Wiper Module for Outdoor Housings

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FACULTY OF ENGINEERING LTH | LUND UNIVERSITY
2019

MASTER THESIS

AXIS COMMUNICATIONS

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LUND
UNIVERSITY

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Published by
Department of Design Sciences
Faculty of Engineering LTH, Lund University
P.O. Box 118, SE-221 00 Lund, Sweden

Subject: Product Development (MMKM05)
Division: Product Development
Supervisor: Per Kristav
Examiner: Axel Nordin

Abstract

This report describes the product development process of a new product series of camera housings, adapted for modular applications. The purpose of the project was to develop a module containing a wiper, adapted for outdoor camera housings. The master thesis was performed at Axis Communications AB, a leading company in the surveillance camera industry.

The camera housings of outdoor surveillance cameras vary with several factors as they implicate different purposes, appearances, requirements and conditions. The products are designed to work in various weather conditions and at the same time meet the customers' stringent requirements. An issue facing all outdoor cameras is that water, snow, dirt or dust can stick to the screen which reduce the visibility and capability of monitoring. Many ways to remove water have been tested and the most reliable way is with a wiper. Available products with wipers today are integrated, which does not enable the customer to add it afterwards. Generally, most product functions are integrated and packaged as one uniform product which makes production time-consuming and costly when new customer needs have to be met. One way to solve this could be by creating modules which would be designed, added and modified as wished.

The advanced and high-quality cameras at Axis comprise many important functions that must be considered when developing a new camera house. Throughout the project, design, contacting and communication interface have been important factors when choosing the best concept. The work has resulted in a concept that consists of three main parts, a housing body, a module and a mounting part.

The dissertation consists of the entire development process, which should be used as a pre-study of possible concepts for further development. The result shows that a product line with modular design is possible to develop and a relevant future product for the Axis portfolio.

Keywords: Product Development, Module, Wiper, Network Cameras, Axis Communications A

Sammanfattning

I denna rapport beskrivs produktutvecklingsprocessen för en ny produktserie av kamerahus, anpassad för moduler. Syftet med projektet var att utveckla en modul som innehåller en vindrutetorkare, anpassad för utomhuskamerahus. Examensarbetet utfördes på Axis Communications AB, ett ledande företag inom industrin för övervakningskameror.

Kamerahusen för utomhusövervakningskameror varierar med flera faktorer eftersom de har olika syften, utseende, krav och villkor. Produkterna är utformade för att fungera under olika väderförhållanden och samtidigt uppfylla kundernas stränga krav. Ett problem för alla utomhuskameror är att vatten, snö, smuts eller damm kan fastna på skärmen vilket minskar sikten och därmed möjligheten att övervaka. Många sätt att ta bort vatten har testats och det mest tillförlitliga sättet är med en vindrutetorkare. Befintliga produkter har integrerade torkare idag vilket gör det omöjligt för kunden att lägga till det efteråt. Generellt integreras de flesta produktfunktionerna och förpackas som en enhetlig produkt vilket gör produktionen tidskrävande och kostsam när nya kundbehov ska uppfyllas. Ett sätt att lösa detta kan vara genom att skapa moduler som kan utformas, läggas till och modifieras efter behag.

De avancerade och högkvalitativa kamerorna på Axis innehåller många viktiga funktioner som måste beaktas när man utvecklar ett nytt kamerahus. Genom projektet har design, kontaktering och kommunikationsgränssnitt varit viktiga faktorer vid valet av bäst koncept. Arbetet har resulterat i ett koncept som består av tre huvuddelar, en huskropp, en modul och en monteringsdel.

Avhandlingen består av hela utvecklingsprocessen, som bör användas som en förundersökning av möjliga koncept för vidareutveckling. Resultatet visar att en ny produktlinje med modulär design är möjligt att utveckla och en relevant framtida produkt för Axis portfölj.

Nyckelord: Produktutveckling, Modul, Vindrutetorkare, Nätverkskameror, Axis Communications AB

Acknowledgments

This master thesis is the result of our Master of Science in Mechanical Engineering at the Faculty of Engineering at Lund University. We would like to thank some key people who have helped us along the way.

Firstly, we would like to thank our supervisors at Axis, Mikael Adervall and Oscar Strand, for supporting us from the beginning, and who made us feel welcomed and part of the Axis culture.

We would also like to thank our supervisor at LTH, Per Kristav, for his valuable inputs, fast response and great creative thinking; all employees at Axis who have helped us, and especially; Johan Beets and Stefan Möller, for showing interest in our project and always being available to us despite having loads of own work to do; thesis workers Einar Lagström, Ella Hjertberg, Tom Lindahl, Simon Hansson and Wilhelm Andrén for support and many good laughs during these 20 weeks.

Finally, we would like to thank Axis for this great and instructive experience

Lund, June 2019

Astrid Jansson and Hanna Wiggman

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List of Abbreviations

CAD	**C**omputer **A**ided **D**esign
FEM	**F**inite **E**lement **M**ethod
IR	**I**nfrared **R**adiation
LED	**L**ight **E**emitting **D**iode
PCB	**P**rinted **C**ircuit **B**oard
PTZ	**P**an **T**ilt **Z**oom

Chapter 1

Introduction

1.1 Background

Axis products are designed to work in various weather conditions. One problem area is water drops on the front window, affecting the image quality. One way to remove water drops is with a wiper. But an integrated permanent wiper solution means that all customers have to pay for the functionality, even if they do not need it. One idea is to have a module based outdoor housing where it is possible to add different types of accessories to the basic housing, e.g. a wiper module. This gives a lot of flexibility to meet the customer needs at the best cost. The camera housings at Axis vary depending on multiple factors because they imply different purposes, appearance, requirements and conditions.

Design of the reference product - The product that was the reference design during the project referred to the design of the camera housings belonging to the group of Fixed Box cameras, which means that the camera housing is fixated and does not include any mechanism that makes it possible to steer the camera. The properties of the cameras can vary but are similarly constructed and they are both for indoor and outdoor use. A good example of a fixed box camera is the AXIS Q1645-LE, see Figure 1.1.

Figure 1.1: The AXIS Q1645-LE.

The camera housing is made of plastic or aluminum and contains a front window made of glass or plastics. The camera housing is parted horizontally, dividing it into a bottom and top part which consists of the walls and the roof. Inside the house, the camera sits on a track which allows adjustments of the distance to the front window. In addition to the optical camera, it also holds a *Printed Circuit Board* (PCB) and space for all cables to connect to the

camera. The PCB is an isolated plate with a pattern of electrical conductors that contains the software of the camera.

1.2 Goals & objectives

The main goal of the thesis was to investigate the design of a wiper module for the next generation outdoor camera housings. Industrial design, power and communication interface, functionality will all be important factors when choosing the best concept. The goal is to have a prototype representing the design and construction of the chosen concept.

1.3 Delimitations

The project should result in a prototype of a wiper module and a concept of a new product line of camera housing adapted for modules. The wiper module should fit the fixed box cameras and be designed for outdoor use. The limited time allocated to this project demanded estimations; only a brief manufacture and cost analysis will be done. The project started from scratch with a pre-study.

1.4 About Axis Communications

The surveilliance company, Axis, was founded 1984 in Lund, by Martin Gren, Mikael Karlsson and Keith Bloodworth. The first network camera was invented back in 1996 and today Axis is the market leader within the security and surveilliance industry. Apart from surveillance cameras, Axis develops their own circuit boards as well as other related products to the cameras. The company has grown a lot these last couple of years and their biggest market is the US. It is an innovative company with 3,253 (2018) employees (Axis Communications AB, 2019).

1.5 Report disposition

- **Chapter 2: Methodology**
- **Chapter 3: Discover** Consists of research and an examination of the different areas involved in surveillance technology to give a broad spectrum of solutions and ideas.
- **Chapter 4: Define** The various factors and areas that impact the project are identified and summarized to different needs, specifications and requirements.
- **Chapter 5: Develop** The developing process of the concept is described from the beginning to the end. Concept generation, concept evaluation, alternative solutions and selections are presented in this chapter.
- **Chapter 6: Deliver** The final choice of prototype is further developed and the final concept is built, tested and presented.
- **Chapter 7: Discussion and Conclusion** This chapter is about analyzing the results and how the project could be further developed.

Chapter 2

Methodology

2.1 Double Diamond

The method chosen for the project was the *Double Diamond* method. The method is a design process model developed by the British Design Council in 2005 (The Design Council, 2019). It is a widely known method and especially useful for consultants, or other externals, when doing product innovation or concept development, see Figure 2.1.

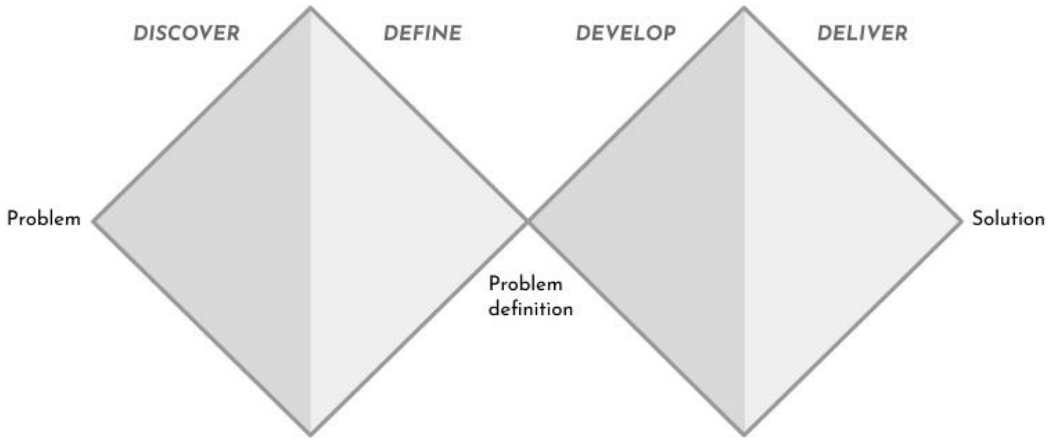


Figure 2.1: The Double Diamond phases.

2.1.1 Discover

In the first phase the focus is to gather as much inspiration and knowledge as possible. The *Discover* phase is characterized by divergent thinking and investigation to broaden the ranges of possible solutions. None or few decisions are made. Rather, emphasis is put on exploration and open-endedness, searching for different aspects in order to solve the problem.

2.1.2 Define

In the second phase, the results of the *Discover* phase are analyzed and summarized to make the information more substantial. The goal is to define the main problem and challenges. Earlier insights can be formulated into a definition of the task by using convergent thinking. This stage consists of preliminary idea generation so that feasible and innovative ideas

are documented and related problems are identified. At this stage, project goals should be established followed by a project plan that fits the time line.

2.1.3 Develop

The *Develop* phase is defined by the many iterations needed when generating ideas, sketching on concepts, making prototypes and testing. Opportunities and solutions are to be further investigated and evaluated in order to get the best solution. Different development methods, rapid prototyping and practical tests make up some of the toolbox required during this phase. A mind-set of trial and error is useful in order to stay open for several possible solutions.

2.1.4 Deliver

Finally, the result of the project is presented. The chosen concept gets a final evaluation, data from tests will be put together and costs calculated. Any design improvements and adjustments will be made. A final prototype or mock-up is presented, including a description of the product.

2.2 Methods

The research involved several methods, which are presented below.

One minute - During a limited time, the task is to sketch one concept. When the time is up, the concept is put aside to start a second round. This can be repeated as many times as wanted. The time can vary, but should not be too long since there should not be room for evaluating the idea. The method is advantageous when the focus is on generating quantity, rather than quality.

Brainstorming - When brainstorming a group jointly works to come up with ideas. All the participants form ideas on spot and share them openly without criticism. Together the group can create new ideas based on others and combine them freely. The goal of brainstorming is that new solutions can be the result of analyzing a problem in different ways (Innovation Toolbox, University of Copenhagen, 2018).

Braindump - Braindumping is very similar to *Brainstorming* but one does it individually and after all participants are done they explain their ideas to the rest (Innovation Toolbox, University of Copenhagen, 2018).

Moodboards - Collecting ideas and putting them together with images in a moodboard is effective to visualize inspiration and connect different ideas. It can also be used as a collage during the design process, summarizing the intended feeling and aesthetics of a concept.

Sketching - Sketching is an essential method during concept developing as it is an effective way of expressing and communicating ideas. It can also stimulate creative thinking.

Co-Creation Mini Workshops - Organizing interactive meetings or mini workshops with few participants is an effective way of getting feedback and new ideas. By inviting employees from the company, with different expertise, one can get get new understandings and perspectives.

Rapid Prototyping - Rapid prototyping is useful when it comes to get a concrete idea of the concept. If a specific solution that does not require advanced technology needs to be tested, this is effective. Simple materials such as cardboard, foam, glue, rest materials or 3D-printing are often sufficient in order to get a feeling of advantages and disadvantages of the concept.

2.3 Key people and contributors at Axis

Table 2.1: Key people and contributors at Axis.

Name	Epithet	Role in project
Andres Vigren	Global Product Manager	Product owner
Stefan Möller	Mechanical Engineer	Construction of Fixed Box cameras
Mikael Adervall	Experienced Mechanical Engineer	Supervisor
Oscar Strand	Engineering Manager	Supervisor
Christian Adielsson	Senior Engineer	Electrical hardware for Fixed Box
Johan Beets	Experienced Engineer (2.0)	Electrical hardware for Fixed Box
Ola Andersson	Senior Engineer	Knowledge about Q8685-E PTZ
Christian Jakobsson	Experienced Engineer	Knowledge about Q8685-E PTZ
Jonas L Sjöberg	Industrial Design	Axis tools, design and technologies

Chapter 3

Discover

3.1 Research set-up

Primarily, it was crucial to fully understand the problem and the background of the project as it would facilitate future work and decisions. Meetings with the product owner and supervisors were set up, followed by a profound research presented below. Early on it was understood that the project included four main areas of interest for the research; Wiper design, Fastening mechanism, Module design and Camera housing.

3.2 Internal research

The internal research was done at Axis through meetings with relevant employees, see Table 2.1 and investigations of already existing products and prototypes. In order to make the project as successful as possible it was essential to take advantage of the know-how within the company. The examined products and prototypes were mainly different variants of camera housings, an integrated wiper solution as well as a module containing an IR-LED. This type of research was performed throughout the project.

3.2.1 The module concept

Generally, with the concept of addable modules it may be possible to satisfy all kinds of customer needs with only a few changes. The concept of modules is based on one kind of product architecture called modular architecture. Ulrich and Eppinger (2012) describes product architecture as: *"the scheme by which the functional elements of the product are arranged into physical chunks and by which the chunks interact."*. What characterize a design of modular architecture is the possibility of changing different parts without affecting others. It is then crucial that the interactions between the chunks are well-defined and that every physical chunk represents one functional element. By accomplishing this, the design of the product becomes more flexible and adaptable. Different parts could be recycled, exchanged or adapted to new requirements (Martinez and Xue, 2016). The opposite of modular architecture is integral architecture, which is not relevant for this project.

In the case of Axis, as for many businesses, it is important to fulfill all the requirements during the procurement process of the customers. The current development process at Axis adopt for clients by making new solutions on existing products. With a camera housing with a larger degree of freedom and possible add-ons or modules, the development process could be more time efficient and less costly. Furthermore, if a product would be multi-functional

and modifiable the company would reduce the risk of missing a procurement. For example, the durability requirements for the camera are very tough. One of these requirements is the level of resistance to external impact, i.e. vandalism. With a housing and front window made of plastic these requirements are satisfied. However, a wiper requires a window made of glass since it otherwise will damage the window. With a glass window the durability requirements cannot be satisfied. A solution to this could be a plastic window complementing the one of glass but that would result in reduced image quality, since glass and plastic have different optical properties. Moreover, it is realised that various modules, or functions, could be needed simultaneously, or added separately at different occasions.

Existing Module Concepts at Axis - Today Axis have a module consisting of an IR-LED, which is placed underneath one of the camera housings. The design of the module can be compared to a white box, and it fits the rest of the design of the camera. With or without the IR-module, the camera appears like one solid product. This solution is functional and easy to install since it is small and have a simple design. However, the possibility of adding an endless amount or variety of external modules like this one is limited. The size of an add-on will affect the possibility of making it to a module, as well as, the kind of function. For example, a wiper is usually an integrated feature as it often requires additional functions such as a front window heating system or protection so that dirt, or similar, does not get stuck onto the wiper.

Other functional elements in the Axis cameras that are more or less modular are the circuit boards. However, the design of these differ depending on the camera.

3.2.2 Wipers

Several meetings with engineers at Axis gave a better understanding of the project and potential improvements of the wiper design and function. Initially, alternative methods of water removal were discussed. However, the conclusion was that the project should result in a wiper solution, since that is what the clients ask for and it is a proven concept at Axis. An analysis of the Axis wipers was therefore done. Two important design features of a wiper are firstly the necessity of a glass front window, in order to avoid scratches, and secondly accomplishing enough pressure against the window to make the water removal effective.

Existing wiper products at Axis - At Axis there are two different wiper solutions today. They differ in several ways including their movement, heating solution and design. See Figure 3.2. The wiper used for the fixed box cameras today, called Axis Wiper Kit B, can be seen in Figure 3.1.

Figure 3.1: Wiper used at Axis.

Figure 3.2: Two variants of wiper solutions. The middle and left camera is named Q8685-E PTZ, and the right one is named Q6215-LE PTZ.

The wiper on Q8685-E PTZ is placed on a positioning unit and is integrated in the front window of the camera. However, it is possible to change only the wiper if needed. The wiper has an angular motion, a robust design and a spring between its axis and the blade to get an optimal pressure towards the window. The wiper is protected by the weather case since it is positioned in the upper corner. The right hand wiper is positioned on a *Pan Tilt Zoom*-camera, also called a PTZ camera. It has a vertical-like motion, similar to a motion in the y-direction. Because of this motion dirt and water gets stuck onto the blade which rather transports the dirt and water upwards and downwards than removing it out of the way. The wiper is made up of spring steel which makes the wiping function too weak and the performance poor. However, the positive aspects of its design is the low weight and that it is easy to exchange, i.e. put on and off. Both of the wipers are controlled manually by an operator and need a heating system to prevent the formation of frost, ice and snow on the window.

Fastening

To be able to add a module to a camera housing, a way of fastening needed to be investigated. Meetings with Axis engineers gave understandings of outdoor camera installation conditions, and it was understood that the environment could be both high up, windy and cold. To deal with these conditions Axis use loose-proof screws for some applications, for example the casings and the external IR-module. Screws are generally used for mounting at Axis, as they provide enough force to make the products both rigid but also sufficiently sealed. The solution for sealing is quite simple as it consists of a rubber band in combination with pressure from the screws when two surfaces are put together. In other terms, a fastening mechanism for a module needs to provide a secure sealing and a robustness in order to fulfill the durability standards. However, there are a few cameras at Axis that are designed with threads for mounting the casing, for example the bullet camera, see Figure 3.3.

