



**EUROPEAN NEW CAR ASSESSMENT PROGRAMME
(Euro NCAP)**



ASSESSMENT PROTOCOL – ADULT OCCUPANT PROTECTION

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ASSESSMENT PROTOCOL – ADULT OCCUPANT PROTECTION

1 INTRODUCTION

Euro NCAP's original assessment protocol was 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. Subsequent versions of the protocol have been developed and released by the Euro NCAP Secretariat. Beginning with Version 5 important changes have been included that have been brought about by the introduction of the overall rating scheme. Individual documents are released for the four main areas of assessment:

- Assessment Protocol – Adult Occupant Protection;
- Assessment Protocol – Child Occupant Protection;
- Assessment Protocol – Pedestrian Occupant Protection;
- Assessment Protocol – Safety Assist;

In addition to these four assessment protocols, a separate document is provided describing the method and criteria by which the overall safety rating is calculated on the basis of the car performance in each of the above areas of assessment.

The following protocol deals with the assessments made in the area of Adult Occupant Protection, in particular in the frontal impact test, the side impact test, the pole test and the whiplash tests.

DISCLAIMER: Euro NCAP has taken all reasonable care to ensure that the information published in this protocol is accurate and reflects the technical decisions taken by the organisation. In the unlikely event that this protocol contains a typographical error or any other inaccuracy, Euro NCAP reserves the right to make corrections and determine the assessment and subsequent result of the affected requirement(s).

2 METHOD OF ASSESSMENT

The starting point for the assessment of adult occupant protection is the dummy response data recorded in four different test configurations: frontal impact, side impact, pole impact and (low speed) rear impact. Initially, each relevant body area is given a score based on the measured dummy parameters. These scores can be adjusted after the test based on supplementary requirements. E.g. for frontal impact, consideration is given to whether the original score 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, foot well distortion and displacement of

the A pillar. The adjustments (or modifiers) based on both inspection and geometrical considerations are applied to the body area assessments to which they are most relevant.

For frontal impact, the score for each body area 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. Side impact and pole impact results relate to the struck-side occupant only, while Whiplash results are valid for any front seat adult occupant. 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.

From the information collected in the four test scenarios, individual test scores are computed for frontal, side and pole impact and whiplash protection. The adjusted score 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, for the driver in side and pole impact and for the driver or passenger in rear impact. Finally, for the complete area of adult occupant protection assessment, the scores for frontal, side, pole and whiplash are summed. The resulting Adult Occupant Protection Score is expressed as a percentage of the maximum achievable number of points.

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.

2.1 Points Calculation

From Phase 3, a sliding scale system of points scoring has been used to calculate points for each measured criterion. This involves two limits for each parameter, a more demanding limit (higher performance), below which a maximum score is obtained and a less demanding limit (lower performance), beyond which no points are scored. In frontal, side, pole and rear* impacts, the maximum score for each body region is four points. Where a value falls between the two limits, the score is calculated by linear interpolation.

For all tests part of the adult occupant protection assessment, capping limits are maintained for criteria related to critical body regions. Exceeding a capping limit generally indicates unacceptable high risk at injury or, in the case of the whiplash test, an unacceptably high seat design parameter. In all cases, this leads to loss of all points related to the tests. Capping limits can be equal to or higher than the lower performance limit, depending on the test.

* Neck only – based on a combination of scores obtained in three individual test conditions.

3 FRONTAL IMPACT ASSESSMENT

3.1 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. The lowest scoring body region of driver or passenger is used to determine the score. For frontal impact, capping is applied on the critical body regions: head, neck and chest.

3.1.1 Head

3.1.1.1 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: HIC₃₆ 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 and capping limit

HIC ₃₆	1000*	(20% risk of injury ≥ AIS3 [1,2])
Resultant Acc. 3 msec exceedence	88g	(*EEVC limit)

3.1.1.2 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 6.8 kg spherical headform test specified in ECE Regulation 12 [3] 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 and capping limit

HIC ₃₆	1000
Resultant peak Acc.	120g
Resultant Acc. 3 msec exceedence	80g

From the face form 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.

3.1.2 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 and capping 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 [4]) (*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.

