SAE DETROIT SECTION

DETROIT SECTION SAE FORMULA SAE WORKSHOP

October 22nd 2011

FRAME DESIGN 101

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FSAE Workshop 2011

Presentation Objective

Agenda

- Basic Requirements
- Side Impact System
- Main Hoop Bracing
- Front Bulkhead Support
- Front Hoop Bracing
- Foot & Toe Protection
- Seat
- Safety Harness Mounting
- Helmet Clearance
- “Percy”
- Cockpit Templates
- Frame Design Process (if we have time)

SEF Submission

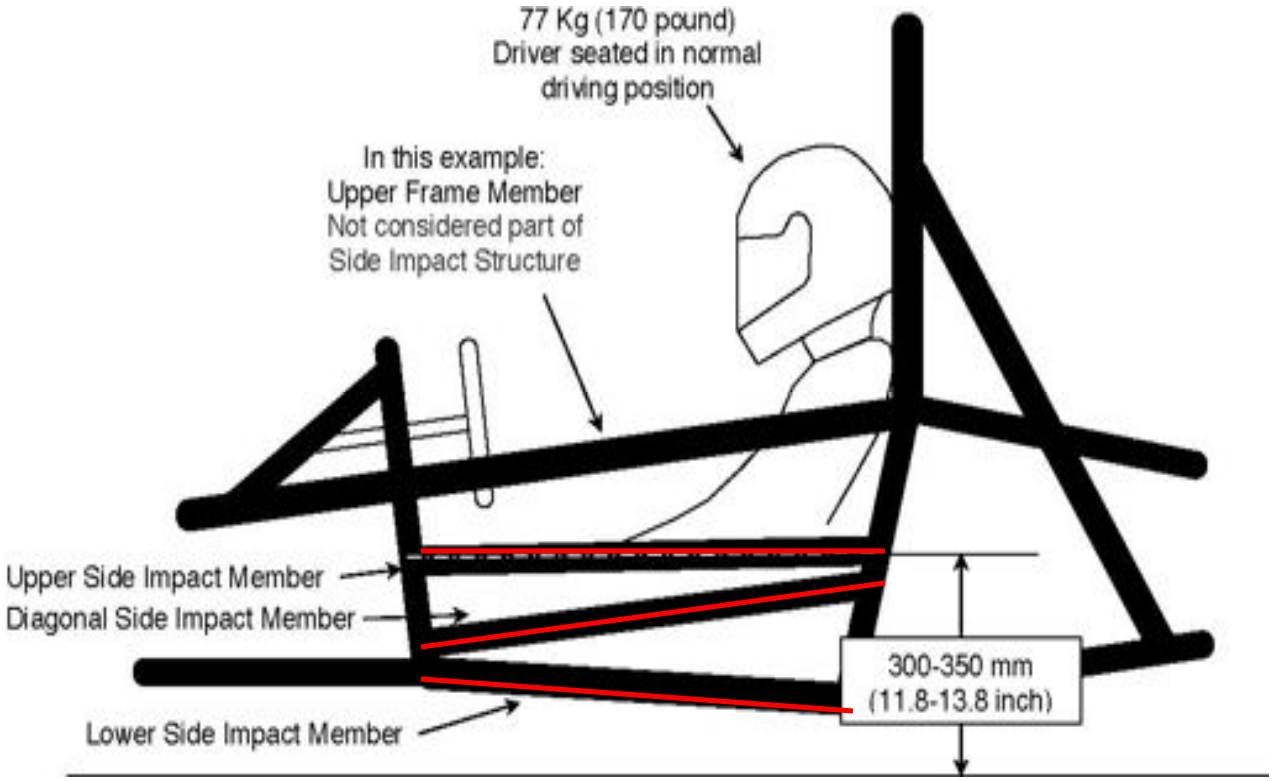
- ALL teams need to submit an SEF!!
- Approvals WILL be required for:
  - Monocoques
  - Deviations from Baseline Material sizes given in B.3.3.1
  - Holes in ANY mandated tube (including shoulder harness mounting bar)
  - Alternate design of IA plate (B.3.20.6)

Basic Rules for Frame Approval

To get a frame approved either via SEF or at Technical Inspection

1. Minimum tube size, 1.00inch OD x 0.049 inch wall
   (25.0 mm x 1.2 mm metric)
2. Triangulation
3. No bent tubes (other than Main Hoop and Front Hoop)
4. Loads from Mandated Tubes go to Structural Nodes

Side Impact Requirements



B.3.24 Tube Frames

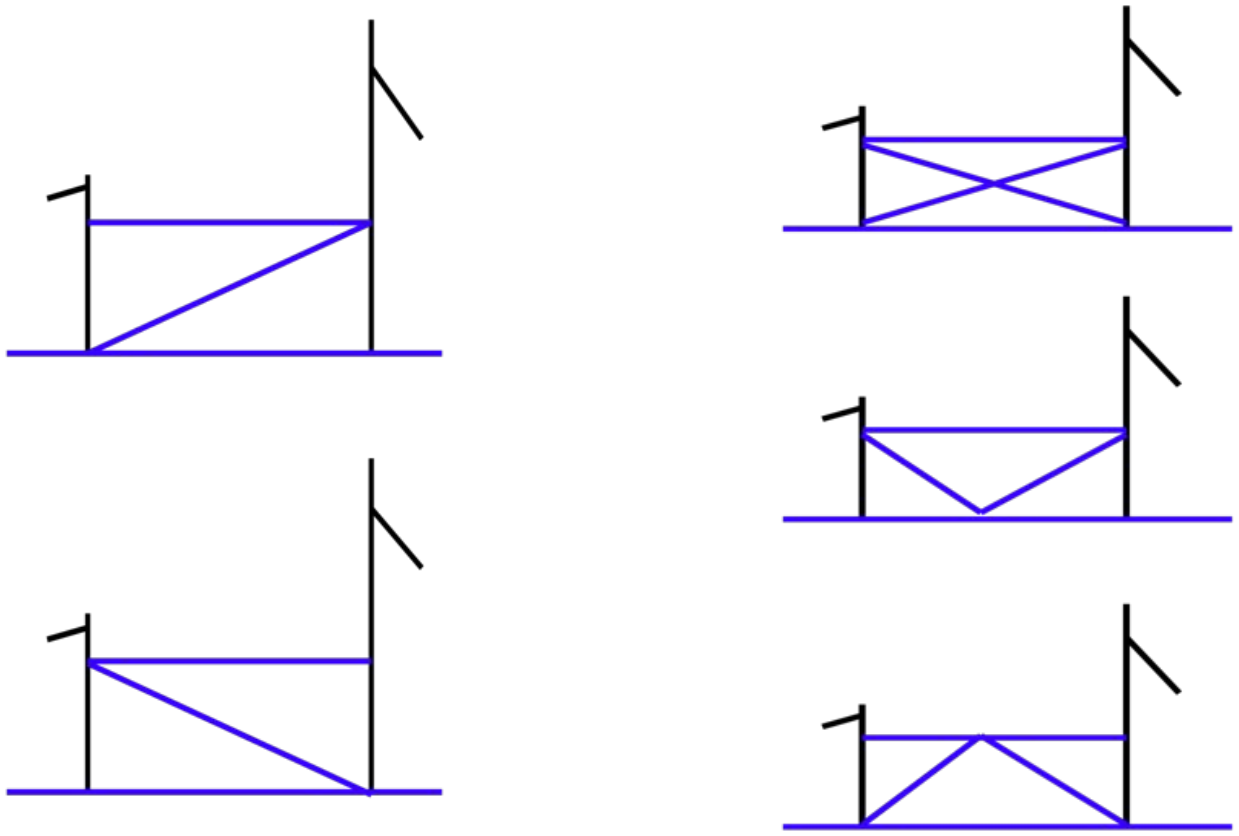
The Side Impact Structure must be comprised of at least three (3) tubular members located on each side of the driver while seated in the normal driving position, as shown in Figure 7. The three (3) required tubular members must be constructed of material per Section 3.3.1. The locations for the three (3) required tubular members are as follows:

B.3.24 Side Impact Protection - Tube Frames

Minimum of three (3) 1.00” OD x 0.065” wall steel tubes or approved equivalent:

- Upper, connecting the Main Hoop and the Front Hoop at between 300 mm (11.8 inch) and 350 mm (13.8 inch) above the ground. *All of the member must be at a height between 300 mm (11.8 inches) and 350 mm (13.8 inches) above the ground.*
- Lower, connecting the bottom of the Main Hoop and the bottom of the Front Hoop.
- A diagonal.
- With proper gusseting and/or triangulation, it is permissible to fabricate the Side Impact Structural members from more than one piece of tubing.

Side Impact Systems



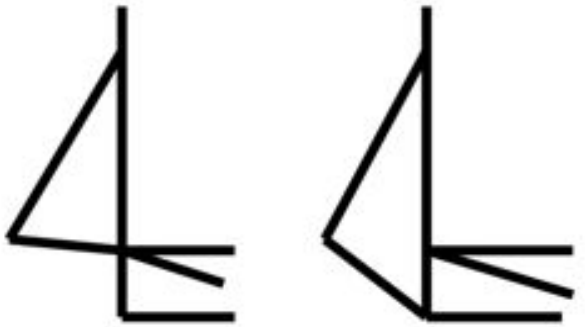
Permissible Configurations

B.3.12.6 - Main Hoop Bracing

- B.3.12.6 The attachment of the Main Hoop braces must be capable of transmitting all loads from the Main Hoop into the Major Structure of the Frame without failing.
- From the lower end of the braces there must be a properly triangulated structure back to the lowest part of the Main Hoop and the node at which the upper side impact tube meets the Main Hoop. This structure must meet the minimum requirements for Main Hoop Bracing Supports (see Rule B.3.3) or an SEF approved alternative.
- Bracing loads must not be fed solely into the engine, transmission or differential, or through suspension components.

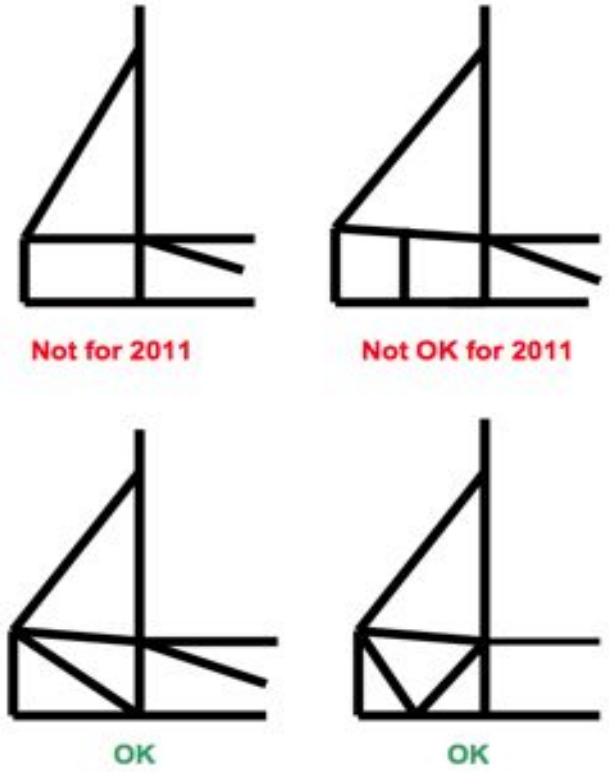
B.3.12.6 - Main Hoop Bracing - Cont'd

- From the lower end of the braces there must be a properly triangulated structure back to the lowest part of the Main Hoop and the node at which the upper side impact tube meets the Main Hoop. This structure must meet the minimum requirements for Main Hoop Bracing Supports (see Rule B.3.3) or an SEF approved alternative.



B.3.12.6 - Main Hoop Bracing - Cont'd

- From the lower end of the braces there must be a properly triangulated structure back to the lowest part of the Main Hoop and the node at which the upper side impact tube meets the Main Hoop. This structure must meet the minimum requirements for Main Hoop Bracing Supports (see Rule B.3.3) or an SEF approved alternative.



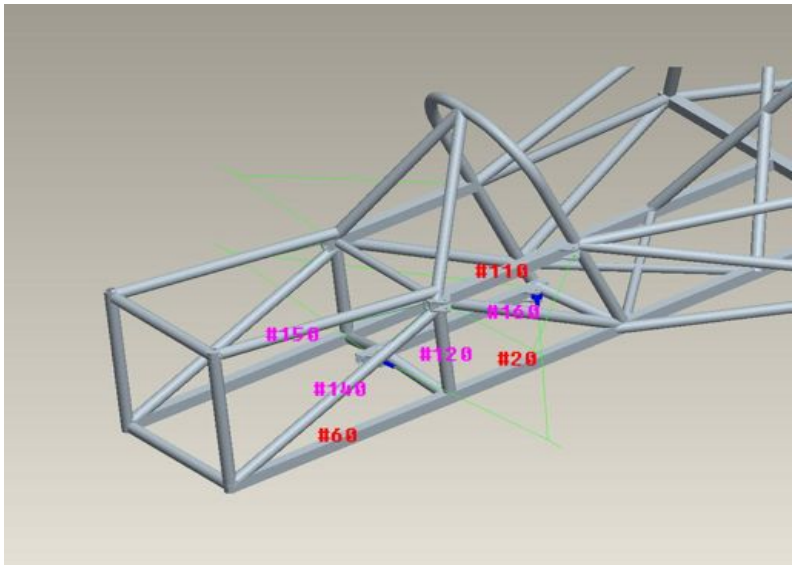
B.3.12.6 Main Hoop Bracing - cont'd

Not OK

OK if Tube Sizes are OK

- From the lower end of the braces there must be a properly triangulated structure back to the lowest part of the Main Hoop **and the node at which the upper side impact tube meets the Main Hoop.** This structure must meet the minimum requirements for Main Hoop Bracing Supports (see Rule B.3.3) or an SEF approved alternative.
- Bracing loads must not be fed solely into the engine, transmission or differential, or through suspension components.

B.3.19 Front Bulkhead Support



A minimum of three (3) tubes supporting the Front Bulkhead on each side.

- One tube per side must be within 2 inches of the top of the Front Bulkhead.
- One tube per side must be at the bottom of the Front Bulkhead.
- The third tube is the diagonal brace.
- All three tubes must meet be 1.00” OD x 0.049” wall or approved equivalent.
- A Front Roll Hoop Brace that goes all the way forward to the Front Bulkhead can be used as one of the three (3) tubes, EXCEPT that it cannot be used as the diagonal brace.
- The diagonal braces must go from a structural node on the Front Bulkhead to a structural node **at the Front Roll Hoop**, and form triangles with the Front Bulkhead and one of the other required tubes on that side.

