EUROPEAN NEW CAR ASSESSMENT PROGRAMME (Euro NCAP)

ASSESSMENT PROTOCOL AND BIOMECHANICAL LIMITS

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Contents

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1 INTRODUCTION

This protocol was originally developed jointly by TRL and Vehicle Safety Consultants Ltd., under contract to the UK Department of the Environment Transport and the Regions and International Testing respectively.

2 Euro NCAP PRINCIPLES

The Euro NCAP programme is designed to provide a fair, meaningful and objective assessment of the impact performance of cars. It is intended to inform consumers, so providing an incentive to manufacturers as well as giving credit to those who excel at occupant or pedestrian protection. The tests used are based on those developed for legislation by the European Enhanced Vehicle safety Committee (EEVC), for frontal and side impact protection of car occupants and for the protection of pedestrians hit by the front of cars.

No stylised test procedure fully reflects the protection provided by a car in the wide variety of accidents which occur on the roads. However, cars that perform well in these tests should provide better protection in accidents than cars which perform less well.

No anthropometric dummies are available which can measure all the potential risks of injury to humans or assess protection for different sizes of occupant in different seating positions. To compensate for this, the assessment procedure takes account of other information related to occupant kinematics, interior contact points and vehicle structure.

Economic constraints prevent the tests from being repeated, so to take account of vehicle and test variations a number of actions have been taken:

a) Manufacturers have been asked to compare the results from these tests with those from tests they may have conducted and to draw our attention to any anomalies they may find. They have also been requested to supply data from their own tests to us for comparison. Several manufacturers have supplied data for this purpose. Apart from considering the effects of test variation and identifying anomalies, no account of such data is taken in rating the cars and it is kept confidential.

b) The overall assessments are based on the combination of multiple results. Variations in any one of these will only have a limited effect on the overall rating.

The least demanding performance boundaries for the frontal and side impact parameters have been set to be equivalent to the limits proposed in the EEVC test procedures. The EEVC limits were set to provide a basic minimum level of protection and only protect in a moderate proportion of accidents. For car occupants, these limits are too lenient to adequately identify best practice in current production cars and to provide a goal for further improvement. Additional, more demanding, protection boundaries have been set, to identify aspects of a car's performance which offer significantly greater protection.

Most parts of most cars fare relatively badly in the pedestrian impact tests. With so few examples where the proposed EEVC limits are met, the need for a less demanding lower level limit has been recognised. This will separate those cars which more nearly reach the EEVC limit from those well away from it.

3 SUMMARY

The starting point for the assessment is the dummy response data. Initially, each body area is given a rating based on the measured dummy parameters. For frontal impact, consideration is given to whether this assessment should be adjusted to reflect occupant kinematics or sensitivity to small changes in contact location, which might influence the protection of different sized occupants in different seating positions. The assessment also considers the structural performance of the car by taking account of such aspects as steering wheel displacement, pedal movement, footwell distortion and displacement of the A pillar. The adjustments based on both inspection and geometrical considerations are applied to the body area assessments to which they are most relevant. These adjustments are conservative but they should be sufficient to warrant consideration by manufacturers.

The adjusted rating for the different body regions is presented, in a visual format of coloured segments within a human body outline. This is presented for the driver and front seat passenger in frontal impact and for the driver in side and pole impact. For the pedestrian impact tests, it is presented in the form of coloured dots on the outline of a car front.

From this information, an overall rating for the car is computed for frontal and side impact protection and separately for pedestrian impact. For occupant protection, the overall rating is based on the driver data, unless part of the passenger fared less well. It is stated that the judgement relates primarily to the driver.

No attempt is made to rate the risk of life threatening injury any differently from the risk of disabling injury. Similarly, no attempt is made to rate the risk of the more serious but less frequent injury any differently from the risk of less serious but more frequent injury. Care has been taken to try to avoid encouraging manufacturers to concentrate their attention on areas which would provide little benefit in accidents.

In addition to the basic Euro NCAP assessment, additional information is recorded and may be reported. In future, some of these additional aspects may be added to the Euro NCAP assessment. In the first series of tests, a three year old child in a child restraint was fitted on the rear seat, in the frontal and side impact tests. In subsequent series, an 18 month old child dummy has been added.

4 SLIDING SCALES

From Phase 3, a sliding scale system of points scoring has been used. This involves two limits for each parameter, a more demanding limit (higher performance), beyond which a maximum score is obtained and a less demanding limit (lower performance), below which no points are scored. In frontal and side impact, the maximum score for each body region is four points. In the pole impact, 2 additional points are available if certain conditions are met. For each impact site in the pedestrian tests, a maximum of two points are available. Where a value falls between the two limits, the score is calculated by linear interpolation.

5 FRONTAL IMPACT ASSESSMENT CRITERIA AND LIMIT VALUES

The basic assessment criteria used for frontal impact, with the upper and lower performance limits for each parameter, are summarised below. Where multiple criteria exist for an individual body region, the lowest scoring parameter is used to determine the performance of that region.

5.1 Head

Drivers with steering wheel airbags and Passengers

If a steering wheel airbag is fitted the following criteria are used to assess the protection of the head for the driver. These criteria are always used for the passenger.

Note: HIC_{36} levels above 1000 have been recorded with airbags, where there is no hard contact and no established risk of internal head injury. A hard contact is assumed, if the peak resultant head acceleration exceeds 80g, or if there is other evidence of hard contact.

If there is no hard contact a score of 4 points is awarded.
If there is hard contact, the following limits are used:

Higher performance limit		
HIC_{36}	650	(5% risk of injury ≥ AIS3 [1,2])
Resultant Acc. 3 msec exceedence	72g	
Lower performance limit		
HIC_{36}	1000*	(20% risk of injury ≥ AIS3 [1,2])
Resultant Acc. 3 msec exceedence	88g	*(*EEVC limit)*

Drivers with no steering wheel airbag

If no steering wheel airbag is fitted, and the following requirements are met in the frontal impact test:

HIC_{36}	<1000
Resultant Acc. 3 msec exceedence	<88g

then, deformable honeycomb faceform tests are carried out on the steering wheel. The tester attempts to choose the most aggressive sites to test and it is expected that two tests will be required, one aimed at the hub and spoke junction and one at the rim and spoke junction. The assessment is then based on the following criteria.

Higher performance limit	
Resultant peak Acc.	80g
Resultant Acc. 3 msec exceedence	65g

Lower performance limit

Honeycomb crush	1mm
HIC_{36}	1000
Resultant peak Acc.	120g
Resultant Acc. 3 msec exceedence	80g

From the faceform tests, a maximum of 2 points are awarded for performance better than the lower limits. For values worse than the lower performance limit, no points are awarded. The results from the worst performing test are used for the assessment. This means that for cars, not equipped with a steering wheel airbag, the maximum score obtainable for the driver's head is 2 points.

5.2 Neck

Higher performance limit

Shear	1.9kN @ 0 msec,	1.2kN @ 25 - 35msec,	1.1kN @ 45msec
Tension	2.7kN @ 0 msec,	2.3kN @ 35msec,	1.1kN @ 60msec
Extension	42Nm		

Lower performance limit

Shear	3.1kN @ 0msec,	1.5kN @ 25 - 35msec,	1.1kN @ 45msec*
Tension	3.3kN @ 0msec,	2.9kN @ 35msec,	1.1kN @ 60msec*
Extension	57Nm*		(Significant risk of injury [3])

*(*EEVC Limits)*

Note: Neck Shear and Tension are assessed from cumulative exceedence plots, with the limits being functions of time. By interpolation, a plot of points against time is computed. The minimum point on this plot gives the score. Plots of the limits and colour rating boundaries are given in Appendix I.

