Developing a graphical user interface for a universal drone docking system to aid inspection use-cases

Graduation Project

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Nest-Fly Technologies

Abstract

Drones are becoming a more widespread technology, however they lack in scalability[2]. For this reason Nest-Fly technologies is developing a Universal Drone Docking System [8]. To make the technology available to the masses, a Graphical User Interface (GUI) has to be designed, accompanied by a demo to showcase the technology. This research aims to find an answer in the context of inspection use-cases, how to develop a GUI for a universal drone docking system, and what user requirements and interaction elements are needed to make the GUI successful. To answer these questions, background research was conducted showing 4 design rules: 1. Place the user in control 2. Reduce the user's memory load 3. Make the interface consistent 4. Provide effective help [9]-[10]. Together with a design process defined as 1. Specify the context of use 2. Specify user requirements 3. Develop the GUI 4. Evaluate the GUI[], using two iterations [13][15]-[17]. In addition, the background research showed the state of the art drone and general interfaces used for reference and inspiration. Using this knowledge an ideation was performed were different brainstorms and interviews were conducted resulting in a first set of requirements and a final concept. This concept was further refined in the specification chapter with usage scenarios , an interaction diagram, a flow-map and usability testing, resulting in an updated requirement list and concept for realisation. In the realisation the findings were used to develop three iterations of the interface using Figma. The interface was evaluated between every iterations resulting in two usability tests and one expert giving new requirements for the new iterations. This showed that the overall usability did not necessarily improve, however, the overall usability was sufficient and resulting in the development of a successful GUI for a Universal Drone Docking System. Next to that a working demo was constructed which could show the technology in action.

Keywords: Drones; Drone Docking System; Drone Docking Station; Graphical User Interface; User Interface Design; Human Computer Interaction.

Acknowledgment

The graduation project is has been a journey. And where the first step could have been taken individually, along the way there were several persons to help make this graduation project a success. First of all, the supervisors Erik Faber and Amr Affifi were there give guidance and advice about different parts of the project. They also helped pass through the tough times a graduation project knows. Seconldy, Yves Lentfert from Nest-Fly Technologies who supplied the assignment for the graduation project and facilitated in building the final demo of the project. Thirdly, a big thanks goes to Dagmar Hogendorp, who a has been there to support with every part of this graduation project. Whatever the question was, she was there to help out. Lastly, a group I cannot forget to mention, is the Line-Up. A group of fellow graduation student who helped each other complete and excel in the graduation period.

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1 Introduction

This report aims to design an intuitive graphical user interface for a drone docking system. The research is done as a graduation project for Creative Technology at the University of Twente. First, the problem is described and the relevance of the research is stated. The second part of this introduction will focus on common terminology and concepts used in this report. Then the goals and research questions of this research will be introduced, after which the general structure of this report is outlined

1.1 Problem Description

In 2018, 43 people lost their lives when a bridge in Italy collapsed [1]. The reason for the collapse was lack of maintenance and lack of inspections. This collapse could have been prevented when the proper inspection had taken place, which would have shown the problems with the bridge. These regular inspection could have been performed autonomously using an already existing technology, Drones.
Drones are becoming a more widespread technology and are used in a diverse arrangement of scenarios [2]. One of these scenarios is the inspection of land area, buildings, and structures. In these kinds of inspection scenarios, it can be very beneficial to have a drone on sight. Drones can be used as an “eye in the sky” during inspection to serve as a different perspective. Having this different perspective can help with a more detailed view or by covering bigger areas.

This is further supported by a report published by ABN Amro [3]. The drone market is the fastest growing market in construction and inspection robots. This is also shown in the numbers, where the market for drones is expected to grow from €3 million in 2021 to an estimated €19 million in 2030 in the Netherlands alone.

Having a drone on location during an inspection is already happening regularly. However, the way drones are deployed does not yield a good scalability factor. The reason for this is the need for multiple people and licenses to deploy the drone. This being a drone pilot and an observer [4]. For that reason, a universal drone docking system has been researched under the project name THE BEAST [5] at Saxion University of Applied Sciences. The research revolved around a drone being able to take-off autonomously from a drone-box and fly to an area when requested. When the drone has performed its mission and given relevant data, it will fly back and land autonomously inside the drone-box, in which it will autonomously start charging again. Ready for the next request. With this box, the need for a drone-pilot, observer and licensing is taken away; this is all included in the system.

This research project created a spin-off called Nest-Fly who are developing the drone-box into a product being able to serve different scenarios. This drone-box will be able to provide inspectors with an extra perspective, without the need to buy expensive equipment, or training of staff.

This drone-box is already under construction and has the goal to be compatible with most drones, with minor modifications. In order to do this the drone-box will be equipped with different kinds of sensors. These sensors will be able to detect the health and status of the drone inside. The information will be used when deploying a drone. Also it will be used to support an interface for end users.

In order to support the inspectors with this kind of technology, they will need to be able to interact with it. Since most inspectors have little knowledge of drone operations and flight regulations, an interface is needed which simply enables them to request a drone for an inspection. This interface will be researched and developed and should give them interaction with the drone and relevant features to facilitate the usage of drones for their use cases.

1.2 Context Analysis

This section will explain some common terminology surrounding the Universal Drone Docking System

1.2.1 (Universal) Drone Docking System

A Drone Docking System is a system consisting of a drone and a drone box [6] as cam be seen in figure 1.1. The drone will be able to automatically take off from the drone box and fly to a specified location. After it has performed a mission the drone will be able to autonomously fly back to its drone box and land inside. Inside this box the drone will start recharging through the landing pad in the box. Also the box will check the drone for damage and check its status.

Figure 1.1 Illustration of a drone docking system [7]

1.2.2 Drone Box

The Drone Box is part of the bigger Drone Docking System and consists of a stationary box in which the drone will land [5]. This also includes all electronics and sensors needed for the operation of the drone box.

1.2.3 Drone/UAV/Aerial Robots

Drones can also be described as Unmanned Aerial Vehicles (UAVs). It can be defined as a flying robot controlled remotely or controlled autonomously through software-management flight plans built into the system working together with GPS and onboard sensors [6]. UAVs can have a multitude of different shapes and designs, however, in this research we will use the term ‘drone’ to refer to flying robots and there will be a focus on quadcopters because of their common usage in inspection use cases.

1.3 The client

Nest-Fly Technologies is a company based in Enschede, Netherlands [8]. They are currently working on building the worlds first universal Drone Docking System. The company’s goal is

to help accelerate the deployment of autonomous drones in the market. They do this by focussing on the development of the drone station only and use the technology to have drones available at any time. By using the drone station of Nest-Fly they hope to make the interaction wit drones and humans more safe, more efficient and easier. They focus on sustainable collaborations which could bring drone technology to new heights.

1.4 Goals and Research questions

1.4.1 Goals

Together with the client, the scope of the research and end goal of the research has been set up.

The goal of this research is to develop a graphical user interface for the universal drone docking system to aid inspection use-cases without the need for an expert drone operator. As a second goal, it was defined that a demo setup of this interface, including a miniature version of the drone box, will be constructed to showcase the possibilities of the interface with this technology.

1.4.2 Research questions

- **In the context of inspection use cases, how to develop a GUI for a universal drone docking system**

In order to answer this research question, a set of sub-questions has also been formulated.

- What are the user requirements for the GUI?
- What interaction elements fulfil the user requirements

1.5 Outline

After the introduction, chapter 2 will give more insight into the subject of drones, interfaces, and drone docking systems using a literature review, next to that, state of the art research will be conducted to create a general overview of the already existing market.

Based on the newly found knowledge, in chapter 3 the methodology will be discussed which will be used during this study, followed by chapter 4 with an ideation of the interface and demo design. In this chapter, the requirements for the interface and demo are set up. After which they will be evaluated and more specified in chapter 5.

Then in chapter 6 the interface and demo will be realized and tested. The interface and demo will be used and tested with real users, of which the results will be evaluated in chapter 7. Using the results of the interface and demo and testing thereof, an answer can be constructed for the main research question and discussed in the conclusion. Lastly, the limitations of the research will be discussed in the last chapter where suggestions for further research are stated.

2 Background Research

This chapter will give background research on the topic of interface design and drones and drone docking systems. It will be started by setting up general guidelines for designing intuitive interfaces. This is followed by a more detailed description of drones and drone docking systems. Then state of the art research on the topic of drone- and drone docking system-interfaces will be presented. This chapter will serve as a basis for the ideation in the next chapter

2.1 Literature research

This section will aim to provide a literature review of key aspects and a process for designing an intuitive User Interface. Afterwards common uses of inspection drones and the capabilities of drones will be discussed.

2.1.1 Graphical user interface design

This overview will consist of three parts. First, it will give insight into the key aspects of GUI design. The second part tries to define the design process for a UI. The third part will consider different approaches to performing the steps of the UI design process.

2.1.1.1 The key aspects of an intuitive User Interface

The definition of an intuitive UI will be different for every user. However, an overview of general key aspects, which are applicable to every UI, can be defined. Sridevi [9] defines key aspects of UI design by presenting the three golden rules, consisting of 1. Place the user in control 2. Reduce the user's memory load 3. Make the interface consistent [9]. Another definition by Chao [9] supports the defined golden rules, but also extends them. Chao [10] argues that an interface should also be identifiable and operational, communicative, have shortcuts, give feedback, and provide effective help [10]. The key aspects of Yang [11] agree with the consistency proposed in the three golden rules of Sridevi [9] and the feedback of Chao [10]. Yang [11] then also defines extra key aspects consisting of visibility, restriction, and mapping and matching. The three golden rules seem to give a basis for the design of an interface, however, more key aspects to these rules seem to be introduced.

The extra key aspects proposed by Chao and Yang [10][11] are more specifically defined when compared to the three golden rules of Sridevi [9] which are very broad. But some of the key aspects of Chao and Yang [10][11] seem to fit under the definition of the three golden rules. When Sridevi [9] is explaining the three golden rules it can be found that the key aspects of identifiability and operationality, communication, having shortcuts defined by Chao [10] and visibility, restriction, mapping, and matching defined by Yang [11] can be placed under golden rule number 2. Reduce user's memory load. Next to that the key aspect of feedback, provided by both Chao [10] and Yang [11] falls under golden rule number 1. Place the user in control, as explained by Sridevi [9]. The last key aspect of Chao [10], providing effective help, does not seem to fit the descriptions of Sridevi's golden rules. Therefore it can be seen as an extension of the golden rules. It is found that the key aspects defined by Chao and Yang [10][11] serve as additions to each golden rule of Sridevi [9]. Where the key aspect of providing effective help defined by Chao [10] is able to serve as an extension for the golden rules. The key aspects of intuitive interface design will therefore from this point be defined as:

1 - Place the user in control
2 - Reduce the user's memory load
3 - Make the interface consistent

4 - Provide effective help

2.1.1.2 Design process of User Interface

The design process of a UI is an iterative cycle of steps that repeats itself every time the UI has been evaluated through expert review and end-user testing[13][15]-[17]. Benyon [16] describes the UI design process in three steps consisting of 1. Classification of user requirements 2. Development of the UI 3. Evaluation of UI. Maquire [15] and Savage [17] break down the user requirements into two parts being 1. Specify the context of use 2. Specify user requirements and organizational requirements. This addition extends the 3 steps of Benyon [16] to not only look at the user but also implement the use-case and structure of the UI. This gives us a definition of the UI design cycle which can be finalized as:

1 - Specifying context of use
2 - Specifying the user and organizational requirements
3 - Developing the UI
4 - Evaluating the UI

Nielsen [13] emphasizes the role of iteration in the design process. The research of Nielsen [13] compared UIs which were designed with and without iteration. The iterated UIs showed a 38% improvement compared to the not iterated UIs. Nielsen [13] argues that in order for the UI design process to yield a good result, a minimum of 2 iterations of the UI design process should be in place [13].

2.1.1.3 Approaches to the User Interface design process

There is a wide variety of ways to approach the UI design process. Reiterer [12] presents us with four approaches. Namely, the Craft, Cognitive Psychologist, Usability Engineering, and Technologist approaches [12]. The Craft approach is not often used because due to its trial-on-error and non-theoretical basis it is very inefficient [12]. The technologist approach is a hypothetically proposed approach, which is based on software learning the theory behind human-computer interaction [12]. For these reasons, the Craft and Technologist approach will not be considered. Another approach to UI design has been researched by Alves et al [14] which aims to base its UI design on the user's personality. Despite yielding good results, it was found that basing a UI on the user’s personality substantially narrowed down the user group to users with specific personality traits [14]. The personality approach is therefore not applicable for general UI design.
The Cognitive Psychologist approach to UI design focuses applies human information processing and problem-solving theories to analyse the user of the interface [12]. This helps to understand the user and create an interface environment that meets their needs. The Usability Engineering approach uses the theories of the Cognitive Psychologist approach to generate methods to enable software engineers to design intuitive UIs [12]. The Cognitive Psychologist and Usability Engineering approach correlates with the UI design process formulated [15]-[17]. These approaches give tools for the UI designer to analyse the user and forms methods for converting this analysis into an actual interface.

Now that an approach to analysing users and developing a UI accordingly has been found, it is necessary to find ways of evaluating the UI. Savage [17] gives us three ways of evaluating a UI using expert reviews, user reviews, and usability testing. Because UI experts are hard to come by, Jeffries [18] offers an extra evaluation without the need for UI experts, the designers themselves can perform a cognitive walkthrough or review the system based on a list of theoretically defined guidelines. Then Maguire [15] has given a detailed overview of the same evaluations provided by Savage [17] and Jeffries [18], where each evaluation is given a detailed explanation and method to perform them.

2.1.1.4 Conclusion and discussion

The goal of this literature review was to get an overview of the key aspects of UI Design and provide a process for designing a UI. From the literature, it is found that there are many ways to define the key aspects of UI design. However, they can be boiled down to four overarching points, which should be considered in every UI. These are 1. Place the user in control 2. Reduce the user's memory load 3. Make the interface consistent 4. Provide effective help. Then the literature seems to agree on a common process for designing a UI. Consisting of an iterative cycle with 4 steps, where a minimum of 2 iterations is required. The steps are 1. Specifying context of use 2. Specifying the user and organizational requirements 3. Developing the UI 4. Evaluating the UI. The literature then provides us with two approaches that help with the first three steps of this process. These are the Cognitive Psychologist and Usability Engineering approaches. The first is based on the theory behind human-computer interaction and the latter gives methods to transform the theory into an interface. Then for the evaluation of the UI, a set of tests is given which consists of expert interviews, user interviews, cognitive walkthroughs, guidelines generation, and usability testing.

The research does run into a few limitations. The first one is that there is a large variety of UI literature that focuses on very specific use cases. Therefore a lot of research is not applicable to general UI design and this review relies on the basis of UI design.

An interesting future research direction is the automation of UI design. This has briefly been mentioned in the review as a still hypothetical approach to UI design. Might this technology become available, a quick increase in the usability of a UI can be expected through the ability of quick design and evaluation. Secondly, it would be interesting to see a development of a UI that is able to adapt based on one's personality. This can give the benefit of a personalized UI with higher usability, and still serve the same target group.

2.1.2 Drones and their capabilities

2.1.2.1 Quadcopter

A quadcopter is a specific type of drone consisting of four motors with propellers constructed in a cross (figure 2.1). Using differential thrust on these motors, the quadcopter can balance itself in the pitch, roll and yaw axis [24].

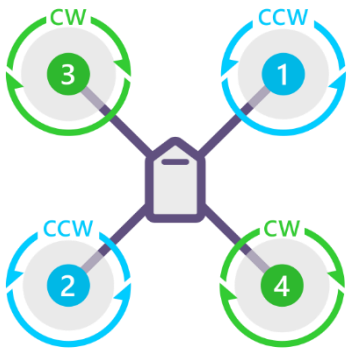


Figure 2.1 Motor layout and motor rotation of quadcopter [24]

2.1.2.2 Pitch, Roll and Yaw

A drone can move itself in 3D space. The axises of these motions have different names (figure 2.2). Roll is associated with the forward to backwards axis, pitch is associated with the left to right axis and yaw is associated with the up and down axis [25].

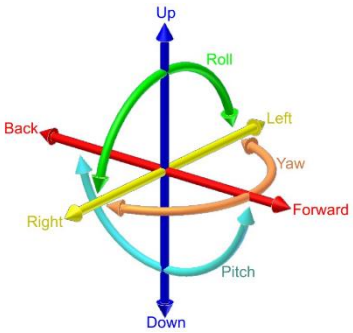


Figure 2.2 Translations and rotations of a Drone in 3D space [25]

2.1.2.3 Autonomous flight

Using the quadcopter configurations and the different translations within space drones are able to perform autonomous missions [26][27]. These missions are based on a set of given waypoints which the drone is able to follow. During these autonomous missions the drone is able to perform different tasks like, taking off, circling a point of interest, and landing [26][27]. Secondly, during a mission drones are capable of actively avoiding obstacles using a set of sensors on the drone [28]. This gives the drone the possibility to alter the flight route when an obstacle is detected and avoid a crash [28]. When the mission has been concluded, the drone is able to fly back to the landing zone and perform a precision landing with high accuracy. To perform this precision landing, different techniques can be used like, fiducials [6], object recognition [29] and IR beams [29].

2.1.2.4 Inspection use cases

Using the different capabilities, drones can and are used in a variety of inspection use cases [30]-[34]. At the moment drones deployed on construction sites to monitor the progress [31], in addition drones are also deployed on constructed buildings for inspections to find maintenance problems[30][31], the same is done for different structures like, infrastructure [32], bridges [33], wind turbines [34], and more. For these inspections drones take high quality photos or videos of the given objects, or they are even capable of making a full 3D scan of the given object [35].

2.2 State of the Art Research

After having done a literature review it is important to do an analysis of the current products already on the market. Doing this will give an overview of what has been implemented in operational drone stations and can give inspiration for the GUI of the Drone Docking System. This section will discuss different types of Drone Docking Systems and GUIs which were chosen for their functions, interface or design to serve as inspiration for the project

2.2.1 Drone Docking System's Graphical User Interfaces

DJI Dock [36]

Figure 2.3 Illustration of DJI Dock [36]

DJI is one of the world's market leaders in drone development [37] and has recently developed a drone docking system [36] (figure 2.3). Because DJI is big in the drone market, this drone docking system is therefore seen as the standard for other companies to live up to.

The DJI Dock consists of a rugged box that is able to withstand all weather conditions. Inside is a Matrice 30 quadcopter that can take off and land autonomously in the box. Upon landing the drone will be centred in the box and start charging from 10-90% in 25 minutes.

The interface which is used to interact with the drone docking system is DJI Flighthub 2 (figure 2.4). This is a cloud-based drone operations platform that connects the drone with the box. Using the software will let you make flight missions for the drone to perform and targets to make scans or pictures of. Integrated into the DJI Flighthub 2 are functions to map the environment, like 2.5D base maps, panoramic synchronization, cloud mapping, and live streaming of the mission. The interface is also able to synchronize with different users in order to work together as a team during the inspection. By using cloud-based APIs which are integrated into the system, The DJI Dock can also be integrated into already existing systems.

In order to operate the DJI Dock, a flight plan has to be made manually. They make use of a 3D view of the 2.5D maps where the flight path is overlaid. To tell the drone where to go waypoints are placed along the mission path. On these waypoints, the drone is able to be assigned different tasks, like taking a photo of this interest point or taking a video. These missions can be scheduled and performed on a regular basis. All media captured by the drone is stored online and can be accessed at any time by the team.

The DJI Dock gives a centralized overview of the status of the drone and box. When something is wrong the software will give an error and let you debug the drone from a distance. Next to that, it will also tell when abnormal situations happen.

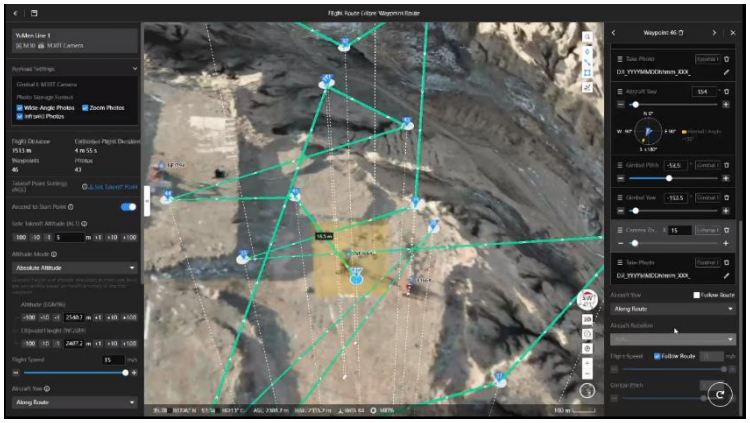


Figure 2.4 DJI FlightHub 2, an interface for the DJI Dock Drone Docking System [36]

Mapture.ai [38]

Figure 2.5 Drone Docking System of Mapture.ai [38]

Mapture.ai has developed a drone docking system based on the DJI Mavic 2 Enterprise [38] (figure 2.5). This drone has RGB and thermal cameras built-in. The box itself is a drawer-styled box, where the landing pad slides outward. The box is able to recharge the drone inside. It is a relatively small box with a small footprint, able to fit in lots of places, and is weatherproof to be also placed outside.

To operate the box mapture.ai has developed an interface for the box, available for both computers and mobile devices. This interface has automated pre-flight checklists and active geofencing to ensure safe operation. They work with a multi-level permission system where the administrator will set the boundaries for the drone. In this way, the system is able to overrule the operator of the drone once it is going beyond these boundaries and make sure the operator cannot make any mistakes during operation.

The interface that is used is called Viewport (figure 2.6). Here the operator can see what the drone is seeing and even take control. Next to that, the operator is able to pre-program a mission that the drone can fly. This is done by setting different waypoints. The pre-programmed missions can be saved and also reperformed. Viewport also has an API, such that it can be integrated with 3rd party systems.

Using this interface, in collaboration with mapture.ai, Twente Airport was the first area in Europe to be guarded by an autonomous drone [39]. The drone docking system can be activated by a triggered sensor or camera in the area and it will autonomously perform an inspection mission. Here it is able to give a good overview of the suspicious situation in the area.

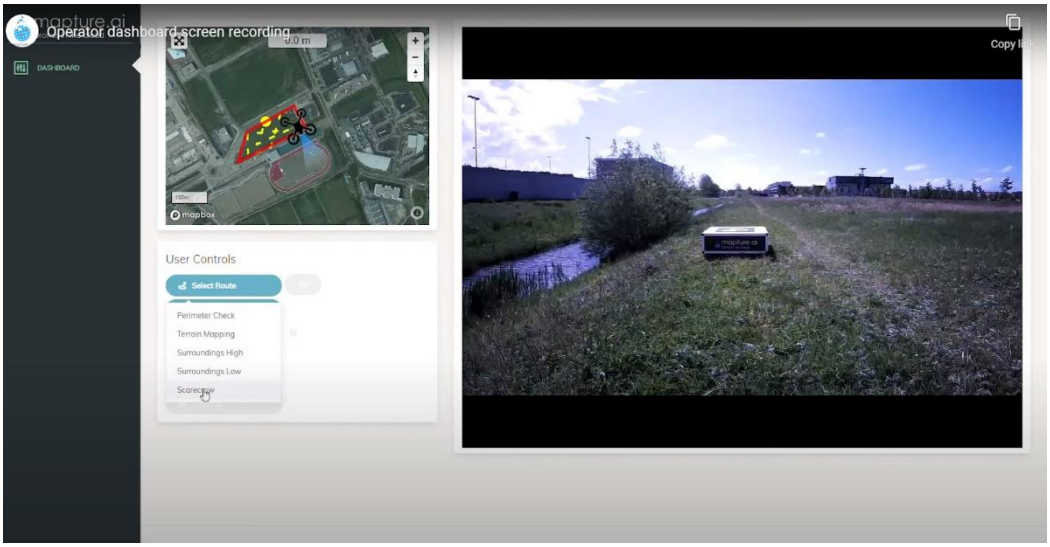


Figure 2.6 Interface to interact with the Mapture.ai Drone Docking System [38]

Nando-Drone [40]

Figure 2.7 Drone Docking System of Nando [40]

The drone box that is produced by Nando is able to slight open and present the drone (figure 2.7). The drone is able to autonomously take-off and land, and when landed the box can recharge the drone. The climate inside the box is also regulated to make sure the drone stays in good condition, and the box is fully weatherproof [40].

The drone itself is built by Nando itself and consists of lightweight materials. With a very long flight time of 70 minutes the drone docking system is capable of long range missions. The drone is also equipped with a camera for night and day vision. Using the camera the system of Nando is capable of detecting objects.

The drone docking system is paired with an interface (figure 2.8). This software enables user to manage the tasks in a simple UI. It displays relevant data about the drone,

the mission, the weather and the data retrieved. The system is able to detect objects in real-time and is able to track and follow this object. The user gets an alert and is able to choose whether or not to pursue the target.

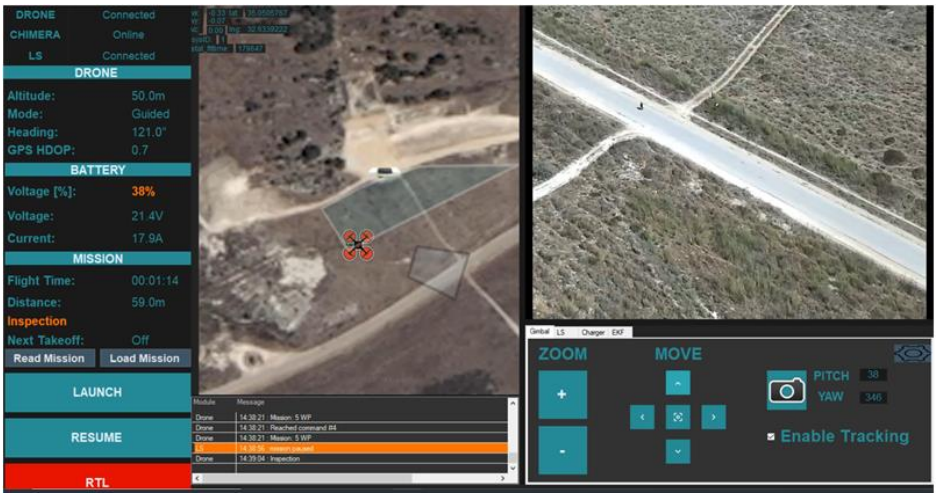


Figure 2.8 Interface of the Nando Drone Docking System [40]

Heisha [41]

Figure 2.9 Drone Docking System of Heisha [41]

The Drone Docking system Heisha is developing is a full solution together with an interface [41]. The box consists of a rotating cylinder to cover the drone (figure 2.9). The box is weatherproof and can be used outside. Inside the box, the drone is centred and will start charging once connected.

To use the drone docking system, Heisha has an accompanying interface, called Freesky (figure 2.10). This interface is for both mobile devices and computers. The interface lets the user set geofences and canopies for saving usage. Also integrated is a gamepad-like keyboard and mouse control to manually control the drone.

The interface facilitates autonomous mission planning which can be achieved by setting waypoints. Using the autonomous mission function, flight paths can be created for different use cases.

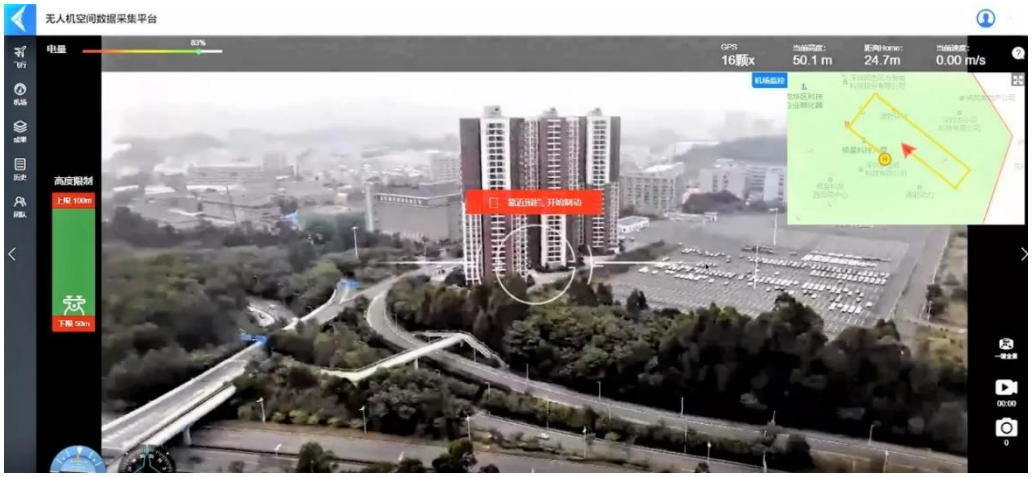


Figure 2.10 Interface of the Drone Docking System of Heisha [41]

2.2.2 Drone Graphical User Interfaces

DJI Fly [42]

The standard interface developed by DJI for personal use is the DJI Fly app [42] (figure 2.11 and 2.12). By downloading this app on a mobile device, the device can be connected to the DJI controller. Through the interface the user can see the flight status of the drone. It will show information like remaining flight time, position, and signal strength. The interface is optimized for video and photography and the functions focus on this aspect. Different settings for the camera can be found and adjusted and the angle of the camera can also be changed in-flight.

The drone can keep its global position autonomously. However using the app it is not possible to pre-program missions, and the drone needs to be flown manually to the preferred positions.

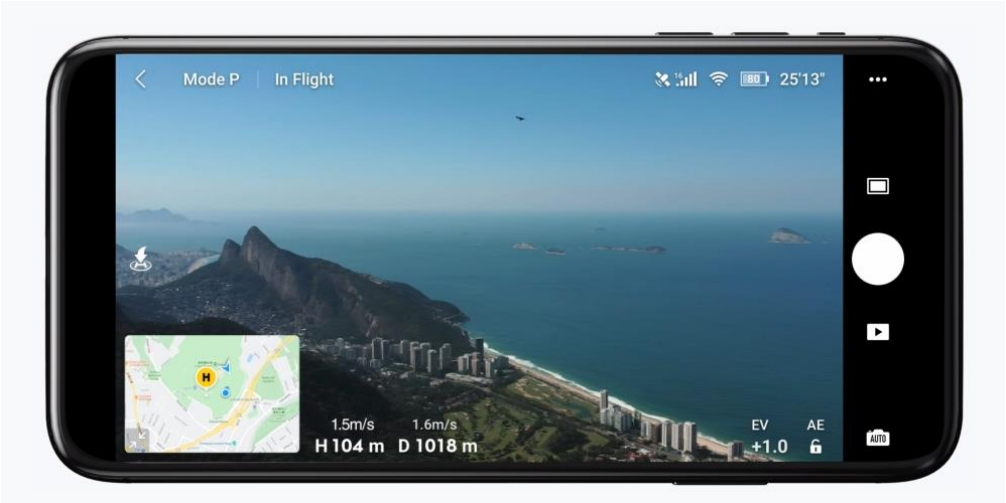


Figure 2.11 DJI Fly picture-mission mode [42]

Figure 2.12 DJI Fly video-mission mode [42]

DJI Pilot 2 [42]

Using DJI pilot (figure 2.13) the enterprise models of DJI can be flown [42]. These models have more functionalities that can be accessed through this interface.

The app gives the opportunity for more inspection-based functions, such as aerial mapping, surveying, and more. Functions like these can also be performed autonomously and using the app the user can program a mission.

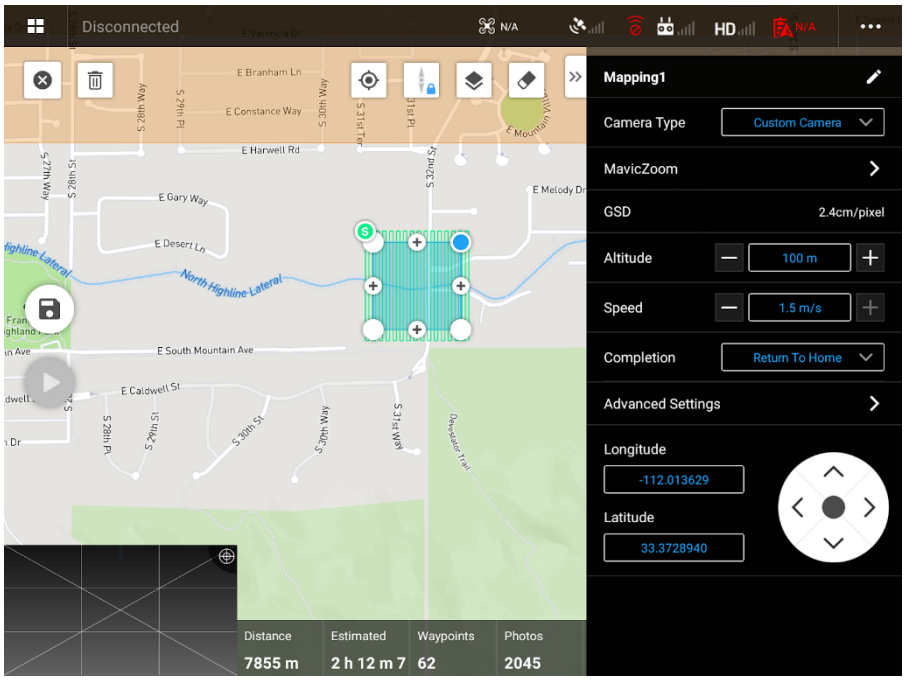


Figure 2.13 DJI Pilot mission planning [42]

QGroundControl [44]

QGroundControl is a high level hobby drone interface [44] (figure 2.14). It provides full flight control for the PX4 and ArduPilot based vehicle setups. The usage is relatively easy and beginner can already start using this software, however experts can dive deeper into the parameters and tune the vehicle to their liking. It shows important data for drones in flight like vehicle position, flight track, waypoints, vehicle instruments and more parameters can be set up. It is an intuitive software which is easily changeable to the user's needs. QGroundControl also supports the creation of autonomous mission and autonomous mission flight. Using waypoints a mission can be setup and saved to perform.

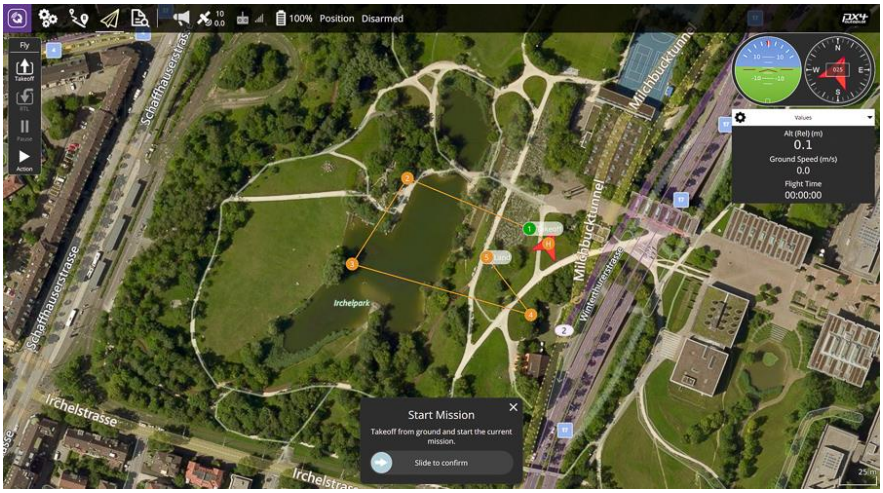


Figure 2.14 QGroundControl Interface [44]

MissionPlanner [45]

Mission planner is a ground control station displaying vehicle info [45] (figure 2.15). Different vehicles can be set up like planes, copters and rovers. These vehicles can be setup and tuned to perform autonomous mission. These mission can be created using waypoints. The status of the vehicle can be monitored live when flying the drone.

Figure 2.15 MissionPlanner Interface [45]

2.2.3 Other Graphical User Interfaces

PrusaSlicer [46]

A slicer is a software that slices a 3D object into layers [46] (figure 2.16). These layers are then converted into lines in a 2D plane. These lines can then be used to create movement paths of the nozzle of a 3D printer to build up the 3D object. It does this by laying out the lines in plastic for every layer. Resulting in the physical 3D object.

During the slicing process, the software is able to predict the time it is going to take to print the 3D object. This time is divided into different sections showing what operations the machine is working on and how long each operation takes. Next to that, it will calculate the amount of material used and the cost of the printing and material.

The software also has parameters you can change. These parameters determine the quality, speed, and success rate of the print. Using the parameters the user can choose the outcome of the print based on the needs it has for that part. As an example, when a print has to be done fast, the quality can be lowered.

PrusaSlicer is a very intuitive to use software and does not need lots of knowledge to operate. When using the factory pre-sets the print will come out as seen in the slicer. This is very useful for inexperienced users of 3D printers. The PrusaSlicer also helps by giving suggestions for errors when it sees the parts are likely to fail. However, as the user gets more comfortable with the interface it can choose to have more settings to tweak it more to their liking.

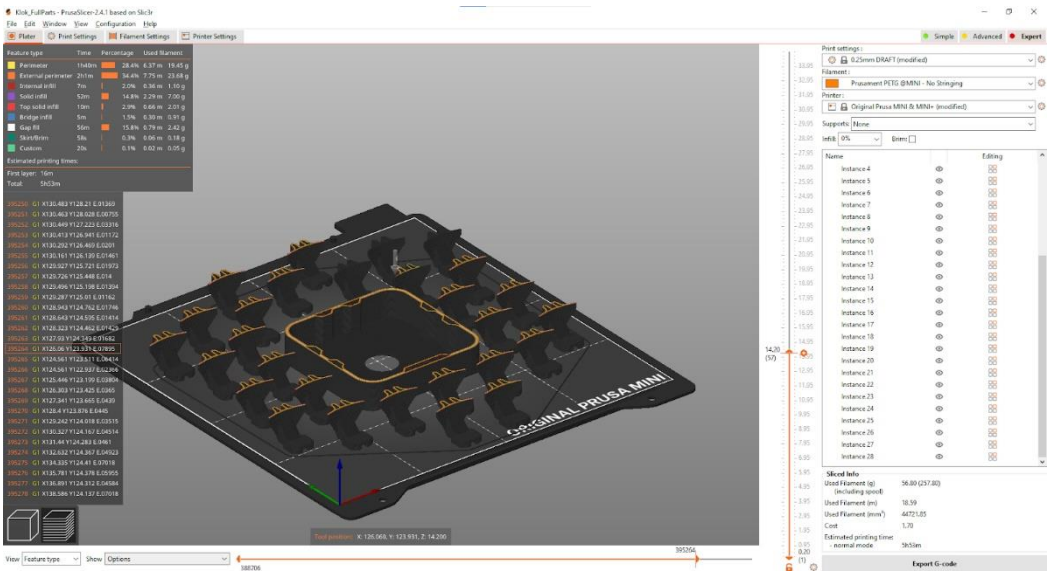


Figure 2.16 PrusaSlicer Interface with sliced parts and path visualisation [46]

GoScooter [47]

GoScooter is a company who is renting mopeds, cars, and bicycles [47]. The renting of these vehicles is done in a new innovative way. All vehicles are shared with everyone who has the GoSharing app installed (figure 2.17). When a user wants to rent a vehicle it can use the app to reserve a vehicle and the user will pay for every minute the vehicle is used.

When reserving a vehicle the user can get to see some of the data about the vehicle. The app will show the location of the vehicle, such that the user is able to locate and use it. Next to that, the user will be able to see the range of the vehicle, through which the user can

estimate if the vehicle can travel the distance they want. And the user will also be presented with the price it will need to pay per minute, giving an opportunity to estimate how much they are going to be paying for their travel.

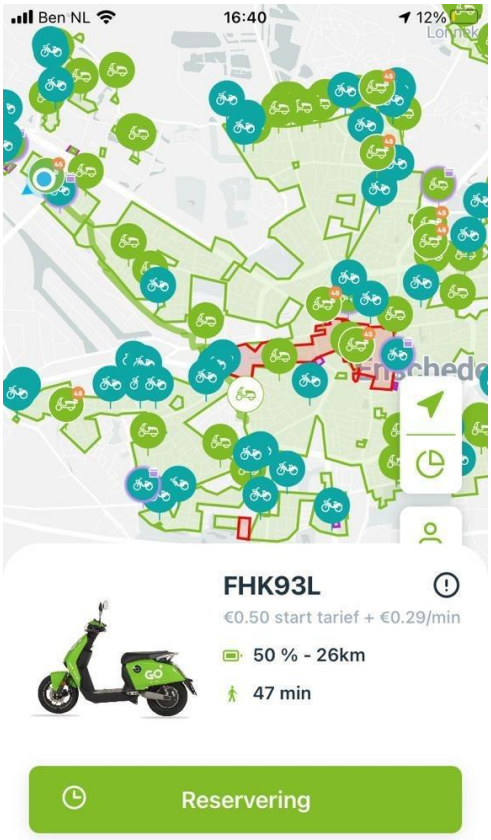


Figure 2.17 GoScooter Interface for ordering a scooter in the city [47]

2.3 Conclusion for Ideation

To have a good basis for starting the ideation a summary of key points will be given about the literature and state of the art research.

Starting with the literature research it can be taken away that when designing an interface, one has to keep in mind the earlier defined rules for intuitive interface design. These rules are:

1. Place the user in control
2. Reduce the user's memory load
3. Make the interface consistent
4. Provide effective help

Furthermore, the design process of a user interface consists of several steps. These steps have to be taken every time a new iteration of the interface is constructed. Next to that, there is a minimum requirement of 2 iterations of the interface, with intermediate user testing, to get to a final version of the interface. The design steps of the user interface design process are:

1. Specify context of use
2. Specify the user and organizational requirements
3. Develop UI
4. Evaluate UI

For the creation of a user interface there are several approaches which can be taken. In this research the Usability Engineering Approach will be used as a way of designing and evaluating the interface. For the evaluation of the interface several methods can be used. These consist of: Expert review, usability testing, cognitive walkthrough, and guidelines.

The state of the art research has shown lots of different interfaces from different companies and views. What can be seen is that all drone or drone docking system interfaces follow roughly the same layout. This consisting of a camera view, map view (with drone location) and settings on the side. With the interfaces you can create and save mission, and different settings for the flight can be changed. The data the drone has captured during a mission can easily be found and reviewed. Looking at the different symbols of all interfaces, it is good practice to reuse some of these to keep consistency between already existing drone interfaces.

Comparing all interfaces, it was found that DJI FlightHub 2 is at the moment the most advanced interface. Most featured other interfaces had were already integrated into the DJI FlightHub 2 interface making it the most versatile on the market. For this reason, the DJI FlightHub 2 can be used to base a first interface of, because of its already good usability.

To add new features to the interface the PrusaSlicer shows some good interaction elements which could be used. These consist of different expert levels, in order to make it more usable for a wider range of users. Secondly, it nicely shows a path generation of an object, this could also be done using a building and an inspection flight path to visualize for the user what the drone is going to do. Lastly, PrusaSlicer nicely shows how much time, material and cost an object. This could also be implemented in the drone interface where the time, range and cost are estimated based on the chosen building.

Then GoSharing shows how sharing of vehicles can be done in an interface. In the interface it is nicely shown where available vehicles are. This could be implemented in the drone interface for the different drone docking stations and their available range. Next to that you are able to reserve a vehicle for your trip, this can be done with the drones as well, where you can book time slots for their usage. Lastly, GoSharing shows nicely where you can and cannot place the vehicles and also where you cannot drive. This is also handy for the drone interface where you are able to inspect buildings and where not.

This newly found information can all be used to guide the ideation of a drone docking system interface. The different perspectives can show new ways of designing this interface for wide range usage.

3 Methods and Techniques

In this chapter different methods and techniques are discussed and explained for gathering data, development of prototypes and evaluation of prototypes. These methods and techniques will be used throughout this thesis in different chapters and phases of the project.

3.1 Creative Technology Design Process

In this part, the Creative Technology design process will be explained. This is a framework for all methods used in this graduation project. The Creative Technology design process was developed by Mader and Eggink [48] and has been illustrated as an iterative process in figure 3.1.

The Creative Technology Design Process consists of four phases:

- Ideation
- Specification
- Realisation
- Evaluation

Ideation

The initial phase of the design process is ideation. This phase aims to generate different ideas or possibilities for the given project and different techniques can be utilized. The phase will start with trying to get an understanding of the user group by performing a stakeholder analysis. To further understand these stakeholder and users, a set of personas will be set up together with one usage scenario. These will help with understanding the users mindset and their goals with the interface. Using the viewpoints of the personas and stakeholders a individual and group brainstorm will be performed to generate ideas. Then to get more detailed information, two expert interviews will be held. These aim to gather info about drones and interface design. This will then be wrapped up with presenting a list of user requirements, first concepts and the final concept. The user requirements will be prioritised using the MoSCoW method, consisting of Must, Should, Could and Won't

Specification

The specification phase aims to further refine the final concept and find detailed requirements for the project. During the specification phase a flow map will show the interaction a user will make with the interface, from this a first low-fidelity prototype is constructed. This low-fidelity prototype will then be user tested to find first interaction problems. To give the interface a consistent look and feel, a style guide will be set up to give tools for designing different parts of the interface. This all will result in a set of new user requirements for the realisation of the interface, together with presenting the refined final concept of the interface.

Realisation

The results of the specification can be used to make a realisation of the interface. The phase of realisation will consist of the creation of the second iteration of the prototype. After a first user test, the realisation will create a second prototype. This second prototype will also be user tested, followed by the creation of the final prototype of this graduation project. In the realisation the different components and changes of the interface will be documented in detail.

Evaluation

The final phase of the design process consists of the evaluation of the prototype. Evaluation will be done using usability tests and an expert review. The participants of the usability testing will be potential users of the interface, with little to no prior drone knowledge. The expert review will take place with an expert in the field of interaction technology.

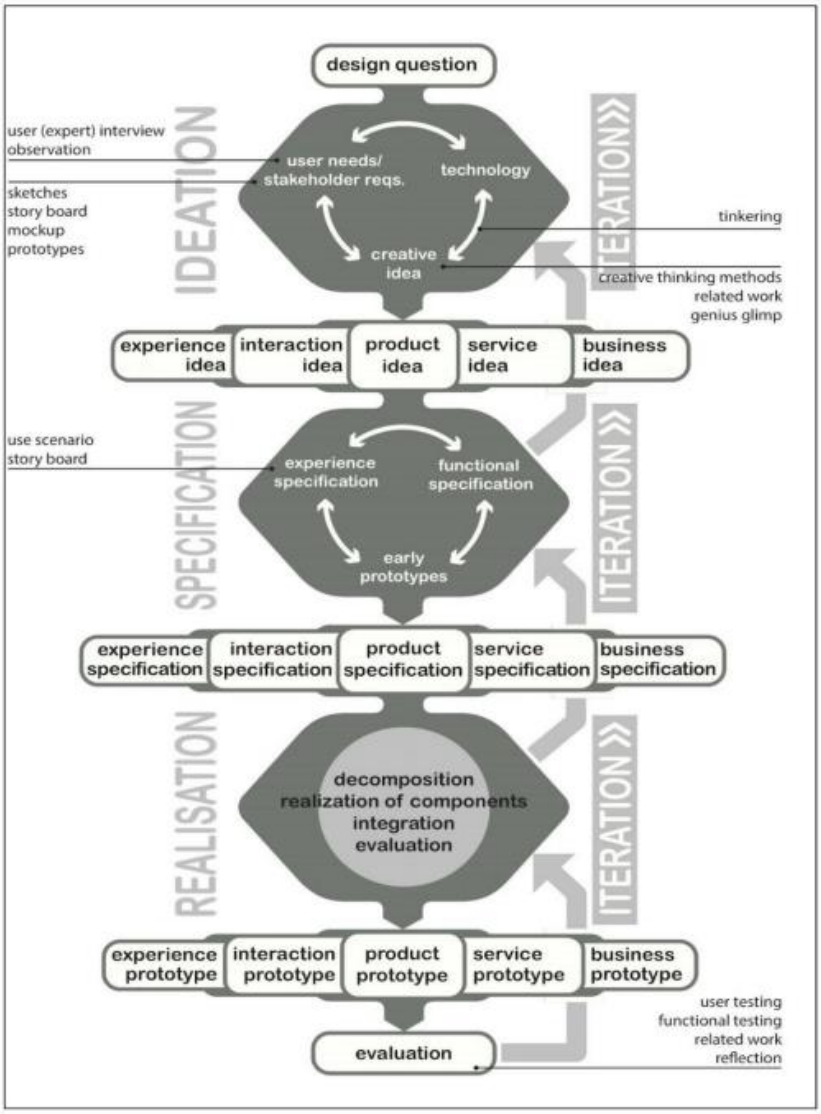


Figure 3.1 Creative Technology Design Process

3.2 Brainstorming

To generate new ideas, brainstorms will be performed. During a brainstorm there is a leader to guide the conversation and satisfy the rules of a brainstorm [49][50]. These rules are relatively simple. First, new ideas should not be put off, so no initial idea should be burned down for any reason. Second, new ideas cannot be impossible, you can come up with some weird and outstanding ideas, but these can serve as steppingstones to different ideas and could even be good ideas. As stated the leader, in this case being the author, will guide the conversation and try maintain the rules. Also the leader will change the topic where needed to

come to more ideas or to further define some ideas. In this thesis two brainstorms where performed, this being an individual brainstorm, and the second being a group brainstorm.

3.2.1 individual brainstorm

An individual brainstorm will keep itself to the same rules as other brainstorm [51]. The difference is that the leader and the participant are the same person. This will bring the ideas of the leader out and put them onto paper. The individual brainstorm was aimed to find different interaction features for the interface.

3.2.2 Group brainstorm

During this brainstorm the author led the conversation. The participants were briefed about the structure of the brainstorm and the rules connected to it. The topic of the research was introduced to get all participants up to date about the project. Then using the earlier explained rules the leader guided the conversation from interaction elements to other intuitive interfaces, to the flow of the interface and tools to build and interface.

3.3 Stakeholder Analysis

A stakeholder is a person, group, or entity that has an impact on decisions either directly or indirectly as defined by Mitchel, Agle and Wood [52]. The framework developed by Sharp, Finkelstein, and Galal [53] will serve as the foundation for the examination of stakeholders influence. It divides each potential baseline stakeholder into 4 groups:

Users are the ones who will actually make use of the interface. They will be arranged in three categories: frequently, sporadically, and never.

Developers are stakeholders who are in involved in creating and building the drone docking system. They are often internal to the company. They also exhibit varying degrees of interest in specific development areas, and their interests may diverge from those of the users.

Legislators are a common example of a stakeholder group or organization that is in charge of enforcing laws or placing restrictions on the use, development, or operation of a system (e.g. data protection laws, constraints appointed by the government).

Decision makers are those who participated in the development of the project and have the authority to influence it in any way.

This project divides stakeholders into groups and then arranges them according to an x, y coordinate system with low, medium, or high values for two factors: influence and interest in the project. In light of this, a representation of the project's stakeholders and potential influencers is provided.

3.4 Personas and Scenarios

To get a better feeling for the different people who will be using the interface, personas and scenarios will be set up [54]. These personas will help us further identify what type of people will be using the interface and what type of characteristics they have. This can help by adapting the interface to certain traits people have. These personas will be coupled to a scenario in which the person will use the interface. Doing this will show what the workflow will be of using the interface, helping with further defining the different menus and buttons needed for all interaction.

3.5 Interviews

Another approach of acquiring the preliminary needs will be through interviews. Interviews will also be used to gain a deeper knowledge of the needs of project participants, including users and clients. Unstructured, semi-structured, and structured interviews are the three main types of interviews that can be conducted [55]. Structured interview follow a strict protocol and do not deviate from the list of questions set up for the interview. Unstructured interviews follow no order or protocol but rather take style of a conversation where the interviewer can go in any direction. A semi-structured interviewing approach will be employed in this study. With the semi-structured approach, the interviewer can emphasize the subjects that are important to them while still letting ideas and recommendations flow. The interviewer must plan the session's organization and prepare interview questions. However is not required to adhere to that system, though. The interviewer can "follow" the path of the conversation and so become the session's guide rather than strictly imposing order if the interviewee's feedback reveals engaging subjects to explore. Semi-structured interviews give room for unexpected ideas to emerge that are pertinent to the subject being discussed but fall outside of the planned questions. Then, because it encourages the emergence of new ideas, this method frequently combines the definitions of an interview and a brainstorming session. This approach is therefore perfect for the ideation stage and will be used in Chapter 4.

3.6 Usability Testing

For the evaluation of the interface usability tests will be conducted. These usability test will consist of an interview beforehand to see how experienced a participant already is with interfaces and drone interfaces. After this the participant will be asked to perform tasks in the interface. During this the participant is asked to think out loud, this will help the researcher to pin-point problem areas in the interface where the interaction is not sufficient or not intuitive. Afterwards the participants will be asked their opinion about the interface and how it could improve in their eyes. This will be summarized into a list of extra requirements for the next version of the interface.
Their will be two evaluations of the interface. This will create two iteration of the interface as stated by Nielsen [13], to get to a good working interface. Each of the evaluation rounds will be performed with 5 participants. More is not needed as this is qualitative research as stated by Nielsen [56]

3.7 Expert Review

When the interface has been finished, the interface will be walked through by an expert in the field of interaction technology. This will help with the further evaluation of the interface and will ensure no theory based interaction elements will be forgotten which can make the interface even better.

3.8 Requirements

The project's criteria include organized goals for the realisation of the interface. They help the author to compile, analyse, and improve the information and conclusions gained from the various research phases. At the conclusion of Chapter 2 "Background Research," some of the requirements for this project were previously suggested. However, as this project moves further, more criteria will be discovered at each level before Chapter 6, "Realisation."

Preliminary requirements are established at the conclusion of Chapter 4, "Ideation," to help concepts become development objectives. Due to the updating of information, Chapter 5's "Specification" conclusions include yet another level of requirement creation. Functional and non-functional items will be distinguished within the requirements. Functional requirements for supportive digital applications will be centred on the interface design, organizational structure. While aesthetics and methods for interacting with the interface content will be the main non-functional needs. A strategy will be used to organize the tasks required for development and to clarify the needs in Chapters 4 and 5. The following are the four groups into which the MoSCoW technique [57] divides and prioritizes requirements:

- **“Must” (Mo):** specifies needs that must be present in the project's final product.
- **“Should” (S):** identifies requirements with a high priority that should to be included when possible.
- **“Could” (Co):** if they do not impose an excessive amount of effort or time—could be included.
- **“Won't” (W)** denotes requirements that the author wishes to incorporate but will not in the current version of the project owing to circumstances or other stakeholders' opinions.

4 Ideation

The background research has provided a set of general rules for designing an interface. These rules are defined as followed:

1 - Place the user in control
2 - Reduce the user's memory load
3 - Make the interface consistent
4 - Provide effective help

These rules will be used throughout the ideation of the interface. This will be done by placing ideated design features and interactive elements at the designated rule. By doing this, each rule will get its own requirements for the interface.

Secondly, it was found in the background research that the DJI FlightHub 2 was the most used and advanced system for drone docking systems it is seen as the market standard. For this reason, the DJI FlightHub 2 interface will be used as a source of ideas and it will be evaluated to find the good and bad features of the interface.

In this ideation chapter, the first concepts and ideas of the interface will be constructed. Next to that the target will be to an answer to the following two sub-questions which are stated in Chapter 1 being:

- *What are the user requirements for the GUI?*
- *What interaction elements can fulfil the user requirements*

In order to answer these questions, different techniques can be used to find an answer to these questions. The ideation will start with a stakeholder analysis by defining the stakeholders which have an influence on the Graduation Project. These stakeholders will then be placed on an influence/interest scale to prioritize which stakeholders are most important. The stakeholder analysis will then be followed up by some scenario sketches of potential users and use cases to get a better understanding of the user's needs. With this information, an individual brainstorm will be conducted to ideate the first concepts. Following that, a group brainstorm will be held to generate more ideas and concepts for the interface. Then two expert interviews will give answers to questions about good and intuitive interface design, and how to properly conduct usability tests. The experts will also be asked to review the DJI FlightHub 2 interface. This will give an overview of the good and bad features of DJI FlightHub 2 which can be used in further ideation. The chapter will conclude with a list of user requirements based on the 4 rules of interface design to include in the interface together with the presentation of the first concepts and final concept.

