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EXPLORATION DOCUMENTATION

TEAM BACON

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Introduction

Design thinking is considered as a creative and analytical process that contributes to the experimentation of creative solutions (Razzouk & Shutte, 2012). This process is built on an iterative cycle that addresses technical feasibility at the same time (Dorst, 2011). When this design thinking process is implemented, managing uncertainty and ambiguous options are done on a regular basis and a more typical linear problem-solving approach is less likely to provide results (Dorst, 2011). The following document shows several ideas and suggestions to include the IALL technology in a final product. In this exploration, different approaches and hints were made, starting from the logical places where lenses are used, like cameras, telescopes or projectors and continuing with more innovative approaches like photonics and free space optical-communication. One thing to remember is that most novel ideas are bad ideas (March, 2010). Hence, weeks of research in different fields, which lead us to deal with trial and error strategies, were set aside in order to focus on our final solution: application of IALL in Virtual Reality Headset. In this field, research and interviews were performed in order to obtain a broad perspective about the possibility of implementing IALL technology.

March, J. G. (20 10). The ambiguities of experience. In *The Ambiguities of Experience*. Cornell University Press.

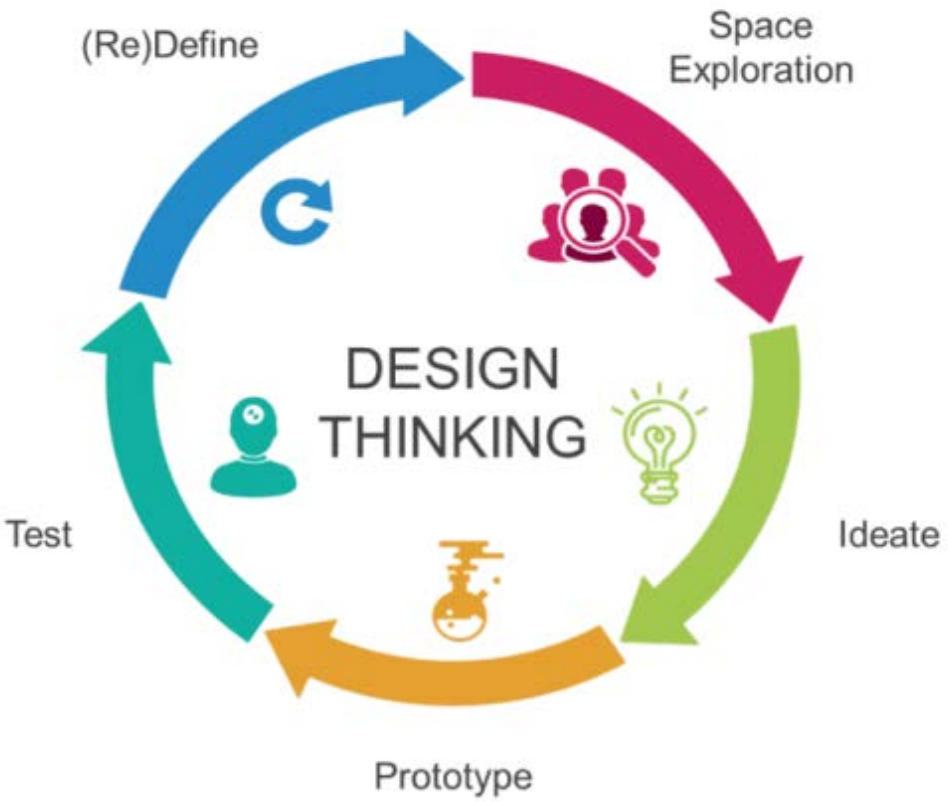
Razzouk, R., & Shute, V. (2012). What is design thinking and why is it important?. *Review of educational research*, *82*(3), 330-348.

Dorst, K. (2011). The core of ‘design thinking’ and its application. Design studies, 32(6),521-532.

Challenge

The major goal of this course is to work on early-stage technology and investigate prospective markets and applications in order to develop product specifications. The main way of design thinking looks like the picture below but a challenge before it can be executed is to figure out what a new technology potentially can do. Therefore, we have explored different jobs and industries where IALL can be used and that led to implementation of the

design thinking below.



1. General areas IALL could be used in

In this chapter we presented some general ideas that we think IALL can be used in. We also have some general information about how Liquid Crystal Lenses work and how they can be adapted.

1.1. General exploration of IALL:

How Liquid Crystal Lenses have been suggested to be used:

“An adaptive-focus lens is a device capable of tuning its focal length by means of the application of an external stimulus”

“Another application sector is the study of the interaction of metamaterials, nanoparticles, and carbon nanotubes with LC.”

“For example, LC can be used to dynamically tune the response of several components of optical communication networks, such as modulators, switches, multiplexers, filters, phase shifters, or fibre polarisation controllers.”
“The use of LC to control or modify signals at millimetre and sub-millimeter wave frequencies is another research field, in which several devices have been proposed, including, among others, tunable antennas, phase shifters, and filters.”
“LC can make unique optical probes for imaging the molecular ordering and chemical patterns of organic surfaces and sensing the chemical reactions such as enzymatic reactions, DNA hybridization, ligand–receptor bindings, and peptide–lipid interactions at the LC/aqueous interface.”
“in addition to the easy integration of LCs in fibre-optics, makes them ideal candidates for the development of distributed sensors.”
Temperature sensing.

- Algorri, J. F., Zografopoulos, D. C., Urruchi, V., & Sánchez-Pena, J. M. (2019). Recent advances in adaptive liquid crystal lenses. Crystals, 9(5), 272.
- https://ec.europa.eu/research-and-innovation/en/horizon-magazine/liquid-crystal-lenses-make-phones-more-efficient

“An adaptive-focus lens is a device capable of tuning its focal length by means of the application of an external stimulus”

“Another application sector is the study of the interaction of metamaterials, nanoparticles, and carbon nanotubes with LC.”
“For example, LC can be used to dynamically tune the response of several components of optical communication networks, such as modulators, switches, multiplexers, filters, phase shifters, or fiber polarization controllers.”
“The use of LC to control or modify signals at millimetre and sub-millimeter wave frequencies is another research field, in which several devices have been proposed, including, among others, tunable antennas, phase shifters, and filters.”
“LC can make unique optical probes for imaging the molecular ordering and chemical patterns of organic surfaces and sensing the chemical reactions such as enzymatic reactions, DNA hybridization, ligand–receptor bindings, and peptide–lipid interactions at the LC/aqueous interface.”

“in addition to the easy integration of LCs in fibre-optics, makes them ideal candidates for the development of distributed sensors.”

Temperature sensing

Lower response time usually is linked with better quality since the photo has more time to update its pixels. However, with a liquid lens, the camera would be able to collect and process the image with its high response time. “Because of their geometry, hypercentric lenses allow us to image the top and the sides of an object simultaneously. This makes them useful for certain inspections tasks, for which otherwise multiple images would have to be acquired and stitched together”

- Algorri, J. F., Zografopoulos, D. C., Urruchi, V., & Sánchez-Pena, J. M. (2019). Recent advances in adaptive liquid crystal lenses. Crystals, 9(5), 272.
- https://ec.europa.eu/research-and-innovation/en/horizon-magazine/liquid-crystal-lenses-make-phones-more-efficient
- https://www.tandfonline.com/doi/pdf/10.1080/21680396.2018.1440256?needAccess=true

1.2. Guidelines

Questions to be answered:

1. How are the jobs from week one being currently done?
2. How have other existing products tried to solve the problem that you have identified?
3. How has the technology of these jobs evolved?
4. What are available solutions on the market?
5. What are their strengths and weaknesses?
6. How do they compare to our companies?

Christensen et al. questions:

1. Do we see any nonconsumption?
2. What workarounds have people invented?
3. What surprising uses have users invented for existing products?

Combining jobs:

1. Where are these new technologies necessary or more impactful?
2. Can we see new markets for this technology?
3. Are there jobs that can be performed that are not done today with the existing technology?

Insights in the Jobs to be done

The jobs to be done by the lens were discussed by identifying its characteristics and areas where lenses are commonly used but there were problems with the solutions.
Insights were taken from the article about the IALL by Geday et al. (nd.) and explored as a novelty. With many areas using a lens, believing in quantity for the first stage to explore as many areas as possible and its possible solutions is important.

1.3. Car cameras

Many automobile cameras are restricted by their ability to concentrate on objects of varied lengths, limiting their ability to observe the environment and be aware of surrounds, or the quality of inexpensive car cameras may be poor. By replacing the camera lens with IALL, the automobile camera may have a wide focal range at varying distances. IALLs technology, when integrated with the LIDAR system, would enable automobile cameras to view at varied distances with excellent resolution and low power consumption, as well as cost-effective LIDAR systems to detect surroundings. As a result, clients will benefit from a long-term, low-cost, and effective automobile security system.

- https://eu.democratandchronicle.com/story/money/business/2016/06/24/7-ways-photonics-change-your-life/84785910/
- Geday et al.

1.4. Light-Projector

Types of projectors that allow the viewing of videos:

DLP Projector: needs a dark environment, but good colours, need to be perfectly placed

LCD Projector: alright quality and comes at all price ranges, colours are not as perfect

LCoS Projectors: very good quality, suffers from too much light, blurriness when image changes fast, just suitable for smaller screens, expansive

LED Projector: decent price but if you want good quality it can get expensive, works also in a surrounding with light, makes no annoying sounds, disadvantages: brightness is not very high, needs certain space for screening

Laser Projector: really good quality but also very expansive

- (The7DifferentTypesofProjectors|Projectorverge.com:https://projectorverge.com/types-of-projectors/)

All types have their advantages and disadvantages, but it seems that in terms of screening movies the least disadvantages are offered by the LED-projectors. Still, the LED projector as with all the other kinds of projectors has its disadvantages. When you want really good quality it can get costly, and it needs a certain range for screening as well as that the brightness is not that high.

With the ALL lens, this gap could be filled. The ALL lens provides fast non-mechanical focusing abilities. That way it can both be used for smaller and bigger screen surfaces. Additionally, it can get rid of annoying sounds that happen through the mechanical focusing of light. When measuring the distance of the projector to the screen through AI the lens of the projector could also automatically adjust and focus on the screen to give a perfect picture.

This lens could revolutionise the way projectors work by not blocking out certain components of the light to create colour or already working with beaming certain colours but using white light and making use of all ifs components. This way the lens combined with AI would not need to have to be attached to a light source. This would allow a flat device that could both work with white artificial light and also with sunlight or every other source of white light. The ALL lens could split the white light into its different colour components and reposition the colours to create a picture. The ALL lens would split up the different colors of the withe light and then beam it to different areas.

This splitting and recompositing the different colour components of the white light could also be used in other areas than screening movies. It could be a cool party light that rearranges all the different colours of the rainbow. Here party locations already work with different colored lights but through the ALL lens there could be maybe a different kind of light feeling or effect be created.

At the moment light can be split into different components through prismas but this does not allow recomposition of the light parts again. With the ALL technology it could be possible to focus the broken up color components on different areas.

These technologies address Jobs to be done in situations where they would improve the current solution. A place where the technology of the ALL lens could create a completely new market is if it were able to make it possible to see different things on the same surface with certain kinds of glasses. This could be achieved through that different information is carried to the viewer through different colors or different wavelengths somehow. A switch on the glasses would let you switch between the different kinds of screenings or there could be different versions of the movies which are fitted for miners or people that do not like to see too much violence

you would have a flat device with a lense in it. Next to it there is a strong computer. With the IALL you could focus the different color components of the lightsource on different points on a surface in front of you.

there are different types of projectors (some are more for creating a picture in the near and some are for creating a picture in the far) → our lens could maybe be one in both.

- https://www.youtube.com/watch?v=3O6qrb1KWBs

- (What are the advantages and disadvantages of LED projectors compared with traditional projectors? : https://tech.znds.com/article/38888.html)1.5. Pest Control

Both for agriculture and livestock Pest control is essential to prevent bigger losses. Here oftentimes farmers make use of chemicals to especially keep smaller animals away from their livestock and their agricultural yield. But those little insects and animals cannot just be dangerous to the profit but also threaten people's life. Very known examples are Dengue Fever Yellow Fever or Malaria which is carried on by Mosquitos,

Kent city- health department identifies 3 types of Mosquito control:

Biological Control: putting a bacterium called BTI in water that is toxic only to mosquitoes and their leaves, other insects are not supposed to be killed.

Chemical Control: Poison that is lakes where the slaves of the mosquitos are in. not good for the environment

Cultural / Source Reduction: try to prevent water from staying still for more than 4 days as this is the time span it takes for the mosquitoes to hatch

- Mosquito Control Methods | Kent, OH (kentohio.org):

  https://www.kentohio.org/244/Mosquito-Control-Methods#:~:text=Methods%20Mosquito%20control%20methods%20include%3A%20Biological%20Control%3A%20A,reduce%20the%20number%20of%20mosquitoes%20in%20an%20area.

1.6. Brain Stimulation

Stimulating the brain with certain very focused waves. Could maybe help against Epilepsy or help in stress reduction or overcoming addictions.

Mental illnesses are a big problem and almost all have their root in the brain. That is why sometimes there are solutions to be found for curing these illnesses by changing something on the brain. The already existing solutions work with electricity or magnetic fields to stimulate the neurons. The electrons can be both implanted in the scule or attached to the head (NIMH » Brain Stimulation Therapies (nih.gov). The electrical stimulation works by electrical impulses stimulating the neurons in the brain.
Already existing solutions are helping people for example against the side effects of parkinson (Deep Brain Stimulation (DBS) | Parkinson's Foundation). But when doing operations on the brain there is always the risk of side effects which could very fast be lethal. The ALL lens could help for the electrical stimulation to be more precise, potentially making use of the technology of redirecting photons.

- https://van.physics.illinois.edu/qa/listing.php?id=2348&t=photons-as-carriers-of-the-electromagnetic-force#:~:text=A%20charged%20object%20with%20an,they%20are%20not%20charged%20themselves.

1.7. Hypercentric optics

Compared to telecentric optics, hypercentric can see depth and with an enhanced field of view, the objective can capture a more holistic photo. This could be used in medical areas or science with the liquid lens as you are able to see a greater area and enhance the vision. With combating the chromatic aberration with the liquid lens, you are able to diminish the distorted aspects of the pictures. The problem in this area that was identified was that hypercentric optics has been used in a limited way but not seen its potential. Additionally, "because of their geometry, hypercentric lenses allow to image the top and the sides of an object simultaneously. This makes them useful for certain inspections tasks, for which otherwise multiple images would have to be acquired and stitched together"

Problem

- Ex security cameras can't see the entirety, only a selected field of vision.

Job

- Enhance vision for cameras and create a vision without chromatic aberration that has a larger field of view.

How?

- Broaden vision and increase sight of vision and sensoring

Solution

- Use the liquid lens with a hypercentric vision to collect light from behind object or around to create a focused and enhanced field of vision

- https://www.researchgate.net/publication/333239914_A_camera_model_for_cameras_with_hypercentric_lenses_and_some_example_applications

1.8. Photosensitive Epilepsy:

LEDs/Displays that are currently in the market produce high flicker rates which can be more than the normal human eye can comprehend(50hz). Any light flickering more than that can affect our health such as headaches, eyestrain, even anxiety, significantly to those who have

photosensitive epilepsy. The techs that are available in the market are usually to make a single light source that continuously transfers the photons that we see as images. Also mostly they are therapeutic, to use it only for a certain amount of time to deliver precisely controlled alternate occlusion but for not regular use. Using the liquid crystal technology that IALL is working on, is to basically improve the auto focus/zoom ability for the lenses without compromising with the quality, which could also control the light that comes through the lenses. Using the liquid crystal technology, it is possible to whirl the patterns of the molecules to control the light that goes through the lenses. Also, with the tech of tunable lenses to adjust the diopters can also help the invented glass to become reusable for other patients.

