

# NPACS TASK FINAL REPORT



## NPACS RESEARCH PROGRAMME

**OUTPUT FOR TASK:** C17 / 1.1.3.17

*Rear Impact*

### Participating Organisations

*IDIADA (Task Leader)*

DATE: 21 November 2005

**TASK:** C17 / 1.1.3.17 *Rear Impact*

## **OBJECTIVES:**

*The objective of this task is to explore the necessity of including a rear impact testing method in the NPACS dynamic test procedures.*

*The work was divided into several subtasks in a sequential approach:*

- *Review conclusions from accident data*
- *Review current testing procedures*
- *Review and comparison of rear impact pulses*
- *Proposal of sled test matrix*
- *Recommendations to TWG*

## **ANNEX:**

*WD18: C17 Progress Report 26 April 2004*

*WD25: C17 Progress Report 5-6 July 2004*

*WD35: C17 Progress Report 2-3 December 2004*

*WD39: C17 Rear Impact Study with Recommendations 23 February 2005*

## **UTILISATION OF OUTPUT:**

*At the NPACS TWG meeting held on 24<sup>th</sup> February 2005 it was agreed that the group recommended the FC not to include the rear impact method in the programme.*

*The issues raised as a result of the research done should be brought to the EEVC WG 18 Child Safety for consideration in a future revision of ECE R44.*



Applus<sup>+</sup>  
IDIADA

NPACS RESEARCH PROGRAMME

WD 18: Progress on Task C17 – Dynamic Testing, Rear Impact

*Gonçal Tejera*

## TASK C17: DYNAMIC TESTING – REAR IMPACT

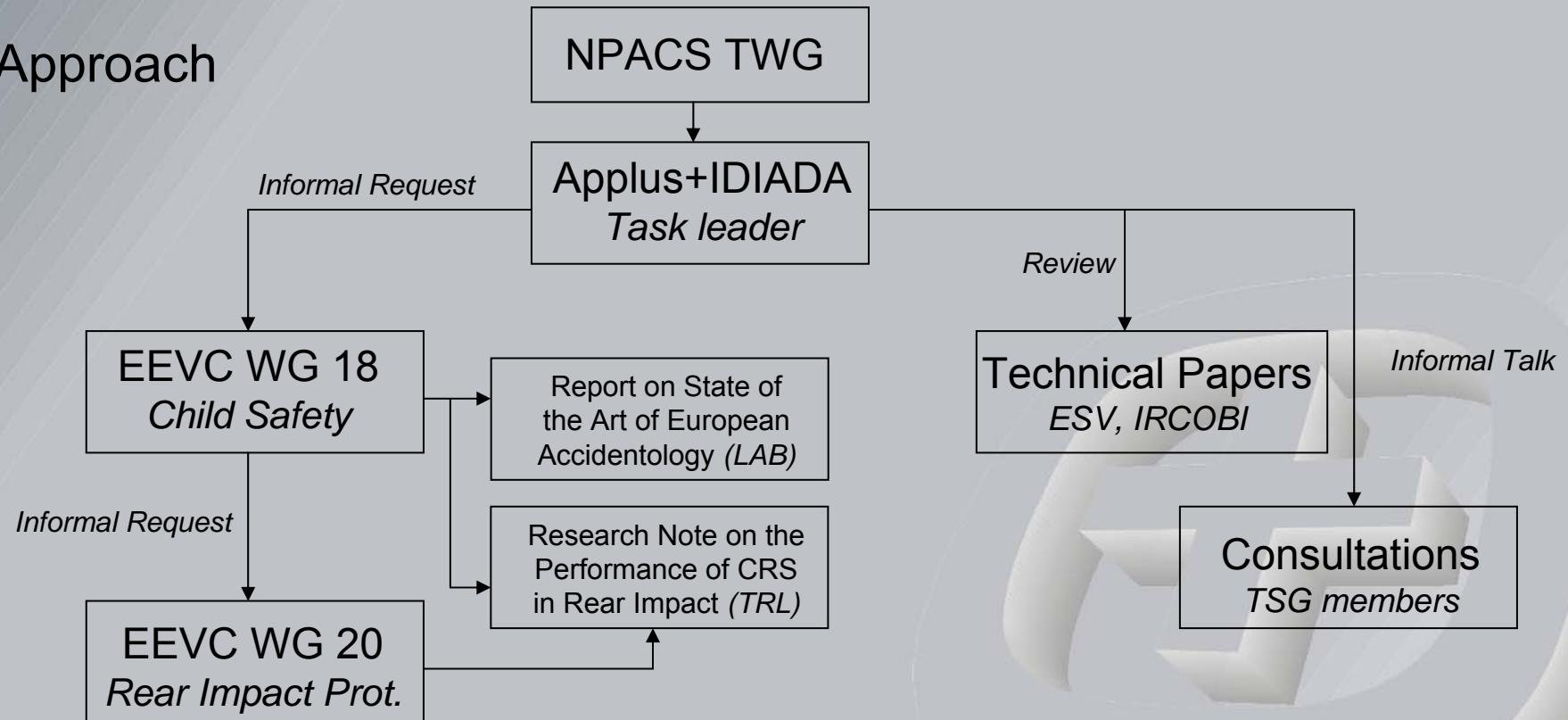
### Contents

1. Review conclusions from accident analysis
2. Review current testing procedures
3. Proposal for NPACS rear impact testing procedure

# TASK C17: DYNAMIC TESTING – REAR IMPACT

## 1. Review conclusions from accident analysis

### Approach



## TASK C17: DYNAMIC TESTING – REAR IMPACT

### 1. Review conclusions from accident analysis

Type of information requested on rear accidents involving children:

- Rear impact distribution
- Impact severity
- Injury frequency
- Injured body regions distribution
- Injury causation



## TASK C17: DYNAMIC TESTING – REAR IMPACT

### 1. Review conclusions from accident analysis

<i>Source</i>	<i>Conclusions</i>
<p>EEVC WG 18 Report (Feb. 03): CCIS Database (UK). Data from Phases Vb and VI. In-depth analysis of 425 children &lt;12 years, restrained or not. All fatal and most serious crashes investigated ⇒ bias towards severe accidents in the db.</p>	<p>Rear impacts represented 12% of the accidents (frontal 64%, side 15%, others 9%) Restraint use for children in rear impacts: 30% restrained 10% unrestrained 17% use claimed 43% unknown</p>
<p>TRL Research Note (March 04): CCIS Sample (UK). Data from in-depth analysis of 657 children.</p>	<p>Rear impacts had the highest proportion (32%) of uninjured (frontal 26%, side 21%). Rear impacts also had the lowest proportion (7%) of moderate or greater injuries, MAIS 2+ (frontal 11%, side 17%).</p>

## TASK C17: DYNAMIC TESTING – REAR IMPACT

### 1. Review conclusions from accident analysis

<i>Source</i>	<i>Conclusions</i>
<p>EEVC WG 18 Report (Feb. 03): Questionnaire Database (UK).</p> <p>Sample containing data from accidents in 1995-2000. A total of 230 children ≤12 years involved. Information about injuries should be treated with caution (based on parents' judgement).</p> <p>Relatively large number of rear impact cases because adults causing an accident are less likely to fill in the forms.</p>	<p>Full rear impacts represented 39% of the accidents and rear corner accidents accounted for 10% of the cases (full frontal 18%, front corner 15%, side 12%).</p> <p>Injury distribution in rear impacts:</p> <ul style="list-style-type: none"> <li>82% no injury (f-68%, s-71%)</li> <li>17% minor (f-31%, s-18%)</li> <li>1% moderate (f-1%, s-11%)</li> </ul>
<p>TRL Research Note (March 04): Questionnaire Sample (UK).</p> <p>Data from in-depth analysis of 289 children.</p> <p>Small sample size distorted results.</p>	<p>Injury distribution in rear impacts:</p> <ul style="list-style-type: none"> <li>84% MAIS 0 (f-72%, s-59%)</li> <li>16% MAIS 1 (f-27%, s-32%)</li> <li>1% MAIS 2+ (f-1%, s-10%)</li> </ul>



## TASK C17: DYNAMIC TESTING – REAR IMPACT

### 1. Review conclusions from accident analysis

<i>Source</i>	<i>Conclusions</i>
<p>EEVC WG 18 Report (Feb. 03): CSFC-1996 (F) In-depth study of 1327 children &lt;10 years involved in 877 vehicle accidents during 1995-96. Only children involved as car passengers – restrained or not- in car to car or car to fixed obstacle accidents.</p> <p>The sample of children involved in rear impacts (83) is not big enough to focus on severe injuries.</p>	<p>Only 6% of the children were involved in rear impacts (60% in frontal, 16% in side, 15% in rollovers).</p> <p>Impact severity: EES <math>\leq</math> 30 km/h in 80% of the rear impacts.</p> <p>Injury distribution in rear impacts:</p> <ul style="list-style-type: none"> <li>59% children uninjured (MAIS 0)</li> <li>31% slightly injured (MAIS 1-2)</li> <li>10% severely injured (MAIS 3+)</li> </ul> <p>Body segments injured in rear impacts (all injury severities):</p> <ul style="list-style-type: none"> <li>head 30%</li> <li>lower limbs 28%</li> <li>neck 13%</li> </ul>

## TASK C17: DYNAMIC TESTING – REAR IMPACT

### 1. Review conclusions from accident analysis

<i>Source</i>	<i>Conclusions</i>
<p>EEVC WG 18 Report (Feb. 03): GIDAS (D) In-depth study of 168 restrained children &lt;12 years involved in car accidents during 1999-2000. Vehicles involved in single collisions against other car or against a fixed obstacle.</p>	<p>Rear impacts represented 21% of the accidents (frontal 53%, struck side 17%, non-struck side 9%).</p> <p>Injury distribution in rear impacts: 71% MAIS 0 29% MAIS 1-2</p> <p>No injuries above MAIS 2 were observed.</p> <p>Injured body segments in rear impacts: the number of injuries is not sufficient to be statistically representative, but tendencies can be seen: the head is the most injured body segment followed by the neck.</p>

## TASK C17: DYNAMIC TESTING – REAR IMPACT

### 1. Review conclusions from accident analysis

<i>Source</i>	<i>Conclusions</i>
<p>Paper “Injury risks of children in cars depending on the type of restraint”. Langwieder K, Hummel T, Finkbeiner F. German Insurance Association (GDV),1999.</p> <p>In-depth study of 593 restrained (CRS or adult seat belt) children &lt;12 years from 448 car accidents in 1990-91.</p>	<p>Rear impacts represented 21.3% of the accidents (frontal 57.3%, side 20.2%, rollover 1.2%).</p> <p>Frequency of injuries in rear impacts:                  24.6% coded as MAIS 0                  70.6% as MAIS 1                  4.8% as MAIS 2</p> <p>No injuries above MAIS 2 were observed</p>
<p>Paper “Injury risks of children in cars depending on the type of restraint”. Langwieder K, Hummel T, Finkbeiner F. German Insurance Association (GDV),1999.</p> <p>Additional in-depth study of 42 restrained babies in G0 RF CRS from 25 accidents in 1995-97.</p>	<p>Frequency of injuries in rear impacts:                  88.9% coded as MAIS 0                  11.1% as MAIS 1</p> <p>No injuries above MAIS 1 were observed</p> <p><i>Remarks: the sample was small and no cases involving G0+ RF CRS</i></p>

## TASK C17: DYNAMIC TESTING – REAR IMPACT

### 1. Review conclusions from accident analysis

<i>Source</i>	<i>Conclusions</i>
<p>Paper “Injuries to children in child restraints”. Fildes B<sup>1</sup>, Charlton J<sup>1</sup>, Fitzharris M<sup>1</sup>, Langwieder K<sup>2</sup>, Hummel T<sup>2</sup>. <sup>1</sup>Monash University Accident Research Centre; <sup>2</sup>German Insurance Association (GDV), IJ Crash 2003 Vol 8 No. 3. Study of 67.228 passengers involved in reported casualty crashes in the state of Victoria (Australia) in the period 1996-2000.</p> <p>In-depth analysis of 103 restrained children involved in 66 crashes between 1996-2000 in Germany. Crashes tended to be fairly severe ones.</p>	<p>Rear impacts represent 1,3% of the average annual crashes for the 0-9 years age group (frontal 51,3%, side 33,3%). Outcome severity for occupants aged 0-9 years in rear impacts: while there were no fatalities, the risk of a serious outcome, however, was roughly twice as high than any other crash type.</p> <p>Injury severity in rear impacts: all cases reported as MAIS 1.</p>

