Need for Pre-Crash Acceleration Data in EDR for accident research and analysis

- Not only to prove vehicle speed but also to detect less intense impacts - such as collisions against vulnerable road users (VRU) by measuring, evaluating and recording of acceleration -

Dr. Dipl.-Ing. Michael Weyde

Publicly appointed and sworn in Expert
for Accident Reconstruction and Evaluation of Accident Data Storage Systems
Member of the Board of the European Association for Accident Research and Analysis, EVU

Source: www.bosch.com 2015

- **U.S. regulation CFR 49 Part 563 is better than nothing, but not state of the art anymore**

- **Legal uncertainties due to faults in the indicated speed by wheel slip and an insufficient sample rate**

- **Redundant measurement and evaluation of acceleration**

- **Possibilities for detection of less intense impacts against vulnerable road users by intelligent evaluation of acceleration**

Minimum of data elements stored in the EDR of an airbag control unit according U.S. regulation, if the delta-V exceeds 8 kph within 0.15 s[1]

Parameter Relevant for accident reconstruction	Duration / Start-time (relativ to start of algorithm and/or deployment time [t0])	sample rate/ frequency in Hz (values per second)
Delta-V longitudinal (cumulative change in speed over time)	0 – 250 ms	100 Hz
Maximum speed-change within 300 ms	0 – 300 ms	n. n.
Time until reaching the maximum Delta-V	0 – 300 ms	n. n.
Vehicle indicated Speed (average wheel speed in a period of 0,5 s)	-5 – 0 s	2 Hz
Position of Throttle and/or Driving-Pedal (%-value of its maximum)	-5 – 0 s	2 Hz
Activation of service-brake (yes/no)	-5 – 0 s	2 Hz
Usage of the belt (contact on belt-buckle of Driver/ Passenger) [yes/no])	-1 s	n. n.
Airbag-warning-light (on/off)	-1 s	n. n.
relative time and duration of any Airbag-deployment	complete event-time	n. n.
Time between 2 deployments, if the Airbag is deployed in stages	as long as it take	n. n.

1) Part 563 Nat'l Highway Traffic Safety Admin. - Event Data Recorders according www.gpo.gov/fdsys/pkg/CFR-2011-title49-vol6/pdf/CFR-2011-title49-vol6-part563.pdf

Why do we need acceleration values prior to collision?

Crash test conducted by University of Zilina in cooperation with University of applied science of Dresden to show the difference between **EDR (Event Data Recorder)** and other measuring devices (i.e. UDS*)

EDR-Data of a 2009‘er Toyota: Crash Test 2017

Toyota Aygo vs. VW T4 - collision speed ???

EDR- vs. UDS*-Data: final position after the crash test

*)
EDR =
***E**vent*
***D**ata*
***R**ecorder*

UDS =
***U**nfall*
***D**aten*
***S**peicher*
which means:
Accident Data Storage-System
(an after sale product of Kienzle)

Toyota Aygo vs. VW T4 - collision speed ???

EDR-Data retrieved from Toyota Airbag-Module:

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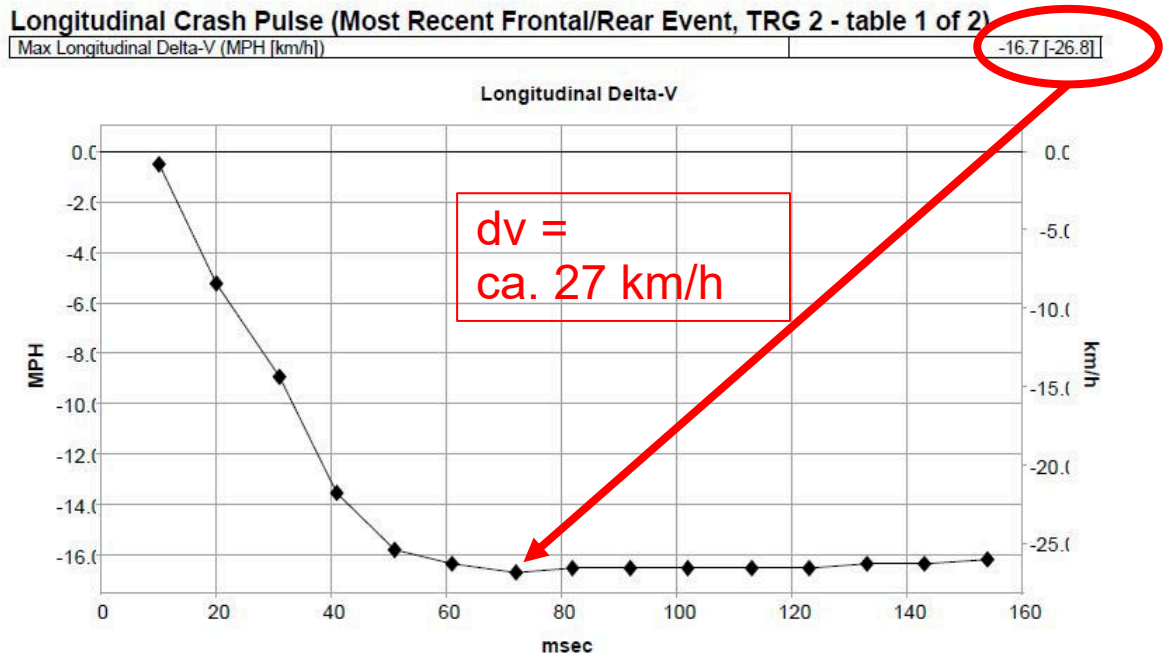
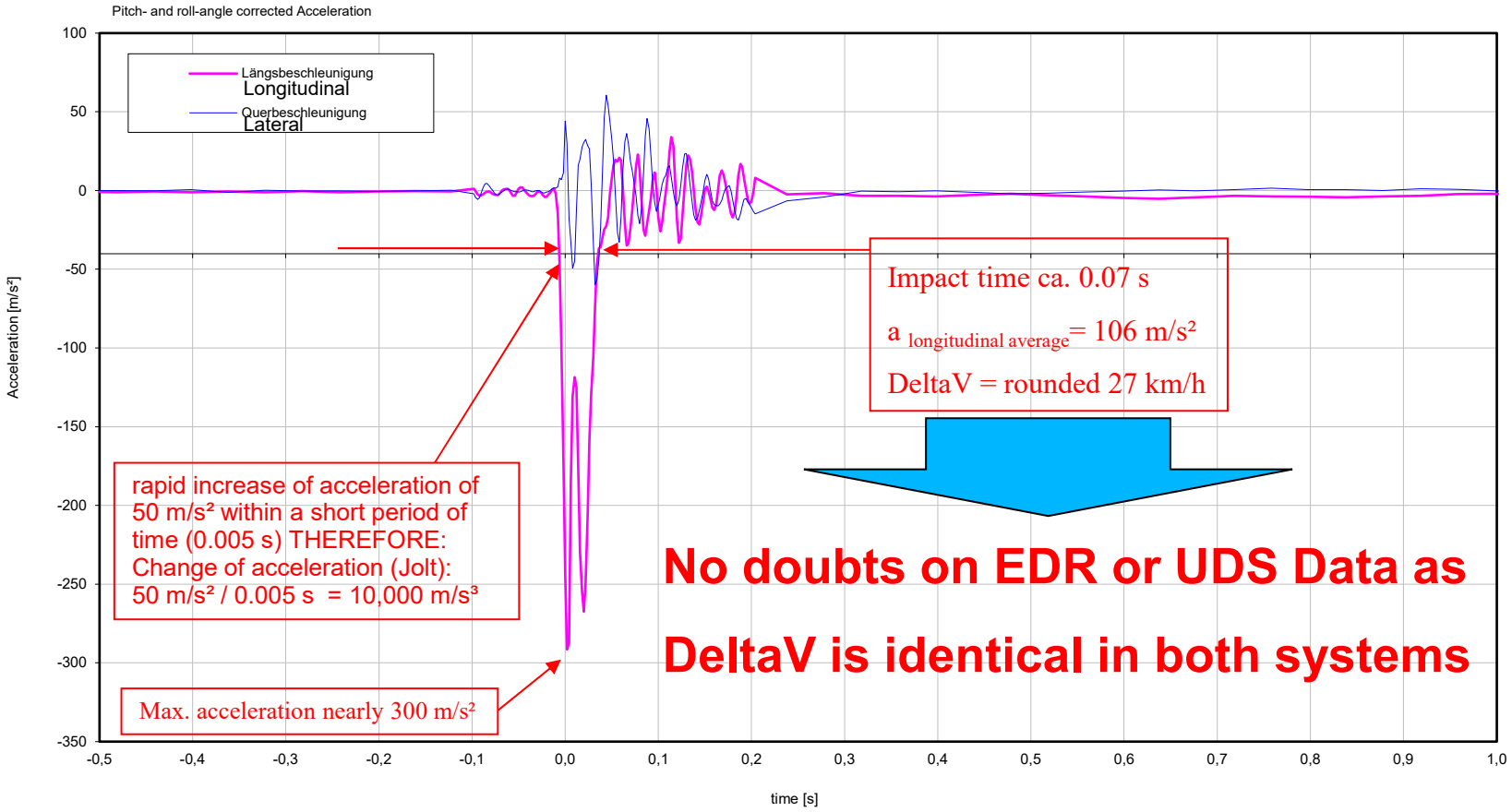
CDR CRASH DATA RETRIEVAL



