Appendix A - Hardware comparison

	CytoCam Model 3&4	Microscan USB3
Photos		
Weight [g]	173	150
Ergonomics (-3 to +3)*	+2	-1
Focus mechanism	Motorised, manual control via the software interface	Manual focus ring
Resolution(s) [pixels]	2048 x 1536 (Native) 1772 x 1328 (compatibility mode)	1280 x 960
Field of view		
Frame rate [fps]	85 - 95	8.5 - 45
Magnification	4 x	5 x
Illumination	12 x LED (525nm)	6 x LED (540nm)
Interface	USB3	USB3

Figure 1: Camera specifications of the Bredius CytoCam and MicroVision MicroScan USB3.

*Note: Ergonomic is scored on a scale from -3 to +3, based on subjective interpretation of the shape, size and weight.

Looking at the technical specifications, the assumption can be made that the CytoCam Model 4 has the better hardware of the three devices.

Appendix B - Interview design

Qualitative interview

Qualitative research is done by interviews (n=6) with clinical experts who have used or still use the CytoCam camera:

Participant	Job title	Organisation	Location
1	Clinical Technologist	Leiden University Medical Center	Leiden, Netherlands
2	Consultant general surgeon	- University Hospitals Birmingham - Royal Centre for Defence Medicine (NHS)	Birmingham, UK
3	Anesthesiology & critical care medicine	Hospital of the University of Pennsylvania	Pennsylvania, USA
4	Researcher cardiovascular medicine	Leiden University Medical Center	Leiden, Netherlands
5	Pediatric critical care	Santa Marta Hospital	Lisbon, Portugal
6	Pediatric cardiologist	Santa Cruz Hospital	Lisbon, Portugal

Figure 2: Background of the participants

Participant	CytoCam Research application	Level of experience with the CytoCam
1	Translational research	Intermediate
2	Translational research	Expert
3	Translational research	Expert
4	Patient data protocol	Intermediate
5	Cardiovascular complications for newborns	Very little, training only
6	Cardiovascular complications for newborns	Very little, training only

Figure 3: Usecase for CytoCam and level of experience.

The interview was semi-structured. Interview questions were drafted, but new questions were also asked on the spot depending on the responses.

Participants 1, 4, 5 and 6 were spoken in person. Participants 2 and 3 were interviewed online as they were not present in the Netherlands.

Data collection from the participants was done via semi-structured interviews. The discussions were done on-location, via online video calling (Zoom) and via email correspondence. The main topic covered will be shared below.

Research questions

- Do you see potential in using video microscopy of the microcirculation for clinical applications, assuming that current technical inhibitors are removed?

- For which purpose did you use the camera?

- For which new applications would you intend to use video microscopy? (E.g. intervention cardiology, organ transplant, and fluid resuscitation.)

- With which other biomarkers should microcirculation data be combined to guide therapy?

- Do you think a hand-held camera is an inhibitor for clinical monitoring?

- Your vision or comments.

Appendix C - Microcirculation parameters

Parameter	Measures	Explanation
Total vascular density (TVD)	Density	The number of microvessels in a screen or crossing a reference gridline
Proportion of perfused vessels (PPV [%])	Perfusion	Ratio between vessels with continuous flow and the total number of vessels
Perfused vascular density (PVD)	Density	Total vascular density multiplied by the proportion of perfused vessels (TVD x PPV)
Microvascular flow index (MFI)	Perfusion	Used to semiquantitatively characterize the velocity of microcirculatory perfusion as absent (0), intermittent (1), sluggish (2), or normal (3)
Red blood cell velocity [µm/sec]	Perfusion	Displacement of a red blood cell along a section of a vessel divided by the time
Heterogeneity flow index	Heterogeneity	Highest MFI minus the lowest site MFI divided by the mean MFI or coefficient of variation of red blood cell velocity

Figure 4: Microcirculation parameters. Adapted from Dubin[1].

Appendix D - Cause of user pains

The potential cause of the pain points are identified as

Pain point	**Causes**
1a	i) Hand-held operation, unsteadiness ii) Lack of feedback: not knowing whether artefacts are present or not. For example, the flow can be impaired because of illness, not because of user error iii) Lack of knowledge: it requires the operator to know what to look for
1b	iv) Physiology of the mouth
1c	iv) Physiology of the mouth
2a	v) The limited space inside the mouth is occupied by other devices
2b	i) Hand-held operation vi) Limited accessibility around the patient vii) Technical limitations: hardware design and software implementation
3	i) Hand-held operation vii) Technical limitations: hardware design
4	vii) Technical limitations: hardware design and software implementation
5	vii) Technical limitations: hardware design (shallow image depth)

Figure 5: Causes of the problems were coded into groups of core causes.

Appendix E - Market attractiveness analysis

New market options

Three applications have been identified as potential new target markets. These are: Intensive care units, hyperbaric oxygen therapy and varicose veins. The context and relevance of these markets will be explained.

Intensive care unit (ICU)
Intensive care medicine is provided by the ICU, a special department within a hospital or health care facility. Patients in intensive care units have life-threatening diseases or injuries that require constant monitoring, life support equipment, and medication to ensure normal functioning. A team of highly trained intensivists, nurses, and respiratory therapists provides care to the critically ill patients. Additionally, ICUs have a higher staff-to-patient ratio and offer advanced medical equipment and resources not often available in general hospital wards. ICUs treat a variety of life-threatening conditions, such as acute respiratory distress syndrome and septic shock. Patients who need to undergo extensive recovery after a major surgery, such as an organ transplant, are also admitted.

Relevancy: There are several reasons why devices for measuring the microcirculation would work in an ICU context. 1) The current CytoCam is already being used in the ICU, albeit for research purposes or patient data collection. 2) Stabilising body functions, such as the microcirculation is one of the purposes of the ICU. It is in their interest to monitor and keep it in check as an impaired work of microcirculation can cause critical organ failure or even death. 3) The ICU utilizes, cutting-edge, expensive equipment to provide the best care.

Market size and growth:
- ICU beds in the Netherlands: 1150 (nvic.nl) - 75 ICU departments
- ICU beds in Europe: 73,585 (Rhodes et al., 2012)
- ICU beds in the USA: 85,247 (kff.org, 2018)

According to a paper by Rodes et al. (2012)[2] the need for critical care capacity is increasing worldwide. More recent papers primarily mention COVID-19 as a factor that applies a lot of pressure on the ICU capacity[3].

Hyperbaric oxygen therapy (HBOT)
Originally used to treat decompression sickness suffered by deep sea divers, hyperbaric oxygen therapy is now used for many various illnesses such as serious infections, carbon dioxide poisoning, wounds caused by burns, diabetes or radiation, and recently it has also been used for Long COVID patients[4, 5, 6]. It works by exposing the patient to higher atmospheric pressure (2-3x) and oxygen content (~100%). This allows the patient to inhale a significantly greater amount of oxygen as normal air has about 21% oxygen. The higher pressure increases the solubility of the oxygen in liquid (Henry's Law). The therapy aims to hyper oxygenate blood plasma, cerebrospinal fluid and lymph fluid. As a result, the plasma contains 10-15x more oxygen, which is enough to bypass the body's normal system of transporting oxygen with red blood cells. Normal red blood cells also get more saturated with oxygen. This allows tissue that has a compromised oxygen supply (hypoxia) due to e.g.

wounds or vessel clots to receive adequate oxygen. Moreover, it promotes healing by releasing growth factors and stem cells. The therapy is given at certain hospitals or specialized clinics. It is only considered hyperbaric oxygen therapy when the patient's whole body is exposed to increased pressure and oxygen. This is done in two ways: a tank where one patient can lay in or a whole pressurized room where multiple patients can sit in. To achieve the desired effects, patients need to undergo multiple sessions ranging from 3 to 40 or more.

Figure 6: A single-person tube and a room for multiple people..

Relevancy: As multiple clinics have reached out to Braedius, there already seems to be interest in utilizing the CytoCam with their therapies. This makes sense as the mechanisms of the therapy influence the oxygen supply to the tissue, which happens at the microcirculation. In critically ill patients, HBOT improves microcirculation regardless of the patient's hemodynamic parameters, which is a key therapeutic target. Acquiring the patient's microcirculatory data is therefore insightful for measuring the effectiveness of the therapy or for therapy guidance. One caveat of the treatment is that the use of electronics inside the tube or chamber is very restricted or prohibited due to the increased fire hazard of oxygen. This makes it difficult to develop a solution that can guarantee a risk-free operation. However, the new device could still be used before and after the session to measure the efficacy of the treatment.

Market size and growth:
In 2006 Germonpré and Kot published a list of registered therapeutic centres for hyperbaric medicine located in Europe[7]. The list contained 139 different centres. For more recent numbers, OXYNET Map was used[8]. This tool shows hyperbaric oxygen centres known in Europe on a map. A total of 196 centers were counted. It must be noted that HBOT Centers are only listed when they request this themselves. Although this method is not highly accurate, it gives a good indication of the potential market size and growth.

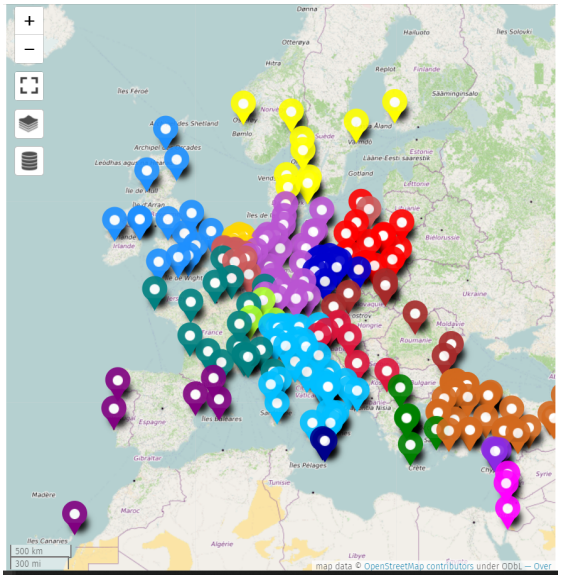


Figure 7: Hyperbaric oxygen therapy clinics in Europe

Varicose Veins

An enlarged, twisted vein is called a varicose vein. Veins that are close to the surface of the skin can become varicose. Veins in the legs are most commonly affected by varicose veins. Due to the increased pressure in the lower body veins caused by standing and walking. Often, varicose veins and spider veins - a mild variation of varicose veins - are merely cosmetic concerns. Varicose veins can also cause discomfort and aching pain for some people. Occasionally, varicose veins cause more serious problems.

Relevancy: The CytoCam is designed to study superficial mucosal (capillary) veins, therefore the technology could perhaps be used to study other types of veins in the body. However, solutions already exist to visualise the affected veins, such as echography[9]. These solutions are part of an established routine and seem to be working well for the application. As varicose veins are large in size, and also visibly by the eye, it is questionable if a technology created for microscopic veins is a good fit.

Market size:

According to whatclinics.com there are 366 locations in Europe that treat varicose veins[10]. These are mostly dermatology centres, laser clinics and medical aesthetic clinics. The accuracy of this site can however not be confirmed.

Conclusion

Based on the data a decision can be made on which market the new innovation will target. The ICU context will be the target market due to the market size, relevancy (technology-application fit), existing customers and contacts. Moreover, a clear market pull has already been showcased for many years, but no company has successfully been able to fulfill the needs and requirements for a true clinical application. However, hyperbaric oxygen medicine should not be completely disregarded as it can serve as a potential secondary target market.

Appendix F - Pros and cons of mucosal and cutaneous tissues

So far, the hand-held vital microscopes are mostly focused on making measurements sublingually or in other areas in the mouth. This is mostly done because of technical restrictions: mucosal tissue has shallow capillaries which allows for non-invasive microcirculatory observations in adults. Cutaneous (skin) measurements on humans have been done but are only limited to neonates due to their very thin skin. However, the mouth as a location for measurements has many drawbacks. Choosing for taking measurements on the skin could introduce many benefits and differentiate the device even more from the current market. The pros and cons of both approaches are laid out below:

Pro mucosal tissue (mouth)	Con mucosal tissue (mouth)
Capillaries near surface	Prone to contamination and difficult to clean
	Very limited amount of surface area and space
	Difficult to attach or stick objects onto

Pro cutaneous tissue (skin)	Con cutaneous tissue (skin)
Easy to clean	Capillaries lay deeper in skin
Big surface area and a lot of space to work with	
Easy to attach or stick objects onto	

Although not ideal, devices that are optimised for sublingual measurements already exist. These devices are hand-held for a reason, as it is very challenging to create a reliable fixated probe for the mouth. Therefore, it could be more interesting to look at a device that makes measurements via the skin. Various existing medical devices have shown that this is possible, such as NIRS and laser Doppler. Furthermore, the microcirculation can behave differently in each part of the body. It can complement the hand-held video microscope and possibly give new medical insights. For this reason, it is chosen that the new device will be made for microcirculatory measurements in the skin.