The issue with the existing tech is that when the lighting switches on and off, the computer screen flickers at a pace that is undetectable to the human eye and still catches the eyes. This flicker causes your pupils to quickly dilate and contract, resulting in a variety of eye problems such as eye strain and weariness. With auto adjusting capability of the IALL, it is possible to tune it to match the flickering and adjust it to the level of making it tolerable for the human eye.

Problem: Existing glasses are not for regular use, therapeutics only. Mostly common are to protect from Blue light only.

Jobs: Glasses to treat epilepsy, seizures, migraine etc that happens from flickering light that affects eyes.

Solution: Introducing regular use of Anti-flickering glasses in all environments. Tunable diopters to make it commercially usable.

- https://www.energyfocus.com/company/flicker-free-technology

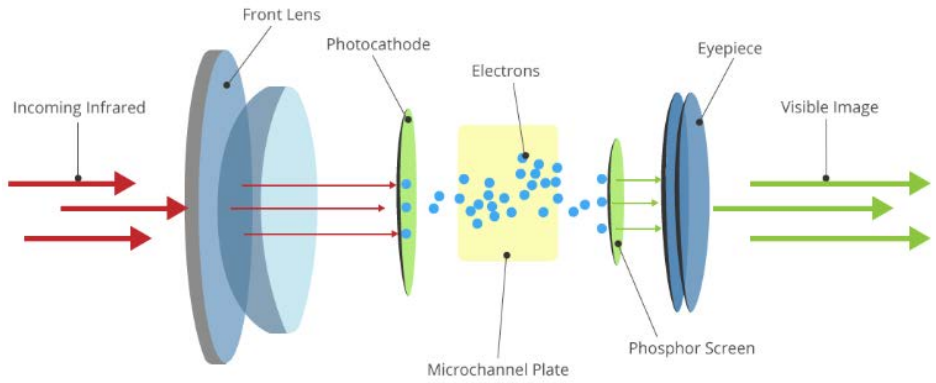
1.9. Internal telescope for damaged eye

Internal telescopes already exist for people with damaged eyes: Miniature Telescope substitution for VisionCare Ophthalmic Technologies. Substitution of this actual technology for our technology which is actually smaller and cheaper. The device is no larger than a pea,

and to date, nearly 400 individuals with end-stage age-related macular degeneration have received implants with a usable-vision success rate of over seventy-five percent.
Macular degeneration damages the retina from the center out. As the sharper central vision is destroyed, people with AMD must increasingly rely on their peripheral vision, which is not nearly so adept at reading text, recognizing faces and the like. Magnification can help, which is where the Implantable Miniature Telescope comes in.

- https://www.afb.org/aw/14/9/15655

1.10. Smaller glasses with night vision and AR.



Problem: prismatics are big
Job: provise focus, vision at night and recognition of the bodies
How: with the use of goggles with ALL + NV + TC

Solution: Small goggles which provide night vision with the use of IR. with the click of a button on one side, the goggles provide more focus. With the button on the other side, the goggles provide Thermal camera vision.

Installation of the lens on helicopter/drone, human use… combining with infrared (human body temperature detection)+ night vision, and also in goggles —-> people rescue, hunters and researchers.

- https://www.ri.se/en/our-stories/ir-technology-use-in-rescue-services
- https://www.universeoptics.com/how-does-night-vision-work/

- https://www.youtube.com/watch?v=rAvnMYqj2c0 TC VS NV

TERMO CAMERA: you need to calibrate according to the climate outside. It depends on the emissivity of material. your body is 37. you will see IF it's not behind a tree, glass, etc… in front.
NIGHT VISION is “day light”: security camera. It has IR (that as we said, you can't see, but makes you shine for the camera.

RADAR: (because of radio, big waves) emit and wait for it will come back. (electromagnetic)
Submarines work with echolocation (acoustic) Some animals, such as elephants, use something similar (both kinds of the same principle). It's not about intensity, it's about frequency.

1.11. Lens in frontal camera that can track eye expressions.

Problem: 7.2% of people in the EU suffer from chronic depression
https://ec.europa.eu/eurostat/web/products-eurostat-news/-/edn-20210910-1
Job: provide professional support to therapist and doctor
How: tracking the identified mood, with the use of of lens, which focus in the recognition of a facial expression with the help of an APP (AI)
Solution with the use of a device as your cell phone, the APP track your mood along the days.
Tracking person mood, which might be useful for a therapist to ident

- https://theconversation.com/ai-is-increasingly-being-used-to-identify-emotions-heres-whats-at-stake-158809
- https://www.ft.com/content/c0b03d1d-f72f-48a8-b342-b4a926109452

1.12. Ultrasonic Imaging

Problem
“An acoustic lens is an attractive device due to its superior ability to image and focus acoustic beams”. The problem with acoustic lenses is that the focal length is fixed once it is made which causes the use of ultrasonic imaging to need more technology and creates a

huge cost. Making the acoustic lens liquid can not only flexibly tune the position of focus, but also avoid greater acoustic impedance

- Molecular Orientation in a VariableFocus Liquid Crystal Lens Induced by Ultrasound Vibration https://www.nature.com/articles/s41598-020-62481-2.pdf

Job

Detects diseases with advanced ultrasound.

Problem

- Babies and moms get sick during labor.

- Breast cancer is the most common form of cancer in women. Not often detected in early stages. → More lethal

Markets

- Sonography

- Mammography (infrared)

- Liquid compound refractive X-ray lens https://opg.optica.org/DirectPDFAccess/F6863D1C-A2D0-43D1-AFD85381A4B3300F_433416/oe-28-15-22144.pdf?da=1&id=433416&seq=0&mobile=no
- Liquid lens with adjustable focus for ultrasonic imaging: https://reader.elsevier.com/reader/sd/pii/S0003682X20308926?token=112600A9AC7D6269A5D8649DF37866148EE200279F9225FB83BC1E9F61CC6CE5E4E0DDBB86022C5A6608DE402E44AEAE&originRegion=eu-west-1&originCreation=20220413081916
  https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=9268177
- Tunable liquid lens equipped virtual reality adapter for scientific, medical, and therapeutic goals https://www.spiedigitallibrary.org/conference-proceedings-of-spie/10817/1081704/Tunable-liquid-lens-equipped-virtual-reality-adapter-for-scientific-medical/10.1117/12.2500292.full

1.14. Random Ideas not fully done

1.14.1. collection of random ideas

Solar panels: Concentrate solar beams, Beam expansion, Focus light on target (https://www.mymagnifier.com/en/product/Fresnel-Solar-Concentrator-Optical-Acrylic-Lens-With-4-Array-For-Green-Energy/Fresnel-Solar-Concentrator-Optical-Acrylic-Lens-SLF16.html

3D-printing

For solar power

(https://www.mymagnifier.com/en/product/Fresnel-Solar-Concentrator-Optical-Acrylic-Lens-With-4-Array-For-Green-Energy/Fresnel-Solar-Concentrator-Optical-Acrylic-Lens-SLF16.html)

Installation of the lens on helicopter/drone, combining infrared (human body temperature detection)+ nigh vision —-> people rescue

(https://www.ri.se/en/our-stories/ir-technology-use-in-rescue-services)--> (questions that come up: its a camera in IR, does lent let IR go throw?; Night vision is kind of IR but still not; NIGHT VISION is “day light”: cheap security camera. it has IR that as we said, you cant see, but makes you shine for the camera.);

https://www.universeoptics.com/how-does-night-vision-work/

TERMO CAMERA (further information: you need to calibrate according the climate outside. It depends on emissivity of materia. your body is 37. you will see IF it's not behind tree, glass, etc… in front.)

RADAR: (cus of radio, big waves) emit and wait it will come back. (electromagnetic); Submarine works with echolocation (acoustic) (Both kind of same principle) For example whales and elephants use echolocation to communicate, its for long distance. its not about intensity, it's about frequency

coding multiplex in optical communication

use it for example in the pizza that they keep it warm all the time. if they use the lens it would be greener.

lens and IR its a camera in IR uses: researchers, hunter…

lent in cell phone which with the use of AI could "show the mood"

Detecting Emotions: https://www.ft.com/content/c0b03d1d-f72f-48a8-b342-b4a926109452

ALL as brain stimulation but that liquid crystals cannot become receptors of electromagnetic fields.

Hypercentric optics (A hypercentric optic can be used to see depth with the reversed logic of as further away you get from the object, the larger it gets.)

Select rays of light, → Liquid

Borescope

(https://www.youtube.com/watch?v=iJ4yL6kaV1A&ab_channel=AppliedScience 2:35)

Fixing **Chromatic aberration in (**We have seen the combination of telecentric and liquid lenses and how it could function in an adequate manner**):**

- Microscopes & telescopes
- Cameras
- Telecentric

Use of lasers:

- https://en.wikipedia.org/wiki/List_of_laser_applications
- https://www.focuslight.com/
- https://www.youtube.com/watch?v=icu2pA47FH4
- https://opg.optica.org/oe/fulltext.cfm?uri=oe-28-15-22144&id=433416

1.14.2. Improving the Field of view (FOV):

Inventing flexible diopters layers: thin layer of diopters that sticks(Removable) to glass surfaces, so anyone can just buy the glasses and use the layers depending on their eyesight.

Lenses that can increase the length of the field of view (Angles). Ex: For them who have one eye/lost eyesight.

1.14.3. Peripheral Vision Glasses (Panorama Glasses)

Problem: limited peripheral vision due to the loss of one eye

Job: provide wider vision
How: with the use of external device who moves further from our eye can avoid the visual limitation of our nose
Solution: external telescopes which already exist, but with the application of our lens, would be small enough to be used as a kind of patch.

- https://www.sciencedaily.com/releases/2013/11/131108102146.htm
- https://www.afb.org/aw/14/9/15655

1.14.4 Fresnel lens for solar power

Ocular disease treatment and management may likewise benefit from progress in fluid dynamics, materials science and microelectronics. Dehydration-resistant materials combined with electro-osmotic flow and reactive oxygen species-scavenging materials--when integrated into lenses--could offer alternative dry eye disease therapies. Liquid crystal cells could replicate the functionality of the pupil and iris arrangement, autonomously filtering incoming light to overcome physiological defects. Embedded, tunable spectral filtering has the potential to mitigate color vision deficiencies.

- https://www.eurekalert.org/news-releases/460016

Ophthalmology and contact lenses and it’s existence in the market:

- https://bioengineeringcommunity.nature.com/posts/a-soft-smart-contact-lens-for-monitoring-of-intraocular-pressures

Select rays of light, → Liquid

- https://www.youtube.com/watch?v=iJ4yL6kaV1A&ab_channel=AppliedScience 2:35

Chromatic aberration

Microscopes & telescopes

Cameras

Telecentric

We have seen the combination of telecentric and liquid lenses and how it could function in an adequate manner.

1.15 Photonics instead of electric cables

"Photonic integrated circuits utilize photons, massless fundamental particles representing a quantum of light, instead of electrons. Photons move at the speed of light through the transmitting medium with almost no interference from other photons. This greatly increases the bandwidth and speed of the circuit while drastically reducing the amount of energy loss, making PICs more power efficient."

- https://www.edmundoptics.com/knowledge-center/trending-in-optics/photonic-electronic-integrated-circuits/
- https://www.youtube.com/watch?v=PljbV-wsxeg

1.15.1 Photonics

Photonics—the science of creating, manipulating, transmitting, and detecting light—is almost everywhere, from smartphone displays to fiber-optic broadband to energy-efficient LED lights and our life-saving laser surgery. As light particles (called photons) replace electrons in many of our key technologies, innovations already underway will improve healthcare, grow food, save energy, reduce pollution, expand connectivity, transform manufacturing and usher in a new mobile era.

- https://digital-strategy.ec.europa.eu/en/policies/photonics

Problem

Expensive, Complexity, it is slow → limitations in space and computing power,

1. Problem: crops get diseases which spread and will reduce or completely destroy the harvest which are difficult to detect with the eye before it is to late

2. current solution: advanced technology to measure health of crops
3. problem with the current technology: It is not accessible to most farmers and they lack the ability to operate it (very complicated and expensive)

1. problem: limitation on what we can do in computing power and space because of the speed of transfer of data (Picture of black hole takes long time to process), information and electricity
2. current solution: using normal lenses to help make it faster
3. problem with the current technology: faster but still not fast enough for some probable future technologies

1. problem: you want to cut certain materials which can not be sawed or detached from one another mechanical
2. current solution: there is lasers that can cut those materials
3. problems with the current solution: hard to cut thicker surfaces because it is hard to redirect and adjust focus of light with the current solution

Job

Reduces cost, enables the zooming function to focus light, enables the use of lenses in more complex ways to for example reduce complexity of construction.

How

Use the lens in photonics to convert light into data and transfer it (instead of electrons). Use lens for laser to focus, in drones combined with sensors to see the health of crops.

Market

In industry 4.0 the need for more customization is needed and the properties of the lens that it is adjustable can be utilized. In agriculture it can be used to scan the health of crops and easier adapt the focus to see better. As a laser it can be used to focus the light and adapt it and combined with photonics it can be even stronger.

- Algorri, J. F., Zografopoulos, D. C., Urruchi, V., & Sánchez-Pena, J. M. (2019). Recent advances in adaptive liquid crystal lenses. Crystals, 9(5), 272.

- https://ec.europa.eu/research-and-innovation/en/horizon-magazine/liquid-crystal-lenses-make-phones-more-efficient
- https://www.actphast.eu/en
- https://actmost.eu/About-us/Micro-Optics
- https://www.edmundoptics.com/knowledge-center/trending-in-optics/photonic-electronic-integrated-circuits/
- https://www.youtube.com/watch?v=PljbV-wsxeg

1.15.2 Agrifood - Photonics

Photonics will help provide safe, nutritious and affordable food for all and build sustainable value chains from farm to fork. Using increasingly accurate sensors and meters, farmers, food processors, and ordinary consumers can monitor and certify the safety, quality, content, and even origin of food anytime, anywhere.

Photonics can monitor soil health and hydrology, predict protein levels in grain harvests, determine when to pick fruit, and map water quality to check the health of fish populations.

- Field Monitoring
- Soil Monitoring
- Control of Harvest
- Machine Operation
- Water Management

1.15.3 Biomedical - Photonics

With forecasts for future double-digit growth, biophotonics is one of the most dynamic and promising markets in the world. Component manufacturers are increasingly focusing on this market and adapting their products to the requirements of system and complete solution providers, creating additional synergies. Breakthroughs in photonics methods and technologies for health and life sciences will help address several major challenges facing Europe and the rest of the world. Due to the changing demographics, especially the aging population, the need to develop new and effective methods and devices to maintain the quality of life through affordable healthcare and the introduction of new low-cost photonics solutions in the healthcare market will be in play an important role in addressing this

challenge. It is also expected that there will be a high demand for photonics solutions in the quality control/assurance of manufacturing processes related to the healthcare market, especially in food and pharmaceutical manufacturing environments that need to meet high quality standards without defects.

Biomedical engineer Chi Hwan Lee has developed a sensor that can be placed on over-the-counter contact lenses to detect glaucoma in patients.

- https://www.visionmonday.com/scene-and-heard/todays-read/article/biomed-engineering-professor-converts-contact-lenses-into-smart-devices-to-monitor-glaucoma/

1.15.4 Industry 4.0 - Photonics

A strong manufacturing industry, and the economic growth and jobs it provides, is critical to Europe's future social sustainability and prosperity. Global competition requires European companies to develop innovative products using new materials and/or new functions, not just through incremental progress to protect niche markets from cheap competition.

