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ESTONIAN
ACADEMY OF ARTS

Department of Machinery

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SKYDIVE TRAINING AND ENTERTAINMENT EQUIPMENT

LANGEVARJUSPORDI TREENINGU -JA MÄNGUVARUSTUS

Author applies for a degree of Master of Technical Sciences (M.Sc.)

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TASK AND OBJECTIVES

2013 /2014 academic year, semester IV

Student:	Kerstin Oppe
Field of study:	Design and Engineering
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Master's Thesis topic: Skydive Training and Entertainment Accessories

Tasks and time frame for their completion:

	Task description	**Completion date**
1	Reaching insights and understanding of user culture, Expectations and perceptions of training and play in skydiving.	10.02.2014
2	To clarify a defined path to begin design and engineering research, begin with simple mock-ups and tests in terms of structure, behavior and function.	20.03.2014
3	To determine the functioning solutions for possible training equipment by prototyping and user testing in realistic environment.	10.04.2014
4	Conclude further development possibilities and market potential from prototyping and user testing results.	20.05.2014

Design and engineering problems to be solved:

A device falling with a stable rate at terminal speed

Device tracking and altitude measuring systems

Resistance of impact with ground and other obstacles

Aircraft safety, free fall safety of the object

Parachute structure and possibilities

Deployment system reliability

User interface design, front-end software

Contents

Abbreviations and Vocabulary

Skydive vocabulary and abbreviations used in this document that is essential for understanding the texts.

USPA - United States Parachute Association

FAI - The Fédération Aéronautique Internationale;
The International Air Sports Federation

DZ - Drop Zone

FS – formation skydiving; Building formations or patterns in a sequence in free fall (FAI)

CF - canopy formation; Sport of flying with parachutes in formation with each other (FAI)

FF - free fly - a way of skydiving which incorporates all dimensional axes during the free fall (FAI)

AAD - Automatic activation device; automatic reserve parachute opening system inside a rig

DIY - Do It Yourself; Home-made objects

A-License - the first level skydiving license a student acquires indicating progressive level of skill and accomplishment (USPA;FAI)

B-License - the second level skydiving license indicating progressive level of skill and accomplishment (USPA;FAI)

C-license - the third level skydiving license indicating progressive level of skill and accomplishment (USPA;FAI)

D-License- the fourth level skydiving license indicating progressive level of skill and accomplishment (USPA;FAI)

E-License - the highest level skydiving license indicating progressive level of skill and accomplishment (USPA;FAI)

AFF - advanced free fall training course for a student skydiver

Student jumper - a skydiver who has not yet qualified for a license (USPA)

Rigger - a person who is licensed to pack, maintain and repair parachutes. An understanding fabrics, hardware, webbing, regulations etc is required (USPA)

Landing pattern - a path agreed on previously with other landers according to wind and landing area and followed by a landing skydiver under canopy. (USPA Skydiveschool)

Free fall - The portion of a parachute jump or drop between aircraft exit and parachute deployment in which the parachute is activated manually by the parachutist at the parachutist's discretion or automatically. (USPA)

Taxiway call - Call for skydivers to board the aircraft for take-off

Gear call - A reminding announcement approximately 10 minutes before taxiway call

Exit -The point on the ground over which skydivers leave the aircraft. (USPA)

Spotting - Selecting the correct ground reference point over which to leave the aircraft, selecting the course for the aircraft to fly, and directing the pilot on jump run to that point.(USPA)

Break-off - an altitude the jump group has previously agreed on where the formation breaks up to fly further from each other and deploy their parachute.

Terminal velocity - steady speed achieved by an object freely falling through a gas or liquid (Encyclopedia Britannica)

Figures

Introduction

The aim of this study is to find a solution that can provide the sky diving community with a safe, fun and useful device for free fall training. In the frame of it, an extensive research on sky diving safety, sky diving accessories is done, as well as a research on the user community traditions, behavior and perceptions. The idea of this topic became intriguing to me as a skydiver after noticing some notions of a possible market gap, the study was purposed to see if that was actually true. This study is put together from the point-of-view of a user as well as a product developer in both research and development. The main concentration in this thesis is on creating a device that feels natural to use in skydiving, it feels safe and it has a potential to becoming a widely spread device to use for training and play.

The current scene of skydiving sport does not have any devices concentrated on free fall training, but there is plenty of evidence of users creating and modifying objects to jump with themselves. Though this unregulated activity can create a pathway to unpredictable scenarios and thus is forbidden in many DZ's. The goal of this thesis is to fill the need of this visible niche with an object that skydivers are allowed to use in DZ's worldwide. The results of research are largely based on empirical observations, while conclusions in the development phase are drawn from practical testing and prototyping.

The back-end software as well as hardware developed in close co-operation with OU Tehnolabor. The prototypes developed during this study were tested by certified and current skydivers, who gave extensive feedback on their experience and thus contributed significantly to the end result. Senior riggers and instructors from both DZ's, where research and user testing took place, are listed as specialists interviewed.

The interviews and consultations that took place for this study provided immensely valuable data that was based on their experience and professional knowledge.

The study begins with defining methodology that is used to structure the thesis and follows with a descriptive form of phases necessary to follow through the method. After defining the method, research begins, with concentrating mainly on behavioral research of users and current training methods as well as closely analyzing a regular schedule of a jump day. The research was based on asking two questions: why and how. The research part ends with analyzing a number of situations where self-made training devices are used by skydivers. In conclusion fo the insights obtained from research, a brief is defined. The brief will become a clear base for the following phase of development.

After the brief, challenges are defined and design research starts to find the best combination of systems to reach the optimal result based on user needs. This process is the longest in the study and the choice narrows down to a more defined product as numerous mock-ups and prototypes are developed and tested. The unpredictable behavior and shortcomings of initial prototypes are used as a base to create further prototypes. This gives a good chance to try out different systems and find out what works best together.

1
Research

1.1 Methodology

The Double Diamond Diagram

This document is framed into the double diamond method. It starts with stating an issue – the very beginning point that is the edge of the left diamond. From there it broadens up as background data is gathered and collected as diverse as possible to see all the aspects of the stated issue. The widest part of the first diamond is the point where the collected data is stated in the most diverse way to see all possibilities of moving forward with the project. From there, it starts narrowing down as all the possibilities are analyzed and from there a brief starts forming.

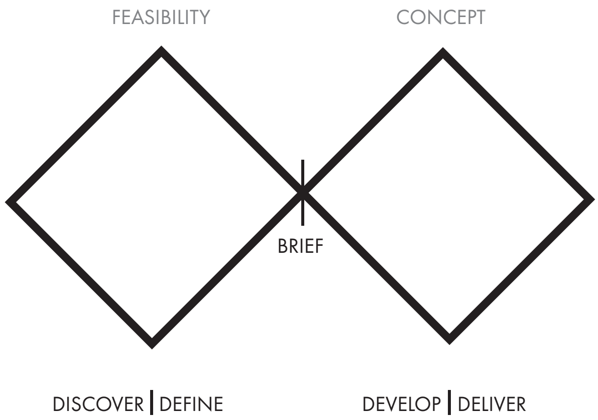


Figure 1.1

The brief is the insight of what could be the defined design problem, the center point of this thesis. It is firmly based on conclusions made from the discovery and defining phase. As the diamonds are connected with this strongly binding middle point, any possible mistakes in the first part will be continuous through all the following phases and will influence the final result.

After the brief and problem definition point, the product development phase begins with widening the second diamond back up by researching all different options to solve the defined problem. After analyzing them, the diamond starts narrowing down again with defining the best solutions after multiple series of tests, evaluations and prototyping.

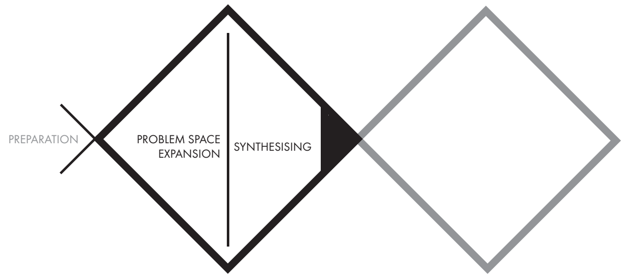
The end result, where the second diamond reaches its tip, is where the results have narrowed down and gathered into a singular product.
Qualitative research methods will be applied as this thesis is about product development that is largely based on research of user community culture and behavior. As a result of this a great amount of data is collected.

It is important to keep in mind, that research subjects do not always know how to react or answer to research questions because those topics may not be previously thoroughly analyzed and solutions may have not been thought of. It is natural for people to not be able to understand and communicate their needs adequately about a possible product if they have not had any previous experience with it. Because of this, it will be essential to investigate the collected data closely and look for notions and behavioral patterns. Those could later become distinctive guidelines for developing a brief. A generally wide range of qualitative and analytical methods are applied in this study and combined with extensive prototyping in the second diamond to reach an optimal solution in terms of engineering and design.

1.2 Phase 1 and 2

Discovery and Defining

Figure 1.2



The first diamond is the initial part, where immense amounts of information is gathered. It will then be structured and categorized to get a wide perspective of the current situation and aspects along with it. In this study, most of the data was gathered during a 3 month research period of observation and practice in the field investigated. The next month was spent to approach the data in various ways and organize it in a way that it can be addressed easily for future reference.

For this purpose, GIGA-mapping was applied as a tool of systems oriented design (Sevaldson; 2014). As a system that is used for displaying immense amounts of information and its interconnectivity, it was a suitable method for this study that concentrates on a select group of users (See Appendix 1). Even though the GIGA-map may be too complex to understand by an observer, it embodies a very important set of categorized information to the researcher who put it together. From there, connections start to form as all is visible to the researcher and insights of the problem take shape.

There were two main DZ's and skydiving clubs, where research took place:

Sky Dance Sky Diving, Davis, CA, USA

Skydive Estonia, Tallinn, Estonia

From those clubs, 9 Interviews and discussions were held in the frame of this study. The interviewed people were active and experienced skydivers, licensed riggers and or owners of USPA/FAI licenses.

Free fall training methods – 2 interviews

Free fall safety – 3 interviews

Skydiver's safety drills and procedures – 2 interviews

Parachute safety and construction – 2 interviews

Interviews were either recorded upon chance or noted. It was important to interview skydivers that were current but had different levels of experience. Two of the interviewed are senior riggers in addition to being experienced skydivers and instructors. In addition, all of the consulted are experienced skydivers, yet some have been in the sport no more than 4 seasons thus can still be considered to be in the exploring and learning phase of skydiving. It was necessary to find different levels of experience and age to get an insight of different mentalities of users, yet maintain what is believed to be safe in all possible cases.

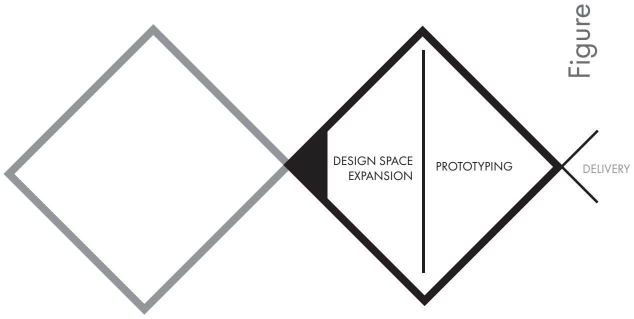
This second part of the first diamond: phase 2 is about defining: consolidating and finding the key points for further investigation of previously obtained data. The information and experience gathered from the research phase is used and filtered multiple times, while analyzing aspects that prove to be important for this study.

The first diamond ends and the second diamond begins with a brief. It is a singular point that connects research and development. It is used to keep focus on what is the defined problem of this study and thus is formed into a compact and graspable format. The possible challenges that are faced with the problem, as well as marketing possibilities are assessed.

1.3 Phase 3 and 4

Development and Delivery

Figure 1.3



The second diamond starts with an extensive research again, to find as many solutions for the problems stated in the brief as possible. In this study, the most efficient way to assess those possibilities was through theory and rapid prototyping both design and engineering challenges. Morphological matrix's (Hubka V., Eder W.E., 1988) were effectively used to categorize all possible solutions in terms of design, engineering and find functional combinations of them.
As the second diamond starts to narrow down, the selected combinations from matrix's are applied to create prototypes. Multiple prototyping was crucial to determine the best possible solutions in practice. Often, unique environment conditions and results of combining different systems together can create unpredictable solutions and interactions that cannot be predicted without prototyping and testing. Testing is carried out in as realistic environment as possible, with authentic users to get sufficient feedback. After every session, the potential real end users were interviewed and their sessions were filmed for further analyzing.

User experience with developed prototypes – 6 interviews

After the prototype has revealed its weaknesses and strengths, the final concept becomes more refined inside and outside, taking form in its entirety. The process of finalizing is carried out as far as possible within the given time frame of this study.

1.4 Users

Skydiving Community

In the frame of this research 70 days was spent in a DZ in California, US. The Sky Dance Sky Diving DZ is known for its wide variety of skydivers that gather there throughout the year to skydive together, hold workshops and training camps.

The DZ is very busy with skydivers and offers fast airplanes, experienced skydive coaches, instructors and riggers. The DZ is also famous for being flexible allowing prototyping different skydiving gear and stunts under supervision of professionals. The American TV-show Mythbusters chose to perform their experiments related to skydiving at Sky Dance in 2007. Due to open nature of the DZ, a wide international community as well professional approach to new product development Sky Dance was seen as a good reasearch and testing ground.

I did 157 jumps within 70 days with a diverse group of people and spent my free time getting to know the skydiving community that gathered there on the jump days. There are people flying in there from New York and Florida as well as Utah and San Francisco monthly or even weekly because Sky Dance is their favorite DZ. This shows commitment to the sport as well as to the people, the environment and the feeling being there gives to them. The researcher was able to document connecting with 34 skydivers, all of whom jumps were done with. The mind set and the values that they carry are quite similar in most cases.

