

UltraLight Steel Auto Closures

PROJECT OVERVIEW

1. Introduction

The UltraLight Steel Auto Closure (ULSAC) concept study has generated steel closure concepts that are lightweight, structurally sound, manufacturable and affordable. ULSAC demonstrates closure concepts that are up to 32 percent lighter than benchmarked averages and meet stringent structural performance targets. They can be fabricated using manufacturing processes and materials that are current and affordable. The concept phase is the first step in the project and provides the opportunity to build demonstration closures.

These impressive results were obtained largely through design concepts that feature technologies such as tailored blanking and hydroforming and materials such as steel sandwich and high and ultra high strength steels.

Like the UltraLight Steel Auto Body (ULSAB) study, the ULSAC study was commissioned by an international consortium of sheet steel producers to assist their automotive customers with viable lightweighting solutions. While the ULSAB study focused on lightweighting the automotive body structure, ULSAC investigates doors, hoods, decklids and hatchbacks. The ULSAC consortium contracted Porsche Engineering Services, Inc. (PES) in Troy, Mich., to provide engineering management for the project and also worked with them to define the project goals.

2. Goals

ULSAC project goals were to define state-of-the-art closures and develop lightweight steel closure concepts that are structurally sound at an affordable cost.

3. Approach

The project approach encompassed benchmarking, target setting and conceptual design, which includes FEA calculation and cost analysis. Benchmarking was performed to define current state-of-the-art design concepts; target setting provided specific objectives to aim for; and conceptual design was undertaken to demonstrate ideas that would meet the established targets and to produce data to support the concepts.

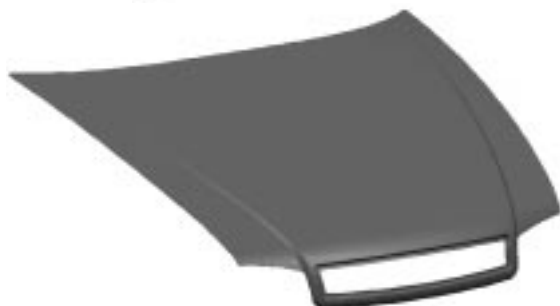
4. Benchmarking

PES benchmarked the following 1997 models:

Audi A6	Mercedes E320
BMW 528i	Mitsubishi Eclipse
Cadillac Sedan Deville	Nissan Sentra
Chevrolet Malibu	Porsche Boxster
Dodge Stratus	Renault Laguna
Ford Contour	Saturn LS
Ford Probe	Toyota Camry
Ford Taurus	VW Golf
Honda Accord	VW Passat



door



hood



decklid



hatch

The benchmark vehicles were chosen to provide specific design concepts to evaluate. For the door these included roof integrated, frame integrated and frameless. Hood design concepts included conventional and grille integrated. The decklid design was the conventional with a tail and the hatch designs were the lift gate type.

The benchmark study established mass (without glass), dimension and structural performance standards for doors, hoods, decklids and hatchbacks. PES normalized this data to make accurate comparisons among the closures and then evaluated designs and components of the benchmarked closures. In addition, PES assessed costs associated with manufacturing each of the closures.

4.1 Doors

Door mass data was collected for the assembly complete, sheet metal and subsystems such as glass, the window regulator, electrical components, latch, lock and hinges, trim and sealing.

Doors were measured for length, height and beltline/bottom, and all measurements include the surface curvature. Length is the longest longitudinal distance along the door from the forward to the rearward most points. Height is the distance from the bottom edge of the door outer panel to the top edge of the frame. The beltline/bottom is the distance from the bottom of the door to the bottom edge of the window opening. PES used these measurements to help calculate true surface area. Material thicknesses were captured with an ultrasonic thickness gage and averaged 0.7 mm for the inner panels and 0.7 mm for the outer panels.

Structural performance test methods and specifications were collected through a survey of respective automakers for each of the benchmarked doors. These specifications represent OEM internal targets and include frame rigidity, door sag, torsional rigidity and check load.

4.2 Hoods

Hood mass data was collected for the assembly complete, sheet metal and subsystems such as the strikers, insulation, sealing and hinges.

Hoods were measured for length and width, the length being the longitudinal distance down the centerline and the width being the plan view width of the hood at its midpoint. All measurements include the surface curvature. PES used these measurements to help calculate true surface area. Material thicknesses were captured with an ultrasonic thickness gage and averaged 0.6 mm for the inner panels and 0.7 mm for the outer panels.

Structural performance test methods and specifications were collected through a survey of respective automakers for each of the benchmarked hoods. These specifications represent OEM internal targets and include torsional rigidity, bending stiffness and side beam stiffnesses.

4.3 Decklids

Decklid mass data was collected for the assembly complete, sheet metal and subsystems such as the lock, trim and sealing.

Decklids were measured for length and width, the length being the longitudinal axis along the centerline, including the tail and the width being the plan view width at the widest point. All measurements include the surface curvature. PES used these measurements to help calculate true surface area. Material thicknesses were captured with an ultrasonic thickness gage and averaged 0.7 mm for the inner panels and 0.7 mm for the outer panels.

Structural performance test methods and specifications were collected through a survey of respective automakers for each of the benchmarked decklids.

These specifications represent OEM internal targets and include torsional rigidity, bending stiffness, side beam stiffnesses and tail stiffness.

4.4 Hatch

Mass data for the hatch was collected for the assembly complete, sheet metal and subsystems such as glass, lock and latch, trim and hinges.

Hatches were measured for length and width. Length measurements followed the surface contour and were calculated along the longitudinal axis down the centerline. Width measurements were taken across the hatch at midpoint. All measurements include the surface curvature. PES used these measurements to help calculate true surface area. Material thicknesses were captured with an ultrasonic thickness gage and averaged 0.7 mm for the inner panels and 0.8 mm for the outer panels.

Structural performance test methods and specifications were collected through a survey of respective automakers for the benchmarked hatch. These specifications represent OEM internal targets and include torsional rigidity and bending stiffness.

4.5 Components

As part of benchmarking, PES also reviewed components for each of the closures. This exercise enabled them to discover the lightest solutions for the component and to find individual components that aid in weight reduction of the whole system. Components reviewed comprised hinge types, check systems, latch types, window regulator systems and modular systems.

4.6 Data

To process all this data for comparison, PES normalized mass, determined the length to hinge spread

ratio and calculated the mass breakdown of each closure. Mass was normalized by dividing the outer surface area into the mass.

Normalized mass

Closure	Normalized mass range (kg/m ²)	Average normalized mass (kg/m ²)
Door	17.0-23.4	19.7
Hood	8.8-14.2	11.5
Decklid	8.9-16.1	11.2
Hatch	12.5-15.4	13.9

The calculation of normalized mass allowed for the mass of paint and gum drops, as specified below.

Mass allowance

Closure	Paint (kg)	Gum drops (kg)
Door	0.15	N/A
Hood	0.2	0.15
Decklid	0.2	0.15
Hatch	0.15	N/A

The hinge spread ratio is an indication of stiffness that can be expected in the closure. As a general rule, the smaller the ratio, the stiffer the closure system. Hinge spread ratio is calculated by dividing the hinge spread into the length. This calculation resulted in a range for the door of 2.7:1 to 4.2:1; for the hood of 0.6:1 to 1.0:1; for the decklid of 0.6:1 to 0.9:1; and for the hatchback of 1.4:1.

PES also calculated mass breakdown to discover opportunities for greatest mass reduction. Calculations for mass breakdown revealed that structure represented approximately 50 percent of the mass of the doors. For hoods and decklids, that number increased to approximately 90 percent. The structure in hatches accounts for about 45 percent of the mass.

After gathering this benchmarking data and processing it appropriately, PES developed mass and performance targets for the closure designs.

5. Target setting

PES developed targets for dimensions, structural performances and mass for doors, hoods, decklids and hatches. Dimensional targets for doors, hoods and decklids were based on ULSAB styling surface dimensions because those dimensions were very close to ULSAC benchmarked averages and they provided PES the outer surface data it needed to conduct this closure study. For hatch dimensional targets, PES used the measurements from a lift gate type hatch, which was the lightest and smallest one benchmarked. Structural performance targets were set at the midpoint in the range from the OEM survey. Mass targets, however, were set for 10 percent better than best-in-class of the benchmarked closures.

Door targets

		Benchmark	Targets
Dimension (mm)			
	Length	1085	1079
	Height	1160	1248
	Beltline/bottom	643	740
Normalized mass (kg/m ²)		19.7	15.5
Structural performance			
	Frame rigidity front/rear	43 (N/mm)	≥ 43 N/mm
	Door sag	287 (N/mm)	≥ 287 N/mm
	Torsional Rigidity	94 (N/mm)	≥ 94 N/mm
	Check load	1.2 mm (set)	< 1.2 mm (set)

Hood targets

		Benchmark	Targets
Dimension (mm)			
	Length	1122	1283
	Width	1455	1402
Normalized mass (kg/m ²)		11.6	8.0
Structural performance (N/mm)			
	Torsional rigidity	5.7	≥ 5.7
	Bending stiffness	4.5	≥ 4.5
	Side beam stiffnesses	110	≥ 110

Decklid targets

		Benchmark	Targets
Dimension (mm)			
	Length	1085	1079
	Width	1220	1241
Normalized mass (kg/m ²)		11.2	8.0
Structural performance (N/mm)			
	Torsional rigidity	5.7	≥ 5.7
	Bending stiffness	4.5	≥ 4.5
	Side beam stiffnesses	110	≥ 110
	Tail stiffness	21	≥ 21

Hatch targets

		Benchmark	Targets
Dimension (mm)			
	Length	1353	930
	Width	1253	1335
Normalized mass (kg/m ²)		13.9	11.3
Structural performance (N/mm)			
	Torsional rigidity	3.5	≥ 3.5
	Bending stiffness	4.5	≥ 4.5

6. Conceptual design

With targets defined, PES developed conceptual designs for each of the closures. ULSAC's design team started with a "clean sheet of paper" and used an iterative holistic approach to design, whereby the structure is treated as an integrated system rather than as an assembly of individual components. The holistic approach emphasizes total structure analysis. Sophisticated computer models aid the process and confirm the effectiveness of the latest optimizations. This approach promotes weight savings and improved structural integrity by enabling engineers to

reduce weight in certain areas while strengthening strategic locations. The net effect is the creation of a more efficient structure.

PES evaluated the closure design concepts selected in the early part of the study and developed optimized solutions. Then they specified materials, processes and joining technologies that would enable them to meet their targets. To guide their efforts at this stage, PES reviewed manufacturing processes they might recommend for the closures and assigned a value to them based on criteria such as feasibility, mass savings and tool cost, to name a few. Based on this subjective analysis, PES directed its attention to design concepts that employed the manufacturing processes that cumulated the most promising scores.

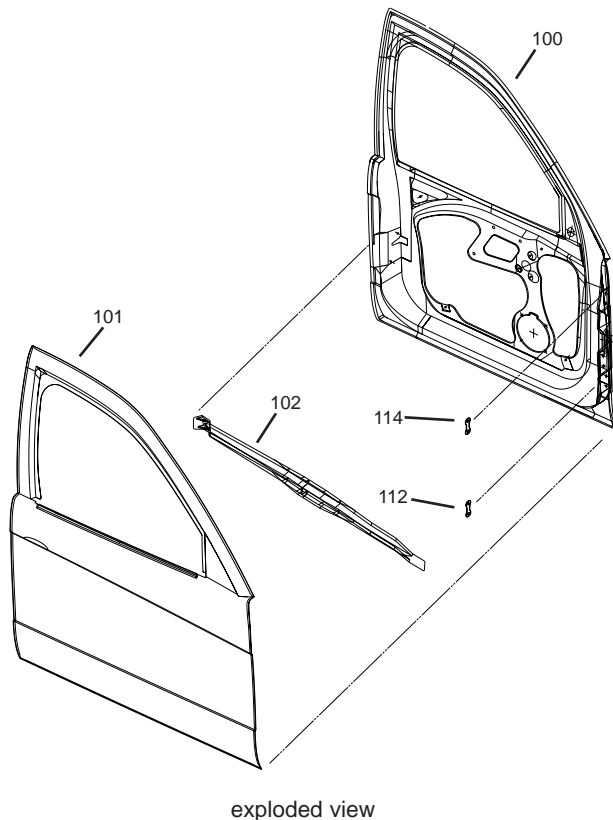
Another initial consideration concerned dent resistance and oil canning. PES guarded against these two problems by following several conventional techniques:

- Feature lines were added to outer panels to stiffen unsupported areas
- Inner panel structures were designed to provide good support to outer panels
- Sheet metal hydroforming was used to increase effective outer panel dent resistance through work hardening
- High strength steel was used for outer panels

All closures are designed to the dimensions identified in the target setting phase of this study. Design concepts for the door included roof integrated, frame integrated and frameless; for the hood it included conventional and grille integrated; for the decklid it included the conventional with a tail; and for the hatch it included the lift gate type.

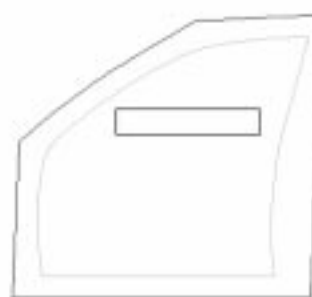
6.1 Door

6.1.1 Roof integrated

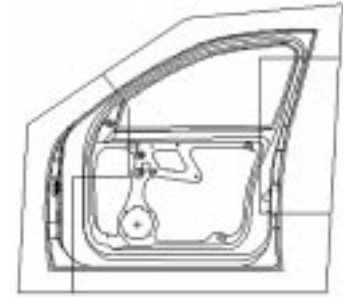


Design highlights

The roof integrated design concept employs a 0.7 mm sheet hydroformed outer panel with feature lines to improve dent resistance and oil canning. PES saves mass and improves formability in the inner panel by specifying non-linear weld lines in the tailored blank. Additional mass savings in this part are gained by using a double cable window regulator thereby eliminating the lower glass drop channels. The tailored blank outer panel reinforces the belt area, increasing stiffness there. High strength steel is specified in the hinge area to withstand sag and check load stresses.



blank layout outer



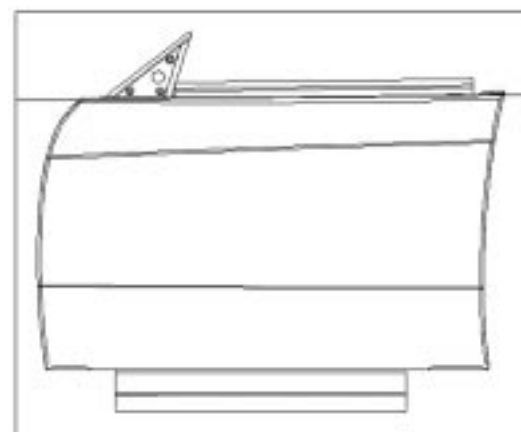
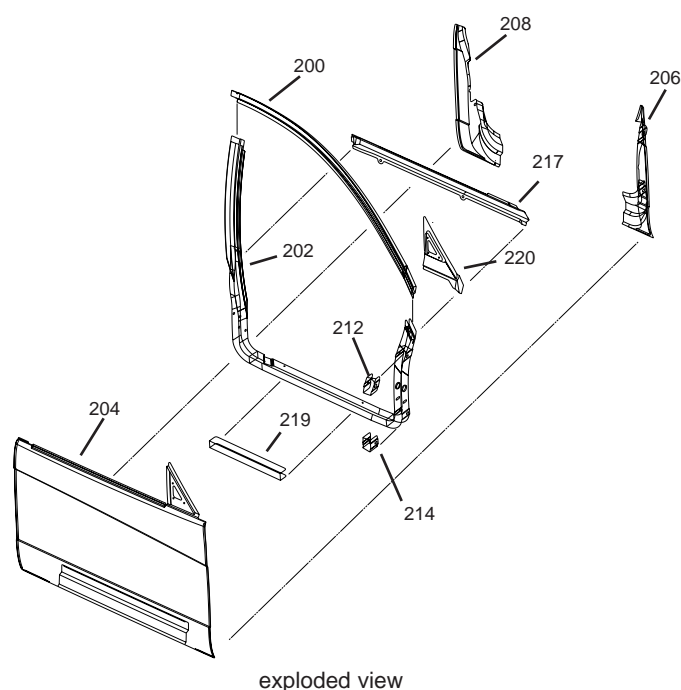
blank layout inner

This design results in the creation of a structure with a normalized mass of 15.1 kg/m² compared with the target of 15.5 kg/m². It is 23 percent lighter than the benchmarked average.

Specifications

	Mass (kg)	Thickness (mm)	Grade (Mpa)	Manufacturing Process	Stock Material	Joining Technology
101 Panel Front Door Outer	5.54	0.7/1.0	210	Hydroformed Sheet	Tailor Welded Blank	Hemmed to Inner, Adhesive Bonding
100 Panel Front Door Inner	5.90	1.5/1.0/0.6	280/140/140	Stamping	Tailor Welded Blank	Hemmed to Outer
102 Impact Beam Front Door	1.46	1.6	1200	Rollformed	Coil	Spot Welding
112/114 Reinf. Hinge Lower/Upper	0.12	2.0	140	Stamping	Coil	Spot Welding, Adhesive Bonding
Paint Allowance	0.15					
Total Mass	13.17					
Normalized Mass (kg/m ²)	15.14					
Surface (m ²)	0.87					

6.1.2 Frame integrated



blank layout

hydroformed tube that forms the lower door frame withstands sag and check load stresses and incorporates the side intrusion beam to save mass. Improved stiffness is created by the continuous connection from the laser welding that is used to attach parts to the hydroformed frame. The frame concept allows better assembly accessibility and subsequent service of the window regulator, latch system and wiring harness.

This design results in the creation of a structure with a normalized mass of 15.5 kg/m² compared with the target of 15.5 kg/m². It is 21 percent lighter than the benchmarked average.

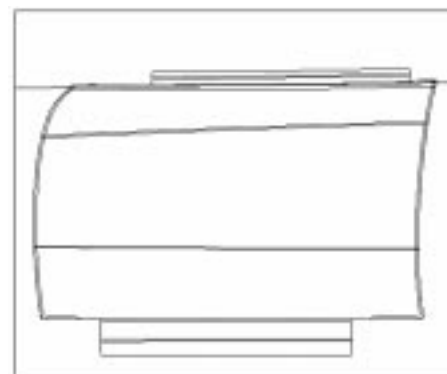
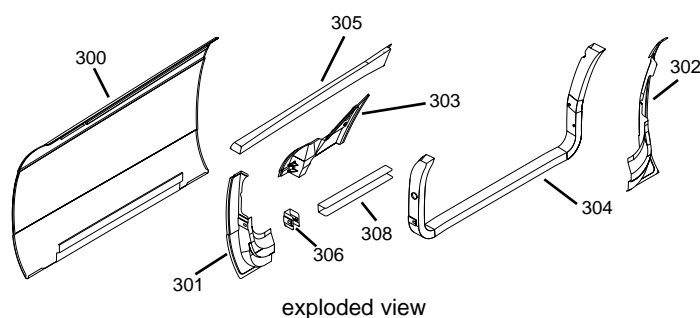
Design highlights

Sheet hydroforming and feature lines create the same benefits for dent resistance in the frame integrated door as in the roof integrated door. The high strength steel

Specifications

	Mass (kg)	Thickness (mm)	Grade (Mpa)	Manufacturing Process	Stock Material	Joining Technology
204 Panel Front Door Outer	5.27	0.7/1.0	210	Sheet Hydroformed	Tailor Welded Blank	Hemmed, Adhesive Bonded
206 Panel Front Door Inner Front	0.47	0.6	140	Stamping	Coil	Hemmed, Adhesive Bonded
208 Panel Front Door Inner Rear	0.48	0.6	140	Stamping	Coil	Hemmed
200 Tube Door Frame Up Front	1.20	0.8	140	Rollformed	Coil	Laser Welded
202 Tube Door Frame Lwr Front	4.11	1.2	280	Tube Hydroformed	Tube	Laser Welded
217 Reinforcement Beltline	0.66	1.0	350	Stamping	Coil	Spot, Laser Welded
220 Reinforced Mirror Flag	0.17	0.7	140	Stamping	Coil	Spot, Laser Welded
219 Reinforcement Impact Beam	0.48	1.2	1200	Rollformed	Coil	Laser Welded
212 Reinforcement Upper Hinge	0.09	1.2	140	Stamping	Coil	Laser Welded
214 Reinforcement Lower Hinge	0.09	1.2	140	Stamping	Coil	Laser Welded
Paint Allowance	0.15					
Total Mass	13.17					
Normalized Mass (kg/m ²)	15.49					
Surface (m ²)	0.85					

6.1.3 Frameless



Design highlights

Sheet hydroforming and feature lines create the same benefits for dent resistance in the frameless door as in the roof integrated and the frame integrated doors. The high strength steel hydroformed tube that forms the lower door frame withstands sag and checkload stresses and incorporates the side intrusion beam to save mass. The frame concept allows better assembly accessibility and subsequent service of the win-

dow regulator, latch system and wiring harness. A thin wall casting used as a structural node to connect the upper and lower frame saves mass by incorporating several features in one part, including the mirror patch, upper hinge and joint node.

This design results in the creation of a structure with a normalized mass of 14.3 kg/m² compared with the target of 15.5 kg/m². It is 27 percent lighter than the benchmarked average.

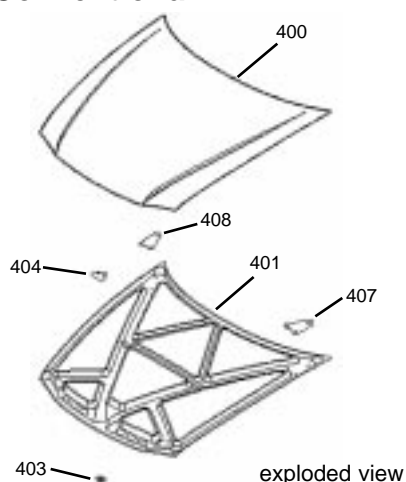
Specifications

	Mass (kg)	Thickness (mm)	Grade (Mpa)	Manufacturing Process	Stock Material	Joining Technology
300 Panel Outer	4.90	0.7/1.0	210	Sheet Hydroformed	Tailor Welded Blank	Hemmed, Adh. Bonded, Laser Welded
301 Panel Inner Front	0.38	0.6	140	Stamping	Coil	Hemmed, Adh. Bonded, Laser Welded
302 Panel Inner Rear	0.41	0.6	140	Stamping	Coil	Hemmed, Adh. Bonded, Laser Welded
304 Tube Door Frame Lower	3.21	1.2	280	Tube Hydroformed	Tube	Laser Welded
303 Bracket Remote Mirror	0.87	1.5	140	Thin Wall Casting	Ingot	Laser Welded
305 Reinforcement Beltline	1.06	0.8	350	Tube Hydroformed	Tube	Laser Welded
308 Reinforcement Impact Beam	0.40	1.0	1200	Rollformed	Coil	Laser Welded
306 Reinforcement Hinge Lower	0.09	1.2	140	Stamping	Coil	Laser Welded
Paint Allowance	0.15					
Total Mass	11.47					
Normalized Mass (kg/m ²)	14.34					
Surface (m ²)	0.80					

6.2 Hood

In conducting this study, PES's first objective was to reach the aggressive mass target of 10 percent below the benchmarked best-in-class. This was a difficult goal for hood designs since the benchmarked closures are already efficient steel structures. In the initial study, PES proposed progressive designs using steel sandwich material to reach mass targets. Given that steel sandwich material is not yet widely used in large production quantities and is more costly, PES recommended an alternative 0.6mm sheet steel for manufacturing inner panels. This alternative demonstrates performance results that are similar to the sandwich material at reduced cost, but with a slight sacrifice to mass savings.

6.2.1 Conventional



Design highlights

This design employs a 0.6 mm sheet hydroformed outer panel and feature lines to improve dent resistance in the thin material. Adhesive bonding is used in the hem flanges for structural performance. To improve stiffness, a 'V' pattern inner panel connects the hinges to the latch area, and a hole — not a depression — is used as a crush initiator in the side beam. Triangular beams designed within the 'V' pattern support the outer panel.

Steel sandwich material is used in the inner panel for mass reduction. This material consists of a 0.8 mm engineered polypropylene core sandwiched between two 0.2 mm sheets of steel. It can withstand bake ovens and can be assembled prior to painting.

This design results in the creation of a structure with a normalized mass of 7.9 kg/m² compared with the target of 8.0 kg/m². It is 32 percent lighter than the benchmarked average.

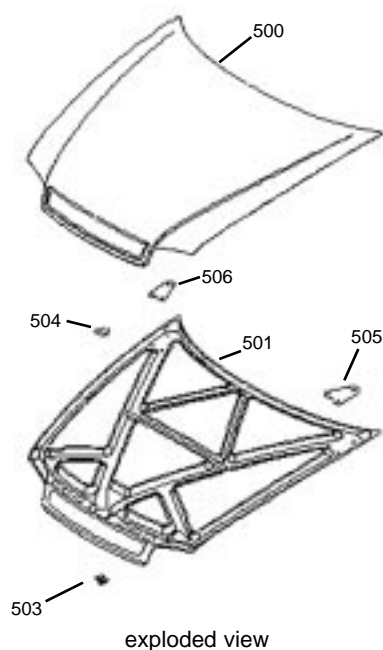
As mentioned in this section's introduction, PES recommended a 0.6 mm sheet steel inner panel as an alternative to more costly sandwich material. This concept demonstrates performance results that are similar to the sandwich material concept but has a normalized mass of 8.5 kg/m² compared with the target of 8.0 kg/m². It is 26 percent lighter than the benchmarked average.

Specifications

	Mass (kg)	Thickness (mm)	Grade (Mpa)	Manufacturing Process	Stock Material	Joining Technology
400 Panel Hood Outer	8.14	0.6	210	Sheet Hydroformed	Coil	Hemmed, Adhesive Bonded
401 Panel Hood Inner	4.39	1.2	Steel Sandwich*	Stamping	Sheet	Hemmed, Adhesive Bonded
403 Striker Assembly Hood	0.07	2.5	140	Stamping	Coil	Bolt-on
404 Reinforcement Striker	0.07	1.5	140	Stamping	Coil	Adhesive Bonded, Self Pierce Riveting
407/408 Reinf. Hinge LH/RH Hood	0.31	1.5	140	Stamping	Coil	Adhesive Bonded, Self Pierce Riveting
Paint & Gumdrops	0.35					
Total Mass	13.33					
Normalized Mass (kg/m ²)	7.93					
Surface (m ²)	1.68					

*Alternative sheet steel concept		Mass (kg)	Thickness (mm)	Grade (Mpa)
	401 Panel Hood Inner	5.33	0.6	140
	Total Mass	14.27		
	Normalized Mass (kg/m ²)	8.49		
	Surface (m ²)	1.68		

6.2.2 Grille integrated



Design highlights

This design concept is similar to the conventional with the addition of a grille formed by extending the inner and outer panels. It employs a sheet hydro-formed outer panel and feature lines to improve dent resistance in the thin material. Adhesive bonding is used in the hem flanges for structural performance. To improve stiffness, a 'V' pattern connects the

hinges to the latch area and a hole — not a depression — is used as a crush initiator in the side beam. Triangular beams designed within the 'V' pattern support the outer panel.

Steel sandwich material is used in the inner panel for mass reduction. This material consists of a 0.8 mm engineered polypropylene core sandwiched between two 0.2 mm sheets of steel. It can withstand bake ovens and can be assembled prior to painting.

This design results in the creation of a structure with a normalized mass of 7.9 kg/m² compared with its target of 8.0 kg/m². It is 32 percent lighter than the benchmarked average.

As mentioned in this section's introduction, PES recommended a 0.6 mm sheet steel inner panel as an alternative to more costly sandwich material. This concept demonstrates performance results that are similar to the sandwich material concept but has a normalized mass of 8.4 kg/m² compared with the target of 8.0 kg/m². It is 27 percent lighter than the benchmarked average.

(The normalized mass of the grille integrated is less than the normalized mass of the conventional hood because its increased surface area results in a larger denominator in the normalization equation.)

Specifications

	Mass (kg)	Thickness (mm)	Grade (Mpa)	Manufacturing Process	Stock Material	Joining Technology
500 Panel Hood Outer	8.37	0.6	210	Sheet Hydroformed	Coil	Hemmed, Adhesive Bonded
501 Panel Hood Inner	4.53	1.2	Steel Sandwich*	Stamping	Sheet	Hemmed, Adhesive Bonded
503 Striker Assembly Hood	0.07	2.5	140	Stamping	Coil	Bolt-on
504 Reinforcement Striker Hood	0.05	1.5	140	Stamping	Coil	Adhesive Bonded, Self-Pierce Riveting
505/506 Reinf. Hinge RH/LH Hood	0.31	1.5	140	Stamping	Coil	Adhesive Bonded, Self-Pierce Riveting

Paint & Gumdrops	0.35
Total Mass	13.68
Normalized Mass (kg/m ²)	7.86
Surface (m ²)	1.74

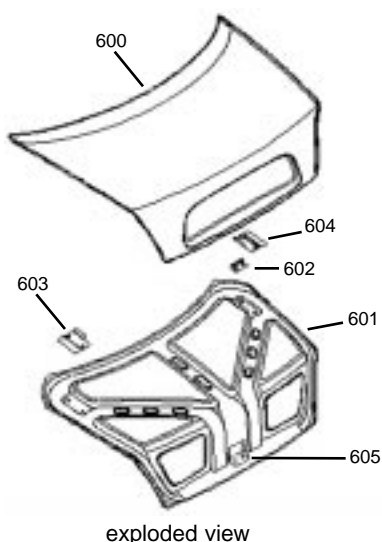
*Alternative sheet steel concept	Mass (kg)	Thickness (mm)	Grade (Mpa)
501 Panel Hood Inner	5.52	0.6	140
Total Mass	14.67		
Normalized Mass (kg/m ²)	8.43		

Surface (m²) 1.74

6.3 Decklid

Similar to the approach taken in developing hood designs, PES sought to reach an aggressive mass target of 10 percent below the benchmarked best-in-class in creating decklid designs. As with hoods, initial concepts used steel sandwich material to achieve mass savings. As an alternative to the higher cost steel sandwich material, PES recommended the use of 0.6 mm sheet steel in manufacturing the inner panel. Again, this alternative demonstrates performance results that are similar to the sandwich material at reduced cost, but with a slight sacrifice to mass savings.

6.3.1 Conventional with tail



Specifications

	Mass (kg)	Thickness (mm)	Grade (Mpa)	Manufacturing Process	Stock Material	Joining Technology
600 Panel Decklid Outer	5.80	0.6	210	Sheet Hydroformed	Coil	Hemme Adhesive Bonded
601 Panel Decklid Inner	3.27	1.2	Steel Sandwich*	Stamping	Sheet	Hemmed, Adhesive Bonded
602 Striker Assembly Decklid	0.07	1.5	140	Stamping	Coil	Bolt-on
603/604 Reinf. Hinge LH/RH Decklid	0.32	1.2	140	Stamping	Coil	Adhesive Bonded, Self-Pierce Riveting
605 Reinforcement Striker Decklid	0.04	1.5	140	Stamping	Coil	Adhesive Bonded, Self-Pierce Riveting
Paint & Gumdrops	0.35					
Total Mass	9.85					
Normalized Mass (kg/m ²)	8.00					

Surface (m²) 1.23

*Alternative sheet steel concept	Mass (kg)	Thickness (mm)	Grade (Mpa)
601 Panel Decklid Inner	3.99	0.6	140
Total Mass	10.57		
Normalized Mass (kg/m ²)	8.59		

Surface (m²) 1.23

Design highlights

This design concept employs a sheet hydro-formed outer panel to improve dent resistance in the thin material. Adhesive bonding is used in the hem flanges for structural performance. To improve stiffness, PES specified a 'V' pattern inner panel to connect the hinges to the latch area; specified down standing flange on both sides; and formed the license plate pocket from the outer panel.

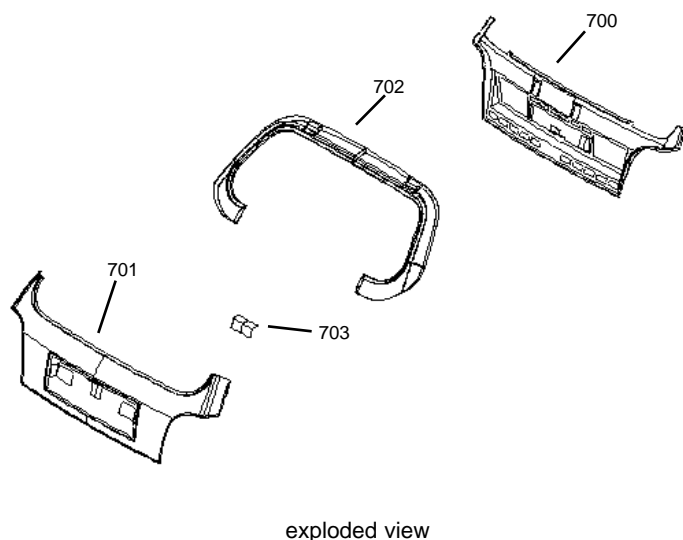
Steel sandwich material is used in the inner panel for mass reduction. This material consists of a 0.8 mm engineered polypropylene core sandwiched between two 0.2 mm sheets of steel. It can withstand bake ovens and can be assembled prior to painting.

This design results in the creation of a structure with a normalized mass of 8.0 kg/m² exactly meeting the target of 8.0 kg/m². It is 29 percent lighter than the benchmarked average.

As mentioned in this section's introduction, PES recommended a 0.6 mm sheet steel inner panel as an alternative to more costly sandwich material. This concept demonstrates performance results that are similar to the sandwich material concept but has a normalized mass of 8.6 kg/m² compared with the target of 8.0 kg/m². It is 23 percent lighter than the benchmarked average.

6.4 Hatch

6.4.1 Lift Gate Type — Tube Hydroformed



Design highlights

This design features a hydroformed tube hatch, laser welded to a conventional inner. A sheet hydroformed outer is then hemmed to the inner panel. The tube hydroforming and assembly process lend inherent integrity to the hatch, while sheet hydroforming provides excellent dent resistance at a thinner gauge.

This design results in the creation of a structure with a normalized mass of 10.3 kg/m² compared with the target of 11.3 kg/m². It is 26 percent lighter than the benchmarked average.

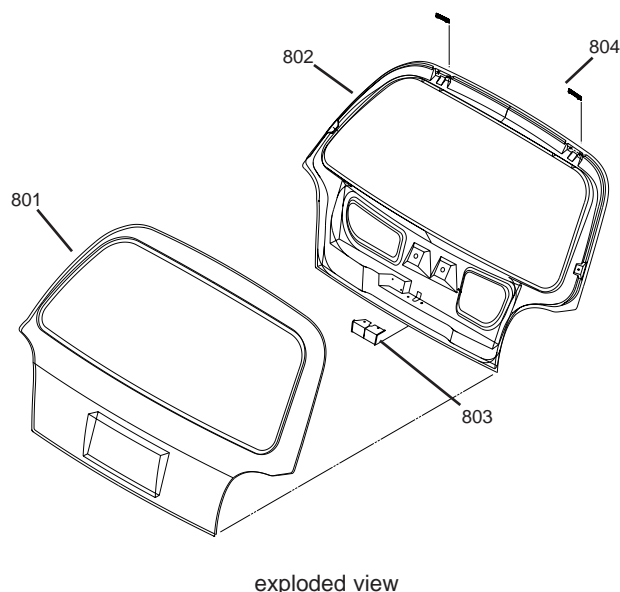
Due to the more complex manufacturing process, this design was slightly above cost baseline targets. For this reason, PES explored alternatives, which resulted in three additional concepts: tailored blank inner, hydroformed ring and sheet hydroformed hatches. The results of these additional concepts are discussed in Sections 6.4.2-6.4.4 following.

Specifications

	Mass (kg)	Thickness (mm)	Grade (Mpa)	Manufacturing Process	Stock Material	Joining Technology
701 Panel Hatchback Outer	1.86	0.6	210	Sheet Hydroformed	Coil	Hemmed, Adhesive Bonded, Laser Welded
700 Panel Hatchback Inner	1.69	0.6	140	Stamping	Coil	Hemmed, Adhesive Bonded, Laser Welded
702 Tube Hatchback	2.89	0.7	140	Tube Hydroformed	Tube	Laser Welded
703 Reinf. Latch Hatchback	0.12	1.5	140	Stamping	Coil	Spot Welded
Paint Allowance	0.15					
Total Mass	6.71					
Normalized Mass (kg/m ²)	10.32					
Surface (m ²)	0.65					

6.4 Hatch

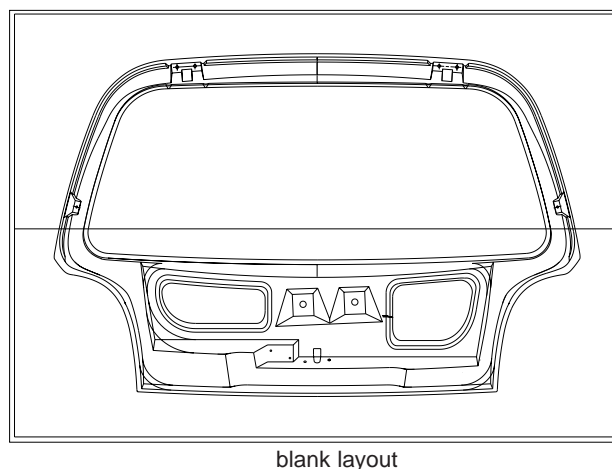
6.4.2 Lift Gate Type — Tailored Blank Inner



Design highlights

In this design, a sheet hydroformed outer is hemmed to a stamped tailored blank inner panel. It provides a lower cost alternative to the tube hydroformed design, while meeting or exceeding mass and performance targets.

The design results in the creation of a structure with a normalized mass of 10.6 kg/m² compared with the target of 11.3 kg/m². It is 24 percent lighter than the benchmarked average.

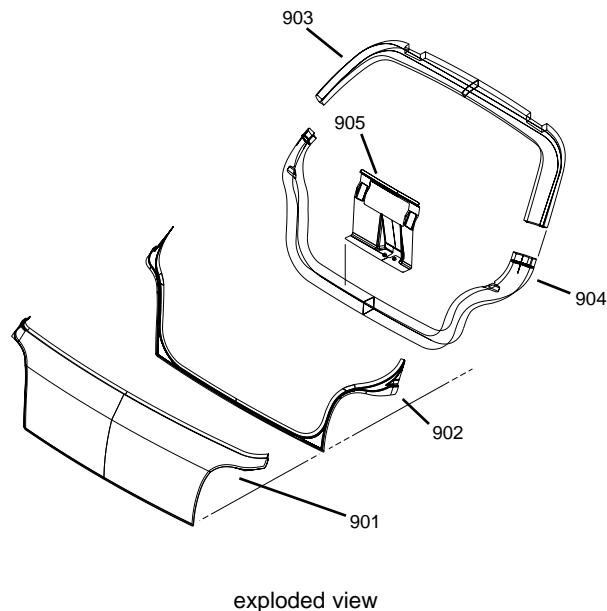


Specifications

	Mass (kg)	Thickness (mm)	Grade (Mpa)	Manufacturing Process	Stock Material	Joining Technology
801 Panel Hatchback Outer	3.28	0.6	210	Sheet Hydroformed	Coil	Hemmed, Adhesive Bonded, Laser Welded
802 Panel Hatchback Inner	3.02	0.6/0.8	140	Stamping	Tailored Blank	Hemmed, Adhesive Bonded, Laser Welded
803 Reinf. Latch Hatchback	0.12	1.5	140	Stamping	Coil	Spot Welded
804 Reinf. Hinge Upper	0.32	1.5	140	Stamping	Coil	Spot Welded
Paint Allowance	0.15					
Total Mass	6.89					
Normalized Mass (kg/m ²)	10.60					
Surface (m ²)	0.65					

6.4 Hatch

6.4.3 Lift Gate Type — Hydroformed Ring



Design highlights

The hydroformed ring design specifies a complete tubular hydroformed frame, eliminating the necessity of a full inner panel. The ring provides intrinsic structural integrity, while saving mass.

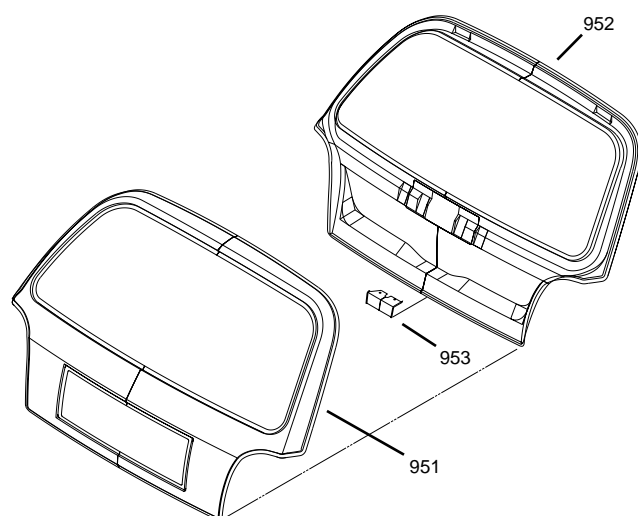
This design results in the creation of a structure with a normalized mass of 10.9 kg/m² compared with the target of 11.3 kg/m². It is 22 percent lighter than the benchmarked average. Due to the very stiff nature of this design approach, further mass reduction will be achievable through additional design development.

Specifications

	Mass (kg)	Thickness (mm)	Grade (Mpa)	Manufacturing Process	Stock Material	Joining Technology
901 Panel Hatchback Outer	2.04	0.6	210	Sheet Hydroformed	Coil	Hemmed
902 Panel Hatchback Inner	0.39	0.6	140	Stamping	Coil	Laser Welded
903 Tube Hatchback Upper	1.85	0.7	140	Tube Hydroformed	Tube	Laser Welded
904 Tube Hatchback Lower	2.23	0.7	140	Tube Hydroformed	Tube	Laser Welded
905 Bracket Hatchback	0.44	0.6	140	Stamping	Coil	Laser Welded, Spot Welded
Paint Allowance	0.15					
Total Mass	7.10					
Normalized Mass (kg/m ²)	10.92					
Surface (m ²)	0.65					

6.4 Hatch

6.4.4 Lift Gate Type — Sheet Hydroformed



exploded view

Design highlights

A conceptual design that creates stiffness at considerable mass savings is achieved with a sheet hydroforming process. A continuous laser weld is used to join inner and outer panels providing a fluid pressure seal for the hydroforming process. In this process, internal forming pressure expands the parts into the molds. The sheet hydroforming process contributes further to local panel stiffness through work hardening of the inner and outer panels. To contribute to torsional stiffness, the glass is bonded to the frame using urethane.

This design results in the creation of a structure with a normalized mass of 9.5 kg/m² compared with the target of 11.3 kg/m². It is 32 percent lighter than the benchmarked average.

This is a preliminary concept that appears to offer a feasible alternative to lift gate design, but requires further PES examination to prove its feasibility.

Specifications

	Mass (kg)	Thickness (mm)	Grade (Mpa)	Manufacturing Process	Stock Material	Joining Technology
951 Panel Hatchback Outer	3.10	0.6	210	Sheet Hydroformed	Coil	Laser Welded
952 Panel Hatchback Inner	2.83	0.6	140	Sheet Hydroformed	Coil	Laser Welded
953 Reinf. Latch Hatchback	0.12	1.5	140	Stamping	Coil	Spot Welded
Paint Allowance	0.15					
Total Mass	6.20					
Normalized Mass (kg/m ²)	9.54					
Surface (m ²)	0.65					

7. FEA Calculations

Throughout the design process, FEA calculations were run on each part to confirm the effectiveness of the latest optimizations and to validate the concepts. FEA models were all shell and very detailed. Spot welds, laser welds and structural adhesives were represented using rigid elements. Gum drops were represented using spring elements with stiffnesses in three directions. Adhesive bonded hem flanges were treated as continuous connections with shell element thickness comprehending material stack up. Hinges were considered rigid so that only compliance of closures was analyzed. All models were run using MSC/NASTRAN. A linear static solution was used for stiffness and strength load cases. A free-free linear dynamic solution was used for normal mode analysis to ensure that the normal mode frequencies of the closures would not couple with the frequencies of the body structure. LS Dyna 3D was used for nonlinear door side intrusion and longitudinal door crush simulations.

7.1 Door

The FEA model size for doors ranges in number of elements from 7,200 to 23,159 and number of nodes from 7,219 to 23,307. These ranges reflect the varying degree of detail in the three door concepts. Structural performance analyses include frame rigidity (except for frameless door), door sag, torsional rigidity and check load. To determine frame rigidity, the door was constrained at the hinges and rear and the door frame was loaded outboard front and rear independently. For door sag, the door was constrained at the hinges and loaded vertically at the latch. To determine torsional rigidity the door was constrained at the hinges and latch while the door was loaded top and bottom at rear to apply torque. For check load, the door was constrained at the hinges with the door in full open position and loaded outboard against the latch. This is an abuse load for which peak stresses are recovered to determine whether permanent deformation would occur. All

door designs met structural performance targets, except in the case of the frame rigidity rear target for the roof integrated design. It did not meet target because rear package constraints prevent the efficient use of material at the belt. An OEM survey showed this result would be acceptable to most automakers. The frame integrated design's rolled section upper frame enabled it to perform especially well in frame rigidity load cases. The frameless design exhibited the best result of the three in door sag. This performance is due mainly to the thin wall casting.

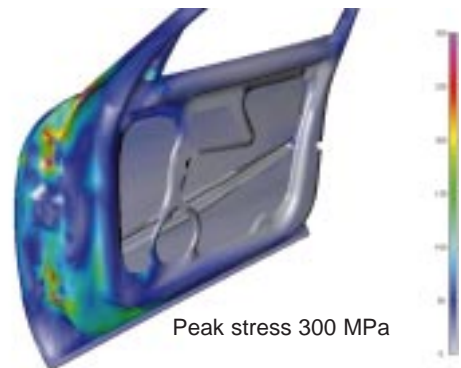
To predict side impact performance, PES subjected the door to a side intrusion load case. First, the side intrusion beams in the model were situated where FMVSS 214 specifies their placement. Then the door was constrained at the hinges and latch and loaded inboard. Only the first six inches of intrusion were simulated due to the lack of door surround definition. The analysis results exceed standards set forth in FMVSS requirement 214.

To judge performance of the door concept during an offset crash, without the use of a full vehicle crash model, a procedure was employed which treats the door as an integrated system. The procedure comprised an idealized longitudinal crush with the door constrained at the hinges, and the door rear loaded until buckling failure occurred. The performance observed for all ULSAC doors would be acceptable to most automakers.

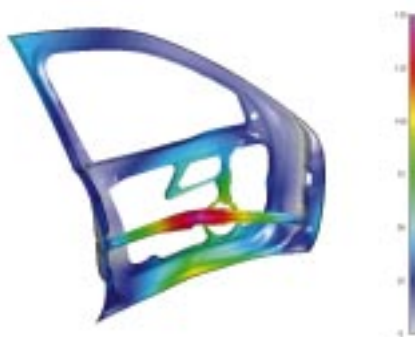
7.1.1 Roof integrated

Structural performance

Load case	Target (N/mm)	Actual (N/mm)
Frame rigidity front	≥ 43	45
Frame rigidity rear	≥ 43	38
Door sag	≥ 287	318
Torsional rigidity upper	≥ 94	272
Torsional rigidity lower	≥ 94	146



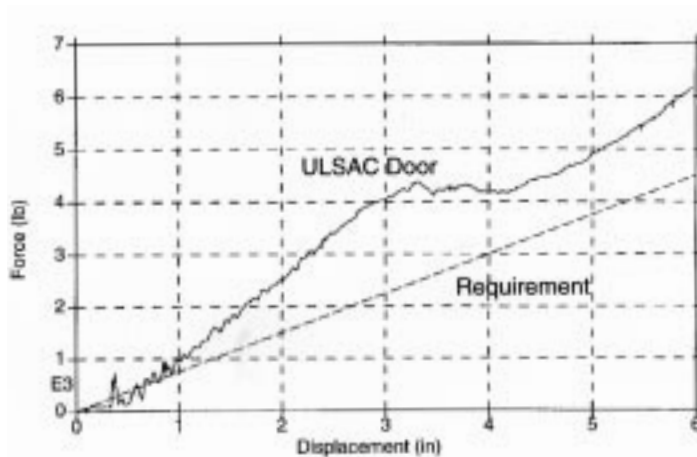
Check load



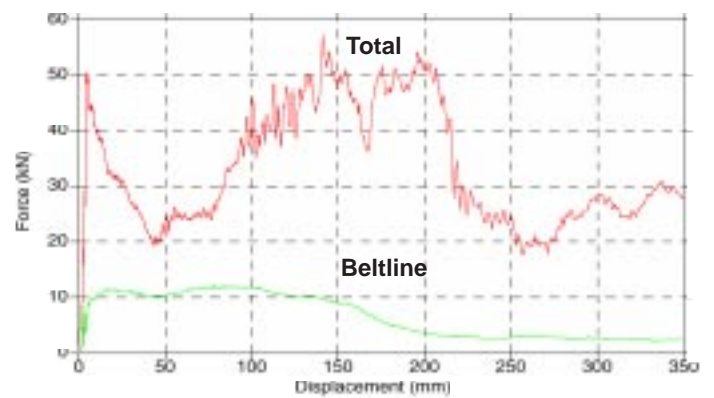
Side intrusion



Longitudinal Door Crush



Load Deflection - Side Intrusion

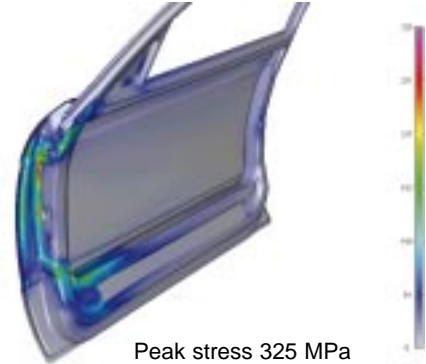


Load Deflection - Door Crush

7.1.2 Frame integrated

Structural performance

Load case	Target (N/mm)	Actual (N/mm)
Frame rigidity front	≥ 43	64
Frame rigidity rear	≥ 43	52
Door sag	≥ 287	299
Torsional rigidity upper	≥ 94	155
Torsional rigidity lower	≥ 94	107



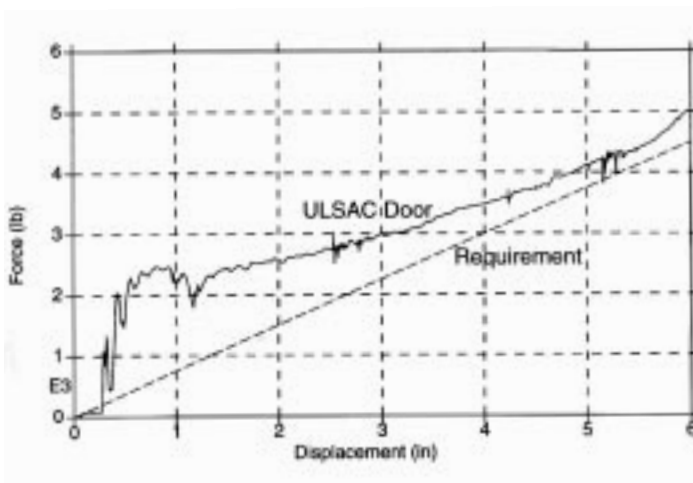
Check load



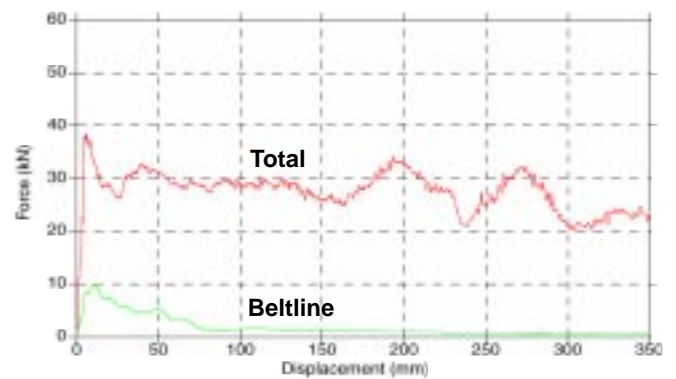
Side intrusion



Longitudinal Door Crush



Load deflection - Side Intrusion

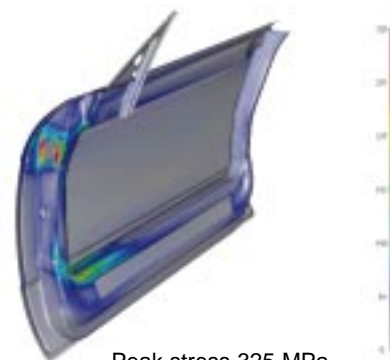


Load Deflection - Door Crush

7.1.3 Frameless

Structural performance

Load case	Target (N/mm)	Actual (N/mm)
Door sag	≥ 287	346
Torsional rigidity upper	≥ 94	170
Torsional rigidity lower	≥ 94	117

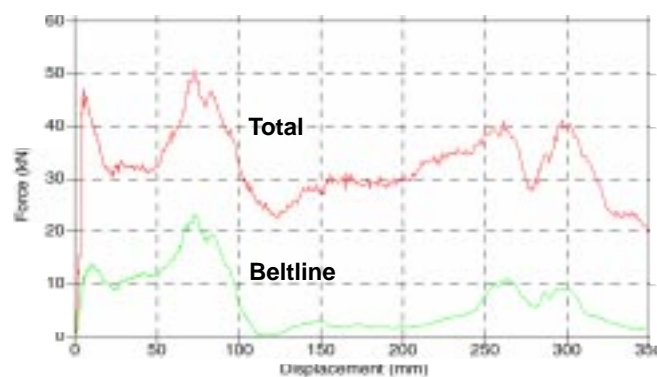


Peak stress 325 MPa

Check load



Longitudinal Door Crush



Load Deflection - Door Crush

7.2 Hood

The FEA model size for hoods ranges in number of elements from 11,164 to 13,359 and number of nodes from 12,251 to 12,416. Structural performance data include torsional rigidity, bending stiffness and beam stiffnesses. To determine torsional rigidity, the hood was constrained at the hinges and at one of the front bump stops while loaded vertically at the unconstrained bump stop. For bending stiffness, the hood was constrained at the hinges while the load was applied at the front edge. To determine side beam stiffnesses, the hood was constrained at the hinges and bump stops while vertical loads were applied independently at each side beam at the centerline of the section.

7.2.1 Conventional

Structural performance

Load case	Target (N/mm)	Actual (N/mm)
Torsional rigidity	≥ 5.8	6.3
Bending stiffness	≥ 4.5	7.2
Front beam stiffness	≥ 110	186
Rear beam stiffness	≥ 110	286
Side beam stiffness	≥ 110	136

This closure met all structural performance targets.

7.2.2 Grille integrated

Structural performance

Load case	Target (N/mm)	Actual (N/mm)
Torsional rigidity	≥ 5.8	6.6
Bending stiffness	≥ 4.5	7.4
Front beam stiffness	≥ 110	195
Rear beam stiffness	≥ 110	282
Side beam stiffness	≥ 110	137

This closure shows results similar to the conventional hood and meets all structural performance targets.

7.3 Decklid

The FEA model size for the decklid included 10,006 elements and 9,053 nodes. Structural performance data for the decklid encompasses torsional rigidity, bending stiffness, beam stiffnesses and tail stiffness. To determine torsional rigidity, the decklid was constrained at the hinges and one of the rear bump stops while it was loaded vertically at the unconstrained bump stop. For bending stiffness, the decklid was constrained at the hinges and loaded vertically at the rear edge on centerline. To determine side beam stiffnesses, the decklid was constrained at the hinges and bump stops while vertical loads were applied independently at each side beam at the centerline of the section. For tail stiffness, the decklid was constrained at the hinges and bump stops while the load was applied forward at the lower rear edge on centerline.

7.3.1 Decklid

Structural performance

Load case	Target (N/mm)	Actual (N/mm)
Torsional rigidity	≥ 5.8	8.9
Bending stiffness	≥ 4.5	25.4
Front beam stiffness	≥ 110	115
Side beam stiffness	≥ 110	147
Tail stiffness	≥ 21	21

This closure demonstrates especially good bending stiffness because the reinforced hinge attachment at the inner panel transfers the load into the sheer wall of the inner panel section. Bending stiffness is also enhanced by the vertically downturned flange, which adds stiffness.

7.4 Hatch

The FEA model size for the hatch ranges in number of elements from 20,792 to 22,395 and number of nodes from 20,794 to 21,364. Structural performance data encompasses torsional rigidity and bending stiffness. To determine torsional rigidity the hatch was constrained at the hinges and at one of the rear bump stops while it was loaded vertically at the unconstrained bump stop. For bending stiffness the hatch was constrained at the hinges while the load was applied vertically at the rear edge on centerline.

7.4.1 Hatch — Tube Hydroformed

Structural performance

Load case	Target (N/mm)	Actual (N/mm)
Torsional rigidity	≥ 3.5	40
Bending stiffness	≥ 4.5	31

This design concept uses a unique tubular hydroformed frame that provides a continuous load path, resulting in impressive rigidity and stiffness numbers.

7.4.2 Hatch — Tailored Blank

Structural performance

Load case	Target (N/mm)	Actual (N/mm)
Torsional rigidity	≥ 3.5	15.1
Bending stiffness	≥ 4.5	8.2

Tailored blank design provides a more traditional manufacturing process with reduced part count, while maintaining acceptable performance.

7.4.3 Hatch — Hydroformed Ring

No FEA calculations were made in this concept phase. This is a preliminary concept that appears to offer a feasible alternative to lift gate designs, but requires further PES examination to prove its feasibility.

7.4.4 Hatch — Sheet Hydroformed

No FEA calculations were made in this concept phase. This is a preliminary concept that appears to offer a feasible alternative to lift gate designs, but requires further PES examination to prove its feasibility.

8. Cost Estimation

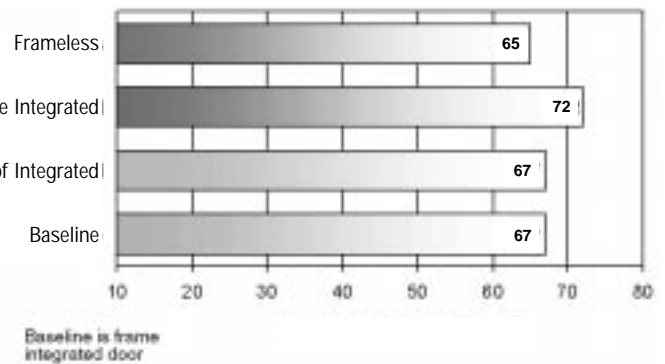
Lightweighting increasingly has become a priority for automakers. They have recently demonstrated their willingness to pay a premium for lightweight solutions that enable them to meet automotive weight requirements. Automakers reveal that they routinely pay up to twice as much for alternative lightweight closures. ULSAC balances light weight with affordable cost.

PES performed a cursory cost analysis of each of the closure concepts it developed for the ULSAC project. To create a baseline with which to compare ULSAC closures, PES developed cost estimates for current closures similar in material, size and geometry. Then PES estimated the cost of the concept based on manufacturing experience and knowledge of business economics.

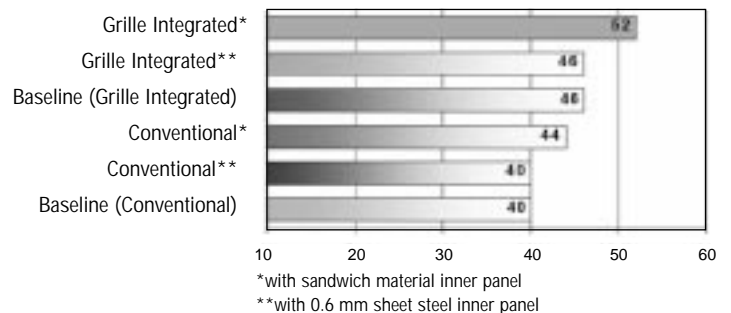
For the doors, this economic analysis showed no cost penalty to a seven percent increase in the costs of the concept compared to baseline. For hoods, it found no additional cost over baseline for the sheet steel solution and an increase of about 10 percent for the steel sandwich design. Likewise, for decklids, the study revealed a six percent increase compared with baseline for the sheet steel solution and about a 16 percent increase for the steel sandwich design. Costs for the concept tube hydroformed hatch came in at approximately 24 percent above baseline due to the costly manufacturing process. The tailored blank inner design could be achieved at a cost only slightly above the aggressive baseline figure. As aforementioned, the hydroformed ring and sheet hydroformed designs are still in preliminary investigative stages, and consequently, no cost estimates are yet available. However, initial examination indicates that these two designs can effect results in the same range as the tailored blank design.

These economic analysis results are shown as follows:

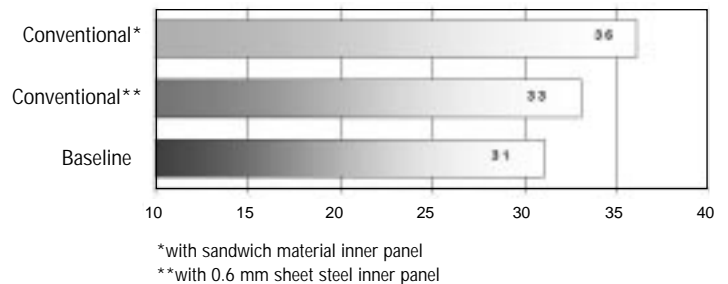
Door



Hood

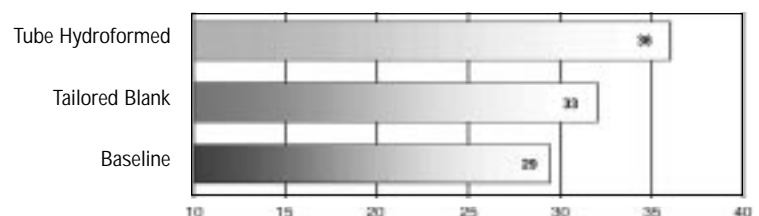


Decklid



Baseline is a conventional decklid

Hatch



Baseline is a conventional decklid

Cost Estimation in Range $\pm 5\%$

9. Conclusion

ULSAC demonstrates steel closure concepts that are lightweight, structurally sound, manufacturable and affordable — workable, real world answers to the increasing challenges of lightweighting. ULSAC closures

- weigh up to 32 percent less than benchmarked averages

- weigh 10 percent less than best-in-class
- meet stringent structural performance targets
- can be fabricated using manufacturing processes and materials that are current and
- can cost no more to build than heavier closures.

Door performance

	Normalized Mass kg/m ²	Frame Rigidity		Torsional Rigidity		Door Sag N/mm	Checkload mm
		Front N/mm	Rear N/mm	Upper N/mm	Lower N/mm		
Targets	15.5	> 43	> 43	≥ 94	≥ 94	287.0	≤1.25 set
Roof Integrated	15.1	45	38	272	146	318.0	N/A
Frame Integrated	15.5	64	52	155	107	299.0	N/A
Frameless	14.3	N/A	N/A	170	117	346.0	N/A

Hood performance

	Normalized Mass kg/m ²	Bending Stiffness N/mm	Torsional Stiffness N/mm	Beam Stiffness		Side Beam Stiffness	
				Front N/mm	Rear N/mm	Left N/mm	Right N/mm
Targets	8.0	4.5	5.8	110	110	110	110
Conventional Sandwich Inner	7.9	7.2	6.3	186	286	136	136
Grille Integrated Sandwich	7.9	7.4	6.6	195	282	137	137
Conventional Sheet Steel Inner	8.5	4.7	6.1	161	276	152	152
Grille Integrated Steel Inner	8.4	4.8	6.2	181	273	156	156

Decklid performance

	Normalized Mass kg/m ²	Bending Stiffness N/mm	Torsional Stiffness N/mm	Beam Stiffness Front N/mm	Side Beam Stiffness		Tailgating N/mm
					Left N/mm	Right N/mm	
Targets	8.0	4.5	5.7	110	110	110	21
Conventional Sandwich	8.0	25.4	8.9	115	147	147	21
Conventional Sheet Steel Inner	8.6	24.0	8.7	115	132	132	19

Hatch performance

	Normalized Mass kg/m ²	Bending Stiffness N/mm	Torsional Stiffness N/mm
Targets	11.3	4.5	3.5
Tube Hydroformed	10.3	31.0	40.0
Tailored Blank	10.6	8.2	15.1
Hydroformed Ring*	10.9	N/A	N/A
Sheet Hydroformed*	9.5	N/A	N/A

*Data not available.

Mass Comparison

	Benchmark (kg/m ²)		Target (kg/m ²)	ULSAC	
	Range	Average		(kg/m ²)	(kg)
Door - Roof Integrated	17.0 - 23.4	19.7	15.5	15.1	13.2
Door - Frame Integrated				15.5	13.2
Door - Frameless				14.3	11.5
Hood - Conventional*	8.8 - 14.2	11.5	8.0	7.9	13.3
Hood - Conventional**				8.5	14.3
Hood - Grille Integrated*				7.9	13.7
Hood - Grille Integrated**				8.4	14.7
Decklid Conventional*	8.9 - 16.1	11.2	8.0	8.0	9.9
Decklid Conventional**				8.6	10.6
Hatch - Tube Hydroformed	12.5 - 15.2	13.9	11.3	10.3	6.7
Hatch - Tailored Blank Inner				10.6	6.9
Hatch - Hydroformed Ring				10.9	7.1
Hatch - Sheet Hydroformed				9.5	6.2

*with sandwich material inner panel

**with 0.6 mm sheet steel inner panel

Cost Comparison (U.S. \$)

	Baseline	ULSAC
Door - Roof Integrated	67 Frame Integrated Door	67
Door - Frame Integrated		72
Door - Frameless		65
Hood - Conventional*	40	44
Hood - Conventional**	40	40
Hood - Grille Integrated*	46	52
Hood - Grille Integrated**	46	46
Decklid - Conventional*	31	36
Decklid - Conventional**	31	33
Hatchback - Tube Hydroformed	29	36
Hatchback - Tailored Blank	29	33

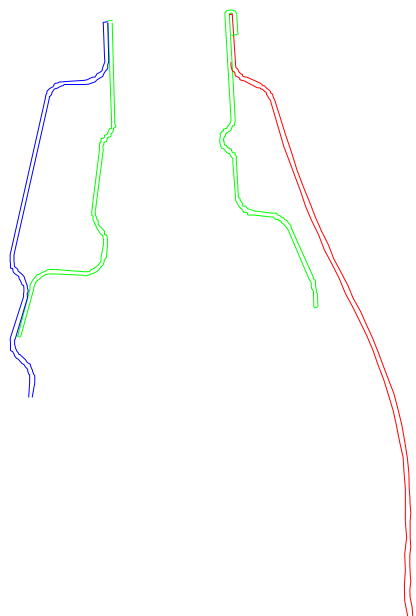
*with sandwich material inner panel

**with 0.6 mm sheet steel inner panel

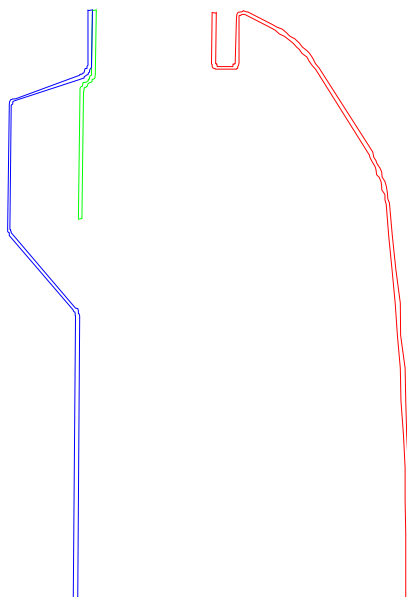


Benchmarking

Data Gathering - Design Evaluation Typical Sections - Door - Beltline



Inner & outer belt
reinforcement



Inner belt
reinforcement



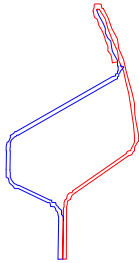
Outer belt
reinforcement



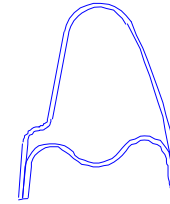


Benchmarking

Data Gathering - Design Evaluation Typical Sections - Door - Frame



Frame into roof inner &
outer panel form section



Frame integral, inner &
outer panel form section



Roll formed section



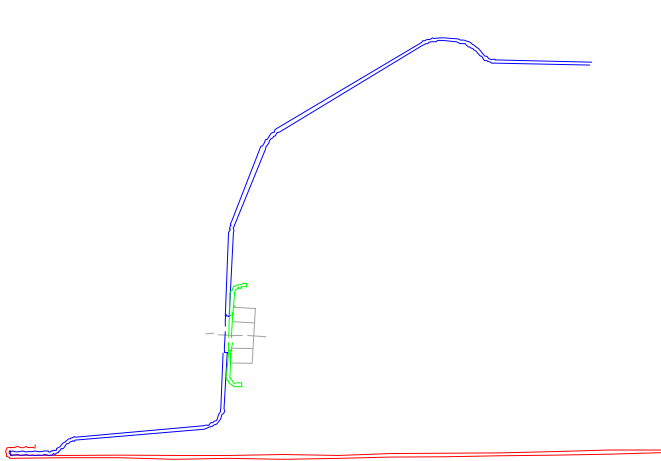
Extruded aluminum
section



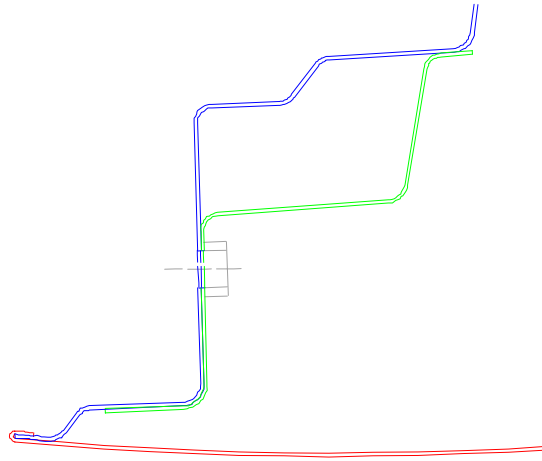


Benchmarking

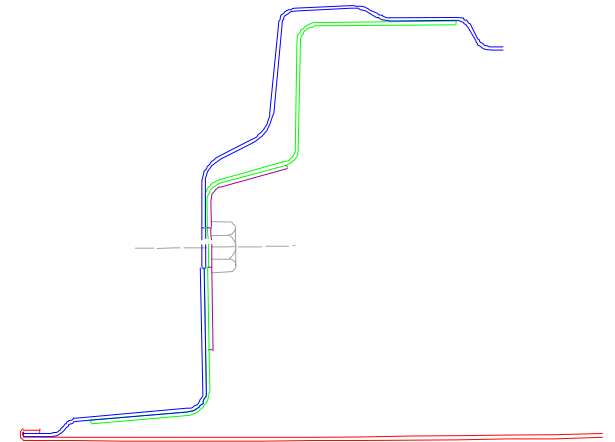
Data Gathering - Design Evaluation Typical Sections - Door - Hinge



Tailor blanked inner
panel



Reinforcement
provides additional
section



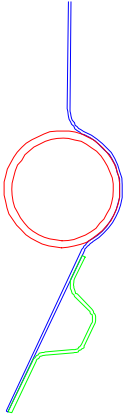
Reinforcement
essentially doubles
inner panel metal



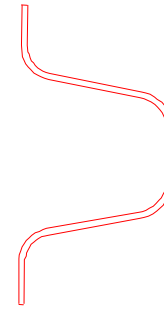


Benchmarking

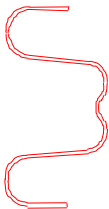
Data Gathering - Design Evaluation Typical Sections - Door - Crash Beam



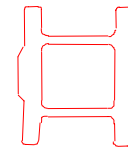
Tube provides good resistance to bending with a small package but constant section



Hat section



Double hat section



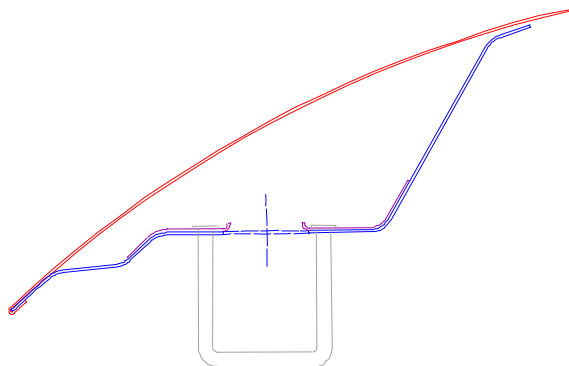
Extruded aluminum
constant section



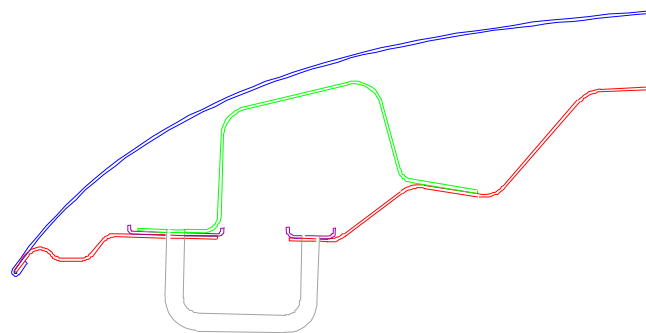


Benchmarking

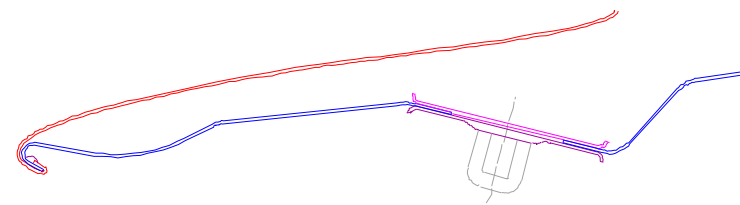
Data Gathering - Design Evaluation Typical Sections - Hood - Latch



Reinforcement doubles
inner panel



Reinforcement forms
additional section & resists
denting load on outer



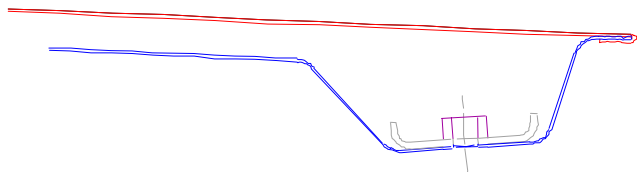
Double sided
reinforcement of the
inner panel



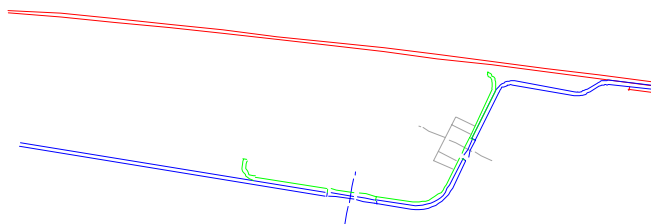


Benchmarking

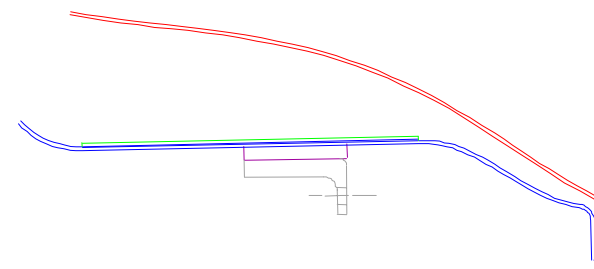
Data Gathering - Design Evaluation Typical Sections - Hood - Hinge



Local reinforcement on
flat of inner panel



Local reinforcement on
side of section



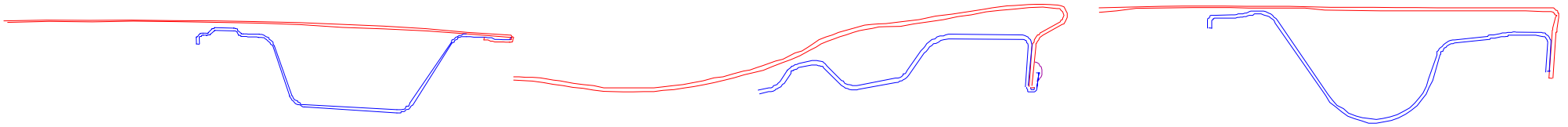
Down-turned flange &
MIG welded hinge





Benchmarking

Data Gathering - Design Evaluation Typical Sections - Hood - Side Beam



Hemmed outer to inner,
horizontal flange

Hemmed inner to outer,
vertical flange

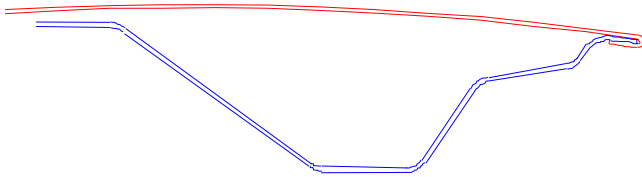
Spot welded outer to
inner, vertical flange