Figure 3.3: Axis bullet camera designed with threads to mount the front window.

3.2.3 Positioning and placement

There are several options of where to place the wiper. Design factors to be considered could be whether to put the wiper aside or make it integrated in the front window and where to place it in order to get a good parking position and cover range. The parking position is the position when the wiper is still and waits for signal. Axis engineers with experience of wiper design emphasized the importance of choosing a suitable parking position for the wiper. The wiper should not reduce the field of view of the camera, impair the image or be placed so that dirt, leaves or similar get stuck on it.

Furthermore, it was examined how to optimally cover the front window with the wiper. A sufficient area needs to be covered to not reduce the field of view. It was understood that various factors affect the cover range; the length of the wiper parts, number of wipers and motion. Furthermore, by analyzing the already existing wipers at Axis, and the CAD-files with graphics describing the field of view of the camera, it was understood that it was not necessary to wipe the entire front window to make the view clear.

Moreover, the size of the module and how to connect the module will also affect the position of the wiper. The weather casing for the camera housing, protecting it from high temperatures and other tough conditions, limit the size of a module, or the position of it. However, this casing could be redesigned if necessary. Exactly where to put the wiper module will be developed during the *Develop* phase when performing the concept generation.

3.2.4 Communication

Manually - At Axis the wipers are controlled manually. They are designed so that an operator decides when to wipe by pushing a button. Other ways of communication have not been tested, however, Axis have looked into different methods of detecting water on the window. These methods include using image analysis, IR-LEDs, dedicated cameras for this purpose as well as capacitance variation of sensors.

Automatically - Wiper systems on cars run automatically by using IR-LEDs. The water detecting systems consists of an emitting IR-LED and a receiving photo diode which responds when not enough IR-light is detected. The water drops on the windshield will diffract the

light and the loss of IR-light is detected by the receiver. The wiping function will run depending on minimum allowed level of received IR-light. When investigating the possibility of this type of communication interface employees at AXIS underlined that it is probably not a complicated nor expensive action, however, it might make the installation a little bit more cumbersome because it adds electronic components. A sensor or diodes would not take up much space nor power according to Axis engineers.

Wireless Communication - Much of the communication between devices today is made via WIFI-communication, which can be obtained by many different solutions. However, whether this would be useful or desirable will not be covered in this project.

3.2.5 Contacting, effect and power supply

There are various ways of how to power the module. The wiper systems in cars, trains and similar vehicles are often run by a steering arm system and electric motors. The examined Axis wiper prototypes had two different solutions of powering the wiper. One of them used a small stepper motor, directly connected to the wiper and placed on the top left corner of the window, beside the camera objective. The other was based on a steering arm system and the engine was placed in the back of the camera housing, close to the circuit board. Joints and links connected the engine with the wiper in the front. The power to the engine was supplied from the *Power over Ethernet* (PoE)-input, placed on the circuit board.

The total available effect output of the camera is limited to 25 W. An IR-diode could require up to 10 W and the Axis stepper motor for a wiper was estimated to require approximately 5 W. The camera itself require 10 W which does not leave much for margin. Increasing the energy input would demand more advanced infrastructure of the customers which would limit the market for Axis.

The contacting to the wiper can be set up through various ways. Axis products have both traditional cable connections and so called board-to-board connections. The board-to-board connection is more expensive but makes the installation very easy since it only requires the connecting parts to be fitted together.

3.2.6 Other aspects

Front window heating - The Axis cameras' high capability of heat transmission prevents them from overheating and can therefore ensure good image quality even in very high temperatures. Consequently, the risk of ice and snow formation has emerged when the temperature is low, which will affect the wiping function. A wiper with the requirement to function in colder parts of the world will therefore need a heating system. Axis has tested classic heaters and heating systems consisting of resistors, which both are used today. Alternative solutions that are currently looked into are a special coating and also a mesh consisting of small metal threads connected to a current. The two last mentioned solutions would require less space in the camera housing and would result in an even heating of the entire front window. Additionally, the two solutions are under investigation and will therefore not be further examined during this thesis project. However, depending on the requirements for the wiper a suiting heating system is necessary.

Installation - The installation of the outdoor cameras could be a quite cumbersome process as it could take place on high altitudes and in tough weather conditions. The installations are performed by professionals, nevertheless, a simple installation is preferred. The number of loose parts should therefore be restricted and preferably able to secure with a safety device. Because of the exposed environment, it is beneficial if the connecting of power is done as simple and fast as possible. The most important installation is the one of the image quality. The camera settings are quite sensitive to disturbance why one should be careful not to expose the camera when not needed. Resetting the image quality is time consuming and will hinder it to operate why caution should be taken when handling the camera.

3.2.7 Product specifications from Axis

The properties of the module need to match the properties of the top quality line of products Axis offer. Both when it comes to different strength requirements, weather impact and design guidelines.

Material properties

The specifications for the latest model of Q-line house, named Q1647-LE was used, see table 3.1.

Table 3.1: Material specifications for Q1647 - LE

Properties	Values
Temperature	Minimum : -40 °C (-40 °F)
	Maximum: 60 °C (140 °F)
Casing	Aluminium
	Plastics
Classifications	IP66
	IP67
	NEMA 4X
	IK10
Life span	10 years

Classifications

The different classifications that Axis products fulfill are common and often required by the customers. All the different classifications have different meanings and below are they briefly described.

IP - IP classifications rate a canister's capability to resist different liquids and particles. The IP is always followed by two digits that shows which scale of resistance the product obtains. The first digit, IP**X**Y, stands for particle resistance and the second digit IPX**Y** for liquid resistance.

IP6X- The test is performed in a dust chamber where the canister is exposed to fine-grained talc powder that circulate in the chamber for 2-8 hours, the conditions for the specific capsule determine the test time. The underpressure inside the canister must not exceed 20 mbar and the airflow can not exceed 60 volume / hour. In addition, a steel wire (Ø 1 mm) is pressed against all the enclosure openings with a compressive force of 1 N. The acceptance conditions for IP6X are fulfilled if no dust has penetrated into the canister (RISE, 2017) .

IPX6 - The housing is sprayed with a water jet (Ø 12.5 mm) from a distance of 2.5-3 meters. The water flow is 100 liters / minute and the duration is 1 min / m^2, and the test must at least last for 3 minutes. To achieve IPX6, maximum level of penetrated water is the quantity that does not affect the properties of the material, and neither compromise the safety (RISE, 2017).

IPX7 - The enclosure is lowered to a depth of 1 m in a water tank and maintained there for 30 minutes. The acceptance conditions for IPX7 are met if no water has penetrated into such quantity or at a place that affects the properties of the material and neither compromise the safety. (RISE, 2017) .

NEMA - National Electrical Manufacturers Association (NEMA) use a classification scale to define whether canisters involving electricity should or should not be used. A standard for NEMA is to define a product from its attributes and quality. The canisters ability to withstand different environmental conditions is measured and classified. The classification is used to facilitate the use for both the user and the manufacturer and improves security, economy and communication (NEMA, 2005) .

NEMA 4X - Axis use the NEMA 4X classification which is a level of NEMA. The classification regards safety of the environment related to a product. The enclosure needs to meet following aspects of protection to become classified as NEMA 4X (NEMA, 2005):

- Protect the engineers and technicians who have contact with the hazardous parts in the enclosure.
- Protect the equipment inside the enclosure against external factors such as wind, ice formation and dust.
- Protect the equipment against wet (rain, sleet, snow, splashing water,and hose directed water).
- Protect it against corrosion.

IK10 - IK class is an international rating scale that classifies an equipment's resistance to external impact. The scale goes from IK00 to IK10 where IK00 does not possess any resistance to vandalism, but IK10 must withstand a direct stroke of 20 Joule. Normally IK10 (20 Joule) is classified as the highest value (Zentiel, 2019). In practice, this corresponds to a 2 kg heavy ball released from a height of one meter. The casing must pass the test three times in a row to be approved.

Color scales

Axis has a design manual to ensure that all products are uniform and to empower the Axis brand. The manual includes all colours used within the company, see Figure 3.4.

Figure 3.4: Color scales from Axis Design manual.

3.3 External research

In order to get inspiration and broaden the research outside the company an external research was done. By using the internet, searching patents and reading research papers a deeper understanding of the project was acquired. The major part of the external research was covered in the early stages of the project and covers different aspects of benchmark.

3.3.1 Module solutions on the market

Both customers and companies are nowadays more aware that production and consumption affects the environment negatively. It has created a demand for products that can be changed according to different needs, i.e. multifunctional products. Products that can be modified according to different conditions are more economical and environmentally friendly and are usually based on modular solutions (Thule Sweden, 2019). Today, there are many products on the market that have a modular architecture. To get inspiration on how a module solution could look like a moodboard was put together, see Figure 3.5. The moodboard also visually summarises the research performed of existing module solutions.

Figure 3.5: Moodboard of module solutions.

3.3.2 The wiper market

A research of different kinds of wipers was done in order to understand different construction aspects. It was understood that placement, quantity, blade design, motion, steering and control mechanism can vary. However, the majority of the wipers analyzed was of the transport industry. These wipers endure harsh weather conditions and are crucial for safe driving, and might therefore have higher requirements than for a camera wiper. A moodboard was put together which summarize different appearances of wipers, see Figure 3.6. Furthermore, a benchmark of surveillance cameras with wipers was performed, see section 3.3.4.

Figure 3.6: Moodboard of wiper alternatives.

3.3.3 The fastening market

Initial brain storming of different types of fastenings was performed and summarized below. The fastenings were considered for the connection between the module and the camera housing. The research and inspiration from internet was summarized as a moodboard, see Figure 3.7.

Fastening alternatives

- Screws, nut and bol
- Screw mounting
- Pressure mechanism
- Magnets
- Hitch/hook - "click on"
- Thermal expansion
- Suction
- Fitting
- Pins or nails
- Buckle
- Ski boot buckle
- Track - camera flash/ GoPro mount
- Adhesives
- Velcro
- Threads

Figure 3.7: Moodboard of fastening alternatives.

3.3.4 Benchmark

A benchmarking focusing on surveillance cameras with wipers was set up. The variety of wipers on the market is not very large but the wipers do have heaters, and fans, to able the wiper to operate regardless weather condition (Hikvision, 2018). This shows that it is important for Axis to offer competitive wipers. See Figure 3.8.

Figure 3.8: Example of surveillance cameras with wipers.

Chapter 4

Define

4.1 Initial delimitation

As a result of the research, insights of various possible solutions and problem areas were obtained. The findings sparked discussions about the task as well as the objectives and purpose of the project. One example of such a discussion concerned the design of the Fixed Box camera wiper. The wiper itself has been tested at Axis and received positive feedback from the customers. The solution is known to be effective for water removal. Therefore tests of this function will not be necessary. On the other hand, the design of the wiper will affect the design of the module. Therefore, the possibility of developing a better wiper should perhaps be investigated to develop the best wiper module possible.

In this chapter the research from the *Discover* phase is summarized and analyzed in order to define needs and establish product requirements. A design brief is presented in the end of this chapter. The design brief functioned as a compass throughout the rest of the project, consisting of the most important constraints and the aim of the project.

4.2 Identifying needs

The needs listed below, were identified based on a meeting with the product owner and the supervisors, see table 2.1.

Identified customer needs.

1. Good sight regardless condition.
2. The camera is affordable.
3. Available options and customization.

Identified Axis needs.

1. An addable wiper solution.
2. It is desirable to remove everything that disturbs the view, but water is the focus.
3. The solution is generic, i.e. other functions can be modulated, and a module can be combined with other modules.
4. The wiper should be aesthetically appealing.

5. Automatic communication for the wiper function is desirable.
6. The module should be easy to install on an already mounted camera.
7. The installation of the module should not risk affecting the settings of the camera.
8. The solution should not reduce the resolution or the field of view for the camera.
9. The module should not damage the camera housing during mounting or disassembling.
10. It is desirable that the front window can be changed independently.

4.3 Problem areas, related functions and sub-functions

The research resulted in greater understanding of the project and its issues, which were defined and categorized into different problem areas, see table 4.1.

Table 4.1: The identified problem areas of a future wiper module.

Problem areas	***Functions***	***Sub-functions***
Wiper	Eliminate water	Position
		Design
		- Number of wipers
		- Number of leads
		- Number of parts
		- Pressure/force
		- Field of view coverage
		- Material
		Communication
		Power supply
		Mechanism
		- Motion
		- Driving force
	Aesthetics	Integrated design
Fastening	Mechanism	Simple and fast installation
		Durability
		Strength
	Design	Material
		Synchronized fastening and camera housing
Module housing	Design	Material
		Sealing
		Installation
		Synchronized fastening and camera housing
	Position	Wiper coverage
		Wiper parking position
	Power supply	Installation
Camera housing	Screen	Material
	Modifications	Possible customization

4.4 First concept ideation

During the *Initial Delimitation* emerged the need of an ideation to explore and concretize new ideas and concepts. The purpose of an ideation early in the process was to obtain new perspectives of the problem and get new understandings. Based on the needs from **4.2 Identifying the needs** and the functions and sub-functions from **4.3 Problems areas, functions and sub-functions**, thirty concepts were generated using the *One Minute Method*. The concepts were analyzed and some problem areas were confirmed. A number of new, mutual denominators were also detected and noted as affecting design factors.

4.5 Product specifications

Based on the *First concept ideation* and the internal and external research a list of product specifications was established. The list of *Product Specifications* was categorized into Requirements, Desirable features, Limitations and Other considerations. The categorization was established to function as a tool during the concept development, in the *Develop* phase.

Requirements

1. The module consists of a wiper.
2. The wiper coverage area is sufficient.
3. The module nor the wiper impair the resolution or field of view.
4. In order to deal with ice and snow, a heater is necessary.
5. The module can be added on already mounted cameras.
6. The installation of the module should be easy.
    - It can be installed under difficult conditions.
    - The connection to power is uncomplicated.
7. The module does not prevent the addition of other modules.
8. The overall design is compact and uniform with other Axis products.
9. The product requirements regarding construction and design are fulfilled, see table 4.2.

Desirable features

1. The module can be combined with several modules.
2. The wiper runs automatically and wipes the window when necessary.
3. The wiper is aesthetically appealing.
4. The module has a generic design and is applicable for other functions.

Limitations

1. Because of the wiper the front window must be of glass to prevent it from scratching the surface.
2. The wiper position will be important since the wiper must be protected and not impact the sight.
3. The total weight of the camera, housing and module should not exceed 5 kg.
4. The total effect available are 25 W and the camera needs 8 W.
5. The water elimination solution should be in form of a wiper, other water removal methods are not of interest.

Other considerations

1. The installation of the module will be performed by a professional.
2. The cost for the general customer should be as low as possible, adding all extra costs to the module and not to the camera housing.
3. The cost of the module should be as low as possible.

- Construction has low complexity, is of few parts and does not require unnecessary material use

4.5.1 Product requirements

The properties and requirements regarding the construction and the design of the module was summarized and categorized in a table, see table 4.2.

Table 4.2: Design requirements for the module.

Areas	***Design requirements***
Material	Plastics Aluminium
Classifications	NEMA 4X IP66 IP6 IK10
Color	Axis White (Light gray) – NCS S 1002-B Black - NCS S 9000-N Silver – RAL 9006 Gray - NCS S 2502-B Dark gray - NCS S 5502-B
Temperature	-40 °C to +60 °C

4.6 Design brief

In order to remove water from the camera window and simultaneously appeal as many customers as possible, a wiper module concept is to be developed. The module should be easy to install and can be combined with other future modules or functions. Furthermore, the module should not reduce the field of view nor reduce the quality of other functions of the camera. If possible, the wiper should run automatically and it should be aesthetically in line with other Axis products.

The purpose of the project is to explore and determine the optimal design, placement and function for a wiper module. However, the focus is how to design the best module solution, rather than the best wiper. In the end a physical mock up will be presented, demonstrating the main functions and features.

Chapter 5

Develop

5.1 Concept development

The development phase consisted mostly of different concept generations. Tools used during this stage of the project were different methods and selections, see Chapter 2. Further development consisted mostly of researching a few selected areas more deeply, as well as making combinations of different ideas to create an optimal concept. The development phase finally resulted in a preliminary concept.

5.1.1 Results from first ideation

The ideation generated during the *Discover* phase gave many new insights, two of them considered most essential. These two insights are presented below.

Front window change - It was found during the *Discover* phase that a wiper requires a glass window since it would otherwise scratch the plastic one. It was understood that this requirement would have a great impact on the design of the wiper module since it increased the number of required parts. A concept generation was performed and was based on how to change the window or include it with the module. Five different constructions were thought possible and are shown in Figure 5.1.

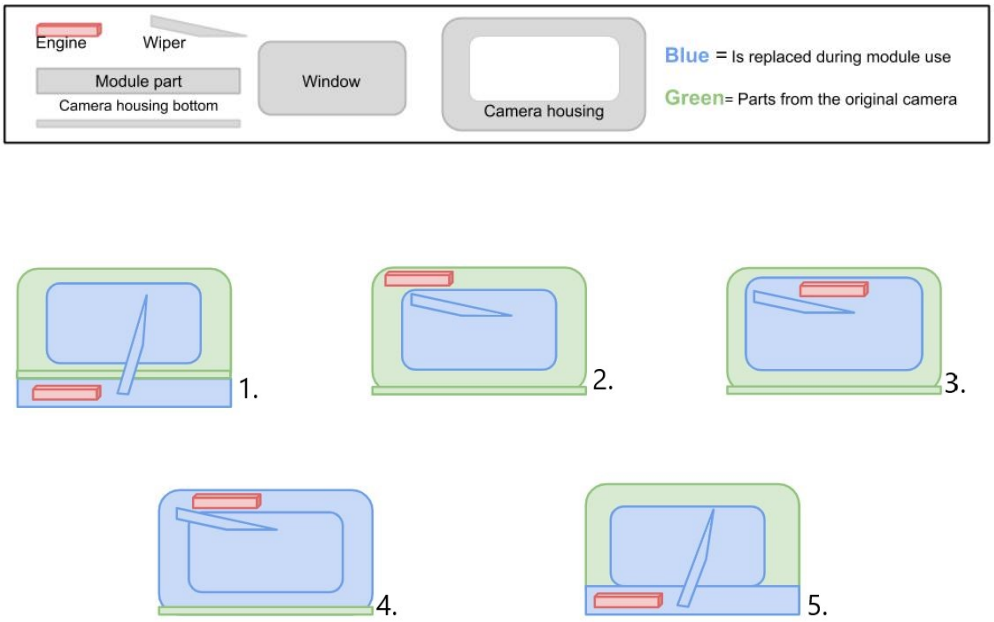


Figure 5.1: Possible solutions for a module with wiper and glass window.