## TASK C17: DYNAMIC TESTING – REAR IMPACT

### 1. Review conclusions from accident analysis

<i>Source</i>	<i>Conclusions</i>
<p>Paper “Performance of seating systems in a FMVSS 301 rear impact crash test”. Saunders III JW, Molino LN, Kuppa S, McKoy FL. 18th ESV Conference, Nagoya, Japan, 2003.</p>	<p>“...NHTSA undertook examining the performance of current seat systems in moderate to high speed rear crashes (<math>\Delta v=22-30</math> km/h)...”</p> <p>Rear impact crashes account for only 8% of all tow away crashes in the NASS/CDS database (frontal 57%, side 25%, rollover 8%).</p> <p>Risk of moderate to severe injuries, MAIS 3+, for rear impacts is 0,5% (frontal 2%, side 2,5%, rollover 6%).</p>

## TASK C17: DYNAMIC TESTING – REAR IMPACT

### 2. Review current testing procedures

#### Legislation tests

<i>Standard</i>	<i>Rear impact</i>
<p>ECE R44.03 United Nations Regulation. Uniform Provisions concerning the approval of restraining devices for child occupants of power-driven vehicles (“Child Restraint Systems”).</p>	<p>Test speed: 30 +2/-0 km/h Pulse: acceleration corridor, upper limit 21g and lower limit 14g. Pulse was not based on accurate accidentology data.</p>
<p>Australian Standard AS AS 1754, Child Restraint Systems for Use in Motor Vehicles. AS 3629.1, Methods of testing child restraints. Part 1-Dynamic testing</p>	<p>When subject to a velocity change not less than 32 km/h, a deceleration of between 14g and 20g shall be achieved within 30 ms. The deceleration shall remain within the range 14g to 20g for not less than 20 ms, but deceleration values outside this range that occur for periods of not greater than 1 ms may be disregarded.</p>

## TASK C17: DYNAMIC TESTING – REAR IMPACT

### 2. Review current testing procedures

#### Consumer tests

<i>Procedure</i>	<i>Rear impact</i>
Australian CREP (Child Restraint Evaluation Program). Introduced in 1994.	Same conditions as AS 1754.

#### Other tests

<i>Procedure</i>	<i>Rear impact</i>
IIWPG Protocol for the Dynamic Testing of Motor Vehicle Seats for Neck Injury Prevention. Draft Version 1.4, January 2004	The target sled acceleration pulse for IIWPG dynamic tests is roughly triangular in shape with a maximum acceleration of 10g occurring at 27 ms and yields a total delta-V of 16 km/h over 91 ms.

## TASK C17: DYNAMIC TESTING – REAR IMPACT

### 3. Proposal for NPACS rear impact testing procedure

#### Background

- Accidentology review shows that, compared to frontal and lateral crashes, rear impacts represent the least frequent and the least injurious accidents for child occupants in Europe.
- The NPACS programme aims at the assessment of the performance of CRS above (or at least equal) the homologation level.
- In the current ECE Regulation a rear impact test is part of the dynamic testing. According to the accident data showed, this test represents a quite severe impact condition.



## TASK C17: DYNAMIC TESTING – REAR IMPACT

## 3. Proposal for NPACS rear impact testing procedure

Bearing in mind the previous, it is recommended that a rear impact test is included in the NPACS programme.

Guidelines for designing rear impact test procedure:

- Pulse: keep ECE R44 until no real-world generic pulse is available
- Bench: same as for NPACS frontal impact, but rear sled tests could have an influence on the frontal bench(es)
- Dummies: same as for NPACS frontal and side impact
- Injury criteria: keep NPACS frontal or ECE R44 until no further biomechanical data is available (especially head and neck)
- Additional assessment: CRS kinematics (especially G0/0+), ...

## TASK C17: DYNAMIC TESTING – REAR IMPACT

### Progress and Next steps

<i>Subtask</i>	<i>Date due</i>	<i>Progress</i>
Review accident data	Until end March 2004	√
Report on accident research to TWG	TWG 26th April 2004	√
Continue review on rear impact pulse	End May 2004	
(CHILD accident reconstruction - Rear impact on G0 RF CRS)	End May-Mid June 2004	
Perform bodyshell sled test(s)	End June 2004	
Report on the need for a rear impact test	TWG 5th July 2004	



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NPACS RESEARCH PROGRAMME

WD Progress on Task C17 – Dynamic Testing, Rear Impact

*Gonçal Tejera*

## TASK C17: DYNAMIC TESTING – REAR IMPACT

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### Contents

NPACS TWG WD25

1. Main conclusions from accident data review
2. Review of rear impact pulses
3. Proposal of sled test matrix
4. Recommendations to TWG
5. Progress and next steps



1. Main conclusions from accident data review

NPACS TWG WD25

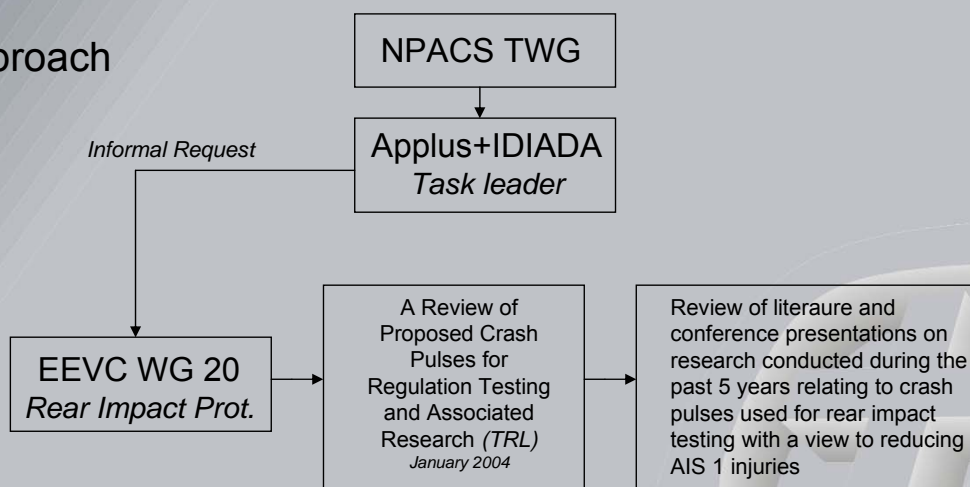
From WD 18:

- Accidentology review shows that, compared to frontal and lateral crashes, rear impacts represent the least frequent and the least injurious accidents for child occupants in Europe.
- Impact severity: in one study it was found that  $EES \leq 30$  km/h in 80% of the rear impacts.
- Injury outcome: nearly all of the injuries reported in rear impacts are coded in the range MAIS 0-2.
- Injuries by body region: in one study it was found that the head is the most injured body segment (30%).
- CRS type: only in one of the studies a specific CRS mass group was studied (G0). The rest of the studies did not distinguish them.

2. Review of rear impact pulses

NPACS TWG WD25

Approach



## 2. Review of rear impact pulses

NPACS TWG WD25

## Review of ESV Papers:

1. Cappon H, Philippens M, Wismans J. *A New Test Method for the Assessment of Neck Injuries in Rear-end Collisions*. Paper 242. ESV Conference 2001
2. Linder A, Avery M, Krafft M, Kullgren A, Svensson M. *Acceleration Pulses and Crash Severity in Low Velocity Rear Impacts-Real World Data and Barrier Tests*. Paper 216. ESV Conference 2001
3. Krafft M, Kullgren A, Ydenius A, Tingvall C. *The Correlation Between Crash Pulse Characteristics and Duration of Symptoms to the Neck-Crash Recording Real Life Rear Impacts*. Paper 174. ESV Conference 2001
4. Linder A, Avery M, Krafft M, Kullgren A. *Change of Velocity and Pulse Characteristics in Rear Impacts: Real World and Vehicle Test Data*. Paper 285. ESV Conference 2003.

## 2. Review of rear impact pulses

NPACS TWG WD25

## Main conclusions from ESV Papers:

- All research activities mentioned in those papers were focused on low speed rear impacts ( $\Delta v \leq 16$  km/h) so as to address the whiplash problematic.
- In real-world rear impacts similar changes of velocity can be generated with various durations and shapes of crash pulses.
- Very few data on real-world high speed rear crashes.
- In one paper (Cappon et al.) was found a reference to high speed rear impacts ( $\Delta v = 30$  km/h) linked to a crash pulse (8,5 g mean g-level). The crash pulse was based on crash data recorder in both real accidents and reconstructions.

2. Review of rear impact pulses

NPACS TWG WD25

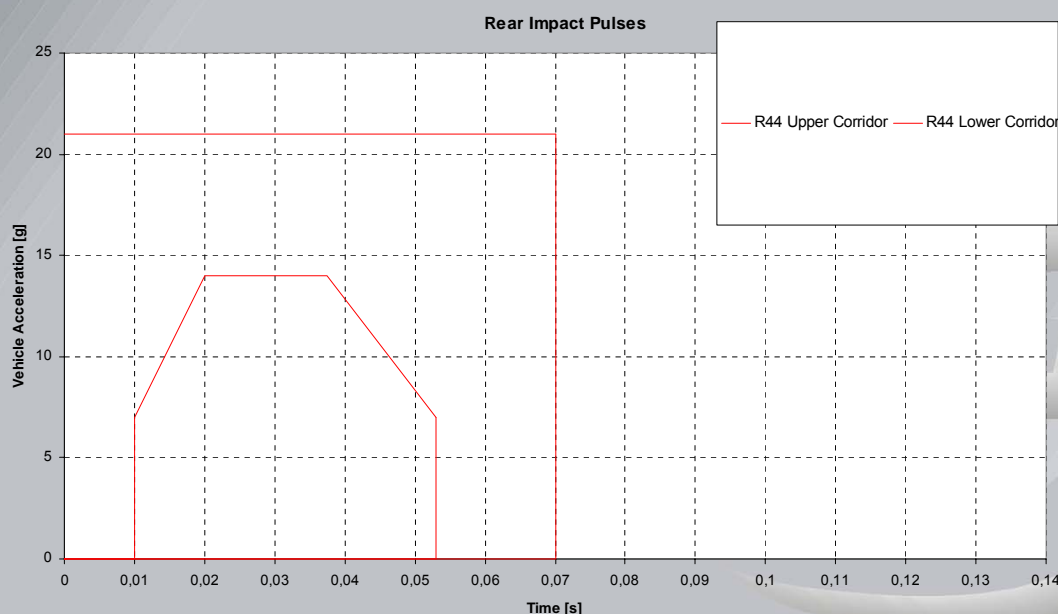
Pulses compared:

- ECE R44: 30±2 km/h, corridor (limits: 14 g lower, 21 g upper)
- Cappon et al. paper: 30 km/h, corridor (8,5 g mean level)
- FMVSS 301 “old”: 50 km/h, 100% overlap, rigid barrier 1800 kg
- FMVSS 301 “new”: 80 km/h, 70% overlap, deformable barrier 1370 kg
- CHILD reconstruction case 1063: car to car rear impact, 80 km/h, 45% overlap, striking car 1495 kg