4.1 Stakeholder Analysis

There are a multitude of stakeholders who have an influence and interest in this graduation project. These stakeholders have been identified and put into different stakeholder groups, after which the stakeholders were mapped into a graph.

Users
Users are all people who will be using the interface, this can be on a professional or personal basis. There are multiple categories to think of when thinking about users. When starting with our least influential users are children and elderly, these are the outliers. They will either not be able to use the interface due to lack of technological knowledge, or simply do not have use cases for it. When looking at students however, they could become users of this technology when thinking about the different projects which are performed at multiple universities. Students will have a user role within this project. The most influential users are working people and companies. These will regularly use the system to inspect their buildings and other structures for work purposes.

Developers
The main developer in this project is Nest-Fly Technologies owned by Yves Lentfert, who is developing the drone docking system to go with the interface. However the box will also need to be implemented and used by other developers to create their own system Therefore other system integrators who will use the box will be of a development role over the project. Nest-Fly is also not using their own drones, the box can be used with any drone. Meaning drone builders also have a development role in this project.

Legislators
There are still lots of laws surrounding the deployment of drones in the Netherlands [4]. At the moment it is not allowed to fly a drone beyond visual line of sight (BVLOS) and without a drone operator [4]. The drone docking system will however always fly BVLOS and without drone operator. In order to deploy this new technology and interface the law will have to allow it, and thus has a big influence. Therefore the government of the Netherlands and its different government bodies will have a legislative role over this further deployment of the project.

Decision-makers
The decision-maker with respect to the drone docking system is Yves Lentfert, owner of Nest-Fly technologies. The goals and vision of Yves will also play a role as a decision-maker in this graduation project. The graduation supervisor Erik Faber and Amr Afifi will be decision-makers within this graduation project. They will guide the project by giving effective feedback and guidance, and together set deadlines for the completion of the project. Next to that, the author of this graduation project will be a decision-maker on the path this project will go on.

The identified stakeholders have been summarized in table 4.1, where all stakeholder are placed in category and given a influence and interest score. This is then further shown in figure 4.1 where a graph visualizes the different stakeholders and their importance.

The stakeholder analysis shows that Yves Lentfert, Erik Faber, Amr Afifi, and the author are the stakeholders with the highest interest in the graduation project. They will also have the most influence on the direction of this graduation project. Closely following are working adults

with high interest, but medium influence. This is a stakeholder group to focus on and interview when arriving at the user tests. Next to the working adults, the students are also a stakeholder group to focus on when arriving at usability testing, because they have a medium interest and influence. The Government has a very high influence on the project because they regulate the deployment of the technology. However, their interest is still medium. Because this project focuses on the interface which could facilitate the technology once it is allowed, the government is not a stakeholder to focus on. Lastly the user group of children and elderly have low interest and influence and will not be focussed on.

Table 4.1 Stakeholders classified by interest and influence

Stakeholder	Role	Interest	Influence
Children	User	low	low
Students	User	medium	medium
Working Adults	User/Developer	high	medium
Elderly	User	low	low
Nest-Fly/Yves Lentfert	Developer/Decision-maker	high	high
Drone builders	Developer	high	medium
System Integrators	Developer	high	medium
Government	Legislator	medium	high
Erik Faber	Decision-maker	high	high
Amr Afifi	Decision-maker	high	high
Author/Dick Dekker	Decision-maker	high	high

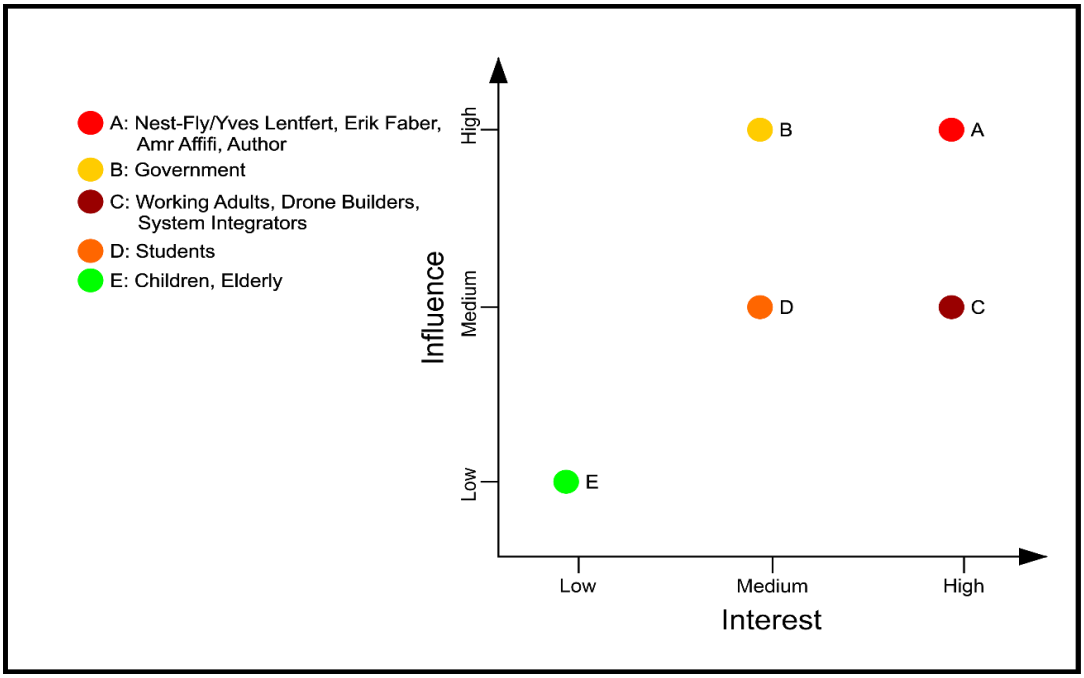


Figure 4.1 Stakeholder mapping based on level of influence and interest

4.2 Individual brainstorm

The individual brainstorm was aimed to focus on the look and feel of the interface. It was constructed in a manner where no ideas are rejected in order to broaden the scope. Then in the end the brainstorm was individually reviewed. This was done to boil down the most significant ideas and trends of the brainstorm. Next to that a moodboard was created for the interface, along with some first sketches of interface layouts. In addition, the outcome of the individual brainstorm was discussed with Yves Lentfert from Nest-Fly. During this conversation a short brainstorm of itself was formed in order to get the opinions of Yves into the moodboard and to try and get companies look and feel as a style guide for the interface. This all has been summarized into a several sketches (figure 4.2) and a moodboard (figure 4.3) which will act as a guide when designing the interface. The full individual brainstorm results can be found in appendix 1

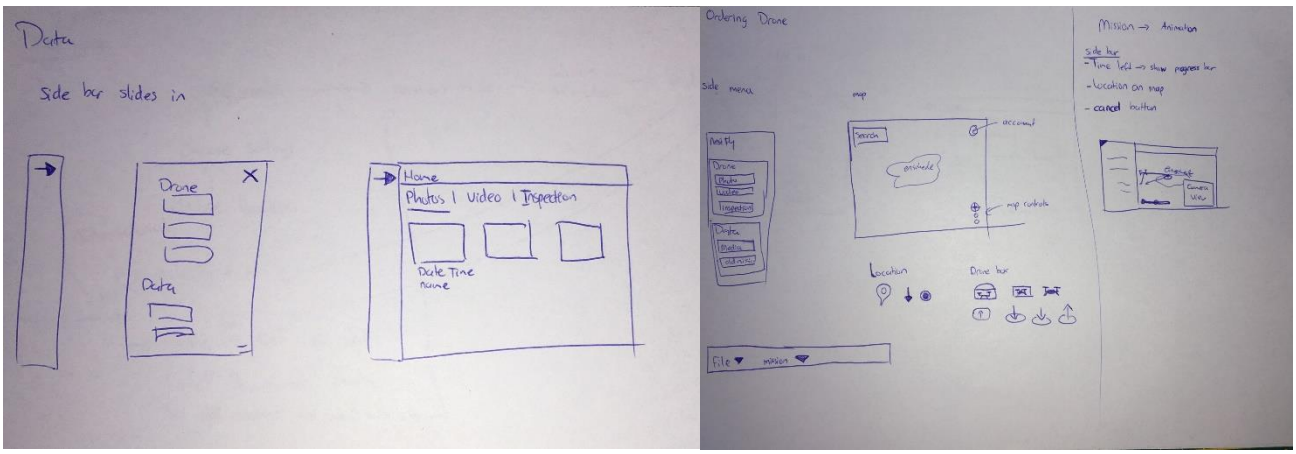


Figure 4.2 Sketches of the interface from individual brainstorm

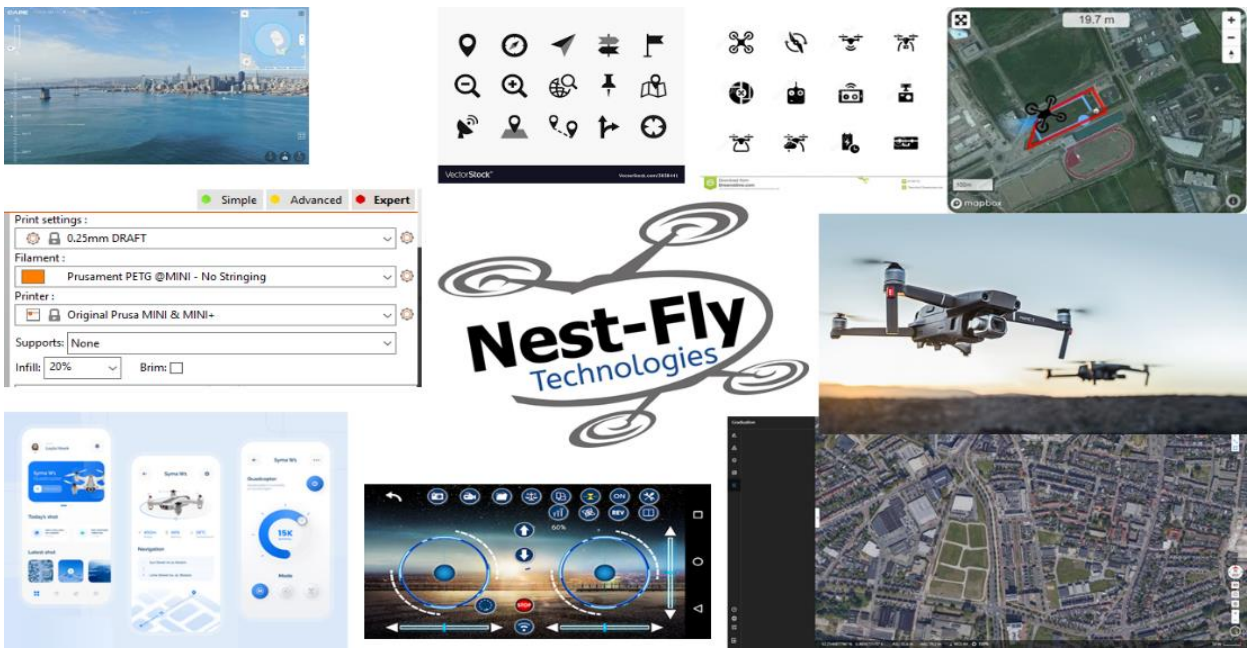


Figure 4.3 Moodboard for the creation of the interface

4.3 Group brainstorm

After an individual brainstorm, a group brainstorm was organized with 4 participants including the author. Here the brainstorm was guided by the author and it was constructed in a similar manner as the individual brainstorm, where all ideas come up as the conversation moves on and no ideas are burned down initially. The scope of the project and current status were explained by the author after which a first question was asked to start the conversation.

The brainstorm was started at intuitive UI design which was followed by an array of interfaces described by the participants. The participants described what they felt were intuitive features of these interfaces which could be used in the drone docking interface. Next to brainstorming about intuitive UI features, also different layouts and structures were taken into the conversation to spread the scope of the brainstorm.

The brainstorm can be summarized by placing the ideated interface features with their respective interface design rules. This lets us set up a first list of user requirements for the interface to be designed (table 4.2). The full brainstorm results can be found in appendix 2.

Table 4.2 List of user requirements based on group brainstorm

1. Place user in control
Give the user a home button
Provide the user with a choice expert levels within the interface
Option between dark and light theme mode
2. Reduce the user's memory load
Keep interface clean and simple, hide or do not implement extra features
Visualize restricted and unrestricted flight areas with colors
3. Make the interface consistent
Place often used features in intuitive locations
4. Provide effective help
Tutorial that guides the user through the interface
Choosing guide for tasks at the beginning of the interface

4.4 Interviews

To gather more detailed info on drones and interface design two expert interviews were conducted. The results of these interviews are described in the section below. The first interview was with Gabriel Damian and the second interview was with Wouter Eggink. The full results of the interview can be found in appendices 3 and 4.

4.5.1 Interview Gabriel Damian, Founder of DroneTeam Twente

Gabriel Damian is the founder of the student team, DroneTeam Twente, he has worked with lots of different interfaces ranging from DJI to Missionplanner to QGroundControl. With all this background knowledge Gabriel is very valuable for drone interface information. The interview was conducted in a semi-structured way.

The interview started with the general question of how a drone interface should be structured. Here Gabriel brought up that most interfaces have a basic map, showing the location of the drone with some flight instruments and a view of the drones camera. He quickly

added that most drone interfaces show too much data on the screen and they have little adjustability. Because Gabriel was very outspoken on his opinion of drone interfaces, he was asked to name some features he missed in current interfaces. This resulted in a list of features Gabriel believed could be helpful in drone interfaces. This list has been visualized in table 4.2 and categorized into the different design rules.

Table 4.3 List of features proposed by Gabriel Damian categorized into design rules

1. Place user in control
Customizability of layout
Customizability of data shown
Being able to switch between video and map view
2. Reduce the user's memory load
The interface should operate as a coworker
Give good symbols, words cannot describe features
Flightplanning, user should have zero control, drone should be coworker
Use points of interest
3. Make the interface consistent
Basic map with flight instruments
Place basic functions on the left
4. Provide effective help
AI asks you questions and adapt
Welcome page with options

4.5.2 Interview Wouter Eggink, Design Expert at the University of Twente

Wouter Eggink is a design professional and design researcher at the University of Twente. His interests are in the relationship between design, technology and society. His research is about the shaping of human-technology relations using Design History and Design for the Future.

The interview with Wouter Eggink was focussed on gathering overall usability details, like interaction elements, usability testing and UI development. Next to that, during the interview DJI FlightHub was shown to Wouter Eggink to give him feel of a drone interface. This followed with his opinion of the interface and where usability problems could occur. Based on this interaction Wouter Eggink gave a set of requirement for a drone interface from his viewpoint, this is summarized in table 4.3.

Table 4.4 User requirements based on the interview with Wouter Eggink categorized into design rules

1. Place user in control
Be able to control the drone
Have influence on where the drone will be flying by suggesting multiple flightpaths
2. Reduce the user's memory load
Buttons should have natural functionality

Good clear map visualisation
3. Make the interface consistent
Interface should be recognized as a drone interface
4. Provide effective help
Clear feedback of actions
Start menu which guides into the interface

4.5 Preliminary concepts

Based on the gathered information in the ideation, a set of concepts was made. These are first concepts and are quickly made to generate different layouts and shapes. In figure 4.4, the first concept is presented, which is a drone interface with inspiration taken from the PrusaSlicer. Another concept was based on general drone interfaces with added control over the drone, with a standard drone camera view (figure 4.5). A concept for the start menu was created by showing prompting the user with a popup and question (figure 4.6). Two concepts were made for the human interaction with buildings and the map (figures 4.7 and 4.8), which also show what data the user sees and options they have. These concepts will be used to generate a final concept for specification.

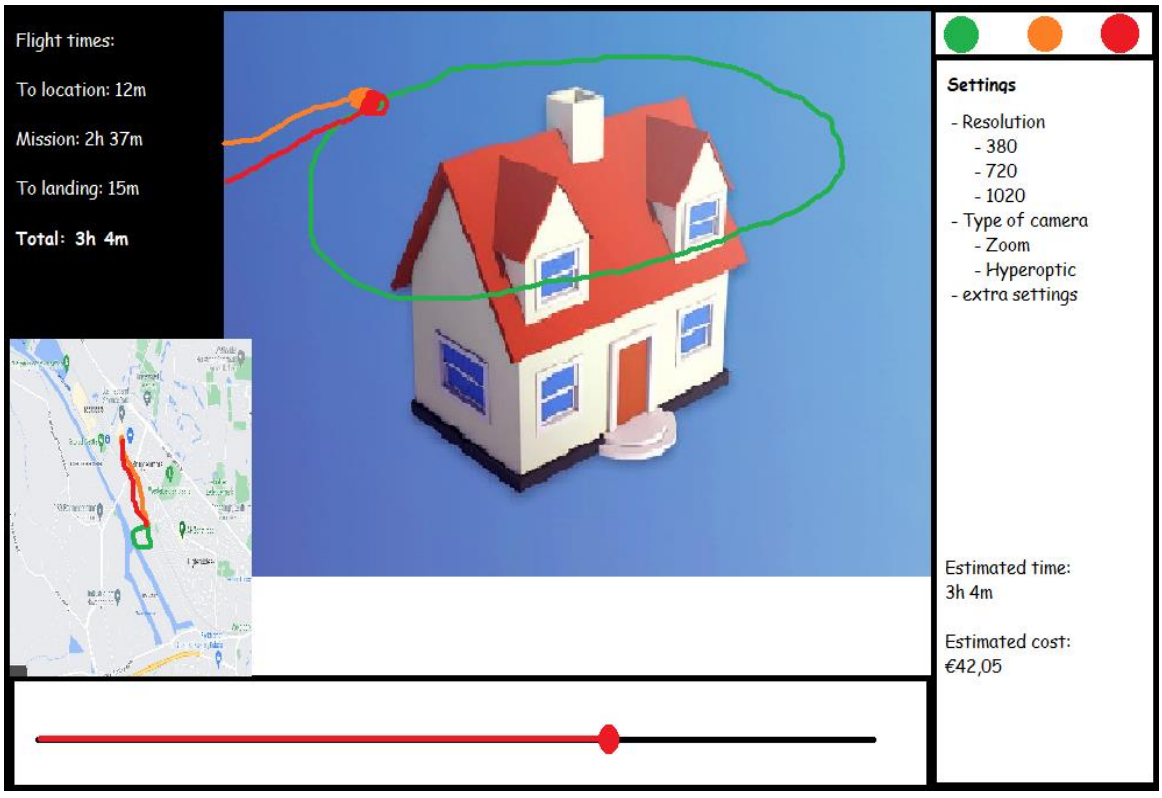


Figure 4.4 Concept with inspiratin of PrusaSlicer and drone interfaces

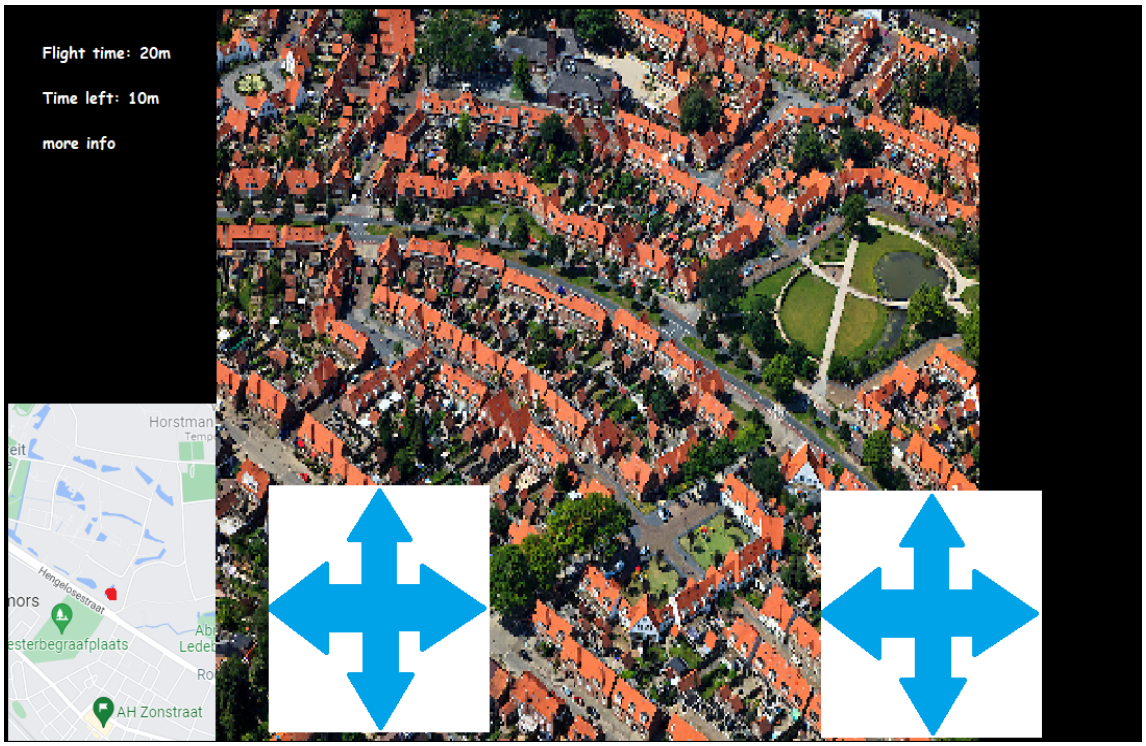


Figure 4.5 Interface concept based on drone interface and added control

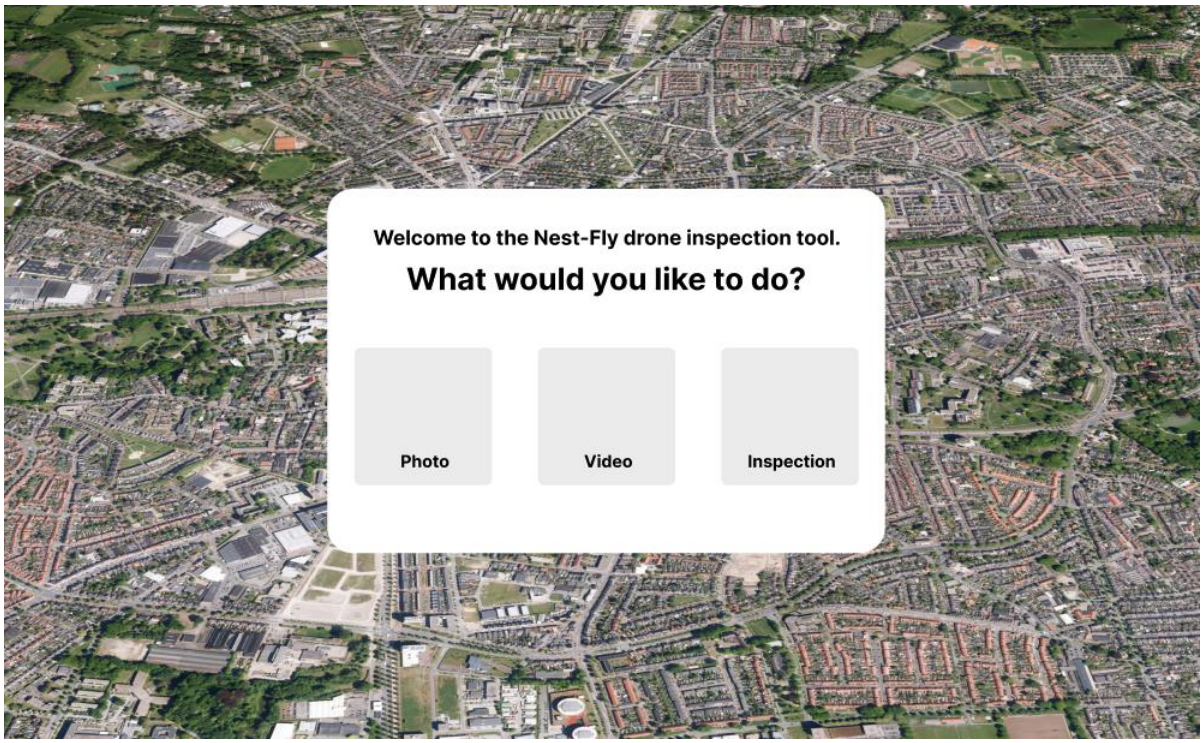


Figure 4.6 Starting menu with question and options

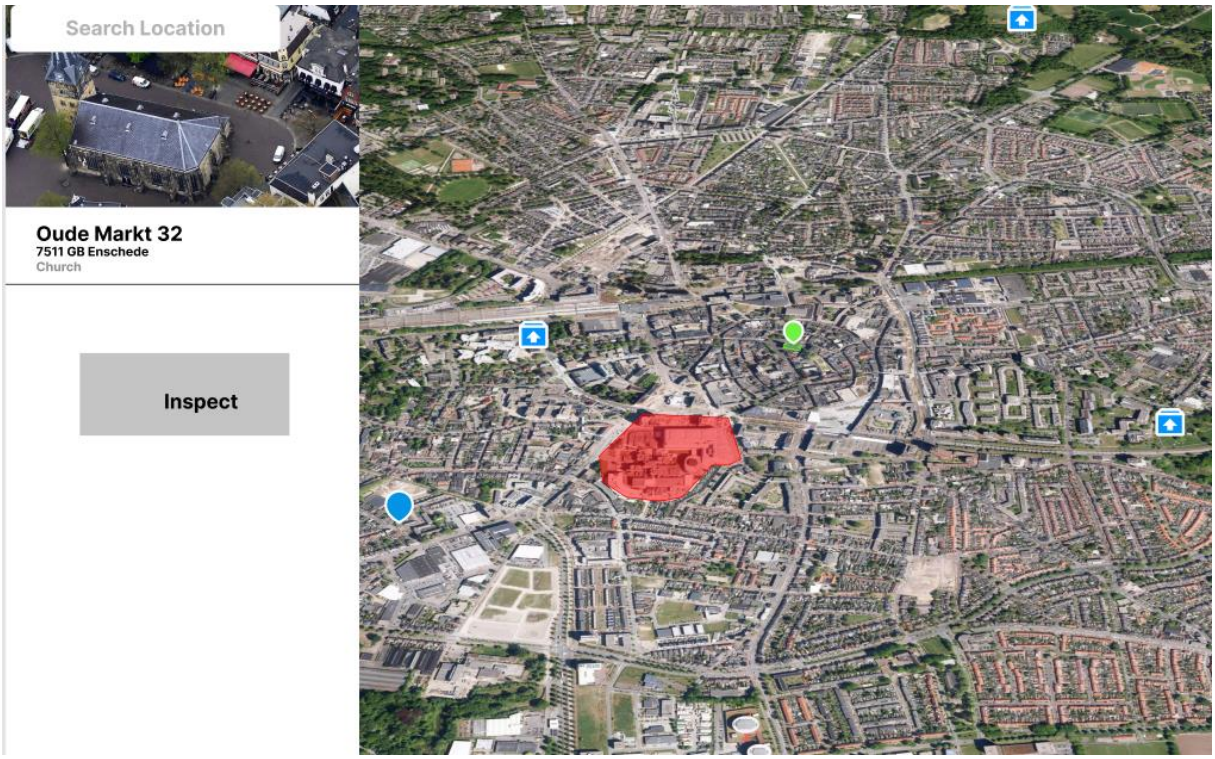


Figure 4.7 Concept for building choosing and map layout

Figure 4.8 Concept for mission options and map layout

4.6 Final concept and list of requirements for Specification

From the ideation a final concept has been made using the found results. The final concept utilizes the earlier made moodboard as basis and the concepts as further inspiration. Next to that the user requirements are mostly implemented, but are however still only aesthetics. The final concept can be seen in figures 4.9.

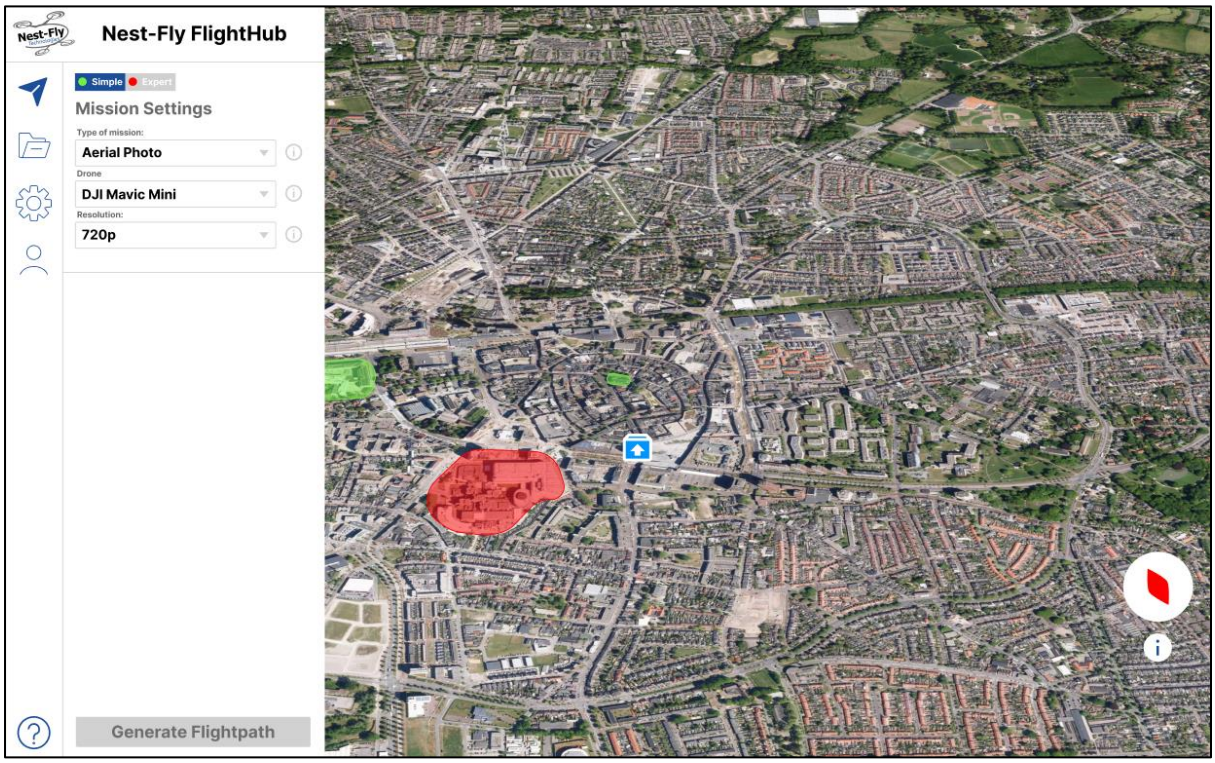


Figure 4.9 Final concept for the Drone Docking System Interface

From the ideation a list of functional and non-functional requirements has been set up. These are then organized in tables using the MoSCoW method. You can find these in table 4.5 and 4.6. These requirements will be used in the specification to further refine the interface design.

Table 3.5 List of functional requirements for specification

MoSCoW	Functional
Must	Give the user a home button
Must	Keep interface clean and simple, hide or do not implement extra features
Must	Visualize restricted and unrestricted flight areas with colors
Must	Tutorial that guides the user through the interface
Must	Choosing guide for tasks at the beginning of the interface
Must	Automated flight planning
Should	Basic map with flight instruments
Should	Place basic functions on the left
Could	Being able to switch between video and map view

Could	Have influence on where the drone will be flying by suggesting multiple flightpaths
Could	Provide the user with a choice of expert levels
Won't	Option between dark and light mode
Won't	Customizability of layout
Won't	Customizability of data shown
Won't	The interface should operate as a coworker
Won't	AI asks you questions and adapt
Won't	Be able to control the drone

Table 4.6 List of non-functional Requirements for specification

MoSCoW	Non-functional
Must	Place often used features in recognizable locations
Must	Give good symbols for features, words cannot describe features
Must	Buttons should have natural functionality
Must	Give clear feedback of actions
Should	Interface should be recognized as a drone interface

5 Specification

The specification chapter aims to further refine the concept of the ideation phase, this is done by first of all setting up personas and use scenarios, after which a interaction diagram and flow map will be set up. Followed is the first low fidelity prototype, which will be user tested to find first problems. All will conclude with a set of requirements for the realisation of the interface.

5.1 Scenario Sketch

In order to better understand the end-user of the drone interface and find interaction the user has with the interface, two user personas and a fitting usage scenario have been developed. These scenario sketches have the purpose to find out what the goals and motivations are for users to interact with the interface and in what context they use the interface. The personas which were developed are Simone ten Apel (32) and Ben Harmsen (45). By knowing their personalities and motives to order drones using the interface, the designer can better imagine what features can be useful for the users. Also, by imagining the interactions the personas will have with the interface, the interface can be further refined.

5.1.1 Personas

Simone ten Apel

Age: 32
Occupation: Dentist
Status: Married
Location: Leeuwarden, Netherlands
Drone interfaces used:

- none

Goals

- Give her children a good place to grow up
- To sell their house at a decent price in order to finance the purchase of a new house.

Needs

- Having a way to sell their house at a higher price

Pain Points

- Busy with work and the children
- Not technical background or drone experience

Familiarity with drones

- None

About
Simone is a young mother of her first child with another one on the way. At the moment she is working as a dentist and together with her husband they bought their first house a couple of years ago. With their family expanding it is their wish to move to a bigger house with more space for the children to have fun and play. Her husband is currently working as an accountant and together they have saved enough money to start looking for a new place. They have seen some very nice and suitable houses. However, with the rising house prices, they need to sell their old house good price in order to be able to finance the new house. Currently, they are looking into ways to improve the value of their house in order to finance the new house.

Ben Harmsen

Age: 45
Occupation: Manager at inspection company
Status: Married
Location: Rotterdam, Netherlands
Drone interfaces used
- DJI

Goals:
- To spend time with his family and make sure they have what they need.

Needs:
- Looking for a way to lower the workload of his job
- Having a better overview of all the projects going on at his job

Pain points:
- Having to spend more time at work than he wants
- Having to manage multiple projects at once

Familiarity with drones:
- High

About
Ben is a hardworking man who has been working at this inspection company for 12 years. He has a lot of experience with inspections, which at the moment are mostly performed by drones. For his job, he is responsible for managing the different inspections that are going on. This can sometimes add up to 10 different inspection projects in a busy week. This can sometimes make him stressed because he is responsible for getting people on site and making sure the job is performed successfully. When something goes wrong, he is held responsible. Next to his job he has a family to take care of. He is very happy with his family and loves to be with them, however, sometimes his job can get in the way when the busy weeks start again. Sometimes Ben wishes his job was not this demanding and that he could live more on his own agenda.

5.1.2 Scenarios

The personas of the different user types can help us engage with the different array of users who could be interacting with the system. The first and second personas, Simone and Ben, will be used to provide two scenario sketches. The scenarios will focus on how the user discovers the interface, and how the user will be interacting with the interface. The first scenario of Simone is described as follows:

"Simone was scrolling on the internet in search of different ways to sell their house. She already had some ideas, but most of them were out of reach. On the internet, she found that the value could increase by cleaning the outside of the house, repainting the inside, reflooring the living room, and more. These were all out of reach because they did not have the time to set up such big renovations. Then she heard a humming sound fly over, at first she thought it was some sort of helicopter, but then she saw a drone flying over her neighbor's house. It did some circles around the house and as fast as it appeared, it was gone again. This got her

thinking about what the drone was doing there. The neighbor, being the tech geek he is, was probably just playing around. But she could not burry the urge to go and ask him.

The neighbor was very friendly and enthusiastic when Simone asked him about the drone flying over. He told her he had ordered the drone online to fly to his house and take some pictures. It was a new service in town which everyone was able to use. The neighbor gave the website link to Simone so she could maybe try it for herself. This had gotten her interest as this could maybe help with selling her house. When she got home she hopped on the internet and typed in the link she got from the neighbor.

On the website, she read through the information, and it said that you were able to get aerial photos of your house for a good price. For the neighbor, this was maybe fun to have, but for Simone this could be a way to show off the house and the nice garden attached to it. So she decided to make an account and start ordering a drone. The interface helped her with suggestions and getting the right drone for the job. She found that the only had to type in her address and a first flight route was already planned for her. However, she was able to choose extra options if she wanted to, like 3D scanning or a video, she decided that a 3D scan was not needed, however, a video would be nice to add. So deciding on a video and some photos she ordered the drone with just the click of a button. The interface gave a green light and she saw the drone taking of real-time and she could see where it was. A couple of minutes later a drone showed up at their house and started to fly around, she could physically see the drone, and see what the drone was seeing in the interface. Once the drone had finished it flew back and Simone got a message via the interface and on her email on how to get her data. She quickly looked into it and saw some amazing shots taken with the drone, this clearly showed the potential the house had! She was very happy with it!

A couple of weeks later the family had moved to a new house, which they were partially able to finance with the revenue of the old house. The drone shots had made a lot of people excited about their old house and the selling was done in a matter of days. They were very grateful they could use drones in order to help them move and raise their kids in a better place. At the moment, Simone is not actively using the drone application, however, she will never forget to recommend or reuse the app once she needs some drone shots again."

To further get into different use cases, a scenario sketch of Ben has also been created. The scenario sketch of Ben is described as follows:

"*Ben's day always start of with checking his email. Managing different projects is all about communication, he has found. In his email he finds a new project he was to coordinate. A client wants to have a drone on sight for an inspection of a construction site, today. Ben looks into his different drone operators and sees that none of them are available tomorrow. Ben knows the client he is working with and does not want to disappoint him. So instead of canceling the request, Ben start searching the internet if there are other companies which could cover the job for him.*

Looking on the internet Ben comes across the website of a Drone Docking System. He sees that he is able to order drones for different inspection use cases with the click of a button. He is intrigued by the ease of use and the high capacity the web application offers. For that reason he decides to try it out for his client to still get a drone on sight.
Ben first of all walks through the help function, to get a better feel for the program and what its capabilities are. He is able to easily click through the help function and find good highlighted info where needed. When he has walked through the help function, Ben finds that he has enough knowledge to start working with the system.

Ben starts configuring the mission for his client. He is able to click the area he wants to inspect, being the construction site of the client. Then Ben can choose the type of mission he wants to perform, in this case the client wants to have a 3D scan of the construction site. Having chosen the mission type, the web application automatically generated a flightpath for Ben. He sees that the drone has taken the area of interest and calculated a flight path circling the construction site, in order to get a full 3D scan. Ben is able to manipulate the map and see the mission path from different angles, he is also able to get a preview of the mission and see if it is up to his standards. Looking at the generated mission, Ben decides to order the drone mission.

The mission starts and the drone takes off, all the while Ben can see what the drone is seeing live and what its location is. Once the drone has arrived at the construction site it start the 3D scan. Ben can look at everything that is happening and sees the 3D scan take place. After the drone has mapped the construction site, it return to its station and Ben is able to get his data. He reviews the data and is satisfied with the results. He emails his client with the data.

The client appreciated the fast response time of Ben and was also satisfied with the data, it helped them with further construction. Ben was also very happy with the Drone Docking System and has decided to use it more often for clients in a hurry. He can see the power of the system and the added value of having a drone on standby, at any time."

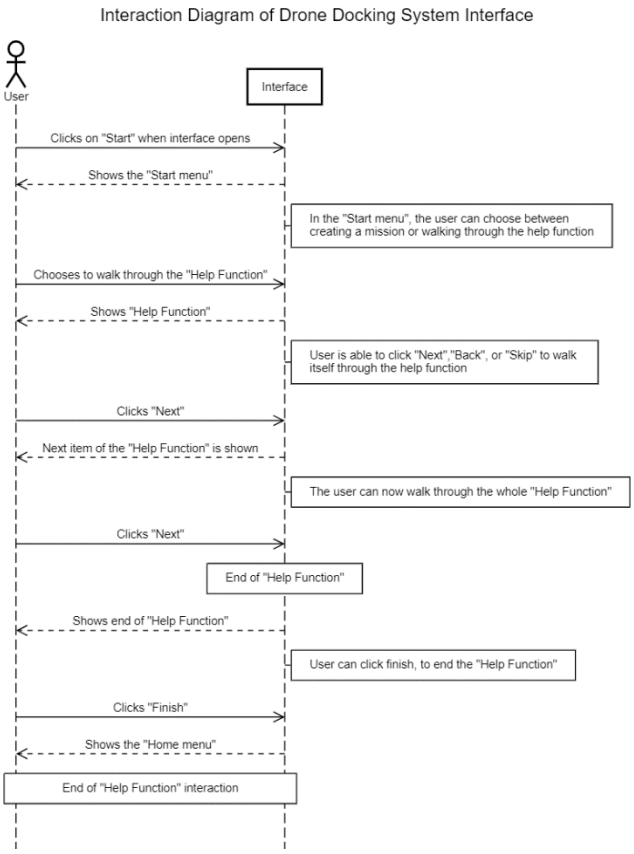


Figure 5.1 Interaction Diagram of interfaces' "Help Function"

5.2 Interaction diagram

From the personas, scenarios and interaction the personas have with the interface, an interaction diagram has been made. This interaction diagram shows the what interaction the user has with the interface and what the interface has to show. Two different interaction diagrams have been made, one for the Help function (figure 5.1), and one for ordering a drone (figure 5.2). The full scale diagrams can be found in appendix 5.

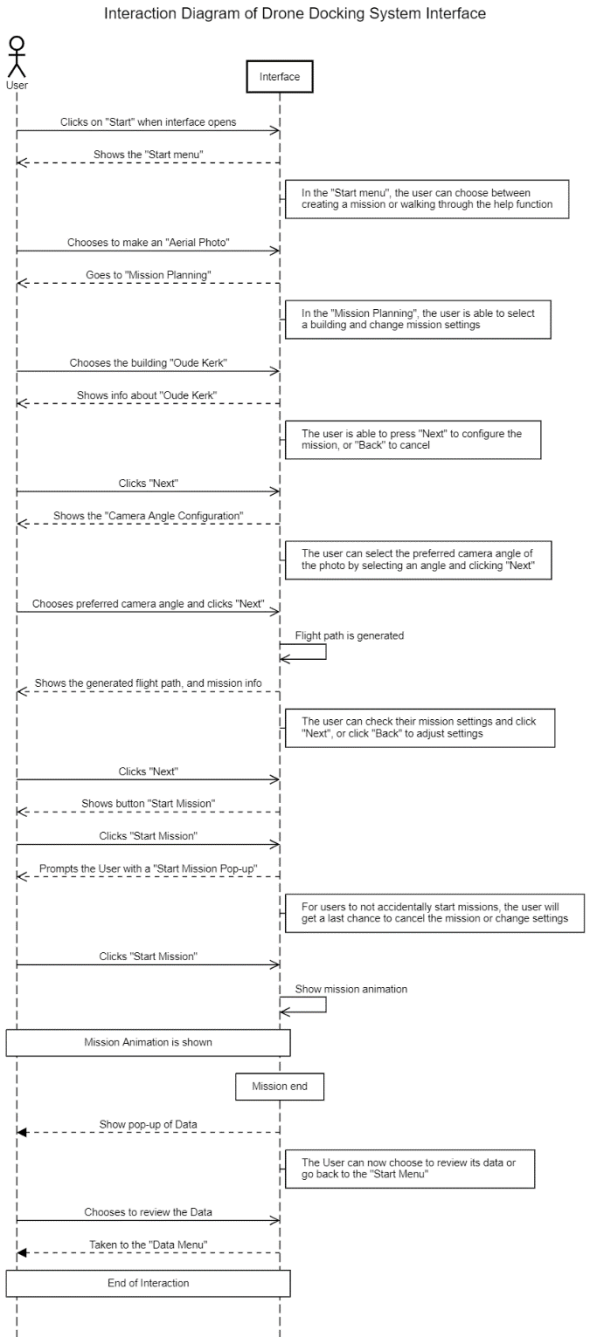


Figure 5.2 Interaction Diagram for ordering a drone using the interface

5.3 Flow map

To get a better view of the flow within the interface a flow map has been constructed. This flow maps shows how all menus interact with each other and what choices have to be made to get to certain menu's. This flow map can be seen in figure 5.3, and a full scale picture can be found in appendix 6. It can be found that in order to create the interface, a Start menu, Home menu, Mission planning menu, Configure Camera, Mission animation, Data menu and help function will need to be created.

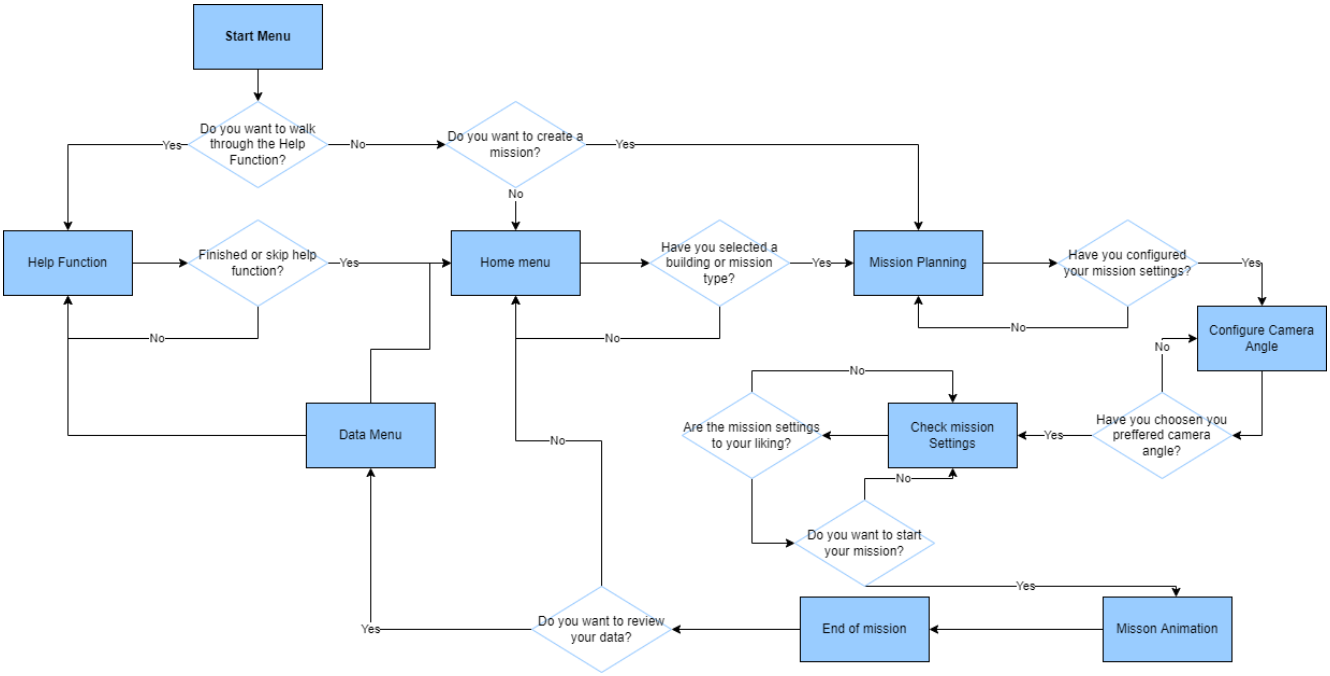


Figure 5.3 Flow map of the drone interface interaction and menu's

5.4 Preliminary style guide

As a last step before creating a next version of the interface, a style guide was constructed. With this style guide a consistent choice of colors, icons, shapes, and fonts can be used throughout the interface. The style guide was constructed together with some input from the stakeholder Yves Lentfert of Nest-Fly Technologies. Using the companies style, logo and colors a similar style guide was constructed for the interface to represent the company in the interface (figure 5.4).

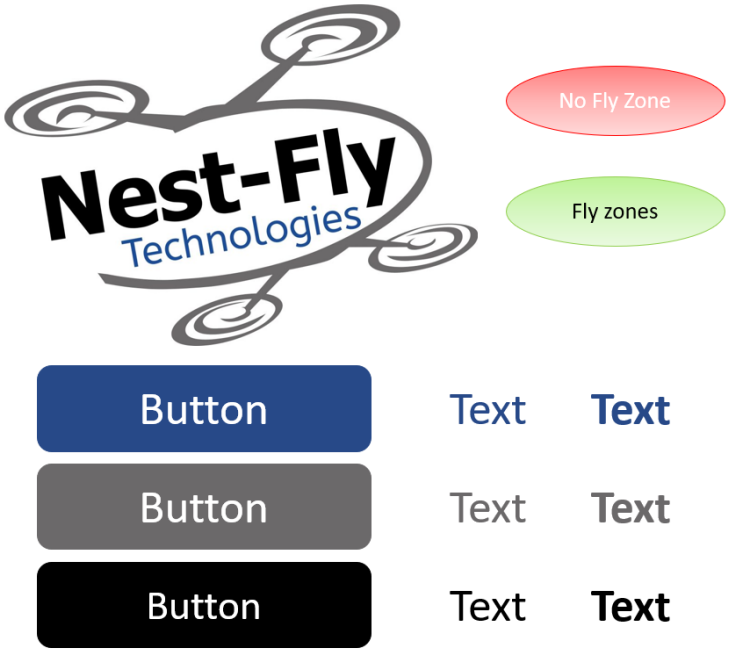


Figure 5.4 Style guide for the interface

5.5 Low fidelity first prototype

Using Figma, a first low fidelity prototype was set up based on the ideas of the ideation chapter. Figma was used because of its ease of use for designing working prototypes. This first prototype was created to be evaluated with a first user. By doing this before making a fully working prototype, the first problems can already be taken out. The first low fidelity prototype can be found in the figures below (figures 5.5 and 5.6)

Figure 5.5 Home menu of the low fidelity prototype

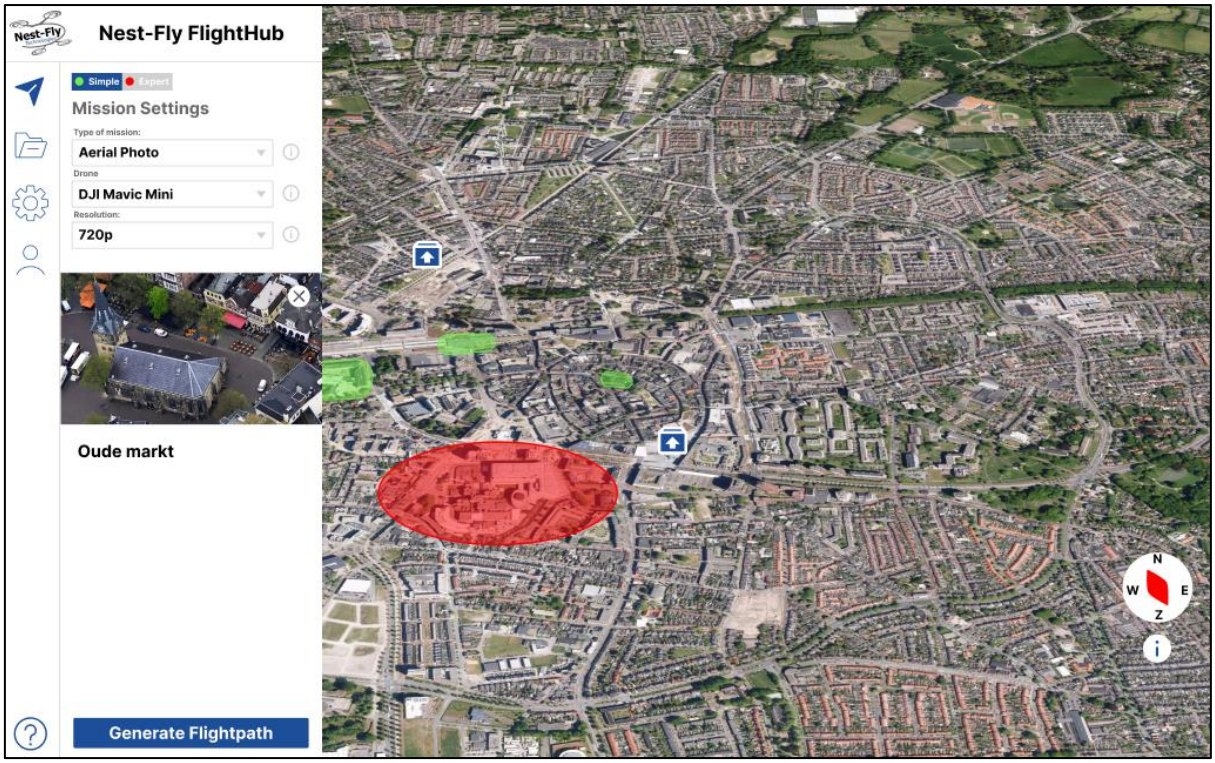


Figure 5.6 Mission planning interface of low fidelity prototype

5.6 Usability Testing

To evaluate the first low fidelity prototype a usability test was conducted. During this test a user is asked to explore the interface and perform some tasks given. During this exploration and task completion the user is asked to think-out-loud. This helps to find problems in the interface and where improvements can be done. The test was performed by a friend of the author who fits the target audience as the user had no to little experience with drone interfaces. Before the start of this usability test the user was informed about the research goals and structure of the test.

Some of the most valuable feedback are listed down below (Tables 5.1 and 5.2). The feedback has been scaled into a set of changes based on the MoScoW scale. These will serve as an addition to the earlier defined requirement in the ideation.

Table 5.1 Functional requirements based on Usability test

MoSCoW	Functional
Must	Point click for the different buildings
Must	Create a more in detail help function
Should	Home button to return should work everywhere

Table 5.2 Non-functional requirements based on Usability test

MoSCoW	Non-functional

Must	Better flow towards the picture making
Should	Better feedback when clicking something

5.7 Second iteration requirements

Based on the findings in this specification chapter, a new set of requirements can be made. These requirements can be used to further develop the interface and make the interface more intuitive for the user. The set of requirements are again separated in functional and non-functional requirements and prioritized using the MoSCoW method (Tables 5.3 and 5.4).

Table 4.3 List of functional requirements for specification

MoSCoW	Functional
Must	Give the user a home button
Must	Keep interface clean and simple, hide or do not implement extra features
Must	Visualize restricted and unrestricted flight areas with colors
Must	Tutorial that guides the user through the interface
Must	Choosing guide for tasks at the beginning of the interface
Must	Automated flight planning
Must	Point click for the different buildings
Must	Create a more in detail help function
Should	Basic map with flight instruments
Should	Home button to return should work everywhere
Should	Place basic functions on the left
Could	Being able to switch between video and map view
Could	Have influence on where the drone will be flying by suggesting multiple flightpaths
Could	Provide the user with a choice of expert levels
Won't	Option between dark and light mode
Won't	Customizability of layout
Won't	Customizability of data shown
Won't	The interface should operate as a coworker
Won't	AI asks you questions and adapt
Won't	Be able to control the drone

Table 4.4 List of non-functional Requirements for specification

MoSCoW	Non-functional
Must	Place often used features in recognizable locations
Must	Give good symbols for features, words cannot describe features

Must	Better flow towards the picture making
Must	Buttons should have natural functionality
Must	Give clear feedback of actions
Should	Interface should be recognized as a drone interface
Should	Better feedback when clicking something

5.8 Conclusion for Realisation

To create a starting point for the realisation the most important points of the specification chapter will be summarized.

The personas and usage scenarios helped to set up an interaction diagram and flow map of the interface (figures 5.1, 5.2 and 5.3). These can be used in the realisation as a guide to create different menus and functions for the user to navigate itself through the interface.

This was followed by setting up a style guide (figure 5.4), which can be used in the realisation to give the interface a consistent look and feel.

