

Development of a New Roof Hatch Solution for Military Trucks

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Division of Machine Design • Department of Design Science • LTH • 2010

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ISRN LUTMDN/TMKT 10/5395 SE

Printed by Media-Tryck, Lund

Acknowledgments

It has been a great experience to work with this project. Throughout these months we have got the opportunity to meet experienced people from various departments within Scania. An inspiring environment and a warm welcome to the actual department, RTB, have contributed to an ideal finish of our studies.

We would like to thank our supervisors at Scania, Dan Svensson and Christoffer Pålsson for the continuous support during our work. A special thanks to Dan for taking us under his wings and showing a great interest in our project.

We would also especially like to thank involved employees in Oskarshamn, foremost Henrik Carlsson, Jan-Inge Karlsson and Rauno Honkonen for all help with the building of our prototypes.

Södertälje, April 2010

Andreas Byström and Josefin Salomonsson

Abstract

This report is a result of a Master Thesis project in mechanical engineering by Andreas Byström and Josefin Salomonsson. The thesis was carried out at Scania CV AB at the department for Special Vehicles and the Division of Machine Design at the Department of Design Science at LTH from November 2009 to April 2010.

Scania has a long tradition of designing and deliver vehicles to national defence forces. Scania's military trucks are built with small modifications from the civilian truck platforms. This gives Scania the ability to offer reliable and cost effective vehicles for military applications. The majority of the military trucks are equipped with a roof hatch. New requirements, due to larger personal body armour and more equipment among the military, demands a larger roof hatch. These demands are expected to increase in the future and to be competitive in this market Scania wants to offer a new roof hatch solution.

The aim of this work has been to design a variant of the current cab roof adapted to support a larger roof hatch. The annual volumes of these trucks are relatively low why the vision to manufacture the solution in the existing cab factory, with limited investments, has have a major impact on this project. By investigating the conditions and starting a dialog with personnel from market, production and development a good view of the specifications required was obtained. This dialog continued throughout the process to ensure that no requirements were neglected. The project has in some degree followed the product development process presented by Ulrich and Eppinger and involves development of design concepts, a concept selection and prototype sessions to verify and test the results.

The proposed design shows that it is possible to come up with a solution that fulfil all the demands and is adapted to be produced in the existing cab factory in a cost efficient way. It was also found that a flexible design, which is more or less independent of the roof hatch design, is preferable. Not only due to the lack of decisions whether or not the roof hatch should be designed by Scania but also to be able to meet specific customer requirements more convenient.

The final solution presented in this report consists of a border that is spot-welded onto the cab roof. On top of this border an external platform is mounted where the roof hatch can be installed. The hole in the cab roof is significantly larger than desired to accommodate various roof hatch designs and potentially be applicable for other applications. In parallel with our project; implementation of a larger roof hatch was carried out on a military truck delivered to Scania Deutschland. It was a great recognition and shows that we are heading in the right direction when they chose to use our border solution for their roof hatch installation.

Key words: Scania, Roof hatch, Trucks, Design, Product Development

Sammanfattning

Den här rapporten redovisar det arbete som utförts av Andreas Byström och Josefin Salomonsson inom ramen för civilingenjörsprogrammet examensarbete. Arbetet har utförts på Scania, avdelningen för specialfordon från november 2009 till april 2010.

Scania har en lång bakgrund som leverantör av militära fordon till försvarsmakter världen över. Scantias militära lastbilar är uppbyggda av samma grundstruktur som de civila lastbilarna och med endast små förändringar anpassas fordonen till militära behov. Detta ger Scania möjligheten att erbjuda tillförlitliga och kostnadseffektiva fordon för olika typer av behov. Majoriteten av dessa fordon är utrustade med en taklucka. Luckan används för spaning men även som en alternativ nödutgång. På grund av att militärer idag har mer utrustning och större kroppsskydd kommer det framöver att finnas behov av en större taklucka som är anpassad för dessa nya krav. Scania har för avsikt att fortsätta vara konkurrenskraftiga på denna marknad och vill därför kunna erbjuda en större taklucka på sina militära fordon.

Syftet med arbetet har varit att utveckla en variant av hyttens tak som möjliggör installation av en större taklucka. Den årliga volymen av militära lastbilar är relativt låg och viljan att med låga investeringskostnader kunna tillverka hytten i den befintliga fabriken har därför i stor utsträckning påverkat arbetet.

Genom att utreda förutsättningarna för projektet och upprätta en dialog med personal från marknad, produktion och utveckling erhöles en bra bild av vilka krav som behövde tillgodoses. Dialogen med dessa personer fortsatte kontinuerligt under hela processen för att säkerställa att inga krav försumrades. Arbetet har drivits som ett utvecklingsprojekt och valda delar av Ulrich och Eppingers metodik har använts där det varit möjligt. Processen har innefattat framtagandet av konceptlösningar, en urvalsprocess och byggandet av prototyper för att testa och verifiera resultatet.

Den föreslagna lösningen visar att det är möjligt att konstruera en lösning som uppfyller samtliga krav och samtidigt är anpassad för att kostnadseffektivt kunna monteras i den befintliga hyttfabriken. Under processen konstaterades att en flexibel lösning som är mer eller mindre oberoende av takluckans konstruktion är att föredra. Detta för att det inte är sagt om en framtida lucka ska utvecklas av Scania eller köpas in externt, men även för att det lättare ska gå att tillgodose specifika kundbehov.

Den slutliga lösningen som presenteras i denna rapport består av en sarg som är svetsad mot hyttens tak. Ovanpå sargen monteras en plattform som möjliggör installation av den större takluckan. Plattformen är tillräckligt stor för att kunna passa olika varianter av takluckor samt potentiellt kunna användas i andra tillämpningar. Parallellt med vårt projekt har en militär lastbil levererats till Tyskland för vidare påbyggnad av en större taklucka. Det var ett stort erkännande och visar att vi är på väg i rätt riktning när de valde att använda vår föreslagna sarglösning för installationen av sin lucka.

Contents

1	Introduction	1
1.1	Background	1
1.2	Objective	2
1.3	Assignment Directive.....	3
1.4	Limitations	3
1.5	Method	4
1.5.1	Initial Phase.....	5
1.5.2	Design Work	5
1.5.3	Analysis.....	6
1.6	About Scania	6
2	Theory	7
2.1	Cab body	7
2.2	Production	9
2.3	Existing solutions.....	11
3	Competitor Analysis.....	13
3.1	Mercedes-Benz.....	13
3.2	MAN	17
3.3	Iveco.....	19
3.4	Tatra	21
3.5	Conclusion	21
4	Specifications	23
4.1	Specification of Requirements	23
4.2	Design Goals.....	25
5	Design Concepts.....	27
5.1	Design ideas	27
5.1.1	Bodywork solution 1	27
5.1.2	Bodywork solution 2	29
5.1.3	Circular roof hatch frame- Modified.....	29
5.1.4	Circular roof hatch frame- New frame.....	30
5.1.5	Rectangular roof hatch	31
5.2	Concept selection	32
5.2.1	Concept screening	32
5.2.2	Further Development	35
5.2.3	Concept Scoring	44
5.3	Prototyping.....	46
6	Concept Development	53
6.1	Design Development.....	53
6.1.1	Coating and Sealing	53
6.1.2	Strength	56
6.1.3	New roof plate.....	57
6.1.4	Interior design	59
6.2	Material selection.....	61
6.3	Prototyping.....	61

7	Cooperation with Sonntag GmbH & Co	63
8	Final Solution.....	67
8.1	Proposed Design	67
8.1.1	Day cab with low roof.....	70
8.1.2	Sleeper cab with normal roof	71
8.2	Solution by Sonntag	72
9	Discussion and Conclusion	73
10	Recommendations	75
11	References	77
12	Register of Figures	79
13	Register of Tables	81
	Appendices	83
	Appendix A	83

1 Introduction

This initial chapter is aimed to give the reader a background of the project as well as its objective and limitations. Included is also a description of the method used throughout the thesis work. The chapter ends with a short introduction to Scania and the department where the project was carried out.

1.1 Background

Scania deliver trucks to national defence forces for material transportation and peace-keeping operations. Scania has a long tradition in producing highly modularized products which enables that customized trucks for different military purposes can be built with small modifications of the civilian versions. The majority of the military trucks are equipped with a roof hatch. The hatch is mainly used for reconnaissance and as an alternative emergency exit. But it can also be used in combination with different features such as a weapon ring or a roof rack.

To be able to fulfil new requirements and take a competitive position in future procurements within the defence market, Scania wants to offer a new roof hatch solution. The roof hatch should be significantly larger than today's roof hatch since a fully-equipped military should, unimpeded, be able to go up and down through the hatch. The demands of a larger roof hatch are expected to increase in the future due to increased body armour and more equipment among the military, but also regarding increased requirements due to safety. Today Scania's military trucks are equipped with a standard, rectangular roof hatch with the dimensions 500x450 mm, Figure 1-1.



Figure 1-1 Existing roof hatch solution

The armed forces of Germany, Bundeswehr has shown interest in ordering military trucks from Scania, equipped with a roof hatch with increased dimensions, either a circular opening with a diameter of 800 mm, or a quadratic opening, 800x800 mm. As a part of the process, a military truck was recently delivered to Scania Deutschland. The truck is currently undergoing an adaption to meet several requirements, including a larger roof hatch. The body work is carried out in Germany by a third party company called Sonntag, more about the cooperation is given in chapter 7.

1.2 Objective

The purpose with this Master Thesis project is to design a variant of the current roof. The new roof structure should be designed to accommodate a hatch with the desired dimension and preferable be able to manufacture in the existing cab factory in Oskarshamn. The latter implicates that the main focus in the design work has been production adaptability of the design.

It is not investigated whether the future hatch will be designed by Scania or if it will be a work done by external bodybuilders. Therefore the primary focus in this thesis is to make a preparation of the roof to enable future installation of a hatch with increased dimension rather than to come up with a design of a new roof hatch.

1. Introduction

As time permits an investigation regarding implementation of desired features, such as a bar for weapons and space for weapon systems should be done. A modification of the interior ceiling, with respect to isolation and interior details should also be discussed in case of time.

1.3 Assignment Directive

The assignment consists of adaptation of the roof for the necessary size of the opening (diameter 800 mm, or square 800x800 mm), with the criteria that the cab shall be possible to produce in the existing factory in Oskarshamn. Below are a summary of materials for investigation.

- Variants of roof¹: Priority 1 is the day cab equipped with a low roof; 16L.
Priority 2 is the sleeper cab equipped with a normal roof; 19N.
In case of time the sleeper cab equipped with a low roof; 19L, should be considered as well.
- The size of the hatch should be either a circular opening with a diameter of 800 mm, or a quadratic opening 800x800 mm.
- Investigation should be done regarding existing roof hatches on the market that could possibly be used.
- The hatch should possibly be equipped with a ring for a machine gun, which is in use on some markets, why a circular opening might be preferable.
- The hatch should be possible to combine with some sort of roof rack or a platform on the roof.
- The hatch should be positioned so that a platform used for reconnaissance can be built inside the cab. The design of a platform is not included in the thesis.
- The roof structure must not be weakened but may rather have to be strengthened to be able to withstand that a weapon with a weight of 200 kg is mounted next to the hatch.
- The annual volume is by estimate 100-200 cabs.

1.4 Limitations

Due to the time limit of this thesis (20 weeks) the focus in this project will be to adapt the existing roof structure to the new roof hatch. Priority will be given to the cabs 16L and 19N. The interior ceiling will not be given priority in the first step.

The existing 3D models of the Cab has been modelled in the CAD software CATIA V4 and the conversion to the newer version V5, which is the version currently used at Scania is not always correct which makes it harder and more time consuming to change the design of existing parts.

¹ A more detailed explanation of the different cab types within Scania is given in chapter 2.1.

Scania's military trucks are ordinary commercial trucks slightly modified to meet military requirements. This sets limitations regarding production since the manufacturing process to a large extent is automated, why major modifications are hard to implement. Another limitation in this project is cost. New investments in customized tools and equipment imply a large cost which is hard to cover by the relatively unequal flow of orders for Military trucks. Therefore a big part of this project has been to come up with alternative solutions to implement the modification in the ordinary manufacturing line.

The cooperation with the Germans was a bit limited by inadequate communication. Despite their great interest in the project the process was slowed down by the language barrier that occurred when not being able to communicate directly with all parties due to insufficient language knowledge.

1.5 Method

A design project that involves a major change of the existing structure implies that a lot of different departments are involved. It is important to understand all the demands and requirements of the product to be developed, but also to be aware of different problems and limitations. The process of the thesis can be divided into three main areas according to Figure 1-2.

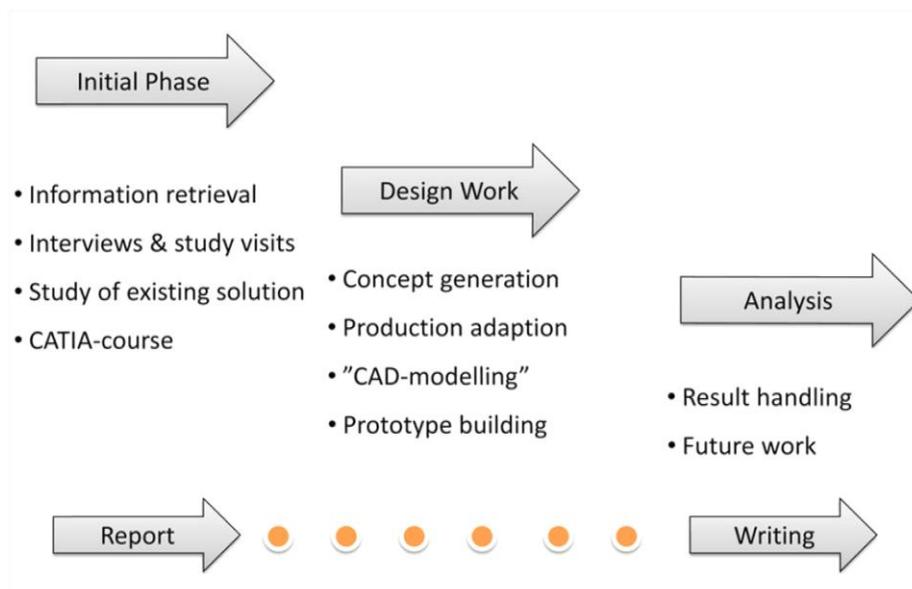


Figure 1-2 Process Flow

The initial phase in the project was constituted by a theory phase where an information retrieval was done to be able to get a better understanding of the main factors that affect the future design work. After sufficient knowledge about demands

1. Introduction

and limitations, the project turned into a design phase, which is the main emphasis of this thesis, where several concept solutions were generated and evaluated. The last phase of the project consists of an analysis. The report has been written continuously besides the project.

1.5.1 Initial Phase

The actual project was originally an inquiry from the German Army, therefore a close cooperation with the product manager at Scania, Heikki Fant, responsible for the defence market and a contact from Scania Deutschland; Frank Reinartz was established in an early phase. A lot of effort was put into the study of competitive solutions on the market to get inspiration and an increased understanding about possible solutions.

To be able to better understand the complexity that this project involves due to a major change in the existing roof structure, a broad knowledge of Scania's production system was necessary to better be able to define certain limitations. Therefore a study visit at the cab production in Oskarshamn was arranged and a meeting with Stanley Gunnarsson, responsible for product preparation for S-orders in Oskarshamn. A continuous contact with Mattias Hammarwall, group manager for the development of cab body and suspension, was also established to get a better understanding of the existing roof structure, and modification possibilities regarding strength and design.

Scania uses the software CATIA V5 when modelling and designing in the computer therefore a 3-weeks education in the actual software was carried out in the beginning of the thesis work. The course concerned part design, assembly and drawings.

1.5.2 Design Work

The design work can be divided into two different phases; the concept generation phase where several ideas were born and evaluated, followed by a concept development phase where a more detailed investigation of the most promising concept was done. During the first phase, selected parts from Ulrich and Eppingers well-known literature, *Product Design and Development*, were used.

The design work was an iterating process, performed in a close collaboration with continuous feedback from involved persons in Oskarshamn, at Scania Deutschland and design managers at Cab body design. All the concepts have been designed based on the same variant of cab, the day cab with low roof. The different variants of cab bodies are described further in chapter 2.1. The final solution was then implemented on the sleeping cab with normal roof as well.

In the end it turned out that the German bodybuilder company, Sonntag, successfully could implement our proposed solution why the design work turned into a more

collaborative process towards the end. More about the collaboration can be read in chapter 1.

1.5.3 Analysis

The last phase of the project aims to present the final solution in an appropriate way and also to give recommendations for further investigations and future work. Our hope is that the suggested design should be that well-conceived that no major problems will occur when the project is completed and implemented in the future.

1.6 About Scania

“Scania’s objective is to deliver optimised heavy trucks and buses, engines and services, provide the best total operating economy for our customers, and thereby be the leading company in our industry. The foundation is our core values, our focus on methods and the dedicated people of Scania.”

Scania is one of the leading manufacturers of trucks and buses and operates in more than 100 countries, worldwide. The company has approximately 35,000 employees over the world. Of these, nearly 3000 work with research and development which is concentrated in Södertälje, Sweden. Södertälje is also where the head quarter and a major production unit are located [1].

Scania is known for its modular product system which with a limited number of components allows a high level of customization to fit customer needs. The modular system enables implementations of new improvements without major changes of the product, since parts can be developed separately and put into production without the launch of a complete new model [2].

RTB is the department for special vehicles within Scania and develops tailor made trucks to satisfy special customer needs and requirements. For example heavy haulage, military and fire fighting vehicles.

2 Theory

To be able to understand possible limitations of the design work a study of today's Cab body and existing manufacturing capability was carried out. Included is also a brief description of existing roof hatch solutions within Scania.

2.1 Cab body

Scania offers a large range of cabs in three different truck series; the P-, G- and R-series. These series are available in different cab versions; short, day and sleeper cabs in various heights. The heights are low, normal, highline and the R-series exclusive version Topline. See the different cabs in Figure 2-1.