2. Review of rear impact pulses

NPACS TWG WD25

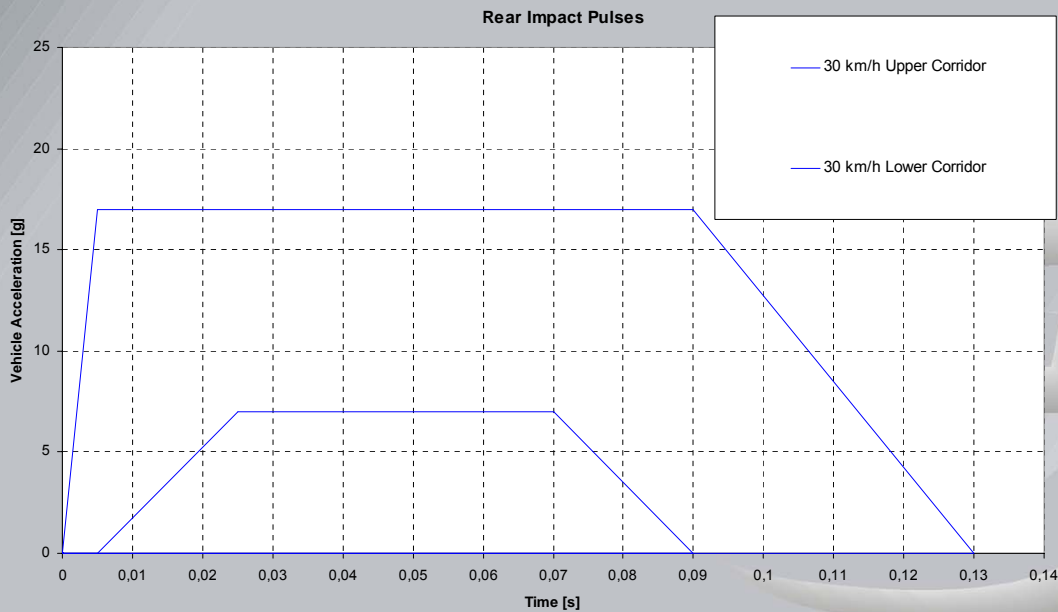
R44 (1981)



2. Review of rear impact pulses

NPACS TWG WD25

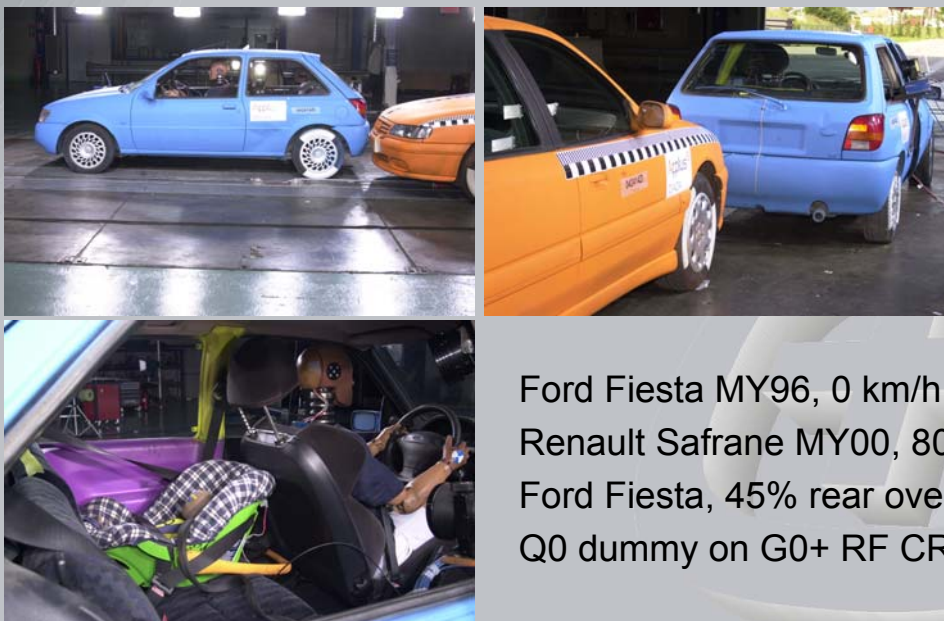
Cappon et al. (2001)



2. Review of rear impact pulses

NPACS TWG WD25

CHILD Project: Reconstruction of rear accident (case 1063)

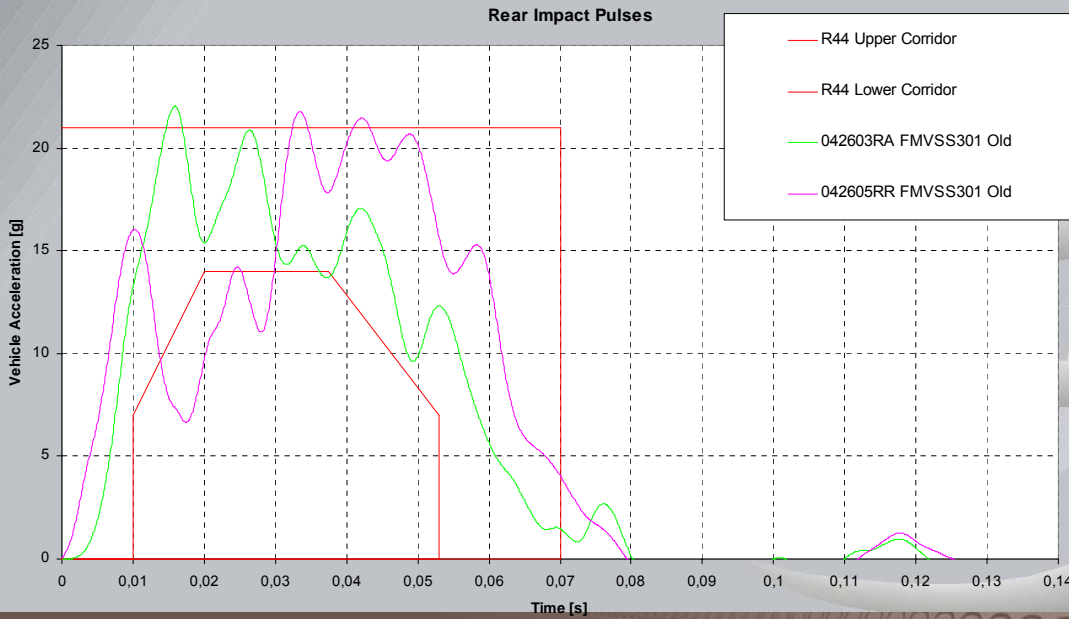


Ford Fiesta MY96, 0 km/h  
Renault Safrane MY00, 80 km/h  
Ford Fiesta, 45% rear overlap  
Q0 dummy on G0+ RF CRS

2. Review of rear impact pulses

NPACS TWG WD25

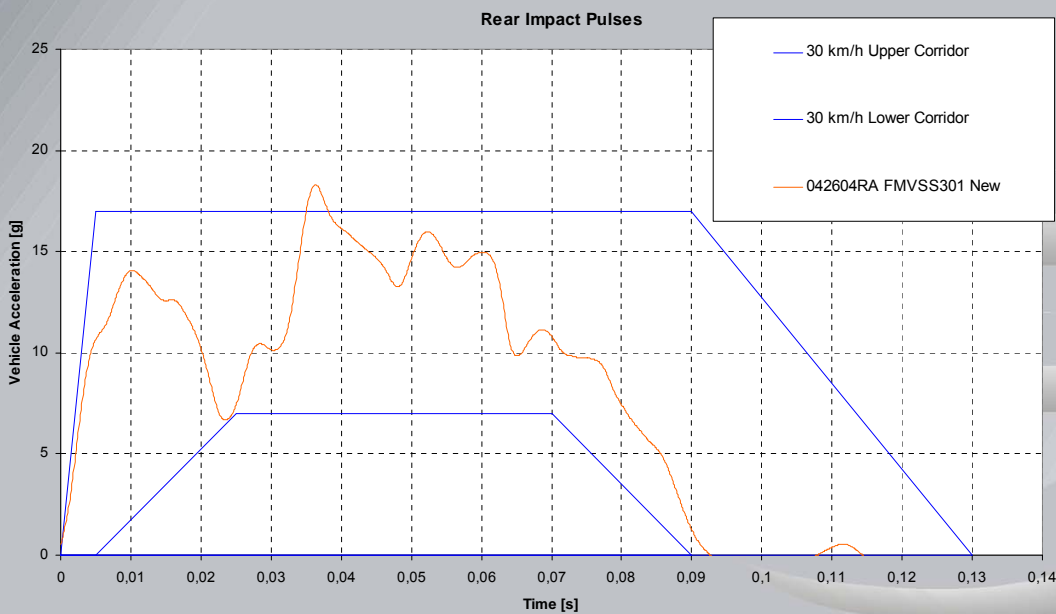
FMVSS 301 “old”: Small family cars MY04 and MY03