This development requires access to key technologies, manufacturing methods and design methods. This means adaptable and evolving factories capable of high-performance, small-scale production, combining flexibility, productivity, extreme precision and zero defects, while maintaining energy and resource efficiency and economic efficiency throughout the supply chain. Key industrial paradigms are shifting: faster time-to-market, broader vision for high performance (i.e. integrating precision, scale or sustainability over productivity), mass customization and service.

The expanding significance of industrial design and the tendency toward customisation, as seen most notably in consumer electronics, will necessitate creative ways for demonstrating new product features and forms, as well as customised manufacturing capabilities.
These great issues will provide chances for new goods and company growth from revolutionary high-tech manufacturing, which will be handled through important enabling technologies such as photonics.

1.15.5. Information & Communication - Photonics

All wireless and cable broadband technologies rely on photonics as a crucial enabler. Optical fiber now transmits over 90% of all data in telecoms, and optical processes are used to manufacture storage media and microprocessors in the microelectronics industry. The marvel of optical fibers allows more knowledge, intellect, and data to be moved from one location to another faster and more precisely than ever before.

Through the development of sophisticated networking technologies, the photonics sector adds new value to the current telecommunications industry, as well as other industries such as chemicals and automotive, helping to reinforce and anchor these traditional businesses and employment in Europe. Photonics is also necessary for the development of more energy-efficient ICT systems.

Optical networking is predicted to play a key role in meeting the demand for expanded ICT capacity while using less energy, opening the path for a future sustainable "green knowledge-based society."

1.15.6. Sustainability - Photonics

Many parts of contemporary life rely on photonics. Green photonics is equally widespread, and it is ideally positioned to address our current environmental and energy issues. Green photonics refers to the most cutting-edge photonics and optoelectronic tools and materials that will minimize power consumption, enable greener production, and generate fresh energy for a variety of applications.

Photovoltaic power production, highly efficient solid-state lighting (SSL), new energy-saving communication technologies, optical sensors for enhanced energy efficiency and decreased pollution, and clean manufacturing employing laser processing are all examples of green photonics.

We will need to develop more efficient ways to create and use energy if our societies are to conserve energy, cut carbon dioxide emissions, and safeguard our delicate environment, and photonics provides solutions for both.

1.15.7. Connected mobility - Photonics

The use of photonics and fiber optic sensor technology in the automotive and aerospace industries has progressed in lockstep with developments in fiber optics and other optoelectronics industries such as solid-state lighting, where LED technology is allowing a new generation of energy efficient lighting systems; optical communications and computing, where fiber optics has radically transformed how data and information is handled; and lasers, which dominate the compact disk, DVD, and laser industries. As a result of this cross-domain synergy, a slew of new technologies, including 3D printers and smart sensors for pressure, temperature, and liquid level sensing, have developed, with many more on the way.

Emerging technologies for cryogenic hydrogen leak detection systems for space applications, a new generation of fiber optic sensor using holography for motion and vibration detection in an automobile bumper shock, and a 360-degree vision system for cars are among the state-of-the-art fiber optic sensor technologies for photonics in Automotive and Aerospace. At the same time, laser machining is allowing significant advancements in the manufacturing process, including Direct Parts Marking, UID, Date Codes, Bar Codes, Time Stamps, and all other permanent markings on parts and components for traceability and code compliance. In the sphere of production, the potential of 3D printing for the automotive and aerospace sectors is likewise a fast expanding phenomena.

1.15.8. Smart cities & living - Photonics

Sensors and metrology skills are in high demand everywhere. Advanced sensor technologies are critical not only for safeguarding the public's safety, security, and health, but also for assuring the quality of our food and other consumer items, as well as for improving production and manufacturing processes. Border, seaport, and airport security require image sensors, smart vision systems, and thermal imagers.

3D imaging, biometric systems, and medical imaging all benefit from advanced sensors. Modern remote sensing techniques provide precise air pollution and vegetation monitoring, which are critical inputs for climate change policy and catastrophe monitoring. Not just in the oil and gas business, but also in the sphere of onshore and offshore wind turbines, the emergence of optical fiber-based sensor technologies today enables for extremely efficient and sustainable use of energy resources.

The incorporation of photonic sensors into big civil engineering structures and airplanes enables for continuous monitoring of their integrity, resulting in increased public infrastructure and transportation safety. Security, metrology, and sensors are three domains that clearly target the world's most vital markets.

2. Optics

In this chapter we present on where we think IALL could be used in the field of optics. This is one of the areas we dicided to focus a little bit more one and conducted some of our own interviews in this field.

2.1. Exploration

2.1.1. Having several pair of glasses as fashion items

Very fashionable people who also have the money usually have a lot of glasses as fashion items. This is very expensive as for every pair of glasses the optician needs to create an individual lens for the specific eyesight correction. Additionally, after customers know the value of their diopters, they can just order glasses online and do not need the opticians anymore. This runs a lot of options out of business.

The solution our product could provide is glasses sharing (opticians could offer that as a new service). You borrow your glasses, or you buy it, and the optician buys it back for a reduced price after you do not want it anymore because your style changes or you feel like something new. The optician has then the possibility to change the dioptric of the glasses each time he sells/ borrows them to a new customer and can make money with that. Additionally, the customers are more forced to buy glasses in person again.

Generally, the idea of a sharing culture becomes more and more popular over the last few years and people also become more open to it.

2.1.2. Changing eyesight for kids

Kids often get worse and worse eyesight over time. This forces parents to buy new pairs of glasses every one or two years. This is both expansive and is also time costly. Especially because one pair of glasses is not enough, and they also need some sports and sunglasses

with the dioptric. This fast adds up to a lot of money very fast and is difficult for a lot of parents to afford.

The IALL could make the glasses adaptable to the changing eyesight and the opticiner could charge a small fee every time he does a correction

2.1.3. Eyesight test

At the moment function with a mechanical change of the dioptric and the machinery to do those eyesight tests is rather big. With the new lens this could change.

2.1.4. All lens connected to AI

At the moment people need to go to the optician to get their dioptrien measured which needs time and resources. AI lenses connected with lenses measures the the dioptrien the person needs and contacts and glasses adapt automatically

2.1.5. related information

Israeli Startup Creates Lenses That automatically adjust by tracking the pupils, to help the wearer focus on objects both far and close up. The Omnifocals has two sensors (plus battery). One is able to track the user pupils. An electrical signal sends the focus of the user to the liquid crystal lens to provide a clear vision.

- https://www.algemeiner.com/2016/03/10/israeli-startup-creates-lenses-that-track-pupils-adjust-to-distance-video/

2.2. Interviews and reviews

In this chapter we showcase our interviews and reviews from people we have interview and the questions we have prepared for it.

2.2.1. Questions for the pedestrians

(ask people on the street who were glasses to fill out the survey):
There is a technology that the diopter of lenses can be adapted:

1. If you could return glasses to the option and he/she would buy them back. Would that be a service you would make use of?

Yes, no

2. If yes, would that make you get glasses more often?

Yes, no

3. How often would you want to change your glasses if it was just connected to a small fee (roundabout 20 to 40€)

1: more often than 4 times a year 2: between 1 to 4 times a year 3: between every and every 4th year 4: less often than every 4th year

4. How often are you changing glasses at the moment

1: more often than 4 times a year 2: between 1 to 4 times a year 3: between every and every 4th year 4: less often than every 4th year

5. How much more less would used galsses have to cost for you to buy used

6. What is your motivations: (1:not so fitting 6: very fitting)

sustainability:	01	02	03	04	05	06
cost:		01	02	03	04	05	06
flexability:	01	02	03	04	05	06

drafted from: Pedestrians: Is this interesting for you? Would you be willing to buy used glasses? Do you feel the need to change glasses? Are new glasses a limitation right now? What would motivate you too use this service? Rank it. Is adjustment something you are interested in?

adjustable lens (mass prod, share glasses, sustainability)

Jobs: sustainability, luxury in restaurants enable people to read the menu, mass production

Questions: What optics do people have? Is there a market? Is there a need for the lens? Can this be a threat?

2.2.2. Interview with an optician

questions for an Optician: What do you think of this new technology? Where do you think it can be used? Can it help your business? Make you relevant again with giving a service (Online). Market for this? What price is realistic? How much will you charge for the service?

The interview:

The interview was conducted with an Optician at Kafa Optik AB in Motala.

The interview started with an explanation of IALL with a focus on that it could change the dioptria and perhaps with an AI automatically change the dioptria depending on eyesight. Our idea with sustainable glasses he thinks will not work because glasses usually get scratched and that is the main reason why people change glasses otherwise he believes there is no need.

Something revolutionary IALL could help with is progressive glasses where he thinks if IALL could regulate the distance and dioptria depending on where a person is looking that it could be a revolutionary product. There is a big need for this especially for older people and the glasses currently are very expensive and people pay for it.

Narrowing down the research to two main fields

Making the decision to narrow the research down to two main areas was due to feasibility and the information given to us in the feedback session. Here, we decided to keep one safe bet (VR) and one that we saw as the greater long-shot but with the potential to have great impact in the future. The previous areas were, therefore, disregarded as their potential to either exploit the network we had and make contact with experts were lower, or the jobs they would solve were not at the same level.

3. Free space communication

In this chapter we researched Free-Space Communication (FSO) which was one of the two ideas we decided to focus more on during the exploitation week. We decribe what FSO is and show where and how it can be used and some prototypes. We also contucted and inteview with a researcher at LiU and a field research.

3.1. The jobs to be done with Free Space Communication, a recap of weeks 1 and 2

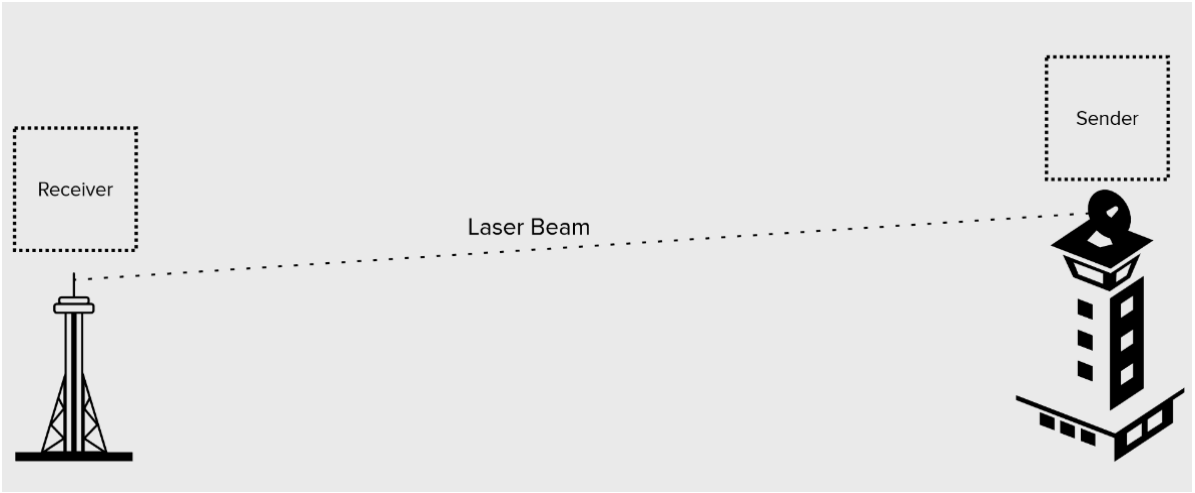
Free-space optical communication is a communication system that wirelessly transmits data for telecommunications or computer networking through light traveling using a laser beam in free space. Enabling the wireless communication that is done through the optical solution has been in research for the last two decades. Lenses that carry out the light beam from the communication device generally point out the encrypted end of information to the decrypted end that is the receiver of the Free space optical device. Most of the existing devices that are in the market are mainly focused on making short time connections in the urban areas where making new connections with wire is much more expensive and difficult.

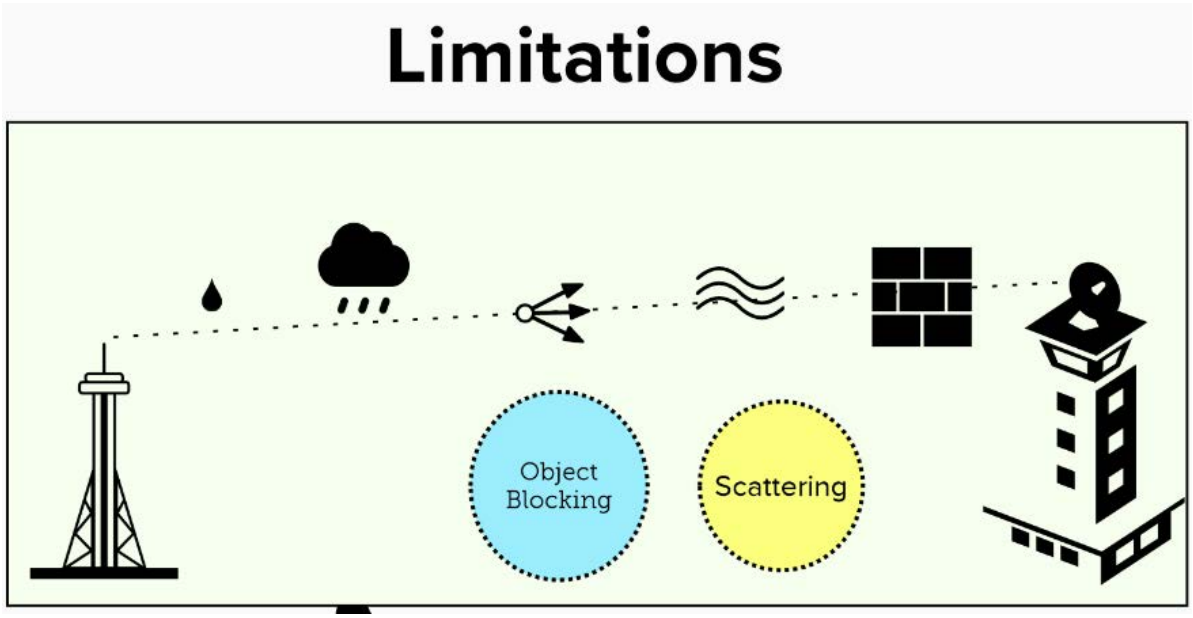
FSO communication could serve the purpose to many other industries as well such as the space, where the communication is required more in a safer way. The advanced technology it has to offer, can ensure a more secure and fast way of internet which is becoming a basic need in the upcoming era. The device of any Free Space Optical communication uses the specialized lenses in both the receiver and senders end to transmit

and receive data, where IALL can play an important role as we know the prototype of the lens can work well with non-mechanical auto-focusing.

FSO devices need to be more precise on sending the light beam to the receiver's end, where the obstacles shouldn't be blocking the data to reach it to the core. IALL can help with emitting more accurate light beams and can direct it to be narrower for it to reach within any given weather condition, which is the most viable obstacle as of now for the FSO's that are in the market. The only limitation as of now is to have a direct line of sight which makes it difficult to travel it to longer range. But if combined with the perfect lens and with the powerful light beam to be sent out to space to the satellite and to come back to the receiver end can reduce that limitation as well. IALL being the lens that can reduce the cost and the size could be a great solution to that where it will make the FSO more possible for longer range, as it will then can emit the beam as however the projection length and narrowness it requires to reach its destination end.

Therefore, in order to make the FSO more accessible in the future, the only limitation that needs to be reduced is the line of sight that it requires to reach its destination. And the second most viable limitation is to travel the beam in longer range, IALL is a solution that opens up the opportunity of the beam to travel longer range. With the non-mechanical focusing, IALL could also reduce the cost of installation of the lenses inside the free space optical devices that are already in the market.