Front Bulkhead Support

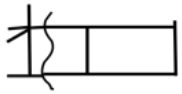
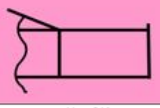
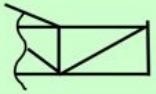
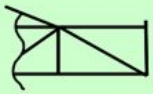
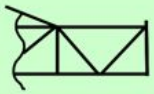
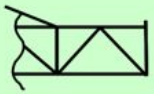
Fig 1	Fig 2	Fig 3
		
Base Drawing	Not OK	OK

Fig 4	Fig 5	Fig 6
		
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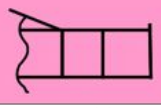	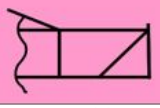	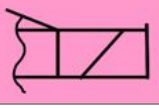
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	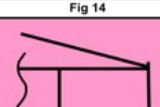	
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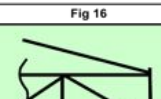	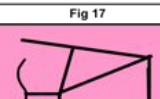	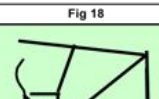
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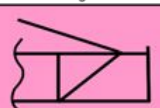		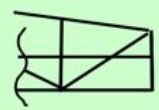
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		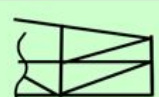
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Fig 28	Fig 29	Fig 30
		
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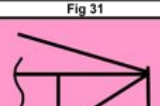
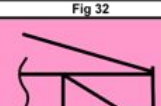
Fig 31	Fig 32	Fig 33
		
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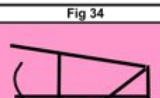	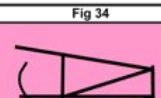
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Front Bulkhead Support

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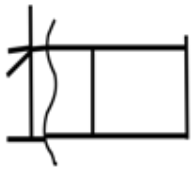		
Base Drawing	Not OK	OK

Fig 4	Fig 5	Fig 6
		
OK	OK	OK

Fig 7	Fig 8	Fig 9
		
Not OK	Not OK	Not OK

Fig 10	Fig 11	Fig 12
		
Not OK	OK	OK

Fig 13	Fig 14	Fig 15
		
Not OK	Not OK	OK

Fig 16	Fig 17	Fig 18
		
OK	Not OK	OK

Front Bulkhead Support - Cont'd

Fig 19	Fig 20	Fig 21
		
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Fig 22	Fig 23	Fig 24
		
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Fig 25	Fig 26	Fig 27
		
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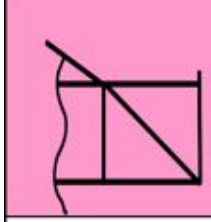
Fig 28	Fig 29	Fig 30
		
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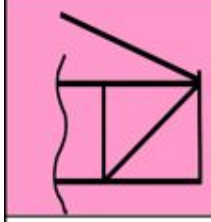
Fig 31	Fig 32	Fig 33
		
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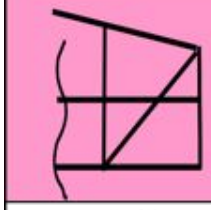
Fig 34	Fig 34
	
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B.3.13 Front Hoop Bracing

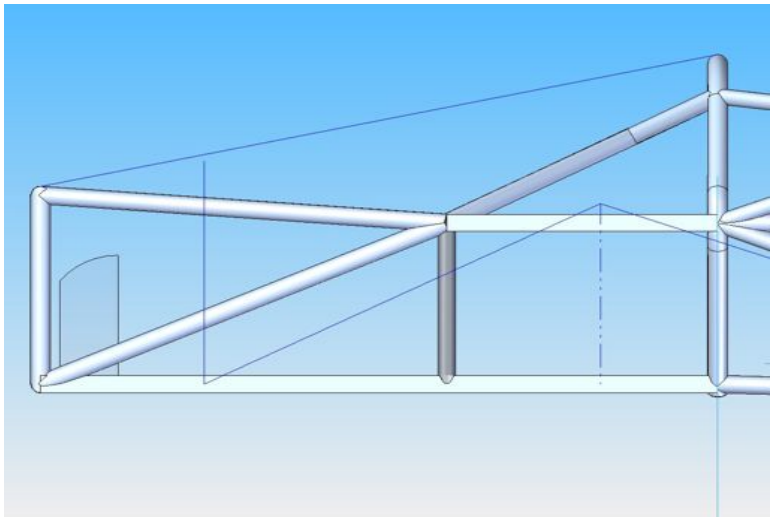
(A) Two braces extending forward on both the left and right sides, 1.00” OD x 0.065” wall steel tubing or approved equivalent.

(C) Constructed such that they protect the driver’s legs and should extend to the structure in front of the driver’s feet. (Note: Not “must extend”)

(D) Attached no more than 50.8 mm (2 in) below the top-most surface of the Front Hoop.

(E) If the front hoop leans rearwards by more than 10 degrees from the vertical, it must be supported by additional bracing to the rear. This bracing must be constructed of material per Section 3.3.3.

B.3.17.1 Foot & Toe Protection



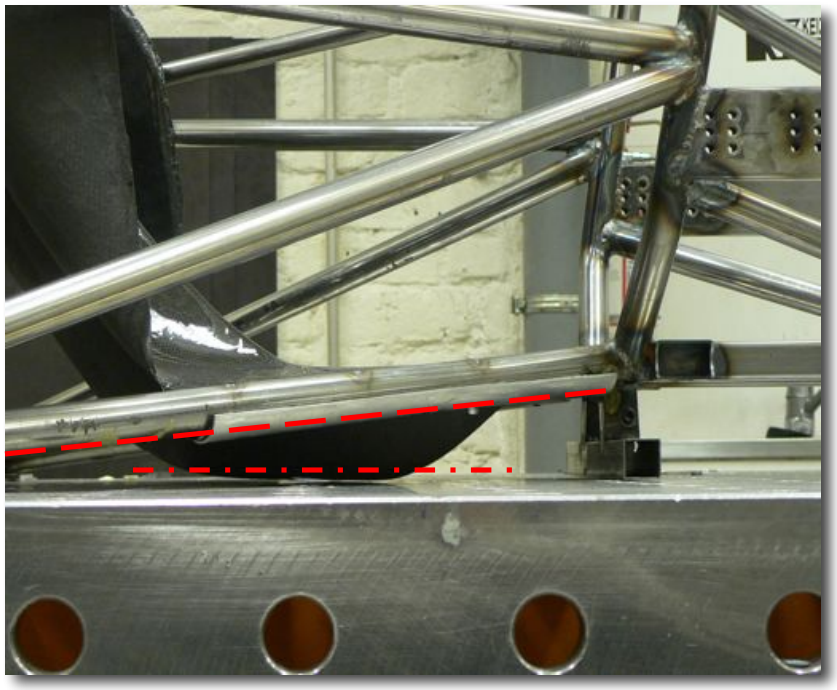
B.3.17.1 Front Impact Structure

The driver's feet must be completely contained within the Major Structure of the Frame. While the driver's feet are touching the pedals, in side and front views no part of the driver's feet can extend above or outside of the Major Structure of the Frame.

B.4.3.1 Seat - Not OK

B.4.3.1 Seat

The lowest point of the driver's seat must be no lower than the bottom surface of the lower frame rails or by having a longitudinal tube (or tubes) that meets the requirements for Side Impact tubing, passing underneath the lowest point of the seat.



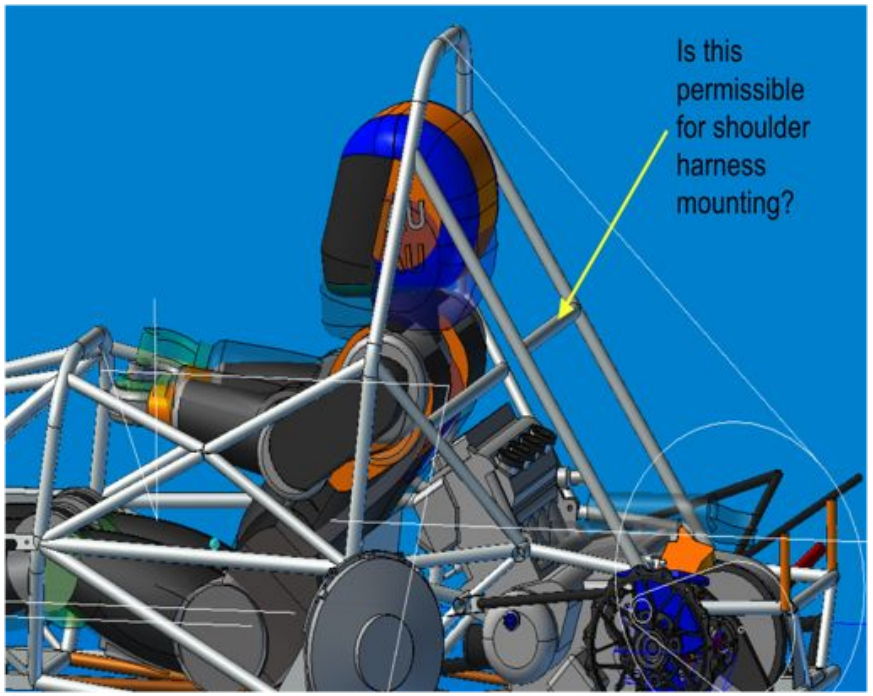
Note: The smallest tube would be 1.00" OD X 0.049" wall)

B.3.3.1 & B.5.4.1
Shoulder Harness Mounting Bar

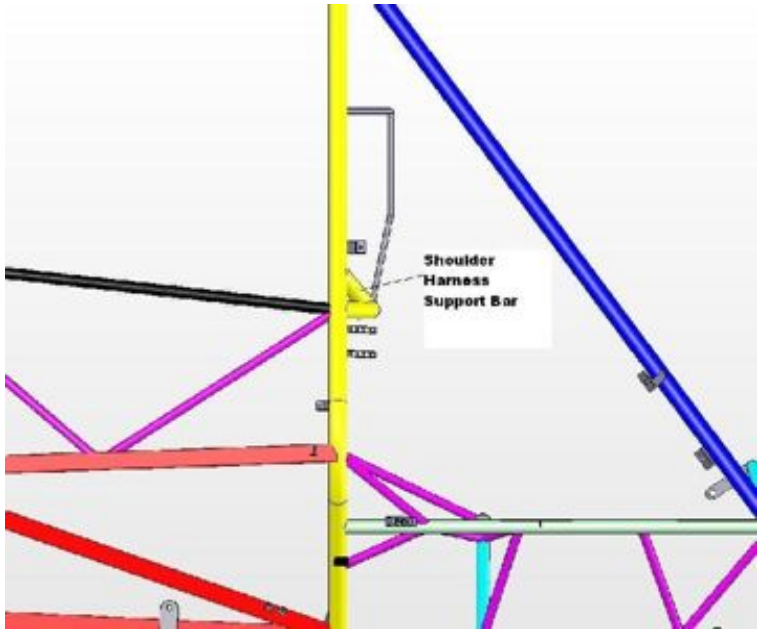
B.3.3.1 - Minimum size must be 1.00” OD x 0.095” wall thickness steel, or approved equivalent. (Was 1.00” OD x 0.065” wall thickness in 2007)

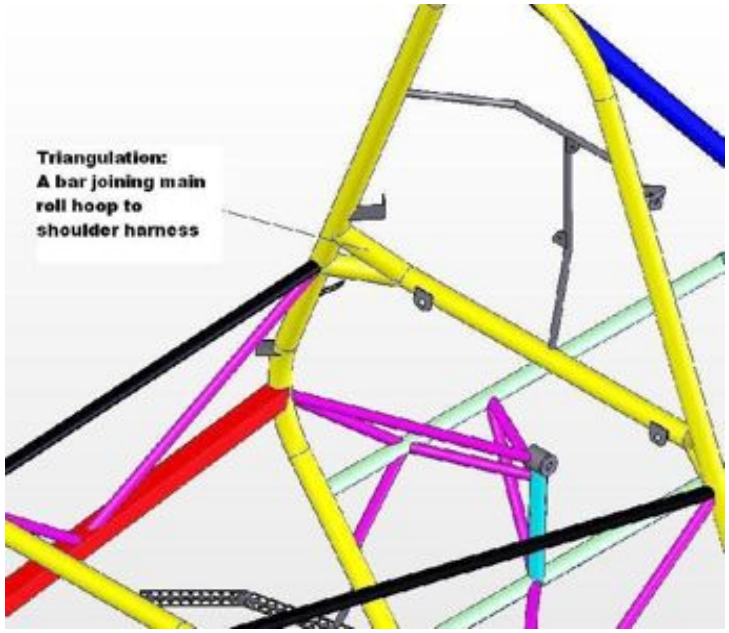
B.5.4.1 - The shoulder harness must be mounted behind the driver to structure that meets the requirements of B.3.3.1. However, it cannot be mounted to the Main Hoop Bracing or attendant structure without additional bracing to prevent loads being transferred into the Main Hoop Bracing.

Hence the system on the right does **not** meet requirements.



B.5.4.2 Shoulder Harness Bar - cont'd





If the harness is mounted to a tube that is not straight, the joints between this tube and the structure to which it is mounted must be reinforced in side view by gussets or triangulation tubes to prevent torsional rotation of the harness mounting tube.

B.5.2 Harness Installation - General

- B.5.2.1 The lap belt, shoulder harness and anti-submarine strap(s) must be securely mounted to the Primary Structure. Such structure and any guide or support for the belts must meet the minimum requirements of B.3.3.1.

- B.5.2.2 The tab to which any harness is attached must have:

  a. A minimum cross sectional area of 60 sq. mms (0.093 sq. ins) of steel to be sheared or failed in tension at any point of the tab, and

  b. A minimum thickness of 1.6 mm (0.63 inches).

  c. Where lap belts and anti-submarine belts use the same attachment point, a minimum cross sectional area of 90 sq. mm (0.140 sq in) of steel to be sheared if failed in tension at any point of the tab.

  Note: Double shear mounting is preferred.

- B.5.2.3 Harnesses, belts and straps **must not pass through a firewall**, i.e. all harness attachment points must be on the driver's side of any firewall.

B.3.38 - Monocoque - Driver's Harness Attachment Points

B.3.38 Monocoque Driver's Harness Attachment Points

- B.3.38.1 The monocoque attachment points for the shoulder and lap belts must support a load of 13 kN (3000 pounds) before failure.
- B.3.38.2 The monocoque attachment points for the anti-submarine belts must support a load of 6.5 kN (1500 pounds) before failure.
- B.3.38.3 If the lap belts and anti-submarine belts are attached to the same attachment point, then this point must support a load of 19.5 kN (4500 pounds) before failure.
- B.3.38.4 The strength of lap belt attachment and shoulder belt attachment must be proven by physical test where the required load is applied to a representative attachment point where the proposed layup and attachment bracket is used.

