ENOP

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Bundesanstalt für Straßenwesen

Status of the ENOP Project (Enable New Occupant Seating Positions)

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LAB ACCIDENTOLOGIE, BIOMÉCANIQUE, COMPORTEMENT HUMAIN

ceesar Help industry and administration to improve road safety

Autoliv

bast Federal Highway Research Institute

COMILLAS UNIVERSIDAD PONTIFICIA ICAI

TOYOTA

CELLBOND ATD

FORVIA

Université Gustave Eiffel

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- Philippe Petit, LAB PSA Renault (FR)
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- Martin Östling, Autoliv Development AB (SE)
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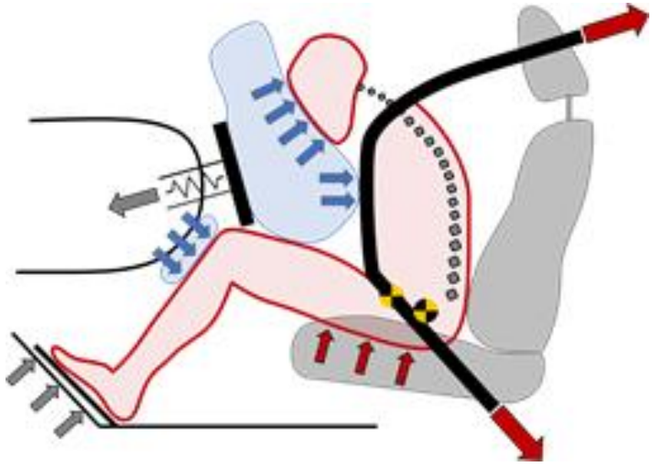
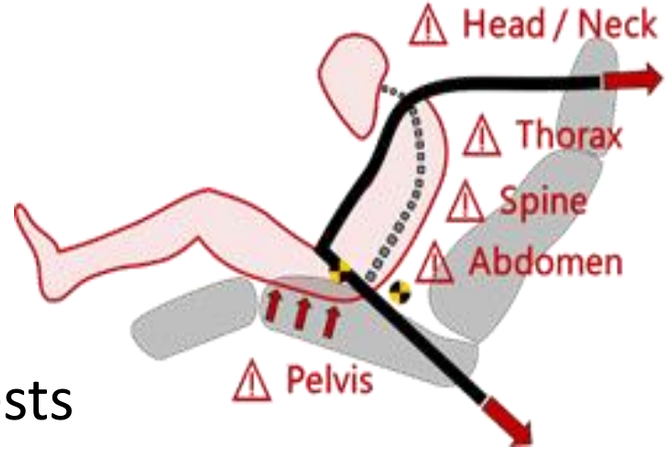
- Olivier Richard, Forvia (FR)
- Philippe Beillas, Université Gustave Eiffel (FR)

- The ENOP project will run 15 PMHS tests in reclined positions to
  - Investigate if new types of injuries appear in recline positions
  - Contribute to biofidelity specifications and validations of ATD's and HMB's
- As part of the activities paired Hybrid-III and THOR M50 tests will be conducted to investigate it's validity in term of kinematics and injury prediction
  - This will involve THOR hardware modification specifications and prototyping
- The consortium consists of 8 members and is coordinated by LAB PSA Renault
  - No external funding
  - Advisory board: NHTSA / VRTC – K. Moorhouse; Univ. Gustave Eiffel – P. Vezin; BASt – B. Lorenz
- **One of the aims of the consortium is to coordinate activities with other initiatives (including NHTSA) in order to ensure that test series are comparable and complementary**

Background and motivation

- New technologies and automated driving vehicles will allow more comfortable seating positions currently not possible
- Occupant safety must be maintained also in these new seating positions creating new challenges. For example, the reclined posture increases the risk of submarining and kinematics of head and neck might be very different
- Appropriate test tools (ATDs and HBMs) and injury assessment criteria for these conditions need further biomechanical reference data.
- ENOP aims to address these gaps by performing PMHS tests in non-conventional positions.





ENOP Objectives and Approach

- Investigate potential new injuries related to non-conventional occupant positions
- Provide reference PMHS test data in non-conventional positions including reclining of both the seat back and seat pan
- Contribute to the biofidelity specifications and validation of ATDs and HBMs
- Run matching tests with three ATDs (Hybrid III 50M, THOR-50M and THOR-50RS)
- Coordinate with other initiatives

ENOP Test Configurations

SP1	SP2	SP3	SP4	SP5
				
Seat pan : 15° Back : 22°	Seat pan : 15° Back : 45°	Seat pan : 25° Back : 45°	Seat pan : 25° Back : 60°	Seat pan : 40° Back : 60°

- 5 Seat positions, frontal crash pulse (50 km/h)
- Pulse, seat / seatback angles chosen to compliment test matrixes of other initiatives
- 3-point seat belt system without airbag (concept designed by Autoliv to reduce the risk of submarining while limiting the risk of pelvis wing and lumbar vertebra fractures)

Links with other Initiatives

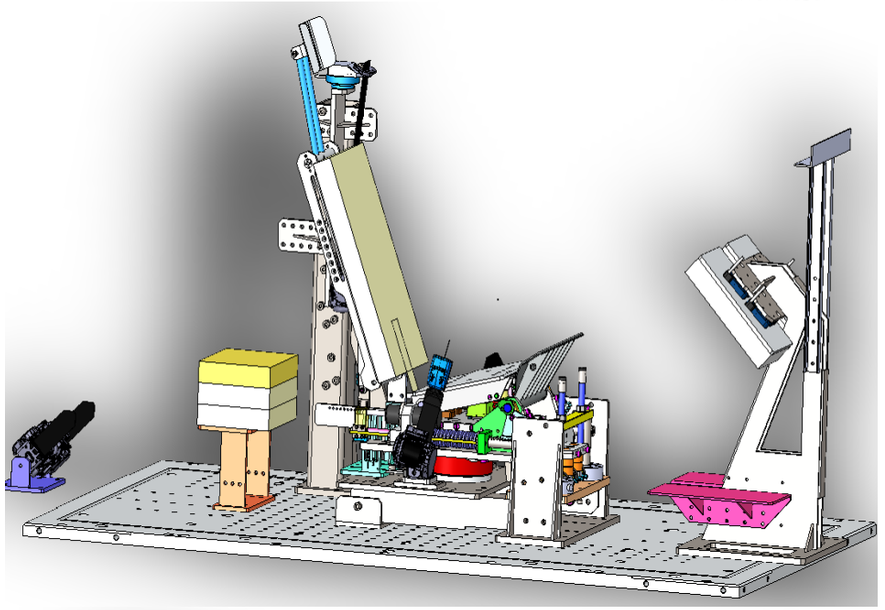
	ENOP	UMTRI	UVA	Forvia
Semi rigid seat	x	x	x	x (stiffer)
Pulse 50 km/h	x		x	x
Pulse 56 km/h		x		
Pulse 30 km/h		x		
Pretension	Triple	Static	Triple	Double (Lapbelt)
Load limitation	Triple	Single (shoulder)	Single (shoulder)	Triple
Tests per specimen	1	3	1	1