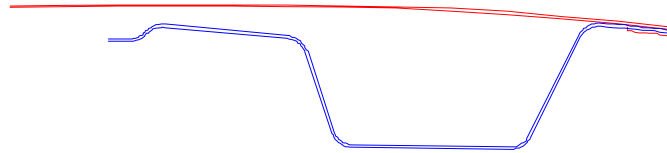


Benchmarking

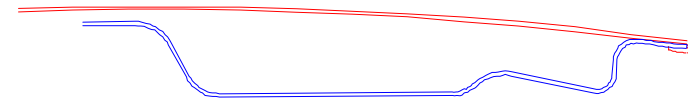
Data Gathering - Design Evaluation Typical Sections - Hood - Rear Beam



Deep section, hemmed rear edge



More traditional depth & profile



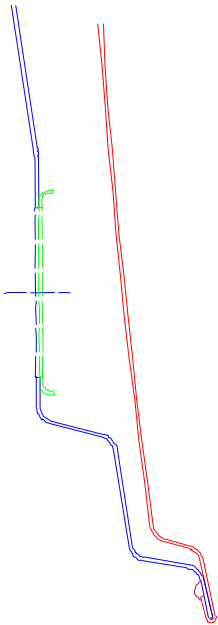
Shallow section, allows additional clearance for plenum



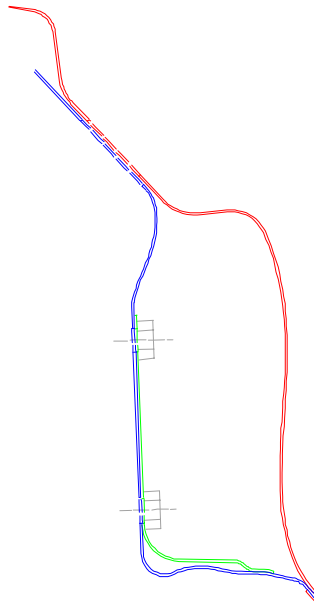


Benchmarking

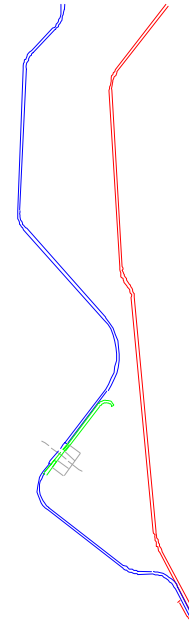
Data Gathering - Design Evaluation Typical Sections - Decklid - Latch



Latch attached to
decklid with doubling
reinforcement



Lock attached to
decklid with doubling
reinforcement



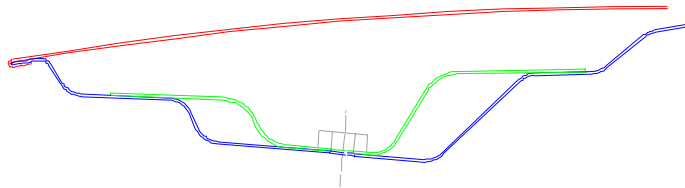
Inner panel reinforced
with local reinforcement





Benchmarking

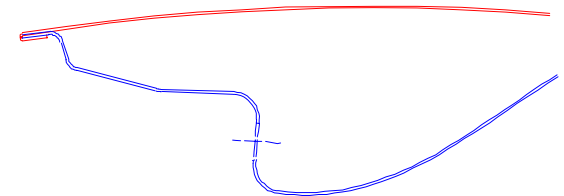
Data Gathering - Design Evaluation Typical Sections - Decklid - Hinge



Reinforcement forms
additional section with
inner panel



Reinforcement doubles
inner panel



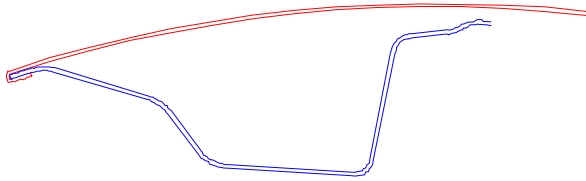
Hinge mounts to
side wall of section



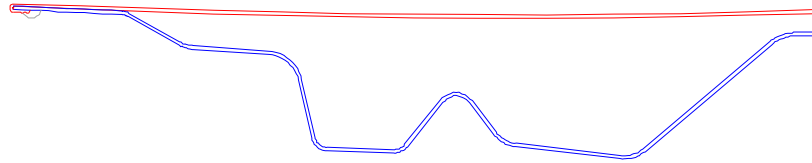


Benchmarking

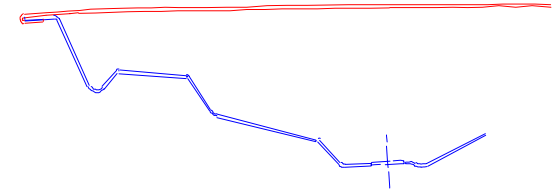
Data Gathering - Design Evaluation Typical Sections - Decklid - Side Beam



Hemmed outer to inner,
simple light section



Hemmed outer to inner,
more complicated heavier
section



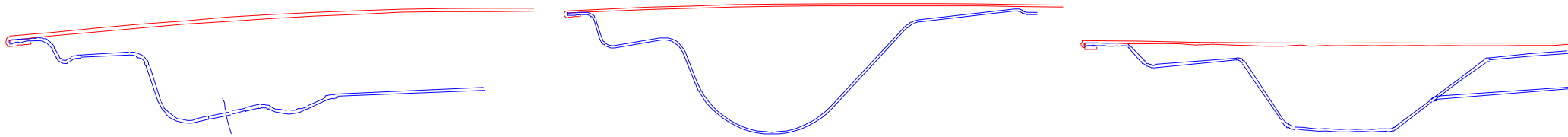
Hemmed outer to inner
deeper section





Benchmarking

***Data Gathering - Design Evaluation
Typical Sections - Decklid - Front Beam***



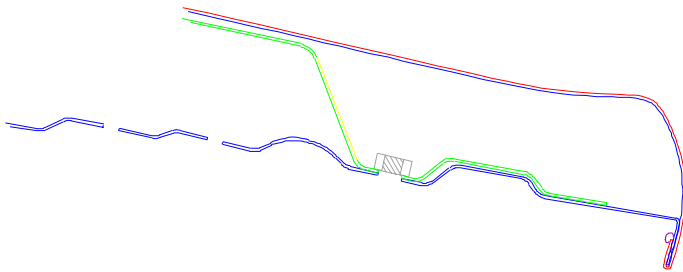
All very similar sections, hemmed outer to inner



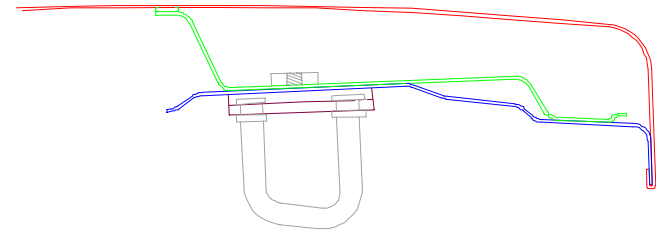


Benchmarking

Data Gathering - Design Evaluation Typical Sections - Hatchback - Latch



Reinforcement forms
section with inner panel



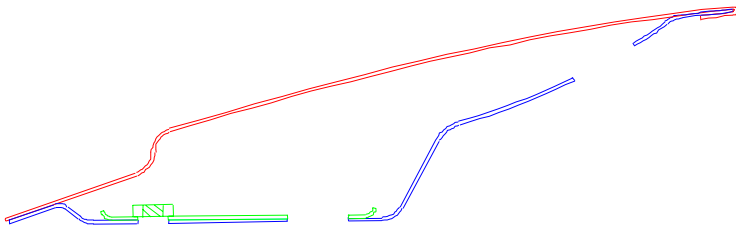
Similar section showing
attachment of striker



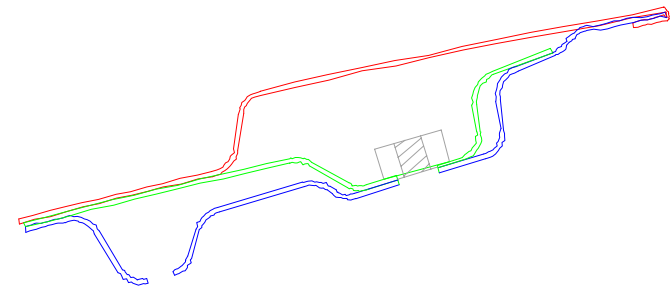


Benchmarking

Data Gathering - Design Evaluation Typical Sections - Hatchback - Hinge



Reinforcement doubles
inner panel



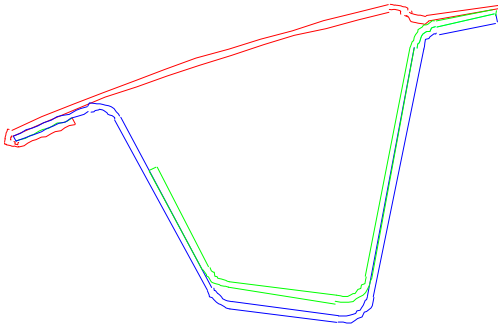
Reinforcement forms
extra boxing



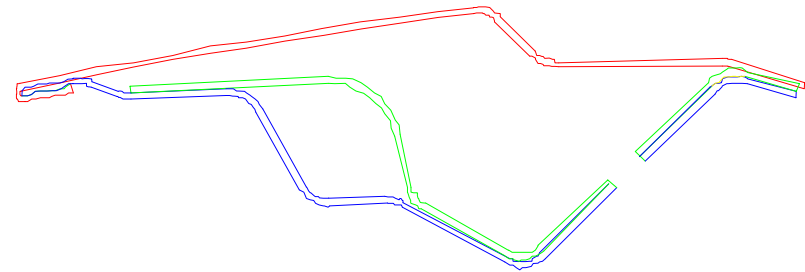


Benchmarking

Data Gathering - Design Evaluation Typical Sections - Hatchback - Side Beam



Side reinforcement with a doubling piece



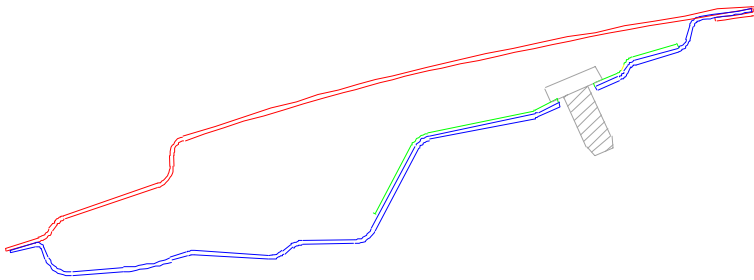
Reinforcement forms extra boxing



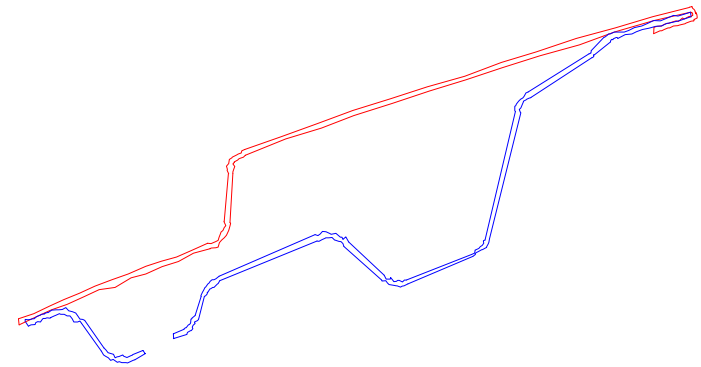


Benchmarking

Data Gathering - Design Evaluation Typical Sections - Hatchback - Front Beam



Spot welded in glass opening
hemmed at trim edge



Similar but smaller section
provides a lighter solution





Benchmarking

Data Gathering - Teardown of Closures Results Sheet - Audi A6

Closure		Door	Hood	Decklid
Weight				
BIW (Bracket, Reinforcement)	kg	9.25		
Door frame Module	kg	3.45		
Door beam (Aluminum)	kg	1.225		
Sum BIW and Door frame	kg	13.93		
Hinge (2X)	kg	1.4		
Latch & Lock	kg	N/A		
Doorcheck	kg	integrated in Hinge		
Window regulator / Door Inner Module	kg	1.8		
Type of Window regulator		Cable		
Mirror	kg	N/A		
Trim / Insulation	kg	N/A		
Sealing	kg	0.6		
Wiring Harness	kg	N/A		
Weight of Speaker	kg	N/A		
Weight Complete	kg	N/A		
Q = BIW / Complete		N/A		
Mass / Surface	kg/sqm	17.85		
Dimensions				
Length (X)	mm	1130		
Height (Z)	mm	1140		
Width (Y)	mm			
True Surface Area Calculated	sqm	0.78		
Depth with / without Trim	mm	0/133		
Material thickness inner / outer panel	mm	1.76/1.36/0.66		
Material thickness Glass	mm	N/A		
Curvature Glass		N/A		
Beltline / Bottom	mm	1085		
Hinge / Hinge (Hingespread)	mm	360		
Length / Hingespread Ratio		3.1		
Hinge / Latch (horizontal / vertical / upr / lwr)	mm	1010/76/290		
Material thickness Hinge	mm	3.9		
Specification				
Number of Brackets / Reinforcements		5		
Number of Parts total		7		
Number of Weldspots		42		
Area / Thickness of Side Intrusion beam		464 / 1.8		
Length of Side Intrusion beam	mm	1025		
Inertia of Side Intrusion beam	mm	63944		
Attachment Type of Side Intrusion beam		bolted		





Benchmarking

Data Gathering - Teardown of Closures Results Sheet - BMW 528i

Closure		Door	Hood	Decklid
Weight				
BIW (Bracket, Reinf., Side Intrusion Beam)	kg	16.4	21.3	12.05
Glass	kg			
Hinge (2X)	kg			
Latch & Lock	kg			
Doorcheck	kg			
Window regulator / Superplug	kg	2		
Type of Window regulator		Cable		
Exterior rear Console	kg			
Mirror	kg			
Trim / Insulation	kg			
Sealing	kg			
Wiring Harness	kg			
Weight of Speaker	kg			
Sum electric components	kg			
Weight Complete	kg			
Q = BIW / Complete				
Mass / Surface	kg/sqm	19.76	13.23	16.07
Dimensions				
Length (X)	mm	1090	1415	780
Height (Z)	mm	1140		
Width (Y)	mm		1525	1200
True Surface Area Calculated	sqm	0.83	1.61	0.75
Depth with / without Trim	mm	210/130		
Material thickness inner / outer panel	mm	0.83/0.77	0.57/1	0.7/0.72
Material thickness Glass	mm	4		
Curvature Glass	mm	N/A		
Beltline / Bottom	mm	665		
Hinge / Hinge (Hingespread)	mm	295	1400	1145
Length / Hingespread Ratio		3.7	1.0	0.7
Hinge / Latch (horizontal / vertical / upr / lwr)	mm	950/50/245	1085/Center	490/Center
Material thickness Hinge	mm	8	4	4
Specification				
Number of Brackets / Reinforcements		8	6	3
Number of Parts total		12	8	5
Number of Weldspots		52	110	27
Area / Thickness of Side Intrusion Beam		225 / 2.48		
Length of Side Intrusion Beam	mm	980		
Inertia of Side Intrusion Beam	mm	75778		
Attachment Type of Side Intrusion Beam		bolted		





Benchmarking

Data Gathering - Teardown of Closures Results Sheet - Cadillac Sedan Deville

Closure		Door	Hood	Decklid
Weight				
BIW (Bracket, Reinf., Side Intrusion Beam)	kg	17.7		
Glass	kg			
Hinge (2X)	kg			
Latch & Lock	kg			
Doorcheck	kg			
Window regulator / Superplug	kg			
Type of Window regulator				
Exterior rear Console	kg			
Mirror	kg			
Trim / Insulation	kg			
Sealing	kg			
Wiring Harness	kg			
Weight of Speaker	kg			
Sum electric components	kg			
Weight Complete	kg			
Q = BIW / Complete				
Mass / Surface	kg/sqm	17.86		
Dimensions				
Length (X)	mm	1150		
Height (Z)	mm	1240		
Width (Y)	mm			
True Surface Area Calculated	sqm	0.99		
Depth with / without Trim	mm	170/145		
Material thickness inner / outer panel	mm	0.77/0.77	0.61/0.7	0.96/0.74
Material thickness Glass	mm			
Curvature Glass	mm			
Beltline / Bottom	mm	705		
Hinge / Hinge (Hingespread)	mm	370		
Length / Hingespread Ratio		3.1		
Hinge / Latch (horizontal / vertical / upr / lwr)	mm	970/180/190		
Material thickness Hinge	mm			
Specification				
Number of Brackets / Reinforcements		9		
Number of Parts total		11		
Number of Weldspots		52		
Area / Thickness of Side Intrusion Beam		233/2.4		
Length of Side Intrusion Beam	mm	890		
Inertia of Side Intrusion Beam	mm	24603		
Attachment Type of Side Intrusion Beam		spotwelded		





Benchmarking

Data Gathering - Teardown of Closures Results Sheet - Chevrolet Malibu

Closure		Door	Hood	Decklid
Weight				
BIW (Bracket, Reinf., Side Intrusion Beam)	kg	16.05	16.05	11
Glass	kg	3.38		
Hinge (2X)	kg	0.48	0.34	0.9
Latch & Lock	kg	0.995	Striker	0.35
Doorcheck	kg	0.255		
Window regulator / Superplug	kg	3.79		
Type of Window regulator		crossarm		
Exterior rear Console	kg			
Mirror	kg	0.97		
Trim / Insulation	kg	3.03	0.52	no
Sealing	kg	2	on Body	on Body
Wiring Harness	kg	0.61		
Weight of Speaker	kg	0.465		
Sum electric components	kg	1.075		
Weight Complete	kg	28.8	16.57	11.6
Q = BIW / Complete		0.56	0.97	0.95
Mass / Surface	kg/sqm	20.58	10.70	11.83
Dimensions				
Length (X)	mm	1075	1170	810
Height (Z)	mm	1165		
Width (Y)	mm		1370	1250
True Surface Area Calculated	sqm	0.78	1.50	0.93
Depth with / without Trim	mm	120/225		
Material thickness inner / outer panel	mm	0.7/0.7	0.61/0.66	0.61/0.66
Material thickness Glass	mm	4		
Curvature Glass	mm	28		
Beltline / Bottom	mm	680		
Hinge / Hinge (Hingespread)	mm	355	1235	1035
Length / Hingespread Ratio		3.0	0.9	0.8
Hinge / Latch (horizontal / vertical / upr / lwr)	mm	995/85/170	940/Center	450/Center
Material thickness Hinge	mm	6.5	3	20x20x1.8
Specification				
Number of Brackets / Reinforcements		7	5	1
Number of Parts total		12	7	3
Number of Weldspots		80	8	2
Area / Thickness of Side Intrusion Beam		236/2		
Length of Side Intrusion Beam	mm	980		
Inertia of Side Intrusion Beam	mm	31146		
Attachment Type of Side Intrusion Beam		spotwelded		





Benchmarking

Data Gathering - Teardown of Closures Results Sheet - Dodge Stratus

Closure		Door	Hood	Hatch
Weight				
BIW (Bracket, Reinf., Side Intrusion Beam)	kg	16.8	15.35	11.65
Glass	kg	3.58		
Hinge (2X)	kg	0.76	0.31	1.95
Latch & Lock	kg	0.76	Striker	0.5
Doorcheck	kg	0.365		
Window regulator / Superplug	kg	2.805		
Type of Window regulator		cross arm		
Exterior rear Console	kg			0.155
Mirror	kg	0.96		
Trim / Insulation	kg	3.08	0.35	0.04
Sealing	kg	2.15	0.3	0.025
Wiring Harness	kg	0.755		
Weight of Speaker	kg	0.925		
Sum electric components	kg	1.68		
Weight Complete	kg	32.17	15.95	12.4
Q = BIW / Complete		0.52	0.96	0.94
Mass / Surface	kg/sqm	20.00	13.23	12.01
Dimensions				
Length (X)	mm	1150	890	870
Height (Z)	mm	1145		
Width (Y)	mm		1450	1085
True Surface Area Calculated	sqm	0.84	1.16	0.97
Surface Area projected	sqm	0.83	1.29	0.95
Depth with / without Trim	mm	210/135		
Material thickness inner / outer panel	mm	0.61/0.79	0.57/0.79	0.51/0.72
Material thickness Glass	mm	4		
Curvature Glass	mm	N/A		
Beltline / Bottom	mm	635		
Hinge / Hinge (Hingespread)	mm	320	1385	1020
Length / Hingespread Ratio		3.6	0.6	0.9
Hinge / Latch (horizontal / vertical / upr / lwr)	mm	1030/130/190	910/Center	445/Center
Material thickness Hinge		5	2.5	2.5
Specification				
Number of Brackets / Reinforcements		7	3	4
Number of Parts total		12	5	6
Number of Weldspots		51	24	23
Area / Thickness of Side intrusion beam		246/1.65		
Length of Side Intrusion Beam	mm	1005		
Inertia of Side Intrusion Beam	mm	133859		
Attachment Type of Side Intrusion Beam		spotwelded		





Benchmarking

Data Gathering - Teardown of Closures Results Sheet - Ford Contour

Closure		Door	Hood	Decklid
Weight				
BIW (Bracket, Reinf., Side Intrusion Beam)	kg	15.844	15.05	9.93
Glass	kg	3.38		
Hinge (2X)	kg	0.66	0.48	1640
Latch & Lock	kg	1.185	Striker	Striker
Doorcheck	kg	0.22		
Window regulator / Superplug	kg	1.855		
Type of Window regulator		single cable		
Exterior rear Console	kg			2.11
Mirror	kg	1.24		
Trim / Insulation	kg	3.115		0.22
Sealing	kg	1.15	0.125	0.02
Wiring Harness	kg	0.95		
Weight of Speaker	kg	0.58		
Sum electric components	kg	1.53		
Weight Complete	kg	29.35	15.175	12.585
Q = BIW / Complete		0.54	0.99	0.79
Mass / Surface	kg/sqm	19.09	14.07	8.87
Dimensions				
Length (X)	mm	1115	955	722
Height (Z)	mm	1170		
Width (Y)	mm		1425	1362
True Surface Area Calculated	sqm	0.83	1.07	1.12
Depth with / without Trim	mm	150/240		
Material thickness inner / outer panel	mm	0.68/0.7	0.59/0.63	0.59/0.63
Material thickness Glass	mm	3.25		
Curvature Glass	mm	26		
Beltline / Bottom	mm	585		
Hinge / Hinge (Hingespread)	mm	315	1400	1210
Length / Hingespread Ratio		3.5	0.7	0.6
Hinge / Latch (horizontal / vertical / upr / lwr)	mm	1015/170/145	880/Center	445/Center
Material thickness Hinge	mm	4.5	4	20x20x2
Specification				
Number of Brackets / Reinforcements		6	3	3
Number of Parts total		8	5	5
Number of Weldspots		106	12	7
Area / Thickness of Side Intrusion Beam		264 / 1.8		
Length of Side Intrusion Beam	mm	840		
Inertia of Side Intrusion Beam	mm	37685		
Attachment Type of Side Intrusion Beam		spotwelded		





Benchmarking

Data Gathering - Teardown of Closures Results Sheet - Ford Probe

Closure		Door	Hood	Hatch
Weight				
BIW (Bracket, Reinf., Side Intrusion Beam)	kg			12.4
Glass	kg			11.8
Hinge (2X)	kg			0.34
Latch & Lock	kg			0.07
Doorcheck	kg			
Window regulator / Superplug	kg			
Type of Window regulator				
Exterior rear Console	kg			0.155
Mirror	kg			
Trim / Insulation	kg			1.6
Sealing	kg			0.25
Wiring Harness	kg			0
Weight of Speaker	kg			
Sum electric components	kg			0
Weight Complete	kg			12.4
Q = BIW / Complete				1.00
Mass / Surface	kg/sqm			14.76
Dimensions				
Length (X)	mm			1370
Height (Z)	mm			
Width (Y)	mm			1260
True Surface Area Calculated	sqm			0.84
Depth with / without Trim	mm			
Material thickness inner / outer panel	mm			0.65/1
Material thickness Glass	mm			
Curvature Glass	mm			
Beltline / Bottom	mm			
Hinge / Hinge (Hingespread)	mm			610
Length / Hingespread Ratio				2.2
Hinge / Latch (horizontal / vertical / upr / lwr)	mm			1250/Center
Material thickness Hinge	mm			2
Specification				
Number of Brackets / Reinforcements				4
Number of Parts total				6
Number of Weldspots				90
Area / Thickness of Side Intrusion Beam				
Length of Side Intrusion Beam	mm			
Inertia of Side Intrusion Beam	mm			
Attachment Type of Side Intrusion Beam				





Benchmarking

Data Gathering - Teardown of Closures Results Sheet - Ford Taurus

Closure		Door	Hood	Decklid
Weight				
BIW (Bracket, Reinf., Side Intrusion Beam)	kg	18.72	21.66	5.9
Glass	kg	3.77		
Hinge (2X)	kg	1.2	0.7	0.42
Latch & Lock	kg	1.22	0.55	0.695
Doorcheck	kg	0.245		
Window regulator / Superplug	kg	2.365		
Type of Window regulator		crossarm		
Exterior rear Console	kg			1.9
Mirror	kg	0.79		
Trim / Insulation	kg	3.7	0.85	0.565
Sealing	kg	2.825	0.22	on Body
Wiring Harness	kg	1.195		0.13
Weight of Speaker	kg	0.765		
Sum electric components	kg	1.96		0.13
Weight Complete	kg	35.97	23.965	9.06
Q = BIW / Complete		0.52	0.90	0.65
Mass / Surface	kg/sqm	20.82	13.37	5.78
Dimensions				
Length (X)	mm	1095	900	810
Height (Z)	mm	1245		
Width (Y)	mm		1550	1335
True Surface Area Calculated	sqm	0.90	1.62	1.02
Depth with / without Trim	mm	340/390		
Material thickness inner / outer panel	mm	0.68 / 0.70	0.6 / 0.7	0.8/0.8
Material thickness Glass	mm	3.95		
Curvature Glass	mm	N/A		
Beltline / Bottom	mm	735		
Hinge / Hinge (Hingespread)	mm	340	1380	1070
Length / Hingespread Ratio		3.2	0.7	0.8
Hinge / Latch (horizontal / vertical / upr / lwr)	mm	950/150/190	630/Center	660/Center
Material thickness Hinge	mm	4	2.53	2.22
Specification				
Number of Brackets / Reinforcements		10	3	3
Number of Parts total		12	5	5
Number of Weldspots		122	128	40
Area / Thickness of Side Intrusion Beam		261 / 1.78		
Length of Side Intrusion Beam	mm	890		
Inertia of Side Intrusion Beam	mm	70407		
Attachment Type of Side Intrusion Beam		spotwelded		





Benchmarking

Data Gathering - Teardown of Closures Results Sheet - Honda Accord

Closure		Door	Hood	Decklid
Weight				
BIW (Bracket, Reinf., Side Intrusion Beam)	kg	15.9	16.78	10.04
Glass	kg	3.055		
Hinge (2X)	kg	0.76	0.7	0.42
Latch & Lock	kg	1.345	Striker	0.78
Doorcheck	kg	1.75		
Window regulator / Superplug	kg	1.285		
Type of Window regulator		Crossarm		
Exterior rear Console	kg			2.15
Mirror	kg	1.085		
Trim / Insulation	kg	3.12	no	on Body
Sealing	kg	0.945	0.22	on Body
Wiring Harness	kg	0.5		0.13
Weight of Speaker	kg	0.555		
Sum electric components	kg	1.055		0.13
Weight Complete	kg	29	19.3	13.45
Q = BIW / Complete		0.55	16.90	0.75
Mass / Surface	kg/sqm	23.38	10.36	10.57
Dimensions				
Length (X)	mm	1115	1115	740
Height (Z)	mm	1130		
Width (Y)	mm		1460	1170
True Surface Area Calculated	sqm	0.68	1.62	0.95
Depth with / without Trim	mm	130/		
Material thickness inner / outer panel	mm	0.6 / 0.72	0.55 / .72	0.66/0.66
Material thickness Glass	mm	3.5		
Curvature Glass	mm	21		
Beltline / Bottom	mm	0		
Hinge / Hinge (Hingespread)	mm	330	1380	1040
Length / Hingespread Ratio		3.4	0.8	0.7
Hinge / Latch (horizontal / vertical / upr / lwr)	mm	1030/120/210	1060/Center	380/Center
Material thickness Hinge	mm	6	2.53	2.22
Specification				
Number of Brackets / Reinforcements		8	3	1
Number of Parts total		12	5	3
Number of Weldspots		52	24	14
Area / Thickness of Side Intrusion Beam		226 / 2.48		
Length of Side Intrusion Beam	mm	850		
Inertia of Side Intrusion Beam	mm	23975		
Attachment Type of Side Intrusion Beam		gaswelded		





Benchmarking

Data Gathering - Teardown of Closures Results Sheet - Mercedes E320

Closure		Door	Hood	Decklid
Weight				
BIW (Bracket, Reinf., Side Intrusion Beam)	kg	13.439	19.86	11.683
Glass	kg	3.362		
Hinge (2X)	kg	1.494	1.558	1.482
Latch & Lock	kg	1.149	0.235	0.542
Doorcheck	kg	0.501		
Window regulator / Superplug	kg	1.45		
Type of Window regulator		crossarm		
Exterior rear Console	kg			
Mirror	kg	N/A		
Trim / Insulation	kg	2.604	2.09	1.034
Sealing	kg	1.574	0.586	1.09
Wiring Harness	kg	N/A		
Weight of Speaker	kg	N/A		
Sum electric components	kg	N/A		
Weight Complete	kg	27.889	26.635	18.319
Q = BIW / Complete		0.48	0.75	0.64
Mass / Surface	kg/sqm	17.01	14.19	10.07
Dimensions				
Length (X)	mm	950	1375	850
Height (Z)	mm	1130		
Width (Y)	mm		1440	1265
True Surface Area Calculated	sqm	0.79	1.40	1.16
Depth with / without Trim	mm	135/210		
Material thickness inner / outer panel	mm	0.74/0.74	0.7/0.8	0.7/0.72
Material thickness Glass	mm	4		
Curvature Glass	mm	N/A		
Beltline / Bottom	mm	645		
Hinge / Hinge (Hingespread)	mm	350	1430	1130
Length / Hingespread Ratio		2.7	1.0	0.8
Hinge / Latch (horizontal / vertical / upr / lwr)	mm	930/60/290	770/252/252	1.8
Material thickness Hinge	mm	5.5	2.5	1.87
Specification				
Number of Brackets / Reinforcements		7	3	5
Number of Parts total		14	5	7
Number of Weldspots		88	34	12
Area / Thickness of Side Intrusion Beam		460/2.75		
Length of Side Intrusion Beam	mm	820		
Inertia of Side Intrusion Beam	mm	163500		
Attachment Type of Side Intrusion Beam		spotwelded		





Benchmarking

Data Gathering - Teardown of Closures Results Sheet - Mitsubishi Eclipse

Closure		Door	Hood	Decklid
Weight				
BIW (Bracket, Reinf., Side Intrusion Beam)	kg			12.6
Glass	kg			11.8
Hinge (2X)	kg			N/A
Latch & Lock	kg			0.105
Doorcheck	kg			1.15
Window regulator / Superplug	kg			
Type of Window regulator				
Exterior rear Console	kg			1.15
Mirror	kg			
Trim / Insulation	kg			1.6
Sealing	kg			on Body
Wiring Harness	kg			on Body
Weight of Speaker	kg			
Sum electric components	kg			0
Weight Complete	kg			24.4
Q = BIW / Complete				0.52
Mass / Surface	kg/sqm	kg/sqm		15.24
Dimensions				
Length (X)	mm			1460
Height (Z)	mm			
Width (Y)	mm			1245
True Surface Area Calculated	sqm			0.83
Depth with / without Trim	mm			
Material thickness inner / outer panel	mm			0.63/0.681
Material thickness Glass	mm			
Curvature Glass	mm			
Beltline / Bottom	mm			
Hinge / Hinge (Hingespread)	mm			700
Length / Hingespread Ratio				2.1
Hinge / Latch (horizontal / vertical / upr / lwr)	mm			1280/Center
Material thickness Hinge	mm			3.2
Specification				
Number of Brackets / Reinforcements				7
Number of Parts total				9
Number of Weldspots				90
Area / Thickness of Side Intrusion Beam				
Length of Side Intrusion Beam	mm			
Inertia of Side Intrusion Beam	mm			
Attachment Type of Side Intrusion Beam				





Benchmarking

Data Gathering - Teardown of Closures Results Sheet - Nissan Sentra

Closure		Door	Hood	Decklid
Weight				
BIW (Bracket, Reinf., Side Intrusion Beam)	kg	15.2	14.05	9.95
Glass	kg	2.835		
Hinge (2X)	kg	0.76	0.54	0.23
Latch & Lock	kg	0.945	Striker	2.044
Doorcheck	kg	0.155		
Window regulator / Superplug	kg	1.195		
Type of Window regulator		cross arm		
Exterior rear Console	kg			1.395
Mirror	kg	0.86		
Trim / Insulation	kg	3.66	no	no
Sealing	kg	0.95	0.24	no
Wiring Harness	kg	0.545		
Weight of Speaker	kg	0.44		
Sum electric components	kg	0.985		
Weight Complete	kg	27.95	14.3	11.8
Q = BIW / Complete		0.54	0.98	0.84
Mass / Surface	kg/sqm	18.10	9.89	9.95
Dimensions				
Length (X)	mm	1100	975	795
Height (Z)	mm	1145		
Width (Y)	mm		1405	1170
True Surface Area Calculated	sqm	0.84	1.42	1.00
Depth with / without Trim	mm	135/235		
Material thickness inner / outer panel	mm	0.59 / .66	0.5 / 0.68	0.57/0.71
Material thickness Glass	mm	3.5		
Curvature Glass	mm	25		
Beltline / Bottom	mm	625		
Hinge / Hinge (Hingespread)	mm	320	1280	1060
Length / Hingespread Ratio		3.4	0.8	0.8
Hinge / Latch (horizontal / vertical / upr / lwr)	mm	980/150/170	870/Center	410/Center
Material thickness Hinge	mm	4.3	3.15	24x24x1.98
Specification				
Number of Brackets / Reinforcements		12	3	5
Number of Parts total		14	5	7
Number of Weldspots		90	20	29
Area / Thickness of Side Intrusion Beam		232.5 / 2.26		
Length of Side Intrusion Beam	mm	840		
Inertia of Side Intrusion Beam	mm	31295		
Attachment Type of Side Intrusion Beam		spotwelded		





Benchmarking

Data Gathering - Teardown of Closures Results Sheet - Porsche Boxster

Closure		Door	Hood	Decklid
Weight				
BIW (Bracket, Reinf., Side Intrusion Beam)	kg	15.17		
Glass	kg	3.49		
Hinge (2X)	kg	1		
Latch & Lock	kg	0.98		
Doorcheck	kg	0.405		
Window regulator / Superplug	kg	1.8		
Type of Window regulator		cable		
Exterior rear Console	kg			
Mirror	kg	N/A		
Trim / Insulation	kg	3.23		
Sealing	kg	0.97		
Wiring Harness	kg	0.64		
Weight of Speaker	kg	N/A		
Sum electric components	kg	N/A		
Weight Complete	kg	29.5		
Q = BIW / Complete		0.51		
Mass / Surface	kg/sqm	kg/sqm	19.96	
Dimensions				
Length (X)	mm	1264		
Height (Z)	mm	622		
Width (Y)	mm			
True Surface Area Calculated	sqm	0.76		
Depth with / without Trim	mm	146/		
Material thickness inner / outer panel	mm	0.8/0.9		
Material thickness Glass	mm	N/A		
Curvature Glass	mm	N/A		
Beltline / Bottom	mm	622		
Hinge / Hinge (Hingespread)	mm	300		
Length / Hingespread Ratio		4.2		
Hinge / Latch (horizontal / vertical / upr / lwr)	mm	1080/105/195		
Material thickness Hinge	mm	die cast		
Specification				
Number of Brackets / Reinforcements		7		
Number of Parts total		9		
Number of Weldspots		0		
Area / Thickness of Side Intrusion Beam		268/1.7		
Length of Side Intrusion Beam	mm	890		
Inertia of Side Intrusion Beam	mm	29566		
Attachment Type of Side Intrusion Beam		bolted		





Benchmarking

Data Gathering - Teardown of Closures Results Sheet - Renault Laguna

Closure		Door	Hood	Hatch
Weight				
BIW (Bracket, Reinf.)	kg	14.911	17.803	13.372
Side Intrusion Beam	kg	2.315		
Door Inner Module	kg	0.88		
BIW Total		18.106	17.803	13.372
Glass	kg	2.993		11.079
Hinge (2X)	kg	1.034	1.818	1.437
Latch & Lock	kg	0.821	Striker	0.881
Doorcheck / Gasstruts	kg	0.231		1.042
Window regulator	kg	1.801		
Type of Window regulator		cross arm		
Exterior rear Console				
Mirror	kg	1.502		
Trim / Insulation	kg	2.462		1.651
Sealing	kg	2.997	0.587	1.548
Wiring Harness	kg	0.442		0.842
Number / Weight of Speaker	kg	N/A		
Sum electric. components	kg	0.442		
Weight Complete	kg	32.831	20.208	31.852
Q = BIW / Complete		0.55	0.88	0.42
Mass / Surface	kg/sqm	kg/sqm	20.12	10.19
			13.14	
Dimensions				
Length (X)	mm	1100	0	0
Height (Z)	mm	1110		
Width (Y)	mm		0	0
True Surface Area Calculated	sqm	0.74	1.75	1.02
Depth with / without Trim	mm	180/145		
Material thickness inner / outer panel	mm	N/A	N/A	N/A
Material thickness Glass	mm	N/A		
Curvature Glass		N/A		
Beltline / Bottom	mm	0		
Hinge / Hinge (Hingespread)	mm	310	0	0
Length / Hingespread Ratio		3.5	N/A	N/A
Hinge / Latch (horizontal / vertical /Upr / lwr	mm	N/A	N/A	N/A
Material thickness Hinge		N/A	N/A	N/A
Specification				
Number of Brackets / Reinforcements		N/A	N/A	N/A
Number of Parts total		N/A	N/A	N/A
Number of Weldspots		N/A	N/A	N/A
Area / Thickness of Side Intrusion beam		N/A		
Length of Side Intrusion beam	mm	N/A		
Inertia of Side Intrusion beam	mm	N/A		
Attachment Type of Side Intrusion beam		N/A		





Benchmarking

Data Gathering - Teardown of Closures Results Sheet - Saturn LS

Closure		Door	Hood	Decklid
Weight				
BIW (Bracket, Reinf., Side Intrusion Beam)	kg	14.18	12.3	9.61
Glass	kg	2.84		
Hinge (2X)	kg	0.7	0.7	0.42
Latch & Lock	kg	1.075	Striker	0.5
Doorcheck	kg	N/A		
Window regulator / Superplug	kg	2.845		
Type of Window regulator		cross arm		
Exterior rear Console	kg			2.15
Mirror	kg	0.745		
Trim / Insulation	kg	2.455	0.45	no
Sealing	kg	1.45	no	no
Wiring Harness	kg	1.95		0.13
Weight of Speaker	kg	0.45		
Sum electric components	kg	2.4		0.13
Weight Complete	kg	27.55	19.3	13.45
Q = BIW / Complete		0.51	0.64	0.71
Mass / Surface	kg/sqm	20.85	8.79	10.92
Dimensions				
Length (X)	mm	975.00	990.00	740.00
Height (Z)	mm	1110		
Width (Y)	mm		1370	1170
True Surface Area Calculated	sqm	0.68	1.4	0.88
Depth with / without Trim	mm	140/115		
Material thickness inner / outer panel	mm	0.72	0.55 / .59	0.66/0.66
Material thickness Glass	mm	3.50		
Curvature Glass	mm	34		
Beltline / Bottom	mm	610		
Hinge / Hinge (Hingespread)	mm	360	1270	1040
Length / Hingespread Ratio		2.7	0.8	0.7
Hinge / Latch (horizontal / vertical / upr / lwr)	mm	960/140/220	820/Center	380/Center
Material thickness Hinge	mm	8	2.6	2.22
Specification				
Number of Brackets / Reinforcements		10.0	3.0	1.0
Number of Parts total		22	5	3
Number of Weldspots		140	16	14
Area / Thickness of Side Intrusion Beam		226 / 2.48		
Length of Side Intrusion Beam	mm	870		
Inertia of Side Intrusion Beam	mm	23975		
Attachment Type of Side Intrusion Beam		gaswelded		





Benchmarking

Data Gathering - Teardown of Closures Results Sheet - Toyota Camry

Closure		Door	Hood	Decklid
Weight				
BIW (Bracket, Reinf., Side Intrusion Beam)	kg	16.7	18.4	12.045
Glass	kg	3.325		
Hinge (2X)	kg	0.76	0.34	1.95
Latch & Lock	kg	1.075	Striker	0.5
Doorcheck	kg	0.155		
Window regulator / Superplug	kg	2.01		
Type of Window regulator		crossarm		
Exterior rear Console	kg			0.8
Mirror	kg	0.76		
Trim / Insulation	kg	3.15	0.675	no
Sealing	kg	1.45	0.26	on Body
Wiring Harness	kg	0.735		
Weight of Speaker	kg	0.675		
Sum electric components	kg	1.41		
Weight Complete	kg	32.75	19.3	13.45
Q = BIW / Complete		0.51	0.95	0.90
Mass / Surface	kg/sqm	21.14	10.82	11.36
Dimensions				
Length (X)	mm	1060	1145	860
Height (Z)	mm	1170		
Width (Y)	mm		1490	1215
True Surface Area Calculated	sqm	0.79	1.70	1.06
Depth with / without Trim	mm	125/210		
Material thickness inner / outer panel	mm	0.74 / 0.7	0.66 / 0.7	0.66/0.7
Material thickness Glass	mm	4		
Curvature Glass	mm	25		
Beltline / Bottom	mm	645		
Hinge / Hinge (Hingespread)	mm	355	1415	1145
Length / Hingespread Ratio		3.0	0.8	0.8
Hinge / Latch (horizontal / vertical / upr / lwr)	mm	985/95/255	1060/Center	445/Center
Material thickness Hinge	mm	5	3.5	20x20x2
Specification				
Number of Brackets / Reinforcements		11	4	3
Number of Parts total		14	7	5
Number of Weldspots		69	23	14
Area / Thickness of Side Intrusion Beam		0 / 3		
Length of Side Intrusion Beam	mm	880/930		
Inertia of Side Intrusion Beam	mm	29040		
Attachment Type of Side Intrusion Beam		spotwelded		





Benchmarking

Data Gathering - Teardown of Closures Results Sheet - VW Golf

Closure		Door	Hood	Decklid
Weight				
BIW (Bracket, Reinf., Side Intrusion Beam)	kg			8.13
Glass	kg			
Hinge (2X)	kg			N/A
Latch & Lock	kg			
Doorcheck	kg			
Window regulator / Superplug	kg			
Type of Window regulator				
Exterior rear Console	kg			
Mirror	kg			
Trim / Insulation	kg			
Sealing	kg			
Wiring Harness	kg			
Weight of Speaker	kg			
Sum electric components	kg			
Weight Complete	kg			0.00
Q = BIW / Complete				
Mass / Surface	kg/sqm	kg/sqm		12.47
Dimensions				
Length (X)	mm			930
Height (Z)	mm			
Width (Y)	mm			1335
True Surface Area Calculated	sqm			0.65
Depth with / without Trim	mm			
Material thickness inner / outer panel	mm			0.63/0.681
Material thickness Glass	mm			
Curvature Glass	mm			
Beltline / Bottom	mm			
Hinge / Hinge (Hingespread)	mm			660
Length / Hingespread Ratio				1.4
Hinge / Latch (horizontal / vertical / upr / lwr)	mm			790/Center
Material thickness Hinge	mm			
Specification				
Number of Brackets / Reinforcements				3
Number of Parts total				5
Number of Weldspots				65
Area / Thickness of Side Intrusion Beam				
Length of Side Intrusion Beam	mm			
Inertia of Side Intrusion Beam	mm			
Attachment Type of Side Intrusion Beam				





Benchmarking

Data Gathering - Teardown of Closures Results Sheet - VW Passat

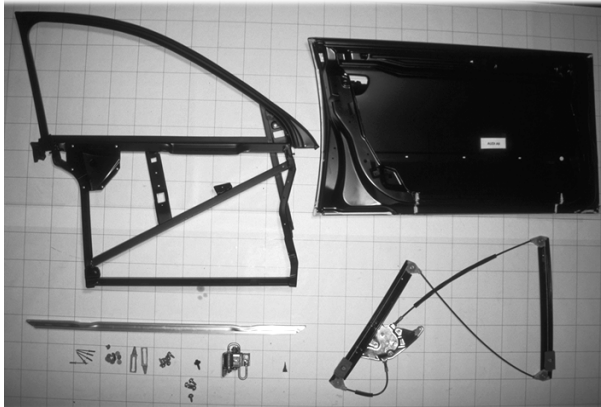
Closure		Door	Hood	Decklid
Weight				
BIW (Bracket, Reinf., Side Intrusion Beam)	kg	16.7	14.9	9.45
Glass	kg			
Hinge (2X)	kg	1.76		
Latch & Lock	kg	0.765		
Doorcheck	kg			
Window regulator / Superplug	kg	3.4		
Type of Window regulator		crossarm		
Exterior rear Console	kg			
Mirror	kg			
Trim / Insulation	kg			
Sealing	kg			
Wiring Harness	kg			
Weight of Speaker	kg	0.55		
Sum electric components	kg			
Weight Complete	kg			
Q = BIW / Complete				
Mass / Surface	kg/sqm	20.12	9.25	12.60
Dimensions				
Length (X)	mm	1100	1415	780
Height (Z)	mm	1160		
Width (Y)	mm		1525	1200
True Surface Area Calculated	sqm	0.83	1.61	0.75
Depth with / without Trim	mm	0/145		
Material thickness inner / outer panel	mm	0.8/0.72	0.7/0.8	0.8/1
Material thickness Glass	mm	4		
Curvature Glass	mm	N/A		
Beltline / Bottom	mm	100		
Hinge / Hinge (Hingespread)	mm	310	1400	1145
Length / Hingespread Ratio		3.5	1.0	0.7
Hinge / Latch (horizontal / vertical / upr / lwr)	mm	1015/70/240	1085/Center	490/Center
Material thickness Hinge	mm	3.9	4	4
Specification				
Number of Brackets / Reinforcements		10	6	3
Number of Parts total		12	8	5
Number of Weldspots		113	110	27
Area / Thickness of Side Intrusion Beam		0 / 1.8		
Length of Side Intrusion Beam	mm	1035		
Inertia of Side Intrusion Beam	mm	15005		
Attachment Type of Side Intrusion Beam		spotwelded		





Benchmarking

Photos - Audi A6



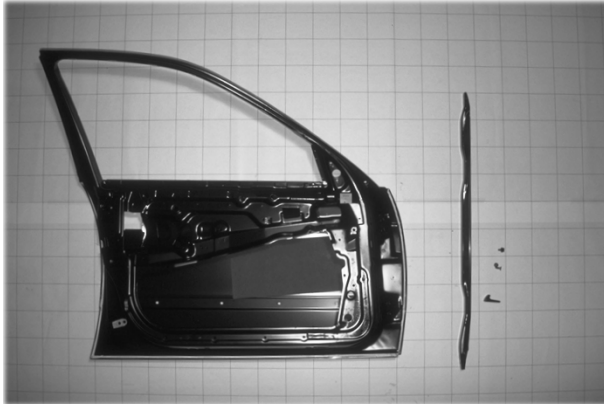
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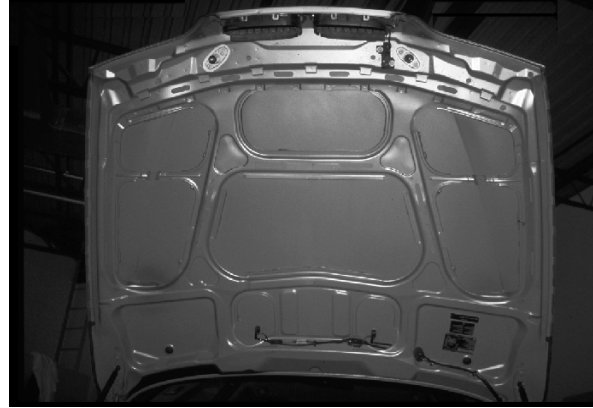


Benchmarking

Photos - BMW 528i



Door



Hood



Hood





Benchmarking

Photos - Cadillac Sedan Deville



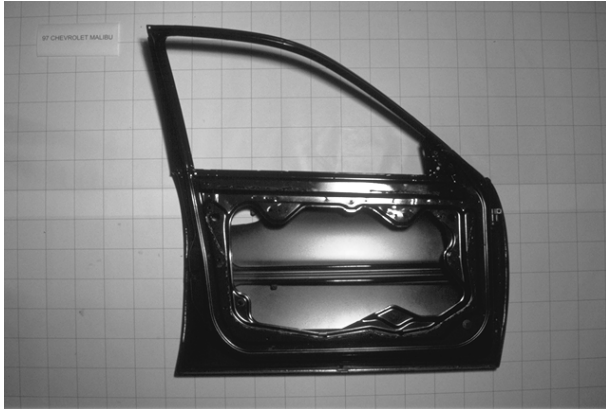
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Benchmarking

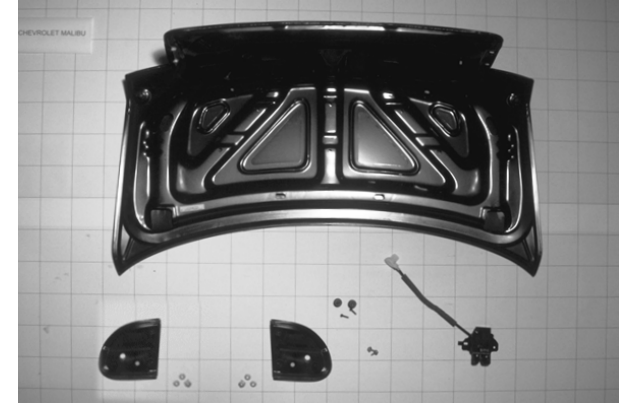
Photos - Chevrolet Malibu



Door



Hood



Decklid



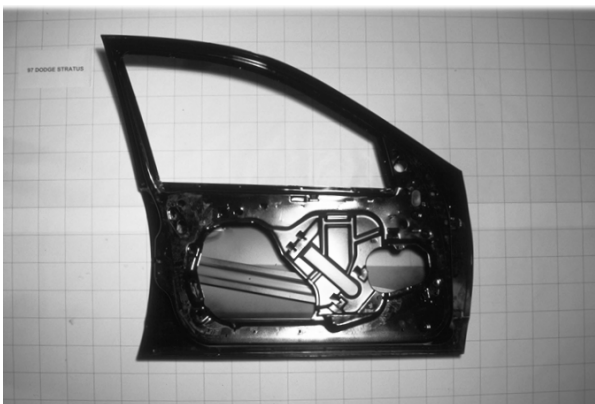
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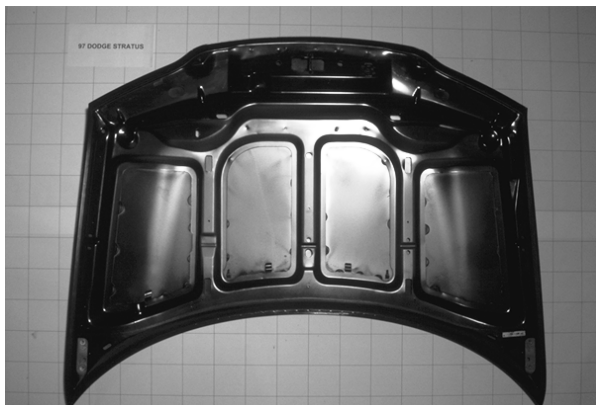


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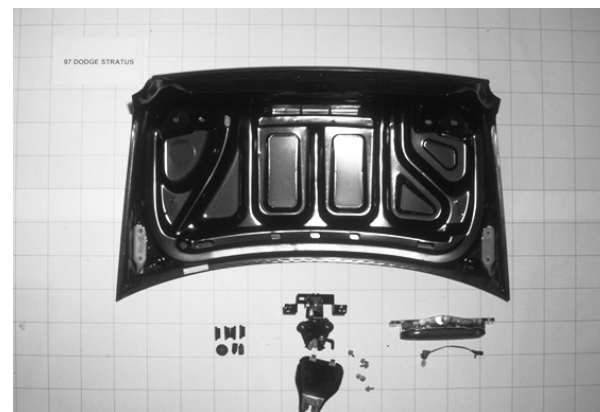
Photos - Dodge Stratus



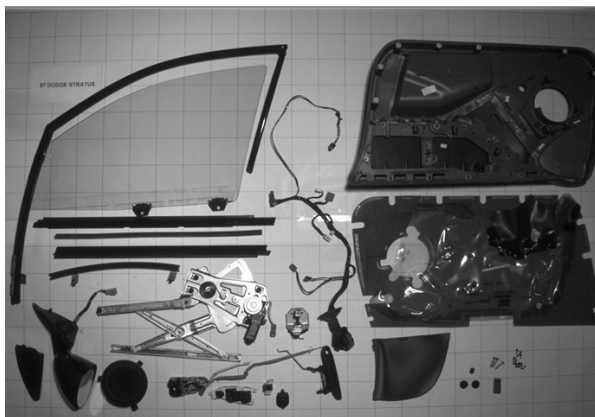
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Hood



Decklid



Door



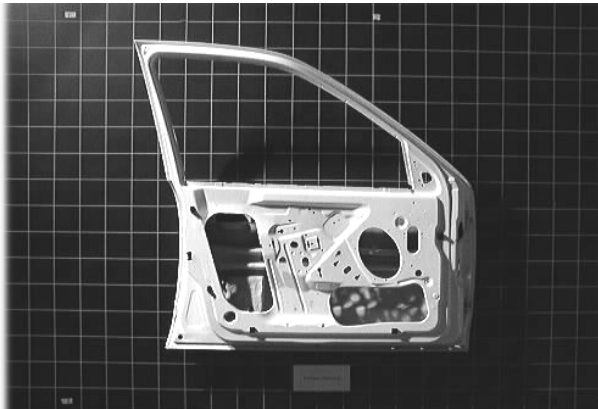
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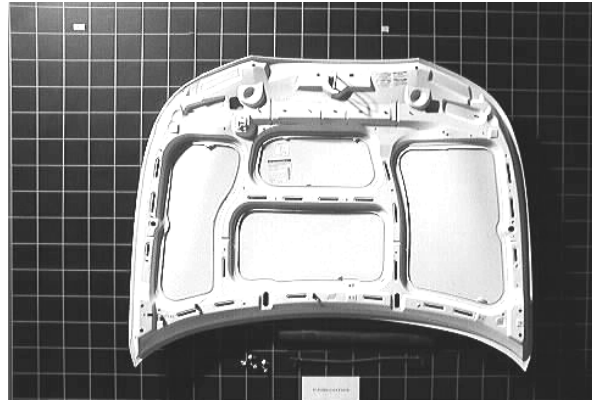


Benchmarking

Photos - Ford Contour



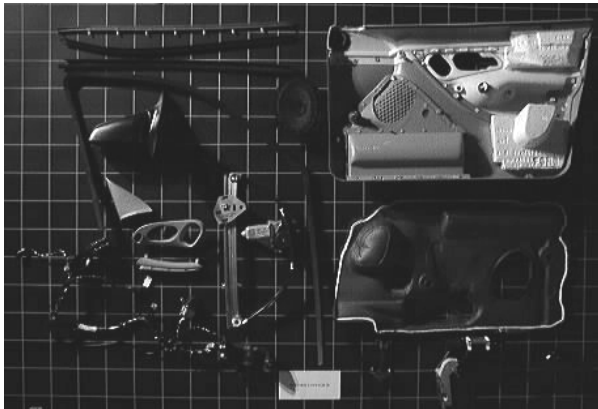
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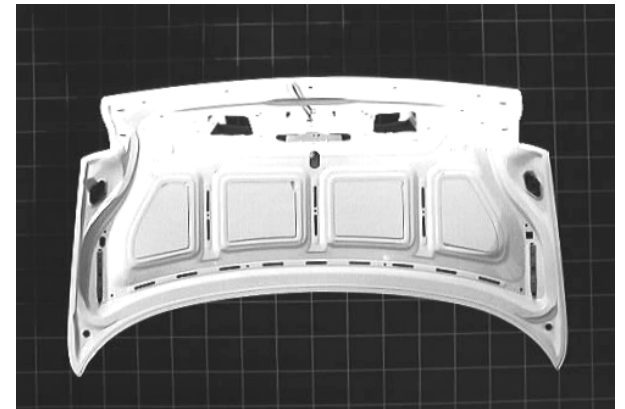
Hood



Decklid



Door



Decklid



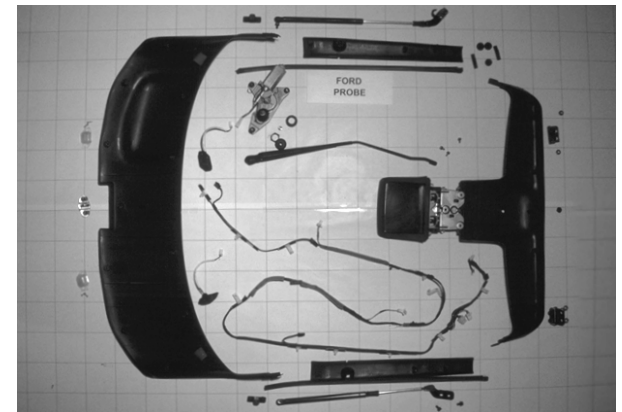


Benchmarking

Photos - Ford Probe



Hatchback



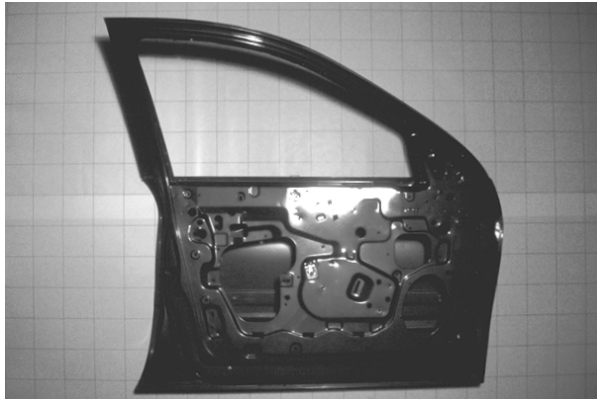
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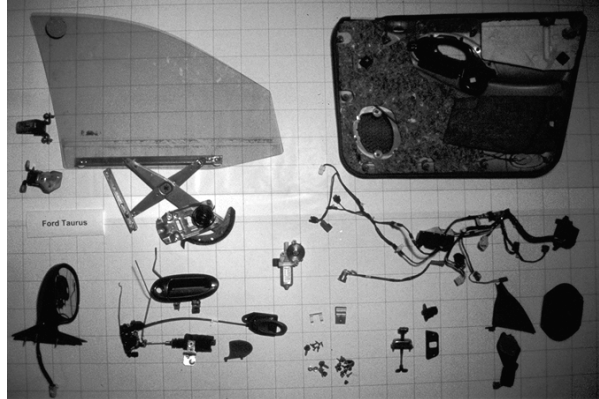


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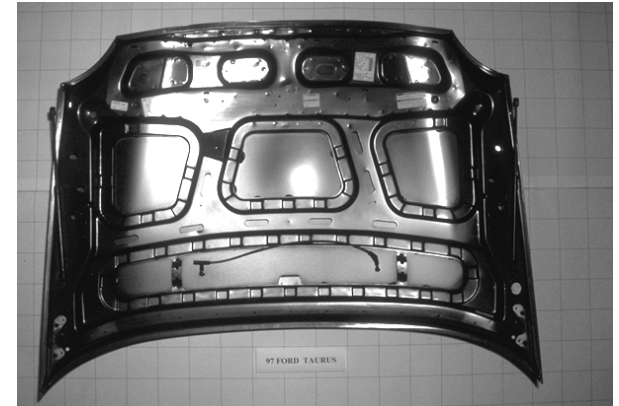
Photos - Ford Taurus



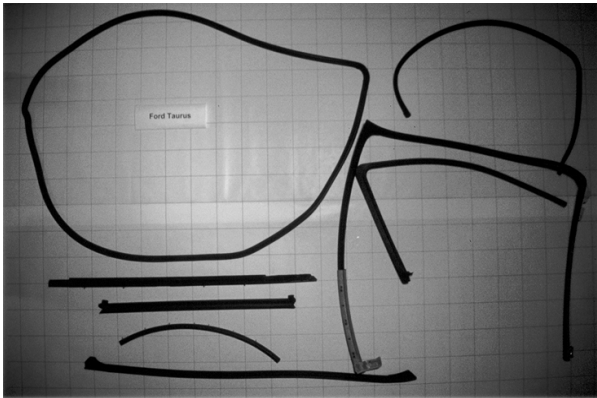
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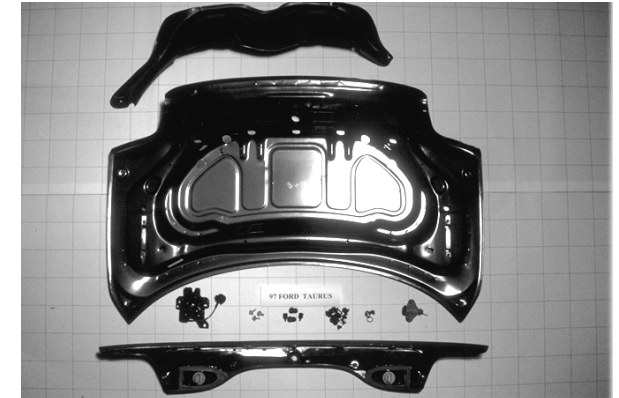
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Hood



Door



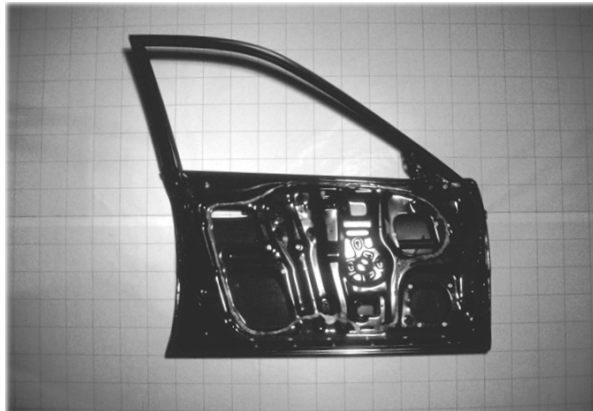
Decklid





Benchmarking

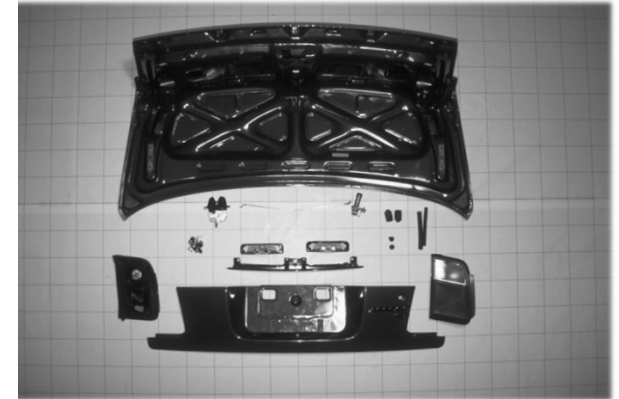
Photos - Honda Accord



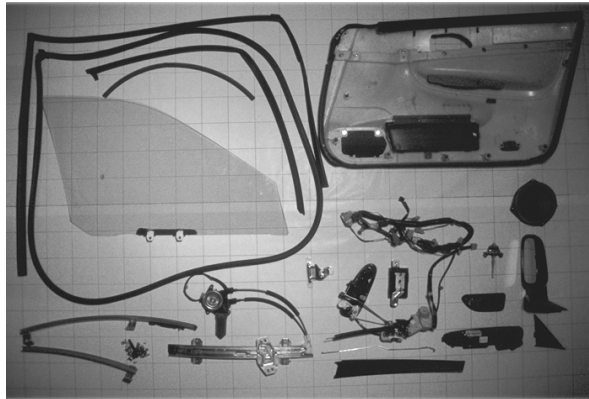
Door



Hood



Decklid



Door



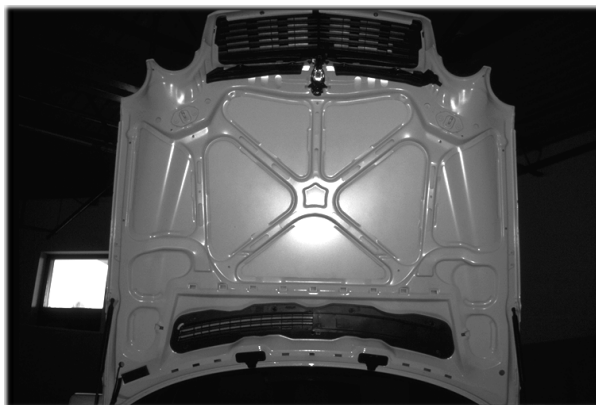


Benchmarking

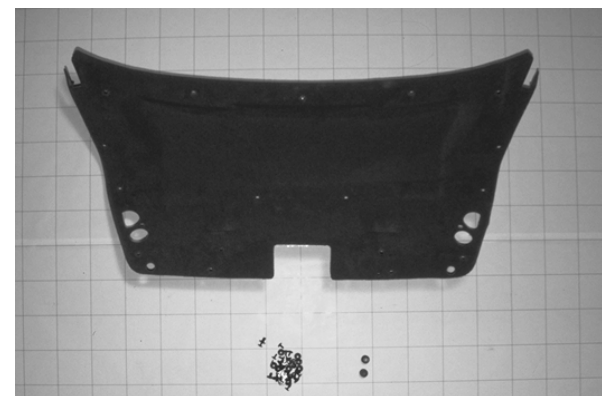
Photos - Mercedes E320



Door



Hood



Decklid



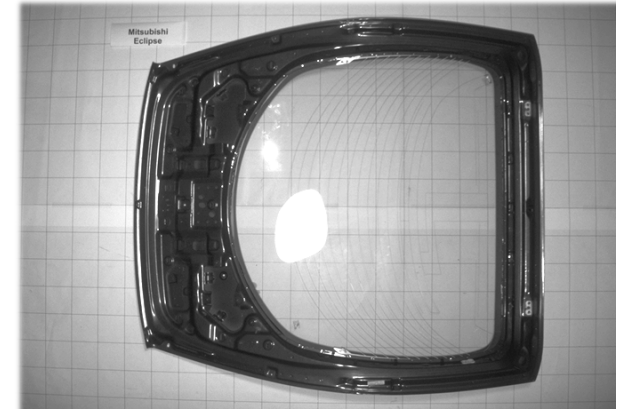
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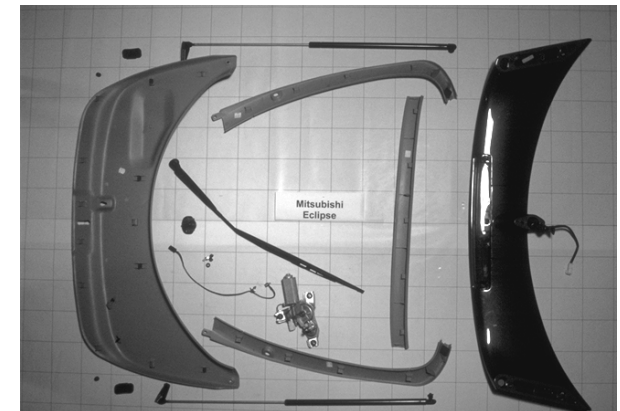


Benchmarking

Photos - Mitsubishi Eclipse



Hatchback



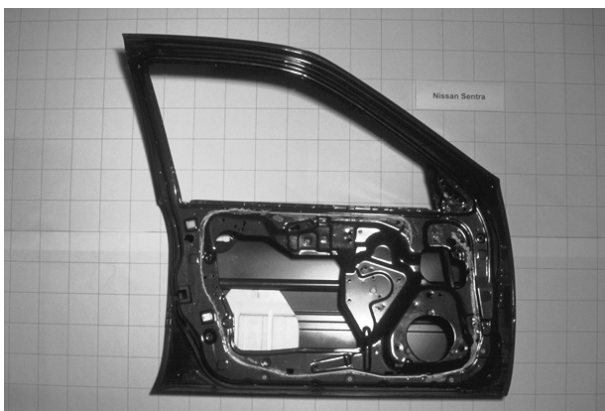
Hatchback





Benchmarking

Photos - Nissan Sentra



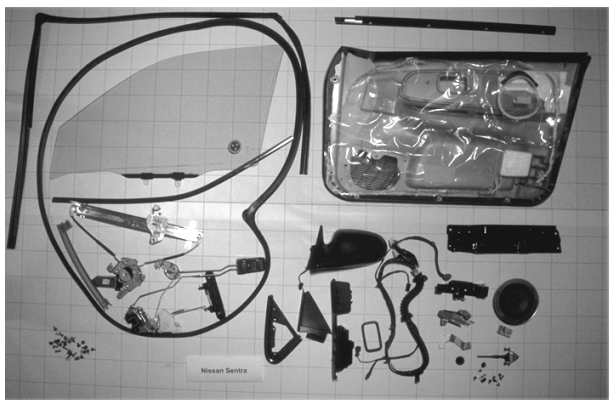
Door



Hood



Decklid



Door





Benchmarking

Photos - Saturn LS



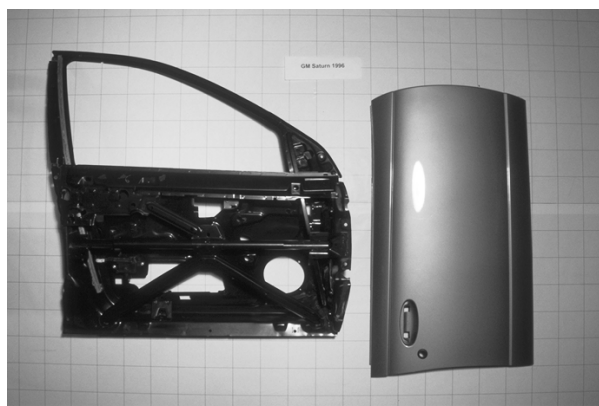
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Door



Hood



Door



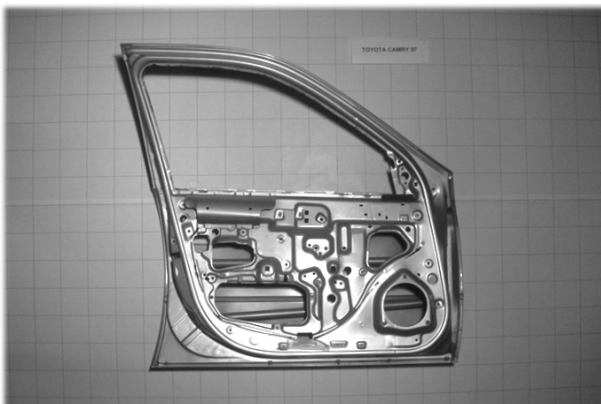
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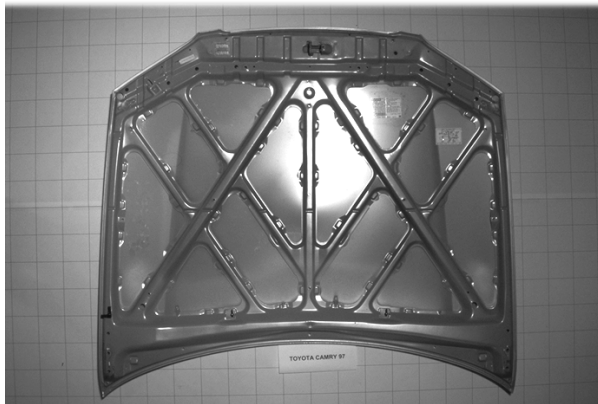