Accumulated loss of speed (dV) over impact time in msec

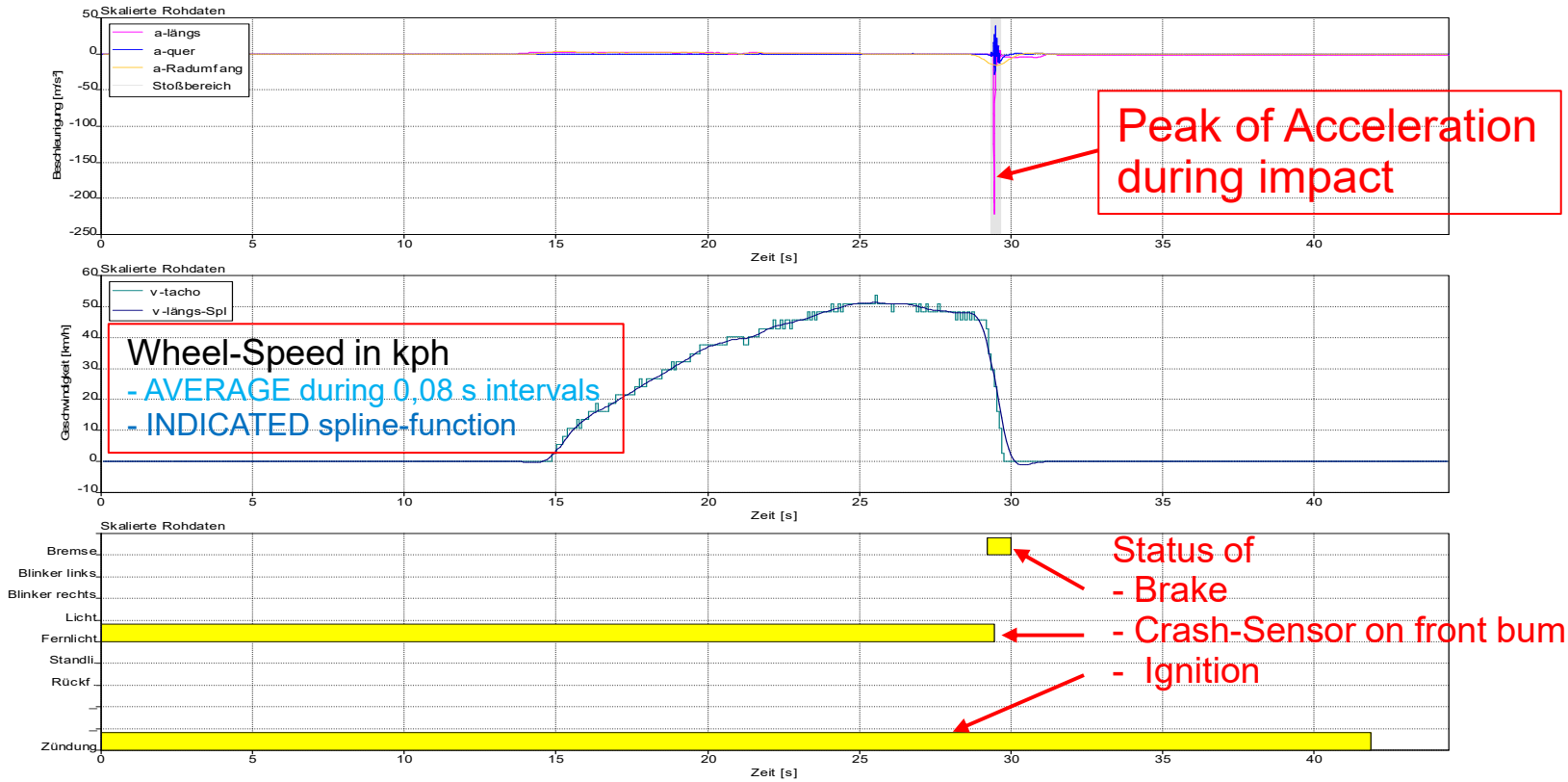
Excerpt of acceleration data retrieved from additional mounted UDS in the Toyota



But – how fast was the Toyota at the collision?