3.1.3 Chest

Higher performance limit

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

Lower performance and capping limit

Compression	50mm*	(50% risk of injury \geq AIS3 [5])
Viscous Criterion	1.0m/sec*	(25% risk of injury \geq AIS4) (*EEVC Limits)

3.1.4 Knee, Femur and Pelvis

Higher performance limit

Femur compression	3.8kN	(5% risk of pelvis injury [6])
Knee slider compressive displacement	6mm	

Lower performance limit

Femur Compression	9.07kN @ 0msec,	7.56kN @ \geq 10msec*	(Femur fracture limit [4])
Knee slider compressive displacement		15mm*	(Cruciate ligament failure limit [4,7]) (*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.

3.1.5 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 [4,8]) (*EEVC Limits)

3.1.6 Foot/Ankle

Higher performance limit

Pedal rearward displacement	100mm	
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Lower performance limit

Pedal rearward displacement	200mm	
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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.

3.2 Modifiers

3.2.1 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 Section 6.

3.2.1.1 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.

Note: Head bottoming-out is defined as follows: 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 frontal impact driver's head (-1). Where, a passenger knee airbag fails to deploy correctly, the penalty will be applied to the frontal impact passenger left and right knee, femur and

pelvis (-1). Where the incorrect deployment affects multiple body parts, the modifier will be applied to each individual body part with a maximum of 2 body regions. For example, where a seat or door mounted side airbag deploys incorrectly in a frontal impact that is intended to provide protection to the head as well as the thorax, abdomen and pelvis, the penalty will be applied to two body regions, -1 to the head and -1 to the chest. This would also be applicable to both the side and pole impacts. 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 seat mounted side airbag deploys incorrectly in the frontal impact. In this case the modifier will be applied to the chest body part for both the side and pole impacts. Where any frontal protection airbag deploys incorrectly, Euro NCAP will not accept knee mapping data for that occupant.

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.

3.2.1.2 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.

When this modifier is applied, Euro NCAP will not accept knee mapping data.

Steering Wheel Contact

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

3.2.1.3 Knee, Femur & Pelvis

Variable Contact

The position of the dummy's knees is 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 [8]. 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 than 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 any of the driver's 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

[†] Reducing to 60mm by 2013.

to the column area and one half of a point to the remainder of the fascia for each knee.

3.2.1.4 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.

3.2.1.5 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. When this modifier is applied, Euro NCAP will not accept knee mapping data.

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.

3.2.2 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 section 6. 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 fascia. 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.

3.2.3 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 frontal impact assessment 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.

3.2.4 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	$\leq 100\text{N}$
Moderate force	$> 100\text{N}$ to $< 500\text{N}$
Extreme hand force	$\geq 500\text{N}$
Tools had to be used	Tools necessary

3.3 Scoring & Visualisation

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 three decimal places), as follows:

Green	4.000	points
Yellow	2.670 - 3.999	points
Orange	1.330 - 2.669	points
Brown	0.001 - 1.329	points
Red	0.000	points

For frontal impact, the body regions are grouped together, with the score 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) and Leg and Foot (i.e. left and right lower leg and foot and ankle). Results are shown separately for driver and passenger.

The contribution of the frontal impact test to the Adult Occupant Protection Score is calculated by

summing the body scores for the relevant body regions, taking the lower of the driver and passenger scores. The total achievable score is 16 points.

4 SIDE AND POLE IMPACT ASSESSMENT

4.1 Criteria and Limit Values

The basic assessment criteria used for both side and pole impacts, 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 by application of modifiers. The concepts behind the modifiers are explained in section 6.

For side impact capping is applied on head, chest, abdomen and pelvis, for pole impact on head only. Where no head protection systems are present, the pole test will not be allowed and the points for that test are set to zero.

Note: The requirement is for the fitment of a head protection system, meaning that the manufacturer is free to use a solution other than an airbag. However, for technologies other than conventional curtain or head airbags, the manufacturer is requested to provide evidence that the system is effective, at least in principle, before a test can be allowed.