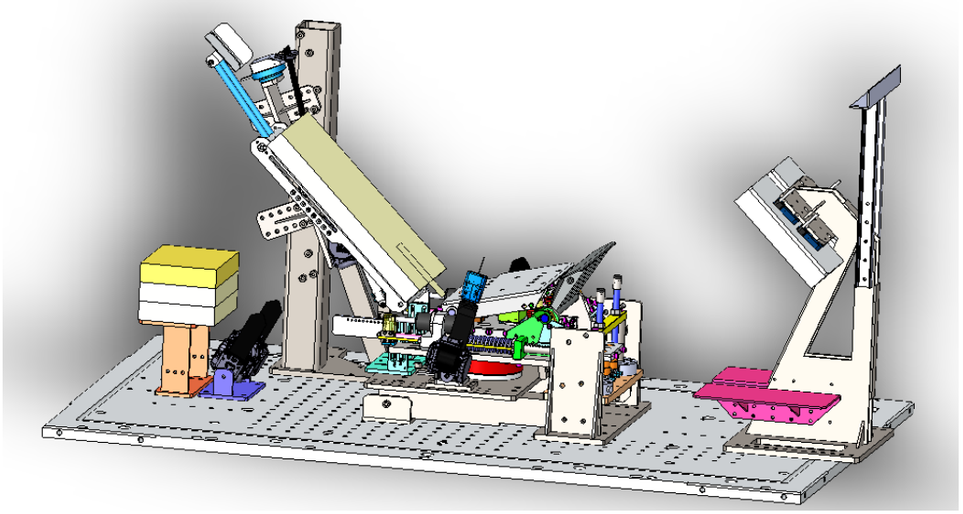
Methods: Sled Tests in ENOP Test Setup and ATD Simulations

- 15 PMHS tests at ICAI-Comillas in 5 seating positions
- In all five ENOP seat configurations, matching sled tests with three different ATDs (Hybrid III 50M, THOR-50M and THOR-50RS) at BASt.
- Test setup duplicated and adapted to be mounted on the sleds at BASt (deceleration sled) and ICAI (inverse sled).
- A test campaign was performed at both test facilities using the same Hybrid III 50M to check for reproducibility → critical to ensure that PMHS and ATD tests are effectively paired.

Test Setup

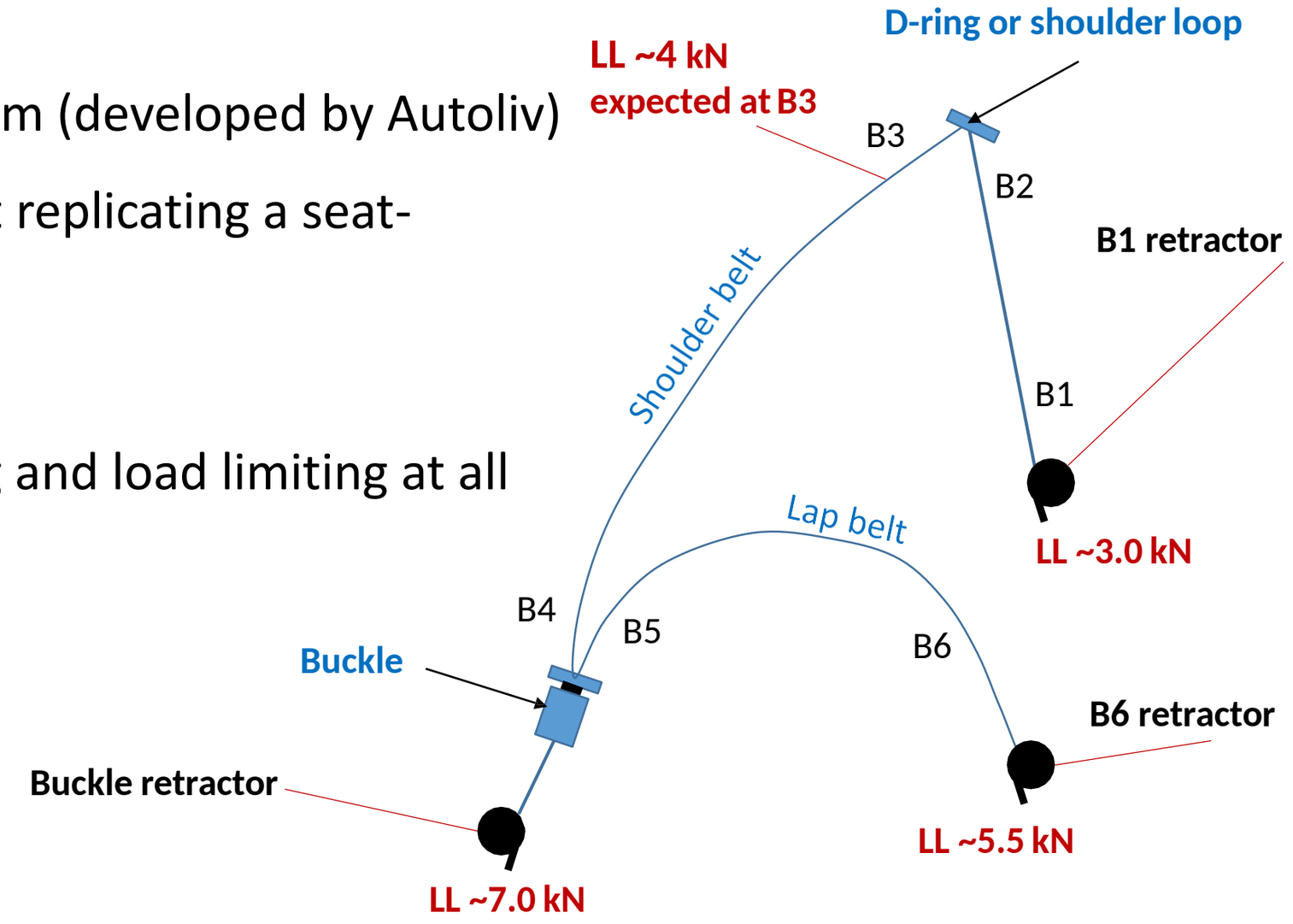
- Adjustable components to achieve the different seating positions
  - Seat and the seat back can be tilted
  - B-pillar with D-ring can be adjusted to simulate a seat integrated belt
- Generic semi-rigid seat composed of two articulated plates: a seat pan and a frontward anti-submarining ramp
- Foot rest
- Knee stoppers as safety measure





