Predicting influence of pre-crash pre-pretensioning of the belt on human motion in emergency avoidance maneuvers

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Public

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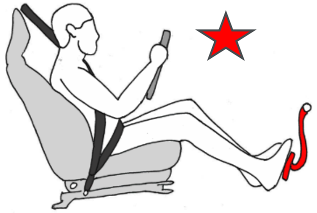
Autobrake with
pre-pretensioning

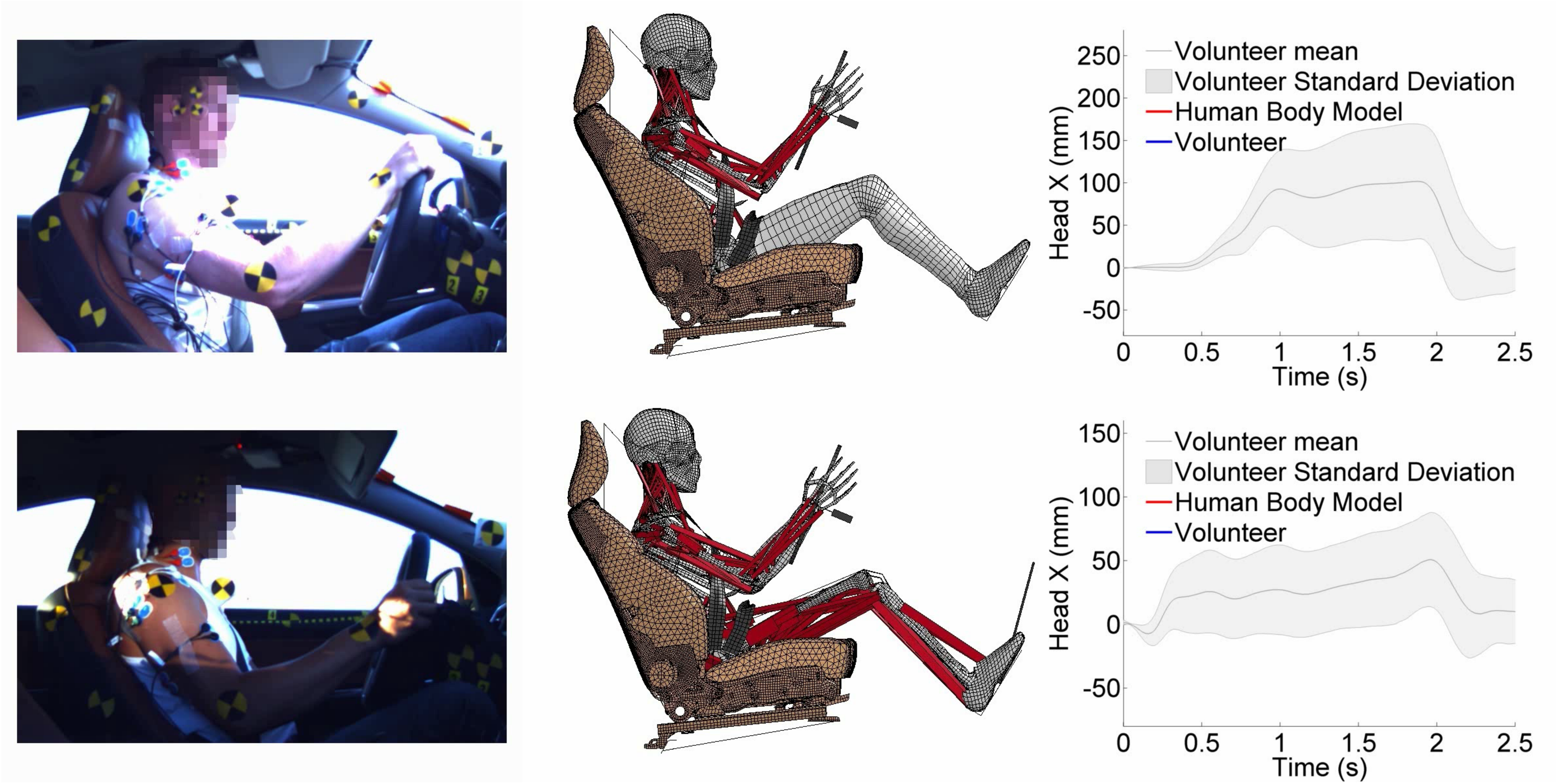
Autobrake without
pre-pretensioning



Driver braking

Background

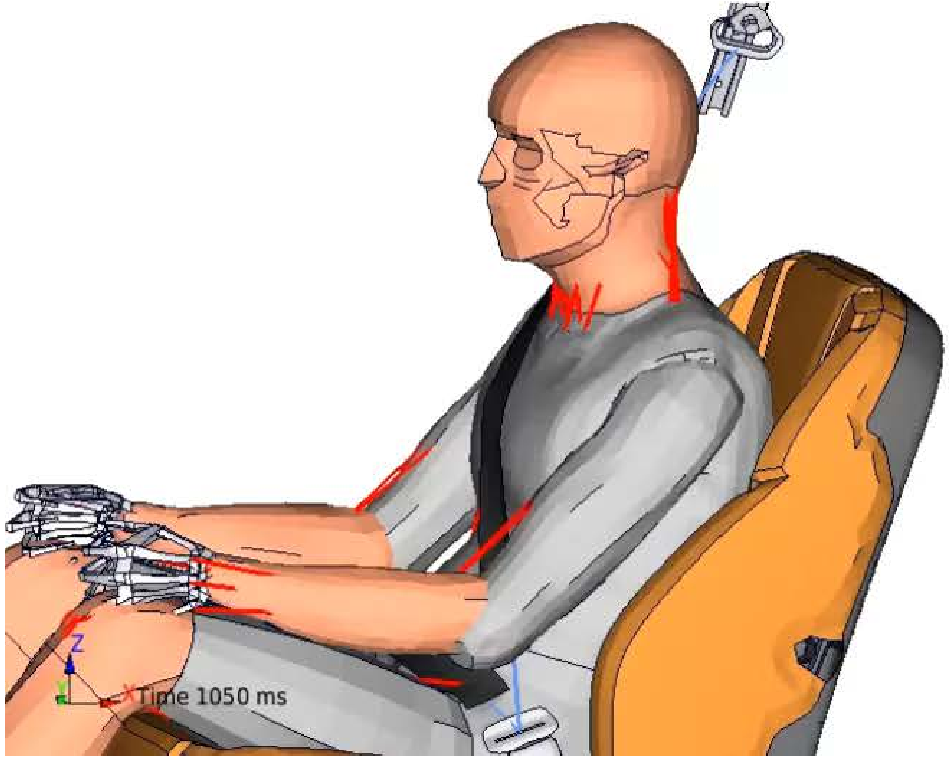
- Pre-crash vehicle safety systems are developed and implemented at a fast rate
  - Autonomous braking already available
  - Autonomous avoidance systems not far away
- Tools to guide the development of vehicle safety systems and verify its performance
- Human Body Models (HBMs) can be used to simulate occupant interactions with vehicle safety systems and study the crash outcome
  - Understand injury mechanisms on a detailed level
  - Determine injury risk
- Tools to simulate low g-levels and long duration crash events
  - Muscles can influence the crash outcome



Östh et. al. (2014). *A Human Body Model With Active Muscles for Simulation of Pre-tensioned Restraints in Autonomous Braking Interventions.* Traffic Injury Prevention Volume 16, Issue 3.

Östh et. al. (2014). *A method to model anticipatory postural control in driver braking events.* Gait & Posture 40 (2014) 664-669.