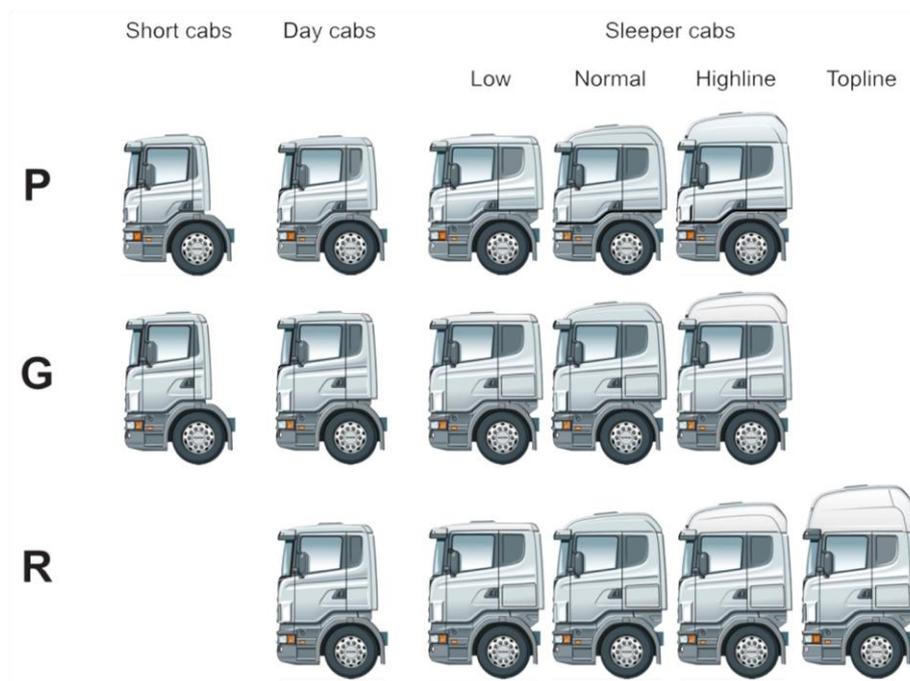


Figure 2-1 Scania Cab Program [3]

The P-series cab is mounted at the lowest position which makes this truck suitable for distribution and construction trucks for its ease of access to the cab. The G-series cab, which is mounted at a higher position, offers better comfort and is more suitable for long-haulage vehicles. The R-series is mounted even higher and is the most exclusive truck series. This truck is designed to offer the best comfort and fuel economy for high demanding long-haulage tasks.

Development of a New Roof Hatch Solution for Military Trucks

The variation in cab length offers different kind of comfort and is suitable for different needs. The short- and the day cabs do not offer any bed as the sleeper versions do. The main priority for this task has been the day cab with low roof and the sleeper cab with normal roof but the sleeper cab with low roof has also been studied. This implies that the roof hatch must fit and be able to mount on three different variants of roof.

The roof structure consists of two lengthways assembly beams (1), one rear cross member (2) and one centre placed roof hatch frame (3), Figure 2-2. As the cabs have different size and inclination of the roof, the lengthways beams are designed to meet these variances but the distance between them is 1180 mm independently of the variant of roof. The same roof hatch frame is therefore mounted on all the above cab versions. These parts are all pressed and then welded together to form the assembled roof structure.

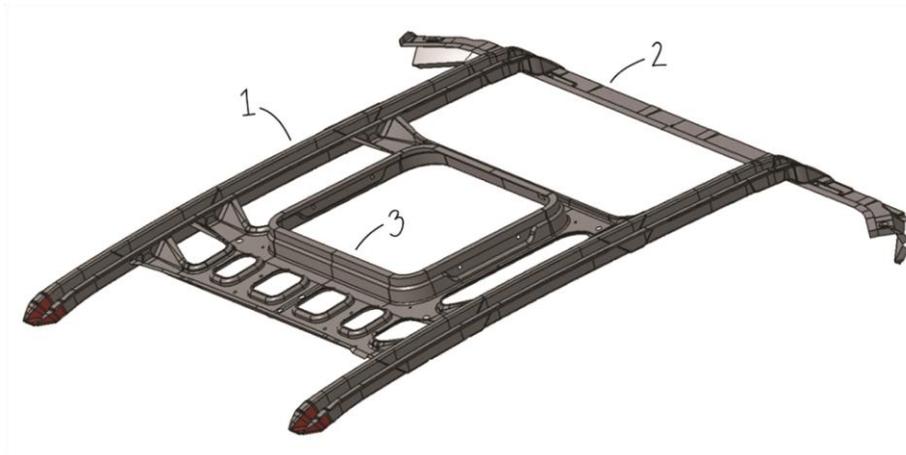


Figure 2-2 Roof structure

2. Theory

On top of this structure the outer panel is mounted. The outer roof panel consists of three parts; two side panels, one at each side of a larger central part, Figure 2-3.

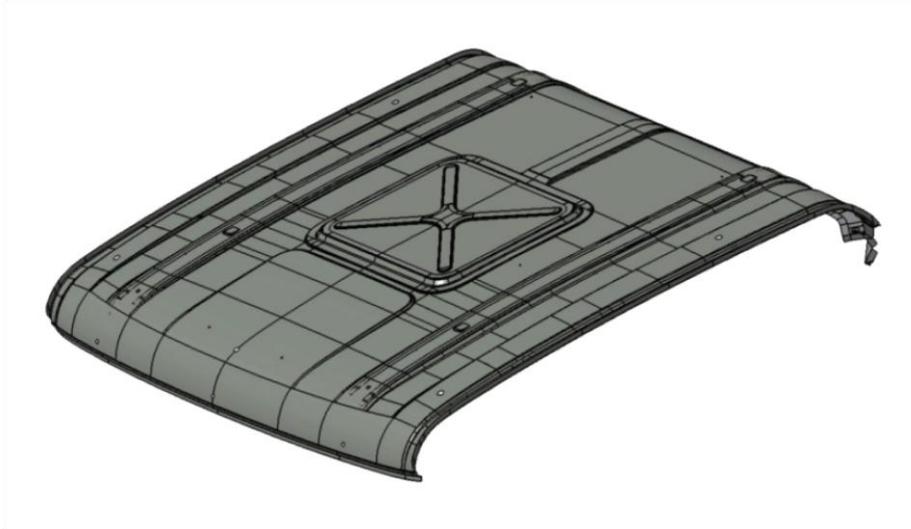


Figure 2-3 Central part of the outer roof panel

2.2 Production

Scania has, according to the same model as Toyota, built its own unique production philosophy; the Scania Production System (SPS). The system is a powerful instrument for increasing productivity and it plays an important part in Scania's success. The purpose of SPS is to make Scania's production more efficient and to eliminate waste in all respects. One of the fundamental principles in SPS is to focus on the working methods, consequently on how to work. This means that the production controls by its condition and its nature to reach good results [4].

Scania's cab production unit is located in Oskarshamn. Today, the factory is responsible for the production of cab frames and the final assembly of the cab body for the entire European market. The factory is to some extent automated. From 2004 to 2007, the productivity increased by 50 percent, from 20 to 30 cabs per employee annually, with limited investments [5].

Figure 2-4 shows an overview of how the production is organised and divided into different zones.

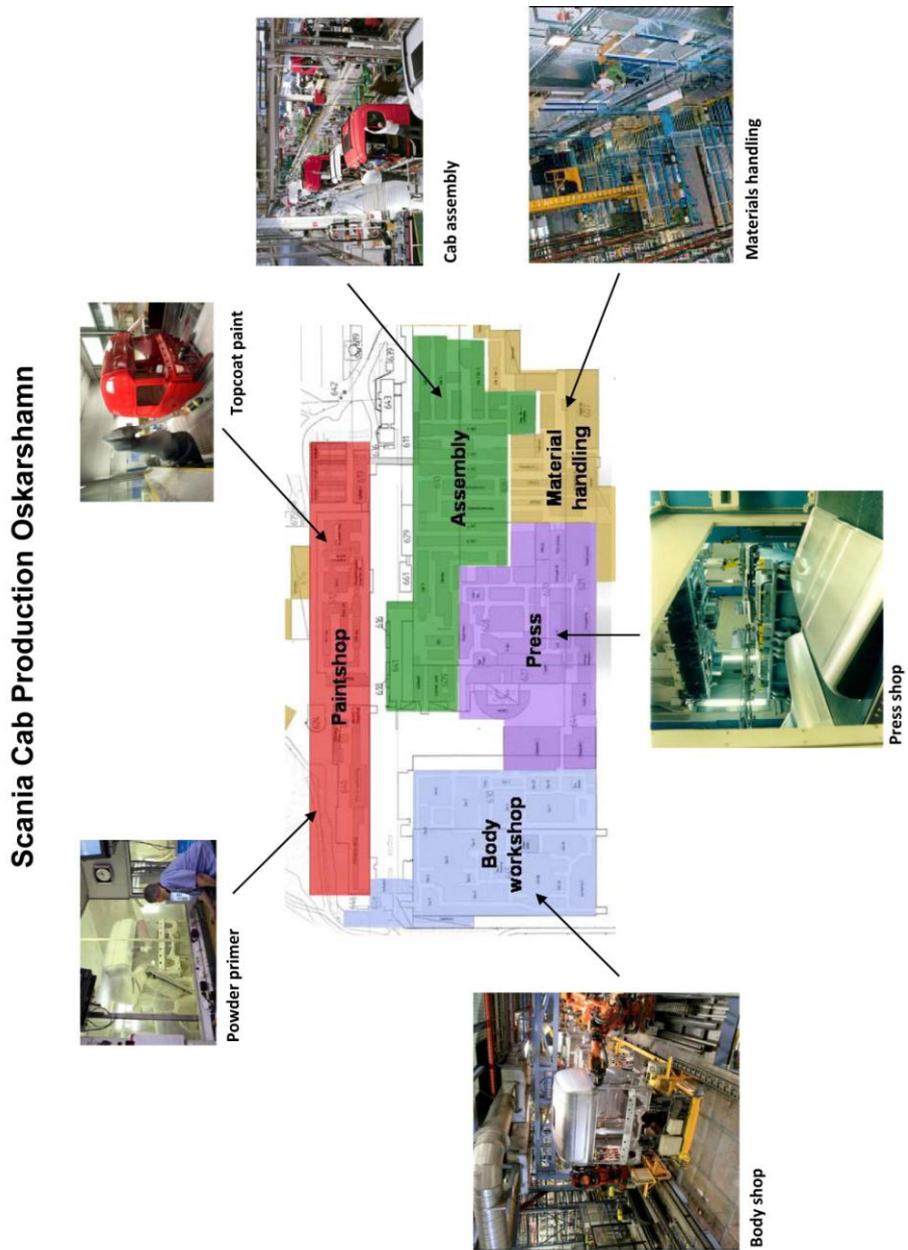


Figure 2-4 Cab production line in Oskarshamn

The body work shop zone is exclusively automated and the robots require repeatability. Therefore major changes in the structure of the body are very hard to implement in the automated line.

2.3 Existing solutions

The civilian trucks are equipped with either a manual or an electrical roof hatch. The manual roof hatch does only enable a small gap for air intake, while the electrical one can slide to a half-open position. The electrical roof hatch is fairly exclusive and therefore not commonly used.

The hatch is attached to the opening mechanism which is fixed to the roof hatch frame. From inside the cab, a lower section is attached for esthetical and isolating aspects, Figure 2-5. A mosquito net and an inner hatch for noise isolation can also be mounted together with the roof hatch.

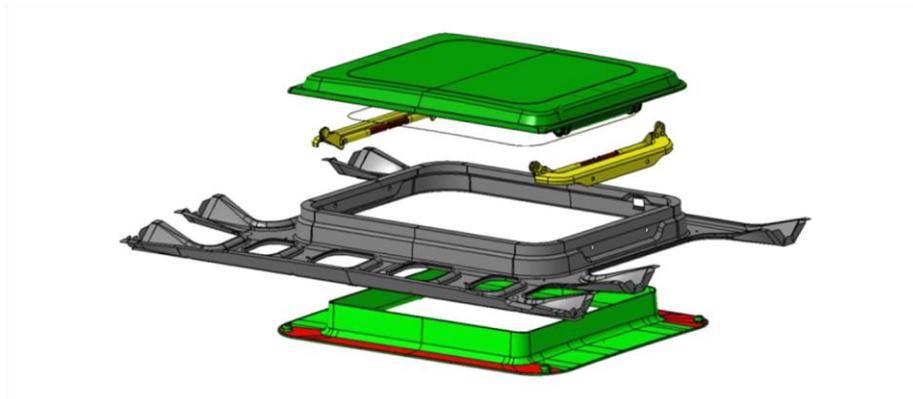


Figure 2-5 Disassembled manual roof hatch

For military vehicles Scania offers a manually foldable roof hatch, Figure 2-6 which gives a larger opening. The dimensions of the opening is 500 x 450 mm and is therefore primary intended as an alternative emergency exit.

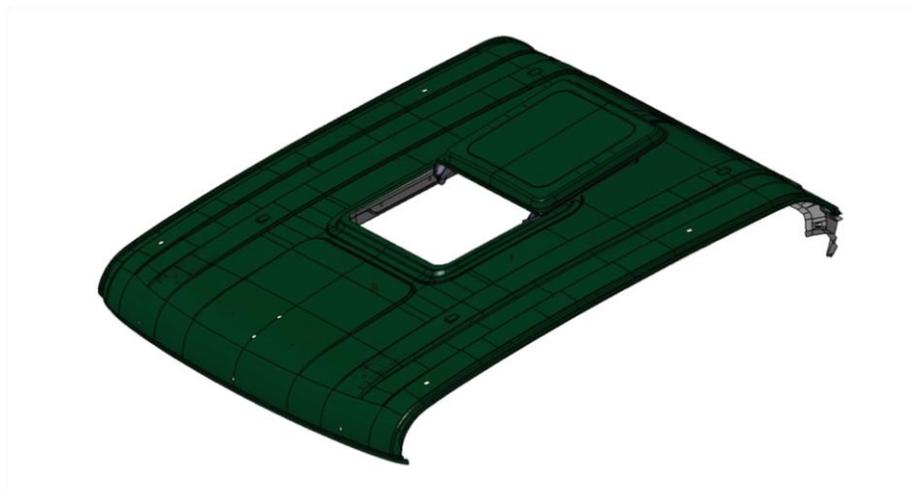


Figure 2-6 Foldable roof hatch

3 Competitor Analysis

To get a general understanding of possible solutions for a new roof hatch, find additional requirements and also to figure out what the customer's need, a market analysis of the current solutions was done. The materials obtained by studying different competitive solutions have to some extent influenced our continued design work and it is obvious that a circular roof hatch is the most common design on the actual market.

What is important to keep in mind is that some competitors have certain trucks developed especially for military use whereas Scania, as previously mentioned, uses its commercial trucks slightly modified to meet military requirements.

During the analysis several relevant questions and thoughts were discussed and aimed to be a help in the continuing design work.

- Circular or rectangular shape?
- Placement of the roof hatch?
- Type of hinge, vertical, horizontal, backward flip?
- Placement of the hinge?
- How is the hatch attached to the roof?
- Is there any platform mounted on the roof?
- Is the roof hatch an off-the-shelf product?
- Other additional features?
- Conflicts with other roof attachments?

3.1 Mercedes-Benz

Mercedes-Benz is a German manufacturer of luxury automobiles, buses, coaches and trucks. Besides that they offer a full range of special vehicles including military trucks. From small, extreme off-road vehicles to larger transportation trucks built on their civilian truck platforms. They can all be optionally equipped with a circular roof hatch in certain configurations.

The Unimog-series designates a range of multi-purpose four wheel drive medium trucks. Standard cabs are equipped with a rectangular roof hatch and are not man-accessible. The optional man-accessible roof, see Figure 3-1, includes, among other things, an access ladder and an assembly frame with sheet metal panelling that is bolted to the cab-roof, and comes as a package. The circular roof hatch is available as an option for this type of roof. The roof hatch is hinged and has a diameter of approximately 700 mm.

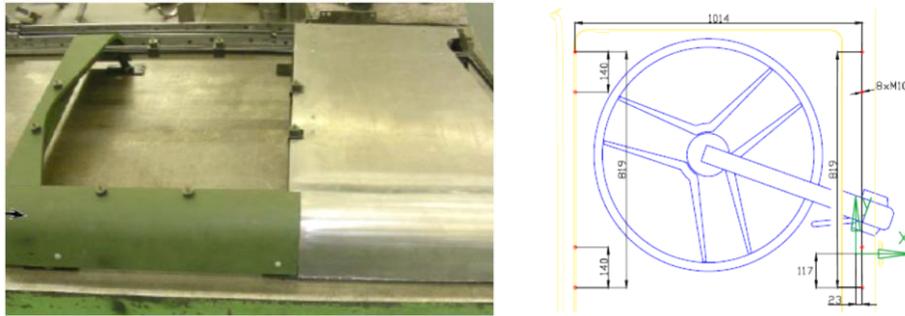


Figure 3-1 Unimog roof and drawing

The Atego and Axor are two semi-heavy trucks from Mercedes ordinary truck range, Figure 3-2. The main components come from the standard production line and additional features are a swivel roof hatch, foldable centre seat and weapon holders, Figure 3-3 [6].



Figure 3-2 Axor Exterior view [6]

3. Competitor Analysis



Figure 3-3 Atego Interior [6]

Mercedes does also offer a larger truck, a military version of its ordinary Actros model, Figure 3-4. The truck is optionally available with features similar to the ones described above with the swivel roof hatch and the foldable seat [6]. In Figure 3-5, the Actros interior is shown to the left. The picture to the right shows the roof hatch from above with a weapon holder mounted over it. The roof hatch slides under the weapon holder when opened.



Figure 3-4 Actros front view [6]



Figure 3-5 The Actros roof hatch equipped with a weapon mount. [6]

3. Competitor Analysis

3.2 MAN

MAN is a German supplier of trucks, buses, diesel engines, turbo machines and special gear units. MAN is, in accordance with Scania, partly controlled by the German carmaker Volkswagen.

The MAN TGA/TGM trucks are ordinary MAN trucks but here specially designed for military use. They can optionally be equipped with a circular roof hatch, but a large electric roof hatch is also available, Figure 3-6.



Figure 3-6 The MAN TGA with an electric roof hatch.

MAN Military Trucks HX and SX series are equipped with an optional pivoting roof hatch and machine gun ring mount, Figure 3-7.



Figure 3-7 MAN SX [7]

Development of a New Roof Hatch Solution for Military Trucks

The roof hatch is an additional module attached on top of the cab and can optionally be installed without the ring mount, Figure 3-8. The HX model has a different roof structure but the roof hatch is identical, Figure 3-9. The SX and HX model are based on the civilian truck MAN TGA but with a large customization to fit extreme military use and the roof hatch is an optional feature for the entire SX and HX series [7].



Figure 3-8 MAN SX roof [7]



Figure 3-9 MAN HX Roof [7]

3.3 Iveco

Iveco started out as a merging of several European vehicle manufactures in 1975, and is today a part of the Fiat group. Iveco has a large defense vehicle division and offers customized trucks from its ordinary truck range; Eurocargo and Stakker, but also more specialized military vehicles such as smaller Light Multi Role Vehicle, LMV [8].

Many of these trucks can be equipped with a roof hatch. Figure 3-10 shows the roof hatch from inside a cab. The roof hatch is manually locked with the handle and the opening of the hatch is managed by the arm to the right. As an additional feature to the roof hatch a weapon mount is attached on top of the roof according to Figure 3-11. The weapon mount is open on the side to allow the roof hatch to slide under it when open.



