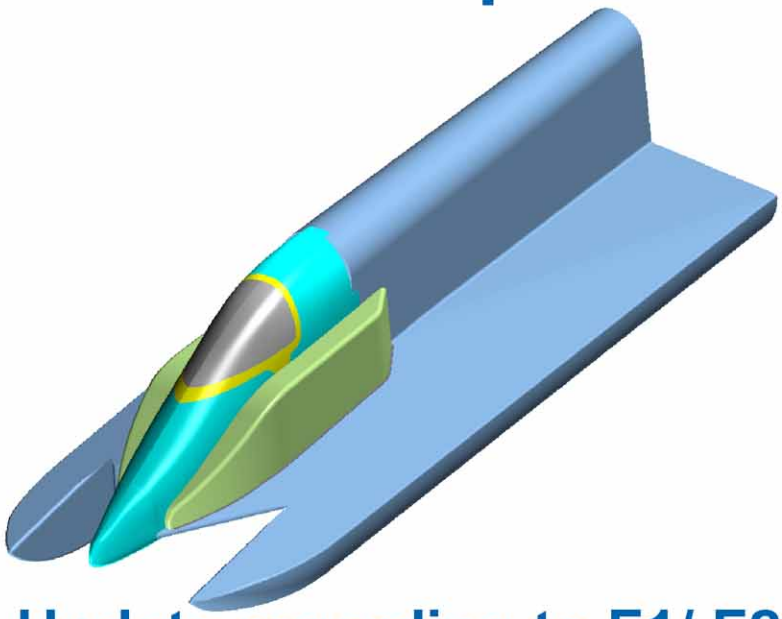
Crash Box
1. Homologation requirements
2. Description



Update regarding to F1/ F2
12 August 2008

Update regarding Test Facility
February 2013

ISATEC GmbH - Rathausstr. 10 - D-52072 Aachen - Tel. +49-241-56816-0 - Fax +49-241-56816-65 - Mail: engineering@isatec-aachen.de

ISATEC designed the crash box to improve energy absorption and to increase the stiffness of the outer shell of the cockpit of a formula racing catamaran in case of a side impact.

ISATEC did not take any other technical aspect into consideration. Such other aspects have to be taken into account in order to assure an over all improvement of the safety by mounting a crash box. These technical aspects are for example necessary changes or improvements of the construction or the strength of the boat, the cockpit or of specific parts of it, the influence of the crash box on the aerodynamical behaviour of the boat and other aspects of technical interaction between the crash box and the boat. To deal with these aspects is the sole responsibility of the relevant boat builder.

Any liability is excluded as far as legally possible except in case of intentional gross negligence. Any dispute or claim resulting out of this contract or use of the crash box will be subject to German law. The jurisdiction is Aachen.

Even if mounted correctly the crash box does not guarantee prevention of injury or death in case of a side impact or another accident.

General requirements

- The side wall has to fulfill separately the existing requirements (rule 509 - reinforced cockpits) allover the cockpit. In addition the crash box has to fulfill the herewith described requirements. **(criterion 1)**
- The crash boxes have to be individually numbered.

Remarks

- Energy absorbing structures must be positioned outside the innner cockpit cell! It depends also on the structural design and the set- up of the other boat, especially their pickles in the case of a T- accident.
- The proposed crash boxes could absorb only *a part* of the energy in case of an accident!

Winglets

- Up to 30cm of length, 10 cm of width (or equivalent area) and 10mm thickness and glued only on a surface area up to length x thickness of winglet are allowed. One winglet per cockpit side is allowed.
- Leave out an area of the joint bare of painting for scrutineering.

Duration

- Three years after introduction.

The homologation requirements for the crash boxes are splittet into three parts

- **Part I:** **Required dimensions and materials**
- **Part II:** **Requirements for the dynamic drop test**
- **Part III:** **Requirements for the glueing interface between crash box and cockpit**

Part I

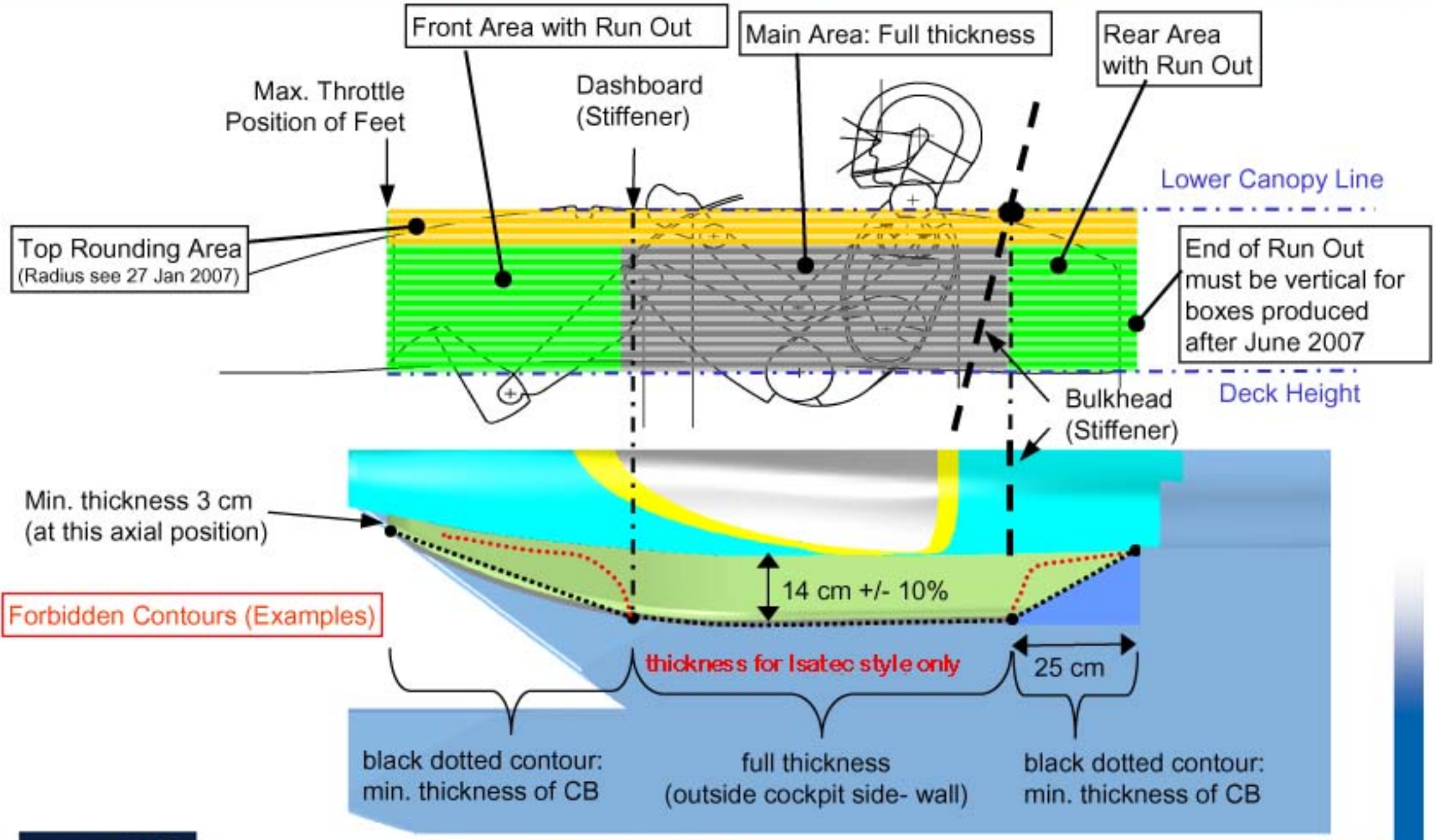
Required dimensions of the Crash Box - Revised by UIM - February 2013

- Thickness for Isatec style only:
  14cm with a tolerance of +/- 10% (hence a minimum of 126mm). **(criterion 2)**
- Covered area: full thickness between the bulkhead and the dashboard with the exception of the top radius (next slide). **(criterion 3)**
- The whole volume of the CB has to be filled with a layered sequence of foam and skin. No hollow areas/ volumes are allowed within the prescribed minimum dimension of the box (black dotted line on p. 5).
- At least 6 foam layers with intermediate skins in the main area (see p. 5) as described on pages 8 and 9. More layers are allowed. **(criterion 4)**
- Cross section for addon crash- boxes: Top radius in segment with full thickness up to 125% of the box thickness, but is strongly recommended to stay below 75%. **(criterion 5)**

Materials

- Thick outer layer with a glass fibre mass per unit area for F1: >= 2000 g/m² (>= 1500 g/m² are possible for F2 applications if not only glass fibres are used) for a proper trigger function of intruding deformable elements and a non- fragile surface during handling. **(criterion 6)**
- The choice of material is free due to the test results. Typically used materials could be E- Glass, Aramid, Carbon or Hybrids.

Crash Box Homologation



Homologation requirements (3/5): Part I- Dimensions

Part II

Requirements for the drop test of crash box samples in conjunction with the steel impactor

- A minimum absorbed energy of 4.0 kJ during drop test as well as a maximal penetration of the box thickness + 15mm (and recommended are maximal 20g on the structure during drop test). **(criterion 7)**
- Drop test at the minimal velocity of 5 km/h to ensure the dynamic character of the test. **(criterion 8)**

Part III

Glueing

- Permanent glueing allover the interface between Crash Box and cockpit is necessary for shear strength in case of an accident.
- Requirements on the glue areas:

1. Border area: Min. shear strength: 1 N/mm²
2. Inner area: Min. shear strength: 0,5 N/mm²

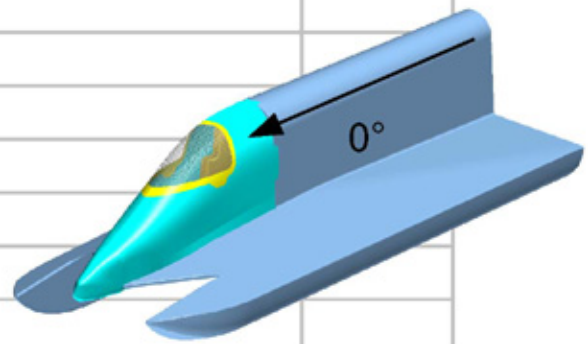
Documentation

- The documentation for approval has to contain the following items:
  - design including geometry, set-up, material specification
  - drop test results containing absorbed energy, g-time graph, force-displacement graph (and video if available)
  - shear test (as described) with fotos and results
  - Box ID number list, which are covered by that documentation
- The documentation must be consistent and traceable concerning all requirements and has to be delivered electronically to UIM
- The full documentation, as described on this page, has to be made for each production lot. For a new production lot with same material and production methods only the manufacturing has to be documented.
- All further changes (e.g. additional parts for the run-out zones) have to be documented in the same way.