2. Review of rear impact pulses

NPACS TWG WD25

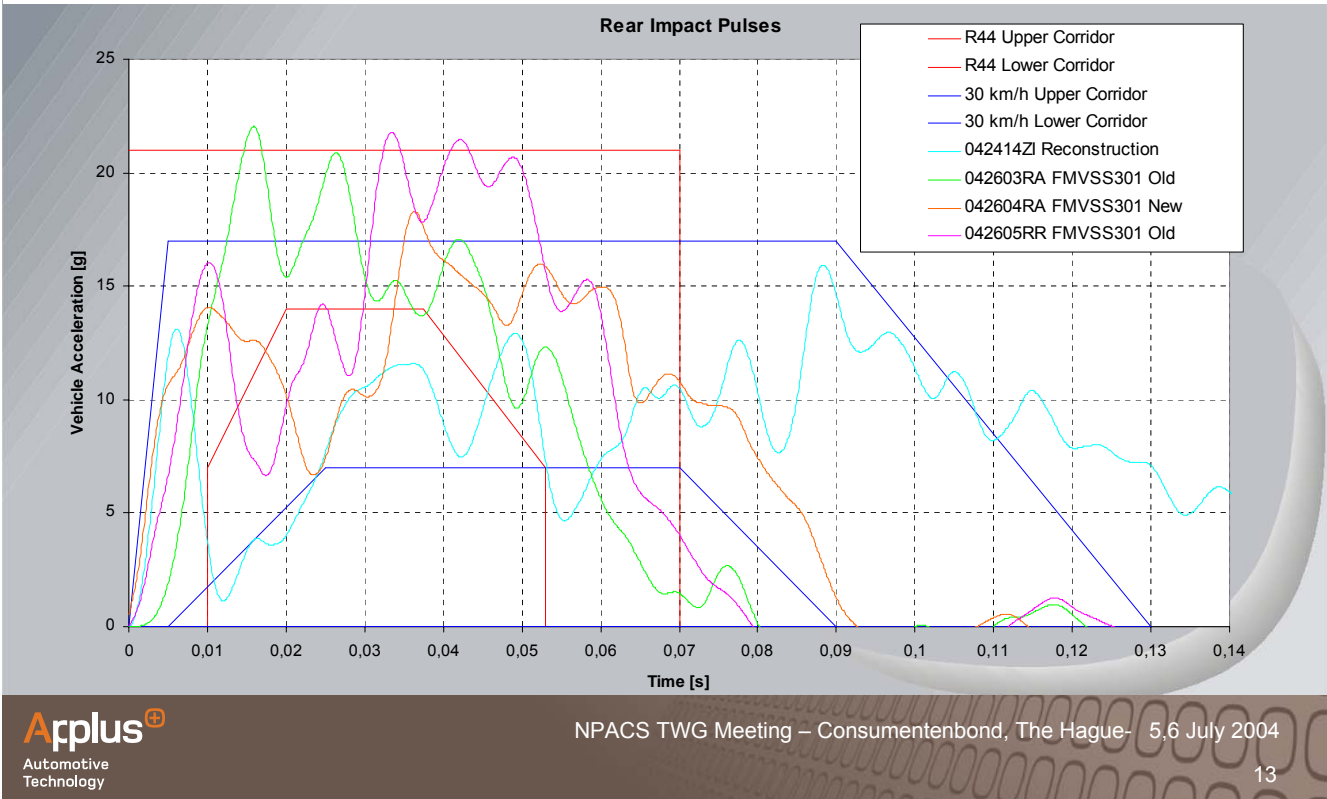
FMVSS 301 “new”: Small family car MY04





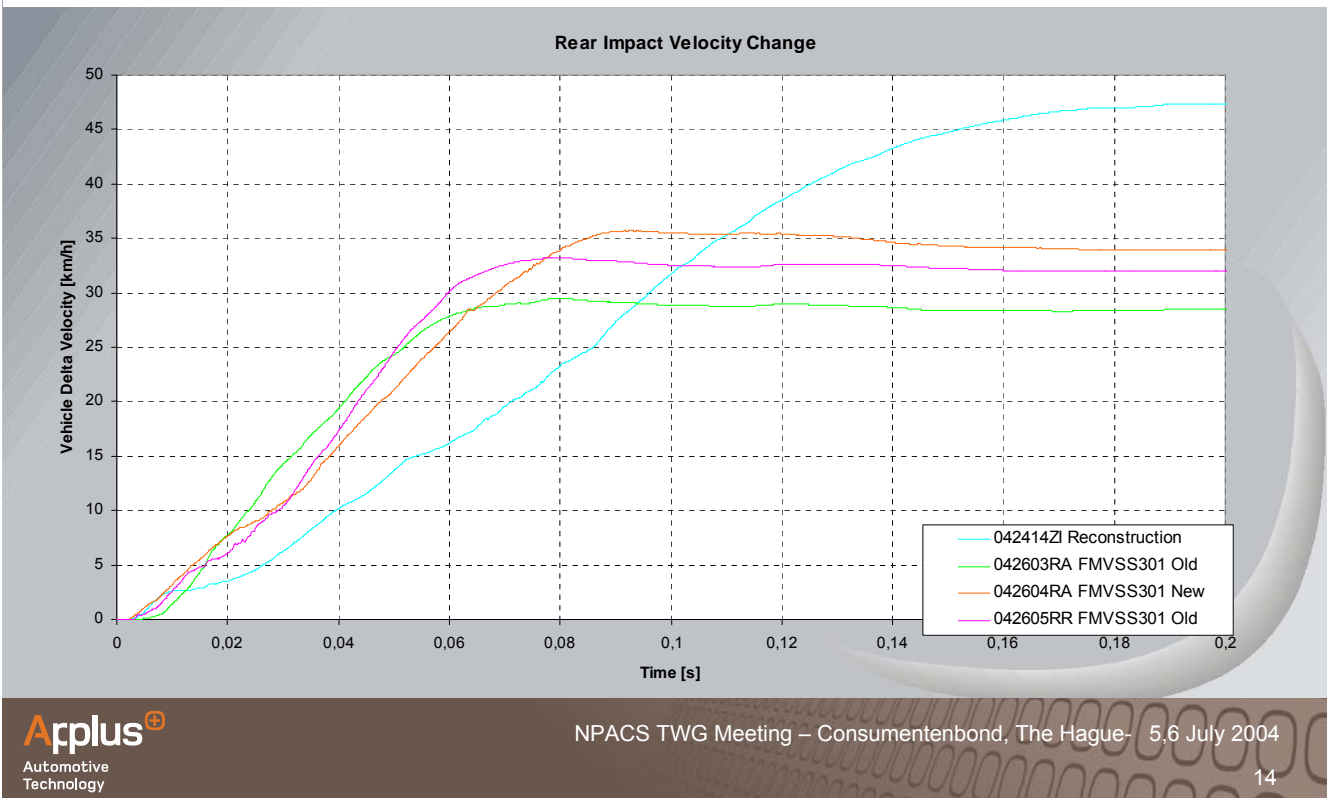
2. Review of rear impact pulses

NPACS TWG WD25



2. Review of rear impact pulses

NPACS TWG WD25

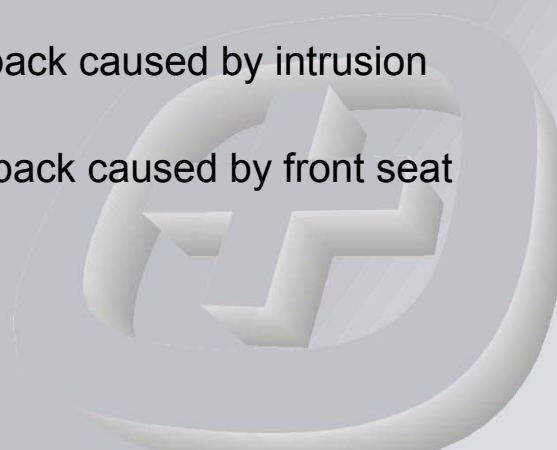


2. Review of rear impact pulses

NPACS TWG WD25

Other issues

- Main goal is to avoid rotation of CRS so as to control head displacement (head contact)
- Influence of deformation of rear seatback caused by intrusion (is this a CRS issue?)
- Influence of deformation of front seatback caused by front seat occupant (is this a CRS issue?)



3. Proposal of sled test matrix

NPACS TWG WD25

Test no.	Pulse type	CRS model	Pulse shape	$\Delta v$ (km/h)	Dummy
1	Cappon et al.	A	sine (average)	30	P 1 1/2
2	Cappon et al.	A	trapezoid (average)	30	P 1 1/2
3	Cappon et al.	A	sine (average)	35	P 1 1/2
4	Cappon et al.	A	trapezoid (average)	35	P 1 1/2
5	R44.04	A	sine (average)	30	P 1 1/2
6	R44.04	A	trapezoid (average)	30	P 1 1/2
7	R44.04	A	sine (average)	35	P 1 1/2
8	R44.04	A	trapezoid (average)	35	P 1 1/2
9	Cappon et al.	B	sine or trapezoid	30 or 35	P 1 1/2
10	Cappon et al.	C	same as 9	same as 9	P 1 1/2
11	R44.04	B	sine or trapezoid	30 or 35	P 1 1/2
12	R44.04	C	same as 11	same as 11	P 1 1/2

- CRS model: A = G0+ without ISOFIX / B = G0+ with ISOFIX (+ support leg?)/ C = G0+ without ISOFIX
- Acceleration sled, bodysell (Golf IV), 0°, no rear seatback intrusion, no front seatback deformation

## 4. Recommendations to TWG

NPACS TWG WD25

- The NPACS programme aims at the assessment of the performance of CRS above (or at least equal) the homologation level.
- In the current ECE R44.04 a rear impact test is part of the dynamic testing for rear facing CRS.



Rear impact protection should be addressed in the NPACS programme by means of a rear impact sled test

## 4. Recommendations to TWG

NPACS TWG WD25

Guidelines for rear impact test procedure:

- CRS: only rear facing seats (?)
- Pulse: pulse type depending on sled; specific curve with tolerance (acceleration sled) or upper & lower limit corridor (braking sled)
- Bench(es): same as for NPACS frontal impact
- Dummies: same as for NPACS frontal and side impact
- Injury criteria: keep NPACS frontal or ECE R44 until no further biomechanical data is available (especially head and neck)
- Additional assessment: head displacement, CRS kinematics, ...

5. Progress and next steps

NPACS TWG WD25

<i>Subtask</i>	<i>Date due</i>	<i>Progress</i>
Review accident data	Until end March 2004	√
Report on accident research to TWG	TWG 26th April 2004	√
Continue review on rear impact pulses	End May 2004	√
(CHILD accident reconstruction - Rear impact on G0+ RF CRS)	(End May-Mid June 2004) Mid June 2004	√
Perform bodyshell sled tests	(End June 2004) July/Sept. 2004	
Report on rear impact test procedure	(TWG 5th-6th July 2004) TWG 13th Sept. 2004 TWG 2nd-3rd Dec. 2004	



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NPACS RESEARCH PROGRAMME

Progress on Task C17 – Dynamic Testing, Rear Impact

*Gonçal Tejera*

**TASK C17: DYNAMIC TESTING – REAR IMPACT**

Rear angled impact - Sled test matrix

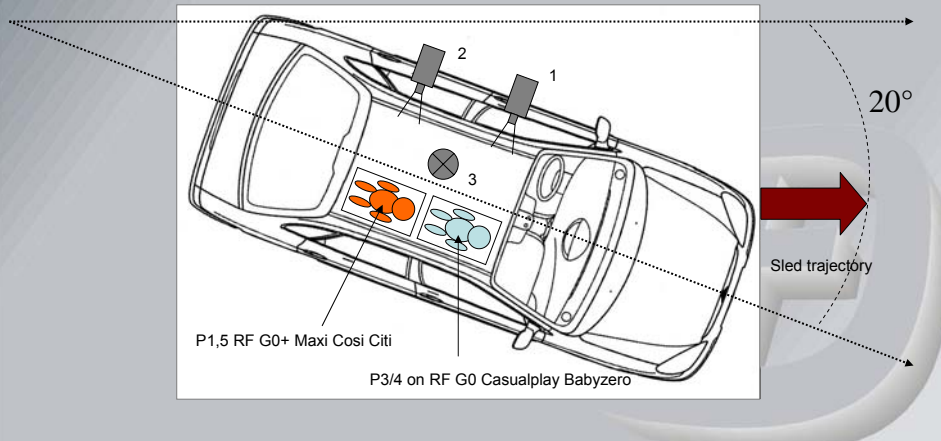
Objective: to explore the influence of a rear angled collision in the head injury risk for infants in rear facing seats

	Test 1	Test 2
Angle	0°	20°
Dummy/CRS front	P ¾ RF G0	P ¾ RF G0
Dummy/CRS rear	P 1 ½ RF G0+	P 1 ½ RF G0+

Bodyshell : Golf IV 5d  
Pulse : Rear ECE R44.04  
Sled : Reverse acceleration

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## Test set-up



# TASK C17: DYNAMIC TESTING – REAR IMPACT

## Films: 0° test



TASK C17: DYNAMIC TESTING – REAR IMPACT

Films: 0° test



TASK C17: DYNAMIC TESTING – REAR IMPACT

Films: 0° test



TASK C17: DYNAMIC TESTING – REAR IMPACT

Pictures: 0° test



before

after

TASK C17: DYNAMIC TESTING – REAR IMPACT

Pictures: 0° test



before

P3/4 on RF G0 seat

after



TASK C17: DYNAMIC TESTING – REAR IMPACT

Pictures: 0° test



P3/4 on RF G0 seat (after test)

TASK C17: DYNAMIC TESTING – REAR IMPACT

Pictures: 0° test



P3/4 on RF G0 seat (after test)

TASK C17: DYNAMIC TESTING – REAR IMPACT

Pictures: 0° test



before

P1,5 on RF G0+ seat

after

TASK C17: DYNAMIC TESTING – REAR IMPACT

Pictures: 0° test



P1,5 on RF G0+ seat (after test)

TASK C17: DYNAMIC TESTING – REAR IMPACT

Films: 20° test



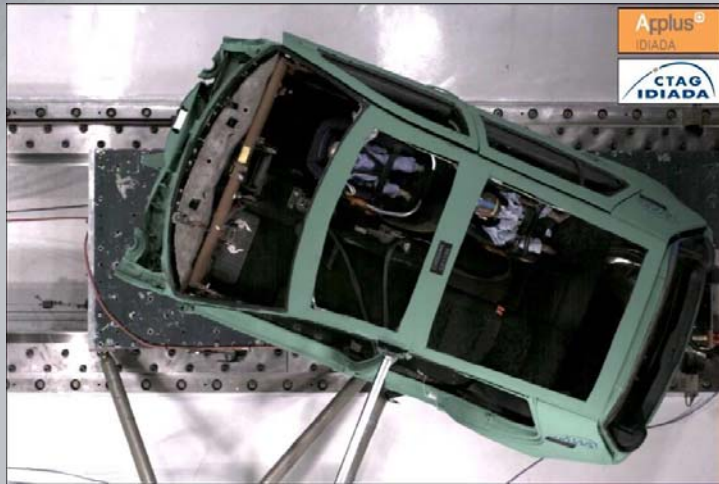
TASK C17: DYNAMIC TESTING – REAR IMPACT

Films: 20° test



TASK C17: DYNAMIC TESTING – REAR IMPACT

Films: 20° test



TASK C17: DYNAMIC TESTING – REAR IMPACT

Pictures: 20° test



TASK C17: DYNAMIC TESTING – REAR IMPACT

Pictures: 20° test



before



after

P3/4 on RF G0 seat

TASK C17: DYNAMIC TESTING – REAR IMPACT

Pictures: 20° test



P3/4 on RF G0  
seat (after test)



Head contact with seat wing

TASK C17: DYNAMIC TESTING – REAR IMPACT

Pictures: 20° test



before

P1,5 on RF G0+ seat

after

TASK C17: DYNAMIC TESTING – REAR IMPACT

Pictures: 20° test



P1,5 on RF G0+ seat  
(after test)

TASK C17: DYNAMIC TESTING – REAR IMPACT

Pictures: P3/4 on RF G0 seat 0° test / 20° test



0° test

20° test

TASK C17: DYNAMIC TESTING – REAR IMPACT

Pictures: P1,5 on RF G0 seat 0° test / 20° test



0° test

20° test

TASK C17: DYNAMIC TESTING – REAR IMPACT

Dummy results - Head

0°	P ¾	P 1 ½	EuroNCAP (0 points)
Head resultant acc. peak (g)	39,3	29,4	-
Head resultant acc. 3ms (g)	36,9	29,1	88

