New Mechanical Platform for Dome Cameras

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MASTER THESIS

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Abstract

This master thesis report describes a product development process with the aim to create a construction which ensures an easier installation by replacing screws with other alternative assembly methods. The project has been performed at Axis Communications AB, which is the market leading company in network cameras.

A previous project called Rocky provided the idea of an excenter lock compressing and holding the camera together, which worked as starting point for one of the sub problems for this thesis. A background study was made to get better understanding of how the installation process works and which different assembly methods occurs in products on the market today. The study showed that screwless assembly methods occurs everywhere and in many different forms, but the most common ones seemed to be snap fits and bayonet solutions.

The final concept consists of three main parts, a mounting bracket where excentre locks are pre-assembled, the chassis and the dome which are assembled together without the use of screws. The chassis is mounted on the bracket by a rotating bayonet which provides feedback to know when it is placed correctly. The locks are first closed partially to hold the dome, enabling rotation of it. The locks are then completely closed and keeps the camera compact.

The result of this thesis shows that a screwless installation of a dome camera is possible.

Keywords: Product Development; Ease of Installation; Screwless Assembly; Excenter Locks; Dome Camera

Sammanfattning

Denna rapport kommer att beskriva en produktutvecklingsprocess med målet att skapa en konstruktion som säkerställer en enklare installation genom att ersätta skruvar med andra monteringsmetoder. Projektet har utförts på Axis Communications AB som är ett marknadsledande företaget inom nätverkskameror.

Ett tidigare projekt som heter Rocky resulterade i idéen om att använda ett excenterlås som komprimerar och håller ihop kameran. Denna idé lade grunden till detta examensarbete och användes som utgångspunkt för ett av delproblemen. En bakgrundsstudie gjordes för att få bättre förståelse för hur installationsprocessen går till och för att se vilka olika monteringsmetoder som används i produkter på marknaden idag. Studien visade att skruvlösa monteringsmetoder förekommer överallt och i många olika former, men att några av de vanligaste var att använda snäppen eller bajonettlösningar.

Det slutgiltiga konceptet består av tre stycken huvuddelar, en monteringsplatta som excenterlåsen är förmonterade på, ett chassi och en dome, som är hopmonterade utan skruvar. Chassit är monterat på plattan genom att använda en roterande bajonett för att återkoppla när chassit är placerat korrekt. Domen hålls mot chassit med ena handen medan låsen placeras korrekt på den, de klickar ner i ett spår på domen och håller den därmed uppe samt möjliggör rotation av den. Sedan stängs och säkras låsen och komprimerar kameran.

Resultatet av denna rapport visar att en skruvlös installation av en dome-kamera är möjlig.

Nyckelord: Produktutveckling; Enkel installation; Skruvlös Montering; Excenterlås; Dome-kamera

Acknowledgments

This thesis has been performed for Axis Communications AB as part of our master program in Mechanical Engineering at LTH. It has been challenging but also very fun and developing. We would like to thank the people who has helped us along the way and made this possible.

Firstly, we would like to thank our supervisor at Axis, Olaf Hoyer, for supporting and helping us during this project. We would also like to thank our supervisor at LTH, Damien Motte, for guiding us through the product development process and always giving us fast feedback.

Other colleagues we would like to thank are Gustav Aronsson, Stefan Larsson and Carl-Axel Alm for their important input during the testing and evaluation process of the project. We would like to give a special thanks to Carl-Axel Alm for always questioning us and motivating us to do more than we thought we could, also for making us feel included and for introducing us to other valuable people at Axis who helped us during this project.

Finally, we would also like to give a big thank you to our colleagues Linn Egelberg and Rakel Hed for pushing and encouraging us during this thesis, with their experience as previous master thesis students at Axis.

Lund, May 2018

Lejla Salić and Johanna Sjöberg

Table of contents

1 Introduction

The following chapter contains a short introduction to the master thesis and includes information about the company, a description of the problem, delimitations and finally key people at Axis.

1.1 Axis Communications

Axis Communications AB is a market leading company in network video cameras. The company is based in Sweden and acting worldwide with partners in 179 countries [1]. They offer different IP-based products and solutions for video and security surveillance. The company was founded in 1984 and started out as an IT company selling print servers [2]. In year 1996 Axis invented the world's first network camera and has since been an innovator in the surveillance industry.

The cameras cover many application areas and consist of fixed box, fixed bullet cameras, fixed dome cameras, pan-tilt-zoom cameras, panoramic cameras and thermal cameras [3]. The division where this master thesis is performed is called Fixed Dome Mechanics. At this division the treated cameras are fixed which means that they don't rotate or move after completed installation.

1.2 Problem Description

1.2.1 **Background**

The main focus of this thesis is to ensure an easy installation by redesigning the components of a P32 camera. This will be done by finding alternative assembly solutions to screws which are used in today's construction. The new way of assembling the camera without screws will also give a cleaner and bigger space within the camera for optics, electronics and other components needed. When

installing the camera today tools are required which can be problematic since they are often mounted high up and a ladder is needed to reach. Prior to the start of this thesis a part solution of the problem was made in a project called Rocky. This part solution is presented in section 3.3.1 Presented Idea.

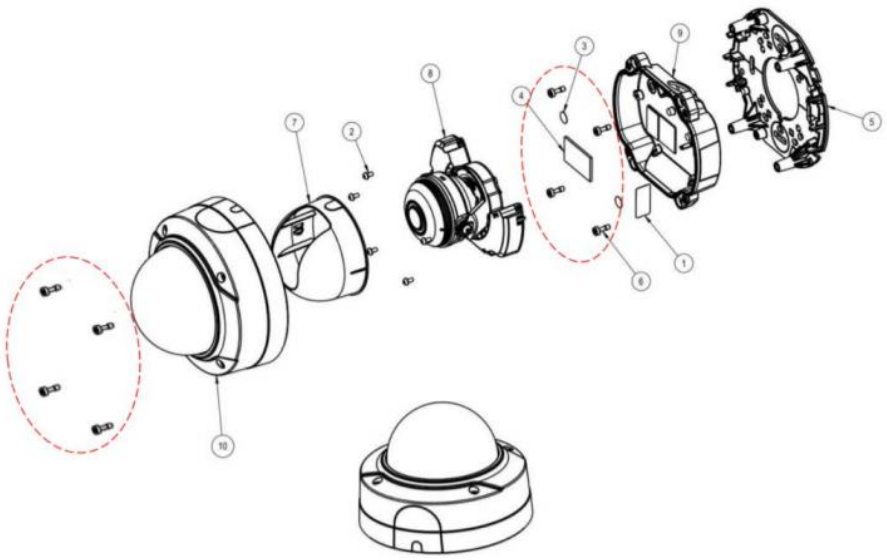


Figure 1.1 Todays construction and assembly of the current outdoor camera [4]

1.2.2 **Goals**

1.2.2.1 Main goal

The main goal of the thesis is to develop a complete solution to ensure an easy installation of the camera, both by further developing and validating existing concept and to complete with missing details. The thesis work will consist of concept development which will be validated by a lot of prototyping and testing. The result will be a working prototype demonstrating the final solution.

1.2.2.2 Change of scope

The final solution is in principle applicable for any fixed dome camera, but this thesis was set to be aimed to fit the P32 cameras that are designed for outdoor use to begin with. It was later on decided that a solution with removal of screws would be better suited for an indoor camera which resulted in further concept generation and selection aiming on the indoor camera.

1.2.3 Delimitations

The focus of this thesis is making the camera easier to assemble and install and since the optics and electrics come preassembled, no time will be spent on placing these in the new camera chassis. The part solution which came as a result from the Rocky project will be used as a starting point in the concept generation.

1.2.4 Key people at Axis

Employees at Axis that have contributed to the thesis work with their knowledge and time are listed in Table 1.1

Table 1.1 Key people at Axis

Name	Title	Role in project
Olaf Hoyer	Experienced Mechanical Engineer	Supervisor
Magnus Lundegård	Engineering Manager, Fixed Domes Mechanics	Manager
Carl-Axel Alm	Senior Expert	Idea creator and sounding board
Gustav Aronsson	Experienced Mechanical Engineer	Idea creator and sounding board
Stefan Larsson	Mechanical Engineer, consultant	Idea creator and sounding board

1.2.5 Report Disposition

The report consists of the following chapters:

Chapter 2: Methodology.

This chapter gives a brief explanation of the method that will be used to execute the thesis work.

Chapter 3: Background Research

The majority of the background research was done under the condition of using an outdoor camera. However, once the scope was changed, the background research already made was still applicable and useful. Only some new conclusions could be drawn and added to the existing ones.

Chapter 4: Product Specifications

The product specifications were gathered from the product requirement specifications of previous similar projects and by verbal communication. Only the level of the vandal-resistance changed together with the scope.

Chapter 5: First Concept Generation and Selection

The first concept generation and selection was completely made under the conditions of using an outdoor camera. The evaluation of the prototypes will show the discussion which led to the change of scope.

Chapter 6: Second Concept Generation

The second concept generation was made under the conditions of designing for an indoor camera using the first ideation as a basis.

Chapter 7: Second Concept Selection

The second concept selection leads up to the final decision with evaluation meetings and installation workshops showing prototyped concept combinations as a basis for the decision.

Chapter 8: Detailed Design

This chapter goes into explaining the reason for different features and how they work. The choice of materials and manufacturing methods are explained and how the Design for Manufacturing has affected the parts.

Chapter 9: Results

Shows every individual part of the final solution and how they interact and work with each other. The final prototype is shown and the specifications are commented. Future work advices what should be done to continue the development of this concept.

Chapter 10: Discussion and conclusion

The result will be discussed as well as the process.

Images that represent a CAD-model is either gathered from Axis database over existing products [4] or created by the authors during this thesis.

2 Methodology

This chapter presents a short description of the methodology used to complete this thesis.

2.1 Planning

The total expected time for this thesis is 20 weeks. During the first weeks a plan was made with the help of a GANTT-chart in which each phase of the project was assigned a specified amount of time and what order they were to be performed. This schedule and what resources that were available can be found in Appendix A.

2.2 Approach

The product development process will follow the method stated in *Product Design and Development* by Ulrich and Eppinger [5] as a base, but with modifications to suit the process of this assignment better.

In addition to this, the knowledge and expertise of the Axis employees will be an important source of information regarding existing products, producibility and how the design process usually works at Axis.

2.3 Background Studies

Before starting the concept development phase, a background study was performed in which the authors looked into the company, the specific camera-series, other cameras inside the company which are assembled without screws as well as competitors. The study also contained a benchmarking phase where solutions in other businesses and patents outside of Axis were explored.

2.4 Concept Development

The complete method of Ulrich and Eppinger [5] consists of a product development process that is divided into six phases where the concept development phase will be the one in focus. The concept development phase is further divided into seven phases were the first phase is to identify customer needs.

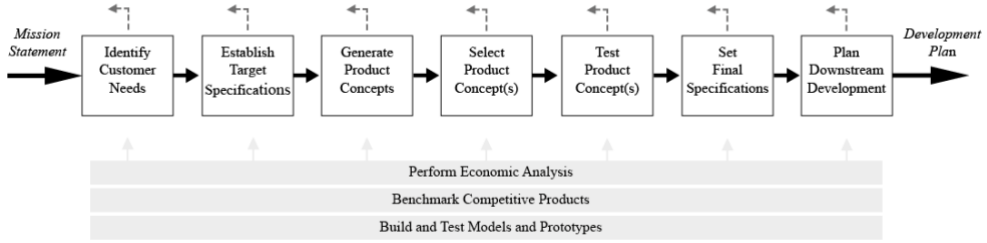


Figure 2.1 Seven phases of concept development in Ulrich and Eppinger [5]

The first steps of the product development process and concept development phase were investigated in the prior Rocky project. Therefore, some of the phases described above will not be performed in this thesis since they have already been handled or are not applicable for this specific project. Some of the phases will be modified and additional phases will be added accordingly to the process seen in Figure 2.2.

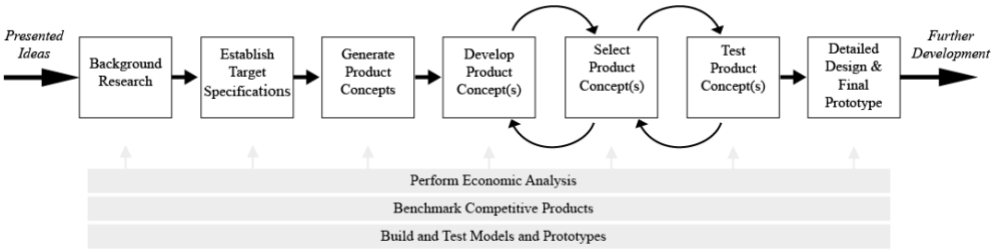


Figure 2.2 Modified version of the concept development phase

2.5 Detailed Design

When the final concept is chosen the detailed design is developed. This detailed design is presented in a later chapter where the final concept also is presented.

3 Background Study

This chapter presents information and conclusions that the background study resulted in. The studies have been carried out within Axis as well as outside of Axis.

3.1 The Camera

Axis have a wide range of different cameras and all cameras have a specific name following a name structure that consists of one initial letter followed by four numbers. The letter and the two first numbers describe the series name, also called the product family name where for e.g. P32 is a product family name.

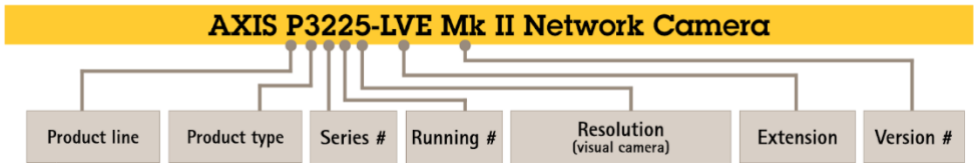


Figure 3.1 Product naming structure [7]

The fixed dome construction will be designed for the P32- camera series. AXIS P32 series consists of both day and night cameras for indoor or outdoor use and are designed to be vandal resistant and cost effective, while they should be easy to use and operate [6]. The "P" in the name stands for "Versatile and advanced video products", "3" implies that it is a fixed dome camera and "2" is the series number [7]. Figure 3.2 shows one of the cameras in the P32-series. Included in the P32-camera package, when it reaches a customer, is a mounting bracket, chassis with preassembled optics, dome and top cover which is used when the camera is mounted onto a ceiling or a wall.

Figure 3.2 Indoor version of P32 [4]

The installation of the P32-camera for outdoor use and indoor use is very similar but differs to some extent due to different materials of the mounting bracket. The outdoor camera has a bracket made from aluminum while the indoor camera has a bracket in plastic. The following steps explains the installation for both cameras and where they differ.

- When installing a P32-camera in a ceiling or onto a wall the mounting bracket is first screwed onto the ceiling or wall.
- An ethernet cable is connected to the camera unit through a drilled hole in the middle of the bracket or a pipe that is attached from the side which is called a conduit (read more about this attachment in appendix E). The camera gets its electrical power and data connection through this cable.
- The chassis and optics which comes preassembled are then attached to the mounting bracket in two different ways.
    - Outdoor camera chassis is attached by screws.
    - Indoor camera chassis is attached through snap fitting
- The dome and top cover come preassembled by screws and are attached through the camera unit into the mounting bracket with four screws, securing the chassis and optics.

3.2 Implication of the change of scope for the background study

The background study was made with the intention of following the first scope where the mounting bracket was assigned aluminum as material. This background study could still be applicable to the new scope for indoor use where the mounting bracket is assigned a plastic material. The approach on the background study is not aimed with a focus on material of the mounting bracket or the environment the camera is installed in, therefore the content of this chapter is relevant regardless of the material of the mounting bracket or differences in environment.

3.3 Within Axis

3.3.1 **The Rocky Concept**

A first idea for facilitating the installation of the camera was presented by the company and was used as a starting point for the thesis work. The idea for one of the subproblem was formed in the Rocky project and was interesting enough to further develop as a thesis work. The Rocky concept consist of an excenter lock which is integrated in the mounting bracket. The lock grabs the upper horizontal surface of the dome and locks the construction together when all components are assembled as seen in Figure 3.3.

The basic idea was to make a securing construction which assembles the components of the camera together before placing the outer cover. The concept was still on a conceptual level and needed both validation and further development to work. Details for the whole camera assembly such as solutions for putting the other components together without using screws were still to be decided. The idea was presented as a 3D-model in Creo and as a 3D-printed model of a small segment of the camera showing one of the excenter locks.

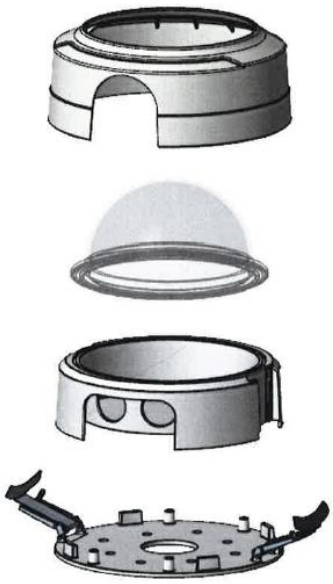


Figure 3.3 Presented concept before assembled [4]

Figure 3.4 Assembling the presented concept [4]

3.3.2 **Existing Products**

There are already several products in Axis product portfolio that are assembled without using screws, either completely or partially. They differ in design depending on different factors such as the weight of the camera, for which market it is aimed at and what kind of environment it will be mounted in. If it is supposed to be placed inside or outside, be vandal-proof or provide protection against intrusion highly affects the design and choice of material.

3.3.2.1 F1004 Bullet

Without using any screws, the complete Bullet is assembled by using different snap fits. The camera is small and compact and feels robust. Once the positioning of every small piece has been identified it is easy to install. The smart construction works since every piece is made from plastic and flexes. “AXIS F1004 Bullet Sensor Unit has a highly compact bullet-style design for easy and discreet installation” [8]. This construction can be used as an inspiration.

Figure 3.5 Axis F1004 Bullet [4]

3.3.2.2 Hedwig M31

Hedwig is a small camera that uses threads to close the camera unit. After placing the glass, it is fixed by twisting a ring on top of it [9].

Figure 3.6 Hedwig M31 [4]

3.3.2.3 Super Fish

This project provided a solution for attaching one metal piece to another without using screws by making an external plastic clip to put into the mounting bracket instead of incorporating it in the construction from the beginning. Since the plastic flexes it can be snapped into a pocket in the bracket and stay in position so the

chassis can be snapped into place. It is a good solution when there is a need to snap two metal parts together and it will be further explored.