Appendix G - Business requirements

Business objectives

By developing a new medical device for monitoring and observing the microcirculation of ICU patients, Braedius aims to achieve the following goals:

1. Create a novel product service solution that offers unique values.
2. Diversify and grow revenue streams.
3. Enter a new market with a higher market potential.
4. Increase total revenue and profit.
5. Increase resources for R&D and employees.
6. Improve technology and knowledge portfolio.
7. Develop stronger branding.

Viability requirements

Requirements	Reason
Expected market size and growth must be validated before the project is started.	To confirm market potential.
The expected target user must be validated in terms of needs and purchasing capabilities.	To confirm if the users need the new solution and if they can finance it.
Competition analysis must be made.	Confirm the strengths and weaknesses of your competitors and identify market gaps.
Expected demand must be validated.	To confirm if there is enough interest in the product to add it to the product mix.
Technology feasibility must be validated.	To confirm if the technology will actually work for the intended use case and if the company is capable of successfully implementing or developing the technology.
The product design outline must be in line with the market trends	The latest trends can greatly influence user adaption and acceptance.

Project management requirements

Requirements	Reason
A detailed project plan must be made outlining the required steps in detail.	To provide structure and foresight for the execution stage and to help eliminate wasteful activities and patterns.
All important deadlines and milestones are included in a detailed schedule.	To monitor progress and get timely deliverables.
Performance metrics must be outlined.	To be able to measure progress.
Communication plans	For effective communication (channels)

Financial requirements

Requirements	Reason
Cost-benefit analysis must be conducted.	To see if the venture is worth pursuing.
Calculate appropriate budget to finalize the project.	To calculate the cost estimation and to plan money allocation effectively.
Make cash flow forecast.	To see if cash flow will be adequate to support the new venture.
Create a financing plan.	To plan ahead on what is the best way to get loans, investments etc.
Capital needs planning.	To get insight into business operation costs and which capital investments need to be made.
Make cost structure forecast.	To determine the required expenditures at the various payment stages of the project.
Perform break-even analysis, Payback period and Return on investment.	To know where we're headed before investing the money.
Risk management	Planning in case of an emergency or opportunity.

Appendix H - Product requirements

- Hands-free operation
- Easy to clean with wipes
- Easy to apply on patient's body
- Easy to remove from patient's body
- Device can be left on the patient's body for multiple days
- Software guides user in the use-process (e.g. application of probe) to minimize mistakes
- Probe can be reapplied to the same exact location on the patient's body
- Data can be interpreted at a glance
- Does not get in the way of other devices in ICU
- Displays microcirculation on cellular level with
    - High frame-rate (minimum 95 fps)
    - High contrast
    - Sharpness and clarity
- Measures and displays following quantitative biomarkers:
    - Total vascular density (TVD)
    - Proportion of perfused vessels (PPV)
    - Perfused vascular density (PVD)
    - Red blood cell velocity
    - Heterogeneity flow index
    - Tissue oxygenation
- Easy to store or put away when not in use

MDR safety regulations

A medical device's design must prioritize safety above all else. It is important for designers and manufacturers to take into account all potential risks and design devices to minimize these risks as much as possible.

Requirements are based on the following regulations or standards:

- Medical Device Regulation (EU MDR) 2017/745
- ISO 16142-1
- IEC 60601
- IEC 62366-1
- IEC 62366-2
- ISO 14971:2019

To determine the medical device class designation, we can use the following information:

Hardware: Class IIA

- Not used for in vitro diagnostics
- Non-invasive, placed on the skin for a duration of 60 min - 30 days
- Rule 10: Active devices intended for diagnosis and monitoring

Software: Class IIA

- Rule 11: Software intended to provide information which is used to take decisions with diagnosis or therapeutic purposes
- Software intended to monitor physiological processes

Patient safety

Requirements	Reason
A risk management process must be established.	to identify and evaluate potential risks associated with the device's use. The manufacturer must then take steps to mitigate these risks to an acceptable level.
Parts that come into contact with the patient should be biocompatible.	Prevent irritation
Device should not have sharp edges or abrasive surfaces.	Prevent damage to the patient's skin
Device should not leak electric current or charge, including static charge	Prevent risk associated with electric shocks and current
Device should not burn or considerably heat up the patient's skin.	Prevent risks associated with burning and heat
Manage risks associated with reasonably foreseeable external influences or environmental conditions, including magnetic fields, external electrical and electromagnetic effects, electrostatic discharge, radiation from diagnostic or therapeutic procedures, pressure, humidity, temperature, variations in pressure and acceleration, or interference with radio signals.	Prevent external influences on compromising the device's performance or safety
The design and construction of electrical or mechanical couplings must minimize all possible risks, such as misconnections.	Prevent device failure due to misconnection
Scales used for measuring, monitoring, or displaying should be designed and manufactured according to ergonomic principles, taking into account their intended purpose, users, and the environment.	Prevent the risk of misreading or incorrectly interpreting data which can lead to incorrect patient therapy guidance
The user, patient, or other person shall be able to dispose of devices and related waste substances safely. In order to ensure the safe disposal of their devices after use, manufacturers must identify and test measures and procedures. Instructions for use should describe such procedures.	Waste materials are safe for disposal
Electronic programmable systems, including software, or software that is in itself a device, must ensure repeatability, reliability, and performance in line with their intended use. If a single fault condition occurs, appropriate measures should be taken to eliminate or reduce as much as possible the associated risks or impairments.	Ensure repeatability, reliability and performance
During the development and manufacture of the software, the state-of-the-art principles, including information security, risk management, verification, and validation, shall be taken into consideration.	Software risk management

The minimum requirements for hardware, IT networks, and IT security measures, including protection against unauthorised access, necessary to run the software must be specified.	Prevent the risk of unauthorized use
Devices where the safety of the patient depends on an external power supply shall include an alarm system to signal any power failure.	Prevent the risk of power supply failure
An alarm system should be included in any device intended to monitor one or more clinical parameters of a patient in order to alert the user if a situation could lead to death or a serious decline in his or her health.	The users should be warned or noticed when the patient is in a critical state of health
Electromagnetic interference should be reduced to the maximum extent possible.	Reduce the possibility of affecting the operation of the devices in question or other devices in the intended environment.
As appropriate, each device shall be accompanied by the information necessary to identify it and its manufacturer, as well as any safety or performance information relevant to the user. If a manufacturer has a website, such information will be made available and kept up to date on the website, as well as on the device itself, on the packaging, and in the instructions for use.	Information on correct use should be easily accessible to prevent incorrect use.
Correct labeling should be present on the device and packaging	Labeling with information on correct uses and potential risks during use should be visible
In order to run the software as intended, minimum requirements concerning hardware, IT network characteristics, and IT security measures, including protection against unauthorised access, are required for devices incorporating electronic programmable systems, including software.	Users should be informed of the requirements to run the software and data connectivities

Technical/functional requirements

Performance requirements

Requirements	**Reason**
The device must be able to create clear videos of the cutaneous microcirculation with no artifacts	This is one of the main features of the device.
The device must not alter the microcirculation.	External factors such as the device itself should not influence the microcirculation for accurate readings.
The device must not increase the temperature of the skin significantly (< 1° C)	Skin temperatures influence the perfusion of vessels.
The device must work continuously without failure due to e.g. overheating	The medical staff must rely on the device for continuous monitoring.

Optical requirements:

Requirements	Reason
Can observe individual red blood cells (7-8 µm)[]	Required to measure flow, perfusion, heterogeneity
Working distance: 1,8 mm - 3 mm depth of skin	Microcirculation resides at these depths in the skin
Optical zoom (mechanical focus system)	Digital zoom causes degradation of image clarity
Field of view: ~ 1,6 x 1,2 mm	Based on CytoCam M4 specification
Focus depth step size: 10 µm	Smallest capillaries are 8-10 µm

Sensor requirements:

Requirements	Reason
High near-infrared light sensitivity (700 - 950 nm)	Light source emits near-infrared light
Optimised for high-speed video capture	To capture the fast flow of red blood cells
Global shutter function (all pixels of the array are exposed simultaneously)	Enabling 'freeze frame' capture of fast-moving events
Frame rate: Minimum 95 fps	Based on CytoCam M4 specification
Shutter speed: 1 - 2 ms	Cytocam M4 specification, reduces motion blur.
Maximum sensor size: 1/2.3	Must fit in a small probe enclosure.

Durability and maintenance

Requirements	Reason
Dust resistance: IP6X rating - fully dust tight.	Dust inside the casing will compromise camera function.
Water resistance: IPX5 Can resist a sustained, low-pressure water jet spray	Moisture should not come into the product to prevent damage to electronics.
Cleaning-chemicals resistant	Detergents and disinfectants are used to clean medical devices
Minimum drop resistance probe: 1 m	Product is used in a hectic environment, the product should be durable

Data management

Requirements	Reason
Data logs of the measured parameters and video samples must be made.	Doctors can refer to medical records to help with future medical treatments or to see what went wrong.
Data logs of recently measured parameters and video samples should be quickly accessible within the device ecosystem.	To prevent data retrieval of recent activity from being a long process.
A means of storing the data for the long term must be available.	Medical records are kept between 5-10 years

Data transfer between the device system and the hospital's IT environment must be possible.	The medical device must be able to work with the hospital's IT environment.

Interactions operator, product and patient

Human factors for operator

Requirements	Reason
Complexity of using the hardware and software should be minimised.	The learning curve of using the device should be kept at a minimum to promote adoption.
Incorrect use should be prevented by limiting options of use.	Mistakes should be made difficult as a result of good design for both hardware and software.
The software should guide the user by using step-by-step processes.	To prevent incorrect use and confusion.
The device must give the user feedback on whether it is being incorrectly used.	To aware the user the device is not used as intended or performing optimally.
The user interface must be clear and easy to understand.	To prevent misinterpretation or confusion.
Setting up the device should require minimal time and effort.	The design of hardware and software should help the user with
The data must be interpretable at a glance	Efficient and quick data interpretation is important for patient treatment and user flow.
The presented data must be legible from 2 meters distance.	Users should be able to read the data from a certain distance in the room to not impede the workflow.
Physical or cognitive strain must be minimised when using hardware or software.	Operations should not bog down user flow, nor affect them emotionally or physically.
Ergonomics and anthropometry should be taken into account when designing hardware and software (interface) features.	Users of all shapes and sizes must be able to effectively use the device system.

Patient interactions and functionality

Requirements	Reason
Inter-patient variety such as in anatomy should be accommodated.	Anatomic differences should not limit the use or performance of the device.
Different thicknesses of skin and fat layers must be accommodated.	- Skin thickness can influence the depth of microcirculation. - Fat tissue interferes with light transmittance.
Negative environmental influences on the patient such as noise should be minimised.	Negative environmental influences on the patient can affect the healing.
The sensor should not irritate the skin of the patient.	Wearing the device must not feel uncomfortable.

Appendix I - Inspiration board

Appendix J - Overview of Design Challenges

DC1: How to observe microcirculation in cutaneous tissue?
- **DC1a:** How to see deeper into the skin?
- **DC1b:** Which light frequency?
- **DC1c:** What type of light source is most suited?

DC2: How to have a low-maintenance Computing unit?

DC3: What does the flow of data look like?

DC4: How to store large amounts of data?
- **DC4a:** How to store recent or quickly accessible data?
- **DC4b:** How to store long-term data?
- **DC4c:** How to store the data safely and securely?

DC5: How to not warm up the skin under the LED lights?
- **DC5a:** How to keep probe temperature under 33 degrees Celsius

DC6: How to monitor microcirculatory data in real-time?
- **DC6a:** How to analyse microcirculatory videos automatically for continuous data output?
- **DC6b:** How to calculate the speed of the flow/ red blood cell
- **DC6c:** How long does a video sample have to be?
- **DC6d:** How to analyse microcirculatory videos under 60 seconds?