20°	P ¾	P 1 ½	EuroNCAP (0 points)
Head resultant acc. peak (g)	120	40,4	-
Head resultant acc. 3ms (g)	39,4	30,5	88

TASK C17: DYNAMIC TESTING – REAR IMPACT

Dummy results - Neck

0°	P ¾	P 1 ½	EuroNCAP (0 points)
Neck Forces Fx/Fy/Fz (kN)	0,6/-1,1	0,3/0/0,7	-
Neck Moments Mx/My/Mz (Nm)	-1,2/-	1,7/5,1/1,1	-
Head vertical acc. 3ms (g)	35,9	28,2	40

20°	P ¾	P 1 ½	EuroNCAP (0 points)
Neck Forces Fx/Fy/Fz (kN)	0,4/-1,0	0,3/0,1/0,7	-
Neck Moments Mx/My/Mz (Nm)	-/0,7/-	8,7/10/2,4	-
Head vertical acc. 3ms (g)	35,9	29,1	40



## Dummy results - Chest

0°	P ¾	P 1 ½	R44 (= 0 points EuroNCAP)
Chest resultant acc. 3ms (g)	51,1	40,8	55
Chest vertical acc. 3ms (g)	29,3	32,9	30

20°	P ¾	P 1 ½	R44 (= 0 points EuroNCAP)
Chest resultant acc. 3ms (g)	50,0	30,7	55
Chest vertical acc. 3ms (g)	38,6	32,3	30

## Test results

- A tendency towards a head contact with the vehicle interior (B pillar) was observed for the P3/4 dummy placed in the front seat in the angled impact (20°). The actual contact took place in the seat wing (but not hard contact)
- A significant pitch rotation of the CRS' is produced during both test conditions (0° and 20°)
- The full pitch rotation (overturning) of the CRS is avoided by the CRS handle performance and by the seat belt blocking system (KISI system)

## Test results

- No significant differences between dummy readings for both test conditions. For P1,5 dummy slightly higher figures for head peak acceleration and neck moments in the 20° test
- The chest vertical acceleration 3ms show high values (above R44 limits) in 3 of the 4 tests

## Test conclusions

- Overturning of the CRS is not a desirable effect because:
  - increases the risk of head contact with the vehicle interior
  - increases the risk of ejection
  - reduces the protection in the event of subsequent impacts (CRS is not correctly positioned after first impact)
  - may increase loads in the occupant
  - increases the risk of interaction with deploying side airbags
  - Increases the risk of interaction with intruding front and rear seatback (due to vehicle deformation, luggage interaction or occupant interaction)

Test conclusions

- CRS parts that seem to be crucial elements to guarantee a good protection in rear impacts are:
  - Handle position
  - Seat belt routing lay-out
  - ISOFIX and stability bars (when available)
  - Occupant position (CRS tilt adjustment)
- Effect of angle: the angled impact could represent a higher risk of head contact with the vehicle interior (B pillar, C pillar, door or window waistline rail) especially in slightly more severe rear impact conditions or with taller child occupants

Rear impact tests – Examples

(Film on rear impact test)

Source: [www.concord.de](http://www.concord.de)

Rear impact tests – Examples



P 1,5 dummy

Source: courtesy of Britax

Rear impact tests – Examples



P 1,5 dummy

Source: courtesy of Britax

## EuroNCAP Child Assessment Protocol (V1.0b, June 2004)

*Dynamic Assessment**General*

- Ejection: if the child dummy is ejected or partially ejected from the CRS, that CRS is awarded zero points for its dynamic performance.
- Head contact *with the vehicle*: if there is head contact with any part of the vehicle, the CRS containing that dummy is awarded zero points for its head and neck performance.

*Frontal impact*

- Head contact *with CRS*: contact is defined by either direct evidence of contact or peak resultant acceleration  $> 80 \text{ g}$   
In the presence of contact, the score is based on the Head Resultant Acceleration 3ms ( $\geq 88 \text{ g} \Rightarrow 0 \text{ points}$ )

## EuroNCAP Child Assessment Protocol (V1.0b, June 2004)

*Dynamic Assessment**Frontal impact (cont.)*

- Neck tension (rearward facing seats): as a surrogate for neck tension, the score is based on the head vertical acceleration 3ms ( $\geq 40 \text{ g} \Rightarrow 0 \text{ points}$ )



Neck tension in FRONTAL impact



Neck tension in REAR impact

- Chest: the chest score is based on the worst scoring of the two parameters, chest resultant acceleration 3ms ( $\geq 55 \text{ g} \Rightarrow 0 \text{ points}$ ) and chest vertical acceleration 3ms ( $\geq 30 \text{ g} \Rightarrow 0 \text{ points}$ )

## Recommendations to NPACS TWG

- Accident data review showed that rear impact represents the least common and least injurious accident condition for restrained children
- However, straight and angled rear sled test results, other sled test results and existing assessment protocols show that there are some issues concerning children protection that should be taken into account for such an impact condition
- The NPACS programme aims at the assessment of the performance of CRS above (or at least equal) the homologation level
- One of the objectives of NPACS is to clearly differentiate between good performer and bad performer CRS in dynamic testing

## Recommendations to NPACS TWG

- EVPSN2 Road Map (pg. 4): research & technology development is required in 3 directions: all impact scenarios (not only frontal and side, but also rear and rollover), all injuries, all road users (all sizes, ages and statures)
- The presence in the market of CRS models with ISOFIX and other devices (support leg, stability bar) will be increased but they will coexist with non ISOFIX child seats



*Bearing all the above in mind*

It is recommended that a dynamic test and an assessment method for rear impact protection is included in the NPACS programme

## Recommendations to NPACS TWG

## Basis for the rear impact test procedure

- CRS type: rearward facing seats (G0 and G0+ but also G1). Forward facing seats could be considered in the future depending on accident data
- Pulse: current R44 or explore other possibilities (see WD18). Pulse type depending on sled; specific curve with tolerance (acceleration sled) or upper & lower limit corridor (braking sled)
- Test bench: same as for NPACS frontal impact
- Angle: according to accident statistics (straight impact vs angled impact) but angled impact showed a potential higher risk of head contact
- Dummies: same as for NPACS frontal

## Recommendations to NPACS TWG

## What could be assessed in the rear impact test?

- Dummy readings
  - ~ Head acceleration (peak resultant, 3ms, peak vertical)
  - ~ Neck forces and moments
  - ~ Chest acceleration (peak resultant, 3ms, peak vertical)
  - ~ ...
- Head excursion (horizontal, vertical)
- Head contact (with vehicle/with CRS)
- CRS rotation\* (angle of CRS back before/after)
- Handle performance
- Seat belt guides performance
- Release of harness buckle during test
- CRS released from seat belt/ISOFIX



Source: www.nasva.go.jp

Recommendations to NPACS TWG

What could be assessed in the rear impact test?

- ISOFIX and stability bar performance (when available)
- Forward movement of CRS base
- Child ejection
- CRS damage
- Occupant position (CRS tilt adjustment)
- ...

*\*Regarding CRS rotation: is it desirable a small amount of rotation as a mechanism of energy absorption or it should be avoided because it exposes the infant to a frontal impact condition against the vehicle interior  
⇒ possible high neck loads (tension/compression)*



Neck tension in REAR impact

Example - will these CRS have the same performance in rear impact?



Source: Applus+IDIADA



Source: www.britax.co.uk



Source: EuroNCAP Child Assessment Protocol



Progress

<i>Subtask</i>	<i>Date</i>	<i>Progress</i>
Report on accident research to TWG	TWG 26th April 2004	√
Report on rear impact pulses	TWG 5th July 2004	√
(CHILD accident reconstruction - Rear impact on G0 RF CRS)	June 2004	√
Perform bodysHELL sled tests	November 2004	√
Report on angled sled results	TWG 2nd-3rd Dec. 2004	√
Recommendations to TWG on rear impact	TWG 2nd-3rd Dec. 2004	√

Next steps

If the continuation of task C17 is agreed by the NPACS TWG...

- Selection of rear impact condition -straight impact vs angled impact- according to sled test results but also accident statistics
- Selection of rear impact pulse
- Selection of assessment parameters
- Definition of assessment method
- Preparation of assessment protocol

## NPACS TASK C17

# REAR IMPACT STUDY WITH RECOMMENDATIONS

Gonçal Tejera, Project Manager, Passive Safety, Applus+IDIADA

February 2005

### 1. OBJECTIVES

The main objectives of this report are as follows:

- To summarise the work carried out in task C17 (rear impact testing methods) until now.
- To make recommendations to the NPACS TWG on what a rear impact procedure might be.
- To evaluate the potential benefits and drawbacks in case such a test method is included in the NPACS dynamic testing protocol.

### 2. BACKGROUND

The review of accident data carried out within this task showed that very little information is available with regard to rear impacts involving child occupants when compared to the large amount of existing data for both frontal and lateral impacts. However, the reviewed rear impact studies showed that rear accidents represent the least frequent and least injurious accidents for children in Europe. As for the injury distribution for body regions, only one of the reports mentioned that the head was the most injured body segment. Bearing in mind the scarce information available, in the TWG held in July 2004 it was suggested that task C17 could explore the influence of rear angled collisions in the head injury risk for infants in rearward facing child restraints.

### 3. WORK CARRIED OUT UNTIL PRESENT

#### 3.1. Methodology

The work was divided into several subtasks following a sequential approach:

- Review conclusions from accident data
- Review current testing procedures
- Review and comparison of rear impact pulses
- Proposal of sled test matrix
- Test results and conclusions

Periodical reports covering the progress in these subtasks were presented at the five NPACS TWGs held throughout 2004 (Brussels 23rd January, Crowthorne 24th April, The Hague 5th-6th July, Bergisch Gladbach 13th September, Paris 2nd-3rd December).

### 3.2. Review conclusions from accident data

Different sources of information were considered for the review of accident data. On the one hand, an informal request for information was made to the organisations dealing with both child and rear impact accident data in Europe. This is the case of the EEVC WG 18 *Child Safety* and EEVC WG 20 *Rear Impact*. Documents from both these two groups and from individual member organisations were obtained. On the other hand, a literature review of technical papers submitted to the main passive safety conferences (ESV, IRCOBI) during the last years was conducted. The purpose of this review was to look for information on rear accident data with regard to the following specific items: rear impact distribution, impact severity, injury frequency, injured body region distribution and injury causation. It must be said, however, that rear accident data in general and rear accident data dealing with child occupants in particular is scarce in comparison to accident data of frontal and lateral impacts. As a result of this search, the following information was obtained (*Table 1*):

Source	Conclusions
[1] EEVC WG 18 Report (Feb. 03): CCIS Database (UK). Data from Phases Vb and VI. In-depth analysis of 425 children <12 years, restrained or not. All fatal and most serious crashes investigated ⇒ bias towards severe accidents in the db.	Rear impacts represented 12% of the accidents (frontal 64%, side 15%, others 9%) Restraint use for children in rear impacts: 30% restrained 10% unrestrained 17% use claimed 43% unknown
[2] TRL Research Note (March 04): CCIS Sample (UK). Data from in-depth analysis of 657 children.	Rear impacts had the highest proportion (32%) of uninjured (frontal 26%, side 21%). Rear impacts also had the lowest proportion (7%) of moderate or greater injuries, MAIS 2+ (frontal 11%, side 17%).
[1] EEVC WG 18 Report (Feb. 03): Questionnaire Database (UK). Sample containing data from accidents in 1995-2000. A total of 230 children ≤12 years involved. Information about injuries should be treated with caution (based on parents' judgement). Relatively large number of rear impact cases because adults causing an accident are less likely to fill in the forms.	Full rear impacts represented 39% of the accidents and rear corner accidents accounted for 10% of the cases (full frontal 18%, front corner 15%, side 12%). Injury distribution in rear impacts: 82% no injury (f-68%, s-71%) 17% minor (f-31%, s-18%) 1% moderate (f-1%, s-11%)
[2] TRL Research Note (March 04): Questionnaire Sample (UK). Data from in-depth analysis of 289 children. Small sample size distorted results.	Injury distribution in rear impacts: 84% MAIS 0 (f-72%, s-59%) 16% MAIS 1 (f-27%, s-32%) 1% MAIS 2+ (f-1%, s-10%)