Figure 3-10 Iveco roof hatch inside



Figure 3-11 Iveco roof hatch outside

3.4 Tatra

Tatra is a relatively small truck manufacturer from Czech Republic. Tatra offers heavy-duty, special and military vehicles. Their military truck line-up is Armax, Force, T815-7 and T810. T810 shown below is the one equipped with a roof hatch [9].

The roof hatch includes a supporting bar for weapons as well as for the user. The roof hatch from Tatra is folded backwards vertically when opened. This solution offers some protection from the back but is harder to combine with different attachments. The frame structure of the roof, aimed to support the roof hatch, appears in the picture to the right, Figure 3-12. The roof hatch module seems to be carried up by two crossing beams attached on both sides of the cab roof.



Figure 3-12 Tatra T810 with a supporting bar installed with the roof hatch [10] [11]

3.5 Conclusion

All major competitors offer a larger roof hatch apart from Volvo where no information regarding a larger roof hatch has been found. One explanation why both Scania and Volvo lack this feature might be the absence of demand from the Swedish Armed Forces. Many European Defence Forces, including the German Bundeswehr, require that military trucks are equipped with a larger roof hatch why it is more or less considered as a standard on the European market.

A conclusion when studying the competitors' solution is that a circular roof hatch seems to be preferable. The majority of the solutions also uses a pivoting or swivel

opening mechanism allowing the roof hatch to slide horizontally, see for example the Mercedes truck in Figure 3-5. This solution is convenient, uses less space and can easily be combined with a roof rack or weapon mount. A weapon mount is a common additional feature and the most common one is a square profile attached above the roof hatch. The roof hatch is mainly placed at a centred position over an additional third seat but some are placed at one side, over the passenger seat. This placement is most common in smaller trucks.

It is impossible to get a complete insight of the competitor's solution. One can only predict how they have solved the installation and manufacturing of their roof hatch solutions but a guess is that many of these installations are made by external bodybuilders at a later stage. The competitor analysis has, to a large extent, inspired our future work and functioned as an aid to come up with a competitive and selling solution.

4 Specifications

The purpose with a design specification is to obtain a high quality, low cost and a well interfaced product. This will help to obtain satisfaction for the customer as well as for the company itself in the end. Initially a specification of requirements, containing both requirements and desires of the product, was established to give a more precise description of the product. These were then interpreted and summarized as design goals aimed to be a support throughout the design work.

4.1 Specification of Requirements

The purpose with the specification of requirements is to give a more precise description of the product to be developed, including more technical requirements. This document is also written to clarify the different demands of the product. The demands come from the customers but also from Scania with respect to production and cost. These have been gathered and formulated by means of discussions with involved people, especially with the product manager for the defence market within Scania and with production managers in Oskarshamn. Although the design of a new roof hatch is not the primary focus in this thesis, the table below does include some requirements and desires that only concern this. The motivation for this is that they are considered to be highly relevant for the design of a new roof structure.

The demands have been divided into requirements and desires according to Table 4-1.

Development of a New Roof Hatch Solution for Military Trucks

Table 4-1 Requirements and Desires

Requirements and Desires	R/D
1. Size and geometry	
Either 800 mm in diameter or 800x800 mm	R
Possible to adjust the position of the hatch according to specific customer demands	D
2. Features	
Possible to open the hatch manually from both in- and outside	R
Possible to combine with a ring for a machine gun	D
Possible to combine with rails or a platform on the roof	D
3. Quality and safety	
Possible to use as an emergency exit	R
Withstand moisture (rain and snow)	R
Pass several specified regulatory requirements, ex R29 ²	R
Corrosion resistant	R
Impact- and shock resistant	R
4. Design	
Flexible design	R
Possible to adapt to different variants of roof	R
Fit in to the design of other military trucks from Scania	D
Withstand that a weapon with a weight of 200 kg can be mounted next to the hatch	R
Robust design with a high-quality impression	D
Safe in a military environment	R
Use standardized parts used within Scania	D
6. Production	
Possible to manufacture in the existing cab factory in Oskarshamn	R
Possible to assemble in an ergonomic and safe way	R
7. Costs	
Avoid expensive investments in new tools and equipment	D
A competitive price of the final product	D

² R29, International UNECE Regulation no. 29 is a major legal requirement on cab strength.

4.2 Design Goals

Based on the specification of requirements it is possible to identify several design goals. The most important demands will be incorporated as design goals and the final solution will then be designed to meet those goals.

There are design goals both with respect to geometry and size, but also regarding production and flexibility. A summary of the goals are given below.

- Accommodate a hatch with the desired size.
- Flexible design; the roof hatch solution should be possible to mount on different cab models.
- Modular thinking.
- Manufacturing friendly; the modified cab should be possible to manufacture in the Oskarshamn plant without any expensive investments.
- Convenient to mount, since a big part of the assembling process is performed manually.
- Robust design.

5 Design Concepts

In the initial stage of the design phase a brainstorming session was held. The session was carried out during a limited time of one week. A frequent discussion with advisors at the department and responsible managers in Oskarshamn assured that the brainstorming was kept on the right track. This activity resulted in six different design concepts. The main focus on the concepts was the opening in the roof and the new roof structure needed to accommodate a new roof hatch.

A concept selection was then done by means of a two-stage selection method, concept screening and concept scoring. The most promising concept was then taken further to the concept development phase.

5.1 Design ideas

5.1.1 Bodywork solution 1

- a) Mounted from above

This design solution consists of an external roof plate (1) that is mounted on the roof. The plate is attached to a specially made border frame (4) with screws (6). The roof hatch set (7) and additional features, such as a weapon ring are then mounted on the roof plate.

This concept has many advantages regarding manufacturing. The cab goes through the ordinary body workshop in the production line without changes and the roof is then reworked before the cab is sent to the paint shop, see Figure 2-4 for an overview of the cab production line. The roof plate (2) is cut open and a new rear cross member (8) is mounted to be able to fit a larger opening. The original lengthways assembly beams (3) are kept intact, and so also parts of the old roof hatch frame (9). A border (4) is then mounted from above and attached to the new roof structure with screw joints (10).

The attachment between the border and the roof structure can be adjusted to obtain a planar surface for the external roof plate to be mounted on. The external roof plate (1) is attached with screws on top of the border, see Figure 5-1 below.

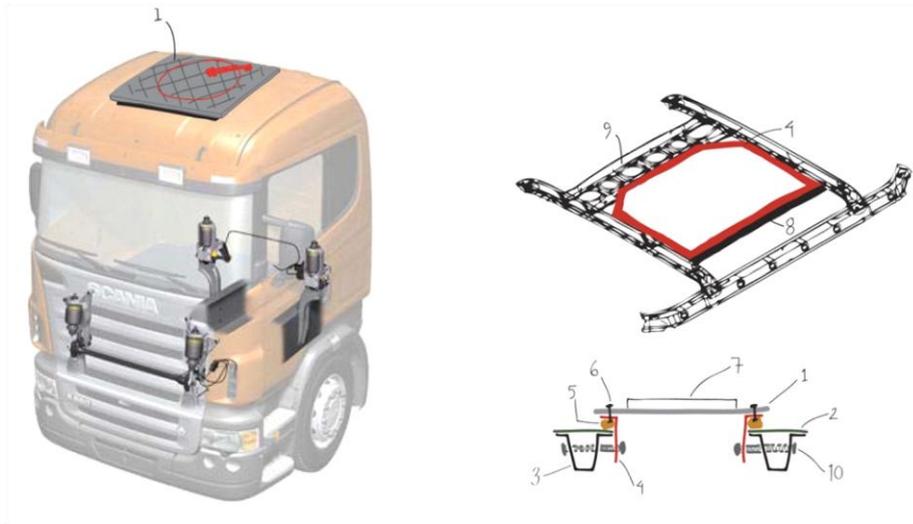


Figure 5-1 Bodywork solution 1 mounted from above

b) Mounted from below

This design concept is very similar to the previous concept, 1a. It consists of an external roof plate (1) that is mounted in the same way as in the previous solution.

These two solutions differ in the way in which the border (4) is attached to the roof structure. In this concept the border is mounted from below and welded to the remaining roof structure according to Figure 5-2.

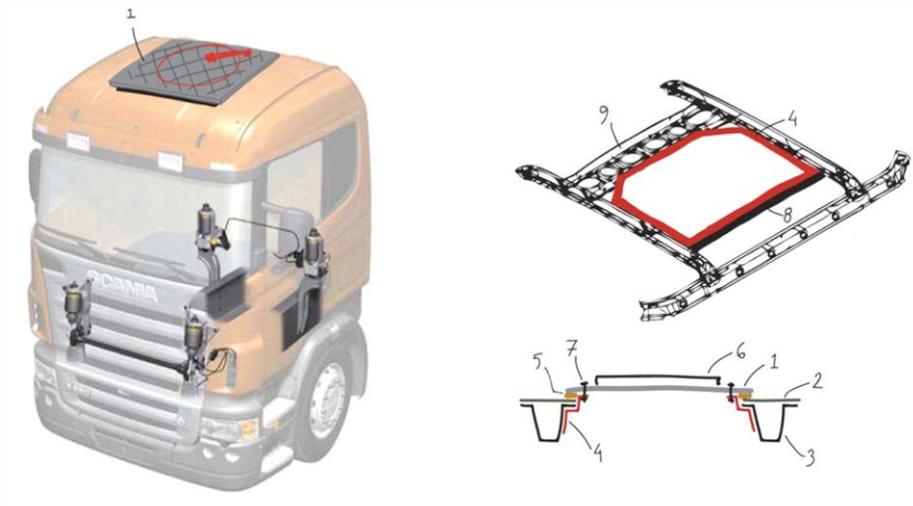


Figure 5-2 Bodywork solution 1 mounted from below

5. Design Concepts

5.1.2 Bodywork solution 2

This design concept does also consist of an external roof module (1) that is mounted on top of the existing roof (3), Figure 5-3. The module is attached directly to the lengthways assembly beams (4). These beams carry the entire weight from the external roof and the roof hatch (2) and no additional support, such as a new cross member, is needed.

In production, changes are made after the body workshop. The roof is cut open and the module is attached to the roof. The roof hatch set (2) is attached at a later stage in the assembly phase.

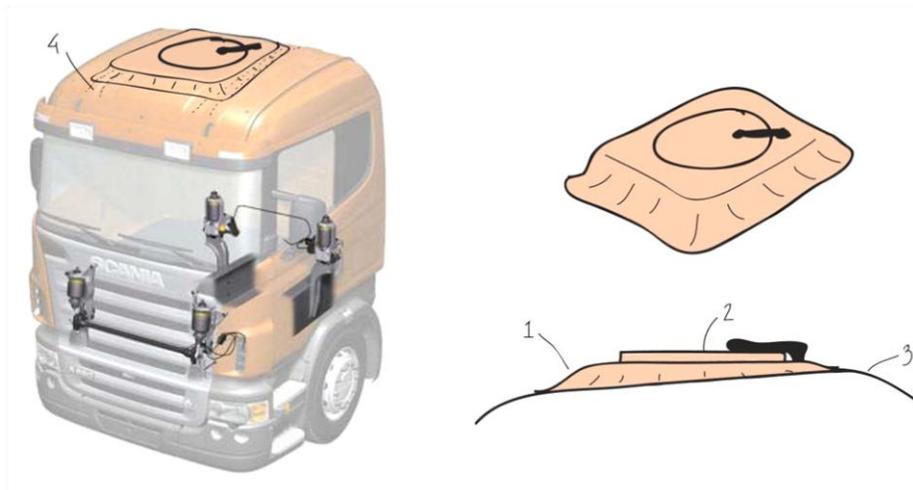


Figure 5-3 Bodywork solution 2

5.1.3 Circular roof hatch frame- Modified

This solution differs from the first three concepts in the way that no external module is added on top of the roof; instead the roof structure is reworked to fit a circular roof hatch. The cab goes through the body workshop production line without the roof panel mounted. The “naked” cab is then reworked for adaptation to the new roof hatch installation before the roof is mounted.

A circular opening is cut and the front part of the current structure (1) remains unchanged. Only small pieces of the two rear cross members (2) remain, these will be used as attachment points for the new frame to be mounted. The new frame (3) will have a circular shape, see Figure 5-4, and is welded to the remaining part of the previous structure. A rear cross member (4) will be mounted; either integrated in the modified frame or mounted separate and then welded to the circular frame. The roof plate, prepared with a circular opening, is then welded on to the cab.

An issue with this solution is that it might be impossible for the robots in the automated line to handle the “naked” cab structure without the roof plate mounted in the initial phase.

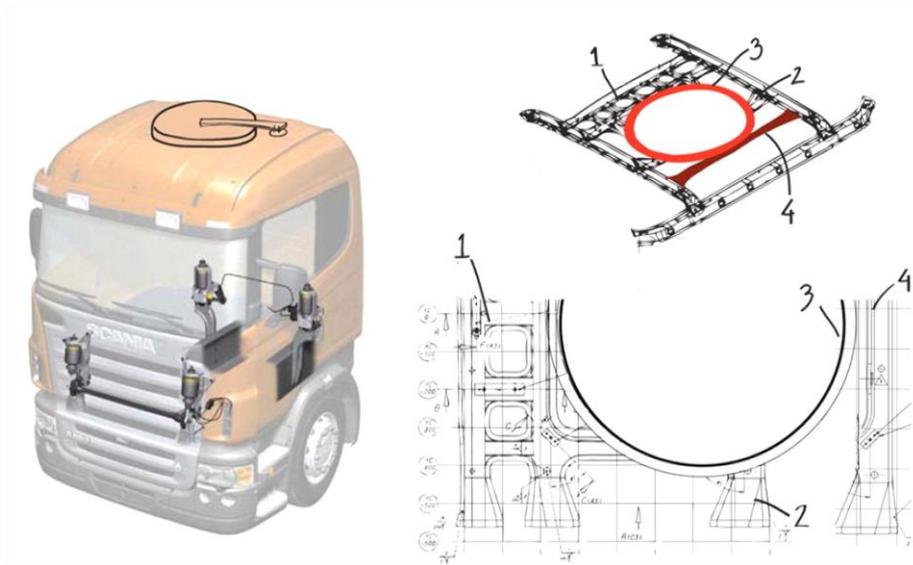


Figure 5-4 Modified, circular roof hatch frame

5.1.4 Circular roof hatch frame- New frame

In this concept the old roof hatch frame is replaced by a new frame, see Figure 5-5. The new frame (1) is designed so that the attachment to the lengthways assembly beams (2) is unchanged. As a consequence, most of the welding points are the same and therefore recognized by the welding robot in the automated line in the production. The new frame is longer and wider to fit the larger roof hatch. A new customized roof plate (3) with a larger opening is finally attached on the top.

5. Design Concepts

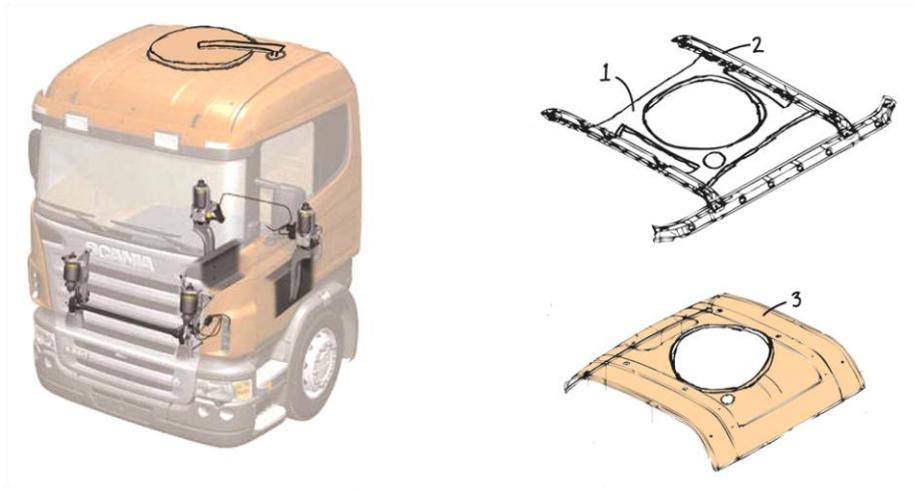


Figure 5-5 Circular roof hatch - New frame

5.1.5 Rectangular roof hatch

Another idea is to keep the rectangular shape of the hatch, with increased dimensions, Figure 5-6. This could be done either by adapting the current roof frame to a bigger hatch or make bodywork and use a sliding hatch. An advantage with the first idea is that this solution has already been implemented once at Scania, therefore there is some knowledge available within this area.

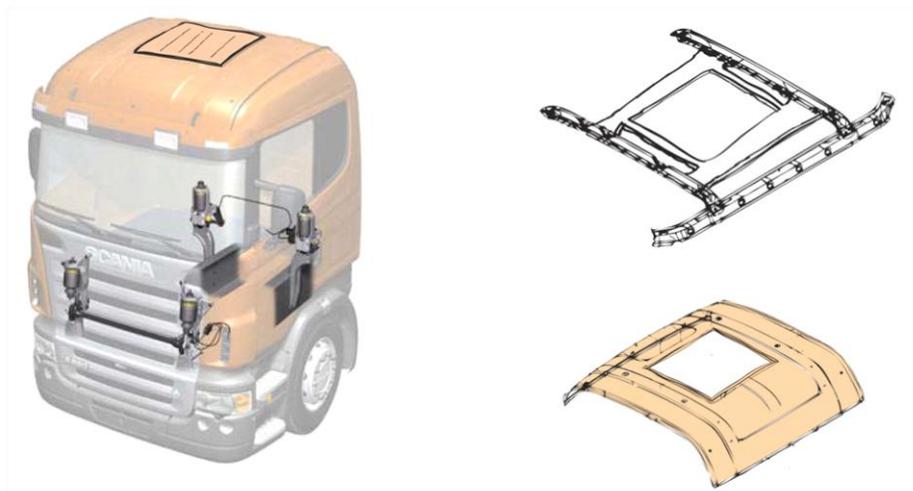


Figure 5-6 Rectangular roof hatch

By studying competitor solutions it is obvious that a circular roof hatch is preferable among international army trucks. A disadvantage of using a rectangular hatch is that the hatch will be much bigger in size, compare to a circular hatch, while the efficient area is the same. The hatch might be too heavy to handle manually. Another consequence is that it will be much more complicated to combine the hatch with different features such as a ring for a machine gun.

5.2 Concept selection

A two-stage concept selection methodology was used to be able to come up with the most promising design concept. The two stages are concept screening followed by concept scoring. Each stage is supported by a decision matrix which is used to rate, rank and select the best concept(s). The first stage is aimed to give a quick evaluation of the design concepts whereas the scoring stage is a more accurate analysis and evaluation of the concepts remaining after the first stage. A more detailed development of the concepts that passed the first stage was carried out, and new concepts were born, before continuing with the concept scoring stage.