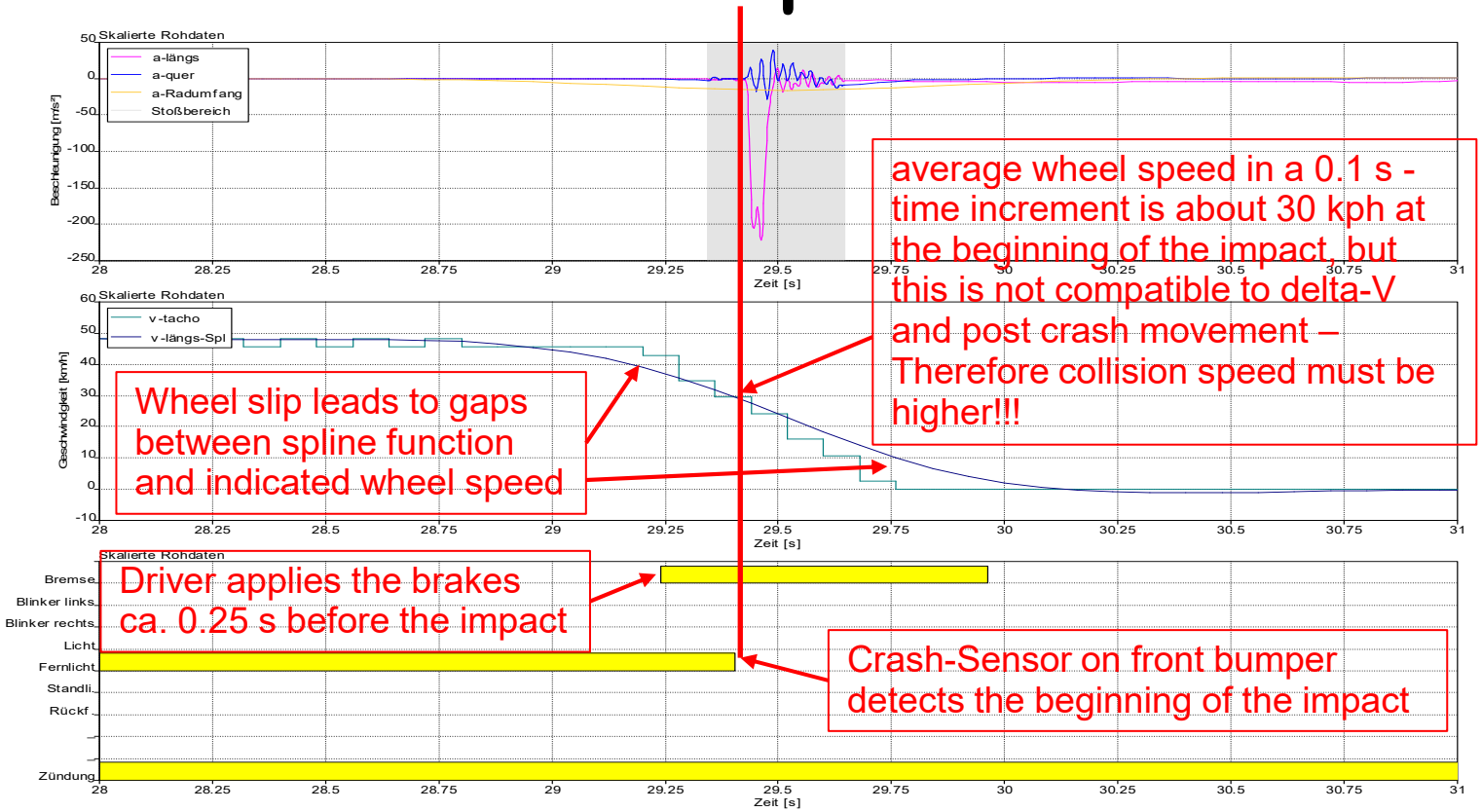
Watch the front wheel just before and during impact!

Acceleration / Wheel-speed / Status-Data



Data retrieved from UDS of Toyota Aygo (collision speed ?)

Acceleration / Wheel-speed / Status-Data

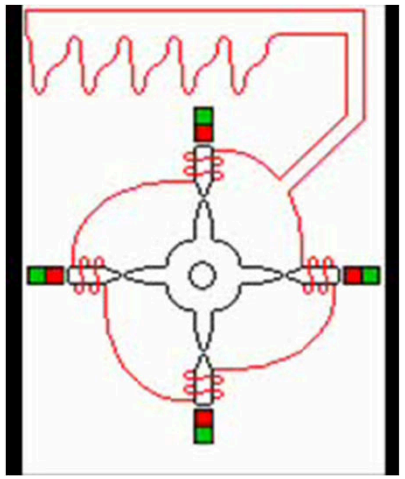


Even a sample rate >10 Hz (values every 0,1 s) does not show correct collision speed, because of wheel slip, if the car is braked before the impact

Sensors for indicated (wheel) speed

Most cars measure their indicated speed by sensors on the wheels, which transform the rotation of each wheel into altering current changes (pulses), therefore not the speed over ground but wheel speed is measured

http://www.kfz-tech.de/SpulenzuendungInd.htm



- Current PULSES are counted in constant time-increments (dt) (PULSES per dt)
- Knowing the distance per PULSE (ds / PULSE), wheel speed is calculated by (ds/dt) = distance per time [i.e. in kph]
- Accuracy depends on the number of pulses per wheel rotation & sample rate. Sample rate of most cars today is > 10 Hz, thus each time increment could be 0,1 s instead of 0,5 s as it is defined in U.S. regulation CFR 49 part 563

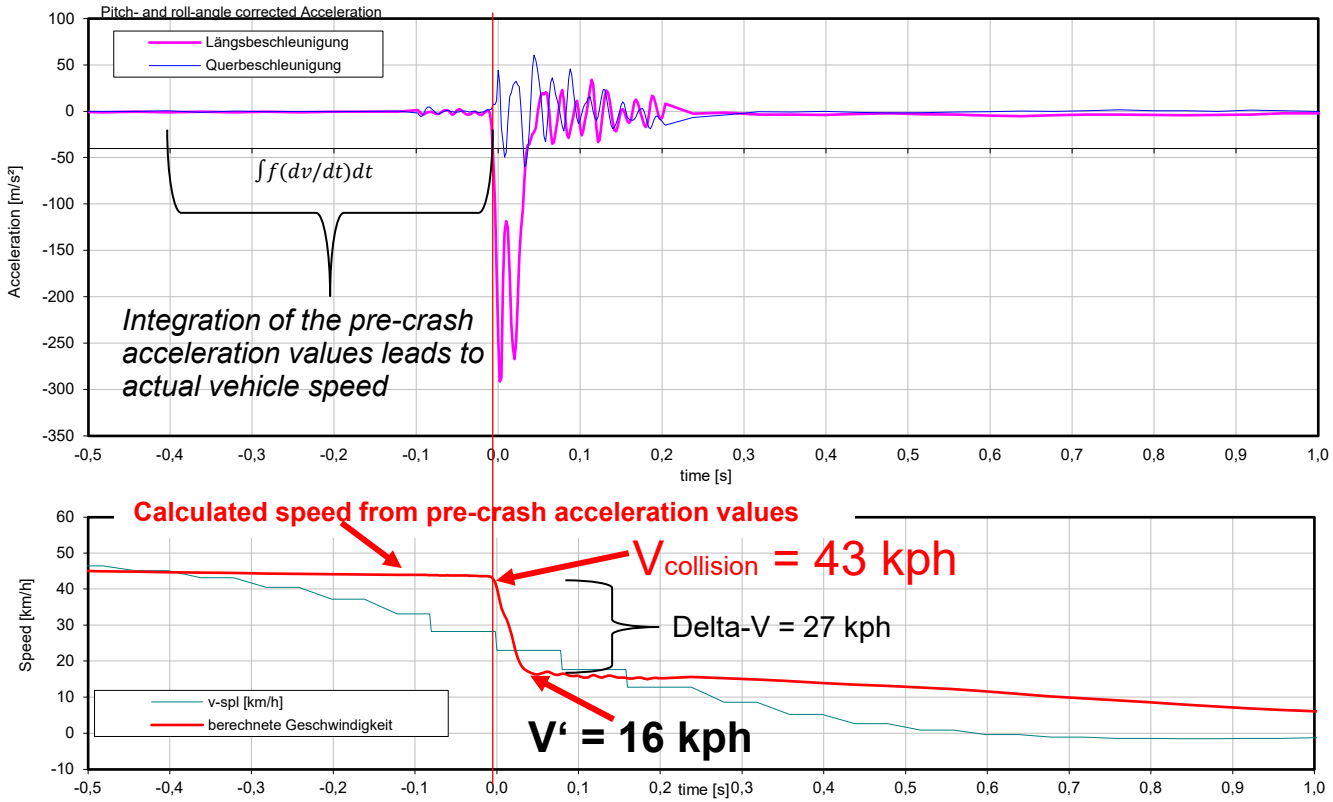
1. Nevertheless, even a time increment of 0.1 s is too long to determine the delta-V, because the entire duration of an impact is often shorter than 0.1 s
2. Wheel-speed measured by the wheels rotation does not match the real speed of the car, especially if the car is braked or heavily accelerated

How fast was the Toyota ?