4.1.1 Head

4.1.1.1 Side impact

Higher performance limit

HIC ₃₆	650	(5% risk of injury ≥ AIS3 [1,2])
Resultant Acc. 3msec exceedence	72g	

Lower performance and capping limit

HIC ₃₆	1000*	(20% risk of injury ≥ AIS3 [1,2])
Resultant Acc. 3msec exceedence	88g	(*EEVC Limit)

4.1.1.2 Pole impact

HIC ₃₆	<1000
Peak Resultant Acc	<80g
No direct head contact with the pole	

4.1.2 Chest

The assessment is based on the worst performing individual rib.

Higher performance limit

Compression	22mm	(5% risk of injury ≥ AIS3 [10])
Viscous Criterion	0.32	(5% risk of injury ≥ AIS3 [10])

Lower performance and capping limit

Compression	42mm*	(30% risk of injury \geq AIS3 [10])
Viscous Criterion	1.0*	(50% risk of injury \geq AIS3 [10])

(*EEVC Limits)

4.1.3 Abdomen

Higher performance limit

Total Abdominal Force	1.0kN
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Lower and capping performance limit

Total Abdominal Force	2.5kN*	(*EEVC Limit)
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4.1.4 Pelvis

Higher performance limit

Pubic Symphysis Force	3.0kN
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Lower performance and capping limit

Pubic Symphysis Force	6.0kN*	(Pelvic fracture in young adults) (*EEVC Limit)
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4.2 Modifiers

4.2.1 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 side impact driver's head (-1). Where the incorrect deployment affects multiple body parts, the modifier will be applied to each individual body part, with a maximum of 2 body regions. For example, where a seat or door mounted side airbag fails to deploy correctly that is intended to provide protection to the head as well as the thorax, abdomen and pelvis, the penalty will be applied to two body regions, the head (-1) and the chest (-1). The two penalties would also be applicable to both the side and pole impacts, which are scaled down in the final vehicle rating.

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. Where a frontal protection airbag deploys incorrectly, knee-mapping is not permitted for the occupant whom the airbag was designed to protect.

4.2.2 Backplate Loading

Where the backplate load F_y 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
 F_y 1.0kN

Lower performance limit
 F_y 4.0kN

4.2.3 T12 Modifier

Where the T12 loads F_y and M_x 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
 F_y 1.5kN ; M_x 150Nm

Lower performance limit
 F_y 2.0kN ; M_x 200Nm

Using SAE J211 sign convention $F_y > 0$ and $M_x < 0$ for LHD vehicles
 $F_y < 0$ and $M_x > 0$ for RHD vehicles

4.2.4 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 side impact assessment 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.

4.2.5 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.

4.3 Scoring & Visualisation

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 three decimal places), as follows:

Green	4.000	points
Yellow	2.670 - 3.999	points
Orange	1.330 - 2.669	points
Brown	0.001 - 1.329	points
Red	0.000	points

For the side and pole impacts and for the child and pedestrian protection, all the individual regions are used. Results are shown separately for side and pole impact.

The contribution of the side and pole impact tests to the Adult Occupant Protection Score is calculated by summing the body scores for the relevant body regions in each of the tests. The total score in side and pole tests together is limited to 16 points. This is achieved by adding up the individual scores (after modifiers have been applied) for the side impact test (max. 16 points) and the pole test (max. 16 points) and dividing the result by two.

5 WHIPLASH SEAT ASSESSMENT

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.

5.1 Criteria and Limit Values

The basic assessment criteria used for whiplash protection assessment, with the upper and lower performance limits for each parameter, are summarised below.

5.1.1 Static Assessments

5.1.1.1 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 three 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 two points allocated to it ranging from plus one to minus one.

5.1.1.2 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 Euro NCAP tests and RCAR test, 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.

5.1.1.3 Worst Case Geometry[‡]

1/n points (where n = the number of front seats) will be available for each front seat scoring more than 0 points in the worst case geometry assessment. For seats where the occupant must adjust the head restraint, the worst case geometry shall be measured in the lowest and rearmost position regardless of whether or not the seat is equipped with an active head restraint. The assessment will be based on the average height and backset taken from at least 9 measurements in the down and back position 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. 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 worst case geometry 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 capping and 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.

[‡] Formerly referred to as "Ease of Adjustment".

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 worst case geometry 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.

