Deviation Request UKTSO-C127c.Dev.002

For an UKTSO approval for CS-UKTSO applicable to Rotorcraft, Transport Aeroplane, and Small Aeroplane Seating Systems

(UKTSO-C127c)

Consultation Paper

1 Introductory Note

The UK CAA has received the following request for Deviation to a CS-UKTSO requirement in accordance with the provisions of Part 21.A.610.

In accordance with the UK CAA Design and Certification procedures, such deviation requests shall be assessed by the authority and be subject to a period of public consultation of not less than 3 weeks except if they have been previously agreed and published by the UK CAA.
All interested persons may send their comments referencing this Deviation Proposal number to the email address Certification.Airworthiness@caa.co.uk. The consultation period will close on 21 August 2026

The final decision shall be published by the UK CAA.

2 UK.UKTSO-C127c.Dev.002 Rotorcraft, Transport Aeroplane, and Small Aeroplane Seating Systems

2.1 Summary of Deviation

The proposed deviation pertains to CS-UKTSO Amendment 17, UKTSO-C127c, Section 3.1.1, which establishes the acceptable interaction between the upper torso restraint and the occupant’s neck across all seat configurations, including forward-facing, rear-facing, side-facing, and oblique seats. This requirement applies to both vertical and longitudinal dynamic test conditions (structural and occupant injury assessments) conducted as part of the qualification procedures specified in SAE AS8049/1B, SAE AS6316, and SAE AS8049C, Section 5.3.9.7.

2.2 Original Requirements

Original test requirement stated in the following minimum performance standards.

- SAE AS8049C, ‘Performance Standard for Seats in Civil Rotorcraft, Transport Aircraft, and General Aviation Aircraft’, dated August 2015 - Section 5.3.9.7 “Retention of Upper Torso Restraint Straps”:

  “Retention of the upper torso restraint straps on the Anthropomorphic Test Device (ATD) shoulders can be verified by observation of photometric or documentary camera coverage. The straps must remain on the ATD's shoulder until the ATD rebounds after the test impact and the upper torso restraint straps are no longer carrying any load. **The straps must not bear on the neck or side of the head** and must not slip to the upper rounded portion of the upper arm during that time period”**.**

- SAE AS8049/1b “Performance Standard for Seats in Civil Rotorcraft, Transport Aircraft, and General Aviation Aircraft”, dated December 2016 - Section 5.3.9.7 “Retention of Upper Torso Restraint Straps”:

  “Retention of the upper torso restraint strap on the ATD's forward shoulder can be verified by observation of photometric or documentary camera coverage. **The strap must remain on the ATD's shoulder until the ATD rebounds after the test impact and the upper torso restraint strap is no longer carrying any load.”**.

- SAE AS6316 “Performance Standards for Oblique Facing Passenger Seats in Transport Aircraft”, dated June 2017 – Table 2 – Occupant injury criteria:

  “(4) Concentrated loading on the neck is unacceptable during any phase of the test and the neck shall not carrying any load between the ATD and the seat system”.

2.3 Industry

Based on the test requirements specified in SAE AS8049C, SAE AS6316 and SAE AS8049/1B Section 5.3.9.7, there is ambiguity regarding the pass/fail criteria requirement for upper torso restraint (shoulder harness) interaction with ATD’s neck.

The standard mandates that the shoulder harness “must not bear on the neck or side of the head”.

2.3.2 Clarification of Terminology

a) ‘Bear on the neck’: To have an effect on or exert pressure or load, or rest with force, on the neck. In this context, bearing on the neck is understood to mean load carrying contact (i.e., predominant load path through the neck) during the dynamic test.

b) ‘Must not bear on the neck’ is understood to be that the upper torso restraint strap must not function as a predominant load path through the neck and must not impose compression, constriction, or concentrated loading on the neck. Conversely, incidental contact of the upper torso restraint is not considered to “bear on the neck (i.e., contact without belt-to-neck compression or without belt routing into the anterior neck and where the belt load path remains across the thorax, whilst under tension load).

2.3.2 Discussion

a) By design, a 3-point restraint system, comprising of a lap belt and single upper torso restraint, requires that the upper torso restraint passes diagonally across the torso from an exit or anchor point near the neck to a buckle.

b) During a typical 16g test (Figure 1), the upper torso restraint remains in or very close to this condition until the belt is loaded as the pulse is applied. Whereupon the predominant motion of the ATD is forwards into the upper torso restraint strap, causing tension loads to build in the strap as it reacts to the flail and restrains the occupant.

   i. Nonetheless, this condition (Figure 1), could introduce conditions where the belt travels towards the neck. This load path influences the behaviour / motion of the ATD by limiting the forward flail, thus achieving the primary purpose of the upper torso restraint.

c) During a 14g test (Figure 2), the initial predominant motion of the ATD is downwards, away from or ‘out’ of the belt as the ATD compresses the seat cushion and seat pan, leading to displacement of the ATD downwards by a relative amount depending on the seat design. This allows for the possibility of relative movement of the upper torso restraint and the ATD before the ATD begins to rotate forwards and rebound upwards to then load the belt.

   i. The interaction between the ATD and the seatbelt and subsequent build-up of loads in the restraint does not start until late in the test (ca. 110 – 120ms) and after the peak sled pulse, providing significant opportunity for the ATD head and neck to move relative to the shoulder restraint once initial tension is lost and prior to any significant interaction between the upper torso restraint and neck.

ii. A ‘grazing’ or brushing contact between the upper torso restraint strap and the ATD neck under 14g conditions (Figure 2) does not introduce a significant change in load path and is unlikely to influence the behaviour/motion of the ATD and is therefore considered incidental in nature.

d) In both test conditions described, a qualitative evaluation of upper torso restraint-to-neck interaction could be performed taking into consideration that the peak restraint tension load is achieved and during that time, that the belt must not slip onto the neck. The potential safety concerns associated with interaction of the upper torso restraint with the neck in both conditions could be also assessed by taking into consideration, the tension load in the upper torso restraint. **However, there are no objective criteria defined, to date, that address this. There is also no correlation, to date, between upper torso restraint tension loads to potential neck injuries.**

