IN SEARCH FOR THE NEW ICONIC MEDIUM FORMAT CAMERA

MASTER THESIS, INTEGRATED PRODUCT DESIGN
INDUSTRIAL DESIGN ENGINEERING

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Reading guide

Blue pages summarise each chapter of the report. Grey boxes on the side of the page provide additional information for more context.

Due to the use of sensitive business intelligence there has been a division made in the appendices, of which one is held confidential and only available to the Graduate Student, Supervisory Team and Company Client of this project. These appendices have the prefix C-.

"Once, even the simple metal needle challenged the conventional thinking of a time."

- Jonathan Ivy

PREFACE

I've always been attracted to craftsmanship and cutting edge technology, especially a combination of the two. Just look at how a Bowers & Wilkins 800 Diamond series speaker is made! But in abstract, the preference for this combination turns out to be a part of my character. Somehow, and this is still a personal introspection, I always find myself looking for a perfect marriage between this uncommon pairing of descriptors. To me, a taste for craftsmanship really took off when I started my own company as a professional photographer almost 8 years ago. Quite many of my clients are companies with a rich history, storytelling products, or brought me to places of craft and passion.

In the final chapter of my Master's, I wanted to find a project in which I could combine my experience in photography and industrial design. From a practical point of view I preferred a company based in Europe, since I wanted to keep visiting my family. After drafting a list of camera manufacturers based in Europe, I found out that Phase One is based in Denmark. To me as a photographer, Phase One is the Lamborghini that you are never get to drive. But that was never going to stop me from applying for a graduation project.

This however required a careful strategy. I knew the general mail address of such a company was never going to forward me to the right person at R&D. So I started searching for ambassadors, professional photographers, who were either promoted with or by Phase One. Photographers need to be accessible, otherwise their business will likely not survive. I contacted around 20 photographers and only one replied with useful information about an inside man at Phase One. Unfortunately, the man didn't work there anymore and an automated reply forwarded me to a second man. This man did work there but kindly let me know that they did not have the capacity to run another project this year.

Although this was bad news, luckily I was in possession of two email addresses so I was able to figure out how company user accounts are structured. This time I went searching on LinkedIn and looked for people at R&D and subsequently I found Morten. A friendly face and a name easily decipherable into an email address. Sending him a mail was a gamble, but after a few days I got an excited mail back from Morten. A few emails later, a conference call and a visit to Copenhagen gave me the opportunity to work on a design proposal that would be suitable for a graduation project.

While I am writing this section I realise how this project became more than another design project. It evolved into more of a personal reflection from start to finish with its ups and downs. I feel proud to have found my own personal niche. Becoming a father during this project certainly changed my perspective on how design can contribute to our life. And as you might predict when you read on in the report, the result from this project was not singular.

SPECIAL THANKS TO

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EXECUTIVE SUMMARY

The original design brief from Phase One was to design a modular medium format camera, based on a mirrorless system. The current XF camera system, based on a conventional optical system, reflects other (full frame) medium format cameras perceived as big and bulky. A mirrorless system can be smaller and lighter, albeit with its own challenges. Maintaining the modularity and system interaction of the whole system were the two key parameters. Apart from the technological challenges, there are also substantial threats from substitute products, that all together change the definition of photography.

The literature review raised concerns on the design brief of the project, thereby minorly shifted the project focus. Not only by the lack of literature sources on camera design, it was also found that the commercial success of a camera is not dependant on the ergonomics. It is more focused on desirable aesthetics, a balanced size-weight ratio, and the technical specifications the system holds. Medium format cameras are renowned for their outstanding image quality. History research showed that several medium format cameras were the groundbreakers for new or better forms of photography. The new abilities enabled the photographer to create historic achievements. The photographic results are marked as icons, which in turn caused the camera to become an icon as well. The meaning of a medium format camera is that of pioneering technology. At this point a different project approach was introduced. Instead of maintaining the principle of a technology push, innovating on the meaning of the product appeared to be more valuable.

A Design-Driven Innovation approach helped structuring the first stage, where one 'listens' to interpreters relevant to the project. In the second stage all the input is assessed, rearranged and interpreted to form a new product proposal. This product proposal went beyond the concept of one camera, to a product family of three specialised cameras. Each addresses specific needs within the application catalog of the World's Most Demanding Photographer (WMDP), a target group defined by Phase One. The focus was made on the conceptualisation of a handheld camera named Momentum, thereby retaining the key parameters of the design brief. This camera addresses the need to capture moments in a dynamic environment. In order to do so, the photographer anticipates on potential moments by getting himself in unique places to get the desired photo. Usually the job assignments demand long handheld working operation, relative to other types of applications, and therefore comfort and proper working principle of the grip had to be taken into account for the design.

Rapid prototyping technique was used to build models in order to validate the concepts. Apart from the aesthetics, with 3D printing it was possible to mimic the estimated weight and balance. To find base for acceptance, five inhouse photographers of Phase One were interviewed after they assessed the concepts. Together with the interview, a comfort questionnaire for hand tools was used to quantify their scores for the concepts.

In two meetings with Product Management and Research & Development, general feedback was acquired on the design and possible future steps. Two out of three concepts were described as desirable and comfortable to hold. Together with the layout of components this provides proof of concept that the camera can be smaller and lighter, without sacrificing image quality or comfort. However the opinions were divided on the different actuators and proposed technology implementation of Machine Learning, indicating a reservation towards more radical innovations.

In order to form a decisive argument for the final concept, an extra interview session was conducted with a professional photographer who is not affiliated with Phase One. In this session, the comfort questionnaire was used as well as EMG as an objective measurement of the muscle activity. In this session concept 2 performed best in terms of comfort scores, aesthetics, and having the lowest muscle activity. In the interview it was mentioned the overall design philosophy of all concepts was well accepted. Although one man's opinion does not provide a basis for acceptance, it creates more cognizance with the company's employees.

With a paradigm shift towards computational photography, the camera as a tool should be much more than a physical object with buttons in order to be meaningful. Medium format cameras used to be the pioneers in technological breakthroughs, but today's culture seems reserved in this segment towards radical innovations. A long term strategic advantage depends on whether any medium format camera company is willing to invest in a new mindset in product development.

GLOSSARY OF TERMS AND ABBREVIATIONS

EVF	Electronic viewfinder, a piece of equipment where the photographer can live view the image the sensor is getting.
LS	Leaf shutter, a type of shutter that is located inside the lens. Metal blades move over each other to block light, triggered by a spring-loaded mechanism.
Modular system	Instead of having all camera components in one housing (like a point-and-shoot), the system is separated in several components that are designed to mix and match for specific uses.
MP	Megapixel, an expression for the resolution of the sensor. The higher amount of Megapixels, the more detail a sensor can capture.
Optical axis	The path of light that enters a chain of elements; from a series of optical lens elements, shutter mechanism to the sensor.
(D)SLR	A single-lens reflex contains a spring-loaded flipping mirror in front of the sensor that directs the light path through a pentaprism to an eyepiece. The D as a prefix refers to Digital, as a SLR can be used in an analogue and digital camera system.
RAW	In full, raw image format. It contains minimally processed data from the image sensor. It is often called the digital negative.

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INTRODUCTION

Since the discovery of photography, it has served mankind in sharing memories, creating awareness as a way for (self) expression. It is broadly exercised by a group ranging from small time hobbyists to highly specialised niche professionals. Photography is an ever growing market which is predicted to grow until at least 2021 (Zion Market Research, 2016). While many photographers think that the market is saturated. Digital photography has become very accessible. Among professionals there are many levels of expertise and specialisations. For clients, the level of detail and quality comes in various price ranges. At the very top of this profession, photographers work with high-grade equipment and are usually accompied with a production team.

Medium format refers to the size of the sensor. It is larger than the more commonly used 35mm (small format) sensor from camera brands like Canon and Nikon. Due to the optical axis, all elements within the camera system depend on the size of the sensor. This makes the entire system with a medium format sensor bigger, more heavy and more difficult to manufacture due to the tolerances. Medium format cameras are less convenient to work handheld with due to their size and weight.

The latest production iteration of a digital sensor is the CMOS sensor, Complementary Metal Oxide Semiconductor. It makes it possible to capture an image without the need of an additional autofocus system or mechanical shutter. Although it still has its early limitations, the potential features it offers makes it interesting to discover new camera systems.

One of the brands that deliver these high-grade cameras is Phase One. They are one of the few brands that design and manufacture digital medium format modular camera systems, both for professional and industrial applications. Other brands in the medium format segment today are Hasselblad, Leica, Pentax and since recently Fujifilm.

Phase One is exploring the possibilities of a modular mirrorless camera system. Theoretically, it can be smaller and lighter without sacrificing image quality. While there are already brands that have launched mirrorless versions of their cameras in the market, the responses are mixed. (Rose, 2017) Besides, from the hurdles of a new technlogy, a preliminary thought is that, from an interaction point-of-view, the current electronic mirrorless systems are insufficient for the full potential of an electronic system.

Designing a mirrorless camera for a brand like Phase One, has two strategic challenges. The medium format segment leans on a rich heritage, the photographers are in general traditionally minded. Yet there's a demand for the best tool on the market while the medium format is slowly losing its competitive advantage over the small format cameras (Canon Technology, 2017) and possibly even a changing definition of digital photography (Mayes, 2015).

Considering the electronic mirrorless system as a technology push, merely a mirrorless version of their current camera would presumably not suffice. A technology push usually does not involve market research. Due to a competitive, yet traditional minded user, a Design-Driven Innovation (Verganti, 2014) approach is used to explore the meaning of the product, and innovate on it to acquire long-term advantage. Radical innovations are not on a technological level but on sociological level as well. (Figure 1)

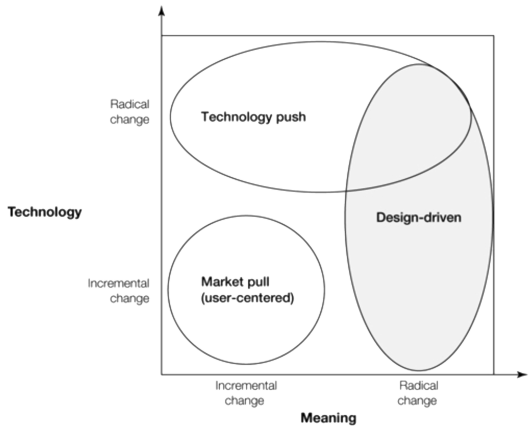


Figure 1. Design-driven innovation.

LITERATURE REVIEW

The initial goal for this project was to design a mirrorless camera where the principle of modularity and balance of the system are key parameters. (Appendix A) In order to lay out a theoretical framework, a literature review was conducted to find articles with a focus on camera ergonomic design, camera body development, and optimal grip size.

This resulted in very few results but prior to the announcement of a new camera, often a series of patents surface on the web. During the search, several patents were found on sensor technologies from Nikon on curved CMOS sensors (U.S. Patent No. P2017-125904A), high resolution 120 Megapixel (MP) small format sensor from Canon (Canon, 2017), a curved medium format sensor in a specific configuration from Sony (U.S. Patent No. 2017-102189) and an organic sensor from Toshiba (U.S. Patent No. 2016-63084). However patents are not fully indicative for a commerical release, however they provide an overall sense of the research & development focus.

In terms of development, due to confidentiality, actual behind-the-scenes of the camera design process could not be found on the web of any camera brand. In some cases, some brands do offer a tour to their manufacturing plant like Canon (Brawley, 2017), Leica (Seymour, 2017), and recently also Hasselblad (Demolder, 2018). This gives a sense of how cameras are assembled and how they are structured. But this does not provide insight on the rationale, merely a showcase on a technological level.

During the parallel assessment of the current Phase One camera, the XF, some basic insights were found on how the biomechanics of the upper limbs work during use of the camera. Due to the weight of the camera, as with other cameras in the same segment, some positions were extremely uncomfortable.

This led to expand the search area towards hand measurements, biomechanical model of the hand, (3D) anthropometric databases, power grip, grip force relation to size, comfort camera design and grip force related to muscle fatigue. Related to cameras, there were no direct literature sources on the internet. Unlike with the automotive industry, where there are hundreds of ergonomic studies, in the photography industry they seem to be either secretive or neglected.

In order to conduct an ergonomic study on the biomechanical system and its corresponding forces, dimensions of the right hand were needed to calculate the magnitude of the forces for several groups of users (ranging from Western to Asian, male or female). Therefore online anthropometric databases were consulted to find the appropriate dimensions (Dined, 2017) (WEAR, 2017) (US Military technical report, 1991) (University of Nottingham, 2000) (Penstate Openlab, 2017). Although basic dimensions were easily accessible such as hand length, but for cameras there's a dimension that was not available (or accurate). The user can't close his hand when holding a camera, which means the thumb plays a crucial role in counteracting on the torsion generated by the camera's center of gravity relative to the grip position. There was no data found relating to this use case.

As in regards to the business context of digital photography, medium format cameras are being critised whether it still has a place in the market from a practical point-of-view (Sanyal, 2017). Together with an interpolating industry where with a shift towards computational photography is happening, there's no such thing anymore as a 'straight photograph' (Mayes, 2015).

PROJECT STRUCTURE

The Design-Driven Innovation process consists of three stages.

Stage 1. Listening
Understanding the surrounding context for this project, by studying the medium format market. Investigating the roles of various stakeholders and other driving forces within this environment. These stakeholders are also called 'intrepreters'. (Figure 2) However in the line of this graduation project, instead of the firm playing a central role, the activity shifts towards the graduate student, the designer, as the initiator and listener.

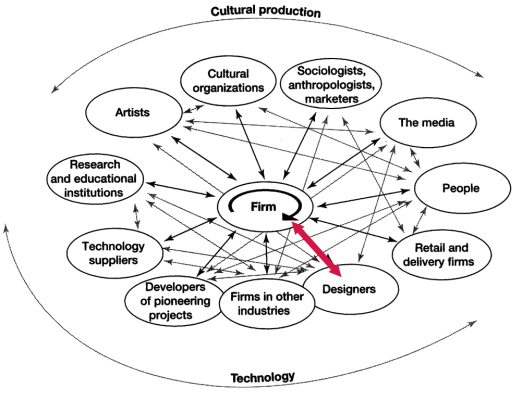


Figure 2. Intrepreters in a collective research laboratory.

Stage 2. Intrepreting
Assessing the knowledge, recombining and integrating the knowledge of the market with relation the switch to a mirrorless system. This concludes with the development of an unique proposal for a product family.

Additionally for this project:
Validation of concepts and prototyping the camera.

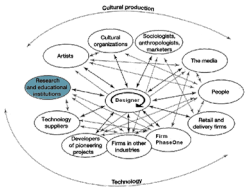
Stage 3. Addressing
Laying the groundwork for radical innovation of the interpreted meaning of the medium format market. Developing a new vision for the firm.

Note: in the final stage the firm is most responsible for executing tasks since it involves interacting with intrepreters and leverage their seductive power. All the interpreters change the life context through technologies they develop and the artwork they create. In that way it makes the proposal more meaningful and attractive when people see it.

STAGE 1. LISTENING

MEDIUM FORMAT CAMERAS

This chapter provides an overview of the current state in professional medium format photography and how various stakeholders play a role in digital professional photography.



WORKING PRINCIPLE OF THE CAMERA

In any form of camera, the device consists of a light sensitive element. This can either be a film negative or the digital sensor. In order to capture a visual image, light has be redirected by a series of optical elements also known as a lens. The optical elements focus the light beams by refraction and can often be moved inside the lens housing, allowing for control of image perspective and focus.

The word photography derives from the greek words 'photos' (light) and 'graphé (drawing). In the early history when people discovered that light could be captured, this changed the people's mind in capturing moments, tell stories and store memories in an image.

An image's appearance is directly dependent on, and proportional to, the exposure of the light-sensitive element over time. The timing of the exposure is controlled by the shutter mechanism. There are various ways to do this, but in all cases its purpose is to shield the light sensitive element from ambient light and to expose it in a timed manner, triggered by the user. Time duration is also known as the shutter speed. In order not to lose image quality this array starting from the optical elements, shutter mechanism towards the light sensitive element need to be placed in line.

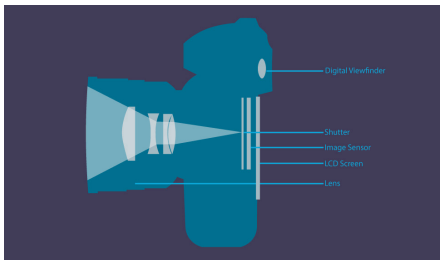


Figure 3. Basic working principle of a mirrorless camera.

BRIEF HISTORY OF THE CAMERA.

In this timeline (Figure 4) there are cameras with significant innovations displayed that changed the way photographers take photos, creating a paradigm shift. The timeline illustrates the first commercial camera till present time, however it is limited to the camera developments that solely steered the professional photography market. In their own respect they acquired an iconic status from the resonance they have created.

The innovations that empowered the photographers' achievements, capturing memorable moments, ultimately defined the iconic status of the camera. The most recent camera development is the digital mirrorless camera system, it benefits from the modularity with interchangeable lenses and the compactness of a point-and-shoot. However the real resonance has to come with time.

Note that prior to The Kodak camera other discoveries and developments have been made where photos were taken by different processes, thereby The Kodak camera is not the first acclaimed camera.