Figure 3.7 Plastic clip attached to aluminum bracket

3.3.2.4 Bastian M30

The Bastian camera is a small camera with a fisheye lens within the Falcor product family [10]. The top cover is attached by using a bayonet solution. Small spikes (a) in the cover matches tracks (b) in the chassis so that it is placed correctly at first, when twisting, another bump (c) is passed over a bulge (d) and snaps into place. It is an interesting solution to look closer at and it could be applied to the P32 camera.

Figure 3.8 Bastian M30 [4]

3.3.2.5 Q32

The Q32 camera uses a bayonet solution between the mounting bracket and an additional mounting pipe. The mounting bracket has three spikes and the pipe has three matching openings with tracks so it can be rotated into the right position. It is quite tricky to match the spikes to the openings but it is still seen as a potential solution for one of the subproblems and could be modified to fit the thesis problem.

3.4 Outside of Axis

The background research outside of Axis consists of different benchmarking sessions and a patent search that boiled down to an identification of different types of solutions that could be of interest.

3.4.1 **Benchmarking**

The benchmarking can be divided into how competitors in the surveillance business install their cameras today and in which other markets solutions could be found.

3.4.1.1 Competitors

The big majority of dome cameras from competitive companies also use screws as the assembly method even though they differ in construction from each other.

3.4.1.1.1 Cisco Video Surveillance

The only alternative solution was found in the “5010/5011 network dome camera” which is a fixed dome camera from Cisco Video Surveillance [11]. It uses magnets to attach the dome liner and then clicking latches to lock the lower dome.

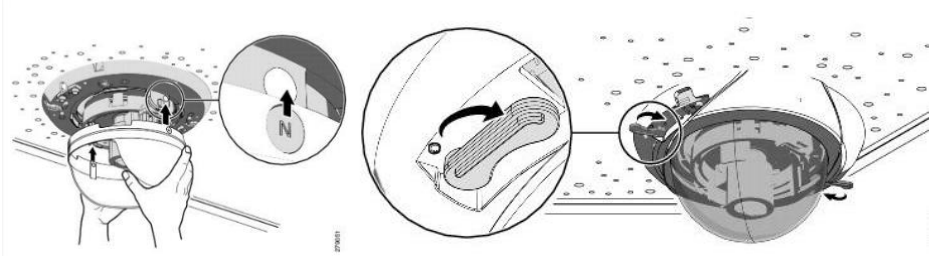


Figure 3.9 Assembling Cisco Video Surveillance camera [11]

3.4.1.2 Other markets

When looking at other markets, the focus can be divided into different parts. First different ways of assembling products without using screws and then how locking and tightening mechanisms are used.

3.4.1.2.1 Assembling

Kitchen products

Many products used in the kitchen exist of several parts that can be put together in a modular way. The most common assembly method that was found is a bayonet solution where you first place and then twist to lock two components together. There are also different security options where many products such as mixers have a barrier that secures that the product cannot be used unless it has been twisted into the right place.

Figure 3.10 Modular kitchen product [12]

Camera lenses

Cameras that have changeable lenses use a bayonet solution most of the time but other solutions like threads and breach locks can also be found on the market. Metal flanges in both the lens and the camera house hook together with a twisting movement. There is a security lock that clicks when the lens is in the right position so the space is sealed and you need to press a release button to remove the lens again.

Figure 3.11 Bayonet on Cannon camera [13]

Toys

There are many modular toys available on the market and an example of this is LEGO where the main principle of the toy is to have an easy assembling and disassembling method to be able to build different shapes and structures. LEGO uses press fitting to put the different pieces together which works for plastic parts.

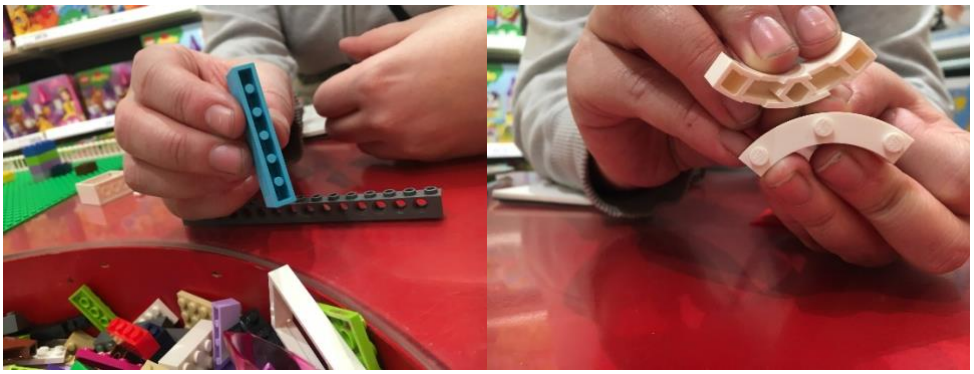


Figure 3.12 LEGO

3.4.1.2.2 Lock

Bottles and jars

A classic example of a lock is the “grandmother jar”, using a simple excenter lock made of steel thread. It is a common construction which is self-locking and with a gasket for making tight closure for bottles and jars that need to keep the inside secured from air. The examples shown is from the IKEA series KORKEN [14] and the simplicity and intuitive design is desirable for this project as well.

Figure 3.13 IKEA KORKEN [14]

Vehicles

To tighten and lock different parts in cars and boats, excenter locks are often used. On a trailer an ordinary excenter lock is used to tighten and close the roof or door. Same application can be used in boats which gives a robust feeling and a robust seal of a construction even if it’s exposed to water and wind.

Figure 3.14 Excenter lock on trailer

Watches

An example of tightening something in an everyday situation is to put on your watch. There are many different assembly types that are used but many of them include parts being folded over each other. It is an interesting and different source of inspiration for the development of the lock.

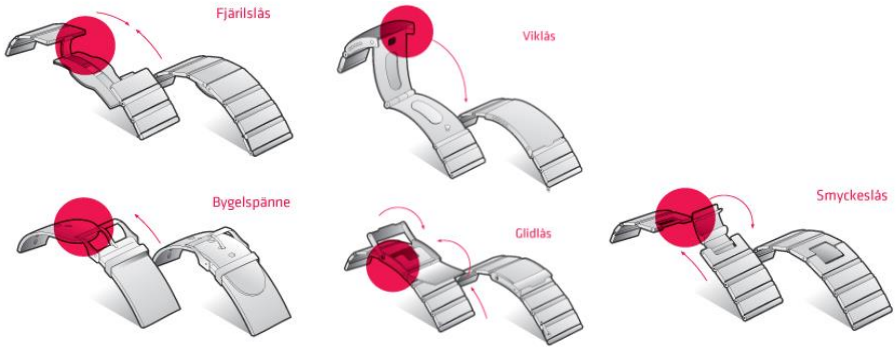


Figure 3.15 Different ways to lock a watch [15]

Ski boots

A ski boot is very stiff, it needs to be wide open to get the foot in and at the same time it needs to be very tight around the foot and leg while skiing. An excenter lock is used because it is easier to create the force with the hands by using the lever and when sealed it takes a lot of power to unlock it. The excenter lock in the ski boot differs a bit from the original excenter lock since it also contains a spring to flex back to its original position.

Figure 3.16 Ski boot with spring

3.4.1.3 Conclusions

There are a huge number of products using different types of assembling methods and even though many use the same basic idea they are all modified to fit in a certain construction and environment. A big challenge with the outdoor camera is the fact that the bracket mount and the chassis are made from aluminum which does not flex. To be able to use the methods which are built around flexing parts, external plastic parts might have to be inserted. If the construction is made for indoor use the bracket is made in plastic which gives more freedom of using flexing details.

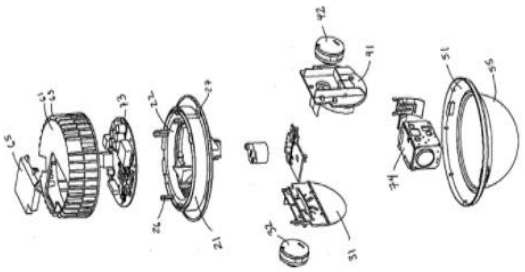
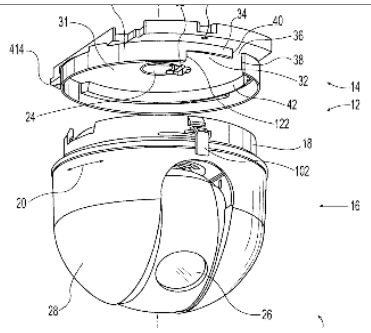
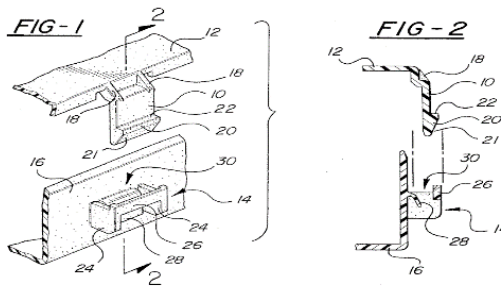
Cameras found at competing companies almost exclusively use screws when installing the camera. The only exception found was a Cisco Video Surveillance camera which uses magnets and latches to assemble the camera. This gives Axis a good opportunity to create a new product which is unlike from anything else available today.

3.4.2 **Patents**

To look further which other existing solutions exist on the market, a patent search was made. The patent search showed different assembly solutions such as snap fits, bayonet, hooks and thread solutions.

The patent search showed that the most common solution to assemble a camera without screws is a snap fit solution or a bayonet solution. Different snap fit solutions are applicable where the snap fit can be placed on the outside of the camera walls or the inside of the walls. Different bayonet solutions are also applicable on the camera were two pieces can be assembled in different ways. One is using a coupling element fixedly mounted to a surface and adapted to provide at least two degrees of rotational freedom and one is using hooks to attach the two pieces. A selection from the patent search can be seen in Table 3.1.

Table 3.1 A selection from the patent search

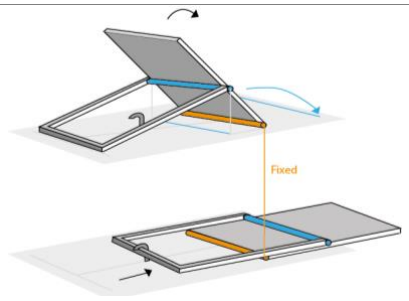
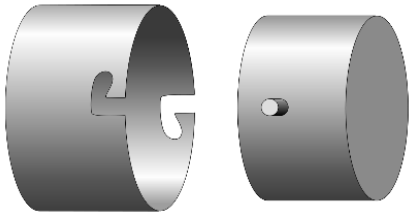
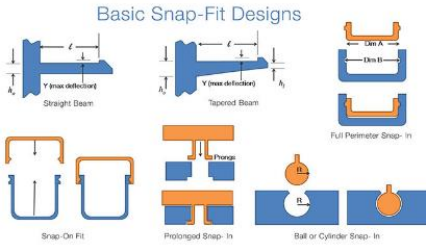
	A camera mounting structure with parts attached together using locking tabs, boss register and clips. Motors are attached by pins (26) that corresponds to slots on support brackets for positioning. A rotatable ring (61) locks the motors [16].
	The camera head is attached to the camera head base with a rotation relative to the mounting frame. A bayonet (34) catches the camera head base (18) and they are coupled through a hook (102) on the mounting frame [17].
	An elastic tab (10) extends outwardly from the second component and into the locking frame opening (30) and is deflected upon insertion of the locking arm into the locking frame opening and maintains the locking arm in a secure engagement [18].

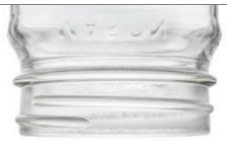
3.4.3 **Different types of assembly constructions**

After looking at different products and principles of assembly methods the most common methods were excenter locks, bayonet and snap fits. There are also many other good assembly methods to get inspired by and use in this project. A summary

of different common assembly methods which have been identified have been put together and are presented in Table 3.2.

Table 3.2 Different types of assembly constructions

Excenter lock		The basic function of an excenter lock is built around two axes changing place, and thereby tightening a construction.
Reversed excenter lock		Works with the same principle as the usual excenter lock but the lever closes the opposite direction. This is the type of lock that was used in the Rocky concept. Picture: [19]
Bayonet mount		This is an attachment method that has one male side with pins standing out and one female receptor with a matching track shaped like the letter L. The male side is placed in the track along the part and then twisted, locking the parts from being separated again. Picture: [20]
Snap fit		The principle of snap-fits is based on the flexibility of the material the snap- fit is made of. To be able to use a snap-fit the material therefore requires flexibility. There are different types of snap- fits but the most common one is the one with a straight or tapered beam Picture: [21].
Hooks with spring		The principle is using a spring to force the movement of the hooks to clamp a component under the hook. Picture: [22]

Threads		Attachment method where two components are assembled by rotation with threads. Picture: [23]
Interlocking		The principle of interlocking is to assemble parts in a way where all directions get locked by each other and then get locked with a final locking part. Picture: [24]

4 Product Specifications

In order to make sure that the final product fulfills the requirements a list of product specifications was made and this chapter covers how these were set up.

4.1 Introduction

Product specifications are set up to give more specific and clear guidance. They are a translation from the customer needs, which can be a bit more subjective, into measurable details. While the customer needs tell the team what the product needs to do, the product specifications should tell the team how to address the customer needs [5]. This section will result in a list of target specifications which contains the metric, ideal value and a value describing the importance of the need since some needs are necessary while others are only desirable.

4.2 Method

The method used for this project follows the proposed method from Ulrich and Eppinger [5] and is completed in the following order:

- Prepare the list of metrics.
- Collect competitive benchmarking information.
- Set ideal target values.

Since this thesis is a continuation of previous projects at Axis, where more research regarding the needs has been done, many of the specifications should be applied to this project as well. The specifications have primarily been gathered from the Product Requirement Specifications (PRS) from Rouge [25] which is the forerunner

to the project Rocky. The specifications that are relevant to this project are presented in Table 4.1 and marked with the source (PRS) and the list is completed with specifications for the new problem description that have been communicated to the authors by the employer.

4.3 List of Specifications

The metrics which have values that are measurable will be validated by discussion and testing of the solutions at Axis.

Table 4.1 List of target specifications

No.	Ref	Metric	Imp.	Units	Ideal value
1	(PRS)	Label with serial number visible under lid	5	Binary	Yes
2	(PRS)	Ease of installation (allow use of WIT)	5	Binary	Yes
3		Time difference to complete mounting (without cables) compared to P32	5	%	-40
4	(PRS)	Product design shall follow Axis Design Guidelines	5	Binary	Yes
5	(PRS)	Product cover shall be able to be removed and replaced	5	Times	>20
6	(PRS)	Vandal-resistant according to IK8*	5	Binary	Pass
7		Securing lock does not exceed outer bracket diameter	5	Binary	Yes
8		Design allows securing lock to press parts together	5	Binary	Yes
9		Chassis carries its own weight before secured	5	Binary	Yes
10		Dome carries its own weight before secured	5	Binary	Yes
11		Intuitive design	4	Subj.	-
12		Tools required at installation **	4	NO.	0
13		Screws used for assembly **	5	NO.	0
14		Dome can be placed at any angle	3	Binary	Yes
15		Contain entering for cables	5	Binary	Yes
16		Robust feeling	4	Subj.	-
17		Distance between bracket and chassis for cables to pass	4	mm	8

*The vandal-resistance for outdoor version is higher (IK10)

** Number after mounting bracket is installed on surface.

5 First Concept Generation and Selection

This chapter covers the decomposition of the problem, solutions for each sub problem (sub solutions) and combinations of the sub solutions into concepts.

5.1 Introduction

To design and develop a product could be difficult if the whole product is treated as one problem. Therefore, the main problem has been divided into four sub problems to simplify the task. These sub problems are treated separately at first and then combined with the other sub problems. The four sub problems are described in the section 5.3 Problem Decomposition.

5.2 Method

To start the concept generation, a brainstorming session was held where the former concept Rocky was considered. A selection of sketches and explanations from this first brainstorming can be found in Appendix B. With the Rocky concept as the starting point, a problem decomposition was made dividing the main problem into sub problems. To generate concepts for each sub problem the background study was used as inspiration where different assembly and product solutions were presented. The three first sub problems were generated simultaneously and concepts for sub problem 4 was generated afterwards.

After discussion with colleagues at the company a concept screening was made according to Ulrich and Eppinger [5]. Some of the concepts generated were not feasible and could be discarded before the concept screening. The reason for

discarding them is described in section 5.8 Systematic exploration. The remaining concepts after the concept screening were combined and three concept combinations were selected in which all sub solutions were represented.

The concept combinations were made into models and resulted in an evaluation of the different sub problems in form of a meeting with experienced colleagues at Axis. Input from the meeting contributed to choosing which solutions should be further developed and which should not. It also contributed to the decision of changing the thesis scope from making an outdoor version camera to making an indoor version instead. The input from the evaluation meeting that led to the change can be found in Appendix C.

5.3 Problem Decomposition

The main problem was divided into four different sub problems to have different focus points during the development process. The division was made accordingly to the different interfaces between the parts of the camera and numbered in the order they are performed during the installation. The identified interfaces can be seen in Figure 5.1 and described in Table 5.1.

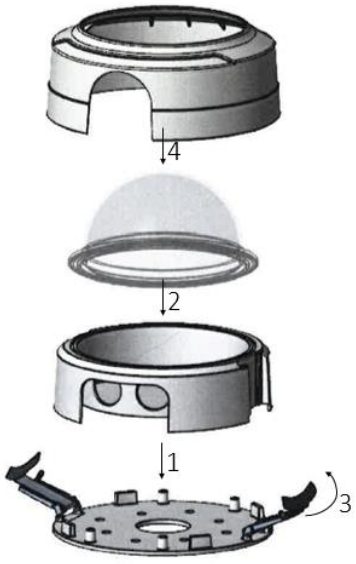


Figure 5.1 Sub problems 1-4 [4]

Table 5.1 Sub problems 1-4

Sub problem	Interface
1	Chassis to mounting bracket
2	Dome to chassis
3	Locking bracket, chassis and dome together
4	Top cover to the rest of the camera

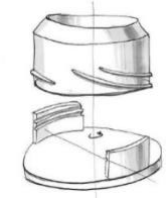
Sub problem 1,2 and 3 interacts but does not depend on each other and one solution can be combined with another without affecting the functionality of the other. To get a better overview of the complete solution, subproblem 1, 2 and 3 are developed parallel and to only get the best combinations a screening of subproblem 1, 2 and 3 were made before combining them. Sub problem 4 is treated separately. All sub problems were discussed individually first, without consideration to the others and with less focus on sub problem 4.

