Development of a Truss Mount with Focus on Ease of Installation

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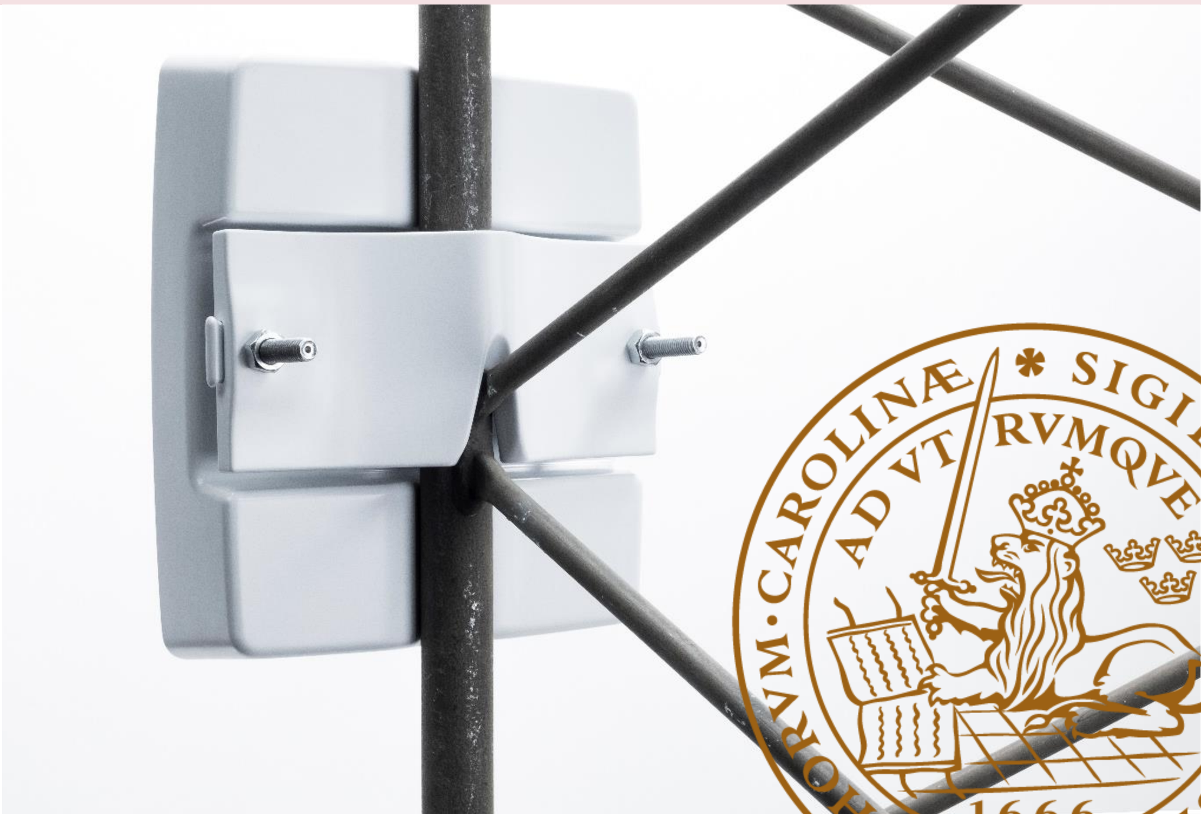

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Abstract

Products of Axis Communications, mostly premium class cameras and wall mounts, have previously been installed on trusses. However, Axis has not provided any means of installation so it has been up to the installers to create their own solutions.

This report describes the research and development of Axis first truss mount. The aim of the master thesis was to both study the environment of the product and the intended user to make it a good fit for both the trusses and the users. The goal was to provide Axis with a concept solution prototype of both a product and a process of installation.

To solve this, the authors applied *Human-centered design* in combination with the *Double Diamond* method. The whole method was iterated twice to provide the team with many opportunities to receive feedback.

The first cycle focused on researching and the insights gained laid the foundation for the direction of development. Many concepts were developed and the cycle ended with choosing one solution and further developing it into a testable prototype.

The prototype then acted as reference for the second round of research. Tests were conducted to see if the users used the product the intended way and if the team had understood the problem correctly.

The final concept has made the process of installation easier through the possibility to, without tools, swiftly clamp the product in place to make it securely fastened for its own weight. This allows for the installation to be made in multiple steps that affords pausing in between. The concept has received good reviews from both users as well as employees at Axis.

Keywords: Truss mount; Product development; Human-centred design; Network cameras; Ease of installation

Sammanfattning

Produkter från Axis Communications, primärt premium kameror och väggfästen, har sedan tidigare varit möjliga att montera på fackverk. Axis har dock aldrig haft en egen montagelösning vilket har lett till att installatörerna får skapa sina egna.

Den här rapporten beskriver utforskandet och utvecklandet av Axis första fackverksfäste. Målet med masteruppsatsen var att studera både miljön som produkten skall vistas i samt dess användare för att kunna göra en lösning som passar både fackverk och användarna. Det förväntade slutresultatet är en konceptuell prototyp av både produkten och dess tänkta användningssekvens.

För att lösa problemet så applicerade författarna ideologin *Human-centered design* i kombination med *Double Diamond* metoden. Hela metoden itererades två gånger för att tillgodose författarna med många möjligheter till feedback.

Den första cykeln fokuserade på att undersöka problemet och de insikter som observerades lade grunden för riktningen på utvecklingsarbetet. Många koncept och idéer utforskades och cykeln avslutades med att ett tillvägagångssätt valdes och förfinades till en testbar prototyp.

Prototypen agerade sedan referenspunkt i den andra cykeln där användartester undersökte ifall användarna använde produkten på rätt sätt och ifall författarna hade förstått problemet korrekt.

Det slutgiltiga konceptet har gjort installationsprocessen enklare genom möjligheten till att, utan verktyg, snabbt klämma ihop fästet runt fackverket så att det håller uppe sin egenvikt. Detta möjliggör att installationen kan utföras i flera steg och att installatörerna tillåts att pausa mellan stegen. Konceptet har mottagits väl av både användare och anställda på Axis.

Nyckelord: Fackverksfäste; Produktutveckling; Människocentrerad design; Nätverkskameror; Enkel installation

Acknowledgements

We would like to extend the biggest of thanks to our supervisors at Axis Communications AB, Agnes Rusz and Johanna Christensson as well as our manager Magnus Sjöberg for encouraging us to explore this thesis in our own manner and to chase the innovative ideas.

We would also like to thank Joakim Palmqvist for his inputs on how to design for installers and for setting up contacts with and taking us to the Port of Trelleborg. Jim Leveau and this team in Trelleborg should also be given big thanks for letting us visit several times. Further on thanks to Stefan Larsson and Kristian Borg for their continuing feedback and savvy ideas and to Stig Frohlund for helping us manufacture several prototype parts.

Finally, we would like to thank our master thesis colleges; Max Guidotti, Michael Båth, Johanna Morell, Johanna Lehander and Rakel Hed for the many laughs and funny conversations in the green booth in the Axis canteen.

Lund, June 2017

Niklas Ingemansson and Mattias Larsson Schölin

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Introduction

This chapter introduces the master thesis, the team and the company and its products briefly. It also contains the initial brief, goals and delimitations for the project.

1.1 Background

1.1.1 Team background

The design team consisted of two master students in mechanical engineering with industrial design at Faculty of Engineering LTH, Lund University, Niklas Ingemansson and Mattias Larsson Schölin. The education has given the students a specialized knowledge in both industrial design, product development and mechanical engineering [1]. Great knowledge in ergonomics, *Computer Aided Design* and *Human-centred design* is something the design team also possess.

1.1.2 University background

Lunds Tekniska Högskola (LTH) is the engineering faculty of Lund University (LU). LU were ranked as the 73th best university in the world according to Topuniversities 2017 [2]. LU is one of northern Europe's oldest universities, it was founded in 1666 has today 47 000 students of which 9 600 study at LTH [3].

1.1.3 Company background

Axis Communications AB, hereafter referred to as Axis, is a global, industry leading company within the surveillance industry with headquarters in Lund, Sweden. The company was founded in 1984 and originally started out as an IT company selling print servers [4]. In 1996 Axis invented the world's first network camera and has since been an innovator in the surveillance industry. 2015 it consisted of 2 139 employees and 80 000 partners in 179 countries and had a turnover of 6 635 billion SEK [5].

Axis product assortment consist of different network cameras, video encoders, accessories, access control products and video management software. The network cameras cover many application areas and consist of *Fixed box* and *Fixed bullet* cameras, *Fixed dome* cameras, *Pan-Tilt-Zoom* cameras, *Panoramic* cameras and *Thermal* cameras [6].

1.2 Problem description

The problem description includes the initial brief, goals and delimitations for the project as well as an initial truss definition.

1.2.1 Initial brief

Axis has a wide portfolio of different cameras and with this there is also a vast number of accessories that allow the cameras to be installed in different ways. There are mounts for poles, with pendants, arms, on corners and even recessed in ceilings. The one accessory that is currently missing from the portfolio is a truss mount.

A truss mount is an accessory that would allow cameras to be installed on framework structures. The most common framework structures or framework poles are the ones seen alongside highways holding signs or in industrial areas like harbours with lights on them.

The most important thing to know about these frameworks is that you are not allowed to make any holes in them or do anything that could potentially damage or weaken their structure.

Since there are no good truss mounts currently on the market these installations are usually done with the help of custom back plates that are created or ordered by the customer or installer themselves.

This master thesis aims at developing a mount that can be used on the most common framework structures and with a big focus on making the complete installation as easy as possible.

The brief will be updated two times throughout the project.

1.2.2 Initial truss definition

The truss, in Swedish called *Fackverk*, seen in Figure 1.1, is a structure that consists of two-force members only, where the members are organized so that the assemblage behaves as a single object [7]. It has been used throughout history, in both wood as well as in metal, as a construction method for example roof construction in houses and for bridges. The most famous truss structure construction is the Eiffel tower.

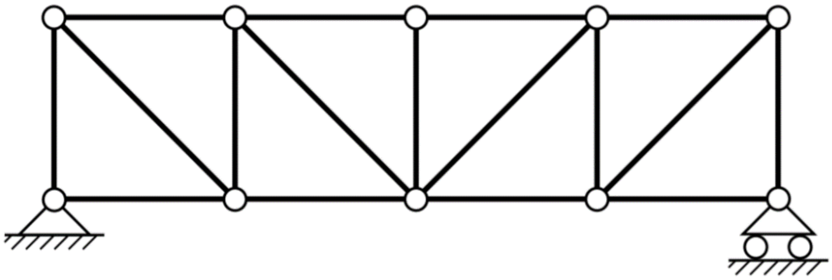

Figure 1.1 A truss [8].

This thesis however will focus on smaller versions used in industrial applications, called truss towers, which will be described more thoroughly in their appropriate chapters.

1.2.3 Initial goals

1.2.3.1 Provided goals

The goal of this thesis was to design a truss mount for Axis cameras that was adapted for the most common framework structures. The design team should acquire a clear understanding of the requirements for this kind of accessory and should integrate them in the product as well as an understanding of the environment of where this mount could be used and how it should be installed.

The design should have been evaluated with the help of prototypes and been concluded with at least one concept solution including a concept prototype.

1.2.3.2 Self-proclaimed goals

While the provided goals gave a clear understanding of the what the end goal of the project was, there were no goals for how to achieve them. Since a focus of the initial brief was to make the complete installation of the mount as easy as possible, a good way to achieve this would be to include the users in the development process. Therefore, a goal set up by the design team was to use a *Human-centred design* process and to explore how well it could work together with a technical development project.

A *Human-centred design* process is an iterative process. Thus, another goal set by the design team was that a development method that would promote a fast and iterative development of the prototypes should be used. The development process should also include at least two cycles of the whole chosen process.

1.2.4 Delimitations

1.2.4.1 Initial delimitations

The project concerned the development of the mount interface between trusses and Axis other mounts, arms and other mounting accessories as well as their network cameras. Information and specifications regarding these were given to the design team by Axis employees. One delimitation was that the design team not needed to evaluate which of these products that should fit with the truss mount, that was given.

The important part of this project is the development of several concepts that will be evaluated and improved through testing and iteration. This means that detailed prototypes will be presented but none of them will be further developed into a production-ready product. Manufacturing, material and cost aspects will be taken into consideration but will not be the focus during the development of the concept and its design.

1.2.4.2 Later delimitations

During the project, new delimitations were decided upon in their respective sections and can also be found here.

In Section 1.1, it was found that the most common trusses had round poles and webs and come in two general designs, triangular and square. These types of trusses were therefore decided to be the focus of this project. The project will also only cover straight vertical trusses. Later in the project, in Section 8.3 Construction constraints, it was decided that trusses with a pole size of 20-45 mm and an angle span of 48-66° for the webs would be the focus of the end concept.

In Section 3.2.1 Relevant industries it was decided that the relevant industries, for the type of trusses this project was aiming for, were the transportation sector and industrial sites. Therefore, the industries critical infrastructure and stadiums, concerts and festivals was removed from the focus of this project. In Section 3.2.2 Relevant markets most information was found about the Swedish market. The Swedish market was therefore chosen as the focus of this project. It was also decided that only one camera at the time should be able to be fastened on the mount.

1.3 Project arrangements

The project spans over 20 weeks of full time studies (30 credits), from January to June 2016, and is divided into the four main phases: *Discover*, *Define*, *Develop* and *Deliver* that span over at least two cycles. These phases are taken from the chosen method, the *Double Diamond* method, explained more in detail in the next chapter. The first and final project plan can be found in Appendix A.

The tasks in the project plan have been equally distributed between the two team members throughout the different phases of the project.

At Axis the team were given two supervisors, Mechanical Engineer Agnes Rusz and Mechanical Engineer Johanna Christensson. The supervisors followed the development closely and provided support together with the closest manager Magnus Sjöberg.

1.3.1 Available resources

1.3.1.1 Testing

At the Axis headquarters, there is a room called *Installation Experience Center* where an environment has been created with simulated real life installation-sites such as brick walls, poles and ceilings. There is also a section of a truss structure in the room. The team had full time access to this room to perform studies, tests and workshops.

Beyond the supervisors the team also had access to other members of the mechanical engineering team to discuss the project and use as test subjects and participants in tests and workshops.

The team also made several visits to the Port of Trelleborg.

1.3.1.2 Manufacturing

Axis provided a free access workshop with tools and a 3D printer to create the prototypes shown in the is thesis. A restricted access workshop at Axis was also used to create some parts with the help of skilled operators.

The final prototype was ordered at *GT Prototyper AB* in Ystad.

2 Method

This chapter introduces the process, the methods and the tools used in this master thesis.

2.1 Product development and design methods

2.1.1 Human-centered design

Human-centered design (HCD) [9] is an approach that puts human needs, capabilities, and behaviours first, then designs to accommodate those needs, capabilities, and ways of behaving.

HCD is a design philosophy. It means starting with a good understanding of people and the needs that the design is intended to meet. This understanding comes primarily though observation, for people themselves are often unaware of their true needs, even unaware of the difficulties they are encountering. Getting the specification of the thing to be defined is one of the hardest parts of design, so much that the *HCD* principle tries to avoid specifying the problem for as long as possible but instead iterate upon repeated approximations. This is done through rapid tests of ideas, and after each test modifying the approach and the problem definition. The result can be products that truly meet the needs of people.

Effective design needs to satisfy a large number of constraints and concerns, including shape and form, cost and efficiency, reliability and effectiveness, understandability and usability, the pleasure of the appearance, the pride of ownership, and the joy of actual use. HCD is a procedure for addressing these requirements, but with emphasis on two things: solving the right problem, and doing so in a way that meets human needs and capabilities.

2.1.2 Double Diamond model

Designers often start by questioning the problem given to them: they expand the scope of the problem, diverging to examine all the fundamental issues that underlie it. Then they converge upon a single problem statement. During the solution phase of their studies, they first expand the space of possible solutions, the divergence phase. Finally, they converge upon a proposed solution. This double diverge-converge pattern was first introduced in 2005 by the *British Design Council*, which called it the *Double Diamond design process model*, that can be seen in Figure 2.1. The Design Council divided the design process into four stages: *Discover* and *Define* – for the divergence and convergence phases of finding the right problem, and *Develop* and *Delive*r – for the divergence and convergence phases of finding the right solution [9][8].

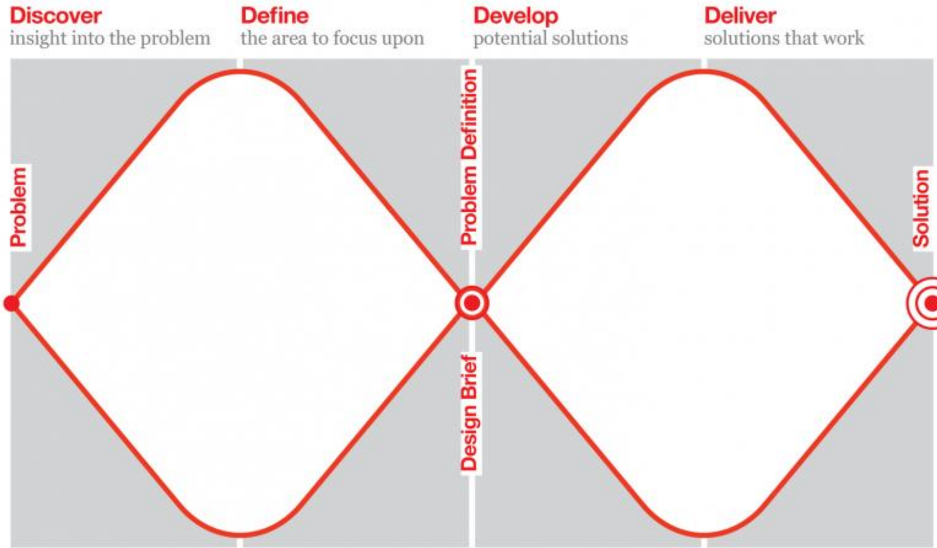

Figure 2.1 The Double Diamond design process model divided in the four phases Discover, Define, Develop and Deliver [10].

This repeated divergence and convergence is important in properly determining the right problem to be solved and then the best way to solve it. It looks chaotic and ill-structured, but it follows well-established principles and procedures.

The name Double-Diamond becomes quite self-explanatory when looking at the shape that the four diverge and converge stages together creates. If the outcome solution at the end of deliver is considered unsatisfying the process can repeat itself.

2.1.3 IDEO Human-centred design methods

The design firm IDEO and its extension IDEO.org is two acclaimed companies that for a long time have practiced *HCD*. IDEO.org have developed a step-by-step guide for *HCD* filled with methods and tools for a successful design process. Figure 2.2 shows the IDEO *HCD* process.

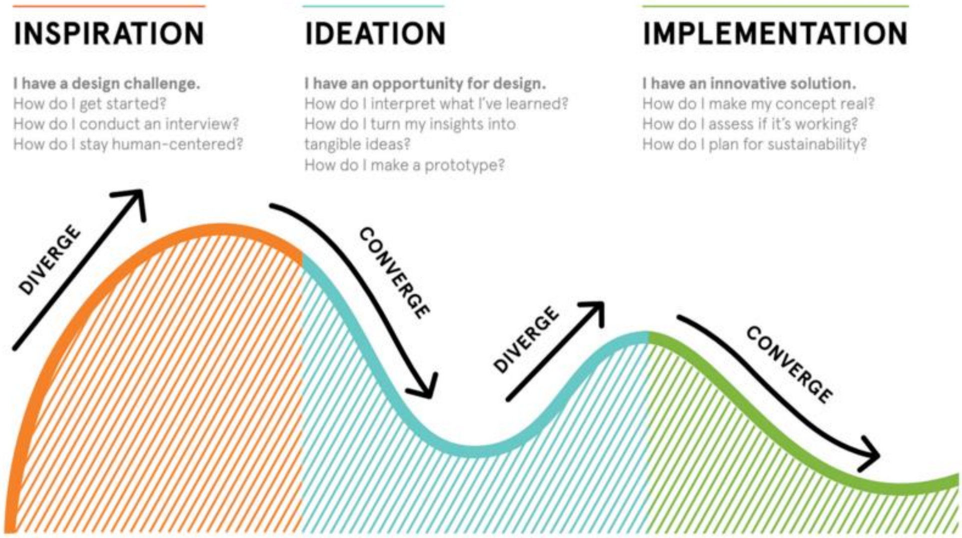

Figure 2.2 The IDEO *Human-centered design* process [11].

Their process is divided into the three phases *Inspiration*, *Ideation* and *Implementation.* The three phases correspond to the four stages in the *Double Diamond* with the *Ideation* phase being split into both the *Define* and the *Develop* phase. The process is designed to get the design team to learn directly from people, to open themselves to a breadth of creative possibilities, and then zero in on what is the most desirable, feasible and viable solution for the people being design for. They recommend diverging and converging a few times, with each cycle the solution will come closer and closer to a market ready solution [11].

2.1.4 Ergonomics

Ergonomics is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principals, data and methods to design in order to optimize human well-being and overall system performance [12]. Below are three ergonomic areas, that this project will touch upon, briefly described.

2.1.4.1 Physical ergonomics

Physical ergonomics is about the humans' body's responses to physical and physiological work demands. Repetitive strain injuries from repetition, vibration, force and posture are the most common types of issues, and thus have design implications [13].

2.1.4.2 Cognitive ergonomics

Cognitive ergonomics is concerned with mental processes, such as perception, memory, reasoning and motor response, as they affect interactions among humans and other elements of a system [12]. The reason for developing with cognitive ergonomics in mind is to improve the mental ease of use, which is just as important as the physical one when performing a complex task.

2.1.4.2.1 Don Norman's Design Principles

Donald Norman, in his book *The Design of Everyday Things* [9], introduced several basic design principles and concepts that are now considered critical for understanding why some designs are more usable and learnable then others. Below are some of the *Design Principles,* that have been used in this project, described.

The term *affordance* refers to the relationship between a physical object and a person. An affordance is a relationship between the properties of an object and the capabilities of the person that determine just how the object could possibly be used.

While affordances determine what actions are possible, *signifiers* communicate where the action should take place. The term signifier refers to any mark or sound, any perceivable indicator that communicates appropriate behaviour to a person.

Feedback is about sending back information about what action has been done and what has been accomplished, allowing the person to continue with the activity.

The design concept of *constraints* refers to determining ways of restricting the kind of user interaction that can take place at a given time. *Forcing functions* are a form of physical constraint: situations in which the actions are constrained so that failure at one stage prevents the next step from happening.

2.1.4.3 Emotional ergonomics

Emotional ergonomics, or emotional design, revolve around how to design products and services so that users will find them attractive, meaningful, engaging and safe to use. The field of emotional ergonomics is concerned with the emotional aspects of peoples' interactions with products, services or systems. Norman [14] writes *"technology should bring more to our lives than the improved performance of tasks; it should be richness and enjoyment."*.

2.2 Implemented method

Since *Human-centred design* is more of a philosophy than a precise method or set of tools, the implemented method became a combination of the *Human-centred design* principals, the *Double Diamond* process model and the methods and tools from IDEO.org. In some parts of the process, methods and tools used at Axis were used in the process.

Dan Nessler is a designer that have come up with what he calls *The Double Diamond revamped*, found in Figure 2.3 below. In it he combines *HCD*, IDEO's methods and tools with the *Double Diamond* process. *The Double Diamond revamped* is his own way of structuring up the different processes, tools and methods [10]. The implemented method has been heavily influenced by this structure.

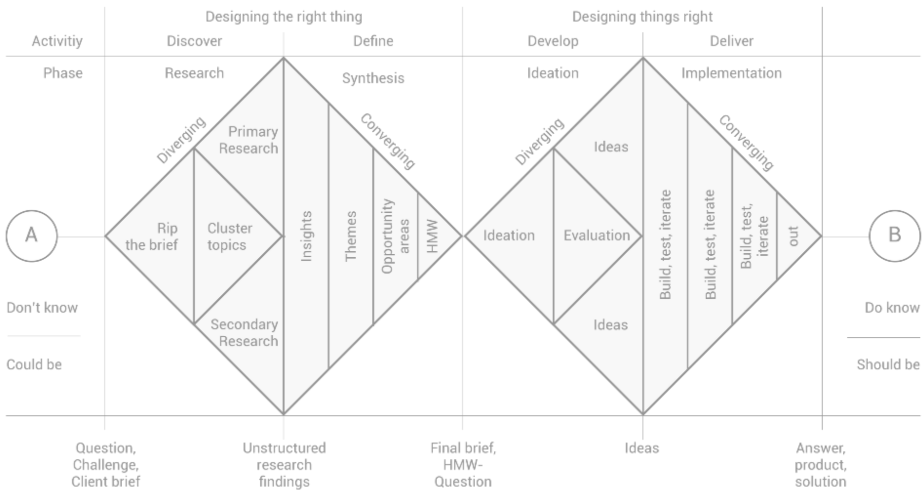

Figure 2.3 The Double Diamond revamped process by Dan Nessler has been used as the implemented method.

When the phases of the process have been executed they rely on the insights, tests and results from the previous one. Using this method only once would not guarantee any improvements over other linear approaches to product development. Much is gained from daring to try things out early, but even more can be learned from iterating the whole process over and over until satisfying results are gained. The conclusions gained in the *Deliver* phase are used as a brief to be tested in the following *Discover* phase. Depending on the organization and the assignment itself, many iterations could be conducted during the development of a product [11]. During this thesis, the team intend to complete at least two iterations of the process, more iterations would have been preferred but due to the limitation to 20 weeks, it felt reasonable not to grasp for too much. The first cycle of the project ended with a prototype that was tested with users and the second cycle ended with a proof of concept and future work for Axis. Due to time limitations, not all parts of the phases have been performed in the second cycle.

2.2.1 Discover

The purpose of the first diamond, seen in Figure 2.4, in the *Double Diamond* process is to figure out that the right thing is being designed. To do that the initial brief must be questioned and challenged. Extensive research has been made to widen the knowledge of the initial problem hence the diverging form of the phase. The *Discover* phase included environmental, technical, market, user and design research made through both primary (field) and secondary (desk) research methods.

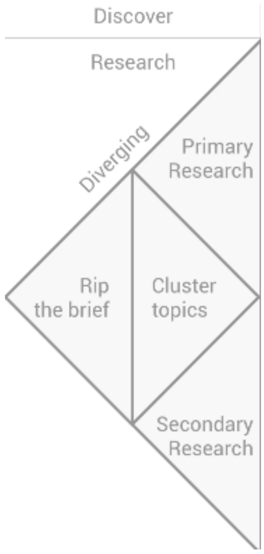

Figure 2.4 The first half of the first diamond showing the *Discover* phase.

2.2.1.1 Rip the brief

The first assumption being made is that the initial brief could be incorrect or at least not complete. To be able to start the research the brief was questioned and ripped into different cluster topics that describe different areas of interest and topics that needed to be researched as well as places that needed to be visited and persons that needed to be interviewed [10].

2.2.1.2 Primary research

Primary research or field research is one of the most important works in the *Human-centred* approach to design. Observing and interviewing the customer and the people who will use the product will give great insights about the needs and desires of them. It will also give insights about how the people solve the problem today and what problems that can arise when they do so [11].

The usual difficulties with doing primary research is to be able to find good and relevant people for the project. Many times, the best interviewees and users are found in distant countries and are hard to find, leading to expensive time and money being spent finding and traveling to them. Therefore, in many projects primary data collection is being skipped. However, the projects that do it usually end up with invaluable insights.

2.2.1.2.1 Interviews

There is no better way to understand the hopes, desires and aspirations of the people being design for than by talking to them directly. Interviews with both mainstream users and extreme users can give vastly different insights. Talking to people at the extreme end can spark creativity by being exposed to use cases, hacks, and design opportunities that talking to mainstream users would not give [11][15]. An idea that suits an extreme user will nearly certainly work for the majority of others.

Interviews with company employees, partner companies or experts can lead to a better understanding of how the company and its markets work as well as give more technical information and feedback.

In this project, interviews have been made mostly by setting up meetings but also through visits, phone calls and emails. Close to 20 different persons have been interviewed. Most of the time a semi-structured interview [16] approach have been used. In a semi-structured interview the prepared questions work as a starting point but the interviewers are still open to having a conversation with the interviewee about the topic and new information that might arise.

2.2.1.2.2 Observations and user tests

Watching users in their natural environment can lead to great insights about a user's behaviour, needs and frustrations [15]. Watching them use competitive products, prototypes or products similar to the product being designed can lead to learnings about how they use the products and the slips and mistakes [9] they might make. These learnings are many times not revealed during interviews, sometimes because the user have not ever thought about doing it another way or simply because certain steps are being made subconsciously. For a design team to be able to step into other peoples, to understand their lives and start to solve problems from their perspective, empathy is key [11].

Observing and testing products in its natural environment can also lead to insights about the environment affecting the product. Observations and testing of products can however also be performed in controlled environments with good results. It can sometimes be useful to test the products on unexperienced users. This since these users not have a built-up process of how they use the product, other human errors can be exposed when they do so.

The team requested to be present and observe an installation of an Axis camera in the Port of Trelleborg, however, due to bad weather conditions the installation was cancelled. This was a big setback and meant that the project became more reliant on the interviews and valuable insights might have been lost. During the visit in

Trelleborg the team had also planned to do an installation test above ground level with one of Axis pole mounts. This test was also cancelled due to the weather.

Axis Installation Experience Center is a controlled installation environment at Axis where the pole mount installation test instead was performed. This to get an understanding within the team on how Axis current products for mounting works. In the second cycle, user tests with prototypes have taken place in the *Experience Center*. Another user test was performed during a second visit to the Port of Trelleborg. During these tests observations have been used to study how the users interact with the given prototypes.

2.2.1.3 Secondary research

Secondary research or desk research is many times an easier way to do research. It involves finding and using information that others already have gathered though primary research. Secondary research is often a quicker and cheaper way of doing research and can also be used in a way of guiding the focus of any subsequent primary research being conducted. However, it can often be hard to find information that exactly address the question in concern and external secondary data can be of suspect quality or outdated.

In this project, both internal and external secondary research were performed. The internal research has mostly consisted of talking to Axis employees and researching their already existing products. The external research has mostly consisted of searching the internet for market and technical information relating to the project [11].

2.2.2 Define

The *Define* phase, seen in Figure 2.5, is where all the raw research findings are being structured, summarized and boiled down to themes, insights and in the end, *How might we* design questions that form the final brief.

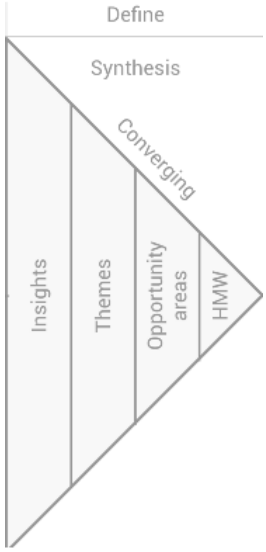

Figure 2.5 The second half of the first diamond showing the *Discover* phase.