Modeling Autonomous Avoidance Maneuvers

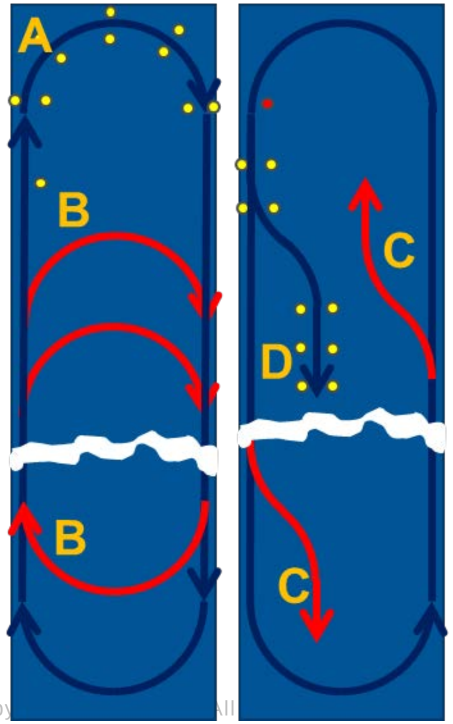


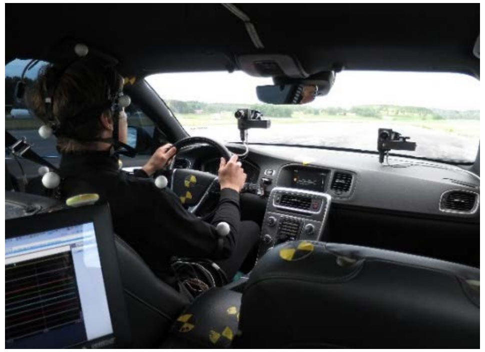
Volunteer Testing

- A) Prepared turns when volunteer is a passenger at 40 kph
- B) Unprepared turns when volunteer is a passenger at 40 kph
- C) Unprepared lane changes at 75 kph, with and without braking (in figure only driver path is indicated)
- D) Driver imitated lane change at 75 kph

Test setup








Volunteer Testing

Test setup

- A) Prepared turns when volunteer is a passenger at 40 kph
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- C) **Unprepared lane changes at 75 kph,** with and **without braking** (in figure only driver path is indicated)
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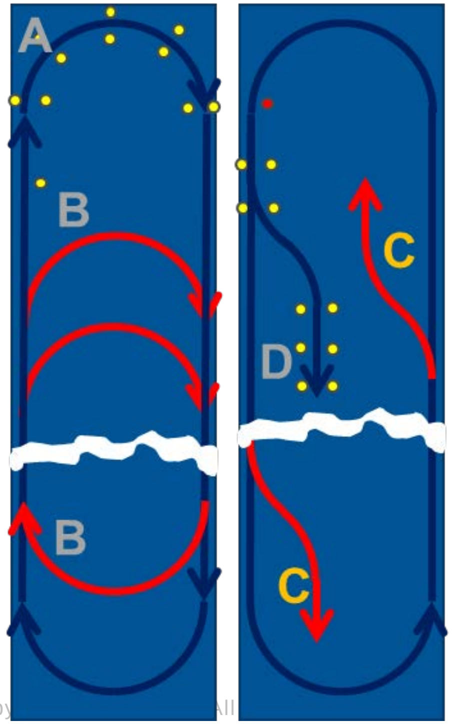

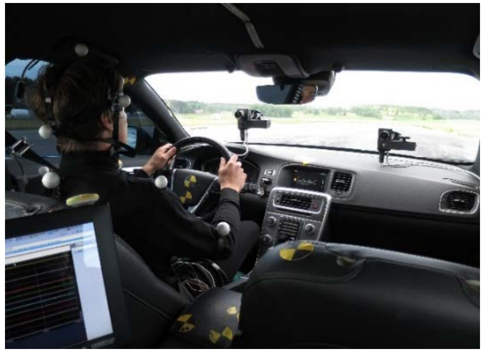

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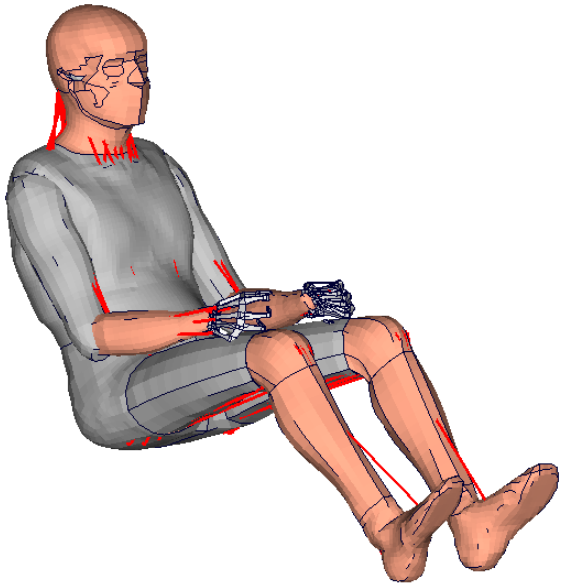
Objective

- Predict the influence of pre-crash pre-pretensioning of the belt on human motion in emergency avoidance maneuvers

Active Human Body Model (A-HBM)

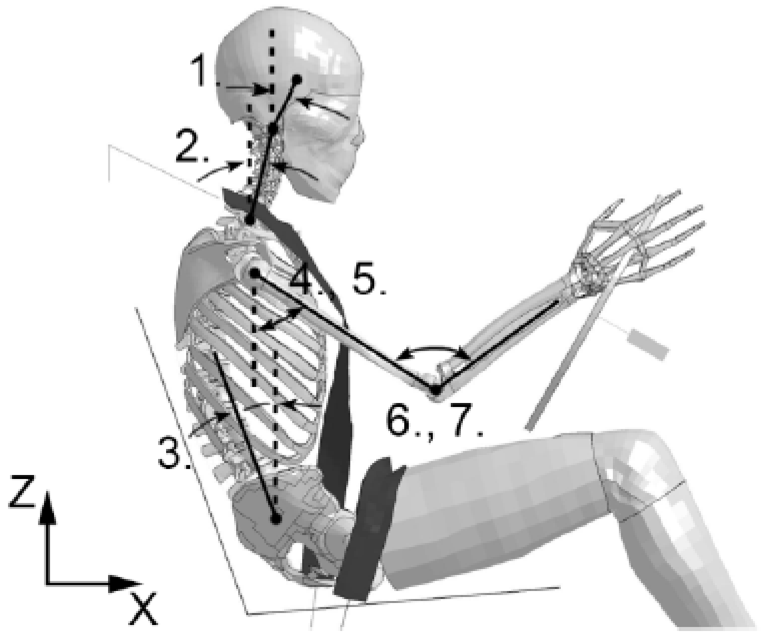
SAFER THUMS A-HBM

- 50%-ile male (175 cm and 77 kg)
- Omnidirectional muscle control
  - Sagittal plane – emergency braking maneuvers
  - Lateral plane – emergency avoidance maneuvers (steering and lane change)



Posture Maintenance of the A-HBM

- 7 Proportional Integral and Derivative (PID) controllers
- Feedback control system
- Angle based posture maintenance



head (1), cervical spine (2), lumbar (3), shoulder (4, 5), elbow (6, 7)