B.5.3 Lap Belt Mounting

- B.5.3.1 The lap belt must pass around the pelvic area below the Anterior Iliac Spines (the hip bones).
- B.5.3.2 The lap belts should not be routed over the sides of the seat. The lap belts should come through the seat at the bottom of the sides of the seat to maximize the wrap of the pelvic surface and continue in a straight line to the anchorage point.
- B.5.3.3 Where the belts or harness pass through a hole in the seat, the seat must be rolled or grommeted to prevent chafing of the belts.
- B.5.3.4 To fit drivers of differing statures correctly, in side view, the lap belt must be capable of pivoting freely by using either a shouldered bolt or an eye bolt attachment, i.e. mounting lap belts by wrapping them around a frame tube is no longer acceptable.

B.5.1 and 5.3 Belts - Upright vs Reclined Driver

B.5.1.1 Definitions

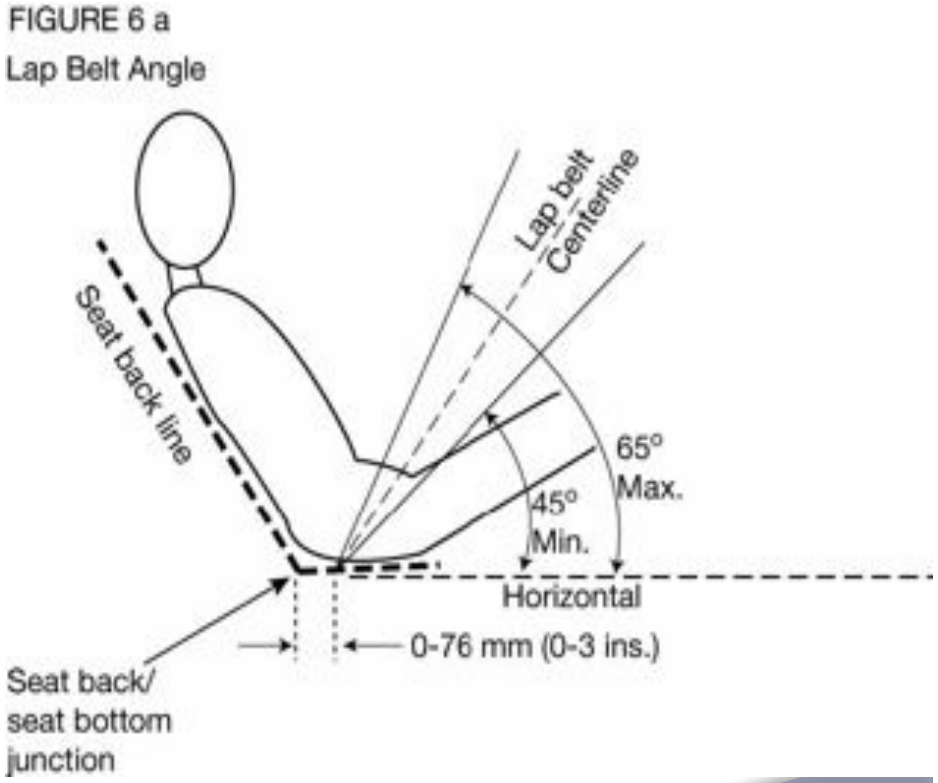
d. An upright driving position is defined as one with a seat back angled at 30 degrees or less from the vertical as measured along the line joining the two 200 mm circles of the template of the 95th percentile male as defined in Rule B.3.9.3 and positioned per B.3.9.4.

e. A reclined driving position is defined as one with a seat back angled at **more than 30 degrees from the vertical** as measured along the line joining the two 200 mm circles of the template of the 95th percentile male as defined in Rule B.3.9.3 and positioned per B.3.9.4.

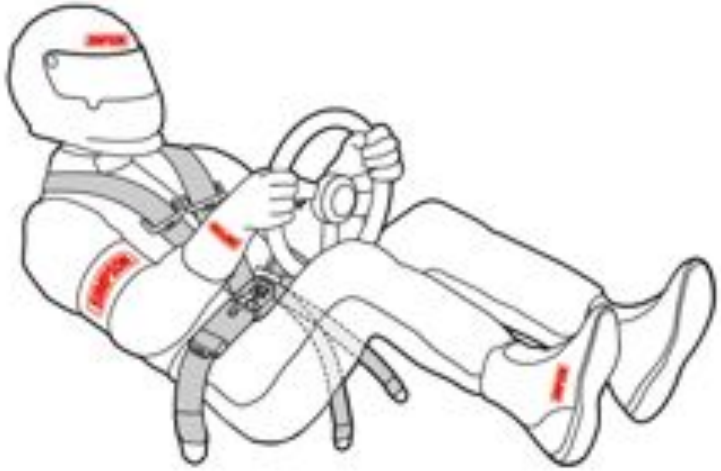
B.5.3.5 Lap Belt Mounting - Upright Driver

With an "upright driving position", in side view, the lap belt must be at an angle of between 45 degrees and 65 degrees to the horizontal. This means that the centerline of the lap belt at the seat bottom should be approximately 0-76 mm (0-3 inch) forward of the seat back to seat bottom junction (see Figure 6a).

FIGURE 6 a
Lap Belt Angle



B.5.1 and 5.3 Belts - Reclined Driver



B.5.1.2.f Cars with a Reclined driving position (see B.5.1.1.e above) must have:

- either a **6 point or 7-point** harness,

AND

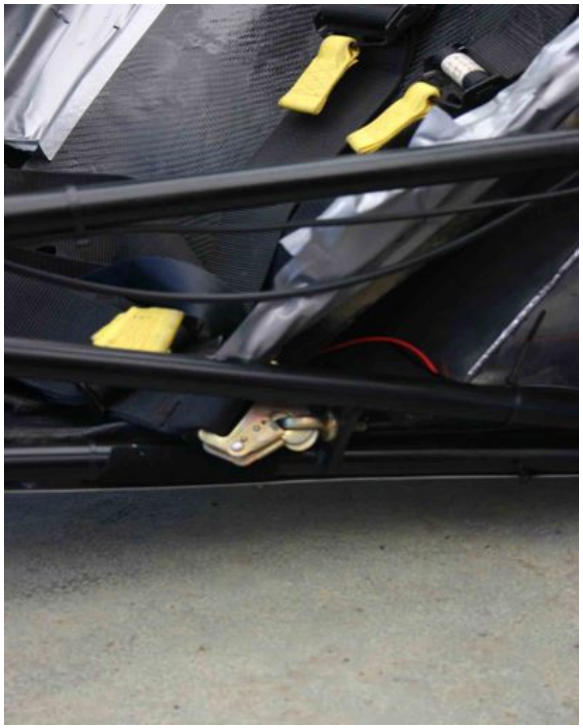
- have either **anti-submarine belts with "quick adjusters"** or
- have **two (2) sets of anti-submarine belts installed.**

B.5.3.6 **With a reclined driving position, in side view the lap belt must be between an angle of 60 degrees and 80 degrees to the horizontal.**

B.5.3.4 Lap Belt Mounting - cont'd

"To fit drivers of differing statures correctly, in side view, the lap belt must be capable of pivoting freely by using either a shouldered bolt or an eye bolt attachment, i.e. mounting lap belts by wrapping them around a frame tube is no longer acceptable."

B.5.3.4 Lap Belt Mounting - cont'd



OK

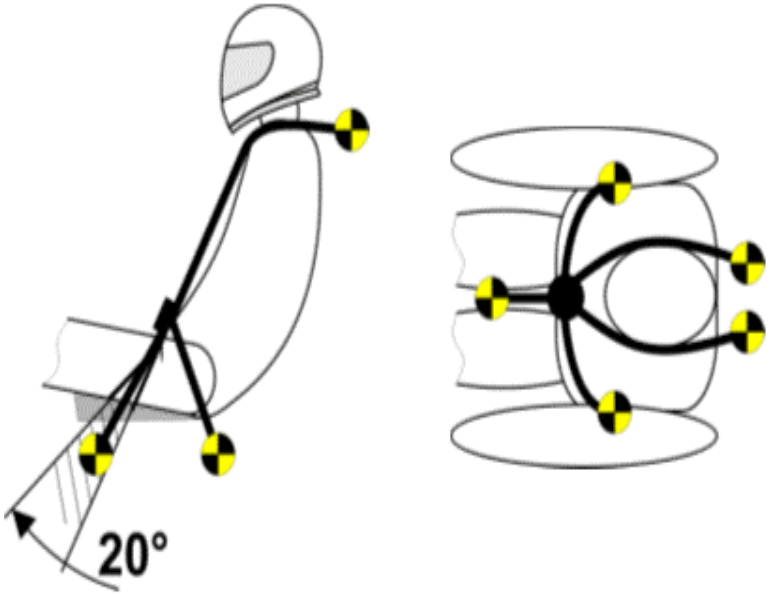
Not OK

"To fit drivers of differing statures correctly, in side view, the lap belt must be capable of pivoting freely by using either a shouldered bolt or an eye bolt attachment, i.e. mounting lap belts by wrapping them around a frame tube is no longer acceptable."

B.5.5 Anti-Submarine Belt Mounting
5 Point System

- B.5.5.1 The anti-submarine belt of a 5 point harness should be mounted in line with, or angled slightly forward of (up to 20 deg), the driver's chest-groin line.

- B.5.1.1.f The chest-groin line is the straight line that in side view follows the line of the shoulder belts from the chest to the release buckle.

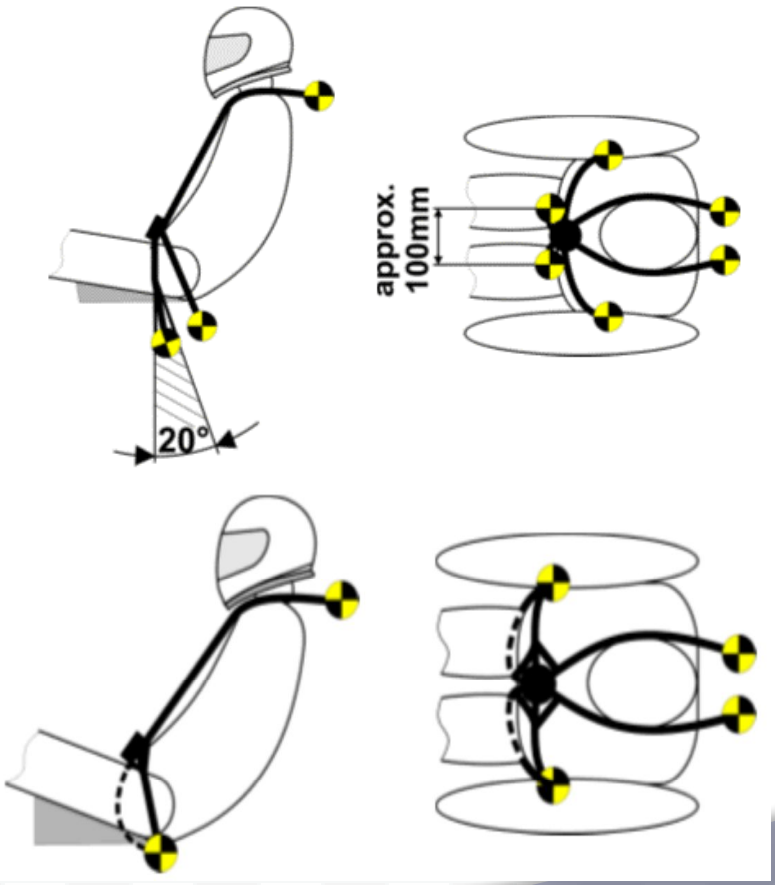


B.5.5 Anti-Submarine Belt Mounting
6 Point System

B.5.5.2 The anti-submarine belts of a 6 point harness should be mounted either:

a. With the belts going vertically down from the groin, or angled up to 20 deg. rearwards. The anchorage points should be approximately 100 mm (4 inches) apart. Or

b. With the anchorage points on the Primary Structure at or near the lap belt anchorages, the driver sitting on the anti-submarine belts, and the belts coming up around the groin to the release buckle.



B.3.9.3 Main & Front Hoops - General Requirements

Helmet Line

3.9.3 When seated normally and restrained by the Driver's Restraint System, the helmet of a 95th percentile male (anthropometrical data) and all of the team's drivers must:

a. Be a minimum of 50.8 mm (2 inches) from the straight line drawn from the top of the main hoop to the top of the front hoop. (Figure 1a)

b. Be a minimum of 50.8 mm (2 inches) from the straight line drawn from the top of the main hoop to the lower end of the main hoop bracing if the bracing extends rearwards. (Figure 1b)

c. Be no further rearwards than the rear surface of the main hoop if the main hoop bracing extends forwards. (Figure 1c)

B.3.9.3 Main & Front Hoops - General Requirements

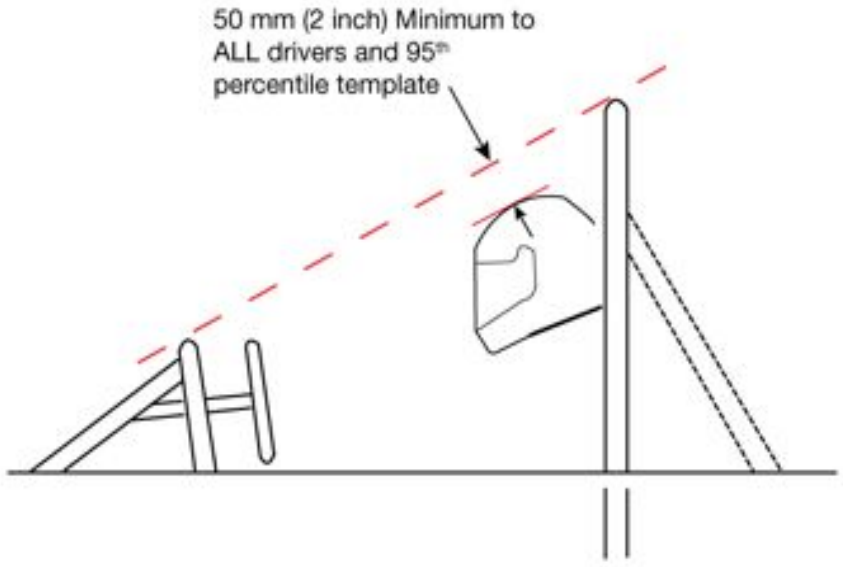


FIGURE 1a

Helmet Line

3.9.3 When seated normally and restrained by the Driver's Restraint System, the helmet of a 95th percentile male (anthropometrical data) and **all of the team's drivers must**:

a. Be a minimum of 50.8 mm (2 inches) from the straight line drawn from the top of the main hoop to the top of the front hoop. (Figure 1a)