Source	Conclusions
<p>[1] EEVC WG 18 Report (Feb. 03): CSFC-1996 (F) In-depth study of 1327 children &lt;10 years involved in 877 vehicle accidents during 1995-96. Only children involved as car passengers –restrained or not- in car to car or car to fixed obstacle accidents. The sample of children involved in rear impacts (83) is not big enough to focus on severe injuries.</p>	<p>Only 6% of the children were involved in rear impacts (60% in frontal, 16% in side, 15% in rollovers). Impact severity: EES <math>\leq</math> 30 km/h in 80% of the rear impacts. Injury distribution in rear impacts: 59% children uninjured (MAIS 0) 31% slightly injured (MAIS 1-2) 10% severely injured (MAIS 3+) Body segments injured in rear impacts (all injury severities): head 30% lower limbs 28% neck 13%</p>
<p>[1] EEVC WG 18 Report (Feb. 03): GIDAS (D) In-depth study of 168 restrained children &lt;12 years involved in car accidents during 1999-2000. Vehicles involved in single collisions against other car or against a fixed obstacle.</p>	<p>Rear impacts represented 21% of the accidents (frontal 53%, struck side 17%, non-struck side 9%). Injury distribution in rear impacts: 71% MAIS 0 29% MAIS 1-2 No injuries above MAIS 2 were observed. Injured body segments in rear impacts: the number of injuries is not sufficient to be statistically representative, but tendencies can be seen: the head is the most injured body segment followed by the neck.</p>
<p>[3] Paper “Injury risks of children in cars depending on the type of restraint”. Langwieder K, Hummel T, Finkbeiner F. German Insurance Association (GDV), 1999. Additional in-depth study of 42 restrained babies in G0 RF CRS from 25 accidents in 1995-97.</p>	<p>Frequency of injuries in rear impacts: 88.9% coded as MAIS 0 11.1% as MAIS 1 No injuries above MAIS 1 were observed <i>Remarks: the sample was small and no cases involving G0+ RF CRS</i></p>
<p>[4] Paper “Injuries to children in child restraints”. Fildes B<sup>1</sup>, Charlton J<sup>1</sup>, Fitzharris M<sup>1</sup>, Langwieder K<sup>2</sup>, Hummel T<sup>2</sup>. <sup>1</sup>Monash University Accident Research Centre; <sup>2</sup>German Insurance Association (GDV), IJ Crash 2003 Vol 8 No. 3. Study of 67.228 passengers involved in reported casualty crashes in the state of Victoria (Australia) in the period 1996-2000. In-depth analysis of 103 restrained children involved in 66 crashes between 1996-2000 in Germany. Crashes tended to be fairly severe ones.</p>	<p>Rear impacts represent 1,3% of the average annual crashes for the 0-9 years age group (frontal 51,3%, side 33,3%). Outcome severity for occupants aged 0-9 years in rear impacts: while there were no fatalities, the risk of a serious outcome, however, was roughly twice as high than any other crash type. Injury severity in rear impacts: all cases reported as MAIS 1.</p>
<p>[5] Paper “Performance of seating systems in a FMVSS 301 rear impact crash test”. Saunders III JW, Molino LN, Kuppa S, McKoy FL. 18th ESV Conference, Nagoya, Japan, 2003.</p>	<p>“...NHTSA undertook examining the performance of current seat systems in moderate to high speed rear crashes (<math>\Delta v=22-30</math> km/h)...” Rear impact crashes account for only 8% of all tow away crashes in the NASS/CDS database (frontal 57%, side 25%, rollover 8%). Risk of moderate to severe injuries, MAIS 3+, for rear impacts is 0,5% (frontal 2%, side 2,5%, rollover 6%).</p>

Table 1: Accident data involving children in rear impacts

As a general conclusion, all the above accident data shows that compared to frontal and lateral crashes, rear impacts represent the least frequent and the least injurious accidents for child occupants in Europe [6]. In particular, nearly all of the injuries reported in rear impacts are coded in the range MAIS 0-2 (0-uninjured; 1,2-slightly injured).

With regard to impact severity, in one study was found that the EES was less or equal to 30 km/h in 80% of the rear impacts. When talking about injury distribution by body region, in one study was stated that the head was the most injured body segment (30%).

### 3.3. Review current testing procedures

The following task was to review any testing procedure existing worldwide dealing with child occupants in rear impact. Both legislative standards and consumer testing procedures were examined (*Tables 2 and 3*). It must be highlighted however that an in-depth review of these testing methods was not the purpose of this subtask. A comprehensive review of all testing procedures –frontal, lateral and rear- including comparison among them was undertaken in Task C1 *Review existing methods* carried out by TRL. Bearing this in mind, the following was obtained:

<i>Test procedure</i>	<i>Rear impact configuration</i>
[7] ECE R44.03 United Nations Regulation. Uniform Provisions concerning the approval of restraining devices for child occupants of power-driven vehicles (“Child Restraint Systems”).	Test speed: 30 +2/-0 km/h Pulse: acceleration corridor, upper limit 21g and lower limit 14g. For G0/G0 <sup>+</sup> rearward facing seats only. Pulse was not based on accurate accident data.
[8] Australian Standard AS AS 1754, Child Restraint Systems for Use in Motor Vehicles. AS 3629.1, Methods of testing child restraints. Part 1-Dynamic testing	When subject to a velocity change not less than 32 km/h, a deceleration of between 14g and 20g shall be achieved within 30 ms. The deceleration shall remain within the range 14g to 20g for not less than 20 ms, but deceleration values outside this range that occur for periods of not greater than 1 ms may be disregarded.

*Table 2: Legislative testing procedures*

<i>Test procedure</i>	<i>Rear impact configuration</i>
[9] Australian CREP (Child Restraint Evaluation Program). Introduced in 1994.	Same conditions as AS 1754.

*Table 3: Consumer testing procedures*

It can be seen that very few testing methods exist with respect to rear impact.

### 3.4. Review and comparison of rear impact pulses

Next step was to find some information regarding the test pulse (acceleration-time curve). For this purpose, pulses from different sources were compared. In the same way as for the accident data review, the approach consisted in consultation with EEVC WG 20 *Rear Impact* experts. Although document [10] and papers [11], [12], [13] and [14] were mainly dealing with

research focused on low speed rear impacts, there was some information on more severe test conditions. In addition, three pulses corresponding to full-scale crash tests were analysed. Two of them consisted of rear impact crashes of a MY 04 small family car according to American standard FMVSS 301 in both “old” and “new” versions. Both versions of the American standard represent the most widely used test procedures when assessing rear impact crasworthiness. The “new” version represents an updated test condition of the previous version taking into account the changes observed in the current American vehicle fleet the last years. The third pulse corresponded to a reconstruction test of a real rear impact accident performed in the framework of the European research project CHILD. In the particular case of the pulse used in the current UN ECE Regulation 44, no information was obtained about the background of the pulse used for rear impact. Summing up, the test pulses compared were:

- ECE R44: 30±2 km/h, corridor (limits: 14 g lower, 21 g upper) (*Figure 1*)
- Cappon et al. paper: 30 km/h, corridor (8,5 g mean level) (*Figure 2*)
- FMVSS 301 “old”: 50 km/h, 100% overlap, rigid barrier 1800 kg
- FMVSS 301 “new”: 80 km/h, 70% overlap, deformable barrier 1370 kg
- CHILD reconstruction case 1063: car to car rear impact, 80 km/h, 45% overlap, striking car 1495 kg, struck car 1115 kg