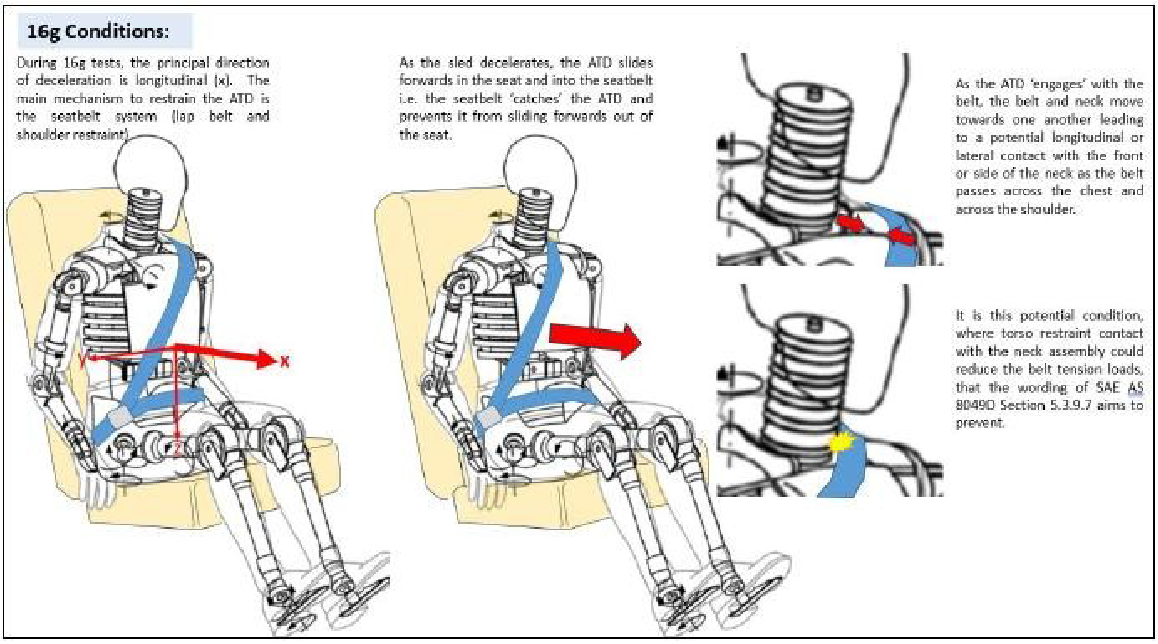

Figure 1 - 16g Loading Scenario

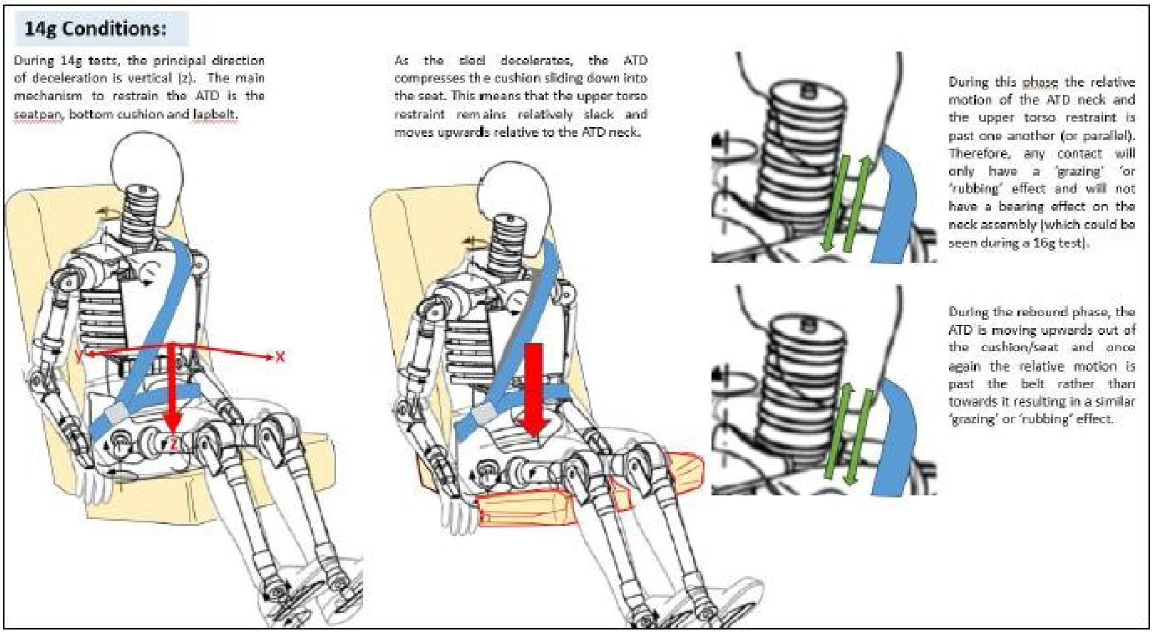

Figure 2 - 14g Loading Scenario

e) Although the standard specifies that the upper torso restraint straps must not bear on the neck or the side of the head, a reasonable contact with the neck could be considered acceptable during 14g, 16g and lower (e.g., 9g threshold) test cases if the contact has no significant influence on the ATD head or neck or their relative movement during the tests. In other words, the proposed criteria will clarify **to what extent contact with the neck can occur, while not resulting in the torso restraint 'bearing on the neck'**.

2.3.3 Clarification of The Neck Anatomic Margin

a) FAA Hybrid III ATD

i. Research Paper 912895 (Thoracic Injury Assessment of Belt Restraint Systems Based on Hybrid III Chest Compression) clarifies that the Hybrid III neck assembly is narrower than the 50th percentile male neck. A belt could be placed or dynamically moved to a position inside the anatomic margin of the human neck, resulting in belt routing that cannot be attained for an occupant. The Hybrid III incorporates a 'belt guide' (Figure 3) at the margin of a 50th percentile male neck to assure that the belt remains on the shoulder, outside the anatomic margin of the neck. Thus, the contact between the belt and belt guide is per the design intent of the ATD.

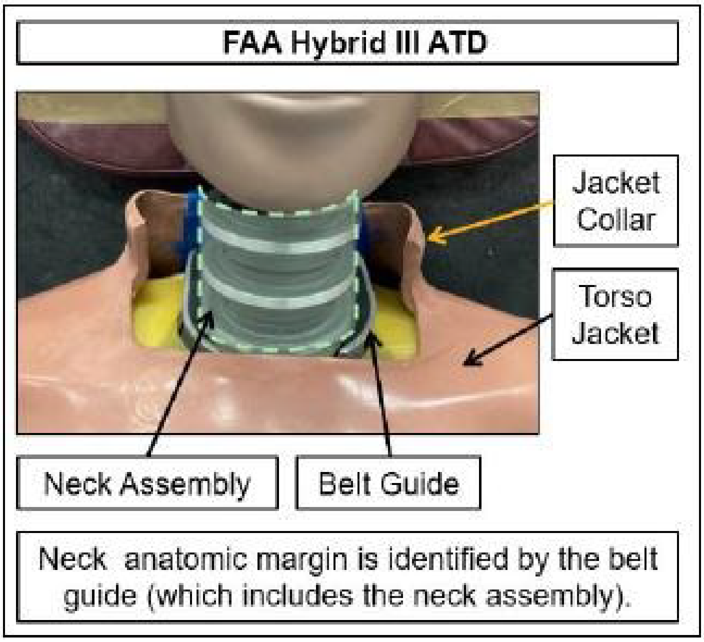

Figure 3 - FAA Hybrid III - Neck Anatomic Margin

b) The 50th percentile Hybrid II ATD neck is part of the ATD head assembly and a close representation of the human neck, shown in Figure 4, (i.e. for a 50th percentile male), which is unlike the FAA Hybrid III ATD.