Benchmarking

Photos - Toyota Camry



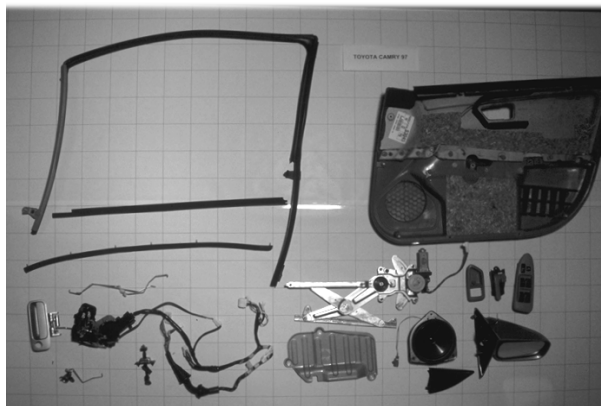
Door



Hood



Decklid



Door



Hood



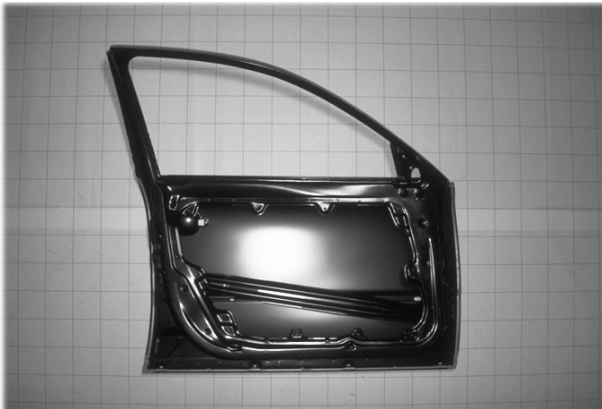
Decklid



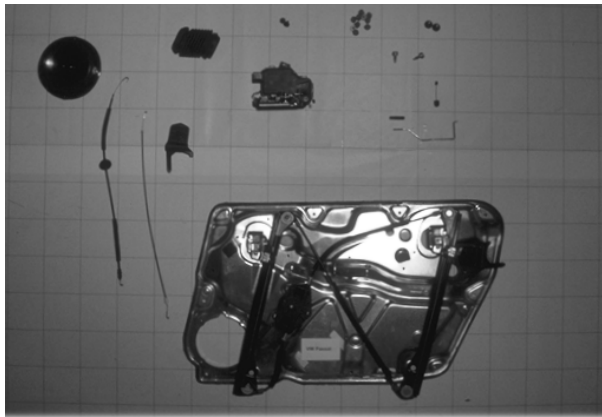


Benchmarking

Photos - VW Passat



Door



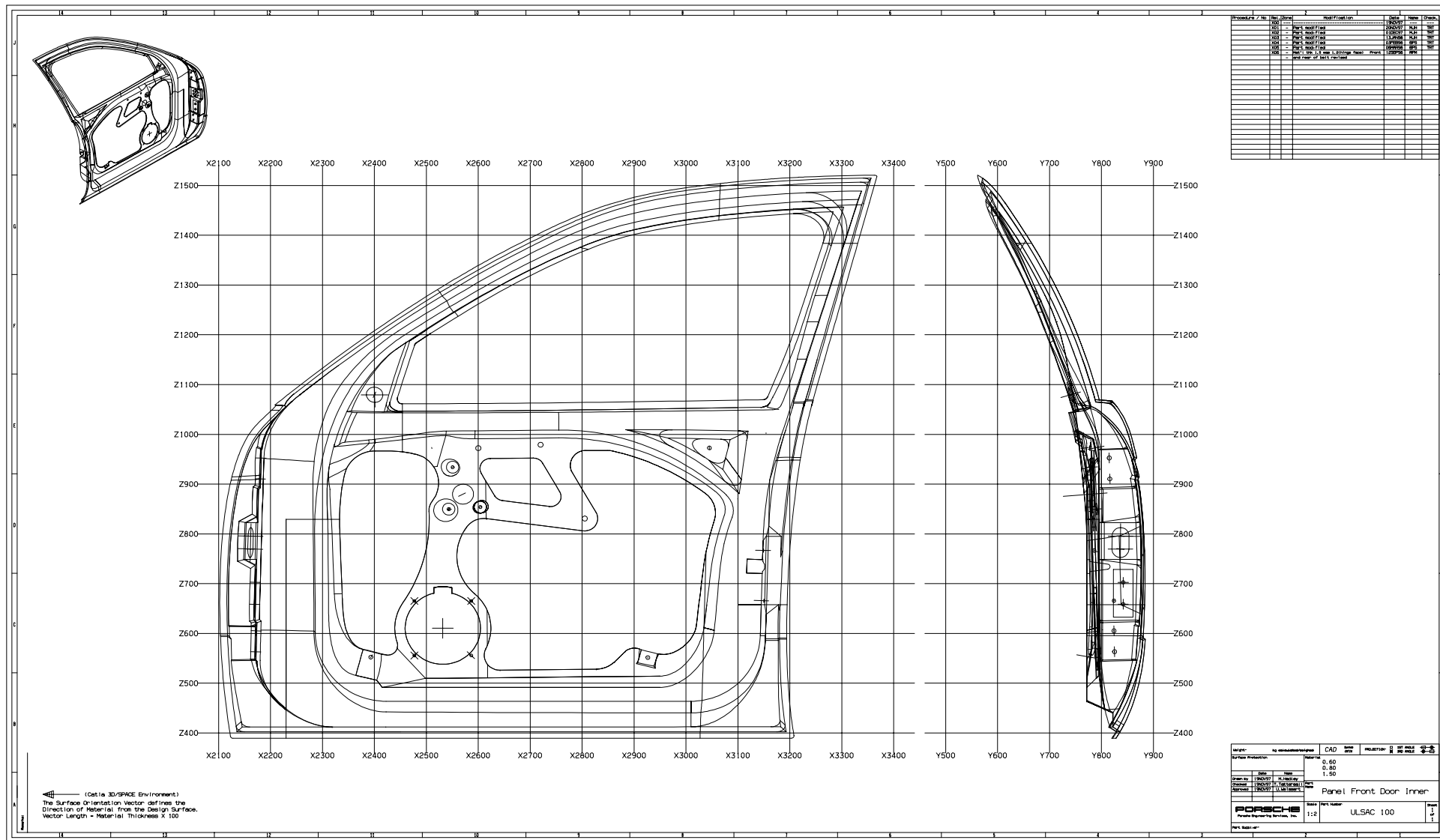
Door





Part Drawings

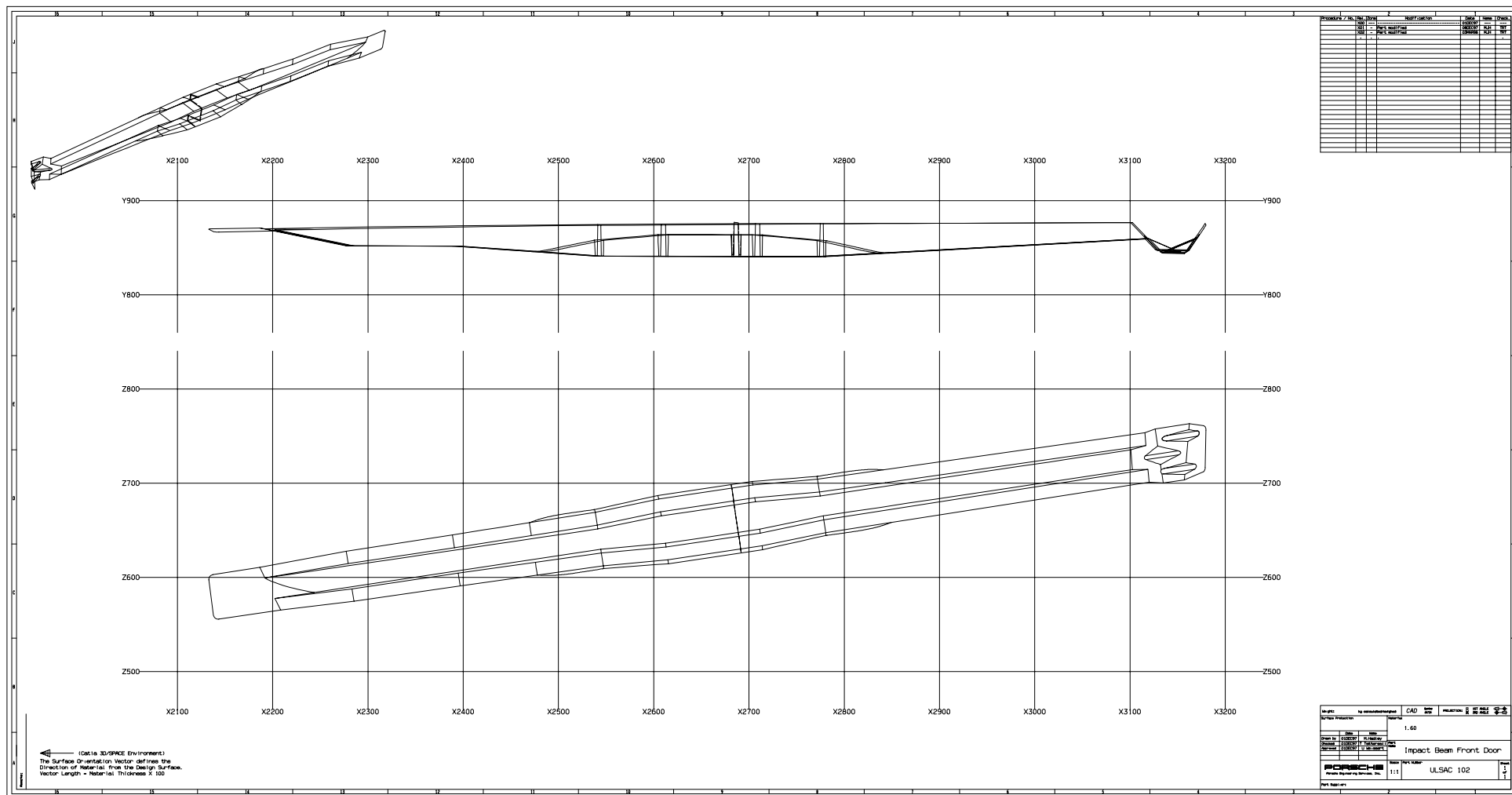
Part 100 - Panel Front Door Inner





Part Drawings

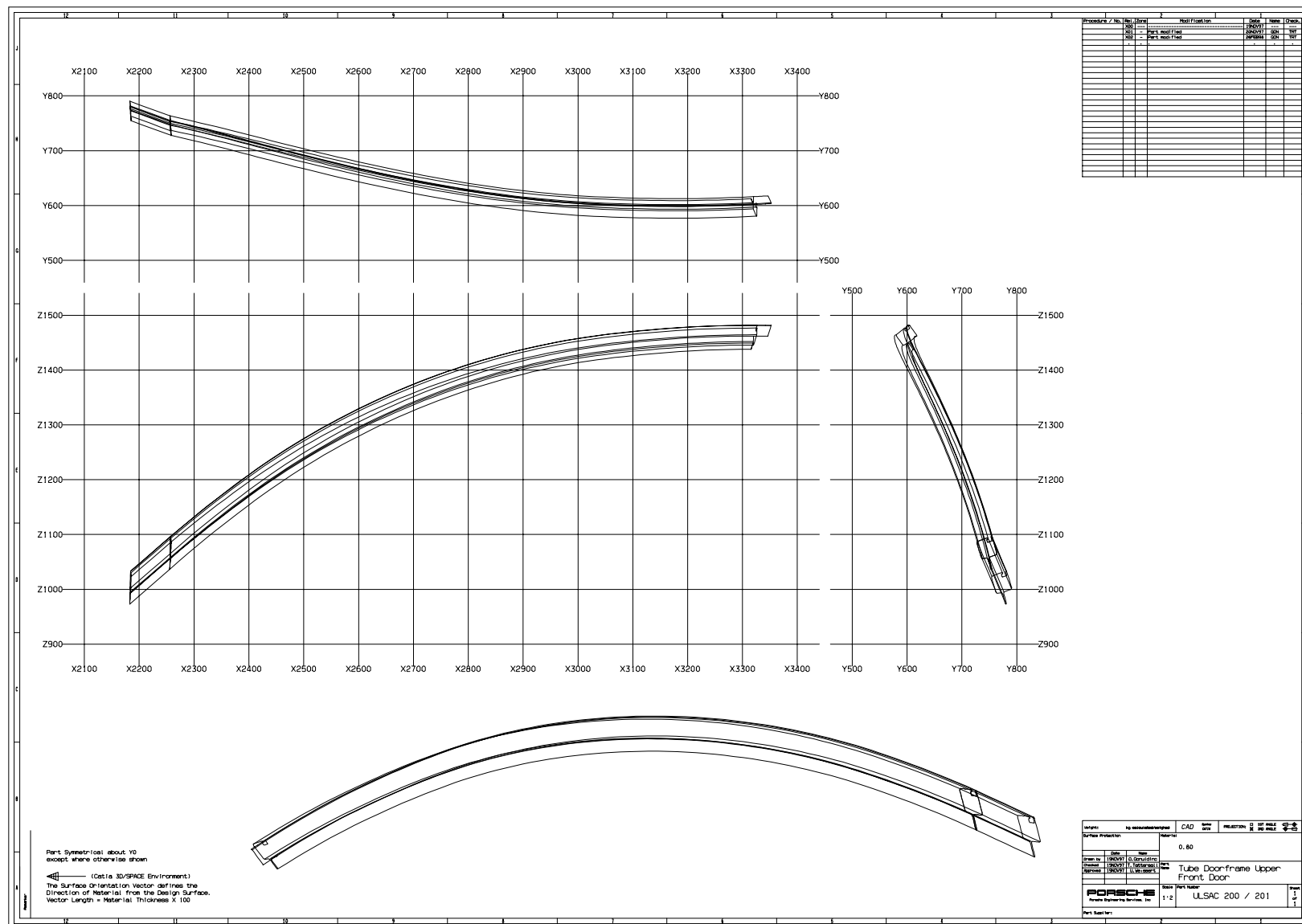
Part 102 - Impact Beam Front Door





Part Drawings

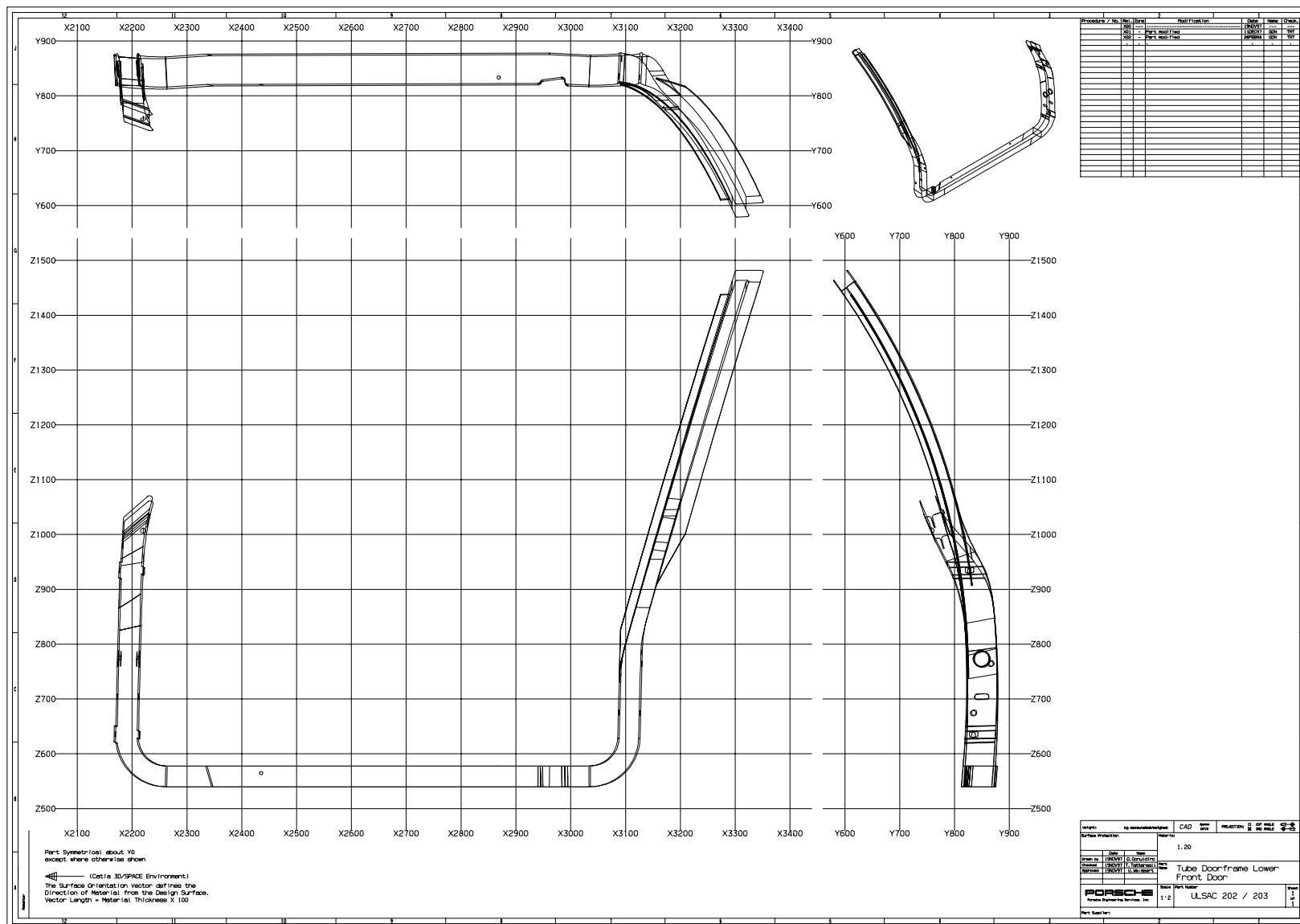
Part 200 - Tube Doorframe Upper Front Door





Part Drawings

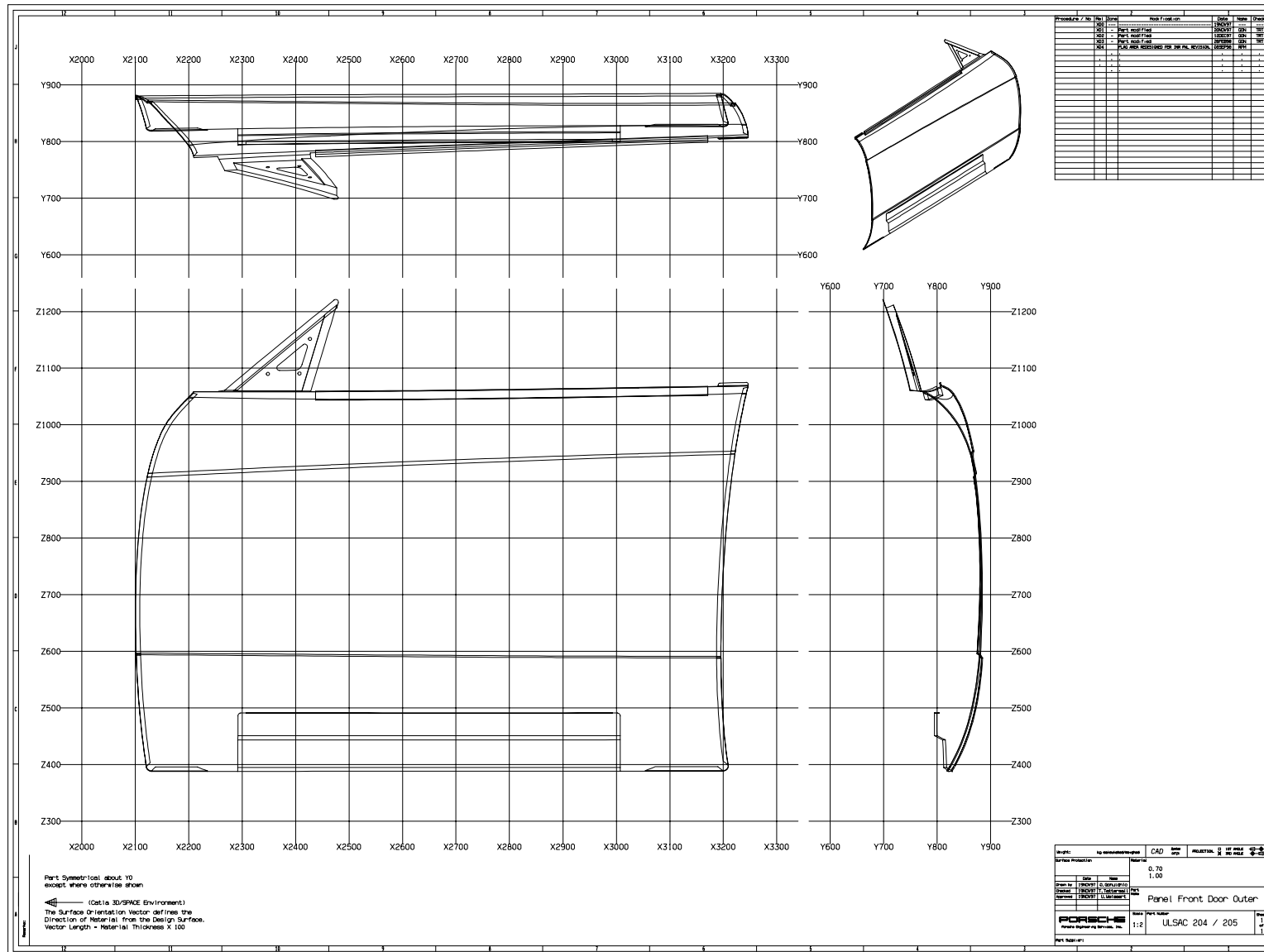
Part 202 - Tube Doorframe Lower Front Door





Part Drawings

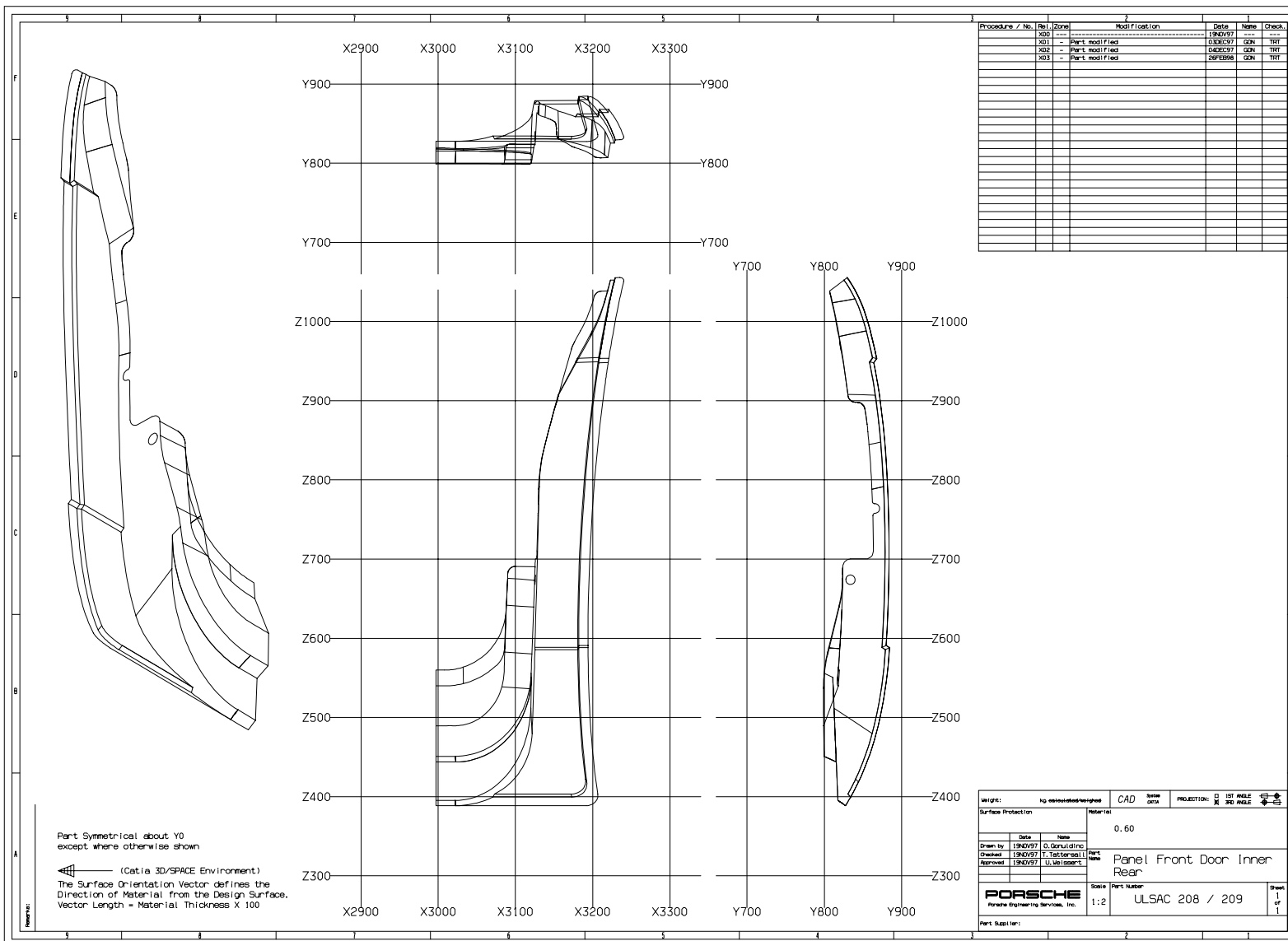
Part 204 - Panel Front Door Outer





Part Drawings

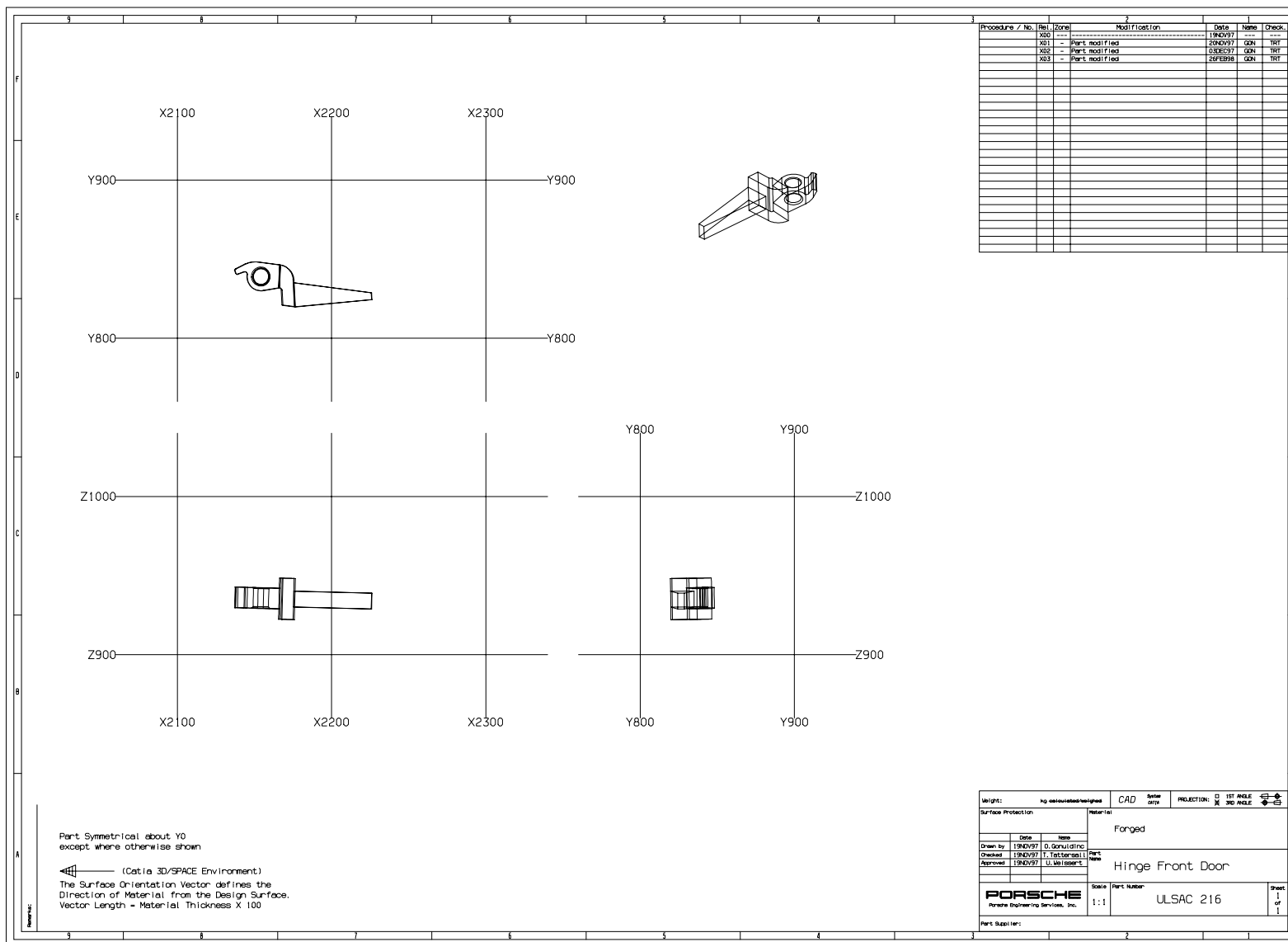
Part 208 - Panel Front Door Inner Rear





Part Drawings

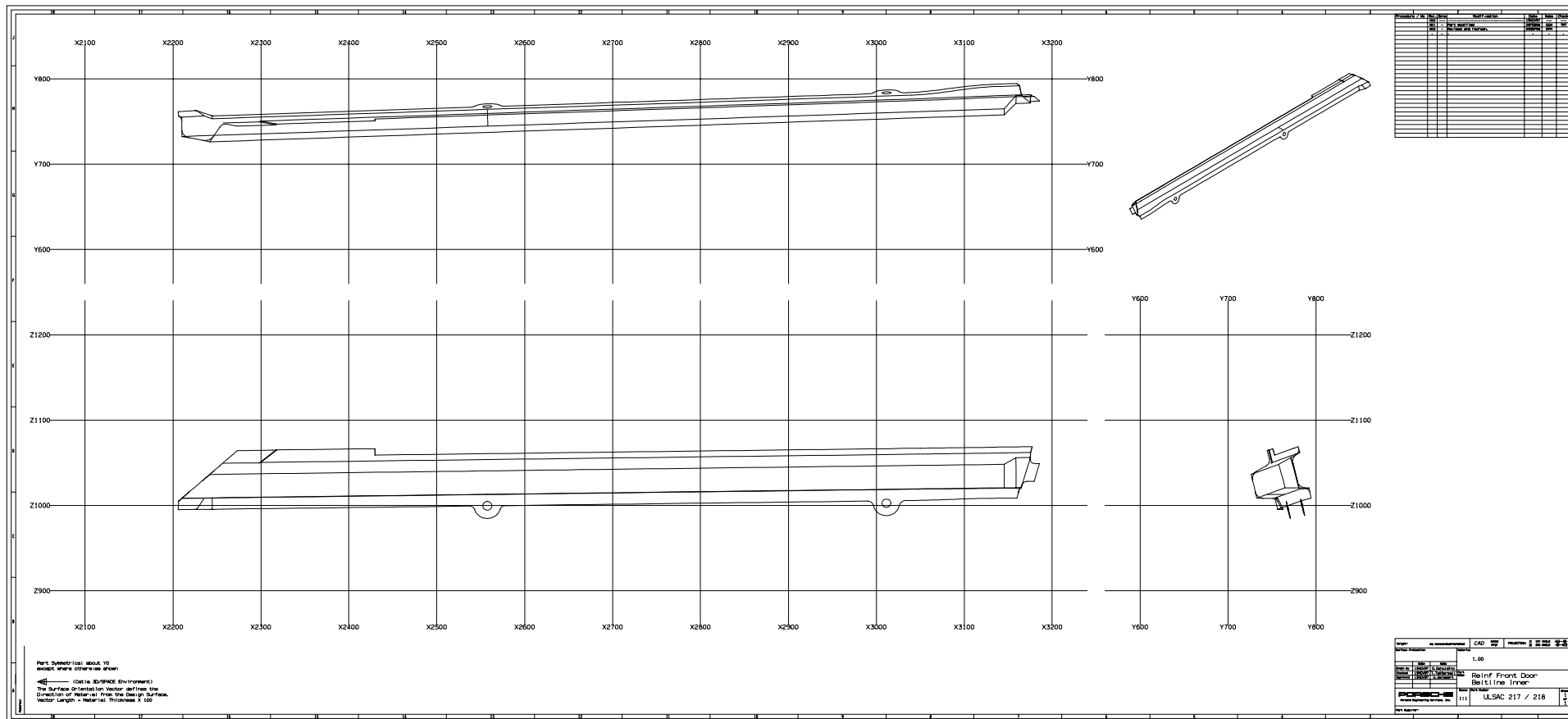
Part 216 - Hinge Front Door (2 required)





Part Drawings

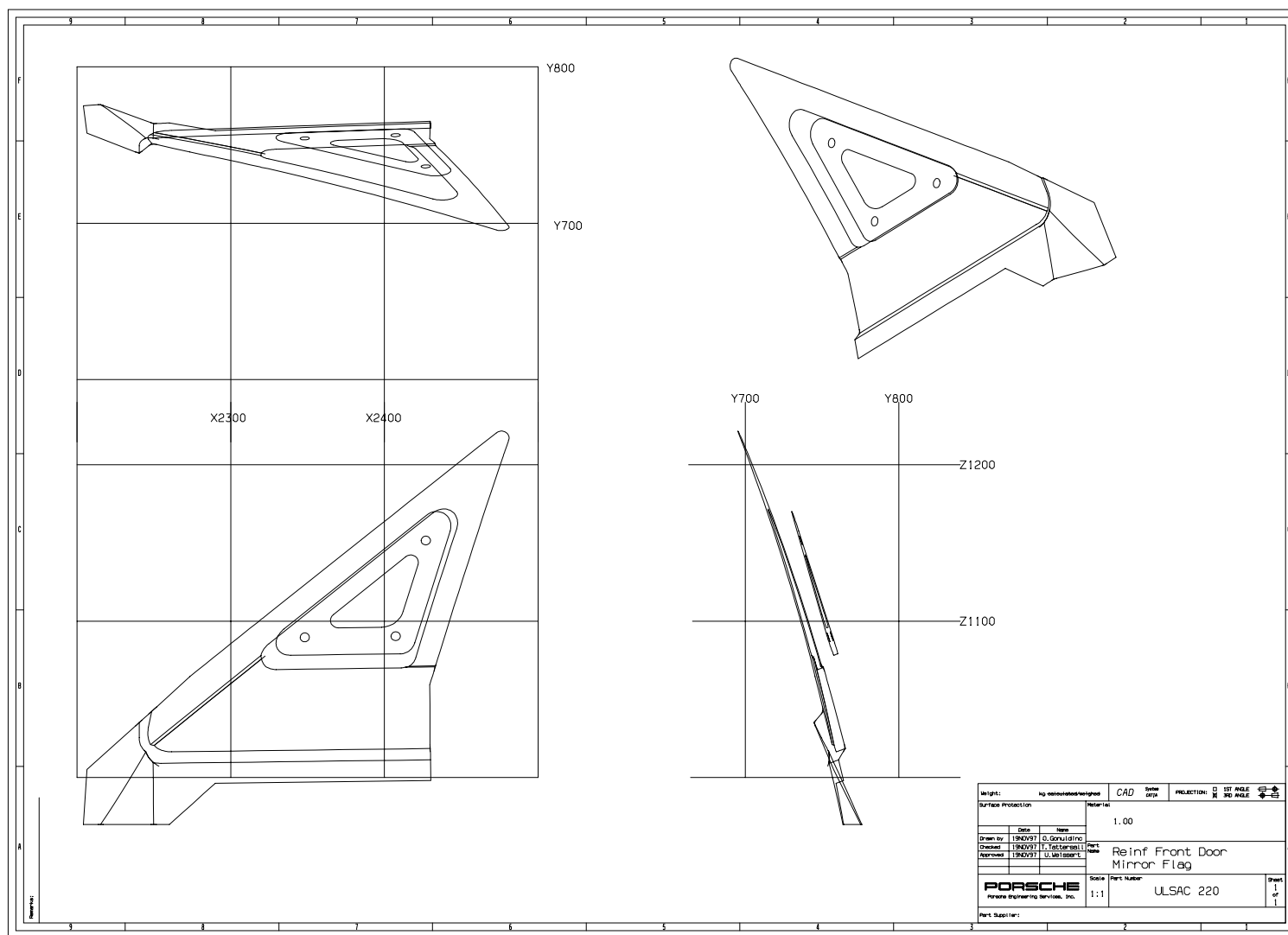
Part 217/218 - Reinforcement Front Door Beltline Inner





Part Drawings

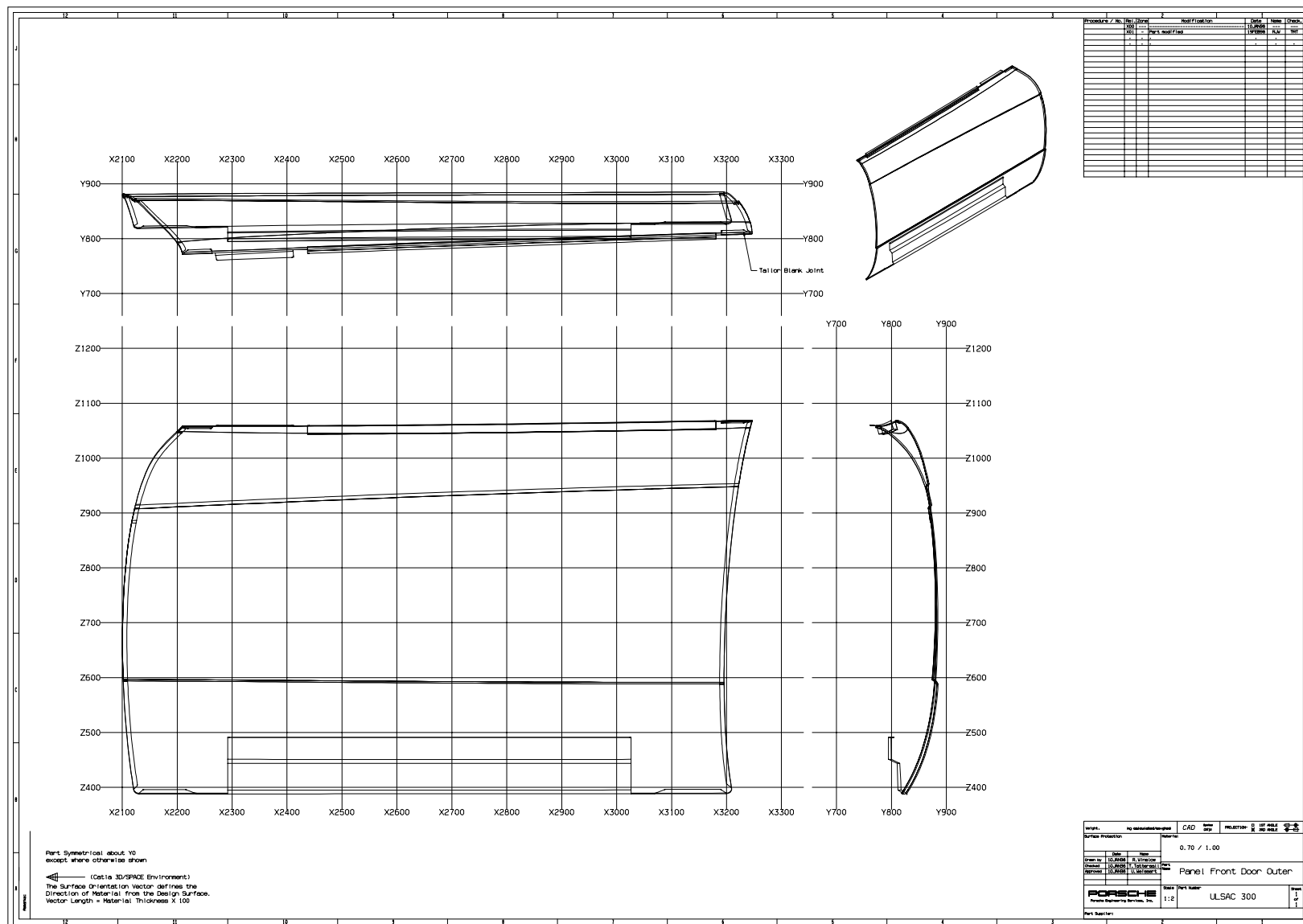
Part 220/221 - Reinforcement Front Door Mirror Flag





Part Drawings

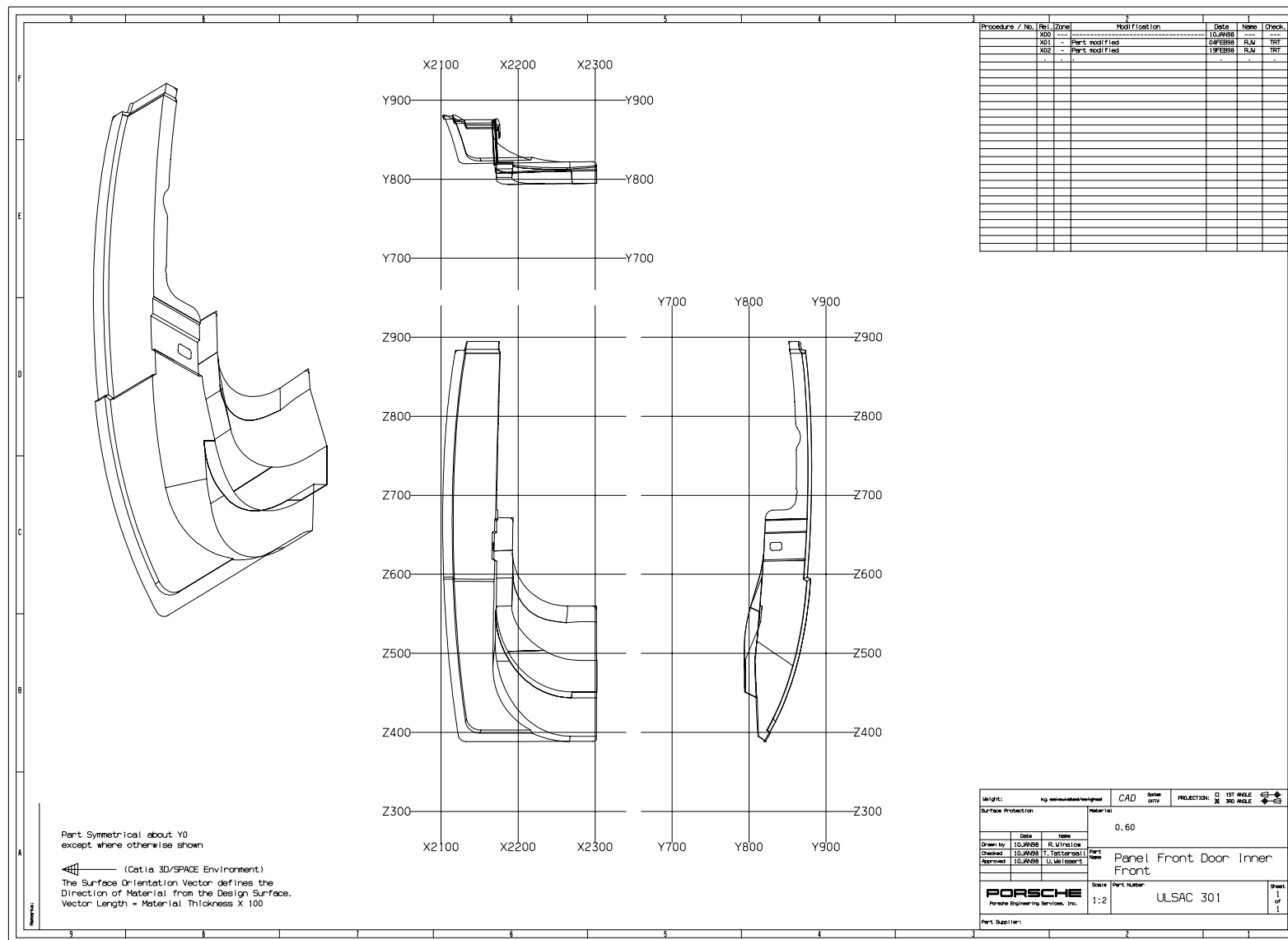
Part 300 - Panel Front Door Outer





Part Drawings

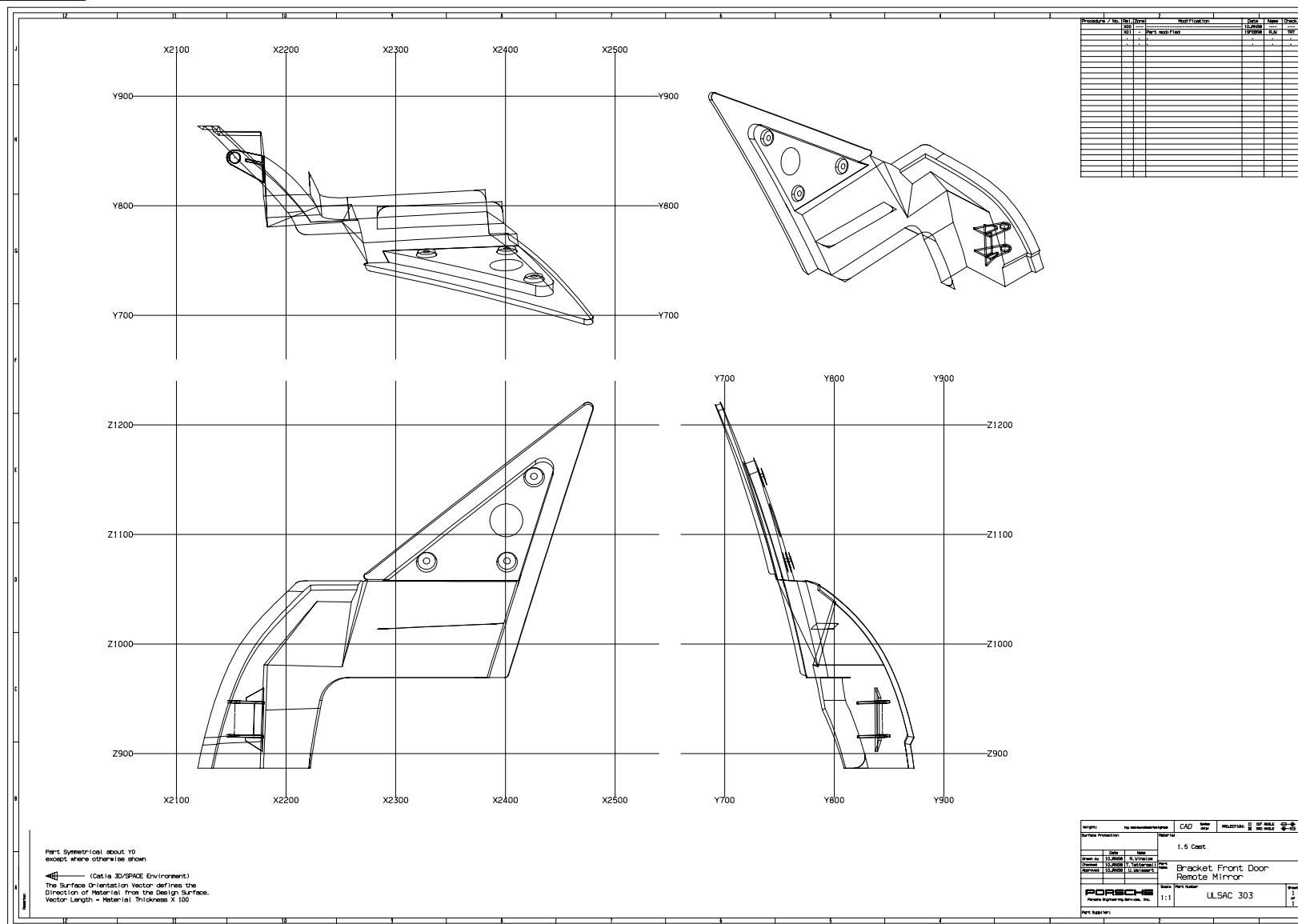
Part 301 - Panel Front Door Inner Front





Part Drawings

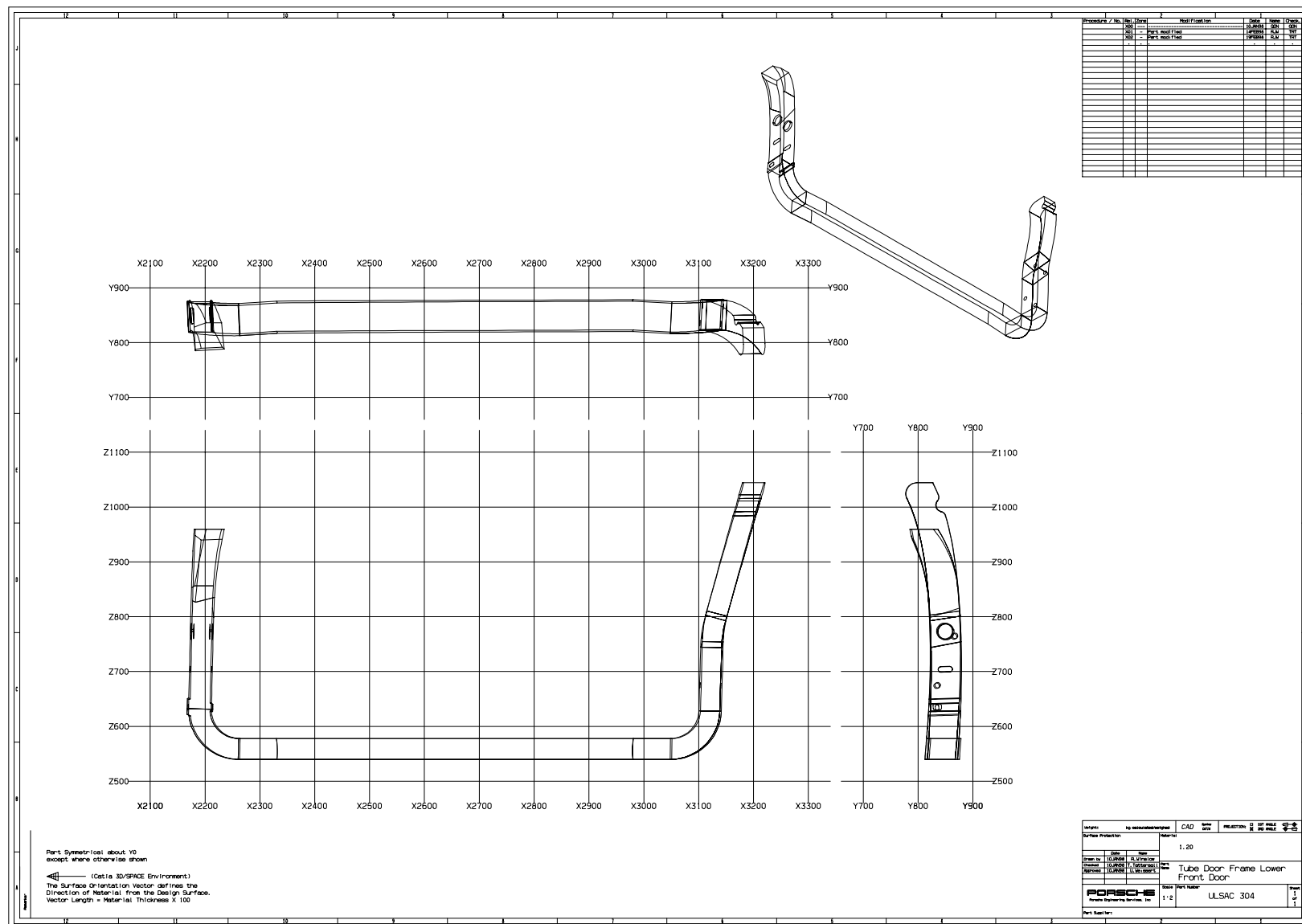
Part 303 - Bracket Front Door Remote Mirror





Part Drawings

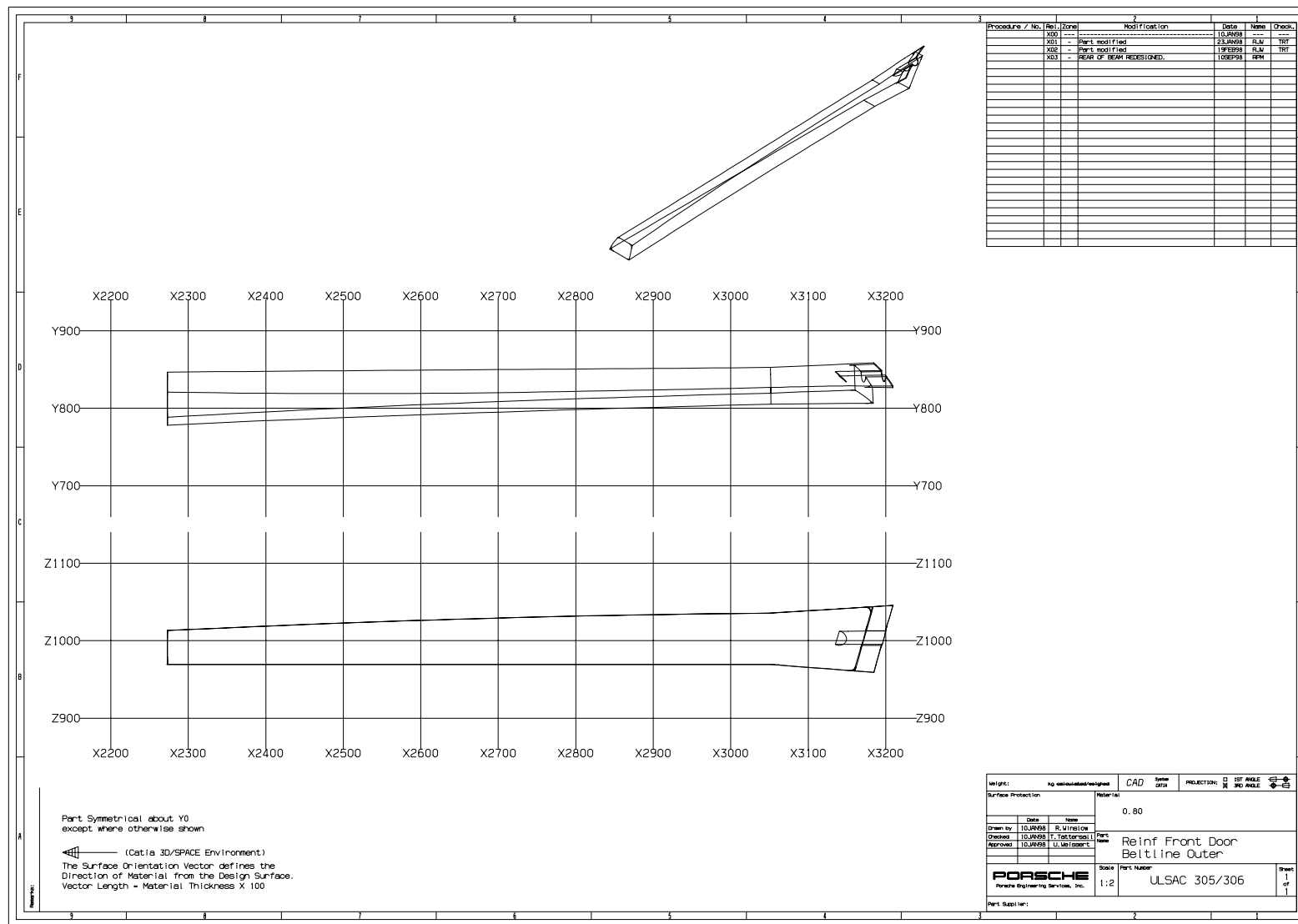
Part 304 - Tube Door Frame Lower Front Door





Part Drawings

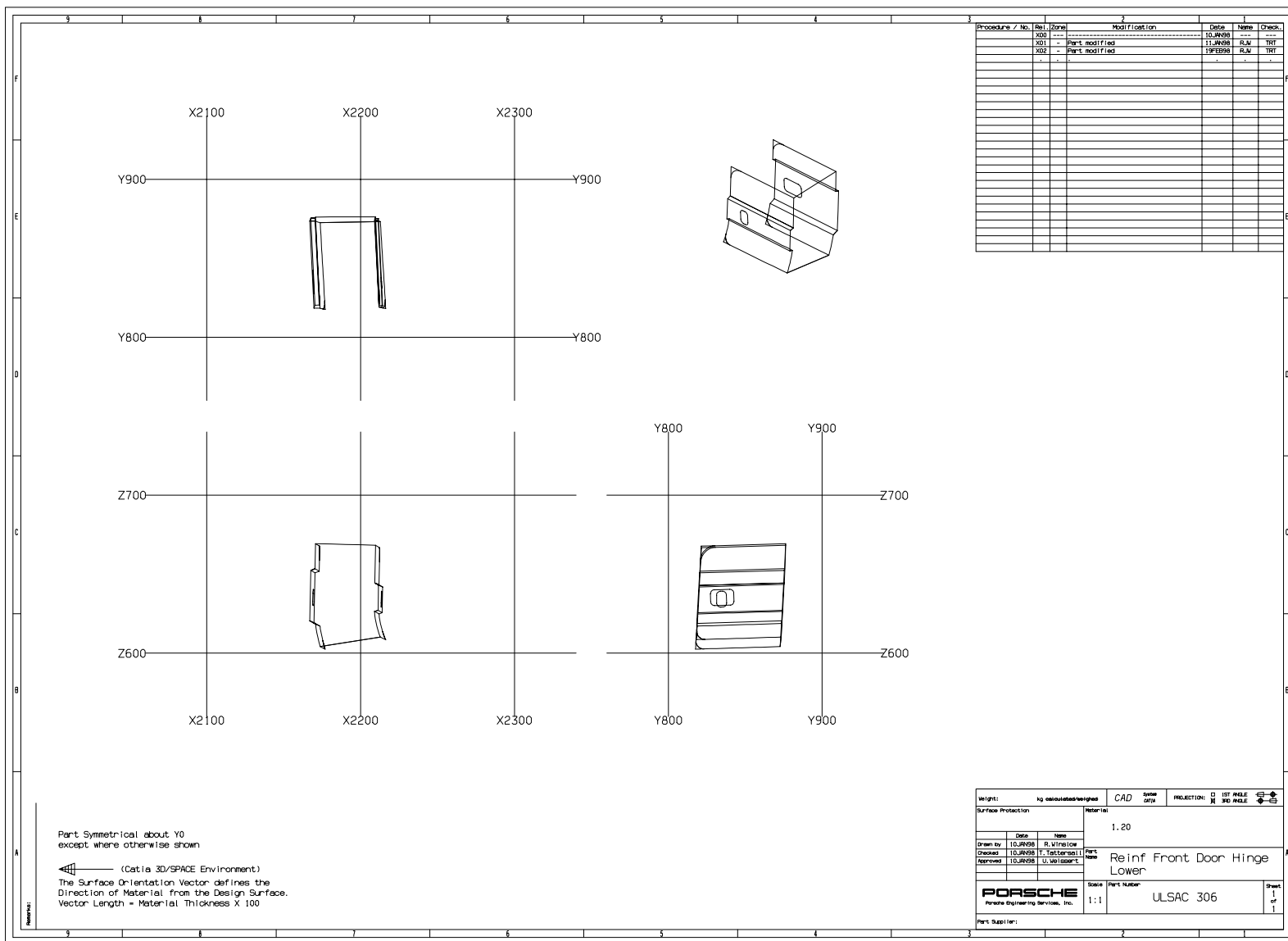
Part 305 - Reinforcement Front Door Beltline Outer





Part Drawings

Part 306 - Reinforcement Front Door Hinge Lower

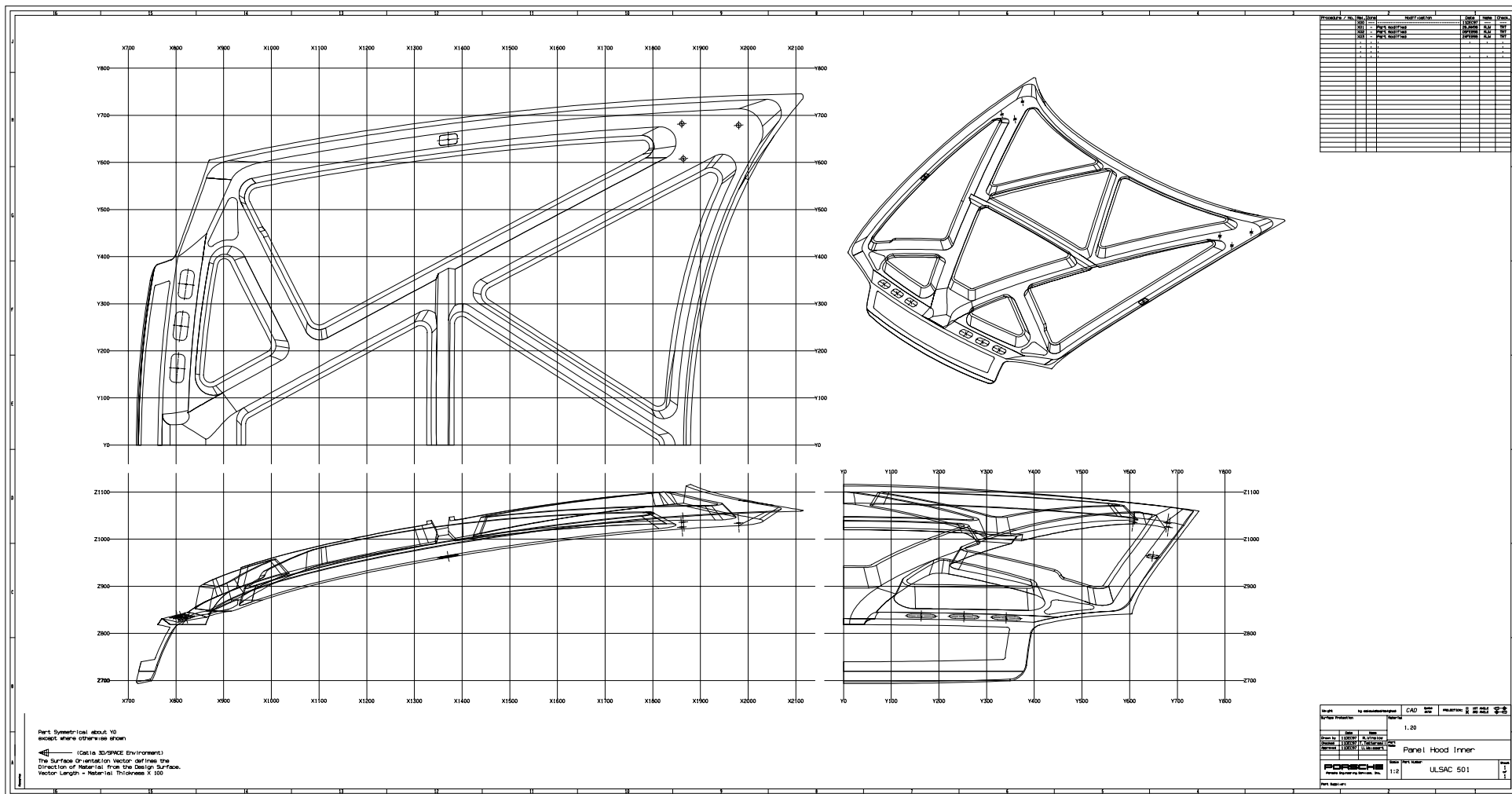






Part Drawings

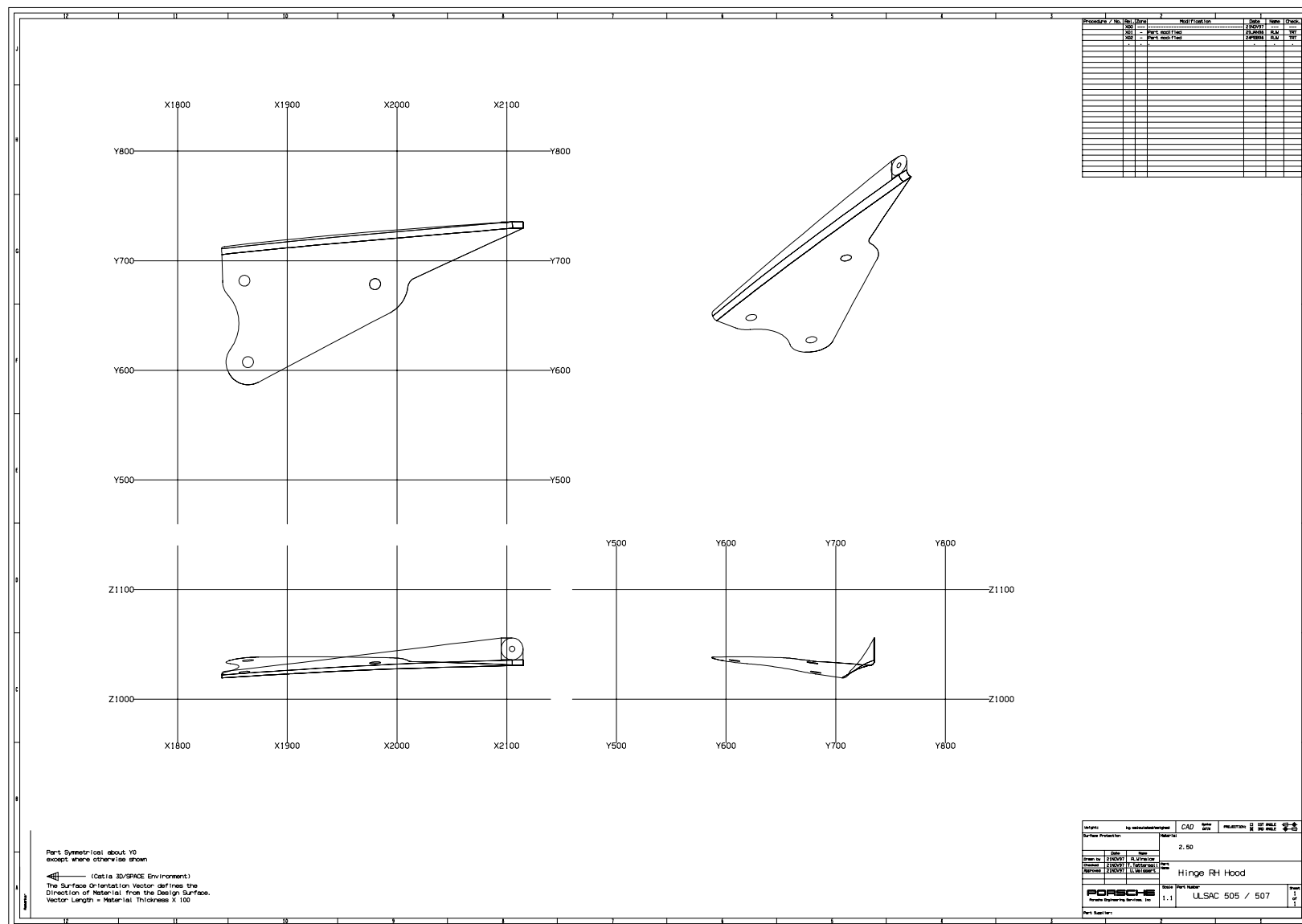
Part 501 - Panel Hood Inner





Part Drawings

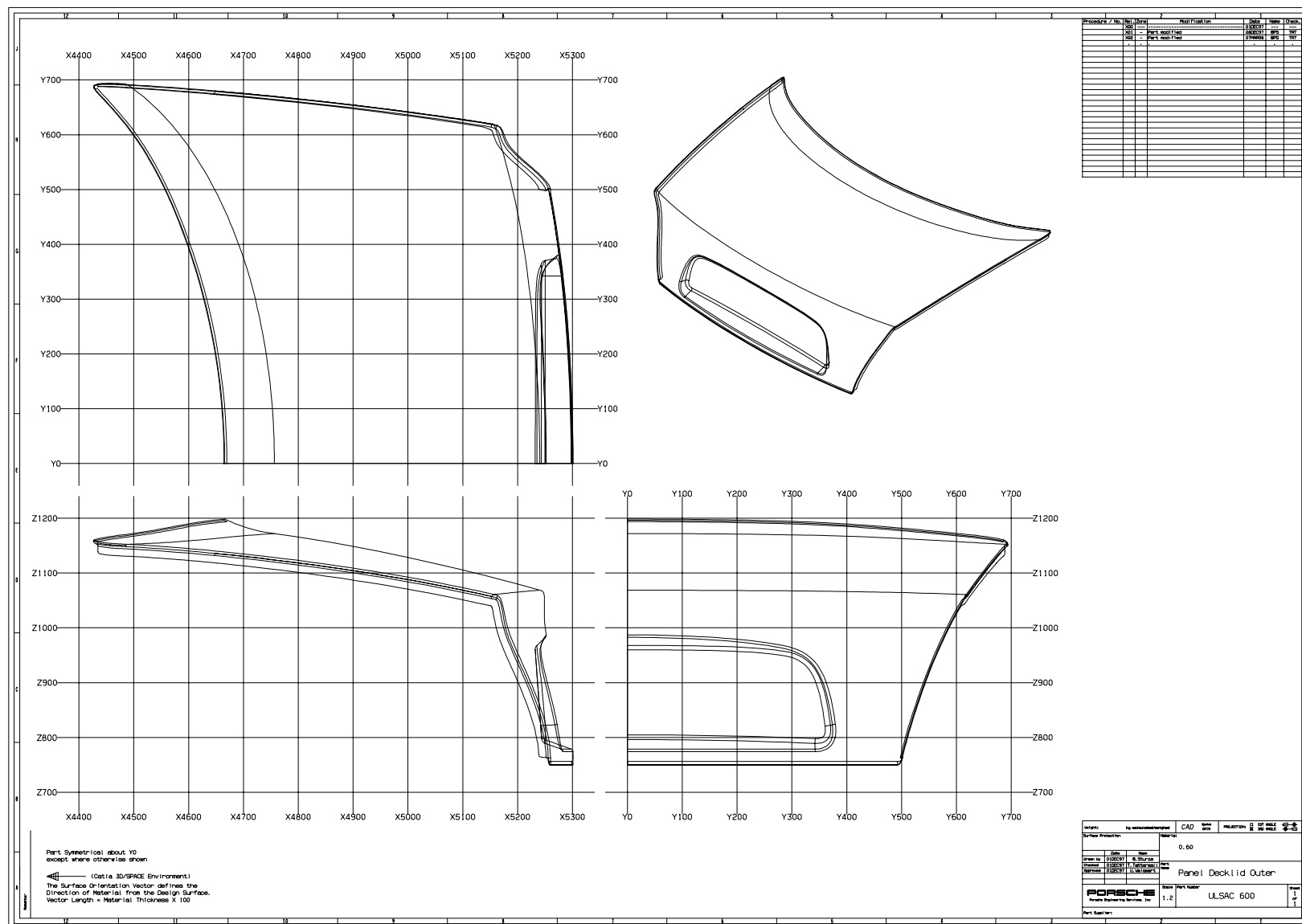
Part 505 - Hinge RH Hood





Part Drawings

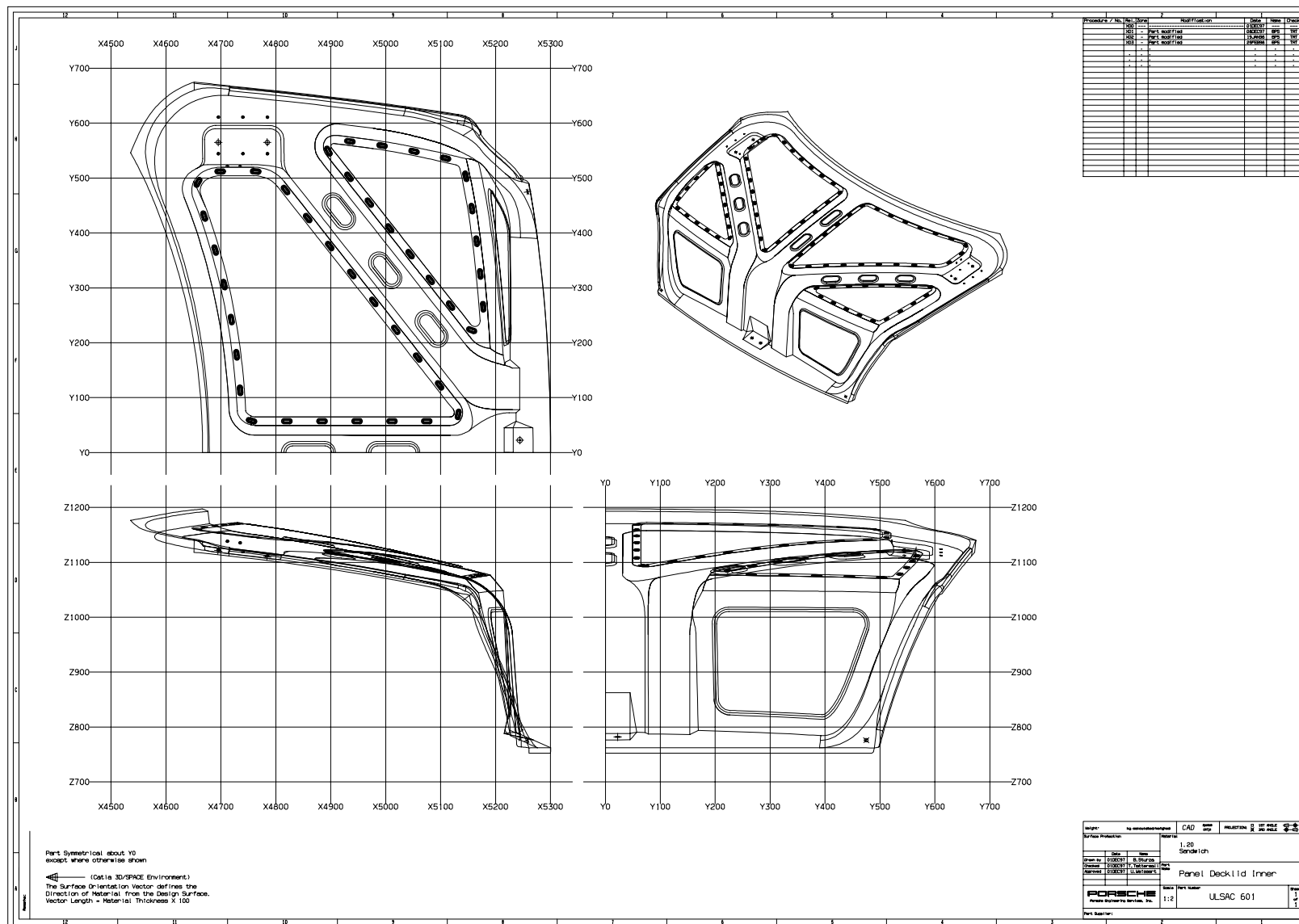
Part 600 - Panel Decklid Outer





Part Drawings

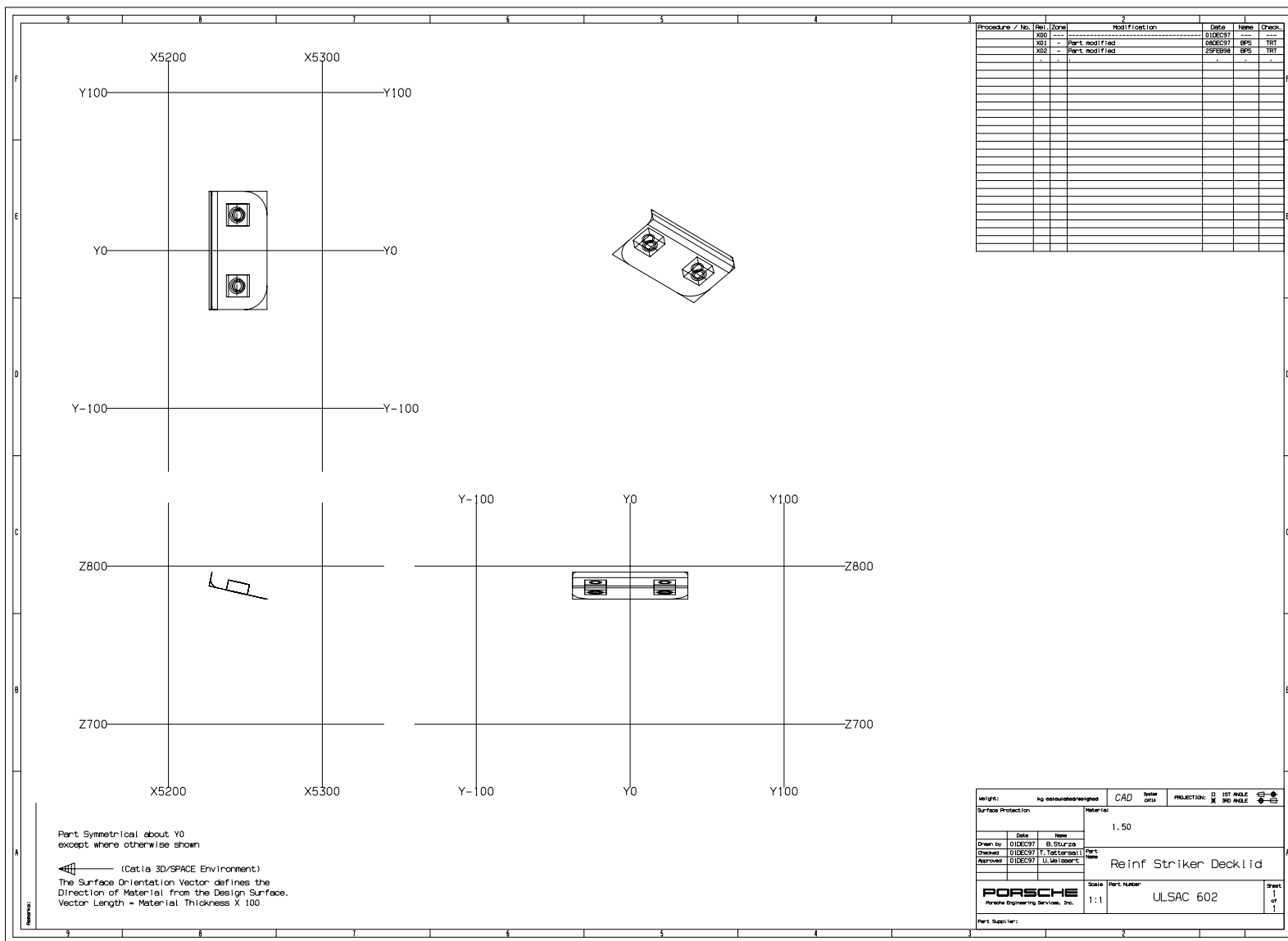
Part 601 - Panel Decklid Inner





Part Drawings

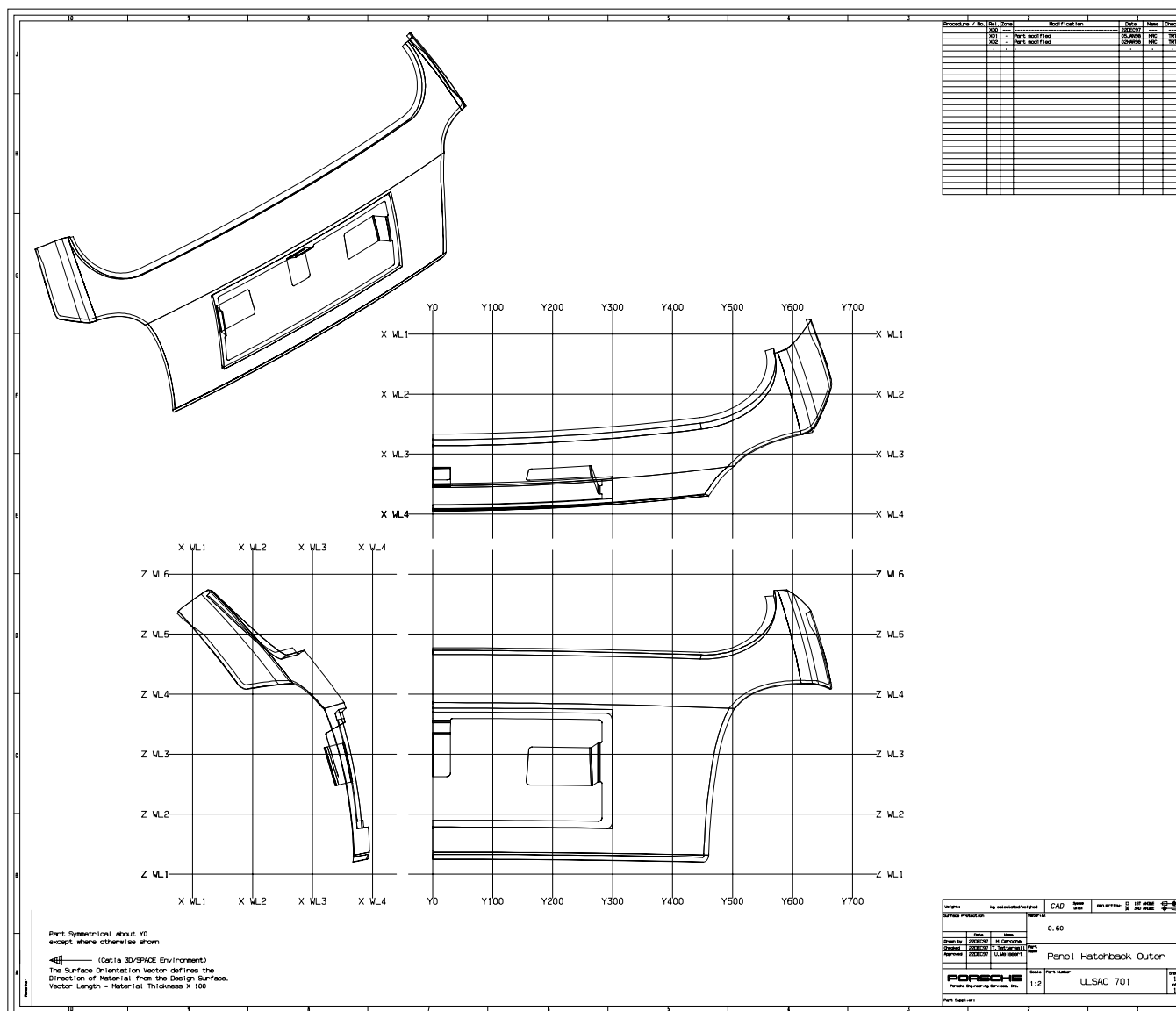
Part 602 - Reinforcement Striker Decklid