1. *The Separate parts module* - The module consists of a wiper and an engine. The front window comes separately.
2. *The Engine module* -The module consists of a wiper and a front window and the standard camera house would always contain an engine.
3. *The Window module* - The module consists of a front window, an engine and a wiper.
4. *The House module* - The module is the camera house but with a wiper, glass front window and an engine.
5. *The Combined module* - The module consists of a wiper, glass front window and an engine, placed outside of the camera house.

Wiper position - Additionally, it was found that the position of the wiper would affect the design, and the position, of the module. Based on meetings and research with engineers, with knowledge of the wiper solutions of the PTZ-camera Q8685-E and Fixed Box cameras, important design factors were discovered.

Wiper design factors:

- The wiper should be protected from the weather.
- The wiper should be placed and positioned so it is protected from snow or dirt.
- The wiper movement should allow water or dirt to drain.

Based on the above, it was investigated where to place a wiper on the window. By sketching different scenarios and discussing the placements, a possible area where one could place the wiper was established, see Figure 5.2. The blue area is where the wiper should be placed and the red area is where the wiper should not be placed. The blue area also consider the parking position of the wiper.

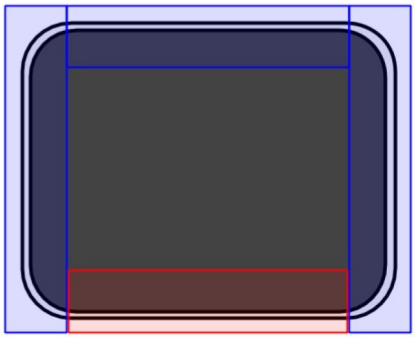


Figure 5.2: Possible placements for a wiper.

Concept selection I

The five concepts were presented to the supervisors at Axis in order to discuss the concepts, acquire more knowledge and to choose a path forward. What differentiated the concepts from each other was the number of parts, the cost for the module versus the cost of the camera housing, easy installation and whether the window would be possible to exchange if damaged. The concepts were discussed during the meeting which resulted in three selected concepts to develop further, see Figure 5.3. Concept 1 was neglected since the construction would be complex with separated components. Concept 2 was neglected because the camera housing would be unnecessarily expensive with the wiper engine, since all customers would need to pay for it. The chosen concepts that were taken forward for further development were the Window module, the House module and the Combined module. These concepts were considered as directions for further development, rather than complete concepts, since they were mere ideas and not particularly investigated.

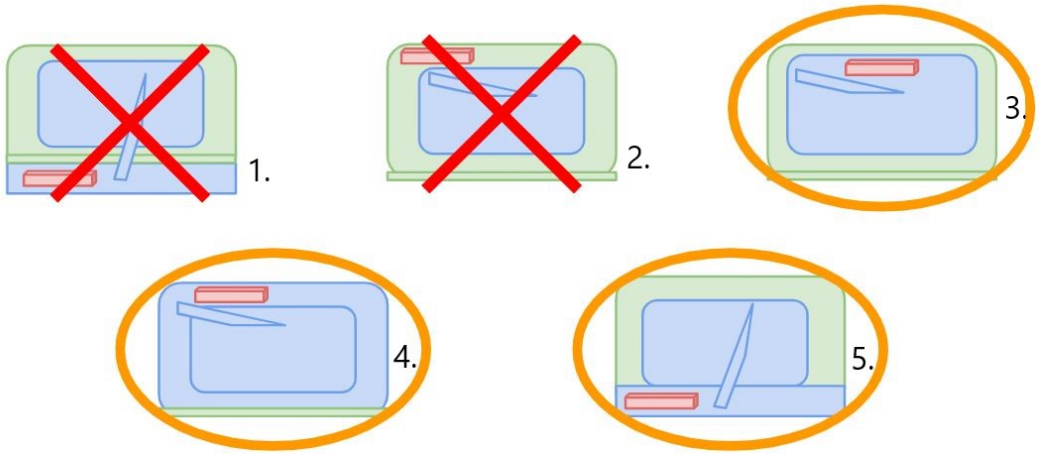


Figure 5.3: First selection process

5.1.2 Concept generation I

With the three main concepts as a basis, further ideation was carried out, focusing on one concept at a time. The goal was to investigate the task even further to fully understand the width of the project. The *One Minute* method was used throughout the concept generation

and the concepts were categorized into eight subgroups to the three main concepts. The concepts and subgroups were mapped and illustrated to get a clearer picture of the process so far, see Figure 5.4.

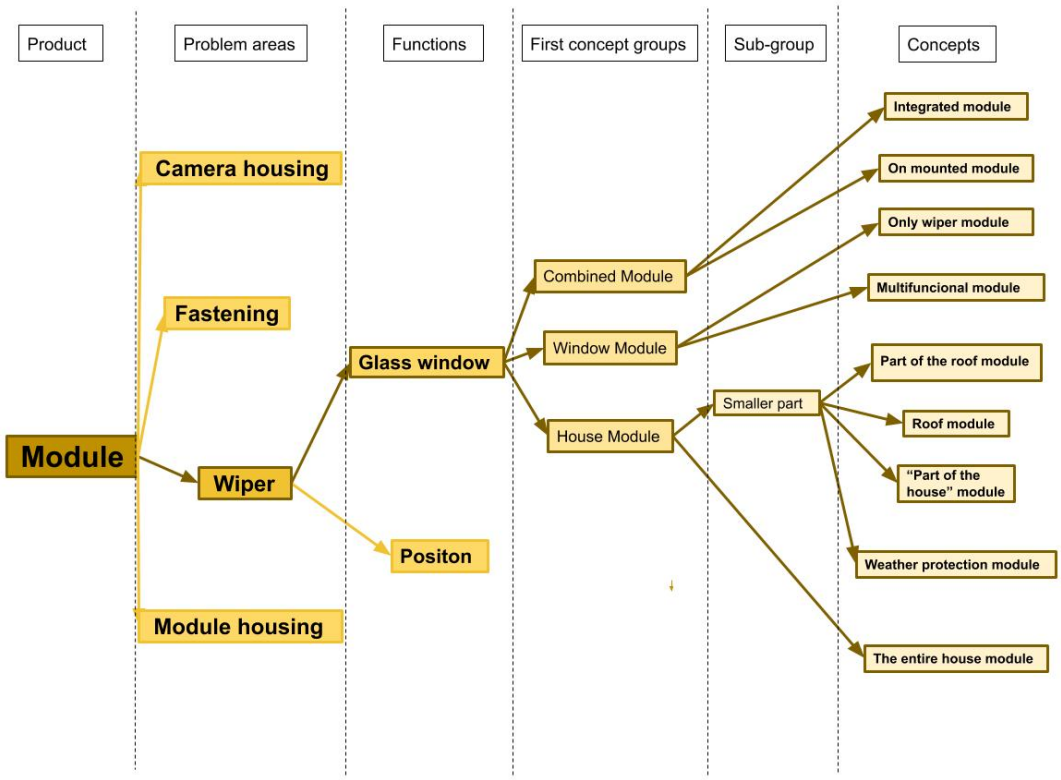


Figure 5.4: Mapping of the work process and concepts .

The House Module - The House Module comprised the entire upper part of the camera housing. The idea was that the House Module could be assembled before hand, by integrating wanted functions into the upper part, all according to the wishes of the customer. The module could be easily swapped with the standardized module out on spot. The House Module could also have attachments or connections so that other modules could be added afterwards. This concept could result in great modifications of the current design of camera housing. The ideation resulted in two subcategories of concepts of the module listed below.

The House Module

- The entire house
- One part of the house

The Combined Module - The Combined Module covered all concepts of the combination of the window, wiper and motor put together as an external part. The module could be differentiated in various ways and some modifications of the camera housing would be required. An example of such a modification could be the fastening mechanism for the module or the power supply connection. A combined module could be more or less integrated with the design of the camera housing. It was understood to be important to consider the trade off between changes to the existing camera house and an integrated, uniform design. About twenty

new concepts were produced which were arranged into three categories listed below.

The Combined Module

- An integrated module
- A side-mounted module
- A module integrated with the weather protection casing

The Window Module - The Window Module refers only to the window of the camera housing. All necessary technology is attached directly to the inside of the glass window, and is swapped against the plastic window. Two subcategories of the module were generated:

The Window Module

- Adapted only for a wiper
- Multi-functional

5.1.3 Concept selection II

From the concept generation, eight subcategories of the three main concepts were produced:

1. Window module adapted only for a wiper
2. Window module multi-functional
3. The entire house
4. The entire roof
5. One part of the house/half house
6. Weather protection casing module
7. Integrated module
8. Side-mounted module

With many concepts generated, a selection was performed. The product specifications were analyzed and the six most vital were chosen to be used during the selection. The concepts with all or all but one specification present succeeded, see table 5.1.

Table 5.1: Second selection of concept design.

Specifications	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
The module consists of a wiper	X	X	X	X	X	X	X	X
The module is easy to install on mounted cameras	X	X	X	X	X	X	X	X
The module does not prevent the addition of other modules	X	X	X		X	X	X	X
The module has an easy power supply connecting	X	X	X	X	X	X	X	X
The module does not reduce the resolution or field of view	X		X	X	X	X	X	X
Low construction complexity	X							X

Concept 4 was considered preventing the addition of other modules as it would be covered with the weather casing. Concept 2 was thought of decreasing the field of view since some additional functions could be large and bulky, and therefore risk reducing the sight. Concept 1 and 3 were defined as being of low complexity as the modules would be relatively small and only small changes of the camera housing would be necessary. However, the concepts that succeeded will be further investigated and developed, see Figure 5.5. The selection was done through discussion. Grading concepts with a rating system is a common method for selection but was considered unsuitable this early in the process.

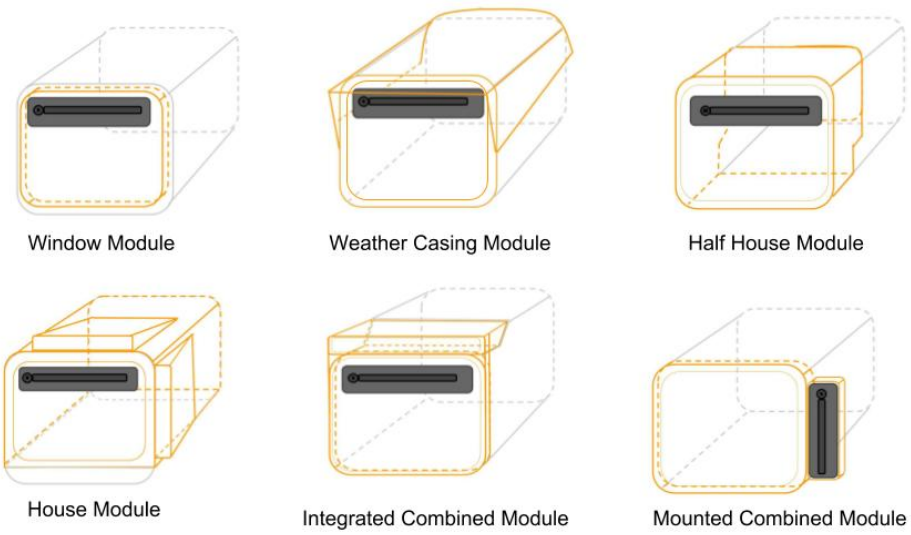


Figure 5.5: Second concept selection

5.2 Concept evaluation and selection

5.2.1 Co-creation session

In order to gather input and feedback, evaluation sessions were organized with one or two Axis employees at a time. The participants were of different expertise and experience, ranging from both senior engineers to other master thesis students at the company. It was decided to do the workshop with few participants to enable an open minded dialog and a liberate way

of thinking. The meetings were performed six times and with 8 people in total. The results are summarized in table 5.2.

Table 5.2: Results from the Co-creation session.

Concepts	***Advantages***	***Disadvantages***
Window Module	Small impact on the housing. Practically feasible. Simple to seal. Feels easy to mount. Possible to combine with different functions. Small size.	Possible space shortage in the housing.
The entire house	Easier to redesign an uniform part. Sleeve function's to fasten modules. Feasible. Probably easiest to mount.	Expensive, a cost issue. The size.
One part of the house	Cheaper to change a small part. Can be used for extensions, i.e. larger camera lenses. Integrated design solution. Opens up for many possibilities.	Difficult to seal.
Weather casing module	The camera is never exposed. Possibly cheaper than changing the entire house	Optical breakage problem. Difficult with the electronics. Bulky and large. Difficult to attach. Reduce the field of view. Complicates the weather. protection.
Integrated module	Good overall appearance.	Sealing can be a difficulty. Requires more changes on the housing.
Side-mounted module	Does not require much redesign of the housing.	Several mounting directions. The appearance is affected.

5.2.2 Discoveries and findings I

Until this point many thoughts and ideas had been realised and generated. With help from Axis employees, and some research on internet, several findings and insights were obtained. The workshops especially resulted in new insights. The new findings would affect the development of the concepts and future design decisions, and are therefore stated below.

Double window - Early on it was investigated if a double window could be a solution, i.e. one of glass and one made of plastic. However, it was concluded that a double window would negatively affect the field of view. Two windows would result in two light diffractions which would result in a more narrow field of view. To add a glass window above an existing plastic window would therefore not be an option.

Heater - It was concluded that with a wiper solution comes the need of a heater. In order to fulfill the requirements of outside temperature, heating in some way will be necessary to prevent the wiper to get stuck because of ice or snow.

Wiper motor - The motor used in one of the wiper solutions today has been proven to be successful. The good durability and stability in performance are high relatively the size of the motor. The motor is expensive, however, it was decided not to investigate further in the matter, but to use the motor if relevant.

Future modular housing - The long-term vision for the project was to have one camera housing containing only addable and modular functions. The vision was taken into account during the first part of the project which widened the variety of solutions. However, it was realised that such a camera housing would require a major reconstruction of the existing camera housing why it was decided to focus only on the wiper module. The vision was still considered throughout the project, by formulating a requirement to *not hinder other modules to be added or to create a design that can vary*.

Sealing - The sealing was understood to be of crucial importance since the camera inside the housing is the most valuable part of the product, and cannot be damaged. Axis use rubber bands and orthogonal force to guarantee a proper sealing, which was the concerned sealing method when investigating how to attach a module. More complex ways of sealing were investigated but it was concluded that the result would be less effective. In some concepts, there were several parts that adjoined to each other in difficult places and that would require extra effort to get a sealed and safe solution. Additionally, having two seals against each other would result in poorer sealing ability.

Field of view - It is crucial that the camera can obtain maximum field of view. It is up to the customer which size is sufficient but it is important that the customer has this option. The camera lens of the high quality series at Axis can be put at different distances from the window, which affect the field of view but also enable larger camera lenses or different IK-levels. The ability to adjust the distance is therefor an important feature.

Design - By thinking innovative and being open-minded many problems can be solved with new design. For example, the sealing problem can be solved by rethinking some features of the design of the camera house. It was noted that it is important to always strive for a solution-oriented and diverse mindset.

5.3 Concept selection III

Based on the co-creation workshops, and the new findings, a third selection was made, see Figure 5.6. A description of the concepts and their advantages is listed below. The description also state why the concepts were chosen.

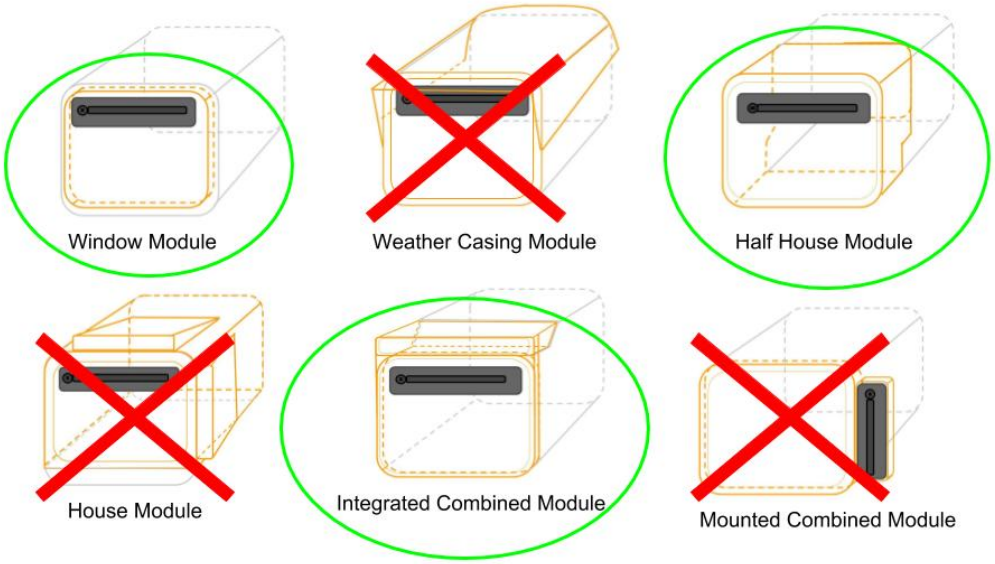


Figure 5.6: Third selection of concept design

- **Module A** (*Window Module*).
  - Similar component exists at Axis (but not as a module), i.e. proven concept.
    - Easy sealing.
    - The fastening mechanism is simple.
    - Easy to install.
  - Does not prevent the addition of other modules.
    - Integrated design.
    - Small part.
  - Small impact on the house.
    - Low additional cost on the standard house.
    - Light and easier changes when reconstruction.
- **Module B** (*Half House Module*).
  - Integrated and complete solution.
    - Nice appearance.

        * Many functions.
    - High degree of design freedom.
        * Easy to customize.
        * Provides many opportunities.
        * Enables extension.
    - Innovative solution.
        * Designed to fit the long-term vision.
        * Versatile construction.

- **Module C** (*Integrated Combined Module*).

    - Integrated and uniform construction.
        * Nice appearance.
        * Small part.
    - Requires relatively little changes to the house.
        * Relative low cost.
        * Relative small change work in the drawing.
    - Fairly high degree of freedom.
        * Provides many opportunities.
        * Provides a place for only modules.

The rejection of the other concepts

The three other concepts were considered to require too many changes on the standard camera house or had an overly complex design. A large part of the discussion regarded the time factor of the project, in other terms the trade off between a more conceptual thinking for the future or a more realistic approach. Furthermore, designing for undefined and future functions was difficult and would make the project more time consuming. It was therefore concluded, by checking the design brief and project goals and purposes, that a more realistic approach was more suitable, as the main goal was to focus on a module with a wiper.