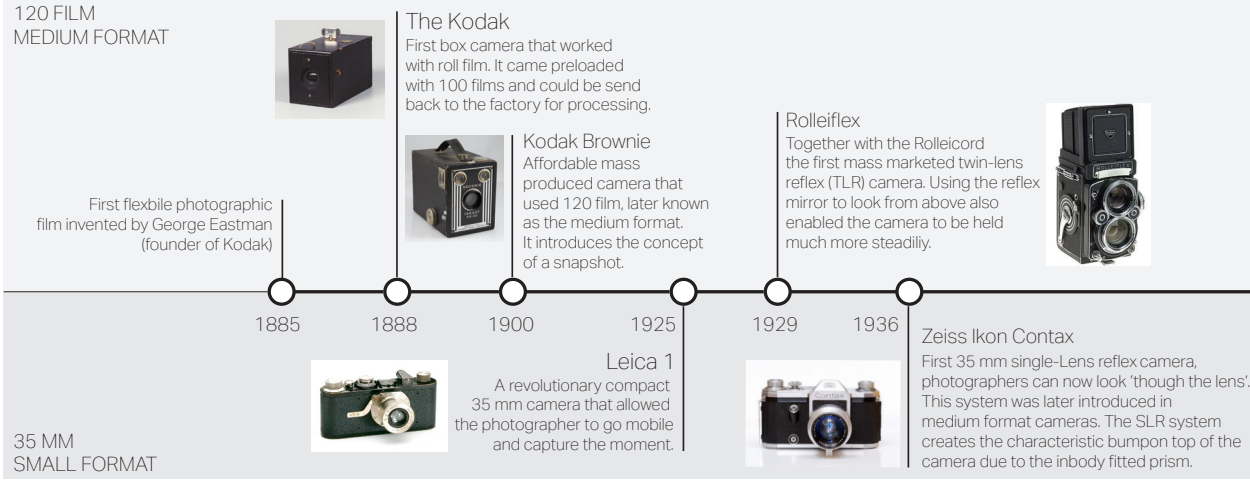


Figure 4. Timeline of relevant camera innovations that revolutionised photography.

THE DEFINITION OF MEDIUM FORMAT

There are various types of cameras and its name usually refers to the form factor or the working principle of the camera. A different way of categorising cameras is based on the size of the light sensitive element, there have been three sizes established: small format, medium format and large format. Within those three categories there are multiple sub-sizes; but the major distinction between those sizes is made by the prefix 'full frame' or 'cropped'. Small format, also known as 35mm, is the most common format for both analogue and digital photography. (Figure 5)

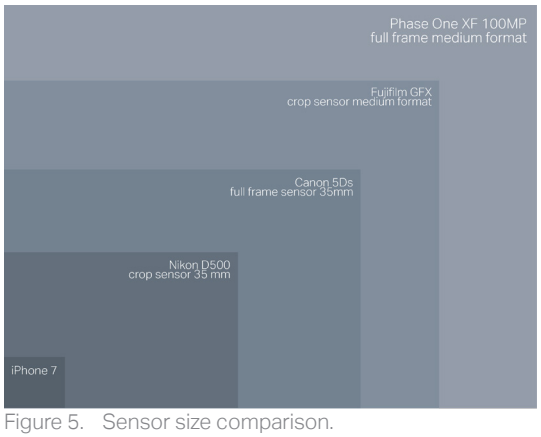


Figure 5. Sensor size comparison.

Medium format cameras are mainly being used by high-end professionals and a few amateur enthusiastics. In the era of analogue photography, these medium format camera's were modular.

One of the prominent features of the modularity is the interchangeable film magazine. This made it possible to switch relatively easy between different films for specific purposes (such as colour and black/white). In general it was possible to interchange other parts as well such as grips, viewfinders, lenses, focus screens, and motor winders. (Figure 6) It differed per brand on the variety of interchangeability. Most common brands are Hasselblad, Mamiya, Contax and Pentax.

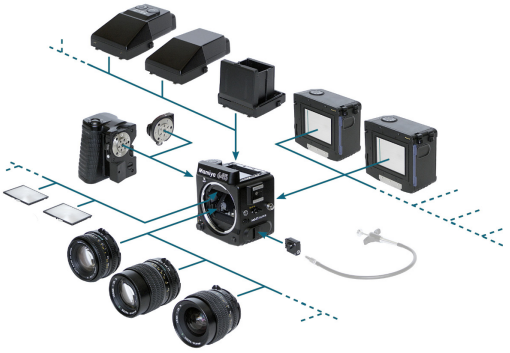


Figure 6. example: Mamiya 645's modularity

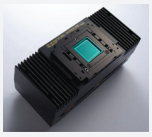
The size of the light sensitive element has a impact on the whole system. The bigger the size, the bigger every element needs to be for it to cover the full sensor. A single-lens reflex system works with a mirror. This mirror is mounted in a spring loaded mechanism which makes way for light rays to enter the sensor if a photo is taken. A bigger mirror is heavier, thus requires a more powerful and rigid mechanism in order to maintain an acceptable shutter latency and precision.

Hasselblad 500 EL Data Camera
The camera that went to the moon. Due to the uncompromising quality at the time, this was camera was chosen and altered to operate in outer space. Its design was adopted from the standard 500 EL/M model.

1959

1962

Nikon F
The first professional 35 mm camera with its range of interchangeable lenses, that overtook the 120 film in popularity.



1991

Leaf DCB1 'the Brick'
First medium format digital back with 4 Megapixels

1999

Nikon D1
The first professional digital SLR that displaced Kodak reign over the professional market.

2002

Hasselblad H1D
The first digital medium format camera system that is designed for digital purposes.

2013

Sony A7
The first mirrorless system camera that was equiped with a full frame 35 mm sensor targeting professional photographers. To this day the alpha series is still succesfull.

2016

Hasselblad X1D
The first medium format mirrorless camera that integrates the sensor, user interface and housing with interchangeable lenses.

WHY MEDIUM FORMAT?

A medium format camera does not necessarily need to be modular. In the time of writing this report, both Hasselblad and Fujifilm launched 'integrated' mirrorless medium format cameras with interchangeable lenses. Both cameras have a cropped medium format sensor.

When it comes to image quality, a bigger sensor is automatically considered to have better quality. It delivers better tonal and detail quality. This is the reason why it's mostly used by professionals. The modularity of medium format also has a favoured feature. This enables the photographer to configure the same camera for more versatility. In turn this also reduces costs because they can do more with the same camera platform.

But in medium format it's not always solely about the quality performance of the sensor. The increased size of the sensor also causes to has a more profound optical effect than small format, and this effect is depth-of-field. It refers to the distance of the nearest and the furthest objects within a focused image. For most viewers this depth creates a more lively experience with the photo and attracts the attention to the subject. (Figure 7)

Therefore the quality of the depth-of-field effect often plays a role in the photographer's mind for the photo. This effect is created by the aperture of the lens, the focal length of the lens and the size of the sensor.

Small format is known as 35 mm analogue film. When digital photography arrived, the size of the sensor was set to the physical size of the 35mm negative, and is confusingly called full frame. Full frame refers to covering the entire area of a negative, yet full frame does not refer to the actual size. Full frame can be used for small, medium and large format cameras. If the sensor does not have the full size of a negative, it is called crop factor or cropped.

Although it's a conscious choice of the photographer to work with a certain aperture and focal length, the size of sensor is a stable factor in this equation. The depth-of-field effect of a medium format camera is considered as more refined.

Figure 7. Shallow depth-of-field effect.

THE PERCEPTION OF MEDIUM FORMAT CAMERA'S

Medium format cameras are generally perceived as fairly large and bulky, especially by female photographers. This is understandable because of the larger size, and subsequent increase in weight, of every element compared to those of a small format camera.

Yet if one would compare various professional cameras, its primal form remains the same and there does not seem to be an alternative to address the size or ease of handling for these cameras. An analysis of various camera primal design, described as the archetype, would presumably deliver interesting leads.

ARCHETYPE ANALYSIS

To develop a fundamental understanding of how cameras are being used, it starts with analysing the origin of the shape. The archetype does not say anything about the commercial success of the camera, merely how it is being held and operated.

In the field of photography, the archetype of a camera has changed only a few times. That is mostly caused by technological innovations. In the time of analogue photography, the film camera's volume was mostly defined by the type of film roll. Since the arrival of a digital sensor, the archetype has remained quite the same. Although there is a large variety in cameras, the origin of all of those bodies has the same build-up.

WHAT IS AN ARCHETYPE?

The word archetype derives from the Latin noun archetypum (Wikipedia, 2017), latinisation of the Greek noun (archetupon), whose adjective form is archetupos, which means "first-molded", which is a compound of archē, "beginning, origin", and tupos, which can mean amongst other things, "pattern," "model," or "type."

THE DIFFERENT ARCHETYPES

By observing the design of the cameras throughout history, especially before 2000, their primal form is defined by function. This explains why the first mass-produced camera is a box because this dates back to the first optical principle 'camera obscura'. (Hammond, 1981) (Figure 8)

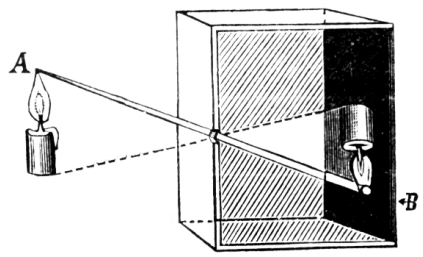


Figure 8. Camera Obscura [source: Wikipedia]

What is noticeable is that the grip on the side of the camera only appeared around the 1980s when autofocus was implemented and space was needed for a film roll, autofocus metering system, motor drive for the lens, and batteries.
Every archetype has its own specific handling and, to a certain extent, the photographer can stabilize its movement and position. Over time, there have been only two distinctive archetypes:

- Box camera
- Side handhold

An analysis explaining the process of the sub-type creation within these archetypes can be found in Appendix C.

The evolution of the camera archetype is driven by its innovations that are functional in terms of capturing an image. User ergonomics or usability only became a part of the design around the turn of the 21st. Even then, the primal form remained the same.

Only the cameras that went (or still are) in production were analyzed and categorized in one of the archetypes. There are outliers, but most of the times they are either prototypes, advanced concepts or miserably failed products.

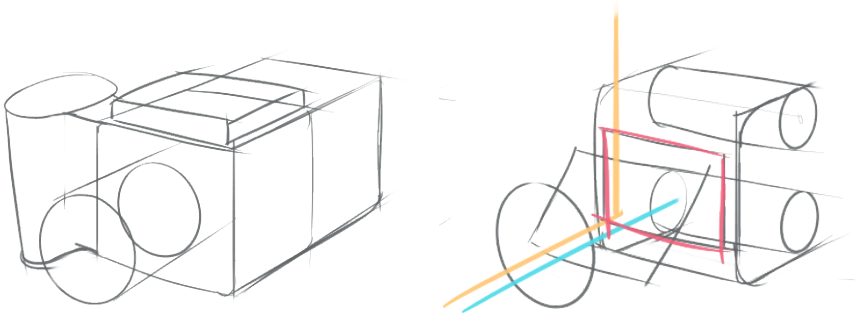


Figure 9. Origin of the body archetype of a medium format camera. The film spool holder with the mirror mechanism explains the boxy enclosure.

Although the side handhold is a logical design choice from a spatial point of view, (Figure 9) it also has an effect on the use. The most important observation is the grip forces a fixation of the hand position and angle on the grip. This observation started with the XF camera, but this can be related to some extend to other camera's with the same archetype.

The reason for the fixated hand position and angle though can be explained. The index finger and thumb are the most precise of a human hand, (Freivalds, 2004) The rest of the fingers and palm are used as a clamp. The index finger and thumb are therefore free from force loads and are used for the button actuation. (Figure 10)

The evolution of the camera started at the first box camera in 1888. Today a digital mirrorless camera could also be considered as a box camera, it merely acts as a spacer between lens and sensor. That is since there are no volume defining elements anymore, other than the sensor and optics.

However due to the electronic system, thus removal of the mirror mechanism, the viewfinder is physically detached from the optical link to the sensor, thereby the viewfinder can virtually be placed anywhere. (Figure 11) It would also be possible to have multiple viewfinders simultaneously or a wireless viewfinder.

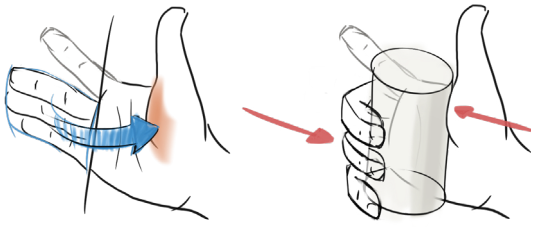


Figure 10. Lower three fingers are pulled towards the thenar muscles.

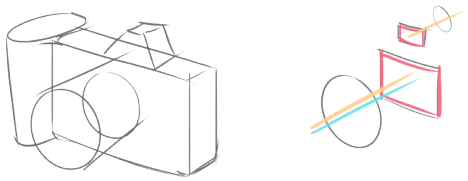


Figure 11. The viewfinder is physically detached from the optical link from lens to sensor. It only consist of a data transfer connection.

The design choices that led to this archetype can be related back to past innovations (such as film spool holder and later a rechargeable battery). Certain limiting aspects such as battery size-to-capacity have defined the raison-d'etre of the current existence of the archetype.

CHAPTER SUMMARY & CONCLUSIONS

A camera works on the principle of exposing a light sensitive element through a bundled light beam in timed matter. This array of elements (from the optical elements, shutter mechanism towards the sensor) need to be placed in line to avoid quality loss.

Medium format cameras are primarily used by high-end professionals. Digital medium format camera's are perceived as high-end equipment and is more commonly used by accomplished professionals.

The modular system for the medium format has a strong heritage. It served the transition into the digital age. While it's not a technical necessity anymore, it is still used to update only specific elements instead of the entire system.

Medium format cameras are considered as fairly large and bulky.

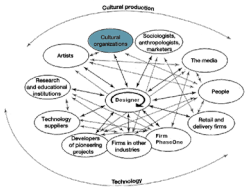
The primal form, described as the archetype, appears to be the same among various professional camera's. It is merely a box with side handhold.

The evolution of the camera started at the first box camera in 1888. Today a digital mirrorless camera could also be considered as a box since there are no volume defining elements anymore, other than the sensor and and lens optics.

With an electronic system, the viewfinder is physically detached from the optical link to the sensor and thereby there are less restrains for the viewfinder. It can virtually be placed anywhere.

UNDERSTANDING THE MEDIUM FORMAT MARKET

The act of photography comes from a traditional profession and/or art. Although there is a business for photography, it's also a personal occupation. The creativity and storytelling is done by the photographer, not the camera nor the business. This creates a wide diversity in personalities and visual styles in photography.



From observing different archetypes in history, the camera evolved incrementally and between iterations the form remained similar. It is a field that has a long history, and due to historical events, perhaps stayed conservative. It is assumed that cameras continue to look similar because of people's perception on how a camera should look. That it is leaning on its heritage and/or the affiliation that photographers would like to have.

During the last decade there is a different side to this culture, and this is especially growing since the arrival of technologies like Unmanned Aerial Vehicles (UAVs). (Figure 12) The UAV allowes the photographer to place the camera in different perspectives that were not possible before. From this development, the question arises if a photographer needs to hold the camera in his/her hand. From a technical point of view this is not necessary.

Figure 12. Phase One XF camera mounted in an UAV.

However for some, particularly the medium format segment, the process is as important as the final outcome. (Henderson, 2016) That is why today some people still shoot film. There lies a pleasure in taking the time to compose corner to corner. Technical cameras (Figure 13) are a unique example of a traditional approach blended with modern technology.

Figure 13. Alpa technical camera with a Phase One digital back.

The components of a technical camera are minimal and camera settings need to be mechanically adjusted for each shot. It not only delivers a unique workflow, but also delivers unparallelled sharp images when used in combination with a modern digital back.

The fact remains that photography is considered to be strongly traditional, or even conservative in some minds. It could explain why the professional cameras look the way they look today. It is the traditional archetype, a box with a handhold, that professionals like to afiiliate themselves with in order to be a professional photographer. And it should be in the interest of the photographer that Phase One harness the tool that enables their creativity, either on an emotional level or at purely technical level.

COMPETITORS

Other mirrorless cameras currently on the market are integrated, meaning all the sensing and processing components are housed within the same housing. This allows for the camera to have a compact and slim body, thereby also reducing weight. Yet the image quality is affected by this. For an uncompromised and upgradeable image quality, the system requires modularity with a digital back. Currently, there is no such camera in the medium format segment other than the technical cameras.

Although Phase One operates on an exceptionally high level of image performance, the threat of substitute products is starting to increase at an alarming rate. (Sanyal, 2017) There are already small format cameras that are equipped with a sensor of 50 Megapixel (MP), but there are rumours surfacing about small format sensors that are able to capture 120 MP (Canon, 2017). The current lens designs confirm this direction, there's evidence suggesting that the latest small format lenses are designed for sensors over 100 MP. Aside from that, photographers could expect new sensor technologies like organic and/or curved image sensors like several patens suggest. (Nikon Patent, 2017) (Sony Patent, 2017) (Panasonic, 2016) (Lackey, 2016) However, as stated in the literature review a patent does not automatically translates into a camera.

Since WMDPs update their camera system on average, every five years, the new system proposed for this project should be future-proof for at least the five years and the additional time to develop the camera system.

MARKET DYNAMICS

Since Phase One works on an exceptionally high level of performance, this lowers the bargaining power of buyers. Phase One puts great effort to being the best. Customers know this and, are in some cases, dependant on that aspect (showmanship, see Appendix C-B).

