Side Impact Test Methods for Evaluating Child Restraint Systems
A Summary for GRSP Informal Group on Child Restraints

3rd Meeting, 13 May 2008 London
Farid Bendjellal on Behalf of Clepa
Working Process

• Defining and sending a template
• Individual organisation completing template
• Contributors
  – Craig Newland DOTARS Australia Australian Standard
  – Heiko Johanssen University Berlin, on behalf of ISO
  – Susan Meyerson NHTSA, US NHTSA developments
  – Michael Grohspietsch Britax Römer, Ulm, EU Example as used today

• Presenting a summary to the Informal Group at its 3rd meeting in London, 13 May
Key Items in the template

1. Accident field data
2. Existing test procedures
3. Correlation and consistency with full scale testing
   1. Repeatability
   2. Reproducibility
4. Costs & adaptability to existing sled test systems
   1. Extra costs over existing standard sled equipment
   2. Knowledge / Experience among certification labs and industry
Australian Standard AS/NZ 1754 & 3629.1 - 2004

Fixed Door; P3 Dummy; ΔV 32 km/h; Pulse 14 – 20 G

NHTSA Research – Takata linear side impact test device

ISO - 2008

Moving Door; Q3 Dummy; ΔV 24-26 km/h; Pulse G?, Door angular velocity corridors for RF and FF seats

BRITAX – ADAC

Moving sled into fixed impactor; Hybrid III 3y & Qs 3; ΔV 32 km/h; Door Velocity 25 km/h

Fixed Door 80°; Q3 Dummy; ΔV 29 km/h; Pulse 15 G
ADAC Procedure within EU Consumer tests

Opel Astra Body 80°; Fixed Door; Q0 – Q6 and P10; ΔV 28 km/h; Pulse 18 G
1. Accident Field Data
   Europe (Child Project)
   USA (NHTSA)
European Child Injury Led Design (CHILD) – Field Data

Farside & Nearside Occupants: Injury Severity 284 Restrained Children

- MAIS0 ou 1: 27%
- MAIS2 ou 3: 48%
- MAIS4+: 25%

Higher risk on struck side

Nearside Occupants - 157 Restrained children

- MAIS 0-1: 30%
- MAIS 2-3: 39%
- MAIS 4+: 21%

Source: Analysis of CHILD Data Related to Side Impacts (Philippe Lesire) - Protection of Children in Cars – 7/8 December 2006 - Munich
European Child Injury Led Design (CHILD) – Field Data

¾ of injuries to the head and face (seat group 0 to 1)
Neck, 2nd most exposed area, inducing often invalidating injuries or death

Source: Analysis of CHILD Data Related to Side Impact (Philippe Lesire) - Protection of Children in Cars – 7/8 December 2006 - Munich
Distribution of U.S. Crash Configurations

- Children represent more than 50% of the rear seat occupants in motor vehicle crashes

Distribution of Crash Configurations for all Children 0 to 12 years old.

Distributions of U.S. Injuries & Impact Locations

Distribution of Relative Impact Locations and Injuries. Side Impact Crashes. Children 1 to 3 years old. $\Delta V \geq 30$ kph

- 24% of the 1 to 3 year olds in the dataset were in crashes with $\Delta V \geq 30$ kph, but these children accounted for 60% of the total number that received a maximum injury of AIS 3 or higher.
U.S. Children in Side Impact Crashes

• Side impacts with $\Delta V > 30$ kph provided 28 children ages 1-3 yrs, with 104 injuries (unweighted due to paucity of data, NASS-CDS)
  – PDOF of side impact crashes is approximately 30° of lateral
  – Near-side and center occupants suffered more severe injuries (AIS2+) than far-side occupants
• Direct contact with vehicle interior responsible for 45% (47) of injuries; 14.4% (15) due to contact with CRS
  – Head - 57% of injuries
  – Torso - 21% of injuries
  – Neck, upper and lower extremities - ranged from 6%-9% of injuries

2. Existing Test Procedures
Australian Requirements

• Side Impact test specifications contained in AS/NZS 3629.1
  (referenced by AS/NZS 1754)
• Two sideways tests
  – Without door
  – With door (door is fixed and rigid)
  – Smallest sized P-dummy for restraint
Side Impact Requirements

For sideways tests with & without door:

• Dummy must be retained in CRS
• CRS must be retained on test rig
• Buckle release force must be less <110N
• Complete separation of load-carrying parts not permitted
• Mass of any part that detaches must be no more than 20 grams
Side Impact Requirements

For sideways test with door

- Except for booster cushions and forward facing harness without chair, head contact to door not permitted
Sideways Test Pulse