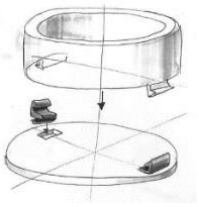
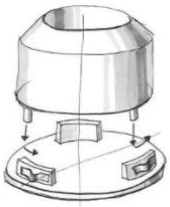
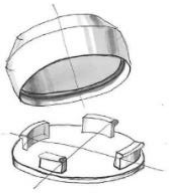
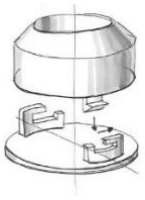
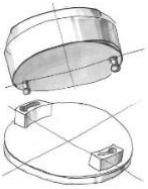
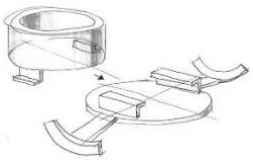
5.4 Sub Problem 1

Sub problem 1 is describing the chassis being mounted onto the mounting bracket. Sub solutions can be seen in Table 5.2.

The starting point for this ideation was that both parts were made from aluminum which created the problem that neither of the parts flexed. Other important factors to consider were that there should be 8 mm between the bracket and chassis for cables and ventilation, it needs play so the lock presses the chassis against the bracket and the chassis should be able to carry its own weight after being mounted.

Table 5.2 Solutions to sub problem 1

Concept	Assembly Type	Description	Picture
1A	Threads	Threads all the way around	

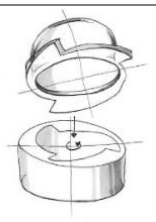
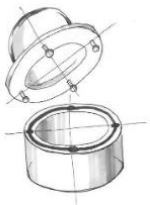
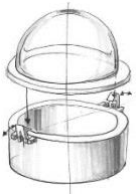
1B	Snap fit	Snap fit where the clip is a small plastic piece that is attached to the metal bracket by another snap fit.	
1C	Snap fit	Snap fit on the side of walls on the bracket. Spikes from the chassis is rotated into the snaps.	
1D	Snap fit	Protrusion and groove on the inside of the chassis	
1E	Bayonet	Peg on the chassis connecting it to a track on the bracket	
1F	Bayonet	Teeth connecting bracket and chassis	
1G	Sliding Pegs	Tracks on the bracket. Sliding the chassis into the bracket tracks.	
1H	Bayonet	Tracks on mounting bracket. Sliding the chassis in while twisting it	

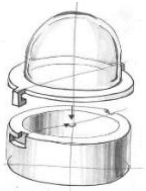
5.5 Sub Problem 2

Sub problem 2 describes the interface between the chassis and the dome. Sub solutions can be seen in Table 5.3.

It is desirable that the dome is rotational symmetrical so it can be placed in any angle, giving the customer more freedom to install it the way that suits them the best. Just as in sub problem 1, there needs to be play and a free upper surface so the dome is in contact with the lock and pressed down. The dome should also leave room for a gasket and carry its own weight.

Table 5.3 Solutions to sub problem 2

Concept	Assembly Type	Description	Picture
2A	Bayonet	Wings in the horizontal direction, matches the upper side of the chassis so the dome can be placed beneath the first surface. When the dome is rotated, the surfaces doesn't match anymore and it is locked from falling	
2B	Bayonet	Teeth in the vertical direction that matches holes on the upper surface of the chassis so it can be placed. When the dome is rotated the teeth goes into slimmer tracks and is locked.	
2C	Press fitting	Inspired by LEGO. By just pushing the parts together the friction will keep it up	
2D	Hooks with springs	Spring hooks on chassis that wants to stand straight up. When the dome is pushed on to the chassis they flex out and goes back when it is in place. To dismantle you must drag the hooks out yourself.	

2E	Threads	Threads all the way around	
2F	Magnets	Magnets attaching the parts together. One of the parts has a magnet that goes all around making it possible to rotate dome as much as you want to	
2G	Hooks	Rotational assembly where a fixed hook on the dome attaches to a track in the chassis.	

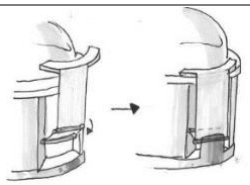
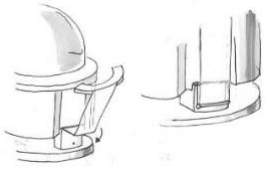
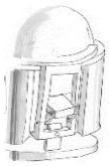
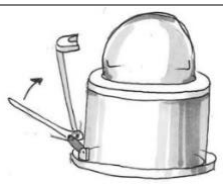
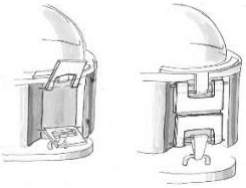
5.6 Sub problem 3

Sub problem 3 describes the lock that will secure and press the camera together. Solutions to the sub problem are presented in Table 5.4.

The ideation used the excenter lock from the Rocky project as a starting point. Things to consider were the fact that it is load bearing and should be easy and intuitive. When closed it should be robust and not go outside of the bracket disturbing the top cover.

Table 5.4 Solutions to sub problem 3

Concept	Description	Picture
3A	Jam can principle, the lock needs to be attached to the mounting bracket somehow	

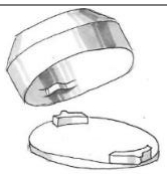
3B	Jam can principle, wall is designed to be flat when the lock is locked and there is more room for grip when demounting. The lock is attached to the mounting bracket.	
3C	Folding lock attached to the chassis with a snap fit at the mounting bracket	
3D	Folding lock attached to the mounting bracket where the chassis is resting to keep 8mm between chassis and bracket	
3E	2 axes connected by small mounting brackets. Attached to chassis by small extrude that moves through the hole of the arm so that the axes can switch direction.	
3F	Rocky: 3 axes, working as a reversed excenter lock. Correct the length of the arm and the links to make the compression better than the original.	
3G	Rocky with springs: Spring pushes the lock towards locked mode	
3H	Two-way excenter lock locking the dome and the mounting bracket separately.	

5.7 Sub Problem 4

Sub problem 4 describes the last step of the installation, placing the top cover, and has not been given as much time as the previous sub problems. Some sub solutions can be seen in Table 5.5

The outside of the camera should remain the same as todays version. The biggest challenge with sub problem 4 is to have an easy way of snapping it on, but at the same time, make it vandal-proof and hard for somebody else to remove it.

Table 5.5 Solutions to sub problem 4

Concept	Assembly Type	Description	Picture
4A	Snap fit	Snap fit where a suitable number of hooks are placed on the mounting bracket and an edge goes along the inside of the cover and snaps over the hook.	
4B	Hooks	Track in the chassis where the cover is mounted	
4C	Bayonet	Two different tracks in the mounting bracket where one keeps the top cover on place in z-direction and one gives feedback in rotational direction.	

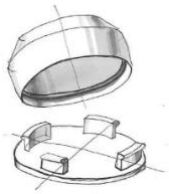
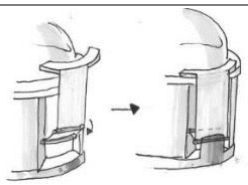
5.7.1 **Implication of the change of scope for sub problem 4**

This will be the final section regarding the top cover development due to an already existing concept in a parallel project. Also, a future delimitation mentioned in section 5.11 contributed to no further development regarding sub problem 4.

5.8 Systematic Exploration

To exclude the unfeasible solutions and reduce the number of solutions a first screening procedure was made. Table 5.6 below shows which solutions were discarded and why. The decisions to exclude solutions were done through discussions between supervisor and the authors of the thesis.

Table 5.6 Excluded solutions

Concept	Picture	Reason why excluded
1D		Once this is mounted it won´t be possible to demount it without destroying it. Demounting must be possible, even if it is very seldom.
2F		Magnets are often expensive. This problem demands a good robust construction and impression and magnets does not provide this.
3A		The concept does not fulfill the need for the surface of the chassis to be smooth since a small handle is sticking out. This will disturb when snapping a potential top cover on.
3C		The solution did not attach the chassis to the mounting bracket in any good way and was therefore excluded, it did work as a starting point for other concepts though.

5.9 Screening concepts

For further selection a concept screening matrix was prepared with selecting criteria inspired by the list of specifications in Table 4.1 in combination with what has been communicated as important by the company. Different selecting criteria

affect different sub problems and are described in Table 5.7. Some criteria affect all three sub problems simultaneously while some criteria are more specific and affect a specific sub problem.

Table 5.7 Selecting criterion

Selecting criterion	Sub problem	Explanation
Easy installation	1, 2, 3	Easy installation requires no tools and no experience, it should be easy to install even if it is high up in a ceiling.
Intuitive design	1, 2, 3	The camera should be designed in such a way that you know how to install it even if it is the first time with no need for manuals or explanations
Innovation height	1, 2, 3	The solution is preferably different from existing cameras at Axis so that they expand their product portfolio.
Demounting	1, 2, 3	It should be possible to demount the parts of the camera, but at the same time, it can`t be too easy either.
Robust impression	1, 2, 3	A more robust construction shows quality in the customers´ eyes, especially on the American market which is a big one for Axis.
Feasible manufacturing	1, 2, 3	The construction should be able to be produced in a big scale with a suitable manufacturing method. Material, number of parts and their complexity are considered.
Feasible construction	1	The possibilities of fulfilling the criteria mentioned before the ideation in section 5.4
Closed space	2	The dome and the chassis should be tight so that no water or dust can reach the optics and electronics. For example, access to a surface to push the dome down.
Rotation symmetrical dome	2	The possibility to place the dome in angle. This is preferable but not a must and will therefore not solely exclude a concept.
Ergonomic	3	The lock should be easy to handle both at single and multiple installations.
Compression function	3	The lock should press the mounting bracket, chassis and dome together and keep the pressure constant.

When doing a screening matrix, a reference solution is used to which every new solution is compared. The reference in this case is the original camera, meaning that sub problem 1 and 2 is compared to the current camera with screws and sub problem 3 is compared to the presented concept from Rocky. If the concept is considered better than the reference it is marked with a (+), if it is equal to the reference it is marked with a (0) and if it is considered worse it is marked with a

(-). In Tables 5.8, 5.9 and 5.10 the evaluations of the remaining solutions for sub problem 1, 2 and 3 are presented. The ones marked with a (Y) are considered worth continuing with.

5.9.1 Sub Problem 1

Table 5.8 Screening matrix sub problem 1 (Y= yes, N=no)

Selection criterion	***Ref***	**1A**	**1B**	**1C**	**1E**	**1F**	**1G**	**1H**
Easy installation	*0*	0	+	+	0	0	+	+
Intuitive design	*0*	+	+	+	0	+	+	+
Innovation height	*0*	0	+	+	0	0	+	+
Demounting	*0*	0	-	+	+	0	+	+
Robust impression	*0*	0	0	-	-	0	0	+
Feasible manufacturing	*0*	0	+	-	+	0	+	0
Feasible construction	*0*	0	0	-	+	0	+	+
Sum +	*0*	1	4	4	3	1	6	6
Sum 0	*7*	6	2	0	3	6	1	1
Sum -	*0*	0	1	3	1	0	0	0
Net score	*0*	1	3	1	2	1	6	6
Rank	*5*	4	2	4	3	4	1	1
Continue?		N	Y	N	N	N	Y	Y

The three chosen sub problems to continue with all got good result in easy installation and intuitive design which was important criteria. Robust impression was also an important criterion which sub solution 1H was superior in. This combined with good result on other criteria contributed to a good total grade for these sub problems.

5.9.2 **Sub Problem 2**

Table 5.9 Screening matrix sub problem 2 (Y= yes, N=no)

Selection criterion	***Ref***	**2A**	**2B**	**2C**	**2D**	**2E**	**2G**
Easy installation	*0*	0	-	+	+	0	+
Intuitive design	*0*	+	+	+	+	0	+
Innovation height	*0*	0	0	+	+	0	0
Demounting	*0*	-	0	+	+	0	+
Robust impression	*0*	-	-	0	0	0	+
Feasible manufacturing	*0*	-	-	-	-	0	-
Closed space	*0*	-	+	+	+	-	+
Rotation symmetrical dome	*0*	+	+	+	+	0	0
Sum +	*0*	2	3	6	6	0	5
Sum 0	*8*	2	2	1	1	7	2
Sum -	*0*	4	3	1	1	1	1
Net score	*0*	-2	0	5	5	-1	4
Rank	*3*	5	3	1	1	4	2
Continue?		N	N	Y	Y	N	Y

The three chosen sub problems to continue with for subproblem 2 also got good result in easy installation and intuitive design. Rotationally symmetrical dome is a special criterion for sub problem 2 and is therefore looked at specially. Sub problem 2C and 2D got a good result for this criterion while sub problem 2G didn't distinguish from the reference. However, sub problem 2G got a good result on robust impression. This combined with good result on other criteria contributed to a good total grade for these three sub problems which were chosen to continue with.

5.9.3 **Sub Problem 3**

Table 5.10 Screening matrix sub problem 3 (Y= yes, N=no)

Selection criterion	***Ref***	**3B**	**3D**	**3E**	**3F**	**3G**	**3H**
Easy installation	*0*	0	0	0	0	+	-
Intuitive design	*0*	+	0	0	0	+	0
Innovation height	*0*	0	0	+	0	+	+
Demounting	*0*	0	0	+	0	+	0
Robust impression	*0*	0	0	+	0	+	+
Feasible manufacturing	*0*	0	0	-	-	0	0
Ergonomic	*0*	-	-	-	0	+	0
Compression function	*0*	+	+	-	+	+	0
Sum +	*0*	2	1	3	1	7	2
Sum 0	*8*	5	6	2	5	1	5
Sum -	*0*	1	1	3	1	0	1
Net score	*0*	1	0	0	0	6	1
Rank	*3*	2	3	3	3	1	2
Continue?		Y	N	N	N	Y	Y

The three chosen sub problems to continue with for sub problem 3 were all quite similar to the reference. Sub problem 3G, where the existing solution from rocky was modified got ranked highest and was superior in this screening. Sub problem 3B and 3H were ranked same but an overall good total grade for all three sub problems contributed to a continuation with these solutions.

5.10 Combinations

Combining all subproblems that passed through the screening process gives a high number of combinations. Since there are three sub solutions for every sub problem, three complete cameras can be combined where every sub solution is unique. To evaluate all subproblems, three combinations are chosen for evaluation and the important thing is to choose so that every sub solution is represented. An overview of the process can be seen in Figure 5.2. The three chosen combinations,

combination C, M and Z together include all sub problems to represent all sub solutions and can be seen in Figures 5.3-5.5. The evaluation will mainly focus on each sub solution separately. To make it easier to prototype and to get the relation to other parts, they should still be tested in a complete camera. Therefore, the combinations were made.

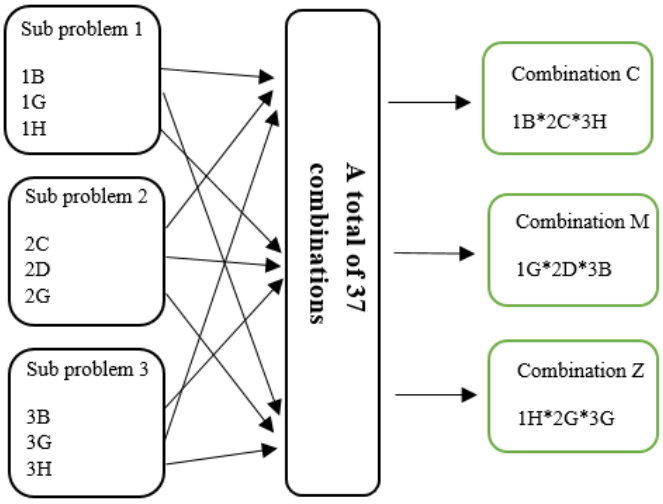


Figure 5.2 Combination tree of the three chosen combinations

Concept combination C showed in Figure 5.3 constist of sub solutions 1B*2C*3H. The chassis is assembled through a snap fit onto the mounting bracket and the dome is assembled through press fitting to the chassis. The lock is attached to the mounting bracket on the bottom and to the dome on the top.

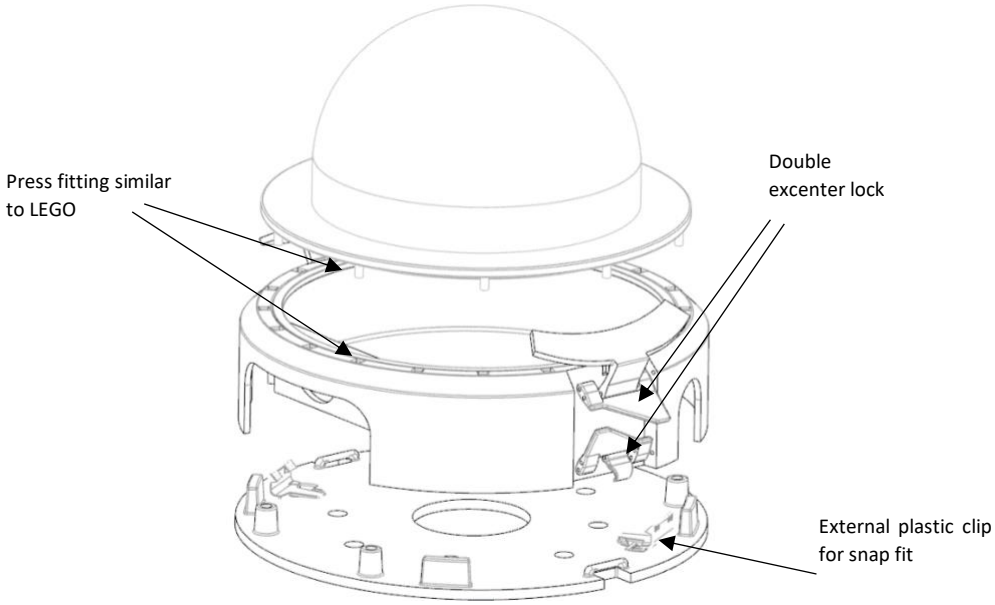


Figure 5.3 Concept combination C

Concept combination M, showed in Figure 5.4 constist of sub solutions 1G*2D*3B. The chassis is assembled by sliding into a bayonet on the mounting bracket and the dome is assembled by snap fits with spring to the chassis. The lock is attached on top of the dome.

