



QUAERO

designed to search



# QUAERO PROJECT

INDUSTRIAL DESIGN

Autumn 2018

The Oslo School of Architecture and Design (AHO)

Diploma by Farid Sayar

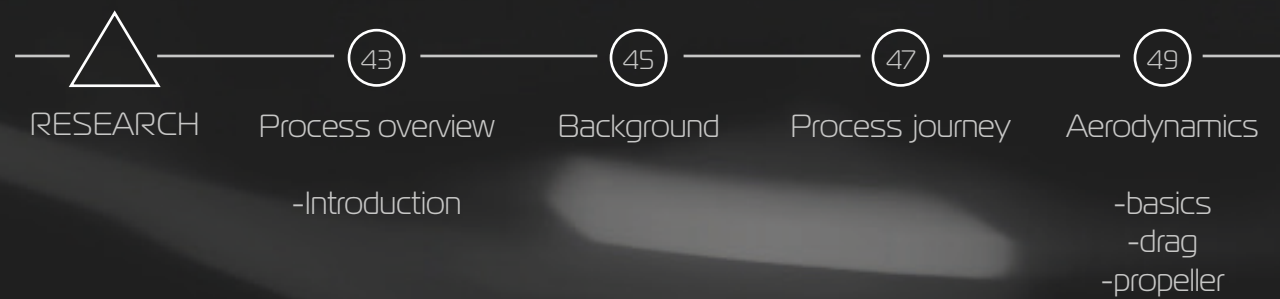
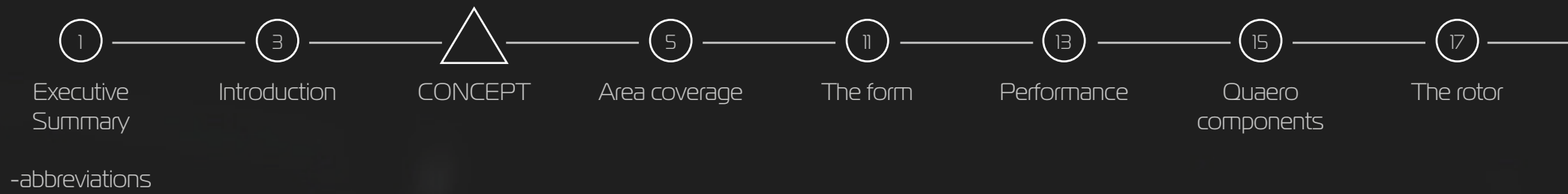
Supervisors: Steinar Killi and Stein Rokseth







# CONTENTS

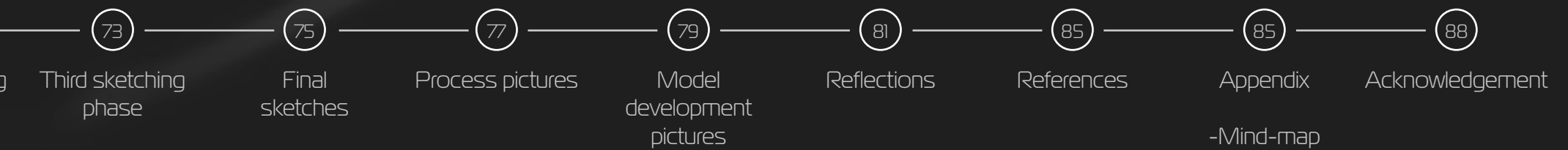
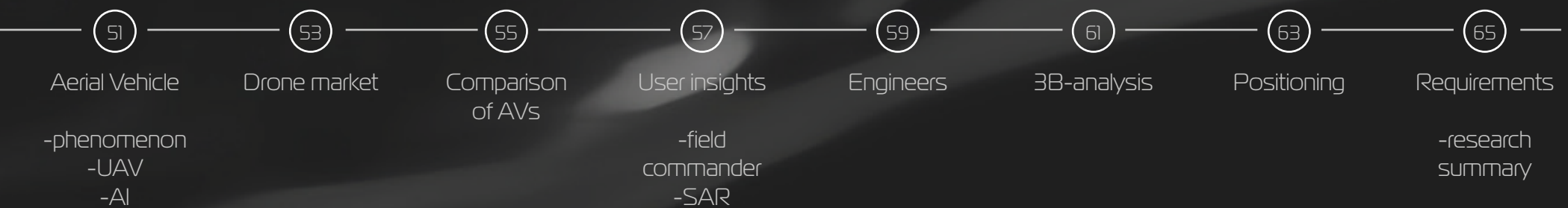


## HOW TO READ THIS REPORT

First part of the report is the presentation of actual concept, the product, its components, features and abilities

Second part is a research process time-line with detailed information about findings and decisions

Final part is documentation of the process



# EXECUTIVE SUMMARY

QUAERO is a concept of a modular mono-copter drone designed mainly for search operations. Distinctive feature of the drone is the possibility to combine several drones into one unit and separate to parts upon arrival to search area. This feature allows to cover more search territory in less time, and can play a huge role in a Search and Rescue operation

Several alike drones can be combined into various different formations before deployment, however a single drone can be used. This concept improves existing solutions by increasing efficiency. It combines vertical take-off and landing function, hover function and remain aerodynamic qualities required for fast and energy efficient travel

Different AI programs will allow this type of drone to be applied in other areas than Search operations, like aerial imaging, 3D-mapping, research, agriculture, policing, maintenance or other automated routine quality check

Advanced software will make it possible for Quaero to regroup while airborne. Each combinatoric formation of the drones should have own program developed, where one drone must be defined as "the main" drone to which all other drones in the formation will relate to for regrouping. Manual program setup or automated recognition is a matter of software complexion level

In general Quaero concept can serve as a base for different appliances in various fields. Commercial, consumer and even military, though that wasn't the aim. It can carry different sensors and cameras. With little improvement it can carry object's like first-aid kit, or safety vest, or what ever might be necessary

Triangular shape of the drone has equal side length with implemented switchable neodymium magnets, making it easy to attach drones. The drone's maneuverability is achieved with Thrust Vectoring coaxial rotor in the middle. It is the same rotor system that lifts the drone vertically and thrusts horizontally



The core of the project is a product I have named Quaero, which means Search in Latin. It's a surveillance aerial vehicle in a Search and Rescue context. I have chosen this topic because it is a growing global problem and becomes more relevant with time. Also because I personally prefer to work with topics that are related to helping people and the society

The approach included design thinking methods and analytical methods. I used engineering creatively, not scientifically to develop the concept and it's form

It was a complicated task with great challenges

## ABBREVIATIONS

AV - aerial vehicle  
UAV - unmanned aerial vehicle  
VTOL - vertical take-off and landing  
RPAS - remotely piloted aircraft system  
UAS - unmanned aircraft system  
SAR - search and rescue  
ESC - electronic speed controller

Thrust - force that moves AV forward  
Yaw - rotation around vertical axis  
Pitch - rotation around horizontal axis perpendicular to thrust vector  
Roll - rotation around thrust vector

# INTRODUCTION

This graduation project is the final work of my five-year academic process at AHO. A self-driven and self-organized independent project of a master degree on an open topic, in which I will show the level of skills and professionalism I have gained during study years as an industrial designer

This Industrial Design work is a creative process with aim to create and develop concept and specifications that optimize the function, value and appearance of product and system for the benefit of users

It includes analytical study of function and form - and the connection between product, user, and environment, and appliance of various design methodologies







# QUAERO

designed to search



# AREA COVERAGE

## CONCEPT

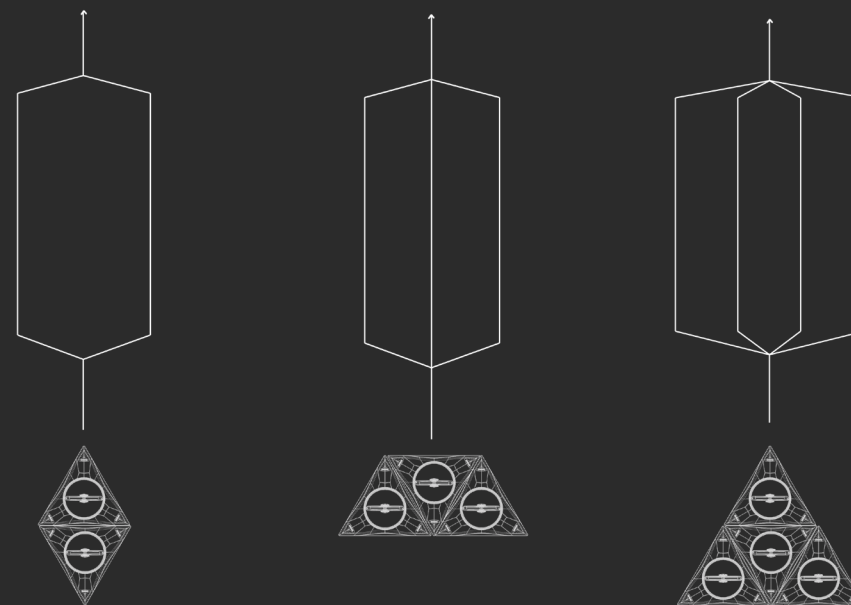
Innovational part of the concept aims to change the fly pattern of an aerial vehicle in a search operation. This traditional pattern is usually used in agriculture, areal mapping and search operation as well. It is usually automated by programming

The new pattern of aerial investigation I suggest will also be programmed into the drone board-computer. Obvious advantage of this pattern is more area coverage in less time. This can be easily calculated by simple math. A reasonable argument here would be "one drone versus several drones is not a fair comparison". And that's what I want to look at more closely:

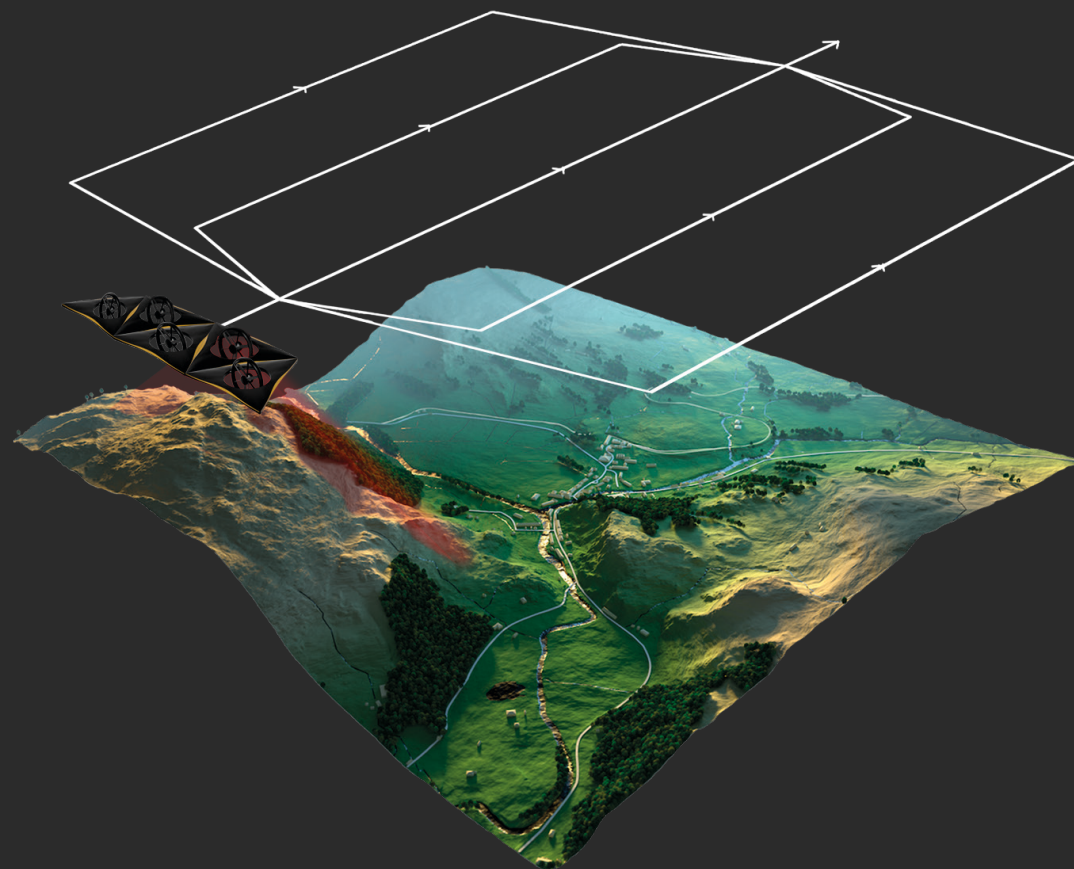
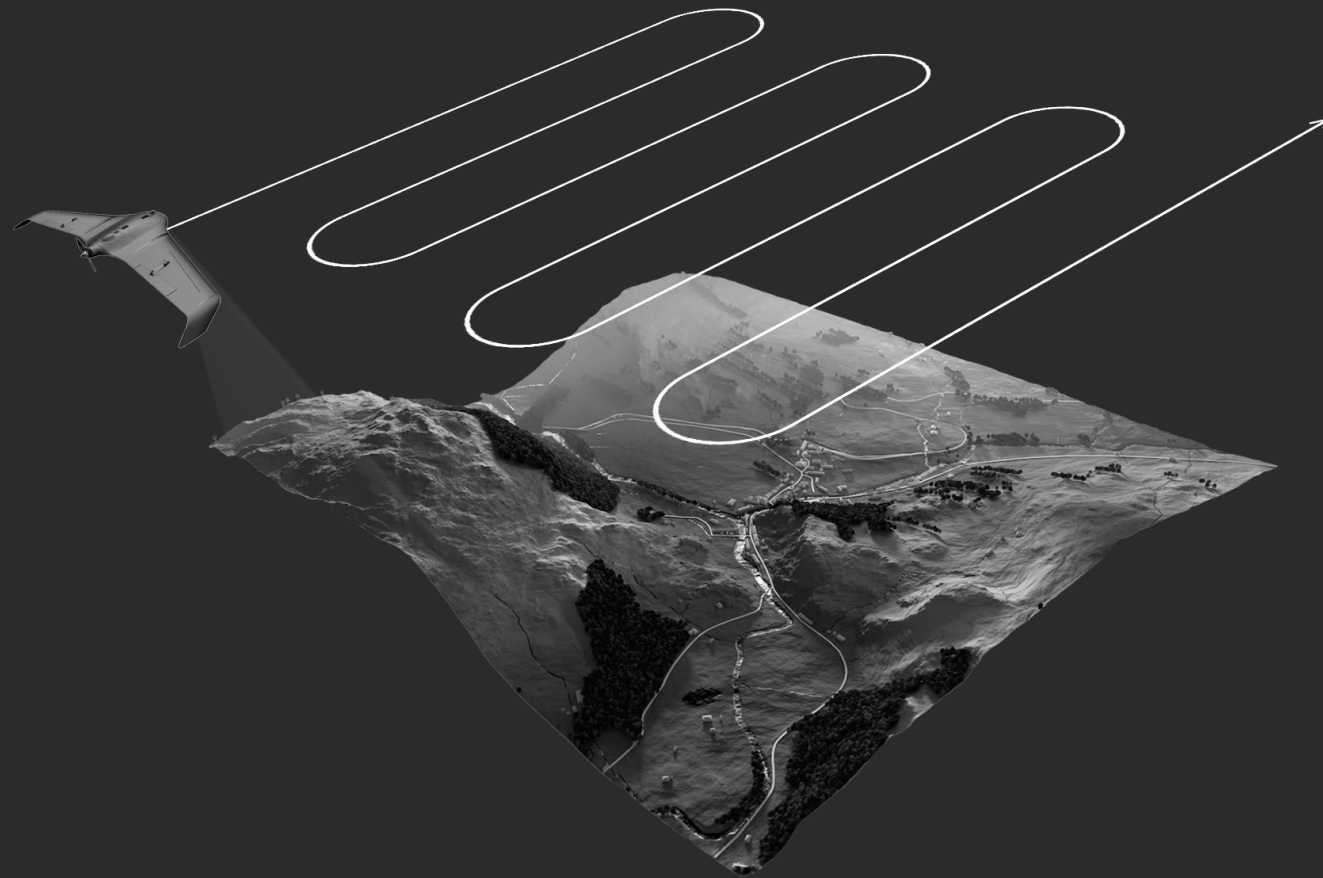
If we use several existing drones and program them to fly in a new suggested pattern, what is the difference from Quaero then?

1. The difference then is that existing drones will not travel as one unit to destination point and will need more space in the air
2. Stationing several drones would also require more space, while Quaero can station tightly together or on top of each other
3. What type of drone would carry out this mission is more interesting. If we use fixed wing drones, they cannot be launched all at the same time, they all would need a take-off area or several catapults, which already complicates the solution significantly. Even if we launch them simultaneously, the swarm of drones would need additional altitude and trajectory correction for each drone, to not collide in the air
4. If we use multi-copters, the problem of altitude correction and space problem is the same, but main issue is then the flight range. Flight range and speed of a multi-copter is significantly lower and can only be used in close areas

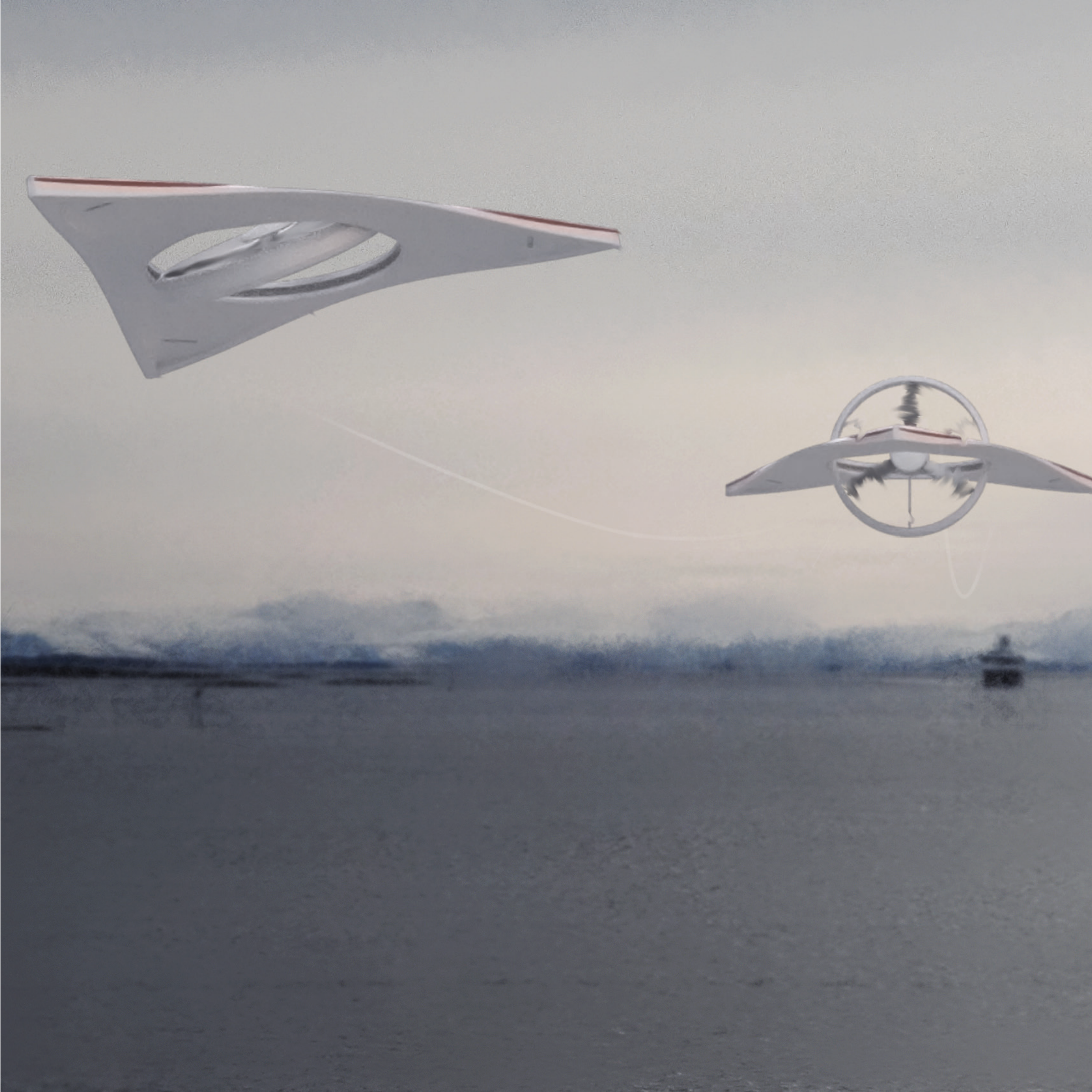
By this said I conclude, that QUAERO is a solution that combines all necessary features in one product. It is a compact unit that can be programmed to deploy automatically (without any additional infrastructure or catapults), reach pointed destination fast and easy, take apart and search the area faster than any existing drone. Installed radio will transmit all received data to user's screen and the person will be found and rescued in no time







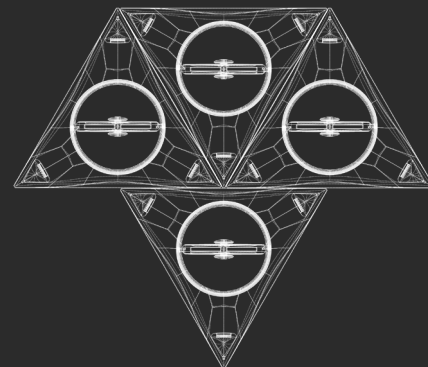
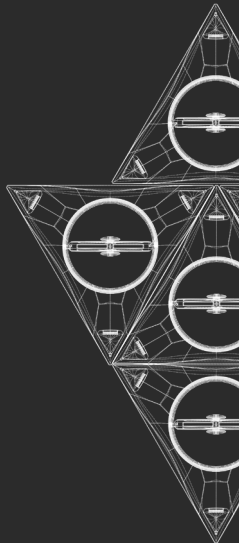
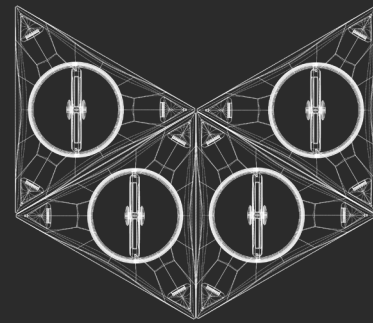
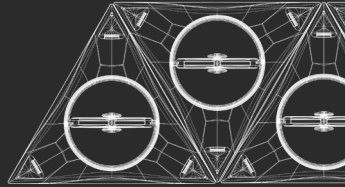
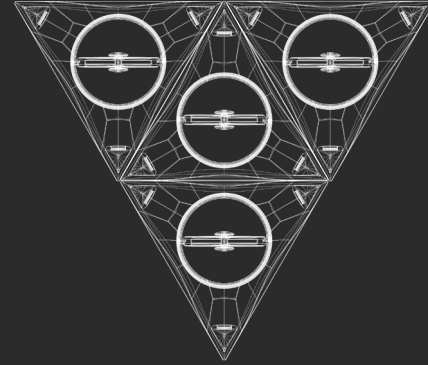
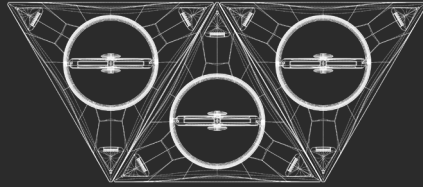
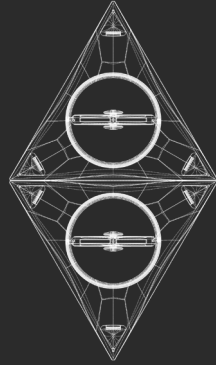
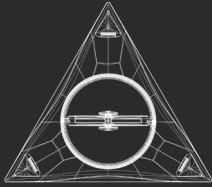