The age of an average skydiver is 20-50. It is not significantly older as the sport itself less than 70 years old (USPA). One of Sky Dance's pilots a the research time was one of the very first AFF instructors in the world, a retired Golden Knight, the official first US Navy skydiving team, and a retired Black Hawk pilot. Speaking to him gave an insight of how the sport came to be and how it evolved into what it is today. The following common features seem to have been present from the very beginning of the sport culture and are the leading features of people who join the community.

Strong dedication and passion towards the sport and the community

The community is much about being playful and experimenting to a certain extent. Even though skydivers do not seem to have a visible pattern in their professions or personalities, they tend to view being at the DZ as being on vacation. It seems it is a way of shutting down daily routine and doing something that requires full attention so the brain can rest.

"The happiness I get from skydiving and the community lasts even after leaving the DZ, it makes the week ahead significantly more positive. I am able to concentrate on my work better." (J. B. Enscoe 2014). Many skydivers talk about the inspiration it gives them. (K. Issel, 2014;M. Lee, 2013). The community forms strong relationships and experienced skydivers are generally very open towards helping out, giving advice and teaching to student skydivers.

Lively Nature, openness to try new and unknown

People take up skydiving for various reasons, but the ones that stay seem to have an equally playful and experimenting nature to a certain extent. This of course varies from person to person, but this is one of the triggers that might have brought them into the sport, what makes them want to try new things and develop their skills further as soon as they see the potential of it. It seems to be about testing the limits of the mind and body. It is understandable for the researcher as an active skydiver for 3 years.

Weariness of possible dangers

The skydiving community is very aware of all possible dangers the sport brings with itself. The whole schooling system is built upon recognizing the dangers and eliminating them. The gear design is approached so the latest engineering accomplishments would make the sport safer and more fool-proof. This is why in a properly regulated DZ, a jumper is required to always wear two parachutes – a main and a regularly professionally packed reserve parachute, an AAD and all other safety accessories when jumping (USPA). "The risks in skydiving as well as necessary rituals to ensure safety are always taught, reminded and practiced" (K. Kasemets, 2014). The rituals will be addressed in later chapters. "DZ's are generally very strict about their safety rules and will not allow activities that clearly endanger students or other skydivers. This is one of the reasons why numerous DZ's will not allow skydivers to jump with accessories or toys"(K. Kasemets, 2014)

Valuing durability and performance over price

Observations show skydiving is not a sport where the price matters significantly when it comes to gear. The overall high prices of gadgets such as audibles, helmets etc (Chutingstar, 2014) could be related to the market size. The active skydiving community is more than 30 000 skydivers (USPA) worldwide. It could also be because economic stability is generally achieved by the people active in the sport.

Tendency to value looks and performance over price

Looking around at DZ's as well as the Internet presence of skydiving community photos, it is clearly visible how skydivers pay a significant attention to the look of their gear. Their suit colors will very often match their helmet, gloves, goggles, rig and parachute color up to just about everything that can have a somehow matching style. It is extremely common and it speaks of the somewhat vain group mentality that occurs in many sports communities. It is of course very human to be somewhat vain, it just occurs in different ways according to person. Bright colors are mostly preferred in skydiving as they stand out in the blue sky and are easy to detect in nature - that is the practical side of it. Should a parachutist land outside the landing zone or lose their parachute, it will be easier to find it from nature if it has bright colors. It is also easy to make a difference in people during free fall if they have recognizable suits.

Valuing performance over price makes sense in this sport, as there is a high demand for accuracy and reliability. Every item should have a clear system of operation and work as expected, or it will be left behind and another option will be chosen. The community discusses the products available on the market with a diverse crowd of skydivers all over the world online. Collective and objective information arises from those forums that can very often become a base for common opinion (Drop zone, 2014).

Online communication

Among other websites, an essential tool for a skydiver to gain knowledge about current news, updates, discussions and reviews of products is dropzone.com. It is the most comprehensive database of skydiving locations worldwide, both online and in print (Drop zone, 2014) It is a forum that embodies an immense amount of information from professional skydivers, riggers, product developers and marketers, product testers and students. It is a website that bonds and grows the community to a stronger and better informed worldwide group.

Strong attention to latest gadgets, electronics, accessories

It is logical, that the relatively young community takes interest in the latest gadgets and electronic devices as they are in the age group of the first rising IT-generation. It can be called a coincidence because of the era we are currently living in. It opens the skydiving market up to digital accessories, as they are widely welcomed and tested out with great curiosity.

1.5 Jump Day
Time Line

A jump day starts with arrival to the DZ or starting a day at the DZ. To bring only the necessary out of the jump day time line, the activities in the time line are categorized into rituals. Rituals can be called frequently repeated actions during the day to check condition, that can decide whether a jump should take place or not. If any of those rituals detects a flaw or a mismatch, the jump could become unnecessarily dangerous.

1.5.1 Weather (see appendix 1; color blue)

There needs to be a variety of weather conditions coming together for an airplane to take skydivers up and for them to be able to jump out from there. A certain degree of visibility, a range of temperature, a range of wind. In some places, such as Sky Dance, the weather is jumpable almost all year round, in Skydive Estonia it is drastically different. In such places, weather conditions are constantly checked and that forms a ritual that, as the GIGA-map (see appendix 1; color blue) research showed, is repeated about 5 times per jump.

1.5.2 Mental state (see appendix 1; color orange)

"It is immensely important, that before a jump, a skydiver has the right mindset for it, a readiness" (K.Kasemets, 2014). This should remain the same throughout the day if multiple jumps are done. A mental state of a skydiver decides how they will react in situations, what is the speed of the reaction and the decision made upon it. The state of mind should be positive and relaxed, yet prioritized and confident. A clear and rational mind should be kept at all times, especially shortly before and during the jump, but a situation-conscious mind is something that a skydiver should have throughout the jump day. If something interrupts it, the jumper might find it necessary to take some time off and retain the previous state of mind.

1.5.3 Gear control (see appendix 1; color green)

This starts even before arriving to the DZ. For everything to go swiftly, all gear should be checked over after certain periods of time. Skydivers mostly use a large suitcase-like bag to accommodate all gear. Besides this, the gear should also be up-to-date, this means the reserve parachute should be repacked by a rigger less than 6 months ago (K.Kasemets, 2014). Gear control in various combinations is done about 5 times before the first jump, and at least 2 before every next jump -on ground and in the aircraft essentially. These should not be forgotten, as an error left unnoticed might cause unplanned situations during the jump.

1.5.4 Conclusions

A jump day begins with packing all gear at an initial location, and heading to the airfield. All gear includes essentials, accessories and commodities. The gear should be checked for its validity. Whether the batteries of all devices are full, as there is still time to charge them. And a more important check -if the rig reserve packing still valid. In the time frame of packing, there is a suitable gap for any actions needed with a possible training device currently under investigation.

Upon arrival to the airfield and before boarding the plane, a few niches also became relevant, on the side of essential concentrated moments, where no distraction should take place. It was apparent that there was possible gap of time, where the device currently under investigation can be addressed. This was the time between finnishing unpacking and registering for a jump and a gear call. This could be used to decide on possible configurations, activation and calibration of a new device used in free fall. Around this time, a jump plan usually takes shape. It states the purpose of the jump, therefore any configurations with a device used during the jump will feel logical for the user to do now. This should include setting the height of landing area as the zero-reference point for height measurer in the device, and parachute deployment height. The height of deployment should be possible to edit either directly or via an application on the owners smartdevice that connects to the device.

Editing and settings should be as easy as possible, because the device is made for one purpose and has few functions for it. The height of deployment should be decided considering height of break-off's, skydivers deployment heights and additional possible specialties that a DZ might have. A local rigger or a responsible instructor should be consulted about this matter.

After gear call, the accessory should remain active, but be largely in the background, to not disturb checks or rituals regarding skydiving safety. The device should thus be on stand-by mode – a state where it is aware of the environment changes, such as altitude changes, the speed of it, battery life expectancy.

1.6 Market Situation

Current Training Methods

1.6.1 Wind tunnel training with a coach

The most common way of training is below a wind turbine that imitates the situation of free falling by blowing a strong current of air from ground up. It is an effective way to train the balance and flow of movements as the practice time in the wind tunnel can be longer than the time during real free fall. This gives a better chance to improve flight skills and learn new techniques, as practice lasts for longer periods of time in a row. A more or less optimal time to be in a wind tunnel per day is about 30 minutes (J.B. Enscoe, 2014). This is equal to more or less 30 real jumps, but an average number of real jumps per day can span from 5-15. Thus the experience of free fall is stronger in the wind tunnel and free fall skills will be learned faster in the frame of a day. Doing more than 12 real jumps a day are usually considered very draining on the jumper both physically and mentally, therefore not safe towards the end. Exceeding the wind tunnel optimal of 30 minutes a day is also considered to be physically extremely draining and therefore not recommended as it can result in injuries.

Price: approx. 800 USD per hour (Tunnel prices, 2014)

If one skydive free fall time is approximately 60 seconds long, an average price of 1 minute of free fall price can be calculated.

800/60 =13,(3)

This means, if trained in wind tunnel, a minute of free fall costs approximately 13,(3) USD.

This can be compared with a cost of about a minute of free fall in a real jump. One jump with personal gear price: approx. 22 USD (Ticket prices, 2014).

This of course is a jump that includes free fall as well as canopy flight. For this reason it is complex to define, how much a minute of free fall in a jump costs, because the value of canopy flight is equally as important in skydiving skills. However to simplify and concentrate only on free fall, it can be stated, that a minute in a wind tunnel is 13,(3) USD and in a real jump it costs approx. 22 USD, varying on the DZ and wind tunnel prices.

This indicates that even though the wind tunnel prices seem high, free fall skills can be obtained faster and cheaper in the wind tunnel then in real jumps.

The conflict is that the wind tunnel is a good tool providing free fall skills but skydiving consists of not only that but also canopy flight skills, which are trained with every jump. "This might be why skydivers who spend more time training in the wind tunnel instead of doing real jumps are prone to have more accidents under canopy" (K. Wyatt, 2014). They lack constant experience with their parachute. From research, It seems a good balance should be found between doing tunnel time and real jumps in skydive training.

1.6.2 On-land coaching

This is the cheapest option of learning and improving free fall skills. The jumper can get advice and instructions from an experienced skydiver, a coach or an instructor before the jump. The jumper will do their best to take the advice and memorize how to improve their skills.

Price: On-land coaching is generally for free as advice upon asking or a part of a student training program such as AFF, where coaching is included in the price.

The conflict with it is that regardless of how well one can explain a situation, people sense free fall differently. Explanations by coaches are still only a theory of something that needs to be tried practically and might work in a different variety of ways for the learner. Being the cheapest way to learn, it still does not work for everyone. People who are slower learners may end up doing for example 5 jumps alone trying to accomplish what they were explained on land and not achieving it, while they might learn it faster when having a helping device with them. "Alone in free fall, it can be complicated for a student to achieve an understanding of ones positioning and movements as there is no reference point, in relation to which the movements can be observed visually" (K. Kasemets 2014).

1.6.3 Jumping with a coach or instructor

This means going on a jump with an experienced skydiver, a coach or an instructor. In this case, the jumper gets on-land coaching and then proceeds to a jump with the same coach and a jump plan. Jumping with a coach is good since the coach as a stable flier gives a good reference point for the learner. This reference point provides understanding of movement that the jumper does himself, and what kind of results shifting his position brings.

1.6.4 Jumping with other skydivers

Jumps with other skydivers, that have been permitted to jump with each other, generally A-license holders and higher. This is a good and most common way to carry on with the sport, practice flight skills and just have fun in the air with friends. This is the cheapest way to better ones skills, but to reach the allowance of it, one needs to obtain at least an A-category license. The group that will do a jump together will generally agree on a jump plan. Depending on the goals and ideas, they will either agree on how they exit, what they do during free fall, when is the break off. To do something special or different, often they jump with accessories such as hula hoops, inflatable pool toys or whatever one has thought to jump with. The jump with those accessories will take place, if the loadmaster or responsible instructor has agreed on it.

1.7 Jumping With DIY Accessories

As previously stated, skydivers can at times jump with accessories that are not designed for jumping. This is an activity that should be addressed more thoroughly as it is very diverse and also controversial. It should first be started with defining the term accessory and the current accessories used in skydive sport.

In this document, skydiving accessories will be considered as essential and non-essential objects or devices that are allowed to accompany a jumper and are either optional or obligatory to have with at a jump in any DZ. A rig -a main and reserve parachute container is not considered an accessory. It is important to list accessories in order to indicate how often they need attention during the jump day and in which way are they designed to work. This helps to define how much time is left and can be devoted for an additional accessory, which is the main objective of this study. Permitted or obligatory accessories in most DZ's devices are the following:

AAD

Automatic deployment system goes inside the rig and is an obligatory device in most DZ's. It is the ultimate safety device, as it measures height and deploys a reserve parachute, in case the jumper has not deployed a parachute is still in terminal speed at a critically low altitude. This altitude ranges from 500-200 meters, depending on the settings of the device.
Actions required to use: Turning the device on to do safety checks and be on standby for the next 12 hours. No additional interaction needed during a 12 hour jump day.

Visual Altimeter

This is an obligatory device in every DZ. It is an altitude measurer worn on the wrist or gear at an easy-to-see location. It is immensely important to be aware of altitude during at all times during a jump as the free fall time before canopy deployment is around a minute. In skydiving school, altitude is taught to be looked at after every action or exercise during free fall and advised to be looked at while approaching landing pattern. (USPA, 2014). One will not be allowed to board an aircraft without having an altimeter on them. Some skydivers, for example wing suit fliers choose to use multiple altimeters" (M. Lee, 2014)
Actions required to use: Turning the device on in the beginning of the day. Some altimeters are on standby mode at all times, and don't require turning on or off.