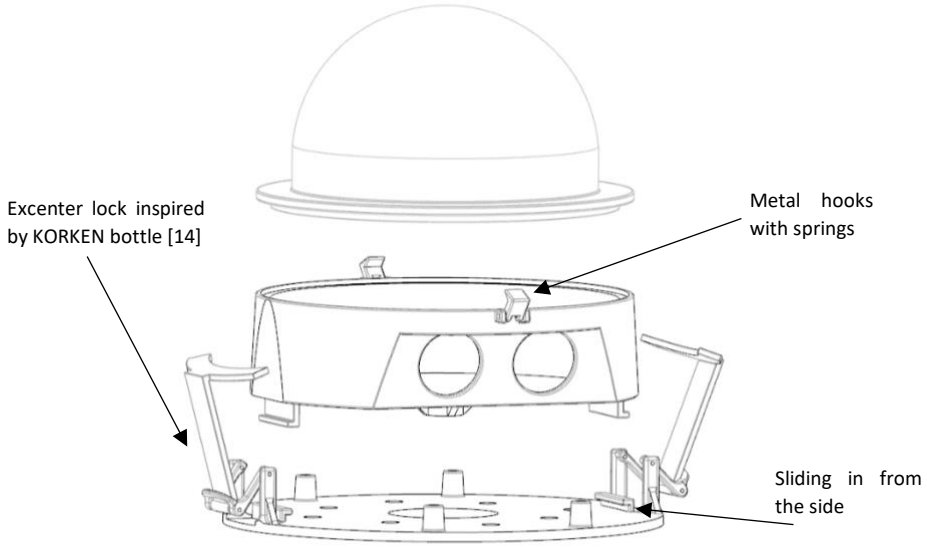


Figure 5.4 Concept combination M

Concept combination Z, showed in Figure 5.4 constist of sub solutions 1H*2G*3G. The chassis is assembled by rotating into a bayonet on the mounting bracket and the dome is also assembled by rotatating into a bayonet on the chassis. The lock is attached on the top of the dome.

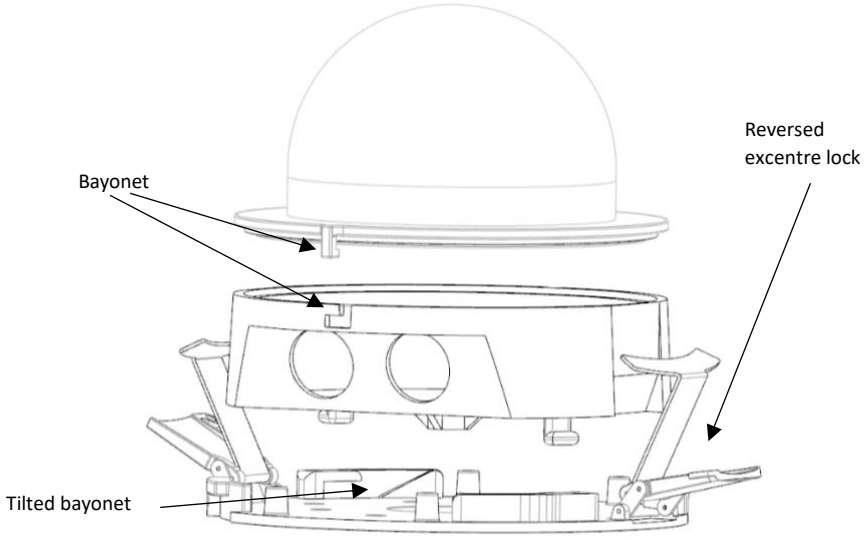


Figure 5.5 Concept combination Z

5.11 Evaluating Concept Combinations

5.11.1 **Setting**

To evaluate the subproblems the three combinations were presented to five Axis employees, Olaf Hoyer, Magnus Lundegård, Gustav Aronsson, Carl-Axel Alm and Stefan Larsson. The combinations were presented at a meeting where all participants got to evaluate each sub problem separately. The questions to be answered were which sub problems should be discarded and which ones should be further developed. The result is presented in Table 5.11 and the notes from the meeting that led to these decisions can be found in appendix C.

5.11.2 **Conclusion**

Table 5.11 Results from meeting

		C		M		Z
Sub problem 1	*1B*	Further develop	*1G*	Discarded	*1H*	Further develop
Sub problem 2	*2C*	Discarded	*2D*	Further develop	*2G*	Discarded
Sub problem 3	*3H*	Discarded	*3B*	Further develop	*3G*	Discarded

The sub problems were discussed somewhat separately and it was quite clear which ones were the favorites to continue to develop together with coming up with new ideas. It was decided that a bayonet felt robust for sub problem 1. However, some sort of feedback for when the chassis is placed correct was missing. Therefore, both the bayonet (1B) and the snap fit (1H) was left to be further developed and maybe combined.

The hooks with springs for sub problem 2 (2D) were considered good but too expensive. Therefore, it will be considered to use a similar external plastic clip as in sub solution 1H for sub problem 2 as well. It was also discussed if it was necessary to have a solution for sub problem 2 or if it is possible to hold the dome with one hand during the installation. This is something that must be further considered and compared to the snap fit. Another idea was that the locks would move inwards when the dome is placed and therefore, hold it up. At last, the most classical excenter lock (3B) will be further developed.

5.11.3 **Change of Scope**

The meeting also resulted in a discussion around the fact that a camera for outdoor use has high vandal-resistance requirements. Even if it would be possible to make a construction strong enough, it was decided that the psychological aspect of trusting the robustness of a camera without screws was too hard to overcome. Therefore, it was decided to change focus to an indoor camera from this point on. It was also decided to not move forward with developing a solution for sub problem 4, since this problem is currently being investigated in another project. The main changes that come together with the change of scope are:

- Vandal-resistance lowered from IK10 to IK8
- Mounting bracket is now made of plastic instead of aluminum
- No further development of the top cover

6 Second Concept Generation

This chapter covers further development and combinations of the sub problems.

6.1 Introduction

Concepts that passed through the evaluation in chapter five need to be further developed and adapted to the change of scope. The change of material of the mounting bracket, outdoor to indoor usage and ideas for further development from the evaluation meeting are taken into consideration in this second concept generation.

6.2 Method

To move forward, a new but limited idea generation was made with the evaluation of the first concepts, the change of scope providing new materials and feedback from the evaluation meeting as a basis. After further discussion, some of the ideas could be discarded due to compromising the robustness of the camera, these can be seen in section 6.6 Systematic Exploration.

A concept combination table was made were all possible combinations can be seen. Four combinations which contained all the sub solutions were chosen based on the possibility of integrating the concepts with each other. Two combinations were prototyped to be used in an installation workshop. By prototyping two of the chosen combinations, an opinion could be formed about all four combinations by analyzing every installation step separately as well. The four combinations can be seen in section 6.7.2 Combinations.

6.3 Sub Problem 1

Sub problem 1 is describing the chassis being mounted onto the mounting bracket. Sub solutions can be seen in Table 6.1.

For the second generation, the starting point was changed to the bracket being in plastic and the chassis aluminum. This gives the opportunity to take advantage of the plastics flexing ability.

Table 6.1 Solutions to sub problem 1

Concept	Assembly Type	Description
1AA	Bayonet & Snap fit	The evaluation meeting resulted in developing a bayonet with feedback in form of a snap fit integrated in the bayonet.
1BB	Snap fit	Changing the material of the bracket opened up for using a snap fit. Inspired by F1004 Bullet described in section 3.3.2.1

6.4 Sub Problem 2

Sub problem 2 describes the interface between the chassis and the dome and sub solutions can be seen in Table 6.2.

The circumstances for the sub problem have not changed. However, the question about the user holding the dome with one hand while installing have been raised and should be investigated.

Table 6.2 Solutions to sub problem 2

Concept	Assembly Type	Description
2AA	Handheld	To hold the dome with the hand while securing the locks should be evaluated.
2BB	Pressed	Integrate an extra feature in the locks so that when the dome is placed, the locks moves inwards and holds the dome in place before they are locked.
2CC	Snap fit	Using hooks as in concept 2D, but as an external flexing plastic clip instead of springs and hooks.
2DD	Rubber loop	Make loops in the rubber gasket that can be pulled around pegs on the chassis.

6.5 Sub Problem 3

The first concept generation and evaluation resulted in the decision to continue with lock 3B, seen in section 5.11 Evaluating Concept Combination. For sub problem 3, no big changes will be made in this concept generation. Small changes to existing concept will be made to make it more robust and intuitive by adding material and signifiers [26]. A variation of lock 3B is made where one of the parts and three axes are replaced by one single bent wire, to make it easier to manufacture

Table 6.3 Solutions to sub problem 3

Concept	Assembly Type	Description
3AA	Excenter lock, axes	The same excenter lock shown in chapter 5 as solution fraction 3B.
3BB	Excenter lock, wire	The same principle as the first lock, however, somewhat simplified with less parts and fine mechanics by replacing parts with a bent wire.

6.6 Systematic Exploration

To exclude the unfeasible solutions a first screening procedure was made. Table 6.4 shows which solutions were discarded and why. The decisions to exclude solutions were done through discussions between supervisor and the authors of the thesis.

Table 6.4 Excluded solutions

Concept	Reason why excluded
2BB	The concept was investigated but to get the desired function, it became too complex to be worth continuing with, in comparison to the extra feature you would gain.
2DD	Since sealing the inside of the camera is an important requirement, it was decided that using the gasket was too big of a risk to continue with.

6.7 Combination of Concepts

Combinations of the remaining concepts were made to get complete solutions to test and evaluate. Combinations were chosen so that all sub solutions were included and both the combinations as a whole and every sub solution separately will be evaluated. By making combinations new opportunities for development might occur. Since they will be evaluated by installation it is important to have complete cameras and therefore, making combinations is necessary even though the sub solutions could be evaluated separately.

6.7.1 **Concept Combination Table**

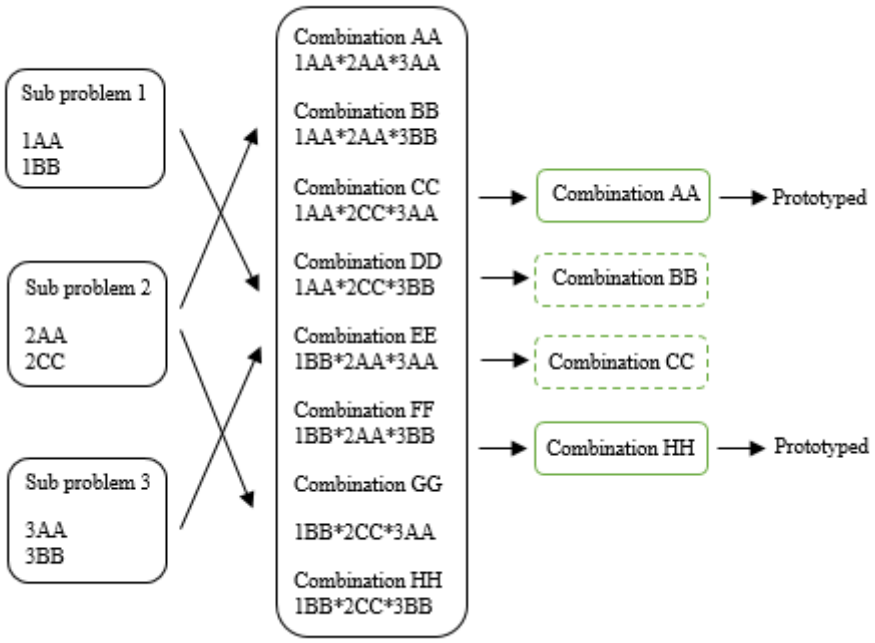


Figure 6.1 Concept combination Table

The three sub problems resulted in eight combinations where the four with the best potential were chosen for evaluation. By prototyping two of them and combining the sub problems in the prototypes, the remaining two could also be evaluated. Combination HH was chosen because there is potential to integrate the two snap fits, 1BB and 2CC, with each other, this development can be seen

in section 6.7.2.4 Combination HH. Evaluating to hold the dome with the hand was an important note from the first evaluation meeting, therefore, combination AA was chosen since it also contains the remaining sub solution of a bayonet concept. Even though these two combinations have been chosen to be tested, the different steps of the installation can be analyzed somewhat separately to form an opinion about the two remaining combinations as well. The other two combinations to be evaluated are combination BB and combination CC.

6.7.2 **Combinations**

6.7.2.1 Combination AA

6.7.2.1.1 Development

A bayonet solution is advantageous because no axial force towards the ceiling or wall is needed to assemble it. The solution from the first ideation was a bayonet where the chassis is twisted into the mounting bracket which lacked feedback or fastening of the chassis in radial direction. To be able to have a better working bayonet, feedback and fastening was desired. Therefore, a snap-fit was created on the side of the mounting bracket, interacting with the outer walls of the chassis, also working as a small guide. This can be seen to the left in Figure 6.2. This solution was not working well enough which contributed to moving the snap solution from the side of the mounting bracket to the horizontal surface of the mounting bracket which can be seen to right in Figure 6.2. Support was added which together with supports on the bottom of the chassis stabilize the rotation around the center when assembling.

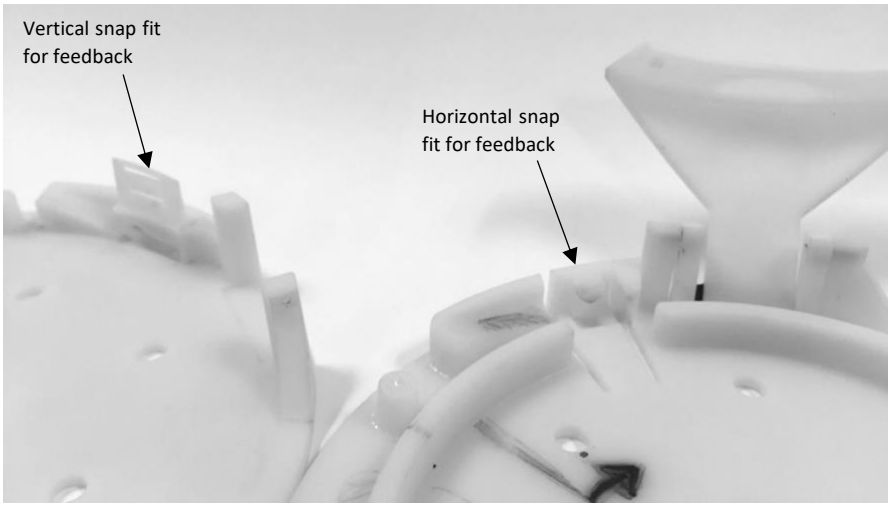


Figure 6.2 Development of snap fit in the bayonet.

6.7.2.1.2 Final combination

The final combination ended in having a snap solution on the horizontal surface of the bracket together with guiding supports. It is a section of the bracket that flexes out from the surfaces on which the bracket is mounted. The solution can be seen in Figure 6.3.

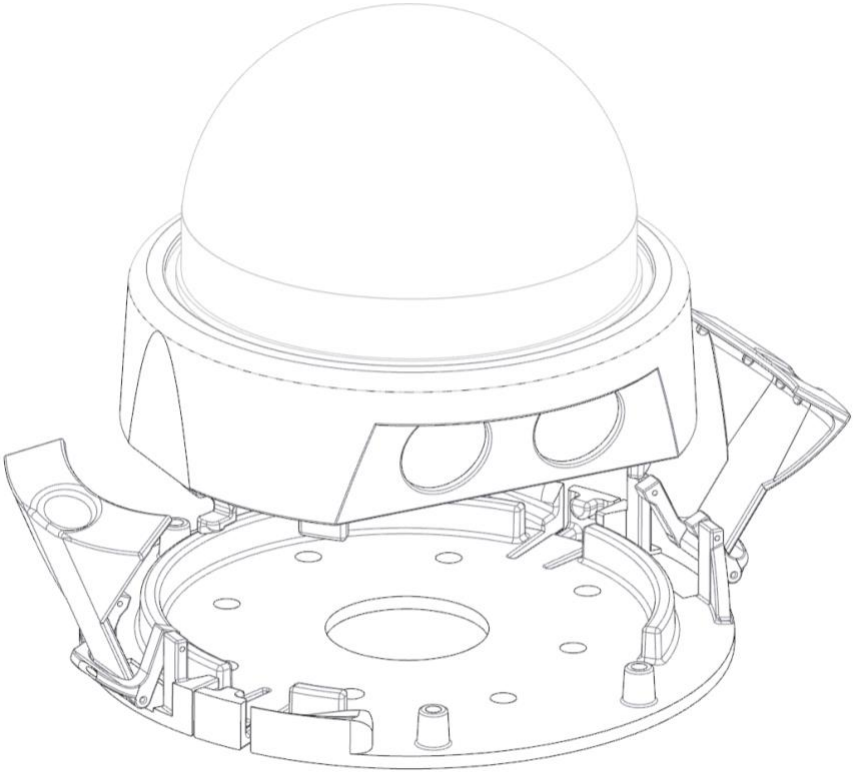


Figure 6.3 Final combination AA

6.7.2.2 Combination BB

Combination BB is similar to combination AA, with the exception of using the wire locks. By testing the two prototypes, a convincing opinion can be formed about combination BB.

6.7.2.3 Combination CC

Combination CC uses the bayonet to solve sub problem 1 but has the option to fasten the dome with snap fits if the alternative to only hold the dome with a hand

turns out to be unfeasible. By testing the two prototypes, a convincing opinion can be formed about combination AA vs. combination CC.

6.7.2.4 Combination HH

6.7.2.4.1 Development

To begin with the two different snap fits were made separate from each other to later be developed into one clip. The development was made by printing a small segment of the camera and trying out the concept as seen in Figure 6.4.

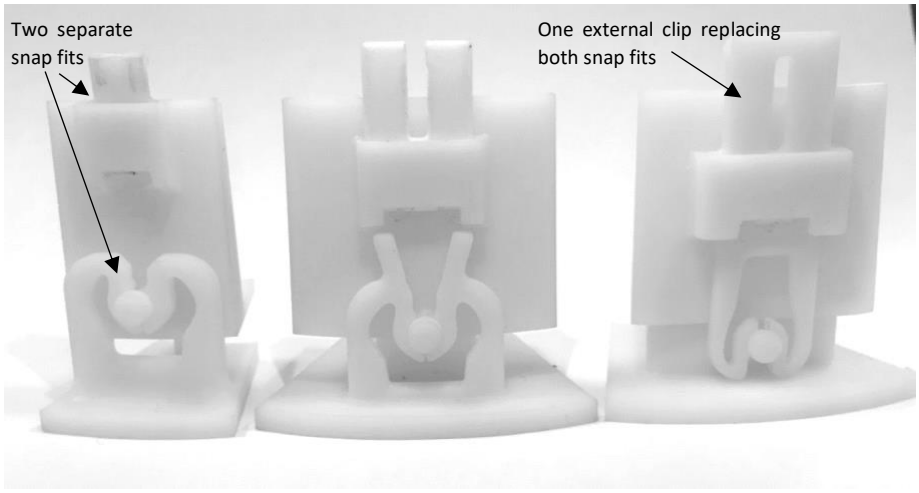


Figure 6.4 Development of combination HH

6.7.2.4.2 Final Combination

The final version has two pockets in which an external plastic clip in snapped into place and locked in all directions. One side of the clip has a circular track that flexes and hugs a spike that is placed on the mounting bracket. The other side of the clip has a normal hook where the dome will be snapped into place. This combination contains the excenter lock which uses one single wire which replaces all the axes. The final concept is shown in Figure 6.5.