2.2.2.1 Downloaded learnings

To be able to make sense of all the notes, photos, impressions and quotes that have been found during the research, the research is divided into different learnings or findings. In this project this have usually been done directly after each interview, meeting, observation or test to get the team to be on the same level and to not forget important findings.

2.2.2.2 Themes

After the *Discover* phase ends a lot of learnings should have been found. By starting to group the downloaded learnings into logical groups, different patterns, similarities and themes started to emerge.

2.2.2.3 Insights

Insights are the dormant truths about the consumer's behaviour and the associated motivation behind it. It is a discovery about the underlying motivations that drive people's actions. The difference between a finding and an insight isn't always apparent, generally an insight should feel inspiring to design for. An insight is not data; it is not an observation and it is not a customer's wish or statement of need. It is what is below, behind a customer's behaviour, a customer's wishes and needs and the data that has been found. It is the motivations and the whys [17]. A proven method to extract just that is to use the Japanese root cause analysis method called the *Five Whys [9]*.

2.2.2.4 How might we

If the themes and insights are identified problem areas that pose challenges to the people being design for, the *How might we questions* are the insight statements reframed as questions, starting with *"How might we",* that turn those challenges into opportunities for design. These types of questions suggest that a solution is possible and offers a chance to answer them in a variety of ways. The *How might we questions* are the basis of the final brief, that is preparing for diverging again in the *Develop* phase with ideation and brainstorm activities [11].

The *How* suggests that the answer is not yet known. It also helps in exploring a variety of endeavours instead of merely executing on what is thought to be the solution. The *Might* emphasizes that the responses might only be possible solutions, not the only solution. It also allows for exploration of multiple possible solutions and not setting on the first that comes to mind. *We* bring in the element of a collaborative effort and suggests that the idea for the solution lies in teamwork [18].

2.2.3 Develop

The Develop phase, seen in Figure 2.6, where nothing is wrong and all ideas are to be viewed as opportunities. At first it is important not to criticize since the phase is about exploring every single idea. Towards the end of the phase it is time to evaluate the ideas and concepts, this since a project only has a certain timeframe and resources, leading the team to not being able to further develop all ideas.

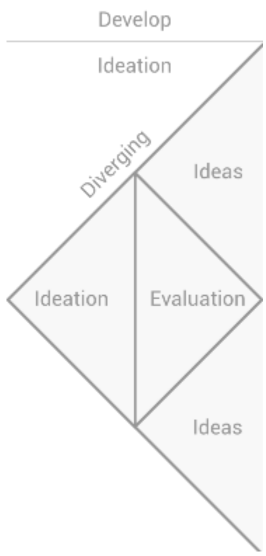

Figure 2.6 The first half of the second diamond showing the *Develop* phase.

2.2.3.1 Ideation

The ideation part of the develop phase is when it is time to be creative and diverge into as many ideas as possible. This is preferably done in brainstorm sessions. Brainstorm sessions can be done with only the design team but can also be done together with co-workers or users. The best policy for a fruitful brainstorm session is always to promote openness, lots of ideas, and creativity over feasibility [11][15]. Brainstorms work best in a group that is positive, optimistic and focused on generating as many ideas as possible. A great way to generate this mindset within the group is to defer judgement, encourage wild ideas, build on the ideas of other, stay focused on the topic, only have one conversation at the time, to be visual and to go for quantity [11].

When a lot of ideas have been generated the only way to know whether an idea is reasonable is to test it. Building a quick prototype or mock-up of each potential solution is a great way to figure out if an idea works. In the early stages of the process, the mock-ups can be pencil sketches, foam and cardboard models, or simple images made with simple drawing tools [9].

In this project the concepts have been divided into two different types, detail concepts that explore more detailed mechanisms and overall structure concepts that explore the overall ways to fasten a mount. To explore the different detail concepts, prototypes have been built using basic hardware store material to test if the mechanisms work. When building the prototypes, the aim has been to go for a *Minimum viable product* [19].

2.2.3.2 Evaluation

Depending on the nature of the project different types of evaluations can be used to compare ideas. Some ideas can consist of just words or fast scribbles and some ideas might consist of more developed prototypes and concepts. This can make it hard to easily compare the ideas with each other. An evaluation of the ideas and concept can consist of doing concept screening and scoring matrixes, by discussing and arguing in the design team, by voting or by just going with the gut feeling of the team [10]. In this project the main evaluation of concepts and prototypes have been performed through discussions within the team and in a workshop with mechanical engineers at Axis.

2.2.3.3 Ideas

After the evaluation, the team will be left with either one or many great ideas. The ideas that were not chosen should not be thrown away, there can always be some part of them that later can be used or combined with the chosen ideas to make them even better. The ideas that are chosen should then be further explored, prototyped and tested.

2.2.4 Deliver

While the *Develop* phase focuses on diverging to find as many ideas at possible the *Deliver* phase, seen in Figure 2.7, focus on improving and incrementally making the concept better by building prototypes and testing them with users over and over again. The first *Deliver* phase aimed at delivering a testable prototype while the second *Deliver* phase aimed at delivering a more finished proof of concept with a more polished prototype.

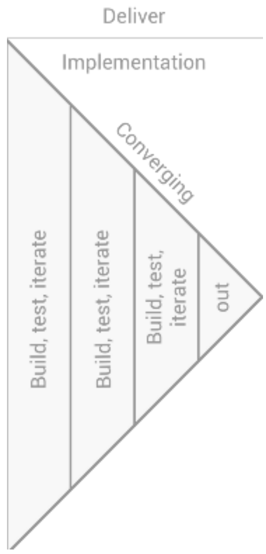

Figure 2.7 The second half of the second diamond showing the *Deliver* phase.

2.2.4.1 Build, test, iterate

If physical prototypes have not been used yet, it is about time. Using CAD tools and sketching is a great way of exploring a concept, however, the best way is usually to fast try to build a prototype of the concept that quickly can be tested. There is no better way to find out how a person will react to or interact with a product than to test it. The first prototypes do not have to be advanced, they can be simple, scrappy prototypes that only focus on testing the critical elements [11][15]. The concept of *Rapid Prototyping* is to only build enough to test an idea, to aim for a *Minimum Viable Product*, and once feedback have been given go back and make it better. Once critical elements have been solved more time can be put into every prototype. In the end, CAD together with 3D-printing can be powerful prototyping tools to refine the solution even more [9].

3 Discover I

The Discover I phase is the start of the product development in this project. This is a diverging phase aimed at questioning the given brief and conducting research.

3.1 Technical research

To get to know the characteristics of the truss structures were cameras commonly are installed and to get to know the system of Axis products that need to work with the truss mount, a technical research was conducted.

3.1.1 Trusses

As stated in the introduction, trusses can come in many different variations. In construction of truss type bridges and roofs, multiple welded beams with different profiles, such as I-profiles or square-profiles, are typically used. However, the most common trusses were found to have a round profile and the pole having a thicker diameter than the web, seen in Figure 3.1.

Figure 3.1 The truss found in Axis Installation Experience Center, is the same as the one found in many harbours. The poles are thicker than the webs.

Figure 3.2 A typical harbour truss carrying lights, this one found in the Port of Trelleborg.

The trusses were found in two general designs, triangular, seen in Figure 3.2, or square, seen in Figure 3.3, and are constructed in steel that has been galvanized to prevent it from rusting.

Marco Tuokko at Scanmast explained that trusses are used to achieve *"Maximum strength using a minimal amount of material"* and a triangular shape is used since it is the simplest geometric figure that will not change shape when the lengths of the sides are fixed **Error! Reference source not found.**. The section of the truss tower located in *Axis Installation Experience Center* is the same as in Port of Trelleborg and is constructed by Scanmast, seen in Figure 3.2.

According to Dennis Karlsson Tunhult, a former employee at Saferoad Vägbelysning AB, the square type is the most common version produced by them in close proximity to roads since it can be assembled as a *portal*, seen in .

Figure 3.3 A Swedish highway truss portal carrying a road sign. This one found near the Axis Headquarters.

Both interviewed sources explained that almost all orders are custom made with regards to the intended area and what products their clients wish to install. Their companies provided inputs on the client's ideas and performed analyses to confirm the needed strength for the truss. The trusses come in varying sizes and the diameter of the pole and the web can also vary.

3.1.2 Axis target products

Researching which Axis products that the truss mount would need to work with has been out of this project's scope, as seen in 1.2.4.1 Initial Delimitations. However, knowing which products that need to interact with and be fastened to the mount is essential for the development of the mount. To get to know which cameras the mount should target, discussions with Michael Chen, Global Product Manager for Accessories and Special Cameras at Axis, were held. After discussions with co-supervisors Rusz and Christensson a hole pattern was chosen and suitable arms and other accessories were decided upon.

3.1.2.1 Cameras

According to Chen, the primary target camera series for a truss mount is the *Q-line*. The *Q-line* network cameras are the most advanced, secure and adaptable video surveillance solutions on the market. Robust and durable in both performance and in design **Error! Reference source not found.**.

The secondary target camera series is the *P-line*. The *P-line* products are adaptable and provide advanced network video capability. Versatile and secure, the multipurpose P-line is suitable for a wide range of mainstream usage.

For both lines the *Fixed box cameras,* seen in Figure 3.4, *Fixed bullet cameras,* seen in Figure 3.5, *Fixed dome cameras,* seen in , *PTZ (Pan Tilt Zoom) cameras,* seen in Figure 3.7, *Panoramic cameras,* seen in Figure 3.8, and *Thermal cameras,* seen in , are included.

Figure 3.4 An Axis Fixed Box Network Camera.

Figure 3.5 An Axis Fixed Bullet Network Camera or an Axis Fixed Bullet Thermal Network Camera.

Figure 3.6 An Axis Fixed Dome Network Camera.

Figure 3.7 An Axis PTZ Network Camera.

Figure 3.8 An Axis Panoramic Network Camera.

3.1.2.2 Arms

Wall mounts, or arms, as some of them are called, are mounts that are fasten on walls to allow the camera to be placed a bit away from the wall. For most *Fixed Dome* cameras, *PTZ* cameras and *Panoramic* cameras this also allow them to be inserted vertically into the arm. The arms can also be fastened on poles by connecting them with an interface to a pole mount. The same could be done with a truss mount. Below are the primary arms and their respective hole pattern, seen in Figure 3.9, thought to be placed on the truss mount described.

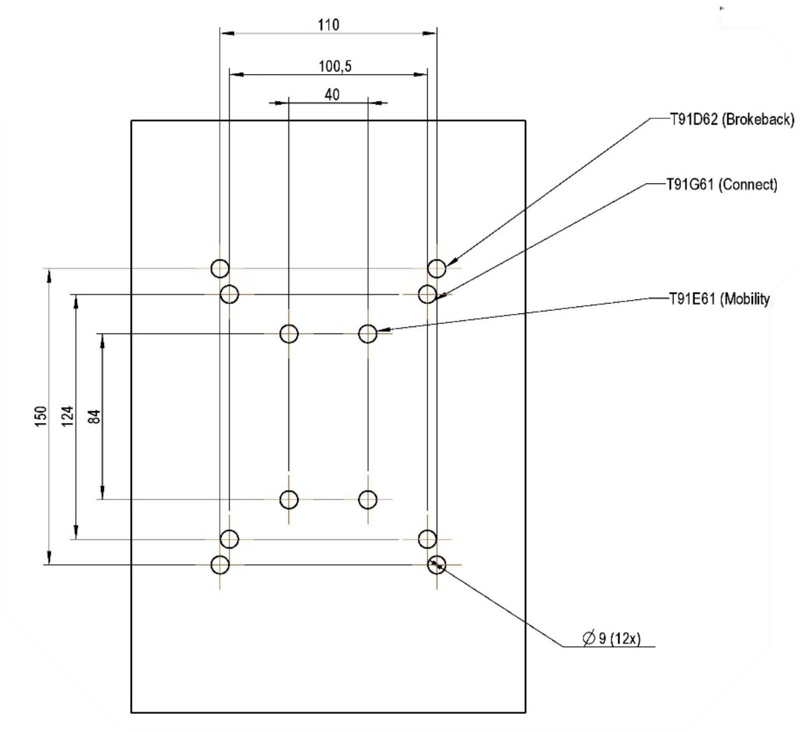

Figure 3.9 The targeted hole pattern including the hole pattern for *Brokeback*, *Connect* and ***Mobility***.

3.1.2.2.1 Brokeback

The *Axis T91D62 Telescopic Parapet Mount,* seen in Figure 3.10 , or *Brokeback,* as it is called internally, is Axis biggest wall mounts. According to Rusz and Christensson, it is important that this truss mount works with this mount. The mount has a long telescopic arm that allows it to exert a large torque on the wall or the mount that it is fastened on. This especially if one of the heavier *PTZ* cameras are fastened on the *Brokeback*. This is the reason this mount has the biggest hole pattern and a very big interface. Right now, there is no perfect solution for fastening

Brokeback to either a pole or a truss. However, a pole mount called *Bro Hug (Axis T91A67)* is being developed at Axis that is aimed specifically at *Brokeback's* more extreme demands.

Figure 3.10 Axis T91D62 Telescopic Parapet Mount (Brokeback).

3.1.2.2.2 Brutus

Brutus a new camera including a specialized arm being developed at Axis. The *Brutus* is a very heavy, big and high quality *PTZ* camera. The whole kit including arm is supposed to weigh around 40 kg. There is a wish at Axis that the developed truss mount shall work with this arm and camera, making it the heaviest kit the truss mount shall be able to hold. This arm is using the same hole pattern as *Brokeback.*

3.1.2.2.3 Connect

The *Axis T91G61Wall Mount*, seen in Figure 3.11, or *Connect* as it is called internally, is a beautiful yet strong wall mount aimed at the bigger *PTZ* cameras (a similar version for fixed dome cameras exists as well called *Fixed Dome Connect (T91H61)*). When the *Connect* need to be fastened on a pole the *Big Hug (Axis T91A57)* pole mount is a great fit. However, there is no good solution for fitting the *Connect* to a truss or a thinner pole. The *Connect's* interface has a smaller hole pattern than *Brokeback*.

Figure 3.11 Axis T91G61 Wall Mount (Connect).

3.1.2.2.4 Mini Connect

The *Axis T91L61 Wall-and-Pole Mount*, seen in Figure 3.12, or *Mini Connect* as it is called internally, is a smaller version of the *Connect*. This mount is shipped with a reversible back interface that can be fitted to both walls and poles. However, there is no good solution for fitting the *Mini Connect* to a truss or a thinner pole. The *Mini Connect* has the same hole pattern as the *Connect* but has a smaller dimension on the interface.

Figure 3.12 Axis T91L61 Wall-and-Pole Mount (Mini Connect)

3.1.2.2.5 Mobility

The *Axis T91E61 Wall Mount*, seen in Figure 3.13, or *Mobility* as it is called internally, is a much simpler wall mount aimed at Axis *Fixed Dome* cameras. This mount has a smaller hole pattern and much smaller interface. The pole mount *Hug (Axis T91A47)* fits *Mobility* well.

Figure 3.13 Axis T91E61 Wall Mount (Mobility)

3.2 Market research

Much of the secondary research conducted consisted of exploring relevant markets and industries as well as exploring already existing solutions and competitor products.

3.2.1 Relevant industries

Scanning the market for industries where trusses, truss and mast towers in combination with surveillance and security cameras were used as well as looking for already existing solutions led to finding the following relevant industries for the product. Unstructured interviews with Axis employees later confirmed that the found industries should be relevant.

3.2.1.1 Transportation

The transportation sector is an important market for Axis. Axis surveillance solutions create safer transportation environments, reduce costs for vandalism and graffiti, enables efficient monitoring of cargo and property and reduce incident response times [22]. The transportation sector is also often the market were trusses are found.

3.2.1.1.1 Harbours

Industrial harbour security is not only about protecting the great number of valuable goods that pass the premises every day. It is also about protecting the harbour as a part of the critical infrastructure. To solve this efficiently, many port authorities and cargo operators have chosen Axis network video solutions. Examples of areas were network cameras can be used in harbours are remote monitoring of container identification numbers, rail car number and other data and remote inspections for container and cargo damage as well as entrance and exits overview.

Many ports have lots of truss towers for lights and surveillance and some of them make their own truss mount solutions by hand. To get a clearer view of this several visits to Port of Trelleborg were made during the project.

3.2.1.1.2 Highways

Highways are a common place for wireframe structures. Typically, so called portals are found holding road signs over highways. Traffic surveillance cameras are typically used to aid commuters, give valuable data to transportation departments, to enforce laws and encourage safe driving [23][24]. Axis have traffic surveillance solutions that ranges from solving congestion and stopped vehicles to serious accidents and extreme weather.

3.2.1.1.3 Airports

Airports are places that commonly have tough surveillance needs. Both indoor and outdoor surveillance are central in airport security. It’s not uncommon to have truss towers on the taxing areas. These can be used to fasten cameras for perimeter protection and to control air traffic.

3.2.1.2 Industrial sites

Construction sites and parking lots for equipment in general have a need for security cameras due to the value of the equipment kept there. As with other similar markets, trusses can be found here. However, in industrial sites they are often found as a roof structure.

3.2.1.3 Critical infrastructure

Critical infrastructure and facilities need to be prepared for all sorts of threats. Everything from incidents and theft to terrorism and natural disasters can cause disruption and safety hazards. Axis surveillance solutions work great as perimeter protection for these kinds of facilities.

3.2.1.3.1 Radio masts

The greatest threats to telecom companies are intruders with criminal or terrorist intent. Having surveillance in place at radio masts, often placed at remote location, can prevent or limit dangerous activity. Examples in Sweden have been both climbing on and damage to mast towers [25][26]. Because of these incidents a big radio mast manufacturer in Sweden have invested a lot of money into video surveillance.

Radio masts often consist of very high framework structures. Since these masts often need to have thicker poles, pole mounts or specially manufactured mounts can be used for mounting cameras. According to Carl Staël von Holstein, Key Account Manager at Axis, a big company in Sweden working with big radio mast have extreme demands on their mounts. He says that they often place between three to seven cameras on the same mount often with speakers as well. Staël von Holstein recommends that the development of the truss mount not to focus on these kind of radio masts and conditions.

3.2.1.4 Stadiums, concerts and festivals

Modern improvements in surveillance technology have made security cameras a great security solution for conventions, concerts, festivals and other large events. Video surveillance can play a significant role in maintaining order and preventing crime at concert events where large excitable crowds, and often alcohol, are present [27].

FX technician Patrik Berg at Arclight FX AB explains that the trusses used for concerts and other temporary events differ much from those in outdoors and industrial applications. Further explanation follows in *3.2.3.2 Stage assembly*.

3.2.2 Relevant markets

From talking with different employees at Axis the following countries were thought of as important markets.

3.2.2.1 USA

According to Michael Chen, Global Product Manager at Axis, 70 % of all of Axis accessories are sold in the US. According to Steve Burdet, Regional Product Manager US at Axis, trusses are not that common in the US. In the US they usually depend on more big, bulky and heavy poles to mount cameras on. Burdet also says that US highway portals can consist of trusses however there is no standard at all in place. Some states use truss structures and some use poles and other solutions. He also mentions that it is very common for Axis cameras to be mounted inside retail stores such as *Target*. Their ceilings resemble truss structures. There are often a lot of cameras there. The US Sales Group at Axis was asked for more information regarding US truss mounting solutions but none answered.

3.2.2.2 UK

According to Ian James, Technical Lead UK and Northern Europe at Axis, and Mark Eggett, Sales Engineer UK at Axis, the vast majority of camera installations with pole mounts are made on dedicated CCTV towers in the UK rather than on trusses. These poles and towers are made with a purpose made camera mounting plate on the top of the poles and towers. There are two main companies that manufacture these towers in the UK. James says that the only places he has seen a truss mount being applicable in the UK would be at ports. Eggett says that he has only come across a couple of installations were cameras have needed to be mounted to a truss structure.

3.2.2.3 Canada

According to Joakim Palmqvist, Product Integration Manager at Axis, Canadian industrial harbours have the same truss towers as the ones found in Port of Trelleborg.

3.2.2.4 Sweden and the Nordics

All the examples in *3.1.1 Relevant industries* are found in the Nordic region, the usage of trusses have been covered in *3.3.1 Types of trusses*.

3.2.2.5 Germany

According to Timo Sache, Product Analyst EMEA, Field Sales, Middle Europe at Axis, the industrial harbour in Rostock, Germany, has the same truss towers as the ones in found in Port of Trelleborg.

3.2.2.6 China

Chen proposed that the team surveyed the Chinese market for opportunities. However, he said that it was not as important as to focus on other markets. While contacts and sources of information were quick to reply about the other markets good information regarding the situation in China was never found.

3.2.3 Benchmarking

The market was scanned for existing truss mount solutions or solutions similar to truss mounts.

3.2.3.1 Axis pole mounts

Axis have a variety of mounts, mounts for walls, roofs, corners and for poles. Two of the most common pole mounts are *Axis T91A47, Hug*, seen in Figure 3.14, and *Axis T91A57, Big Hug*, seen in Figure 3.15. Both are fastened with metal straps and a special tightening tool. These can be mounted on poles with a big variety of thicknesses, however these are not optimal for very thin poles seen on trusses due to the usage of metal straps and their wide profile.

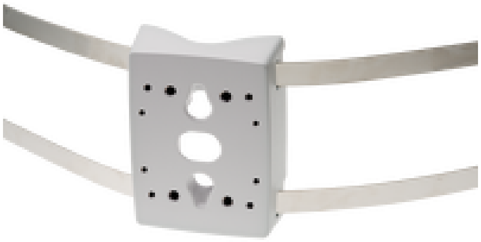

Figure 3.14 ***Axis T91A47 Pole Mount (Hug)***

Figure 3.15 ***Axis T91A57 Pole Mount (Big Hug)***

The team installed the *Big Hug* pole mount, together with the *Connect* arm, described in Section 1.1 and seen in , and a *PTZ* camera, seen in , on a pole. Another test was performed were a *Connect* arm and a *PTZ* camera was installed on a wall as a reference.

It was noted that the straps that Axis use for installation with its pole mounts works in a suboptimal manner. The straps require a special tool, does not allow the user to pause during the installation process and are difficult to tighten properly. The team was not able to fasten the pole mount even when the two worked together. This struggle was later confirmed with several Axis employees whom also expressed their difficulties, seen in Figure 3.16 , using the straps. Many learnings were found on how not to design things.

Figure 3.16 During the installation test of *Big Hug* many frustrations were expressed with the metal straps.

Mounting the *Connect* arm, seen in Figure 3.17, provided a better experience. It was possible to only mount the back interface of the arm before connecting the major parts, which meant that the installation process could be made in steps and paused if needed to. When the *PTZ* was to be installed in the arm, it as well could be done in two steps with a possibility to pause between. The backside of the camera was first slotted in to visible key hole slots and twisted to lock in position. Then it was screwed in place using preassembled anti-loss screws. Both screwing actions were done with one single type of screw head so only one type of standardised tool was needed. This installation worked in a manner that had been found as preferable in the previous interviews with installers.

Figure 3.17 An *PTZ camera* fastened on the bottom part of the *Connect arm* that is **mounted to the *Big Hug* pole mount.**

3.2.3.2 Competitive products

No real competitive product has been found fastening network cameras on trusses. However, one competitor has been found making a mount that works with horizontal trusses and some integrators and truss manufacturers have been found making their own mounts for truss installations.

3.2.3.2.1 Truss manufacturer solutions

Truss manufacturers provide solutions for mounting if their clients wish to attach cameras or other fixtures, seen in Figure 3.18. While efficient at accommodating any type of product from any manufacturer they include many different parts that needs to installed in numerous steps and aligned separately.

Figure 3.18 Different truss mounting solutions on a truss from Scanmast.

3.2.3.2.2 Special homemade truss mounts

Several sites have been found to make their own truss mount solutions. These are typically tailor made for the truss or mast and camera in question. In the Port of Trelleborg they have a workshop that makes their own mounting solutions with plates and clamps from regular hardware stores. According to the team there, these mounts usually consists of a big piece of sheet metal that matches the width of the truss. Holes are then drilled in the sheet metal for the interface of a camera and arm and around the areas of the two poles to be able to fit clamps around the poles and through the holes. These are then tightened with nuts. Anders Thornberg, Smith at the workshop in the Port of Trelleborg, says that the process today includes measuring the truss and the shipped camera and arm, buying parts, manufacturing by hand and then installing.

3.2.3.2.3 NOVATTACH

NOVATTACH [28] is a company that aims to simplify the process of mounting cameras and other devices. Their patented [29] truss mount solution, seen in Figure 3.19, uses a steel threaded hook that attaches the mount to one of the trusses poles, it is then simply fasten by spinning the camera onto the truss. No screws and no tools needed. Even though this solution is smart and easy to install it seems to be restricted to smaller and lighter cameras. Also since it operates on a different type of truss, it’s not directly applicable on the type of truss this thesis focuses on.

Figure 3.19 The NOVATTACH mounting solution.

3.2.3.2.4 Truss mounts for other products

There are a lot of different solutions on the market for mounting other products than security cameras on trusses. Solution have been found for TV monitors, projectors, speakers and lights.

Speakers and lights are usually hanged on horizontal trusses and tighten with a clamp and a security wire. From talking with Berg at Arclight it was understood that stage assembly, the place were lights and speakers are mounted, is all about making the mounting process fast. These devices are usually fastened on the truss on the ground and then lifted in place.

Truss mounts for TV monitors are mostly made to be fasten at both poles on the truss. They are fastened with clamps that fit a variety of truss and pole dimensions, though these are usually ordered separately. In some solutions, the clamps can be fastened on a variety of places on the mount so that it can fit different sized trusses.

3.3 User research

Axis has an indirect sales model that is complex enough in itself to fill up its own thesis. But the general principle is that they never sell directly to the end customer and hence does not have regular contact with these. Since it was of importance for this thesis to meet the intended users contact was made with Product Integration Manager Joakim Palmqvist to set up at study visit at one of the few places where Axis has regular exchange of information with end users. The decided place to visit was the Port of Trelleborg since the most common placement for cameras there are on trusses and since he has a good relation with the workers there. One source of information is however not enough so to get a broader understanding many interviews were conducted, in person or over the phone, with people who worked with installing or had good knowledge of Axis products.

3.3.1 Installers

Interviews were conducted with both installers, one seen in Figure 3.20, that has previously installed Axis products and those who has not, this means that some findings are not directly applicable on this project but provide valuable insights on the theme of high altitude installation in general. An example being that some other applications and installations found during interviews could include the event of more than 100 m climbing and the usage of helicopters.

Figure 3.20 Jim Leveau, Chief of Security at the Port of Trelleborg, was one of the people being interviewed.

While every interviewee had their own specific problems and ideas of what they expected from a solution many shared the same view of what they wanted in general.

According to everyone interviewed, installations on the targeted type of truss will be performed above ground level. This puts constraints on how a product can and will be handled. Dropping a screw on the ground differs much from the event of dropping a screw at 15 m, not only could it hurt someone below but also if the dropped part is essential to the installation it would mean that the whole installation would need to be postponed until they have descended and re-ascended.

Also, many expressed that *"everything becomes harder at above ground level"* and continued explaining that the truss will be moving in the wind, vibrations from passing cars or trucks would transfer up into the truss. If climbing was the ascent of choice the need to support their own weight would also become a challenge. The most likely scenario is that a sky lift will be used to elevate the installer in a basket to a desired height and provide a floor to stand on. This basket will however also be exposed to swaying, it is even a likely scenario that the basket and the truss tower will be swaying in opposite directions, making it even harder to control the situation. Installers expressed a desire to be able to pause the installation to hold on to themselves if the swaying became too intense.

As one interviewee said*: "something as trivial as using both your hands at the same time or moving one meter sideways becomes a challenge, now imagine installing a product with multiple screws or straps"*.

From the interviews, it was confirmed that few installations of products on trusses used any pre-bought mounts. The general principle was that the installer had good knowledge of how to create a custom mount made from assorted parts in a hardware store. If they were to use a bought product they expressed a need for the product to be universal, since if modifications were needed it would be easier for them to make a mount from scratch.

3.3.2 Buyers

Even though the installer will be the one using the product, it is rarely the case that the same person will be the one buying it. A buyer will most likely never interact with the product unless it is at an exhibition or similar event. However, they are the ones deciding on what will be bought and what not so making sure the product plays to their needs as well is important for the product to be successful. Kristian Borg, Mechnical Engineer at Axis, explained that many times products, screws and thicknesses are oversized just to look like they are tough, to be attractive to the buyers. Price is also an important aspect to the buyers. When Michael Chen is asked if he must choose between a truss mount with great design and high price contra a product with a bit inferior design and a competitive price, he chooses the latter. A competitive price is real important to the buyers on the accessory market.

3.3.3 Extreme users

3.3.3.1 Climbers

The activity of installations at high altitudes could draw parallels from climbing. A brief interview with weekend climber Johan Hansson concluded that when selecting his equipment, he was looking for products that he felt he could rely on and that could fill multiple purposes. The reliability is important since the equipment will at times support the full weight of the climber, should it fail, the climber could be in immediate danger of falling. The equipment's ability to be useful in multiple situations matters since a climber only has space for and only can carry a certain amount or weight, if tools are multipurpose, less equipment can be brought.

3.3.3.2 Stage assembly

Trusses are also used as building material for music stages, venues and other short term installations. These, however, differ much from the other found in *3.1.1 Relevant industries*, both in construction and in usage. The trusses in this area are made of aluminium and are designed for rapid assembly and easy disassembly. Also, the fixtures (speakers, lights, etc.) differ as they will be covered by roof and has less demanding requirements on their stability and longevity.

According to Berg at Arclight, all installations are performed at ground level and later brought to the desired height with the help of engine powered winches.

3.3.4 Available resources during installation

3.3.4.1 Reaching installation altitude

The most common type of ascent is the above-named sky lift. An aerial platform able to transport installers from ground level up to a desired height. A sky lift can for example be found as mounted on a truck, on legs and as its own vehicle. Climbing up along the truss or on a provided ladder is a possibility but according to the interviews it is unlikely in the intended scenario.

3.3.4.2 Tools

Installers will have access to cordless power tools and other standard tools when performing installations. According to Palmqvist, being able to use power tools is always appreciated by the integrators.

3.4 Environmental research

To get to know the environment around the trusses were cameras are supposed to be installed an environmental research was conducted.

3.4.1 Weather

Since the truss mount is aimed at installations in outdoor environments, weather will be an important factor to consider. The weather will affect the product through rain, temperature variations, sun and wind. However, sun and temperature variations was not thought to be important to the development of the truss mount and therefore not researched any further.