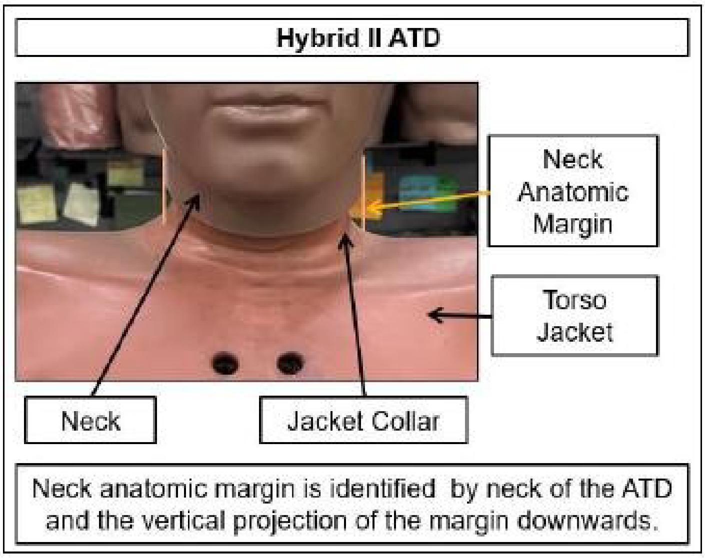

Figure 4 - Hybrid II - Neck Anatomic Margin

2.3.4 MOC Proposal

From the rationale outlined in the previous sections, supported by the evidence reviewed and researched (detailed in Appendix A), it is proposed that the upper torso restraint strap shall be allowed to contact the neck, during the dynamic event, while loaded, at a maximum upper torso restraint strap tension load value of 2500 N (562 lb.). Industry research identifies this load value as associated with a maximum Abbreviated Injury Scale (AIS) Level 1.

2.3.4.1 Demonstration of Compliance with FAA Hybrid III ATD

a) Pass / Fail Criteria for tests with FAA Hybrid III ATD:

i) Evaluation Criteria (Photometric and upper torso restraint tension load review):

(1) The tension load in the upper torso restraint strap shall not exceed 2500 N (562 lb.) at any point that the strap contacts the neck (which includes the belt guide and the neck assembly).
Note 1: At tension loads of 2500 N (562 lb.) or lower, it is permissible for the upper torso restraint strap to contact any part of the ATD neck (such as the belt guide, the rigid tape attached to the belt guide (Figure 5), and the neck assembly).
Note 2: If there is evidence that the upper torso restraint strap contacts the ATD torso jacket at a tension load higher than 2500 N (562 lb.) and it is evident that the torso jacket is compressed against the belt guide, the test is null. The jacket must be cut off to expose the belt guide (Figure 6 & Figure 7) so that assessment of contact is clear.

ii) Proposed approach for evaluation:

(1) Cut the ATD T-Shirt to expose the belt guide.
(2) Fix a rigid tape/coloured paper vertically on the inner surface of the belt guide. A minimum of 20mm of the tape should be exposed above the upper edge of the belt guide. (Figure 5).
(3) The ATD torso jacket should be cut so that the belt guide is fully visible to improve observation of contact. Examples of this cut out are shown in Figure 6 & Figure 7 **Note:** The marking of the belt guide and the rigid tape should be in contrast with the colour of the ATD T-shirt and of the upper torso restraint strap in order to facilitate contact assessment.
(4) Assessment should also be conducted to evaluate any torso jacket movement or slippage toward the neck when the upper torso restraint strap is under load.