DC7: How to fixate the sensor to the patient's skin?

DC8: How to prevent motion artefacts?
- **DC8a:** How to keep the CytoCam in its place?

DC9: How to prevent pressure artefacts?
- **DC9a:** How to not apply (too much) pressure

DC10: How to keep bubbles from being trapped in front of the viewing area

DC11: How to keep contaminants from the video image?
- **DC11a:** How to clean the lens?
- **DC11b:** How to clean the measurement surface (skin)?
- **DC11c:** How to prevent contaminants from getting on the lens/skin during monitoring? (E.g. blood, fluids, dirt, food etc.)

DC12: How to measure at the same spot on the skin, pre-, intra-, and post-operative?

DC13: How to minimize/prevent light reflections from the skin?
- **DC13a:** Fluid interface to combat reflections from the skin and improve light transmission -> Which type of fluid is best?

DC14: How to fit the sensor, electronics and optic system in such a small compartment?

DC15: How to make the probe unit even smaller? E.g. for infants or placing it on the thenar eminence.

DC16: How to display the data?

DC17: How to prevent user error?

DC18: How to integrate the system into ICU rooms (with various designs and layouts)?

DC19: How to store the probes and accessories?

Appendix K - Solving the Design Challenges

DC1: How to observe microcirculation in cutaneous tissue?

DC1a: How to see deeper into the skin?

DC1b: Which light frequency?

DC1c: What type of light source is most suited?

An appointment was made with dr. ir. Ger de Graaf (TU Delft, faculty EEMCS), an expert in the field of optical spectroscopy for biomedical applications to get a better understanding of the possibilities. Although he could not recommend specific wavelengths for this application, papers with relevant data and graphs were shared. He also gave the advice to look at current devices and to ultimately empirically test different lightwaves to see what works best with the intended goal.

Figure 6 gives an overview of all the wavelengths that were used in various devices and scientific papers.

Found wavelength [nm]	**Based on**	**Source**
685, 730, 770, 810, 870	LEDs used in NIRS tissue oximetry system by Edwards Scientific	Product brochure [88]
770 and 940	Respective peaks of deoxyhaemoglobin and oxyhaemoglobin within the near-infrared window.	Paper [89]
660 and 940	LEDs used in pulse oximeters. 660 nm for deoxyhaemoglobin and 940 nm for oxyhaemoglobin	[90]

Figure 8: Wavelengths used by near-infrared devices and mentioned in literature.

Figure 6 will be used as a reference to pick a selection of LEDs to do testing with.
The following LEDs have been sourced from mouser.com, a large electronics component supplier:

- 720 nm
- 770 nm
- 810 nm
- 880 nm
- 900 nm
- 940 nm

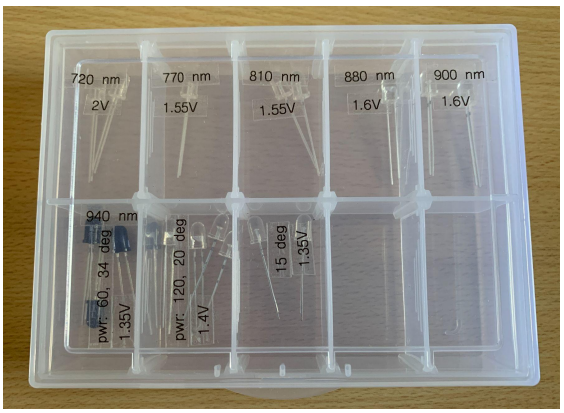


Figure 9: A box containing the near-infrared lights. The LEDs are sorted and labelled with their specifications.

Note: Ideally the only variable of the LEDs should be the wavelength. However, this was not available at the supplier. The sourced LEDs are all of the 5 mm types, but the light intensity and beam angle are different which will have an effect on the outcome.

Experiment 1: Light transmission through human skin and tissue

The objective of the test: To compare how well the various wavelengths travel through the skin

Test setup: The tip of the index finger was placed directly on top of the LED, which was powered by a battery. A smartphone in a tripod was used to take pictures of the top side of the fingertip. The room was completely dark. The LEDs shown in Figure 7 were used for testing. As a reference LEDs emitting light in the visual spectrum were also tested.

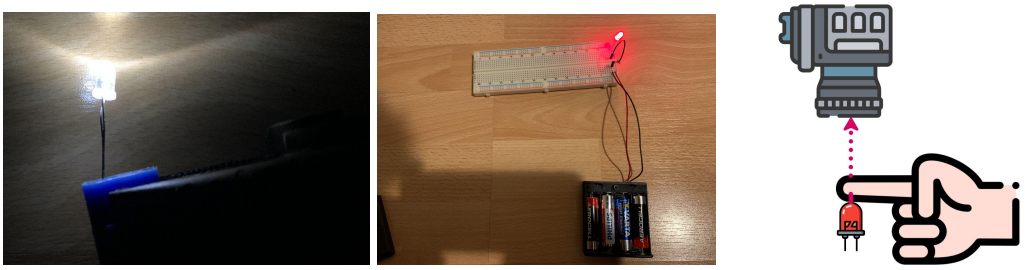


Figure 10: Test setup for experiment 1.

Results: The green LED (550 nm) performed the worst and the orange LED (600 nm) second worst. No light was transmitted through the finger with the green led and only a little bit of light was seen with the orange LED. The red LED (680 nm) performed a lot better. 720 nm and 770 nm were barely visible to the naked eye. The LEDs emitting longer wavelengths of light were invisible. However, 720 nm and 770 nm were still picked up by the smartphone camera. Longer wavelengths, however, were not picked up by the camera. After doing some research it turned out most cameras have an infrared filter, as this benefits normal (daylight) photography. After looking at the spec sheet of the sensor used for the CytoCam, it turned out it can be used for near-infrared light photography. Nonetheless, the LED with 720 nm also showed great results.

770 nm was already barely being picked up by the camera and can not be seen as a valid test entry.

Figure 11: Photos of the index finger with the various LEDs.

Notes: This experiment is meant as a crude test to see how the different lightwaves behave through human tissue. The LEDs in the visible spectrum (green, orange, red) had a lot more light output than the near-infrared LEDs. Light output influences the amount of light that can be seen through the finger. The optics and electronics such as the camera sensor also play a role in the output of the image. It is therefore advised that a similar test should be conducted but with prototypes that are close to the production model.

Conclusions: 1) The red LED and near-infrared LEDs showed far superior light transmission through human skin than green light. 2) The sensor for the probe camera should be able to detect near-infrared light.

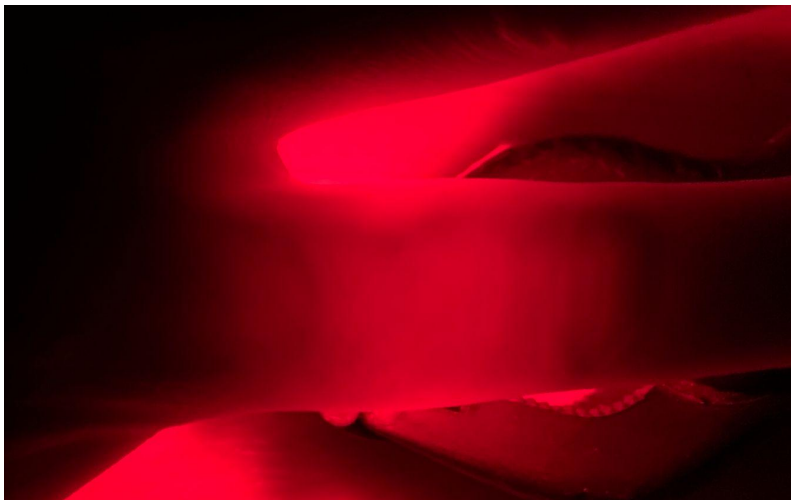


Figure 11: The light transmission through the base of the finger near the knuckle. Red light was used for this picture.

Experiment 2: Vein visualisation in skin

The objective of the test: To see how well veins in the skin can be visualised by using various wavelengths

Test setup: One LED at a time was used to illuminate the back of the hand (fist). A smartphone on a tripod was used to take photos. The room was completely dark. The green and orange LED were not used for this test.

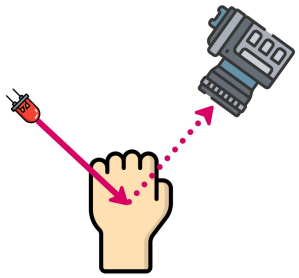


Figure 13: Test setup for experiment 2.

Results: The near-infrared light (720 nm) showed a better contrast between the skin and veins compared to the red light. 770 nm also looked good on the screen of the smartphone, but there were difficulties with getting a sharp image as there was too little light picked up by the phone camera. The other LEDs could not be picked up by the phone camera.

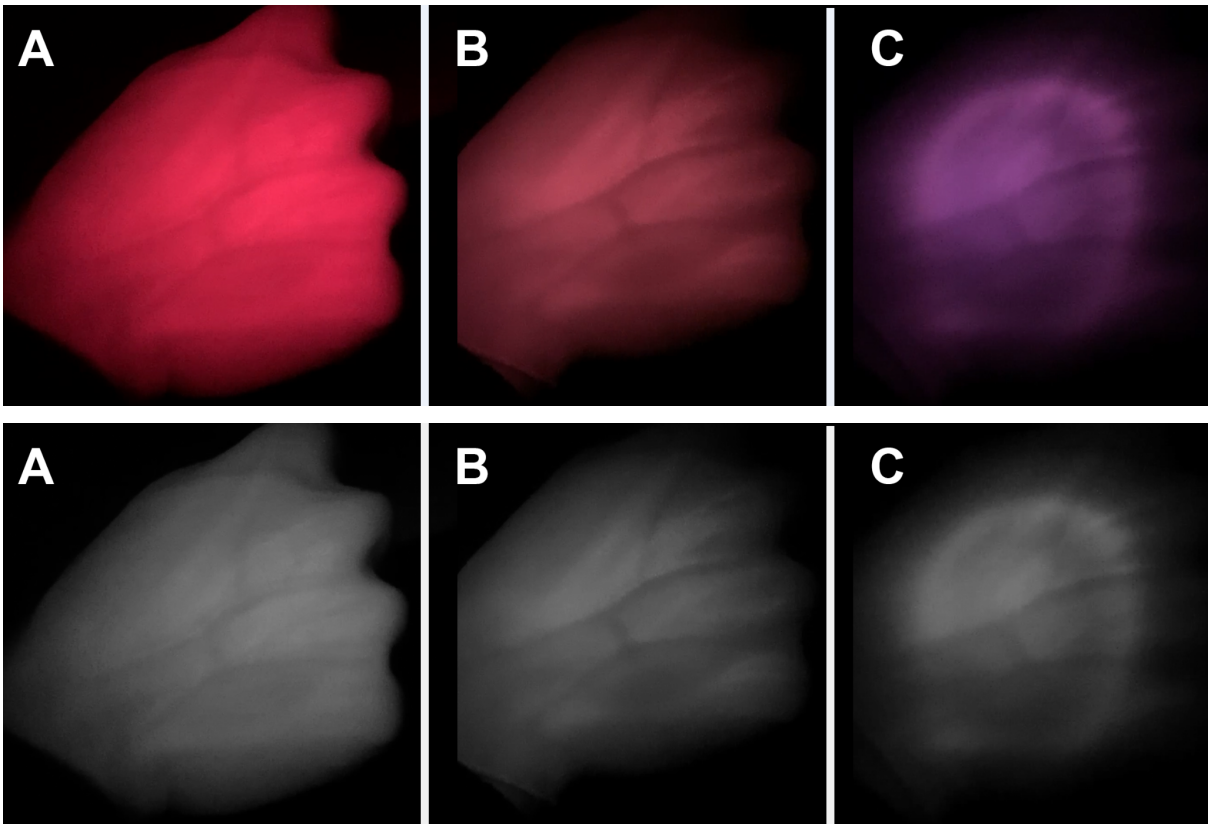


Figure 14: Photos of the back of the hand using 680 nm (A), 720 nm (B) and 770 nm (C) LEDs. The top row has the original photos taken by the smartphone. The bottom row has a black-white filter to show the veins more clearly.

Notes: Also here many variables are at play that influence the outcome such as the camera sensor limitations and the different power outputs of the LEDs. It is also good to know that not all wavelengths used in modern NIRS devices are used for targeting haemoglobin. Newer devices also use wavelengths to target other molecules and can subtract these from the image output for more accurate results.

