# B • Fast | B • Smart

Technology Driven Innovation **by Design**

***Product report***

Aalborg University

MSc02 / Grp 05

April 2021

# Titel page

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33

# Content



# Introduction

When traveling to Mars your vestibular system (focus on training balance and eye-hand coordination) gets challenged because of the low gravity. In the 2060s small colonies will be established on Mars, and here the Martians will have to be active, to stay healthy and be able to return to Earth after a 2-3 years stay. This combined with the long-distance to home on Earth, family and friends jeopardize the mental health of the space travellers.

The project focuses on motivation to exercise the vestibular system as part of the obligatory training. This project does not only accommodate an exercise tool but also boost the mental and physical health by making the training fun in a social community setting.

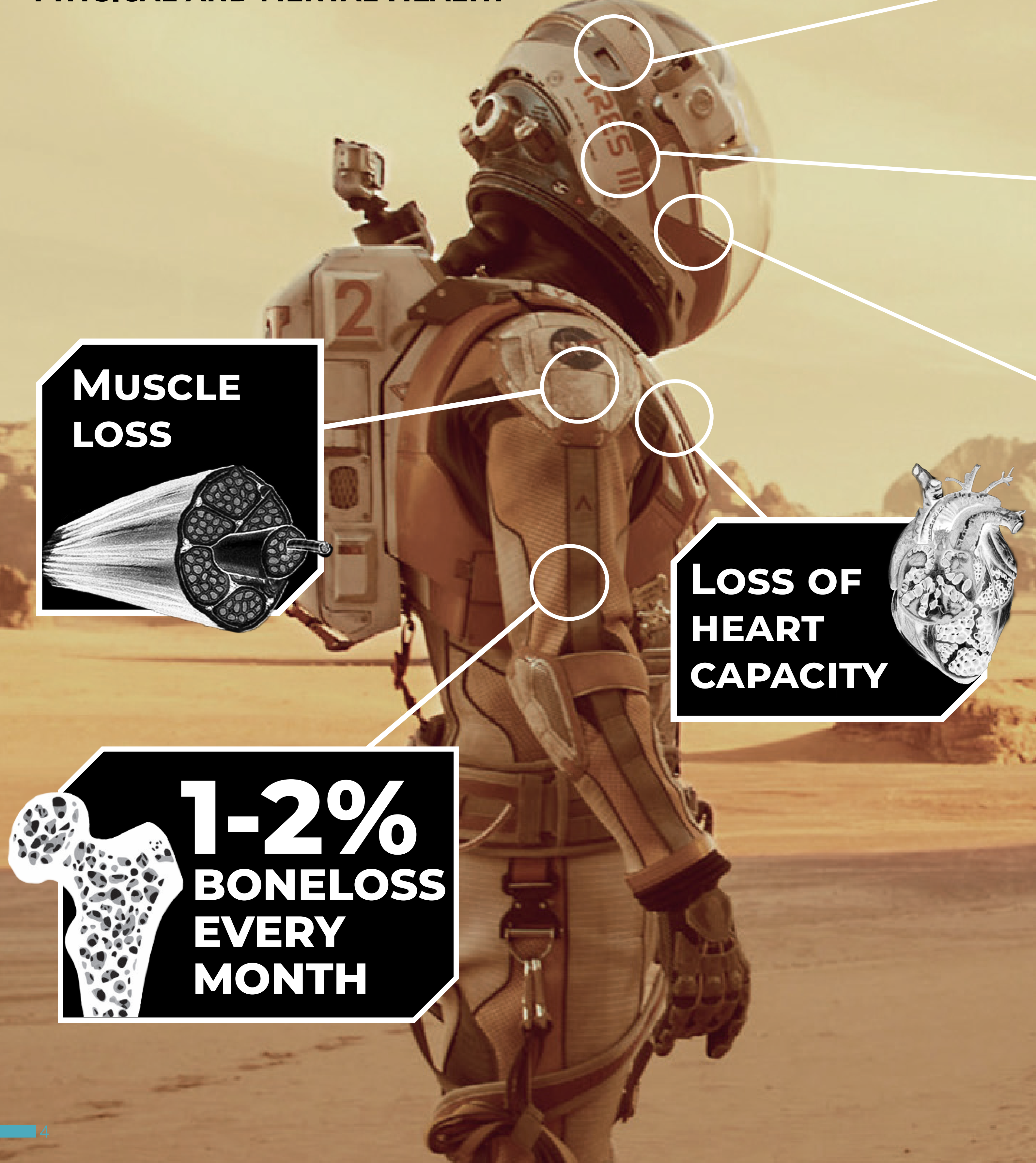
The approach of motivation and physical activity benefits the brain and will be used for reframing to new learning experiences in primary schools.

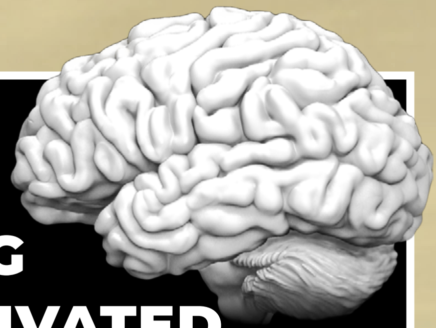
## Want the full experience?

In the PDF toolbar go to: View - Page Display - Two page view
Repeat and check of "*Show cover page in two page view*"

# PROBLEMS OF STAYING HEALTHY IN SPACE

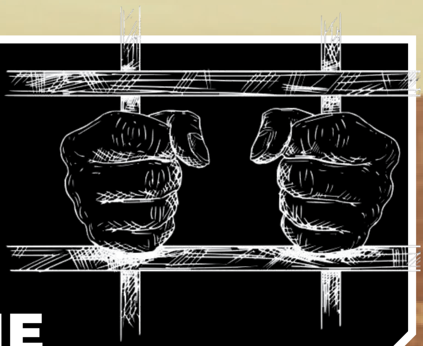
**MICRO GRAVITY'S VITAL EFFECT ON THE ASTRONAUTS PHYSICAL AND MENTAL HEALTH**





**Mentally challenging to stay motivated**

**Interferes with the vestibular system**



**Social isolation far away from home**

## Problem definition

*"How to create a product that supports the obligatory training in strengthening the 'loco motor system' that helps overcome the effects of micrograviity on Mars?"*

## Vision

To arouse enthusiasm for space travellers to fulfil the obligational training.

# B•FAST

## Stay healthy - Stay motivated

***"We don't stop playing because we grow old; we grow old because we stop playing."***

*- George Bernard Shaw*

**B•Fast** takes you on a journey to another planet where space and time do not exist. Experience the rush while your eye-hand coordination and balance get challenged.

**B•Fast** connects Martians with family and friends on Earth, through a captivating exercise that makes a fun element in the Martians obligatory training pass.

Fight your friends to **B**e the **FAST**est!

## Elements of B•Fast

Use the elements to B•Fast, or as extra value to other training passes

Main Unit

Vibration Board

ACTION!

AR Lenses

Gravity Harness


App

# Set up

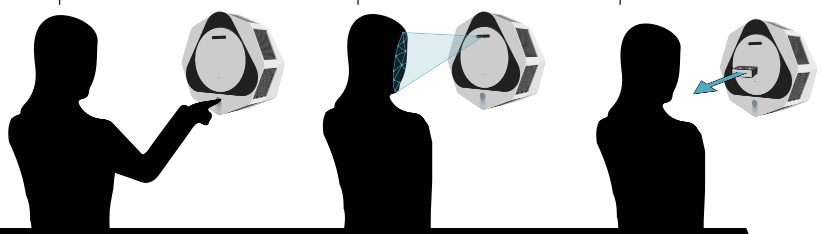
**Turn on Main Unit**
The main unit must be turned on by pressing the button.

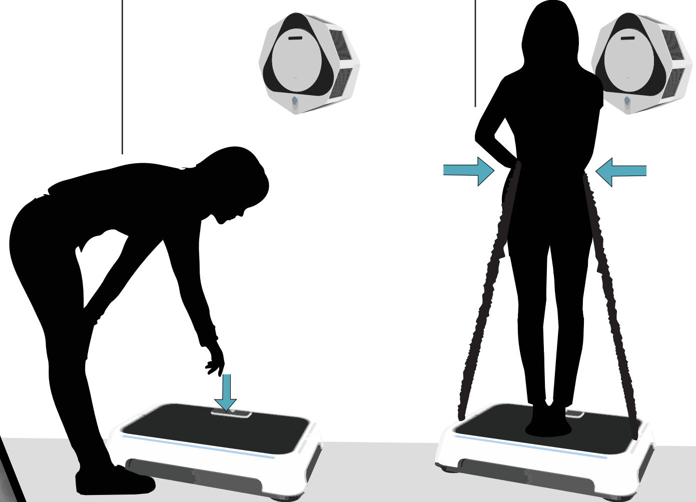
**Face scan**
The player's face is scanned.

**The lenses**
A drawer in the Main Unit will open to the user's lenses, which are subsequently placed in the eyes.

**Turn on Vibration Board**
The vibration board is turned on by pressing the button, where it is also possible to manual-ly adjust the vibrations.

**Attach Harness**
The harness is attached to the player, who is now ready to play.



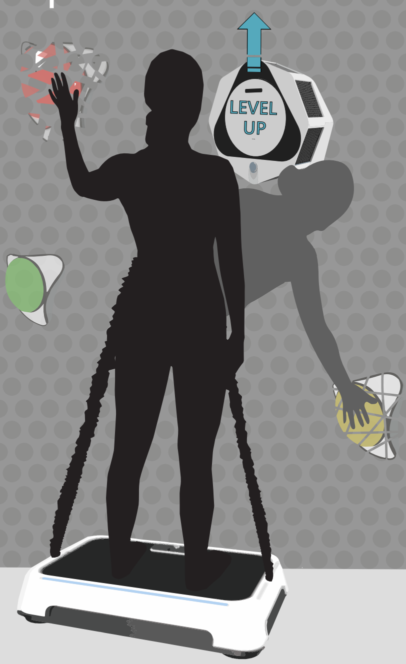


# INTER-ACTION

**3, 2, 1 GO!**
The game counts down from 3, 2, 1, GO! and the game is on.
You have 3 lives. If you miss a spot, the level will reset. If you loose all, it is game over.

**Level Up**
If you do not lose all three lives, you will continually level up to a more difficult level.
You will also be continuously informed of how long you have the opportunity to play without exceeding the recommended vibration time.

**New High Score**
When all three lives have been used you will see the result and whether you have achieved a new high score.



## On Mars

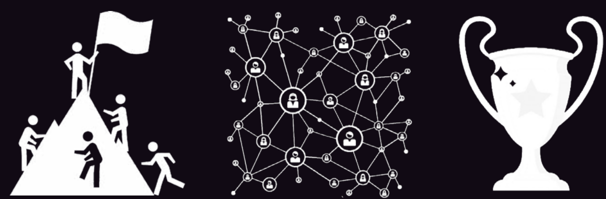
### The Game
Same basic principles in the game as on Mars, but without the harness.

### League
After the game, the player can check the result and see if the other players are beaten.


## On Earth

### League
When the game is over you can through the app challenge friends and family with the achieved high score.

# Motivation
Gamification is the solution space to motivate the user. This is a combination of a competition element, a comunity where there is contact between Earth and Mars, as well as a final acknowledgment of the completed levels.



Competitive | Communnity | Acknowledgement

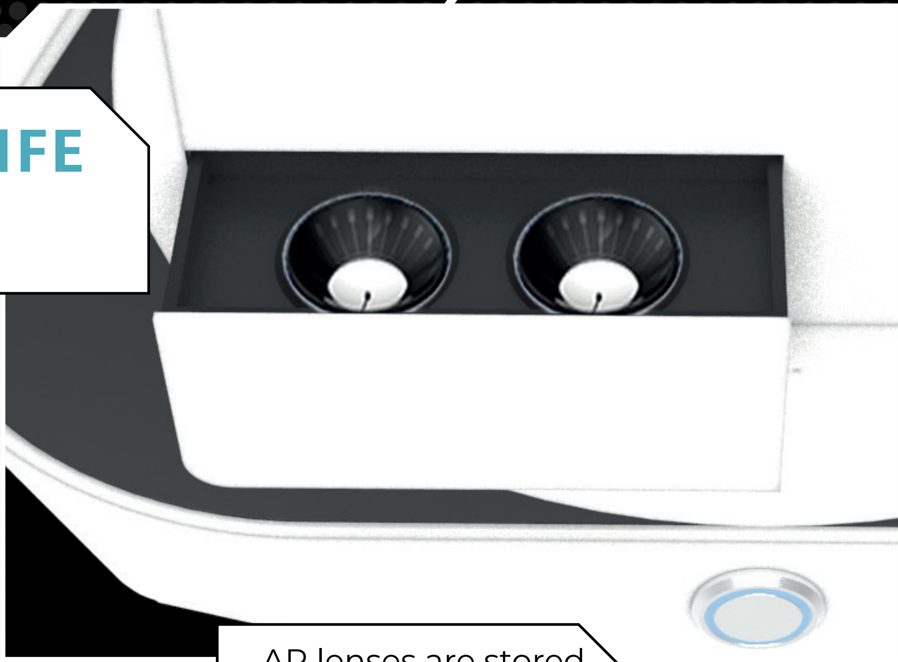
## Benefits
With gamification and motivational elements, B•Fast is built on the basic principles of eye-hand-coordination, which helps to improve the vestibular system. Besides, the pace of the game also increases in parallel with the level increases, which also contributes to an increased heart rate. This aspect means the Martians can take advantage of B•Fast in continuation of their obligatory cardio training.

# SEE THE GAME

## B•FAST COMES TO LIFE THROUGH AR

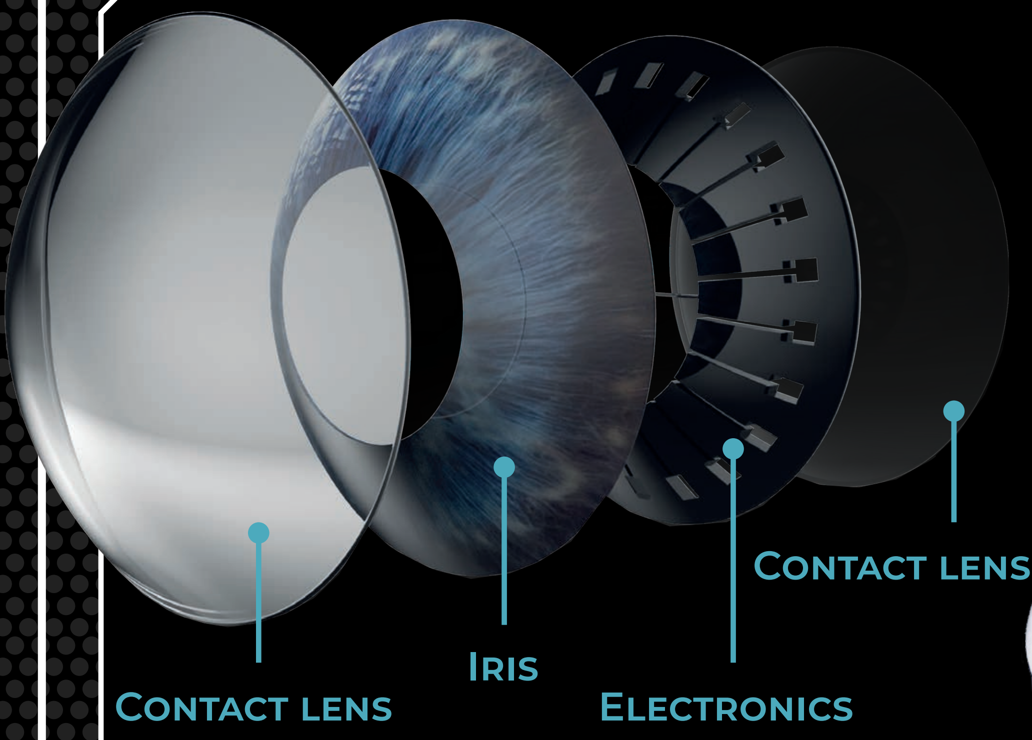
As soon as you put on your AR lenses, the world around you will be transformed, and you will find yourself in the heat of the game.

The spots will keep coming begging you to B•Fast and tap them before it is to late.



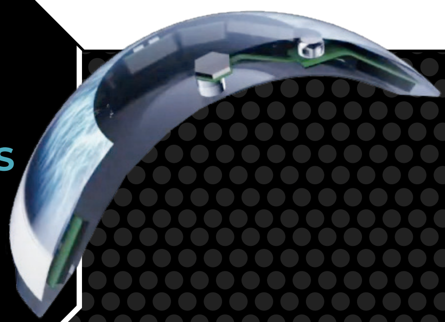
AR lenses are stored in small drawers in the Main Unit. There is room for four pairs of lenses in each unit.

Storage




The AR lenses consists of four layers; 2 layers of contact lenses, a layer of iris to hide the electronic for other people and the last layers is all the electronics.

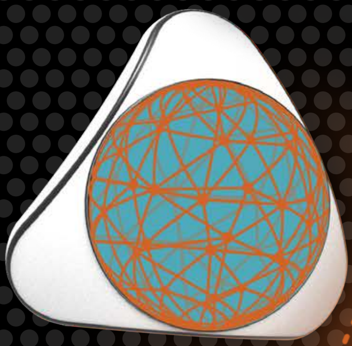
Construction

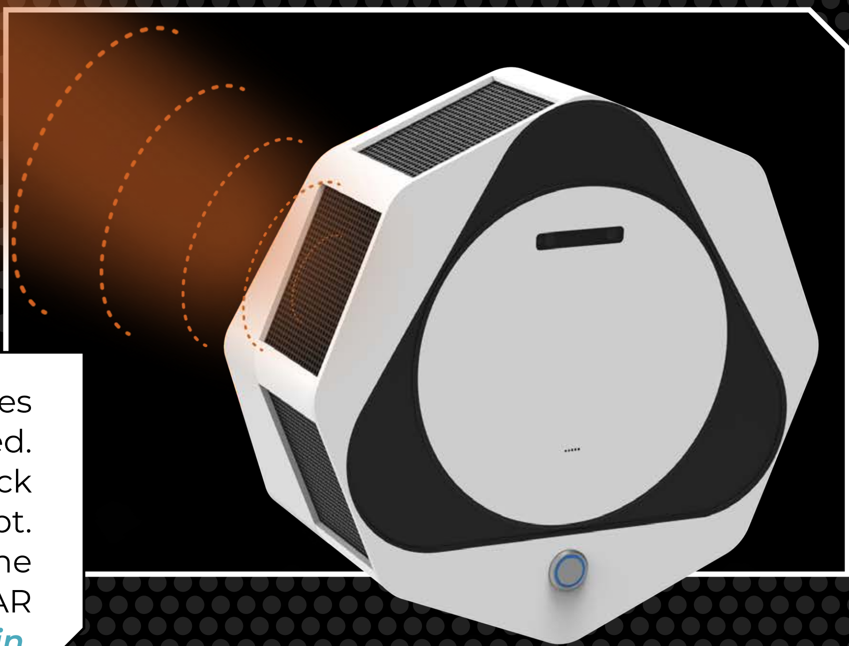


# FEEL THE TOUCH

## THE MAGICAL TOUCH OF A VIRTUAL SPOT

Can you imagine touchable holograms?
This is as close as it gets.





### Excitment

Pressing a big button, makes most people feel excited. Through Ultra Haptic feedback the excitement is kept. Making you wanna touch the spots you see through AR *over and over again.*

### Ultra Haptic Feedback

By making ultra-sound waves arrive at the same point in space at the same time, the waves makes enough force to create pressure points you can feel.

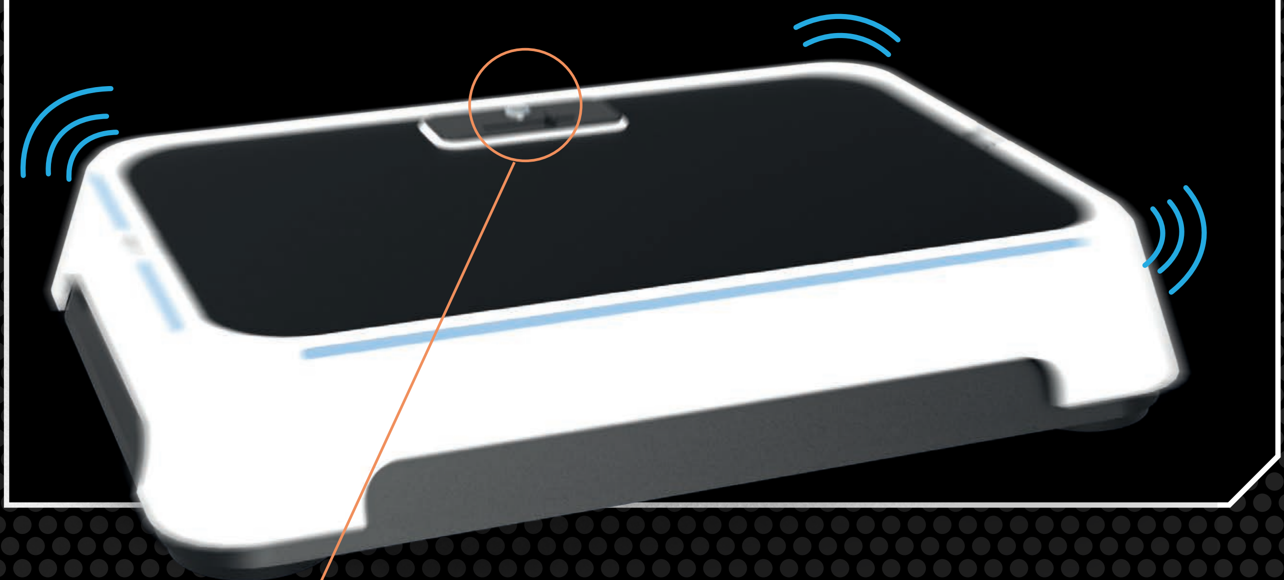
# EXPERIENCE THE VIBRATIONS

## Feel the vibrating rush

**The vibration board will complete the Circle of B•Fast.
When you enter the board, the scene is set.**

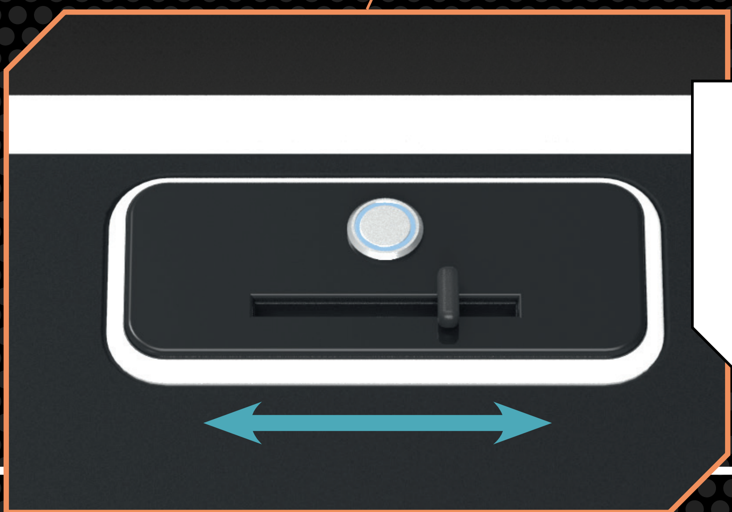
**Benefits**

The vibrations reduce the risk of bone loss and maintain the muscle mass when space traveling. The balance is challenged when standing on the board and fastly changing direction in the body to tap the spots.



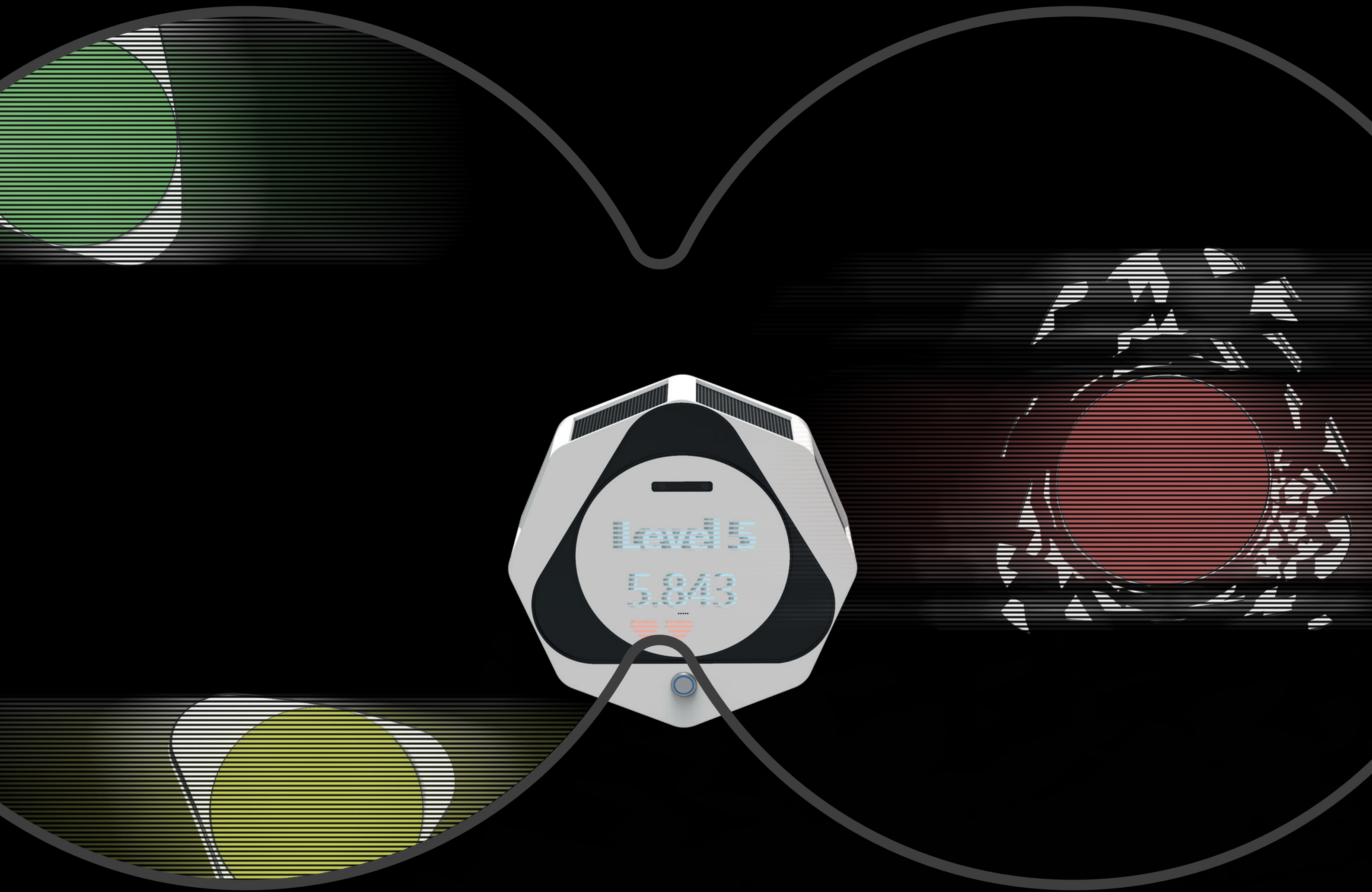
**Control panel**

Turn on the vibration board on the button.
The vibrations can be adjusted on the board and can vibrate with up to 0.5 G for 30 minutes.

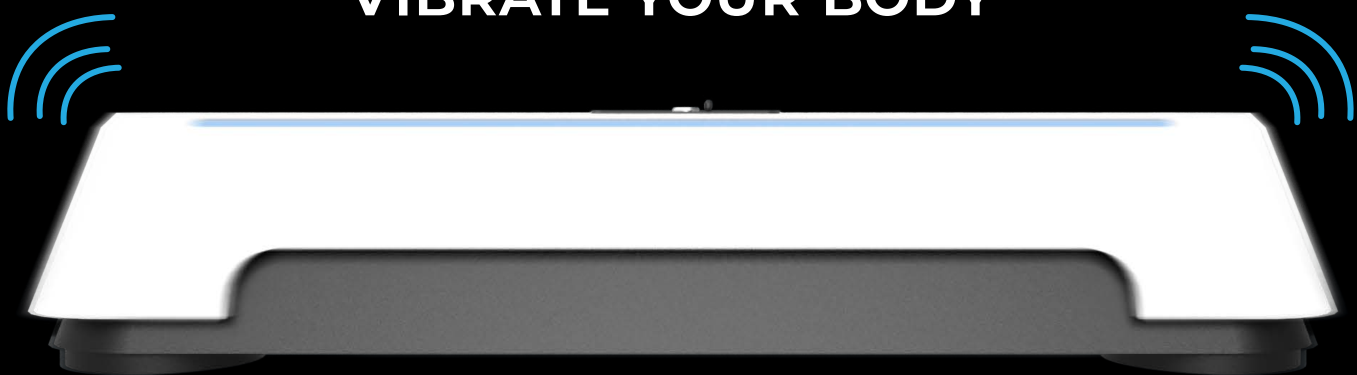


# B·FAST

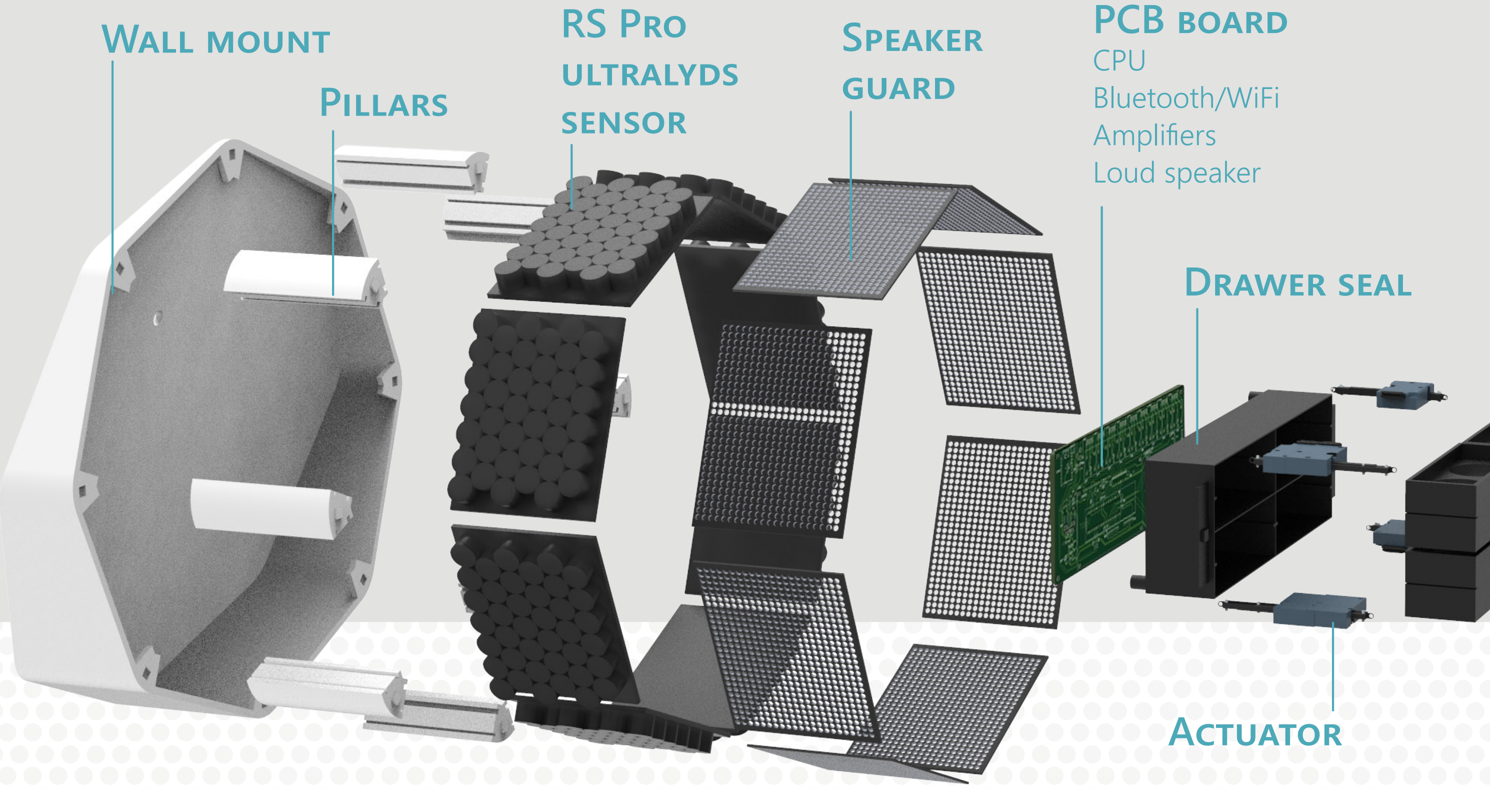
## See the game through your eyes




## Vibrate your body



# CONSTRUCTION

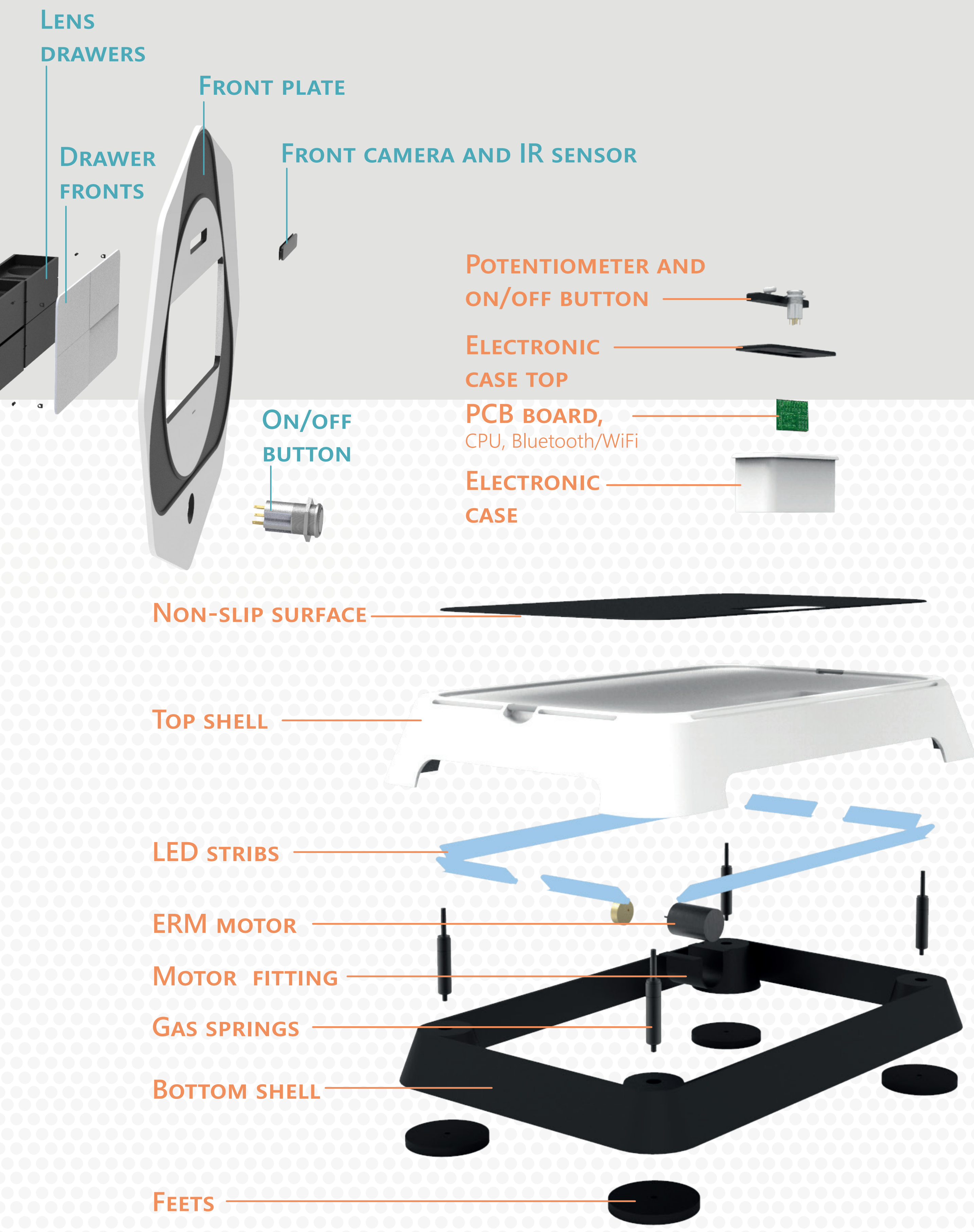



## Main Unit

| | |
|---|---|
| **Material:** | Bio-plastic |
| **Production Method:** | 3D Printing |
| **Measures:** | 232 (h) x 232 (l) x 125 (d) |
| **Features:** | Ultra haptic feedback, Facial recognition, 4 AR lens containers, Automatic drawers |

## Vibration Board

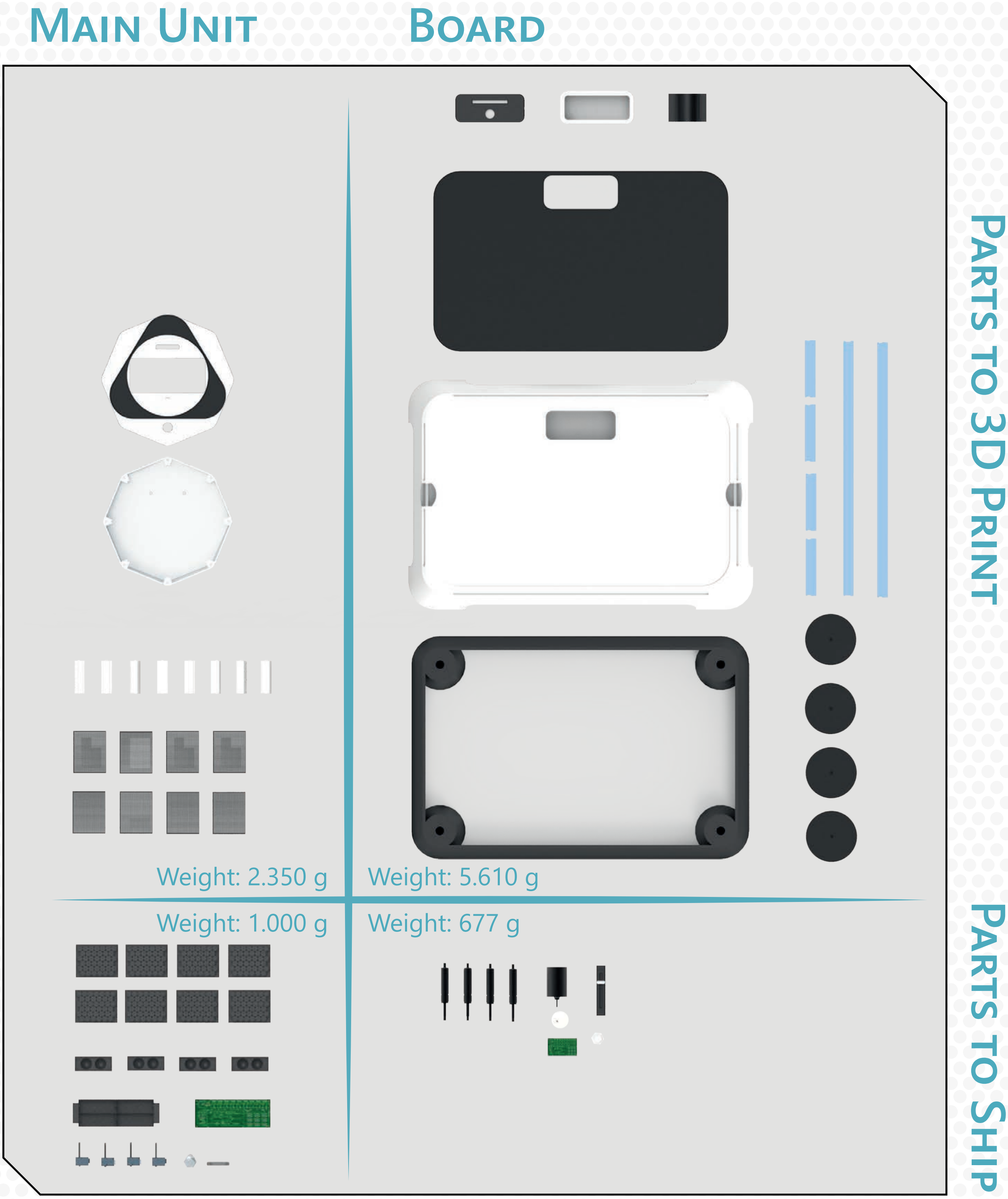
| | |
|---|---|
| **Material:** | Bio-plastic |
| **Production Method:** | 3D Printing |
| **Measures:** | 90 (h) x 600 (l) x 400 (d) |
| **Motor:** | ERM |
| **Vibration effect:** | Up to 0,5 G |
| **Features:** | Gassprings, LED strips |


Lens drawers
Front plate
Drawer fronts
Front camera and IR sensor
Potentiometer and on/off button
Electronic case top
PCB board,
CPU, Bluetooth/WiFi
On/off button
Electronic case
Non-slip surface
Top shell
LED stribs
ERM motor
Motor fitting
Gas springs
Bottom shell
Feets

# SHIPMENT

## 83% of B-Fast (weight) will be produced on Mars

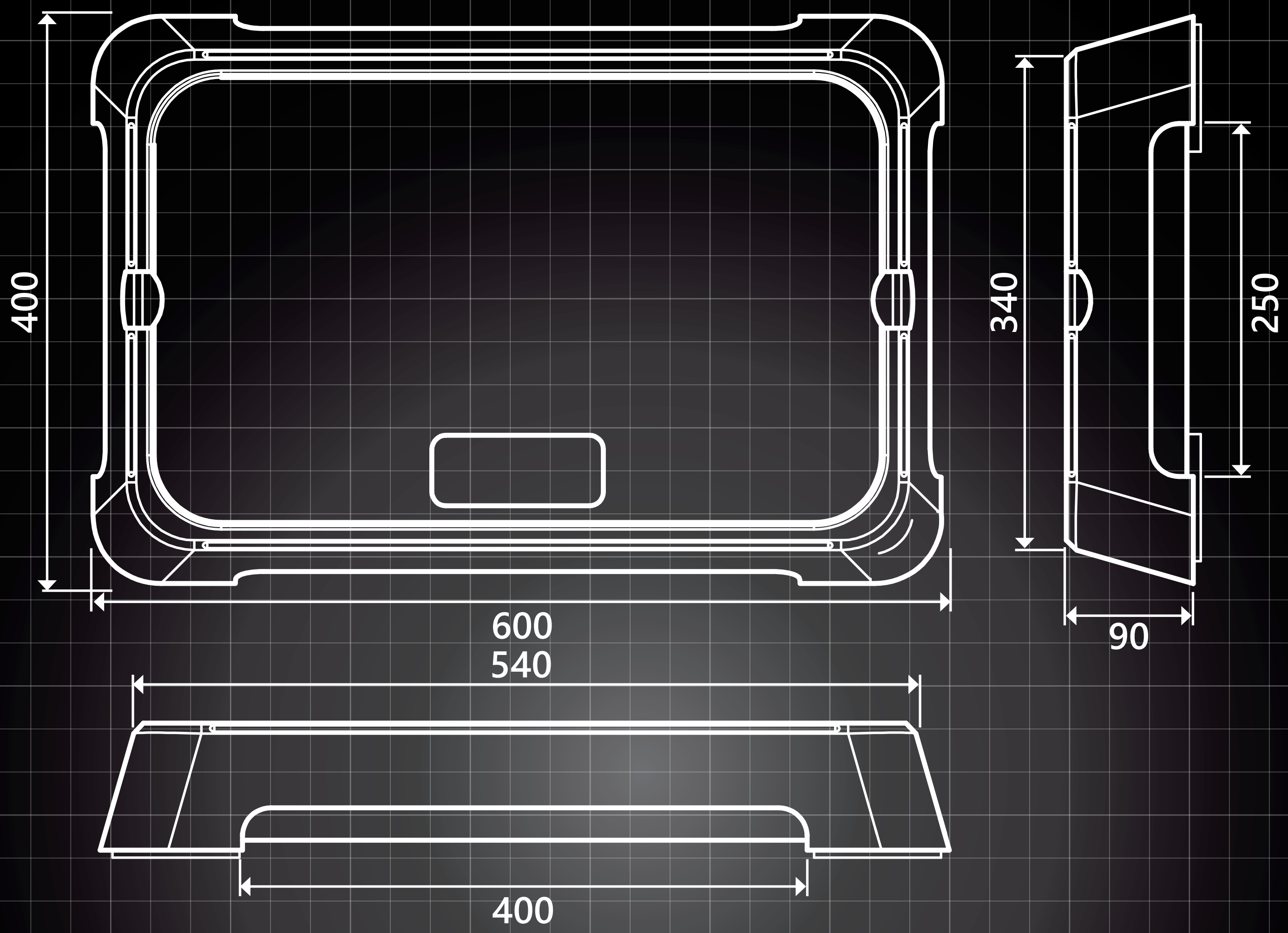
B-Fast is designed to be produced on Mars.
Electronic components, AR lenses, and the belonging drawer module for protection will be shipped from Earth.