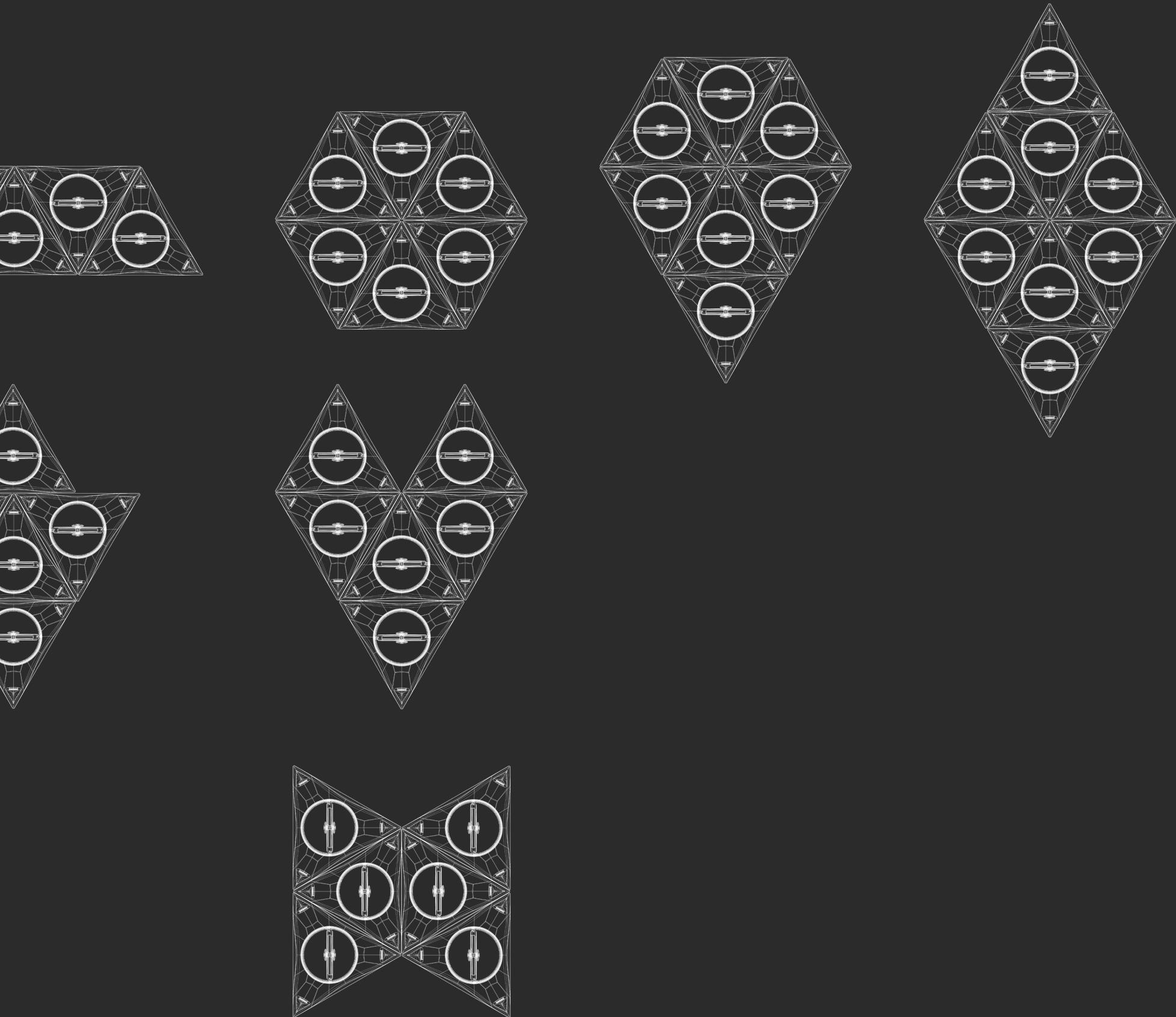






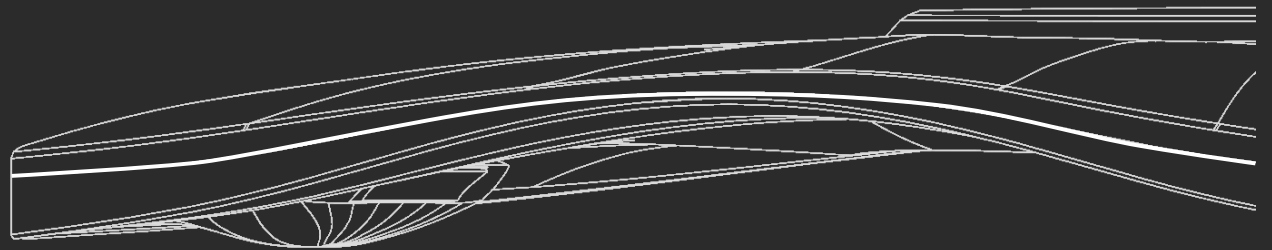






# THE FORM

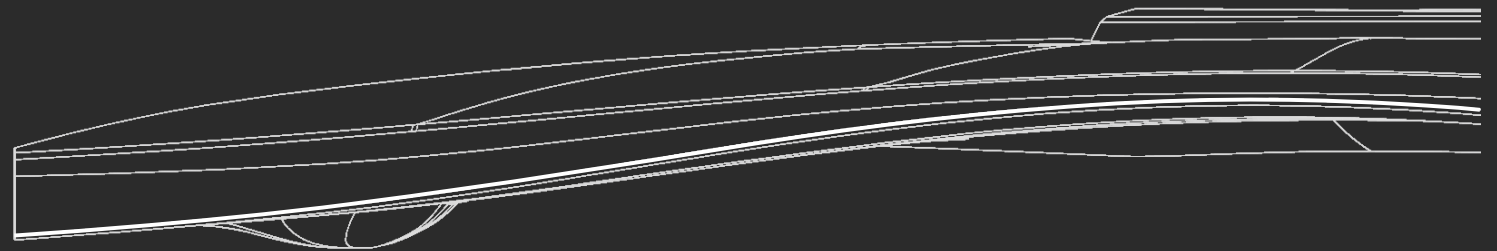
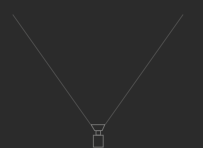
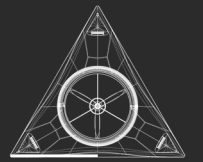
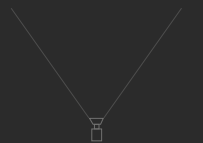
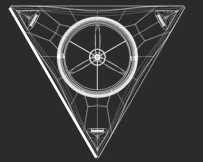
## CONCEPT

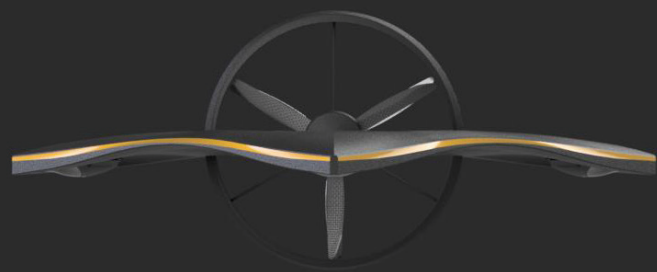
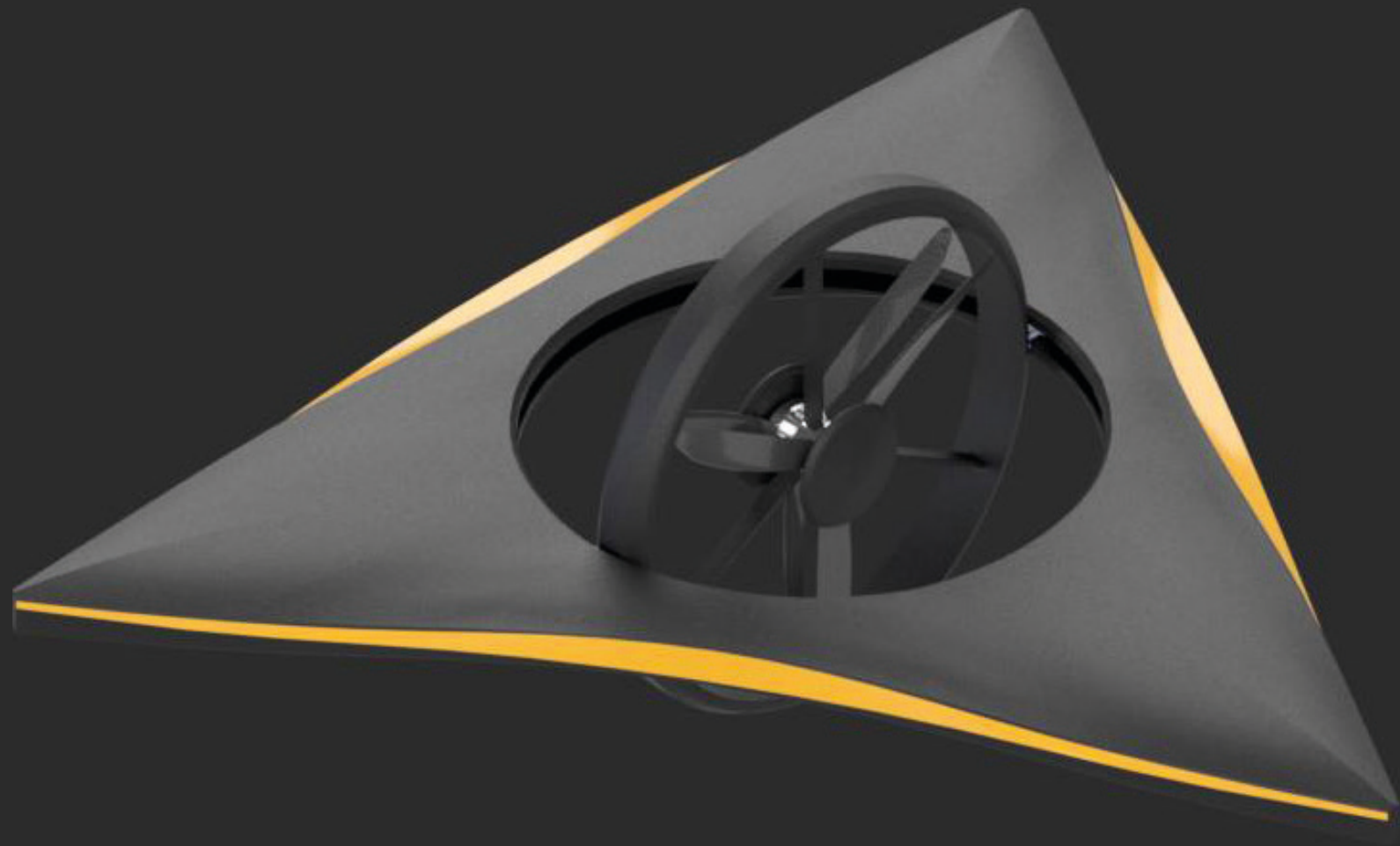


Presented form is the result of a balance between aerodynamics, form combinatoriness, simplicity, and technical needs

One of the difficulties in form development were the fact that good connection between drones can be acquired with certain height of the side "wall", that would meet quite strong air resistance. The decision was to make this straight angle "wall" as small as possible in relation to overall size, and create a smooth transition from geometric lines to amorphous lines, where the air will flow with minimum resistance

Wings of an ultrasonic jet have triangular shape seen from top-view, they are called delta-wing. This allows jets to fly from 5 to 8 of sound speed. Despite the fact that I do not have a goal to exceed the speed of sound, even though the shape is triangular and differs by its aerodynamic qualities from a jet plane, I consider this to be the right choice of shape

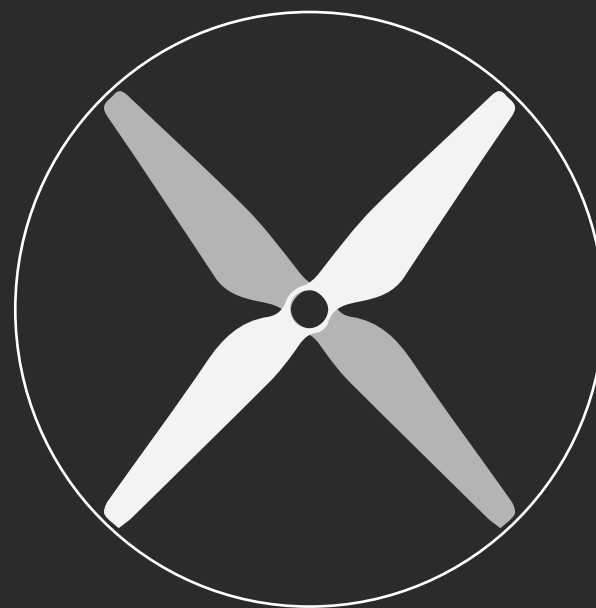
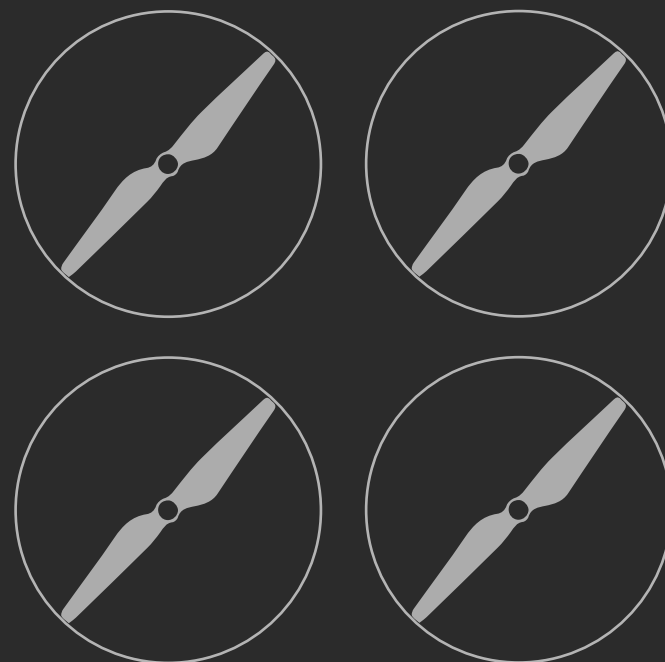




## PERFORMANCE

Size relation between components presented in the concept is hypothetical. Precise definition of size relation would need an advanced engineering approach with multiple steps of iterations and tests

I justified the size by comparing with examples of conventional quad-copters. For instance, DJI Mavic Pro weights 734 gram and uses 4 propellers 21.1 cm in diameter, to fly for 27 minutes<sup>[1]</sup>. The same lifting power can be achieved with two counter-rotating propellers bigger diameter. According to Florent Lucas in his Study of counter-rotating coaxial rotors in hover "Coaxial rotor system is more efficient than a single rotor if the number of blade per rotor is the same"<sup>[2]</sup>.







# QUAERO COMPONENTS

## CONCEPT

### Body

The body is the main area of lift

### Rotor duct

Blade protection and turbulence reductor

### 2 propellers

Main propulsion component

### 2 rotor engines ( plus coaxial shafts )

Propeller drivers

### 2 engine covers

Protection and cover for engines and radio

### 2 pair of small duct engines

Rotates the duct in 2 axis and holds it in place

### 3 sensor hubs

Where camera and sensors will be stored

### Radio translator / receiver

To receive commands and send data

### Board computer ( inbuilt ESC )

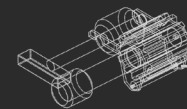
Brain of the Quaero

### 2 batteries

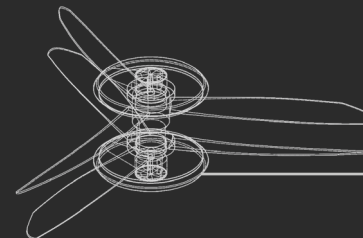
As counter balance to other electronics

### 18 switchable neodymium magnets

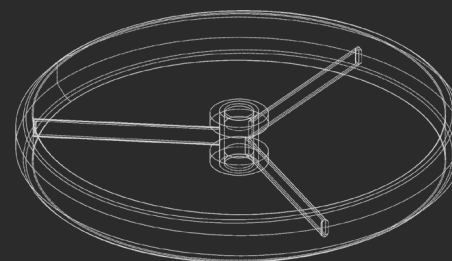
To connect several drones ( controlled with CPU )



