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5-YEARS STATUS REPORT OF THE ADVANCED OFFSET FRONTAL CRASH PROTECTION

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ABSTRACT

This paper will provide an overview of the work progress of the advanced offset frontal crash protection group of IHRA. It resumes, including tables, the strategy of the group to cope the commitment to achieve an harmonized frontal crash protection procedure taking into account the different world wide views in this field.

INTRODUCTION

At the ESV Government Focal Point Meeting on International Harmonized Research Agenda held in Melbourne in May 1996, six research fields on passive safety were highlighted as the ones in which harmonization efforts could be most fruitful.
The leadership of future activities in each field was assigned to a specific country.
In particular the E.U. accepted the leadership in the field of Frontal Collision Safety.
The task of the Working group was to develop internationally agreed test procedures designed to improve to improve the car structures in order to enhance the level of occupant protection provided in frontal impacts. This was to be accomplished by defining unified injury criteria and, if needed, geometrical criteria on a common basis.
In order to provide a complete understanding, it is useful to set the Melbourne decision in its historical context.
The Melbourne decision was the first concrete follow-up of the International Regulatory Harmonization of the Transatlantic Automotive Industry Conference held in Washington on 10/11 April 1996. The participants in that meeting stressed the importance of cooperative preregulatory research for establishing the basis for harmonized global regulations in the motor vehicle sector. Furthermore, it was recommended that the ESV conference in Melbourne should be used to start the development of such a program.
At that time, the USA (FMVSS 208), Canada (CMVSS 208), Japan (J208) and Australia (ADR 69) were the only countries in the world which had implemented standards addressing occupant protection in frontal crashes. These standards required full frontal crash tests against a rigid wall at 30 mph (48,3km/h).

In the meantime, the European directive aimed to the same objective (but based instead on an offset deformable barrier impact with 40% overlap) was debated at Parliament and Council (96/79/EC Directive published in January 1997).
Even though the aim of the standards was to ensure the occupant protection in real crash accidents they were based on two different approaches.

?? The FMVSS 208 as well as the CMVSS 208, J208 and ADR 69, were addressed to the optimization of the restraint systems and at this aim full frontal crash test against rigid wall at 30mph (48 km/h) was considered the most suitable by NHTSA because it reproduced the highest deceleration pulse.
?? The European legislative approach, taking reference with accident analysis , was based on the consideration that contact with intrusion was the predominant injury cause in accident. Therefore, focussing on the intrusion problem and considering that offset collisions constitute a large proportion of severe crashes, a test procedure replicating the most important characteristics of a car-to-car offset collision was developed.
The conclusion was to use in a 40% overlap crash an offset fixed deformable barrier capable to load the car structure in a realistic way absorbing as little energy as possible but replicating the essential loadings and deformation patterns of a real car-to-car crash.

From the philosophical point of view today, 5 years after the Melbourne decision, even though there is a world wide shared common term of reference (the collision of two equal cars), the differences on both testing parameters and

tools are diverging, and the USA standard and the European directive represent the extremes of the spectrum of the various solutions adopted by the different countries in the world.
Consequently, frequent references to the above regulations will be made in the context of the present report.
In the above scenario, even though the two schools have produced different solutions, it appears evident that the harmonization of an advanced offset crash protection could represent the first step toward a globally harmonized crash procedure.
It has to be remarked that basically two main developing tendencies on frontal collision standard were present:

1) In the USA the U.S. Congress has given mandate to NHTSA to develop an offset frontal crash protection standard which should be harmonized (if possible) with the European standard. Furthermore, a long term activity was to be continued by NHTSA in order to develop a offset frontal test procedure carried out with a mobile deformable barrier (MDB).
2) In Europe the Commission has given mandate to EEVC to review the present Directive on Frontal Collision.

Due to the short time scale available to conduct a full review process, the European Commission and EEVC agreed that an immediate review of European accident data was necessary as background to some of the review topics.