5.1.2 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 0.50 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-start). The high severity pulse will be subject to an additional seatback deflection assessment where a three point penalty will be applied to seats with a rotation of 32.0° 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.

5.1.2.1 Low Severity Pulse

Criterion*	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

* All parameters calculated until T-HRC-end, except rebound velocity.

5.1.2.2 Medium Severity Pulse

Criterion*	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

* All parameters calculated until THRC-end, except rebound velocity.

5.1.2.3 High Severity Pulse

Criterion*	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	32.0°		

* All parameters calculated until THRC-end, except rebound velocity.

5.2 Modifiers

5.2.1 Seatback Dynamic Deflection

The high severity pulse will be subject to an additional seatback deflection assessment where a three point penalty will be applied to the overall score where seats have a rotation of 32.0° or greater.

5.2.2 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 (e.g. preventing realistic ramping up) or exploits a dummy artefact.

5.3 Scoring & Visualisation

5.3.1 Scoring

5.3.1.1 Raw Score

The protocol allows for a maximum score of 11 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 explained below.

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 lower 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.

	<i>Points available</i>
<i>Static assessments</i>	
<i>HR geometry</i>	<i>-1 to +1 points</i>
<i>Worst case geometry</i>	<i>1 point</i>
<i>Dynamic assessments</i>	
<i>Low severity pulse</i>	<i>3 points</i>
<i>Medium severity pulse</i>	<i>3 points</i>
<i>High severity pulse</i>	<i>3 points</i>
<i>Modifiers</i>	
<i>Seatback deflection</i>	<i>-3 points</i>
<i>Dummy artefact loading</i>	<i>-2 points</i>
<i>Maximum points</i>	<i>11 points</i>

5.3.1.2 Scaled Score

The raw score is scaled to a maximum of 4 points by multiplication by a factor of 4/11. Scaled scores less than zero are set to zero points.

5.3.2 Visualisation

For whiplash, the protection provided for the neck of a front seat adult occupant is presented visually using a coloured head and neck graphic. The colour used is based on the scaled points (rounded to three decimal places), as follows:

Green	3.000 – 4.000 points
Orange	1.500 – 2.999 points
Red	0.000 – 1.499 points

6 CONCEPTS BEHIND THE ASSESSMENTS

6.1 Frontal Impact

6.1.1 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.*

6.1.2 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.

6.1.3 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.*

6.1.4 Abdomen

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

6.1.5 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.

6.1.6 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.

6.1.7 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.*

6.2 Side and 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.

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.

CONCEPT: Seat position in side impact

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 may be given to the level of protection in other seating positions.

