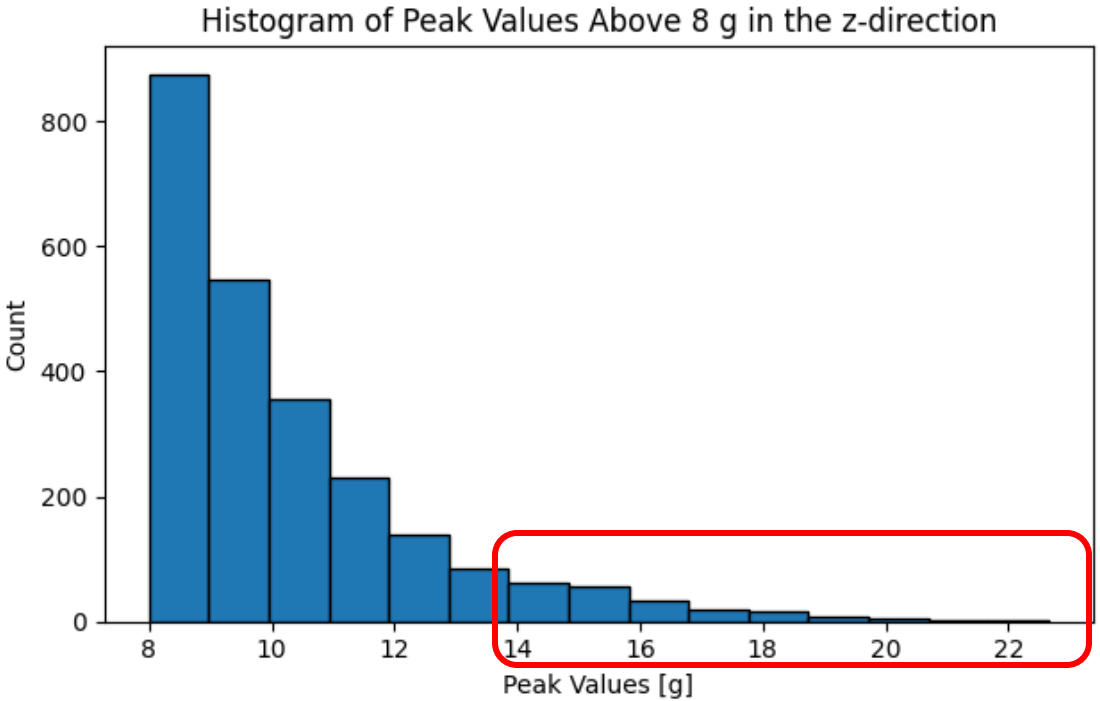


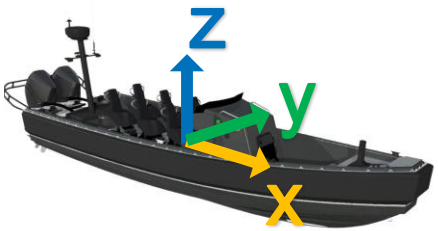
Instrumentation and data collection

- Data were collected in:
  - Southern Norway with a few trips to Sweden and Denmark in summer 2022.
  - In Gothenburg in fall 2024.
- The boats were mostly traveling in open water.
- No report injuries during or after the data recordings.



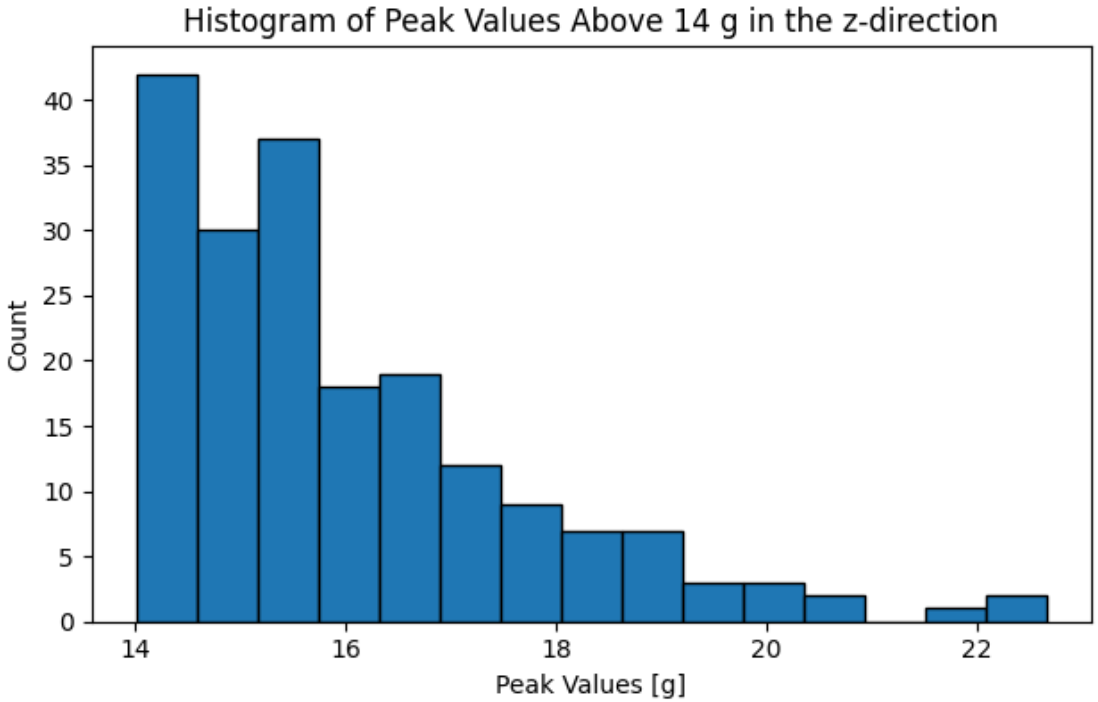
Histogram boat z-acceleration above 8 g in all tests