Part Drawings

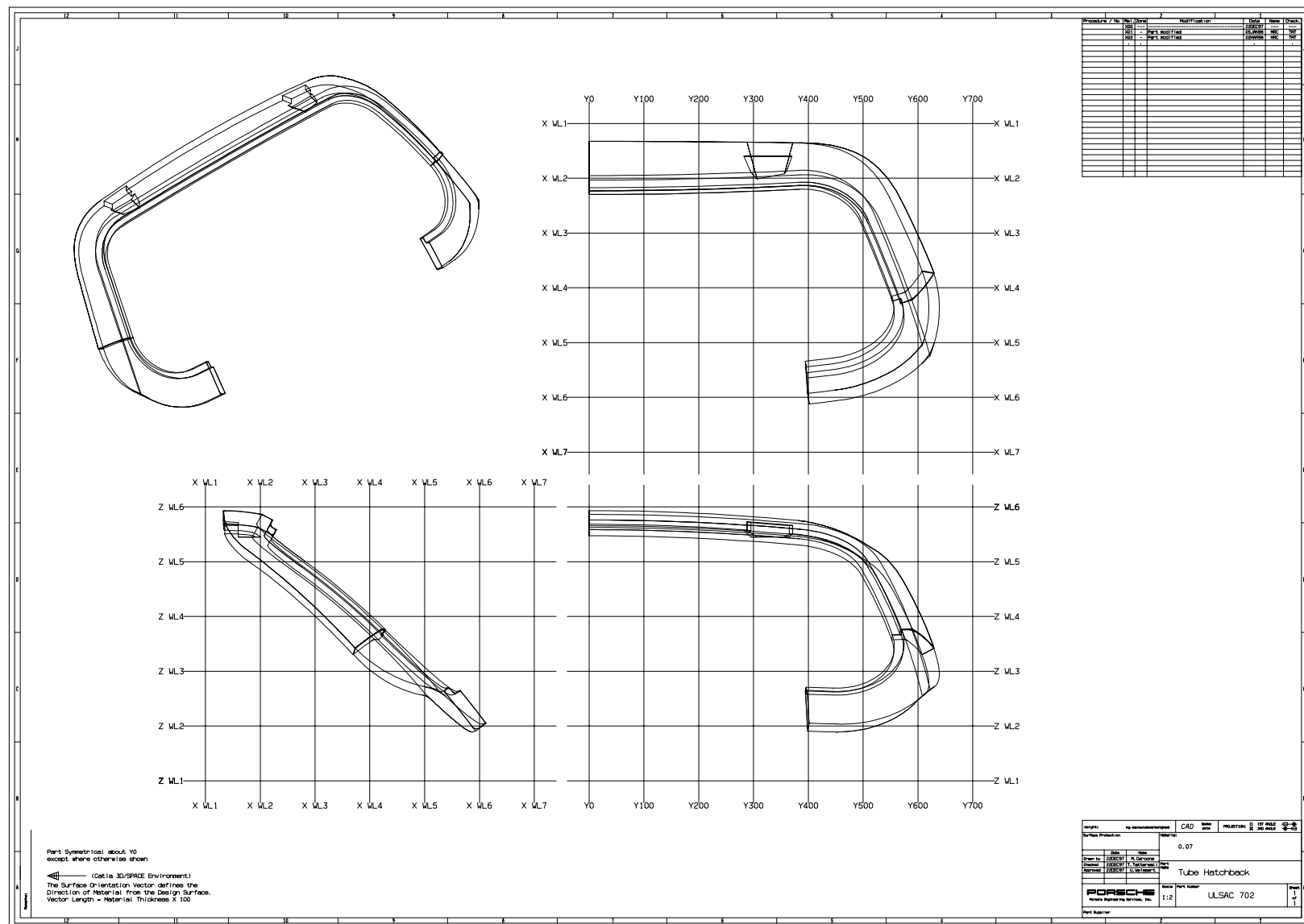
Part 701 - Panel Hatchback Outer





Part Drawings

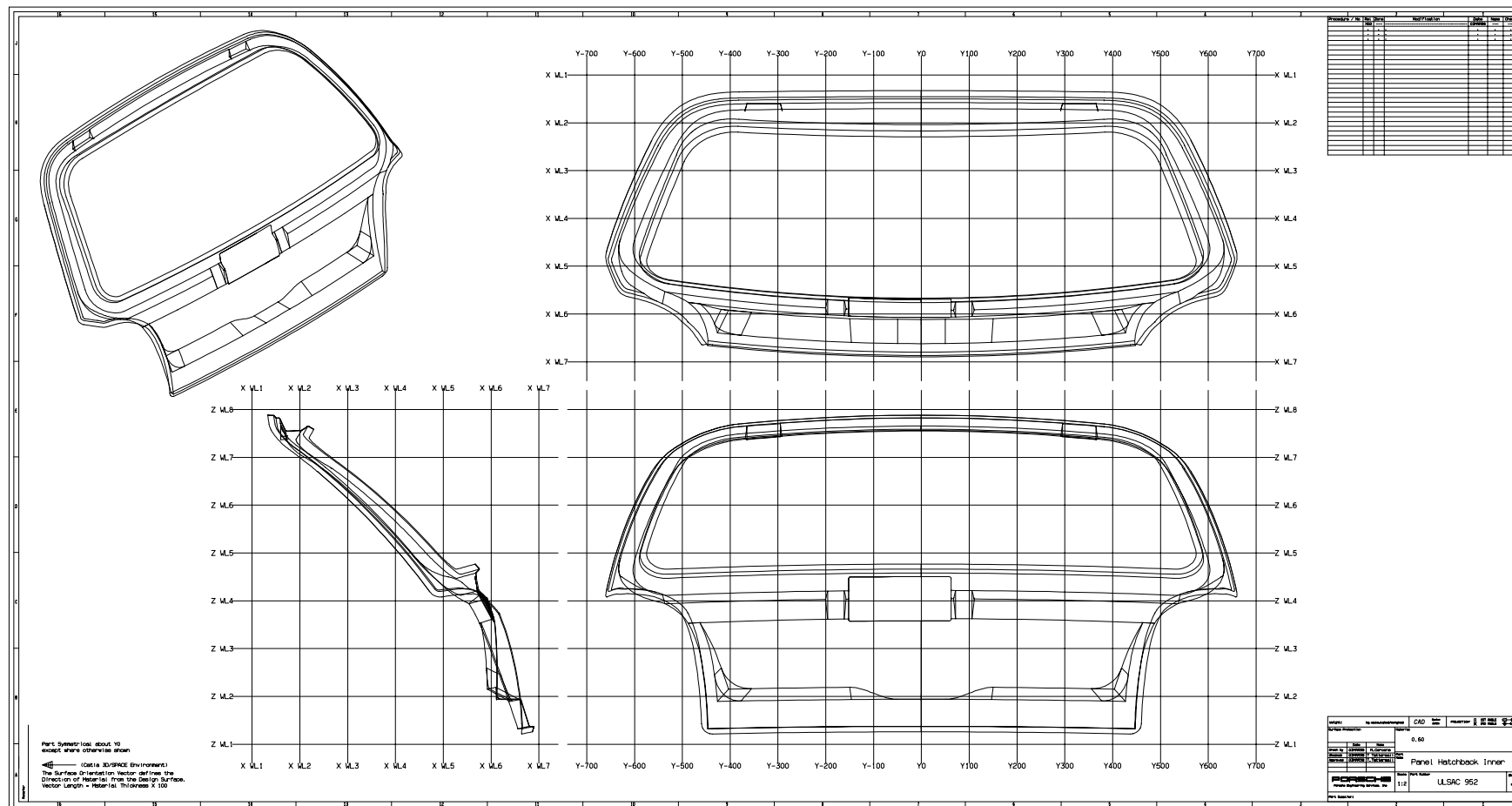
Part 702 - Tube Hatchback





Part Drawings

Part 952 - Panel Hatchback Inner - Sheet Hydroformed

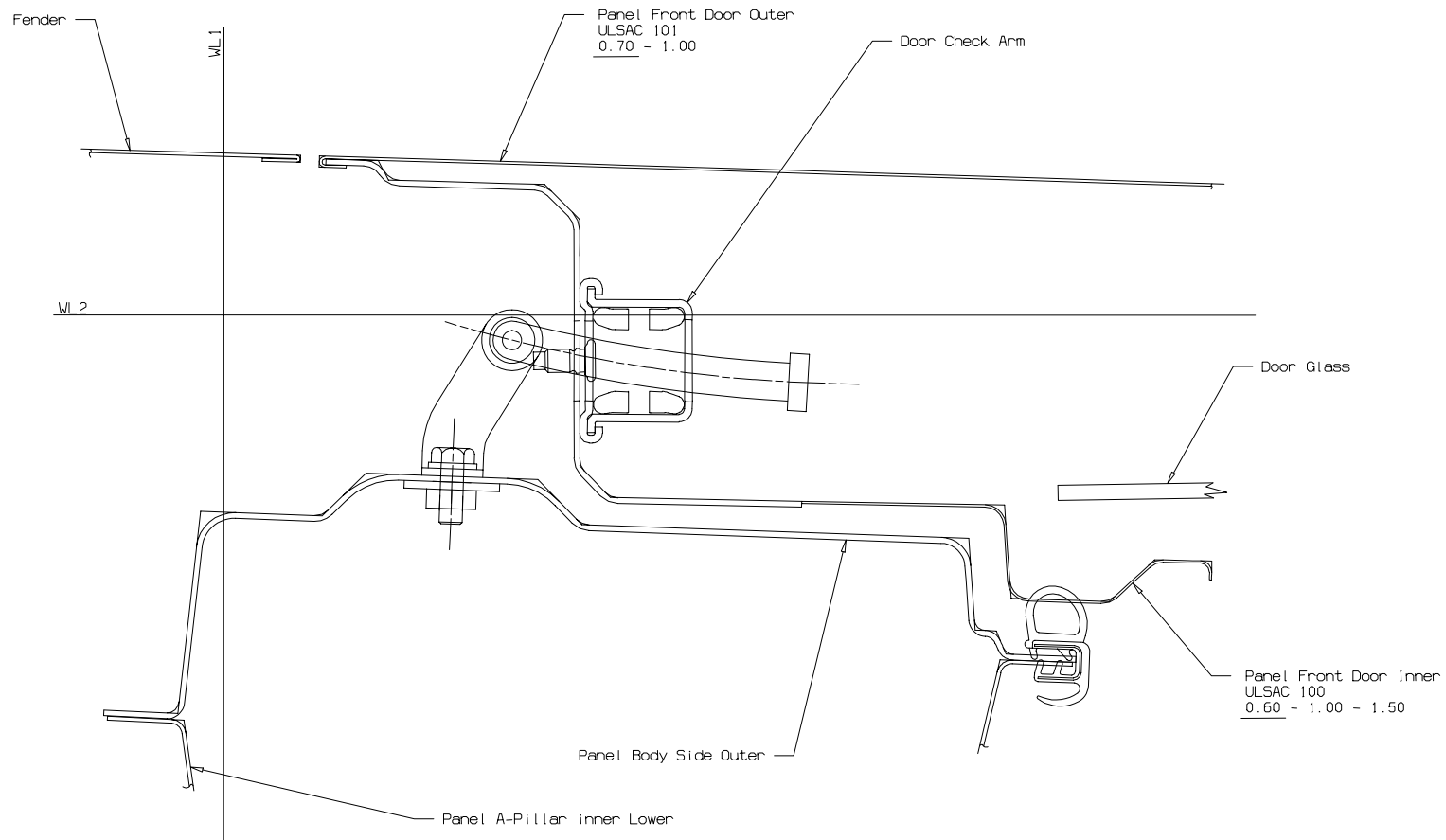




Conceptual Design

Selected Design Concepts - Doors Roof Integrated - Typical Sections

Section A1

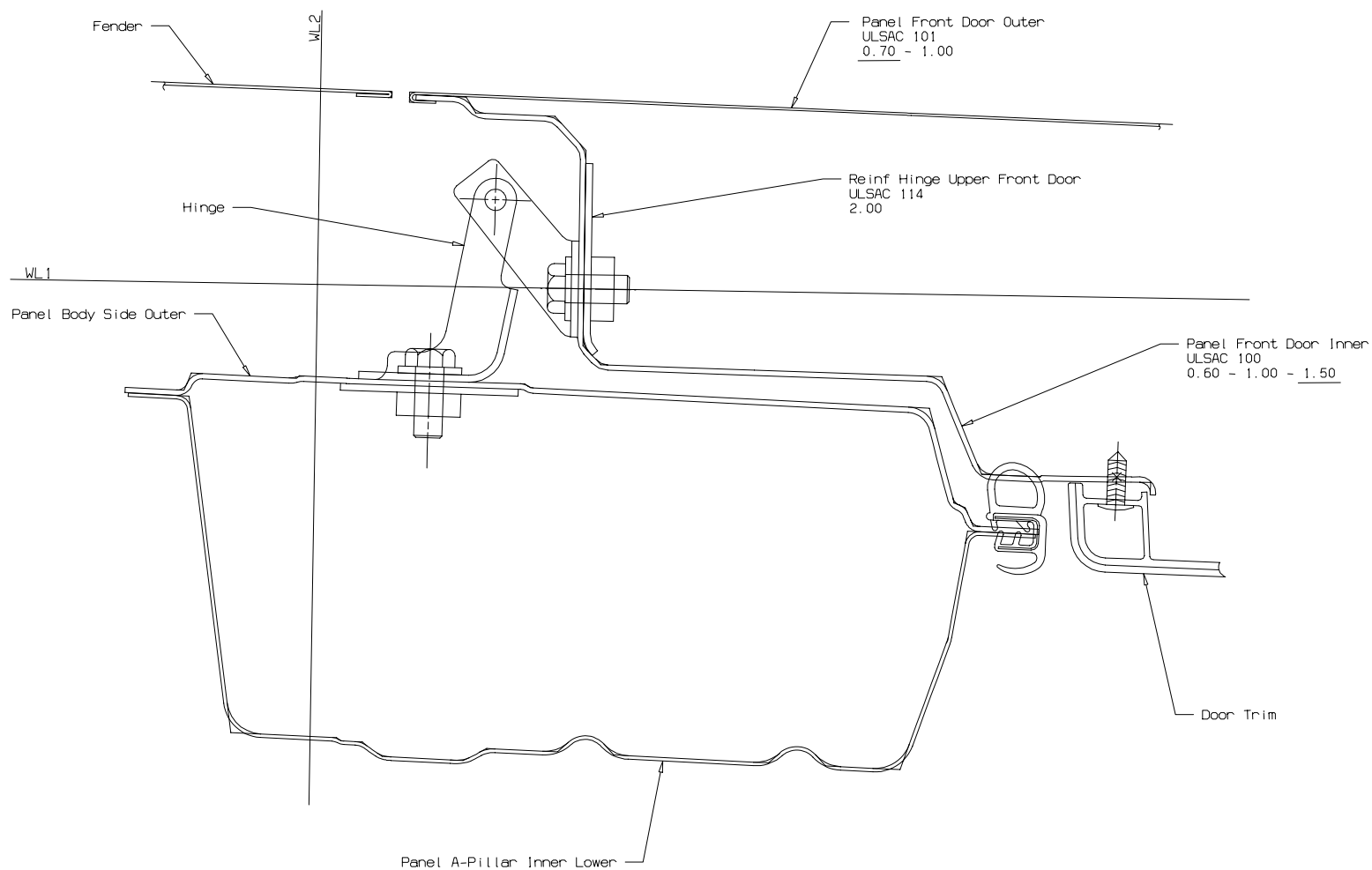




Conceptual Design

Selected Design Concepts - Doors Roof Integrated - Typical Sections

Section B1

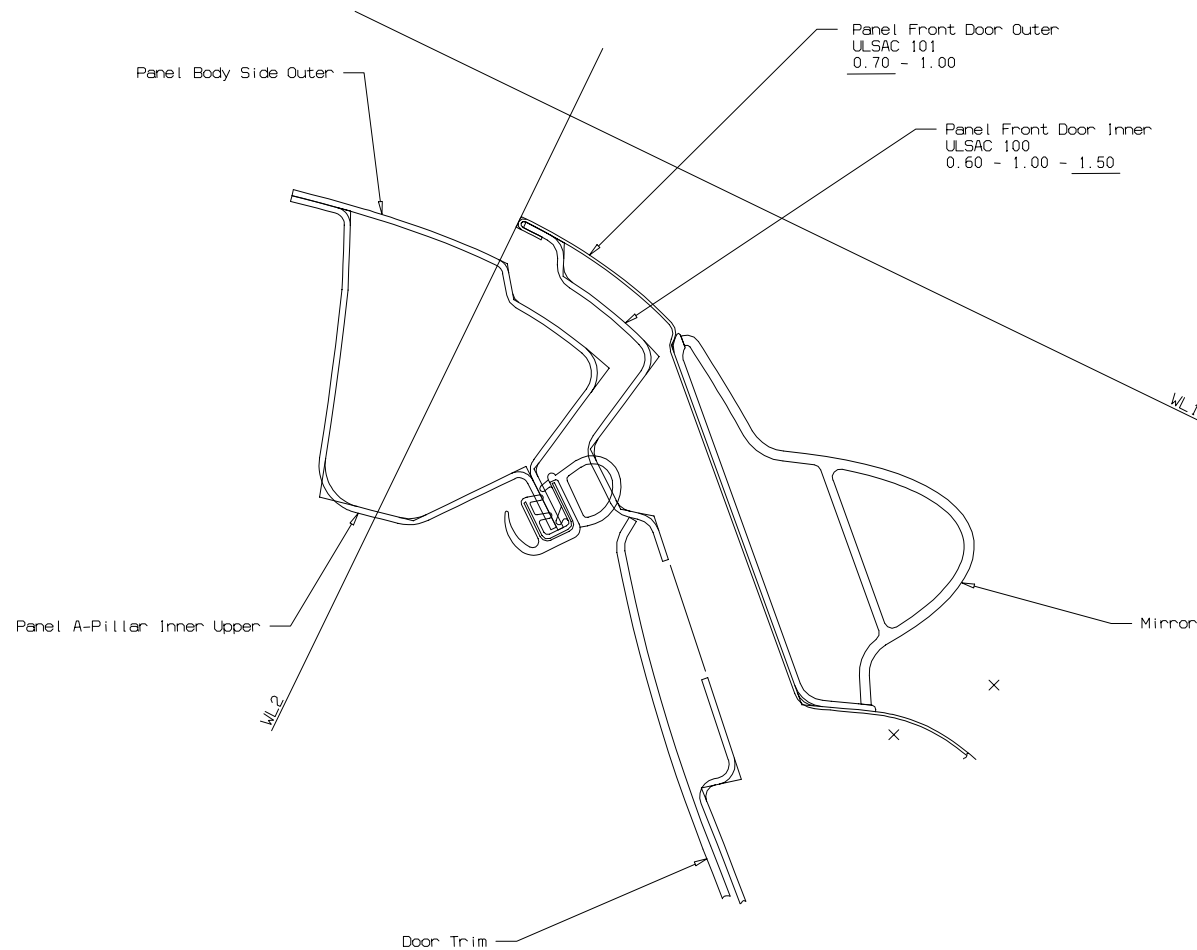




Conceptual Design

Selected Design Concepts - Doors Roof Integrated - Typical Sections

Section C1

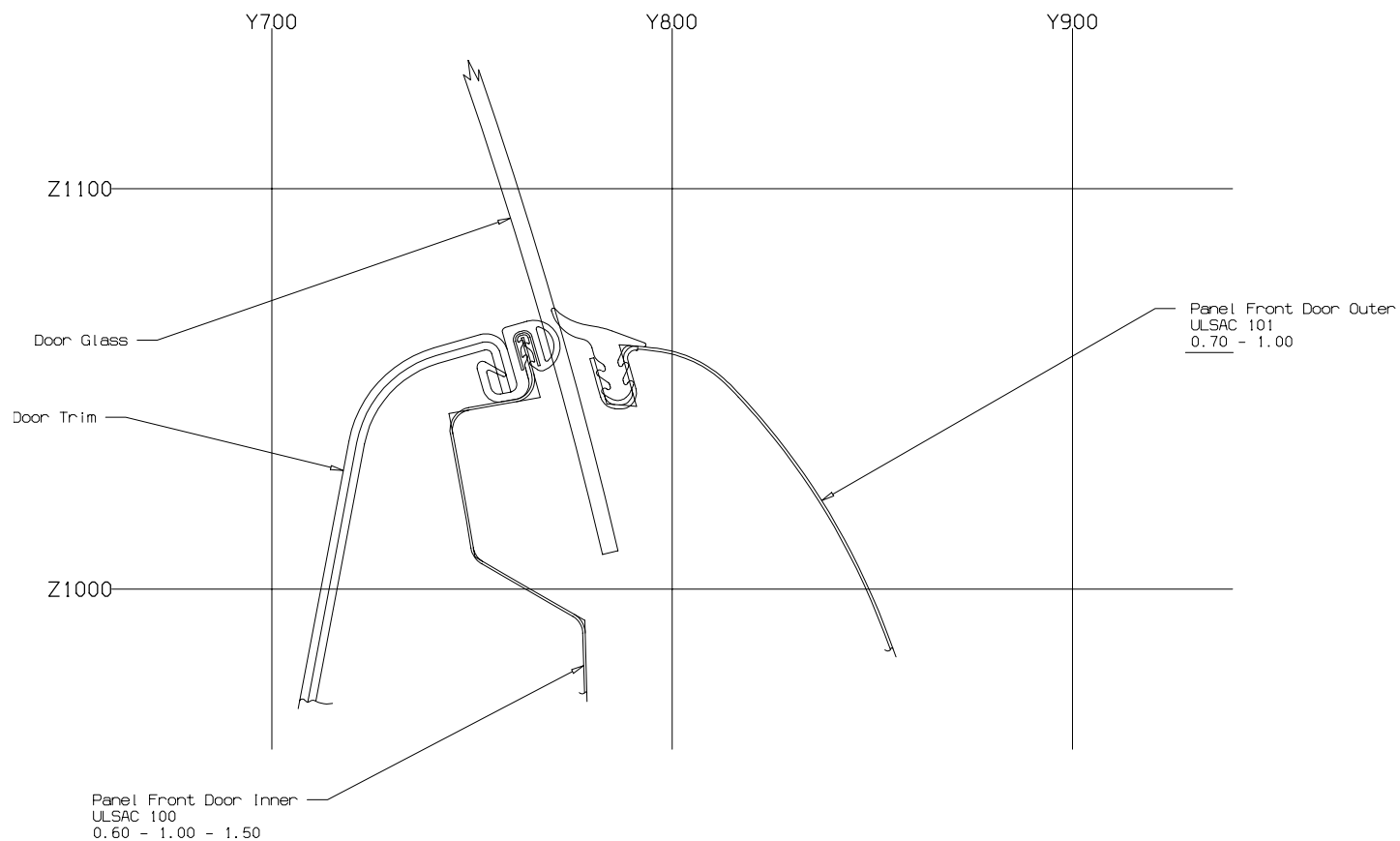




Conceptual Design

Selected Design Concepts - Doors Roof Integrated - Typical Sections

Section D1

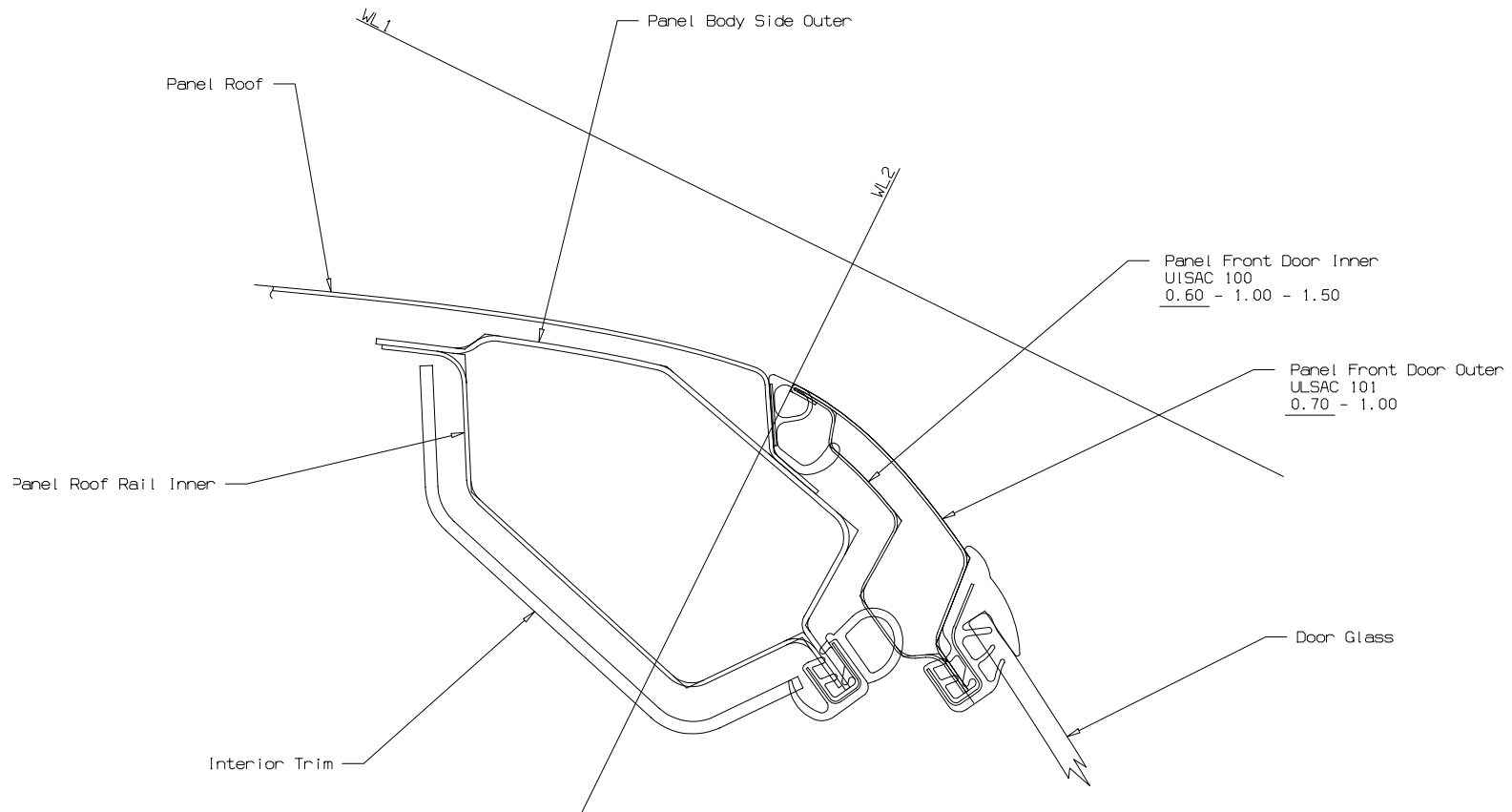




Conceptual Design

Selected Design Concepts - Doors Roof Integrated - Typical Sections

Section E1

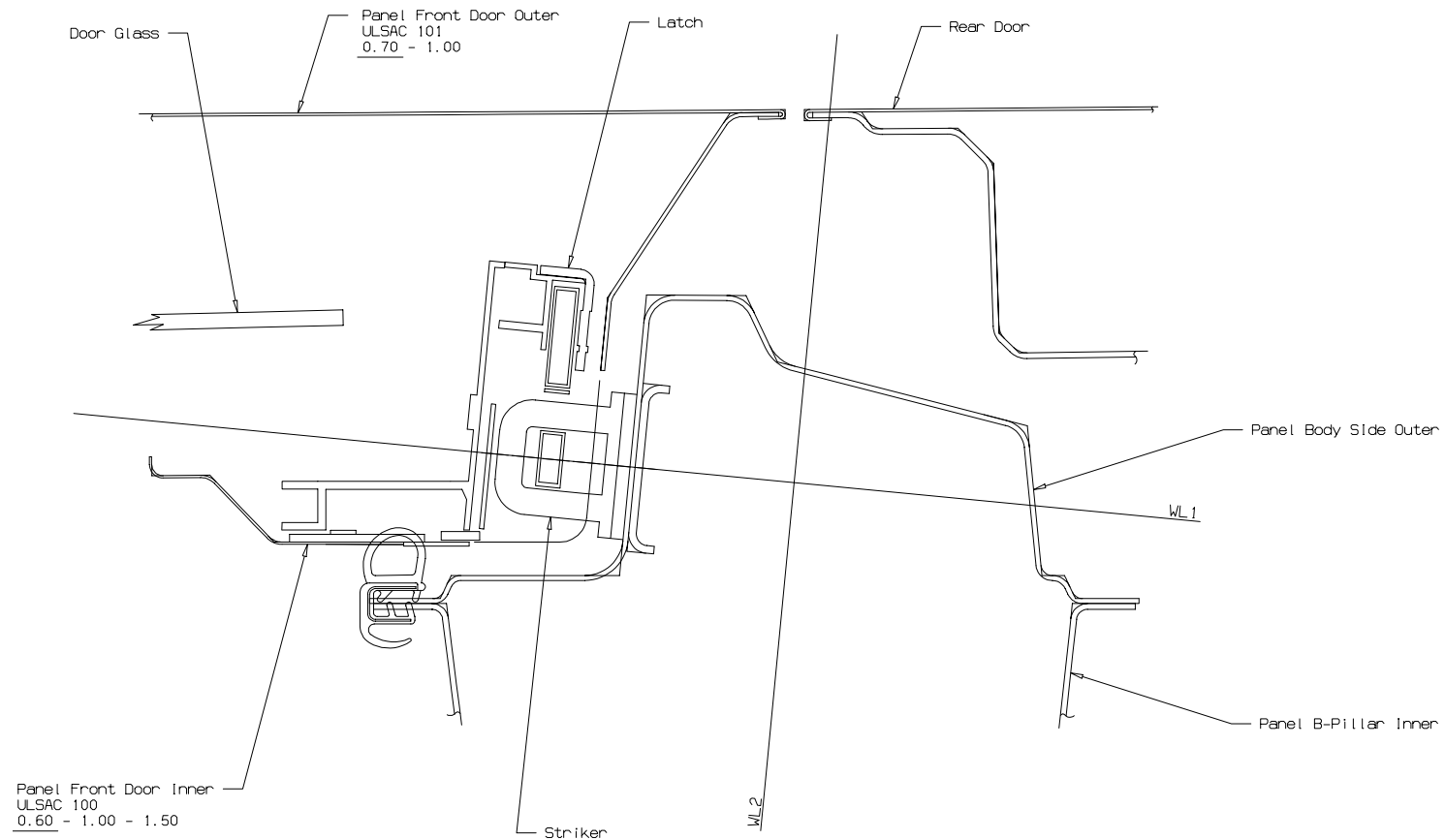




Conceptual Design

Selected Design Concepts - Doors Roof Integrated - Typical Sections

Section F1

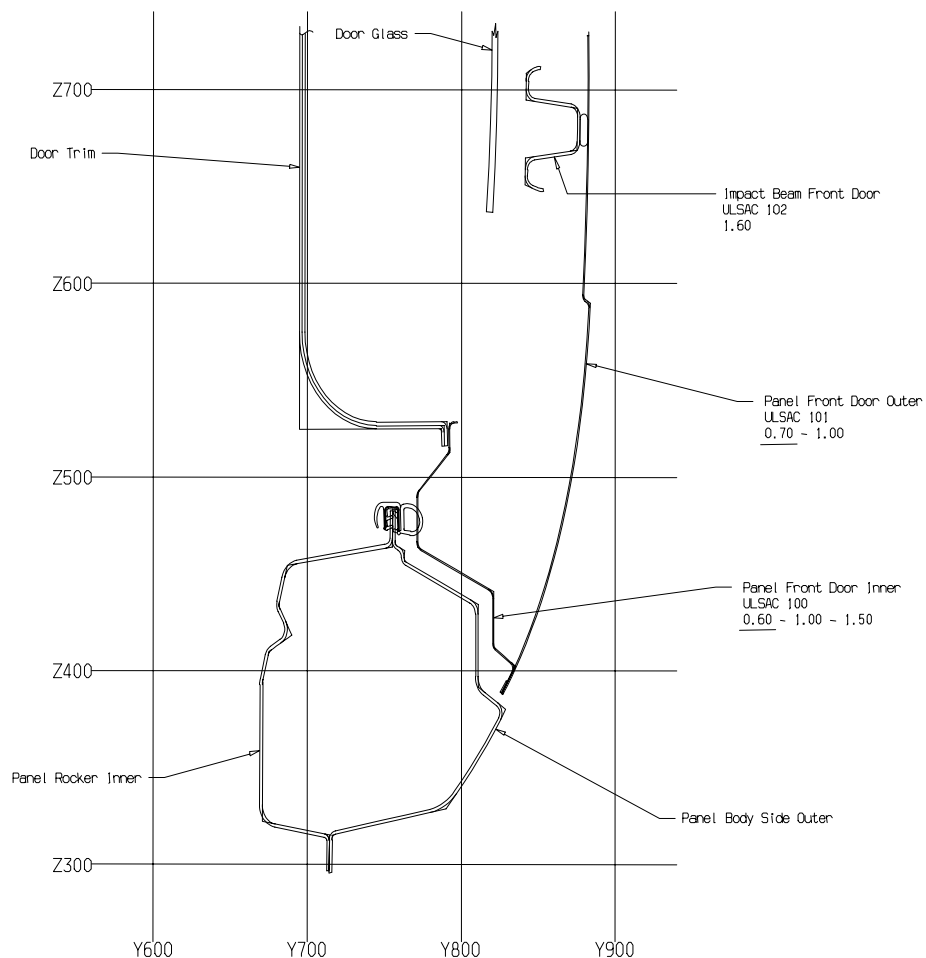




Conceptual Design

Selected Design Concepts - Doors Roof Integrated - Typical Sections

Section G1

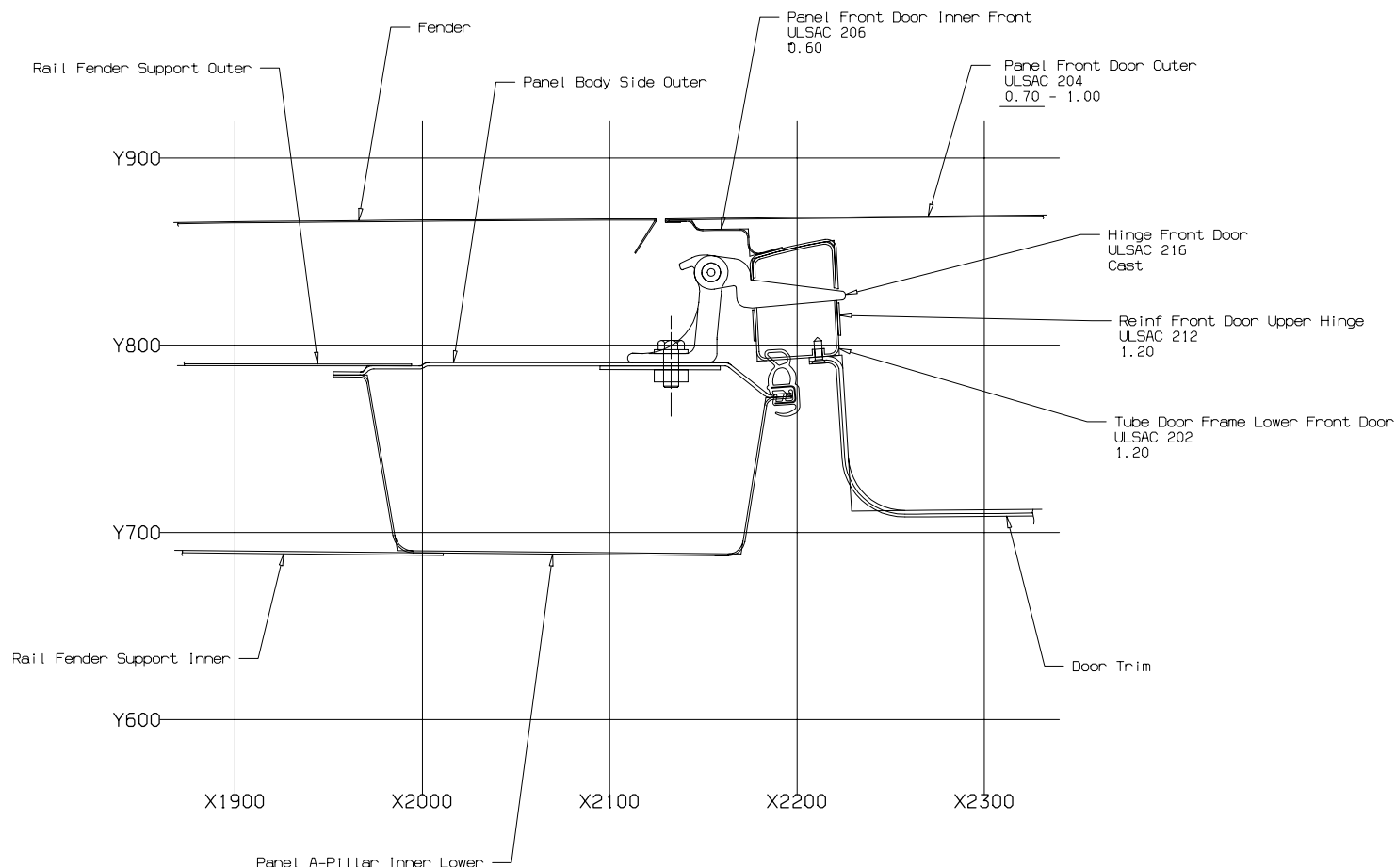




Conceptual Design

Selected Design Concepts - Doors Frame Integrated - Typical Sections

Section A2

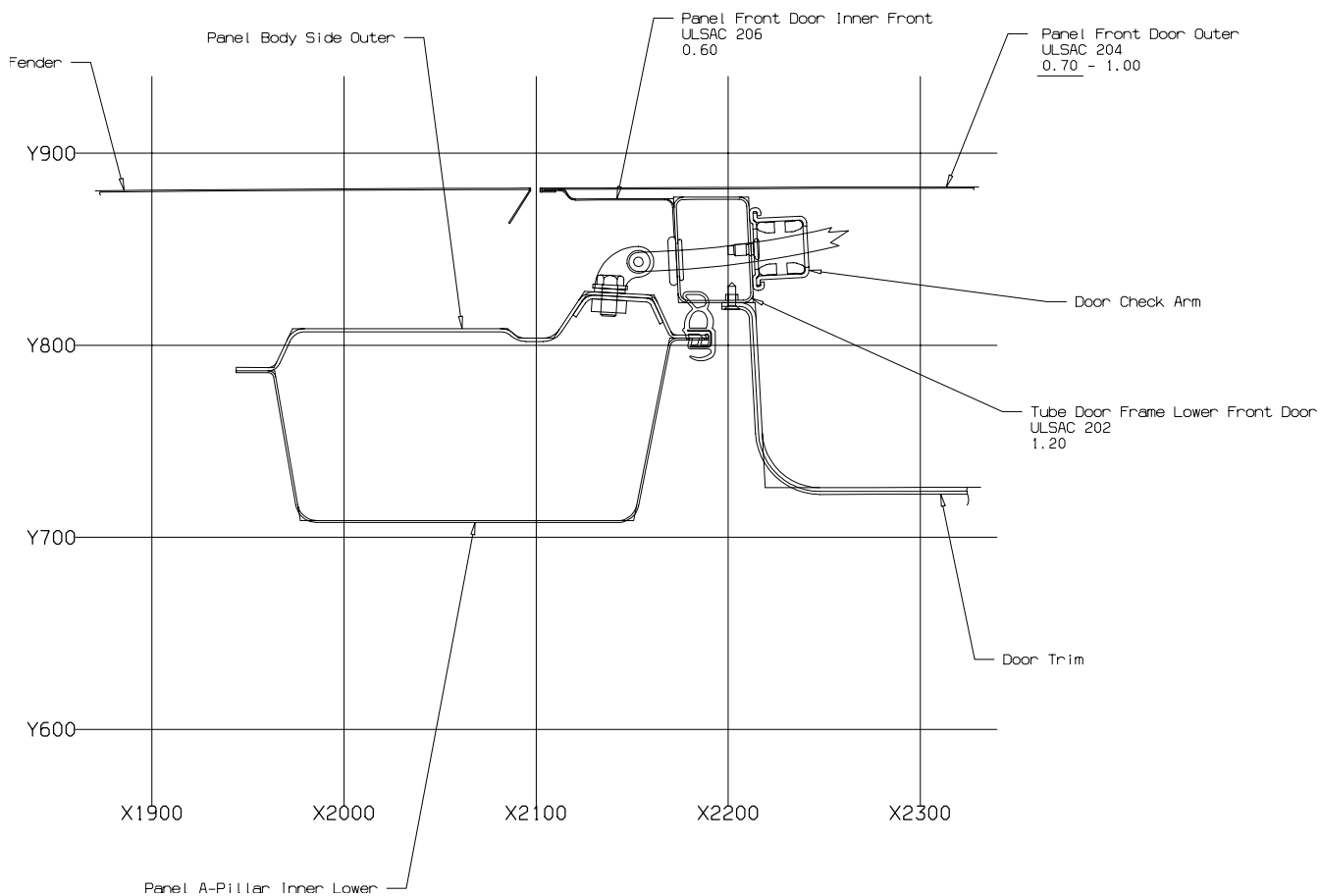




Conceptual Design

Selected Design Concepts - Doors Frame Integrated - Typical Sections

Section B2

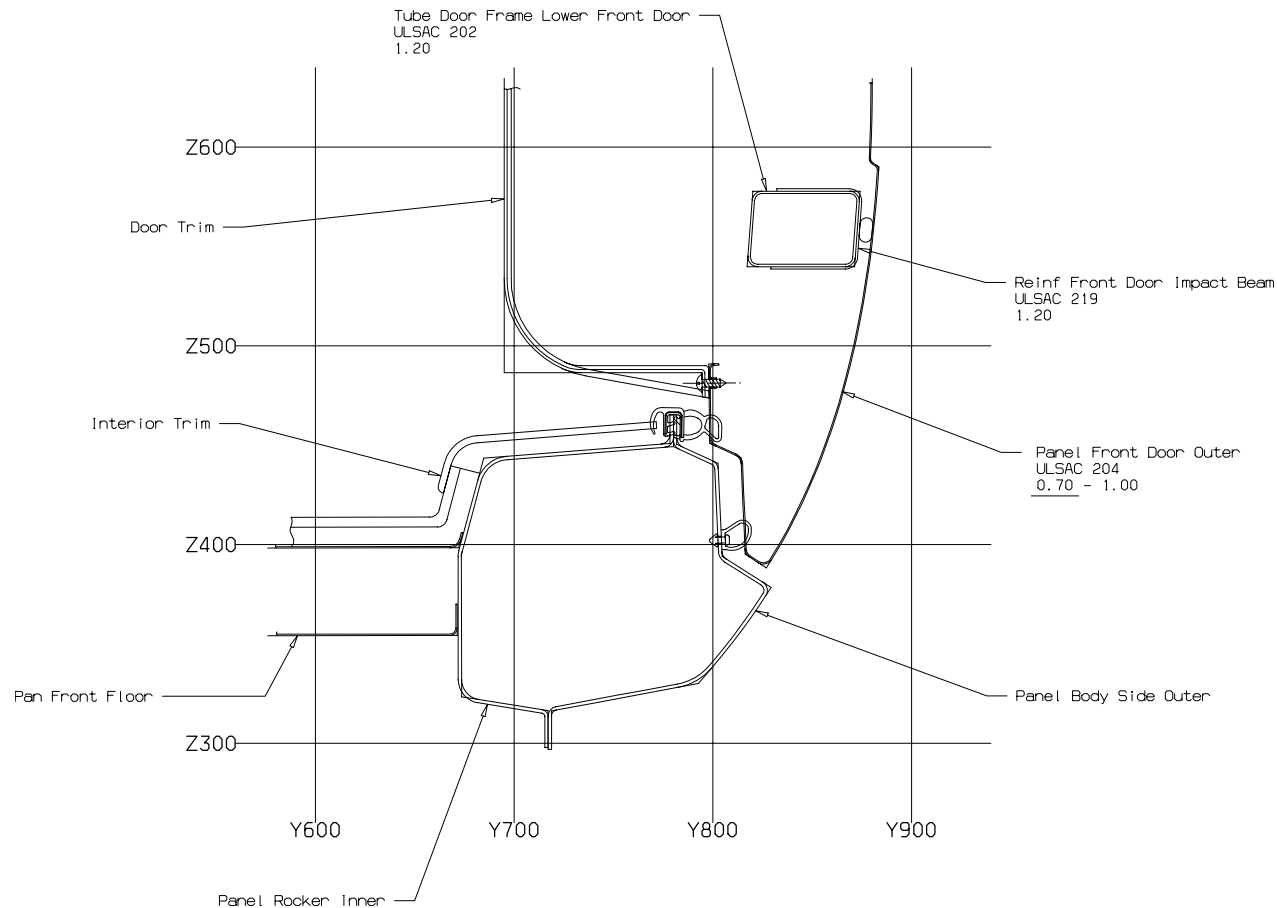




Conceptual Design

Selected Design Concepts - Doors Frame Integrated - Typical Sections

Section C2

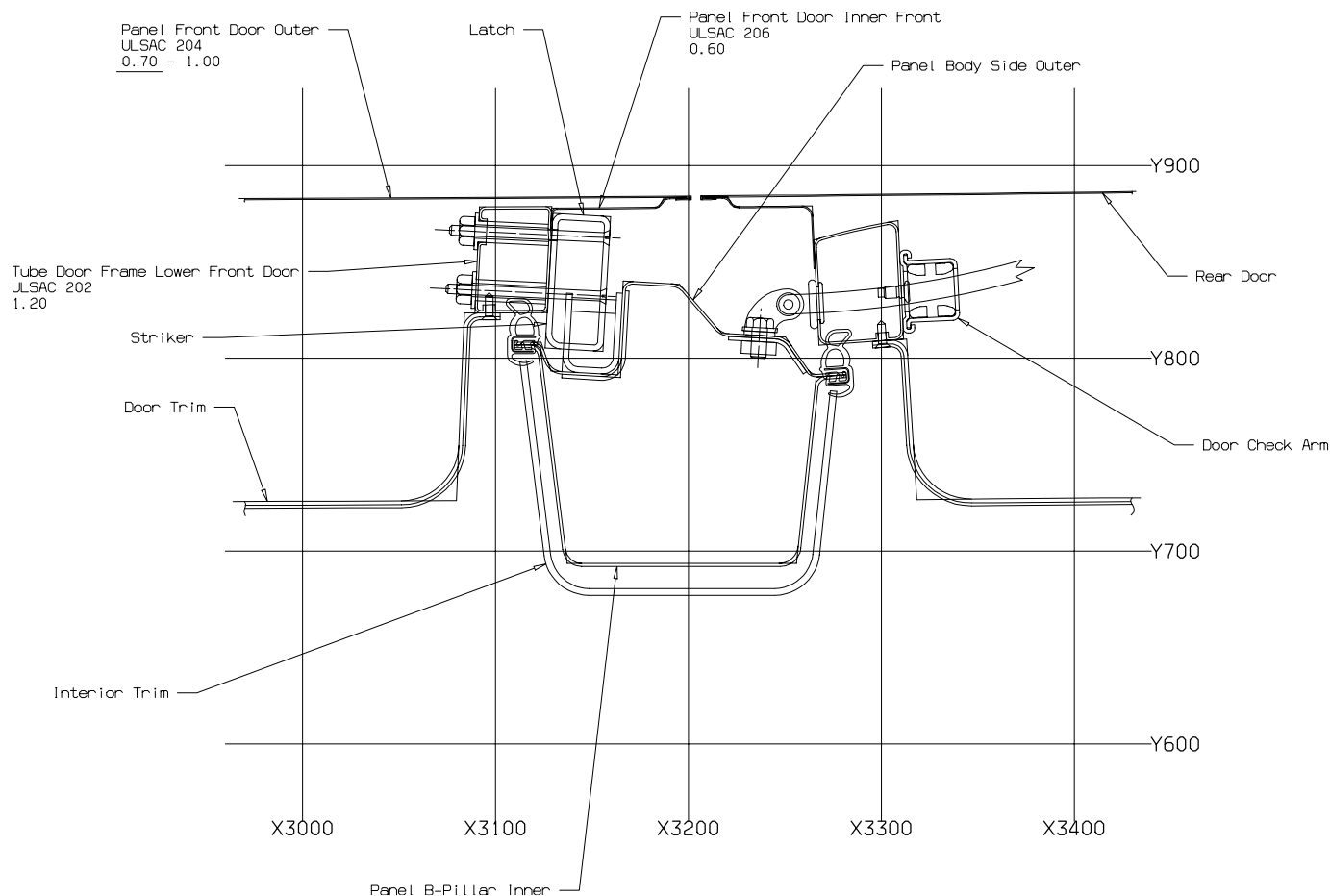




Conceptual Design

Selected Design Concepts - Doors Frame Integrated - Typical Sections

Section D2

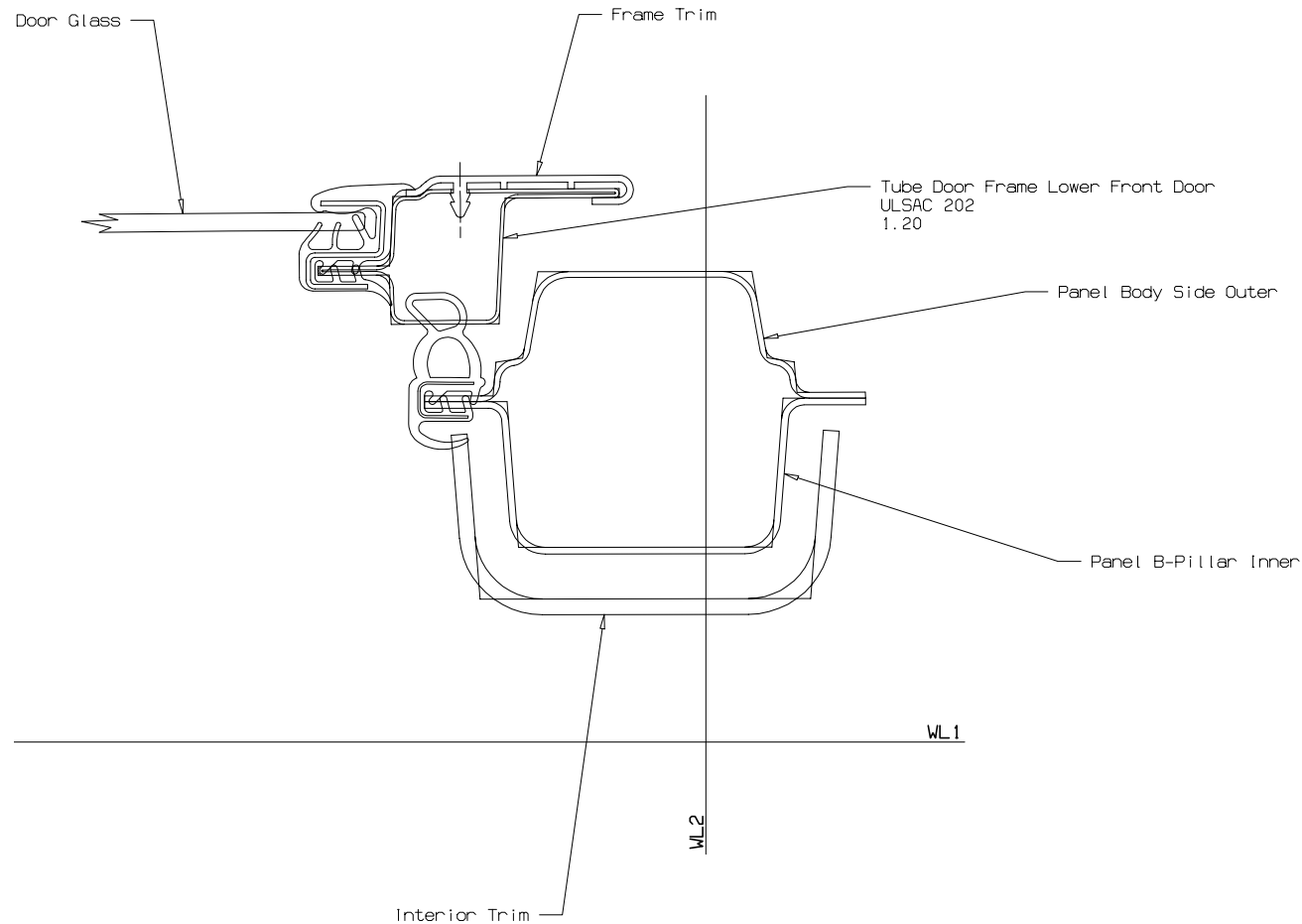




Conceptual Design

Selected Design Concepts - Doors Frame Integrated - Typical Sections

Section E2

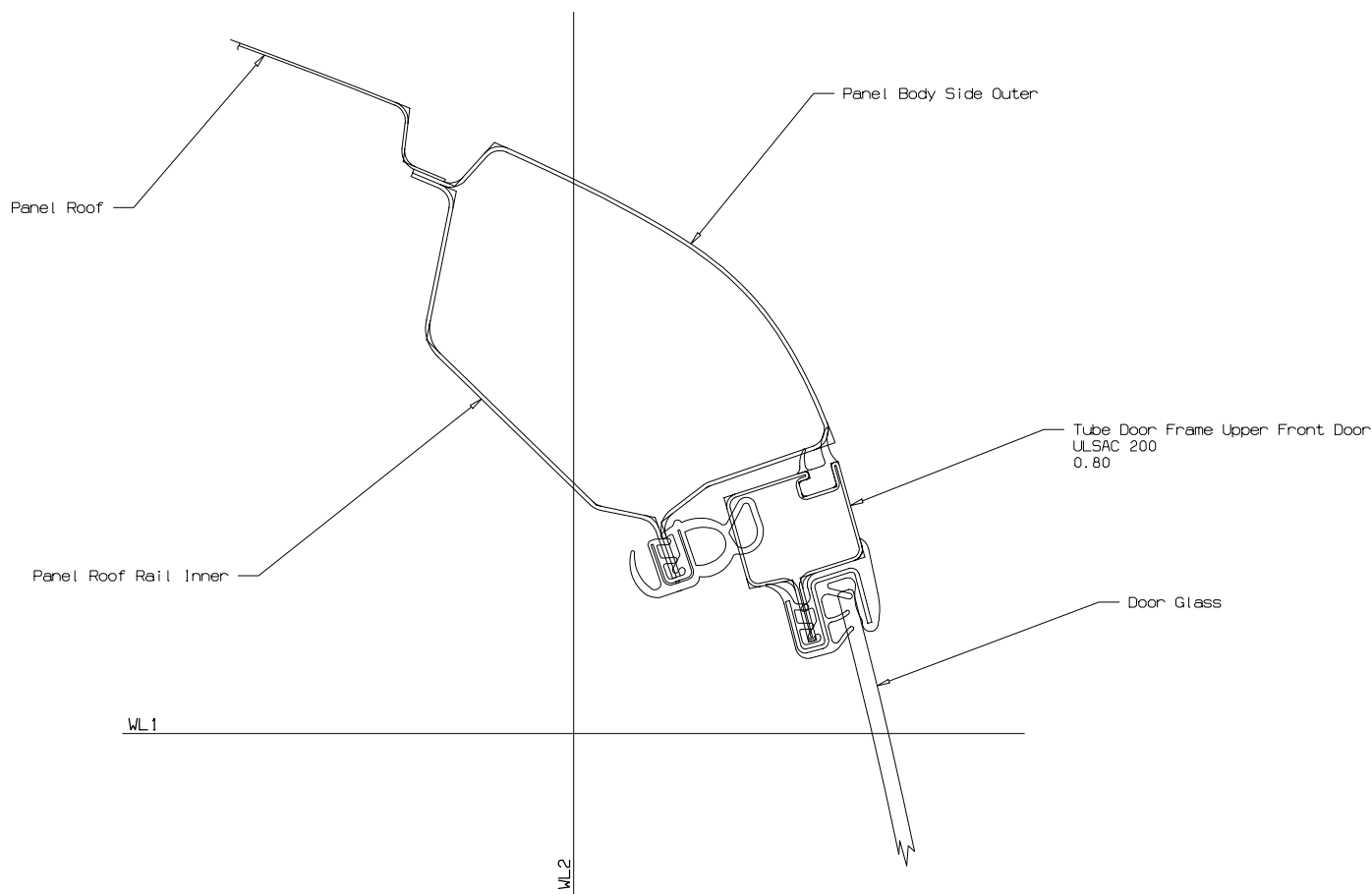




Conceptual Design

Selected Design Concepts - Doors Frame Integrated - Typical Sections

Section F2

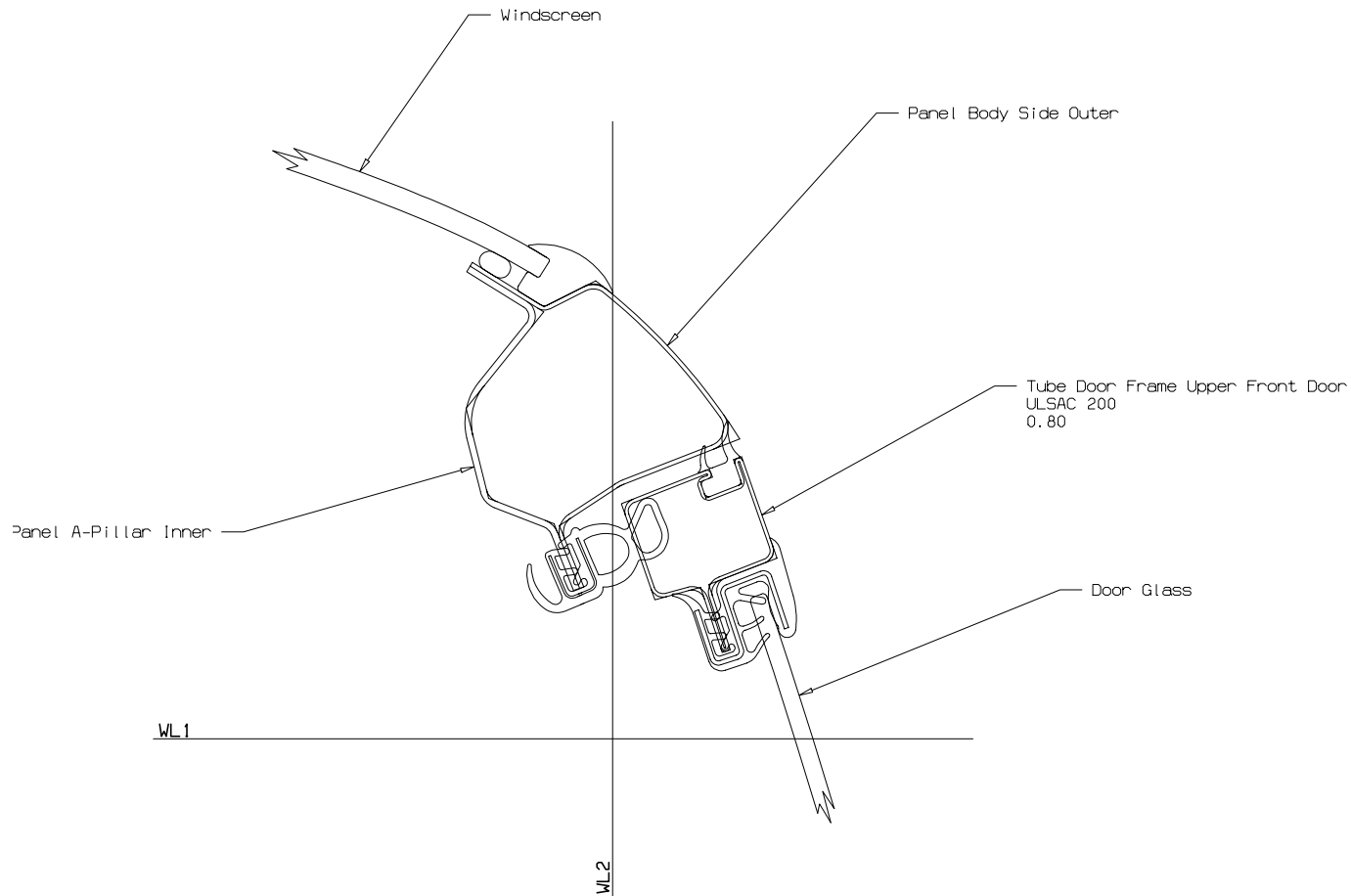




Conceptual Design

Selected Design Concepts - Doors Frame Integrated - Typical Sections

Section G2

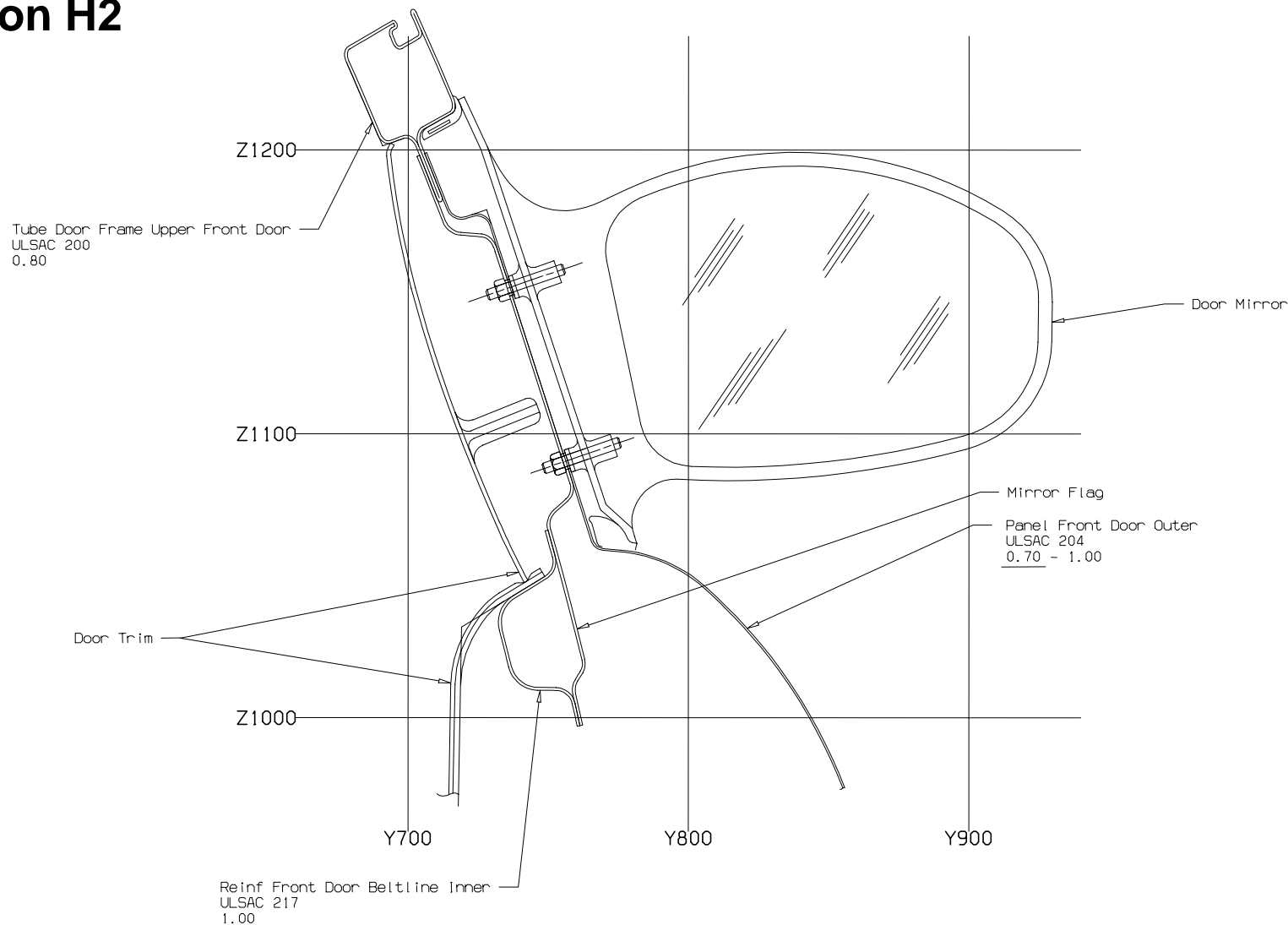




Conceptual Design

Selected Design Concepts - Doors Frame Integrated - Typical Sections

Section H2

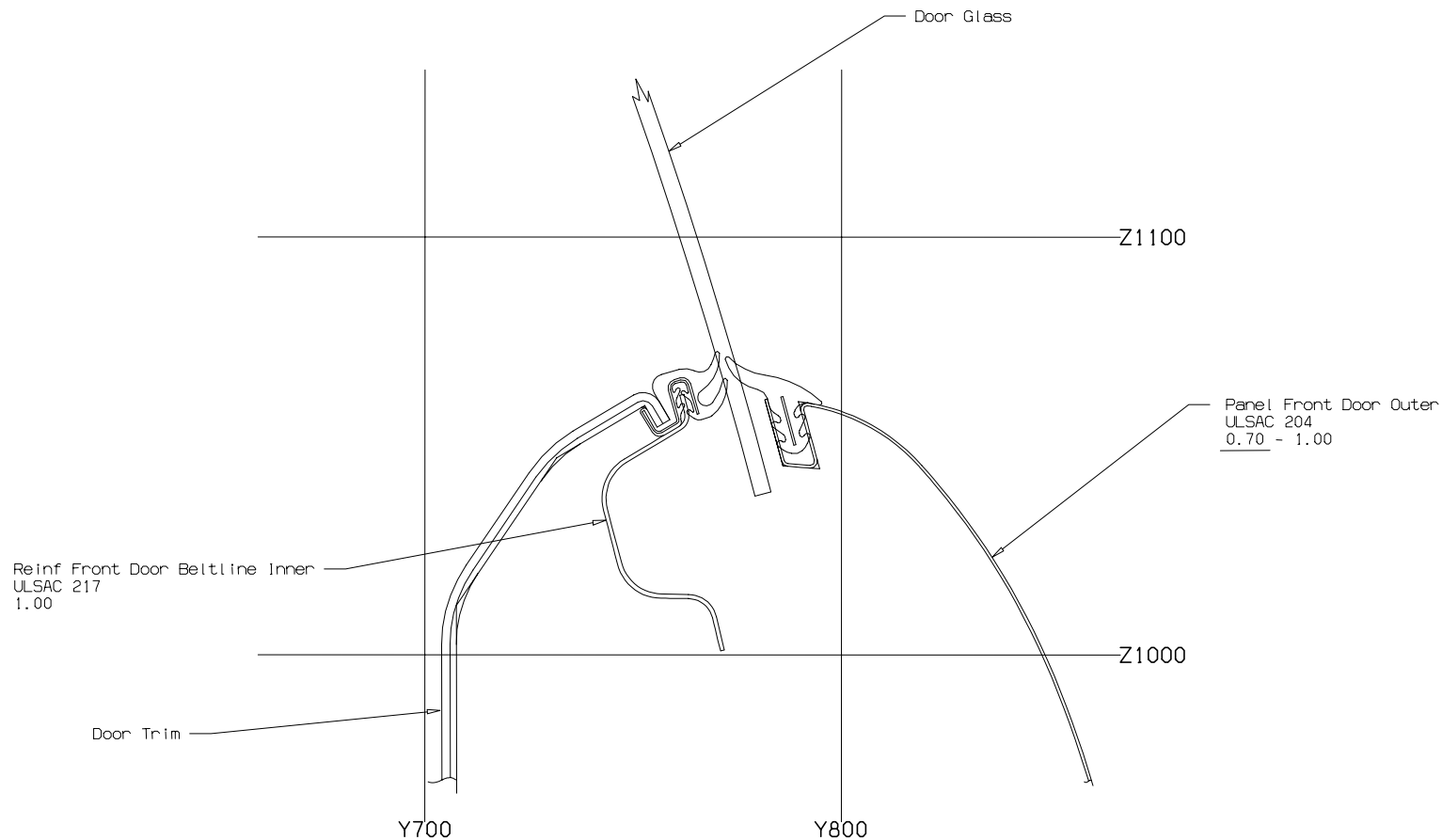




Conceptual Design

Selected Design Concepts - Doors Frame Integrated - Typical Sections

Section I2

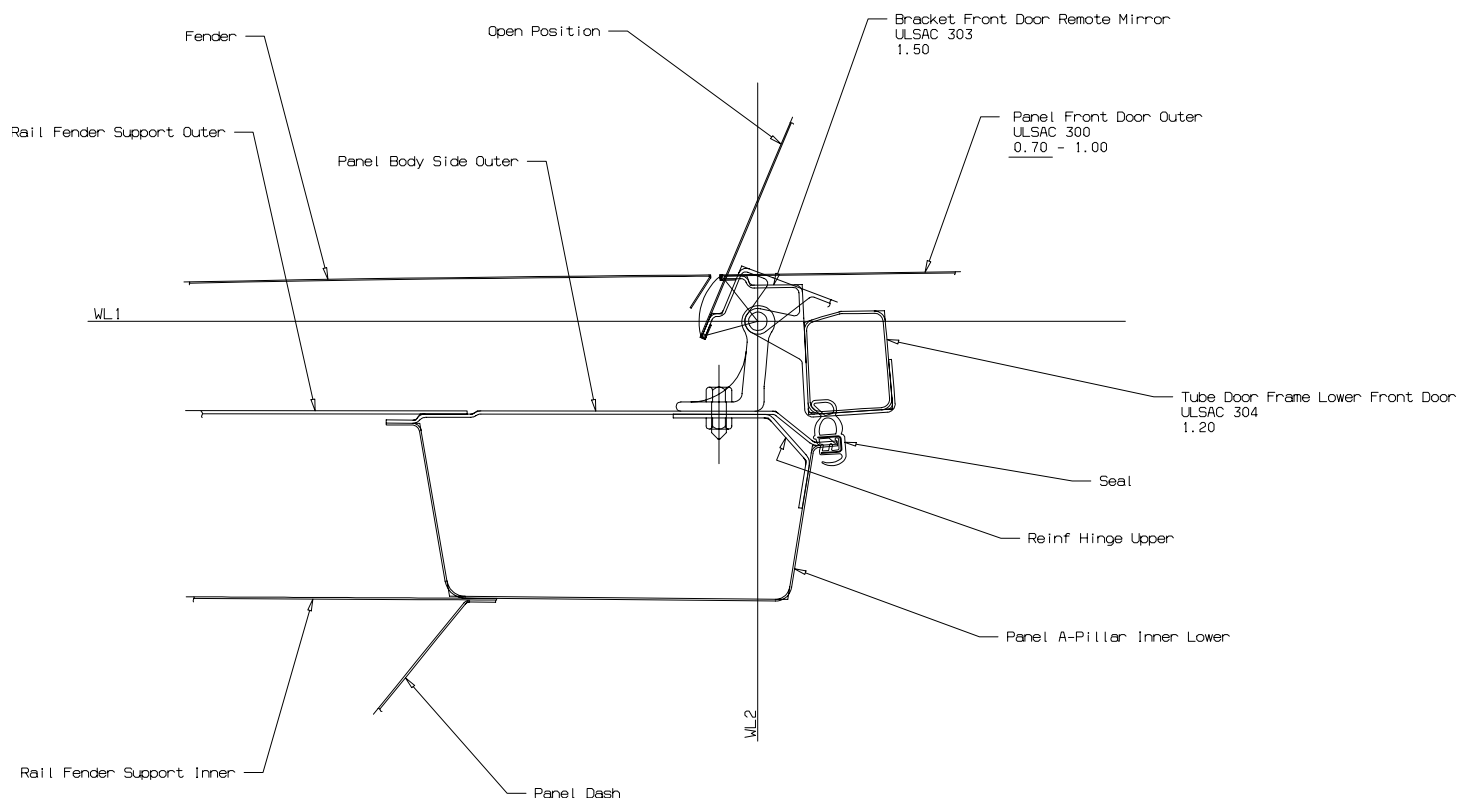




Conceptual Design

Selected Design Concepts - Doors Frameless - Typical Sections

Section A3

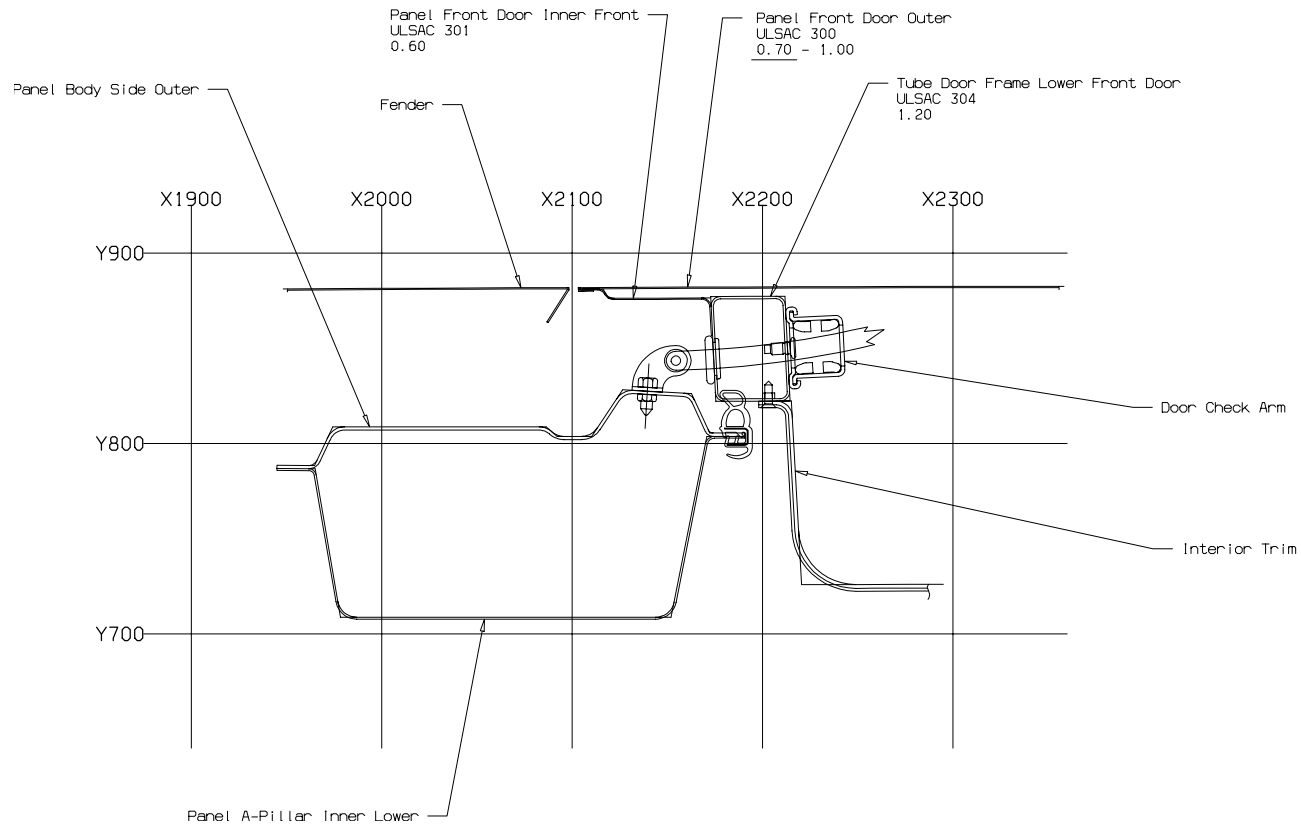




Conceptual Design

Selected Design Concepts - Doors Frameless - Typical Sections

Section B3

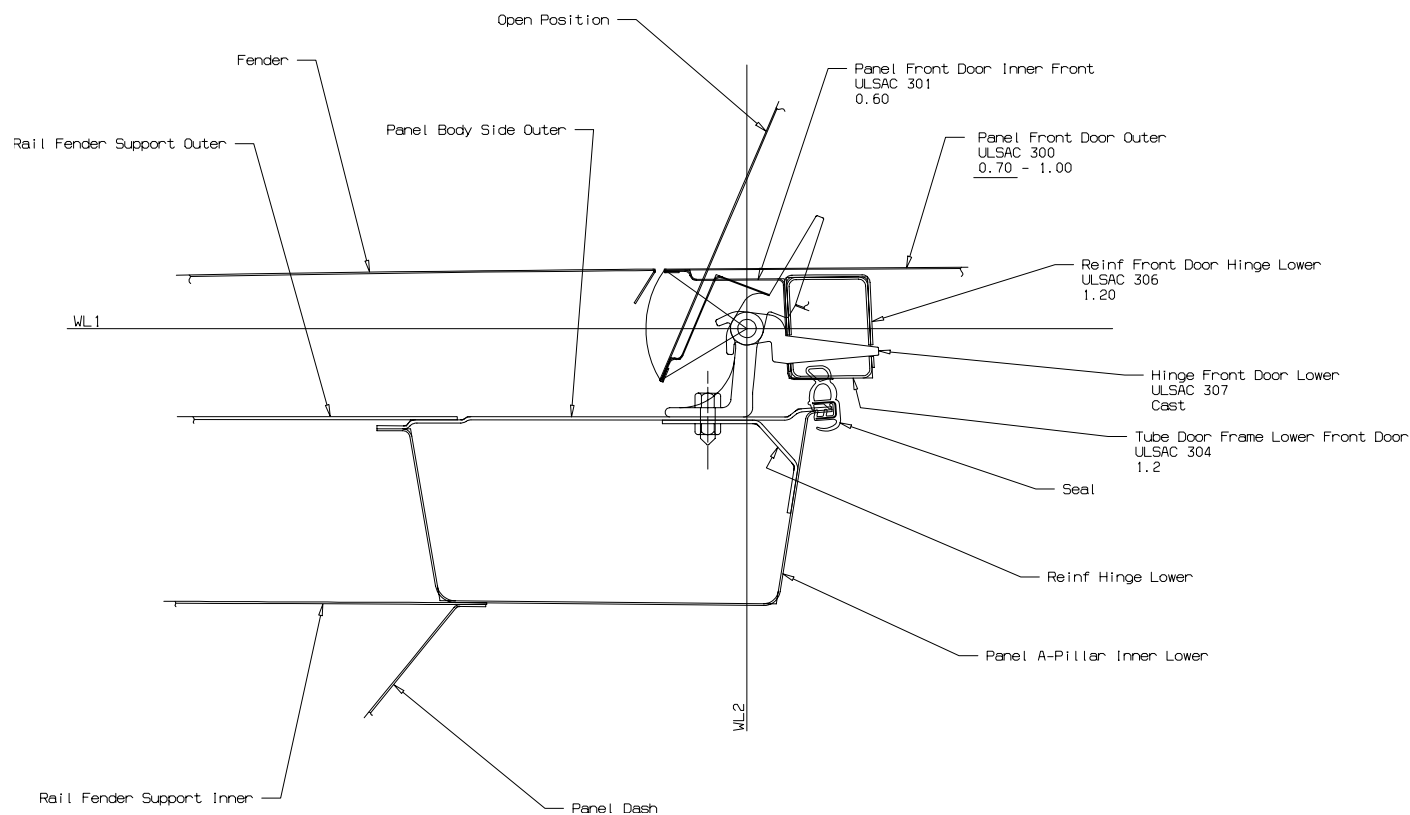




Conceptual Design

Selected Design Concepts - Doors Frameless - Typical Sections

Section C3

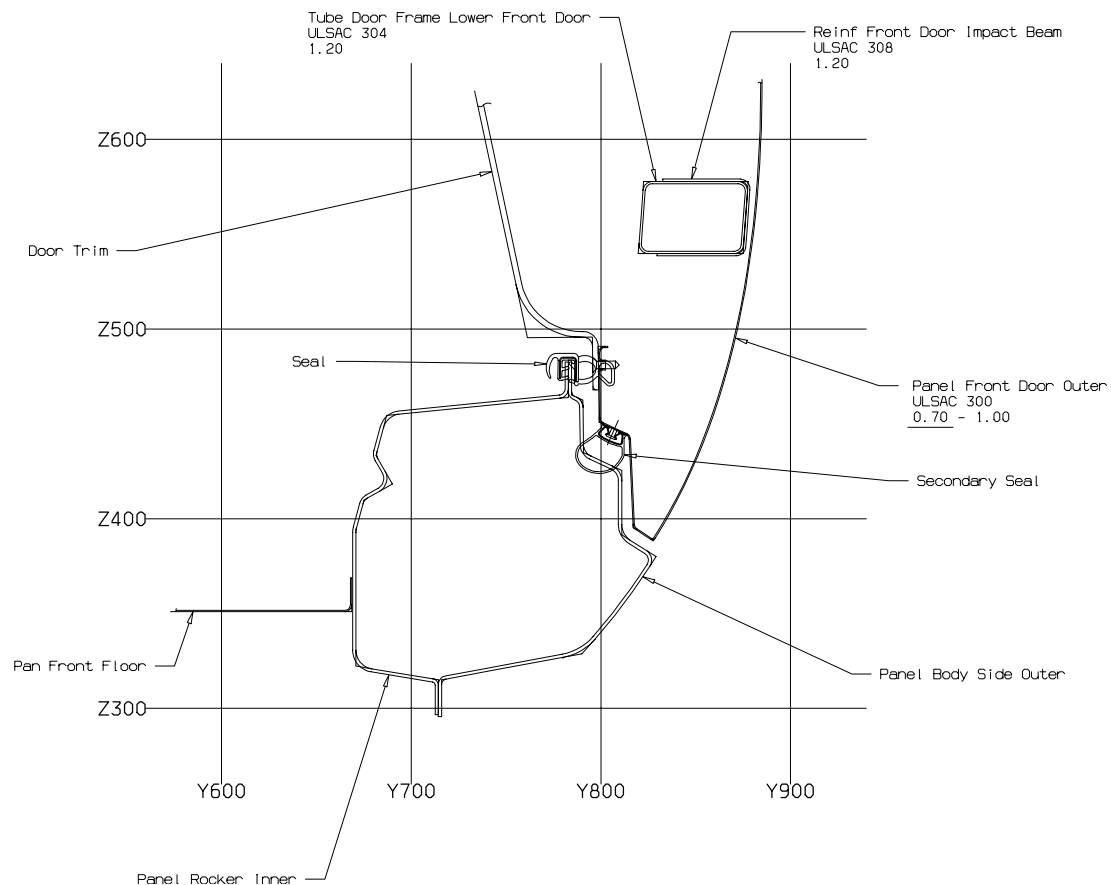




Conceptual Design

Selected Design Concepts - Doors Frameless - Typical Sections

Section D3