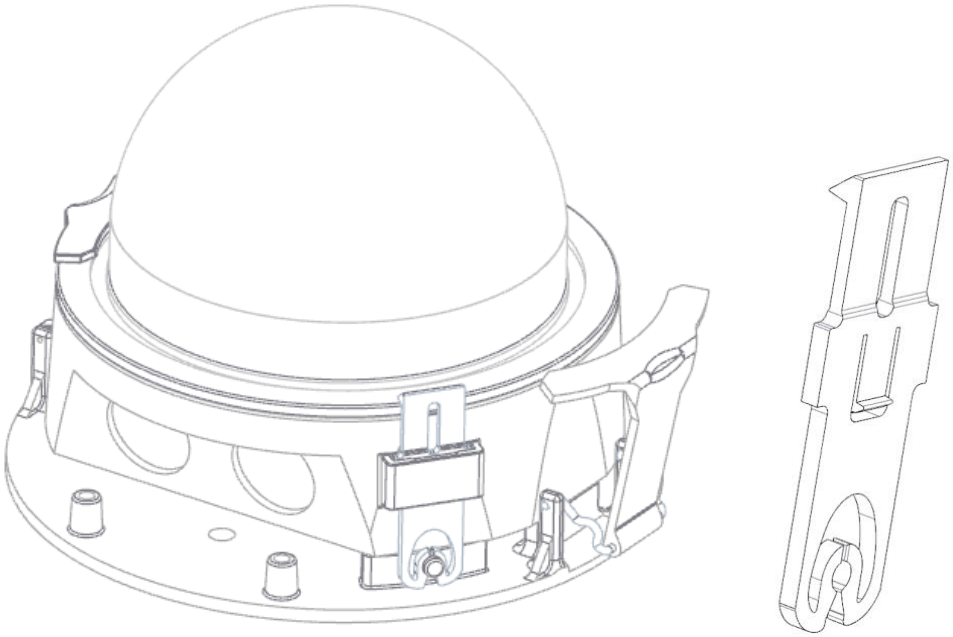


Figure 6.5 Final combination HH

Placing the spike on the bracket is advantageous because all the flexing parts are in the external clip which means that the solution is applicable to more cameras regardless to the material of the mounting bracket.

7 Second Concept Selection

In this chapter, the testing of the remaining combinations will be described and a final choice will be presented after evaluation in form of a scoring matrix.

7.1 Introduction

Concept selection is the phase were the concept combinations are evaluated compared to the criteria, comparing the relative strengths and weaknesses of the concepts and finally choosing one [5]. Out of the four different combinations that were chosen to be evaluated, only two were prototyped. These two prototyped combinations contained all the chosen fraction solutions for the different sub problems so that all four combinations could be evaluated during testing.

7.2 Method

Ulrich and Eppinger present a six-step method to evaluate and choose between the concepts by scoring them. This was followed with slight modification since combinations already has been made and chosen to cover all reasonable outcomes. The modified steps are:

- Test combinations to get feedback and input for the scoring
- Prepare matrix
- Score combinations
- Rank combinations
- Choose combination
- Reflect

To evaluate the different combinations a matrix was made where the different concept combinations were scored. To get feedback on how the different concepts were perceived and the functionality of them in order to get a reasonable and fair scoring, an installation workshop was held. The workshop involved an evaluation of the two prototypes with colleagues that participated in the first concept evaluation.

To get input on which criteria are important when evaluating the concepts, a meeting with the PIM-team (Product Introduction Management), who has huge experience from installing cameras at a customer level, was held. The criteria which were used in the concept screening in chapter 5 was updated and supplemented to fit the concepts at this level.

After scoring, the combinations were ranked and one final concept combination was chosen. This choice was later discussed and evaluated.

7.3 Testing and Evaluation of Concept Combinations

The execution and results from the two activities are briefly explained in the following sections. Notes from the meetings that led to these conclusions can be found in appendix D.

7.3.1 **Installation Workshop**

7.3.1.1 Setting

To evaluate the concepts two prototyped combinations were presented in form of an installation workshop to four Axis employees, Olaf Hoyer, Gustav Aronsson, Carl-Axel Alm and Stefan Larsson. Each participant installed and demounted the two prototypes in the ceiling and thereafter, pros and cons with the solutions were discussed. By analyzing the different steps of the installations, all four combinations could be discussed and evaluated.

7.3.1.2 Conclusion

All solutions were considered good and feasible. The fraction solution 1AA with the bayonet solution gave a good impression of robustness. The snap fit concept in combination HH was liked since it was one integrated clip but did not give a convincing feeling of robustness and therefore the bayonet was more

advantageous. The snap-fit holding the dome was considered good but not necessarily needed. Combination CC which contained the bayonet and a clip for the dome was therefore considered excessive. The two locks were also considered good with no big differences, but the lock with the bent wire was preferred due to its clean looks and easy construction.

7.3.2 **PIM meeting**

7.3.2.1 Setting

The prototypes were presented to the PIM-member Joakim Palmqvist who has great experience with installing cameras at a customer level. The installation process was discussed in general and the prototypes were shown and discussed with his knowledge as a reference.

7.3.2.2 Conclusion

Both prototypes seemed feasible for installation but the bayonet 1AA in combination AA gave a more robust feeling than the snap-fit in combination HH. Another point was that the installer often must change the way to apply the dome depending on what angle the camera should be aimed in. Therefore, the clips holding the dome could be a source of irritation. The installer is by law required to stand safely when working high up, therefore it is okay to assume that both hands can be used during the installation, making the clips unnecessary. The lock with bent wire was also preferred due to same reasons as mentioned in the workshop.

Other important factors to consider are 1) that it should take time for someone to break into the camera so the chance of them ending up on the surveillance video is bigger and 2) that it is preferable to make sure the bayonet works together with the external accessory conduit. The function of the conduit can be read about in appendix E.

7.4 Scoring Matrix

After the Installation Workshop and PIM-meeting a final selection could be made, but to clarify the selection the input from the workshop and meeting were transformed to a scoring matrix. To transform the input from the workshop and meeting into a selection, a scoring matrix was prepared with selecting criteria from the first screening matrix as a basis. Some criteria were removed since all concepts

on this level fulfill it and no diversion would be made. Other criteria were kept as they were, some were updated so the explanation suits the concepts at this level and one criterion was added. The updated selecting criteria can be seen in Table 7.1.

Table 7.1 Updated selecting criteria

Selecting criterion	Status	Explanation
Easy installation	Updated	A general feeling of ease when installing.
Intuitive design	Remains	The camera should be designed in such a way that you know how to install it even if it is the first time with no need for manuals or explanations.
Innovation height	Removed	All combinations fulfill this criterion equally
Demounting	Removed	All combinations fulfill this criterion equally
Robust impression	Remains	A more robust construction shows quality in customers eyes, especially on the American market which is a big one for Axis.
Feasible manufacturing	Remains	The construction should be able to be produced in a big scale with a suitable manufacturing method. Material, number of parts and their complexity are considered.
Feasible construction	Removed	All combinations fulfill this criterion equally
Closed space	Removed	All combinations fulfill this criterion equally
Rotation symmetrical dome	Removed	All combinations fulfill this criterion equally
Ergonomic	Updated	The whole installing process should be easy to handle both at single and multiple installations and feedback is offered to make it smooth.
Compression function	Removed	All combinations fulfill this criterion equally
Reinstalling dome	Added	Since placing the dome several times during one installation is common, ease of reinstallation of the dome is important.

When scoring the combinations in the scoring matrix no external reference is used and instead, the combinations are compared to each other as a reference. The selection criteria are of different importance and is given a weight factor (WF), where the most important criterion has the highest percentage. The scoring of the combinations is in a range from 1 to 5 according to Table 7.2.

Table 7.2 Condition when scoring the remaining combinations

Relative performance	Score
Much worse than reference	1
Worse than reference	2
Same as reference	3
Better than reference	4
Much better than reference	5

After giving a score, each score is multiplied with corresponding criterion´s weight factor resulting in a weighted score (WS). Lastly the total weighted score is summarized and ranked. The scoring and the result can be seen in Table 7.3.

Table 7.3 Concept scoring matrix (Y=yes, N=no)

Concept Combination		**AA**		**BB**		**CC**		**HH**	
Selection criterion	**WF**	**Score**	**WS**	**Score**	**WS**	**Score**	**WS**	**Score**	**WS**
Easy installation	20 %	4	0,8	4	0,8	5	1	5	1
Intuitive design	15 %	4	0,6	5	0,75	4	0,6	5	0,75
Robust impression	25 %	4	1	5	1,25	3	0,75	3	0,75
Feasible manufacturing	10 %	3	0,3	5	0,5	1	0,1	3	0,3
Ergonomic	10 %	4	0,4	4	0,4	3	0,3	3	0,3
Reinstalling dome	20 %	5	1	5	1	2	0,4	2	0,4
Total score		24	4,1	28	4,7	18	3,15	21	3,5
Rank		2		1		4		3	
Continue?		N		Y		N		N	

The added criterion of possibility to reinstall the dome made combination CC and HH, which uses the snap fit to hold the dome, to score low. Combination CC was considered excessive and therefore it also scored low on feasible manufacturing since it contains many features. The combinations containing the bayonet for sub problem 1 scored higher on robust impression and also ergonomic since feedback is received when it is correctly placed and no axial force towards the ceiling is needed. The lock with the bent wire contains less parts, is more intuitive to handle and easier to manufacture than the other lock, making the combinations containing them score higher. Putting all of this together made combination BB score the highest out of all. The final selection contains that the installer should

hold the dome with the hands and because of this, it will be investigated if adjustments could be made to the locks so they hold the dome before closing. This will be explained further in chapter 8 Detailed design.

7.5 Final Selection

The final combination that is chosen is combination BB. The different sub solutions solving each sub problem can be seen in Table 7.4 and a picture of the combination can be seen in Figure 7.1.

Table 7.4 Composition of concept combination BB

Sub problem	Concept combination BB
1	Bayonet with flexing part in bracket for feedback
2	Hold with hands
3	Excenter lock with all axes made from one bent wire.

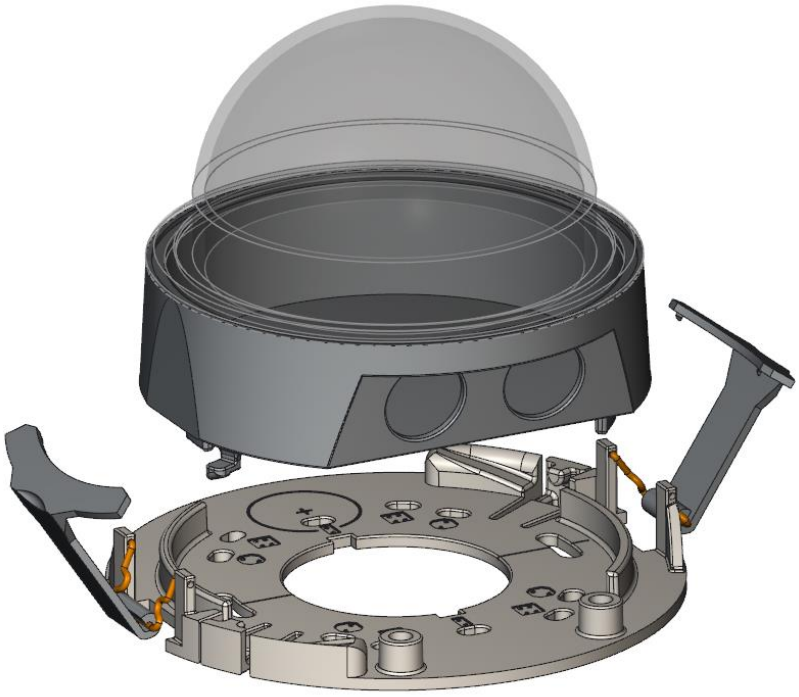


Figure 7.1 The final concept combination BB

8 Detailed Design

This chapter covers the detailed design of the chosen concept including design for manufacturing and going into detail of the designed features in the different parts.

8.1 Introduction

To systematically develop and improve the chosen combination, it is divided into different features. These features are developed in an iterative manner where details are added and modified.

8.2 Method

The features were developed by multiple iterations to adapt the design to the working concept. Communication with supervisors and colleagues contributed to this development and iterations of the detailed design. The subjects Design for Manufacturing (DFM) and design in different materials was considered continuously during the detailed design to optimize the design, this is described more in detail in section 8.3 Choice of Material. Development of the features were modelled in Creo and are presented in respective chapter.

8.3 Choice of Material

The choice of material was decided in the beginning of this thesis where guidelines for assigning material to each part was presented by the company. To follow the design guidelines and making the concept more applicable to the existing assortment, the same materials as in existing P32 are preferred to use.

The chassis is assigned aluminum as material since it is light and is a conductive material with the purpose of leading heat from the camera. The dome is assigned Polycarbonate (PC). The materials assigned to the chassis and dome applies for both outdoor and indoor use. The mounting bracket differs in assigned material for outdoor and indoor use where aluminum is assigned as material for outdoor use and glass fiber reinforced Polyamide (PA+GF) is assigned as material for indoor use. This thesis aims at the camera for indoor use which means that the bracket is in PA with high percentage of glass fiber, making it relatively stiff but with some flexing properties left which are used in this concept.

The lock should bear static load to endure holding the construction together, therefore sheet metal is preferred over plastic since the plastic properties may change over time during static load.

8.4 Design for Manufacturing

Design for manufacturing is product design and process planning made into one activity. About 70% of manufacturing costs are determined by design decisions, which makes it important to have DFM in mind when designing. The goal is to design a product that is easily and economically manufactured by following some general guidelines [27]. For example, reducing the total number of parts means less inventory, handling, processing time etc. which is a good opportunity to reduce manufacturing costs. This was one of the reasons the lock with one bent wire was chosen, since three axes and one handle was replaced by one single part. A selection of the other guidelines are; Use standard components; Design parts to be multi-functional; Avoid separate fasteners and choose a suitable manufacturing method.

8.4.1 **Design in Sheet Metal**

Sheet metal is a metal that is formed and processed into thin, flat parts. In metalworking, sheet metal can be cut and bent into different ways giving a big variety of making shapes and designs. The thickness of the sheets can vary where thin sheets are called foil or leaf, and thick sheets are called plates [28]. For indoor use no stainless properties are required from the material. Thinner sheets and no stainless properties in the material are easier to work with and bend into the right

shapes. Therefore, after consultation with colleagues and looking at similar existing details, the thickness resulted in 1.2 mm for the sheet metal lock.

To manufacture the locks, sheet metal in steel is chosen as material. A cut-out piece in sheet metal is bent into the right shape creating the final design of the lock. Creo PTC Manufacturing was used to create a reliable construction for manufacturing in sheet metal where a flat pattern of the sheet metal was made, seen in Figure 8.1 below. To make sure the ability to manufacture the part the Creo model was sent to Axis usual supplies who confirmed it was possible.

Figure 8.1 Flat pattern of the sheet metal lock in Creo Manufacturing

8.4.2 **Design in Plastic**

When designing in plastic there are several things to consider optimizing the construction. Due to high volume manufacturing, injection molding is the desired manufacturing method for the mounting bracket. Ulf Bruder lists ten design rules in *User´s Guide to Plastic* [29] for molding in thermoplastics where some were more focused on than others:

1. Remember that plastics are not metals
2. Consider the specific characteristics of plastics
3. Design with regard to future recycling
4. Integrate several functions into one component
5. Maintain an even wall thickness
6. Avoid sharp corners
7. Use ribs to increase stiffness
8. Be careful with gate location and dimensions
9. Avoid tight tolerances
10. Choose a suitable assembly method

The towers where the locks are attached have been stiffened by ribs according to Bruders design rule. All sharp edges were removed by rounding them with a suitable radius. Small adjustments to the design have been made along the way to make the wall thickness even throughout the whole design. The thickness is aimed at 3 mm (a variation of +/- 15% is still considered even) which is in the recommended range for thermoplastics of 1.5-4 mm.

8.4.3 **Design in Cast Aluminum**

The chassis is made by aluminum casting which gives the designer reasonable freedom, complicated designs can be manufactured in quite easy ways. The major things to consider are that draft angles are needed, parting between the two mold halves will create a parting line and almost always some sort of post processing will occur to take into account [30].

8.5 Mounting Bracket

The mounting bracket is developed to further improve the installation process and to be more user-friendly. This is explained in the following sections.

8.5.1 **Guiding for Assembly**

When using the bayonet to assemble the chassis with the mounting bracket, guidance makes it easier. Without guidance the assembling is harder and an effect called the drawer effect occurs which makes the chassis difficult to insert and

assemble. The drawer effect called “byrålådeeffekten” in Swedish has the meaning that the sliding of the chassis pegs into the bayonet is not smooth, making the chassis wobble during assembling and maybe jam before assembling is done. Therefore, supports are added on the mounting bracket combined with supports underneath the chassis, acting together as a guiding.

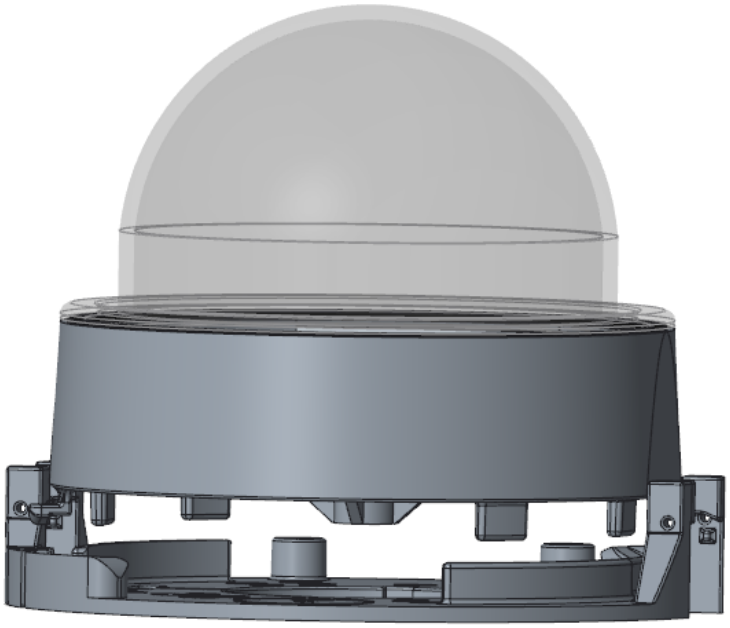


Figure 8.6 Showing matching supports on bracket and chassis creating guidance

8.5.2 **Adding Standard Attachment Holes and Prints**

Attachment of the mounting bracket onto the ceiling or a wall could be made in several ways. The mounting bracket for the existing P32-camera has different holes and prints on the bracket that should be applied on this concept to be able to fit into the product assortment. These holes and prints were added which forced the construction of the guiding to be modified. The guiding was moved and cutback to not interfere with the holes.