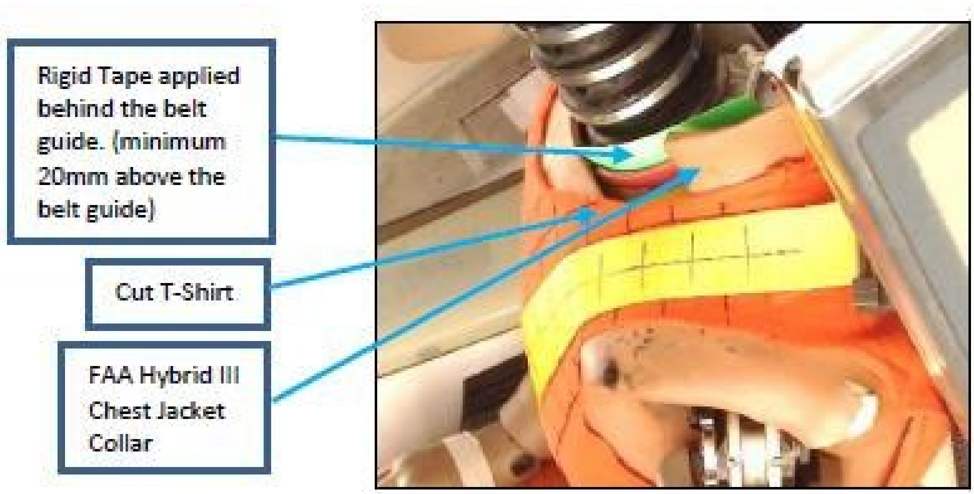

Figure 5 - Identification of Contact with Belt Guide on FAA HIII ATD

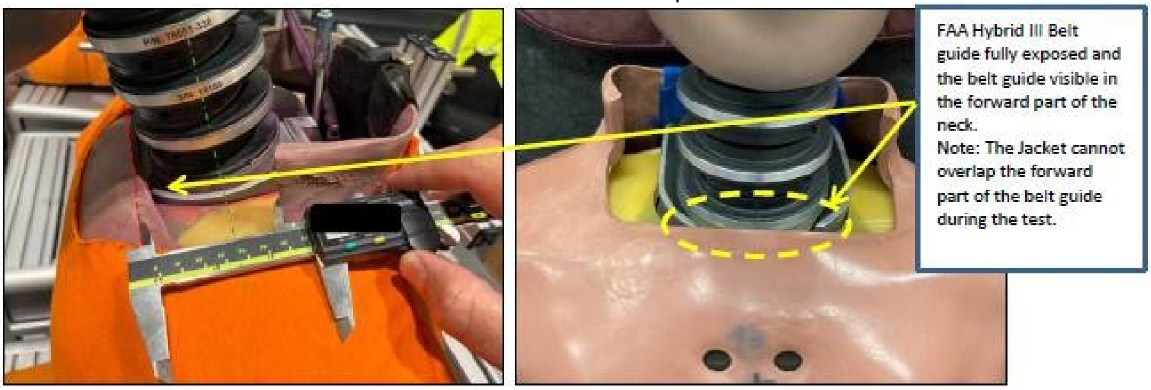

Figure 6 - Expose the belt guide at the areas shown

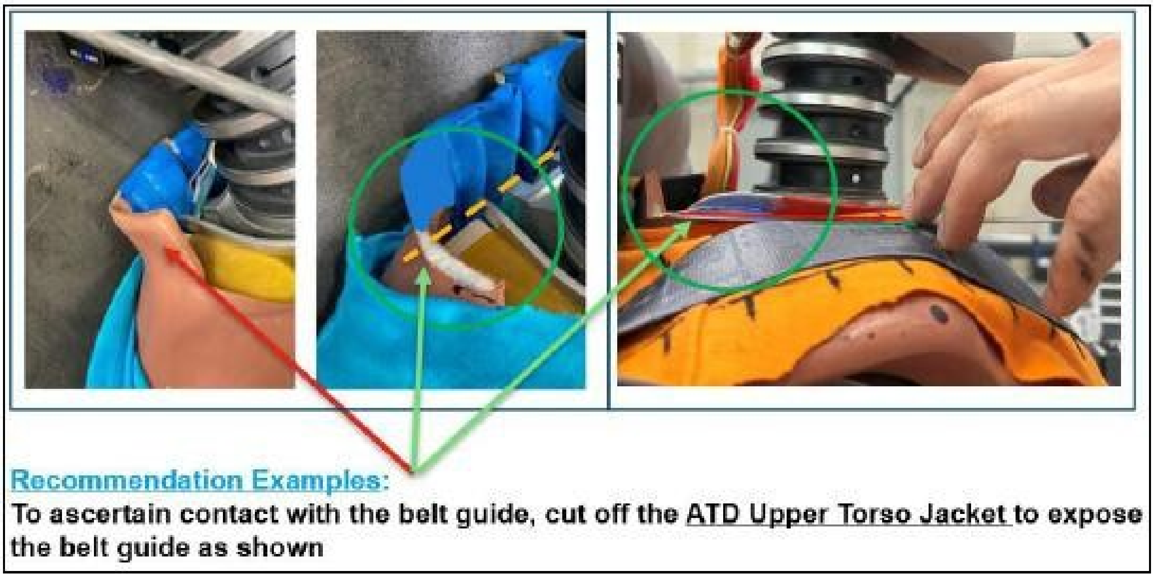

Figure 7 - Example of area of the ATD Torso Jacket cut-off to expose the belt guide

iii. Examples of acceptable contact of the upper torso restraint strap with the FAA Hybrid III ATD neck, for strap tension load values of 2500 N (562 lb.) and lower, are shown in Figure 8.

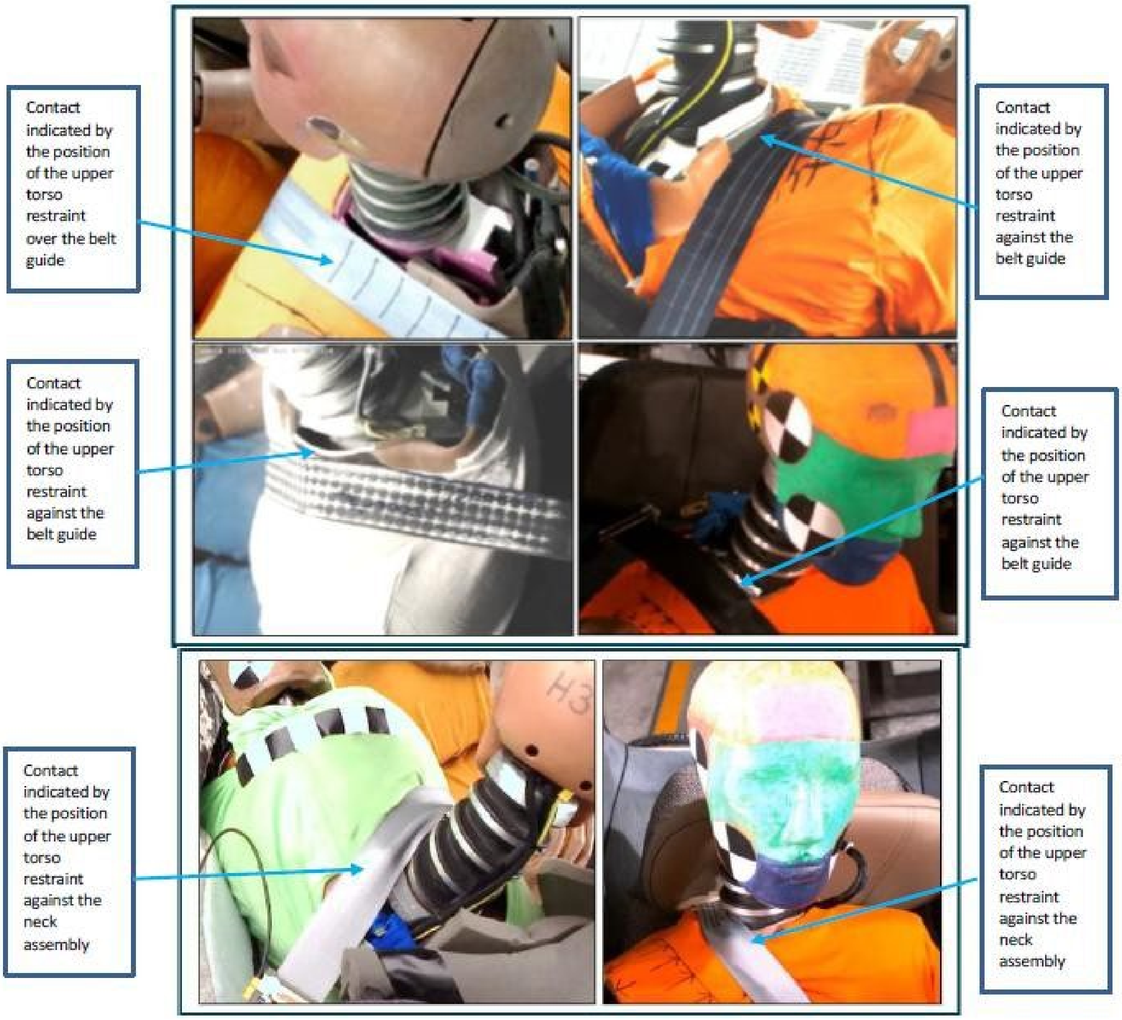

Figure 8 - Acceptable contact with belt guide without further review. (upper torso restraint tension load of 2500 N (562 lb) or lower)