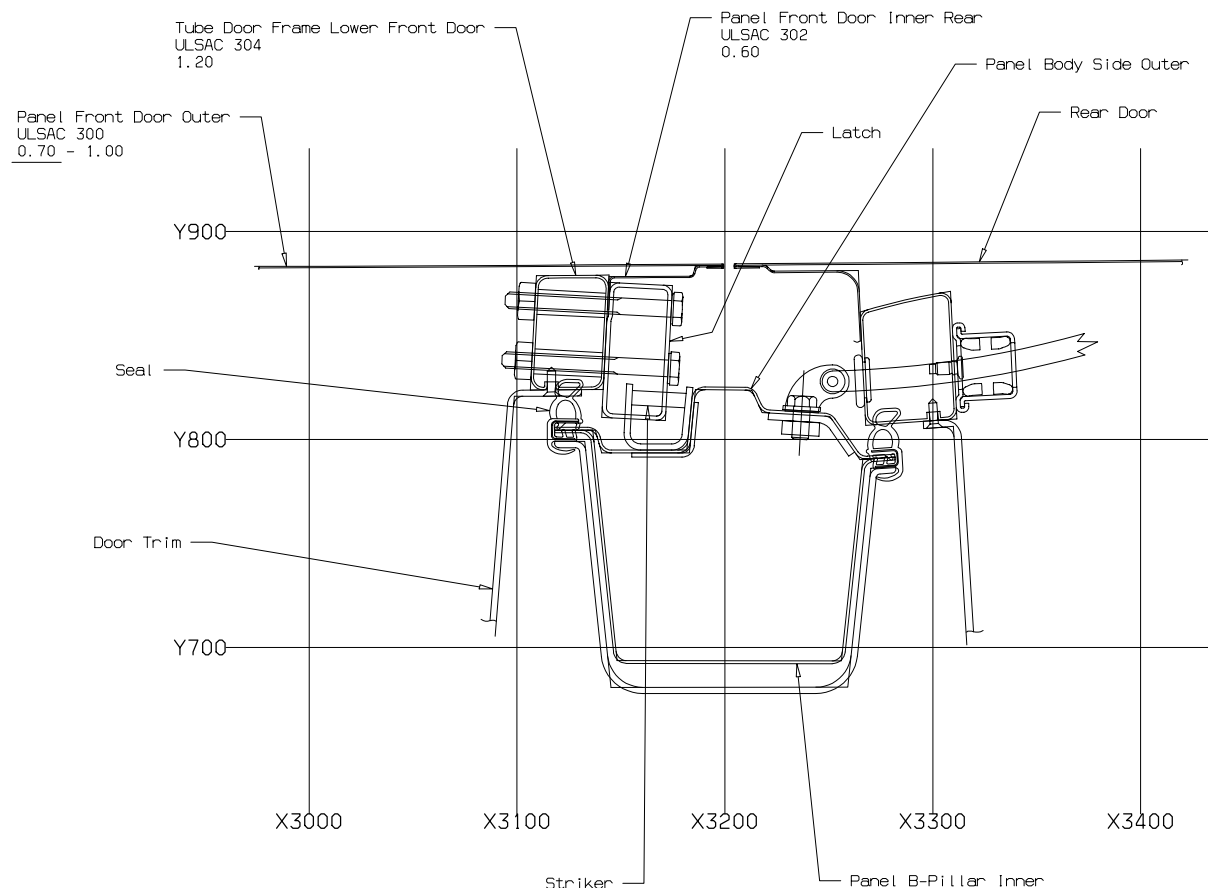




Conceptual Design

Selected Design Concepts - Doors Frameless - Typical Sections

Section E3

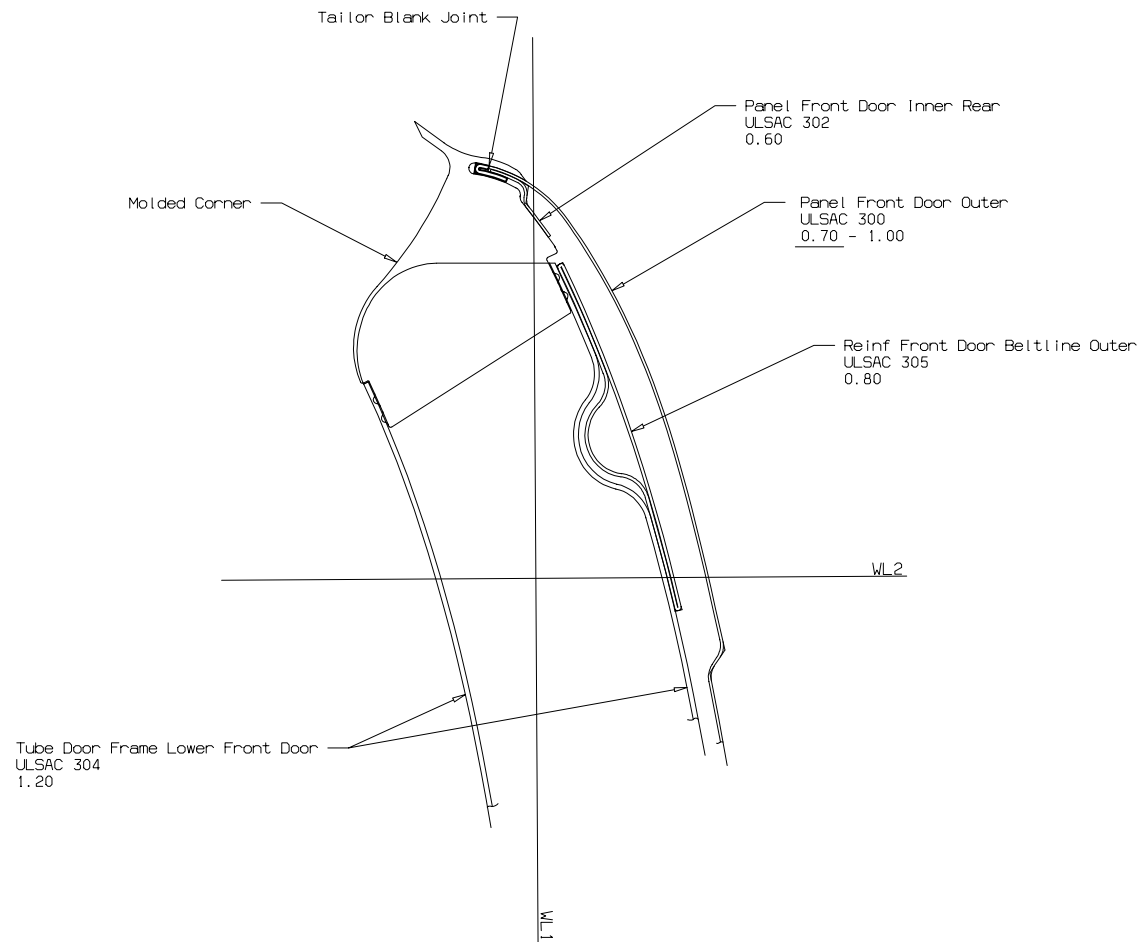




Conceptual Design

Selected Design Concepts - Doors Frameless - Typical Sections

Section F3

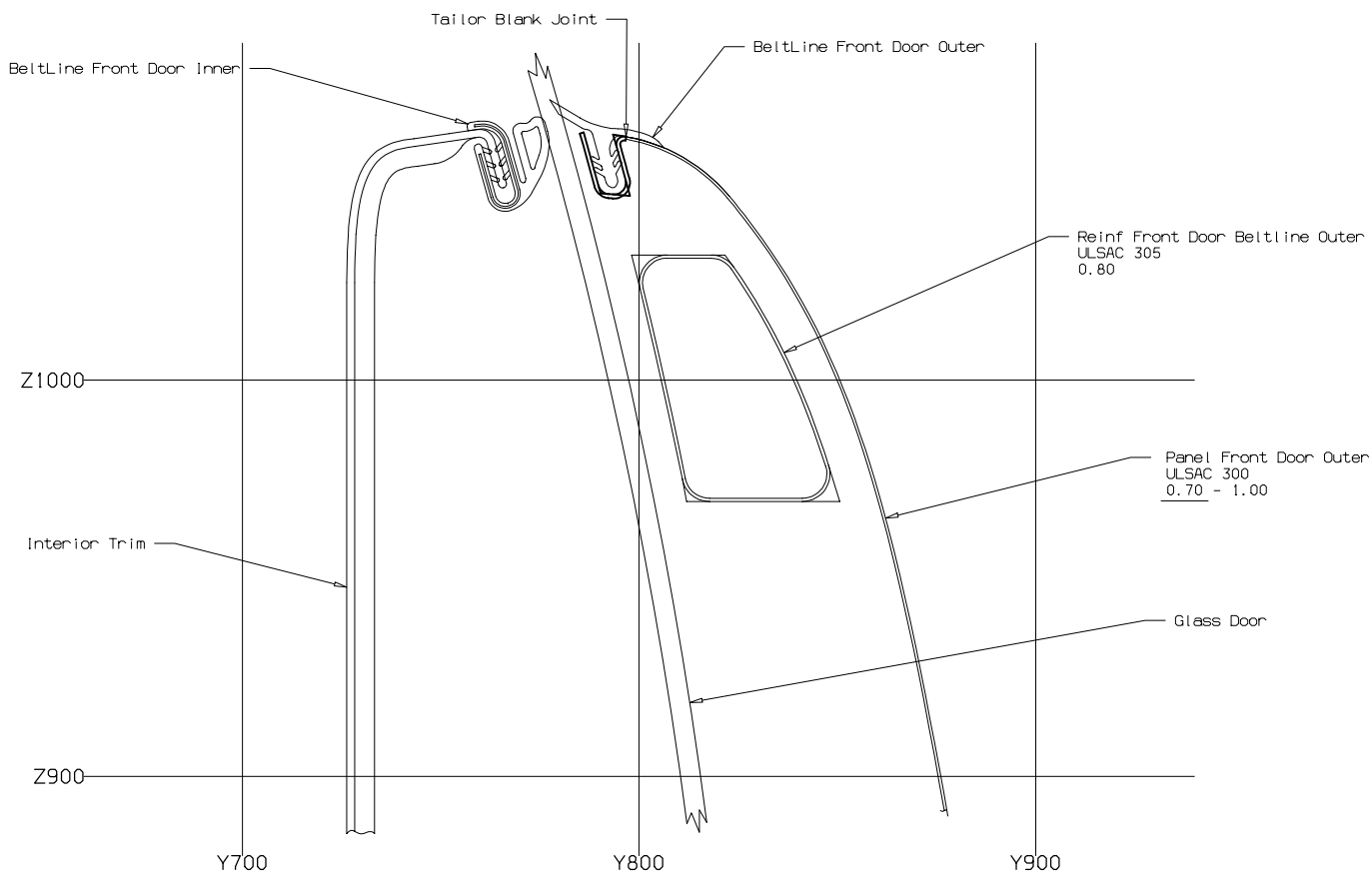




Conceptual Design

Selected Design Concepts - Doors Frameless - Typical Sections

Section G3

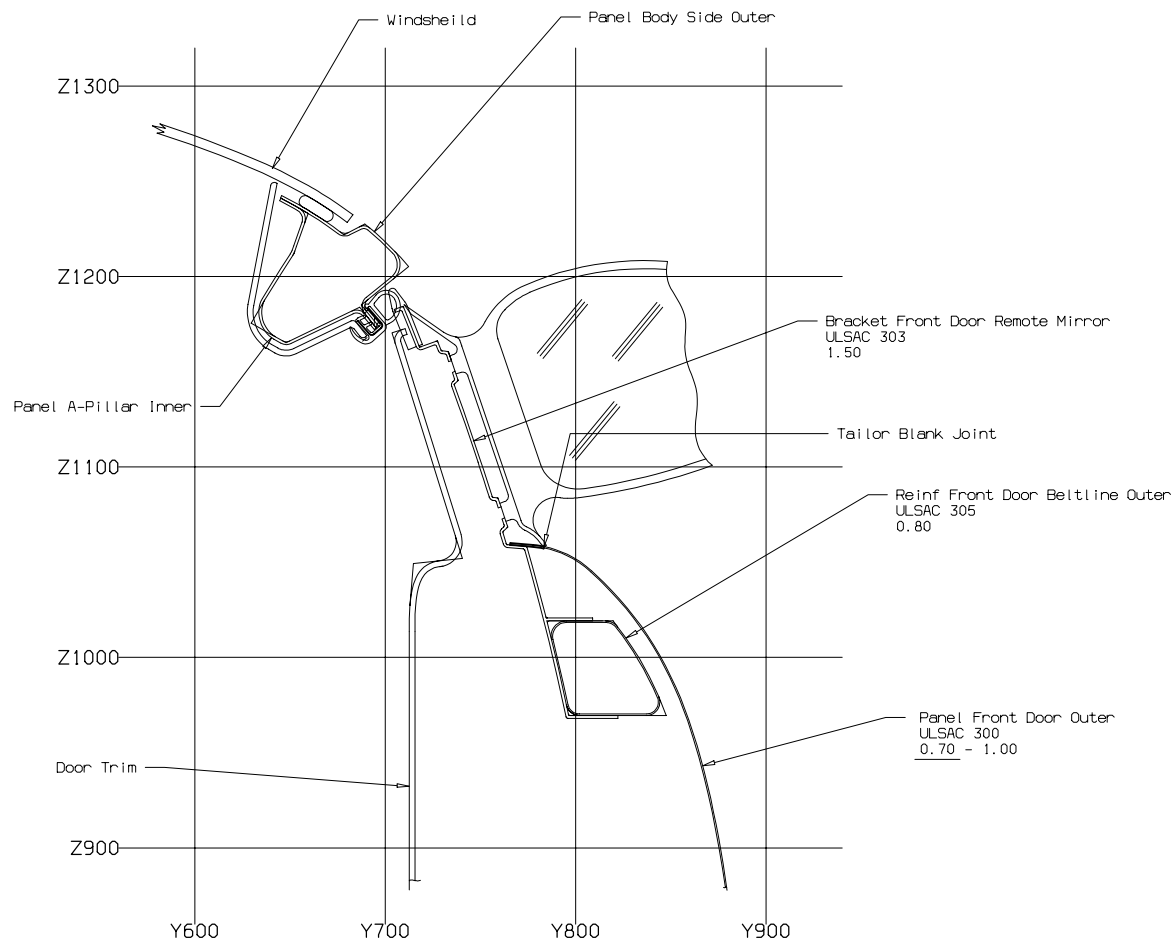




Conceptual Design

Selected Design Concepts - Doors Frameless - Typical Sections

Section H3

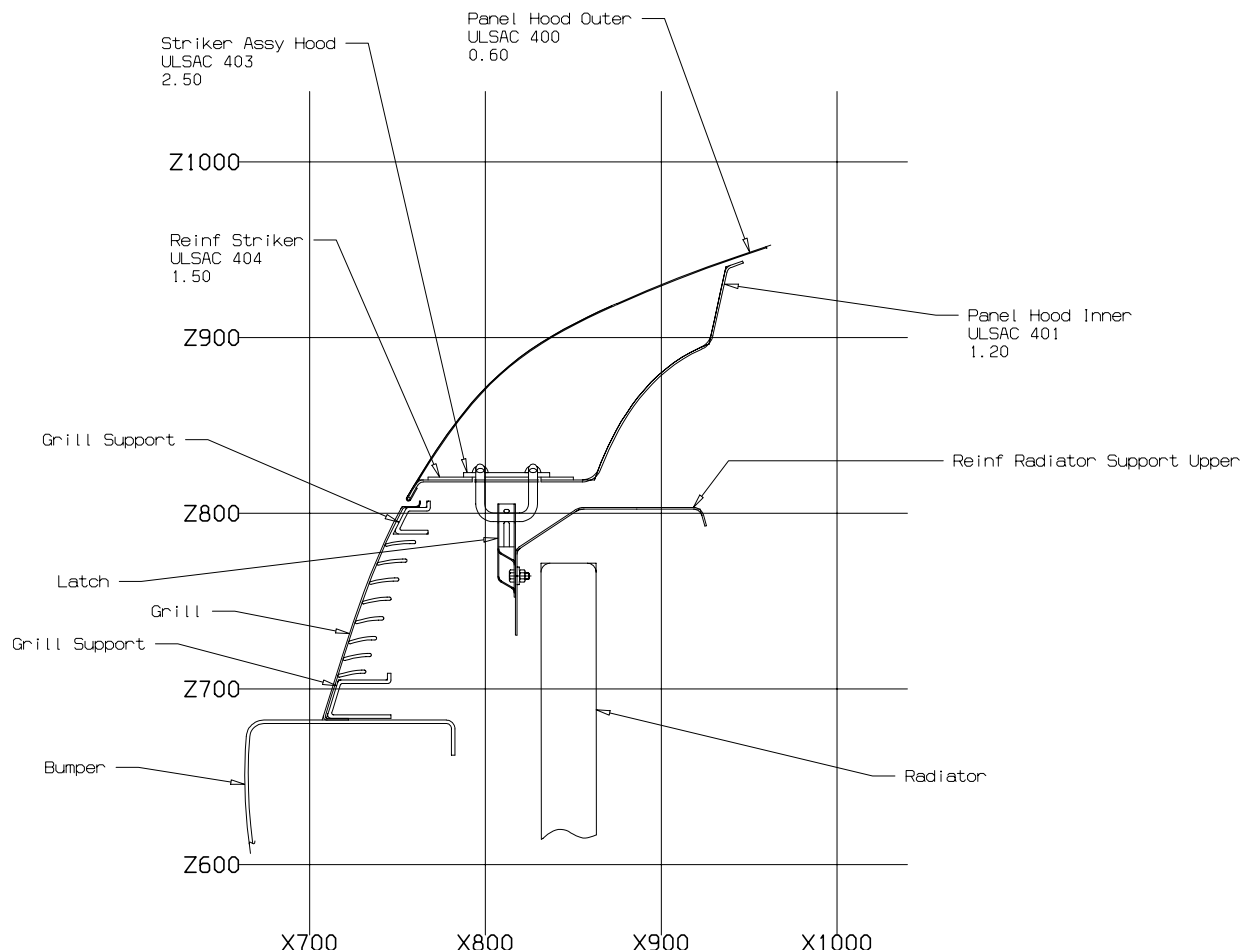




Conceptual Design

Selected Design Concepts - Hoods Conventional - Typical Sections

Section A4

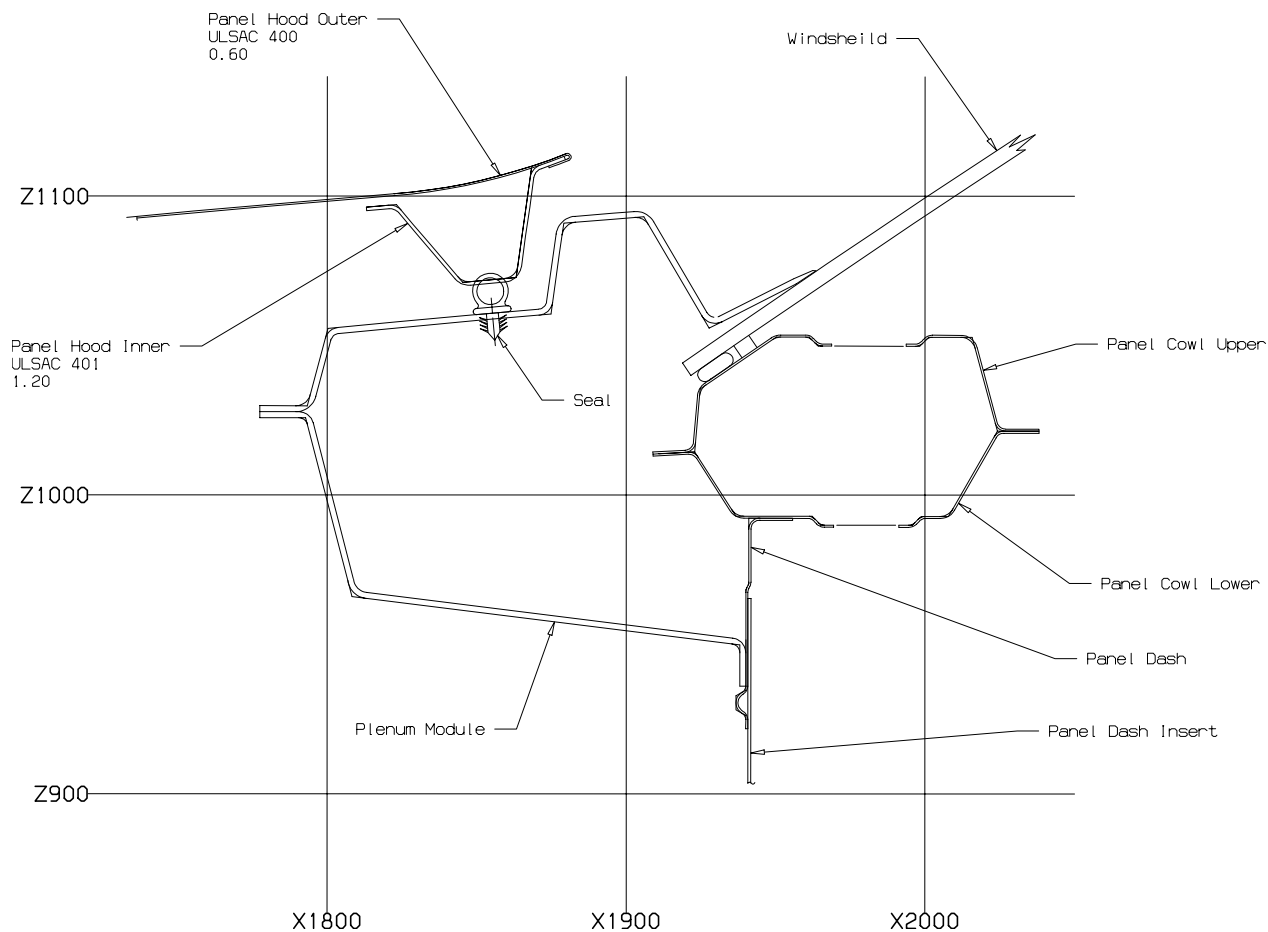




Conceptual Design

Selected Design Concepts - Hoods Conventional - Typical Sections

Section B4

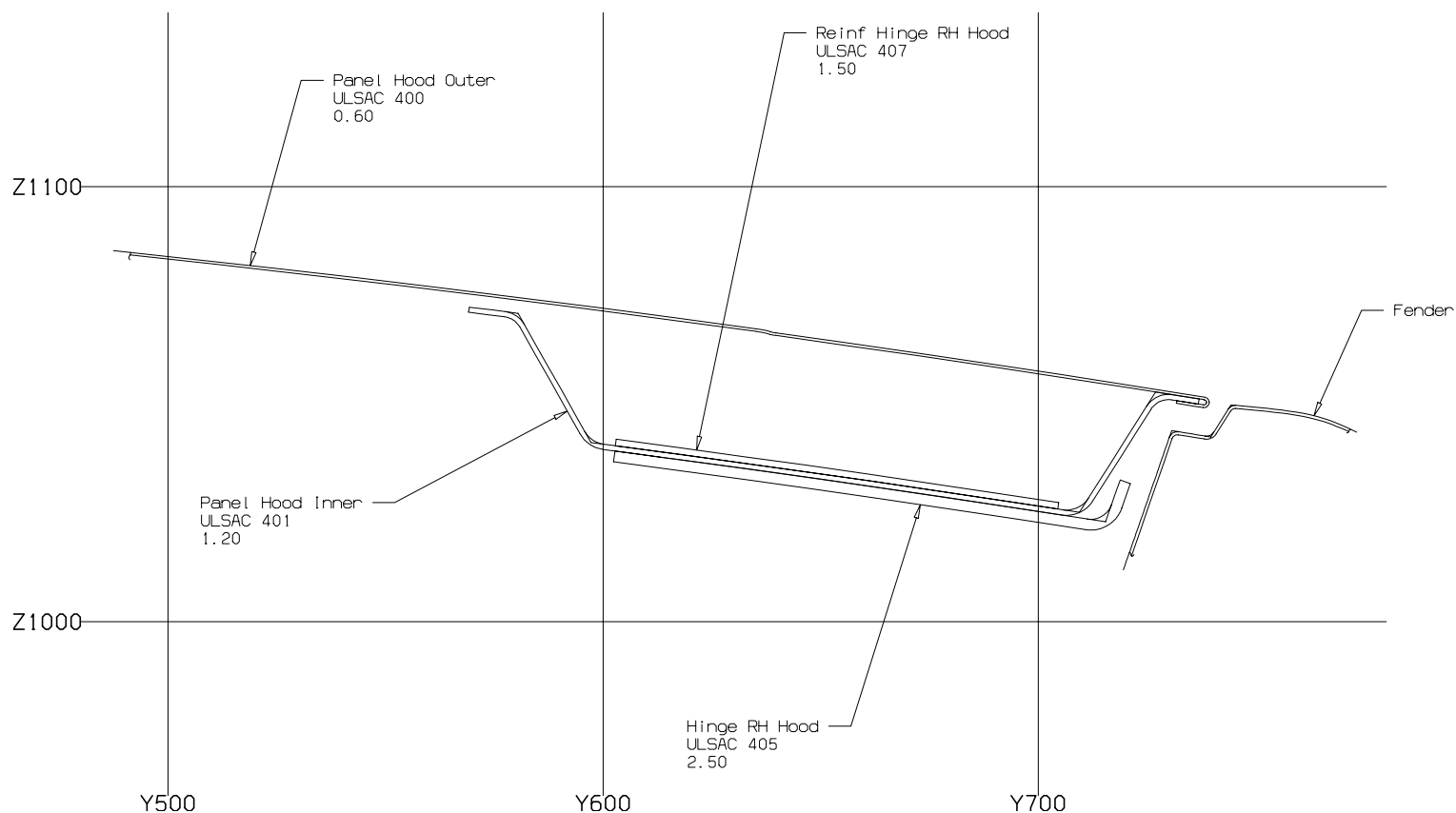




Conceptual Design

Selected Design Concepts - Hoods Conventional - Typical Sections

Section C4

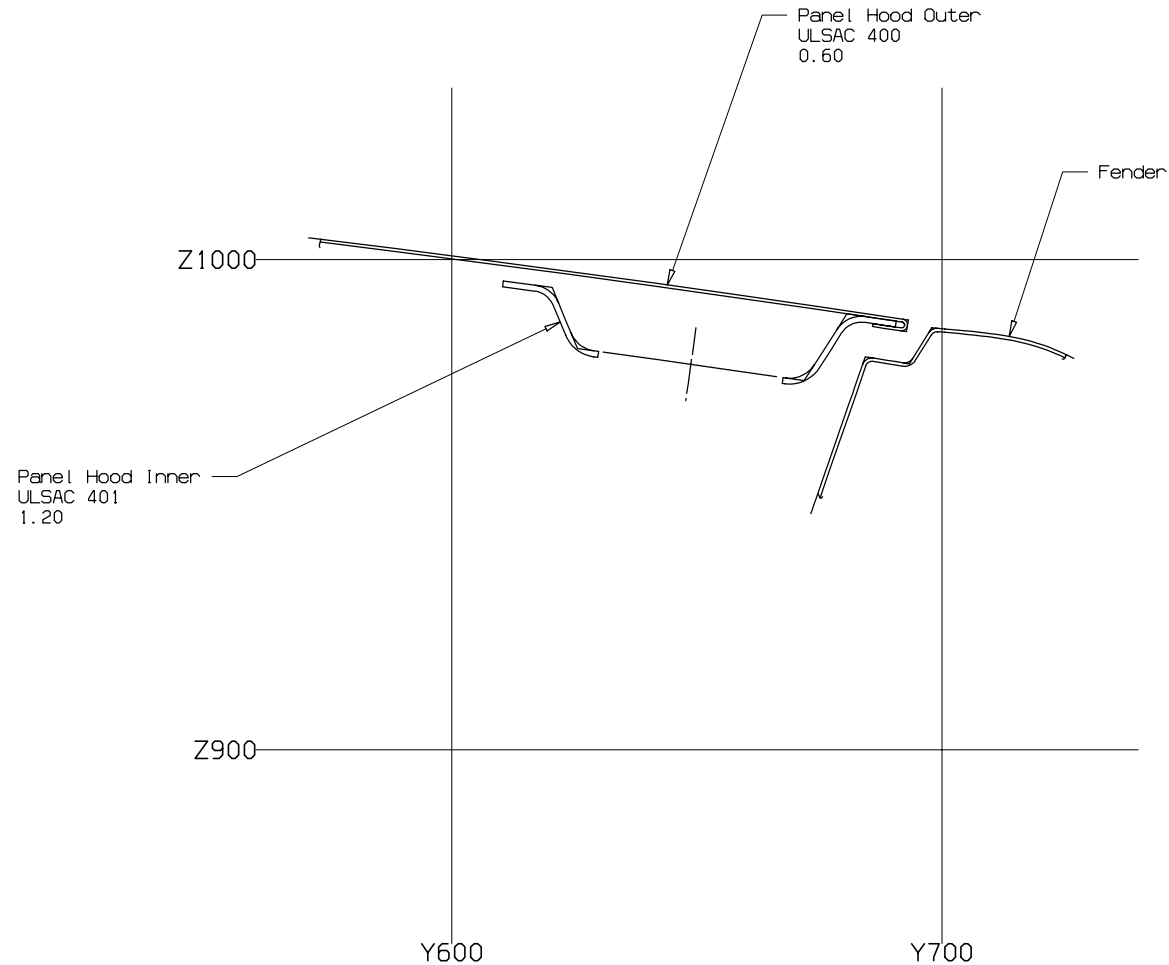




Conceptual Design

Selected Design Concepts - Hoods Conventional - Typical Sections

Section D4

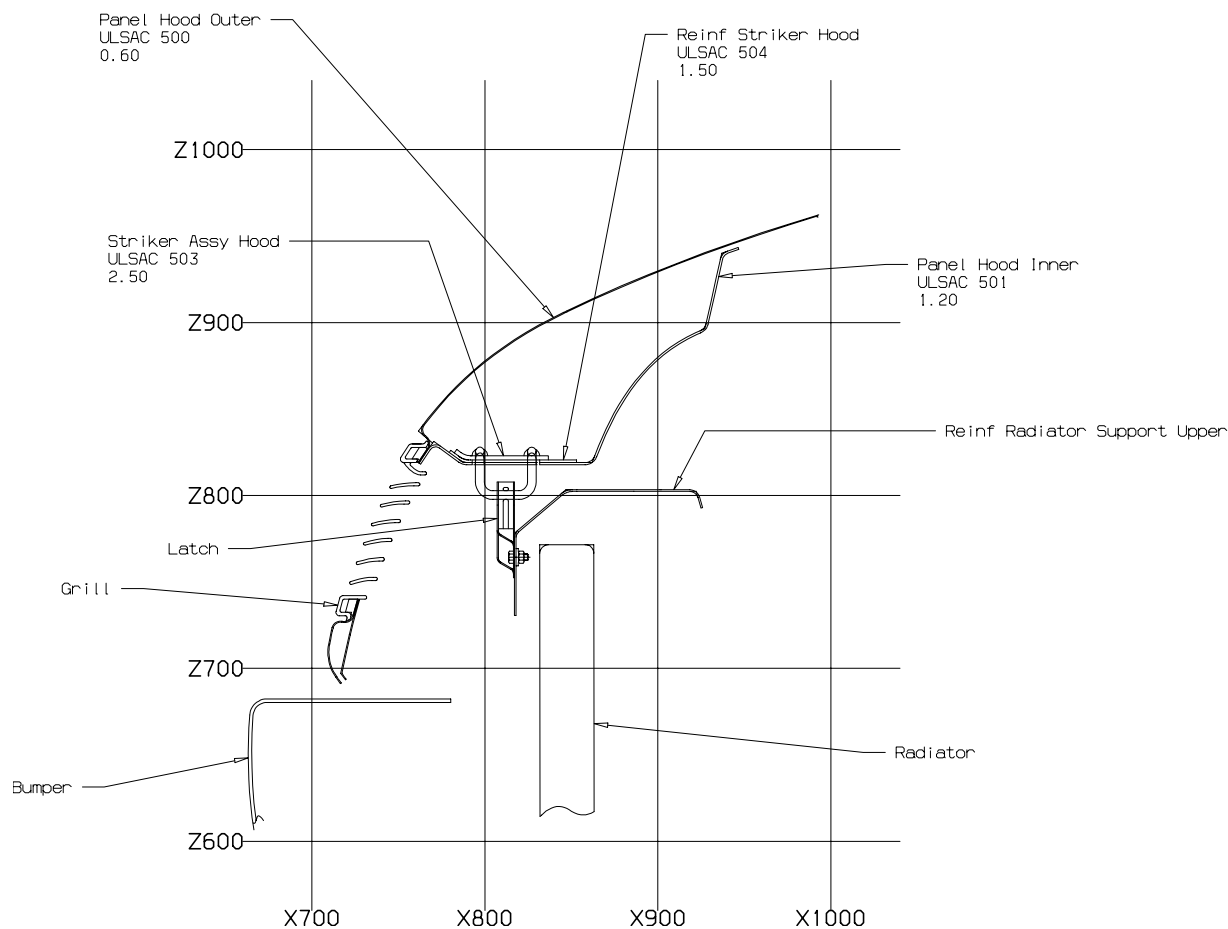




Conceptual Design

Selected Design Concepts - Hoods Grille Integrated - Typical Sections

Section A5

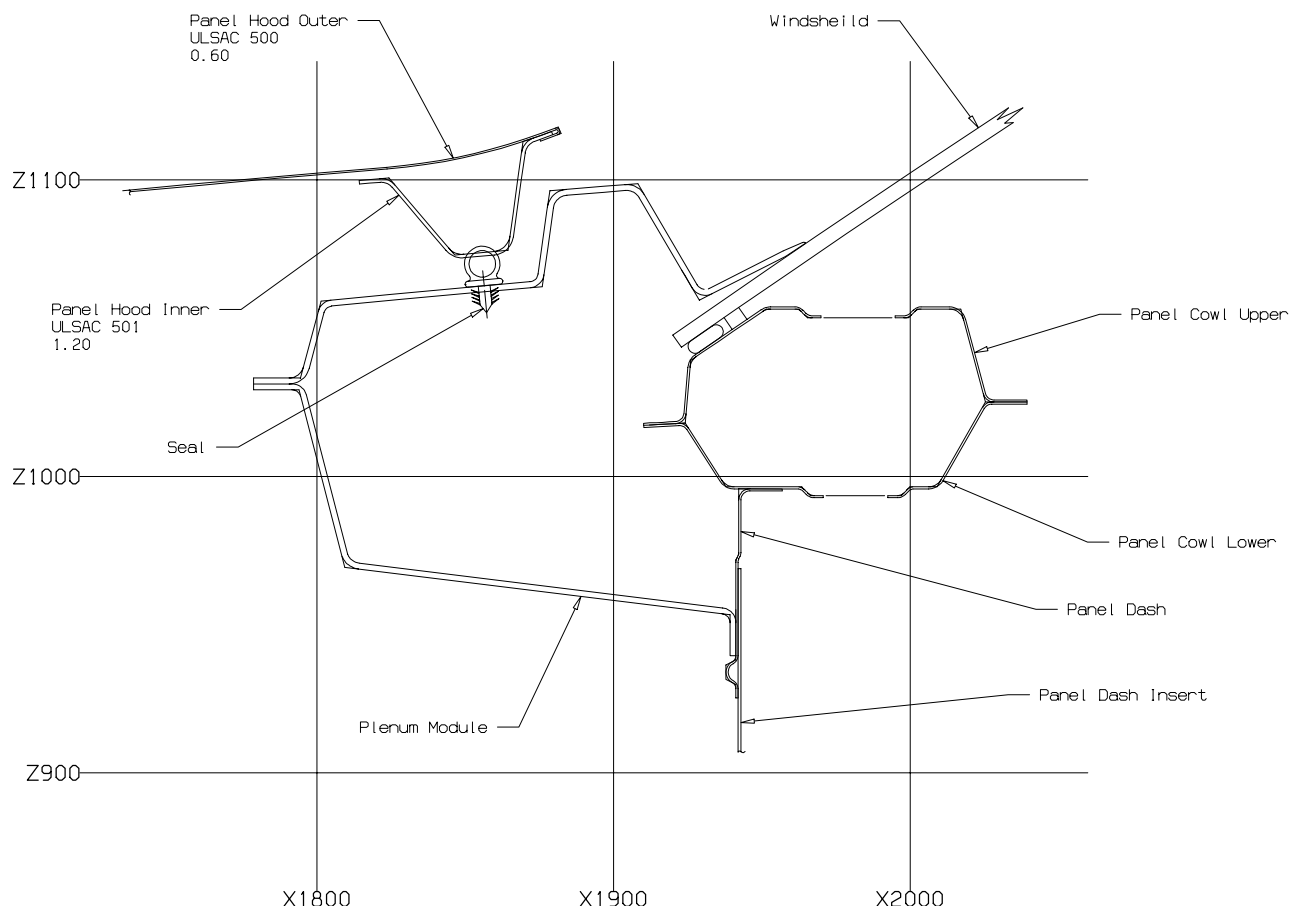




Conceptual Design

Selected Design Concepts - Hoods Grille Integrated - Typical Sections

Section B5

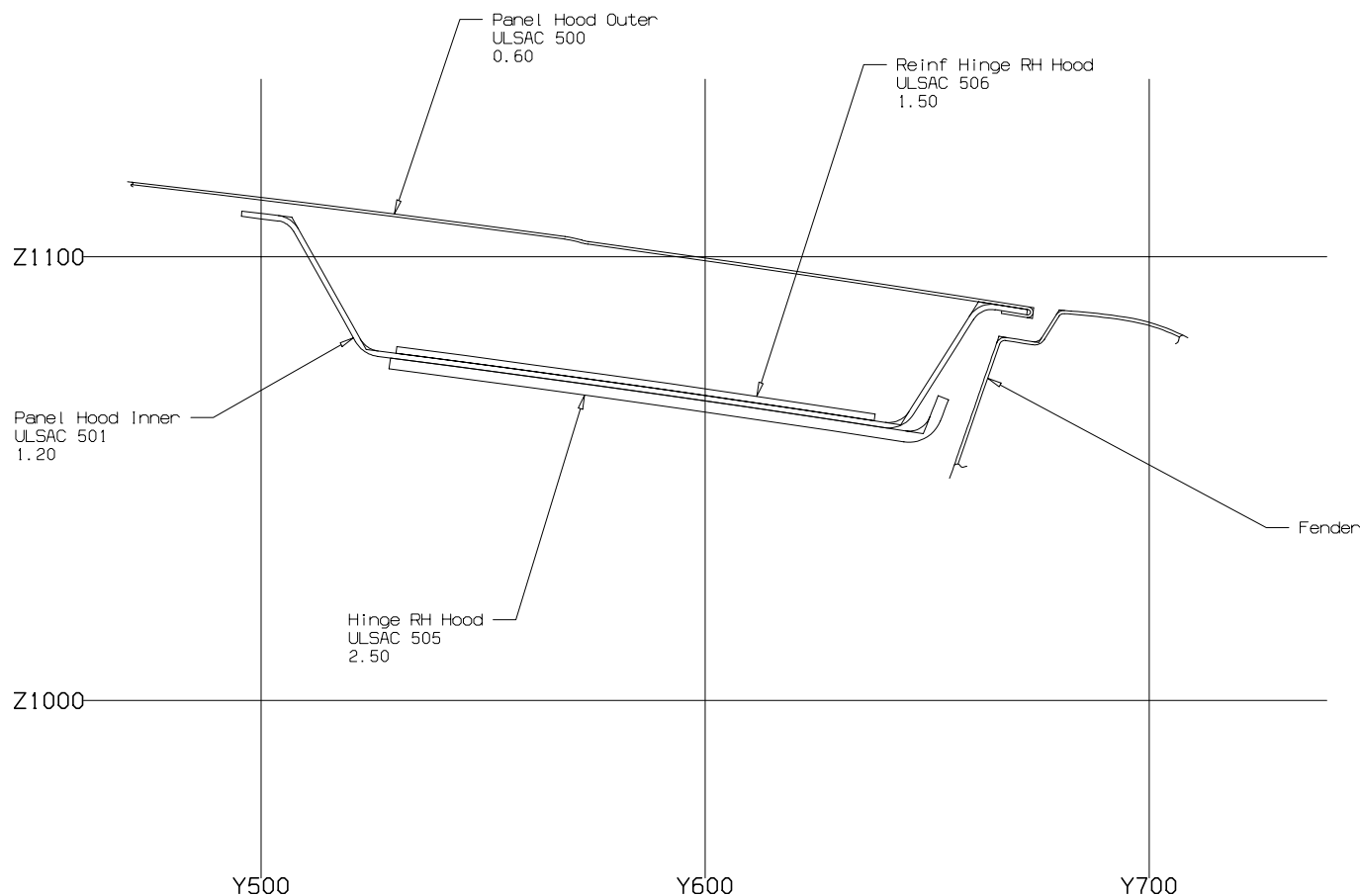




Conceptual Design

Selected Design Concepts - Hoods Grille Integrated - Typical Sections

Section C5

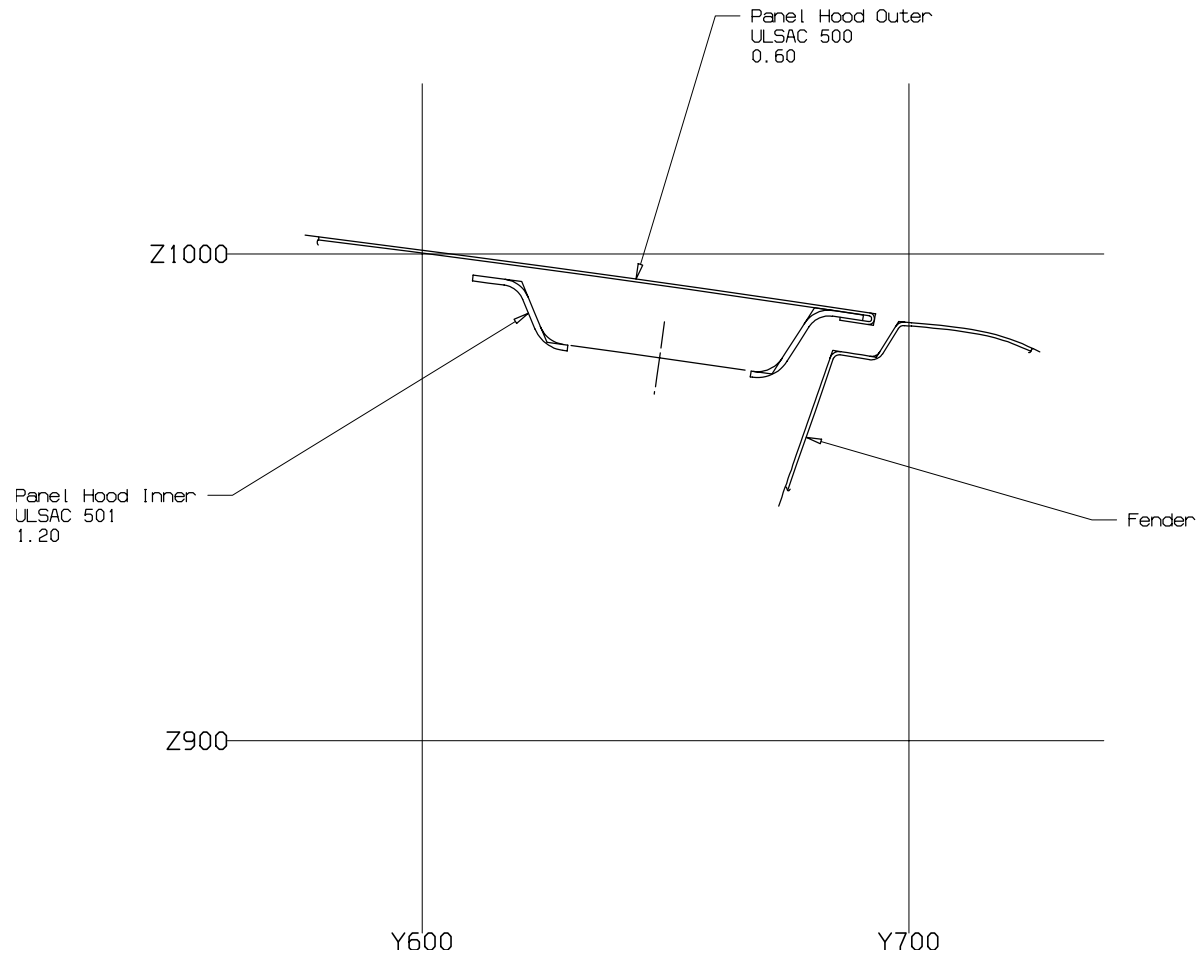




Conceptual Design

Selected Design Concepts - Hoods Grille Integrated - Typical Sections

Section D5

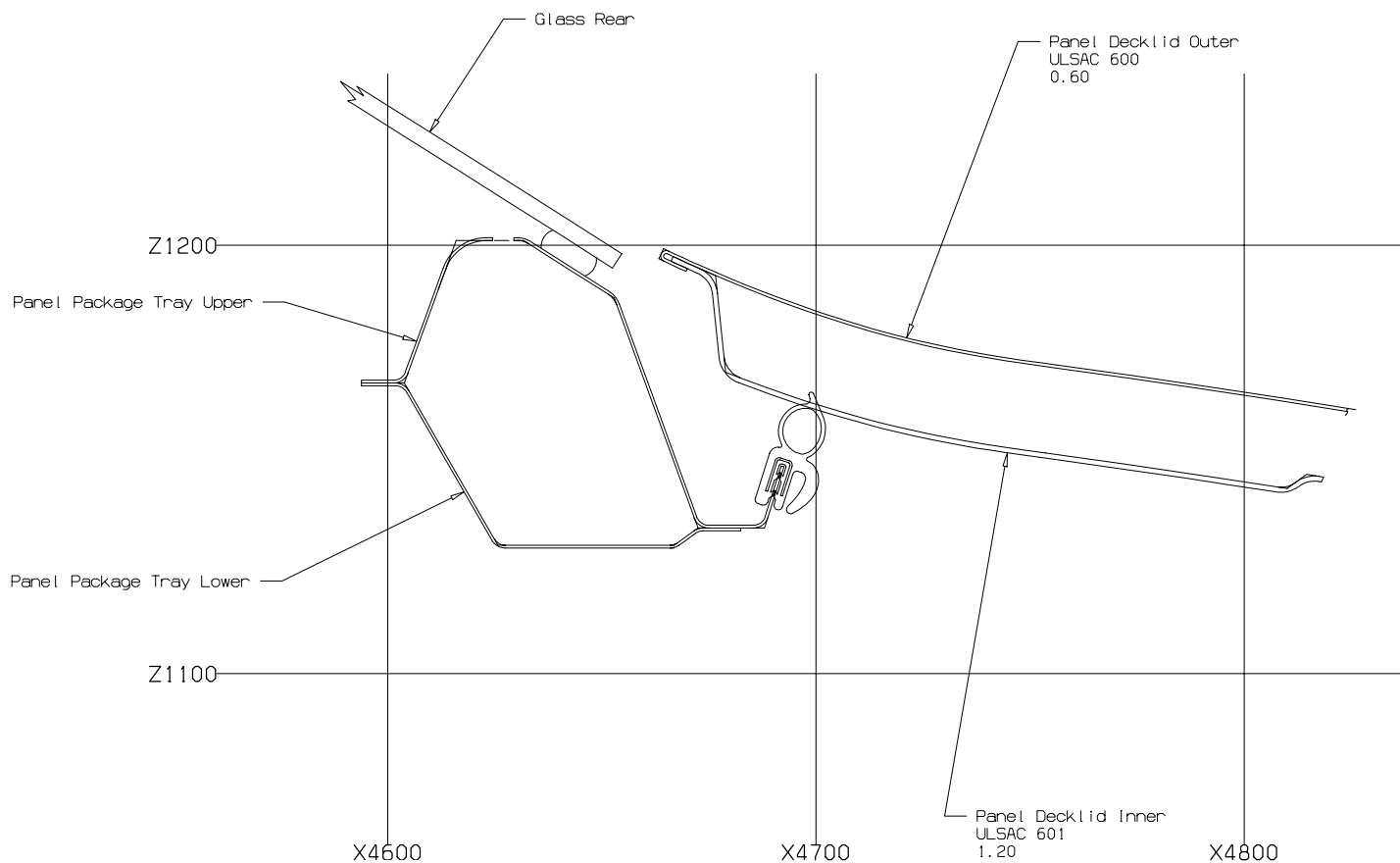




Conceptual Design

Selected Design Concepts - Decklid Conventional - Typical Sections

Section A6

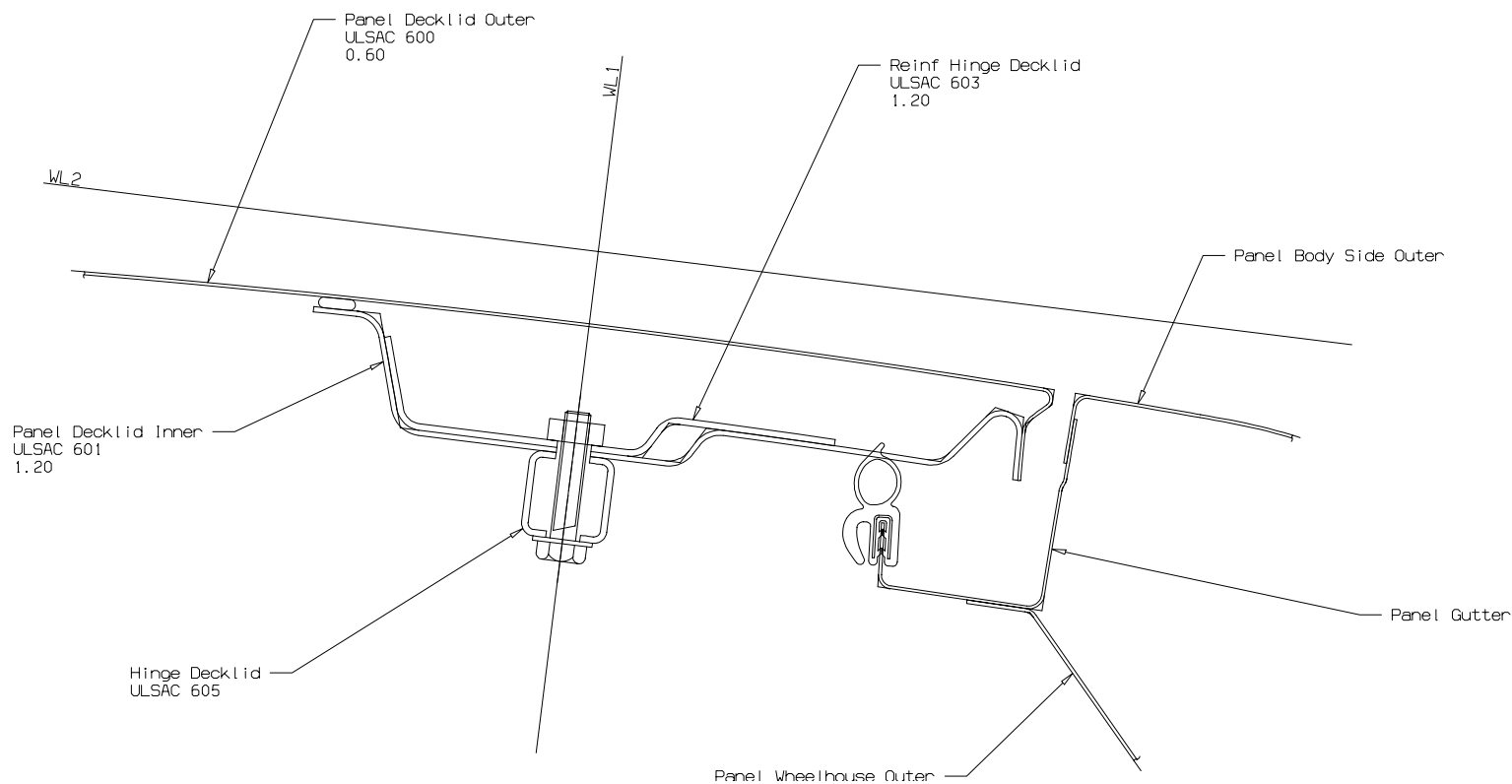




Conceptual Design

Selected Design Concepts - Decklid Conventional - Typical Sections

Section B6

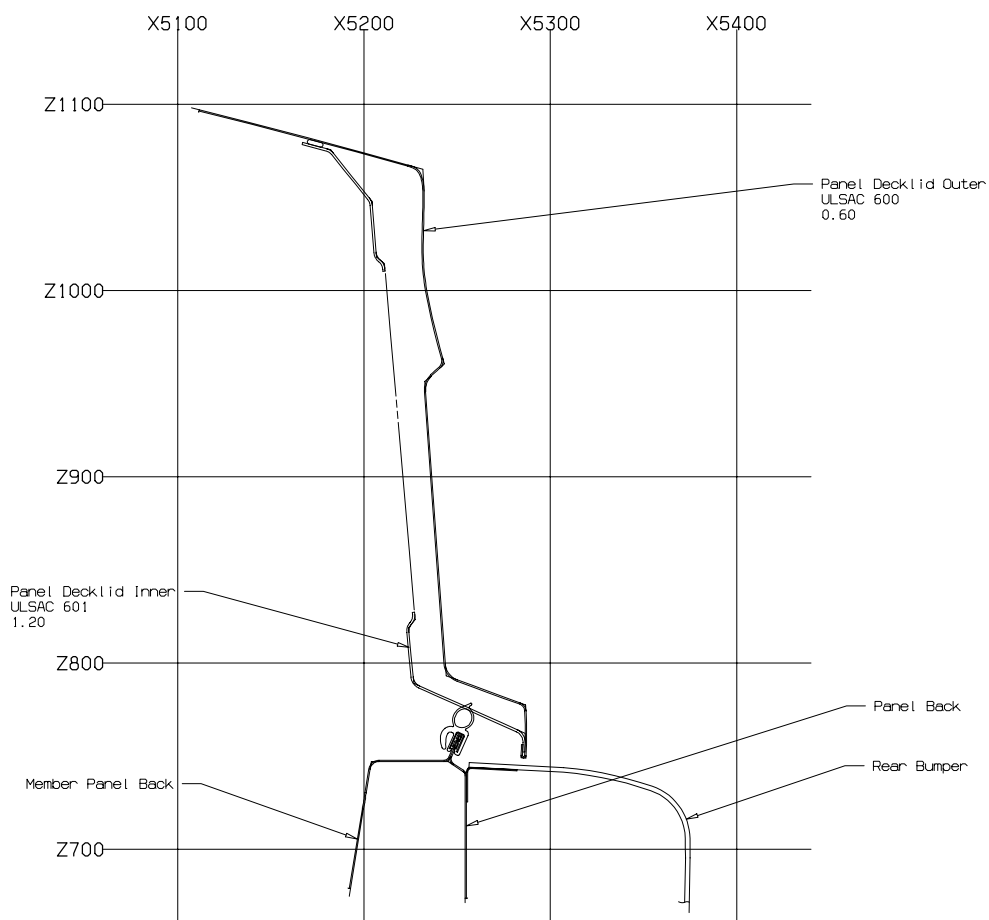




Conceptual Design

Selected Design Concepts - Decklid Conventional - Typical Sections

Section C6

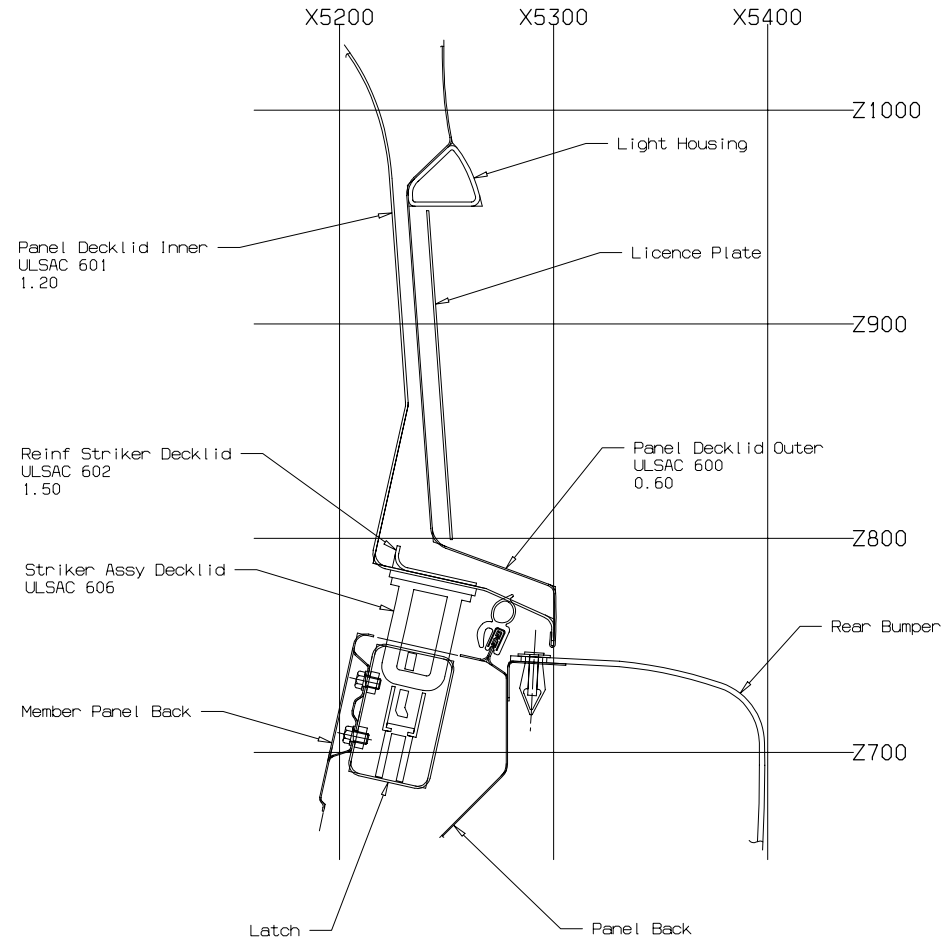




Conceptual Design

Selected Design Concepts - Decklid Conventional - Typical Sections

Section D6

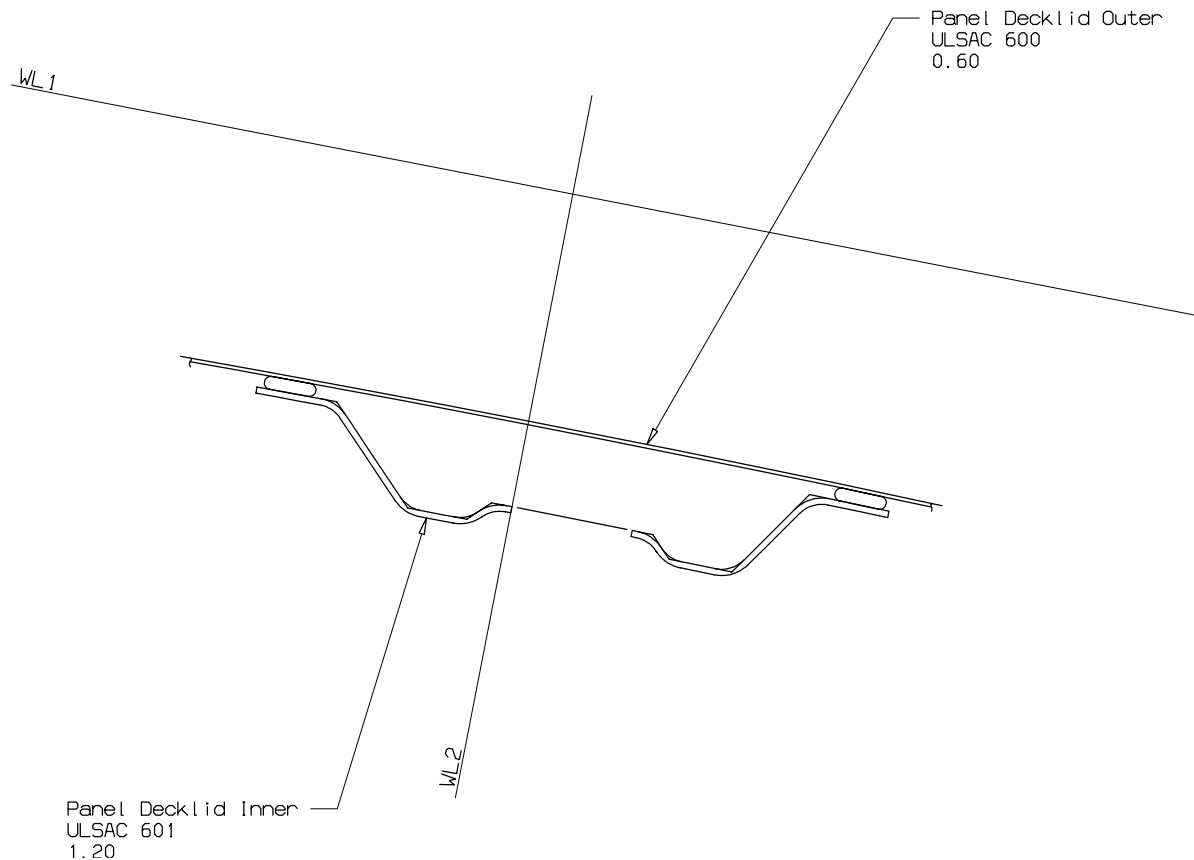




Conceptual Design

Selected Design Concepts - Decklid Conventional - Typical Sections

Section E6

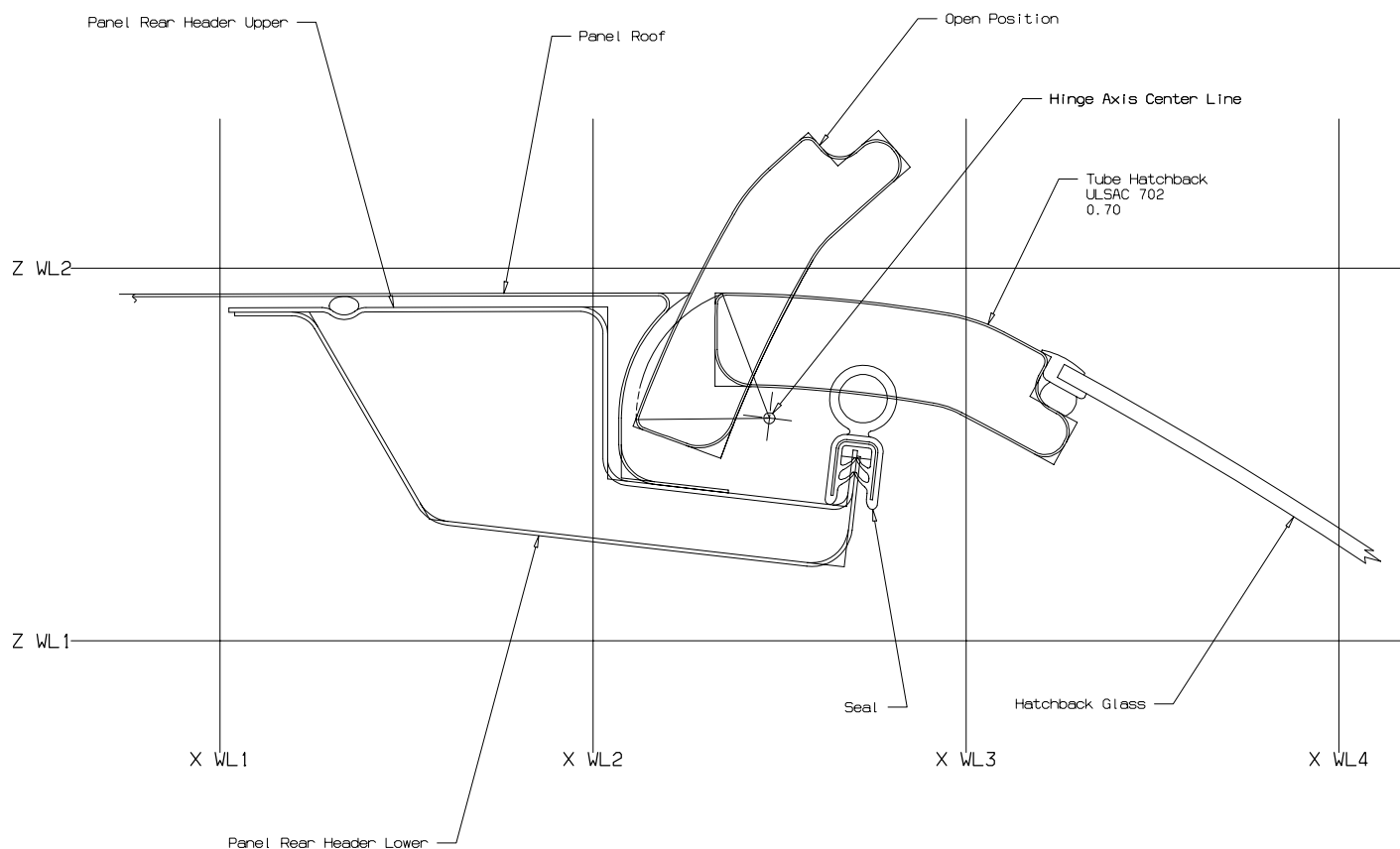




Conceptual Design

Selected Design Concepts - Hatchbacks Tube Hydroformed - Typical Sections

Section A7

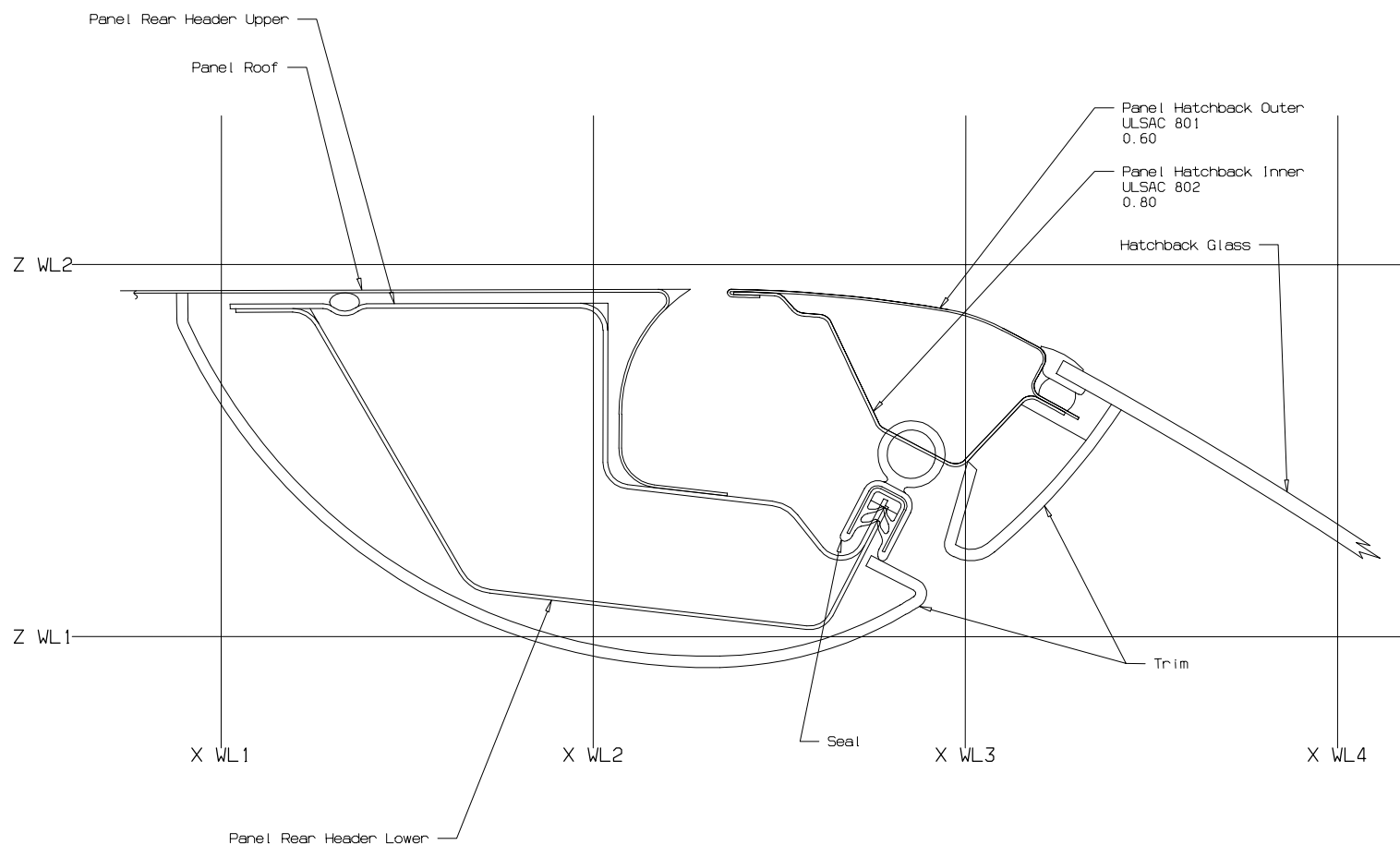




Conceptual Design

Selected Design Concepts - Hatchbacks Tailored Blank - Typical Sections

Section A8

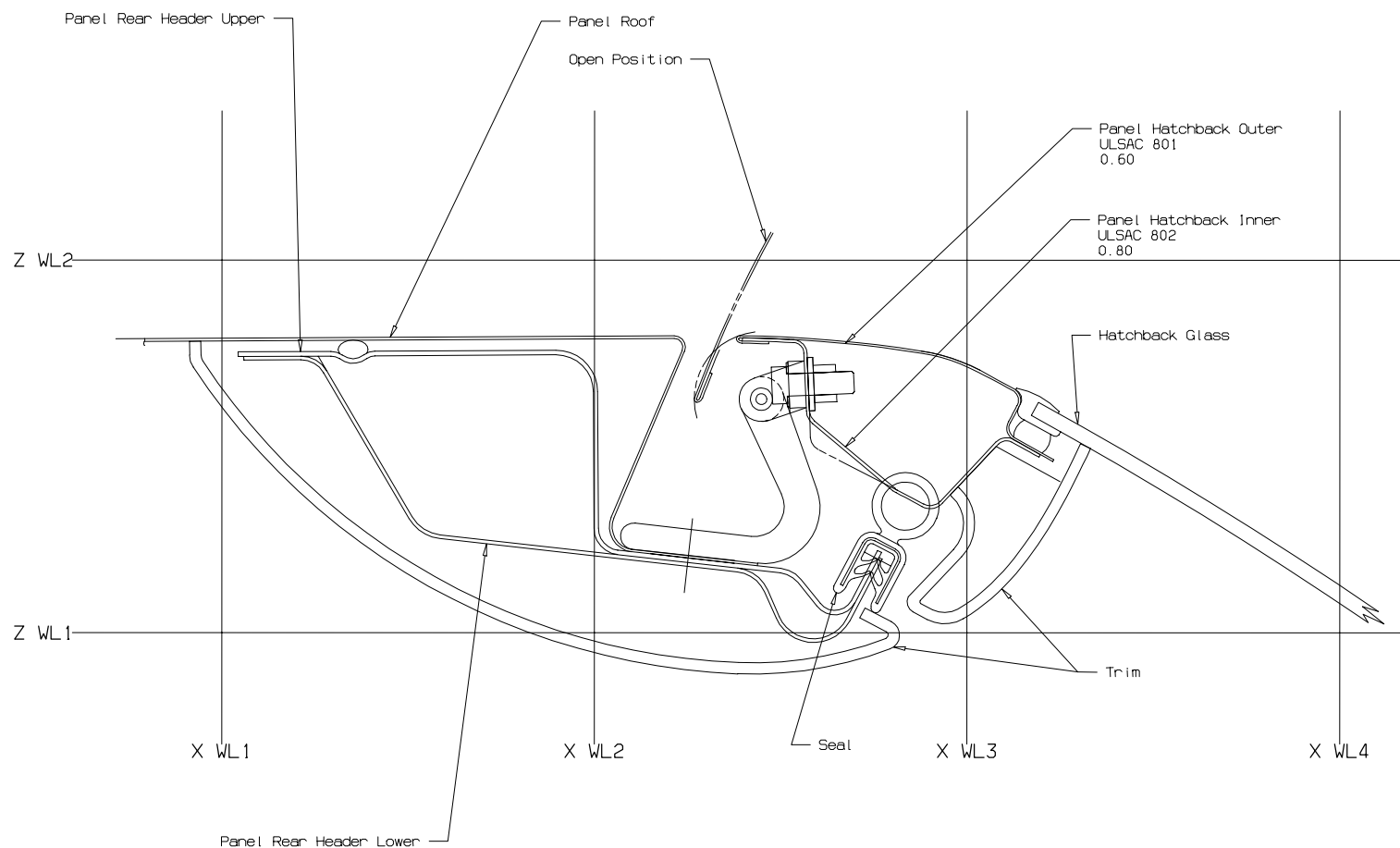




Conceptual Design

Selected Design Concepts - Hatchbacks Tailored Blank - Typical Sections

Section B8

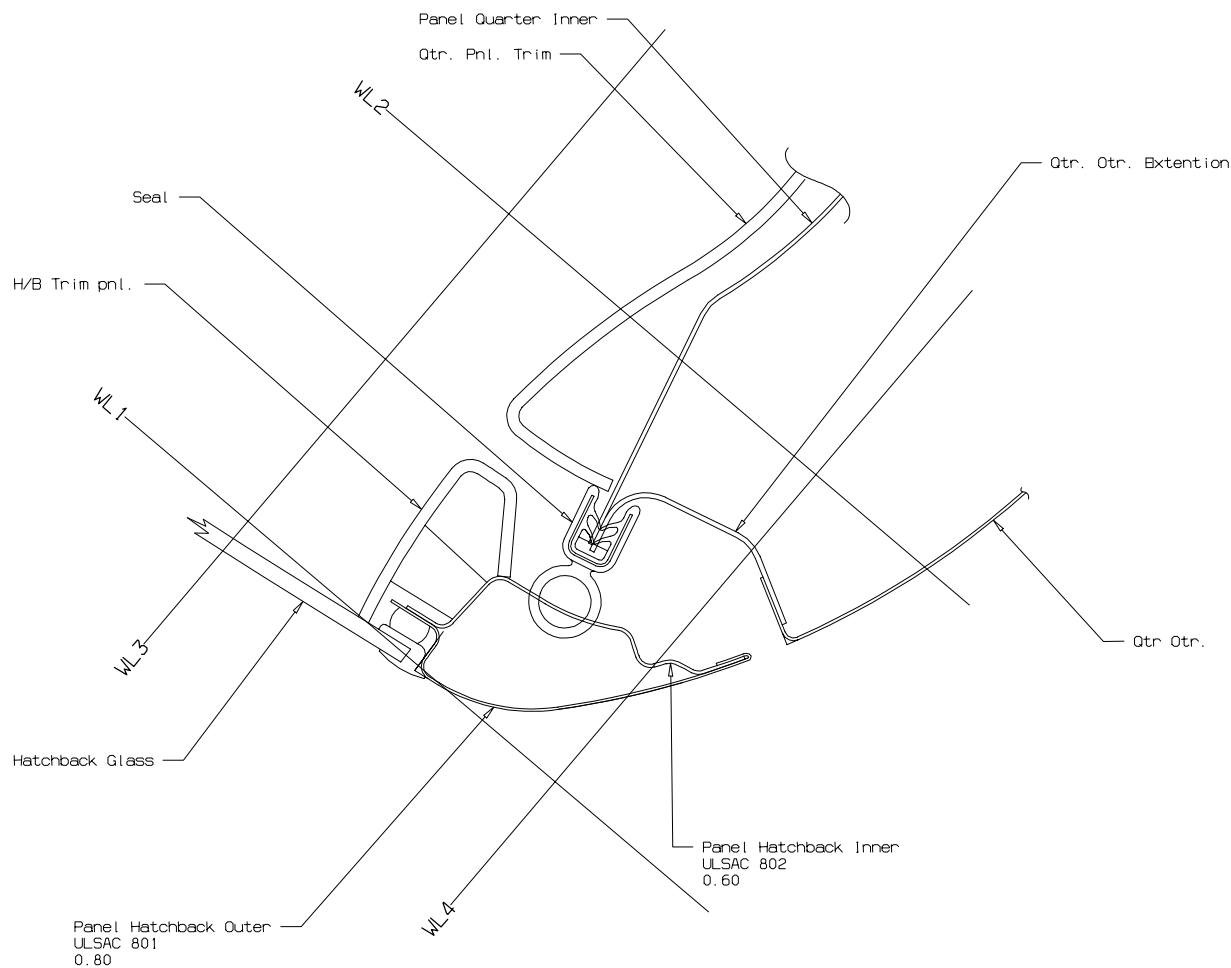




Conceptual Design

Selected Design Concepts - Hatchbacks Tailored Blank - Typical Sections

Section C8

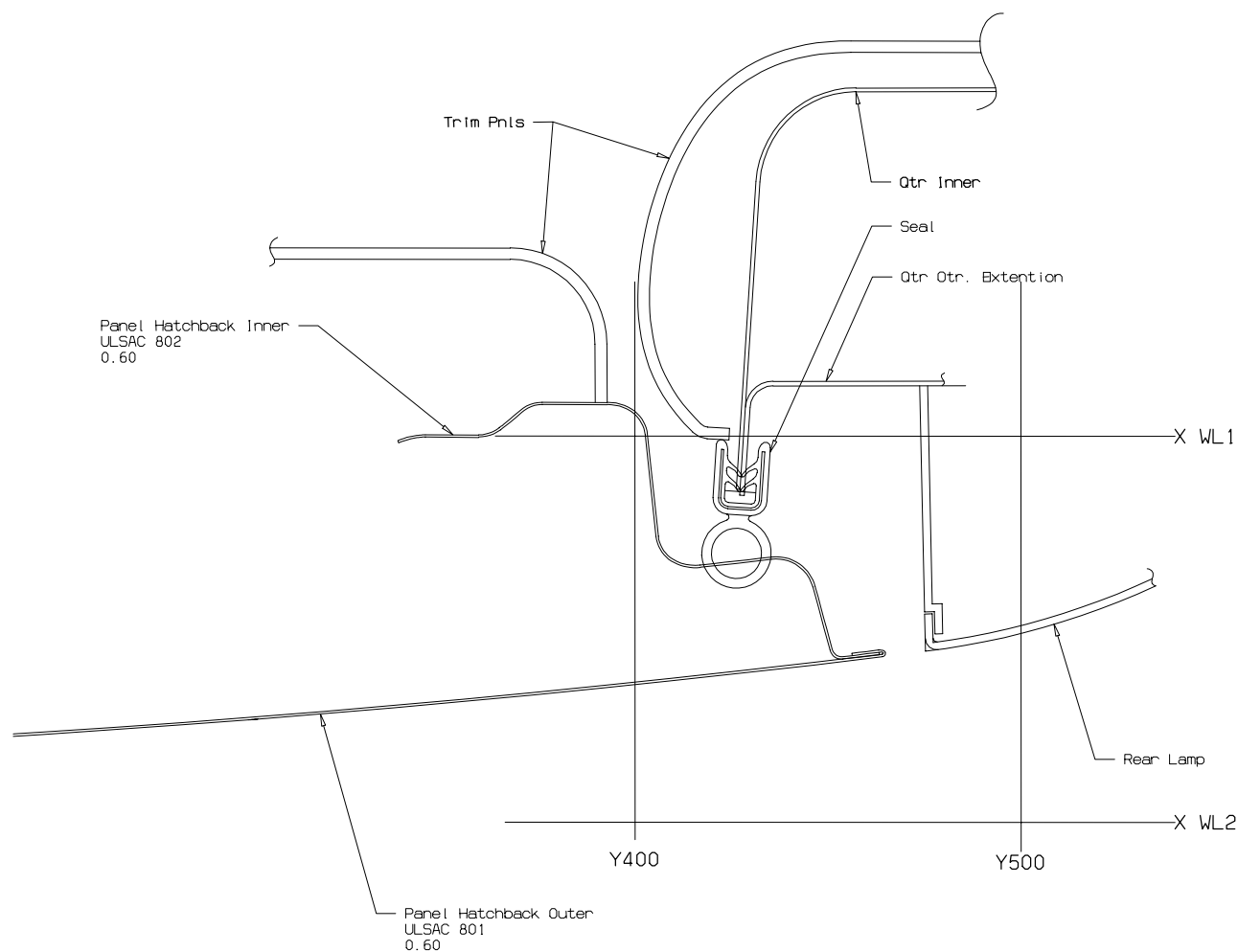




Conceptual Design

Selected Design Concepts - Hatchbacks Tailored Blank - Typical Sections