B.3.9.3 Main & Front Hoops - General Requirements

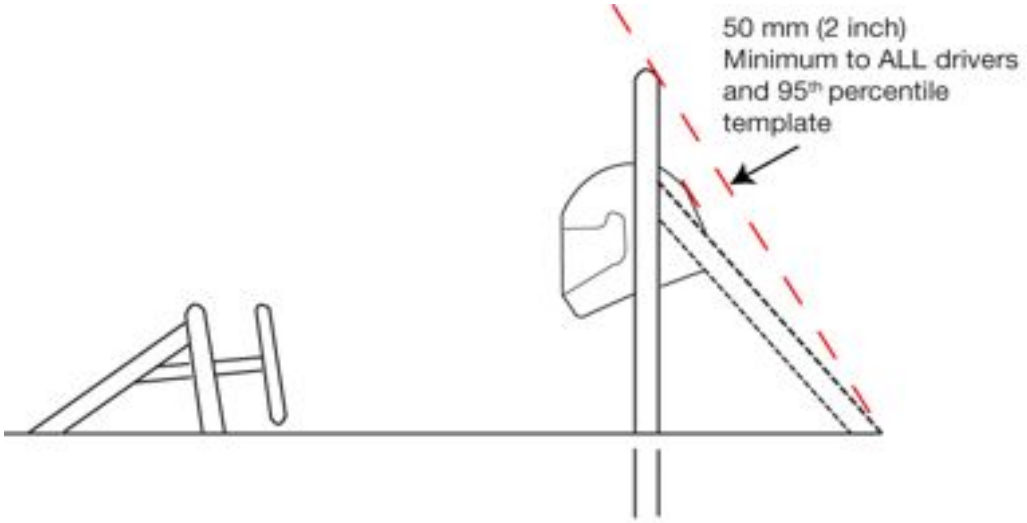


FIGURE 1b

Helmet Line

3.9.3 When seated normally and restrained by the Driver's Restraint System, the helmet of a 95th percentile male (anthropometrical data) and **all of the team's drivers must**:

b. Be a minimum of 50.8 mm (2 inches) from the straight line drawn from the top of the main hoop to the lower end of the main hoop bracing if the bracing extends rearwards. (Figure 1b)

B.3.9.3 Main & Front Hoops - General Requirements

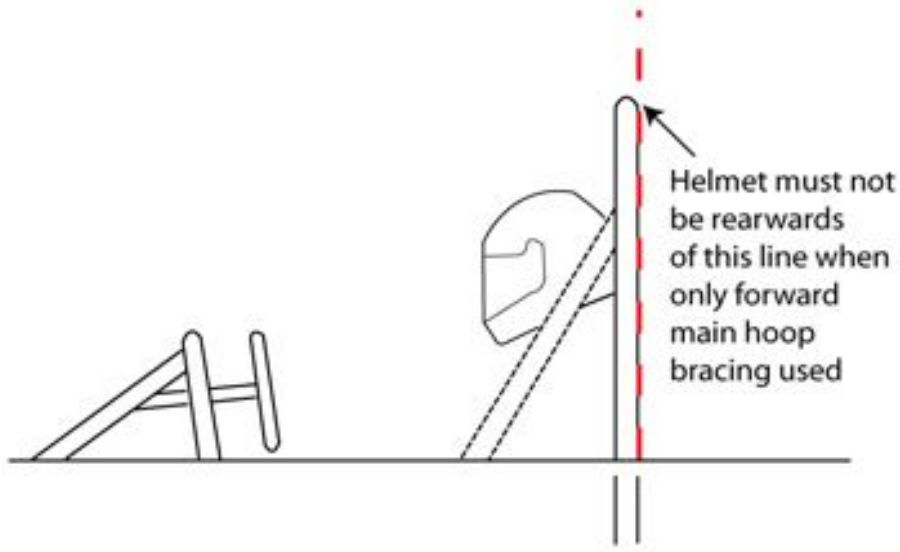


FIGURE 1c

Helmet Line

3.9.3 When seated normally and restrained by the Driver's Restraint System, the helmet of a 95th percentile male (anthropometrical data) and **all of the team's drivers must:**

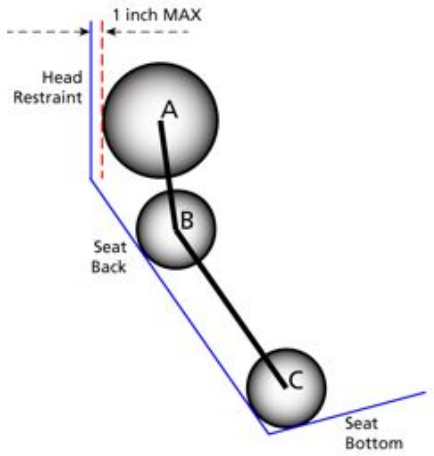
c. Be no further rearwards than the rear surface of the main hoop if the main hoop bracing extends forwards. (Figure 1c)

B.3.9.4 Main & Front Hoops-General Requirements - Percy

B.3.9.4 The 95th percentile male template will be positioned as follows: (See Figure 2.)

- The seat will be adjusted to the rearmost position,
- The bottom 200 mm circle will be placed at the junction of the seat back and the seat bottom, tangential to both.
- The middle 200 mm circle, representing the shoulders, will be positioned on the seat back.
- The upper 300 mm circle will be positioned no more than 25.4 mm (1 inch) away from the head restraint (i.e. where the driver's helmet would normally be located while driving).

"Percy" – 95th Percentile Male with Helmet

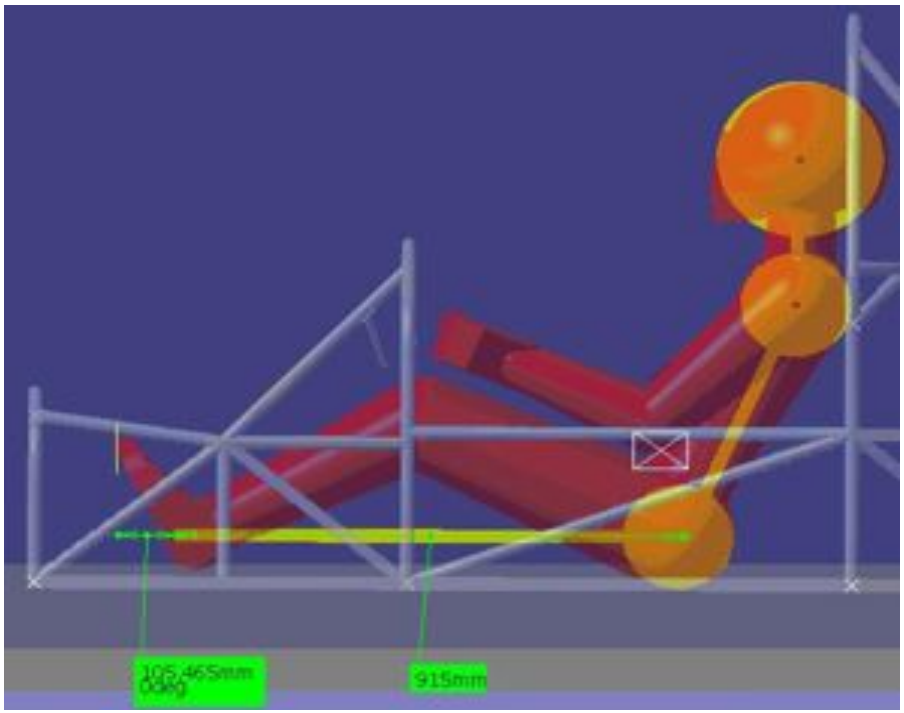


Circle A = Head with helmet – 300 mm diameter
Circle B = Shoulders – 200 mm diameter
Circle C = Hips and buttocks – 200 mm diameter

Line A-B = 280 mm from centerpoint to centerpoint
Line B-C = 490 mm from centerpoint to centerpoint

FIGURE 2

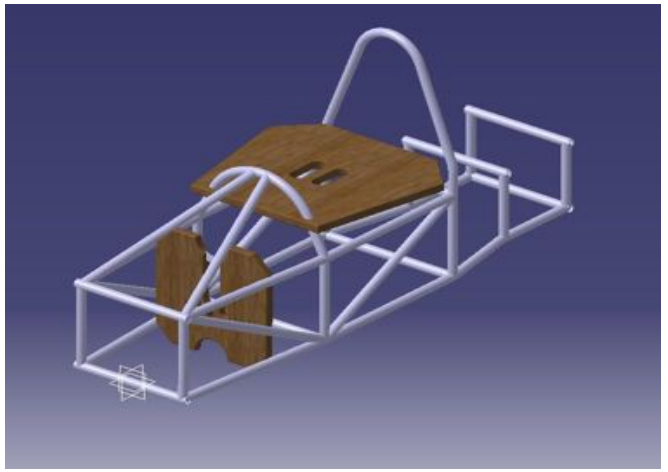
Percy's Placement



Formula Hybrid Rule - The bottom 200 mm circle will be placed on the seat bottom with the center of the circle ("Percy's" hips and buttocks) no less than 91.5 cms (36 inches) from the rear face of the pedals in their most forward position.

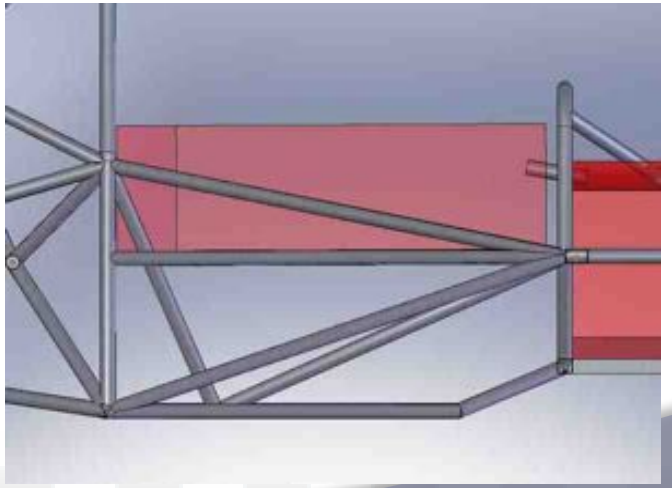
B.4.1 Cockpit Opening

- B.4.1.1 In order to ensure that the opening giving access to the cockpit is of adequate size, a template shown in Figure 8 will be inserted into the cockpit opening. It will be held horizontally and inserted vertically until it has passed below the top bar of the Side Impact Structure (or until it is 350 mm above the ground for monocoque cars). *No fore and aft translation of the template will be permitted during insertion.*



- B.4.1.2 During this test, the steering wheel, steering column, seat and all padding may be removed. The firewall may not be moved or removed.

Presenter's note: Only those things mentioned above may be removed, nothing else, including the shifter.

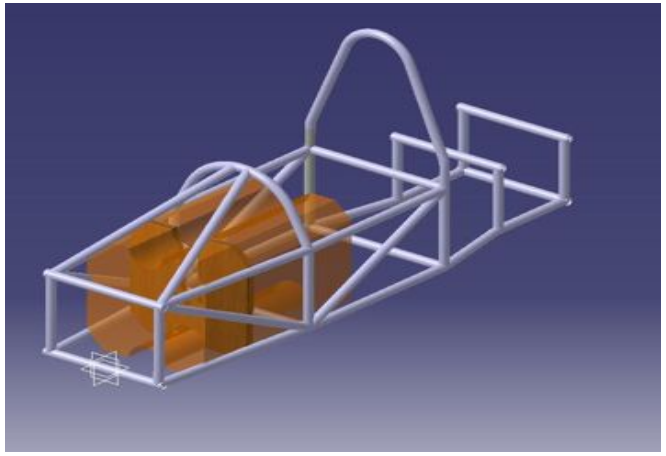


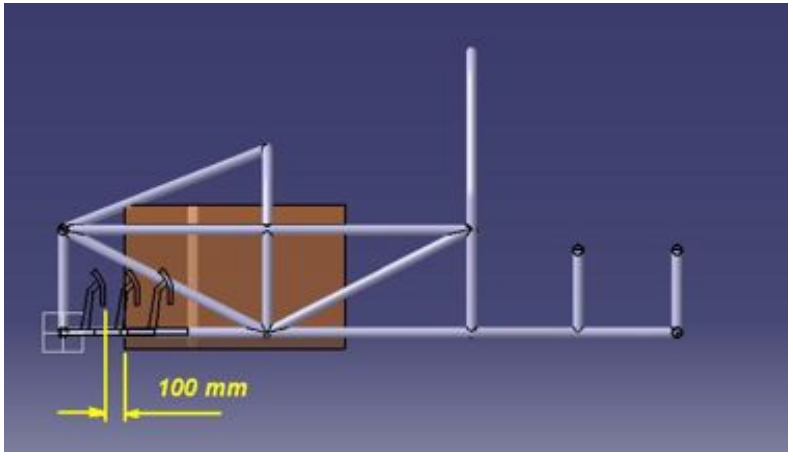
B.4.2 Cockpit Internal Cross Section

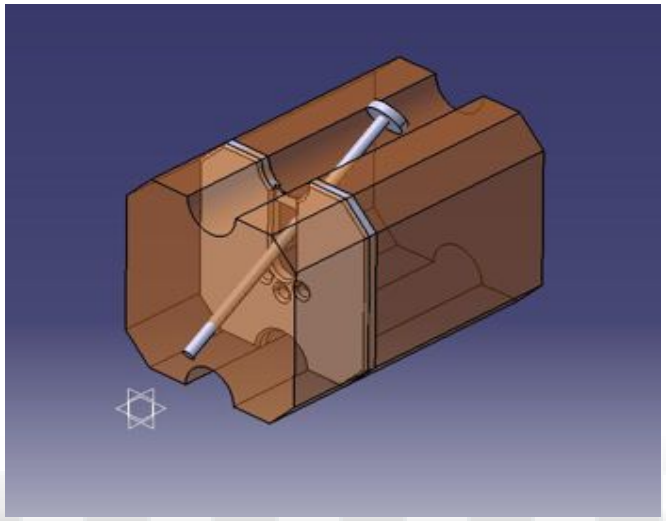
- B.4.2.1 A free vertical cross section, which allows the template shown in Figure 9 to be passed horizontally through the cockpit to a point 100 mm (4 inches) rearwards of the face of the rearmost pedal when in the inoperative position, must be maintained over its entire length. If the pedals are adjustable, they will be put in their most forward position.
- B.4.2.2 The template, with maximum thickness of 7mm (0.275 inch), will be held vertically and inserted into the cockpit opening rearward of the Front Roll Hoop, as close to the Front Roll Hoop as the car's design will allow.
- B.4.2.3 The only items that may be removed for this test are the steering wheel, and any padding required by Rule B.5.7 Driver's Leg Protection **that can be easily removed without the use of tools with the driver in the seat**. The seat may NOT be removed.

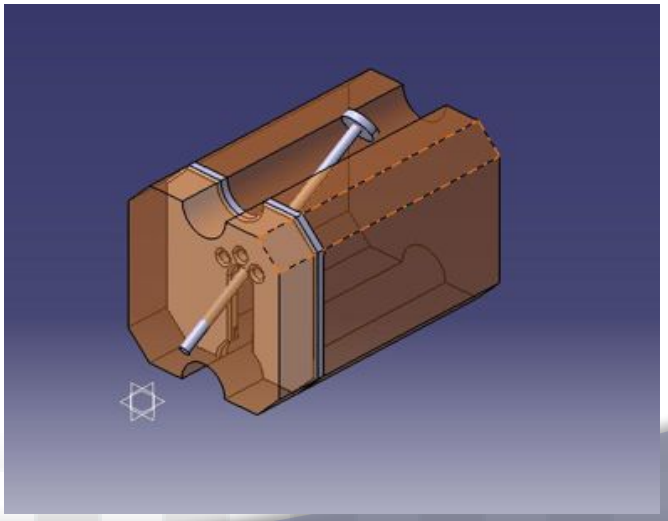
Note: Cables, wires, hoses, tubes, etc. must not impede the passage of the templates required by B.4.1 and B.4.2.