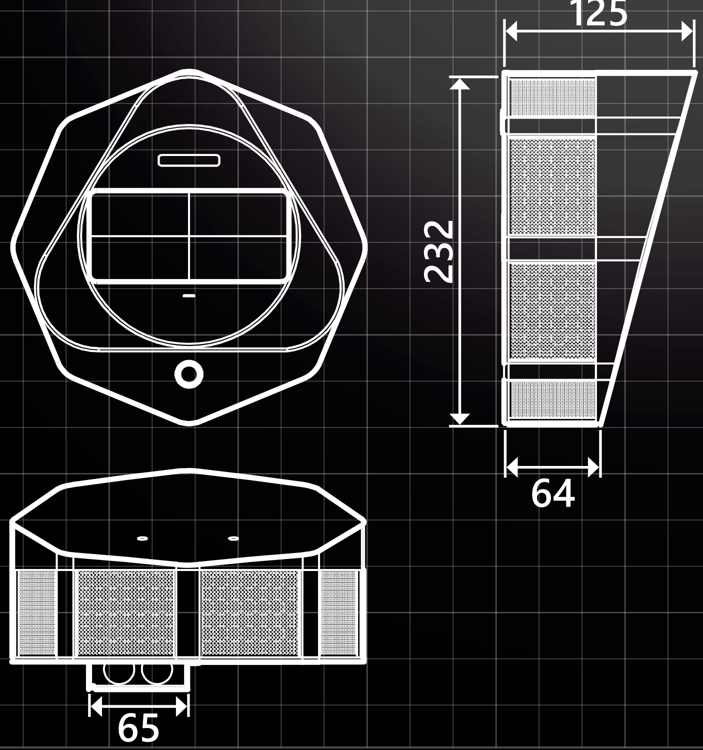

Shipment Price 4.800 DKK

# MAIN DRAWINGS

## Vibration Board



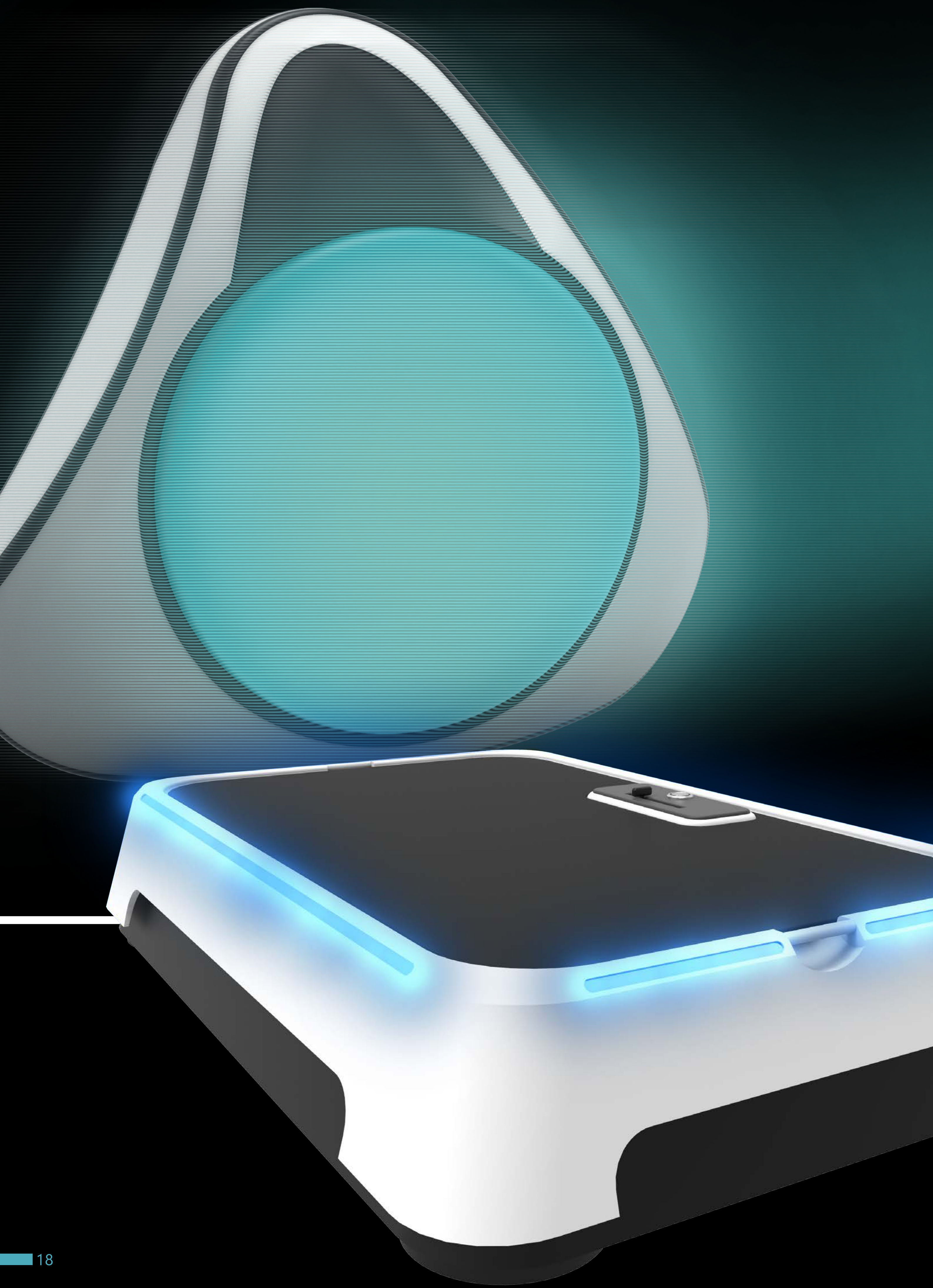

## Main Unit




**Scale:** 1:5

**Measure unit:** mm

**Destination:** Mars



# B • FAST

# PROCESS TIMELINE

A process timeline trough time and space of the development

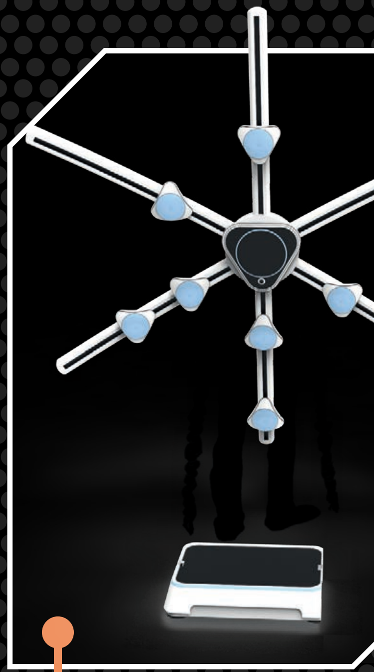
## Hololistic approach
Training in space

**Sum-up**

- A hololistic approach
- Set the center of attention *(training, social or mental)*
- Can the motivation be something else than gamification?

M. 1

*Milestones*

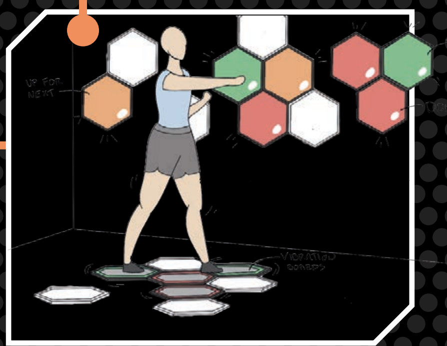


## The Spa
The vest

M. 3

M. 2

## Three concepts
Three exercise focuses

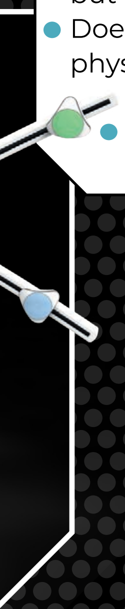


**Sum-up**

- Precision of requriments
- Confusement about the physical benefits. *What is the focus?*
- The framing changed from a supplementing product for the leisure time to an addition to the obligatory training.

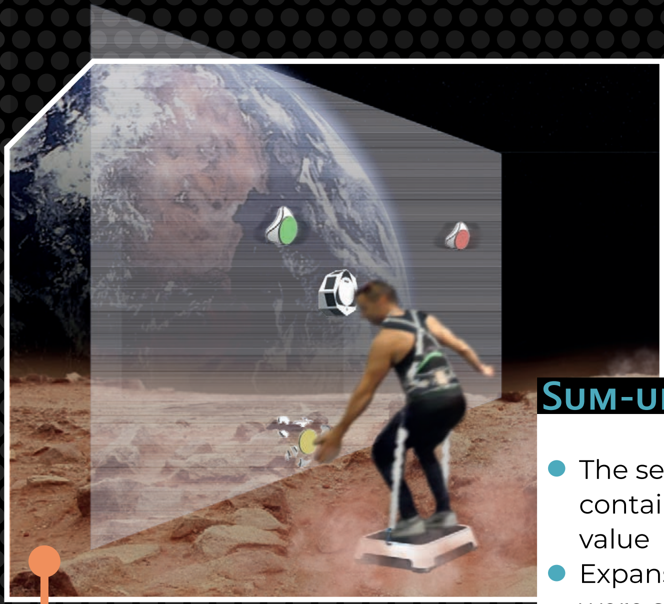
## Sum-up

- Gamification gives extra value, but is it maintaining?
- Does the product have to be physical - or can a virtual setup give the same benefits?
- Focus on training the vestibular system



# cy Rail

## ibular system



# B•Fast

## Sum-up

- The seperate elements contains a lot of product value
- Expansion possibilities were seen
- Implementation of internal and external motivation

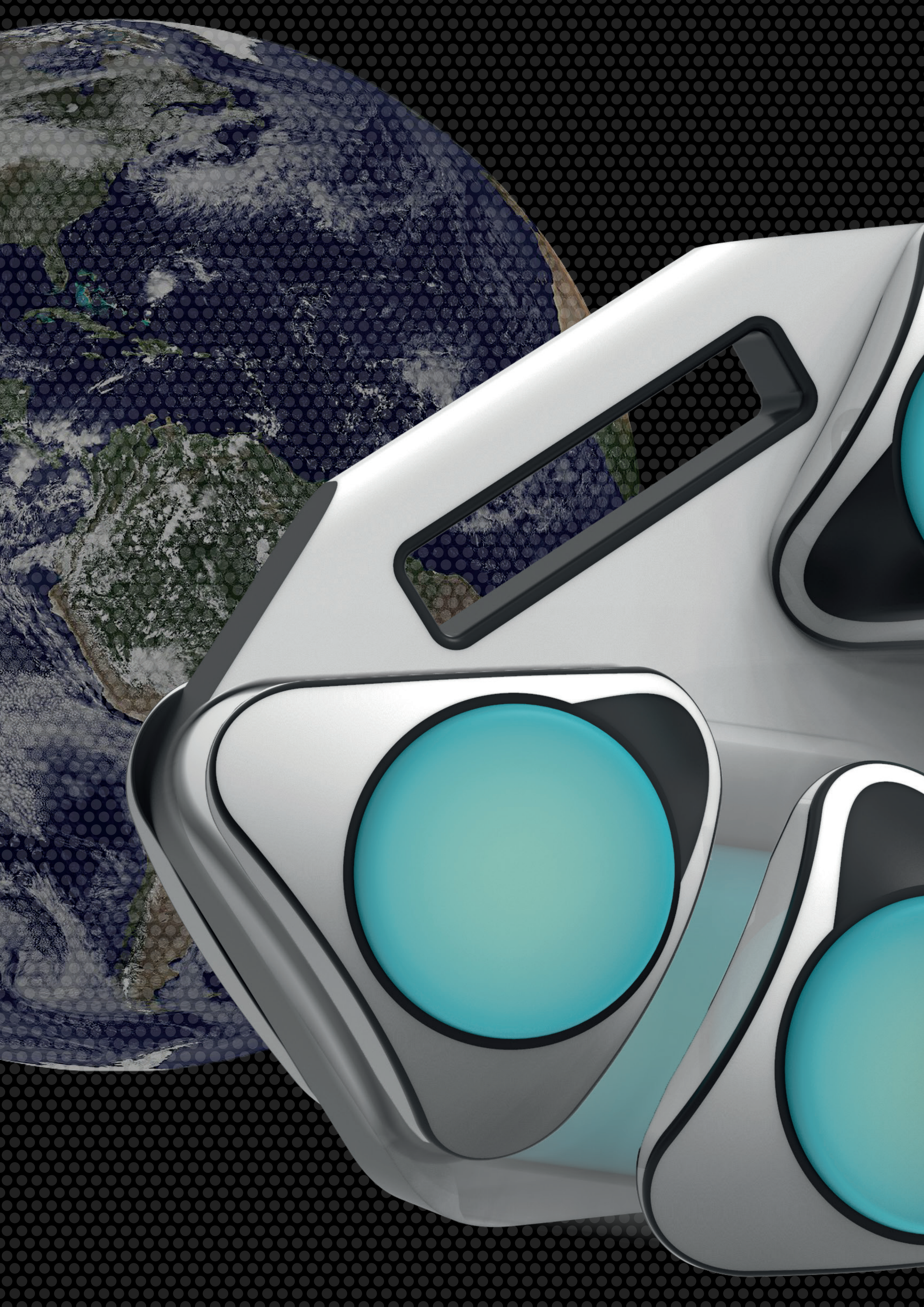
M. 4

M. 5

# B•Smart

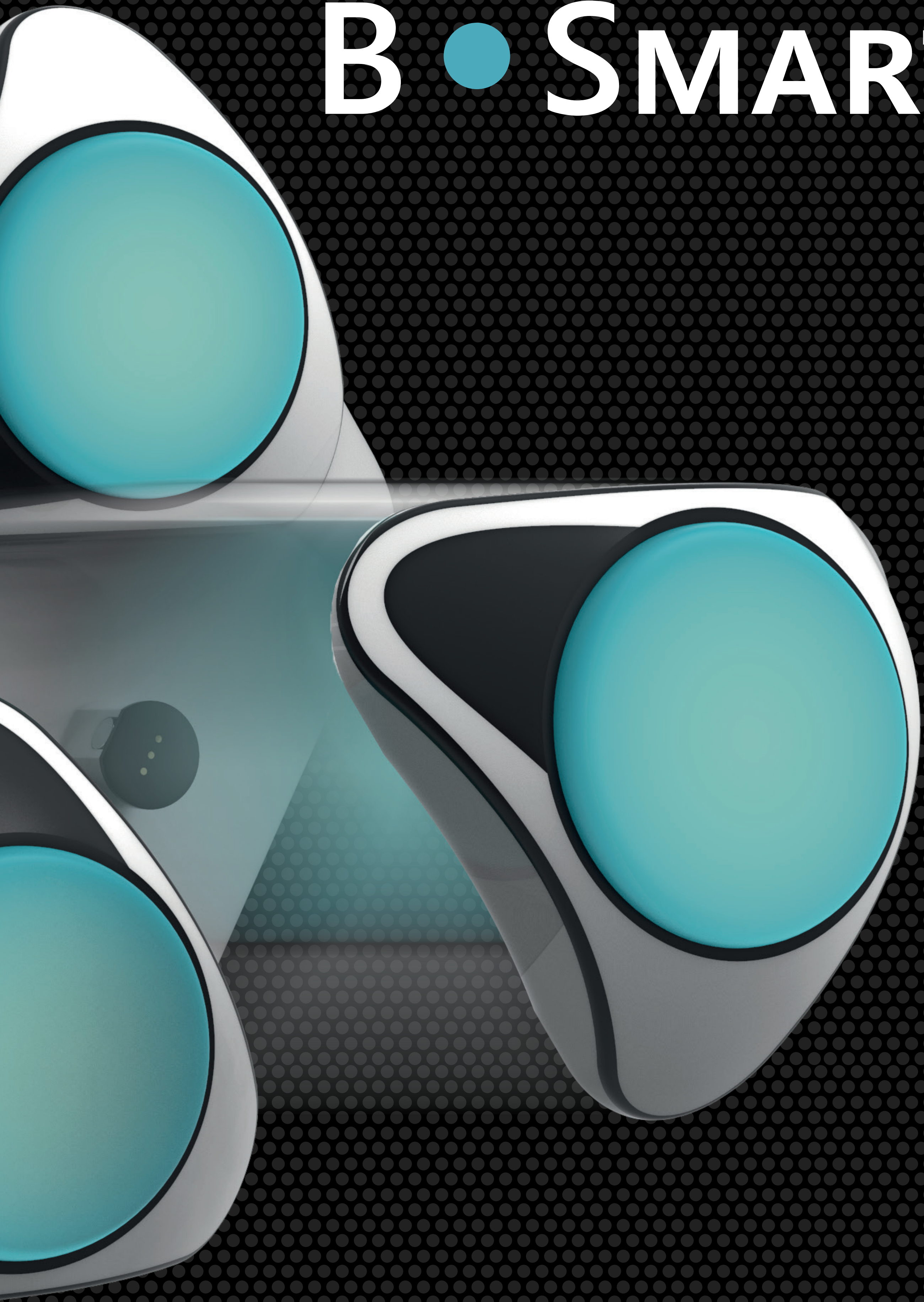
- Clear connection to original framing
- Potential for B-Smart to become a trend
- Concern about the narrow case of primary schools
- To start on the B2B market was seen as difficult

## Sum-up



REFRAMING TO EARTH

# B•SMART



# B·SMART

## Keep Playing- Keep Learning

### *ACTIVE LEARNING WITH A HOLISTIC APPROACH*

**B•Smart** creates a new way to learn. Set up an obstacle course on the way to the answers. Maybe you must jump over a stream or crawl through a tunnel. Every step takes you closer to new knowledge through physical activity.

**B•Smart** connects kids in primary school through active learning. Choose a quiz on the app, see the question - and then run, *run like the wind*, to the right spot, to place your answer.

Challenge your class to **B**e the **Smart**est and the fastest.

### Reframing Strategy

The strategy for reframing was to incorporate central elements from the original product, B-Fast. Hereby the reframing centered around a holistic approach by motivating someone, to do something that needs to be done through gamification. At the same time the active element, aesthetics and interaction was kept as a part of the concept.

A recently renewed School Reform, that states that 45 minutes of physical activity must be implemented each day in the schools teaching time, led to B-Smart seeming like a natural extension and reframing of B-Fast.

## Elements


App

8 spots

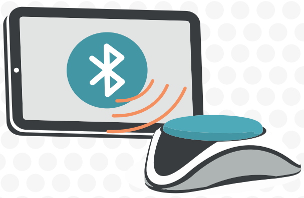
Charging Station

# CREATE, PLAY, LEARN

## *Create a learning experience that will not be forgotten*

**B•Smart** will transform quizzing into active learning and physical activity. This will create the best possible framework for motivating learning and social interaction.

## HOW TO GET STARTED



**1. Connect to the spot trough the B-Smart app**

**2. Select a topic and a quiz**


**3. Answer the questions by hitting the spots**


**4. See ranking and score in the app**

## Experience great diversity

**Teach a physical interactive lesson**

Let the pupils be active and engage in a physical learning game

**Boost teamwork**

Let the pupils learn teamwork and communication by playing in teams


**Create your own quiz**

Let the pupils create their own quizes, to reach learning and understanding

**Break the ice**

Get to know your classmates in a fun, learning and competitive way

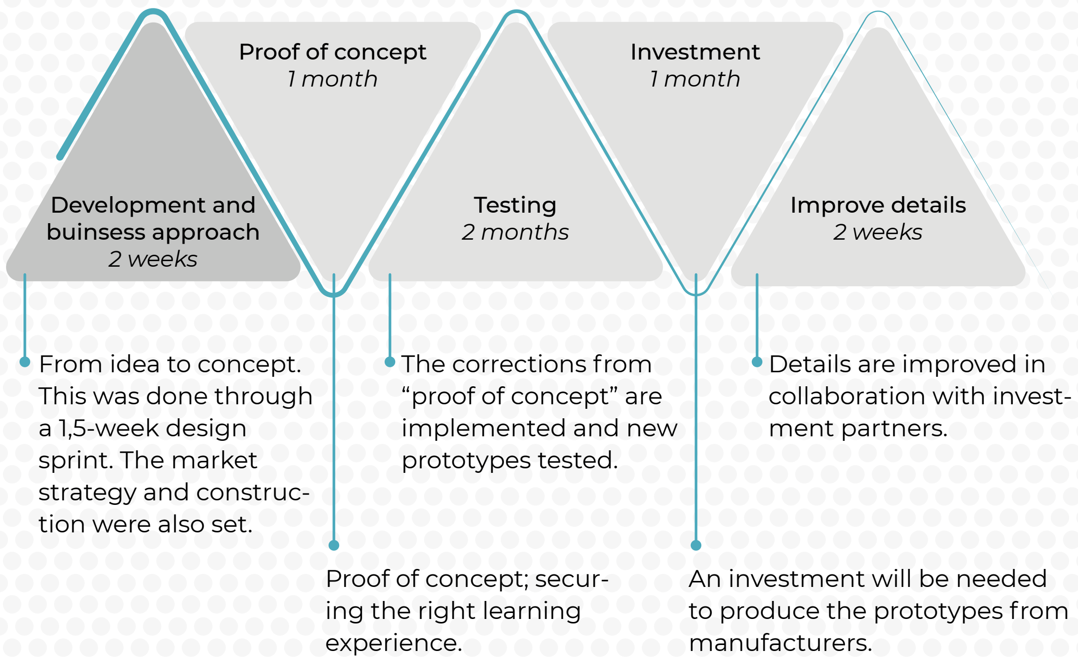
# MARKET STRATEGY

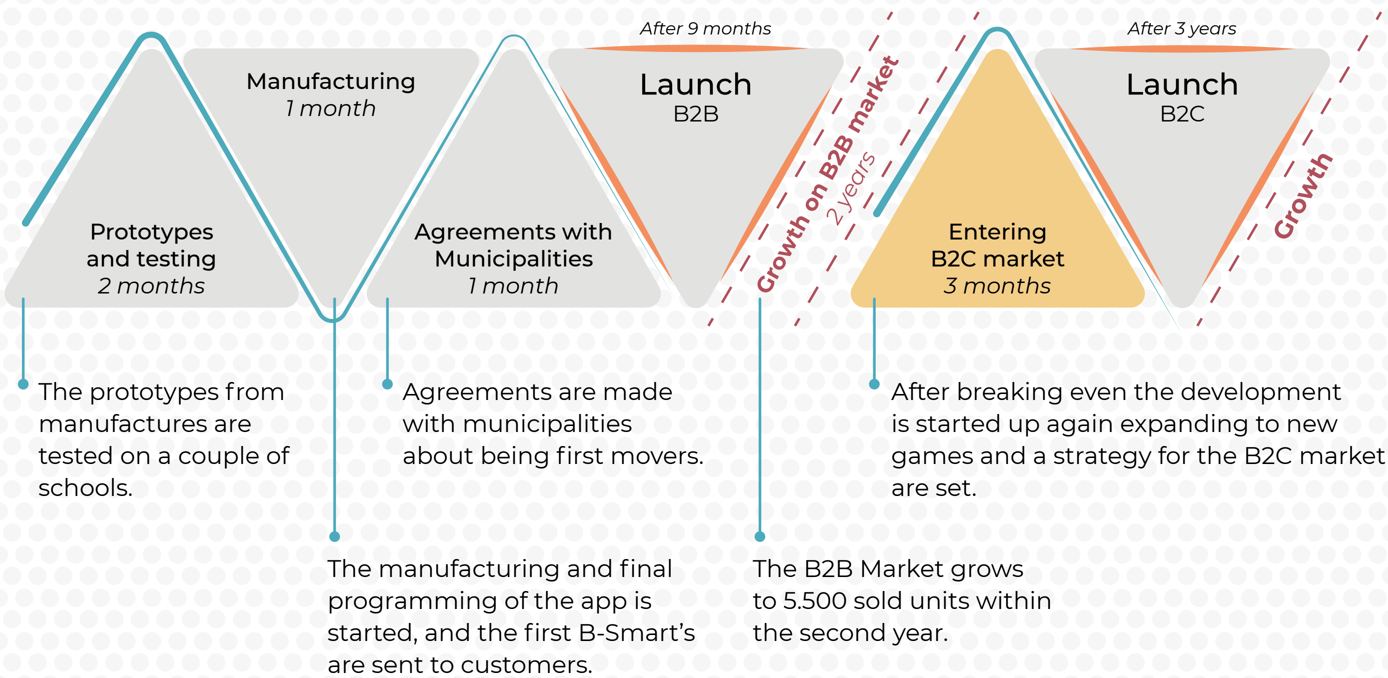
To exploit the potential of multiple markets a business strategy with a focus on high accessibility will be pursued.

By starting on the B2B market it will be possible to approach municipalities and thereby making agreements with multiple schools at the same time.

The schools are approached at first to give the teachers a tool for active learning.
By making the children aware of B-Smart through school, they will already know it when it is released on the B2C market. In this way, the children will also work as an extra marketing channel by telling stories about B-Smart to their families.

## The go-to-market strategy



## Market potential

**B•Smart** is designed for active learning in the primary schools in Denmark, which counts 2.390 schools with 660.000 pupils, but the potential goes beyond the schools and Denmark.

With small adjustments **B•Smart** can target the private market as an exam help for university students or as a rethinking of a family quiz.

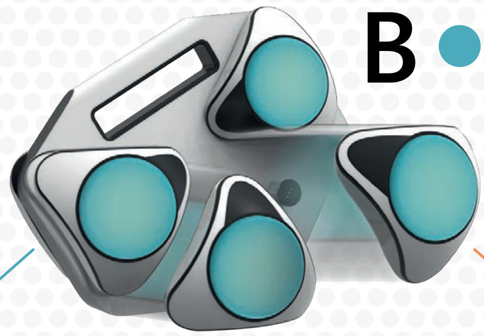
**2.390 Schools** with 17-18 classes

**262 High schools** with around 19 classes

**100.000 students** at universities etc.

**80.000 Families** in Denmark

## Market approach



# B • Fast

### B2B: Sales Channels

**Cold canvas:** Approaching schools and municipalities directly.
**SKI Supplier or 'Udbudsvagten':** Here you can make a bid on a predefined task as a competition.
**Conferences:** within active learning, could be a door to the market.

### B2C: Sales Channels

**Physical Stores:** Where toys and games are sold like Bilka or Bog&Ide.
**Online stores:** Known and well-visited websites as Coolshop.dk.
**Own website:** Skipping all the intermediaries, resulting in more money earned.

# MANUFACTURING COST

The production cost is based on the cost of the components, and the cost of injection molds and production. The sales price is established as twice as much as the manufacturing cost.

Electronic components:
288 DKK

Non-electronic parts & manufacturing:
219 DKK

=

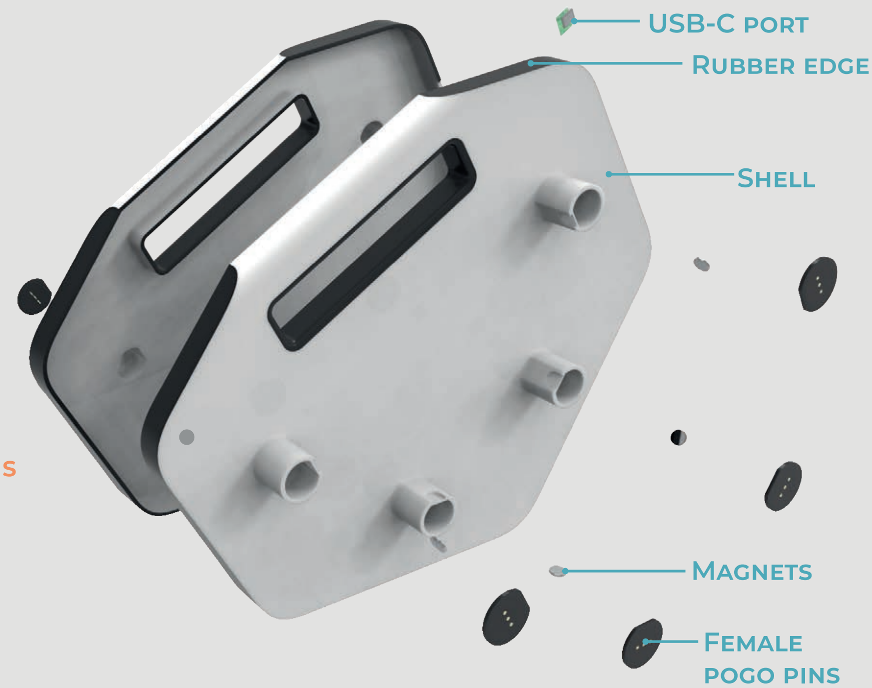
1 unit = 8 spots and 1 charging station

Production cost:
(at 5.500 units)
507 DKK

Sales price (B2B):
1.000 DKK

# CONSTRUCTION

App subscription:
5 units: 4.000 DKK
10 units: 6.000 DKK


## Spot

**Material:** ABS

**Production Method:** Injection molding

**Measures:** 210 (h) x 210 (l) x 40 (d)

**Features:** RGB LED, Bluetooth

## Charging Station

**Material:** ABS

**Production Method:** Injection molding

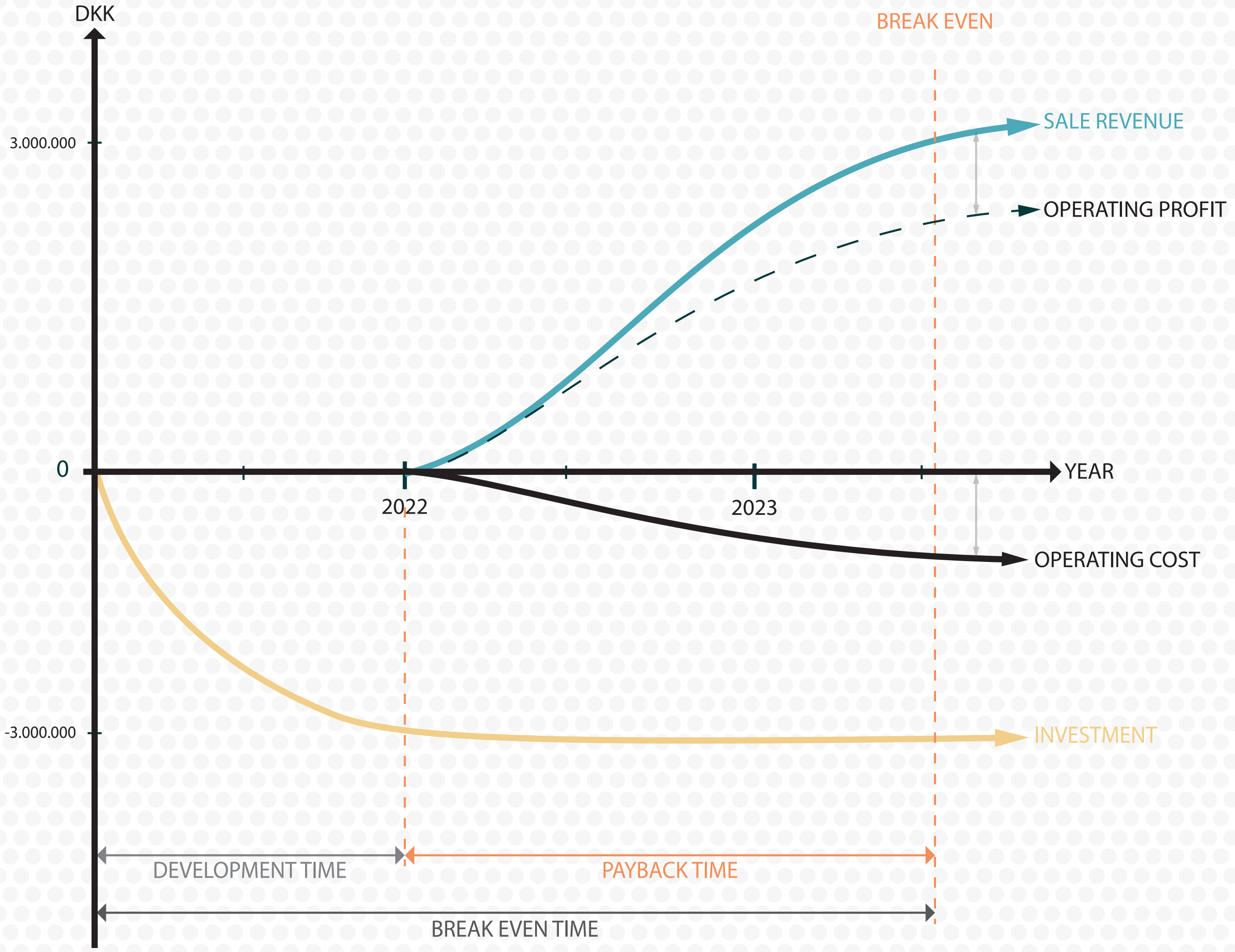
**Measures:** 317 (h) x 364 (l) x 46 (d)

**Features:** Magnetic charging

# CASHFLOW

Based on the estimated size of the Danish B2B marked, 5500 units are sold in the first two years. After two years the product could expand from B2B marked to the B2C market and even more, products are sold. Wages for manufacturing are included in the calculation.

The cashflow is made based on a Net Present Value (NPV) which shows the time from development to break-even from 2021 to 2024.




Investment:
Mould & App development

**3.000.000 DKK**

Payback time:

**2 years**

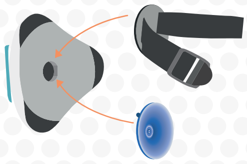
The investment is needed to start the manufacturing process. When the 5500 units are sold the investment will be paid back.

The payback time is around two years from starting the manufacturing and selling the product to schools.

# FUTURE OPPUTUNITIES

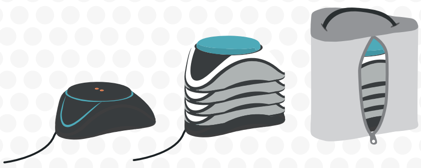
B•Smart's quiz game is only the beginning. With a mindset of taking over the market within active learning, new games and whole product lines can be developed. The possibilities are endless.

## Product line



### Add-on's
Straps and Suction cups for placing the spots on trees, windows, etc.

### Version 2.0
Adding a speaker in B-Smart, to e.g. learn spelling or a language.



### B2C Version
A version for the private market, with a smaller charger and a bag.

## Games

### Relay
Program the spots on the app, and use them for relay.

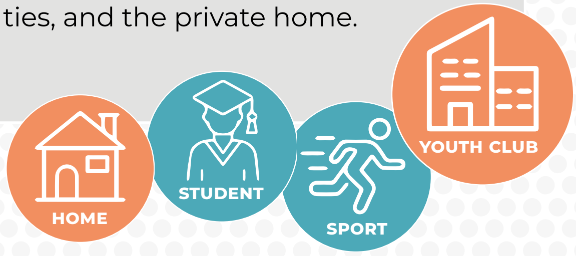

### Reaction game
Run to the spot that lights up and tap it! Continue to the next. The fastest wins! Or learn new languages, by pronouncing a word before tapping the spot.


### Memory game
Having a speaker in B-Smart makes it possible to use sound, as a way to learn a word. One spot contains the word, the matching spot contains the spelling of it.


### Adventure games
Go through a story with challenges to overcome using the spots. Climb over mountains by solving a math problem or match an animal with its food.

## Future Stakeholders

B•Smart has great potential when it comes to various Stakeholders. It can potentially be developed for students, youth clubs, sports activities, and the private home.