Both stages consist of a six-step process which was taken to gradually exclude the least promising concepts. The six steps are [12 pp. 124-129]:

1. Prepare the selection matrix.
2. Rate the concepts.
3. Rank the concepts.
4. Combine and improve the concepts.
5. Select one or more concepts.
6. Reflect on the result and the process.

5.2.1 Concept screening

This first stage is based on a method developed by the late Stuart Pugh in the 1980s and is often called Pugh concept selection (Pugh, 1990). The purpose with concept screening is to narrow the numbers of concepts quickly and then improve the remaining concepts before the final selection. This is done systematically by means of the six steps mentioned previously [12 pp. 130-133].

First the selection matrix was prepared, and the selection criteria were chosen based on the specification of requirements identified earlier in the thesis work. The criteria do mainly focus on the modified roof structure rather than the hatch itself since that is the main focus in the thesis work. At this stage, each criterion was given equal weight why it was essential to only include highly relevant criteria. Finally a reference concept was chosen to become a benchmark, against which all other concepts are rated. In this case the reference was set to be the existing solution, Figure 2-6, since the future design is aimed to be a complement to this solution. Note that Body work

5. Design Concepts

solution 1 includes both the solution “mounted from above” and “mounted from below” since these are considered to be very similar according to the level of detail at this stage. A relative scoring system was used to rate the different concepts according to the grading system presented below.

Rating	Relative Performance
+	Better than reference
0	Same as reference
-	Worse than reference

A summation was done for each concept, followed by a discussion, which made it obvious to identify the more promising concepts. The Concept Screening matrix is shown in Table 5-1. The evaluation was done together with responsible advisors at Scania.

Development of a New Roof Hatch Solution for Military Trucks

Table 5-1 Concept Screening

Concepts						
Selection Criteria	Reference-Old solution	1 Body work solution 1 (1a, 1b)	2 Body work solution 2	3 Circular - Modified frame	4 Circular - New frame	5 Rectangular
Easy to mount	0	0	-	-	0	0
Low cost	0	0	-	-	-	-
Ease of manufacture	0	0	-	-	-	-
Integrated design	0	0	+	0	0	0
Ease of combining with desired features	0	+	+	+	+	0
Ability to adapt to different variants of roof	0	+	0	0	0	0
Sum +'s	0	2	2	1	1	0
Sum 0's	6	4	1	2	3	4
Sum -'s	0	0	3	3	2	2
Net Score	0	2	-1	-2	-1	-2
Rank	2	1	3	4	3	4
Continue?	No	Yes	No	No	No	No

5. Design Concepts

According to the evaluation above, body work solution 1, which in turn consists of the two solutions 1a and 1b, were the two concepts that proceeded from the first stage. The primary advantages with these two concepts are their ability to adapt to different variants of roof and their flexibility in design, in compliance with the unique modular system within Scania. The external roof plate functions as a platform and can easily be adjusted to accommodate different designs of the roof hatch. These two concepts are more or less independent of the design of the hatch. Another benefit is that they do not require any expensive investments in new tools, unlike most of the other concepts that would have required investments in new press tools.

5.2.2 Further Development

To be able to compare the two remaining concepts, 1a “mounted from above” and 1b “mounted from below” and preferable come up with some new, improved concepts an investigation was done, both regarding design and manufacturing. A further development and a more detailed design were done in CATIA V5, which made it easier to discover some issues and difficulties with the suggested solutions. Throughout this part of the design work a frequent contact with involved personnel, especially from the production side, was established to make sure that all requirements were fulfilled.

The two remaining concepts have a lot of similarities. The reworking of the actual roof is done in the same way for the two concepts. The cab goes through the ordinary cab body workshop before it is reworked to fit a larger, non-standard roof hatch. Figure 5-7 below shows an overview of how the cab looks like after the body workshop. The roof is made transparent to visualize hidden structure (yellow).

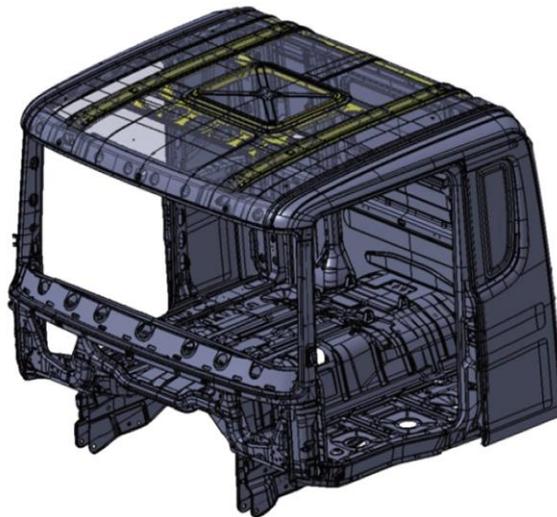


Figure 5-7 Cab body after the body workshop

The roof is cut open according to Figure 5-8; the larger opening causes a change in the previous roof structure (Figure 2-2). The rear part of the original roof hatch frame is removed and a new rear cross member is mounted to support a larger opening, see Figure 5-9.

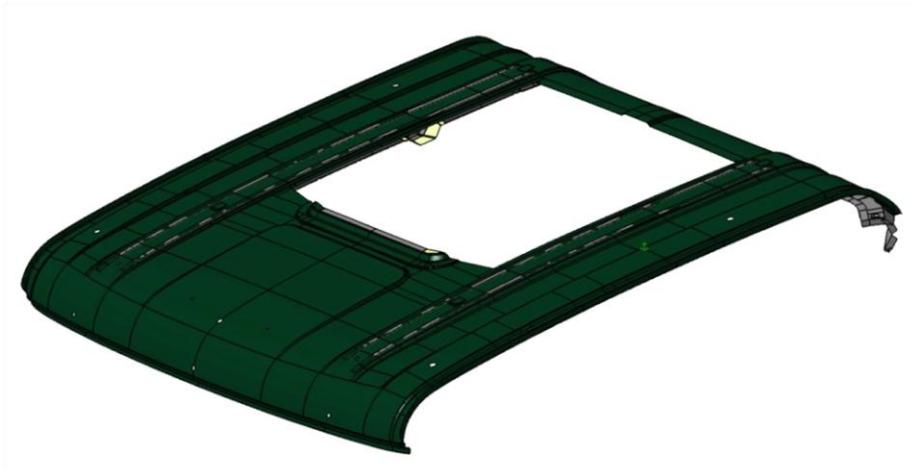


Figure 5-8 Opening in the roof

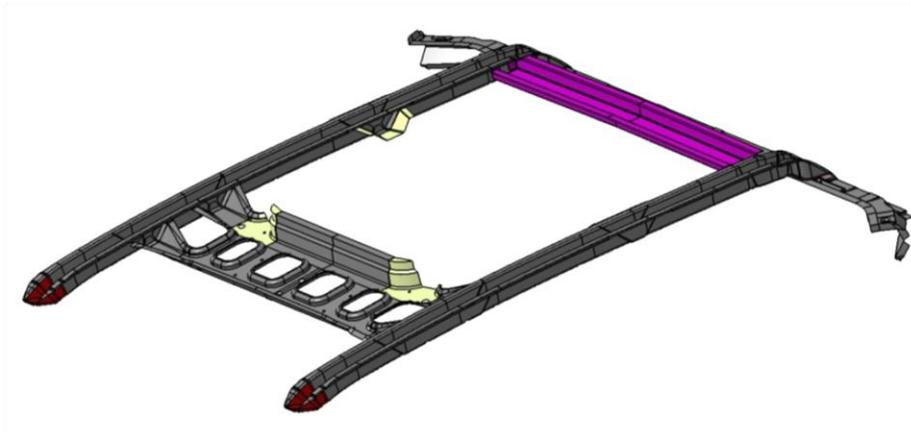


Figure 5-9 Modified roof structure seen without the roof

After the initial cutting stage the two concepts differ and they are therefore presented separately below.

In the first concept, concept 1, the border is mounted from above. The border is made up of L-profiles that are welded together before the border is attached to the roof, Figure 5-10. The flanges on the border beams are out-turned to make the opening as large as possible but also to enable support from the front part of the roof hatch frame during mounting.

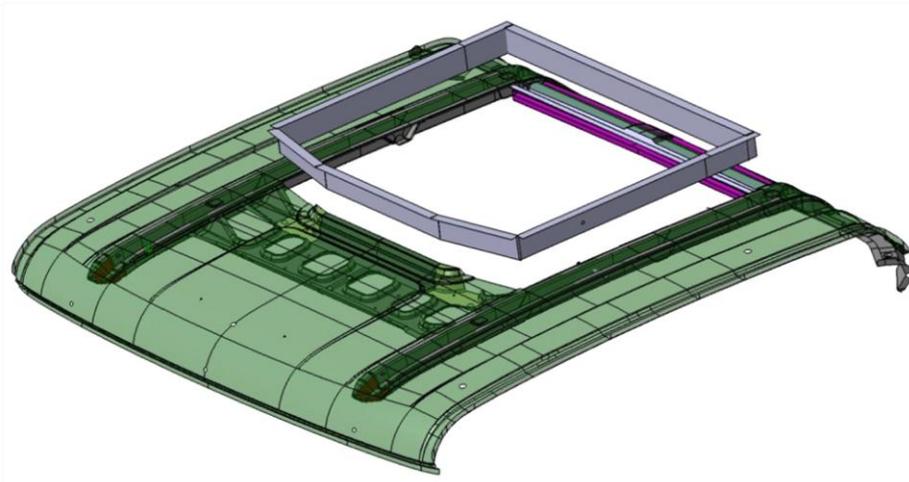


Figure 5-10 Border, concept 1

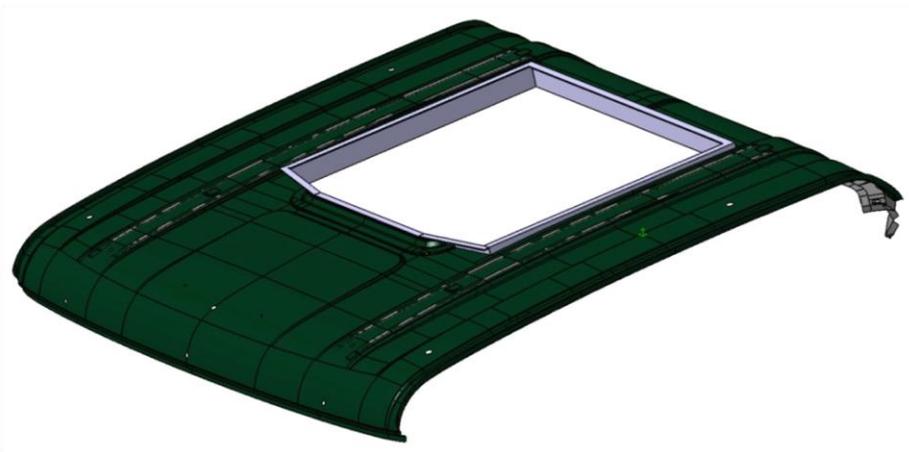


Figure 5-11 Border attached to the roof, concept 1

The border is then fasten towards the lengthways beams with screws, Figure 5-12. One option is to have a slit in the border to be able to fix its position and height at certain points. This is also a good solution regarding a flexibility point of view since the slits can enable mounting on different roof heights and therefore adapt to different roof structures.

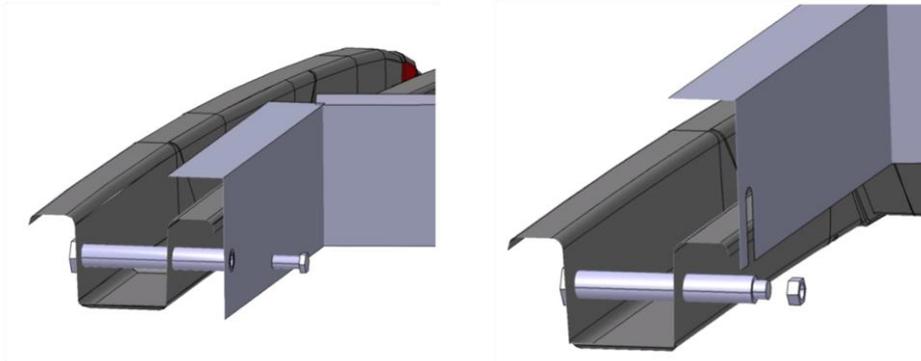


Figure 5-12 Screw attachment and the alternative slit, concept 1

On top of the border the external roof plate is attached to the flanges with screws, Figure 5-13. The design of this platform is dependent on the actual roof hatch kit.

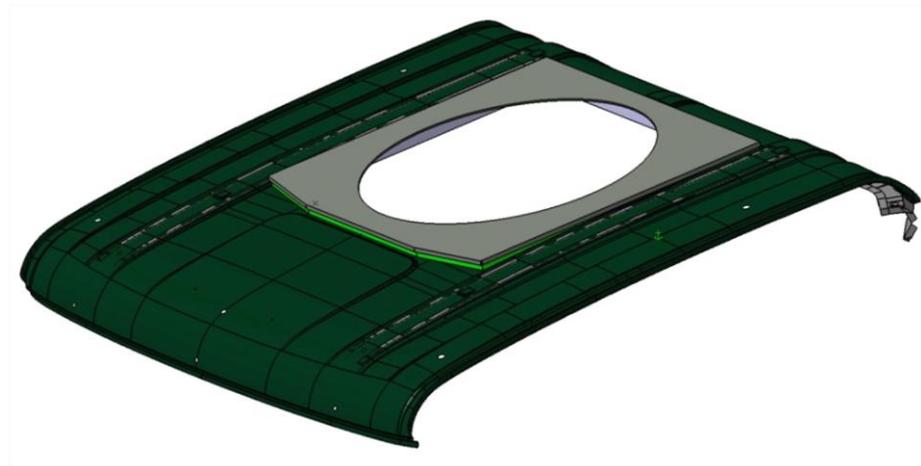


Figure 5-13 Roof with external roof plate

The second concept, concept 2, differs from the first concept in how the border is designed. The shape of the border does only enable mounting from below; see Figure 5-16 for a detailed view of the cross section. The border is pushed through the opening in the roof according to Figure 5-14 and Figure 5-15. The flanges are, unlike the first concept, turned towards the inside of the opening to enable mounting from below. The border is then spot welded towards the lengthways beams and the rear cross member according to Figure 5-16.

5. Design Concepts



Figure 5-14 Border mounted from below, concept 2

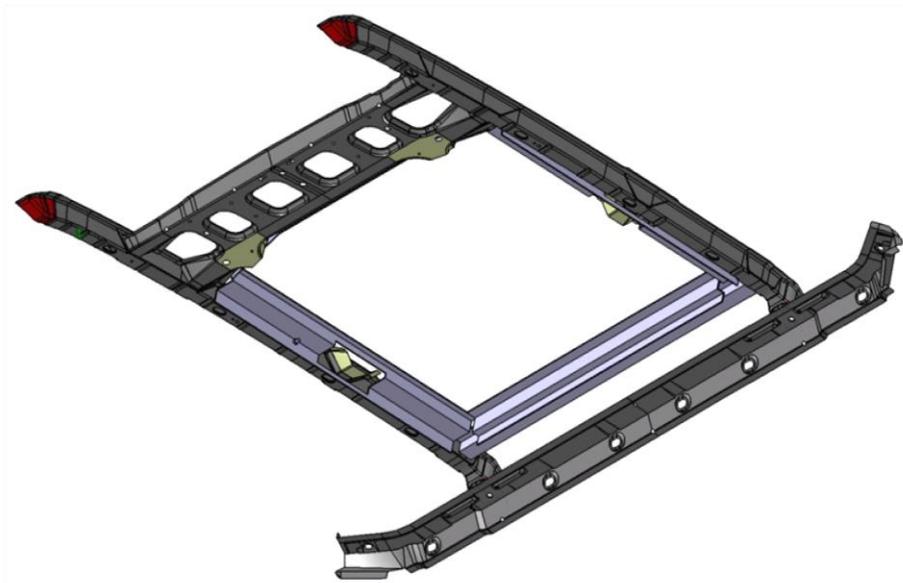


Figure 5-15 View from below, concept 2

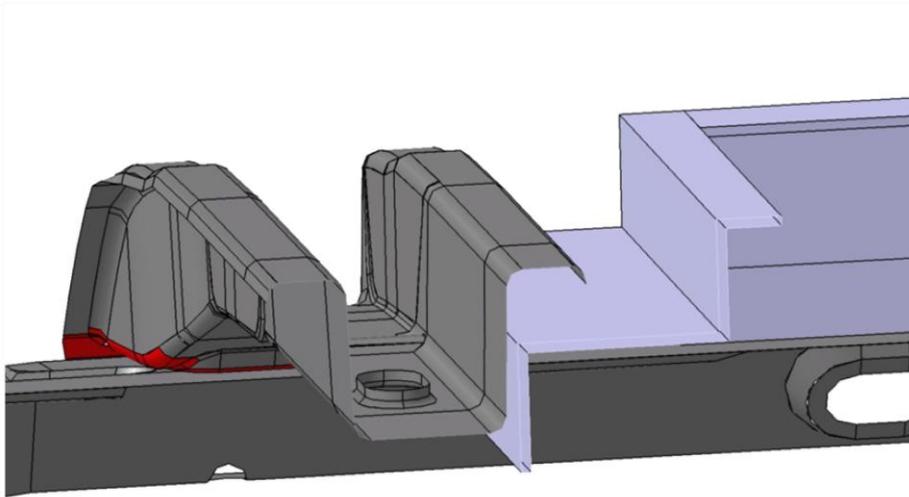


Figure 5-16 Cross section view of the border, concept 2

The biggest issue with the two concepts, concept 1 and concept 2, is the sealing problem between the roof and the border. Due to the actual tolerances within metal cutting (± 2 mm on each side) it is unavoidably that a space occurs between the border and the roof, see Figure 5-17.

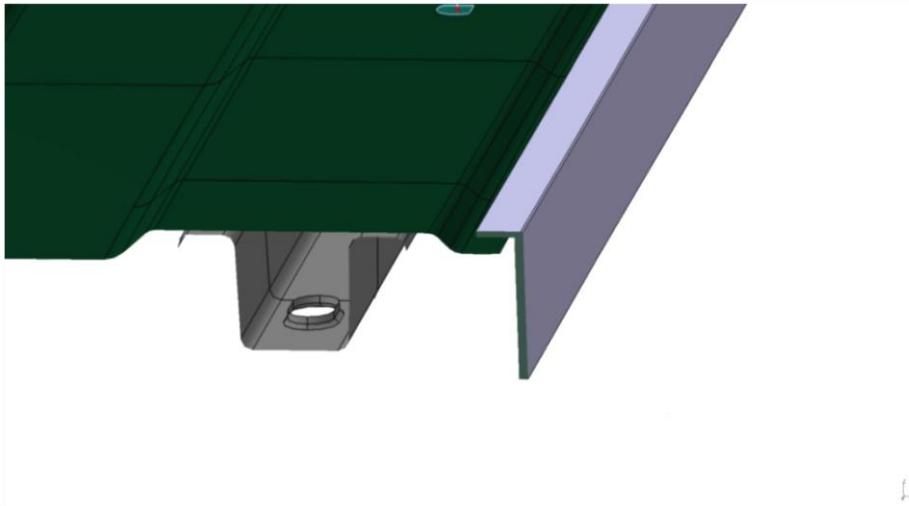


Figure 5-17 Space between the roof and the border

The varying height of the border due to the slope of the roof and the non-planar locating face is also a concern regarding finding a suitable sealing. Different ideas and suggestions were discussed and one of them is shown below in Figure 5-18 and Figure 5-19.