5.3 Chest

Higher performance limit

Compression	22mm	(5% risk of injury ≥ AIS3 [4])
Viscous Criterion	0.5m/sec	(5% risk of injury ≥ AIS4)

Lower performance limit

Compression	50mm*	(50% risk of injury ≥ AIS3 [4])
Viscous Criterion	1.0m/sec*	(25% risk of injury ≥ AIS4)

*(*EEVC Limits)*

5.4 Knee, Femur and Pelvis

Higher performance limit		
Femur compression	3.8kN	(5% risk of pelvis injury [5])
Knee slider compressive displacement	6mm	
Lower performance limit		
Femur Compression	9.07kN @ 0msec,	7.56kN @ ≥ 10msec* (Femur fracture limit [3])
Knee slider compressive displacement	15mm*	(Cruciate ligament failure limit [3,6])
		*(*EEVC Limit)*

Note: Femur compression is assessed from a cumulative exceedence plot, with the limits being functions of time. By interpolation, a plot of points against time is computed. The minimum point on this plot gives the score. Plots of the limits and colour rating boundaries are given in Appendix I.

5.5 Lower Leg

Higher performance limit		
Tibia Index	0.4	
Tibia Compression	2kN	
Lower performance limit		
Tibia Index	1.3*	
Tibia Compression	8kN*	(10% risk of fracture [3,7])
		*(*EEVC Limits)*

5.6 Foot/Ankle

Higher performance limit	
Pedal rearward displacement	100mm
Lower performance limit	
Pedal rearward displacement	200mm

Notes:

1 Pedal displacement is measured for all pedals with no load applied to them.

2 If any of the pedals are designed to completely release from their mountings during the impact, no account is taken of the pedal displacement, provided that release occurred in the test and that the pedal retains no significant resistance to movement.

3 If a mechanism is present to move the pedal forwards in an impact, the resulting position of

the pedal is used in the assessment.

4 The passenger's foot/ankle protection is not currently assessed.

5 Footwell intrusion is currently being measured. It is expected that requirements for footwell intrusion will be added in the near future.

6 FRONTAL IMPACT MODIFIERS

6.1 Driver

The score generated from driver dummy data may be modified where the protection for different sized occupants or occupants in different seating positions, or accidents of slightly different severity, can be expected to be worse than that indicated by the dummy readings or deformation data alone. In any single body region, the score may reduce by up to a maximum of two points. The concepts behind the modifiers are explained in a later section.

6.1.1 Head

Unstable Contact on the airbag
If during the forward movement of the head its centre of gravity moves further than the outside edge of the airbag, head contact is deemed to be unstable. The score is reduced by one point. If for any other reason head protection by the airbag is compromised, such as by detachment of the steering wheel from the column, or bottoming-out of the airbag by the dummy head, the modifier is also applied.

Head bottoming-out is defined as:
There is a definite rapid increase in the slope of one or more of the head acceleration traces, at a time when the dummy head is deep within the airbag. The acceleration spike associated with the bottoming out should last for more than 3ms.
The acceleration spike associated with the bottoming out should generate a peak value more than 5 g above the likely level to have been reached if the spike had not occurred. This level will be established by smooth extrapolation of the curve between the start and end of the bottoming out spike.

Hazardous airbag deployment
If, within the head zone, the airbag unfolds in a manner in which a flap develops, which sweeps across the face of an occupant vertically or horizontally the -1 point modifier for unstable airbag contact will be applied to the head score. If the airbag material deploys rearward, within the “head zone” at more than 90 m/s, the -1 point modifier will be applied to the head score. Further details are contained in Euro NCAP Technical Bulletin TB 001.

Incorrect airbag deployment
Any airbag(s) which does not deploy fully in the designed manner will attract a -1 point modifier applicable to each of the most relevant body part(s) for the affected occupant. For example, where a steering wheel mounted airbag is deemed to have deployed incorrectly, the penalty will be applied to the driver’s head (-1). Where, a passenger knee airbag fails to deploy correctly, the penalty will be applied to the knee, femur and pelvis of the passenger (-1). Where the incorrect deployment affects multiple body parts, the modifier will be applied to each individual part. The modifier will be

applied even if the airbag was not intended to offer protection in that particular impact. For example, the penalty will be applied if a thorax protecting side airbag deploys incorrectly in the frontal impact. In this case the modifier will be applied to the side impact chest body part.

Unstable Contact on a Steering Wheel without an Air Bag
If, during the forward movement of the head, its centre of gravity moves radially outwards further than the outside edge of the steering wheel rim, head contact is deemed to be unstable. The score is reduced by one point. If for any other reason head contact on the steering wheel is unstable, such as detachment of the steering wheel from the column, the modifier is also applied.

Displacement of the steering column
The score is reduced for excessive rearward, lateral or upward static displacement of the top end of the steering column. Up to 90 percent of the EEVC limits, there is no penalty. Beyond 110 percent of the EEVC limits, there is a penalty of one point. Between these limits, the penalty is generated by linear interpolation. The EEVC recommended limits are: 100mm rearwards, 80mm upwards and 100mm lateral movement. The modifier used in the assessment is based on the worst of the rearward, lateral and upward penalties.

6.1.2 Chest

Displacement of the A Pillar
The score is reduced for excessive rearward displacement of the driver's front door pillar, at a height of 100mm below the lowest level of the side window aperture. Up to 100mm displacement there is no penalty. Above 200mm there is a penalty of two points. Between these limits, the penalty is generated by linear interpolation.

Integrity of the passenger compartment
Where the structural integrity of the passenger compartment is deemed to have been compromised, a penalty of one point is applied. The loss of structural integrity may be indicated by characteristics such as:

- Door latch or hinge failure, unless the door is adequately retained by the door frame.
- Buckling or other failure of the door resulting in severe loss of fore/aft compressive strength.
- Separation or near separation of the cross facia rail to A pillar joint.
- Severe loss of strength of the door aperture.

Steering Wheel Contact
Where there is obvious direct loading of the chest from the steering wheel, a one point penalty is applied.

6.1.3 Knee, Femur & Pelvis

Variable Contact
The position of the dummy's knees are specified by the test protocol. Consequently, their point of contact on the facia is pre-determined. This is not the case with human drivers, who may have their knees in a variety of positions prior to impact. Different sized occupant and those seated in different positions may also have different knee contact locations on the facia and their knees may penetrate into the facia to a greater extent. In order to take some account of this, a larger area of potential knee contact is considered. If contact at other points, within this greater area, would be more aggressive penalties are applied.

The area considered extends vertically 50mm above and below the maximum height of the actual knee impact location [10]. Vertically upwards, consideration is given to the region up to 50mm above the maximum height of knee contact in the test. If the steering column has risen during the test it may be repositioned to its lowest setting if possible. Horizontally, for the outboard leg, it extends from the centre of the steering column to the end of the facia. For the inboard leg, it extends from the centre of the steering column the same distance inboard, unless knee contact would be prevented by some structure such as a centre console. Over the whole area, an additional penetration depth of 20mm is considered, beyond that identified as the maximum knee penetration in the test. The region considered for each knee is generated independently. Where, over these areas and this depth, femur loads greater that 3.8kN and/or knee slider displacements greater than 6mm would be expected, a one point penalty is applied to the relevant leg.

Concentrated Loading
The biomechanical tests, which provided the injury tolerance data, were carried out using a padded impactor which spread the load over the knee. Where there are structures in the knee impact area which could concentrate forces on part of the knee, a one point penalty is applied to the relevant leg.

Where a manufacturer is able to show, by means of acceptable test data, that the Variable Contact and/or Concentrated Loading modifiers should not be applied, the penalties may be removed.

If the Concentrated load modifier is not applied to both of the driver knees, the left and right knee zones (defined above) will both be split into two further areas, a 'column' area and the rest of the facia. The column area for each knee will extend 75mm* from the centreline of the steering column and the remainder of the facia will form the other area for each knee. As a result, the one point penalty for Variable Contact will be divided into two with one half of a point being applied to the column area and one half of a point to the remainder of the facia for each knee.
*[Reducing to 60mm by 2013]

6.1.4 Lower Leg

Upward Displacement of the worst performing Pedal
The score is reduced for excessive upward static displacement of the pedals. Up to 90 percent of the limit considered by EEVC, there is no penalty. Beyond 110 percent of the limit, there is a penalty of one point. Between these limits, the penalty is generated by linear interpolation. The limit agreed by EEVC was 80mm.