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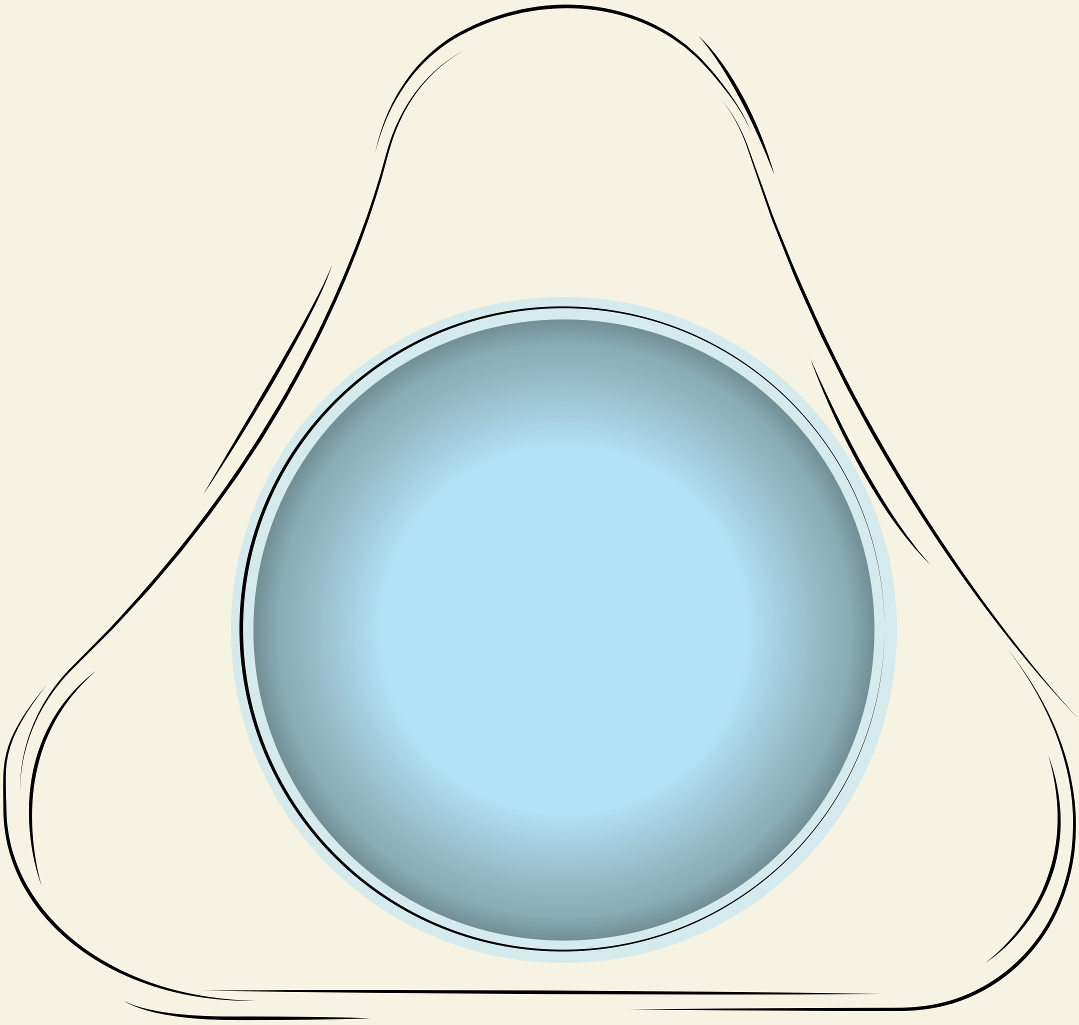
# Technology Driven Innovation **by Design**

***Process report***

Aalborg University

MSc02 / Grp 05

April 2021



B • Fast | B • Smart

# 0.0 Titel page

**Report type:**
Process report

**Theme:**
Technology Innovation Driven by Design

**Team:**
MSc02 / Grp 5

**Group members:**
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**Project start:**
02.02.2021

**Submission:**
22.04.2021

**Main supervisior:**
Mário Barros

**Co-Supervisor:**
Sven Vestergaard

**Pages:**
85

**Appendix:**
63

# 0.1 Prephase

This project is made by five MSc02 Industrial Design students at Aalborg University within the theme of *Technology Driven Innovation by Design*.

The project deals with designing a training system for citizens on Mars in the 2060s and afterward reframing it for Earth. The development of the two products is documented through this process report and appendix. It is presented through the product reports and associated technical drawings.

A big thank you to our supervisors Mário Barros and Sven Vestergaard while also Thomas A. E. Andersen, Managing Director at Danish Aerospace Company needs a big thank you for his collaboration.

# 0.2 Abstrakt

Denne proces rapport omhandler udviklingen af et primært og sekundært produkt. Det primære produkt er designet til en kontekst på Mars i 2060'erne. Gennem projektet bliver det fysiske, sociale og mentale helbred koblet sammen. Som beboer på Mars skal man træne minimum 2 timer om dagen, for at vedligeholde sin fysik, grundet den lave tyngdekraft. Dette er en forudsætning for at kroppen bibeholder den rette styrke, når de rumrejsende vender tilbage til Jorden efter 2-3 års ophold.

Det primære forløb resulterede i produktforslaget B-Fast. Et produkt som træner det vestibulære system gennem et reaktionsspil. Udviklingen af B-Fast har haft et stort fokus på motivations faktorer og fremtidens teknologiske løsninger. Med dette er det forsøgt at skabe de bedst mulige forudsætninger for at B-Fast forbliver sjov, dag efter dag, og samtidig giver et mentalt boost. Dette er gjort gennem gamification, belønnings systemer, et konkurrenceelement og fællesskab.

Det sekundære forløb bestod af en design sprint. Igennem denne blev hovedgreber fra B-Fast overført i form af motivation, gamification og fysisk aktivitet. Disse elementer og virkemidler, som skal give et mentalt boost og motiverer brugeren, blev brugt til at skabe produktforslaget, B-Smart, et quiz baseret spil, der gennem læring kan aktivere folkeskoleelever.

# 0.3 Reading guide

### Documentation

This project consists of the following documentation, which should be read in the indicated order:

**Product report (Mars):** A presentation of a product proposal for Mars in the 2060s.
**Reframed product report (Earth):** A presentation of the reframed product proposal to Earth at its current stage and business aspects according to this.
**Process report:** A transparent walkthrough of the design process of both proposals. Central findings of the activities are included in the report, whereas further details can be found in the appendix.
**Technical drawings**: Drawings over the two product proposals with specifications and dimensions.
**Appendix:** A selection of analysis and activities are done throughout the project in more detail. Text written in italics here is direct quotes from sources.

### References

The full reference list and Illustration list is found at the end of the 6.0 Epilogue section. References are referred to by Harvard Method, with *(Author(s), year of publication, possibly page number)* directly in the text.

The report illustrations are numbered as "*Ill. x - Description off the illustration*", as in referred to in the text with "*(ill. x)*". All illustrations without sources are produced by the group members.

Appendix is referred to as (*app. x*) in the text and can be found in the separately attached document.

## Want the full experience?

In the PDF toolbar go to:
View - Page Display - Two page view

Repeat and chek of "*Show cover page in two page view*"

### Reading guide for process report

This reading guide is for the process report, which is divided into six phases: *1.0 Discover, 2.0 Define, 3.0 Develop, 4.0 Deliver, 5.0 Reframing, and 6.0 Epilogue*. The phases 1.0-5.0 follows the five Milestones sat throughout the project period and the Double Diamond model. Each chapter begins with a short introduction and ends with a sum-up of the current phase.

There will be referred to two user groups:
**Space travellers**: A not fully trained person going to Mars (like a biologist).
**Astronauts**: A person who has gone through a professional space training program.

### Markers

For securing readability throughout the report, a selection of markers had been added. These are intended for highlighting key finding in the process:

✔ Requirement found within the processed task.

✖ Boundary: a previous requirement dismissed or invalidated due the processed task.

! Specification: a requirement tuned into a design specification due the processed task.

***Bold italic text mark's introduction to the current text paragraph.***

***Bold italic text in a red box mark's the outro of the current text paragraph.***

! Marker for highlighting important points in writing paragraphs.

# 0.3 Content

## PHASE 1.0 DISCOVER

### A journey to Mars



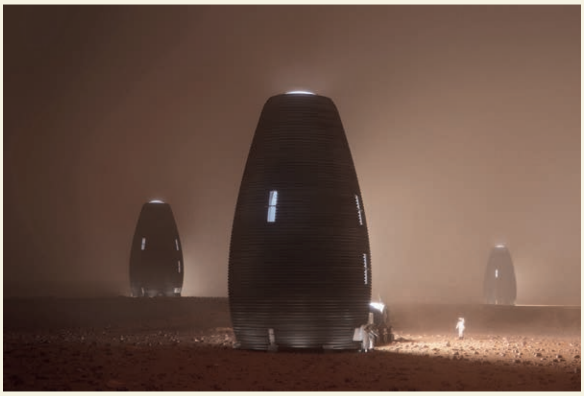
## PHASE 2.0 DEFINE

### Staying in Balance



## PHASE 3.0 DEVELOP

### Stay Strong and have Fun



# PHASE 4.0 DELIVER

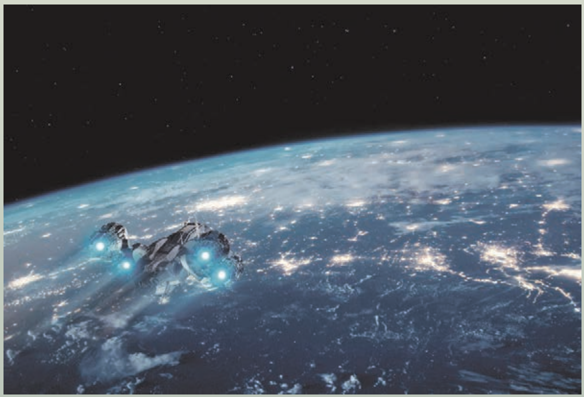
## A SAFE LANDING



# PHASE 5.0 REFRAMING

## BACK TO EARTH





# PHASE 6.0 EPILOGUE

## TRAVEL DIARY

# 0.5 Introduction

Being active benefits not only the body but also the mind. In the 2060s small colonies will be established on Mars, and here the Martians will have to be active, to stay healthy and be able to return to Earth after 2-3 years stay.

The tough environment means that they must stay i nside the hole period on Mars unless equipped a large space suit. This combined with the long distance to their home on Earth, family and friends jeopardize the mental and social health of the astronauts and space Travellers.

The project focuses on motivation to exercise the vestibular system as part of the obligatory training. This project does not only accommodate an exercise tool but also boost the mental and physical health by making the training fun in a social community setting.

The approach of motivation and physical activity benefits the brain and will be used for reframing to new learning experiences in primary schools.

# 0.6 Project Approach

***The overall project approach has been iterative and followed the Double Diamond model, by alternately diverging and converging. The ideation process for the original framing was based on Striims Ideation model (Ill. 1).***

## Double diamond

The Double Diamond model focuses on a thorough problem investigation. The model consists of the four phases: *Discover, Define, Develop and Deliver* which alternately diverges and converges. (Ill. 1)

### Discover
Possible problems are found as well as the user group's needs, through hypothesis and research.

### Define
Discussions and analyses are made from possible problems and ideas. Narrowing down to a more concrete design brief.

### Develop
With a design brief settled ideation gets approached and the development takes multiple iterations through testing, model work, and sketching.

### Deliver
The detailing phase summarizes the project. Elements like materials, shape, and technology are addressed here.

(Design Council, 2005)

## Striim's Ideation Model

Striim's ideation model is based on the five phases: *Focusing, Idea creation, Summary, Ideation, and Idea Evaluation* (Ill. 2).

### Focusing
The assignment gets specified and formulated in an open problem formulation.

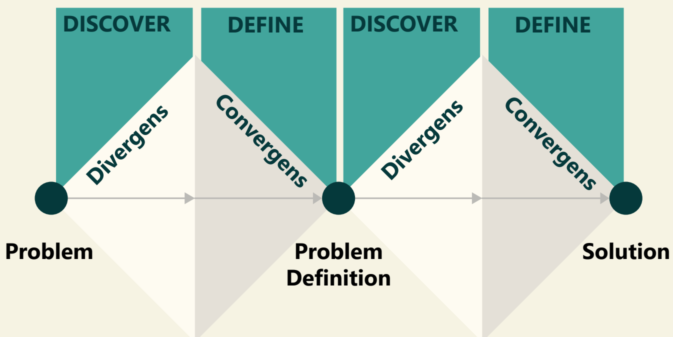
### Idea creation
The phase contains critique less ideation. The focus is on emptying the head, with no evaluation. Ideation methods like "*association chain*" can be used here.

### Summary
A translation phase, to create an overview of the found ideas. They are evaluated and some are chosen for further work in the next phase.

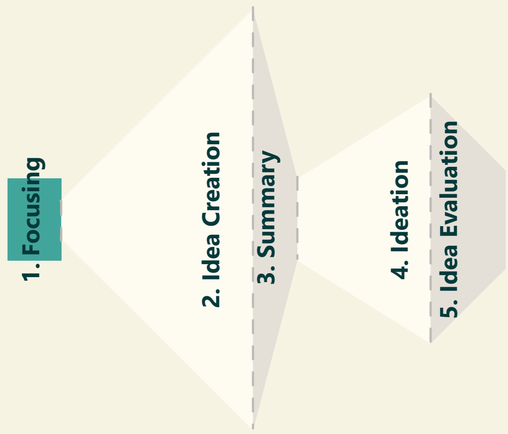
### Ideation
From the chosen ideas from the last phase new ideas are brought to the table. The phase includes switches between "*creative thinking*" and "*logical thinking*".

### Idea evaluation
In the last phase the final ideas get evaluated. Each idea is compared to the found requirements.

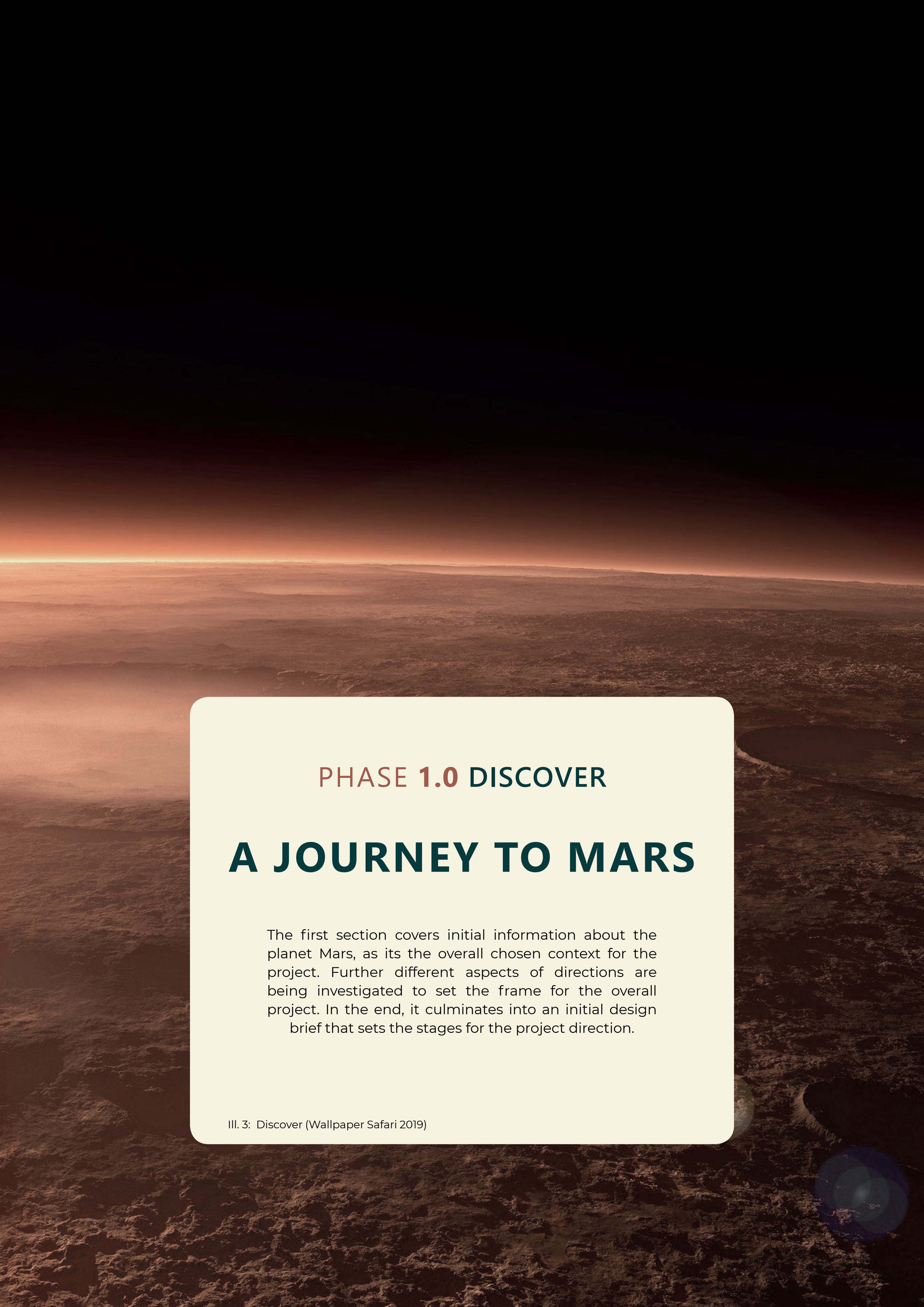
(Striim 2001, Pp. 49-62)




Ill. 1: Double Diamond (Design Council, 2005)




Ill. 2: Striim's Ideation Model (Striim 2001, Pp. 49-62)



## PHASE **1.0** DISCOVER

# A JOURNEY TO MARS

The first section covers initial information about the planet Mars, as its the overall chosen context for the project. Further different aspects of directions are being investigated to set the frame for the overall project. In the end, it culminates into an initial design brief that sets the stages for the project direction.

Ill. 3:  Discover (Wallpaper Safari 2019)

# 1.1 The planet Mars

## The choice of Mars

***Established on the fact that this project originates from the planet Mars, it is hereby found how the planet's circumstances are. This will inform which requirements the product development needs to consider.***

### Mars

Mars is considered to be the most Earth-like planet, which also forms the basis for why science is working towards being able to colonize in particular Mars (Mehlsen, 2019).

Mars is known as the red planet since it is covered with red dust. All over the planet, there are canyons, volcanos, and dry lakes.

Mars is only half the size of Earth, and it is slightly further away from the Sun. This means a day on Mars is 24 hours and 39 minutes and a year consists of 687 Earth days. (May, 2020)

### The travel

The distance between Mars and Earth varies depending on their orbits around the sun. The shortest distance between these two planets is about 56 million km, and the longest distance is up to 401 million km. (Redd, 2017)

The fastest spacecraft so far travels at 58.000 km/h, which means that by the shortest distance between Earth and Mars it will take about 40 days of travel. However, the average time of travel to Mars is 162 days. These traveling times are depending on the planet's orbits (*which have an elliptical shape*) and will vary between six and eight months. (One, 2020)

### Environmental conditions

Mars is a very cold planet (temperature: -63° C to -120° C). The temperature level cannot be compared with the temperatures on Earth since the atmosphere on Mars is thin. On the contradictory the research states that in -63° C you would only need to wear a sweater to keep warm because the heat would stay with you for a longer period.

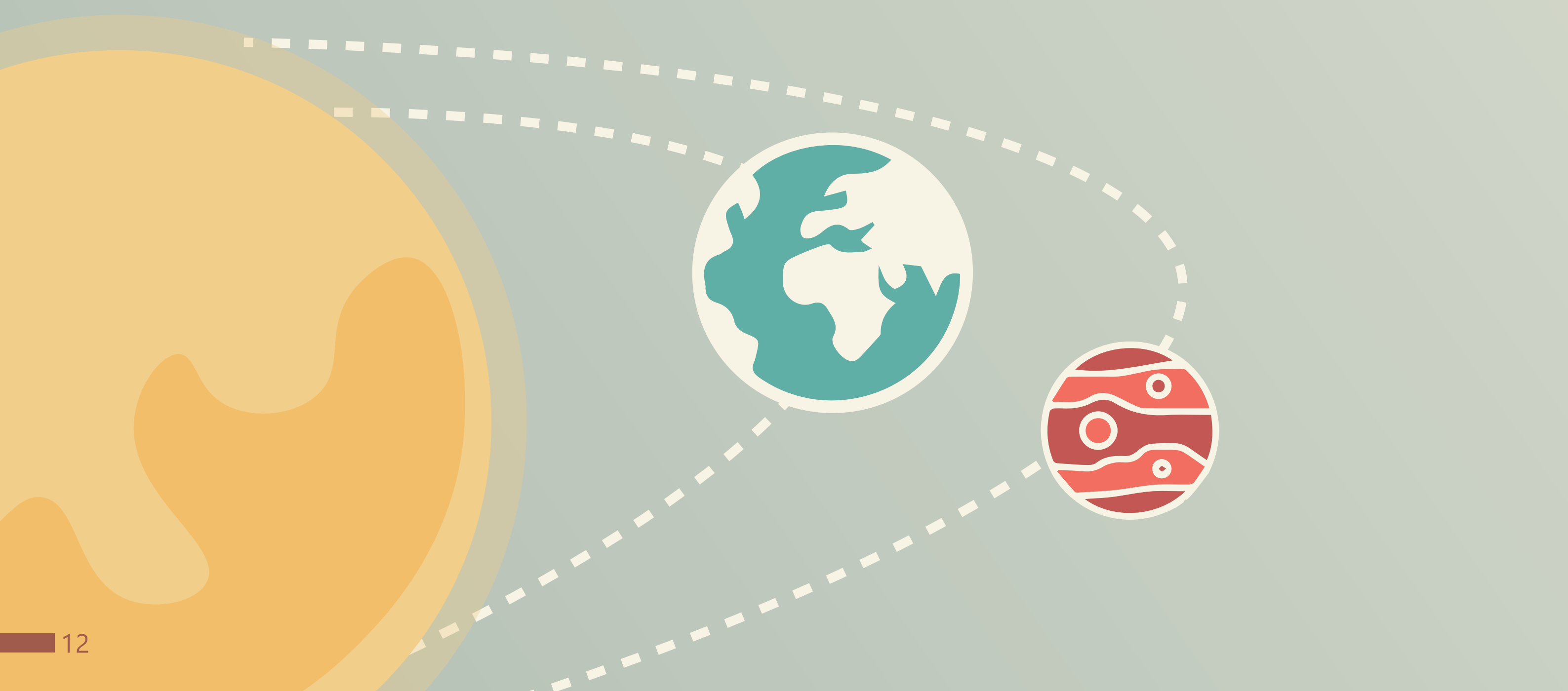
Additionally, Mars has clouds and wind like on Earth, however, the winds on Mars can create dangerous sandstorms that can last for months, making the outdoor environments dangerous without a protection shelter. (Hall, 2017) This kind of protection is also needed against the radiation on Mars (One, 2013).

Because the atmosphere is much thinner on Mars and contains 95% Carbon dioxide and less than 1% oxygen meaning that humans cannot breathe on Mars without oxygen supplements (May, 2020).

The gravity on Mars is about 1/3 of what it is on Earth. So, a person who weighs 100 kg on Earth would weigh around 35 kg on Mars. And because of the gravity, a dropped object would fall slower, and people will walk slower than on Earth. (May, 2020)

### Planet colonization

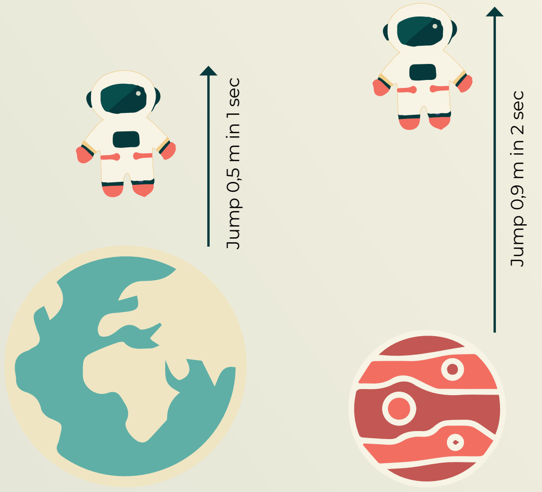
Colonizing Mars is categorized and time-framed in a table of disruptive technologies (app. 2). Creating colonies in space is in their red category, indicating it as a technology with a distant future in plus 20 years before it becomes a reality, however, it is also written that there are ongoing studies. (Foresight, 2018)



### The gravity effect on the human body

The change in gravity will affect the human body.
A major problem is, how the bone mass is reduced and accordingly gives weaker bones. The change in gravity can also make the muscles shrink over time. Besides the fluids in the body are shifting upward to the head and gives pressure on the eyes that can cause vision problems. Consequently, this change in gravity provides some health challenges. (Romero & Bowman, 2018)

The consequences are investigated on the International Space Station (ISS) and on the Mars One mission which aims to establish a human settlement on the planet Mars (One, 2020).




Gravity on Earth: 9,81 m/s2

Gravity on Mars 3,71 m/s2

Ill. 4: Gravity on Earth and Mars

- ✓ Maintaining the physical health
- ✓ Must work with Martian gravity
- ✓ Indoor use

***Colonies in space is a technology with a distant future, plus 20 years, before it becomes a reality, however, it is also stated that there are ongoing studies investigating this. (Foresight, 2018) (app. 2)***

# 1.2 Choice of focus

An early brainstorm of potential directions (app. 3), as well as concurrent research, was conducted to be able to map potential directions for the project. Based on this and general interest among the group, four directions were chosen for further research and mapping of potential issues thereof (app. 3).

### Food in space

- In request to colonize Mars, it is needed to be able to produce food.
- It can be a challenge to create the right environment on Mars that enables people to grow edible plants etc.
- The challenge also lies in how people on Mars should get the necessary nutrition without depending on rations of food or other resources from Earth.

### Transport on Mars

- A challenge is how to move safely on Mars outside the future shelters.

### Children on Mars

- The fact of having kids on Mars is far into the future and is more uncertain, which also applies to toys or so, for children in space.
- An important aspect of humans and children in space is to strengthen their bones and muscles. It could be necessary to create more fun exercise experiences for children on Mars to make them accommodate the obligatory training.

### Winter depression (space)

- Astronauts do not get enough D-vitamins.
- It can cause problems with mental health and concentration. In the worst-case lead to depression or/and stress.

***From these, some of the basic principles were gathered and combined for further work. The primary ones were winter depression and children in space. The essentials in these were mental health and how this could be combined with a fun element and made more playful. This will be the focus for further project framing.***

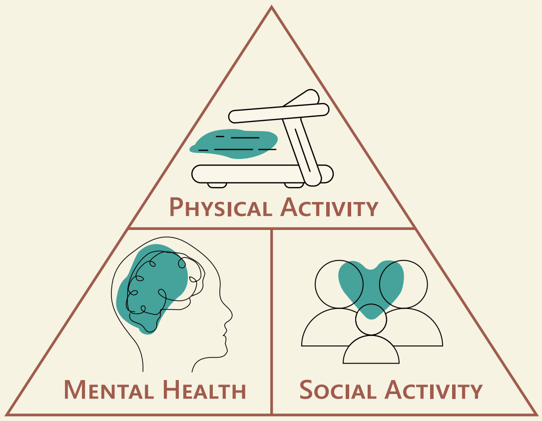
# 1.3 Main Focus

***With the choice of focus a frame was set, to start finding information within the subject. The idea was to work with a holistic approach. It was found how the astronauts' mental health is affected when they are on missions in space, and how to affect mental health positively through sports and games.***

## A Holistic Approach

With a holistic approach, the focus for the project gets three-folded and contains three elements: *Physical Activity, Mental Health, and Social Activity (ill. 5).*

Physical Activity is the centre for later product development, but with the mental and social benefits of being active in mind it adds an extra aspect to consider.



Ill. 5: Holistic approach

## Mental Health in Space

When Astronauts are going to space, one of the concerns is their mental health. It will be affected in three different ways: *sleep, radiation, and social isolation (combined with the long-distance to home).*

### Sleep

In space, there is not the same 24-hour clock that we got on Earth. At the *International Space Station* (ISS) that orbits around Earth, one 24-hour Earth-day consists of 16 sunrises and sunsets. Meaning that one day is only 90 minutes (Nissen, 2015).

At ISS there is therefore artificial light, which impacts the sleep because it is blue light – like screens do on Earth. At Mars, one day (*called a Sol*) corresponds to 24 hours and 37 minutes. The Martians will need to live inside the whole time, why they almost only will be affected by artificial light – and not the sun (Deziel, 2017).

**Consequence**: Lack executive of functions or their mental processes involving decision making and concentration (Turner, 2019).

FACT

To help astronauts with the feeling of social isolation NASA has developed the acronym C-O-N-N-E-C-T. It represents seven key terms, that help astronauts to maintain good psychological health (*Community, Openness, Networking, Needs, Expeditionary Mindset, Countermeasures, Training and Preparation*). (Perez, 2021)

### Social isolation

When astronauts are sent to space on month-long missions, they experience various aspects of social isolation and confinement.

In 2010-2011 the *Russian Federal Space Agency* (Roscosmos) made an experiment called Mars500 to see how social isolation far away from home affects astronauts. This was done by isolating six crewmembers in 540 days simulating that they were on Mars. This increased physical autonomy and decline of motivation to work and overall activities. (Agency, n.d.; Ushakov, et al., 2014)

Additionally, NASA has made studies on the negative impact of social isolation and how it affects the health and performance. These studies have been done both in space and on Earth (in field locations in Antarctica). The negative effect on social isolation will only become larger as the distance to Earth becomes longer. (Perez, 2020)

**Consequence**: Range from reduced immune function to sleeplessness. The feeling of loneliness causes higher anxiety and depression. These things are also linked to poor cardiovascular health and cognitive function. (Tulane University, 2020)

***A holistic approach for the concept development was set and information about the consequences within sleep issues and social isolation. Parameters that NASA is studying.***

# Games and Sports: Positive Effect on Mental Health

### Boardgames
Playing board games has many positive effects on mental health. This is caused by the release of endorphins in the brain (*the natural feel-good chemicals in the body*) when playing. Boardgames helps:

- Ward off stress and depression
- Improve brain functions
- Improve relationships and your connection to others
- Stave off loneliness (Mounsher, 2017)
- Keep you feel young and energetic

(Robinson, et al., 2020) (Nakao, 2019)

### Sports games
When being active endorphins are released in the brain as well. Being active can reduce depression and anxiety (Peirce, et al., 2018). Playing a team sport has the following benefits:

- Human connection
- Reduce stress, depression and anxiety
- Gives a better night's sleep
- Accomplishment and pride (Carless & Douglas, 2010)
- Hopefulness for the future (Carless & Douglas, 2010)

(Beyond Blue, n.d.)

> *"We don't stop playing because we grow old; we grow old because we stop playing."*
> George Bernard Shaw (Robinson, et al., 2020)

# Maintain the Motivation

With the knowledge about games having a positive effect on mental health, it is investigated which elements to incorporate in a product to keep users engage in the activity.

### Competing or working together
Working together improves the social stimulation of the game and increases the excitement (Griffiths , 2015.).

### Acknowledgment
By providing positive feedback to the players as they overcome challenges it will promote a sense of mastery and competence (Yee, n.d.).

### Being equal in skill level
When being in a state of flow, players become *focused, loses track of time, and are motivated to continue playing* because they are having fun. The flow states occur when challenges are perfectly balanced with skill level. (Kowert, n.d.)

### Learn by doing (discovery)
By letting people learn on the go it allows to start playing without using a long time learning the rules without actually playing (Yee, n.d.).

### Gamer motivation model
The model (ill. 6) consists of 12 parameters to maintain the users' interest. Research have been made on each parameter, and especially *community and competing* contributes positively to keep the excitement. (Quantic Foundry, n.d.; Yee, n.d.)

| Action<br>"Boom!" | Social<br>"Let's Play Together" | Mastery<br>"Let me think" | Achievement<br>"I want more" | Immersion<br>"Once upon a time" | Creativity<br>"What if?" |
|---|---|---|---|---|---|
| Destruction<br>*Guns. Explosives. Chaos. Mayhem* | Competition<br>*Duels. Matches. High on Ranking* | Challenge<br>*Practice. High Difficulty. Challanges.* | Completion<br>*Get All Collectibles. Complete All Misions* | Fantasy<br>*Being someone else, somewhere else.* | Design<br>*Expression. Customization.* |
| Excitement<br>*Fast-Paced. Action. Surprises. Thrills.* | Community<br>*Team Spirit. Chatting. Interacting* | Strategy<br>*Thinking Ahead. Making Decisions.* | Power<br>*Powerful Character. Power Equipment* | Story<br>*Elaborate plots. Interesting Characters.* | Discovery<br>*Explore. Tinker. Experiment.* |

Ill. 6: Gamer Motivation Model (Quantic Foundry, n.d.)

- ✔ Release endorphins
- ✔ Acknowledgement by overcoming challenges
- ✔ Include social elements (competition and community)

***It is found that astronauts in space can be affected negatively by their mental health because of sleep disorders and social isolation. A solution to this could be physical activity and games, where endorphins are released. For this to work on a longer mission in space, the interest in being active and playing games needs to be maintained. To do this, elements as acknowledgement, community and competition can be used.***

# 1.4 Initial Design brief

***The following phase converts the collected data into an initial solution-space for the project. This was done through a problem definition, vision, needs, and wishes as well as some initial focus points. With inspiration from Steen Agger's need graduation (Agger, 1984) the initiating requirements are divided into needs (as must be fulfilled) and wishes (that are strived for). The focus points were considered as possible requirements at that time in the process.***

## Problem definition

"How to make a product that motivates people on Mars to strengthen both mental and physical health by reducing the feel of exercise being an obligation?"

## Vision

Create a state where the participants are in a "flow", where they lose track of time and keeps them motivated to continue engaging in the activity.

## Needs

- Indoor use
- Must work with Martian gravity
- Release endorphins

## Whishes

- Maintaining the physical health
- Acknowledgment by overcoming challenges
- Include social elements (competition and community)

## Focus points

- Coss-Generational
- The heart rate should go up
- Easy to approach and understanding
- Competing or working together
- Produced on Mars
- Supplement to original training
- Equal in skill level
- Learn by doing
- Imitate Earth gravity

## Context: Mars

Ill. 7: Context: Mars

# 1.5 Milestone 1

The response at Milestone 1 came with some valid points from the supervisors. Overall, the holistic approach by combining the *mental, physical, and social* in a solution for helping the space travels or astronauts was received well. It was seen that all three elements would positively influence each other. However, it became clear, that the focus on the main issue (physical activity) in the solutions space (mental, social, or physical) should be the centre of attention.

Additionally, it was pointed out that the concept direction could benefit from taking a step back, to make sure the gamification approach was the right way or if there was another kind of motivation factors, the solution could benefit from. The gaming element could be added later, but for now, the framing needed more investigation. Furthermore, it seemed that the project was missing some clear challenges and precogitation.

A possible context was also presented, as a framing for the product development. This context was investigated further in the next phase and presented in the next chapter (*2.0 Define*). Despite this, the supervisors saw the context as a good boundary for the project.

The last vital point of feedback led to transportation, how the size and weight of the larger concept could be an issue.

# 1.6 Sum-Up

## Acquired Knowledge

- *The Martian conditions and effects on the body*
- *The distance and travel to Mars*
- *How Astronauts are exposed to health problems both mentally and physically in space*
- *Social isolation is a big mental health factor affecting astronauts*
- *Games, sports, and different factors of motivation can positively affects the mental health*

## Further Course

- *Step back and reconsider the framing*
- *Clear guidelines for timeframe and context*
- *Investigate the physical effects on the body for being in space and the current solutions used*
- *Investigate solutions space through technologies and concept development*

PHASE **2.0** DEFINE

# STAY STONG AND HAVE FUN

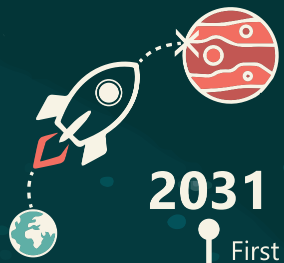
The second section is Define. This is done by setting up an estimated timeline for future space travel, which projects the needs of the specific points in time.

From this, a more specific context will be defined to set a frame in which the project needs to fit into. The project will from this stage, be defined from a problem-oriented perspective, and through ideation, the solution space will be investigated. At the end of the defining phase, a design brief will set the overall frame and the direction for the project.

Ill. 8: Define (Miro Medium, n.d.)

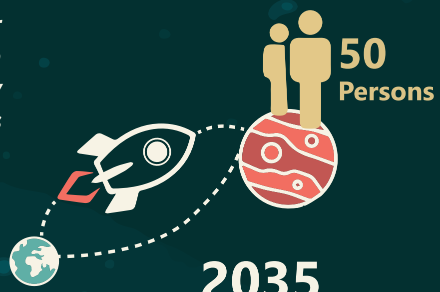
# 2.1 Timeline

*A timeline was made iteratively with other research and ideation, to show and frame which stage in time to focus on. Here it was found how the future of space travels to Mars will happen, as well as when colonization will become a reality. (HumanMars, 2019)*



**2031**

First humans on Mars. Two spaceships with 12 astronauts in each will travel to robotically prepared Mars base: Alpha (in 2030). With their spaceship as a temporary habitat.




**2035**

Some of the crew is returning to Earth.

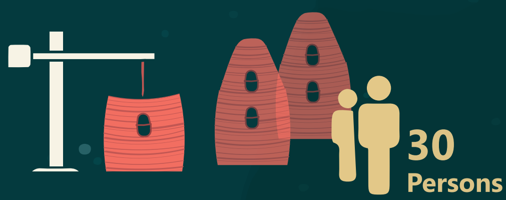
50 scientists, workers, and colonists land on the Mars base: Alpha. The scientist crew is rotating every 26 months and going back to Earth.

**2021**

**Stage 1**

Second crew land on Mars with 30 astronauts. The first ground-based habitat and a hydroponic greenhouse are built on Mars.

**2033**




Two heavy spaceships lands on Mars, one with 400 passengers and another with 200 miners. The population on Mars is now 1200 people.

The Blue Mars base about a thousand miles from Mars Base Alpha is established, with 100 workers.