Sandwich

	No.	Material	Orientation [°]	Quantity Fiber [g/m²]
Outside	1	**1**	0/90 // +45/-45	2000
	2	2	-	
	3	1	0/90 // +45/-45	720
	4	2	-	
	5	1	0/90 // +45/-45	720
	6	2	-	
	7	1	0/90 // +45/-45	720
	8	2	-	
	9	1	0/90 // +45/-45	720
	10	2	-	
	11	1	0/90 // +45/-45	720
	12	2	-	
Inside	13	**1**	0/90 // +45/-45	2000
			(0°parallel to longitudinal boat axis)	
			each 50 % of 0/90 & 50% of +45/-45	

6 or more layers (foam and skin) stacked



When the box is glued onto the cockpit, its sidewall acts as the inner box sandwich skin and layer 13 is not needed. This layer is necessary for the test samples in any case.

Material

Glassfiber	1	Woven Fabric (equal share in both directions), E-Glass, ca. 68 tex
PVC	2	Foam, 20 mm, 60 kg/m³ with impact energy absorbing capabilities, without up to 80 kg/m³
Total Thickness		14 cm +/- 10% (tolerance due to sum of all defined layers plus glue)

Sandwich						
		No.	Material	Orientation (2)	Quantity Fiber	Density Foam
				[°]	[g/m²]	[kg/m³]
Outside		1	Glass (1)	0/90	>1500 (m)	-
		2	Airex C70.55	-		55
		3	Glass (3)	0/90	600	-
		4	Airex C70.55	-		55
		5	Glass (3)	0/90	600	-
		6	Airex C70.55	-		55
		7	Glass (3)	0/90	400	-
		8	Airex C70.75	-		75
		9	Glass (3)	0/90	400	-
		10	Airex C70.75	-		75
		11	Glass (3)	0/90	400	-
		12	Airex C70.75	-		75
Inside		13	Glass (1)(4)	0/90	>1500 (m)	-
				(0° parallel to longitudinal boat axis)		

(1)	Woven Fabric (equal share in both directions), free choice of material due to test results (26.11.2007)			
	(typically Glass, also Kevlar, Carbon or Hybrids are allowed) PE is not recommended until further notice			
(2)	0%90° and +45%-45°, alternatively			
(3)	Woven Fabric (equal share in both directions)			
	E-Glass and Kevlar shows imilar results in this case for same fiber quantity (g/m²)			
(4)	only required for test samples, must be equal to the top skin			

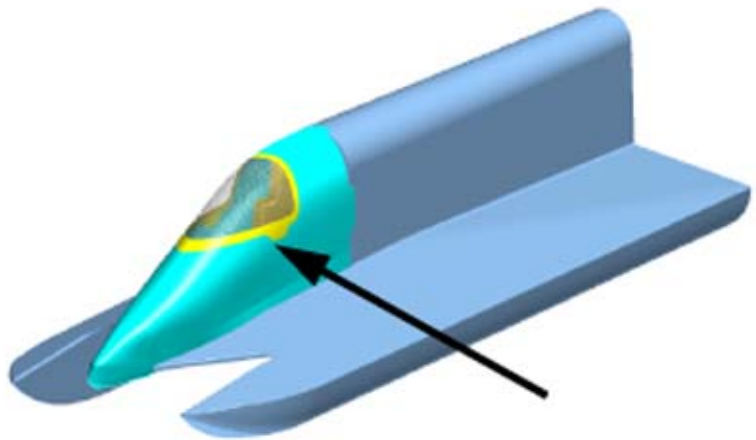
This document describes crash-boxes, reducing the impact on the pilot during T-accidents. For existing boats they will be added on the outside of the cockpits, for new boats they can be integrated in the cockpit design as the outer layers.

The set-up, the base-materials, the design for existing boats and the necessary test with requirements are described.

In the appendix there are given some advises for the design/mounting.

It is strongly advised that the balance point of the boat be recorded before adding the crash boxes (Revised by UIM Feb 2013).

The basis are scanned data of a cockpit extended by simple geometry.

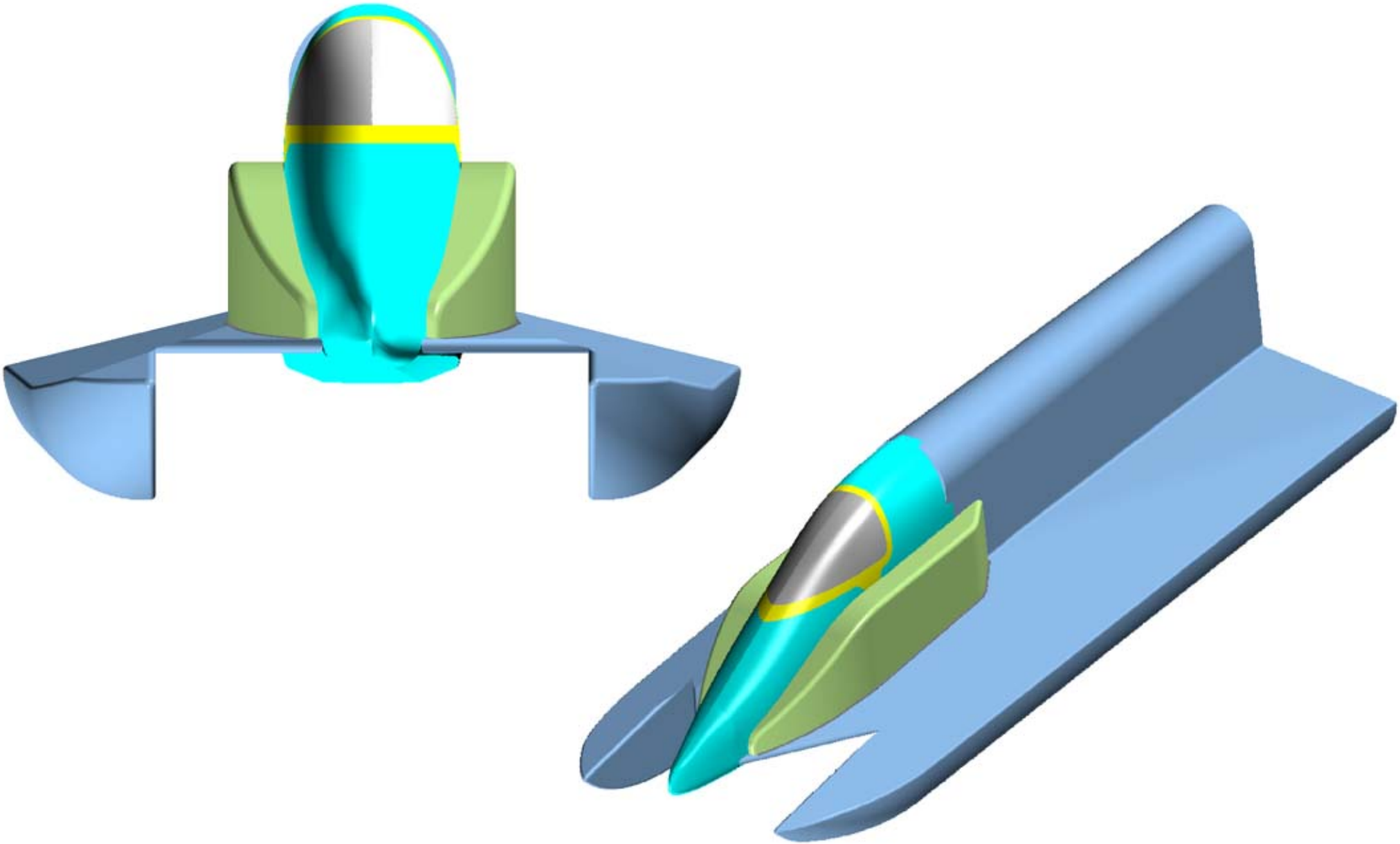


- Cockpit should be stiffened (s. accident Polli), crash-box does it
  [cars: stiff safety cell for passengers]
- Additional energy should be absorbed outside to reduce load on pilot and injury risk for pilot
  [cars with crash zones outside safety cell → energy absorption]

Remarks

Energy absorbing structures must be positioned outside the innner cockpit cell! It depends also on the structural design and the set-up of the other boat, especially their pickles in the case of a T-accident.

The proposed crash boxes could absorb only *a part* of the energy in case of an accident!