6.1.5 Foot & Ankle

Footwell Rupture
The score is reduced if there is significant rupture of the footwell area. This is usually due to separation of spot welded seams. A one point penalty is applied for footwell rupture. The footwell rupture may either pose a direct threat to the driver's feet, or be sufficiently extensive to threaten the stability of footwell response.

Pedal Blocking
Where the rearward displacement of a 'blocked' pedal exceeds 175mm relative to the pre-test measurement, a one point penalty is applied to the driver's foot and ankle assessment. A pedal is blocked when the forward movement of the intruded pedal under a load of 200N is <25mm. Between 50mm and 175mm of rearward displacement the penalty is calculated using a sliding scale between 0 to 1 points.

6.2 Passenger

The score generated from passenger dummy data may be modified where the protection for different sized occupants or occupants in different seating positions, or accidents of slightly different severity, can be expected to be worse than that indicated by the dummy readings alone. In any single body region, the score may reduce by up to a maximum of two points. The concepts behind the modifiers are explained in a later section. The modifiers applicable to the passenger are:

Unstable Contact on the airbag
Hazardous airbag deployment
Incorrect airbag deployment
Knee, Femur & Pelvis, Variable Contact
Knee, Femur & Pelvis, Concentrated loading

The assessments airbag stability, head bottoming-out (where present) and the knee impact areas are the same as for driver. For the outboard knee, the lateral range of the knee impact area extends from the centre line of the passenger seat to the outboard end of the facia. For the inboard knee, the area extends the same distance inboard of the seat centre line, unless knee contact is prevented by the presence of some structure such as the centre console. The passenger knee zones and penalties will

not be divided into two areas even if the Concentrated load modifier is not applied.

6.3 Door Opening during the Impact

When a door opens in the test, a minus one-point modifier will be applied to the score for that test. The modifier will be applied to the overall vehicle score for every door (including tailgates and moveable roofs) that opens. The number of door opening modifiers that can be applied to the vehicle score is not limited.

Concept: The intention is to ensure that the structural integrity is maintained. The underlying principle is to minimise the risks of occupant ejection occurring.
The 'door opening' modifier will be applied if any of the following have occurred:

- the latch has fully released or shows significant partial release, either by release of its components from one another, or effective separation of one part of the latch from its supporting structure
- the latch has moved away from the fully latched condition
- if any hinge has released either from the door or bodyshell or due to internal hinge failure
- if there is a loss of structure between the hinges and latches
- if door or hinges fail whilst the door opening tests are being conducted post impact, as loading from an occupant could have a similar effect.
- if there was any potential risk of occupant ejection and/or partial ejection/entrapment from openings such as sliding doors or moveable roofs. Dynamic opening during the impact of any apertures, such as roofs, will also be considered even if the openings have closed post test.
- if both side doors latch together with no b-pillar or other form of restraint, the modifier may apply to both the front and rear doors.

6.4 Door Opening Forces after the Impact

The force required to unlatch and open each side door to an angle of 45 degrees is measured after the impact. A record is also made of any doors which unlatch or open in the impact. Currently, this information is not used in the assessment but it may be referred to in the text of the published reports.

Door opening forces are categorised as follows:

Opens normally	Normal hand force is sufficient
Limited force	≤ 100N
Moderate force	> 100N to < 500N
Extreme hand force	≥ 500N
Tools had to be used	Tools necessary

7 SIDE IMPACT ASSESSMENT CRITERIA AND LIMIT VALUES

The basic assessment criteria used for side impact, with the upper and lower performance limits for each parameter, are summarised below. Where multiple criteria exist for an individual body region, the lowest scoring parameter is used to determine the performance of that region. In any single body region, the score may reduce by up to a maximum of two points. The concepts behind the modifiers are explained in a later section.

7.1 Head

Cars Fitted with Head Protecting Side Impact Airbags

If there is no evidence of hard contact, four points are awarded. If there is evidence of hard contact the criteria given for cars without a head protecting airbag are applied.

Note: HIC_{36} levels above 1000 have been recorded with airbags, where there is no hard contact and no established risk of internal head injury. A hard contact is assumed, if the peak resultant head acceleration exceeds 80g, or if there is other evidence of hard contact.

Provided that four points are scored for head protection in the distributed deformable face barrier side impact test, the manufacturer has the option to fund a side impact pole test. If, in this test, the following criteria are met, the car will be awarded two additional points.

HIC_{36}	<1000
Peak Resultant Acc	<80g
No direct head contact with the pole	

Cars not Fitted with Head Protecting Side Impact Airbags

Higher performance limit		
HIC_{36}	650	(5% risk of injury ≥ AIS3 [1,2])
Resultant Acc. 3msec exceedence	72g	
Lower performance limit		
HIC_{36}	1000*	(20% risk of injury ≥ AIS3 [1,2])
Resultant Acc. 3msec exceedence	88g	*(*EEVC Limit)*

7.2 Chest

The assessment is based on the worst performing individual rib

Higher performance limit		
Compression	22mm	(5% risk of injury ≥ AIS3 [8])
Viscous Criterion	0.32	(5% risk of injury ≥ AIS3 [8])
Lower performance limit		
Compression	42mm*	(30% risk of injury ≥ AIS3 [8])
Viscous Criterion	1.0*	(50% risk of injury ≥ AIS3 [8])
		*(*EEVC Limits)*

7.3 Abdomen

Higher performance limit		
Total Abdominal Force	1.0kN	
Lower performance limit		
Total Abdominal Force	2.5kN*	*(*EEVC Limit)*

7.4 Pelvis

Higher performance limit		
Pubic Symphysis Force	3.0kN	
Lower performance limit		
Pubic Symphysis Force	6.0kN*	(Pelvic fracture in young adults)
		*(*EEVC Limit)*

8 SIDE IMPACT MODIFIERS

8.1 Incorrect airbag deployment

Any airbag(s) which does not deploy fully in the designed manner will attract a -1 point modifier applicable to each of the most relevant body part(s) for the affected occupant. For example, where a head curtain airbag is deemed to have deployed incorrectly, the penalty will be applied to the driver's head (-1). Where the incorrect deployment affects multiple body parts, the modifier will be applied to each individual part. For example, where a seat mounted head and thorax airbag fails to deploy correctly for both the head and chest, the penalty will be applied to the head (-1) and the chest (-1). The modifier will be applied even if the airbag was not intended to offer protection in that particular impact. For example, the penalty will be applied if a driver's knee airbag deploys incorrectly in a side or pole impact. In this case the modifier will be applied to both frontal impact driver knee, femur and pelvis body parts.

8.2 Backplate

Where the backplate load Fy exceeds 4.0kN, a two point penalty is applied to the driver's chest assessment. Between 1.0kN and 4.0kN the penalty is calculated using a sliding scale from 0 to 2 points. Only loads applied to the backplate, which might unload the chest by accelerating the spine away from the intruding side are counted.

Higher performance limit	
Fy	1.0kN
Lower performance limit	
Fy	4.0kN

8.3 T12 Modifier

Where the T12 loads Fy and Mx exceed 2.0kN or 200Nm respectively, a two point penalty is applied to the driver's chest assessment. Between 1.5kN – 2.0kN or 150Nm – 200Nm the penalty is calculated using a sliding scale from 0 to 2 points. The assessment is based upon the worst performing parameter. Only loads which are transmitted up the spine, which might unload the chest during the loading phase of the impact, will be considered.

Higher performance limit			
Fy	1.5kN	Mx	150Nm
Lower performance limit			
Fy	2.0kN	Mx	200Nm

Using SAE J211 sign convention $Fy > 0$ and $Mx < 0$ for LHD vehicles
$Fy < 0$ and $Mx > 0$ for RHD vehicles

8.4 Door Opening during the Impact

When a door opens in the test, a minus one-point modifier will be applied to the score for that test. The modifier will be applied to the overall vehicle score for every door (including tailgates and moveable roofs) that opens. The number of door opening modifiers that can be applied to the vehicle score is not limited.