Section D8

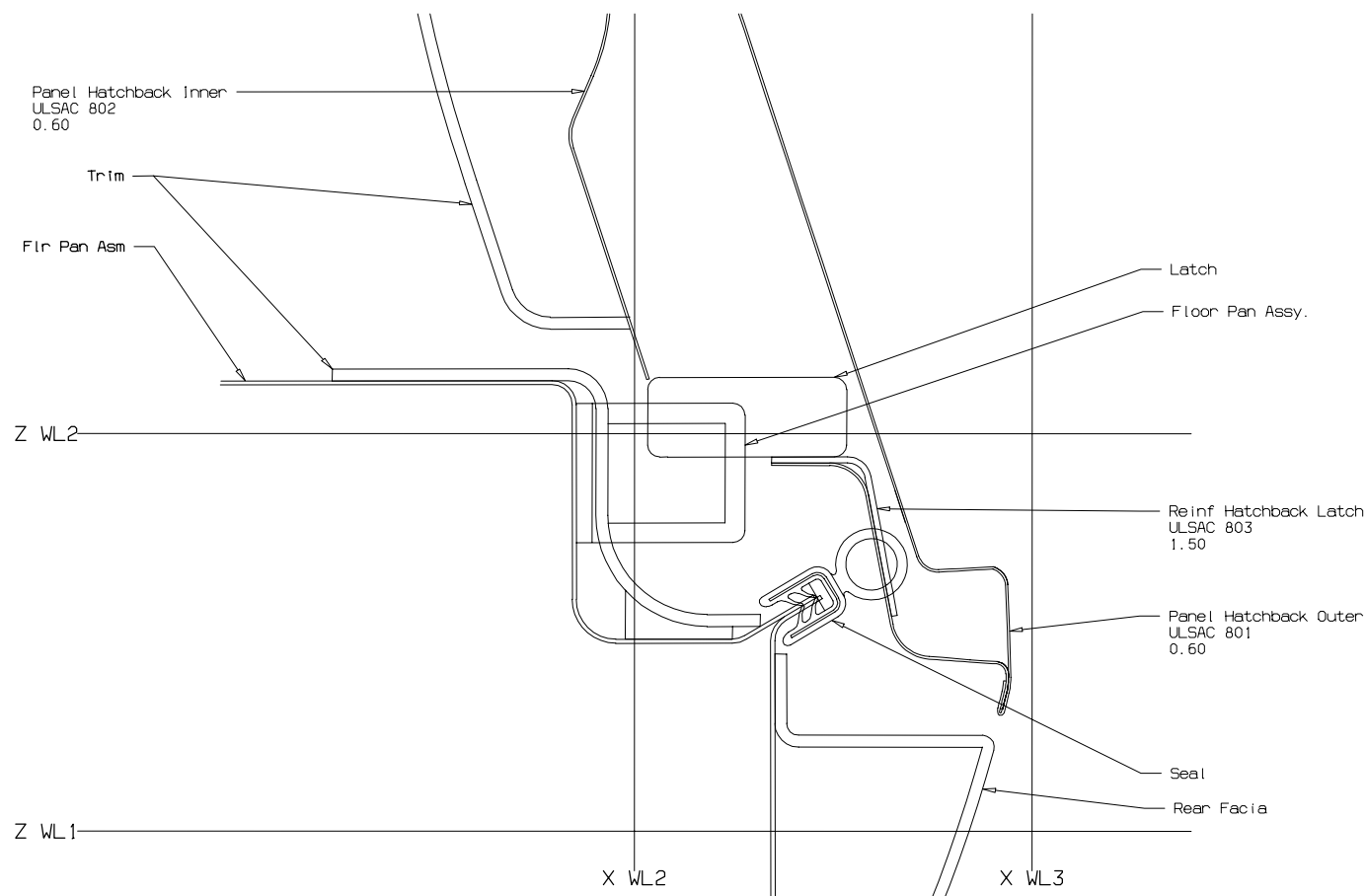




Conceptual Design

Selected Design Concepts - Hatchbacks Tailored Blank - Typical Sections

Section E8

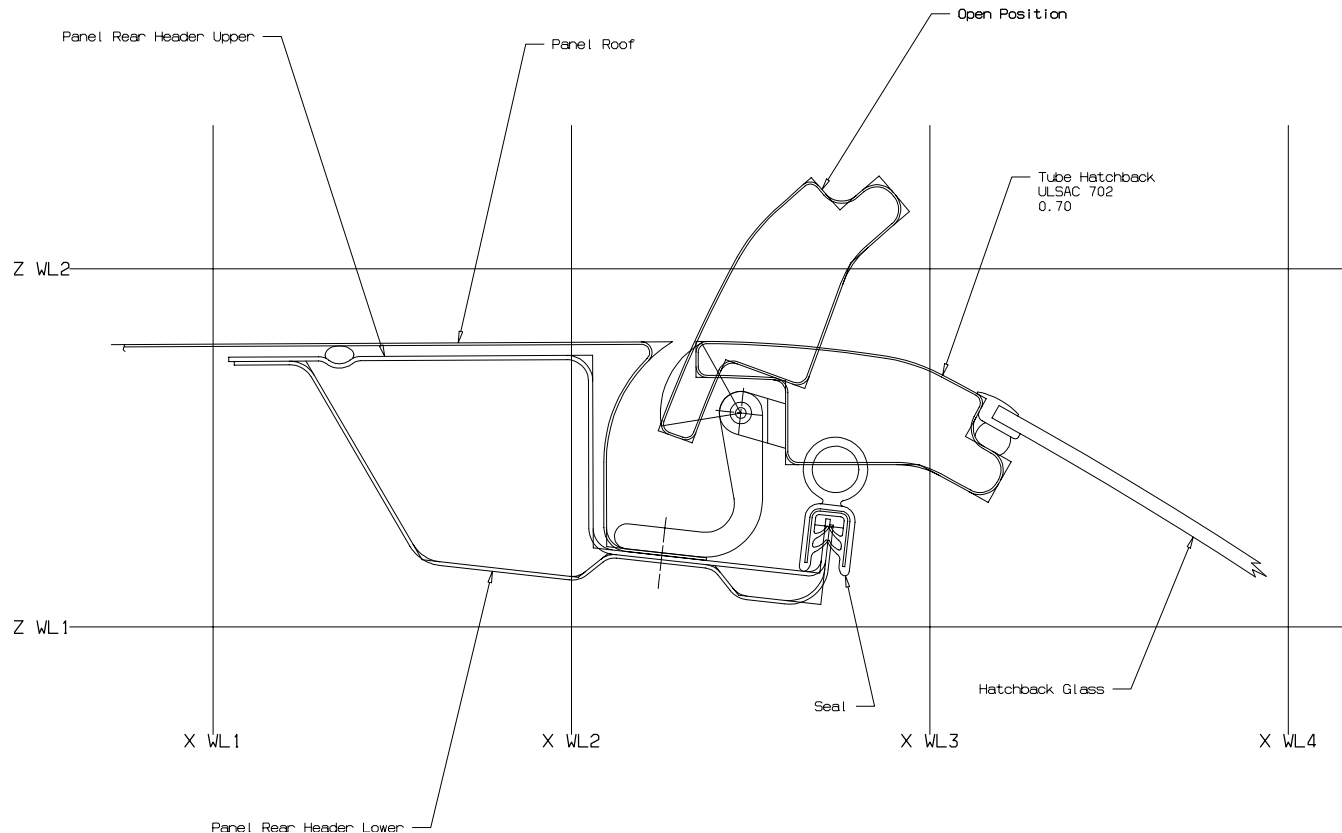




Conceptual Design

Selected Design Concepts - Hatchbacks Tube Hydroformed - Typical Sections

Section B7

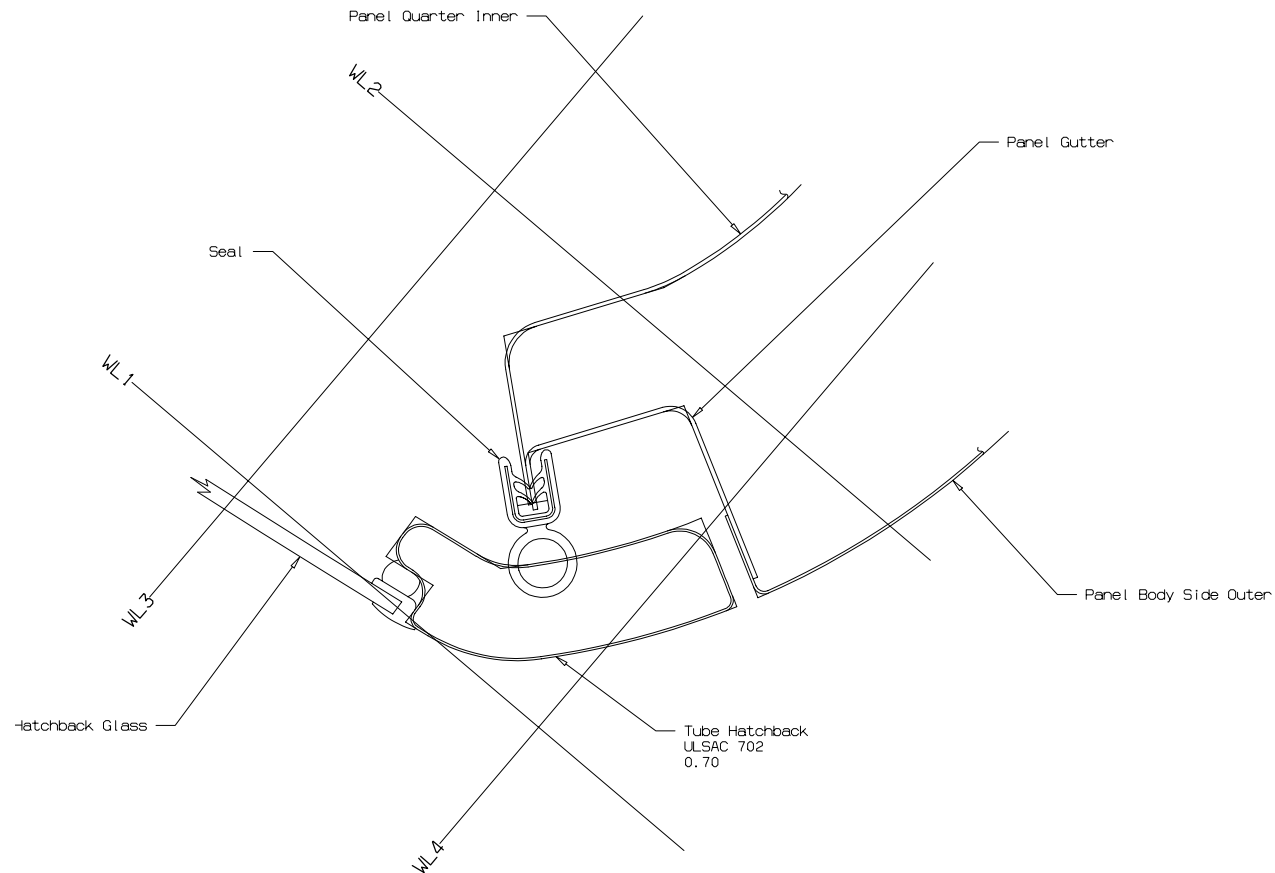




Conceptual Design

Selected Design Concepts - Hatchbacks Tube Hydroformed - Typical Sections

Section C7

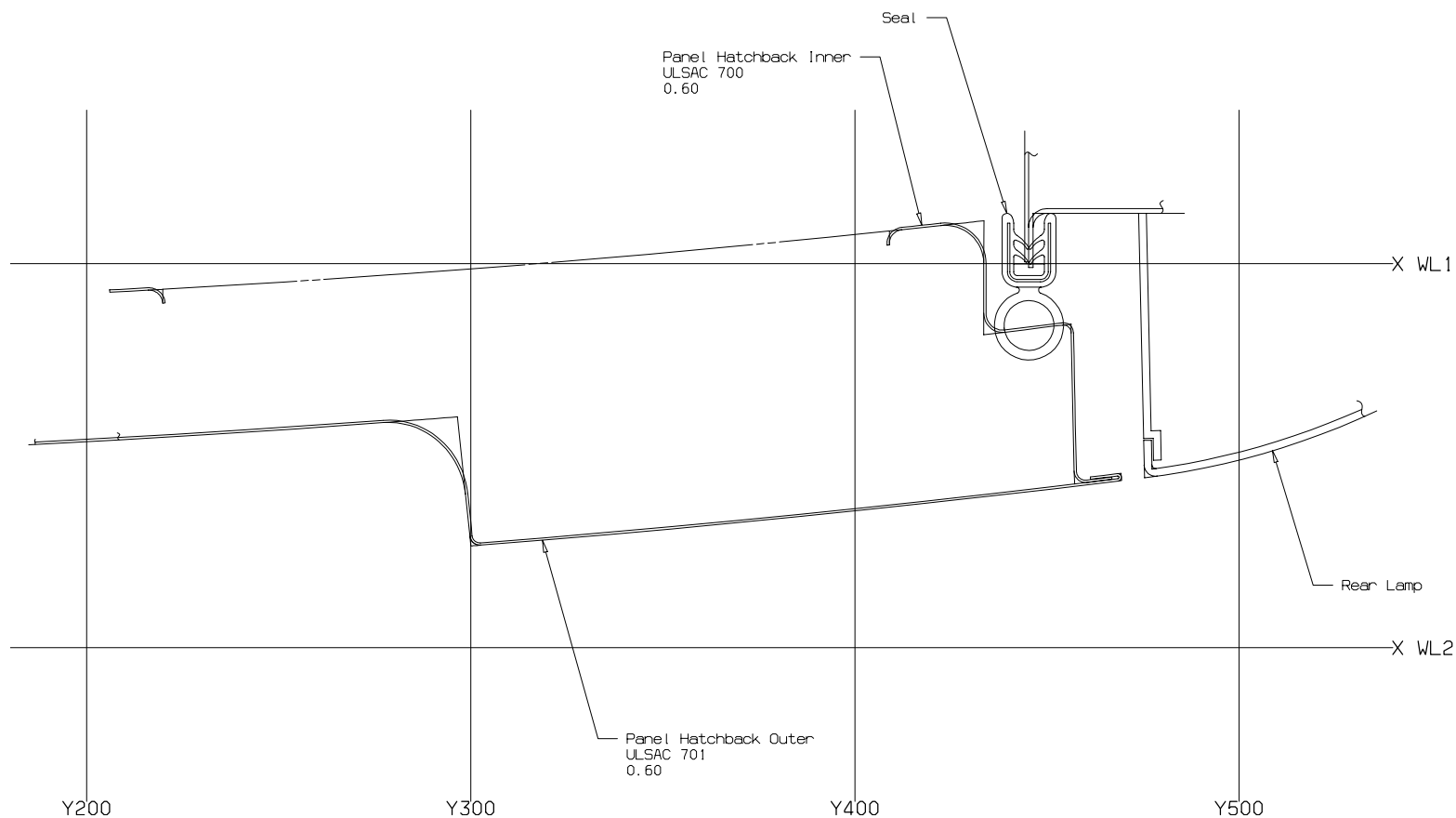




Conceptual Design

Selected Design Concepts - Hatchbacks Tube Hydroformed - Typical Sections

Section D7

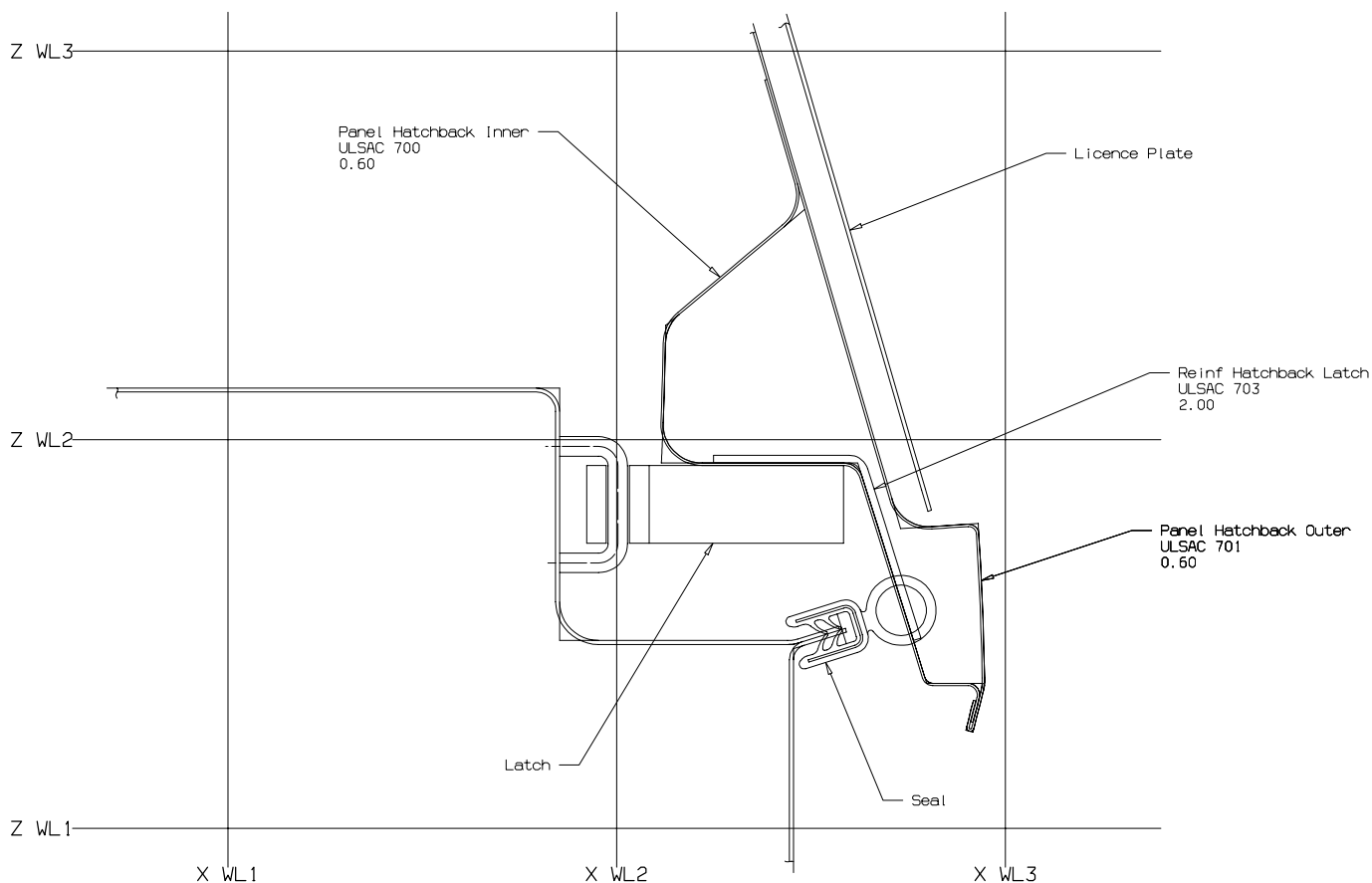




Conceptual Design

Selected Design Concepts - Hatchbacks Tube Hydroformed - Typical Sections

Section E7

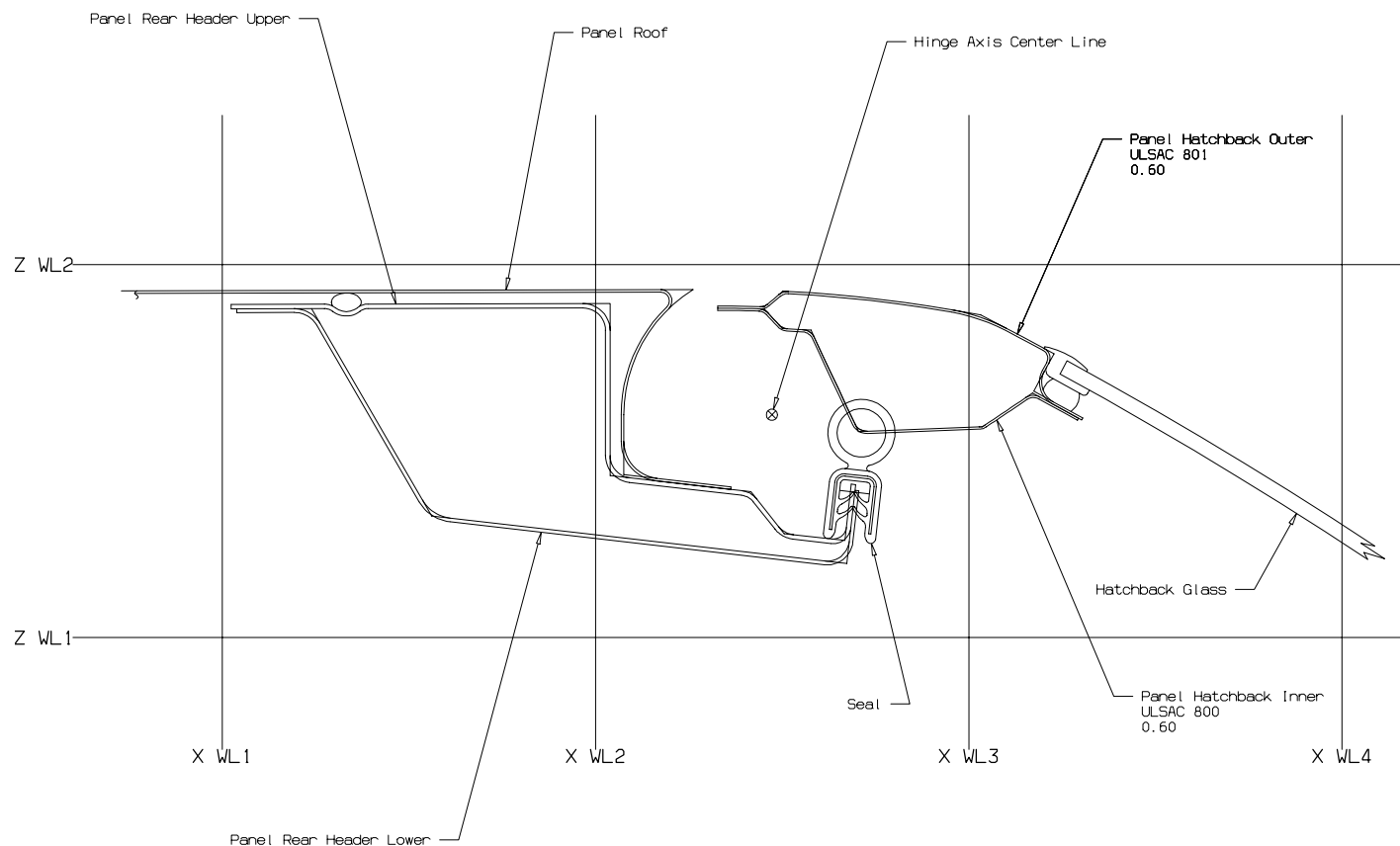




Conceptual Design

Selected Design Concepts - Hatchbacks Sheet Hydroformed - Typical Sections

Section A9.5

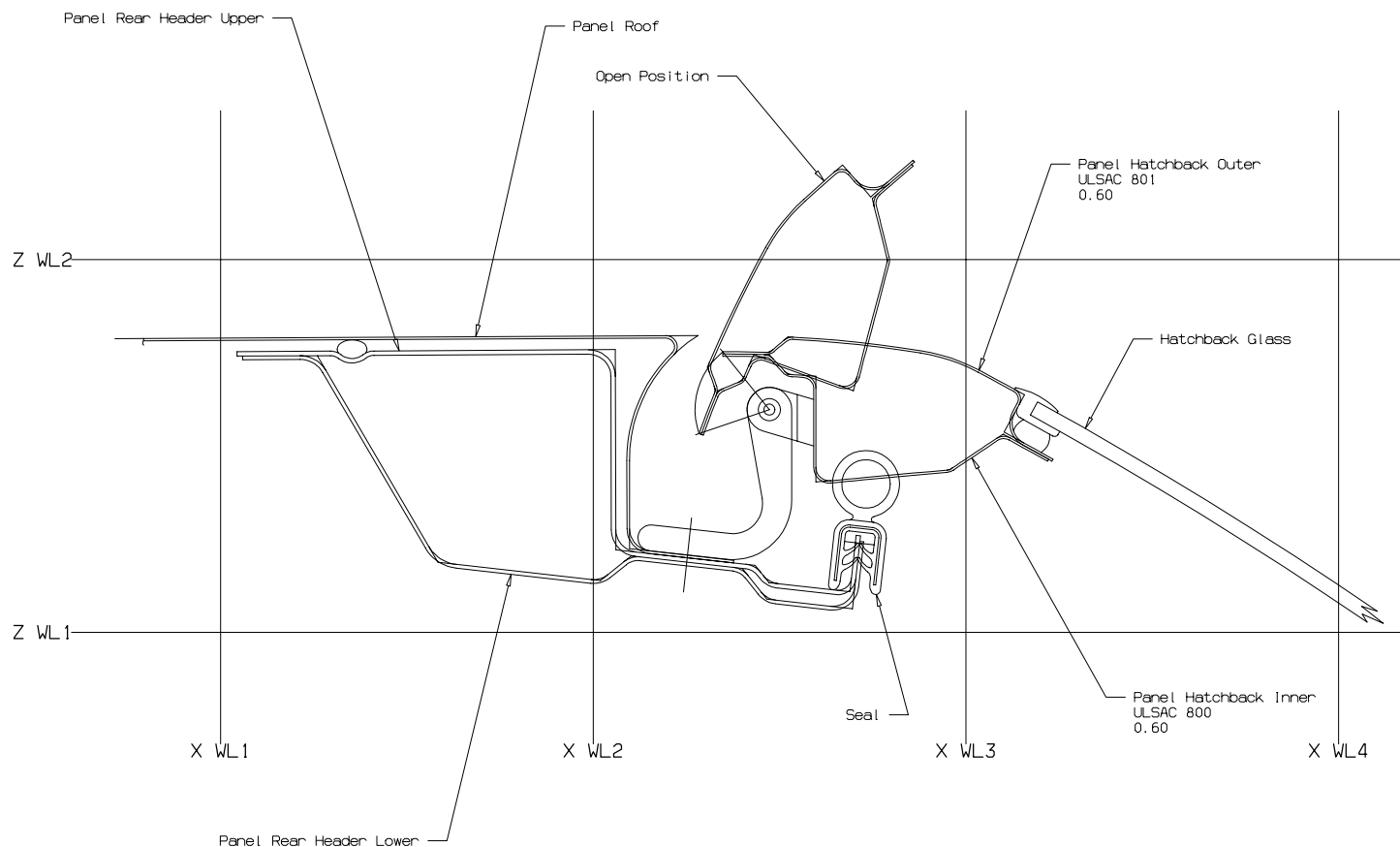




Conceptual Design

Selected Design Concepts - Hatchbacks Sheet Hydroformed - Typical Sections

Section B9.5

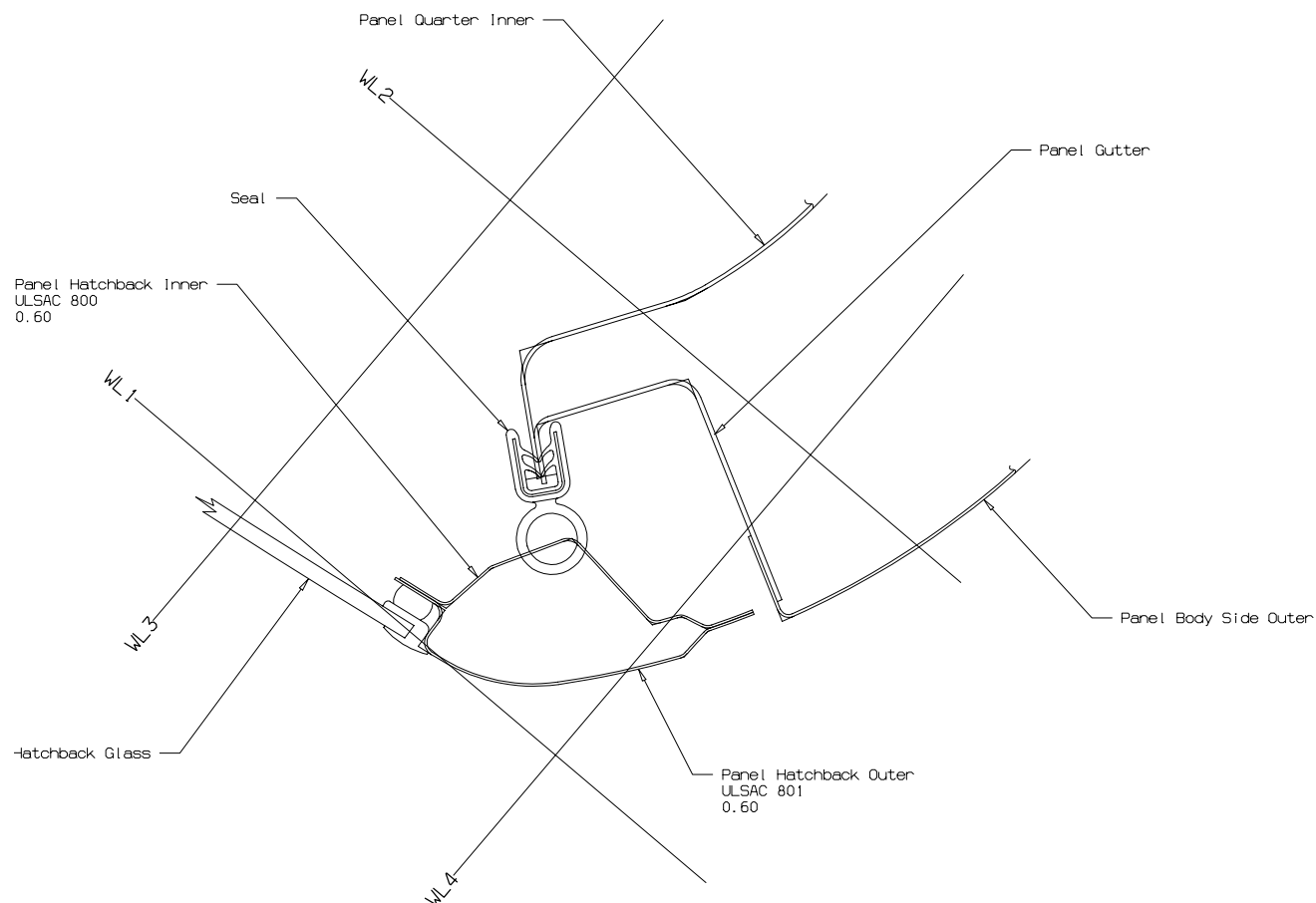




Conceptual Design

Selected Design Concepts - Hatchbacks Sheet Hydroformed - Typical Sections

Section C9.5

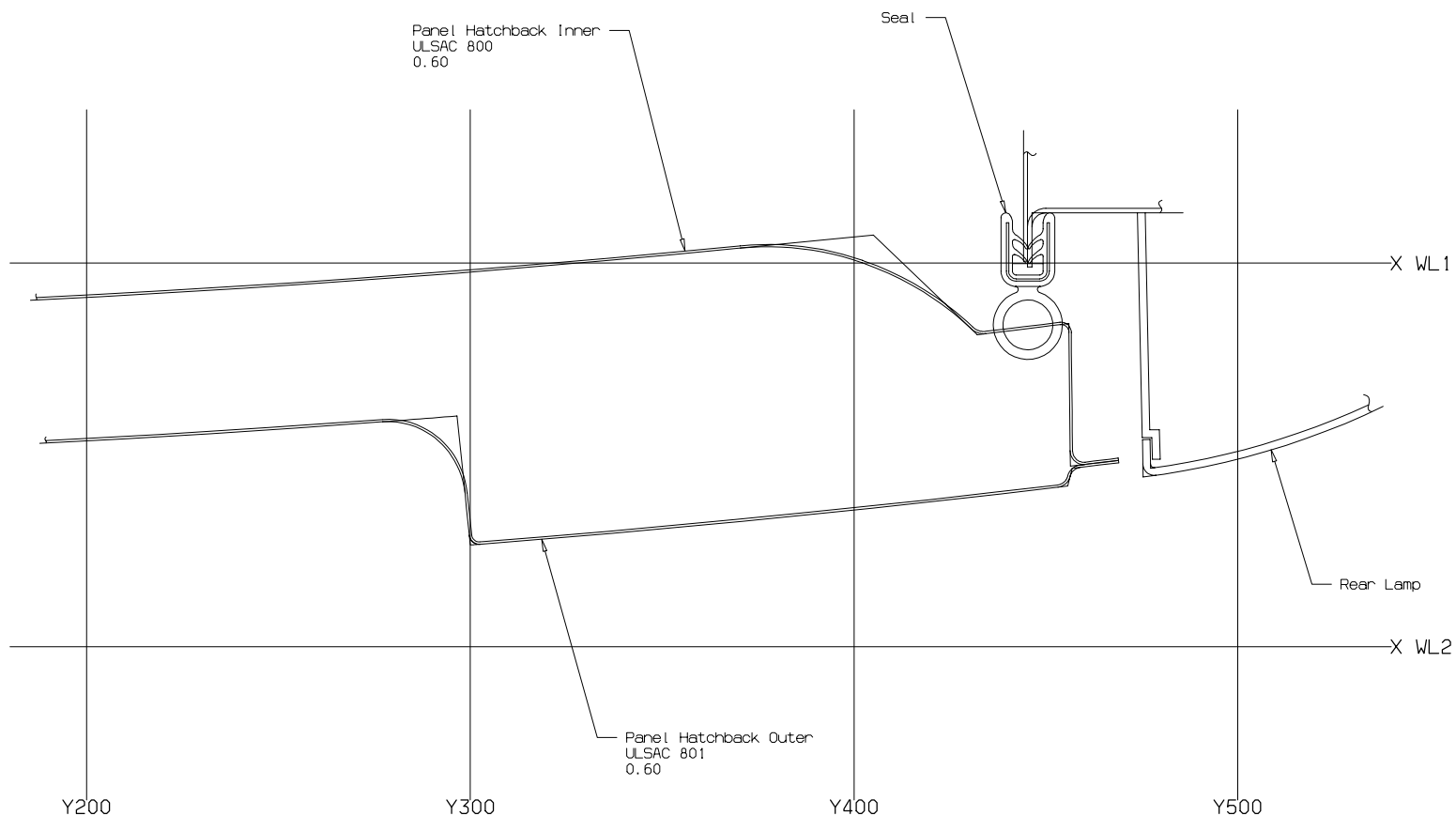




Conceptual Design

Selected Design Concepts - Hatchbacks Sheet Hydroformed - Typical Sections

Section D9.5

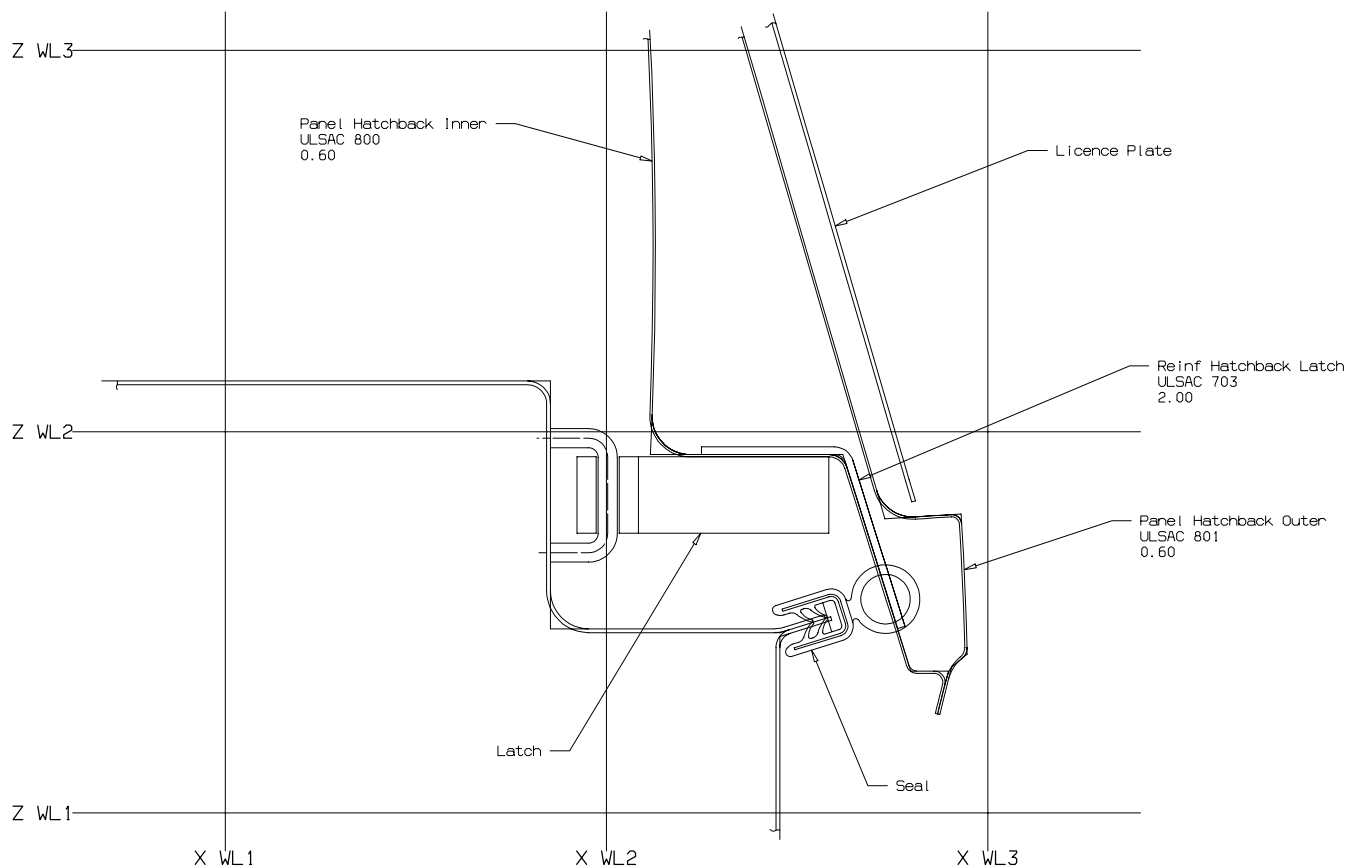




Conceptual Design

Selected Design Concepts - Hatchbacks Sheet Hydroformed - Typical Sections

Section E9.5

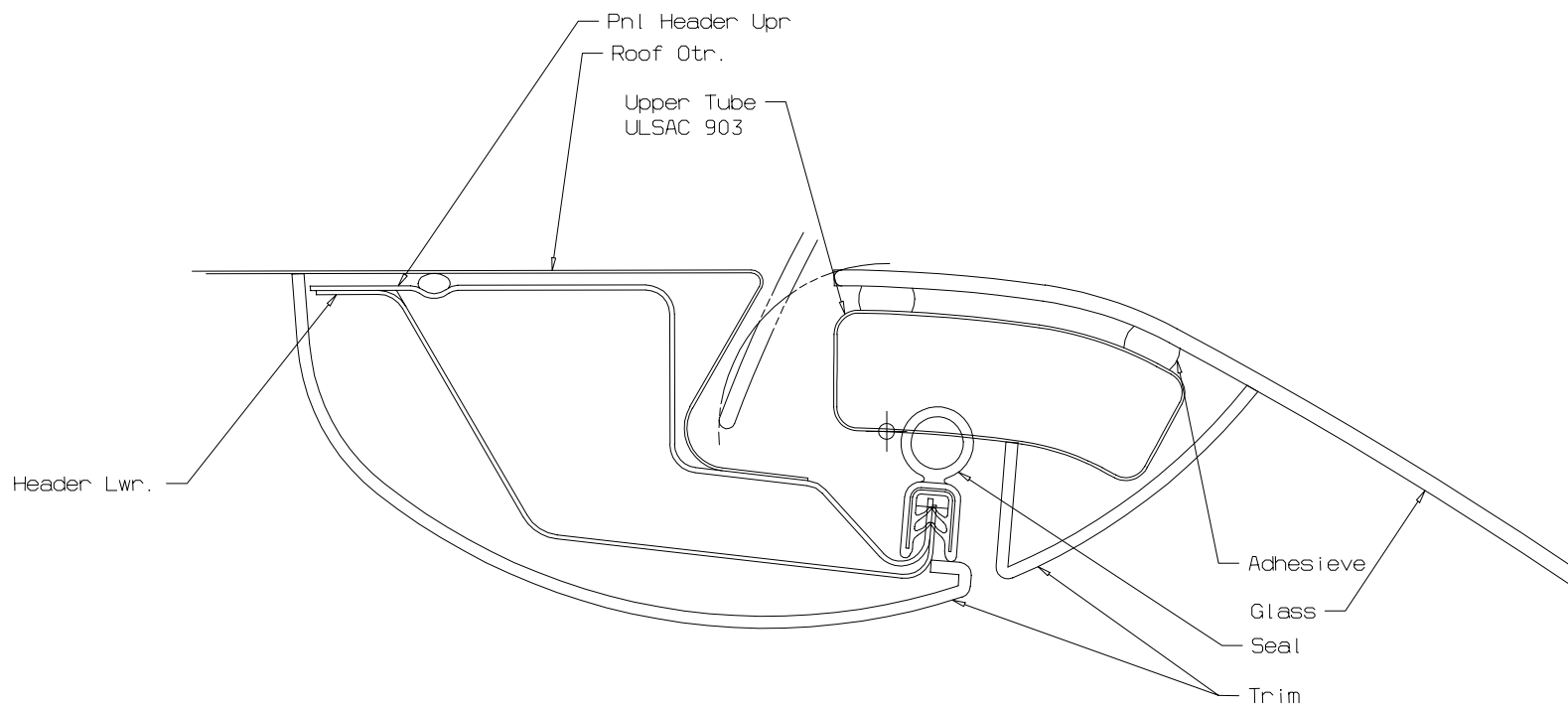




Conceptual Design

Selected Design Concepts - Hatchbacks Hydroformed Ring - Typical Sections

Section A9

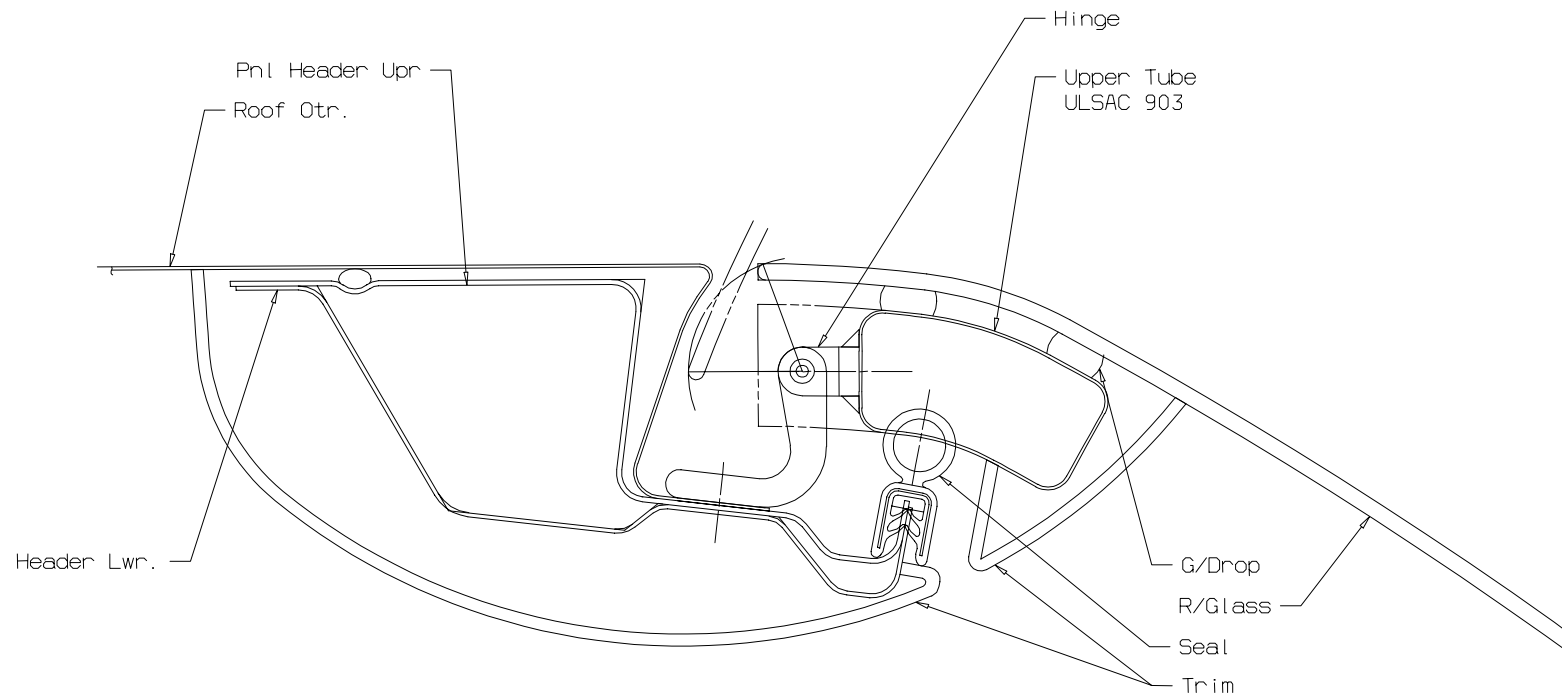




Conceptual Design

Selected Design Concepts - Hatchbacks Hydroformed Ring - Typical Sections

Section B9

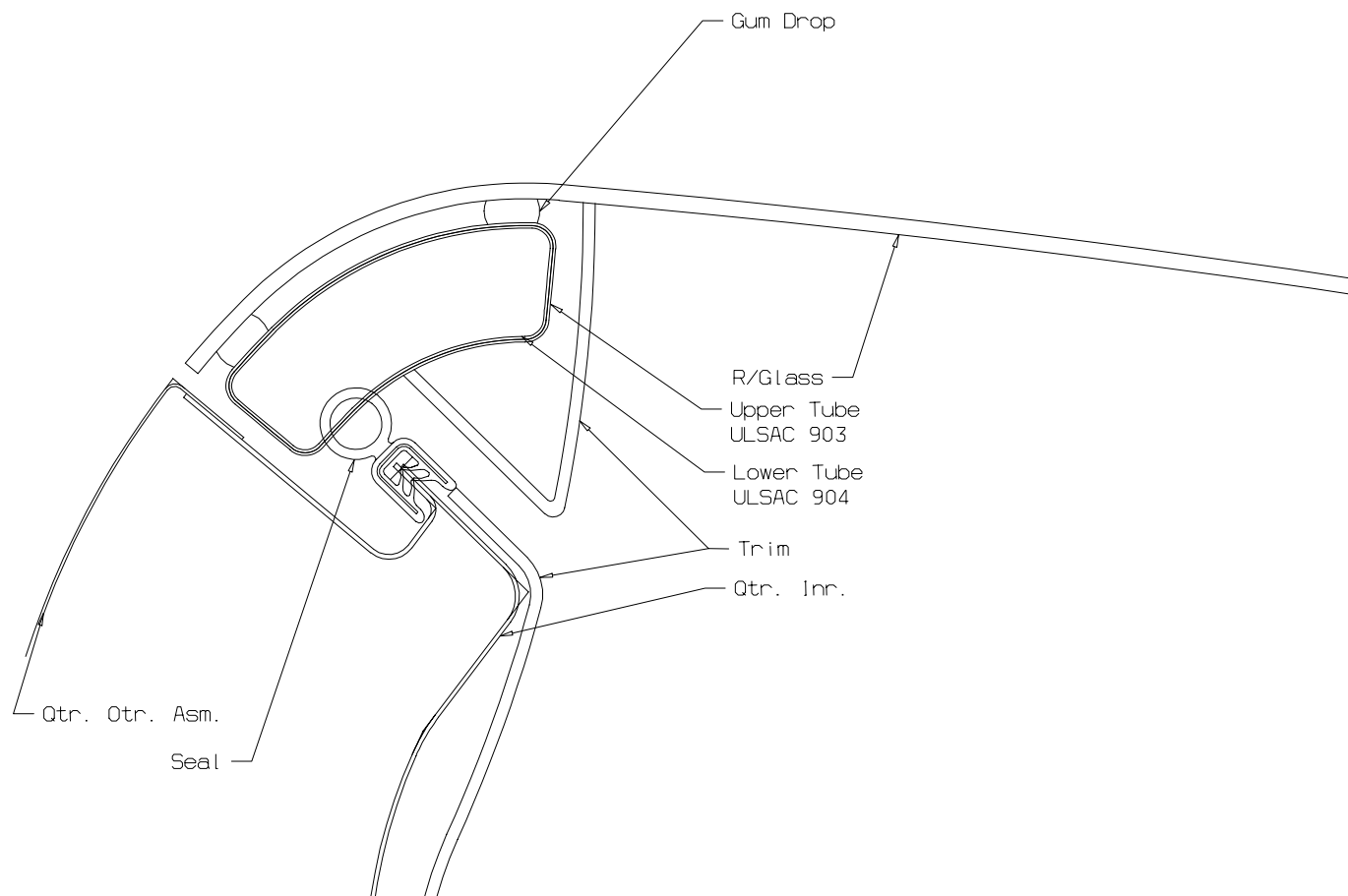




Conceptual Design

Selected Design Concepts - Hatchbacks Hydroformed Ring - Typical Sections

Section C9

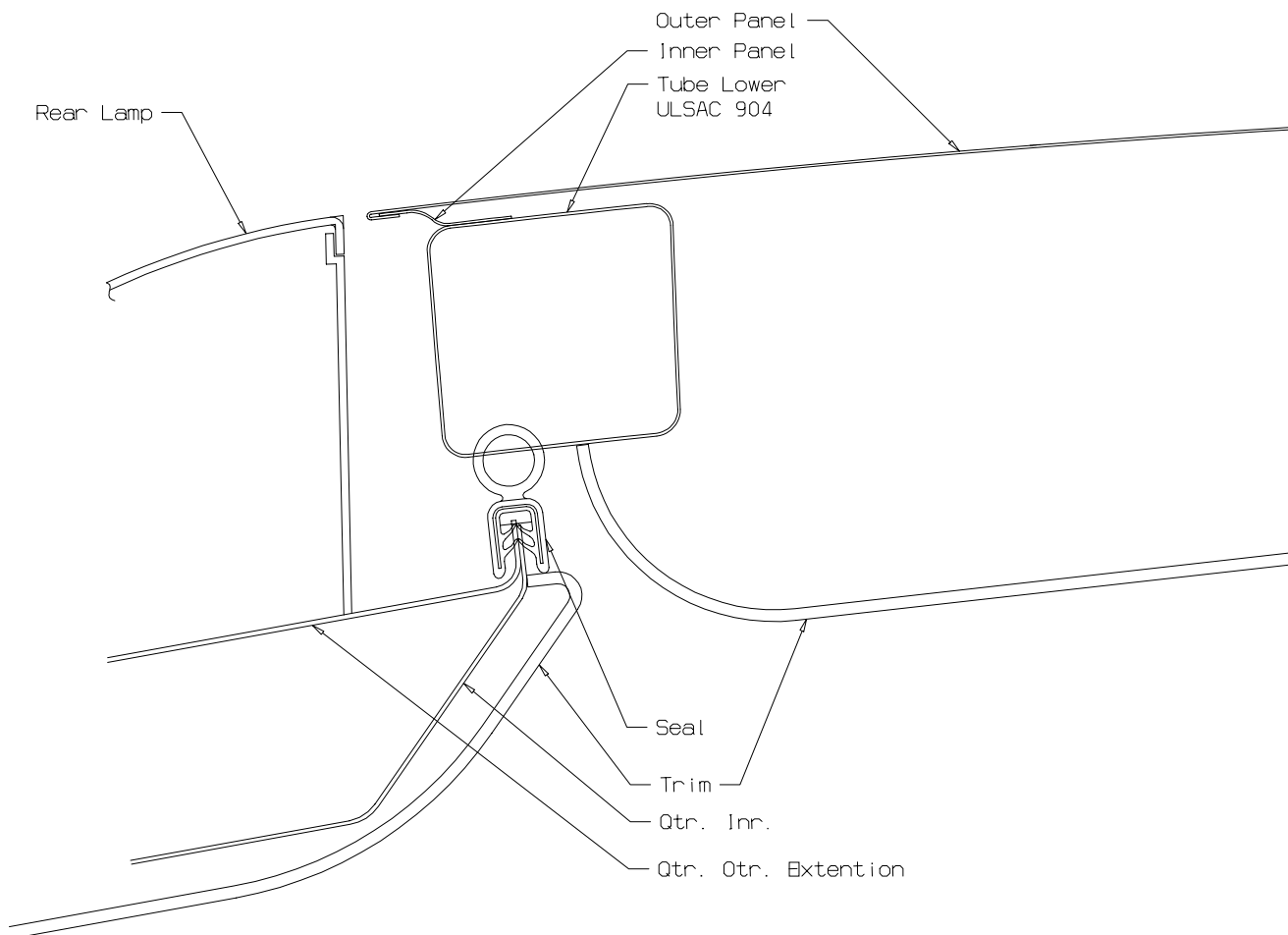




Conceptual Design

Selected Design Concepts - Hatchbacks Hydroformed Ring - Typical Sections

Section D9

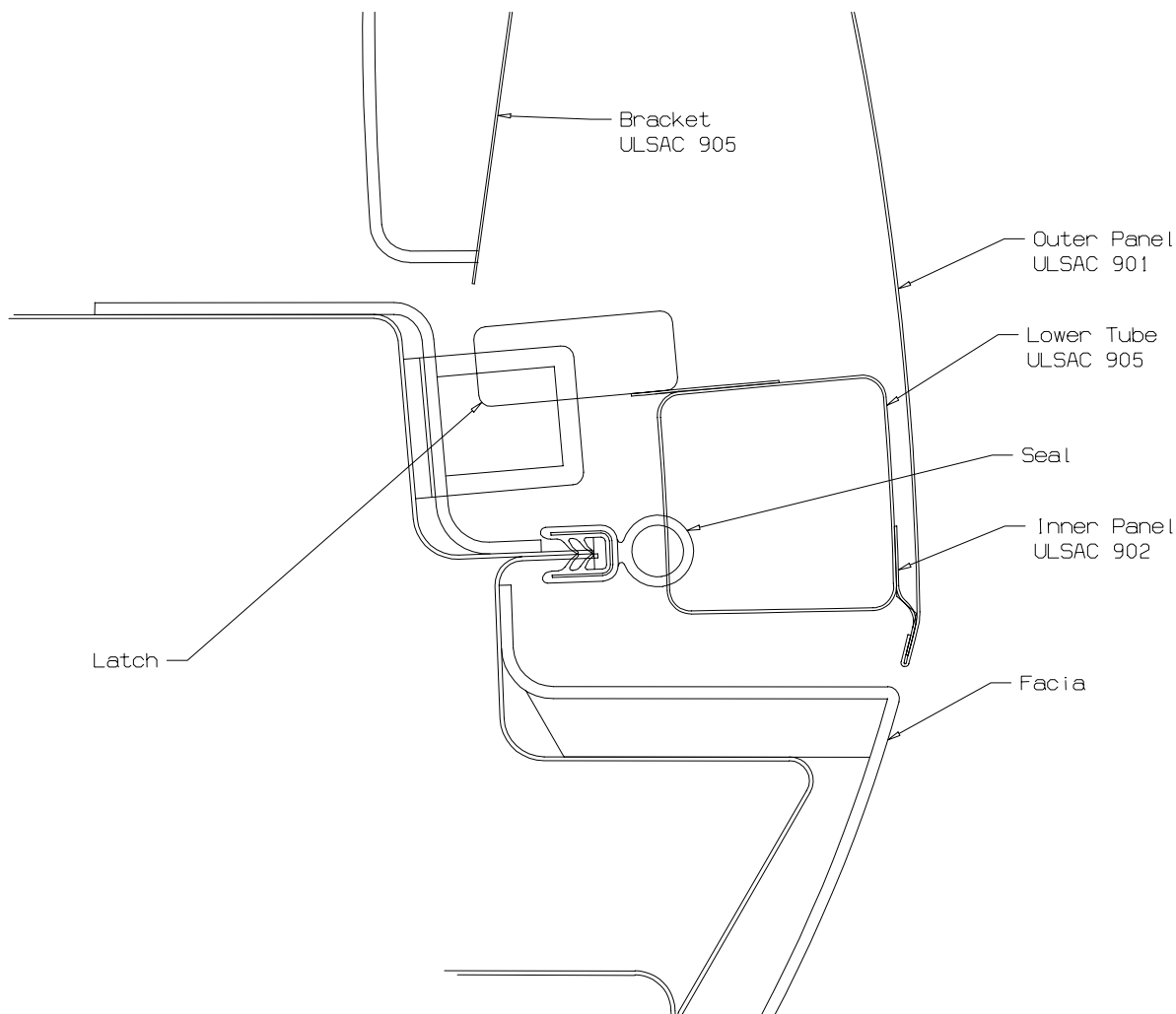




Conceptual Design

Selected Design Concepts - Hatchbacks Hydroformed Ring - Typical Sections

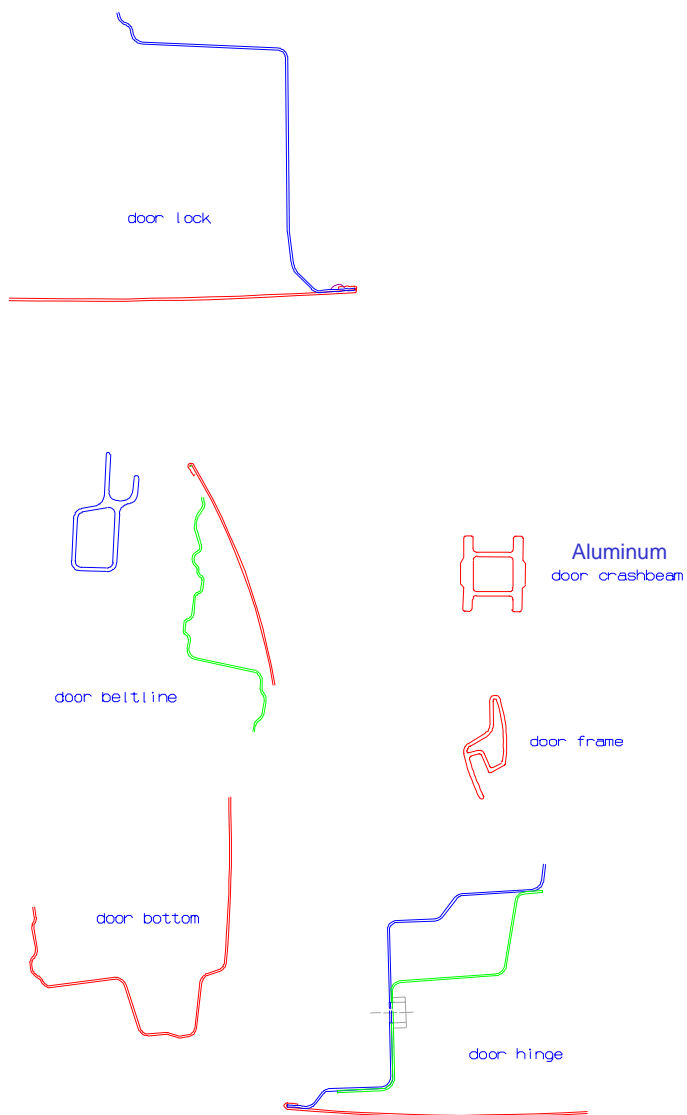
Section E9





Benchmarking

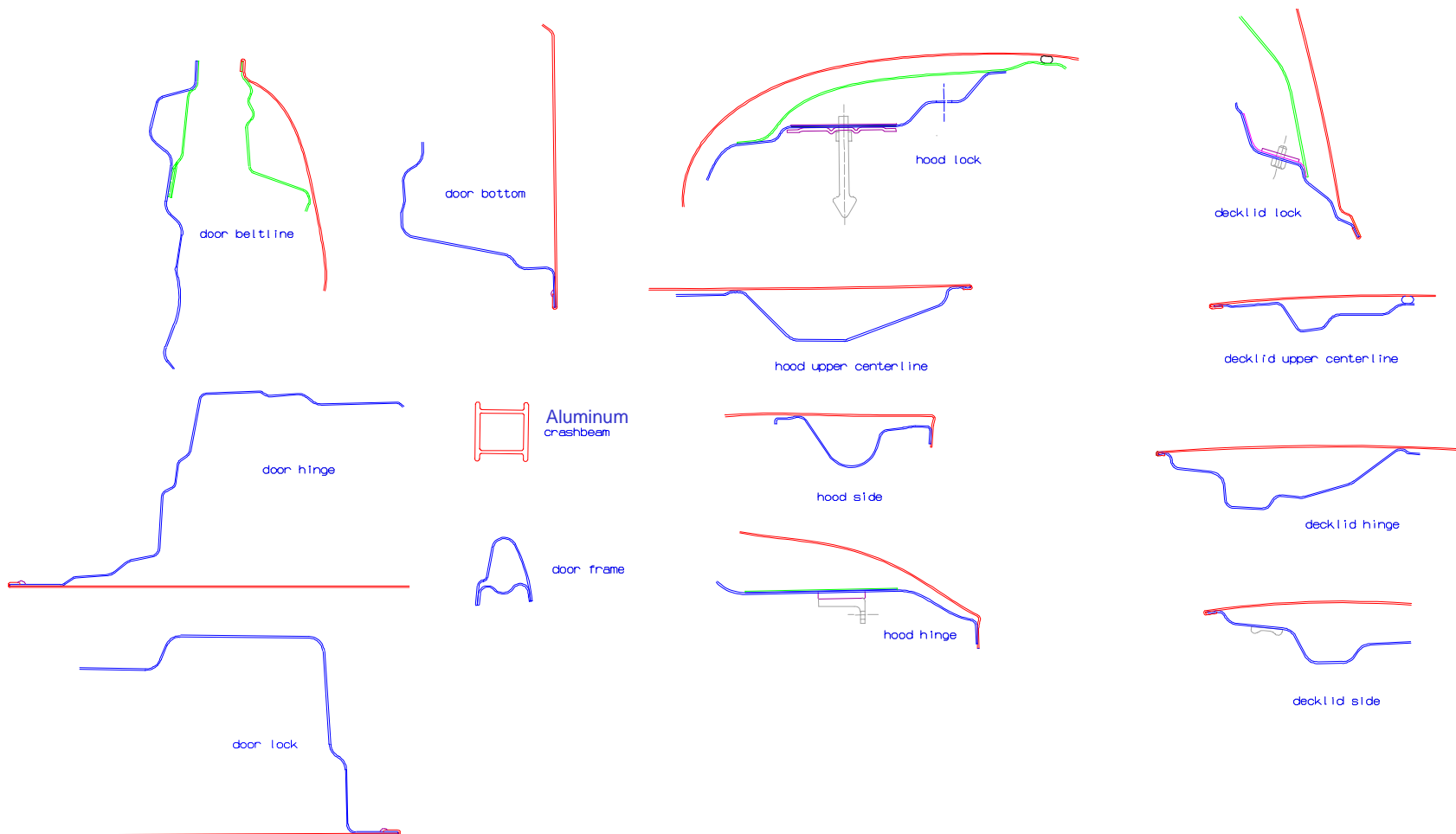
Typical Sections - Audi A6





Benchmarking

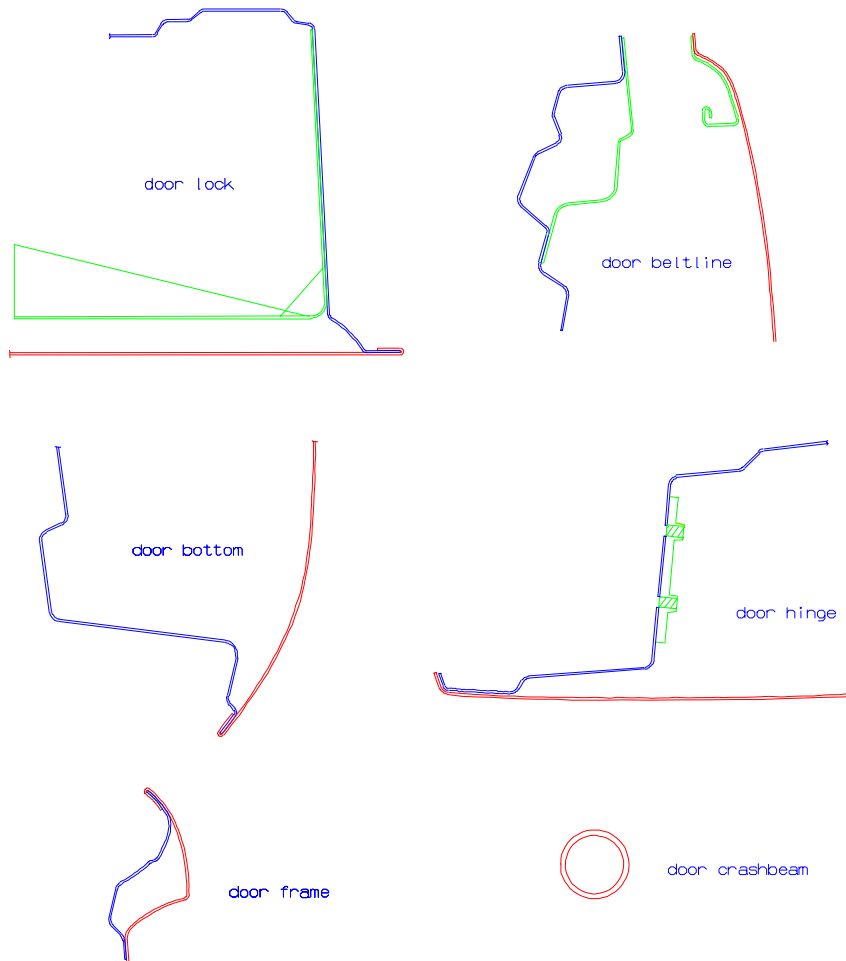
Typical Sections - BMW 528i





Benchmarking

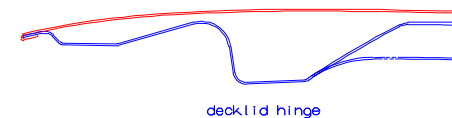
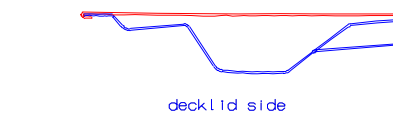
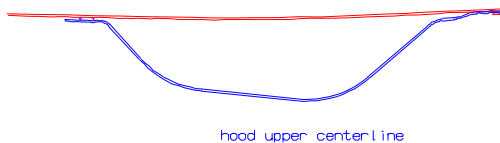
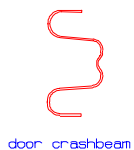
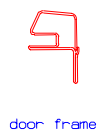
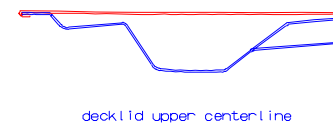
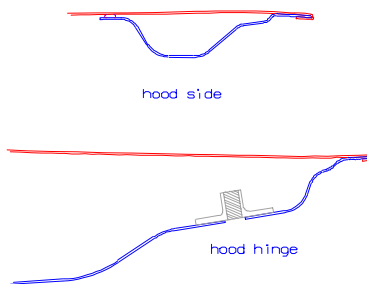
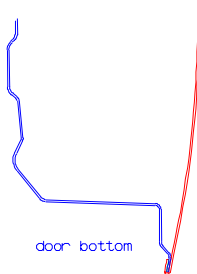
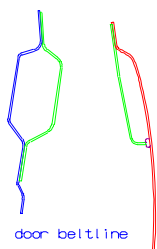
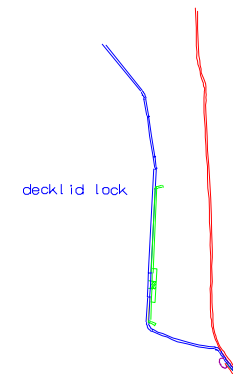
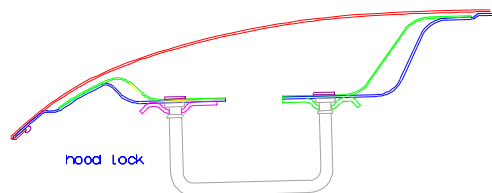
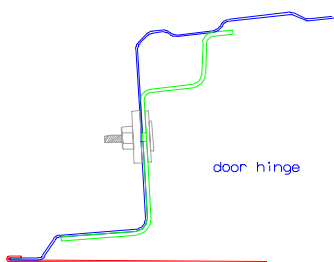
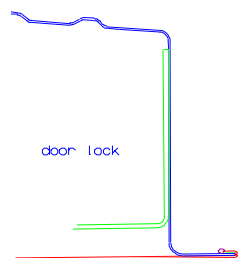
Typical Sections - Cadillac Sedan Deville