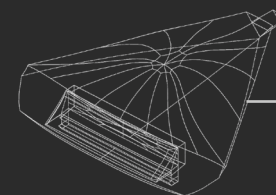
small duct engine



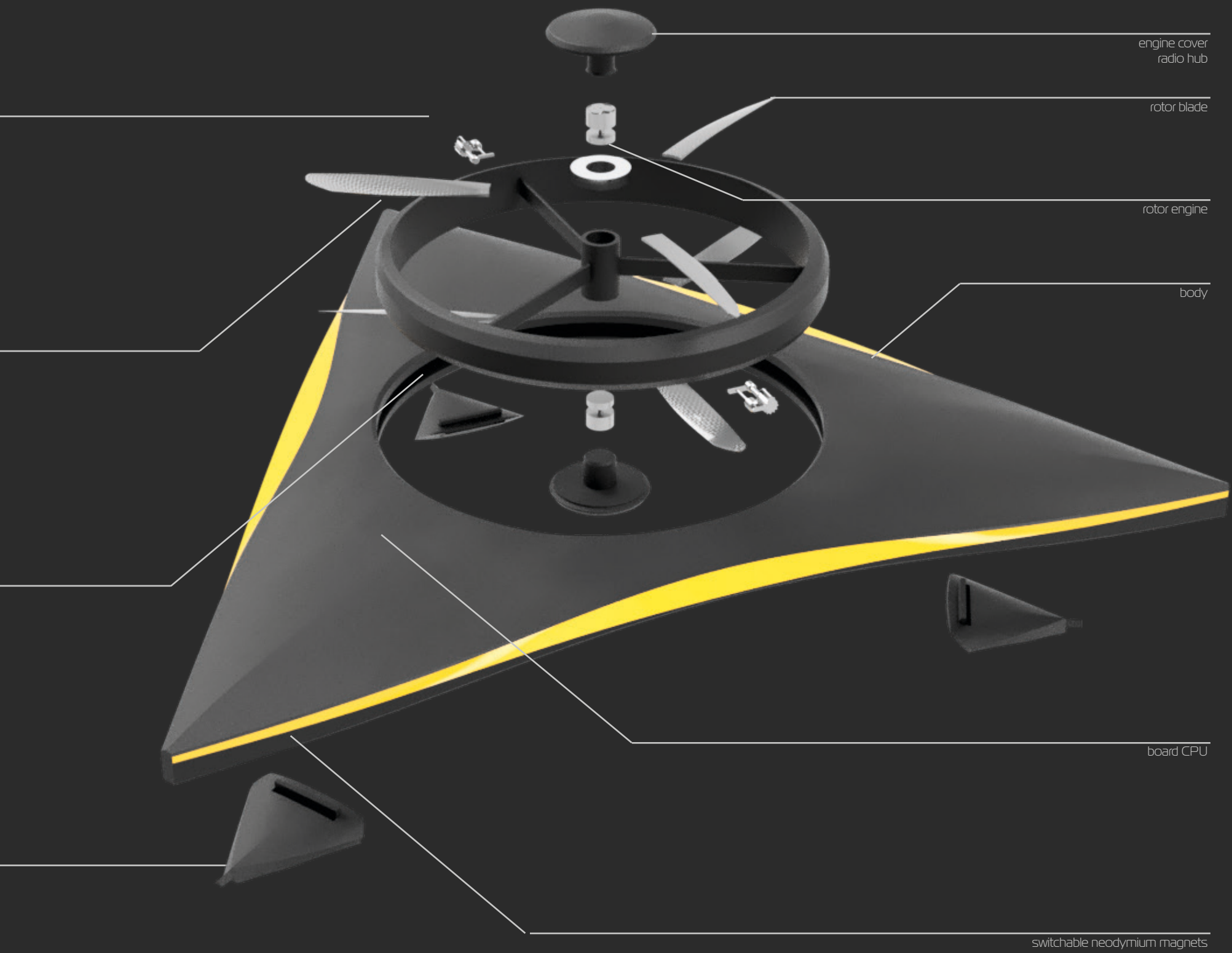
rotor



rotor duct



sensor hub



engine cover  
radio hub

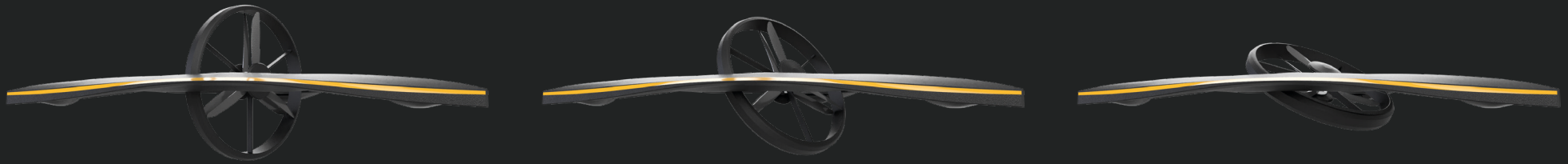
rotor blade

rotor engine

body

board CPU

switchable neodymium magnets

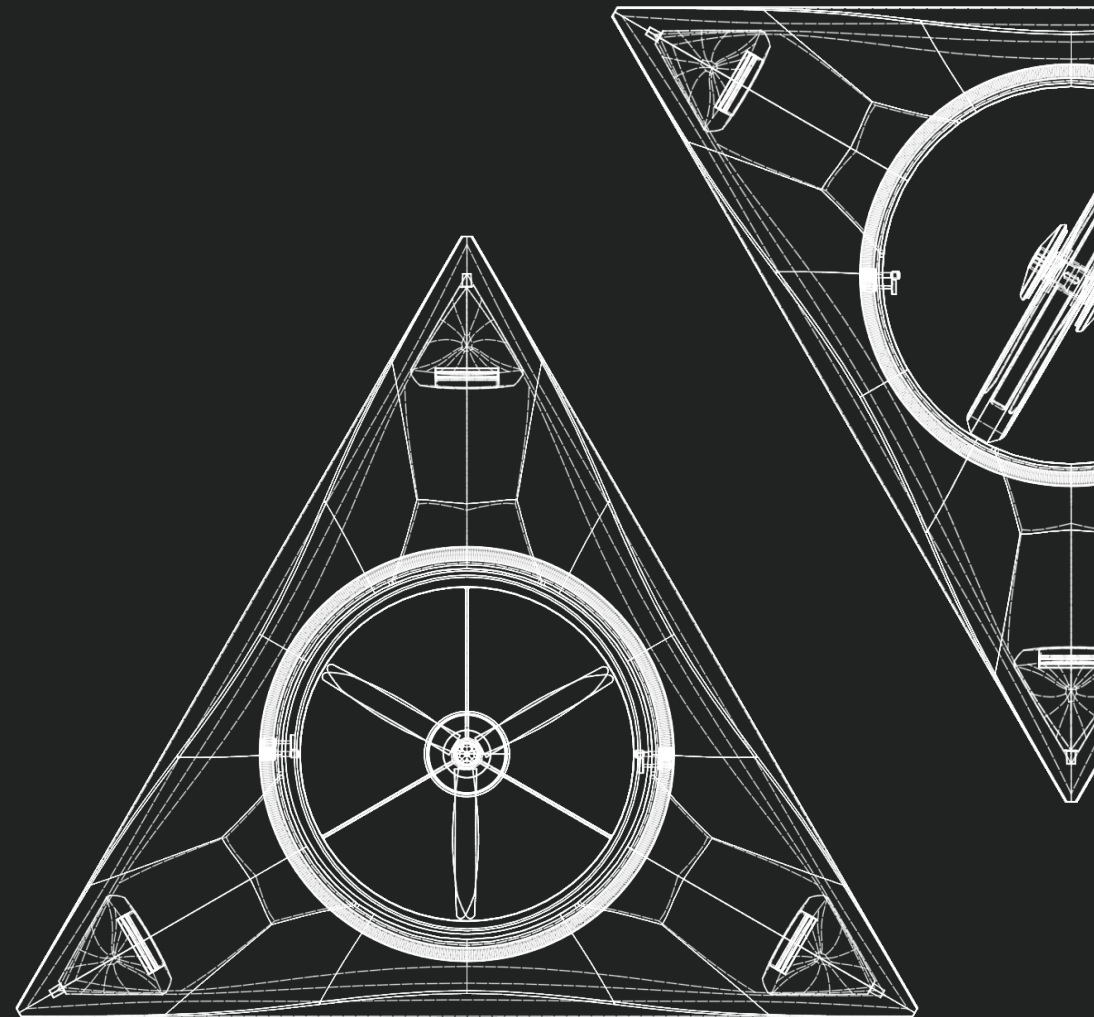


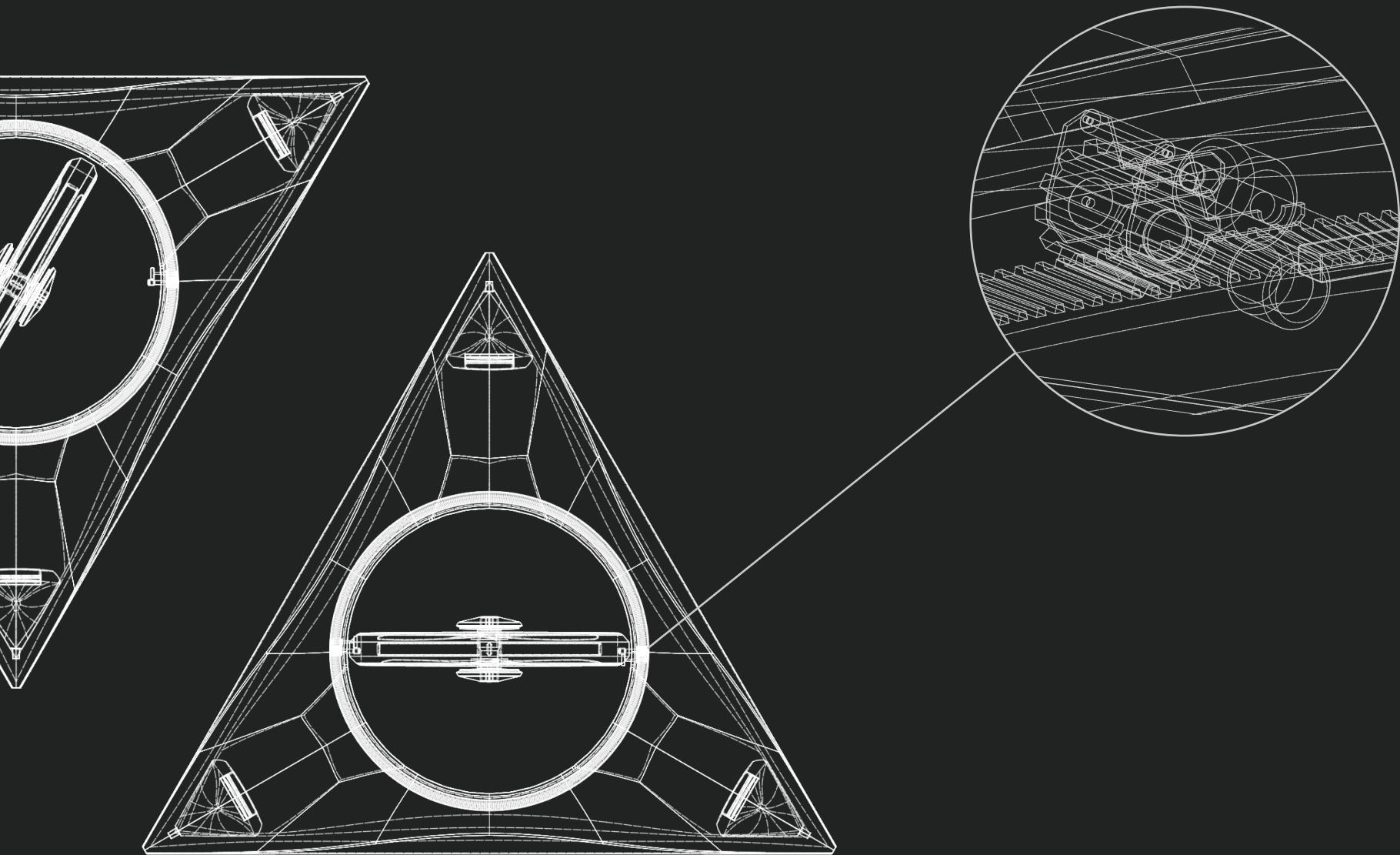
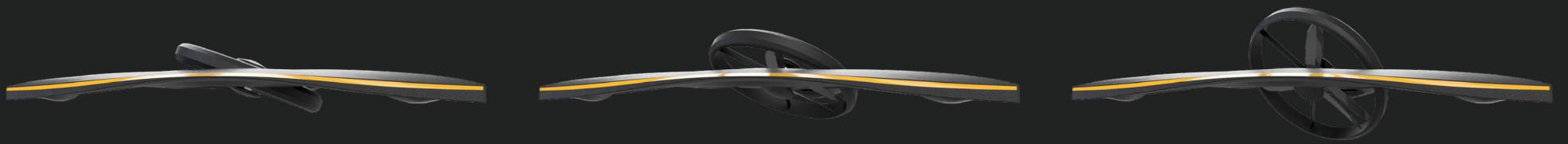
## THE ROTOR

Primary mechanism of QUAERO is the system which will allow to use the same rotary-system to lift the drone into the air and to thrust forward. This is called Thrust Vectoring. The rotary-duct can rotate 90 degree around a horizontal axis which will make Thrust vectoring possible. On one hand it eases the whole drone by 2 or more strong motors (compared to a multi-copter). On the other hand it adds two smaller motors inside the body to rotate the rotary-duct. The benefit of such system is pointed out in the research part of the report: One bigger rotor creates more lift for the same amount of energy than four smaller rotors

Mechanical gears on two opposite sides of the rotary-duct is connected to a rail inside the main body, this mechanism will make the duct rotate around vertical axis allowing change of the thrust vector

To maneavure in the air Quaero can use torque effect like a helicopter. Electronic speed controller will regulate speed of lower or upper propeller to roll the drone, when the duct is in vertical position, or yaw when in horizontal position<sup>[3]</sup>







## CONNECTION

Iteration process, analysis and tests have shown that in order to connect drones together the overall form of one drone have to satisfy several requirements. For instance the side of the drone either must be straight or mirrored to the opposite drone to make good connection. Mirrored sides would complicate the form and create asymmetry, which will influence aerodynamics and stability of the drone. Straight lines are much simpler solution, though the connection between drones might be weaker. I have looked into different ways of connecting the drones mechanically, but it doesn't seem convenient enough. Reconnecting in the air would require super advanced programming to make it possible

I used simple geometrical forms like squares, circles, triangles and hexagons to test and study form possibilities. The hexagon is a natural way of combining swarm of units into something bigger, we can see many examples of that in the nature, and it is often used in design and architecture

Qualitative sketching and analysis of this form couldn't satisfy the requirements I have set for the product. The most «sharp» side of a hexagon does not result into a streamlined aerodynamic form, and would meet a lot of air resistance during a flight. Equilateral triangle on the other hand fulfills those requirements. Straight line side is suitable for making a good enough connection between drones.

For connection purpose strong neodymium magnets is used. Switchable mechanism controlled by board CPU will disconnect drones while in the air. It works in a way that when the switch is on it blocks magnetic field mechanically





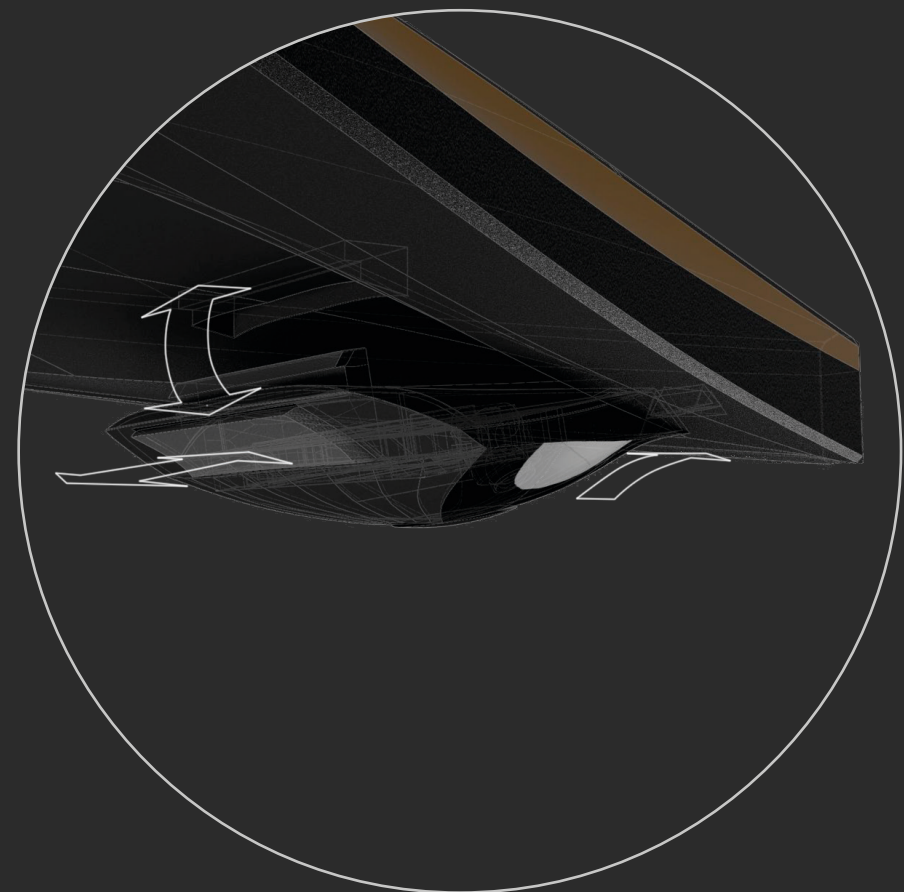
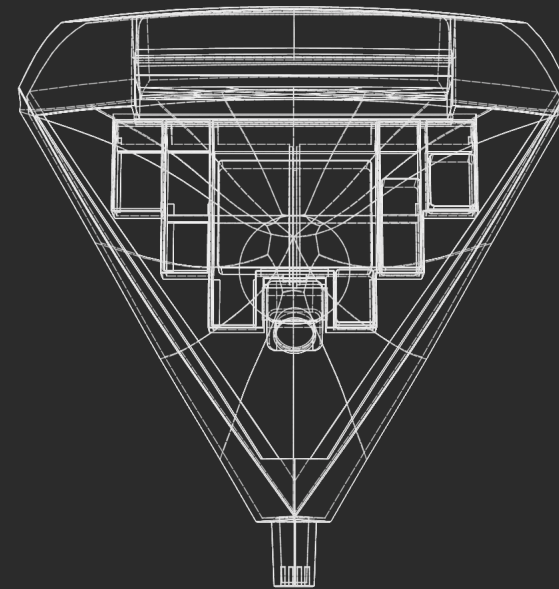
## SENSOR-HUB

Quaero drone will perform search operations with help of high resolution cameras and sensors. For this purpose I have designed a small Sensor Hub with a Plexiglas cover in which all the necessary sensors will be stored. Since Quaero can be used for few different purposes, I imagine that each user will adapt the Hub for the specific need, manually detaching the hub by a simple push of a button and inserting required hardware inside

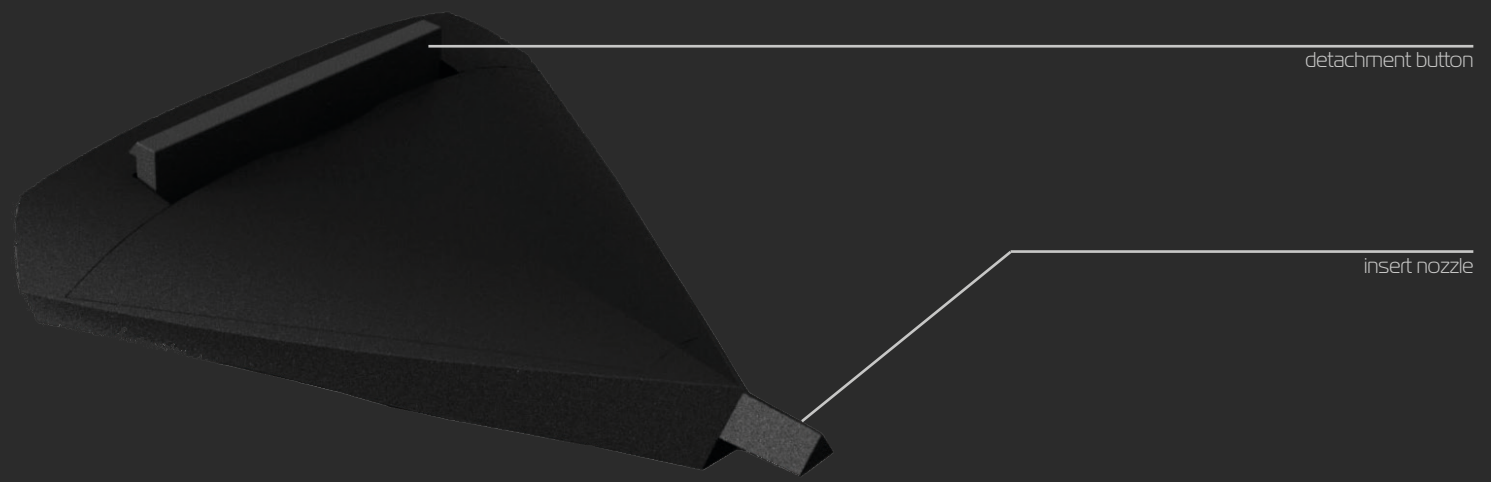
Cameras and sensors can be easily inserted as specially designed cartridges into free slots inside the sensor hub. Advanced software will transform data received into image data for the user

List of possible and important sensors for Quaero search drone<sup>[4]</sup>:

- Infrared capture
- Thermal image IIR
- Camera
- Multispectral image
- AIR analysis (LIDAR)
- Methane detector

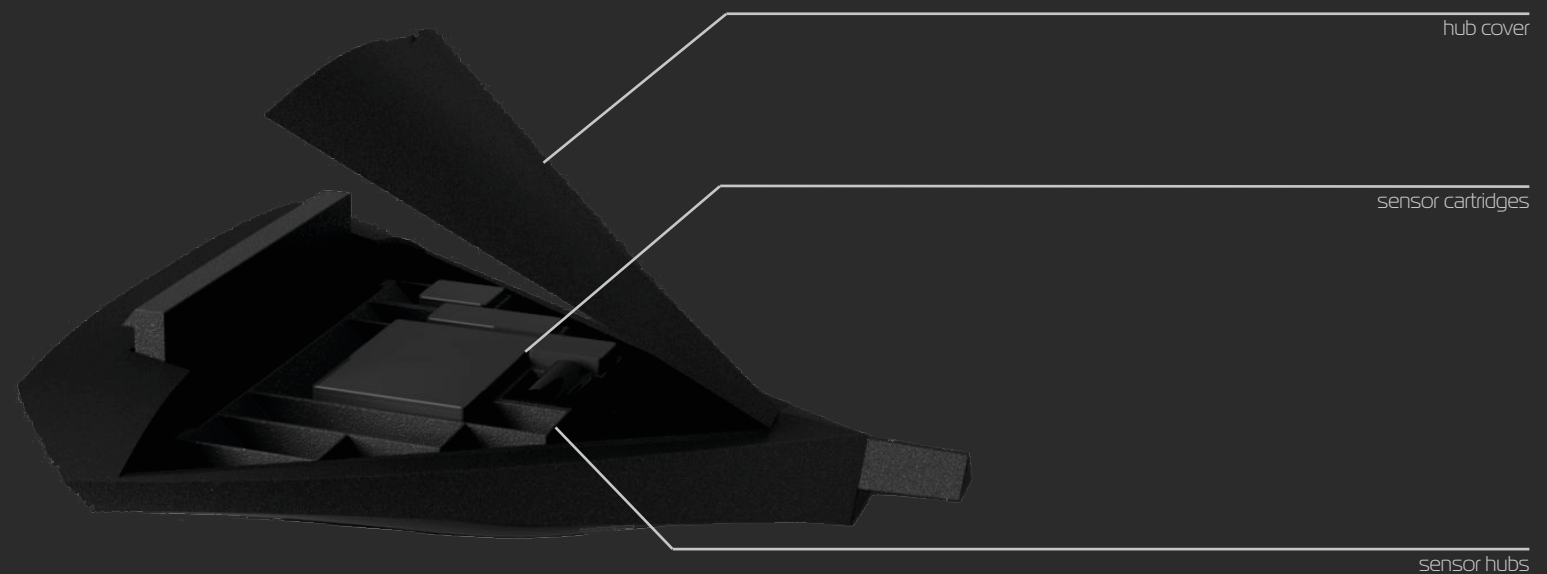






detachment button

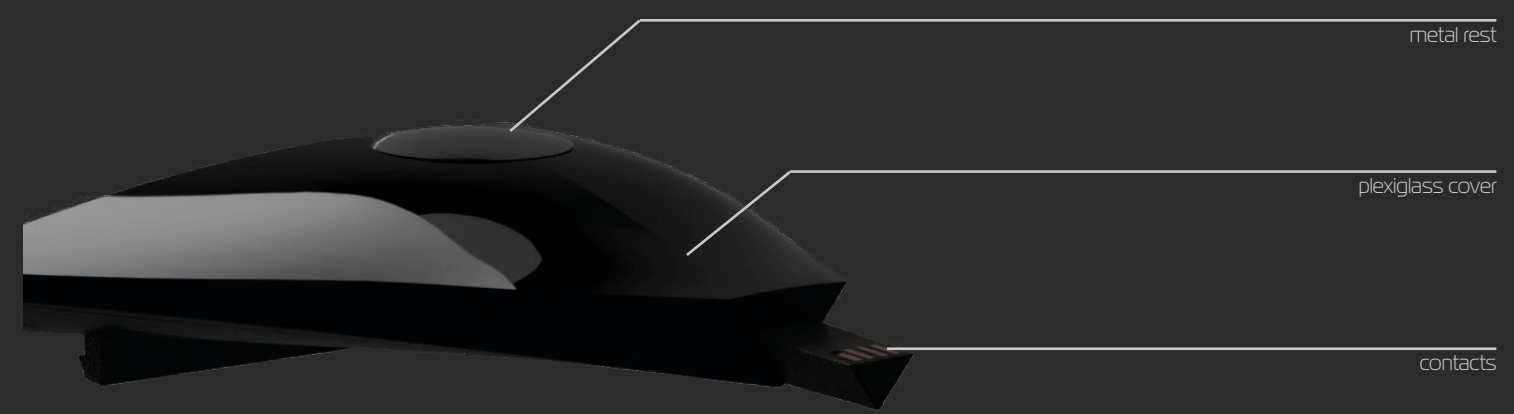
insert nozzle



hub cover

sensor cartridges

sensor hubs



metal rest

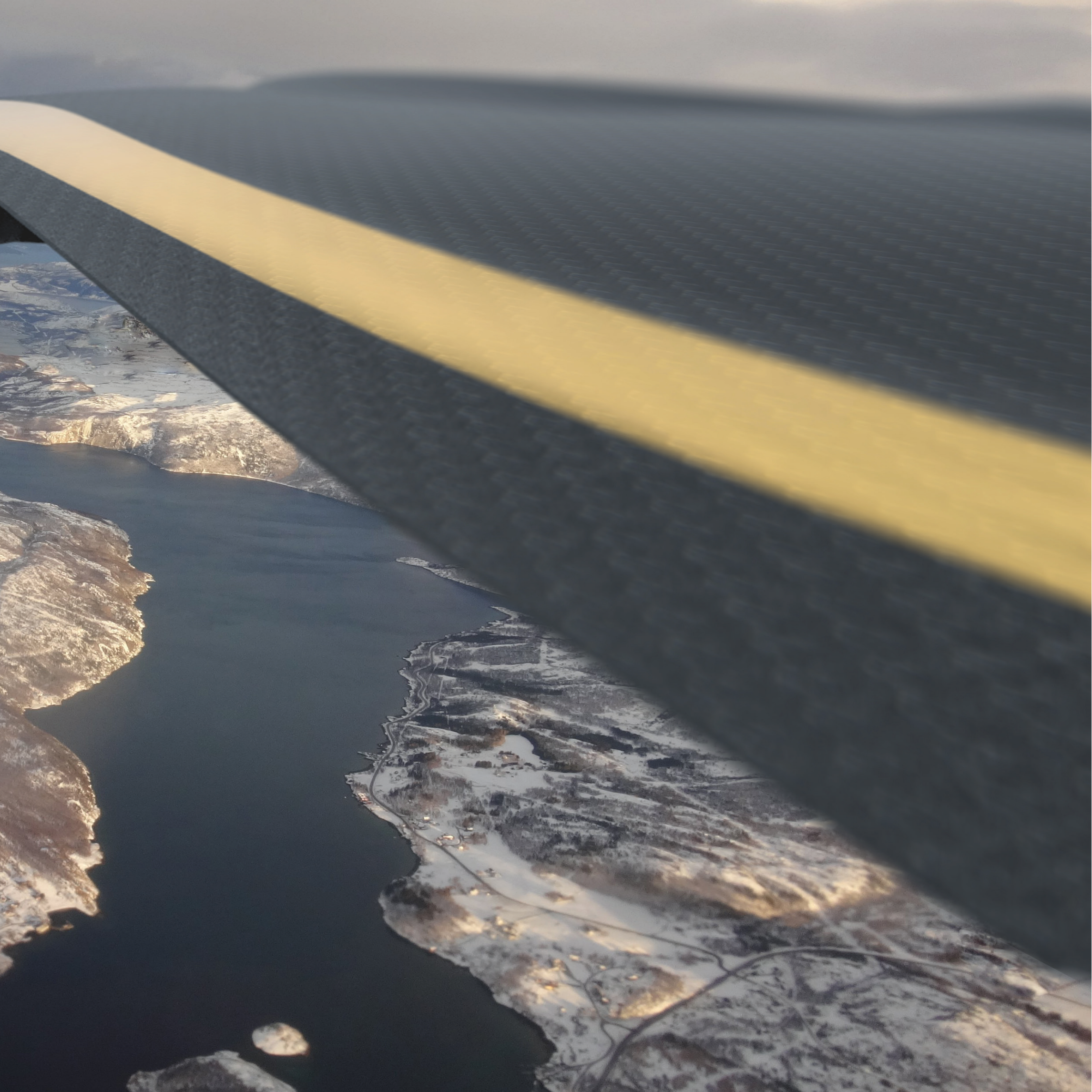
plexiglass cover

contacts

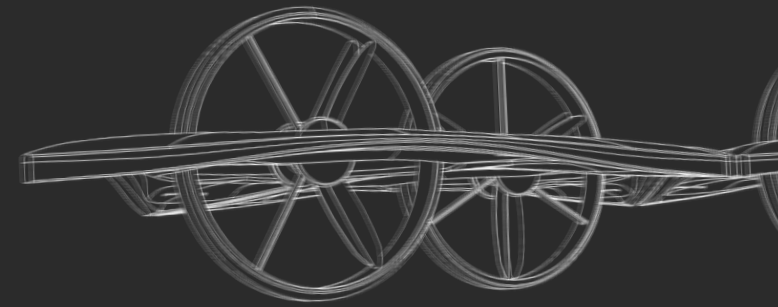












## CONTROL

There are three ways to control UAV's<sup>[5]</sup>:

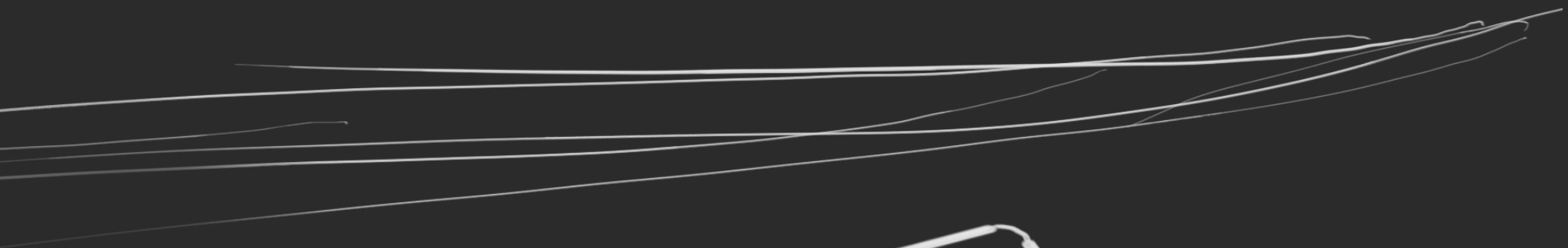
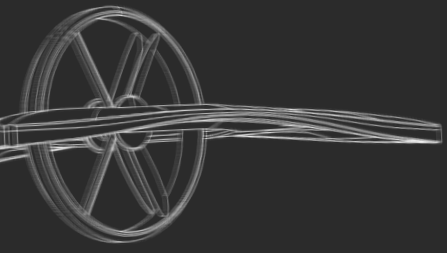
- With direct visual contact and remote control with a joystick or program
- Without direct visual contact, piloted through drone camera point of view. Steered with joystick or special program
- Automated flight program

The main control device for Quaero should be a tablet. The software should include both automated flight- and direct control programs

Main purpose of a tablet is to receive image data from the drone. If we imagine that Quaero is a part of a "emergency system", to which safety crew, police and other actors have direct access, then images should be retranslated to other monitors as well. Via Internet or radio signals

Imagine situation where either field commander, or any rescue crew is out in the field and have a need of immediate drone action. A portable control device like tablet would fulfill this requirement. Rescuers will not have to contact the control center to send coordinates, then wait for a response, and later the pilots themselves in a helicopter or plane. This is a very time and money consuming operation





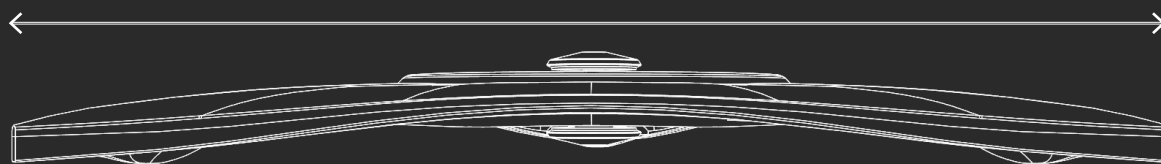
## USER INTERACTION

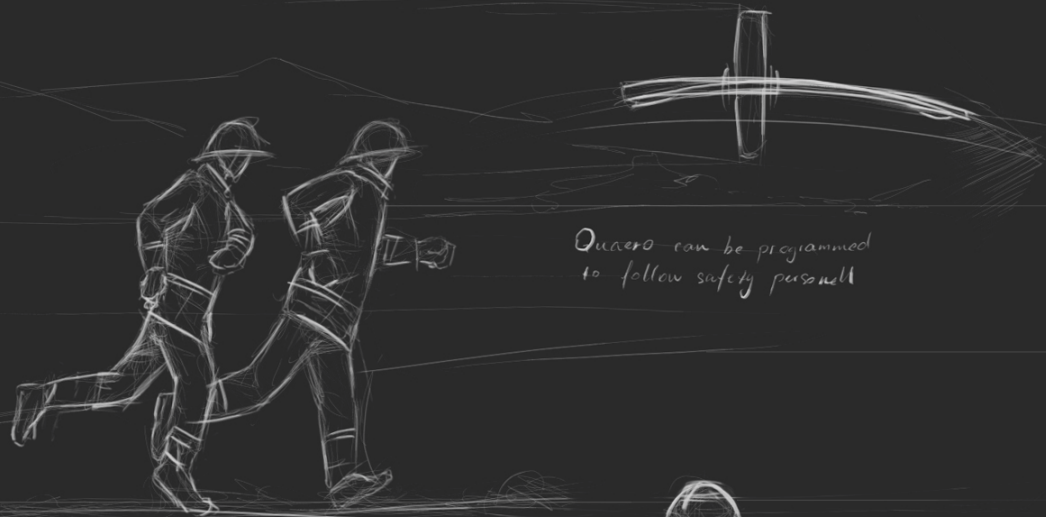
The interaction with Quaero can be treated as an interaction with the robot. In the ideal case, when Quaero is technically correct and has all necessary software, then the interaction with it will be through assignments of tasks. Tasks like "Search this area for male age 35", or "Look for fire in this area", or similar programmable tasks which will be translated to Quaero via tablet. In these scenarios GPS locator will play an important role, since the drone will rely on constant coordinates synchronization, both for correcting the route and for user feedback

The size of the drone is a compromise between what a person can carry, how big it should be to travel far and carry necessary electronics, and how to be relatively weather/wind resistant

180 CM

100 CM

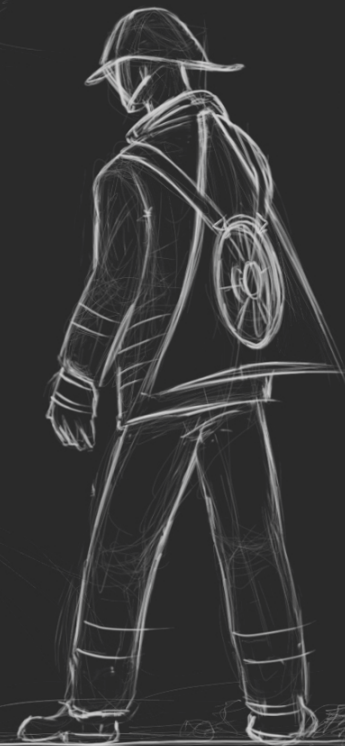




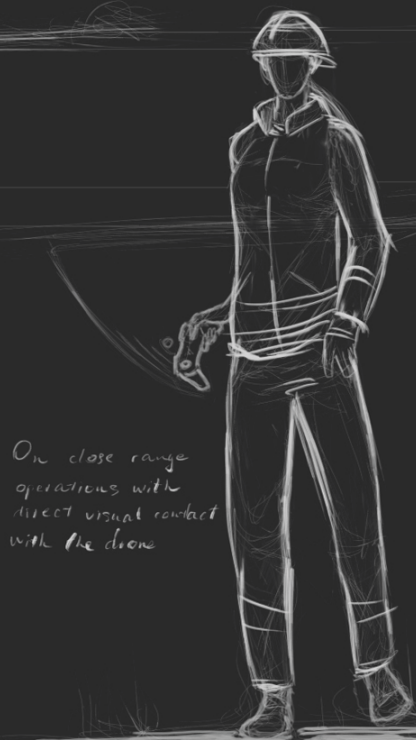
Quarro can be programmed to follow safety personnel



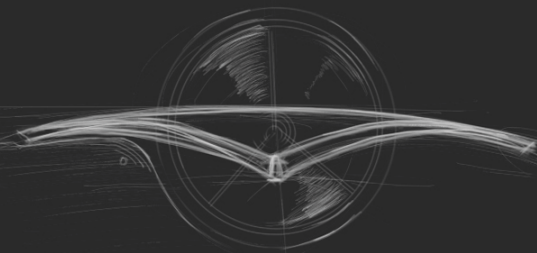
Quarro should be programmed to recognize people with heat sensors.



The drone can be easily carried on the back to the deployment point after completion of operation.



On close range operations with direct visual contact with the drone









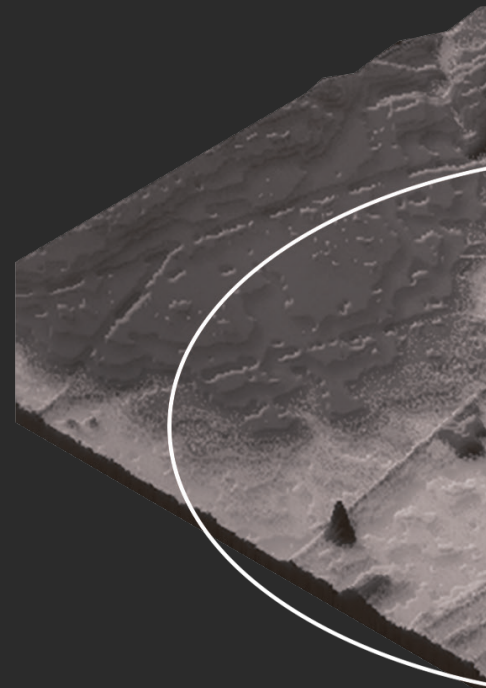
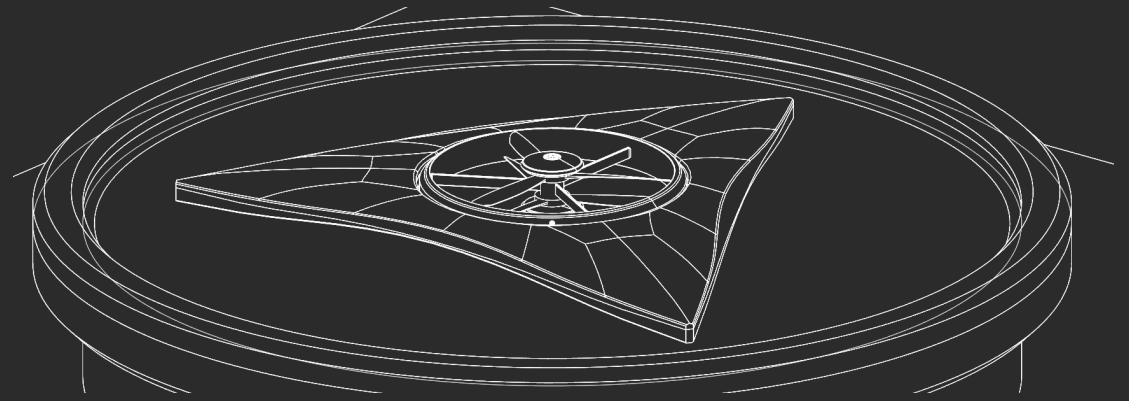


## SET IN SYSTEM

In a future perspective I imagine that emergency situations, including search and rescue are operated with one united system. In this scenario the government or private organizations can use Quaero as main surveillance tool. Stationary bases, where the drones will recharge and wait for commands. Each base is stationed in moderate or high level of risk area. The bases are interconnected and synchronized with governmental safety department central. The bases will cover intersecting perimeters for additional drone support option

When emergency call will be recieved, the decision will be made and nearest drone or group of drones will be deployed to situation area. While the rescue group preparing and heading towards emergency point, the drone is already searching for the exact location. Images are translated live to a tablet. Moving rescue group is already aware of some details and preparing necessary equipment. The chance for operation success have already increased

By the same principle Quaero drone can be used for autonomous schedule surveillance. Searching for wildfire or other threats in the base perimeter. The dron can lift autonomously, do its route and come back for recharging. Without any direct human contact















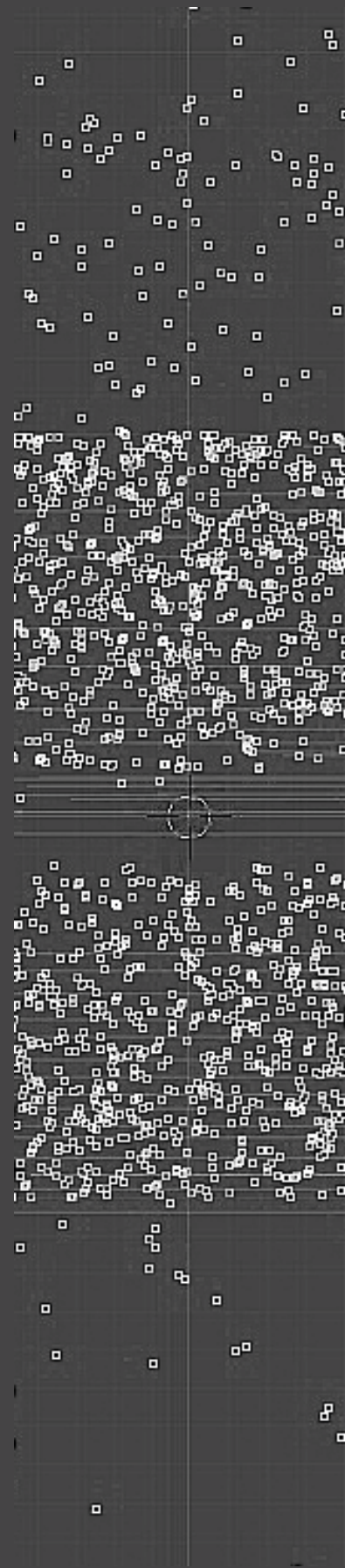


# CFD SIMULATION

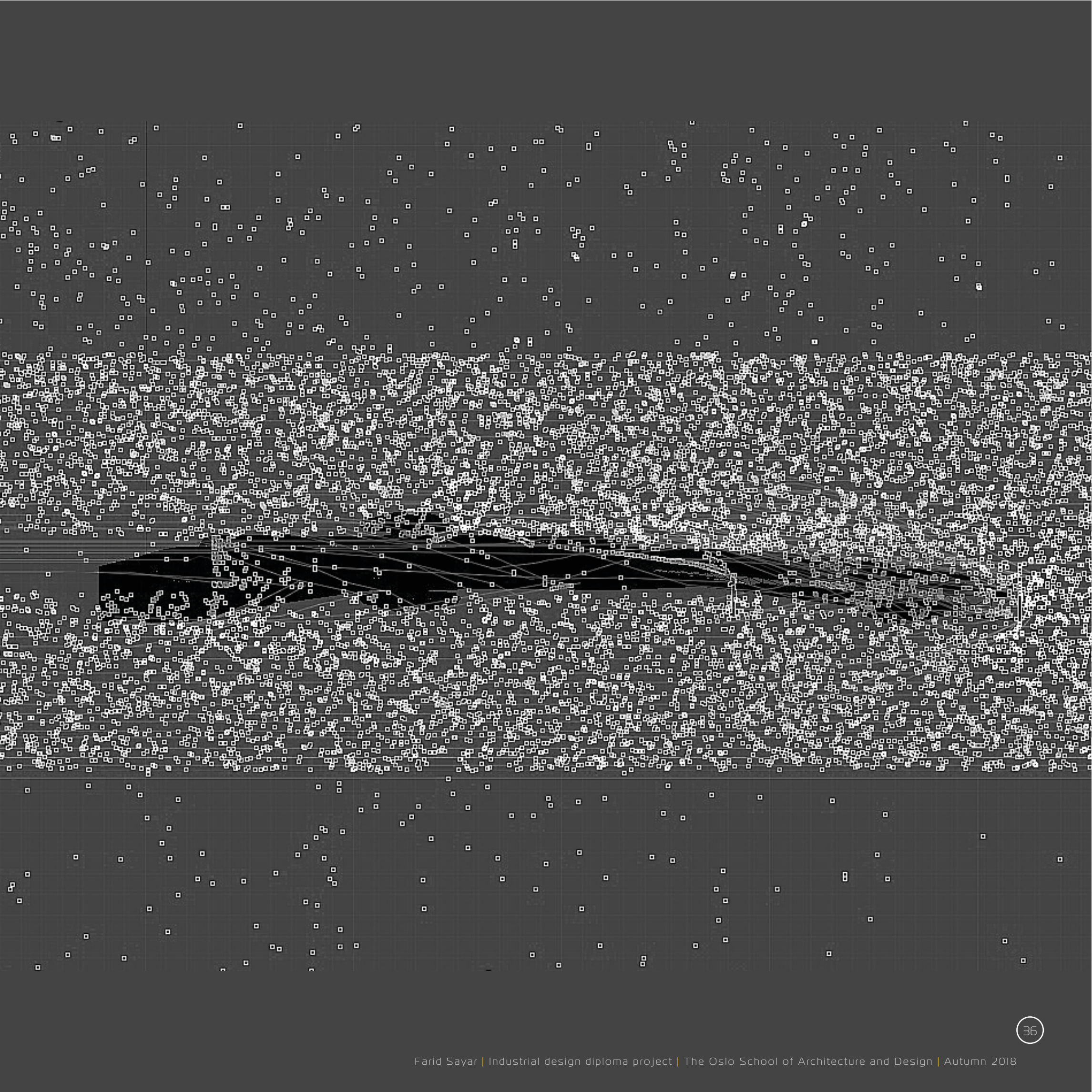
Calculation of aerodynamic qualities is a complex engineering work. It is outside the scope of this thesis to perform such detailed calculation

I proceeded from the basic principles of aerodynamics and laws of physics, and used logical conclusions, as well as I studied various aerial vehicles forms and their aerodynamic properties. By this principle Quaero form was developed. To confirm my assumption, I conducted a computer simulation that illustrates the airflow around Quaero. Based on this I can only assume that Quaero will generate aerodynamic lift. Whether it's sufficient or not I cannot say, further engineering test required for certainty

I also assume that triangular shape fits quite well for high speed travel, since the Fighter-jets are formed this way too.









# OTHER APPLIANCE

CONCEPT

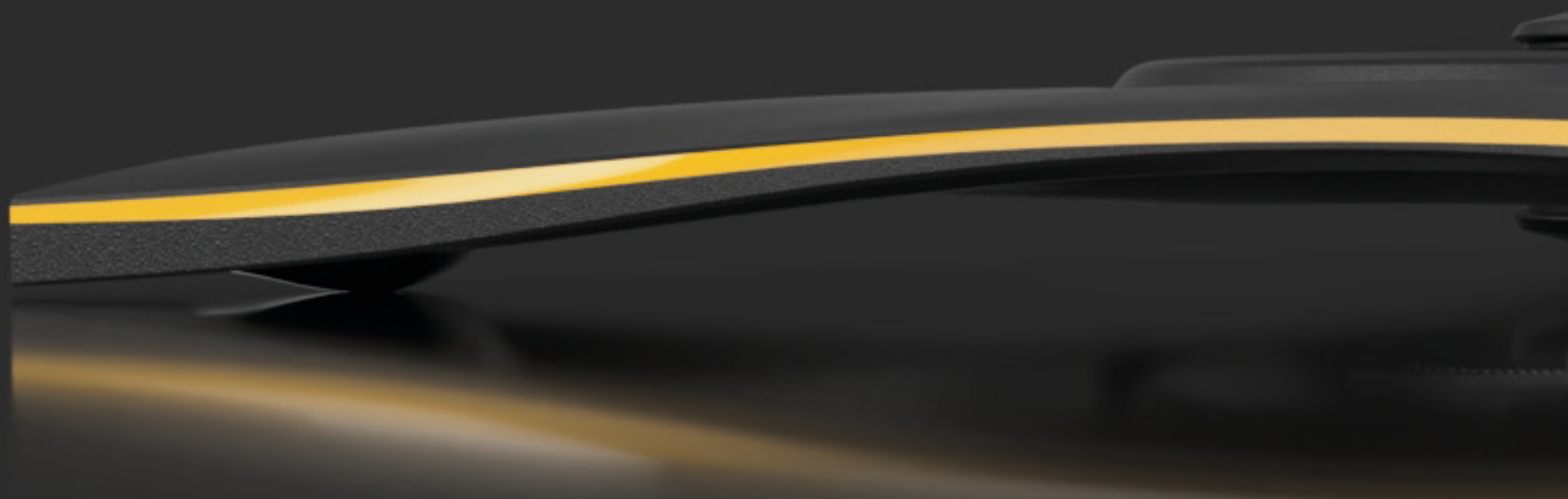


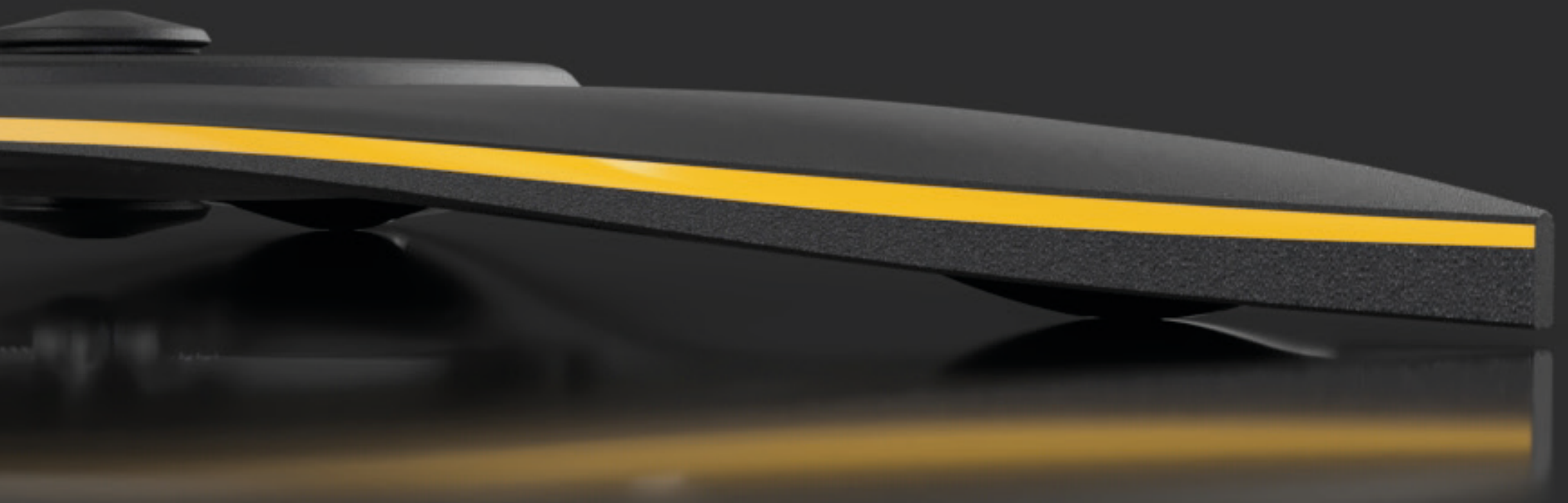
## SURVEILLANCE

Function of QUAERO can be applied in surveillance, search, location, detection and similar. For this purpose drone's main characteristics should be easy deployment, fast arrival and reliable signal for image delivery. By fulfilling these requirements Quaero drone can be used for automated surveillance of vast territories, for instance, wildfire guard as illustrated here.