- Velocity change $\geq 32$km/h
- Acceleration of between 14g-20g achieved within 30ms
- Acceleration to remain within the range 14g-20g for 20ms
- Pulse requirement to be met during calibration test (using rigid mass instead of child restraint and test dummy)
Side Impact Requirements

New (draft) requirements for test with door:

- Added test with largest sized P-dummy for restraint
- Extended door structure (enclose the opening previously permitted)
- Dummy head must be contained within child restraint, or must be $\geq 25\text{mm}$ from door at all times during test
Side Impact Requirements

- Test method is simple and repeatable
- Limited biofidelity of P3 acknowledged
  - Robust injury criteria and IARVs not required
ISO Test Method
ISO Side Impact Test Method - System Definition

- NPACS and ISO Tests have some similarities
  - NPACS intended for CRS rating / ISO intended also for type approval
- Hinged panel system
  - modified ECE R44 test bench
  - worst case conditions with maximum intrusion close to dummy’s head
  - 90° angle
  - delta-v 25 km/h
  - linear intrusion velocity:
    - ISO: approx. 7 to 10 m/s
    - NPACS: approx. 9 to 12 m/s
ISO Side Impact Test Method - A System Definition

• Panel dimensions
  – based on geometry measurement data of a large number of different car from in the late nineties

• Panel padding
  – impactor tests with different doors and different spots on each door
ISO Side Impact Test Method - A System Definition

• Panel velocity
  – in order to obtain same input conditions for RF and FF CRS the corridors need to be different
    • distance between hinge line and head position different for RF and FF (geometrical differences)
  – different corridors for ISO and NPACS
    • ISO less severe (not primary intended for rating)
    • NPACS corridor tend to be sensitive to different sled designs (based on numerical simulation); not a major issue for NPACS as all labs are using comparable set-ups
    • ISO corridor with different timing
ISO and NPACS Side Impact Test Method - A System Definition

FF configuration
ISO and NPACS Side Impact Test Method - A System Definition

FF configuration
ISO and NPACS Side Impact Test Method - A System Definition

RF configuration
ISO and NPACS Side Impact Test Method – Panel Geometry RF
ISO and NPACS Side Impact Test Method – Panel Geometry FF
ISO and NPACS Side Impact Test Method – Padding material

Car 1
Car 2
Car 3
Padding
ISO and NPACS Side Impact Test Method – Delta-v
ISO Side Impact Test Method – Angular Velocity and Angle FF

1 Angular velocity upper boundary line before 38 ms
2 Defined angular velocity rectangle (11.9 – 13.6 rad/s at 38-42 ms)
3 Angular velocity lower boundary line after 42 ms
4 Angular velocity upper boundary line after 42 ms
5 Defined angle rectangular (16° -17° at 38-42 ms)
NPACS Side Impact Test Method – Angular Velocity and Angle FF
ISO Side Impact Test Method – Angular Velocity and Angle RF

1. Angular velocity upper boundary line before 38 ms
2. Defined angular velocity rectangle (9.5 - 10.9 rad/s at 38-42 ms)
3. Angular velocity lower boundary line after 42 ms
4. Angular velocity upper boundary line after 42 ms
5. Defined angle rectangular (16° -17° at 38-42 ms)
NPACS Side Impact Test Method – Angular Velocity and Angle RF
ISO and NPACS Side Impact Test Method – General Layout FF

Panel position before impact

Panel position at maximum intrusion
ISO and NPACS Side Impact Test Method – General Layout RF

Panel position before impact

Panel position at maximum intrusion
NHTSA Research Side Impact Test Method (under evaluation)
NHTSA Research Side Impact Test Method being Evaluated

- Takata linear side impact test device
  - Configurations
    - Lateral (90°) impact angle
    - Oblique angled impact (10°)
  - Parameters
    - Sled Pulse – $\frac{1}{2}$ sine
    - Sled Velocity – 20 mph
    - Seat Initial Positioning – 260 mm from honeycomb
    - Seat velocity – 17-18 mph
NHTSA Test Configuration being Evaluated
(Takata Sled Device)
Dummies being Evaluated in NHTSA Research

3Cs Neck and Head with Hybrid III 3-year-old

Qs 3-year-old
Side Impact / Britax

• Test set-up
• Test parameters
• Test results
• Comparison to EuroNCAP results
Test Set-up & Parameters/ Britax

- ECE 44.04 seat bench
- 80° impact angle
- Fixed door
- Door dimension and position similar to ISO/TC22/SC12/WG1N555R