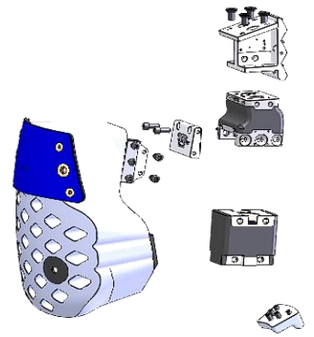
Restraint System

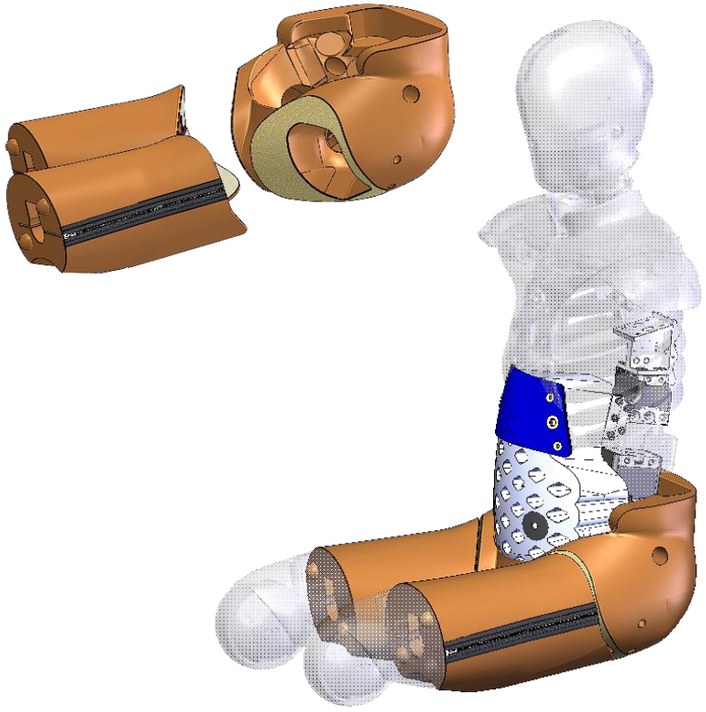
- A conceptual seat belt system (developed by Autoliv)
- Continuous 3-point seatbelt replicating a seat-integrated belt system
- Crash-locking tongue
- Pyrotechnical pretensioning and load limiting at all three belt anchorage points



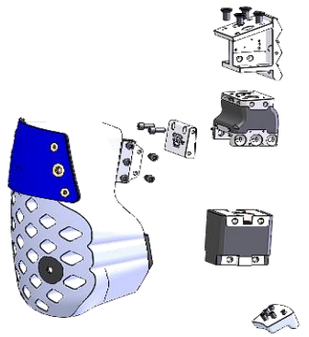
Reclined Seating Modifications Kit (THOR-50RS)

- To consider new occupant positions in automated vehicles, NHTSA conducted a study of the positioning limitations of THOR-50M when used in reclined seating
- Subsequently a Reclined Seating Modifications Kit was developed by UVA and Cellbond in a NHTSA funded project addressing these limitations
- The THOR-50M with RS kit can accommodate positions from upright to 50-55°
- Maintaining performance consistent with the standard THOR-50M in the conventional upright seat position



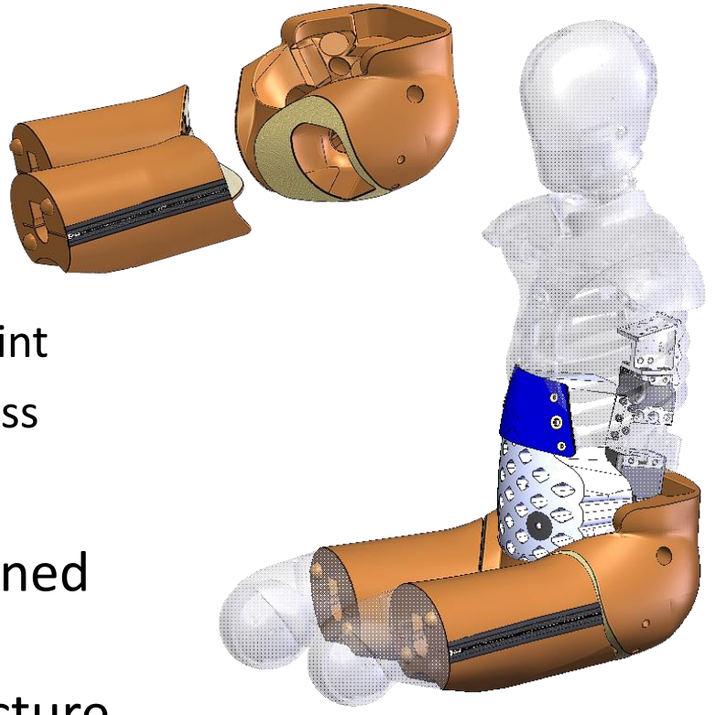


Reclined Seating Modifications Kit (THOR-50RS)