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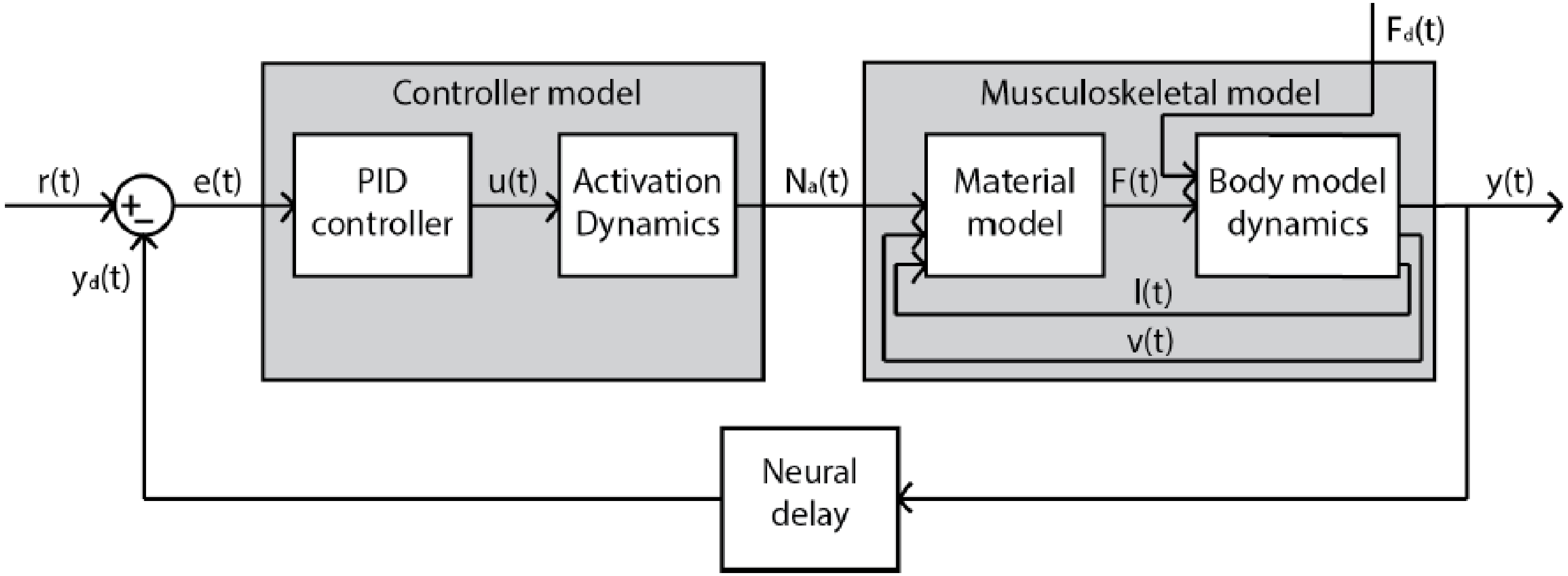
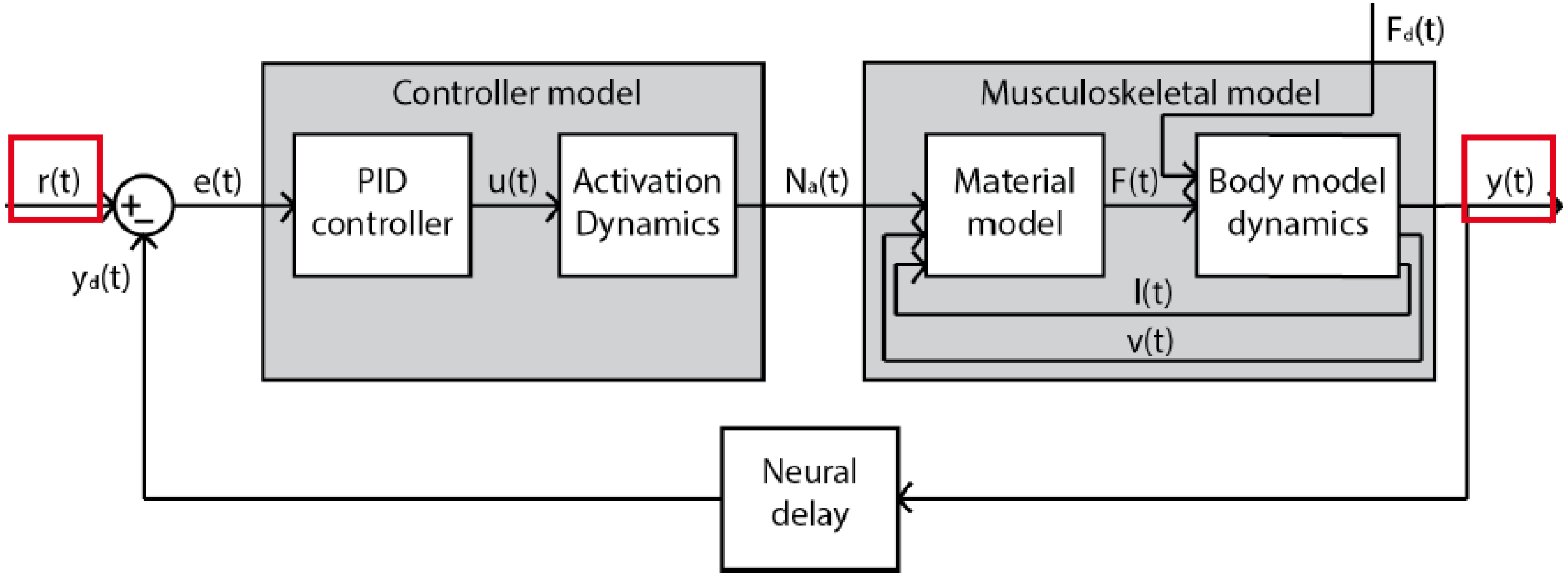
Muscular Feedback Control System

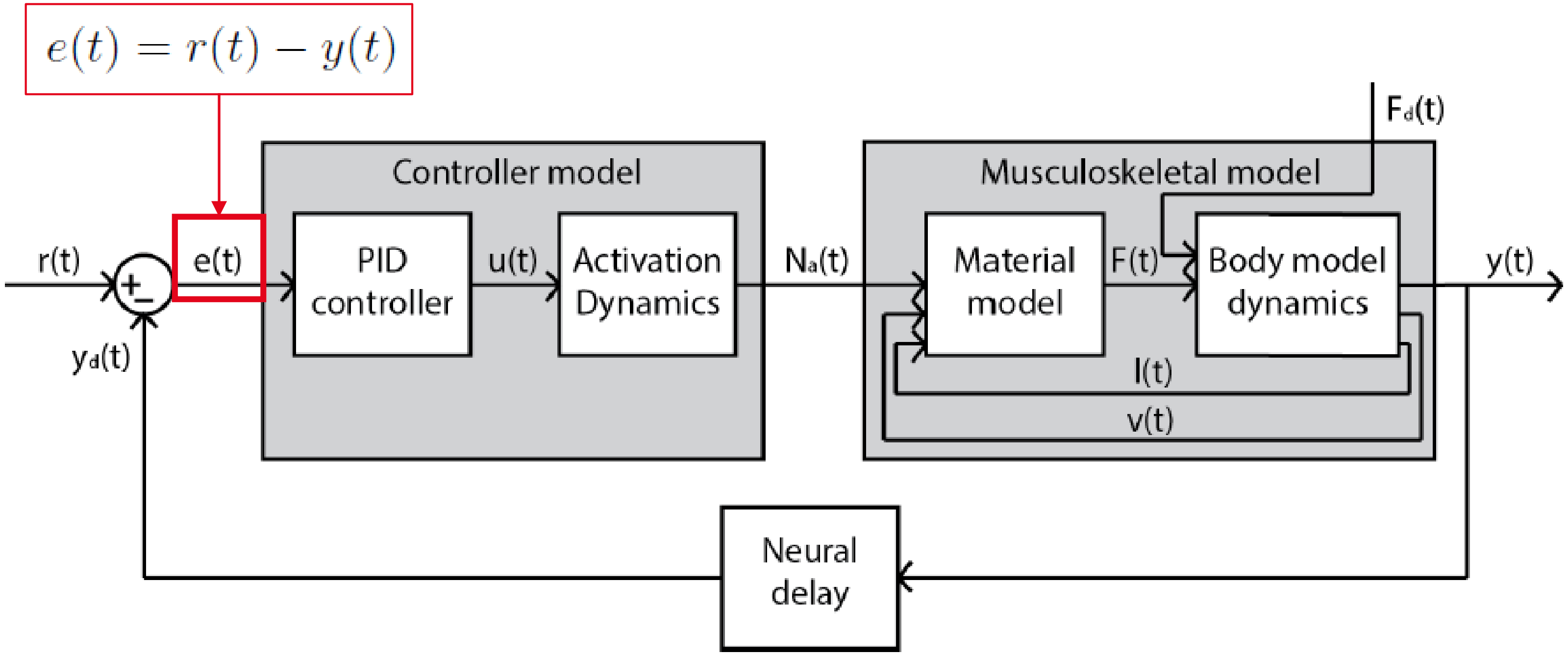


Muscular Feedback Control System



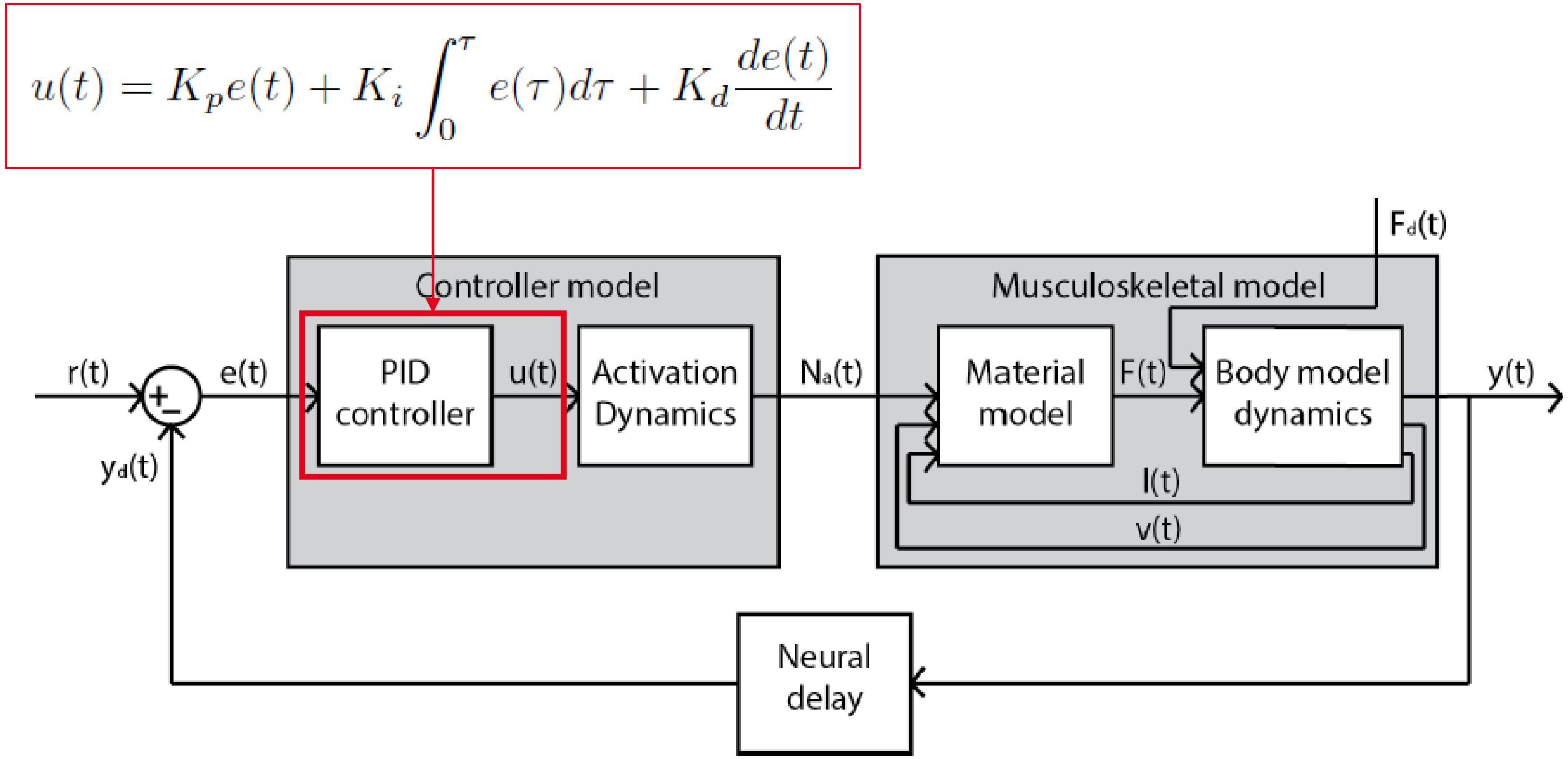
- r(t) – reference state
- y(t) – current state