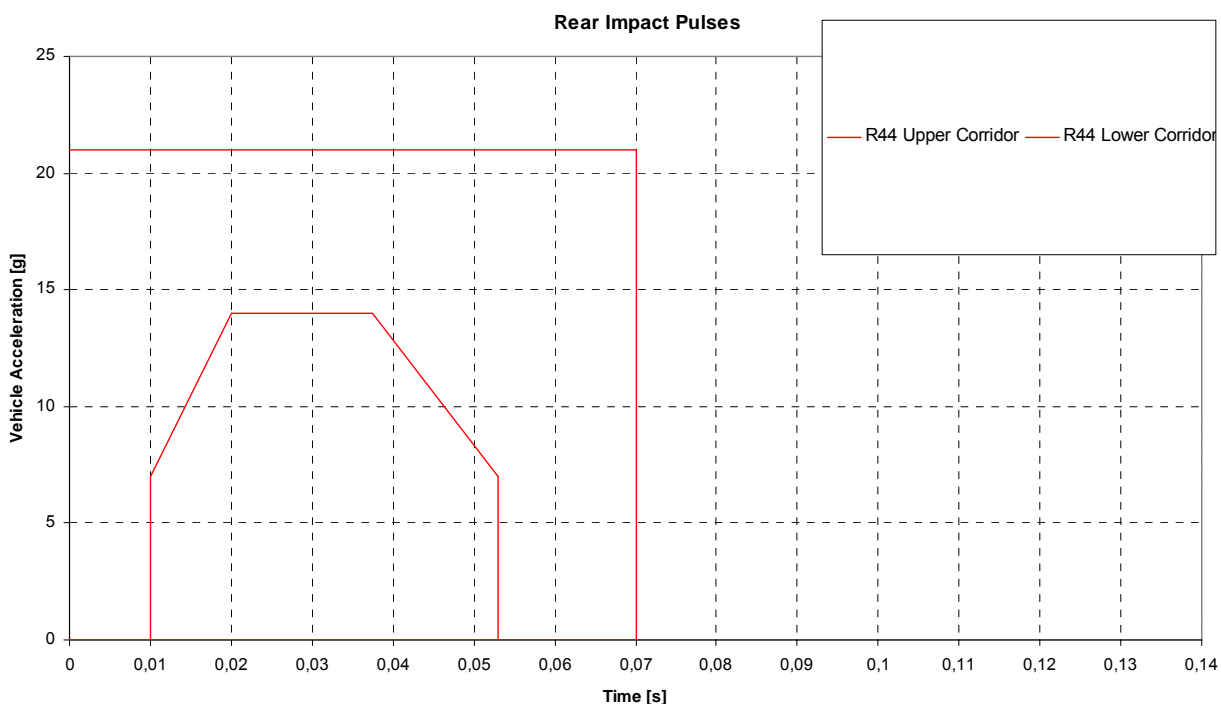


Figure 1: UN ECE R44 pulse corridor for rear impact

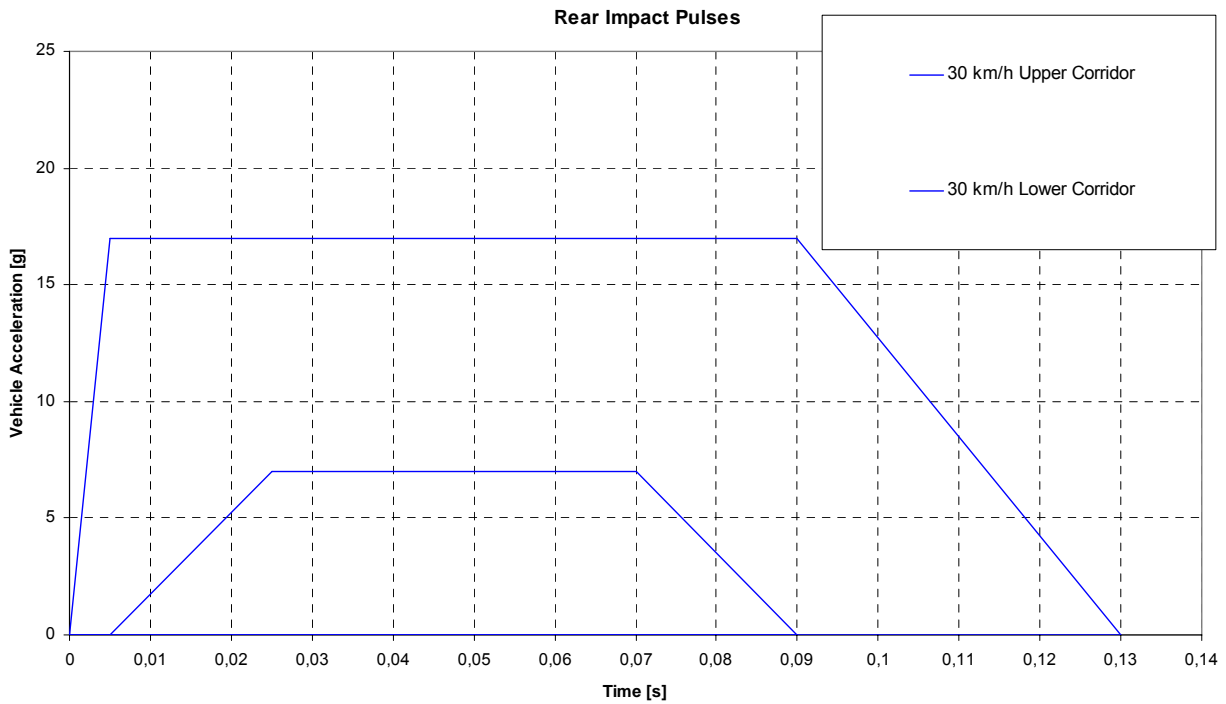


Figure 2: Cappon et al. corridor

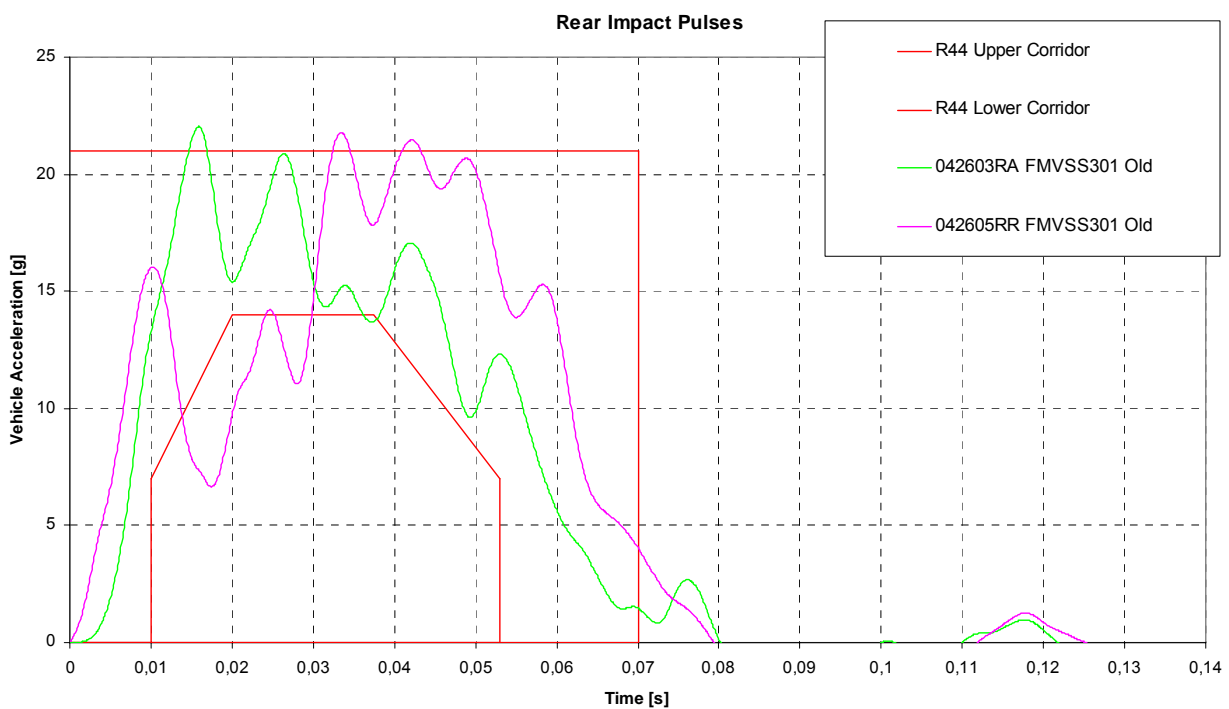


Figure 3: FMVSS 301 "old" crash test pulses compared to UN ECE R44 corridor

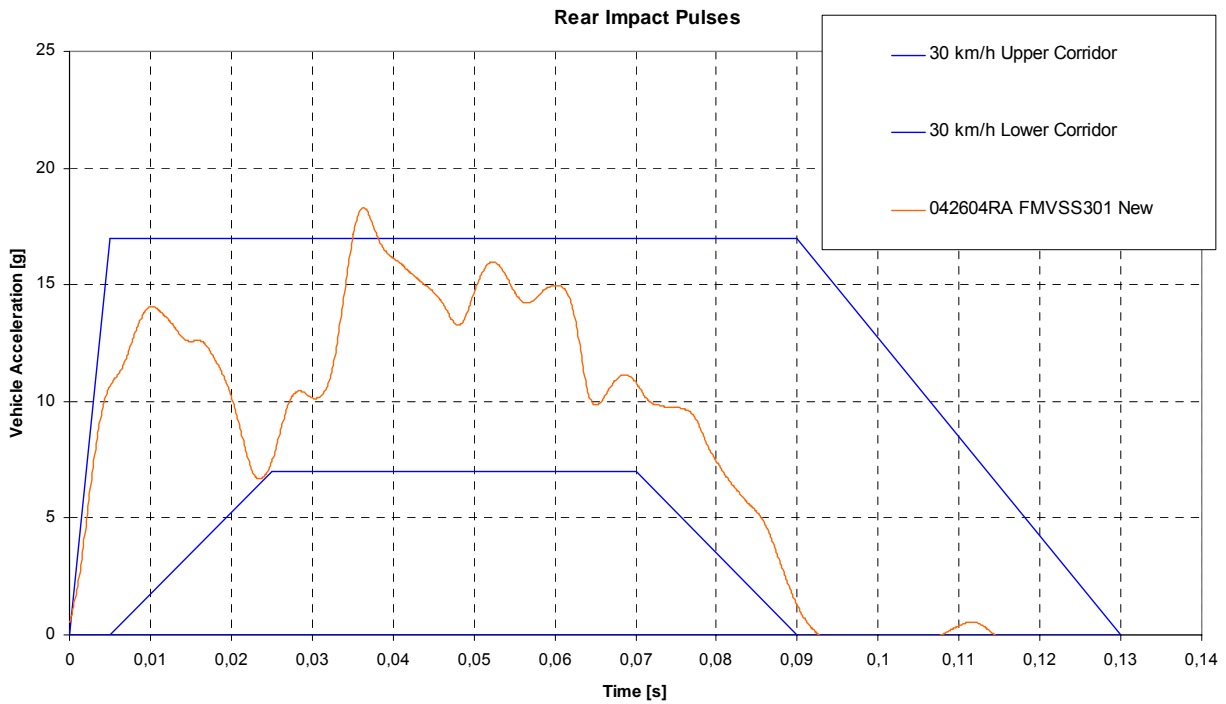


Figure 4: FMVSS 301 "new" crash test pulse compared to Cappon et al. corridor

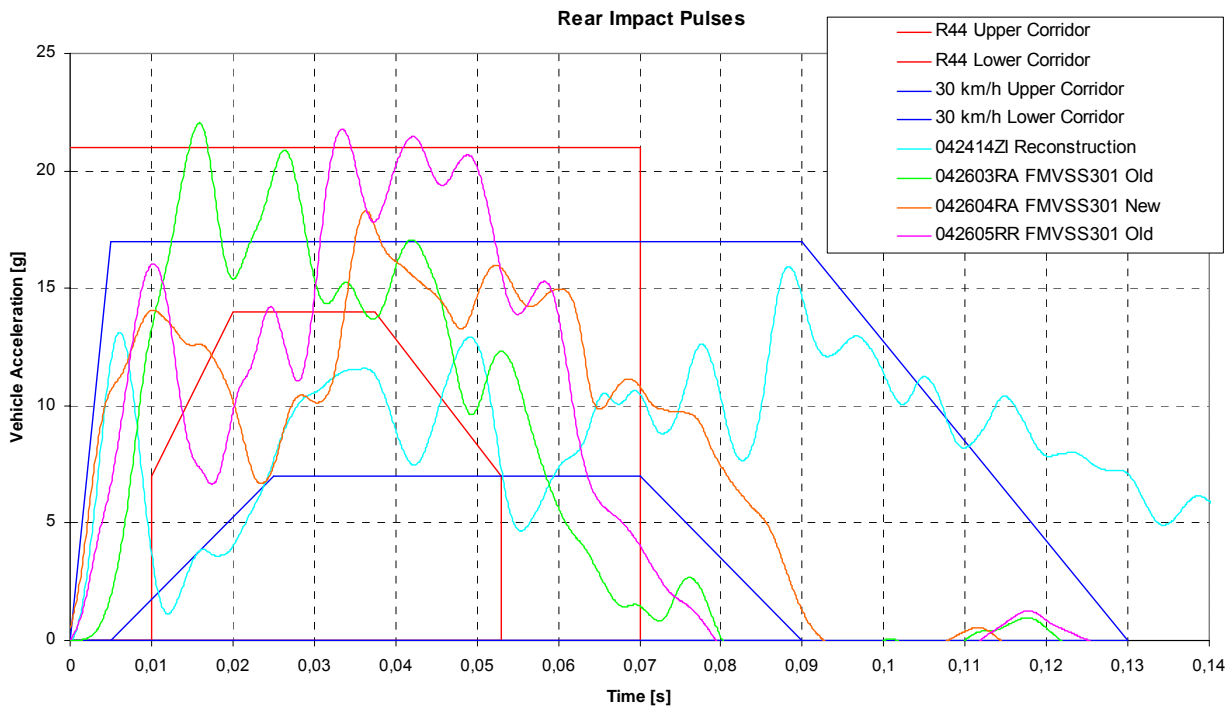


Figure 5: Comparison of all pulses and corridors



In *Figures 3, 4 and 5* it can be seen that full-vehicle rear impacts according to the “old” version of the American standard fit quite well the UN ECE Reg 44 corridor whereas the Cappon et al. corridor is a good representation of the “new” version of the American standard. Although general conclusions cannot be reached with such a very limited number of tests, this comparison shows an interesting tendency since it throws some light on the UN ECE Reg. 44 rear test pulse mentioned before in the sense that it represents a quite severe impact condition but, may not represent the situation in which current vehicles and occupants are involved with regard to rear accidents.

### 3.5. Proposal of sled test matrix

Having in mind all the previous results regarding accident data and pulse review, the need for a rear impact test for the NPACS programme was still not clear. The following step should consider some sled tests to study in depth this question. During the TWG held in The Hague on July 5<sup>th</sup> and 6<sup>th</sup> [15], a sled test matrix was proposed consisting in a combination of pulse type, pulse shape, CRS model and change in velocity (*Table 4*):

Test no.	Pulse type	CRS model	Pulse shape	$\Delta v$ (km/h)	Dummy
1	Cappon et al.	A	sine (average)	30	P 1 1/2
2	Cappon et al.	A	trapezoid (average)	30	P 1 1/2
3	Cappon et al.	A	sine (average)	35	P 1 1/2
4	Cappon et al.	A	trapezoid (average)	35	P 1 1/2
5	R44.04	A	sine (average)	30	P 1 1/2
6	R44.04	A	trapezoid (average)	30	P 1 1/2
7	R44.04	A	sine (average)	35	P 1 1/2
8	R44.04	A	trapezoid (average)	35	P 1 1/2
9	Cappon et al.	B	sine or trapezoid	30 or 35	P 1 1/2
10	Cappon et al.	C	same as 9	same as 9	P 1 1/2
11	R44.04	B	sine or trapezoid	30 or 35	P 1 1/2
12	R44.04	C	same as 11	same as 11	P 1 1/2

CRS models: A = G0<sup>+</sup> without ISOFIX / B = G0<sup>+</sup> with ISOFIX (+ support leg)/ C = G0<sup>+</sup> without ISOFIX