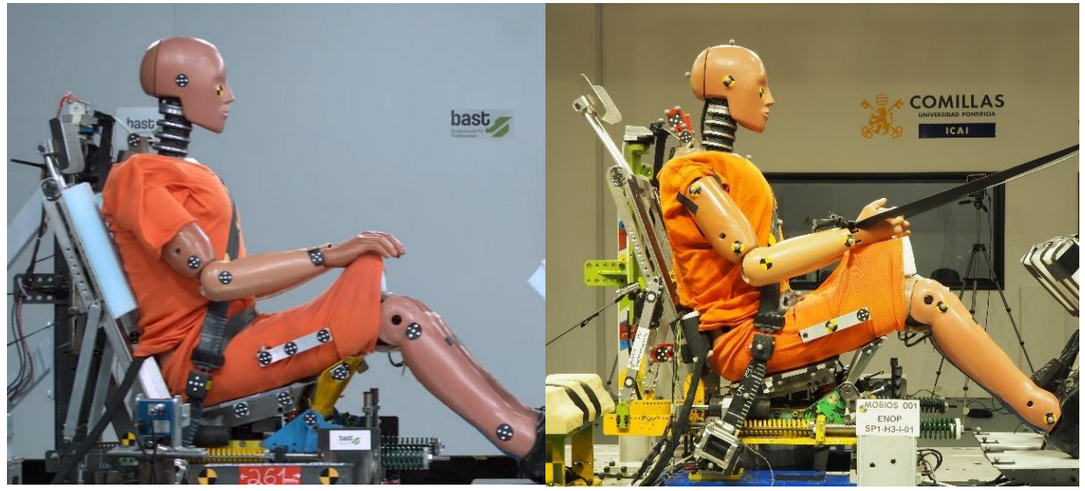
Main components:

- Articulated pelvis and thigh fleshes decoupling upper legs from pelvis allowing torso to articulate as a single structure
- Reduced buttock thickness in the articulated pelvis flesh with redesigned coccyx/sacrum to improve pelvis rotation
- Lower thoracic spine flex joint replacing the lumbar spine pitch adjuster
  - Redistributing stress across spinal column, away from lumbar spine flex joint
  - Stiffer lumbar spine flex joint to accommodate for the overall spine stiffness reduction
- Unified abdomen prevents gaps from opening in the torso in reclined positions by acting as singular unit for the entire abdomen cavity being capable of compression and extension via honeycomb structure

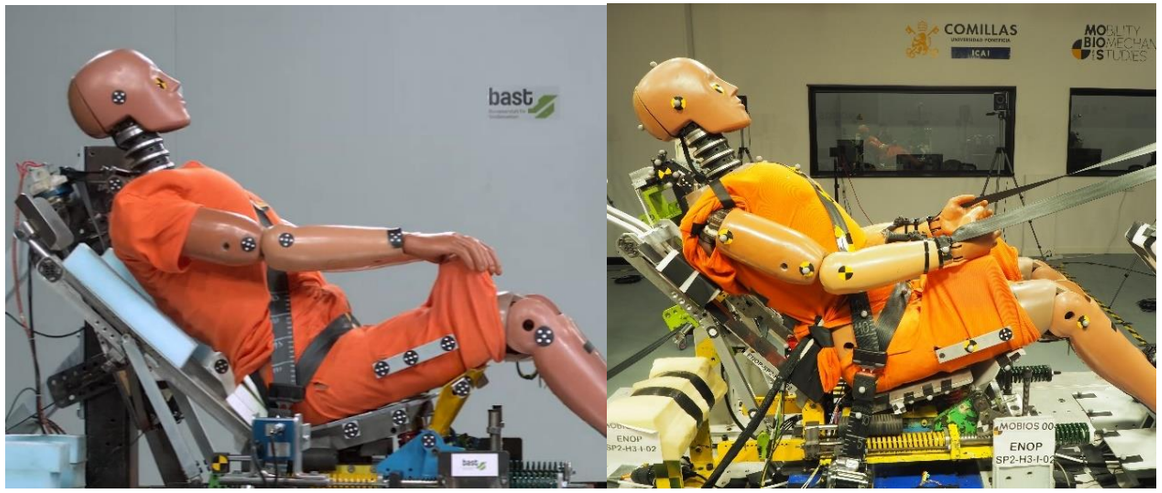


Hybrid III 50M Tests at BASt and ICAI

- To ensure the reproducibility of the results obtained in the test fixtures at ICAI and BASt, preliminary tests using the same Hybrid III 50M were conducted in each lab in ENOP SP1 and ENOP SP2



ENOP SP1



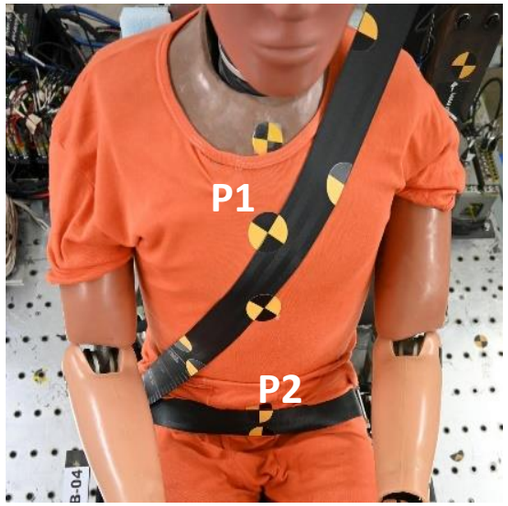
ENOP SP2

Hybrid III 50M Positioning Target Deviation between BASt and ICAI

- To ensure comparability, a detailed ATD positioning and belt installation procedure was prepared including belt routing target values with small deviation tolerances