This initial review of seven topic areas (including test speed, neck injury criteria, the extension to N1 vehicles, measurement of footwell intrusion, and biomechanical alternative to the steering wheel movement) was conducted by a consortium of four European partners, formed from members of EEVC WG13 (side imp act) and EEVC WG16 (frontal impact).

For cost reasons, the use of multiple tests is less appropriate in a type approval environment than in one using self certification. This factor has influenced the thinking of the group.

DEVELOPMENT OF THE WORKS

1. Management of the meetings

1.1 The following nine meetings were held after the nomination of the delegates:

29 September 1997 in Rome
23 January 1998 in Madrid
14-15 September 1998 in Rome
16-17 February 1999 in London
8-9 July 1999 in Berlin
16-17 November in Delft
3 February 2000 in Madrid
16 June 2000 in London
15 November 2000 in London

According to the guide lines agreed by the IHRA Steering Committee, apart from the meetings held in Rome, all the other meetings were held adjacent to those of the other IHRA groups.

1.2 Nominations and Attendance

Since the beginning, the delegates of the USA, Canada, Japan, Australia and Europe (EEVC) plus the secretary of the IHRA compatibility group have participated in the meetings. At the third meeting (Rome September 1998), representatives of the Industry started to attend the meetings on a regular basis.

2 Preliminary Analysis

Since the first meeting, the group devoted its activity to the assessment of the different frontal impact procedures currently used in Europe and USA, and taking into account the changes of vehicle fleet, due to the increase in the latter of light trucks and vans (LTVs), i.e., pickup trucks, sport utility vehicles.
Concerning the accident analysis, the group took note of the fact that there was a gap among the European data and the data available in the countries adopting FMVSS No. 208 or derivative rules.

As matter of facts due to the long period of application of FMVSS No. 208, USA and Canada had at their disposal significant statistical data on the benefits introduced by the implementation of the Standard. On that basis, they had already initiated research in order to increase both the target population to be protected and the protection levels.
On the European side, where 96/79 EC Directive is still in an intermediate phase of application, according to the mandate of the European Parliament and of the Council, the accident analysis was mainly oriented in the mandate of the Commission.
For the above reasons, when discussing items and distinguishing characteristics of miscellaneous existing standards on which activities were in progress, the most important contribution was given by the delegate of the USA, where research using different barrier types with different impact speeds was in progress. Furthermore this country has remarkably developed in this research activity, the connections among different risks displayed by using dummies (i.e., the 5^{th}%ile female and 95^{th}%ile male) different than the 50^{th}%ile male, on which base the vehicle structure is tailored.
Toward this research, Canada contributed complementary activities to the US research by making deeper the knowledge of dummy/Air-Bag interactions.
During the discussions, the delegate of the USA announced that on the basis of the preliminary studies, NHTSA had planned a two stage program: in the short term, the U.S. was studying the potential benefits of the EEVC frontal test procedure under the US crash environment; while in the longer term, as a second stage, a new test procedure based on a Mobile Deformable Barrier, probably with an angled approach, was envisioned.
If the first stage (adoption of a modified EEVC test procedure) proved not to have potential benefit for the USA, the first stage would be abandoned and work would concentrate on the second stage.
On this basis, the group adopted the two stage approach:

?? Stage one (to be finalized for the Amsterdam ESV): based on the possibility of harmonizing the existing different test methodologies;
?? Stage two: aimed to new test techniques to be developed according to the evolution of car fleets and to new targets of protection (to be finalized by 2008). Anyway in this case, due to the fact that studies on compatibility and on new instrumented dummies are still in progress, no decision was made.

For what concerns characteristics of miscellaneous existing standards, which activities are in progress, were pointed out.
On the base of such characteristics, a table to define the main aspects was drawn. On each of these, the participants of the group engaged to develop specific activities and to give out results.