5.4 Further investigation

5.4.1 Preliminary design

It was found to be difficult to decide which one of the three chosen concepts to further develop. Because the concepts were very similar and no testing of design, construction, fastening mechanisms or other design factors had been performed it was difficult to rate them. The concepts had different advantages and disadvantages why it was decided to combine all of them. The *Flex Module* was created, see Figure 5.7, with the aim to get the optimal construction by first testing important components of the product.

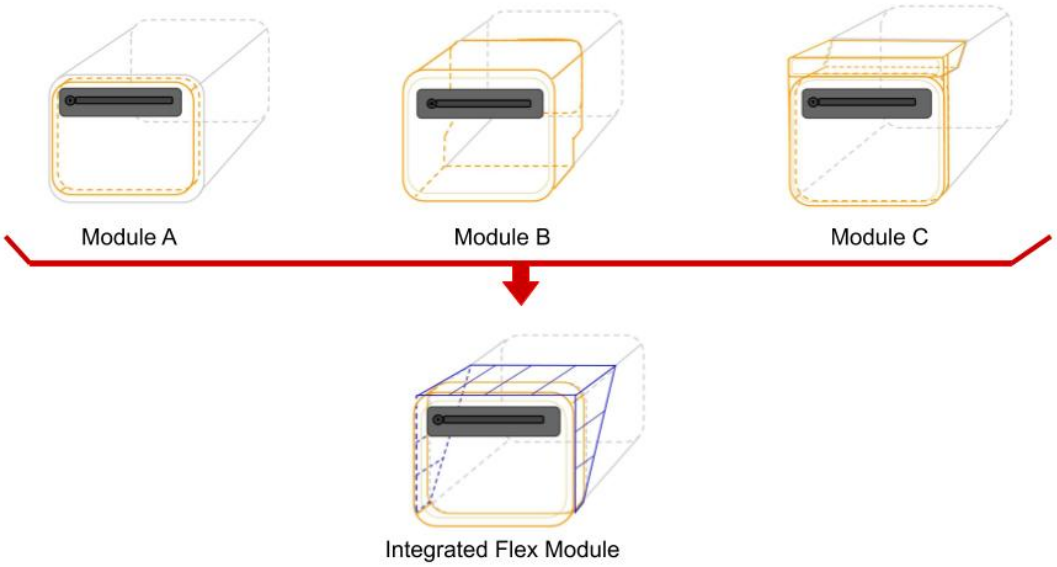


Figure 5.7: Module A, B and C became the Flex Module

The *Flex Module*, shown in Figure 5.8, consisted of an original part (orange part) and a part that could be customized (blue part). The advantage was that even if the construction varied, the fastening mechanism, the connection area and thus also the sealing, would always be the same. The *Flex Module* was a preliminary design, functioning as a reference for the upcoming development process. As stated earlier, the final design would be affected by the required features of the module, why such features needed to be investigated in order to decide on the design.

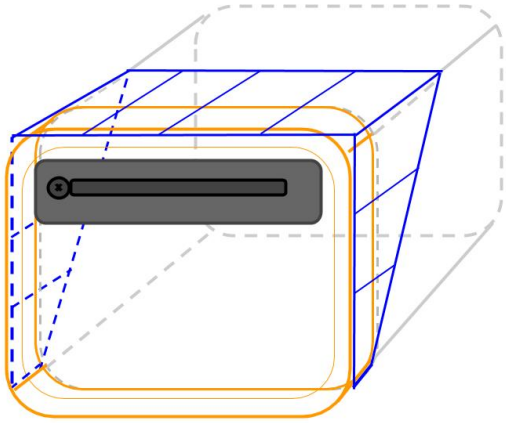


Figure 5.8: Flex Module, the orange part represent the basic module and the blue area can be customized.

5.4.2 Discoveries and findings II

Compatibility - talking to the mechanical engineers of the IR-module it was found out how Axis products usually are developed. It was emphasized that products usually are developed according to customer requirements or specific situations, why components generally vary. A component, for example an IR-sensor, could therefore vary in size, power requirements and communication. The issue of not being able to standardize products could be solved with modular design. However, considering the wiper module, it was determined to focus solely at the wiper function, without considering other functions, making it adaptable without preventing other modules to be added or created.

Design - A discussion of the camera housing and possible changes to it resulted in the understanding of new design possibilities. The project's time line and vision was discussed and it was concluded that the project should be based on a conceptual level. Furthermore, there were no directives of producing it for the near future. The new directive regarding the design opened up for making larger changes to the camera housing. It was described that one could think of a new product line of camera housings. A module requiring major changes could therefore be a solution for the project.

Regarding the earlier selection of concept, *Concept selection III*, the decision remained the same. The concepts that were not chosen were still considered too complex or expensive. The chosen concepts were all fitting the project description and met the requirements. The development of the Flex module was therefor continued.

5.4.3 Design of camera housing

Sketching on different possibilities for the Flex module, and looking through old concept generations resulted in two concept designs for the Flex module.

The two parts camera housing - An idea that took shape during the project was to reconstruct the camera housing so it would be opened vertically instead of horizontally. The housings for the Fixed Box solutions have a bottom and a "lid" which consists of the walls and the top. With a vertical opening, the casing would only consist of one standardized part in the back, and a module placed in the front. The advantages would be an easy sealing between the module and the casing. Issues would be how to design the inside of the standardized casing so both customers and operators could reach relevant components. Furthermore, the assembling during manufacturing might be more complex. One idea to solve that issue was to put all components on a sled and with tracks, see Figure 5.9.

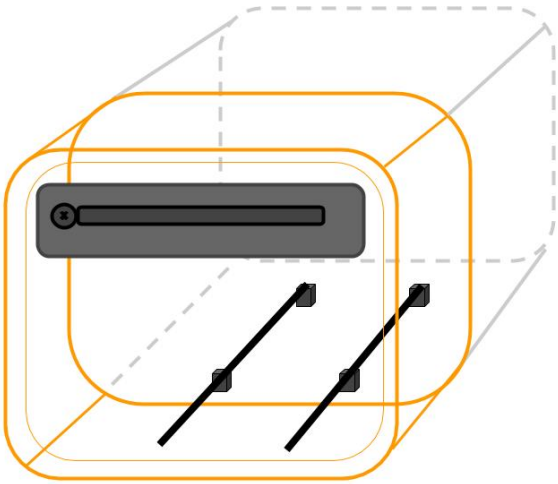


Figure 5.9: The camera housing in two parts.

The three parts camera housing

The second design kept the division on the traditional camera housing in the horizontal direction, but with the addition of a module in the front, see Figure 5.10. This solution would be sealed in a similar manner as the design above. With a "top lid", like the traditional design of the Fixed Box cameras, the assembling during manufacturing is facilitated.

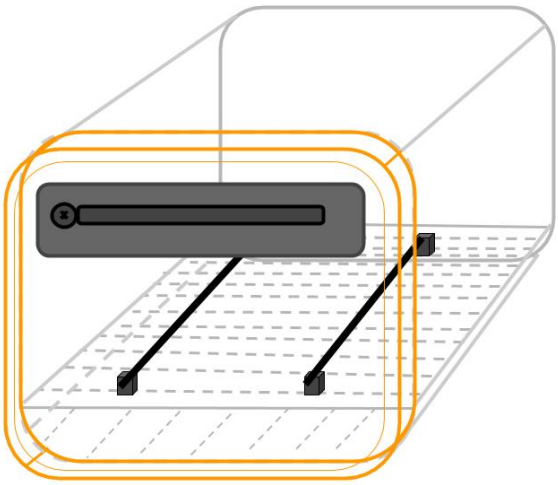


Figure 5.10: The camera housing consisting of three parts.

Selection of camera house design

After discussions about different variants of the two design concepts of the camera housing, it was concluded that *The two parts camera housing* was taken further in the process. In the list below the motives are listed.

Main reasons for why the design was chosen.

- The two part camera housing opens up for more flexibility and design freedom for the module.
- The installation and connection are adapted for modular use.
- The installation is simple.
- Has a proven and functional sealing.
- Does not prevent different designs of modules or combinations of modules.
- The standardized back part will be the same regardless of the module.
- It is the beginning of the development of a new camera body and product.

5.4.4 Fastening mechanism

With the Flex module as a basis, it was concluded that an important part of the module was how to fasten the module. The concept generation number six was carried out. First, a new research session was conducted on attachment mechanisms that could be compatible with the Flex Module design, see Figure 5.11.

Figure 5.11: Moodboard from the second research of fastening mechanisms.

The focus was to create a strong and simple attachment mechanism that would be easy to use and time-efficient, that would only require one or no tool. Several attachment concepts were produced which generated four overall groups, which were:

Screws - Screws are generally used at Axis and proven to both fulfill durability and sealing tests. Screws would be used to fasten the module from the outside, see Figure 5.12. The glass window and the wiper should still be able to be replaced separately, since this is convenient if the window would break. At Axis there are windows that are screwed from either the outside or the inside. There are also cameras with windows that can be changed if the glass breaks. No tests of this fastening will be done since screws are already a proven concept.

Figure 5.12: Fasten the module with screws from the outside of the camera house.

Screw thread - Another concept was to use threads inside the camera body and the module. Screw threads were thought of being a quick and easy attachment mechanism that would not require any tools. Inspiration was taken from how camera lenses are attached to camera houses. To prevent anyone without permission from taking the module off, the thread fastening would also include an Axis identity screw to secure the module, or similar. The front of the Axis bullet cameras are designed with threads to attach the front glass with the camera housing. The concept of threads is therefor considered to be a proven concept, see Figure 5.13.

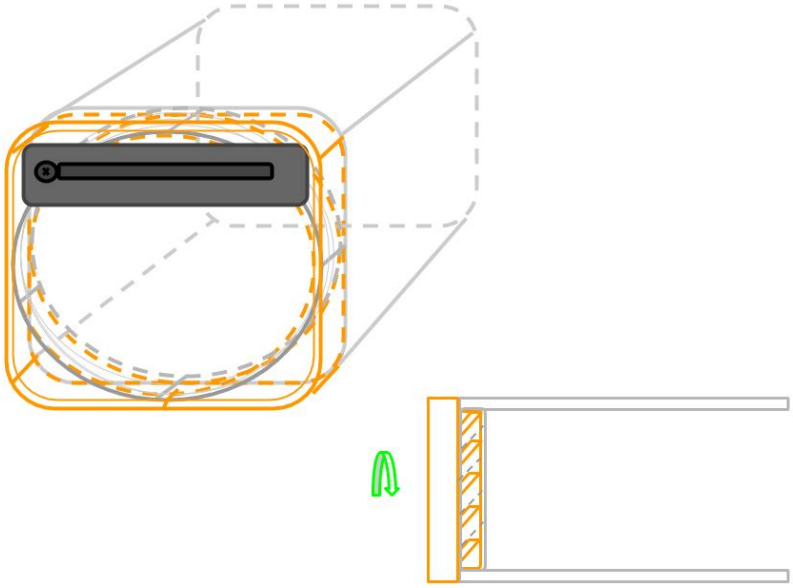


Figure 5.13: Fasten the module with screw threads.

Enlargement Regulation - The concept was based on the idea of creating sufficient force from the inside so that the module would be fastened properly in an easy way. Similar to bicycle or ski helmets one would from the outside adjust the fastening mechanism on the inside. On helmets the device sits like a frame around the head and is regulated with a screw that can tighten it around the head. The concept for the module would be an inverted motion, making the device larger on the inside, pushing towards the walls, see Figure 5.14.

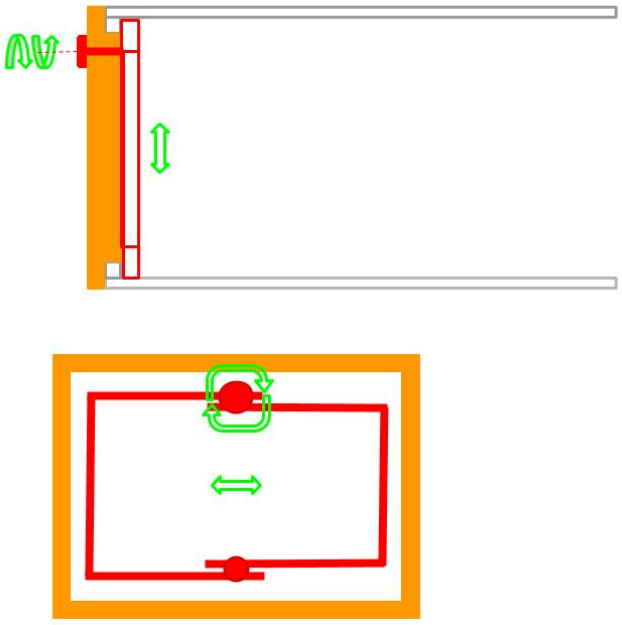


Figure 5.14: Fasten the module by an enlargement regulation.

Spikes - By using spikes one could with a lever principal attach and tighten two parts. With such a mechanism, the module and the camera house would have a female and a male part that fit together, see Figure 5.15. The parts are forced together, and since the bottom part would be fixated, thanks to the spikes, a pressure would arise when the opposite side of the module is pushed to the housing. The module could be secured with a screw or similar.

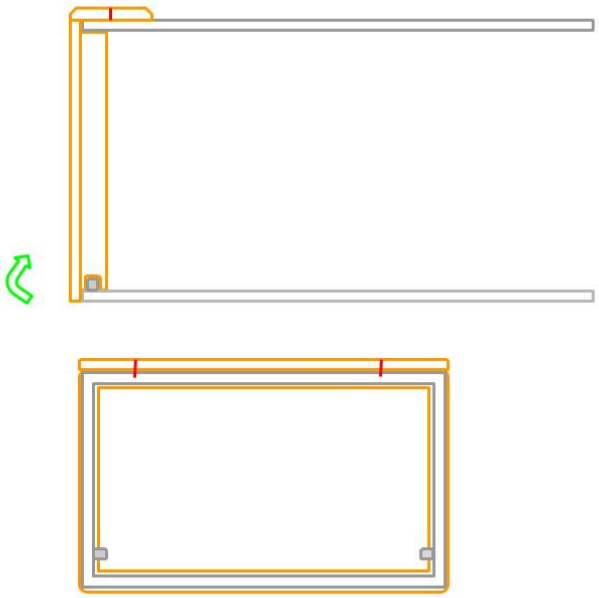


Figure 5.15: Fasten the module with a mechanism that includes spikes.

Hinges - Front doors have hinges and were an inspiration to this idea. The connection between the doorway and the door gets very tight and is well sealed. The housing and the module would have a female part or a male part that fit together. With hinges, the module could safely hang on the camera house, when other installments are being processed, and then fastened with a screw or similar. It would be crucial to create enough pressure from the sealing and fastening component, so that the sealing between the housing and module would be sufficient. See Figure 5.16.

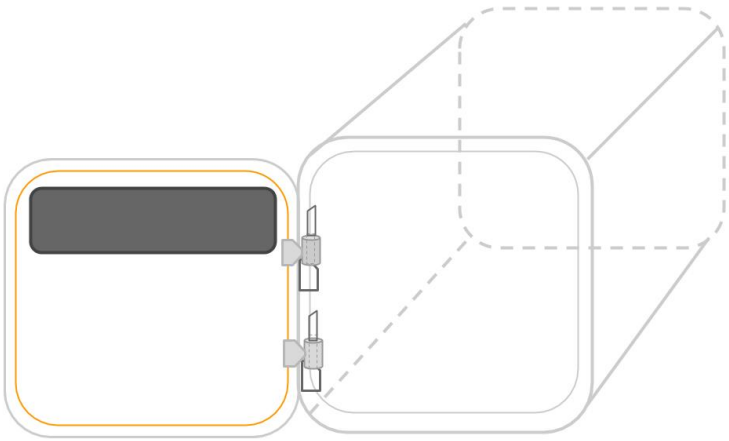


Figure 5.16: Fasten the module with a mechanism that includes hinges.

Fastening selection I

A rating system was used to rate the different fastening mechanisms to choose the best options. The scale ranged from 1 to 5, and the concepts with lowest points were not considered further. See Table 5.3.

Table 5.3: First selection of fastening mechanism.

Specifications	**Screws**	**Screw thread**	**Enlargement**	**Spikes**	**Hinges**
Fragile.	5	3	1	1	3
Simplicity of construction.	5	4	1	3	3
Durable.	5	3	1	2	3
Adaptable.	4	3	4	4	5
Sealed.	4	2	1	1	3
Simple and fast installation.	4	5	5	5	5
Result	27	20	13	16	22

Explanation of fastening specifications:

Fragile - Refers only to the mechanism itself and how fragile all the parts are. A high score means that it is not delicate.
Simplicity of construction - Refers to how many parts the mechanism consists of and how difficult it is to produce. A high score means it is a simple construction.
Durable - Refers to the strength and durability of the entire assembly. A high score means that it has high durability.
Adaptable - Refers to how easy it is to customize and change the module. A high score means that it is easy customized.
Sealed - Refers to how likely it is that the fastening mechanism gives good sealing. A high score means that it most likely would result in sufficient sealing.

Simple and fast installation - Refers to how easy it is to install the module at a mounted camera. A high score means that would be a quick and easy installation.

5.4.5 Rapid prototyping

With the different options, listed in table 5.4, it was important to sketch and test them in order to decide on which to produce. Even though it was decided to continue with the concept of a two-parts housing, the other concept option has been listed to show that the fastening concepts would apply to that one too.

Firstly, sketches of the concepts were done, and then a 3D sketch using CAD was done in Creo. Some concepts were also printed with a 3D printer at the office. Printing details, or making them of foam, are good methods for testing the concepts in reality. With physical prototypes it is easier to understand dimensions, important design factors and it is easier to detect new areas of interest or issues.

Table 5.4: Different combinations of design and fastening mechanism.

Fasten mechanism	*Two parts*	*Three parts*
Thread Screws	**A1**	**A2**
Screws	**B1**	**B2**
Hinges	**C1**	**C2**
Spikes	**D1**	**D2**

The fastening concepts with hinges, *C1* and *C2*, and the spikes concept, D1 and D2, were never tested with prototypes since it was realised that it would be impossible to close the module and housing because of the camera lens. Since the position of the camera lens should be possible to move back and forth, it is important to be able to put the camera lens in its correct position and afterwards attach the module. If the module is fastened on one of the sides, the camera lens could disable it from closing, why the concepts were not further tested.

First print

In order to check the capacity and quality of the printer, the *A1* was printed as a test. Since the office printer was basic the result of the first prototype was good enough to get a result but not to test the actual mechanism, see Figure 5.17, 5.18, and 5.19. Therefore, it was decided to make another CAD drawing of the prototypes but in a smaller scale and with other dimensions.