Muscular Feedback Control System



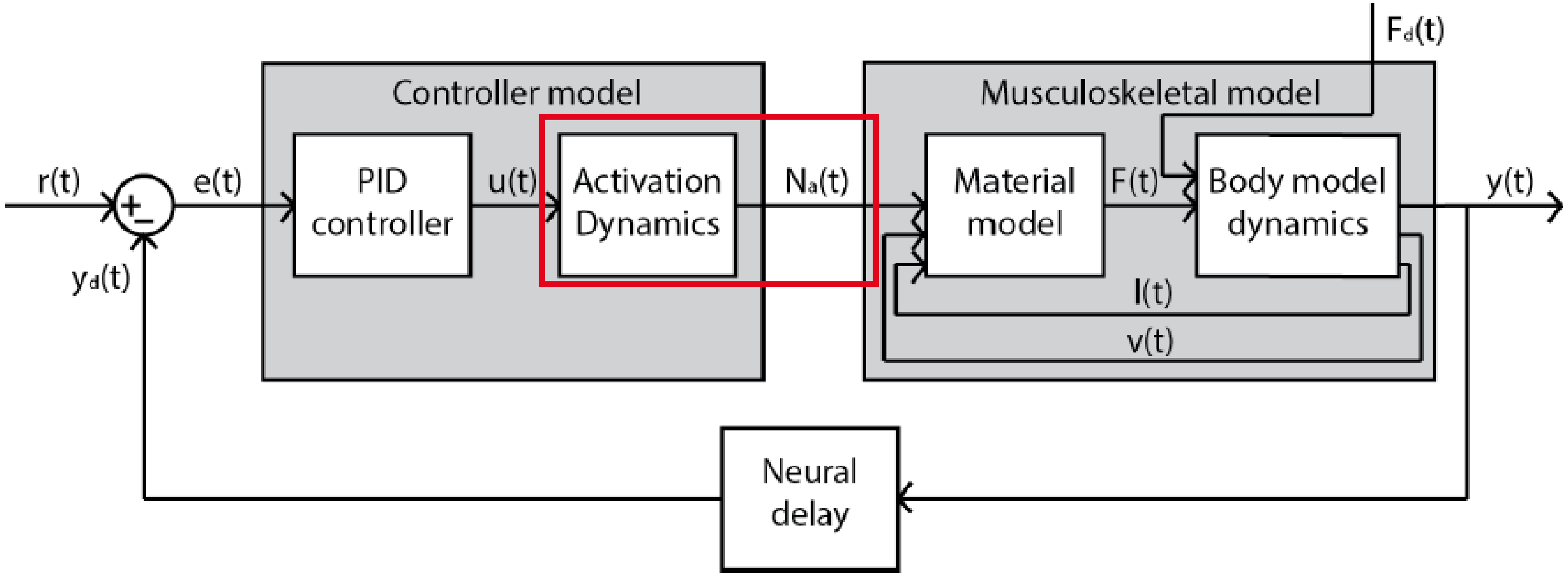
- e(t) – error (diviation of the model from the reference state)