**2048**

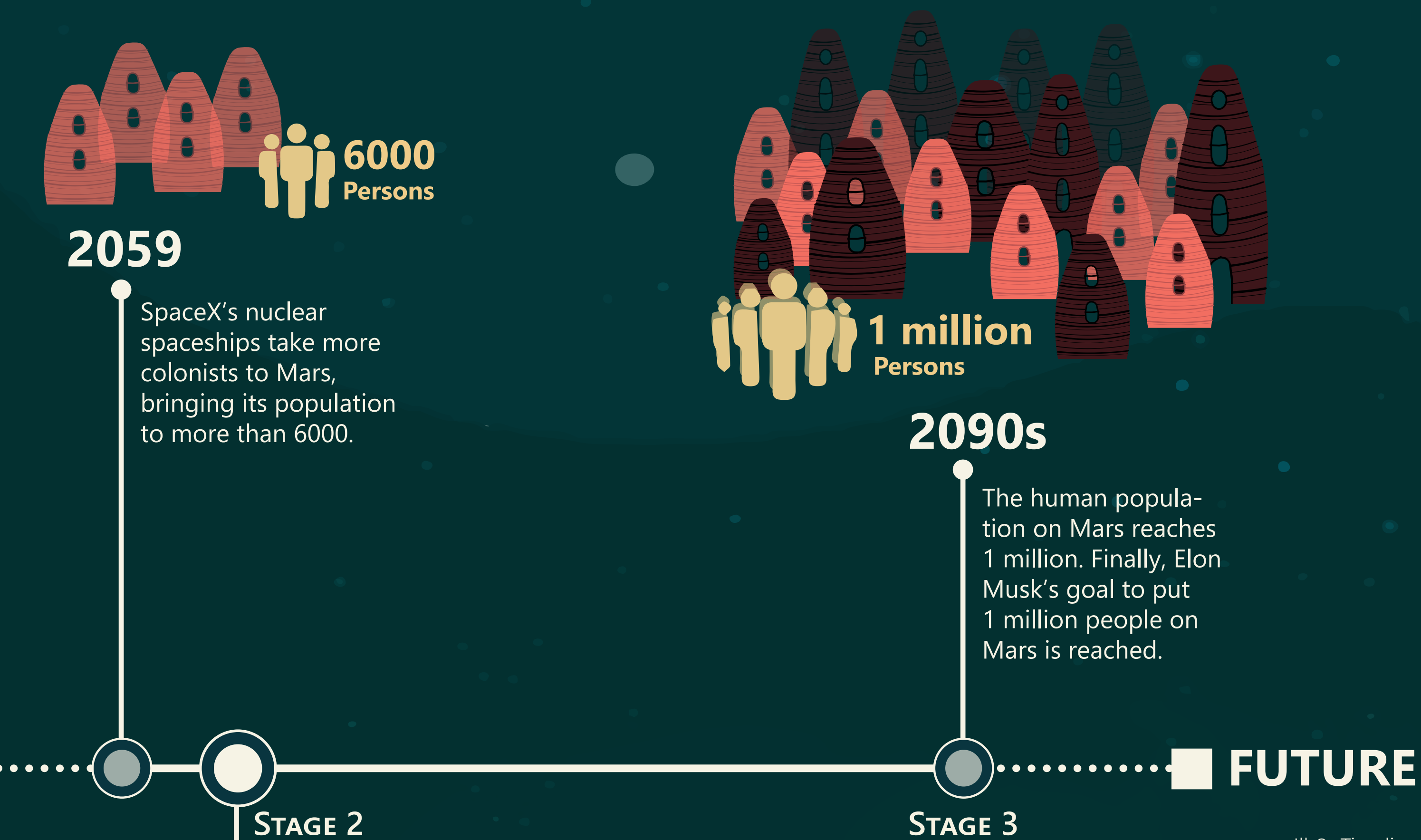

*From the timeline, the evolution of colonization on Mars is divided into three stages:*

*1) The first is the stage where few astronauts and trained humans for space travel begin building settlements and setting up other necessary resources.*

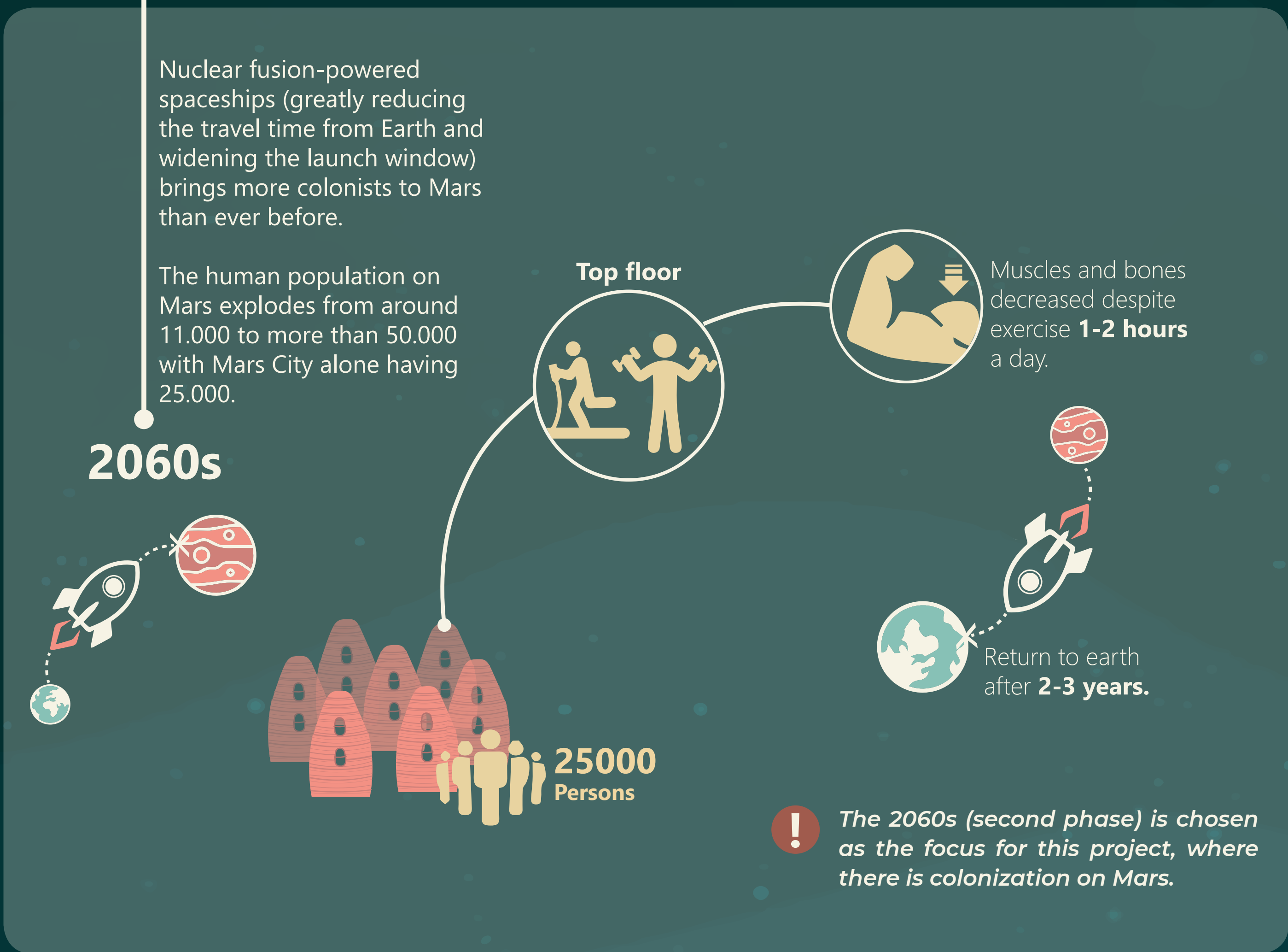
*2) The second stage is the resources and buildings ready for human use and colonization of Mars. At this stage, ordinary people can begin to settle on Mars, though still only with a duration of 2-3 years.*

*3) The last and third stage have made Mars independent of the Earth's resources and Mars now inhabits a large population. (HumanMars, 2019)*

*Finally, as market on ill. 9, the focus for this project will be at stage 2 (the 2060's).*




Ill. 9: Timeline



# 2.2 Housing on Mars

***Based upon the chosen stage two, where Mars will be a habitat for a small city-sized colony, the scene in which the solution would be used, were investigated. The Marsha Project won a NASA competition of housing propositions for Mars and was chosen as a case study and frame for the project (app. 4).***

## Case: Marsha House

Marsha was created by the New York-based architecture firm AI SpaceFactory. The habitat is designed to be built mainly by robots. The construction is based on accessible material on Mars and can be 3D-printed using a mixture of plant-based polymer and ground-up Martian rocks. Marsha is designed with a double-walled structure (ill. 12) to withstand the rough environment. The structure ensures that the habitat does not expand like a balloon, because of the difference in the atmosphere from the Martian outside to the Earth-like inside (Reilly, 2020).

Marsha offers different surprising elements, for social and mental health. Marsha is designed with four floors (ill. 12). The big skylight and the intermittent windows connect all the levels (AI SpaceFactory, n.d.).

! On the top floor is a room for *Recreation & exercise*, this will be the stage for product development.

### Assumption

! Marsha House is a conceptual building; the accurate dimensions of the upper room are unknown. The room is estimated to have a conical shape with the measurements seen on ill. 11. It is estimated to be 18 m² (app. 4).

***Understanding the Marsha House, the fourth floor, for recreation and exercise, and knowing the estimated size of the room, will be used as a frame for the development of concepts.***

***The possibility of making artificial gravity inside, will not be an opportunity on Mars, based upon the problems of creating artificial gravity in a spaceship (see fact box). Therefore, the gravity conditions inside Marsha will be the same as outside.***

✓ Installation on: Floor or rounded wall

✓ Indoor space: 18 m², h: 1,6m, wall slope: 75°

✓ Indoor use

Ill. 10: Marsha on Mars (3D Natives, 2018)

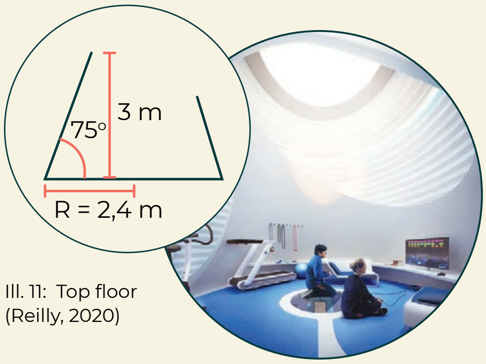
Fact

## Artificial gravity

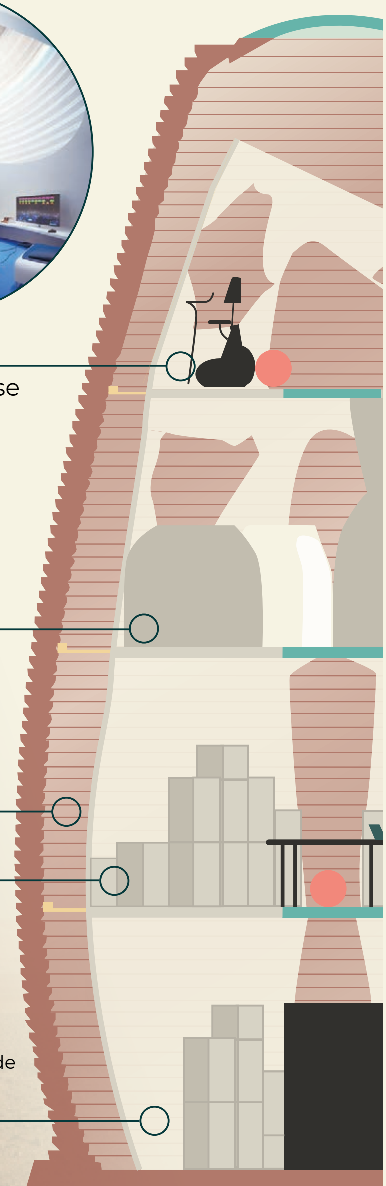
To create Earth-like gravity, you need to simulate centrifugal force, in which a solution proposes utilizing a spinning cylinder, sphere, or torus.

Varying the radius and rotation force, you can affect the simulated gravity. The radius of rotation grows with the square of the orbital period, meaning a doubling of the orbital period requires four times increase in the rotation. (McFadden, 2017)

The problem is the size. A small spaceship needs to rotate fast, therefore generating gravity requires a very large spaceship to be able to spin very slowly. Further people get dizzy and lightheaded if the rotation portion of the spaceship were too small because blood would be drawn away from the brain. The price of boosting such a big spaceship into orbit would be huge. (Feltman, 2013) (app. 5)




Ill. 11: Top floor (Reilly, 2020)




Ill. 12: Marsha House, inside

# 2.3 Workout In Space

***Still having a holistic approach, the physical health of being in space were investigated. In space, astronauts are exposed to microgravity, which causes physiological changes as muscle atrophy, bone loss, and reduction in aerobic capacity. This affects the astronauts' performance in mission tasks (Reckart, 2020). The problems of being in space and the equipment used for maintaining the astronauts' physics is addressed (app. 6).***

## What happens to the body in space?

### Bone loss

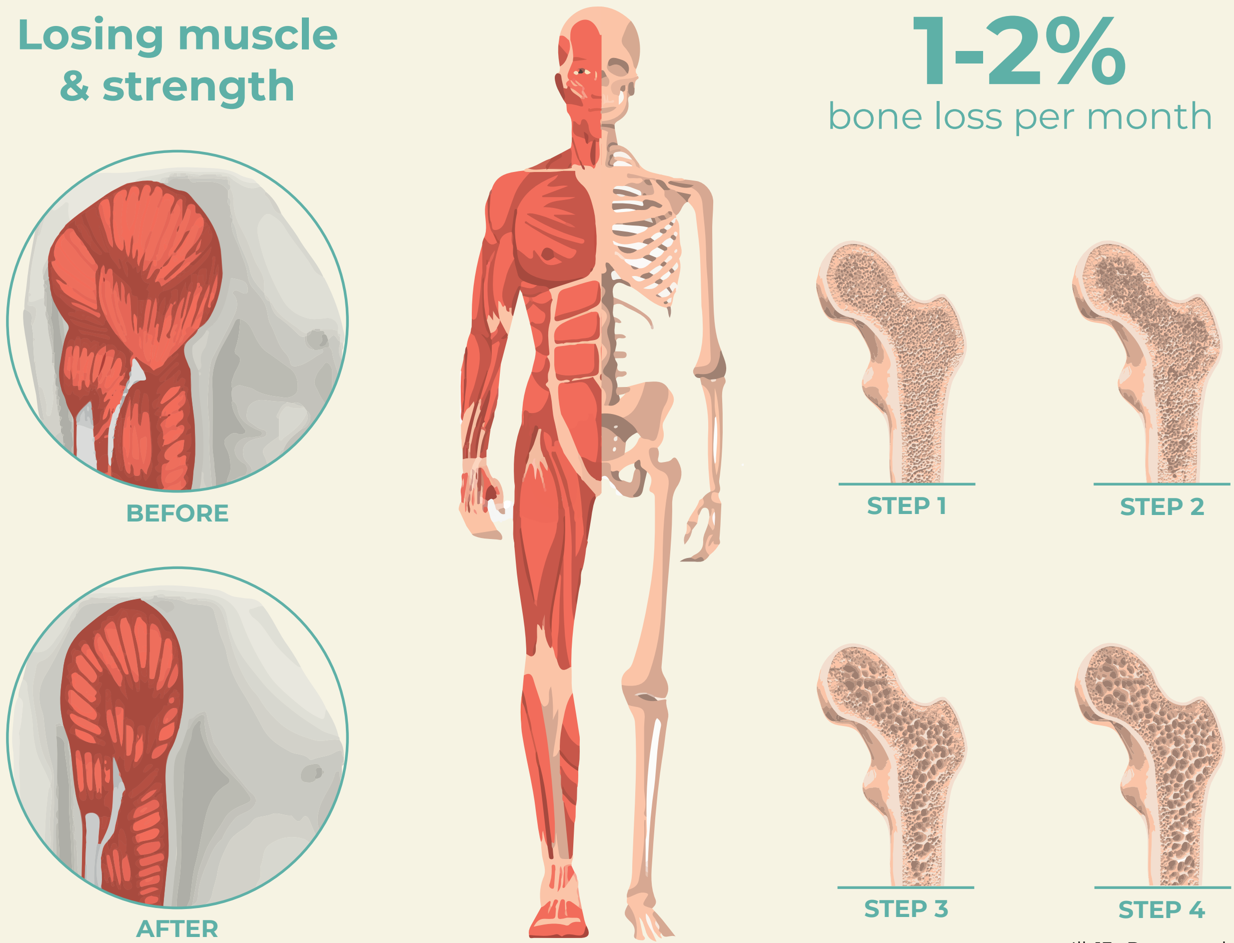
Different from the high gravity on Earth, the microgravity on Mars causes bone loss (Rajendran, 2019). In average astronauts loses 1% of their bone density per month (ill. 13), which on earth corresponds to an old person losing 1% per year (Government of Canada, 2019). The difference is that on Earth your bones constantly break down and rebuild themselves, caused by shocks from running. In zero gravity, astronaut's bones do not experience the stress of supporting the body against gravity.
To reduce bone loss, they must exercise a minimum of two hours per day (app. 6). Load-bearing activities, such as running, and walking is some of the best ways on Earth to build bone mass. In space, astronauts need to strap themselves on treadmills, with a gravity harness, to get the same benefits. (Rajendran, 2019)

### Muscle strength

Muscle fitness, on both long and short space flights results in decrements of muscle atrophy, lower fatigue resistance, and reduced power and strength (ill. 13). Primarily these effects are observed in the lower limbs and postural muscles. Studies from space flights and unloading during space flights show that resistance exercise is partially effective in preventing loss of muscle fitness. (NASA, 2020)

### The cardiovascular system

Microgravity also impacts the cardiovascular system, which includes both heart and blood flow. Our system has learned to operate in Earth's gravity while sitting, lying down, and standing (Johnson 2020, a). The impact of microgravity affects the heart's ability to pump blood and provide oxygen to cells in the whole body. This causes serious consequences because the heart adapts to the pressure in weightlessness and changes in blood distribution. This is a problem, particularly when landing on planets, because it causes dizziness and fainting (Johnson, 2020, b). To maintain aerobic fitness in space, the current exercise strategy is six days per week with cardiovascular exercise (NASA, 2015).




Ill. 13: Bones and muscle

# Training Equipment in Space

A selection of exercise equipment used or tested for '*The International Space Station*' (ISS), were investigated to find how the use of the machines can prevent some of the physiological decomposition happening in microgravity.

### Treadmill T2

Ill. 14: Treadmill (Peacock, n. d.)

**Exercise focus:** Running

The treadmill T2 is used on ISS. To make it possible to run in space a harness west with bungee cords, is used to imitate gravity pull on the astronauts while running. They use hooks to adjust the amount of resistance they need from the bungee cords, when running (NASA Johnson, 2013).

**Analyzed physical impact:**
Prevents muscle loss, bone decomposition and maintain the cardiovascular system.

### Bicycle - CEVIS

Ill. 15: Bicycle (Keim, 2009)

**Exercise focus:** Aerobic and cardiovascular exercise

The '*Cycle Ergometer with Vibration Isolation and Stabilization System*' (CEVIS) used on ISS and is a part of the crewmembers weekly training. CEVIS is computer controlled and can maintain a very accurate workload suiting each individual crewmember. It has a mass of 26,8 kg. (Danish Aerospace Company, n.d.)

**Analyzed physical impact:**
Helps to prevent muscle loss and maintain the cardiovascular system.

### Advanced Restive Exercise Device (ARED)

Ill. 16: ARED (Johnson, 2017)

**Exercise focus:** Resistance exercise

'*The Advanced Restive Exercise Device*' (ARED) is on board the ISS. It is used for multiple weightlifting exercises like squats, deadlift etc. The 'ARED' also includes a cable making the user able to do cable exercise like curls, crunches, triceps extensions etc. The machine has a load range from 0 to 272 kg. (NASA Video, 2013)

**Analyzed physical impact:**
Helps to prevent muscle loss.

### The Miniature Exercise Device (MED-2)

Ill. 17: MED-2 (Zumbado, 2016)

**Exercise focus:** Aerobic and resistance exercise

'*The Miniature Exercise Device (MED-2)*' is a small compact training device for longer space journeys. MED-2 uses power for resistance training, while recharging itself when astronauts are doing an aerobic workout. Weighs only 30 kg and has a resistance range between 2-150 kg. (NASA, 2016)

**Analyzed physical impact:**
Helps to prevent muscle loss and maintain cardiovascular system.

Maintain the cardiovascular system

Help to prevent muscle loss

Help to prevent decomposition of bones

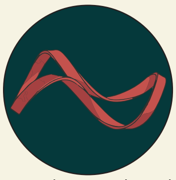
***Understanding the training done on the ISS to reduce physical decomposition of the astronauts, made it clear that some of the problems will occur on Mars as well. The impact will though be less vital, because of the Martian gravity. A gap is seen, due to only one exercise seems to have a direct impact on preventing bone loss.***

# 2.4 Principles

## Training principles

***The use of technologies and principles can contribute to more effective training. Several training principles has been investigated, to both understand what exists and what effect these gives, as well as be able to apply similar principles to the concept.***

### Resistance band



Ill. 18: Resistance band

Resistance band training is an effective training in space compared to free weight training, which only works in the vertical plane in combination with gravity. With resistance bands, the force is created in the direction in which the band is stretched - the elastic force. This means that bands make it possible to exercise both in horizontal and vertical planes but also in all other directions and angles, which is an advantage in space. (Set, 2019)

**Opportunity:** The flexibility of the resistance band and this independent training direction is especially useful in space. Elastics can advantageously also be implemented in the concept for Mars, even though a little gravity is present. It can be used both to pull the user downwards or as resistance to astronauts' primary training routine.

### Vibration board

Ill. 19: Vibrations

The use of vibration is already known and dates all the way back to the 1800s, where it was developed by Russian astronauts and Olympians in the 1960s and used to improve performance.

The vibration technique is already used in space to prevent bone loss and strengthen the muscles.

A vibration board stimulate a higher gravity force (or g-force) on the human body. This makes it necessary for the user to establish their balance which activates the muscles. (Admin, 2017)

**Opportunity:** Vibrations will also be an advantage to implement in the concept, as it contributes to building both muscle, bone and can act as a good addition to the current training in space.

### Occlusion training

Ill. 20: Occlusion

Occlusion training is also called '*blood flow restriction training*' (BFR), where the principle is to decrease the time, it takes to build muscle strength and size.

This is done by fastening a strap around the muscles, which makes the band block the veins and thereby increase the blood lactate concentration. Hereby, it is possible to get the same benefit as with high intensity training without the same effort. (Frothingham, 2020)

It is revealed that crewmembers on spaceflights who is performing daily high-intensity training return to Earth in a better physical shape than those who just train low-intensity training (Hckney, et al., 2012).

**Opportunity:** BFR training can be an advantage to use, and the simple bands can help optimizing e.g., astronauts training. In addition, this principle can also be an advantage to implement in concept development.

## Technologies

***Various technologies were investigated to gain an insight into which techniques and production principles will be possible to use for the concept. This project is based on the future, which gives uncertainties as to whether new technologies have matured for use. For this, the 'Table and Disruptive Technologies' (app. 2) is used to predict future technologies (other technologies can be found in app. 7).***

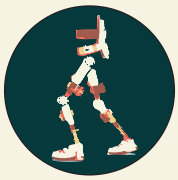
***Four technologies have been assessed to have potential for this project, as well as these are already in use and under development:***

Ill. 21: VR Glasses

### Virtual reality

'Fully Immersive Virtual Reality' gives the user a realistic simulation experience. It is a combination of seeing and hearing the environment but also having to interact with the simulation (Heizenrader, 2019). It is typically used for gaming and entertainment.

**Opportunity:**
Virtual reality could be used to make the concepts more entertaining.



Ill. 22: Exoskeleton

### Exoskeleton

An exoskeleton is an external skeleton that can help people overcome injuries or enhance their strength. The frame is worn outside the body and is powered by multiple motors. This technology could be used to help people regain strength or skills (Wakefield, 2018).

**Opportunity:**
A reversed edition of an exoskeleton could be used, to simulate the impact of Earth gravity.

Ill. 23: 3D printing

### 3D printing

3D printing could be the best way to manufacture things for Mars, because it will reduce the amount needed to be shipped from Earth. It can cost between 130,000 and 580,000 DKK per kg to ship cargo to Mars (Kramer & Mosher, 2016).

**Opportunity:**
By 3D printing on Mars, it becomes cheaper and easier to create a livable environment.

Ill. 24: Computerized clothing

### Computerized clothing

There is a huge opportunity to create a new generation of wear-able devices. By using conductive thread, it is possible to sow small electronics into clothing. It could be by adding small sensors, LED, and other electronics into the clothing. (Gella, 2016).

**Opportunity:**
Computerized clothing could be used to track peoples' health on Mars.

✔ Include vibration board

✔ Include occlusion band

✔ Track of progress and shape of the body

***These principles, in relation to both the production possibilities on Mars but also principles in relation to training, had to be further explored on whether they can be implemented in an overall concept. From this, several requirements were also set.***

# 2.5 Initiating Ideation

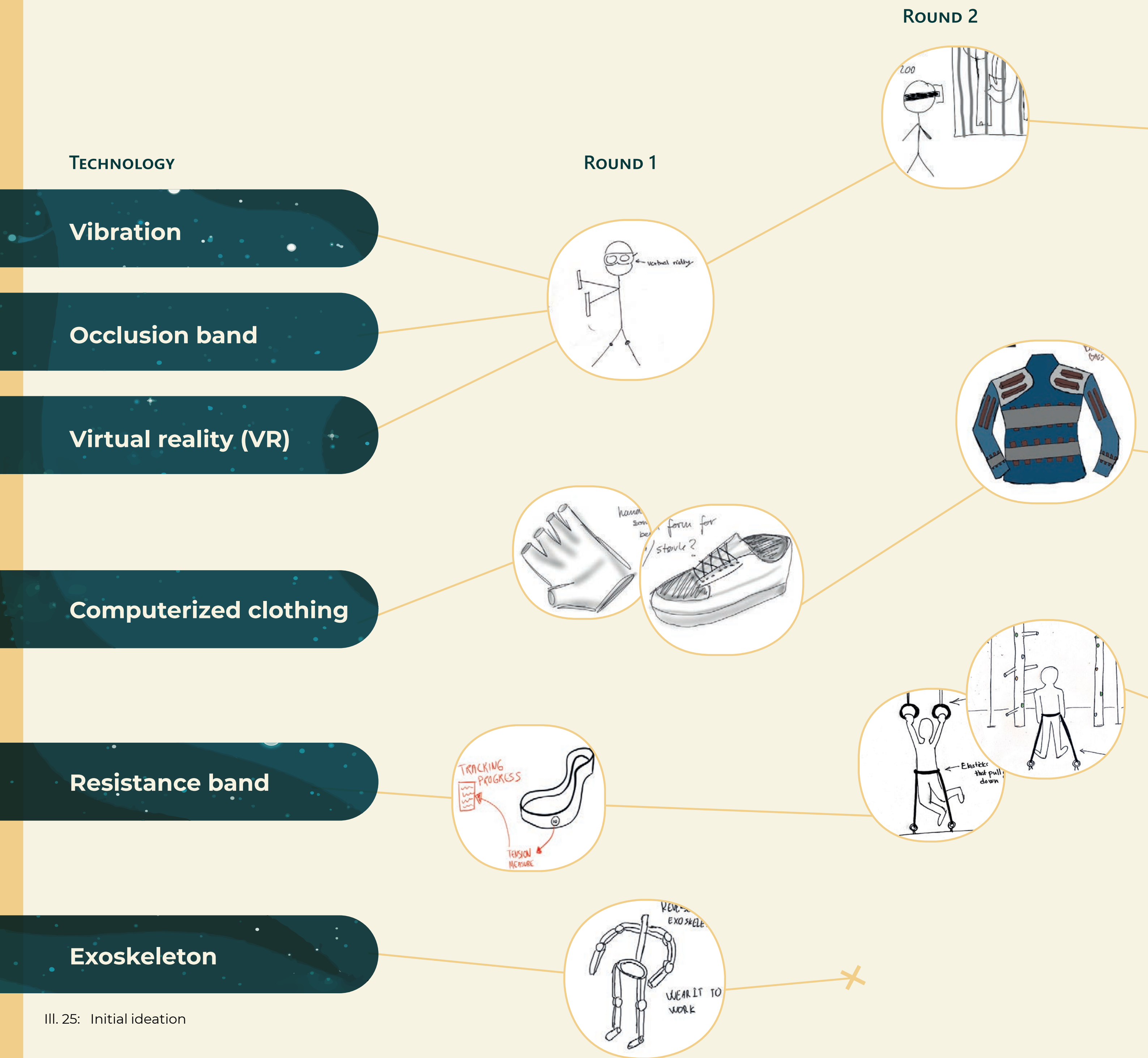
***Multiple sketching rounds for future colonization on Mars were made. These iterations occurred parallel with generating the timeline (p. 20-21), as well as an investigation in potential technologies. A selection of the sketches can be seen below, and the rest in app. 8-10. The approach for the ideation were based on Striim's ideation model (Striim, 2001).***

### ROUND 1: 4 SCENARIOS

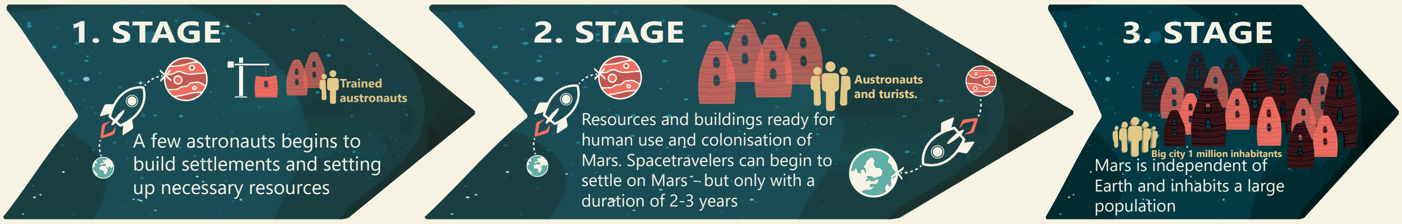
The first round of sketching was centred around Striims first phase of ideation: *Focusing* (Striim, 2001 pp. 49-62).

It was based on the division of colonization into 3 stages (ill. 26) plus the journey to Mars, which these concepts had to deal with (sketches and clustering in app. 8).

Based on short ideation for these stages, it was observed through clustering (Tollestrup, 2019), that the iterations were made mostly aiming at the second and third stage, which led to these stages being the starting point. Besides, investigated technologies were used for further iteration.




Ill. 25: Initial ideation




Ill. 26: Timeline stages

### Round 2: Association chain

With the ideation method '*Association Chain*' as a part of Striim's second phase of '*Idea Creation*' (Striim, 2001, pp. 49-62, 72-79), the next round of ideation focussed on the second and third stage of the timeline (ill. 26).
From here some interesting principles were pointed out (app. 9), and three directions were chosen for further ideation.

### Round 3: Three directions

For each of the three directions: VR, Weight suit, and reaction training an idea was developed to be used in a later *Brainpool* (Tollestrup, 2004, pp. 284-286).
The used training methods and technologies was investigated parallel (p. 24-25).

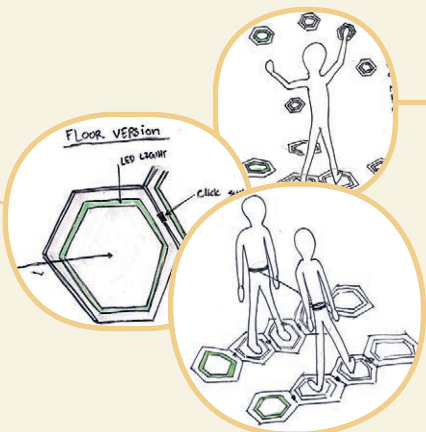
### Round 3

## VR

While running on a treadmill small shocks strengthens the user's bones while the use of occlusion bands will put pressure on the muscles.
On top of this VR takes the user to their favourite forest, mountain or road back home on Earth.


## Weight suit

A weight suit as a substitute for microgravity. In this way, an artificial force on muscles and bones which can be a substitution for the Earth-gravity's effect on the human body.
The suit can be computerized and track the body's condition as well.




## Reaction

A reaction game for motivation and learning to navigate under new gravity conditions.
With resistance bands, the load of the workout will not be affected by the changed gravity.

***The presented iterations occurred parallel with generating the timeline (p. 20-21), as well as an investigation in potential technologies. From this, three concept directions occurred: VR, Reaction training, and a weight suit. These three directions were investigated further.***

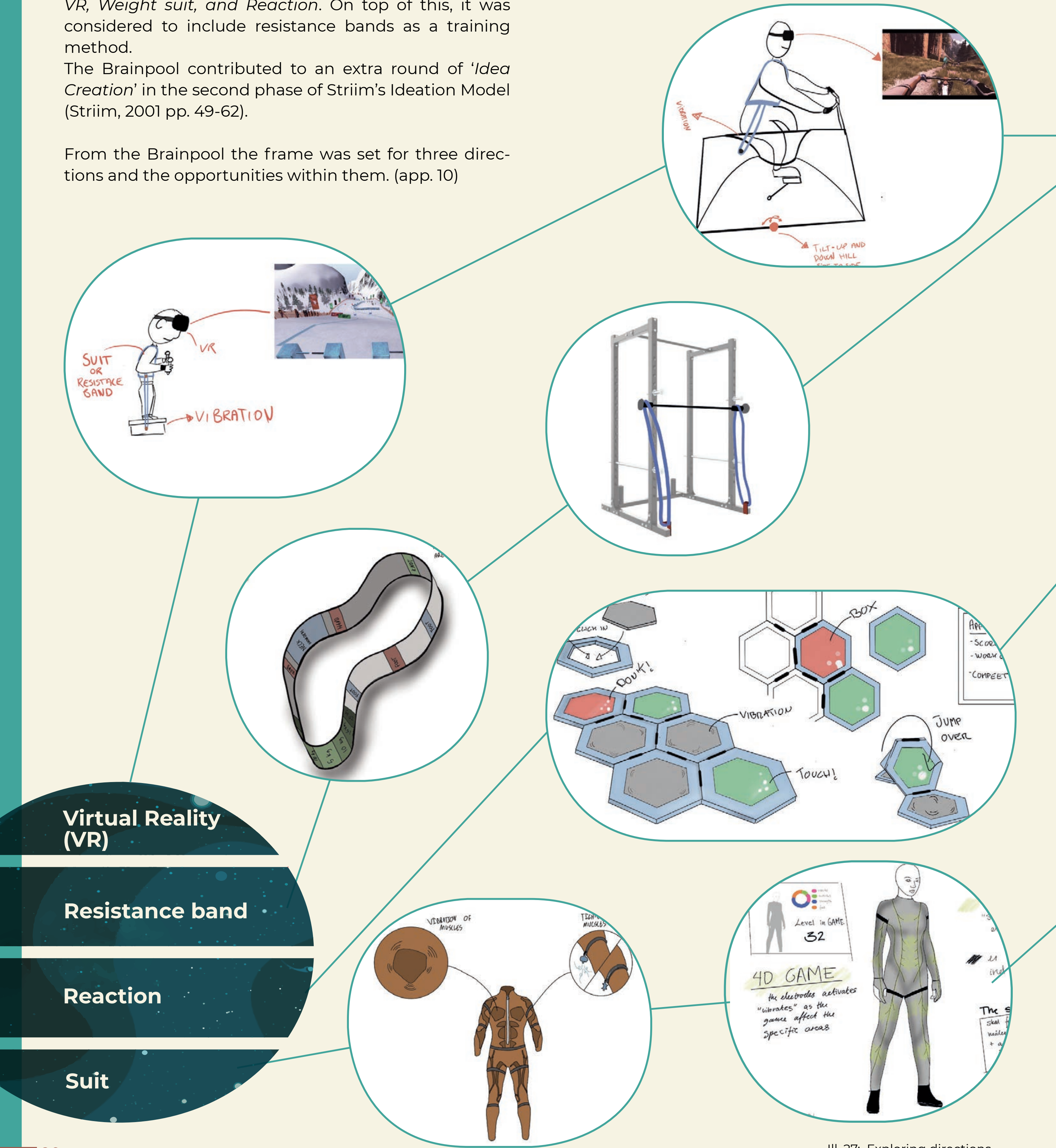
# 2.6 Exploring Directions

***The three concepts from previous ideation 1, was further explored to find opportunities within them (and can be seen in app. 10-11). In parallel with this iteration, several methods and technologies were investigated. The approach for ideation was continuously based on Striim's ideation model (Striim, 2001).***

### Brainpool

The three concepts in this round of iteration were based on a *Brainpool* (Tollestrup, 2004, pp. 284-286), including: *VR, Weight suit, and Reaction*. On top of this, it was considered to include resistance bands as a training method.
The Brainpool contributed to an extra round of '*Idea Creation*' in the second phase of Striim's Ideation Model (Striim, 2001 pp. 49-62).

From the Brainpool the frame was set for three directions and the opportunities within them. (app. 10)




Ill. 27: Exploring directions

## Three Concepts

Three frames were set to develop three concepts. This was done by *Combinatoric* used in the Summery phase of Striim's ideation model, a transition phase to Idea development (Striim, 2001, pp. 49-62).

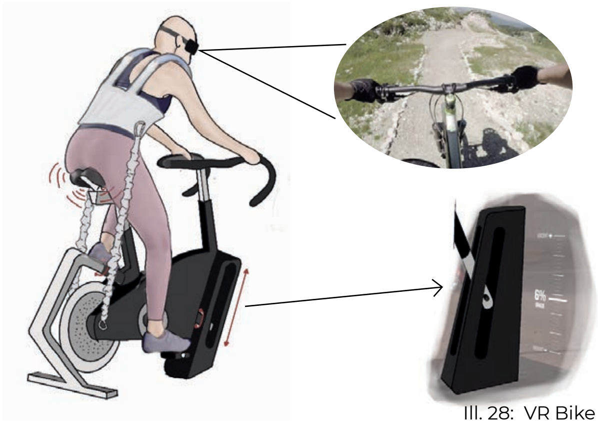
The concepts were presented at Milestone 2 for feedback. For each concept core values and technologies was noted. See an elaborated walkthrough of the concepts in app. 11.

### VR Bike

With VR glasses and a vibrating bike, it will feel like driving through a forest. The bike will have a balance and elevation element to strengthen the experience.

**Core values**
- Playful
- Connection to Earth
- 4D Experience

**Technology**
- VR glasses
- Vibrations
- Harness west
- Elevation element

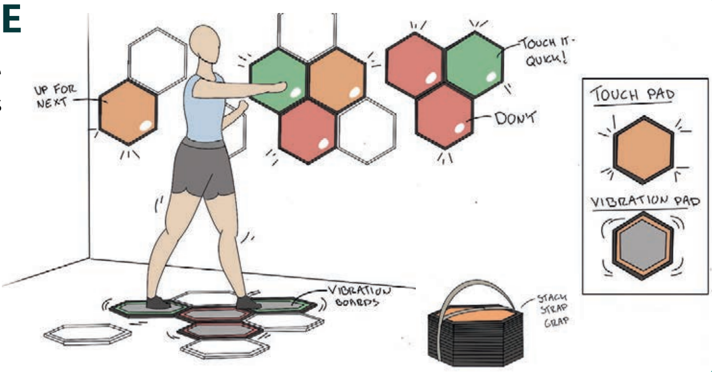

Ill. 28: VR Bike

### Hexagonal Reaction Game

Collect the Hexagon plates as you like. The shape gives endless possibilities. When something lights green, you need to tap it.

**Core values**
- Playful
- Transportable
- A smaller product
- Expandable

**Technology**
- Vibration boards
- Possibility: Occlusion bands
- Possibility: Interactive touch screens



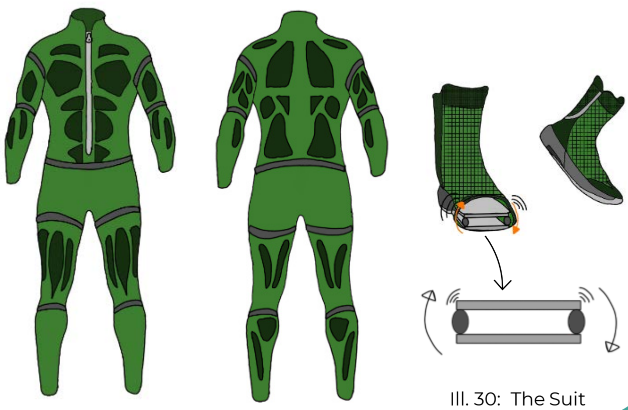
Ill. 29: Reaction Game

### The Suite

The suit works by tracking the user's body condition through a workout. At the same time, it adds extra value to the workout with vibrations and occlusion.

**Core values**
- Body tracking
- Can be used at any training session

**Technology**
- Computerized clothing
- Vibration shoes
- Occlusion bands


Ill. 30: The Suit

***The three specified concepts each had interesting elements and challenges. They fitted into different points in the timeline and different scenarios. To evaluate the concepts and choose a direction, the framing of the stages in the timeline, and daily scenario for the users needed to be clarified.***

# 2.7 Revised Design brief

***In the end of the second phase, Define, the framing and direction for the project became clearer, which is why the design brief and requirements were revised. The problem and vision were redefined while the Core Design Framework method were used to point out center of attention (Rosenstand & Vistisen 2017).***

## Problem definition

"How to design a product that physically activates people on Mars, as a supplement to the obligatory training?"

## Vision

Encourage people to be motivated to stay healthy.

## Value Alignment


Ill. 31: Core Design Framework (Rosenstand & Vistisen 2017)

## Target Requirements

The requirements for the product proposal are presented by the method of *Ulrich and Eppinger* (Ulrich & Eppinger, 2000), and are rated from 6-1* according to *Core Design Framework* (app. 12). With inspiration from *Steen Agger's need graduation* (Agger, 1984) the rating 6-4 as *needs* that must be fulfilled and rating 3-1 is considered as *wishes* to strive for.

| Need no. | Metric | Unit | Value | Imp. | Source |
|---|---|---|---|---|---|
| 1 | Maintaining the physical health | - | Binary | 6 | 1.1 |
| 2 | Must work with Martian gravity | $m/s^2$ | 3,711 | 6 | 1.1 |
| 3 | Indoor use | - | Binary | 6 | 1.1 , 2.2 |
| 4 | Release endorphins | - | Binary | 2 | 1.3 |
| 5 | Acknowledgment by overcoming challenges | - | Binary | 1 | 1.3 |
| 6 | Include social elements *(competition and community)* | - | Binary | 1 | 1.3 |
| 7 | Installation on: Floor or rounded wall | - | Binary | 6 | 2.2 |
| 8 | Indoor space | $m^2$<br>m *(h)*<br>° *(slope)* | 18<br>1,6<br>75 | 6 | 2.2 |
| 9 | Help to prevent muscle loss | - | Binary | 6 | 2.3 |
| 10 | Help to prevent decomposition of bones | - | Binary | 6 | 2.3 |
| 11 | Help to maintain the cardiovascular system | - | Binary | 3 | 2.3 |
| 12 | Include vibration board | - | Binary | 6 | 2.3 |
| 13 | Include occlusion band | - | Binary | 3 | 2.3 |
| 14 | Track of progress | - | Binary | 1 | 2.3 |
| 15 | Track of shape of the body | - | Binary | 1 | 2.3 |

*6 = highest rating,
1 = lowest rating

# 2.8 Milestone 2

The feedback at Milestone 2 centered around the realism of the three presented concepts (p. 29). There needed to be more precision to the requirements, more numbers. At the same time, it was asked for a parallel to rehabilitation training.