- Estimation Results
  - **Experts**
    - Min: 20 kph
    - Max. : 50 kph Average = 35 kph
  - **Laymen**
    - Min: 15 km/h
    - Max. : 60 km/h Average = 37,5 km/h

Delta-V according to EDR and UDS = 27 kph
Indicated Speed (V_{wheel}) = ca. 30 kph
And how fast was Toyota actually?

Only INTEGRATION of ACCELERATION
leads to actual vehicle speed



Crash Test 2017: Toyota‘s collision speed = 43 kph

Interim Conclusion:

- If there is no Acceleration-Data saved prior to the impact, collision speed is not to be reconstructed suffenciently by present EDR according to U.S. regulation CFR 49 Part 563, because wheel speed differs enormously from real speed, if the car is braked and/or accelerated before the crash

- a sample rate of 2 Hz is too low for pre-crash data, especially for vehicle speed but also for status data

Legal uncertainty due to incomplete and misinterpreted EDR data

Not only for a correct jurisprudence but also for research reasons it is important to understand, what the driver had actually done before the impact, therefore the sample rate of pre-crash data should be higher than usual human action routines in driving

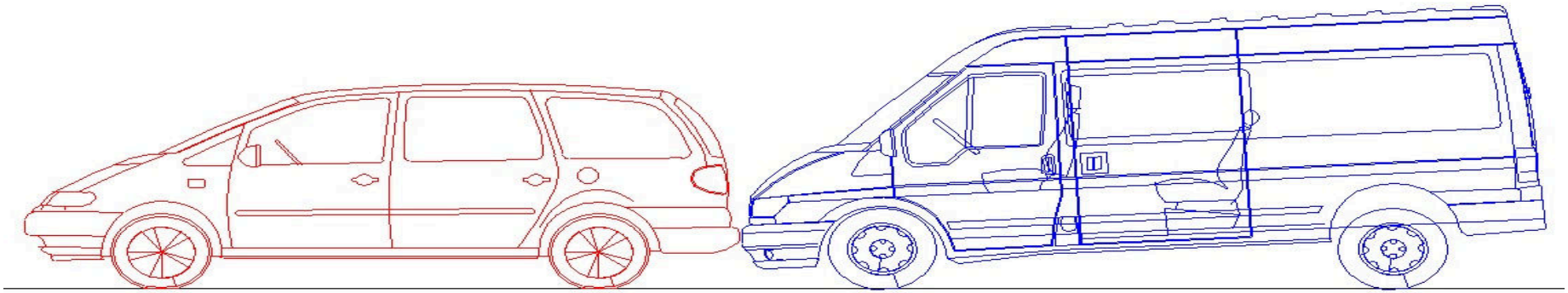
Case Study: Rear End Collision

Damage at the rear of car in front

Bumping vehicle

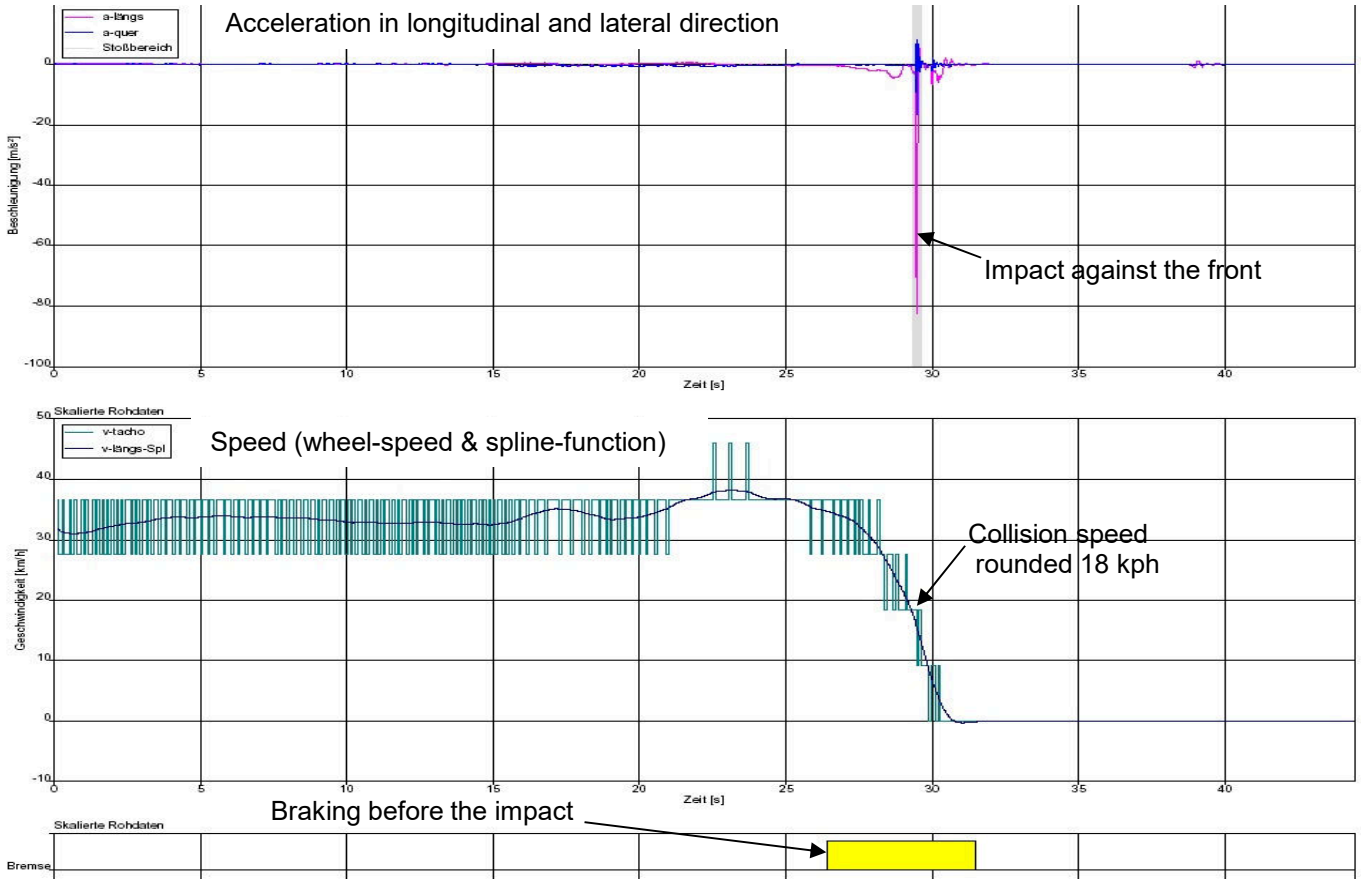
Damage at the front of vehicle,responsible for the crash