2.3.4.1 Demonstration of Compliance with Hybrid II ATD

a) Pass/Fail criteria for tests with Hybrid II ATD:

i) Evaluation Criteria (Photometric and upper torso restraint tension load review):

(1) The tension load in the upper torso restraint strap shall not exceed 2500 N (562 lb.) at any point that the strap contacts the ATD face and neck (area bound by the red line and its vertical projection, per Figure 9).
Note 1: At tension loads of 2500 N (562 lb.) or lower, it is permissible for the upper torso restraint strap to contact the neck projection assessment area (per Figure 9) and to go below or inside the anatomic margin of the neck (per Figure 10).
Note 2: Contact of the upper torso restraint strap at any other area clarified in Figure 9 is permissible, regardless of the strap tension load.
Note 3: If there is evidence that the upper torso restraint strap contacts the ATD jacket at a tension load higher than 2500 N (562 lb.) and it is evident that the jacket is compressed against the Hybrid II ATD neck (area identified by the red line, per Figure 10), the test is null. The test should be repeated using a different jacket (on the same Hybrid II ATD or on another Hybrid II ATD) so that assessment of contact with the neck is clear.

ii) Proposed approach for evaluation:

(1) Cut the ATD T-Shirt to expose neck projection assessment area.

(2) The marking on the ATD neck should be in contrasting colour with the colour of the ATD T-shirt and of the shoulder harness.

(3) Assessment should also be conducted to evaluate any torso jacket movement or slippage toward the neck when the upper torso restraint strap is under load.

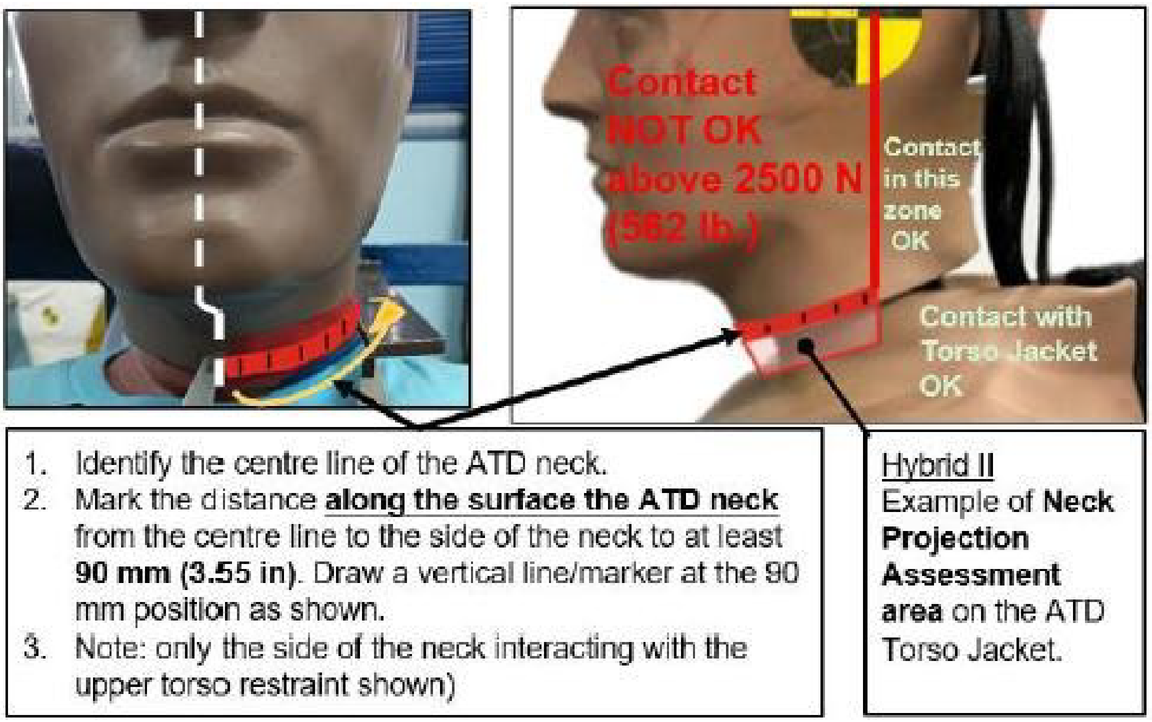

Figure 9 - Hybrid II ATD Marking to facilitate identification of contact

Note: This stay-out zone is conservatively derived per APPENDIX A Section 3 and Figure 12.