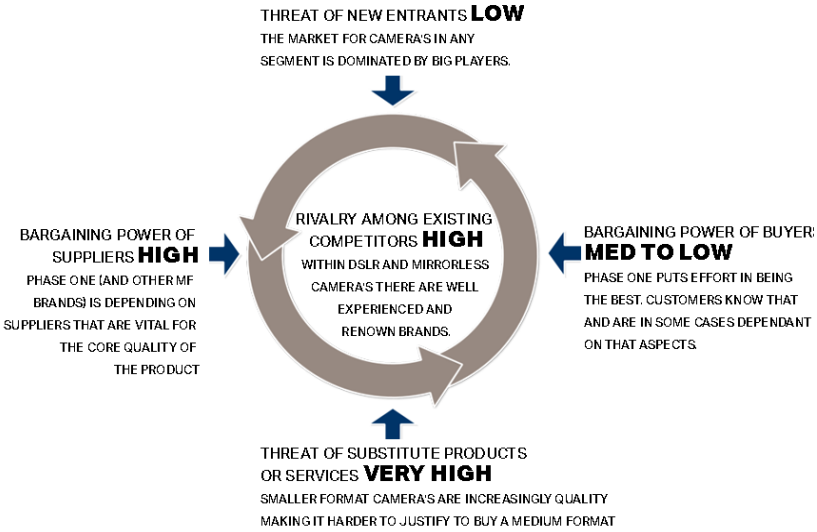
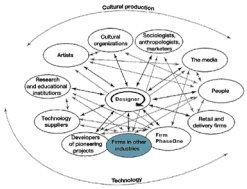


Figure 14. Porter's Five forces

A strategic advantage can be gained by distinguishing oneself from existing competitors by creating the potential substitute product itself which continues to hold a low level bargaining power of buyers. In this case the situation with the suppliers persist in its present state.



One such substitute product could be the modular mirrorless camera system, which does not exist at the moment and could create a fully capable camera for specific target groups. The principle of modularity would allow to serve multiple target groups by having a customised setup based on the customer's preferred interaction.

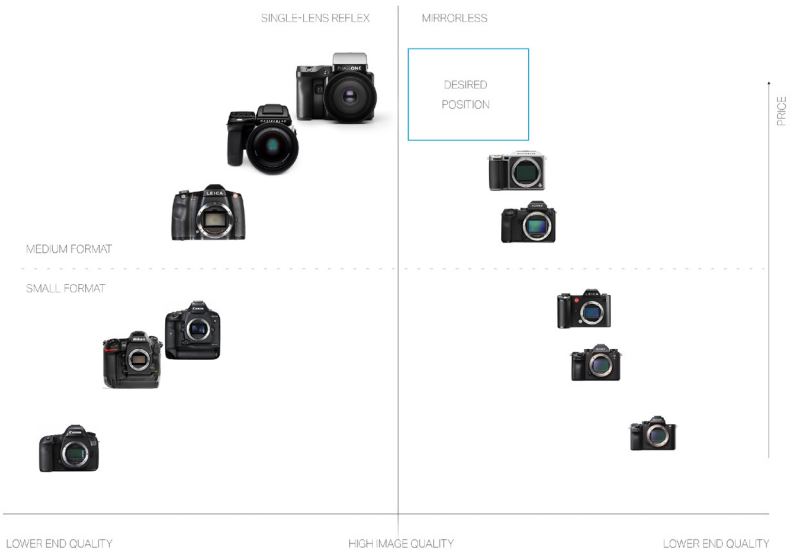
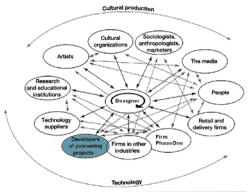


Figure 15. Overview of competitors compared based on the image quality, price, type of system and size of sensor.



FUTURE CONTEXT FACTORS

Emerging Technologies

According to Gartner (2016), there are three key technology trends that deliver high degrees of competitive advantage over the next five to ten years.

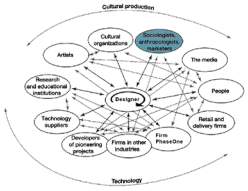
Figure 16. Gartner Hype cycle 2016

Transparently immersive experiences becomes more human centric. Example of critical technology is gesture control.

Perceptual Smart Machine age that harnesses data in order to adapt to new situations. Example of critical technology is smart dust and machine learning.

The platform revolution that forms a bridge between humans and techology. Example of critical technology is Neuromorphic hardware and IoT.

SOCIOLOGICAL FACTOR



The ratio between genders in photographers is not equally divided:
Phase One users - 9 : 1 (m / f)
(Appendix D4)
Industry general ratio - 6 : 4 (m / f)

There's a high potential for optimising the sizing the camera to fit with wide range of hand sizes. This relates to the grip span and positioning of the shutter release button. It also causes awareness of inequity. Implementation of technology should be inclusive and accessible, as it can bring down barriers in society. Designing for equity, or even beyond equity, to make art through technology will create a bright future.

ADDRESSABLE MARKETS IN THE FUTURE OF PHOTOGRAPHY

The global market for digital photography is growing and is expected to reach a value of USD 110.79 billion by 2021 (Zion Market Research, 2016). Particularly Asia-Pacific region is expected to be the fastest growing regional market.

Within Phase One, a number of addressable markets is realised from global wealth reports and digital trends reports in photography. Addressable markets are people that have the time and money to invest in a Phase One system. The best estimate for the total WMDP market with CMOS sensors is enclosed in Appendix C-D. Although it's unrealistic to address everyone, even 6% would be good starting point. That totals to 6.000 production units for the new camera system over 3-5 years.

Currently the XF covers 6% of the CMOS addressable markets.

OUTDOOR INDUSTRIY

The outdoors always has been popular and business is growing in all segments (tourism, clothing, sports) (Sandler Research, 2017) One example is that Sport Climbing is for the first time a discipline of the Olympic Games 2020. (IFSC, 2017)

A growing audience also increases budgets for commercial shoots for outdoor brands. Outdoor advertisements are a good example of how different applications are combined into one job setting (landscape, sports, and documentary photography). Phase One has very few customers in these applications, anticipating on the needs for this segment would create new addressable markets.

CHAPTER SUMMARY & CONCLUSIONS

In the medium format market segment, the process of taking photos is just as important as the result. The new camera in that sense should satisfy on a performance level but also on an emotional level.

There are already competitors on the market with mirrorless cameras, although currently there is no modular full-frame mirrorless camera. Phase One aims for the best performing mirrorless system, even if that comes with a high price tag.

There is a strategic advantage in creating a potential substitute in order to preempt the competition.

An ergonomically designed camera alone does not seem to overcome the market dynamics.

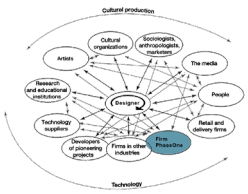
Implementing one of the emerging technologies that would contribute to the field of professional photography would gain competitive advantage.

Removing the size barrier of the camera-grip for users with smaller hands has a high market potential.

An outdoor capable camera would have interest in the near future due to an expanding business in outdoor sports and recreational acitivities. It increases the rate in outdoor advertisements and would grow cross-segment oppotunities.

PHASE**ONE**

A brief history of the company and their mission statement.



Phase One A/S is a manufacturer of high-end medium format cameras and is based in Denmark. It is a technology-driven company and its core vision is to deliver the best image quality possible to the top-tier professionals. The company was the first to start developing digital scanbacks in 1993, and soon after digital backs. Digital backs were initially developed to be mounted on medium format analogue cameras, therefore the form factor remained the same (comparable with for example a lens bayonet mount). In past, it was common to have a camera and digital back from different brands (such as Hasselblad). In 2009, they purchased a majority share of Mamiya Leaf, a Japanese camera manufacturer. In this way, Phase One was able to offer a full digital system; the camera, lenses, and digital backs.

THE DIGITAL BACK; ITS RAISON D'ÊTRE

The modularity of the medium format also facilitated a gradual transition into digital photography where the film magazines could be replaced by scanbacks, then later by digital backs. A digital back is a digital capture engine; it contains a sensor, processor, storage, and a user interface. This way the old camera systems could still be used and not to mention, their precious line-up of lenses. This made it financially attractive for professionals to switch into digital photography. When digital photography became the new standard in all segments, the modular system for the medium format remained. While it is not a technical necessity anymore, this business model works well for photographers by allowing an update to the sensor and not an entire system.

The digital back is Phase One's biggest revenue stream. Photographers upgrade, on average, their digital back every two years (Figure 17). On average a digital back cost €30.000,-

A side benefit from having a separate capture engine is the possibility to also mount it on a technical camera. As mentioned before this type of camera requires more in-depth knowledge of manual operations. But due to its minimal construction, hence the manual operation, it can achieve a higher image quality since there are less obstructive elements. It is worth mentioning that a technical camera is a simple form of mirrorless camera.

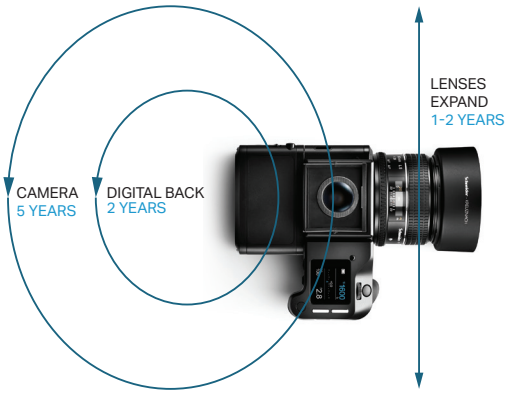


Figure 17. Average renewal cycle for WMDPs

TECH-DRIVEN COMPANY.

With a vision to deliver the best image quality possible, Phase One's innovation roadmap is driven by the push of new technologies. In the first generations of digital backs they were equipped with the type of sensor called charge-coupled device (CCD). In recent years there has been a new sensor technology in development, complementary metal-oxide semiconductor (CMOS).

Phase One is gradually switching into using solely CMOS sensors based on the predicted maximum quality that can be achieved being higher than the previous CCD sensor. ("CMOS infographic,"2016)

Up until this point, Phase One has been actively working on delivering the latest technology innovations to their customers in a manner of technology push.

PRODUCT PORTFOLIO

Phase One mainly targets two markets, the world's most demanding photographer (WMDP), and industrial applications (such as digitisation of historic collections and aerial applications).

Phase One's statement is their products are what the world's best photography is made of, meaning that their product innovations are all in search for the best image quality possible. (Phase One, 2017)

In particular, the WMDP products showcase this very well. Although products are heavy but they strive for the best image possible. For the WMDP, the company launched a new camera system; the XF system alongside with a new range of digital backs. Next to physical products, Phase One also has a photo-editing software, Capture One which is able to render the raw images from the camera. (Figure 18)

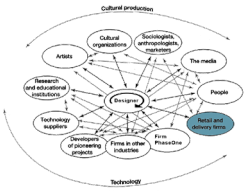
Developing products that are at the bleeding edge of technology has led to an extensive support program. Camera's need to be serviced due to unforeseen malfunctions. The pro customers are aware of this and they accept this in order to have the best equipment. (Appendix C-A1)

Phase One's origin traces back to the market transition into digital photography, by developing only digital backs. After acquiring Mamiya, they started taking shares from the key players by providing a full camera digital system. In order to continue growth, Phase One's strategy aims to upgrade the existing base by creating demand and thereby 'make the medium format market'. (Appendix C-D)

The modularity enables the photographer to update the digital back more frequently than that it would with an integrated system, so the photographer knows he is working with the best equipment.

Figure 18. Phase One product portfolio

Due to the digital back being the biggest revenue stream it makes sense to maintain the principle modularity and strive to expand upon this principle.



SUPPLY CHAIN

Phase One controls almost every aspect in the development of their products, from mechanical design to firmware coding. Most of the departments are located at the headquarters in Copenhagen, but some are working together with departments in Israel (Industrial) and Japan (Lenses and Manufacturing).

List of R&D departments:

- Mechanics and Optics
- Electronics
- Lens Design
- Firmware
- QA Test
- Automation
- Software (Capture One)

The lens designs originally derive from Phase One's in-house engineers, but they are validated and manufactured by German lens manufacturer Schneider Kreuznach (in Japan).

For the maturation of a new camera project, Phase One is able to perform this fully in-house. However, the tasks of industrial design are out-sourced to various parties. The ability to develop products from beginning to end, creates a unique possibility for radical innovation on completely new products by making use of experience from all departments.

RETAIL CHAIN

Phase One has a small selection of partners around the world that are in direct contact with (potential) customers. Usually these partners are main stores for high-end photographic equipment. Next to sales, rental services and hosting workshops are also included by the partner's activities. Returns and repairs are either done by certified sales partners, or they act as an intermediary with Phase One. This creates a short link between customer and camera company.

SONY SEMICON SENSORS

Sony is the biggest supplier of digital image sensors. (Appendix C-A3). Currently, they are one of the best (maybe even thé best) is semiconductors, they are masters of the production process. Medium format sensors are expensive to manufacture, but even more so to develop. This creates a high threshold for experimenting in different kinds or different types of CMOS sensors for Sony. This is, however, an unfavourable position to be in for a company like Phase One which depends on a niche supplier of its core products.

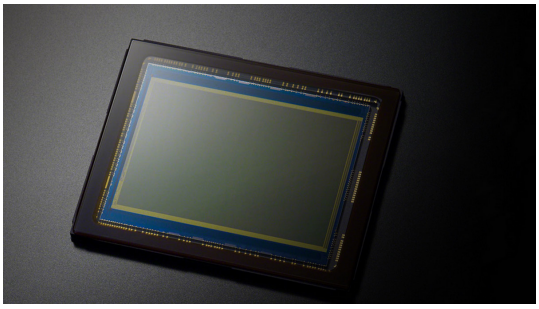


Figure 19. Sony CMOS sensor

CMOS SENSORS

The working principle of a CMOS sensor makes it possible to capture an image in acceptable latency without a mechanical shutter (eg. focal plane shutter or leaf shutter). A CMOS chip uses an A/D converter for every column of pixels, in which the entire sensor array must still be converted one row at a time. This results in a small time delay between each row's readout. This effect, which is called a rolling shutter, is also found in a focal plane shutter commonly used in a SLR system. The total number of pixels digitized by any one converter is significantly reduced, enabling shorter readout times and consequently faster frame rates. This makes the SLR system redundant in terms of shutter speeds. Removing the mirror will help reducing the size and weight of the body drastically. But the switch from a DSLR to a mirrorless system implicates more than just removing the mirror mechanism. Before getting into a new technology, the physical entity of the current camera is assessed.

CHAPTER SUMMARY & CONCLUSIONS

Phase One is a technology-driven company, for the best image quality possible.

Phase One, most recent technology push was the switch to CMOS sensors. This allows capturing images without the single-lens reflex, mirror mechanism and the focal plane shutter.

The company's biggest revenue stream comes from the digital backs. The new camera system should therefore retain the modularity with digital backs and future prospects.

The company is capable of providing a full product ecosystem; from hardware development with appropriate firmware, to the image post-processing software, as well as a dedicated technical support program for customers.

Phase One focuses on upgrading the medium format existing customer base, by creating demand and thereby 'making the medium format market'.

Industrial Design is not an integrated part in Phase One's R&D.

Sony is the supplier for the CMOS sensor. Currently, they are master of the production process and are gaining a monopoly on the semiconductor market. This is a unfavourable situation for Phase One to be in considering the sensor is a vital part of their core product.

Any sensor innovations come from Sony, which is less likely to happen that for smaller format sensors. In order to come to a meaningful innovation, this has to be found outside the sensor capabilities.

THE XF CAMERA SYSTEM

The XF camera system is Phase One's flagship camera platform that expands the legacy platform of Mamiya. It is specifically designed for the WMDP as a modular camera system. Within a modular medium format system, the camera system acts as a spinal for the complete system. Every component is mounted on the camera, it must provide a rigid construction.

PERFORMANCE SPECIFICATIONS

(with the IQ3 100 MP digital back)

Resolution	101 Megapixel
Colour depth	16 bit
Dynamic range	15 stops
Sensitivity (ISO)	50 - 12.800
Sensor size	53.4 x 40.1 mm
Active pixels	11.608 x 8708
Output image at 300 DPI	98.3 x 73.2 cm
Weight	(batteries included)
XF camera body	935 g
prism viewfinder	505 g
IQ3 digital back	722 g
SK 80 mm LS lens	585 g
Total	3035 g

Figure 20. Phase One XF camera body

Retail price	
XF camera body	€ 6.295,-
prism viewfinder	€ 2.368,-
IQ3 100 MP	€ 34.700,-
SK LS lens	€ 3.000 - 7.000,-
Total	€ 46.363,-

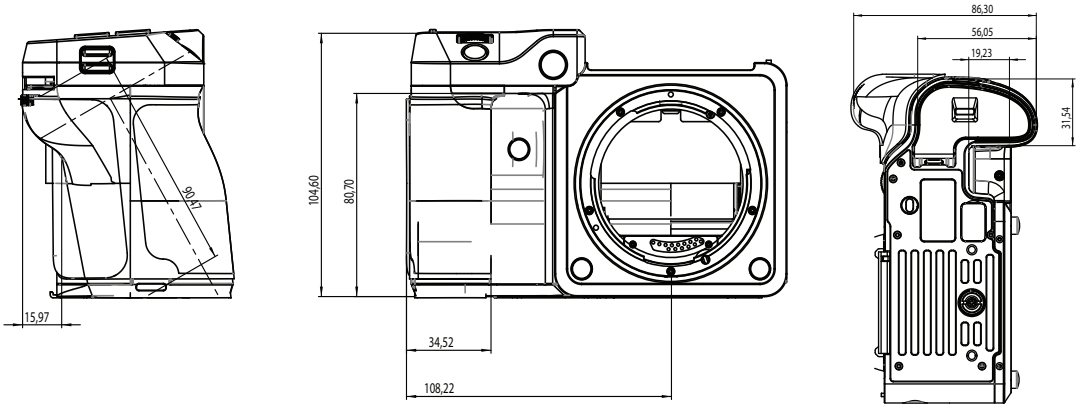


Figure 21. Technical drawing of the XF camera system [mm] source: Phase One CAD files.

Figure 22. Photographer holding the XF camera using a prism viewfinder.

FUNCTIONALITY BREAKDOWN

The camera is the primary interface for the user, therefore both the physical and cognitive ergonomics are of utmost importance.

For the next system, Phase One wants to mount the viewfinder on top of the digital back. Maintaining the principle of modularity renders the functionality of the construction to be the same as the XF, except for the positioning of the viewfinder.

In terms of camera operations (Figure 23), all functions need to be implemented in the next system although the appearance of those functions is still open. Meaning for instance a shutter release button does not necessarily need to be on the same place and/or be the same type of 'button'.