- Maximum sled deceleration 15g
- Impact speed 25km/h
Side Impact / ADAC

As Used in EU Consumer Tests Stiftung Varentest
Test set-up / ADAC

- Opel Astra H white body
- Vehicle seat bench
- Vehicle anchor points with retractors
- 80° impact angle
- Fixed door with 21-mm-styrodur insert

- Vehicle deceleration similar to Euro NCAP
- Impact speed 28 km/h
- Maximum sled deceleration 18g
- Braking distance approx. 300mm
Dummies / ADAC

- FTSS Q0 – Q6
- TNO P10
3. Correlation and consistency with full scale testing
Repeatability
Reproducibility
Sideways Test Pulse

- Since door does not intrude, test pulse represents gross motion of struck vehicle
- Comparison of CRS sideways tests (actual test pulses, not calibration pulses) with non-struck B-Pillar acceleration from MDB-to-vehicle and vehicle-to-vehicle tests
  - 50 km/h bullet
  - Stationary target
  - 90°impact angle
Nissan Micra vs Ford EL Falcon

Landrover Freelander vs Ford EL Falcon

Landrover Freelander vs Ford AU Falcon
Comparison of Lateral Acceleration Pulses

- Crashlab Sled (9 sideways tests)
- ECE R95 Ford Ka non-struck B-Pillar
- IIHS MDB EL Falcon non-struck B-Pillar
- ECE R95 EL Falcon non-struck B-Pillar
- Micra vs EL Falcon non-struck B-Pillar
- Freelander vs AU Falcon non-struck B-Pillar
- Freelander vs AU Falcon non-struck B-Pillar
- Freelander vs EL Falcon non-struck B-Pillar
- Freelander vs EL Falcon non-struck B-Pillar
ISO and NPACS Side Impact Test Method – Correlation to FST (Full Scale Tests)

• Correlation tests took place before changes of the set-up
  – changes to NPACS minor
  – changes to ISO need additional analysis
ISO and NPACS Side Impact Test Method – Correlation to FST Car - TUB SIPCRRS

TUB FF Head Acceleration

TUB FF Neck Tension Force

TUB FF Neck Bending Moments

TUB FF Chest Acceleration
ISO and NPACS Side Impact Test Method – Correlation to FST - Car TUB SIPCRS

TUB FF Chest Deflection

TUB FF Pelvis Acceleration
ISO and NPACS Side Impact Test Method – Correlation to FST – RF Car TUB SIPC RS

TUB RF Head Acceleration

TUB RF Chest Acceleration

TUB RF Pelvis Acceleration
ISO and NPACS Side Impact Test Method – Correlation to FST

• Following slides show comparison of FST and TUB sled tests conducted within NPACS
  – 6 different CRS (3 RF and 3 FF) in three different cars
  – comparison to different test procedures
  – BS: baby shell, infant carrier
  – HS I: group I with integral harness, FF
  – HBB: high back booster
ISO and NPACS Side Impact Test Method – Correlation to FST

![Graph showing acceleration (a3ms [g]) for different test conditions (BS1 TUB1, BS1 TUB2, BS1 car1, BS1 car2, BS1 car3) for head, chest, and pelvis measurements.](image-url)
ISO and NPACS Side Impact Test Method – Correlation to FST
ISO and NPACS Side Impact Test Method – Correlation to FST

![Graph showing correlation between different tests and impact levels for head, chest, and pelvis.]

- BS3 TUB
- BS3 car1
- BS3 car2
- BS3 car3
ISO and NPACS Side Impact Test Method – Correlation to FST

![Graph showing acceleration (a3ms [g]) for different conditions and body parts (head, chest, pelvis)]
ISO and NPACS Side Impact Test Method – Correlation to FST

![Graph showing correlation between ISO and NPACS Side Impact Test Method and FST](image-url)
ISO and NPACS Side Impact Test Method – Correlation to FST

![Diagram showing a3ms [g] values for different body regions and conditions.](image-url)
ISO and NPACS Side Impact Test Method – Repeatability

- Repeatability and Reproducibility checked by numerical simulation at TNO and TUB
- Repeatability tests conducted in various development stages
- Most recent test in April 2008
  - repeatability: same lab same set-up same dummy
  - in house reproducibility, same lab, same set-up but different dummy of same type
- Reproducibility
  - Tests conducted at ADAC, TUB, TRL (not yet published)
ISO and NPACS Side Impact Test Method – TNO Simulation

• Comparison of different sled and panel velocities within the originally given corridors