B.4.2 Cockpit Internal Cross Section - Cont'd









Questions?

Frame Design Process

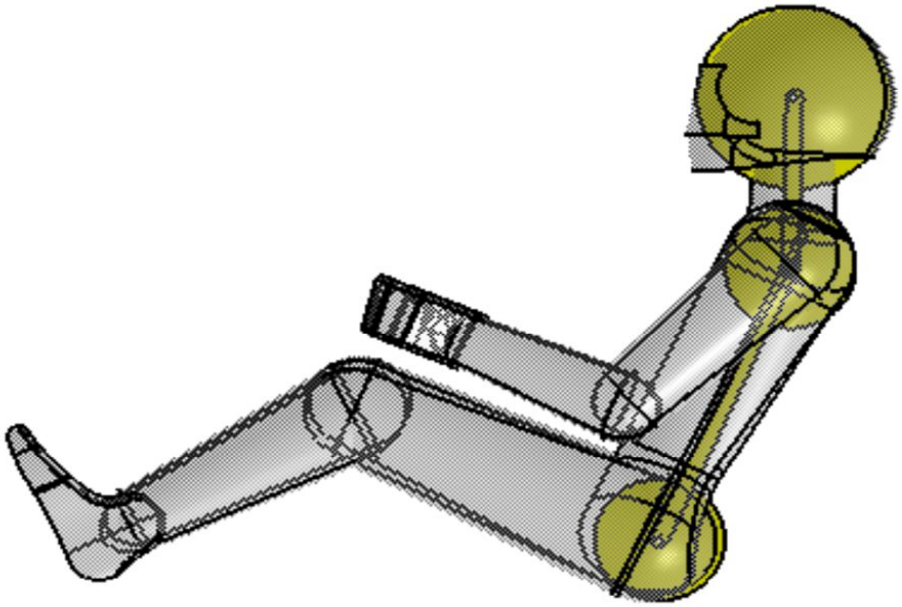
Where do you start?

What is YOUR process?

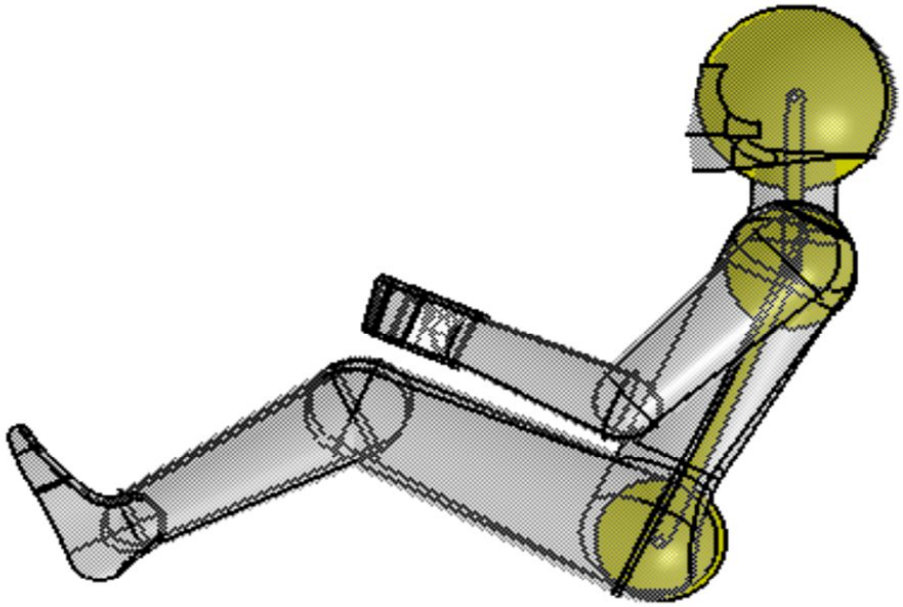
Frame Design Process

- Examine current design
- Start with “Percy” with legs (and tallest driver if over 6’ 1 1/2”)
- Add engine/transmission
- Add cockpit template envelopes
- Add suspension pick-up points and rocker mounts
- Rough out tubing configuration
- SUBMIT SEF!!
- Add safety harness mounts
- Add engine/transmission mounts
- Check SEF submission still valid
- Perform FEA for torsional rigidity

Frame Design Process



Frame Design Process



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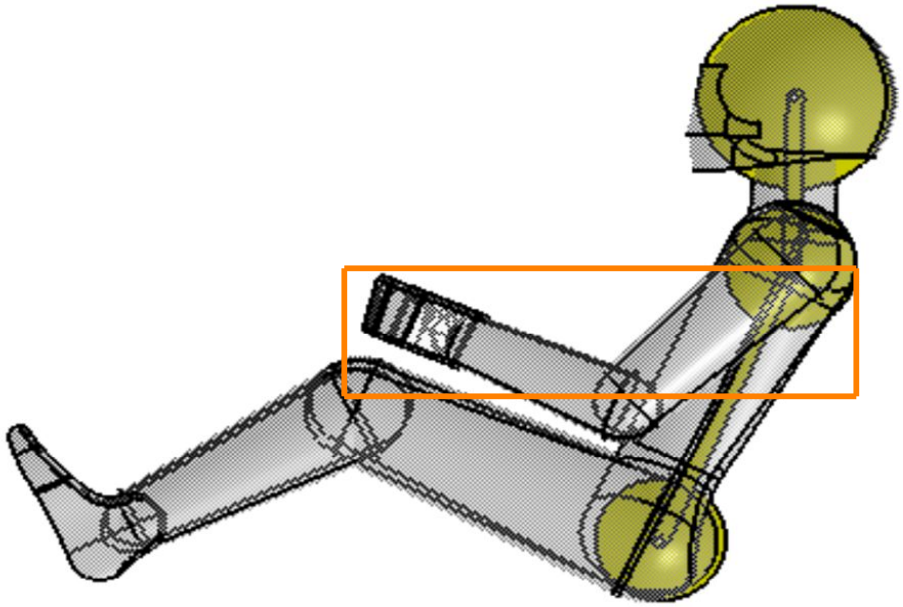

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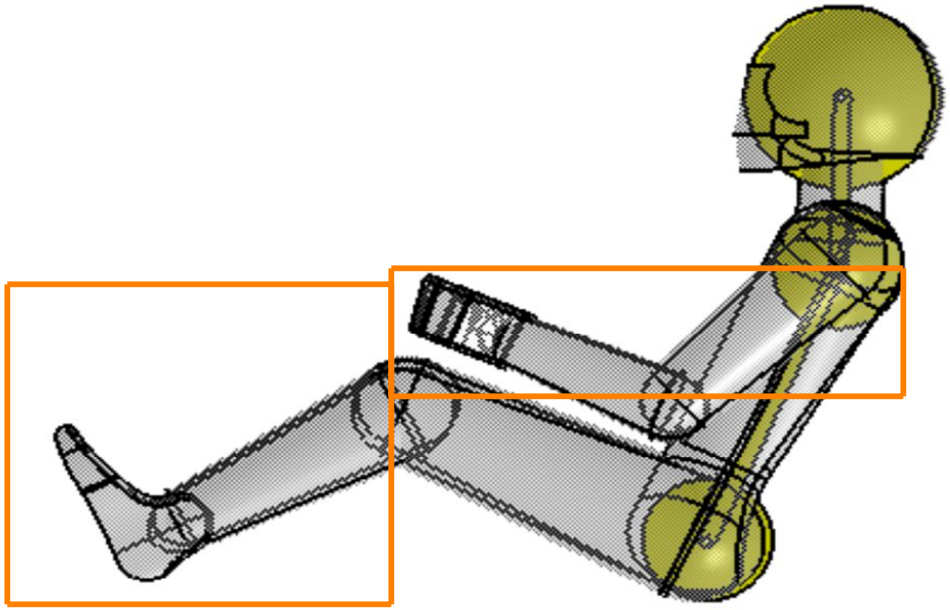

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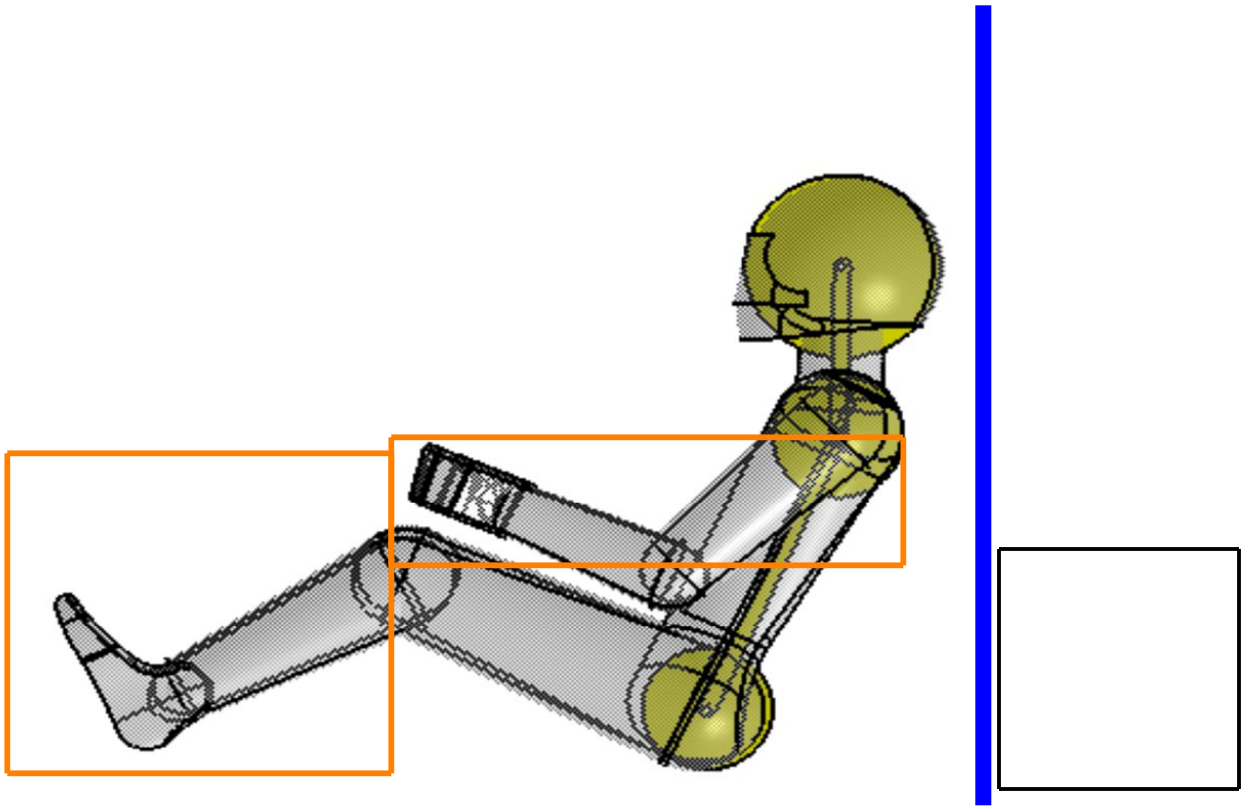

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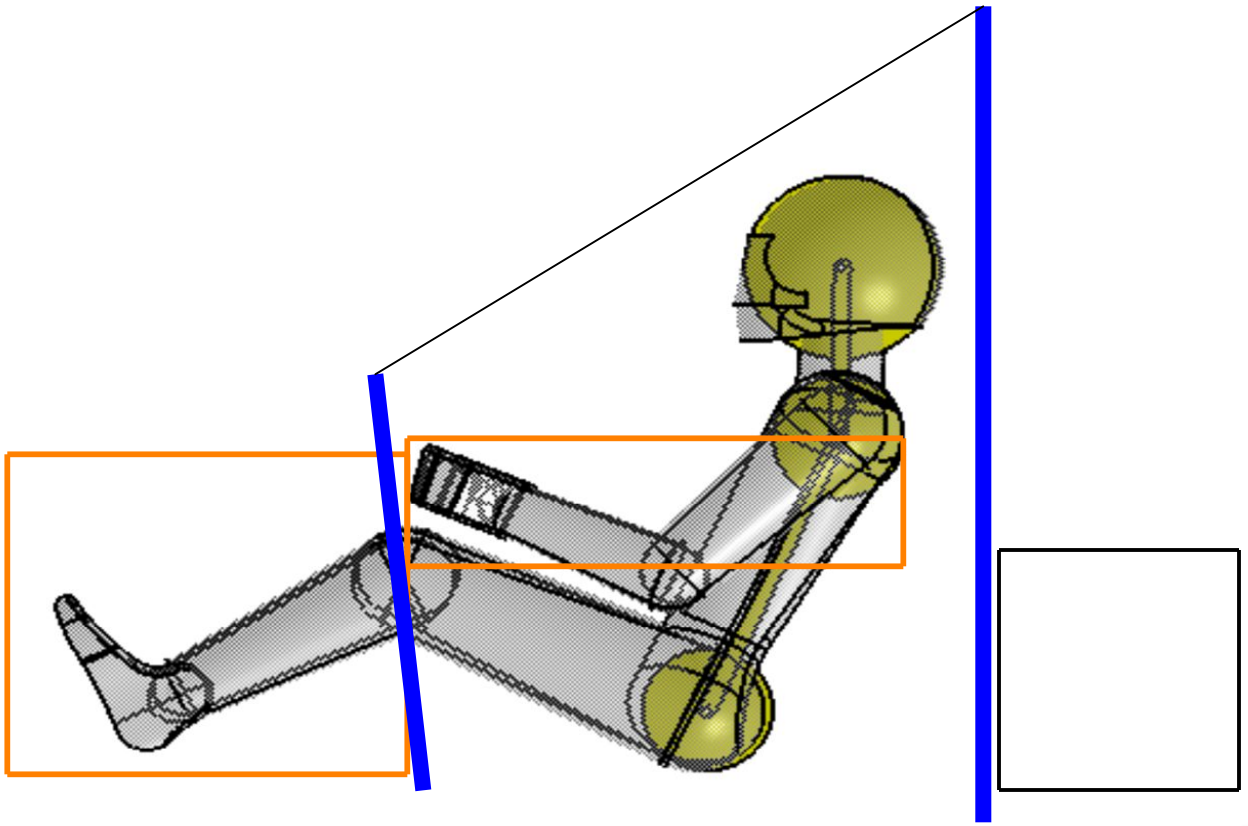