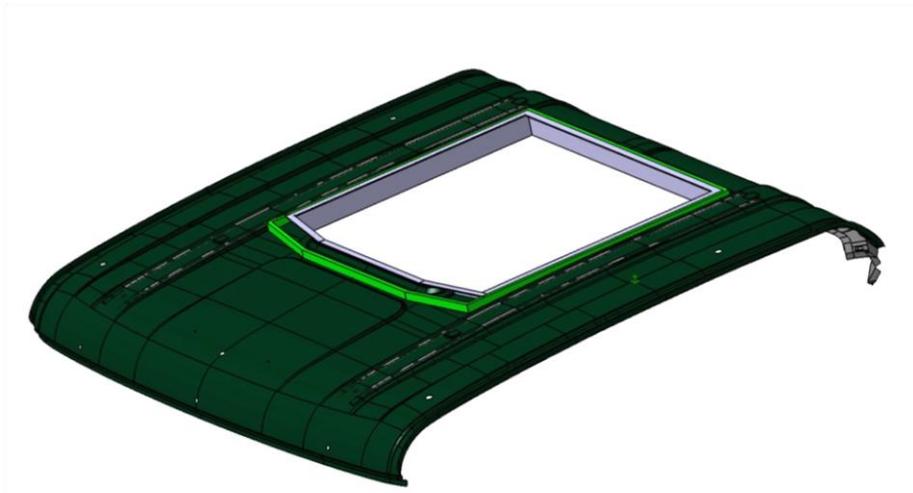


Figure 5-18 Suggestion to a sealing

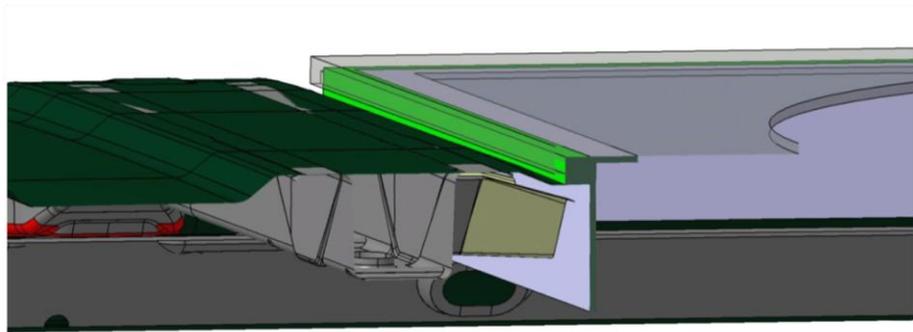


Figure 5-19 Cross section view of the sealing

A more detailed investigation regarding the sealing problem for the two concepts was left out and instead a third concept, concept 3, was born in conversation with involved personnel from the cab production in Oskarshamn. This concept is based on the same principle with a big rectangular opening, a border and an external platform. The difference lies in the design of the border.

In this case the border is attached on top of the roof in connection with the opening. The border is based on the use of an extra roof sheet that is cut according to Figure 5-20.

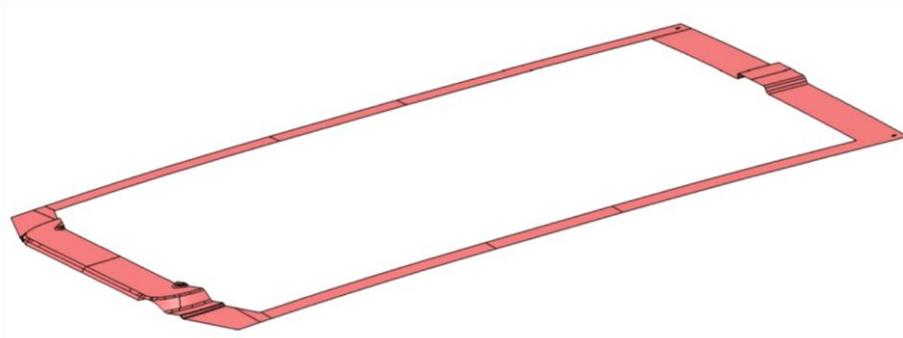


Figure 5-20 Base for the border frame

This will function as a base for the border frame. Since the profile of the base is identical to the one on the roof it is easy to mount it on the roof and a big part of the sealing problem is solved.

A vertical border, made up of L-profiles, is initially prepared with laser cut to follow the actual shape of the roof, see Figure 5-21. The profiles are then folded and welded together to a complete border frame, Figure 5-22, before it is welded on to the base, according to Figure 5-23.



Figure 5-21 Unfolded L-profile, prepared with laser cut

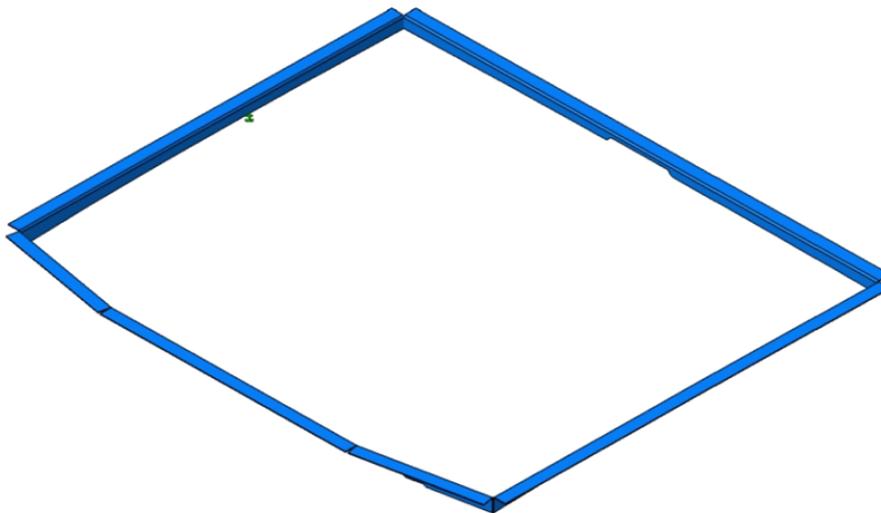


Figure 5-22 Vertical border, folded and welded together

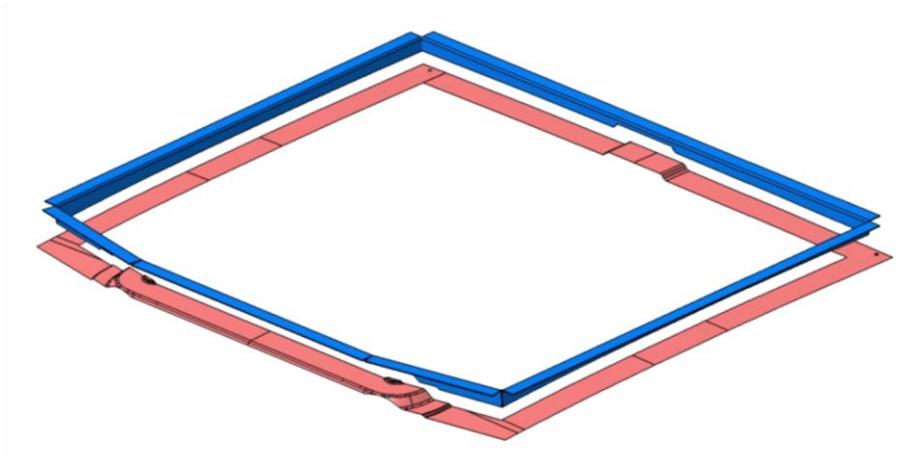


Figure 5-23 Overview of solution with a new border

Sealing can easily be attached in the joint between the base and the L-profile. A complete component can then be attached on top of the roof, according to Figure 5-24, without any extra assembling steps, which is another advantage with this concept.

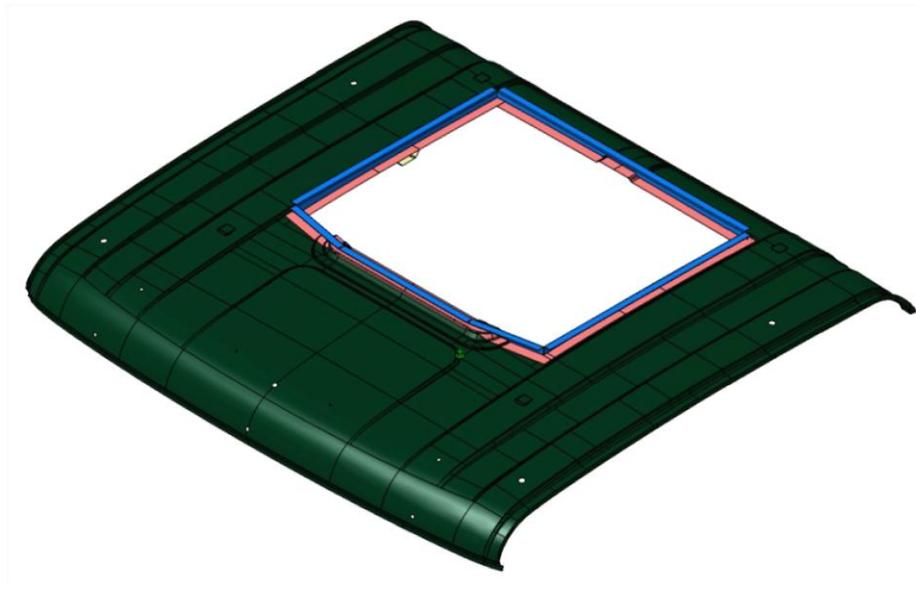


Figure 5-24 Complete solution, concept 3

The external roof plate is then mounted in the same way as in the previous concepts.

5.2.3 Concept Scoring

The second and last stage, in the concept selection aims to identify the best concept. The increased resolution among the concepts due to a more detailed investigation in the previous stage makes it possible with a refined comparison. The selection matrix is similar to the one in the concept screening, but more detail has been added to the selection criteria. Another difference is the rating system, instead of a relative scoring system a weighted system is used in the concept scoring stage. 100 percentage points are allocated among the various selection criteria in the matrix. Unlike the first stage, one single reference concept was not used as a benchmark since it is of average performance relative to all of the criteria and that will lead to “scale compression” for some of the criteria. Instead different reference points were used for the various selection criteria; these get rating 3 and are signified by bold rating values in the concept scoring matrix shown in Table 5-2 below.

Each concept was then rated on how well it met the selection criteria according to the grading system presented below.

Rating	Relative Performance
1	Much worse than reference
2	Worse than reference
3	Same as reference
4	Better than reference
5	Much better than reference

The total score for each concept is the sum of the weighted scores:

$$S_j = \sum_{i=1}^n r_{ij} w_i$$

Where r_{ij} is the raw rating of concept j for the i th criterion, w_i is the weighting for the i th criterion, n is the number of criterion and S_j is the total score for concept j [12 pp. 134-137]. As with the previous screening process, the evaluation was done in agreement with responsible advisors at Scania.

5. Design Concepts

Table 5-2 Concept Scoring

Concepts							
Selection Criteria	Weight	1		2		3	
		Rate	Weighted Score	Rate	Weighted Score	Rate	Weighted Score
Manufacturing Ease	30						
Low number of assembly steps	5	3	15	3	15	3	15
Low complexity	10	4	40	3	30	4	40
Possibility to manufacture in Oskarshamn	15	3	45	3	45	3	45
Combination possibilities	10						
Weapon ring	5	3	15	3	15	3	15
Roof rack	5	3	15	3	15	3	15
Adaptable design	15						
Adaptability to different cab roof	5	4	20	3	15	3	15
Enable modular system	10	3	30	3	30	4	40
Design	25						
Integrated design	3	3	9	3	9	3	9
Robust design	10	3	30	3	30	3	30
Easy to seal	12	3	36	3	36	4	48
Low cost	20						
Low material cost	5	3	15	3	15	3	15
Low tool cost	10	3	30	3	30	5	50
Low time cost	5	3	15	2	10	4	20
Total Score	100		315		295		327
Rank			2		3		1

Based on the evaluation above, concept three got the highest score and was ranked as number one. According to Ulrich and Eppinger it is essential to supplement the evaluation, done in the concept scoring, with a discussion to ensure that the selected concept is the one with the greatest potential for success [12 p. 137]. Together with involved people at the Cab production in Oskarshamn, the three concepts were reviewed, and it could be concluded that the final ranking of the three concepts agreed with our opinions. The main reason why Concept 3 was considered to have the greatest potential for success was its ease of manufacturing and the possibilities to solve the sealing problem in a convenient way.

5.3 Prototyping

To better see the potential of the selected concept, a prototype session was planned at the prototype workshop in Oskarshamn. Drawings of the parts were prepared in CATIA V5 and sent to the workshop. During our visit, meetings with people with knowledge of the production and sealing capability were held to discuss the proposed solution. It was also of interest to see how the outer roof plate and the roof structure were affected by the actual cutting, why a more detailed investigation of the manufacturing procedure was done in cooperation with personnel in the prototype workshop. The roof plate and the roof structure appeared to be easy to cut and with a custom made fixture, relatively small tolerances are possible to obtain.

An overview of the result of the prototype can be seen in Figure 5-25.



Figure 5-25 Border and opening in the roof

5. Design Concepts

It was shown to be very useful to get the chance to see and touch the prototype in reality. New problems and possibilities could be discovered that earlier had been hidden. The use of the base of the border, Figure 5-20, was discussed and the conclusion was that it did not contribute to strengthen the roof any further. Since the border itself appeared to have the tolerances to enable a good sealing between itself and the roof plate, a decision to remove the base from the design was taken.

Based upon the new, modified solution several issues were discussed and analyzed. All the suggested improvements were taken further to the next stage of the design work, the concept development. An investigation of how to implement the design in the production line was also done, since that is highly relevant to be able to reach the objective with this thesis.

The following photos, illustrate a summary of the first draft of the prototype and some critical issues to be further developed. The front part of the border has a relatively poor support from the underlying beam compare to the side and the rear part of the border. Figure 5-26, illustrates the remaining part of the roof hatch frame, which aims to support the front part of the border. The circumscribed areas are the most critical parts. A more detailed view is given in Figure 5-27. As can be seen in the picture there is a gap between the roof plate and roof hatch frame. The gap implies that the structure is weakened and problems may occur when load is applied to the structure.



Figure 5-26 Front part of the remaining roof hatch frame

5. Design Concepts

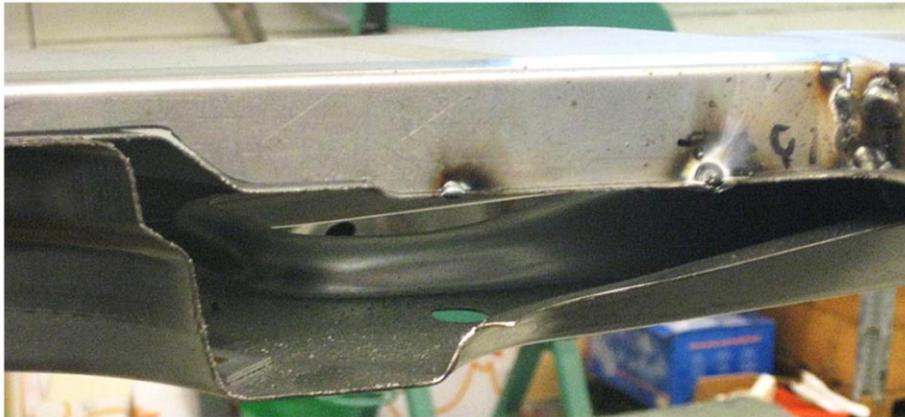


Figure 5-27 Critical part of the front border

The side part of the border is mounted close to the lengthways assembly beams which makes the design very rigid. It was discussed how near the wrinkled part of the roof panel the border should be mounted to be able to seal. The initial distance can be seen in Figure 5-30, but it was found out that a more suitable placement was to eliminate the distance to a minimal. The attachment of the border on the roof was also discussed. The distance between the border and opening in the roof was of interest, Figure 5-28. This first prototype was MAG-welded but different alternatives were discussed, since this method is considered to be relatively sortie and therefore undesired in the production line.

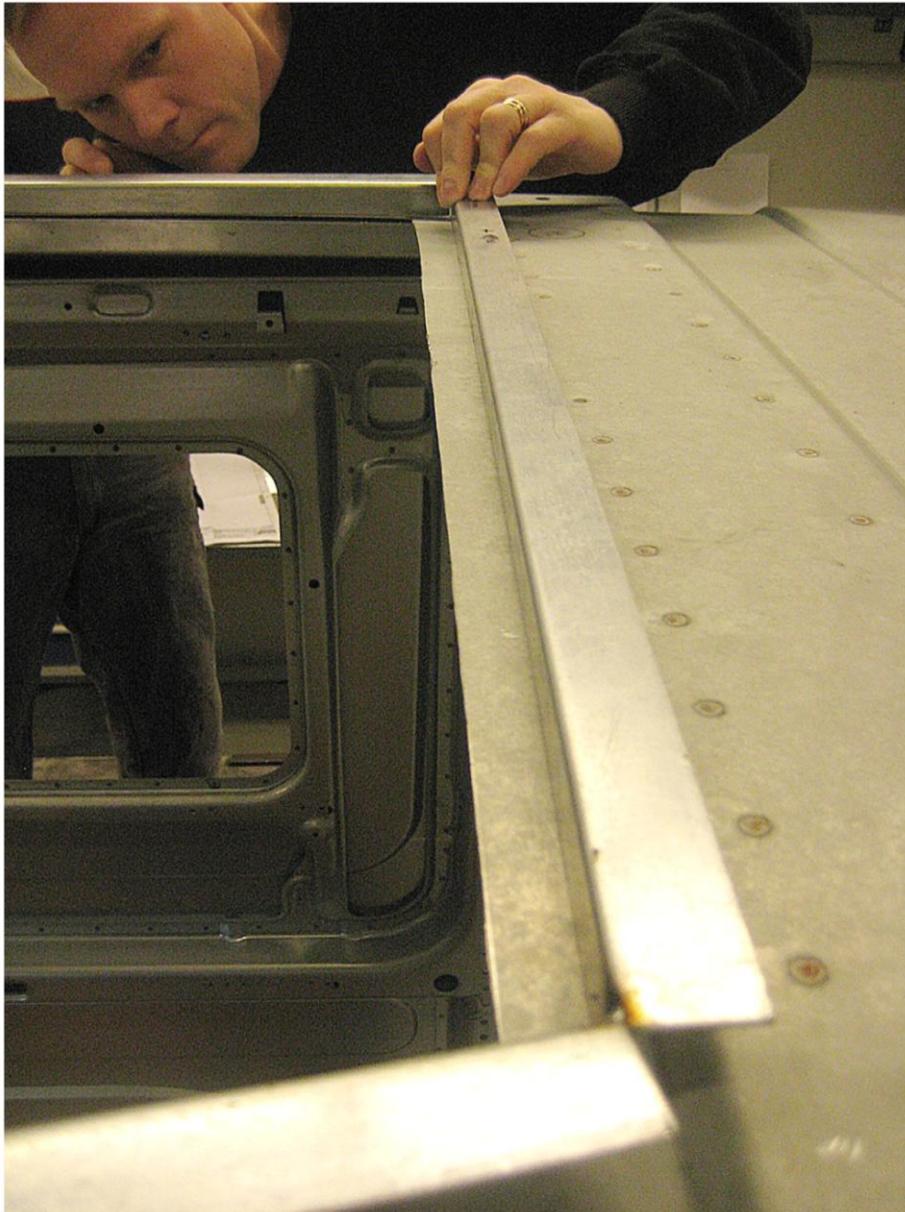


Figure 5-28 Border side

The prototype was cut by hand, but relatively narrow tolerances were possible to obtain, see Figure 5-29. The real product will be cut with a machine, with even more narrow tolerances why the sealing between the border and the roof is manageable. A discussion regarding a new improved design in the corners of the border was carried out; since these are another critical part of the design seen from a sealing point of view, see Figure 5-30.