Concept: The intention is to ensure that the structural integrity is maintained. The underlying principle is to minimise the risks of occupant ejection occurring.
The 'door opening' modifier will be applied if any of the following have occurred:

- the latch has fully released or shows significant partial release, either by release of its components from one another, or effective separation of one part of the latch from its supporting structure
- the latch has moved away from the fully latched condition
- if any hinge has released either from the door or bodyshell or due to internal hinge failure
- if there is a loss of structure between the hinges and latches
- if door or hinges fail whilst the door opening tests are being conducted post impact, as loading from an occupant could have a similar effect.
- if there was any potential risk of occupant ejection and/or partial ejection/entrapment from openings such as sliding doors or moveable roofs. Dynamic opening during the impact of any apertures, such as roofs, will also be considered even if the openings have closed post test.
- if both side doors latch together with no b-pillar or other form of restraint, the modifier may apply to both the front and rear doors.

8.5 Door Opening Forces after the Impact

A check is made to ensure that the doors on the non-struck side can be opened. The doors on the struck side are not opened.

9 POLE IMPACT MODIFIERS

9.1 Incorrect airbag deployment

Any airbag(s) which does not deploy fully in the designed manner will attract a -1 point modifier applicable to each of the most relevant body part(s) for the affected occupant. For example, where a head curtain airbag is deemed to have deployed incorrectly, the penalty will be applied to the driver's head (-1). Where the incorrect deployment affects multiple body parts, the modifier will be applied to each individual part. For example, where a seat mounted head and thorax airbag fails to deploy correctly for both the head and chest, the penalty will be applied to the head (-1) and the thorax (-1). The modifier will be applied even if the airbag was not intended to offer protection in that particular impact. For example, the penalty will be applied if a driver's knee airbag deploys incorrectly in a side or pole impact. In this case the modifier will be applied to both frontal impact driver knee, femur and pelvis body parts.

9.2 Door Opening during the Impact

When a door opens in the test, a minus one-point modifier will be applied to the score for that test. The modifier will be applied to the overall vehicle score for every door (including tailgates and moveable roofs) that opens. The number of door opening modifiers that can be applied to the vehicle score is not limited.

Concept: The intention is to ensure that the structural integrity is maintained. The underlying principle is to minimise the risks of occupant ejection occurring.
The 'door opening' modifier will be applied if any of the following have occurred:

- the latch has fully released or shows significant partial release, either by release of its components from one another, or effective separation of one part of the latch from its supporting structure
- the latch has moved away from the fully latched condition
- if any hinge has released either from the door or bodyshell or due to internal hinge failure
- if there is a loss of structure between the hinges and latches
- if door or hinges fail whilst the door opening tests are being conducted post impact, as loading from an occupant could have a similar effect.
- if there was any potential risk of occupant ejection and/or partial ejection/entrapment from openings such as sliding doors or moveable roofs. Dynamic opening during the impact of any apertures, such as roofs, will also be considered even if the openings have closed post test.
- if both side doors latch together with no b-pillar or other form of restraint, the modifier may apply to both the front and rear doors.

10 WHIPLASH SEAT ASSESSMENT CRITERIA AND LIMIT VALUES

10.1 Specification of seat to be tested

The details of the seat(s) that will be tested by Euro NCAP are contained in Section 2.7 of the Euro NCAP Car Specification, Sponsorship, Testing and Re-testing Protocol.

10.2 Static Assessments

10.2.1 Head restraint geometry assessment

The assessment is based on the worst performing parameter from either the height or backset:

Higher performance limit:
Height: 0mm below top height of HPM & HRMD
Backset: 40mm

Lower performance limit:
Height: 80mm below top height of HPM & HRMD
Backset: 100mm

The geometric assessment will be based on the average height and backset taken from at least 9 measurements obtained across all of the seats provided for assessment. A minimum of 3 drops per seat shall be performed to ensure consistent measurements are obtained on each individual seat. Where obvious outlying HRMD/HPM measurements occur, further installations shall be undertaken on that seat to ascertain whether differences are due to the individual installation or seat to seat variability.

Where a seat has a non-reversible head restraint and qualifies for a geometric assessment in the deployed position, additional seats shall be provided by the vehicle manufacturer for measurement.

The geometry assessment has 2 points allocated to it ranging from plus one to minus one.

10.2.2 Active head restraint geometry assessment

Pro-active systems
Where the vehicle manufacturer can provide convincing evidence, to the Euro NCAP Secretariat that the system always deploys to a stable position prior to the head contacting the head restraint throughout the entire range of Euro NCAP rear impact scenarios, the geometric assessment will be

based upon the deployed geometry. Deployment must occur in the time period where whiplash protection is required and the system must have reached its full extent of travel or have been prevented from further travel by contact with the dummy head. The low speed RCAR bumper test will also be considered where the 5th percentile female Hybrid III dummy is used. Where the head restraint does not deploy as intended, in any situation including any one of the Euro NCAP tests, the undeployed static measurements would then be used for the geometric assessment. If the head restraint is specifically designed not to deploy in any one of the tests, then the geometric assessment will be made in the non-deployed position.

Re-active systems
Where the vehicle manufacturer can provide convincing evidence, to the Euro NCAP Secretariat that the system always fully deploys and locks in a stable position prior to the head contacting the head rest through the entire range of Euro NCAP rear impact scenarios, the geometric assessment will be based upon the deployed geometry. The robustness of re-active systems, which utilise body mass as a trigger, must also be proven for a range of occupant sizes including the 5th percentile female at a low severity pulse. The low speed RCAR bumper test will be considered where the 5th percentile female Hybrid III dummy is used. Where the manufacturer's evidence is accepted, the geometric assessment will subsequently be based on the post test head restraint position that was observed in the low severity test with 5th percentile female HIII. The post test position shall be replicated using a new seat for the geometric assessment.

Any information regarding pro-active or re-active systems MUST be supplied to the Secretariat in advance of the commencement of the whiplash assessment.

10.2.3 Ease of adjustment

1/n points (where n = the number of front seats) will be available for each front seat scoring more than 0 points in the ease of adjustment geometric assessment. For seats where the occupant must adjust the head restraint, the ease of adjustment geometry shall be measured in the lowest and rearmost position. Alternatively, a means of ensuring that the head restraint is correctly positioned for different sized occupants without specific occupant action shall be offered. For these automatically adjusting head restraints, the ease of adjustment geometric assessment shall be measured in the position as obtained in Section 5.6. of the Euro NCAP Whiplash Testing Protocol.

This credit will only be available to seats performing well dynamically, with a raw score greater than 4.50 points after all modifiers have been applied.

For the dynamic test of self adjusting head restraints, the seat should be set in the position as obtained in Section 5.6. of the Euro NCAP Whiplash Testing Protocol and the corresponding head restraint height should be used irrespective of whether this is the mid height position of the head restraint itself.

For pro-active and re-active head restraints that qualify for geometric assessment in the deployed position, the ease of adjustment assessment will be based on that same deployed position.

The individual front seats are scored separately for this feature as cars have been encountered in which different provisions are made for the driver and front passenger seats and the system also allows for cars with three front seats. Where the manufacturer can provide evidence that the front seats are equivalent in terms of the ease of adjustment assessment, the seats will be scored equally. Where this is not the case, the manufacturer will be asked to provide an additional seat for assessment.

10.3 Dynamic assessments

A sliding scale system of points scoring shall be applied with two limits for each seat design parameter, a more demanding higher performance limit, below which a maximum score is obtained and a less demanding lower performance limit, beyond which no points are scored. Where a value falls between the two limits, the score is calculated by linear interpolation.

The maximum score for each parameter is 0.5 points, with a maximum of 3 points available per test. For each of the tests, the score for each of the seven parameters is calculated. The overall score for a single dynamic test is the sum of the scores for NIC, Nkm, Head rebound velocity, neck shear and neck tension, plus the maximum score from either T1 acceleration or head restraint contact time (T-HRC). The high severity pulse will be subject to an additional seatback deflection assessment where a one point penalty will be applied to seats with a rotation of 40° or greater. In the medium term, seat translation may also need to be controlled but, for the interim solution, only rotational control of the seat back is specified. The relevant performance criteria for each pulse are detailed below.