There was an overall confusion about the physical benefits of the concepts, and exactly what the focus was. The confusion occurred because the three concepts wanted too much and did not relate enough to the chosen context. Additionally, the framing of the physical benefits of the concepts was not clear. However, something interesting was seen in the concept: *Hexagonal Reaction Training*.

Until Milestone 2 the concept development centered around being a supplement to the obligatory training, something that the astronauts and space travelers could use in their leisure time. A greater potential was seen in a product used as an addition to the obligatory training, which would set up a different use-case. Here an interesting challenge could be how to maintain motivation and make a part of the obligatory training fun.

Ill. 32: Context: Mars, 2060s

# 2.9 Sum-Up

## Acquired knowledge

- Context: 2060s where 25000 people live on Mars for 2-3 years at a time
- The Marsha House's room for *Recreation & exercise*, where the product development will be centered
- Being in space results in 1-2 % Bone loss per month and decrements of muscle atrophy as well
- Occlusion bands, resistance bands, and vibration boards can benefit workouts in space
- Virtual Reality, reversed exoskeleton, 3D printing, and computerized clothing are interesting technologies that could benefit the concept

## Further course

- **Evaluation of the three concepts**
- **Clear direction: Who are the users? What benefits should they have from using the product?**
- **Product development from a clear direction**
- **Precision of Requirements**

PHASE **3.0** DEVELOP

# STAYING IN BALANCE

The third section covers the development phase. In the development phase, the target users of the product will be defined to create a more specific frame for the product.

This will include a deeper look into the health problems of microgravity and the development of a concept that can help prevent it.

Ill. 33: Develop (Jooinn, n.d.)

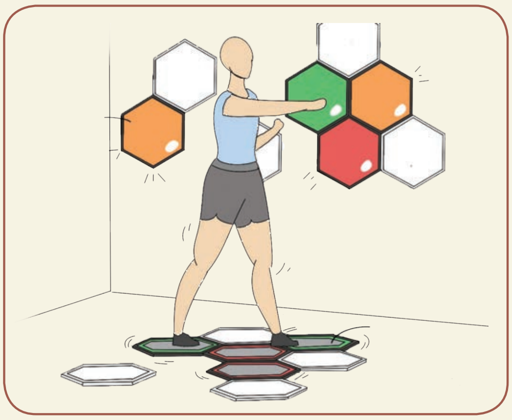
# 3.1 Evaluation of concepts

***It was necessary to create an overview to choose a concept direction for further ideation and development (Striim, 2001, pp. 49-62). Three concepts were assessed based on SWOT analysis (Iværkst, 2018), gain from benefits, but also assessed based on the ranked requirements (Ulrich and Eppinger, 2012).***

### Concept 1: The Suit

Ill. 34: The Suit

### Concept 2: Hexo Game



Ill. 35: Hexo game

### Concept 3: Mars Bike

Ill. 36: Mars Bike

## SWOT

To evaluate the concepts a SWOT analysis was set up (app. 13). It was observed that:

### Concept 1

Concept 1 had possibilities and strengths both since it had the Mars factor and is in the Blue Ocean Market with computerized clothing technology.
Besides, the suit enables feedback and tracking, and is suitable for gaming, however, the suit would be an "*accessory*".

### Concept 2

Concept 2 had the desired playful element, as well as an option to customize and vary to different levels. The possibility to expand the game with other accessories are present, such as resistance- and occlusion bands.
The challenge of whether the game would get boring over time, needed to be investigated.

### Concept 3

Concept 3 was designed as an already known exercise. The possibilities here were looking into the VR universe and how a 4D feeling can be delivered through vibration and movement of the bike to suit the terrain.
Like concept 2, the concern was to whether it would become boring over time, or it would only appeal to a specific user group. Besides, the concept of an exercise bike is already well-known and used form of training on the ISS.

## Gain from Benefits

The SWOT analysis gave no clear direction but led to a further investigation into concepts 2 and 3. While looking at the possibilities of the concepts and whether there were any overlooked opportunities, the concepts was compared to the form of training that they should strive for.

Concept 3 focused on cardio training, while concept 2 had elements of balance and creates a playful exercise (app. 14).

## Requirements Assessment

The three concepts were further assessed and ranked based on the generated '*Target Requirements*' (p. 30) (Ulrich and Eppinger, 2012). This method was combined with the '*Core Design Framework*' which uses a point system to rate the concepts.

From the rating concept 2 won, however, it was very close in terms of points. Thus, there were also generated some patterns and criteria which can be used for further development (app. 15).

### Choice

Concept 2 was chosen for further development, but with an ongoing uncertainty. It needed to be clear whether the concept could fit into the obligatory training and if the balance and reaction training makes sense to do on Mars. There were also uncertainties about how the concept would be affected by the microgravity on Mars.

***Based on the evaluation of the three concepts, concept 2 was chosen. From here, concept 2 must be further developed. Additionally, more research is needed to confirm or deny, doubts about the effect microgravity has on the function of the concept and if the exercise can work as a substitute for the obligational training.***

# 3.2 Martians daily routine

***To understand when, what and who, in connection to the chosen timeframe (timeline; stage 2 – p. 27, ill. 26), an understanding of the everyday life on ISS was investigated and framed around a target group. To do this a primary and secondary persona were used (Brown, 2020). This was to determine a clearer direction and requirements for the concept. A more detailed version and background sources of the following is found in app. 16.***

## Primary Persona: Karsten Iversen

| | |
|---|---|
| **Age:** | 41 years old |
| **Home:** | Svenborg, Denmark, Earth |
| **Current Residence:** | Marsha on Mars |
| **Occupation:** | Geologist |
| **Family:** | Wife, a boy & Girl (11-13 years old) |
| **Hobbies:** | Padel tennis, Fantasy Football, Reading |
| **Training for Mars:** | 6 months (estimated (app. 16)) |

Ill. 37: Karsten (Wagner, n.d.)

**Biography:**

Karsten works as a geologist on Mars and has been staying there for 21 months. Besides work, Karsten spends a lot of his time, making daily video messages to his family, to stay connected. He misses his family a lot, and tries to compensate for that, by playing *Fantasy-Football* with his son, which is possible even with the long distance.

Furthermore, he misses playing paddle tennis with his friends. This hobby allowed him to be social and have fun in a playful and competitive manner. Competitive games have always existed him, whereas the workout session on Mars bores him.

## Secondary Persona: Christina Hammock Koch

| | |
|---|---|
| **Age:** | 42 years old |
| **Home:** | Houston, Texas, Earth |
| **Current Residence:** | MARSHA on Mars |
| **Occupation:** | NASA astronaut |
| **Family:** | Husband and a girl (10 years) |
| **Hobbies:** | Backpacking, running, yoga and traveling |
| **Training for Mars:** | 2 Years NASA astronaut candidate training (Potter, 2020) |

Ill. 38: Christina (Tonnessen, 2020)

**Biography:**

Christina has a Master of Science in Electrical Engineering. She became a NASA astronaut of class 2013 (Tonnessen, 2020). Christina knows the importance of staying in touch with her husband and parents is good for her mental well-being as she has been in space before. She likes to run in her leisure time on Mars because she knows how essential it is to stay in shape. She is also very self-aware, which is why she likes to challenge herself both physically and mentally.

## Daily rutine

The following daily timeframe on Mars is set up according to the personas and is based on the daily routine of astronauts living on the ISS (WS 16) (Schouboe, 2020).

**7.00**
Alarm wake Karsten & Christina.

**7.05**
Toilet visit and personal hygiene.

**7.15**
Breakfast.

**8.00 - 9.30**
1.5 hours are set aside for morning exercise. Here Karsten & Christina is using the strength training machine.

**9.35**
Personal hygiene & gets ready for work.

**10.30**
They go to work.

**17.00**
Off work.

**17.15**
Preparing dinner and eat.

**18.00 - 19.00**
1 hour for evening exercise. Here Karsten & Christina is using the fitness bike or a treadmill.

**19.00**
Personal hygiene (bath) and health are checked.

**19.30**
Leisure time (e.g. checking e-mails & contact to earth).

**21.30**
Pre-sleep, using dimmed blue light to relax before sleep.

**Rest** Sleep

Ill. 39: Daily Rutine

- Duration: 10-30 min.
- Cross-Generational (10-60 years)
- Competing element
- Body monitoring

***Given the personas, it was set that the product development must reach both space travelers and astronauts. Comparing the uses to concept 2, it is framed to work within the afternoon cardio training of their daily routine (marked in yellow ill. 39).***

# 3.3 Locomotion in hypergravity

***With the choice of concept 2, more research on the effects on the body was needed. The following contains information about the locomotor system, vestibular system, how they are affected, and what can be done to prevent the consequences of being in space does to these human systems.***

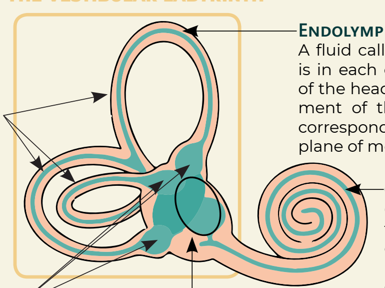
FACT

### The Locomotor system

The musculoskeletal system or locomotor system consists of *the skeletal muscles, tendons, skeleton, joints, ligaments, and connective tissue*. This system provides us *support, shape, stability, and movement*. (Better Health Channel, 2020; Sendic, 2021)

### The vestibular system

The vestibular system is a sensory system responsible for providing our brain with information about the head position, spatial orientation, and motion. This is responsible for u*pholding balance, stabilizing the body and head during movements, while maintaining posture*.
The vestibular system's main components are found in the inner ear and consist of interconnected compartments together called the vestibular labyrinth (ill. 40) (Neuroscientifically Challenged, 2015; Neuroscientifically Challenged, n.d.).




Ill. 40: The vestibular system

## Effects on the systems

Previous spaceflights revealed that astronauts suffer from problems related to the locomotor system, as experiencing *changes in tendon elasticity, muscle atrophy, and altered neural control of posture and movement, as well as a loss of muscle and bone tissue* (app. 17). A problem that is exacerbated, when landing after a long space flight.

The sudden transition from weightlessness to gravity on Mars can lead to lethal problems. Due to reduced *control of movements, posture, or muscle weakness.* Simple injuries will be problematic to treat with limited or non-medical assistance on Mars (Lacquaniti, et al., 2017).

Research on prolonged bed rest shows that reduced effects of gravity on movements results in reduced motor performance (Lacquaniti, et al., 2017). Two studies found, explains how exercise during bed rest can prevent deconditioning of *the skeletal, cardiovascular and muscular system* (Mathews, et al, 2007; Kramer, et al., 2017) (read more in app. 19).

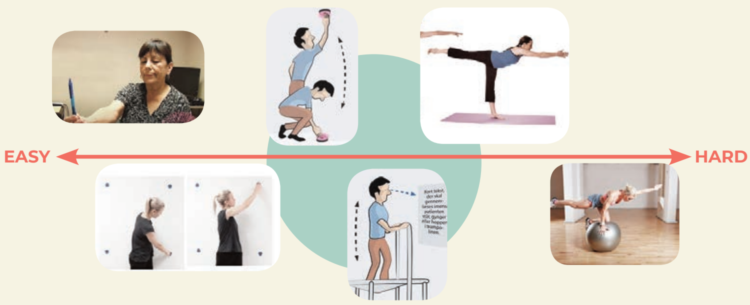
Today the current countermeasure in space is daily exercise, especially running on a treadmill (p. 24, ill. 14-17). This only prevents motor problems limited (Lacquaniti, et al., 2017). One reason for this is the lack of training of the vestibular system, that controls the balance.

To stimulate the effects of reduced gravity on all physiological systems in training, before space missions, is challenging. An Apollo crew mainly trained in the '*Lunar Landing Training Vehicle*', which cannot simulate the effect 0,16 G on the Moon has on the vestibular system. This led to most of the astronauts feeling 'wobbly' stepping onto the lunar surface. On the ISS the gravity replacement systems used for exercise, do not include exercise of the vestibular system. (Lacquaniti, et al., 2017)

## Training: Vestibular system

To counteract the dizziness and balance problems related to the locomotor- and vestibular system while space traveling, research of balance training was done. Ill. 41 lists pictures of exercises from easy to hard. The green circle shows which spectrum the concept should aim at.

Research shows three parameters are used to train the vestibular system (app. 18): *Eye-hand (body) coordination, balance, and posture.*




Ill. 41: Scale of difficulty (House Institute, 2015) (AUH, 2020) (Fysioterapeuten, 2019) (Pinimg, n.d.)(Arndal, 2013)

✔ Focus on Eye-Hand coordination
✔ Adjustable for different loco-motor systems
✔ Challange the balance

***Training of the locomotor systems requires training of the vestibular system. Hand-eye-coordination and balance are one of the key training methods. Conclusively a spectrum defining the difficulty was set for a wide span in the target group.***

# 3.4 Challenge the Concept

***With a starting point in concept 2 (p. 34), the gained knowledge about personas, the locomotor- and vestibular systems an ideation was made. The concept was challenged to explore the best solution, within phase three and four of Striim's ideation model (Striim, 2001 pp. 49-62).***

## Round 1: Sketching

The first round centred around Striim's fourth phase: *idea generation* (Striim, 2001 pp. 49-62), and based upon being a part of the obligational training. The solutions were divided into two possibilities (see below) (app. 20).

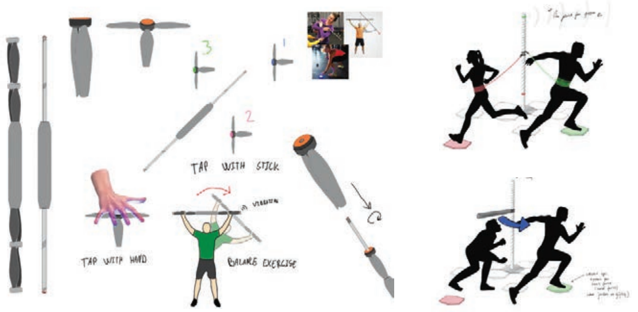
## Round 2: Testing

The testing was focused on evaluating the possibilities based on user feedback in Striim's fourth phase, to narrow down to one concept. Find the tests in app. 21.

### Spots and Stick

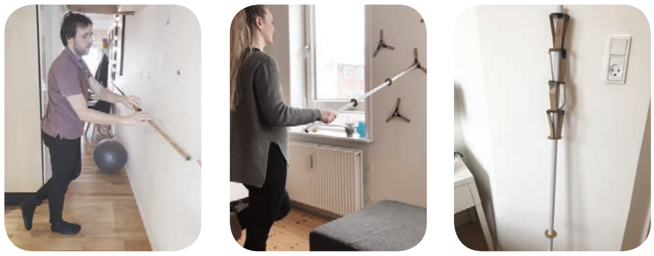
#### Sketching

Includes an interactive stick with a motion sensor, where the spots are mounted on. Spots are placeable on the wall and the floor. The stick can also be attached vertically to the floor and can count the score.



Ill. 42: Spots and stick

#### Testing



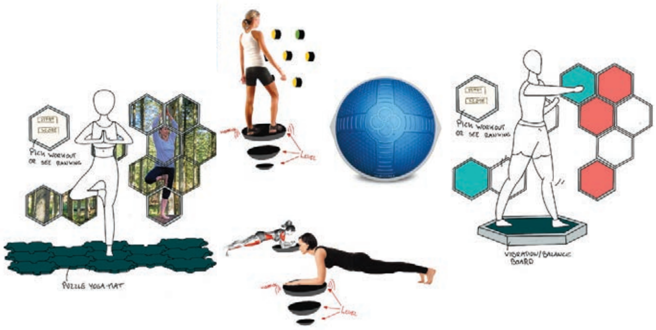
Ill. 43: Spots and stick, test

- Easy to reach the spots with the stick.
- It does not require much movement in the body (only shoulders and upper body).
- Difficult to regain balance if lost, because your hands are locked on the stick.
- Lesser eye-hand coordination.
- The spots must be bigger to hit with the stick.
- The tested stick was too light.

### Spots and Board

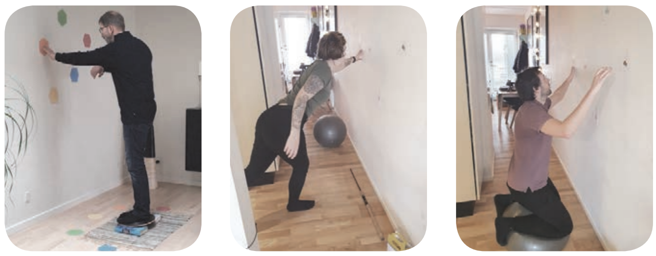
#### Sketching

Single board or modular floorboard including balance and vibration training. Universal spots placeable on the wall and the floor. Screen to shows the score. Possible multi-player function, and different game modes.



Ill. 44: Spots and board

#### Testing



Ill. 45: Spots and board, test

- Big movements in the body (upper body, legs, etc.).
- Micro adjustments in ankle muscles to keep balance.
- Combination of balance board and eye-hand coordination is challenging.
- Good with the non-slip surface on balance board. !
- Benefits from increasement in levels. !
- The user got warm by doing the exercise.
- Liked tapping the buttons – physical feedback.

✗ Include occlusion band

✓ Non-slip surface (board)

✓ Spots on wall and floor

✓ Track of progress

***Considering, that the concept should challenge eye-hand coordination and balance while increasing the pulse, the possibility 'spots and board', was chosen to explore further. This removed the requirement for occlusion band.***

# 3.5 Zoom in: Board

***The challenge of the concept (app. 20, 21) resulted in a concept including a board that challenges the balance and at the same time gives benefits of vibrations. Therefore, an investigation of construction and function possibilities of balance- and vibration boards was made, to specify a solution that could combine these two.***

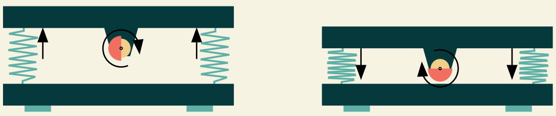
## Vibration Element

### Board structure

The vibration board's structure must consist of four elements (app. 22):

**1)** A top plate: the plate the user stands on.
**2)** Equal suspension of the board
**3)** A bottom plate
**4)** A DC motor that makes the top board vibrate.

The motor needs to be fastened on the top plate, making the vibrations go directly to the user standing on it (Vibration Therapeutic® 2020).



Ill. 46: Vibration board structure

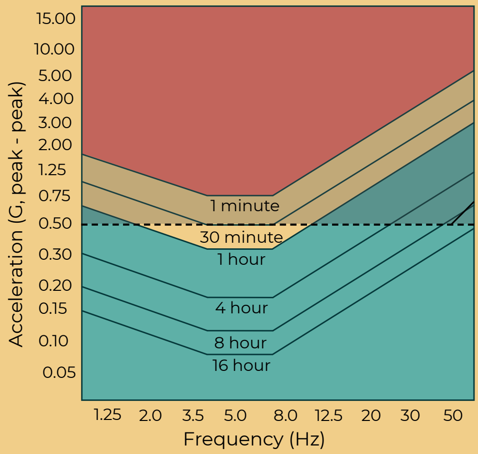
### Vertical vibrations

Suspension is needed to absorb the vibration of the top plate, making sure that the board does not jump on the floor and that the vibrations will only create vertical movement. The Motor needs to be a DC motor with an eccentric block (ERM motor), with enough power to vibrate the weight of the user (app. 22).

FACT

### Vibration Level

The vibration of the board is a vital factor because it creates a force on the users' body that acts as the gravitational force. The force of vibrations the user can receive, without it going from a benefit to being harmful, is explained by the ISO-2631 guidelines (Muir, Kiel, et al. 2013). By setting a timeframe for the exercise, a maximum acceleration force can be set (Illu. 47).




Ill. 47: ISO-2631, Vibration level (Muir, Kiel, et al. 2013)

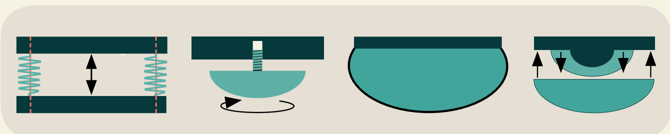
Maximum acc. force: 0.5 G

Motor type: ERM motor

## Balance Element

The *construction, shape, interaction surface, size, and tilt function* of the balance board were investigated. The most common shape of a balance board is round. This contributes to the use-case because of the tilting point making it tilt an equal amount in all directions (app. 23, 24).

Besides, the size and surface were tested. The size is set for the user to be able to make small adjustments (app. 24). The surface had different results depending on the use-case, but common was that it needs to be anti-slippery (app. 23).
It was also investigated how to make the tilt function scalable in level (ill.48) (app. 23).



Ill. 48: Balance element

Diameter 45-50 cm

Non-slip surface

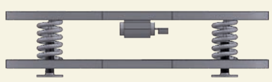
Include inflatable balance-pillow

***With the use of Tjalve's 'Struktur-variationmetode' (Tjalve, 1976) two concepts of the board were made which will be brought on to further development (app. 25).***

***Concept 1's (ill. 49) principles rely on two plates, connected by four springs with wires running through, making it able to be tightened or loosened to change the level of balance (app. 22).***

***Concept 2's principles are taken from the know 'BOSU® NEXGEN™ HOME BALANCE TRAINER' (BOSU, 2020) with the possibility of changing the air pressure, making the level of balance scalable, while including the vibration in the top board (app. 25).***

### Concept 1



Ill. 49: Tjalve 1

### Concept 2

Ill. 50: Tjalve 2

# 3.6 Zoom in: Spots

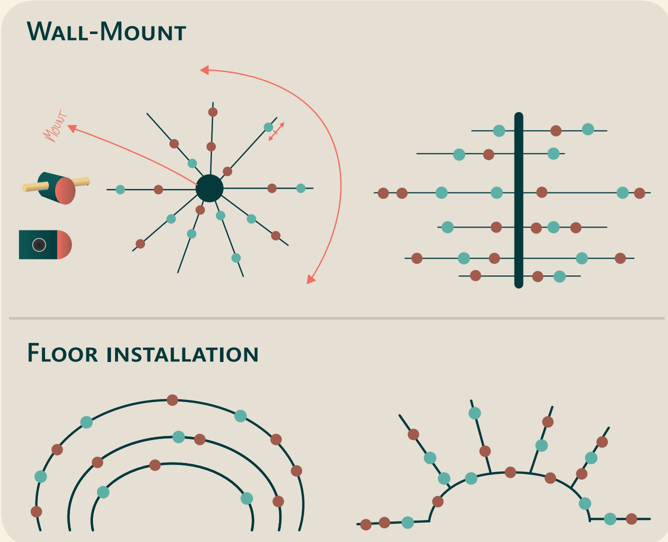
***One of the main questions about the spots was how to mount them on the wall. Different proposals for this were made, in addition to testing the right size, softness, quantity, and reachability.***

## Mounting

To find the best way to mount the spots on the wall, some reference products were found, which makes mounting and demounting easy. In these products, there was used magnets, suction cups, and double-sided adhesive tape (app 26).
The mounting of the spots needs to fit on the walls in Marsha house (p. 22).

Due to missing knowledge about the material and surface of the inner walls in Marsha house, it was chosen to work with one mount, that contains multiple spots which can be moved around.

Some possibilities within a mounting were found, either as a wall-mount or floor installation (ill. 51).




Ill. 51: Mounting

## Testing

To set up some requirements for the spots, tests were made. This was to discover *how big the spots need to be if the material/softness has a meaning, how many spots are needed, and how wide the reachability should be.*
The tests were set up with spots made of cardboard put up on a wall (ill. 52) (app. 27).

### Size

Spots with a diameter from 3-9 cm were tested (ill. 52, pic 1). 3-5 cm felt too small to push on the wall, and 8-9 too easy to hit.

### Surface

The surface was tested by adding different materials on the spots (ill. 52, pic. 2). It was discovered that the game element was the most fun when the touch gave feedback, and the user could feel they pushed something (ill. 52, pic. 5).

### Quantity of spots and Reachability

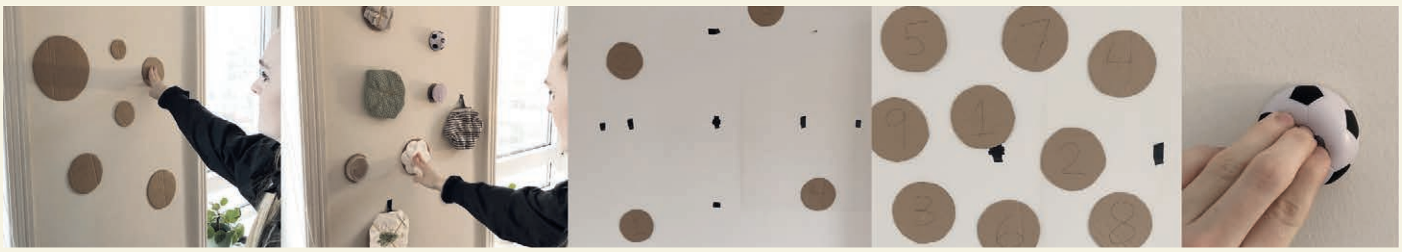
A combined test was made to find the best reachability and quantity of spots. This with 4, 6, and 9 spots placed within a circle with diameters of 60, 100 and 170 cm (ill. 52, pic. 3+4) (app. 27).

With the spots placed close together, it was easy and fast to hit the right one. The medium circle (100 cm) challenged it a bit more, and the widest one (170 cm) was the hardest. At the same time, the pulse on the users raised when testing the widest circle, and they made a lot of twists in the upper body. These facts contribute to fulfilling the requirements for the workout.

The number of spots also had a big impact on the difficulty. The more spots, the harder - but this also resulted in slower movement towards the spot and more mistakes were made.

- ✔ Functional feedback (spots)
- ✔ Spots on a wall mount
- ✔ Size of Spots: 6-7 cm
- ✔ Reachability (spots): 120-170 cm (d)
- ✔ 6-9 Spots

Ill. 52: Testing spots



***It was found that the spots must be fastened on a mounting, because of too many unknowns about the wall material and surface. This investigation led to some new requirements in connection to the spots.***

# 3.7 Clarification

***Parallel to the development of the concept some uncertainties were spotted and needed clarification. This was iterated parallel with interviewing Thomas A. E. Andersen, from the Danish Aerospace Centre (DAC). The interview clarifies aspects of benefits, possibilities, and uncertainties within the project (app. 28).***

## Summary of interview

### Balance and Coordination

Thomas from DAC firstly clarified the importance of stimulating the mental psyche and the vestibular system (page 14, 23, and 36). One thing Thomas was certain about was that exercise on Mars is possible: "*If you can get your heart rate up on Earth, then you can also get your heart rate up on Mars, but it may take a little more work.*"

He confirmed that the ability to coordinate and balance is reduced after being in space. As seen today the astronauts only have regular weightlifting equipment, which only stimulates the big muscles. Equipment that makes your body twist, for training small muscles is missing. (Training of small muscles increases balance.)

He also confirmed that a vibration board is a good supplement for the current form of training, but that it cannot replace the other exercise forms. Whereas the balance board would not work properly on Mars, caused by the low gravity.

### Movement on Mars

He explained that you would walk slower on Mars, and therefore, attaching the user to the board would be beneficial to compensate the 1/3 gravitational pull-down. He also described how relational movements in the arms would perform the same as on Earth (if you are in a regular atmosphere). As he said: "*Arm movements will be the same whether it is on Mars or Earth as these are bothered by the muscles.*"

### Motivation to Exercise

One element he enlightened was the motivation factor: "*If you are going to travel to Mars in 7-8 months, you may get tired of running or cycling, where it is nice to be able to vary the form of exercise or combine it with an entertaining element,*" he stated and referred to astronauts that trained lesser because of lack of motivation. He pointed out two aspects of motivation: Doing different kinds of exercises or the visual and/or competing element while doing it (app. 28).

## Clarifications

### Product Try-Out

A test on both a BOSU ball and vibration board was done separately. The test showed that both products were highly difficult to balance on and that vibration seemed to be enough (app. 29). This led to three worries about the combination:

- Is it overly challenging?
- Will the board become too big?
- Are the floor-spots suitable with the board?

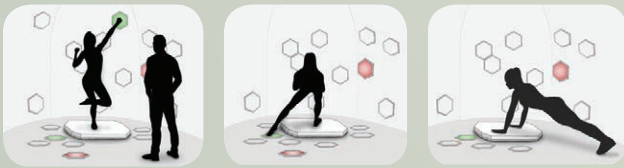
Ill. 53: BOSU Balll (Fitshop.dk, n.d.)

Ill. 54: Vibration Board

### Mapping of Possibilities

Parallel to the interview with Thomas, the group tried to identify different scenarios of use for the concept (app. 30). It was figured out that:

**1)** The concept needed a precise purpose
**2)** Based upon the interview (legs moving slower), the spots on the floor do not make sense.



Ill. 55: Use cases

### New board size test

Based on removing the balance ball and floor spots, the board size was reconsidered. Research on vibrations boards and a new test set new dimensions for the board and made a wish for its height (app. 31).

Ill. 56: Board size


~~Spots on wall and floor~~ ✗

~~Include inflatable balance-pillow~~ ✗

✓ Hight on board: H: 13-17 cm

✓ Board dimensions: L: 52-57 cm, W: 32-37 cm

✓ The user must be attached to the board.

***The interview with Thomas A. E. Andersen, cleared out some uncertainties which lead to removing the spots on the floor and balance board. Further, it became clear that balance exercise was missing on missions to space today.***

# 3.8 Direction for Semantics

***With the methods of 4 pleasures and 6 factors for happiness, a direction for the semantics of the product was set. These were linked to the personas (p. 35), by taking a step back and set requirements in terms of identity, product benefits, and relevant visual, additive, and tactile messages within the concept.***

## 4 Pleasures

The method '*4 Pleasures*' was used to identify the users' expectations (Jordan, 1997, pp. 249-252). Jordans '*4 Pleasure Framework*' helps to clarify what users find attractive within products (*product benefits*).

### 1) Physiological pleasure

*What we sense: smells, feels, hears and tastes.*

**The concept must:**
- Sound like a supporting audience.
- Feel like making the perfect smash in tennis
- Look like a big red tempting button.

**Product benefits:**
- Argument feedforward: Spots light up
- Functional feedback: Spots change color/turns of when hit
- Functional feedback: sound = overcoming a challenge

### 3) Psychological pleasure

*The cognitive - how the product can affect the cognitive properties.*

**The concept must:**
- Include overcoming a tasks
- Challenge in keeping focus
- Have high Usability

**Product benefits:**
- Higher level as you improve
- Tracking of improvement !
- Training body control
- Learning by doing !

### 2) Social Pleasure

*The social relationship - The "belonging" of a special group.*

**The concept must:**
- Create a feeling of being together with someone
- Create a feeling of being home, on Earth
- Be a part of the Martian Community

**Product benefits:**
- The possibility of tow-player exercise
- Compare high scores with players on Earth !
- Familiarity with thing you would use on Earth

### 4) Ideological pleasure

*Ideals/values - the connection of values and ideals in a product.*

**The concept must:**
- Radiate of being a fun exercise
- Radiate of being an effectful exercise
- Motivate to exercise

**Product benefits:**
- Multiple use cases
- Be mindful
- Be competitive

✔ Facilitate learning by doing

✔ Connect to Earth through places or persons

## 6 Factors of Happiness

To understand the schematics of the design language in comparison to the personas, the tool '*6 factors of happiness*' was used (Demirbilek and Sener, 2003, pp. 1346-1360). Herby the most relevant *haptic, auditive and visual messages* were identified. The chosen factors are marked below.

From the chosen factors to put a focus on in the development it was seen that the product could:

- Provoke competitiveness and fast eye-hand coordination by the spots changing colours.
- Be familiar by making the aesthetics have a retro space vibe relatable to the Stormtroopers from StarWars (style board in app. 32).

!

| | | |
|---|---|---|
| **Senses**<br>Hear (clicking sound, open a lid etc.), See (style, design ect.), feel (feedback and tactility), smell (choice of material) | **FUN**<br>'Humanized' products. Something funny, friend, and/or warm. Can open for a dialog – without a purpose. | **CUTENESS**<br>Using reference to animal and faces – can often evoke 'happiness' and a feeling of protection |
| **Familiarity**<br>Common references are used to place the product in a category. Must build on prior knowledge of users. | **METONYMY - SENSE & FUNCTION**<br>Reference trough something attractive by association into something spiritual, exclusive, or other. The story comes before the product. | **COLORS**<br>Can tranquilizing or amplify emotions, indicate use, personalize, guide for use as well as provoke or down tone functions. |

Ill. 57: 6 Factors of Happiness (Demirbilek and Sener, 2003, pp. 1346-1360)

✔ Esthetics with a *retro space vibe*

✔ Inhereted feedback when hitting a spot

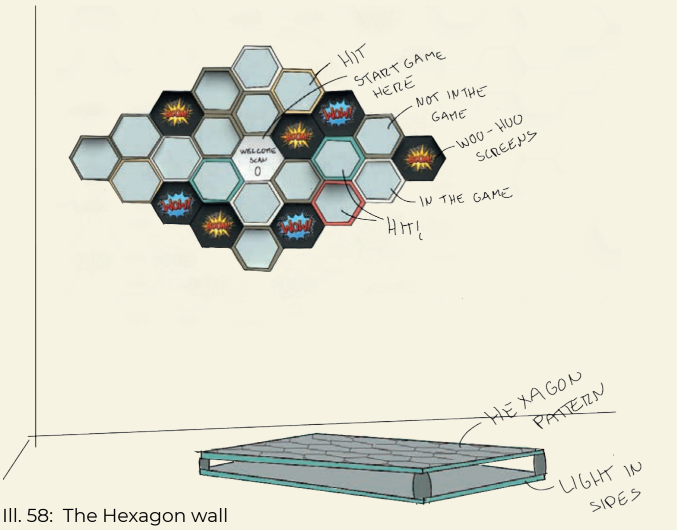
***Hereby some new user-based and schematic requirements were found. The following step is to combine the newfound knowledge into a more specified concept.***

# 3.9 Updated direction

***After setting a requirement for the spots to be fastened on a wall mount and several supplementing requirements and boundaries for both spots and vibration board a concretization of the concept was needed. The overall idea behind "spots and board" (p. 37) did no longer fit the new requirements. This process functioned as the last part of the creative process, where idea evaluation was done, and an idea selection in the end (Striim, 2001 pp. 49-62).***

## Idea Evaluation

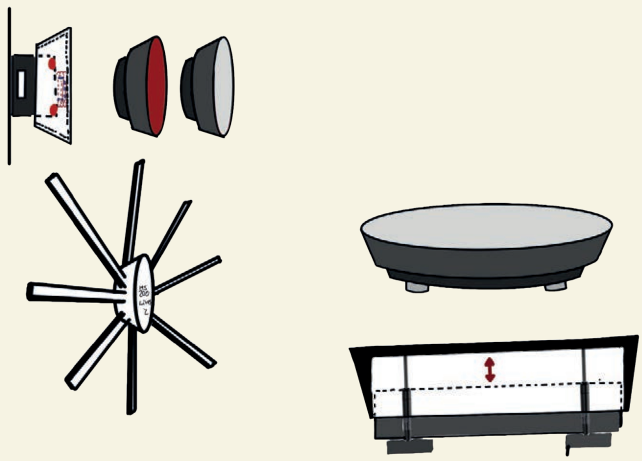
Based on concept 1 the Hexo Game (p. 34), new concepts were generated. From each of the four suggestions, advantages and disadvantages were assessed to be able to better select a concept.




Ill. 58: The Hexagon wall

### Concept A – The Hexagon wall

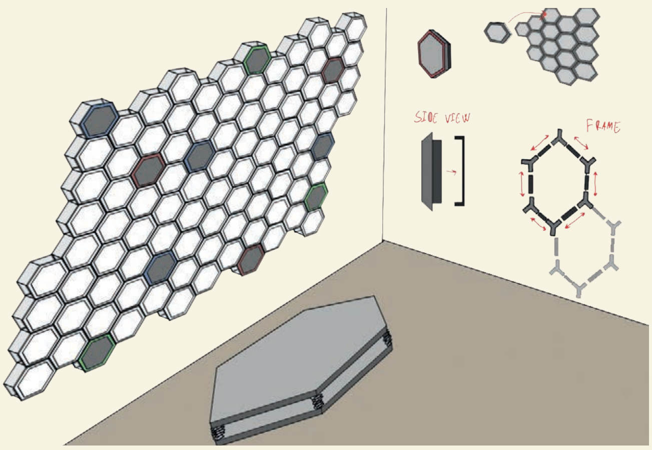
Hexagons were the prominent element. Consisting of a whole wall of hexagons, which together creates a work of art. Some are spots to hit, while others are screens.
**Disadvantage**: Large material consumption.



Ill. 59: The Rail buttons

### Concept B – The Rail buttons

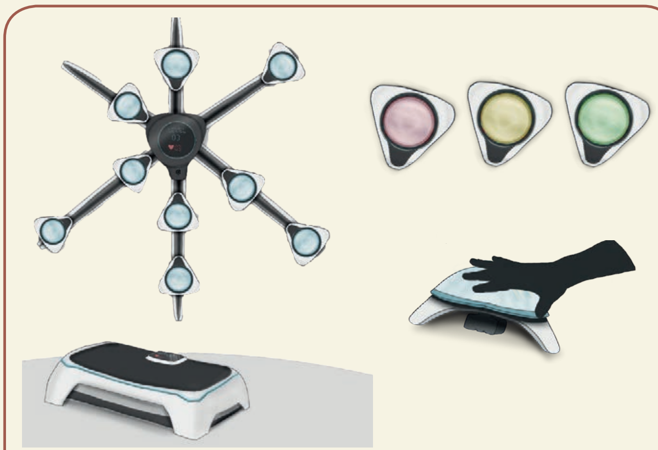
This concept focused on, construction principles regarding both board and spots which should hang on rails mounted on the wall.
**Disadvantage**: Missing identity.




Ill. 60: The Modular wall

### Concept C – The Modular wall

Hexagons were again the prominent element but in a more modular construction (intended to be 3D printed). Here 6-9 spots should be placed into the skeletons holes and by moving the spots the degree of difficulties in the game could also be adjusted.
**Disadvantage**: Large material consumption.



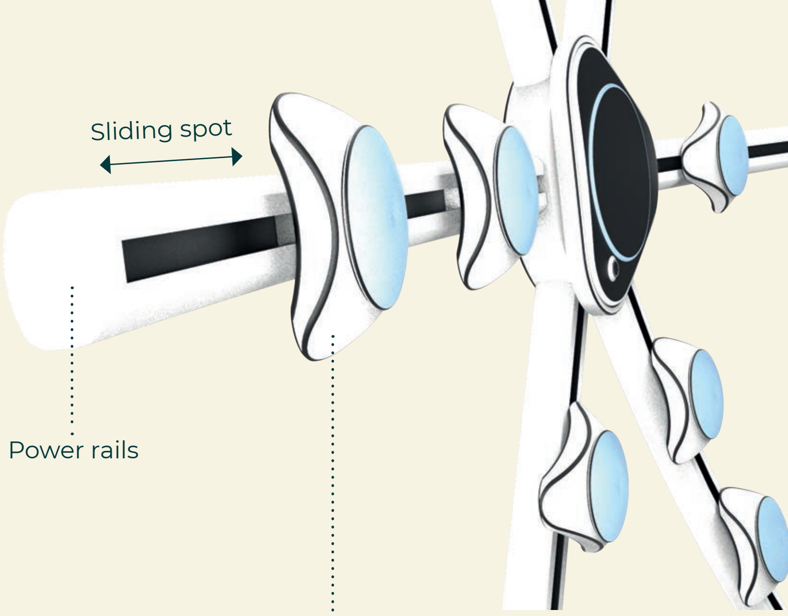
Ill. 61: The Spacy Rail

### Concept D – The Spacy rail

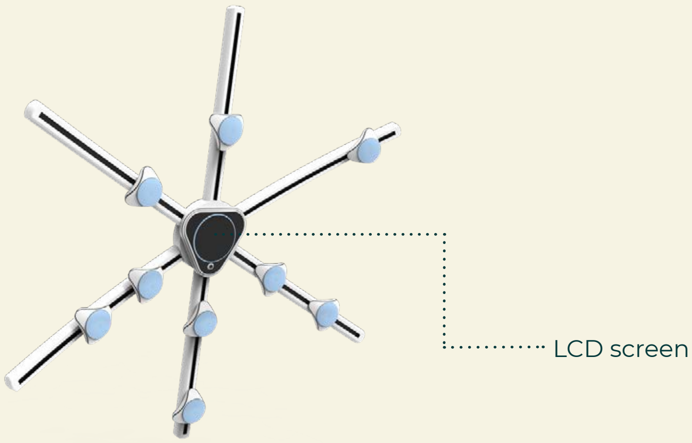
The focus was especially the requirement of a "*retro space vibe*". The spots were placed in rails, where they could be moved to adjust the degree of difficulty. The spots light up in three different colors to indicate how many points the user will get when hitting them.
**Disadvantage**: Construction considerations

# Concept update

Concept D was chosen for further development, combined with construction elements from concept B. This was seen as the concept with the most potential to fulfill all requirements.