Muscular Feedback Control System



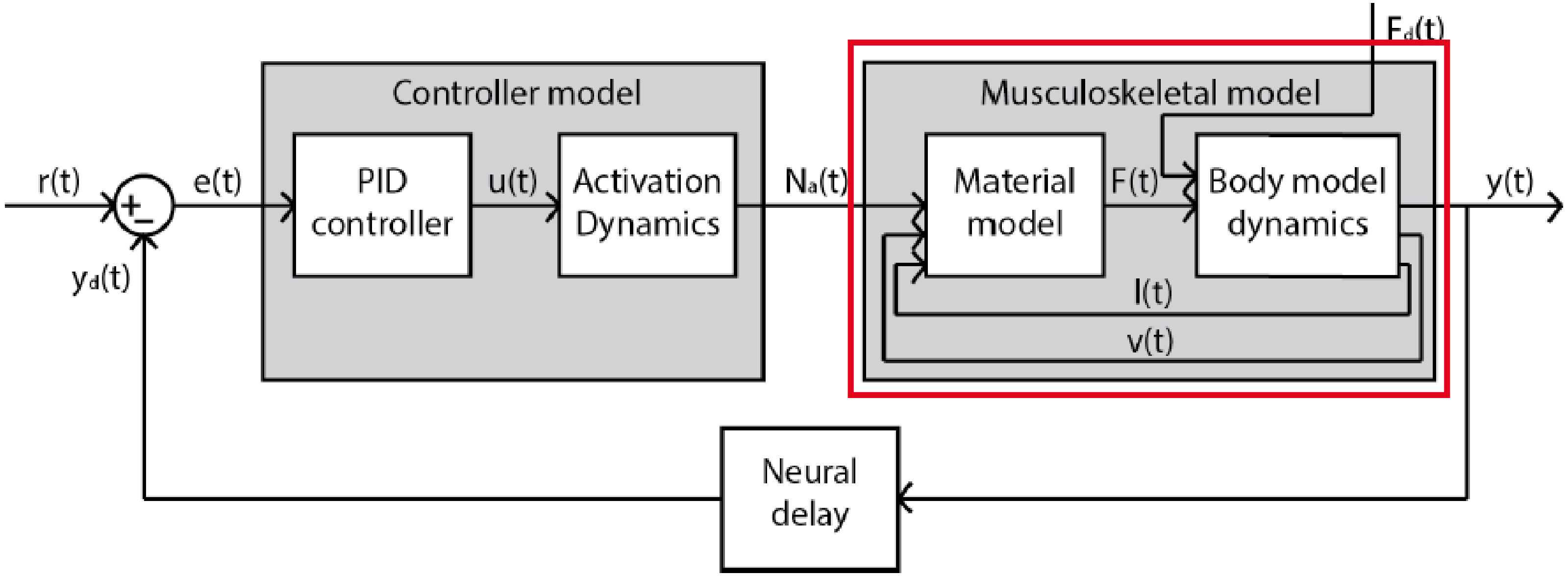
- u(t) – controller signal

Muscular Feedback Control System



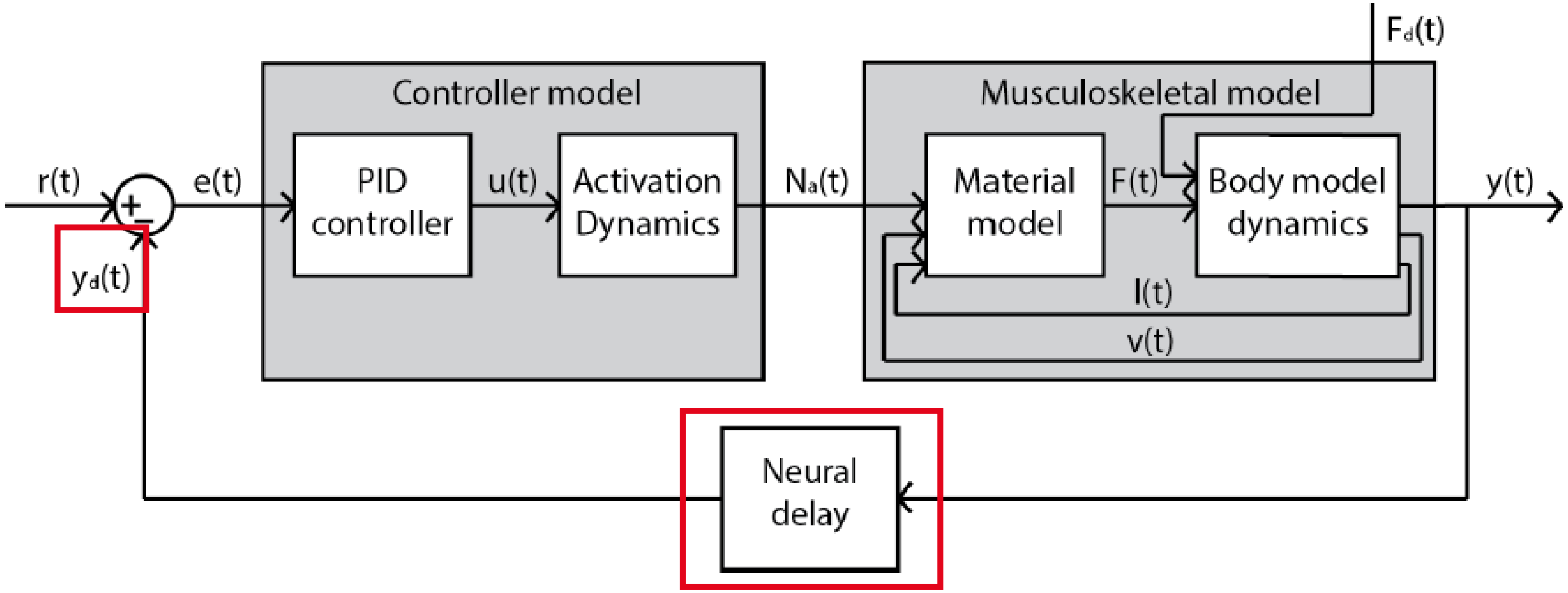
- Activation Dynamics – type of muscle activation
- $N_a(t)$ – magnitude of muscle activation

Muscular Feedback Control System



- Musculoskeletal model generates movement of the body part

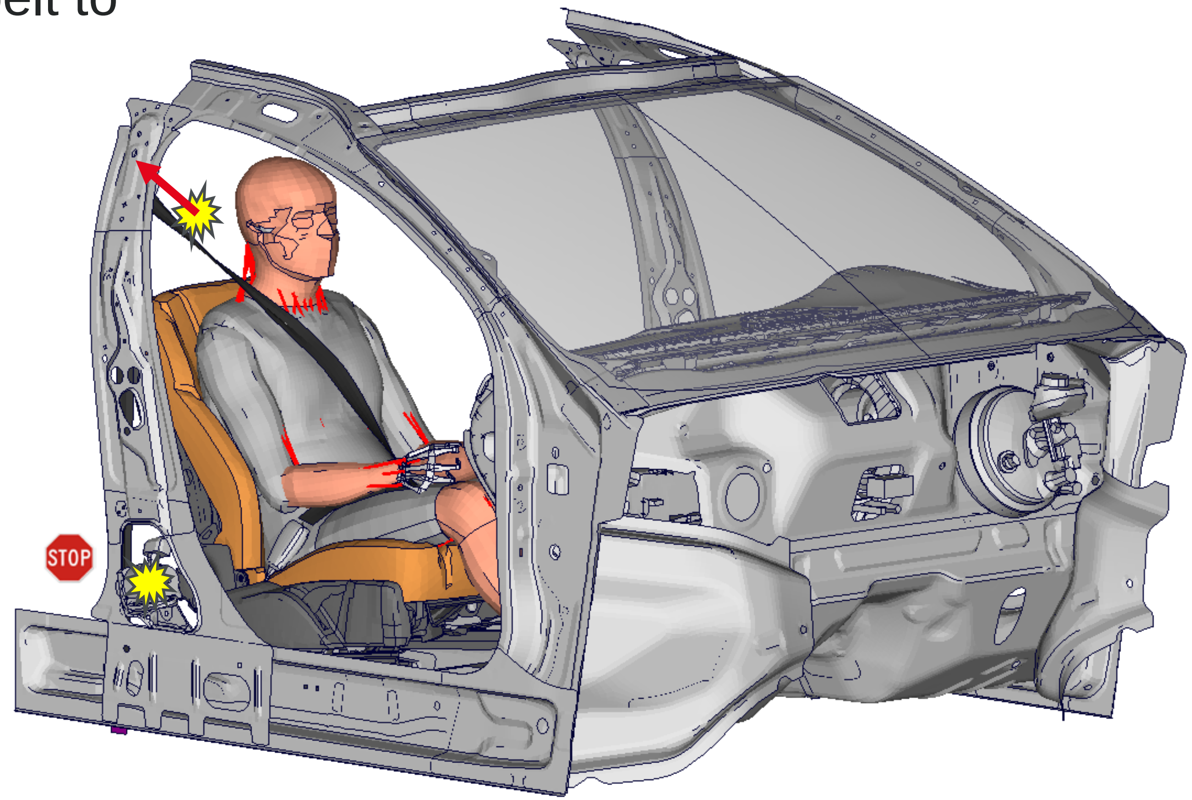
Muscular Feedback Control System



- Feedback of the new state with a neural delay
- New state is again compared with the reference state

Pre-crash Safety Systems

- Seat belt pre-pretensioning
  - Tightening of the belt to remove slack
- Retractor locking
  - Stops belt pay-out



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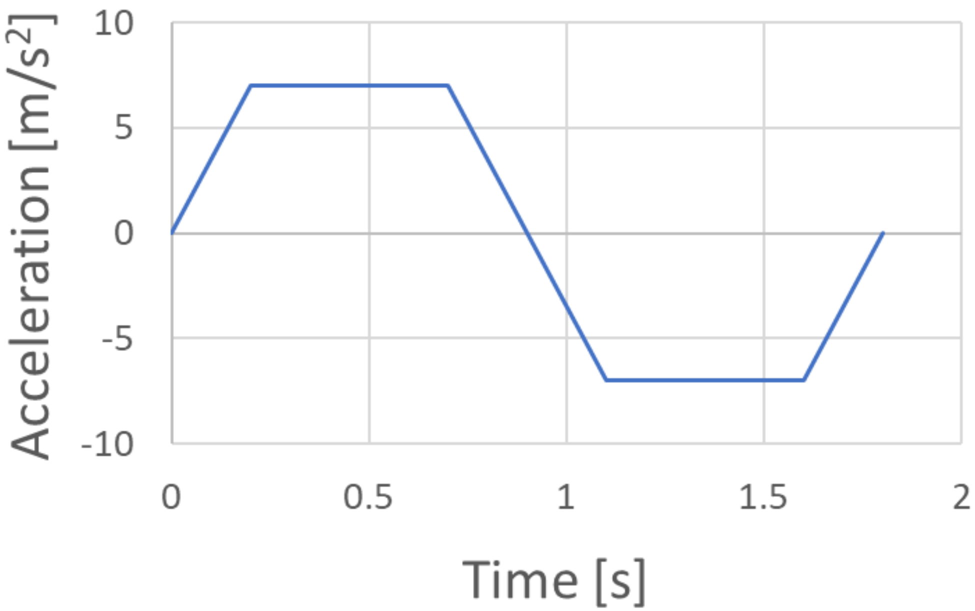
Avoidance Scenario