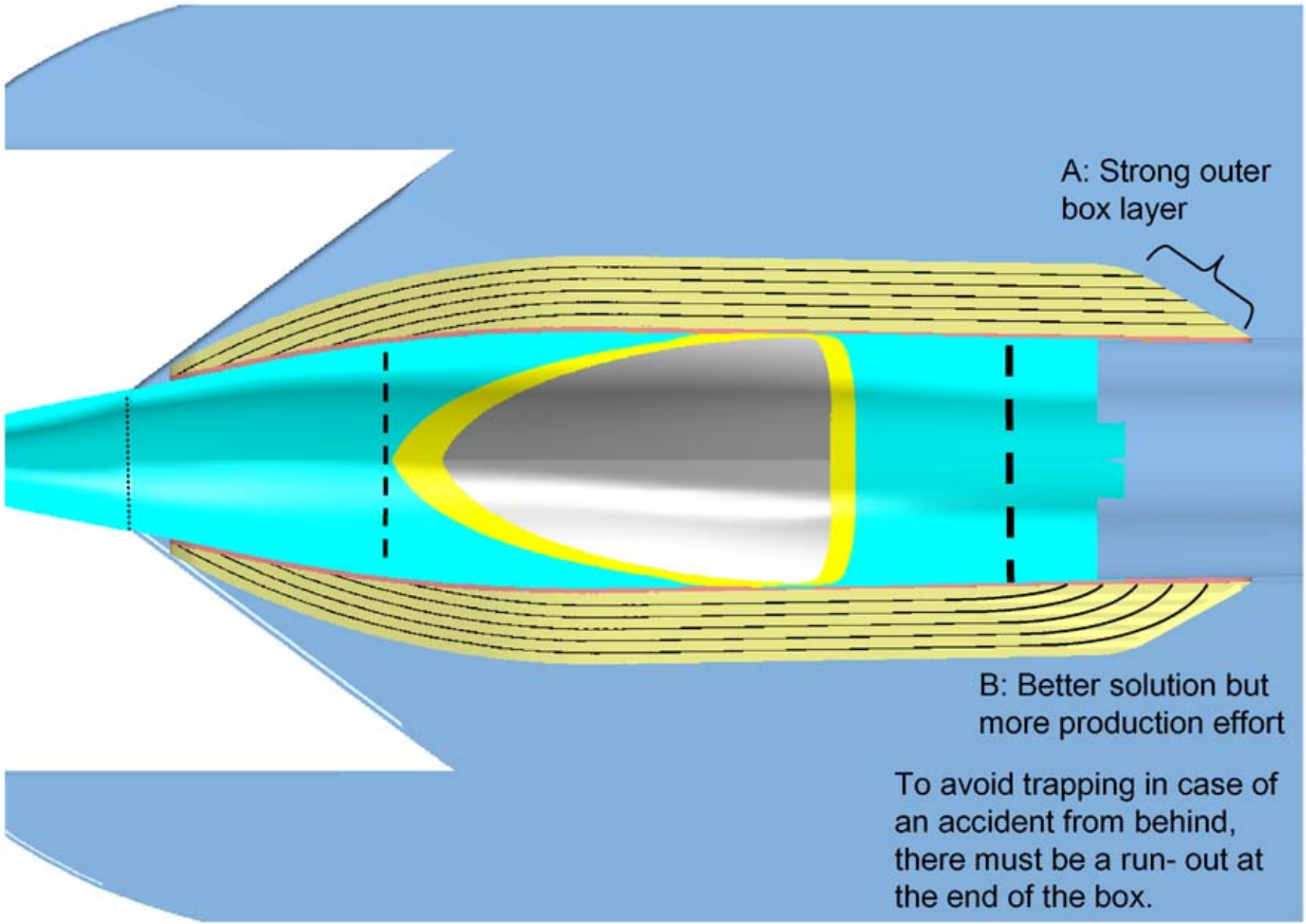


Proposed shape with run-out is chosen due to low impact on up-force

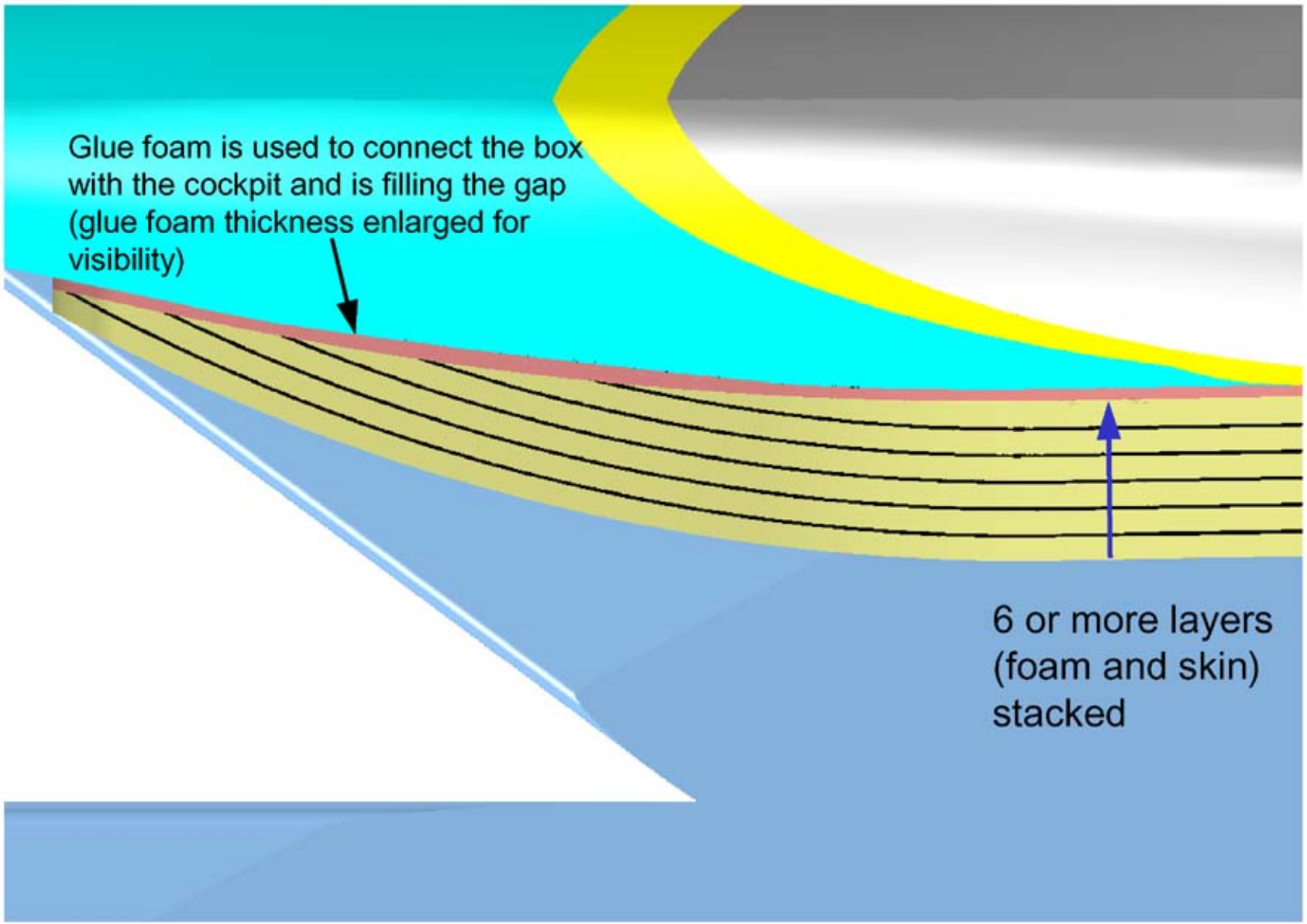
Line showing continuous wall thickness

Therefore the sandwich core layers (foam) are typically cut each to shape this contour. The outer skins must continue to the front end for a proper function, like shown

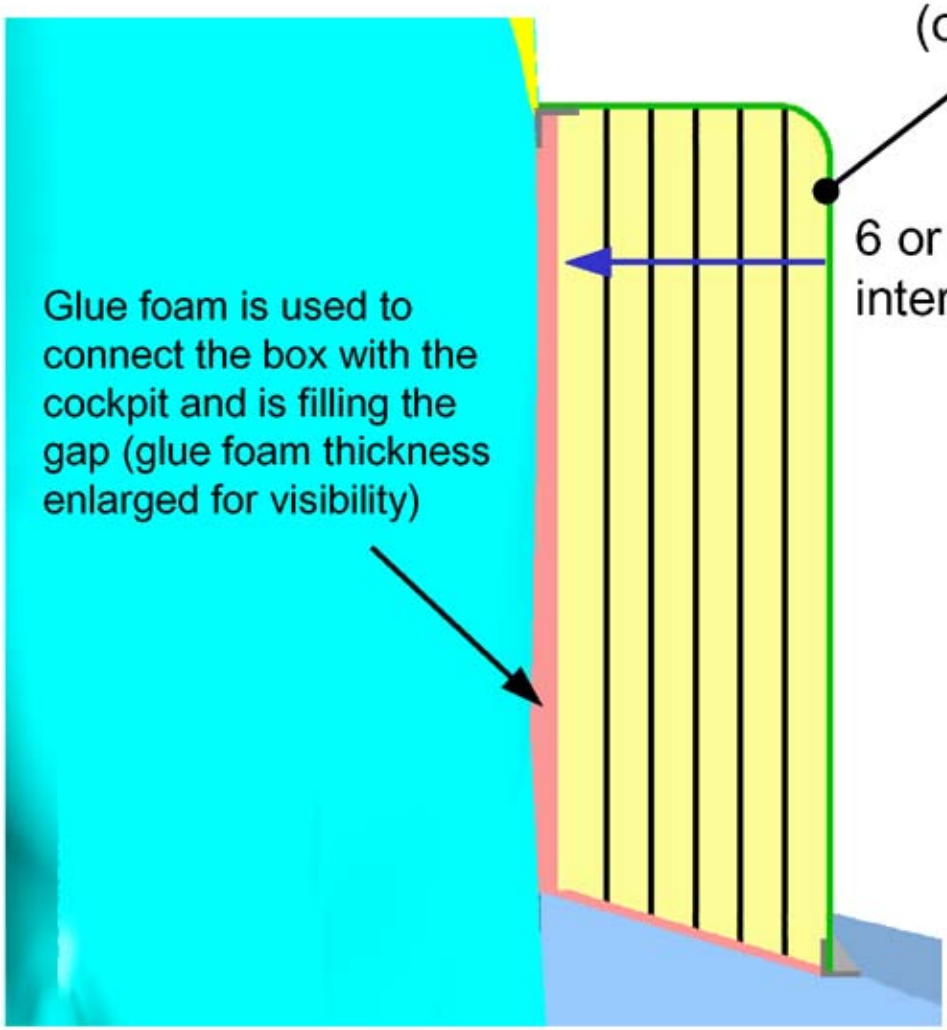
Description (6/18): Shape 1/2 (Outer Skin Layer Not Shown)