WORKING PRINCIPLE OF THE GRIP

A full analysis of the XF grip can be found in Appendix F.

The user is unable to fully close their hand when holding the camera. (Figure 24) This means that holding up the camera without support from the left hand is based entirely on grip force from the right hand. Rubber is used on front and back side of the XF grip, adding a friction coefficient of 1.16. With a total weight of 2.635 gram the vertical component of the required grip force is 22,2 N.

Note that this calculation includes a standard 80 mm lens, which is fairly light in Phase One's range of leaf shutter lenses. Switching to bigger lenses will increase the weight and shift the balance forward, thus minimum grip force.

The thenar muscles is a group of muscles attached to the thumb. This area of the thumb provides a stable and comfortable point of contact. In terms of placing the hand, for an effective clamp the thenar muscles should be placed behind the camera. (Figure 25) This is followed by wrapping the fingers around the grip.

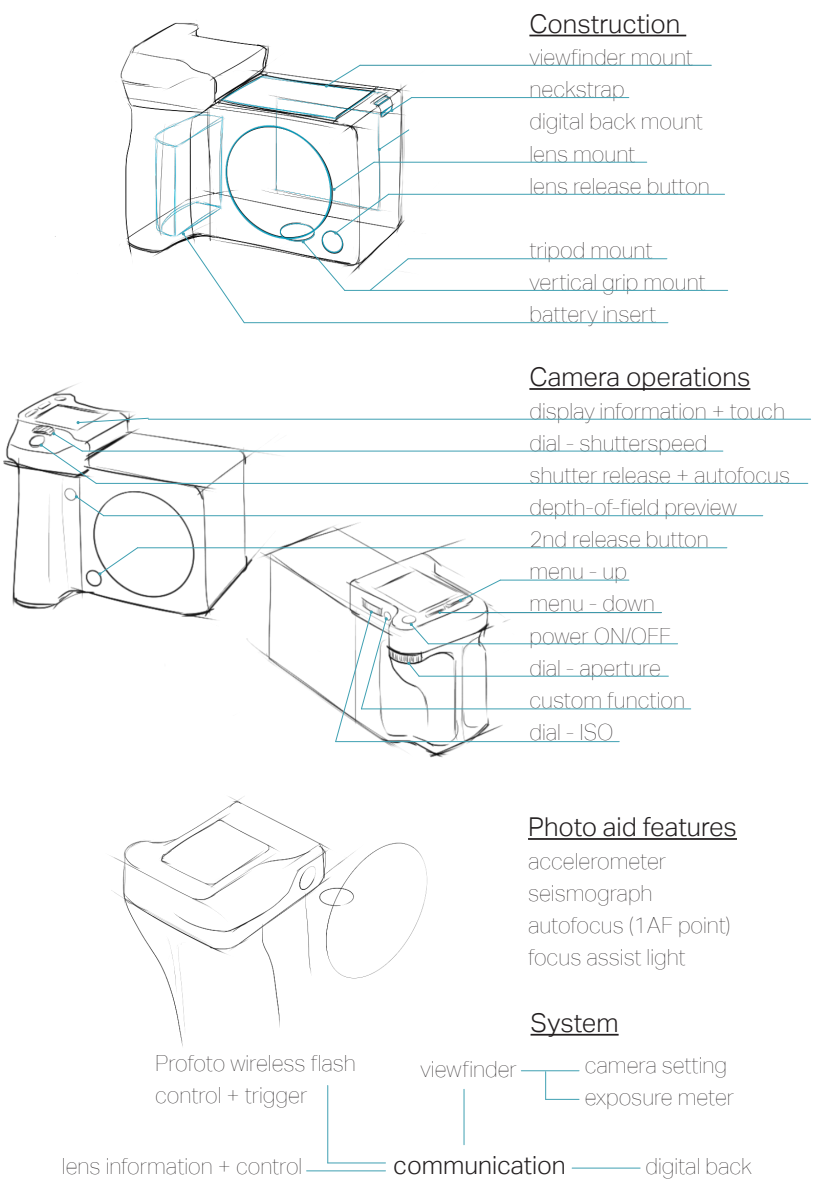


Figure 23. Functionality Breakdown of the XF camera

The thumb, which is sitting at the back of the camera, does two things: while carrying the camera or taking a photo, the thumb can be used for a firm grip. Between taking photos the thumb can be used to control the dials to adjust the camera settings. In this case only the thenar muscles have contact with the grip at the back. This is the basic working principle of the grip.

Figure 24. User can't close their hand on the grip.

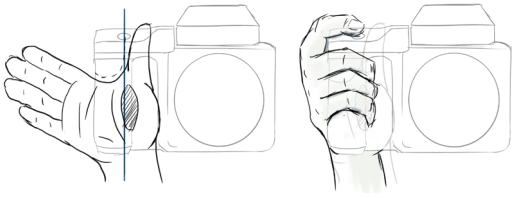
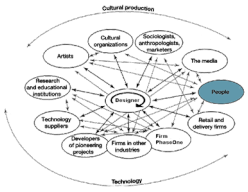
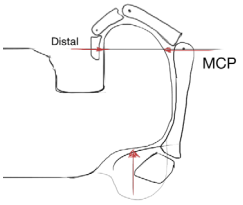


Figure 25. Placement of the hand on the camera.





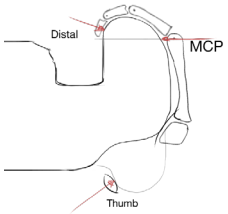


Figure 26. Force balance comparison with big and small hand. (bone perspective)

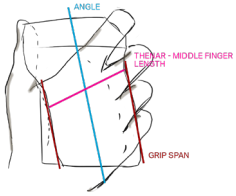


Figure 27. Grip span

Although in most cases a photographer has two hands on the camera with the left hand supporting the camera and controlling the lens, there are significant moments in a workflow where the photographers carry and control the camera with one hand. (Figure 29)

THE CAMERA IN RELATION TO THE HUMAN BODY

The goal is to take a photo, the index finger therefore should be able to reach the shutter release button and the rest of the fingers will be placed accordingly within this reach. The hand should be placed in such a way that the index finger is positioned at the shutter release button, which prevents it from aiding in gripping the camera.

The XF has an average grip span of 60 mm. If a hand is not long enough, it will have an effect on the force play on the grip. This generally still results in prioritising placing the distal digits on the recess. (Figure 26) This creates an imbalance in the force play with the fingers and the thenar, where the thumb is needed to compensate in the equilibrium. Yet this is very uncomfortable for the thumb and some actuators become can unusuable.

Due to the combination of the working principle of the grip, position of the shutter release button, and the vertical alignment of the grip; holding the camera at eye-level height will cause the wrist to be in ulnar deviation. (Figure 27) In ulnar deviation of the wrist, the maximum grip force is reduced by 20%. (Freivalds, 2004)

Not all fingers are equally strong. The middle finger is the strongest by providing 28,7% of the total grip force, followed by index, ring, and little finger. Since the index finger is not used for the clamping on the grip while taking a photo, this results in a 26,5% loss for the maximum achievable grip strength. (Freivalds, 2004)

Not using the index finger combined with the wrist in ulnar deviation, demands a higher maximum power grip of the user for him/her to hold the camera. For the minimum force of 22,2 N, after compensation of the loss, the grip strength of the user has to be at least 37,6 N.

When comparing this with a study in maximum static grip study, the average woman will not be able to hold the XF camera at all. (Appendix F) The actual percentile range is not possible, however this result so far highlights a noteable issue in the XF grip design. Either the ergonomic aspect was undervalued during development, or the XF is designed for the upper percentiles of hand sizes.

Figure 28. The XF camera is, for many female photographers, too large to use handheld.

Figure 29. WMDP'ers can find themselves in extreme conditions to take the desired perspective/photo. This sometimes limits them controlling the camera with only one hand.

CHAPTER SUMMARY & CONCLUSIONS

The camera body acts as a spinal within the whole system, providing a rigid construction between lens and digital back. The camera also provides an user interface to control the camera system.

For one-handed use, preventing the camera from falling out of the right hand is only accomplished by grip force. The minimum grip force required is 22,2 N (for a standard setup with a 80 mm). With a heavier lens this force will increase and creates a different force balance.

The maximum grip force is reduced by 41% due to the ulnar deviation of the wrist and not using the index finger. A more neutral angle of the wrist would help regain grip strength.

The grip span of the XF camera affects the maximum achievable static grip. This is too large for most women. Some won't be able to hold and lift the camera with one hand at all.

The thenar is a group of muscles that provides a stable and comfortable area for point of contact, which helps for a stable power grip.

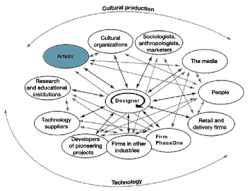
During image capture, placing the distal joint parallel with the recess takes precedence over correct placement of thenar when the gripping hand is too small. However, compensation with a thumb is undesirable due to the discomfort and the inability of using the thumb for button control.

The shutter release button determines the angle and position of the hand on the grip (with an allowed deviation of 15 degrees).

A smaller hand also affects the point of force engagement for levelling the camera. The smaller the hand, the more force needs to be engaged by the wrist to compensate the torque.

THE WORLD'S MOST DEMANDING PHOTOGRAPHER

Phase One has definded their target group as the World's Most Demanding Photographer. This chapter explains the definition and how this influences the design brief.



DEFINITION

Phase One strives for the best image quality possible. In that sense they describe their target group as the 'World's Most Demanding Photographer' (WMDP); a group considered to be the top-tier of all photographers globally. However, the specific needs among the photographers is varied and product management department of Phase One has classified them on multiple levels.
The four different levels are followed by their financial and creative success (ordered according to the career ladder): (see Appendix C-B for futher details)

- Talents
- Working Professional
- Commercial Elite
- Artistic Elite

Photography can be exercised in multiple categories, subcategories, and hybrid versions across categories. Although there is not a global and/or scientifically defined list of categories, Phase One has made their own catalogue for the types of photography. (Figure 30)

NUMBERS

The actual number of current Phase One customers is not easy to acquire and remains an estimate. The number of sales does not correspond with actual customers since photographers can own multiple systems and there are also rental units. This is because the company has not implemented the active registrations (equals customers) into their common data set. The data input that is available however is retrieved from active registrations coming from the software Capture One. During the registration, the photographers can also provide information on their specialties and contact details.

These numbers had to be extrapolated from the CRM database based on a varied set of parameters. (Appendix C-C) The number was defined by digital back owners (IQ1, IQ2, and IQ3 owners), in this way for instance the customers that own a Phase One digital back with a Hasselblad mount are also included in the data.

This comes to a total of 4.269 active registrations, therefore customers. The XF system was only launched in 2015, which provides insight on the amount of production units per year.

The top 3 countries of customers are United States, (25,58%) Germany (7,74%) and Japan (6,24%). (Appendix D4)

Figure 30. Phase One application catalog of the WMDP.

The ratio between male and female Phase One photographers is 89% versus 11 %. (Appendix D4) This is expected due to findings of the XF grip analysis, the camera is probably too heavy for most women. In this case it is hard to say whether that is because of a skewed market pull (male versus female) or the design focus of the product.

WORKFLOW

A workflow can be seen as how the photographer approaches a shoot and the method that assures him of good results. The consistency and/or the data redundancy can also have an effect. It very much depends on the type of photographer and the intention of the assignment how the workflow is designed. One photographer can have many workflows.

Based on the behind-the-scenes footage, use cases (Appendix H) and insights from Product Management, it was possible to derive at two sequences of activities. (Appendix I) This provides insight on the actions of a photographer, and in which order they are performed for him to complete a task. For an Action & Sports photographer, when it comes to taking a photo, multiple loops can occur that cycle between composing, adjusting camera settings, interaction with subject and re-taking a photo. The photographers create an evironment for themselves to move around in while maintaining the atmosphere of the photoshoot.

POSTURE ANALYSIS

To see how photographers using a Phase One system move and work with the camera, various behind-the-scenes footage clips was observed. (Appendix G)

The variety of use-cases is broad, with many different postures. On assignment the set is usually tailored to the photographer's needs for the photo, for example, the use of tripods, external lighting, and a team of various assistants. In more challenging conditions, the set is led more by getting the photographer to the right position (Figure 31), with ropes or attributes like stairs or mounted seat.

Figure 31. An Action & Sports photographer on assignment on a climbing crack.

Tilting the heavy camera for a period of time can be uncomfortable due to the required clamp on the grip. This becomes a bigger issue when you take the freedom of movement for different photo perspectives into consideration. While the whole human body moves for a different angle, the angle of the hand stays the same, causing the wrist to move into highly uncomfortable angles. In this archetype, that same clamp causes the uncomfortable angles for the wrist.

During a session a photographer always changes his body posture and micro-adjusts the position and angle of the camera in favour of the composition. The photographer often uses his whole body to change the perspective, in order to avoid painful or awkward wrist positions. The question is if they're aware of this at all.

The variables that have an effect on the posture and camera control dynamics are listed in Appendix J. The variables were defined by the observation and from own experience as a professional photographer.

Later in history, due to the use of a reflex mirror, the waist level finder is logical evolution that both enhanced the user interaction and the stability.

FREEDOM OF MOVEMENT AND CREATIVITY

Photography in general is a creative occupation, whether professional or not. The photographer, considered as a creative mind, is the curator of how an image will be captured. The diversity in factors that influence how an image can look creates innumerable possibilities for the end result. Out of these innumerable possibilities a photographer can develop his style to distinguish himself from the competition.

A photographer decides the content and composition of the image, which largely determines the use of perspective. Depending on the application, the number of different perspectives can be remarkably high. For an event photographer the freedom of movement is an important aspect to capture the story or atmosphere of the event. The type of hardware, the environment, and subject influence the way a photographer works with his camera and how he moves or stands within that environment. The different perspectives can be achieved by changing his body or with the help of attributes or vehicles.

WHAT DOES IT MEAN TO WORK WITH PHASE ONE CAMERAS?

They strive for the closest interpretation of their envisioned image and the tool is a vital element in their process to get there. They expect the most out of their tool, the highest quality and precision available. The end result becomes more than simply pressing the shutter release button. Phase One is always active delivering the highest quality and precision, and that has established a close relationship with their customers.

As medium format cameras are at the front end of digital imaging, some photographers make use of this fact as part of their showmanship towards clients and their audience.

Figure 32. A Fashion & Beauty WMDP at work in her studio.

CHAPTER SUMMARY & CONCLUSIONS

Phase One describes their target group as the world's most demanding photographer (WMDP).

This group consists of small number of photographers (~ 5.000) with very specific requirements for their workflows.

The XF camera is predominantly used in studio settings or for landscape photography. This is due to the size and weight of the camera, but also due to its relatively slow auto-focus.

The camera acts is a tool that enables the creative mind of the professional. In this sense, it should never steer the photographer nor limit the workflow of the photographer.

Based on the posture analysis the camera is used in a broad range of environments with various body postures.

The photographer uses his whole body to change the perspective in order to avoid painful or awkward wrist positions. The question is if they're aware of this at all.

WMDPs expect the most from their tool because it helps bring them to the closest interpration of their envisioned image.

STAGE 2. INTERPRETING

THE SWITCH TO A MIRRORLESS SYSTEM

A mirrorless camera system can be smaller than a SLR version while maintaining the same image quality.

The switch involves more than just removing the mirror and resizing the camera. There are a few aspects to consider like the business and supply chains, competitors, and the limited size of the target group. But there is also one fundamental aspect that will change; the optical prism viewfinder will be replaced by an alternative type of viewfinder. The alternative at this point directs towards an electronic viewfinder (EVF). (Figure 33)

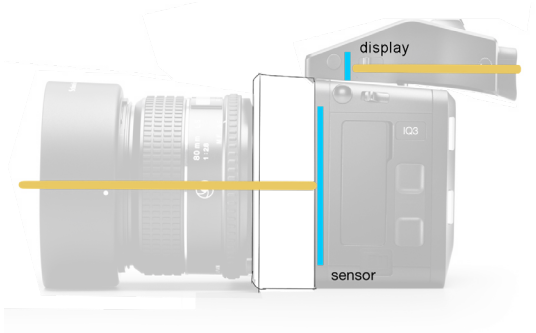


Figure 33. Representation of an electronic viewfinder in a mirrorless system. Yellow lines indicate the user's view entering the system

A mirrorless system in this form becomes a full electronic system; opening up a whole range of possibilities compared to a traditional SLR. There are already mirrorless cameras on the market but those cameras lack responsiveness and do not take advantage of the full potential. The lack of responsiveness has caused reluctance for mirrorless systems in the community of professional photographers, especially in the top tier. (Rose, 2017) The processing power that is required for the viewfinder is not sufficient to keep the visual feedback real-time from the sensor. However it is assumed that this won't be an issue in the near future due to the consistent doubling evolvement of computing power. (Gartner, 2016)

From a cost-effective approach the handling and control could be realised in a simple grip as a screw-fastened add-on to a simple body/box.

Although there are mirrorless systems on the market for a few years, Phase One's medium format competitors Hasselblad and Fujifilm have taken a shot at a mirrorless medium format system. And although reviews report that the electronic viewfinder is good, they are not perfectly smooth and not fully operationable.

A summary of the features and implications for switching from a SLR to a mirrorless variant are listed here:

Features
- Smaller
- Lighter
- No mechanical parts
  -this increases the durability
- No vibration by mirror
  -this also improves image quality
- Presumably cheaper due to the absence of expensive delicate mechanical parts.
- No/lower shutter noise.

Implications
- Different AF system; contrast based instead of phase detection. (Appendix C-A3)
- Alternative to an optical viewfinder needed.
- Weight balance shift with a conventional digital back with a viewfinder mounted on the digital back.

Although with a relatively heavy modular system, the digital back can counteract on the weight of the lenses. This favours the balance while the camera.