Audible

This is a small digital altimeter that is inserted in the helmet or on goggles, right next to the ear. It can be programmed to alert the jumper with a high pitched sound sequence at determined heights. In most, but not all DZ's one audible is required. "In some DZ's, two audibles, one next to each ear, are obligatory"(M. Lee, 2014). This is a precautional method in case one audible fails to measure height accurately.
Actions required to use: Turning the device on in the beginning of the day. Some altimeters are on standby mode at all times, and don't require turning on or off.

Helmet

For student-jumpers, a helmet is obligatory. From d-license and up, a helmet is optional, but advised (USPA, 2014). A helmet can be full-faced or not, can house audibles and everything that a jumper can think of attaching to it, starting from a camera.

Slider packer

A magnet-shutting or a DIY accessory that is used to tie the slider of a main canopy to the back of the rig. It is used by a number of experienced jumpers. "Using the slider packer, the canopy obtains a faster speed and provides better flight quality"(J.B. Enscoe, 2014).
Actions required to use: A time of adjusting the slider between the packer under canopy. Should be done after parachute opening and all canopy

safety checks.

Gloves

Gloves are optional for most DZ's. Some DZ's in colder countries, such as Estonia, advise student skydivers to wear gloves(K. Kasemets, 2014).

Goggles

Obligatory in DZ's as it is severely uncomfortable to be in free fall without goggles. A jumper is obligated to wear goggles if they do not have a full face helmet, in which case the problem is solved by a visor screen.

Camera

Attached to a helmet, a camera is allowed to be worn by a jumper after their 200th jump and up (USPA, 2014). FAI requires a jumper with a camera to have at least a B-category license. (FAI, 2014).

Actions required: Turning the device on at the start of a jump. Generally right before exit or when preferred. The level of concentration needed upon exit for any jump though, is high. This is why a camera should not be worn by a person with little experience in skydiving as concentrating on whether the camera is turned on or not can be distracting to other important aspects of the jump.

Besides the previously described accessories, no every-day objects and devices should be worn during a jump. They are considered forbidden for safety reasons. "This includes watches, any kinds of jewelery, rings, and other floppy wearables. This is because any residue of cloth or matter in free fall can get tackled into a jumpers rig, altimeter, helmet or body parts" (K. Kasemets, 2014). This can cause complications before or while deploying a parachute and thus making the short time of a jump very dangerous.

Another important reason is maintaining the safety of the environment below the airspace skydivers use. It is irrational to litter it with DIY accessories and remains of them, that have reached the ground, were never caught and will not be searched for.

1.7.1 Student Jumpers and Accessories

"In regulated DZ's, students are not allowed to jump with any DIY accessories. The reason for that is they might not only create a dangerous situation in air by getting tackled or somehow attached with the accessories, but they can also serve as a distraction that can cause the student not to remember the standard safety procedures, such as looking at the altimeter multiple times during free fall"(K.Kasemets, 2014). The main rule is, that one hand, the right hand should always be free before deployment and not holding any obstacles, as it is the hand that should pull the parachute open. (K. Wyatt, 2014). From this, it can be concluded that any obstacles that are attached to the skydivers body should have as little edges and corners as possible to prevent any kind of tackling and ripping. The pulling and ripping forces are extremely powerful, as the moving speeds exceed 200km/h. "If there is a chance of an accessory becoming a dangerous obstacle during aircraft flight or free fall detected, the accessory will be asked to be left behind before entering the aircraft by the loadmaster or the instructor responsible"(K. Kasemets, 2014). The second conclusion is that any possible accessory accompanying a student jumper on free fall should not catch their attention in a way that would cause them to forget about safety procedures. Rather, if possible, it should emphasize them or remind them to the student.

1.7.2 Experienced Skydivers and Accessories

As an experienced jumper is free to make jump-plans individually, there are still restrictions depending on the DZ. "Many DZ’s do not allow jumping with any kind of accessories that do not play a certain role in the safety of the jump, but to a certain length, things are negotiable with the DZ owner and instructors" (K. Kasemets, 2014). Despite these restrictions, upon searching the Internet, it is possible to find plenty of evidence of skydivers jumping with a very wide range of accessories that are home-made. This kind of behavior shows the creative nature of skydiving community, which was analyzed in this documents section of user community The DZ this research took place at had a DIY toy on approximately every 2nd load up. There are about 10-24 jump loads a day, depending on external conditions and speed of the airplane. This makes about 5-10 DIY jumps a day at one DZ. It indicates a possible product niche, as the DIY accessories used are with flaws and therefore pose risks to the jumpers and the environment, yet they jumps with them are still done frequently.

The next paragraphs are examples of jumps, some of which have been video recorded and posted online, where DIY accessories are used. The paragraphs will analyze the jumps and accessories.

1.7.2.1 Bowling Ball

Here, a widely seen video can be assessed from the web (AXIS Flight School TV, 2011). The video is of a jump that involves a bowling ball with an approximately 3 m cord tied to it.
Weight of an average bowling ball is approximately 7 kg. The bowling ball’s ratio of size and weight looks to gains similar speed with the FF sky divers, as is seen on the video. "A general speed during seat-fly can be from 200-280 m/s varying from people to techniques."(K. Issel, 2014). The ball is easily visible thus it is hard to lose in free fall. The chord provides additional surface area when the ball is moved, thus making the movement less aggressive and more subtle.

Figure 1.4

The jump was participated by 4 FF sky divers, clearly experienced ones, holding a bowling ball in hand on exit and letting go of it after the exit. The jumpers movements are well defined and fairly accurate. This indicates they have a strong base of free fall experience as they can control their movements very well. This jump lasts a typical sequence of about 40-60 seconds and in the video, the FF sky divers touch and bounce the bowling ball around between each other until break-off. Break-off in this video means tracking away from the bowling ball as well as other jumpers before parachute deployment. The video has a lot of views probably because this jump would almost never be allowed to take place elsewhere because of the dangers it poses.

Importance of Exit Order

Before any parachute deployment, a jumper does not want to be close to any other jumpers in air, as the deployment of a parachute means rapid change of speed and possible changes in flight direction. Break-off is the time before deployment that is taken by each jumper to get further form other jumpers in order to avoid unexpected collisions before, during and after canopy openings. (USPA, 2014). As there was a bowling ball in the sky falling in terminal speed in the video currently under analyzing, the jumpers would not want the bowling ball falling higher than them, while they are under canopy, as there is a danger the bowling ball could cross paths with the canopy and fall through it. There should not be any jumpers higher the bowling ball either, as every jumper has their own fall rate depending on their current position and a faster falling jumper could fall past or collide with bowling ball that. This is why an exit order varies in DZ's due to environmental or external conditions, but most commonly organized in a way, that jumpers exit the plane from bigger formations to smaller, starting with belly fliers, then FF skydivers, following with student jumpers and tandems. (Skydive Elsinore, 2014) The reasoning behind it is, that "the bigger the jump group, the bigger surface is taken under it, thus they will fall slower and drift more than smaller groups of jumpers. " (Skydive Arizona Production). As a result to this, the groups that float more and fall slower should exit before the faster falling groups. This prevents lighter groups drifting on top of the faster group that excited before them. It gives better horizontal separation during parachute deployment time.

This gives an insight of the exit order being closely related to the skydiving accessories. When talking about jumping with a bowling ball, it is only allowed in rare cases when the jumpers with the ball are first out to exit – the ball does not have any danger of falling on groups that exited previously.

After Break-off

The jumpers will deploy their parachute, but the bowling ball will not. As opening a parachute while holding a bowling ball in one hand can be very dangerous to the jumper and to the deployed canopy is not seen as a reasonable option. Since this video was shot in the Arizona desert, there was no need to catch the bowling ball – there was supposedly no habitation below it. Therefore this unique situation was only allowed due to its environmental conditions, experience level of jumpers, careful spotting and exit order.

Reasons For The Jump

After the research period in a DZ, an insight of behavioral reasons for doing these kinds of jumps becomes clearer. As common for all sports, the initial purpose of jumps with DIY accessories is practicing flying skills through play. Jumpers make up games they could play to refine their capabilities to move precisely through air. In the case currently analyzed, the game was to fetch a bowling ball from one to other and touch it without crashing into it. The careful manner of the jumpers is visible from their movement, as they try to get close to the ball without losing balance. Keeping balance in air, especially in FF, is physically draining and requires extensive practice. Other reasons to justify jumping wit DIY accessories mostly all relate closely to traditional social sports and games experience. The joy comes from doing something together that involves physical exertion

1.7.2.2 Tennis ball Filled with Steel Pellets

A case of DIY skydiving accessory in Estonian skydiving club is of an old tennis ball, that has been filled with steel pellets for weight (J. Võsu, 2013). It was used for fetch games and chasing it. The jumper, in this case, and experienced one, would throw it as far away as possible and then chase it down and catch it. A regular tennis ball diameter is about 6-7cm.

The ratio of the weight and size made it fall faster than a regular flier, therefore it needed a new approach and a more diverse set of skills to catch up with the ball. It is another valid example of how rapid movement and precision in air was practiced through a made-up game. In this case, one of the jumpers would attempt to catch the ball before parachute deployment altitude. The chances of successfully catching the ball are usually hard to predict. "After catching the ball though, deployment is easy, as the tennis ball is easy to grip with one hand and the other hand is free to deploy the jumpers parachute. This was the main reason a tennis ball was chosen as the toy." (J. Võsu, 2013).

Exit Order

The jumpers with the ball would exit first and be given a delay time of up to 10 seconds until the next jump group would exit. The reasoning behind this was, that the tennis ball's speed was then unknown, so it was rendered best to let the ball jumpers exit first so there would be no chance of the ball catching up to previous jumpers below. The ball-jumpers would also have to exit above a great field so the chance of it hitting a building or a car at terminal speed would be minimal, and they would be given a long separation time after it.

1.7.2.3 Inflatable Animal

A very common toy to take with on jumps in DZ's that allow it is an inflatable object. There are numerous examples of this on youtube.com as it is a common practice among skydivers to add another element of fun and unpredictability into the jump. An inflatable animal can be considered safer than the previous 2 examples as it contains air, not weights and it does not take up space on the airplane until reached heights. Ascending to exit altitudes, the air gets thinner, so the toy inflates, and likewise deflates on descent. For the jumper, the purpose of jumping with the toy is to try to hold on to it as long as possible and achieve a stable flight position with the toy. This though, is very hard to achieve, as the toy has no weight and much surface, in contrast to the jumper.

After Exit

"Usually, what the jumper discovers during free fall is, that the harder they try to hold on to the toy, the more unstable it gets. For example It could develop a strong orbit and rotation." (M. Lee, 2013). This is a good exercise, as the jumper learns one of the key points to free fall stability -holding the body in control, but in a loose way. A stiff body position is not aerodynamic and becomes unstable faster. A relaxed posture is thus very important. Jumping with the toy, one gets an understanding of that quite soon. Holding on to the toy and trying to stabilize it brings stiffness to the jumpers body and therefore makes their position more unstable with the toy, and as a result, they start to spin around in the air and gain speed.

Before Deployment

Letting go of the inflatable is never advised, as it will not be possible to catch it due to difference of fall rate. In these cases, the toy lands individually where the wind takes it. It depends on the DZ owners and jumpers themselves, if they will go look for it or not. The good side to this is that an uninflated toy will land slowly and there is no danger of it causing any damage by breaking something underneath it. However, deploying a parachute with an item in hand, that could snap out of there and get stuck into the jumpers opening parachute, poses bigger risks than letting go of it and let it land somewhere on its own. Since the training purposes have ended with deployment, the inflatable is of no value to be kept, when it might make the parachute deployment process more risky. During 3 months of on-DZ observing, I witnessed quite a few deflated inflatables falling down from the sky, landing on random fields, without anyone going to find and collect them.

Conclusion

As a DIY toy, or an object, that is brought into the activity from a differently purposed environment, it already obtains a clear personality and states its function. This adds a touch of humor to the jump and the element of fun is always a welcome aspect in jumps that do not have a serious purpose. It is also relatively cheap, which justifies its one-time usage in jumps. The toy does also not need any calibration and care, which makes it easy to use. The downside is the inconsiderable wasting of material, and using the ground below the airfield as a littering area.

1.7.2.4 Vladiball

Vladiball from Ukraine is a first toy designed for skydiving. It is not a commonly used item in the skydiving community. One reason for this might be because the product has a very weak presence in the modern marketing field such as digital media. Extremely few channels that the skydive community uses to get information online represent the Vladiball in any way. After finding a few videos of jumps with Vladiball from the web, a situation can be described. The ball is about tennis ball-size that would fit into a hand and is filled with weights, and in addition to that it has a top cylinder part, that houses a membrane and a determination system. On top of the cylinder part, that there is a short tail that works as a stabilizer that gives the ball a certain direction of descent.

Before Exit

During ascent, the ball should be activated to explode at the wanted altitude. After this, it should be ready for free fall. If for some reason, the ball is not calibrated before exit, it will not explode and fall towards the ground at terminal speed when not caught by the jumper. A problem with this system is, that it is a distraction in the airplane from the things the jumper should really be thinking about. During ascent, it is crucial to be aware of one gear checks -whether the jumping gear is attached to the body properly including the chest strap and leg straps, whether the main and reserve deployment and cutaway handles are intact and the emergency drill is remembered in the back of the mind, whether the main parachute loop is attached and has not moved out of place during aircraft flight. Also remembering the exit order and how many seconds you need to leave the group that exits previously. After those, the remaining of the accessories should be checked – the altimeter and the audible and whether they are working accurately, the helmet attachments. On observation I documented the tradition of the skydivers checking each other 's gear attached on their back in the airplane before exit, to assure safety. This a healthy part of pre-jump rituals and should not be interrupted or forgotten because of trivial activities, such as calibrating an accessory that is not attached to the skydiver.

After Exit

The ball flies with the jumpers, and it can be used for playing catch. Through games created with it, the ball is a good device to practice movement accuracy and body control in free fall. The Vladiball is about the size of a tennis ball with a cylinder on top of it, which looks more or less easy to catch, if grabbed strategically from the round part. The cylinder part though, does not look like a handy thing to get a good grip on.