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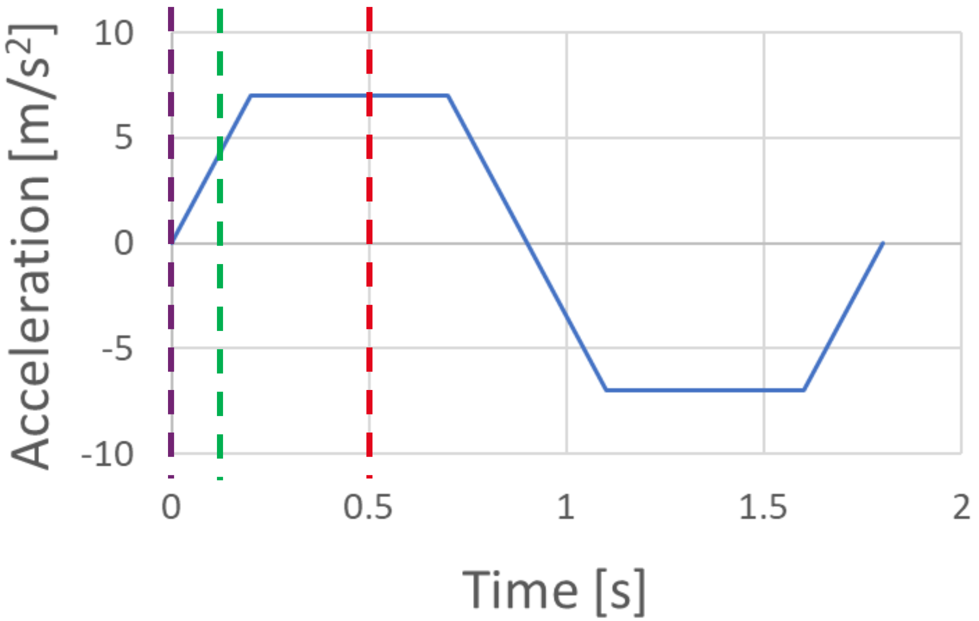
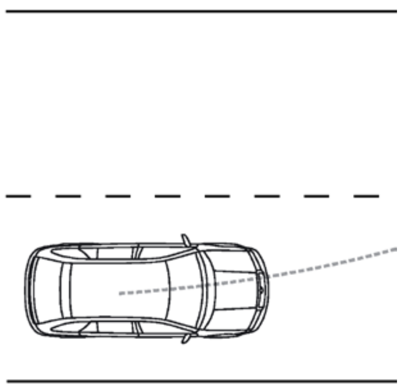
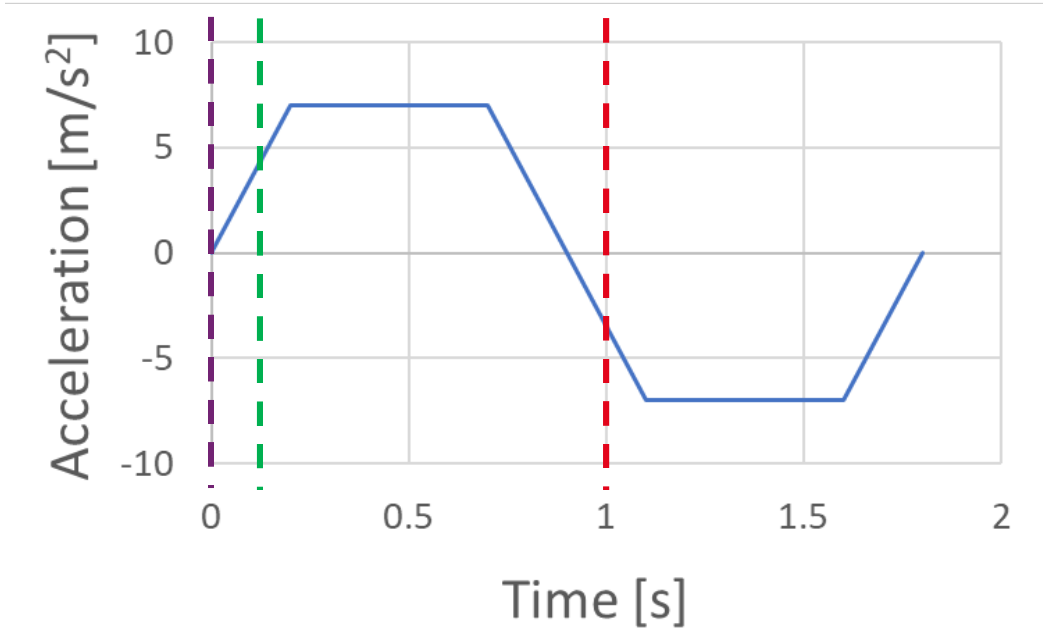
Avoidance Scenario

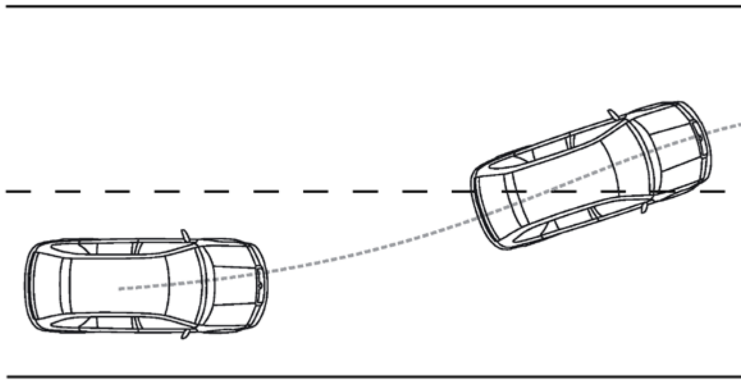




- $T_{avoidance} = 0.5\ s$
- $T_{pre-pretensioning} = 0\ s$
- $T_{retractor\ locking} = 20\ ms$

Avoidance Scenario





- $T_{avoidance} = 1.0\ s$
- $T_{pre-pretensioning} = 0\ s$
- $T_{retractor\ locking} = 20\ ms$

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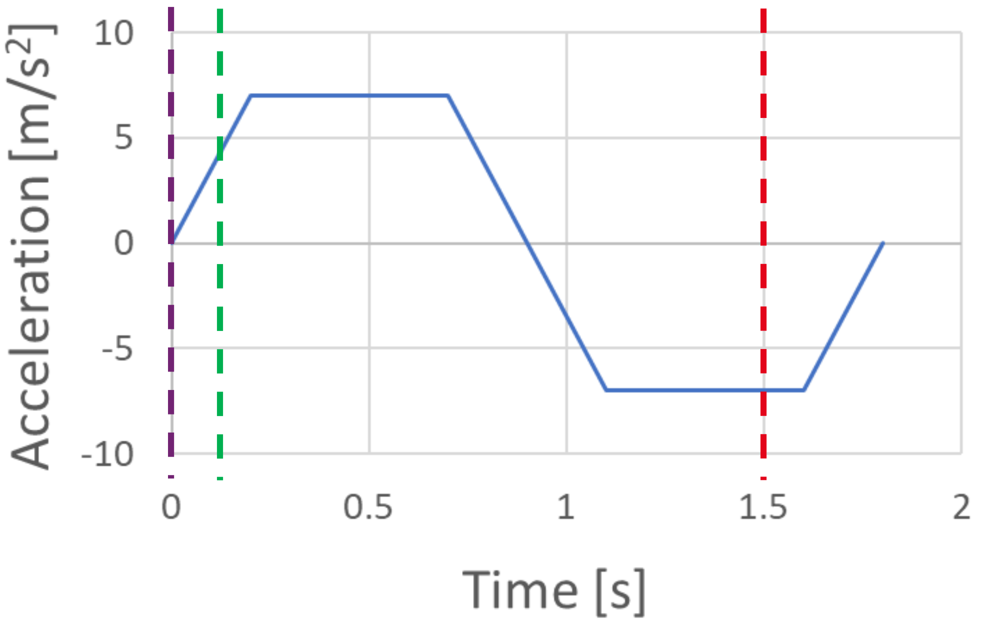
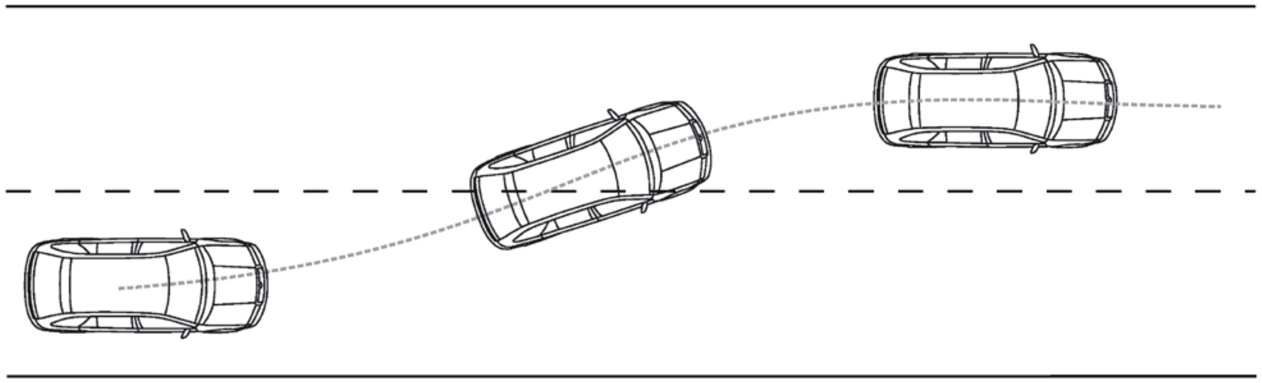
Avoidance Scenario





- $T_{avoidance} = 1.5\ s$
- $T_{pre-pretensioning} = 0\ s$
- $T_{retractor\ locking} = 20\ ms$