6.3 Door Opening (Front, Side, Pole Impact)

***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 Whiplash

6.4.1 Geometry Assessment

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

6.4.2 Worst Case Geometry

***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 (worst case) position.*

6.4.3 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.*

6.4.4 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.*

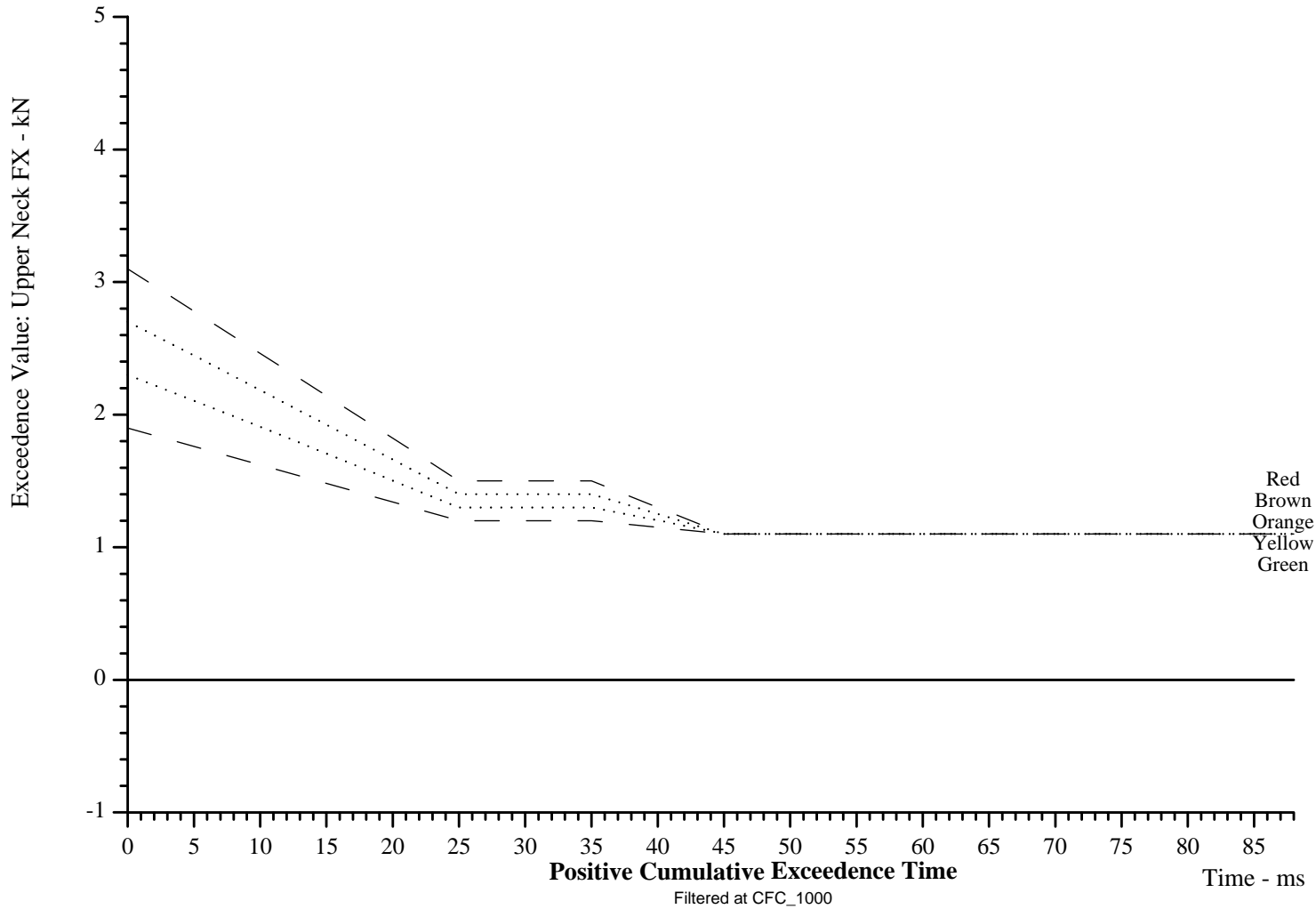
7 REFERENCES

- 1 Prasad, P. and H. Mertz. *The position of the US delegation to the ISO Working Group 6 on the use of HIC in the automotive environment*. SAE Paper 851246. 1985
- 2 Mertz, H., P. Prasad and G. Nusholtz. *Head Injury Risk Assessment for forehead impacts*. SAE paper 960099 (also ISO WG6 document N447)
- 3 ECE Regulation 12 Revision 3 - Uniform Provisions Concerning the Approval of Vehicles With Regard To the Protection of the Driver against the Steering Mechanism in the Event of Impact. 1994.
- 4 Mertz, H. *Anthropomorphic test devices*. Accidental Injury - Biomechanics and Prevention, Chapter 4. Ed. Alan Nahum and John Melvin. Pub. Springer-Verlag 1993.
- 5 Mertz, H., J. Horsch, G. Horn and R Lowne. *Hybrid III sternal deflection associated with thoracic injury severities on occupants restrained with force-limiting shoulder belts*. SAE paper 910812. 1991.
- 6 Wall, J., R. Lowne and J. Harris. *The determination of tolerable loadings for car occupants in impacts*. Proc 6th ESV Conference. 1976
- 7 Viano, D., C. Culver, R. Haut, J. Melvin, M. Bender, R. Culver and R. Levine. *Bolster impacts to the knee and tibia of human cadavers and an anthropomorphic dummy*. SAE Paper 780896, Proc 22nd Stapp conference.
- 8 EEVC WG. *The Validation of the EEVC Frontal Impact Test Procedure*. Proc 15th ESV Conference, Melbourne, 1996.
- 9 Schneider, L.W., Vogel, M. and Bosio, C.A. Locations of driver knees relative to knee bolster design. The University of Michigan Transportation Research Institute, Ann Arbor, Michigan. UMTRI-88-40. September 1988.
- 10 Lowne, R. and E. Janssen. *Thorax injury probability estimation using production prototype EUROSID*. ISO/TC22/SC12/WG6 document N302.