Benchmarking

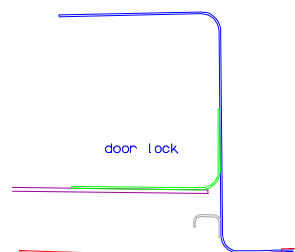
Typical Sections - Chevrolet Malibu



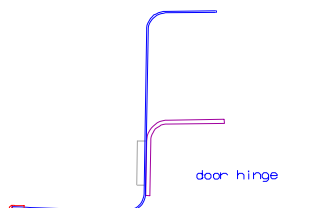


Benchmarking

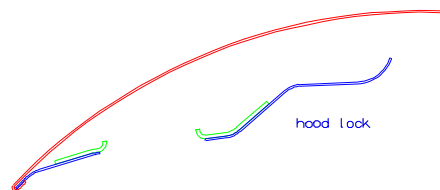
Typical Sections - Dodge Stratus



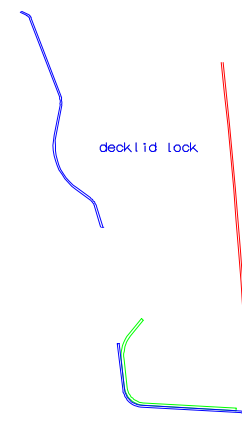
door lock



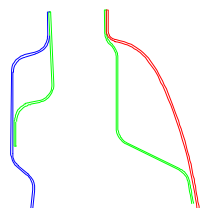
door hinge



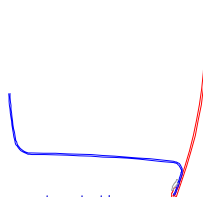
hood lock



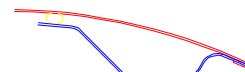
decklid lock



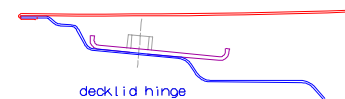
door beltline



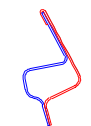
door bottom



hood side



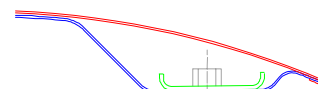
decklid hinge



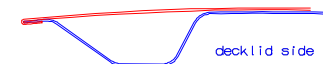
door frame



door crashbeam



hood hinge



decklid side



hood upper centerline



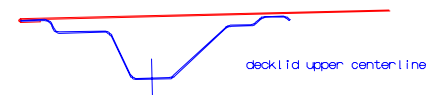
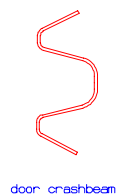
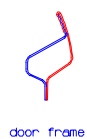
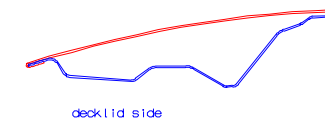
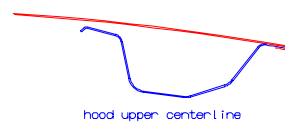
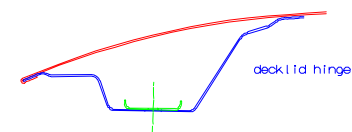
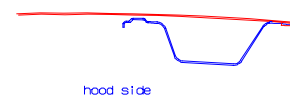
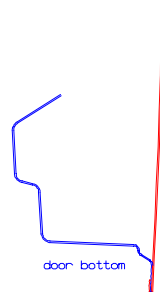
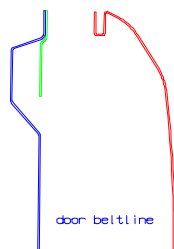
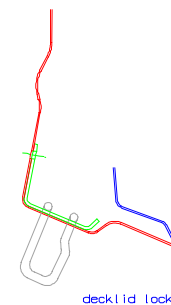
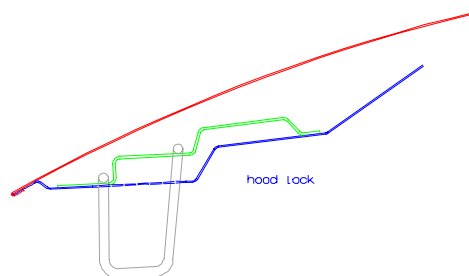
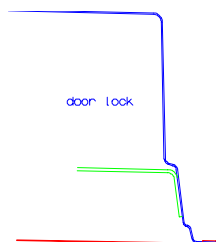
decklid upper centerline





Benchmarking

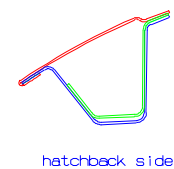
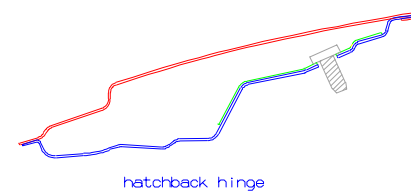
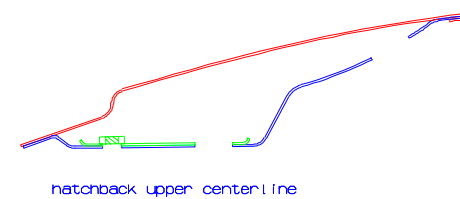
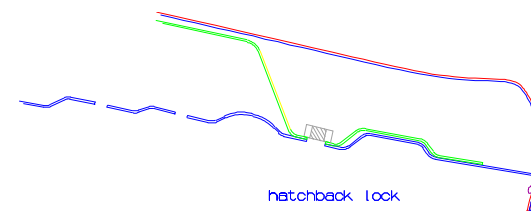
Typical Sections - Ford Contour





Benchmarking

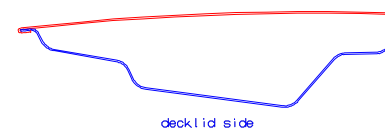
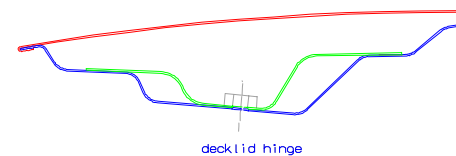
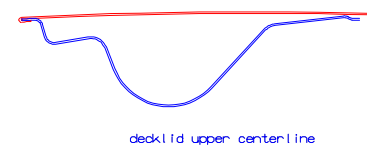
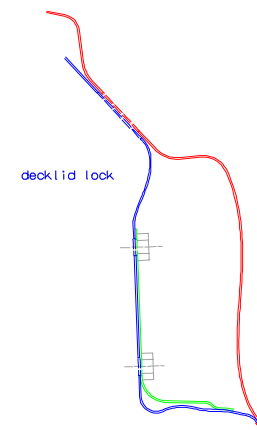
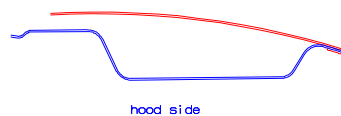
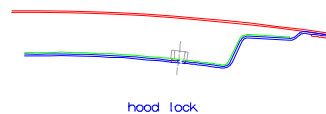
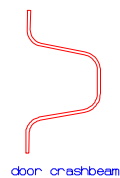
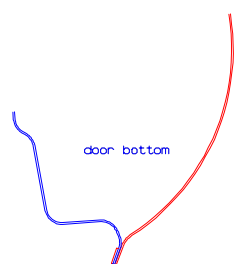
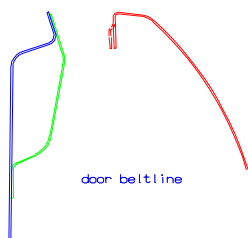
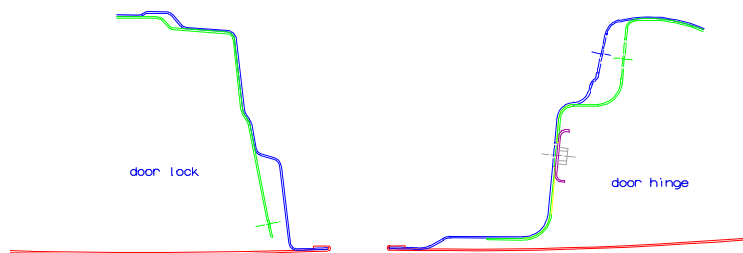
Typical Sections - Ford Probe





Benchmarking

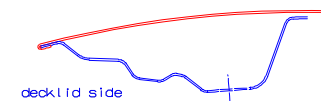
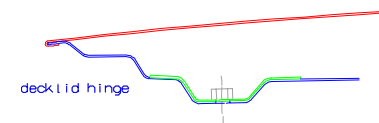
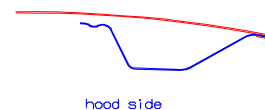
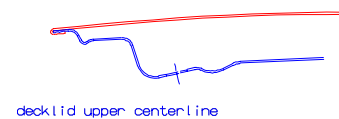
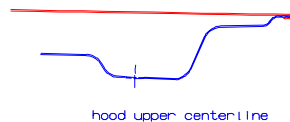
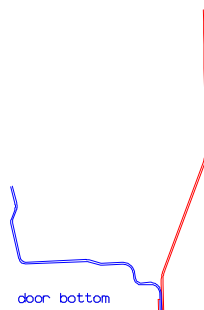
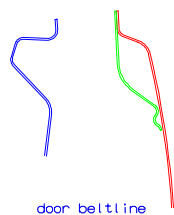
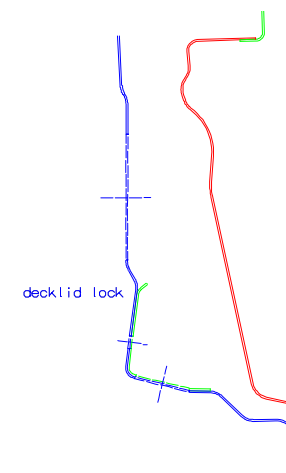
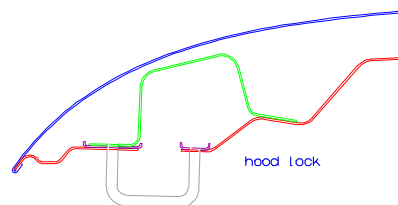
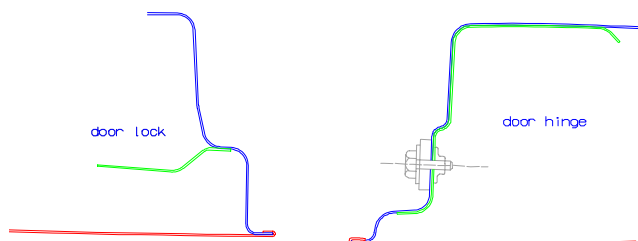
Typical Sections - Ford Taurus





Benchmarking

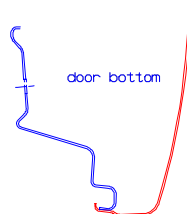
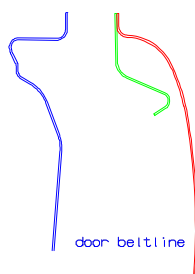
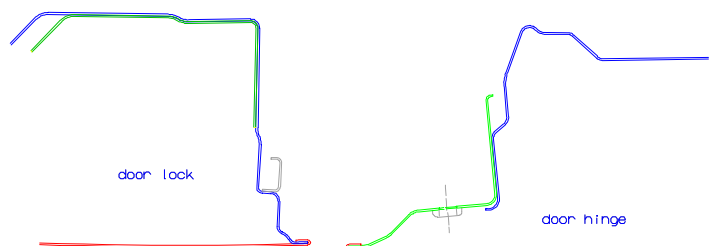
Typical Sections - Honda Accord





Benchmarking

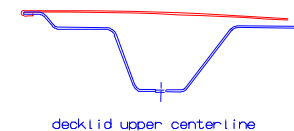
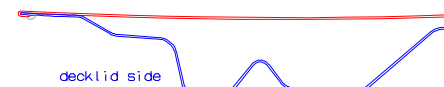
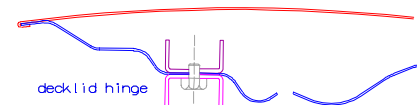
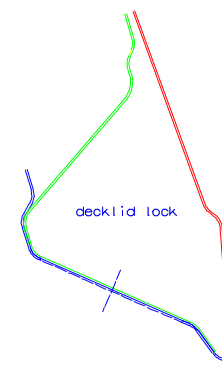
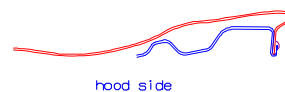
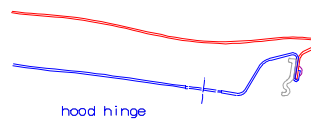
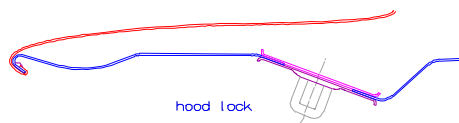
Typical Sections - Mercedes E320



door frame



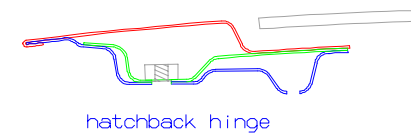
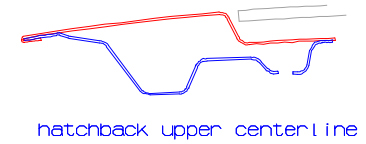
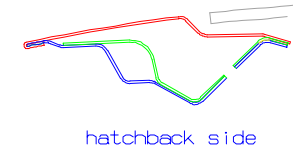
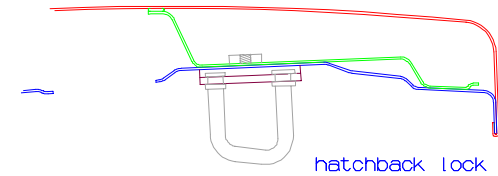
door crashbeam





Benchmarking

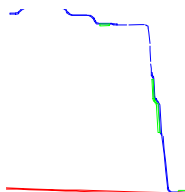
Typical Sections - Mitsubishi Eclipse



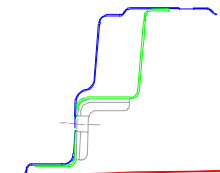


Benchmarking

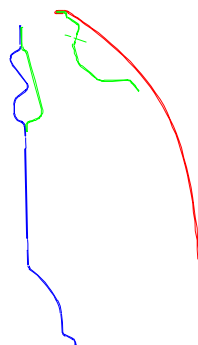
Typical Sections - Porsche Boxster



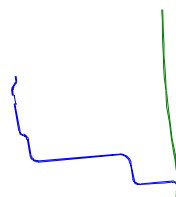
door lock



door hinge



door beltline



door bottom



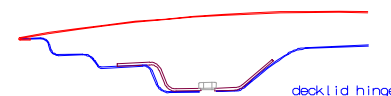
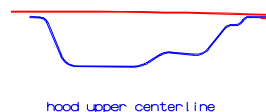
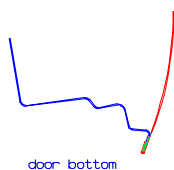
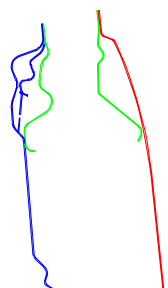
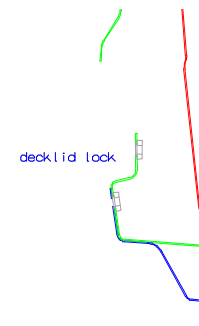
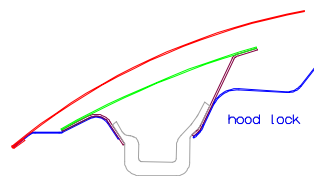
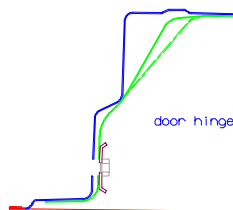
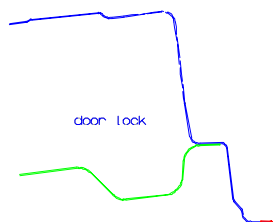
door crashbeam





Benchmarking

Typical Sections - Nissan Sentra



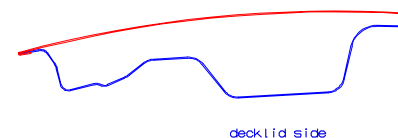
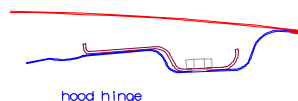
door beltline

hood side

decklid upper centerline



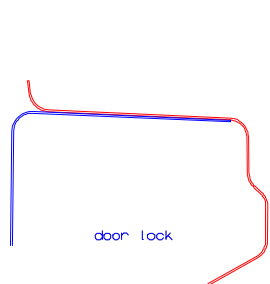
door crashbeam



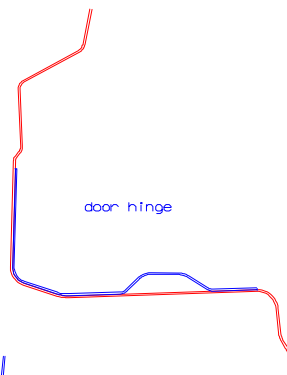


Benchmarking

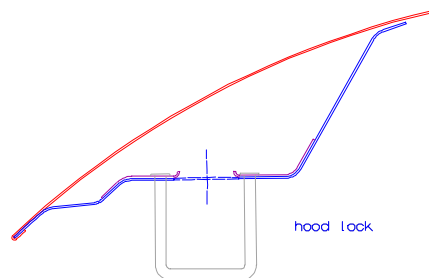
Typical Sections - Saturn LS



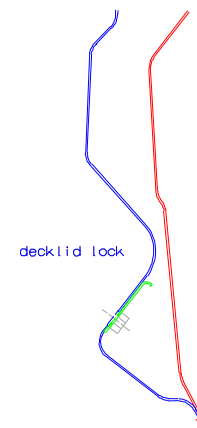
door lock



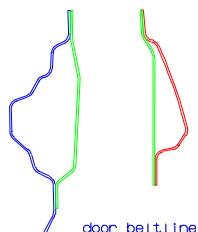
door hinge



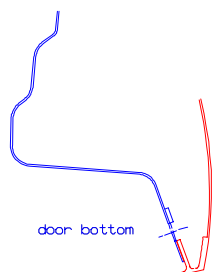
hood lock



decklid lock



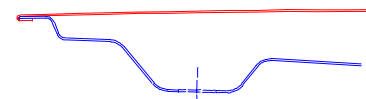
door beltline



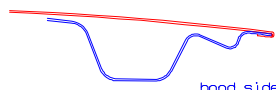
door bottom



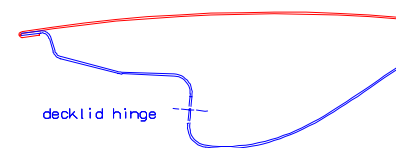
hood upper centerline



decklid upper centerline



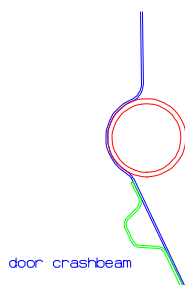
hood side



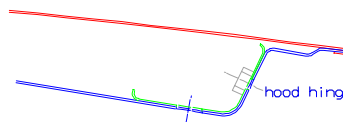
decklid hinge



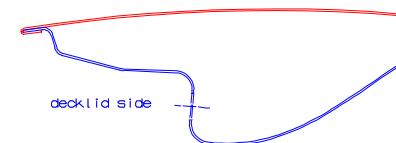
door frame



door crashbeam



hood hinge



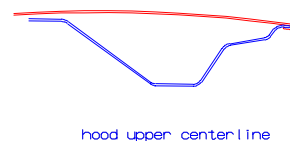
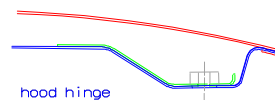
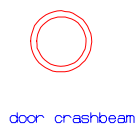
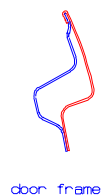
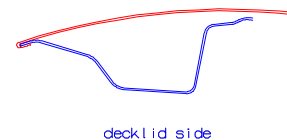
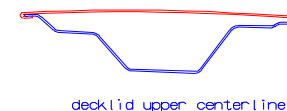
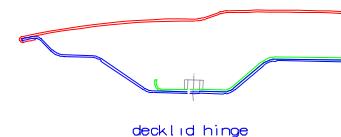
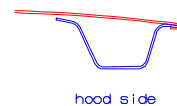
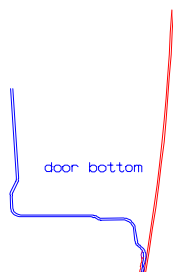
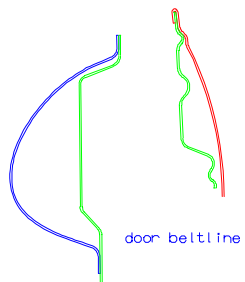
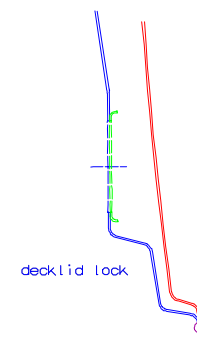
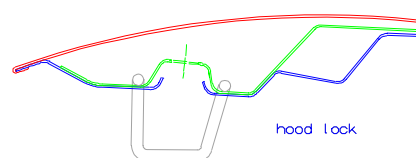
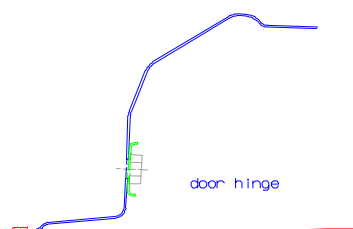
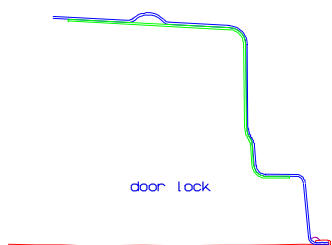
decklid side





Benchmarking

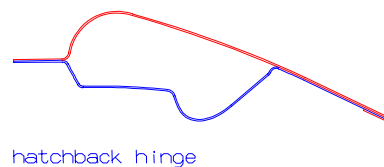
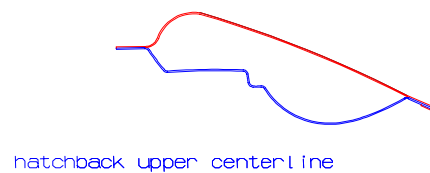
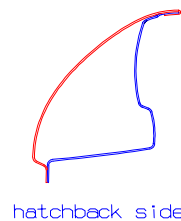
Typical Sections - Toyota Camry





Benchmarking

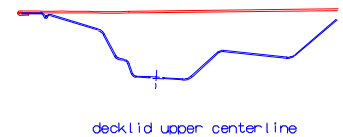
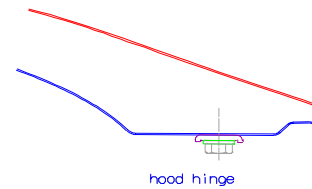
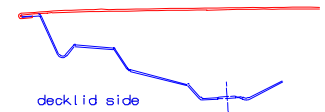
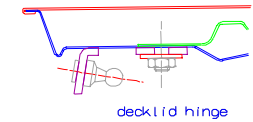
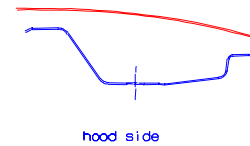
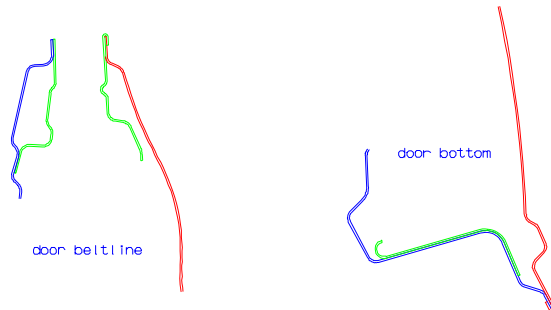
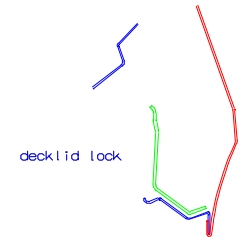
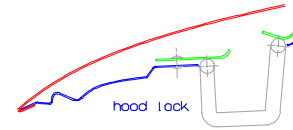
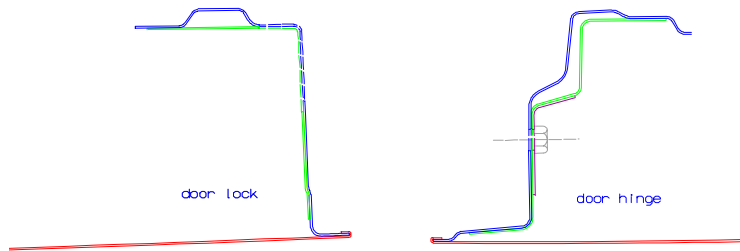
Typical Sections - VW Golf





Benchmarking

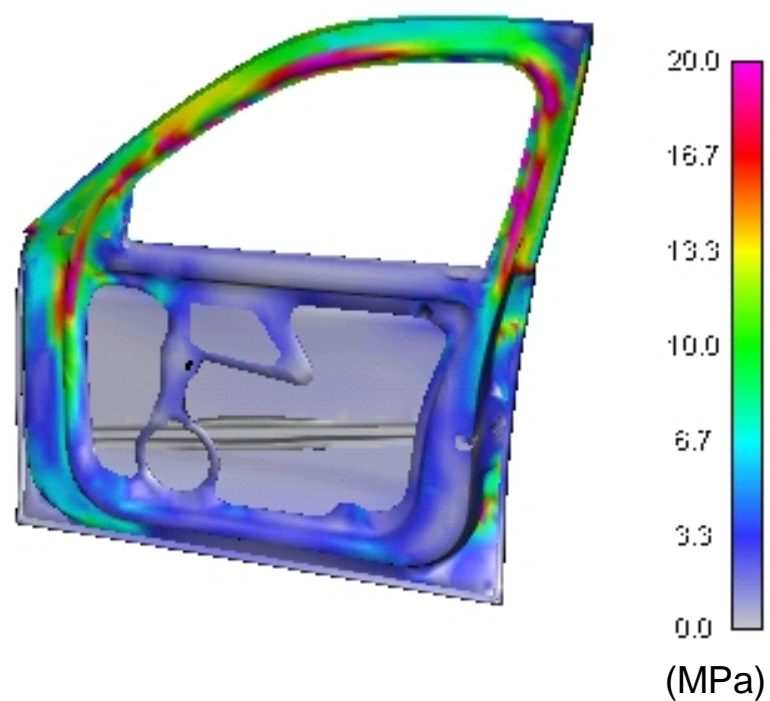
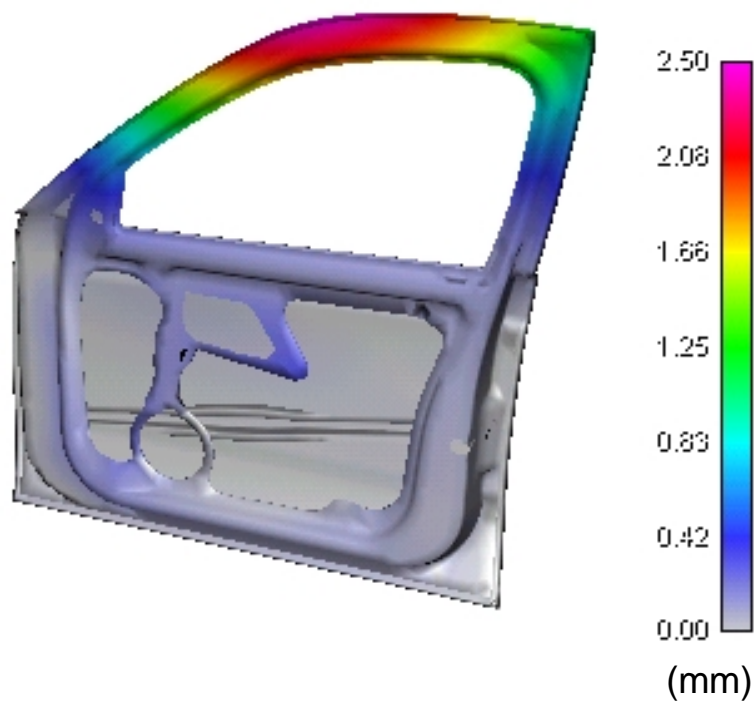
Typical Sections - VW Passat





FEA Calculation

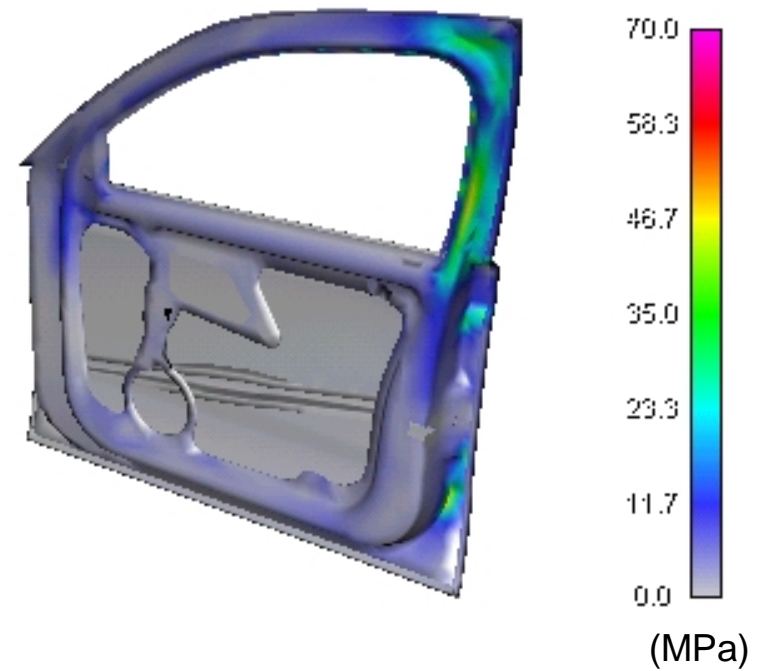
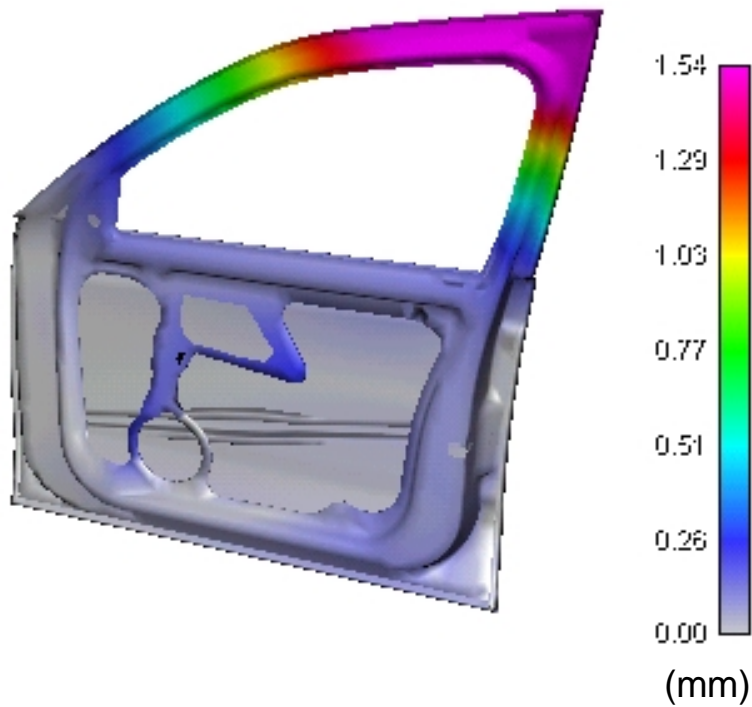
Results - Door - Roof Integrated Frame Rigidity Front - Deformation & Stress Plots





FEA Calculation

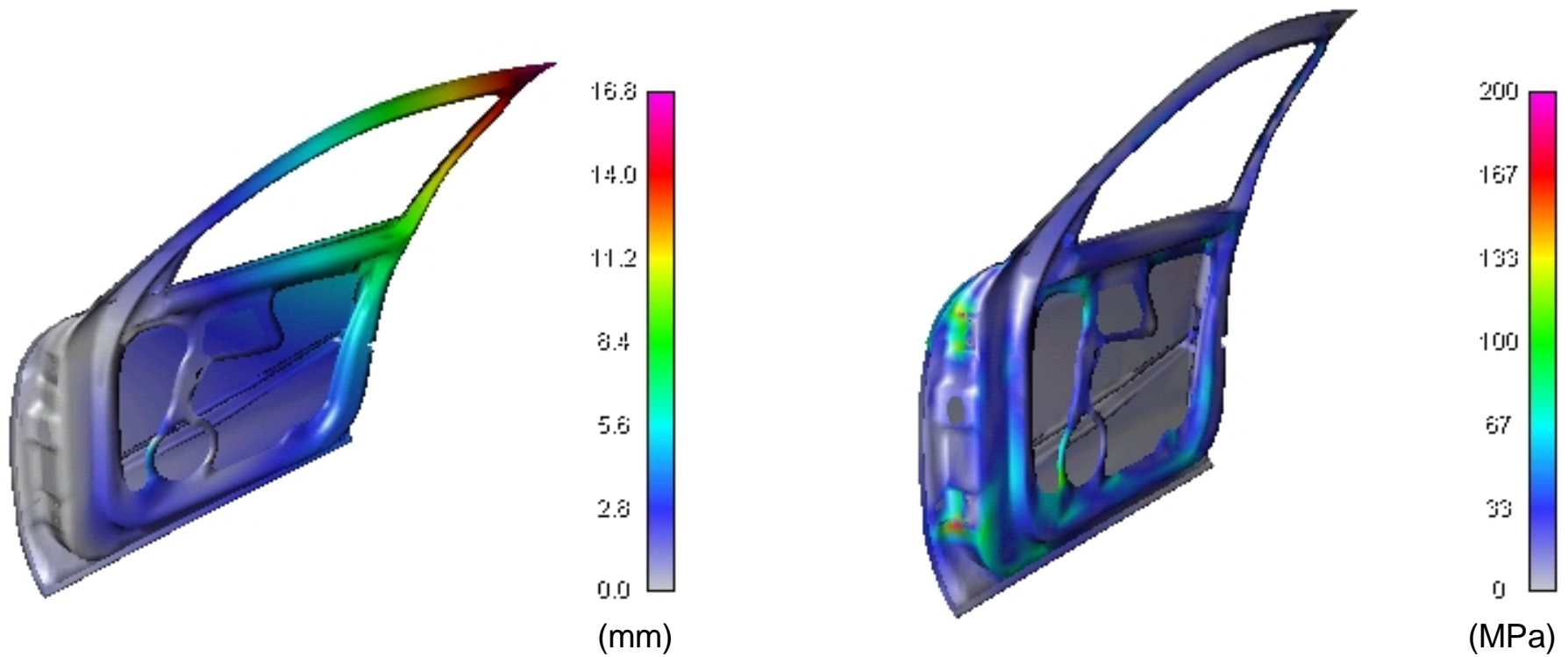
Results - Door - Roof Integrated Frame Rigidity Rear - Deformation & Stress Plots





FEA Calculation

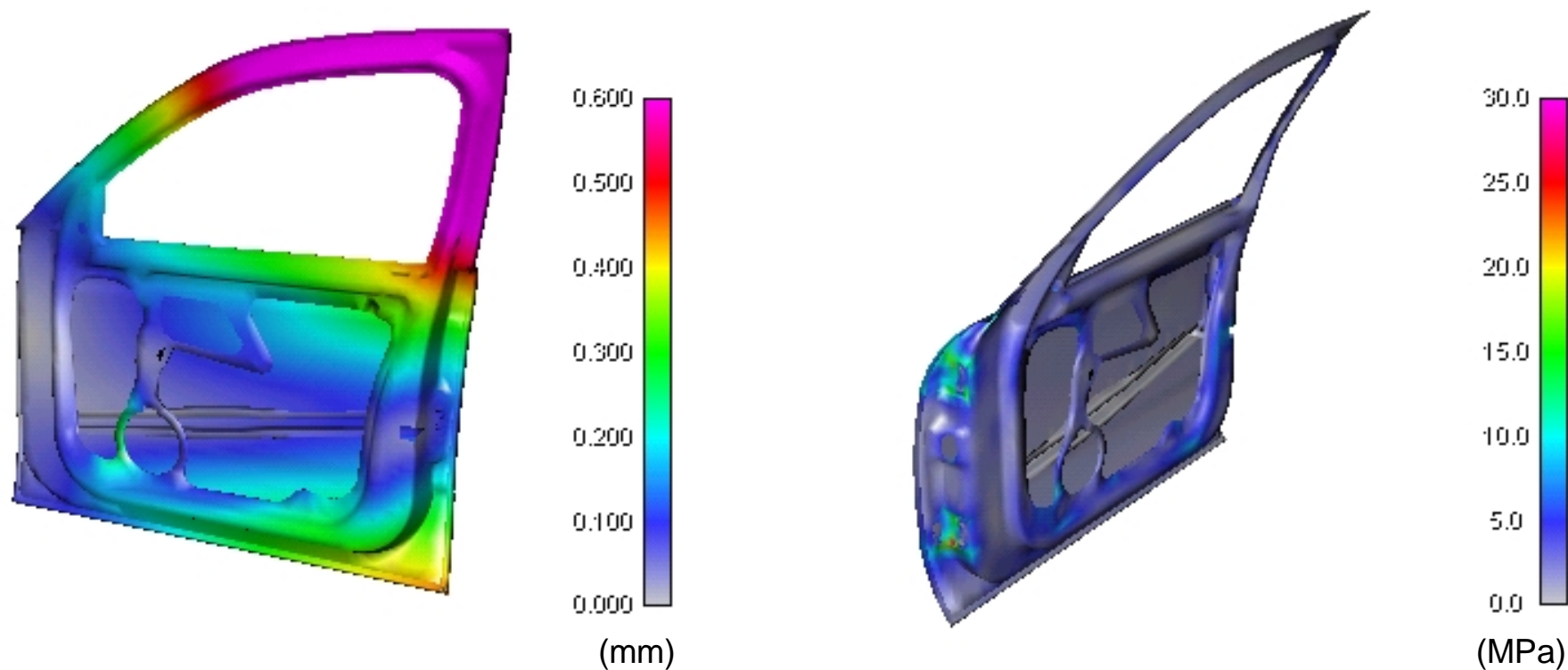
Results - Door - Roof Integrated Door Sag - Deformation & Stress Plots





FEA Calculation

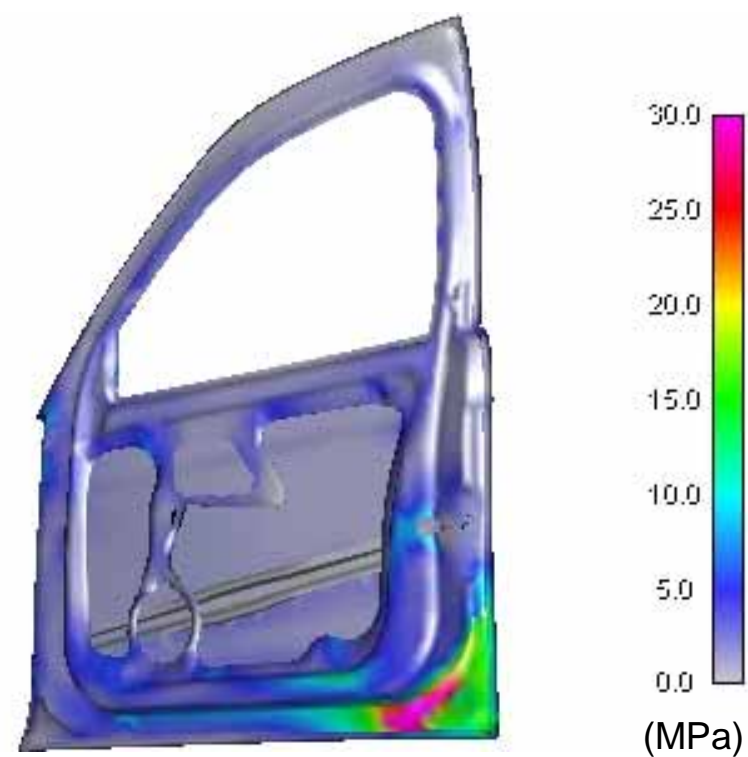
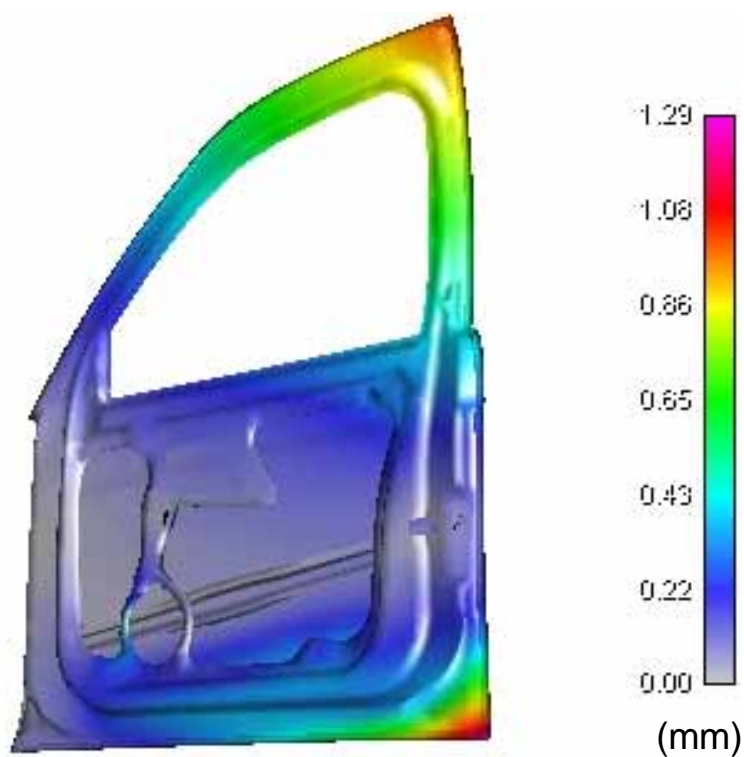
Results - Door - Roof Integrated Torsional Rigidity Upper - Deformation & Stress Plots





FEA Calculation

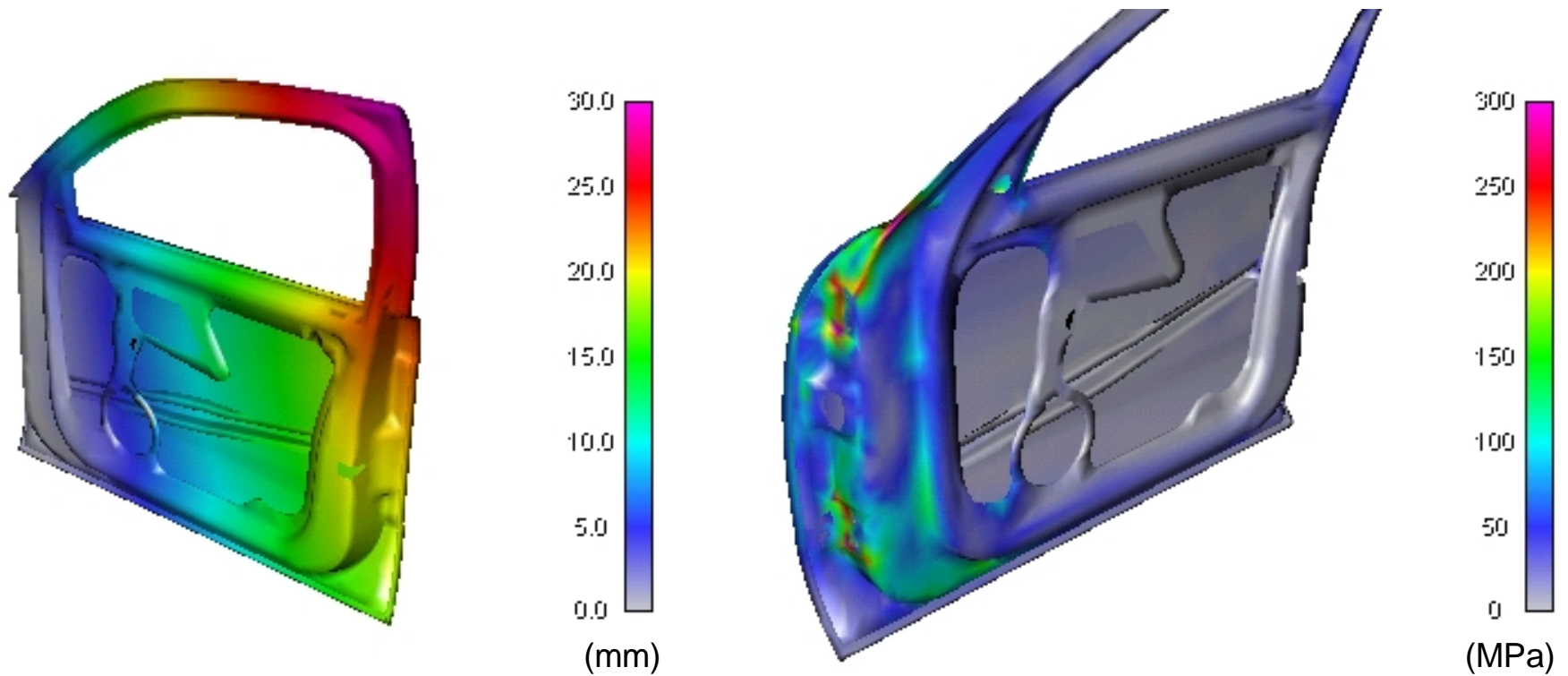
***Results - Door - Roof Integrated
Torsional Rigidity Lower - Deformation & Stress Plots***





FEA Calculation

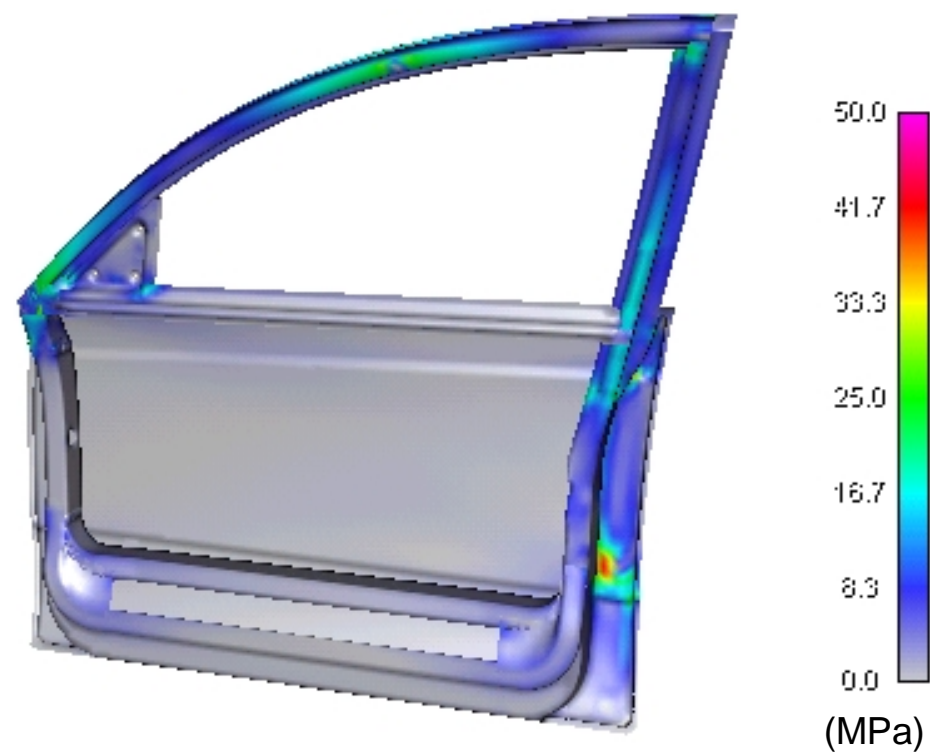
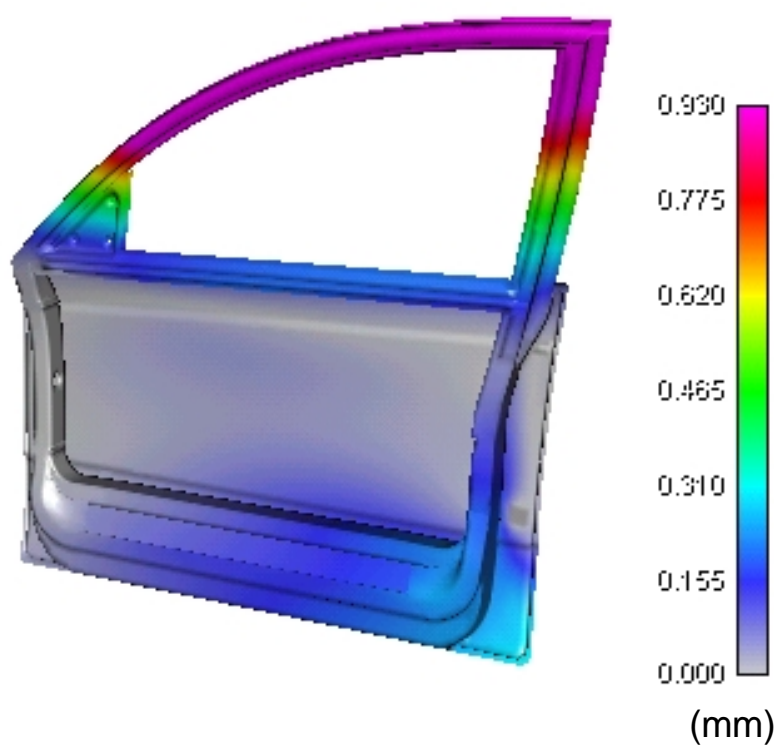
Results - Door - Roof Integrated Checkload - Deformation & Stress Plots





FEA Calculation

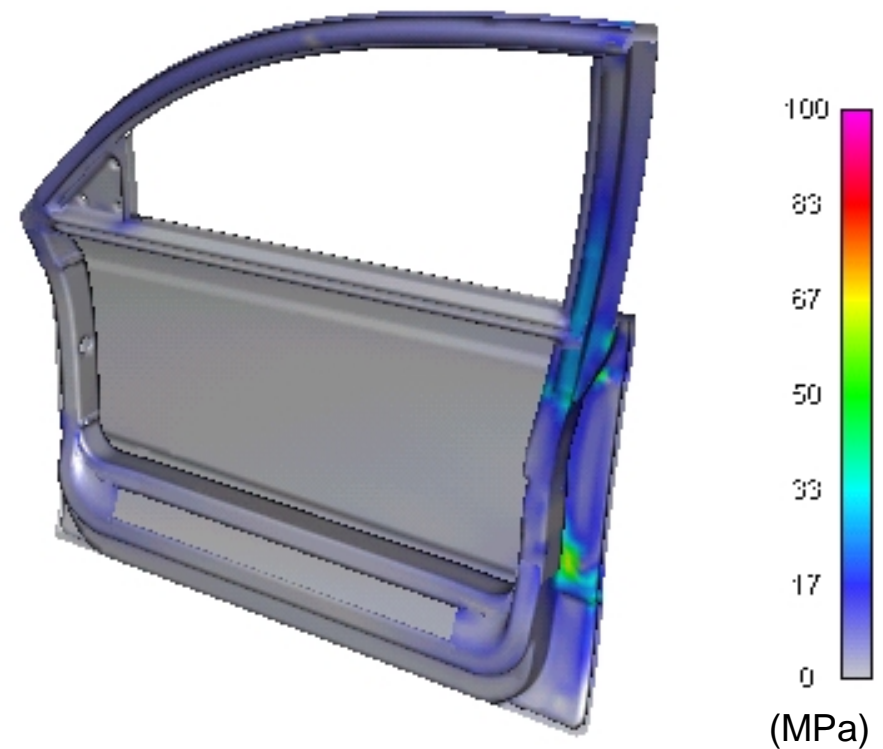
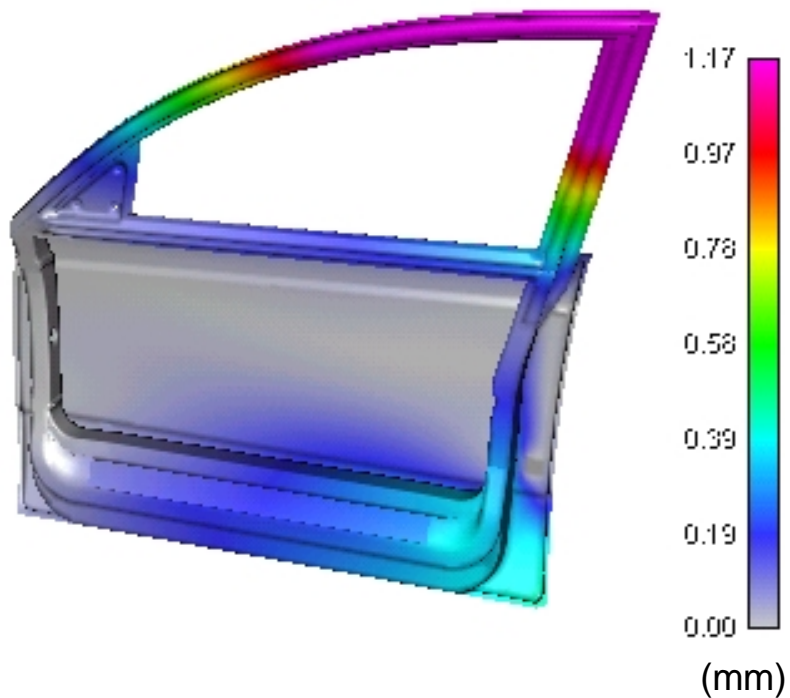
Results - Door - Frame Integrated Frame Rigidity Front - Deformation & Stress Plots





FEA Calculation

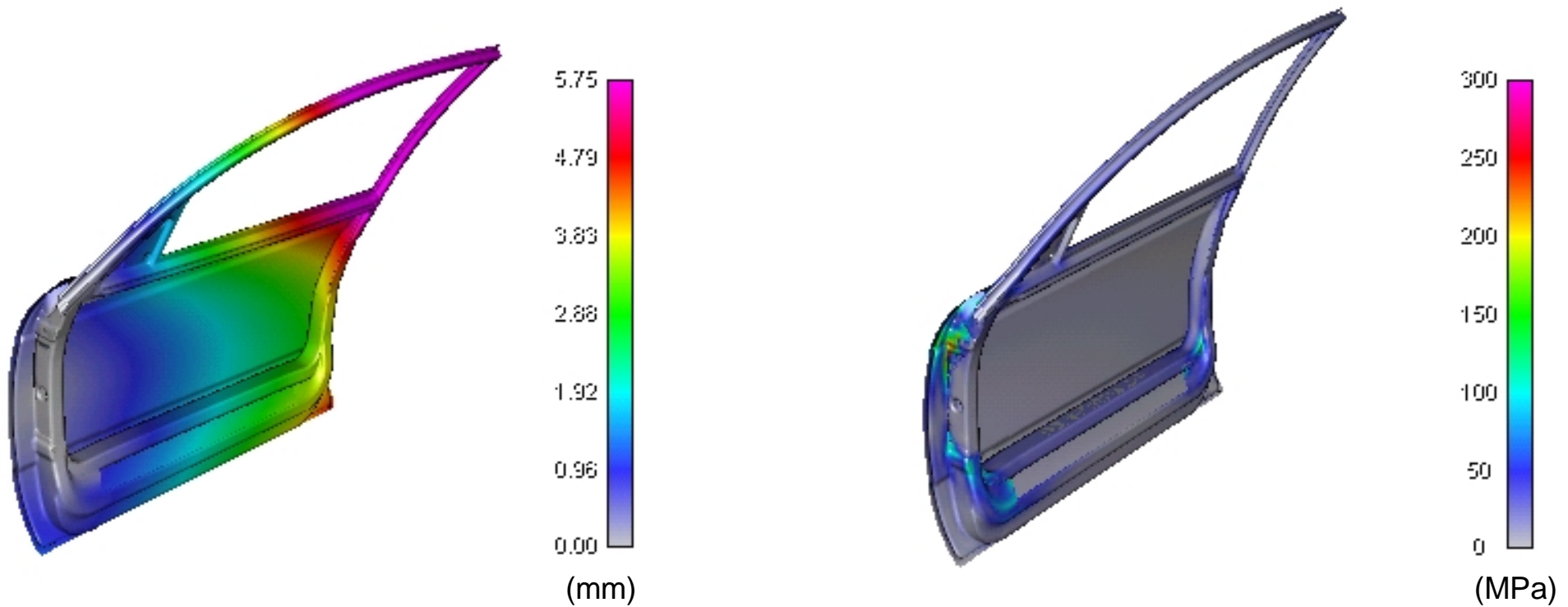
Results - Door - Frame Integrated Frame Rigidity Rear - Deformation & Stress Plots





FEA Calculation

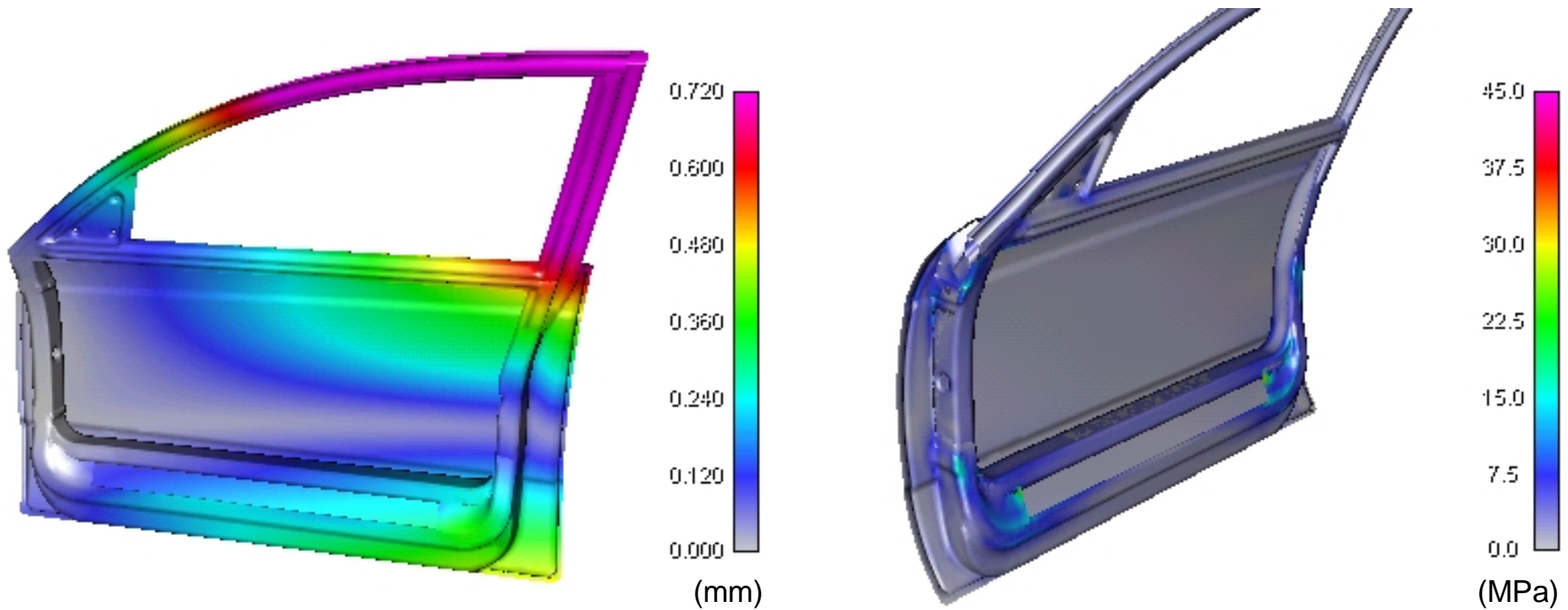
Results - Door - Frame Integrated Door Sag - Deformation & Stress Plots





FEA Calculation

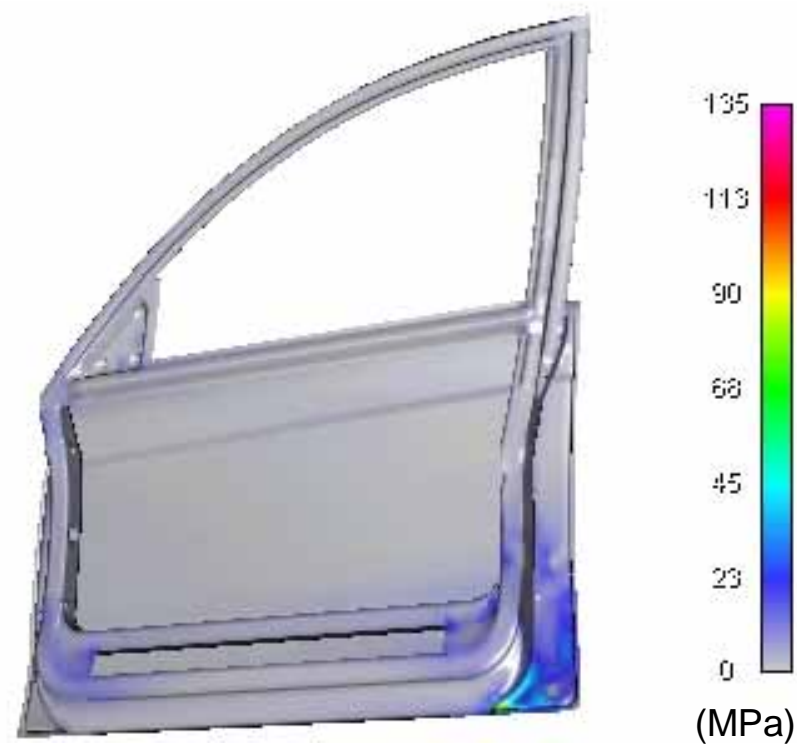
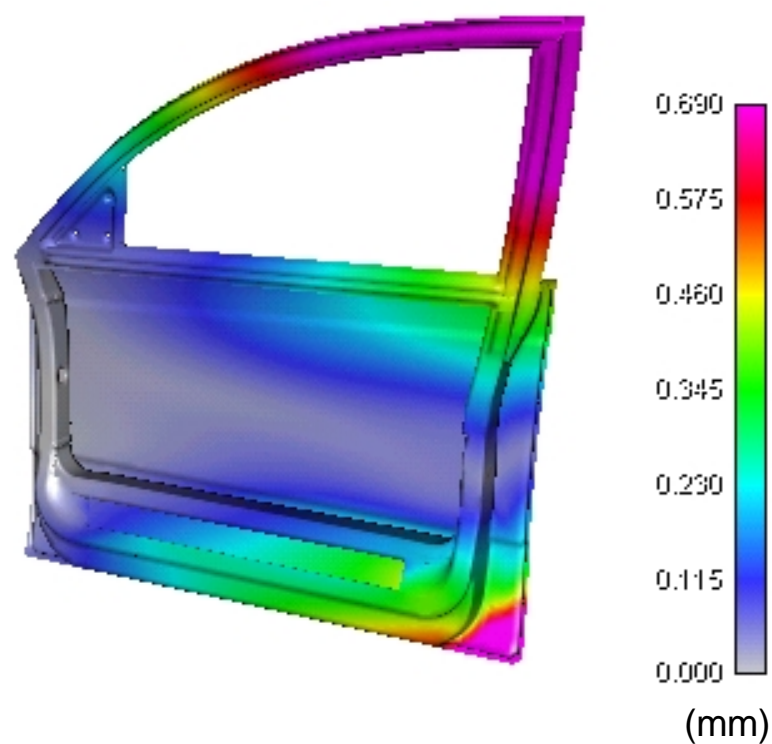
Results - Door - Frame Integrated Torsional Rigidity Upper - Deformation & Stress Plots





FEA Calculation

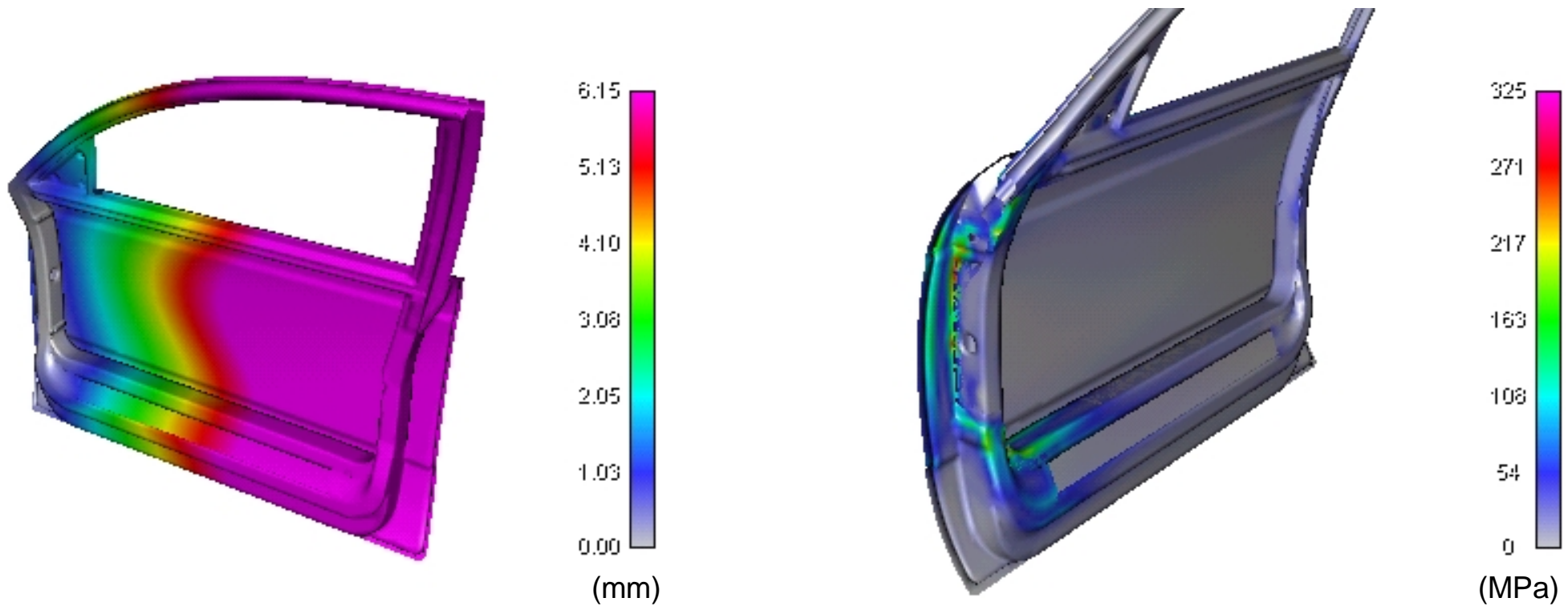
***Results - Door - Frame Integrated
Torsional Rigidity Lower - Deformation & Stress Plots***





FEA Calculation

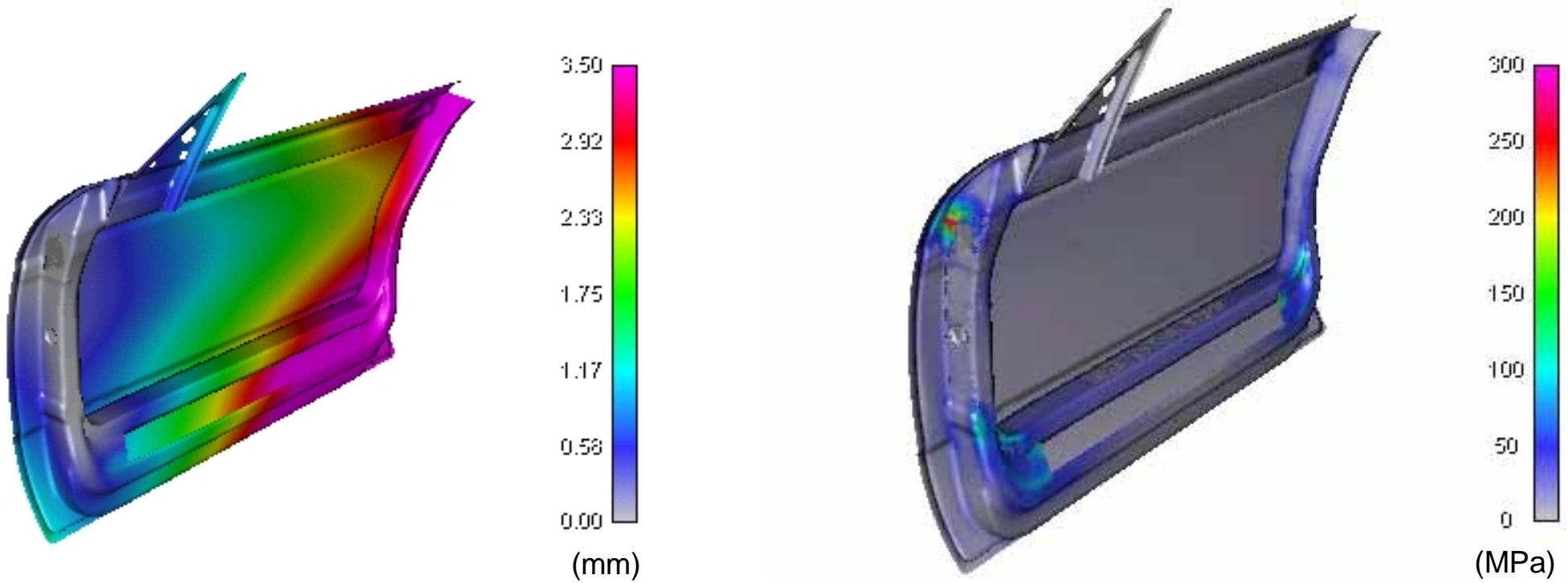
Results - Door - Frame Integrated Checkload - Deformation & Stress Plots





FEA Calculation

Results - Door - Frameless **Door Sag - Deformation & Stress Plots**

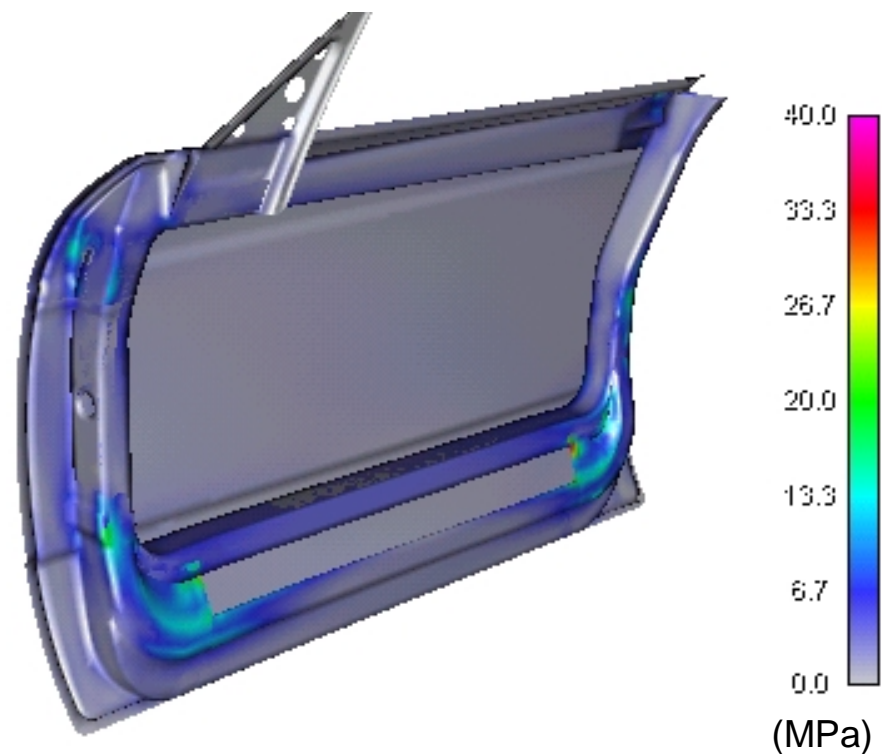
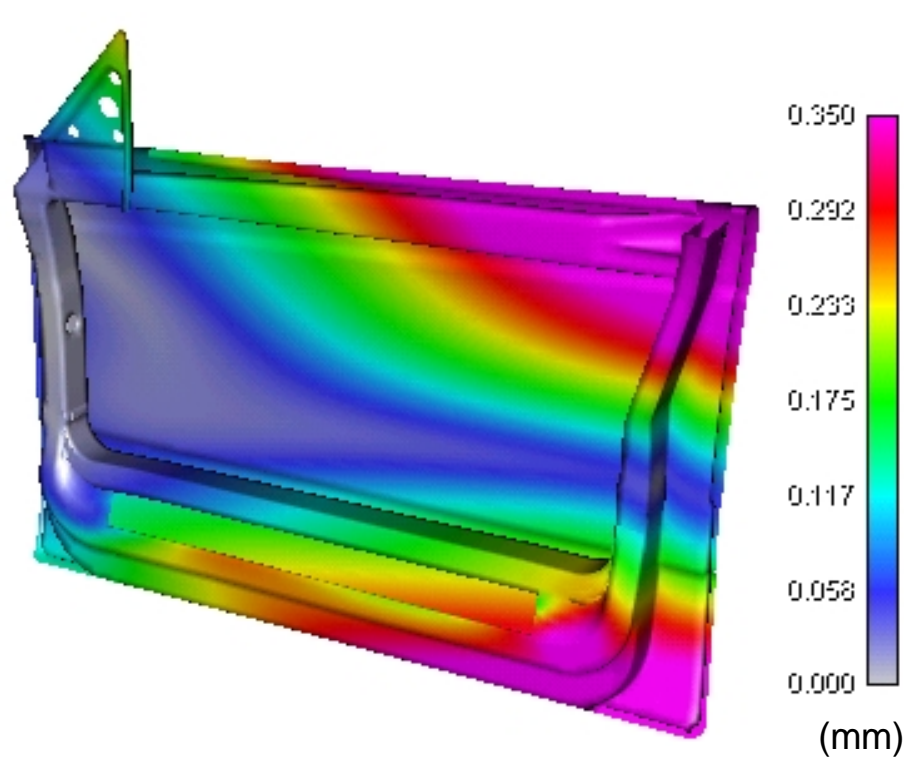