10.3.1 Low severity pulse

	Higher performance	**Lower performance**	**Capping Limit**
NIC	9.00	15.00	18.30
Nkm	0.12	0.35	0.50
Rebound velocity (m/s)	3.0	4.4	4.7
Upper Neck Shear Fx (N)	30	110	187
Upper Neck Tension Fz (N)	270	610	734
T1 acceleration* (g)	9.40	12.00	14.10
T-HRC (s)	61	83	95

* up to T-HRC

10.3.2 Medium severity pulse

	Higher performance	Lower performance	Capping Limit
NIC	11.00	24.00	27.00
Nkm	0.15	0.55	0.69
Rebound velocity (m/s)	3.2	4.8	5.2
Upper Neck Shear Fx (N)	30	190	290
Upper Neck Tension Fz (N)	360	750	900
T1 acceleration* (g)	9.30	13.10	15.55
T-HRC	57	82	92

* up to T-HRC

10.3.3 High severity pulse

	Higher performance	Lower performance	Capping Limit
NIC	13.00	23.00	25.50
Nkm	0.22	0.47	0.78
Rebound velocity (m/s)	4.1	5.5	6.0
Upper Neck Shear Fx (N)	30	210	364
Upper Neck Tension Fz (N)	470	770	1024
T1 acceleration* (g)	12.50	15.90	17.80
T-HRC	53	80	92
Seatback Deflection assessment	40°		

* up to T-HRC

11 WHIPLASH MODIFIERS

11.1 Seatback dynamic deflection: The high severity pulse will be subject to an additional seatback deflection assessment where a one point penalty will be applied to seats with a rotation of 40° or greater

11.2 Dummy artefact loading: A two point negative modifier would be applied as a means of penalising any seat that, by design, places unfavourable loading on other body areas or exploits a dummy artefact.

12 PEDESTRIAN IMPACT ASSESSMENT CRITERIA AND LIMIT VALUES

The basic assessment criteria used for the pedestrian impact tests, with the upper and lower performance limits for each parameter, are summarised below. Where multiple criteria exist for an individual test, the lowest scoring parameter is used to determine the performance of that test.

12.1 Headform

Higher performance limit		
HIC_{15}	1000*	(20% risk of injury ≥ AIS3 [1,2])
		*(*EEVC Limit)*
Lower performance limit		
HIC_{15}	1350	

12.2 Upper Legform

Higher performance limit		
Bending Moment	300Nm*	(18% risk of femur/pelvis fracture)
Sum of forces	5.0kN*	(20% risk of femur/pelvis fracture)
		*(*EEVC Limits)*
Lower performance limit		
Bending Moment	380Nm	(33% risk of femur/pelvis fracture)
Sum of forces	6.0kN	(36% risk of femur/pelvis fracture)

12.3 Legform

Higher performance limit		
Tibia deceleration	150g*	(27% risk of lower leg fracture) [9]
Knee shear displacement	6mm*	[9]
Knee bending angle	15º *	[9]
		*(*EEVC Limits)*
Lower performance limit		
Tibia deceleration	200g	(46% risk of lower leg fracture)
Knee shear displacement	7mm	
Knee bending angle	20º	

13 VISUAL PRESENTATION

For frontal and side impact, the protection provided for adults for each body region are presented visually, using coloured segments within body outlines. The colour used is based on the points awarded for that body region (rounded to two decimal places), as follows:

Green	4.00	points
Yellow	2.67 - 3.99	points
Orange	1.33 - 2.66	points
Brown	0.01 - 1.32	points
Red	0.00	points

The method of presenting the pole impact results are as follows:

- A passed pole test gives a green star overlaying the side impact driver's head.
- A marginal pass is shown as a yellow star overlaying the side impact driver's head.
- A failed pole test is shown as an empty star overlaying the side impact driver's head.
- A car that has not been subjected to a pole test has nothing added to the graphic.

For pedestrians, the protection provided by each test site is illustrated by a coloured area, on an outline of the front of the car. The colour used is based on the points awarded for that test site (rounded to two decimal places), as follows:

Green	2	points
Yellow	0.01 – 1.99	points
Red	0	points

14 OVERALL ASSESSMENTS

An overall assessment is presented for frontal and side impact protection. This is normally based on the driver scores, unless any body region for the passenger receives a lower score. In this case the score for the passenger is used for that body region. A separate overall assessment is currently made for pedestrian protection.

14.1 The overall assessment are computed as follows

For frontal impact, the body regions are grouped together, with the rating for the grouped body region being that of the worst performing region or limb. The grouped regions are:

Head and Neck
Chest
Knee, Femur, Pelvis (i.e. left and right femur and knee slider)
Leg and Foot (i.e. left and right lower leg and foot and ankle)

For the distributed barrier side impact and for the pedestrian tests, all the individual regions are used. For the pole test, only the head is considered at present.

To obtain the overall ratings, the points gained by each region are added together. Frontal and distributed barrier side impact each have four regions which can each be awarded up to four points. The pole test potentially contributes a further 2 points. This gives a possible maximum overall score of 34 points.

For pedestrian impact, each of the potential 18 test sites can be awarded up to two points, giving a possible overall score of 36 points. However, If the vehicle manufacturer chooses to fund additional tests either in the legform, upper legform or headform test area the score would be calculated as follows:

Example:

Headform testing:
Euro NCAP test produces a HIC of 1300 = 0.07 points/quarter
Additional test produces a HIC of 1050 = 0.43 points/quarter

Euro NCAP test Score	**Extra Test Score**	**Number of manufacturer nominated quarters**	**Area Score**	
0.07		0	(0.07 x 4)	= 0.29
0.07	0.43	1	(0.07 x 3)+(0.43 x 1)	= 0.64
0.07	0.43	2	(0.07 x 2)+(0.43 x 2)	= 1.00
0.07	0.43	3	(0.07 x 1)+(0.43 x 3)	= 1.36

Legform/upper legform testing (based upon the worst result of any parameter):
Euro NCAP test produces a knee bending angle of 19° = 0.2 points/half
Additional test produces a tibia acceleration 175g = 0.5 points/half

Euro NCAP test Score	**Extra Test Score**	**Number of manufacturer nominated halves**	**Area Score**
0.20		0	0.20 x 2 = 0.40
0.20	0.50	1	0.20+0.50 = 0.70

Where the spacing requirements between impacts prevent the worst case location from being tested, the area in question will be given the most appropriate score from an adjacent area within that particular sixth or half.

In each case, the overall score is rounded to the nearest integer only after the front, side and pole impact scores have been added.
For example:
Front impact score = 7.51
Side impact score = 10.87
Total score = 18.38
Final score = 18 points

14.2 Relationship between Points and Stars for Frontal and Side Tests

The overall scores and the balance between side and front scores are then used to generate star ratings. Vehicles which perform very poorly in the frontal or side tests have their star rating restricted to show that they do not provide good all-round protection.

There will be a minimum number of points required in both the frontal and side impact (excluding the pole test) assessments to achieve a star rating. The following limits are applied after the individual test scores have been rounded:

14.3 Total Points and Balance Applied to Star Values

Provided there is a balance between the Frontal and Side Impacts the following applies:

33 - 40	points	5 stars
25 - 32	points	4 stars
17 - 24	points	3 stars
9 - 16	points	2 stars
1 - 8	points	1 star
0	points	0 stars

However if the balance is lacking then the following hurdles are applied:

Minimum points required in each test (after rounding):	Star rating:
13 points	5
9 points	4
5 points	3
2 points	2

14.4 Struck Through Stars

Concerns have been expressed that some cars were being "recommended" by the media, on the basis of their star rating, even when some important body region was poorly protected. Where this problem might occur, the final star for occupant protection is struck through with a single diagonal red line.

The final star is struck through when zero points are scored, on the basis of dummy response alone, for any body region where there is **"an unacceptably high risk of life-threatening injury."** In frontal impact, body regions which could give rise to a struck through star are: head, neck and chest. In the distributed barrier side impact they are: head, chest, abdomen and pelvis.