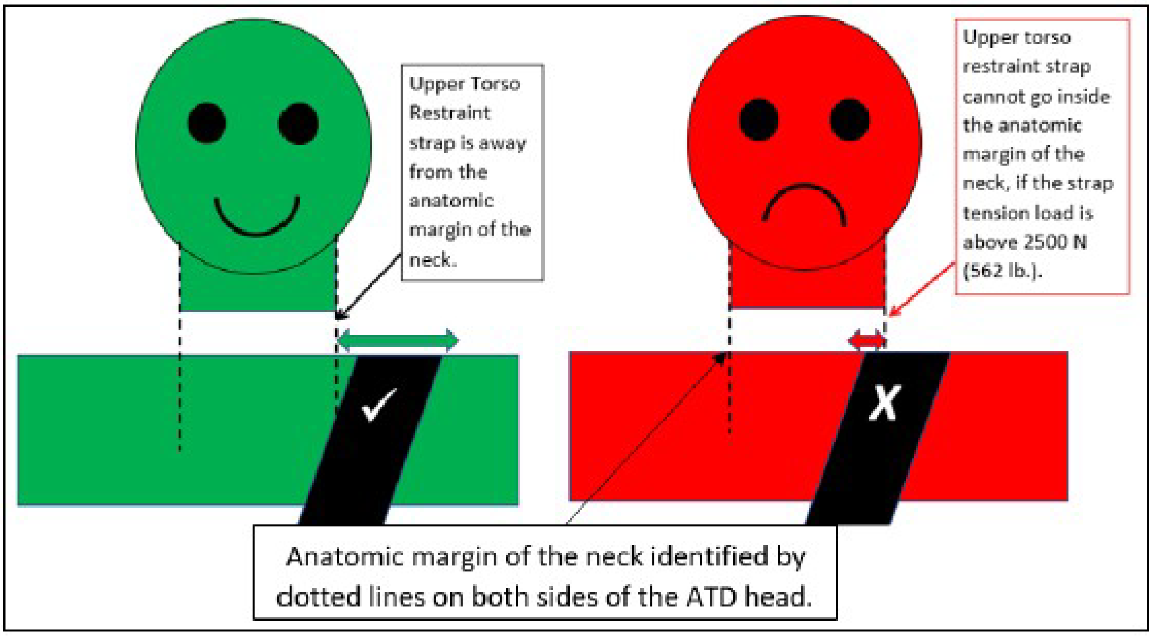

Figure 10 - Acceptable and Unacceptable contact with the anatomic margin of the neck

2.4 Equivalent Level of Safety

In the context of mitigating occupant injury, the UK CAA considers the criteria proposed in paragraph 2.3.4 to be appropriate. The research data presented in Appendix 1, encompassing both automotive and aviation studies, demonstrate that upper torso restraints are highly effective in reducing the risk of serious injury by restraining the torso and thereby limiting occupant flail.

As documented in SAE Paper 902313, Neck Response and Injury Assessment Using Cadavers and the US-SID for Far Side Lateral Impacts (1990), the automotive industry conducted lateral impact testing using seven Post-Mortem Human Subjects (PMHS) at impact angles of 60 and 90 degrees, resulting in loading of the shoulder restraint system [Ref A.4.a]. During these tests, upper torso restraint tension loads reached 2,500 N (562 lb). Subsequent examination of the subjects' cervical spines revealed either no injury or only minor injuries, classified as AIS 0 or AIS 1. While aviation regulations permit injuries below AIS 3, the upper torso restraint load at which neck injuries would progress to AIS 2 or AIS 3 has not been established. Consequently, the proposed limit of 2,500 N (562 lb) is considered conservative.

For the FAA Hybrid III Anthropomorphic Test Device (ATD), the Neck Anatomic Margin is defined in paragraph (a) of Appendix 1, based on Research Paper 912895, Thoracic Injury Assessment of Belt Restraint Systems Based on Hybrid III Chest Compression.

For the Hybrid II ATD, the shoulder-harness stay-out zone applicable when upper torso restraint tension loads exceed 2,500 N (562 lb) has been conservatively derived in accordance with Appendix 1, Section 4, and Figure 12.

2.5 UK CAA position

The UK CAA accepts the deviation.

APPENDIX 1
SUPPLEMENTARY DATA & RESEARCH REFERENCES

1) Abbreviated Injury Scale (AIS) - Extract from FAA Report - Civil Aircraft Side-Facing Seat Research Summary (R. DeWeese, D. Moorcroft, A. Abramowitz & J. Pellettiere; 2012)

a) This report uses the latest advancements in side-facing seat impact testing technology and biomechanical knowledge to identify new testing / injury assessment methods necessary to provide a safety level for side facing seats that is the same as that of forward or aft facing seats.
b) The AIS (Abbreviated Injury Scale) is reviewed and presented in detail.
c) To allow occupant egress following a survivable aviation accident, it is accepted that injuries should be kept to AIS 2 or lower.

2) **Review of Automotive Industry Research & tests.**

a) Relevant research and test evidence is available within the automotive industry to help understand belt interactions with the neck.
b) The automotive industry research also uses the Abbreviated Injury Scale (AIS) criteria to define injury limits. As such, the data presented within the automotive research and tests can be used for the purpose of an objective assessment, in cases where the automotive test conditions are representative of an aircraft seat dynamic test condition.
c) The automotive industry testing covers crash test angles at varying range, from 0 degree to 90 degrees (side impact) tests.
d) To make a conservative assessment of upper torso restraint contact with the neck, the oblique and side impact automotive tests are primarily considered (e.g., tests where the impact angle is between 60 to 90 degrees to the occupant.
e) In research by BMW [A.4a], 'Far side' lateral impact tests have been carried out where the impact direction of the ATD head and neck is towards the upper torso restraint strap. In this test

condition, the seat belt installation (especially the upper torso restraint strap) is 'reversely' installed, creating a real loading condition between the strap and the ATD neck. The test subjects used in these tests are cadavers and US SID. The collision velocity was 50 km/h. The maximum upper torso restraint forces measured were 2500 n (562 lb.). Analysis of the highspeed films, lateral head-neck bending angles of 40 to 65 degrees were noted and investigated. There were no head, thorax or pelvic injuries observed on the cadavers. Upper torso induced minor injuries at the skin on the neck, neck muscles and cervical spine, with a maximum AIS of 1. The impact energy of the tests was a close representation of aircraft seat dynamic test conditions, (with the impact velocity at 50 km/h, with a peak of 18g, when compared with 16g dynamic test condition, which represents an impact velocity of 48.3 km/h). The 'reverse' installation of the upper torso restraint closely represents aircraft seat upper torso restraint installation. The test orientation ensures maximum interaction of the upper torso restraint with the neck and as such this research is relevant to the intent of this technical proposal.

f) Automotive testing performed by Ford [A.4c and Figure 11], shows comparable ATD behaviour when compared to aircraft seat dynamic side testing (90 degrees impact). Tests were performed at a pulse of 15g-16g, with impact velocity of 21 km/h. The tests performed were supplemented with Post-Mortem Human Subjects (PMHS) to gather information on the upper torso restraint interactions with soft tissue of the neck. PMHS upper and lower body were unrestricted during the side-impact tests. The PMHS carotid arteries were pressurized in an attempt to simulate the corresponding neck vascular response of living humans. Post-test autopsies conducted on all test subjects indicated an absence of test-induced arterial or vertebral injuries, resulting in AIS of less than 2. The tension loads recorded in the upper torso restraint straps ranged between 1400 N (352 lb.) and 2000 N (449 lb.). As shown in Figure 11, the behaviour of the ATD and PMHS in these tests aid in an improved assessment of the belt interaction with the neck. The post-test autopsies confirm the absence of serious injuries to the neck and blood vessels at the specified test loads.