Ill. 63: Concept update, spots



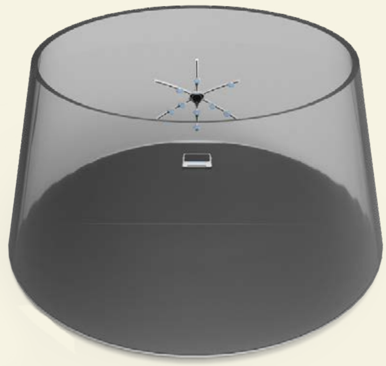

Ill. 62: Concept update, rail

## Rail and Spots

The spots were placed on a rail on the wall. The rail function as a power supply for the spots, by sliding the spots onto the rails (ill. 63). The same principle as power rails used in the ceiling for lamps (app. 33).

The rail is made with a small bend (ill. 64, 65), to counteract the round walls in Marsha house (p. 22). They are connected to an LCD screen in the center (ill. 62).

The LCD screen, electronics, and cobber for the power rail were intended to be shipped from Earth. The remaining parts of the spots and rails to be 3D printed on Mars.



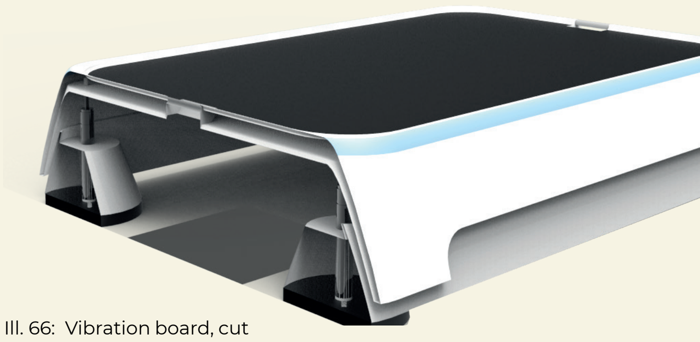
Ill. 64: Concept update, in Marsha house

Ill. 65: Concept update, rounded rail

## Vibration Board

The vibration board included a ERM motor to generate the vibrations. With springs implemented (ill. 66), the vibrations can be controlled to be vertical.

The electronic components, motor, and gas springs were intended to be shipped from Earth and the shells of the board to be 3D printed on Mars.



Ill. 66: Vibration board, cut

## Elements of the concept

The overall concept consists of *a vibration board, a gravity-harness, a wall mount with a screen, spots, and a (not yet developed) game connection.*


Ill. 67: Concept update, elements

***The concept was updated to fulfill the newly found requirements. With the light shifting on the wall, training eye-hand-coordination gets playful. The difficulty of the workout changes through the game by moving the spots to a new position. The usability and motivational elements needed to be set to have a compiled concept.***

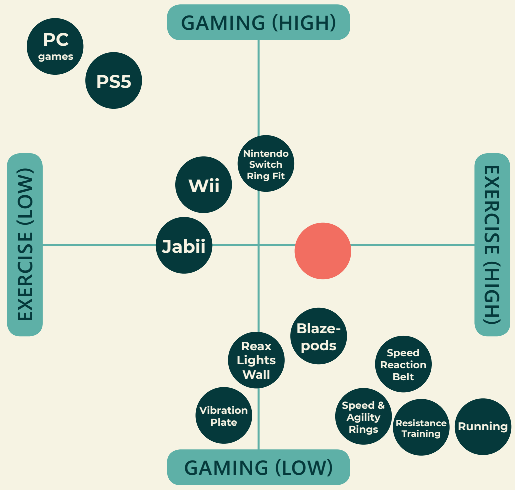
# 3.10 Usability

***With an updated direction settled the connection between the work-out and the gaming element as motivation factor was explored. Existing products were examined to draw inspiration and translate some principles into the concept. Interactions of the game occurred iteratively with the concept development.***

## Perceptual mapping

To identify types of usability, a perceptual mapping was made to segment products within the targeting market (see product pictures in app. 34). A perceptual mapping visually represents where a product or brand is placed among competitors (KOSAKA, n.d.). Note that in 2060, these games will have developed radically. It is assessed that the values in today's products within gaming and exercise will remain in future versions.

*The Spacy Rail* was assessed to target the market by aiming for both gaming and exercise (ill. 68, red dot). This was used as a benchmark in the development.




Ill. 68: Perceptual mapping

## Flowchart

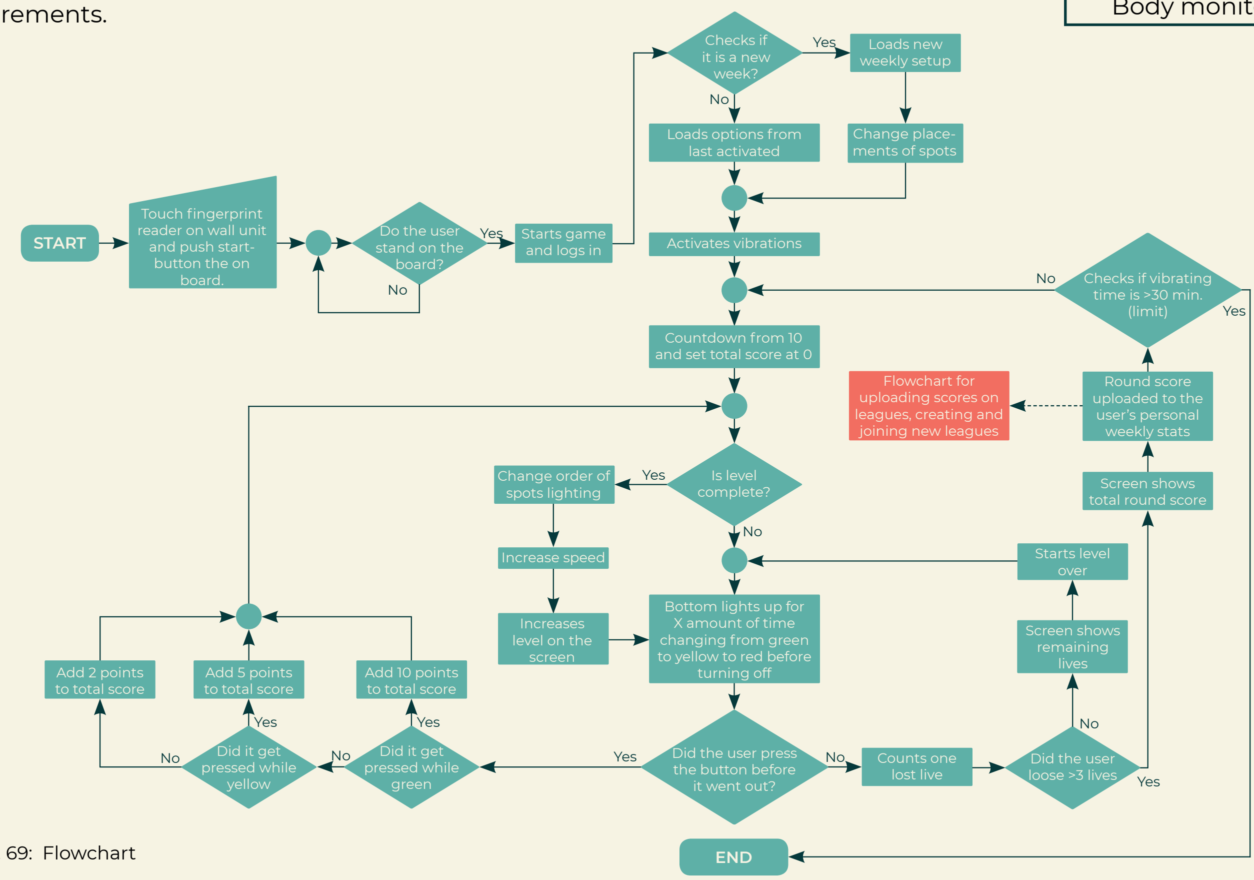
As a part of the iterative development process, the construction of the game and work-out was done.
A morphological diagram (app. 35) listed possible interactions and functions (*visualization of score, levels, acknowledgment, etc.*), and was integrated into variations of flowcharts (app. 36), to find the best combination of the game and interaction.

The flowchart beneath (ill. 69) was assessed as the best possible construction on the game, which set new requirements.

It was concluded that the connection to Earth should be done by uploading the user's scores to a league (flowcharts in app. 36, ill. 69, red box), making them able to compete against families and friends.
Other than that, the requirement track of body shape was eliminated.

✓ Connect to Earth through game-leagues

✗ Body monitoring




Ill. 69: Flowchart

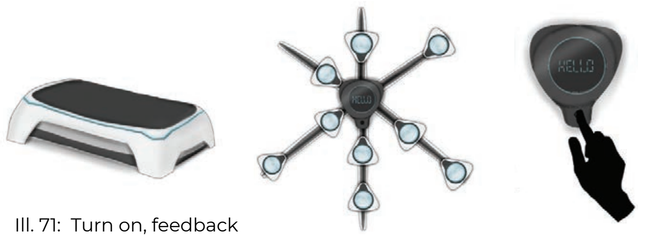
# Interaction flow

Based upon the flowchart a visual representation of the game within the concept was made. Here interaction surfaces and *inherent, functional, and augmented feedforward and feedback* functions were visualized (Wensveen, et. al., 2004) (app. 37). The focus was on designing an eye-hand-coordination exercise game, well knowing the possibility of expanding the game to other exercises and use-cases.

## Turn on

Ill. 70: Turn on

Inherent feedforward: Feeling a tactile button on the board and the wall mount to turn equipment on.
A button is placed on each unit to allow the use of the board and wall mount separately.



Ill. 71: Turn on, feedback

Augmented feedback: Light in spots and board when turned on. The blue light indicating: "*Ready to go*".
Functional feedback: The screen writes '*Hello*' telling the user: "*Ready to use*".

## Start

Augmented feedforward: Shows to push the button to start the weekly exercise.

Inherent and functional feedback: Tapping the tactile button and the LCD-screen start to countdown for starting the exercise.

Ill. 72: LCD Screen

## How to train & the game

Ill. 73: Spots color change

Augmented feedforward: The spots lights up and change color from green to yellow to red - to provoke how fast you need to tap the buttons (p. 41).
Green = 10 point. Yellow = 5 point. Red = 2 points.
The light went out before tapping = 0 points.

Ill. 74: Spots, feedback

Inherent feedforward: The spots should look and feel like a large "buzzer"-button that needs to be tapped.
Augmented feedback: When tapping the spot, the light will turn off.

Augmented and functional feedback; by visually using the LCD screen and spots with colors and sound, to tell the user how they are doing:

Point scores on screen.

Sound and screen telling the user that a challenge has been overcome and levels up.

Screen and sound, showing the user lost a life.

Screen and sound, telling the user that they have set a new personal high score.

Functional feedforward: Screen showing time left between levels/lost lives.

Ill. 75: Visual feedback

Possibility to use the board separate

Acknowledgements for overcoming challenges *(sound effects and top scores)*

A display to show score and ranking

***Based on the usability, a clearer direction on the functions and the exercise-game were defined. From this, the detailing could begin, and components, materials, and production methods be defined.***

# 3.11 Final Design brief

***Through the third phase, Develop, a clarification in terms of direction and solution space was set. This resulted in a final more specific design brief and updated requirements. (The final requirements can be tracked back to Target Requirements at p. 30 by 'need no.')***

## Problem definition

"How to create a product that supports the obligatory training in strengthening the '*loco motor system*' that helps overcome the effects of microgravity on Mars?"

## Mission

To close the gap of activity motivation between highly trained astronauts and space travellers.

## Vision

To arouse enthusiasm for space travellers to fulfil the obligational training.

# 3.12 Milestone 3

The feedback at Milestone 3 was primarily divided into two parts: The gamification and the physical product.

It was questioned if the engagement to the workout/ game would keep being fun over time. The gamification was seen as an extra value to the product, fun and interesting, next to the clarified training (the main function). An opportunity for variety was seen as a requirement.

Also, the physical product was questioned. Did it have to be physical - or could a virtual setup give the same benefits? It was advised to minimize physical elements and look at the future super-system, to fit the solution better.

# 3.13 Sum-Up

## Acquired knowledge

- The locomotor and vestibular system are challenged on Mars due to the lower gravity
- To train the vestibular system the focus must be on balance, eye-hand coordination, and postural control
- Vibrations can benefit the skeleton, but too many or too extreme vibrations can cause damage
- Functional and inherent feedback in the spots have a big impact on the users' engagement
- Balance boards will not work as intended in lower gravity

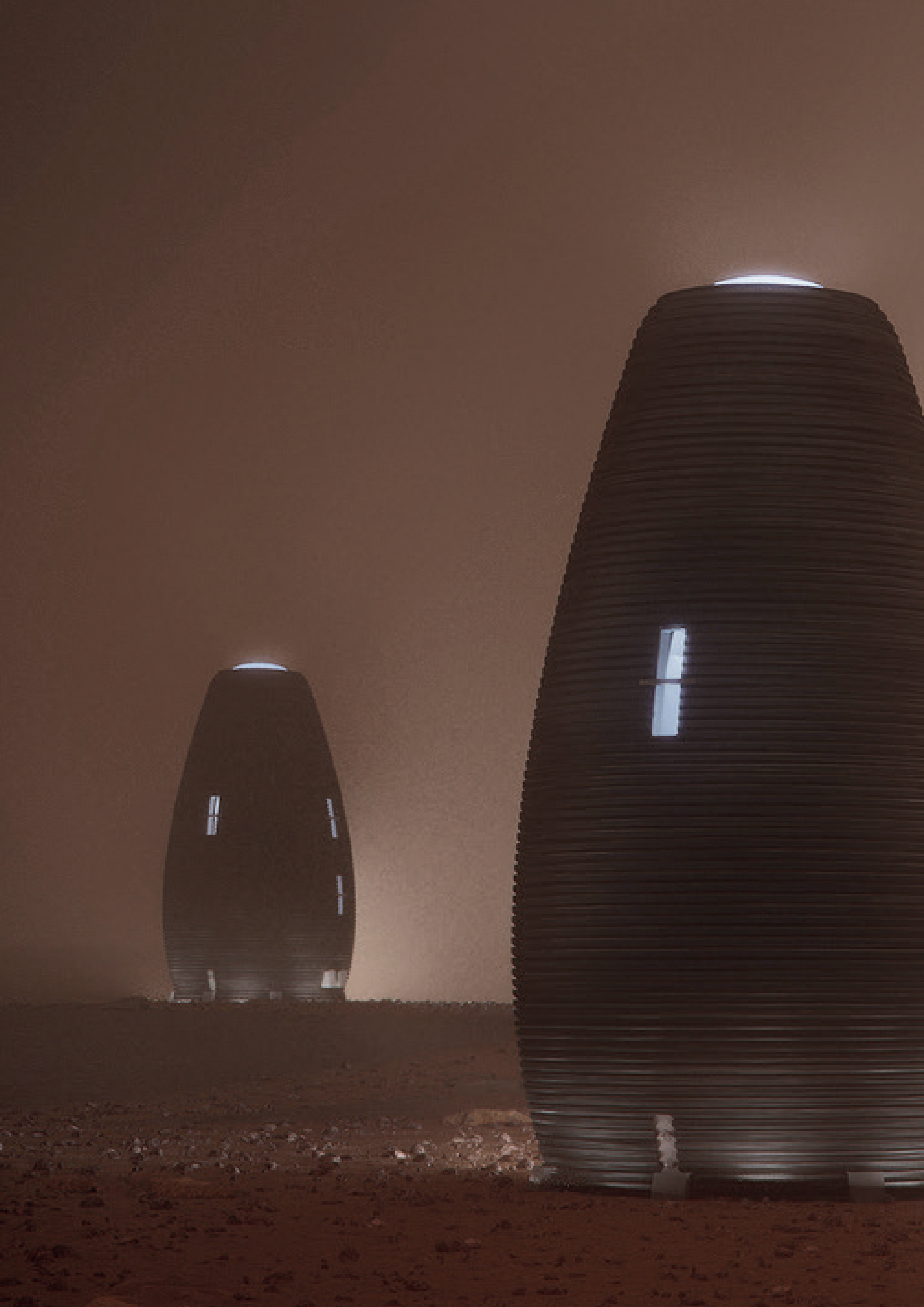
## Further course

- Look into the super-system, production possibilities on Mars in the future
- Challenge the concept - can we strip down on the material used?
- Detail components: material and production
- Clarify the game-element

# Final Requirements

| No. | Need no. | Metric | Unit | Value | Imp. | Source | |
|---|---|---|---|---|---|---|---|
| 1 | 3 | Indoor use | - | Binary | 6 | 1.1 , 2.2 | General |
| 2 | 7 | Installation on: Rounded wall | - | Binary | 6 | 2.2, 3.7 | |
| 3 | 8 | Indoor space | $m^2$<br>m *(h)*<br>° *(slope)* | 18<br>1,6<br>75 | 6 | 2.2 | |
| 4 | 1 | Help to prevent muscle loss | - | Binary | 3 | 2.3 | Work-out |
| 5 | 1 | Help to prevent decomposition of bones | - | Binary | 6 | 2.3 | |
| 6 | 1 | Help to maintain the cardiovascular system | - | Binary | 3 | 2.3 | |
| 7 | - | Duration | Minuts | 10-30 | 6 | 3.2 | |
| 8 | 1, 2 | Focus on Eye-Hand coordination | - | Binary | 6 | 3.3 | |
| 9 | 1 | Challange the balance | - | Binary | 6 | 3.3 | |
| 10 | - | Adjustable for different loco-motor systems | - | Binary | 6 | 3.3 | |
| 11 | 4 | Acknowledgment by overcoming challenges | - | Binary | 4 | 1.3, 3.10 | Motivation |
| 12 | 4 | Include social elements *(competition and community)* | - | Binary | 4 | 1.3 | |
| 13 | 14 | Track of progress | - | Binary | 4 | 2.3, 3.4 | |
| 14 | - | Cross-Generational | Years | 10-60 | 4 | 3.2 | |
| 15 | - | Facilitate learning by doing | - | Binary | 1 | 3.8 | |
| 16 | - | Esthetics: Retro-Space vibe | - | Binary | 1 | 3.8 | |
| 17 | 4, 6 | Connect to Earth through game-leagues | - | Binary | 4 | 3.8, 3.10 | |
| 18 | 4 | A display to show score and ranking | - | Binary | 1 | 3.10 | |
| 19 | - | Non-slip surface on Board | - | Binary | 5 | 3.4, 3.5 | Board |
| 20 | 12, 1, 2 | Maximum accelaration force (Board) | G-Force | 0.5 | 6 | 2.3, 3.5 | |
| 21 | 12, 1 | Include ERM motor | - | Binary | 5 | 2.3, 3.5 | |
| 22 | - | Board dimensions | cm (l)<br>cm (w)<br>cm (h) | 52-57<br>43-37<br>13-17 | 5 | 3.5, 3.7 | |
| 23 | 2 | The user must be attached to the board | - | Binary | 6 | 3.7 | |
| 24 | - | Possibility to use the board seperate | - | Binary | 2 | 3.10 | |
| 25 | - | Spots on a wall-mount | Qty. | 6-9 | 4 | 3.4, 3.6 | Main Unit |
| 26 | 4 | Functional and inheret feedback in Sports | - | Binary | 4 | 3.6, 3.8 | |
| 27 | - | Size of Spots | cm | 6-7 | 5 | 3.6 | |
| 28 | - | Reachability of Spots | cm (d) | 120-170 | 5 | 3.6 | |
| 29 | 24 | Spots on the floor | - | Binary | 6 | 3.4, 3.7 | Boundaries |
| 30 | 2 | Include inflatable balance pillow | - | Binary | 6 | 3.5, 3.7 | |
| 31 | 15 | Body monitoring | - | Binary | 1 | 2.3, 3.10 | |
| 32 | 13 | Include occlusion band | - | Binary | 3 | 2.3, 3.4 | |

*6 = highest rating,
1 = lowest rating



## PHASE **4.0** DELIVER

# A SAFE LANDING

The fourth section covers the deliver phase. This includes the final development of the concept making it into a final product proposal.

This is done by including available production technology on mars, making sure nothing unnecessary is transported from Earth. The technology used is adjusted to reflect what can be expected of the 2060s that the concept is developed for. Finally, a clear definition of motivation factors and gameplay is defined.

Ill. 76: Define (archdaily, n.d.)

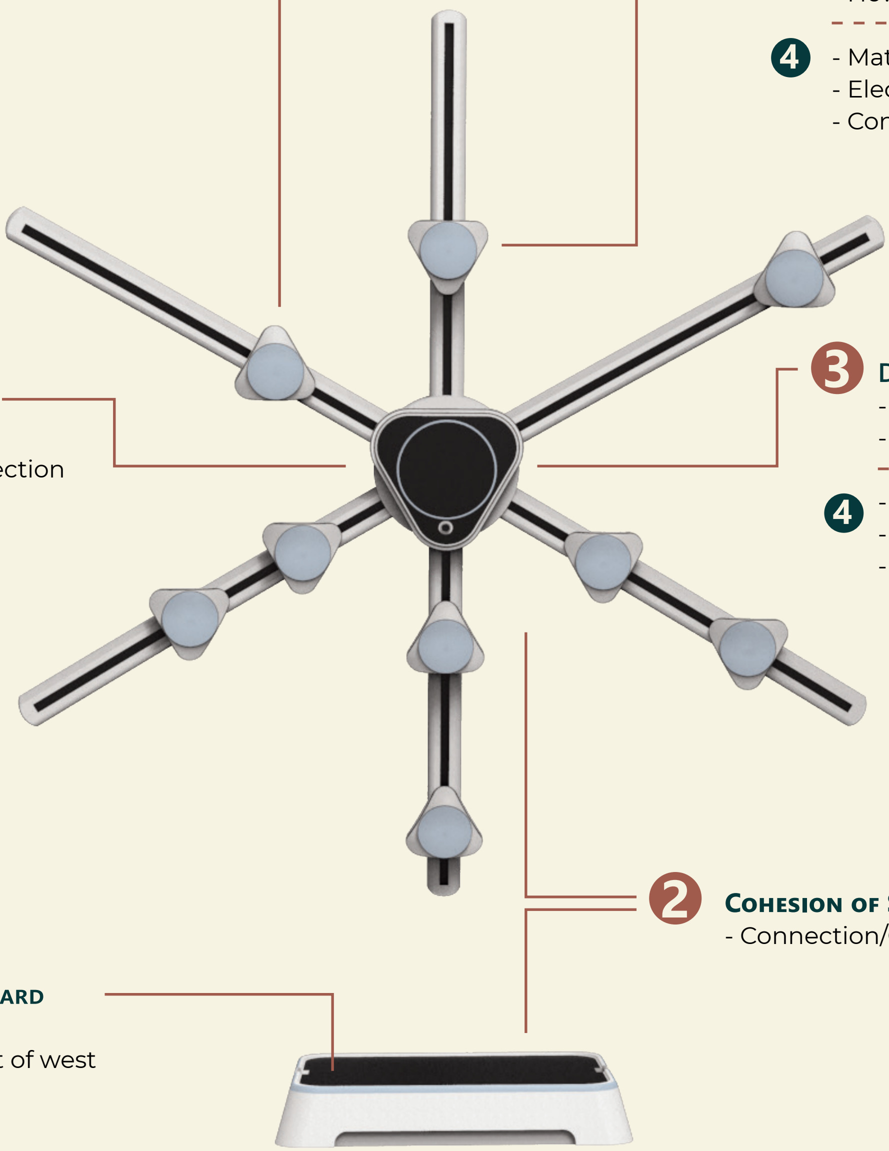
# 4.1 Concept Segmentation

***To detail the concept, it was divided into smaller segments. Under each segment, it was noted which elements there were missing details. In this way, an overview was made, and the further work started where most elements were lacking and ending with a combination of the game league and production details.***

The elements on the illustration are marked with their priority from 1-4 (1 is the one with highest priority)

**Fact**

**Identity**
Through the iterative deliver phase, the product proposal got a clear identity as B•FAST



**1 Cohesion of Spots and Rail**
- Connection
- Placement of Spots
- Communication with display

**1 Rail and Spots**
- Strip down components
- Number of spots
- How it works

**4**
- Materials
- Electronics
- Construction/Assembly

**3 The Game**
- Interface
- Earth connection
- Motivation
- The League
- Flowchart

**3 Display**
- The interaction/visuals
- Who is playing?

**4**
- Materials
- Electronics
- Construction/Assembly

**2 Cohesion of Spots/Rail and Board**
- Connection/Communication

**2 Vibration board**
- Springs
- Attachment of west
- Interaction
- Motor

**4**
- Materials
- Electronics
- Construction/Assembly

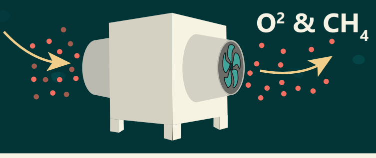
Ill. 77: Concept Segmentation

# 4.2 Technology timeline

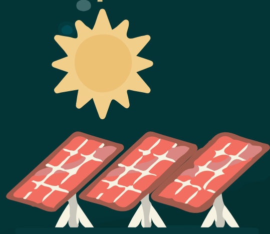
*A timeline of technology was made to find what expected manufacturing methods will be available on Mars in the 2060s (HumanMars, 2019).*

**2021**

### Atmospheric propellant




### Solar panels



### Water

**2027**

Two spaceships land on Mars, both have a small nuclear power reactor and an automatic atmospheric propellant plant that produces oxygen and methane from the Martian atmosphere.

### Nuclear power reactor

**2032**

### Storage

A solar array is built to supplement the nuclear power plant. They start mining ice to get water and build a ground-based ISRU system (*In-Situ Resource Utilization*) capable of producing and store water, nitrogen argon, and liquid methane.

*It is assumed that there is enough power, electricity, water, and breathable air at this point to survive on Mars with resources produced on site.*

**2034**

Extraction of Martian regolith and separation of chemicals, which can be used in ISRU system.

### Mining

**2036**

The ISRU capabilities on Mars are extended not only to produce air and water, but also steel, bricks, cement, basic fertilizers, plastics, and silica products. The use of industrial size 3D printers is also incorporated.

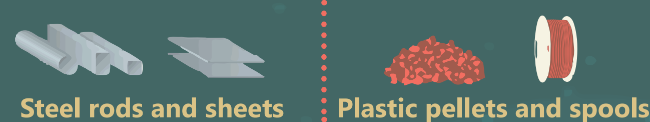
### Steel


Steel is made by grinding the raw material, melting it down and casting it as rods or sheets (NSC, 2017).

### Plastic


The plastic is made from gas, oil and plants which is redefined to make plastic polymers. It is then extruded to pellets or spools (Thisisplastics, 2021).

### Materials available




**2050**

The ISRU and industrial capabilities on Mars are greatly extended, using the resources harvested, refined & processed. The first factories on Mars that are manufacturing complex products are settled.

**2060**

Parts of B-Fast produced on Mars

*In the 2060s the manufacturing capabilities are assumed to consist of a variety of manufacturing methods. In the 2030's it might only be the most essential that is a priority due to limited resources. But in the 2060s there could be resources and capability for less essential products like B-Fast.*

**FUTURE**

*Go to (app. 38) for full description of steel and plastic making.*

Ill. 78: Technology timeline

# 4.3 Detail and Challenge: Rail

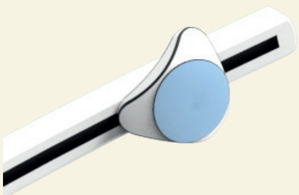
***B-Fast had a big rail system with physical buttons, which is an expensive solution due to shipment and production on Mars. It was therefore investigated how B-Fast could be stripped down, without losing the gain of training and feedback.***

## Physical vs Virtual Spots

It was investigated if upcoming virtual technology can replace the physical rails. Products on the market were found and mapped from virtual to physical as inspiration (app. 39), from where four opportunities were set (see table below).

The discussion was whether a virtual spot with sound and visual feedback could replace the feeling when touching a physical spot? This was tested (app. 40). The result of the test was that it is important to have some physical feedback because it enhances the experience.

### Physical button



Ill. 79: Physical button

Provides physical feedback and travel distance when pushing spots, but it increases the material consumption.

### Hand-held haptic button

Ill. 80: VR controller (komplett, n.d.)

The controllers have haptic feedback inside. This gives the user the feeling of touching a spot, which shows through VR.

### Touch button

Ill. 81: Touch screen(indiamart, n.d.)

A touch screen allows variation and expansion, but the feedback when pressing it is missing.

### Projected touch button

Ill. 82: Projector (CM, n.d.)

Projected spots are all virtual making the feedback limited to visual.

## How to strip down?

Sketching and desktop research on ways to strip down the concept was made (app. 39, 41 and 42). Some of the possibilities that were explored were: *interactive projectors, Tesla suit, VR gloves, ultra haptic feedback, and AR.* The development was summed up in the two possibilities below.

### Choice of concept

It was decided to use AR to visualize spots and information, combined with ultra haptic feedback. The combination seems future-safe and opens for expansion possibilities. The solution stripped down components from a rail system to one central main unit.

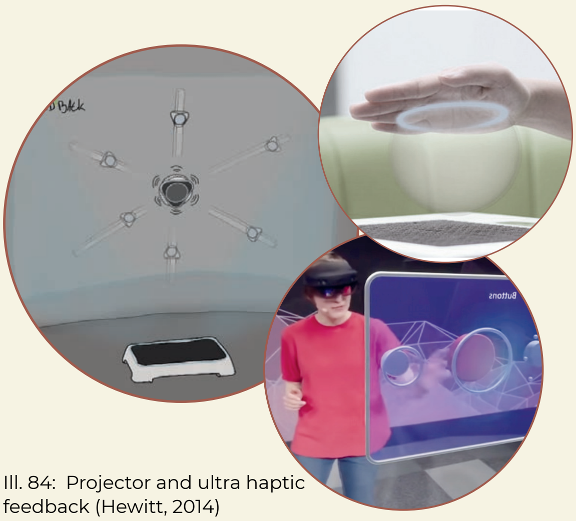
### Feedback glove and Interactive projector

One of the ideas was to move the feedback from the spot to the hand. This would give the user inherent feedback when tapping a projected picture.

Ill. 83: Glove and projector

### Projected spots with ultra haptic feedback

By using ultra haptic feedback the feeling of a spot can be simulated. The future potential is great combined with AR (as a projector might be outdated in 2060).



Ill. 84: Projector and ultra haptic feedback (Hewitt, 2014)

# Technology

The technology behind AR and ultra haptic feedback was explored simultaneously with the sketching process. To map the possibilities for the two technologies "*The nine-window model*" (Silverstein et al. 2008) (app 43) was used to make assumptions on the future of AR and ultra haptic feedback.

## Ultra haptic feedback

To put it simply, haptics is a technology, which allows the user to interact with computer-based devices by receiving tactile and force feedback through vibrations. Haptic feedback simulates the physical properties of an object. (Dybsky, 2017) This gives the user physical feedback like touching a button.

### How it works

Ultra-haptic feedback is small ultrasound speakers placed in an array. Every speaker can be individually controlled and when triggered with a very specific time difference the ultrasound waves arrive at the same point in space at the same time. The combined ultrasound waves have enough force to create tiny pressure points that the user's skin can detect (ill. 85). The focal points can be positioned in a 3D space and can be programmed to change in real-time. (Ultraleap, 2021)

Ill. 85: Ultra haptic feedback (Hewitt, 2014)

## AR - Argument Reality

*"Augmented reality (AR) is superimposed digital information overlaid on a user's view of a physical environment."*

– Leon Laroue, technical product manager of augmented reality solutions (Overby, 2019)

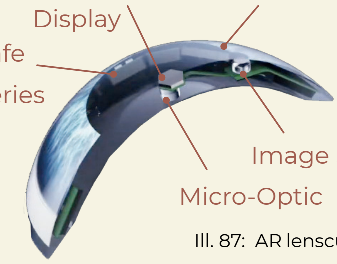
AR glasses like the Microsoft HoloLens are transparent smart glasses that enable an optical-see-through AR experience (Overby, 2019). The technology is currently being used in 2021, so it is assumed that in the 2060s a smaller and better version of AR will be used. Therefore, AR contact lenses are used in B-Fast.

Ill. 86: AR glasses to lens (Microsoft, n.d.)(The Verge, 2017)

### AR Contact lenses

Mojo Lenses are AR contact lenses (ill. 87). The lenses use a tiny projector to send information to your retinas. It only blocks a small fraction of the total light entering your pupil, so that it does not impact your normal vision more than a typical pair of glasses (Cardinal, 2020).

Mojo found that accurate, high-speed, eye tracking was essential. The lenses move with your eye, the only hardware required is the typical accelerometer/magnetometer/gyro setup. It will require another wearable to control it to serve as a relay between the lenses and your phone. (Cardinal, 2020) (It is assumed that it can be placed in the Main Unit in 2060).



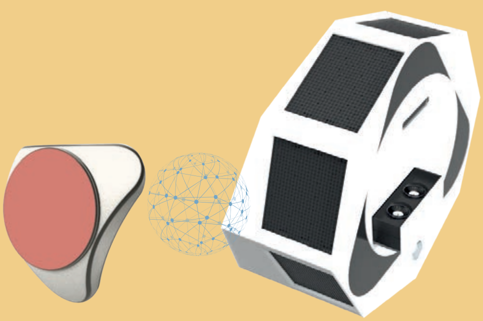

Ill. 87: AR lenscut (The Verge, 2017)

# The Main Unit

The final concept is a main unit with ultrasound speakers all around the edge to simulate the feeling of the buttons (ill. 88). The buttons can only be seen through the AR lenses, that are stored inside the Main unit and connects through it.

Ultra haptic feedback

Includes AR Lenses



Ill. 88: The main unit, update

***B-Fast has gone from a big physical rail with spots, to a small main unit with ultra-haptic feedback and AR contact lenses. This reduces the materials used and the manufacturing processes while also opening the possibilities for the exercises available.***

# 4.4 Detail: Vibration board

***At the zoom-in on the board (p. 38), the level of vibrations on 0.5 G and construction principles was found. The detailing of the board includes interaction with the board, construction principles, choice of motor, and springs.***

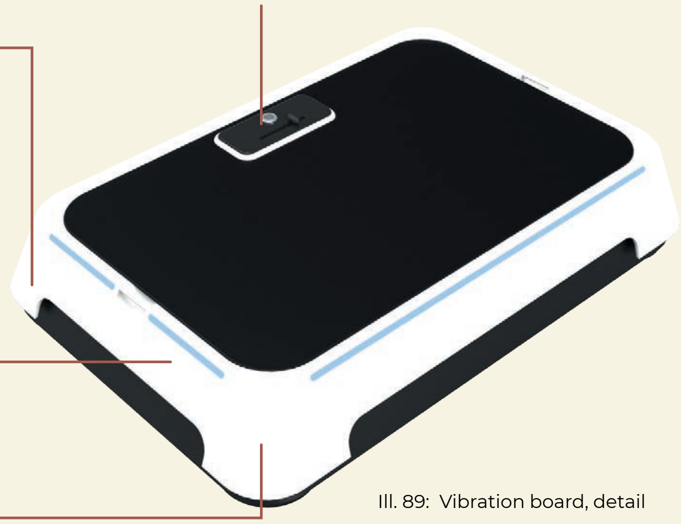
## Interaction

### Double shell
The board's main function is to give vibrations to the user. The top shell will vibrate with the user.
With the closed form, a finger cannot get stuck between any parts.
The notches in the sides make the board light and the contrast between black and white makes it *seem floating*.

### LED Strips
Along the sides, there are mounted LED strips. These will provide augmented feedback, letting the user know if it is turned on or off with blue light and provide feedback during the game. When it is game over it will light up red.

### Vibration activation
The try-out (app. 29) showed that a normal vibration board's vibrations make it jump over the floor, if it is started without a user upon it. To make sure that does not happen, a countdown to game start, will give the user time to step onto the board, before the vibrations starts.

### Control panel
A small control panel is placed on the top. The placement gives the board a direction. By having an on/off button and a slider for controlling the vibrations manually, the board can be used for other workouts than the B-Fast game.



Ill. 89: Vibration board, detail

## Vibration Motor

Vibrations can be applied with two different motor types (ERM and LRA). The motor requirements:

**Amplitude:** 0.5 G (p. 38)
**Frequency:** max. 50 Hz
**Brass weight:** 50 g

The requirements were found from calculations (app. 44), which stated the motor needs to be able to vibrate a person on 100 kg (equivalent to 33 kg on Mars due to 1/3 gravity).

### Choice of motor
Both LRA and ERM motors can vibrate with an amplitude of 0.5 G. The motor should have a frequency of a maximum of 50 Hz, and the LRA cannot run with such a low frequency. The ERM can run below 50 Hz, which is a matter of how much voltage is sent to the motor.
The LRA motor is very small and usually used for haptic feedback in devices like phones - it is not meant to vibrate multiple kilos, and brass on 50 g will not be able to fit inside. (Microdrives, n.d.)
From these considerations, an ERM motor was chosen, since it is suitable to fit the ISO standard (p. 38).

Fact

### Motor Types

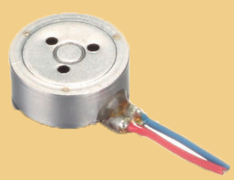
**ERM**

Ill. 90: ERM (Microdrivers, n.d.)

An ERM motor has an eccentric rotating mass (ERM). It uses a small, unbalanced mass on a DC motor, when it rotates it creates a force that translates into vibrations.

**Amplitude:** 0.25-150 G
**Frequency:** 30-500 Hz
(Microdrives, n.d.)

**LRA**



Ill. 91: LRA (made-in-china, n.d.)

An LRA motor (Linear Resonant Actuator) has a small internal mass, which is attached to a spring. The mass creates a force that translates into vibrations.

**Amplitude:** 0.75-2 G
**Frequency:** 150-250 Hz
(Microdrives, n.d.)

# Vibration Absorption

To make the board vibrate, the motor is attached to the top shell, which stands upon four springs in each corner. The function of the springs is to allow the top shell to vibrate and absorb some of the vibrations down towards the floor. A compression spring and a gas spring were considered (app. 45).

### Choice of spring

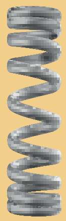
Comparing the two types of springs, the gas spring can store the most energy, give a specific output, and are more customizable than a compression spring. The compression spring are restricted to a few basic features (Monroe, 2019) (app. 45).

The “*kickback*” (when pressure is released) is cheaper and faster in a compression spring, but the operation is less smooth and stable than a gas spring (iMovR, n.d.).

It is chosen to use gas springs because of the smooth and stable movement, and long lifetime due to the Martian conditions. With this, it is possible to compile the vibration board with the ISO standard requirement for vibrations.

Fact

## Spring Types



### Compression spring

The energy is stored when the spring is compressed and the pressure is released.
It relies on deformation in the material and has an elastics limit to how much it can be deformed without breaking (European springs & pressings, 2017).
**Lifetime**: 10.000-15.000 uses over 5 years (James spring & wire company, 2017)

### Gas spring

Uses pressurized gas to store the energy in the spring. This means the gas spring does not rely on deformation in the material to store energy.
The pressurized gas pushed the rod which creates energy similar to compression springs (Lesjöfors, n.d.).
**Lifetime**: 10.000-100.000 uses over 5 years (Suspa, n.d.)

# Construction principles

The board is designed with two shells. The top shell will vibrate with the user, and the bottom shell will encapture the springs.

The ERM motor will be attached to the outer shell, that the user stands on. This is fastened on the four gas springs, absorbing the vibrations towards the floor and making the top vibrate with the user.

The inner shell is a frame, with cones in each corner. The function of the inner shell is to keep everything in place and make sure no fingers get in trouble.

The gas springs will be fasted on the outer shell, go through a middle hole in the inner shell’s corners, and locked on the feet.

A small box on the standing surface contains a control panel and all electronics.