14.5 Whiplash Raw Score

The protocol allows for a maximum score of eleven points as a result of carrying out the three severities of whiplash test, assuming no negative modifiers have been applied. This score is known as the raw score and its components are shown below. When incorporated into the final vehicle rating, an appropriate scaling factor will be applied to the raw score. Currently, the scaling factor is still under consideration.

Dynamic assessments

Each severity of whiplash test pulse results in a maximum of 3 points being awarded based on the measured criteria. Half a point is awarded for each of NIC, Nkm, Head rebound velocity, F_x and F_y. A further half point is awarded on the basis of the best score from either T1 acceleration or head restraint contact time (T-HRC).

If any of NIC, Nkm, Head rebound velocity, neck shear or tension exceed the capping limit, no score is given for that pulse. Additionally, if both T1 and head restraint contact time exceed the higher performance limit and either one also exceeds the relevant capping limit, no score is given for the pulse.

The sum of the scores from the dynamic tests is then subject to the application of the modifiers.

	Points available
Static assessments	
HR geometry	-1 to +1 points
Ease of adjustment	1 point
Dynamic assessments	
Low severity pulse	3 points
Medium severity pulse	3 points
High severity pulse	3 points
Modifiers	
Seatback deflection	-1 point
Dummy artefact loading	-2 points
Maximum points	**11 points**

15 CONCEPTS BEHIND THE ASSESSMENTS

15.1 Frontal Impact

Head

CONCEPT*: The driver's head should be predictably restrained by the airbag, and should remain protected by the airbag during the dummy's forward movement. There should be no bottoming out of the airbag.*

CONCEPT: *Hazardous airbag deployment*
The deployment mode of the airbag should not pose a risk of facial injury to occupants of any size.

CONCEPT: *Incorrect airbag deployment*
All airbags that deploy during an impact should do so fully and in the designed manner so as to provide the maximum amount of protection to occupants available. It is expected that, where required, all airbags should deploy in a robust manner regardless of the impact scenario.

CONCEPT*: Geometric control of steering wheel movement is needed to ensure that the airbag launch platform remains as close as possible to the design position, to protect a full range of occupant sizes.*

Neck

CONCEPT: *Neck injuries are frequent, but relatively little is known about appropriate injury criteria. The neck criteria recommended by EEVC are used to identify poorly designed restraint systems. It is not expected that many cars will fail these requirements.*

In addition to the EEVC recommended limits, additional ones have been added, at the request of the car manufacturers. It is assumed that good restraint systems will have no problems meeting these criteria.

Chest

CONCEPT*: Rib compression is used as the main guide to injury risk. It is expected that the Viscous Criterion will only identify cars with poorly performing restraint systems.*

The injury risk data is relevant for seat belt only loading rather than combined seat belt and airbag loading. No change is made in the event of combined seat belt and airbag restraint. This avoids value judgements about the extent of airbag restraint on the chest and is in line with the EEVC recommendation.

CONCEPT: *There is an interrelationship between chest loading, as measured by the above dummy*

criteria, and intrusion. To ensure that a good balance is struck, a geometric criterion on waist level intrusion, as measured by door pillar movement at waist level, is used.

CONCEPT: *When the passenger compartment becomes unstable, any additional load can result in unpredictable excessive further collapse of the passenger compartment. When the passenger compartment becomes unstable the repeatability of the car's response in the test becomes poor and confidence in the car's performance is reduced.*
CONCEPT: *The chest performance criteria are developed for loads applied by a seat belt. The more concentrated loading from a "stiff" steering wheel exposes the chest to direct loading injury.*

Abdomen

Protection of the abdomen is important, but no criteria or assessment techniques are available at present.

Knee, Femur & Pelvis

CONCEPT*: Transmitting loads through the knee joint from the upper part of the tibia to the femur can lead to cruciate ligament failure.*

Zero knee slider displacement is both desirable and possible. The higher performance limit allows for some possible movement due to forces transmitted axially up the tibia.

CONCEPT: *The knee impact area should have uniformly good properties over a wide area of potential impact sites. This is to account for people sitting with their knees in different positions and slight variations in impact angle. The characteristics of the area should not change markedly if knee penetration is slightly greater than that observed with the 50 percentile dummy in this test. This takes into account the protection of different sized occupants or occupants in different seating positions.*

CONCEPT*: Loading on the knee should be well distributed and avoid concentration that could result in localised damage to the knee.*

The injury tolerance work that supports the legislative femur criterion was conducted with padded impactors that spread the load over the knee.

Lower Leg

CONCEPT: *Loads resulting in fracture of the tibia produce bending moments and forces measurable at the upper and lower ends of the tibia. These measurements on the tibia relate to risk of tibia fracture.*

At the request of the car manufacturers, further limits were added to those proposed for lower leg protection. These limits can be expected to help protect the ankle joint.

CONCEPT: *Pedal blocking*
There should be no blocking of any foot operated pedals which have displaced rearward after the impact; blocked pedals represent a greater hazard to the lower limbs of the driver than non-blocked pedals.

Foot and Ankle

CONCEPT: *Expert opinion suggests that a Tibia Index of less than 0.2 would be necessary to prevent ankle joint failure. Until a biofidelic ankle and foot become available, the assessment will be based on intrusion. Intrusion is highly correlated with the risk of injury.*

CONCEPT*: Rupture of the footwell exposes the occupant to additional dangers. Objects outside the passenger compartment may enter, parts of the occupant may contact items outside the passenger compartment, there is a risk from exposed edges and the structure may become unstable.*

15.2 Side Impact

CONCEPT: *Incorrect airbag deployment*
All airbags that deploy during an impact should do so fully and in the designed manner so as to provide the maximum amount of protection to occupants available. It is expected that, where required, all airbags should deploy in a robust manner regardless of the impact scenario.

CONCEPT: *Backplate*
Poor dummy biofidelity should not be exploited in such a way that compromises other outputs from the dummy.

CONCEPT: *T12*
Poor dummy biofidelity should not be exploited in such a way that compromises other outputs from the dummy.

15.3 Pole impact

CONCEPT: *Incorrect airbag deployment*
All airbags that deploy during an impact should do so fully and in the designed manner so as to provide the maximum amount of protection to occupants available. It is expected that, where required, all airbags should deploy in a robust manner regardless of the impact scenario.

15.4 Seating Position in Side Impact

CONCEPT: *Effective side impact protection needs to consider all sizes of occupants. This concept is included in the EU Directive. Currently, side impact tests are conducted with the seat in the design position. In future, consideration will be given to the level of protection in other seating positions.*

15.5 Pole Test

The pole test is included as a test of systems designed to provide head protection in a wide range of side impact situations. It is necessary as the current distributed barrier side impact test presents no threat to the head from outside the vehicle. Reliance on the distributed barrier side impact test alone tends to give false assurance of the protection offered to the head in side impact.

15.6 Whiplash

Geometry assessment
CONCEPT: *This is used to encourage front seats to have optimum geometry in terms of both height and backset.*

Ease of adjustment
CONCEPT: *The head restraint should be ideally placed for optimal dynamic performance without occupants of different size taking any action other than simply adjusting the seat to suit their leg length. This implies that the head restraint should either be fixed, automatically adjust to the optimal position or should be an adjustable restraint that provides optimum position even in its fully down position.*

Seatback dynamic deflection
CONCEPT: *The seat distortion should be controlled so that a front occupant is not liable to ejection from behind the seat belt in a rear impact and the risk of interaction between the front and rear occupants is minimised.*

Dummy artefact loading
CONCEPT: *A two point negative modifier will be applied to any seat that, by design, places unfavourable loading on other parts of the body as a result of the head restraint mechanism. This modifier shall also penalise any design feature aimed at exploiting any dummy artefact. This is seen as a clear incentive to avoid such design, and an essential feature to safeguard Euro NCAP's position for future designs.*

16 PEDESTRIAN TESTS

With the current level of pedestrian protection provided by car fronts, it would be optimistic to expect protection levels to exceed those proposed by the EEVC. In order to discriminate between cars which more nearly meet the EEVC requirements from those which greatly exceed them, a lower limit has been set. This has been derived from experience gained in the early phases of Euro NCAP.