Simulation Matrix

Pre-crash avoidance time	Pre-pretensioning level
0.5s	-
0.5s	300N
1.0s	-
1.0s	300N
1.5s	-
1.5s	300N

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Results

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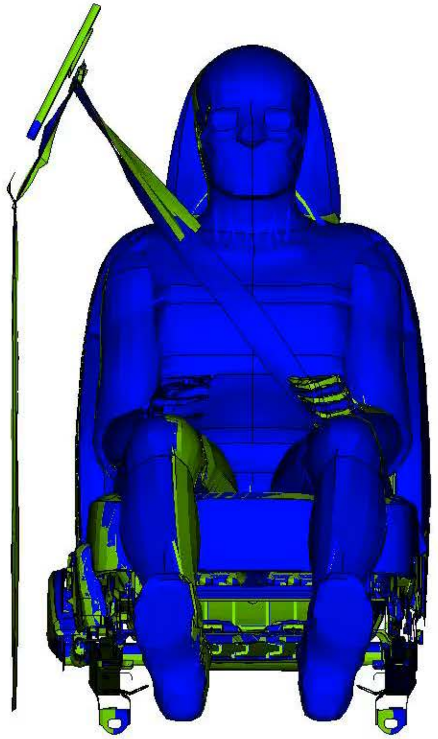
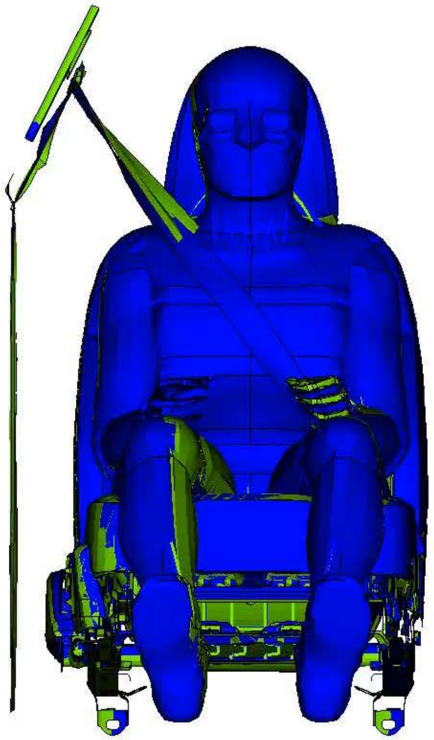
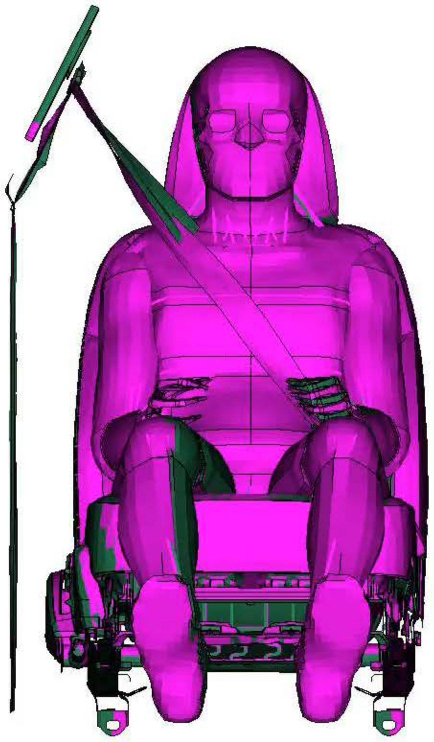
- Without pre-pretensioning
- 300N pre-pretensioning