Ill. 92: Vibration board, cut

| Vibration amplitude: 0.5 G | Load on board: 50-100 kg | Board size: 59 x 39 x 12 cm | Motortype: ERM |
|---|---|---|---|

***The vibration board was detailed with a focus on usability and functionality. With a double shell, a control panel and LED strips giving augmented feedback the board will be easy to use. A ERM motor with the right dimensions was found to vibrate a person on 50-100 kg with 0.5 G, and gas springs were chosen to absorb and yield for the vibrations. All things combined in a double-shell construction.***

# 4.5 Motivation

***One of the key points has been to create a product that will motivate users to fulfil their obligatory training. By not being able to test a fully operational product on users, other measures like testing parts of the concept and including different motivational aspects of gamification have been used to ensure the product's relevance.***

FACT

## Internal and external motivation

In the discovery phase, a study about motivation within gamification was carried out (p. 15). It concluded that factors like *competition, acknowledgment, and a community* are big motivational factors that B-Fast will have to rely on.

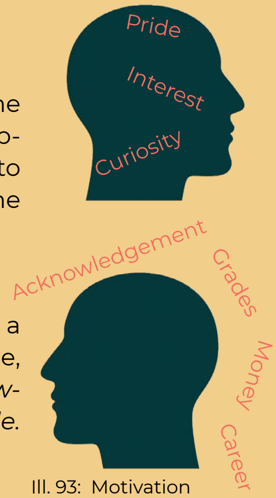
The motivation factors of B-Fast can be further explained, by looking into *the internal and external motivational effects.*

### Internal motivation

The internal motivation is the user's expectations, skill development, urge, and willingness to complete goals. It is built on the satisfaction users experiences

### External Motivation

The external motivation is a reward from an outside source, this can be in form of *acknowledgement, salary, or a grade.* (Dvorak, 2018)




Ill. 93: Motivation

## Equipment

B-Fast consists of 6 elements on Mars (ill. 94). On Earth, the same equipment is needed, but without the harness that helps the astronauts counteract the microgravity.

The user's internal motivation will be spiked, by using new and exciting technology, which will provoke an urge to develop new skills.


Ill. 94: Equitment

## The league

The league is what links B-Fast's community. Both participants on Earth and co-works on Mars can be challenged. The league is found on an app (ill. 95), and use different elements to motivate:

### Ranking

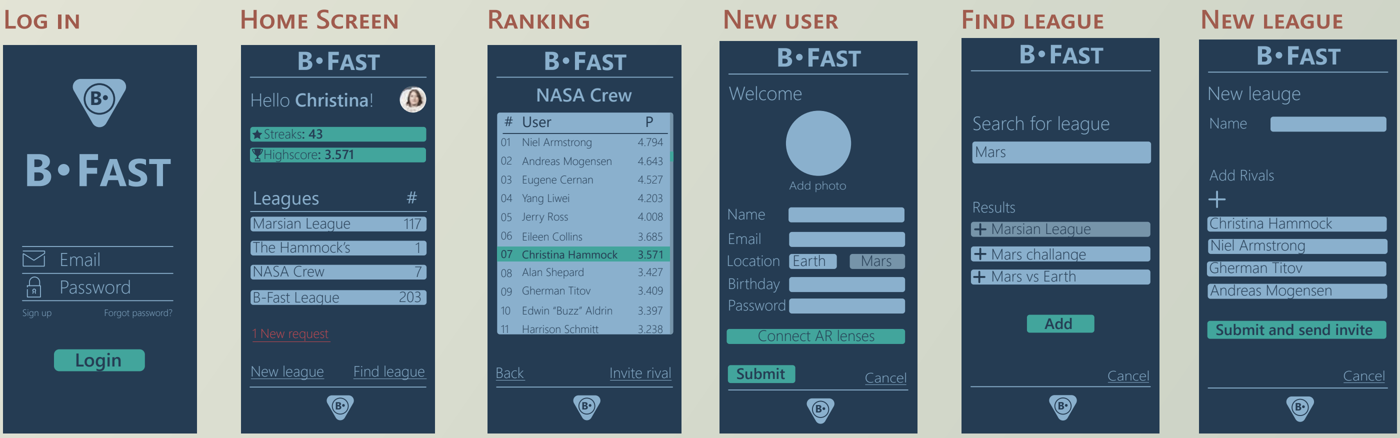
The external motivation is provoked by ranking the user against family members, colleagues, or friends, based on a score that reflects the user's abilities within the game.

### Streak

A streak gives the user an internal satisfaction of achieving new goals, but also an external by giving a count that reflects the user's persistence.

### Skill level and community

The league provokes internal motivation by being able to develop skills in the game while the timeframe gives the user a goal to accomplish. The league also represents the community that leads to a higher motivation (p. 15).

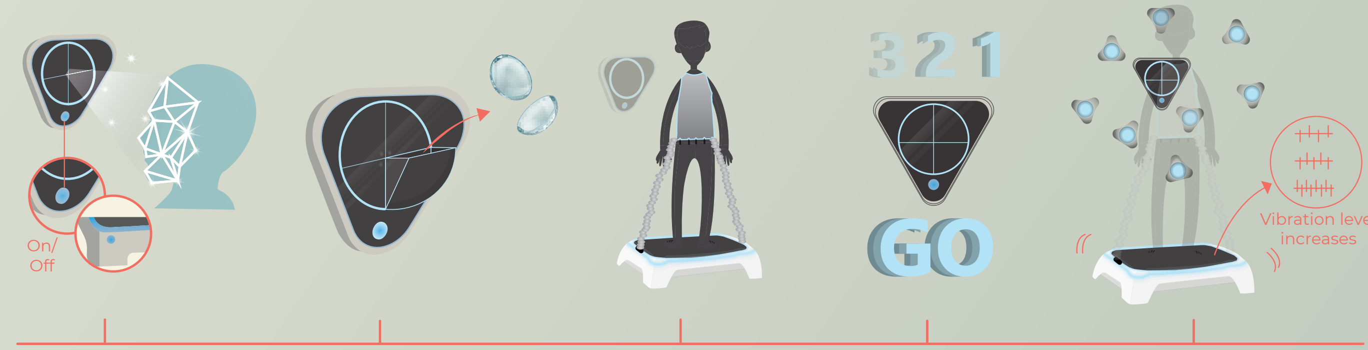



Ill. 95: B-Fast app interface

# The game

## 1 Prepare

To prepare the game a series of step needs to be performed by the user (app. 46) (ill. 96). The steps gets the user into the right mindset; like stepping into the boxing ring or onto a stage. By personalizing the experience, the user will be able to work on their score which leads to internal motivation.




**1)** Turn on board and main unit

**2)** Login by Face-scan

**3)** AR Lenses pops out

**4)** Step up on the board

**5)** Attach the harnesses

**6)** Count down to Game start

**7)** Spots lights up

**8)** Vibration level increases

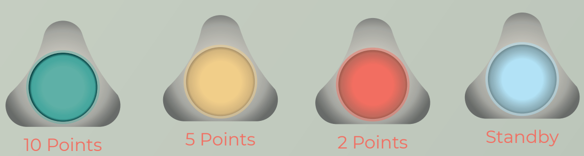
Ill. 96: B-Fast, prepare scenario

## 2 Play

When using B-Fast a circuit of steps will happen (app. 46). Spots will appear in green after a while it turns yellow, then red before disappearing. The colour and points reflect how fast the user taps the spots (ill. 99).
The colour change increases the possibilities of improving skill and therefore spikes the internal motivation while giving an external reward of points (ill. 97).
The user will get acknowledgments from the game by completing levels (ill. 98) and feeling the difficulty rising, this will also be shown as visual feedback on the main unit.
A life will be lost if the spot is not tapped before disappearing. This will reset the level. The user can always track their score on the main unit to get the competing element into the game and make the user strive for a better result than their opponents.


Ill. 97: B-Fast, play


Ill. 98: B-Fast, level up




Ill. 99: B-Fast points

## 3 Game over

The game will end when losing all three lives. The track of progress by comparing total scores (ill. 100) will provide external motivation. Allowing the users to compare scores fulfils their urge for competing (internal motivation).
The game will also give information continuously about how much time is left to play. If the 30 minutes are up, the game will stop automatically. The time limit is caused to keep the health benefits intact (p. 38). The timeframe has the benefit of pushing the user to be efficient while playing, to fulfil their expectation of progressing within the game.


Ill. 100: B-Fast, highscore

! Gaming community

! Daily streak

! Topscore wins

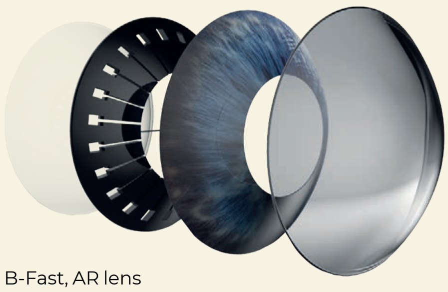
! Facial Recognition

! Leauge based

***B-Fast delivers a more intriguing exercise, that can be substituted for the former monotonous cardiovascular training while incorporating the training of the vestibular system. B-Fast is based on principles from gamification and both the internal and external motivations that follows.***

# 4.6 Operation Value Chain

***Iterative detailing of the spots, main unit's, and board' electronics components was found to make the system work correctly. This happened hand-in-hand with construction considerations in form of what to ship to Mars/ produce on-site and choice of production and materials.***



Ill. 101: B-Fast, AR lens

## Components

### AR Lenses

To give the best possible user experience and expanding possibilities, B-Fast uses AR lenses. The lenses must be costume-made for the individual. The technology is developed but is not FDA approved yet (Perry, 2021).
The AR lenses are constructed in four layers (ill. 101); two layers of lenses, one layer of electronics, and one that looks like an iris. (Mojo, 2020) (p. 52)

### Main Unit

The Main Unit (ill 102) is designed to be hung on the walls inside Marsha House which are rounded (p. 22), why the back lid of the Main Unit is rounded as well and fitted to the slope. The shape of the Main Unit is octagonal to point the 312 ultrasound speakers for ultra-haptic feedback in all directions (Dybsky, 2017).

The PCB board includes the CPU, the antenna, a WIFI and Bluetooth component, a small speaker, and audio amplifiers. A push-button is used for turning the Main Unit on/off.

In the centre of the Main Unit, there are four drawers for the AR lenses. In here they can be charged and cleaned in the salty water. The drawers work with Micro Linear Actuators, making them able to open automatically when using face recognition by the front camera and IR sensor

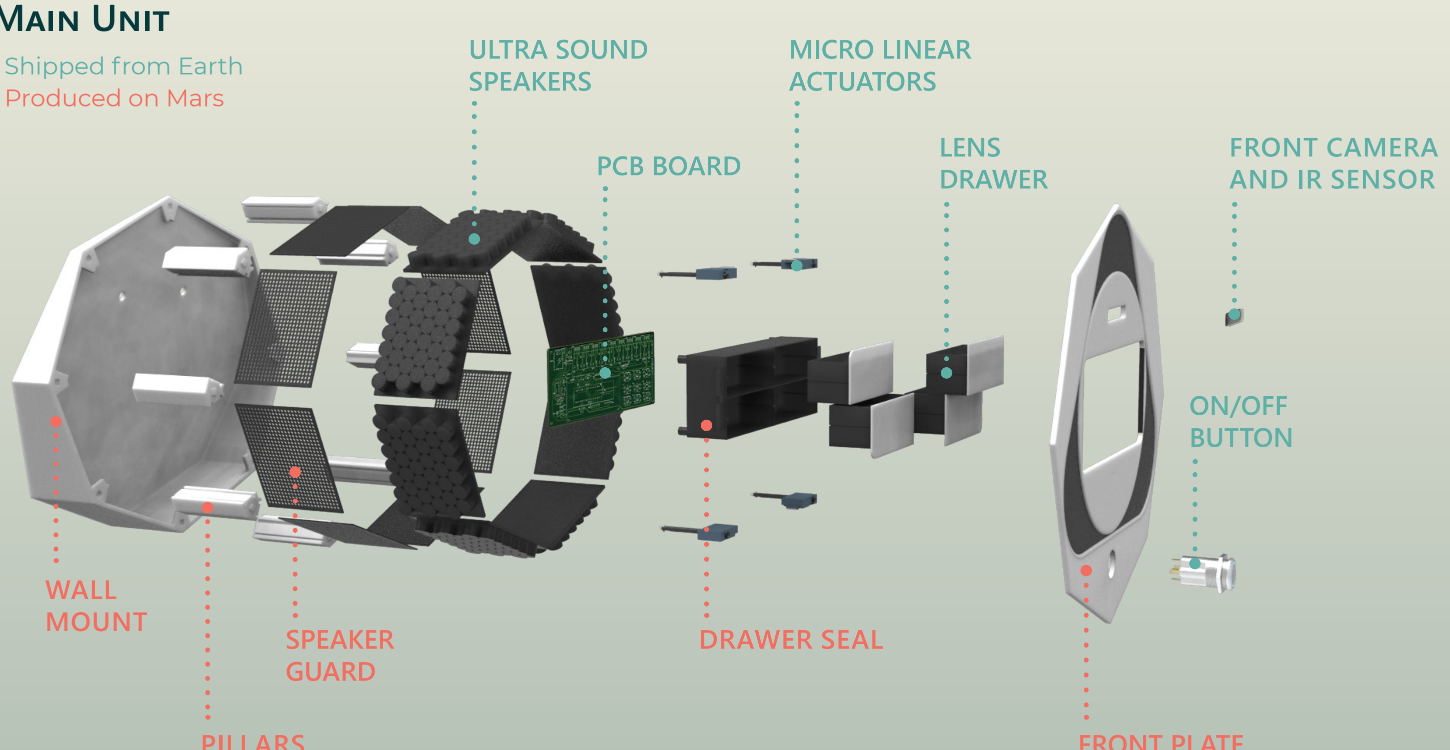
### Vibration Board

The vibration board (ill. 103) must be turned on by a on/off button. When using the vibration board separately the vibrations can be controlled by a potentiometer. The board provides augmented feedback by LED strips, which also sets a "*game-mode*" mood.

The core components of the board are the ERM motor and four gas springs (p. 54. The components can be seen in app. 47 and the connection of them in a Block diagram in app. 48 and a flowchart in app. 46.

## Main Unit

Shipped from Earth
Produced on Mars




Ill. 102: B-Fast, Main Unit, exploded

# Shipping

Through the process, it was considered carefully to strip as much down on parts to ship as possible. The parts that must be shipped (marked with green ill. 102 and 103) includes all electronics, the AR lenses, and drawer modules.

When shipping to space, the shipping costs depend on the weight. From calculations on shipping costs with the cheapest spaceship (assumed it will be even cheaper in the future), the shipping costs for one B-Fast are **4.800 DKK** (app. 49 and p. 40).

# Production and Materials

### 3D Printing

Production possibilities were investigated earlier (p. 51). B-Fast is constructed with a modular architecture build up in shells. The shells are mainly produced in bioplastic by 3D printing (marked in red in ill. 102 and 103). In this way, the shells can be printed while waiting on the shipment of electronics, and then assembled on site.

### Bioplastic

Bioplastic is used as it can be produced on Mars from biomass and achieves the same properties as other plastics (Grusgaard, 2020).

Bio-polyethylene (HPDE) is used for the shells. HPDE is bio-based and non-degradable plastic, which is chosen as the product must be durable and not degrade over time (Grusgaard, 2019). For the non-slip surface on the board, PVC is used. This can also be produced on Mars as bioplastic. The feet on the board to absorb vibrations are made in bio-rubber.

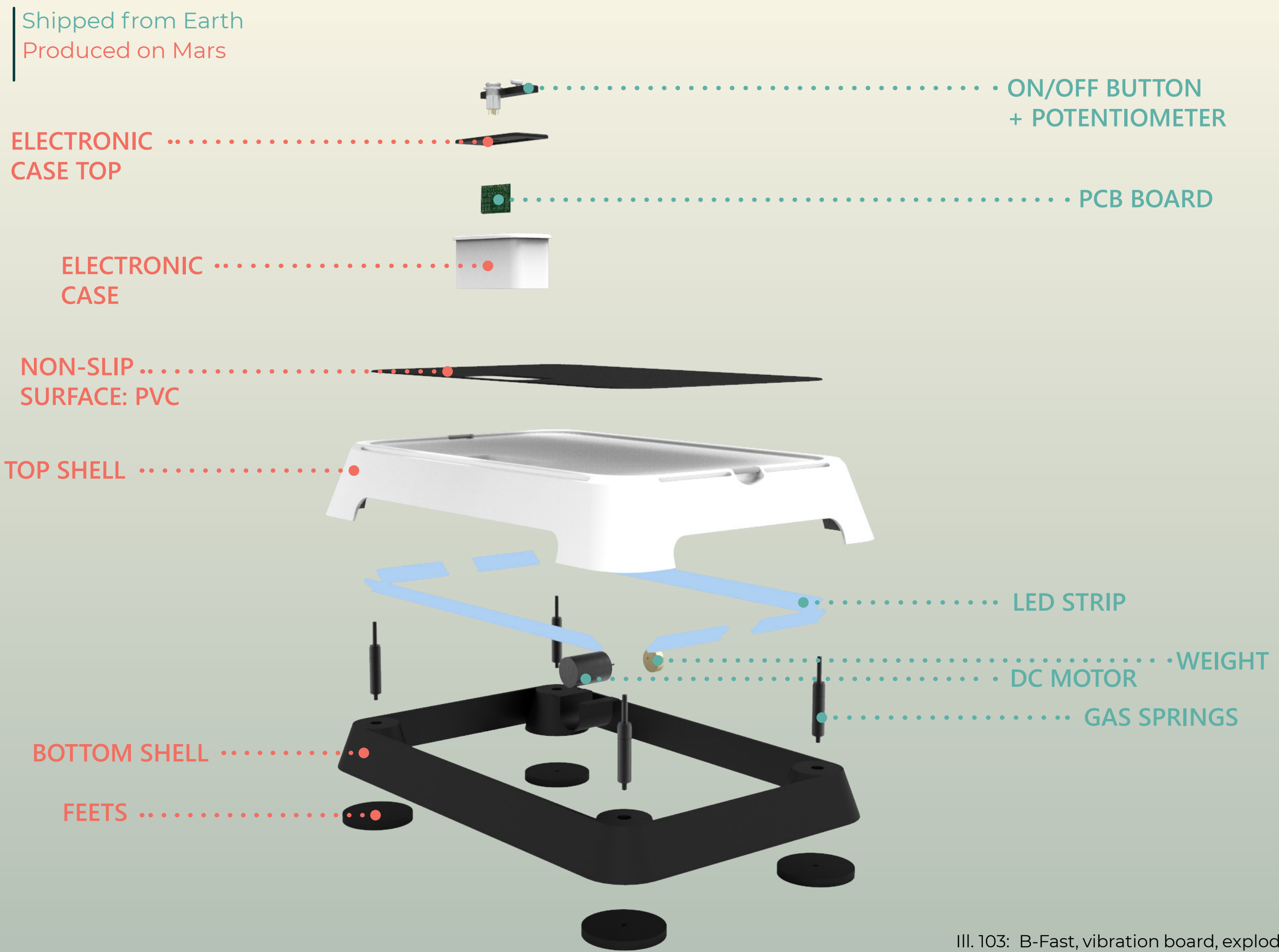
Alternative production possibilities have been investigated (app 50).

3D printed in Bioplastic

Fits the wall in Marsha house

Vibration damping towards the floor

## Vibration Board




Ill. 103: B-Fast, vibration board, exploded

# 4.7 Target Specifications

***The last phases development and deliver, handled all requirements through detailing. This resulted in product specifications that evolved from the final requirements (p. 47). (The specifications can be tracked back to the Final Requirements at p. 47 by 'need no.')***

| Spec. no. | Need no. | Metric | Source | |
|---|---|---|---|---|
| 1 | 26 | Ultra haptic feedback | 4.3 | Main Unit |
| 2 | 8, 13 | Includes AR lenses | 4.3 | |
| 2 | 8, 9 | Training of balance and eye-hand coordination | 3.3 | |
| 2 | 20 | Vibration amplitude: 0.5 G | 4.4 | Board |
| 2 | 20 | Load on board: 50-100 kg | 4.4 | |
| 2 | 22 | Board size: 59 x 39 x 12 cm | 4.4 | |
| 2 | 21 | Motor: ERM | 4.4 | |
| 2 | 12, 13, 17 | Gaming community | 4.5 | Motivation |
| 2 | 11, 18 | Daily streak | 4.5 | |
| 2 | 11, 13, 14 | Topscore wins | 4.5 | |
| 2 | 13 | Facial Recognition | 4.5 | |
| 2 | 12, 13, 17 | Leauge based | 4.5 | |
| 1 | 26 | 3D printed in Bioplastic | 4.6 | Construction |
| 2 | 2, 3 | Fits the walls in Marsha house | 4.6 | |
| 2 | 1 | Vibration damping towards the floor | 4.6 | |

## 4.8 Milestone 4

At Milestone 4 the feedback addressed the product value and motivation.

It was pointed out, that the different elements of B-Fast include more product value than presented. The opportunities and values in using the elements apart would be good selling points. The vibration board is designed, so it can be used separately for other training purposes - and the AR lenses will properly be as normal to have as a smartphone is today.

B-Fast is designed for playing a specific game, ensuring the right movements to train the vestibular system. Also, here the opportunity of expanding into the development of other games is clear. In this way, B-Fast would function as a new platform/gaming device.

The work with motivation and maintenance was mentioned several times. *How can we make sure, the users keep engaging with the product?* The whole process has been focused on motivation factors from the gaming world which was tied together in internal and external motivation. These factors are implemented in different ways, to give the best possible circumstances for engagement and fun day after day.

At last, the league design as an app was questioned. The criticism was based on apps been an old-school solution and mentioned as a misfit. On the other hand, the future technologies used (AR and ultra-haptic feedback) as well as the opportunity of changing AR with holograms in the future, were perceived well.
The app was chosen as a solution to keep a connection to Earthly belongings, but if it is outdated in the 2060s, we can only guess.

## 4.9 Sum-Up

### Acquired Knowledge

- In the 2060s there will be different manufacturing capabilities on Mars, including the production of bioplastic.
- With a AR lenses and ultra haptic feedback, a feeling of touching and seeing a real thing can be made.
- All shells of B-Fast can be 3D printed on Mars.
- Only the electronic components and drawers with the AR lenses must be shipped.
- With a ERM motor and gas springs, the right outcome of vibrations within the board can be secured.
- Motivation can be both internal and external, both types are included multiple times in B-Fast.

### Further course

- Finding the key values within B-Fast for reframing to Earth.
- Setting up a reframing design brief.

## PHASE **5.0** REFRAMING

# BACK TO EARTH

The fifth section contains a reframing of the product developed for Mars in the four previous phases.

The reframing phase covers how the knowledge obtained from the first four stages, can be used to produce a quick pace product. Through this phase a new present context on Earth will be clarified and how B-Fast can be adjusted and fit into this scenario. The general structure and production of the product will be conveyed, while a larger focus on the business aspect will be included.

Ill. 104: Reframing (latestwallpapershd, n.d.)

# 5.1 Reframing to Earth

***While reframing it was necessary to shortly divergence to open the solution space, before selecting a direction to convergence from (Design Council, 2005). Four initial concepts were assessed and evaluated (app. 51). The chosen concept was framed into a target group, that lead to the initial design brief followed by mapping of interaction possibilities (based on knowledge from the original product proposal).***

## Setting a direction

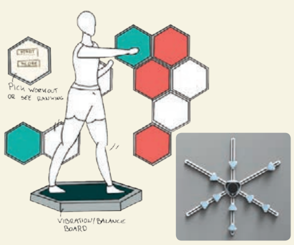
Previously a holistic approach was used to create B-fast (p. 14). Here the solution proposal, gamified exercise equipment with an app, was created to motivate the space travellers and astronauts to do obligational training.

By keeping the holistic approach and use of gamification as a motivation factor (p. 14-15) for the reframing, different implementations and possibilities on Earth were ideated on. Due to the limited amount of time, the solution space was diverged shortly before converged into a chosen concept. Through three rounds of ideation different approaches to target groups were considered (app. 51).

The four concepts which had the most potential was chosen for evaluation (see below) using pros, cons, USP's and market potential as value parameters.
Concept 3 was chosen for further development, due to its biggest market potential.

CHOISE

### Concept 1



Ill. 105: Concept 1

Designing B-Fast to fit on Earth, for home-training, gyms or mental breaks at an office.

The solution is big and permanent since it cannot be moved due to installation on the wall and might result in a smaller market.

### Concept 2


Ill. 106: Concept 2

A large scale version of La Boca (Ultra Board Games, n.d.). It has a mastery element and can be placed on offices or universities to create a break with a social aspect between co-workers.

The solution is big and low tech which narrows down expansion possibilities.

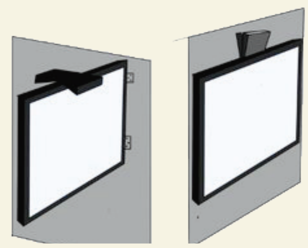
### Concept 3


Ill. 107: Concept 3

A quiz game with spots, using a tablet as the platform for the game.
The product has big market potential. It can be used for active learning in all grades (from pre-school to university) or a family quiz.

The solution is lacking a specific target group.

### Concept 4



Ill. 108: Concept 4

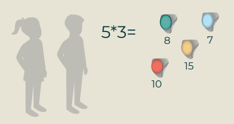
A big touch screen where different games can be implemented.
The screen has big customizability, fits places in offices and school, and could have multiple uses.

The solution is close to other solutions on the market.

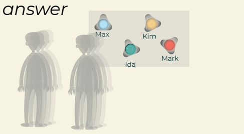
### Context Definition

To create a clear frame, three implementation cases were defined (ill. 109).
Primary schools were chosen for context as a physical and active learning tool.

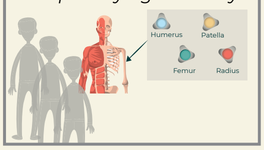
Primary school
*Two kids learning math*




High school
*Two teams, one runs and answer*




University
*Group studying anatomy*

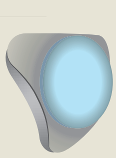



Ill. 109: Context definition

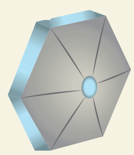
### Aesthetics Direction

The design of the spots was shortly considered (ill. 110). It was decided to work with the same shape as B-Fast, to maintain a resemblance.

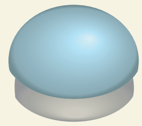
Spacy



Edgy



Buzzer



Ill. 110: Aesthetics direction

# Design Brief: Reframing

***The following is a reframing of the final design brief from Mars, in terms of problem definition, vision and mission. Initial design parameters were set up, to define possible requirements due to the short timeframe. These are based on knowledge from the Martian framing.***

## Problem definition

"How to create a product that supports the obligatory learning goals through physical activity and active learning?"

## Mission

To close the gap between motivation for learning and being physically active.

## Vision

To arouse pupils' enthusiasm for learning through social and physical activity.

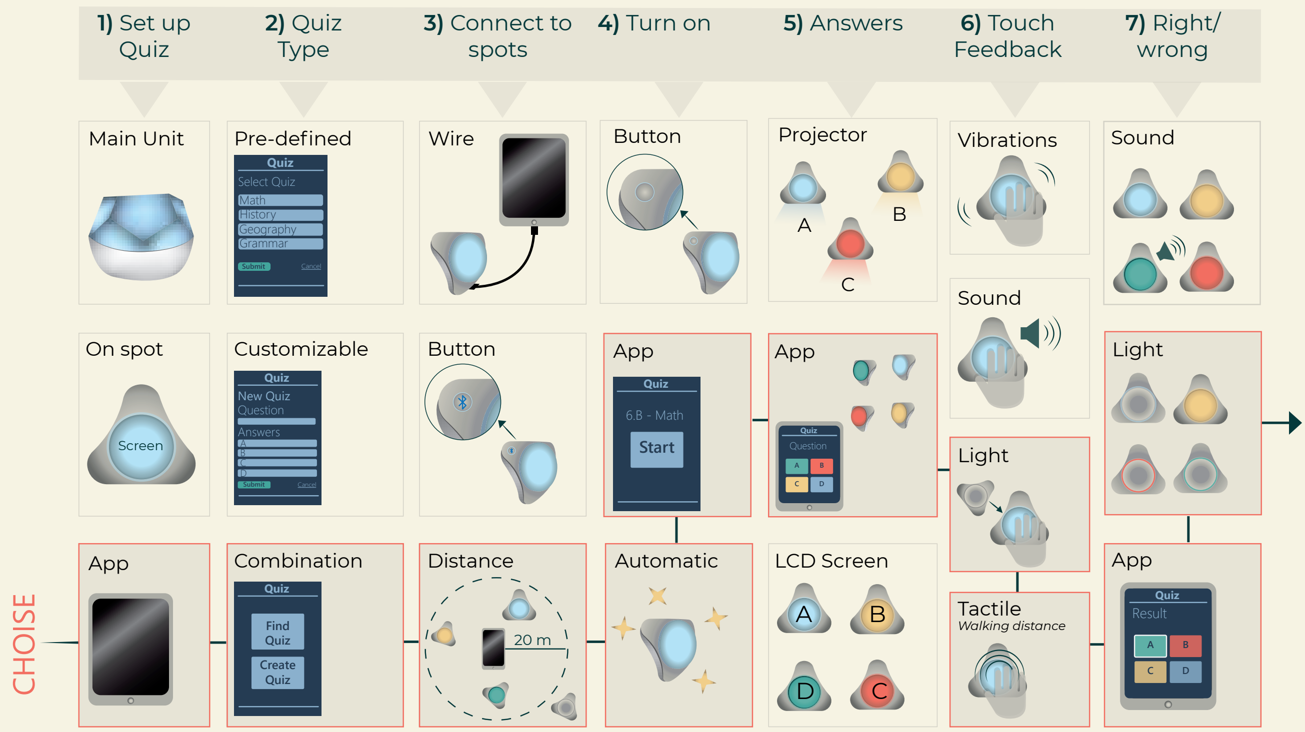
## Design parameters

- Competing or working together
- Include social element
- Learn by doing
- Movable spots - Create physical quiz game
- Customizable platform - tablet
- Functional feedback in spots
- Colours as indicators
- Impact social, mental, and physical development
- Context: Primary schools

## Morphological diagram

Based on the design brief and previous knowledge a morphological diagram (A.G.C. van Boeijen et. al.) was created (ill. 111). Considered was how to maintain motivation (p. 14-15), spike senses (p. 41) and use of feedback (Wensveen et. al 2004).

This showcases the framing around the concept and the chosen solution marked with a grey box with a red frame.
Please note that the diagram was made iterative with the research found on the next page.




Ill. 111: Morphological diagram

***A design brief and overall direction for the reframing were set. Further development will deal with physical and active learning, through an active quiz.***

# 5.2 Active Learning

***This section will investigate the frame set by the problem definition of creating a product that includes physical and active learning in schools. An investigation of how active learning can breach the barrier of social interaction by making the pupils' participate actively while learning. Gamification will be a key point of this investigation because of the mental health benefits it brings along with increased motivation.***

## What is active learning?

Active learning enables pupils' interaction or participation in the learning process, instead of taking information in passively. Pupils enhance their performance when getting the opportunity to actively take part in the learning process. This nourishes the brain and allows it to learn new information, correct earlier misunderstandings, and reconsider existing statements and thoughts.
Active learning includes *discussions, reviews, practicing, problem-solving, exploration conceptualizing, applications, etc.* The brain is encouraged through active learning to activate cognitive and sensory networks, which help you process new information. (Parker et al., 2019; Smart Sparrow, n.d.) (app. 52)

## Kahoot

FACT

Kahoot is getting widely used as a learning tool for almost every age group in the school system. This is caused by the simple structure and customizable way of obtaining and conveying knowledge actively and playfully. Kahoot's platform allows for a variety of possible tools for learning, which makes it suitable for many scenarios and levels of difficulty. Kahoot is based on question-based learning but also includes the *possibilities of active learning, problem-based learning, project-based learning, cooperative and collaborative learning.* The diversity in the possibilities makes it an ideal platform for learning, with the only downside to it, being the lack of physical interaction. (app. 52)

## Learning though Physical Activity

The brain is more active during and after physical activity. When moving, the brain activity improves. (Nielsen, 2016).

### Movement implemented in the schools

As a part of the Danish primary school reform paragraph §15, the tutoring should be organized, so the pupils get an average of 45 minutes of exercise and movement each day (Retsinformation, 2017). The intention is to provide children and young people with good health and further support learning the different subjects. Besides, the movement must all contain an educational aim (Børne- og Undervisningsministeriet, 2020).

The Ministry of Children and Education suggests three ways of including physical movement as part of the teaching:

1) Movement sequences can be added to vocational education to support learning and training.
2) As part of the supporting teaching, movement can be implemented.
3) Movement can be arranged in collaboration with the local association life, such as cultural or sports associations, and can be extended to proceed over a longer period.

(Børne- og Undervisningsministeriet, 2020).

### Learning benefits of Physical Activity

A lot of research suggests that movement can promote learning. In an evaluation booklet from 'Kræftens Bekæmpelse' made in 2018, concerning the program '*Play on line*', was that:

- Physical activity integrated into the teaching, has been proven to strengthen learning.
- Improves cognition when physical activity is used in extension of the bookish learning. This relates to *the perception of space, working memory, problem-solving, language skills, logical thinking, self-perception, and attention.*
- Physical activity can improve brain development through learning and experience. To be as beneficial as possible the physical activity needs to be challenging, vary, and involve successful experiences.
- Through physical activity children's well-being was improved. Well-being must be understood concerning mental, emotional, and social processes while motivating participation in activities.

(Bangsbo et al, 2016; Pedersen et al., 2016) (app. 52)

Must facilitate active learning

Must be quiz based

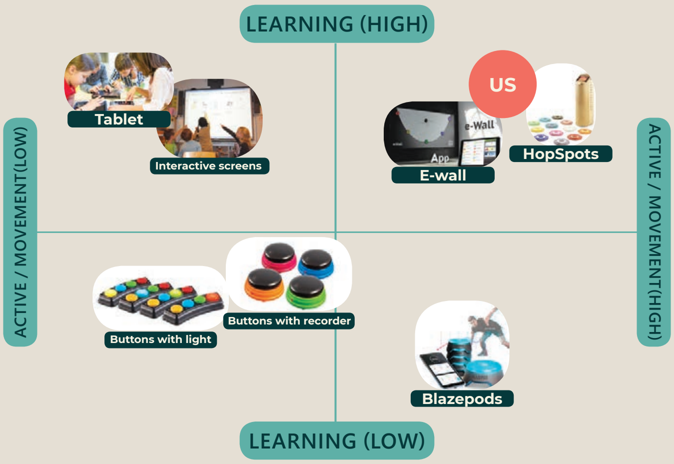
***Based on this research some unique selling points can be taken further on to develop the product:***
***- The product ensures that children and young people engage in social interaction.***
***- The product enables children and young people to learn actively through physical activity.***
***- The product should motivate children and young people to participate actively in their education.***
***- The product should foster social skills, creativity and teamwork.***

# 5.3 Development

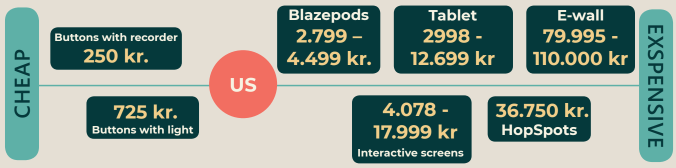
***Market research on products that relates to active learning and movement, was conducted and mapped (app. 53), to set up a solution space. This was used for further development (app. 54 and 55).***

## Market analysis

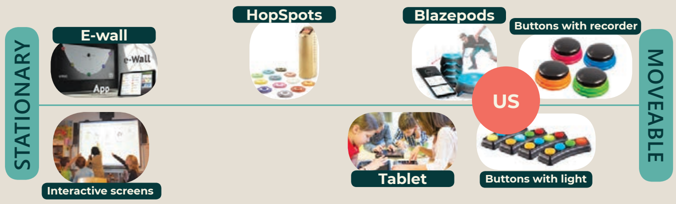
Perceptual mappings (KOSAKA, n.d.) were created. These mapped at first the balance between learning and movement (ill. 112) (app. 53), setting up guidelines for the development (red dot).
The same products were used to make a perceptual mapping on price (ill. 113), movability (ill. 114), social interaction, and aesthetics (app. 53)
The mappings were used as a steppingstone for further development of construction, choice of materials, production methods, and market strategy.




Ill. 112: Perceptual mapping, movement&learning (minbyholstebro, 2018) (Hansen, 2012)(e-wall, n.d.)(Hotspots, n.d.)(legeakadamiet, n.d.)(amazon, n.d.)




Ill. 113: Perceptual mapping, price




Ill. 114: Perceptual mapping, Stationeary/moveble (minbyholstebro, 2018) (Hansen, 2012)(e-wall, n.d.)(Hotspots, n.d.)(legeakadamiet, n.d.)(amazon, n.d.)

## From ideation to concept

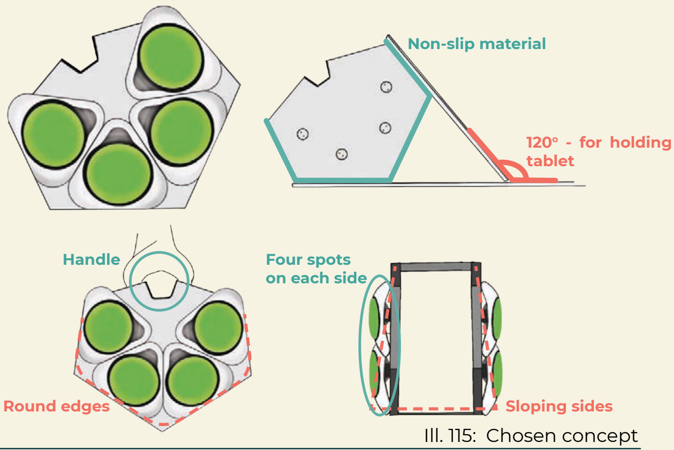
### Ideation

The perceptual mapping showed that the spots should be movable and a charging station for the spots was needed. Therefor the concept consists of a charging station and eight spots (ideation in app. 54).
The main function of the concept is an active quiz (p. 66) for two teams, with four answer possibilities for each team (*one unit = charging station for eight spots*). Ill. 115 shows the chosen concept.

### Testing

Using the charging stations as a 'platform' for holding the tablet, containing the quiz, was found useful.
A test set the angle for the table to 120 degrees (app. 54). Non-slip material on the edge was decided to secure the tablet from sliding (blue line ill. 115).

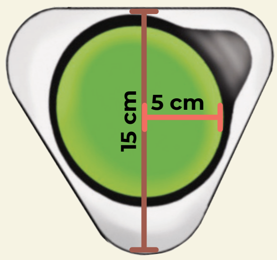
The charging station's size was set in coherence with testing the best spot size and a pleasant walking experience (app. 55 and ill. 116,117). The push-surface of the spot was set to a radius of 5 cm (ill. 118).