Before Deployment

Before deployment time, the ball can and cannot be caught. It will explode if it is not caught before the set altitude. If caught, the ball should be deactivated by the jumper. This action though, can be considered not safe itself, as it is a distraction for the jumper, especially when the height is getting close to deployment altitude. Distractions could potentially lead to the jumper delaying deploying his parachute later than planned, thus not a sufficient amount of time to open a reserve parachute, should there be a malfunction in the main parachute. In the opposite case when the ball is not caught and it explodes, it does not pose a risk to the jumpers or the habitation to the ground below it. Nevertheless, it seems to be an irrational way of using resources, as one ball costs 50 U.S dollars, and after about a minute of play it ends up being litter on the ground. In addition to this, the ball is not made from sustainable materials, and this kind of environment littering should not be acceptable in the modern society. Neither does it convey a positive impression of the skydiving community and their considerations of the environment below the airfield.

Conclusion

The Vladiball never penetrated skydive market in a strong way. That could be because it did not spread due to weak marketing work, high pricing for the value offered and the mismatch with the skydiver's common mentality of purchasing things for the long run. The product also does not communicate with the user in an attractive way, it fails to form a bond with them, and demands action without clear and indicative feedback. Through research, It seems these last issues are a problem of unresolved product design.

1.7.3 Conclusion

The chart below indicates how 4 current training methods displayed in dark gray and 4 analyzed situations displayed in light gray, that reflect the need for a new product in the skydiving sport market. It shows, what the users themselves have created, to fill the current need, and how one product has been developed, yet it is flawed in many cases and for those reasons it has not been successful. This gives a suggestive understanding of what could the product, a new accessory for free fall, be like and what it would have to do, to meet the needs, that the situations seem to be give an insight of.

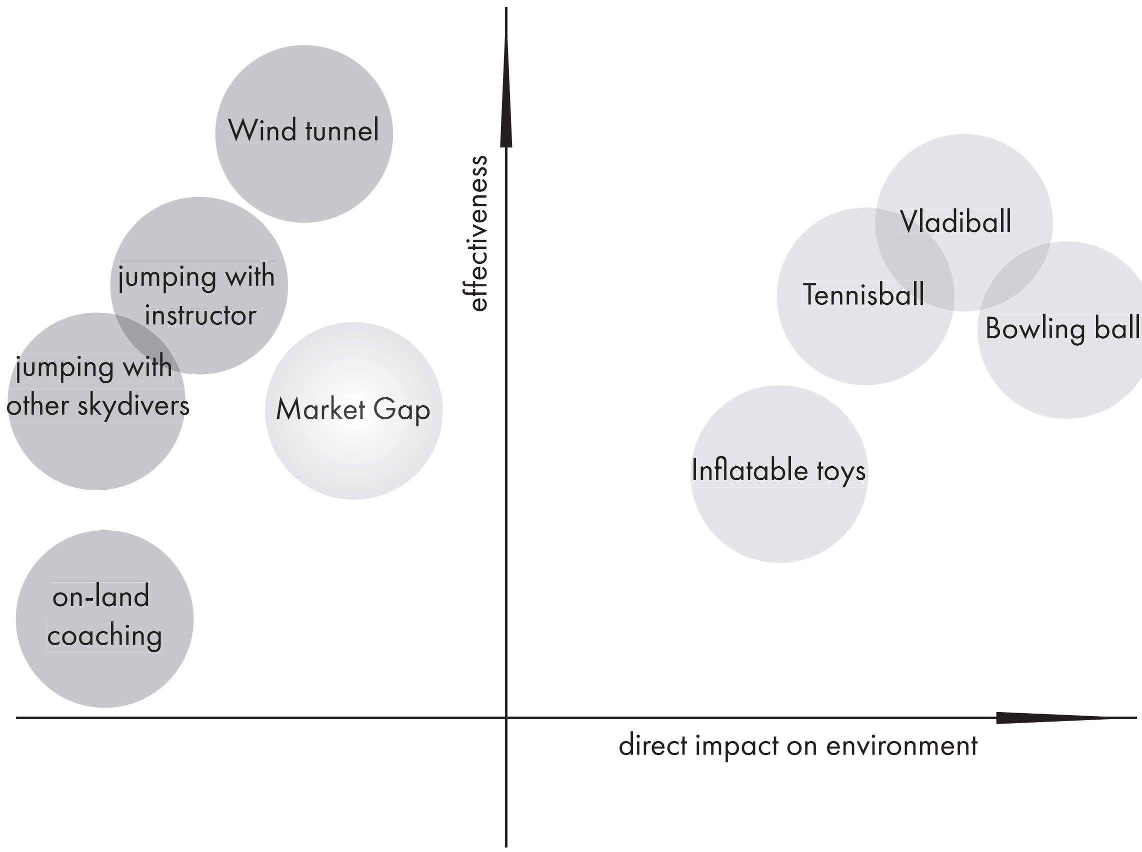


Figure 1.4

2
Brief

Based on insights obtained from the research phase, the brief can be formed. To describe the hypothetical problem in a short way, it could be stated as follows:

The skydiving community appears to have a need for an accessory that skydivers can use in free fall, that is expressive, interactive, diverse enough to invite skydivers to create games, to train balance and accuracy of movement.

The accessory functions and interface should fit seamlessly into the jump day routine without interrupting the safety procedures and drills at any given time from entering to the plane until landing with the parachute. In addition to this, it should not harm or litter the environment below the airfield in any way.

2.2 Constraints

2.2.1 Ascent

Should an accessory be brought with to the aircraft, it should be possible to fasten it to a safety belt or a skydiver. This is for example done with helmets in many DZ's (sky dance for example). The helmets are either held firmly in the hand or fastened to the jumpers chest strap or seat belt. This is because the airplanes for skydivers are generally small planes with strong acceleration, which might cause non-fastened obstacles to fly around in the airplane and collide with a person. The same situation could also happen at any time turbulence occurs during the flight.

2.2.2 Exit

This is a period when the door is opened in the aircraft, for spotting and jumpers to start exiting. The plane is moving with great forward speed and not gaining altitude at that period of time. Since there is no wind in the aircraft and there is a strong wind current outside it, there will be air currents entering from the door. These currents catching anything floppy or not firmly attached on the skydiver or in aircraft, can cause the items to move or drag anything attached to it around or out of the airplane. This is one of the reasons why any string, or a hanging piece of cloth can cause much trouble in an airplane with an open door.

2.2.3 Free Fall

Right after exit, it takes a skydiver approximately 10 seconds to reach terminal velocity, depending on their body position. After reaching terminal speed, depending on the body position and size of the jumper, the speeds can reach from falling 160 km/h up to 300 km/h. The speeds vary quite widely, it takes jumpers who have different fall rates time to adjust and learn how to fly with different speeds and keep up with other skydivers either heavier or lighter than them. It is a skill that needs to be practiced. When jumping from a common altitude of 4.0 km the free fall time lasts about 60 seconds, depending on the jumpers speed and parachute opening altitude. During that time, speed varies and picks up in time.

The accessory would have to accommodate the same characteristics in free fall. If possible, it might also be adjustable when it comes to its fall rate, so that people with different weights could jump with it.

The accessory should also not distract the jumper from safety procedures in free fall. The jumper should remain height-conscious at all times and not forget the altitudes for break-off and parachute deployment. This is one of the reasons why students are not allowed to jump with a camera –there is a possibility they will think about filming or be filmed instead of safety procedures. 60 seconds is a very short time, and if any procedures are forgotten, the situation might become dangerous as altitude disappears fast. If anything, it could possibly be an indicator or a reminder of break-off time or deployment time. This way, it might make the jump safer than before in terms of forgetting safety procedures. Then again, the riggers warn about digital accessories as reminders, because as a result "jumpers might become dependent on them and expect the time alert coming from an accessory rather than remaining altitude conscious themselves" (K. Mourron, 2013). "An audible, for example should not be a reminder to deploy the parachute. Skydivers themselves should remain altitude conscious enough to deploy the parachute at the right time and rather hear the audible as an assuring factor." (K. Mourron, 2013). If in the last case the digital accessory fails from alerting anything that is expected from it, the actual break-off height or parachute deployment height may be left unnoticed. The new accessory should take these dangers into account.

2.2.4 Free Fall Before and During Deployment

"A general main parachute deployment height should be about 1100m below landing ground" (K. Kasemets, 2014). Before that, a break-off time is needed, to get as far away as possible from other jumpers in sight. A jumper should not deploy too close to another one as deployment can cause rapid change of direction of movement, and cause collisions. The same goes to an accessory. A jumper should either hold the accessory firmly in their left hand (deployment handle is on the right side of the rig) or be as far away from it as possible. In this case far away in terms of height should be the parachute deployer being higher than the falling training device and not below it. The option of holding it or having it attached to oneself would need a very close inspection when considered, because a deploying parachute stops the person attached to it from falling approx. 200 km/h to less than 6 m/s depending on the wing load.

Great forces apply to the falling object during deployment and because of this, the accessory could become loose and cause damage to the jumper or their gear if not attached or gripped firmly.

2.2.5 Canopy Flight and Before Landing

Probably the best case would be not attaching it to the jumper and let it land itself, as it then poses less risks for the jumper and their gear. In this case of course, it should not be falling at terminal speed right below any deployed parachutes, as it might fall through a canopy or get wrapped into one.

In the situation of it being attached to the jumper or gripped by them, it should not prohibit the following safety procedures after deployment: Checking the canopy’s condition, altitude and environment. The flier needs to check the canopy’s breaks and/or risers and for this, both hands should be free for use. A possibility could be, that the accessory then could be swiftly attached to the jumper to free up hands. "Attaching something on the jumper though, is risky as it is then another obstacle, that a canopy could get tangled in" (J.B.Enscoe, 2014). Should the main parachute not fly correctly and not be safe to land with, the flier should follow the safety procedures, release the main parachute and deploy the reserve parachute. In this case, a fast reaction is necessary and an accessory should in no case be thought of.

If this situation occurs, one should immediately let go of the accessory, as the descent rate of the jumper is at that moment slow enough to let the accessory fall away from them. This clears all possibilities of the accessory becoming a dangerous obstacle that either disturbs, interrupts or endangers the opening process of the reserve parachute.

2.2.6 On Landing

An accessory should not interrupt being aware of the landing conditions and location, the landing pattern, other landing skydivers. It is important for nothing to interrupt the flare, nor become a dangerous obstacle if the skydiver has misjudged their height and as a result will collide with the ground in an unexpected way.

2.2.7 Post-Jump

After landing, there is time to debrief and analyze the jump, repack the canopy and possibly get ready for a next jump, this can take 20 minutes up to a few hours depending on the airplane and business of the DZ. This leaves a gap of free time any accessories could be dealt with, to locate, calibrate or other.

2.3 Behavior

The previous constraints draw out the behavioral properties of the accessory developed. The behavior can be described best with a operation flowchart (Figure 2.1). These are the new functions the accessory should have that are driven from the hypothetical brief and in close consideration of all the constraints. The validity of the chart will be assessed with prototyping and is open for necessary changes.

To see, where and how the new accessory would fit with its functions, it is necessary to go back to the jump day time line and find the gaps, where the accessory could be interacted with before and after the jump, without it distracting the normal flow of the day with is safety procedures and