3.4.1.1 Wind

The truss mount, with camera and accessories, will be exposed to wind and it is important that it does not move, rotate, vibrate or fall since this will affect the camera view. The wind can be of different strengths and directions and therefore the mount must be fastened hard enough against the truss to prevent this from happening. Weather data provided from the Port of Trelleborg showed that wind speeds of upwards 13.5 m/s in was to be expected in general. The highest recorded wind speed last year was 26 m/s, data is provided in Appendix D. To put this in perspective, if these speeds were over land, the general result means that large trees will be swaying and it will be hard to walk unhindered into the wind. Last year's peak is according to SMHI [30] strong enough to pull trees by its roots and cause severe damage to houses.

When consulting with Marko Tuokko at Scanmast he described that when calculating the needed strength of their client's trusses they made their calculations with the strongest measured wind in the intended area over the last 50 years as input.

3.4.1.2 Corrosion

Trusses are rarely placed in covered spaces and are therefore galvanized to withstand corrosion, even in the wettest of conditions. A product that is fastened on a truss should also have a resistance to corrosion since it cannot be expected to receive continuous service.

3.4.2 Insects and spiders

There is a problem with bugs getting into the outdoor cameras. Specifically, bees and wasps may cause danger when the camera is being serviced. To keep wasps from nesting, Axis products should not have any gaps larger than 3 mm [31].

Another aspect to be concerned of is that spiders like the heat produced by the cameras. This could lead to spiders nesting inside the mount or cameras which could lead to the camera lens getting dirty and triggering costly false alarms, according to Timo Sache.

3.4.3 Vibrations

Axis cameras are well equipped to handle vibrations due to algorithms that stabilizes the video feed. However, vibrations from surrounding environment caused by traffic and weather could lead to fatigue and failure in the material. Different standards exist to categorize different levels of vibrations. All products designed by Axis should be tested for vibrations and shock according to an international standard [32].

4 Define I

The Define I phase is all about boiling down all the research and findings found in Discover I and formulate that into a new brief.

4.1 Structure of the define phase

In some ways, this phase was conducted in tandem with the *Discover* phase. The findings presented here were written down immediately after or during the different research phases. The big difference is that while *Discover* was a divergent phase, *Define* is convergent. It was in this phase decisions were made upon the relevance of each finding and how they fit into the bigger picture.

4.2 Insights

During the *Discover* phase, a vast collection of valuable quotes and specific findings was gathered on post-its as well as in videos, audio-transcripts and in written form. Anything that was thought to be of significance was highlighted.

Since a finding is not enough to draw a general conclusion, a multitude of these findings had to be collected from different sources to confidently calling it an insight. Each interviewee responded to a question in their own manner, but from putting the answers next to each other and considering the whole context, parallels could be drawn that indicated towards the underlying problem that all of them described. Another good way of finding the underlying problem has been to use the *Five Whys* method on the findings. In the end ten insights, seen in Table 4.1, were formulated from the total of 44 findings.

Table 4.1 The ten insights found.

#	*Insights*
1	Installers want a solution that is efficient through it being intuitive and prohibiting erroneous behaviour.
2	It is important to take the installers limited resources into account.
3	Installers want to install mounts facing them.
4	The design should fit all trusses inside a specific size range.
5	Installers want a broad selection of positions to fasten the solution and can change the orientation and/or location.
6	Installers will only use products they trust
7	The buyer and the user will have different views on what is important.
8	Weather, water, salt, corrosion and consistent vibrations will expose the products.
9	Trusses have strict requirements and may not be tampered with.
10	The most common trusses consist of round poles and webs.

4.3 Themes

The insights opened many opportunities for exploration. However, starting off by just evaluating them one by one could be very time inefficient since most of them had some sort of relevance towards others in the mix. Combining these together and categorizing them under relevant themes can give a clearer picture and whole areas worth of exploration. Included in these themes are the insights that were created from the findings. The found themes can be found in Table 4.2.

Table 4.2 The ten insights divided into five themes.

Themes	#	*Insights*
Ease of installation	1	Installers want a solution that is efficient through it being intuitive and prohibiting erroneous behaviour
	2	It is important to take the installers limited resources into account.
	3	Installers want to install mounts facing them.
Flexibility	4	The design should fit all trusses inside a specific size range.
	5	Installers want a broad selection of positions to fasten the solution and can change the orientation and/or location.
Reliability	6	Installers will only use products they trust
Value	7	The buyer and the user will have different views on what is important.
Construction constraints	8	Weather, salty corrosion and vibrations will expose the product.
	9	Trusses have strict requirements and may not be tampered with.
	10	The most common trusses consist of round poles and webs.

4.4 How might we

The idea of a *How might we* question is to generate a question that is full of opportunity. To generate the *How might we* questions the insights were reframed as questions using different methods. Brainstorming was used to generate several how might we questions for each insight. The second iteration of questions chosen are listed in Table 4.3. When brainstorming, it felt that some of the insights behaved more like constraints that not would create questions that would be opportunities for design. No questions were chosen for these insights; however, the insights were kept to take into consideration in later phases.

Table 4.3 The ten insights made into How might we questions.

Themes	*#*	*Insights*	*How might we questions*
Ease of installation	1	Installers want a solution that is efficient through it being intuitive and prohibiting erroneous behaviour	How might we create a truss mount where the installation only can be completed in the correct order?
			How might we create a two-step solution were the mount is first attached and then tightened?
			How might we create a truss mount with as few loose parts as possible?
	2	It is important to take the installers limited resources into account.	How might we create a truss mount that can be mounted with only one hand?
			How might we create a truss mount with as few separate parts as possible?
	3	Installers want to install mounts facing them.	How might we create a truss mount that the installers can install ergonomically?
Flexibility	4	The design should fit all trusses inside a specific size range.	How might we create a mount that fits different dimensions of the truss poles?
			How might we create a mount that fit different widths of trusses?
	5	Installers want a broad selection of positions to fasten the solution and can change the orientation and/or location.	How might we create a truss mount where the camera can be placed on several places on the truss?
Reliability	6	Installers will only use products they trust	How might we create a solution that instils trust?

4.5 Functions

The *How might we* questions were supposed to kick-start the *Develop* phase but when trying to use them in ideation sessions, it was discovered that the questions did not instil the intended curiosity, rather the opposite. The formulations felt constraining and prohibited imagination. The first reaction to this was to iterate on the formulations and figure out why this was occurring. A second set of *How might we* questions were formulated (the ones found in Table 4.4), and while these showed some progress it was not good enough to justify using them just for the sake of it.

It was decided to make a pivot towards setting up goals that the product should fulfil. It did not feel as theoretically correct but it opened for imagination and led to the team coming up with interesting ideas. From these goals, it was possible to decide upon five areas of functions where a working product needs to have at least three of these to be a viable option. By combining these functions in different orders different types of concepts started to arise. The chosen functions can be found in Table 4.4.

This deviation from the planned method will be further discussed in the *Discussion* chapter.

Table 4.4 The five functions explained.

Function	*Description*
Vary width	Since the width of trusses vary a solution that uses two of the truss poles would need to have the function of varying its width.
Tighten width	One way to fasten a mount is to make a solution that can tighten the mount between the two poles of the truss.
Vary diameter	Since the poles on trusses vary in diameter a solution that can fit on poles with different diameters would need to be able to vary its diameter. This function is essential to all concepts.
Secure for self-weight	To ease up the installation it would be good to be able to pre-mount the mount so that it can hold its own weight. The installer is then able to release the mount and tighten with both hands. This function is thought to be included in all concepts.
Tighten for load	The mount need to have some sort of function that tightens the mount on the truss. This function need to hold the load of both the mount and the camera as well as other accessories.

4.6 New brief

The new brief finds all original statements, found in Section 1.2.1 Initial brief, to be of interest. The *Insights* as valuable statements to fall back on when developing, the *Themes* have been added as areas to focus on. The *How Might We* questions have been kept to provide opportunities for design and the *Functions* will build up the basis for how the truss mount needs to function.

4.6.1 New delimitations

Since the US, UK and Chinese market seemed to only use trusses to a limited extent and no good intel could be found regarding manufacturers operating in those areas it was decided to not actively pursue solutions optimised for those markets. The focus forward becomes Sweden and the Nordics due to the access of information and possibilities for testing.

Mainly Scanmast but also Saferoad to some extent operated in all markets in the segment of *Transportation* and *Industries* found in above in Section 3.1.1 Relevant industries. It was decided to discard the segment *Critical infrastructure* due to inputs from Staël von Hornstein. *Stadiums, concerts and festivals* were also discarded since few similarities were found both in installation needs as well as in the type of truss used.

5 Develop I

The Develop I phase is a diverging phase were the new brief is used to generate tons of ideas and concepts.

5.1 Structure of the develop phase

Starting this phase the functions from the *Define* phase were being explored by looking at similar functions in other products. These were gathered in so called function boards. The function boards started the ideation process together with sketching and brainstorm activities. The ideas were then tried out in different lo-fi prototypes and sketches that turned into more detailed concept with specific mechanisms as well as broader overall structure concepts. During the phase the concepts have been evaluated by building prototypes, testing them and then iterating. The phase concluded with a workshop where it was decided which concepts that should be further developed.

5.2 Function boards

To get inspiration products that have the different functions, found in Section 4.5 Functions, was gathered and placed on boards. These can be found in Appendix C.

5.3 Idea generation

Using the function boards as inspiration, ideas for solutions for each function were being generated through sketching and brainstorming activities. It was important for the design team to be open minded, positive and defer judgement about each other's ideas. Wild and crazy ideas were encouraged since these can remove the creative constraints and give rise to creative leaps. The goal of this idea generation was to come up with as many ideas and mechanisms for the functions as possible. The ideas that were thought as most tangible is collected in Table 5.1. A selection of sketches and scribbles can be found in Figure 5.1.

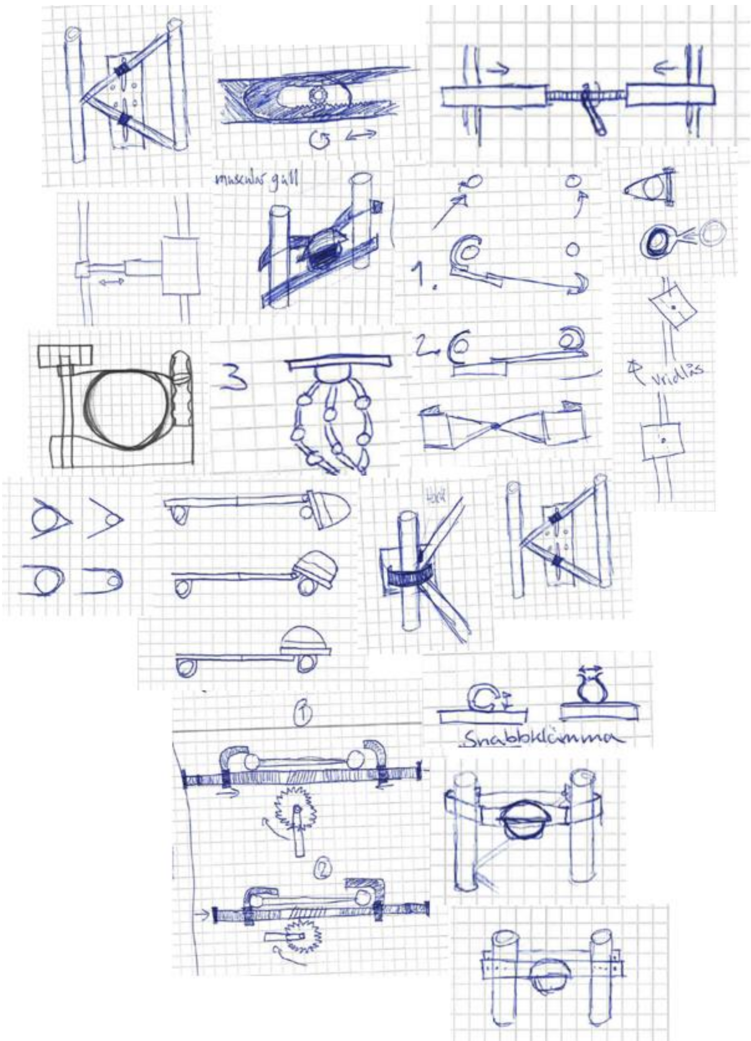

Figure 5.1 A selection of sketches and scribbles from the idea generation.

Table 5.1 Different solution ideas for the different functions.

Vary width	*Tighten width*	*Vary diameter*	*Secure for self-weight*	*Tighten for load*
Screwing	Screwing	Inserts	Magnetism	Deformation
Telescope	Elastic	Vary anchor point on bracket	Clip	Metal straps
Elastic	Magnetism	Longer friction area	Bayonet	*Tighten width*
Bolt lock	Jack-screw	Slap wrap	Fishing hook / cable ties	Screw bracket
Extension		Adjusting plates sideways	Velcro straps	Ski boot buckle
		Pre-set shapes of different diameters	Slap wrap (bi-stable structure)	
			Interlock	

5.4 Detail concepts

To explore the different ideas and test how the solutions work lo-fi prototypes were built and sketches were drawn. Some of the concepts explored only one solution on one function but most of them test several different solutions and functions. Below are the different concepts described.

5.4.1 Detail concept A: Clip

This concept was a concept that tried to integrate metal straps with the functions *Vary diameter*, *Secure for self-weight* and *Tighten for load*. The idea is that the metal strap can be deformed to fit a wide range of poles. The strap was on one side attached to a spring that is strong enough to hold the mount's own weight. The strap has then, on the other side, a continuous hole where a screw can fit. A screw is then fastened to a sheet metal plate through a big hole. On the screw a metal block is screwed that fits the hole. To tighten the metal strap around a pole the metal strap can be screwed on the screw, then the metal block can be screwed on till the metal strap tightens around the pole. Figure 5.2 shows a prototype of the concept, however, in this prototype the spring has not been implemented.

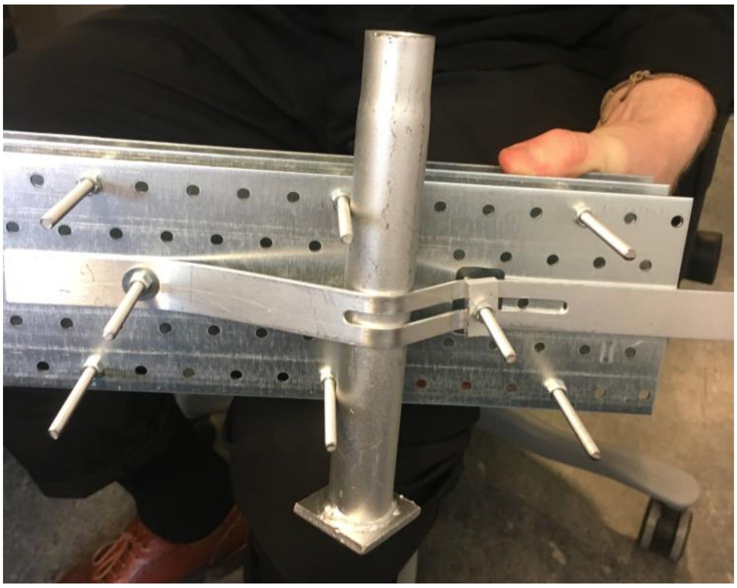

Figure 5.2 A prototype of Detail concept A: Clip.

5.4.2 Detail concept B: Polygrip

This concept try out the function *Vary diameter* and *Tighten for load* by using the same mechanism that a tongue-and-groove pliers use. A prototype was being built, seen in Figure 5.3, where a piece of sheet metal was being attached to the tongue-and-groove plier mechanism on one side. On the other side a long hole had been milled in the sheet metal where a screw can be inserted and tightened with a nut. The tongue-and-groove mechanism was being built by drilling multiple holes in a row with a specific distance between them that allows the holes to overlap.

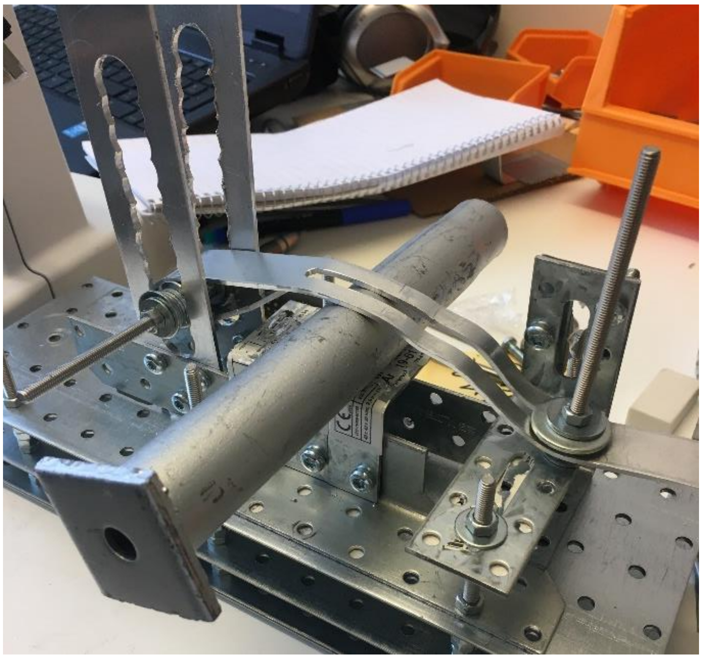

Figure 5.3 A prototype of Detail concept B: Polygrip.

5.4.3 Detail concept C: Cable tie

This concept was inspired by the concept of a fish hook, where the hook can easily penetrate the fish when inserted but then the barb hinders it from being pulled out of the fish. Translating this to a concept for fastening the mount to a pole, the ratchet mechanism [33] in cable ties were being used. Four cable tie heads were cut and placed around a hole on a sheet metal plate, seen in Figure 5.4. A screw can then be inserted into the hole. The ratchet mechanism then makes it easy to push the screw down through the hole but not to pull it out again the other way. The screw can be screwed out to be removed.

Figure 5.4 The placement of the cut cable ties in the prototype of Detail concept C: Cable tie.

On the prototype, two of these holes have been made allowing two screws to be attached to a bracket. The plate is then placed against a pole and then the bracket with the screws are pushed through the holes. This makes the prototype able to barely hold its own weight, seen in Figure 5.5, though to tighten it a nut needs to be screwed on the back of the screw against the plate. This solution also allows for different diameters on the pole.

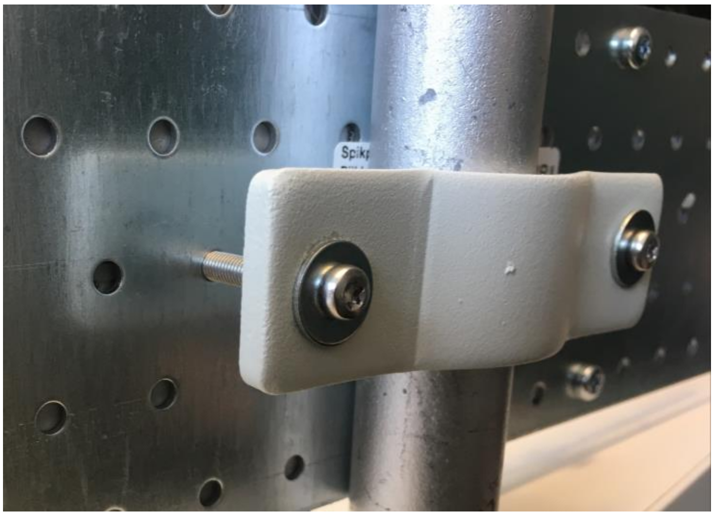

Figure 5.5 The prototype of Detail concept C: Cable tie is able to barely hold its own weight against a pole.

The questions that came to mind after trying out this concept was; does there exist a nut that has these ratchet mechanism abilities and will it be powerful enough to hold its own weight?

5.4.4 Detail concept D: Telescope and turnbuckle

This concept tests out the functions *Vary width* and *Tighten width*. A telescoping part was combined with a turnbuckle in different set-ups. The turnbuckle functions both as a varying as well as a tightening part while the telescope only has the varying function.

A turnbuckle is usually a device for adjusting the tension or length of robes, cables and other tensioning systems [34]. It consists of two threaded eye bolts, one screwed into each end of a small metal frame, one with a left-hand thread and the other with a right-hand thread. The tension and length can be adjusted by rotating the frame, which causes both eye bolts to be screwed in or out simultaneously, without twisting the eye bolts.

Using a turnbuckle there are several places on it that could be a place for the camera interface. Connecting it to the end of the bolt can be one solution and connecting it to the metal frame is another. If the camera interface is connected to the small metal frame it will too be rotating. To be able to have a fixed position in the middle a telescoping part was combined in parallel with the turnbuckle, seen in Figure 5.6. This worked but a learning from this prototype was that using the turnbuckle for varying the width is not optimal since it takes quite some time to adjust large lengths. The telescoping part was better at this while the turnbuckle still was good for tightening.

Figure 5.6 The first prototype of detail concept D: Telescope and turnbuckle.

To solve this a second prototype was built, seen in Figure 5.7 and Figure 5.8. In this version, the small metal frame was split and put inside two cylinders that fit into each other. The two cylinders worked as the telescoping part. Their relative positions could also be locked by rotating them in different directions.

Figure 5.7 The second prototype of detail concept D: Telescope and turnbuckle in the collapsed mode.

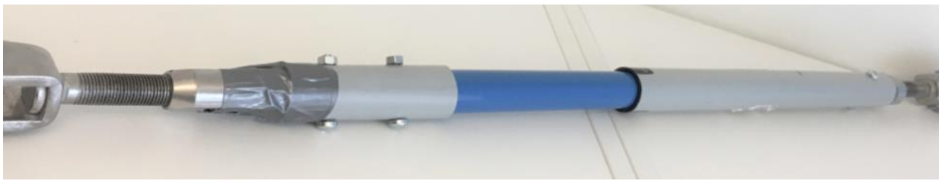

Figure 5.8 The second prototype of detail concept D: Telescope and turnbuckle in the extended mode.

The way this prototype worked was that

1. The length is adjusted by pulling the cylinders away from each other.
2. By rotating the cylinders in different directions their relative positions are locked.
3. By continuing to rotate both cylinders in the same directions the turnbuckle bolts will tighten it.

5.4.5 Detail concept E: Elastic

This concept is testing how an elastic mechanism could work to *Vary width*, *Tighten width* and *Secure for self-weight*. In the prototype, simple rubber bands are used to for the elastic mechanism. This concept was only briefly explored.

5.5 Overall structure concepts

The overall structure concepts describe how the different functions and detail concept can work together as complete solutions. All three of the overall structure concepts need to have at least three of the functions to be a viable solution.

5.5.1 Overall structure concept X: Fasten on one pole

This overall structure concept is similar to the current existing pole mounts, found in Section 3.2.3.1 Axis pole mounts. The mount was fastened on one pole, seen in Figure 5.9, with detail concepts *A: Clip, B: Polygrip* or *C: Cable tie*. Most of Axis pole mounts today do not work with very thin poles and are not especially easy to install. The challenge with this concept was to make it work with thin poles as well as with wider poles while still being able to fasten it hard enough to prevent rotation. The function *Secure for self-weight* is essential for making the installation easier than with today's pole mounts.

Figure 5.9 A prototype of *Overall structure concept Y: Fasten on one pole.*

5.5.2 Overall structure concept Y: Fasten on two poles

This overall structure concept uses two of the poles of the truss, one pole as the primary and the other pole as the secondary, seen in Figure 5.10. This means that the camera interface will be attached to the primary pole and the secondary pole has the function of prohibiting rotating. In this the telescoping function from detail concept *D: Telescope and turnbuckle* could be used to *Vary width* and the fastening mechanisms from detail concept *A: Clip, B: Polygrip* and *C: Cable tie* can be used on one or two positions on the primary pole and one position on the secondary.

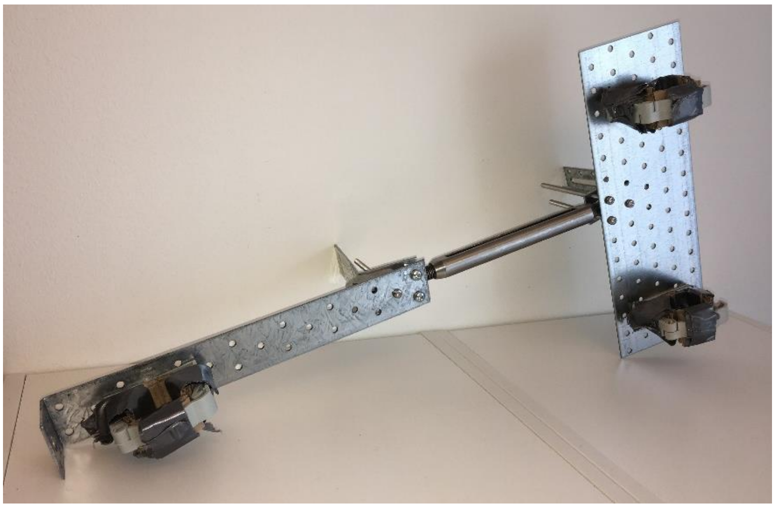

Figure 5.10 A prototype of *Overall structure concept Y: Fasten on two poles*.

Fastening the mount on two poles adds complexity to the mount and to the installation process. Is it necessary to fasten the mount on two poles? The role of the secondary pole is only to prohibit rotation but if overall structure concept *X: Fasten* *on one pole* can do this while only using one pole that seems like a more viable way to go.

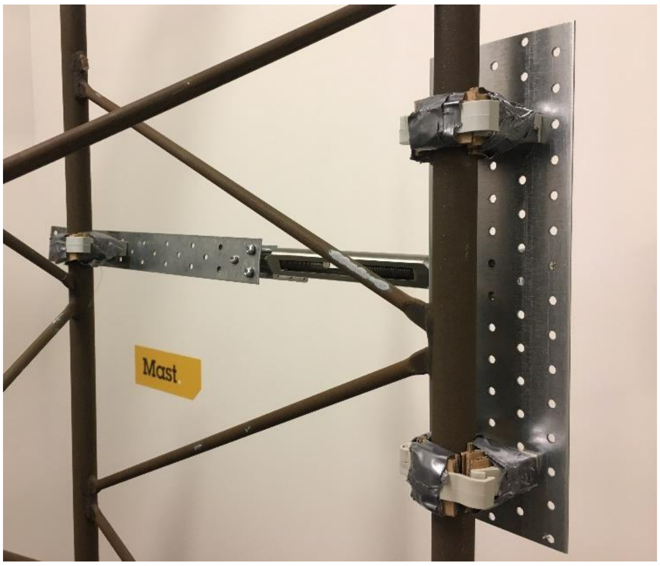

Figure 5.11 A prototype of *Overall structure concept Y: Fasten on two poles* fastened on a truss.

5.5.3 Overall structure concept Z: Tighten between two poles

The idea behind this concept is that two of the poles on the truss is being used to fasten the mount, seen in Figure 5.13 and Figure 5.14. The concept uses the functions *Vary width* and *Tighten width* by using the turnbuckle and a telescoping mechanism from *Detail concept D: Telescope and turnbuckle*. The concept consists of two hooks that fit the two poles of the truss. These hooks are then assembled with a turnbuckle and a telescope mechanism, making it possible to tighten the hooks in between the poles. A possible solution, to be able to vary the diameter of the hooks, could be to use the ratchet mechanism from detail concept *C: Cable tie*. The interface to the camera is supposed to be assemble somewhere in the middle, seen in Figure 5.12.

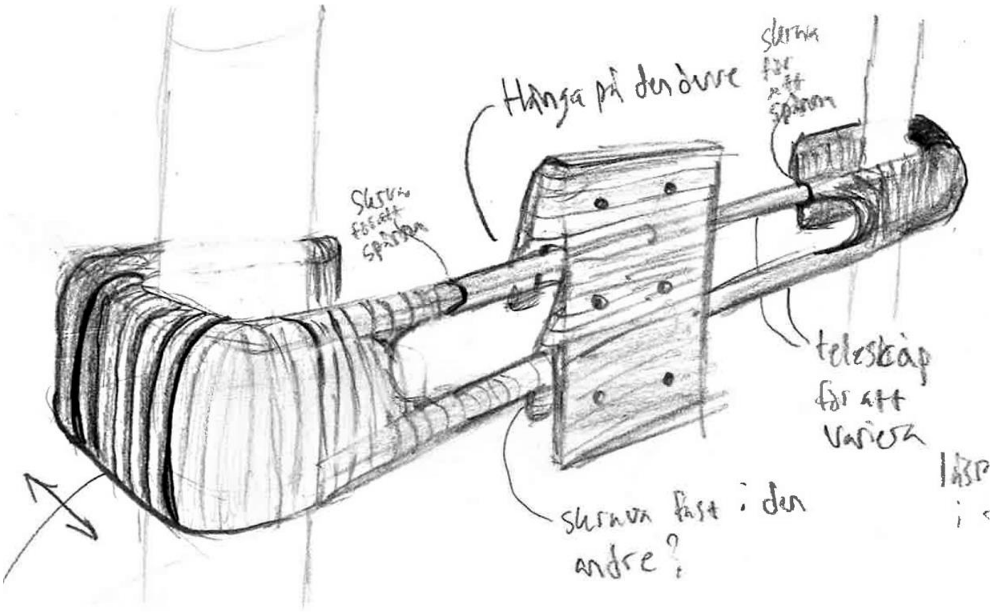

Figure 5.12 A sketch of the *Overall structure concept Z: Tighten between two poles.*

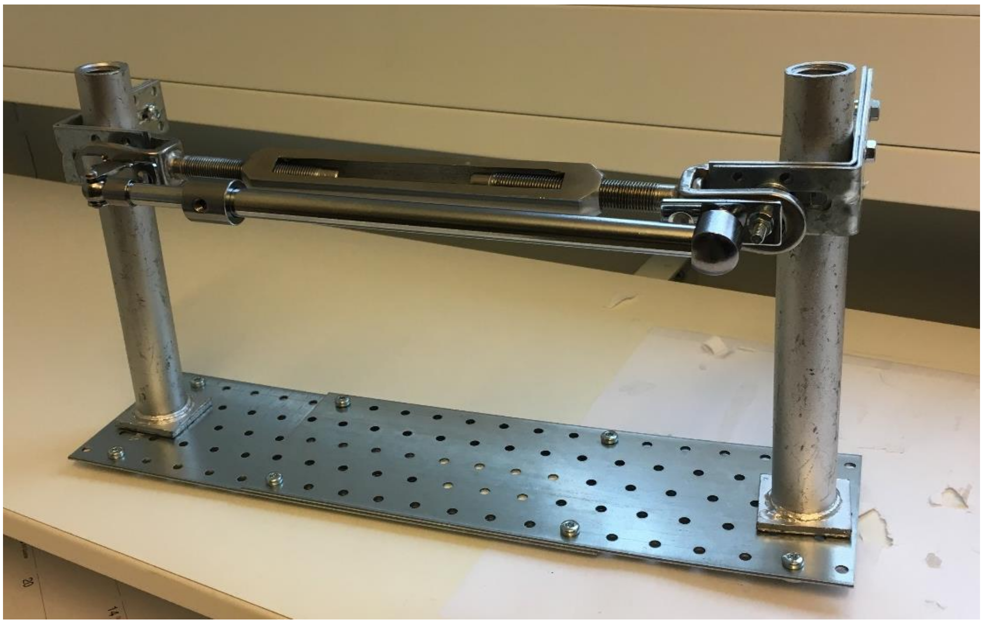

Figure 5.13 The first prototype of *Overall structure concept Z: Tighten between two poles* tightened between two poles.