8.6 Excenter Lock

The excenter lock has been further developed to solve specific input from the evaluation meetings and to make the overall installation process better. The reason for the added features and their design will be explained in the following sections.

8.6.1 **Keeping the Locks from Interfering with the Chassis**

When installing the camera in the ceiling during the workshop, it was noticed that the locks sometimes due to gravity, hung in a position disturbing the application of the chassis. To avoid this, angled blocks were added to the towers, blocking the bent wire and the lock from rotating the whole way. This can be seen in Figure 8.2. Another feature that was added, were two bumps on the inside of the towers, which together with the blocks locks the wire in the other angular direction while installing the chassis. This was done because the bracket can also be mounted on a wall and the gravity might affect the locks differently. The wire will however pass the bumps when pressure is applied due to the flexibility of the wire and extra feedback is given that the locks are being secured.

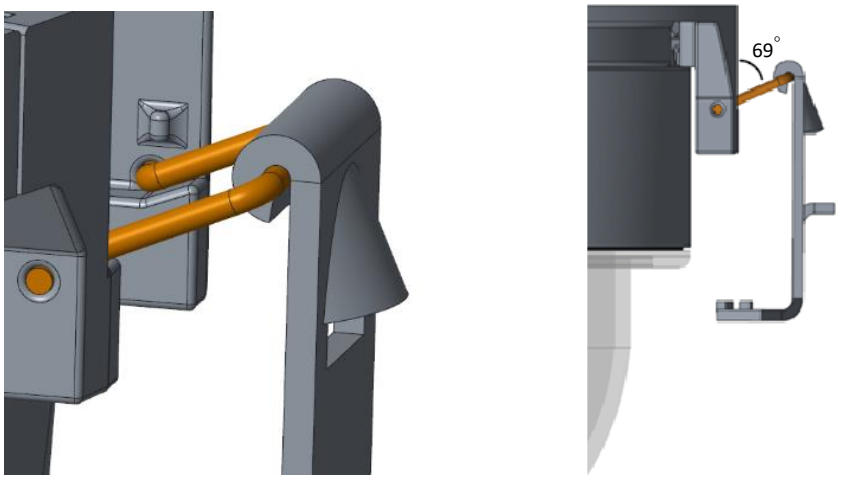


Figure 8.2 Angled blocks stops the wire and the locks hangs vertically

8.6.2 **Securing the Locks Position and Holding the Dome**

To secure that the locks stay in place both before and after locked, teeth on the edge of the horizontal surface of the lock and a matching track in the dome were made. These can be seen in Figure 8.3. When placing the lock correctly on the dome, the teeth pops into the track and stays there due to the blocks locking the wire in that direction. The action is enhanced by a clicking sound providing feedback. Getting the right angle on the blocks meant a combination of getting the lock away from the house and being able to reach the dome with the teeth at the same time. It was decided by testing prototyped segments of the camera.

Before the locks are completely closed and the teeth have been popped into the track, the locks hold the dome securely and it is possible for the installer to let go. In this position it is also possible to rotate the dome to the desired angle.

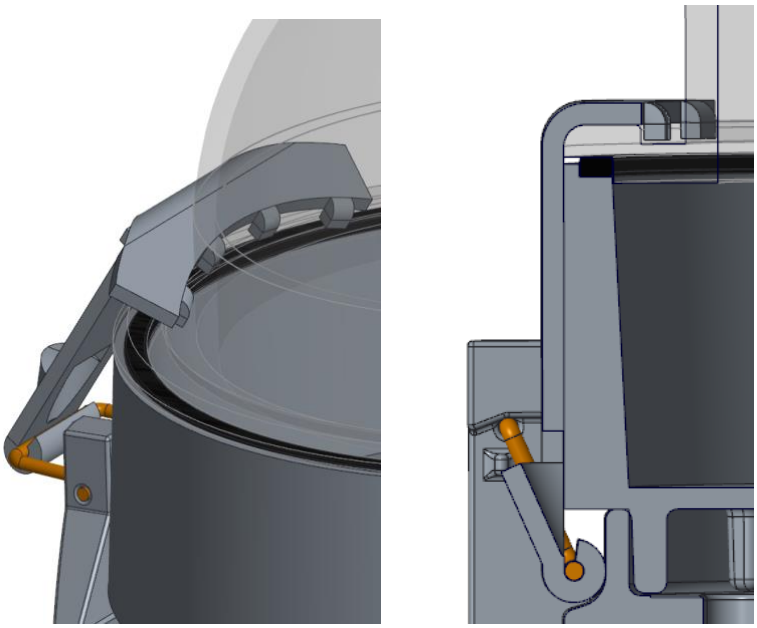


Figure 8.3 Teeth on lock placed in track on dome to prevent dislocation and enable rotation of dome. Left: From above when lock isn´t completely closed and it is possible to let go of or rotate the dome. Right: A cross section from the side when lock is closed and position secured.

8.6.3 **Open the Lock**

Since the lock is tight when secured, and there is no room to grab it by the axis due to the ceiling or the wall, a feature to open it was needed. A punched pocket was

created so a chisel of some sort can be used as a lever to bend it open again. The pocket can be seen in Figure 8.4.

8.6.4 **Safety Screw**

The customer will have the chance to add an extra safety screw to the camera for additional safety. It is important to recognize that the screw is an additional option and the construction does not require it to function as seen in Figure 8.4. The screw is not supposed to stop an intruder completely but rather making the process more time consuming and demanding because it requires tools.

Figure 8.4 Pocket for opening the lock and a safety screw from lock to bracket towers

8.7 Chassis

The chassis has been further developed to solve interference and connections with other parts. This is explained in the following sections.

8.7.1 **Avoiding Interference with Conduit Attachment**

There are several accessories that are applicable to the P32-camera today, one of them is the conduit attachment. The conduit attachment is an accessory that attach an external pipe for cables on the side of the camera, which can be seen in Appendix E. When the chassis was assembled onto the mounting bracket, the chassis was interfering with the conduit attachment since it is twisted on, which lead to removal of material on the chassis as seen in Figure 8.5

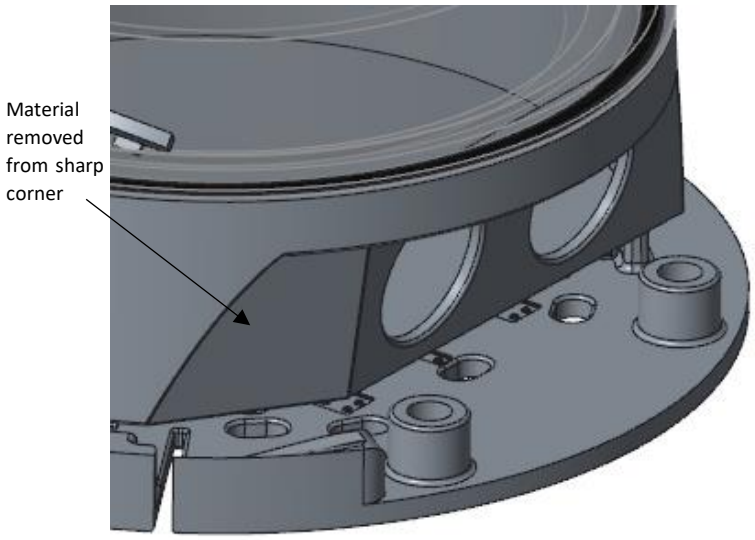


Figure 8.5 Removed material from chassis due to interference with conduit

8.7.2 **Gasket**

The gasket is supposed to be tucked around a wall on the dome and fits in a track on top of the chassis. When the locks are in its end position, the gasket is supposed to be 20% compressed. To able to lock them, at one point the gasket needs to flex and be more than 20% compressed since the axes change position. Therefore, a part of the gasket is visible after the locks are secured.

9 Results

This chapter covers the overview of the final concept, the final installation process and recommendations on further work to Axis.

9.1 Introduction

During the project the authors have aimed to achieve a design that solves the scope of this thesis in an innovative and intuitive way. The results are presented with models from Creo with explanations about selected parts. A step-by-step guide of the installation process is made and presented in section 9.3 Working Principle and Table 9.1. The list of specifications which can be seen in section 4.3 List of Specifications, is compared to the result and summarized in Table 9.4. If more time was available, further development would be done according to the thoughts and suggestions which are presented in Section 9.8 Future work.

9.2 Parts Included

The final concept consists of three main parts and a lock that is integrated in the mounting bracket connecting all parts together. The main parts are referred to as the mounting bracket, chassis and dome. The main parts will be described one by one in this section.

9.2.1 **Mounting Bracket**

Figure 9.1-9.3 shows the mounting bracket with the two locks attached to it. Features included in the mounting bracket are attachment of the chassis and attachment for the locks. Figure 9.1 gives an overview of how the bracket and locks come pre-assembled and the placement of different features on the mounting bracket.

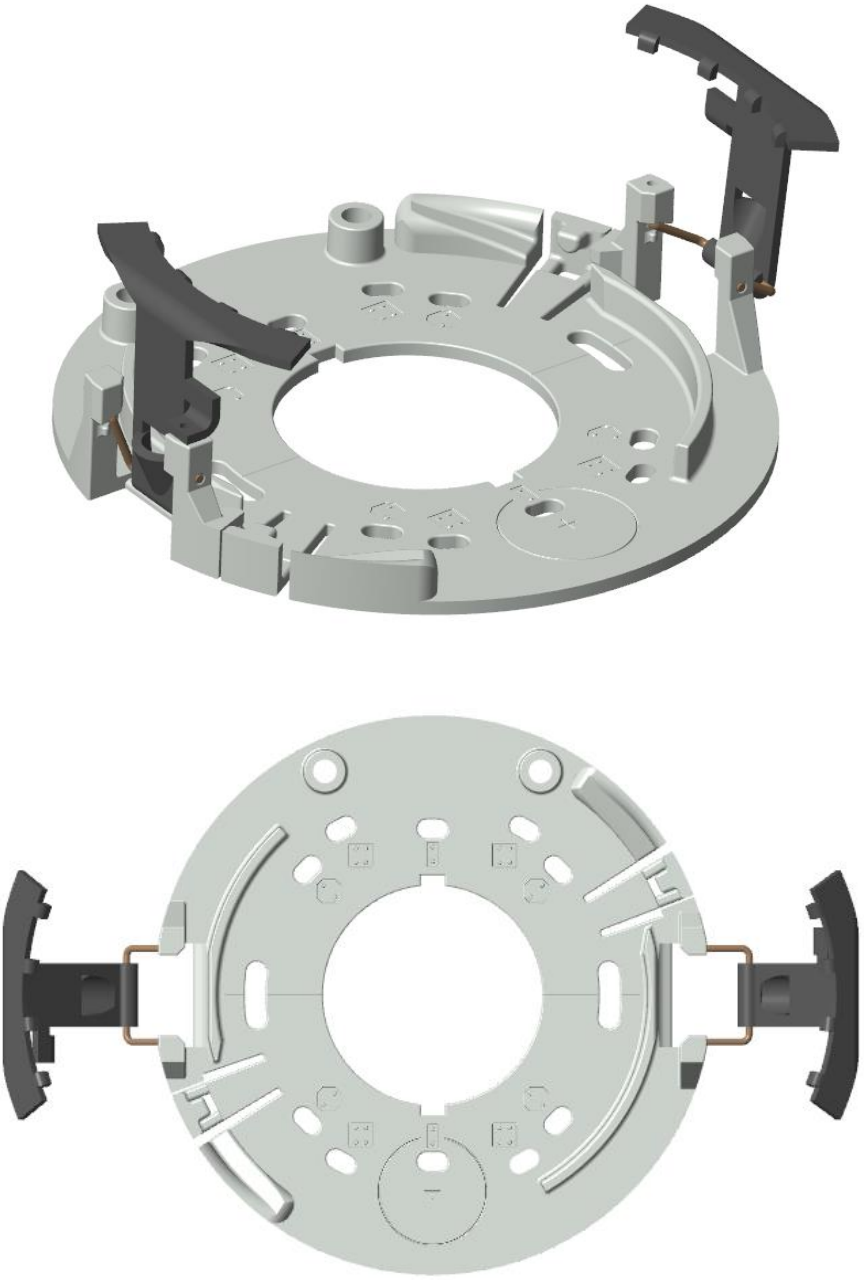


Figure 9.1 Mounting bracket with locks attached. Top: Perspective with one lock neutral and one lock closed. Bottom: From above

For attachment of the chassis a bayonet solution is made where the bracket has a flexing section which both gives feedback when assembling and keeps the chassis from rotating back. Support and a slope is made as guidance for making the interaction with the chassis smoother. One of the two groups with slope and flexing section is shown in Figure 9.2.

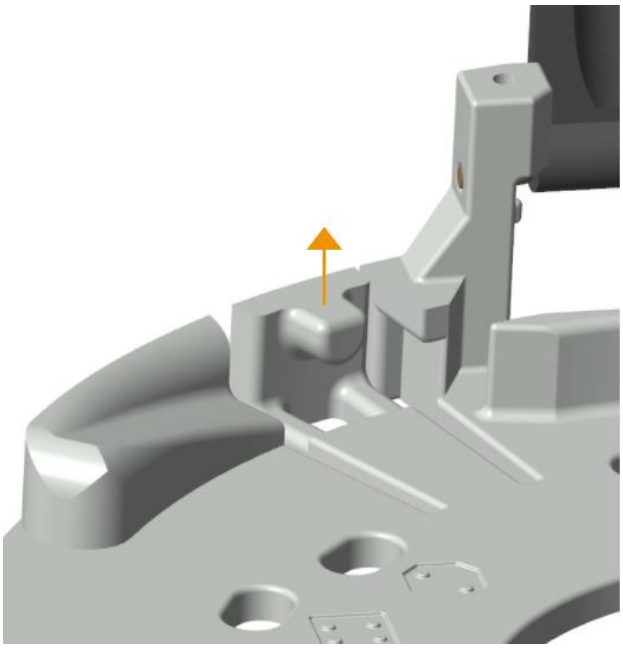


Figure 9.2 Flexing section in mounting bracket that moves upwards when the peg on the chassis pass it

Two towers are designed for attaching each lock and to limit its rotation to the correct angles. The lock consists of two parts, a bent wire and a sheet-metal part. The sheet metal part is attached to the bent wire which in turn is attached to the towers in the mounting bracket. The sheet metal part is designed with teeth on the edge to be able to grip a track in the dome, it also has a punched feature creating a pocket for demounting the lock. An optional safety screw could be used for extra safety if the customer wants to. This safety screw is placed through a flange in the lock which is placed above one of the towers. The lock, the bent wire and the towers they are attached to can be seen in Figure 9.3.

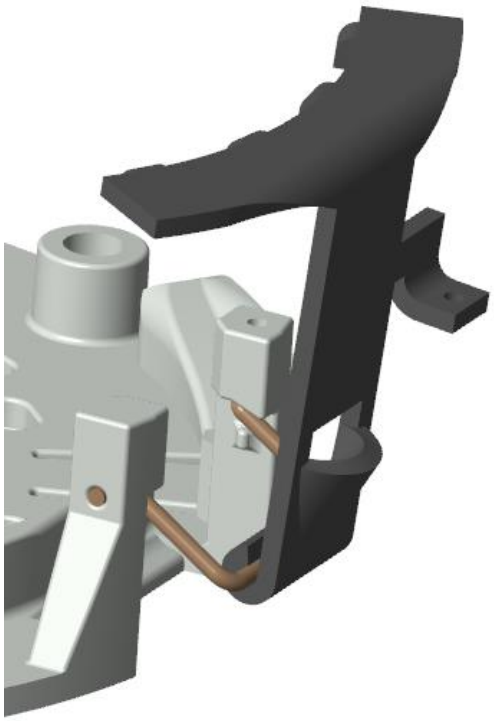


Figure 9.3 Towers connecting bracket to wire to lock

9.2.2 **Chassis**

Figure 9.4 and 9.5 shows the chassis. Features included in the chassis are two holes for cable pull through, supports on the bottom for guiding and two pegs for assembling to the bayonet in the mounting bracket. An overview of the chassis can be seen in Figure 9.4. The holes are placed at an angular wall in the chassis, this creates a possibility for bigger size of the holes and an easier pull through of the cables. The four supports on the bottom of the chassis are aligned to fit with the support on the mounting bracket, this gives guidance when assembling the chassis. The pegs are the most important feature in the chassis, they have the function of attaching the chassis to the mounting bracket. The design of the pegs is adapted to the slope on the mounting bracket which results in a triangular form of the pegs. When mounting the chassis, the pegs are visible from above which makes it easier to see how the chassis should be oriented on the mounting bracket. A closeup of the pegs and guiding support can be seen in Figure 9.5.