From the low fidelity first prototype and the usability testing followed an extra set of requirements (tables 5.1 and 5.2). These were added to the earlier defined requirements in the ideation to further specify the user interface and make it better (tables 5.3 and 5.4). These can be used in the realisation to create a working and intuitive interface.

6 Realisation

This chapter will address the development and implementation of the UI (User Interface) of the Drone Docking System. This interface will facilitate the usage of drones during inspection use cases of non-drone experts. The chapter will start with an explanation of the assets and software tools which were used to create the UI. The realisation of the interface will be described in two iterative cycles resulting in a final prototype. Each realisation will be followed by an user evaluation of that version UI (further explained in the chapter 7 Evaluation). Based on the theory of Nielsen [13] a minimum of two iterations of a UI is required to get to a functional UI design, each evaluation of the interfaces will need to be done with a minimum of 5 people to get qualitative data about the interface [56].

6.1 Digital Tools

For developing a graphical user interface many tools are available which are mostly software based tools. These help with layout and interactions between different parts of the interface. For the realisation of the interface a software tool was found which had all functions needed to make a functional UI. This tool will be discussed as well as some digital resources for creating or using assets and elements in the UI.

6.1.1 Figma software tool (v.2022)[58]

Figma is a vector based graphical editor which has built in prototyping tools for designing interactions. It is based on UI/UX design for web- and mobile-based applications and can be used for both lofi and hifi prototyping. Figma was the main program used for the development of the UI. It was chosen because of its powerful tools and functions, and for its focus on interface design. Using Figma, different templates and interaction can be used to make a mock-up interface which can evolve to a full-fledged working interface. These templates are based of real devices like computers and mobile phones. In this way an interface can be directly created which fits on those devices.

6.1.2 Sources

Figma.com/community [59]
Figma has a large community working on different UI prototypes. Some of the people working on their own prototypes post it to the community and make it available for everyone to use. Searching this community, a drone interface template with a working map was found [60], this template became the basis of the UI and gave tools to understand the working of Figma. Next to that, a free icon template was found [61]. This icon template facilitated most icons that can be found in the interface. These icons were carefully chosen based on their looks and a consistent look of icons was followed in the UI.

Mapsicle Plugin for Figma (v.2022) [62]
Mapsicle is a map viewer plugin for Figma. The mapsicle plugin is able to generate a map of your chosen location from different angles and different views. Next to that, using the scroll function in Figma, you are able to make the map interactive and scrollable. This gives the user the feeling that they are in control of the map.

6.2 Realisation 1

The first realisation of the UI was based upon the gathered knowledge from the ideation and specifications chapter. Mostly the flow map was used to configure the flow inside the interface. (figure 6.1). This section will provide information about the decisions behind both the content and design of realisation 1 of the UI. This section will provide a summary of the constructed interface of realisation 1.

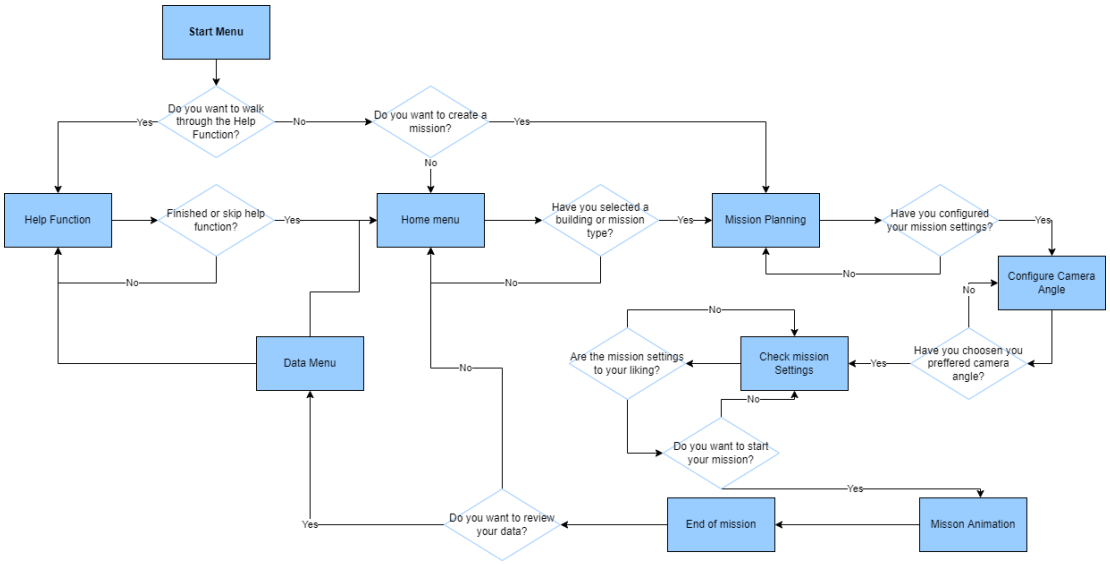


Figure 6.1 Flow map of the drone interface interaction and menu's

6.2.1 Log in screen

For the realisation of the interface it was chosen to not create a log in screen for the users. The reason for this decision is the scope of the research. The research aims to find an intuitive way for users to order a drone for their inspection use cases. This means that the focus is more on interaction elements between the user and the interface of ordering a drone and not logging into the application. Secondly, because logging into an application is nowadays a standard procedure for most apps and websites, it is considered an unimportant interaction element for this research.

However, to still give the user a sense of starting an app or website, the whole login procedure has been interchanged with a simple start button. The start screen was based on the logo of the stakeholder Nest-Fly and the same colours were also used. As a generic name the interface was given the title, Nest-Fly FlightHub. Below in figure 6.2 you can find the start screen. This start screen was not changed during all realisations, since there was not feedback on it.

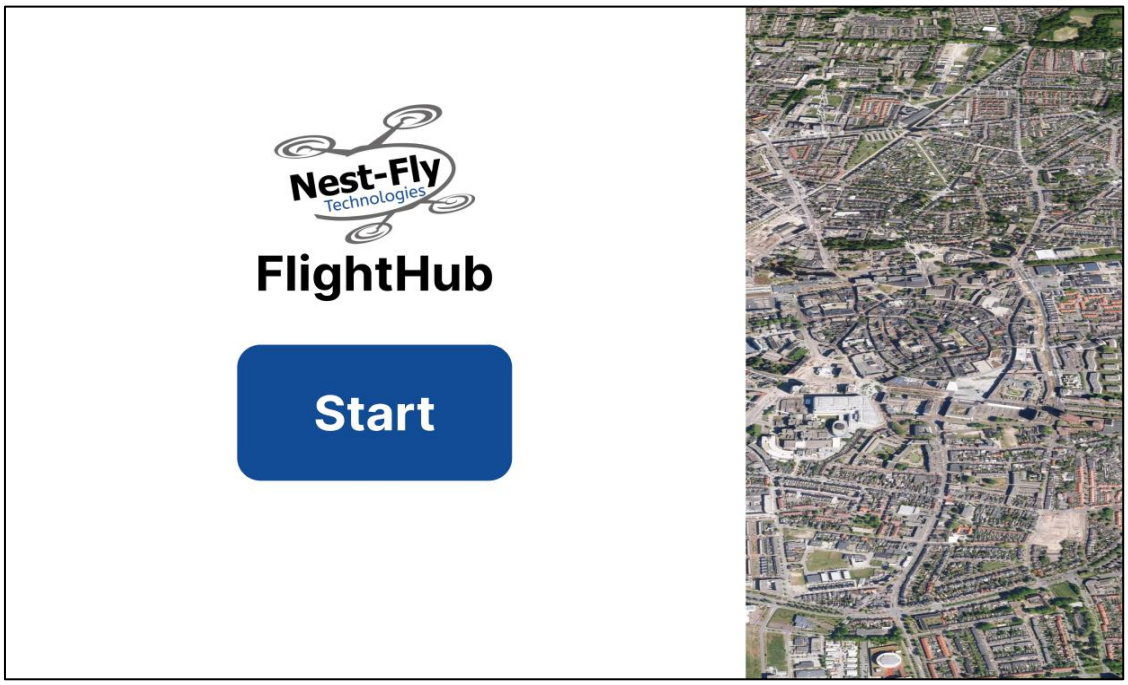


Figure 6.2 Image of the interfaces start screen

6.2.2 Map view

The map view was made using the Mapsicle plugin in Figma. This creates a map from the chosen area and lets you select a view of your liking. For this realisation, it was chosen to create a slightly slanted map to give a more 3D feeling. It was not possible to create a 3D map of a city with 3D buildings. This would have been favourable, however, due to the Figma capabilities this could not be implemented. The view of the map was chosen to be a satellite view, such that individual buildings can be identified. The map can be moved by scrolling the mouse or grabbing the map itself to move it around. Due to constrains in the Figma building tool, the user is not able to zoom into the map. Next to that the user is not able to change the map view, also because this would extremely complexify the interface for user testing. Also, using the Mapsicle plugin, only a small area of the map can be shown. In this case the user can see the city of Enschede and some surrounding suburbs.

On the map in figure 6.3, different icons can be seen. It was chosen to identify selectable buildings with green areas on the map to highlight them. These green areas are clickable to be able to select a building. Then to give the user a sense of where they can and cannot fly, also no-fly zones are present in the map. When hovering the no-fly zone it gives a pop-up about the no-fly zone. These are identified using a red area marking. Then for the drone docking stations, small icons where chosen with an arrow up, indicating a drone can fly out. When hovering these icons, more info is given about the drone docking station and the drone inside. Lastly, a compass and legend were integrated into the map. The compass is non-functional, but acts as a consistency icon to let user know they are working with a map, since most maps have compasses. The icon button is functional and when hovering shows the maps legend, explaining all areas and icons.

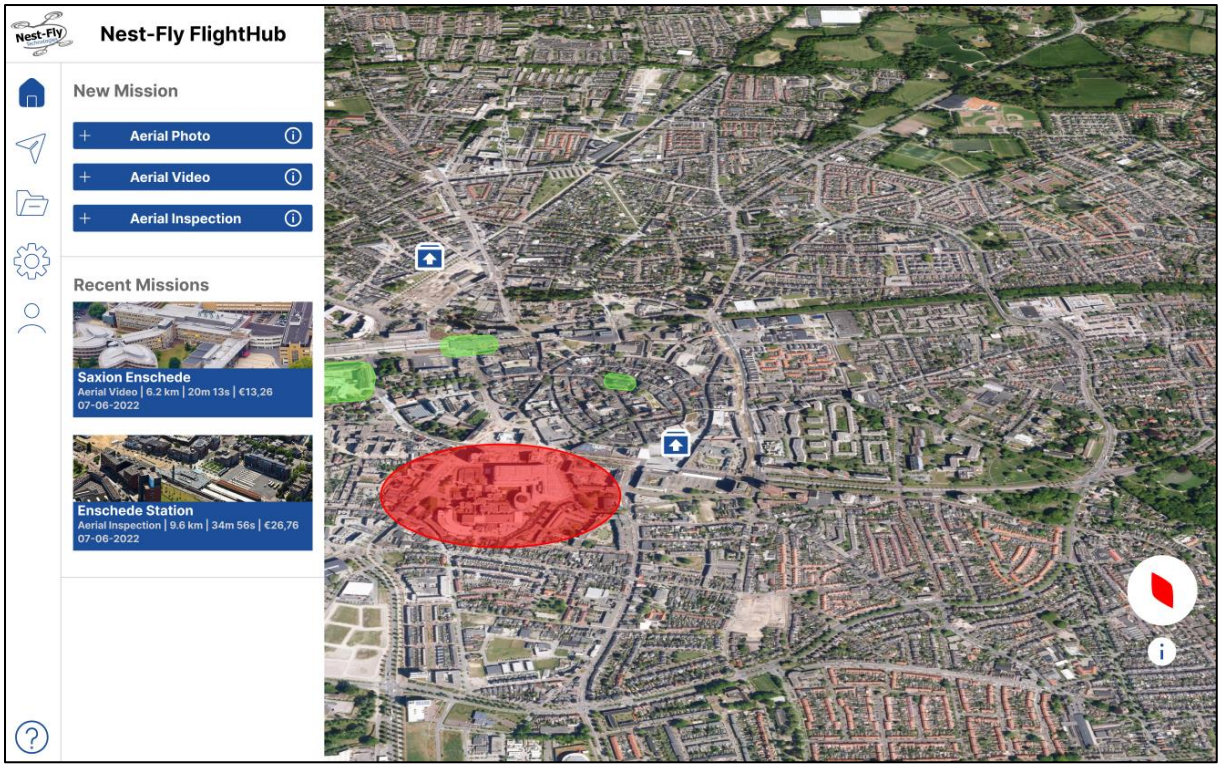


Figure 6.3 Home screen with map view

6.2.3 Home menu

On the side of the home menu of figure 6.3, the side bar can be seen. This is the way the user navigates itself through the interface, being able to go to the mission menu, data menu, settings, profile and on the bottom the help menu. In the home menu, effective help tried to be given in the form of the standard options, Aerial Photo, Aerial Video and Aerial Inspection. It was chosen to not have a pop-up in the beginning, but to show the options of the interface on the side standard. Some recent missions are also shown in the home menu. These recent mission are non-functional, but could later be used when a user quickly want to get to and old missions data or flight path. This home menu is the starting place of the interface. However, for user testing, the interface will start in the help menu which will be explained later.

6.2.4 Drone Mission-planning menu

When having chosen a mission type and selected a building the user will be prompted with the mission-menu (figure 6.4). Here different parameters can be chosen for the chosen flight type. In this case three options being, type of mission, type of drone, and resolution. These are very minimal settings as the interface does most of the mission planning for the user to reduce cognitive load. Next to this the user has a preview of the building they have chosen and are prompted with a button to generate a flight-path. When clicking this button the interface will calculate a flight path and the mission details (figure 6.5). The mission details are arbitrary numbers and there to provide feedback to the user. The flight-path has been drawn and ends in a circle to mimic the flight-path of the drone circling the building and taking photos. The user is still able to adjust settings and recalculate the flight path and details if they wish to do so. Also, if they are satisfied with the prompted mission, they can start the mission.

Figure 6.4 Mission settings menu

Figure 6.5 Mission settings menu with calculated flight-path and mission details

6.3.5 Mission animation

When the user clicks on the start mission button in the mission settings menu, the interface will continue to the mission animation (figure 6.6). This is in place to give the users a live view of the drones location and camera (top-right corner) when the mission is taking place. It also shows the progress of the mission with a sliding bar and time left. At this point in the realisation the mission animation is a still picture and there as a placeholder, just for usability testing. The user is able to click the finish mission button to end the animation and continue. The user will then be prompted with a pop-up containing an end of mission statement and guiding them to their data (figure 6.7).

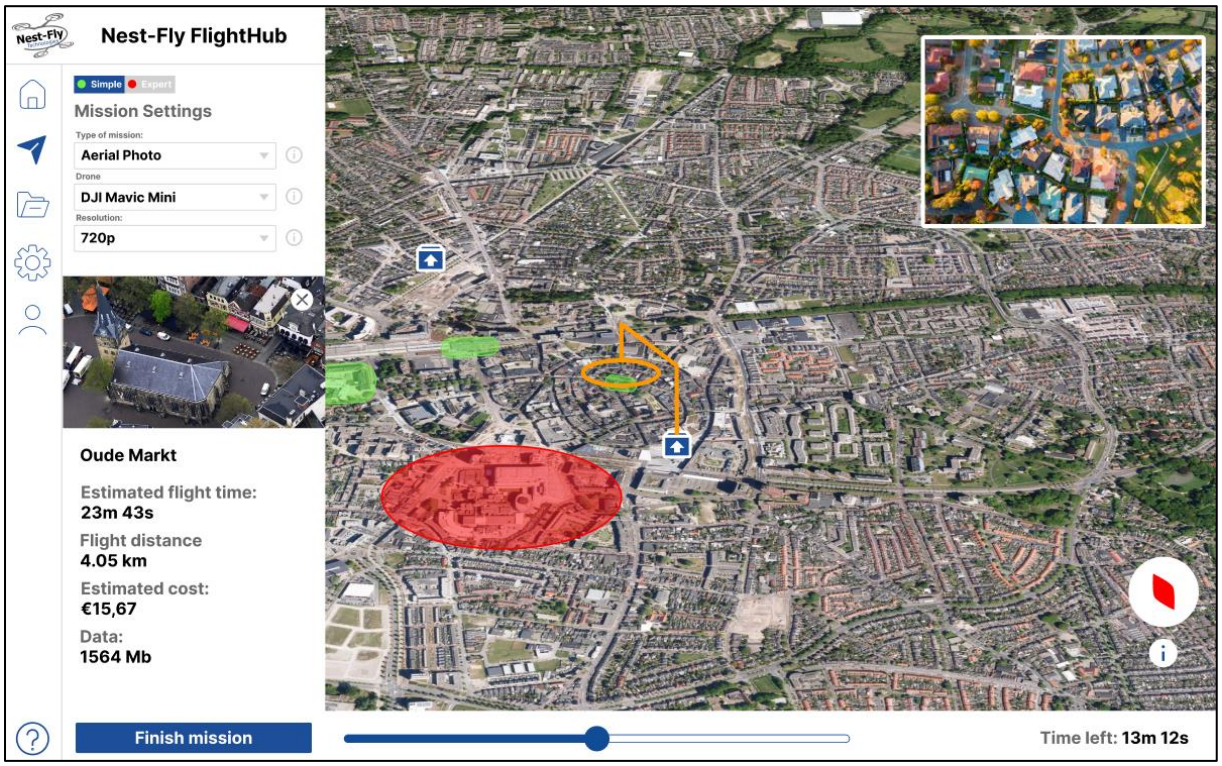


Figure 6.6 Mission Animation

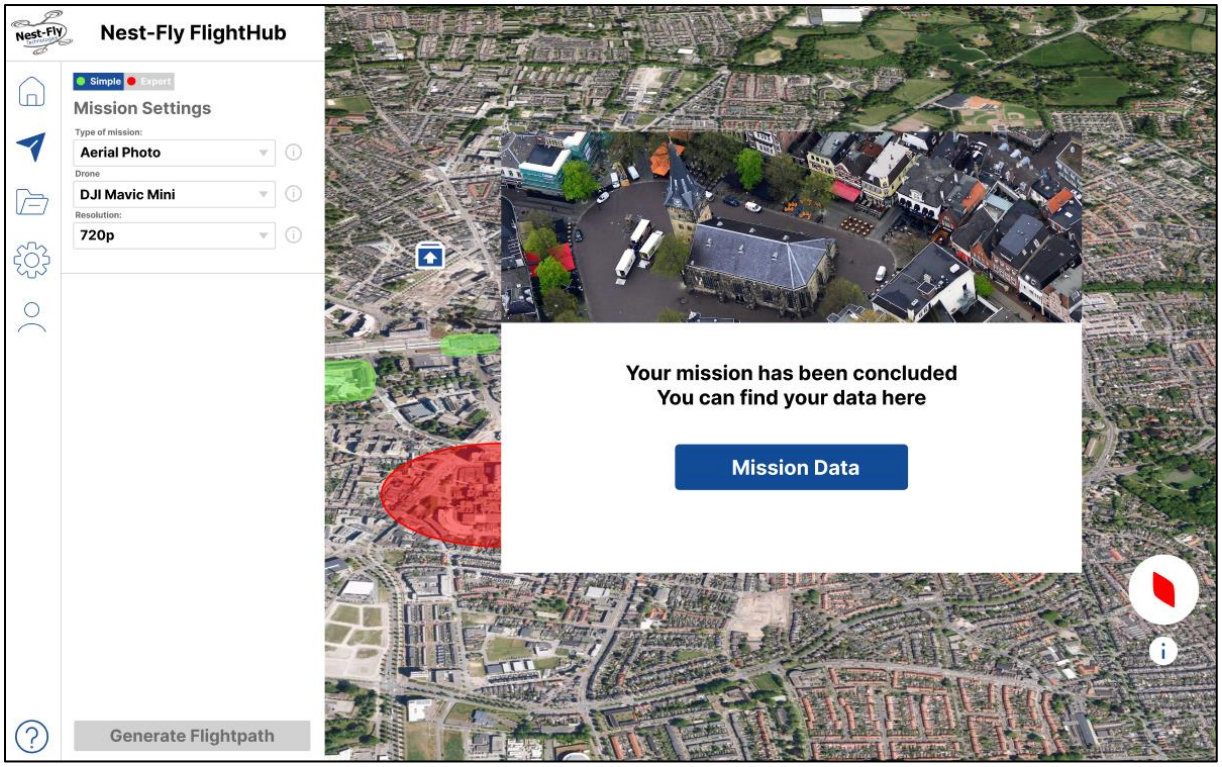


Figure 6.7 End of mission pop-up after mission animation

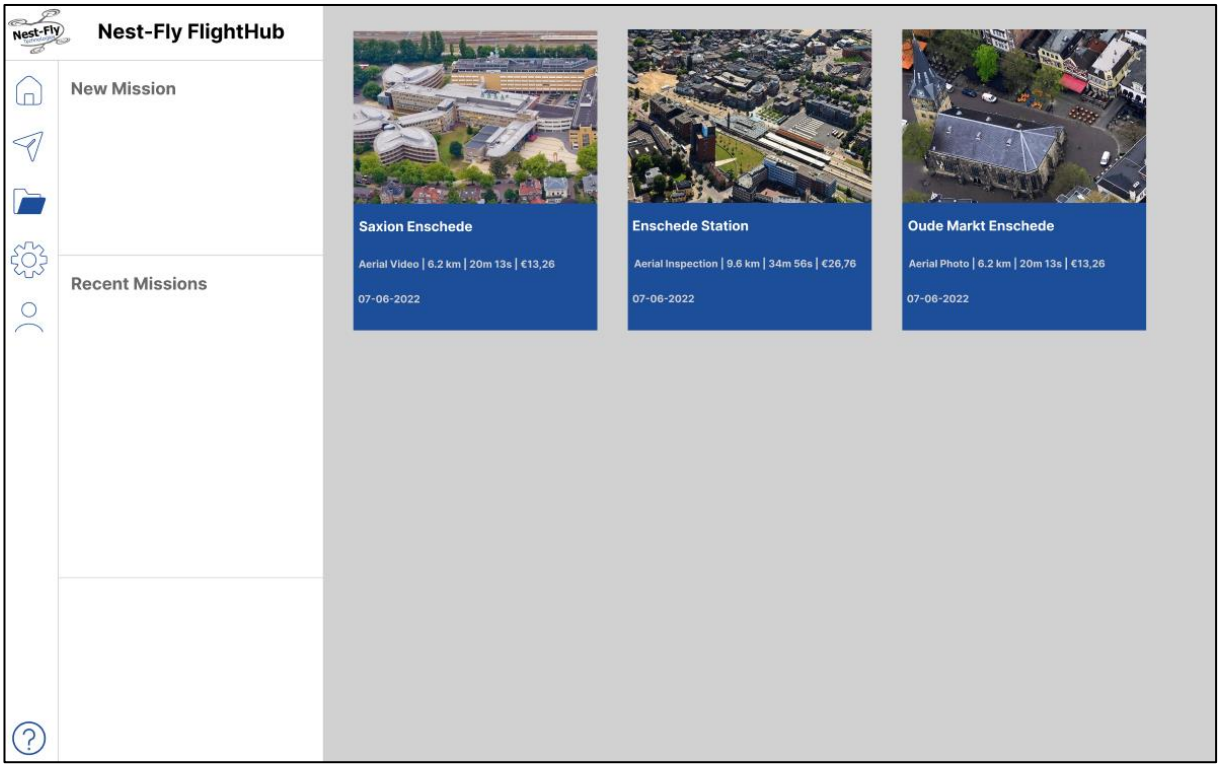


Figure 6.8 Data Menu

6.2.6 Data menu

In the data menu (figure 6.8) the missions with their data can be seen. This menu is here as a mock-up and the different data blocks are not clickable. This is with the reason that it does not add to the research goal. Since the research looks to facilitate users in ordering a drone for they use-case, the data review is after the mission has been conducted.

6.2.7 Help Function

To provide help to users who need it, a help function has been made to support users. The help function guides the user through the interface and its functions. Also it explains how to order a drone and what can be seen and done in the different menus. This help is provided in the form of different pop-ups and pointing arrows at the different buttons. The pop-ups move around near to the location of the explained functions to guide attention to those parts of the interface. A user can at any time choose to continue or skip the help function. Some examples are given in figure 6.9 and 6.10.

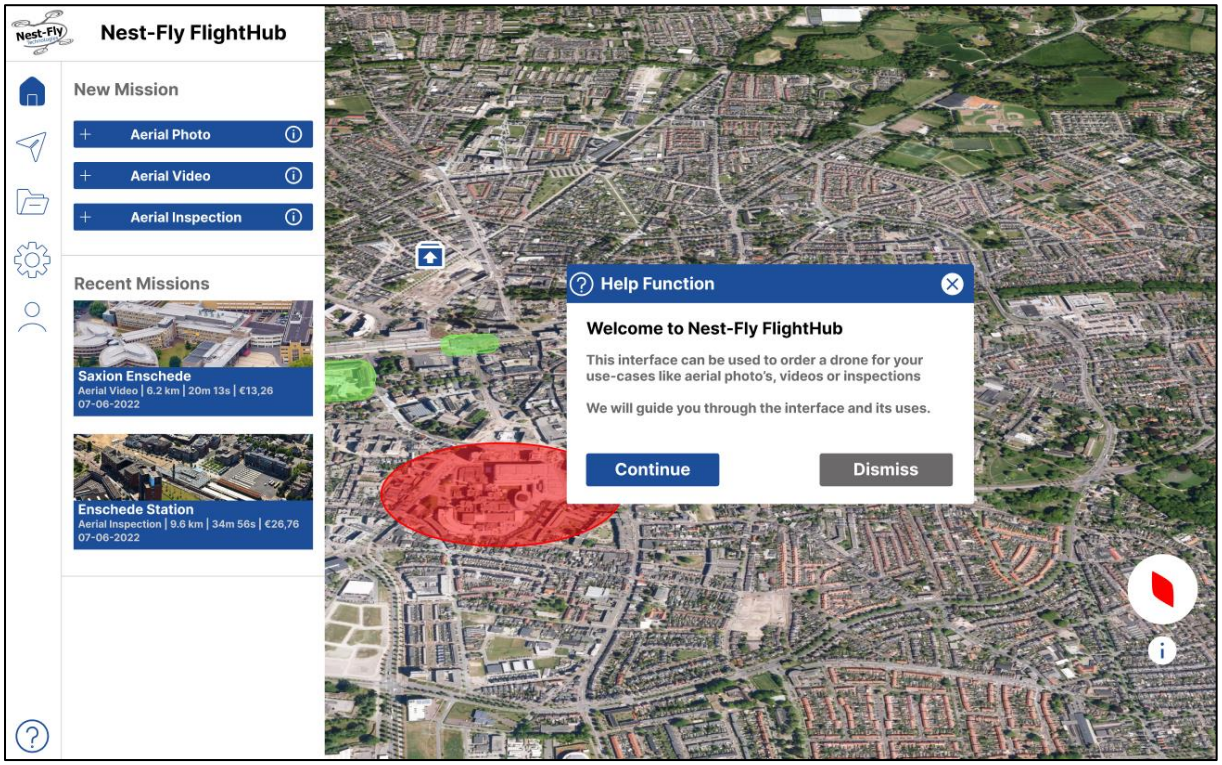


Figure 6.9 Start of help function, and start of the interface during usability testing

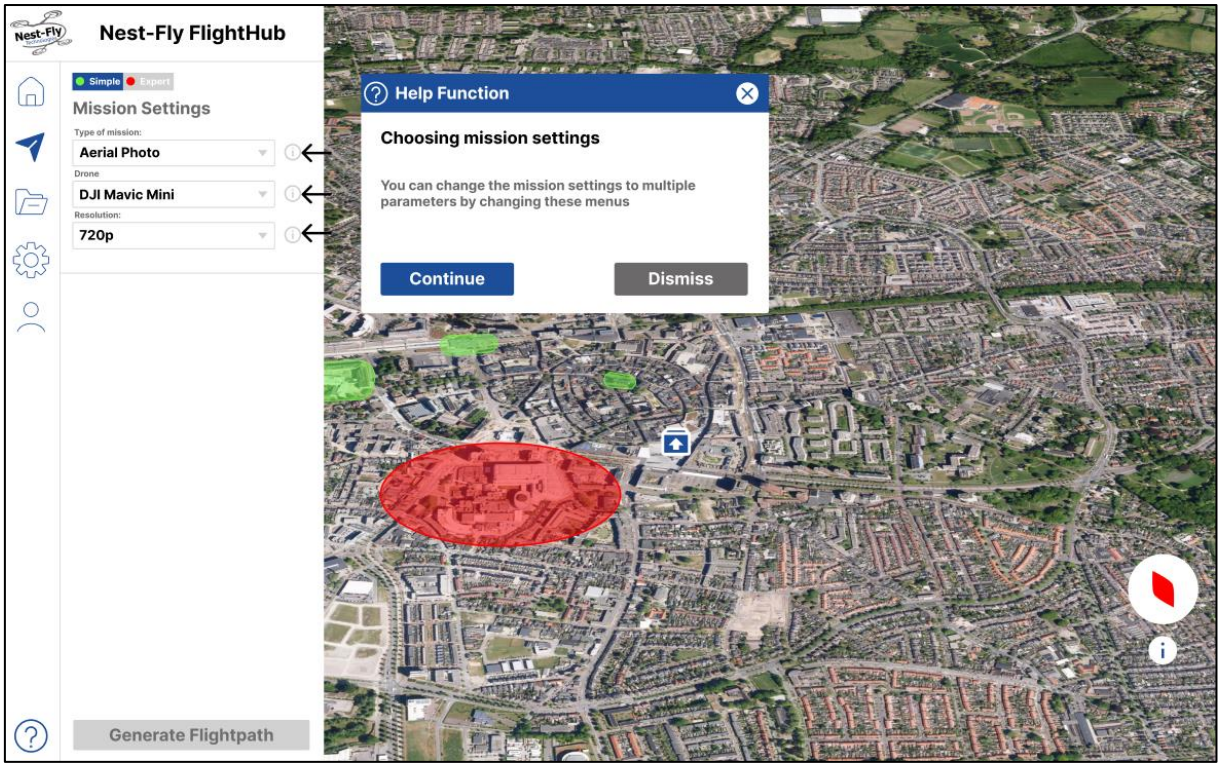


Figure 6.10 Help function, showing mission settings with arrows and movable pop-up

6.2.8 Summary of Realisation 1 in user requirements

The first realisation of the interface was based upon earlier defined functional and non-functional requirements in the specification chapter. Using this list of requirements a short analysation can be done on how these requirements were implemented in the first realisation (Tables 6.1 and 6.2). Here it will also be shown which requirements were not implemented and with what reason.

Table 6.1 Functional requirments and their implementation in Realisation 1

MoSCoW	Functional	Implementation
Must	Give the user a home button	Side bar has home button which brings user back to home menu
Must	Visualize restricted and unrestricted flight areas with colors	Using red and green colors, the flight areas are visualized
Must	Tutorial that guides the user through the interface	Help function where the user is explained the most important functions
Must	Choosing guide for tasks at the beginning of the interface	User can choose mission type in the side bar.
Must	Automated flight planning	Flight path is generated based on chosen building
Must	Point click for the different buildings	User is able to click on different buildings
Must	Create a more in detail help function	Help function is now extended to incorporate more details
Should	Basic map with flight instruments	Mission animation shows camera view and progress
Should	Home button to return should work everywhere	Home button now works in every menu
Should	Place basic functions on the left	All functionalities are placed on the left of the screen
Could	Being able to switch between video and map view	User can click camera view to get a close up
Could	Have influence on where the drone will be flying by suggesting multiple flightpaths	Not implemented due to time constraints
Could	Provide the user with a choice of expert levels	User can choose, but nothing changes yet
Won't	Option between dark and light mode	
Won't	Customizability of layout	
Won't	Customizability of data shown	
Won't	The interface should operate as a coworker	
Won't	AI asks you questions and adapt	
Won't	Be able to control the drone	

Table 6.2 List of non-functional Requirements for specification

MoSCoW	Non-functional	Implementation
Must	Place often used features in recognizable locations	All important features are clearly shown
Must	Give good symbols for features, words cannot describe features	For all functions simple and clear icons have been chosen
Must	Better flow towards the picture making	User is given more clear help for creating a mission
Must	Buttons should have natural functionality	All buttons are clickable and serve no other purpose
Must	Give clear feedback of actions	Users can hover some icons and when clicked the interface changes
Must	Keep interface clean and simple, hide or do not implement extra features	As little as possible setting are implemented in the system
Should	Interface should be recognized as a drone interface	Using drone icons and drone wording
Should	Better feedback when clicking something	Extra feedback is added on click.

6.3 Realisation 2

Using the gathered results of evaluation 1, a new set of requirements has been set up (See evaluation 1 in Chapter 7 Evaluation). These are used in realisation 2 to change the interface based on user feedback. This will result in a new interface which should be more usable and can be used for a new evaluation round. In this section a walkthrough of all changes to the interface in realisation 2 will be discussed and design choices will be explained.

6.3.1 Map view

The map view was adapted to be more intuitive for the user. To implement this, on the green areas a hover and click was added (see figure 6.11). When hovering the icon, a pop-up shows the information about the hovered buildings and what action a user could take. Secondly, when clicking on the create mission button the user will be taken to the mission planning interface to configure their mission. Secondly the compass was made more readable for the user, as with the old compass the participants were confused what the icon meant. Lastly the legend was made more understandable for the user by adding the naming of the figure to the legend and making the words more clear, in figure 6.12 the old and new legend can be seen.

6.3.2 Home menu

The home menu can be seen in figure 6.11. To the home menu no changes were made as most participants of the user test were able to navigate themselves through this menu and perform their task. It was also clear that users could click one of the mission options and get to the mission planning interface in that way.

Figure 6.11 Home menu of realisation 2

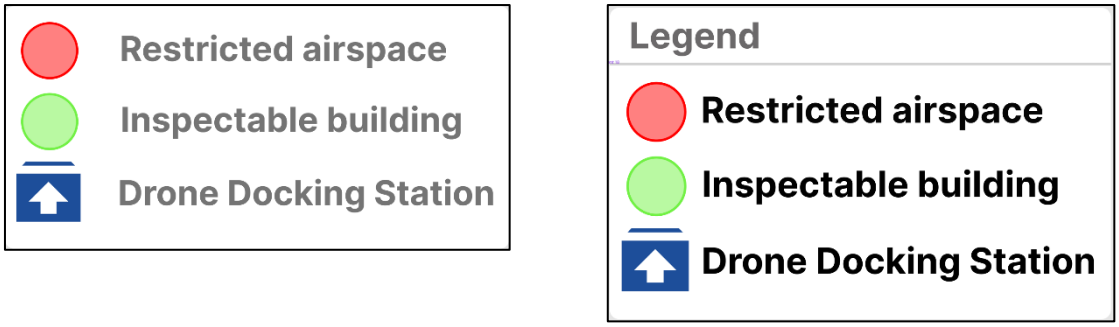


Figure 6.12 Old and new legend side by side

6.3.3 Drone Mission-planning menu

Also in the drone mission-planning menu (figure 6.13) the hover and click on the inspectable buildings was added. Next to that, since for some participants it was hard to realize what the different areas meant. To help the user it is asks to select one of the green areas of your interest to inspect as a reminder what the areas are. Also the choices of mission parameters have been changed to more simple settings, and the mission type has been highlighted such that the user is reminded of the most important setting.

Secondly, when the user has chosen a building (figure 6.14), it will see more information about the building and the map is given an icon on the selected building. This gives the user more feedback and awareness of what is happening, and going to happen in the interface. The drone docking stations are now also hover able and show information about the station. Lastly, when the user has fully configured the mission, a flight path will be generated and shown. These both have been changed to show a more clear picture of the users mission and the flight path the drone is going to take. This can be seen in figure 6.16 were also an extra flightpath view has been implemented in the small picture of the building at the mission info. Some inspiration for the info about the building was taken from Google Maps' way of showing building information [63].

Figure 6.13 Drone mission-planning of realisation 2

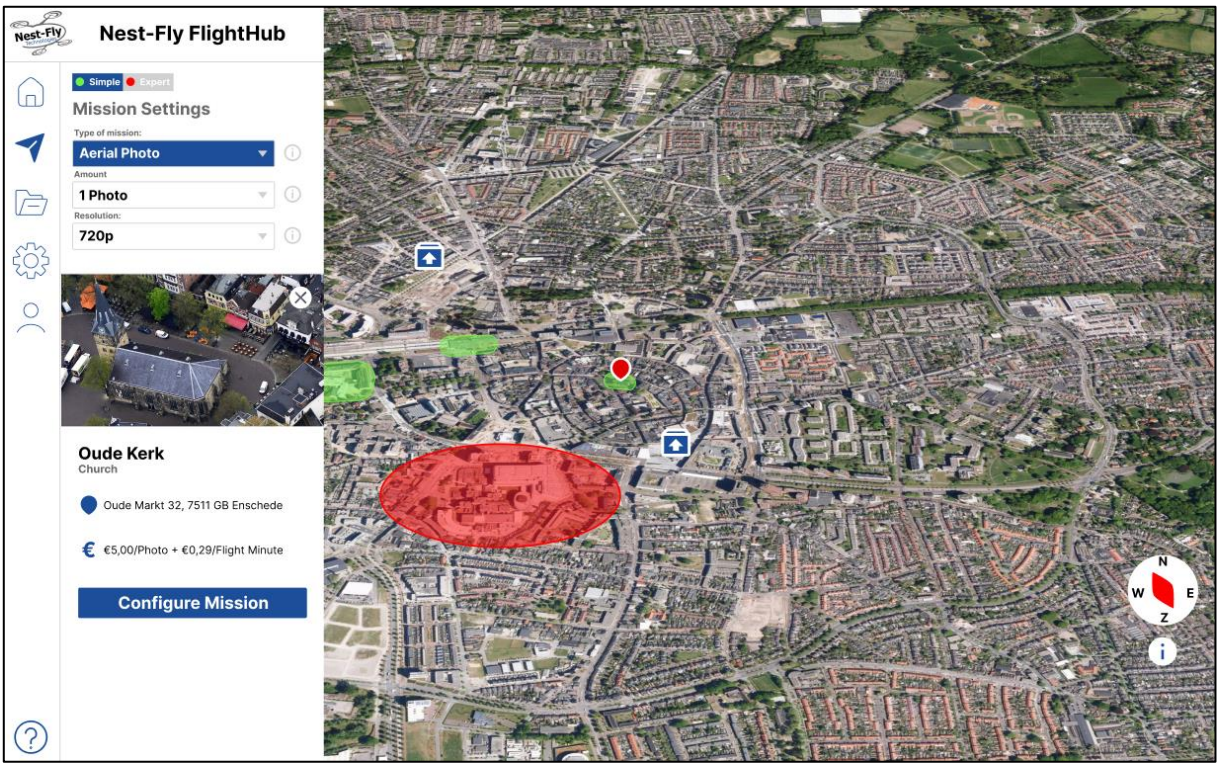


Figure 6.14 Drone Mission-planning interface when a building has been selected

6.3.4 Configuring camera position and angle

A big change that happened in the interface is the addition of a camera configuration menu (Figure 6.15). This menu was added to give users more control over the photos they were going to take. Its works by giving the user a zoomed in view of their selected building. Around the building different green squares appear, these are green to keep consistency (green = hoverable, green = clickable). When hovering the square, a blue square cone shows the area that will be photographed. When the user clicks on the green square it will be selected and the button for generate flight path will turn green, giving feedback that the user has configured the camera angle. Here also help is given to the user by describing what they need to do in the menu to complete the configuration. This can be seen in the side bar where an image icon with green area and text explains the task. For the camera angle in realisation 2, only one option can be chosen, this was done to quickly implement the feature for testing and to not unnecessarily spend time on the addition of the feature.

6.3.5 Mission animation

When the user has fully configured the mission and agree with the mission details, the user is able to start the mission. This mission animation is fully animated in realisation 2 in order to give the user the feeling that they really started a drone mission (figure 6.16). Other changes to the mission animation menu are the progress bar. This now shows a drone logo as indicator and the percentage completed of the mission. Secondly, the video feed has now been made clear with a red circle and the words live video feed, to show the user what the extra picture in frame is. There is also a drone picture following the given flight path, and it also appears in the smaller view showing how it will make the picture. The mission animation has also been given a abort mission button to give the user control over their mission, such that the user can abort at any time might they choose to not continue the mission.

When the mission has ended the interface will show a pop-up of where to get the data (figure 6.17). The user now has three options, either click the button mission data and go to data, or click away the pop-up and stay in the mission animation, or click finish in the bottom left corner and go back to the home menu. This gives the user more control over the mission ending and what the user wants to do next.

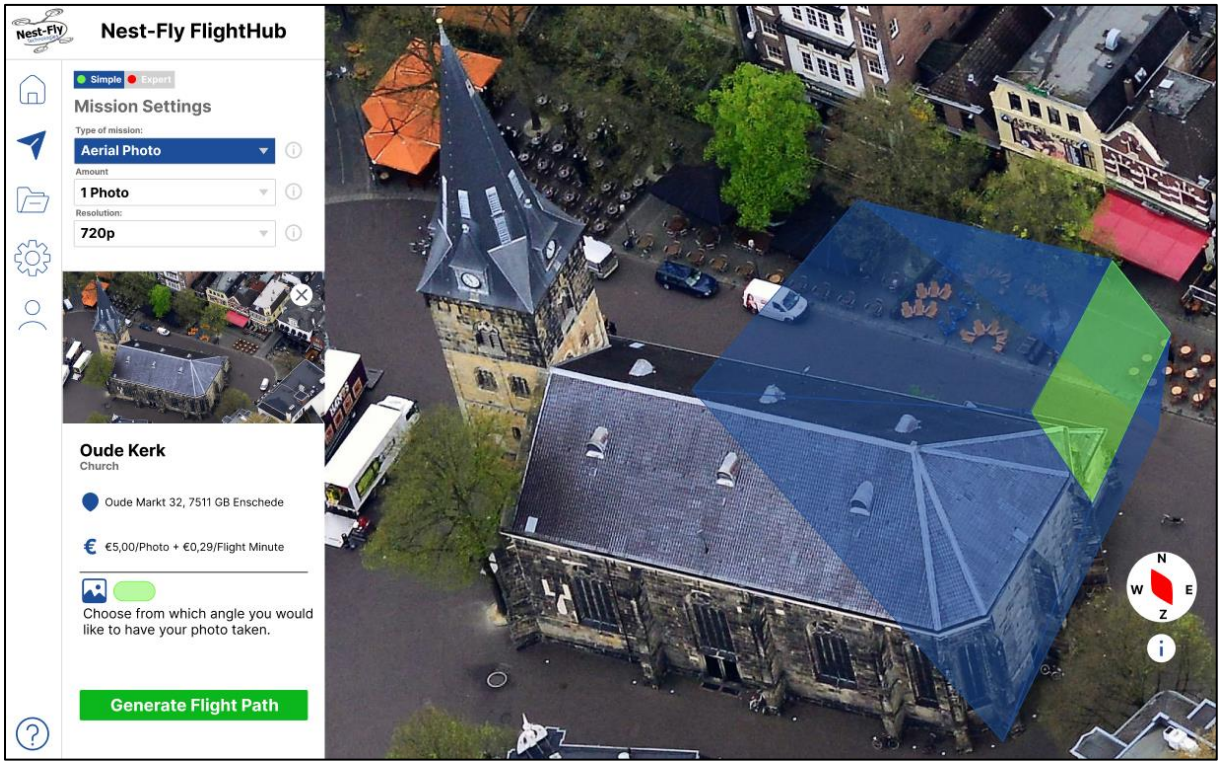


Figure 6.15 Camera configuration menu

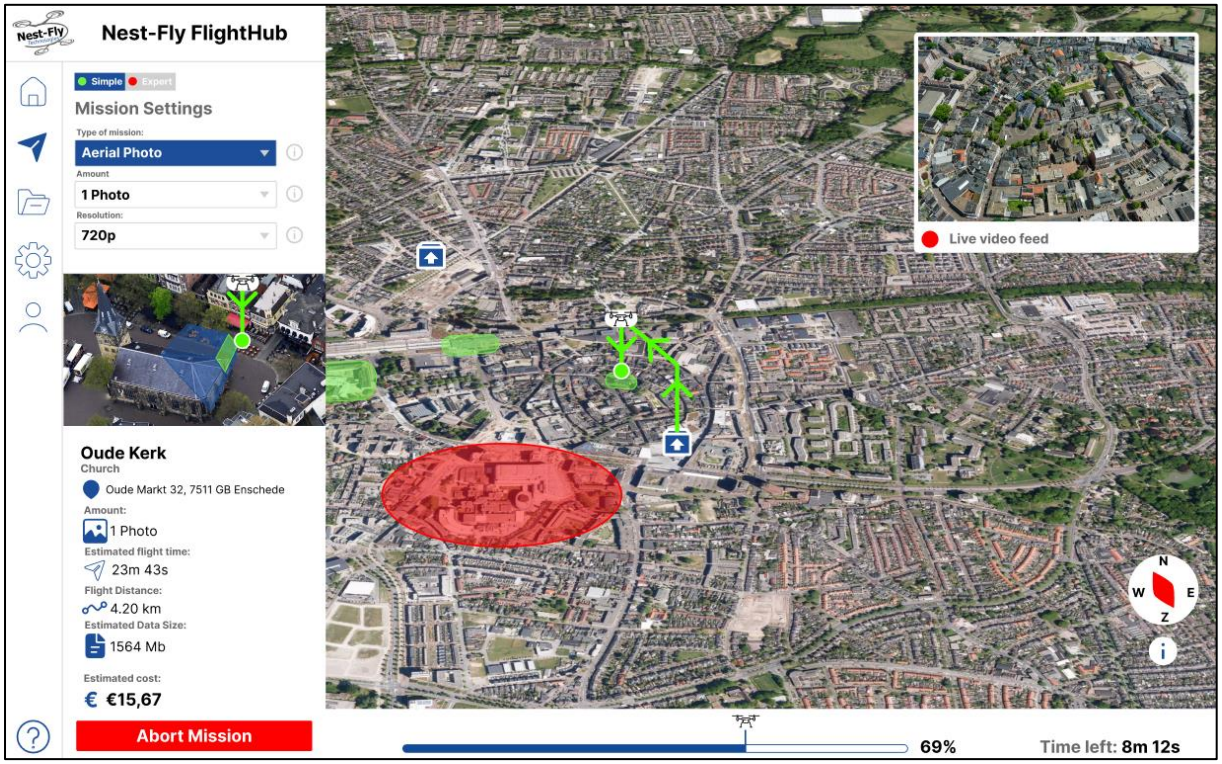


Figure 6.16 Mission animation menu

Figure 6.17 Concluded mission pop-up in mission animation

6.3.6 Help function

The help function has received the biggest changes when comparing realisation 1 with realisation 2. The feedback of the participants was that, although the help function was useful, it was not intuitive and the explained features were hard to find. Therefore it was needed to change the help function. First of all the help function was extended to give a more thorough walkthrough of the interface. This could already help by explaining more features and how they worked. Secondly, instead of using arrows, it was chosen to highlight the parts which were explained. This idea came from the IntroJS website [64], where a walkthrough is shown and the different features are highlighted. The changes in the help function can be seen in figure 6.17 and 6.18 as two examples. What was taken from the help function of the previous iteration was the movement of pop-ups. This seemed to be liked by the participants and was carried over to this next interface. Also the help function now has a back button such that the user can go back when needed.

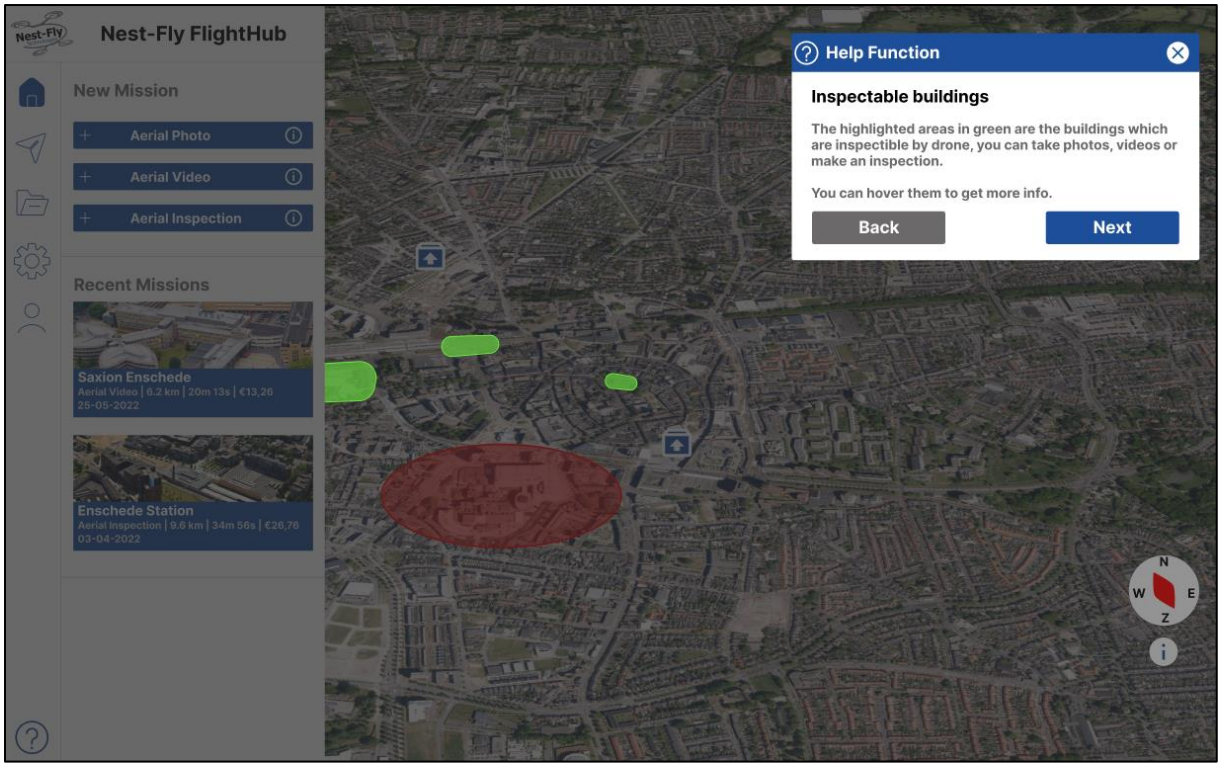


Figure 6.18 Help function, highlighting and explaining the green areas on the map

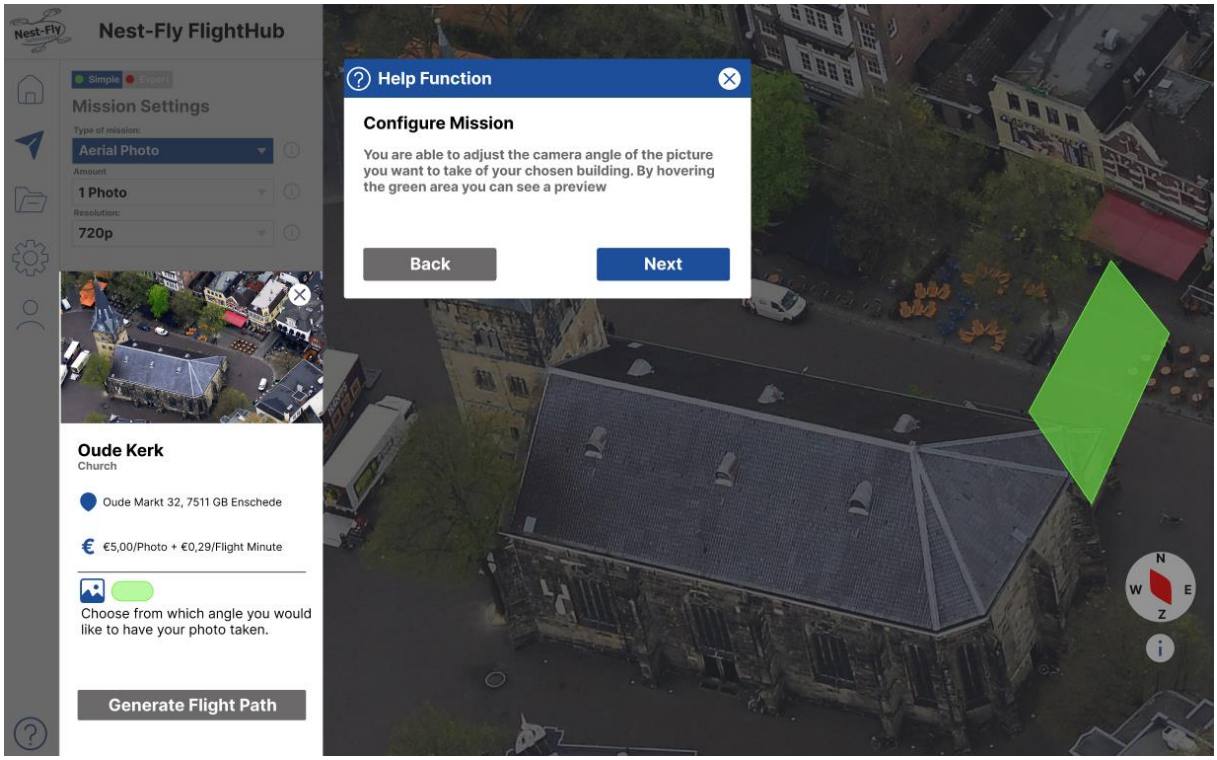


Figure 6.19 Help function, highlighting and explaining how to choose the camera angle of photos

6.3.7 Summary of Realisation 2 in user requirements

From the first evaluation of the interface a set of requirements was made. These requirements were the building blocks used to improve the interface and create the second iteration of the interface. Below in tables 6.3 and 6.4 a summary can be found about how each requirements was implemented into the interface. Some requirements were not implemented into this version of the interface, the reason for not implementing certain requirements can be found in the tables.

Table 6.3 Functional requirements and their implementations in realisation 2

MoSCoW	Functional	Implementation
Must	Legend needs to be clearer	A clearer indication about the legend and the words have a more pronounced body
Must	Progress bar should show percentage of flight progress	Added percentage to progress bar, updates during animation
Must	Progress bar needs to get rid of the circle and incorporate a drone sign as pointer	Indicator now has a line and a drone icon to indicate the mission progress
Must	Live video feed in mission animation should have the text: "Live Video Feed"	Text added with a red circle to identify the picture as the drones live video feed
Must	Each point of interest should be hoverable and clickable	Each point of interest is hoverable and clickable to select the building
Must	Each point of interest should have clear feedback and info when hovered	When hovered, the interface gives a pop-up displaying information about the point of interest
Must	Flight path needs to be visualized in a clearer way	Flight path visualisation improved by brighter color, added direction and end point
Must	The help function should have a back button	Back button implemented into the help function
Must	Show clearly what the icons on the map are	Updated legend
Should	Start mission button should be more clear	Start mission button has been made green color to stand out more
Should	Mission should be a fully working animation	Mission animation has been added with live progress bar, drone flight path and video feed
Should	Add a close button at the concluded mission pop-up	Concluded mission has extra options for the user to choose and pop-up has a close button
Should	Drone Docking stations need info when they are hovered	More info on hover for the drone docking stations added
Could	Compass is too basic and needs a directional letters NESW	Added letters to North, East, South and West poles
Could	make the cross in mission planning more clear	Not implemented due to time constrains
Could	Side bar can be smaller and have a toggle	Not implemented due to time constrains
Won't	Be able to sort the data in the data menu	
Won't	Add more different views to the map	
Won't	Be able to zoom into the map	
Won't	Make the mission parameters functional	
Won't	Make the expert mode funcional	

Won't	Make the data in the data menu viewable and downloadable	

Table 6.4 Non-functional requirements and their implementation in realisation 2

MoSCoW	Non-functional	Implementation
Must	The mission parameter options should be simplified for better usability and understandability	Options are simplified where the chosen mission type is most important other parameters are based on the mission type
Must	The Help function should be more intuitive, and the users attention needs to be pulled to the explained interface functions	Help function expanded to be more thorough, added highlighting for better guidance through the help function
Must	User needs a way of choosing the angle and place at which the picture of the building will be taken	User can choose angle on a zoomed in view of the chosen building. This is done with a green square and visualisation of what the camera would see
Should	Make a more clear path to the mission planning interface	All areas are now hoverable and possible action are shown with the different points of interest. These can also be clicked to navigate through the interface
Could	The whole interface should be working through the map	The choosing of building is done through the map after which the map functions as visualisation .
Won't	User should be able to make its own inspectable area	
Won't	Show how the user would pay for his drone mission	
Won't	Data menu needs more explanation of functions	

6.4 Realisation 3 - Final prototype

To create the final prototype of the interface, the results of evaluation 2 are used (see evaluation 2 in Chapter 7 Evaluation). These have been summarized into a set of requirements for the final version of the interface. This section will summarize the changes done to the create the final interface and will summarize the changes using the list of requirements. The full final interface can be found in appendix 7.