Figure 5.14 The second prototype of *Overall structure concept Z: Tighten between two poles* tightened between two sides of wood board.

5.6 Concept evaluation

The evaluation of the different ideas and concepts was done continuously throughout the whole *Develop* phase primarily through building lo-fi prototyping and then testing them. The ones that performed well were further developed and the ones that did not were scraped or changed.

5.6.1 Concept workshop

Concluding the phase a part of the mechanical engineers at the department were gathered at a workshop where the different functions, detail concepts and overall structure concepts were being presented. The purpose of the workshop was to gain a basis for deciding which concept that should be developed further as well as seeing if the department had other ideas and concepts. After the presentation, discussions about the different concepts were being held. Topics about installation, complexity, price, material and strength were being raised. Much of the discussion was about whether the mount needs to be fastened on one or several poles.

Overall structure concept *X*: *Fasten on one pole* was thought of as the most viable and the least complex option, if it was possible to prevent rotation using only one pole. The consensus of the workshop is that this should be possible, however, this needs further investigation and testing and if proven wrong the workshop thought that some iteration of overall structure concept *Y: Fasten on two poles* could be used to fixate rotation.

The workshop liked the idea of overall structure concept *Z: Tighten between two poles*. The concept felt innovative and new however concerns were raised about the complexity and price of the concept as well as the size of the components.

Comparing detail concepts *A: Clip, B: Polygrip* or *C: Cable tie*, *C: Cable tie* was thought of as the most innovative and viable concept. The workshop thought *B: Polygrip* was a bit complex and concerns were being raised about the complexity and number of components of the concept. Concept *A: Clip* was thought of as quite similar to the existing pole mounts with metal straps.

During the workshop a new idea of how to further develop detail concept *C*: *Cable tie* was provided that created even more confidence that this was an interesting way to go.

Concluding, the workshop was a good way to get feedback, criticism and a basis for deciding which concept to further develop. Beginning the *Deliver* phase, the focus has been to further develop the overall structure concept *X*: *Fasten on one pole* with an iteration of detail concept *C: Cable tie*. However, lessons learned from all concepts and prototypes have been used in the further development of the concept.

6 Deliver I

The Deliver I phase is a converging phase were evaluated concepts from Develop I are further developed by building, testing and iterating to get to a better solution step-by-step.

6.1 Structure of the deliver phase

The purpose of this phase is to further develop the chosen concept from the *Develop* phase. Many decisions about the concept is made in this phase, therefore the phase is divided in the parts that make up the concept. However, first the different iterations of the whole concept will be shown.

One goal of this phase is to have decided on how all the parts shall work together. At the same time, another goal is to make a testable prototype that works the way that has been decided upon. Forces, strength and manufacturability is being thought of but is not the focus of this phase.

6.2 Iterations

As stated above, the chosen concept for fastening was concept *C: Cable tie* which focused on tightening the mount around the truss structure by pushing two parts together and a ratchet mechanism that prohibits them from be being pulled back out again. However, the early idea lacked a solution on how to create enough frictional force between the two plates and the truss to hold its own weight. An idea of how to solve this was spawned during the concept workshop, hence the *Deliver* phase started off with convergent iterative idea generation to implement this idea into concept *C: Cable tie*. *Iteration I* is the idea that was provided to the team from a colleague and the further iterations are attempts to solve the different problems and ideas that arouse. Explanations on the different areas in which decisions were made are found after the iterations.

Throughout the iterations, the tested ideas were implemented on a shape that mimicked the Axis product *Big Hug*. More on this in Section 6.7.1 Design.

6.2.1 Iteration I

The idea is to allow the backside of the mount to flex. This flexing motion will apply forces onto the truss structure that in return will provide a greater frictional force than just tightening the mount around the structure. Figure 6.1 shows the first experiment.

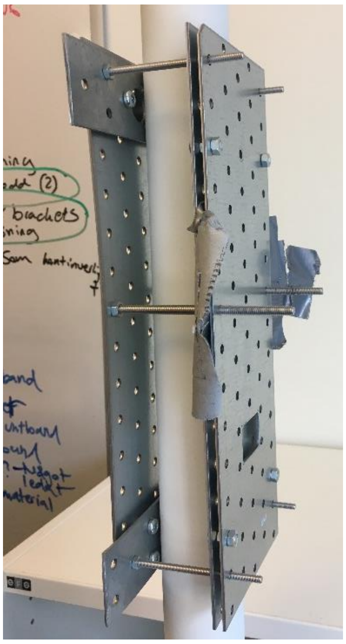

Figure 6.1 A prototype of *Iteration I.*

6.2.2 Iteration II

The idea with the first iteration is that the front and back part of the mount is placed against the pole. Holes for the screws in the middle will have the snap mechanism. The middle part of the back part will be so thin that it can elastically flex. When the snap screws are inserted the integrator will push the back part so that the screws snap in the front part and so that the back part flex. This will give a greater force allowing the mount to hold its own weight. Figure 6.2 and Figure 6.3 shows a sketch and a CAD assembly of *Iteration II*.

When placing the CAD model against a truss it was noticed that the back part will not fit, the webs of the truss was in the way.

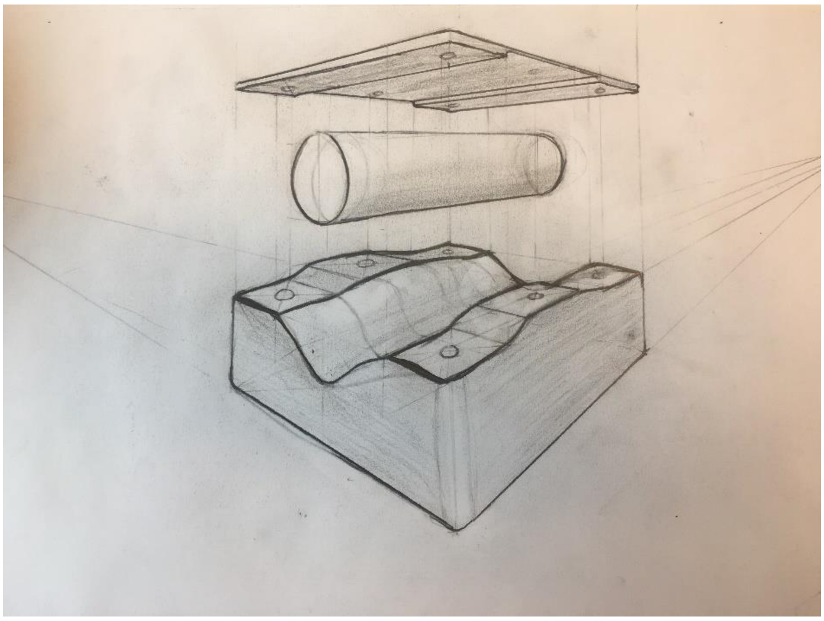

Figure 6.2 A sketch showing an exploded view of *Iteration II* with a pole.

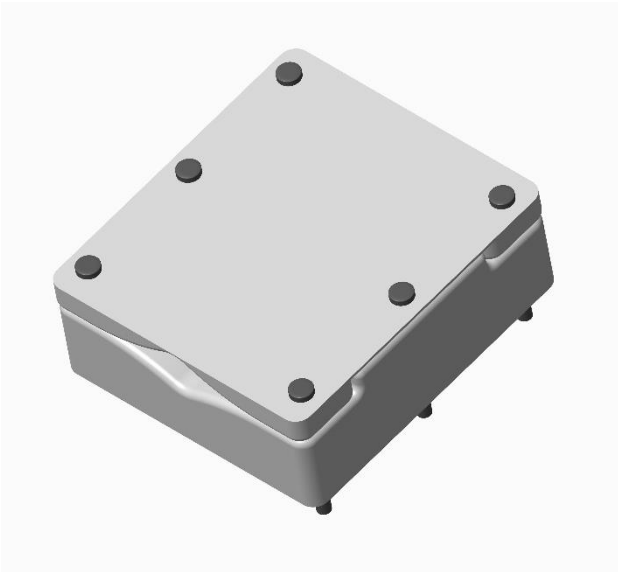

Figure 6.3 A CAD assembly of *Iteration II*.

6.2.3 Iteration III

A way to keep the flexing mechanism of the first iteration is to separate the back part into four parts, two brackets and two flexing plates, seen in Figure 6.4. This makes it possible for the back part to be placed against the truss were the webs are. However, it will probably not be easy to put together these four parts once they are in place.

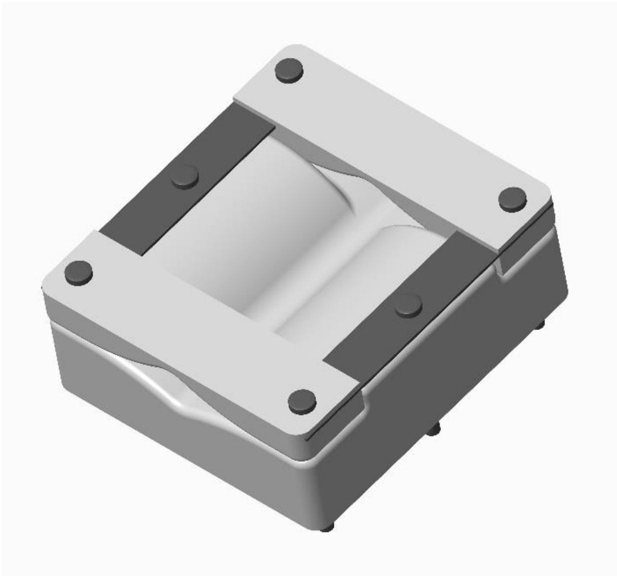

Figure 6.4 A CAD assembly of *Iteration III*.

6.2.4 Iteration IV

Figure 6.5 shows an early prototype of the fourth iteration. In this iteration, the flexing plates have been scrapped for a new concept were the extra force is being exerted by two push springs instead. The back part of the mount, or the bracket, is made into a double bracket with push springs in between. One version is made with two brackets, seen in Figure 6.6, and one with only one bracket in the middle, seen in Figure 6.7. The two-bracket solution only have the push springs and snap mechanism on the upper bracket. Several different push springs were bought and tested to see which force that was necessary.

Figure 6.5 An early prototype of the concept of *Iteration IV* including the snap mechanism and a double bracket with push springs.

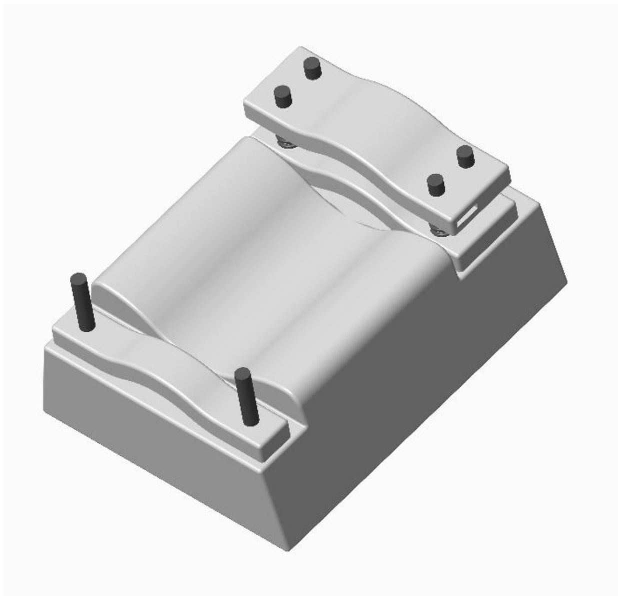

Figure 6.6 A CAD assembly of the two-bracket version of *Iteration IV* with push springs.

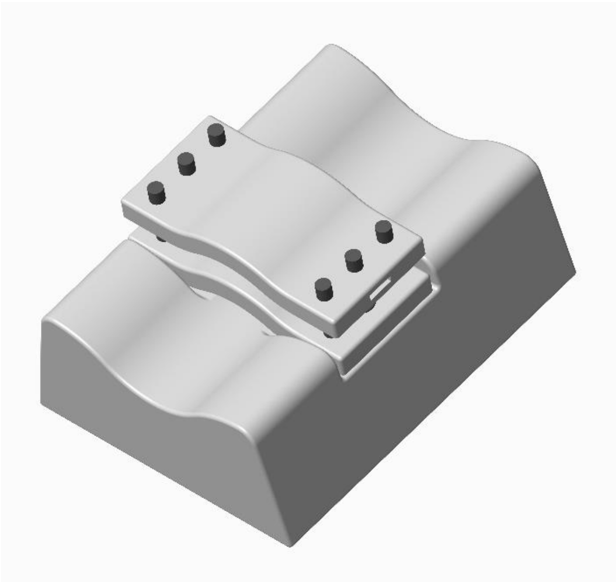

Figure 6.7 A CAD assembly of the one-bracket version of *Iteration IV* with push springs.

6.2.5 Iteration V

Iteration V is made in the same way as *Iteration IV* but in this version, the push springs have been changed to leaf springs. This eliminates the need for a double bracket. This version is in one way very reminiscent of *Iteration III* but in this version, the flexing plates are placed against the pole, exerting its force on the pole instead of on the screws. With the knowledge about which force that was needed with the push springs in *Iteration IV*, the dimensions of the leaf springs were calculated and leaf springs were ordered. The two-bracket version can be seen in Figure 6.8 and the one-bracket version can be seen in Figure 6.9. The one-bracket version was also made in two sheet metal versions, seen in Figure 6.10 and in Figure 6.11.

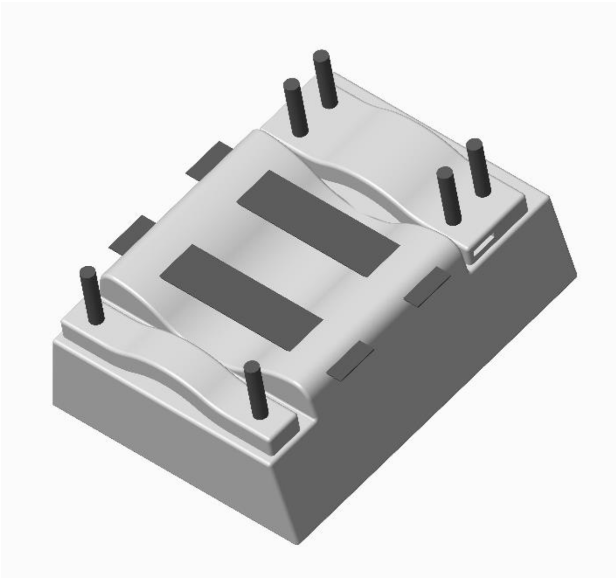

Figure 6.8 A CAD assembly of the casted two-bracket version of *Iteration V*.

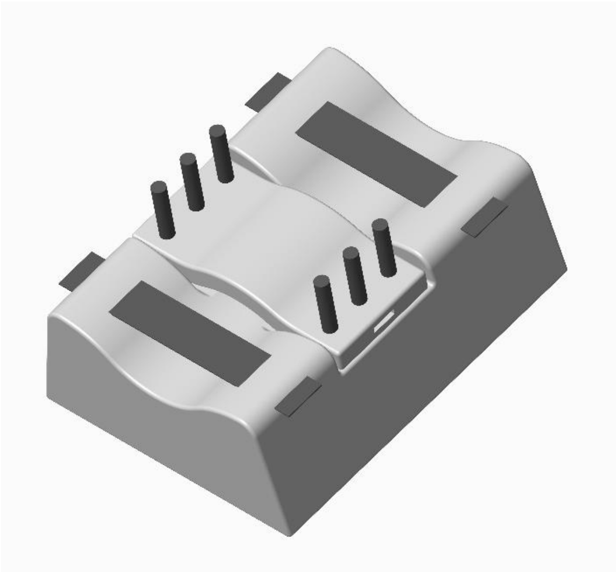

Figure 6.9 A CAD assembly of the casted one-bracket version of *Iteration V*.

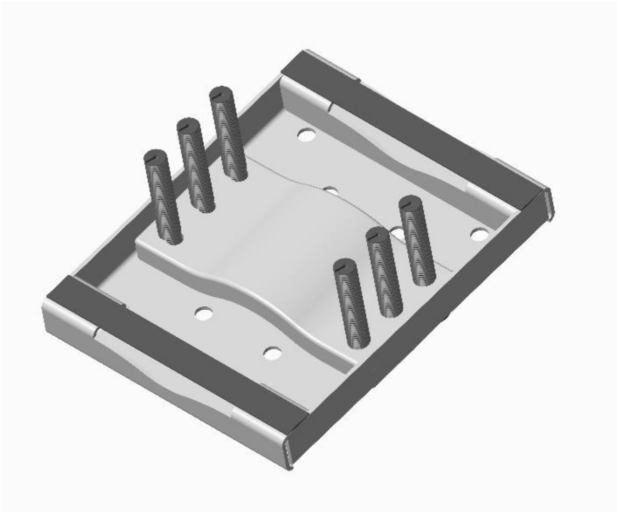

Figure 6.10 A CAD assembly of the bended sheet metal one-bracket version of *Iteration V*.

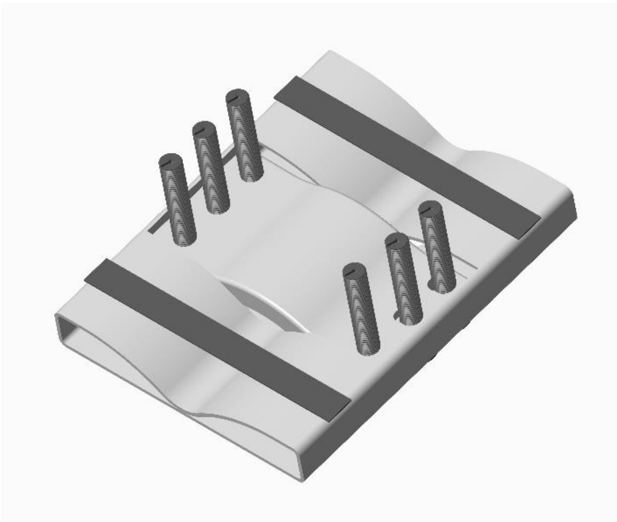

Figure 6.11 A CAD assembly of the extruded sheet metal one-bracket version of *Iteration V*.

6.2.6 Testable prototype of Iteration V

If *Iteration IV* and V focused on how the two different spring concepts can be realized, the *Testable prototype* focuses on building a prototype that can be tested in a real environment, seen in Figure 6.12. This prototype did not focus on aesthetics but solely on testing if the installation process and the functions of *Iteration V* works.

The user test in the next chapter was tested with this prototype. Figure 6.13 shows the prototype being fastened to a truss.

Figure 6.12 An exploded CAD assembly of the *Testable prototype of Iteration V*.

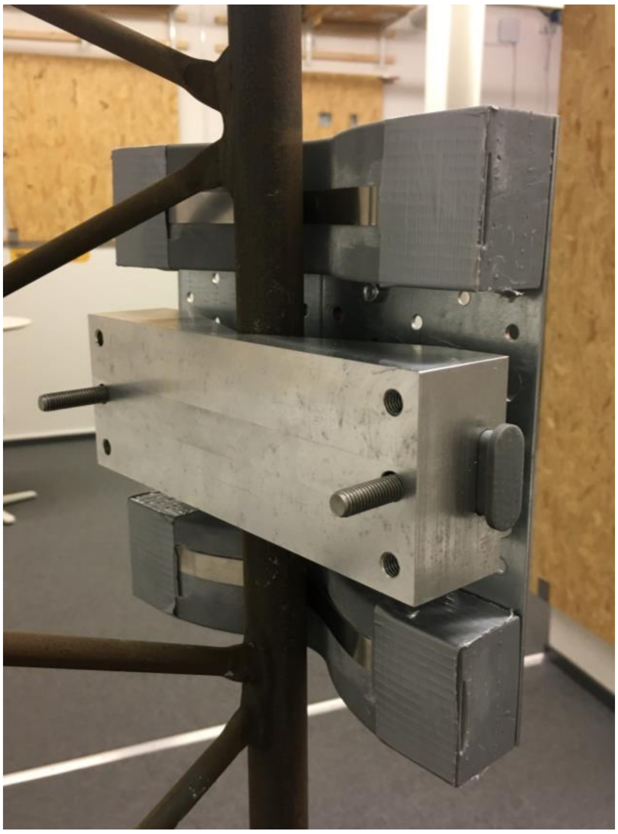

Figure 6.13 The prototype of the *Testable prototype of Iteration V* fastened on a truss.

6.3 Screws

6.3.1 Placement

6.3.1.1 Screwed from interface

Having all the screws being screwed from the interface feels like the most viable way to go since that is the side that will be most accessible for the integrator. This will also allow the screws to stick out from the bracket in towards the centre of the truss. Having them being screwed from the interface also creates an interlock [9]. The integrator is forced to fasten these screws before the integrator attaches the camera or arm to the mount.

6.3.1.2 Screwed from bracket

Having all screws being screwed from the bracket does not feel intuitive. This will mean that the integrator must bend over around the mount and screw the screws from inside the truss. Another disadvantage is that the screws then must stick out from the interface which can interfere with the camera or arm that is supposed to be placed on the interface.

6.3.1.3 Mixed placement

One alternative could be to have the screws being screwed from the interface as above but let the ratchet screw be fasten from the bracket. This placement still has the disadvantage with that these screws will stick out of the interface.

6.3.2 Size

6.3.2.1 M5

M5 screws where used in the earlier prototypes because long M5 screws with thread all the way was found at Axis. These screws, however, do not give a very sturdy look, a bigger set of screws would probably be preferred.

6.3.2.2 M8

The M8 screws are bigger and give a sturdier look and feel. M8 screws are already used on many other mounts interfaces towards the cameras and arm. Therefore, it would be preferable to use these screws all over the mount, since this eases up the installation process.

6.3.3 Head

As a standard Axis uses *Torx* heads on their screws, seen in Figure 6.14. Since the screws that are being used to fasten arms and cameras on *Big Hug* have a *Torx 30* head, this product should make use of the same head so that the installer does not need to change tools.

Figure 6.14 A *Torx* screw head.

6.3.4 Threading

To allow the mount to be fasten at a wide range of pole diameters the whole screw should be threaded. Have the whole screw threaded allows the bracket to be fasten along the whole screw. The screw can then also be fastened in the interface.

6.3.5 Anti-loss screws

Anti-loss screws are screws that Axis often use on their products. These screws are convenient for installers, as it prevents the risk of losing the screws during installation. However, since the screws need to have threading all over the screws this can be hard to implement.

6.4 Ratchet mechanism

A ratchet is a mechanical device that allows for continuous linear motion, seen in Figure 6.16, or rotary motion, seen in Figure 6.15, in only one direction while preventing motion in the opposite direction. Cable ties use the ratchet mechanism to allow for continuous linear motion in one direction. That mechanism in cable ties was the inspiration to the mechanism developed in the chosen concept [33].

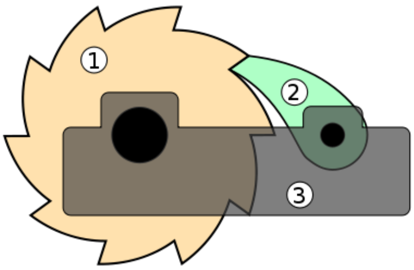

Figure 6.15 The ratchet mechanism with rotaty motion. Where *1* is the rotary teeth section, *2* is the pawl and *3* is the base the two is mounted on [33].

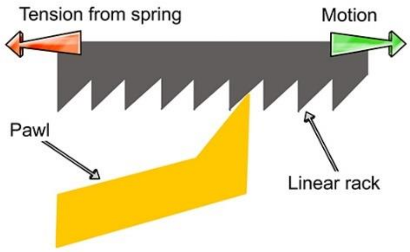

Figure 6.16 The ratchet mechanism with linear motion.

In the chosen prototype, from *Develop I*, the pawl of four cut cable ties were used to encircle a hole. Then a screw was pulled through the hole. The thread on the screw was used as the cable tie's teeth section. This worked, however, further development was needed to make it a more viable solution.

6.4.1 Teeth section

The screw was kept as the cylindrical teeth section, primarily because a *Snap washer*, as the developed pawl section will be called, can be unscrewed off a screw. A second reason for using screws is that the screws have many threads per axial distance which allows for a more precise adjusting. How many threads a screw have per axial distance is defined by its pitch. Coarse threads have a larger threadform relative to screw diameter, were fine threads have a smaller threadform relative to screw diameter. A fine M5 and course M8 were used when designing and prototyping the first versions of the Snap washer.

Cylindrical forms other than screws were thought of to be use as the teeth section. However, these forms did not perform as well as the screw.

6.4.2 Pawl section

The desire was to find a *Snap washer* on the market, but after an extensive search and questioning of colleagues no applicable solution could be found. It was decided that it was a crucial part to the chosen prototype and therefore needed to be developed.

6.4.2.1 3D-printed design

The pawl on a cable tie was analysed, mimicked in CAD and then 3D-printed and tested on the screws in many iterations, found in Appendix D. Six pawls were placed in a circle facing the axis of the circle and were then put together by a solid circle.

The final iterations had double rows of pawls with a pitch that matched the M8 screw, seen in Figure 6.17Figure A.5 SEQ Figure * ARABIC \s 1 5. These works well on the screw, however, when a load was added the *Snap washer* broke. If made in the right plastic this design probably would work better.

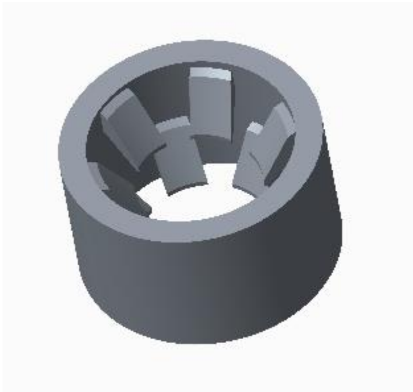

Figure 6.17 The final iteration of the M8 double *Snap washer* with pitch.

6.4.2.2 Internal star lock washer

After doing all the 3D-printed versions, out of a coincident the *Internal star lock washer* was found. The *Internal star lock washer,* seen in Figure 6.18, works like the design above and are made in steel. It is a standard product at Lesjöfors that can be bought in bulk instead of having Axis to manufacture them. The star washer is originally made to fit a cylinder that when pulled back will lock onto it by cutting into the cylinder. However, it seems to fit a screw as well and it holds the loads from some of the more powerful push springs well. To optimise the washer the pawls had to be bended a bit.

Figure 6.18 The *Internal star lock washer* from Lesjöfors fastened on a cylinder.

6.4.3 Placement

The placement of the ratchet mechanism is dependent on the placement of the screws. A desirable feature for the design is to be able to take out the washer and be able replace it. A holder could be designed to accommodate the star lock washer.

Since it is desired to not have the screw go out from the front of the interface, it is not desired to have the ratchet mechanism being placed in the interface.

Having the ratchet mechanism being placed in the bracket is a better choice since this matches better with the screws. However, this will probably increase the thickness and the complexity of the manufacturing of the bracket.

6.5 Spring mechanism

The spring mechanism is designed to exert an extra force between the two parts and the pole so that the friction will be higher allowing the mount to hold its own weight.

6.5.1 Type

6.5.1.1 Push spring

A push spring, seen in Figure 6.19, is a standard product for multiple uses. With two plates separated by push springs a force could be created that would create friction between the pole and the mount.

Figure 6.19 A push spring from Lesjöfors.

6.5.1.2 Leaf spring

Leaf springs are mostly used in larger scales in cars and trucks. The benefit here would be that the need for two plates would disappear as the spring itself will create the surface for friction. Leaf springs are sheet metal made of spring steel, seen in Figure 6.20, which makes them very elastic.

Figure 6.20 A leaf spring from Lesjöfors.

6.5.2 Placement

To translate the force from the push springs a double bracket was designed were the push spring were placed in between the two brackets that it consisted of. Since the snap screws are supposed to come out of the interface and not the bracket, the springs in the double bracket would have to be fastened in both brackets. This would probably be possible but it is a drawback. It would probably be possible to place a similar bracket on the surfaces on the interface that touches the pole but it felt like a sleeker design to have the mechanism in the bracket.

The inner bracket in the double bracket could possibly have the function of a leaf spring if made in the right material and thin enough. To place the leaf springs in the interface, slots need to be made. The slots should be tight enough so that the leaf spring do not fall of, but loose enough so that they can move horizontally.

6.6 Bracket

6.6.1 Number of brackets

6.6.1.1 One bracket

Using only one bracket, seen in Figure 6.21 and Figure 6.22, would reduce the number of loose parts to only two which is attractive since less things to keep track of is convenient.at high altitude installation. A one bracket solution would also allow for all the holes for the tightening screws to be aligned in one swift motion.

From the provided hole pattern, it was analysed that the most suitable placement for a bracket would be between the upper and lower interface holes. A one bracket solution would make use of this space most efficiently since placing a bracket in the middle would not interfere with the interface hole profile. One negative aspect that needs to be acknowledged is that the central placement of the bracket might cause problems with the diagonals of the truss, mostly at the smaller size-range. It was concluded that the placement will not prohibit placement but that the number of placements available will be limited.

Figure 6.21 The bracket for the one-bracket version of *Iteration V*.

Figure 6.22 The double bracket with push springs for the one-bracket version of *Iteration IV*.

6.6.1.2 Two brackets

To work around the problem of the diagonals of the truss a solution with two brackets were developed, seen in Figure 6.23 and Figure 6.24. The ratchet mechanism would only need to be implemented into one of these. Therefore, they were made into different sizes, keeping four screws for tightening. While the two-bracket solution provided some extra flexibility to available fastening placements the increase did not feel big enough to motivate separating the bracket.

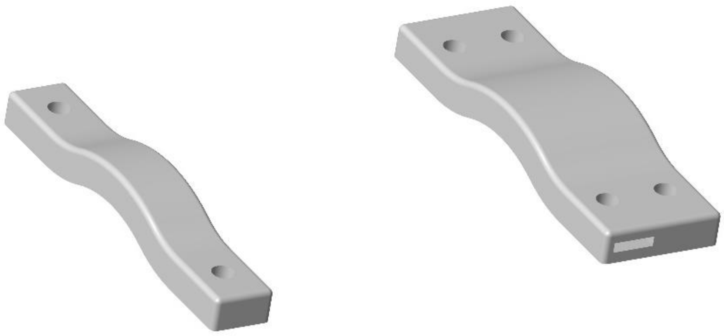

Figure 6.23 The two brackets for the two-bracket version of *Iteration V*.