Today wildfire is observed by national security personnel, either from observation towers or by local guards living in houses and huts in outskirts<sup>[6]</sup>. In this context Quaero drone comes as an evolutionary solution. Detection of problem can be done easier and earlier. But also gathered data will improve decision-making, thereby improve reaction of active personnel and thus influence the outcome of the emergency situation









## VISUAL STYLE

The name QUAERO means SEARCH in Latin, which also contains AERO that fits well for this project description.

Appearance of Quaero is partly predefined by its function and technical/aerodynamic requirements. From a top view this form is geometrical and has symmetry, but it also includes amorphous lines and surfaces seen from different angles. The language of this shape is influenced by my personal aesthetic preferences. I wanted somehow to reflect the seriousness and reliability in the form, give it a purposeful and semi-aggressive appeal.

The colors I have chosen is dark gray and cadmium yellow. The cadmium yellow lines on the sides are actually reflexion surfaces made for location of the drone after an operation, by safety personnel. The yellow color is also quite visible in natural surroundings during the day. But of course, as any other product Quaero should have several color variety, adapted for different environments and uses, like suggested on images here.

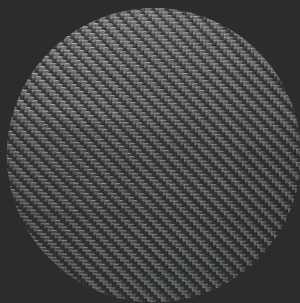
Reinforced carbon-fiber polymer is best suited material for an AV today. It is light and strong

MagistraIC

font used



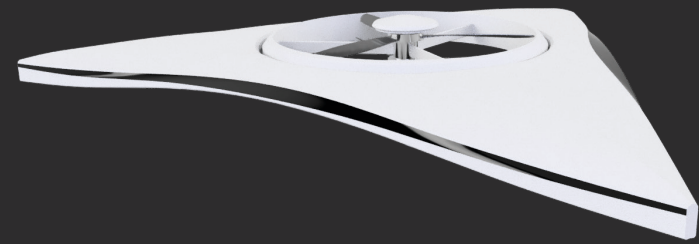
#fcc00d  
C0 M27 Y93 K0



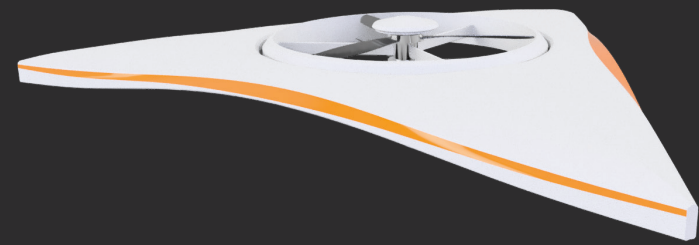
Carbon-fiber texture



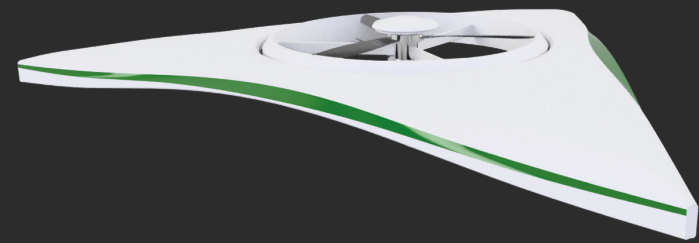
Winter



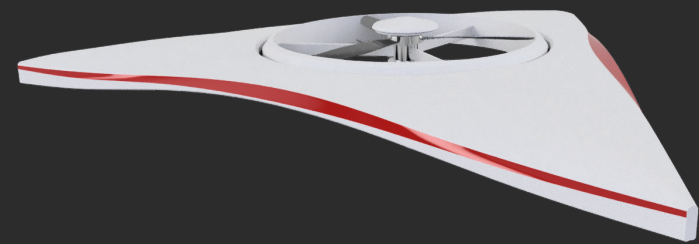
Night



Naval



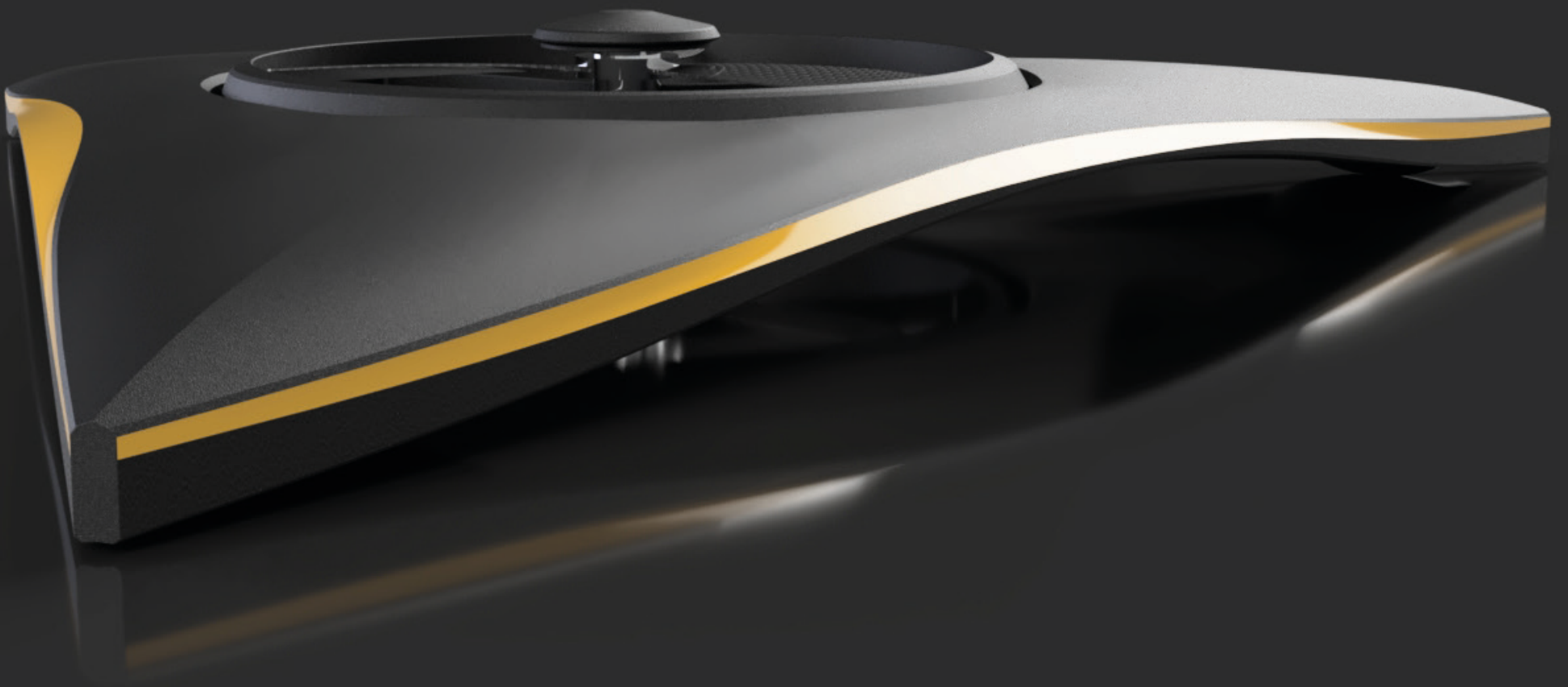
Desert



Fire



Day



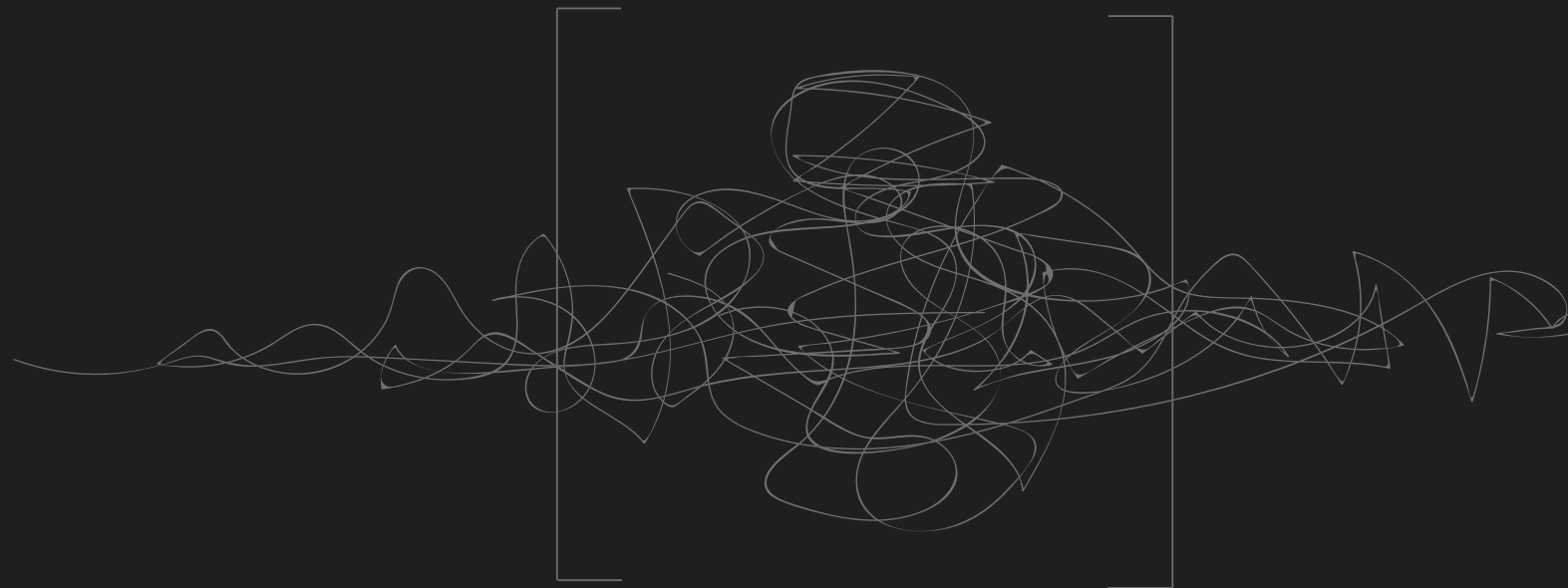




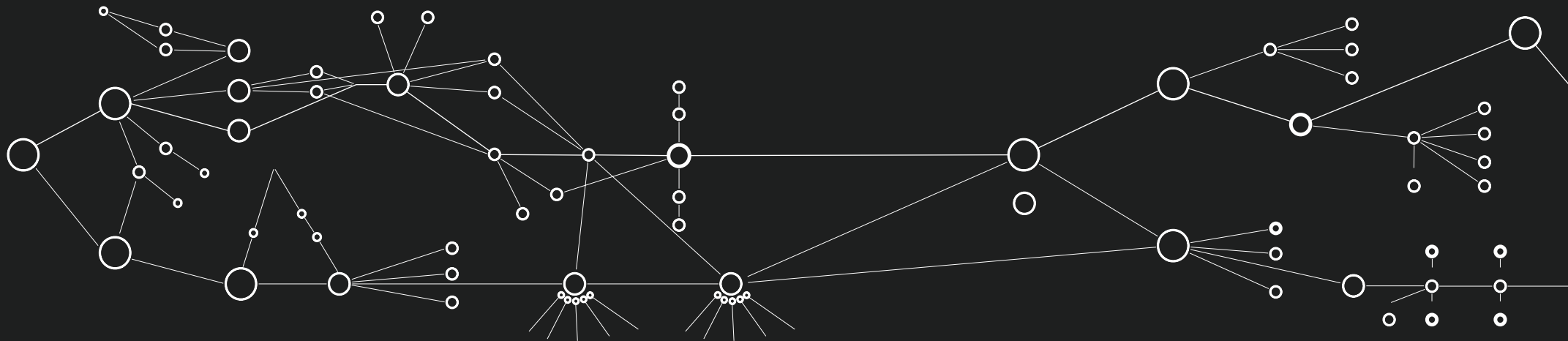
# PROCESS OVERVIEW

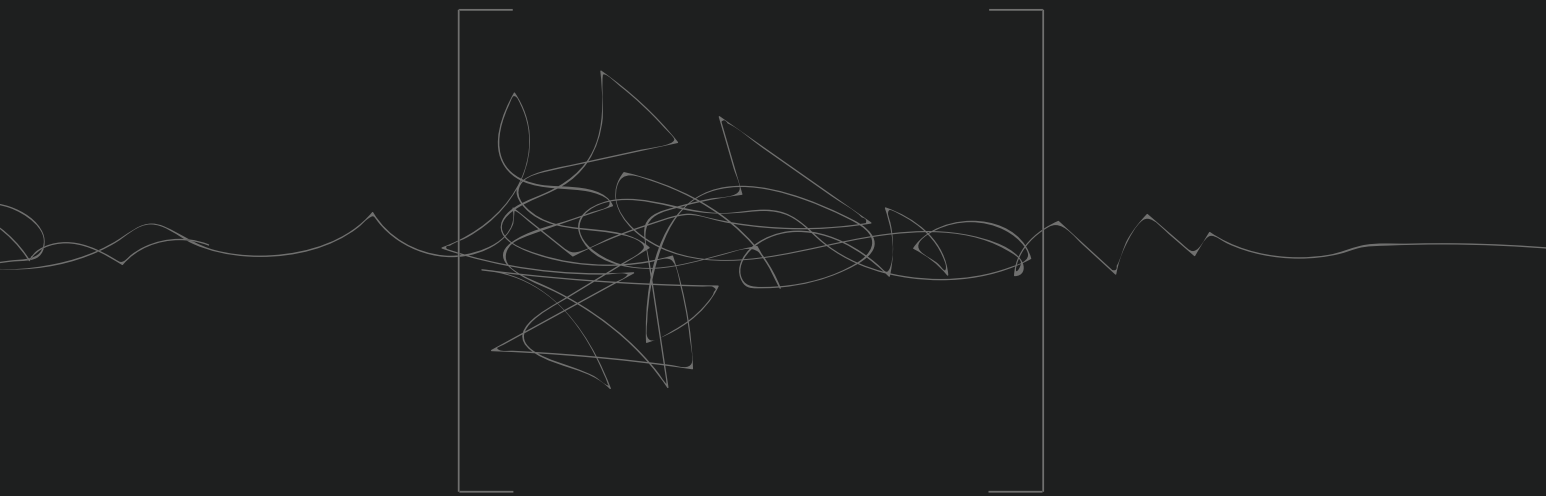
## INTRODUCTION

This illustration show the whole design process in a simplified way. The sequence can be divided into two main phases - Concept development and Product development. Production, detailing and execution are not illustrated here.



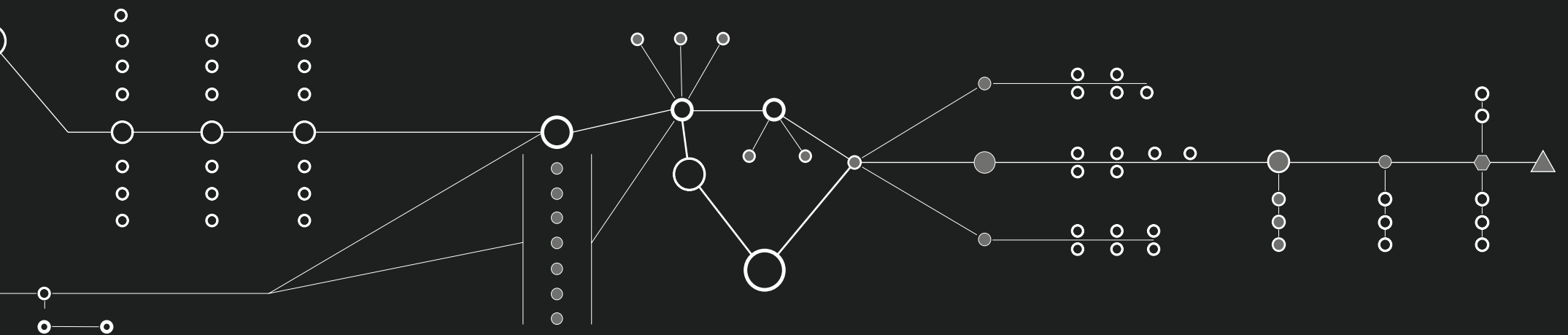
## CONCEPT DEVELOPMENT





Every decision in the process is based on findings made during research and investigation of particular topic. All steps in the process have direct or indirect relation to each other. The complex of findings have passed through my personal analysis and judgment thus formed the concept and its form

## PRODUCT DEVELOPMENT







# BACKGROUND

## RESEARCH

Wildfire and problems around this natural threat was my starting point in the research. During investigation my research field broadened to Search and Rescue operations. These topics are in the same field, thus relevant to the defined scope

### ABOUT WILDFIRE

Wildfire is a global problem with increasing threat to our societies. Millions hectares of forest is being destroyed by wildfire yearly. During dry season thousands of people are working to observe, prevent and put out wildfire globally

Most often cause of wildfire are people's inadequate behavior in the nature, rarely natural causes. Wildfire can reach up to 70 km/h speed burning everything in it's path, emitting large amount of bad gases, displacing wildlife, destroying Eco-systems, causing infrastructural damage and even causing deaths<sup>[7]</sup>

Accumulated drought effect is caused by global changes in the climate. Water scarcity and dry air is causing plants to die out making them highly flammable. As a result fire is catching







up on dried trees faster than a car driving in a city, while the young forests are more resistant to fire

To prevent a wildfire it has to be spotted in its starting phase and reported early in order to act accordingly. But it is considered practically impossible to observe the entire territory of a country simultaneously, especially in big countries like Russia, China or Brazil. Another difficulty is availability of cost-efficient tools to observe those territories. There are simply too few solutions that are made specifically for this purpose, which are not simple enough and require extra infrastructural expenses. Other AV's have a short flight range and low energy efficiency

I believe design can help to improve existing system of surveillance and detection, or create new one's to decrease damage done to nature, human infrastructure, and avoid loss of lives, both of local residents under threat and rescue crew





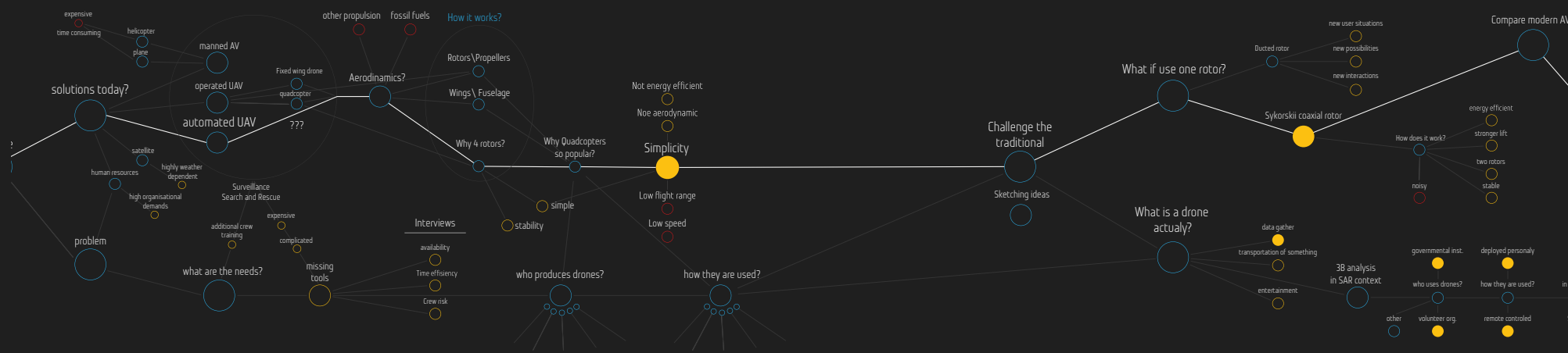
# PROCESS JOURNEY

This illustrations show the whole design process in a simplified way. The sequence can be divided into two main phases - Concept development and Product development

## RESEARCH

### GENERAL RESEARCH

### NARROW RESEARCH



### LIST OF RESEARCH TOPICS



RESEARCH TOPIC

Users and purposes

Interviews

Physics



POSITIVE FINDING

- What solutions exist today?
- What are the problems?
- What are the needs of guard / safety crew?
- What aerial vehicles are used in surveillance, search, rescue, investigation operations?
- What is UAV?
- Why quad-copters are so popular?
- Who produces drone / UAV's?
- Who uses drones?
- How drones are used?
- In what situations drones are used?
- Why the form is like it is?
- What are helicopter pros and cons in use?
- What are fixed-wing plane pros and cons in use?
- What are quad-copters pros and cons in use?
- Who people call to start SAR?
- Who's responsible for initiation of SAR operation?

- How firemen react to emergency calls?
- What are the action sequence?
- Who is responsible of operation?
- What tools are available for them?
- Who makes decision?
- How is the rescue operation carried out?
- What is the reaction time?
- How territories are observed?
- In what sense drones can be useful?

- Aerodynamics, how does it work?
- How propellers work?
- How wings work?
- How to minimize drag force?
- What is turbulence?
- Can turbulence force be transformed into propulsion force?
- Can a drone fly with one rotor?
- What is MACH?
- What is their range flight?
- What are the speed limits?
- How aerial vehicles react to different weather conditions?