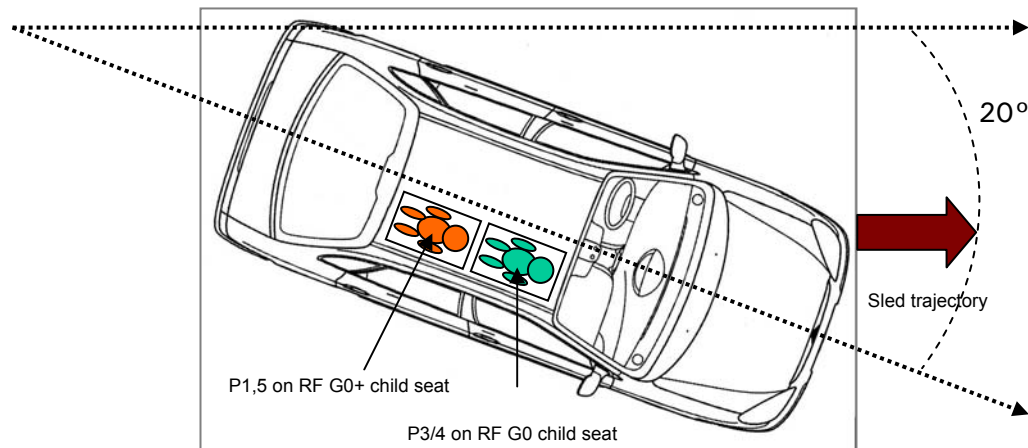
*Table 4: Proposed test matrix (July 2004)*

Following the presentation of the accident data review and this sled test matrix, some TWG members considered that accident data clearly showed that there was no need to address rear impact protection in the NPACS programme and therefore performing the above mentioned tests was not necessary. In the end it was agreed to take an approach which consisted in the study of the particular case of rear angled impacts by means of a reduced test matrix (*Table 5*):

	Test 1	Test 2
Angle	0°	20°
Dummy/CRS front	P ¾ RF G0	P ¾ RF G0
Dummy/CRS rear	P 1 ½ RF G0+	P 1 ½ RF G0+

*Table 5: Proposed test matrix (September 2004)*

The specific purpose of these tests was to investigate head injury risk for child occupants in rearward facing seats in the case of rear angled collisions compared to the fully straight impact. Child seats were placed on a vehicle body and tested according to UN ECE R44.03 rear pulse (see *Figure 5* for 20° test set-up).



*Figure 5: 20° Test set-up*

### 3.6. Test results and conclusions

The main results of the tests, presented at the TWG held in December 2004 [16], are summarised below:

- A tendency towards a head contact with the vehicle interior (B pillar) was observed for the P3/4 dummy placed in the front seat in the angled impact (20°). The actual contact took place in the seat wing but it was not a hard contact (head peak resultant acceleration less than 80 g, which is the limit for hard contact)
- A significant pitch rotation of the CRS' is produced during both test conditions (0° and 20°)
- The full pitch rotation (overturning) of the CRS is avoided by the CRS handle performance and by the seat belt blocking system (KISI system) present for that particular vehicle
- No significant differences between dummy readings for both test conditions. For P1,5 dummy slightly higher figures for head peak acceleration and neck moments in the 20° test were obtained
- Chest vertical acceleration 3ms show high values (above R44 limits) in 3 of the 4 dummy results

Bearing in mind the above mentioned test results, the following conclusions can be drawn:

- Overturning of the CRS is not a desirable effect because it might:
  - increase the risk of head contact with the vehicle interior
  - increase the risk of ejection
  - reduce the protection in the event of subsequent impacts (CRS is not correctly positioned after first impact)
  - increase loads in the occupant
  - increase the risk of interaction with deploying side airbags
  - Increase the risk of interaction with intruding front and rear seatback (due to vehicle deformation and luggage or occupant interaction)
- CRS parts that seem to be crucial elements to guarantee a good protection in rear impacts are:
  - Handle position
  - Seat belt routing lay-out
  - ISOFIX and stability bars (when available)
  - Occupant position (CRS tilt adjustment)
- Effect of angle: the angled impact could represent a higher risk of head contact with the vehicle interior (B pillar, C pillar, door or window waistline rail) especially in slightly more severe rear impact conditions than the one tested or with taller children

## 2. RECOMMENDED REAR IMPACT TEST PROCEDURE

The following recommendations were proposed to the TWG members:

- Accident data review showed that rear impact represents the least common and least injurious accident condition for restrained children in Europe
- However, straight and angled rear sled test results, other sled test results and existing assessment protocols show that there are some issues concerning children protection that should be taken into account for such an impact condition
- The NPACS programme aims at the assessment of the performance of CRS above (or at least equal) the homologation level
- One of the objectives of NPACS is to clearly differentiate between good performer and bad performer CRS in dynamic testing
- As stated in the EVPSN Roadmap ([17], pg. 4), research & technology development is required in 3 directions: all impact scenarios (not only frontal and side, but also rear and rollover), all injuries, all road users (all sizes, ages and statures)
- The presence in the market of CRS models with ISOFIX and other devices (support leg, stability bar) will be increased but they will coexist with non ISOFIX child seats

It is therefore recommended that a dynamic test and an assessment method for rear impact protection is included in the NPACS programme.

The basis for such a test method could be:

- CRS type: rearward facing seats (G0 and G0<sup>+</sup> but also G1). Forward facing seats could be considered in the future depending on accident data
- Pulse: current R44 or explore other possibilities (see WD18). Pulse type depending on sled; specific curve with tolerance (acceleration sled) or upper & lower limit corridor (braking sled)
- Test bench: same as for NPACS frontal impact
- Angle: the implementation of an angled impact condition should be based on specific accident statistics (importance of straight impact vs. angled impact) but angled impact showed a potential higher risk of head contact. In the accident data review no data dealing with this issue was found, so it will need further investigation
- Dummies: same as for NPACS frontal

Parameters to be assessed could include:

- Dummy readings
  - Head acceleration (peak resultant, 3ms, peak vertical)
  - Neck forces and moments
  - Chest acceleration (peak resultant, 3ms, peak vertical)
  - Any other as proposed by other current research programmes
- Head excursion (horizontal, vertical)
- Head contact (with vehicle/with CRS)
- CRS rotation\* (angle of CRS back before/after)
- Handle performance
- Seat belt guides performance
- Behaviour of harness buckle during test
- CRS released from seat belt/ISOFIX
- ISOFIX and stability bar performance (when available)
- Forward movement of CRS base
- Child ejection
- CRS damage
- Occupant position (CRS tilt adjustment)

\* Regarding CRS rotation: is it desirable a small amount of rotation as an energy absorption mechanism or should it be avoided because it exposes the infant to an impact against the vehicle interior? ⇒ possible high neck loads (tension/compression)

Detailed test and assessment protocols would be prepared should the TWG take the decision to incorporate rear impact into the programme.

### 3. EVALUATION OF POTENTIAL BENEFITS AND DRAWBACKS

A review of the accident data shows that rear impact accidents do not need to be addressed as a priority when talking about child safety. However, this does not mean that they should not

be taken into account if a comprehensive child safety approach is aimed at, since their contribution to the injury outcome of children in car accidents is not negligible. Results of straight and angled rear sled tests presented to the TWG, although very limited, show evidence of some potential injury risk situations and undesired effects in the CRS behaviour.

Indeed, test conclusions show that full or even partial pitch rotation of the CRS is an undesirable effect in the event of a rear impact. Furthermore angled impacts may represent a higher risk of head contact, although this should be confirmed by specific real world accident data not available at present. The basic test procedure proposed in section 2 of this document takes into account the biomechanical and kinematic parameters contained in Regulation 44 considering its current limits as the minimum safety level –that is the homologation level- to be demanded to a CRS. However the proposal presented is a step forward in enhanced child safety in rear accidents because it addresses a key aspect in this impact condition, that is the rotation of the CRS and its effects on the protection offered to child occupants.

Child seat pitch rotation and the effect of angled impact are issues not currently addressed in the rear impact condition included in the European standard. In fact, in Regulation 44 anti-rotation devices are taken into account only with regard to frontal impact in the following ways:

- An anti-rotation device for an ISOFIX universal child restraint system consists of the ISOFIX top-tether
- An anti-rotation device for an ISOFIX semi-universal child restraint system consists of either a top tether, the vehicle dashboard or a support leg intended to limit the rotation of the restraint during a frontal impact
- For ISOFIX, universal and semi-universal child restraint systems the vehicle itself does not constitute an anti-rotation device

However the anti-rotation devices mentioned above are not effective in the event of a rear impact since they do not avoid full or partial rotation of the child seat.

In addition, in R44 the kinematic behaviour of children using *universal*, *restricted* and *semi-universal* rearward facing child seats is only evaluated by the fulfilment of a given limit for both horizontal and vertical head displacement for the rear -and also in the front- test conditions. For example, in the particular case of group 0 CRS not supported by the dashboard, the head of the manikin shall not pass the planes AB, AD and DE (see *Figure 6*) .

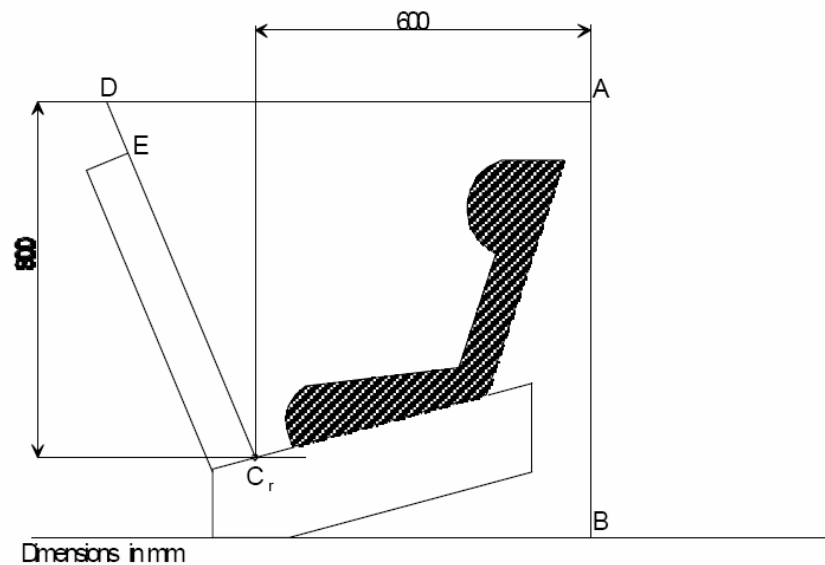


Figure 6: Head displacement limits for group 0 CRS not supported by the dashboard

On the other hand, in the specific case of child restraints of the *specific vehicle* category, when tested in a complete vehicle or a vehicle body shell, the requirement says that the head shall not come into contact with any part of the vehicle. Should such a contact occur, the speed of the impact of the head shall be less than 24 km/h and the part contacted shall meet the requirements of the energy absorption test laid down in Regulation 21, Annex 4.

In conclusion, the incorporation of a rear impact method in the NPACS as pointed out in this document would be beneficial because it will:

- address the issue of the pitch rotation of CRS and its consequences for child safety
- let countermeasures be developed to minimise the risk of head contact with the vehicle interior (in case the angled test condition is selected)
- help differentiate between good and bad child seat performers
- prevent poor CRS designs going unnoticed
- encourage CRS manufacturers to engineer safer child seats by going deeply into a load condition not sufficiently addressed in the current approval standard
- promote anti-rotation devices to be designed also for this type of impact

On the contrary, the main disadvantage of including rear impact in the NPACS is the increased test costs for the programme because of the need of an additional dynamic test. However this extra cost is deemed to be very low when compared to the benefits mentioned above and also bearing in mind that sled tests and not full scale tests are involved in the regular phase of the programme. In addition, tests will be performed on test benches and not using vehicles. On the other hand, a significant increase in development costs of child seats so as to incorporate the new requirements is not expected to happen since this impact condition is already considered for the fulfilment of the current Regulation.

## Glossary of terms

CRS	Child Restraint System
ECE	Economic Commission for Europe
EES	Energy Equivalent Speed
EEVC	European Enhanced Vehicle-safety Committee
ESV	Enhanced Safety of Vehicles
EVPSN	European Vehicle Passive Safety Network
FMVSS	Federal Motor Vehicle Safety Standard
IRCOBI	International Research Council on the Biomechanics of Impact
MAIS	Maximum Abbreviated Injury Scale
MY	Model Year
NPACS	New Programme for the Assessment of Child Seats
RF	Rearward Facing
TWG	Technical Working Group
UN	United Nations
WD	Working Document
WG	Working Group

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