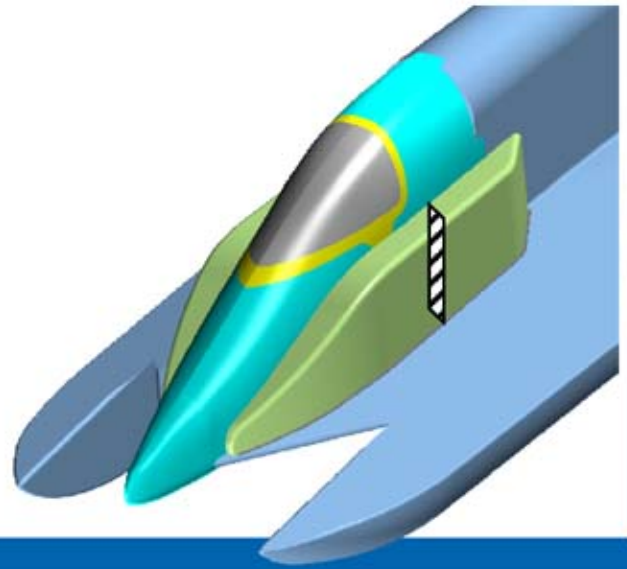
Description (7/18): Shape 2/2 (Outer Skin Layer Not Shown)

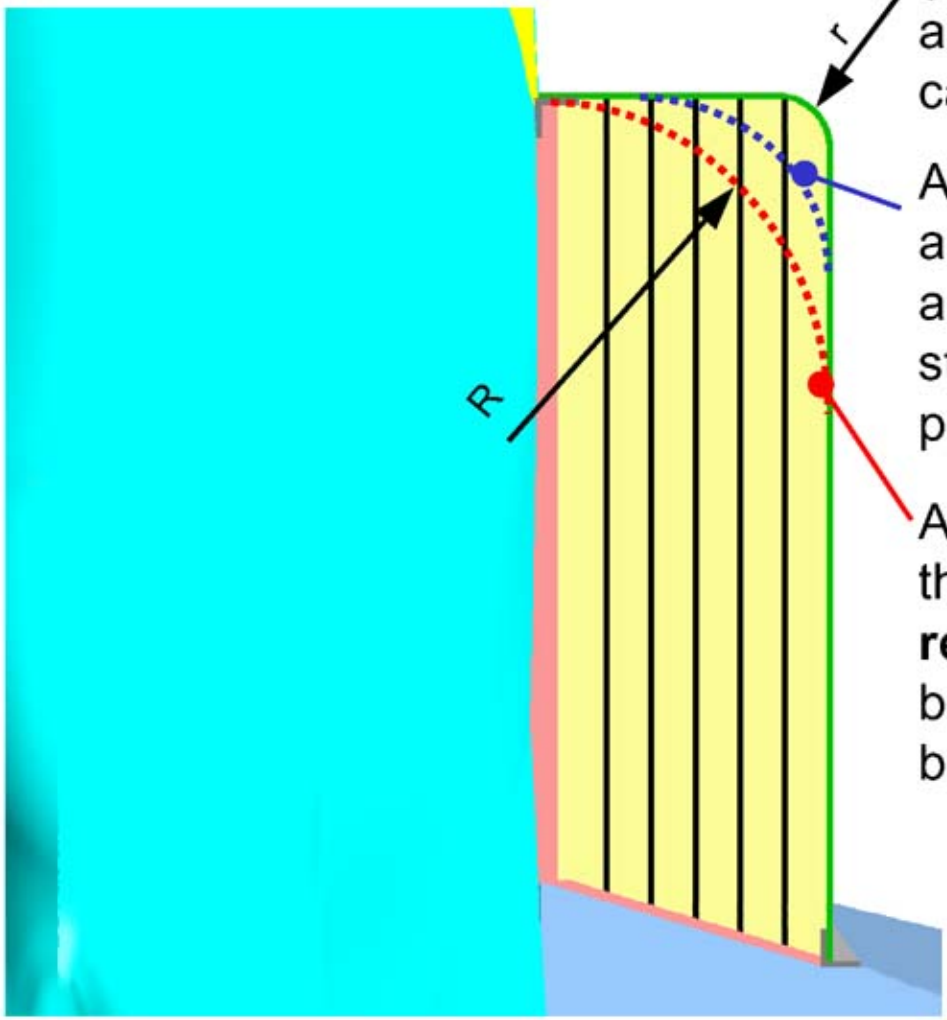


Description (8/18): Connection Box/Cockpit (Outer Skin Layer Not Shown)



Total mass of the 2 crash boxes: 20-25 kg (foam density of ca. 60 kg/m³)

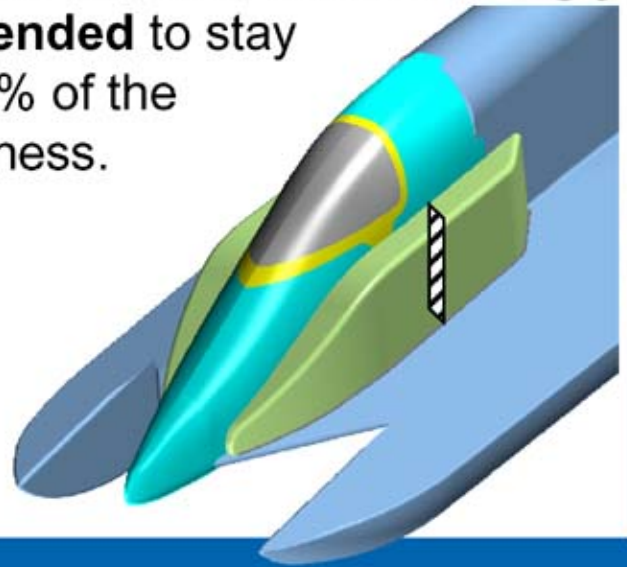




A small radius r was chosen to guide an impactor from the side as less as possible towards the canopy.

A more rounded shape can be accepted as a compromise between aerodynamic requirements (driving stability) and best design for pilot protection.

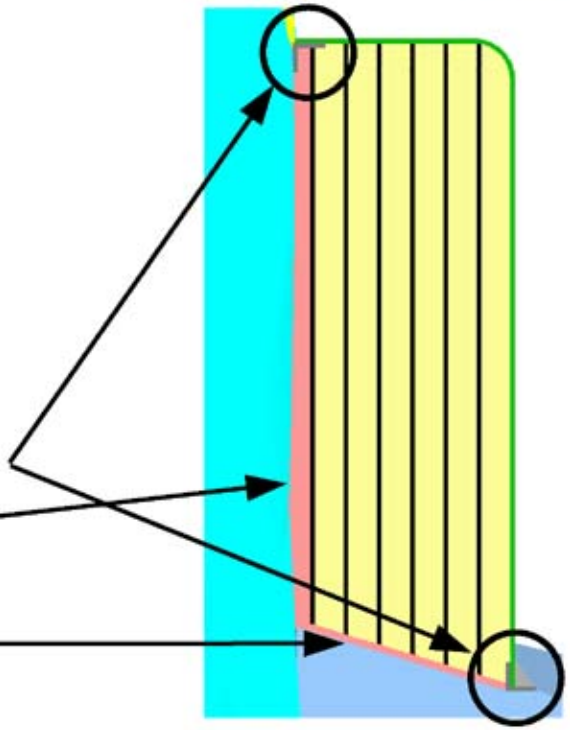
A radius R up to 125% of the box thickness is allowed, but it's **strongly recommended** to stay below 75% of the box thickness.



The box must be glued with the whole surface to the cockpit to ensure the stiffening effect on the cockpit as well as the proper energy absorption. This gluing can be done by PU-foam (closed porous, for marine applications). Glue areas:

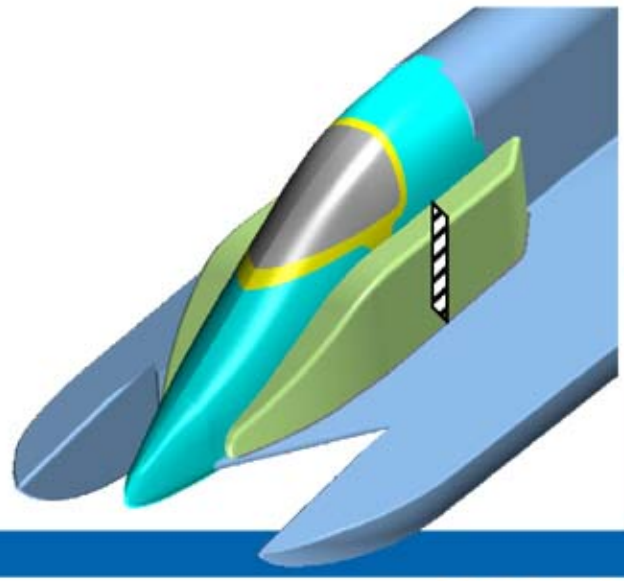
1. Border area with a width of min. 30mm (see appendix: for example L-profile with its flange width or the width of the extended box sandwich skin)

2. Inner area



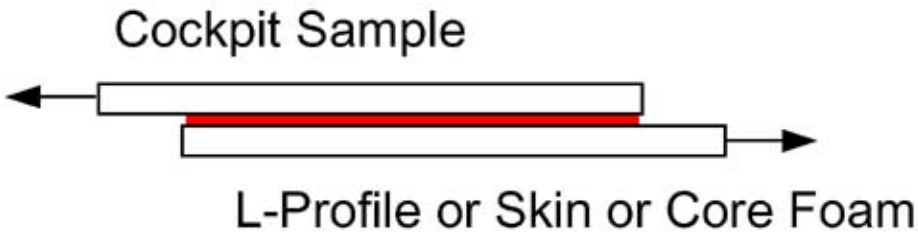
Due to elastic deformation of the boat during racing, the margin between the box and the boat tends to peel off, therefore this must be a focus for high production quality.

The box must be connected permanently to the cockpit. This should be inspected periodically.