3.2 Deeper Exploitation, Week 3&4

3.2.1 Free Space Optics applications:

The need for FSO in different industries is crucial. Using this advanced technology is not only important for ensuring the new ways of working and sharing knowledge and information to the public and personnel, but also for guaranteeing the quality, security, cost effectiveness and transmitting real-time data at the speed of light in the form of a laser beam. There are a number of applications, the FSO technology can be used as a source of transferring data. By networking and telecommunication, FSO transmit information or an image through invisible light from point of sending to point of receiving with the high efficiency and low distortion. Moreover, FSO can be helpful in temporary network installation for events or other purposes such as disaster recovery or security purposes for communication. FSO is now being used for communications between spacecraft, including elements of satellite constellations.

The FSO helps in enterprise connectivity as this technology laser lines are ideal for joining local area network segments that are housed in buildings separated by public roadways or other right-of-way property due to their ease of installation. It can also be useful in service acceleration to provide instant service to fiber-optic customers while their fiber infrastructure is being laid or failed. Finally, FSO seems a promising solution to the connection of end-users to the service providers.

- https://www.hindawi.com/journals/ijo/2015/945483/

Free Space Optics Advantages:

FSO covers long distances with low bit error rates (BER) high speed rates, the high bandwidth and high-speed connection up to Gbps which is far more beyond the alternative systems. It transmits data through very narrow and directional beams. It provides immunity from electromagnetic interference, electronic light does not interfere with radio communications, interact with other systems or compromise transmissions from aircraft and ships.

Moreover, using FSO in public areas is safe for eyes, no health hazards so even a bird can fly unharmed through a beam. The deployment is quick and easy while low maintenance (Practical). The cost of installation is lower as compared to fiber networks and licence-free long-range operation (in contrast with radio communication).

- https://www.intechopen.com/chapters/47585
- https://www.iberdrola.com/innovation/lifi-technology#:~:text=LiFi%20(light%20fidelity)%20is%20a,internet%20signal%20through%20light%20waves

3.2.2 Space communication

Space communication for deep-space missions, inter-satellite data transfer and Earth monitoring requires high-speed data connectivity. The reach is fundamentally dictated by the available transmission power, the aperture size, and the receiver sensitivity. A transition from radio-frequency links to optical links is now seriously being considered, as this greatly reduces the channel loss caused by diffraction. A widely studied approach uses power-efficient formats along with nanowire-based photon-counting receivers cooled to a

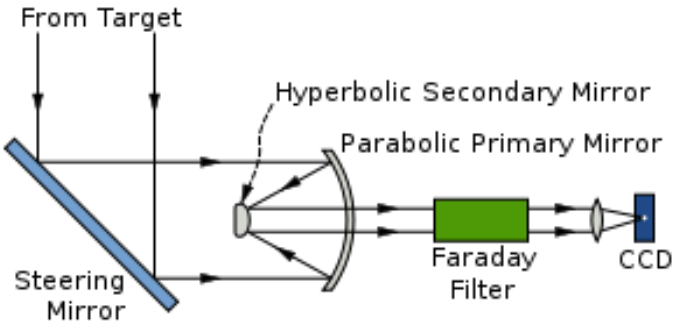
few Kelvins operating at speeds below 1 Gb/s. However, to achieve the multi-Gb/s data rates that will be required in the future, systems relying on pre-amplified receivers together with advanced signal generation and processing techniques from fiber communications are also considered. The sensitivity of such systems is largely determined by the noise figure (NF) of the pre-amplifier, which is theoretically 3 dB for almost all amplifiers. Phase-sensitive optical amplifiers (PSAs) with their uniquely low NF of 0 dB promise to provide the best possible sensitivity for Gb/s-rate long-haul free-space links. Here, we demonstrate a novel approach using a PSA-based receiver in a free-space transmission experiment with an unprecedented bit-error-free, black-box sensitivity of 1 photon-per-information-bit (PPB) at an information rate of 10.5 Gb/s. The system adopts a simple modulation format (quadrature-phase-shift keying, QPSK), standard digital signal processing for signal recovery and forward-error correction and is straightforwardly scalable to higher data rates.

- https://pubmed.ncbi.nlm.nih.gov/32944229/

3.2.3 Laser tracking and communication

Without an atomic line filter, laser tracking and communication may be difficult. Usually, intensified charge-coupled device cameras must be used in conjunction with simple dielectric optical filters (e.g. interference filters) to detect laser emissions at a distance. Intensified CCDs are inefficient and necessitate the use of a pulsed laser transmission within the visible spectrum. With the superior filtering system of an ALF, a non-intensified CCD may be used with a continuous wave laser more efficiently. "[Atomic line filters] with passbands of about 0.001 nm have been developed to improve the background rejection of conventionally filtered laser receivers". The total energy consumption of the latter system is "30 to 35 times less" than that of the former, so space-based, underwater and agile laser communications with ALFs have been proposed and developed.

- https://en.wikipedia.org/wiki/Atomic_line_filter)



Source: Wikipedia

The cassegrain system consists of two reflecting surfaces: a concave parabolic main dish and a convex hyperbolic secondary dish. Cassegrain telescope has shorter main reflector focal lengths, and hence is more compact than conventional parabolic reflectors as shown in fig 3. This kind of optical telescope can get much higher gain than others. The magnification of the telescope serves to decrease the divergence of the beam, thus making it spread out less.

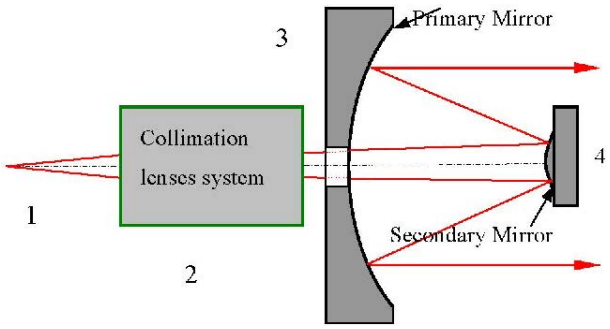


Figure 3.Schmidt Cassegrain antenna

- https://www.hindawi.com/journals/ijo/2015/945483/

3.3 Interviews & Field study

These interviews were conducted in a semi-structured way in order to see how free-space optical communication (FSO) works and where and how it could be implemented.
We prepared questions for different interviews depending on if we were interviewing a researcher, organization, company, or pedestrian. To get in contact with them we sent emails

and went to specific organizations and companies working with FSO and asked for interviews and field studies. We got in contact with some researchers but only one had time for an interview. The interview provided us with a contact to also conduct some field studies regarding optical communication and how lasers can be used to communicate.

3.3.1 Interview Questions

We prepared some general questions for the semi-structured interview and they were the following:

1. What is your main problem with optical space communication?
2. Do you have any problems regarding your optical lenses?
3. How are you currently using optical lenses in space communication?
4. Do you work with Liquid crystal lenses in general? If not, do you think it might work?
5. How are you using optical space communication right now?
6. Do you think a new lens that can direct the data more specifically will help improve space communication or data transfer?
7. How close are we to getting satellite broadband services?
8. What's the market for optical space communication?

3.3.2 Interview with Guilherme

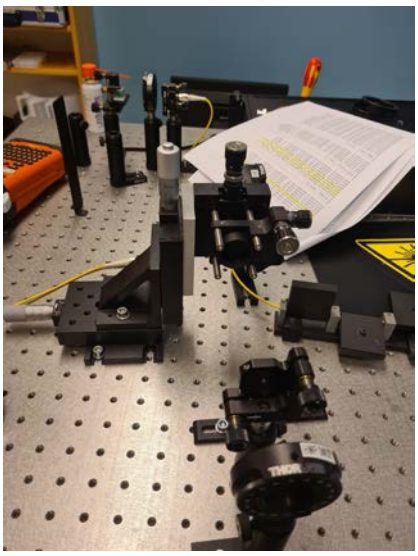
The interview we conducted was with a researcher in optical communication at Linköping University.

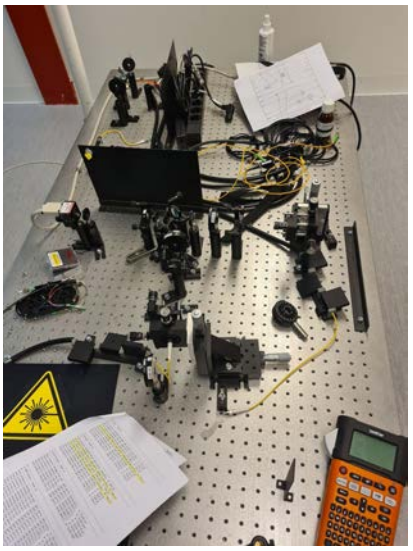
The interview provided us with insight into how optical communication works and helps us to continue with our research in free-space optical communication. Guilherme provided some problems including the communications and some existing solutions. The problems

with FSO are that it needs a line of sight and cannot be blocked by anything. Another is that it is affected by gravity and this needs to be considered. One more problem is that the beam after a certain distance starts to scatter or spread. Lastly, he mentioned that the beam could also be affected by the weather. Due to the semi-structured interview, we asked him if he believes that IALL could help with the problems FSO is currently facing. He believes it can help with especially beam scattering and beam spread but may help with more such as absorption.

3.3.3 Field study in FSO

We conducted some field research or were invited by Guilherme to test how optical communication could work on a smaller scale. Initially he showed us how it would work and then we tested it. He also provided us some insight into how light could work as an internet connection.





3.3.4 Emails regarding FSO

Researchers:

Hello Peter,

We are a group of students studying for a master's in strategy and management in the international organization at Linköping University and are currently looking into problems and solutions in optical communication aka free space laser communication. We are working on a project of optical solution for the ongoing semester and found your article on *"One photon-per-bit receiver using near-noiseless phase-sensitive amplification."* which we

found interesting and was wondering if you have the time to answer some of our questions regarding optical communication. We would love to have a conversation with you in any mode of communication you prefer. Due to the timeframe of the project being limited we would prefer to have a meeting with you this week or the following week. Do you have time to accept our invitation for an online meeting?

Looking forward to hearing from you,

Kind regards,

Anes Handanagic

Space station:

Hello,

We are a group of students studying for a master's in strategy and management in International organization at Linköping University and are currently looking into problems and solutions in optical space communication. We are working on a project of optical solution for the ongoing semester and was wondering if you have the time to answer some of our questions regarding opticals space communication. We would love to have a conversation with you in any mode of communication you prefer. Do you have time to accept our invitation for a short online meeting?

Looking forward to hearing from you,
Kind regards,
Anes Handanagic

SAAB:

Hello,

We are a group of students studying a masters in strategy and management in international organizations at Linköping University and are currently looking into problems and solutions in optical space communication. We are working on a project of optical solution for the ongoing semester and was wondering if you have the time to answer some of our questions regarding opticals space communication. We are also wondering if it is possible to conduct

some field studies regarding optical communication?
Due to the timeframe of the project being limited we would prefer to have a meeting with you this week or the following week. Do you have time for a meeting and is a visitation possible?

Looking forward to hearing from you,

Kind regards,
Anes Handanagic

3.4. Big producers of the coming generation of FSO:

3.4.1 FSONA

While most metro fiber rings have sufficient capacity, carriers typically cannot afford installing fiber to every building in a given location, which limits revenue possibilities and frustrates commercial clients. SONAbeam® solutions enable service providers to expand their fiber ring revenue base by adding lateral lines to off-net facilities, allowing them to respond swiftly and cost-effectively to any customer's request. Customer-Provided Access Arrangements (CPAAs) are another appealing way to boost backbone fiber income using FSO.

- http://www.fsona.com/solutions.php?sec=sp

As requirements grow and utilization of corporate networks expands, the need to connect off-net facilities with high bandwidth increases. Companies, airports, hospitals and schools can use safe, secure SONAbeam® optical wireless links to connect buildings within their campus environments. Offering the speed of fiber optic cable at much lower cost and much greater flexibility than fixed link wireline solutions, SONAbeam® links can readily be redeployed in the event of a site consolidation or move.

- http://www.fsona.com/solutions.php?sec=enterprise

3.4.2 Cable Free

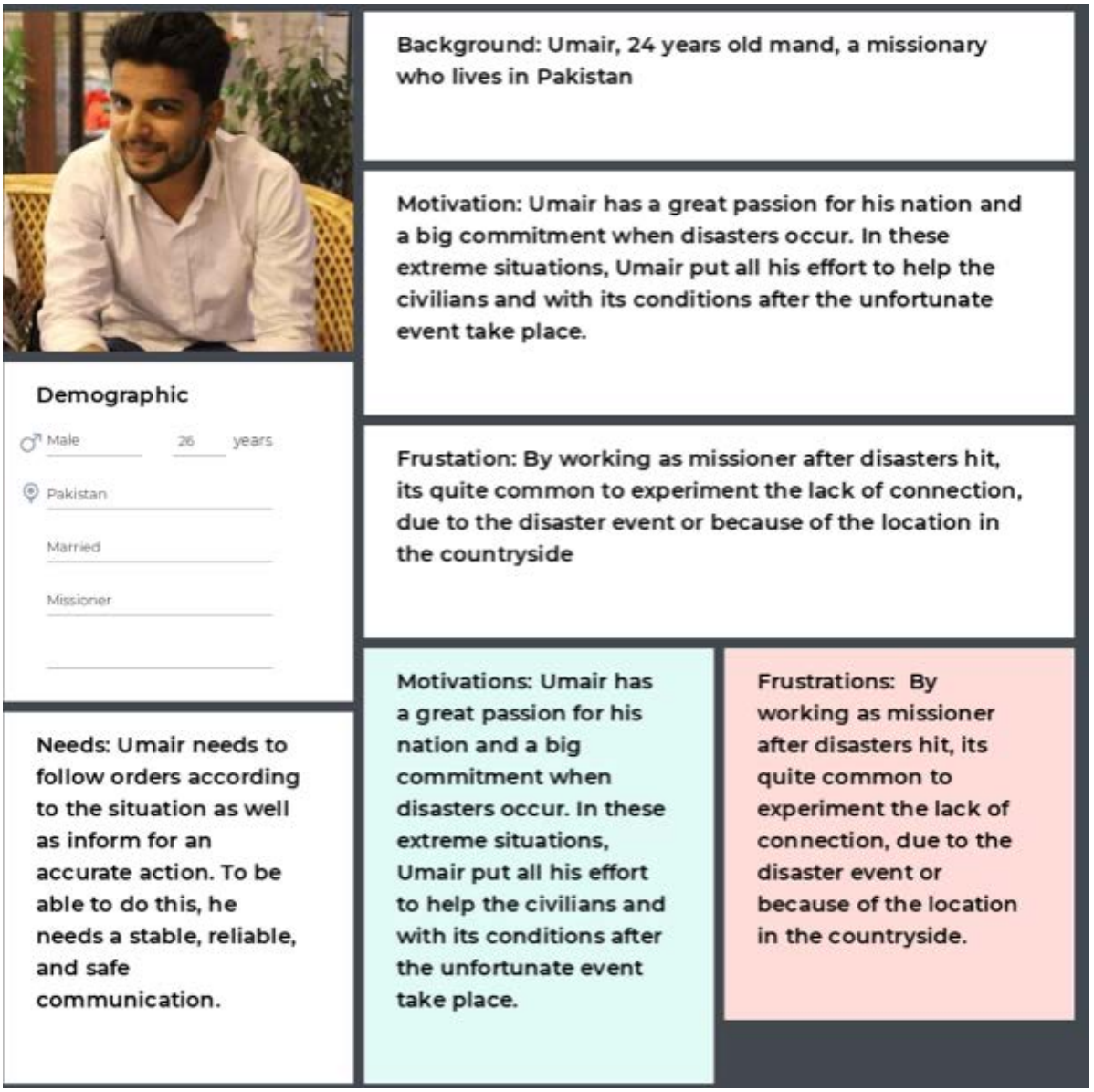
With hundreds of commercial installations in a range of applications since 1997, Wireless Excellence has been the pioneer of trustworthy FSO (Optical Wireless) technology. ATPC to counteract fading sides in harsh settings, industry-leading flawlessly fit performance, and validated steady beam optical technology are among the advanced features of our CableFree FSO devices. CableFree Free Space Optical devices are built with a deep understanding of the problems of free space optical data transfer, providing the highest levels of availability and performance.