g) Automotive 'roll-over' tests [A.4d] were conducted to evaluate occupant interactions within seats with upper torso restraints. The roll-over tests are conducted with a speed of approximately 45km/h. In the 'reversed' installation, the upper torso restraints interacted with the vertical surface of the ATD neck. The lower neck bending loads were reviewed to be extremely low (i.e., <1KN), indicating harmless belt to neck interactions.

h) Research conducted by Volvo [A.4k] combined accident investigation, staged collisions and simulated collisions involving three-point harnessed occupants in frontal force collisions to provide a means of correlating injury with forces and/or other physical parameters associated with the injuries. With strict screening to ensure complete data on each accident, 128 cases involving 169 occupants at barrier impact velocities of 3-85 km/h were compared with the results from 11 staged collisions and 72 simulated collisions. There were 14 rib cage injuries at velocities of 16-85 km/h at injury levels of AIS 2 and 3. A single AIS 4 injury was the most serious injury and consisted of ruptured spleen. The most serious brain injury was AIS 2. Out of the number of collisions, only 14 occupants had AIS 3 injuries. No abdominal organ injuries, thoracic organ injuries, clavicle fracture, breast injures, or eye injuries were reported and there were no AIS 5 or fatalities in the sample. This extensive collision research evidence confirms the upper torso restraint strap is highly effective in mitigating injuries to the torso, rib and sternum areas. It was noted from the research material that *the overall tolerance level for 50% injury at the AIS 3 level is 72 km/h (45 mph) at an upper torso restraint strap tension load of 8585 N (1930 lb.) and a peak resultant chest acceleration of 85g*. This upper tolerance of upper torso restraint load helps to frame the criticality limits of interactions of torso restraint with the neck. Referring to the research by BMW (A.5a) where AIS 1 was recorded for crash test at 50 km/h and the registered upper torso restraint loading was 2500 N (562 lb.).

i) In summary, the automotive crash test evidence reviewed demonstrates that in the longitudinal test conditions, the resulting AIS level is still quite low (i.e. within AIS<2). This indicates that on 16g dynamic load conditions, the criticality of interactions with the neck is low. [A.4a] [A.4c] [A.4f].

j) The automotive research has not evaluated test conditions in the downwards direction (i.e., 14g down). These test load cases, where the upper torso restraint is only touching or sliding against the neck, are likely to produce AIS levels even lower than those seen during the automotive (longitudinal) side impact tests (i.e., AIS<<2).

k) Following the research review and data presented the following observations are concluded:
   i) There is relevant research evidence within the automotive industry to help assess acceptable belt interactions with the neck.
   ii) The Abbreviated Injury Scale can be used as a common link between automotive research and the aerospace seat dynamic test conditions, and their corresponding injury assessment criteria.
   iii) The extent to which the belt interacts with the neck in automotive testing research is much more pronounced than the incidental contact of belt with the neck bracket, seen during aircraft seat dynamic testing. [A.5a].
   iv) Automotive tests have shown that during tests where upper torso restraint tension loads are recorded, the maximum restraint loads of up to 562 lb. correspond to an AIS 1. Although aviation regulation disallows serious injuries (i.e., permits injuries that are less than AIS 3), it is unknown, at what upper torso restraint tension load, the neck would reach AIS 2 or AIS 3. Therefore, the proposed limit of 2500 N (562 lb.) is conservative.
   v) Further research reviewed from Volvo [A.5k] has presented that the overall tolerance level for 50% injury at the AIS 3 level is 72 km/h (45 mph) at an upper torso restraint strap tension load of 8585 N (1930 lb.) and a peak resultant chest acceleration of 85g.

l) Based on the research, it is indeed possible to define acceptable interactions between the shoulder harness and the neck.

Stapp Car Crash Journal, Vol. 50 (November 2006), pp. 267-298

2006-22-0012

Biomechanics of 4-Point Seat Belt Systems in Farside Impacts

Stephen W. Rouhana, Sundeep V. Kankanala, Priya Prasad
Ford Motor Company

Jonathan D. Rupp*, Thomas A. Jeffreys*, Lawrence W. Schneider*†
*University of Michigan Transportation Research Institute
†The University of Michigan Department of Biomedical Engineering

ABSTRACT – The biomechanical behavior of a harness style 4-point seat belt system in farside impacts was investigated through dummy and post mortem human subject tests. Specifically, this study was conducted to evaluate the effect of the inboard shoulder belt portion of a 4-point seat belt on the risk of vertebral and soft-tissue neck injuries during simulated farside impacts.

Two series of sled tests simulating farside impacts were completed with crash dummies of different sizes, masses and designs to determine the forces and moments on the neck associated with loading of the shoulder belt. The tests were also performed to help determine the appropriate dummy to use in further testing. The BioSID and SID-IIs reasonably simulated the expected kinematics response and appeared to be reasonable dummies to use for further testing. Analysis also showed that dummy injury measures were lower than injury assessment reference values used in development of side impact airbags.

Countermeasures that reduce head excursions must be designed to not increase the likelihood of injury to other body regions. The thorax restraint used in the present study increased lateral chest displacements to injurious levels. An inboard shoulder belt also reduced head excursions, but proper belt placement is critical. Specific placement directly over the shoulder is easier to control in a ATD than it would be in a real human. A mispositioned shoulder belt, such as the high position for the inboard belt (Configurations 8-9, 14-15) may cause high loads and neck lateral bending, placing the internal structures such as the vascular system and spinal column at risk for trauma (Sinson et al. 2003). Rouhana et al. (2006) tested a four-point belt system using PMHS in a far side impact mode and demonstrated no carotid artery injury with optimal "low" belt positioning. In the PMHS test for configuration-9 with a "high" belt position a carotid artery intimal tear was found after histological sectioning was done. This injury did not occur on the "pinching" (right) side, but rather on the "stretching" (left) side. The tension mechanism for carotid artery intimal tears has been well documented (Stemper et al. 2008) and appears to be the cause in this

Figure 11 - Example of Automotive Industry Test / Research and relevant extract

3) Serious Injury

a) The level of injury for an Abbreviated Injury Scale (AIS) level 2, is associated with contusion and hematoma (bruises under skin).

b) The level of injury for AIS 3 is associated with obstruction of airways and avulsion (body tissue, skin or bone forcibly torn away from attachment, penetrating / laceration / Carotid artery / Vertebral Artery/ Jugular Vein puncture and injuries associated with Nerve bilateral), with 20% blood loss (serious injury).