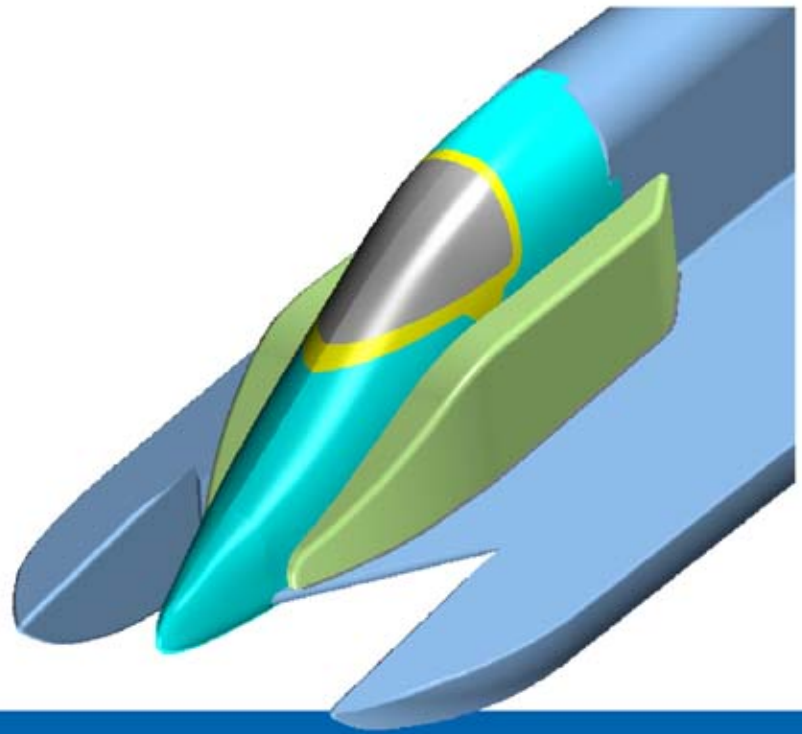
The producer must perform and document the following tests to ensure the gluing quality:

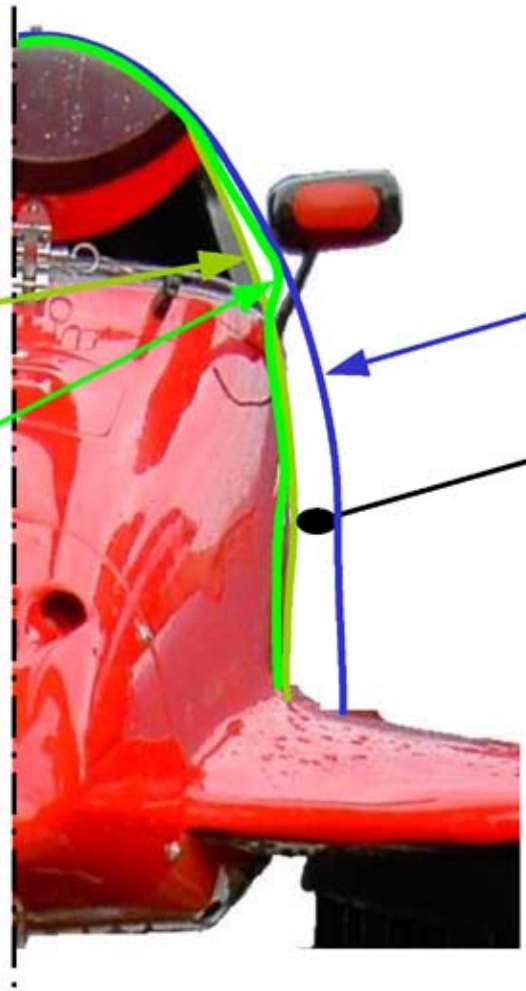
Samples from either side will be produced and glued together with the same procedures and materials used for the box. Then a simple tension test is performed and the nominal shear strength determined.



Requirements on the glue areas:

1. Border area: Min. shear strength: 1 N/mm²
2. Inner area: Min. shear strength: 0,5 N/mm²





Shape of Pilot Safety Cell nowadays

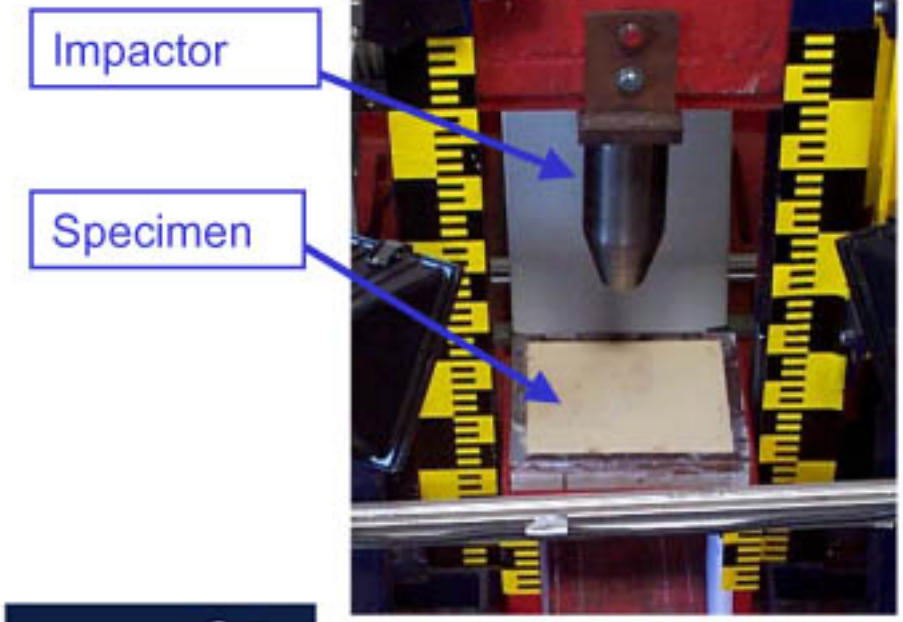
Future Pilot Safety Cell (3000N) with Smooth Transition to avoid Trapping

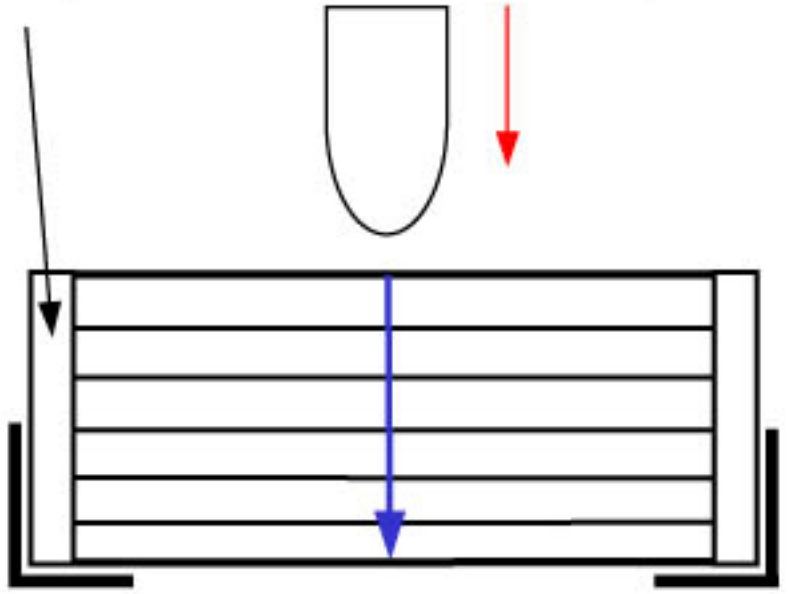
Wider cockpits in the future

Crash box outside safety cell

Energy absorbing structures must be positioned outside the cockpit cell!

- For each **production lot**, a dynamic test has to be performed, similar to the original test, as described below.
  (A simple static test could not ensure the energy absorption capability)
- Dynamic Test (3 test samples needed):
  - Impactor Geometry: see slide „steel impactor“ and attached drawing
  - Drop Mass: e.g. 430 kg
  - Drop Height: e.g. 1,1 m (initial drop height, see next slide)
  - Panel Size: 33,0 cm x 33,0 cm - Do not include any frame around the outside
    Revised by the UIM - February 2013
  - Panel Support: L-Profile, flange width max. 50mm



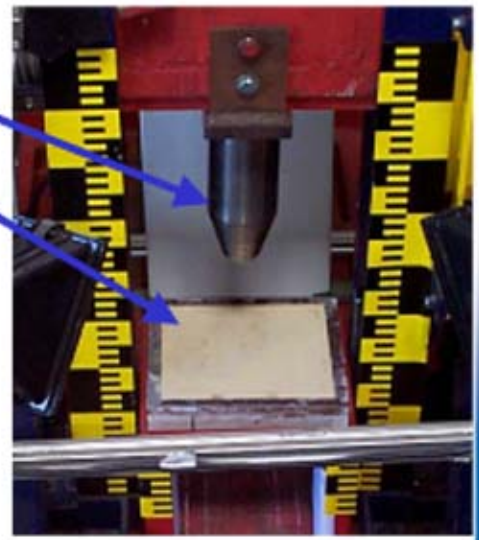


- **The test is to be done by the Politecnico di Milan Italy. Rivised by UIM January 2013. Refer to the "Procedure Letter for Crash Boxes" at the UIM web site for the exact procedure.**
  - The contact name at the university is Eng. Andrea Milanese (office phone number: +390223997160; email: andrea.milanese@polomi.it).
  - The address of the iniversity is: Politecnico di Milano - Piazza L. da Vinci, 32 - 20133 Milano P.IVA 04376620151 - CF 80057930150
  - Costs: The boat builder is to send three samples to the university. The cost of testing the three samples is to be E1500 plus VAT if applicable.

- **Results:**
  - Absorbed Energy: ca. 4,7 kJ
  - The impactor destroys bottom layer only partially
  - See also attached AVI-files.