	SP1	SP2
H-Point	X = ±4 mm Z = ±2 mm	X = ±3 mm Z = ±3 mm
Head CoG	X = ±5 mm Z = ±4 mm	X = ±18 mm Z = ±9 mm
Pelvis Angle	Y = ±0.1°	Y = ±0.7°
Thorax Angle	Y = ±0.5°	Y = ±2.1°
Head Angle	Y = ±0.5°	Y = ±2.6°

	SP1	SP2
Shoulder Belt (P1)	X = ±2 mm Z = ±3 mm	X = ±1 mm Z = ±4 mm
Lab Belt (P2)	X = ±5 mm Z = ±2 mm	X = ±4 mm Z = ±6 mm



Simulation Model of the ENOP Test Setup

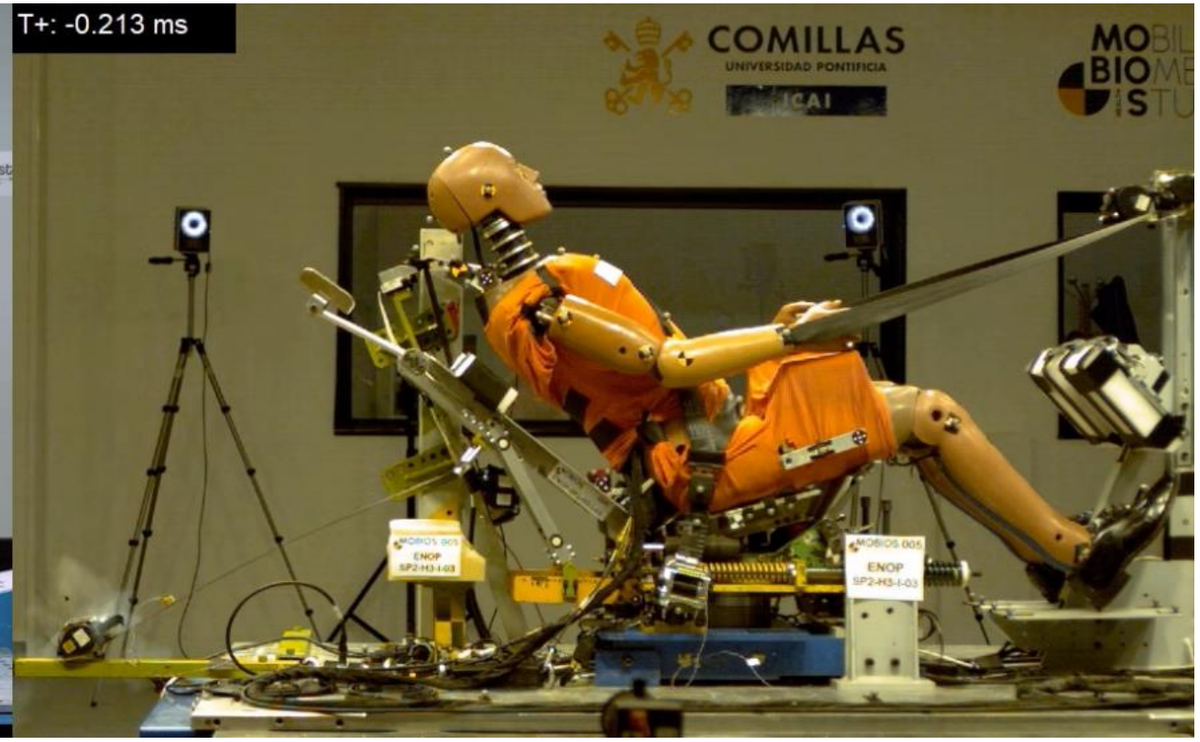
- The ENOP test programme was supported by FE-simulations
- An FE model of the test setup was developed to match the ENOP test conditions and validated against tests with Hybrid III 50M
- The FE model of the test setup will be further validated using sled test data from upcoming tests within ENOP
- It can also be used for HBM validation against the ENOP PMHS test data

Preliminary Results: Hybrid III Tests at ICAI and BASt –SP1

- Comparison of Hybrid III ATD kinematics ICAI vs. BASt in SP1

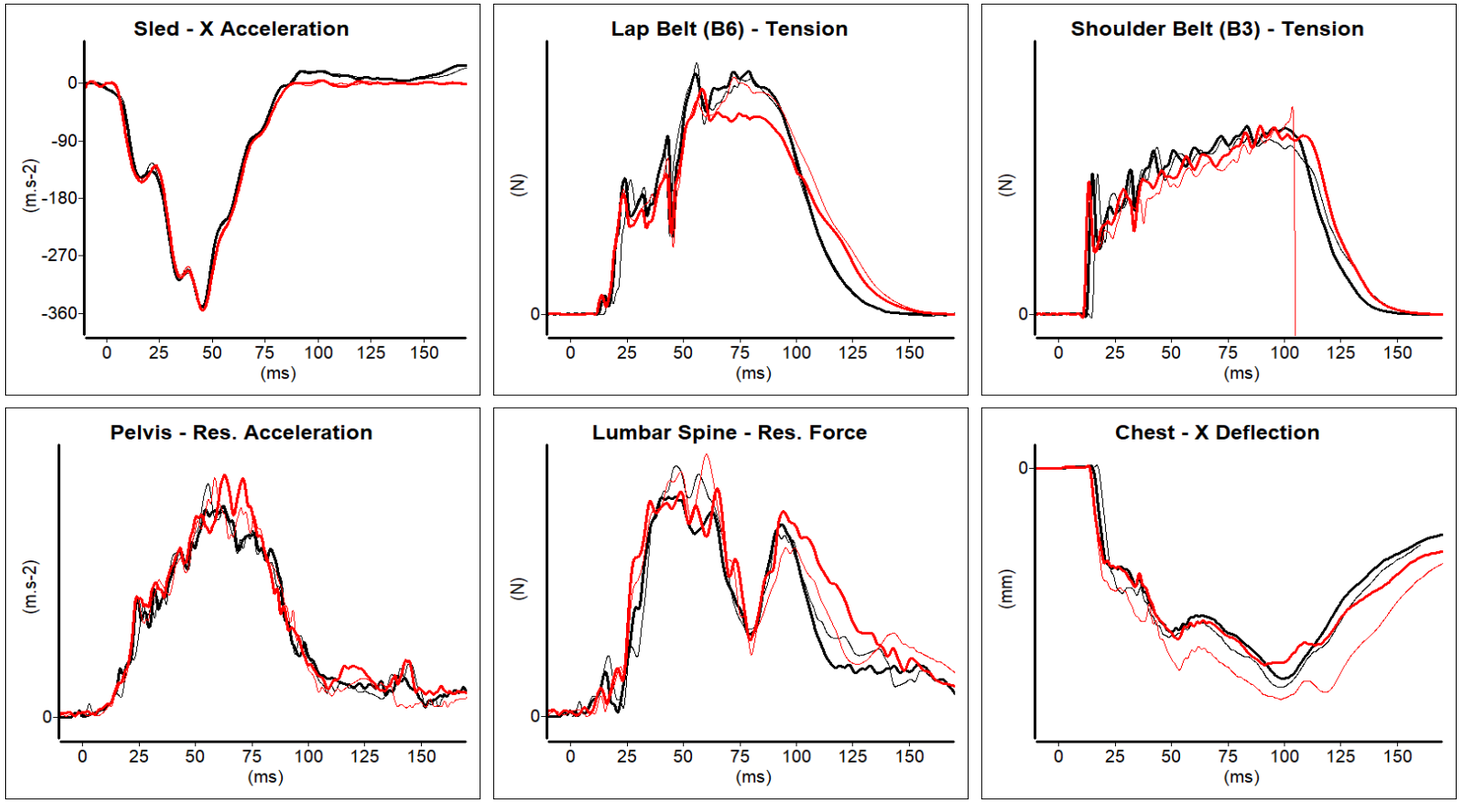
Preliminary Results: Hybrid III Tests at ICAI and BASt –SP2