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APPENDIX I

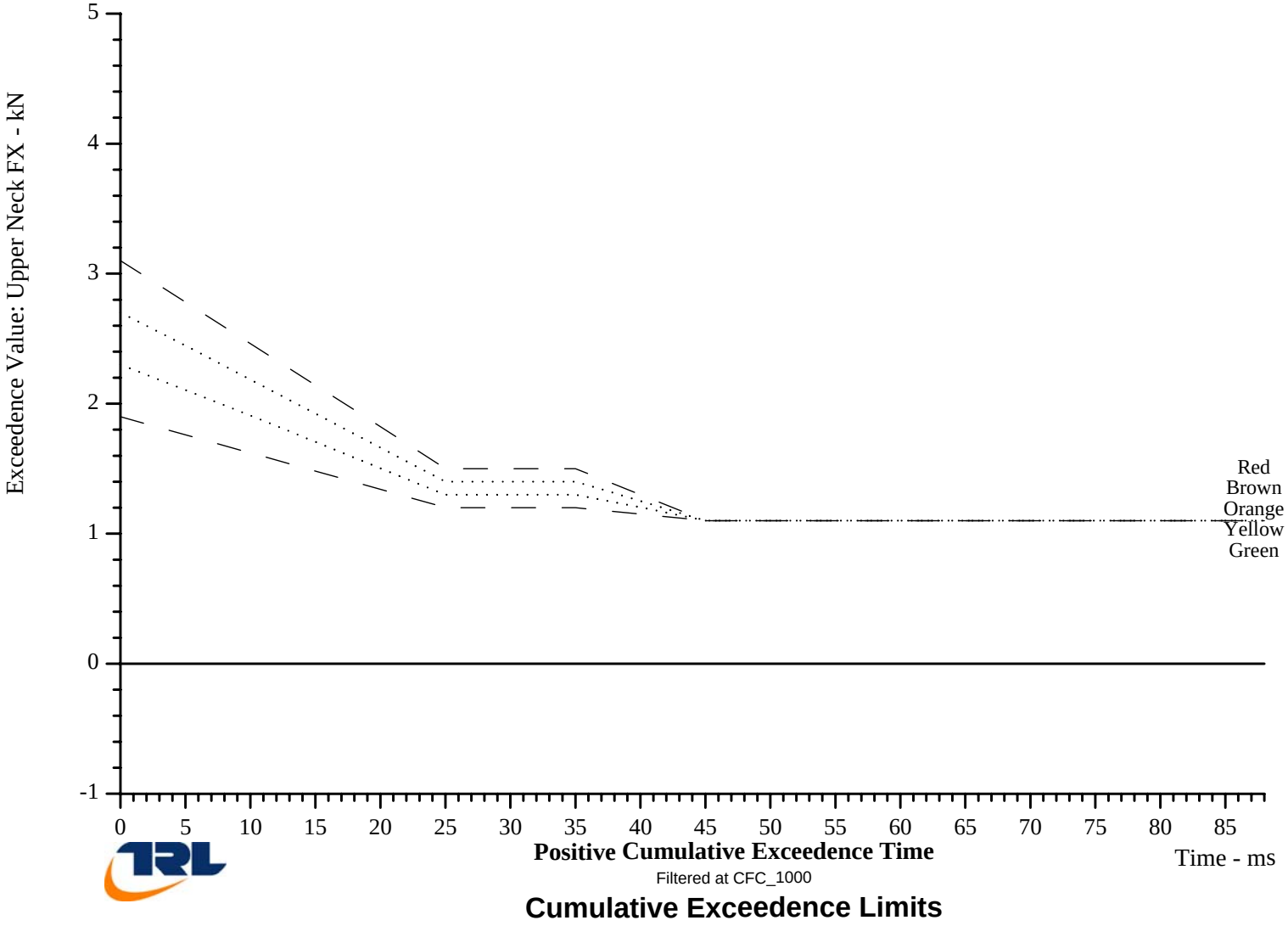
GRAPHICAL LIMITS FOR CUMULATIVE EXCEEDENCE PARAMETERS

1 Upper Neck Shear FX - Positive

2 Upper Neck Shear FX - Negative

3 Upper Neck Tension FZ

4 Femur Compression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45
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55
60
65
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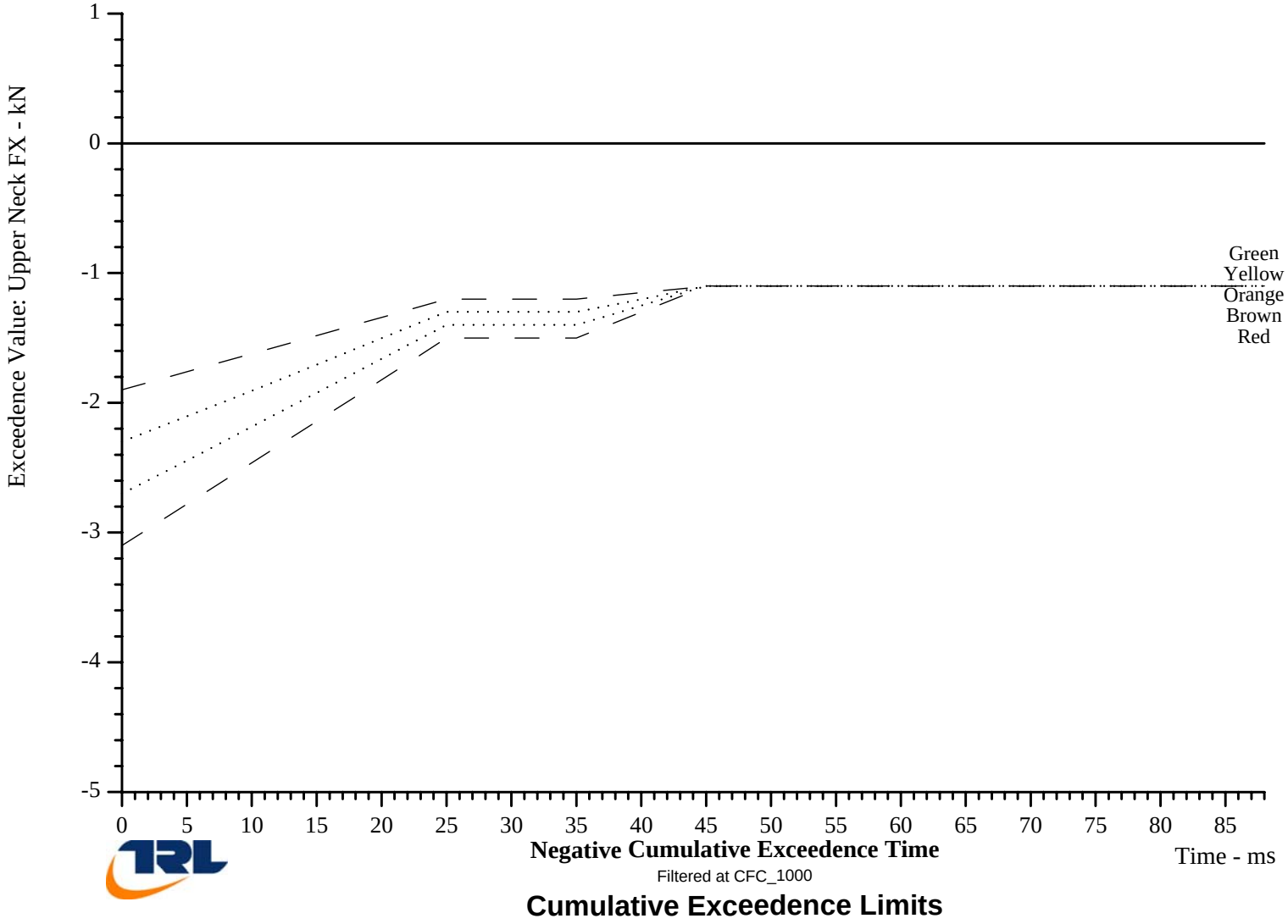
Positive Cumulative Exceedence Time
Filtered at CFC_1000
Cumulative Exceedence Limits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30