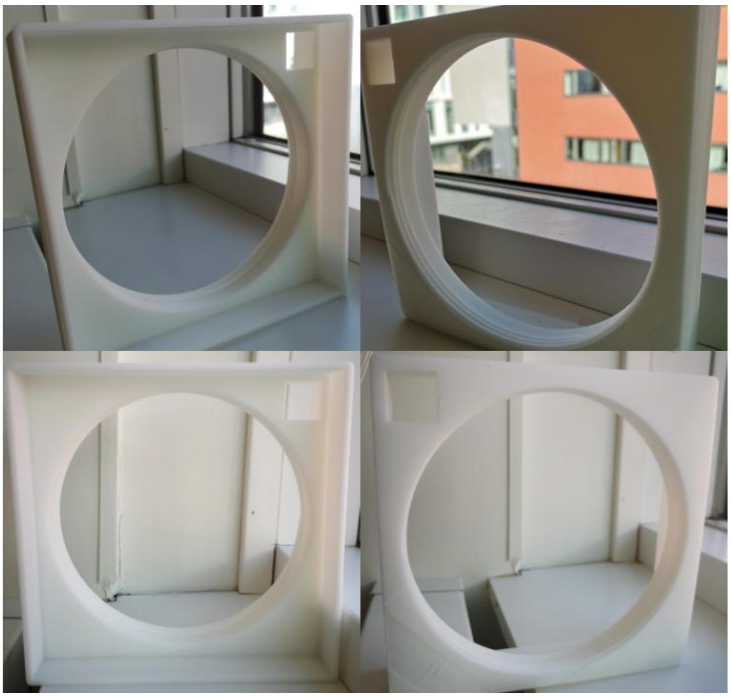


Figure 5.17: First 3D-printed prototype with screw threads, female part, A1.

Figure 5.18: First 3D-printed prototype with screw threads, male part, A1.

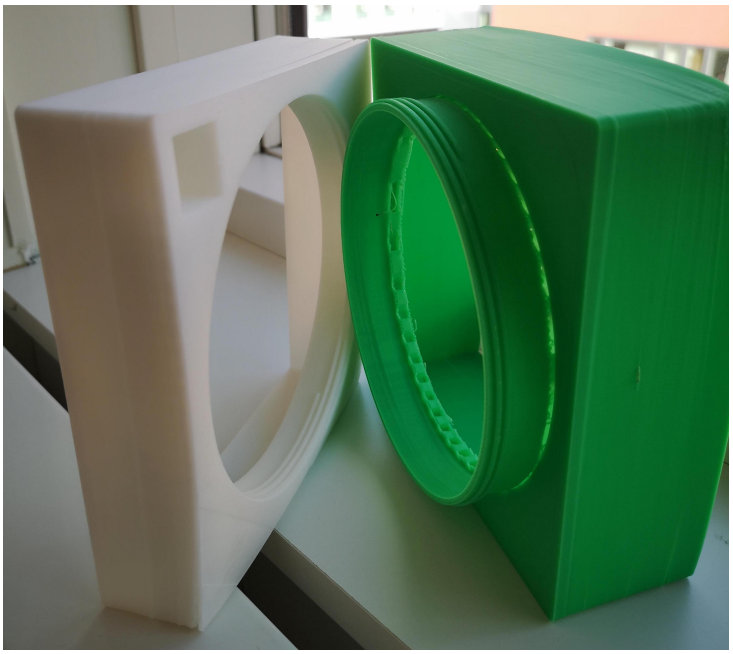


Figure 5.19: First 3D-printed prototype with screw threads, A1.

Second print

In the second print session, the concepts *A1* and *B1* were printed with new dimensions and the results were improved. The dimensions were smaller than a normal camera house. In this way the fastening mechanisms could be tested but it made it impossible to get a sense of the real size of the concept. However, it gave a feeling of how the two-part design would look like in reality and how the fastening mechanisms would function. Unfortunately the printer gave somewhat distorted and vaulted results. However, it did not prevent the testing of the mechanisms. See Figure 5.20 to Figure 5.24.

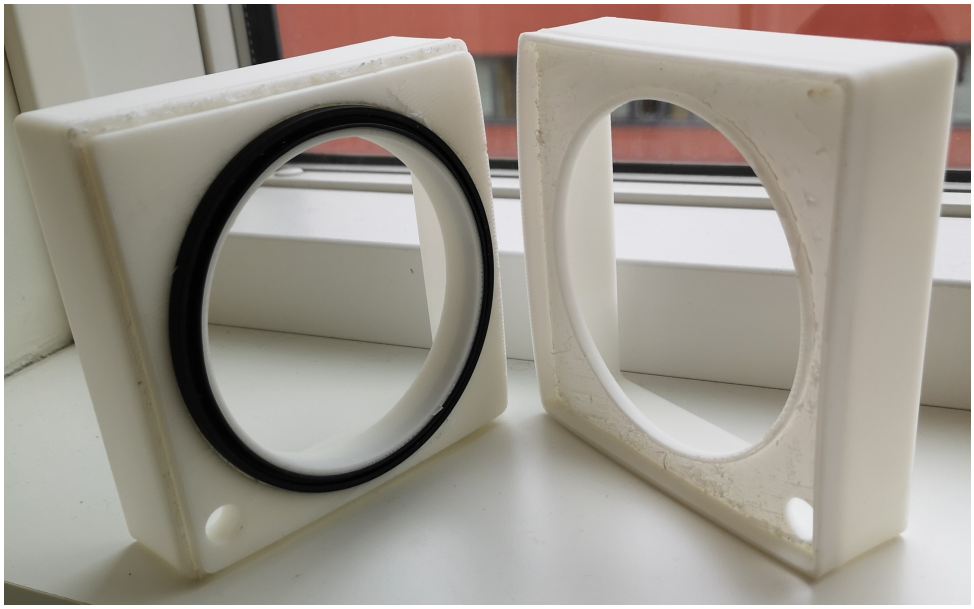


Figure 5.20: Second 3D-printed prototype with screw threads, A1

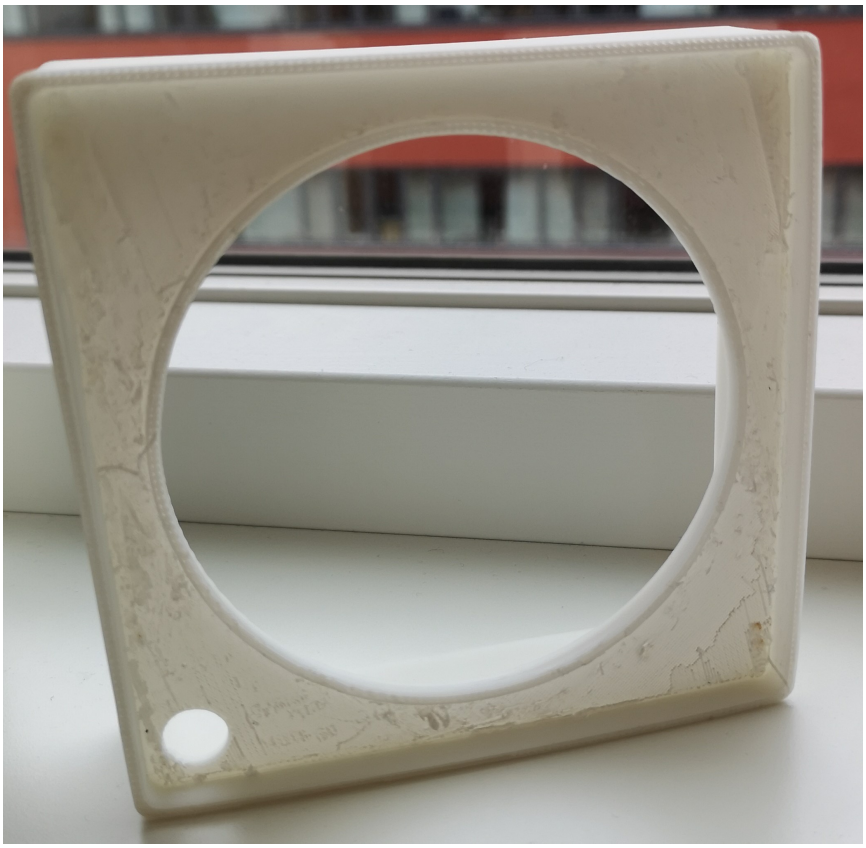


Figure 5.21: Second 3D-printed prototype with screw threads, A1.

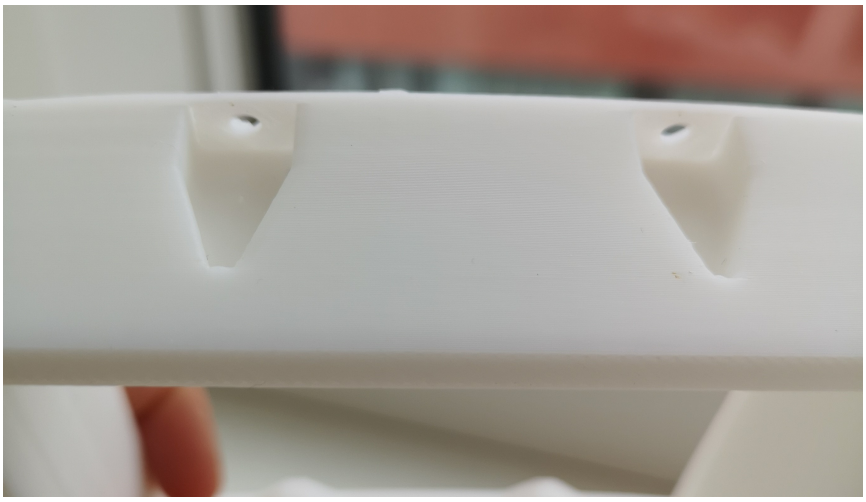


Figure 5.22: First 3D-printed prototype with tracks,screw holes B1.

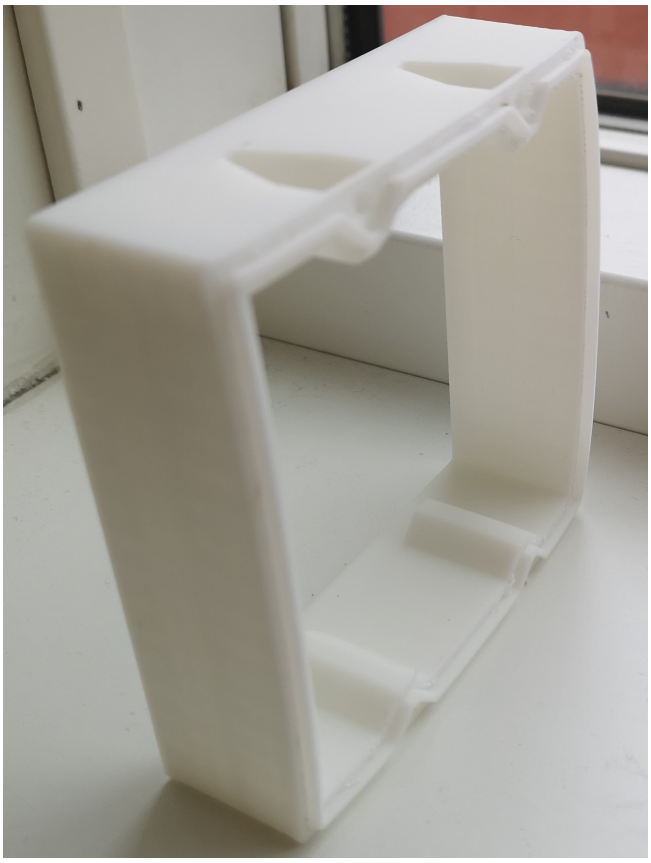


Figure 5.23: First 3D-printed prototype with tracks, male part B1.

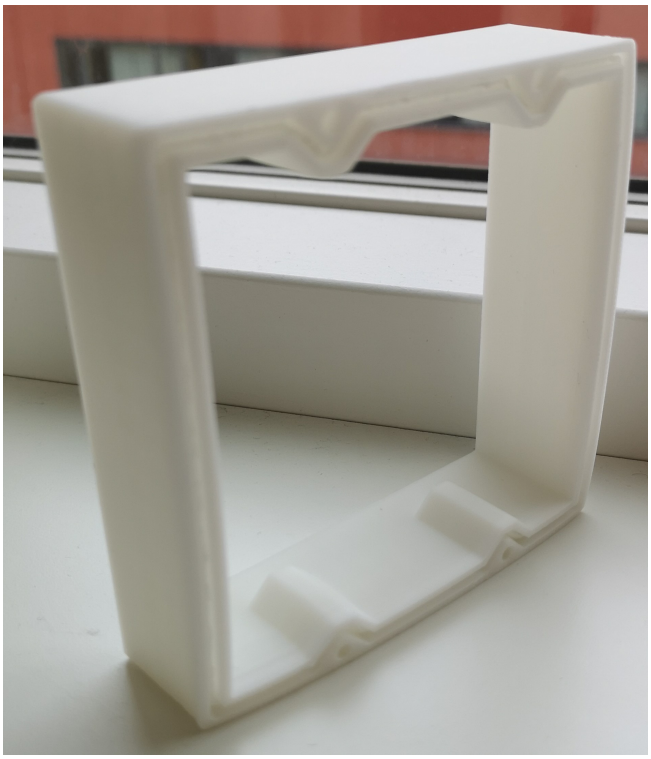


Figure 5.24: First 3D-printed prototype with tracks, female part B1.

5.4.6 Fastening selection II

The two tested mechanisms were analysed. Shape, size, complexity, use of tools and accessibility were considered factors. The *A1* concept, the connection area had the shape of a circle and the *B1* concept had a shape of a square. See Figure 5.25.

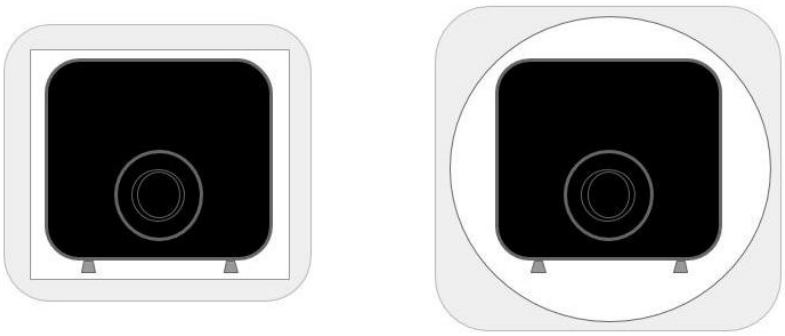


Figure 5.25: Connection area in shape of a circle and a square.

It was concluded that the circular opening for concept *A1* would need to be very wide in order to fit the camera and to enable the adjustment of its position. This would make the entire product very large. The circular opening would also result in extra spacing, see Figure 5.26, that was thought of being unnecessary and consequently increase cost. Because of these reasons concept *B1* was chosen. Since screws were considered a proven concept, it was probable that the concept would pass the durability and sealing tests. It might not be the fastest or easiest way of attaching the module, but it was considered more important that the durability and sealing requirements were fulfilled.

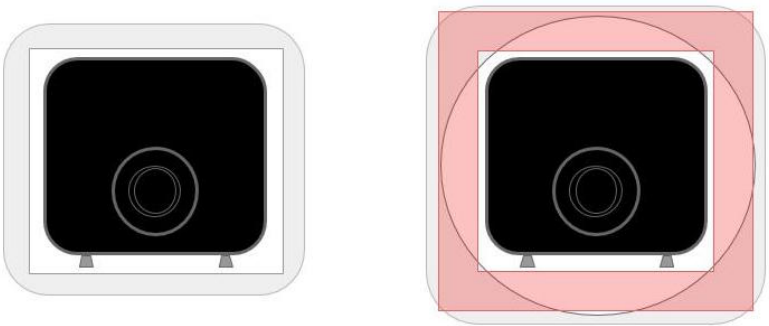


Figure 5.26: Comparison between the fastening designs, the red area demonstrate the excessive space caused by the round design.

5.4.7 Determination of camera housing design

The concept development resulted in many insights of the camera product as a whole. It was realised that if one wanted more functions to be applicable as modules, it would be better with a camera housing better adopted for different modules. A camera housing parted vertically would give the opportunity to redesign the front, making the front to a module for any desired function or functions. The *Three Parts Housing* concept was not further investigated since a three parts camera housing would be a more complex construction than with only two parts. Furthermore, the *Two Parts Housing* concept was also chosen because of its level of innovation. There are no vertically parted Fixed Box camera housings, which could be of interest to the company. Therefore it was decided to further develop the idea of creating such a camera housing, see Figure 5.27. The concept of a vertically parted camera housing was developed further and the decisions regarding the final concept's design are listed below.

- The housing will consist of two parts, a body and a module.
- Connection area will have the shape of a square.
- Fastening mechanism should be of screws.
- The network connection between the body and module should be a board to board.
- The installation board and the camera need to be easy accessed, and the camera lens position adjustable, why a sled, track or similar needs to be developed.

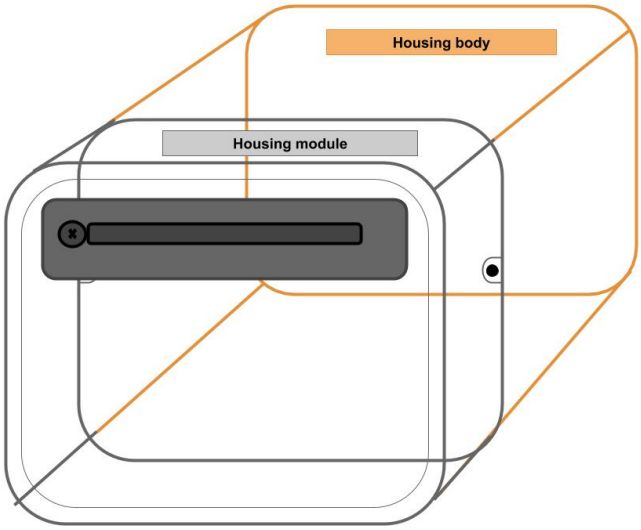


Figure 5.27: The determined design of the camera housing with the module included.

Chapter 6

Deliver

6.1 Final concept development

When a concept had been determined the details of the concept was developed. Since the module concept included a new design of the camera housing, many components had to be considered. It was realised that in order to design a viable module the entire housing needed to be optimized for this use. Therefore much focus was put on how to design the standardized part optimally, the part that would be the back of the housing. What has been mostly focused on was how to be able to assemble and install the product easily and effectively, how to achieve proper heat flow inside the camera and how to design the interior so that operators and customers can access relevant components and settings.

6.1.1 Development of details

The surveillance cameras of Axis are advanced and consist of many components in order to achieve high image quality and durability. Important features of the camera is the ability to move the camera lens, so that larger lenses fit, and the PCB, with extra inputs for audio or adding external features. Axis has worked a lot to achieve a balanced heat flow of the camera, and to keep the inside temperature low even if the outside temperature is high. These aspects have been taken into consideration during the development of the details. The interior of the cameras can vary, but the fixed box camera interior could be presented as in Figure 6.1. The figure shows how the camera lens and the PCB are connected, and how the camera is powered.