Table 1.
Topics of interest

WORKING MATTER	USA	CAN	EEVC	J	AUS
Trolley	X		X		
Types of barriers	X	X	X	X	X
- stiff	X	x	X		X
- deformable	X	x	X		X
Impact angle	X		X		
Dummy	X	X	X		X
- 5^{th}%ile female	X	x			X
- 95^{th}%ile male	X	x			
Impact speed	X	X	X	X	X
Performance criteria	X	X	X	X	X
- footwell intrusion	X		X		X
- steering wheel	X		X		
intrusion	X	X			
- abdomen injury	X				
detection	X	x			
- arm injury					
Air-Bag performance	X	X			X
- Deployment time & effects.		x			
Extension to vehicle of category N1.			X		

As the various meetings followed one another, EEVC was developing the review of the Directive on Frontal Collision on the base of the European Commission mandate. And in this framework, EuroNCAP was a landmark in bringing forward experiences that have been transferred into the revision of Frontal Impact Directive.

S.1 Discussion related to stage 1

S.1.1. Extension of the scope of the 96/79/EC Directive to vehicle of category N1.

This is a specific European problem since the scope of the 96/79/EC Directive in its present version is addressed only to M1 vehicles (passenger cars).
The problem was raised because FMVSS 208 and derivative standards already include those vehicles in their scope.
In order to clarify the situation, OICA produced a document representing a compendium of the different classification of those vehicles in the different legislation.

EUROPE	USA	JAPAN	AUSTRALIA
N1	Light duty vehicles	Commercial vehicles	NA
Up to 3500kg	Up to 8500lbs	Up to 2800kg	Up to 3500kg

The problem has been recently solved when the EEVC in its final report to the European Commission concluded that vehicles of category N1 up to 2,5 tonnes should be included in the scope of the 96/79/EC Directive.

S.1.2 The test tools

S.1.2.1 Barrier

Concerning the stage 1, this is a problem related to the mandate given by the European Commission to the EEVC.
The conclusion of EEVC was not to pursue a revision of the barrier face design for stage 1, this for the following to reasons:

1. the EEVC believes that the application of the Directive to M1 and N1 vehicles greater than 2.5 tons may require a review of the barrier face design, but this has not been addressed.
2. They considered wise to await for a new test procedure for compatibility before applying the requirements of the ODB test to these vehicles.

Moreover the EEVC representative pointed out that experience with EuroNCAP testing demonstrated that an increase in the test speed would not result in the need to modify the deformable face design.

From the USA side, for the time being, NHTSA stated that a combination of the full frontal rigid barrier unbelted test and an oblique, 0-to-30 degrees rigid barrier test is sufficient to guide manufacturers towards crashworthy vehicles. They believed that these two tests account for 62% of the target population, and these tests (1) have resulted in reduced fatalities and injuries in the US; (2) have led to reduced intrusion and softer crash pulses, and (3) do not have to result in aggressive air bags resulting in injury to out-of-position children.

According to the NHTSA opinion the present European Offset Deformable Barrier (ODB) presented some deficiencies which affect the reproducibility of real crashes. First, it was not possible for the ODB to replicate the correct velocity change (? V) and the energy absorption for the target car simultaneously for the same impact severity. Second no account was taken of the advantage seen for heavier cars when considering other cars.
Anyway on the basis of test performed in the USA, it appeared that EEVC test procedure might offer advantages to the USA if used with a 5^{th}%ile female dummy, based on the dummy injury measures in some preliminary tests. A fixed mass mobile barrier would take into account the mass ratio effect and would allow the “correct” velocity change (? V).

In the mean time, NHTSA has focused the possible improvements of the present barrier, potentially on the Mobile Deformable Barrier (MDB).

From the European side the EEVC representative stressed that European ODB its face specifications provide a compromise between replication of loading and vehicle deformation, energy absorption and deceleration, this because that barrier envisaged to replicate the essential loading and deformation patterns of car-to-car real crash.

The performance of the ODB test has been more thoroughly researched than any of the potential MDB tests being considered.