- Comparison of Hybrid III ATD kinematics ICAI vs. BASt in SP2



Preliminary Results: Hybrid III Tests at ICAI and BASt –SP1

- The similarity of all recorded ATD and sled measurements was evaluated.
- Examples of measurements from ENOP SP1:

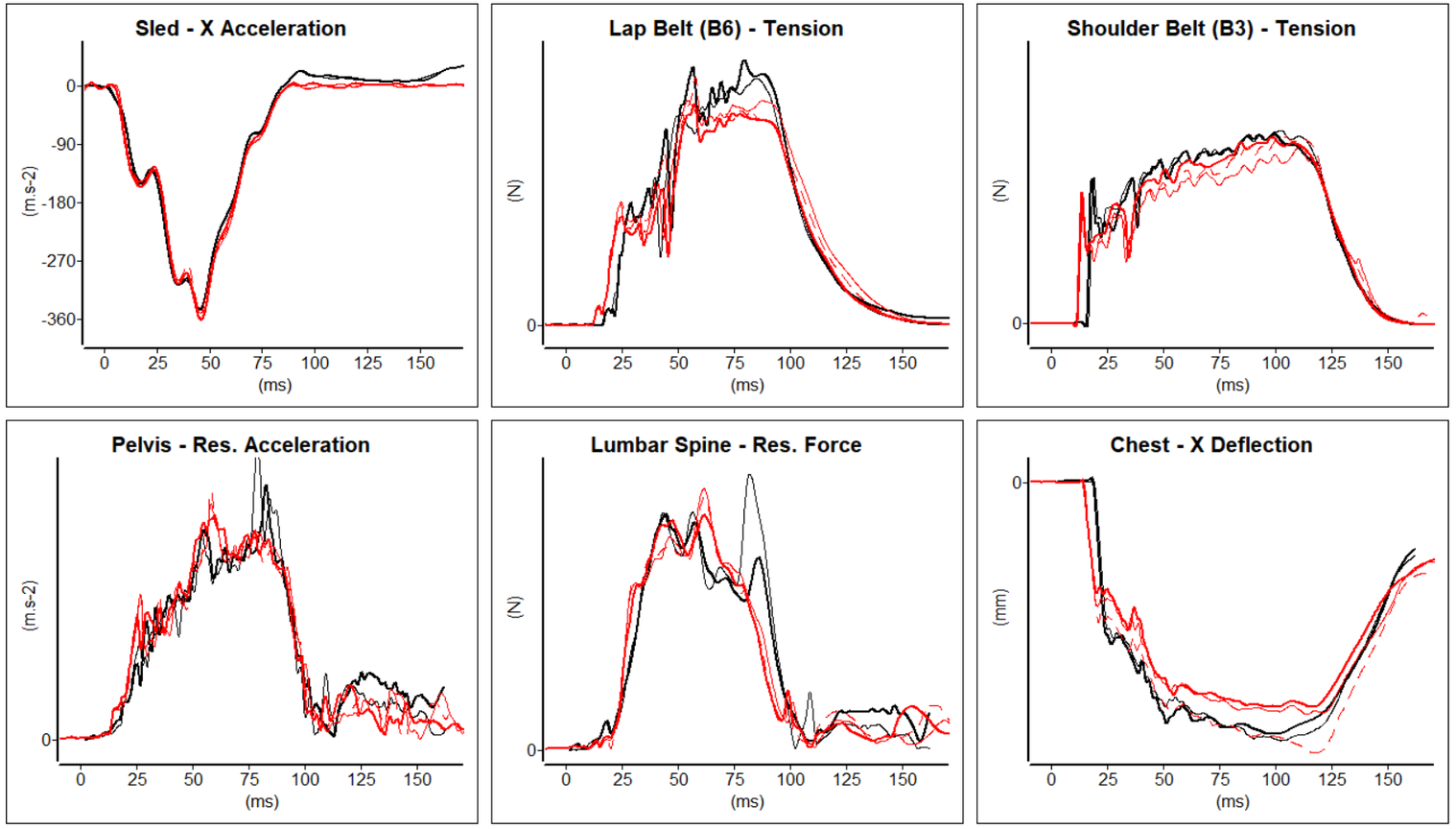


ICAI tests (N=2)