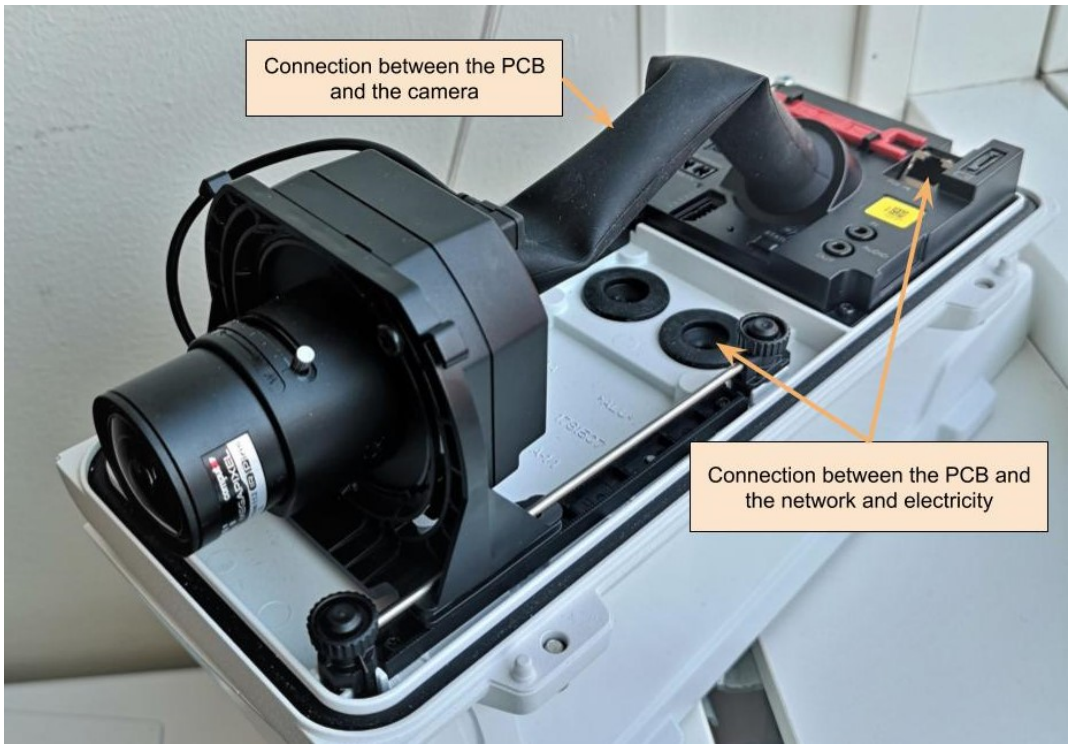


Figure 6.1: The inside of a fixed box camera.

Camera sled

With a two part camera house, split vertically, it was realised that some kind of sled, tracks or scaffold would be needed in order to achieve the ability to adjust the camera lens position. The design factors that were considered was the ability to mount the camera optics and to adjust the position of it easily. Different ideas of tracks, rails or sleds were considered. It was finally decided that the solution would be placed on a sled. With a sled it would be easy to mount the camera components, position the camera lens in advance and then mount the assembly into the camera. The other interior parts would be easy accessed since the sled can be pulled out. The dimensions of the sled would fit the tracks the camera can slide on to adjust its position. The camera housing would be adopted to fit this sled. However, it is realised that this detail is important to investigate further but because of the tight time plan this could not take a large part of the scope of the project.

Placement of the PCB

When deciding where to put the PCB there are numerous factors to consider. The outputs should be accessible and since the PCB generate a lot of heat, achieve proper cooling is important. It was found that is is recommendable to place the PCB directly onto the chassis, since the aluminum housing is a good conductor and the outer air will cool it sufficiently. Cooling could be solved by using fans, but fans are usually fragile and could be a costly solution. A brainstorming session resulted in many ideas covering different positions for the PCB, including or not the camera sled. When talking to constructors at Axis it was determined that the best solution was to place it somewhere onto the chassis, see Figure 6.2.

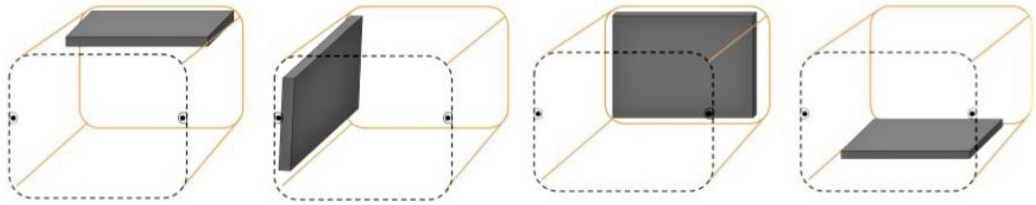
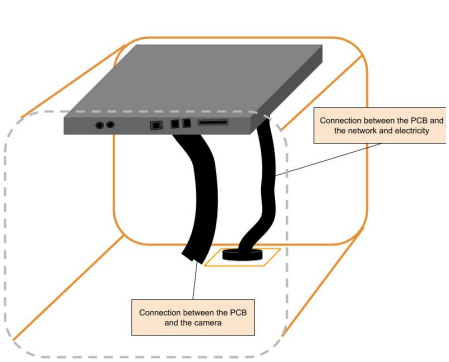
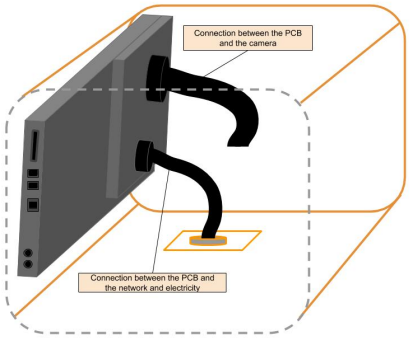


Figure 6.2: The determined design with the PCB in the roof, on the side, in the back or on the floor.

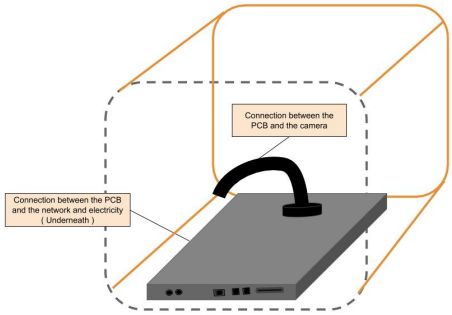


(a) PCB placed in the roof.

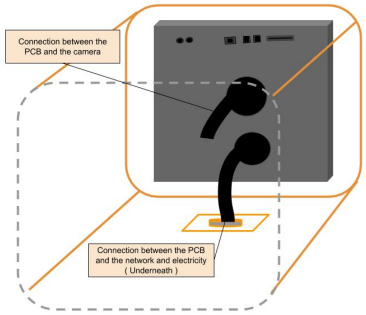


(b) PCB placed on the side.

Figure 6.3: Placements of the PCB on the roof and on the side.



(a) PCB placed on the bottom.



(b) PCB placed in the back.

Figure 6.4: Placements of the PCB on the bottom and in the back.

Selection of PCB position

In order to select the best placement for the PCB, the size of the cables and the accessibility of the outputs needed to be considered since they take up space and could limit the accessibility. Figure 6.3a, 6.3b, 6.4a and 6.4b summarize these aspects. To determine the placement a voting based on a criteria matrix was performed, see table 6.1.

The voting was based on a grading system of +, - or 0, since the concepts were quite similar but varied slightly. Moreover, a rating system with a larger scale was thought unnecessary.

The concept with highest grade would be chosen.

Table 6.1: Selection of PCB placement.

PCB placement	***A***	***B***	***C***	***D***
Aesthetics	**–**	**0**	**0**	**+**
Cooling	**–**	**0**	**+**	**+**
Cord length	**–**	**0**	**+**	**0**
Mounting in production	**–**	**–**	**–**	**+**
Accessibility for installer	**+**	**+**	**+**	**–**
Connection to module	**+**	**+**	**+**	**–**
Flex cord	**0**	**0**	**0**	**+**
Accessibility for customer	**+**	**+**	**+**	**0**
Results	**-1**	**+2**	**+4**	**+2**

Further prototyping of details

The vote gave a clear result, and concept C was decided to be further developed. The other two concepts with positive results remained in the process as backups. Concept *A* was dropped after the voting.

With a chosen concept one could start the design of the details, such as how to seal the PCB, how to access the components and how to connect to them, see Figure 6.5.

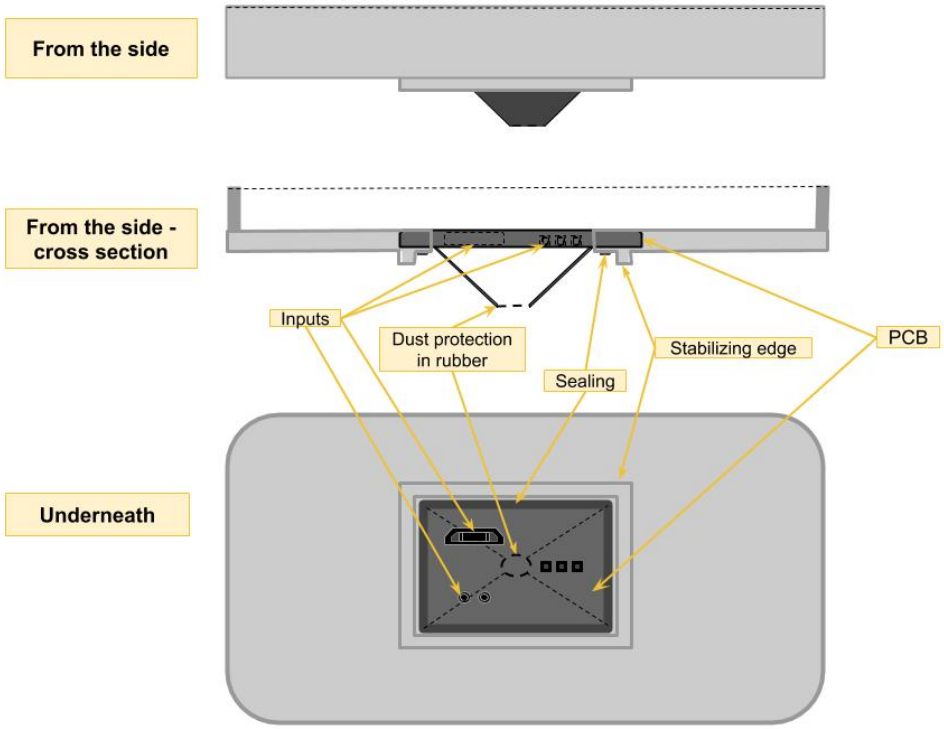


Figure 6.5: Further development of the PCB placement.

Wall mount

With the chosen concept of the PCB placement, the connection between the camera housing and the wall mount became crucial for the durability and sealing of the product. It was also important to consider the required space around the PCB for the connectors and cables. The cables and cords require space since they should not be too flexed or bent. The wall mount is provided by Axis, why a mounting part needed to be constructed. The design of the mounting part aimed both for an integrated aesthetic of the entire product and the requirements for durability, space and sealing.

Module size and components

The size of the module was decided to be adapted to the already existing wiper at Axis. The measurements of the module are therefor translated to include a motor, a heating system, cables and other components for connecting the module with the PCB and the camera body. The considered heating system is a traditional system used in the all the cameras that are compatible with the Axis Wiper Kit B today. A future heating system may be different, for example requiring less energy or space, and since electronic details were not the main focus of the project, there was not enough time for the development of a heating system. This also applies to the power connection between the module and the camera body. The board-to-board connection would be a good option since it would facilitate the installment even more, however, it is expensive.

The wiper module is constructed to be an example of a possible module. It is designed so that it should be easy to adjust the measurements to include other requested features. The design of the module will therefore be square-like and simple.

Wiper design

Based on earlier considerations of placement of the wiper and its design, it was decided to keep the majority of the construction. In this way the module and the wiper components would be compatible and since it was stated that the wiper was functioning well it was not prioritized to further develop the entire construction. Furthermore, it was realised that one wiper should be sufficient clear the window from water. By placing the wiper up in the left corner it would both get protection when it is in parking mode and not disturb the field of view.

The aesthetics of the wiper was the only aspect further developed since it was a desired requirement and a property that had not been greatly developed at the company. A quick concept generation was performed but the design was mainly based on ideas to improve the existing wiper. The aim with the new appearance was to make it more protected, uniform and compact.

6.1.2 Industrial design

Before the final design was determined, it was shown to one of Axis' industrial designers. The Axis design was described as aiming for a calm and smooth design, avoiding sharp edges or outstanding features. Lines and edges should be soft and follow the same direction. The camera housing and the module were redesigned to better fit the Axis design guidelines.

6.2 Final design

The final construction consists of a camera body, a module, a camera sled and a mounting part that connects the body to the wall mount which attaches to the wall. The overall design is smooth and uniform, and is in line with similar Axis products. See Figures 6.6, 6.7, 6.8, 6.9 and 6.10.

Figure 6.6: The final design.

Figure 6.7: The final design, construction overview.

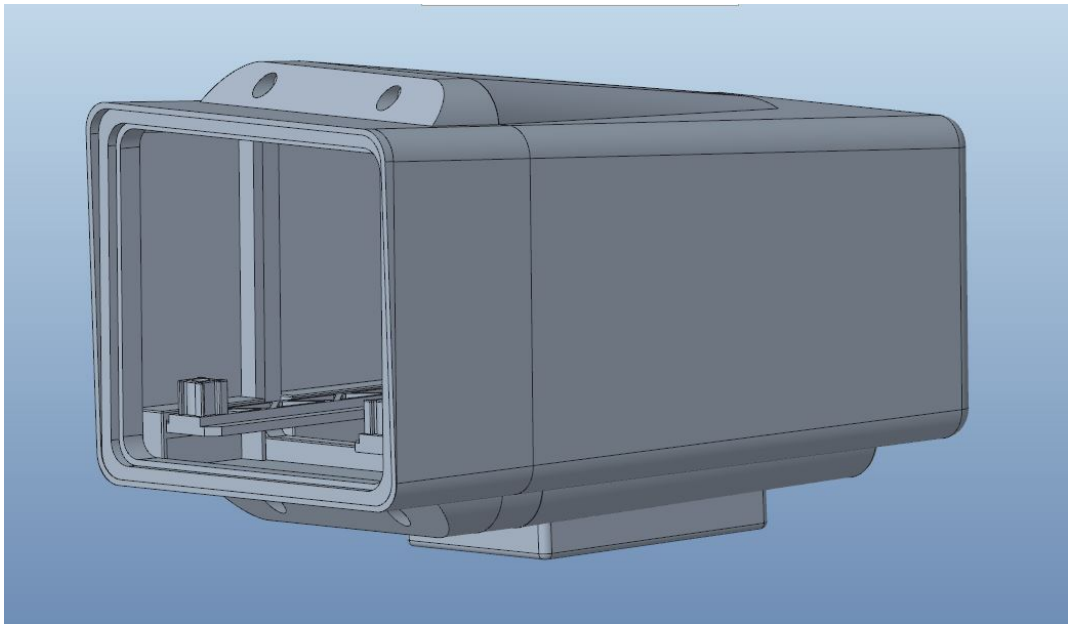


Figure 6.8: The final design in Creo, without window and wiper.

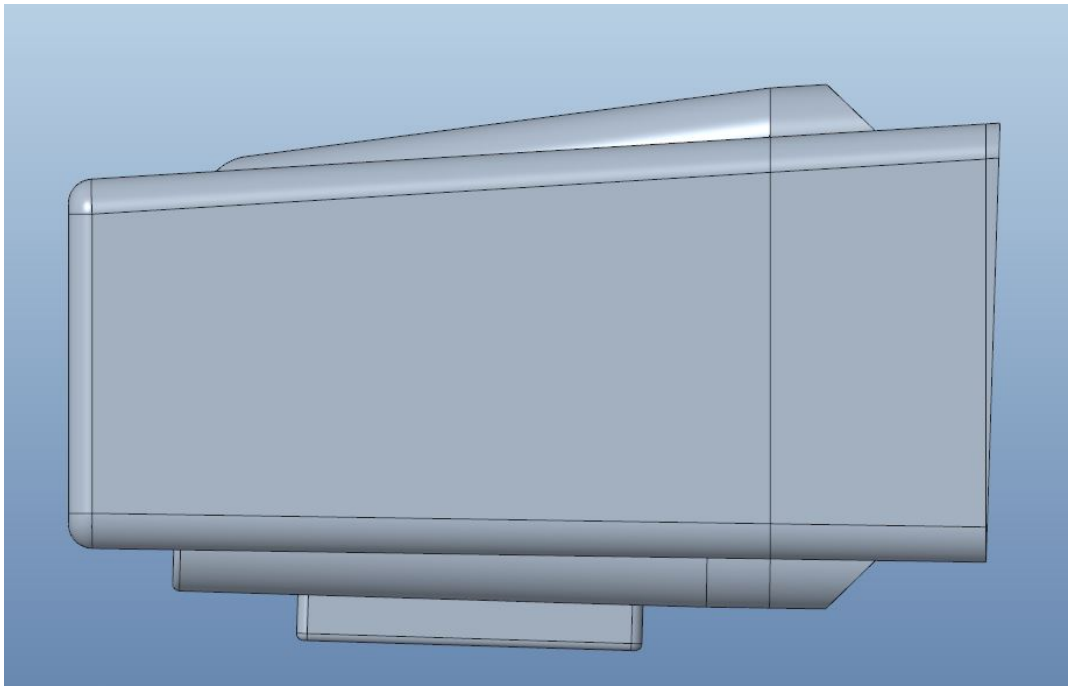


Figure 6.9: The final design from the side in Creo, without window and wiper.