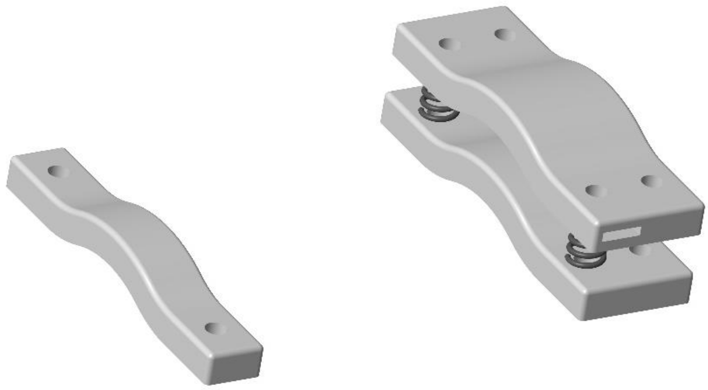

Figure 6.24 The two brackets, including the double bracket with push springs, for the two-bracket version of *Iteration IV*.

6.6.2 Design

The shape of the bracket is designed with a diameter that can match the diameter of quite big poles. In this design, it is the space between the pairs of screws that limit the bracket to fit on bigger poles. A small slot is made for the *Snap washer* to be inserted over one screw on both sides. On the version of the bracket in *Iteration IV* the bracket has been made into a double bracket with the push springs in between.

6.7 Interface

6.7.1 Design

Before designing the interface many of Axis, as well as other manufacturer´s, pole mounts were carefully examined and after discussing, with the makers of each Axis mounts, seen in Figure 6.25, why the different mounts had been designed the way they had, several versions were made.

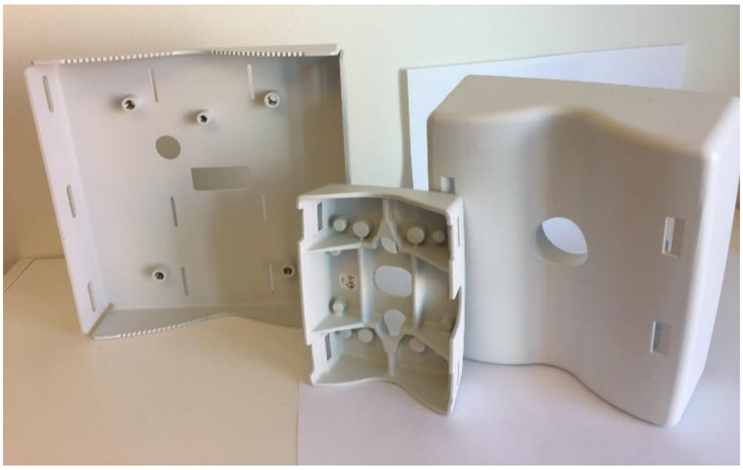

Figure 6.25 The Axis Pole Mount *Hug* family including *Bro Hug, Hug* and *Big Hug.*

6.7.1.1 Casted

For the casted version, inspiration was taken from *Big Hug*, seen to the right in Figure 6.25. *Big Hug* is fastened with metal straps to poles with a diameter of 60-400 mm and its interface has two of the three hole patterns that are needed for the truss mount.

To be able to incorporate the bracket design into the *Big Hug* shape some adjustments were needed to be made. The holes for the screws that will go through the bracket needs to be placed so that they do not interfere with the holes for the interface screws. The place on *Big Hug* that has the best potential for this is in the middle. Therefore, it seems more plausible to incorporate the one bracket solution in the middle, seen in Figure 6.28 and Figure 6.29. To make the two-bracket solution, seen in Figure 6.26 and Figure 6.27, work at least one, on each side, of the holes for the bracket screws need to be shared with the interface screw. This could probably be done but adds complexity to the product. Since the front of the interface is hollow there need to be extrusions to allow the holes to be in level with the front plane.

The only difference to the interface, if the leaf spring version is being used, is that there need to be tight slots through the elevated pole area were the leaf springs can be inserted.

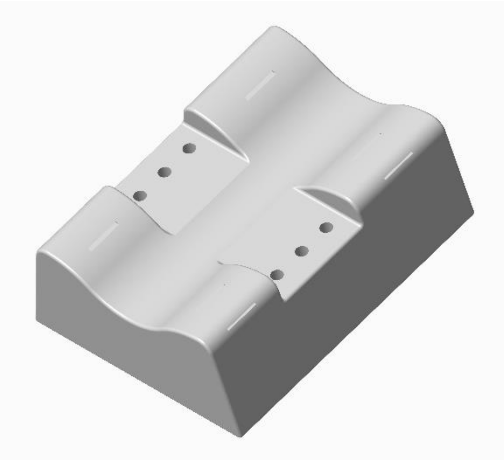

Figure 6.26 The back of the two-bracket version of the interface of *Iteration IV* and It*eration V*.

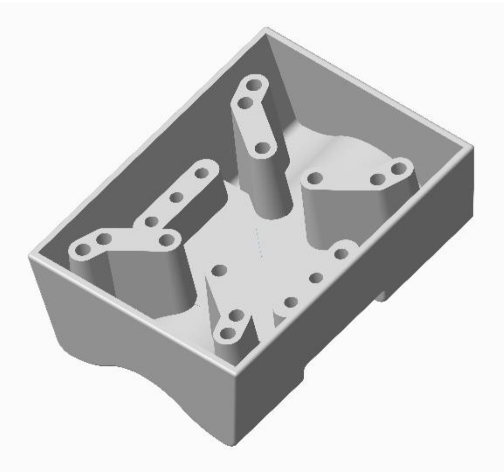

Figure 6.27 The front of the two-bracket version of the interface of *Iteration IV* and It*eration V*.

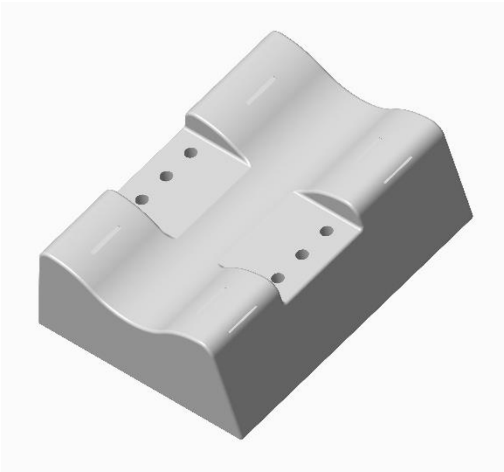

Figure 6.28 The back of the one-bracket version of the interface of *Iteration IV* and It*eration V*.

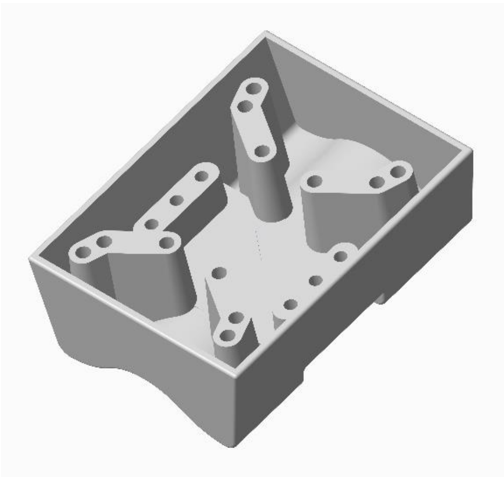

Figure 6.29 The front of the one-bracket version of the interface of *Iteration IV* and It*eration V*.

6.7.1.2 Sheet metal

Two different sheet metal solutions for the interface were thought of. One that could be bended to get the right shape, seen in Figure 6.30 and Figure 6.31, and one that either could be bended or possibly be extruded, seen in Figure 6.32 and Figure 6.33. A problem that could arise with both versions is that the heads of the bracket screws will stick out from the flat back of the interface which can interfere with the arms and cameras that are supposed to be fasten there. This could probably be solved by recessing the holes. A positive thing is that the front looks more like a front than the casted option. However, questions have been raised about whether a sheet metal version look and feel Axis. It probably does not feel as robust as the casted version does.

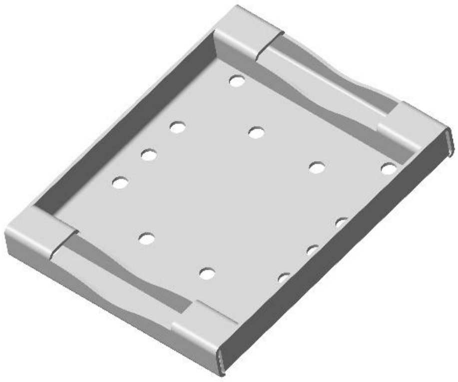

Figure 6.30 The back of the bended sheet metal version of the interface of *Iteration V*.

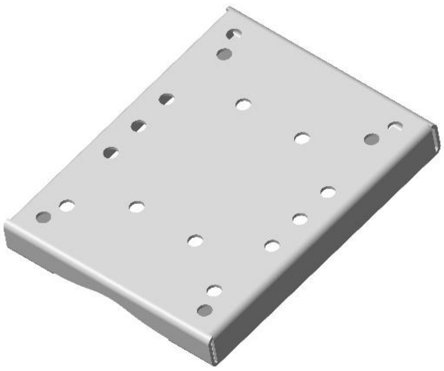

Figure 6.31 The front of the bended sheet metal version of the interface of *Iteration V*.

Figure 6.32 The back of the extruded sheet metal version of the interface of *Iteration V*.

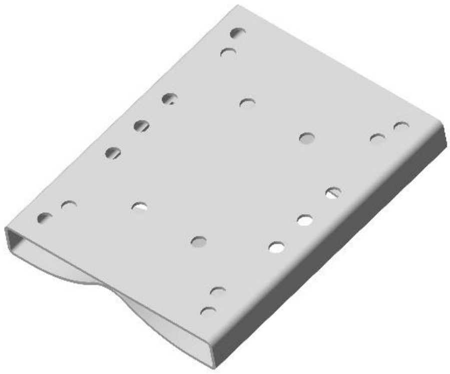

Figure 6.33 The front of the extruded sheet metal version of the interface of *Iteration V*.

In the end the casted option was chosen since the design team thought this version felt more sturdy and robust as well as more Axis. This version could also fit well with the *Connect* arm.

6.7.2 Dimensions

The dimensions of the interface have been made to match the popular *Axis T91G61 Wall Mount*, internally called *Connect*. This mount is usually used for PTZ cameras together with *Big Hug* on poles. However, the *Connect* is not the biggest interface that the truss mount need to hold, the arm called *Brokeback* has a bigger interface. When the *Brokeback* is placed on the truss mount it will extend outside the edge of the interface. This will probably only be an aesthetic issue and not an issue about strength since the pattern for *Brokeback* is included in the mount.

It can however be a bigger problem when smaller interfaces are placed on the truss mount. Then there will be a lot of open space that probably would look weird but also be a popular nesting place for insects. This can probably be solved by making a plate with the same size as the mount that can be attached on the mount before attaching the smaller interfaces.

6.8 Results

Concluding the last phase of the first cycle of the *Double Diamond* method, detail concept *C: Cable tie* and overall structure concept *X: Fasten on one pole* have been further developed though six iterations. Throughout the iterations many decisions have been made that have lead up to the final iteration. A one bracket solution has been chosen that is fastened to a casted interface with six screws. Two of the screws called the *Snap screws* are used together with a *Snap washer* consisting of a modified star lock washer inserted with a holder in two slots in the bracket. By pushing the two screws, that are attached to the interface, through the star lock washers the mount can quickly be pre-mounted. Two leaf springs attached to the interface will exert an extra force to the truss pole helping the snap mechanism to hold the mount in place before the four *Tightening screws* are fastened with a power tool. A prototype of *Iteration V* has been made that will allow the concept to be tested with users.

Entering the next cycle of the Double Diamond method, the concept was tested on users and their feedback was implemented into the product. New research was conducted to further improve the concept and installation process.

7 Discover II

The Discover II is the start of the second cycle of the Double Diamond process. In this chapter the developed concept from Deliver I was tested and new research was conducted.

7.1 User tests

To test the concept and the installation process that was decided upon in the deliver phase several workshops were set up to test the *Testable prototype*.

7.1.1 Axis employees

Four test workshops with Axis employees was set up, one workshop with Joakim Palmqvist, Product Integration Manager, and three workshops with different mechanical engineers at the EVP department. The tests in the workshops were performed on the truss in the *Axis Installation Experience Center*. The tests started with giving the test persons the *Testable prototype* disassembled. They were then asked to assemble it and to explain how they thought it was working. They were only guided or interrupted if there was a chance of permanently damaging parts of the prototype. When the prototype was assembled, they were asked to install the mount on the truss while explaining what they were thinking and doing. All thoughts and comments as well as observations where written down.

Overall most of the test persons understood quite quickly how to assemble the prototype and how it was supposed to work, even though they had never seen it before. Some did not understand the need for leaf springs and some did not understand how the star lock washer was supposed to work. When inserting the holder for the star lock washer some persons inserted them upside down and then tried to push the screws through.

When placing the interface against the truss almost all the test persons placed it against the pole of the truss as intended but tried to lock it against the webs of the truss. This is a placement that would not work with the bracket. When asked why they did that most persons answered that that was their way of trying to prevent rotation. After doing that most persons placed the interface on the intended place and started to align the bracket with the interface around the pole.

When starting to push together the two parts, several different grips could be observed. Most persons with big hands used the intended grip that is placing both thumbs on the front of the interface, while with the rest of the fingers pulling the bracket against the pole. Some persons used one hand on the bracket and one hand on the interface to push together the parts against the pole. This grip allowed them to exert more force on the two parts but also made it easier to put the bracket askew.

All the test persons liked the concept of using the screws together with the star lock washer and liked how the first stage of the installation did not require any tools. Some thought that it would be even better if only one hand was needed for this step but also understood that the required size of the mount makes this hard. Discussions about how the make this step of the installation even easier were held and many solutions of how to further develop the step was raised. One person felt that there was a risk of getting fingers crushed between the two parts when pushing them together.

Another question that was raised by one of the test persons was whether the leaf springs was needed. He then tried to fasten the mount without the leaf springs. This worked as well as with the leaf springs. Discussions about if a material with higher friction could be added to the surfaces that touches the pole instead of using the leaf springs was raised.

The last step was to fasten the rest of the screws with a power tool. It was noticed that the holes on the interface and the bracket was not perfectly aligned when the bracket had been put in place. This made it harder to fasten the rest of the screws. Many of the persons asked whether these screws were needed. Some suggested that nuts could be placed on the back of the first two screws instead of having the rest of the screws.

However, the big question was whether this type of mount would prevent rotation. Especially when a long arm and a heavy camera will be attached. Since the last four screws never was fasten as intended this could not be tested. Most of the test persons had a feeling that something had to be added to the mount to prevent rotation. Again, many suggestions on how to solve this were raised.

7.1.2 Real users

To test the prototype with real users another trip to the Port of Trelleborg was arranged with Joakim Palmqvist. At the site the test was conducted with the Port of Trelleborg employees Anders Thornberg, Smith, Roger Andersson, Smith, Linus Olsson, Electrician, and Jim Leveau, Chief of Security, seen in Figure 7.1. Thornberg, Andersson and Olsson work in a team in the workshop at the site. The primary duties of the team are maintenance of the harbour. Their job includes mounting and servicing of Axis cameras as well as creating their own mounts for different locations including locations that require truss mounts. Palmqvist, that has met with the team many times before, describes the team as a team that consists of problem solvers. They do not see issues or problems, they see solutions. He also describes them as being very honest in their opinions.

Figure 7.1 Anders Thornberg, Smith at Port of Trelleborg, Joakim Palmqvist, Product Integration Manager at Axis, Roger Andersson, Smith at Port of Trelleborg, Linus Olsson, Electrician at Port of Trelleborg and Jim Leveau, Chief of Security at Port of Trelleborg and Mattias Larsson Schölin at the test site in Trelleborg conducting a user test.

The test is conducted outdoors on a standard Port of Trelleborg truss that is lying down. Before the mount is fasten on the truss the team examines the mount and some of the parts are clarified. Andersson then starts to mount the prototype on the truss, seen in Figure 7.2. He says that it feels good.

Figure 7.2 Roger Andersson trying out the *Testable prototype* while Jim Leveau is instructing him.

The talk continues about how the mount can prevent rotation. Thornberg thinks that if grooves are made in the bracket then the mount will be attached hard enough to prevent rotation. He explains that if the mount is made of aluminium it will not be able to damage the truss since the truss is made of steel, that is a harder metal then aluminium.

After the test at Axis one of the suggestions was to make a K- or X-profile, described further down in Section 9.2 Preventing rotation, in the back of the interface that would allow it to lock on to the webs of the truss and prevent rotation. Since those test a foam mock-up had been made that was showed to the harbour team. When asked if they see any problems with locking on to the webs, Leveau answers that he does not see any problems with this. He says that the webs not are too weak to be locked on to. A downside with the K- and X-profile could be that there only will be a limited amount of positions to fasten the mount on but Leveau think that these positions are enough. The team agrees with Leveau and say that this would be a great solution.

When talking about the screws and the threaded holes of the bracket, the team mentions that they wish to have holes without thread and instead place a nut on the back of the screws. This because threaded holes in aluminium will get patina and the screw will then get stuck. If the same happens with a nut they can just cut off the nut. They also think that nuts on the snap screws can replace the four tightening screws. Thornberg say that two M8 screws should be strong enough.

The team thought the snap mechanism was a sensible and smart concept and the idea of making the snap mechanism removable was also received positively. Olsson say that many times the mount might need to be moved or changed during the installation and making the mechanism removable during installation would allow them to do that.

All in all, the prototype made a good impression on the team and they thought that the development was on the right track. They thought that if the snap mechanism can be removable and if rotation can be prevented then it will be a great product. They also thought that the K-profile is interesting as a possible solution to prevent rotation.

7.2 Manufacturing and material research

Materials have been researched to correspond to the requirements for the specific parts, and to suit the design rules for the different product lines at Axis.

7.2.1 Die casted aluminium

Aluminium is the most commonly used metal in Axis products. Aluminium is a metal suitable for casting, which was the preferred manufacturing method. Die casting is a manufacturing process in which molten metal is poured or forced into steel moulds. The moulds, also known as tools or dies, are created using steel and are specially design for each project. This allows each component to be created with accuracy and repeatability [35] Inserts also should be used if the screws are supposed to be unscrewed more than five to ten times. *HELICOIL* inserts, seen in Figure 7.3, are standard for Axis to use when threads need to be placed in aluminium.

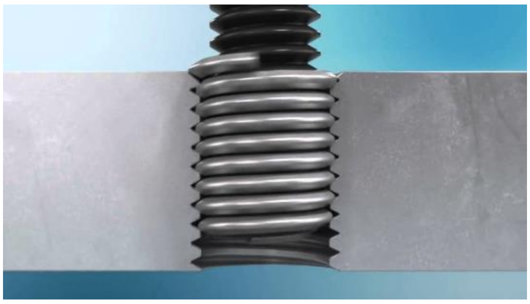

Figure 7.3 The insertion of a HELICOIL in a threaded aluminium hole.

7.2.2 Punching of star lock washers

The star lock washers used in the prototype are bought as a standard product from Lesjöfors. To fit the intended screws, they need to be altered by hand to work with the pitch of the thread. Instead of doing this by hand they could be punched. Punching is a metal forming process that uses a punch press to force a tool, called a punch, through the workpiece to create a hole via shearing. Punching is one of the cheapest methods for creating holes in sheet metal in medium and high production volumes [36]. This could probably be done by Axis themselves or by a partnership with Lesjöfors.

7.3 Ergonomic research

7.3.1 Grip ergonomics

During the testing with Axis employees it became obvious that the prototype became increasingly hard to use, the smaller the hands were on the test subject. This motivated a study on how a grip should be designed to better afford the intended action.

7.3.1.1 Grip types

There are many ways to grip things, but with tools it is in most cases a decision between a power grip and a pinch grip. The pinch grip, seen in Figure 7.5, provides control for precision and accuracy and is gripped between the thumb and the fingertips. While the power grip, seen in Figure 7.4, provides maximum hand power for high force tasks and is gripped with all the fingers wrapping around the handle [37].

Figure 7.4 The power grip used on a hammer.

Figure 7.5 The pinch grip used on a hammer.

7.3.1.2 Tool type

The intended installation draws parallels from double-handled tools since the two points of contact with the hand are divided with a grip span. The span is measured as the distance between the thumb joint and the fingertips when the tool is either opened or closed. For a power grip, seen in Figure 7.6, the open span should be no longer than ~87 mm and the closed not shorter than ~44 mm [37]. This, however, is a factor that is sensitive to the size of the users' hands but due to the fact that maximum power is not required, staying somewhere in that range should be sufficient [38]. If the grip is of the type single handle [37] the diameter should be ~30 - ~50 mm.

Figure 7.6 The open span power grip used on a tool.

7.4 Truss Research

While the first research concluded that the most common truss shape was the one with circular poles and diagonals, it left the size range open since the team was still pursuing a general solution to mounting on poles. When it had been decided to narrow the size range different manufacturers were interviewed again. The conclusion of this research was that the circular poles operated in the range of 20-40 mm in diameter and the diagonals in a range between 12-15 mm. Also, the angle of the diagonals could differ from 48-66°.

7.5 Industrial design research

The *Axis Design Manual 2.0* is a collection of best practices and efficient design solutions useful when developing hardware at Axis. The products at Axis are the key carriers of the corporate identity. Therefore, a key to defining the Axis brand identity is effectively communicating the visions and values by means of the identity and image of their products – their product identity. Axis product design guidelines include their present *Industrial design direction*, their three key values and focus areas. To get a further understanding of Axis design guidelines a meeting with Axis Design Manager Daniel Åhman was set up.

Robust sophistication defines the present *Industrial design direction* at Axis at the moment of this thesis [39]. Åhman says that this has been the direction for some years now and he stresses that the product design always need to be refreshed and updated to fit today's market needs. A way that Axis classifies its products is in how visible a product shall be. In some use cases a camera shall be almost invisible or discrete to not make people feel monitored and watched and in other cases a more semi-discrete or even obtrusive approach might be the way to go to scare away people from restricted areas.

Åhman also explains that Axis has some design characteristics that helps the products further communicate the Axis brand and a visual consistency throughout the product lines and categories. Examples of these characteristics are a wing detail, a step division, a bevel etc. shown in Figure 7.7.

Figure 7.7 The Axis design characteristics; wing detail, bevel, black lens ring and step division shown on an Axis PTZ Network Camera.

The three key values; *Solidity*, *Precision* and *Simplicity* [40] are the fundamental values that Axis products shall strive to be described by. The key values are described further in Table 7.1 and Figure 7.8 shows how the key values can be used on a product.

Table 7.1 Axis describe their three key values with the following words.

Solidity	***Precision***	***Simplicity***
Secure	Refined	Best solutions
Durable	Superior solutions	Optimized
Robust solutions	Sophisticated	Scandinavian
Trustworthy	Innovative	Ease of use
Reliable	Professional	Uncomplicated
Performance	Market leader	Intuitive
Quality	Quality	Quality

Figure 7.8 The Axis key values *Solidity, Precison and Simplicity* shown on an Axis PTZ Network Camera.

Accessories like mounts are an example of products that should feel way more robust and solid than they should feel precise and sophisticated. Åhman explains that Axis cameras are the products that are supposed to carry the most of Axis identity, design characteristics and brand. He says that Axis mounts are suppose have less of an identity. The key values *Solidity* and *Simplicity* are more important than *Precision* when defining the mounts. He also says that almost all mounts use the colour *Axis White.*

When the shape of Axis products was discussed with Åhman, he mentions that Axis tries to avoid shapes that feel organic and natural. He says that they do not want their products to look like faces, animals or other natural shapes. A way to avoid this is to make use of more straight lines and smaller crisper radiuses. He mentions that if he were to redesign *Big Hug* today he would make the radiuses a bit smaller and sharper.

7.6 Patent research

To research if the concept was patentable a *POP, Patent One Pager,* was written and a meeting with Emma Östby, Patent Engineer at Axis, was set up. Östby and the Patent group at Axis did a review of the *POP* as well as a prior art search. The prior art search showed that there exists earlier know solutions based on a one-way mounting solution. Östby says that even if these solutions are used in other applications, they are used to solve similar problems. To be able to work around this prior art the patent would need to go deeper into the technical details, but that would also make the potential scope of protection very narrow and easy to bypass. Östby and her team did not see a way forward for a patent due to prior art in the field. Östby is quick to note that this does not mean that it is not a smart solution or a solution that would fail in the market or with users.

8 Define II

The Define II phase is again about boiling down the new findings from the new research and user tests to form yet another brief.

8.1 Structure of the define phase

The second *Define* phase will not be structured in the exact same way as the first *Define* phase. In this phase the most important insights found in the user test and in the new research will be stated, these insights will be more hands-on then the ones found in the earlier *Define* phase. Construction constraints will be defined in this phase. No new themes were found and no *How might we questions* were used since the insights gathered were more practical in nature.

8.2 New insights

The most important user insight found during the user tests with the prototype can be found in Table 8.1 below.

Table 8.1 The eight new insights found in the second *Define* phase.

#	*Insights*
11	Users do not seem to believe that the mount will be able to prevent rotation around the pole.
12	Users want to be able to remove the snap mechanism during installation.
13	Users prefer nuts on the screws on the back of the bracket instead of having threaded holes in the bracket.
14	Users felt that two screws could be enough.
15	Users with smaller hands had a hard time gripping both the interface and the bracket the way it was meant to.
16	Users felt that it was hard to know where to place their fingers.
17	Users felt that it was hard to align the snap screws to the bracket holes
18	Users wished that the snap mechanism should not start directly after aligning the screws in the holes.

8.3 Construction constraints

Based on the insights gained from the truss research, grip ergonomic research and *Insight 15* a decision was made to shrink the operating size of the mount. The previous iterations could fit poles up to the size of 100 mm. The new limit would be 45 mm. The value of 45mm was chosen since the manufacturers had hinted at that in some rare cases the diameter of the pole could be thicker than the standard due to special requirements from their customers. The smallest pole size designed for became 20 mm, since there was no reason to believe that thinner poles existed.

Since a strong grip on the product would be preferable in the intended environment of usage it was decided to pursue the power grip. The smaller range of dimensions felt reasonable as it would mean a shorter grip span and therefore help provide a better grip. In *Testable prototype* the screws for the snap mechanism were 130 mm long, the new goal would be to make them in a length that would guarantee that the open grip span is shorter than the recommended maximum of 87 mm.

8.3.1.1 Cabling hole

A cabling hole in the back of the interface was thought not to be necessary since the cable not will be pulled out into a drilled hole in the truss pole. The cabling holes of the arms will be used instead to pull out the cable downwards, a practice that is already implemented by installers. According to Borg, one of the creators of B*ig Hug*, this cabling hole, seen in Figure 8.1 was one of the restrictions that made the *Big Hug* as thick as it is, without this hole it is possible to shrink the size down to a size that is more suitable to hold with a comfortable power grip.

Figure 8.1 The cabling hole and its implications shown on *Big Hug*.

8.4 New brief

All the previous statements found in Section 1.2.1 The problem description includes the initial brief, goals and delimitations for the project as well as an initial truss definition.

Initial brief and in 4.6 New brief were still of interest. Many new insights have been acquired from the tests and the second round of research, but continuing into the next *Develop* phase the limited project time required the team to choose which parts and insights that required a diverging ideation process and which parts that needed a more converging and incremental development process. Preventing rotation and optimising the snap mechanism became the focus of the *Develop* phase, since these two felt essential to solve for the concept to work. The other insights were taken into consideration in the following *Deliver* phase.

9 Develop II

The Develop II phase focuses on generating new ideas for some of the parts in the concept.

9.1 Structure of the develop phase

The goal of this phase is to explore the areas chosen in the previous phase. The timeline is not perfectly linear due to problems finding a date for the second visit to Trelleborg. Hence, the ideas for the below explained K-profile and X-profile started their development before the user test in the port.

9.2 Preventing rotation

To be able to prevent rotation has been an important feature in earlier concepts, it was clear from the user tests that this still had not been solved. Moving on to the second *Develop* phase this is one of the focus areas that needs to be diverged on. Brainstorming started together with some of the Axis mechanical engineers during the tests and was also the start of this phase. Below are some of the concepts that had potential. The old concept of using the other pole as a secondary fastening point will not be investigated here, it was still thought of as a complex way of solving the problem.

9.2.1 K-profile

The idea for the *K-profile* concept is to use the webs of the truss to lock the mount on to them. The back of the interface will have tracks that are shaped like a *K* that matches the webs of the truss. This shape would only allow the mount to be placed on the positions on the truss where the webs intersect. On a triangle-shaped truss this would allow the mount to be placed in six different angles and on a rectangle-shaped truss this would allow the mount to be placed in four different angles.

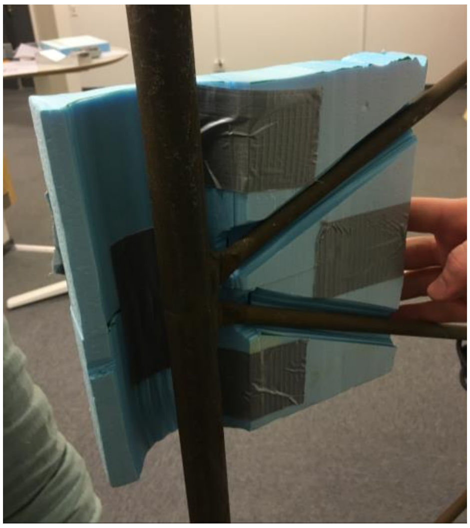

Figure 9.1 The foam mock-up of the preventing rotation concept the *K-profile.*

The first K-profile mock-up was made by cutting out the K-tracks in foam to match the truss in the *Axis Installation Experience Center*, seen in Figure 9.1. The mock-up match the truss perfectly and felt very stable when hold against the truss. The track for the pole was also decentred. However, since the thickness and angle of the webs differs from different trusses the tracks need to be flexible to that.

A new version was made in CAD. In this version, the side of the tracks had different angles that spanned between 48° to 66° from the point of intersection of the webs.

This seemed to be a good solution until the bracket was supposed to be designed. To make a bracket that will both tighten around the pole and around the webs, when both the pole and the webs vary in diameter, did not seem possible when the bracket is mounted parallel to the interface. To mount the bracket in ways that would work with this rotation preventative concept the whole concept would need to be changed and that would not the time limit of this project allow.

Before the problem with the bracket was introduced, the foam mock-up was shown at the test with the installers in the Port of Trelleborg and the concept was greeted with positivism.

9.2.2 X-profile

The idea for the *X-profile* was the same as the *K-profile* but in this version, the track for the pole was kept in the centre of the interface with tracks for locking the interface to the webs was made on both sides of the pole track making up the shape of an *X*. This allows the mount to be placed on more positions and in more angles than the *K-profile*. This concept also keeps the bilateral symmetry of the interface and bracket.