BASt tests (N=2)

Preliminary Results: Hybrid III Tests at ICAI and BASt – SP2

- Examples of measurements from ENOP SP2:

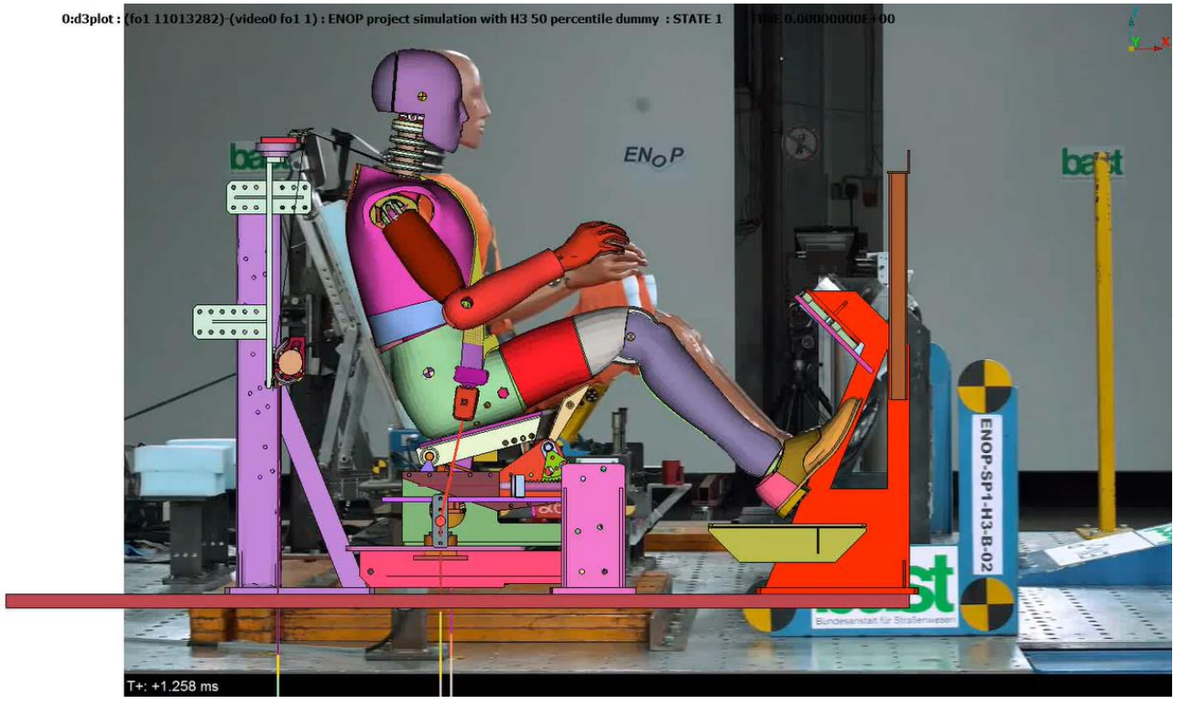


ICAI tests (N=2)

BASt tests (N=3)

Preliminary Results: Hybrid III Simulations

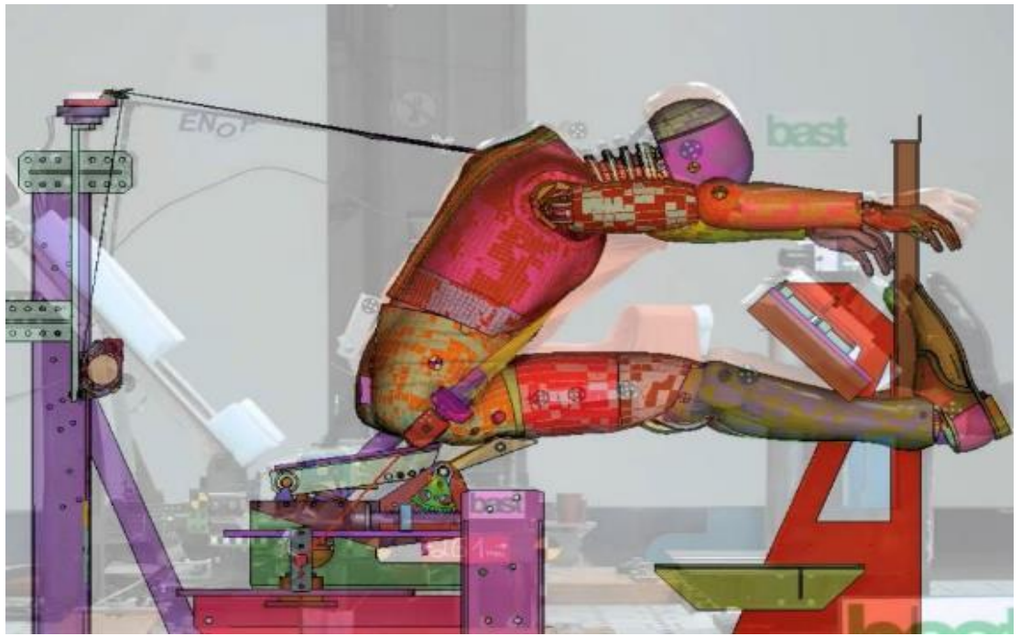
- Overlay of FE-simulation and Hybrid III test at BASt in SP1