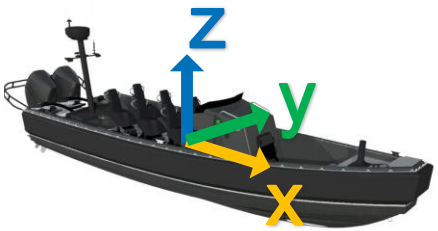




All data from Norway,
position: Boat, direction: z, filter: Butterworth 100hz

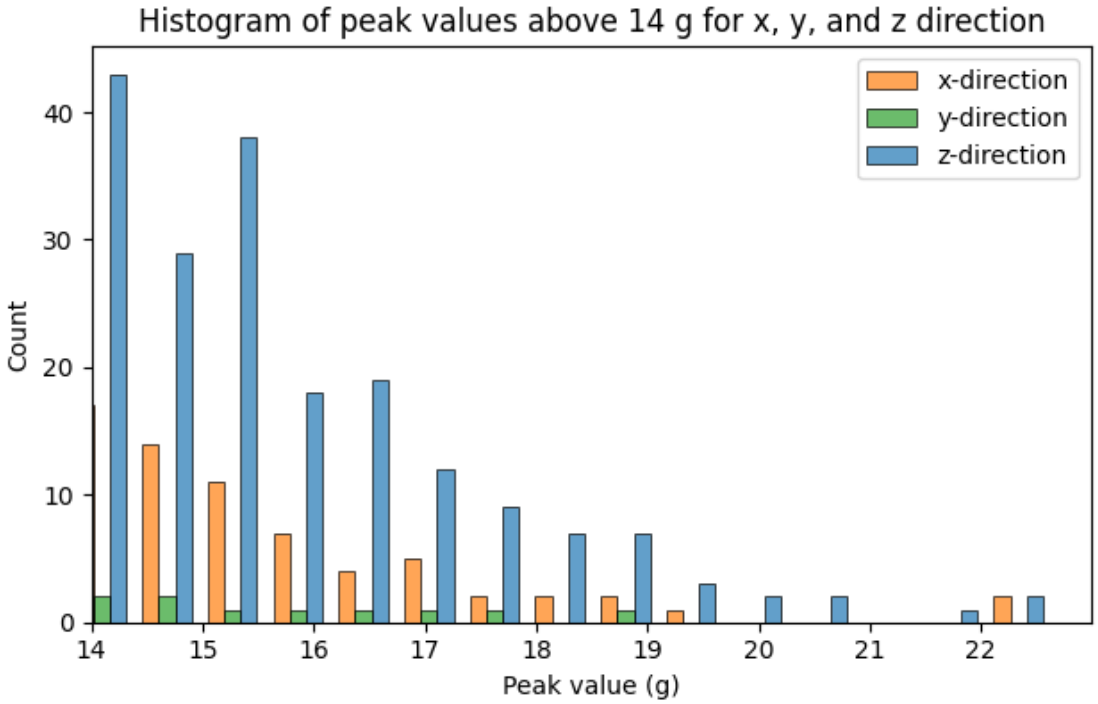
Histogram boat z-acceleration above 14 g in all tests

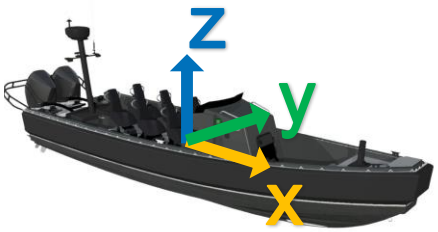




All data from Norway,
position: Boat, direction: z, filter: Butterworth 100hz

Histogram boat accelerations in tests where maximum z-acceleration was above 14 g



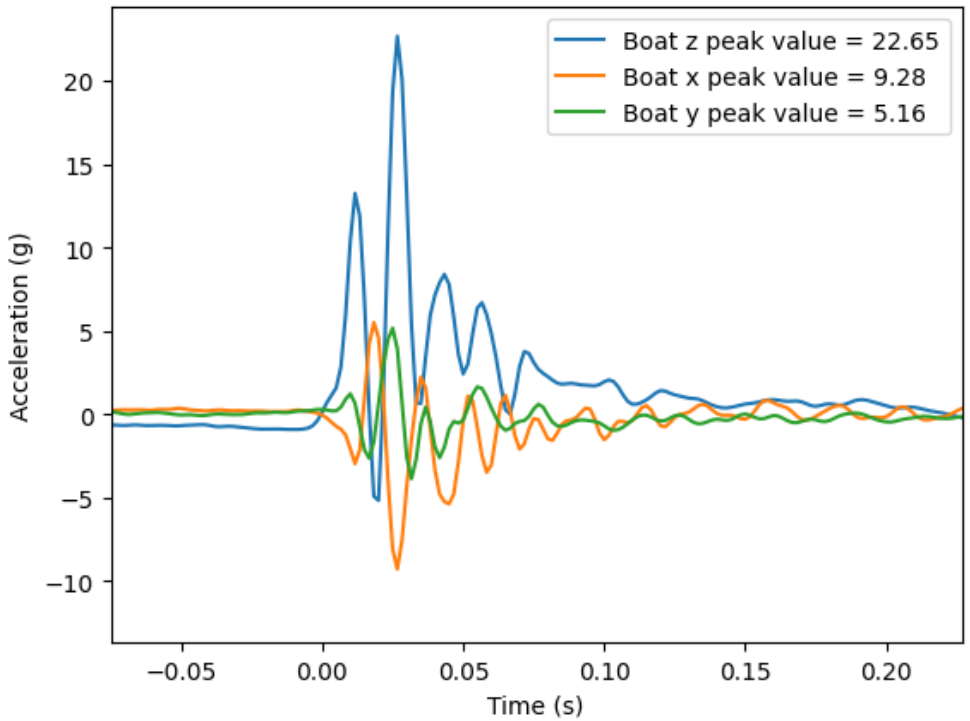


All data from Norway,
position: Boat, direction: z, filter: Butterworth 100hz

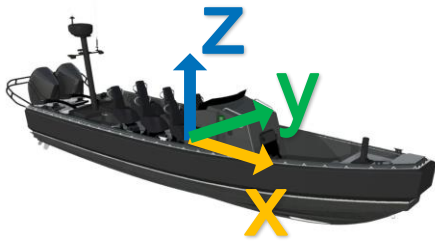
Summary HS-boat data histograms

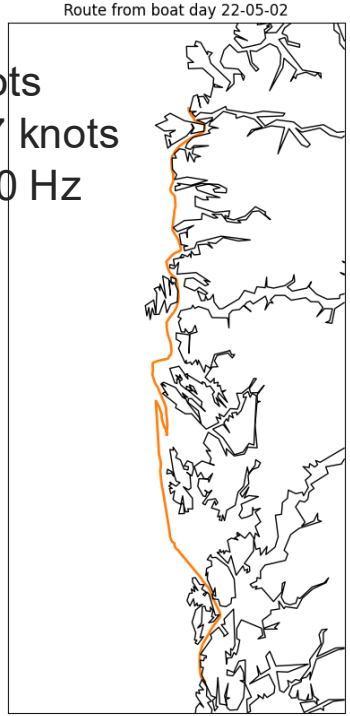
- During the testing:
  - Maximum boat z-acceleration was about 23 g.
  - More than 2000 impacts that resulted in boat z-accelerations above 8 g but below 14 g.
  - Some 188 impacts with waves that resulted in boat z-accelerations above 14 g.
  - Boat side accelerations and retardations varied but was occasionally above 10 g.