FOCAL FLANGE DISTANCE

Removing the mirror and shorten the distance between the lens and sensor has an effect on the lens design. Having a smaller distance is less preferred due to the limit of the Chief Ray Angle (CRA) of the sensor. If light rays enter the sensor on a too steep angle, the light will cross penetrate different filter layers of the sensor (Figure 34) causing to have incorrect colour and detail rendering.

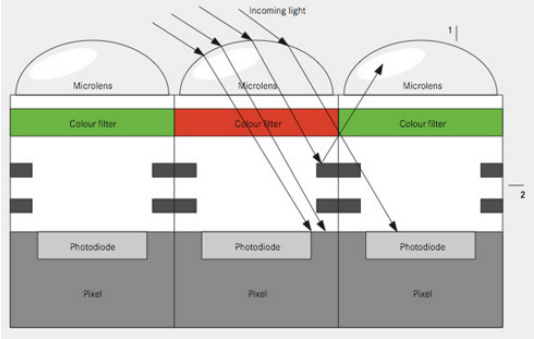


Figure 34. Illustration of light entering the sensor on a steep angle (exceeding the CRA)

Starting point is a focal flange distance of 15 - 25 mm (Appendix D1). According to the R&D department this is an acceptable distance to start with.

Because of the shortened focal flange distance, the bayonet mount increases and lenses need to be redesigned to comply with the CRA of the angle. Although this is not the focus of this project, having to redesign the entire range requires a high investment. A side-effect can have for some lenses to become wider.

As an interim solution, Phase One can make special mechanical shutters to replace a dying old type of mechanical shutter for technical cameras (Appendix C-A2). The dimensions of the mounting plate (and its focal flange distance) could be shared with the intended mirrorless system. Again this is not a part of the project, but it is a wish to keep in mind with.

AUTO FOCUS SYSTEM

The mirror mechanism in a SLR not only provides the ability to look 'through-the-lens', but also to work with a phase detection system. (Figure 35) A metering system that can calculate the distance (triangulation) for a focus point.

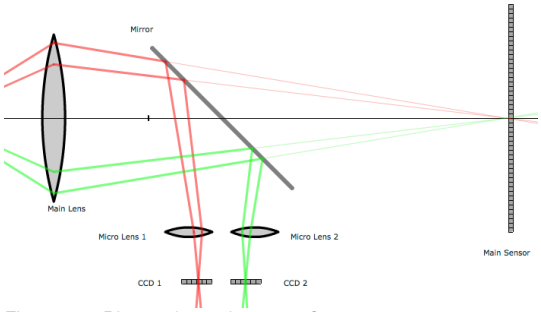


Figure 35. Phase detection auto focus system.

In a mirrorless system the phase detection system is also removed. A different method for metering is contast-based, this can be performed by the sensor. The disadvantage of this method is that it is by nature slower than a phase detection system. That has to do with the contrast based system has only one evalution point and needs to find out in which direction the focus lens has to move to. This is one of the reasons why reviewers user the word lack of responsiveness.

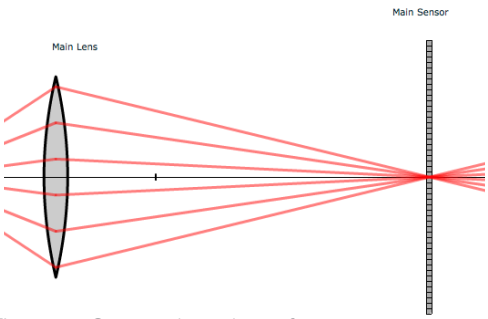


Figure 36. Contrast based auto focus system.

A solution to this would be to have an additional metering system or to have a hybrid sensor that has dedicated phase-detect pixels on the sensor. However this type of innovation would have to come from the supplier and this is extremely expensive to develop. (Appendix C-A3) An additional triangulation metering system is possible but the nodes need to be placed relatively far ahead from each other in order to achieve the required accuracy for sensors of 200 MP.

The distance between the flange of the lens mount and the sensor is called a flange focal distance. This is an important aspect in lens design.

AN ALTERNATIVE VIEWFINDER

As mentioned before an alternative is needed for the optical prism viewfinder. Apart from the previously mentioned EVF, there is also an other type of viewfinder that is commonly used next to the SLR and that is the rangefinder camera. Fujifilm even developed a hybrid rangefinder that uses the optical system with an electronic overlay.

Rangefinder camera

This type of viewfinder does not look 'through-the-lens' but can be built very compact and has the advantage of using an optical link. For film cameras there is a focus evaluation system developed that uses the parallax effect. (Figure 37)

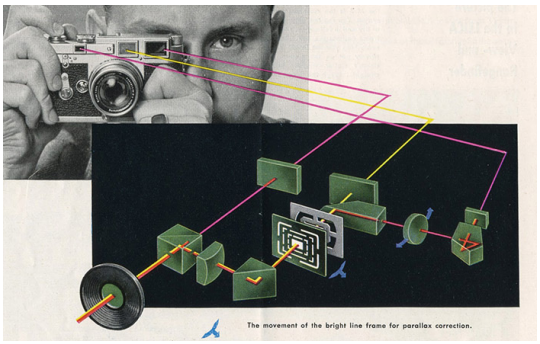


Figure 37. Explanation of Leica M3 rangefinder camera.

Electronic Viewfinder

The EVF consists of a display and a nearfocus oculair. The display uses a direct data feed from the imaging sensor. Although it requires significant processing power for a real-time feedback, theoretically it can be placed or moved anywhere. (Figure 38)

Figure 38. Fujifilm GFX-50s tiltable EVF

In a mirrorless system and with modern technology there are less volume-defining factors such as a mirror and battery (at least not as a standard factor). (SolidState Technology, n.d.). This expands the design freedom for the camera body and its user interface. A new and unique interaction can be established with this system and is likely to be necessary to establish a successful product.

It needs to be remembered that the mirrorless system is an emerging technology and the single-lens-reflex is an old system. However current technology is not there yet to serve the top-tier to full capacity. For the next generation, it is assumed that the mirrorless technology will be sufficiently developed for full responsiveness and capacity.

For a completely new design of the camera, regardless of the to-be used technology and yet to be designed body archetype, from a marketing point of view the camera needs to look desirable for it in order to sell. (Appendix C-A1)

A mirrorless system consists of multiple parts, it requires a redesign for almost every element in the system for it to function optimally. This implies the camera, lenses, viewfinder and an optional adapter for XF lenses.

Preliminary thoughts is an ergonomic design that excels in handling while being a desirable object.

CHAPTER SUMMARY & CONCLUSIONS

Phase One's vision is to 'make the medium format market'.

A mirrorless system requires a redesign for almost every element in the system.

Switching to a mirrorless system not only significantly affects the body volume, and therefore its balance, it also affects the interaction with the photographer due to a different autofocus system and a different visual feedback (the viewfinder).

The electronic viewfinder will be mounted on a new generation of digital backs. This shifts the weight balance even more.

It assumed that processing power will be sufficient in the near future to provide a real-time videofeed from the sensor.

The mirrorless system will be at least equipped with a contrast based autofocus system that comes from the sensor. Any additional metering system has to be developed by Phase One.

INTERPRETATION

To continue Phase One's mission in striving for the highest image quality possible, the new camera should also be intended for the top-tier professionals. Phase One started in the era of transitioning into digital, later on taking share from other digital medium format brands into a new era where Phase One could be the last man standing and therefore 'making the MF market' (Appendix C-D).

Based on the results from the first stage, there are four aspects of the camera that can be addressed in order to create a more meaningfull product.

1. Specialised cameras, where the camera body is more tailored to the photographer's needs (in a certain application branche).

2. Considering the camera as a hand tool. Addressing the fixation of the hand on the grip, reduce awkward wrist positions for various body positions. Yet respecting the perception of a professional camera.

3. User interface design that takes advantage of the Perceptual Smart Machine (Machine Learning).

4. Size options, based on a base model various grip size options can be included in order to remove size barriers.

Some of the design directions require additional input that comes from other directions, thereby it recreates a more sequential approach. Given the timeframe for this project, a focus is needed to meet the expected delivrables. Any form of information that comes up during the design process, will be shared in a list of recommendations.

Recommendation for the company is to take on the other following design directions after completion this project.

SCOPE

In this project the aim is to design the physical representation of a mirrorless medium format camera. In that sense, the outcome of design direction 1 and 2 will deliver the desired result.

However, instead of designing all of the specialised cameras, this project will focus only on one specialised camera in which also design direction 2 can be implemented. That would be a handheld application.

The goal with this scope is to provide somethin meaningful and to layout a concept that anticipates on the found needs, shortcomings and create new niches in a highly competitive market.

In terms of the other options: design direction 3, the use of Perceptual Smart Machine, is a promising direction but this requires an extra study on the user interaction before it gets to an embodiment concept, that lies beyond the timeframe of this project.

For design direction 4 to succeed, it requires more indepth knowledge of the hand biomechanics and corresponding accurate anthropometric data. This on its own can be considered as a new R&D project where the outcome would not only serve this generation of cameras, but the next generations to come.

PRODUCT PROPOSAL

The vision is to design a camera that is true to its heritage, through resemblance to its predecessor, with a future-proof electronic platform and form that, by its flexibility and adaptability, effectuates a more personal act of photography.

For the flexible means of handling it aims at solving the awkward wrist positions that occurs with any modern handheld camera today, without the addition of rotating mechanics. Solving awkward wrist positions will increase the stability and postpone fatigue in the upper limbs.

This same electronic platform makes way for technology trends as the Perceptual Smart Machine and can lead to new ways of taking photos that are on the frontier of what's possible in an interpolating industry. Making thereby a new mark in any class of photography.

The new camera is considered to be a smart (hand) tool and therefore the camera system should enable, not interfere with, the photographer's art and expression.

Rationale

A new generation of medium format camera is not something that comes every year. (Phase One Update Cycle) The equipment is high-end, takes a longer time to develop and it has to cope with the threat of substitute products from the small format segment. (Market Dynamics)

The challenge lies in designing a new innovative camera body where its predecessor derives from an archetype that has been used for a few decades. From a traditional point-of-view this is the go-to archetype that professionals affiliate with. Where people have a conservative mind in how this device should look, at the same it is expected to bring innovation. In terms of image quality, this totally depends on the sensor and optics so that would not change the situation.

Medium format cameras are renowned for their cutting edge technology and unparalleled image quality. However with the current market dynamics, solely a new camera that acts as a spacer and a handle will not find the desired establishment in the mirrorless market.

In this time, where medium format camera brands are making an entry in the mirrorless market, the opportunity rises to do something new that again can create a paradigm shift as it did in the past with the TLR, space expedition, and the transition from film to a digital back.

It's that same revolutionising effect that created the medium format iconic status. For a paradigm shift to happen, this has to go beyond a spacer and a handle. Acting upon the interpolating industry and emerging technologies, it has to take full advantage of the possibilities of the electronic platform.

PRODUCT FAMILY OF THE MIRRORLESS CAMERA

MAKE THE MEDIUM FORMAT MARKET

The WMDP consists of a diverse group of top-tier professionals from various areas of expertise and demographics. This group also includes the potential WMDPs that are not yet familiar with Phase One. The Phase One XF camera system is a big and heavy camera, and is intended as an allrounder. Although the camera in general is received well in its segment, as an allrounder design compromises had to be made. This causes niche needs in other high-end market applications to be either partially or not met.

The Phase One mirrorless camera as an allround camera will likely not have the desired establishment due to customer's expectation and market dynamics. To make a real mark in the medium format market, the mirrorless camera should not be considered as one allround camera.

In fact, due to the modular system, it makes it convenient to develop multiple specialised camera systems without stepping away from the platform. By addressing niche needs, it is assumed that there will be a higher market penetration. The best guess for increase rate is at least 1-2%, on top of the 6% of the addressable markets (with an allrounder) according to the company's calculations.

SPECIALISATION

In order to properly address niche needs, photography applications from Phase One's catalog were examined and clustered based on commonly used attributes and workflow. The applications within a cluster share the same type of environment, commonly used attributes and most of all the photographer's key value. A cluster of applications forms a valuable group of photographers to design a specialised camera for.

Based on market research commissioned by Phase One, it is also possible to estimate the size of these clusters expressed as addressable markets. The process of how the clusters were made can be found in Appendix L.

From a preliminary set of four clusters, the proposed product family is a set of three cameras that serves the entire catalog of applications. This is where Phase One's product portfolio can be meaningful and obtain a strategic advantage in a highly competitive market.

In the process of clustering applications, Danish words were used to characterise what they represent.

During initiation of this project, the ergonomics and balance were stated as first challenges. (Appendix A) This focusses on either Momentum or Udtryk,.

Despite Momentum serves the smallest group of the family, this is the elected cluster to initiate the product family with. The XF already has a strong coverage in Udtryk and for Stilhed a different mindset is needed due to its fundamentally different style of photography. In addition to that, the context for Momentum is getting more track and will likely to gain more interest.

Momentum and Udtryk are both clustered from handheld applications, the distinction between these two clusters is the type of environment and subject. The type of photoshoots can directed (in Udtryk) and less directed for capturing moments. The environment of Momentum is a dynamic one, whereas with Udtryk this usually happens in a controlled environment (for instance in a studio with external light sources). There might be a possibility these two can be merged together into one camera.

1. Stilhed [stillness]
Applications: Landscape, Architecture, Product, Creative Still Life, Automotive

2. Momentum [momentum]
Applications: Action & Sports, Journalism & Documentary, Events & Weddings

3. Udtryk [expression]
Applications: Portrait, Fashion & Beauty

Can the camera only be used by applications within Momentum?

No, any other creative professionals can use the camera as they desire. The camera will also be usable for tripod users within Stilhed, but presumably their interaction with the grip will be passive. In most cases the distinctive values do not interfere with each other (if you leave out the super niche values). The focus remains for handheld applications from Momentum.

CONCEPT FRAMEWORK

MAIN FUNCTION

Provide a handheld grip in a mirrorless camera system, which provides a modular construction to connect a Phase One digital back and leaf shutter lenses.

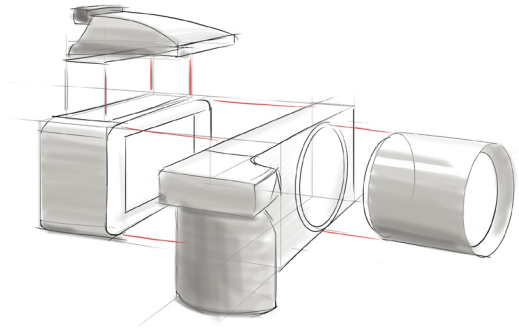


Figure 39. Configuration for the Momentum camera, where the EVF is mounted on top of the digital back.

The Momemtum is intended for a group of photographers classified in:

- Action & Sports
- Journalism & Documentary
- Events & Weddings

Within this group the mutual value is a lightweight system that provides good handling to move around with. Specific to the photoshoot, the subject is mostly not fully directed by the photographer, thereby leaving the moment of capture out to the authentic expression of the subject. The photographer needs to be able to anticipate on this and one of the ways is to create an environment in which they can move around in and where the subject can perform.

To summarise, the user profile of a Momentum photographer can be decribed as:

1. When on assignment, they mainly use the camera handheld, for relatively longer periods of time.

2. They create an environment for the photo:

    2.1. for unique perspectives

    2.2. to move around in.

    2.3. to collaborate with assistants and the use of additional attributes (such as lighting, reflectors, etc.)

3. Unique, slight undirected photo productions (expeditions, documentaries, weddings) where efficiency, confirmation during image review and reliability are key values.

Figure 40. Example of a photoshoot location for an A&S photographer.

TRANSLATING USER VALUES INTO PRODUCT FUNTIONALITY.

The build-up for this transformation is:
1. Requirement/task [is satisfied by]
2. Function [is realised by]
3. Component [is implemented how]
4. Design / Solution

The ability to capture (spontaneous) moments
- satisfied by fast and simple reaction, therefore the amount of activities for the user to take photos should be reduced. This can be implemented by having an adaptable user interface.

Anticipate on potential moments
- is satisfied being in the right place on the right time, therefore moving around should be as convenient as possible. This can be implemented by a grip that requires less repositioning (for instance when moving from rest position to active).

Shoot from unique perspectives
- is satisfied by shooting from different postures, therefore the grip should allow full functionality between the postures. This can be implemented by an array of strategically placed actuators.

Long period of handheld operation
- is satisfied when fatigue in the muscles is postponed, therefore the grip should be well-fitted with the user. This can be implemented by a working principle that is more accommodating to different hand sizes.

SUB FUNCTIONS (HOW-TOS)

From the functionalities, a list of how-tos have been developed in order to iniate a structured ideation phase.

1. How to provide a better handling for the right wrist when shooting on eye-level? [handheld handling]
2. How to provide a better handling the right wrist position when shooting on waist-level? [handheld handling]
3. How to switch with the hand position between these various positions? [less repositioning]
4. How can the camera sense a different hand position? [adaptable user interface]
5. What kind of actuator can be used for the shutter release button that requires less positioning? [adaptable user interface and sociological influence]
6. How to maximise the range of users to reach the shutter release button? [Long handheld and sociological influence]

What | A specialised full frame medium format mirrorless camera system with an open electronic platform.

Who | Photographers categorized in handheld applications of the WMDP catalogue. For example: A&S, J&D and E&W.

Where | Outdoor and on set, varying from mountain glaciers to restaurants.

When | It is used when a lighter system is preferred and during longer handheld assignments.

Why | Mirrorless cameras can have the same high quality as DSLRs, but without the delicate mechanics.

How | By designing a grip that anticipates on awkward wrist positions, it postpones fatique and enlarges the potential group that can carry and operate the camera.