NEGATIVE FINDING

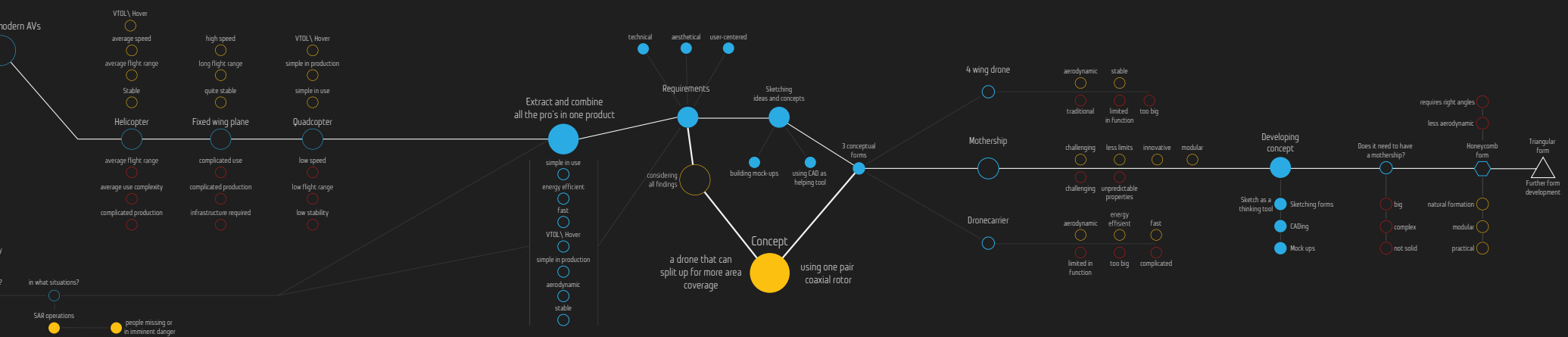


DEVELOPMENT



IMPORTANT FINDING

# CONCEPT REFINEMENT



## LIST OF SOME FINDINGS

### Technical

How does a helicopter work?  
 How does a airplane work?  
 How quad-copters work?  
 How UAV are controlled?  
 How to calculate lift for a drone?  
 Why quad-copters fly so little?  
 What sensors are used by UAV's?  
 What hardware drones use?  
 How UAV's stabilize?  
 What is Sikorsky rotors?  
 What is a rotor duct?  
 Why should rotors be ducted?

### Positive

There are practically no automated UAV's operating in surveillance or SAR operations

The key needs of main users are:  
 Time efficiency, reliability and tools availability

Due to low aerodynamic properties and low energy efficiency quad-copters are extremely popular because of their simplicity in production, use and maintenance

Sikorsky coaxial rotors are an energy efficient way of AV thrust. It is also more stable than one rotor

One rotor with bigger diameter creates more lift for less power than four rotors smaller diameter

All drone uses can be categorized into two groups: data gather (image, analysis data) and transportation of something or someone. Entertainment purposes are neglected due to project scope.

Fixed-wing planes are most energy efficient, while quad-copters are most simple

### Negative

Search and rescue operations are a high cost solution. They require time to make decision, prepare, then deploy, locate and carry out mission. Planes, helicopters and sometimes UAVs are used to spot the problem

Satellites can't be used for observing due to high dependence on clear sky

Firemen lack tools to carry out surveillance missions without using additional personnel. Some stations do use drones, but they rely on special trained crew to use them

Traditional quad-copters are not energy efficient tools and have low flight range thus low credibility when it comes to search and rescue operations

Sikorsky rotary system are efficient, but noisy

Helicopter and traditional fixed wing planes are energy efficient solutions, but extremely complicated in terms of production, control, maintenance and use



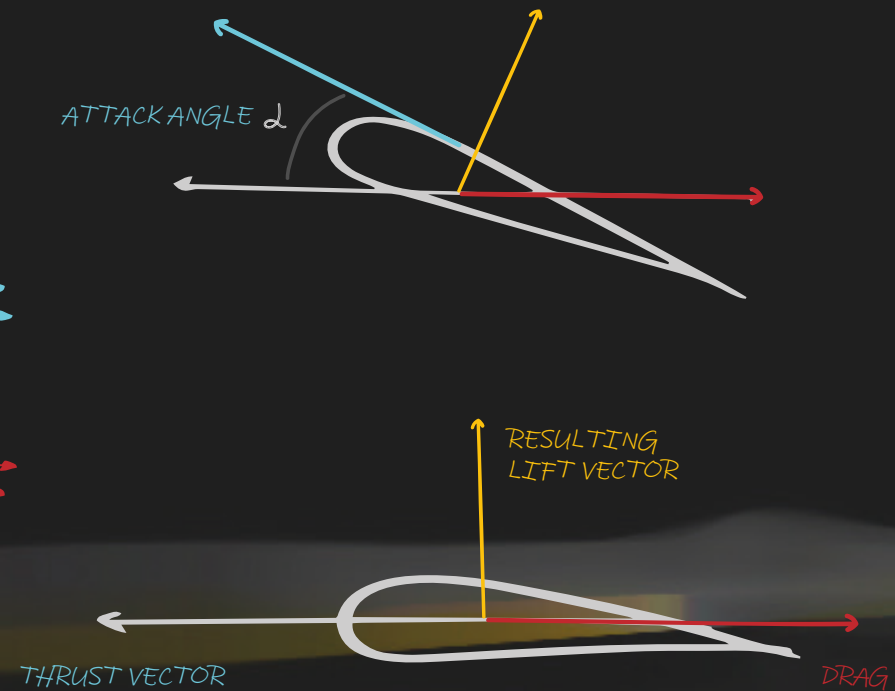
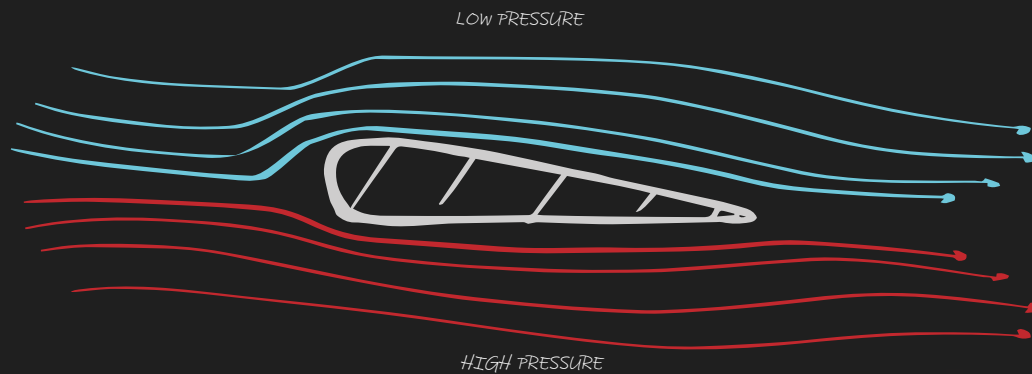


# AERODYNAMICS

RESEARCH

Understanding the motion of air around an object (often called a flow field) enables the calculation of forces and moments acting on the object. In many aerodynamics problems, the forces of interest are the fundamental forces of flight: lift, drag, thrust, and weight. Of these, lift and drag are aerodynamic forces, i.e. forces due to air flow over a solid body<sup>[8]</sup>.

This is an important aspect in this project.

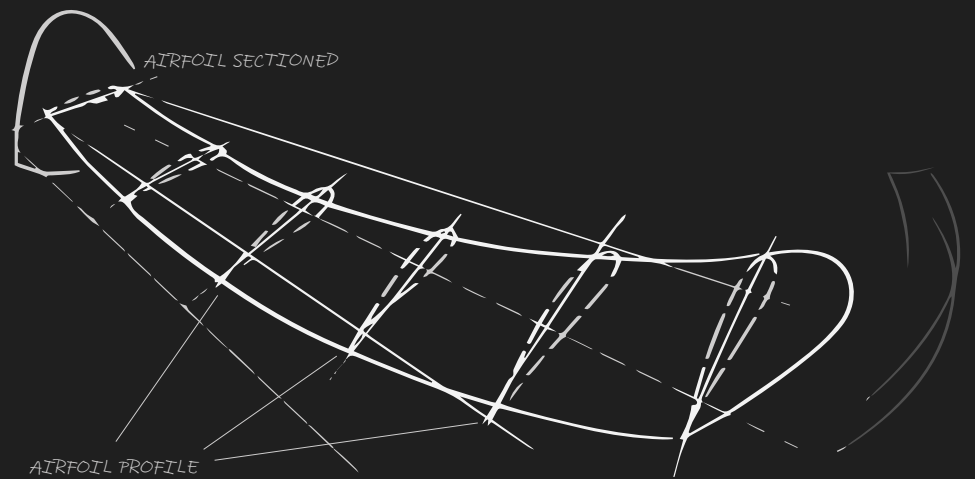
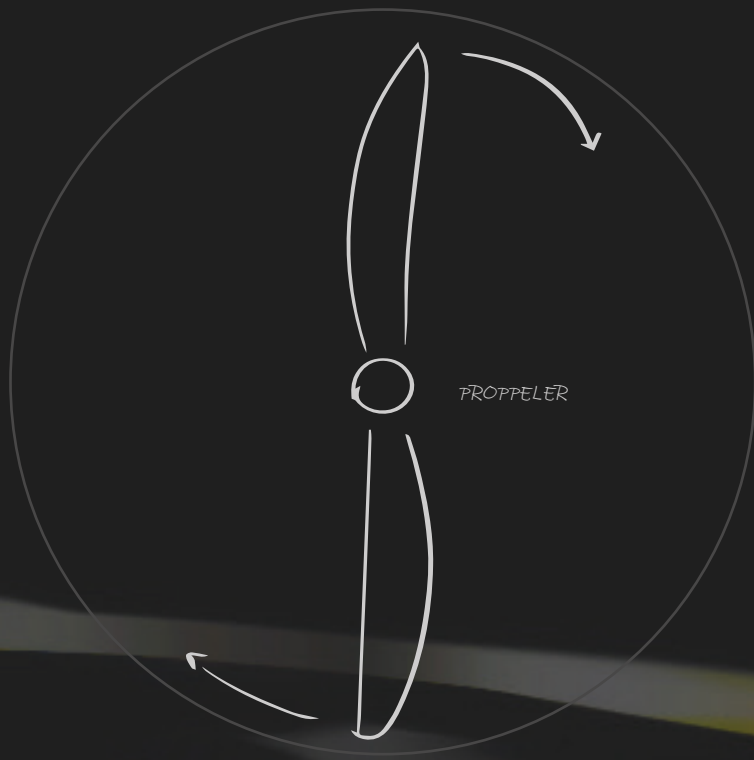


## BASICS

In order to make an object fly in the air it must have a certain speed and have body parts that will create aerodynamic lift. Airflow beneath the object must have higher density, and lower density above. In this way high density particles (gas / air) tend to space where density is lower - above the object, creating so called «lift» of the object. The lift is dependent on the flight speed, air resistance / drag and area of lift. The higher is the speed, the more lift object gains. The lift is also dependent on area of lift, object's form streamlineness, air density, or «attack angle» when we look at wings / airfoils and propellers

## DRAG

Drag is the resistance of air, a force that slows down a flying object, but also is a factor of its lift. Drag is a force that cannot be avoided, but can be minimized in order to have lower energy loss. Study of aerodynamics is an extremely complicated field that has evolved significantly for past 100 years. Scientists have successfully exceeded the speed of sound by many times. It is outside of this project's scope. Understanding of basic principals is sufficient enough to make correct assumptions and analysis



## ROTOR / PROPELLER

Rotors work in the same aerodynamic principal. The section of a rotary blade is usually quite similar to airfoil wing but is twisted from shaft to blade tip because of its rotational movement. During rotation high density air from beneath pushes rotary blades up and creates the lift.

Rotation of one rotor attached to a solid body will create coaxial to blade movement force vector that will rotate the object in same direction as rotor, this is called Toque effect. This can be balanced by placing a coaxial counter-rotating rotor

## REFERENCE

Aerodynamics, from Greek aer (air) +  $\mu$  (dynamics), is the study of the motion of air, particularly its interaction with a solid object, such as an airplane wing<sup>[8]</sup>



WIKIPEDIA  
The Free Encyclopedia



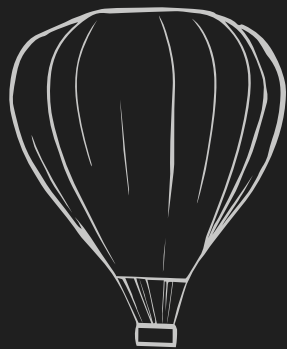


# AERIAL VEHICLE

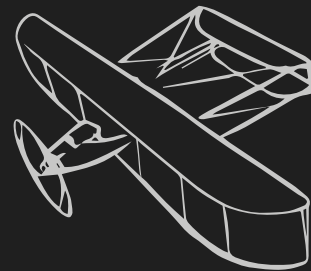
A look into historical development of aerial vehicles gives an overview on what aerial vehicle phenomenon is actually about. Functions and means of AV are taken apart for deeper study and analysis. It becomes clear that origin of AV phenomenon does not change over time, while technology does. Then it is only matter of rearrangement and implementation of new technology and knowledge into a new, evolutionary product

## RESEARCH

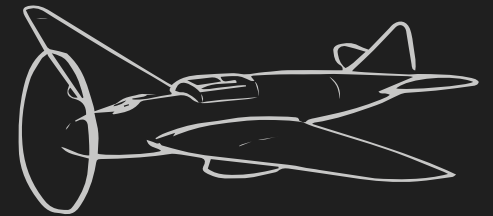
1800



1900



1940



## PHENOMENON

When we look into the phenomenon of aerial vehicles, we can see that in historical perspective the concept of «flying» has changed its form without changing the purpose. In the beginning a «flying machine» was something that could take us very high up to get an overview or transport somebody. Overview gave us a new perspective on nature and landscapes. Obvious advantages are that there are no obstacles when we fly and there are no speed limits (relatively). Today the purposes of aerial vehicles remain the same - either transport something / someone or gather different information.

Aerial vehicles have evolved and turned into small AV's that don't have to carry a person. They have become small but still efficient just like if a pilot would navigate them. In this way we get our free of obstacles, free of speed limits transport for our «eyes», in which high resolution cameras and sensors replace the actual eyes. This development alienates us from the object itself, but leaves the ability to see from great height. Modern technology exceeds our vision abilities and allowing us to see in the night or through objects with help of advanced sensors. If we implement available today technological advantages, we can meet the needs for many years to come

Put simple this project is about designing an efficient and available transportation tool for our «eyes» in a search operation context

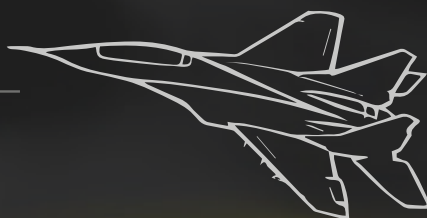


One of the first airborne pictures. James Wallace Black, 1860<sup>[9]</sup>

1960



1980



2000



## UAV

An unmanned aerial vehicle (UAV), commonly known as a drone, is an aircraft without a human pilot aboard. UAV's are a component of an unmanned aircraft system (UAS); which include a UAV, a ground-based controller, and a system of communications between the two. The flight of UAV's may operate with various degrees of autonomy: either under remote control by a human operator or autonomously by on-board computers

Compared to manned aircraft, UAV's were originally used for missions too «dull, dirty or dangerous» for humans. While they originated mostly in military applications, their use is rapidly expanding to commercial, scientific, recreational, agricultural, and other applications, such as policing, peacekeeping, and surveillance, product deliveries, aerial photography, agriculture, smuggling, and drone racing. Civilian UAV's now vastly outnumber military UAV's, with estimates of over a million sold by 2015, so they can be seen as an early commercial application of autonomous things, to be followed by the autonomous car and home robots<sup>[10]</sup>



## ARTIFICIAL INTELLIGENCE

<sup>[11]</sup>“Autonomous” drones’ capabilities will extend beyond autonomous flight—it will also span autonomous ongoing operation, which will solve the current issue of limited battery life for drones and void the need for skilled operators to swap batteries or recharge the drones. Drone batteries typically limit their flight to around 15-30 minutes in the air, but could eventually offer 24/7, continuous operations for inspection, surveillance, and delivery. At an even more sophisticated level, drones will develop autonomous task performance. With this, drones will create insights based on harvested data and automatically translate them into decisions and actions. Imagine a drone continuously monitoring volumes of construction materials and ordering supplies on a real-time basis as necessary. “The next generation of drones will not need pilots at all—just orders.”

Swarm Intelligence will allow multiple drones to collaborate imitating the way certain groups of animals work together, swarm intelligence leverages AI to plan the activities of hundreds if not thousands of robots, allowing drones to collectively achieve larger, more complex tasks. Currently, collaborative robots are trained by humans; however, we are nearing a time when robots can “think” and train each other without humans. Groups of drones can cover sprawling geographic locations and carry out specialized tasks at the same time. They can also form a network—that is, if drone B is too far away from the control center to communicate with it, but is close enough to drone A, it can effectively pass a message down the line

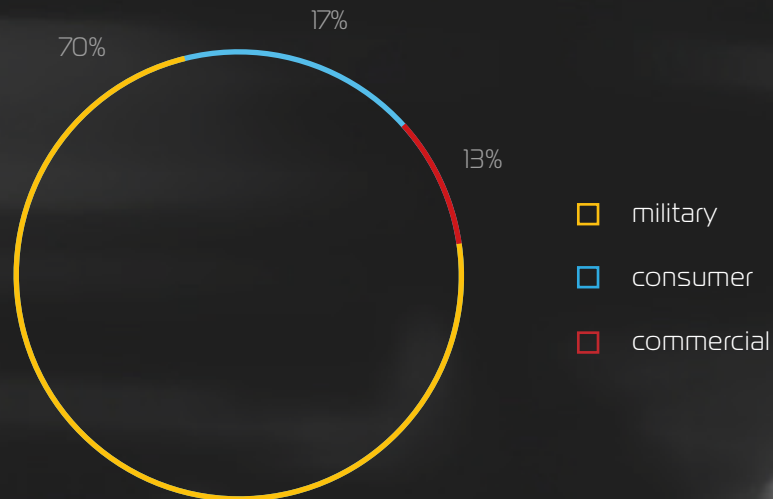




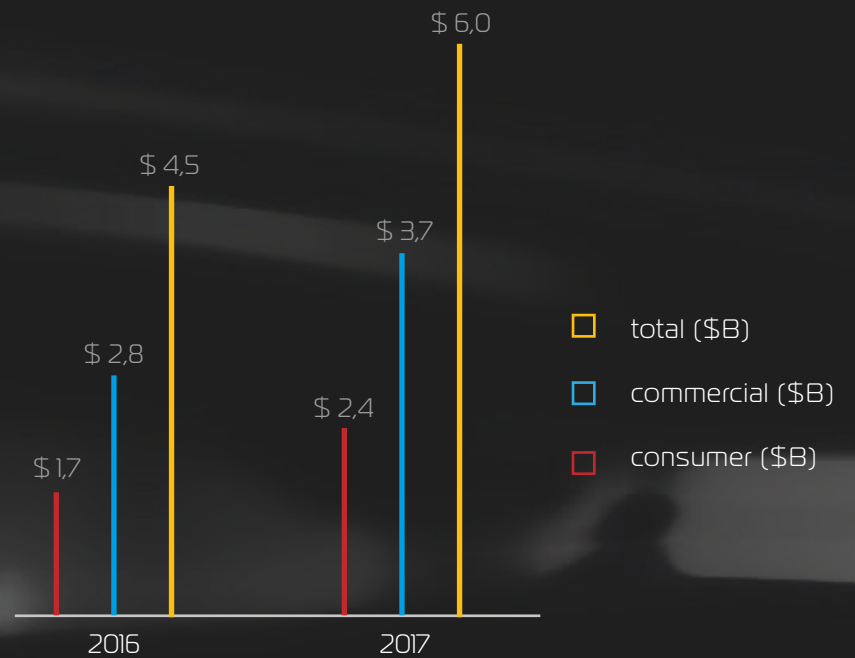
# DRONE MARKET

RESEARCH

Drone market by sector



Drone market revenues by sector

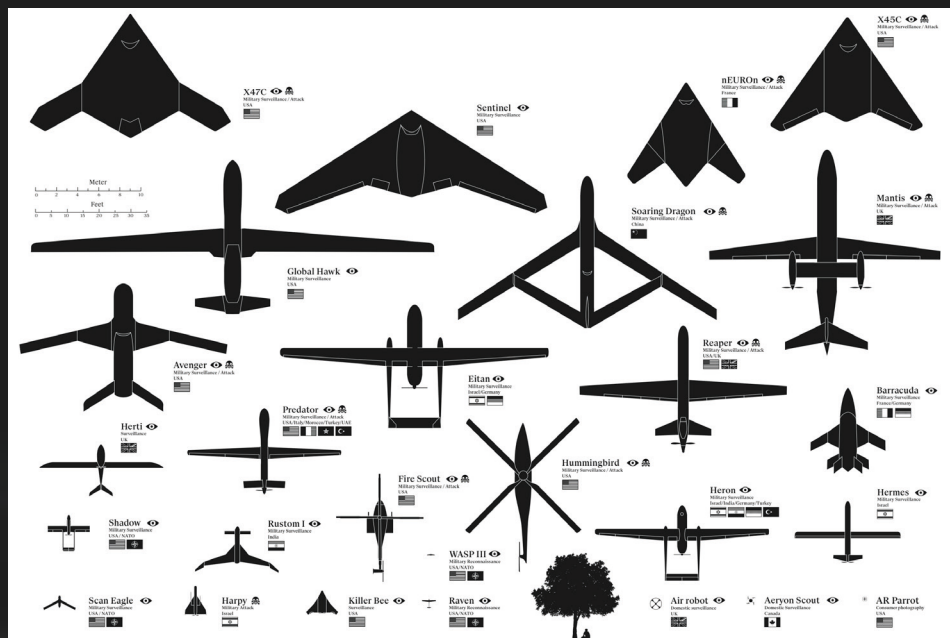


## DRONE MARKET SIZE

The drone market will grow steadily in the consumer, commercial, and military sectors. In a 2016 report, Goldman Sachs estimated that drone technologies will reach a total market size of \$100 billion between 2016 and 2020. Though 70% of this figure would be linked to military activities, the commercial business represents the fastest growth opportunity, projected to reach \$13 billion between 2016 and 2020.<sup>[1]</sup>

## MAIN DRONE USES

- Environmental
- Sports
- Policing
- Insurance
- Conservation
- Counting stockpiles
- Construction
- Imaging
- Show / Light-show
- Marketing
- Search and rescue
- Agriculture (Taxi)
- Package delivery
- Filming
- Entertainment
- Hobby
- War / Scouting / bombs



Surveillance drones



Some drone manufacturers



Fixed-wing drone catapult

## FIXED-WING COMPLICATIONS

As mentioned before, the drones are used either for transportation of something or data gather. Almost all conventional uses of drones fall under these two categories

Point of interest in this research were drones that are used for observation in distant territories. Most important feature of such drone is a longer flight time, meaning energy efficiency. The wings or aerodynamic lift play the main role in this sense. When an AV has aerodynamic qualities it uses much less energy when it flies

Standard winged drone require take off / landing site to deploy, or a catapult to launch it in the air. These infrastructural requirements complicate the use of such drone and increase time of deployment. In search and rescue context both of these aspects play a huge role. Time inefficiency plus low availability are lowering reliability in these tools, which lowers chance of implementation of these tools