Example boat acceleration, Norway

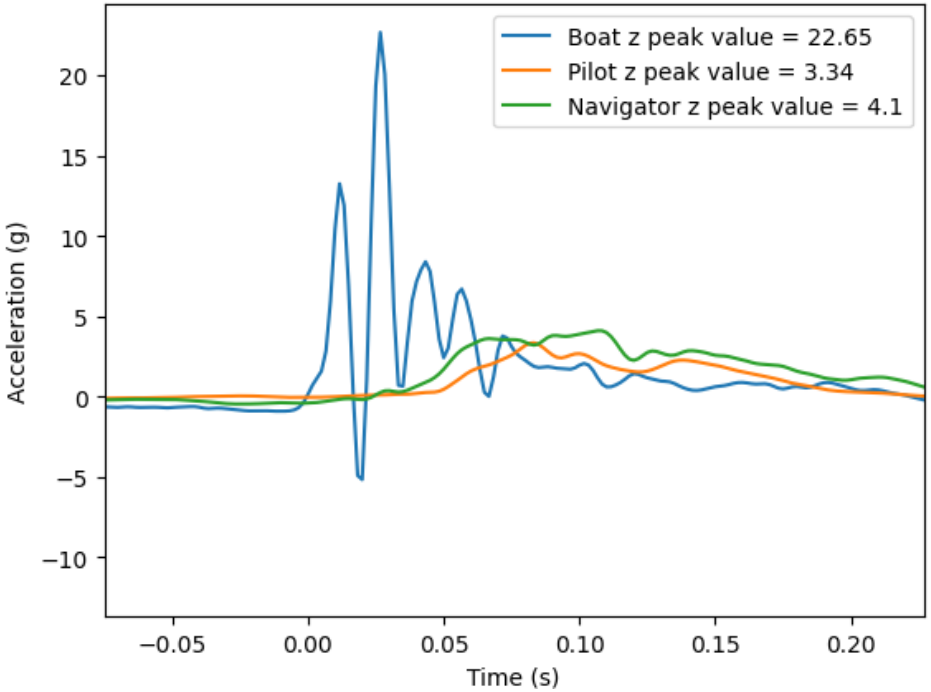


Test date 2022-05-02
Mean RIB velocity 34 knots
Maximum RIB velocity 47 knots
Filter cutoff frequency 100 Hz





Example boat and pilot and navigator accelerations, Norway



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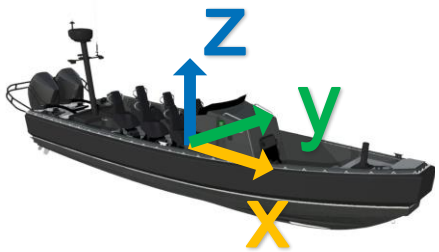

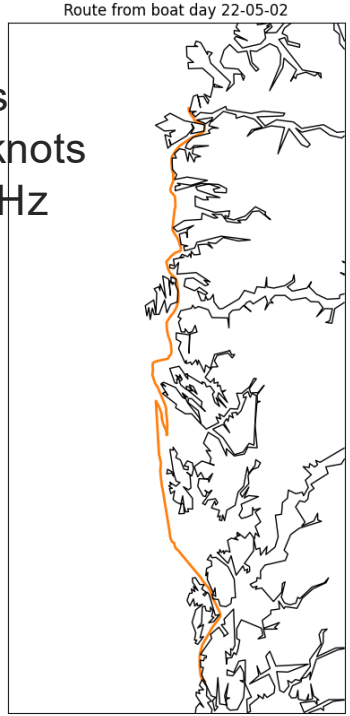

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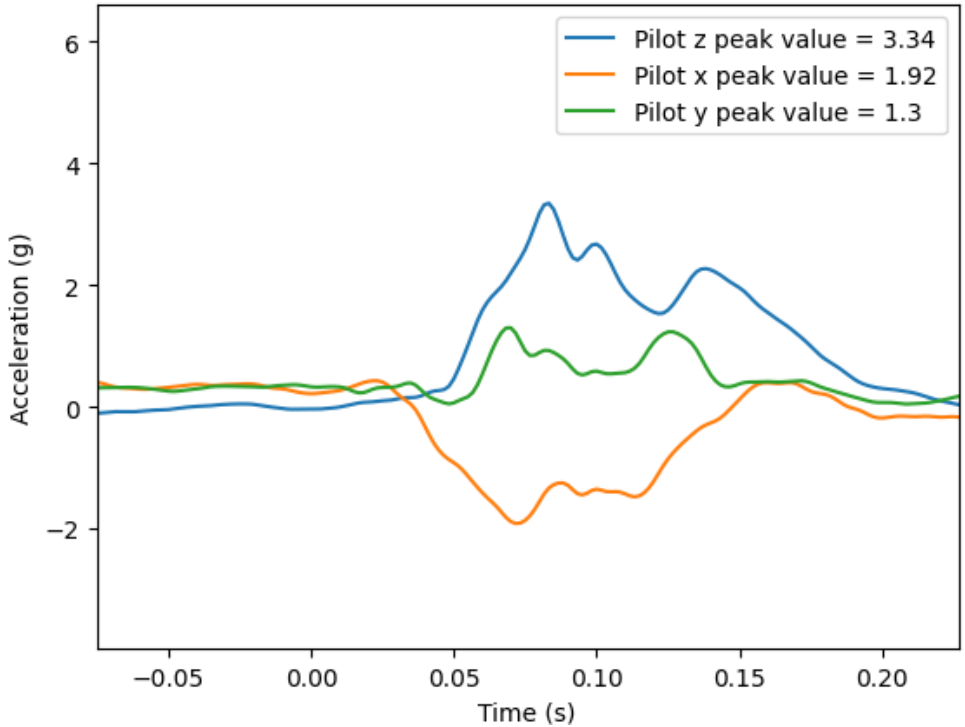