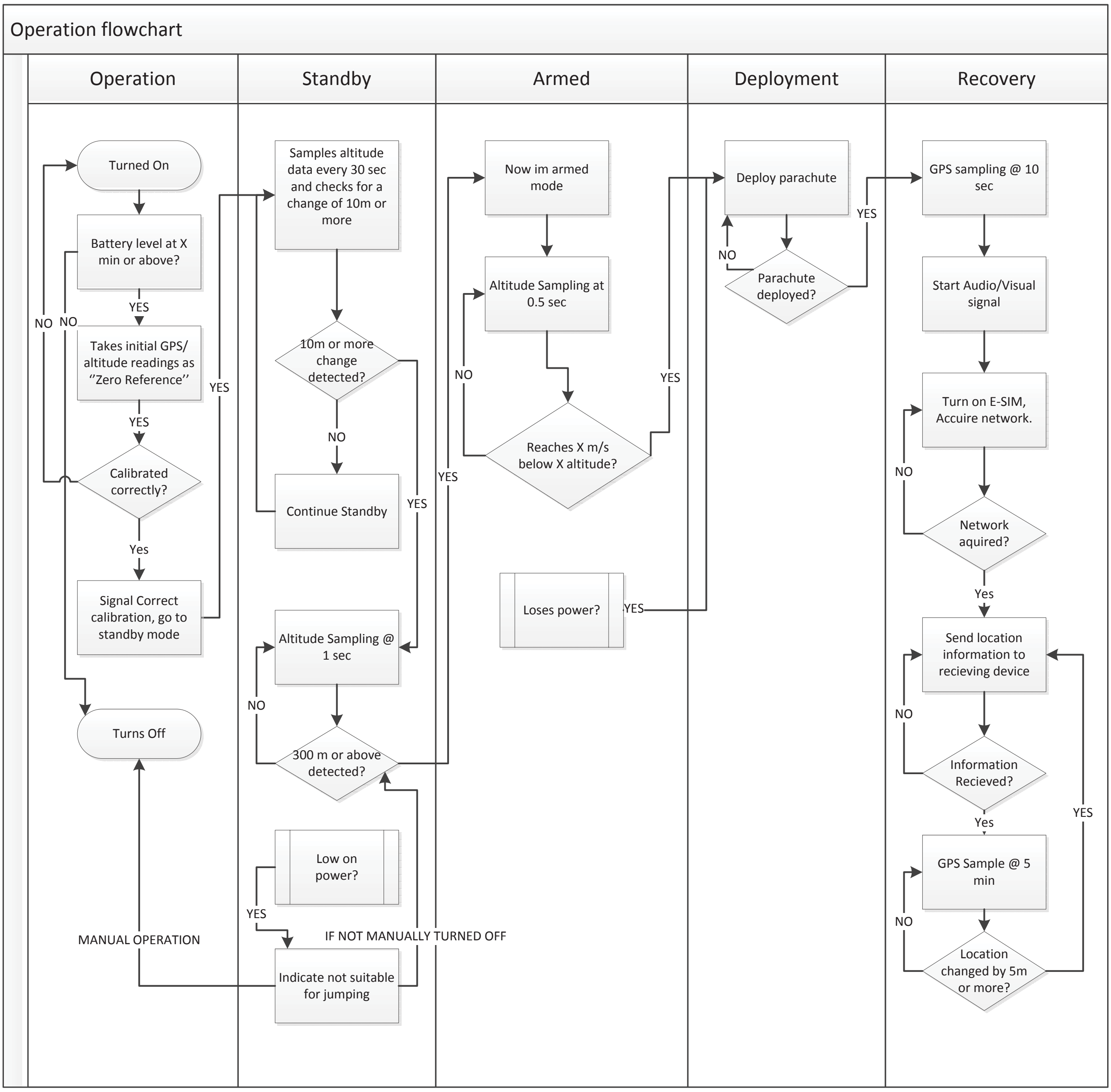

Operation flowchart
Operation
Standby
Armed
Deployment
Recovery
Turned On
Battery level at X min or above?
YES
NO
NO
Takes initial GPS/ altitude readings as ''Zero Reference''
YES
Calibrated correctly?
Yes
Signal Correct calibration, go to standby mode
YES
Turns Off
MANUAL OPERATION
Samples altitude data every 30 sec and checks for a change of 10m or more
10m or more change detected?
NO
Continue Standby
YES
Altitude Sampling @ 1 sec
NO
300 m or above detected?
Low on power?
YES
Indicate not suitable for jumping
IF NOT MANUALLY TURNED OFF
YES
Now im armed mode
Altitude Sampling at 0.5 sec
NO
Reaches X m/s below X altitude?
YES
Loses power?
YES
Deploy parachute
NO
Parachute deployed?
YES
GPS sampling @ 10 sec
Start Audio/Visual signal
Turn on E-SIM, Accuire network.
NO
Network aquired?
Yes
Send location information to recieving device
NO
Information Recieved?
Yes
GPS Sample @ 5 min
NO
Location changed by 5m or more?
YES

Figure 2.1

The flowchart should work collectively on two devices. Device 1 will be the accessory, that is used during the jump. The approximate behavior of it is indicated below in Figure 2.2
This chart indicates which actions are required by the user to get the device ready for a training jump and how to deactivate it.

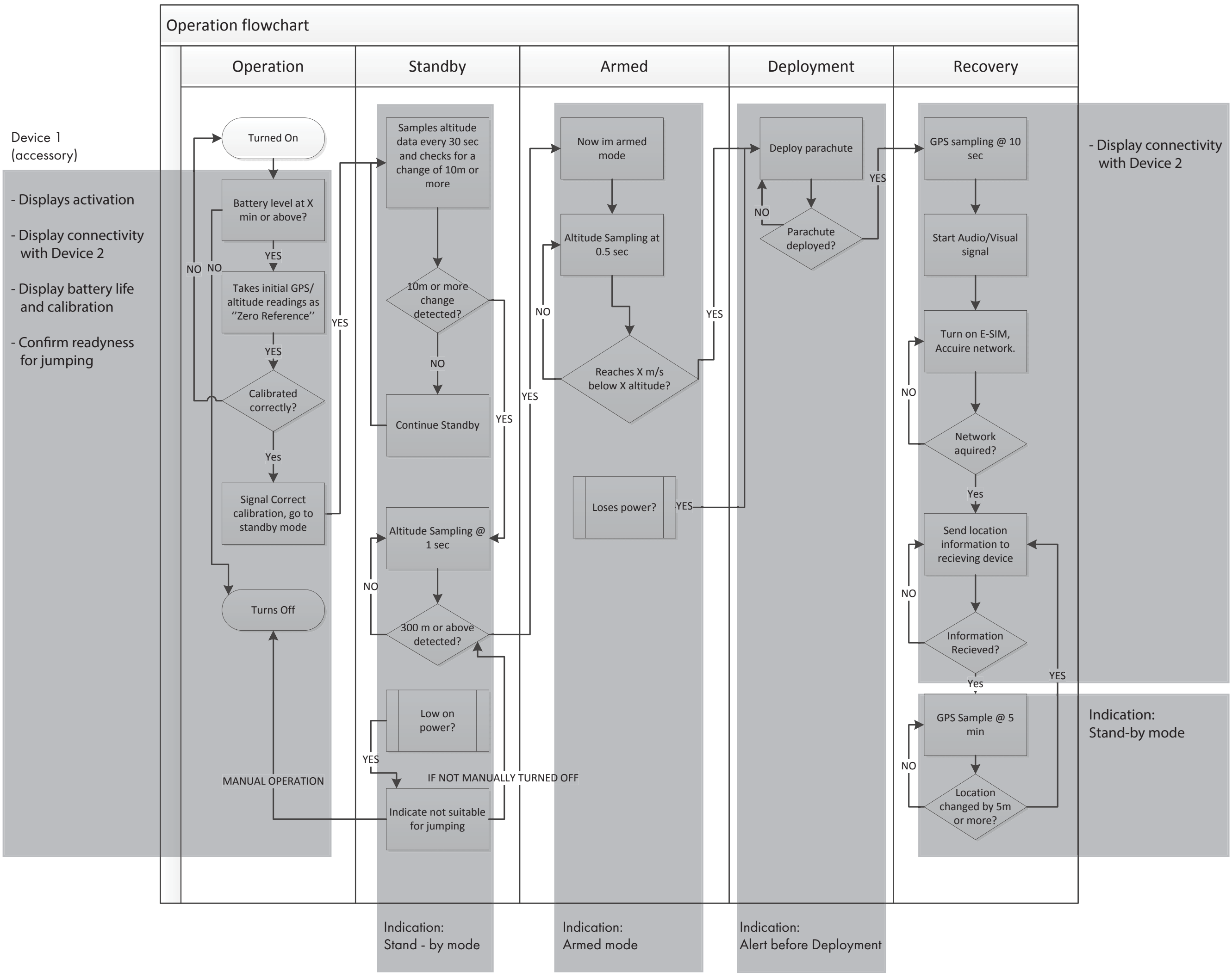


Figure 2.2

Device 2 will be the app that works together with device 1. It provides a log of data about previous jumps and locations as well as times of free fall. The app makes device 1 locatable by receiving data about landing location. The approximate behavior of it is indicated below in Figure 2.3

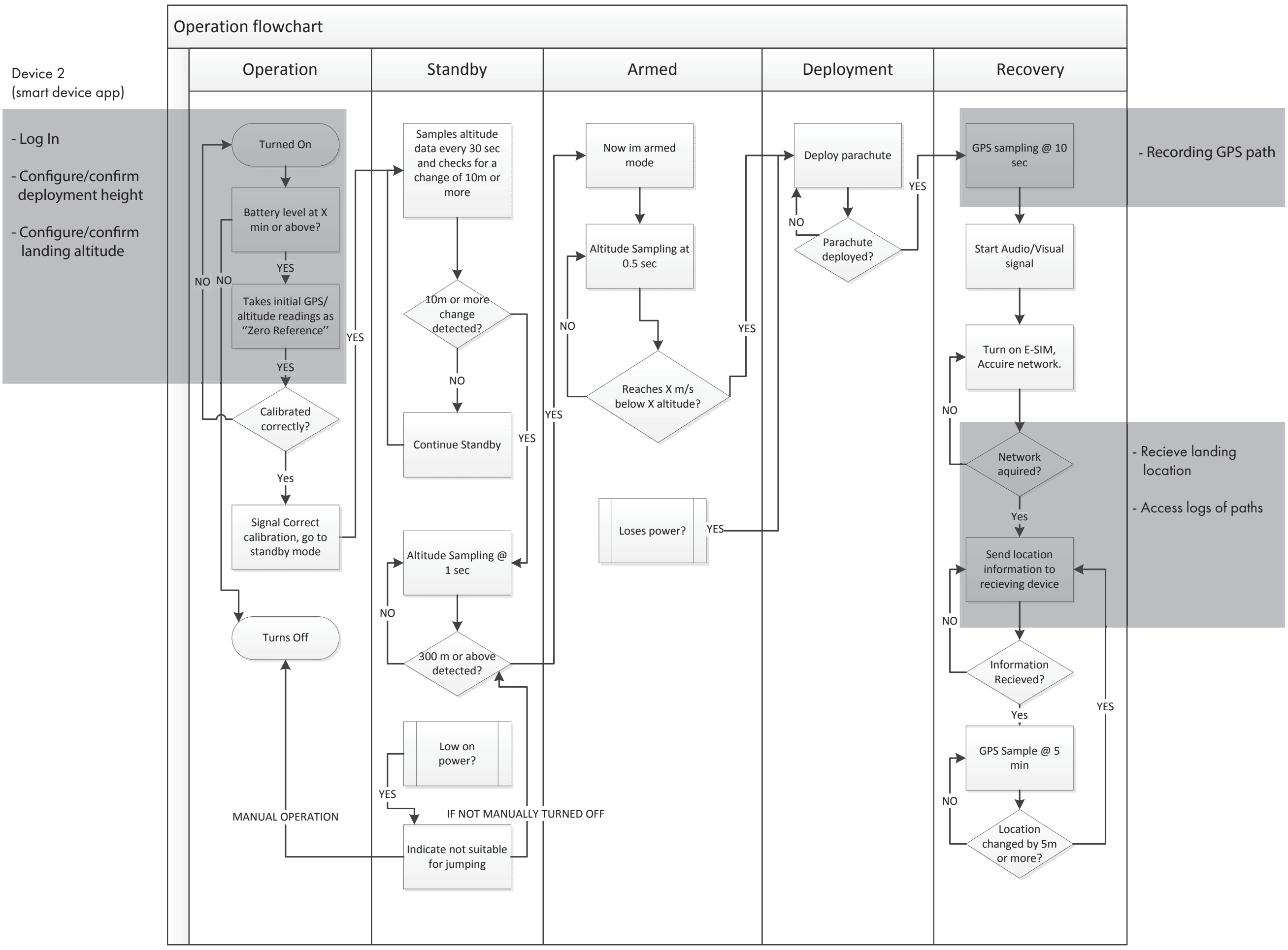


Figure 2.3

2.3.1 User interface

Front-end software development

The Biggest question with creating an effective user interface was how much should the device interact with the user and how much of it should be through a smartdevice application. After the jump, locating the ball will clearly work best through the owners phone. It was a challenge to define, how big of a part in the user interface the app would play. There were also restrictions when it came to the device - any buttons or touch-sensitive surfaces would need to be secured in a way, that when touched, held or played with in any manner, the device's status and activity would not change. More importantly, it should be clear to the user, that there is no possible way to change the device's status with touching it. Firstly, because knowledge of it can change the users behavior with the device, when it comes to training and play. It could cause the user to try to use it differently than they normally would. Secondly, this kind of cautiousness could distract the jumper from concentrating on a number of important drills during the jump – safety checks before boarding, on ascent, during free fall and landing.

It seems, that the device should indicate its status clearly from every point of observation. It should also be visibly clear that it is unchangeable. Its presence during the jump should not cause them to think about the device's status, rather it should be reassuring and encouraging, with no trace of possibility, that a nudge or touch could change its determined functions.

Interaction through smartdevice application
This lead to considerations that maybe most of the configurations and device settings could be done through a smartdevice application, so that there is no fear that the changes might happen randomly when using the device itself. The application could connect to the training device through GSM as well as bluetooth.

To get the user well acquainted with the application, it would make sense to have more functions in it then just locating the ball. To ease using the device, some other functions could be configured through the application. The effective part about it is that the smartdevice provides a sufficient screen for obtaining, editing information and, whereas an indicative screen on the ball would be a vulnerable area for a device that is supposed to get thrown and kicked around. The device itself should show now areas of vulnerability as it may result in the user behaving differently with it during training.

3 Concepts

3.1 Concept Development

The first concept was developed upon insights and constraints of the brief. Research provided the behavioral signs of frequent attempts of play in free fall, the lack of legal or allowed accessories for training in authentic environment.

Research has also indicated the potential of fast advancement in flight skills through games and a possible general match of what the user community would accept and be curious about. All of this directed the concept development to a free fall toy that calls the jumpers for improvisation and intuitive behavior while practicing their flight skills.

To find the most efficient way to meet all demands and obey the constraints of the brief, a morphological matrix for solutions seemed to be the best.

Figure 3.1 indicates a morphological matrix of primary functions.

Figure 3.1.1

FUNCTION	CONCEPT 1	CONCEPT 2	CONCEPT 3
TERMINAL VELOCITY 200 km/h	CALCULATED WEIGHTS ATTATCHED IN INTERIOR	STRUCTURE EQUALS INITIAL WEIGHT	SHAPE SHIFTING
AVOIDING GROUND IMPACT	PARACHUTE DEPLOYMENT	PARACHUTE DEPLOYMENT	POCKETED SLIDER
IN-AIR IMPACT PRECAUTION	TAIL, HIGLY VISIBLE	GLOWING SURFACE	TAIL, GLOWING SURF.
DETECTING ITS HEIGHT	GPS	BAROMETER	BAROMETER
LOCATOR	GPS TO GSM	GPS TO GSM	GPS TO GSM
PARACHUTE OPENING CONNECTION	SOLENOID LATCH ACTUATOR - PULL	VACUUM LATCH	MECHANICAL SYSTEM
RECORDING LOCATION AND MOVEMENT	GPS TO GSM	GPS TO GSM	GPS TO GSM
STABLE FLIGHT IN FREEFALL	TAIL (LENGTH 1000 MM)	TAIL, SURFACE TEXTURES	SURFACE TEXTURE, TAIL

Figure 3.1

In order to choose the best options for concepts, a number of possibilities for each function was assessed in the chart below, figure 3.2.