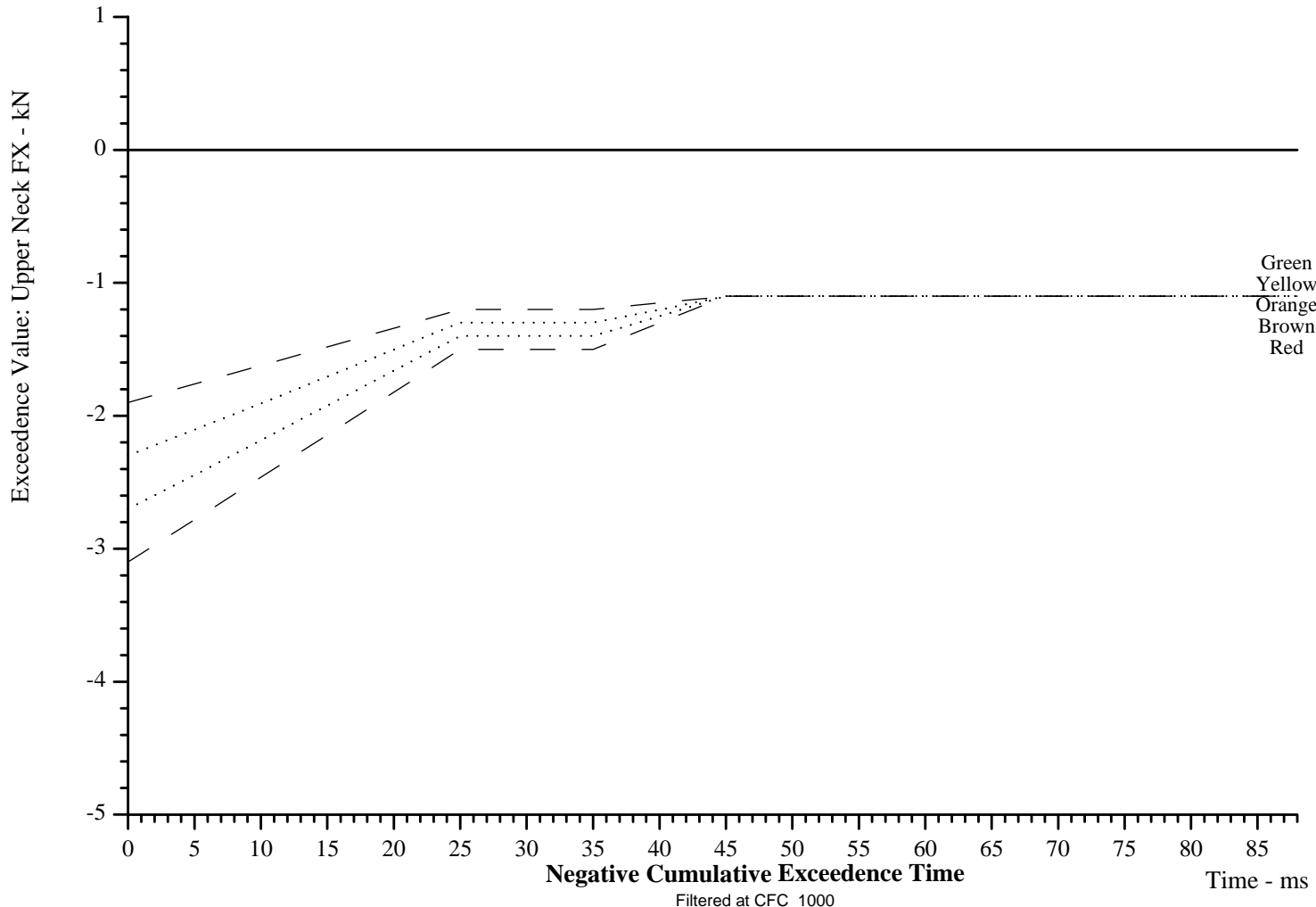
APPENDIX I

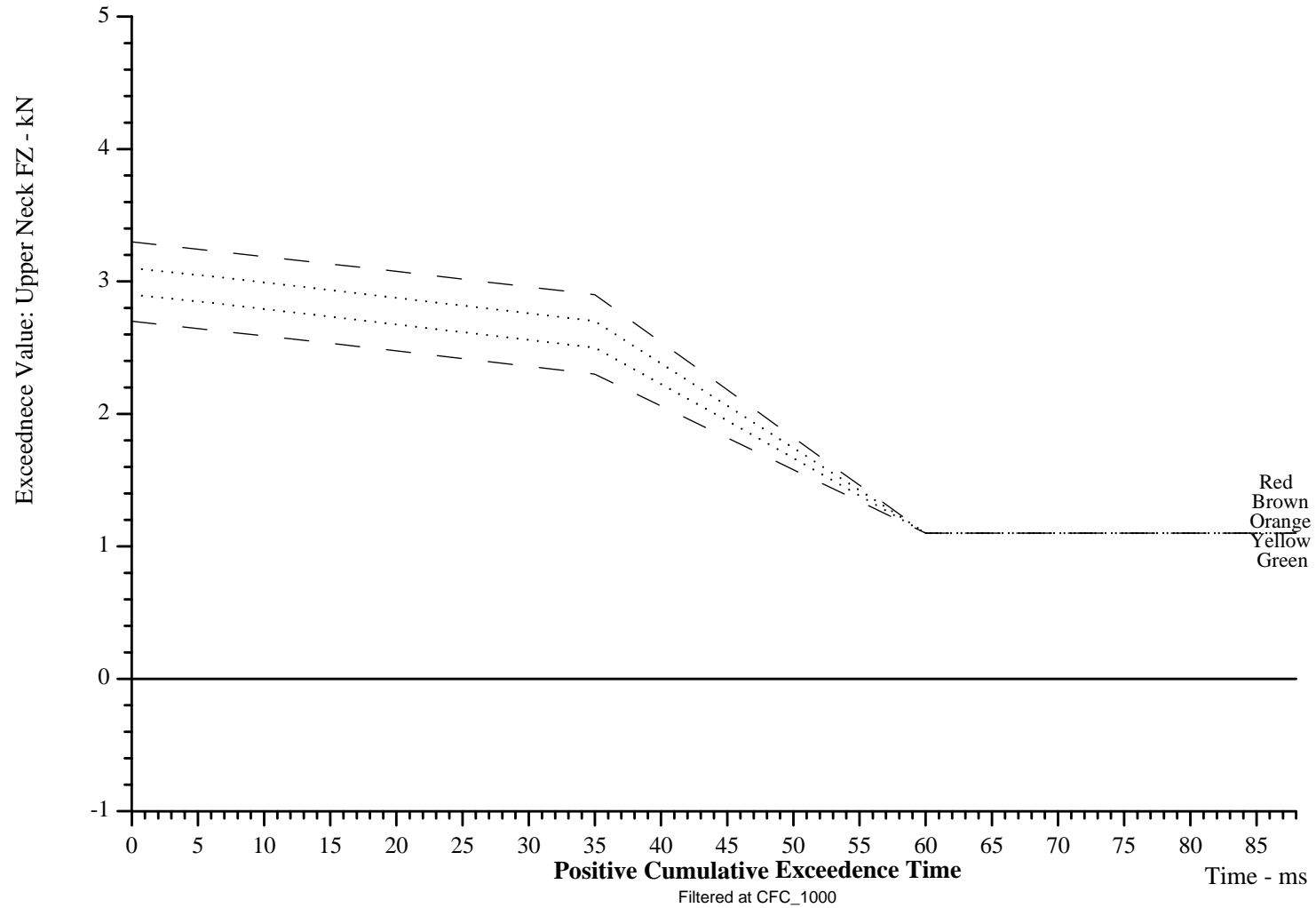
GRAPHICAL LIMITS FOR CUMULATIVE EXCEEDENCE PARAMETERS

- 1 Upper Neck Shear FX - Positive
- 2 Upper Neck Shear FX - Negative
- 3 Upper Neck Tension FZ
- 4 Femur Compression