GIVEN BASE DIMENSIONS

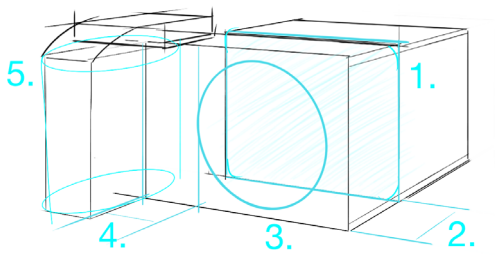


Figure 41. Given base dimensions.

1. Mount area of the Phase One digital back. Phase One continues their line of digital backs. The current mount area covered on the camera is 97 x 88 mm.
2. Focal Flange Distance The lens design engineers estimate a workable focal flange distance at 25 mm between the lens and the digital back.
3. Lens bayonet mount (diameter) In combination with the chief ray angle and rear lens element limitations, the lens bayonet mount can be calculated and estimated at 77 mm.
4. Space for fingers between lens and grip. This dimension is determined by the largest user. The P90 Western male has finger thickness of 2,30 cm. With a tolerance of 10% for clothing (gloves), the space between the lens and grip is set to 2,6 cm.
5. Orientation and angle of the grip. While the grip is fixed, the angle of the grip can be designed at a certain degree. This affects the angle of the wrist while holding the camera. The goal is to have the most neutral wrist position while having the arms close to the body. The general rotation of the grip can be rotated in all 3 axes.

DESIGN LANGUAGE

The XF camera system is Phase One's first full system. Making observations on the design language can only be done on one product, it is therefore too early to say whether the styling was strategically. However, a design language was obtained by observing the XF according to the automotive form hierachy (Grondelle van, 2011).

When considering the main volumes of the camera, the XF has three main blocks and has a cubic appearrance.

Figure 42. Volume and package.

In terms of surfacing, due to the cubic appearrance the amount of curved surfaces is minimized. Seen from the front, numerous features are separate and can be interpreted as a visual expression of the camera's modularity.

Figure 43. Visual breaks that express modularity.

However despite the geometric appearrance, at the shutter release button there's a double curvature line that can be seen as the hallmark of the XF. This can be seen from front and top view.

Figure 44. Design details, chamfers contribute to the geometric appaerrance.

ADAPTABILITY

A function of the camera that contribute to switching position is an adaptable user interface. This function could be supported by using Machine Learning. It is a field of computer science that uses statistical techniques to give computer systems the ability to "learn" with data, without being explicitly programmed. This topic is mentioned as an added value to the concept but is not a explicit focus of the project.

In the XF camera, the allocation of functions for the actuators can be set for a specific job. It is possible to change the set of preassigned functions, if a photographer is active within multiple applications. Yet the allocation of functions is only intended for one hand position (eye level) and thereby restricts the positioning of the hand.

From the desire to shoot from multiple angles, the grip should enable this as best as possible. Current cameras from today are designed only to receive input from the photographer. Without feedback from the camera, this input is being channelled and actuates anything what it should actuate. This however limits the possibilities what can be possible as a camera tool. Any today's camera is not aware of the user's behaviour or body position.

With an emerging technology trend as 'perceptual smart machine', sensing capabilities are now combined with big data and high computation speeds. A machine will be more capable of understanding what the user intends to do and can adapt to this.

A professional would be still in control, but instead of solely controlling the camera, the professional can focus more on the imagined photo and therefore controls the end result. Machine Learning can be implemented in multiple ways and to any extend. Machine learning can work on multiple levels in which in the top level, the camera cooperates to take a photo:

1. Adapt to hand position, re-allocates button functionality.
2. Object awareness, micro adjusts focus.
3. Light awareness, (micro) adjusts light settings. (can adapt to post-process styles)
4. Timing awareness, takes the photo before photographer can react.

For implementing Machine Learning a series of additional sensors are required for data input. It depends on the design goal what type of data input is required. In the case of hand positioning, the grip should be aware of the hand's presence and its actual position.

The full potential of machine learning and the implementation deserves a dedicated study and would be part of previously mentioned design direction 3 (user interface with perceptual smart machine)

STAGE 3. ADDRESSING

As mentioned before, the true act of addressing the concept in the DDI approach is an act that is mostly performed by the firm since it involves collaborating with artists, marketers and retail firms. Only then can the new product proposal become more meaningful.

MORPHOLOGICAL CHART

The morphological chart (Figure 45) is a method to generate ideas in an analytical and systematic manner. Sub functions of the product are taken as a starting point to develop different solutions. The combination of sub-solutions are used in order to arrive at three concepts.

The list of subfunctions in the morphological chart does not cover every requirement the camera should fulfill. Yet this list focuses on creating a meaningful user interaction and functional handling of the grip, as they are prioritised in this stage in order to achieve greatness.

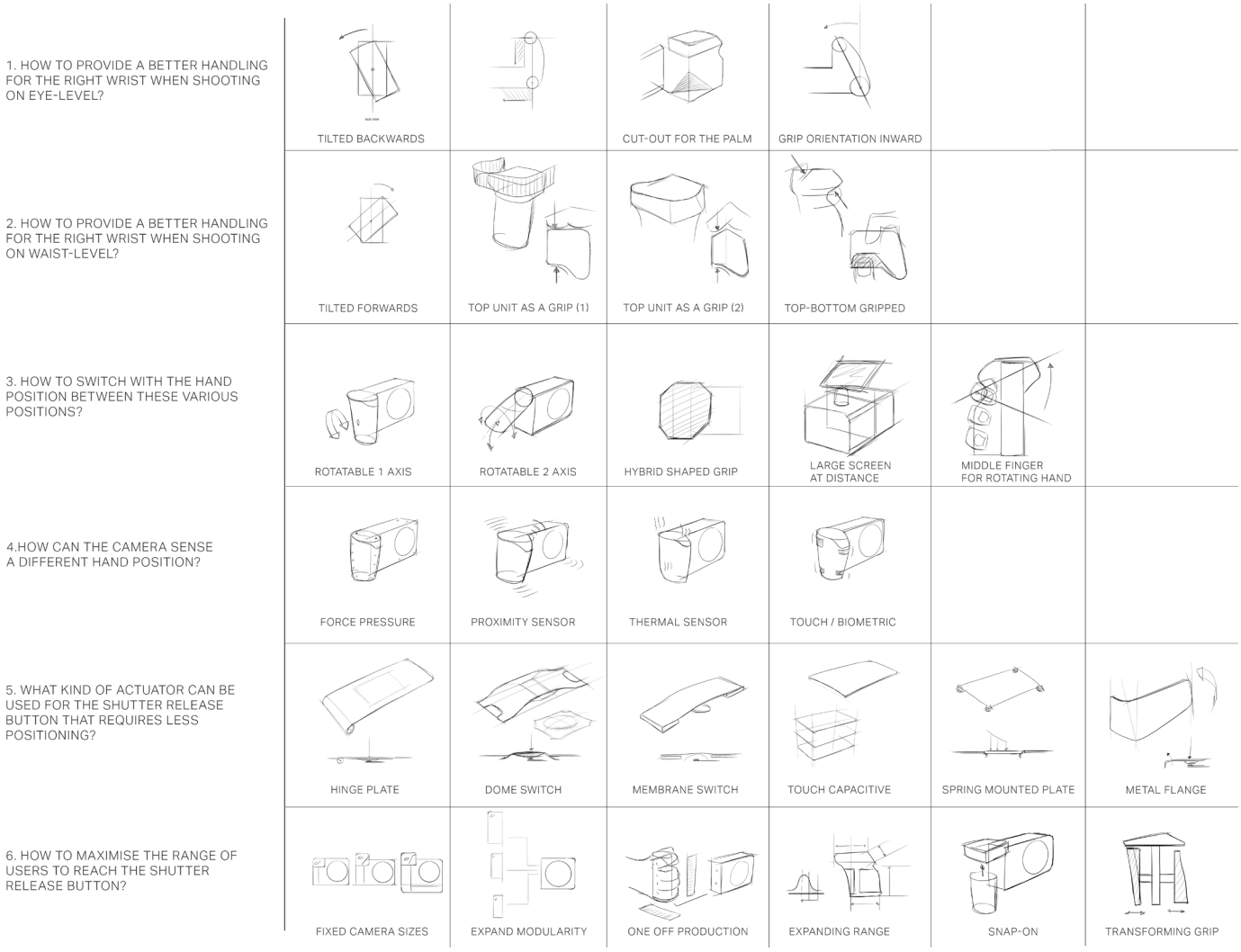


Figure 45. Solutions for the sub functions are presented in a morphological chart.

Aside from ideation in sketches, sculpted foam-blocks wer used to enhance the quality of ideas. During this phase, the set of parameters (Figure 46) was taken into account with room for exploring aesthetic features. During this phase, it was important to find a balance between the grip parameters (working principle, dimensions) and system parameters (components, connectors) while at the same time making an attempt to arrive at something desireable.

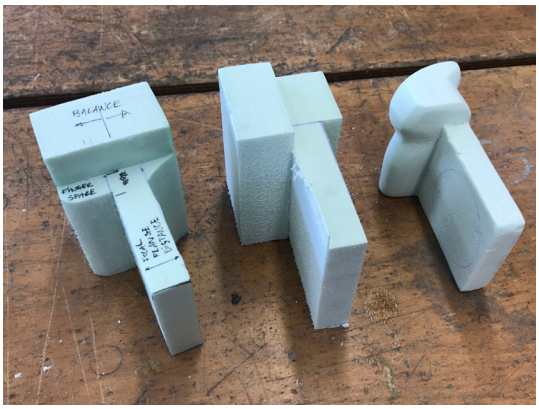


Figure 46. Three stages in order to arrive at an idea.

THE VIEWFINDER

The viewfinder is an important element in the camera system for how the photographer interacts with the camera. It is a tool that helps with composing, adjusting settings, and in most cases it helps with stabilising the camera since it adds an extra point of contact with the body.

The need for unique perspectives, in which the two-fold need of an eyepiece (ocular) viewfinder and waist-level viewfinder covers most of the line of view on the camera should be as convenient and efficient as possible. A two-in-one solution would work best. Due to the removal of the pentaprism, the eyepiece is signicantly reduced in size to a small display, diopter, and a piece of rubber.

Together with considering the volume of the XF viewfinder, this creates space for an additional display. A larger display, fitted flat that will provide feedback when looking down on the camera. (Figure 47)

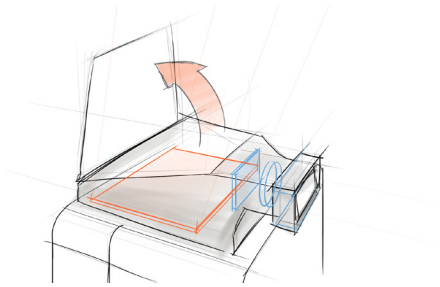


Figure 47. Two types of viewfinders in one housing.

Due to the configuration of the Momentum, the viewfinder will be mounted on the digital back. This creates a direct link to transfer visual data from the source; the sensor. In order to keep the main volumes balanced, maintaining Phase One's design language, the viewfinder will also cover the top of the camera to the front. A rubber gasket can be used to assure a good fit with the camera since it does not require any mechanical connections.

Switching between view modes is achieved simply, by flipping up the aluminium hatch on top. (Figure 47)

When taking a photo, both viewfinders are able to display more information than the standard composition. Exposure simulation and image overlays are features that have been requested accross several applications (Appendix E3). The user interface should anticipate on this, therefore it is recommended to take this into account when mapping the menu settings and button functionality. It is estimated that at least one extra function button would be needed.

Since balance and weight are two important aspects that influence the handling of the camera, and the perception of its comfort, rapid prototyping technique (3D printing) will be used to mimic the design and for the ability to aggravate the models.

CONCEPTS FOR MOMENTUM

To arrive at concept design, sketching was used to explore body form language. In addition, recreating sketch ideas with styrofoam was used to enhance the quality of the ideas. Appendix L shows the iteration steps towards the intermediate three concepts.

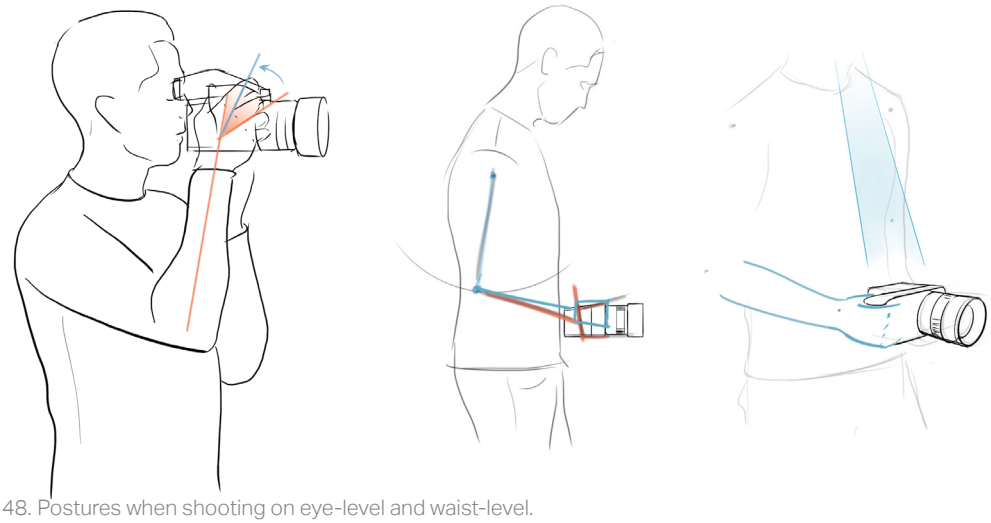


Figure 48. Postures when shooting on eye-level and waist-level.

All concepts work on the basis of having two primal volumes; the grip and the user interface on top. Both incorporate a grip, that allows use of the camera in two positions. They can be described as eye-level and waist-level. For switching between these grip positions, the middle finger works as a fulcrum that the whole hand maneuvers around. (Figure 49) In this way, the user would not have to let go of the grip in order to switch to something else.

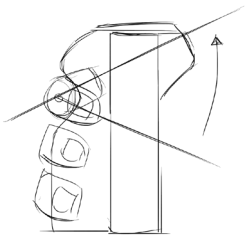


Figure 49. Middle finger as fulcrum.