S.1.2.2 Anthropomorphic test dummy

On the basis of a study carried out by EEVC, the European Union has issued the Directive 1999/98/EC that amends the procedure of the ankle calibration stipulated in the 96/79/EC Directive.
It was noted that in the European Union Directive, the dummy's foot is simply laying on the accelerator pedal rather than exercising a braking action, the reason being that the present dummies don't allow that.
The above consideration raised an interesting debate on the dummies potential vis a vis of the assessment of the injuries affecting other body segments. The results of the discussions are reported in the following paragraph 1.3.2.

S.1.3 The test parameters

S.1.3.1 Impact speed

Due to the close correlation with the studies held by the IHRA compatibility group, the impact speed has been one of the more discussed items on the various meetings.
The various points of view expressed by the delegations are reported as follows:

EEVC formerly advocated a higher test speed in order to encompass a reasonable proportion of seriously injured occupants that are currently subjected and to improve the structural efficiency of the vehicle. Also USA, Canada and Australia endorsed a higher velocity for the first stage.
Japan suggested that collision speed of the ODB test must be adjusted in order to accurately reproduce the deformation and the injury criteria of Car-to-Car crash test for vehicles smaller or larger from each other.

Japan reported studies on real conditions of Japanese Road Traffic and Traffic Accident in order to define impact test speed value. According to this survey, Japan suggested that in order to take into account the compatibility problems the decision on test speed should depend on the curb weight. Japan concluded that the deformation and injury criteria data of Car-to-Car crash test could be reproduced by the ODB test.
Anyway EEVC admitted that a higher speed might increase the vehicle's overall frontal stiffness.
Accordingly injuries caused by higher deceleration could be envisaged.
Following studies on vehicle samples demonstrated that the contact injuries predominated, suggesting that higher test speed, which acts on a small increase in acceleration, would beneficial overall.
In the final stage of the discussion on this item, Australia had views for 64km/h test speed as a first step. Anyway, the delegate advocated considering the effect of compatibility before increasing the test speed above 60 km/h.

At the meeting held in Berlin in July 1999, the group made the decision to follow the principle of the "self protection of vehicles."
Than the representative of the EEVC pointed out that even tough the accident analysis shows that the impact speed of 65 km/h since to be the solution much more devoted to self-protection of vehicles, there is some concern that this value could lead to stiffer cars. Therefore, a 60 km/h test should be more advisable in absence of extra data. When further information becomes available, 65 km/h would be reconsidered. Consequently EEVC, in compliance with the mandate of the European Commission recommended that EC review this issue again when more is known about the likely influence on compatibility.

On the above basis, the USA representative agreed on considering the same values for the stage 1.

S.1.3.2 Performance criteria

The group took note that the EEVC report to the European Commission :

- Confirms that the criteria adopted in the present Directive remains the best currently available with the currently available dummy,
- Stresses the importance of the present Neck Injury Criterion,
- Informs that a proposal for a criterion on intrusion in the footwell and a reliable and consistent measurement method of this intrusion is under development, and
- Concludes that there is an urgent need for more biomechanical research and for the development of improved dummies.

Concerning the NIC, the delegate from USA announced that the NHTSA was ready to include their newly developed neck injury criterion in the upgrade to FMVSS No. 208.
Concerning the footwell intrusion criterion, the delegate from Australia fully supported the idea of having it geometric or injury based.
Concerning the need for more biomechanical research and for the development of improved dummies, the group decided for immediate action.
Which, also because vehicle design is evolving as the result of recent regulatory developments and consumer testing, additional potential injuries that can be foreseen but may not be obvious with the current dummies.
Consequent to that decision, a list of questions concerning the increased versatility of the dummy required to make it possible to cover a larger field of measurements was completed by the group. Furthermore, the group decided also to send it to the compatibility group for endorsement and then to biomechanics group for further action (see annex to this report).