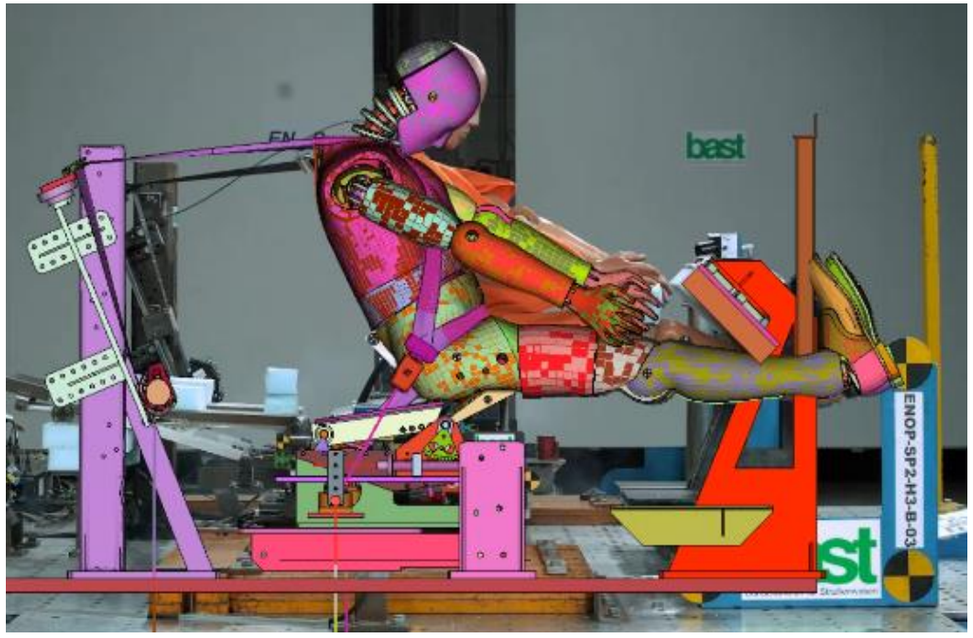


- Overall kinematics of the ATD are very similar between test and simulation.
- The validation status of the model is reasonable and will be further improved.

Preliminary Results: Hybrid III Simulations

- Max excursion comparison between FE-simulation and test in SP1 and SP2:





- Pelvis and torso movement are fairly comparable.
- The head of the CAE model shows some higher rotation compared to the test.

Discussion

- The reproducibility tests conducted on Hybrid III 50M were found to be satisfactory to start the PMHS test series.
- Running the paired PMHS and ATD tests in two separate test facilities was chosen to share the workloads and to allow for semi-parallel tasks.
- Performing matching tests in two facilities using two test setups proved to be challenging. For example small details such as vibration of the D-ring might influence the friction between the belt and the D-ring and cannot be corrected using post processing.

Discussion

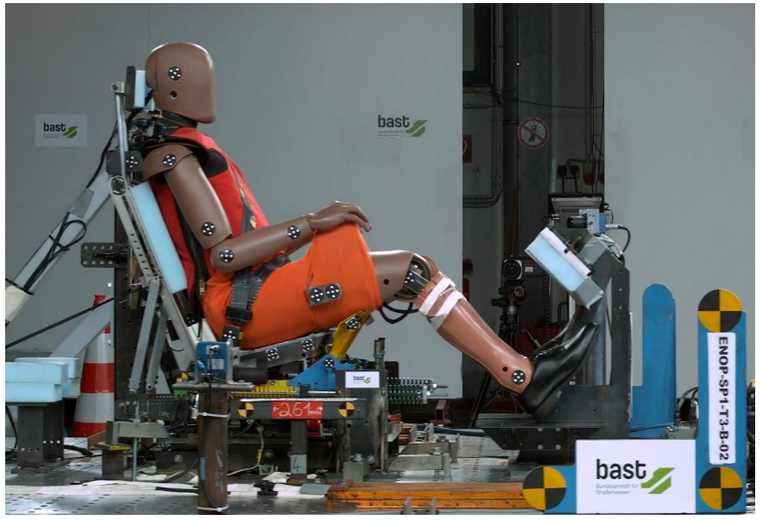
- All the test setup documentation (including the CAD, CAE models of the setup, etc.) and procedures as well as the differences identified between the two test facilities will be carefully documented in the project deliverables.
- However, this experience clearly raised the question of the robustness of the injury risk curves developed using paired tests or simulations of PMHS performed decades prior to the matching ATD tests or HBM simulations by separate teams based only on the publications available.

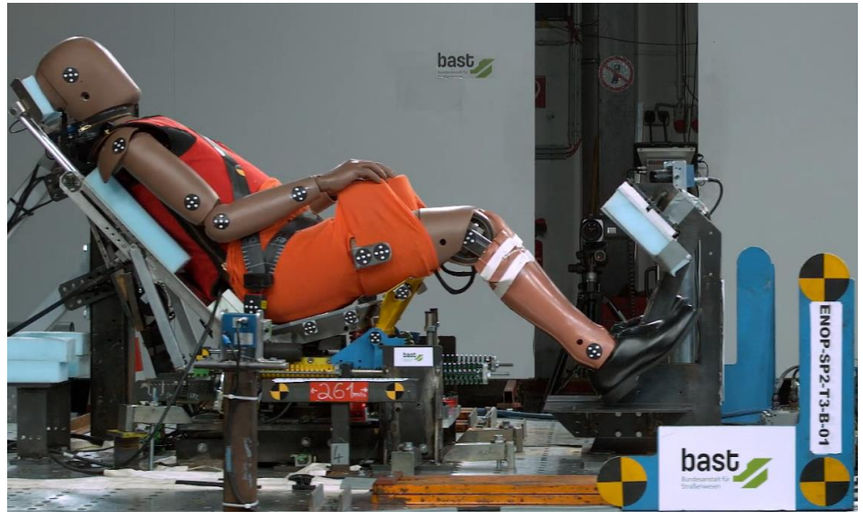
Conclusions

- Validation of reproducibility is satisfactory based on tests with Hybrid III 50M in the two test facilities BASt and ICAI.
- The PMHS campaign has started at ICAI and the matching ATD tests at BASt shall promptly follow.
- Based on the experience gained in the project, the ENOP consortium will provide the research community with detailed material to ensure that the tests are reproducible in the future both physically and numerically.

Summary and Outlook

- ICAI performed four PMHS tests (in SP2) so far. Three more PMHS tests in SP1 condition to be completed in April 2024, 9 more before end of June 2024.
- ATD tests with Hybrid III, THOR-50M and THOR-50RS with updated parts in SP1 and SP2 were recently conducted at BASt.





- Further ATD tests matching the PMHS tests will be systematically conducted after the PMHS tests such that the ATD test conditions strictly match the boundary conditions.

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Thank you!

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