Figure 3.2

FUNCTION	SYSTEM	**NEGATIVE**	**POSITIVE**
STABLE TERMINAL VELOCITY 200 KM/H	WEIGHTS ATTATCHED EXTERIOR	freefall speeds will turn any attatchment points shabby due to heavy vibration May cause instability	Visble presence
	WEIGHTS ATTATCHED INTERIOR	May be forgotten May crash and move inside upon impacts, needs a strong skeleton to keep it steady Needs to be attatched very securely, otherwise will cause instability	no exterior disturbance
	STRUCTURE/SKELETON IS WEIGHT	Needs secure attatchment	if securely attatched, saves space and covers 2 functions no exterior disturbance
	SURFACE SIZE CHANGE	Instablity issues with different shapes devices inside need to be flexible for change	easy to switch, no additions needed
AVOIDING GROUND IMPACT	PARACHUTE	needs extra housing needs repacking	works best for heavy objects slows speed according to size
	SPRINGS	limited use for speeds, transfers energy to other surfaces, takes up much space and adds weight	
	INFLATABLE PROTECTIVE CASE	limited use for speeds needs a separate system need for repacking	possibilities for effective ground protection fast opening
IN-AIR IMPACT PRECAUTION	SOFT CASING/SURFACE	too weak	surface finnish possibilities
	NOTICABLE ALERTING LOOKS	only works in the visibility area	visible presence, communication
DETECTING HEIGHT	GPS	can disapear at an unpreidctable time for an unpredictable amount of time dependent on GPS networks and coverage	takes almost no space has shown to be trustworthy when good coverage
	BAROMETER	extra piece of hardware in the device that can go wrong	takes almost no space
	AIR PRESSURE	needs further research of possibilities device is very vibration and impact sensitive	fool-proof system that requires no power
LOCATOR	GPS AND GSM		SMALL AND EFFECTIVE, can be connected with smart devices
	BLUETOOTH	connection distances are too small for possible ball locations over 200m	quick detection within a small radius
	RECCO	does not go through thick surfaces such as trees and rocks short range	works with snow and short coverage
PARACHUTE OPENING CONNECTION	MAGNETIC	influences electronic, gps and other metal devices	strong hold
	SOLENOID LATCH PULL	needs a lot of power to operate under parachute pulling pressure	works when power is lost
	VACUUM SOLENOID	needs further inspection, but so far, research shows it works well for the purpose needed	strong hold works when power is lost
STABLE FLIGHT IN FREEFALL	TAIL	gets shabby very fast	creates an air drag that prevents unpredictable and rapid movement stabilizes all movement generally makes the ball well visible can work as parachute deployer
	SURFACE TEXTURES	only capable of keeping rotation and orbiting under control	creates distinctive features
FALL RATE CHANGING	SHAPE SHIFTING	eaction needs to be rapid, infailable in order to function effectively	no need to calibrate weights
	DETATCHABLE WEIGHTS	need to calibrate weights before using	provides stable fall rates without malfunctions

Previous experience has shown that prototyping gives most accurate results to determine the final and most reliable solutions in the matrix. For this, the most feasible and promising solutions were put together into an initial prototype to see how the systems and functions influence each other and work together.

3.2 Prototype 1

3.2.1 Stable Free fall Speed

To obtain and maintain a free fall speed of regular belly flight, which is approximately 200km/h the prototype, should be the ratio of a certain size and weight. Since the size was fixed previously to r=100mm, the theoretical necessary body mass could be calculated.

Weight = 754.46 g

Therefore, to obtain the same free fall speed as a belly flier, the ball would need to weigh approximately 754 g

3.2.2 Avoiding Ground Impact

In a case where the skydiver fails to catch the accessory in time before landing, the ball would need to land itself without becoming a dangerous obstacle falling towards the ground at terminal speed. To eliminate this possibility, a parachute was chosen as the most efficient way to reduce its fall rate significantly, to a soft landing. A balance of wing load was needed though, to ensure safe landing but also not to make the landing too slow because in that case the parachute can cause a drift from the initial opening location. The ball under canopy could cover inconveniently big distances and they would be hard to estimate on windier days. To determine the size for an optimal parachute, 48 hours of multiple parachute tests in terms of size and shape were done in the frame of this thesis. The results of them were the base for all further concepts of this project and therefore crucial to the development of this thesis.

The material of the parachute was determined by the properties it needs to have to land an object of nearly 1 kg. The porosity of a traditional modern parachute material is 0, which means no air will go through the fabric hence it will function as a speed reducer by capturing air under it with downward movement.

The sports canopy has a rectangular or an elliptical shape and was designed to be steered by a person and hence to maintain forward movement. Because of this, a round canopy model seemed more reasonable. Its symmetrical shape has been used from the beginning of parachuting history to land objects with less forward movement (USPA, 2014), as it captures air into the dome-like canopy. The line length that holds the canopy was specified after a couple of test-jumps upon seeing what does not disturb the full opening of the parachute yet maintains minimum possible length to fit inside the object restrictions.

To assure ease of production, the research for an optimal round parachute for a 754g object started with the easiest possible solution - to create additional surface to reduce the objects fall rate. For this, the first attempt was cutting out a round shape from zero porosity cloth with the surface area of 2sqft to attach it to the object. According to a wing load calculator (Drop zone, 2014), a 2sqft parachute will create a wing load of 0.85

to a 754g object. This gave a theoretical base that this size could safely land an object of such weight. Along the test drops, the simple round parachute was optimized to avoid air escaping from under the parachute, thus making it more dome-like. "The process of this would also lessen fabric surface and as a result it would take up less space when packing". (K. Wyatt, 2014). The first test drops were all done with a device mock-up with an weight of 800g. The weight was imitated with a bottle filled with water and was intentionally made heavier than 754.46 g.

Figure 3.3

The test jumps indicated, that the parachute opening might be too fast and thus put unnecessary stress on the lines and the device itself. Therefore a symmetrical slider was constructed for the parachute to slow down the opening thus lessening pulling stresses on both the parachute and the device.

Figure 3.4

Figure 3.5

Figure 3.6

After test drops with an open parachute, the last drops were done with a closed device, to see the parachute opening time and practical stress on the device. For this, the closed device was taken 200m above the ground with a drone (by Krakul OU) and released to free fall. From there, the device opened the parachute and landed. The last drone drops indicated the following:

Parachute opening time: 4-5 seconds depending on packing

Drift: approximately 50 m towards wind direction, with wind speed of 5-6 m/s.

No visible signs of fracture or damage on the device, lines or parachute.

3.2.2.1 Conclusions on Parachute Prototyping

With results as such, the parachute prototype proved to fill the needs of the device. A ratio of a parachute, that fit the container, yet was effectively capable of landing the device with a minor drift was found. The multiple different ways of packing it all proved that when put into a container with lines untangled, the parachute will open with no malfunctions. Thus no specific packing method was not developed during this thesis because there was no initial need for it. This, however should be addressed in further development.

Figure 3.9

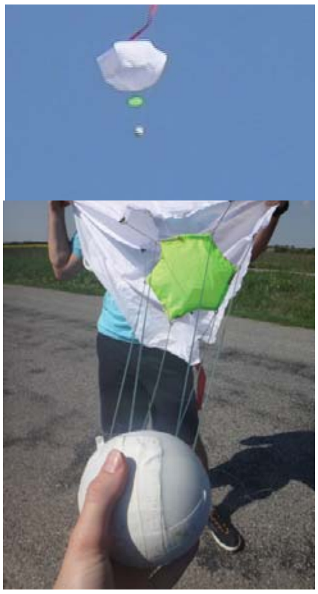


Figure 3.10

3.2.3 Parachute Deployment System

The opening system for prototype 1 (further referred to as P1) was determined for its size and way of functioning. Since the opening should enable the parachute to exit the case, the best case would be, if there was only one joint point to secure closing and opening. The more joint points, the bigger is the possibility, that one of them will cause malfunctions.

In addition to that, magnets and metal joints can interrupt proper functioning of the systems inside the case. Because of these reasons, the best solution seemed to be using a solenoid latch actuator (Pull) to hold the parachute container shut until a certain height, and then release it with a single simple movement. A pull solenoid was chosen because for a push solenoid constant power input would be needed from closing the parachute until releasing it again at a given altitude. This would drain any battery, whereas the solenoid pull only needs power for the moment of parachute release. A 5V solenoid with dimensions of 30x14x16 mm (Figure 3.8) suited the size criteria. It would need to be connected to the circuit board (Figure 3.7).

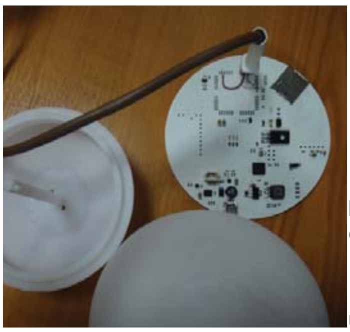


Figure 3.7

Figure 3.8

3.2.4 Height Detector and Locator

GPS that could be attached to the circuit board had two assignments - measuring height and location. The two would first be measured when turning on the object to determine the landing spot, then intensively measured during take-off and jump to detect ascent, descent and parachute deployment height and finally to mark the landing spot. The GPS module used in P1 was a Ublox all in one module UP501. It would communicate with the micro-controller and give the micro-controller the location coordinates. The module dimensions were 22x22x8 mm.

For this object the circuit board would connect, power and transform information from GPS to solenoid opening system. The circuit board and programming and assembly was done by Tehnolabor OU. The whole system would be controlled by a micro-controller Atmel XMEGA A4U.The circuit was powered by a Li-Ion battery that could be charged through the micro USB plug. A single chip Li-Ion charge management IC handles the charging current. A micro SIM-card was also added to the circuit board so the object could be located by GSM and GPS from a smart device.

3.2.5 Flight Stabilizer

A tail with a length of 1m was chosen for P1 for the drag it creates during free fall. A tail longer than 1 m could for practical reasons potentially pose a threat to an opening parachute when it is caught by a jumper before parachute deployment. A shorter tail creates less drag thus has a smaller impact on movement stabilizing during falling and less strength for parachute deployment. The tail in air will act as an opener of the parachute from inside the object, when the solenoid has unlocked the object itself. As a result of this, the parachute will inflate and open fast when in free fall, but when the solenoid accidentally unlocks the parachute when it is not in free fall, the tail will not pull it open.

3.3 P1 Testing

P1 was taken to Sky Dance, CA, as the winter weather conditions were not suitable for test jumps in Estonia. The jumps were done by three skydivers with diverse experience. J. B. Enscoe, P. Roben, and K. Issel. After each jump, the jumpers were debriefed, the videos were reviewed and conclusions were made.

3.3.1 P1 Testing Conditions

The conditions are indicated on the following page, Figure 3.11.

3.3.2 Test Jump 1

From 4200 m, 3 skydivers exited the plane last in jump order. The object was held in a firm grip of one test-jumper K. Issel. The object was let go approximately 10 seconds after exit. The next 40 seconds of free fall the jumpers were trying to fly with the same speed as the object was falling at. This proved to be difficult, as the ball was falling moderately fast. The speed of it was later determined approximately 235 km/h, which was too fast for belly flying.

The jumpers had to adjust their position accordingly to keep up with the fall rate of the object. Due to the off-centerdness of the weights inside the object, it developed a small circular orbit, with a radius about 5 cm around itself as it gathered speed in free fall. This orbit and rotation caused it to pick up speed more because of the turbulence of spinning. This did not pose a threat to the skydivers but it did make catching it lightly harder. Before break-off the object was caught again by K. Issel and held in his left hand when deploying and eventually landing.

Figure 3.11

CONDITIONS CHART 1

	JUMP 1;2	RESULTS	SHORTCOMINGS
WEIGHTS	INTERIOR, 758 G	produced sufficient weight for an approximate free fall speed	causes instability and rotation in free fall when not firmly attached in interior, vibration
GENERAL MASS	822 g (weights plus general mass 64g)	free fall speed 235 km/h, interior instability	interior instability caused the ball to develop an approx. 5 cm wide orbit around itself
GPS	functioning	functions well when ball recovery initiated	unreliable in free fall, can lose connection at any time for an x amount of time
STABILITY	TAIL	functions as stabilizer and parachute opener	edges get shabby after first jump when not sewed and glued properly
EXIT	tail rolled around ball, held with 2 hands	successful when tail secured and not open during exit	-
PARACHUTE	caught before deployment	was not deployed	-
FREE FALL	developed 235 km/h speed 15 sec after exit	inaccurate fall rate	speed too fast for regular belly flyers and too slow for vertical flyers
AFTER BREAK-OFF	jumper deployed parahute while holding object in left hand	successful	object outer radius could be a little smaller
LANDING	jumper landed with ball in left hand held from tail	successful	could be developed on to make grip better, easyer
SAFETY PROCEDURES	immediately letting go of object when malfunction detected	was not neccesarry	-
REINFORCEMENT SKELETON	fortyfying the ball while deployment	3d printed structure to evaluate size and assembly space	not strong enough to test strength properties in practice

3.3.3 Conclusions on Device

Test jumps with P1 showed shortcomings that could be replaced with more reliable solutions. The instability of flight and developing rotation during free fall could be fixed by a different and more symmetrical distribution of weights inside the object. The vibration, that a jump naturally causes, must not cause any systems or objects inside the ball to disassemble or move from its place.

This can hypothetically be fixed by pouring all the components including the weights into a unifying mass.

Additionally in order to save space, the structural skeleton that reinforces the ball and weight function could be united. In this case, the skeleton could be made of a heavy metal that provides

sufficient weight needed for belly flying.
The fall rate of the object did not match the one needed - it was 35 km/h faster. The weight calculations thus were not accurately applicable in practice and needed modifications.