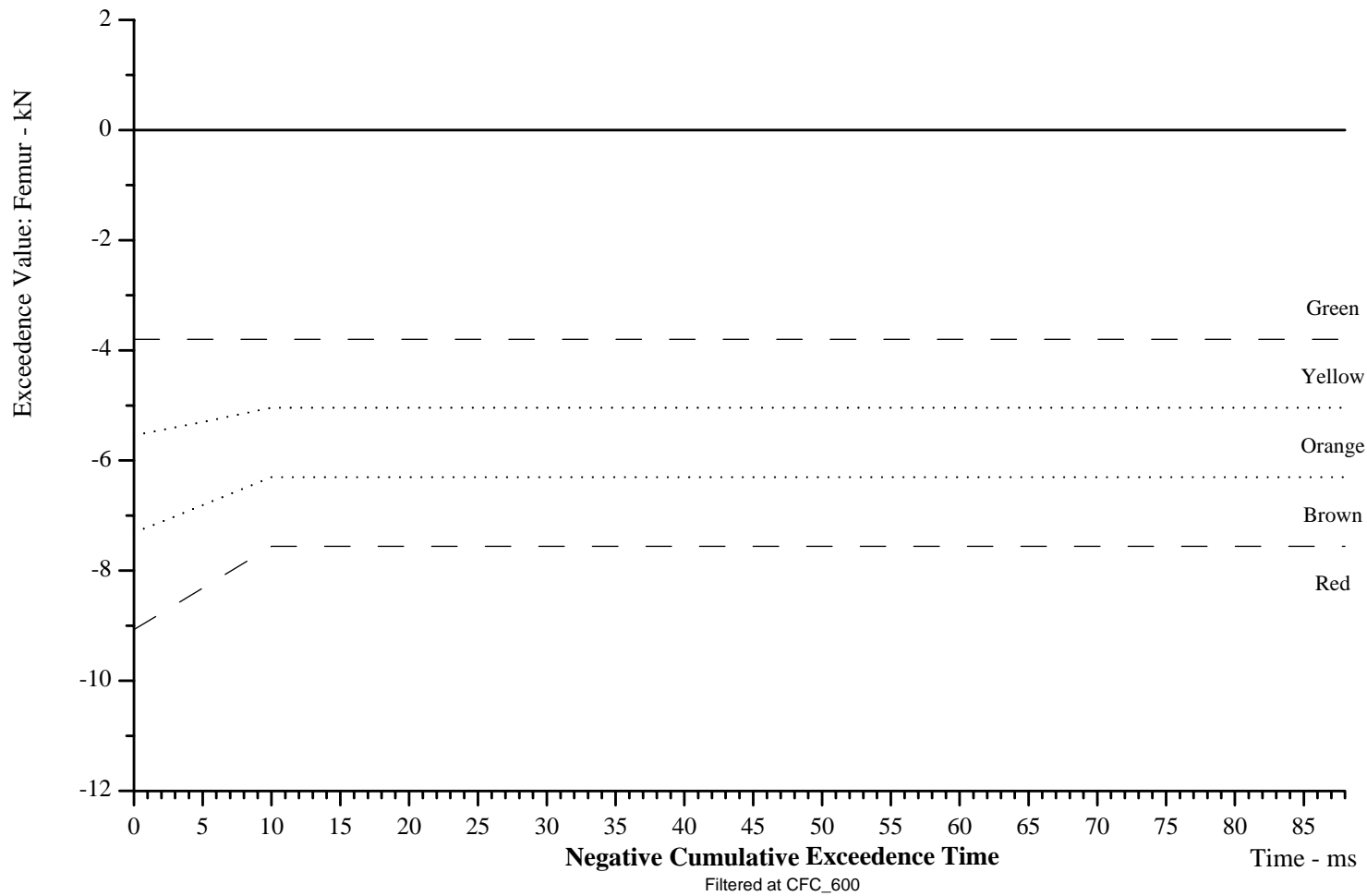


Cumulative Exceedence Limits





Cumulative Exceedence Limits



Negative Cumulative Exceedence Time

Filtered at CFC_600

Cumulative Exceedence Limits