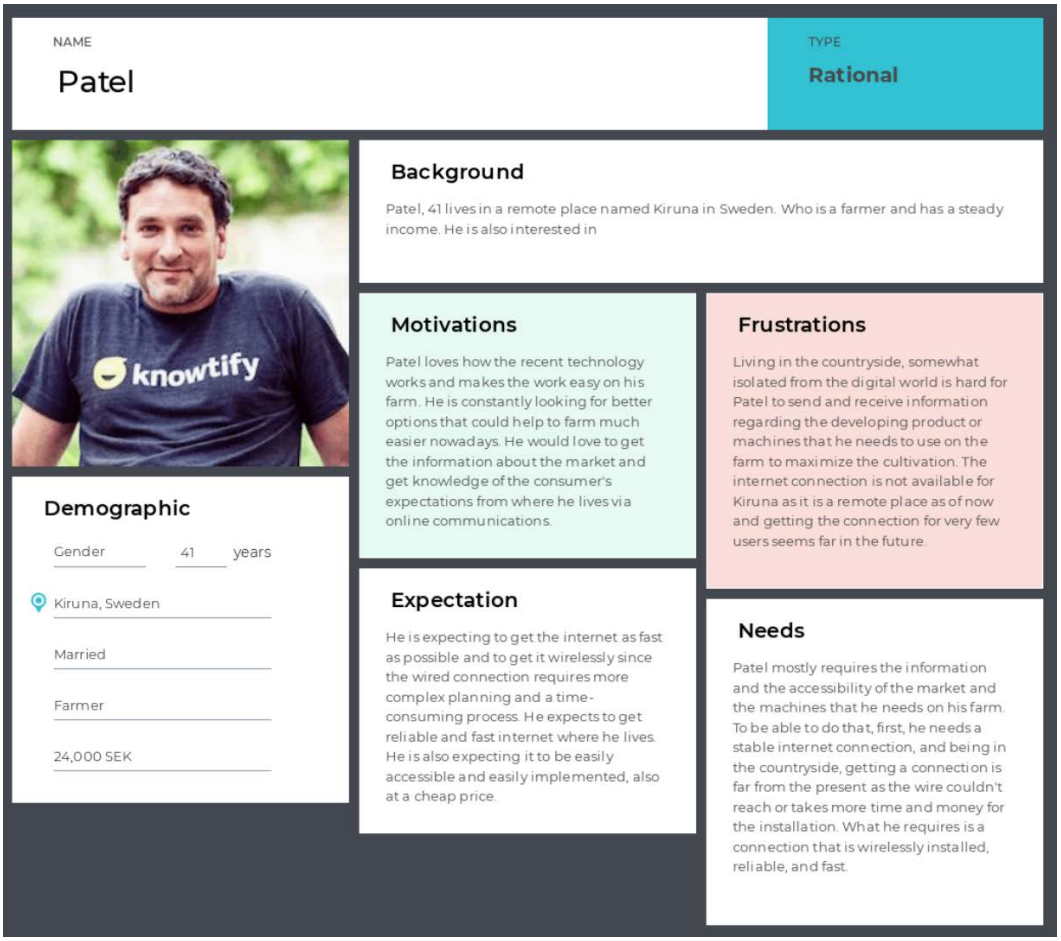
Applications:

Thousands of mission-critical customer networks around the world use CableFree FSO links for a variety of purposes, “including 4G/LTE backhaul, CPRI fronthaul, 3G and 2G networks, corporate networks, finance, energy, oil and gas exploration, power utilities, education, healthcare, broadcast with HD-SDI video, perimeter security, and CCTV networks”.

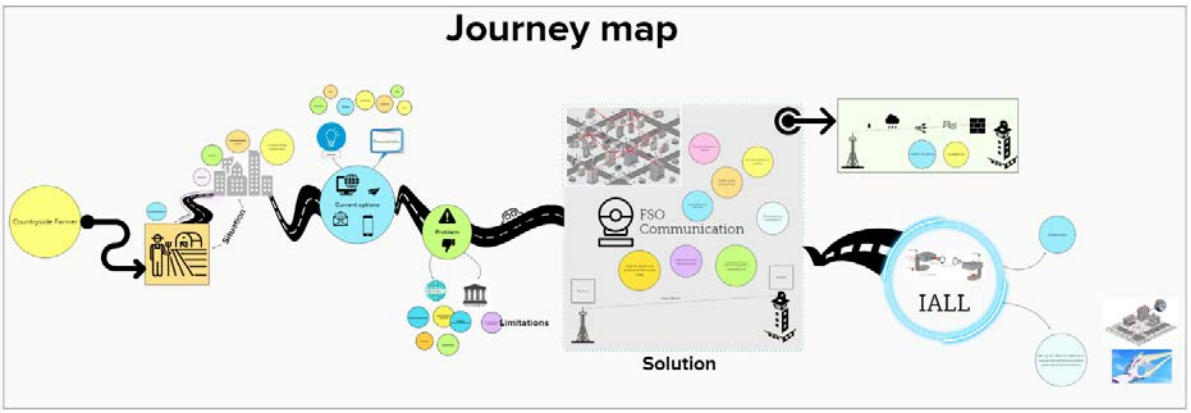
- https://www.cablefree.net/cablefree-free-space-optics-fso/

3.5 Persona and POVs

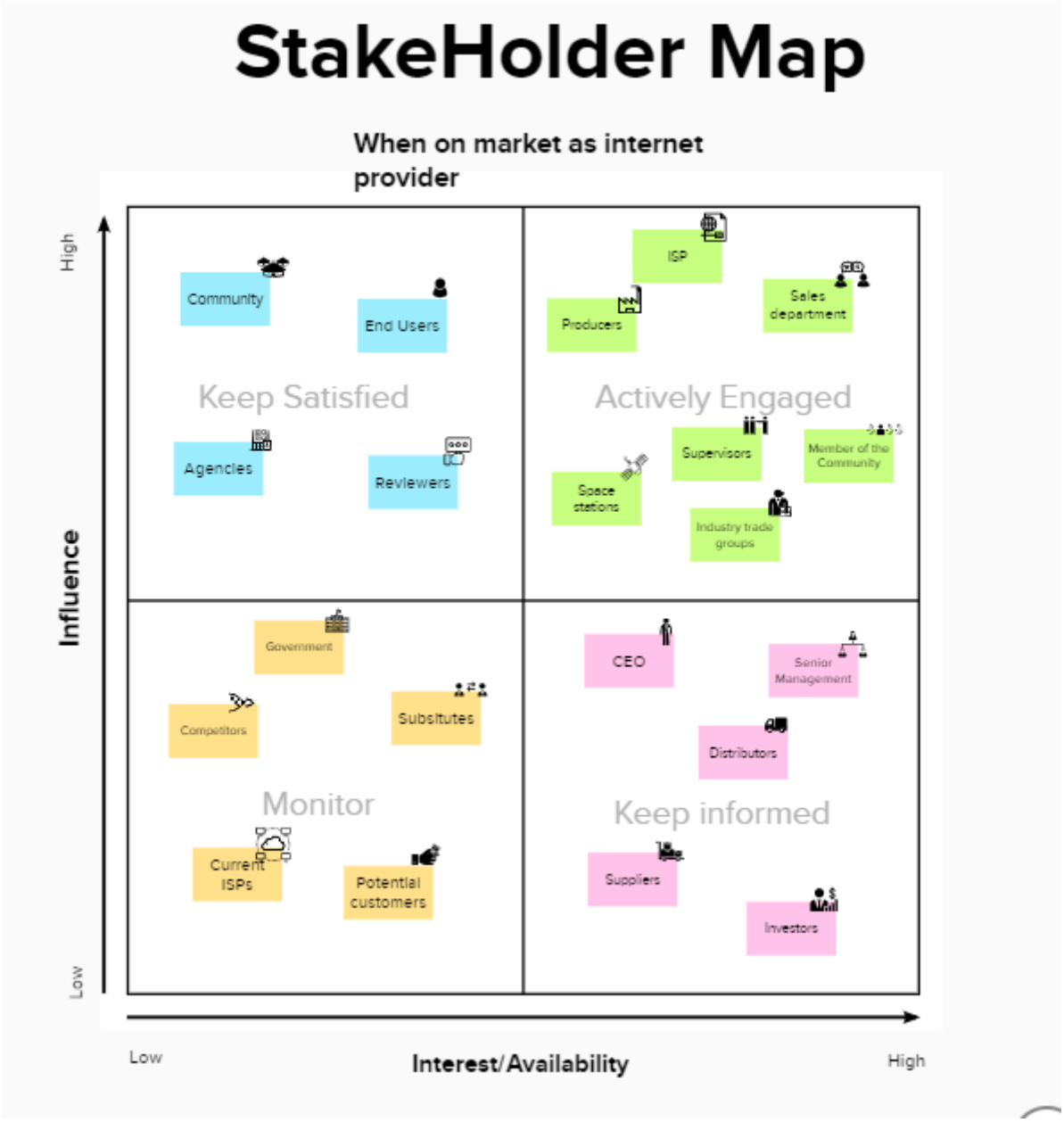




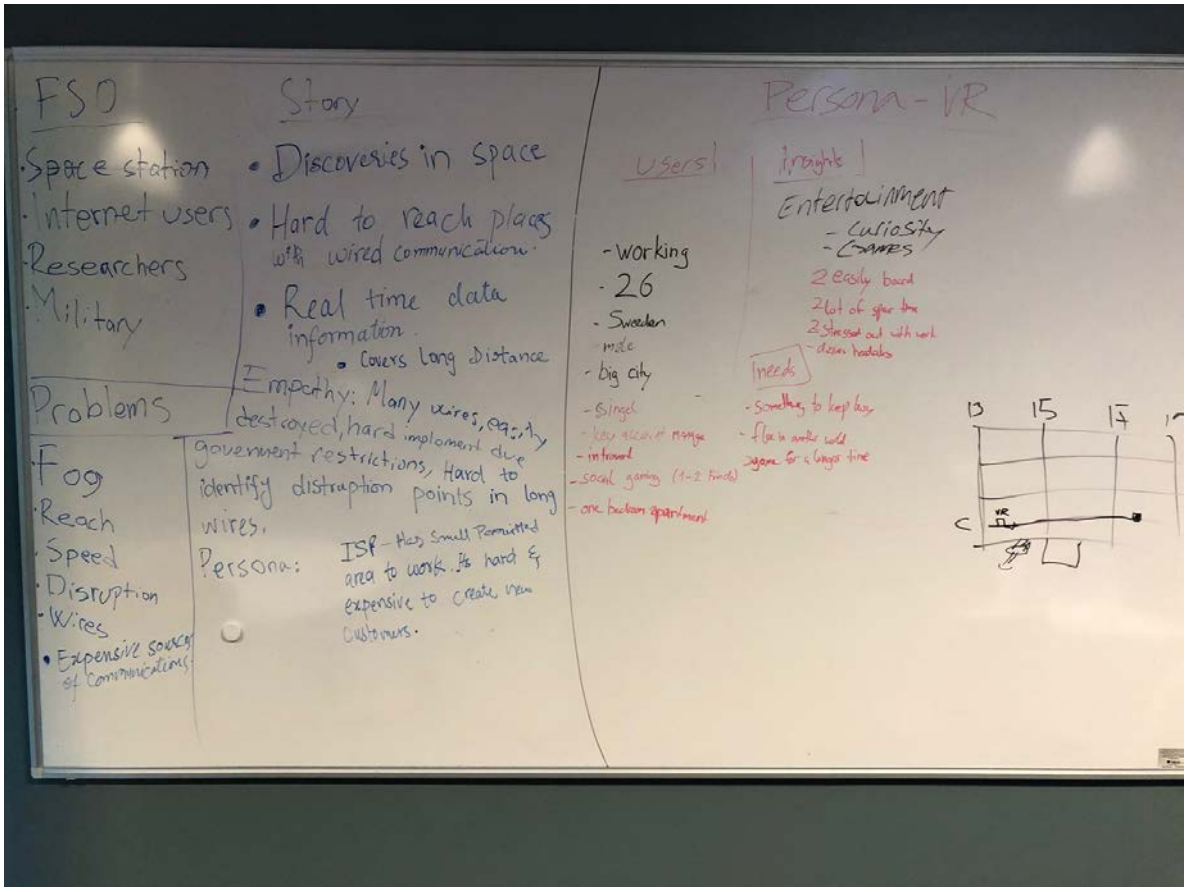
3.6. Journey Map



3.7. Stakeholder Map



3.8. Appendix FSO



Decision to drop FSO and Choose VR as main idea

The decision to drop the free space optics and to focus on VR was decided through evaluation of the different stages. Firstly, the amount of research done and both qualitative and quantitative information collected was greater in virtual reality. We saw that we had a network where we could get hold of experts in the field and also get hold of user reviews to fully see the jobs and the current problems. With the aim of the course to create a product that performs a job, getting information from users of their experiences became easier with VR.

4. Virtual Reality

In this chapter we display our findings about VR. This is our main idea that we decided to go with. We describe our exploration and exploitation we have done regarding VR and showcase our interviews we had.

4.1. The jobs to be done with Virtual Reality, a recap of weeks 1 and 2

The boom of augmented and virtual reality in industries like gaming, healthcare or sports simulation, has increased the need to access this technology on a more regular frequency. The use of VR headsets makes users connect the fictional world with the actual reality, however, for some users, the bulky size and visual discomfort or nausea caused when wearing these, do not allow them to enjoy the experience. A more adapted way of watching video games and making people be part of it contributes to the high demand that these tools/instruments have acquired in recent years. In more focused fields, like medicine, the importance of observation of different parts of the body in a fictional environment has also encouraged this technology to develop further.

In this type of tool, there is a display and a set of lenses on the screen that allows the projection of images. As it was stated before, the current products in the market have a bulky size that most of the time is not comfortable for the users. Besides that, the price is sometimes a barrier for potential customers. Despite most of them fulfilling the requirements for a good experience of having a VR headset with the presence of a variety of lenses, the main requirements and possible areas of improvement for VR glasses are high resolutions and fast response time, with the reduction of the size and its motion blurs The diffraction pattern of lenses in VR should have a small pitch and be easier to focus. The current products in the market have a limited scope and sometimes the image is hard to focus on with proper pixel quality, meaning that the motion could be blurred. In addition, the verge accommodation, the chromatic aberration, and a limited scope because of the blurred motion in the lense are also a matter of concern in the current ones. The size and other characteristics of IALL technology could contribute to these concerns. Since the liquid crystal has the advantage of eliminating chromatic aberration, decreasing blurriness, and contributing to a fast refocus with an accessible price; this technology could increase the reach of VR headsets to the above-mentioned industries and people in general.

In current VR sets, in order to solve the current market requirements, the trend of using Fresnel lenses has increased. These lenses are thin and have become the alternative solution for this type of product. However, these are not so cheap and do not produce a very focused image. For this reason, cameras usually have several lenses to have good image quality, and not only a fresnel lens. In addition, sometimes they might also create chromatic aberration. Hence, the possibility of the implementation of IALL opens the scope of improving the actual offer in the market, offering the job of a more accessible and improved product, without motion blurs and a thinner size, which can have an impact in different industries in which Virtual Reality is more present nowadays. The implementation of IALL in VR headsets could enhance the competitiveness of the current companies that are now present in the market. Google, Sony, HTC are only one of the big players that might be interested in an alternative option for the production of the VR headsets.