One shortcoming was also addressed about the tail – the initial prototype had simply a 1 meter long 0 porosity cloth as a tail. This proved to get shabby after only 1 jump because of intense air friction. P2 tail should thus have sewn edges.
P1 opening mechanism was not tested during jumps however it was tested on the ground. The solenoid latch worked in theory but in practice it failed to work as expected due to environmental factors. The problem did not appear, when the movement was tested with no upward pressure that occurs in free fall.

When imitating the free fall situation however, when the fall rate wind applies on the tails surface, the pressure is also applied on the solenoid. This pressure proved to immobilize the 5V solenoid. The power used to unlock the parachute loop was not enough when the parachute applied an upward pulling motion on it. Therefore the solenoid opening system needed to be changed into something more reliable in the next prototype.

GPS and GSM installed into P1 was tested on the ground and it proved to effectively work at tracking records and being a locator device.
GPS however did not function reliably as a height detector. The speeds appeared to be too fast for the GPS to effectively determine the deployment height and there was no accurate way to predict when the signal could disappear and come back. Thus P2 had to have a better system for height determination.

3.3.4 Conclusions on User Experience

"Even though the object was hard to catch up to when falling, it was still both fun and physically challenging as the skill of rapidly and accurately modifying ones fall rate during free fall is a very important one." (J.B. Enscoe). In that sense, it can be said that the object roughly achieved its purpose. It was also noted that the objects radius could be a couple of mm smaller. This way it would still be big enough to comfortably catch and detect it but holding it in firm grip with one hand would be more convenient, especially if the jumper has smaller hands.

Figure 3.12

Figure 3.13

3.4 Prototype 2

Development of prototype 2 (further referred to as P2) was based on Concept 2 (functions indicated in Figure 3.1) and on the conclusions of P1 testing. The following changes were made from P1:

3.4.1 Stable Free fall Speed 2

To have P2 behave better than p2 in free fall with no orbiting and spinning, the weights were this time attached firmly to the interior and the space around it was cast in wax to reduce vibration. Wax was the most feasible means to melt and use for casting when it came to rapid prototyping. In the final product, wax would be substituted with molding rubber. For a requested speed of 200km/h (K.Issel, 2014), the added weight was reduced to 580g. The weight number was achieved through observing previous theoretical calculations from C1 and making corrections based on the practical results.
The overall weight would thus shrink to 729 g, thus it would be 28 grams lighter then P1.

3.4.2 Height detector - Barometer

As the GPS in P1 proved to be inaccurate at high falling speeds, it was replaced with a barometer that connected to the circuit board. The altitude of the object would be calculated through air pressure which is measured by a free scale semiconductor pressure sensor MPX6115 for measuring absolute pressure. The sensor gives an analog output to the micro-controller. The pressure change, that the semiconductor indicates can be translated into a needed deployment height and thus can be much more accurate and reliable than a GPS for altitude measurements. 2 regular jumps were done just to test the barometer alone, which proved its accuracy, and then it was attached to the circuit board. GPS however would also remain on the circuit board so the ball could be located when lost. The GSM module (Telit GL series) will communicate with the micro-controller. The micro-controller will be using the module only for receiving and sending SMS. The barometer used in P2 was chosen for its small size that fit effectively on the circuit board and suitable voltage.

3.4.3 Flight stabilizer - Tail

The tail from P1 was kept the same length but sewn from all edges to prolong its usability. The length of it remained 1 m.

3.4.4 Parachute Deployment System

As the solenoid, that fit in terms of voltage and size, did not have enough output to deploy the needed parachute, a new system was needed to replace it. A vacuum solenoid was considered to be the solution as a system that can withstand high pull-force, that was a shortcoming with the previous solution. After a few practical tests a vacuum solenoid proved its properties to be suitable, but there was another shortcoming. The air pressure changes on take-off, free fall and landing are unequal, and the system inside the device developed should be independent from air pressure change. A solenoid that uses vacuum however, might be sensitive to air pressure change, and for this reason, It was later considered as an unsuitable option for a deployment system. For this reason, the test jumps with P2, the release mechanism was not used or tested. However, other improvements

3.5 P2 Testing

Since the modifications were done on the spot after tests with P1, the test jumps with P2 were also conducted in Sky Dance, CA. The same test jumpers were kept as they gave objective information and comparison with P1. After each jump, the skydivers were debriefed, the videos made by them were reviewed and conclusions were made.

3.5.1 P1 Testing Conditions

The conditions are indicated on Figure 3.14.

Figure 3.14

CONDITIONS CHART 2

	JUMP 1;2	RESULTS	SHORTCOMINGS
WEIGHTS	INTERIOR, 665 G	produced sufficient weight for free fall 200 km/h	-
GENERAL MASS	729 g (weights plus general mass 64g)	stable, non-orbiting object	-
GPS	functioning	locateable after deployment	-
STABILITY	TAIL, sewed edges	functions as stabilizer and parachute opener	-
EXIT	tail rolled around ball, held with 2 hands	successful when tail secured and not open during exit	-
PARACHUTE	caught before deployment	was not deployed	-
FREE FALL	stabile flight, possible to play with it belly speed	accurate fall rate	-
AFTER BREAK-OFF	jumper deployed parahute while holding object in left hand	successful	object outer radius could be 3 mm smaller
LANDING	jumper landed with ball in left hand held from tail	successful	Grip needs to be better, object 3 mm smaller in diameter
SAFETY PROCEDURES	immediately letting go of object when malfunction detected	was not neccesarry	-
REINFORCEMENT SKELETON	fortyfying the ball while deployment	3d printed structure to evaluate size and assembly space	not strong enough to test strength properties in practice

3.5.2 Test Jumps 1;2

From 4200 m, 3 skydivers exited the plane last in jump order. The object was held in a firm grip of the same test-jumper (K. Issel, 2014), two test jumpers (J.B.Enscoe, P. Roben) were filming the jump and participating in interactions with the device. The object was let into independent fall approximately 10 seconds after exit to get into a stable position. The next 40 seconds of free fall the skydivers tried to play with the object and observe its behavior. The object was falling with a suitable bell-flight speed now.

It was later determined that the speed was approximately 200 km/h. The skydiver could catch the ball much easier than P1 because it did not generate an orbiting movement by itself. They had enough time to catch it, let go of it again, fly around it, closer to it and further from it. Before break-off the object was caught again by K. Issel and held in his left hand when deploying and eventually landing. The shell and structure of P1 was kept the same for P2, as the resizing of it should not change its aerodynamic properties and its radius can be reduced only after the size of circuit board and the rest of the equipment is reduced.

Figure 3.15.1

3.5.3 Unplanned Situation Documentation and Discoveries

After exiting and letting the object go from grip, the jump videos show that the ball drifts about 2-4 m away from the holder during the first approximately 10 seconds. This is not due to instability of the test-jumpers, it is probably a case of wind drift and how a body surface causes drift (Skydive Arizona Production, 2014). Since the objects surface is significantly smaller than a belly fliers surface, yet the fall rate is similar, the object will drift with a different arch after exiting a moving plane. This does not cause any problems, but it is good to be aware of it, as the jumper with the object will then immediately be expecting this situation and compensate their movement accordingly. This way, the possibility of losing the ball after letting it go is smaller.

3.5.4 Conclusions on Device

Test jumps with P2 were assuring as many of the unpredictable issues of P1 were eliminated or relieved. The object was falling with a stable speed suitable for belly fliers. The sewed tail showed better wear resistance. The barometer worked as expected with no shortcomings and displayed heights rapidly and accurately, leaving the trail mapping and locating the lost ball to GPS and GSM.

Figure 3.15.2

3.5.5 Conclusions on User experience

As after the first jumps, the test jumpers continued showing great interest in the object. The jumps 3-4 were said to be much more exciting as the object was falling with a comfortable speed, thus games and tricks could be played with it without much worry of keeping up with the speed. It was easy to spot and catch it as it flew in a stable manner unless it was moved by another flier. Approaching it successfully though, needed accuracy and experience. "It would take more than 5 jumps with the object for a skydiver with little experience to start approaching, catching and throwing it, but the level of skills the skydiver acquires during those jumps are very valuable and they will prove greatly useful when jumping with other skydivers in both FS and FF" (J.B.Enscoe, 2014). As better flying skills are acquired, more complex games can be created and practiced. This practice is only possible because the object is designed for not only play but also to adapt with mistakes in the game. "If the object would not deploy its parachute upon landing when not caught or lost in air, if it wouldn't have a stable free fall speed, skydivers would not be allowed to practice their skills with it for safety reasons to begin with" (P. Roben, 2014).

Figure 3.15.3

3.6 Delivery

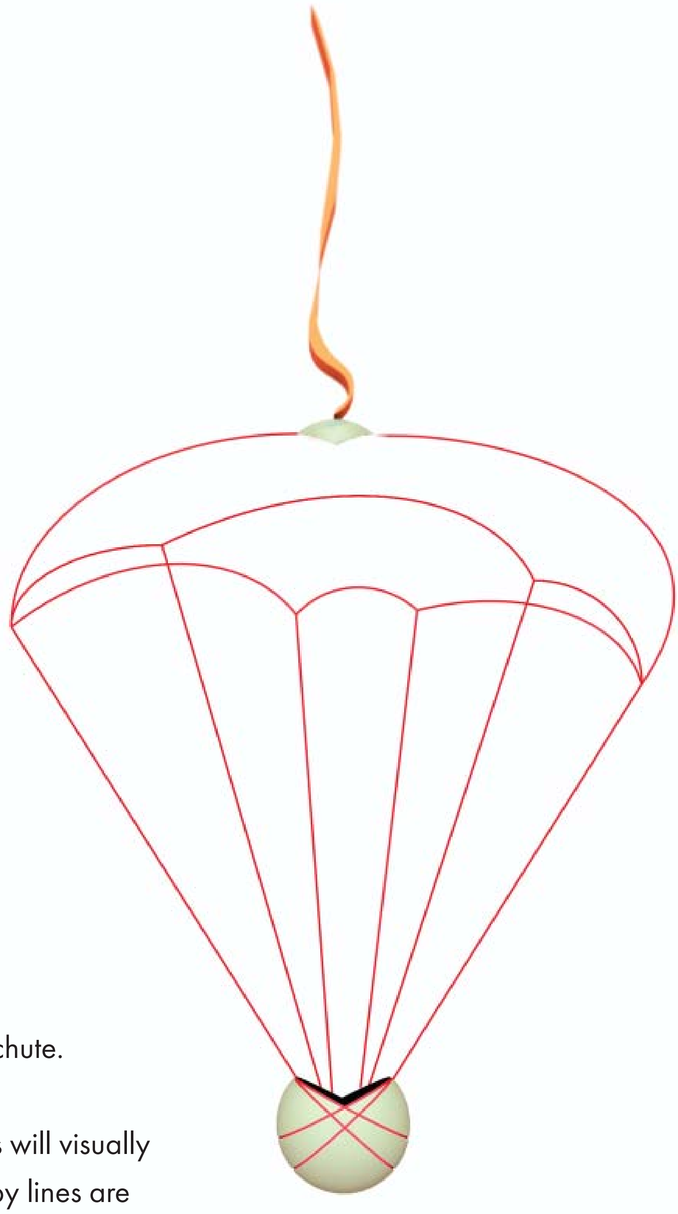


Figure 3.17

The Lines on the device
indicate connectivity to a parachute.

When the parachute deploys, the lines will visually
lengthen,and will look like the canopy lines are
wrapped around a simple sphere

Figure 3.16

Figure 3.18

Behaviour

The line colour indicates readyness and status of the device.

Lines: White - Device calibrated correctly and turned on. Device ready for skydiving.

Lines: Blue - Device has detected being in free fall.

Lines: Red - Below 1500m abve landing. Device in armed mode.

Lines: Red - blinking: Ready to deploy parachute

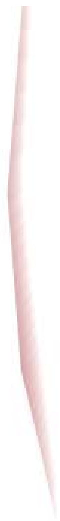
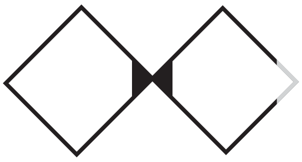


Figure 3.19

Surface color speculations.
Dark matte surface, easily graspable rubber on the device might indicate the color of the lines in a more vibrant way.



3.7 Further Development

The product development phase was the most extensive process in the study as it took multiple rounds of mock-ups and prototyping to reach a set of hardware that would meet the criteria needed. Due to this, some core aspects in product design development will be considered as further investigation and testing to reach the end product as a whole. These aspects are are the following.

3.7.1 User interface of the smartdevice app

The outlines and functions are already clear in terms of what the app should achieve. Programming in P2 reached to the point, where GPS and GSM communicate location effectively with a smartdevice via SMS. To take this further, the front-end and back-end development of the app is to be prototyped further to find an optimal interface, that is self-explanatory for the user and fits their expectaions and perceptions in terms of device behavior.

3.7.2 Parachute Deployment System

The solutions chosen for P1 and P2 did not work as expected and this part of the device needs further research and prototyping. The system for it needs to fit into the device as a whole and be as reliable as possible in terms of keeping the parachute container firmly closed before deployment and then effectively release the parachute from the container quickly with the pull-force of the tail in terminal velocity.

Figure 3.15.3

3.7.3 Device Body and Assembly

The primary priority was to find out if all the necessary functions can effectively be fit into the developed device, have it falling at a set rate in a stable position, and get it to land itself safely. Beacause of these priorities, questions about casing, assembly and production will have the main focus in future development. An insight of the design is already there, driven from the function and behavioral needs of it, but further mock-ups and prototypes will better specify the final result.