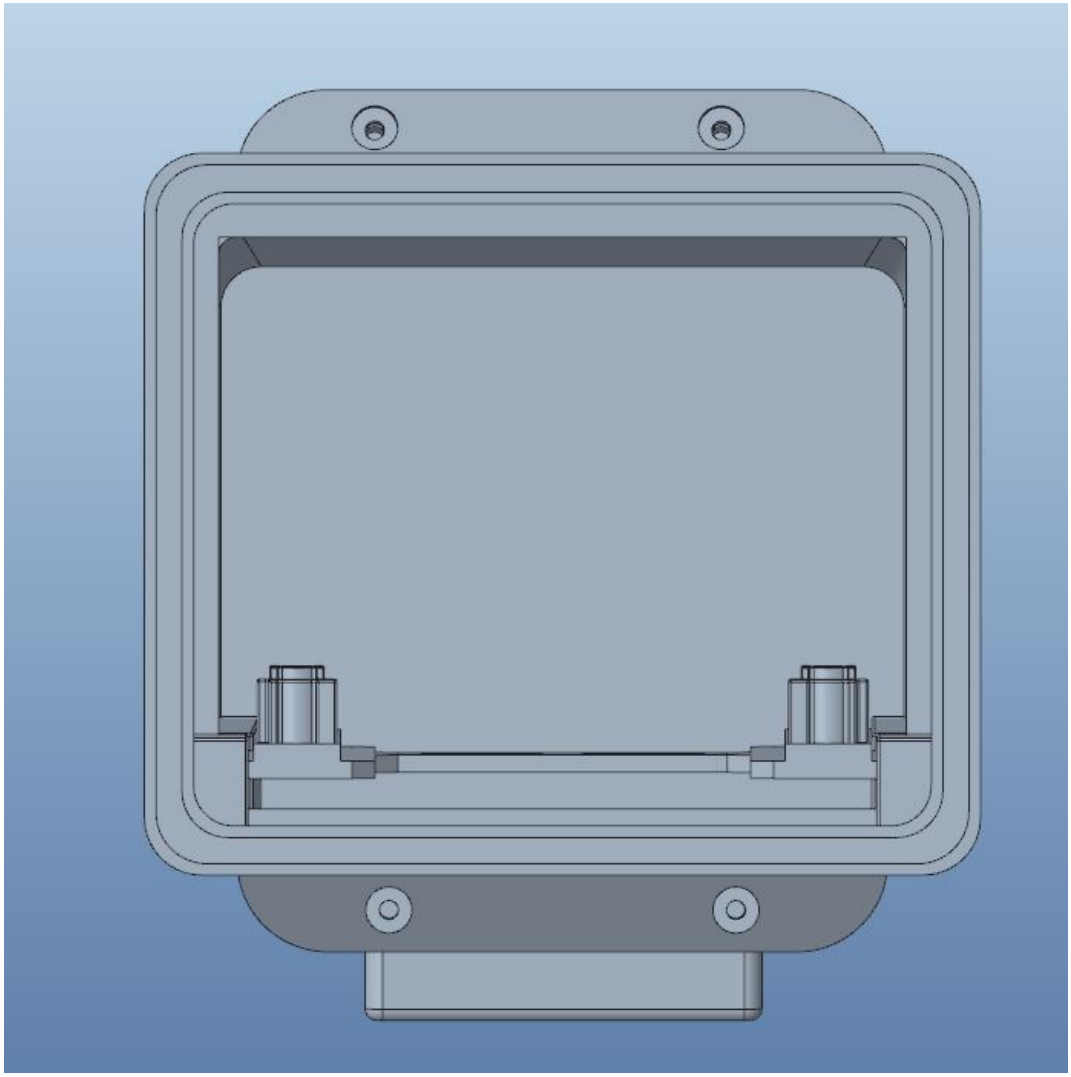


Figure 6.10: The final design from the front in Creo, without window and wiper.

Drawing - A simple drawing of the assembly, with some relevant dimensions to get an understanding of the size of the product, is shown in Figure 6.11.

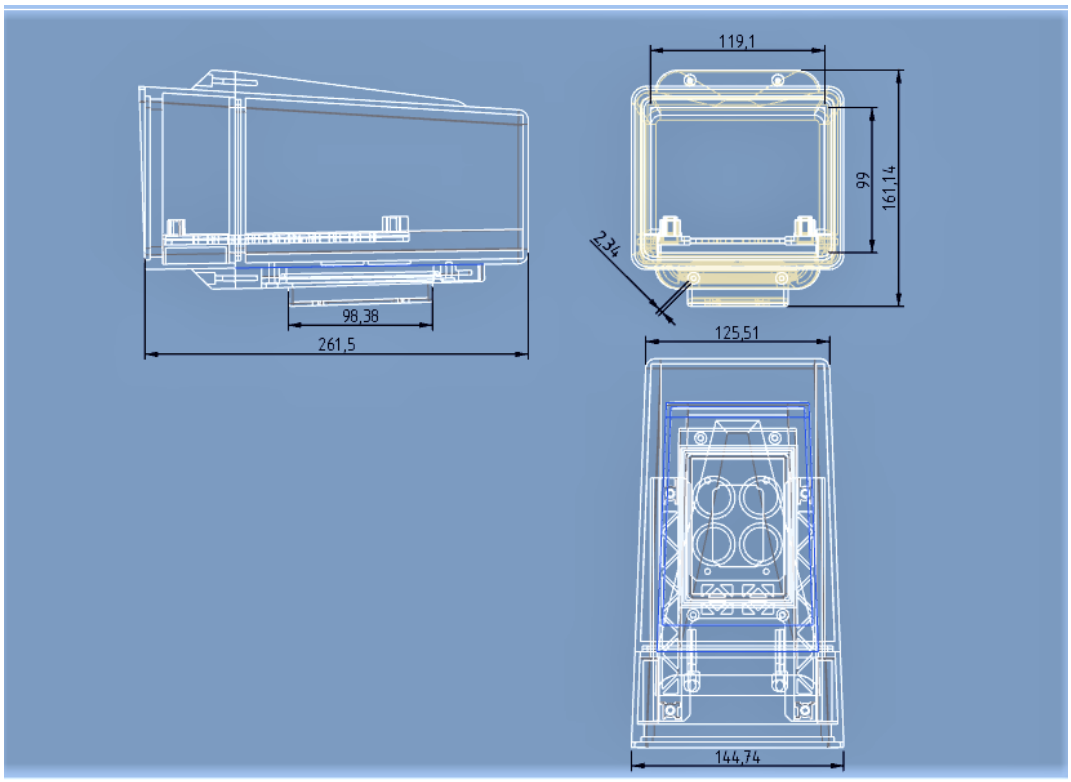


Figure 6.11: The final design with some overview dimensions.

6.2.1 Final design of the parts

The camera housing body

The camera body is the core of the product which connect both to the mounting part and the module, see Figure 6.12. The track inside of it is for the camera sled. In the bottom there are holes for cord sealing that will cover the cables and make the housing water and dust proof. The design of the body is shaped according with the module. The bottom edge and the top edge are prepared with holes for screws.

Figure 6.12: The final design of the body.

The module

The module is the part that can be redesigned according to the needs, see Figure 6.13. The high freedom of design makes it possible to include different features such as a wiper, IR sensors, a longer front for larger camera lenses and so forth. It is designed to be easily fastened and sealed to the camera body. These properties would not be affected when including other functions, to make sure that the elementary requirements are fulfilled and to save time when redesigning the module.

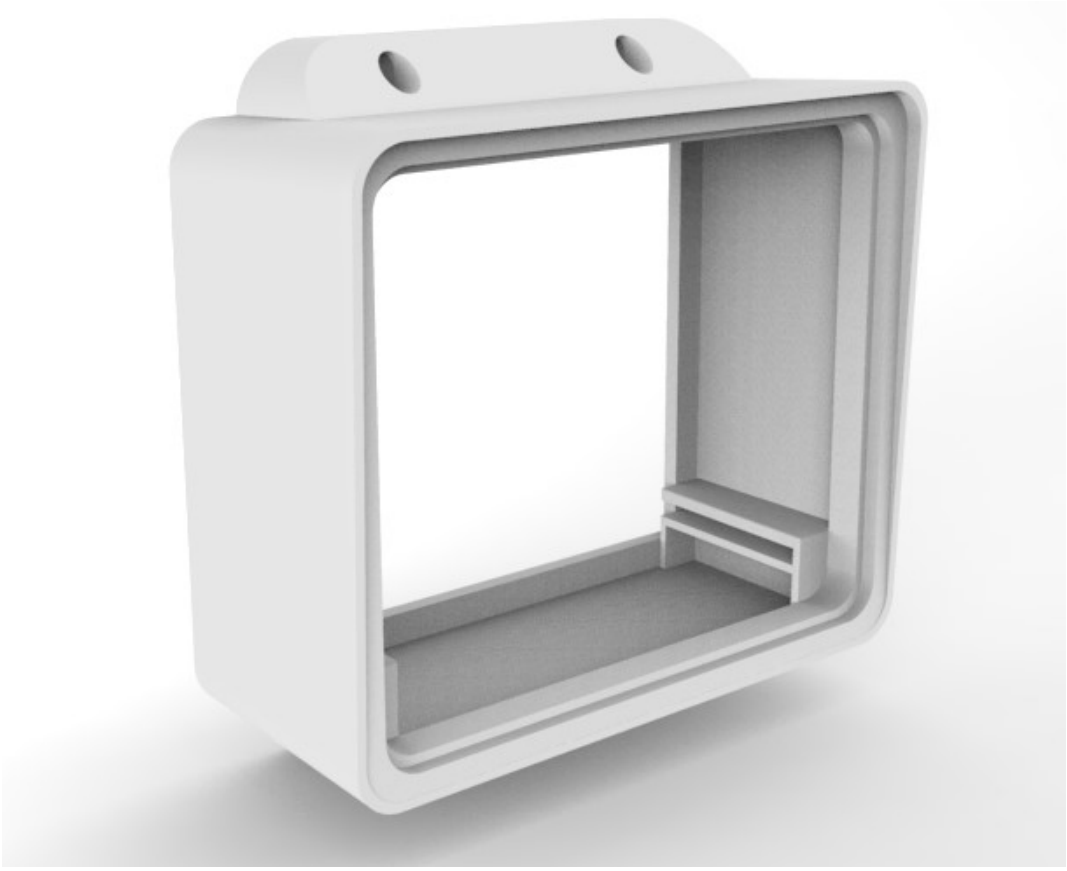


Figure 6.13: The final module design without glass window and wiper.

Mounting part

The mounting part is constructed to give space for the cables that connect from the wall mount to the PCB in the camera housing body, see Figure 6.14. The mounting part protect the cables and the PCB and makes the connection waterproof. It is also designed to fit the wall mount and to fit the overall design of the entire product.

Figure 6.14: The final design of the mounting part.

Camera sled

The purpose of the camera sled is to make mounting of the PCB and the camera easy. It is also designed to enable adjustments of the camera lens position. With the sled one also wants to make the inside of the camera body accessible. It has a light and optimized design to save material and release hot air from the PCB and the camera, see Figure 6.15 and 6.16. Figure 6.17 shows the mounted standard housing with the camera sled mounted inside.

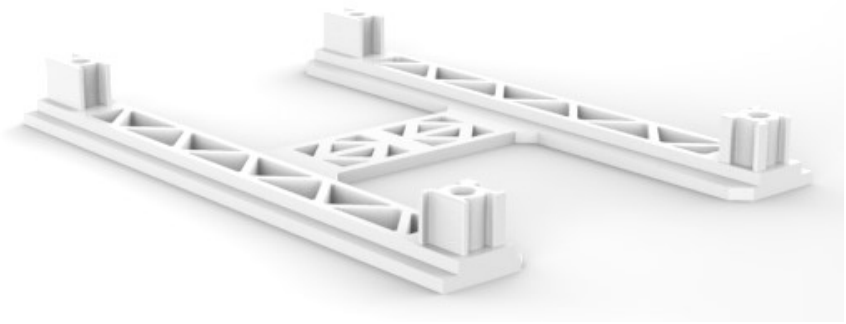


Figure 6.15: The final design of the camera sled.

Figure 6.16: The final design of the assembled camera sled prototype.

Figure 6.17: The final design of the assembled standardized housing with mounted camera sled.

6.2.2 Mounting

The fastening and mounting of parts are done with screws, see Figure 6.18, 6.19 and 6.20. It is a proven and used method that meets the requirement for strength and sealing. The body also have a function that makes is possible to hang the body onto the mounting plate to facilitate the connection of the cables.

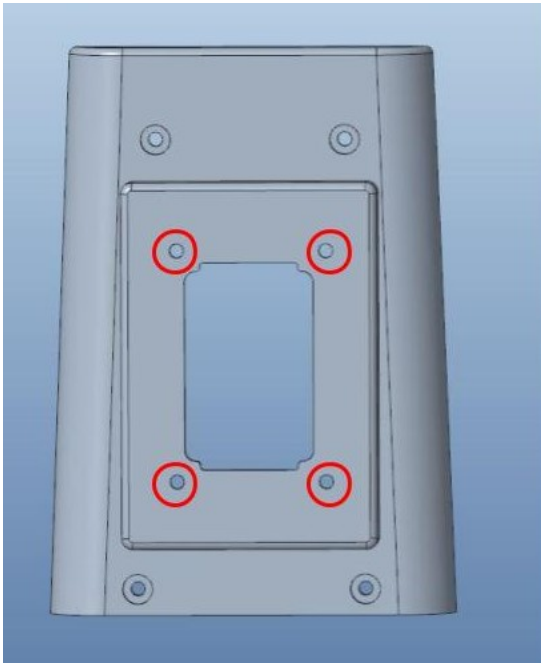


Figure 6.18: Screw holes on the mounting part where the wall mount will be fastened.

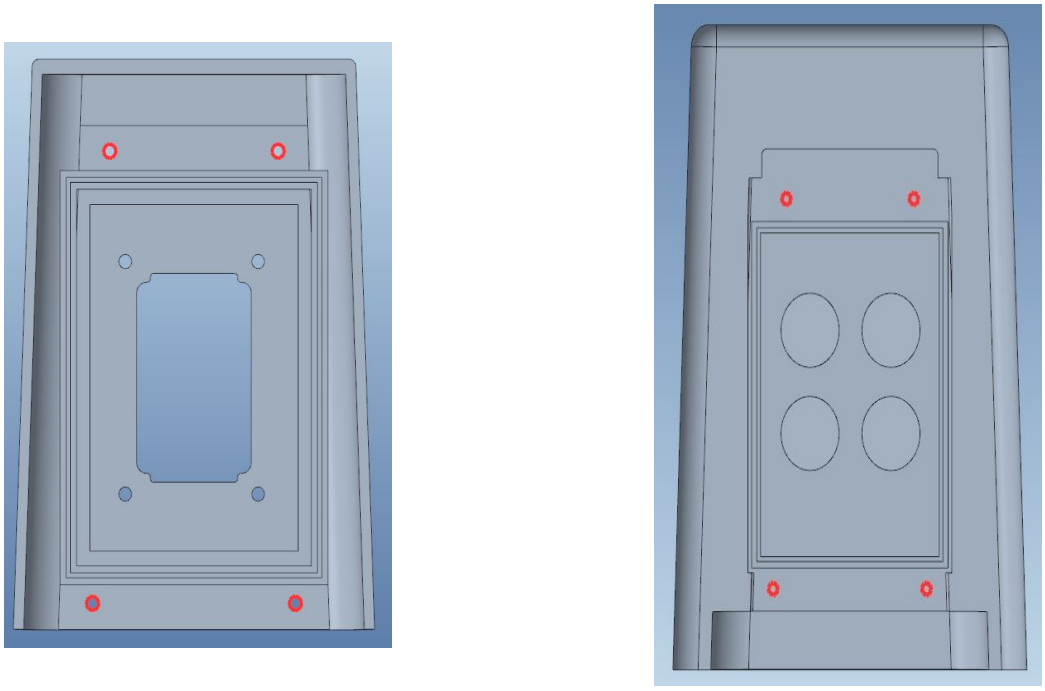


Figure 6.19: Fastening between the mounting part and body.

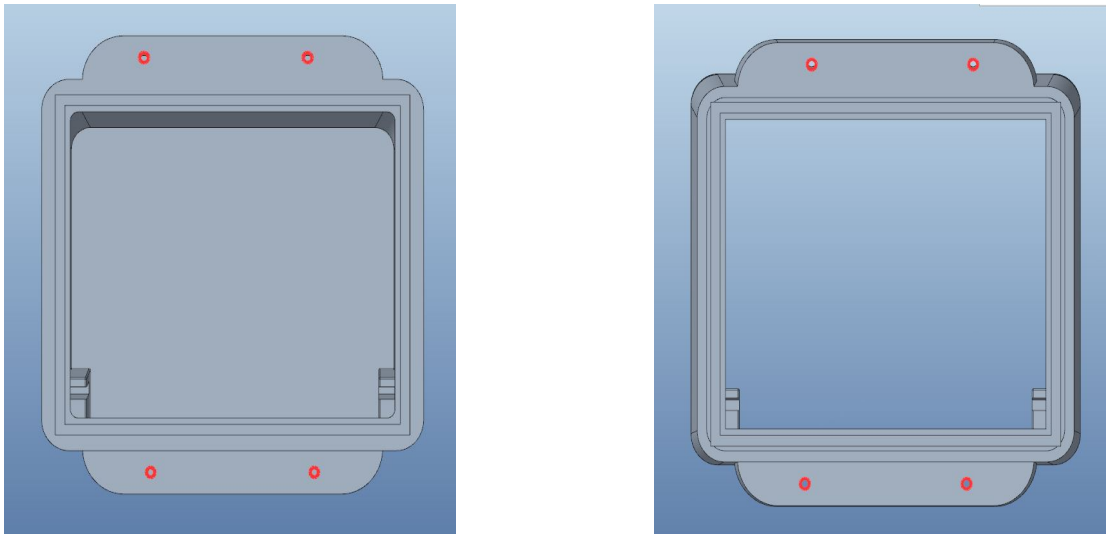


Figure 6.20: Fastening between the body and the module.

6.2.3 Sealing

The sealing function consists of a female strip and a male strip that has the same shape and fit together but leave a small space between them. In the gap, a rubber band that has the same shape as the strip will be placed. When the parts are pressed together, the rubber band will be squeezed together so that it becomes completely water and dust-tight in the joint between the two pieces. This function is used between the module and the body see, Figure 6.21 and see Figure 6.22.