S.1.4. Miscellaneous

S.1.4.1 Modeling

NHTSA: in order to provide additional crash response data, a series of finite element simulations using an available Dodge Neon model as the base line vehicle was conduced by the Agency. These simulations were conducted using LS-DYNA version 9.40. These included simulating 49 km/h (30mph) full frontal rigid wall tests at different angles. Also included were simulations of a fixed full frontal deformable barrier. Finally vehicle-to-vehicle collision were simulated.
The finite element crash simulations were used to evaluate the occupant compartment deceleration and velocity profiles as well as the intrusion for the various test configurations. The deceleration profiles from the finite element simulations were used to drive MADYMO articulated mass models. The MADYMO models evaluated the potential for the occupant injury in the test configurations.

S.2 Discussion related to stage 2.

Since the borderline between the two stages was identified in the adoption of a new crash test based on the use of a MDB, the group discussed what would be more appropriate for stage 2. The MDB could be one of the features but it is still under discussion that it should be the way to be followed.
According to the results of the NHTSA investigation, an MDB offers the opportunity of performing an angled offset frontal crash test procedure. An angled impact is also seen as being more demanding with consequentially greater potential benefits. On the other hand, an MDB-based test procedure poses different problems. One potential difficulty is the repeatability for the test procedure. Also it may lead to vehicle designs optimized for the selected angle, unless the test procedure specified a range of angles.

Moreover, MDB to car impacts have demonstrated that there seems to be an overriding effect from the MDB that may be unrealistic. Accordingly, a comparative evaluation of advantages and disadvantages of MDB vis a vis of the fixed one, was developed by the group. The results of the debate are summarized in the following table.

Table 2.
Trolley-based Frontal Offset Impact Test Procedure

ADVANTAGES	**ALTERNATIVE APPROACH TO ACHIEVE SAME ADVANTAGE WITH FIXED BARRIER**
1. Takes into account the effects of the Mass Ratio of the impacting vehicles	Change impact speed with vehicle mass.
2. Can include angular effects on the deformation and intrusion characteristics	No known alternative.
3. Can include a possible measure of Compatibility (by, for instance, measuring the vehicle and/or trolley acceleration	Measure the force on the fixed barrier behind the deformable face.
4. The acceleration pulse, ? V and energy distribution is 'correct'.	No known alternative.
DISADVANTAGES	**POSSIBLE ACTIONS TO REDUCE THE DISADVANTAGE**
1. Complex test procedure for "moving barrier-moving car" (High speed trolley vibrations, difficulties to videorecord impact effects between mobile trolley and car)	?Reduce complexity by ?testing co-linearly
2. Repeatability of more complex test may be poor (for "moving barrier-moving car").	?and/or using moving barrier to stationary car?
3. Limited number of test laboratories with capability to perform trolley to vehicle testing.	Investigate
4. Unknown ground and other interaction effects, especially if one vehicle stationary while the other travels at higher speed – to represent both vehicles moving.	?
5. Need to agree on a harmonised barrier mass when vehicle fleet differs.	Agree to differ

CONCLUSIONS

The group agreed that it would be desirable for two frontal impact tests to be adopted universally. Firstly, an offset deformable barrier test, to assess the intrusion resistance of the vehicle's structure and secondly, a full width fixed barrier test, to control occupant deceleration.

This could be achieved most easily by the universal adoption of the European ODB test and the "restrained occupant / perpendicular impact" elements of the US full width test. The appended document details the current and proposed application of these test procedures.

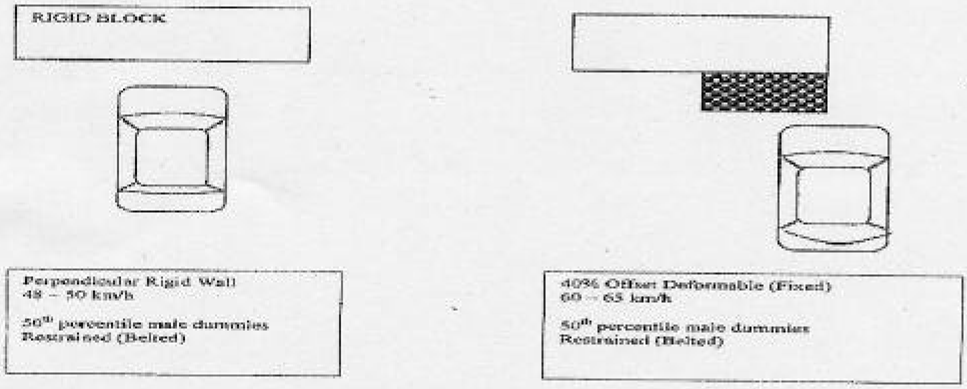
This combination of tests represents two of the most important frontal impact crash configurations. It is expected to result in vehicle designs which provide improved protection over a wide range of frontal impact accidents.