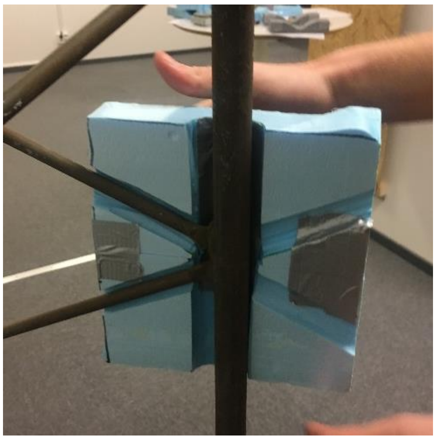

Figure 9.2 The foam mock-up of the preventing rotation concept the *X-profile.*

The first mock-up was just like the *K-profile* made of foam, seen in Figure 9.2, and the second version was made in CAD. The same problem with the bracket was found in this concept.

9.2.3 Bracket jack

Another concept that was thought of was the concept of making a triangular jack in the bracket, seen in Figure 9.3, that would allow the bracket to slide over one of the webs of the truss, locking the position of the mount in the Z-direction and preventing rotation. The triangular shape of the jack would allow the bracket to slide over webs with different diameters. This concept probably would not be as effective as the K- and X-concepts had the potential to be but will probably do its job well.

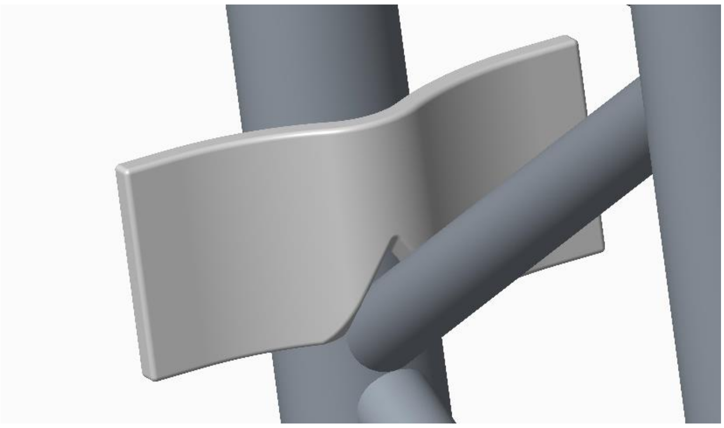

Figure 9.3 The bracket jack concept.

9.2.4 Grooves in the bracket

Another concept that has been discussed though the project as well as during the user tests, is the concept of adding grooves in the bracket. The question is whether this will increase or decrease the friction between the two areas. The grooves will probably not cut into the truss since the bracket is made of aluminium and the truss is made of steel. Another idea was to increase the friction between the bracket and the pole by making a rougher or more adhesive area on the bracket. This could either be done by adding a material with more friction on the bracket or by using a rougher surface finish on the bracket. Time did however not let the team to investigate this further. This will be left for further development.

9.3 Optimizing the snap mechanism

An important insight that was found in the user test was the wish to be able to remove the snap mechanism so that the installation could be aborted and the mount easily could be moved. Another wish was to be able to push the bracket on the screws easier and then can use the snap mechanism in the end to tighten. The concepts described below try to solve this.

9.3.1 Removable U-shape

The concept of the *Removable U-shape* is that the star lock washer and the holder for the washer is cut in a U-shape, seen in Figure 9.4. This allows the washer and holder to be pulled out from the hole in the bracket even when the screws are inserted. The biggest uncertainty with this concept was whether the snap mechanism still would work. A new holder with a U-shape was made in CAD and 3D-printed and a star lock washer was cut so that an angle of 60° of the washer was removed allowing four of the pawls to be kept. The new holder was inserted into the *Testable prototype*. When tested, the new washers worked just as good as before and the holders could easily be pulled out of the holes allowing the bracket to be pulled out of the screws.

Figure 9.4 A 3D-printed prototype of the *Removable U-shape* concept.

9.3.2 Keyhole U-shape

In the *Keyhole U-shape* concept the star lock washer is again cut in a U-shape but in this version, the washer is fixed in the bracket, seen in Figure 9.5. The two circular holes on the bracket have been turned into rectangles with circular ends. This means that the screw can be inserted into the bottommost circular end without snapping and then in the end when then snap mechanism is required for tightening, the bracket is pulled down and the cut star lock washer works as usual. Since the U-shaped washers worked with the removable U-shape this concept too seems plausible.

Figure 9.5 The *Keyhole U-shape* in the bracket.

9.4 Further development

Due to time constraints and the problems faced with implementing the bracket with *K-profile* and *X-profile,* a call was made to focus only on the *Bracket jack,* which will be further developed in the following phase. Grooves and material with higher friction in the bracket have been left for future work.

While both concepts for optimizing the snap mechanism was interesting, due to time constraints only the *Removable U-shape* was tested, and therefore chosen as the as the initial concept for the snap mechanism moving on to the next *Deliver* phase.

10 Deliver II

The Deliver II phase is about finalizing the concept through building, testing and iterating.

10.1 Structure of the deliver phase

The purpose of this phase is to again further develop the concept. Incorporating the new insights from the *Define* phase and new ideas from the *Develop* phase. Many decisions about the concept is made in this phase, therefore the phase is divided in the parts that make up the concept. The goal of this phase is to deliver a final prototype for this project that communicate the concept in the best way possible, however, because of the limited time frame some aspects have been left for future work.

10.2 Iterations

Explanations on the different areas in which decisions were made as well as more detailed pictures of the parts are found after the iterations.

10.2.1 Iteration VI

To create a more final design; more time, thought and effort was put into creating new versions of all the parts in CAD. The new insights and construction constraint found and the explored concepts of the *Develop* phase have been integrated in *Iteration VI,* seen in Figure 10.1 and Figure 10.2. This lead to a new more developed shape of the interface based on the *Big Hug* front and sides, a new bracket including the new B*racket jack* concept and the new *Removable U-shape* concept for the snap mechanism as well as shorter screws with nuts. The springs from the latest iterations have also been removed. This iteration was 3D-printed to get a sense of how the shape of the parts worked as well as to be able to try out grip positions and postures.

Figure 10.1 An assembly of the back of *Iteration VI*.

Figure 10.2 An assembly of the front of *Iteration VI*.

10.2.2 Iteration VII

Waiting for the 3D-print of *Iteration VI* to be finished, some minor additions were made. In this iteration, seen in Figure 10.3 and Figure 10.4, the bracket has been reinforced on several places and ribs have been added between the hole extrudes. At the same time a new shorter special made anti-loss screws was designed that would allow the integrators to use power tools from the front of the interface while holding the nuts with a wrench.

Figure 10.3 An assembly of the back of *Iteration VII*.

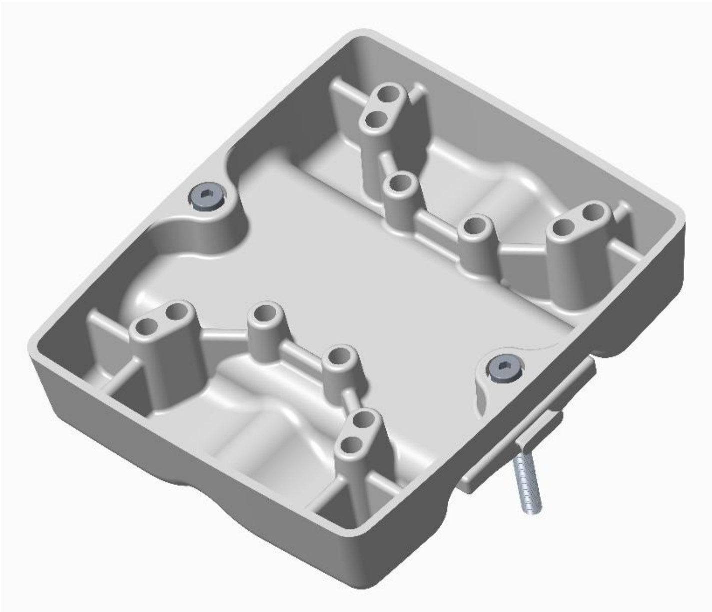

Figure 10.4 An assembly of the front of *Iteration VII.*

10.2.3 Iteration VIII

When the 3D-print of *Iteration VI* arrived a new installation test was made with some engineers at Axis to try out how people would hold and grip the mount when they install it. That lead to a new elevation in the interface meant to improve the grip of the mount. The industrial design aspects of *Iteration VI* and *VII* was also discussed with Axis Design Manager which lead to some adjustments to the different parts. The washer holder was changed to a combination of the *Removable U-shape* and *Keyhole U-shape* concepts. The bracket jack was tried against the webs of a truss which lead to it getting a slimmer profile. *Iteration VIII*, seen in Figure 10.5 and Figure 10.6, was then ordered as a finale 3D-printed prototype.

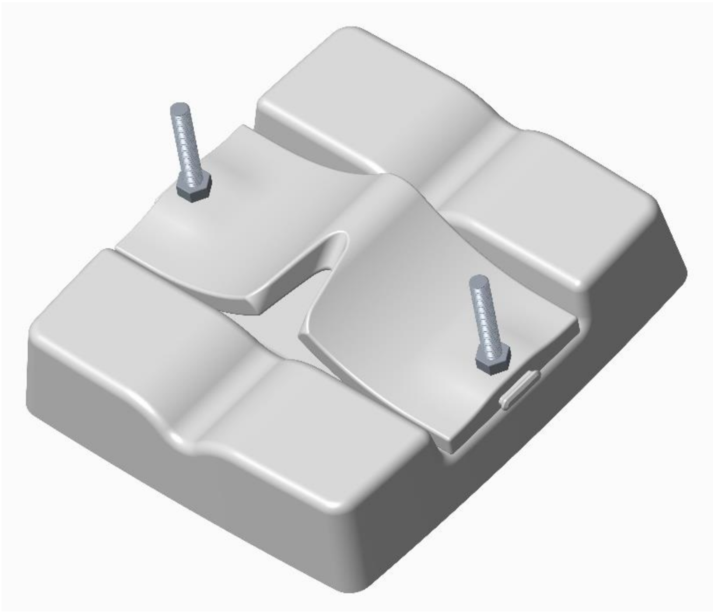

Figure 10.5 An assembly of the back of *Iteration VIII*.

Figure 10.6 An assembly of the front of *Iteration VIII*.

10.3 Interface

10.3.1 Shape and dimensions

The rim of the front of the interface was created by mimicking the shape of the rim of *Big Hug*. The rim has a slightly curved shape with curved edges. The rim then continues up towards the back with a slanted angle inwards. This is vital since it is going to be casted.

The back of the interface consists of two ridges, one on the top and on the bottom of the back, with the pole diameter profile track. The middle of the back consists of an immersed extrusion with two holes for the bracket. *Iteration VI,* seen in Figure 10.7, was then 3D-printed to get a sense of how the shape felt when holding it.

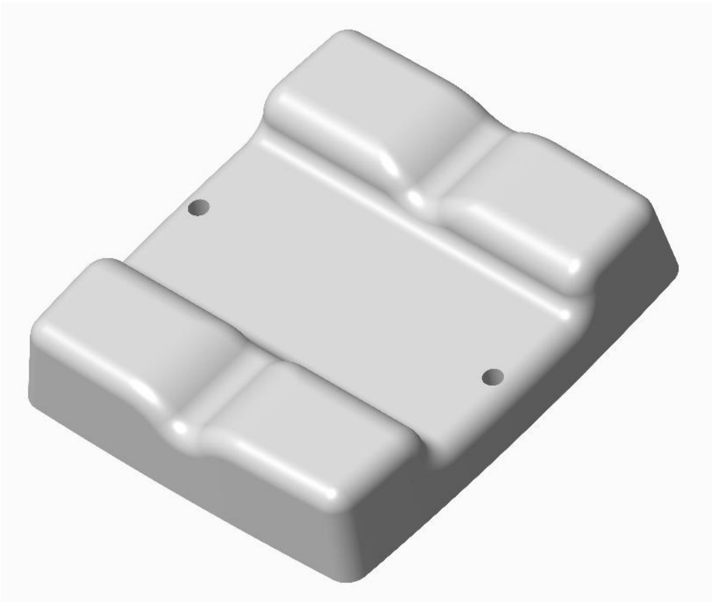

Figure 10.7 The back of the interface of *Iteration VI.*

10.3.1.1 Size changes

With the new limited size range, decided upon in Section 8.3 Construction constraints, the profile track could be made shallower which together with not needing a cabling hole created a size that was easier to grip.

10.3.1.1.1 Profile size

The shape was changed in *Iteration VI* and did not receive further changes throughout the phase. The shape was made so that a 20 mm pole could lie at the bottom, seen in Figure 10.8, and when the diameter increases towards 45 mm the pole will be fastened against the tangency plane of the arcs to the left and right.

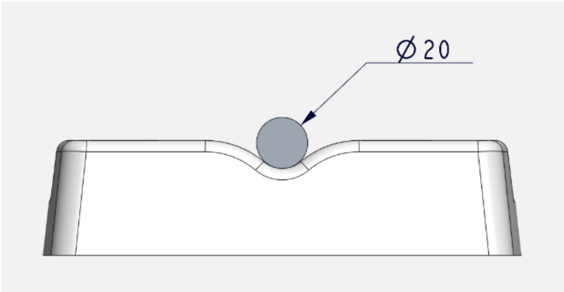

Figure 10.8 *Iteration VIII* assembled with minimum pole size.

10.3.1.1.2 Grip thickness

The reduced overall thickness led to opportunities to improve the grip of the interface. This change was also made in *Iteration VI* and did not change further on. The thickness, in the middle, where the interface is meant to be held was designed to 25 mm. This is below the size of comfortable grip for single handle tools, but was considered as acceptable since this grip only was needed when aligning the two parts.

10.3.1.2 Industrial design

To get feedback on how well the new interface matched *Axis Design Guidelines* the CAD of *Iteration VII* was shown to Axis Design Manager Daniel Åhman. All in all, he thought that the design of the interface worked, looked good and communicated the *Solidity* feel. However, he thought that some adjustments could be made to further communicate the Axis characteristics. He thought that the big 10 mm radiuses made the interface look more organic, a bit like a soap. To fix this he recommended making the radiuses smaller to give the interface a crisper look.

In *Iteration VIII*, seen in Figure 10.9, all radiuses except the edges on the side of the interface was changed to 2 mm. This felt good on the front, however, on the back it felt a bit too small. The back radiuses were later changed to 5 mm, which gave the back a crisper Axis feeling.

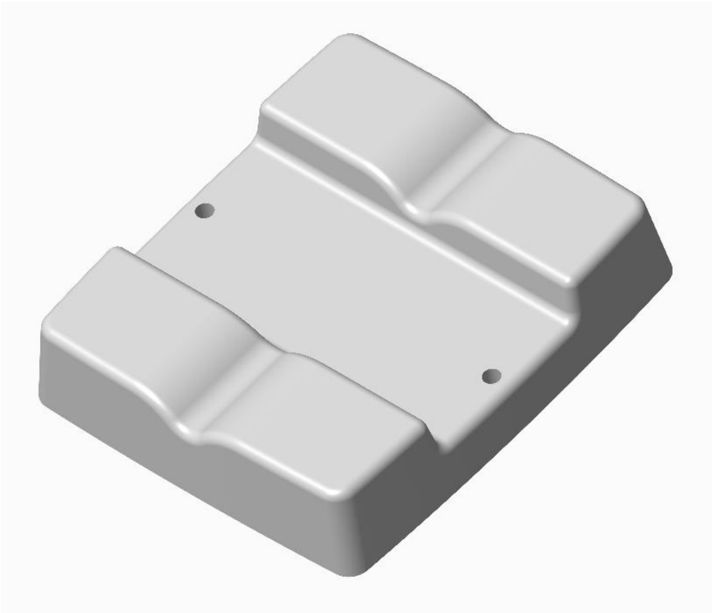

Figure 10.9 The back of the interface of *Iteration VIII.*

10.3.2 Holes

The holes of the front of the interface has been created by creating rounded extrudes with slanted sides around the holes, seen in Figure 10.10. *HELICOIL* inserts for M8 screws are supposed to be inserted in all the holes.

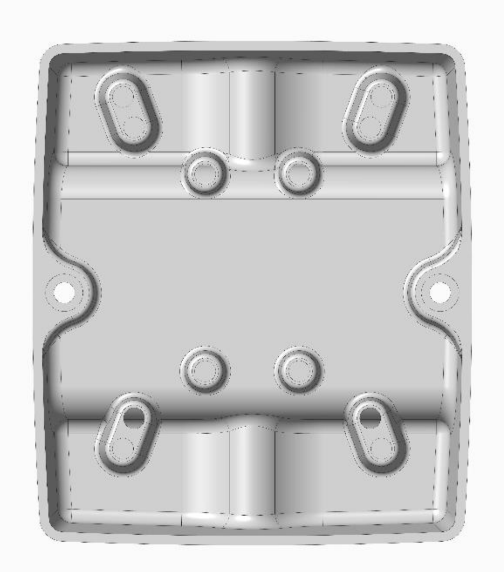

Figure 10.10 The front of the interface of *Iteration VI* showing the holes and the extrudes our them.

Åhman recommended moving the snapping holes away from the edges since they were breaking though the radius of the edge on the back, seen in Figure 10.11. In I*teration VIII* when the radiuses on the back were changed to 5 mm, the snapping holes did not break through the radius anymore, seen in Figure 10.12. Hence, moving them was not necessary.

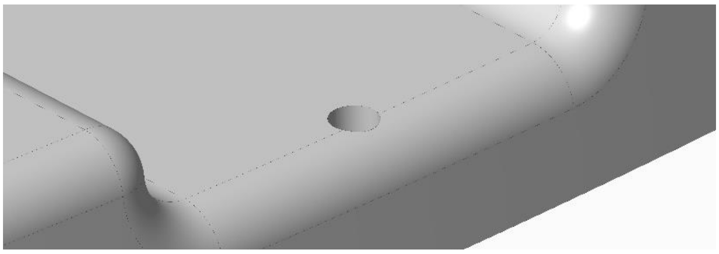

Figure 10.11 The hole for the snap screws in the interface of *Iteration VI* and *Iteration VII* is breaking though the radius of the interface.

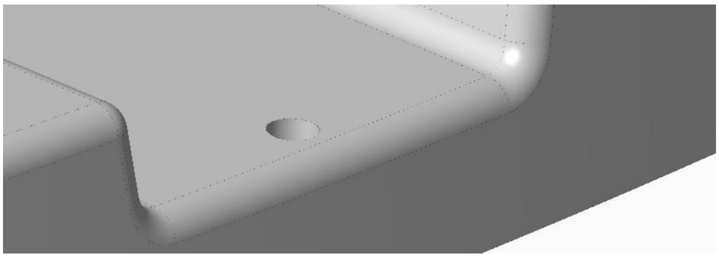

Figure 10.12 The hole for the snap screws in the interface of *Iteration VIII* is not breaking though the radius of the interface.

10.3.3 Ribs

Between the rim of the interface and the hole extrudes, ribs have been placed to strengthen the construction in *Iteration VII*, seen in Figure 10.13. Åhman thought that the ribs gave a feeling of reliability. However, even though he understands that the placement of the ribs is dependent on the hole pattern he thinks that the ribs only should be placed in straight lines to avoid creating patterns that could feel organic. He also thinks that the ribs should have smaller radiuses and maybe even be as high as the hole drafts.

Figure 10.13 The front of the interface of *Iteration VII* showing the added ribs.

Since no calculations have been made to optimise the placement of the ribs, the placement was made by comparing it to the rib placement of *Big Hug*. Several different placements were tried after meeting with Åhman yet the placement was kept as in *Iteration VII* solely because the design team thought it looked better. However, the radiuses of the ribs were changed to 2 mm and the ribs were broadened, seen in Figure 10.14.

Figure 10.14 The front of the interface of *Iteration VII* showing the modified ribs.

10.3.4 Elevation for grip

The rounded extrude for the two holes for the snap screws, seen in Figure 10.15, are so close to the rim that they can be used as an elevated place to place the grip of the integrators hands. Åhman thinks that the elevation for grip is a smart feature. However, he thinks the lines can be straight angled lines instead of curved lines.

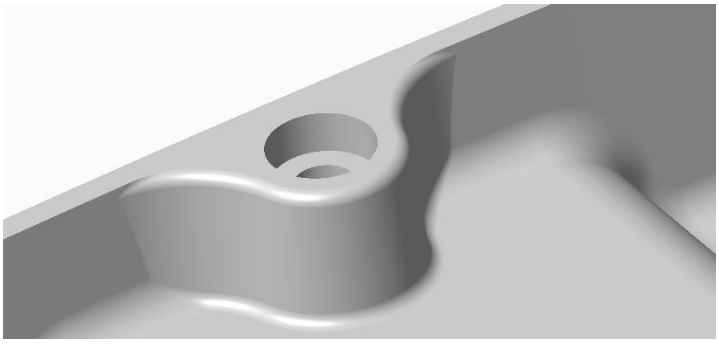

Figure 10.15 The elevation around the snap screw holes used to place the grip on *Iteration VI* and *Iteration VII*.

When the 3D-printed prototype of *Iteration VI* was received, it was clear that the elevation afforded the intended power grip, but also the pinch grip. To reach a conclusion on what grip a possible user would use naturally a grip test was conducted. In the test, the subject was ordered to mount the prototype the way that they felt was intended and most comfortable for them.

Due to time limitations, only five people performed the test. Four of these had seen the prototype before and had performed previous tests, the last one had never been included in the process before. The tests, however, were coherent, four out of five in the group, including the person who had never seen it before naturally used the power grip, seen in Figure 10.17, while the last one naturally used the pinch grip, seen in Figure 10.16. During the following discussion regarding their decision they expressed that the size of the grip span made it a natural choice and that the, in the future, added weight of aluminium and high altitude installation would further weigh in in favour of the grips.

Figure 10.16 The pinch grip used on the prototype of *Iteration VI.*

Figure 10.17 The power grip used on the prototype of *Iteration VI*.

They also liked that the rounded extrude provided a signifier on where to place their hands but argued that it could be developed further to better accommodate the thumb and smoothen out the pressure points during the power grip.

The feedback laid ground to some of the improvements made in *Iteration VIII* where the extrude for the holes took an asymmetrical look. The lower part had a slightly bigger area to provide relief for the palm of the thumb. The upper part was reshaped into a long chamfer that provided support for the thumb, and the transition from flat to chamfer was rounded significantly to eliminate the sharp edge. The new elevation can be seen in Figure 10.18.

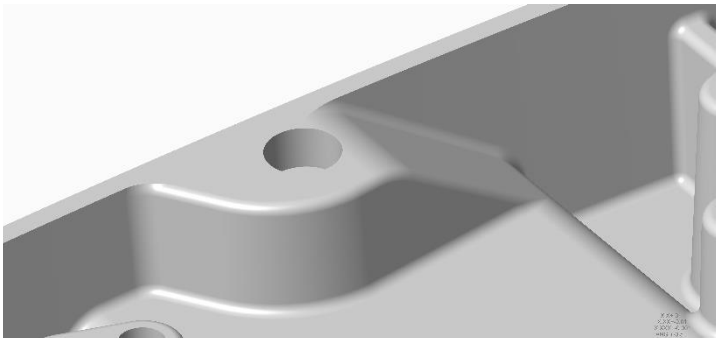

Figure 10.18 The elevation around the snap screw holes used to place the grip on *Iteration VIII*. The elevation is designed to give a natural place for palm and thumb.

10.3.5 Spring mechanism

Since the new jack in the bracket prevents the mount from moving in the Z-direction and since the *Testable prototype* worked without the leaf springs, the leaf springs and the leaf spring holes in the interface was removed from the concept in *Iteration VI*. One could argue that the *Testable prototype* itself had some flexing in its interface since its made of sheet metal, and that a casted aluminium interface and bracket not will work the same way. This is something that should be tested in the future and have been left as future work.

10.4 Bracket

Big changes occurred in between *Iteration V* and *Iteration VI* due to the feedback received from the user tests. Chamfering was added to the holes in *Iteration VII* to help guide the snap screws into the bracket holes.

10.4.1 Profile size

The profile of the bracket was changed in *Iteration VI*, with the input from Section 8.3 Construction constraints, and did not change in the following iterations. While the interface has its smallest diameter set at the minimum requirement, the bracket was given a wider profile matching the diameter of the maximum value of 45 mm. The reasoning for this is that while the poles grip onto the tangency of the interface it can lay perpendicular to the bottom of the bracket, seen in Figure 10.19. If one of the parts were to flex it is most likely that the bracket will be the one to, and if flexing occurs this will lead to the arcing surfaces to wrap around the pole.

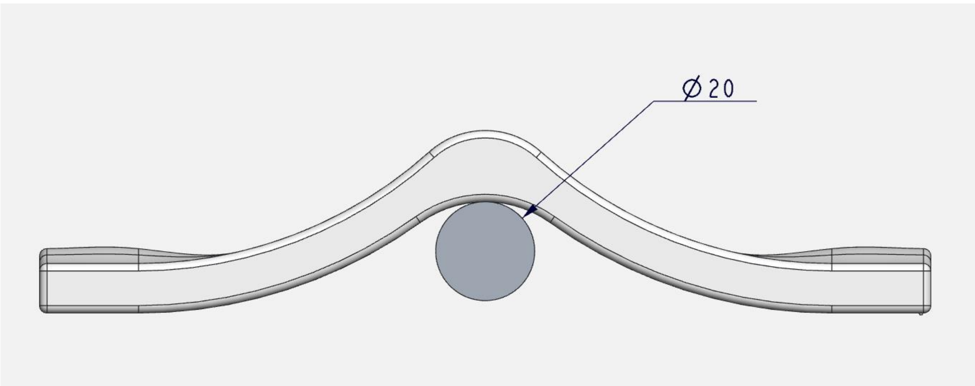

Figure 10.19 *Iteration VIII* assembled with minimum pole size.

This difference in size does not cause an issue regarding the possibility to clamp onto the smallest of poles since when assembled together at minimum distance the enclosed diameter is 12 mm.

10.4.2 Jack

The bracket jack concept was integrated into the concept, seen in Figure 10.20, and some different versions was made to better match the webs of the trusses. In *Iteration VII,* seen in Figure 10.21, the thickness of the bracket over the jack was increased since the jack probably will create stress concentrations. The extent of the fortification was not simulated or analysed in this thesis, it only serves as an indication on how the weakness can be addressed. Åhman thought the increased thickness worked well, however, he thought that the jack could get a tighter feel by using more straight lines instead of curved lines. In *Iteration VIII,* the straight lines were inserted, however, this made the end of the jack smaller which was not desired since the bracket then could not be applied to larger truss webs. The jack was changed back to the curved version but it was made tighter, seen in Figure 10.22.

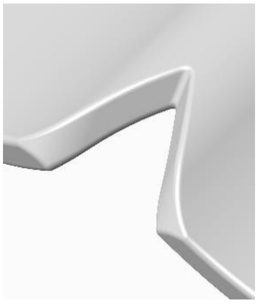

Figure 10.20 The jack of the bracket in *Iteration VI.*

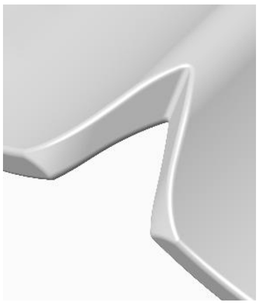

Figure 10.21 The jack of the bracket in *Iteration VII* with a reinforcement over the jack.

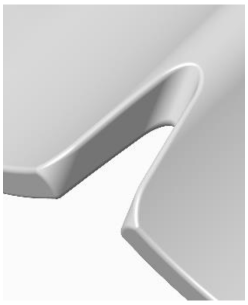

Figure 10.22 The tighter jack of the bracket in *Iteration VIII.*

10.4.3 Grip

Since some users felt that they did not know where they were supposed to place their fingers on the bracket a slight elevation was made over the hole, seen in Figure 10.23. This so that the integrators could get a sense of where to put their fingers and where the screw will come out. The elevation where also placed above the holes to strengthen on the thinnest area of the bracket. Åhman thought this feature was nice, however, he thought it felt a bit to organic. An idea is to redesign the elevation as the Axis design characteristic, the wing, even though this normally not is done on accessories. This was however never tried due to limited time constraints.

Figure 10.23 The bracket from *Iteration VIII* shown from the side showing the reinforcement over the hole that also give a hint of where to place the fingers.

10.4.4 Snap mechanism

10.4.4.1 Removeable

The removable *U-shape* concept was integrated into the bracket in *Iteration VI* and a thinner star lock washer holder was made, seen in Figure 10.24. However, Åhman, Borg, Rusz and Christensson commented that maybe the holder does not need to be fully removable, it could maybe be able to be moved between two fixed locations, kind of like the *Keyhole* concept. In *Iteration VIII* a new version of the star lock washer holder was made, seen in Figure 10.25, that was fully removeable when no screw was inserted. However, when a screw is inserted the holder can only be toggled between two positions, one position that allows the screw to move freely and one position that applies the snap mechanism. The new hole shape of the holder had the shape of an 8 and is therefore called the *8-shape*.

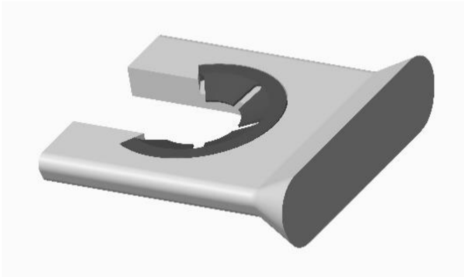

Figure 10.24 The *Removable U-shape* concept of the star lock washer holder in *Iteration VI* and *Iteration VII*.

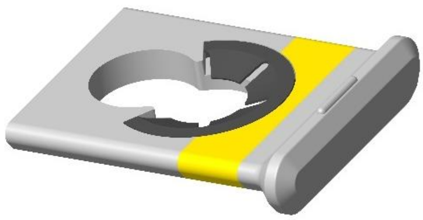

Figure 10.25 The new *8-shape* concept of the star lock washer holder in *Iteration VIII* with a new grip and signifiers.

10.4.4.2 Forcing functions and signifier

To only make it possible to insert the star lock washer holders the right way the sides of the holder and sides of the hole in the bracket was given a slight angle in *Iteration VII*, seen in Figure 10.26, so that it is impossible to insert the star lock washer upside down. The design team thought that this was great for hindering the wrong insertion. However, the angle was not visible to people who tried it, the people instead felt frustration, kind of like when an USB cable is inserted the wrong way**Error! Reference source not found.**. To avoid this frustration the holder was again redesigned in *Iteration VIII* with a steeper angle to make it more visible, seen in Figure 10.27. A thin extruded line was also placed as a signifier on both the front of the bracket and on the front side of the holder to indicate that the sides belong together.