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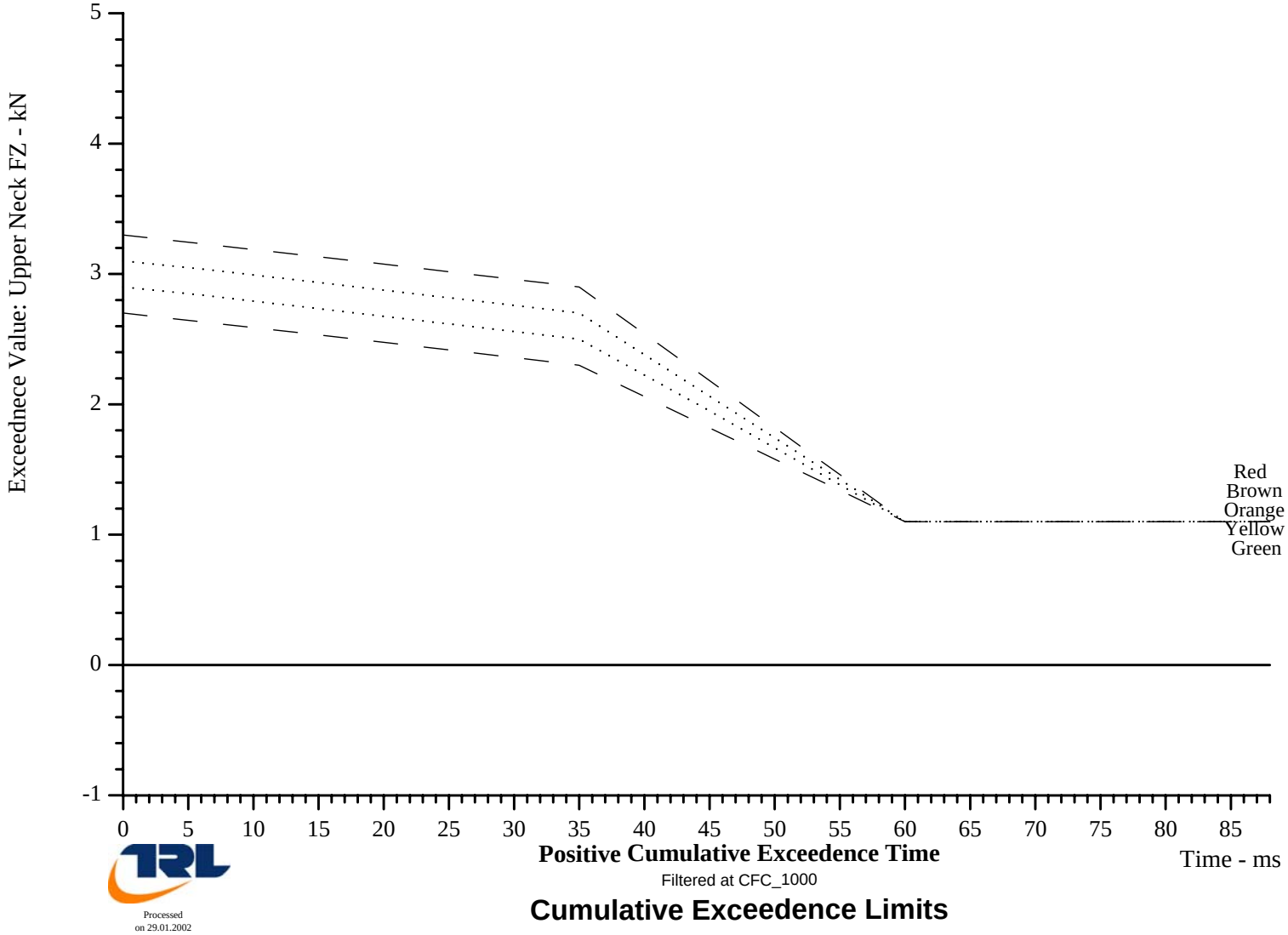
40
45
50
55
60
65
70
75
80
85
Time - ms
Green
Yellow
Orange
Brown
Red
Negative Cumulative Exceedence Time
Filtered at CFC_1000
Cumulative Exceedence Limits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45
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85
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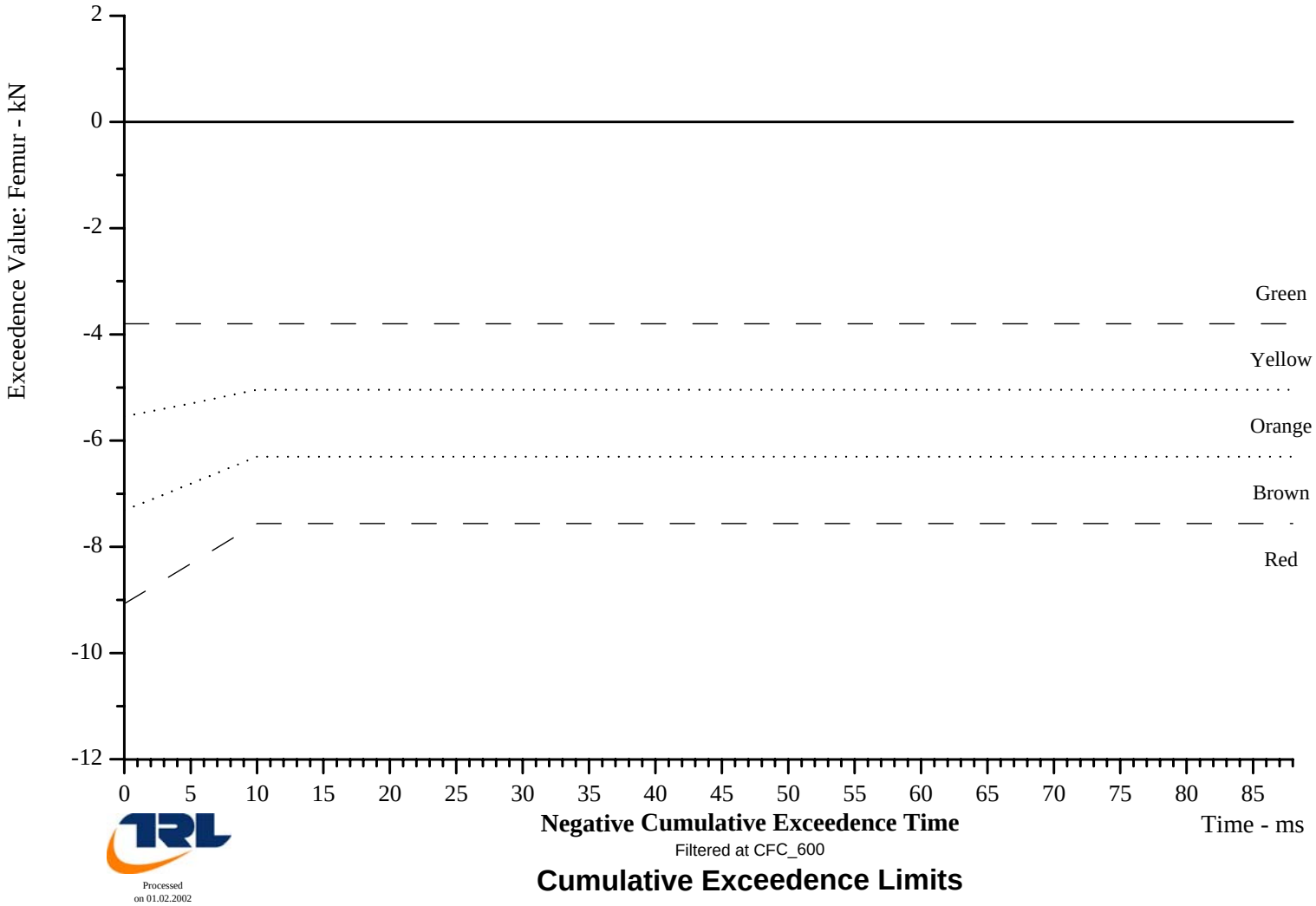
Cumulative Exceedence Limits
Processed
on 29.01.2002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Cumulative Exceedence Limits
Processed
on 01.02.2002