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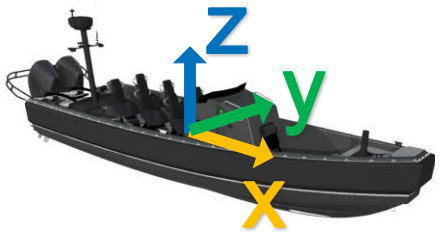
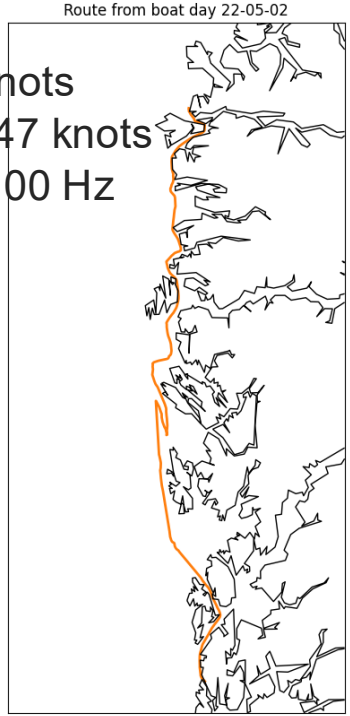
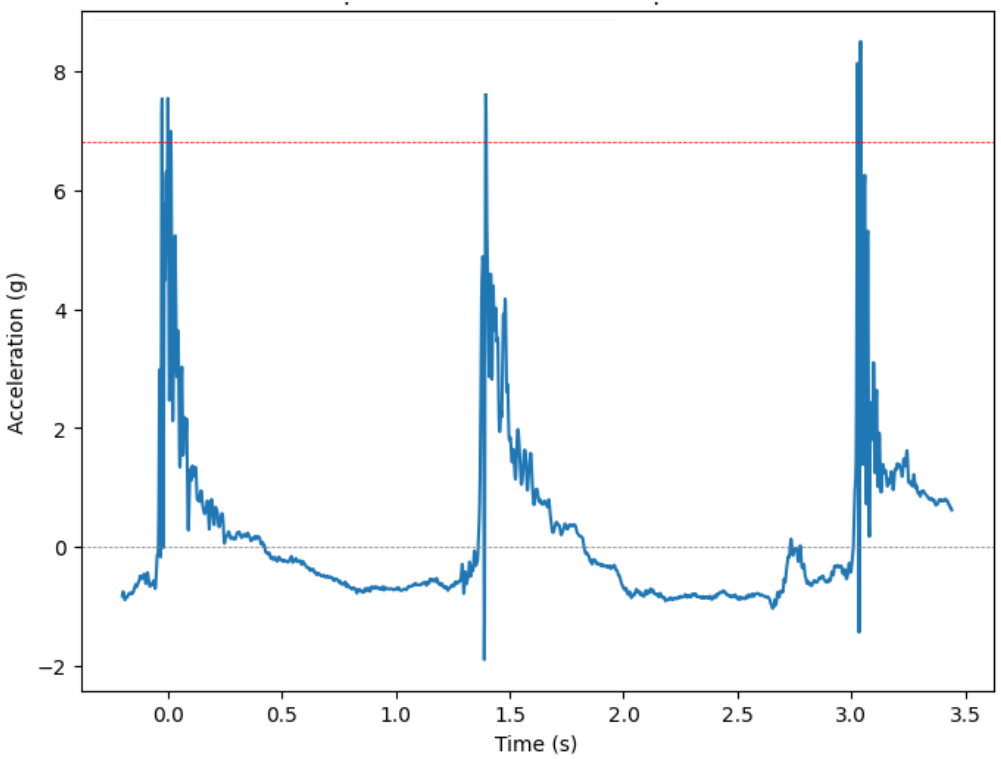




Example repeated boat z-accelerations, Norway



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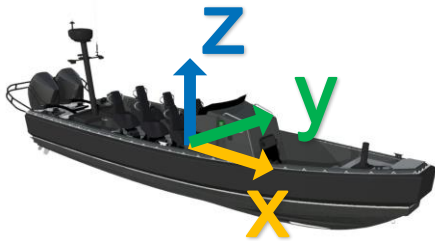
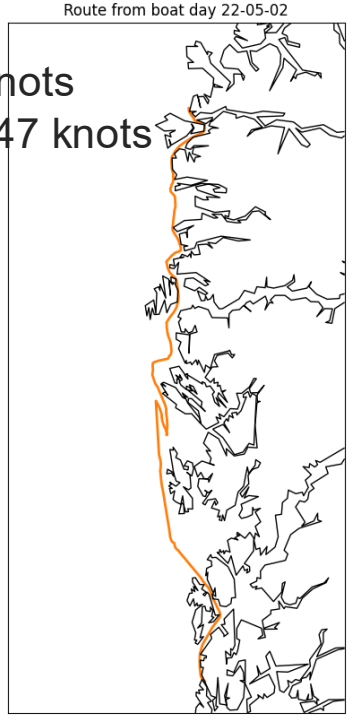
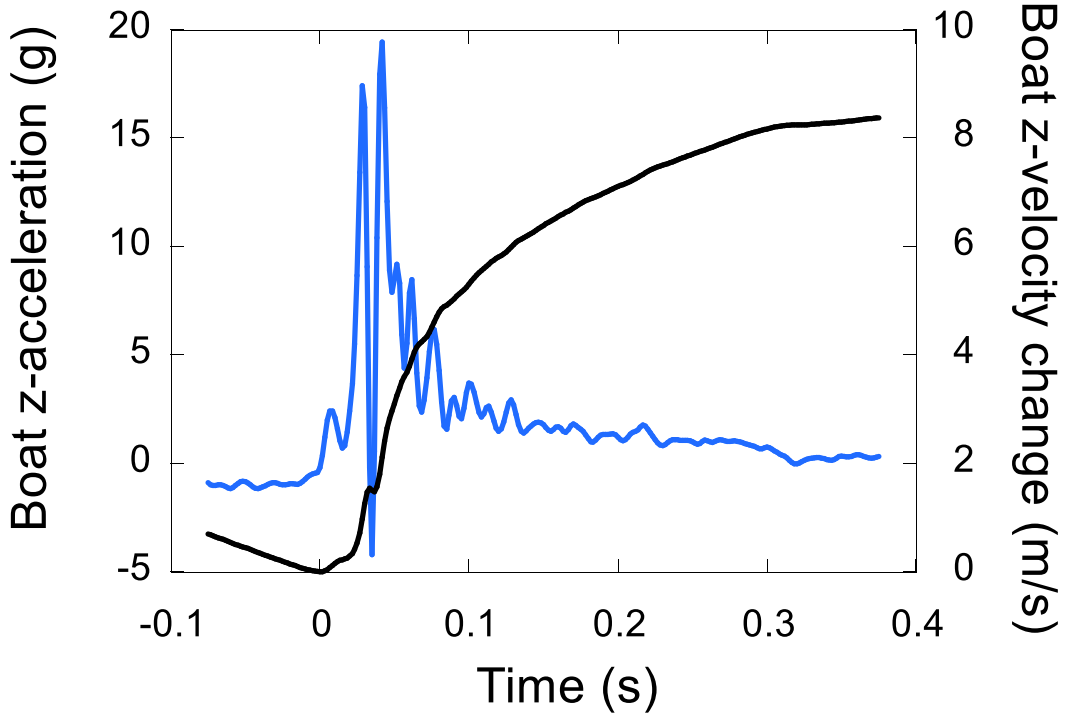