Conclusions: A combination of high tissue transmission and haemoglobin absorption will result in the best results. This allows for the visualisation of deeper microcirculatory beds and high contrast. Unfortunately, these experiments could not give an answer on which specific wavelength should be used, however, many practical insights were made. Another test should be made by using the CytoCam with various near-infrared LEDs to assess the microcirculation visualisation in the skin.

LEDs will be used as light sources as these can be made into very small dimensions and due to their efficiency have little heat output. Laser diodes are more powerful but are more difficult to drive and generate a lot more heat. Lastly, Braedius has much more experience with using LEDs than other types of light sources.

DC2: How to have a low-maintenance Computing unit?

The computing unit needs to reliably operate continuously for weeks or even months with minimal to no maintenance. So-called “rugged PCs” that are dust-sealed and don’t have any moving parts (e.g. fans) are not uncommon for medical applications. There are various suppliers that can configure a system for Braedius’ applications.

Figure 15: Example of a rugged PC.

DC3: What does the flow of data look like?

It is assumed the same system design of the current CytoCam will be adopted:

- A camera for video acquisition of the microcirculation
- A computer to:
    - Control and power the camera
    - Run the monitoring software
    - Analyse the video and turn this into quantitative patient data
- A monitor to display the software and visualise the patient data

See Figure 16 for a visual representation of the data flow and transformations.

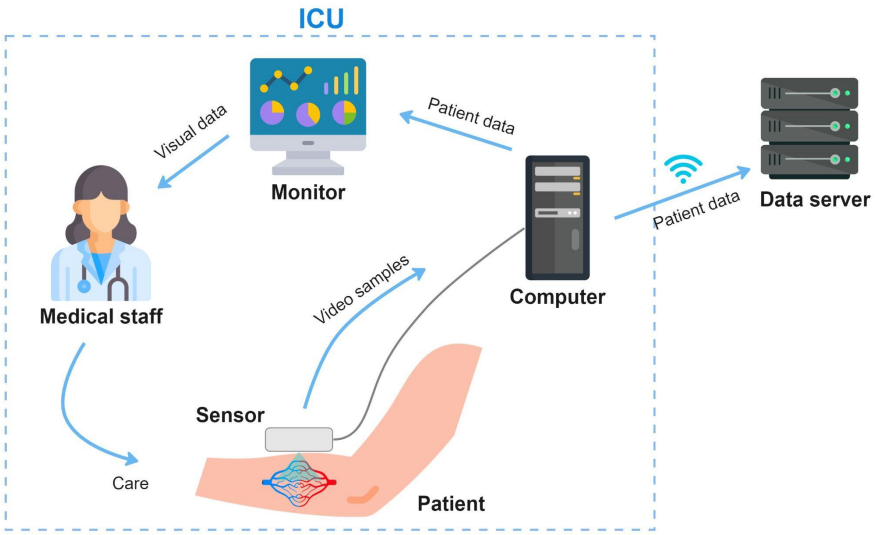


Figure 16: Flow and transformation of data of the system

DC4: How to store large amounts of data?

- **DC4a:** How to store recent or quickly accessible data?
- **DC4b:** How to store long-term data?
- **DC4c:** How to store the data safely and securely?

Recent data can be stored locally on the computer that drives the camera probe. Long-term data storage can be sent wirelessly to the hospital's server system. Hospitals are already equipped with a wireless network as part of their data infrastructure for medical data transmission, patient monitoring and communications[5]. The system needs to be able to communicate with this wireless local network.

Once the data is already uploaded to the hospital's server (either locally or in the cloud), it is dependent on the hospital's security measures to keep it secure. However, the wireless transmission from the Braedius system to the hospital's network is also a point of vulnerability as this can be intercepted by unauthorised parties. Therefore, this should be up to date and in line with the hospital's latest safety protocols. Data encryption of the wireless transfer is one example of a security measure.

DC5: How to not warm up the skin under the LED lights?

External influence on the microcirculation should be avoided at all costs to maintain accurate and dependable measurements. One of these influences is warmth. Heating up the skin will result in influencing the microcirculation and therefore the camera probe should emit as little heat as possible. The main causes of the camera heating up or emitting warmth are when it is recording videos and when the LEDs are on. Minimising and optimising the duration and frequency of these moments should result in manageable heat control. Braedius suggests a video sample duration of 5 seconds as this should be long enough for accurate data analysis and won't require the computer to process for long. Figure 17 shows a proposal for the video capture protocol. This means the data of the microcirculation will be updated every minute and five seconds. The red line represents the temperature differences in the skin. The

temperature difference should be insignificant enough not to have any influence on the microcirculation.

Figure 17: Proposed intervals of video capture and pauses in between.

DC6: How to monitor microcirculatory data in real-time?

DC6a: How to analyse microcirculatory videos automatically for continuous data output?

DC6b: How to calculate the speed of the flow/ red blood cell

DC6c: How long does a video sample have to be?

DC6d: How to analyse microcirculatory videos under 60 seconds?

The camera probe should autonomously make video samples in a predefined interval. The time between the video capture can be used to analyse the video sample. With modern computers, 60 seconds should be enough to analyse a 5-second video sample. The proposal for the video duration was already defined in the previous Design Challenge.

New hardware has emerged in the past few years that is optimised for visual machine learning. These could theoretically analyse the video samples in a much shorter time. An example is Nvidia's Jetson line of AI hardware computing solutions. However, developing for a totally new architecture requires a lot of time and thus money. Furthermore, the longer pauses between the video capture moments help with the temperature management. Figure 18 shows the timeline for the video capture, video analysis and data display output.

Figure 18: Timeline for the video capture, video analysis and data display output.

This means the data will update around every minute and there will also be a delay of around a minute between the physiological occurrence and the displayed data. However, in theory, this should be sufficient for accurate haemodynamic management and monitoring.

DC7: How to fixate the sensor on the patient's skin?

Many of the sensor probes used in healthcare are inserted into a holder or cradle, which in turn is attached to the patient's skin. An example is the wireless sensors used for continuous glucose monitoring (Figure 19).

Figure 19: Dexcom G6 glucose meter[6].

This cradle or holder can be fixated onto the patient by means of adhesion, sleeve or adjustable strap (Figure 20).

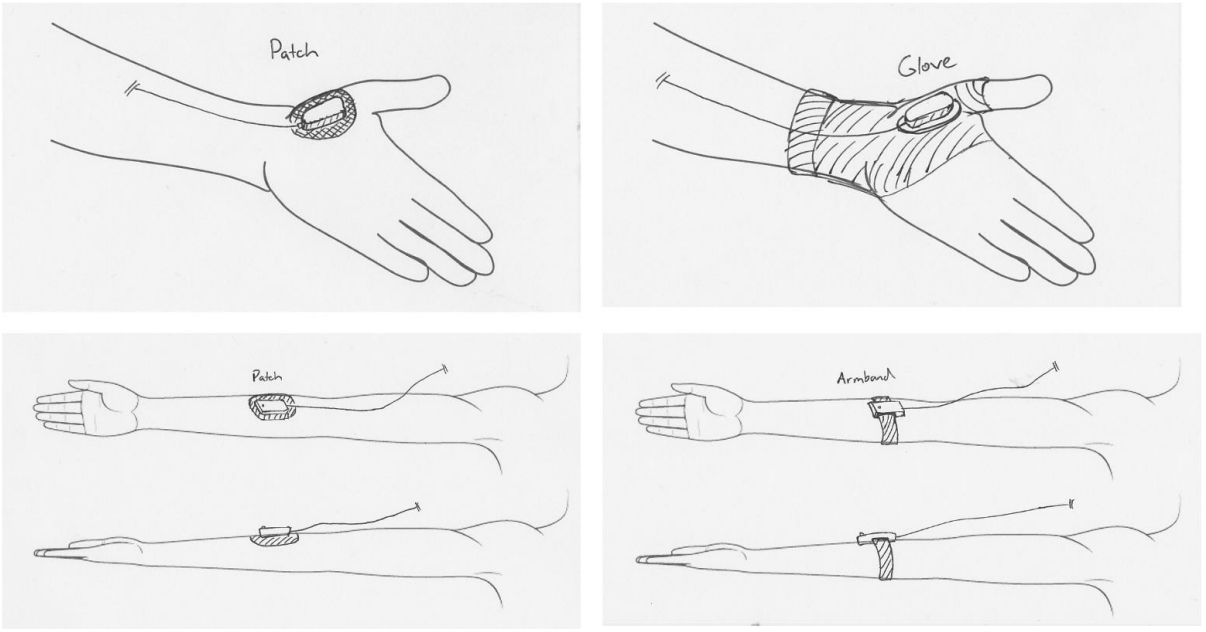


Figure 20: Sketches were made to illustrate the different ways of attaching the camera probe to the patient.

DC8: How to prevent motion artefacts?

DC8a: How to keep the CytoCam in its place?

The solutions presented in DC7 should keep the camera sensor properly in place, especially the adhesion method. An anti-slip coating (e.g. medical silicone) on the underside of the probe holder should prevent it from moving around for the sleeve or strap method.

Keeping the video samples at a shorter length should also help with not including motion artefacts. Ideally, the system should check the video quality of the sample and then accept or reject this before analysing the video. A new video should be made automatically if the sample has reason to be coined as invalid.

DC9: How to prevent pressure artefacts?

DC9a: How to not apply (too much) pressure?

A large area will help with spreading the pressure and thus not influencing the local microcirculation. The probe holder will provide this large surface area. Since the device is hands-free the only pressure on the skin would be caused by the weight of the device. However, the strap method has the potential to cause restriction when the strap is pulled too tightly.

One way to prevent pressure altogether is to make no-contact measurements. This means the lens itself hovers slightly above the skin.

DC10: How to minimize/prevent light reflections from the skin?

DC13a: Fluid interface to combat reflections from the skin and improve light transmission -> Which type of fluid is best?

Dan Milstein is a lead user of the CytoCam and has extensive experience with video acquisition of the microcirculation in various types of tissues. He recommends using paraffin oil as a transmission media between the camera lens and the skin. In microscopy, this is called an immersion oil. The high refraction index of the oil is similar to that of the lens and prevents the light beams from refracting, giving a direct path into the skin. This increases the aperture, which is the optical resolution to see details. Liquid paraffin is safe for the skin as it is used in a lot of skincare creams such as Vaseline and eczema creams.

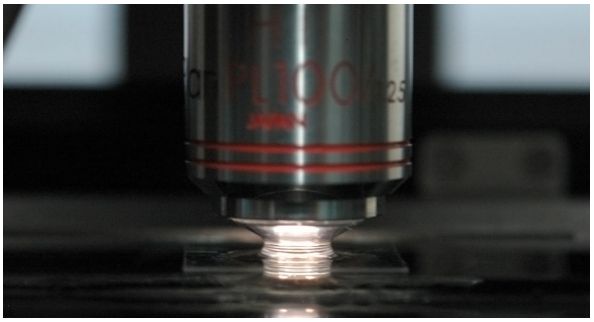


Figure 21: Both the lens of the microscope objective and the specimen are immersed in oil[7].

DC11: How to keep air bubbles from being trapped in front of the viewing area?

The solution for this Design Challenge was taken from the Apple watch. Similarly to the camera probe, it used LEDs to measure biometrics in the skin. The part that contains the LEDs and optodes (light sensors) is a glass dome. This dome shape should push the air bubbles in the immersion oil aside, allowing for an obstructed view into the skin.

DC12: How to keep contaminants from the video image?

DC11a: How to clean the lens?

DC11b: How to clean the measurement surface (skin)?

DC11c: How to prevent contaminants from getting on the lens/skin during monitoring? (E.g. blood, fluids, dirt, food etc.)

The skin of the patient and the lens of the camera probe should be cleaned before application to prevent contamination of the lens. In the ICU and other departments, it is common to have cleaning wipes, usually containing alcohol to clean devices or to disinfect parts of the skin of the patient. The probe holder should act as a barrier to prevent contamination from happening during monitoring.

Figure 22: Disinfectant wet wipes used for patients and medical appliances.

DC13: How to measure at the same spot on the skin, pre-, intra-, and post-operative?

By making the camera probe easily removable from the holder, it can be temporarily removed for a procedure and later be reinstalled at the exact same location.