• When staying with in the corridors
  – sled acceleration minor influence
  – panel velocity minor influence
  – panel timing (starting time of panel rotation) important influence
ISO and NPACS Side Impact Test Method – TNO Simulation

original corridors
ISO and NPACS Side Impact Test Method – TNO Simulation

- Original corridors

- CRS - Door relative velocity [m/s]
  - 15 rad/s door
  - 14 rad/s door
  - 16 rad/s door

- Time of contact [ms]
modified corridors to solve problems identified in TNO simulations
ISO and NPACS Side Impact Test Method – TUB Simulation

modified corridors to solve problems identified in TNO simulations
NPACS Side Impact Test Method – Reproducibility

Group I CRS with Q1

- head a3ms [g]
- upper neck MR [Nm]
- upper neck FR [10 N]
- chest a3ms [g]
- chest DS [mm]
- pelvis a3ms [g]

ADAC TUB
NPACS Side Impact Test Method – Reproducibility

Group I CRS with Q3

![Bar chart showing measurements for different body parts with ADAC and TUB data.]

- Head a3ms [g]
- Upper neck MR [Nm]
- Upper neck FR [10 N]
- Chest a3ms [g]
- Chest DS [mm]
- Pelvis a3ms [g]
Test Results / Britax
booster cushion without backrest

<table>
<thead>
<tr>
<th>chest [g]</th>
<th>head [g]</th>
<th>HIC 36</th>
</tr>
</thead>
<tbody>
<tr>
<td>90,2</td>
<td>143,6</td>
<td>2905</td>
</tr>
</tbody>
</table>
Comparison to EuroNCAP results
Infant Carrier G0 belted Dummy TNO P18 months

<table>
<thead>
<tr>
<th>chest [g]</th>
<th>head [g]</th>
<th>HIC 36</th>
</tr>
</thead>
<tbody>
<tr>
<td>58,1</td>
<td>92,6</td>
<td>592</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>chest [g]</th>
<th>head [g]</th>
<th>HIC 36</th>
</tr>
</thead>
<tbody>
<tr>
<td>31,0</td>
<td>45,7</td>
<td>151</td>
</tr>
</tbody>
</table>
Comparison to EuroNCAP results
Infant Carrier G0 Isofix Dummy TNO P18 months

<table>
<thead>
<tr>
<th></th>
<th>chest [g]</th>
<th>head [g]</th>
<th>HIC 36</th>
</tr>
</thead>
<tbody>
<tr>
<td>Britax sled test</td>
<td>49,3</td>
<td>84,4</td>
<td>512</td>
</tr>
<tr>
<td>Compact car EuroNCAP 2007</td>
<td>45,9</td>
<td>71,0</td>
<td>384</td>
</tr>
<tr>
<td>Middle-sized class EuroNCAP 2007</td>
<td>34,6</td>
<td>47,5</td>
<td>167</td>
</tr>
</tbody>
</table>
4. Costs & adaptability to existing sled test systems
   Extra costs over existing standard sled equipment
   Knowledge / Experience among certification labs and industry
ISO/ NPACS – Cost / Adaptability / Knowledge

• Costs:
  – extra cost needed for implementing the equipment
    • Approx. 30 k€ when externally ordered (deceleration device), without dummies
  – to conduct the test
    • Minor differences to frontal impact
• Adaptability to existing sled or test device
  – Compatibility with deceleration and acceleration devices
    • Acceleration devices more complicated, UTAC is currently working on realisation on acceleration sled
  – Consider your regional reference (UN ECE 44, AS/NZ 1754) and establish 3 levels?
    • Level 3/Need major modifications and add-ons
• Knowledge / Experience among certification labs and industry
  – Labs working with the test procedure
    • ADAC, TNO, TRL, TUB
  – Labs implementing
    • UTAC
  – Probably others as well
regional reference not well understood, for my point of view, turning an existing system by any angle is already major modification
Heiko Johannsen; 23/04/2008
Proposed Dummy and Performance Criteria
Proposed Dummy – TBC

• Type of dummy, or dummies
• The level of biofidelity
• Dummy repeatability
• Dummy sensitivity to design changes
• Performance criteria
  – Which body areas, parameters
Next Steps

• Feedback from experts at the 3rd meeting of informal group
• Complete this summary with other methods, NPACS
• Where necessary, complete description of test methods and their attributes.
Acknowledgments

- This summary has been established thanks to contributions from:
  - Craig Newland, Mike Lumley, Dotars AU, Britax AU
  - Susan Meyerson, NHTSA, USA
  - Heiko Johanssen for ISO, EU
  - Michael Grohspietsch, Britax Römer, EU