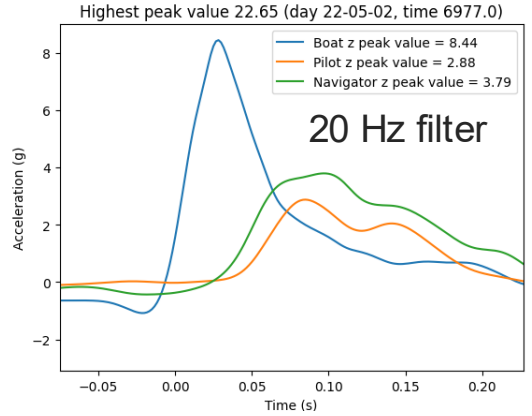
Example boat velocity change, Norway

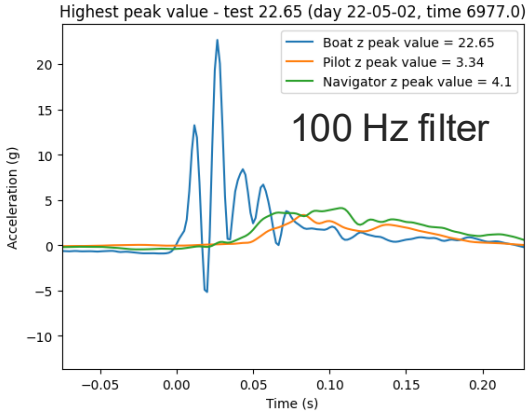
- Vertical velocity change rather high.
- 8 m/s velocity change
  = 29 km/h
  = jump from 3.2 m



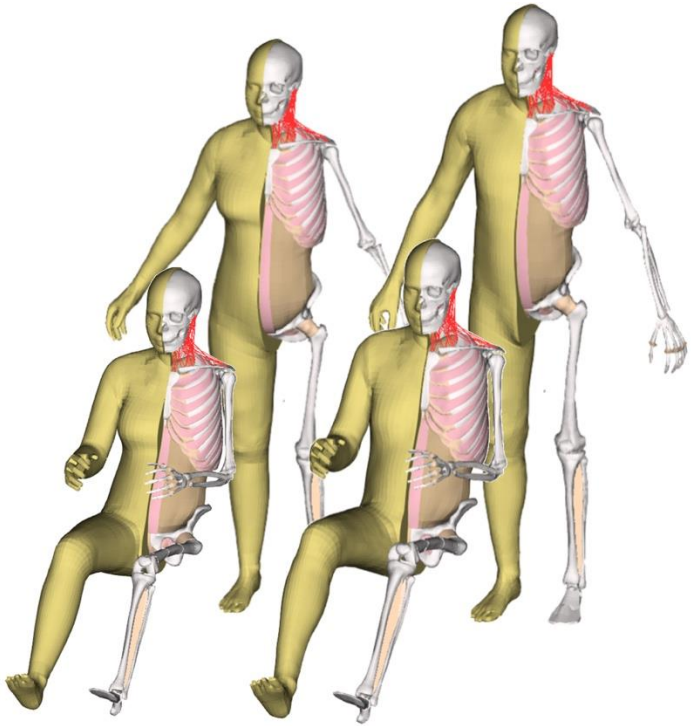
Summary boat, pilot and navigator acceleration data

- Maximum boat z-acceleration was higher than 20 g in several test.
- Maximum pilot hip z-accelerations were below 7 g.
- Boat acceleration is a function of filter class; we adopted 100 Hz cut of frequency.
- Important to document pilot accelerometer mounting – the transducer was likely not perfectly aligned in some tests.





Simulation of Pilot seat interaction using the VIVA+ HBM



Used v2.0 of VIVA+, available at openvt.org

Open source and 100% transparency

Detailed Human Body Model (HBM) for prediction of injury risk

Developed with extra focus on prediction of:

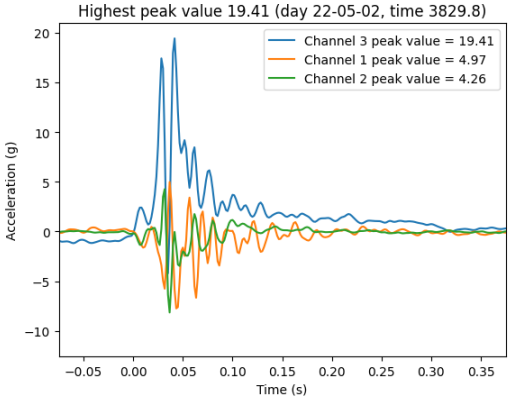
- Rib fractures
- Lumbar spine fractures
- Femur fractures
- Skull fractures
- And soft tissue neck injuries