There are various ways to insert the camera probe into the holder: sliding, pressing, dropping etc. Ideally, the probe goes in and out vertically. This way it won't be obstructed by other devices or body parts of the patient. A mechanism should be integrated to hold the probe securely in place. This mechanism should allow for easy and quick installation and removal.

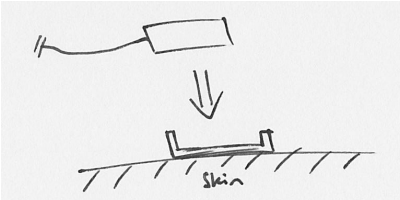


Figure 23: Vertical insertion of the probe into the holder.

DC14: How to fit the sensor, electronics and optic system in such a small compartment?

Ideally, the camera probe should be made very compact. To reduce development time and costs the components of the CytoCam can be repurposed and fitted inside the probe housing. A reconfiguration of the internal layout needs to be done.

The Classified Appendix will show the proposed solution for the internal layout. The components and the configuration thereof will dictate the size of the probe housing. One of the limiting factors that are bound to physical laws is the required path length of the light to achieve a certain magnification.

DC15: How to make the probe unit even smaller? E.g. for infants or for placing it on the thenar eminence.

By using smaller components and optics that require a shorter path of light, the probe can fit into a smaller housing. The components that take up the most space are the image sensor, optics, focus mechanism and PCB.

The following possible solutions have been found:

- A new innovation for the smartphone industry is the compact camera module with optical zoom capabilities. These are modules containing the camera sensor, optics and focus mechanism in a very small package (Figure 24).
- Shrinking the PCB is usually not possible due to the size of the electronic sub-components. However, the PCB could be placed into a separate housing (Figure 25).

Figure 24: Compact camera module containing the sensor, optics and focus mechanism.

These solutions should theoretically allow for a very small sensor probe housing. A smaller probe should allow for more placement options.

The drawbacks of using completely new components are the longer development times and bigger development costs. There is also no guarantee this approach is feasible as the idea of the separate PCB might not work and the smaller components might not be suitable for this application.

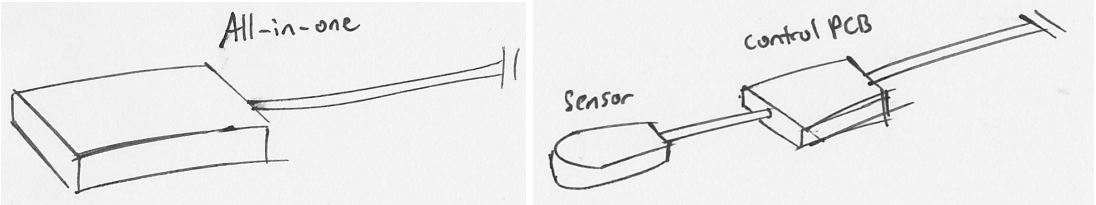


Figure 25: Two different configurations of the probe design.

DC16: How to display the data?

The design for the data display was inspired by existing devices that are used for the ICU. High contrast, usage of colours, big fonts and indicators of certain states were several properties that seem common for these interfaces.

The goal is that the user can see and interpret the data from a distance in very little time. The parameters that should be displayed as stated in the requirements are depicted in the design of the concept interface. Some parameters concern trends and can't be used as absolute values (TVD, PVD). These parameters include graphs and an indicator for the amount of change. Other parameters are used for absolute values (PVV, Flow, HI) and have a status indicator. Green indicates a good value, yellow requires extra attention and red means a bad value and requires immediate attention. Figure 26 depicts the values of a healthy patient.

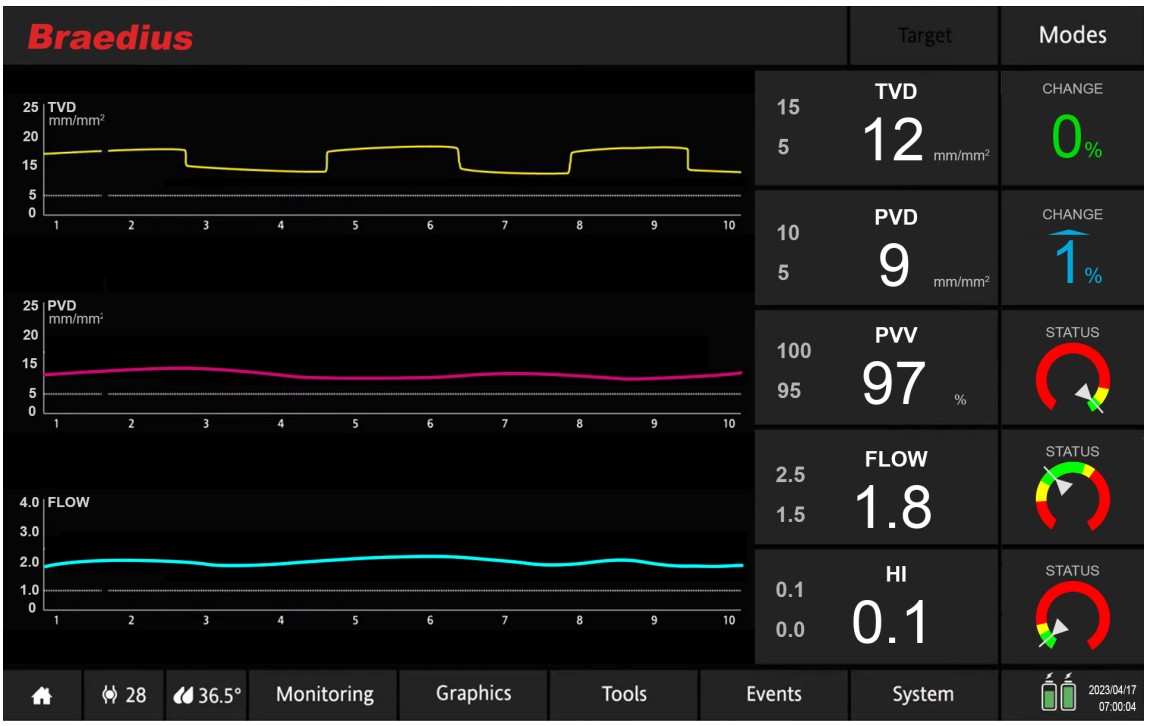


Figure 26: Data interface design - healthy parameters.

The status or change indicators will have a red border when unacceptable values are measured to draw the attention of the medical staff.

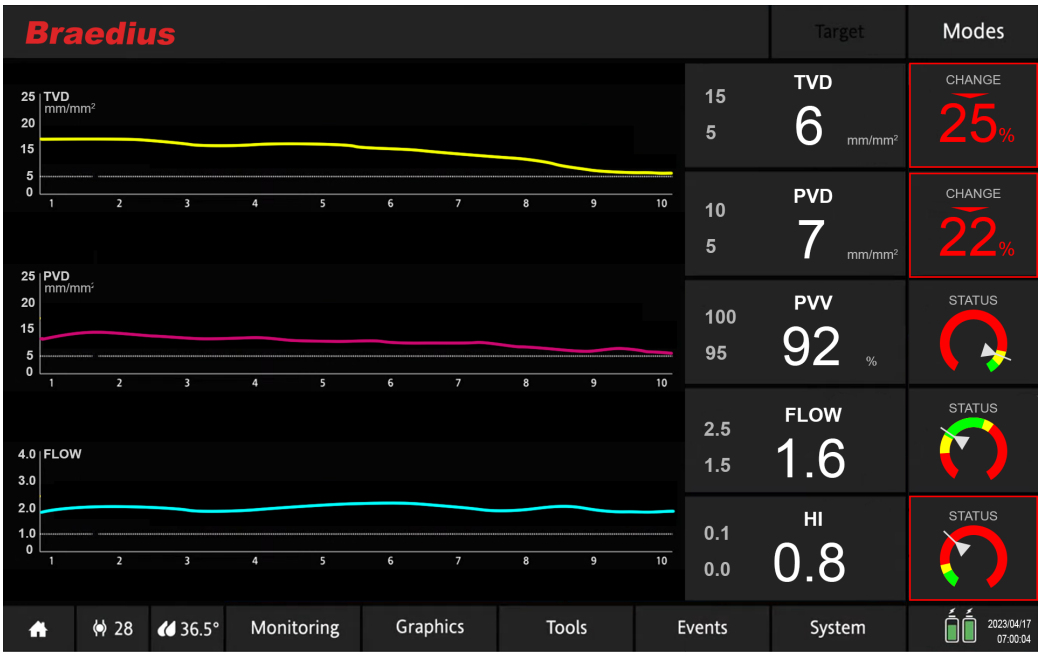


Figure 27: Data interface design - critical parameters.

The data from other devices such as heartbeat, blood oxygen content, carbon dioxide content and blood pressure can be linked to the system and displayed on the same screen. This way the healthcare will have a complete overview of all the haemodynamic parameters.

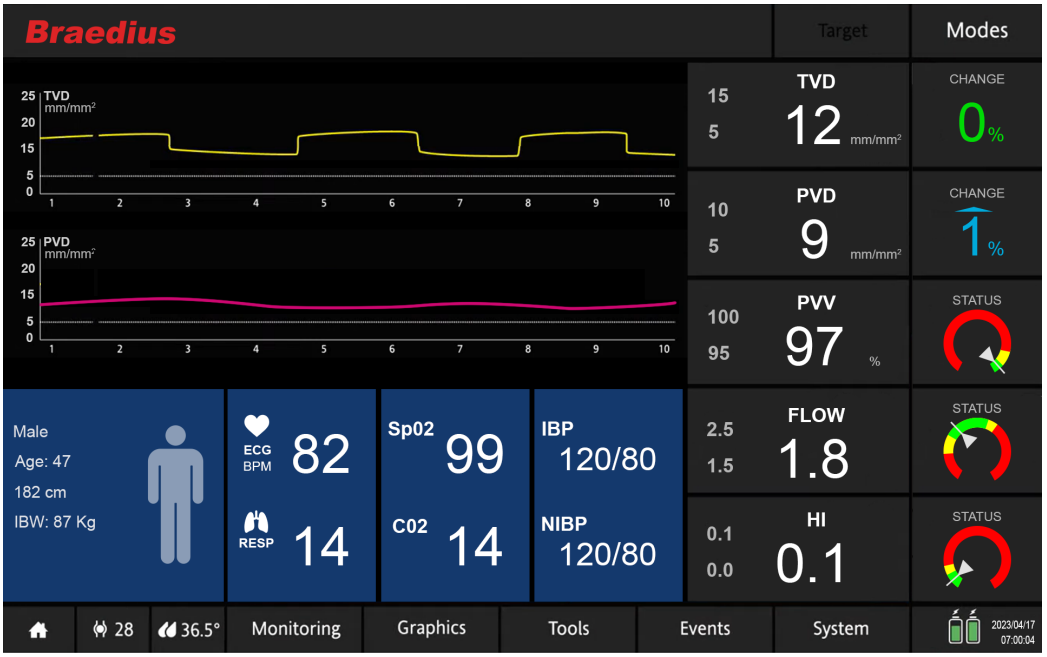


Figure 28: Data interface design - inclusion of extra parameters.

DC17: How to prevent user error?

Even if the product is very easy and simple to use, there is always a chance of user error. Especially in a high-stress environment such as the ICU. The software should guide the user with actions that require extra care or have multiple steps that could potentially go wrong. For example, a correct application of the probe is crucial for reliable data output. Figure 29 shows an example of how the software can guide the user with the application of the probe by showing the different steps.