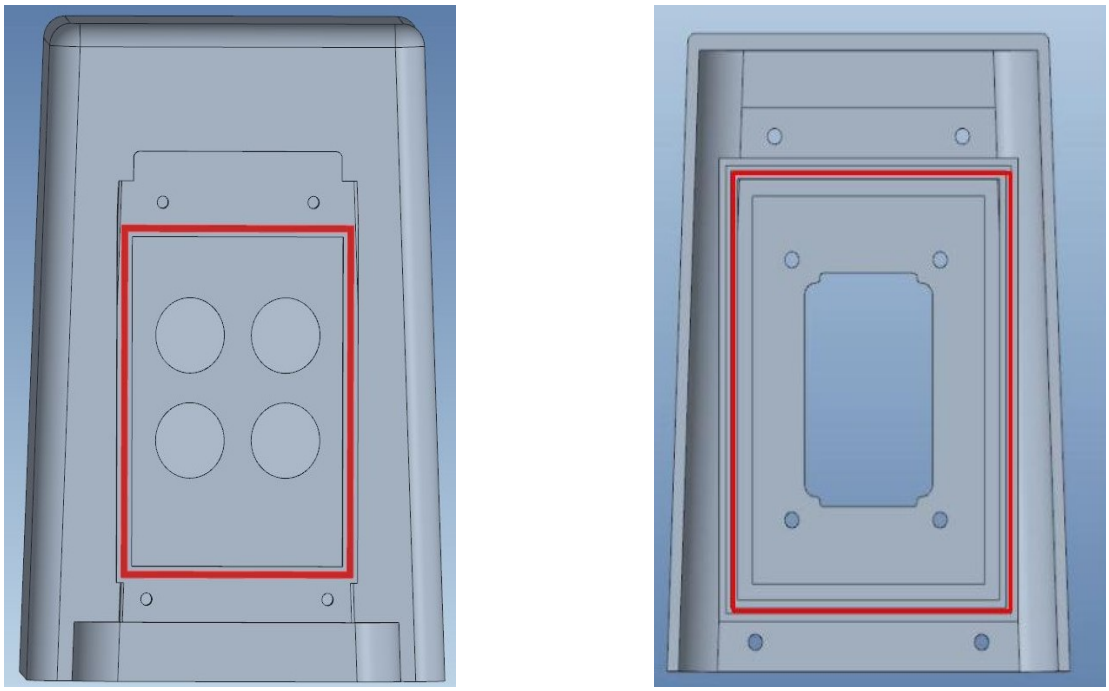


Figure 6.21: Sealing between the body and the mounting part.

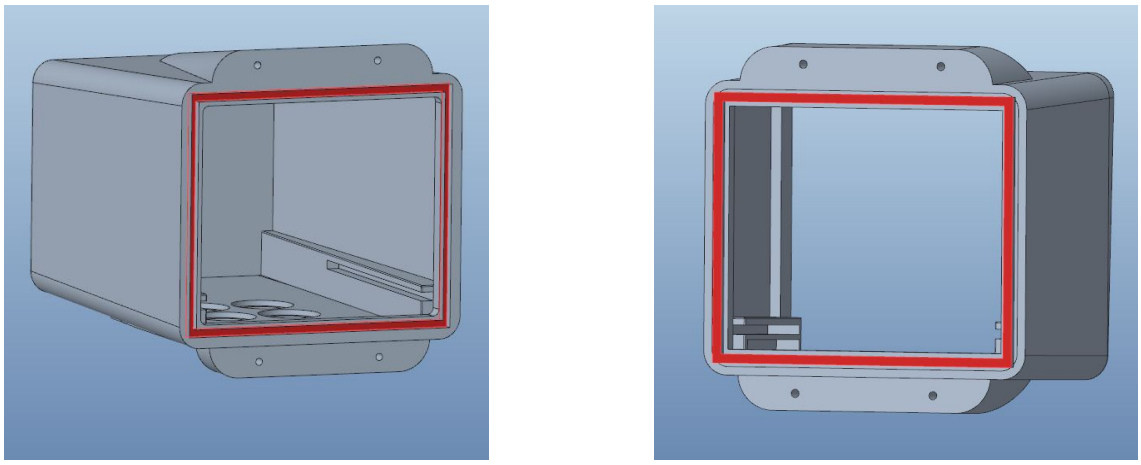


Figure 6.22: Sealing between the body and module.

Cable sealing - The cable sealing that protect the PCB and the cable connectors is provided by Axis. It will make the more delicate areas water- and dustproof, as the holes for the cords, see Figure 6.23.

Figure 6.23: Cable grommet for sealing.

6.2.4 Final design of the wiper

The final design of the wiper comprises a new appearance for the wiper blade and arm. It follows the lines of the rest of the camera housing and has a more uniform look, see Figure 6.24 and 6.25 .

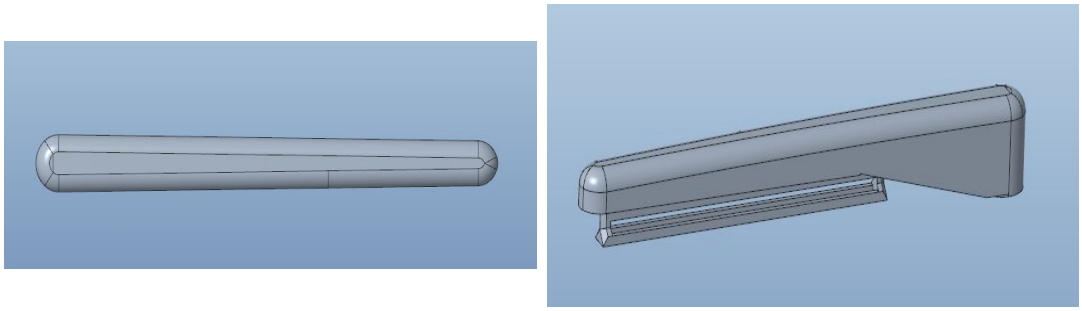


Figure 6.24: Final design of the wiper cover.

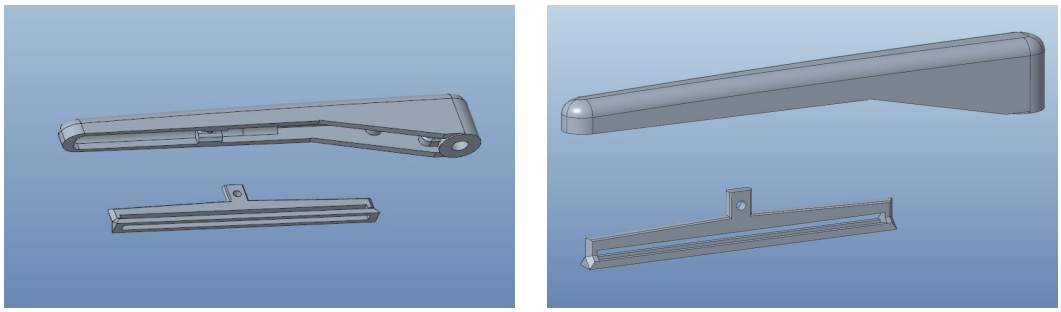


Figure 6.25: Final design of the wiper cover and blade.

6.3 Manufacturing

The produced concept will affect the manufacturing of the product, as well as the mounting. The back part, the camera housing body, the mounting part and the module will be made of aluminum in order to fulfill the IK-requirements. These parts can be produced through casting. Casting parts will require the design to be adjusted for this manufacturing method and producing a core that is as simple as possible. Furthermore, to optimize the weight, and prize, of the product, the interior should be made of plastic when suitable. This applies to the sled and the related tracks. These parts could be injection moulded, a cheap and common method for plastic parts that include joints, brackets, or housings (Creative Mechanisms, 2015). However, the prototype has been 3D-printed why it is not optimized for production yet. The ability to manufacture the parts will be a concern for future development of the product.

6.4 Design of the prototype

The assembled prototype is shown in Figure 6.26.

Figure 6.26: The final design of the assembled prototype.

Chapter 7

Discussion and conclusion

This chapter aims to analyze the result of the project as well as widen the perspective of the project, the consequences and future prospects.

7.1 Discussion and analysis

7.1.1 Design and function

This thesis project started off with the aim to construct a functional module, i.e. an external and addable part with a wiper as the main function. This background has shaped the development of the project which resulted in a wiper module as well as a new design for the camera housing. It is possible that other results could have been obtained with another background or starting point. Throughout the project, a general modular design has been considered but has not been the main focus. A different design for a modular housing could have been created with another focus. Similarly, the request to design a module, as part of a new product line for the future, was understood quite late in the development process. However, with the wiper function as the main request the project resulted in a wiper module with flexible design and with the possibility to include many different functions.

Initially the wiper function was profoundly researched and investigated. The knowledge of what a wiper consists of and what features it requires was useful for the project, but the research of all the details has not been used. Similarly, the research of methods of controlling the wiper automatically, or alternative heating systems, has not been practically implemented because of the conceptual level of the result. Furthermore, general modular design became more important as the project progressed and the focus grew to be the development of a new camera housing. It was realised how many features an Axis camera consists of and how many details that are of great significance for the quality of the product. The main functions were prioritized; sufficient sealing, access and connection to relevant features, and proper heat flow. However, no tests have been done to prove that the requirements were fulfilled. Making tests was not prioritized as they were not considered applicable in this stage of the development process, and therefore is testing recommended for the future.

The fixed box cameras are normally parted horizontally, dividing the camera housing to a bottom with an upper cover. The produced concept is divided vertically which gives greater flexibility regarding the design of the module. Moreover, the result implies a new interface and requires a new way of interacting with the product. The camera sled was developed in order to facilitate settings and accessibility of various functions of the inside. However, with an extra part the mounting might be more complicated, and by putting the most valuable feature on a loose part, higher vulnerability could be an issue when mounting or adjusting

the camera. Nevertheless, the idea of the sled is to facilitate the application of the module, and by developing it further it can be optimized.

Finally, this concept has been produced to minimize cost and maximize the formability to meet the varying customer requirements. To confirm that these intentions have been successfully accomplished, a cost and function analysis should be performed. At this stage of the process, it is difficult to tell if a modular design would lead to reduced production time and cost, and if it really would meet all customer requirements. Since it has not been part of the scope of this thesis such analysis has not been performed. However, it is realised that these factors are important and need to be considered, why such analysis is recommended to do.

7.1.2 Process

The process has overall gone well, the report and the design process has been done continuously, which has resulted in a progressive work flow. The only bigger mishap was that the producing time of the prototype was longer than expected and not included in the project plan. When that information came to knowledge a stressful period followed where all parts needed to be completed quickly to be printed in time. Otherwise the process has more or less followed the time plan that was set in the beginning of the project, even though the focus has been changed during the process.

During this process, we have tried to have a good and open communication. Even so, important information has been overlooked and misunderstandings have occurred. Since we have talked to many different people, with different visions, much useful knowledge have been obtained, however, it has also led to confusion about what should be the biggest focus for the product. If we were to do the project again, it would have started with a meeting gathering everyone involved to agree on a common vision. Because, even though we aimed to be transparent and communicative, some issues could have been handled even earlier and under arranged forms. This is something we will take with us into our working life.

7.1.3 Requirements and goals

The requirements were established when the project aimed for constructing one wiper module. Because of change of direction, some requirements could have been added and some of them are not relevant anymore, but all requirements that were set up have been met, except one. The only requirement that was not perfectly fulfilled was the *Installation of the module should be simple.* Since that specific requirement consists of many different aspects which not all of them met, it cannot be counted as satisfied. With reservation for that, all requirements were met. All limitations were taken into consideration and fulfilled, which is important for the feasibility of the concept.

7.2 Future development

7.2.1 Other potential concept

Except from the chosen concept there were other concepts that could be interesting for Axis. Early in the process, a concept of a module adopted for the window was investigated. The *Window module* is a compact module consisting of all required wiper components and is optimized only for the wiper function. The module would not contain other functions but

it has other advantages such as easy handling during mounting and assembling. It is also a concept that is easily implemented in the Axis product line, since it would not require larger changes of the camera housing. The *Window module* could therefor be interesting to further develop.

7.2.2 Unfinished ideas

Due to the limited time frame, there were many ideas that could not be prioritized. Parts that can be further developed are the camera sled, cable connection and attachment between body and module.

The camera sled was one of many solutions to enable simple interaction with the camera and the interior of the camera body. One example was to have rods on both sides inside the body and simply clamp the camera on the rods, see Figure 7.1. In any case, the idea was to combine the sled with the body as one part.

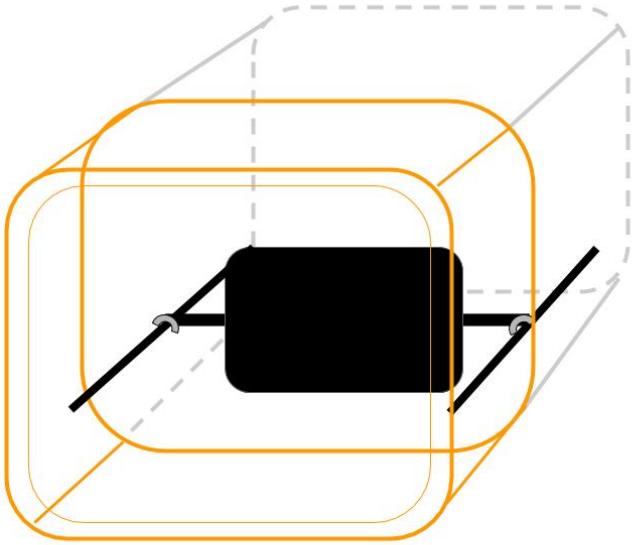


Figure 7.1: Example of rods on the inside of the camera housing body.

An idea that emerged late in the process was a concealed screw mechanism that would have worked as a bracket between the module and the body, see Figure 7.2. The mechanism would then consist of a female and a male part. The female part would have included small gears that would be connected to a screw. For each time the screw is tightened, the tighter the module is pressed against the camera housing. That could have created a more high-tech look without screws visual from the outside, and also a more uniform design.

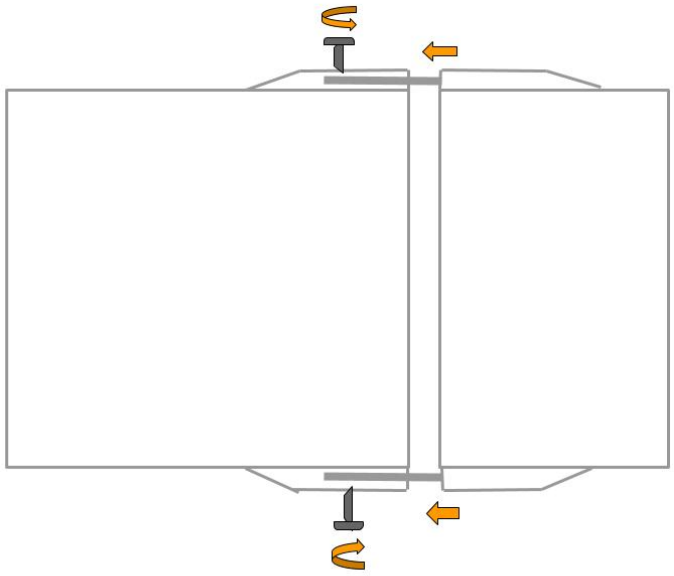


Figure 7.2: Example on concealed screw mechanism

7.2.3 Further recommendations

There were various factors of uncertainty during this project. Because the project was more of a pre-study, the construction and design were in focus, which is why making analyses was not prioritized. Before the product can be classified as complete, design optimization and tests need to be performed.

Tests - The construction and its dimensions should be analyzed with FEM (Finite Element Method). With FEM, the strength, durability and heat flow can be verified. Tests for checking the sealing also need to be preformed, to make sure the pressure between the body and module is sufficient. The placement of the PCB needs to be confirmed so it provides enough cooling, enough space and that the connection for cables is functioning. A transmission and heat flow analysis has to be performed, regarding the entire assembly, to make sure that no parts will become overheated. Finally, the center of gravity must be calculated and adjusted so that the camera body is in balance, regardless of how big or heavy the module is.

Design of the module - All the measurements of the concept have been adopted to the wiper function and to make the product as small as possible. However, optimizing the measurements is necessary and to do so it could be interesting to analyze possible "standard" modules. A standard module could be a module containing popular functions many customers ask for, and these modules could have the same size so that they easily fit the camera body. I.e. the camera body is adapted to these modules.

Design of the wiper - Since the project changed direction as the project progressed the exact wiper construction and design became less important. The focus became instead to develop a camera housing adopted for modules. However, developing the design of the wiper was a desired requirement from Axis and much time was initially spent on analyzing the location and all the different features accompanying the wiper. Knowing the components of a wiper

has been of great use when designing the module but not used when prototyping. A new design was developed but needs to be further developed and tested.

7.3 Conclusion

The project consisted mainly of a thorough research which resulted in a broad variety of solutions and finally a prototype that constitutes a good basis for further development. The thesis should be used as a pre-study since the concepts presented should be further investigated and developed.

The thesis resulted in a prototype of a preferred concept which in an innovative way attained the most important requirements and some additional. The concept implies a new way of interacting with the camera and infinite ways of redesigning the module to include many different functions.

The entire project has been a positive experience that has brought with it new impressions and lessons. We have got an insight in a large and successful company, and understandings of how many components, people and properties constitute a high-quality and advanced product. It has been a challenging task to include everything, since new requirements and delimitations emerged as the project progressed. Setting up a correct schedule and project plan covering 20 weeks was also quite tricky but with smaller modifications the project was successfully completed.

Bibliography

Axis Communications AB (2019). *Axis Communications, About Axis*. [Online; accessed 24-January-2019]. URL: https://www.axis.com/about-axis.

Creative Mechanisms (2015). *Creative Mechanisms, Everything You Need To Know About Injection Molding*. [Online; accessed 21-may-2019]. URL: https://www.creativemechanisms.com/blog/everything-you-need-to-know-about-injection-molding.

Hikvision (2018). *Hikvision, Hikvision DS-1331HZ-HW Camera Outdoor Housing*. [Online; accessed 23-may-2019]. URL: https://www.hikvision.com/europe/Products/Accessories/Camera-Housing/DS-1331HZ-HW-1.

Innovation Toolbox, University of Copenhagen (2018). *The Innovation Toolbox, Method: Classic Brainstorm*. [Online; accessed 28-January-2019]. URL: https://innovationenglish.sites.ku.dk/metode/classic-brainstorm/.

Martinez, M. and D. Xue (2016). "Development of Adaptable Products Based on Modular Design and Optimization Methods". In: *Elsevier B.V* 50.9, pp. 70–75. URL: https://doi.org/10.1016/j.procir.2016.04.078.

NEMA (2005). *NEMA, NEMA Encolsure Types*. [Online; accessed 28-jan-2019]. URL: https://www.nema.org/Products/Documents/nema-enclosure-types.pdf.

RISE (2017). *RISE, IP-klassning*. [Online; accessed 28-jan-2019]. URL: https://www.sp.se/sv/index/services/ip/sidor/default.aspx.

The Design Council (2019). *Design Council, The Design Process: What is the Double Diamond?* [Online; accessed 24-January-2019]. URL: https://www.designcouncil.org.uk/news-opinion/design-process-what-double-diamond.

Thule Sweden (2019). *Thule Sweden,Thule och hållbarhet*. [Online; accessed 25-April-2019]. URL: https://www.thule.com/sv-se/se/about-thule/environment#p3.

Ulrich, K. T. and S. D. Eppinger (2012). *Product Design and Development, Fifth Edition*. 1221 Avenue of the Americas, New York, NY 10020.: McGraw-Hill.

Zentiel (2019). *Zentiel, IK10*. [Online; accessed 28-jan-2019]. URL: https://www.zenitel.com/technology/environment/ik10.