6.4.1 Introduction menu

To give the user more help when starting the interface, an introduction menu has been added (figure 6.20). This is the landing page of the interface where the user is asked what to do. Next to that the user can choose to walk through the help function. It is also possible to skip this introduction menu and go to the home menu.

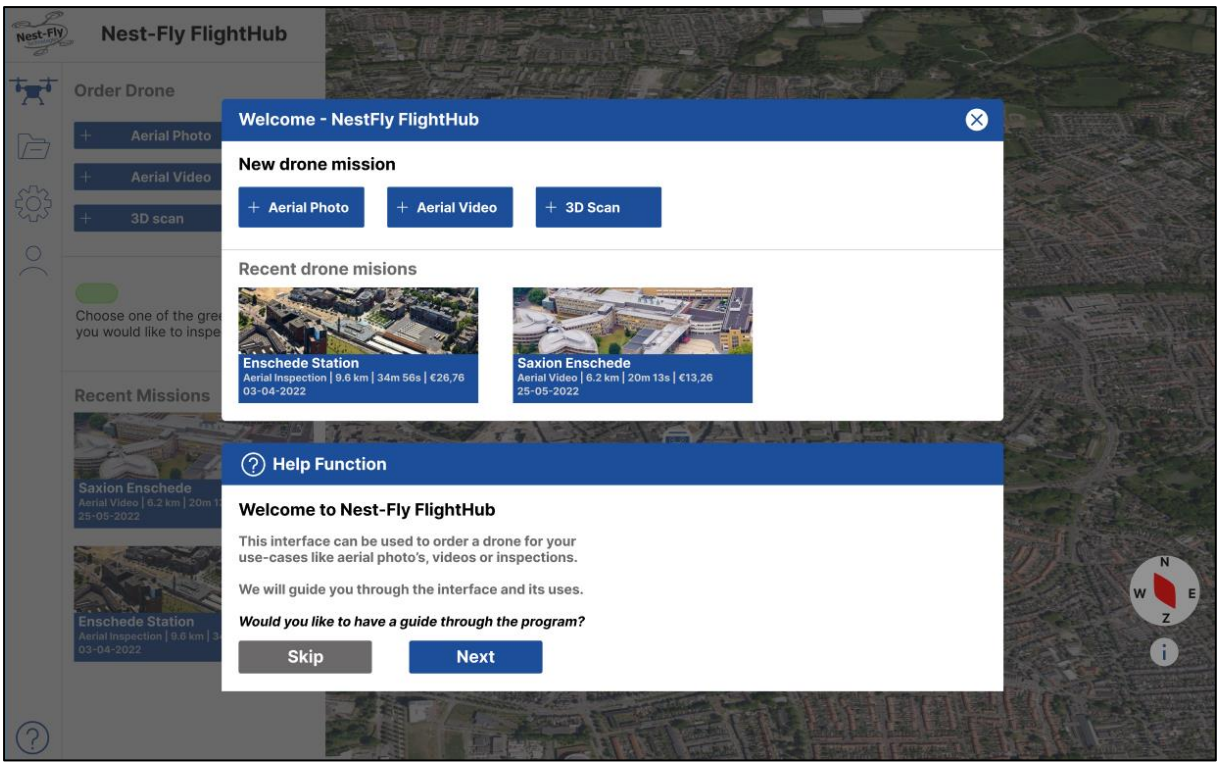


Figure 6.20 Introduction menu where the user will start their journey in the interface

6.4.2 Home menu

The home menu in the final interface is not a home menu anymore (figure 6.21). Instead it has been incorporated into the mission menu. Making the home menu the start of making a mission, since some participants and the expert were confused by the step towards the mission interface when choosing a mission option.

In the home menu a new icon in the sidebar is also present, this is a drone icon and shows that the user is in the drone mission menu. This is done do bring the drone more forward into the interface. To bring the drone more forward also the name of the mission has been changed to “order drone” and the drone docking station have a drone icon on them. To make the different mission options more clear the mission type “Aerial inspection” has been changed

to “3D scan”. The green areas on the map have also received an icon resembling a house, this has been after the participants had some difficulties understanding the green areas.

A search bar has also been added, the search bar itself is not functional and the user is not able to input words, however it has been put in to resemble a search bar since the participants wanted to search for their house.

Figure 6.21 Home menu of final interface

6.4.3 Drone Mission-planning menu

Based on the feedback from the participants, the drone mission-planning menu has been given some addition (figure 6.22). First of all, a feedback bar has been implemented, this will further be explained in the section about the configuration of camera angle. Secondly, a list of buildings has been added where the user can choose from. This was done to give the user some quick choices of buildings and should lead to less searching. This was suggested because the green areas do not directly give information. This way, when looking for a particular building, it can be found quicker. Lastly, the menu now has a back and forward button, giving the user more situational awareness within the interface

6.4.4 Configuring camera position and angle

In the configuration menu a feedback bar has been added (figure 6.23), because participants wanted more feedback in configuring the mission. Inspiration was taken from some web shops where you are guided with choosing and paying your order. This should give the user feedback about the steps they are taking within the interface and shows them where in the process they are. Secondly, a back button has been added such that users can go back to change settings. Lastly the angle that can be chosen has been highlighted since some users were unable to understand where to select camera angles.

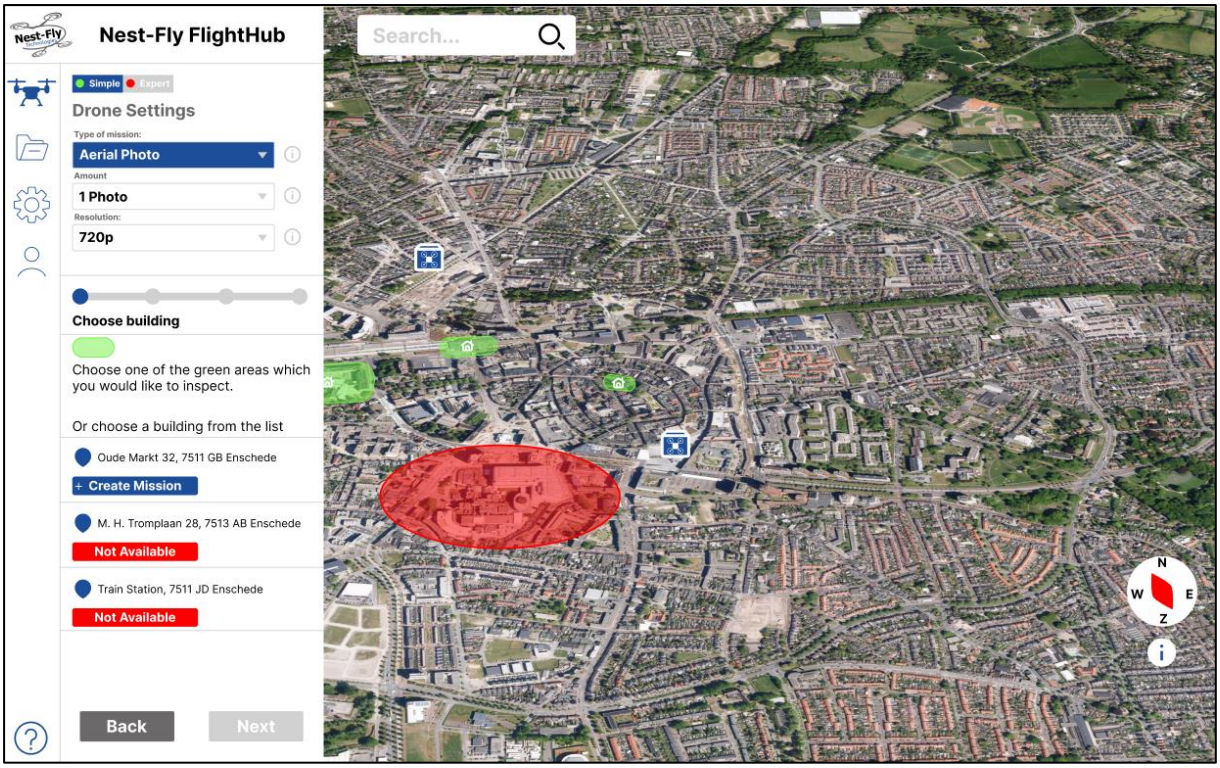


Figure 6.22 Drone mission planning menu with new feedback bar and list of buildings

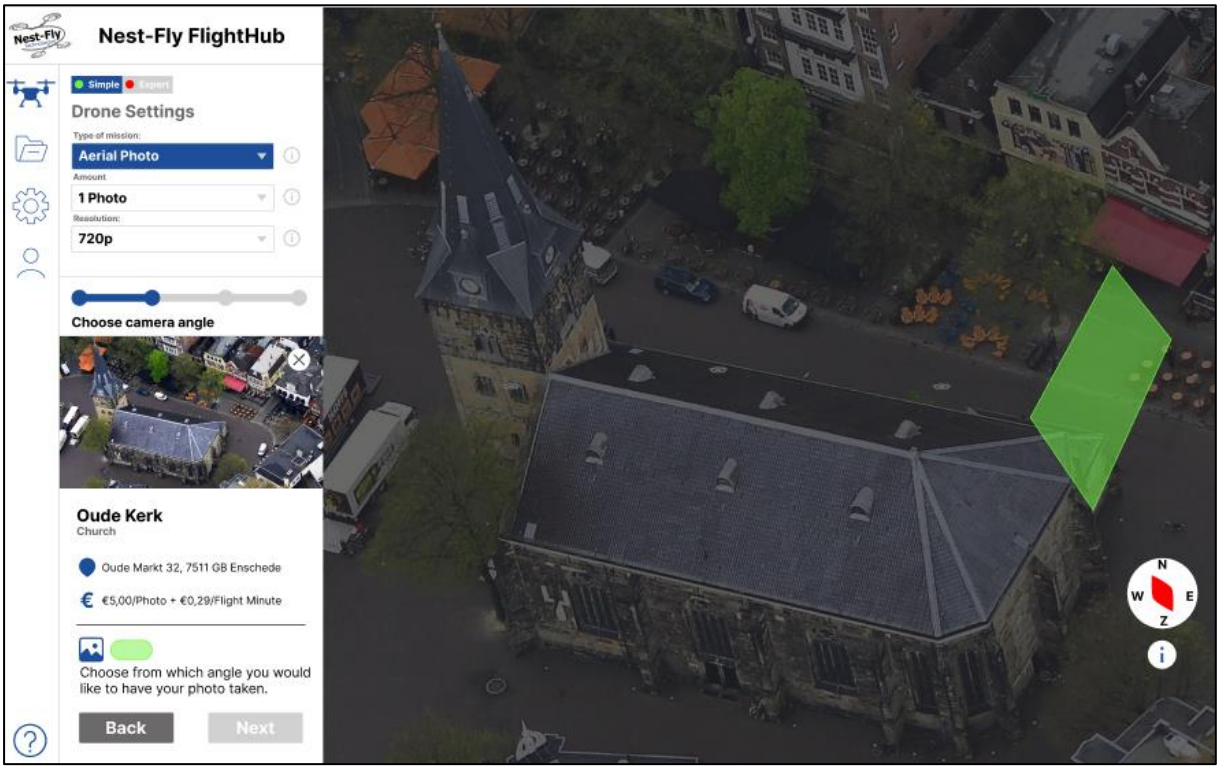


Figure 6.23 Camera configuration menu with changed feedback button and clearer camera angle choices

6.4.5 Mission animation

The mission animation has been extended with a pop-up at the start of the mission (figure 6.24). This has been done to give the user an explanation about the mission they configured. This also gives them a last chance to review their settings and agree with them. The rest of the mission animation has been kept the same.

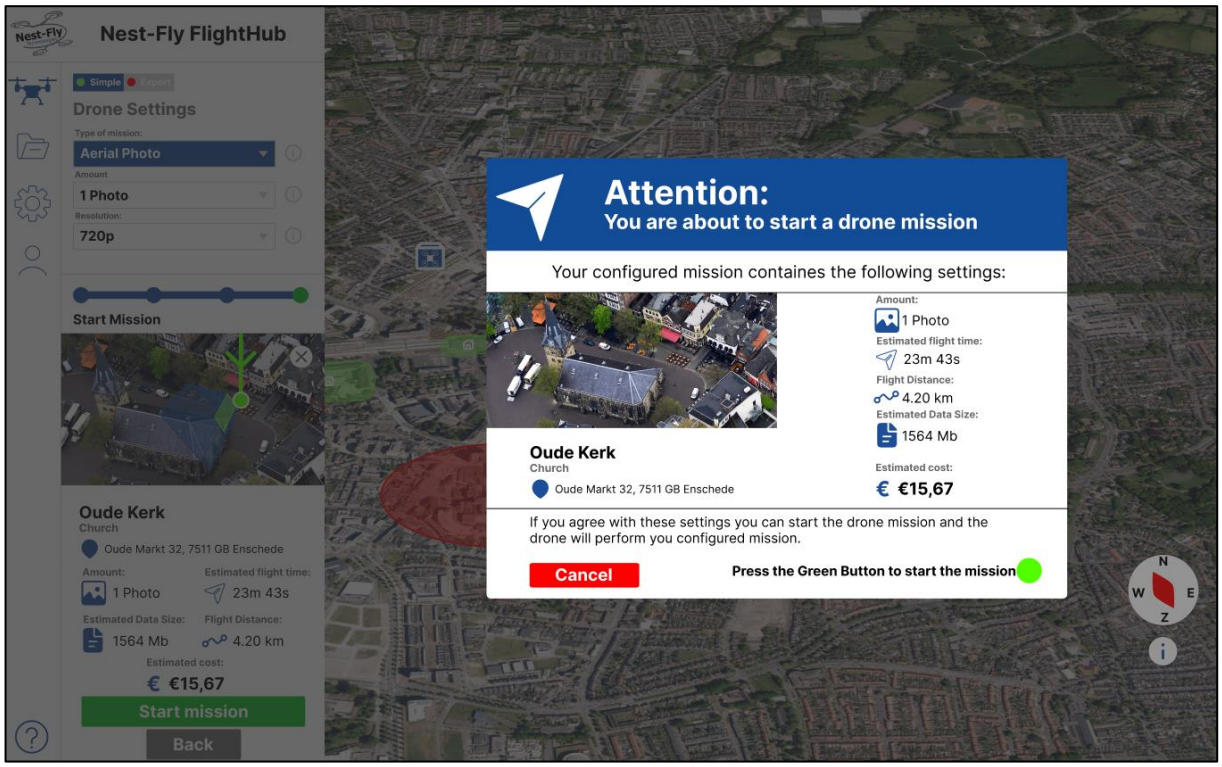


Figure 6.24 Pop-up before the start of the mission animation

6.4.6 Data menu

Since most participants were confused with the data menu, some small changes have been implemented to improve the clarity of the menu (figure 6.25). The side bar has been given proper wording and an explanation of the menu. Then the data has been sorted based on date, where the newest mission data has been placed above and older data below. Also a download button was added to each mission to give the user an understanding of how the data will be downloaded.

6.4.7 Help function

The help function has mostly stayed similar to the previous version (figure 6.26). The help function has been adapted to incorporate the changes in the different menu's and add an explanation of the side bar.

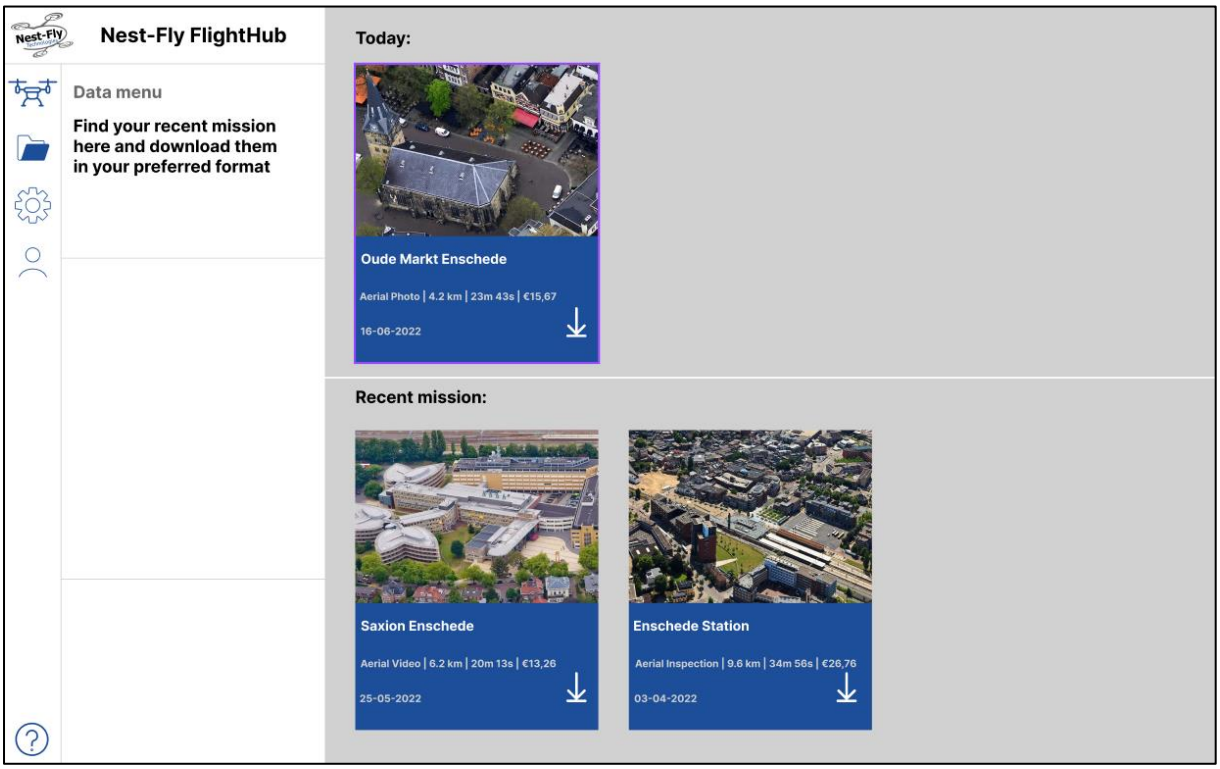


Figure 6.25 Improved data menu for clarity

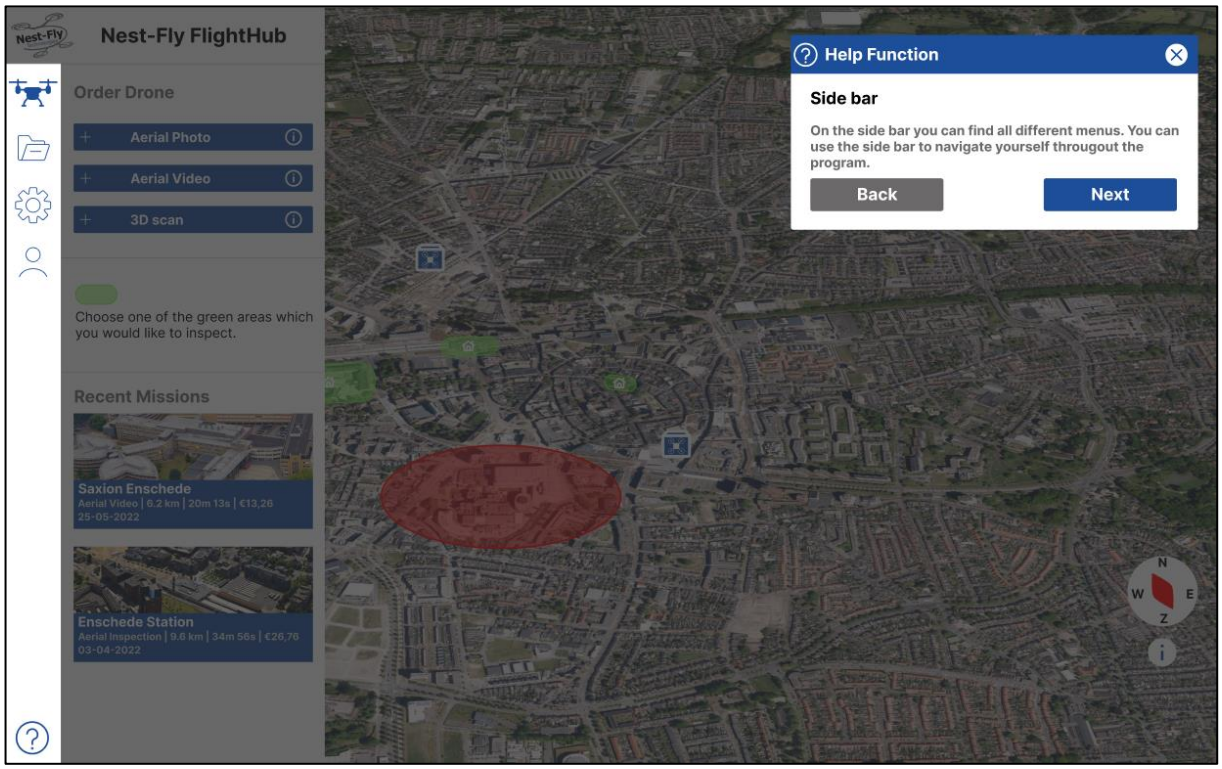


Figure 6.26 Help menu, addition of side bar explanation

6.4.8 Summary of the final prototype in user requirements

From the second evaluation of the interface a set of requirements was made. These requirements were the building blocks used to improve the interface and create the final iteration of the interface. Below in tables 6.5 and 6.6 a summary can be found about how each requirements was implemented into the interface. Some requirements were not implemented into this version of the interface, the reason for not implementing certain requirements can be found in the tables.

Table 6.1 Functional requirements and implementation in final prototype

MoSCoW	Functional	Implementation
Must	Give green areas clear icon	Green areas have received icons resembling a house
Must	Show legend in help function	Legend is now shown when explained
Must	Create a clear start of the interface, with help function included	Interface now has a landing page where the user can choose its mission or walk through the help function
Must	Drone should come more forwards in the interface	Drone icons have been added to the sidebar, drone docking station, and wording of mission has been changed to "order drone"
Must	Drone Docking Stations need clearer icons	Drone docking stations now have a clear top view icon of a drone
Must	Add undo button to menus	During each part of the mission configuration the user is able to move to the previous step
Must	Add a pop-up before starting the mission	Pop up added with all info about the mission and question to check
Must	Home menu can be incorporated into the mission menu	Deleted home icon and added home settings into mission interface
Should	Explain the menu bar in the help function	Side bar has been highlighted and explained
Could	Add a search bar to the interface	Search bar is added to help users search their building
Could	List of buildings to choose from	Buildings have been visualised in sidebar list and can be chosen
Could	Generate flight path button can be clearer	Whole menu buttons have been made consistent and added a feedback bar to show where the user is
Could	Data shows the mission which has been flown	Mission in interface has been moved up, and is shown first
Could	Show how you can download the data	Download button has been added
Won't	Example videos and photos	not implemented due to irrelevance
Won't	Specific help per feature when needed	Not implemented due to time constraints
Won't	Weather conditions can be shown	Not implemented due to irrelevance
Won't	Add the option of a 3D map	Not implemented due to Figma incapability

Table 6.2 Non-functional requirements and their implementation in final prototype

MoSCoW	Non-functional	Implementation
Must	Better feedback in configuration menu when choosing camera angle	The configuration menu now has feedback bar to help the user maintain situational awareness
Should	"Aerial inspection" term needs clearer wording	Wording has been changed to "3D scan"
Should	Change wording of "inspectable buildings"	Wording changed to "buildings"

6.5 Realisation of the Demo

Together with Yves Lentfert from Nest-Fly Technologies, it was discussed to make an demonstration of the technology using the design GUI. Together with Yves, the demonstration was ideated an specified after which the realisation took place. Because this is not part of the main research scope, the ideation, specification and realisation of the interface have been placed in appendix 12. In this section the end result of the demonstration will be shown and explained.

The demonstration consists a foldable table, which fits inside a flight case. This foldable table can be unfolded out of the flight case, after which the flight case serves as the tables stand. On the table a digital display showcases the interface. Using a computer mouse the user of the demonstration is able to navigate itself through the interface. The table also included a miniature version of a Drone Docking System which holds a real drone. On the table is a green button is fitted to operate the demonstration. A sticker of the map of Enschede and the logo of Nest-Fly wrap around the table to make it aesthetically look good.

When the user has navigated itself through the interface, the user is able to start a mission by pressing the green button. This will set in motion the interface by displaying the mission animation. At the same time the Drone Docking Station will open presenting the drone. A drone operator can then let the drone take-off after which it is landed back in the box. The full demonstration can be found in figure 6.27.

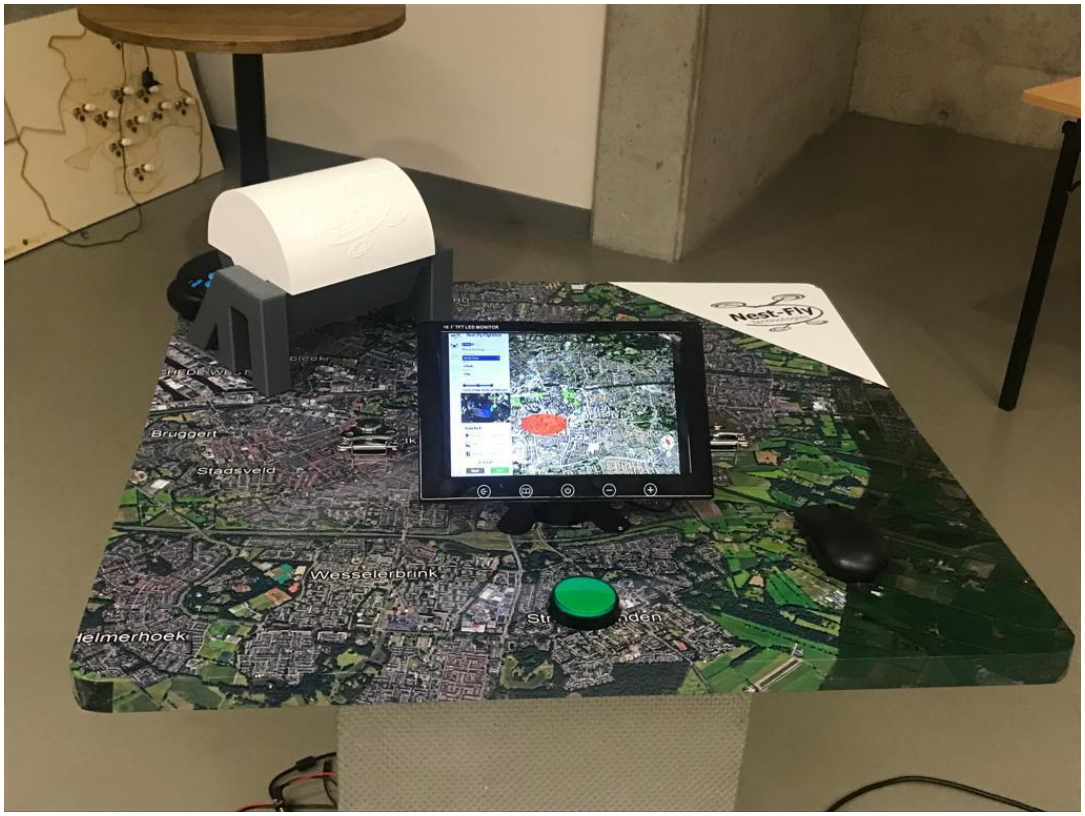


Figure 6.27 Picture of full Demo build.

7 Evaluation

In order to test the functionality of interface realisation 1 an evaluation of this interface was conducted. For the evaluation 1, usability tests were performed with 5 participants. These users where chosen out of the stakeholder groups of students and working adults. As a criteria the participants could not have much prior drone knowledge, as this could hinder the research, since the research is aimed on non-drone-experts.

These usability tests also included a small pre- and post-test interview. The pre-test interview was aimed to gather a bit more information on the participants prior interface experience and more specifically drone interface experience. The post-test interview asked the participant questions about the interface and their experience with the interface. Here the user was also asked to give its thoughts on the design, flow and usability of the interface and how they would maybe change it.

The full pre- and post-test interview and usability test can be found in appendix 8. Below is given a small summary of the conducted test. This evaluation method has also been reviewed by the EEMCS ethics committee of the University of Twente. The ethical documents can be found in appendix 9.

7.1 Evaluation procedure

In this section the different parts of the both evaluations will be discussed and explained.

7.1.1 Pre-test interview

The pre-test interview was conducted to gather info about the users prior interface experience and more particularly, gather info about the users prior drone interface experience. The pre-test interview consisted of the following questions:

- What apps and websites do you use on a regular basis?
- On what device do you typically use these apps and websites?
- How many hours per day do you use these apps and websites?
- Have you ever used a drone interface before?
- If yes, what drone interface did or do you use?
- What device did or do you typically use to use these drone interfaces?
- How often did or do you use these drone interfaces per week?

7.1.2 Usability Test

For the usability the participant was will work with the interface and perform a set of tasks within the interface. During the usability test the participant is asked to think out loud, such that the researcher can write along with the participants thoughts about the interface. The starting interface of the usability test was the help function, such that the user can first of all learn the interface after which they could use it.

For the usability test of realisation 1 the following tasks were given:

- Could you walk through the help function?
- Can you order a drone for me to take a photo of a building of your liking?

7.1.3 Post-test interview

The post-test interview consists of set of questions to get the participants opinion about the interface. In these questions they are given the space to suggest any changes to improve usability, show what was good about the interface and where they got stuck.

The post-test interview consisted of the following questions:

- What features in the interface did you find most valuable and why?
- What prevented you from completing a task?
- How clear were the given tasks on a scale of 1 to 10?
- How would you describe the overall usability of the interface on a scale of 1 to 10?
- If you could change some things in the interface, what would these be and why?

7.1.4 Expert Review

For evaluation 2, and expert review was also conducted. The expert who was asked is DR. R.H. De Freitas Gouveia, an expert in the field of human computer interaction. The expert review consisted of a short usability test, more structured as a walkthrough. Where the expert got given the same tasks as the participants of the usability test. This gave the expert a goal within the interface and an understanding what had to happen in the interface. This can give the expert tools for judgement of the interface to give his opinion about the interface based on the task that had to be performed.

After the walkthrough the expert was asked the same post-interview questions as the participants of the usability test. With the expert a more unstructured interview style was used to get into a discussion about the interface and discover last places for improvements.

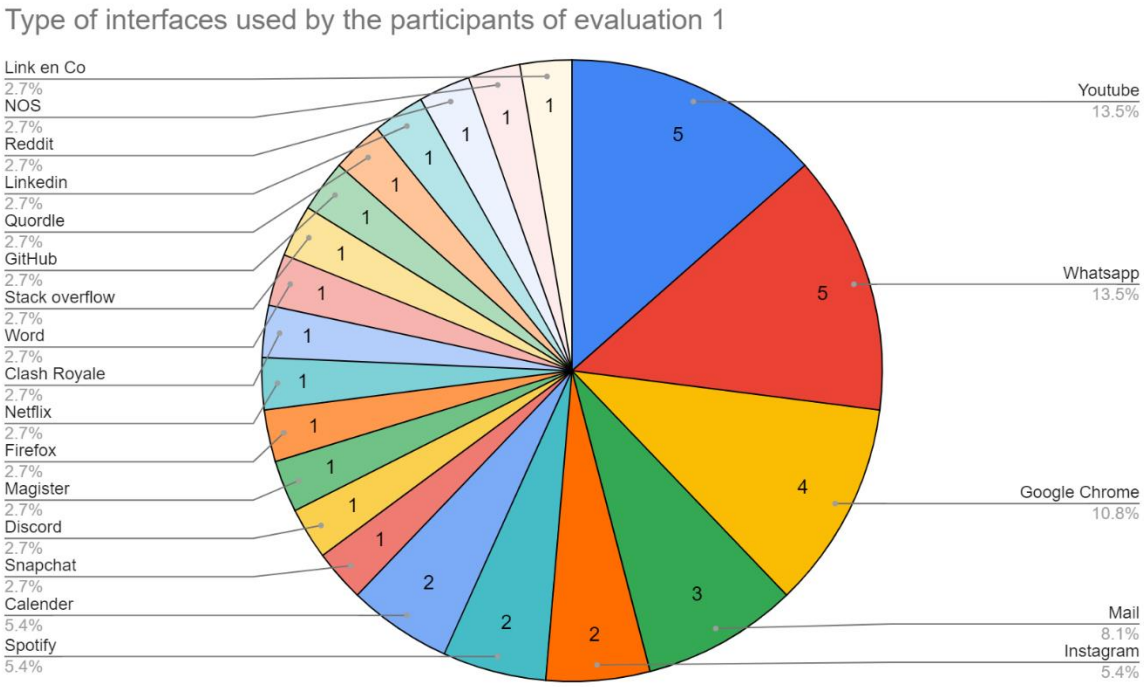
7.2 Evaluation 1

After the evaluation was concluded the results were analysed. These results showed where improvements within the interface could be, but also what features were good about the interface. The summarized results can be found in this section. The full data gathered from evaluation 1 can be found in appendix 10.

7.2.1 Pre-test interview Results

The pre-test interview has gathered data about the participants prior knowledge and experience with general and drone interfaces. A summary of the most important results of the pre-test interview, including an analysation of the data will be provided.

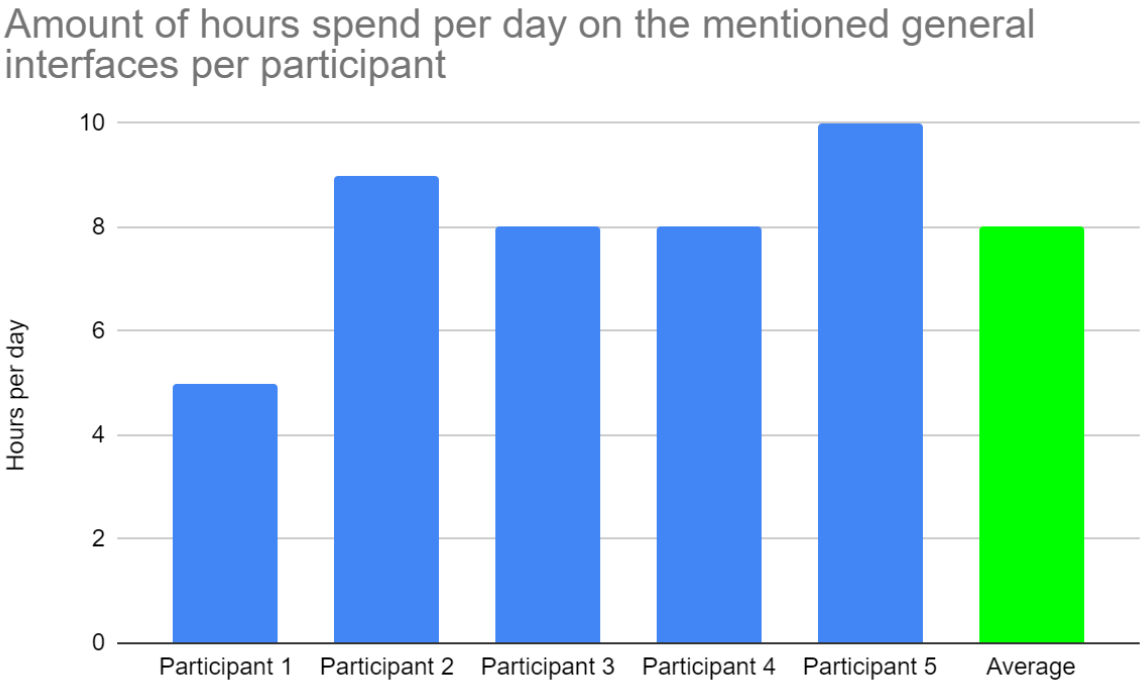
What apps and websites do you use on a regular basis?



Graph 7.1 Pie chart of the different general interfaces used by the participants.

Graph 7.1 shows that the all participants have experience with different general interfaces and even share general interface experience between each other. The common general interfaces are in this case Youtube, Whatsapp, and Google Chrome.

How many hours per day do you use these apps and websites?



Graph 7.2 Column Chart of the amount of hours per day every participant spends on the earlier mentioned general interfaces, including an average time of all participants.

In graph 7.2 one can see that all users spend a fair amount of time per day on the earlier mentioned interfaces. With graph 6.1 and 6.2 a statement can be made that all participants should be experienced interface users and have a prior knowledge of general interfaces. Then it could also be said that the participants have prior general interface knowledge.

Have you ever used a drone interface before?

None of the participants had ever used a drone interface before. This means that all participants have no prior drone interface knowledge and therefore fit into the target group of this research.

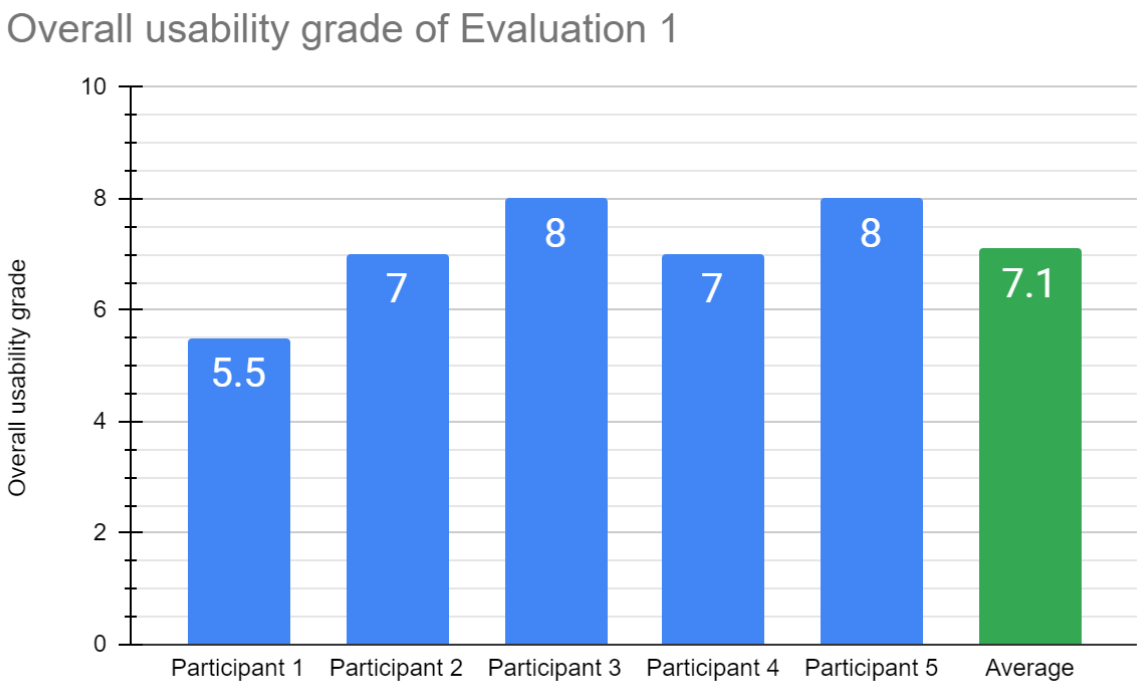
7.2.2 Usability Test and Post-test interview Results

The results of the usability test and post-test interview are taken together. This is done with the reason that during the usability test and in the post-interview, the thoughts and opinions of the participant are gathered.

The participants stated that the legend of the map could be made clearer, this with the reason that in realisation 1 the legend had grey text, together with that it should be clearly explained what the icons on the map are. Next to that, it must be added that all points of interest and icons should be able to show info when hovered, this must also be done to create better feedback for the participants. Then participants also added that the flightpath visualisation was not adequate and must be made more visible for the users. At the mission animation, the participants were unsure what the sliding bar represented, and for that reason it must be made clearer using a drone icon and a percentage rating. In addition, the Live video feed in the top right corner should be accompanied with the text “Live Video Feed” to let the users know what it is. The mission animation itself was not working in realisation 1, and this caused some confusion, therefore it the mission animation should be made into a working animation to give feedback to the user. The participants also suggested to give less options in the mission planning, since most users have no drone knowledge. In the help function the participants stated that most explained functions were hard to find, therefore the help function needs a clearer way of pointing to functions. Next to that, some participants would like to be able to choose their own camera angle in the interface. Lastly, the participants gave some small additions like, adding extra buttons, having the sidebar toggle, and adding letters to the compass to make it more clear.

All these comments are taken into account and result in a table with a table of functional and non-functional requirements for the next iteration of the interface. These can then be scaled on the MoSCoW scale, giving priority to the requirements. The functional requirements can be seen in table 6.1. In table 6.2 all non-functional requirements can be found. This set of requirements will guide the changes that need to be made to the second iteration of the interface.

In the post-test interview the participants were also asked to give a grade of the overall usability of the interface. As can be seen in graph 7.3 the average grade of realisation 1, based on the participants opinions, was a 7.1.



Graph 7.3 Overall usability grade per participant of evaluation 1 with an average grade calculated

Overall, the users were able to navigate themselves through the interface. Also all were able to finish the given task. This showed that the interface itself was already usable and that some changes to the interface can only improve its functionalities.

7.2.3 User Requirements for Realisation 2

Based on the results of evaluation 1, a new requirements list for the next iteration of the interface has been set up. This will be used during the next realisation to make more usable interface. The set of requirements can be seen in tables 7.1 and 7.2. These requirements are a set of new requirements for the development which are placed on top of the old requirements.

Table 7.3 List of functional Requirements for the next iteration of the interface based on the Evaluation 1 results

MoSCoW	Functional
Must	Legend needs to be clearer
Must	Progress bar should show percentage of flight progress
Must	Progress bar needs to get rid of the circle and incorporate a drone sign as pointer
Must	Live video feed in mission animation should have the text: "Live Video Feed"
Must	Each point of interest should be hoverable and clickable
Must	Each point of interest should have clear feedback and info when hovered
Must	Flight path needs to be visualized in a clearer way

Must	The help function should have a back button
Must	Show clearly what the icons on the map are
Should	Start mission button should be more clear
Should	Mission should be a fully working animation
Should	Add a cross button at the concluded mission pop-up
Should	Drone Docking stations need info when they are hovered
Could	Compass is too basic and needs a directional letters NESW
Could	make the cross in mission planning more clear
Could	Side bar can be smaller and have a toggle
Won't	Be able to sort the data in the data menu
Won't	Add more different views to the map
Won't	Be able to zoom into the map
Won't	Make the mission parameters functional
Won't	Make the expert mode funcional
Won't	Make the data in the data menu viewable and downloadable

Table 7.4 List of non-functional Requirements for the next iteration of the interface based on the Evaluation 1 results

MoSCoW	Non-functional
Must	The mission parameter options should be simplified for better usability and understandability
Must	The Help function should be more intuitive, and the users attention needs to be pulled to the explained interface functions
Must	User needs a way of choosing the angle and place at which the picture of the building will be taken
Should	Make a more clear path to the mission planning interface
Could	The whole interface should be working through the map
Won't	User should be able to make their own inspectable area
Won't	Show how the user would pay for his drone mission
Won't	Data menu needs more explanation of functions

7.3 Evaluation 2

For the evaluation of the second iteration of the interface the same pre- and post-test interviews were used as in the first evaluation. However the Usability test changed slightly. During evaluation the focus is on the intuitiveness of the interface. Therefore it was chosen in in this evaluation to not let the users walk through the help function before performing tasks. This should show the participants first interactions with the interface and if the participants are able to intuitively know how the interface works. The tasks of the usability test stayed the same, but were in this case swapped. For this evaluation, also an Expert Review was conducted. This expert review would help with finding other usability issues based on the knowledge and intuition of an expert.

Each part of the evaluation will be discussed together with the results and the evaluation will be finalized with a new set of requirements for the final prototype.

After the evaluation was concluded the results were analysed. These results showed where improvements within the interface could be, but also what features were good about the interface. The summarized results can be found in this section. The full data gathered from evaluation 2 can be found in appendix 11.

7.3.1 Pre-test interview Results

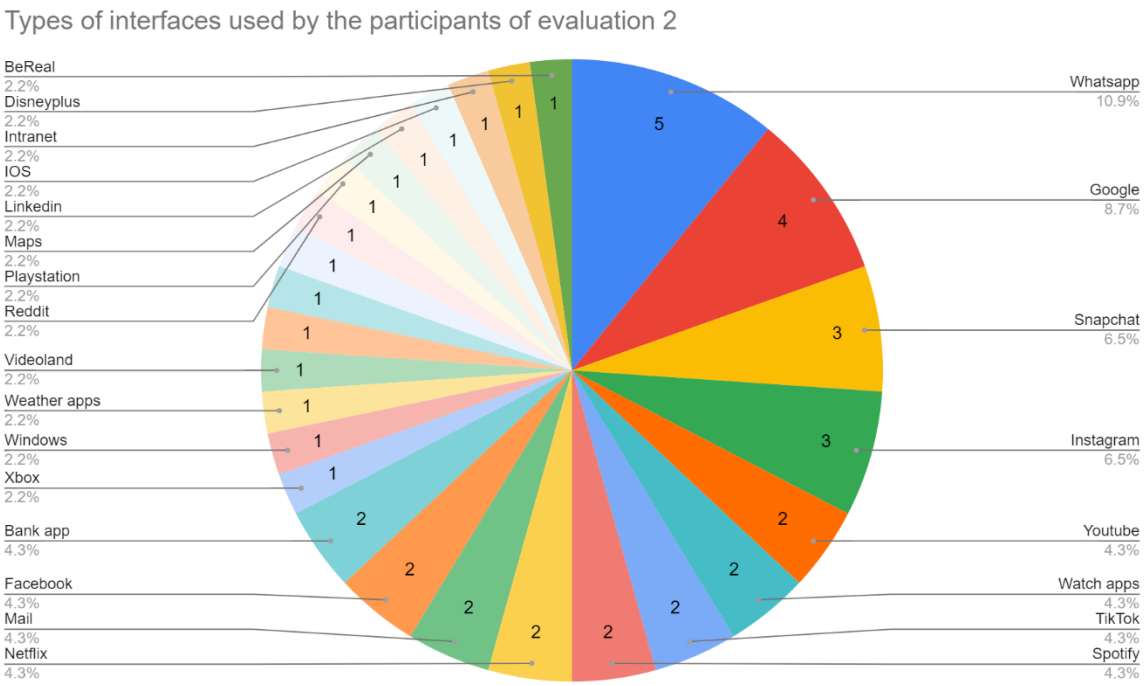
The pre-test interview has gathered data about the participants prior knowledge and experience with general and drone interfaces. A summary of the most important results of the pre-test interview, including an analysation of the data will be provided.

What apps and websites do you use on a regular basis?

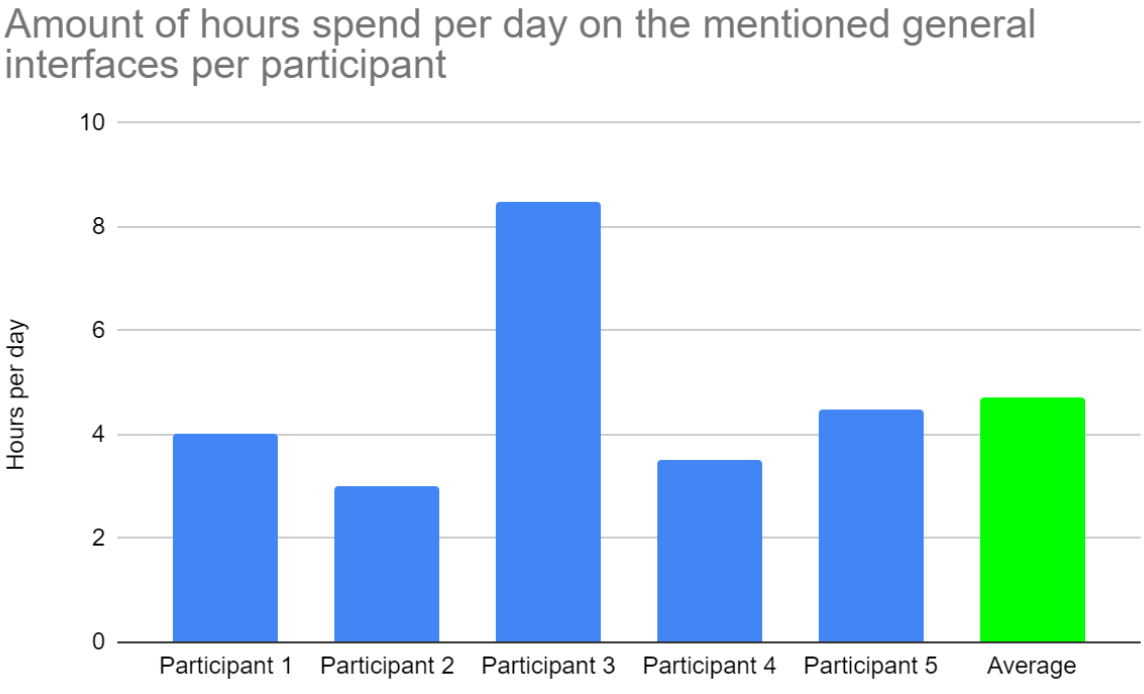
Graph 6.4 shows that the all participants have experience with different general interfaces and even share general interface experience between each other. The common general interfaces are in this case Whatsapp, Google, Snapchat, and Instagram.

How many hours per day do you use these apps and websites?

In graph 6.5 it can be seen that all users spend a fair amount of time per day on the earlier mentioned interfaces. Although that it is less than the participants in evaluation 1, it is still a large part of their day spend with interfaces. With graph 7.4 and 7.5 a statement can be made that all participants should be experienced interface users and have a prior knowledge of general interfaces. Then it could also be said that the participants have prior general interface knowledge.



Graph 7.4 Pie chart of the different general interfaces used by the participants of evaluation 2



Graph 7.5 Column Chart of the amount of hours per day every participant spends on the earlier mentioned general interfaces, including an average time of all participants.

Have you ever used a drone interface before?

Two of the participants stated that they had used a drone interface before. Upon further questioning these participants explained that the interface they had used was the DJI controller for drones. This is a physical drone interface. They also stated that they had not intensively used a digital drone interface before for controlling a drone. Therefore it can be stated that all participants of evaluation 2 have zero to no prior drone interface knowledge and thus belong to the target group of the research.

7.3.2 Usability Test and Post-test interview Results

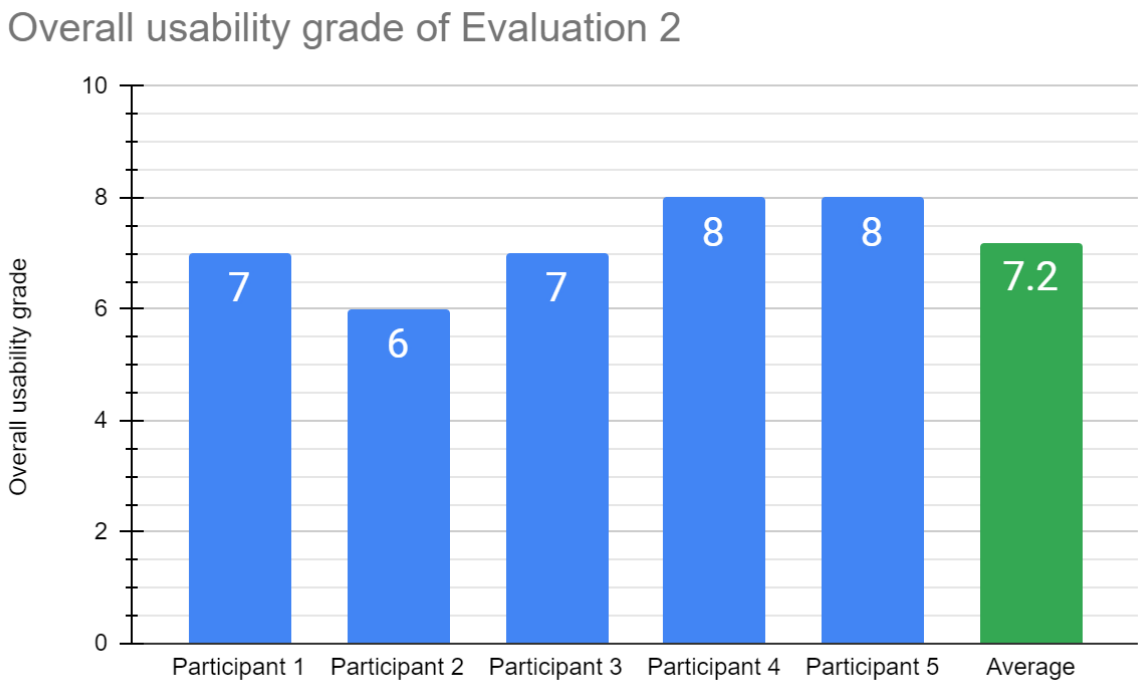
The results of the usability test and the post-test interview have again been taken together with the reason that both hold qualitative data about the interface. What could be seen during the testing was that for some participants it was still unclear what the green areas were, also because this time, they did not walk through the help function beforehand. Also the term Aerial inspection in the home menu was unclear to some of the participants. Next to that, most participants were missing the drone in the interface. It was unclear what a mission was and why the interface was based on this. The drone part of the interface should come more forward. Another suggestion came that it could be an improvement to have a list of buildings to choose from, next to being able to click on the map. However, still most of them managed to quickly understand the working of the interface and continue.

The new added feature where the user can choose their own camera angle was very much appreciated by the participants. For some of the participants it was a bit harder to understand where they had to click in order to choose their angle. Also the choice of only one angle could be increased according to most participants. In the configuration menu some participants also wanted to go back to a previously made choice, but this was not possible. There was also a comment on the flow of the mission configuration, the comment was that there was to little feedback about what was happening when the user clicked on the next menu. Therefore an addition feedback bar can be implemented to aid with this.

When starting the drone mission, one participant was confused about the mission, because the participant did not anticipate on the movements on the screen in the animated mission. Therefor the participant quickly clicked on abort mission. To help with this it was suggested to create a pop-up before starting a mission, this could help with creating a good expectation of the upcoming flight and another point to check you mission details.

The help function was very much appreciated by all users, there were little comments about it. These were that the menu bar should be explained, and that some wording was confusing. The big comment was that it would be good to create this as the start of the interface, together with mission options to guide the user into the interface. Here the user should be able to choose if they want the help function, or already start creating a mission. This first menu should serve as a clear start of the interface.

During the post-test interview all participants were asked to give a grade on the overall usability of the system. This can be seen in graph 7.6, where the average grade for the second iteration of the interface was a 7.2, overall a sufficient grade.



Graph 7.6 Overall usability grade of participants in Evaluation 2

7.3.3 Expert Review Results

The expert review showed some good extra insights into the interface, and secondly the expert was satisfied with the usability of the interface.