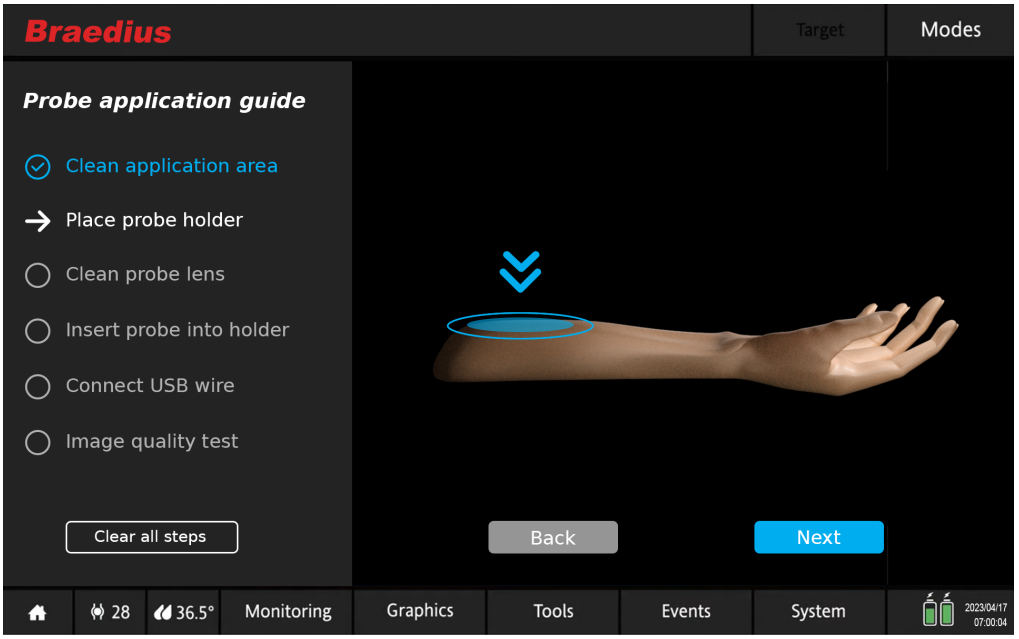


Figure 29: Data interface design - critical parameters.

DC18: How to integrate the system into ICU rooms (with various designs and layouts)?

Looking at ICU rooms from different institutes, there is a high variety in room design and layout. Most of the devices in the ICU are either integrated (e.g. into the supply unit) or in the form of a trolley. For more flexibility, the trolley form factor will be chosen. This should accommodate all the different room designs and layout and gives the customer flexibility in how to deploy it.

DC19: How to store the probes and accessories?

It is best to store all the components and accessories required for the monitoring system to be stored in one location: the trolley. This way the different items are easy to find and accessible. The probes and accessories can be stored in closed drawers in the trolley to protect them from dust and other risks.

Appendix L - Concept details

Trolley system

Figure 30: Back side of the trolley system.

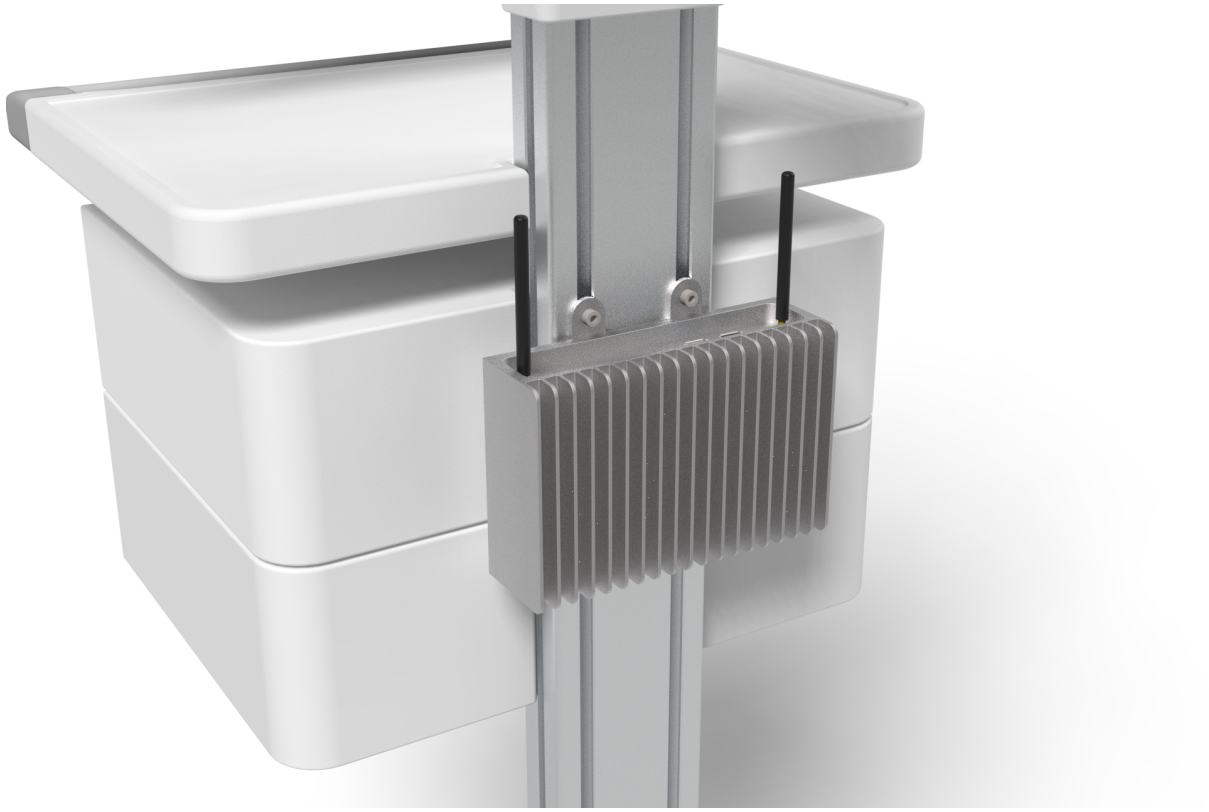


Figure 31: Detail shot of the rugged computer. The USB-3 ports for the camera probe's wire is located on the top. The black antennas allow for wireless communication with the hospital's network system. The power wire is plugged in via the bottom.

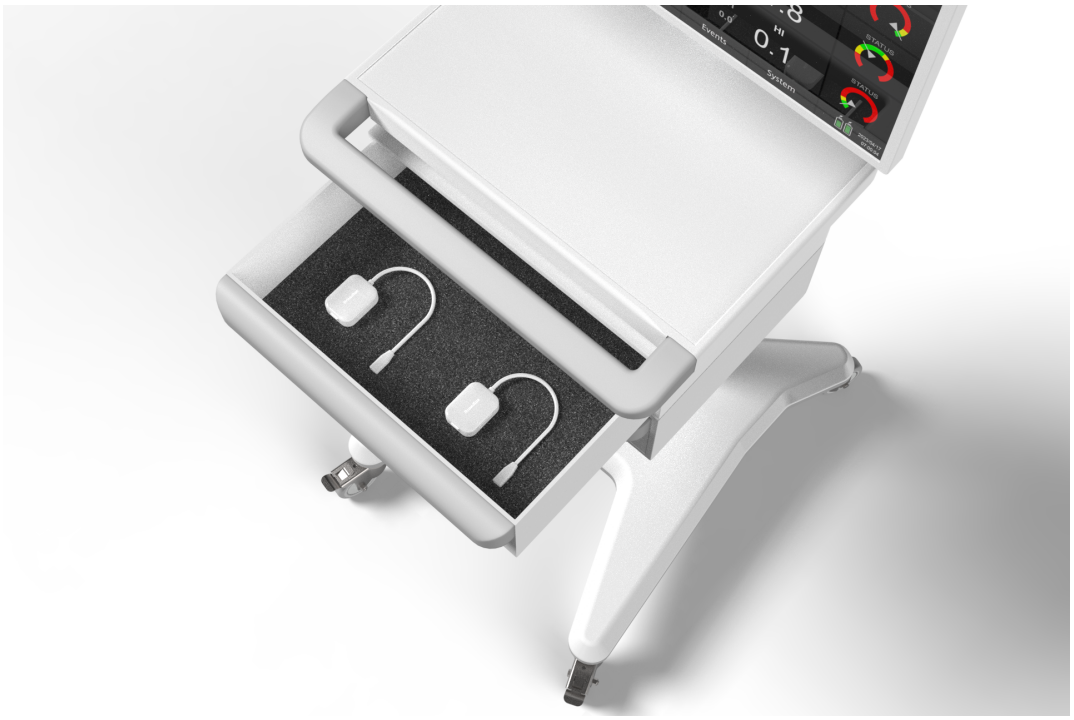


Figure 32: The top drawer is used to store the camera probes.

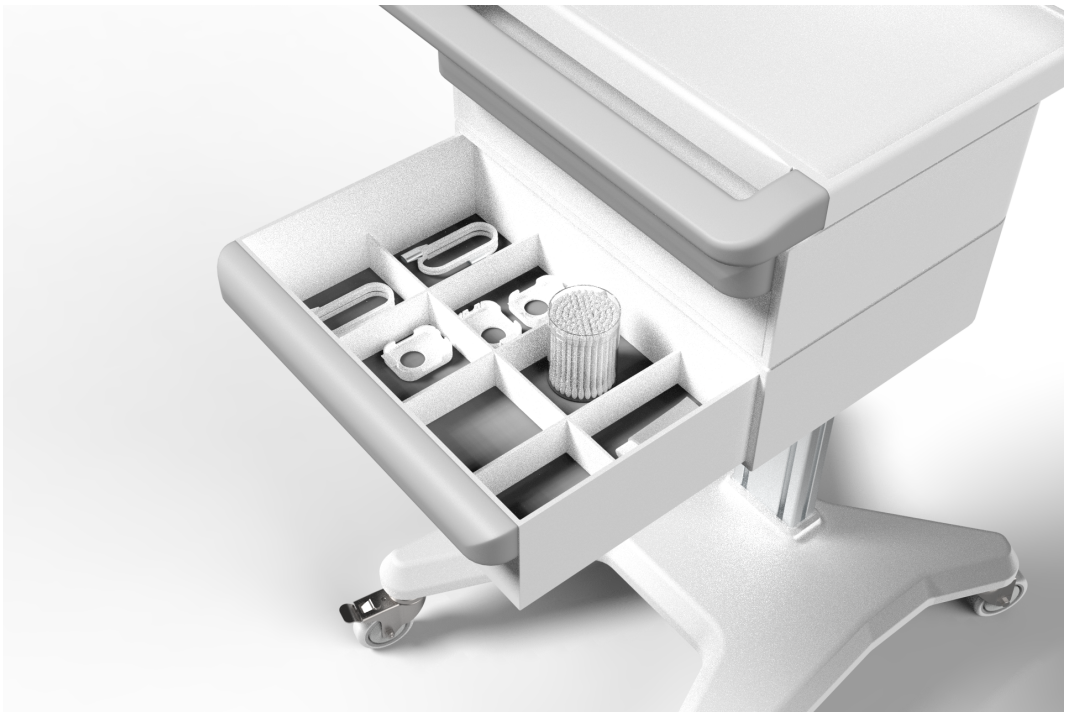


Figure 33: The bottom drawer can be used for all the accessories such as the probe holders, USB wires, paraffin oil, cleaning wipes etc.

Probe and probe holder design

Figure 34: Probe design. A short wire with an external female connector is attached to the probe to save room inside the housing and for a more manageable solution (e.g. a long cable that is permanently attached to the probe).

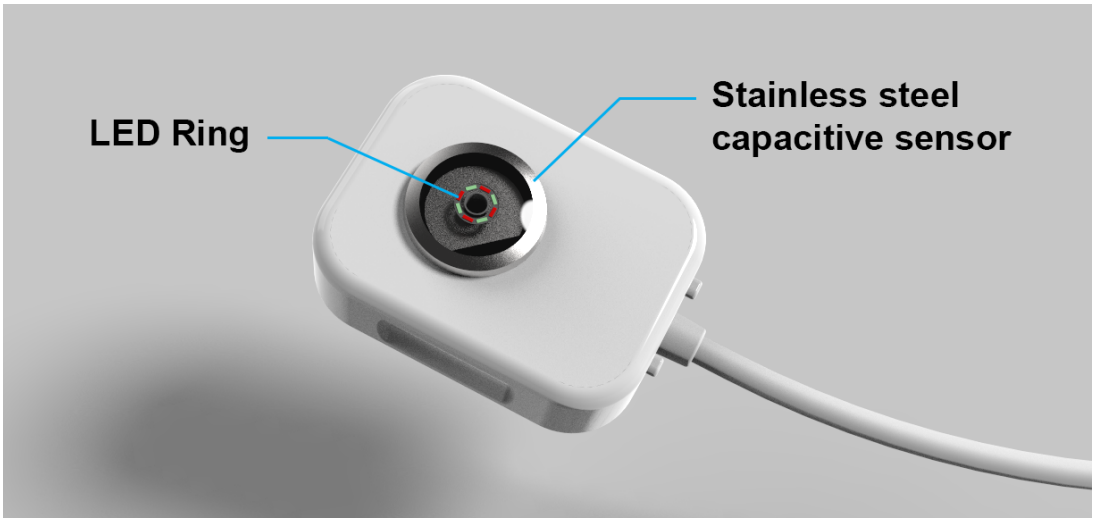


Figure 35: Underside of the probe. The LED ring can have two or more types of LEDs to target e.g. the oxygenated and deoxygenated state of haemoglobin. The edge of the glass dome has a stainless steel ring connected to a capacitive touch sensor. This allows for pressure feedback. When it comes into contact with the patient's skin, it will notify the user too much pressure is applied.