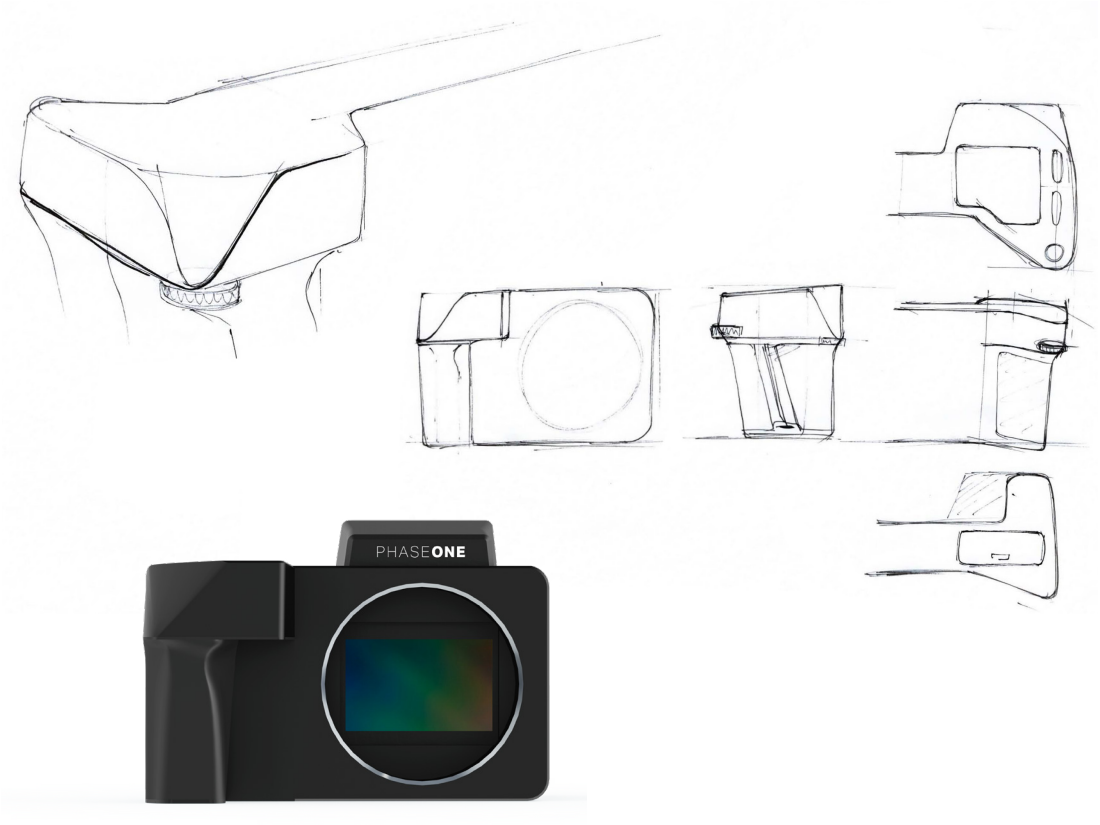


Figure 50. Concept 1

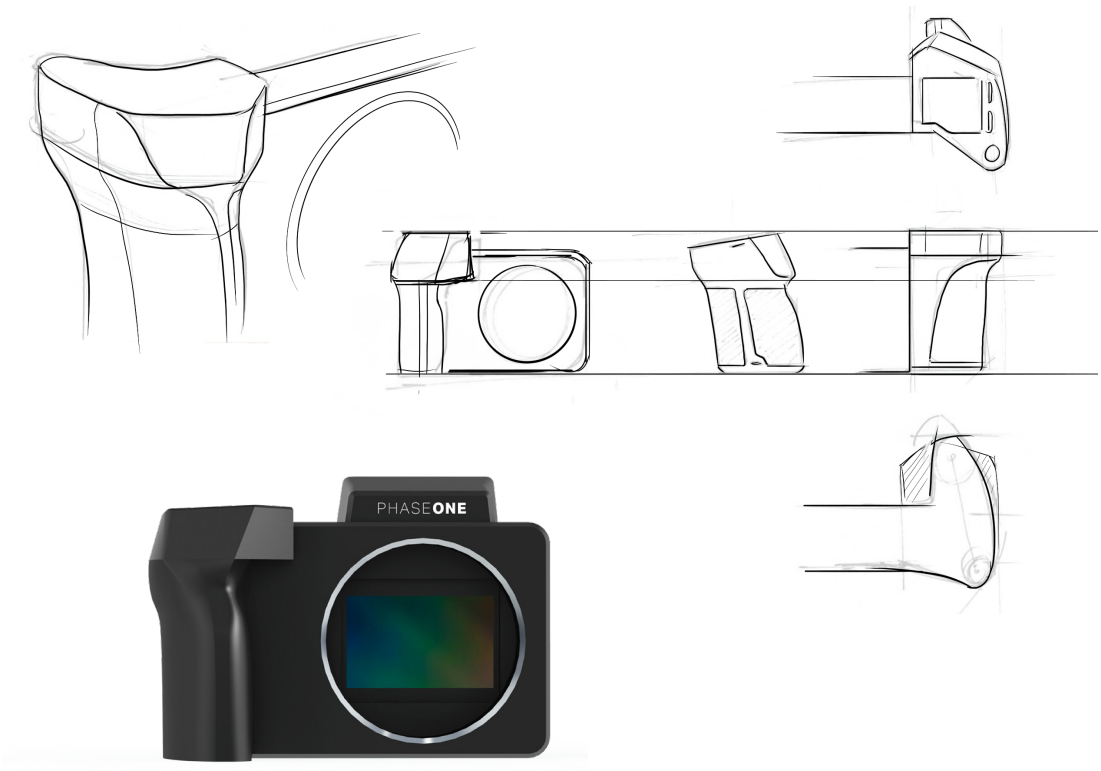


Figure 51. Concept 2

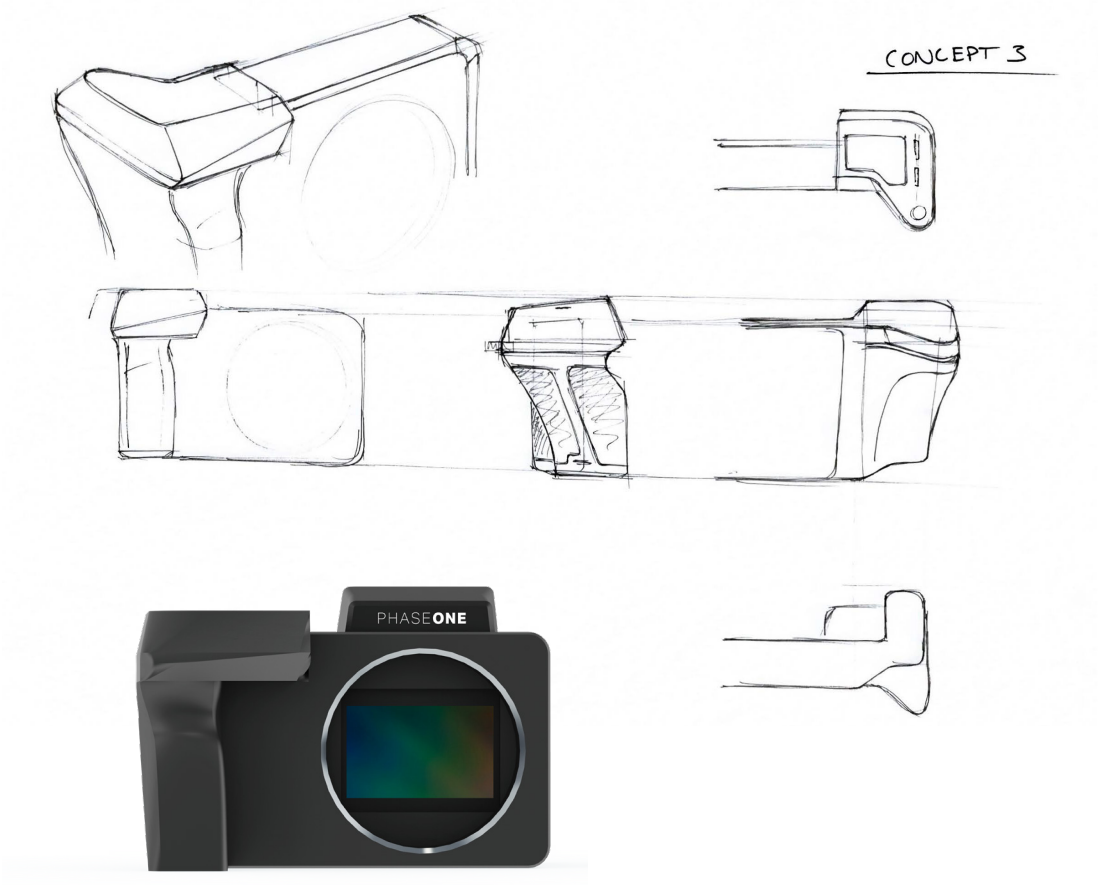


Figure 52. Concept 3

PROTOTYPING

This chapter explains the progress from conceptualisation into prototyping phase. In the prototyping phase it is the goal to make concepts tangible so the functionality of the ideas can be tested.

The camera is a product that balances a mixture of many qualities (ergonomics, technological, perceptual, cultural, etc) In this stage of development, where the primal form is still undecided, the form that ergonomically supports the two-fold of the view modes and the aesthetics are two elements that need to be verified first.

In that sense, an accurate representation is required; produced at the estimated weight of the mirrorless camera system.

The foam models were transformed into a CAD model (Figure 53), using a digital caliper to measure section for section. A full desription of the prototyping phase can be found in Appendix M.

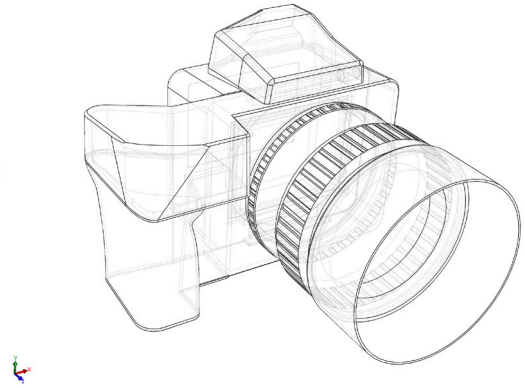


Figure 53. Screenshot of concept 1 in SolidWorks.

The goal was to produce visual prototypes that would resemble an appearrance as close as possible to the intended body design. Selected interviewees could then provide their input on the aesthetics, their perception of use, and the overall feel.

Each concept was 3D printed (Figure 54), then an assessement of the grip, and finally optimised again in the CAD model. Also due to the modularity and changing mass properties, every component was modelled separately and 3D-printed hollow so it could be weighted with sand.

To further replicate the estimated balance, within the camera there has been made a divider to imitate the presence of a battery.

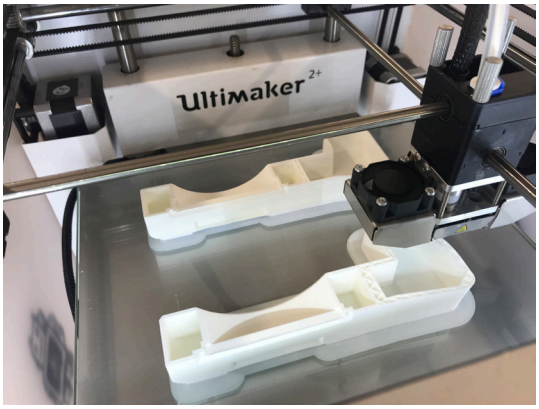


Figure 54. Models are being 3D printed.

The estimated weight of the camera's components:

- Digital Back (IQ5)	700 g
- EVF	300 g
- Camera (with battery)	350 g
- Lens LS 80mm	500 g
- Lens LS 110 mm	900 g
Total weight (w/ 80mm lens)	1850 g

The weight estimation was based on expert estimations, CAD mass calculation (based on the use of magnesium alloy) and in agreement with Phase One engineers.

The camera could be printed in one piece, although the camera would consist over several (constructional) parts. And instead producing three digital backs, one digital back was made with the use of a mounting plate of a digital back. Spare parts from digital backs and cover plates were used for the mechanical connection between the camera and the digital back. This enabled to either mount the prototyped digital back or a working digital back on all three concepts.

In the models, little cutouts were modelled to fit the metal brackets. A combination of construction glue and screws made sure a good fit with the models.

The models were weighted, and the difference with the estimated weight was compensated by fill it with sand. Mounting kit was used to close the drill holes.

Figure 55. Metal brackets, Phase One spare parts, were mounted in the 3D printed models.

Figure 56. A mounting plate from a Phase One digital back can thereby be fitted to the the printed model.

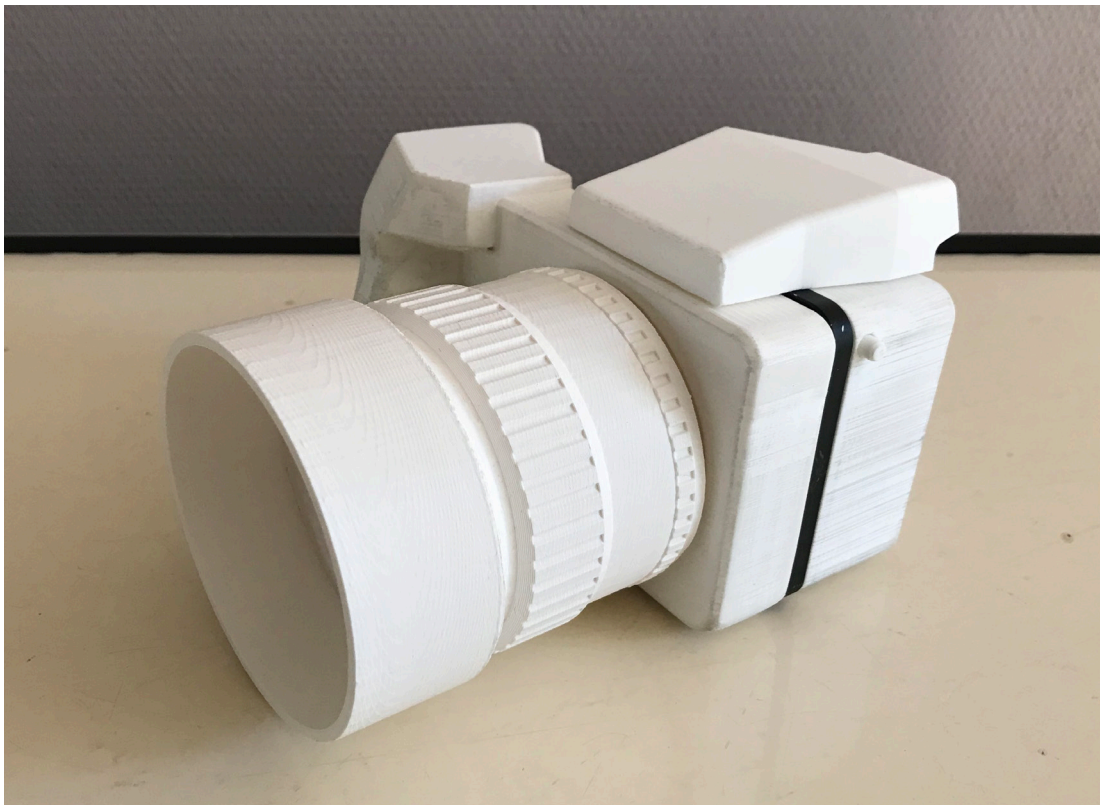


Figure 57. All 3D-printed parts combined together..

USER RESEARCH

To validate the intermediate concepts and to gain input for a final concept, a visit to Phase One's headquarters in Copenhagen was made to talk with in-house photographers and engineers.

The goal was to validate the aesthetics of the concepts and the comfort of the grips. In addition to that, during the meetings the concept of having an adaptable user interface was discussed to find base for acceptance. The visit consisted of four arranged meetings and several small talks on the corridor.

The first two meetings were with Product Management and R&D, a summary of both meetings can be found in Appendix C-A5 and C-A6. This mostly involved discussing technical features of the camera.

The last two meetings were with in total 5 in-house photographers, to gain insight on the feel for the grips and pratical use. In these two meetings, hand measurements were taken and subjective measurement on discomfort and a questionnaire was conducted. The used materials can be found in Appendix N.

Figure 58. Participants are reviewing the concepts and filling in the questionnaire.

The meetings were private, where they were asked to hold the camera and simulate how they would use the camera (Figure 58). The own findings were recorded on audio, notes and/or photos. The sum of scores from the questionnaire and handmap can be seen in Figure 59, the complete data set can be found in Appendix O.

To gather more data but due to the lack of time, five extra people were asked for hand measurements and to assess any points of discomfort.

Summary

n=10	C1	C2	C3
Points of discomfort	29	20	41
After easy solvers	(21)	(12)	(21)

n=5

Descriptors	C1	C2	C3
Fit	6,00	5,60	4,20
Task Performance	6,30	6,00	4,85
Feel	5,80	5,20	4,80
Comfort after use	5,80	5,20	3,40

Figure 59. Sum of all scores.

CONCLUSION

The general conclusion from the four meetings is that Concept 1 and 2 both scored well (aesthetically and in terms of comfort) and show a high potential for further development.

Concept 3 was in terms of looks too far of people's perception of a camera, however on comfort-level it scored well by people with large hands. During the meetings more specific details on the design were shared that will be taken with for the next iteration.

Although a short visit to Copenhagen was fruitful with interesting input, there were diffusive opinions on the implementation of the camera. The idea of a 'perceptual smart machine' or an adaptable user interface seemed too far of people's mind and in that sense too radical. However these opinions might be biased as they otherwise would incline they would want to change traditional photography.

OBJECTIVE MEASUREMENT

In addition to the gathered input in Copenhagen, an additional meeting was scheduled with a stand-alone professional photographer to countereffect the assumed biased opions. In order to find validation on the comfort performance, electromyography was used to measure muscle activity. Discomfort can be correlated with a higher muscle activity (Kuijt-Evers, 2007) In this study, the three concepts were compared with the Phase One XF camera system.

The photographer was asked to repeatedly switch between 'active' (Figure 60) and 'rest' posture in a timed manner. Afterwards he was asked to fill in the comfort questionnaire, which provided time for the muscles to recover for the next measurement.

Figure 60. Participant holds the camaera in an active state during an EMG measurement.

There was a significant difference in muscle activity between the XF and the concepts, where the XF showed higher muscle activity. This result was expected, since the new system has a lower weight and therefore causes less stress on the muscles.

After each EMG measurement, the photographer was asked to describe what he thinks and feels while he was assessing the concepts. This supported the scores of the questionnaire. The full data set can be found in Appendix P.

Summary Michael Graste

	C1	C2	C3
Points of discomfort	4	1	3
After easy solvers	(3)	(1)	(0)

Descriptors	C1	C2	C3
Fit	4,00	6,25	6,25
Task Performance	6,00	6,50	6,00
Feel	6,33	6,00	5,67
Comfort after use	6,00	7,00	6,00

Close to finish of the study, the concept of having an adaptable user interface and the future of photography were discussed. The waist-level viewfinder and an automated user interface would a much appreciated feature that would enhance the quality of his job assignments. However the future context with computational photography seemed premature in his mind and had no strong opinions on this topic.

CONCLUSION

With this study, concept 2 scored overall best considering the aethestics, comfort and having the second lowest muscle activity. The participant also mentioned a strong argument, the grip of concept 2 feels great when picking it up. Concept 2 will therefore be used for the next iteration towards the final concept.

EMG values

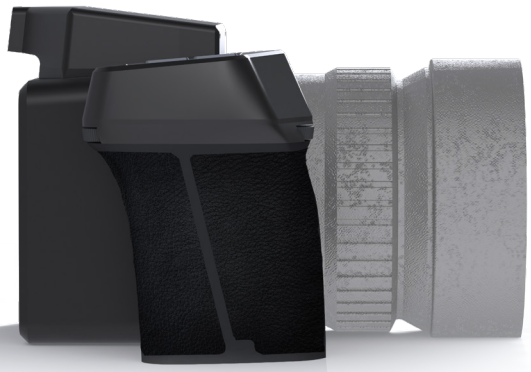
Phase One XF
Peak: 0,3 mV
Active range: 0,15 - 0,25 mV
Rest range: 0,08 - 0,15 mV

Concept 1
Peak: 0,18 mV
Active range: 0,12 - 0,16 mV
Rest range: 0,08 - 0,12 mV

Concept 2
Peak: 0,16 mV
Active range: 0,12 - 0,14 mV
Rest range: 0,06 - 0,1 mV

Concept 3
Peak: 0,17 mV
Active range: 0,1 - 0,13 mV
Rest range: 0,06 - 0,1 mV

PHASE ONE MOMENTUM



DIVISION OF SUB-ASSEMBLIES

Although at this point there is no detailing on mechanical constructions, a general idea of the assembly has been laid out here. (Figure 61) Overall it will use the division principle of the XF as a starting point, although with several recommendations for improvements.