Some points where brought up to improve the overall usability of the interface. First of all it would be beneficial to have an undo or back button in the configuration menu. This helps when users need to change earlier decided settings. Secondly, for non-drone experts there needs to be a better explanation of the green areas with icons or text and the wording, inspectable building, is unclear. Also the wording of mission is unclear, this needs to change to a more drone focussed word. Next to that, it could help if the users sees the amount of money they need to pay earlier, such that during the configuration setup, they know what different settings do to the price.

One other comment which came up during the discussion is the functionality of the home screen. Upon further discussion, it was found that the home screen did not add any valuable extra interaction. Therefore the home screen can be changed to the mission screen and make the home menu and mission menu, the same menu. Also the amount of paths to make a mission are unclear, more guidance is needed along the way to make it more clear for the user in what ways a mission can be structured.

Overall the expert stated that the usability of the interface was good. The overall grade for usability given by the expert was an 8.5. This shows that, in this stage, the interface is already usable and intuitive, and minor improvements can only make it better.

7.3.4 User Requirement for Final Prototype

Bases on the results of evaluation 2, a new set of requirements has been set up to help with making the final prototype of the interface. These requirements can be seen in table 6.3 and 6.4 and are split up in functional and non-functional requirements. These requirements are a set of new requirements for the development which are placed on top of the old requirements.

Table 7.5 Functional requirements based on evaluation 2

MoSCoW	Functional
Must	Add click to green areas in home menu
Must	Show legend in help function
Must	Create a clear start of the interface, with help function included
Must	Drone should come more forwards in the interface
Must	Drone Docking Statinos need clearer icons
Must	Wording of "mission" needs to change to "order drone"
Must	Add undo button to menus
Must	Add a pop-up before starting the mission
Must	Home menu can be incorporated into the mission menu
Should	Have extra icons for the buildings
Should	Explain the menu bar in the help function
Could	Add a search bar to the interface
Could	List of buldings to choose from
Could	Generate flight path button can be clearer
Could	Data shows the mission which has been flown
Could	Show how you can download the data
Won't	Example videos and photos
Won't	Specific help per feature when needed
Won't	Weather conditions can be shown
Won't	Add the option of a 3D map

Table 7 6 Non-functional requirements bases on evaluation 2

MoSCoW	Non-functional
Must	Better feedback in configuration menu when choosing camera angle
Should	"Aerial inspection" term needs clearer wording
Should	Change wording of "inspectable buildings"

7.3 Discussion of Evaluation Results

On the basis of the depicted results of the evaluation it can be stated that the usability of the final interface is sufficient for all users. However, when comparing the usability grades of the first and second evaluation, no significant improvement can be seen.

This minor improvement could be explained when looking at the background research. Here Nielsen [13] stated that a minimum of 2 iterations are needed to come to usable interface. Using this theory, it can be expected that both evaluation 1 and evaluation 2 are going to come across problems within the interface. Therefore, both evaluations could come across a comparable level of problems and thus result in a similar usability grade, explaining the minor difference.

Another factor which could have explained the minor improvement in usability are the participants. Since all participants had no prior drone interface knowledge, all participants experienced a drone interface for the first time. This can result in all participants coming across problems in the interface due to lack of knowledge. Between the two participants groups of evaluation 1 and evaluation 2, this knowledge gap could have been comparable and resulted in the minor difference. This can be further supported by the participants opinions, which were subject to change throughout the usability test. Were in evaluation 1, most participants had some difficulties in ordering a drone for the first time, when asked afterwards (now having pre-knowledge) most said that it was pretty intuitive. In evaluation 2, this same comment was made after the users used the help function, and it was stated that if the help function was presented earlier, the participants would know how the interface worked.

Aside the minor improvement between evaluation 1 and evaluation 2, it can be said that the usability did increase based on the user requirements. It can be stated that there were no repetitions of user requirements, and therefore the user requirements of evaluation 1 were implemented well. Secondly, the list of requirements in evaluation 2, in both functional and non-functional requirements, contains less requirements compared to evaluation 1, which could be seen as an improvement in usability.

The usability results could have also been impacted by the total requirements integrated. This has three reasons, being irrelevance, restrictions of Figma, and time constraints. Between realisation 1, 2 and 3 some requirements were not implemented due to irrelevance, these were mostly constrained to the data menu, payment and some settings. These were deemed irrelevant because they were not adding to the experience of ordering a drone, but would rather come after, or only when expert user would use the system. Other requirements were not implemented due to restrictions in Figma. Some of the requirements in this case are map functionalities, getting settings to work, and extending existing features like camera angle and building choice. Lastly, requirement were not added due to time constraints. This was due to the fast cycle between iterations and time constrain of the whole graduation project.

Being able to have implemented all requirements could have made the interface more functional and could make the participants less confused and this could have impacted the usability.

Looking back at the research and the process thereof, it can be found that there are some limitations to the research that could have had an impact on the results. However, based on the evaluation results it can also be seen that the usability of the interface was sufficient and that a successful GUI has been developed.

8 Conclusion & Future Work

In this chapter a conclusion to the research and research questions will be given. Next to that suggestions for further research will be described.

8.1 Conclusion

At the beginning of the graduation project a set of research questions was established and these are repeated below, starting with the main research question:

- **In the context of inspection use cases, how to develop a GUI for a universal drone docking system**

In order to answer this research question, a set of sub-questions was also been formulated.

- *What are the user requirements for the GUI?*
- *What interaction elements fulfil the user requirements*

To find an answer to the research questions extensive literature and state of the art research was performed on GUI design and drone docking systems. A large part of the research was also accomplished in the ideation and specification phase. These sections consisted of brainstorms with university students, expert interviews, construction of personas and according use scenarios and prototyping. To come to a final interface design, usability tests were conducted and using the results a final interface could be constructed using a digital interface design tool.

In conclusion, from the research and development of the prototype answers can be constructed to the established research questions. The findings of the research and conclusions are outlined below.

Answering the first sub-question: *What are the user requirement for the GUI?.* It can be seen in the ideation and specification that a first basis of requirements was set up. The final user requirements were presented at evaluation 2 of the Evaluation. Concluding, the user requirements have a basis, but are subject to change based on user feedback and can consist of a wide variety of user requirements.

Answering the second sub-question: *What interaction elements fulfil the user requirements?* It can be stated, based on the interface, that the interaction elements consist of clickable buttons, map interactions, choosing of camera angle, mission animation, and choosing mission paraments.

It can be stated that a successful GUI has been developed for the Drone Docking System. Using that statement, the main research question: *In the context of inspection use cases, how to develop a GUI for a universal drone docking system?*, is answered by of a basis of 4 rules, being,

1. Place the user in control
2. Reduce the user's memory load
3. Make the interface consistent
4. Provide effective help.

And the design process, utilizing the 4 rules and the Usability Engineering approach.

- Specify context of use
- Specify user requirements
- Delevelop GUI
- Evaluate GUI

8.2 Recommendation for future work

While the development of a GUI for a Drone Docking System could be considered a success, some of the additional work was deemed to be outside the scope of this graduation project. Therefore, this section will discuss some of the future work needed to improve upon the GUI and make it into a working program.

The first recommendation for future work of the GUI, is to continue with usability testing the GUI. As can be seen from the conclusion of the first sub-question in Chapter 8.1 conclusion, the user requirements are subject to change and can only improve when more usability tests are conducted.

A crucial recommendation for future work of the GUI, is to develop the GUI further into a working web-based application. This would make the GUI capable of working together with different systems and can be brought to the user over the internet. This would also include researching the data structure behind the GUI and incorporating this into the web-based application.

Another recommendation is to research connecting the GUI to a Drone Docking System, making the GUI operational. Developing this new technology would also include the research about the placement of the Drone Docking Systems to cover the most ground.

The last recommendation would be to research the business case behind the GUI and Drone Docking System. Here the focus would be to find a profitable business using the technology, including how much users would pay for the service, what is needed for maintenance of the system and what revenue streams would be.

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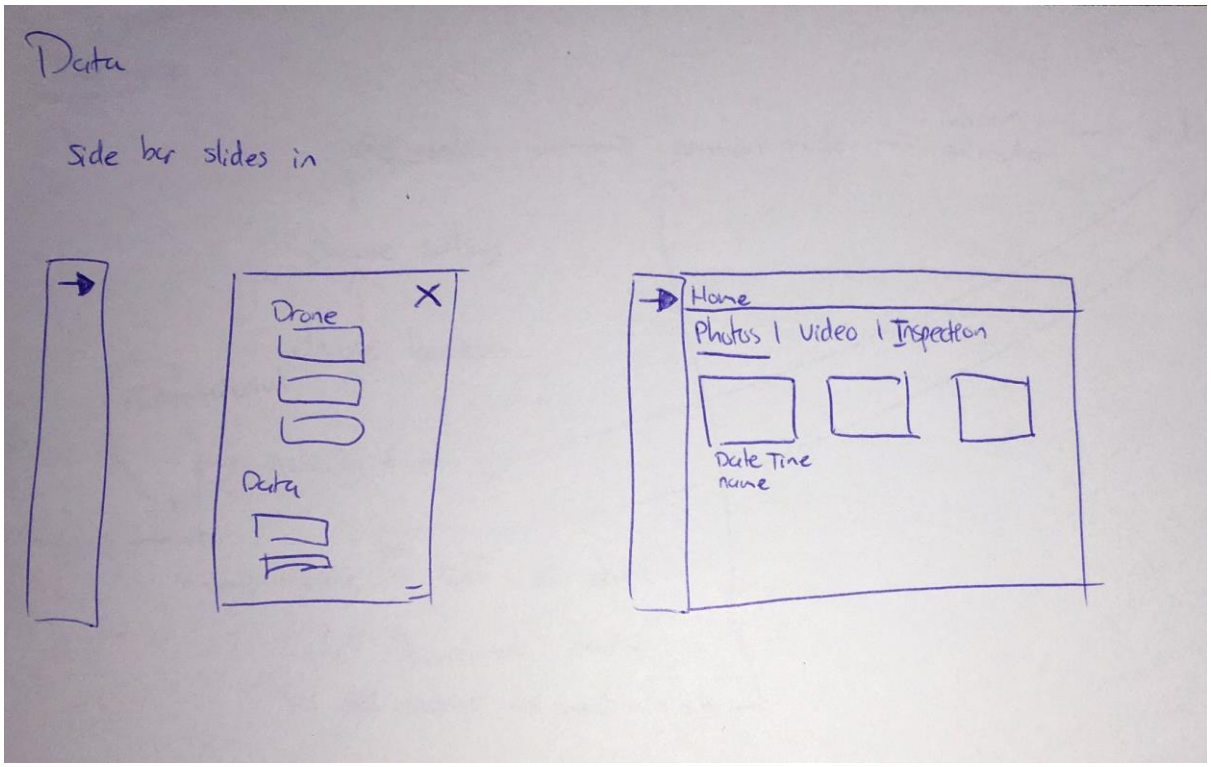
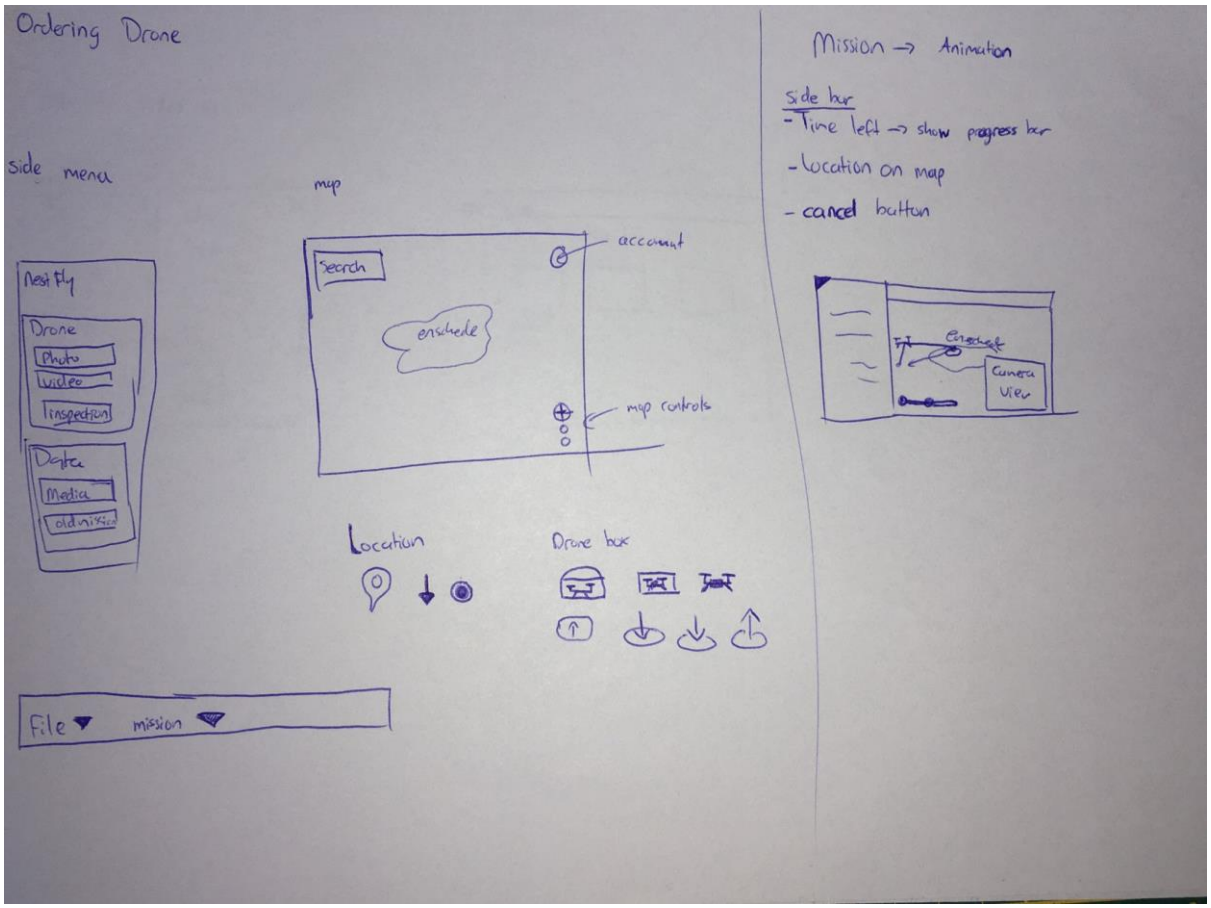
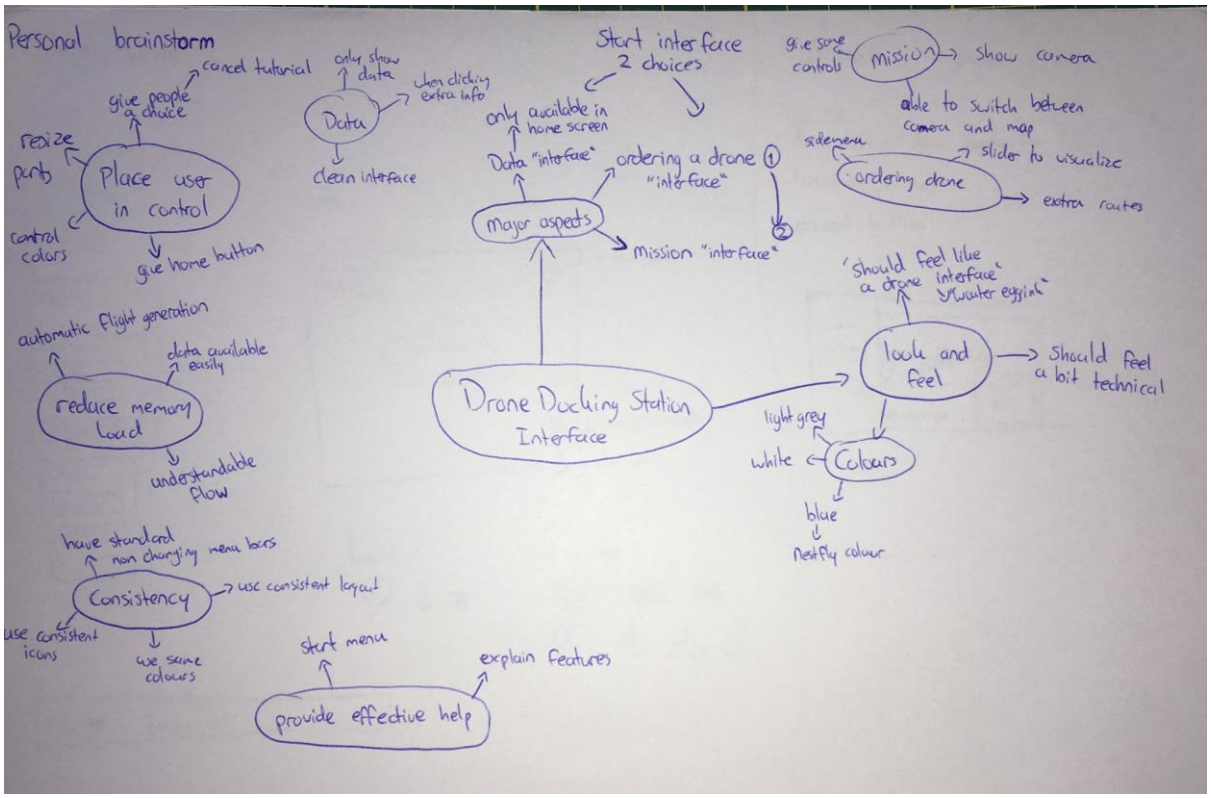
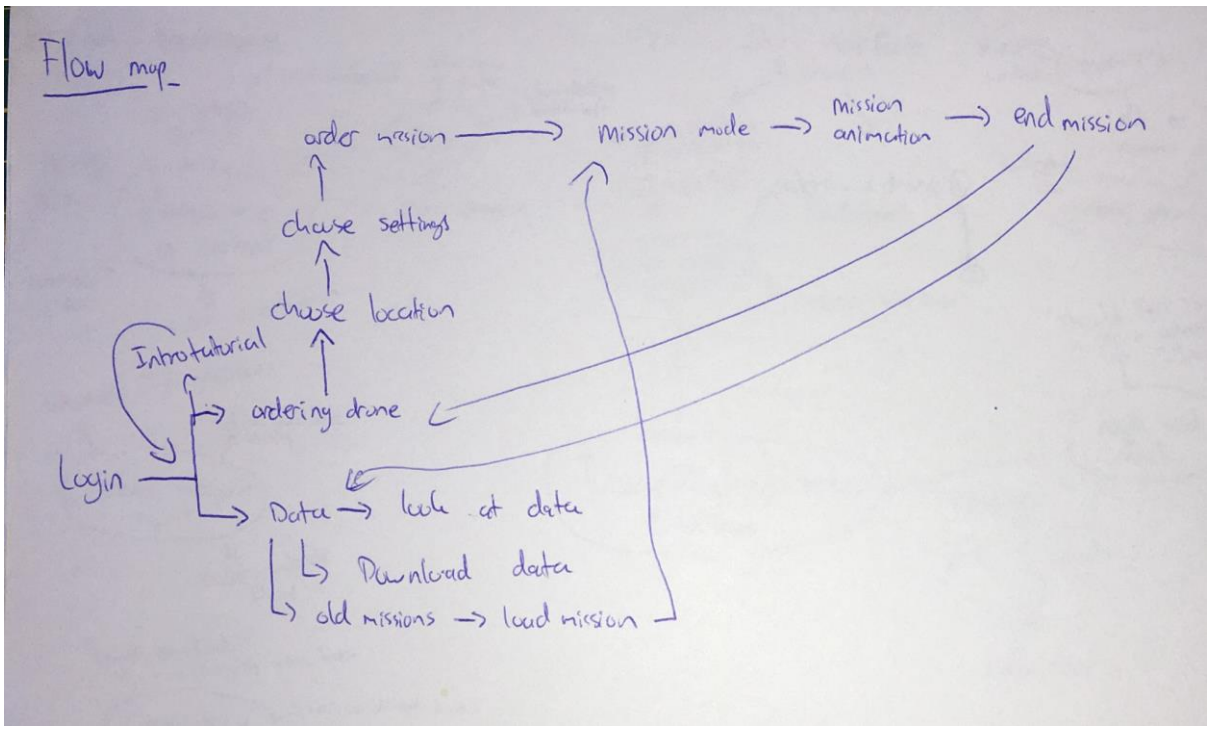
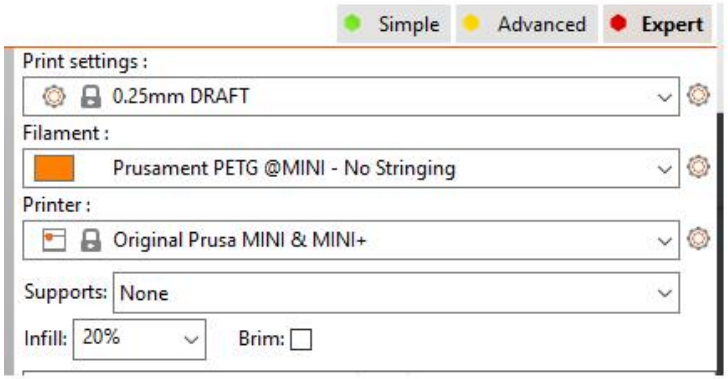
Appendix 1 – Individual brainstorm results



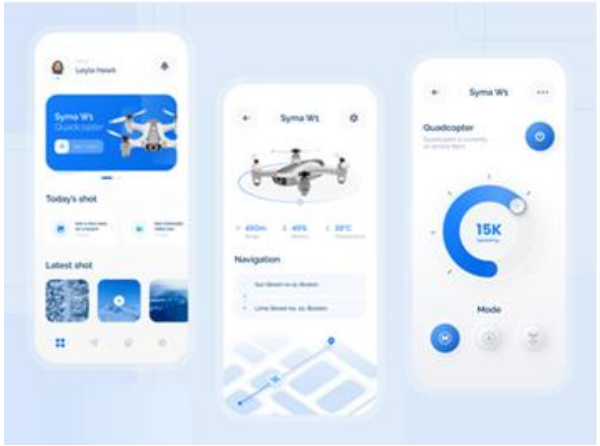


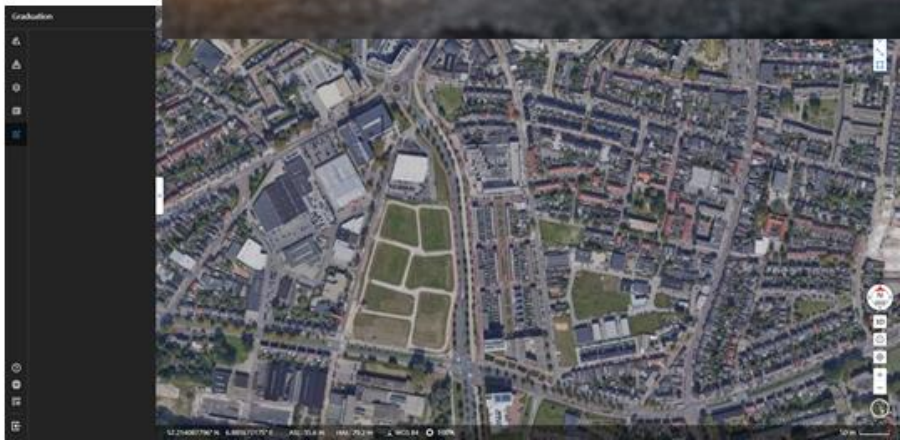

Personal brainstorm
cancel tutorial
only show data
when clicking extra info
give people a choice
resize parts
Place user in control
Data
clean interface
control colors
give home button
Start interface 2 choices
only available in home screen
Data "interface"
ordering a drone "interface"
Major aspects
mission "interface"
give some controls
Mission
show camera
able to switch between camera and map
sidemenu
slider to visualize
ordering drone
extra routes
automatic flight generation
data available easily
reduce memory load
understandable flow
'should feel like a drone interface' 'easter egging'
look and feel
should feel a bit technical
Drone Docking Station Interface
light grey
white
Colours
blue
Netflix colour
have standard non changing menu bars
Consistency
use consistent layout
use consistent icons
use same colours
start menu
explain features
provide effective help


Flow map
order mission
mission mode
mission animation
end mission
choose settings
choose location
Intro tutorial
ordering drone
Login
Data
look at data
Download data
old missions
load mission

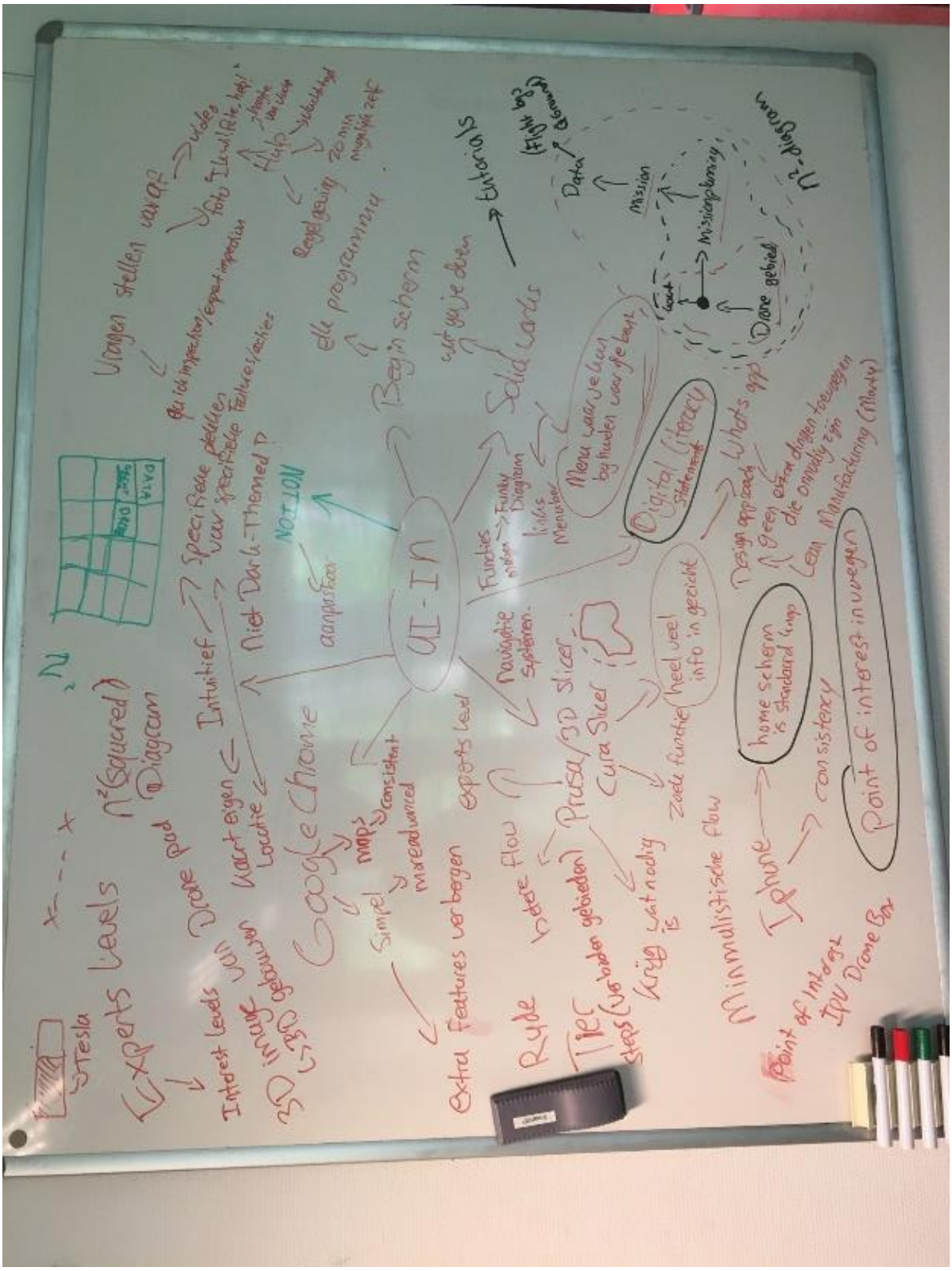


Nest-Fly Technologies





Appendix 2 – Group brainstorm results



Appendix 3 – Interview Gabriel Damian

Using these features Gabriel was asked to conceptualize an interface for a drone docking system.

Basic map with flight instruments
Most interfaces have to many features
Missed features

- Customizability of layout
- Customizability of data shown
- It should be a coworker
- AI asks you questions and adapt
- Would use it on computer
- Give good symbols, words can not describe features
- Flightplanning, user should have zero control, drone should be coworker
- Use points of interest
- Being able to switch between video and map view
- Audio should be included in the interface
- Basic functions on the left
- Welcome page with options
- Progress bar
- Show where data is saved

DJI FlightHub2

- **Liked**
- Estimated flight data is good
- Clear equipment
- 3D view with camera is nice
- **Disliked**
- Icons can be clearer
- Not clear where the landing will be
- To many options
- Features are unclear and buttons are weird
- Too much info and parameters
- **Missed**
- Size of gathered data would be nice

Summary:

- Drones flying over itself are fine as long as it is not to frequent and not to much noise it is fine
- Would use it in company environment, not individually
- Has used multiple drone interfaces like DJI, Missionplanner, QGroundControl, Simple Remotes, FPV, Terminal Command, DroneKit
- Good to have sound with your video
- Basic map with flight instruments is good to have

- Most interfaces have too much features
    - Gives lots of freedom but less customizalbe
- Missed features:
    - Customizability
    - Visual look can improve
    - No info overload
    - It should become your coworking, not somebody you fully instruct
    - AI, Ask you question to adapt the interface based on expertise
- Would use it mostly on computer
- Give good animation for the different features, words do not explain it fully
- Give good waypoint visualisation
- Flight planning:
    - User should have zero control
    - Drone should be coworker
- For control of the drone
    - Use video and click on points of interest
    - Tablet touching or mouse clicking
- Design:
    - Depends on job
    - 3D map + video/audio
    - Be able to switch between map and video feed
    - Basic functions on the left
    - Welcome page with options
    - Point of interest mapping
    - Progress bar
    - Show where the data is saved

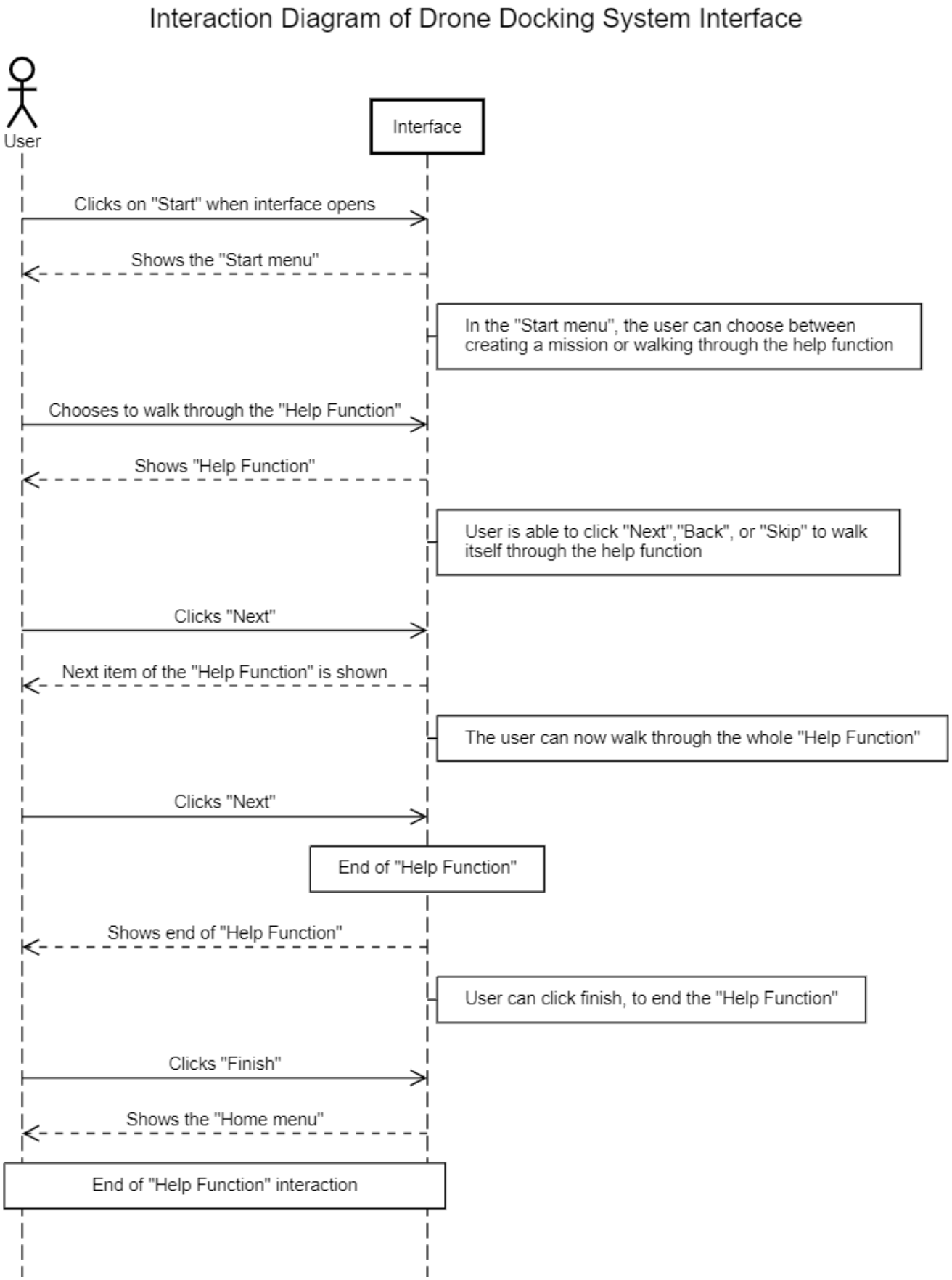
- Impressions of DJI Dock Flighthub2
    - So much info and parameters
    - Estimated flight data is good
    - Size of the data gathered would be nice
    - Liked:
        - Equipment clear
        - 3D view with camera visualisation is nice
    - Disliked
        - Icons can be clearer
        - Not clear where landing is
        - To many options
        - Features that are there are unclear, buttons are weird

Appendix 4 – Interview Wouter Eggink

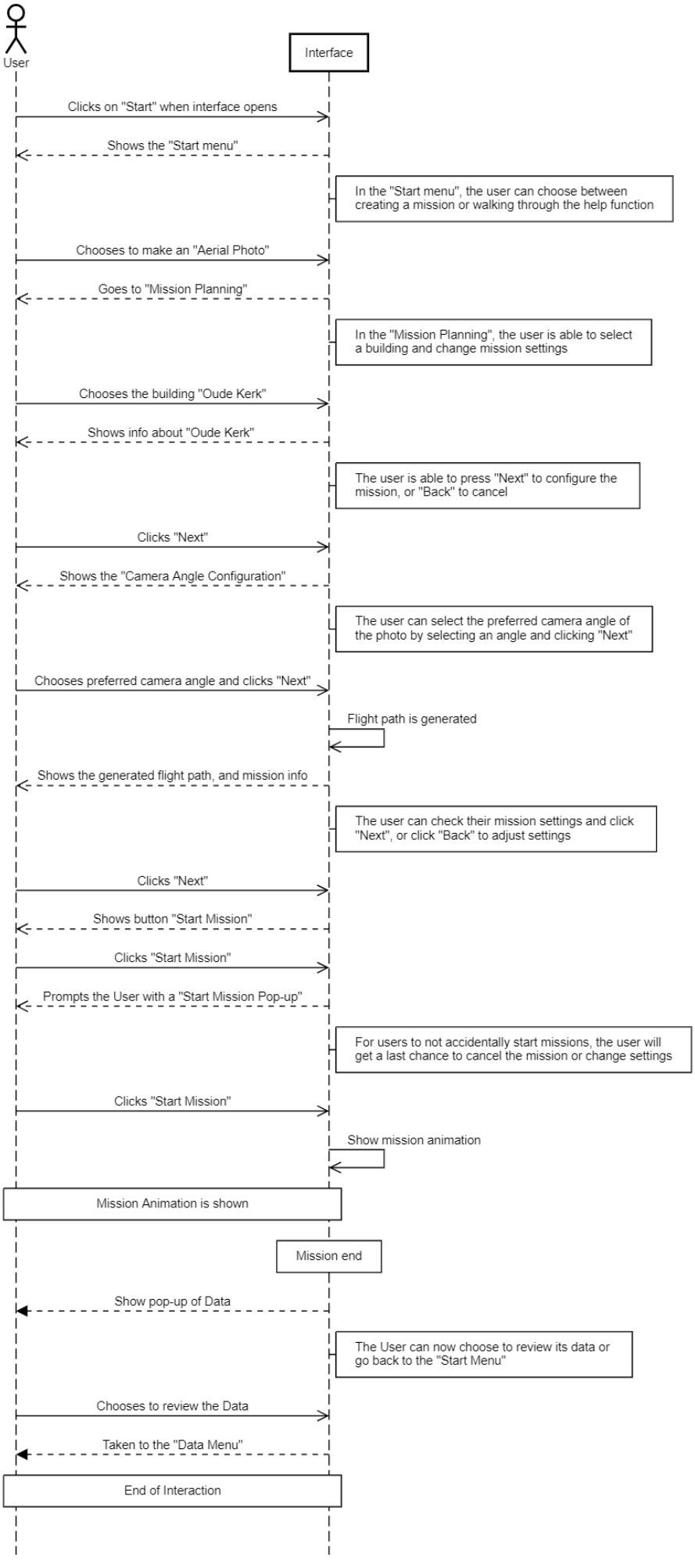
Summary:

- Thoughts about drone docking interface
    - Good timing, however lots of unsolved problems
    - Would not be nice, since it creates lots of sound
    - Not knowing who is flying can be scary
- Drone interfaces
    - Has never used them before
- Interfaces themselves
    - Should be recognizalbe
    - Buttons should have natural functionality
- Interaction
    - Clear image, clear feedback of actions
    - Drone should be shown to take off, as feedback for instance
- Flight planning
    - Has no clue how that works
    - Should have good visualisations
        - Where can and cannot I fly?
    - In the beginning I want to fiddle around with it, but at a later point I just want to let it perform my missions
    - Control over the drone in the beginning to get to learn it, then I need to get trust in the system and let it fly on its own.
    - The fascination with the technology needs extra help to get them to use it.
- Design:
    - Like an ordering website, to order pizzas, but now it is drones
    - Cockpit view of mission and what is happening
    - Have influence on where the drone will be flying and where not, you can suggest different routes just like google maps does
- Impression of DJI Dock Flighthub2
    - Starts to get an idea of a drone interface
    - Looks like you need lots of drone expertise to use the interface
    - I need help, introduction on what we are going to do, photo or video
    - Looks more like programming a drone to me
    - Liked:
        - Visualisation of the flightpath
    - Disliked:
        - Not for me
        - Unclear what is what and for beginners even more so
        - No hierarchies in the interface
        - Lots of new features
        - Technical dashboard

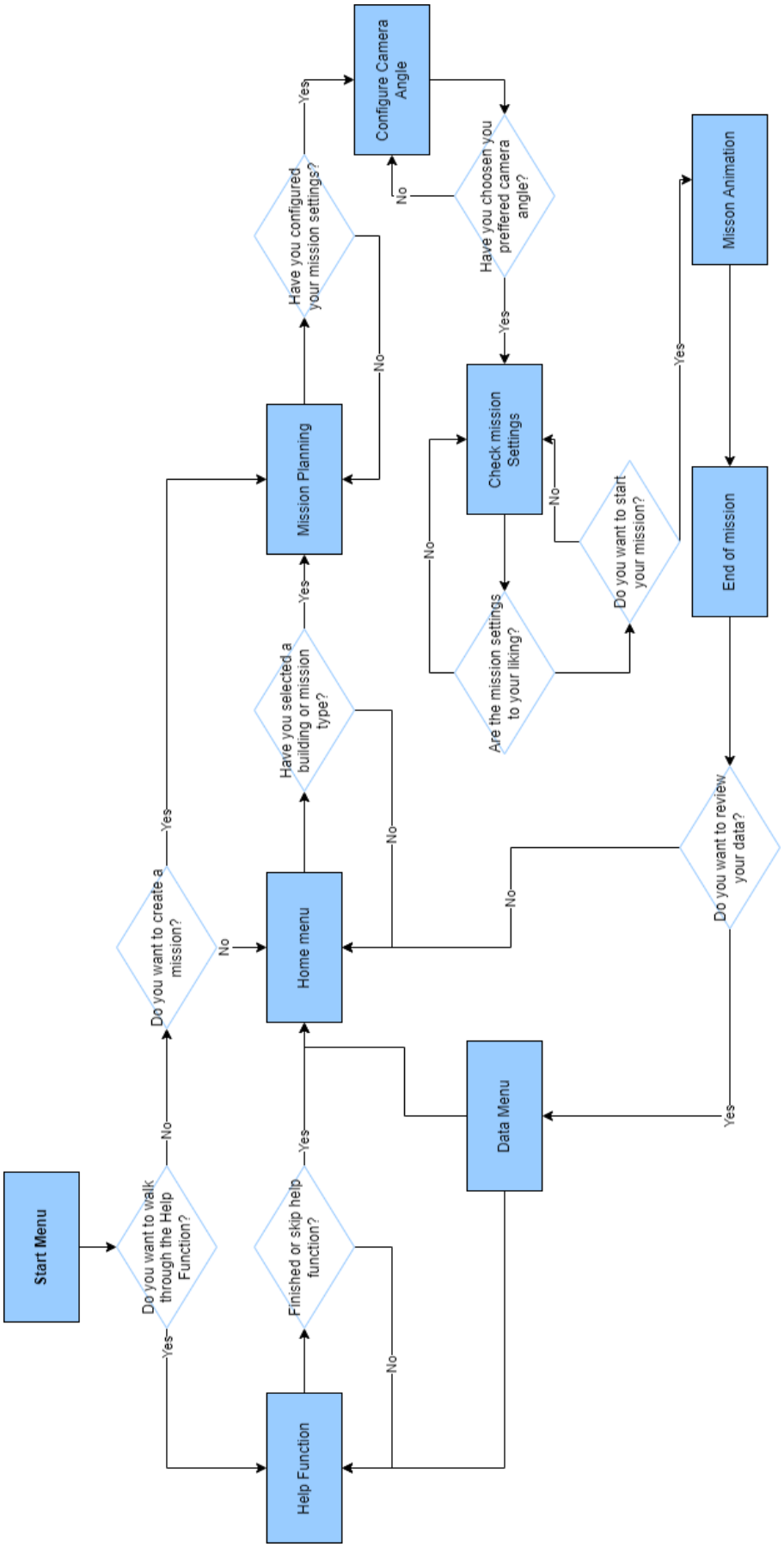
Appendix 5 – Full scale Interaction Diagrams



Interaction Diagram of Drone Docking System Interface



Appendix 6 – Full scale Flow Diagram

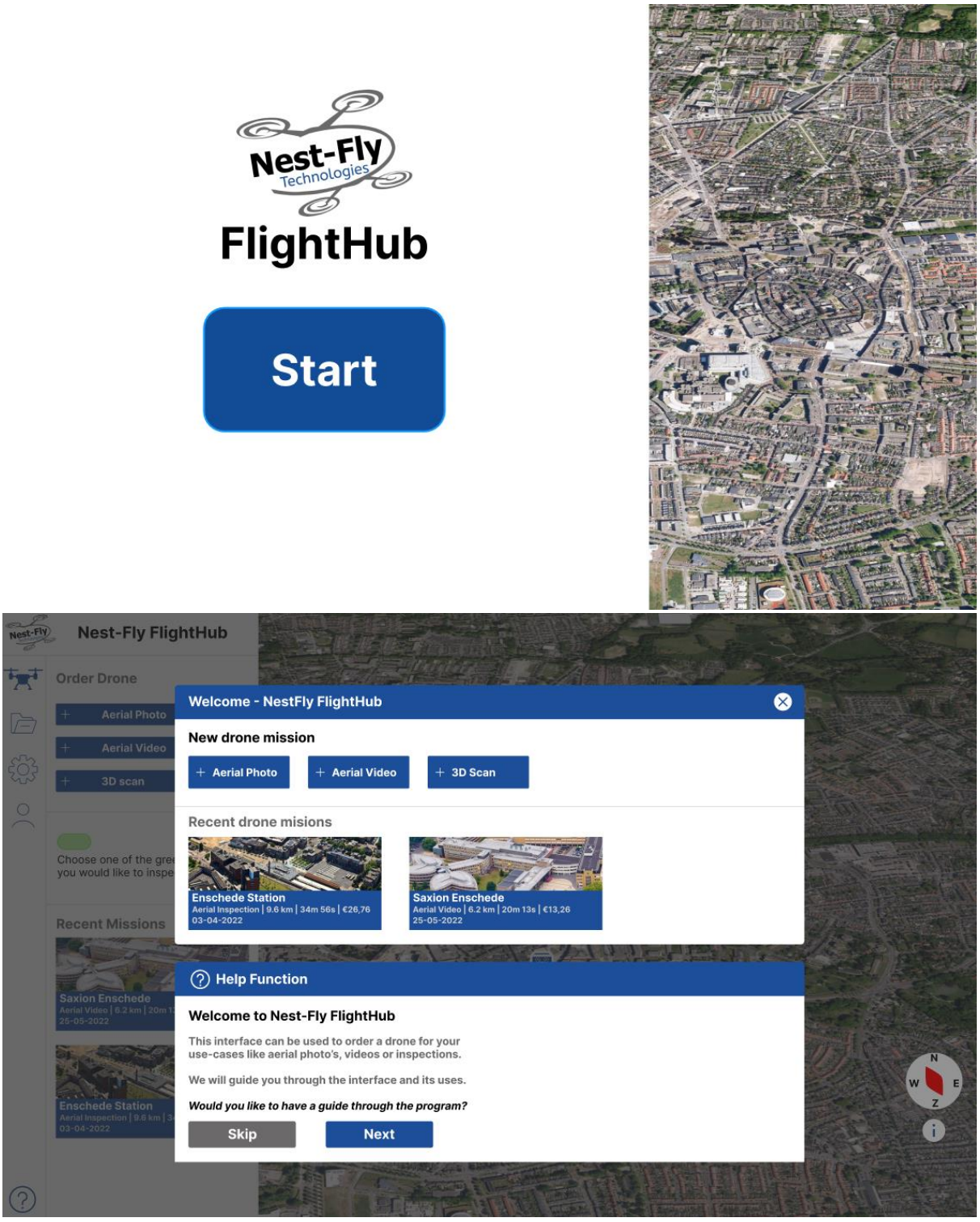


Appendix 7 – Final Realisation of the Interface

The full interactive final iteration of the interface can be found here: https://www.figma.com/proto/pW7TR67D4AxfdsrPEv2jhD/Docking-Interface?page-id=0%3A1&node-id=61%3A280&viewport=-16633%2C2373%2C0.92&scaling=min-zoom&starting-point-node-id=61%3A280&show-proto-sidebar=1

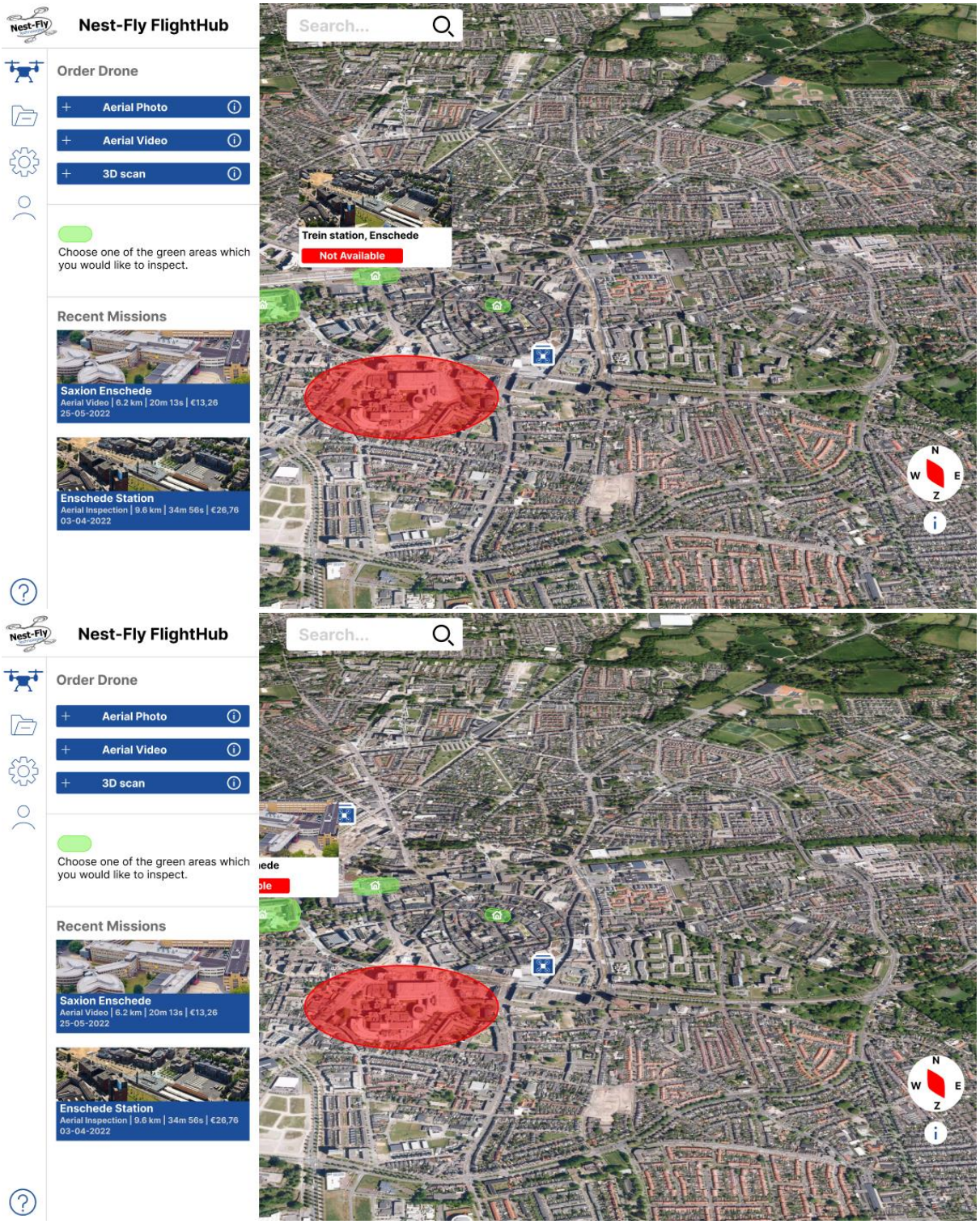
The interface is also described with pictures further in this appendix.