Simulation of Pilot seat interaction using the VIVA+ HBM

Pilot seat

Rigid “pilot” seat

200ms zero gravity followed by acceleration pulse shown below



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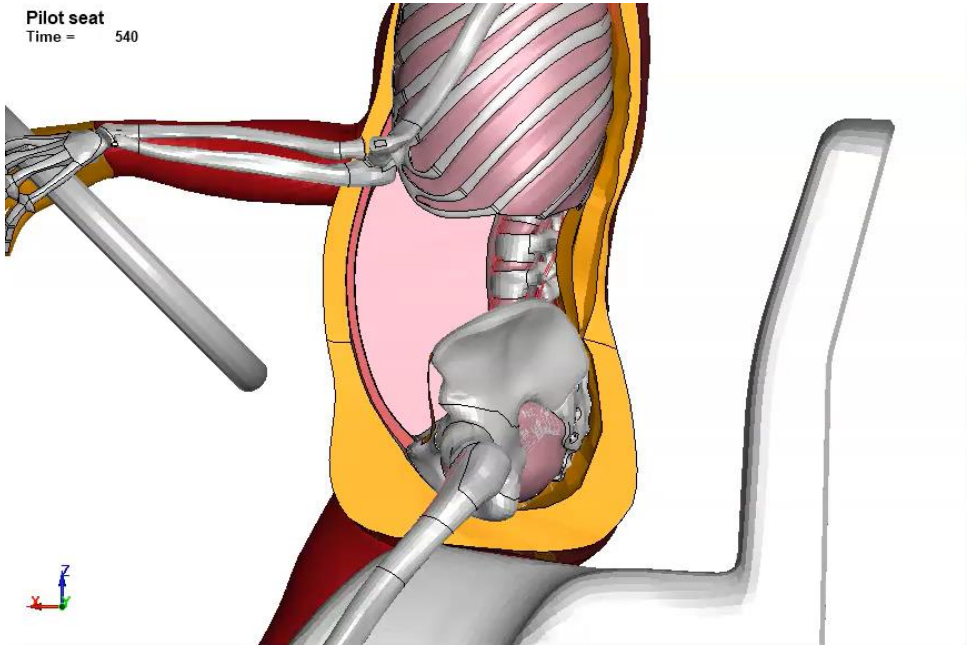
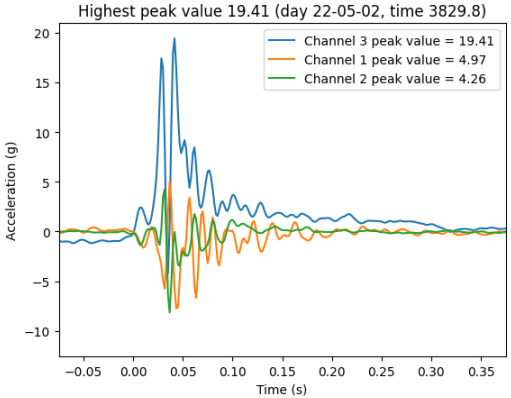
Simulation of Pilot seat interaction using the VIVA+ HBM

Close up of lumbar spine in pilot seat (camera follows boat)

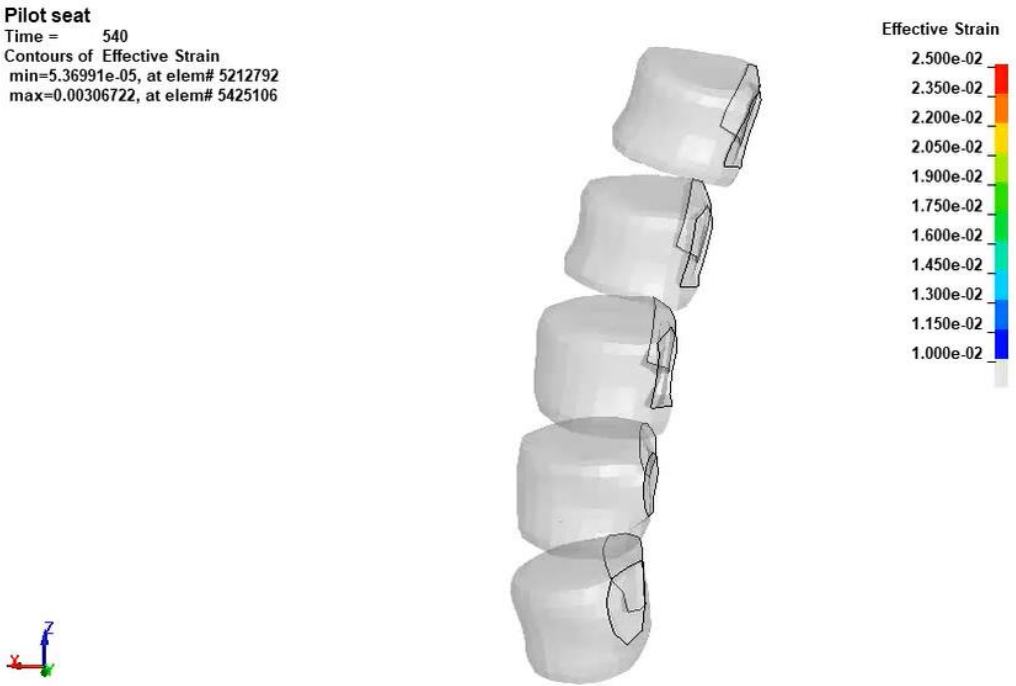


200ms zero gravity followed by acceleration pulse shown below

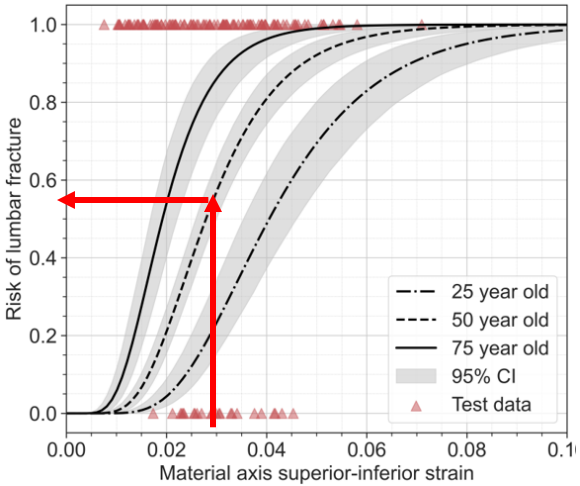


Simulation of Pilot seat interaction using the VIVA+ HBM

Close up of lumbar spine in pilot seat (camera follows sacrum)



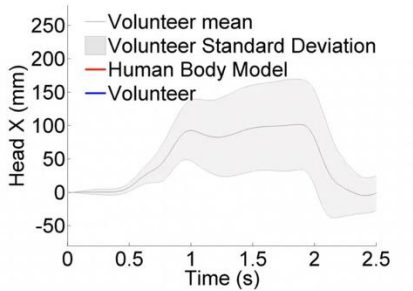
Lumbar spine compression fracture - Injury risk function developed for vehicle occupants



NOTE: The lumbar strains are overpredicted in the current model!

Simulation of Pilot seat interaction using the VIVA+ HBM

- HBMs can be used to predict injury risk, e.g. lumbar spine compression fractures.
- The current model lacks muscle tone, which will result in overprediction of lumbar spine loading.
- We have experience (and data) for modelling of active muscles for vehicle occupants, but currently lack data from seakeeping.



Conclusions

- An automated analysis tool that can analyse large amount of HS boat data presented.
- Additional developments in the summer and fall.
- Simulations of HS boat slamming with HBMs to guide seat selection and design are possible.
  - Muscle model updates pending.
  - Measure seat and foot forces in volunteer HS boating.