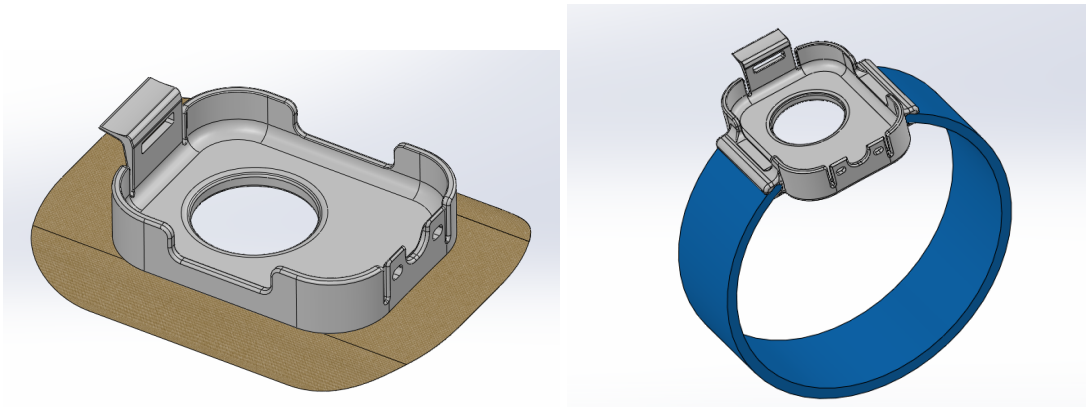


Figure 36: Two types of holders. Both did well in the usability testing, but more in-depth mock tests with e.g. ICU nurses and doctors need to be done to see which performs better. Perhaps both can be offered to the market to suit different user needs.

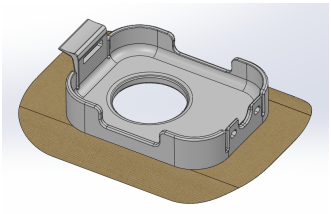
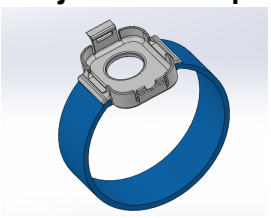
Stick-on holder	Adjustable strap
	
✓ Very secure fixation ✓ Easy application ✓ Can't cause vessel restriction ✗ Singular use, needs to be disposed of afterwards ✗ More difficult to reposition or adjust once it is placed on the skin	✓ Reusable (less waste) ✓ Easy to re-apply or to make adjustments on positioning location ✗ Incorrect use of the strap can cause a loose fixation (too loose) or constriction of the arm (too tight)

Figure 37: Pros and cons of the two probe holder types.

At this point, there is no data to discard either of the probe holder types. The stick-on holder offers a more foolproof application and a reliable fixation on the skin. On the other hand, there is also merit in using the reusable holder with the adjustable strap. Either type can be more favourable depending on the specific situation, workflow and the user's needs and values.

Appendix M - Context visuals

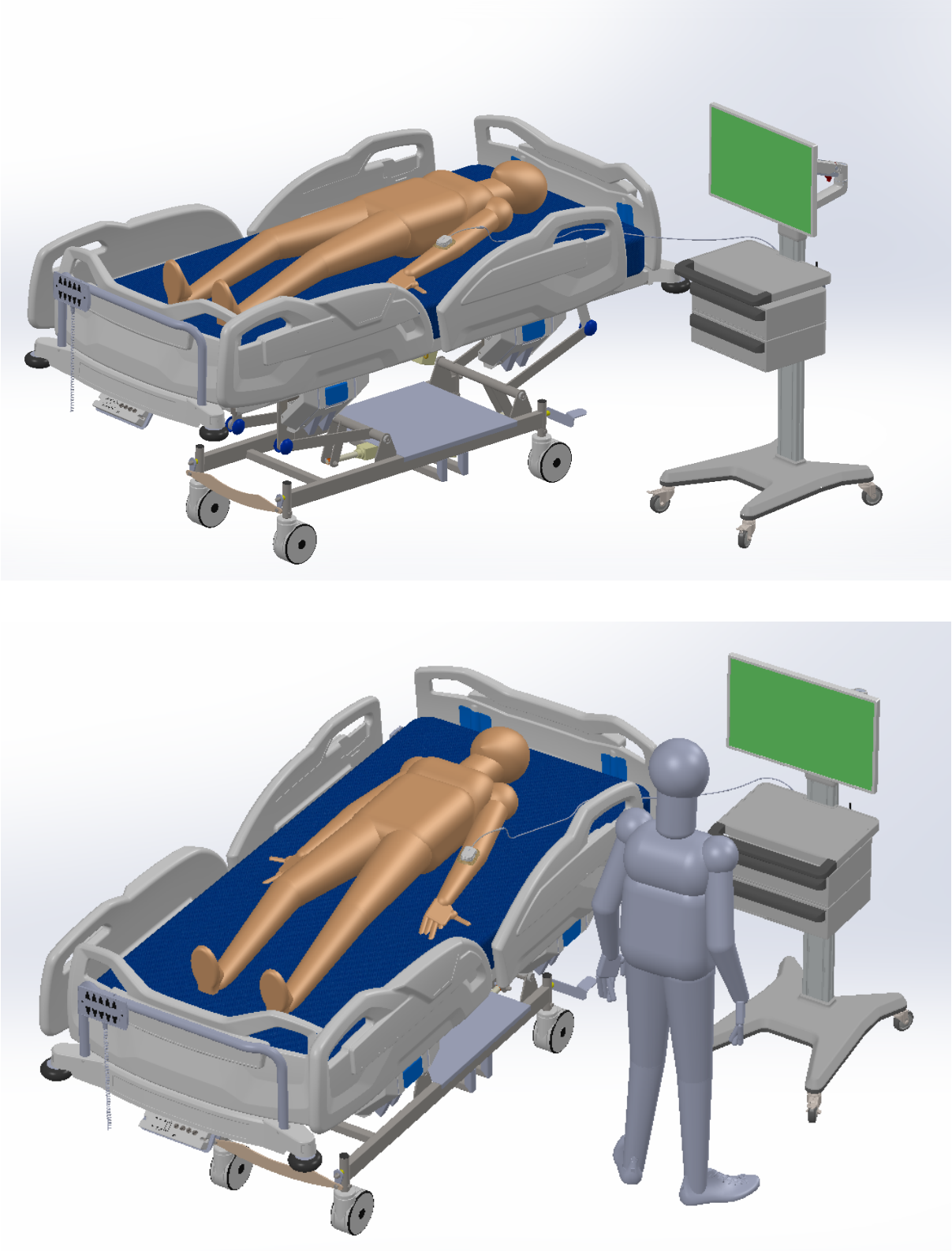


Figure 38: Virtual mockup of the hands-free monitoring system which includes the patient on a bed and a healthcare professional observing the real-time data.

Figure 98: The mockup is placed into a more representative context: photos of actual ICU rooms with other equipment.

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DESIGN FOR our future

TU Delft

IDE Master Graduation

Project team, Procedural checks and personal Project brief

This document contains the agreements made between student and supervisory team about the student's IDE Master Graduation Project. This document can also include the involvement of an external organisation, however, it does not cover any legal employment relationship that the student and the client (might) agree upon. Next to that, this document facilitates the required procedural checks. In this document:

- The student defines the team, what he/she is going to do/deliver and how that will come about.
- SSC E&SA (Shared Service Center, Education & Student Affairs) reports on the student's registration and study progress.
- IDE's Board of Examiners confirms if the student is allowed to start the Graduation Project.

USE ADOBE ACROBAT READER TO OPEN, EDIT AND SAVE THIS DOCUMENT

Download again and reopen in case you tried other software, such as Preview (Mac) or a webbrowser.

STUDENT DATA & MASTER PROGRAMME

Save this form according the format "IDE Master Graduation Project Brief_familyname_firstname_studentnumber_dd-mm-yyyy". Complete all blue parts of the form and include the approved Project Brief in your Graduation Report as Appendix 1 !

family name	Hoeksema
initials	R. B. P.
given name	Rindu
student number	4216075
street & no.	
zipcode & city	
country	
phone	
email	

Your master programme (only select the options that apply to you):

IDE master(s): ( ) IPD ( ) DfI (★) SPD

2nd non-IDE master:

individual programme: - - (give date of approval)

honours programme: ( ) Honours Programme Master

specialisation / annotation: (★) Medisign ( ) Tech. in Sustainable Design ( ) Entrepeneurship

SUPERVISORY TEAM **

Fill in the required data for the supervisory team members. Please check the instructions on the right !

** chair	Lianne Simonse	dept. / section:	DOS
** mentor	Armağan Albayrak	dept. / section:	HCD
2nd mentor	Frank Messie		
	organisation: Braedius Medical B.V.		
	city: Huizen	country:	Netherlands

comments (optional)

Chair should request the IDE Board of Examiners for approval of a non-IDE mentor, including a motivation letter and c.v..

Second mentor only applies in case the assignment is hosted by an external organisation.

Ensure a heterogeneous team. In case you wish to include two team members from the same section, please explain why.

APPROVAL PROJECT BRIEF

To be filled in by the chair of the supervisory team.

chair Lianne Simonse date 29 - 09 - 2022 signature Lianne Simonse Digitally signed by Lianne Simonse Date: 2022.09.29 17:32:09 +02'00'

CHECK STUDY PROGRESS

To be filled in by the SSC E&SA (Shared Service Center, Education & Student Affairs), after approval of the project brief by the Chair. The study progress will be checked for a 2nd time just before the green light meeting.

Master electives no. of EC accumulated in total: 27 EC

Of which, taking the conditional requirements into account, can be part of the exam programme 27 EC

List of electives obtained before the third semester without approval of the BoE

(x) YES all 1st year master courses passed

( ) NO missing 1st year master courses are:

name K. Veldman date 4 - 10 - 2022 signature

FORMAL APPROVAL GRADUATION PROJECT

To be filled in by the Board of Examiners of IDE TU Delft. Please check the supervisory team and study the parts of the brief marked **. Next, please assess, (dis)approve and sign this Project Brief, by using the criteria below.

- Does the project fit within the (MSc)-programme of the student (taking into account, if described, the activities done next to the obligatory MSc specific courses)?
- Is the level of the project challenging enough for a MSc IDE graduating student?
- Is the project expected to be doable within 100 working days/20 weeks ?
- Does the composition of the supervisory team comply with the regulations and fit the assignment ?

Content: (V) APPROVED ( ) NOT APPROVED

Procedure: (V) APPROVED ( ) NOT APPROVED

- also approved for Medisign

comments

name Monique von Morgen date 17/10/2022 signature MvM

Initials & Name R. B. P. Hoeksema Student number 4216075

Title of Project New implementations for the CytoCam medical camera

New implementations for the CytoCam medical camera — project title

Please state the title of your graduation project (above) and the start date and end date (below). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

start date 29 - 09 - 2022 — 12 - 03 - 2023 end date

INTRODUCTION **

Please describe, the context of your project, and address the main stakeholders (interests) within this context in a concise yet complete manner. Who are involved, what do they value and how do they currently operate within the given context? What are the main opportunities and limitations you are currently aware of (cultural- and social norms, resources (time, money,...), technology, ...).

The Braedius CytoCam is a system for the real-time observation of the human microcirculation. The handheld video microscope platform supports the medical professional to better understand the microcirculatory condition caused by a disease as well as the effects and effectiveness of an applied therapy.

Intended use
This product is intended to be used for visualisation of micro-circulation in tissue in:
- Orifices of the human body which may be non-invasively accessed
- Cutaneous surfaces

All other uses are not allowed unless under the following conditions:
- the purpose of the usage as device in a research study approved by an academic institution
- the device has been scrutinised and approved by the safety authorities of the institution
- the measurement protocol has been approved by the medical ethical committee of the institution
- the measurement has been explained to the study subject and his agreement has been obtained

Limitations
It must be clear that the CytoCam system does not give any advise or direction how to treat a patient. The physician will remain responsible for choosing a specific therapy and to monitor the progress of the condition of the patient, but it very well can support the physician to take better decisions. As such it is a complementary tool to guide therapy.