- **Requirements:**
  - Min. Absorbed Energy: 4,0 kj . . .
  - Based on the 1. test with the initial drop height, the height may be adapted for the 2. test, so that the impactor reaches the bottom layer, but penetrates it max. by 15 mm

- **Recommendation of maximal 20g on the structure**



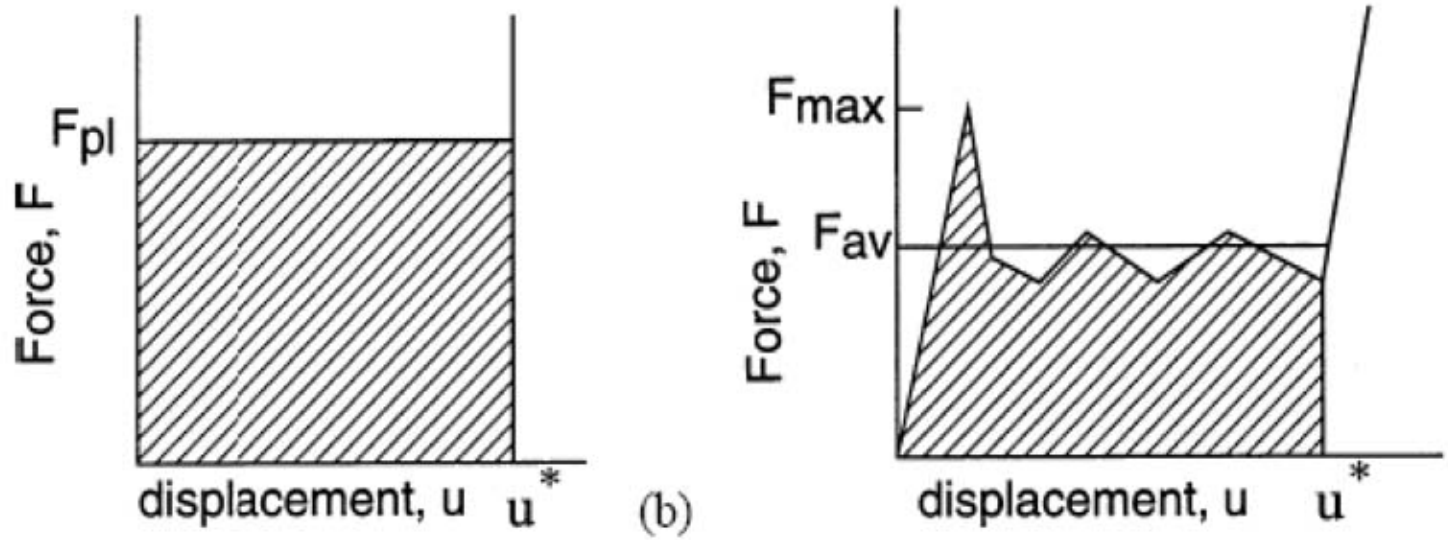
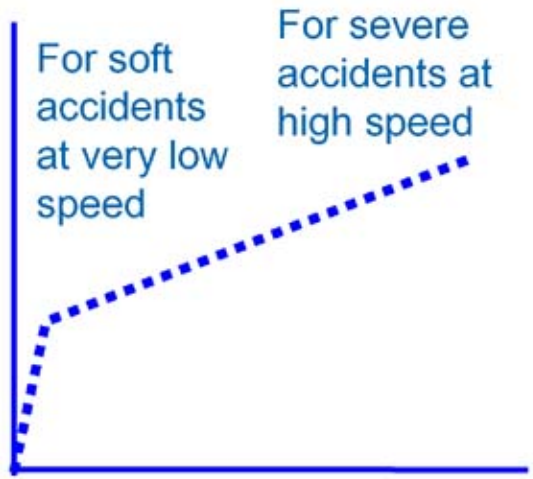
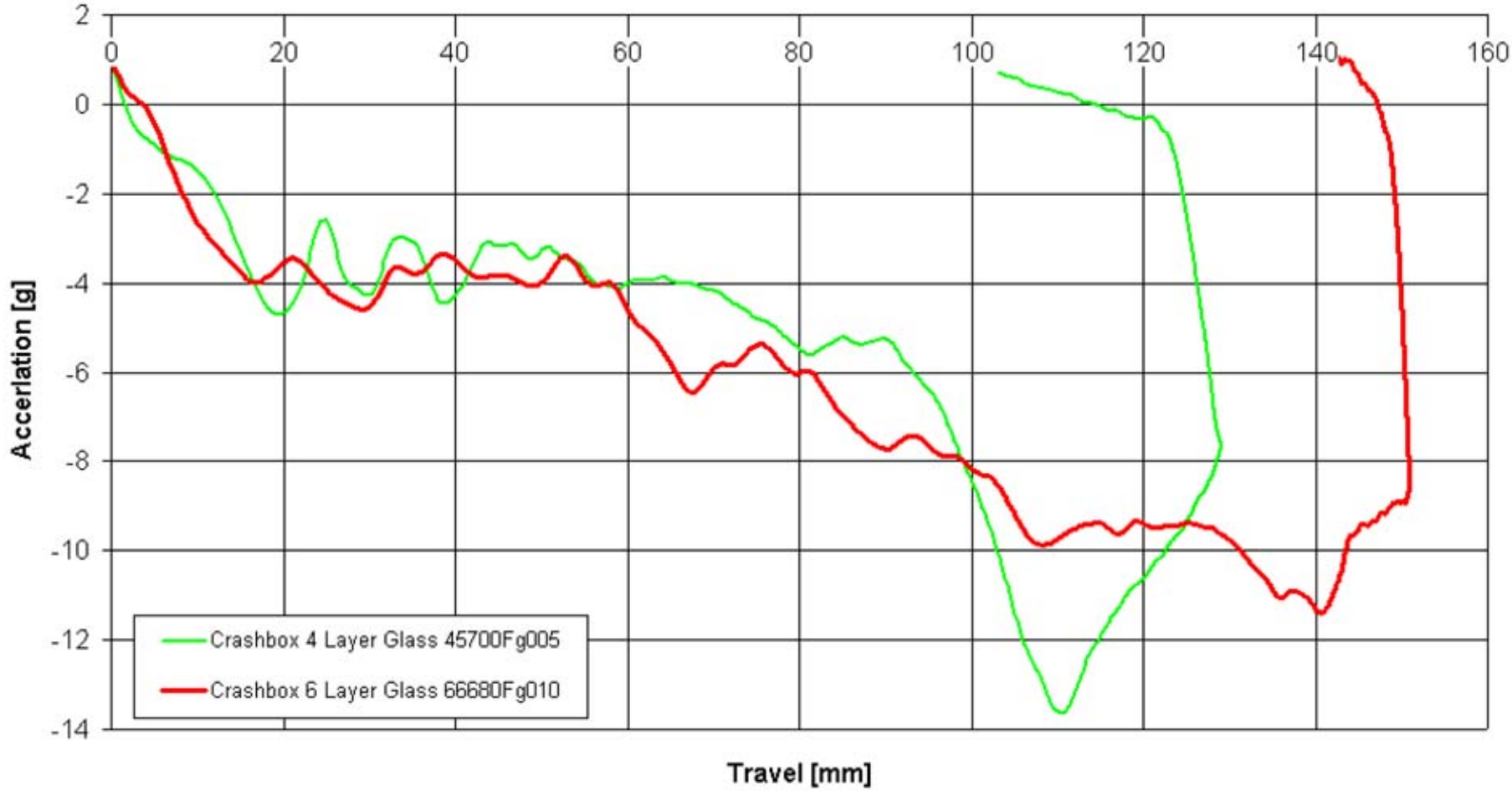


Figure 1. (a) The force-deflection characteristic of an ideal energy absorber; (b) Typical force-deflection characteristic of a practical energy absorber.

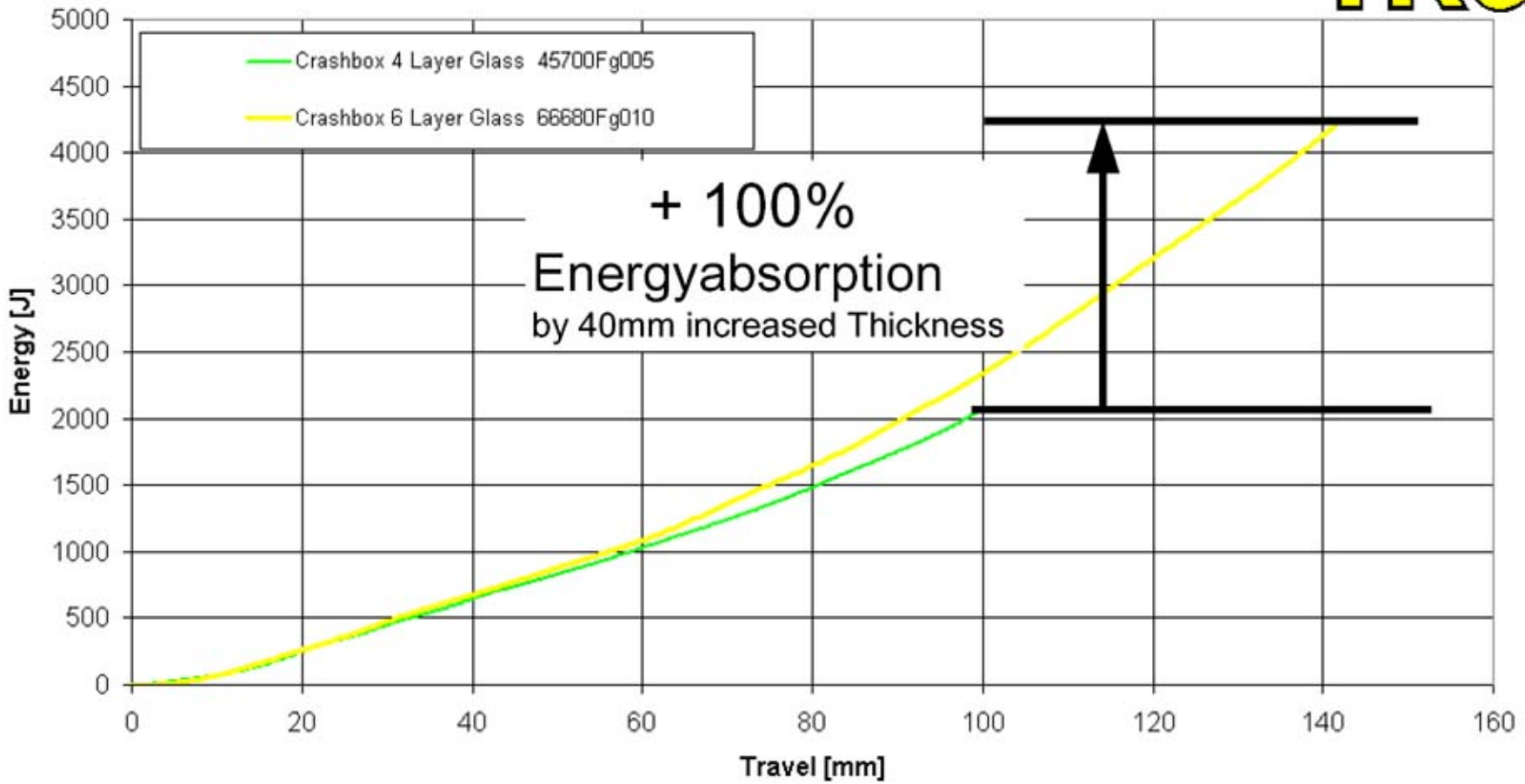


Comparison			
Drop tower test	Acceleration-travel-diagram	Crash mass: 430 kg	



66680Fg012	Side crash box 6 Layer/14cm Glass Aramide 2/3			
Drop tower test	Energy-travel-diagram	vo= 4,79 m/s	Crash mass: 430 kg	17.10.2006