Main path:




Nest-Fly FlightHub
Order Drone
Aerial Photo
Aerial Video
3D scan
Choose one of the green areas which you would like to inspect.
Recent Missions
Saxion Enschede
Aerial Video | 6.2 km | 20m 13s | €13,26
25-05-2022
Enschede Station
Aerial Inspection | 9.6 km | 34m 56s | €26,76
03-04-2022
Search...
N
W
E
Z


Nest-Fly FlightHub
Order Drone
Aerial Photo
Aerial Video
3D scan
Choose one of the green areas which you would like to inspect.
Recent Missions
Saxion Enschede
Aerial Video | 6.2 km | 20m 13s | €13,26
25-05-2022
Enschede Station
Aerial Inspection | 9.6 km | 34m 56s | €26,76
03-04-2022
Search...
Oude markt, Enschede
Create Mission
N
W
E
Z


Nest-Fly FlightHub
Order Drone
Aerial Photo
Aerial Video
3D scan
Choose one of the green areas which you would like to inspect.
Recent Missions
Saxion Enschede
Aerial Video | 6.2 km | 20m 13s | €13,26
25-05-2022
Enschede Station
Aerial Inspection | 9.6 km | 34m 56s | €26,76
03-04-2022
Search...
Trein station, Enschede
Not Available
N
W
E
Z
Nest-Fly FlightHub
Order Drone
Aerial Photo
Aerial Video
3D scan
Choose one of the green areas which you would like to inspect.
Recent Missions
Saxion Enschede
Aerial Video | 6.2 km | 20m 13s | €13,26
25-05-2022
Enschede Station
Aerial Inspection | 9.6 km | 34m 56s | €26,76
03-04-2022
Search...
N
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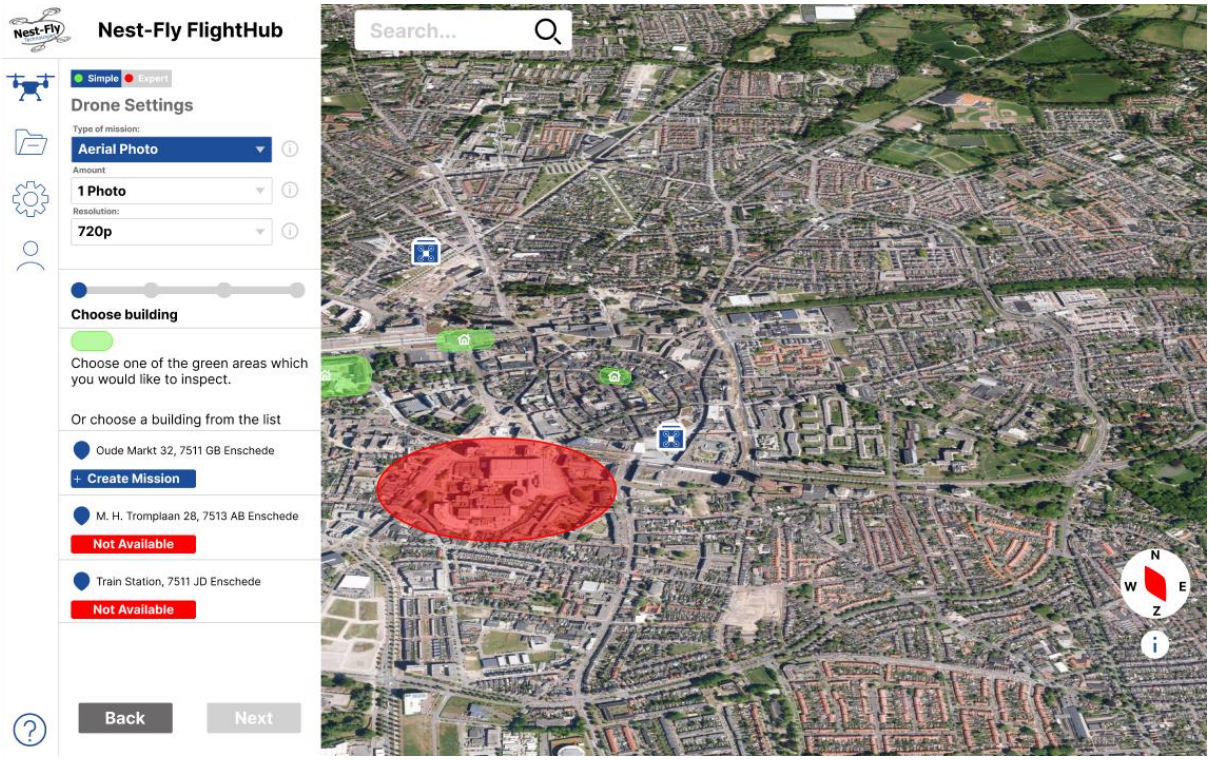
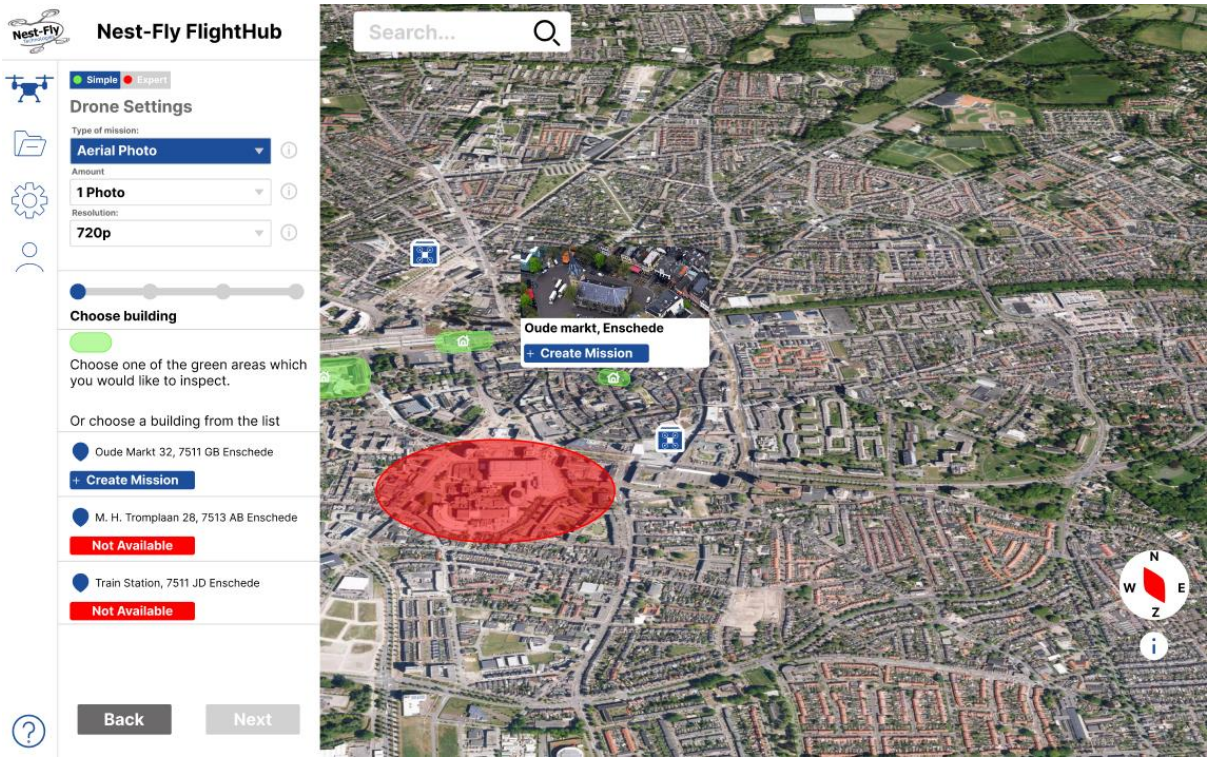
Z


Nest-Fly FlightHub
Simple
Expert
Drone Settings
Type of mission:
Aerial Photo
Amount
1 Photo
Resolution:
720p
Choose building
Choose one of the green areas which you would like to inspect.
Or choose a building from the list
Oude Markt 32, 7511 GB Enschede
+ Create Mission
M. H. Tromplaan 28, 7513 AB Enschede
Not Available
Train Station, 7511 JD Enschede
Not Available
Back
Next
Search...
N
W
E
Z


Nest-Fly FlightHub
Simple
Expert
Drone Settings
Type of mission:
Aerial Photo
Amount
1 Photo
Resolution:
720p
Choose building
Choose one of the green areas which you would like to inspect.
Or choose a building from the list
Oude Markt 32, 7511 GB Enschede
+ Create Mission
M. H. Tromplaan 28, 7513 AB Enschede
Not Available
Train Station, 7511 JD Enschede
Not Available
Back
Next
Search...
Oude markt, Enschede
+ Create Mission
N
W
E
Z


Nest-Fly FlightHub
Simple
Expert
Drone Settings
Type of mission:
Aerial Photo
Amount
1 Photo
Resolution:
720p
Choose building
Choose one of the green areas which you would like to inspect.
Or choose a building from the list
Oude Markt 32, 7511 GB Enschede
+ Create Mission
M. H. Tromplaan 28, 7513 AB Enschede
Not Available
Train Station, 7511 JD Enschede
Not Available
Back
Next
Search...
Trein station, Enschede
Not Available
N
W
E
Z


Nest-Fly FlightHub
Simple
Expert
Drone Settings
Type of mission:
Aerial Photo
Amount
1 Photo
Resolution:
720p
Choose building
Choose one of the green areas which you would like to inspect.
Or choose a building from the list
Oude Markt 32, 7511 GB Enschede
+ Create Mission
M. H. Tromplaan 28, 7513 AB Enschede
Not Available
Train Station, 7511 JD Enschede
Not Available
Back
Next
Search...
N
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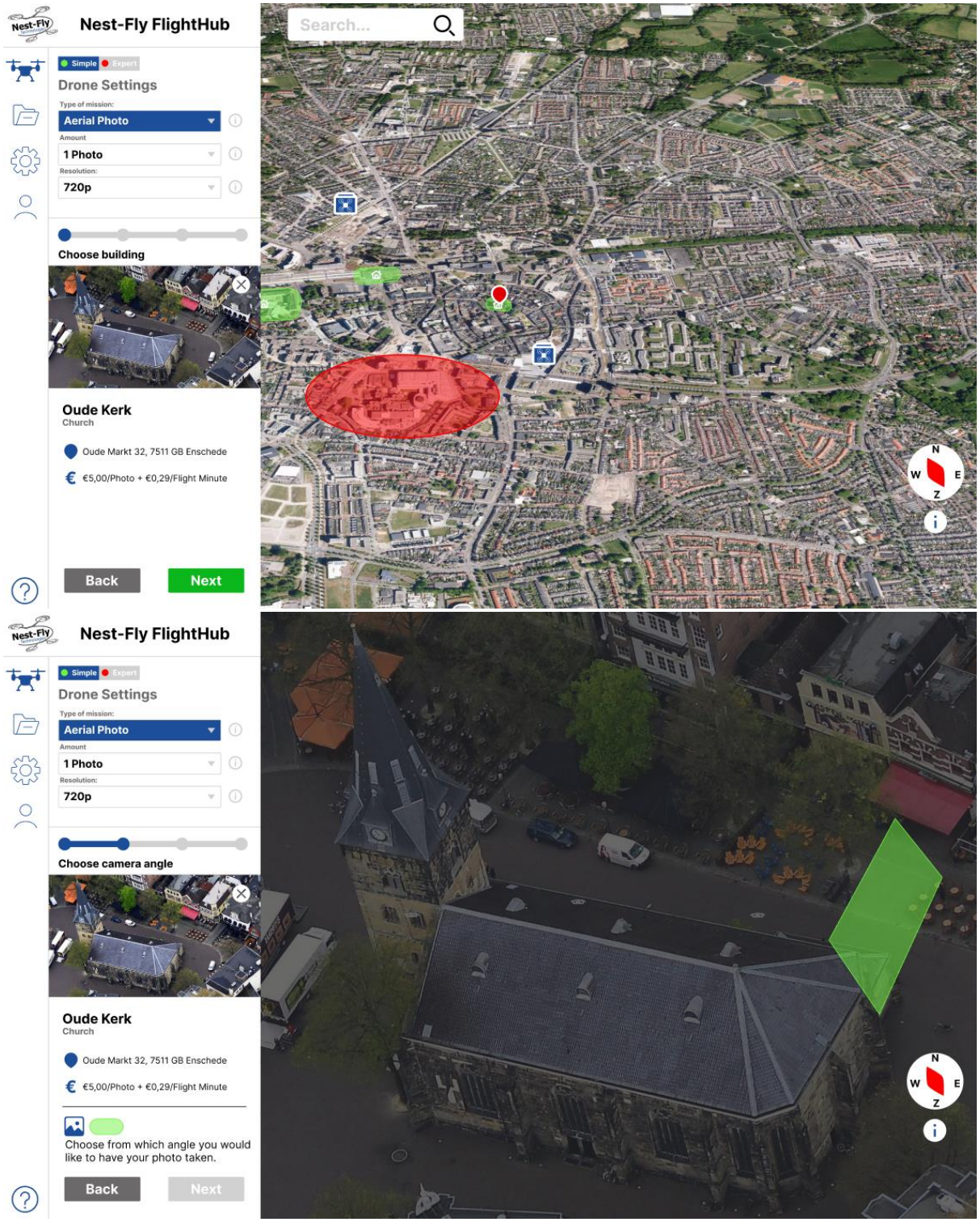
Z


Nest-Fly FlightHub
Simple
Expert
Drone Settings
Type of mission:
Aerial Photo
Amount
1 Photo
Resolution:
720p
Choose building
Oude Kerk
Church
Oude Markt 32, 7511 GB Enschede
€5,00/Photo + €0,29/Flight Minute
Back
Next
Search...
N
W
E
Z
Nest-Fly FlightHub
Simple
Expert
Drone Settings
Type of mission:
Aerial Photo
Amount
1 Photo
Resolution:
720p
Choose camera angle
Oude Kerk
Church
Oude Markt 32, 7511 GB Enschede
€5,00/Photo + €0,29/Flight Minute
Choose from which angle you would like to have your photo taken.
Back
Next
N
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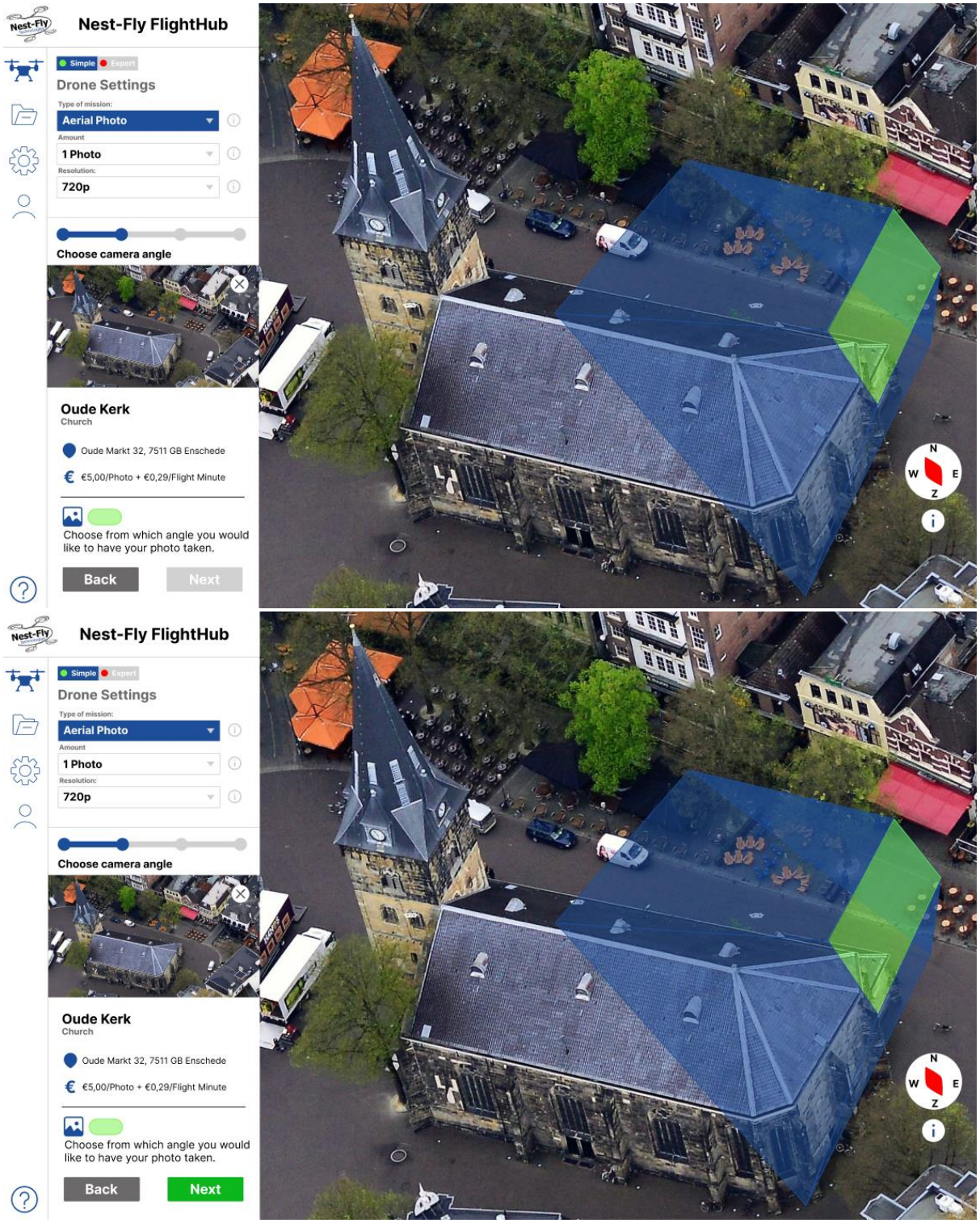
Nest-Fly FlightHub
Simple
Expert
Drone Settings
Type of mission:
Aerial Photo
Amount
1 Photo
Resolution:
720p
Choose camera angle
Oude Kerk
Church
Oude Markt 32, 7511 GB Enschede
€5,00/Photo + €0,29/Flight Minute
Choose from which angle you would like to have your photo taken.
Back
Next
N
W
E
Z
Nest-Fly FlightHub
Simple
Expert
Drone Settings
Type of mission:
Aerial Photo
Amount
1 Photo
Resolution:
720p
Choose camera angle
Oude Kerk
Church
Oude Markt 32, 7511 GB Enschede
€5,00/Photo + €0,29/Flight Minute
Choose from which angle you would like to have your photo taken.
Back
Next
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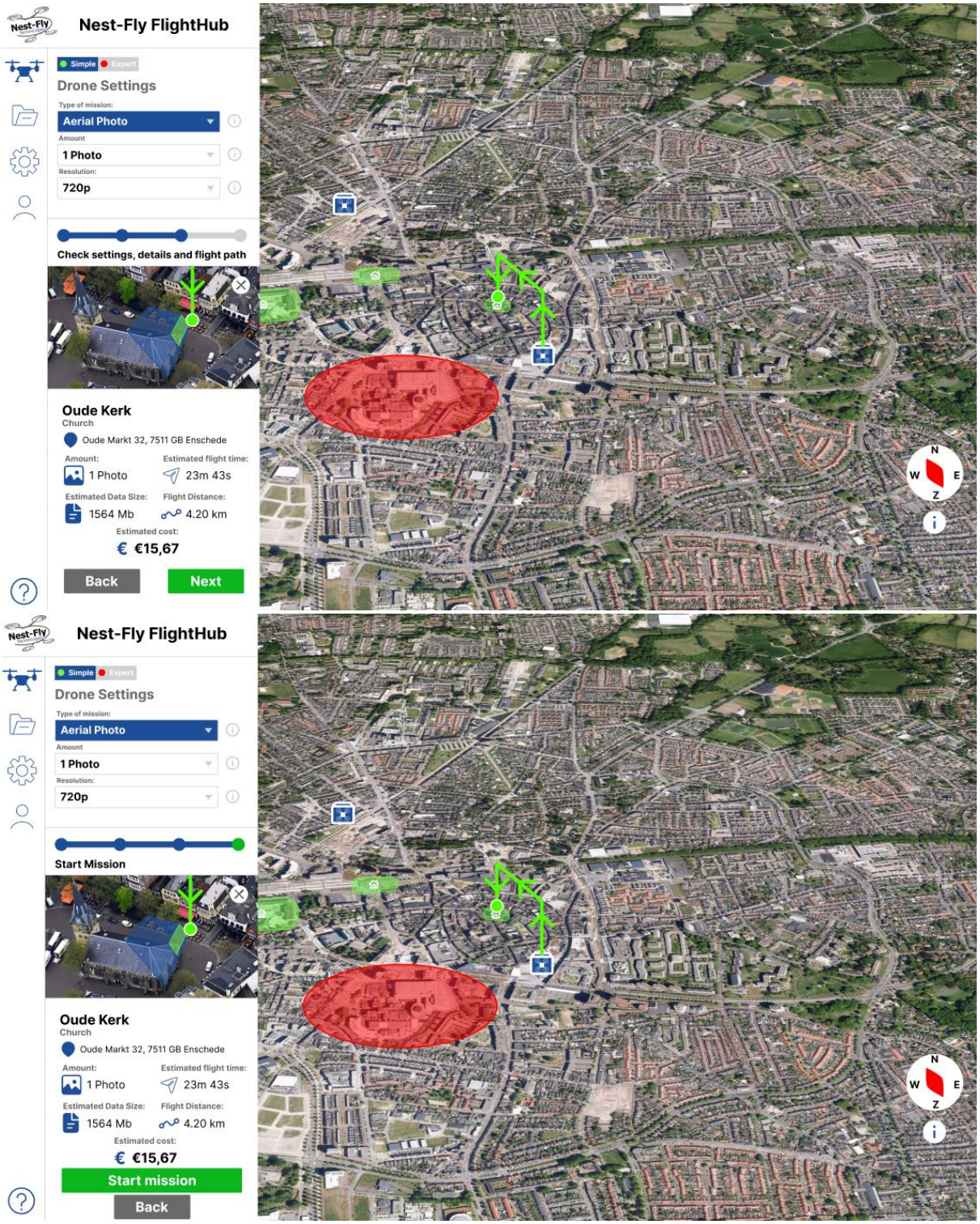
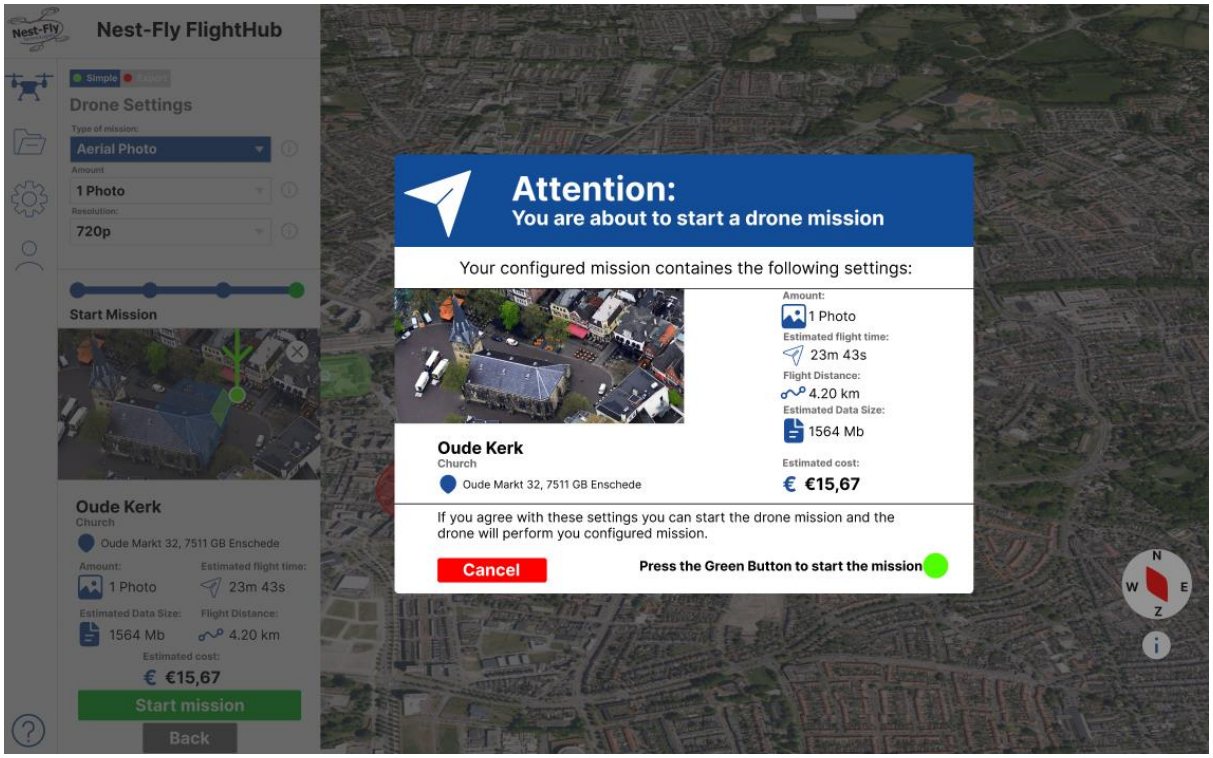
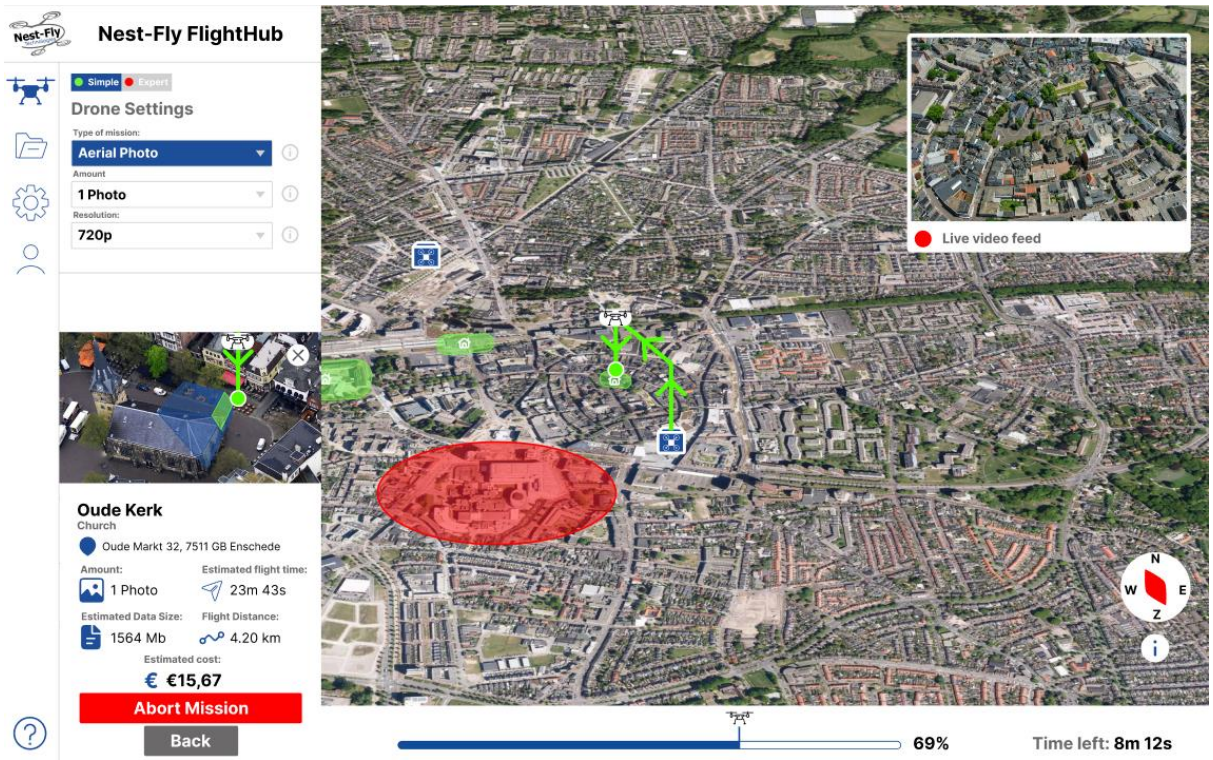
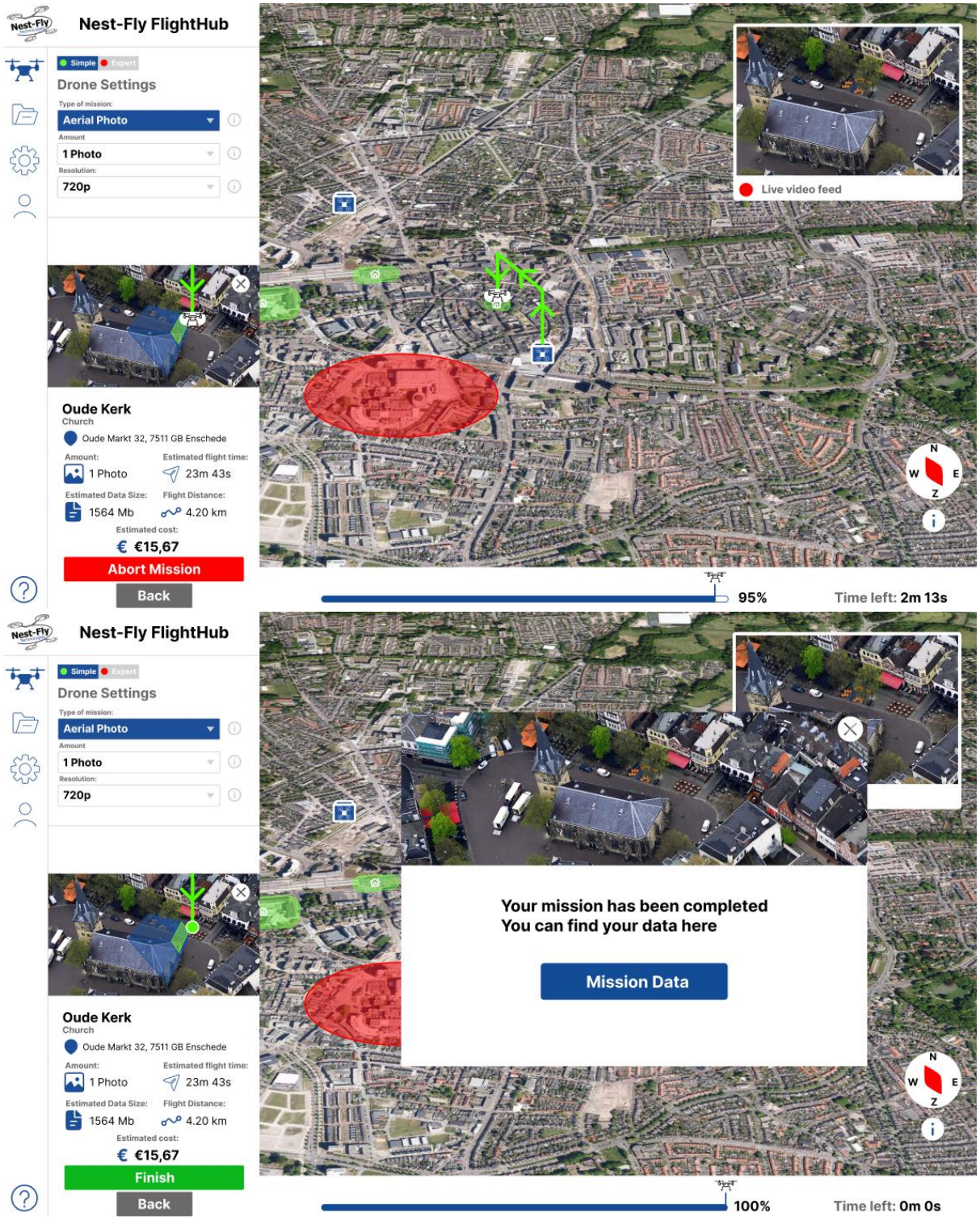

Nest-Fly FlightHub
Simple
Expert
Drone Settings
Type of mission:
Aerial Photo
Amount
1 Photo
Resolution:
720p
Check settings, details and flight path
Oude Kerk
Church
Oude Markt 32, 7511 GB Enschede
Amount:
1 Photo
Estimated flight time:
23m 43s
Estimated Data Size:
1564 Mb
Flight Distance:
4.20 km
Estimated cost:
€ €15,67
Back
Next
N
W
E
Z
Nest-Fly FlightHub
Simple
Expert
Drone Settings
Type of mission:
Aerial Photo
Amount
1 Photo
Resolution:
720p
Start Mission
Oude Kerk
Church
Oude Markt 32, 7511 GB Enschede
Amount:
1 Photo
Estimated flight time:
23m 43s
Estimated Data Size:
1564 Mb
Flight Distance:
4.20 km
Estimated cost:
€ €15,67
Start mission
Back
N
W
E
Z


Nest-Fly FlightHub
Drone Settings
Aerial Photo
1 Photo
720p
Start Mission
Oude Kerk
Church
Oude Markt 32, 7511 GB Enschede
Amount:
1 Photo
Estimated flight time:
23m 43s
Estimated Data Size:
1564 Mb
Flight Distance:
4.20 km
Estimated cost:
€ €15,67
Start mission
Back
Attention:
You are about to start a drone mission
Your configured mission containes the following settings:
Amount:
1 Photo
Estimated flight time:
23m 43s
Flight Distance:
4.20 km
Estimated Data Size:
1564 Mb
Oude Kerk
Church
Oude Markt 32, 7511 GB Enschede
Estimated cost:
€ €15,67
If you agree with these settings you can start the drone mission and the drone will perform you configured mission.
Cancel
Press the Green Button to start the mission


Nest-Fly FlightHub
Drone Settings
Aerial Photo
1 Photo
720p
Oude Kerk
Church
Oude Markt 32, 7511 GB Enschede
Amount:
1 Photo
Estimated flight time:
23m 43s
Estimated Data Size:
1564 Mb
Flight Distance:
4.20 km
Estimated cost:
€ €15,67
Abort Mission
Back
Live video feed
2%
Time left: 22m 12s

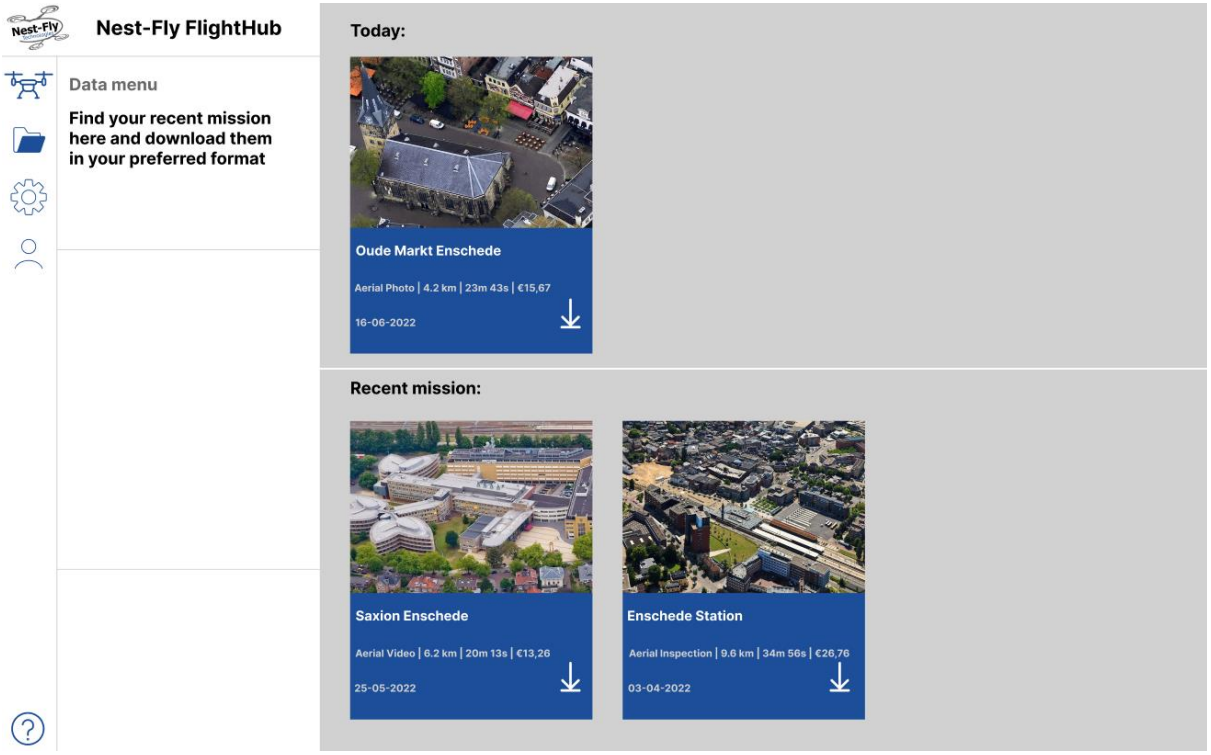

Nest-Fly FlightHub
Simple
Expert
Drone Settings
Type of mission:
Aerial Photo
Amount
1 Photo
Resolution:
720p
Oude Kerk
Church
Oude Markt 32, 7511 GB Enschede
Amount:
1 Photo
Estimated flight time:
23m 43s
Estimated Data Size:
1564 Mb
Flight Distance:
4.20 km
Estimated cost:
€ €15,67
Abort Mission
Back
Live video feed
N
W
E
Z
32%
Time left: 15m 05s


Nest-Fly FlightHub
Simple
Expert
Drone Settings
Type of mission:
Aerial Photo
Amount
1 Photo
Resolution:
720p
Oude Kerk
Church
Oude Markt 32, 7511 GB Enschede
Amount:
1 Photo
Estimated flight time:
23m 43s
Estimated Data Size:
1564 Mb
Flight Distance:
4.20 km
Estimated cost:
€ €15,67
Abort Mission
Back
Live video feed
N
W
E
Z
69%
Time left: 8m 12s

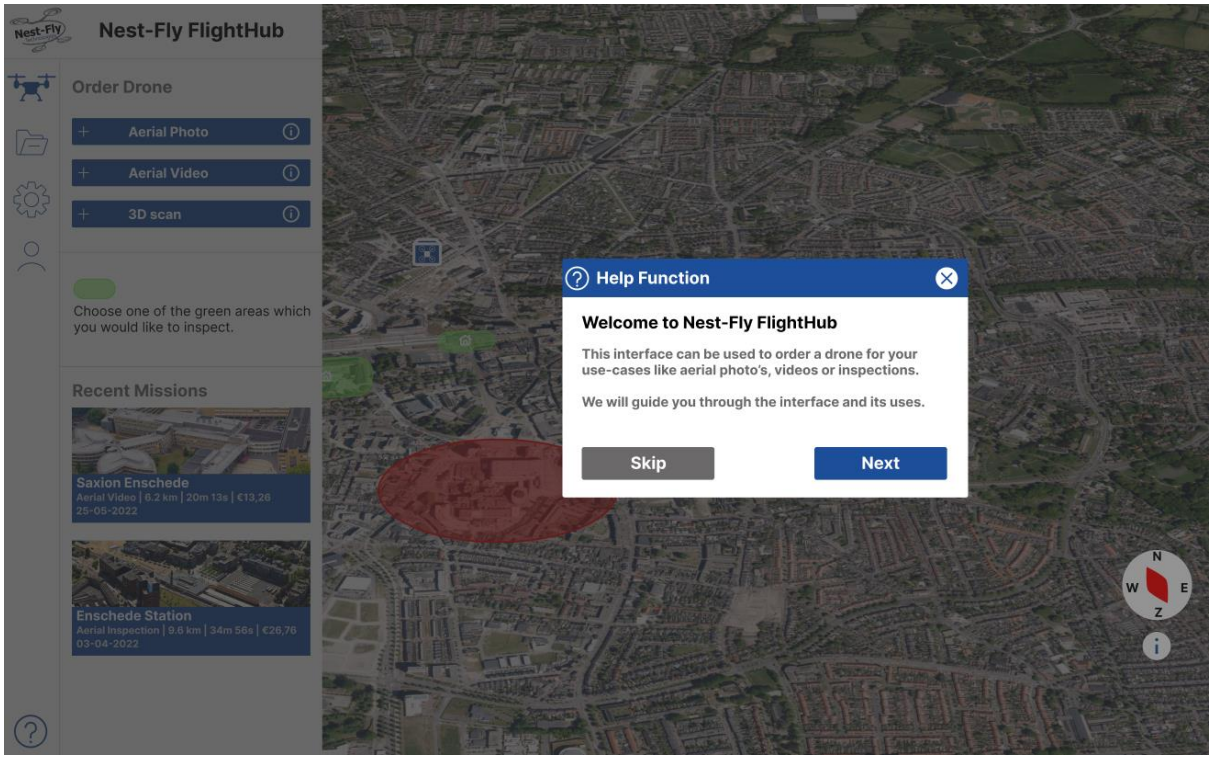

Nest-Fly FlightHub
Simple
Expert
Drone Settings
Type of mission:
Aerial Photo
Amount
1 Photo
Resolution:
720p
Oude Kerk
Church
Oude Markt 32, 7511 GB Enschede
Amount:
1 Photo
Estimated flight time:
23m 43s
Estimated Data Size:
1564 Mb
Flight Distance:
4.20 km
Estimated cost:
€ €15,67
Abort Mission
Back
Live video feed
N
W
E
Z
95%
Time left: 2m 13s
Nest-Fly FlightHub
Simple
Expert
Drone Settings
Type of mission:
Aerial Photo
Amount
1 Photo
Resolution:
720p
Oude Kerk
Church
Oude Markt 32, 7511 GB Enschede
Amount:
1 Photo
Estimated flight time:
23m 43s
Estimated Data Size:
1564 Mb
Flight Distance:
4.20 km
Estimated cost:
€ €15,67
Finish
Back
Your mission has been completed
You can find your data here
Mission Data
N
W
E
Z
100%
Time left: 0m 0s

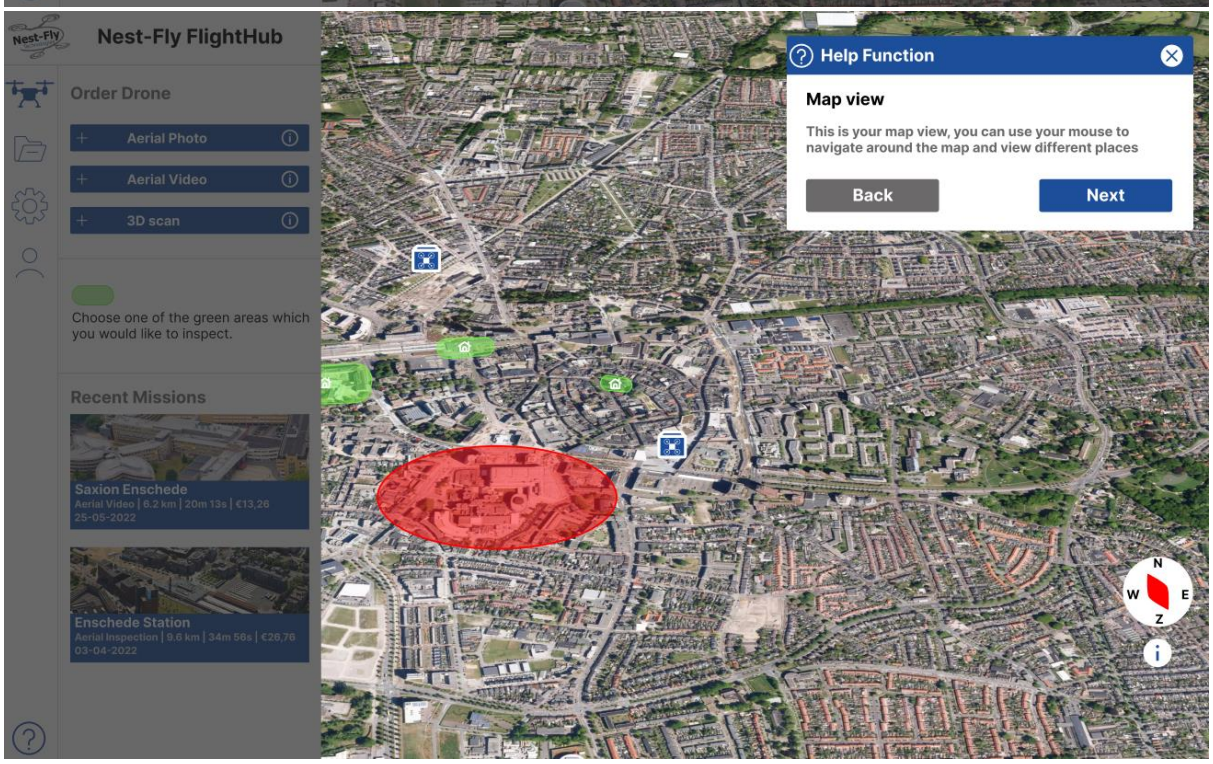

Nest-Fly FlightHub
Simple
Expert
Drone Settings
Type of mission:
Aerial Photo
Amount
1 Photo
Resolution:
720p
Oude Kerk
Church
Oude Markt 32, 7511 GB Enschede
Amount:
1 Photo
Estimated flight time:
23m 43s
Estimated Data Size:
1564 Mb
Flight Distance:
4.20 km
Estimated cost:
€ €15,67
Finish
Back
Live video feed
N
W
E
Z
100%
Time left: 0m 0s

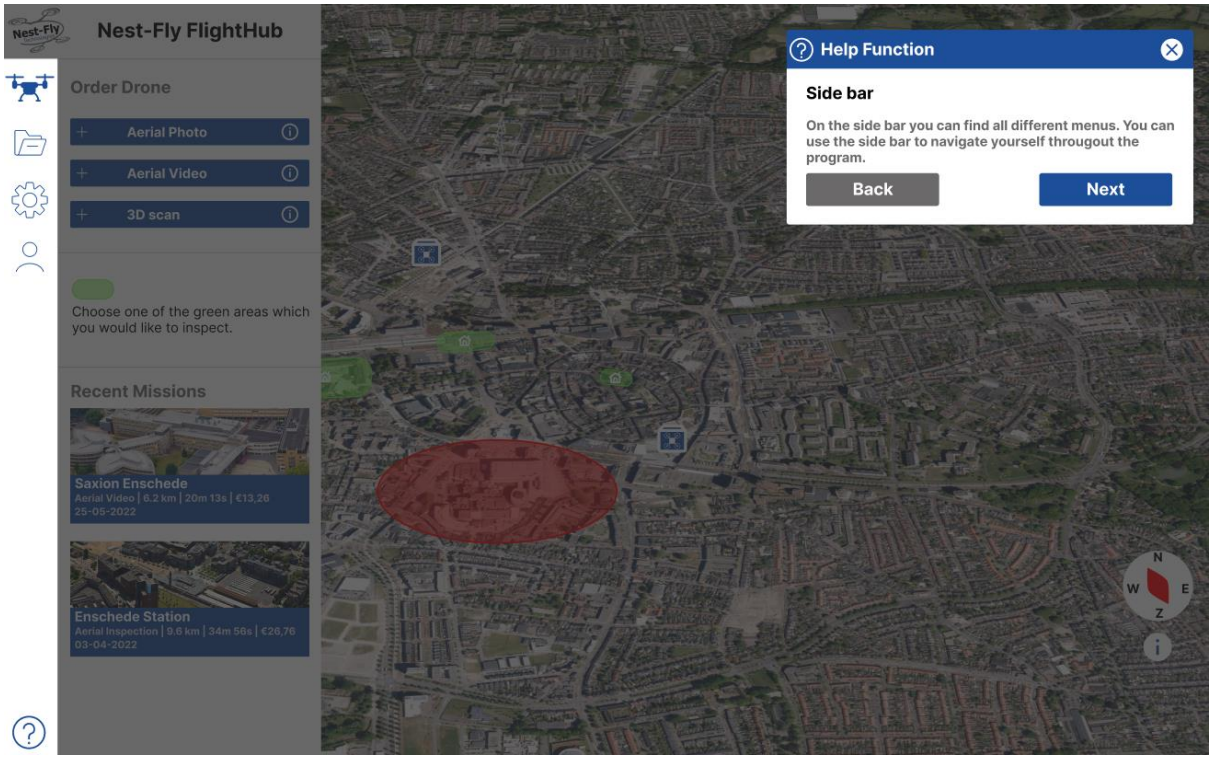
Data menu:

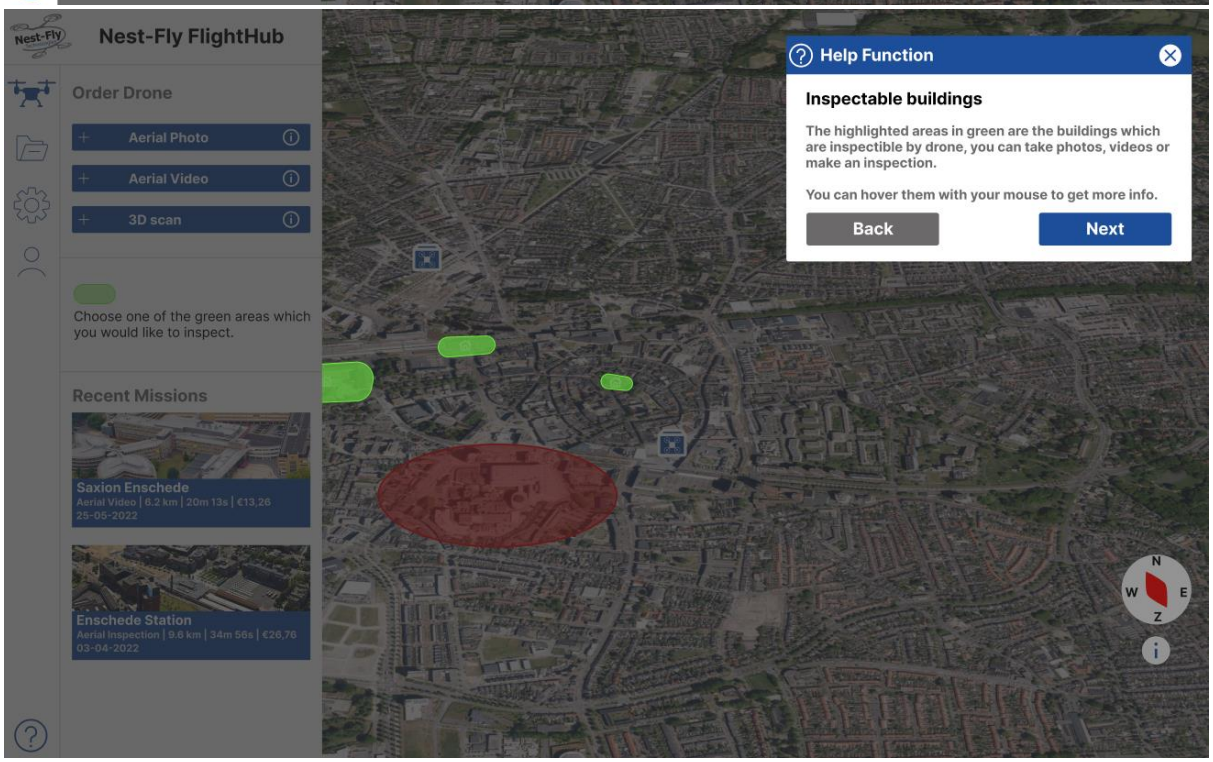

Nest-Fly FlightHub
Data menu
Find your recent mission here and download them in your preferred format
Today:
Oude Markt Enschede
Aerial Photo | 4.2 km | 23m 43s | €15,67
16-06-2022
Recent mission:
Saxion Enschede
Aerial Video | 6.2 km | 20m 13s | €13,26
25-05-2022
Enschede Station
Aerial Inspection | 9.6 km | 34m 56s | €26,76
03-04-2022

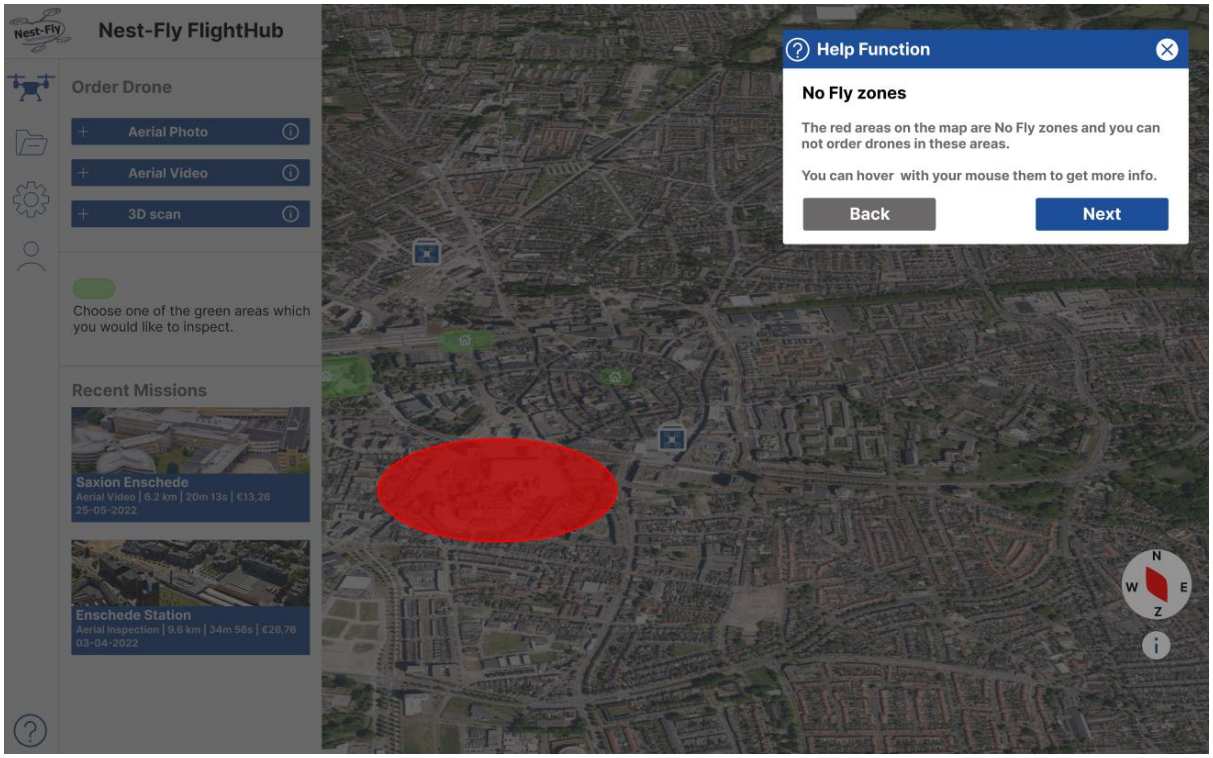
Help function:

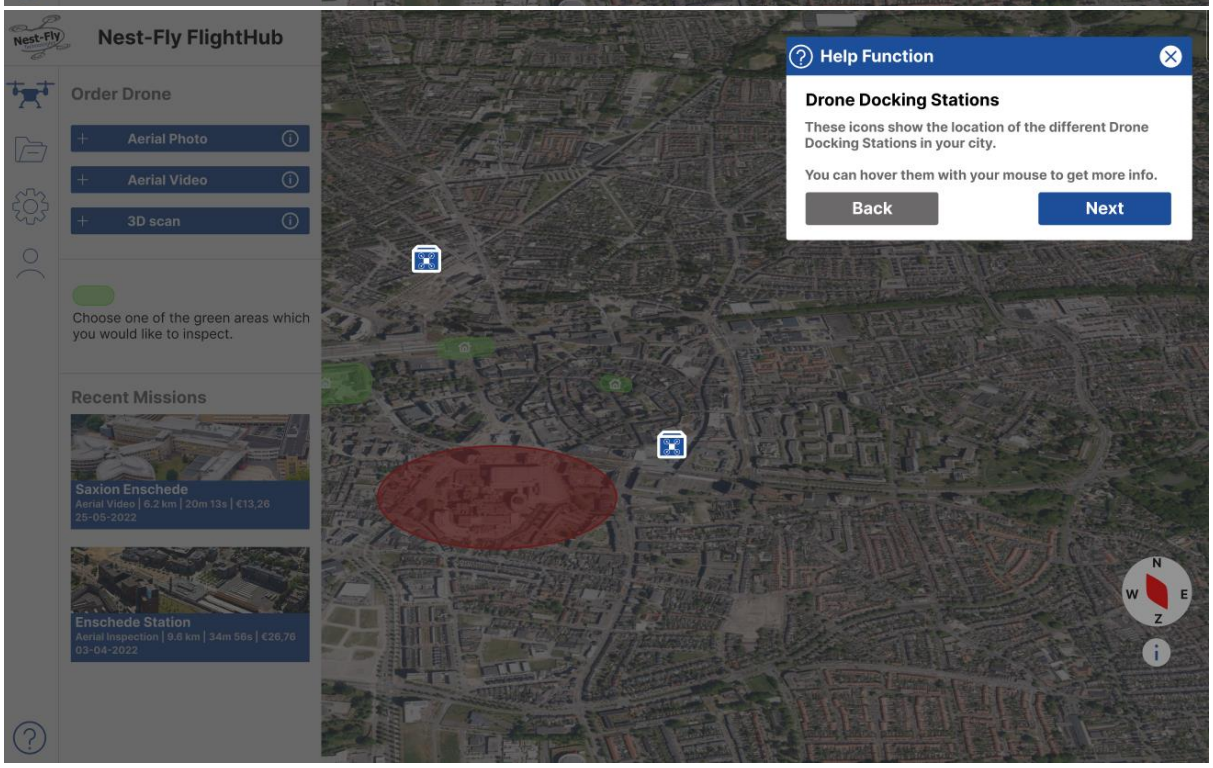


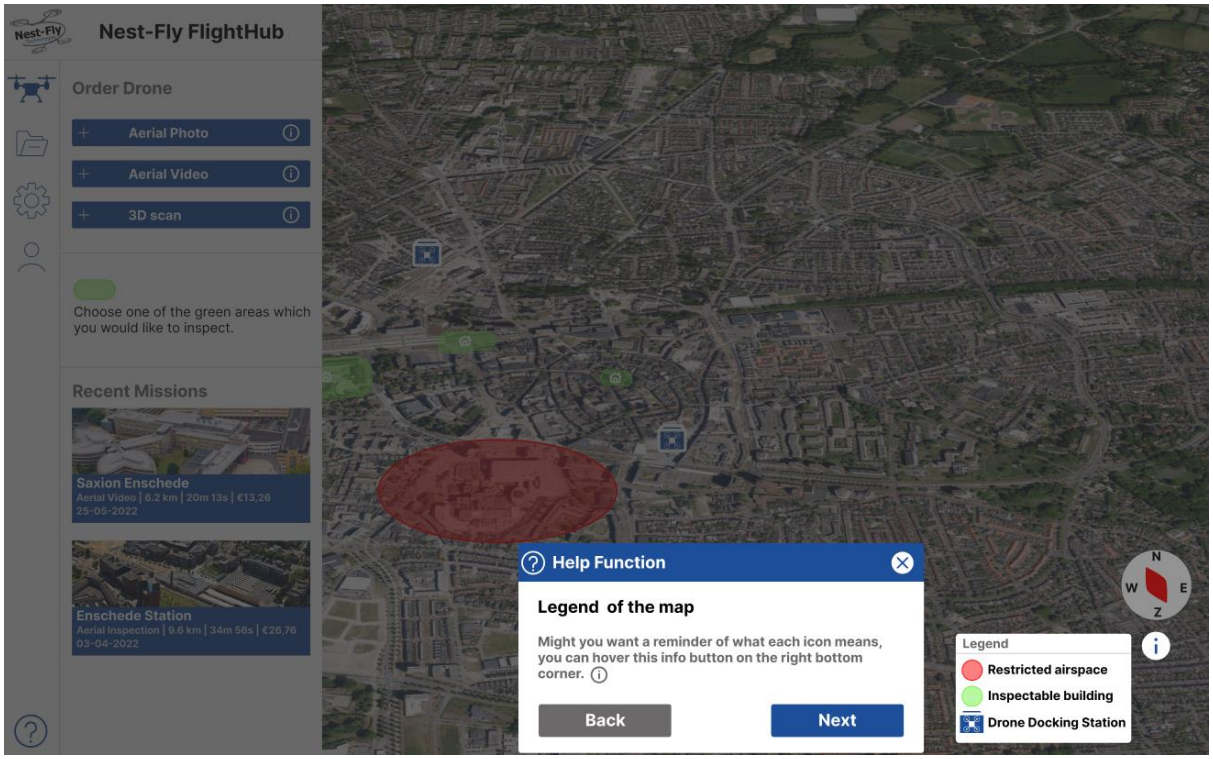


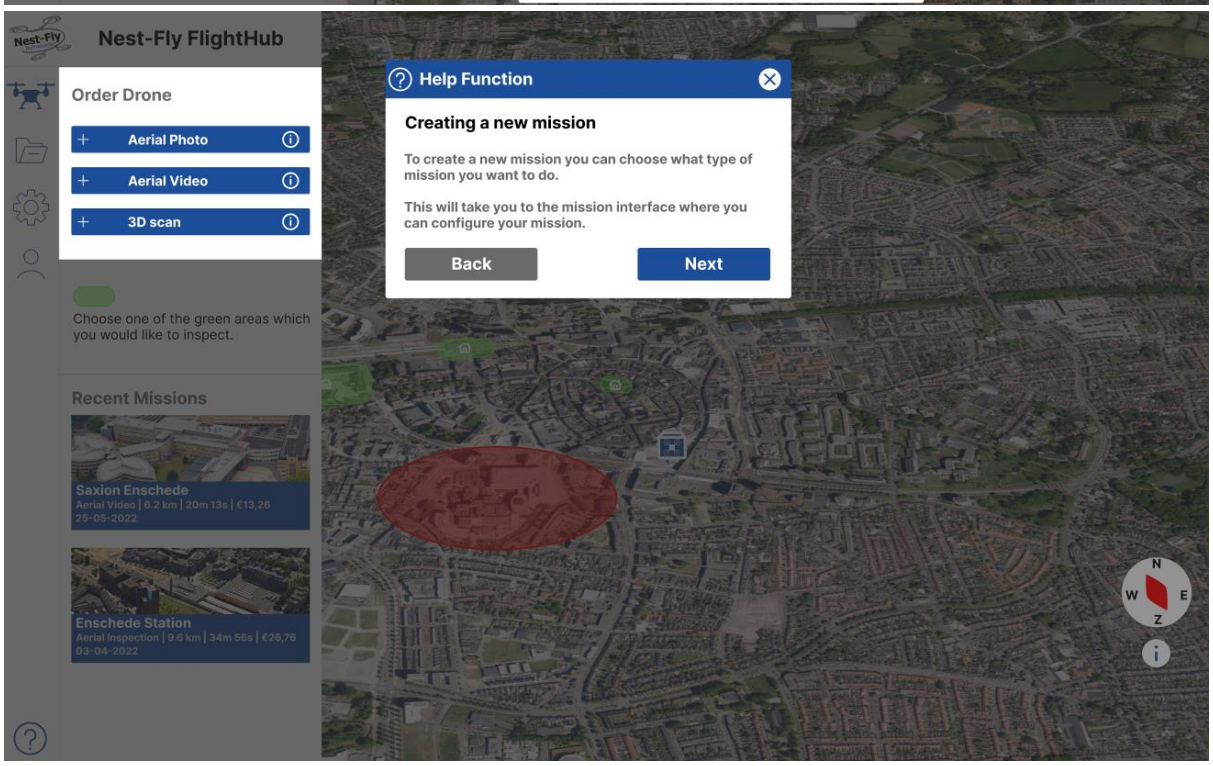

Nest-Fly FlightHub
Order Drone
Aerial Photo
Aerial Video
3D scan
Choose one of the green areas which you would like to inspect.
Recent Missions
Saxion Enschede
Aerial Video | 6.2 km | 20m 13s | €13,26
25-05-2022
Enschede Station
Aerial Inspection | 9.6 km | 34m 56s | €26,76
03-04-2022
Help Function
Side bar
On the side bar you can find all different menus. You can use the side bar to navigate yourself througout the program.
Back
Next
N
W
E
Z