Future work

- Make the HS boat analysis software easy to use.
- Include pain or injury data in the analysis.
- Make the analysis software available open source.
- Introduce hip accelerometer evaluation tool.
- Determine leg strength in volunteer test with boat pilots.
- Introduce pilot leg strength in Viva+ Human Body Model.

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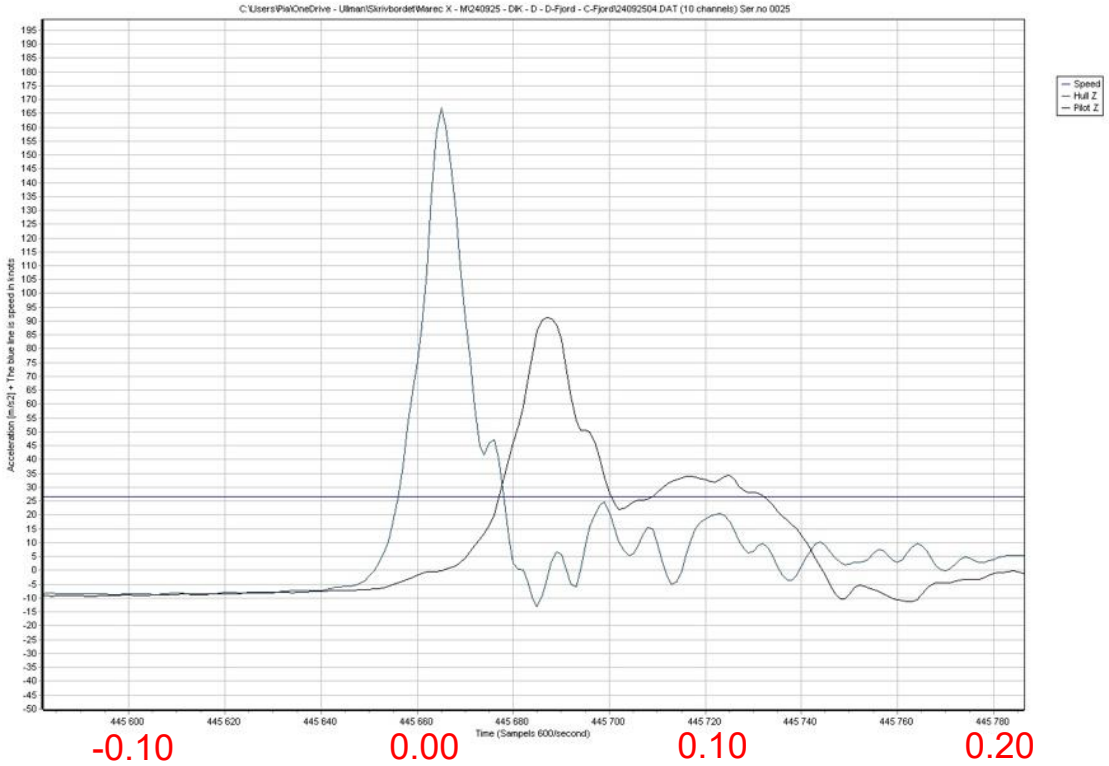
Om tidskalan är
i enheten sample
(600 sample/s)



Om tidskalan är
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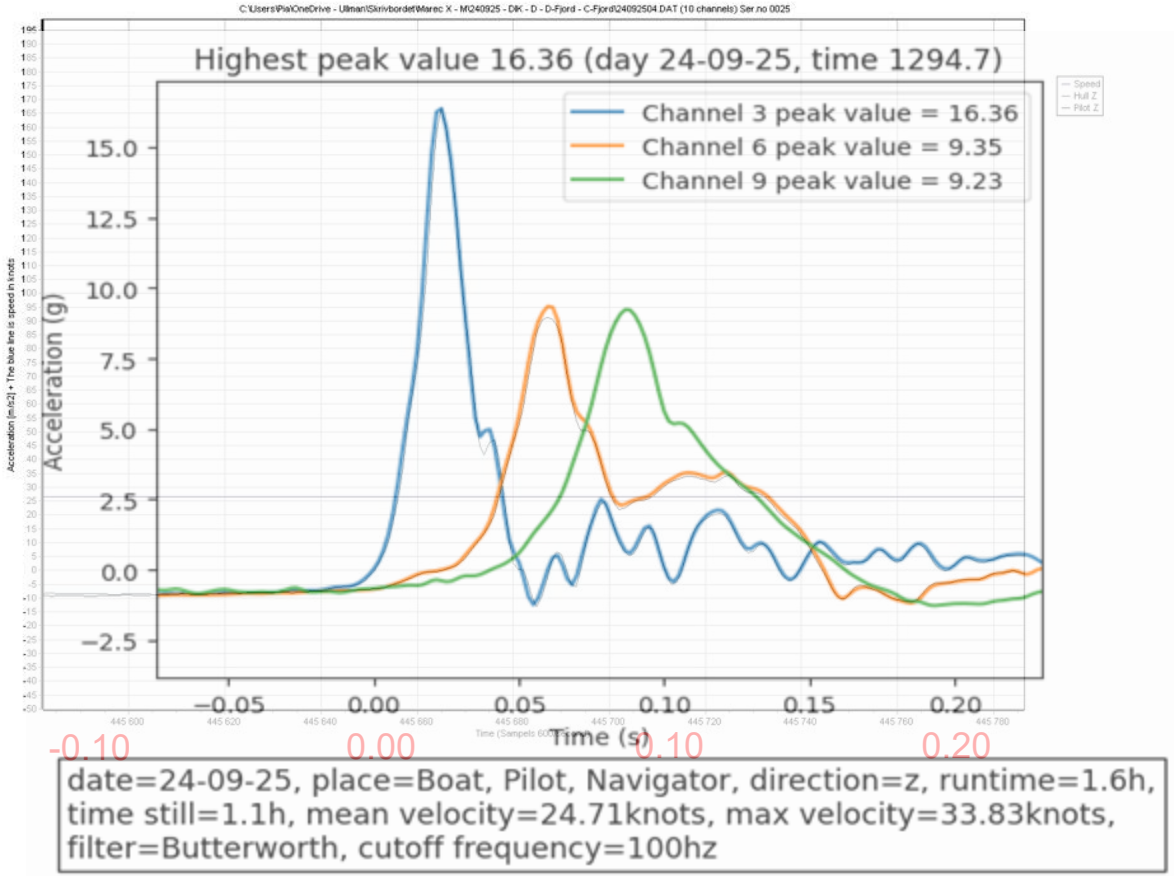