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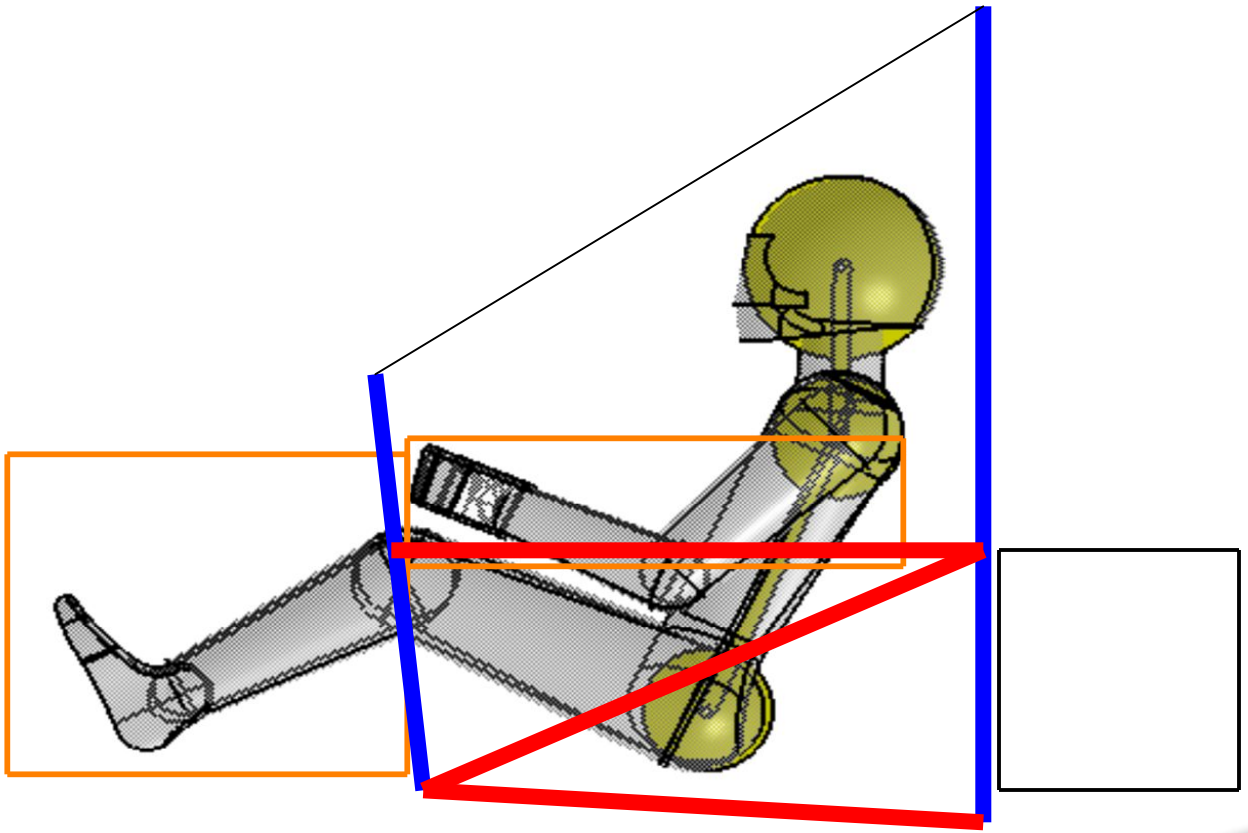

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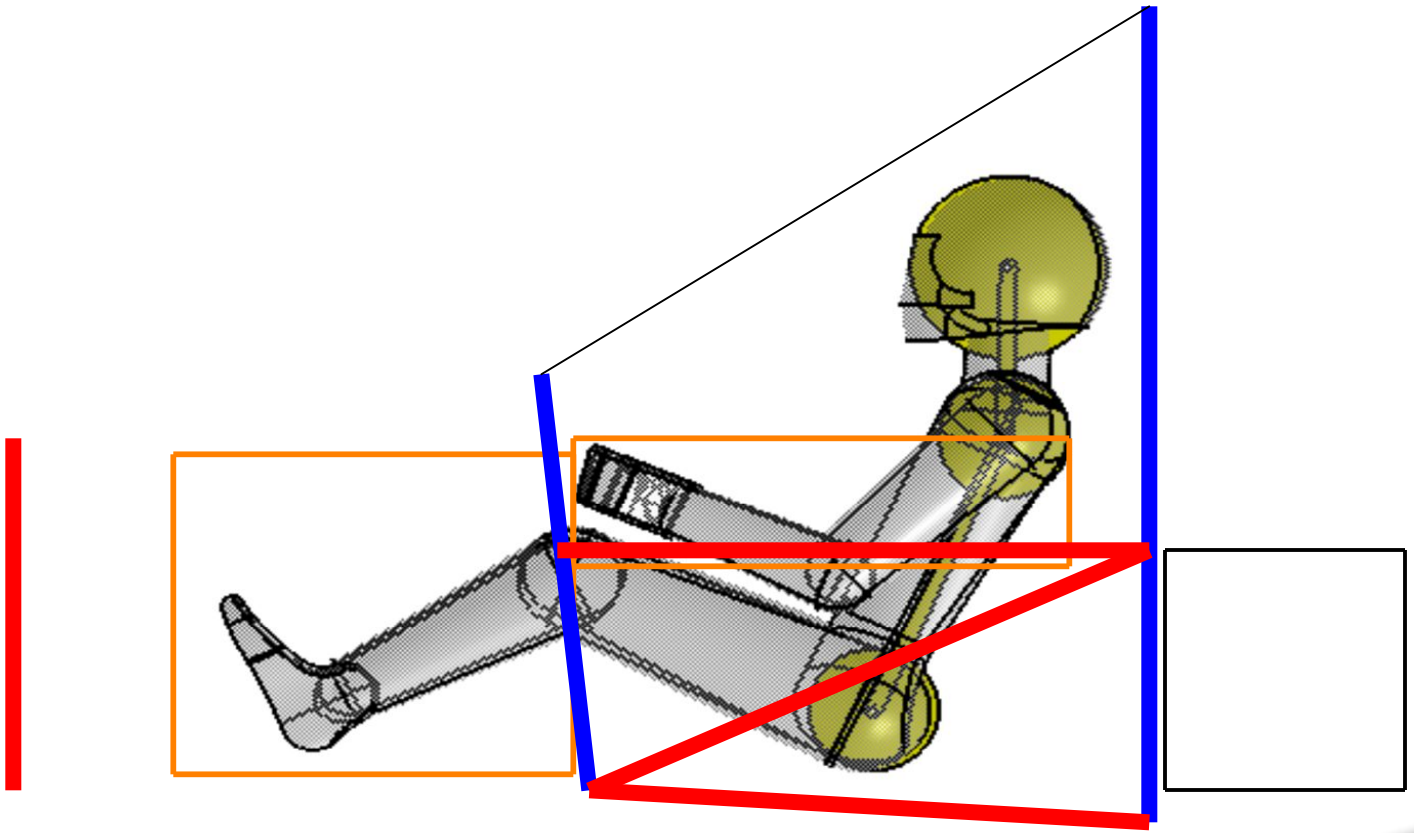

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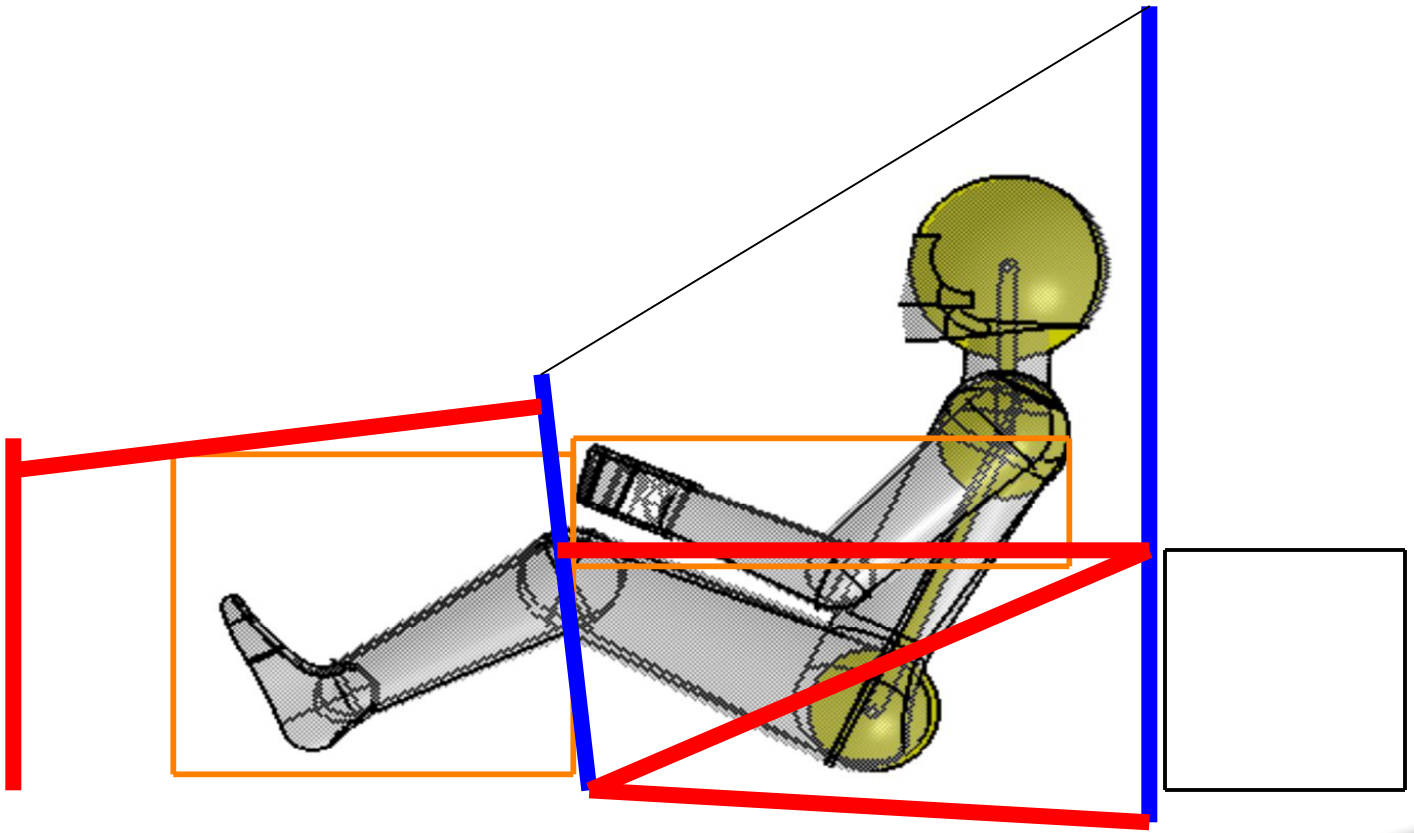

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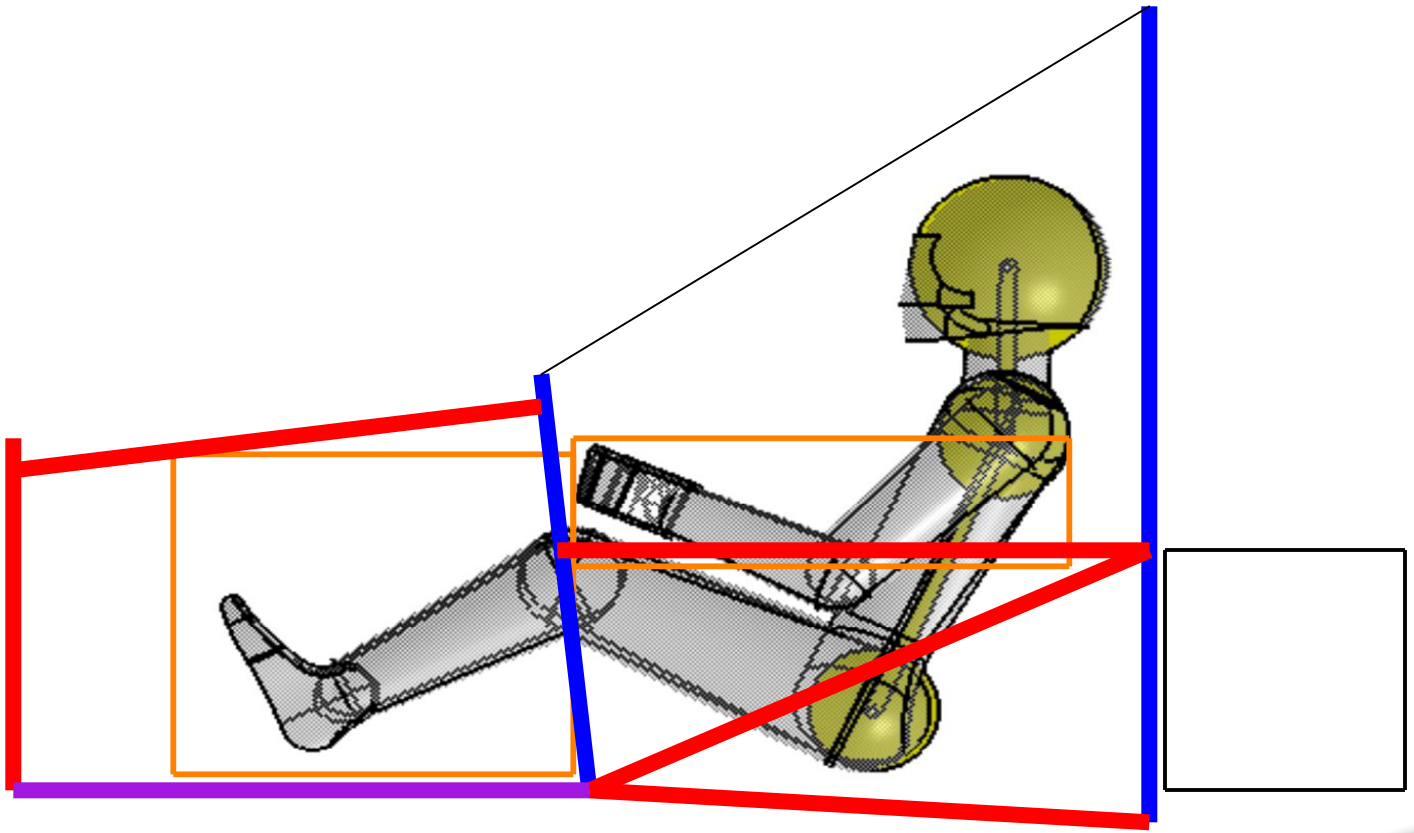