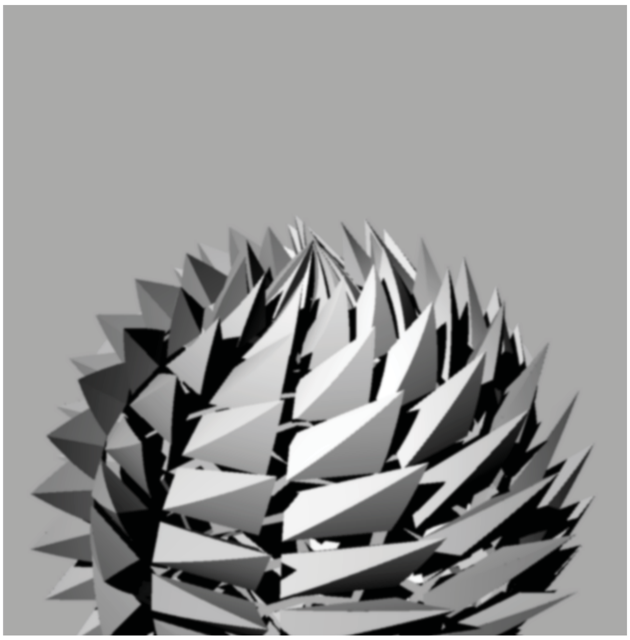


Figure 3.16

Conclusion

The insights concluded from research indicated, that the user community behavior hints on a market niche for a device for training and play in free fall. The research also outlined the concepts by giving constraints in terms of safety in many aspects such as aircraft safety, DZ as well as general skydive community safety customs.

From there, the aim of concept development was to find set of suitable systems that work collectively in an optimal way to meet those user needs and fill the market gap. For this, a device for free fall, a smartball that skydivers can play and train with began to be developed.

The primary priority there was to find out if all the necessary functions can effectively be fit into the developed device, have it falling at a set rate in a stable position, and get it to land itself safely. Since so far there is no dominant market competition for the device developed in this study, it was difficult for the users examined to define what they actually want before they were presented with a product with clear functions. These doubts were eased after extensive user testing with developed prototypes, seeing that the device brought fourth positive excitement and natural improvisational behavior in all skydivers that got the chance to interact and jump with it.

The product development phase was the longest process in the study as it took multiple rounds of prototyping to reach a set of hardware that would meet the criteria needed. Due to this, some core aspects in product design development will be considered as further investigation and testing to reach the end product as a whole.

These aspects are:

Developing an effective interface for the device as well as the smartdevice app.

Further prototyping the casing and assembly

Further prototyping the parachute deployment system

The conclusions of both research and development phase also show, that there are two possible ways to move forward with the device marketing wise. One option is to design the interfaces so that there can be one owner for one device, and the data collected to the owners smartdevice gains value in time as statistics becomes more accurate. In this case the user can get information about the jumps made and their skills improving.

The other option would be every DZ owning a device as such and renting it out for skydivers, thus providing them with a training device in a controlled environment. This would free users from the need to buy another product, and give the possibility to use the training and play device upon choice per jump. Then, the weight of responsibility in terms of locating the ball would fall upon the DZ as well as data collected would be gathered by the DZ. The actual jumpers would in this case not form a personal bond with the device and the interaction with it is expected to be slightly different.

Kokkuvõte

Magistrtöö üks põhieesmärke oli uurida langevarjuspordi vabalangemise oskuste treenimiseks kasutatavaid meetodeid ja vahendeid. Töö käigus olid vaatluse all nii traditsioonilised ning iseenesest mõistetavad meetodid, kuid ka mitte-traditsioonilised meetodid. Uurimuse käigus selgines ning kinnitus esijalgne teooria, millele viitasid langevarjuspordi harrastajaskonna käitumise mustrid, et vabalangemise oskuste arendamiseks on olemas turu nišš treeningu -ja mänguvahendile.

Edasine tootearenduse uuring, mis toimus põhjalikult lähedases kontaktis langevarju spordi harrastajatega, viis detailsemate arusaamisteni, mis võiks olla nende ootused ja arusaamised võimalikust treeningvahendist. Noor, kaasaegne ja progressiivne kasutajaskond viitas tehnoloogia vastu avatusele ja ilmutas huvi varustuse vastu, mis on personaliseeritav ja kauakestev, mis kutsub endaga tegutsema ning liidab meelelahutusliku treeningu viisiga harrastajaid loomulikul viisil.

Peale sellele järgnevat esmast kontseptide arendamise faasi said defineeritud funktsioonid, mida vastav vahend vajab, et täita kasutajaskonna ootuseid ja vajadusi, ning algas nendele funktsioonidele sobivate süsteemide testimine. Selle käigus selgenes fakt, et vajalike süsteemide kokku kombineerimine eelnevalt püstitatud ktireeriumite raamesse muudab need süsteemid väga tundlikuks üksteise suhtes, ning ühe süsteemi mitte ootuspäraselt funktsioneerimine võib tuua kaasa ka teiste süsteemide läbikukkumise. Mitmekihiline prototüüpimine, nende kiire edasiarendamine ning ümberkombineerimine viis lõppfaasis tulemuseni, kus arenduses olev vahend oli kriteeriumitele vastav ning kollektiivselt funktsioneeriv. Katsetused, mis jõudsid töövalmis seisukorda võib kokku võtta järgmiselt:

Treeningu-ja mänguvahend, sümmeetriline sfäär koos stabiliseerijaga lendab vabalangejaga samal ühtlasel kiirusel ning on heaks orienteerumispunktiks vabalangemises liikujale.

Vahendiga mängimine, sellele lähenemine, kinni püüdmine ja viskamine treenib efektiivselt vabalangemise liikumise oskusi ja parandab reaktsioonivõimet. Treeningvahendi külg-suunalise liikumise kiirust saab muuta stabilisaatori pikkuse muutmisega.

Vahendit on lihtne püüda nii ühe kui ka mõlema käega. Teda saab hoida ühes käes, kui langevarjuril on vaja avada enda langevari.

Treeningvahendiga hüppel ei ole kohustust ta enne varju avanemist kinni püüda. Langevarjur keskendub esijärjekorras ise enda turvalisusega. Kui vahend jääb vabalangemise kiirusesse on ta võimeline avama endale langevarju ise, mõõtes baromeetriga oma kõrgust.

Treeningvahend maandub langevarjuga ilma vigastusteta, tuulega 5-6 m/s kandub pall avamise asukohast umbes 50m kaugusele tuule puhumise suunas.

Treeningvahend on ühenduses omaniku nutitelefoniga, mille kaudu on võimalik peale maandumist kadunud vahend üles leida. Pallis asuva GPS ja GSM vahendusel jõuab maandunud palli asukoht ning info vabalangemise aja, tuulesuuna ning kiiruste kohta omaniku nutitelefoni.

Omanik saab nutitelefoni kaudu kalibreerida palli langevarju avamiskõrgust ja break-offi märguannet.

Aspektid, mis kuuluvad edasise ja jätkuva tootearenduse alla, on järgmised:

Toote korpus ning selle kinnitused ning märguannete süsteemid.

Nutitelefoni aplikatsiooni ning treeningvahendi kasutajaliides.

Langevarju avamismehhanismi töökindluse prototüüpimine ning edasiste variantide analüüs.

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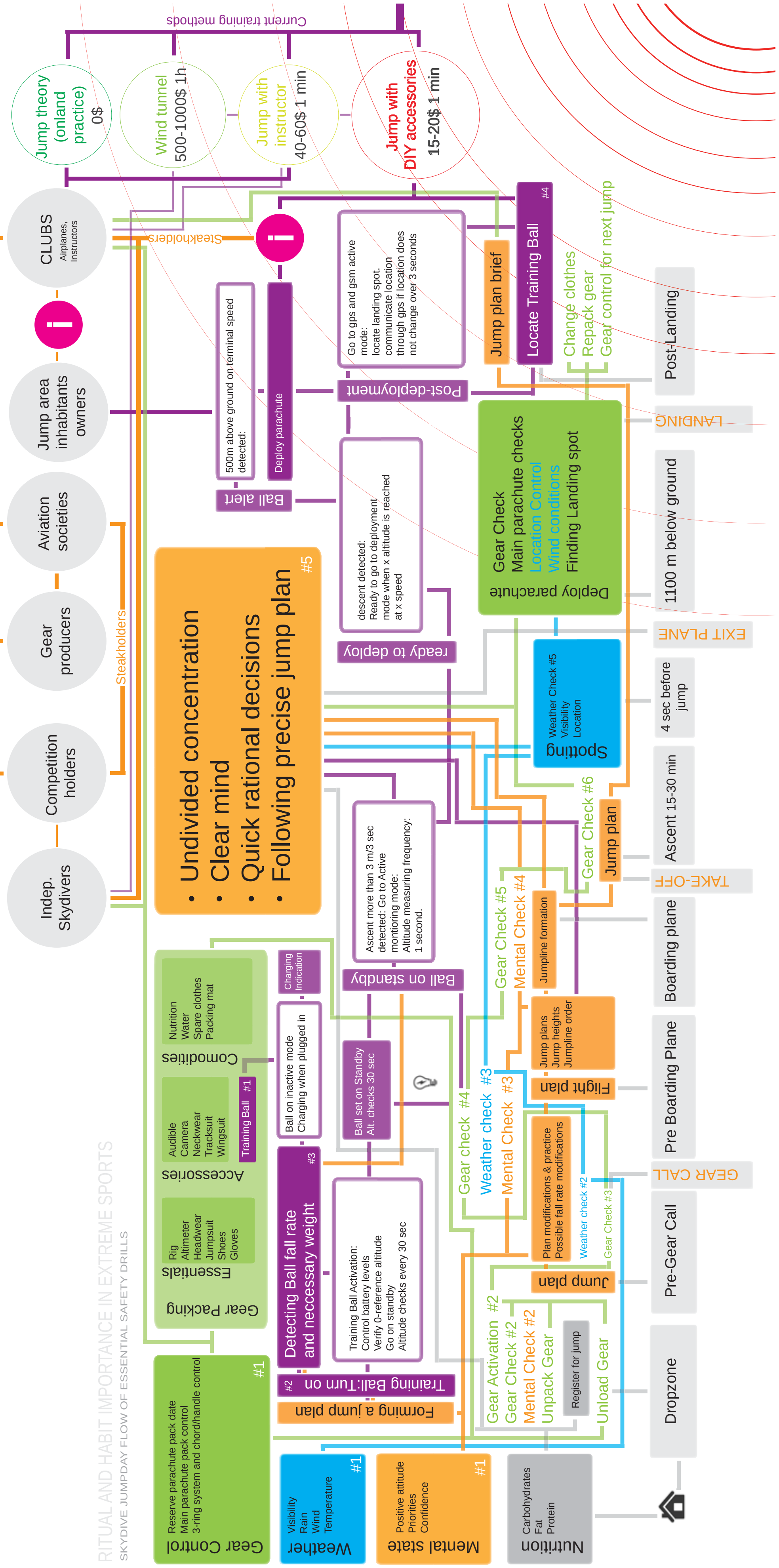
Appendixes

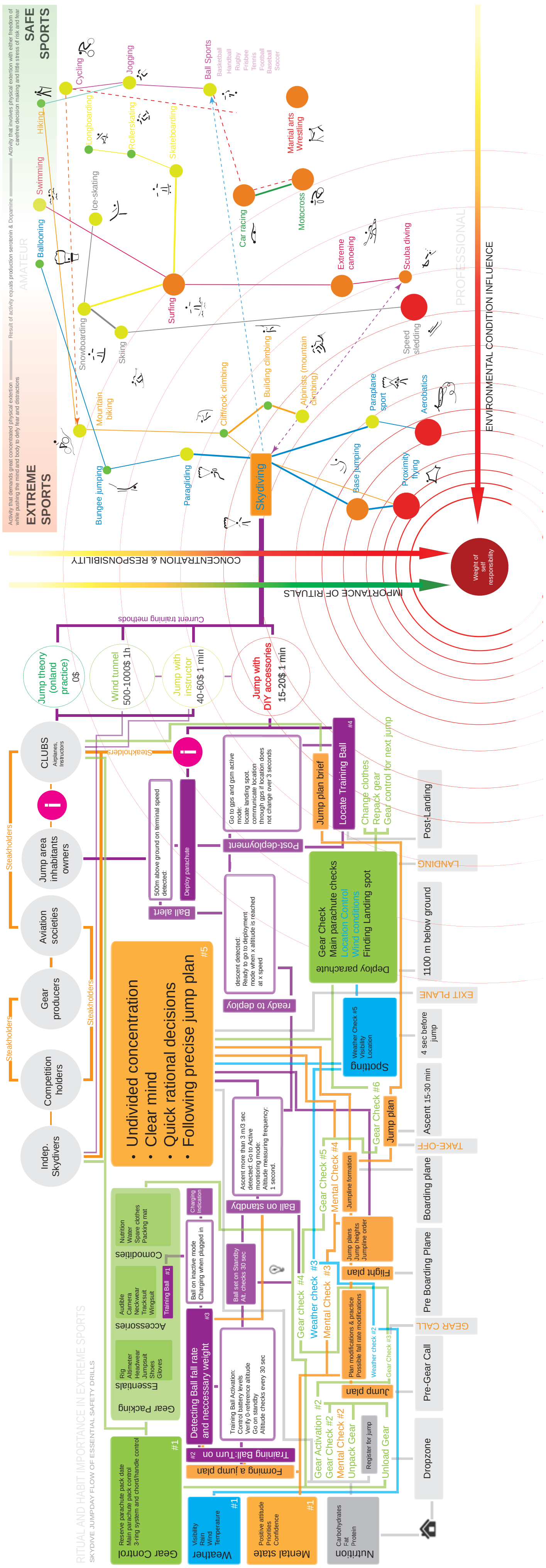
Appendix 1

GIGA-mapping
Skydive Jump Day
Time Line



Appendix 2

GIGA-mapping
Skydive Jump Day
Time Line, Extreme Sports vs Safe Sports
Ritual Weights



Appendix 3

P2 Test-Jump recordings

Appendix 3

P2 Test-Jump recordings