VR works as there is a lens at the front that redirects the vision from the user. This makes the eyes of the user be deceived and believe that the object it is looking at (screen and its visuals) is further away than it really is, which makes the person be able to focus with the eyes. Eyes in general cannot focus on an item that is too close to the eye since the eye lens cannot bend to the point where it can focus

- (https://www.youtube.com/watch?v=NCBEYaC876A&ab_channel=VRCover).

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Liquid Crystal Lenses in Augmented Reality Yi-Hsin Lin and Yu-Jen Wang

- https://sid.onlinelibrary.wiley.com/doi/epdf/10.1002/sdtp.11677

VR Lens basics: Present and Future

- https://www.tomshardware.com/news/virtual-reality-lens-basics-vr,36182.html

Liquid Crystal Lenses in Augmented Reality Yi-Hsin Lin and Yu-Jen Wang

- https://sid.onlinelibrary.wiley.com/doi/epdf/10.1002/sdtp.11677
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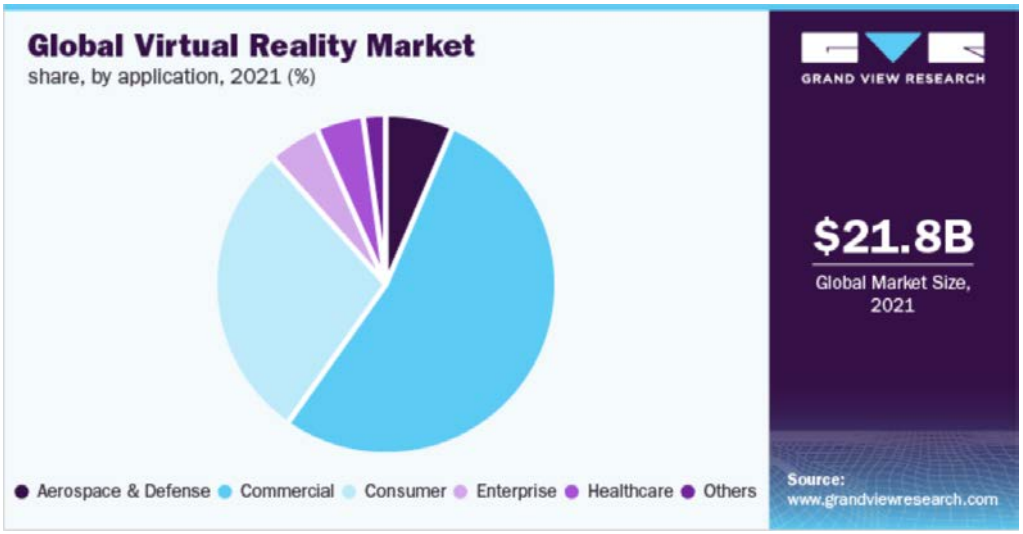
- Piskunov, D. E., Danilova, S. V., Tigaev, V. O., Borisov, V. N., & Popov, M. V. (2020, March). Tunable lens for AR headset. In Digital Optics for Immersive Displays II (Vol. 11350, p. 113500F). International Society for Optics and Photonics.

- 'cool-down session' of 15 minutes per 30 minutes played (UK Government, 2020). https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/923616/safety-domestic-vr-systems.pdf



4.2. Deeper Exploitation, Week 3 and 4

4.2.1. The task for weeks 3 and 4

Armchair research: Who are the main users? What drives them and how do they influence one another? What kind of processes are involved? What do people do, and what kind of tools and technology do they use? What are the main challenges, problems, and pains that these users experience in existing solutions and processes (i.e. in what way do they do a poor job?)? What are things that are difficult to do? research articles, newspaper articles, trade magazines, documentaries, YouTube clips

Plan: Mission 2

- Technical information about VR headsets and how it could be improved through IALL.
- Ask VR LiU David Beuger→ Prepare questions
- Qualitative Interview VR→ Headset users (acquaintance, online community)
- Find stores Linkoping sell VR glasses. → ask customers' opinions/complaints: Elgiganten, Webhallen, Kjell Company, XMRealityAB, Mediamarkt (city center/Tornby)
- Conntect Master

4.2.2. What causes the problem

Current sites and information about virtual reality recommend users to cut down on the amount of time spent in the VR space to combat nausea. This is a solution that discourages the user to use or even buy a VR headset (https://www.space.com/motion-sickness-in-vr). The optical flow of the visuals is a critical factor that impacts how people react to moving images. Four in ten people are affected by such motion sickness and will therefore stumble upon these problems, which will cause fewer people to use the device. (https://www.tandfonline.com/doi/full/10.1080/10447318.2020.1778351). For others, it will be exhausting and they might be scared off by the reviews from others

For the human eye natural resting is essential for the long-lasting sight, and without it, the eye will not be able to recover from intense sessions of extreme focus at near sight. The lenses that are currently used use a sort of mechanical focus switch to help the eye to see virtual reality as the real world. With a liquid lens, the focus of the eye could be switched without the mechanical change and be a cheaper alternative that would be able to change the focal range and focus. “To build an AR/VR display system satisfying all the above-mentioned requirements is extremely challenging using traditional optics, not to mention the display itself should also have a compact form factor and lightweight for comfortable wearing experience” (https://link.springer.com/content/pdf/10.1186/s43593-021-00003-x.pdf). Generally, it is recommended currently to take a 10-15 minute break for every 30 minutes you play. https://www.businessinsider.com/reason-virtual-reality-hasnt-taken-off-future-technology-2018-11?r=US&IR=T) Currently, users seem to experience more nausea from the cheaper alternatives due to their decreased fps (frames per second) and fov (field of view), as well as refresh rate.

Jobs to be done: Eliminate Nausea, dizziness, motion blurs, bulky size

How: IALL tech. thinner, better focus of the image, non-chromatic aberration, cheaper.

Article describing the problem and tasks to be fixed with a regular lc lens, not adaptive

“Most existing AR/VR headsets have a fixed focal length and cannot transfer a virtual image in the required plane. For simultaneous observation through an AR device of real objects located at different distances, virtual image can be displaced along optical axis by LC lens.” (Piskunov et al., 2020)

“Another problem of current AR/VR headsets forming stereoscopic images is the vergence-accommodation conflict (VAC). The eyes accommodation and convergence distances are always equal in natural conditions. In near-to eye display systems, the accommodation of the eyes remains fixed on the apparent display distance.” (Piskunov et al., 2020)

“The vergence-accommodation conflict is commonly associated with headache, eyes’ fatigue and nausea so its elimination could increase the eye comfort of HMD users. A tunable LC lens may be one of the solutions as it allows to vary a position of virtual images and, therefore, to mitigate the vergence-accommodation conflict.“ (Piskunov et al., 2020)

“One more problem of current AR/VR headsets is the support of HMD users with prescription glasses. Similarly to VAC mitigation, a tunable LC lens in AR headset can be also used for correction of eye refraction errors, e.g. myopia, hyperopia, presbyopia.” (Piskunov et al., 2020)

“Therefore, the tasks for adjustable LC lenses in HMD can be formulated as following:
- to provide realistic sense of depth of virtual reality image;
- to mitigate the vergence-accommodation conflict (VAC);
- to eliminate prescription eyewear under the HMD and deliver automatic accommodation for users with presbyopia. In addition, lens should be compact and lightweight for comfortable wearing on head.” (Piskunov et al., 2020)

- https://www.spiedigitallibrary.org/conference-proceedings-of-spie/11350/113500F/Tunable-lens-for-AR-headset/10.1117/12.2565635.full?SSO=1

4.2.3 Motion Blur

Motion blur is a phenomenon that is common in both general VR usage and analog video games. It is usually caused by the frames per second not being able to keep up with fast directional movement. In VR, as the user is turning and making movements identical to real life, there is huge pressure on the game to be able to process the environment to create smoother transitions. In reality, your brain is able to filter out motion blur, which a game cannot replicate. Motion clarity is therefore extremely important to VR. (Google “what causes motion blur vr”).

- Can a liquid crystal lens have a positive impact on FPS in VR?

With the Fresnel lens which is often used to make the lens thinner, you lose light in the process → less efficient (potentially bigger light source and battery needed) to make this less of a problem it is also a possibility to work with a less fragmented lens which will make the image less sharp.

4.3. Interviews & User Reviews

These interviews were conducted in a semi-structured way in order to see the perspective of the current users of the VR headsets. Some of them were answered by acquaintances of members of the group and some others were done by members of online communities, like the Facebook group AR & VR Developers and the forum Virtual Reality (VR) Gaming & Metaverse Exploration Community.

4.3.1. Questions to think about for users

How has been your experience with the VR headset?
Why did you buy it?
What problems have you identified?
Is there anything you would like to improve?
What do you consider is the more challenging/uncomfortable feature they have?
Why do you think not so many people have this tool? Price/experience
Have you ever felt nausea or dizziness when using this headset?
How do you feel about wearing regular glasses + a headset?
Do you regret buying this headset?

4.3.2. USERS REVIEW

4.3.2.1. USER 1

My overall experience has been pretty good. The problem perhaps that for me personally I think is a device that weighs too much, at least mine, and the straps slip a little. I would like it to improve, especially the weight issue. The same, the weight is the most uncomfortable. I think a lot of people don't use them because they haven't tried them or maybe they think

they're expensive, but nowadays I think there are cheap options. The first time I got a little dizzy, but only at first. I use them from time to time, I guess because there isn't much material to watch with them either. I do not regret it.

4.3.2.2 USER 2

1. How has been your experience with the VR headset?
   Good, interesting, captivating, impressive
2. What problems have you identified?
   None too significant. I didn't play for long, but I suspect over a longer period of time, the VR headset would start to feel a bit heavy for my neck
3. Is there anything you would like to improve?
   Weight of the headset (maybe). The graphics resolution
4. What do you consider is the more challenging/uncomfortable feature they have?
   Bulky
5. Why do you think not so many people have this tool? Price/experience
   Price
6. Have you ever felt nausea or dizziness when using this headset?
   No
7. How do you feel about wearing regular glasses + headset?
   I can only imagine it may be a bit uncomfortable. I do not wear glasses
8. Do you regret buying this headset?
   Never bought one. I used it in a games room

4.3.2.3 USER 3

1. How has been your experience with the VR headset?
   Mostly positive
2. What problems have you identified?
   When using it with a PC link, the floor calibration resets at times, e.g. even if I'm still crouched the avatar would stand up randomly
3. Is there anything you would like to improve?
   More straightforward and functional wireless connection to PC would be nice
4. What do you consider is the more challenging/uncomfortable feature they have?
   Customizability could be better, e.g. these only have 3 horizontal positions for the lenses
5. Why do you think not so many people have this tool? Price/experience?

Price and perception of VR as being a niche/gaming technology

6. Have you ever felt nausea or dizziness when using this headset?
   Yes, the intensity depends on the app/environment
7. How do you feel about wearing regular glasses + headset?
   I never had a need for glasses with the headset, however there was a glass spacer with it, so I guess it would be fine
8. Do you regret buying this headset?
   No

4.3.2.4 USER 4

1. What has been your experience with the VR headset?
   I worked with HTC Vive and own Oculus Quest (1st). I also had experience with Hololens, Magic Leap, and Varjo.
2. What problems have you identified?
   Initially, the point was about price and PC setup. I don't like wires for headsets (missing flexibility and freedom of motion). What I don't like about Oculus - it is not working perfectly if there is much light in the area.
3. Is there anything you would like to improve?
   Better quality for 3D models, longer battery life, better live sharing options (direct to TV)
4. What do you consider is the more challenging/uncomfortable feature they have?
   wires, free-roaming
5. Why do you think not so many people have this tool? Price/experience
   Price, laziness (not willing to learn how to work in VR), low information on what can be done in VR.
6. Have you ever felt nausea or dizziness when using this headset?
   Several times, when the graphics are too heavy for the device and it starts lagging.
7. How do you feel about wearing regular glasses + a headset?
   I have good eyesight, so it's not about me.
8. Do you regret buying this headset?
   Nope. I am a tech fan and I would like to try more new devices.

4.3.2.5 USER 5

I have used the Windows XR headset, the oculus quest 2, the oculus go, and the HTC vive. I spent the last 7 years teaching people how to create VR content and worked on a VR project

as part of a NASA project. I hope I can answer some of your questions. Tethered headsets are very constraining, and all headsets are uncomfortable after an extended session as they tend to get sweaty. Some of the problems include vertigo and nausea.

4.3.2.6 USER 6

The problem with the headset is that sometimes it gets blurry and foggy (the lens will get cloudy), especially when sometimes I use it for an hour and watch movies with strangers (in a cinema). I have also suffered from nausea, especially in the games in which you have to move and then stop moving, like a rollercoaster I tried, and then I took it off after a second. I think that the problem is that you are moving in the game but are not actually moving in real life. I think that the price is the main barrier that scares people, although the headset has become more and more popular. VR headset with glasses: it is more uncomfortable, and might scratch the lenses. I did not realize the existence of chromatic aberration in mine. One of the coolest features for me is that I can play piano in the VR set, Quest 2. I think that what could be improved is not having the Frame (the frame reminds you that you are not actually in the VR).

4.3.2.7 USER 7

I tried it once for 2 hours, just with slow games and motion blurriness seemed not to be a problem but I was indeed scared of running into something. In three words, I would describe the general experience as underwhelming, unsupported, and unfinished. I like it but I think it has a very long way to go before it could even have the ability to go mainstream. They are fun but overpriced and limited. I think that the product in general needs more work.

4.3.2.8 USER 8

My first experience with VR was great and it was cool to see a kind of parallel universe in that sense. My first time playing was at an event center where you needed to book your spot and then could play for an hour or two. It was me and a friend who played at the same time and competed. Although we booked the time for an hour, we needed to stop for a while since we were not used to it and it felt like my head was spinning. I think the VR concept is really cool and it could become the future for many different areas. However, as it currently stands, I don't see myself buying a device myself since I don't think it's worth buying knowing the price and the fact that I would only be able to play it a few minutes at a time. For me, motion sickness was an issue the first time, and even at later times when I've tried

it, I haven't been able to play for too long. I don't know if this is a problem for only me, but I would love to see a device where this wouldn't be the case.

4.3.3. Our Experience from the Field Research - VR Lab LiU

4.3.3.1. User 1

In the beginning the headset was very comfortable but with time it became heavy on the nose. Especially with the games, I had to move my head a lot like spiderman I started feeling dizzy. After I took off the glasses the headache continued to last for some time but went away after about 30 minutes. During the use of the glasses, I realized the limited field of view which was a reminder that this was not real even though everything was quite realistic. Another thing that took away from completely getting lost in the VR-world was the quality. It was still possible to see the different pixels which made the experience more exhausting I think.

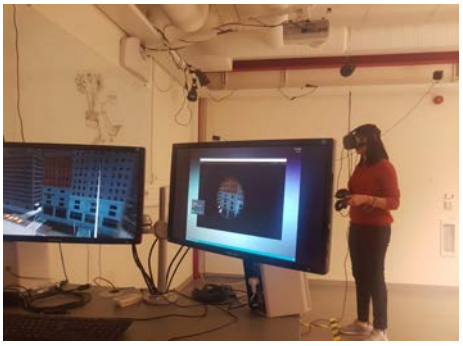
4.3.3.2. User 2

The experience was good in general terms although wearing glasses with the headset could be slightly uncomfortable, especially if the glasses get tarnished when putting the headset on. Also, after being able to put it, I could identify the limited field that could be achieved with the lens and that the frame was the object that did not allow a full immersion, since seeing it would always make you realize you are in a virtual world. Besides that, already with the headset on, the quality of the images was not that much sharp sometimes, in particular in certain games. After being immersed for a few minutes, you could feel that moving the head towards the objective in the game could also cause a certain type of dizziness because some things were blurred. When taking the headset off, I could feel instability and this could even last for a while more, especially seeing in the screen what other people saw in the game. I think that after using it regularly, I would need to take breaks constantly, so I would not be a potential customer if the motion blurreness is not solved.