Application research
Research is being done on the use of the microcirculaion assessment as a tool with potential applications in several areas, including:
- Critical Care Medicine
- Abdominal / Cardiac Surgery
- Urogynaecology
- Cardiology
- ECMO (Extracorporeal membrane oxygenation)
- LVAD (Left Ventricular Assist Device) placement

The device is currently used by hospitals, research labs and even the military. Although intended for humans, the cytocam is also used for research on animals such as mice.

Although the Cytocam has been proven to be effective for its intended use, the market that wants these specifications and can or is willing to pay for the asking price, is very small.
Furthermore, with the current model of the device there are operational limitations such as not being able to execute long or consecutive mearuements and can only being able to see 2 mm into the tissue. The latter causes the device to be used in only very few parts of the body such as under the tongue, where a lot of small blood vessels reside.

space available for images / figures on next page

introduction (continued): space for images

image / figure 1: CytoCam in hand (left) and during use (right)

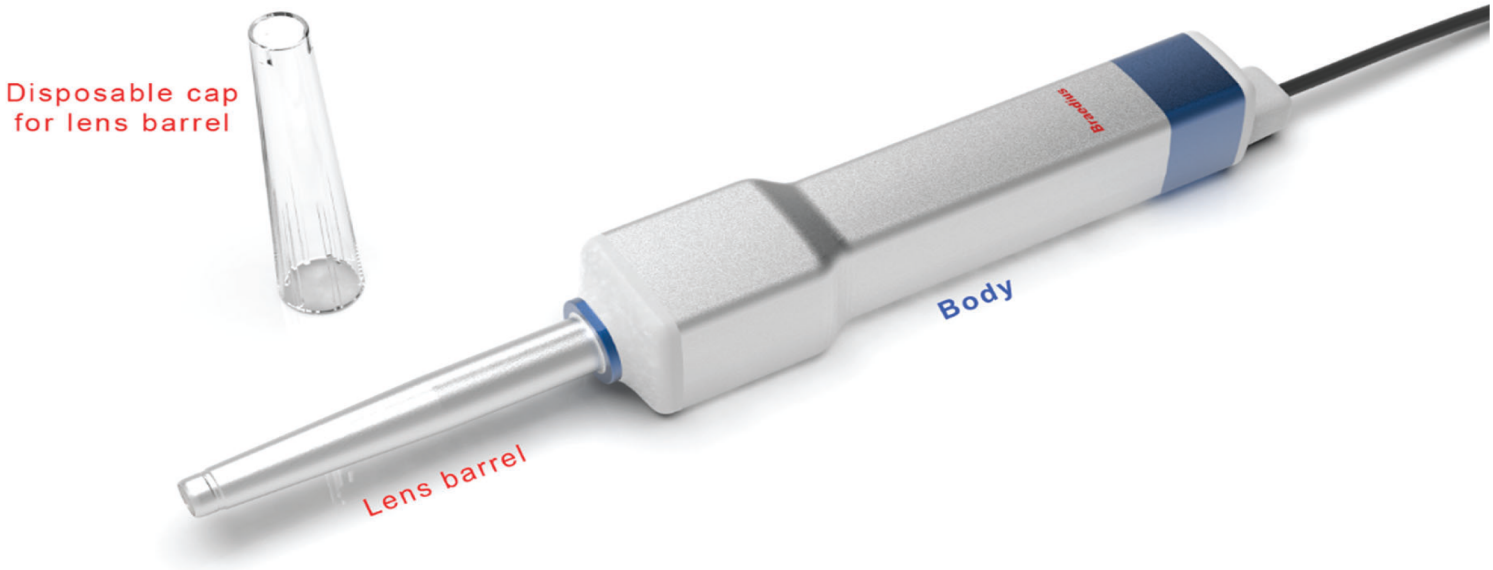


image / figure 2: Overview of the CytoCam device

PROBLEM DEFINITION **

Limit and define the scope and solution space of your project to one that is manageable within one Master Graduation Project of 30 EC (= 20 full time weeks or 100 working days) and clearly indicate what issue(s) should be addressed in this project.

As a small company Braedius Medical BV serves a very niche market. Currently it's offering one main product (CytoCam) with auxiliary products such as (panel)PC's and services such as training courses. As the company has ambitions to grow, it has decided to try to increase revenue by expanding its product portfolio. The aim is to use the intellectual property that is already availible for the company and research which needs can be fulfilled with this IP. More specifically, we want to re-use/maintain the camera body (figure 2) and redesign the lens barrel so it would serve a different use case.

Currently the CytoCam is used for short measurements/observations, however, there are instances where long-term observations are required. This is not possible with the current design as it is manually operated by a specialist. This is one example of a need that can potentially be solved. Current and potential clients have voiced more suggestions and requests, but it is not clear yet which direction the next project should go. Therefore, I saw an opportunity to make this into my graduation: to research a market need and solution fit that is the most strategic for the company.

ASSIGNMENT **

State in 2 or 3 sentences what you are going to research, design, create and / or generate, that will solve (part of) the issue(s) pointed out in "problem definition". Then illustrate this assignment by indicating what kind of solution you expect and / or aim to deliver, for instance: a product, a product-service combination, a strategy illustrated through product or product-service combination ideas, ... In case of a Specialisation and/or Annotation, make sure the assignment reflects this/these.

To develop a product concept+strategy for a suitable need in the medical industry that makes the most sense in regards of clinical impact and business. The latter aspect will regard feasibility, cost, competition and market need + fit.

Increasing revenue can be done in the following manners:
- Sell more products to existing customers
- Sell products to new customers/markets
- Expand auxilliary products and services (products and services that are required to operate the main product)

Initial potential applications that will be researched:
- IC, perioperative -Oral camera
- Hyperbaric oxygen therapy - same spot measurement to measure change in vessel density before and after treatment in tank, e.g. on scalp (neck), measurement under dermis, different kind of light. Many clinics all over the world exist for this treatment.
- Blood circulation problems in legs, varicose veins, "restless" legs, measurement under the dermis, different kind of light. Many clinics around the world, connecting to devices for improving blood flow (Bemer group)

One application with the best potential will be chosen substantiated by research and will be the focus of the remaining part of the project.

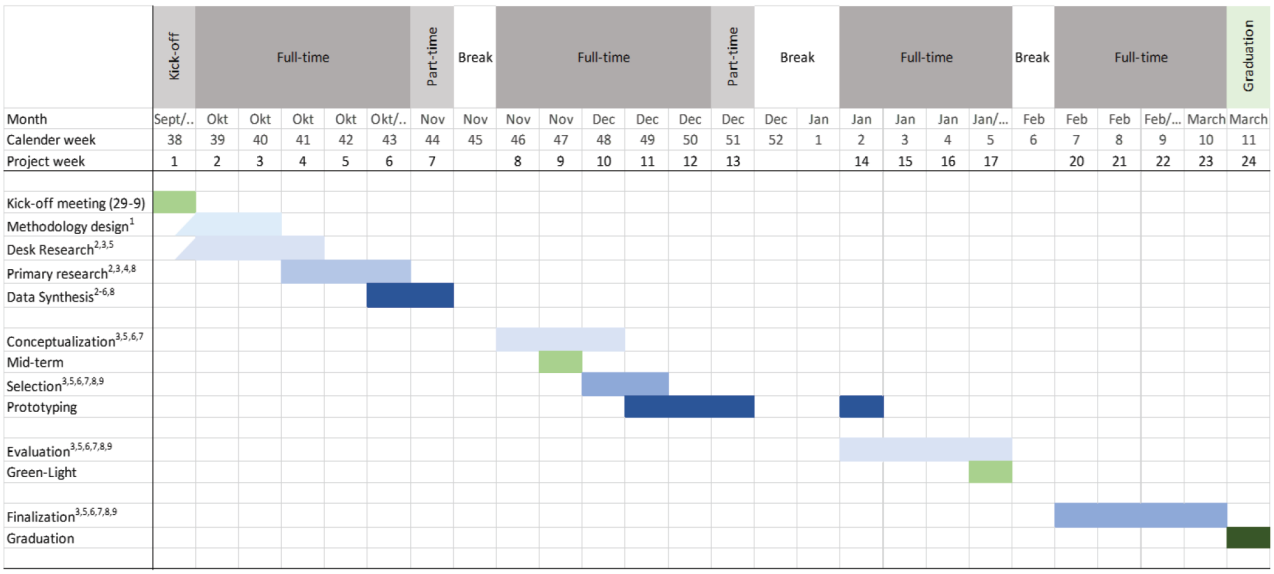
Initials & Name R. B. P. Hoeksema Student number 4216075

Title of Project New implementations for the CytoCam medical camera

PLANNING AND APPROACH **

Include a Gantt Chart (replace the example below - more examples can be found in Manual 2) that shows the different phases of your project, deliverables you have in mind, meetings, and how you plan to spend your time. Please note that all activities should fit within the given net time of 30 EC = 20 full time weeks or 100 working days, and your planning should include a kick-off meeting, mid-term meeting, green light meeting and graduation ceremony. Illustrate your Gantt Chart by, for instance, explaining your approach, and please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any, for instance because of holidays or parallel activities.

start date 29 - 9 - 2022 12 - 3 - 2023 end date



Learnings from SPD and Medisign courses will be used for the activities in this graduation project such as: (1)DTM, (2)SPD Research, (3)DSP, (4)C&C, (5)Roadmapping (6)New Product Economics, (7)Brand &Product Commercialisation, (8)Capita selecta, (9)Rules and regulations for medical devices

Approach:
The first week will be spent on creating a framework in which the project can be finished on time but will produce the best possible results (within the limited time). Criteria will be established so the decision making process will be more efficient and substantiated. Then, secondary (literature) and primary research will be conducted. The research will mainly focus on the market and technology. Primary research will be done by interviews and observations of clinical practices. The data will then be used to map the various needs and requirements. A technology strategy will be synthesized which will asses both the needs of the users and the capabilities of the company to find the right fit. A requirement design of the chosen end-user will be made and is used for the concept design. A prototype will be used to validate and test the concept with the stakeholders. The prototype is used as a tool for communication and therefore does not have to be (fully) functional. A short-term roadmap will be strategized to outline the following steps on how to turn the concept into an end-product and what best way is to introduce it into the market.

Deliverables:
- Report - containing experiences, results and data from above mentioned activities
- Concept visualisations - Renders, tecnical drawings
- Physical prototype of concept - Used as a communication tool
- Demo Video

Two weeks in the planning are marked as part-time, as I will be busy with work in these periods. An extra week off is planned in November to take a break. Other breaks coincide with public holidays as per the academic calendar.

Initials & Name R. B. P. Hoeksema Student number 4216075

Title of Project New implementations for the CytoCam medical camera

MOTIVATION AND PERSONAL AMBITIONS

Explain why you set up this project, what competences you want to prove and learn. For example: acquired competences from your MSc programme, the elective semester, extra-curricular activities (etc.) and point out the competences you have yet developed. Optionally, describe which personal learning ambitions you explicitly want to address in this project, on top of the learning objectives of the Graduation Project, such as: in depth knowledge a on specific subject, broadening your competences or experimenting with a specific tool and/or methodology, ... Stick to no more than five ambitions.

As of now I have experience in designing products for the company. This also includes procurements of parts, manufacturing, design-file management. So for this project I would like the opportunity to learn more about the client and business side of things. One of the goals of this project is to talk to industry experts, users and current/potential clients. As an industrial design engineer I want to be a bridge between technology and user needs.

Furthermore, I want to improve my time manegement and planning skills.

What attracts me to the medical industry is giving me the opportunity to innovate and work with technology that improves lives. And from the experience I have so far working with medical related projects, there are still many problems that need to be tackled. As my dad says, there will always be a need for improvement in the medical industry. By the end of this project I aim to be more experienced in finding opportunities that can bring a positive clinical impact ánd increase profitability.

FINAL COMMENTS

In case your project brief needs final comments, please add any information you think is relevant.

Initials & Name R. B. P. Hoeksema Student number 4216075

Title of Project New implementations for the CytoCam medical camera