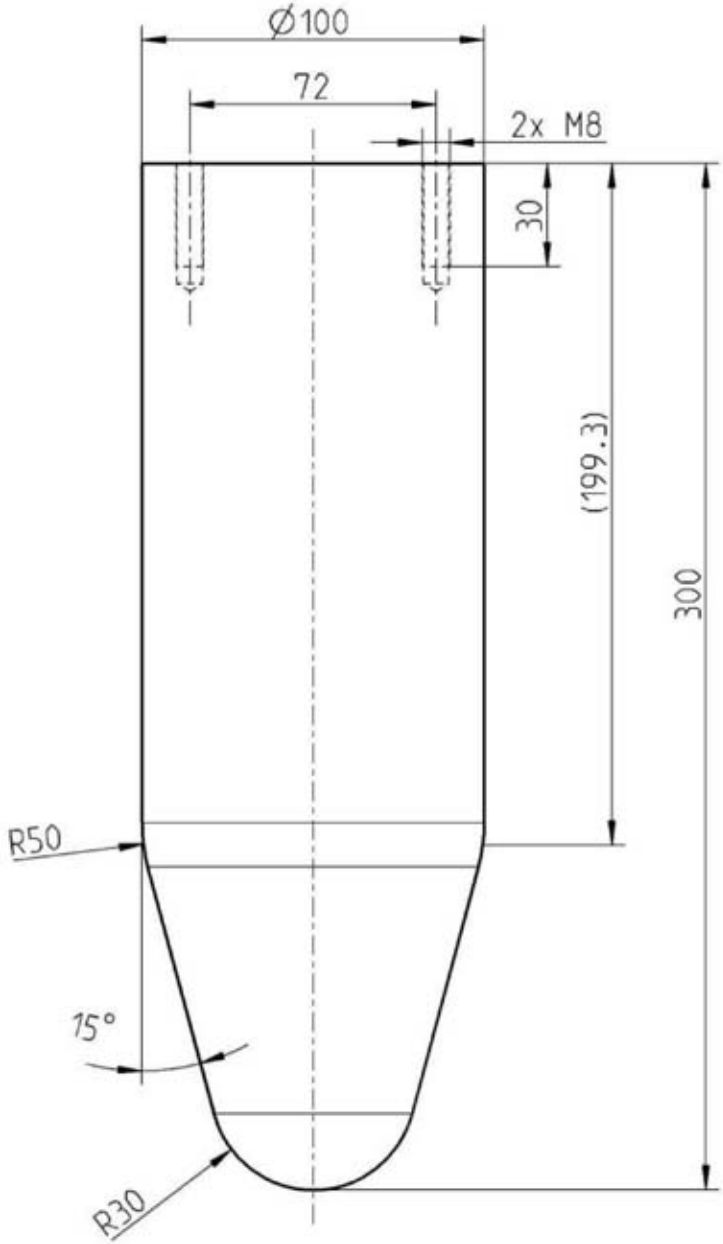
fka



Appendices

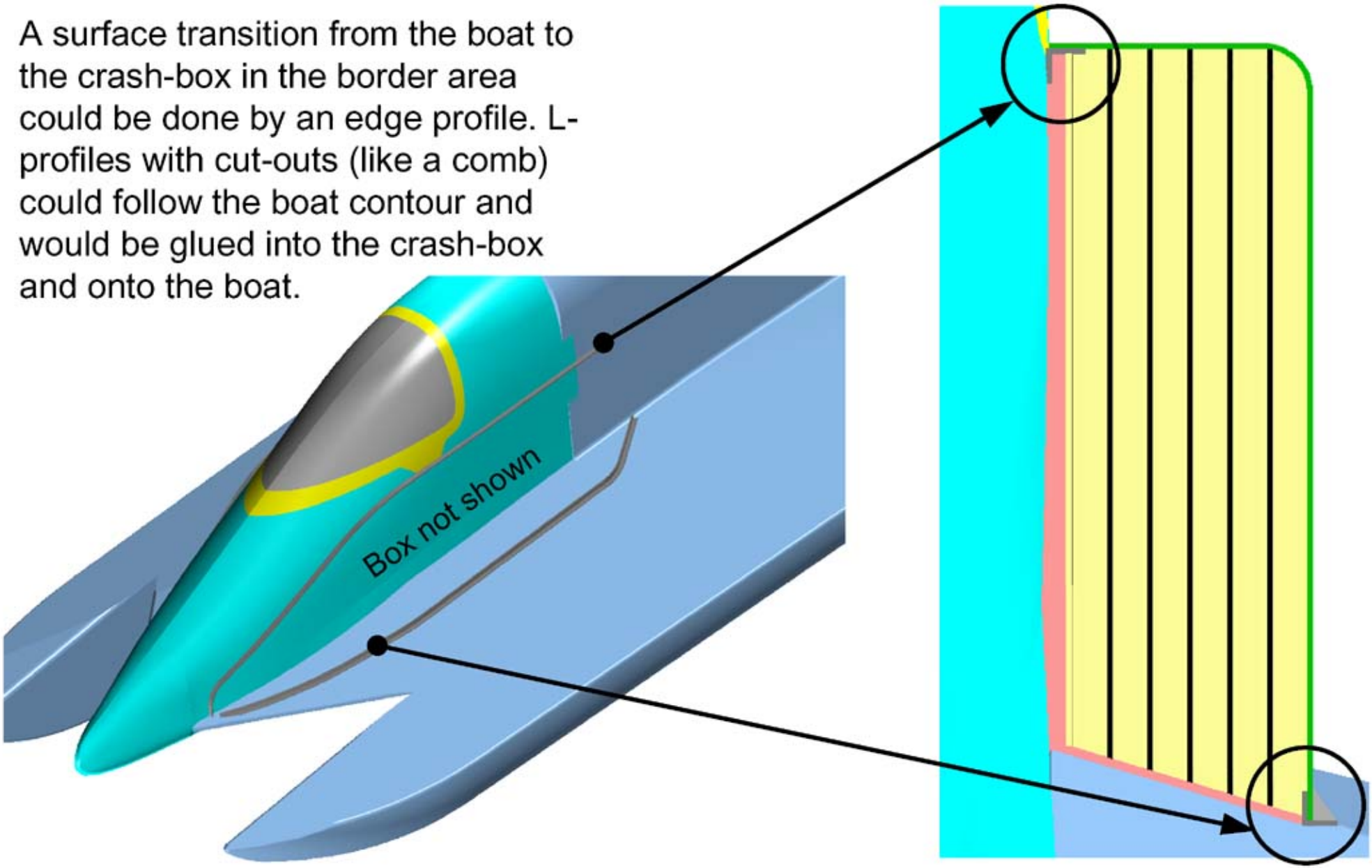
Advises

Standard steel impactor for internal UIM-tests with the geometry similar to the pickle.



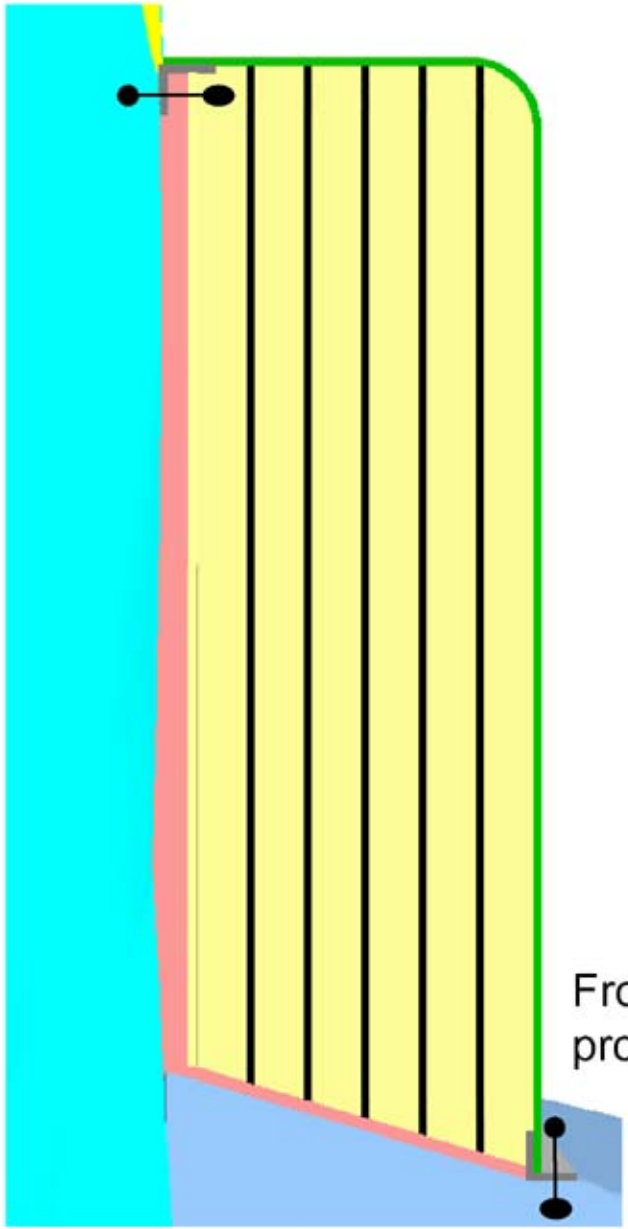
Taken from attached Drawing:
„1777_0001_1_v1.PDF “

A surface transition from the boat to the crash-box in the border area could be done by an edge profile. L-profiles with cut-outs (like a comb) could follow the boat contour and would be glued into the crash-box and onto the boat.