FEA Calculation

Results - Door - Frameless

Torsional Rigidity Upper - Deformation & Stress Plots

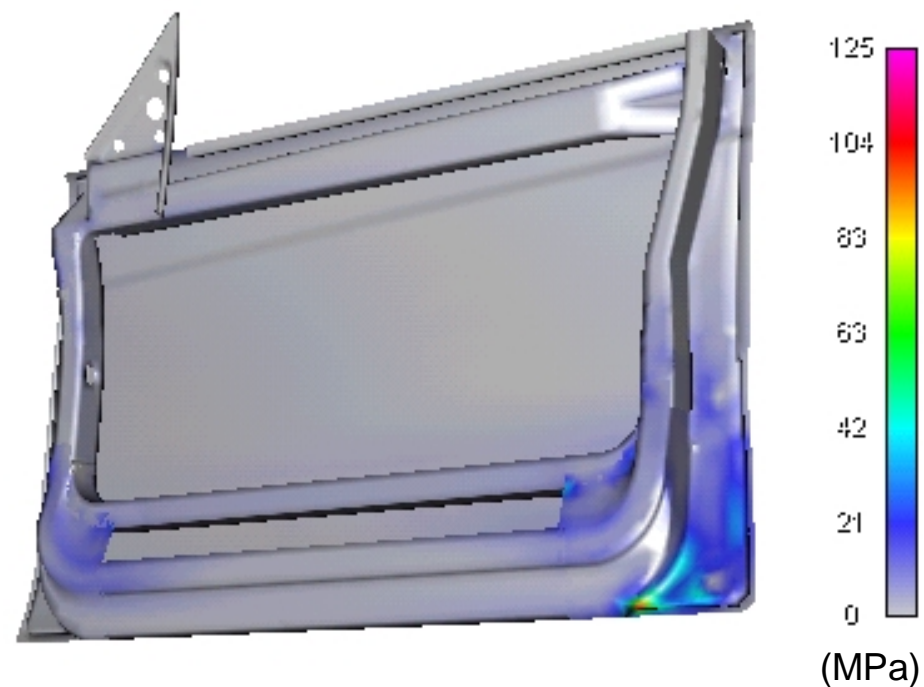
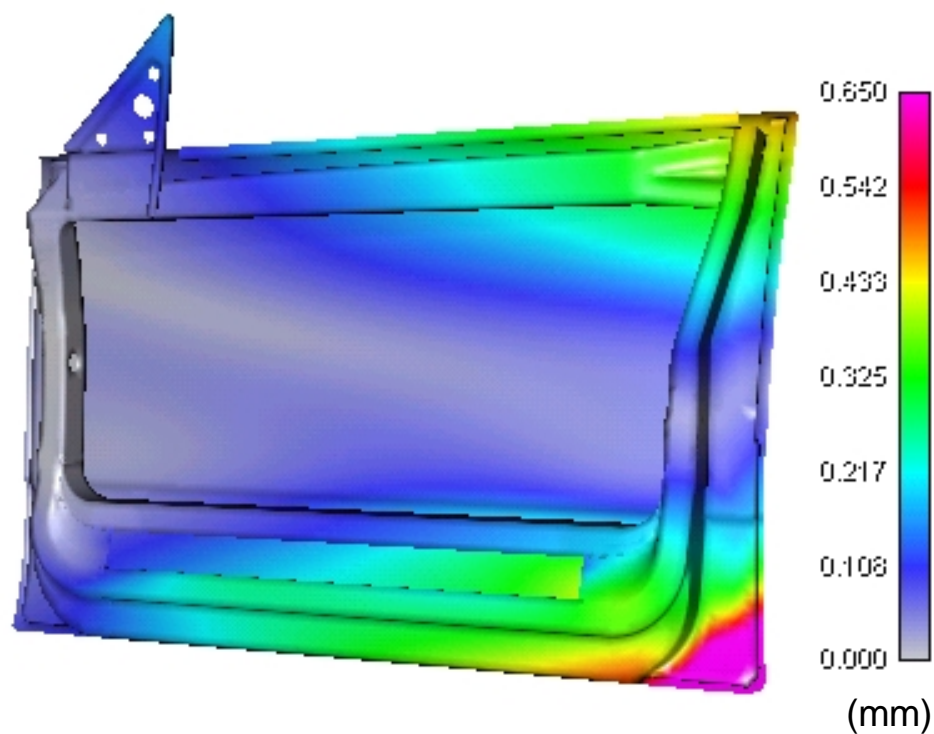




FEA Calculation

Results - Door - Frameless

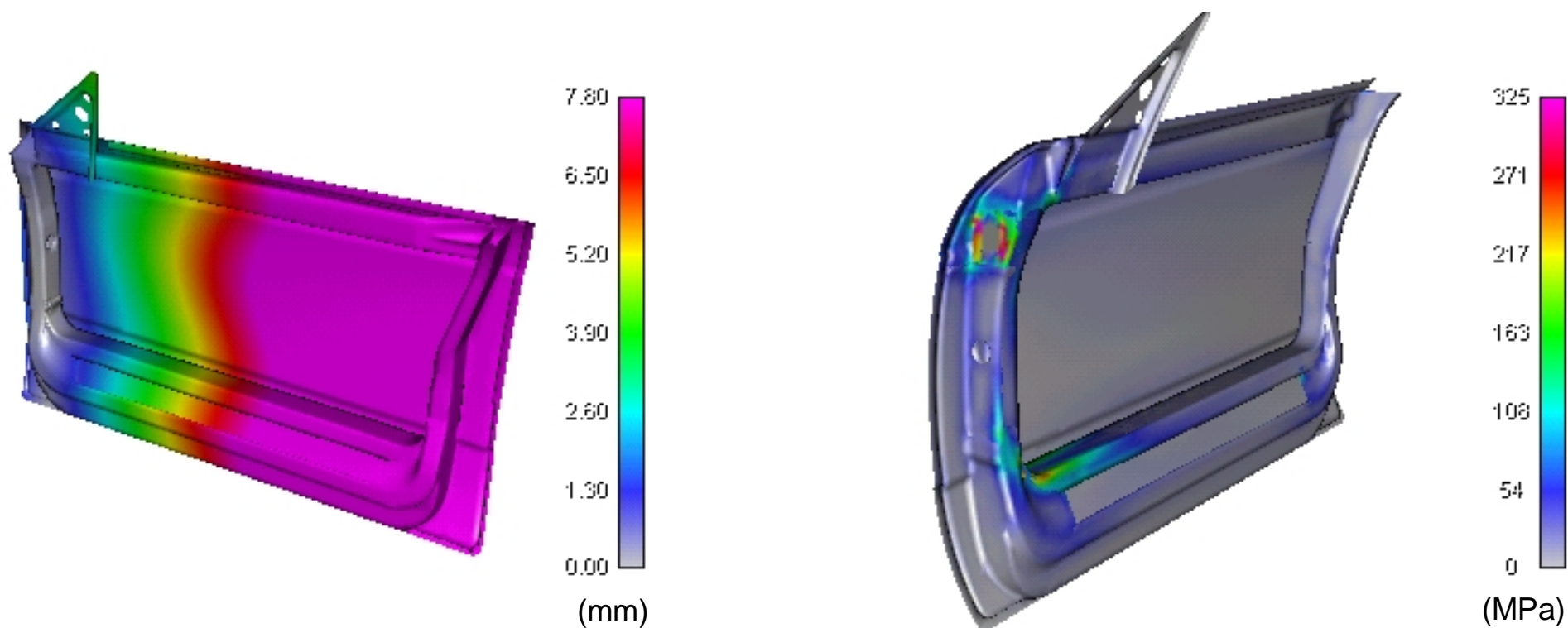
Torsional Rigidity Lower - Deformation & Stress Plots





FEA Calculation

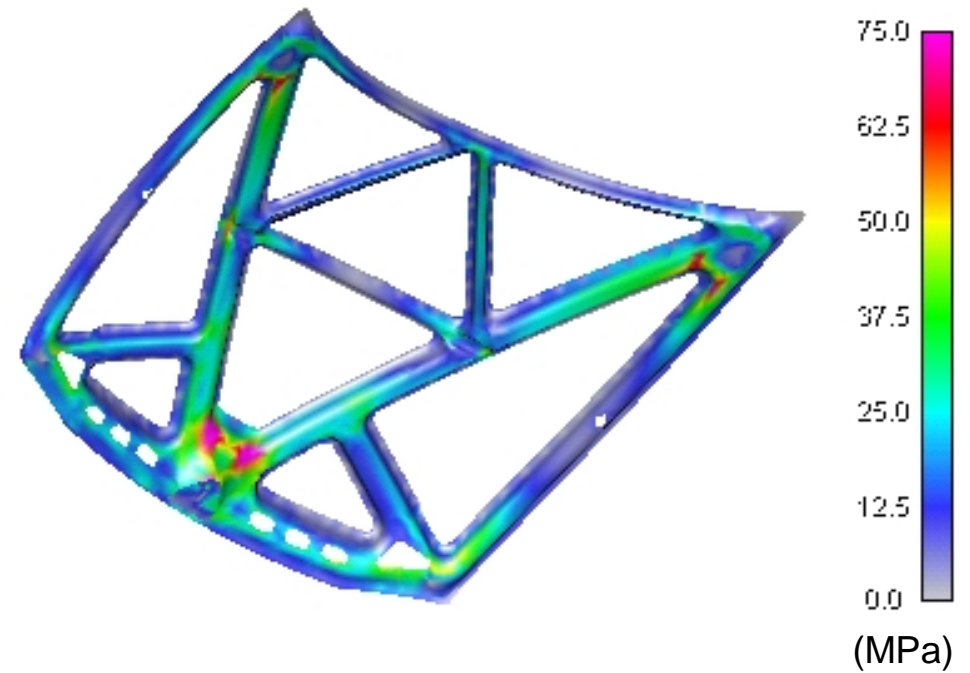
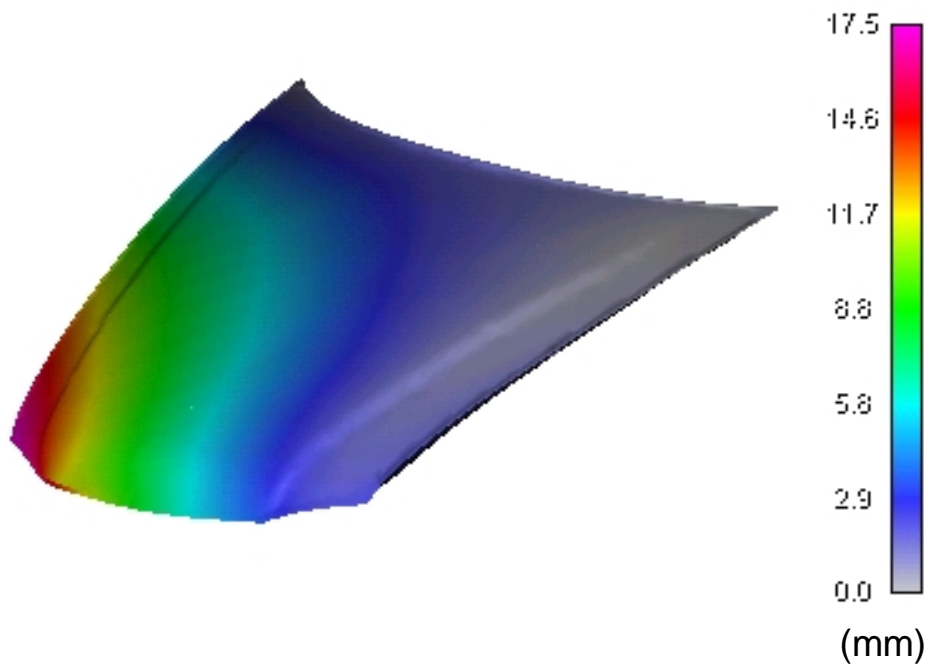
Results - Door - Frameless **Checkload - Deformation & Stress Plots**





FEA Calculation

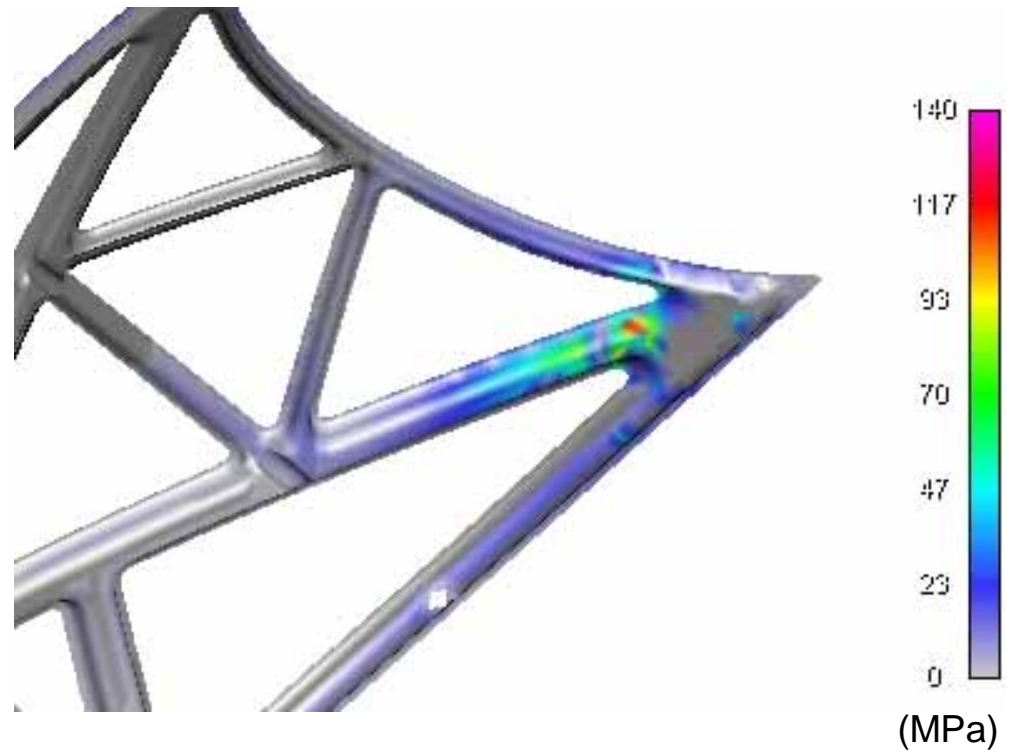
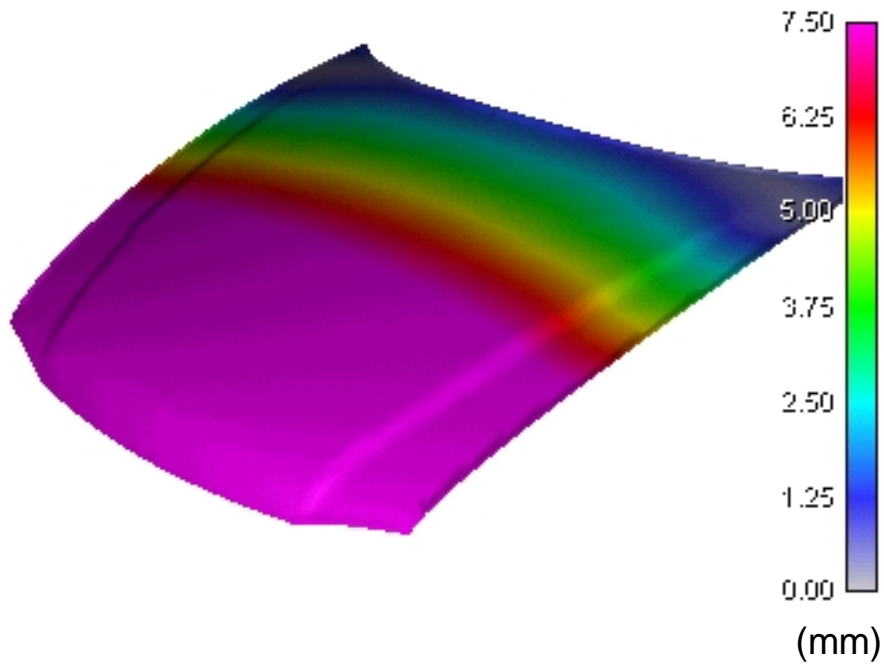
Results - Hood - Conventional Torsional Rigidity - Deformation & Stress Plots





FEA Calculation

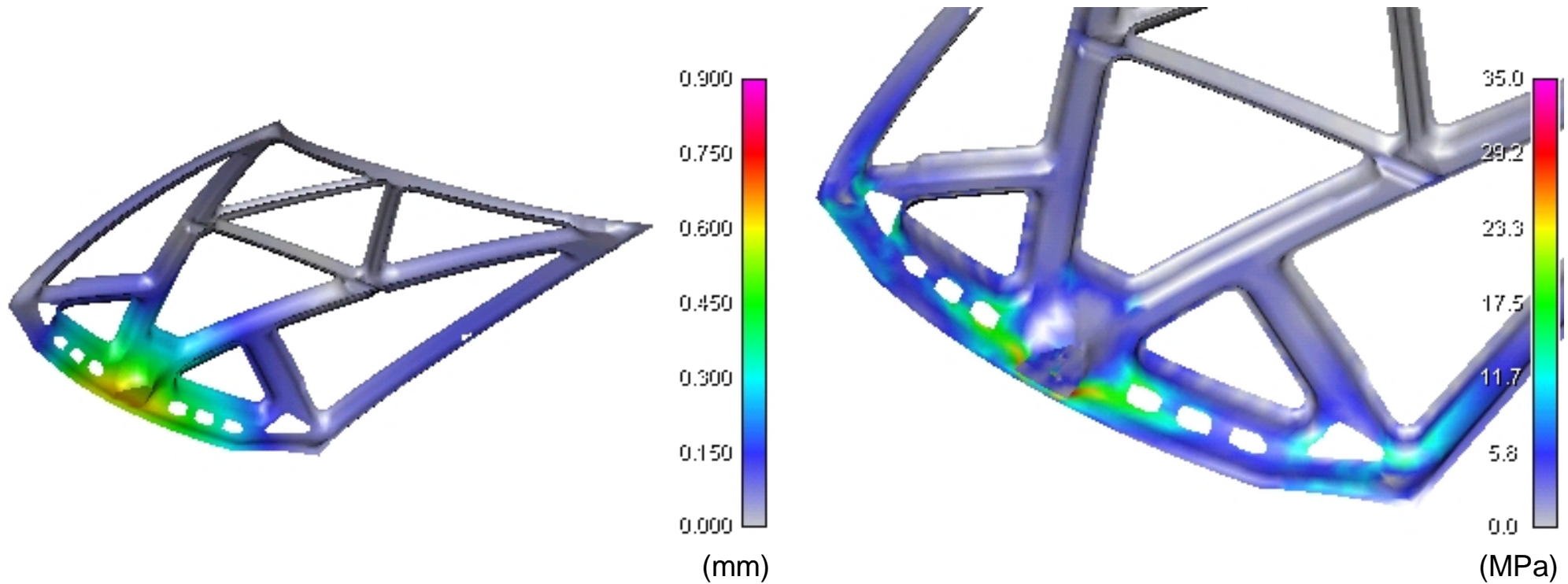
Results - Hood - Conventional Bending Stiffness - Deformation & Stress Plots





FEA Calculation

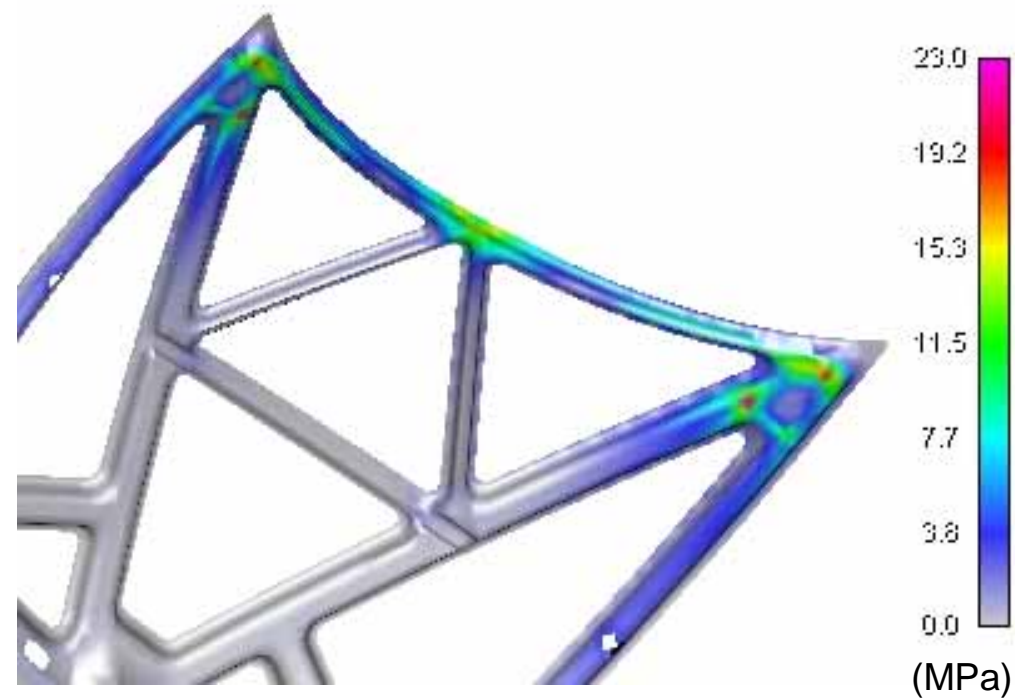
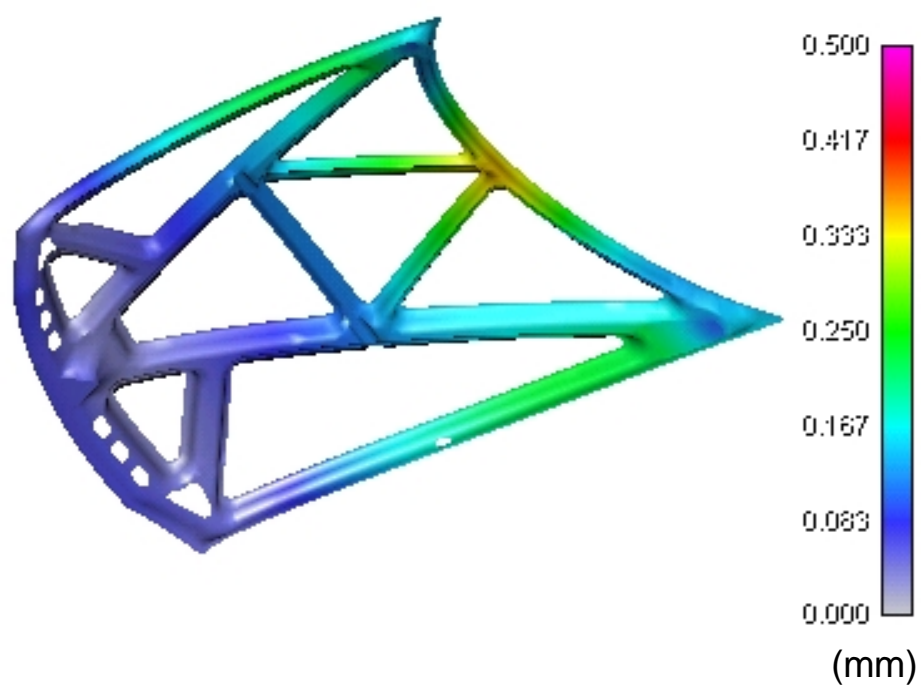
Results - Hood - Conventional Front Beam - Deformation & Stress Plots





FEA Calculation

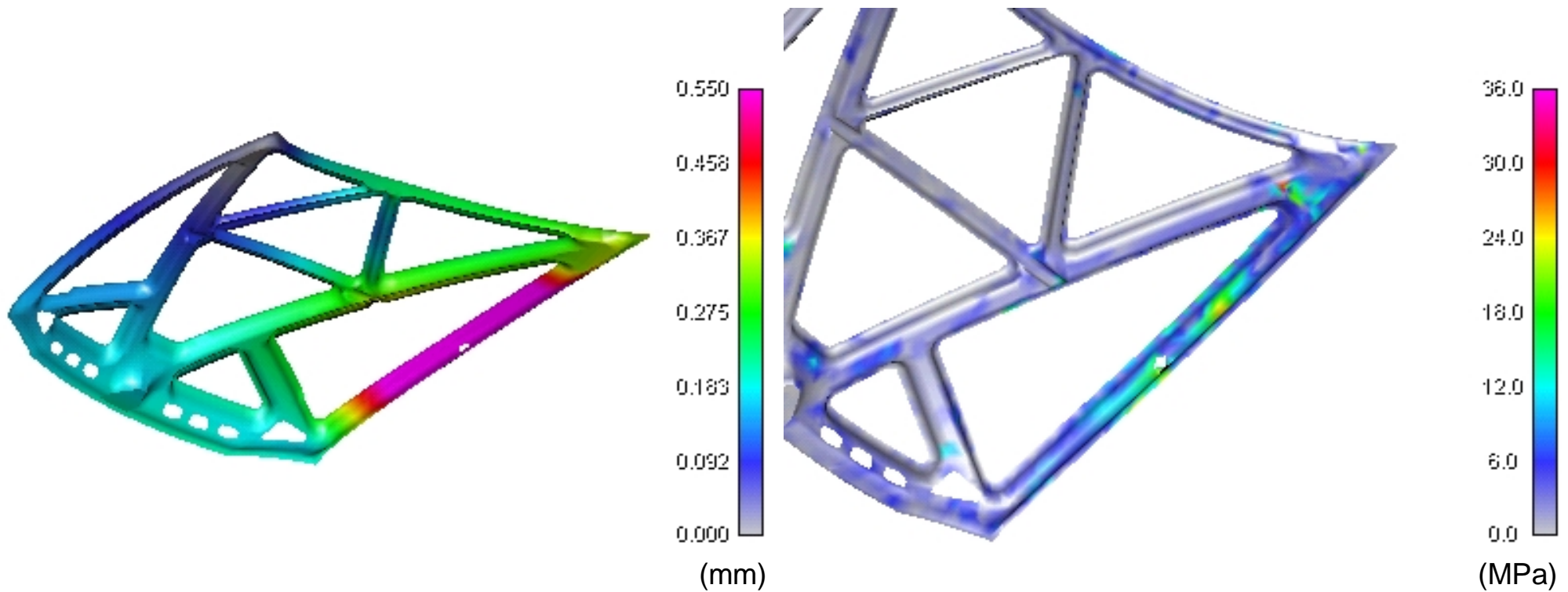
Results - Hood - Conventional Rear Beam - Deformation & Stress Plots





FEA Calculation

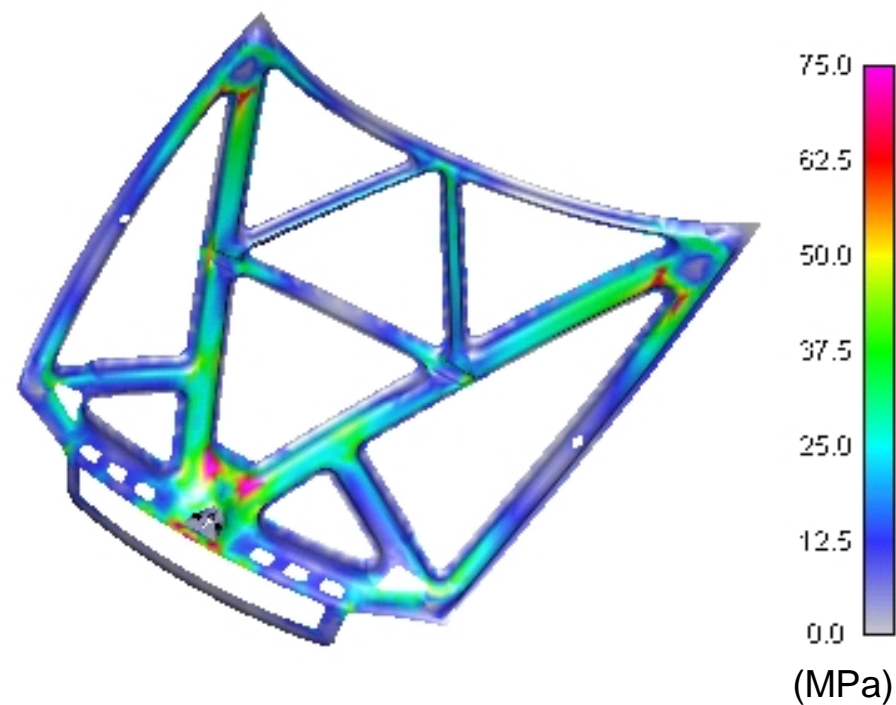
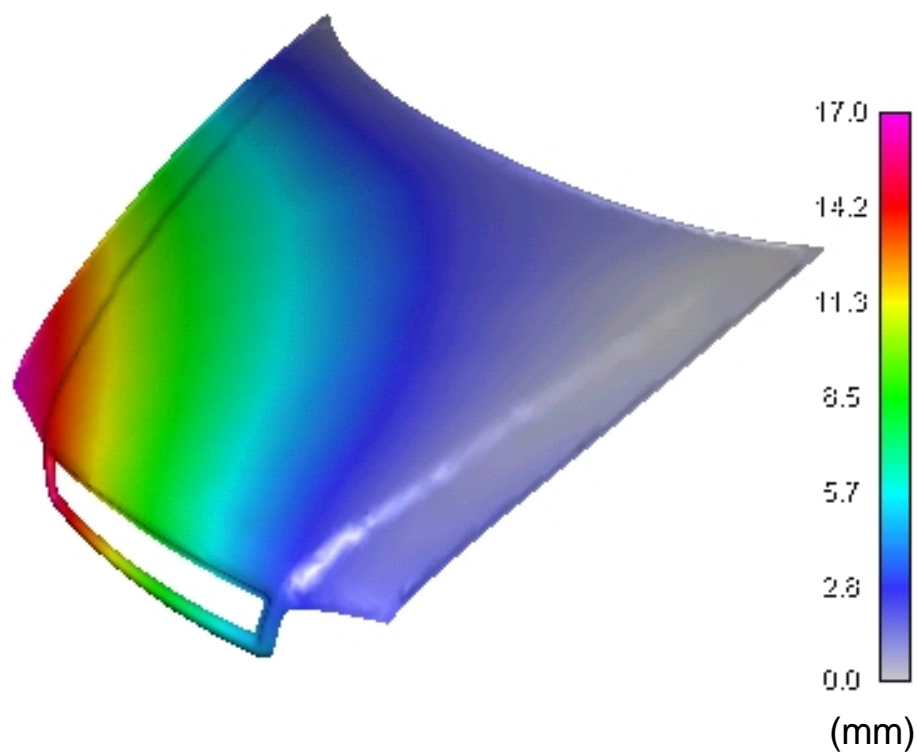
Results - Hood - Conventional Side Beam - Deformation & Stress Plots





FEA Calculation

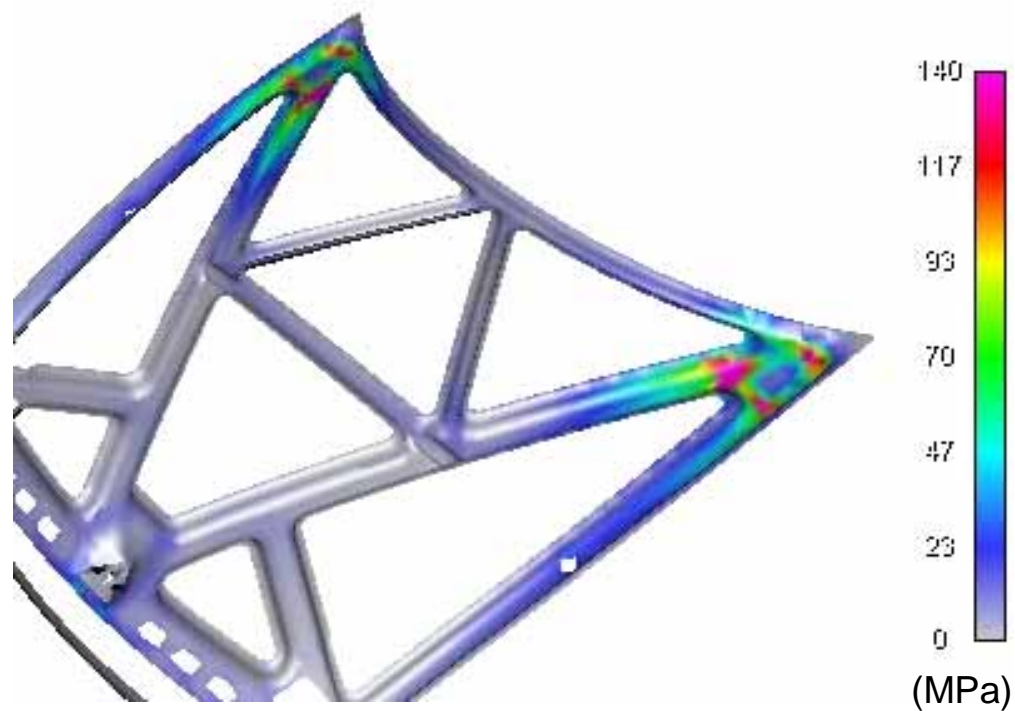
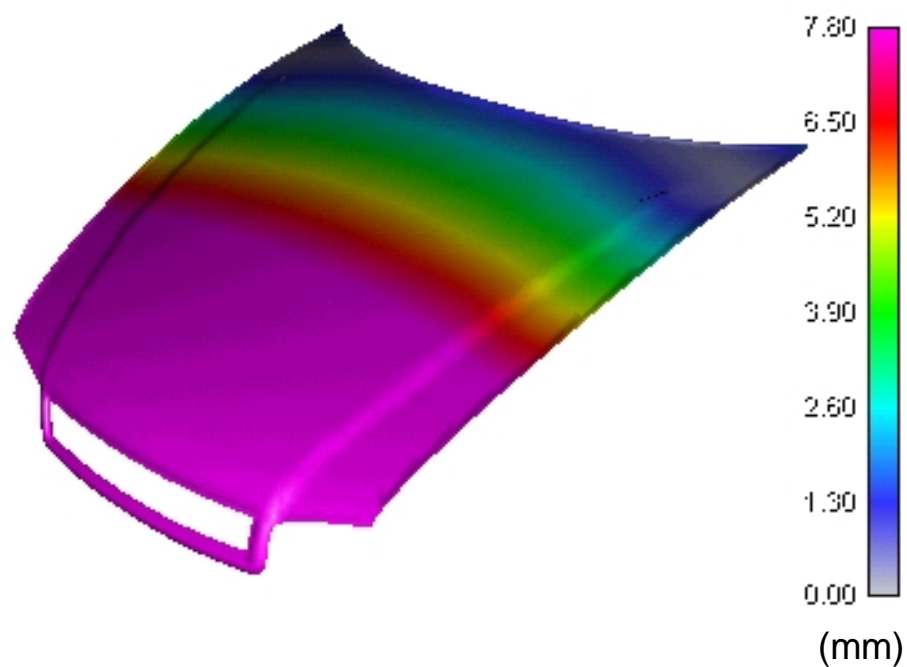
Results - Hood - Grille Integrated Torsional Rigidity - Deformation & Stress Plots





FEA Calculation

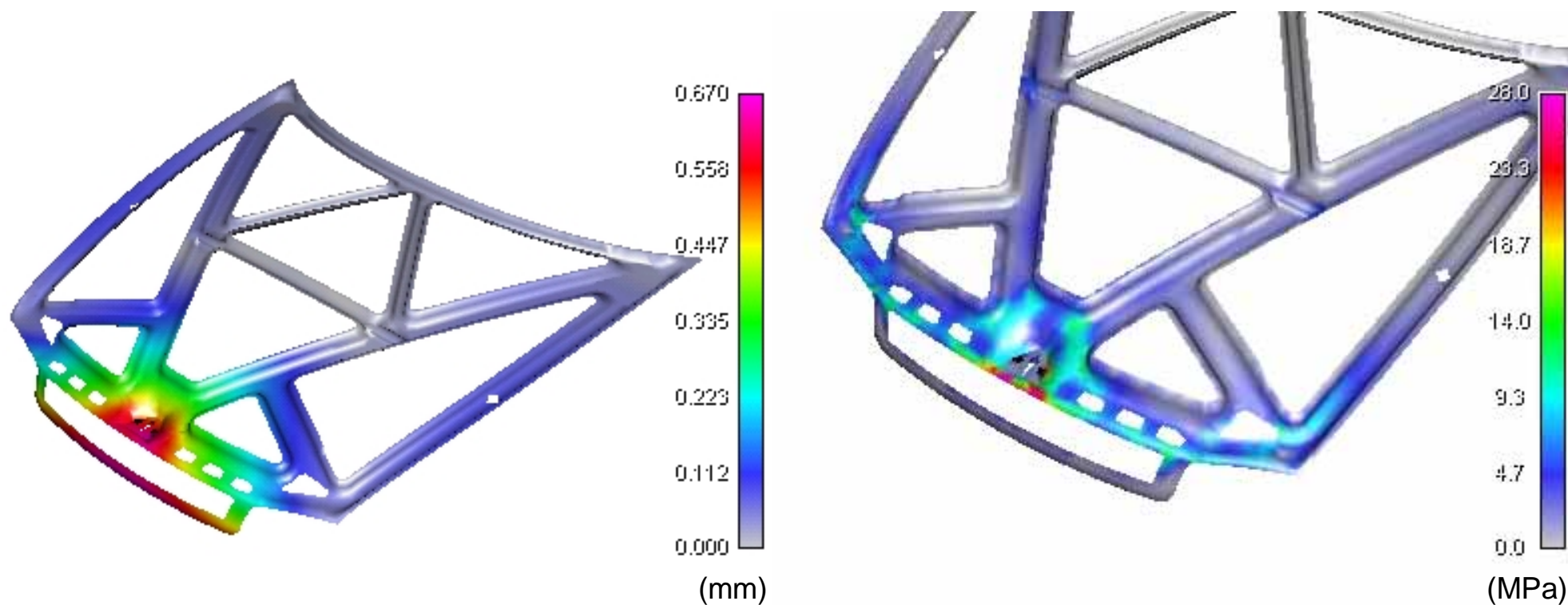
Results - Hood - Grille Integrated Bending Stiffness - Deformation & Stress Plots





FEA Calculation

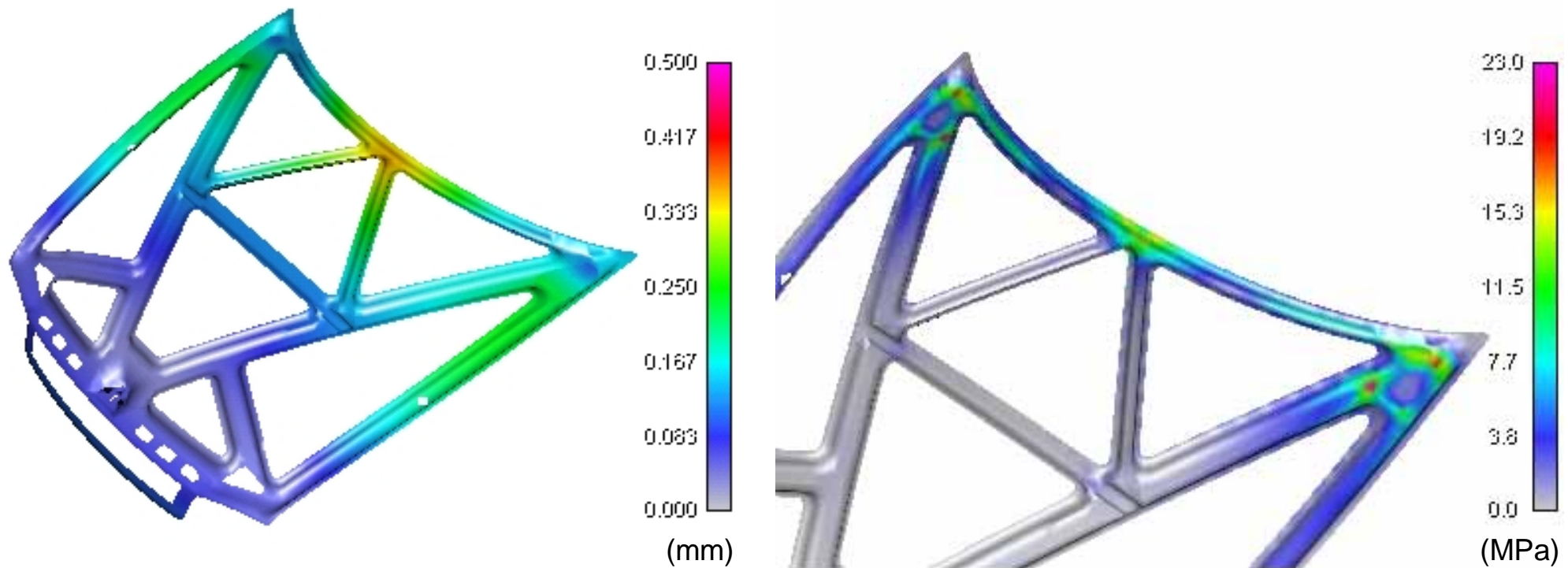
Results - Hood - Grille Integrated Front Beam - Deformation & Stress Plots





FEA Calculation

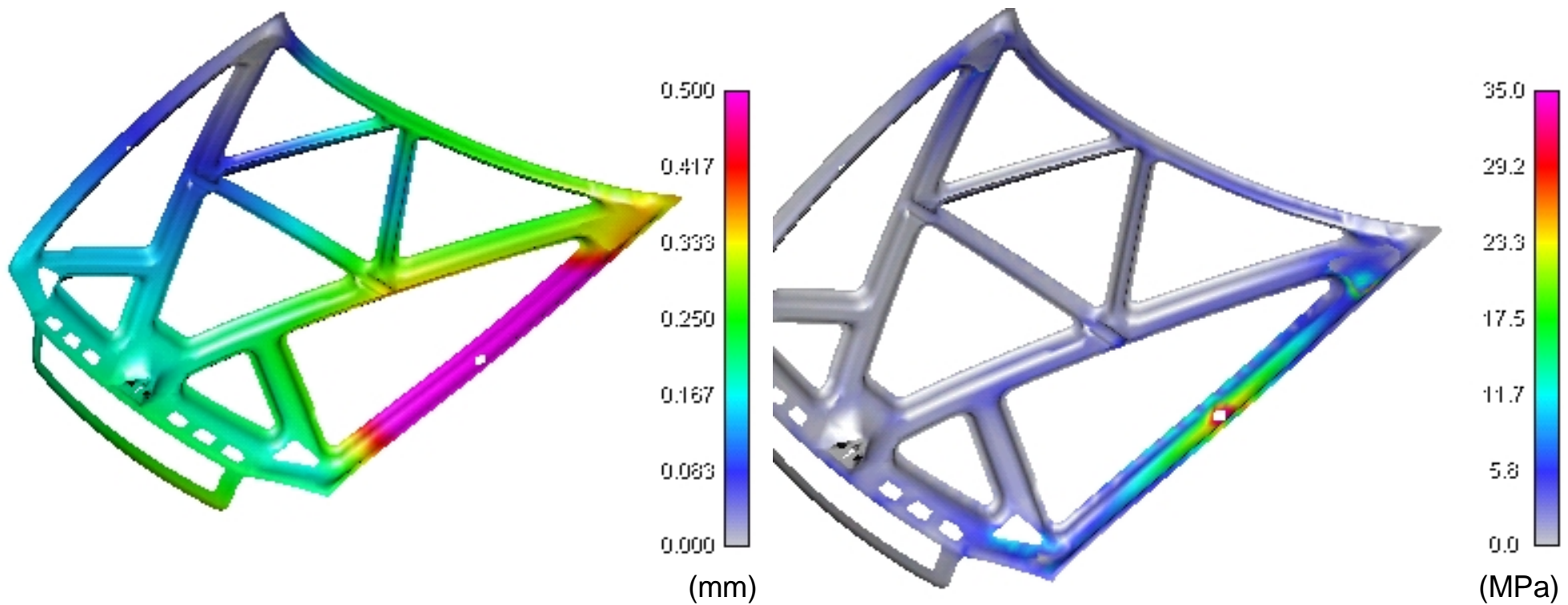
Results - Hood - Grille Integrated Rear Beam - Deformation & Stress Plots





FEA Calculation

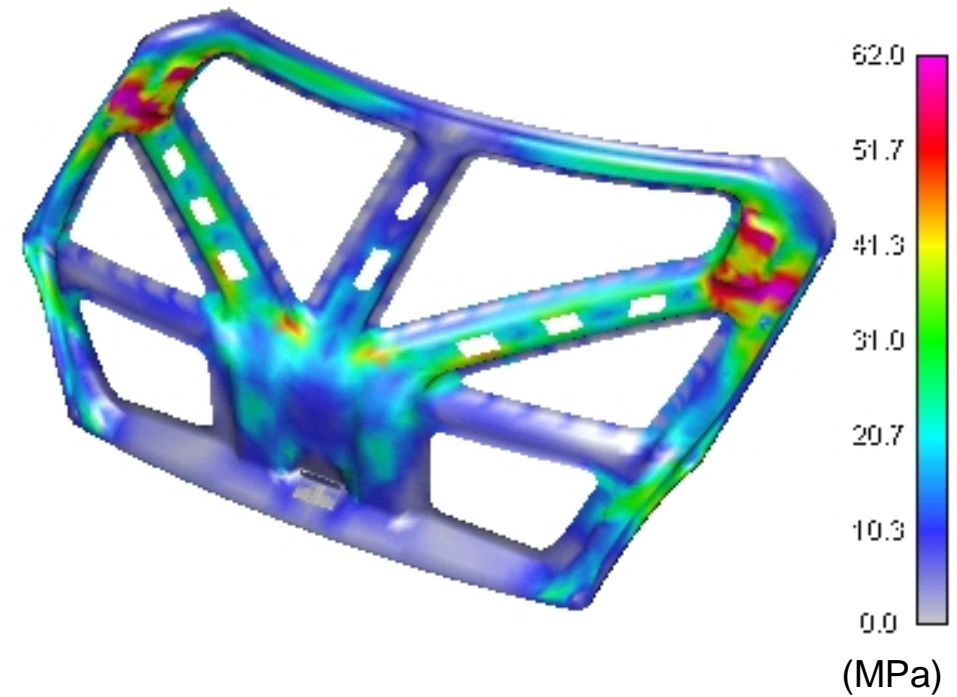
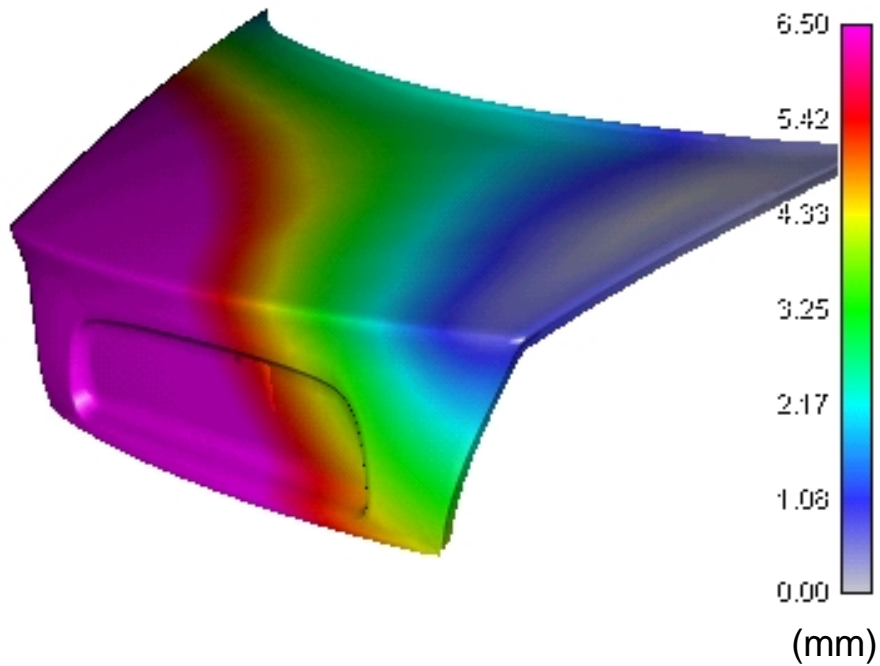
Results - Hood - Grille Integrated Side Beam - Deformation & Stress Plots





FEA Calculation

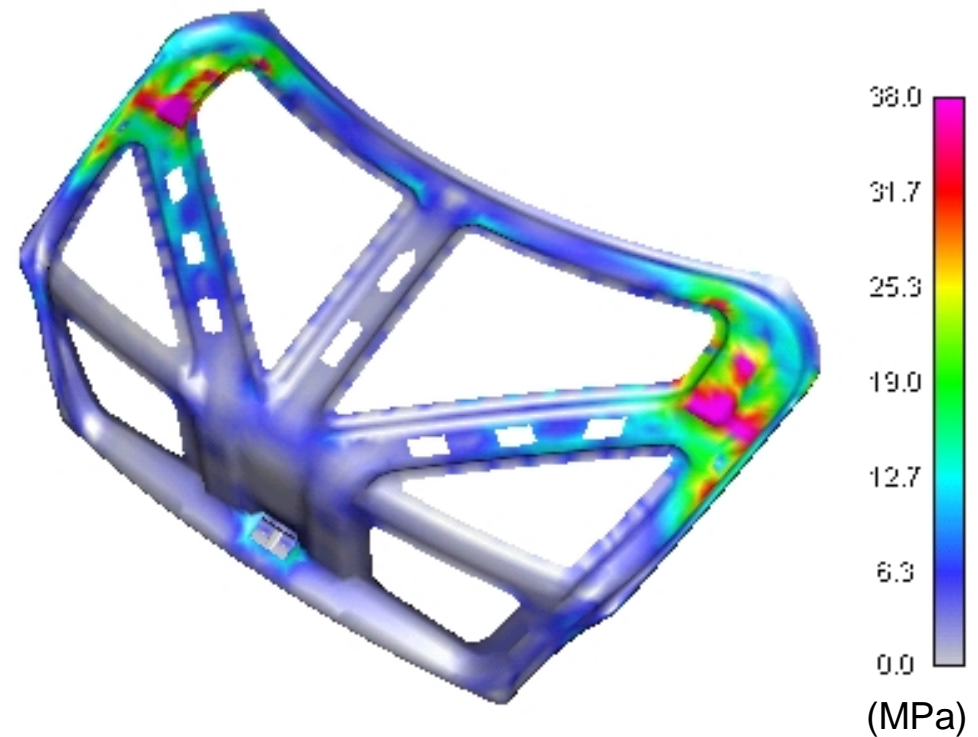
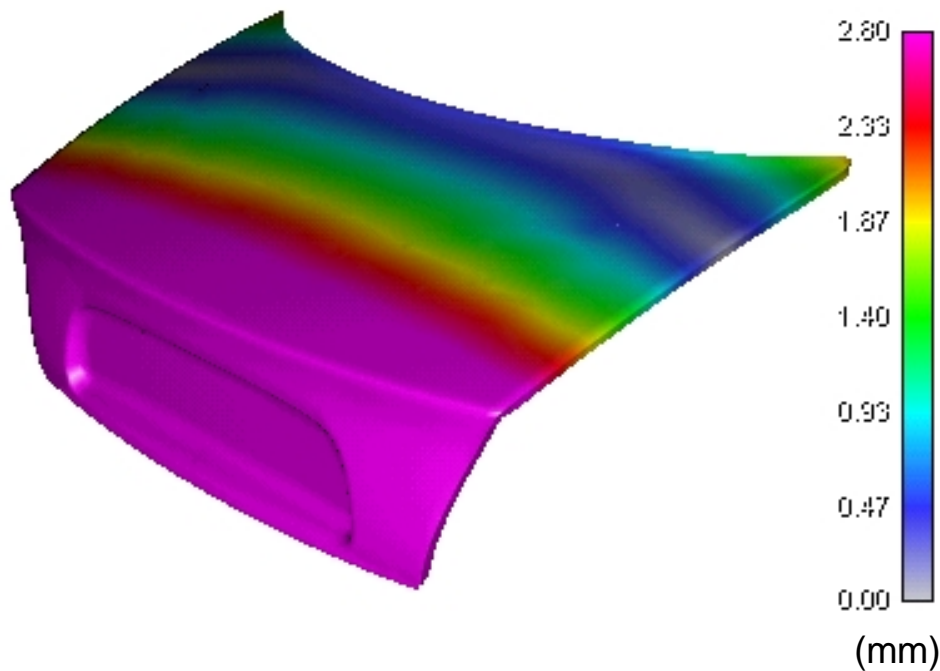
Results - Decklid - Conventional Torsional Rigidity - Deformation & Stress Plots





FEA Calculation

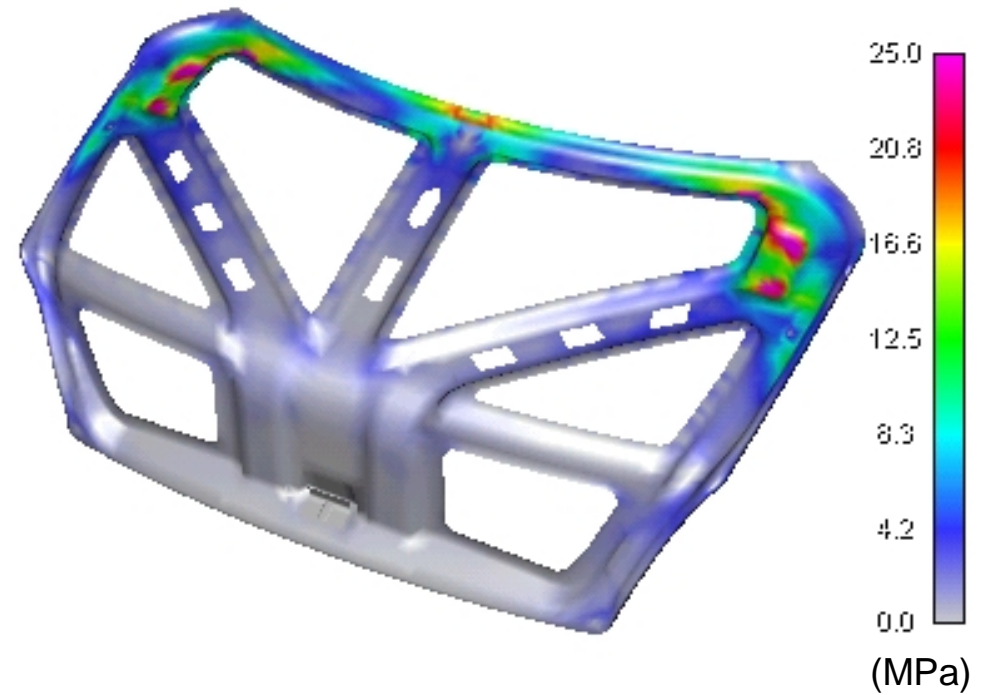
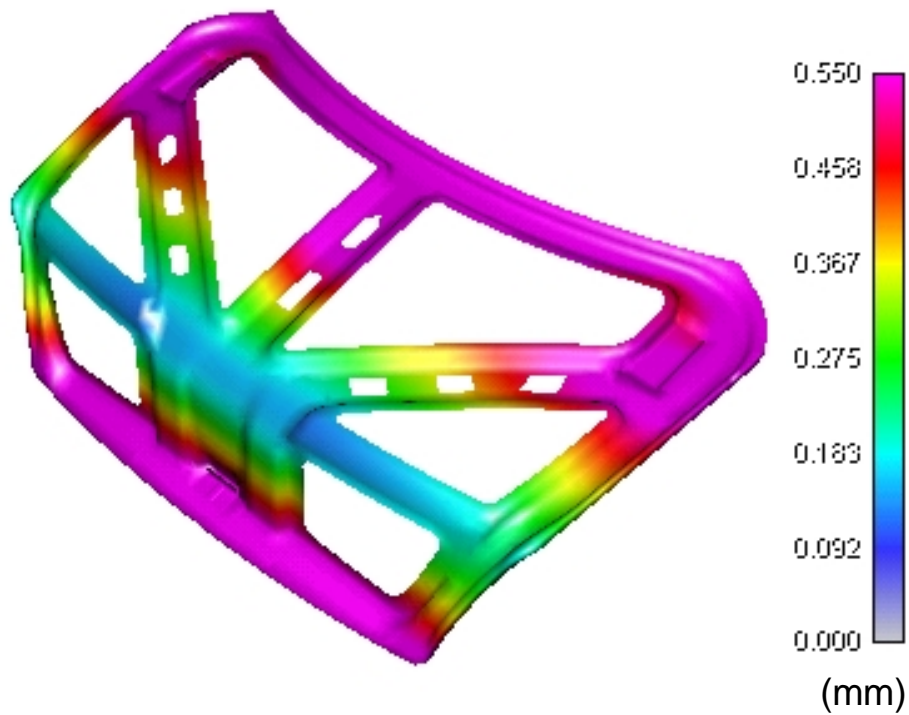
Results - Decklid - Conventional Bending Stiffness - Deformation & Stress Plots





FEA Calculation

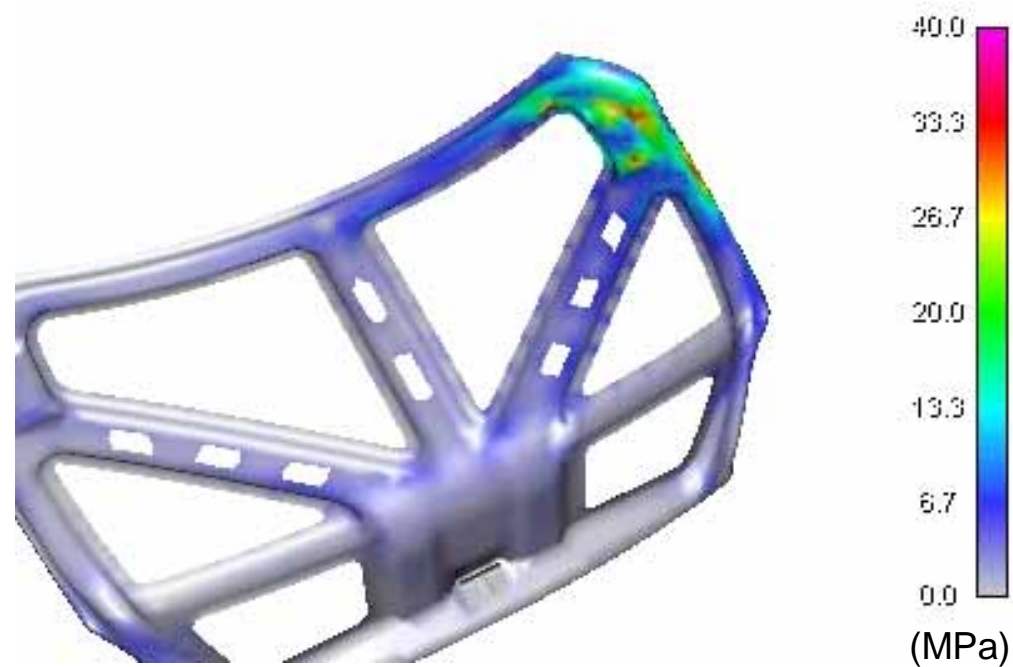
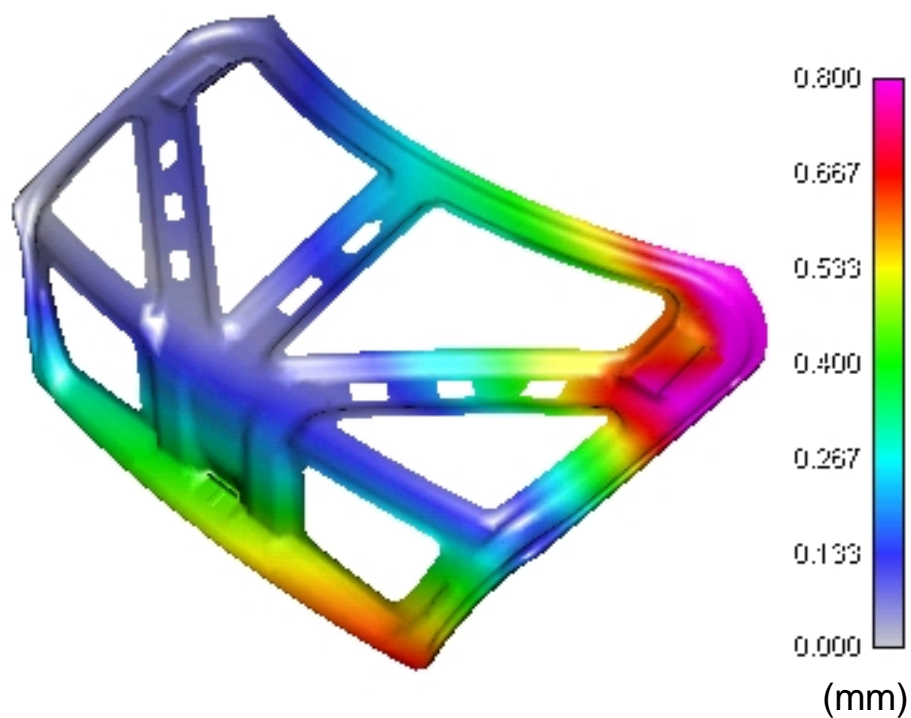
Results - Decklid - Conventional Front Beam - Deformation & Stress Plots





FEA Calculation

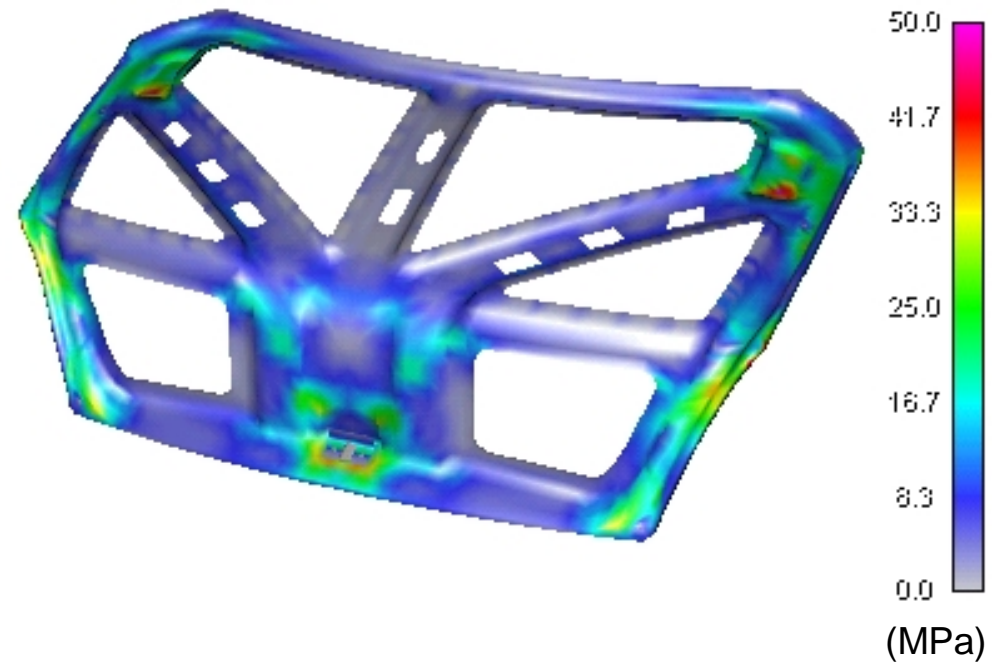
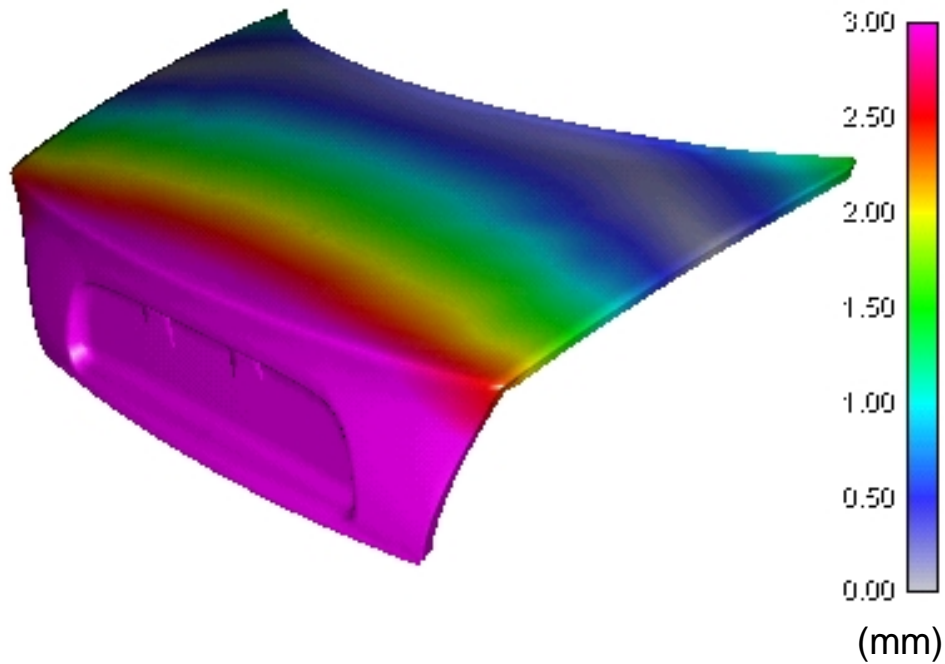
Results - Decklid - Conventional Side Beam - Deformation & Stress Plots





FEA Calculation

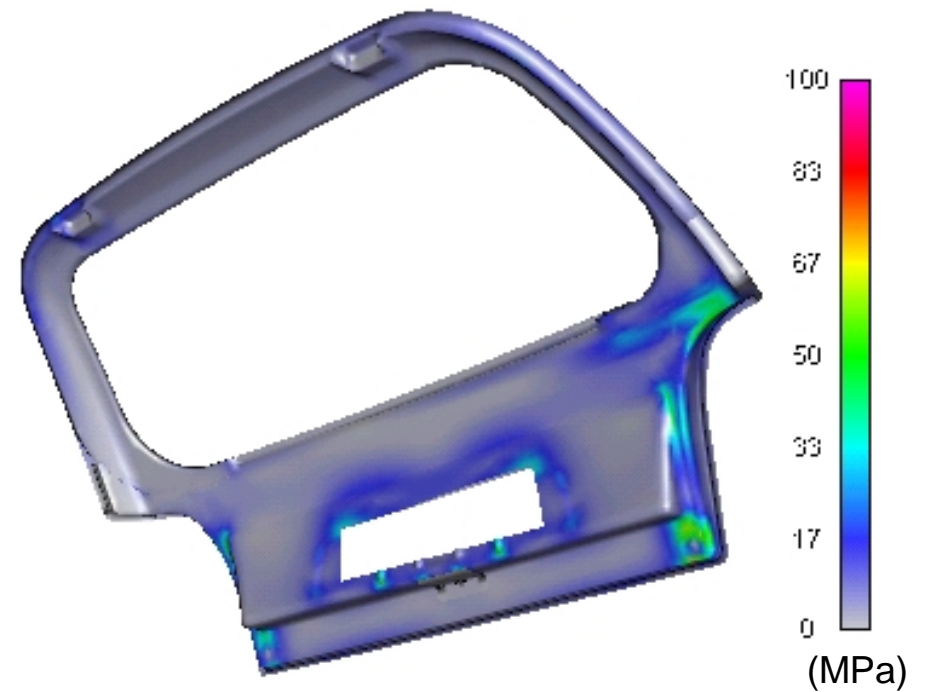
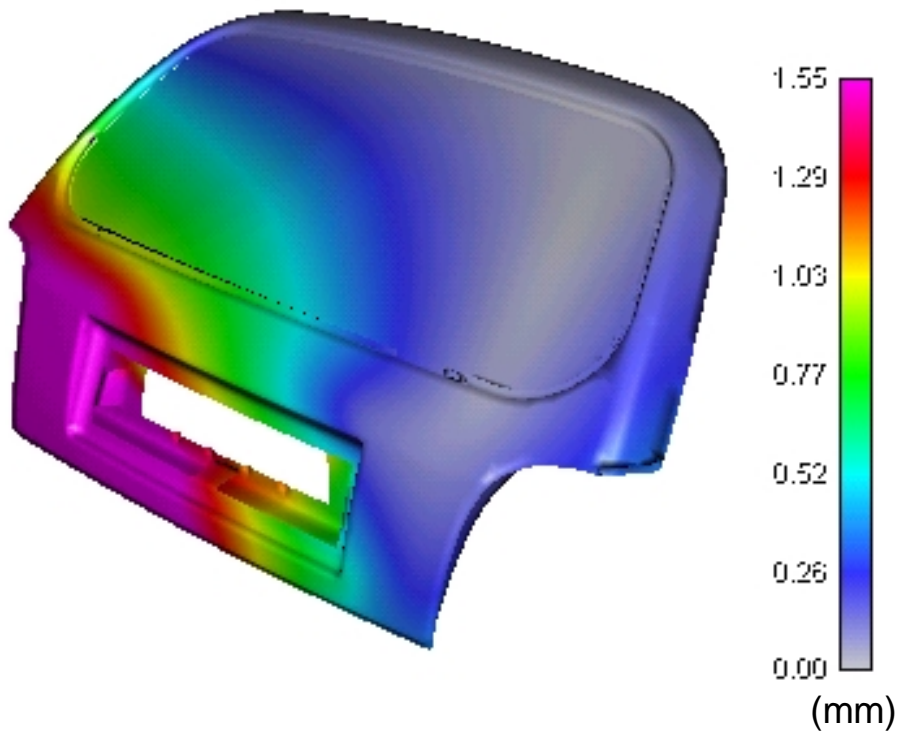
Results - Decklid - Conventional Tail Stiffness - Deformation & Stress Plots





FEA Calculation

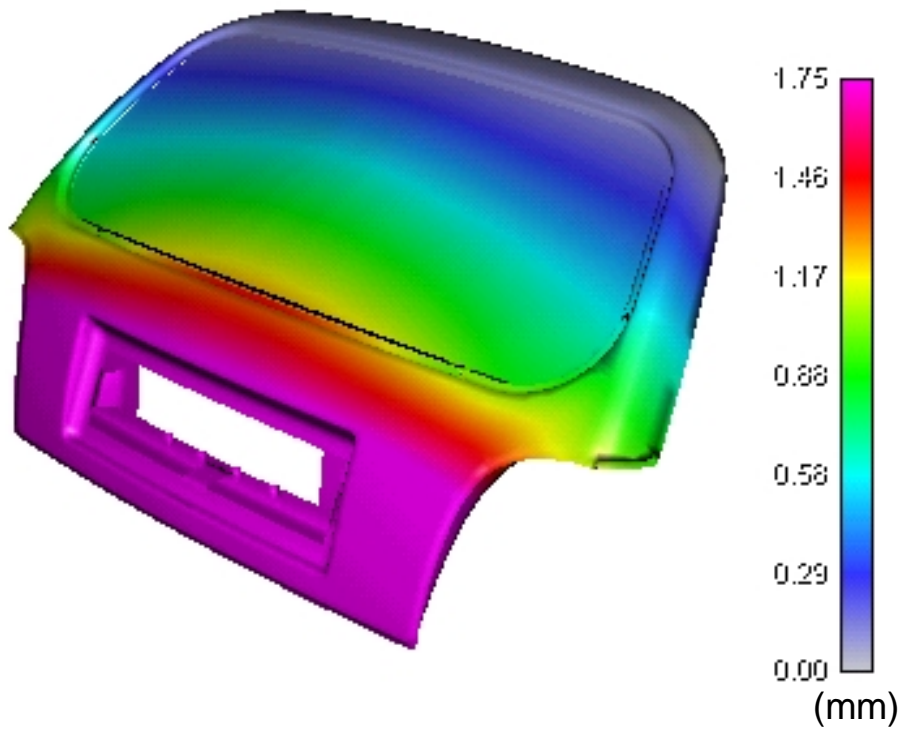
Results - Hatchback - Tube Hydroformed Torsional Rigidity - Deformation & Stress Plots





FEA Calculation

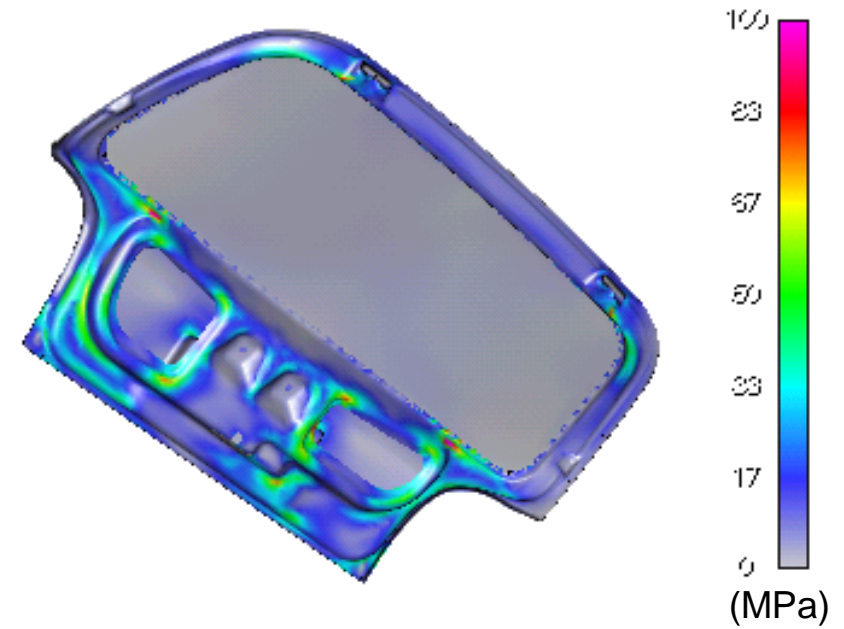
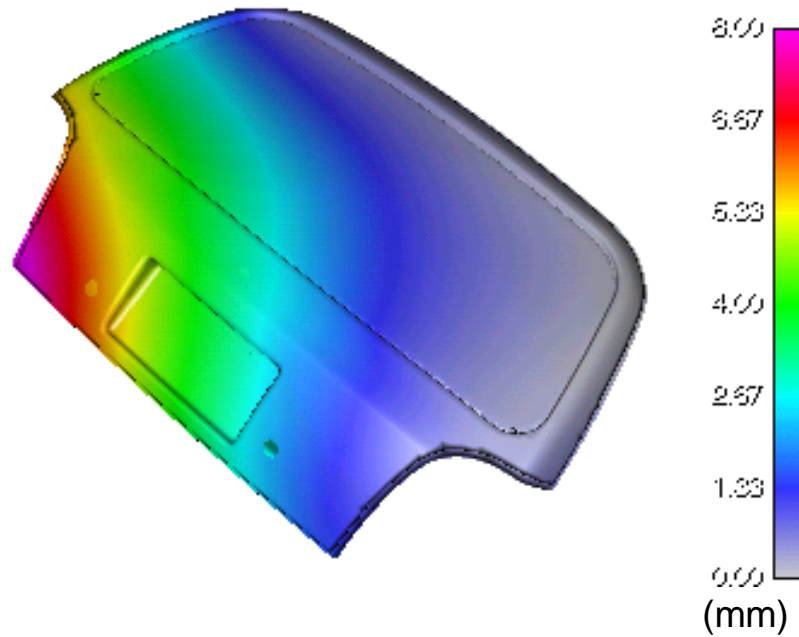
Results - Hatchback - Tube Hydroformed Bending Stiffness - Deformation & Stress Plots





FEA Calculation

Results - Hatchback - Tailored Blank Inner Torsional Rigidity - Deformation & Stress Plots





FEA Calculation

Results - Hatchback - Tailored Blank Inner

Bending Stiffness - Deformation & Stress Plots