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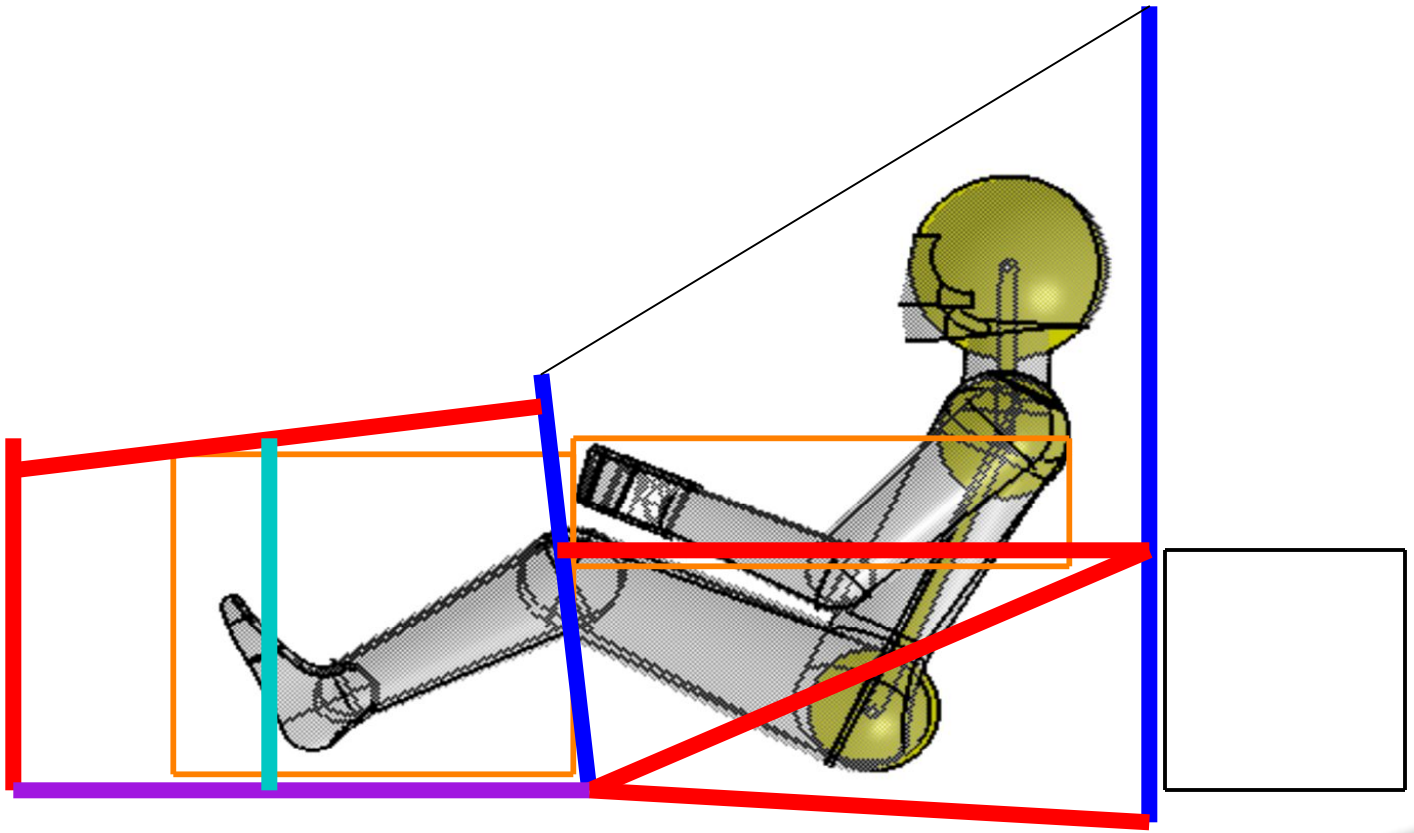

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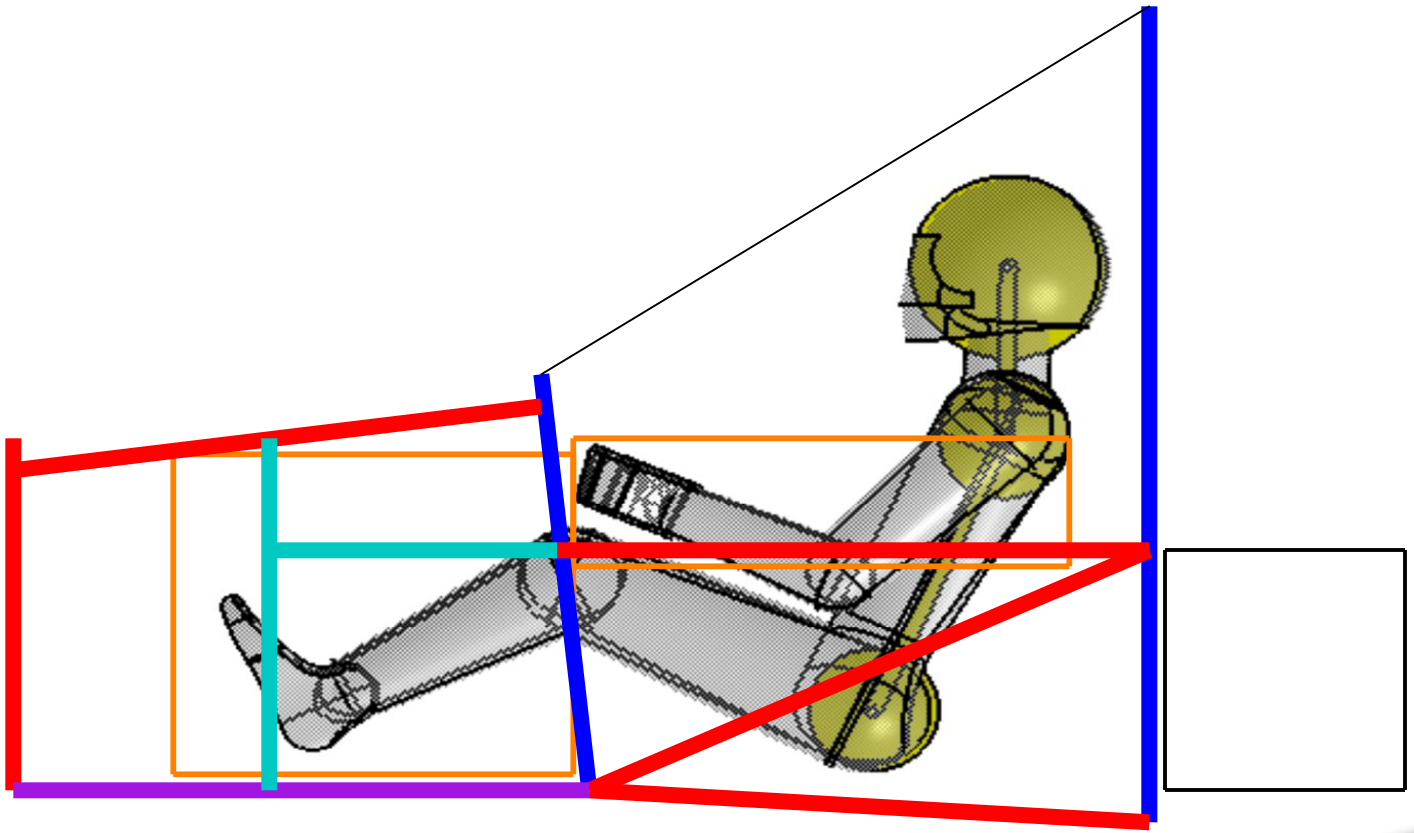

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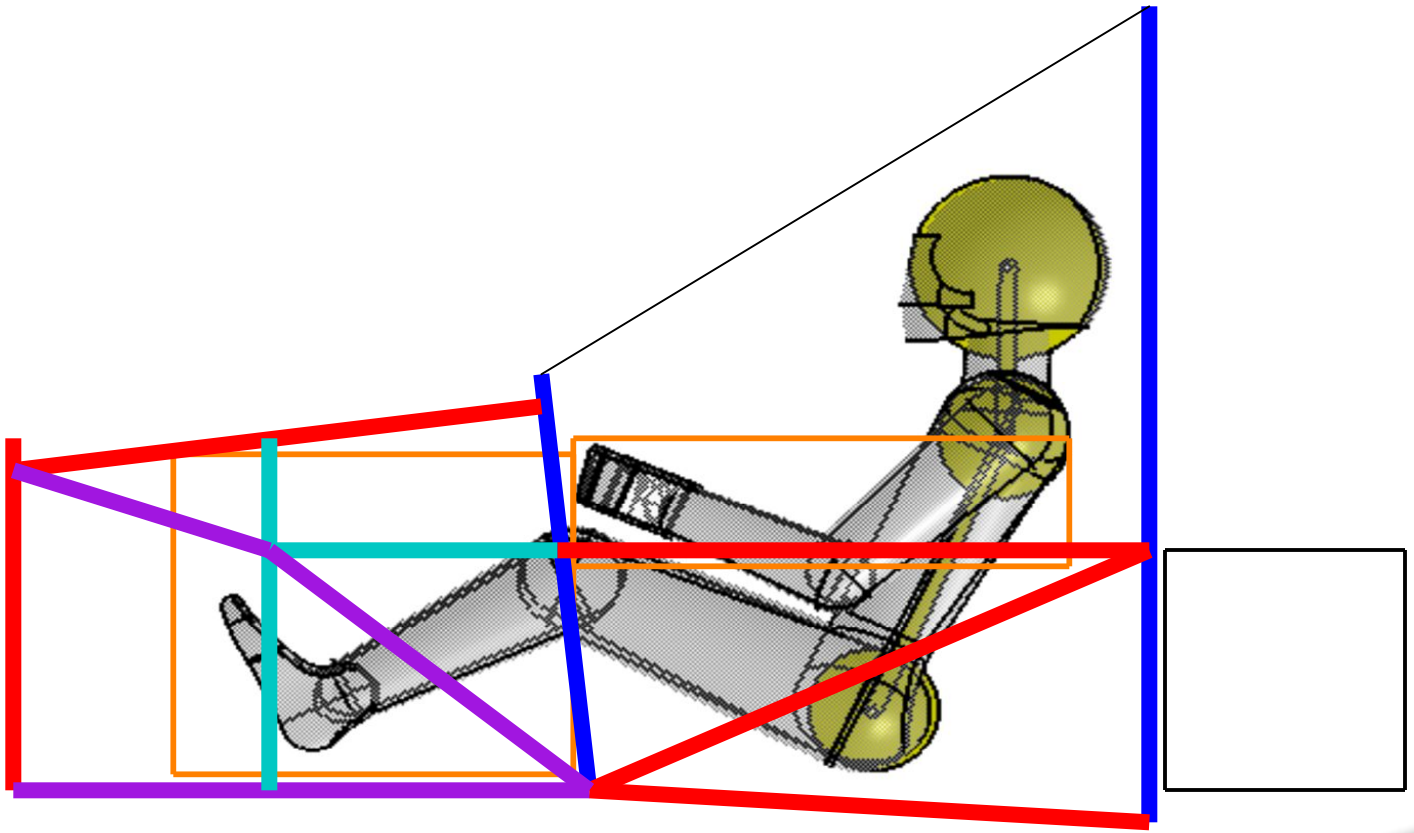

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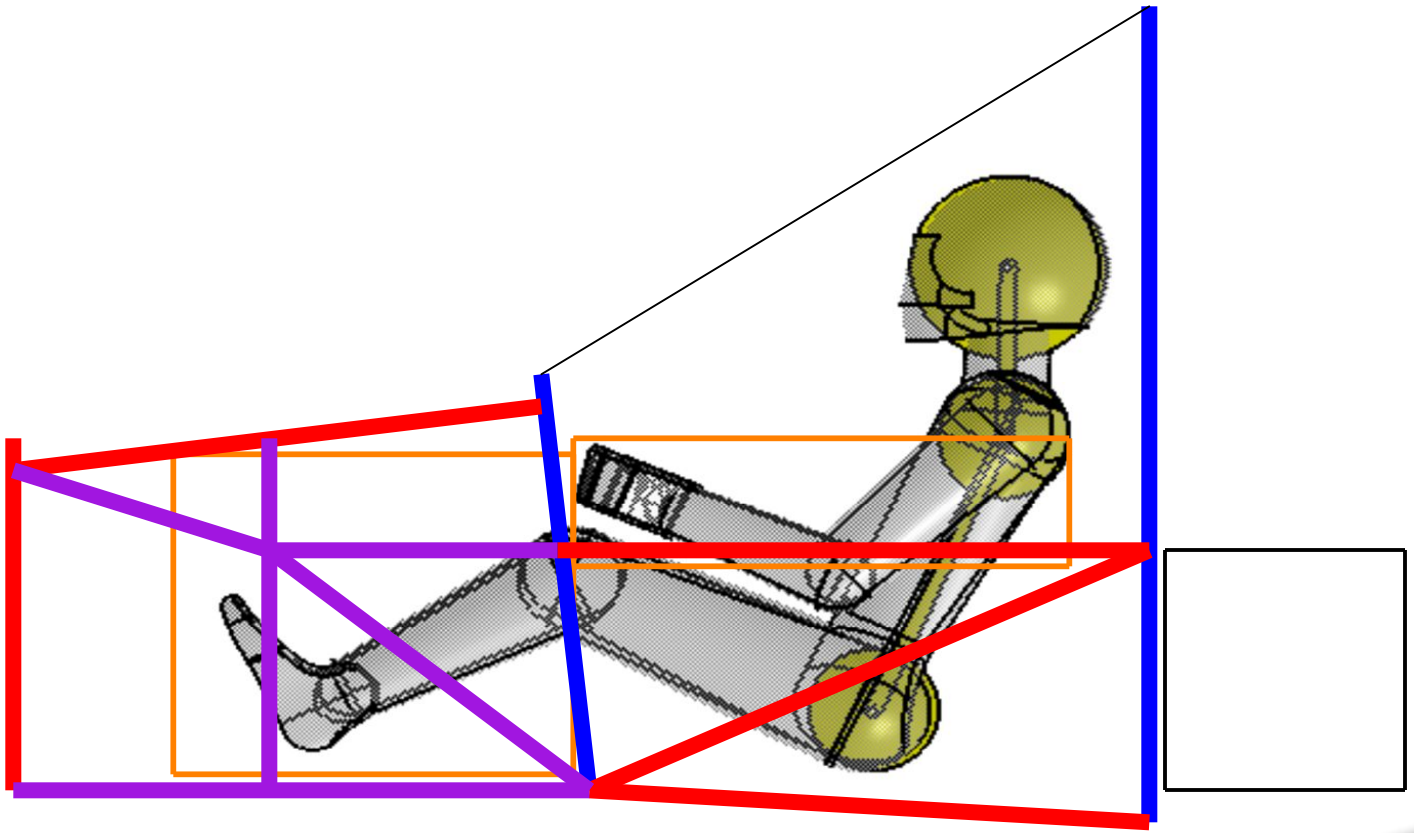