Current research indicates that such improvements in self protection can be made without compromising compatibility.

Australia has already implemented both the offset deformable and full width tests. In the US, NHTSA has implemented a low speed (40 km/h) offset deformable test and is planning to propose a higher speed (60 or 64 km/h) offset deformable test, which is also being considered by the Japanese MOT. In Europe, the EEVC is developing a proposal for adding a full width frontal impact test.

Further research may show how enhanced frontal impact tests may be developed, for example, to improve compatibility. However, the early worldwide adoption of this "two test approach" would be an important step in addressing the priority issues in frontal impact crashes.

FRONTAL IMPACT TEST CONFIGURATIONS – POTENTIAL COMMON APPROACH
PHASE I



POTENTIAL COMMON TEST CONDITIONS									
BARRIER	Angle	Dummy	Belted?	Speed Km/h	Interest				
					USA	Europe	Australia	Canada	Japan
Rigid, 100% overlap	Perp.	50%	Yes	40-50	In now: 0-48 Later: 0-56	Discussing 48 to 56	In: ≥48,3	In: 0-48	In: 48-50
Fixed ODB 40% overlap	Perp.	50%	Yes	60-65	In 40, 60 to be proposed	In 56, 60 to be proposed	In 56, 60 to be proposed and to be aligned with ECE	60 may be propose d	No, 60 under discu ssion
POTENTIAL ADDITIONAL TEST CONDITIONS									
Rigid 100% overlap	±30	50%	Yes	0 - 48	No longer in				
	0,±30	50%	No	32 - 40	In				
	0	5%	Yes	0 - 48	In; 0-48 0-56 to be proposed		≥48,3 to be proposed	0 - 48 to be propose d	
	0	5%	No	32 - 40	In				
Fixed ODB 40% overlap	Perp.	5%	Yes	0 - 60	0-40 In, 0-60 to be proposed		40 to be proposed	0-40 to be propose d	

Annex **: Biomechanical aspects to be taken into account in the development of the future crash test procedure** (point S 1.3.2.)

IHRA Offset Frontal AFC 22c(table 2)

BODY REGION	INJURY TYPE	ASSESSMENT PARAMETER & DERIVED PARAMETERS	CURRENTLY MEASURED (FMVSS or EC DIR.)	Hybrid III Capable?	Advanced Dummies Capable?	IMPORTANCE (h-HIGH, M-medium, L-low)
CHEST	Skeletal injury	Compression (overall/local)	F C E A	✓	✓	H
		Rate of Compression	E A	✓	✓	L
		V*C		✓	✓	L
		Acceleration	J F A	✓	✓	L
		Force		X	X	?
		Other?		-	-	
	Internal organ injury	Compression (overall/local)	Ditto	✓	✓	H
		Rate of Compression		✓	✓	H
		V*C		✓	✓	H
		Acceleration		✓	✓	L?
		Force		X	X	?
		Other?		-		
THORACIC SPINE	Skeletal injury	Shear force	X	X	X	L
		Axial force		X	X	L
		Bending moment		X	✓	M
		Angular displacement		X	✓	L
		Other		-		
	Ligamentous/Spinal Cord/ soft tissue	Shear force	X	X	X	L
		Axial force		X	✓	L
		Bending moment		X	✓	M
		Other?		-		
ABDOMEN	Internal organ injury	Compression (overall/local)	X	(Static)	✓	H
		Rate of compression		X	✓	H
		V*C		X	✓	H
		Force		X	?	?
		Other?		-	?	
LUMBAR SPINE	Skeletal injury	Shear force	X	✓	✓	H
		Axial force		✓	✓	M
		Bending moment		✓	✓	H
		Other		-		
	Ligamentous/Spinal Cord/ soft tissue	Shear force	X	✓	✓	H
		Axial force		✓	✓	M
		Bending moment		✓	✓	H
		Other	-	-		