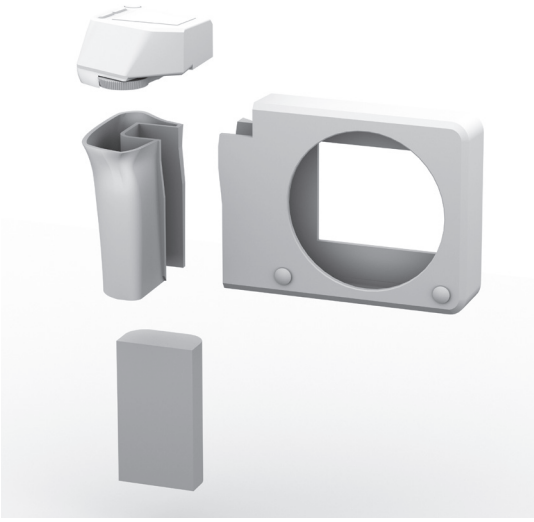


Figure 61. Exploded view of subassemblies, including battery

FOCAL FLANGE DISTANCE

The XF is constructed with a chassis that holds the spring-loaded mirror mechanism and autofocus drive motor. To finish, a series of aluminium milled parts are screwed on the chassis to function as the enclosure. the focal flange distance is a crucial aspect to uphold in camera manufacturing. The chassis of the XF has markers, milled with a tight tolerance to ensure the distance to the sensor of the digital back is exact and consistent after repeatedly mounting and dismounting the digital back. This is also used as reference plane for the autofocus measuring unit.

CAMERA SPACER

In a mirrorless system, where the mirror mechanism is omitted, the focal flange distance has been reduced to 25 mm and within this space there are no mechanical requirements of fitting a delicate mechanism. It only acts as a spacer between lens and digital back. Therefore it is proposed to switch to a more unified body where the enclosure also functions as a structural part.The redesigned spacer should be designed in such a way that during machining, the exact distance for the focal flange distance can be ensured. This is to reduce parts, material and assumably also assembly time.

Heat management, although not addressed in this project, is necessary with faster processors and smaller bodies. In a unified construction, the enclosure can be used as a heatsink to expel generated heat.

GRIP

The grip of the XF mainly consists of two subassemblies, the grip and the user interface (top unit with all the buttons). The grip itself is injection moulded with several inserts for mechanical fasteners. It also upholds a compartment for the battery. As can be seen in Figure 62 with the newly designed grip the original battery will still fit although it is positioned perpendicular. It is proposed to let the compartment be part of the camera spacer. This decreases the constraining factors that affect the volume of the grip. In any case when Phase One considers making a small size version of the grip, the battery is positioned conveniently.

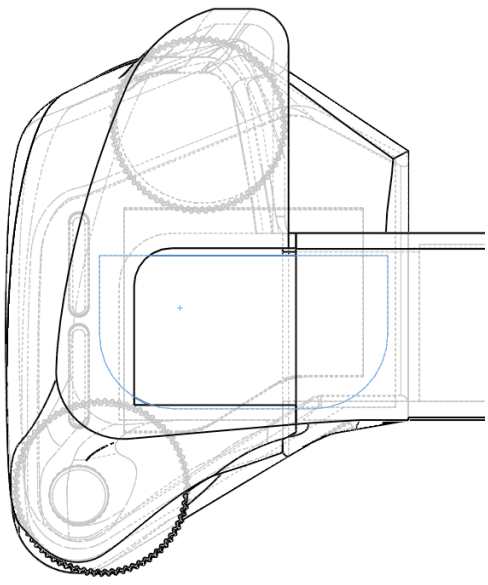


Figure 62. Battery (highlighted blue), fitted inside camera.

ELECTRONICS

The current XF has a set of actuators that covers a broad range of functions. This set of actuators has been maintained as a starting point. For further development it is recommended to reassess the range of buttons and their placement. As to provide proof of concept that the volume of the new grip is sufficient to hold a working user interface, a preliminary layout of electronics has been made.

Primary user interface from XF includes:

- Shutter release buttons (2x) - half press buttons
- Scroll dials (3x)
- Menu buttons (2x)
- Power button
- Customisable function button (2x) - half press buttons
- (Lens release button)

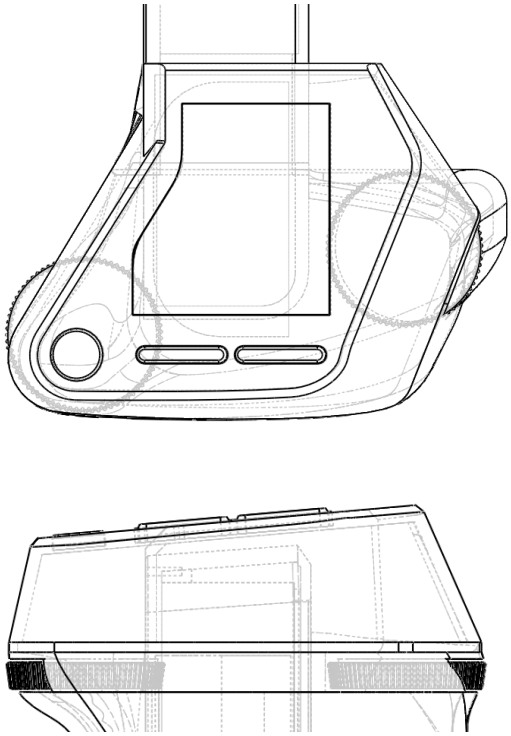


Figure 63. Wireframe of the UI subassembly

In order to reduce space, it is proposed to replace back scroll wheel with a tiltable scroll wheel. This type of scroll wheel is commonly used in computer mouses, it adds two more functions by tilting left or right. The overall volume is comparable to the XF user interface assembly, therefore proves its feasibility in terms of volume.

ADAPTABLE USER INTERFACE

Aside from the standard set of actuators, the adaptability is enabled by the addition of sensors and a microchip that reads and processes the data.

This includes:

- A pair of small cameras - helps with autofocus (phase detection) and object recognition.
- Awareness sensors (proximity / IR) to sense presence of the hands locally.
- Inertial measurement unit (IMU)
- GPS
- Microchip, as can be described as the bionic chip of the camera.

The components for the adapatability are common units, however it's the program code and the use of the bionic chip that empowers the camera. In order to implement this succesful, support from experts are needed to program a tailored-made system.

VIEWFINDER

This includes:

- Display for waist level view mode (2,5")
- High resolution display for eyepiece, including optical diopter for close focus.
- Phase detection system, as mentioned with the adaptable user interface.
- Additional customisable function button to change view settings.

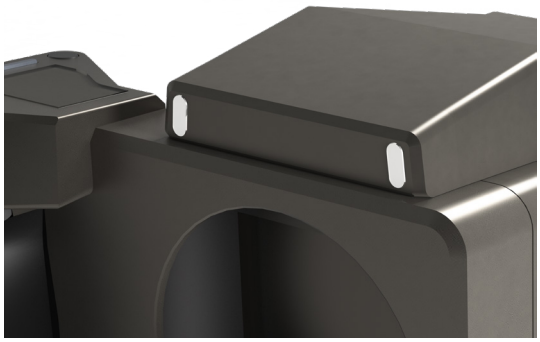


Figure 64. Two small cameras, the size of a smartphone camera, are installed in the EVF for phase detection to use for autofocus.

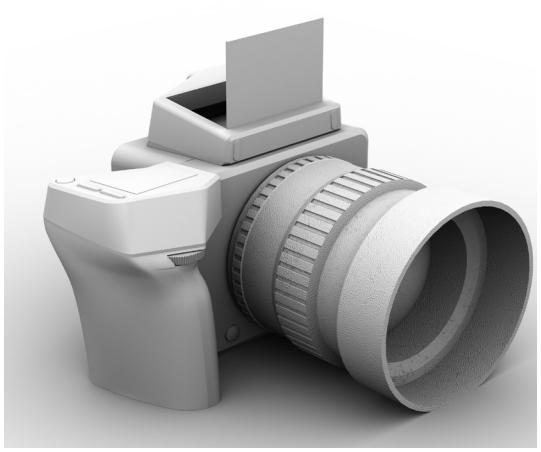


Figure 65. A small hood can be pulled up to activate the waist-level viewfinder.

A small hood on top of the viewfinder covers the diplay for the waist-level viewfinder. When pulled up, the hood and the deepened display maintain good visibility in bright sunlight.

The advantage of having a display as a viewfinder compared to an optical; is the additional features that can be implemented. Commercial photographers on assignment for an advertisement often work with a template for the lay-out. An electronic viewfinder can put the template as an overlay on top of the live view.

An electronic viewfinder consumes more batterylife than an optical viewfinder. Therefore smart power management is critical. An effort into increasing battery capacity would be recommended.

SHUTTER RELEASE BUTTON

In order to increase the range of people being able to handle the camera properly, the area for the shutter release has been increased from a single button to a flange. The mechanics for actuating the shutter release are concealed underneath. In the morphological chart several options were opted, however at this point it assumed a spring mounted flange looks like the most promising option. It is a mechanical experience, it can handle displacement in any direction on the entire area and works with gloves.

Having a flange as a touchpoint not only addresses a larger target group, it also serves the aesthetics of the camera. Due to the minimalist appearance, the second shutter release is located next to it without being shrieking. (Figure 66)

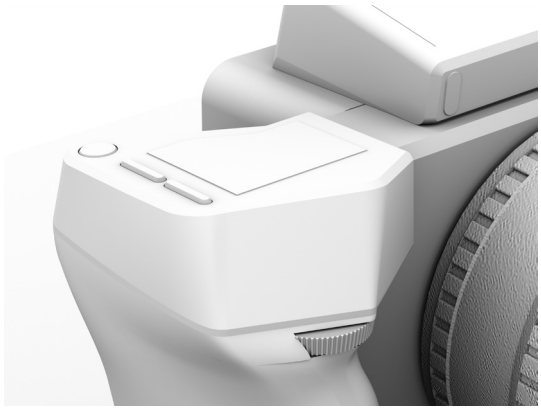


Figure 66. The two shutter release flanges are located next to each other and a minimalistic appearance.

USE CASE OF HOW AND WHEN THE ADAPTABLE USER INTERFACE OPERATES.

FUTURE VISION

Since the product proposal is a product family, the envisioned future vision is divided for three cameras.

MOMENTUM

The ultimate camera tool is a camera that provides excellent comfort and functionality for everyone, and a system that lets the photographer capture his envisioned creation through computationally-aided photography. With a shape-shifting grip, inspired by BMW's light visionary concept car GINA (Figure 66), the systematic barrier for size issues has been removed. State-of-the-art actuators make sure that the right function is in the right place at the right time. The Momentum is there to help capture the photographer's vision, creating stunning photographic images.

Figure 67. The GINA Light Visionary Model is a fabric-skinned shape-shifting sports car concept built by BMW

UDTRYK

Udtryk concentrates on the interaction between the photographer and subject. Connecting and communicating with a model is a vital part of capturing authentic expressions. Body language of the photographer plays a vital role in that. This camera consists of the classically designed box camera, held in one hand, and a wireless grip held in the other hand. A magnetic connector can bring the two together if desired. The ability to freely move your hands creates more focus on the subject, rather than the tool. Wireless communication is the camera's forte, being fully integrated in the studio environment.

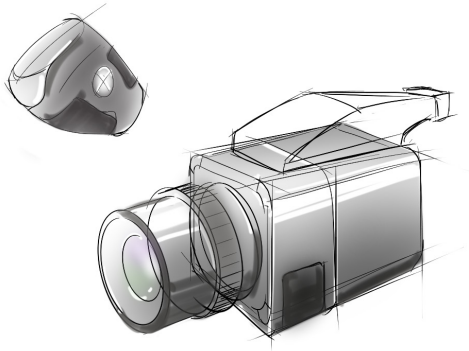


Figure 68. Wireless grip of Udtryk

STILHED

As it is assumed that authenticity will always have a place in digital imaging, Stilhed is a remarkable combination of a technical camera with a pure mechanical interaction but built on an electronic platform that streamlines the post-process workflow. The platform is aware of mechanical settings, automatically creating metadata and based on the metadata the software is able to create an unique calibration profile for each photo. This creates an interaction where photographers can focus more on the act of photography and the journey towards it.

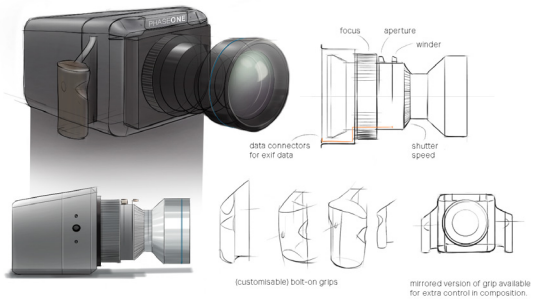


Figure 69. Sketches for the Stilhed camera, a more modern technical camera.

CONCLUSION

The initial challenge for this graduation project was to design a medium format camera, based on a mirrorless system with an interchangeable digital back. This comes from the desire to make a smaller and lighter camera, in which the shifted weight balance and new system interaction were the two key parameters. The grip analysis of the current XF camera system brought two observations, the grip span is only to be held effectively for a small range of the upper percentile (for dimensions of hand-size) of the global population; and that the side handhold causes the wrist to be in ulnar deviation. This has a negative effect on the freedom of movement, comfort, and achievable grip force.

The project went a step further after learning about the heritage of the medium format and its iconic status. A medium format camera is not only a respected piece of equipment, it is a representation of technological breakthroughs that enabled photographers through time to achieve new and better forms of photography. The achievements, photographic results of the photographer in turn gave the camera an iconic status. History research also showed that the form archetype comes from an evolution of volume defining system elements, which over time created an affiliation of how a professional camera should look.

Despite a rich heritage, with today's market dynamics the threat of substitute products (small format cameras) and rivalry among competitors being very high, the mere switch to a mirrorless system in itself would not find the desired establishment of a new iconic medium format camera. From a tech-driven company such as Phase One, the proposition was to switch from a technology push to a different approach called Design-Driven Innovation. This strategy focuses on the innovation of meaning, rather than incremental innovations from a technology push or market pull.

The first stage of the design process led to numerous conclusions. Phase One's target group, defined as the 'World's Most Demanding Photographer', consists of a small but very diverse and highly skilled group of professional photographers. Although Phase One's catalog of applications covers almost the entire industry, their current XF camera system as an allrounder has a dominant presence in only a few applications. The few applications where men assume medium format cameras are relevant. The sociological mismatch with a potential customer base, unfulfilled specific needs, upcoming markets such as the outdoor industry led to a much broader vision than one camera. The proposition is to step away from the traditional mindset of one allrounder and propose a product family of three different specialised cameras.

The next step is the conceptualisation of a camera, this focused on a group within handheld applications in demanding and dynamic outdoor environments. This group of photographers require a camera tool that allows them to create unique perspectives and to capture (spontaneous) moments. The design process resulted in a camera concept that resembles the traditional form archetype, thereby respecting its heritage. But the concept has been enriched with the ergonomic support for a two-fold of perspectives (eye-level and waist-level). This is the first fundamental aspect of the concept.

In order to anticipate a dynamic environment that a photographer moves around in, an adaptable user interface re-allocates button functions to the user's hand when switching posture. The adaptable user interface builds on the technological trend 'Perceptual Smart Machine', where the adaptability is only the first level of the technology's potential. This is based on the prognosis that in the future no photo will be just a 'straight photograph', but where digital imaging shifts towards computational photography. This already happens when light gets interpolated by RAW processing algorithms. This will evolve into where everything will be an amalgam, an interpretation, an enhancement or a variation – either by the photographer as the auteur or by the camera itself. The Perceptual Smart Machine makes the camera platform future proof and is thereby the second fundamental aspects of the concept.

The ergonomic and functional support for two-fold postures integrated in one grip is an unconventional approach in camera design, especially in the niche of medium format. To find base for acceptance, a visit to Phase One's headquarters in Copenhagen created the ability to have interview sessions with several in-house photographers and engineers. During these sessions three concepts were presented and tested on handling. The idea of Machine Learning started a discussion which led to divied opinions. However, aside from that, the overall handling and the aesthetics were positively received. Two out of three concepts were perceived as being desirable. This is a requirement from a business perspective, otherwise it won't sell. Together with the draft lay-out of components, the models provided proof of concept that a mirrorless system can be smaller and lighter without sacrificing image quality or comfort.

DISCUSSION

The improved working principle of the grip addresses a larger audience, but it is the adaptable user interface and possibility of preparing for computational photography that will make this handheld camera unique. The question remains whether this camera has the potential to be the next icon. Although this can only be said after a period of time when the product is launched into market, the first big question that needs to be addressed is whether the conservative nature of professional photographers will hinder the progress of these innovations. Is the medium format in a future context only a romantic fairytale? Or will it become the pioneer depicts a deeper understanding of a photographic image?

RECOMMENDATIONS

1. From a personal point of view, Phase One will be one of the last brands standing in the medium format segment and they might get a monopoly in that market segment. Nevertheless, it is crucial that decision-making forums are still being held by future-minded people, as it can happen that being the best causes a company to stop innovating.

2. From previous meetings, Phase One considered several times to manufacture the mirrorless camera simply as a spacer with handle. The strongest recommendation, as an extension from the project's conclusion, is to consider it as a respected piece of equipment therefore deserving the proper effort to truly make something meaningful and innovative. The conservative nature of photographers does not mean the development of cameras should be the same.

3. As an extension of the second recommendation. Create a creative platform, alternatively a subsidiary of the company, that focuses purely on future visions and advanced concepts. Not only does it serve as a continuous flow of inspiration for future development, the results from these projects can also be shared publicly to inspire the audience and start a dialogue. Ultimately the findings can diffuse into next iterations for either professional or industrial cameras.

4. Keep exploring new state-of-the-art actuators as they are the physical connection between the photographer and the user interface. This helps with the process in recommendation 5.

5. For further development of the adaptable user interface, include experts in the field of Machine Learning and Interaction Design.

   5.1. Machine Learning among other things correlates user behaviour and preferences, making the camera a smarter tool. Within Machine Learning, Big Data is an important asset. The acquired data is not only helpful for taking a photo, but also to streamline the post-processing workflows in Capture One software.

   5.2. An Interaction Designer can help integrate the functionality between the actuators, touch screen, viewfinders, and shooting modes in order to succeed as it is intended.

6. Although the grip of the Momentum has been improved to fit a larger range of users, an ergonomic expert could help in optimising the final details of the grip. When curvatures are optimised, this will reduce tendon pull force and increases the sense of comfort.

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