Collision Position from compatible traces of contact

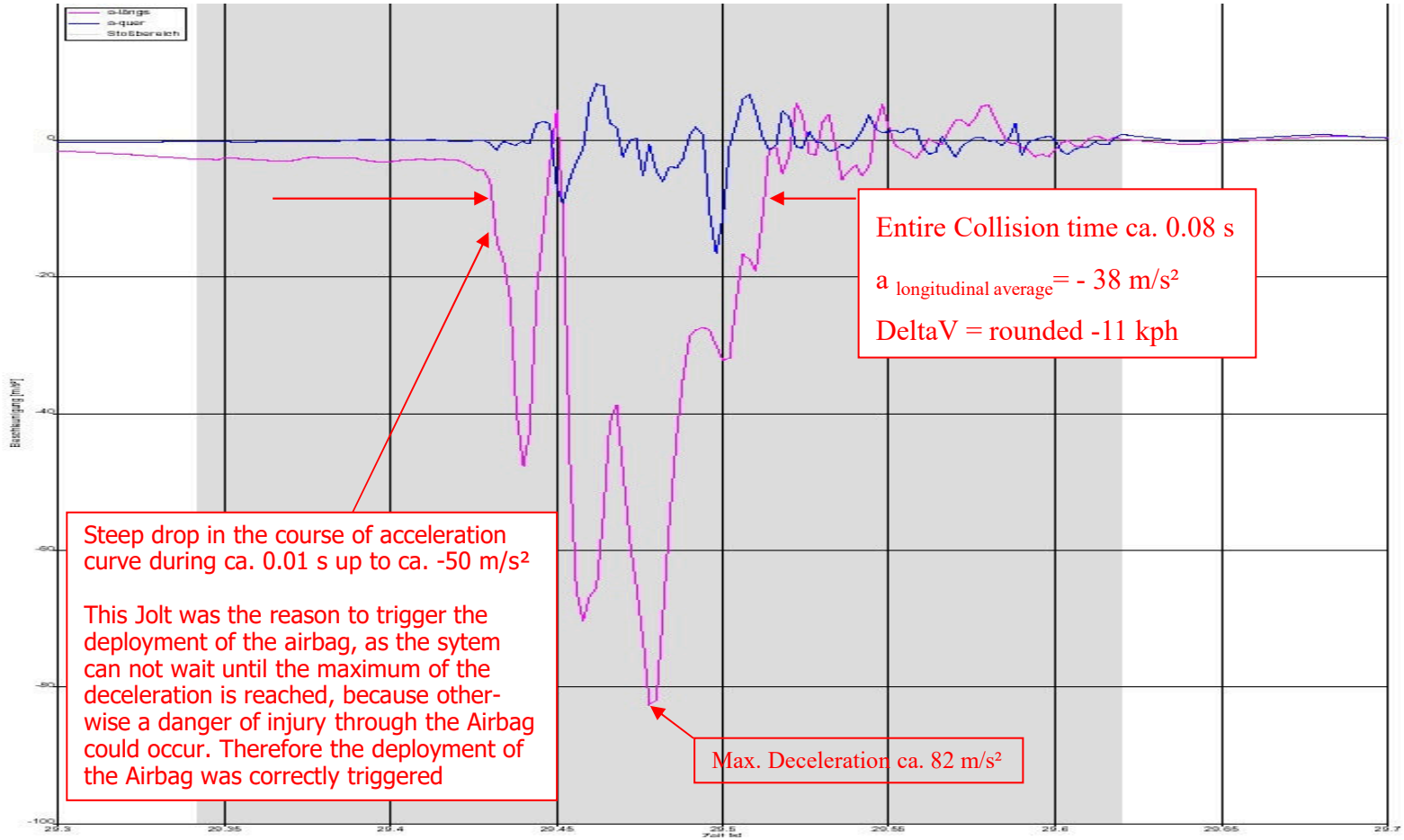


Bumping car (Ford Transit) was in a braked position at the moment of impact due to a pitch angle, which was needed to match the traces produced by its registration plate at the rear bumper of the car in front

Overview of acceleration, speed and status data



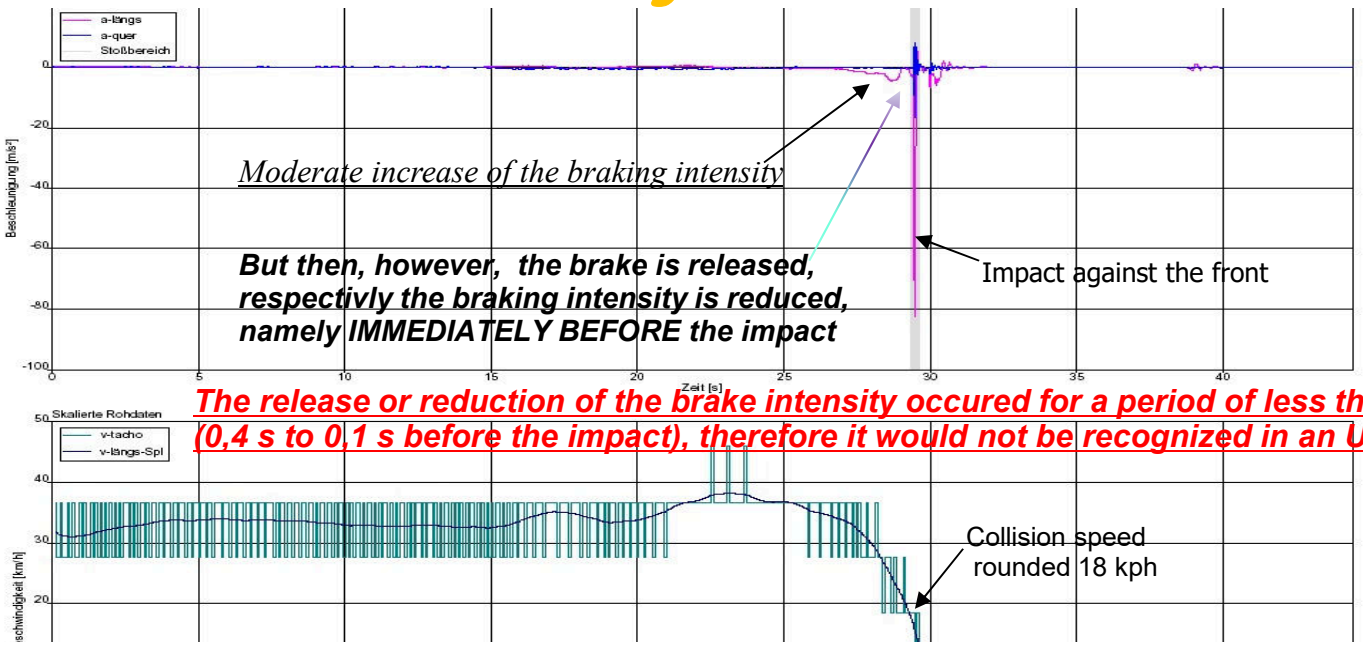
Excerpt of the acceleration recorded in UDS of the bumping vehicle Ford Transit



Did you notice anything else in the pre-collision data of the Ford Transit?

Evidence of the intentional causation of claims through the use of driving data, if the sample rate of the status data and the acceleration is high enough prior to the impact

Look closely to the data:



The release or reduction of the brake intensity occured for a period of less than 0,3 s (0,4 s to 0,1 s before the impact), therefore it would not be recognized in an U.S. EDR

Later, the driver of the bumping-car was accused and convicted for insurance fraud (LG Munich, 17.O.972/05) He was confessing and admitted to have tried it three times, but each time he was afraid and braked too much. Even after the last impact the damage of the car in front was not high enough, so that the owner of this vehicle asked him to crash again, but then the driver of the Ford Transit refused, because its Airbags had deployed.