Considering these findings I studied how can a drone have VTOL and hover functions and remain aerodynamic qualities at the same time

<sup>[12]</sup>Manufacturers of drones specialize on fixed-wing drones and multi-copters mainly. Not many produce drones for surveillance and search operation purposes. I have studied the market to understand what is offered and in what degree they solve existing challenges in SAR field

One of the findings is that most drones produced are built on the same principals, where the form is very often pre-defined by the function. Offered solutions are highly dependent on technological trends, where efficiency is measured by type of battery and engine installed. Very few attempts to make changes conceptually to traditional fixed-wing plane or multi-copters

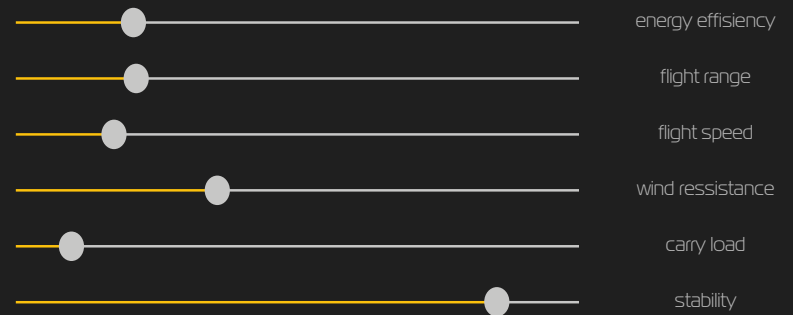
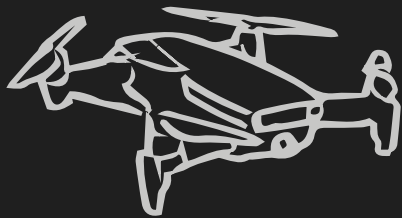
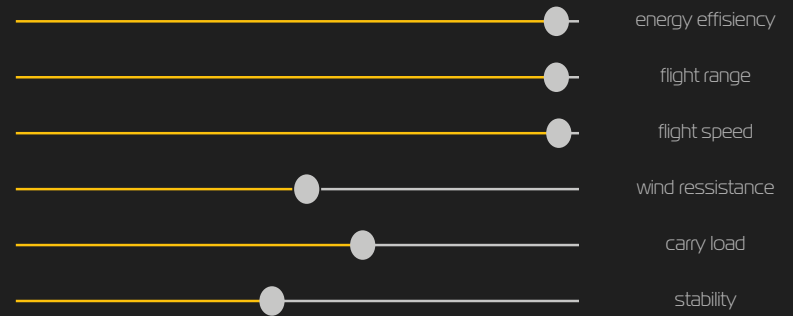
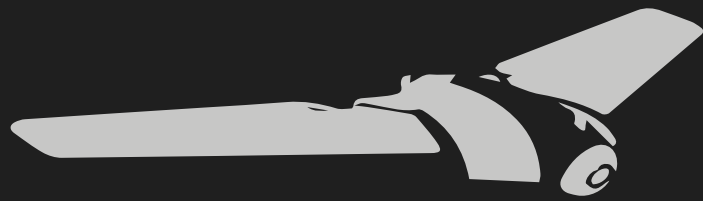




# COMPARISON

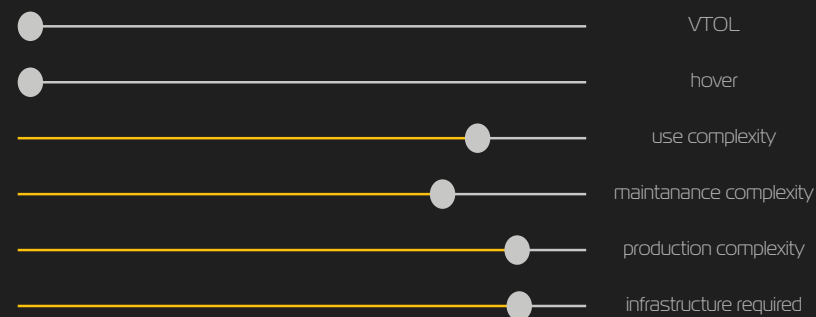
RESEARCH

I want to illustrate the basic technical properties difference of three main types of AV's. The properties shown below are approximate and only represent general relation between these types. Usually they vary in form, function and abilities, from product to product



Study of these three main types of AV were a part of re-research. I studied how they work and what are their benefits. Weather they are feasible or efficient enough. If not, why? What kind of improvements are required? Who uses them and how? How complicated are they? What are the technical capabilities?

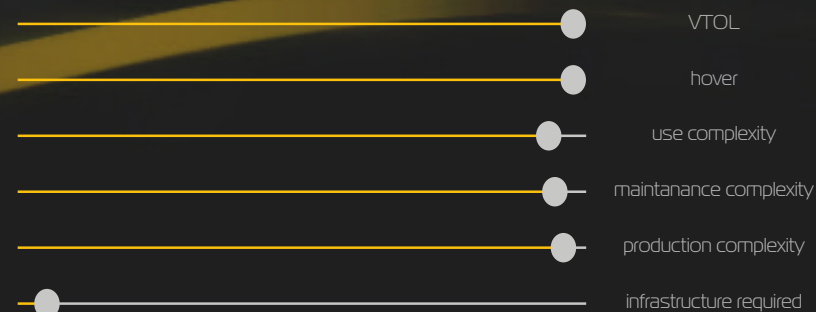
Here I want to summarize shortly finding results of this exploration. I'm ignoring the details here and looking at AV's from a pragmatic point of view, naming only relevant to project properties



## FIXED-WING PLANE

A fixed-wing plane is an aerial vehicle with relatively high aerodynamic properties. They vary from low speed planes to high speed planes. A distinctive feature is that a fixed-wing AV can plane on wings if the thrust engines fail, and can land safely

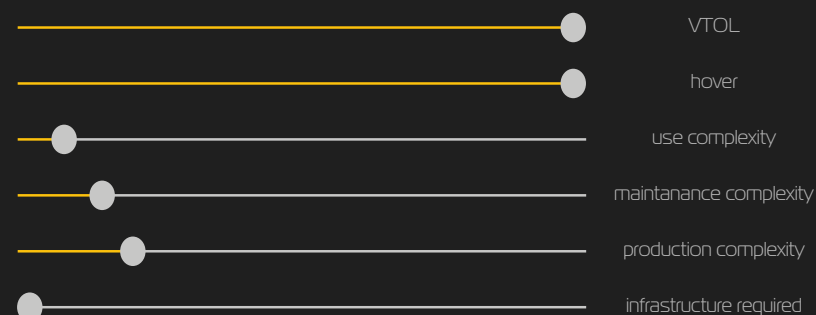
The negative side of fixed-wing planes are a take off / landing site requirement, meaning extra infrastructural expenses and the need of complicated hardware for landing. Control of such drone also requires piloting skills



## HELICOPTER

A helicopter is a type of AV that uses rotors to lift itself and to thrust forward. It uses either one rotor or several coaxial rotors. It also has additional smaller rotor on the backside called anti-torque tail rotor. It is used to control pitch and yaw movements of helicopter

Helicopter is a relatively complex system, but it has a high maneuverability compared to a fixed-wing plane. It can lift vertically and hover, and is less energy-efficient than a fixed-wing plane



## MULTI-COPTER

<sup>[3]</sup>Multi-copters are a relatively new AV's on the market, usually much smaller size. They work on the same principals as helicopter, but using 4 - 6 - 8 and more identical rotors to lift and steer. The reason for pair number of rotors is to counter torque effect and simplify controlling

Multi-copters are popular hobby toys because of their simplicity in exploitation, production and control





# USER INSIGHTS

## RESEARCH

Governmental Fire and safety department, and volunteer organizations are main actors in Search and Rescue operations. I have arranged interviews with representatives of Fire and Safety department in Oslo to gather insight needed for my project.



Daniel Johansen is a fireman at the main firestation in Oslo.

## FIELD COMMANDER

From the user perspective the drone can play significant role in analysis of dangerous situations. In some fire departments the drones are used to observe local areas, examine burning buildings, and to find «hot zones» after put-out fire in the nature, like it was in a wildfire on the outskirts of Oslo in August 2018

Field commanders drive around all day and receive signals from different sources. They are the key in initiation of operation and they have to rely on a subjective assessment of the situation. The decision or reaction is highly dependent on where they are at the moment and whether they have available tools to examine the situation closely. Time saving analysis can play a key role in an emergency situation. It is important in this matter to have a reliable tool available - whether stationed locally or in possession of field commanders. Real time information would influence the decision, resource spending and outcome of an operation positively.



-Time is the most valuable resource in any fire and safety situation

-There are four main «Scene commanders» driving out in fields of Oslo that have access to many different signal sources, concerning fire and safety

-Scene commanders are the main observers and initiators of emergency operations

-Analysis of the situation is an important part of operation, it gives more chances to save people and infrastructure and secures lives of firemen

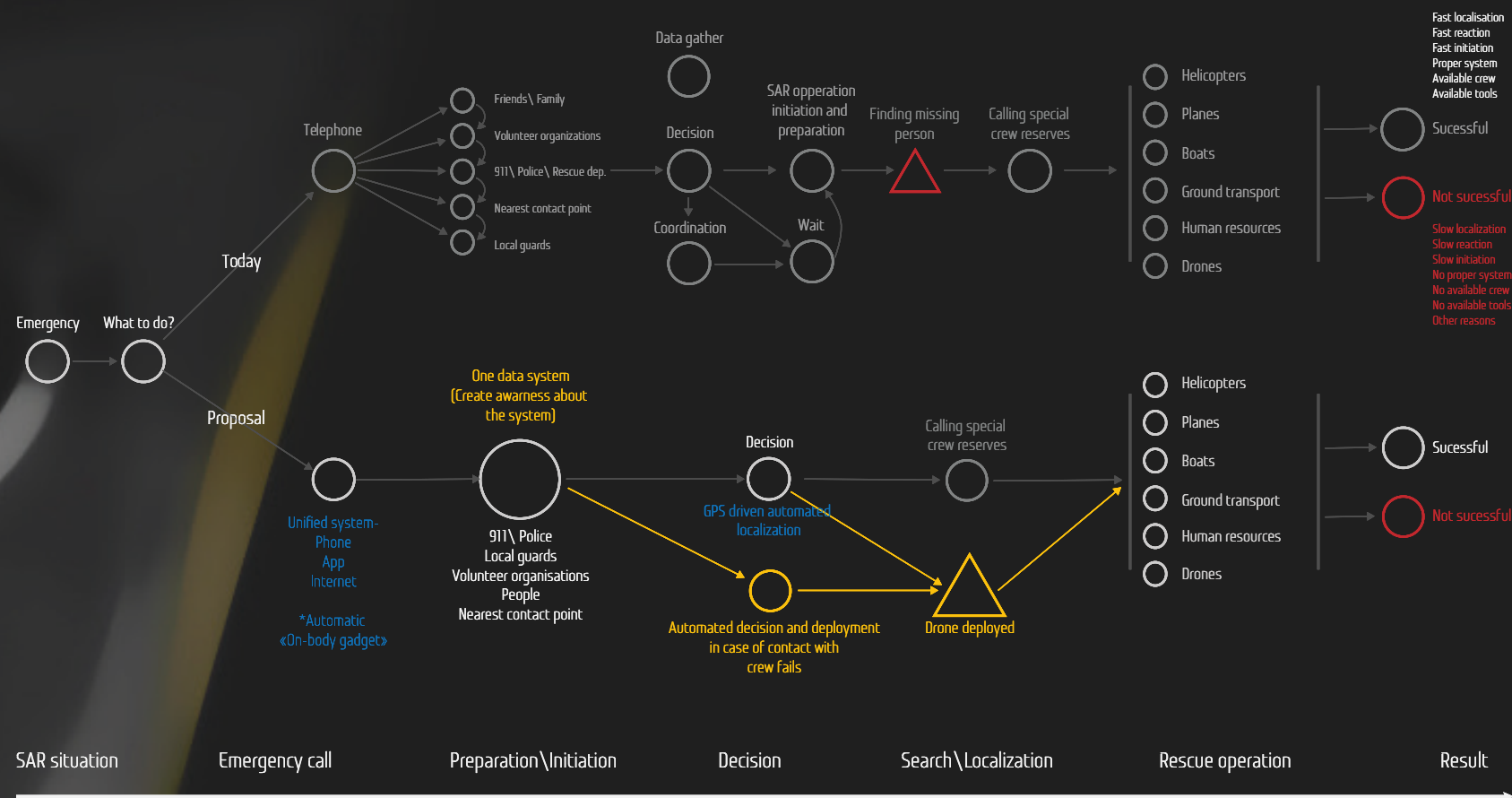
-Drones can play significant role in situation analysis

-Aerial overview is a valuable resource when it comes to analysis of burning building or finding «hot zones» on the landscape after fire is put out

-Usually police helicopter or volunteers with drones are hired for aerial investigation

-Would be used more if it wasn't that expensive

-Certificate required to use drones



## SAR OPERATION

[14] To determine where the actual improvement is needed I have created this simple map of interactions. It illustrates how SAR operation is initiated and carried out today and how it could work.

One obvious weakness today is segmented system when it comes to informing about SAR situation. The actors are interconnected but not unified into a working system. Time consuming process complicates the data gather, preparation, initiation and coordination of operation

Other point that drew my attention is decision making and initiation of SAR mission. It's unclear who makes decision and based on what. Most of it is based on phone-calls and verbal information

Third is the localization of source problem. I have discovered that usually after initiation of a SAR operation piloted helicopters and planes are used for search of lost or endangered people. That is extremely costly and time consuming tools, not to mention advanced skills of special crew required

Based on new findings my research broadened to Search and Rescue operations. This is what my project aims to improve, particularly searching part of the operation. I want to point out that there are clear system weaknesses that need attention and improvement. This illustration shows where this project is positioned in a chain of actions, even though system design is not the aim of the project. However further improvements can be done to the system, including proposed product concept

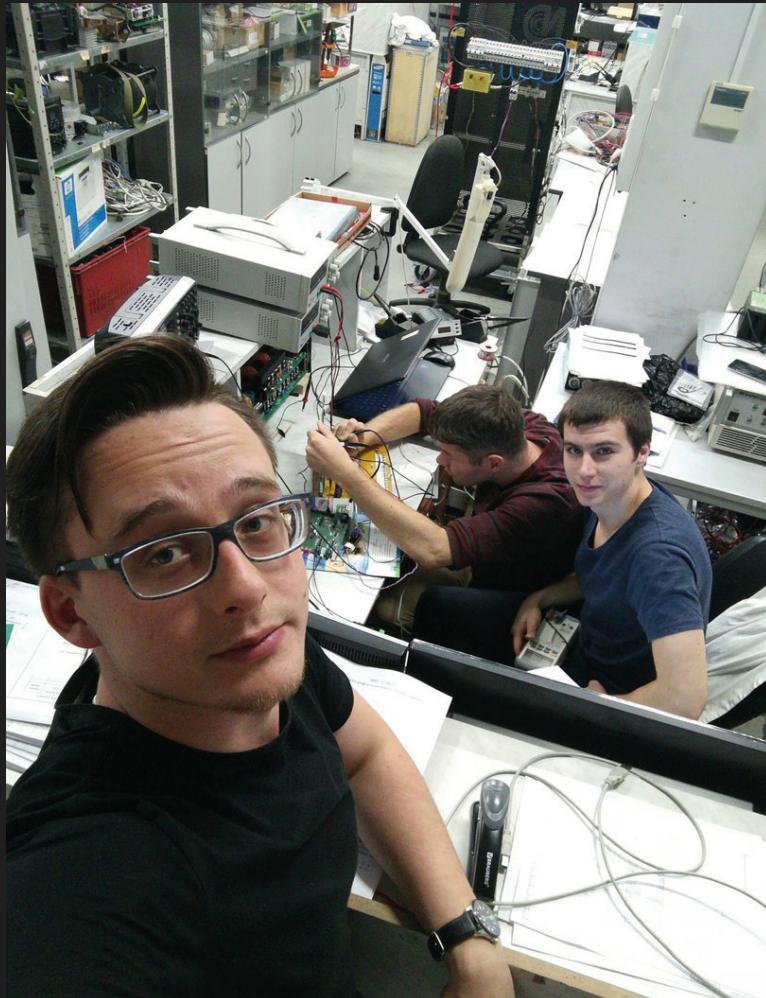




# ENGINEERS LOOK

## RESEARCH

I have contact engineer friend and he has brought up my concept to his engineer team to discuss whether my assumptions about the concept is wrong or right. Here is what they said



Engineer team from Moscow

Considering this feedback I realize that this concept would require a deep engineering testing. Different calculations would be needed. Possibly even reconsideration of Mono-rotor system. In this project I proceed with a mono-copter thrust system, as a hypothesis that needs testing, since quantity of rotors is not the core of the project.



-From top of the head the form doesn't seem like it wouldn't fly or not be aerodynamic enough. Analytical test needs to be done to be sure

-Stabilization would be the hardest to achieve here. Counter rotating rotors is good and they would exclude torque effect, theoretically. In real life conditions nothing is perfect and all small errors in the form, weather, air density and turbulence will cause wobble and shaking of the drone. Stabilization of that would require additional sensors and hardware.

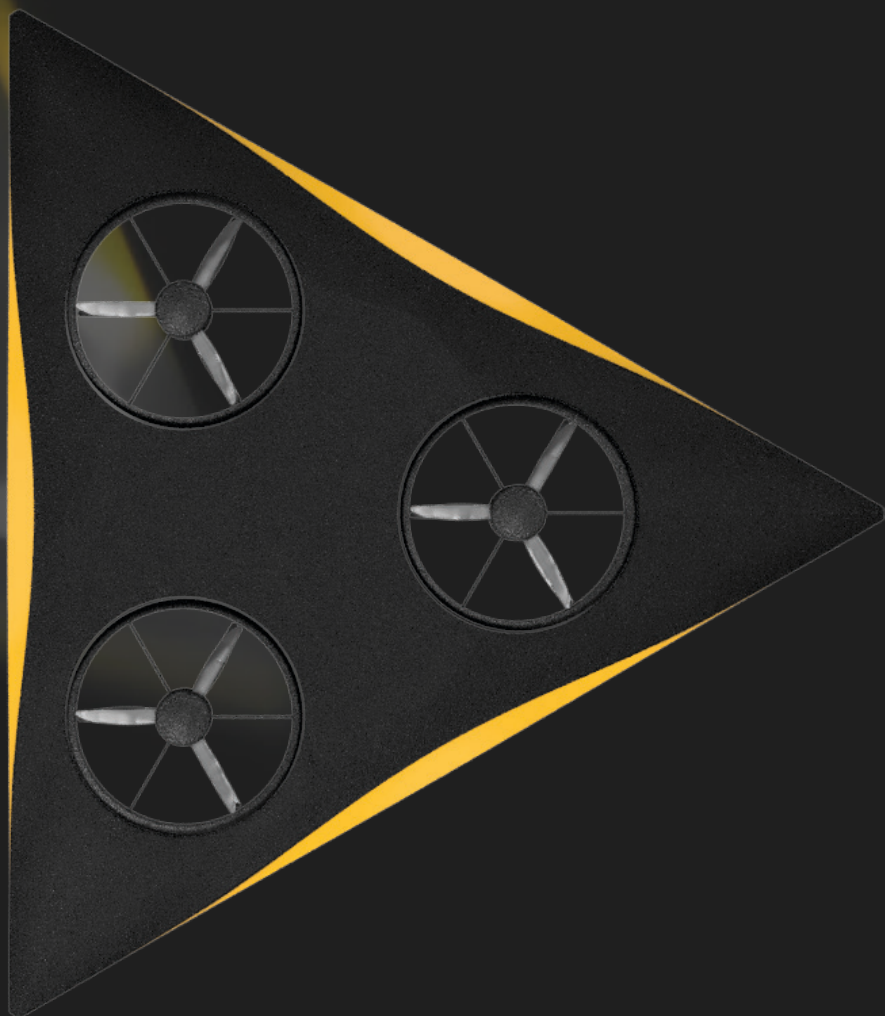
-Steering of this drone will require more advanced software than any other aerial vehicle. Would require very advanced control system.

-The more drones combined the more stable it will be

-If this form would have several propellers inside the body instead of one, the problem of stability would be solved much easier

-Other than that lifting, thrust vectoring assumptions seem right. As said, production of such drone will need a lot of analytical development, tube test, balance control etc.





Comments of Olaf Hallan Graven, a professor at Buskerud Highschool

"You should model it in a program that can simulate it. Control can most likely be done using only the engine, it will in practice act as a "thrust vector" engine. Such a thrust vector engine is used in some fighter jets, then as a jet engine. I am very unsure how this will be because the air flow will hit a part of your wing

The concept of connecting several is clever, this will lead to better lifting and thus cheaper (Minor energy) to move the drones together. You should possibly also look at formation flight (as birds do) and how much less effective it may be, if pairing is only for transportation. If pairing is to lift something that's heavy, then it's another matter

From a clean engineer's point of view, I'm unsure how the engine is being constructed. I need the ring around which will turn the engine, also the shaft that will tilt it. These are parts that are exposed to a lot of forces and therefore must be designed with care. Possible but not quite straight forward. You also have a potential energy transfer to the engines (many things that matter here and it's not only a good combination of wires). All this is possible to fix but requires some work

One final challenge is also if all these engines can be rotated / moved fast enough to control a drone in the air

The concept is interesting and there are many who attempt to combine drones, no one has been completely successful yet"





# 3B-ANALYSIS

## RESEARCH

Who are the users? How is it used? In what situation it is used?

This method was used to study thoroughly, map out and analyze the SAR topic. It gives an idea of how user group might interact with the product, or what features would actually be useful to them

### WHO

Main user group is mostly male adults from 18 to 50 years in good physical condition.

-Safety personnel with first aid training or higher medical qualification.

-Local guards and other volunteer safety crew with specialist at disposal, like divers, rock climbers, snow scooter drivers and others

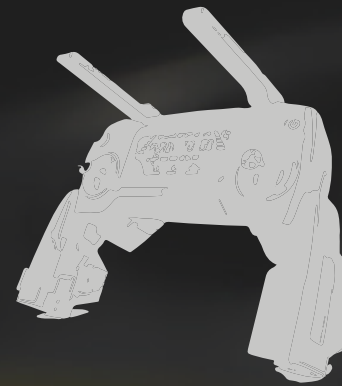
### HOW

There are several ways to control UAV's:

-With direct visual contact and remote controlling with a joystick or program

-Without direct visual contact, piloted through drone camera point of view. Steered with joystick or special program

-Automated flight program installed into drone ESC



DJI Mavic Pro controller

### WHAT SITUATIONS

Scenarios qualified as a SAR operation is when people are lost or are in imminent danger. Situation reasons and factor may very significantly. Our point of interest is when people are threatened in far city outskirts, usually in the nature landscapes, like mountains, rivers, ocean, forests, coast and similar. Practically it is hard to reach areas

### WHAT

Imminent danger  
Lost  
Accident  
Abduction  
other...

### FACTORS

Human factor  
Incautious  
Extreme Sport  
Natural disaster  
Equipment failure  
Weather conditions  
other...