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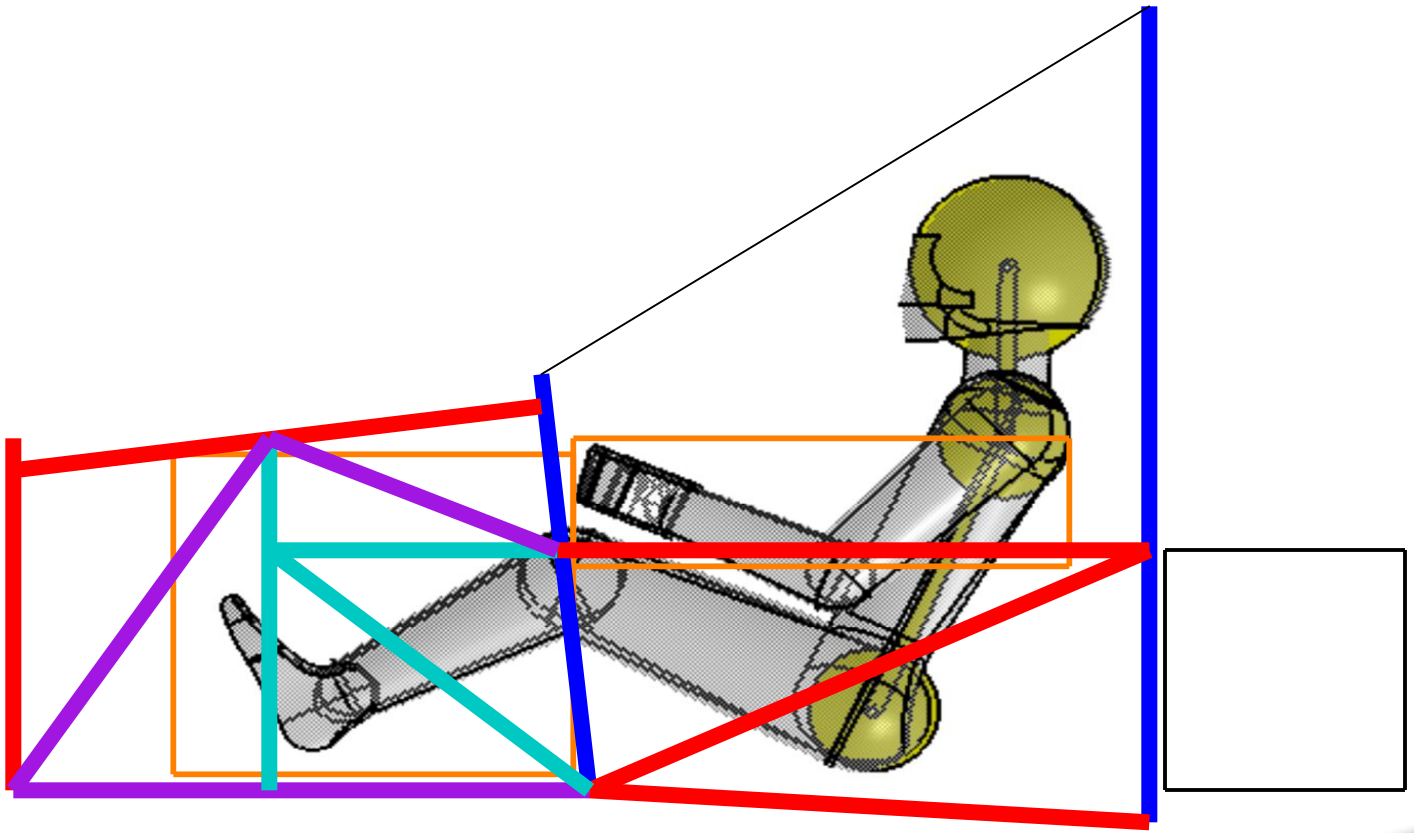

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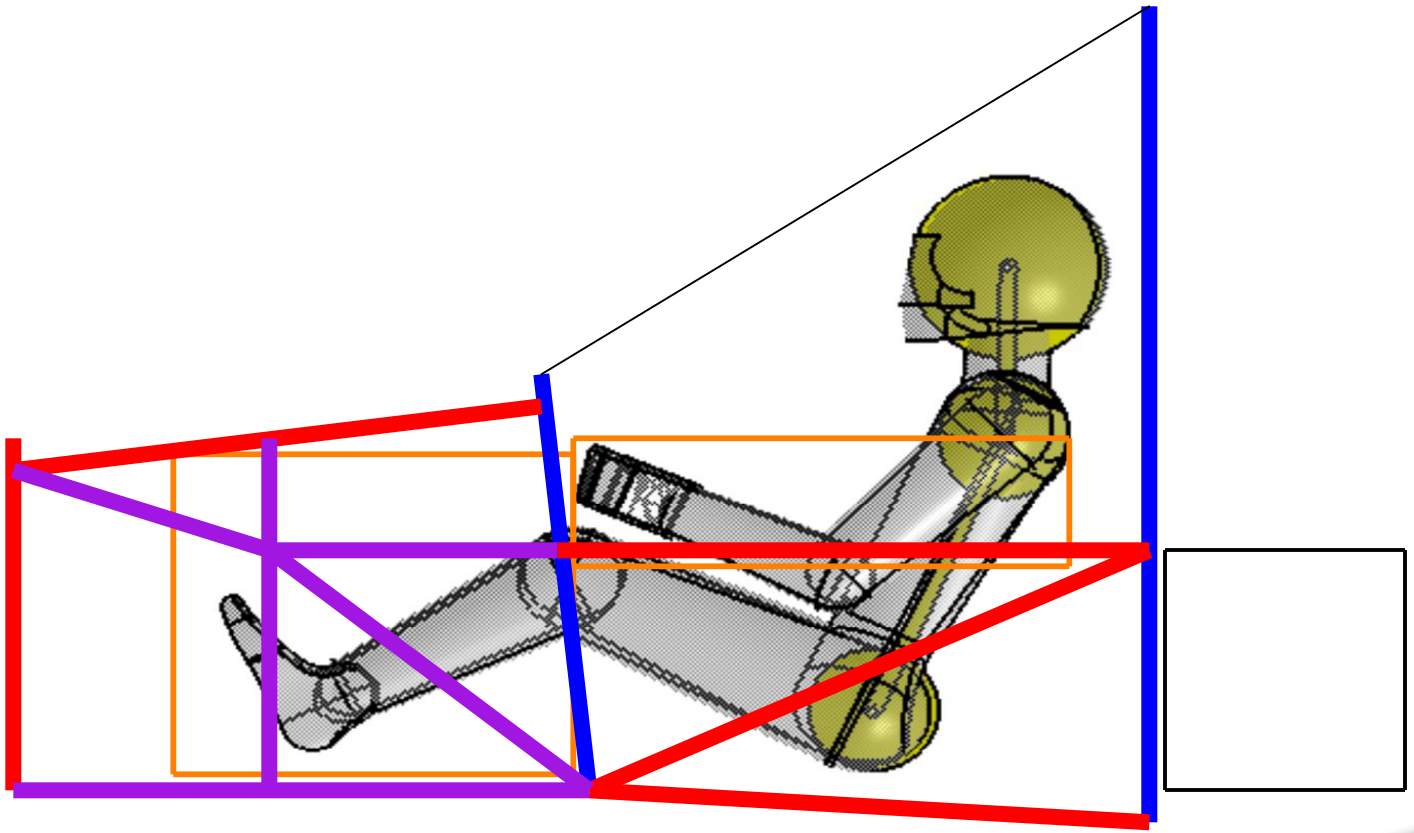

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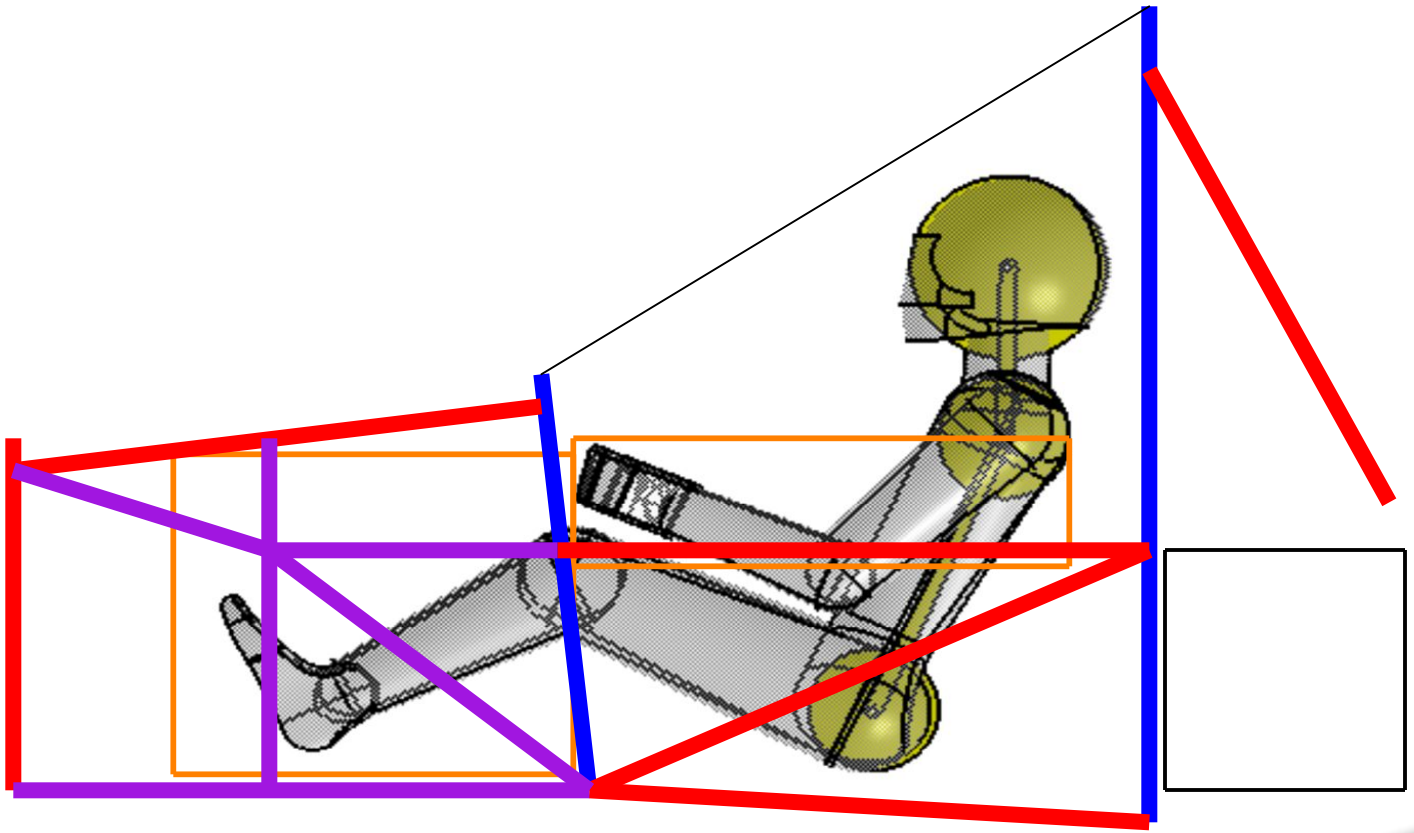

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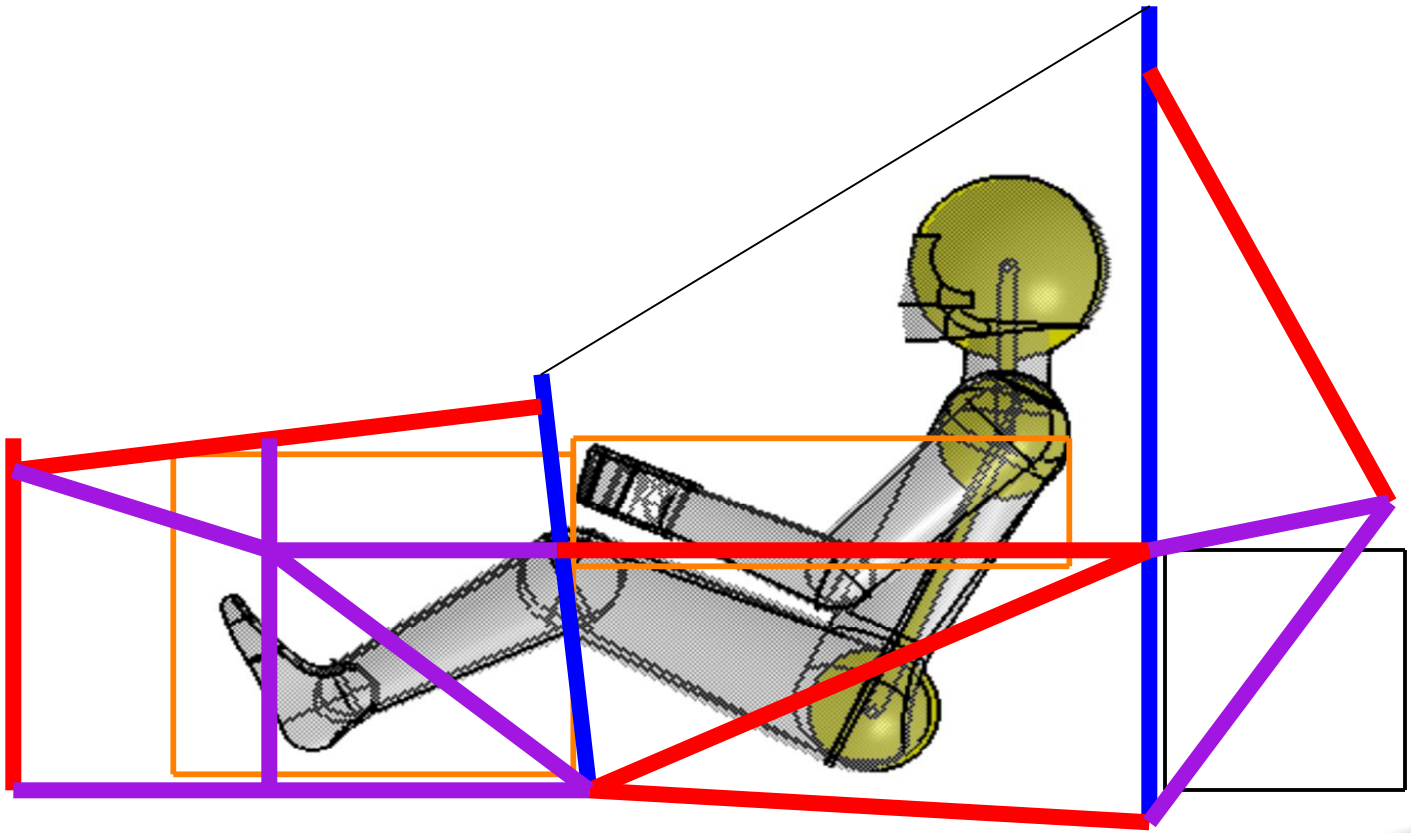

Questions?