4.3.3.3. User 3

Playing around with the VR headset for the first time in a year, it took some time to get used to the settings and adapting to the situation. The first thing I noticed when exploring was the very limited vision of the headset. Firstly, I made a comparison between my field of view in

the virtual world and real life and saw some great differences. Furthermore, for me, the quality seemed a bit pixelated in some of the games. Whether that is due to the games themselves or the display and its lens is to be determined. However, after playing for some 15 minutes and sitting down, there were some feelings of instability. Readjusting to the real world after playing was a process, and my head was spinning a bit. Although it was the first time playing and trying to understand the aspects of the lens, I left with a feeling of huge room for improvement.



4.3.4. Customer Experience – Online research

Searching online for general comments and opinions of users of VR, it could be said that in general this technology, despite having several supporters, also have some contradictors. These people think that this type of tool is not good and the glasses are uncomfortable.

For some users, making this type of technology accessible in the market is not worth it, because it is not accessible for everyone, starting with the price. This user argues that “mostly programmers and developers are the only people who can do anything other than a team's call with it. For everyone else it will just become astronomically expensive face time on your head”. In his opinion, Hololens2 is not even necessary for general users without specific knowledge in the tech field. Also, some users consider that this tech, instead of bringing people together in a virtual world, would make them more distant. “I'm inspired to throw away every electronic I own and run to live in the forest”, some users consider it as a very invasive technology because it could make lose the daily basis human interaction.

- https://www.youtube.com/watch?v=uIHPPtPBgHk

In the case of the Oculus Quest Advance All One, the most popular Facebook headset, has received also bad reviews, in particular with the blurry issue. “Whoever thought of this (in

Facebook) should be fired. Also I was told the lens has blurry issues". Users with knowledge in the field considered that the addition of a Fresnel lens came with a blur effect that stopped users from buying it. "Fresnel lens added a ghosting effect or blur effect which is a major drawback to buying this. Chromatic aberration is still visible (red & blue fringes) even after 4 years of evolution. This is an AR/VR Game Developer review. Still, there is room for improvement". Other general users complained that the periphery all the time was blurred, so the straps needed to be adjusted constantly to be used tight into the face, and that using glasses does affect the experience in a bad way. "Everything in your periphery will be blurred so adjust the strap every time you wear it, it should be sticking to your face tightly. If you have glasses then they need to be small as my computer glasses did not fit but I think you will have some problems when using it with glasses".

- https://www.amazon.com/Oculus-Quest-Advanced-All-One-2/dp/B09DCMWRKP?th

In general forums, what users mostly commented about were the size and comfortableness of the headset. One of the users even compared them to high heels, "you put up with the discomfort because of how good things look." They were suggesting that if the headset was much smaller, it could also be much more comfortable. "It is highly desirable for a VR headset to have high resolution, wide field-of-view (FOV), the unnoticeable image blurs, compact size, and lightweight" however, also some of them were aware that if the developers increased the FOV, could lead to some issues for the headset. "Nevertheless, full-color images presented in a large FOV could suffer from noticeable color breakups caused by the lateral chromatic aberration".

- https://forums.oculusvr.com/t5/General/There-is-no-such-thing-as-a-comfortable-headset/td-p/804465

4.3.5. Interview Guide with Expert

An interview was conducted with an optician that has done some research in the field of optics and now works as an optician. The following questions were asked.

Are you familiar with Liquid Crystal Lense? (Or liquid lens in general) It's an alternative to the fresnel lens with non-mechanical flexible focus through a liquid
- He was familiar with the Liquid Crystal Lense and believes it may be an alternative due to the focus possibilities IALL has.

What do you know about lenses in VR glasses?

- He has tried them and played games with them and knows the lenses that are used in them.

Do you have any ideas of what could improve those lenses?

- An improvement that can possibly be fixed using a lens is to remove the frame from line of sight so even though it is there we may not see it.

What are the problems an improved lens would solve?

- The lens could possibly solve the problem they have right now with progressive glasses. But he is not sure if that helps VR.

What alternatives in the market are there for the fresnel lens?

- Not specific that he knows where it is not used at the moment.

Is chromatic aberration a common problem with general lenses?

-Yes this is a problem but can be solved to almost perfection.

What causes motion blur? (optics perspective)

-The function of the eye of brian. The eye only sees what it is looking at at the moment but the brain makes the rest up.

Can lenses help to improve the field of view in the VR glasses?

- Yes, it can work as an add-on to the human eye.

Vergence Accommodation conflict often happens in 3D visualization. Could it be solved through LCL?

- He did not know.

Do you know any current problem/area of improvement related to the lenses used in VR headsets?

Is there a characteristic of the lens that makes people tired?

- If the lens is wrongly formed and perhaps has the wrong dioptria it can make people feel tired.

4.3.5.1.Possible questions:

- Color breakup and chromatic aberration with the headset on, has it ever happened to you? If so, when does it happen?
- Chromatic problem
- Have students always had a pleasant experience within the lab?
- What is the reason for the motion sickness people use when using this device?
- graphic designer
- Are there reasons that cause dizziness other than motion blur?
- Is there a difference between more expensive and cheaper alternatives when it comes to nausea to your knowledge? What are the causes?
- At our field research the salesperson talked about a new improved version of VR glasses. Do you know anything about it and do you know the state of the motion blurriness and the technology?
- Do you think a lens with a better focus would decrease the weight of the product? Or is it the display that makes it bulky? → improve question
- Can a liquid crystal lens have a positive impact on FramesPerSecond in VR?
- Vergence Accommodation conflict often happens in 3D visualization. Could it be solved through LCL? –> Optics
- Are there any limitations caused by the lens?
- can you tell us more about the combination of wearing glasses and using the headset
- is there a way to reduce the distance between the lens and the eye in the headset and also the distance between the screen and the lens? (what characteristics would lenses that reduce this distance need)

4.3.5.2. Expert and Researcher in the field of VR:

- he is more behind the software of the VR REality
- generally there is a big need for improvement of the VR experience (could also include the lens)
- Chromatic aberration is a problem for VR users and something that could definitely be improved

- it would be really nice to expand the field of view
- problem not in the lense → but in the frameworks per second
- better experience without chromatic aberration
- getting rid of lags
- what the lense is fixing: there is just a very short distance to the screen, with the lens this distance is about 2 meters
- could be an option for built-in eyesight correction into the VR glasses
- if the lense could be curved that could open new possibilities
- the problem is that the VR glasses are very exhausting for your eyes and therefore they make you very fast tired/ you get headaches
- 120 frames per second would create a very nice picture
- For the combination of Phone and VR glasses, the lense is still built into the Headset
- a very high-resolution expansive headset is vario/visio-headset (Finnish company)
- the price difference mostly results from frames per second
- there is also a Visualization center in Nörrköping
- in the old day screens with liquid crystals were used to freeze
- he sees potential in fixing chromatic aberration → it is not completely unwanted as it can be less exhausting if there is chromatic aberration but at the moment it is determined by the lens and it would be better to be able to determine it with the chromatic aberration.
- A liquid crystal lens could not help to increase the frames per second, but it can help to create a better inmmersive level.
- The lens is not that heavy of a component in the headset → exchanging the lens would not offer much potential for weight reduction
- most gamers use VR headsets

AR

- there is also a lense involved
- the Headset is very expensive and therefore it is more difficult to create a market for it

4.3.6. Questions to the optician

- Are you familiar with Liquid Crystal Lense? (Or liquid lens in general) It's an alternative to the fresnel lens with non-mechanical flexible focus through a liquid
- What do you know about lenses in VR glasses
- Do you have any ideas of what could improve those lenses
- What are the problems an improved lens would solve
- What alternatives in the market are there for the fresnel lens
- Can you explain the chromatic aberration
- Is chromatic aberration a common problem with general lenses?
- What causes motion blur? (optics perspective)
- Can lenses help to improve the field of view in VR glasses?
- Vergence Accommodation conflict often happens in 3D visualization. Could it be solved through LCL?
- Do you know any current problem/area of improvement related to the lenses used in VR headsets?
- Is there a characteristic of the lens that makes people tired?
- Is there any lense in the market that increases the FOV (field of view)? What characteristics does this have?
- Can you bend the lens? Are there already lenses that can be bent?

4.3.7. Interview with Salespeople

4.3.7.1. Interview Guide for Salesperson

- Is it popular to buy VR headsets?
- What is the stereotype of people buying the product? What is the most common customer opinion/motivation when buying the headsets?
- What do you think prevents customers from buying VR glasses?
- Have you ever experienced VR through these lenses? What do you think about it?
- Have you had returns or complaints about the product?
- Which brand do you think has the best characteristics and why?
- What makes the price difference between products? Any technical or particular features of the headsets?
- How has been the technical development of the product over the years? What improvements have you noticed?

4.3.7.2. Salesperson 1

Is it popular to buy VR headsets?
yes, quite a bit
What is the stereotype of people buying the product?
Parents to their kids + 20 to 30´s
What do you think prevents customers from buying the VR glasses?
Price and parents worry if it can be harmful.
Have you ever experienced VR through these lenses? What do you think about it?
I love them but I am not a big fan for their use.
What makes the prices difference between products? Any technical or particular features of the headsets? 220FOV vs 90 FOV

4.3.7.3. Salesperson 2

From our Field-trip (at Elgiganten):
The biggest reason why people do not buy VR glasses is the price. The biggest return of VR glasses is due to motion sickness (some people even describe that they had to puke from the experience). Salesperson says that according to his opinion it is not just the motion blurriness that makes people sick but also other factors (based on the stories he got from customers and also friends). There will be a new headset version soon and, according to the

salesperson, it is expected to has less motion blurriness but that the price will be higher. Possible area of research. Oculus, Playstation and one more product sales increased a lot in the last weeks and are bought by all kinds of people (all genders and ages). From his personal experience: you get a headache after a long play, there is a big shortage of VR glasses in Sweden due to corona.

In Media Markt and Kell and company, they did not have VR glasses. Media Markt did sell them in the past, 8 years ago. Why did they stop? No answer from salesperson

4.4. Two big producers of the coming generation of headsets:

Meta:

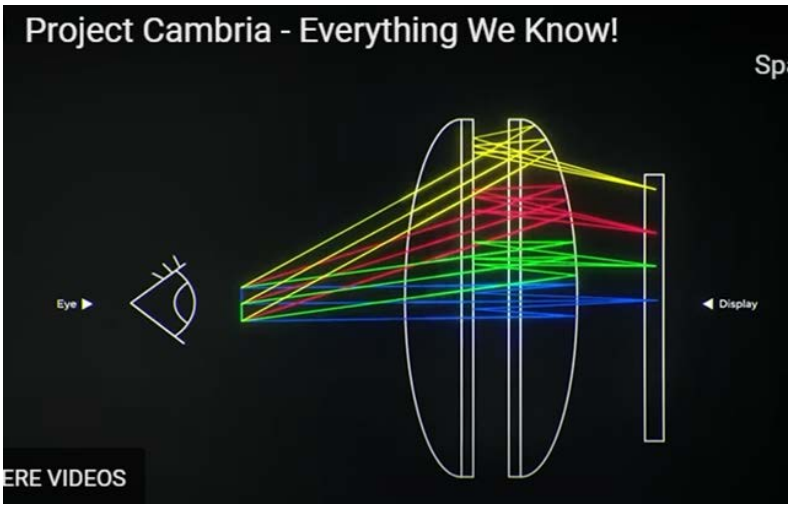
- stand-alone

questline: cheaper

- passthrough just possible in several shades of gray
- no eye-tracking

Cambria line: more expansive

- high resolution colored passthrough of the real world around you possible



- wider field of view than quest line
- eye-tracking
- face tracking: to mirror face expressions
- much more compact

multi layered element pancake lenses which are in front of the usual fresnel lense
→ reason for weight, much more compact way to transport images to your eyes and make it a lot less bulky

- Project Cambria: Everything About Meta's Next Headset (uploadvr.com)

Playstation:

- lightweight.
- Lower pixel resolution than oculus
- Oculus: 1,600 × 1,440 pixels per-eye, PSVR 960 × 1080 pixels.
- Need an external camera to be connected to PS4.
- Superior color control
- PS Processor - better performance.
- VR2 Fresnel lenses, VR non-fresnel lens

Things to look for

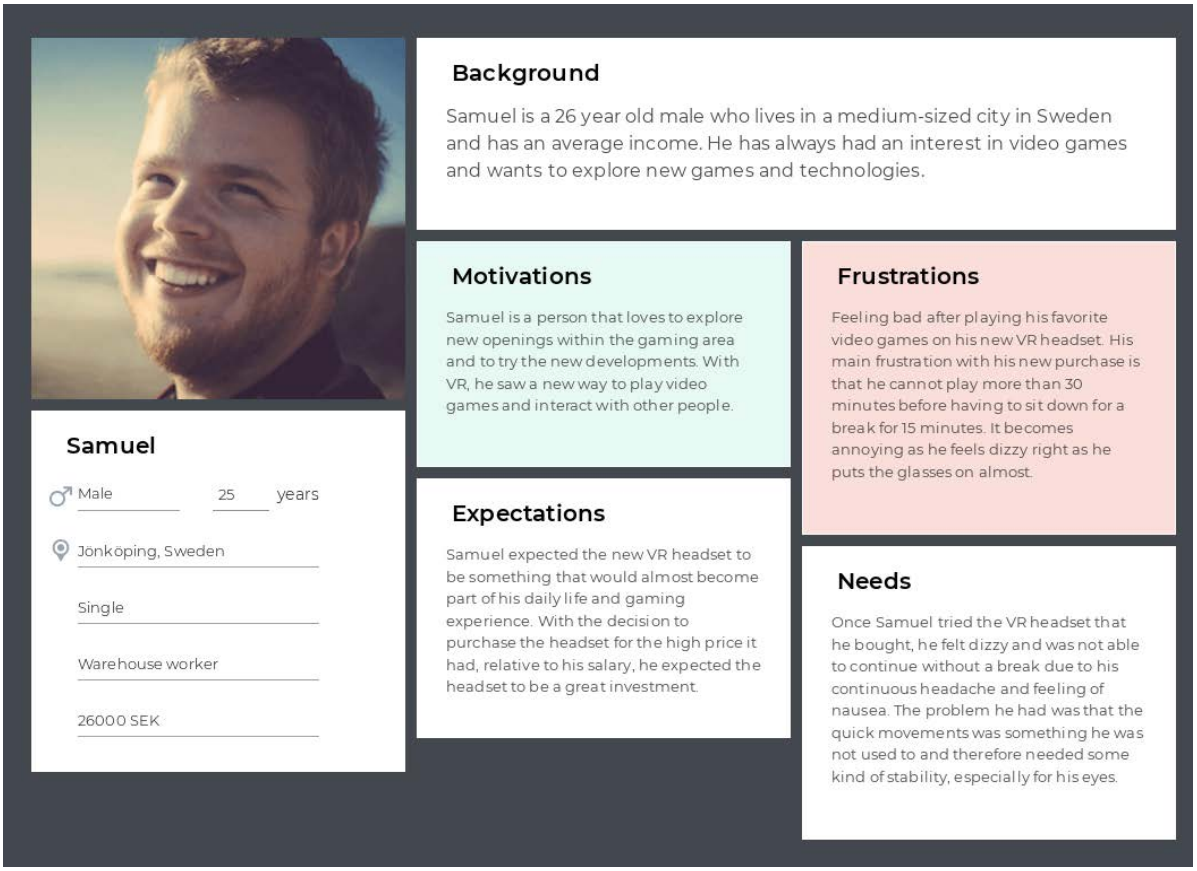
inter-pupilar distance (IPD) - Distance between the center (pupil) of the eyes. Used for the appropriate prescription glasses, since the optical center of the lens should be aligned to the center of the pupil. Oculus Quest has the option of adapting to 3 different IPDs, improving the focus of the glass.