Ill. 115: Chosen concept

Ill. 116: Spot size, test

Ill. 117: Walking test




Ill. 118: Spot size

✔ Tablet angle: 120 degrees

✔ Number of spots: 8

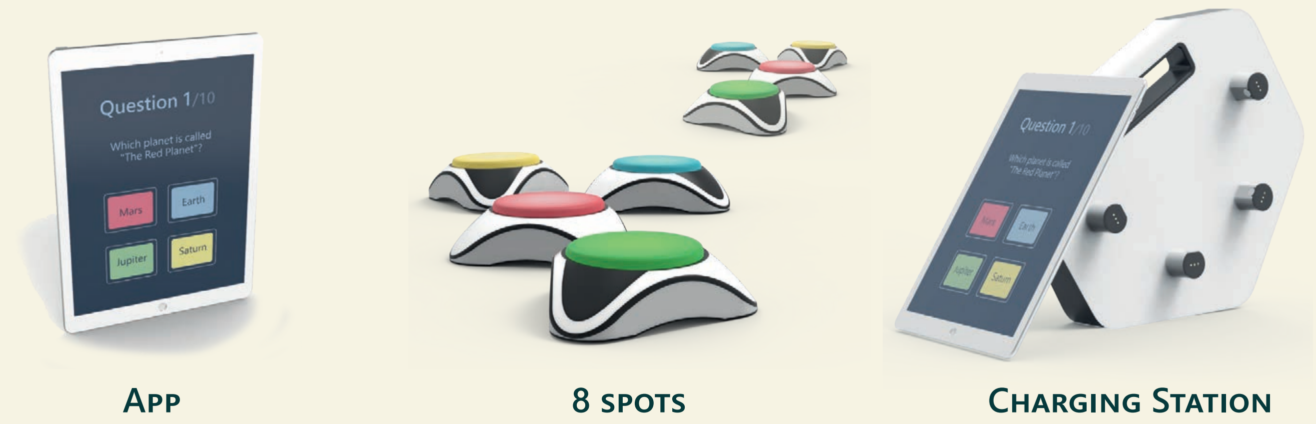
✔ Non-slip material on edges (charging station)

✔ Spot dimensions: Triangle 15 cm (h), Push button 5 cm (r)

***The market analysis showed where the concept should stand out. Based upon those factors a concept was developed through ideation and testing, consisting of a transportable charging station with 8 spots.***

# 5.4 B-Smart: Use

***B-Smart consists of three elements: an app, 8 spots, and a charging station. The spots can be transported and charged on the charging station. The quiz is managed from an app where the spots are connected to.***



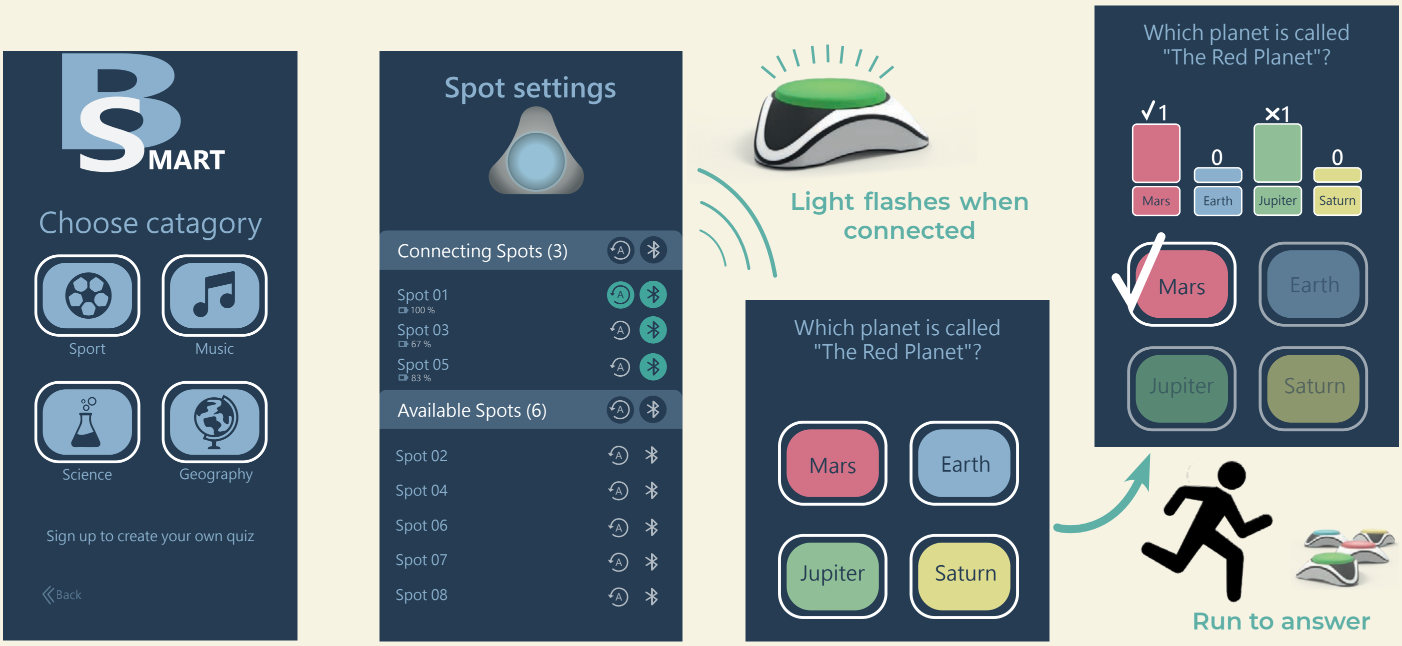

Ill. 119: B-Smart, elements

## Setup & Connection

The app takes inspiration from Kahoot (Kahoot, 2021) but with active learning as a focus. The key functions of the app are presented on ill. 120, find the rest in app. 56.
Sign into the app and choose a predefined category or make a quiz. In the app, the user can: Start quiz, set up the game, see the questions and answer options.
The spots are connected to the app by Bluetooth. Each pupil or team can have up to four answer possibilities.

## The Quiz

The spots can be used for active learning when placed further apart so the pupils need to run to answer. The questions are displayed with four colours on the tablet, matching the colour-code equal to the colour on a spot.
The pupils can only answer by pressing the spot.
When each team has answered the question, the right answer is displayed on the tablet.




Ill. 120: B-Smart, use

Tablet station | Quiz based | Customizable app | One set include 8 spots | Facilitates active learning

***B-Smart makes an active learning device for teachers as they want to make the teaching more active and fun for the pupils. The gamification aspect motivates the pupils to learn in a new way through the exercise. B-Smart is designed to make no limit of active learning; the users decide the frame.***

# 5.5 Construction

***Here a final detailing of both the spots and the charging station will be reviewed. This review will include knowledge about material, production, price, and electronic components (details in app. 57 and 58).***

A unit covers eight spots and one charging station. To produce a unit for use in primary school, it is necessary to produce a product that can withstand a lot and has an enclosed structure.

### Charging Station

The two identical shells of the charging station are produced by injection moulding in ABS. A hole for the USB-C charging port is cut out, at an upward angle for optimal visibility, after the part has been injection moulded. This ensure only one mould is necessary to produce the shell. Female pogo pins are mounted on the charging station making sure the male part will not be damaged in the very exposed positioning. Magnets are used to fix the pogo pins together and the straight surface, that the magnets are placed on, makes sure that the pogo male pins does not rotate of the female pogo pins. (app. 57)

### Spots

For the top part of a spot, the transparent push surface, acrylic is used. Acrylic is a strong material and UV resistant. The material is used for many kids toys because the material has no toxins in it. This material is also optimal for use with light because of the transparency of the material. The rest of the shell is produced from ABS, like the charging station, because of the many colours and the cheap price of the material. Every shell part is injection moulded.

The PCB board includes the CPU and a Bluetooth component. A push button is mounted on the backside of the transparent push surface to deliver tactile feedback to the user. RGB LEDs' are mounted around the button to light through the transparent surface. The 3.7v 500mAh battery will make the button work over longer periods, while the pogo pins and magnets allow for secure charging of the spots. (Details in app. 57)

Fact

**Production price estimation**
*1 unit = 8 spots and 1 charging unit*

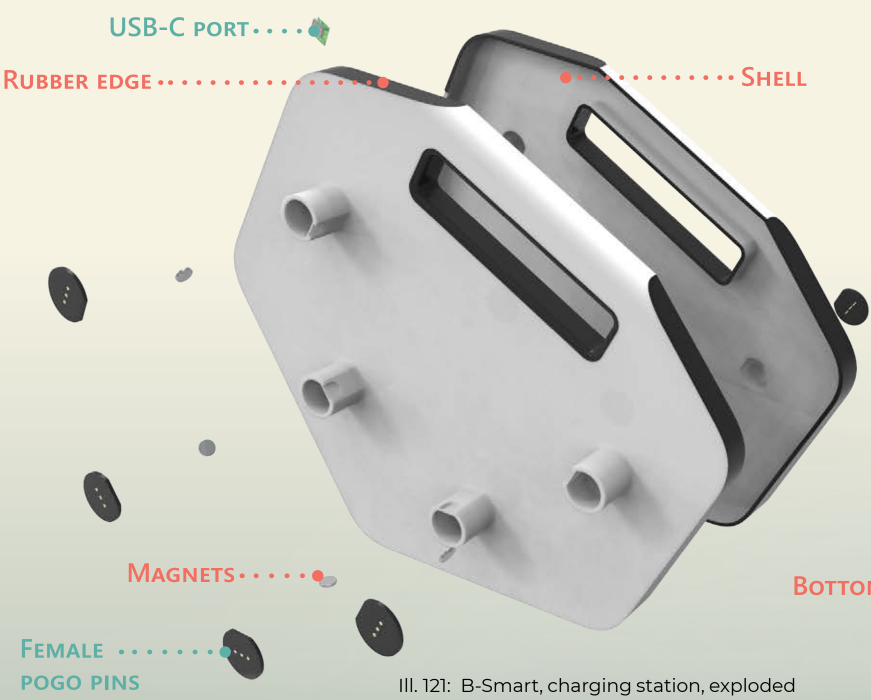
Electronic components:
**288 DKK**

Non-electronic parts + production:
**219 DKK**
App. 57 and 58

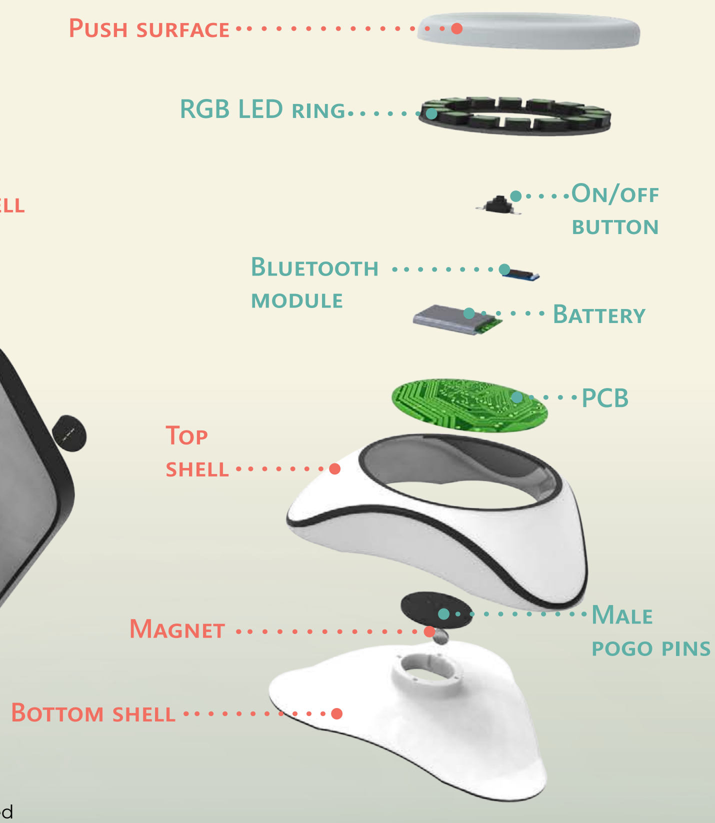
**Sale price: 1.000 DKK**

## Charging station and Spots

Electronic component
Non-electronic component




Ill. 121: B-Smart, charging station, exploded




Ill. 122: B-Smart, spot, exploded

! Secure charging

! Wireless spots

! Multible colour lighting

! Tacktile and visual feedback

***This price is an estimate of only the physical product. Large potential is seen in the yearly fees the connected app can bring to the value. Therefore, the entry price buying into the physical product is kept low.***

# 5.6 Market Strategy

***A business-model framework was made to create an overview of the business aspects that has an impact. The model evaluates a start-up business (Hulme, 2010) (ill.123). Some of the elements will in this section be elaborated.***

## Business-model Framework

**Growth Strategy**
B-Smart has the potential to expand into the B2C markets, after getting commonly known on the B2B market. Besides, there is also the opportunity to develop the associated app.

**Partners**
Investments are needed to start up the development and production. This could include investors with interest in active learning.

**Capabilities**
Production partners must be found. The production location is considered (ex. Denmark or Poland). Technical components purchased (ex. in China). The shipping costs are a part of the considerations.

**Cost** !
To give an estimated bid for the cost of the product, a cashflow and an NPV are made. (ill. 127)

**Value Proposition** !
The value in the B-smart is based on Active learning (p. 66)

**Channel** !
The product will be promoted to schools and municipalities through cold canvas and conferences.

**Pricing Model** !
The pricing strategy allows more products to be added and there is a subscription element through the associated app (described through models of business patterns)

**Market Segments** !
B2B is the focus as a market segmentation for a start.
Later this can be expanded further. For a start, the schools in Denmark are seen as potential customers.

**Competitive Strategy**
It is especially the price B-Smart competes on, compared to other products on the market (ill. 113 p. 67), as well as on the possibilities for further app development.

Ill. 123: Buisness model framework (Humle, 2010)

**Fact**

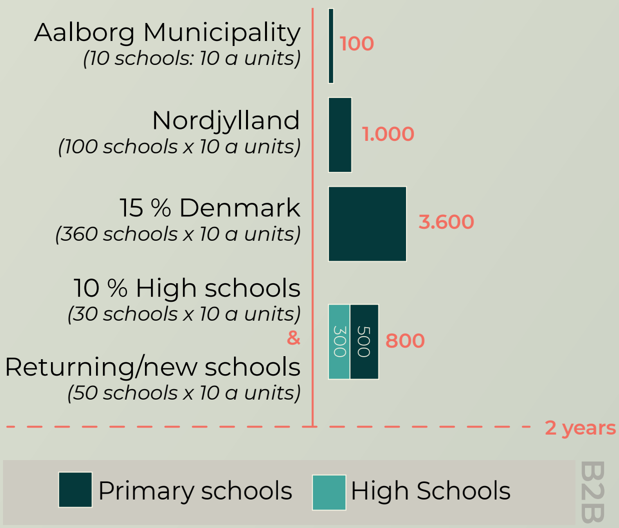
! **1 Unit** = 1 Charging station with 8 spots

## Value Proposition and Market Segment

One of the essentials in this Business-Model framework is the value proposition and the market segment.
The core value in B-Smart is active learning, which initially addresses schools as potential buyers. Besides, municipalities can also be potential buyers to approach many schools at once.

To specify which and how many potential users there are within the B2B segment, it has been investigated how many schools there are at the national level (app. 59). A best-case and worst-case scenario were assessed concerning how many schools that potentially would buy B-Smart over time (app. 59). Based on the worst-case scenario, the starting point for B-Smart will include sales to 550 schools which each buys 10 units.

Total sales in 2 years: **5.500 units** !




Ill. 124: Expected sales

# Channels

A big potential is seen in the B2B market and there are different approaches to enter this market. One way to promote B-Smart is through the 'cold canvassing' approach. Here the contact is made directly with potential customers, and thereby interests and hopefully, sales are made (Jones, 2019).
Another option is newsletters, to promote B-Smart's possibilities to new customers or so existing users can see extensions of the app or other possible acquisitions.

The B2B market can be approached by being approved as a SKI supplier (requires approvals and payment) (Santerelli, 2020) or through 'Udbudsvagten'. Here you can keep an eye on possible defined tasks. The product needs to exceed other product that delivers similar solutions.

Conferences which, for example, deal with active learning, could also be a door to the market. Here, B-Smart can both be promoted, but it is also possible to create contacts for sales. (app. 60)

# Pricing Models

To be competitive on the market, a sales price was set. Here, possible business patterns were used (app. 61). For B2B, two patterns were seen as potential for B-Smart. (Business Model Toolbox, 2021)

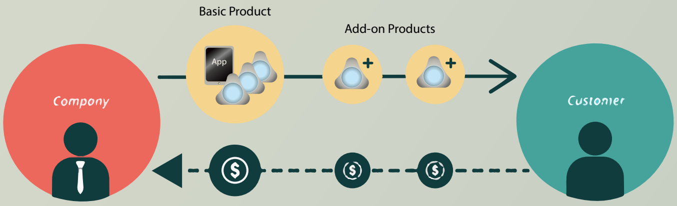
The first is 'Add-on', where schools buy a basic product (one unit). This makes the customer able to subsequently expand by purchasing more spots or unlock functions in the app (ill. 125).

The second pattern relates specifically to the included app. Here a subscription solution is used, as this provides the profit to develop the app on an ongoing basis. The subscription would be on an annual basis and the cost depends on which offer the user buys into (ill. 126).

Other subscriber agreements for existing products were examined to set a price for B-Smart. (app. 61)

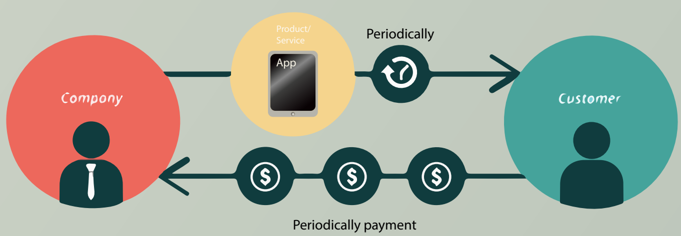
**Subscribtion**
5 units: **4.000 DKK**
10 units: **6.000 DKK**

### Add-On

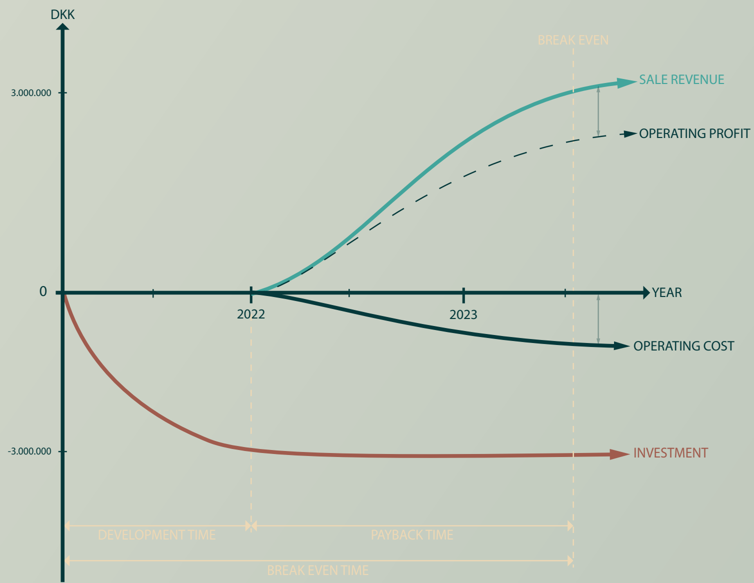



Ill. 125: Buisness pattern, Add-on (Business Model Toolbox, 2021)

### Subscription




Ill. 126: Buisness pattern, Subscription (Business Model Toolbox, 2021)




Ill. 127: Cash flow

# Cost

A simple Net Present Value (NPV) was made for the estimated potential sales for B-Smart to create an overview of the cashflow and ultimately reveal whether it will be a good business case in the long run. The product's production price was calculated at 507 DKK for 1 unit (app. 57) and a sales price at 1.000 DKK was set.
*The simplified NPV showed a profit after selling 5.500 Units over two years (app. 62).*

However, the calculation lacks income and outcome from the app development and subscriptions.
The profit from app subscriptions equivalent to 5.500 units will be 220,000 DKK (if every subscription is for 10 Units a 6.000 DKK/year) (app. 62). The cashflow is visualized on ill. 127.

Production costs (1 unit): **507 DKK**
Sales price (1 unit): **1.000 DKK**

***The opportunities with B-Smart and the associated app are many. These have been explored to see expansion possibilities in the future and increase market potential.***
***The opportunities within expansion could be within other learning games (ex. reaction games), new add-ons as a supplement to the spots, or collaborations with other providers like Kahoot (app. 63).***

# 5.7 Requirements & Specifications

***The reframing lasted one week, which led to it being handled as a design sprint. This resulted in only one round of requirement setting, while some were kept from the original framing. The requirements were quickly translated to final specifications (Ulrich & Eppinger, 2000). The initial design brief (p. 65) was not revised due to the sprint approach.***

## Final Requirements

| No. | Need no. | Metric | Unit | Value | Source | |
|---|---|---|---|---|---|---|
| 1 | - | Must facilitate active learning | - | Binary | 5.2 | Reframing |
| 2 | - | Must be quiz based | - | Binary | 5.2 | Reframing |
| 3 | - | Non-slip material on edges (charging station) | - | Binary | 5.3 | Reframing |
| 4 | - | Tablet angle | degrees | 120 | 5.3 | Reframing |
| 5 | - | Number of spots | quantity | 8 | 5.3 | Reframing |
| 6 | - | Spot dimensions | cm | 15 (h)<br>5 (r) | 5.3 | Reframing |
| 7 | 6 | Help to maintain the cardiovascular system | - | Binary | 2.3 | Original framing |
| 8 | 11 | Acknowledgment by overcoming challenges | - | Binary | 1.3, 3.10 | Original framing |
| 9 | 12 | Include social elements *(competition and community)* | - | Binary | 1.3 | Original framing |
| 10 | 14 | Cross-Generational | Years | 10-60 | 3.2 | Original framing |
| 11 | 15 | Facilitate learning by doing | - | Binary | 3.8 | Original framing |
| 12 | 16 | Esthetics: Retro-Space vibe | - | Binary | 3.8 | Original framing |
| 13 | 26 | Functional and inheret feedback in Sports | - | Binary | 3.6, 3.8 | Original framing |

*refers to final design brief p 3.11

## Specifications

| Spec. no. | Need no. | Metric | Source |
|---|---|---|---|
| 1 | 3, 4 | Tablet station | 5.4 |
| 2 | 2 | Quiz based | 5.4 |
| 3 | 1, 9 | Costumizable app | 5.4 |
| 4 | 9, 10 | One set includes 8 spots | 5.4 |
| 5 | 1 | Facilitates active learning | 5.4 |
| 6 | 11 | Secure charging | 5.5 |
| 7 | 7 | Wireless spots | 5.5 |
| 8 | 8, 13 | Multiple color lighting | 5.5 |
| 9 | 13 | Tactile and visual feedback | 5.5 |

*refers to final requriments above

# 5.8 Milestone 5

At Milestone 5 the connection to the original framing for Mars was seen as natural and clear. The feedback centered around three topics: Community, expansion possibilities, and the B2B market approach.

To bring in the elements of activity and gamification to a learning situation were perceived well. It was seen as good timing, caused by the social element due to the schools starting to open again after corona lockdown. The potential for B-Smart to become a trend was addressed.

At the same time, a concern about the narrow use case was mentioned. It was questioned about the capability, weather it will be possible to keep developing on a Q&A based product to keep it interesting.

The idea of approaching the B2B market first was perceived with doubt. The viewpoint was, that the B2B market is difficult to enter. The outcome of a higher learning curve needs to be proved before they will buy.

At last, it was discussed if collaborations with existing platforms like Kahoot would be beneficial, instead of developing a specific app for B-Smart. This could both open for expansion possibilities, but also narrow them down. In terms of the primary school framing, a specific app was though mentioned as smart, since the requirements from the schools may be specific.

# 5.9 Sum-Up

## Acquired Knowledge

- Active learning facilitates pupils to actively take part in the learning process
- A combination of physical activity and learning strengthens the learning and outcome from it
- To be competitive on the market, the solution must be movable and be sold for 1.000-2.000 DKK
- A transportable charging station was designed for 8 spots
- An app makes it possible to set up any quiz the user wants
- Production price for one unit is 507 DKK.
- B-Smart is sold for 1.000 DKK, break-even will enter right before 2 years has passed

## Further course

- Conclude the whole project
- Reflection upon the Martian and Earth framing

## PHASE 6.0 EPILOGUE

# TRAVEL DIARY

The finishing section covers a conclusion on the product proposal for Mars and reframed version for Earth. Additionally, the process and product proposals, as well as the framing for Mars and the reframing for Earth, are reflected upon.

Ill. 128: Epilogue (Yuri, n.d.)

# 6.1 Conclusion

### Framing
With the main topic of designing for space, this project focused on Mars. This was later framed to motivating training of the vestibular system (*eye-hand coordination and balance*).

Before diving into the project, the conditions on Mars were investigated including environment and daily routine. It was found that space travellers must train a minimum of two hours a day to maintain physics caused by the microgravity. The current equipment for training in space is focused on the cardiovascular system (running, biking, etc.) and strength (cable drawing). This led to different new approaches of making the existing training equipment and methods more appealing by adding different kinds of fun factors.

### Focus points
Through research and an interview, it became clear that decomposition of bones happens fast in space, and the vestibular system was challenged. This increases the risk of falling, something that in space can have fatal consequences, because of no health care system. At the same time, motor skills and balance will be inferior.

With this knowledge, the project took a turn, and the focus became three folded:

1)Challenge and train eye-hand coordination and balance
2) Find a way to slow down the decomposition of bones
3) Motivating to do the activity trough gamification

It was found that a vibration board was developed for Russian astronauts to affect the body, in the same way as shocks from walking in Earth gravity, meaning the right amount of vibration can slow down the decompression of bones.
It was also found how gaming and exercise can be beneficial for mental health. Elements from gaming theories about maintenance and motivation, like *acknowledgment, competition, and community*, were implemented to spike the fun factor.

### B-Fast: Reaction game
The process resulted in the product proposal B-Fast, which uses technologies thought to be relevant in the future. B-Fast consists of the main elements *AR lenses, a vibration board, and Main Unit* combined into a reaction game.
The vibration board challenges the balance and benefits the bones. The Main Unit uses ultra haptic feedback, which makes it possible to tap spots, that are seen through the AR lenses. The whole concept is bound together in an app, making the users able to set up leagues with family and friends.

### B-Smart: The active quiz
The main elements from B-Fast were found and reused for reframing, with B-Smart as the result. An active quiz for active learning in primary schools. Here the spots were implemented, but now as answer possibilities, that can be placed where the user wants them to. In this way, the quiz can be handled from an app, and the kids run to the spots for answering.

The benefits of improved learning by implementing active learning and physical activity were found as the reason for the product to exist. For B-Smart a market strategy was set, and a cashflow was made. This shows that B-Smart would be a beneficial business with a lot of potential, that in the worst-case scenario would have a 'break even' right before 2 years.

# 6.2 Reflection

The following refection covers the project's two parts; original framing for Mars and the reframing for Earth. Furthermore, it approaches *the two product proposals, the business aspect, and product architecture, as well as the level of innovation*. This will be considered due to theoretical methods and on a practical level (Elaboration of the used methods can be found in app. 1)

## Process approach

This section seeks to identify the struggles of working with a framing far into the future and how it was navigated through '*The Fuzzy Front End*' (FFE) (Koen et.al., 2002). This leads to the different challenges, in terms of designing for Mars and later reframing for Earth. The limited resources for testing due to both corona and the Martians conditions will also be elaborated.

### Dealing with Mars and the fuzzy front end
The process of the original product proposal, B-Fast, is evaluated through Koen's (2002) view on *'The Fuzzy Front End'* of an innovation process and '*The Knowns and Unknowns Framework*' (Justo, 2019; Mantovani, 2020).

The project started with a blank piece of paper, where there were many '*Unknown Unknowns*' (Justo, 2019; Mantovani, 2020) factors to address. At that time, knowledge of Mars and associated conditions were very limited to non, which meant that it was necessary to study Mars, and in that way, try to create more '*known*' factors to develop on. This was mainly done through desktop research.

Working within FFE (Koen et.al., 2002) mainly with *'unknown unknowns', 'known unknowns'*, and making estimated assumptions based on the gained knowledge, was difficult. Every time new understanding was achieved it led to new unsawed questions, making the process even more frustrating, as seen in the many iterations. Taking this into account from '*The Future Cone*' perspective (Voros, 2017), many of the concepts considered was '*projected future*'. The solutions span from computerized clothing to low-tech solutions built on present technologies. The safety of a low-tech solution led to choosing those. The implementation of fitting future '*preferable*' and '*probable*' technologies (as AR lenses and the ultra haptic feedback) first happened in the Deliver phase.

An ongoing '*known unknown*' in the process was the missing understanding of how the gravity conditions would affect the movement of the body, and especially the upper body. Considering this continuous question, that kept coming back through each iteration, resulted in spending a long time in the fuzzy front end of the process.
Desktop research was a big part of the attempt to find answers to this problem, however, this gave different statements about the problem and thus necessary to take a different approach, in which an expert in the field was contacted. After an interview with Thomas A. E. Andersen from Danish Aerospace Company, the uncertainty was turned into a '*known known*' which gave the process momentum again. And yet the product proposal was mainly built on research, leaving B-Fast as a '*known unknown*', still to be tested.

### About Framing - and Reframing

Throughout the project, various methods have been used both in terms of designing for Mars and Earth. There were several differences between the two processes, where in particular the applicable timeframe for the two product proposals was different. The process of designing B-Fast for Mars lasted seven weeks. In contrast, the reframing for Earth resulting in B-Smart lasted 6 days. This meant more time for detailing and exploration of possibilities for the original framing.

The process of the proposal for Mars was done with a mixture of two iterative process models, '*Double Diamond*' (Design Council, 2005) and '*Striim's Idea Development Model*' (Striim, 2001) (p. 9). In contrast, the reframing process for Earth was more structured as a sprint (Visual Paradigm, n.d.). The sprint was approached with background knowledge from the previous studies from B-fast, combined with new specific requirements for B-Smart concerning elements as active learning.

These different approaches have had clear effects on product proposals. Relating to the Martian concept, the longer-lasting converging and divergent process has resulted in a very technical solution, because of the more complex user scenario and future perspective. In contrast the product proposals for Earth were done as a sprint and ended in a less technical solution, as the approach had its focus on keeping the price low and the scenario was in present time. In particular, this would have an impact on the marketing and possible sales of the product, which was not applicable to Mars.

A challenge, especially for the development of the product for Mars, was the many assumptions that created a basis for decision-making. In contrast, the development of the product proposal to Earth was more manageable and the problem itself, more recognizable, which meant that the detailing part could go significantly faster.

### Research-based vs. User-oriented design approach

The overall process has been mostly research-based due to two significant impacts: Corona lockdown and Martian conditions. Corona had an impact on the whole process, hence everything was done and shared digitally. This made the process more research-based than desired. The user-oriented approach was missing due to the assembly ban. The other impact was caused by the project's context on Mars. The low gravity among other Martian conditions made the performed tests questionable. Unknown factors as with a context on Earth easily can be tested, had to be desktop researched and assumed instead.

The outcome of the research-based proposal for Mars, B-Fast, can be reflected upon regarding *Erik Lerdahl's vision-based model* (Lerdahl, 2001). On the '*spiritual level*', B-Fast implement a holistic approach for maintaining the health of space travellers. Considering the 'contextual level' in correlation to the '*principal level*', the user interaction, and structure of the concept was based on low-tech tests with cardboard mock-ups of the spots, a try-out of a vibration board, and tests with a balance board. Because of the missing accesses to the workshops and users, B-Fast is built mainly on methods as '*6 factor of happiness*' and research about maintenance and motivation underlined with feedback and feedforward, for the needed interactions (p. 15, 41, and 45). The functionalities on the 'principal level' are in this way associated directly with the interactions and symbols on the *'contextual level'*.

This was a confusing point, as it was visible that many solutions for interaction were feasible on the '*contextual level*'. With a more user-oriented approach, it may have led to a quicker and more clear direction towards the best form of interaction and which functional principles to implement. This approach could also have given better evidence for the choices made.
On the '*material level*', the chosen technologies (ultra haptic feedback and AR lenses), are just one way the wanted interaction can be achieved. Further, the chosen production methods and materials are built on research including expert-based assumptions of the future.

Both concepts (B-Fast and B-Smart) implements gamification as a motivation factor, to perform a task in which the participant might not feel like doing. An ongoing uncertainty of the concepts is the game part. The two games were never tested fully due to the mentioned limitations, and therefore they are built on evidence from research as scientific articles and similar products on the market. As many and as valid as a possible low-tech test with mock-ups were made. These were used to validate some parameters as sizes and challenge level of standing on a vibration board or balance board when trying to hit some spots placed on the wall. Even so, it still leaves the question within the fun and motivation of the games, in which further development would include testing on multiple users with more advanced prototypes. At this point, the argumentation can only be validated through theories.

### A Digital process

As motioned the whole process has been structured digitally, this was done through a virtual group room, called *Miro*. Here an overall schedule was made. In addition, a two-week schedule was made, in which task and upcoming deadlines was presented, which made it possible to focus on the coming task ahead. The overall online planning structure functioned well.

Since a physical group room was not available, the ideation methods, sketching, and mock-up, was done individually, and then shared on Miro and discussed over Microsoft Teams. This process overall worked well, but the group did experience some unclearness along the way regarding the testing and mock-ups. This was due to the lack of physical interaction, where dimensions and visual size in real life, was not possible. As a result, the group ended up redoing some of the tests individually.

Another consideration is that the communication of found information took a longer time than normal. This could be a result of, not being able to share information throughout the day, as done under normal circumstances at the university. Normally this makes it possible to help each other faster if one gets stuck. This can also be done digitally, but the project showed that the waiting time to get an answer is longer, because not everybody is reachable at the moment you seek help or input. The missing body language and direct reactions on sketches during ideation were also missing.

## Business, Market and Product architecture

This section identifies and reflects upon the elements of focus that vary from market and business to production considerations within the two framings.

### The Modular Architecture of B-Fast

As mentioned, the '*material level*' in which the production, construction, and materials (Lerdahl, 2001) of B-Fast are built upon assumption-based research for the future of Mars. Considering this would change over time, as the space travellers would advance their production methods on Mars, the construction of B-Fast has been with a *modular architecture platform* in mind especially regarding *the process architecture* (Sanchez, 1999).

Each of the 3D printed parts on Mars is designed to be easy to replace if broken, which will expand the lifetime of the B-Fast. This is an important consideration cornering the limited resources on Mars, in which producing a new B-Fast every time one might break, is expensive in materials. Even so, the interfaces in the product architecture are not designed to substitute a specific component or one of the product parts. This means the product is an integrated product rather than a modular product regarding the product interfaces.

Considering this, the modular architecture is more connected to the process architecture, whereas the production methods can be shifted from 3D printing to any other method preferable for plastic production (with few redesigns for the components) if it becomes available as well as it becomes necessary to mass-produce on Mars. But also, the assembly was taking into consideration, because of the space traveller's capabilities in this regard could be limited. Therefore, small joints were added in the printed parts to make everything fit perfectly together.

### Niche targeting becomes a springboard for broader targeting when reframing

Due to the framing of the Martian part of the project, the solution B-Fast is designed as a *Niche-specific platform* (Meyer, 1997), with a specified game designed for maintaining the health of space travellers. Reflection upon this there is no guarantee that the designed game would not get boring in the long run. An attempt to accommodate that is to use platform design with *ultra haptic feedback, AR lenses, and an app*, making it possible to expand to other games. The technologies are therefore designed with a '*beachhead approach*' (Meyer, 1997). This makes it possible to leverage in targeting different segments. This was a key consideration when designing for Earth through the reframing part.

In the short reframing ideation sprint, B-Smart's leveraging possibilities of a target segment were considered. Some of these include quizzes for families, education purposes, or designing new games for different segments on the market. Due to the sprint approach, it was decided to focus on a physical and active educational quiz for schools. In retrospect, it is considered if this was the right market approach. When dealing with the public sector, many restrictions and rules must be complied with. Therefore, there is some unsureness about the implementation time.

As mentioned in Millstone 5, the combination of a physical product with an app was well received because of the potential market possibilities for leveraging. In retrospect, the leveraging possibilities can be seen in two ways, on the physical product itself and in the app.
Considering the physical product, the leveraging can both be vertical and horizontal creating products hitting different price points as segments e.g., a B-Smart version focusing on the B2C market playing games together with your family at home or creating add-ons for implementing the spots to a reaction game programmed by the users through the app.
This urged for further innovation in terms of the '*product and position*', and also the '*process*' in the 4P model (Hansen, 2014).

The app's possibilities are more in terms of a *beachhead approach* (Meyer, 1997) where the features are more user-defined and can be adjusted accordingly. Just within the school segment, the app can be used to 'vertically target' students in different educational levels, making the app cheaper or more expensive deepening on how complex the game should be. Furthermore, it can 'horizontally leverage' targeting different segments within the school, as reaches using it in language teaching or it can be used in gym class. But this leaves the consideration about the physical product being necessary?

### Physical product vs. Virtual product

As mentioned, the production of the Martian product proposal, B-Fast, is designed to produce as many parts on Mars as possible, to lower the shipping costs.
Unlike the B-Fast product architecture, B-Smart was mainly focused upon simplifying the architecture to as few components as possible, to make the product cheap to produce. This was especially a market strategy to be competitive on the price point.

B-Smart needs a tablet to work. This leaves the question if the physical product is necessary since similar quizzes and games can be found on the tablet.
Reflecting upon this the intention of having a physical product is found in the research. A new school reform implements movement as a way of learning, in which it is underlined that there exists a latent need of being active in schools (B.-N.Sanders, 2002). Considering this, B-Smart makes a '*market pull*' (Verganti, 2010) in which the need for something physical to engage with becomes important. As we see from the research movement is not only good for the body but also for the mind and on the social aspects.

If B-Smart was made into a digital product the costs of production and materials would be eliminated, but the purpose and meaning on the '*spiritual level*' (Lerdahl, 2001) would disappear.

## Innovation level

Considering the two product proposals, this section aims to identify how innovative the solutions have been on different parameters by using *the 4P model by Hansen et.al* (2014) and *Verganti's tree design views* (2010).

By looking far into the future, B-Fast sought to advance the perception of training equipment for space. It is not just a piece of training equipment helping you to maintain the physical health, through *motivation, fun, competing, and helps the space travellers feeling connected to their families on Earth*. This was generally achieved by innovating on '*paradigm/product*' in *the 4P model* (ill. 129) (Hansen et. al., 2014) by implementing different technologies in a new use case.

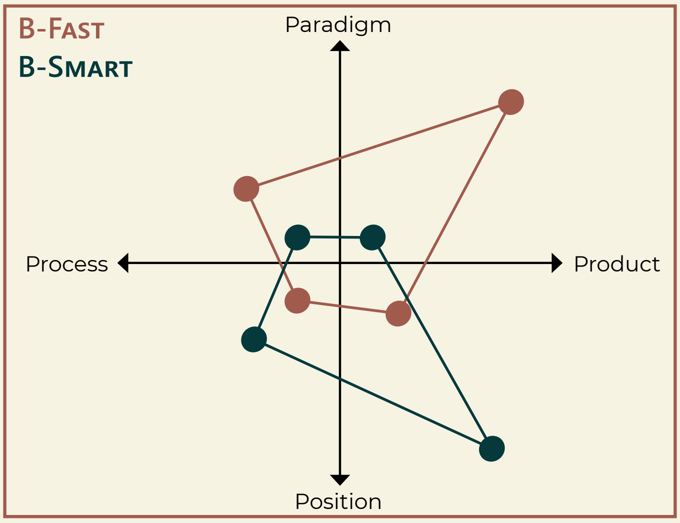
Considering the Main Unit of B-Fast, the level of innovation is high, because of the incorporated AR lenses and ultra haptic feedback. These two technologies are new and not fully developed but will be in the timeframe of 40 years from now.
A reflection on this is also whether simply replacing some of the features with digital technologies is enough to make the product more innovative.

The vibration board and app, as well as the use of the gravity harness, are products that exist already, which is lowering the level of innovation. And yet again the context in which the product is used underlines the 'paradigm' shift within the proposal. One concern regarding B-Fast is if the product can be seen as one gathered solution or it is seen as individual parts?

B-Fast can be considered as a '*technology push*' (Verganti, 2010), by its use of both existing and new technologies as the defining part of the concept. One question, however, kept occurring, whether the game would be fair to the Martians if they were to compete against players on Earth? This question leads back to the possibility of testing, as well as this question is immensely difficult to figure out based on assumptions.

In contrast, B-Smart for Earth regarding *the 4P model* does not innovate as much on the '*product/paradigm*', but more on the '*process/position*' (ill. 129) (Hansen et. al., 2014). Due to that the product itself, because of its functional principles, its simple construction, and electronic components on the '*contextual level*' and '*material level*' is easy to copy (Lerdahl, 2001).
As it has been considered the product should be competitive on price and target primary schools, whereas the innovation lies in the '*process/position*'. This is also related to the product not making a '*technology push*' but is designed as a '*market pull*'. The product is an attempt to meet different users' needs.

First of all, an *explicit need* occurred associated with the new school reform implementing more movement during the school day. This results in teachers missing tools for implementing the movement in normally stationary classes. Most of all a *latent need* occurs of the pupils needing, more than ever (due to Corona), to be given a frame for social engagement (B.-N.Sanders, 2002).




Ill. 129: Innovation level, B-Fast and B-Smart (Hansen et. al., 2014)

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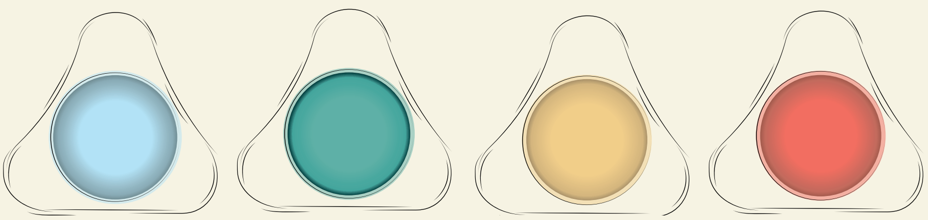

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