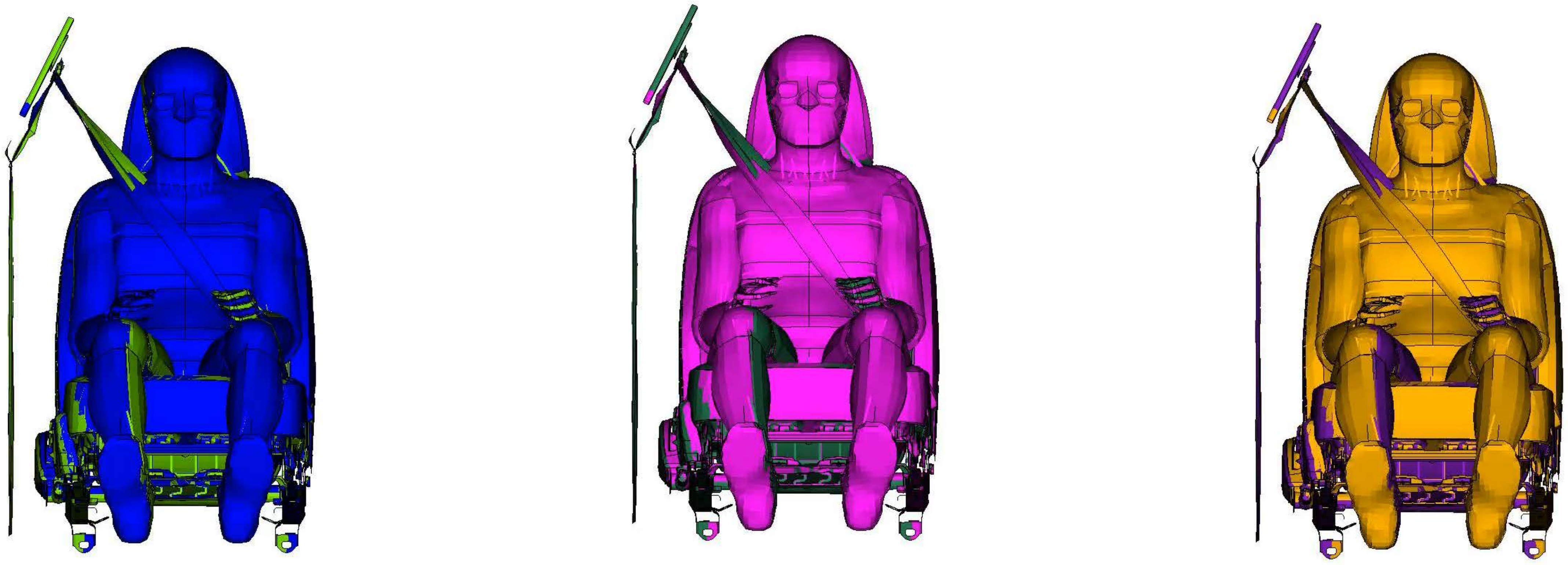


- Without pre-pretensioning
- 300N pre-pretensioning

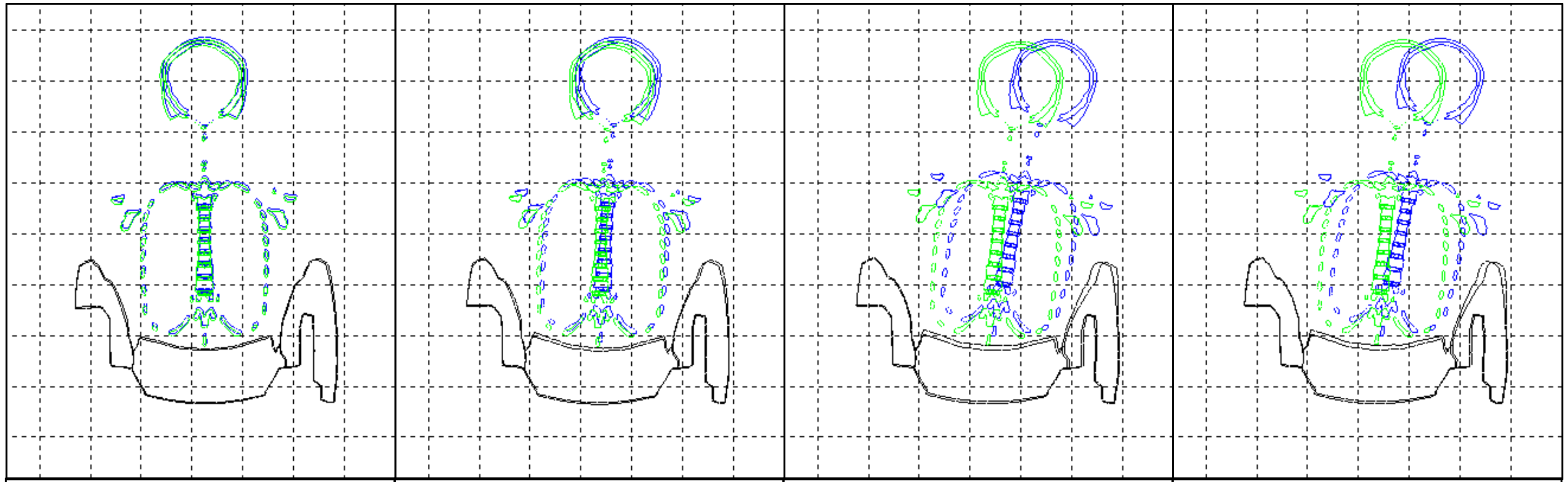




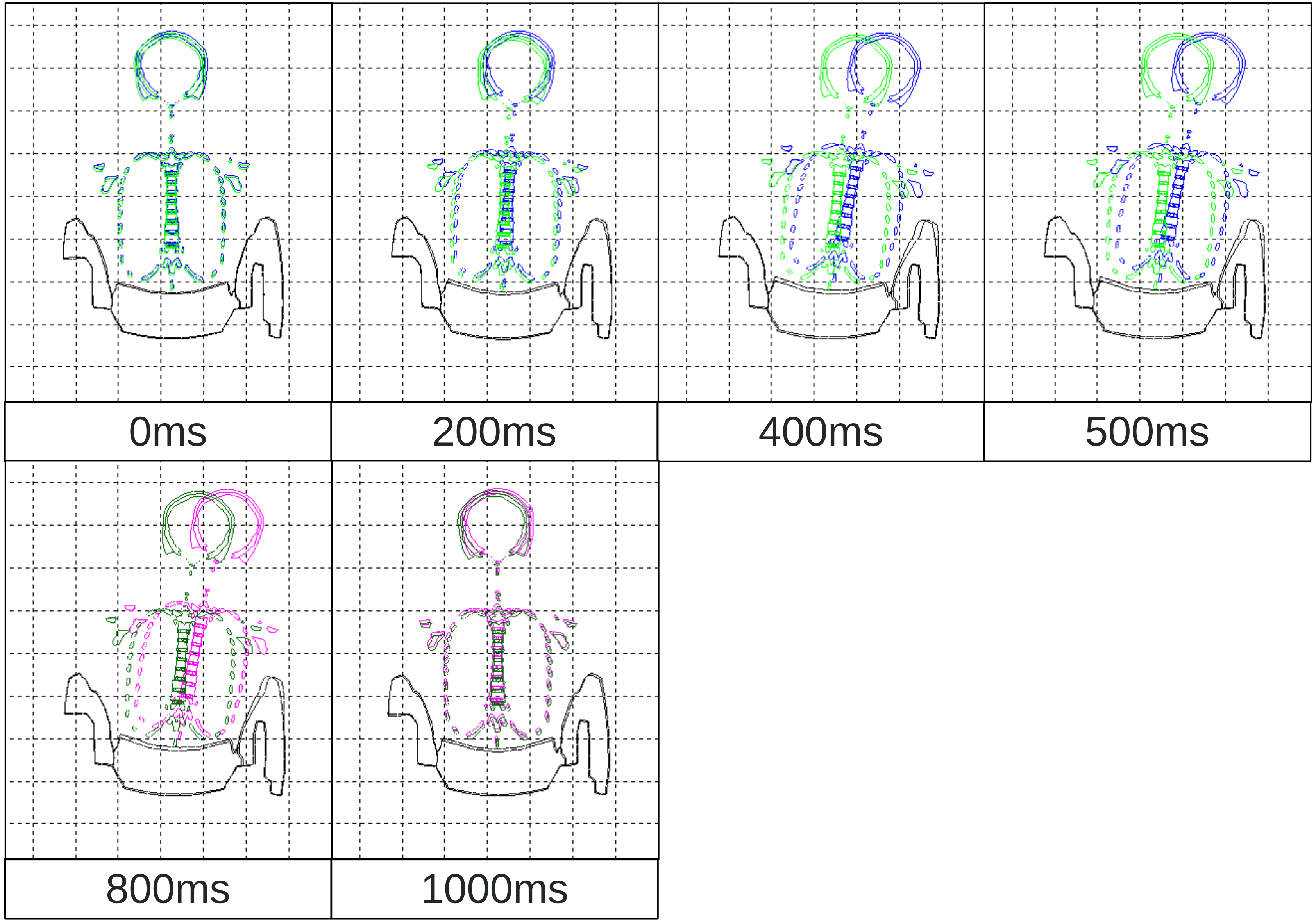
- Without pre-pretensioning
- 300N pre-pretensioning



- Without pre-pretensioning
- 300N pre-pretensioning



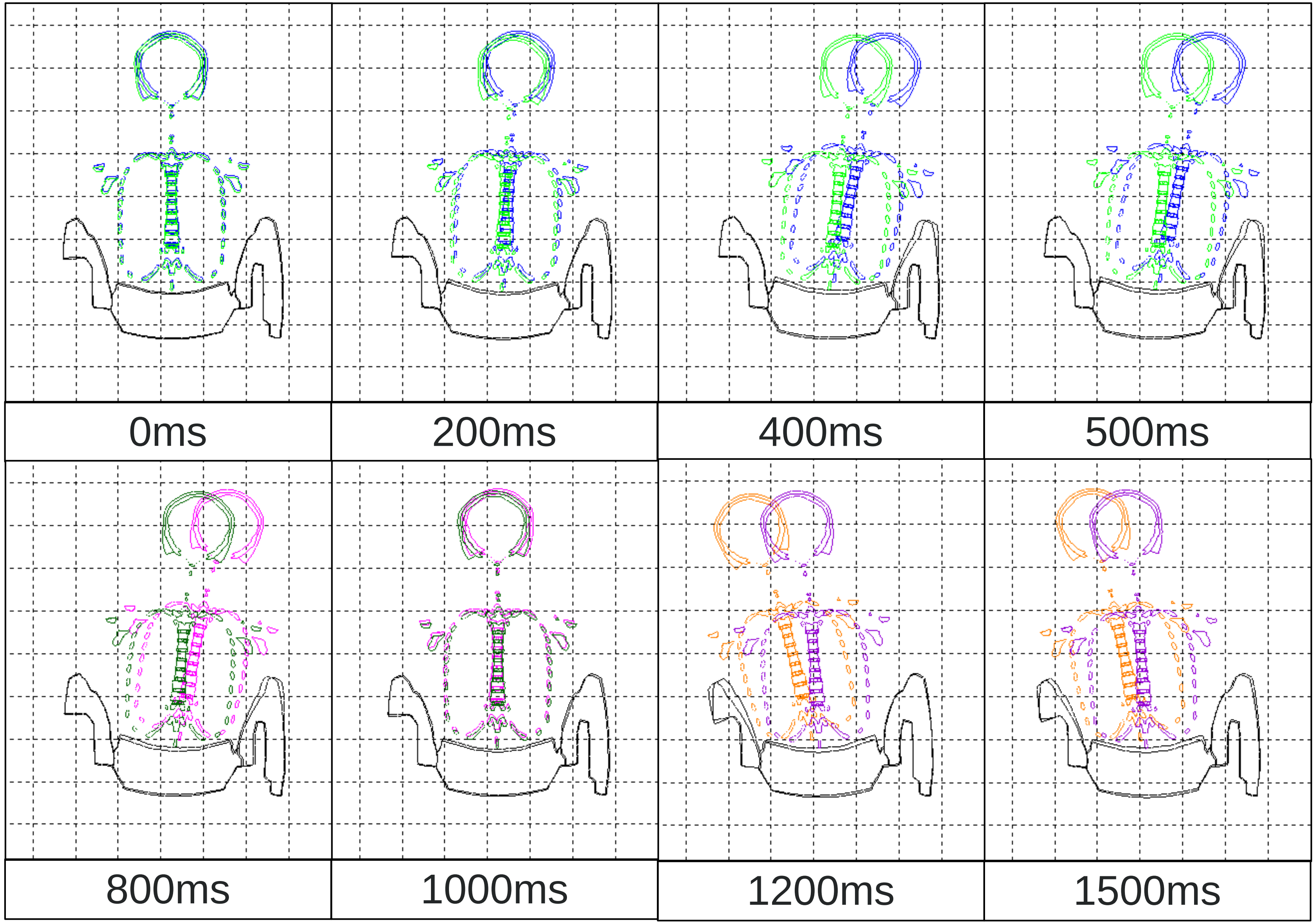
0ms	200ms	400ms	500ms



Without pre-pretensioning

300N pre-pretensioning

- Without pre-pretensioning
- 300N pre-pretensioning



Conclusion

- Pre-crash pre-pretensioning has high influence on occupant kinematics

- Head lateral displacement reduced with pre-pretensioning
  - 70 mm for 0.5 s and 1.0 s pre-crash avoidance
  - 100 mm for 1.5 s pre-crash avoidance

- HBMs are effective tools in vehicle safety system development and verification

- Modeling muscles in HBMs are necessary for biofidelity in pre-crash events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