- https://www.allaboutvision.com/eye-care/measure-pupillary-distance/

4.5. Persona and POVs

Persona #1: The gamer

Samuel, 26, comes from a medium-size city in Sweden and has an average income. He has been interested in games and technology for a long time, so he decides to see how VR headsets work and their properties. Samuel gets to try one headset at a convention for a few minutes. After some days of thinking, he decided to buy the headset and started trying it immediately. After some hours he gets nausea and dizziness when playing a new game. Disappointed, Samuel decides to return the headset because he realizes that the inconvenience is bigger than the benefit of having it.



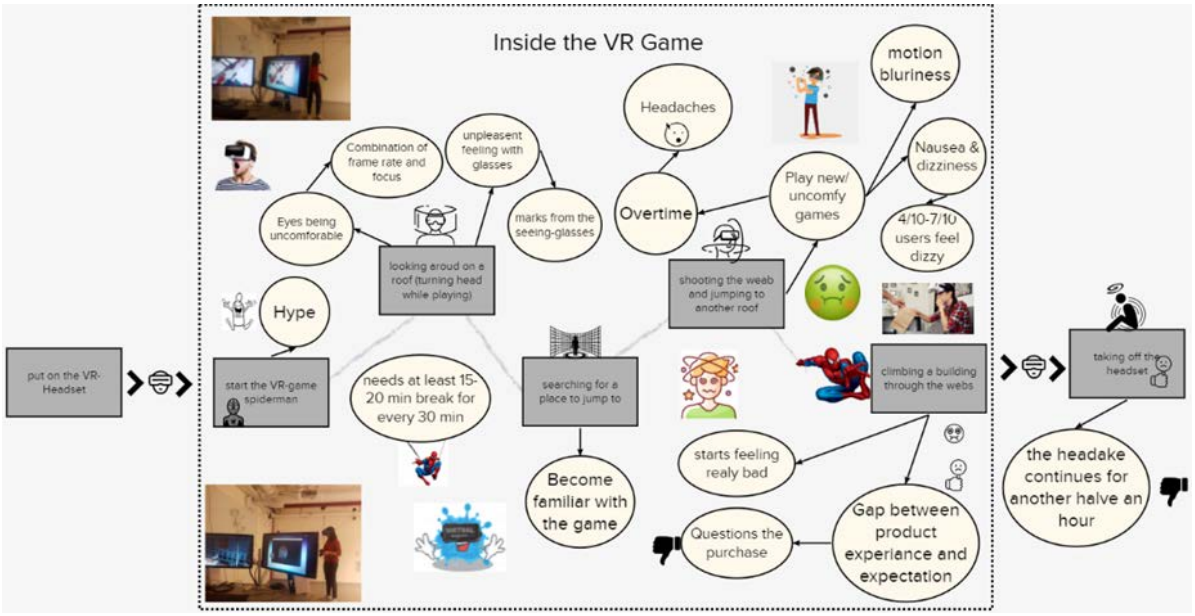
Persona #2: The “tech-guy”

Alex is a 35-year-old male working in the tech industry which is generally a lucrative field to work in. With his interests being in new technology and innovation, Alex is always looking to acquire the latest releases. As the new VR headset will include improved FOV and focus for the user, he sees potential and would want to lay his hands on it as he puts a lot of importance on the details. He has yet to experience any type of problems with the headset. However, that is not the largest factor that determines his purchase. Although indirectly, the new technology allows for a better experience and makes him satisfied.

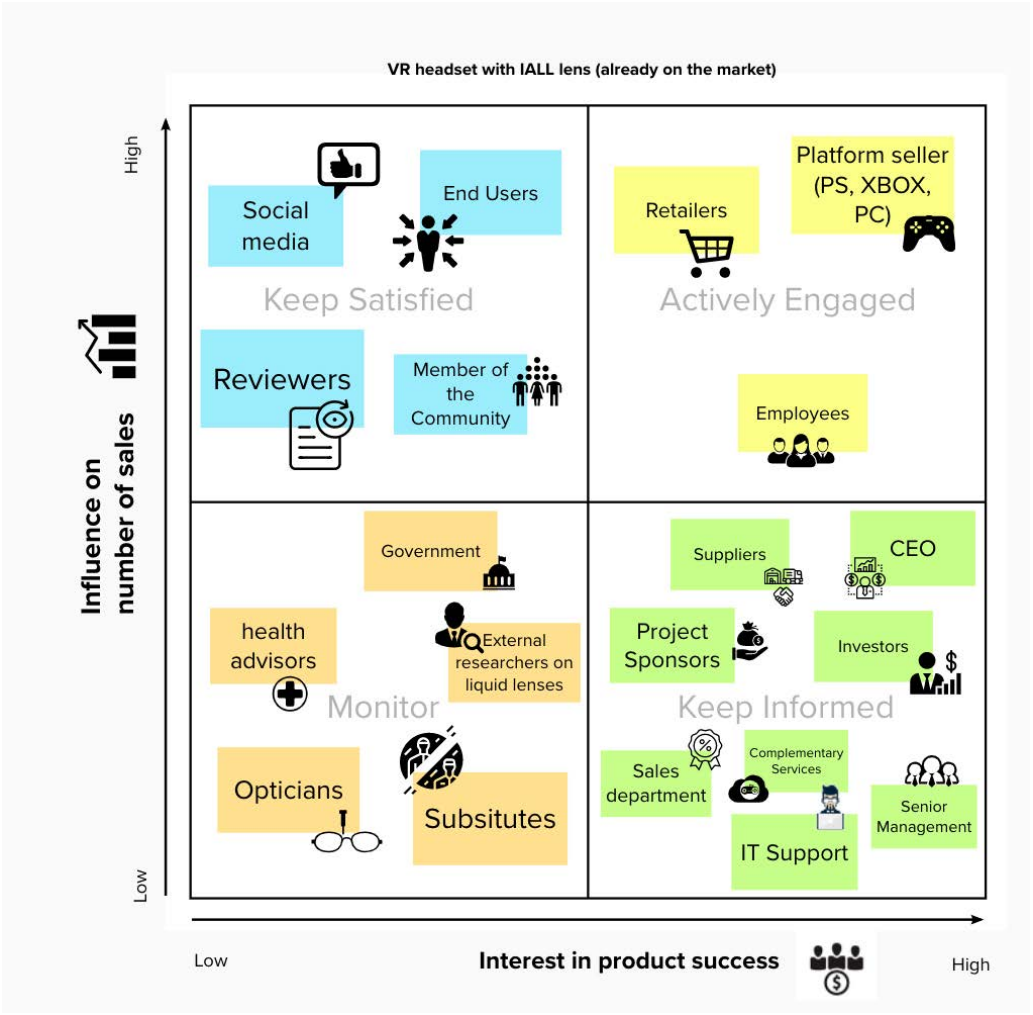
User	**Need**	**Insight**
Samuel is a 26 year old male who lives in a medium-sized city in Sweden and has an average income. He has always had an interest in video games and wants to explore new games.	Once Samuel tried the VR headset that he bought, he felt dizzy and was not able to continue without a break to calm his nerves. The problem he had was that the quick movements were something he was not used to and therefore needed some kind of stability, especially for his eyes.	Because he was not satisfied with the product and it did not perform as he wanted it to, he decided to hand it back to the store he once bought it from. Without the special liquid crystal lens, he could not manage the motion sickness as his eyes could not focus entirely.
Alex is a 35 years old male, working in the tech industry in Ireland. He has a high income and has always been interested in the new tech	After buying the headset offered on the market, Alex felt that he wanted the quality of the actual VR headset to be improved, in	The newly bought headset does not cover Alex’s expectations since he cares about the technical details of the things he buys and was

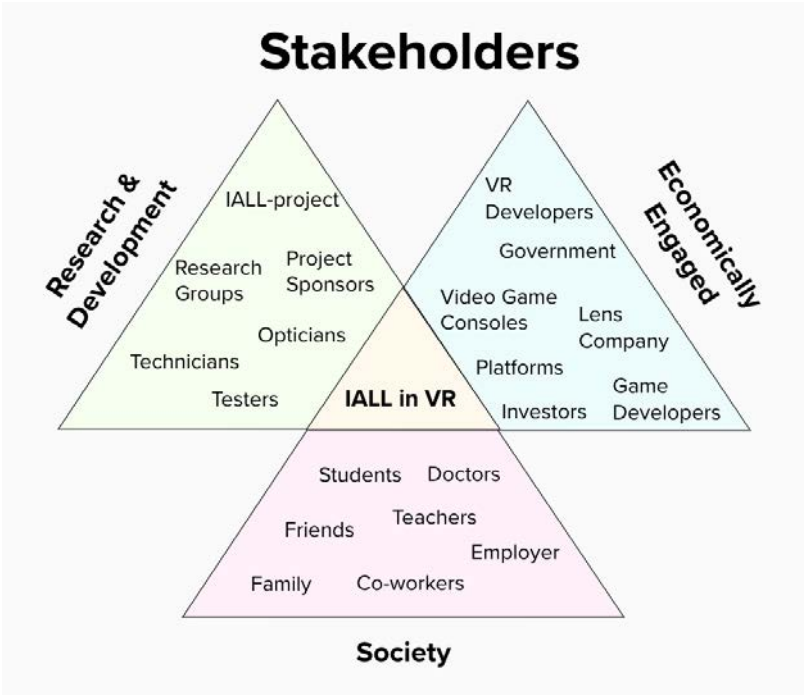
tools coming in the market.	order to have a higher resolution in the pixels per inch. He cares about having a better visualization of the VR world with a higher definition.	hoping for something with a better definition. He is interested in how the replacement of the actual fresnel lense with the liquid crystal lens, improves the quality of the PPI in the image and enhances the definition.

4.5. Journey Map



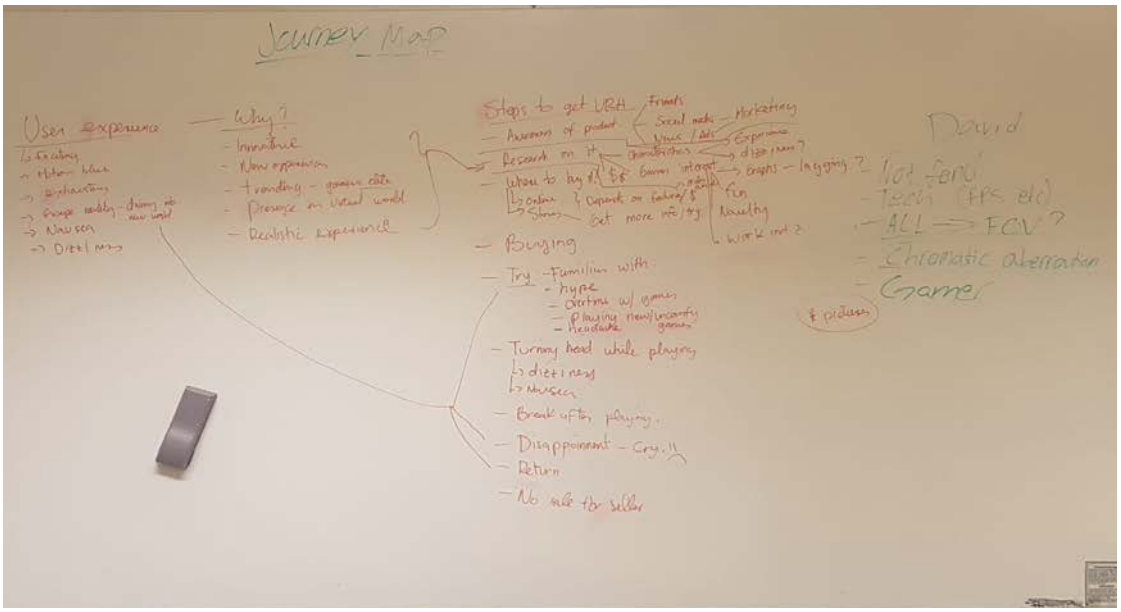
4.6. Stakeholder Maps



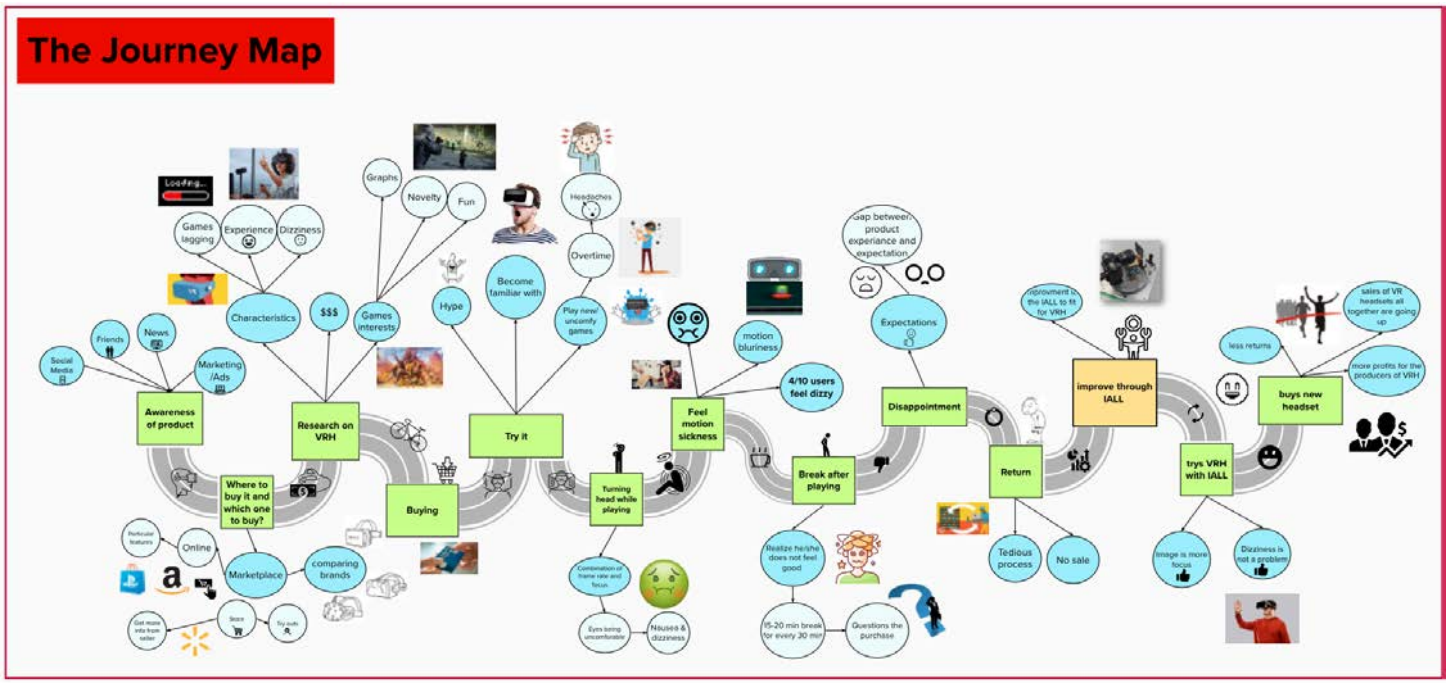


4.7. Appendices VR:

Appendix I: Journey Map (Work in Progress)



Appendix II: first version Journey Maps



Appendix III: Stakeholder Map (Work in Progress)