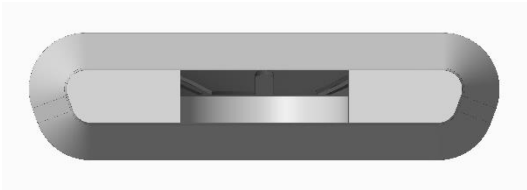

Figure 10.26 The *Removable U-shape* concept of the star lock washer holder in *Iteration VI* and *Iteration VII* viewed from the back showing the constraining shape.

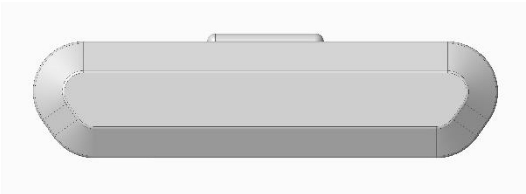

Figure 10.27 The new *8-shape* concept of the star lock washer holder in *Iteration VIII* viewed from the back showing the constraining shape and the new signifier.

To communicate in which mode the star lock washer holders are in, a small strip of yellow was painted on the holder as a signifier, seen in Figure 10.25. The strip is only visible when the holder is in the non-snapping mode. Yellow is traditionally used as people associate yellow with warnings.

10.4.4.3 Grip

The grip of the holder was changed in *Iteration VI* to a more angled grip, seen in Figure 10.24. In *Iteration VIII* that grip was changed into having angles on both sides, seen in Figure 10.25. This made the grip a bit sturdier to use with gloves. The perceived grip affordance was considered higher on the new grip than on the earlier version. However, when the final prototype arrived the grip felt a bit too small to grip, especially with gloves.

10.5 Tightening mechanism

Since the integrators in the Port of Trelleborg, Palmqvist and some of the engineers at Axis felt that it was enough to only have two screws that both work for tightening and for the snap mechanism, the other four screws were removed. This worked since the integrators preferred nuts on the back of the screws. However, it still felt important to be able to use a power tool from the front of the interface. This was accomplished by using a special made anti-loss screws, seen in Figure 10.28, and a HELICOIL thread in the holes.

From the head of the screw down the screw starts with having a diameter that is the same as the thinnest diameter of the thread, d_{min}, on a length that is the same as the length of the hole in the interface. The rest of the screw has a M8 thread. What this accomplishes is that the screw can be screwed freely while still being fixed along its axis so that when a nut is held against the back of the screw the screw will not move but the nut will.

Figure 10.28 The special made anti loss M8 screw.

10.5.1 Screw length

Changing the requirements for the pole diameters had many improvements on the usability. The largest benefit of these was that the snap screws became significantly shorter, since this dimension decided on how long the open grip span would be. From a previous 130 mm, the length was decreased to 85 mm, including the head, a distance that is close to the maximum required but still inside its range. It is worth noting that the screws could have been made even shorter to shorten the grip span but it was more important to provide some extra spacing and room for nuts.

10.6 Parts dependent on the grip span

While the dimensions of the interface, bracket and the screw length are described separately they were dependent on each other during their optimization and some clarifications needs to be written on their dependency.

First, the length of the open grip span's, described in 7.3.1.2, most dependent parameter is the length of the screws as they define the distance that the bracket will start its installation from the interface.

The grip thickness of the interface could have been made thicker than 25 mm to accommodate a correct grip size for a single handle tool. Making it thicker would however have interfered with the length of the screw coming out of the backside of the interface. The encircled diameter when the interface and bracket is in contact is 12 mm which means that the bracket must retract 8 mm to capture the minimum size pole, as seen in. Figure 10.29. To be able to fit the widest pole the bracket retracts a total of 34,5 mm, which leaves 12,5 extra mm not counting washers and nuts, seen in Figure 10.30. As mentioned above in *Screw length* the extra spacing behind was important and therefore the team went with the thinner grip.

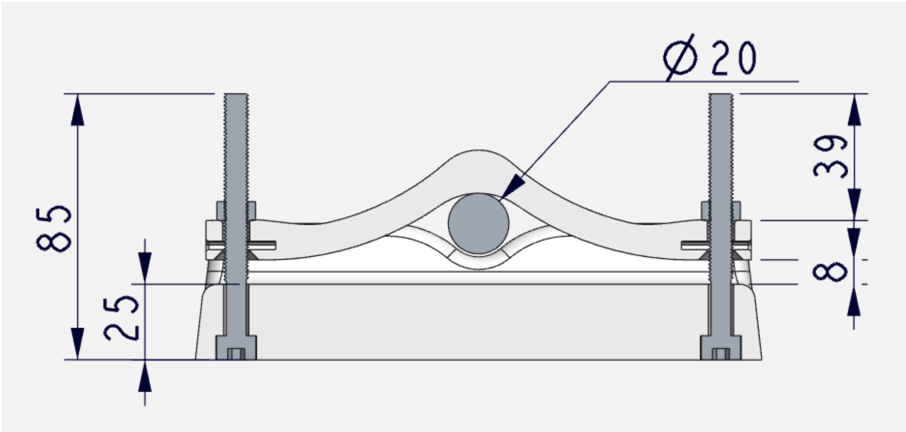

Figure 10.29 Relations between parts assembled around minimum size pole

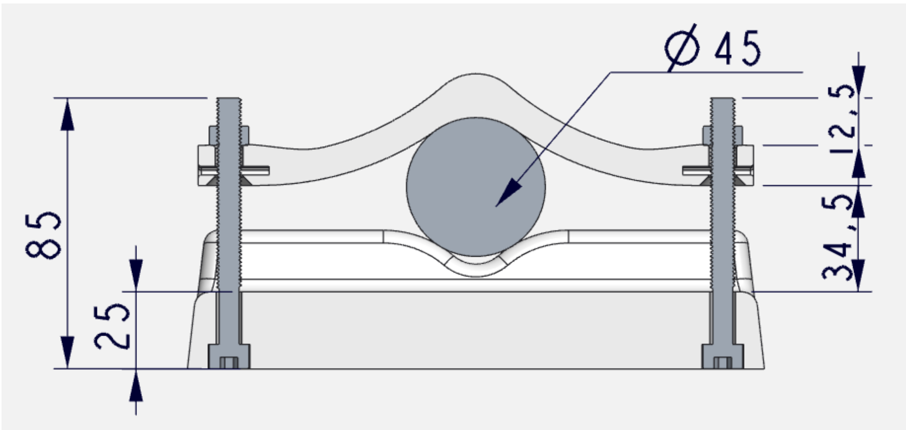

Figure 10.30 Relations between parts assembled around maximum size pole

10.7 Extra plate

To still have an insect safe mount when a smaller arm that uses the *Mobility* hole pattern is attached, an extra plate, seen in Figure 10.31, could be fasten to the front of the mount, seen in Figure 10.32. The holes in the plate will not be threaded since the *Mobility* holes and threads of the interface still can be used. The upper *Brokeback* holes was used to fasten the plate to the interface before fastening the arm on the plate. The plate is only a cover for aesthetic reasons and to prevent insects from nesting.

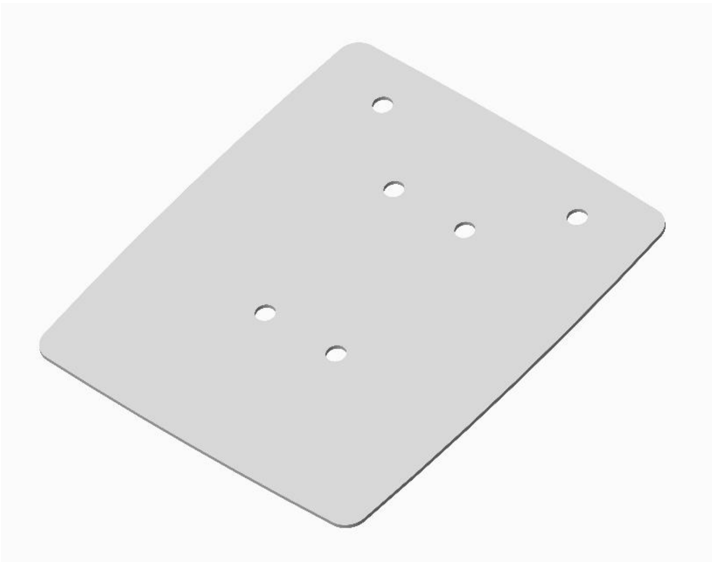

Figure 10.31 The extra plate used for the *Mobility* arm.

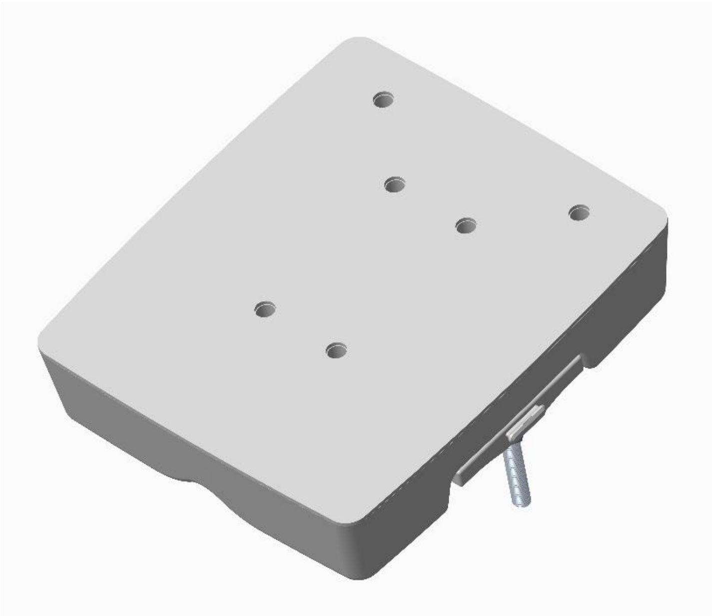

Figure 10.32 The extra plate used for mobility align with *Iteration VIII.*

10.8 Material

Throughout the project metal has always been thought of as the most viable material for the truss mount since the targeted arms and cameras can weigh up to 40 kg. Since aluminium is a light yet strong material used in many of Axis products, especially for mounts, it was chosen as the material for the interface and the bracket. The star lock washer holder will be made in injection moulded plastic since it will be cheaper and does not need to take up load. The screws should be made in stainless steel to prevent rusting and the star lock washers will be punched from a sheet metal.

10.9 Colouring and finish

Since most Axis products uses the *Axis White* colour as its base colour it was decided that the truss mount should have this colour as well. The interface and the bracket will be powder coated. At Axis, most external aluminium parts are powder coated. Powder coating is a tougher surface treatment compared to wet paint that is great for outdoor products that are supposed to withstand harsh weather conditions [41].

11 Result

In this chapter an overview of the final concept, the final prototype and the final installation process will be presented.

Throughout the project the team has strived to achieve a design that solves the users' needs in a new and intuitive way. As a proof of concept this prototype embodies that ambition. The team has developed a new way of installing Axis products on a circular surface and this one is optimized to work on all trusses in the focused area. With the number of tests performed and feedback received regarding the product and its installations process it can be concluded that it is a solution in the right direction.

This would not be the end for the development if more time was available and the current challenges will be presented in *13.1 Future work.*

11.1 Overview of the final concept

The final concept, seen in Figure 11.1, consisted of the following parts:

- One white powder coated casted aluminium interface with *HELICOIL* inserts.
- One white powder coated casted aluminium bracket.
- Two injection moulded washer holders with two punched U-shaped internal star lock washers.
- Two anti-loss M8 screws with *Torx 30* heads.
- Two M8 nuts.

The screws will be screwed in place in the interface and the washer holders will be inserted in the bracket before the installation take place.

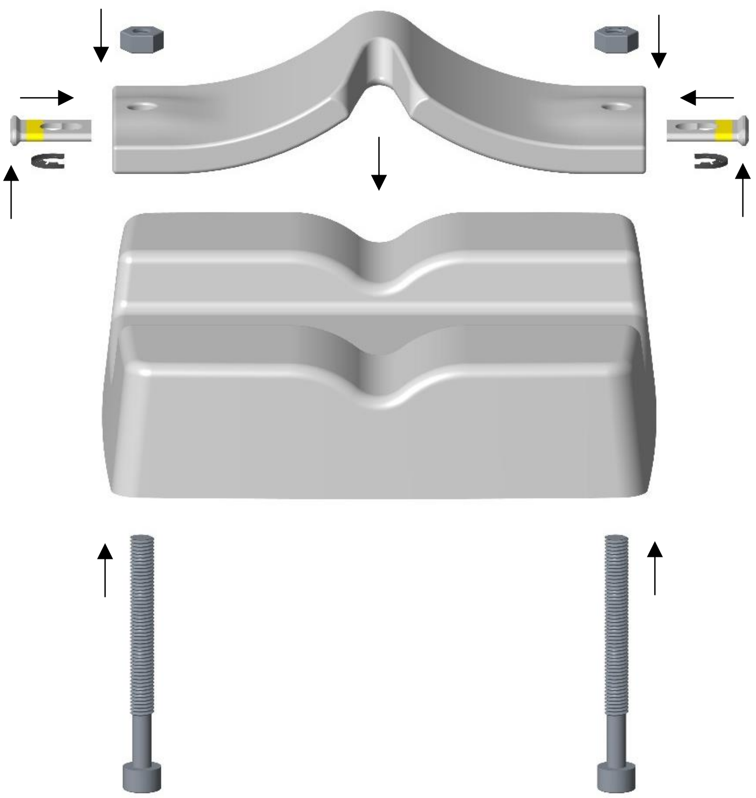

Figure 11.1 An exploded view of the final concept.

11.2 Final prototype

The final prototype, seen in Figure 11.2 and Figure 11.3, consisted of

- One interface made in *Polyamid PA2200, PA12,* using the 3D-printing method *Selective Laser Sintering, SLS,* at GT Prototyper AB. The front of the interface has been coated in *Axis White*. HELICOIL inserts have been inserted in the two holes.
- One 3D-printed bracket made in *PA12* using *SLS* at GT Prototyper AB. The outside of the bracket has been coated in *Axis White.*
- Two 3D-printed washer holders made in *PA12* using *SLS* at GT Prototyper AB with two cut and modified U-shaped internal star lock washers from Lesjöfors. The grip of the holder has been coated in *Axis White.*

- Two anti-loss M8 screws with *Torx 40*. The screws have been milled to get the appropriate anti-loss properties.
- Two M8 nuts.

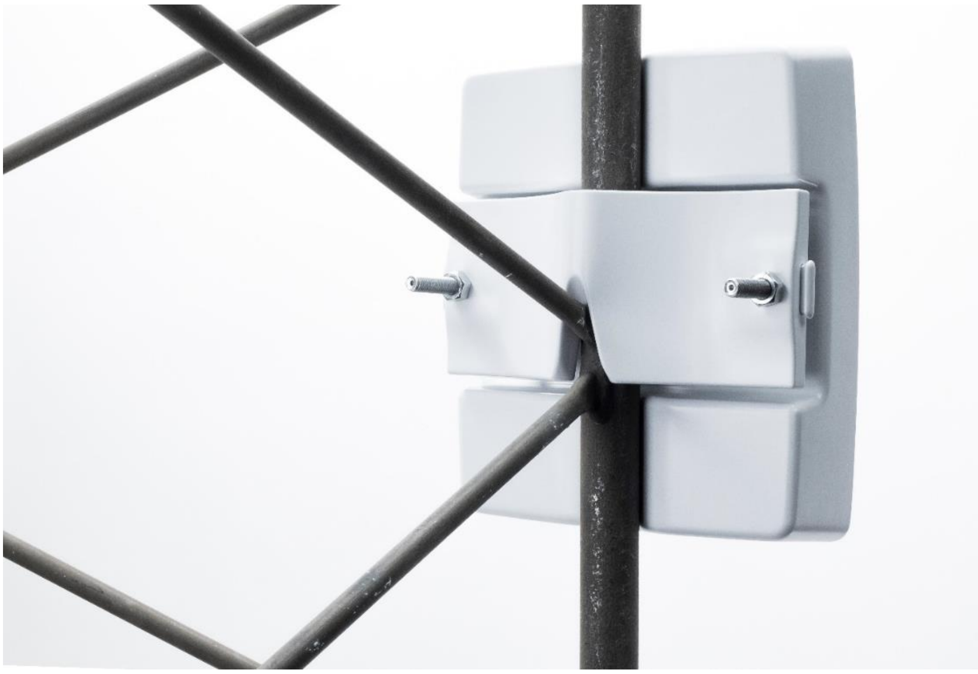

Figure 11.2 The final prototype installed on a truss.

Figure 11.3 The final prototype installed on a truss.

11.3 Final installation process

In this chapter, the intended way of installing the product is described and shown with its eight steps.

The process starts with using a firm power grip to position the interface close to the intended installation placement on the truss, seen in Figure 11.4.

Figure 11.4 Step one of the installation process.

The bracket is then held with the other hand, placed over the web and the two holes are aligned with the two screws, seen in Figure 11.5.

Figure 11.5 Step two of the installation process.

The grip is then changed to a power grip for both hands grasping both the interface and the bracket, seen in Figure 11.6

Figure 11.6 Step three of the installation process.

The power grip provides good strength to close the distance between the interface and the bracket. This action clamps the parts around the pole thanks to the snap mechanism. The friction between the materials holds the two parts in place seen in Figure 11.7.

Figure 11.7 Step four of the installation process.

After this step the product will hold its own weight and does not need any support from the installer, seen in Figure 11.8. If the previous step did not exert enough force to hold it in place it will not slide far. The jack, described in Section 10.4.2 Jack, will if sliding occurs place itself over the web. From this point, all the following steps can now be paused in between.

Figure 11.8 Step five of the installation process.

Nuts can now be placed on the screws and be screwed into position by hand seen in Figure 11.9.

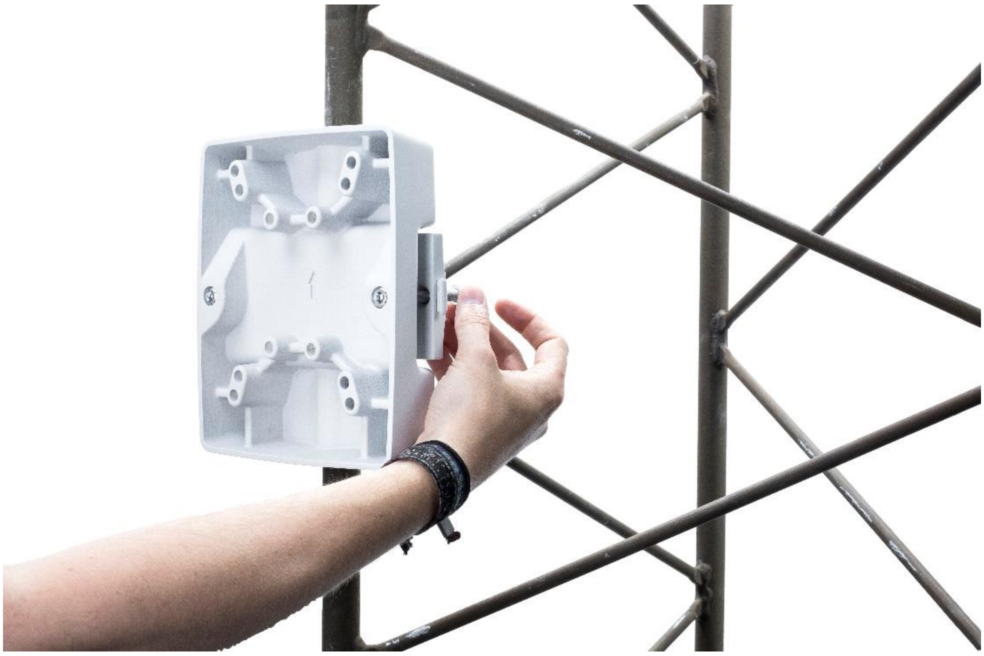

Figure 11.9 Step six of the installation process.

To tighten the nuts, they need to have their rotation fixed. A closed wrench could be used for this operation and since the screws can rotate freely a power tool can be used from the front to apply the torque needed, seen in Figure 11.10.

Figure 11.10 Step seven of the installation process.

With both nuts now securely tightened the installation is complete, as seen in Figure 11.11. The product is now ready to have an arm and later a camera connected to it.

Figure 11.11 Step eight of the installation process.

11.4 Assembly with Axis target products

All the three desired arms and in the extension, the desired cameras can be mounted on the final concept. In Figure 11.12-Figure 11.15, the *Connect*, *Mini Connect, Brokeback* and *Mobility* arms have been assembled with the final concept and with *PTZ* and *Fixed Dome* cameras. The *Mini Connect* and the *Mobility* assemblies required the extra plate, presented in Section 10.7 Extra plate.

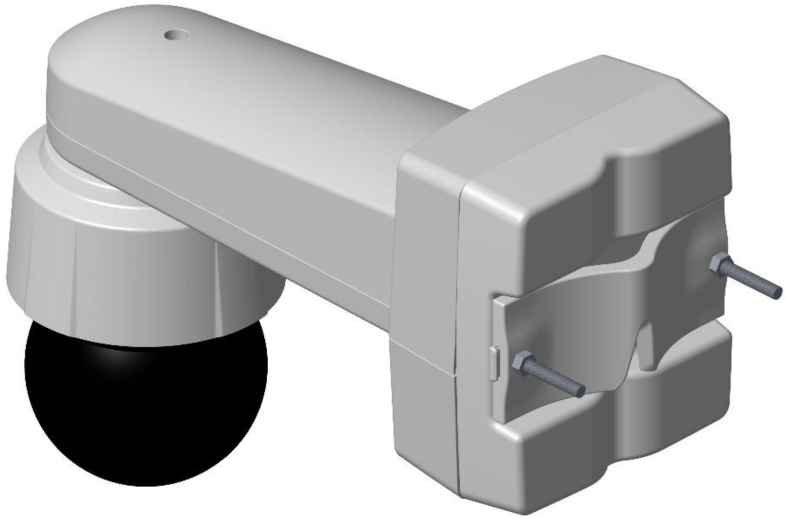

Figure 11.12 The final concept assembled with the *Connect* arm and a *PTZ* camera.

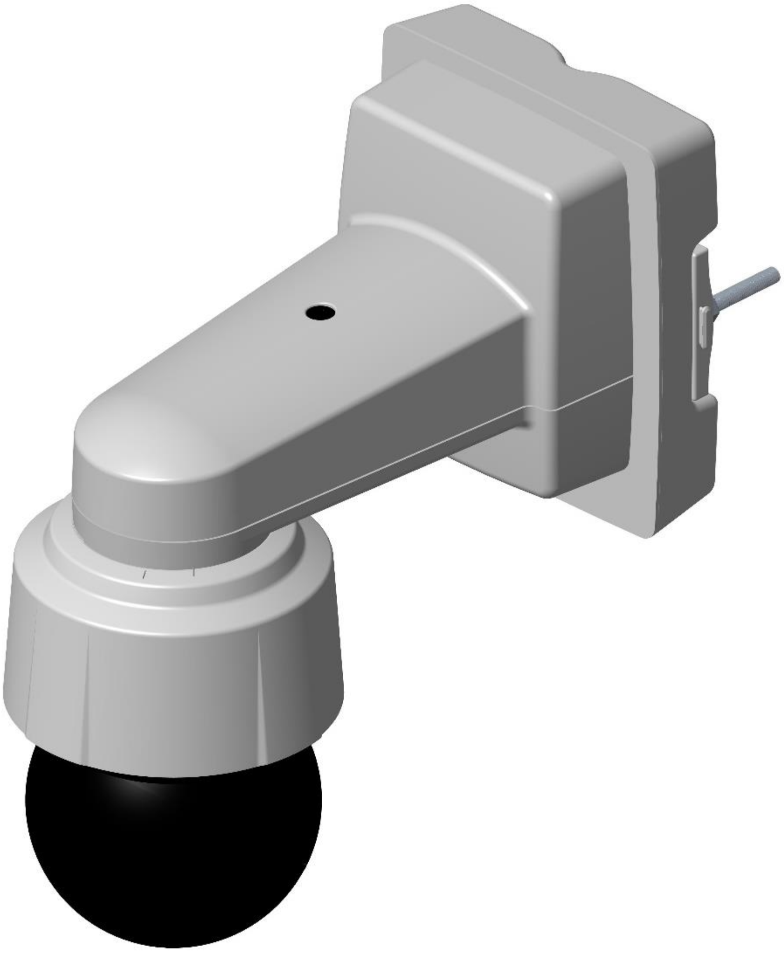

Figure 11.13 The final concept with the extra plate assembled with the *Mini Connect* and a *PTZ* camera.

Figure 11.14 The final concept assembled with the *Brokeback* arm and a *PTZ* camera.

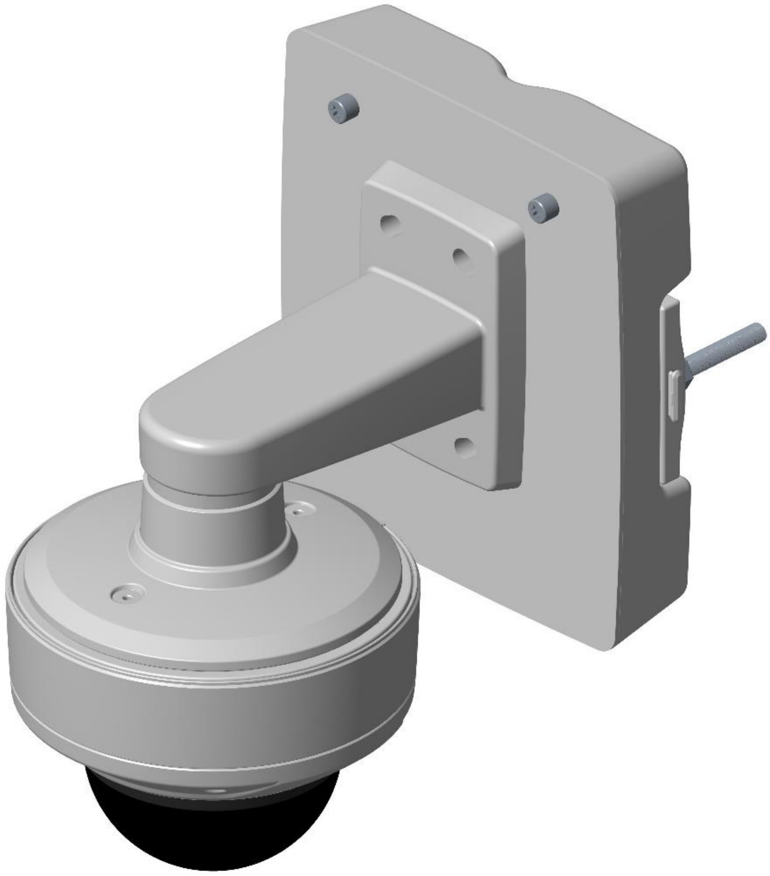

Figure 11.15 The final concept with the extra plate assembled with the *Mobility* arm and a *Fixed Dome* camera.

11.5 Fulfilment

11.5.1 Goals

In, Section 1.2.3 Initial goals, it is stated that Axis wanted a concept solution and a concept prototype, since this have been provided, that goal was reached. The team feel that the emphasis on keeping the users' needs and limitations in focus throughout the projected was consistent. Thus, the team's own goal of using a *Human-centered design* process has, while harder to prove, also been reached. The team also completed two full cycles of the *Double Diamond* design process.

11.5.2 Insights

The insights described in *Define I* and *Define II* and how they have been fulfilled have been described in .

Table 11.1 The insights described in *Define I* and *Define II* and how they have been fulfilled have been described below.

#	*Insights*	*Fulfilment*
1	Installers want a solution that is efficient through it being intuitive and prohibiting erroneous behaviour.	Many of Norman's design principals have been integrated in the product leading to an intuitive product that prohibits erroneous behaviour.
2	It is important to take the installers limited resources into account.	The final concept can be performed in steps and only the last step requires tools that can be used without holding the product.
3	Installers want to install mounts facing them.	The final concept can be installed with the installers facing the mount. A power tool can be used on the front of the interface.
4	The design should fit all trusses inside a specific size range.	The design will fit the truss pole diameter span of 20-45 mm, which is more than the identified span. The bracket jack should work well with the identified web diameter span.
5	Installers want a broad selection of positions to fasten the solution and can change the orientation and/or location.	The mount can be installed in six different angles on a triangular truss and in four different angles on a quadratic truss.
6	Installers will only use products they trust.	The design of the product look and feel robust and includes two large M8 screws.
7	The buyer and the user will have different views on what is important.	The mount looks aesthetically pleasing to attract buyers.
8	Weather, water, salt, corrosion and consistent vibrations will expose the products.	The mount will be powder coated to be able to withstand water, salt and corrosion. The screws, nuts and star look washer will be made in stainless steel.
9	Trusses have strict requirements and may not be tampered with.	The mount does not damage the truss.

10	The most common trusses consist of round poles and webs.	The mount has been designed to fit round poles and webs.
11	Users do not seem to believe that the mount will be able to prevent rotation around the pole.	The bracket jack has been implemented to prevent rotation around the pole.
12	Users want to be able to remove the snap mechanism during installation.	The snap mechanism can be toggled to a non-snapping mode.
13	Users prefer nuts on the screws on the back of the bracket instead of having threaded holes in the bracket.	The mount requires nuts on the screws to tighten the mount to the truss.
14	Users felt that two screws could be enough.	The mount has two screws that can be used both with the snap mechanism and to tighten with nuts.
15	Users with smaller hands had a hard time gripping both the interface and the bracket the way it was meant to.	The grip span has been design for a correct ergonomical power grip.
16	Users felt that it was hard to know where to place their fingers.	An elevated area has been integrated around the holes of the bracket.
17	Users felt that it was hard to align the snap screws to the bracket holes	Chamfers have been implemented around the holes of the bracket.
18	Users wished that the snap mechanism should not start directly after aligning the screws in the holes.	Chamfers have been implemented around the holes of the bracket.

12 Discussion

In the discussion, the method and the results will be looked at with a critical eye and discussed.

12.1 Method

12.1.1 Human-centered design

The *Human-centered design* approach was something the design team felt was a fun and engaging approach to try on a project like this, a project that is focuses on the interaction between user and technology. It was early on decided as a self-proclaimed goal from the design team to go with this approach. The question now is how well did it work in this project and how well was it used in the project?

The design team thinks that the usage of this approach has affected this project and the design team positively. The approach enforced the design team to put more effort into finding users, interviewing them and observing them. It also let the team to start with focusing on the human aspects of the project instead of the technical. Sure, this have also let to that some of the construction constraints have been put in rather late in the concepts and many of the more technical aspects such as strength and other calculation have been left for future work. It also let the team to focus more on the installation process rather than on the fact that the product should work with trusses. This is something the team could do because *HCD* encourages questioning of the given problem. All in all, this probably have led to a better solution, and also one that Axis might be able to implement into other products as well.

Another important aspect of *HCD* is to iterate upon repeated approximations through rapid prototyping and testing. This have been used widely throughout the phases of this project with good results.