i) Within the automotive research, there are no recorded cases where this level of injury occurs because of the upper torso restraint contact with the neck. ii) Likewise, such injuries are extremely unlikely as the upper torso restraint strap is not a sharp object that would puncture the skin via compression contact.

iii) In terms of strangulation as a possible injury mode, pressure on the carotid artery, jugular, trachea is not considered, as pressure will need to be applied for 10s before person is unconscious, whereas the crash impact takes place in milliseconds. (Source Ref : https://www.supremecourt.gov/opinions/URLs_Cited/OT2021/21-783/21-783-2.pdf). The most likely case of an AIS 3 injury scenario is when upper torso restraint contacts the neck with a force that is large enough and sustained (>10s) to result in damage to larynx and trachea.

iv) This leads to the conclusion that airway obstruction and avulsion injuries are non-existent in the crash test conditions that seats are subjected to.

c) A typical anatomy of the neck is shown in Figure 12. The carotid artery is located within the upper half, forward zone of the neck (i.e., within the anterior triangle of the neck, shown in green) and is bound by the Sternocleidomastoid muscle. This information helps clarify the potential area where, contact of the upper torso restraint on the neck, may result in serious injury and therefore can be used to identify an area where such contact would be acceptable.

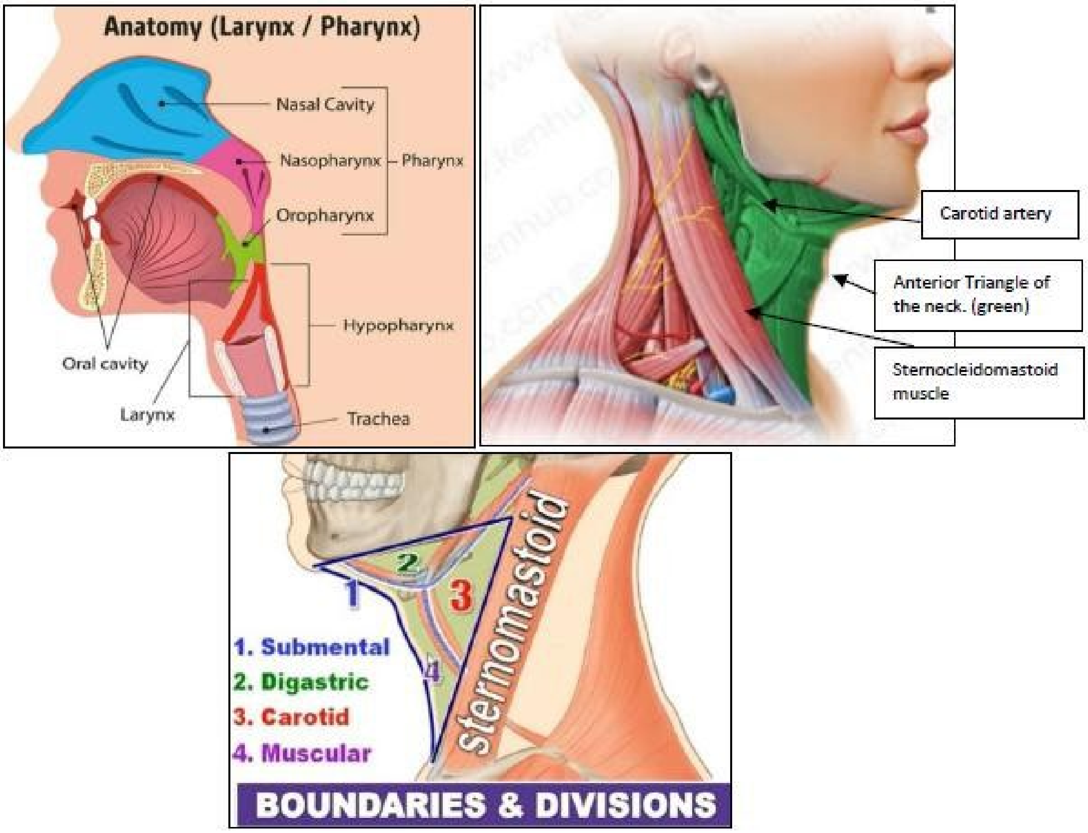

Figure 12 - Clarification of Neck Area and Anterior Triangle of the Neck (Source: https://www.kenhub.com/en/library/anatomy/carotid-triangle)

In Summary, although bearing of the upper torso restraint onto the torso fulfils the intent of dynamic test, measures can be put in place to clarify what areas of the neck could be considered prone to sustained compression or injury leading to AIS >3 levels. This evaluation is intended to be further reviewed as part of a follow-on phase (Phase 2) to this proposal.

4) References to Research Data

a) SAE 902313: Neck Response and Injury assessment using Cadavers and the US-SID for Far Side Lateral Impacts, 1990.

b) SAE 912895: Thoracic Injury Assessment of Belt Restraint Systems Based on Hybrid Ill Chest Compression, 1991.

c) Stapp Car Crash Journal, Vol 50: Biomechanics of 4-Point Seat Belt Systems in Far-side Impacts, Ford, 2006.

d) Research Paper 05-0204: Seat Integrated 3 Point Belt with Reversed Geometry and an Inboard Torso Side-Support Airbag for Improved Protection in Rollover, 2006.

e) DOT/FAA/AM-12/18: Office of Aerospace Medicine - Civil Aircraft Side-Facing Seat Research Summary, 2012.

f) Accident Report NTSB/AAR-14/01: Descent Below Visual Glidepath and Impact with Seawall Asiana Airlines Flight 214 Boeing 777-200ER, HL7742 San Francisco, California, 2014.

g) SAE Paper No 791005: Response of Belt Restrained Subjects in Simulated Lateral Impact" from J. Horsch, D. Schneider, C. Kroell.

h) Paper 98-S8-W-23: Vehicle Far Side Impact Crashes; Accident Research Centre, Monash University, Clayton, Australia; from R. Stolinski & R. Grzebieta.

i) Stapp Car Crash Journal, Vol 51: Comparison of PMHS, WorldSID, and THOR-NT Responses in Simulated Far Side Impact, Frank A. Pintar, Narayan Yoganandan, and Brian D. Stemper, Medical College of Wisconsin and VA Medical Center Research, Milwaukee, Wisconsin, 2007.

j) Report no. 294: ‘Occupant Protection in Far-Side Crashes’; B. Fildes, K. Digges; Monash University Accident Research Centre.

k) SAE 741181: Three-Point Harness Accident and Laboratory Data Comparison; L. M. Patrick, N. Bohlin and A. Anderson.