Braking shortly before the impact might not be seen in an U.S. EDR

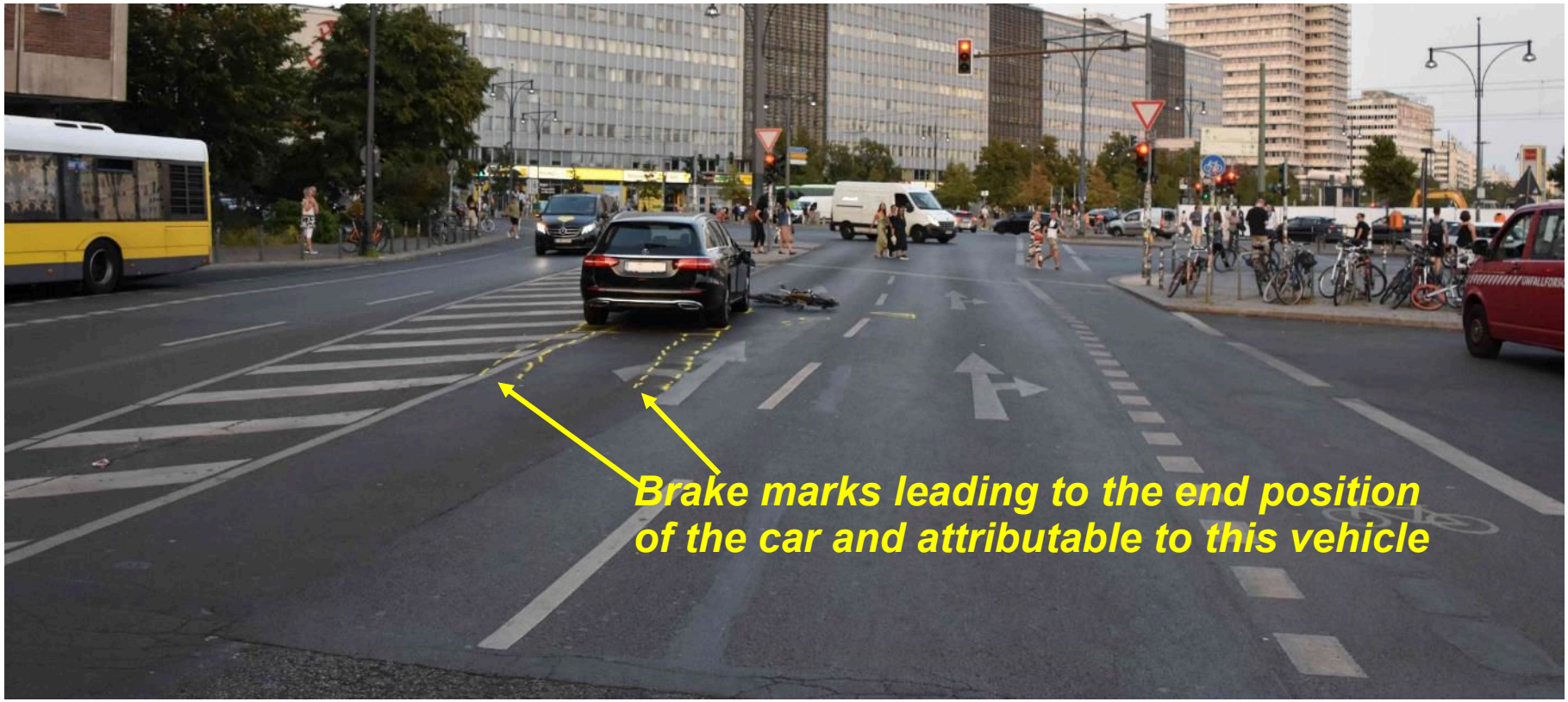
Later, the driver of the bumping Ford Transit was accused and convicted for insurance fraud (Regional Court Munich, 17.O.972/05)

He was confessing and admitted to have tried it three times, but each time he was afraid and braked too much.

Even after the last impact the damage of the car in front was not high enough, so that the owner of this vehicle asked him to crash again, but then the driver of the Ford Transit refused, because its Airbags had deployed.

But, could it also happen in a real accident, that braking before the impact would not be recognized in an U.S. EDR, although the driver tried to avoid the crash?

Case Study: Car vs. Cyclist



Accident Scene with final positions of car and bicycle

Case Study: Car vs. Cyclist

Relative position between car and bicycle at the beginning of impact to match the damage

Case Study: Car vs. Cyclist

Last speed sample „59 kph“, equals ca. 16,4 m/s

No braking before the impact according to pre-crash data in EDR

Impact against the front
Algorithm started because of Sensor in the front bumper for active protection system in the hood

Last Speed Sample is saved nearly 0,5 s (*0,453 ms*) before impact (*t0*)
This means that the car might have moved roughly 7 m before the impact, changed its speed and status of the service brake without recognition in the EDR.
Therefore, EDR data might not show the true status of service brake!!!

Mercedes vs bicycle

time	Speed, vehicle indicated	Accelerator pedal	Engine RPM (combustion engine)	Steering input	Service brake activation	ABS activity	Stability control
	km/h	%	rpm	deg			
-5	34	35	1408	-22	off	off	off
-4,5	36	53	1472	-14	off	off	off
-4	38	53	1600	-6	off	off	off
-3,5	41	59	1792	8	off	off	off
-3	45	80	1920	22	off	off	off
-2,5	51	79	2176	20	off	off	off
-2	55	50	2368	14	off	off	off
-1,5	57	31	2432	4	off	off	off
-1	58	0	2432	0	off	off	off
-0,5	58	24	2496	0	off	off	off
0	59	0	2432	-4	off	off	off

time from time zero to algo start (pedestrian) [impact on front bumper]	12 ms
Time from time zero to algo start (front)	algorithm not started
Time from time zero to algo start (side)	algorithm not started
Time from time zero to algo start (rear)	algorithm not started
time from last sample of speed information to Event (t0)	453 ms
Maximum Delta v longitude [km/h]	-4 km/h
time delta V longitude	70 ms
Maximum Delta v lateral [km/h]	0 km/h
time delta V lateral	55 ms