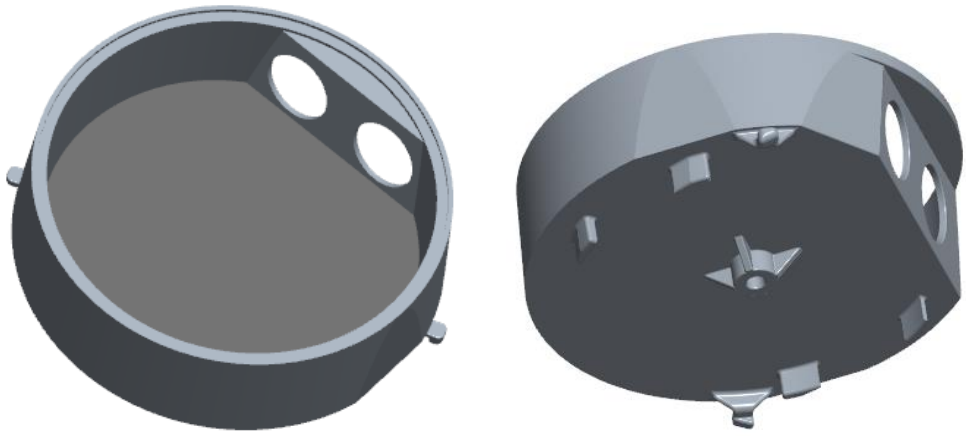


Figure 9.4 Chassis shown from above (left) and from under (right)

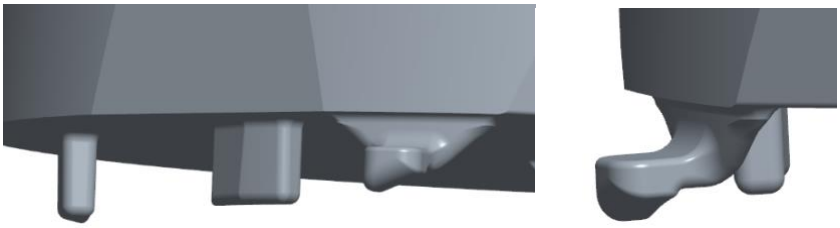


Figure 9.5 Showing support for guidance and the angled peg that slides into the bracket

9.2.3 **Dome**

New features included in the dome comparing to the current P32-camera are a rotationally symmetric feature and a track on the top of the dome-flange made for attachment of the locks. The gasket is stretched around a wall on the bottom of the flange. These features can be seen in Figure 9.6 below.

Figure 9.6 Dome with gasket pre-assembled. Middle and right: Cross section showing the track on top of the flange and the placement of gasket around wall under the flange

9.3 Working Principle

Figure 9.7-9.11 shows the installation of the camera and how the parts interact with each other. Later, Table 9.3 goes more into detail how the user interacts with the camera during the installation, describing it step by step and including all external steps like placing and sealing the cables.

Figure 9.7 Left: mounting the bracket in the ceiling with screws, locks hanging vertically due to gravity. Right: Placing the chassis on bracket

Figure 9.8 Twisting the chassis clockwise to make it slide into the bayonet

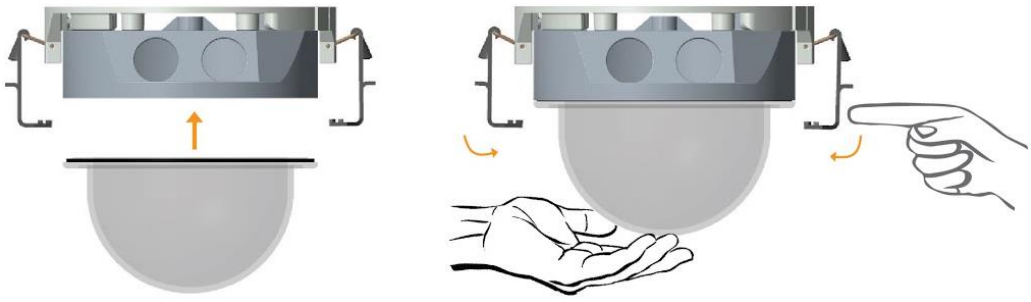


Figure 9.9 Left: placing the dome on the chassis. Right: Hold the dome with hand until the teeth on the locks are placed in track on dome

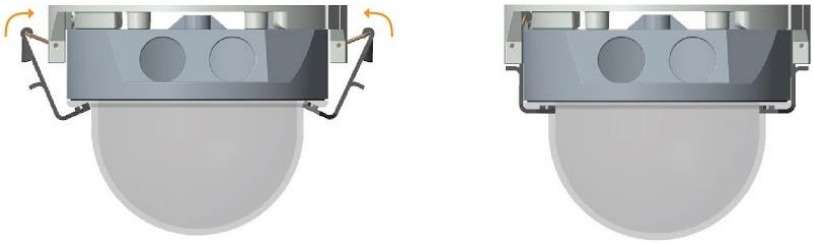


Figure 9.10 Left: Locks are attached on dome (now possible to rotate dome) and needs to be secured by closing the other end. Right: Locks secured

Figure 9.11 Extra safety optional to customer by placing a screw on closed locks

9.4 Prototype

The final prototype is 3D-printed using stereolithography technique (SLA) with Acrylonitrile butadiene styrene (ABS) as material and a bent metal wire. The construction was made with the aim to consider the plastic rules, metal manufacturing rules and sheet metal manufacturing rules, presented in section 8.4 Design for Manufacturing. But to be able to make a durable and stable 3D-print, some walls and features are made thicker just for prototyping. The parts have been painted to distinguish them from each other and point out their differences in material. The different parts and the assembled prototype can be seen in Figure 9.12 and 9.13

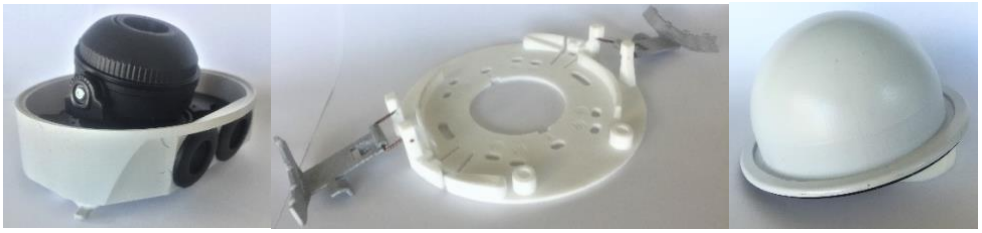


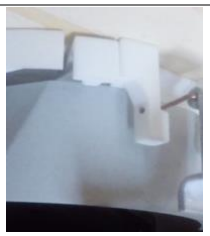
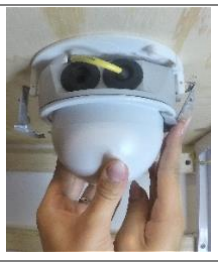
Figure 9.12 Prototyped parts

Figure 9.13 Assembled prototype

9.5 Installation Process

To show how the installer interacts with the parts during the installation, the whole process has been photographed and can be seen together with explanations in Table 9.1

Table 9.1 Interaction between installer and camera during installation step by step

1		The only step where heavy tools are needed. Mount the bracket by screws.	**2**		Pull the ethernet cable from the ceiling and attach gasket on it.
3		The cable has been pulled through the small hole in the gasket and the cable can be placed.	**4**		The chassis is moved towards the bracket. Thanks to the angled stops, the locks are not disturbing.
5		While the chassis is rotated it moves closer to the bracket.	**6**		The installer gets feedback when the section flexes and a clicking sound when it is attached.
7		The chassis is stable and won´t wobble or rotate back unless you apply force.	**8**		The cover on the cable can be removed with both hands.
9		The cable is connected to the camera module and the gasket is placed in the chassis. This requires both hands.	**10**		The dome is placed on the chassis. Tracks make sure you feel when it is placed correctly.
11		While holding the dome with one hand, the other can click the first lock into the track on the dome.	**12**		A clicking sound provides good feedback so the installer feels when it is placed.

13		Use the other hand to partially close the second lock.	**14**		With both locks partially closed, they will hold the dome up and the installer can let go.
15		Possibility to rotate the dome and check if the angle is correct until satisfied.	**16**		When the angle is correct, the first lock is easily closed with one hand
17		The other lock is closed. Possible to close them at the same time when used to the installation process.	**18**		The installation is done with less static positions for the installer, making it more comfortable.

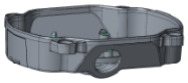
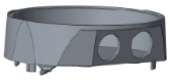
9.6 Comparison to P32

To get perspective on how the new concept stands against the current camera, two important comparisons were made.

9.6.1 **Cost of Good (COG)**

The prices of the included components have been estimated to make sure the difference isn´t too big. The prices for the P32 parts have been gathered from colleagues and the internal database. The estimations for the new concept have been made by finding similar details in other cameras to compare with. The prices can be seen in Table 9.2

Table 9.2 COG for P32 and estimated COG for new concept

P32 indoor	$	New concept	$
Dome 	3.71	**Dome** 	3.71
Chassis 	1.49	**Chassis** 	1.49
Bracket + inserts 	1.48	**Bracket** 	1.03
Screws x4 	0.4	**Locks** 	0.8
		Bent wire 	0.4
Total cost of good:	**7.08 $**		**7.43 $**

The dome, chassis and bracket in both cameras are very similar, made from the same material and by the same manufacturing method which led to the assumption that they have the same price. However, the bracket for P32 includes 4 metal inserts which cost 0.113 USD per detail that makes sure the screws doesn´t destroy the plastic. These will not be included in the new bracket since no screws will be used and the cost has therefore been subtracted. Screws are usually not included in the calculations since they are very cheap. Since these screws are custom made and come preassembled, they come with an extra cost and have been included in the calculations. The new locks have been compared to a sheet metal detail in another camera which is the same size and same complexity. The bent wire is an estimation.

The result shows that the COG for the new concept is 35 cents more expensive which is considered relative little.

9.6.2 Installation Time

Since reduction of the installation time of the camera was part of the specifications, a time study was made to see how the new construction has affected the installation time. When the installation was timed, only the steps which have been affected by the new design have been included. This means that the bracket was already installed in the ceiling and no cables have been used since the steps are performed in the same way as before.

Something that was brought up in section 7.3.2 PIM-meeting was that it is normal for the installer to take the dome down after installation to adjust the angle of the camera module inside. For that reason, this was timed as well. The time is from the camera being fully installed until the dome has been taken completely off and been reinstalled again.

Table 9.2 shows the time keeping and the time difference for installation and adjusting the dome. The numbers shown are an average time calculated after ten installations of each case.

A completed installation of the P32 camera includes the top cover unlike the new concept. To make the times comparable, five seconds will be added to the average installation time of the new concept to represent snapping a potential top cover on.

Table 9.3 Average of installation time

	Installation time	Adjusting dome
P32 indoor 	66 s	76 s
New concept 	17+5 = 22 s	17 s
Time difference	44 s	59 s

The new concept is faster in both installation time and adjusting the dome. Since not all installation steps have been included in this time keeping, a percentage of the total time reduction can´t be calculated. The time difference is big, and if the dome has to be adjusted it will become exponentially bigger. If a big number of installations will be done, the installation time also plays a big role in the total cost of ownership.

To see if specification number 3 in chapter 4 (the installation time should decrease by 40 %) has been fulfilled, the installation of the bracket was timed. The average time was 27 seconds and since it is the same for both cameras the time difference will still be 44 seconds. The percentage has been calculated accordingly:

$$\frac{44}{66+27} = 0{,}47311 = 47\ \%$$

9.7 Specifications

The specifications that were established in chapter four were examined if they were fulfilled. The table below shows the same specifications and if they have been fulfilled or not.

Table 9.4 Fulfillment of list of specifications

No.	Ref	Metric	Imp.	Units	deal value	Fulfilled?
1	(PRS)	Label with serial number visible under lid	5	Binary	Yes	Yes
2	(PRS)	Ease of installation (allow use of WIT)	5	Binary	Yes	Yes
3		Time difference to complete mounting (without cables) compared to P32	5	%	-40	-47
4	(PRS)	Product design shall follow Axis Design Guidelines	5	Binary	Yes	Yes
5	(PRS)	Product cover shall be able to be removed and replaced	5	Times	>20	Yes
6	(PRS)	Vandal-resistant according to IK8*	5	Binary	Pass	Test required
7		Securing lock does not exceed outer bracket diameter	5	Binary	Yes	Yes
8		Design allows securing lock to press parts together	5	Binary	Yes	Yes
9		Chassis carries its own weight before secured	5	Binary	Yes	Yes
10		Dome carries its own weight before secured	5	Binary	Yes	When locks are half placed
11		Intuitive design	4	Subj.	-	Yes
12		Tools required at installation**	4	NO.	0	0
13		Screws used for assembly**	5	NO.	0	0 (safety screw optional)
14		Dome can be placed at any angle	3	Binary	Yes	Yes
15		Contain entering for cables	5	Binary	Yes	Yes
16		Robust feeling	4	Subj.	-	Yes
17		Distance between bracket and chassis for cables to pass	4	mm	8	8

*The vandal-resistance for outdoor version is higher (IK10)

** Number after installation of mounting bracket on surface

9.8 Future Work

Even though this thesis has come a long way there are some things that need to be further developed and considered before the project can be finalized. The main focus would be to continue with testing the concept with different aspects. A prototype with the correct materials is needed to test the different features fully. For example, the locks are designed so the weight and stiffness from the metal is advantageous, the flexing sections of the bracket need to be tested in the correct plastic and hold the chassis with the correct weight. To test the function of the locks is of high importance since they will hold the camera together and load bearing, doing this with the correct material is important so that reliable conclusions can be made and the design can be optimized.

The slopes and guiding for the chassis on the mounting bracket could be improved. This could be done with adding more indications showing how the chassis should be oriented and twisted.

Since the shape of the chassis has changed, the optics and electronics must be adjusted so they fit in the new surroundings. When this is done, a more excessive user test with installers who has the right experience would be done. This way a real and more convincing comparison to the original P32-camera could be made.

A mold flow analysis should be performed on the mounting bracket and the chassis to make sure the material flows evenly throughout the parts. The most critical parts are the pegs under the chassis and the towers on the bracket because they are smaller and longer. The appropriate number of gates might have to be investigated to make sure the whole part gets fully filled, which can lead to unforeseen weld lines that disturb the design.

The safety screw can be further developed to become more user friendly to the customer. The screw is desired to be anti-loss, which means pre-attached in the hole to prevent it from disappearing. One idea is to place the screw half way down on top of the tower on the bracket and then make the hole on the lock U-shaped so it can be placed around the screw from the side. The screw is then tightened.

For now, the only accessory taken in consideration is the conduit. Since Axis has many more accessories like a recessed mount for soft ceilings for example, it would be necessary to investigate how the concept interacts with the other accessories. To make the concept applicable and realistic, it should work together with as many accessories as possible.

Lastly, a cost analysis should be performed to investigate how the price would be affected compared to today's camera. The cost of good (COG) might be higher than on the original camera since it contains more parts, but faster and more comfortable installation can compensate making the total cost of ownership (TCO) lower and the installer more satisfied.

10 Discussion and Conclusion

This chapter covers discussion and reflections made during the process of this project.

10.1 Discussion

10.1.1 **Specifications**

The specifications for this project was a combination of specifications from previous projects and wishes that were communicated by the supervisors. The most important specifications, easy installation and intuitive design, were considered more during this thesis than other specifications. Some specifications were only considered in the end of the project because of its easy implementation, like Label with serial number visible under lid. Some specifications could not be fulfilled or examined, like testing IK8. This could be examined if each part was prototyped in the right material but we did not have the opportunity to do this, therefore we were not able to test the vandal resistance.

10.1.2 **Change of Scope**

The change of scope affected the specifications somewhat, where the vandal resistance property was decreased from level IK10 to IK8. The cover was dismissed for further development and the material of the mounting bracket was changed from aluminum to plastic. Of these changes the only one actually affecting the further development was the change of material for the mounting bracket, where possibilities for using flexing parts in the mounting bracket became available. This was a feature that was used in the final concept and therefore it was the only change that really made an impact on the future work. The background study that had been made before the change of scope was still applicable, but some time had

to be spent on reevaluating the time schedule and exploring new ideas based on the new scope.

10.1.3 **Concept Generation and Selection**

Starting with brainstorming sessions early on might not have given a lot of technical detailed solutions but it was a great way to get the creative thinking going. It helped understanding the problem and what difficulties might arise. Since it was the installation of the whole camera, the task involved many interfaces. This made the problem decomposition vital to be able to break down the problem into smaller subjects, it could have been possible to break down every sub problem into even smaller focus points to make it clearer and make sure not to miss any interesting sub solutions.

Selecting concepts to move forward with is a hard task, especially when you have to do it in an early stage when the concepts aren't too developed. Evaluating which concepts have potential before any details or real prototypes have been made had to be based on discussion with more experienced colleagues and rough guesses. Since the time is limited and too much time can´t be spent on developing all concepts into detail before choosing, this is what was done. This means that there might be concepts that were dismissed early on that still has potential to be developed into something good.

Having prototypes to compare concepts in a further developed state helped a lot to form an opinion. However, if a prototype is presented to people outside the closest colleagues it must be good. A not working prototype might reflect on how people see the concept, so it might harm more than it helps.

The last selection between using a bayonet or an integrated plastic clip to hold the chassis resulted in choosing the bayonet. The participants from the evaluation meetings did however like the plastic clip as well and didn't think that a choice had to be made, both were worth further developing. Due to time a choice was made anyway and the one that suited this project the most was selected. This means that a partially developed clip is available for future projects.

10.1.4 **Final Concept**

The final concept is presented as a 3D-printed prototype which does not give a realistic or robust feeling of the concept. Prototyping in the right material for each

part would contribute to a more realistic feeling and it would also be possible to make a vandal resistance test which would give a good feedback of the durability of the concept. With this said we cannot tell if the final concept is vandal resistant. If the project is continued and the concept vandal resistance is failed the different part solutions could maybe be applied to other cameras in the Axis assortment.

Comparing this concept to the current P32-camera it is difficult to say if it can resist the same vandal resistance as the current camera. But with the reduced number of screws and components and more user-friendly installation process, it can be said that the concept is superior to the current correspondent camera.

The final shape of the chassis differs from the original one since the new is round. This means that the optics and electronics, which were excluded from the scope, will have to be replaced with a matching shape. However, after talking to colleagues, using a round shape is not a problem but rather preferable due to the simplicity.

10.1.5 **Our thoughts**

During this thesis we have evolved and learned a lot. The benchmarking process gave us a wide picture of assembly methods which gave us a good start with the process and concept generation. Testing and prototyping gave us a great knowledge in prototyping and 3D-printing but also a learning that using prototypes for evaluating concepts is a good way.

We had some problems during the process where the change of scope was a big turnover in our mindset and working process. It was quite troublesome but after we got familiar with the new approach it turned out quite good. The change contributed to new possibilities and better ideas which resulted in a good final concept.

10.1.6 **Reception at Axis**

The final concept was well met by supervisors and co-workers at Axis. The concept had a new approach that is different from other typical constructions at Axis and therefore many were interested in our new and quite different concept. The different working principles got good reviews where the rotationally symmetrical dome was a feature many liked. This is because it’s a special and desired feature many would like to add in different constructions. The feature of the locks holding

the dome was also very interesting for many co-workers, more than we expected. These two features were the features most people liked because it enabled the dome to rotate into the desired angle and at the same time having the locks holding the dome.