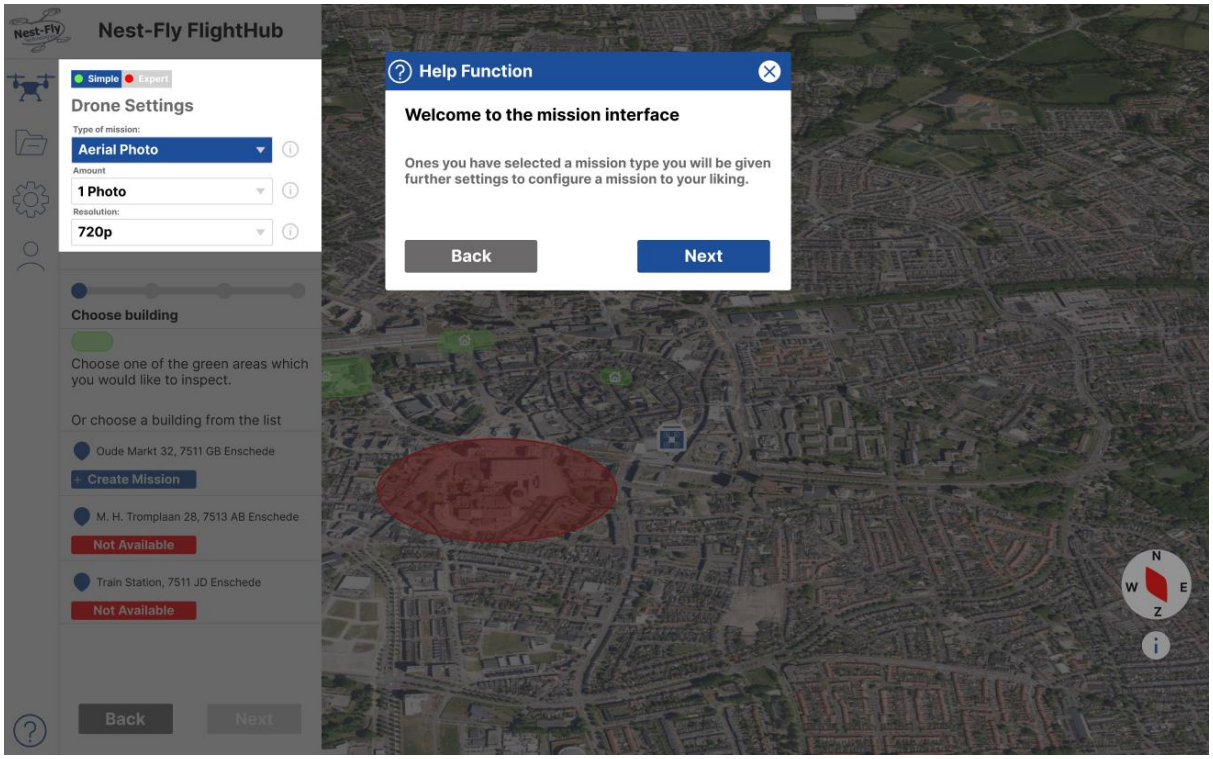

Nest-Fly FlightHub
Order Drone
Aerial Photo
Aerial Video
3D scan
Choose one of the green areas which you would like to inspect.
Recent Missions
Saxion Enschede
Aerial Video | 6.2 km | 20m 13s | €13,26
25-05-2022
Enschede Station
Aerial Inspection | 9.6 km | 34m 56s | €26,76
03-04-2022
Help Function
Inspectable buildings
The highlighted areas in green are the buildings which are inspectible by drone, you can take photos, videos or make an inspection.
You can hover them with your mouse to get more info.
Back
Next
N
W
E
Z

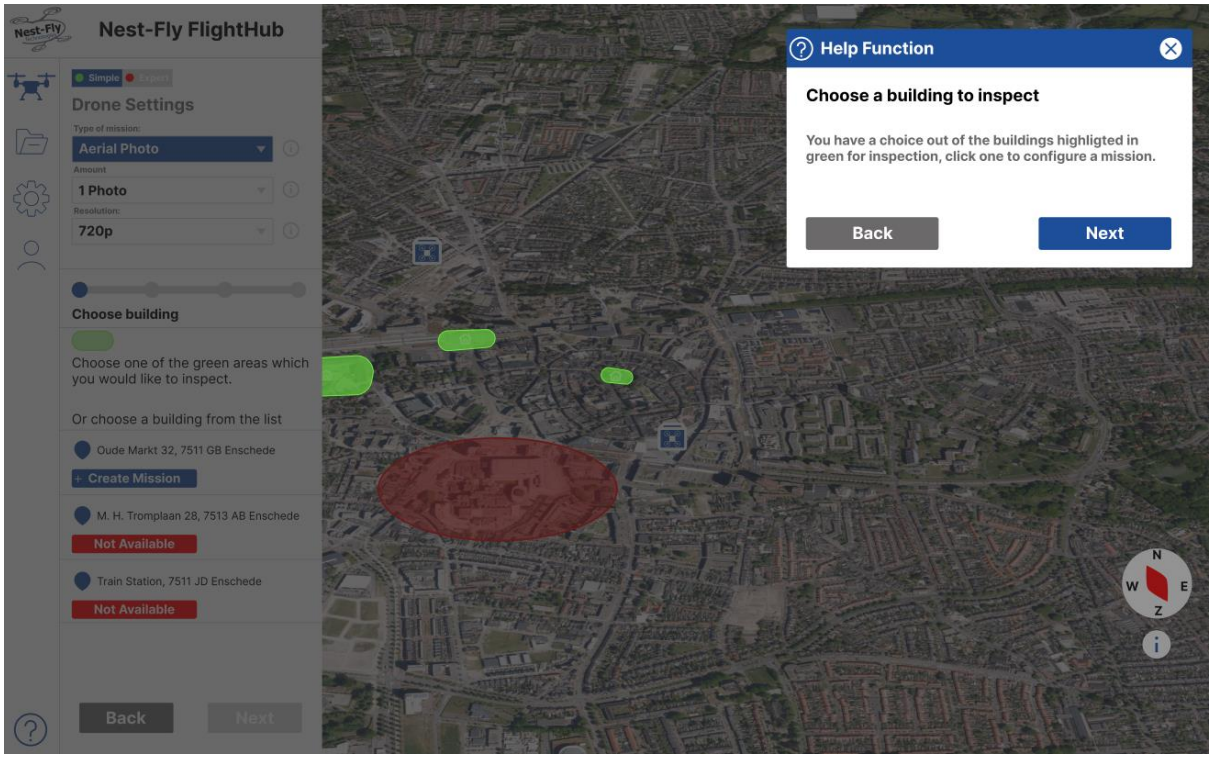

Nest-Fly FlightHub
Order Drone
Aerial Photo
Aerial Video
3D scan
Choose one of the green areas which you would like to inspect.
Recent Missions
Saxion Enschede
Aerial Video | 6.2 km | 20m 13s | €13,26
25-05-2022
Enschede Station
Aerial Inspection | 9.6 km | 34m 56s | €26,76
03-04-2022
Help Function
No Fly zones
The red areas on the map are No Fly zones and you can not order drones in these areas.
You can hover with your mouse them to get more info.
Back
Next
N
W
E
Z

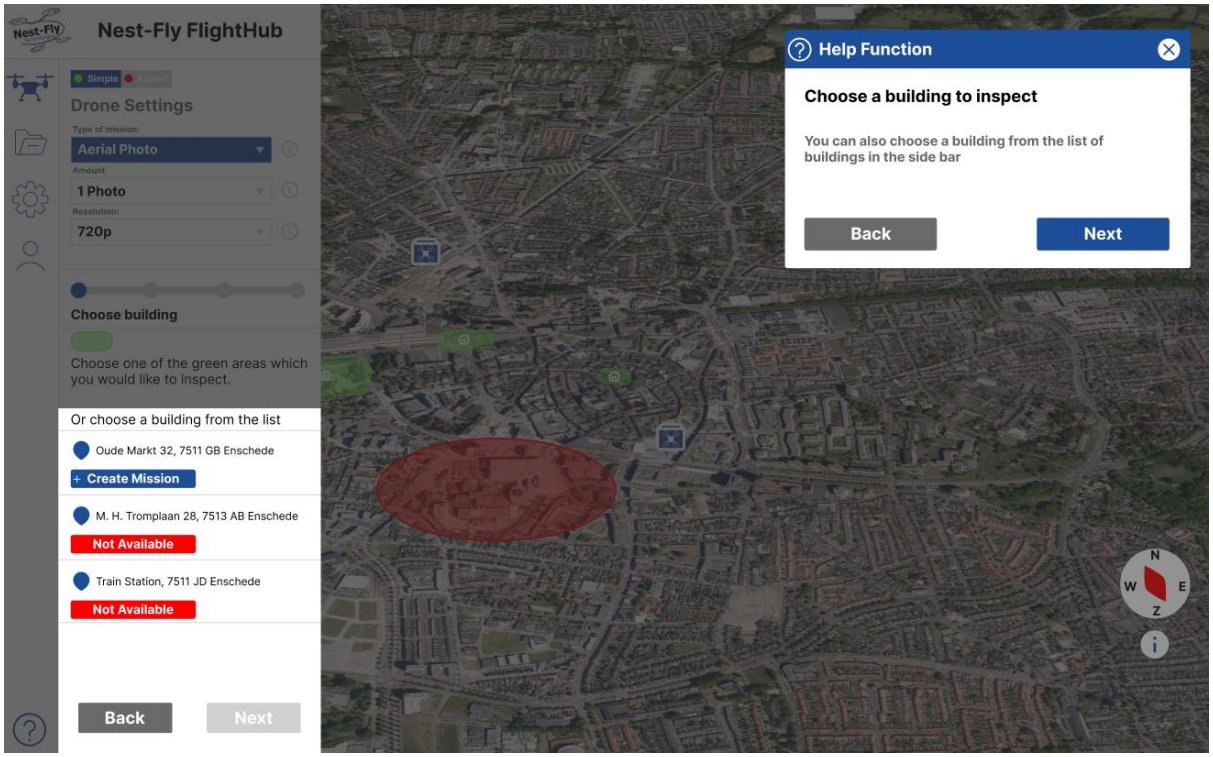

Nest-Fly FlightHub
Order Drone
Aerial Photo
Aerial Video
3D scan
Choose one of the green areas which you would like to inspect.
Recent Missions
Saxion Enschede
Aerial Video | 6.2 km | 20m 13s | €13,26
25-05-2022
Enschede Station
Aerial Inspection | 9.6 km | 34m 56s | €26,76
03-04-2022
Help Function
Drone Docking Stations
These icons show the location of the different Drone Docking Stations in your city.
You can hover them with your mouse to get more info.
Back
Next
N
W
E
Z

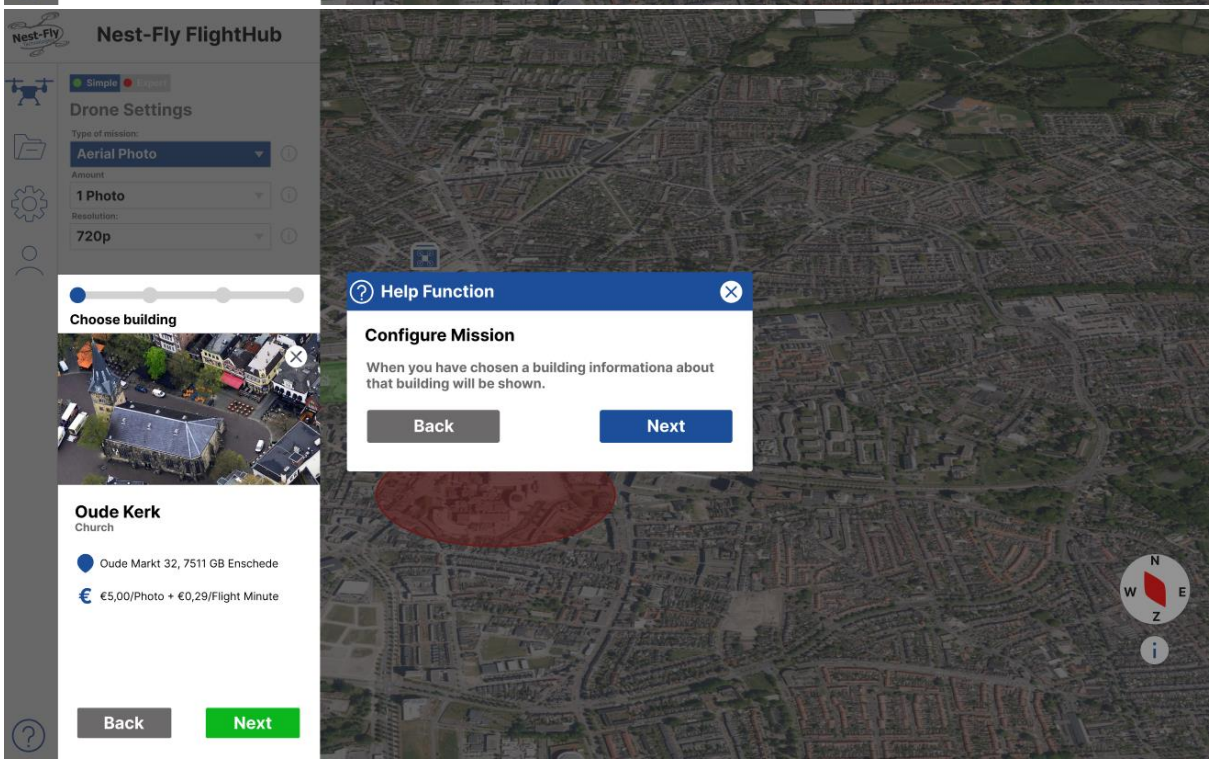

Nest-Fly FlightHub
Order Drone
Aerial Photo
Aerial Video
3D scan
Choose one of the green areas which you would like to inspect.
Recent Missions
Saxion Enschede
Aerial Video | 6.2 km | 20m 13s | €13,26
25-05-2022
Enschede Station
Aerial Inspection | 9.6 km | 34m 56s | €26,76
03-04-2022
Help Function
Legend of the map
Might you want a reminder of what each icon means, you can hover this info button on the right bottom corner.
Back
Next
Legend
Restricted airspace
Inspectable building
Drone Docking Station
N
W
E
Z

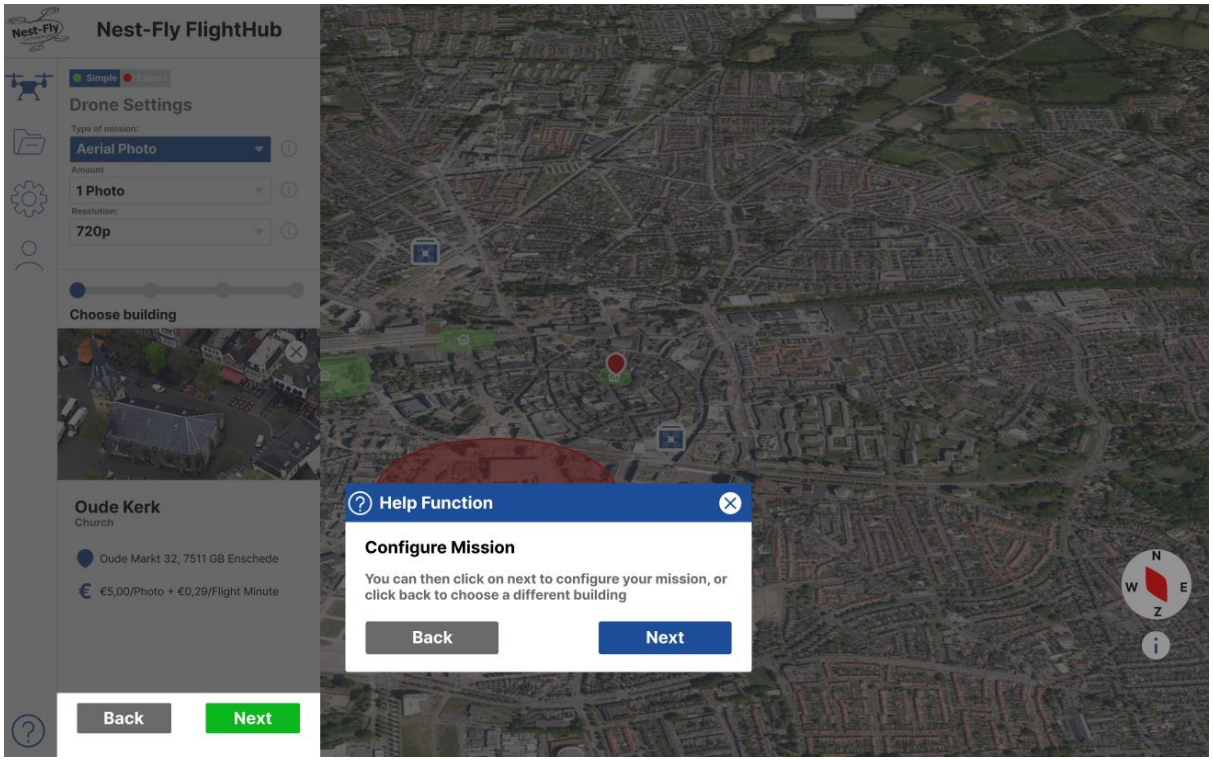

Nest-Fly FlightHub
Order Drone
Aerial Photo
Aerial Video
3D scan
Choose one of the green areas which you would like to inspect.
Recent Missions
Saxion Enschede
Aerial Video | 6.2 km | 20m 13s | €13,26
25-05-2022
Enschede Station
Aerial Inspection | 9.6 km | 34m 56s | €26,76
03-04-2022
Help Function
Creating a new mission
To create a new mission you can choose what type of mission you want to do.
This will take you to the mission interface where you can configure your mission.
Back
Next
N
W
E
Z

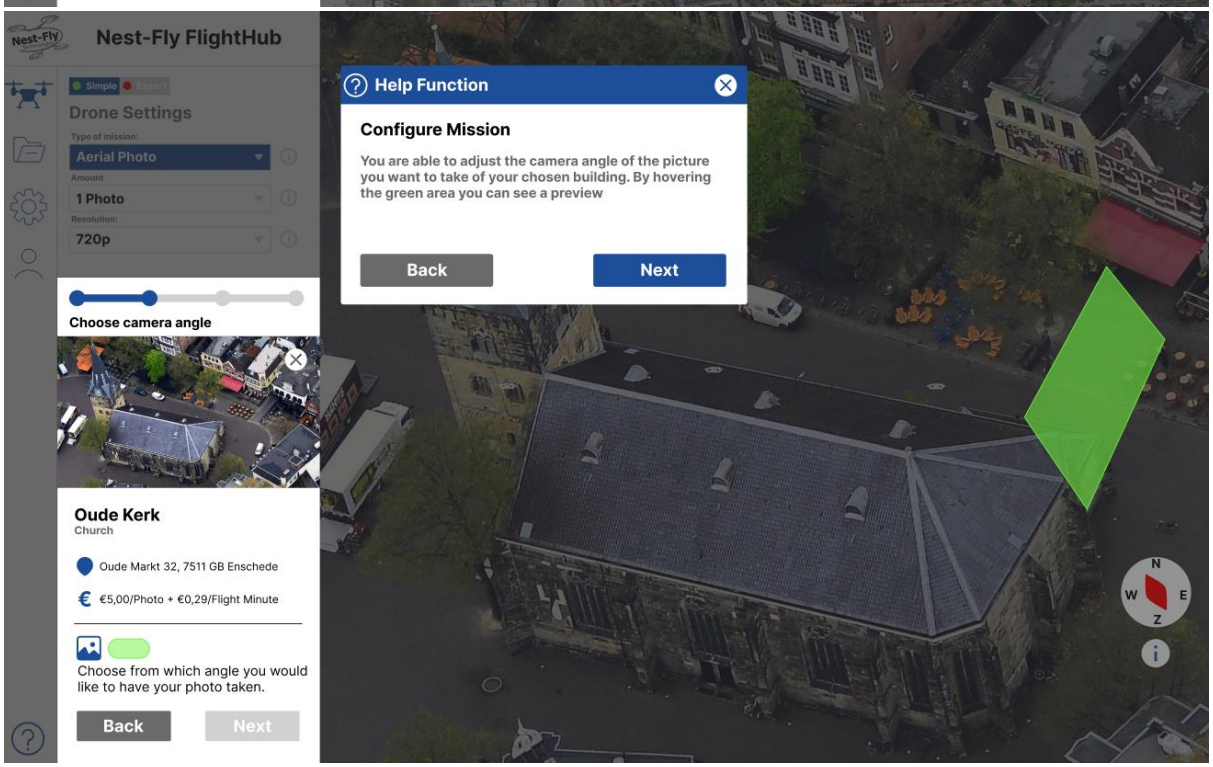

Nest-Fly FlightHub
Simple
Expert
Drone Settings
Type of mission:
Aerial Photo
Amount
1 Photo
Resolution:
720p
Choose building
Choose one of the green areas which you would like to inspect.
Or choose a building from the list
Oude Markt 32, 7511 GB Enschede
Create Mission
M. H. Tromplaan 28, 7513 AB Enschede
Not Available
Train Station, 7511 JD Enschede
Not Available
Back
Next
Help Function
Welcome to the mission interface
Ones you have selected a mission type you will be given further settings to configure a mission to your liking.
Back
Next
N
W
E
Z

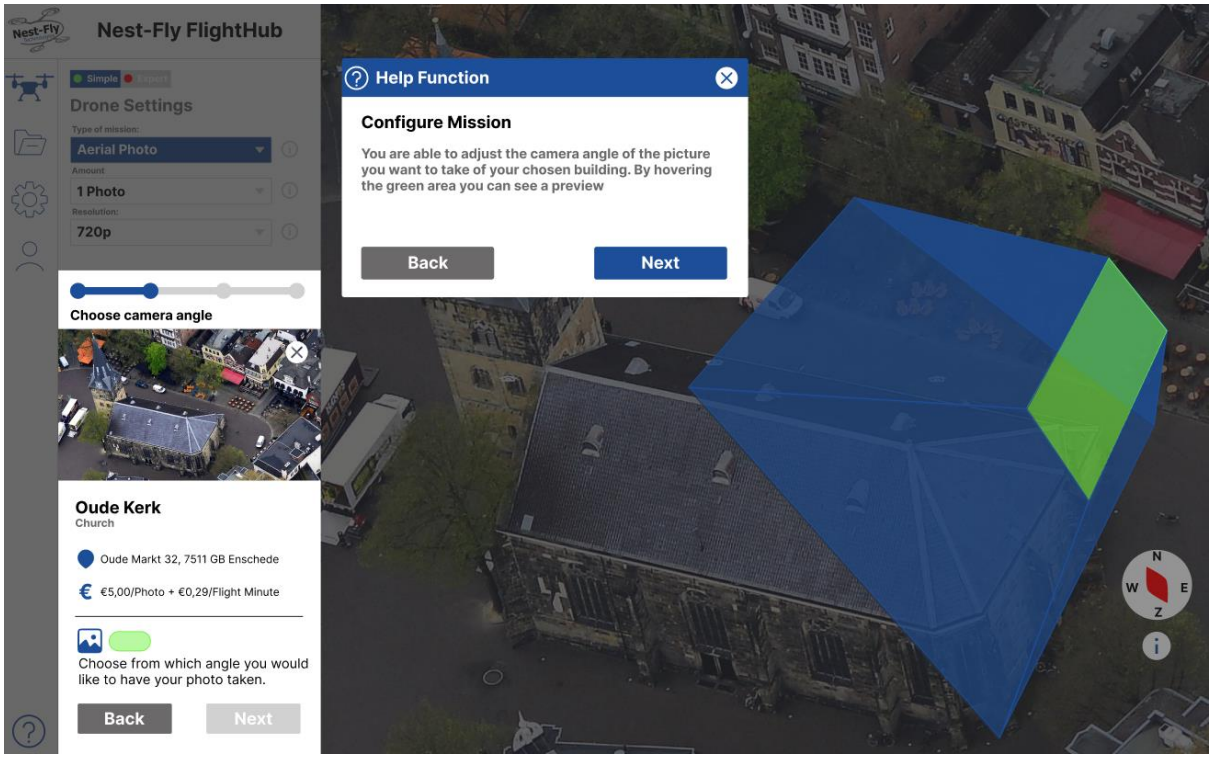

Nest-Fly FlightHub
Simple
Expert
Drone Settings
Type of mission:
Aerial Photo
Amount
1 Photo
Resolution:
720p
Choose building
Choose one of the green areas which you would like to inspect.
Or choose a building from the list
Oude Markt 32, 7511 GB Enschede
Create Mission
M. H. Tromplaan 28, 7513 AB Enschede
Not Available
Train Station, 7511 JD Enschede
Not Available
Back
Next
Help Function
Choose a building to inspect
You have a choice out of the buildings highligted in green for inspection, click one to configure a mission.
Back
Next
N
W
E
Z

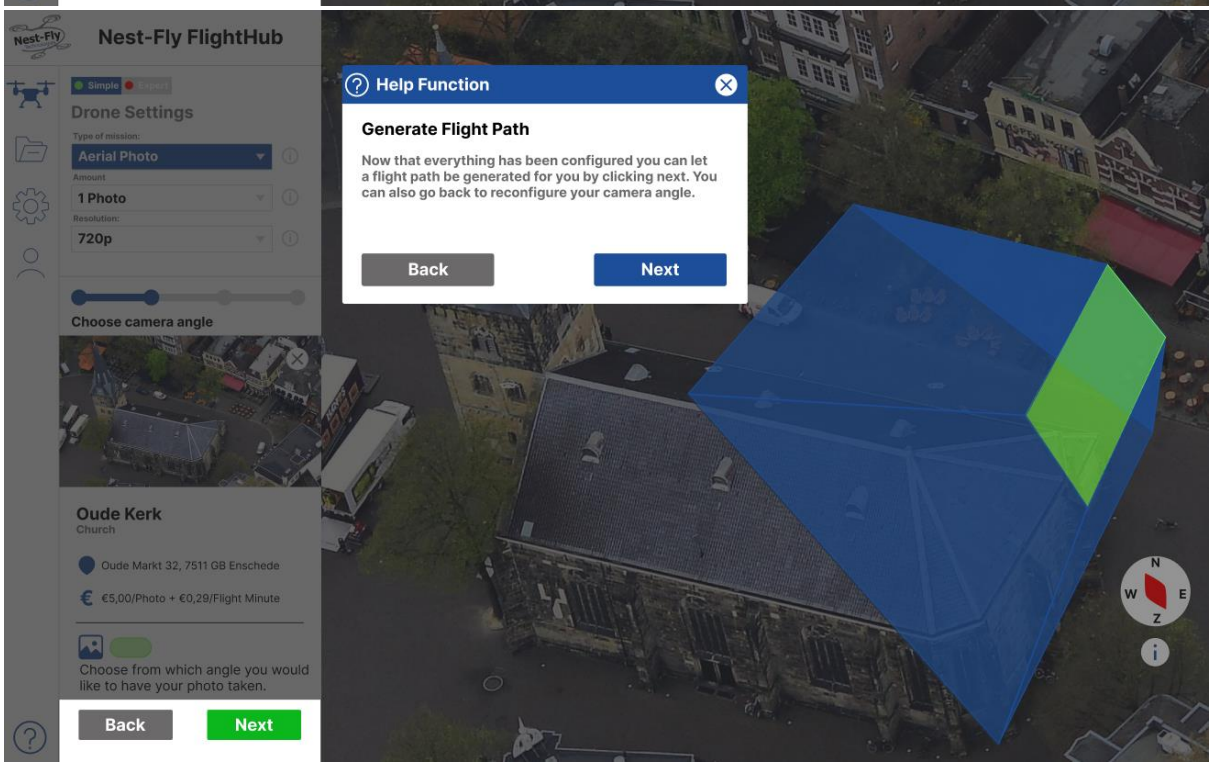

Nest-Fly FlightHub
Simple
Expert
Drone Settings
Type of mission:
Aerial Photo
Amount
1 Photo
Resolution:
720p
Choose building
Choose one of the green areas which you would like to inspect.
Or choose a building from the list
Oude Markt 32, 7511 GB Enschede
+ Create Mission
M. H. Tromplaan 28, 7513 AB Enschede
Not Available
Train Station, 7511 JD Enschede
Not Available
Back
Next
Help Function
Choose a building to inspect
You can also choose a building from the list of buildings in the side bar
Back
Next
N
W
E
Z

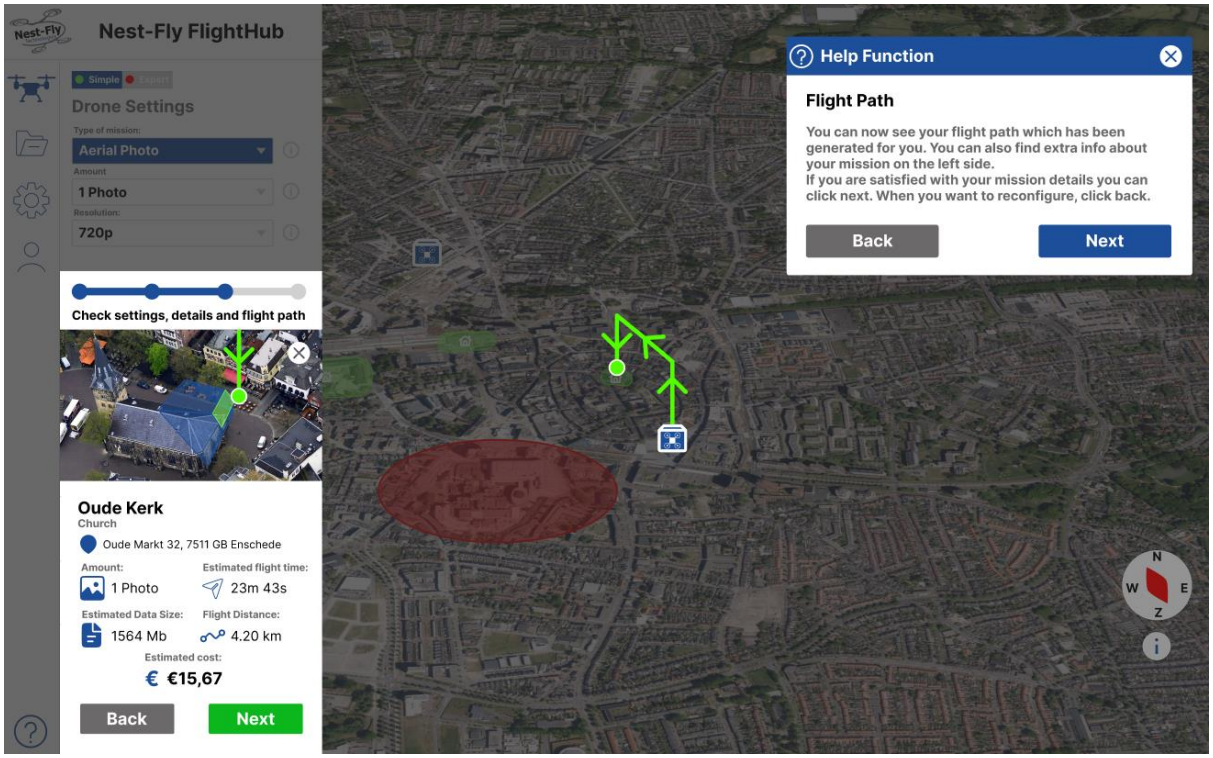

Nest-Fly FlightHub
Simple
Expert
Drone Settings
Type of mission:
Aerial Photo
Amount
1 Photo
Resolution:
720p
Choose building
Oude Kerk
Church
Oude Markt 32, 7511 GB Enschede
€5,00/Photo + €0,29/Flight Minute
Back
Next
Help Function
Configure Mission
When you have chosen a building informationa about that building will be shown.
Back
Next
N
W
E
Z

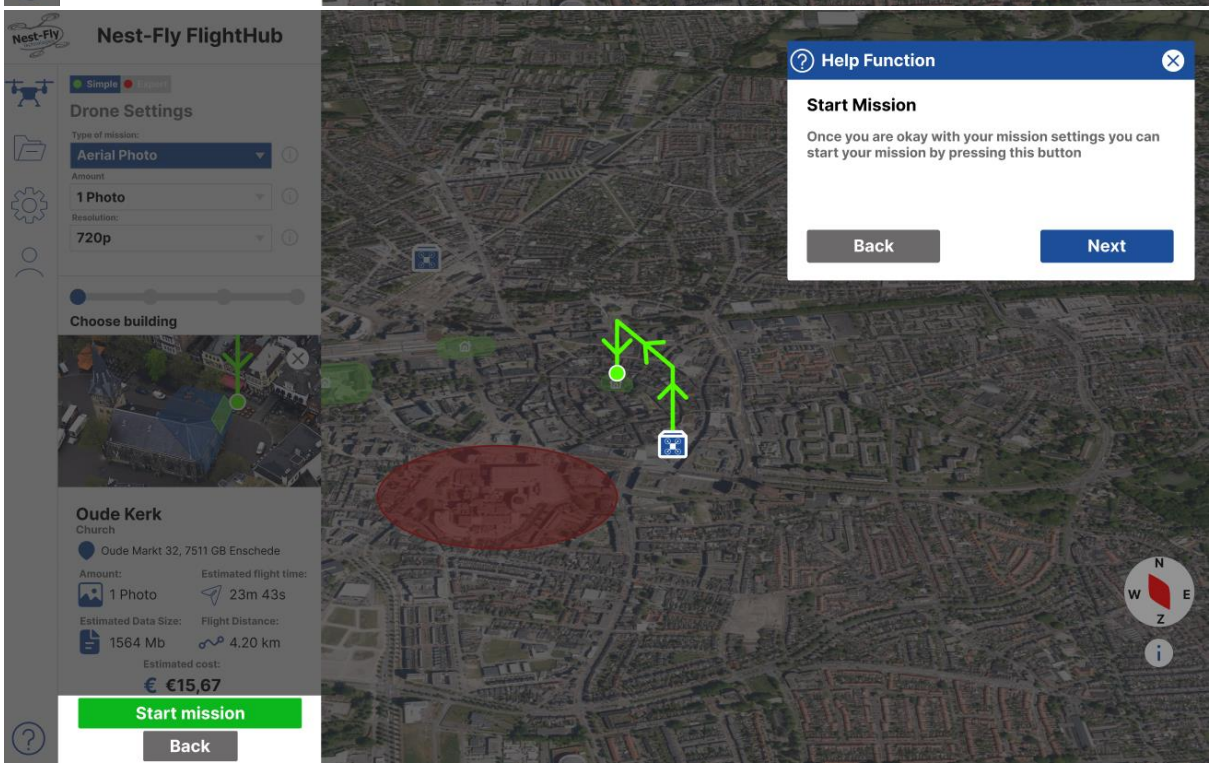

Nest-Fly FlightHub
Drone Settings
Aerial Photo
1 Photo
720p
Choose building
Oude Kerk
Church
Oude Markt 32, 7511 GB Enschede
€5,00/Photo + €0,29/Flight Minute
Back
Next
Help Function
Configure Mission
You can then click on next to configure your mission, or click back to choose a different building
Back
Next

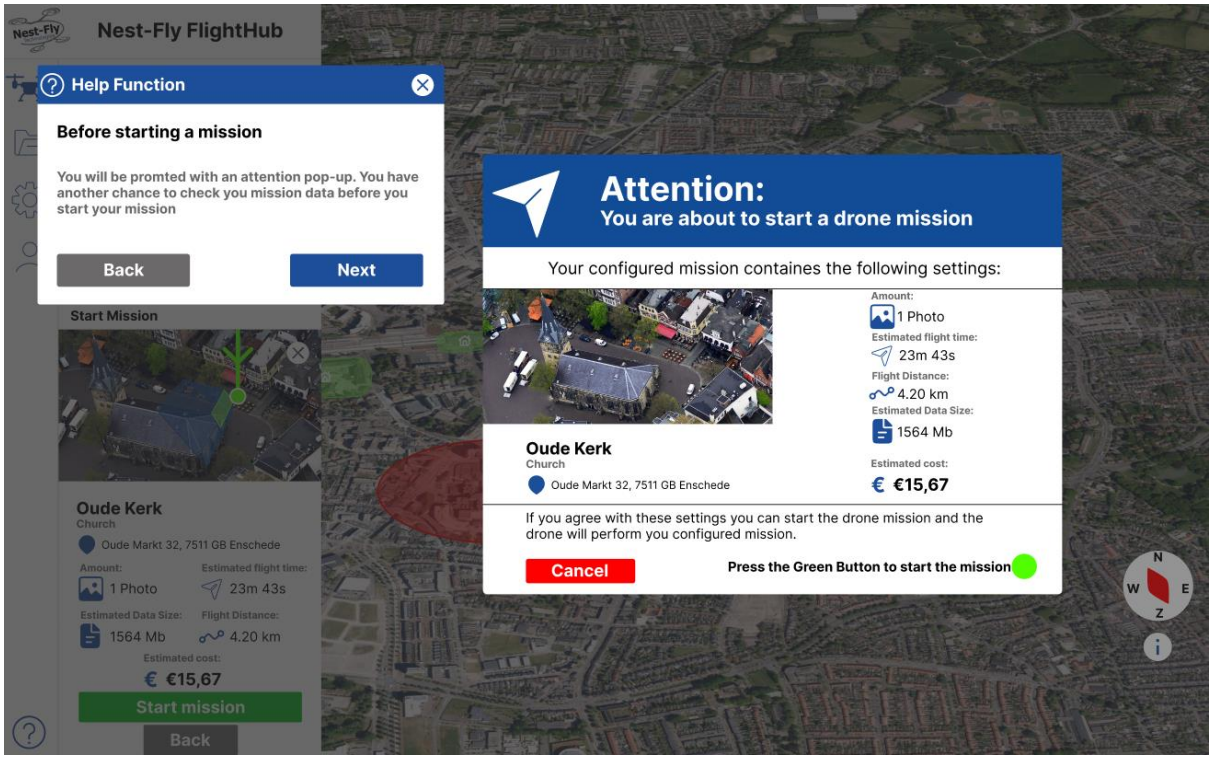

Nest-Fly FlightHub
Drone Settings
Aerial Photo
1 Photo
720p
Choose camera angle
Oude Kerk
Church
Oude Markt 32, 7511 GB Enschede
€5,00/Photo + €0,29/Flight Minute
Choose from which angle you would like to have your photo taken.
Back
Next
Help Function
Configure Mission
You are able to adjust the camera angle of the picture you want to take of your chosen building. By hovering the green area you can see a preview
Back
Next

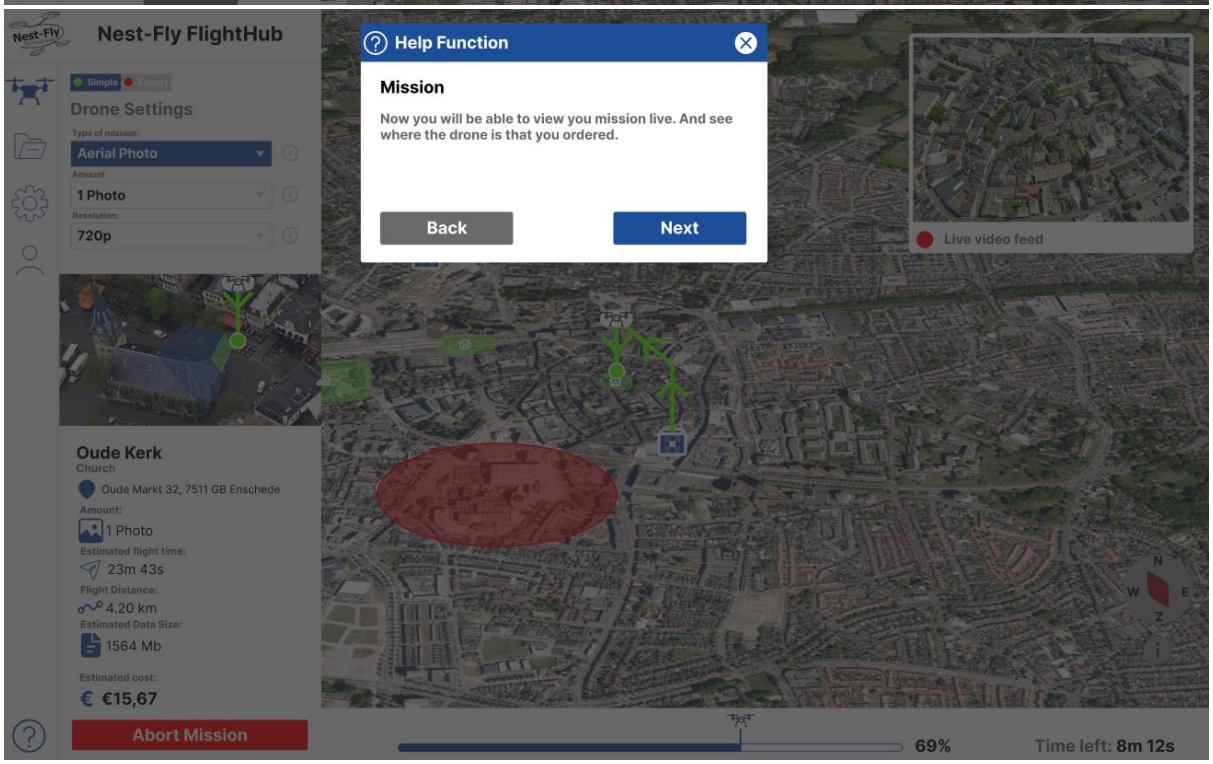

Nest-Fly FlightHub
Drone Settings
Aerial Photo
1 Photo
720p
Choose camera angle
Oude Kerk
Church
Oude Markt 32, 7511 GB Enschede
€5,00/Photo + €0,29/Flight Minute
Choose from which angle you would like to have your photo taken.
Back
Next
Help Function
Configure Mission
You are able to adjust the camera angle of the picture you want to take of your chosen building. By hovering the green area you can see a preview
Back
Next

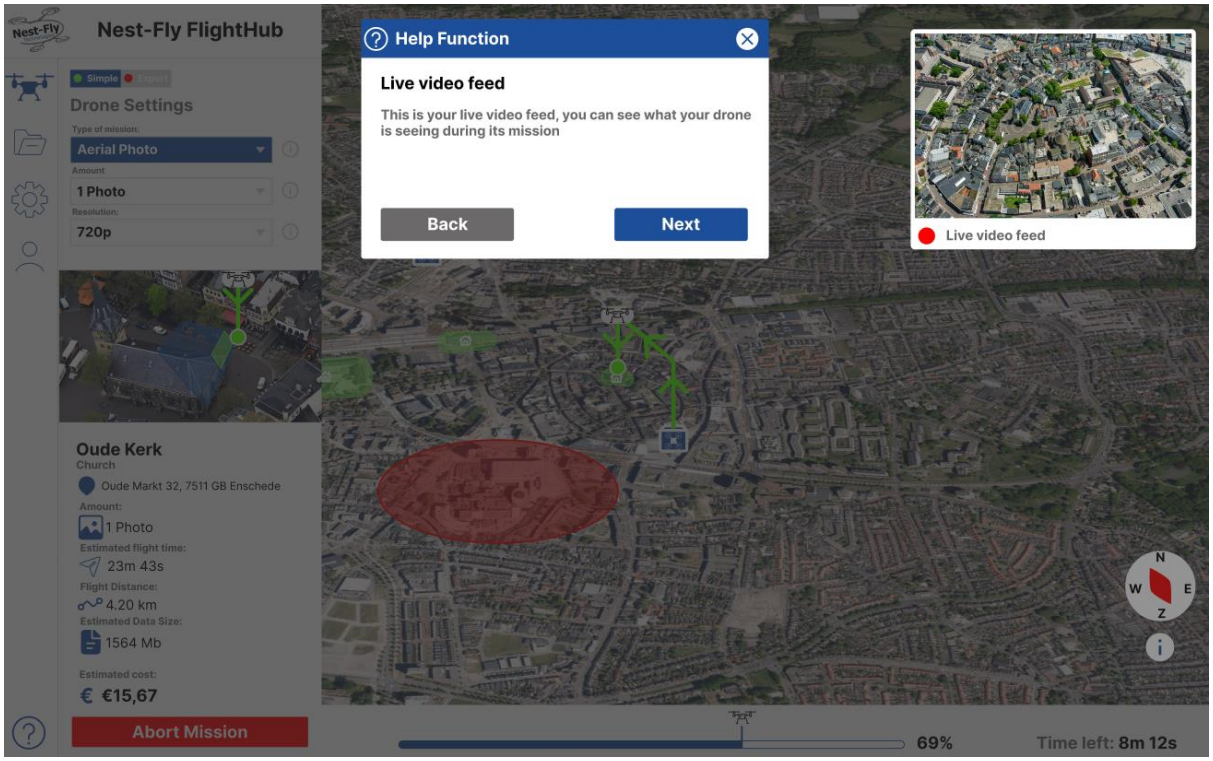

Nest-Fly FlightHub
Drone Settings
Aerial Photo
1 Photo
720p
Choose camera angle
Oude Kerk
Church
Oude Markt 32, 7511 GB Enschede
€5,00/Photo + €0,29/Flight Minute
Choose from which angle you would like to have your photo taken.
Back
Next
Help Function
Generate Flight Path
Now that everything has been configured you can let a flight path be generated for you by clicking next. You can also go back to reconfigure your camera angle.
Back
Next

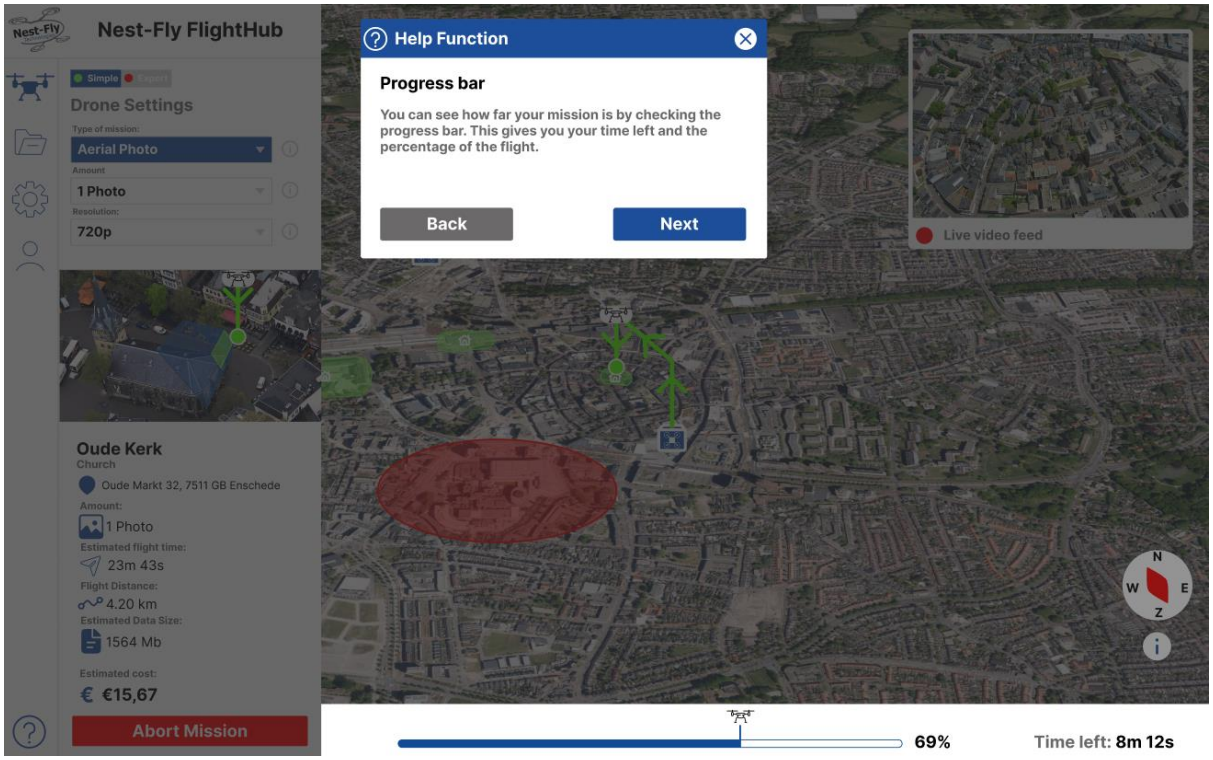

Nest-Fly FlightHub
Drone Settings
Aerial Photo
1 Photo
720p
Check settings, details and flight path
Oude Kerk
Church
Oude Markt 32, 7511 GB Enschede
Amount:
1 Photo
Estimated flight time:
23m 43s
Estimated Data Size:
1564 Mb
Flight Distance:
4.20 km
Estimated cost:
€ €15,67
Back
Next
Help Function
Flight Path
You can now see your flight path which has been generated for you. You can also find extra info about your mission on the left side.
If you are satisfied with your mission details you can click next. When you want to reconfigure, click back.
Back
Next

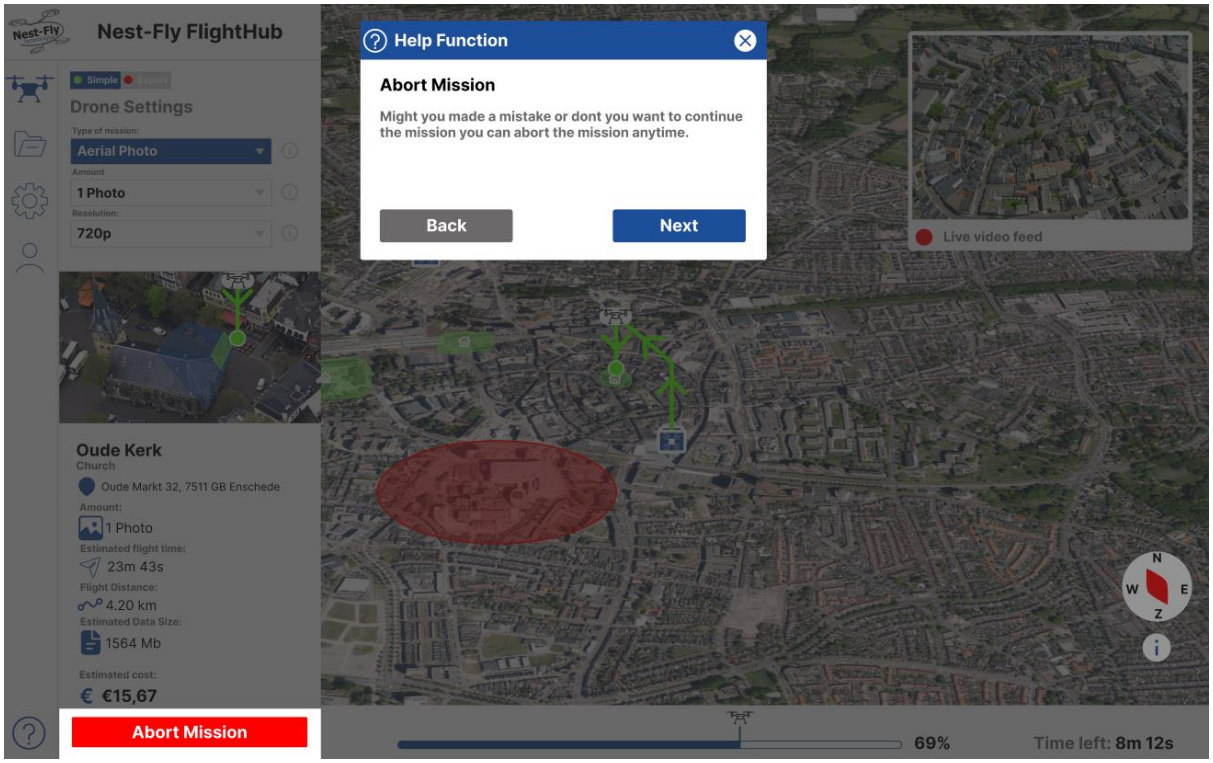

Nest-Fly FlightHub
Drone Settings
Aerial Photo
1 Photo
720p
Choose building
Oude Kerk
Church
Oude Markt 32, 7511 GB Enschede
Amount:
1 Photo
Estimated flight time:
23m 43s
Estimated Data Size:
1564 Mb
Flight Distance:
4.20 km
Estimated cost:
€ €15,67
Start mission
Back
Help Function
Start Mission
Once you are okay with your mission settings you can start your mission by pressing this button
Back
Next