From inside the cockpit through the side wall.

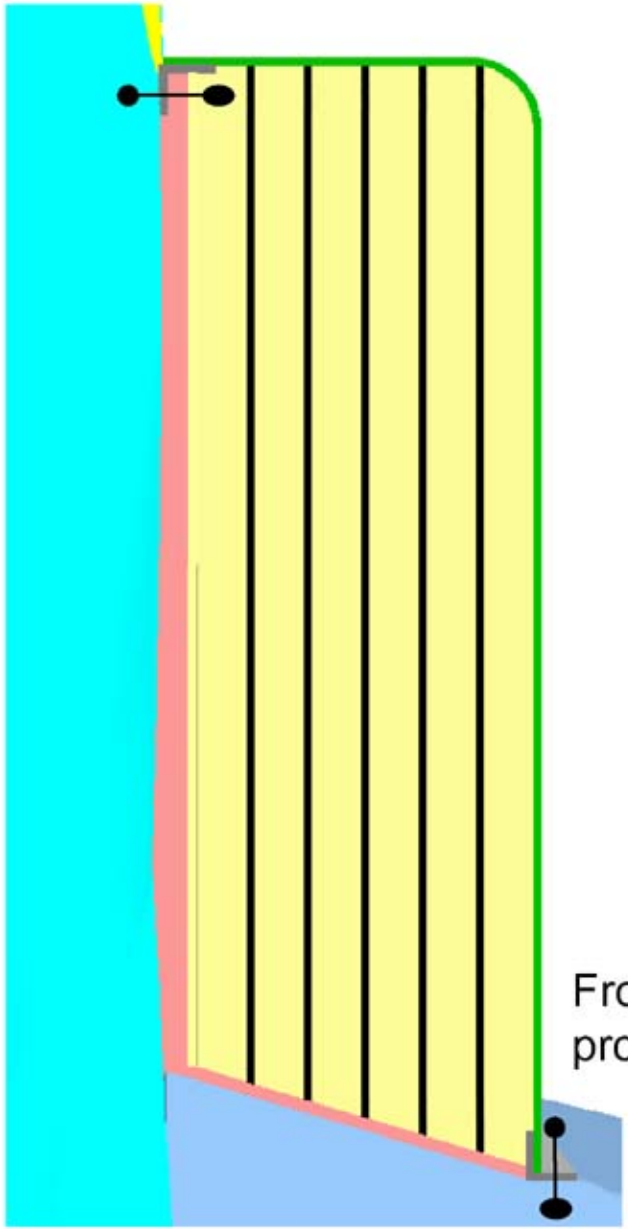
Boltings or rivets could supplement the gluing between the L-profile and the boat.



From outside through the edge profile into the deck.

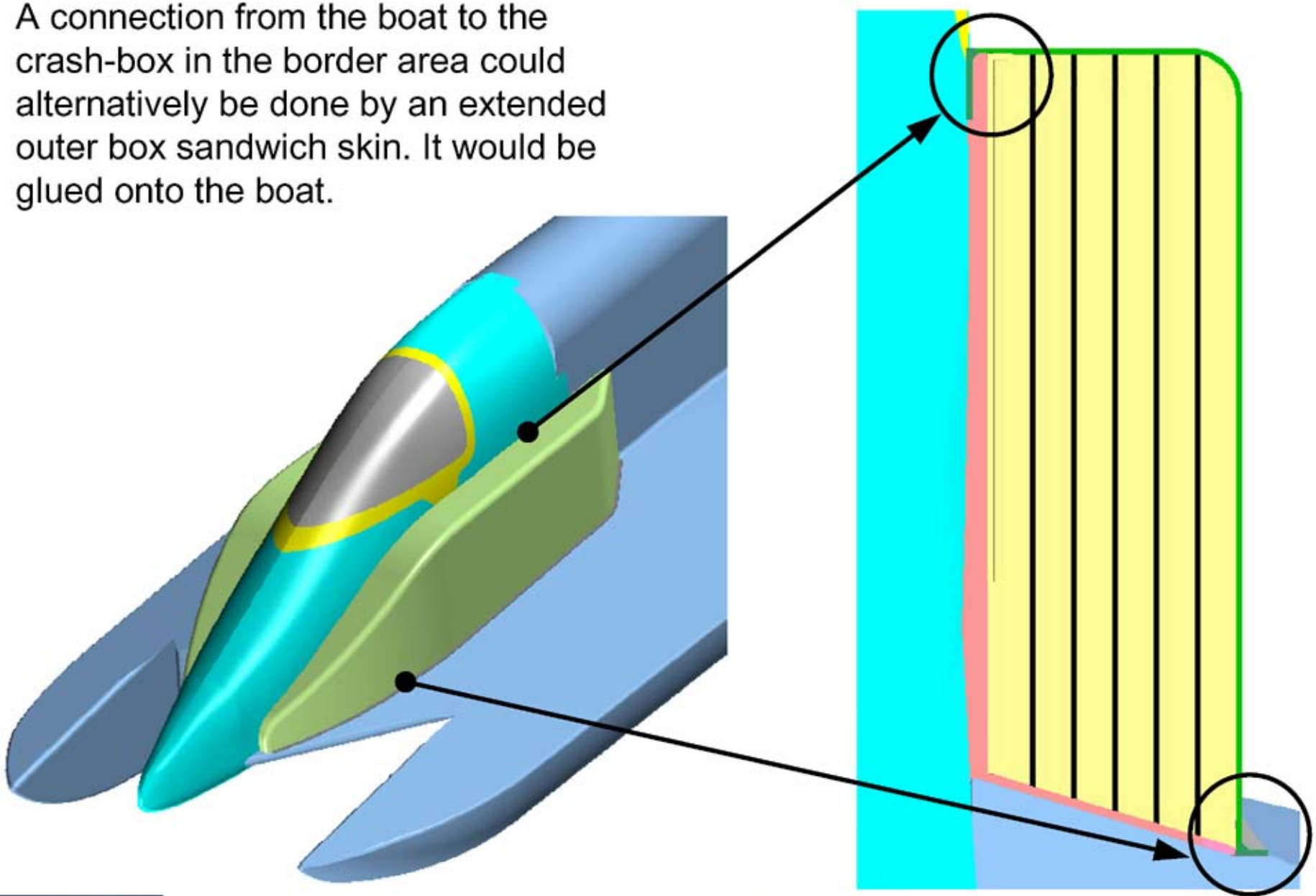
From inside the cockpit through the side wall.

Boltings or rivets could supplement the gluing between the L-profile and the boat.



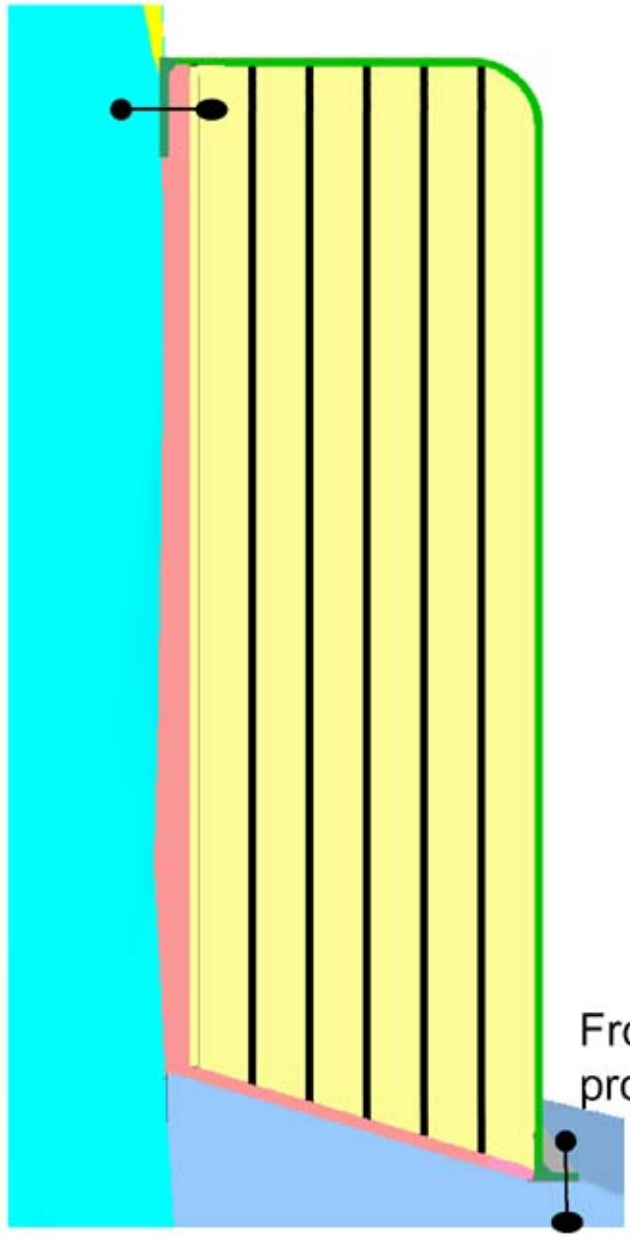
From outside through the edge profile into the deck.

A connection from the boat to the crash-box in the border area could alternatively be done by an extended outer box sandwich skin. It would be glued onto the boat.



From inside the cockpit through the side wall.

Boltings or rivets can be used to extend the gluing between the extended outer box skin and the boat.



From outside through the edge profile into the deck.