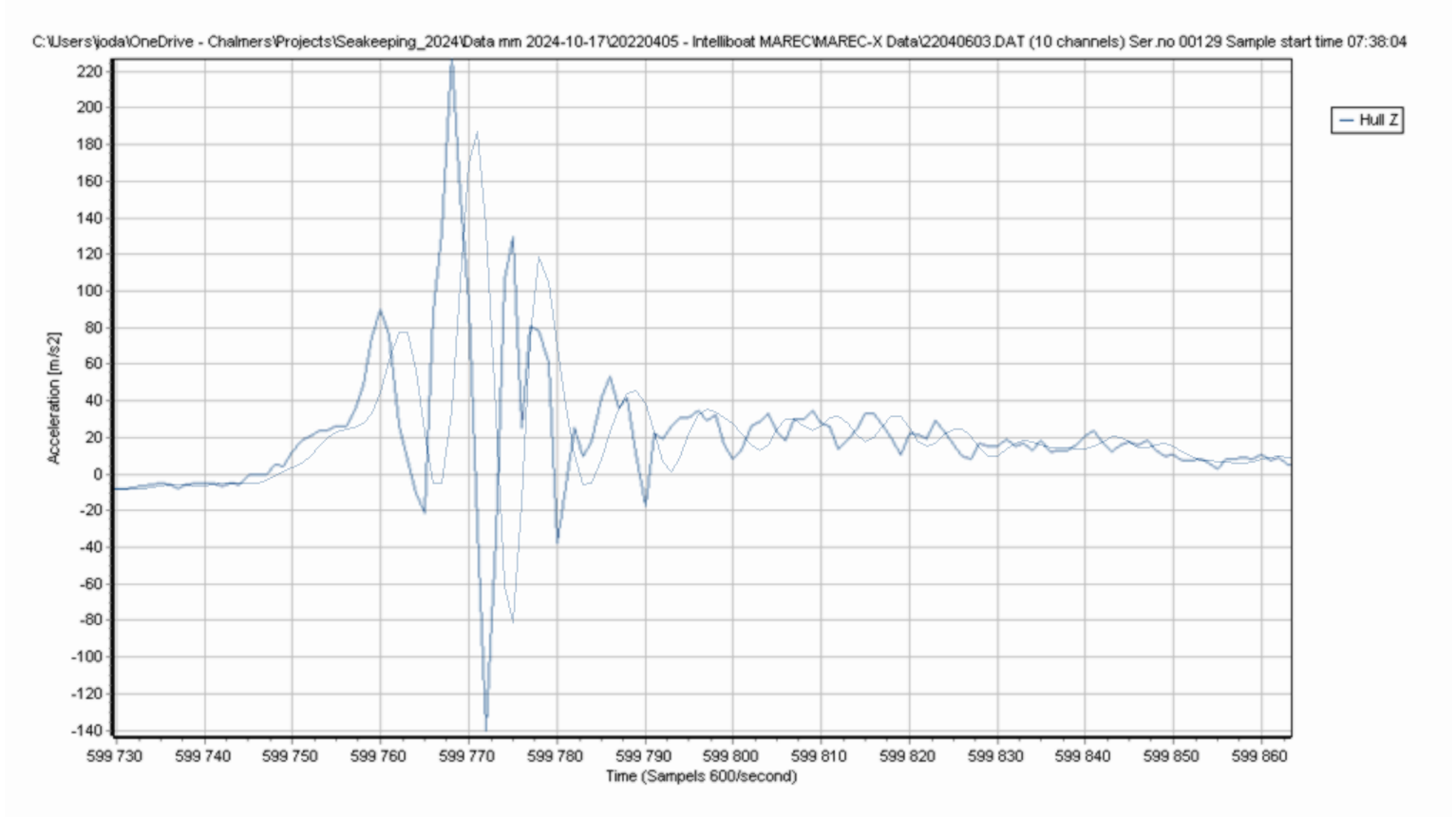
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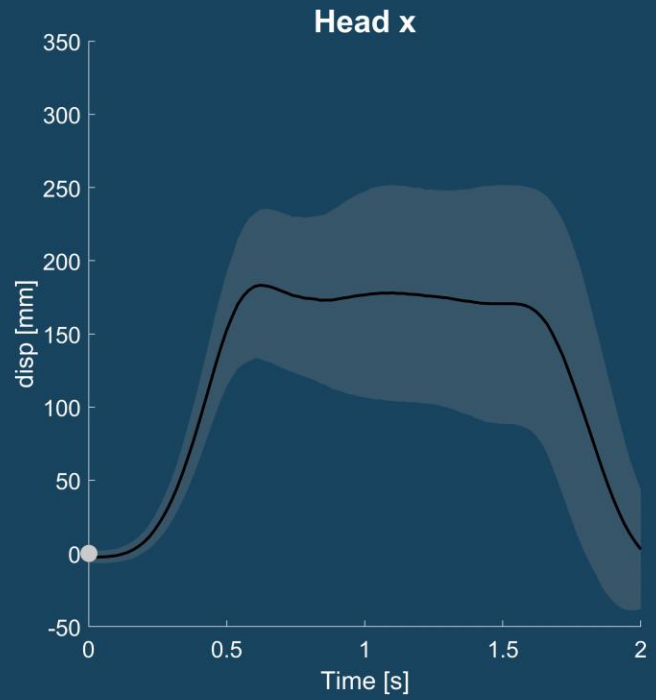
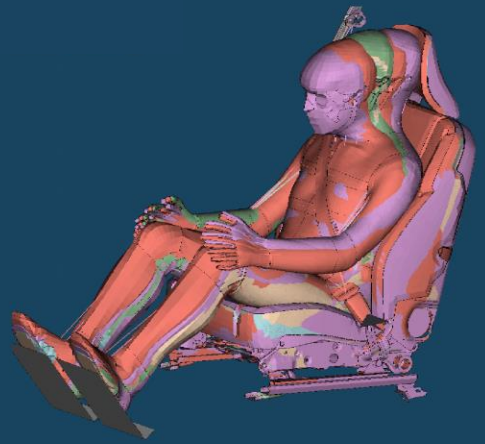
Hull Z
Acceleration [m/s2]
220
200
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
599 730
599 740
599 750
599 760
599 770
599 780
599 790
599 800
599 810
599 820
599 830
599 840
599 850
599 860
Time (Sampels 600/second)

Active muscle modeling in braking





Paper B