However, there are some aspects of the project were the design team has not been able to perform as well as the approach suggests. The approach suggests that many different users should be involved often during a design project. The team has, however, not been able to find as many real users as wanted and it has been hard to involve to ones found more than a couple of time. This and bad luck has also led to less observations being made. However, co-workers and other people have sometimes been used as stand-ins for real users. More on the problem of finding real users is discussed in 12.1.2.1.1 below.

The problem of not having enough users to study spilled over into how the problem was formulated. The team never got to observe how the installers in Trelleborg acted in their normal environment, performing their everyday tasks. The only time observations occurred was when the team was conducting tests, which meant that some type of interaction with the user was required. This was problematic since focus was then on the prototype that was tested instead of on the general situation. This means that valuable insights might not have been found.

A good counterbalance to the said problems would have been to observe the users from a distance to see how their words differed from their actions and search for latent needs unaware to them. With more access to users, the opportunities for performing that needed type of observation would have increased.

12.1.2 Double Diamond model

The *Double Diamond design process model* has in hindsight been a great model to work with in this project. The diverge-converge pattern has been a good model for knowing when to focus the thinking on expanding and exploring new areas and ideas and when to focus the thinking on boiling down research and improving ideas and concepts. The *Double Diamond revamped*, Dan Nessler's attempt of structuring *HCD* with the *Double Diamond* even further have been a good structure to go back to when feeling lost. However, sometimes it made the design team focus to much on the process and structure rather than the project itself. Below different areas that stand out during the process will be discussed.

12.1.2.1 Discover

The *Discover* phases were phases that was very important to this project since the project is exploring a new area for Axis. Sjöberg says that this part of a project is often something that the engineers at Axis do not spend enough time on. He thinks it is key to a project of this type and so does the design team in hindsight. Even though these the phases were essential, some areas are worth discussion and criticizing.

12.1.2.1.1 Finding the right users

Using a *Human-centred design* process requires humans and users to be involved throughout the whole process. However, to be able to involve them they must first be found. In this project that has not always been very easy. One reason for this might be Axis business model that is an indirect sales model. Axis works in partnership with distributers, system integrators and resellers to sell, distribute and install Axis products. They are the ones that reach the end-customers and end-users. Another reason might be that the project explores a new product in a new area for Axis and not many people at Axis have any knowledge about which system integrator companies that do truss installations.

It has been great to have the Port of Trelleborg system integrators as a source for both research and testing but they still are only one source at one site in one country. Even though time and availability to visit other countries are reasonable limitations in a master thesis project, it would still be good to be able to confirm and test the concept on more users.

12.1.2.1.2 Conducting an extensive market research

Since Axis is a global company most Axis products will also be sold globally. A product being developed in Sweden needs to resonate and work all over the world. Therefore, doing a broad and extensive market research is important. Even though many sources of information all over the world have been contacted, it has been easier to get more information about the Swedish market. This have probably affected the outcome of this project.

From the information gathered, it seems like a plausible explanation for the lack of information, is that the usage of truss towers is not used as much in countries outside of the Nordic region. This is, however, just a notion and have probably not been confirmed with enough sources.

12.1.2.1.3 Truss research

Since this project is about designing a truss mount that work with many different trusses all over the world, it is important to do an extensive truss research. Early in the project it was found that no standard for trusses exists and that their shape and dimensions vary. This lead the project to focus on making a flexible mount that would fit trusses with different diameters. However, in the end a narrower diameter span was chosen for the mount that was only confirmed with two Swedish manufacturers. This is probably not enough to guarantee that the product will work all around the world but given the time frame and access to information the team felt that it was best to act on these sources as their only input.

12.1.2.2 Define

The *Define* phases was the phase were the design team struggled the most. Both with formulating insights and with the *How might we questions.* These areas are discussed below.

12.1.2.2.1 Insights versus technical specifications

In the method, it is written *that "Insights are the dormant truths about the consumer's behaviour and the associated motivation behind it."*. When defining the insights found during the *Discover* phase, the design team felt that it was hard to separate the insights that were associated with consumer or user behaviour and the more technical insights. It felt that the human-centred approach sometimes focused so much on humans and left no room for technical specifications. In the theory, it was never mentioned how technical specifications should be inserted into the process. The way the design team solved this was to treat the most important technical specifications as insights but not use those insights to create *How might we questions*, since they were not thought to be opportunities for design. This allowed the design team to not feel too constrained in their ideation. The technical insights were then used to improve the concept in the *Deliver* phase. While this seems to have worked out well, in some cases during the project some technical specifications might have been inserted a bit late. This sometimes made the design team spend unnecessary time on things that in the end would not work.

12.1.2.2.2 Creating How Might We questions

The *How might we question* is not just a buzzword; the three words have been specifically chosen to promote creative problem solving [42] and have been used by some of the most successful companies today. They can be tricky to formulate though, as the design team found out during this project.

What happened was that the questions felt restricting instead of providing support and sparking imagination. The first reaction to this was to iterate and try to look for wrongdoings in the formulation and understand if some important information had been missed out.

After studying other examples of where these questions have been used with great success it was concluded what these had in common; they had an open solution whereas this thesis revolved around the design of a specific solution (an open question for this thesis to research on could have been *"how to reinvent installation"*). A question the team is left with after this thesis is whether the *How might we questions* are a viable way to go when designing a smaller part of a system that has restrictions from both the environment and from other dependent products?

12.1.2.3 Develop

The *Develop* phases were probably the most fun phases of the project and the real value of rapid prototyping and testing was understood.

12.1.2.3.1 The value of rapid prototyping

Throughout the project many prototypes have been made to test if concepts work as thought. This has been key to this project since most prototypes aimed at exploring different mechanisms. These can be hard to understand and describe in sketches since many parts must come together in the correct manner. The focus throughout the project, apart from the final prototype, was always to keep the prototypes at the level of *Minimum viable product.* The team feels that a good amount of time was spent on each prototype and few parts took too long to construct. If however, too much time is spent on each prototype, the value of rapid prototyping drastically diminishes.

12.1.2.3.2 Matrix evaluations versus other evaluations

Early in the project the design team felt that more strict evaluation methods, usually used in a more linear process like the *Ulrich & Eppinger development method*, were not to be used in this project. It was felt that a more intuitive way is to build prototypes and test them on people rather than look at too developed CAD mock-ups and try to score them against a lot of construction constraints. These construction constraints can be implemented later and if the concept not would work with those constraints, the concept should be remade or reconsidered. This is only possible if the concepts not are too developed directly, instead working with a *Minimum Viable Product* and only testing some critical aspects at the time is key for time to not run away too fast.

12.1.2.4 Deliver

The *Deliver* phases has been the phases where the design team have been able to showcase skills in CAD and prototyping. It has been interesting to be able to use much 3D-printing together with processing material, bought in hardware stores, in the Axis workshop to prototype. It feels like the iterative converging phase have helped improving the concepts.

12.1.3 Iterative process

The decision to use an iterative process with at least two cycles seems like a good decision. It gave the design team a chance to go out and test a prototype and then go back to do new research. Which led to more concrete insights to find solutions for when back at the drawing board. The first cycle took, however, more time than the team had thought. Maybe too much time was spent on developing things that felt important at the time but then was scraped when tested. This is easy to say in hindsight, but looking back at the project plan and outcome, found in Appendix A, the first cycle could probably have been done faster.

During this thesis, many paths for solutions were pursued. While some ended up in the result some fell off along the way. Two examples of this are the *6.4.2 Snap washer* and a whole quest for deciding between different types of springs. The snap washer was developed since a satisfying product could not be found through extensive searches and discussions with employees at Axis or other sources. When the solution used in the end was stumbled upon, the team did not hesitate to change even though a lot of time had been invested. From an outside perspective, it might look like a lot of time was wasted, but at the time of their relevance, these ideas were thought to be essential to the solution. It, however, feels natural to end up exploring new ideas when developing a new product category like the truss mount is to Axis.

12.2 Final concept

Considering that the whole project was executed in a span of 20 weeks the decisions and solutions decided upon should be considered as a success. With more time, more areas might have been explored and other possible solutions might have been found. Some areas were delimitated during the project and since the goal was to aim for a proof of concept it is logical that further development will be needed, these areas can be found further down in the Section 13.1 Future work.

The final prototype has not been tested with the real users in Trelleborg yet, but considering that all insights found in *Define II* has been implemented it is likely that they would consider it another step in the right direction. At Axis however, many colleges and other stakeholders have unanimously expressed that the final concept and the installation process is a good solution. One of these being Michael Chen, responsible for Axis accessory product range, who voiced his enthusiasm for the solution and hinted at it being put into further development in the near future.

Comparing this product to its competitors is difficult since there are so many differences. But with the reduced number of components and a more user friendly installation process, while not sacrificing any flexibility or applicability with Axis products it can be concluded that it is superior to its competitors.

12.2.1 Fulfilment of functions

The final solution used the combination of the three functions *Secure for self-weight*, *Vary diameter* and *Tighten for load*, described in Section 4.5 Functions. And while the functions were not developed in isolation it is of importance to describe them separately.

12.2.1.1 Secure for self-weight

The action to secure for self-weight can be performed swiftly and is the most tested part of the product since the user tests mainly focused on this. The improvements made to the grip and guiding makes it easy to handle for all hand sizes. Even if the installation would need to be paused, between Figure 11.5 and Figure 11.7, the snap mechanism is strong enough to let it hang around the pole. It is liked by the users and could possibly in the future become the standard for how Axis mounts their products around poles in general.

12.2.1.2 Vary diameter

Using a bracket allows for great flexibility in diameters. It is also easy to optimize if the size range is known since it is a matter of how the bracket is shaped. As long as the sizes are narrower than the distance between the screws all diameters can be designed for. A limitation to discuss is however that when the size of the diameter increases, so does also the length of the snap screw. The length of the final screw presented is almost at the maximum length for an ergonomic power grip, lengthening it further could complicate the installation process.

12.2.1.3 Tighten for load

Using screws and nuts allows for great strength and can be combined with washers or double nuts to keep it tight even when vibration occurs. The solution with anti-loss screws also allows for power tools to be used, which was found desirable by users. The combination of the two also allows for controlled usage of torque. Using only two points of tightening could lead to problems with cross tightening as one side will pull the bracket before the other.

13 Conclusion

The conclusion, includes all the conclusions of this master thesis as well as recommendations for the future.

13.1 Future work

During the project Christensson, Rusz, Sjöberg, Chen and many other Axis employees have been positive to the project continuing being a project at Axis. Below can the design team's recommendations for future work be found.

13.1.1 Test strength

During this project, no real strength calculations have been made, however, the interface have often been compared to other similar mounts that have been described as oversized. The screws have also been thought to be oversized. This have been done to get a feeling of solidity and to make a product that will be trusted by both integrators and buyers. The bracket on the other hand might be the part that the design team do not know if it is strong enough. This since the jack in the bracket might create stress concentrations that could weaken the bracket. The design team recommends Axis to do FEM analyses as well as physical tests on a die casted prototype to know if any parts need reinforcements.

13.1.2 Cost estimation

As stated in the *Discover* phase, to have a competitive price on Axis accessories is important to get the buyers to buy the products, according to Chen. Even though cost has affected some of the decisions in the project, cost and price have not been the focus of this thesis and no real cost analysis has been made. This is something that Axis should do if this project continues at Axis.

13.1.3 Number of screws

The number of screws was in the second cycle of the process changed from six to two screws mostly because the users felt that two screws would be enough and because it improved the ease of installation. But also, since they preferred having nuts on the snap screws instead of having more screws. Since no aluminium prototype could be ordered tightening with only two screws and nut have not been fully tested. This is something Axis need to do if the project is further developed. Confirming that two screws feels enough should also be checked with more integrators.

13.1.4 Placement on truss

In theory, the web should only be exposed to pure tension or compression forces. The solution of preventing rotation by having the bracket jack lock on to the web will exert forces on the web from a different angle when the arm and the camera attached is exposed to wind. This would then in theory, not be a good idea. Many sources of information indicate that this is not a problem in practice, due to the fact that all trusses are dimensioned to withstand many times the normal forces it will be exposed to. It is not fully confirmed in this thesis and it is a recommendation to both simulate and perform real tests on the matter.

13.1.5 Springs

In the second cycle of the process the concept of using springs was suddenly phased out. This was done since the bracket jack could fixate the mount in the Z-direction. However, if integrators would want to install the mount in a position that would not allow the jack to be used, then the function *Secure for self-weight* have not been tested on a prototype with the right material and the right weight. It is recommended that Axis tests and confirm that this function works even when the jack is not used. If it would not work, then using spring might be something to consider again.

13.1.6 Friction areas

Friction areas and grooves in the bracket is another concept that was thought of as rotation preventative. Due to limited time, that concept was never tested. This could be something Axis could look further into.

13.1.7 Star lock washer holder

The final star lock washer holder is fully removable when the screws are not inserted and can be toggled between to modes when the screws are inserted. To not being able to fully remove the holder have been a wish from some users. This could be something Axis can look further into if the project is further developed.

13.1.8 Protect inserts from water

A comment that came from a co-worker late in the project was that the holes and inserts for the snapping screws not are protected from rain and water on the back of the interface. This might be something that needs to be looked into.

13.1.9 Extra plate

The extra plate was designed for the *Mobility* arm, however, the *Mini Connect* will too need the extra plate. The *Connect* hole pattern should be added to the plate. A cabling hole would be needed on the plate for the *Mobility* arm since the arm does not include one.

13.1.10Non-perpendicular trusses

The result of this thesis requires the truss to be straight and to have the same width throughout a section. In practical applications, trusses might be leaning due to poor installation and some manufacturers provide solutions with a width that becomes smaller along its length. It was delimitated during this thesis to not study this topic but it is recommended to solve this problem to guarantee that the solution works in every environment.

13.2 Scalability

13.2.1 Truss diameter

During the first cycle of the process, the mount was designed to work with a bigger span of truss pole diameters. The truss pole diameter was then further researched and the mount was optimised for a diameter span of 20-40 mm. However, in the *Testable prototype* the concept was proven to work with a pole diameter of 100 mm. Though after user test, grip research and truss research the concept was changed to work with the smaller span, there might be a possibility to scale the concept with modifications to match trusses with bigger diameters. This might be an interesting area for Axis to further investigate. When the diameter of a truss increases, the truss behaves more like a pole, leading to the next topic.

13.2.2 Pole mounts

Throughout the project co-workers at Axis have talked about their disdain for the metal straps of the current pole mounts. And when the design team tried to install the metal strap mounts the team had the same feelings. During the project one question have always been; can the installation process and the concept work with poles as well? Since the truss poles, that the truss mount aims to work with, almost work the same way as thin poles, the mount might work with these as well. It is only the bracket jack that cannot be used on the poles, but if rotation can be prevented for lighter cameras without the jack it can be interesting for Axis to investigate this further. If the mount could be scaled up to work with bigger truss poles the mount or concept could probably be scale up to work with bigger regular poles.

13.2.3 Horizontal trusses

This thesis has focused on mounting on vertical trusses, however, in some industries and markets mounting on horizontal trusses can be preferred. At the moment, this does not work with the truss mount. If Axis finds this important the hole pattern and the shape could maybe be rotated 90° to fit the arms and the truss in a horizontal position.

13.3 Final recommendation

Concluding, the design team recommends Axis to develop this concept further since it has a great potential of becoming the new way that Axis installs its mounts and has a great potential of giving Axis an advantage over competitors when it comes to giving integrators an easy installation. This thesis has also done a broad research in the new area of mounting on trusses and delivered a new concept that works well. However, more development is required to finalize the product and put it into production.

The design team also concludes that a *HCD* approach can very well be used to put more focus on understanding users, on rapid prototyping and on questioning the given problem in a mechanical design project like this one. It is however preferable if a good amount of users are available for all types of research and testing.

14 References

[1] LTH. Utbildningen. Retrieved May 30, 2017, from http://www.lth.se/utbildning/maskinteknik_td

[2] TopUniversities. QS World University Rankings. Retrieved May 30, 2017, from https://www.topuniversities.com/university-rankings/world-university-rankings/2016

[3] LTH. About LTH. Retrieved May 30, 2017, from http://www.lth.se/english/about-lth/

[4] Axis Communications AB. History. Retrieved May 30, 2017, from https://www.axis.com/gb/en/about-axis/history

[5] Axis Communications AB. About Axis. Retrieved May 30, 2017, from https://www.axis.com/gb/en/about-axis

[6] Axis Communications AB. Products and solutions. Retrieved May 30, 2017, from https://www.axis.com/gb/en/products-and-solutions

[7] Plesha, M., Gray, G., & Costanzo, F. (2013) *Engineering Mechanics: statics* (2nd ed.). New York: McGraw-Hill Companies Inc.

[8] Krenk, S. Høgsberg, J. (2013) *Statis and Mechanics of Structures*. Dordrecht, Netherlands: Spring Science+Busniess Media Dordrecht

[9] Norman, D. (2013) *The Design of Everyday Things Revised and Expanded Edition*. New York: Basic Books.

[10] Nessler, D. How to apply a design thinking, HCD, UX or any creative process from scratch. Retrieved February 6, 2017, from https://medium.com/digital-experience-design/how-to-apply-a-design-thinking-hcd-ux-or-any-creative-process-from-scratch-b8786efbf812

[11] IDEO.org. (2015) *The Field Guide to Human-Centered Design*. Canada.

[12] International Ergonomics Association. What is Ergonomics?. Retrieved May 3, 2017, from http://www.iea.cc/whats/index.html

[13] The Usability Body of Knowledge. Physical Ergonomics. Retrieved May 2, 2017, from http://www.usabilitybok.org/physical-ergonomics

[14] Norman, D. (2005) *Emotional Design: Why We Love (or Hate) Everyday Things*. New York: Basic Books.

[15] Brown, T. (2009) *Change By Design*. New York: HarperCollins Publishers.

[16] Robert Wood Johnson Foundation. Semi-structured Interviews. Retrieved February 10, 2017, from http://www.qualres.org/HomeSemi-3629.html

[17] Dalton, J. What Is Insight? The 5 Principles Of Insight Definition. Retrieved March 16, 2017, from https://thrivethinking.com/2016/03/28/what-is-insight-definition/

[18] Interaction Design Foundation. How might we… . Retrieved March 16, 2017, from https://public-media.interaction-design.org/pdf/How-Might-We.pdf

[19] Techopedia. Minimum viable product. Retrieved June 15, 2017, from: https://www.techopedia.com/definition/27809/minimum-viable-product-mvp

[20] Ricker, N. C. (1912) *A Treat on Design and Construction of Roofs*. New York: JWiley & Sons.

[21] Axis Communications. Product Lines and Product Naming. Retrieved March 8, 2017, from http://galaxis.axis.com/Handbooks/AxisDesignManual/Pages/productlines.aspx

[22] Axis Communications. Transportation. Retrieved March 2, 2017, from https://www.axis.com/se/sv/solutions-by-industry/transportation

[23] VideoSurveillance.com. Video Surveillance for Traffic. Retrieved March 2, 2017 from https://www.videosurveillance.com/traffic.asp

[24] Axis Communcations. What is Traffic?. Retrieved March 2, 2017, from http://galaxis.axis.com/IndustrySegments/Transportation/Traffic/SitePages/Visitors.aspx

[25] Backyard. (23 September, 2016) Climbing Sweden's HIGHEST tower (1100ft, Busted). Retrieved 3 March, 2017, from https://www.youtube.com/watch?v=JyCNllPy8A4

[26] Sveriges Radio. (16 May, 2016) Teracom: Livsfarligt att klättra I radiomasten. Retrieved 3 March, 2017, from http://sverigesradio.se/sida/artikel.aspx?programid=95&artikel=6432936

[27] VideoSurveillance.com. Convention Security. Retrieved March 3, 2017, from https://www.videosurveillance.com/events-conventions.asp

[28] NOVATTACH. Home page. Retrieved May 30, 2017, from http://www.novattach.com/wp/

[29] Newhouse, C. (2016). *Equipment mounting bracket for steel truss and method for electrical equipment.* Patent U.S. 9,518,699.

[30] SMHI. Skalor för vindhastighet. Retrieved May 24, 2017, from https://www.smhi.se/kunskapsbanken/meteorologi/skalor-for-vindhastighet-1.252

[31] Axis Communications. Insects. Retrieved May 24, 2017, from http://galaxis.axis.com/Handbooks/AxisDesignManual/Pages/insects.aspx

[32] Axis Communications. Vibration & Shock. Retrieved march 8, 2017, from http://galaxis.axis.com/Handbooks/AxisDesignManual/Pages/schock.aspx

[33] Creative Mechanisms. Engineering Mechanisms: Ratchets. Retrieved May 24, 2017, from https://www.creativemechanisms.com/ratchets

[34] Wikipedia. Turnbuckle. Retrieved May 24, 2017, from https://en.wikipedia.org/wiki/Turnbuckle

[35] DYNACAST. Die Casting. Retrieved April 19, 2017, from https://www.dynacast.com/die-casting

[36] ADVANTAGE Fabricated Metals. Punching. Retrieved, April 19, 2017, from http://www.advantagefabricatedmetals.com/punching-process.html

[37] National Institute for Occupational Safety and Health. (2004). *Easy Ergonomics: A Guide to selecting Non-Powered Hand Tools*. Retrieved, April 24, 2017, from https://www.cdc.gov/niosh/docs/2004-164/pdfs/2004-164.pdf

[38] Moore, S. M. Torma-Krajewski, J Steiner, L. J. (2011) *Practical Demonstrations of Ergonomic Principles*. (Report No. 9684). Pittsburgh: National Institute for Occupational Safety and Health. Retrieved April 24, 2017, from https://www.cdc.gov/niosh/mining/UserFiles/works/pdfs/2011-191.pdf

[39] Axis Communications. ID Direction. Retrieved May 19, 2017, from http://galaxis.axis.com/Handbooks/AxisDesignManual/Pages/direction.aspx

[40] Axis Communications. Product design – Key Values. Retrieved May 19, 2017, from http://galaxis.axis.com/Handbooks/AxisDesignManual/Pages/keyvalues.aspx

[41] Axis Communications. Surface Treatment. Retrieved May 19, 2017 from http://galaxis.axis.com/Handbooks/AxisDesignManual/Pages/surfacetreatment.aspx

[42] A More Beautiful Question. Beginning great questions with "How Might We". Retrieved March 16, 2017, from http://amorebeautifulquestion.com/beginning-great-questions-how-might/

Appendix A Time plan

In this appendix, the original as well as the final time plan will be presented.

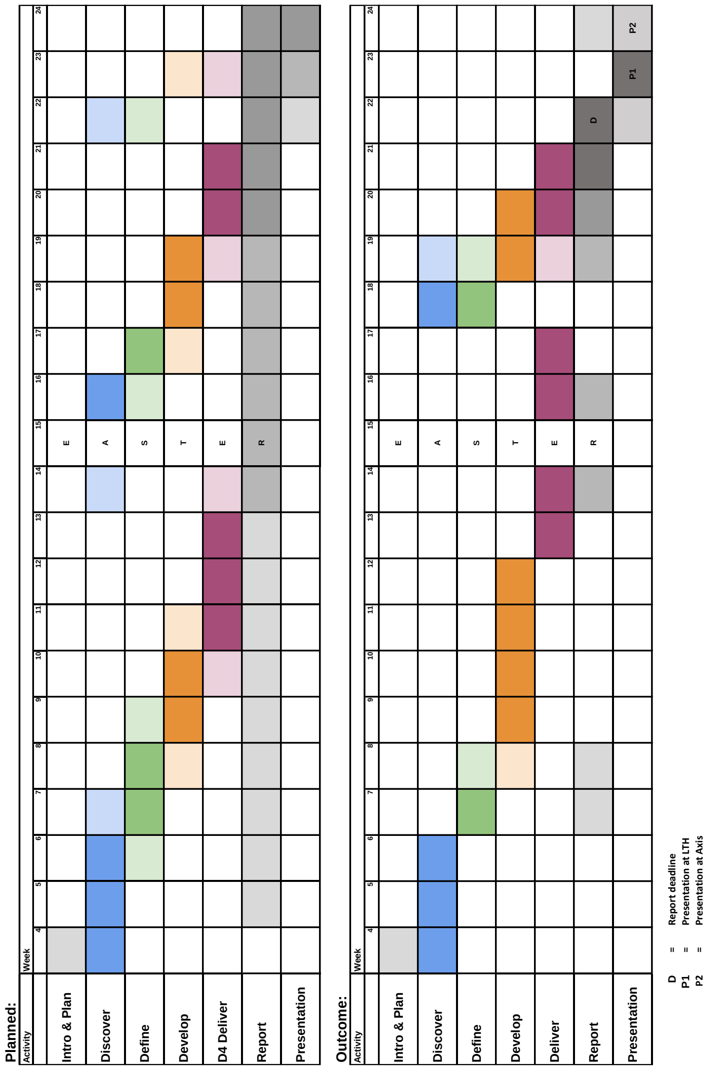

Figure A.1 Time plans for the project

Appendix B Function boards

In this appendix, the function boards used in the Develop I phase will be laid out.

The function boards include things that can be related to the functions described in 4.5. Figure B.1 includes things that can be adjusted relating to the functions *Vary width* and *Vary diameter* and Figure B.2 includes things that can be tightened relating to the function *Tighten width* and *Tighten for load.*

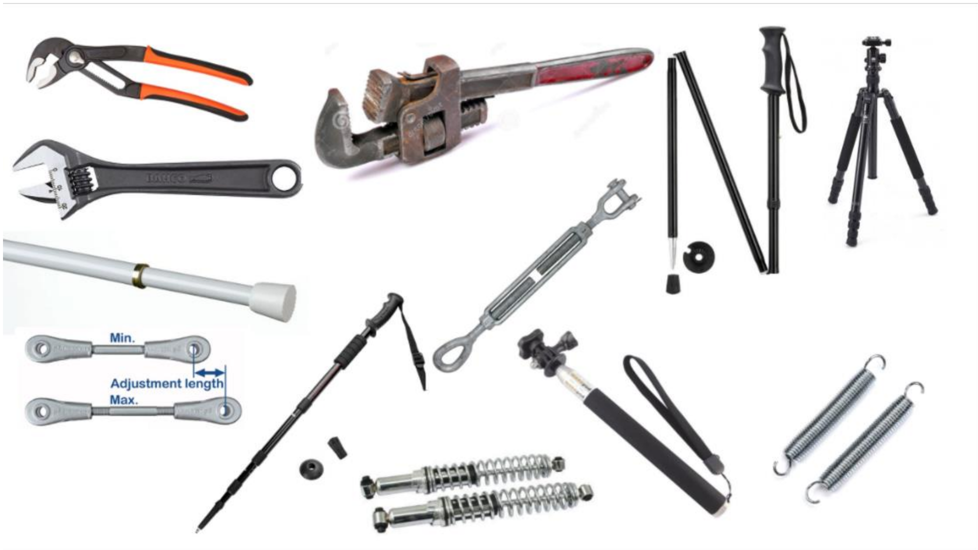

Figure B.1 Function board with things that can be adjusted.

Figure B.1 Function board with things that can be tightened.

Appendix C Wind data

Wind data from the Port of Trelleborg will be provided here.

The wind data from the port of Trelleborg was provided in the form of Excel spreadsheets. Each control point in the sheet gave data for the wind the last four hours and gave an average wind speed and the maximum wind speed for that point.

Figure C.1 shows a summarized version of the data. The full data can be made available upon request.

WINDDATA PORT OF TRELLEBORG, ALL SPEEDS ARE IN M/S		
MONTH	MAX AVERAGE WIND	MAX WIND
JUNE	10,8	18
JULY	7	9
AUGUST	13,9	17,3
SEPTEMBER	14,1	19,6
OCTOBER	13,8	17,1
NOVEMBER	14,1	18,1
DECEMBER	19,7	25,6
AVERAGE	13,34285714	17,81428571

Figure C.1 Table of wind speeds.

Appendix D – Development of snap washer

The development of the snap washer is further explained.

The chosen concept in *Develop I* was *Detail concept C: Cable Tie,* found in Section 5.4.3 Detail concept C: Cable tie. Its snap mechanism consisted of four cut cable ties placed around a hole. Before the star lock washer was found a lot of development was put into making a 3D-printed *Snap washer* work.

D.1 Without pitch – Profile I

The pawl on a cable tie was analysed, mimicked in CAD and then 3D-printed and tested on the screws in many iterations. In the first version, the pitch of the screw was not accounted for. One version was designed for the M5 screw, seen in Figure A.1, and one for the M8 screw seen in Figure A.2. The M8 version performed the best, primarily because the threads are bigger, which makes it easier for the pawls to get a grip of the threads. The M5 version did not get a grip on the threads. The edge of the profile was getting abraded. The tip of the profile needs to be thicker.

Since there is no pitch on the two versions it is noticed that the load is distributed uneven. This makes it possible to dislocate the *Snap washer*.

Figure A.1 The M5 *Snap washer* with the first profile, without pitch.

Figure A.2 The M8 *Snap washer* with the first profile, without pitch.

D.2 Without pitch – Profile II

In the second version, the shape of the screw was analysed more closely and a new profile was developed for the M5 that better matched the shape of the screw. The new profile had a thicker tip however pitch was not accounted for in this version either. This version worked, however, not perfectly; some material was still getting abraded. The uneven load is not noticed as much as in the former version.

The new profile should be able to be scaled to bigger screws.

D.3 With pitch – Profile II

In the third version, the pitch of the M5 screw is applied to the pawls, seen in Figure A.3. This version works very well. It was resisting pull back very good and was quite stable. It also has a nice snapping sound that gives feedback and it screws off easily.

Figure A.3 The M5 *Snap washer* with the second profile, without pitch.

D.4 With pitch – Profile II – Double

In the fourth version, another circle of pawls is placed above the former circle of pawls, seen in Figure A.4 and Figure A.5. The thickness of the design is increased a bit to make room for the new circle. This version performs better on all accounts. However, when tested with different types of push springs placed on screws the *Snap washer* could not hold the force and broke.

Figure A.4 The M5 double *Snap washer* with the second profile, with pitch.

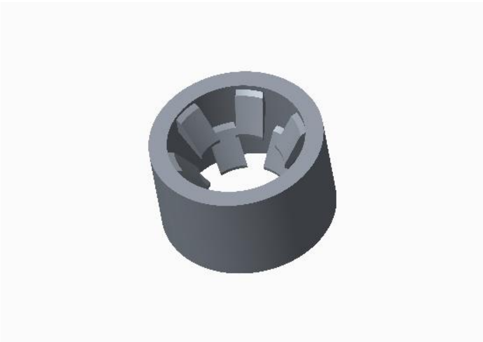

Figure A.5 The M8 double *Snap washer* with the second profile, with pitch.

14.1 With pitch – Profile III - Double

In the fifth version, the shape is scaled up to fit a M8 screw, this since these are the screws thought of to be used. The design of the shape is again optimized to fit the screw. However, the 3D prints did not work as well as the former versions did.