5. Design Concepts

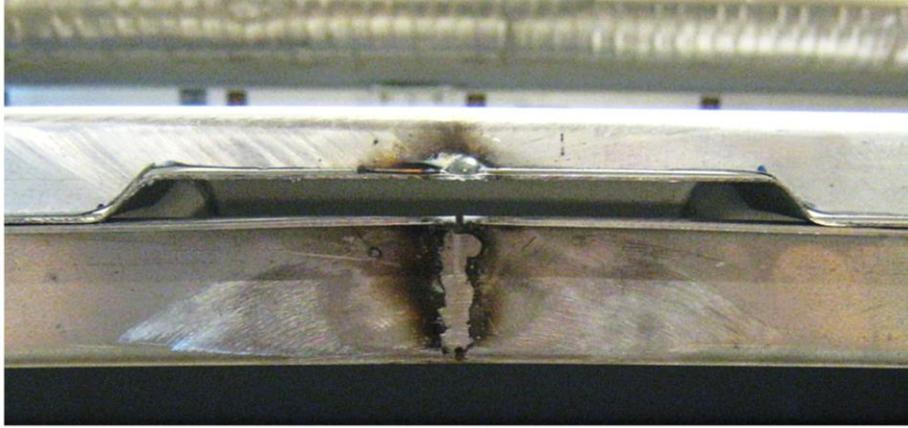


Figure 5-29 Rear part of border, showing the tolerance of the cutting

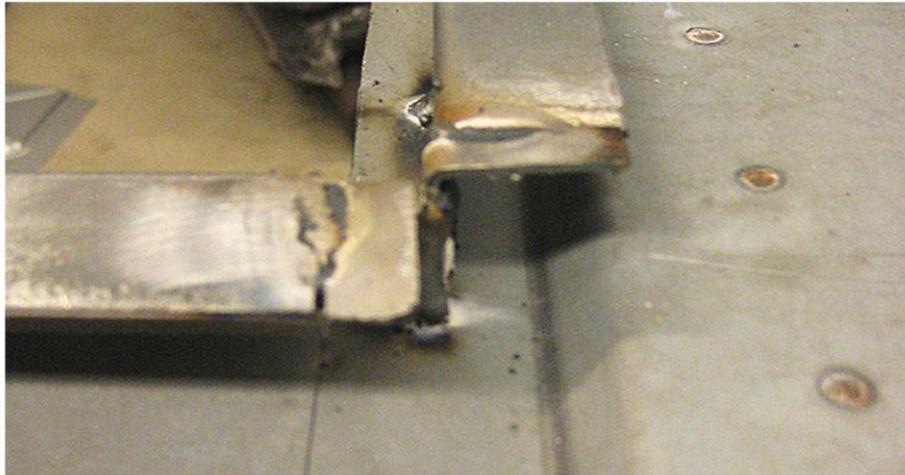


Figure 5-30 Rear corner of border

6 Concept Development

During the first prototype session in Oskarshamn some modifications were done to the suggested solution. The base, consisting of a part from an extra roof plate, was eliminated from the design. A test was prepared to investigate how the design worked with respect to sealing and painting. The strength of the structure was estimated and some possible improvements to obtain a robust design were discussed.

In this chapter, the concept development phase, these questions were further investigated and several modifications were done which lead to a new improved concept followed by a second prototype session.

6.1 Design Development

The border was redesigned to obtain a more robust design and to meet several desires from a manufacturing point of view, Figure 6-1. The modifications done are motivated and described into more detail in the chapters below.

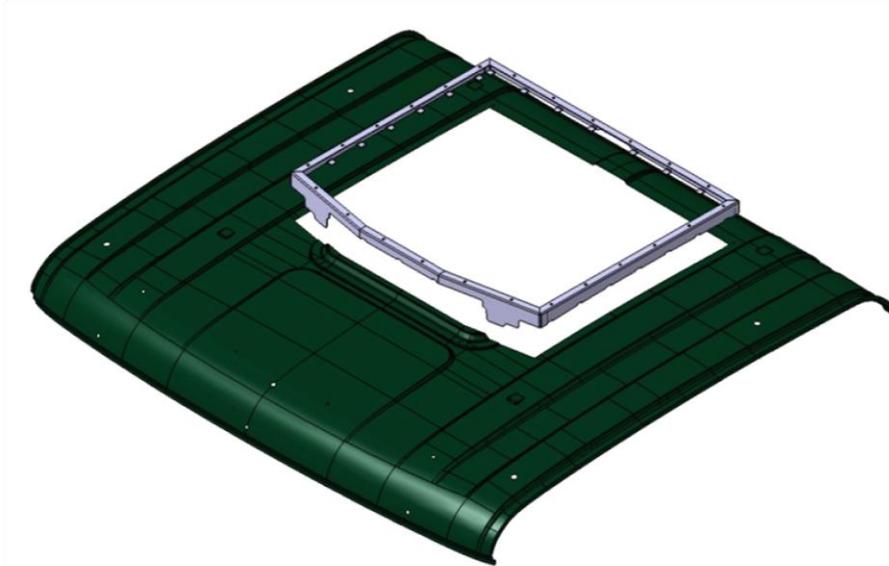


Figure 6-1 Overview of redesigned concept

6.1.1 Coating and Sealing

A major change in the cab design, like the one with a new roof hatch, does to some extent affect all parts of the automated production line, including the paint shop. The paint shop consists of different treatments, the primer painting including pre treatments, seam sealing and powder coating followed by a final top coating.

Development of a New Roof Hatch Solution for Military Trucks

The roof of the cab is powder coated by a coating device, customized for the cab roof. The device is equipped with a number of nozzles, which feed the roof with powder horizontally. These are fixed and cannot be adjusted.

The proposed design of the border will lead to an undesired Faraday cage effect³. With the flanges bended outwards it is impossible to provide critical areas with enough powder, see Figure 6-2, which can lead to corrosion on exposed surfaces. According to Scania standard, STD4103en⁴ it is a requirement with a certain thickness of the underlying primer and top coat. To be able to fulfil this requirement and to simplify the operation in the paint shop, a decision about flipping the flanges, 180°, to an inward position was taken, see Figure 6-2. The height of the border was increased to further facilitate the operation. A common problem when changes are done to the design is that an improvement of one function is achieved at the expense of another. When flipping the flanges inwards the screw joints on the border imply a potential way for leakage in to the cab through the joints.

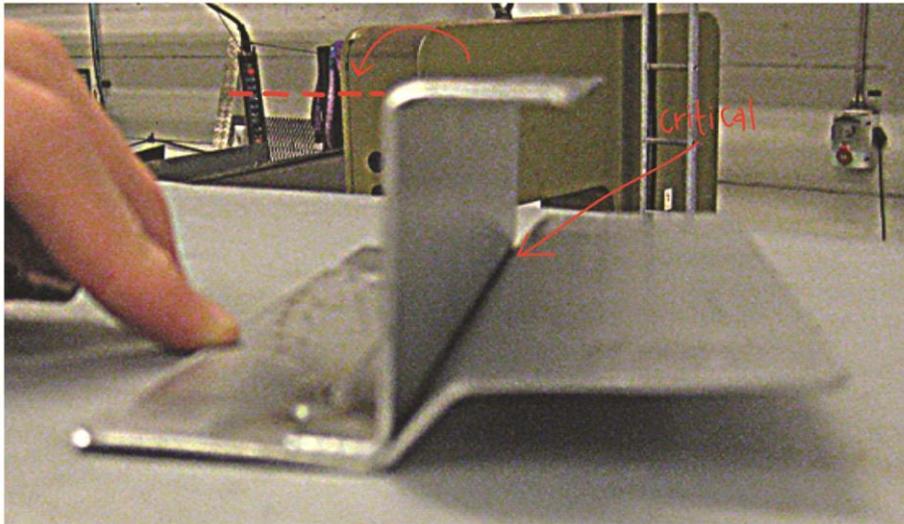


Figure 6-2 Test for sealing and painting issues

One of our biggest challenges throughout the design work has been the sealing between the border and the roof. Since the roof is one of the most exposed areas on the truck it is essential with a well working sealing to avoid leakage. The proposed design enables to use the same seam sealing applied to other joints on the cab. The sealing is applied in the paint shop by a robot with an extruding nozzle.

³The Faraday Cage Effect is a common problem associated with electrostatic powder coating and describes the problem getting the powder to adhere to the surface of an enclosed area. This is the result of resistance created by the presence of an electrostatic force.

⁴ Scania STD4103en. Surface treatment – Powder primer for cab and cab related parts – Requirements, 2008-04-10.

7. Cooperation with Sonntag GmbH & Co

To ensure a tight joint and to enable spot welding during assembling, the lower edges of the border were prepared with bended lips, Figure 6-3. Due to insufficient access for a spot welder at the front part of the border, these lips have been provided with smaller holes, according to Figure 6-4, to enable for plug welding.

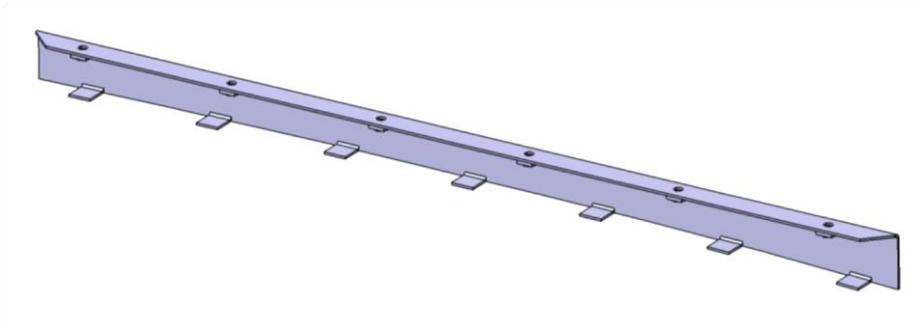


Figure 6-3 Side part of border

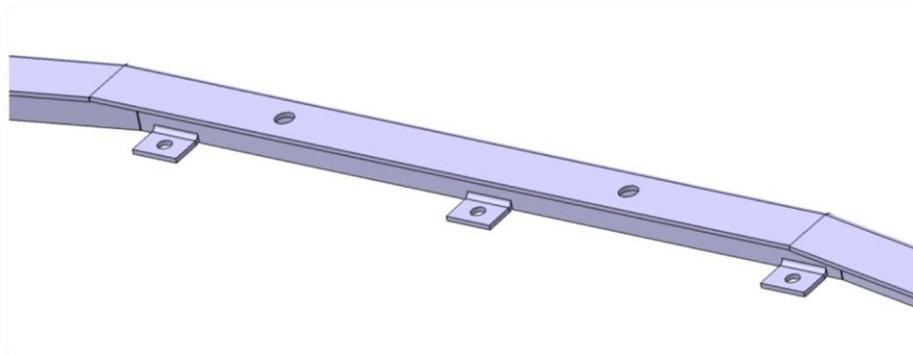


Figure 6-4 Front part, with holes for plug welding

To obtain a tight joint in the corners, the rear and the front part of the border have been prepared with vertical flanges to enable over-lapping and the top flanges are cut in a 45 degree angle, Figure 6-5.

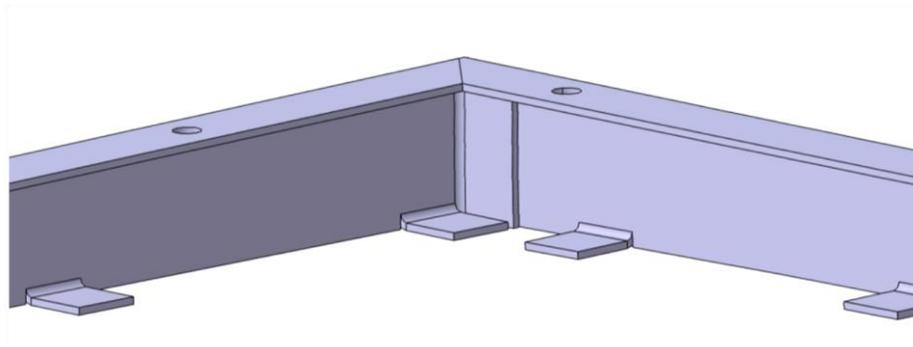


Figure 6-5 Redesigned rear corner of border

6.1.2 Strength

A robust design was one of the design requirements identified in the initial phase of the project. The design has to be able to bear the roof hatch kit and the load from a soldier's exit and entering, additional features such as the weapon ring will use the existing thread pads and rail system and therefore not affect the new design.

During the first prototype session an attempt to estimate the strength of the design was done. When applying a vertical force to the prototype it was seen that the front part of the border was flexing modestly. An understandable reason for this is the weakening at this position due to the initial cutting of the previous roof structure, for a review see Figure 5-26. To strengthen the current structure, the bottom cutting of the border was redesigned to include a pad, covering the open part of the roof hatch frame, Figure 6-6. These pads are welded on to the structure to better distribute the load. The strength of the structure will be further increased when mounting the external roof plate on top of the border. Another advantage with the pads is that they will function as an aid to fix the border in the length direction when mounting the border on the roof, Figure 6-7.

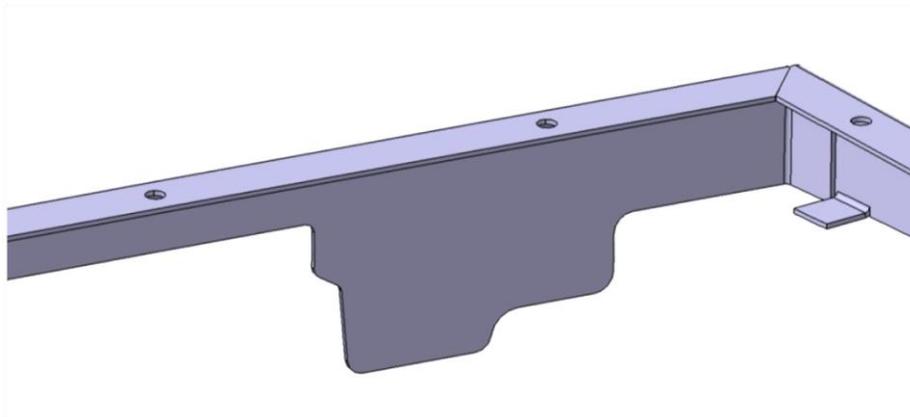


Figure 6-6 Front part of the border with the new cutting

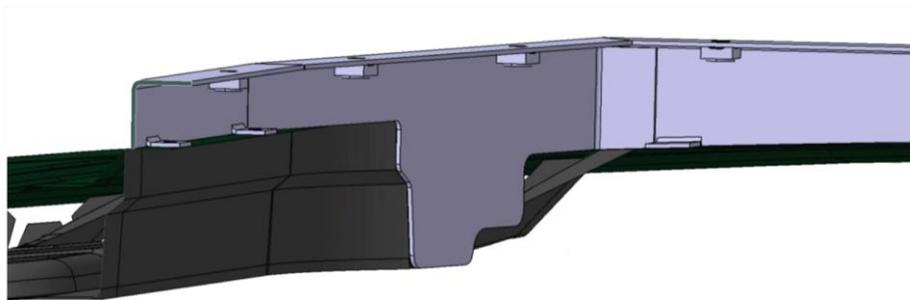


Figure 6-7 Front part attached to the roof hatch frame

6.1.3 New roof plate

One of the primary advantages with the suggested solution is the flexibility in design and the independency of the actual roof hatch design. The design with a large opening and a border opens up for different customized roof plates. These can be designed to fit different roof hatches or for use in other applications such as a platform for different fire fighting equipments. The border is prepared with weld nuts, mounted below the flanges, where the roof plate will be fastened with screws, Figure 6-8. An alternative to weld nuts is clip nuts which easily can be fastened on the border without welding, Figure 6-9. The Clip nut is threaded and does also give spacing between the border and the external plate but this is an article which is not that commonly used within Scania.

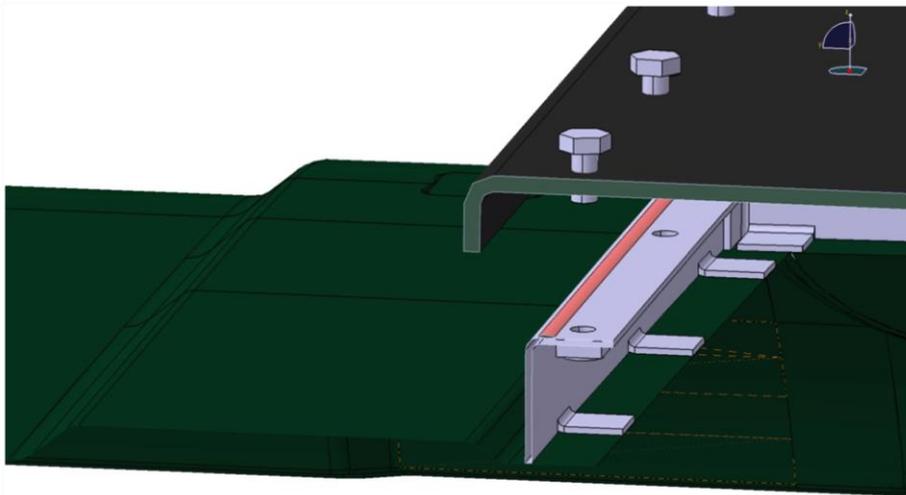


Figure 6-8 Screw joint with weld nuts



Figure 6-9 Clip nut

Whether or not the bodybuilder has developed its own platform, Scania still needs to provide the truck with an external plate to cover the opening and protect the interior design during transportation. A challenge with the roof plate is to find an appropriate

sealing between the plate and the border. Since the roof plate should be easy to remove, it is necessary with a non-permanent sealing joint. A customized Nitto strip is considered to be suitable for this purpose. This article can be found on other joints on the cab, for instance in the sealing joints on the door. An illustration of the sealing applied on the flanges is given in Figure 6-10. To relieve the sealant from the pressure through the screw joint it is necessary with some kind of spacing washer between the border flanges and the new roof plate. One alternative is to use spacing screws; a limitation with this choice is that this article can only be found in the size M6 in the existing assortment within Scania. Another option is to use regular screws in combination with some kind of metal braces that would function as spacing washers but contribute to a more uniformly distributed pressure, see Figure 6-11.