Table 2 Injury Criteria Requirement by Body Region and Injury Type

BODY REGION	INJURY TYPE	ASSESSMENT PARAMETER & DERIVED PARAMETERS	CURRENTLY MEASURED (FMVSS or EC DIR.)	Hybrid III Capable?	Advanced Dummies Capable?	IMPORTANCE (h-HIGH, M-medium, L-low)
HEAD	Brain Injury – 'linear – type'	Linear acceleration; peak, HIC -other?	F A C E J(linear C)	✓	✓	H
	Brain Injury – 'rotational type'	Rotational acceleration -other?		✓	✓	?
	Skull fracture	Linear acceleration; peak, HIC -other		✓	✓	H
	Other					
FACE	Facial bone fracture	Localised force, pressure Total force -other	X	X	✓	?
NECK	Skeletal injury	Bending moment Axial force Shear force Angular displacement Other?	F E A F E A F E A UPPER ONLY F(COMBINED)	✓ ✓ ✓ X -	✓ ✓ ✓ ✓ X	M/H H L/M ?
	Ligamentous/Spinal Cord/ soft tissue	Shear force Axial force Bending moment Torsion moment Other	Ditto	✓ ✓ ✓ X -	✓ ✓ ✓ ✓	L/M H M/H
	Other Soft tissue damage	?		X		
	WAD (whiplash)	Neck moment Relative acceleration (Head/Thorax) Shear force, Pressure Other?		✓ ✓ ✓ X -	✓ ✓ ✓ X	? ? ? ? H
SHOULDER	Clavicle fracture	Seat belt tension Other?		X	X ✓	M M

NOTE: the WG would prefer to have an on-dummy measurement for this

BODY REGION	INJURY TYPE	ASSESSMENT PARAMETER & DERIVED PARAMETERS	CURRENTLY MEASURED (FMVSS or EC DIR.)	Hybrid III Capable?	Advanced Dummies Capable?	IMPORTANCE (h-HIGH, M-medium, L-low)
PELVIS	Fracture (through seat belt Tension or loading through knee/femur)	Force		X	?	H
		Acceleration	X	✓	✓	M
		Other?		-		
FEMUR	Fracture	Compressive force	F C J A E	✓	✓	H
		Bending moment, Torsion		✓	✓	H
		Other?		-		
KNEE	Skeletal injury	Force		X	X	H
		Pressure	X	X	X	H
		Other		-		
	Soft tissue damage (flesh ligaments)	Force		X	X	H
		Pressure	X A E	X	X	H
		Femur-tibia translation		✓	✓	H
		Other		-		
TIBIA	Fracture	Force	E A	✓	✓	H
		Bending moment	E A	✓	✓	H
ANKLE	Fracture	Force			✓	H
		Bending moment		X	✓	H
		Angular displacement	X		✓	H
		Angular velocity		-	✓	H
		Acceleration			✓	
		Other				
FOOT	Fracture of metatarsals and other bones	Force		X	✓	H
		Pressure	X	X	X	L/M?
		Acceleration		✓	✓	L/M?
		Other				
ARM/WRIST	Fracture/dislocation	Force		(✓)	(✓)	L
		Bending moment	X	(✓)	(✓)	H
		Acceleration		(✓)	(✓)	M
		Other		-		

In developing this table, account should be taken of:

1 the current requirements in existing national regulations
2 areas and injuries not currently included
3 statistics and other factors available to jutify changes
4 priorities for the revised list
5 procedure for developing the revision