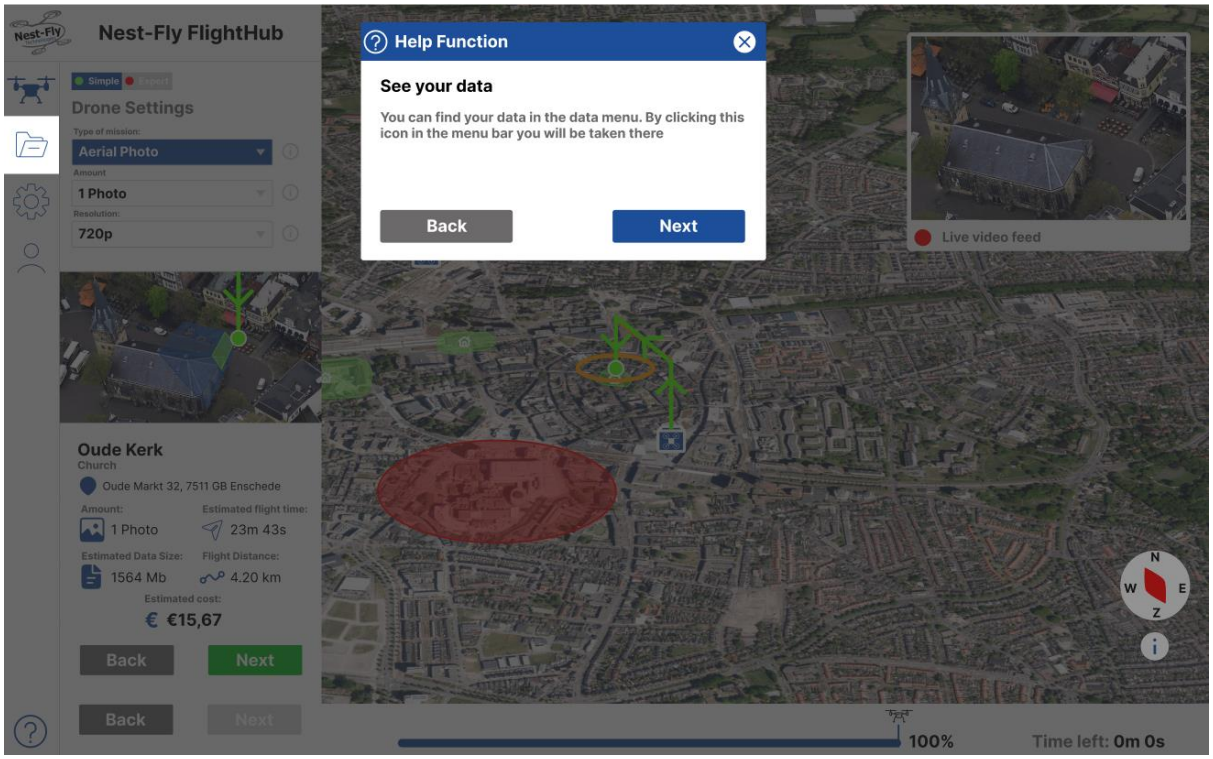

Nest-Fly FlightHub
Help Function
Before starting a mission
You will be promted with an attention pop-up. You have another chance to check you mission data before you start your mission
Back
Next
Start Mission
Oude Kerk
Church
Oude Markt 32, 7511 GB Enschede
Amount:
1 Photo
Estimated flight time:
23m 43s
Estimated Data Size:
1564 Mb
Flight Distance:
4.20 km
Estimated cost:
€ €15,67
Start mission
Back
Attention:
You are about to start a drone mission
Your configured mission containes the following settings:
Oude Kerk
Church
Oude Markt 32, 7511 GB Enschede
Amount:
1 Photo
Estimated flight time:
23m 43s
Flight Distance:
4.20 km
Estimated Data Size:
1564 Mb
Estimated cost:
€ €15,67
If you agree with these settings you can start the drone mission and the drone will perform you configured mission.
Cancel
Press the Green Button to start the mission

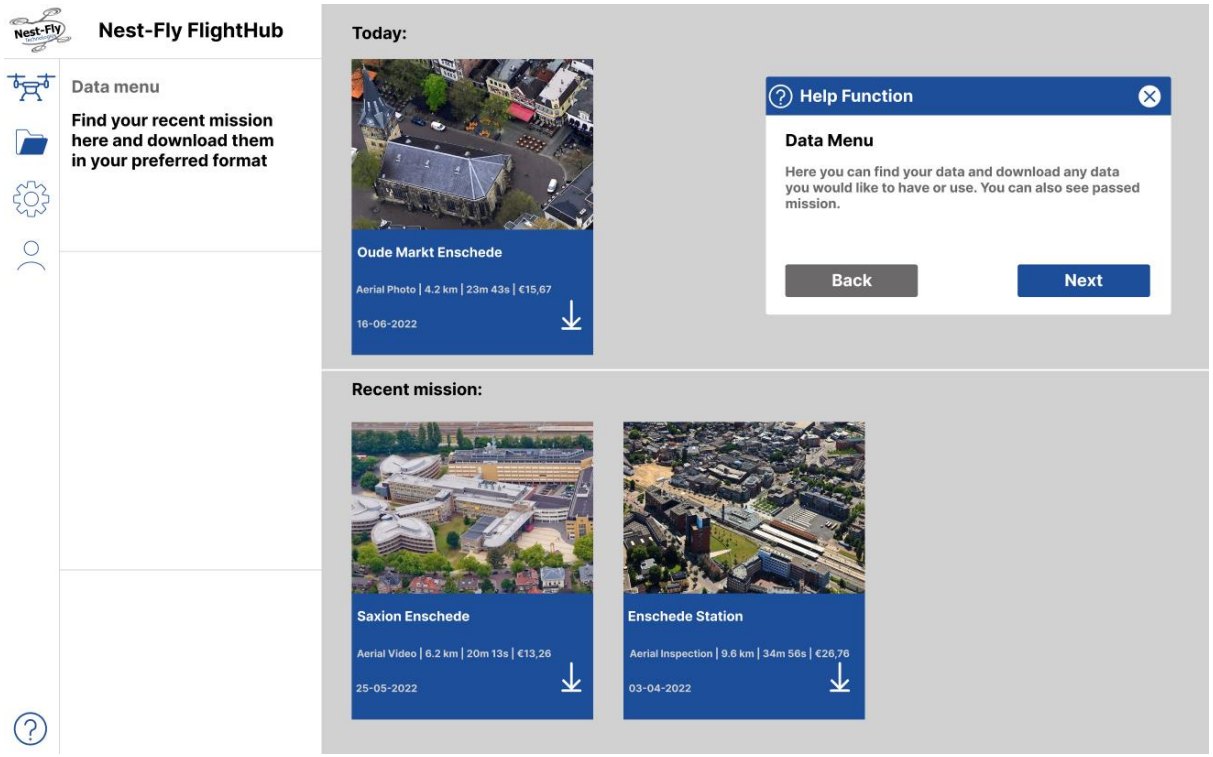

Nest-Fly FlightHub
Drone Settings
Type of mission:
Aerial Photo
Amount
1 Photo
Resolution:
720p
Oude Kerk
Church
Oude Markt 32, 7511 GB Enschede
Amount:
1 Photo
Estimated flight time:
23m 43s
Flight Distance:
4.20 km
Estimated Data Size:
1564 Mb
Estimated cost:
€ €15,67
Abort Mission
Help Function
Mission
Now you will be able to view you mission live. And see where the drone is that you ordered.
Back
Next
Live video feed
69%
Time left: 8m 12s

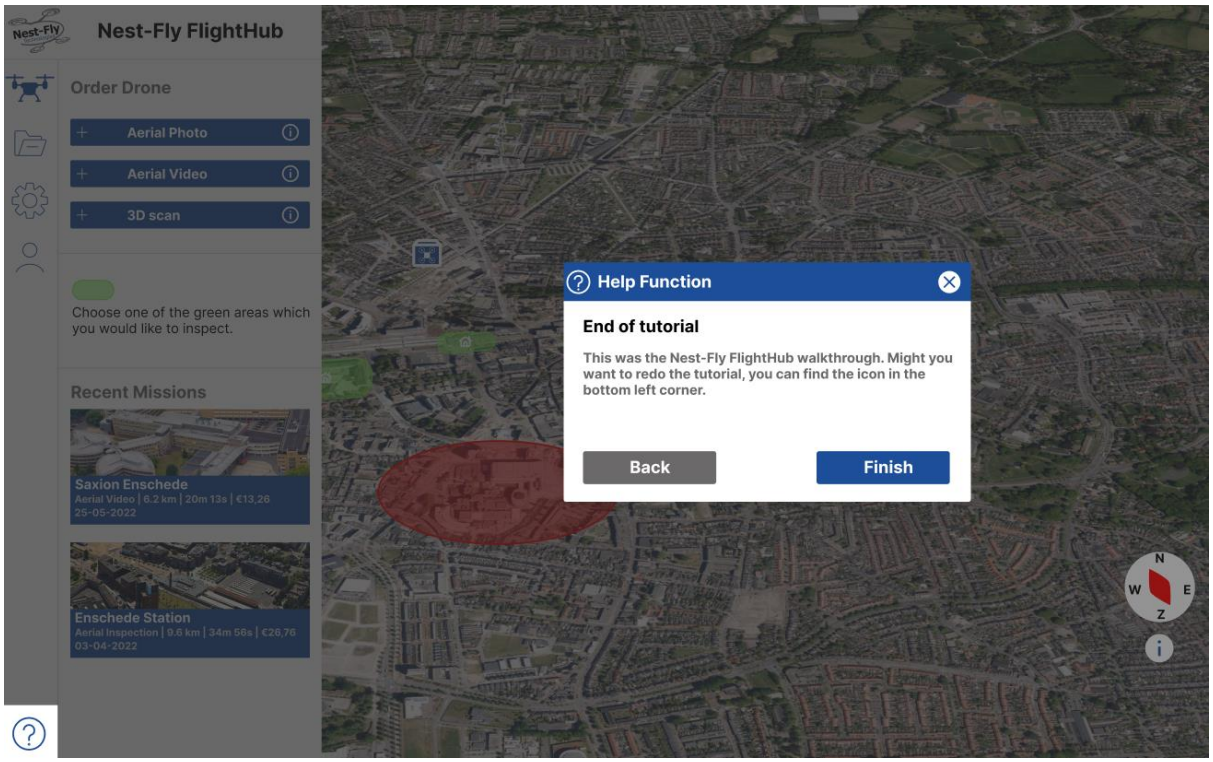

Nest-Fly FlightHub
Drone Settings
Aerial Photo
1 Photo
720p
Oude Kerk
Church
Oude Markt 32, 7511 GB Enschede
1 Photo
23m 43s
4.20 km
1564 Mb
€15,67
Abort Mission
Help Function
Live video feed
This is your live video feed, you can see what your drone is seeing during its mission
Back
Next
Live video feed
69%
Time left: 8m 12s


Nest-Fly FlightHub
Drone Settings
Aerial Photo
1 Photo
720p
Oude Kerk
Church
Oude Markt 32, 7511 GB Enschede
1 Photo
23m 43s
4.20 km
1564 Mb
€15,67
Abort Mission
Help Function
Progress bar
You can see how far your mission is by checking the progress bar. This gives you your time left and the percentage of the flight.
Back
Next
Live video feed
69%
Time left: 8m 12s


Nest-Fly FlightHub
Drone Settings
Aerial Photo
1 Photo
720p
Oude Kerk
Church
Oude Markt 32, 7511 GB Enschede
1 Photo
23m 43s
4.20 km
1564 Mb
€15,67
Abort Mission
Help Function
Abort Mission
Might you made a mistake or dont you want to continue the mission you can abort the mission anytime.
Back
Next
Live video feed
69%
Time left: 8m 12s


Nest-Fly FlightHub
Drone Settings
Aerial Photo
1 Photo
720p
Oude Kerk
Church
Oude Markt 32, 7511 GB Enschede
1 Photo
23m 43s
1564 Mb
4.20 km
€15,67
Back
Next
Back
Next
Help Function
See your data
You can find your data in the data menu. By clicking this icon in the menu bar you will be taken there
Back
Next
Live video feed
100%
Time left: 0m 0s


Nest-Fly FlightHub
Data menu
Find your recent mission here and download them in your preferred format
Today:
Oude Markt Enschede
Aerial Photo | 4.2 km | 23m 43s | €15,67
16-06-2022
Help Function
Data Menu
Here you can find your data and download any data you would like to have or use. You can also see passed mission.
Back
Next
Recent mission:
Saxion Enschede
Aerial Video | 6.2 km | 20m 13s | €13,26
25-05-2022
Enschede Station
Aerial Inspection | 9.6 km | 34m 56s | €26,76
03-04-2022


Nest-Fly FlightHub
Order Drone
Aerial Photo
Aerial Video
3D scan
Choose one of the green areas which you would like to inspect.
Recent Missions
Saxion Enschede
Aerial Video | 6.2 km | 20m 13s | €13,26
25-05-2022
Enschede Station
Aerial Inspection | 9.6 km | 34m 56s | €26,76
03-04-2022
Help Function
End of tutorial
This was the Nest-Fly FlightHub walkthrough. Might you want to redo the tutorial, you can find the icon in the bottom left corner.
Back
Finish
N
W
E
Z

Appendix 8 – Pre- and Post-Test interview & Usability Test

User Interface | Semi-Structred Interview

Hello! This form will be used to make notes about the usability study, and the questions will be asked by the researcher to the participant

The results will be anonymous.

Pre-Testing Questions

Before we start the interview, some questions will be asked about your pre existing experience with interfaces

1. What apps and websites do you use on a regular basis?

Tick all that apply.

- [ ] Youtube
- [ ] Instagram
- [ ] Linkedin
- [ ] Facebook
- [ ] Snapchat
- [ ] Whatsapp
- [ ] Spotify
- [ ] Other: _____

2. What device do you typically use to use these apps and websites?

Tick all that apply.

- [ ] Mobile Phone
- [ ] Tablet
- [ ] Laptop
- [ ] Stationary Computer
- [ ] Other: _____

3. How often do you use these apps and websites per day?

Mark only one oval.

1	2	3	4	5	6	7	8	9	10	
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Hours

4. Have you ever used a drone interface before?

Mark only one oval.

- ◯ Yes
- ◯ No
- ◯ Other: _____

5. If yes, what drone interface did or do you use?

Tick all that apply.

- ☐ None
- ☐ DJI
- ☐ QGroundControl
- ☐ MissionPlanner
- ☐ Other: _____

6. What device did or do you typically use to use these drone interfaces?

Tick all that apply.

- ☐ None
- ☐ Mobile Phone
- ☐ Tablet
- ☐ Laptop
- ☐ Stationary Computer
- ☐ Other: _____

7. How often did or do you use these drone interfaces per week?

Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Hours

Post-test questions 1

8. What features do you find most valuable and why?

9. What prevented you from completing a task?

Post-test questions 2

After the usability test come a couple questions about the interface and what has come up during the test

10. How clear where the test assignments?

Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Unclear	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Clear

11. How would you describe your overall experienc with this interface?

Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Bad	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Good

12. If you would change things in this interface, what would it be and why?

Usability Test

During this usability test you will be asked to perform a number of tasks with the interface. This will take around 30 minutes to complete, if you have any questions please ask them. During the usability test I would like you to ask to think out loud, this way I am able to think along with you and find any problems with the interface. Here it is possible that I will ask you some questions to further specify your thoughts about the interface. Also I will be asking you questions whenever I need any extra clarification about your actions or thoughts about the interface.

Lastly you are free to refuse answering questions and you can withdraw from the study at any time, without having to give a reason.

Any questions beforehand?

We will start with some questions before we start to further scope down your experience level with interfaces and drone interfaces.

We will move on to the usability test, here I will ask you to perform a number of tasks. During these task I would like to ask you to think out loud. This way I can know what your thoughts are about the interface, I will also ask you questions to further specify your thoughts about the interface.

Any questions beforehand?

Tasks:

1. Could you walk through the help function of the interface?

2. Can you order a drone for me to inspect this (points at one of the buildings) building?

3. Can you order a drone for me to inspect this (points at one of the buildings) building and while it is inspecting change the camera view to a point of your interest?

Thank you, this was the usability test. We will now move on to the post test questions, do you have any questions before we start with the next section?

End usability test, now I will give you a short debriefing and you can ask any questions you still have left about the research or interface.

Appendix 9 – Ethical consent forms

Consent Form for Usability Testing of User Interface for Drone Docking System Network

YOU WILL BE GIVEN A COPY OF THIS INFORMED CONSENT FORM

Please tick the appropriate boxes	**Yes**	**No**
Taking part in the study		
I have read and understood the study information dated [07/06/2022], or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	○	○
I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	○	○
I understand that participating in the study involves the exploratory research of a Drone Docking System interface where I will be asked questions about my experience with interfaces, drone interfaces and questions about how a drone interface can be constructed. Next that I understand that I will be reviewing a already existing drone docking system interface. Also, I understand that written notes are taken about my answers and opinions.	○	○
Use of the information in the study		
I understand that information I provide will be used for the further development of an interface, for showing results of the questionnaire and review, and for writing a graduation report. This can be in the form of notes, quotes, summarized answers, tables, problem points, and more.	○	○
Future use and reuse of the information by others		
I give permission for the exploratory research that I provide to be archived in the form of anonymous notes and anonymous questionnaires in *C:\Users\Dick Dekker\Documents\Creative Technology\Year 4\Graduation Project\User Evaluation Results* so it can be used for future research and learning.	○	○

Signatures

_____	_____	_____
Name of participant [printed]	Signature	Date

I have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

_____	_____	_____
Researcher name [printed]	Signature	Date

UNIVERSITY OF TWENTE.

Consent Form for Usability Testing of User Interface for Drone Docking System Network

YOU WILL BE GIVEN A COPY OF THIS INFORMED CONSENT FORM

Please tick the appropriate boxes	**Yes**	**No**
Taking part in the study		
I have read and understood the study information dated [06/06/2022], or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	○	○
I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	○	○
I understand that participating in the study involves the usability test of a Drone Docking System interface where I will perform tasks like ordering a drone and reviewing drone data. Also, I understand that written notes are taken about my actions and thoughts, followed up with an interview about my user experience, performed by the researcher, where notes are taken about your answers.	○	○
Use of the information in the study		
I understand that information I provide will be used for the further development of an interface, for showing results of usability testing, and for writing a graduation report. This can be in the form of notes, quotes, summarized answers, tables, problem points, and more.	○	○
Future use and reuse of the information by others		
I give permission for the usability results that I provide to be archived in the form of anonymous notes and anonymous questionnaires in *C:\Users\Dick Dekker\Documents\Creative Technology\Year 4\Graduation Project\User Evaluation Results* so it can be used for future research and learning.	○	○

Signatures

_____	_____	_____
Name of participant [printed]	Signature	Date

I have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

_____	_____	_____
Researcher name [printed]	Signature	Date

UNIVERSITY OF TWENTE.

Study contact details for further information: Dick Dekker, d.p.dekker@student.utwente.nl

Contact Information for Questions about Your Rights as a Research Participant

If you have questions about your rights as a research participant, or wish to obtain information, ask questions, or discuss any concerns about this study with someone other than the researcher(s), please contact the Secretary of the Ethics Committee Information & Computer Science: ethicscommittee-CIS@utwente.nl

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Appendix 10 – Evaluation 1 Results

Participant 1		
Pre-Test questions	*Usability Test*	*Post test interview*
What apps and websites do you use on a regular basis?	**Walk through of help function**	**What features do you find most valuable and why?**
Youtube	Pop up not centered	Map, however needs more functionality, like chaning view and controlling the map
Instagram	typing mistake, an should be any	Map, everything should be possible to do through the map
Snapchat	unclear guidance arrows	Side bar should be smaller and have a toggle
Whatsapp	**Overall**	presets for non drone users, less options, because you dont know what it is
Discord	A bit all over the place	Quality, speed
Google		Kosten live updaten
Magister	**Ordering a drone for photo**	Tilted view is annoying of the map
	hard to find points of interest	
What device do you typically use these apps and websites?	was not able to click on all buildings	**What prevented you from completing a task?**
Mobile phone	clearly explain points of interest	Not much, was only a bit unintuitive.
Laptop	map can more ways of viewing	Lots of buttons, needs better file location
Stationary computer	Feedback about each point of interest	inspectable building, better naming
	Animation of the mission	What is the relevance of the no-fly zone
How often do you use these apps and websites per day?		User needs to make its own scannable area
5		
		How clear were the test assignments?
Have you ever used a drone interface before?		10
No		
		How would you describe the overall experience with the interface?
		5.5
		Everything is still hardcoded, map doesnt show everything, mission map smaller
		If you would change one thing in the interface, what would it be and why
		Map, more views and change icons
		Icons, see clearly what everything is, explain standard things, search function
		retractable left side

Participant 2		
Pre-Test questions	*Usability Test*	*Post test interview*
What apps and websites do you use on a regular basis?	**Walk through of help function**	**What features do you find most valuable and why?**
Youtube	does not like help functions and skips it	different settings, clearly see what something does with the settings
Whatsapp		this improves usability
Spotify	**Ordering a drone for photo**	Control zoom on the map
Google Chrome	Understand that the green spots are clickable	Help function is fine, but can improve
Firefox	Want to take photo of Oude Markt	rest looked good
	different settings do not work yet	
	expert mode doesnt work yet	
	finds it easily	**What prevented you from completing a task?**
What device do you typically use these apps and websites?	misses mission animation	buttons that did not work
Mobile phone	**overall**	actions that did not work
Laptop	reasonably intuitive	
Stationary computer	some functions did not work	**How clear were the test assignments?**
	unclear	10
How often do you use thesse apps and websites per day?	Mission needs more explanation	
9	You want more control over your taken photo	**How would you describe the overall experience with the interface?**
	Be able to choose your angle of the photo	7
Have you ever used a drone interface before?	How do I pay, where does it go	
No		**If you would change one thing in the interface, what would it be and why**
	Walk through of help function	better map, be able to really choose your own location
	an is any	clearer legend
	More clear arrows	goal of making a picture
	bad navigation	Be able to make specific shots
	does not finish it because he does not click the next menu	choose pictures what you want beforehand

Participant 3		
Pre-Test questions	*Usability Test*	*Post test interview*
What apps and websites do you use on a regular basis?	**Walk through of help function**	**What features do you find most valuable and why?**
Youtube	Clear placement	Home screen, you see everything
Whatsapp	maybe a more bright color	Data is a nice overview
Spotify	Help function closer to arrows	Live view also nice, map is also nice
Google Chrome	Clearer click options	
Outlook	**Overall**	**What prevented you from completing a task?**
Netflix	Good help function	Help, has double function to order drones, could go to one
Rooster app uni	Data menu with extra text is clear	more feedback at hovers, and pop ups to show what what is
Clash royale	Needs clearer arrows	Help function, directly show the legend
Word		Compass needs more explanation
	Ordering a drone for photo	
What device do you typically use these apps and websites?	Slide down menus do not work	**How clear were the test assignments?**
Mobile phone	flight path not clear	9
Laptop	percentage at progress bar	
	text on live view video of the drone	**How would you describe the overall experience with the interface?**
How often do you use thesse apps and websites per day?	**Overall**	8
8	Good	
	End generate flight path	**If you would change one thing in the interface, what would it be and why**
Have you ever used a drone interface before?	progress balk, get dot away and percentage added	Make one path to the mission planning
No		Recent mission + Data mission need to be made
		Expert mode + explanation implementing
		Mission animation
		Mission flight + new plans ones you have started the mission

Participant 4		
Pre-Test questions	*Usability Test*	*Post test interview*
What apps and websites do you use on a regular basis?	**Walk through of help function**	**What features do you find most valuable and why?**
Youtube	No point at end of sentence	map with selection of buildings, lots of info in nice manner
Whatsapp	The help function changes position, this is a bit weird	Menu is clear and has good tabs
Google Chrome	Arrows unclear	
Stack overflow	Niet duidelijk Icon legend	
githy	You can not click the missions in help	**What prevented you from completing a task?**
Gitlab	omcirkelen van objecten mist	Did not know what I had to do at the mission, needs mission animation
Gira	continue aan rechterkant niet links	Show clearly what everything is on te map, with hover or transparent letters
Webstorm		
Intelegie		
Hotmail	**Ordering a drone for photo**	
Quordle	Parameters werken niet	**How clear were the test assignments?**
	Clear what image in the topright corner is, this is video feed	9
What device do you typically use these apps and websites?	progress bar onduidelijk	
Laptop	finish mission, no flyzone hover should be off	**How would you describe the overall experience with the interface?**
	Show what data has been gathered, place this first	7
How often do you use thesse apps and websites per day?	Clearer data stream	
8		**If you would change one thing in the interface, what would it be and why**
	Overall	progress bar in the mission
Have you ever used a drone interface before?	Expert does not work	cross button end screen
No	cross is unclear in the mission planning	Compass needs a north
	explanation at live video feed	
	Get circle away at progress bar	
	progress bar needs drone sign and explanation	
	cross button at concluded mission	
	Show what has been flown today	

Participant 5		
Pre-Test questions	*Usability Test*	*Post test interview*
What apps and websites do you use on a regular basis?	**Walk through of help function**	**What features do you find most valuable and why?**
Youtube	Green areas are unclear	map with selection of buildings, lots of info in nice manner
Instagram	Icon of information not found in help	Wants more info about the building
Linkedin	menus need to work, settings tab	Good menu for choices
Whatsapp	Unclear clicking	Slider should be changed
Reddit	Back button for help function	
Link en Co	**Overall**	**What prevented you from completing a task?**
Mail	Arrows needt to be more clear	Mission start, and mission animation
Calender	more explanation at data	Start mission button is at a weird place
NOS	Box location change is nice	Make start button green
		How clear were the test assignments?
	Ordering a drone for photo	10
What device do you typically use these apps and websites?	Menus do not work, parameter settings	
Mobile Phone	Expert does not work	**How would you describe the overall experience with the interface?**
Laptop	Slider unclear	8
Tablet	Data is not clickable	
	good structure same as take-out	**If you would change one thing in the interface, what would it be and why**
How often do you use thesse apps and websites per day?	Wants to view expert and simple mode	Start mission button should move up and be more clear
10	Data organized per viewed mission	Bigger selection of buildings
	have a choice of camera angle	Show intuitively what each green area building is
Have you ever used a drone interface before?		Flight path visualizer clearer
No		

Appendix 11 – Evaluation 2 Results

Participant 1 (6)		
Pre-Test questions	*Usability Test*	*Post test interview*
What apps and websites do you use on a regular basis?	**Ordering a drone for photo**	**What features do you find most valuable and why?**
Youtube	A click has to be added in the main scree	Live view off progress bar is nice
Whatsapp	Angle of camera was needs to be clearer	Info before you fly is nice
Reddit	info in configure gone	
Google		
	Walk through of help function	**What prevented you from completing a task?**
	Help icon is hard to find	Choosing a camera angle was hard to find
	show legend	Hulp button was hard to find
	Help is very clear	
What device do you typically use these apps and websites?	**Overall**	
Mobile phone	Nice	
Laptop	Menu's do not work	
		How clear were the test assignments?
	Most important points	8
How often do you use thesse apps and websites per day?	Click added to green areas	Did not know what to expect when searching for help function
4	Choosing camera angle can be clearer	**How would you describe the overall experience with the interface?**
	Info in configure gone?	7
Have you ever used a drone interface before?	Help icon is hard to find	
Yes	Show legend in help function	
	menu's do not work	**If you would change one thing in the interface, what would it be and why**
Drone Controller	List of buldings to choose from	Would make a list of buildings to choose from
0 hours a week	3d map would be nice	3D map would be nicer
	help function can be shown at the start	Help function at the beginning

Participant 2 (7)		
Pre-Test questions	*Usability Test*	*Post test interview*
What apps and websites do you use on a regular basis?	**Ordering a drone for photo**	**What features do you find most valuable and why?**
Linkedin	Does not know where to start	The amount of money
facebook	To I need to find the church first or can I select a drone first	mission time
whatsapp	Where is the drone?	Progress bar
Outlook	Generate flight path is hard to find, should be clearer	Live feed camera
Weather apps	Drone docking stations have unclear icons	Side bar clear
Snelstart booking	Red areas on map are for experts is thought	Would like to see how the data can be saved
Rabobank	Show which mission has been flown in the data	
	Overall	**What prevented you from completing a task?**
What device do you typically use these apps and websites?	I am missing the drone in the interface, where can I choose a	The configure menu for camera angle does not have good feedback
Mobile phone	New drone mission or order drone	You are suddenly taken there
Laptop	Nice data and animation	Config menu needs clear feedback
	more feedback at config menu	The green was a bit unclear compared to the red
	Steps are stationairy, wants undo	No clear start of the interface, where do you start your interaction
How often do you use thesse apps and websites per day?		Add clear start to the interface
3		Add icons to green areas
	Walk through of help function	**How clear were the test assignments?**
Have you ever used a drone interface before?	Fastly found the help button	8.5
Have seen some but not interacted, only with controller	Word: hover, is this for drones or the mouse?	**How would you describe the overall experience with the interface?**
Knows the one from Deck180	Legend should be shown	6
However 0 hours a week	Mission --> Drone mission	Unclear starting point and no clear feedback in config menu
	Privacy of live feed is questionable	**If you would change one thing in the interface, what would it be and why**
	Uploaden/downloaden off data	Clear starting point of the interface
	Would not use a help function himself, but thisone was clear	Button saying "order drone"
		Drone boxes icon clearer with drone inside
	Be able to inspect bigger areas	Weather conditions can be shown for flight
	Be able to fill in adress	Search tab
	Aerial inspection term is unclear, what does it mean?	Undo button
		çlearer feedback in choosing camera angle

Participant 3 (8)		
Pre-Test questions	*Usability Test*	*Post test interview*
What apps and websites do you use on a regular basis?	**Ordering a drone for photo**	**What features do you find most valuable and why?**
Youtube	Where is the drone, looking for a drone to order	Choosing of camera angle and the visualisation of it
instagram	Green area needs to be clickable	Grey to green of generate flight path is very clear
Snapchat	ordering drone is unclear	Setting and progress bar are nice
Whatsapp	What is the goal of interface, ordering a foto or ordering a dr	Pictures are clear
Safari	The configure menu is clear	Data after the mission can be clearer
Google	No back function for the menus	
Solidworks	Data at end of mission is unclear, do I get it on the mail	
Ios	Afraid to click away the prompt to loose the data	
Call Of Duty	Can not download datat or share it	**What prevented you from completing a task?**
Playstation	No size of the data	wanting to order a drone and seeing create mission is weird
Xbox	Side bar is clear	Drone should come more to the front in interface
Windows	Drone should be more present in the interface	Make clear what the start of the interface is
		Data at the end needs more features
	Help function	
What device do you typically use these apps and websites?	Clear	**How clear were the test assignments?**
Mobile phone	Hover, is that for mouse or drone?	8
Laptop	Might should be if (I do not agree however)	
Playstation	Straight lines with angles map conflict	**How would you describe the overall experience with the interface?**
How often do you use thesse apps and websites per day?	3D map would be great	7
8.5	Very clear!	
		If you would change one thing in the interface, what would it be and why
Have you ever used a drone interface before?		More map views, illustrative map
No		3D map
		Compass can be nicer
		Colors, does not feel like a drone interface yet

Participant 4 (9)		
Pre-Test questions	*Usability Test*	*Post test interview*
What apps and websites do you use on a regular basis?	**Ordering a drone for photo**	**What features do you find most valuable and why?**
Instagram	Can not find how to order a drone	Help function helps nicely
Facebook	Green should have clickable optoin	Live feed is nice, you know what is happening
Snapchat	A lot of guessing	Nice program, nicely structured.
Whatsapp	Again looking for a drone	
Spotify	Map should have explanation of green areas and icons for b	**What prevented you from completing a task?**
TikTok		Nope
Cooking websites	Is very clear	My english is not the best
Gmail		
Outlook		
FitBit	**Help function**	
Netflix	Found fast	**How clear were the test assignments?**
Disney Plus	Walkthrough is easy	8 before walking through the help
Chrome	Very clear	10 after walking through the help
Maps	All points are discussed	**How would you describe the overall experience with the interface?**
		8
	Most important points	**If you would change one thing in the interface, what would it be and why**
What device do you typically use these apps and websites?	Open help as pop up when starting the interface	Not really
Laptop	Green areas should be clickable	Open help as pop-up menu at the beginning of the interface
Mobile phone	The drone should come more to the front of the interface	
How often do you use thesse apps and websites per day?	Map should have explanation of green areas	
3.5	Map should have building icons	
Have you ever used a drone interface before?		
no		

Participant 5 (10)		
Pre-Test questions	*Usability Test*	*Post test interview*
What apps and websites do you use on a regular basis?	**Ordering a drone for photo**	**What features do you find most valuable and why?**
instagram	Green is clear in the mission planning	Choosing an angle was nicely done
snapchat	I would do it this way	no unclear bullshit
whatsapp	Camera angle is clear	very usable and intuitive
spotify	Doubt with mission planning/ generate flightpath	
Chrome	Abort mission, did not know what was happening and panicked	
TikTok	Should be given a clear feedback before the mission is start	**What prevented you from completing a task?**
BeReal	Did not understand the drone would be flying	Wanted to make a foto but the mission looked like it was recording a video
Studie Apps		Make clear when mission start and what is going to happen
Sillo	Flow is good	Pop up start mission
Horloge app	Where is the church	
Step counter	Add a search bar	**How clear were the test assignments?**
Bank account app	Good colors	10
Netflix	Good camera angle choosing	
Video land		**How would you describe the overall experience with the interface?**
SPSS	**Help function**	8
Intranet	Hover is for drones or mous?	
	very extensive	**If you would change one thing in the interface, what would it be and why**
What device do you typically use these apps and websites?	Could use specific help when someone is stuck	Search bar to search for adress
Mobile Phone	explain menu bar	example photos and videos
Laptop		
How often do you use thesse apps and websites per day?		
4.5		
Have you ever used a drone interface before?		
No		

Appendix 12 – Demo design process

The demo was created to showcase the impact the technology can have on the industry by bringing it to the user in a safe manner. This process started with the ideation of the demo, followed by a quick specification and ending in the creation of the demo.

12.1 Ideation

Together with the team at Nest-Fly technologies a brainstorm was conducted into how the demonstration would look and what should be included in the demonstration. This resulted in a list of requirements and a set of concepts. Followed by a the presentation of a final concept.

12.1.1 Demo requirements

From the brainstorm with Nest-Fly the following set of requirements was set up (table 12.1).

Table 12.1 List of requirements for the Demo

MoSCoW	Requirement
Must	Easy to transport
Must	Big start button
Must	Wired Mouse
Must	Sticker as table top
Should	Minimum build up time
Could	Raspberry Pi as built in computer
Wont	Fly a circle with the drone

12.1.2 Demo concepts

Using the brainstorm ideas and requirements a set of concepts was created. These can be seen in figure 12.1.

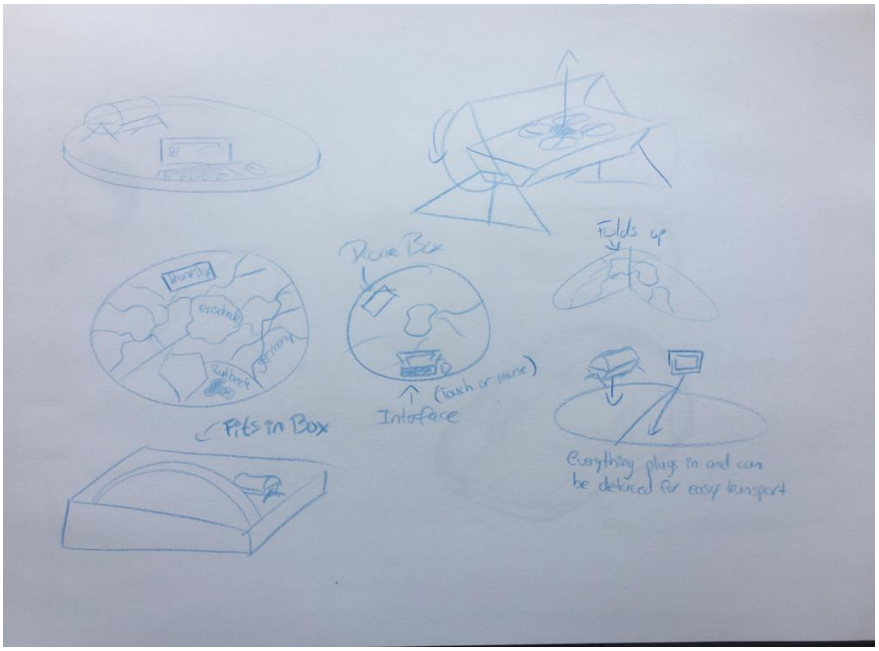

Figure 12.1 Concepts for demo design

12.1.3 Final concept of demo design

The final concept can be found in figure 12.2. Here the drone docking station is situated in the left corner and screen in the middle, the table is covered by a sticker of Ensched\12.2 Specification

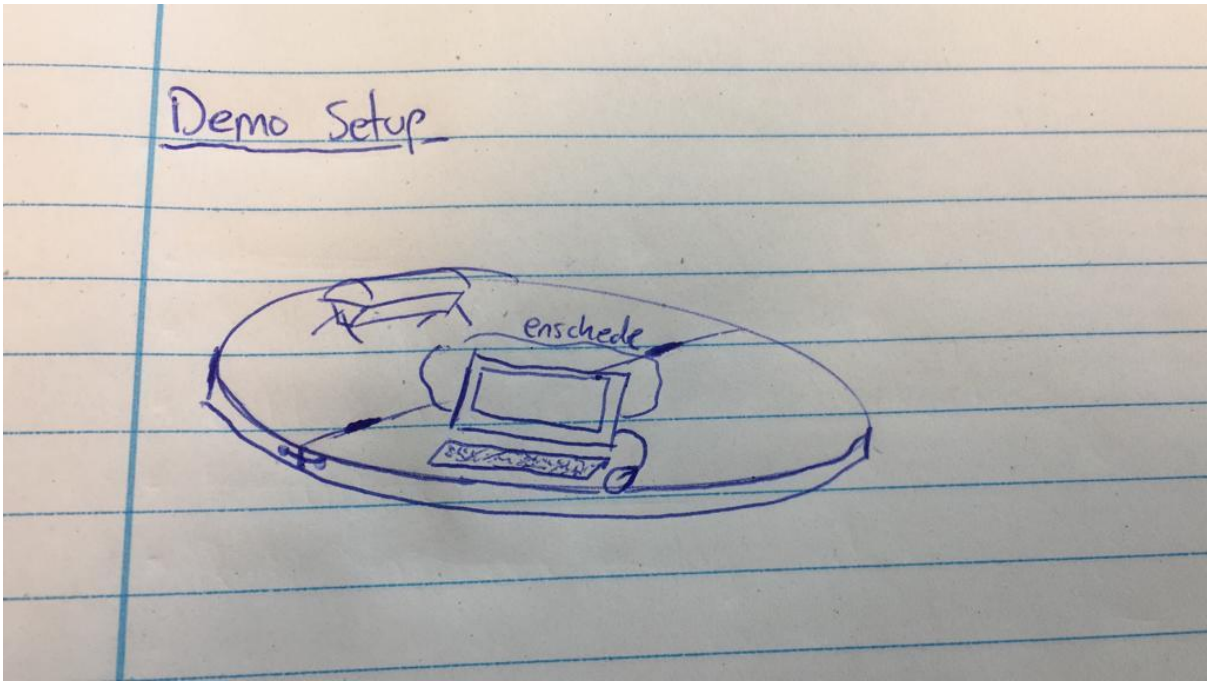

Figure 12.2 Final concept of the demo design

12.2 Specification

During the specification of the demo, the concepts were critically looked after which one concept was chosen to further develop. The refinement of the concept was realised by creating a detailed design in SolidWorks and setting up a list of materials.

12.2.1 Solidworks Design

The SolidWorks design incorporates all parts within the demo and shows where they are placed. This gives a good indication of how the demo will be constructed and what materials are needed for construction. The full design can be seen in figure 12.3.

12.2.3 Electrical circuit

In order to let parts connect to each other, different electronics are needed. These consist of motors (to move the drone docking station lid), microcontrollers (to control the system), buttons (for inputs) and wires. The connections between these components has been visualized in figure 12.4.

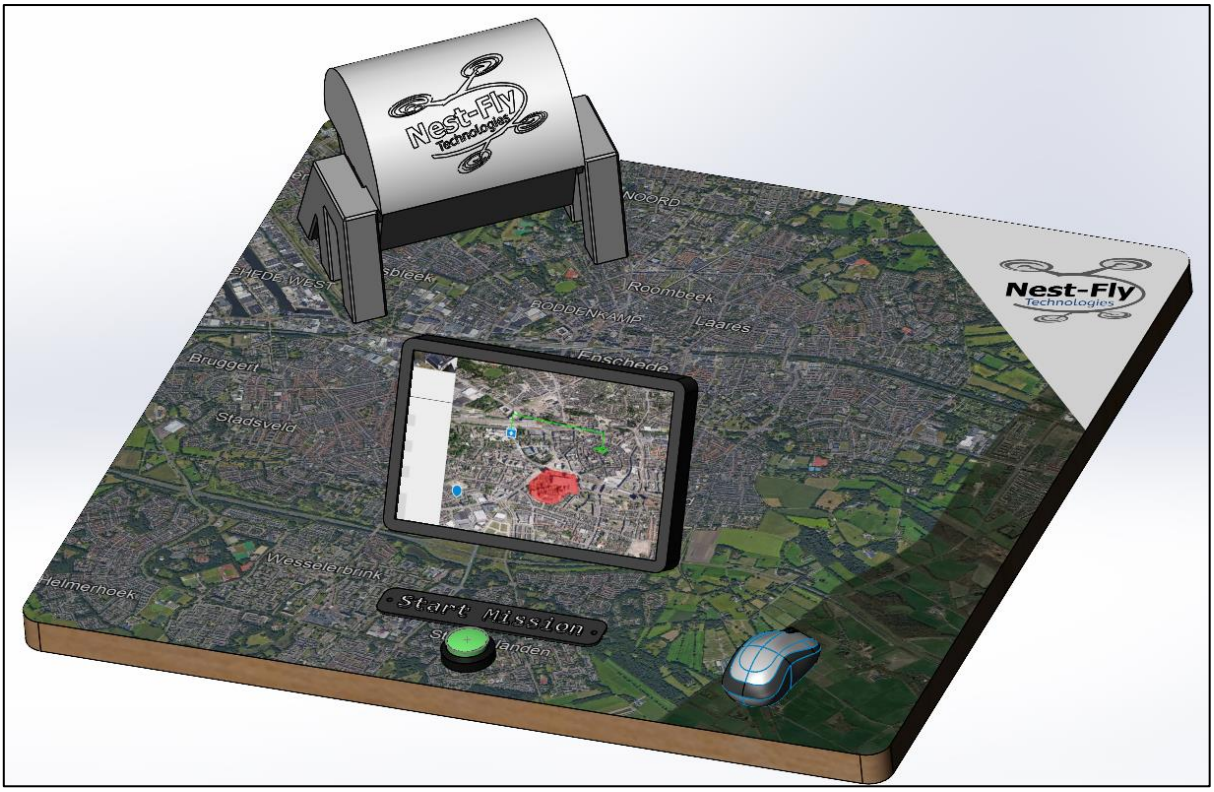

Figure 12.3 Full detailed design of demo in SolidWorks

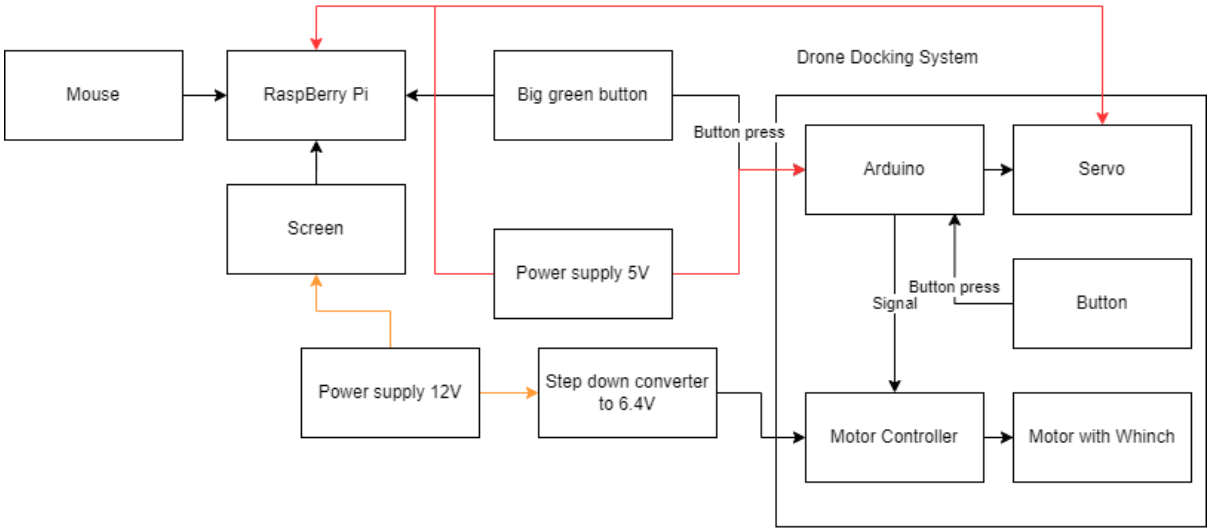

Figure 12.4 Schematic sketch of electronics

12.2.3 List of materials

From the detailed demo design in Solidworks, a list of materials can be set up. This list of materials consists of raw building materials and a set of off the shelf components. This list can be found in table 12.2.

Table 12.2 List of materials for Demo construction

Materials	Amount
Wood for table	1
Hinges	4
Latches	4
Small computer screen	1
Hdmi to analog	1
Micro hdmi to hdmi	1
Raspberry Pi	1
Analog cable	1
Computer mouse	1
Big green button	1
Arduino Nano or Uno	2
Mini Drone	1
Servo motor	1
DC motor	1
Motor driver	1
Big sticker of Enschede	1
Power supply	1
3D filament PETG White and grey	2
Servo motor 9g	1
bax shop corners	1

12.3 Realisation

The realisation of the demo was done using different building techniques like lasercutting, 3D printing, soldering and more. In this section the realisation will be explained and design choices will be shown along the way.

12.3.1 Drone Docking Station

Body

Using a 3D printer, the different parts of the Drone Docking Station were able to be printed. These were design to receive threaded inserts, melted into the plastic to create thread for M3 bolts. This way the legs could be attached to the body and the Drone Docking Station could be secured in place on the table. The lid was made to pressure fit, while still remaining smooth enough to open and close. Resulting in the body of the body of the Drone Docking Station (figure 12.5)

Electronics

The electronics could then be installed into the Drone Docking System as designed in SolidWorks (figure 12.6). These were attached together using the diagram in the specification. To make the system more reliable, the microcontroller was soldered to the different components on a custom PCB.

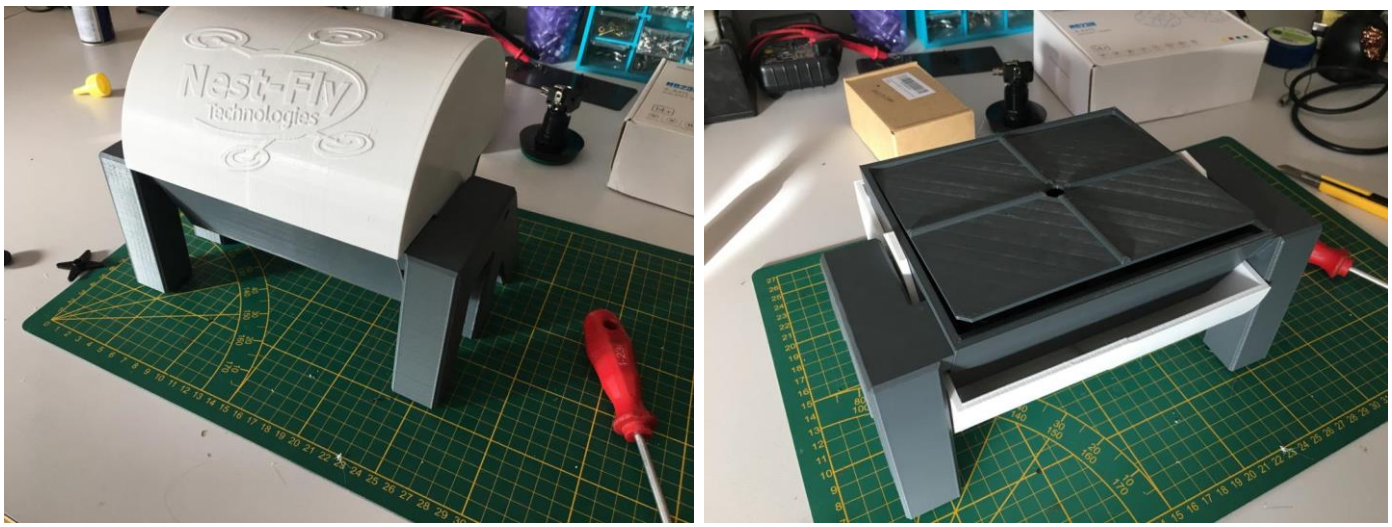

Figure 12.5 Body of the Miniature Drone Docking Station

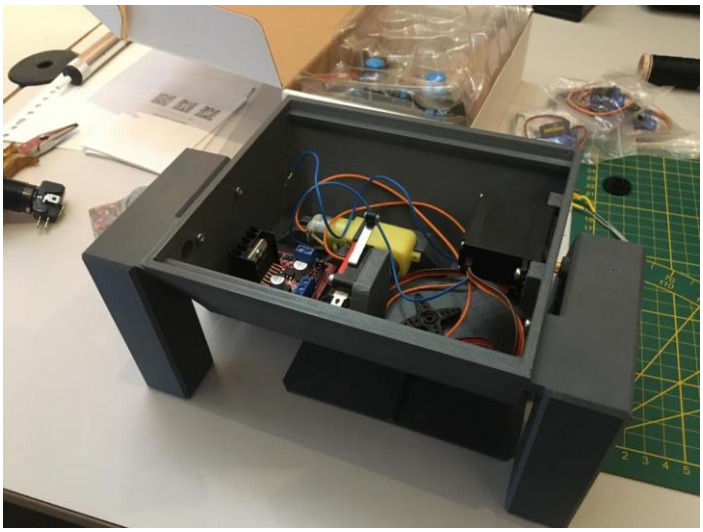

Figure 12.6 Electronics inside the Drone Docking System

12.3.2 Table

The table was constructed out of 3 layers of laser cut wood. These were glued together to create two halves of the table. To make the table foldable, hinges were used to attach the two halves together. On the other side latches were added to secure the table when unfolded (figure 12.7).

Three holes were drilled into the table after finding the rough placement of all components. Two for routing the cables of the Drone Docking station, Computer Screen and Mouse, and one to house the green button. All components were then attached to the table in their designated spots (figure 12.8).

Once everything was secured to the table, everything could be wired together underneath the table based on the earlier showed electrical diagram. This was all needly tugged away out of sight of the user.

Lastly the sticker was added onto the table top to finish of the demo setup (figure 12.9).

Figure 12.7 TableTop of Demo setup

Figure 12.8 Table Top with hinges and components installed

12.3.3 Conclusion of realisation

In figure 12.9 the final interface can be seen. This was created to showcase the technology of a Drone Docking System accompanied by a Graphical User Interface.

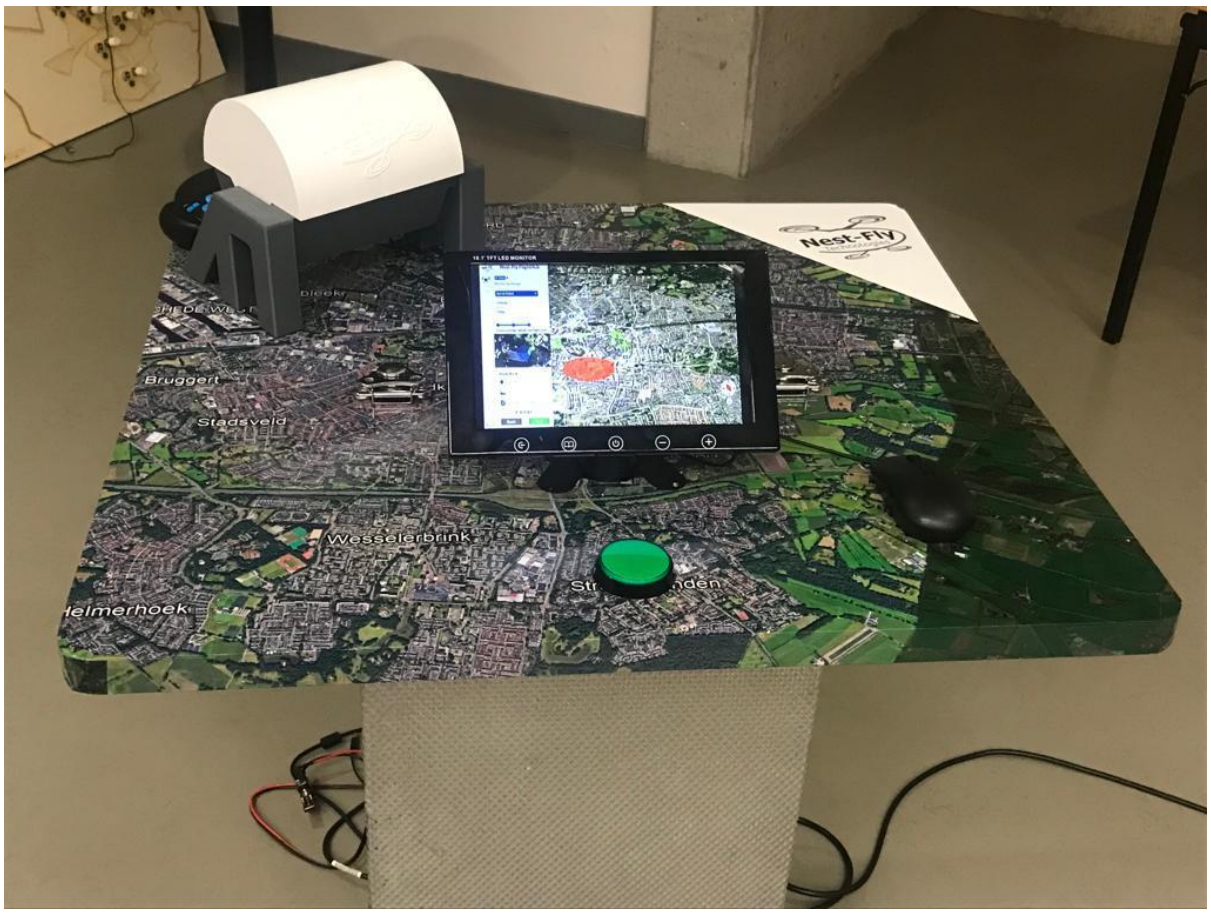

Figure 12.9 Final Demo Setup

Looking back at the requirements setup, not all were able to be implemented. It was found that the Raspberry Pi, which was purchased for this project, was not fast enough to run the interface in Figma. Therefore, this was switched out to a laptop plugged into the HDMI of the screen and connected to the button using an Arduino Uno as keyboard emulator. The table is foldable, however to get is into the box, the drone docking station has to be taken off. This all results in the following list of requirements with their implementations (Table 12.3).

Table 12.3 Demo requirements and their implementation

MoSCoW	Requirement	Implementation
Must	Easy to transport	Foldable table
Must	Big start button	Green pressable button in table
Must	Wired Mouse	Wired to laptop using Arduino Keyboard emulator
Must	Sticker as table top	Vinyl sticker of map of Enschede
Should	Minimum build up time	Table has to be unfolded and Drone Docking Station has to be installed.
Could	Raspberry Pi as built in computer	Not powerful enough
Wont	Fly a circle with the drone	