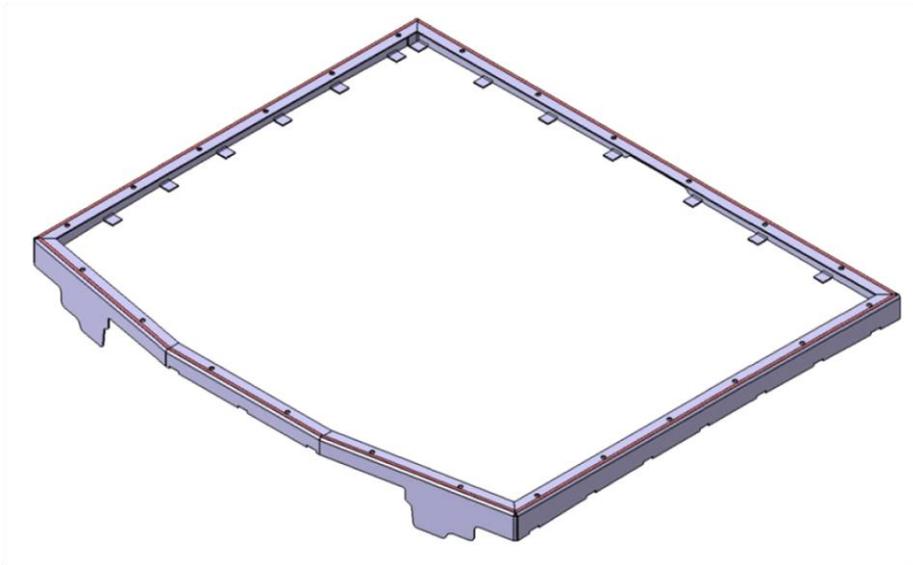


Figure 6-10 Border prepared with sealing

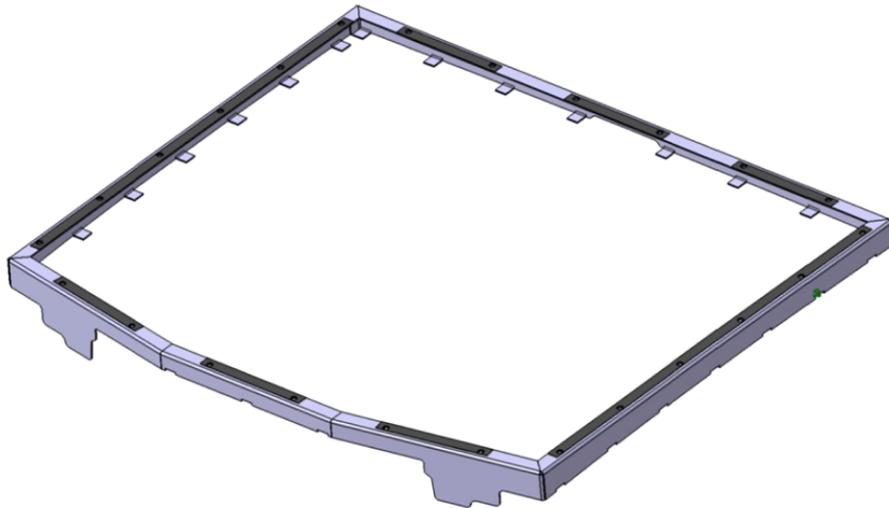


Figure 6-11 Metal braces

To seal the screw joints, thread sealant is applied to the screws and sealing washers can be used as further protection on top of the roof, Figure 6-12. The sealing washer can only be found in size M8 in the existing assortment why a conflict occurs when combining this with the previously presented screw joint solution using spacing screws.



Figure 6-12 Sealing washer

6.1.4 Interior design

The headlining in the cab is custom made for today's roof hatch opening. The design only differs for cabs delivered without roof hatch where the opening is covered, figure 6-13. A rework of the headlining is therefore necessary. One alternative is to design a new headlining for cabs with the large roof hatch, but this is both expensive and will only be useful for that specific roof solution. A better solution might be to make an even larger opening in the headlining as well and then design the ceiling for

the platform and the new roof hatch on its own. This larger cut will affect the placement of the interior lights why a repositioning of these needs to be done.

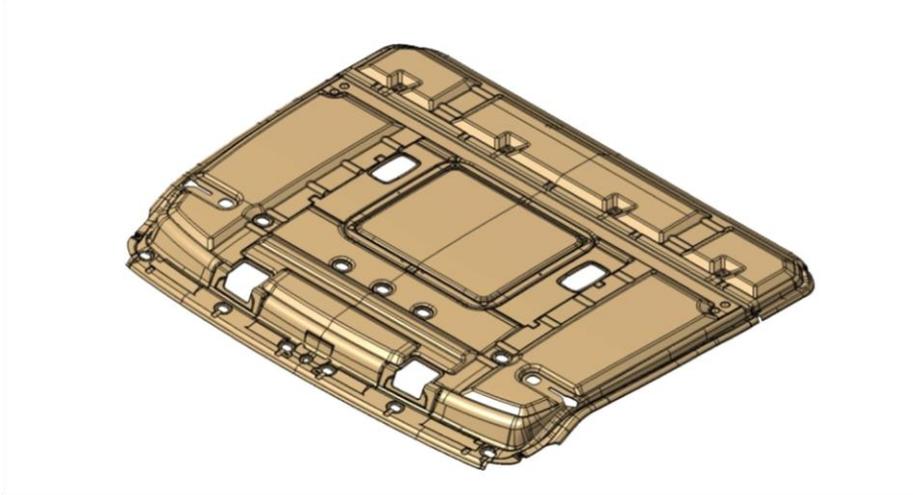


Figure 6-13 Headlining

The interior ceiling is attached to the roof structure in nut plates mounted on the roof hatch frame. The larger opening in the roof implies that the rear attachment points are removed, therefore holes for mounting of new nut plates were prepared in the rear cross member. Additionally, drain holes were added to the rear cross member at its lowest position to manage conditioning treatment of the cab body in the paint shop, Figure 6-14. This is needed as an in- and outlet for the liquid used during the treatment.



Figure 6-14 Hole for nut plate (left) and drain holes at the end (right) on the cross member.

According to the previous discussion there are no attachment points in the original design of the rear headlining, why an alternative attachment needs to be investigated. A section cut of the actual area is given in Figure 6-15. The problem is the distance and position of the holes. As seen the headlining is not horizontal below the cross member. A bracket mounted perpendicular to the cross member should make it possible to move the attachment to a more suitable position.

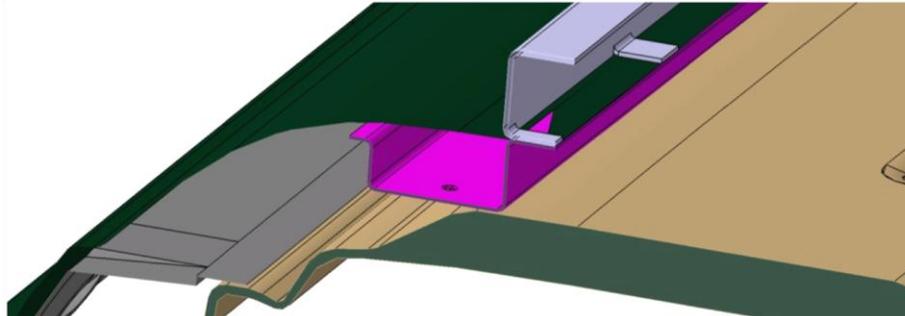


Figure 6-15 Section cut of rear cross member and headlining

6.2 Material selection

It is essential that the material used for the border is cheap, easy to form and resistant to corrosion. A commonly used material in the automotive industry is hot-dip galvanized sheet metal. This material shows great forming and material properties and gives a cost-effective corrosion protection. One commonly used material is the steel DX54 with a Z100 coating, where 100 represent the weight per unit area, g/m^2 . Narrow tolerances for the yield strength motivate the use of this steel.

One disadvantage with this choice of material is that it is a moulding sheet with a minimal order quantity of 1 tonne. In the actual case, the annual volume is estimated to be somewhere between 100-200 cabs. Therefore an alternative choice of material is cold rolled sheet that is galvanized with a coating thickness of $7 \mu\text{m}$.

6.3 Prototyping

In cooperation with the prototype workshop in Oskarshamn a second prototype was prepared with the proposed design changes.

The preparation with lips at regular intervals at the lower edge of the border in combination with an increased height of the border implied a much more convenient and efficient mounting procedure. The design change with the flanges turned 180 degrees did not have any negative impact from a mounting point of view.

The new cutting of the front part of the border seemed to work very well and showed effect on the strength of the design, see Figure 6-16. The width of the border flanges was sufficient to fit the weld nuts. Placement and amount of welds nuts was discussed with the personnel. The result of the second prototype is shown in Figure 6-17.



Figure 6-16 Caps on the front part of the border



Figure 6-17 New, modified prototype

7 Cooperation with Sonntag GmbH & Co

The bodywork, including the implementation of a larger roof hatch, of the military truck being delivered to Germany recently, was done by the third party company, Sonntag GmbH & Co. Since it is of Scania's intention to find a well working factory solution for a larger roof hatch a collaborative development process was established with Sonntag.

The future idea is that the truck should be prepared with a larger opening and a border that enables mounting of a platform including a larger roof hatch before being sent to the bodybuilder for further treatment. This option is a win-win situation since it would save time and money for both parties.

After several phone meetings and a frequent contact via email a visit in Lennestadt was planned in the beginning of March. Before the visit, ideas were discussed and drawings of the proposed solution were sent to Sonntag. Scania Deutschland and Sonntag were very excited with the ideas and found the solution interesting to use.

The proposed design turned out to be successful and Sonntag decided to implement the solution on the mentioned truck. At Sonntag, the accountable designer presented the solution of the roof hatch, weapon mount and how it was attached to the border and the cab, Figure 7-1.

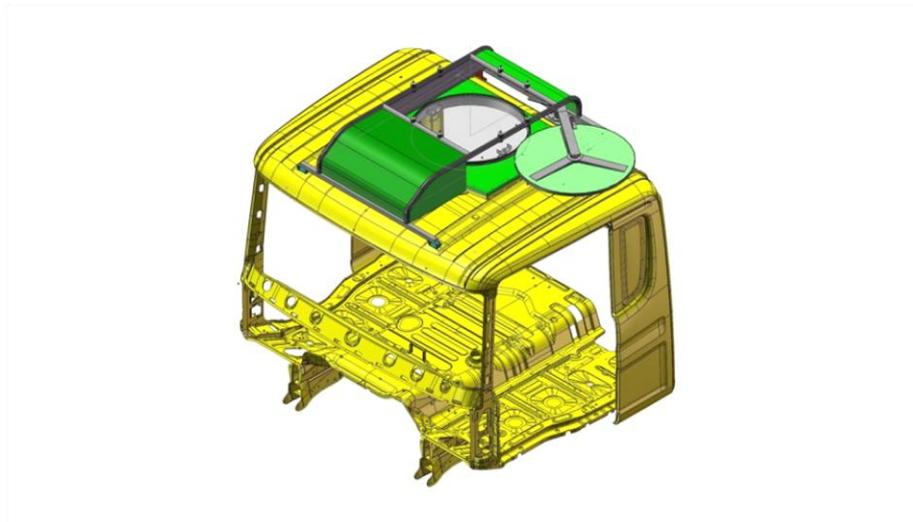


Figure 7-1 Roof hatch from Sonntag

Development of a New Roof Hatch Solution for Military Trucks

The roof hatch and the weapon mount were mounted on the cab in the existing thread pad used by the roof rack and rail system. Both the hatch and the weapon mount are similar to the ones mounted on the Mercedes Actros truck, discussed in the competitor analysis in chapter 3. See for example Figure 3-5. The roof hatch slides under the weapon mount when being opened and fixed at the outer point.

In the workshop, a prototype solution on the actual truck had been prepared, Figure 7-2. The prototype was done according to the drawings of the border and the border was spot welded onto the cab roof.

The border will be sealed on both the in- and outside of the joint between the border and the cab roof. Between the border and the external plate a sealant with gluing effect will be used. The circular opening will have a rubber cover to get a better finish.

For Sonntag's solution the external plate does only consist of the actual opening for the roof hatch. The opening mechanism and the roof hatch arm are attached on the weapon mount. This is possible due to the fact that the hatch opens up with a push from underneath which activates a spring inside the opening mechanism, rather than by a handle inside the cab.



Figure 7-2 Roof hatch and weapon mount

7. Cooperation with Sonntag GmbH & Co

The roof hatch was positioned slightly to the right to enable a better driving comfort and allow the hatch to slide open without exceeding the cab width, Figure 7-3. The position of the foldable seat was then centred against the opening of the roof hatch, Figure 7-4.



Figure 7-3 Roof hatch in open position



Figure 7-4 Opening in the roof and foldable seat

Development of a New Roof Hatch Solution for Military Trucks

One special requirement for this customer was a measurement of 1200 mm between the back of the folded seat and the weapon holder. This was fulfilled with no affect on the border as the weapon mount is mounted separately. This is one of the strengths with the proposed solution, a large opening and an external plate enables the roof hatch to be placed where it is most suitable and have a design that meet specific customer requirements without having to redesign the roof.

8 Final Solution

This part of the thesis contains a presentation of the final solution. The proposed design is highly customized to meet requirements from a production point of view. The idea with the design is to achieve a high degree of flexibility for the customer.

This has been implemented by designing a larger opening in the roof. The proposal with a platform attached on top of a robust border makes the design independent of the actual design of the roof hatch. The final product fulfils all the design goals presented in chapter 4.2 as well as the assignment directives in the initial chapter. The design is customized to fit the day cab with low roof and the sleeper cab with normal roof. The two cases are presented separately in chapter 8.1.1 and 8.1.2 respectively. The same concept can be used for the sleeper cab with low roof, with only minor adjustments. An example of a complete design with the roof hatch attached to the platform, done by Sonntag, is given in chapter 8.2.

All the drawings can be found in Scania's drawing archive. The part numbers are shown in Appendix A.

8.1 Proposed Design

The design is customized to fit two variants of cabs. The main difference between the two is the inclination of the roof, illustrated in the figure below, Figure 8-1.



Figure 8-1 Day cab (left) and sleeper cab (right)

This is also the only thing that has affected the differences in design between the two design proposals. Except from the adjustment of the height of the border to obtain a planar surface for the platform, the two proposals are identical to each other.

A larger opening in the roof is cut open manually using a specially adapted fixture, see Figure 8-2. This is done after the body work shop in the ordinary production line.

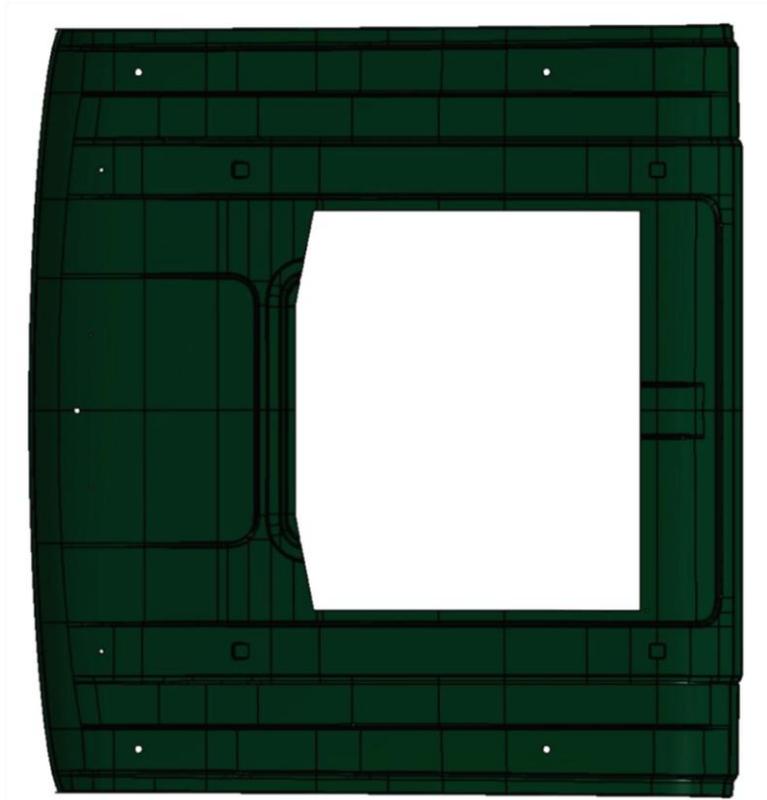


Figure 8-2 Larger opening in the roof

The border is made of galvanized steel and has been provided with lips at regular intervals around the lower edge. This design enables to use spot welding when attaching it to the roof which is an advantage from a production point of view. An exception is done to the three lips at the front part of the border. Due to insufficient space, these have been provided with holes to enable for plug welding. Additionally the front part of the border has been provided with caps to obtain a more robust solution. These are aimed at further strengthen the remaining part of the current roof hatch frame. A detailed illustration of the border is given in Figure 8-3.

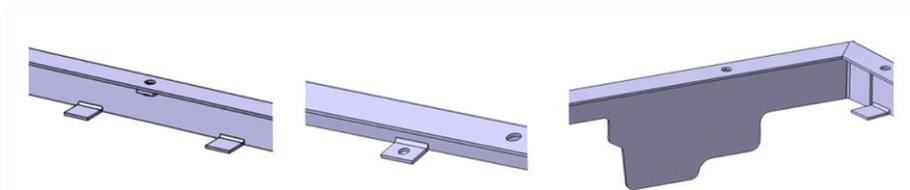


Figure 8-3 Lips (left), Holes for plug welding (middle), the cap in the front (right)

8. Final Solution

The flanges of the border are bended inwards to enable for an automated coating process in the paint shop. This does also facilitate the sealing procedure. The sealing is applied in the paint shop, before the coating procedure, by a robot with an extruding nozzle. An illustration of the sealant is given in Figure 8-4 below.