The bayonet solution was considered good because no axial force was needed and that it gave a good feedback when correctly placed was also good. Same reasoning applied for the locks where the locks also gave a good feedback when locked.

10.2 Conclusion

The recommendation for Axis is to use the findings from this thesis as a starting point for implementation in a real camera. By using this concept and producing realistic prototypes in the correct material so they can be tested or use the ideas as inspiration for further development. Section 9.7 concludes what should be done to take this concept from a conceptual level to a manufactured and selling unit.

With small modifications, this concept could be applied to other cameras as well by scaling it in size or place the features differently, using the working principle as a base.

This project and the prototype shows that an installation without screws is possible and due to a lack of this type of surveillance cameras on the market, a big market opportunity.

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Appendix A GANTT Chart and Resources

The appendix shows how the work has been divided between the students, what resources were available, the planned GANTT chart and an updated chart showing how the work was executed.

A.1 Resources

The thesis work is carried out by two students at the Mechanical Engineering program of the Faculty of Engineering at LTH in Lund and corresponds to 20 weeks of full time work each. The work has been divided equally between the two students and most activities have been done together as a team. Axis will during this time provide such equipment which Axis evaluates is necessary for the assignment. The CAD software provided at Axis is Creo Parametric 3.0 PTC. 3D-printers are available at Axis but also at Lund University, the printer at Axis uses stereolithography technique (SLA) with ABS as material and the printer at the university uses selective laser sintering (SLS) with the material Polyamide. The two techniques give different characteristics to the printed models and will be used depending on what the printed model is expected to perform.

A.2 Planned GANTT Chart

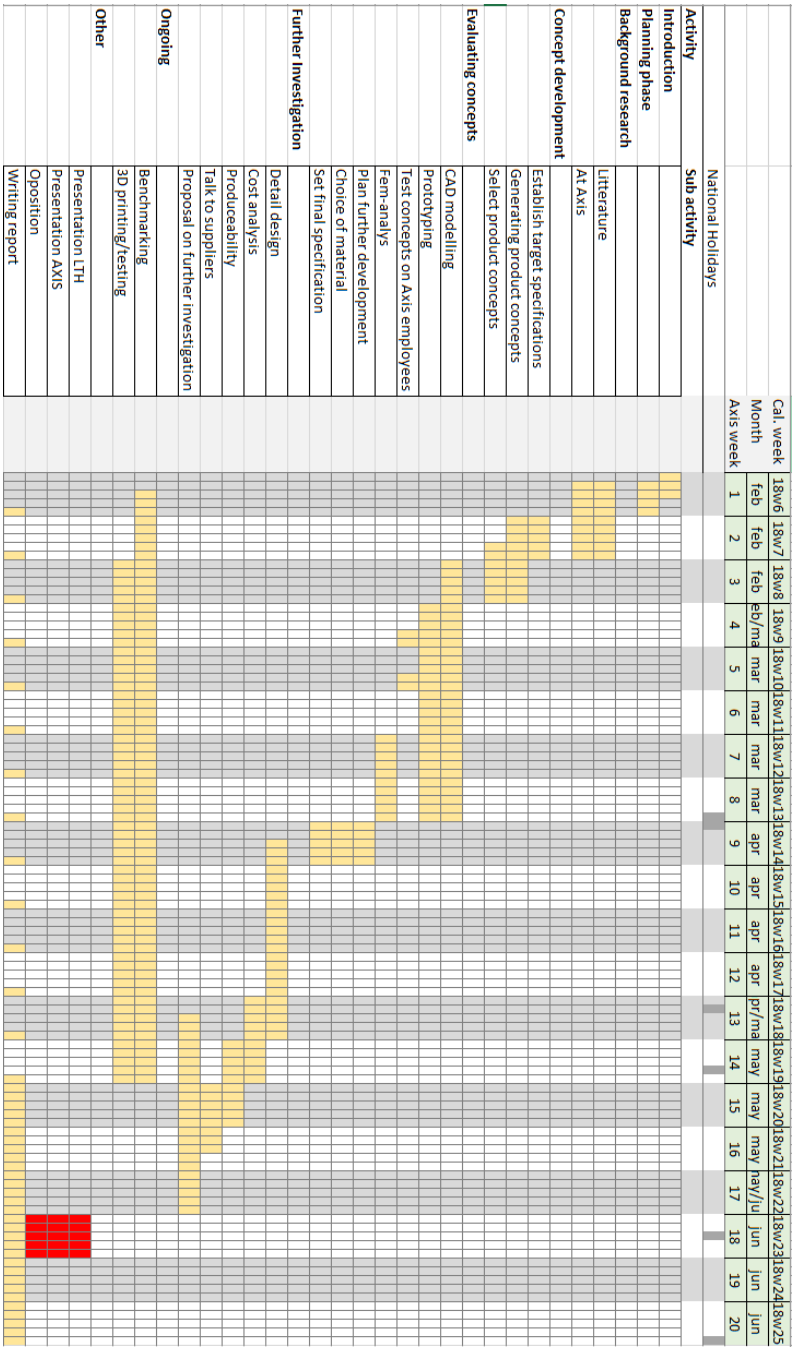


Figure A.1 Planned GANTT chart

A.3 Executed GANTT Chart

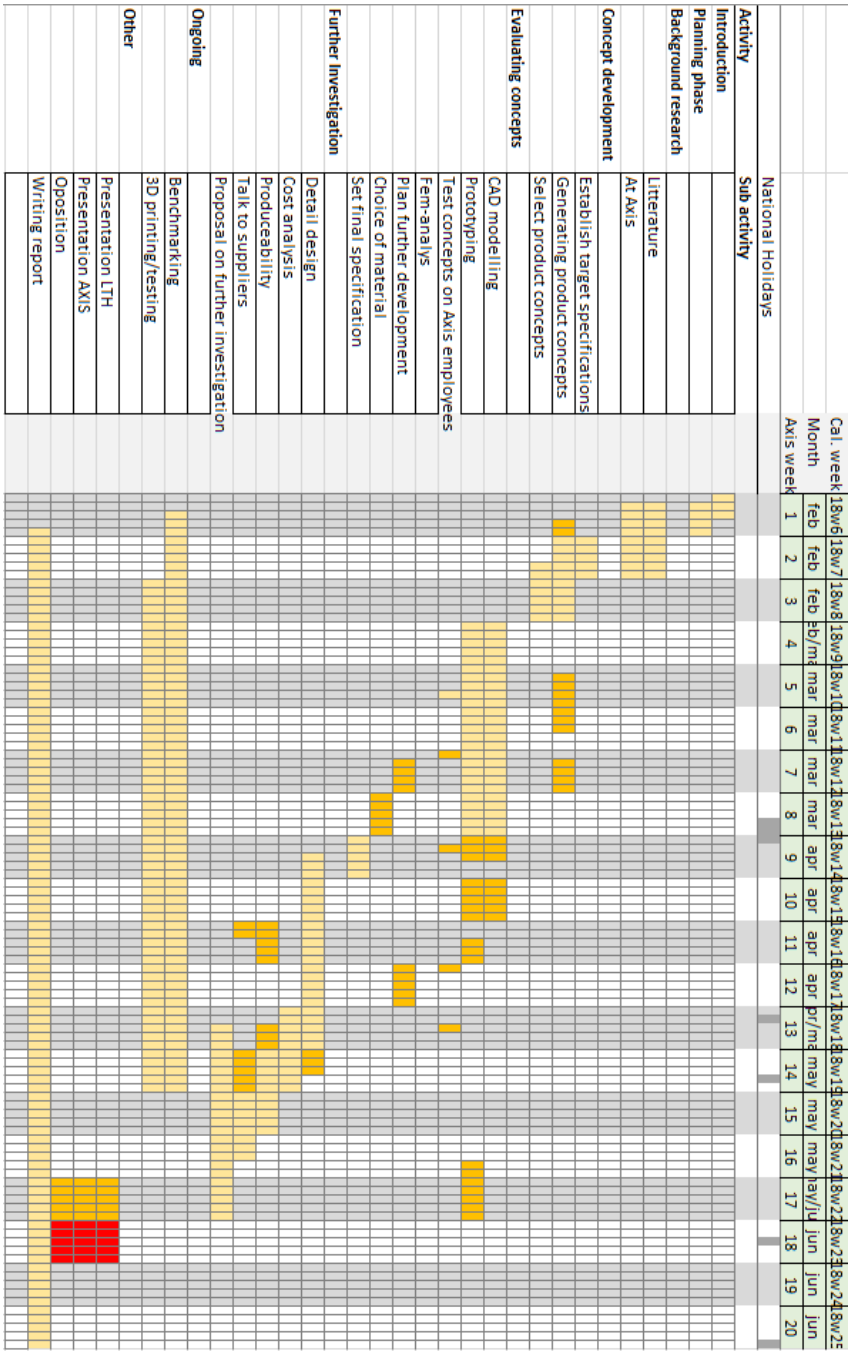
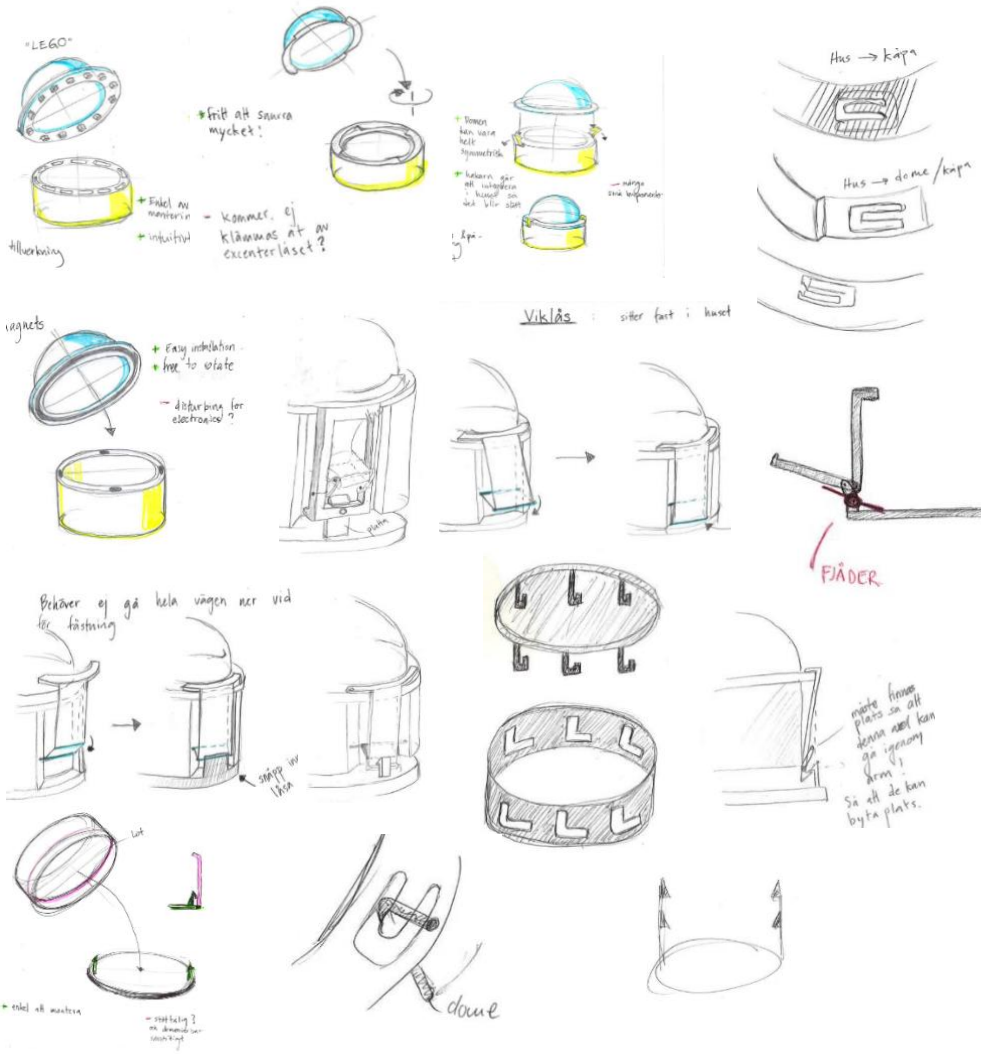


Figure A.2 Executed GANTT chart where darker yellow symbolizes added time.

Appendix B Brainstorming 1

Ideas generated during brainstorming session held week one and two of the thesis work.



Appendix C Evaluation of Concept Generation 1

Notes from meeting with five Axis employees, Olaf Hoyer, Magnus Lundegård, Gustav Aronsson, Carl-Axel Alm and Stefan Larsson. All participants got to evaluate each subproblem separately. Main learnings from the meeting are summarized in Table G.1 and used when selecting between which sub problems should be further developed.

Table G.1 Input from evaluation meeting

Sub Problem 1	Sub Problem 2	Sub Problem 3	Sub problem 4	Other
Slide concept 1.G is sloped because of delimitations when mounting the chassis horizontal in direction Concept with snap fit and bayonet can be combined Putting pressure on the mounting bracket when installing does not work on weak roofs Bayonet solution and no pressure when installing is preferable when the roof is weak Rotational lock must be developed if bayonet is used to secure it and to give more feedback "Drawer problem" making it wobble for the bayonet solution	Lego concept 2.C is sloped because of its difficulty to manufacture the construction Snap fit concept 2.D is good because it's ability of rotational symmetry Bayonet could also be a good solution Magnets are too expensive Rather use plastic flex than springs because it will be expensive Evaluate if dome can be hold with just the hands Use lock to hold up the dome?	Concept 2.H with two locks was considered to small and was therefore sloped Rocky concept 2.G was considered not as good as concept 2.B and was therefore sloped	Top cover has already been developed in a side project that could be applicable to this thesis solution. Therefore, sub problem 4 will not be further developed or considered in this thesis.	Change the scope from outdoor use of the camera to indoor use. Bracket mount should be made in plastic and not in metal Vandal resistance is changed from IK10 to IK8 Strengthen the construction for better vandal resistance

Appendix D Evaluation of Concept Generation 2

Two activities were held to evaluate the concepts from concept generation 2, one installation workshop with employees from the fixed dome department and one evaluation meeting with a Product Introduction Manager.

D.1 Installation Workshop

Notes from meeting with four Axis employees, Olaf Hoyer, Gustav Aronsson, Carl-Axel Alm and Stefan Larsson. All participants got to install both cameras in the ceiling where the brackets where pre- mounted. Combining fraction solutions from the cameras with each other were also discussed, making up other combination from the concept combination table. Main learnings from the workshop are summarized in Table D.1 and used when making a final selection.

Table D.1 Notes from installation workshop

Combination AA	Combination HH	Other combinations	Other
The bayonet with feedback feels robust. Make sure the twisting movement doesn't disturb the conduit mounting. The locks were in the way when placing the chassis. To use your hands to hold the dome were not considered a problem. Somewhat hard to lock the excenter lock from the correct position the first time you try.	A good-looking solution. But harder to trust that the snap fits will hold the chassis. Easier snap fits than the ones on the P32 today. The locks look better with less small parts. Easier to manufacture The locks need a way to be opened after being secured. Add more clips around the camera and then use the top cover to make them the compressor.	Lock 3BB from combination HH was the favorite so they should be further developed. Replacing the others is making combination AA into combination BB It is possible to add snap fits to combination AA if you don't want to hold the dome with your hand, making combination AA into combination CC or DD depending on the locks.	Both combinations were considered good and worthy to continue with. The locks need to stay away from the bracket when the chassis is being mounted. Lock 3BB looks like it should be manufactured as bent sheet metal and the wire is easily bent.

D.2 PIM-meeting

Notes from meeting with Joakim Palmqvist who is part of the PIM-team, Product Introduction Management, and has big experience within installation in the field and input from the customers. Both cameras were shown and discussed with his experience as a reference. Main learnings from the meeting are summarized in Table D.2 and used when making a final selection.

Table D.2 Notes from PIM-meeting

General input	Installation	Safety	To do
Overall: Two good cameras, no big issues with either of them. P33 is a popular camera even though it is worse quality because you can change individual parts without changing the whole camera. Look at M30 that uses bayonet but locks the SD-card so even if you can get into the camera you can't steal the SD-card. Bayonet is more intuitive and robust. The clip in the snap fit could be in metal to make it more robust. You need to be able to reinstall the cameras.	It is okay that the camera requires two hands since the installer has to be standing that safe by law anyway. It happens that parts of the camera need replacement; therefore, it has to take being dismantled several times. During installation, the dome usually needs to be placed several times from different angles to get the desired picture, therefore, the snap fits might be a problem. The installers work fast so errors can occur, like placing the dome in the wrong direction. Therefore, it must be easy to change.	It is a good idea to have some optional securing feature on the locks, like a screw or a sprint. Even though all cameras are possible to take down and destroy if you really want to, it is good to at least make it harder. If it takes longer time, the perpetrator might end up on the surveillance video at least.	Placing the bayonet correct from the beginning can be improved. Make sure it fits with the conduit, but it shouldn't be a problem because it twists a short distance. It makes a big difference if you have the optics inside during the installation or not. Should watch a real installation so a fair comparison can be made. Think about the TCO = total cost of ownership.

Appendix E Conduit

When installing the P32 camera it is possible to use a conduit as an extra feature. When it isn't possible to drill a hole in the wall or ceiling to connect the cables from behind, an external pipe with cables inside can be connected from the side instead. The end of the pipe is connected to screw towers on the bracket with a small plastic cover.

Figure E.1 Conduit bracket [31]

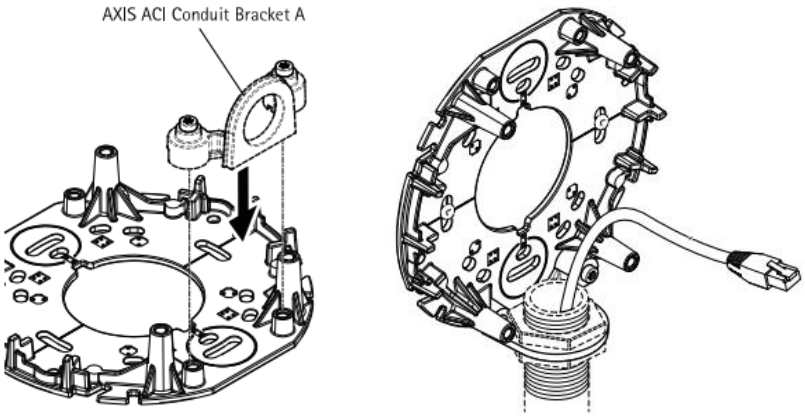


Figure E.2 Installation and function of conduit [32]