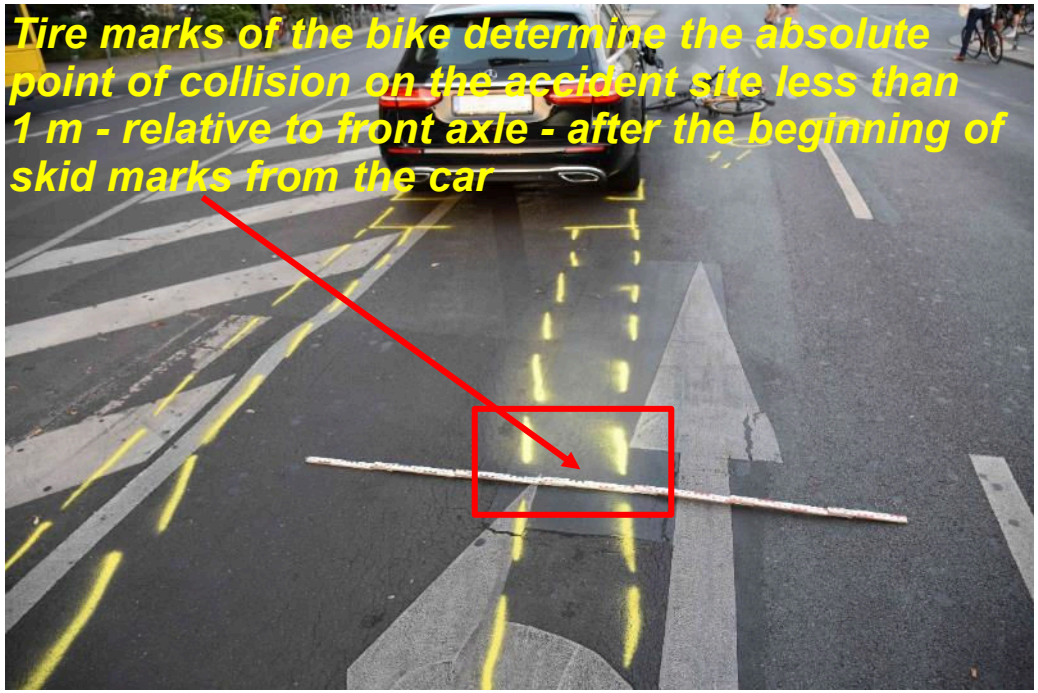
Post-Crash DATA

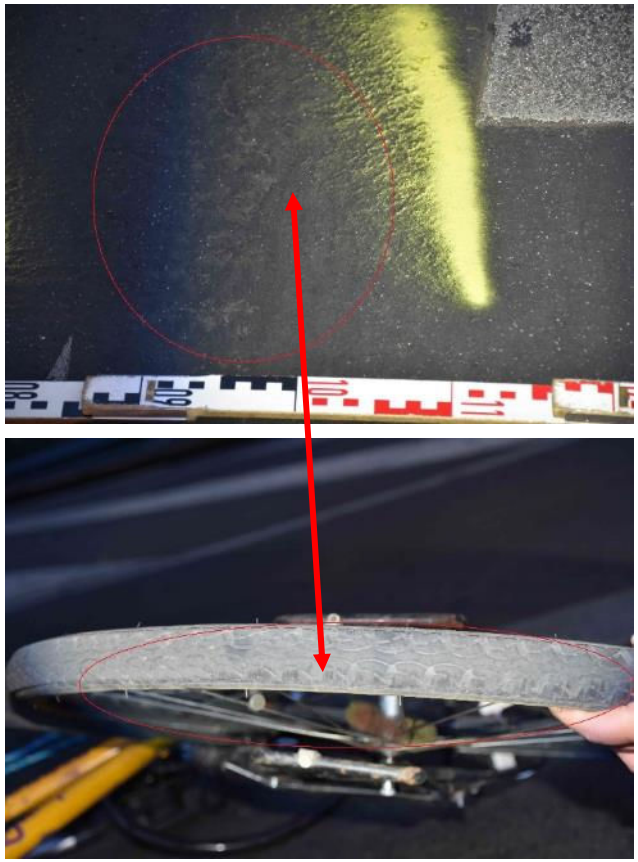
Zeit [ms]	Delta-V, longitudinal	Delta-V, lateral
0	-1	0
10	-1	0
20	-2	0
30	-2	0
40	-2	0
50	-3	0
60	-3	0
70	-4	0

Delta-V = 4 kph; therefore, we wouldn't have EDR Data, if the car had not been equipped with an active protection system for pedestrians in its front (Pop-up Hood)

EDR data of the Car according to U.S. Regulation CFR 49 Part 563, retrieved by OEM

Case Study: Car vs. Cyclist



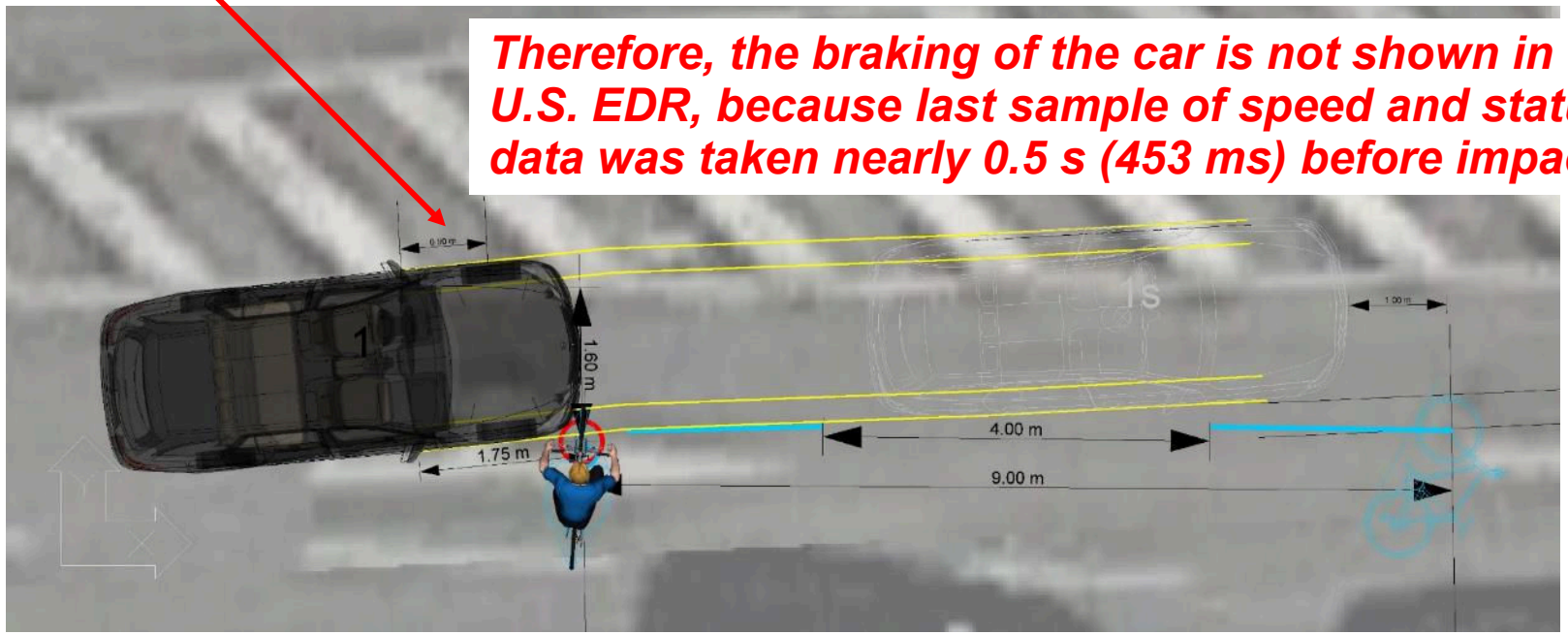


Tire marks determine positions of car and bicycle at the moment of the impact between front bumper of the car and front wheel of the bicycle

Case Study: Car vs. Cyclist

As the car moved less than 1 m after the beginning of brake-mark but before the impact, it may taken less than 0.1 s between the start of braking and the collision

Therefore, the braking of the car is not shown in the U.S. EDR, because last sample of speed and status data was taken nearly 0.5 s (453 ms) before impact



Sketch of the accident Scene to show, that the car moved less than 1 after the beginning of brake-mark until the point of collision, based on the front axle

Interim Conclusion:

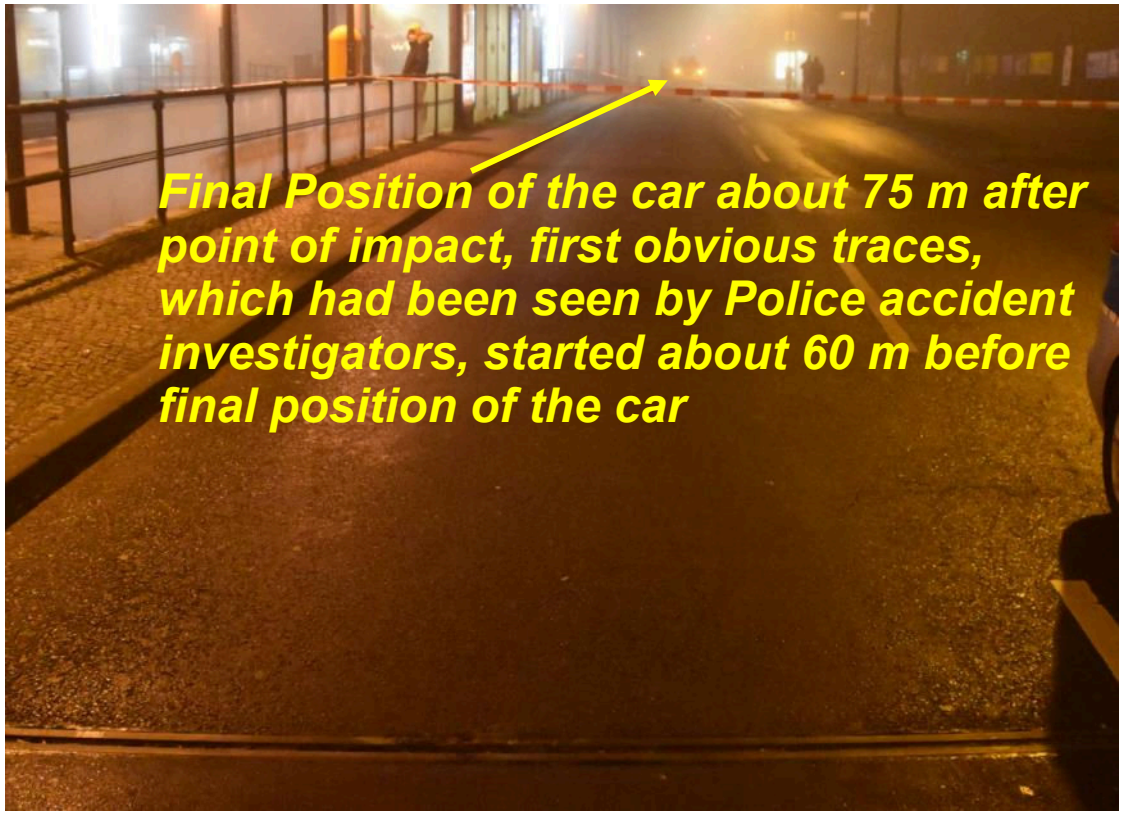
- a sample rate of 2 Hz (0,5 s per sample) might lead to miss-interpretation and wrong jurisprudence, because for instance braking shortly before an impact will not be recognized by an U.S. EDR

- Correspondent to typical times for driving actions the sample rate of speed and status date should be 10 Hz (0,1 s per sample) prior to impact - Accuracy of synchronisation must be similar!

- Acceleration (longitudinal and lateral) should also be recorded pre-crash with 100 Hz, in order to prove the actual vehicle speed redundantly from its wheel speed

- Delta-V is generally below 8 kph in a normal car due to an impact against a pedestrian or cyclist, thus we need a different trigger for crash detection

Case Study: Car vs. Pedestrian



Accident Scene with nearly no traces on the actual point of collision

Case Study: Car vs. Pedestrian

No EDR Data even after a severe impact against a Pedestrian

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CDR CRASH DATA RETRIEVAL

IMPORTANT NOTICE: Robert Bosch LLC and the manufacturers whose vehicles are accessible using the CDR System urge end users to use the latest production release of the Crash Data Retrieval system software when viewing, printing or exporting any retrieved data from within the CDR program. Using the latest version of the CDR software is the best way to ensure that retrieved data has been translated using the most current information provided by the manufacturers of the vehicles supported by this product.

CDR File Information

User Entered VIN	WVGZZZ1TZJ
User	Dr. Michael Weyde
Case Number	VU 2244
EDR Data Imaging Date	20
Crash Date	20
Filename	WVGZZZ1TZJ ACM_B VU CDRX
Saved on	Februar at
Imaged with CDR version	Crash Data Retrieval Tool 19.3
Imaged with Software Licensed to (Company Name)	Ingenieurbuero Priester und Weyde
Reported with CDR version	Crash Data Retrieval Tool 19.3
Reported with Software Licensed to (Company Name)	Ingenieurbuero Priester und Weyde
EDR Device Type	Airbag Control Module
Event(s) recovered	None

Pedestrian was killed by a Volkswagen Touran which was equipped with an U.S. EDR and an additional mounted Accident Data Storage System (UDS)

Case Study: Car vs. Pedestrian

Even after such a severe impact against a pedestrian the Delta-V in the car is only about 6 kph within 0.15s

No Data in an U. S. EDR because Delta-V over 0.15 s is too low to trigger a recording

Data from UDS: Acceleration (top graphic) and wheel speed (graphic below) of the car about 2 s before and after the impact against the pedestrian, as well as average values over 0.15 s during impact

Case Study: Car vs. Pedestrian

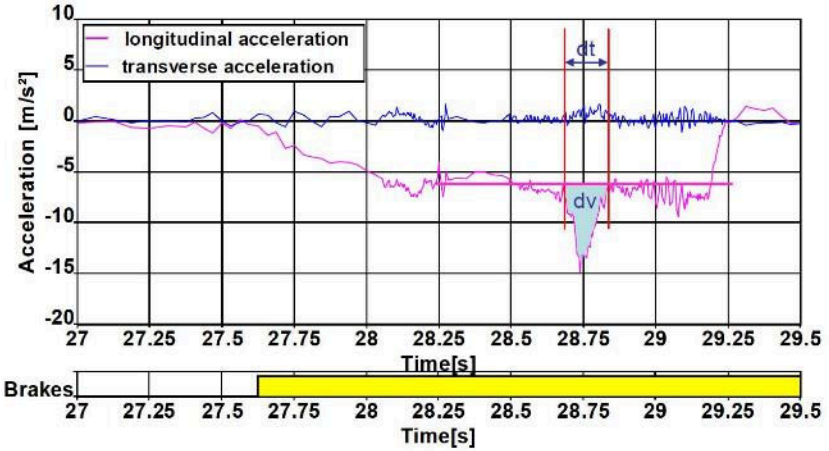
Although the car was braked prior to the impact, it is clearly possible to differentiate normal driving from an impact against a pedestrian by evaluation of the change in acceleration, the so called Jolt, even if the Delta-V during impact is rather small

Data from UDS: Acceleration (top graphic), wheel speed (graphic in the middle) and status data (lowest graphic) about 0.6 s before and after the impact against the pedestrian, as well as average values over 0.25 s before impact

Jolt-Trigger, described in VERONICA-Project*

- ***Evaluation of acceleration to determine a distinctive relative change, a Jolt, is state of the art not only to trigger an Airbag Deployment, but also to recognize any kind of impact***

- ***Delta-V on its own is insufficient to differentiate normal driving from an impact against a vulnerable road user***



*)
EUROPEAN COMMISSION
DIRECTORATE-GENERAL FOR ENERGY AND TRANSPORT
Vehicle Event Recording based on Intelligent Crash Assessment
VERONICA – II
(EC Contract No. TREN-07-ST-S07.70764)
Authors: Schmidt-Cotta, Ralf-Roland e.a.
10-06-2009

Summary:

- If there is no Acceleration-Data saved prior to the impact, collision speed is not to be reconstructed suffenciently by present EDR according to U.S. regulation CFR 49 Part 563, because wheel speed differs enormously from real speed, if the car is braked and/or accelerated before the crash

- Neither braking, acceleration or steering behavior nor the real trajectory of the car is to be reconstructed, if there is no longitudinal and lateral acceleration saved in an appropriate sample rate in the EDR

- No collisions with vulnerable road users (VRU), such as pedestrians or cyclists are detected by the present EDR, because according to CFR 49 Part 563 a speed change of more than 8 kph within 0,15 s is needed to trigger the recording of data, but real case studies show that the speed change of a normal car seldomly exceeds 6 kph due to an impact against VRU

Conclusions and Outlook:

- **Record longitudinal and lateral acceleration over 5 s pre crash with a sample rate of min. 100 Hz**

- **Record wheel and/or indicated speed as well as the status of brake- and driving-pedal with a sample rate of min. 10 Hz**

- **Trigger an EDR-Recording by intelligent Jolt-Detection (see VERONICA Project) in order to detect an impact against vulnerable road users**

… thank your for your attention!!!