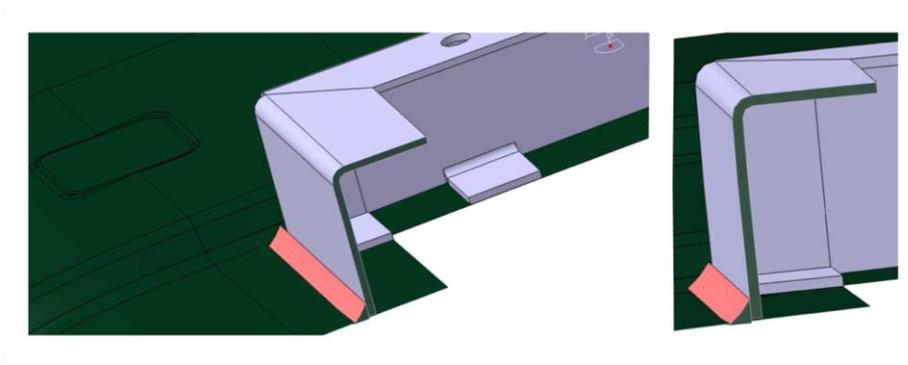


Figure 8-4 Sealant applied between the border and the roof

24 weld nuts are equally distributed along the underside of the flanges to allow for screw joints between the border and the platform. It is not necessary to use all 24 holes for screw joints, especially if the new roof plate is intended solely as a protection during transportation. A halving of the number of screw joints would be a great time saving during the assembling procedure. By providing the border with an excess of weld nuts the customer will have the opportunity to use as many as needed in that particular case.

A rubber strip is attached along the top surfaces of the flanges to allow for a convenient sealing between till border and the platform. Some sort of sealing washer is necessary to avoid that the strip loses its elasticity over time. For this purpose either spacing screws or metal braces can be used. Sealing washers on top of the roof plate in combination with thread sealant are aimed at prevent leakage through the screw joints. This sealing joint has the advantage of being possible to remove easily. Because the roof plate mainly will be intended for transportation use, designed to fit all different cab versions, this was a necessary requirement. The idea in the end is that the customer should have the opportunity be able to mount its own, customized platform on top of the border, after delivery. Figure 8-5 shows proposed sealing solution. The new roof plate, mounted on top of the border can be seen to the right.

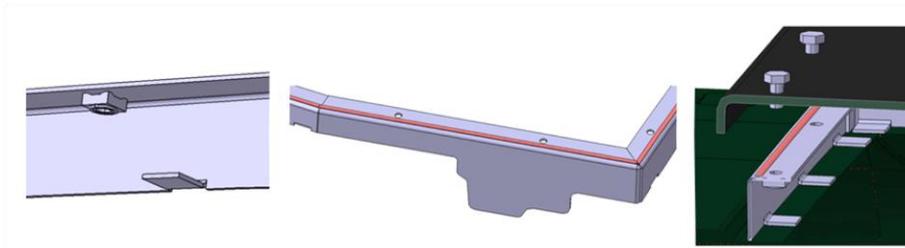


Figure 8-5 Weld nuts (left), Sealing (middle), sealing and screw joint (right)

The border and the new roof plate will be manufactured by an external supplier. A visit together with the supplier quality manager was done at the supplier to clarify the design before requesting a quotation.

8.1.1 Day cab with low roof

This variant of cab was the one used throughout the entire design work in this project. It was also this cab that was mounted on the truck being delivered to Germany recently. Additionally the two prototypes were built on this kind of cab. Therefore more knowledge has been gained about this variant of cab. An overview of the solution for the day cab with low roof is seen in Figure 8-6.

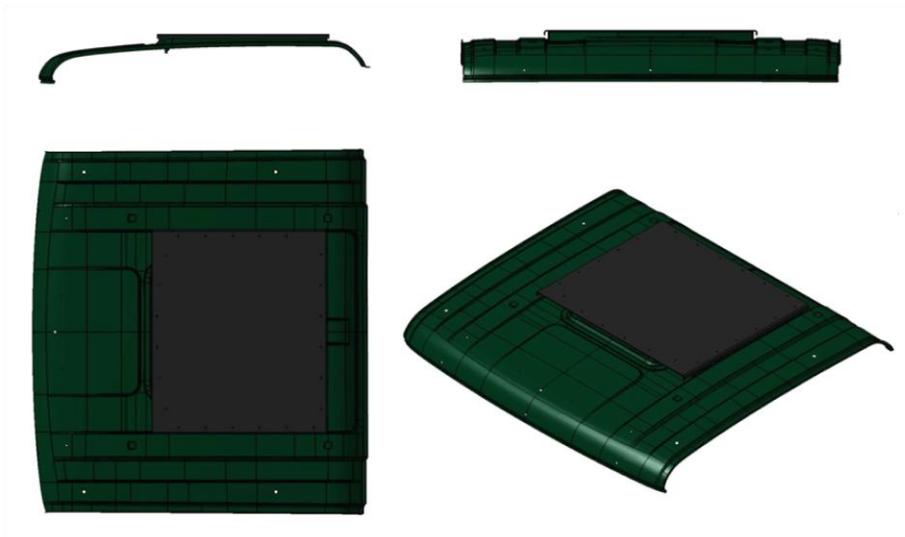


Figure 8-6 Day cab with low roof, CG/CP16

This day cab has the advantage of having a relatively flat roof why a very smooth integration of the suggested solution could be obtained on this cab.

8. Final Solution

8.1.2 Sleeper cab with normal roof

Due to the inclination of the roof in combination with a desire of a planar surface for the new roof plate to be mounted, it is necessary to adjust the height of the border. The minimum distance between the flange and the lower part of the border to enable for a convenient spot welding was estimated to be about 35 mm. The estimation was done by studying and measure the equivalent distances on the solution for the day cab, since we knew that this design was possible to implement in reality. The same critical value was used when designing the border for the version with normal roof.

Due to this adjustment of the border it is possible to use the same design for the new roof plate. An overview of the solution for the sleeper cab is given Figure 8-7.



Figure 8-7 Sleeper cab with normal roof, CR19

8.2 Solution by Sonntag

The truck delivered to Germany was a day cab with low roof, equivalent to the one discussed in 8.1.1. The border is done according to our drawings whereas they used their own design for the platform. An overview of their solution is given in Figure 8-8.

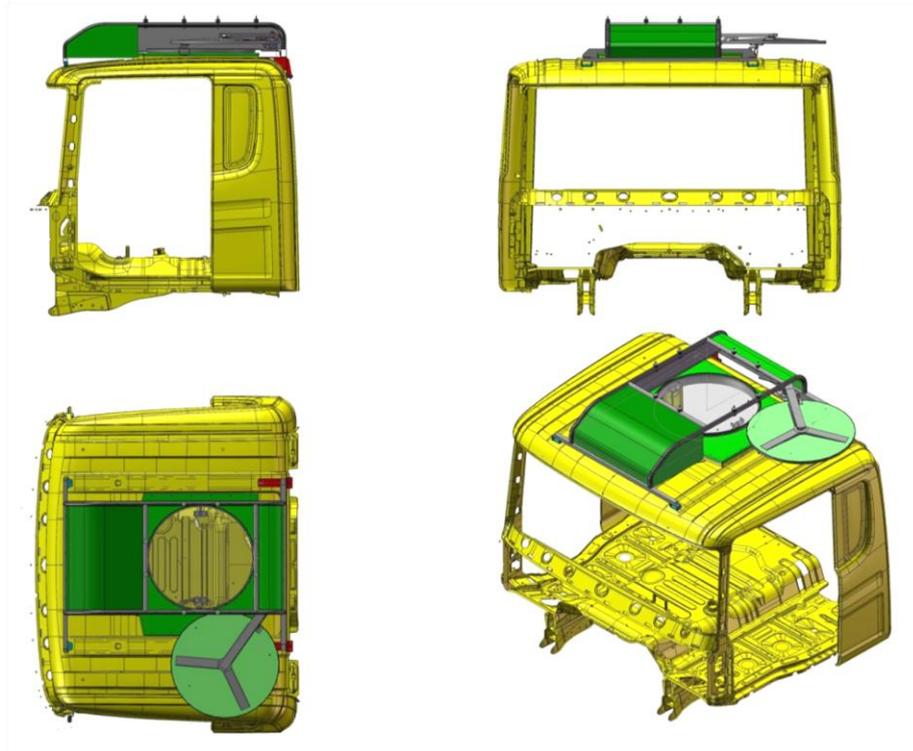


Figure 8-8 Overview of Sonntag's solution

9 Discussion and Conclusion

The purpose with this Master Thesis was to investigate the opportunities to implement a larger roof hatch on the military trucks within Scania. The focus was to design a variant of the current roof that should be able to accommodate a hatch with the desired dimensions.

The goal with the design was that it should be possible to manufacture in the existing cab factory in Oskarshamn. Due to a relative low annual volume for military trucks, expensive investments should be avoided. Therefore the primary focus in the design work has been production adaptability of the new roof structure. The design of the new roof structure should also be integrated with the regular design of military trucks within Scania and meet the requirements regarding strength and robustness.

It was not investigated whether the future hatch should be a design by Scania or special-order item, why no information about the design of the roof hatch was available. Therefore an additional design goal, with a flexible solution, was found during our work; a desire of a solution that was more or less independent of the roof hatch design.

To better be able to understand the limitations regarding production, several visits at the cab production plant in Oskarshamn were done. We also got the opportunity to build prototypes of our proposed design which was a big help for identifying improvements. Especially improvements from a production point of view, including a convenient assembling procedure.

Thanks to a great cooperation with concerned departments, especially people from cab production and the market side, this project ended up in a solution that meets the objective with this project. We believe that we have successfully achieved the beforehand established assignment directive for this Master Thesis.

The solution:

- Has a flexible design
Adapted to different variants of cabs
More or less independent of the roof hatch design
- Is adapted to enable production in the existing cab factory
No expensive tool investments
Convenient to mount with only minor impacts on the ordinary production flow
- Opens up for other areas of use
A platform for other applications, e.g. fire fighting

- Has an integrated design
Fits in to the design of military vehicles within Scania
Despite a large operation the design is well integrated with the cab roof

In parallel with our project, the implementation of a larger roof hatch was carried out in reality on a military truck being delivered to Scania Deutschland recently. The body work was carried out by a third party company called Sonntag. The intention in the future is to be able to prepare the truck for future bodywork before being delivered, since that would be a win-win situation. A close cooperation was established with Sonntag to enable an optimization of the factory preparation.

During the work it was a bit problematic to get input and answers from Germany despite their interest in the project. The reason for this could be uncertainties regarding responsibility roles and information flow within the project. It was not clear what they expected from us. After several phone meetings and a continuous contact via email contact our proposed solution, including drawings, was sent to Sonntag and a visit was planned in early March. The proposed design was met by positive response and could successfully be built on the actual truck. The solution did also demonstrate its compatibility with a larger, circular roof hatch.

Although the idea with the proposed design is that it should work on any market, the German market has to a large influenced our design work. A more intense cooperation with the Germans might have taken the project in another direction. At the same time this should probable have influenced the solution to be more focused towards this customer's specific demands and not being as flexible as the solution presented above.

To sum up, we believe that it is a great success that the solution has been implemented on the military truck being delivered to Germany. It confirms that the design actually works in reality.

10 Recommendations

To take one step further in the design work it is essential with more information about the actual roof hatch design. That is more or less a requirement to be able to redesign the headlining and come up with solutions regarding isolations and noise protection. By doing a market analysis among the European army forces, a deeper knowledge can be gained about possible roof hatch designs. Are there any potential suppliers of a roof hatch or should it be a design by Scania? One can predict that different Army forces have different demands regarding the roof hatch design, why it may be sufficient to provide the customer with a preparation for a larger roof hatch as with the suggested solution. The latter might be an alternative way of marketing the product as a flexible product with a lot of opportunities, not only used for military applications.

Further, the new design of the roof structure needs to be tested and verified so that it meets certain requirements regarding strength and robustness. Tests will be performed on the German truck and some information regarding the results might be useful for future work. No matter what, it is necessary to follow up the work done by Sonntag on the truck for the German Bundeswehr.

The sealing between the border and the new roof plate need to be further investigated and finalized. A problem with the more convenient solution of the two, the one with spacing screws, is the absence of including articles in the standard assortment within Scania. The spacing screws can only be found in M6 whereas the only sealing washers available are in M8. An introduction of a new standard article in the standard assortment is very costly and hard to implement. Perhaps alternative solutions to the sealing washers on top of the roof can be found. The solution with the metal braces, on the other hand, requires a development of new articles. It is a trade off between cost and convenience, as in many other cases.

Regarding production, fixtures for mounting need to be prepared and a simulation of the imagined production flow might be necessary to discover potential improvements of the design. Additionally it might be a good idea to order a prototype of the border to verify the order before accepting the quotation. The prototype being built in Oskarshamn was manually made, including the border, why minor adjustments more easily could be made.

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12 Register of Figures

Figure 1-1 Existing roof hatch solution	2
Figure 1-2 Process Flow	4
Figure 2-1 Scania Cab Program [3]	7
Figure 2-2 Roof structure	8
Figure 2-3 Central part of the outer roof panel	9
Figure 2-4 Cab production line in Oskarshamn	10
Figure 2-5 Disassembled manual roof hatch.....	11
Figure 2-6 Foldable roof hatch.....	11
Figure 3-1 Unimog roof and drawing	14
Figure 3-2 Axor Exterior view [6]	14
Figure 3-3 Atego Interior [6]	15
Figure 3-4 Actros front view [6].....	16
Figure 3-5 The Actros roof hatch equipped with a weapon mount. [6]	16
Figure 3-6 The MAN TGA with an electric roof hatch.	17
Figure 3-7 MAN SX [7].....	17
Figure 3-8 MAN SX roof [7]	18
Figure 3-9 MAN HX Roof [7]	18
Figure 3-10 Iveco roof hatch inside	19
Figure 3-11 Iveco roof hatch outside	20
Figure 3-12 Tatra T810 with a supporting bar installed with the roof hatch [10] [11]	21
Figure 5-1 Bodywork solution 1 mounted from above	28
Figure 5-2 Bodywork solution 1 mounted from below	28
Figure 5-3 Bodywork solution 2	29
Figure 5-4 Modified, circular roof hatch frame	30
Figure 5-5 Circular roof hatch - New frame	31
Figure 5-6 Rectangular roof hatch	31
Figure 5-7 Cab body after the body workshop.....	35
Figure 5-8 Opening in the roof	36
Figure 5-9 Modified roof structure seen without the roof.....	36
Figure 5-10 Border, concept 1	37
Figure 5-11 Border attached to the roof, concept 1	37
Figure 5-12 Screw attachment and the alternative slit, concept 1	38
Figure 5-13 Roof with external roof plate.....	38
Figure 5-14 Border mounted from below, concept 2	39
Figure 5-15 View from below, concept 2	39
Figure 5-16 Cross section view of the border, concept 2.....	40
Figure 5-17 Space between the roof and the border	40
Figure 5-18 Suggestion to a sealing.....	41
Figure 5-19 Cross section view of the sealing	41
Figure 5-20 Base for the border frame	42
Figure 5-21 Unfolded L-profile, prepared with laser cut	42
Figure 5-22 Vertical border, folded and welded together	42
Figure 5-23 Overview of solution with a new border	43

Development of a New Roof Hatch Solution for Military Trucks

Figure 5-24 Complete solution, concept 3	43
Figure 5-25 Border and opening in the roof.....	46
Figure 5-26 Front part of the remaining roof hatch frame	48
Figure 5-27 Critical part of the front border	49
Figure 5-28 Border side	50
Figure 5-29 Rear part of border, showing the tolerance of the cutting	51
Figure 5-30 Rear corner of border	51
Figure 6-1 Overview of redesigned concept	53
Figure 6-2 Test for sealing and painting issues.....	54
Figure 6-3 Side part of border.....	55
Figure 6-4 Front part, with holes for plug welding.....	55
Figure 6-5 Redesigned rear corner of border	55
Figure 6-6 Front part of the border with the new cutting.....	56
Figure 6-7 Front part attached to the roof hatch frame	56
Figure 6-8 Screw joint with weld nuts	57
Figure 6-9 Clip nut.....	57
Figure 6-10 Border prepared with sealing	58
Figure 6-11 Metal braces	59
Figure 6-12 Sealing washer.....	59
Figure 6-13 Headlining	60
Figure 6-14 Hole for nut plate (left) and drain holes at the end (right) on the cross member.	60
Figure 6-15 Section cut of rear cross member and headlining.....	61
Figure 6-16 Caps on the front part of the border	62
Figure 6-17 New, modified prototype.....	62
Figure 7-1 Roof hatch from Sonntag	63
Figure 7-2 Roof hatch and weapon mount.....	64
Figure 7-3 Roof hatch in open position	65
Figure 7-4 Opening in the roof and foldable seat	65
Figure 8-1 Day cab (left) and sleeper cab (right).....	67
Figure 8-2 Larger opening in the roof.....	68
Figure 8-3 Lips (left), Holes for plug welding (middle), the cap in the front (right)..	68
Figure 8-4 Sealant applied between the border and the roof.....	69
Figure 8-5 Weld nuts (left), Sealing (middle), sealing and screw joint (right)	70
Figure 8-6 Day cab with low roof, CG/CP16	70
Figure 8-7 Sleeper cab with normal roof, CR19	71
Figure 8-8 Overview of Sonntag's solution.....	72

13 Register of Tables

Table 4-1 Requirements and Desires	24
Table 5-1 Concept Screening	34
Table 5-2 Concept Scoring	45

Appendices

Appendix A

All the parts that have been designed in this project are given in Table 1, including specific part numbers. The drawings can be found in Scania drawing archive.

Table 1 CAD drawings

Denomination	Scania part number	Cab Version
Roof center panel	2020559	Day cab, CR16, Low roof
Roof hatch frame	2020561	Day cab, CR16, Low roof
Frame assy	2020563	Day cab, CR16, Low roof
Frame part, front	2020576	Day cab, CR16, Low roof
Frame part, rear	2020575	Day cab, CR16, Low roof
Frame part, left	2020577	Day cab, CR16, Low roof
Frame part, right	2020578	Day cab, CR16, Low roof
Roof center panel	2020560	Sleeper cab, CR19, Normal roof
Roof hatch frame	2020562	Sleeper cab, CR19, Normal roof
Frame assy	2020564	Sleeper cab, CR19, Normal roof
Frame part, front	2020579	Sleeper cab, CR19, Normal roof
Frame part, rear	2020574	Sleeper cab, CR19, Normal roof
Frame part, left	2020580	Sleeper cab, CR19, Normal roof
Frame part, right	2020581	Sleeper cab, CR19, Normal roof
Roof plate	2020582	Common
Rear cross member	2020583	Common