### WHERE

Mountains  
Forrest  
Coast  
Field  
River  
Ocean  
Desert

### SITUATIONS

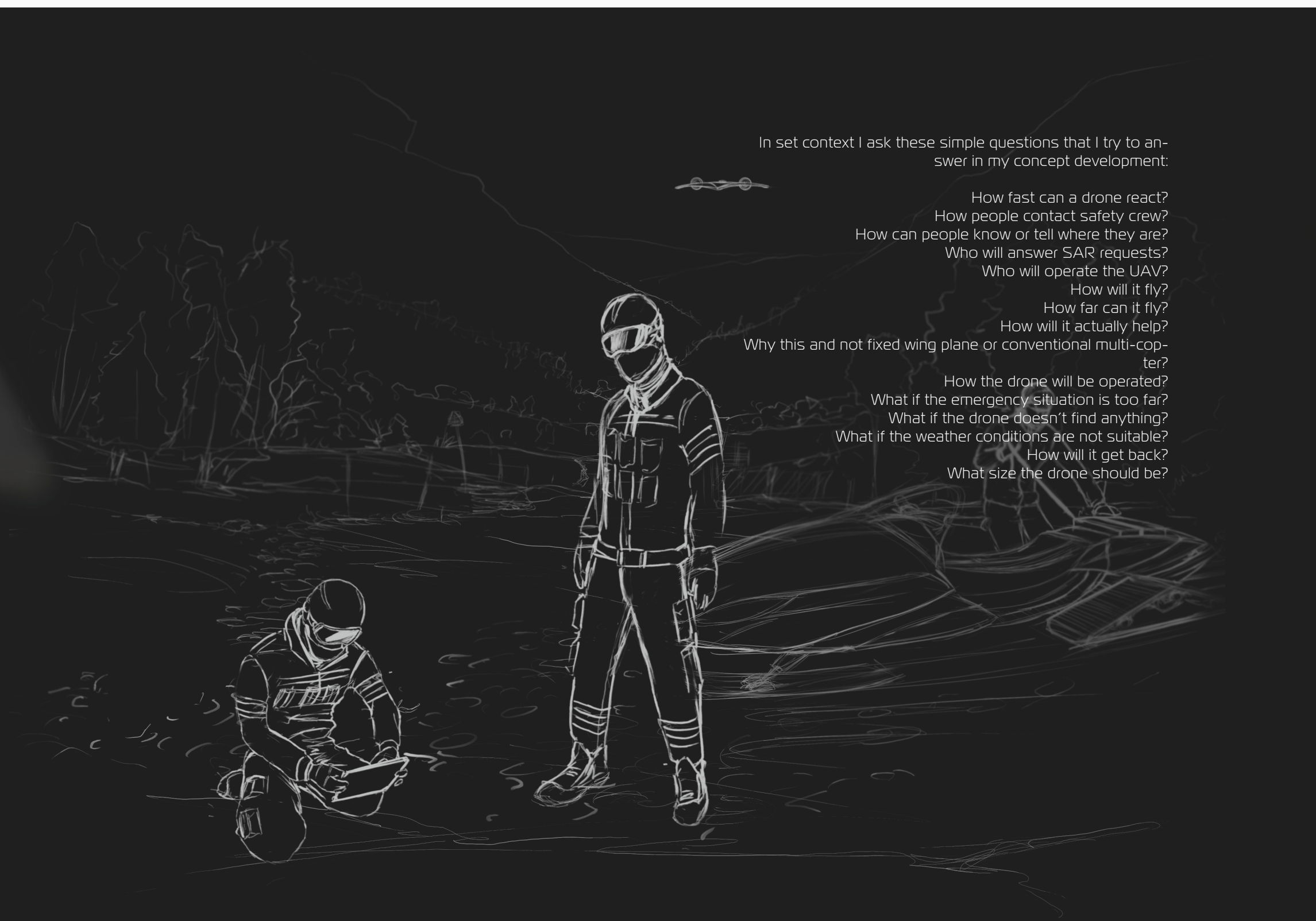
Natural disasters  
Earthquake  
Fire  
Wildfire  
Flood  
Tornado  
Storm  
Lightning hits  
Droughts  
Sand storms  
Avalanche  
other...

NATURE



URBAN

Earthquake  
Flood  
Tornado  
Terrorist attack  
War-zone  
Tourism



In set context I ask these simple questions that I try to answer in my concept development:

How fast can a drone react?  
How people contact safety crew?  
How can people know or tell where they are?  
Who will answer SAR requests?  
Who will operate the UAV?  
How will it fly?  
How far can it fly?  
How will it actually help?

Why this and not fixed wing plane or conventional multi-copter?

How the drone will be operated?  
What if the emergency situation is too far?  
What if the drone doesn't find anything?  
What if the weather conditions are not suitable?  
How will it get back?  
What size the drone should be?

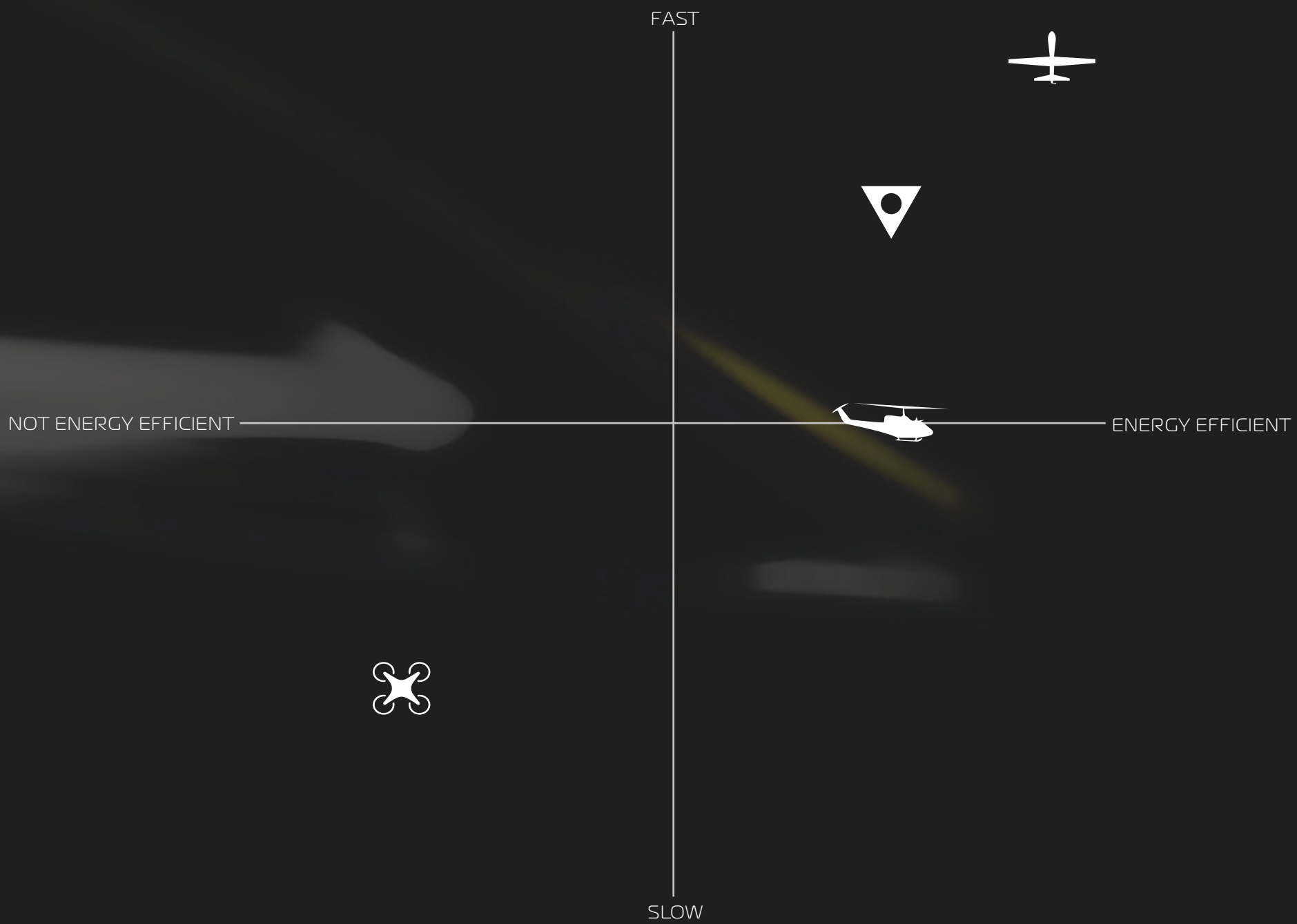


# POSITIONING

RESEARCH

A simple positioning of the concept in relation to conventional aerial vehicles. This is a hypothetical assumption. Fair enough to say that Quaero is not a simple AV from a technical point of view. It is simple in its ideal, theoretical user situation









# REQUIREMENTS

## CONCEPT DEVELOPMENT

### MUST

- Modular combinatoric form
- VTOL / Hover function
- Aerodynamic form
- Energy efficient solution
- Provide long flight range
- Fast fly speed
- Maneuverable
- Technical
- Sensor's hub
- Long range radio
- GPS tracker
- Camera

### SHOULD

- Automatic mission deployment
- Autonomous lift off/  
Landing
- Certain stability
- Average wind tolerance
- Collision resistance
- Easy exploitation

### COULD

- Carry objects
- Slots for additional  
Hardware

The research was summarized into a set of requirements for the product. It tells what features, properties and abilities my product should have to satisfy problem definition.

I decided to combine all advantages of conventional AV's into a new product and try to minimize disadvantages

# HOW TO IMPROVE EFFICIENCY AND AVAILABILITY OF AN AERIAL VEHICLE IN SEARCH AND RESCUE SCENARIO WITH DESIGN?

## RESEARCH SUMMARY

The research process was a complex of actions I have made in parallel. One of the main methods I used was Mind-map. It helped me to organize findings, thoughts and ideas, see the bigger picture, discover relations, find strong and weak points in the process. As well as it helped to reflect on my own design process

During research I used sketching as a thinking tool. Each finding changed my understanding and perception of idea around what should be designed and how it should be designed. A systemic overview played a role in definition of context, problem and needs, where I applied fast analysis to influence, reshape and refine ideas during research

User perspectives gave me valuable insight about the practice and direct interactions with similar products. It gave me understanding about practice in real SAR situations. I have considered open and silent insights that have given me the idea about what a search AV should be like, not only today, but in the near future as well

It is quite important to consider technological trends that affect interactions directly. Whether it's an engine that increases flight speed, or super light material, or interactive touch-screen, they all influence experience of the product. Constant exchange of command signals and response from the product is what forms our feel about the product experience. While in this concept the interaction with product is not a dramatical need, it is still one of the small things that will influence the end result. In the end the outcome of a SAR operation is what will form the idea of whether product is reliable or not

I aimed to make a product that can function undoubtedly well in set context. Relatively robust and collision resistant aerial vehicle with VTOL function, aerodynamic form, innovative, and energy efficient. The product should have a purposeful, semi-aggressive appeal because of the seriousness of its function

Problem definition ————— How to improve efficiency and availability of an aerial vehicle in Search and Rescue scenario with design?

What are the needs? ————— The need is an AV that is made specifically for search operations and includes necessary features in the design, not traditional quad-copter equipped with camera

What is the context? ————— Emergency situations. Governmental or humanitarian organizations out on the field. When people, infrastructure, nature or animals are in danger

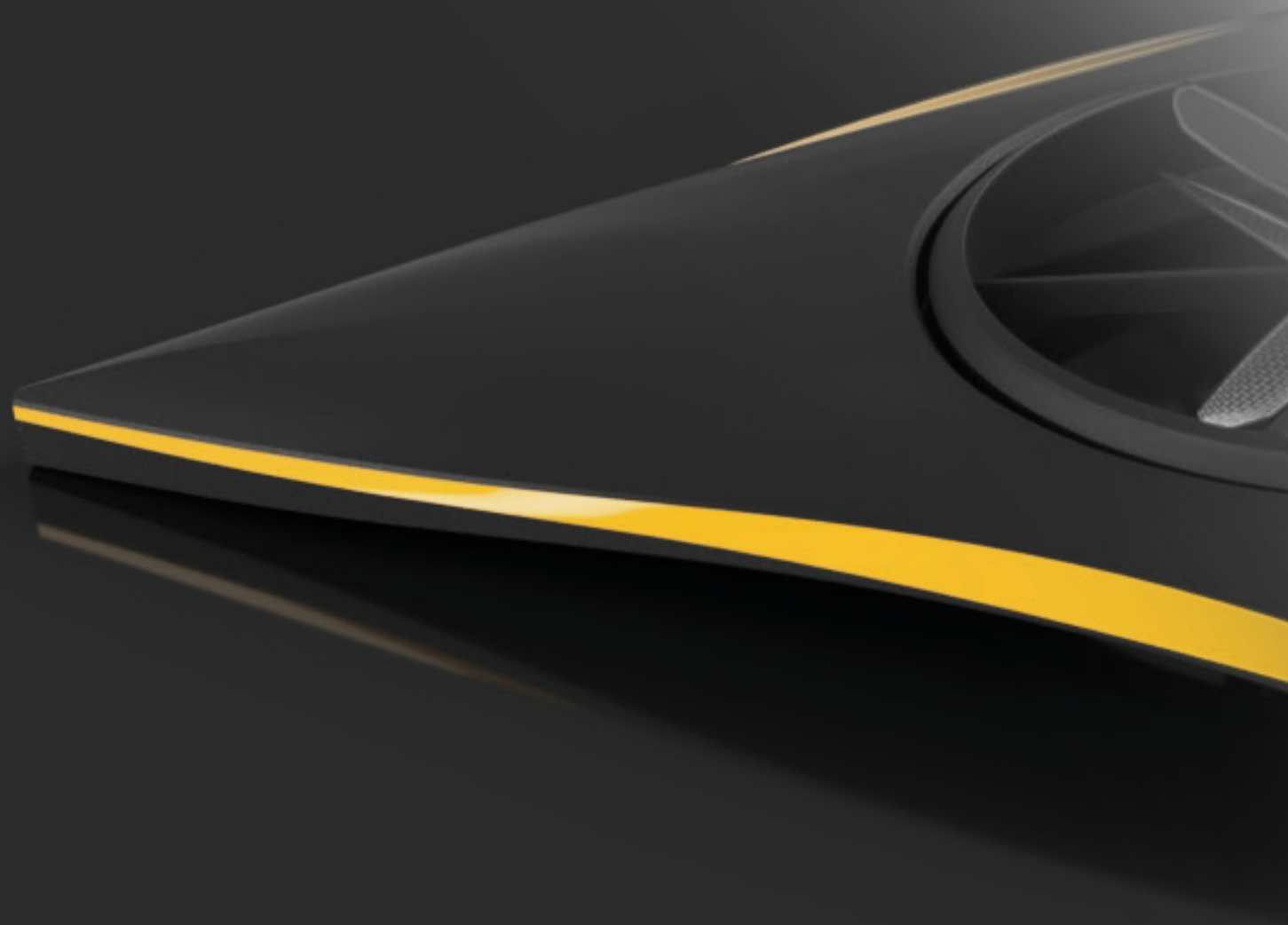
What is the value? ————— The value is time / energy efficiency and reliability

How to challenge traditional? ————— Combination of advantages of fixed-wing plane, helicopter and multi-copter into one innovative AV

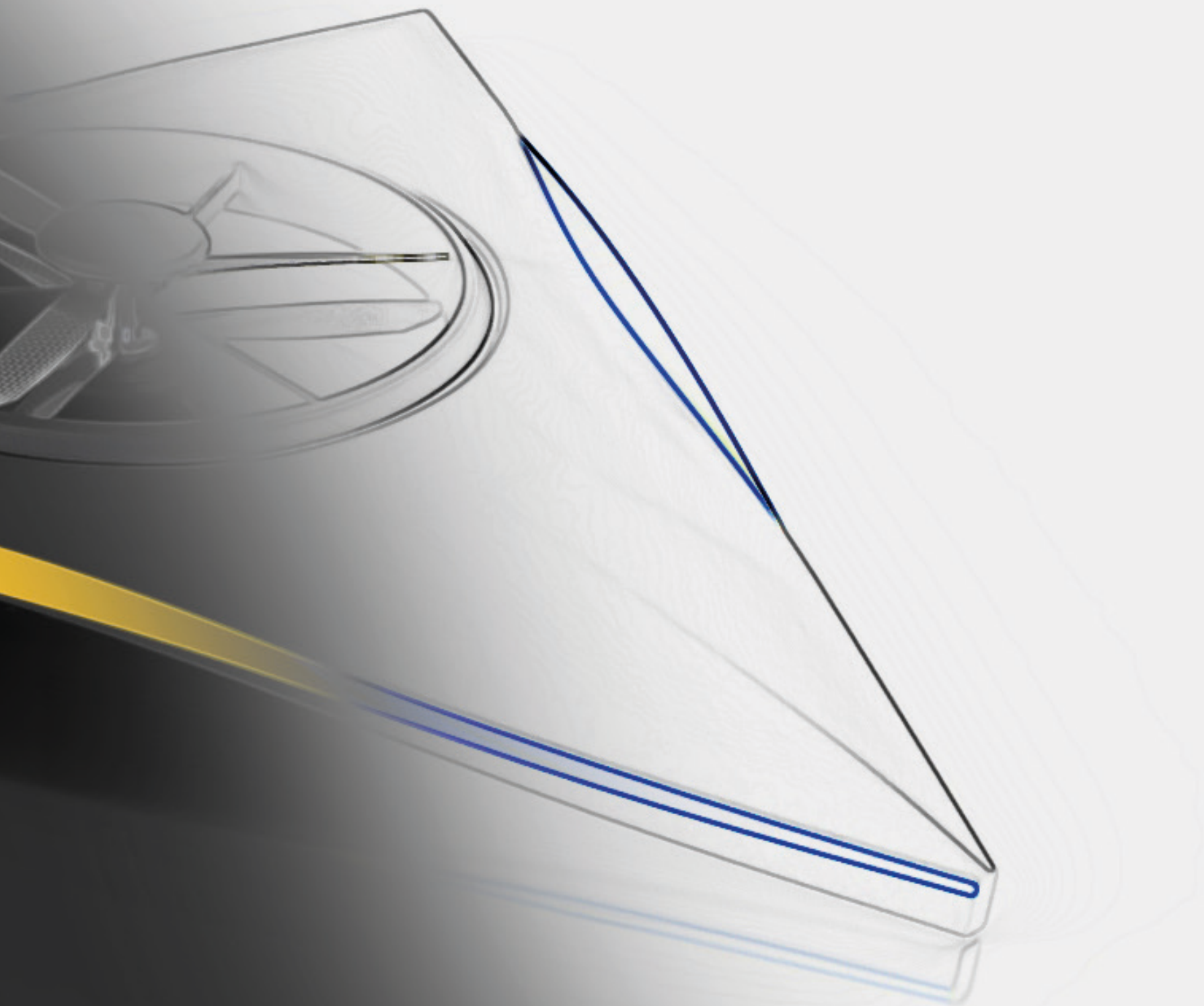
What are the trends and perspectives? ————— The trends show that SAR drones are being produced and developed worldwide. Growing numbers of accidents show that the demand will also grow

What are the risks and challenges? ————— Weather conditions including wind strength can be a major problem. Simplicity is a questionable feature

# DEVELOPMENT PHASE

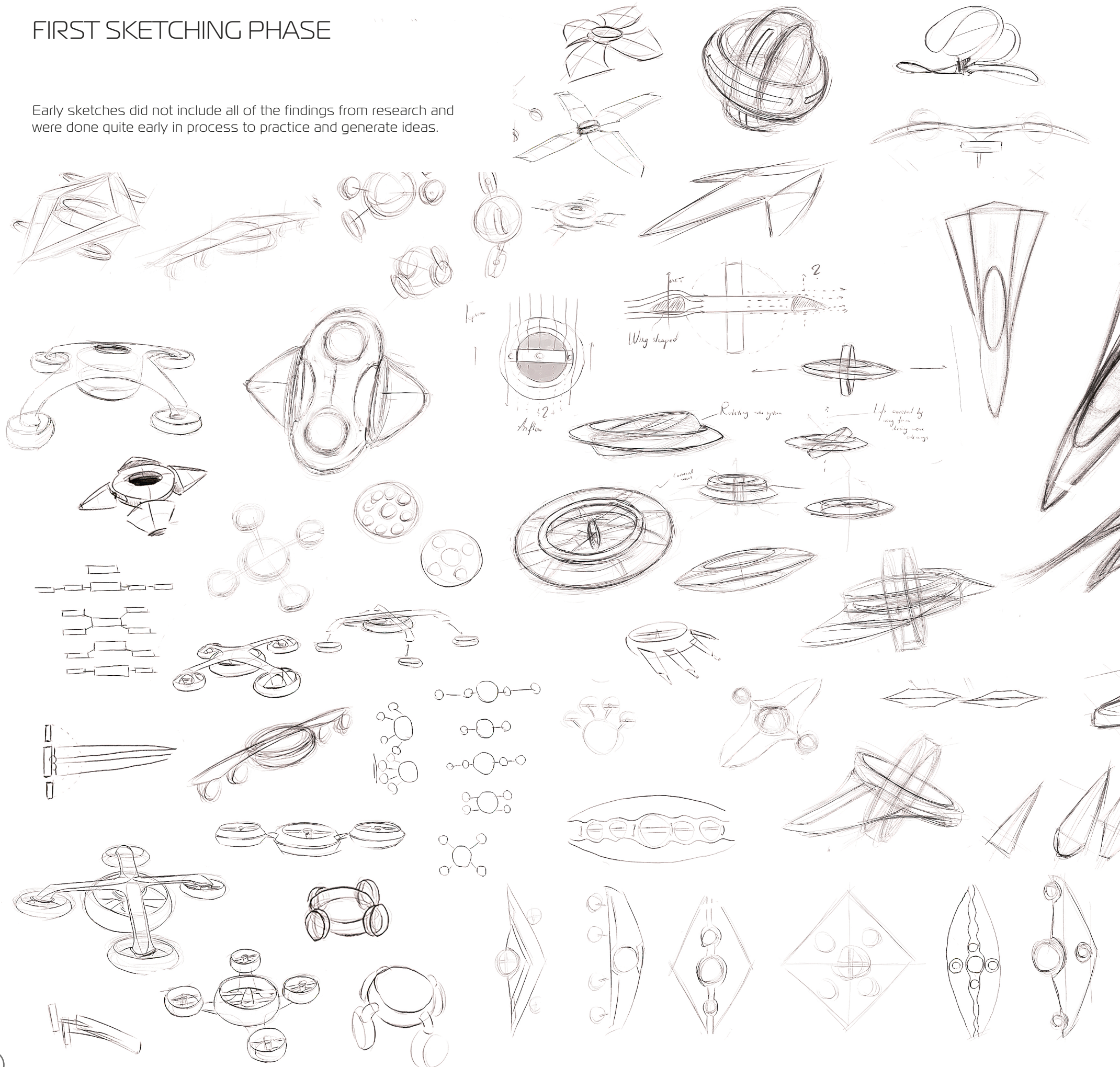




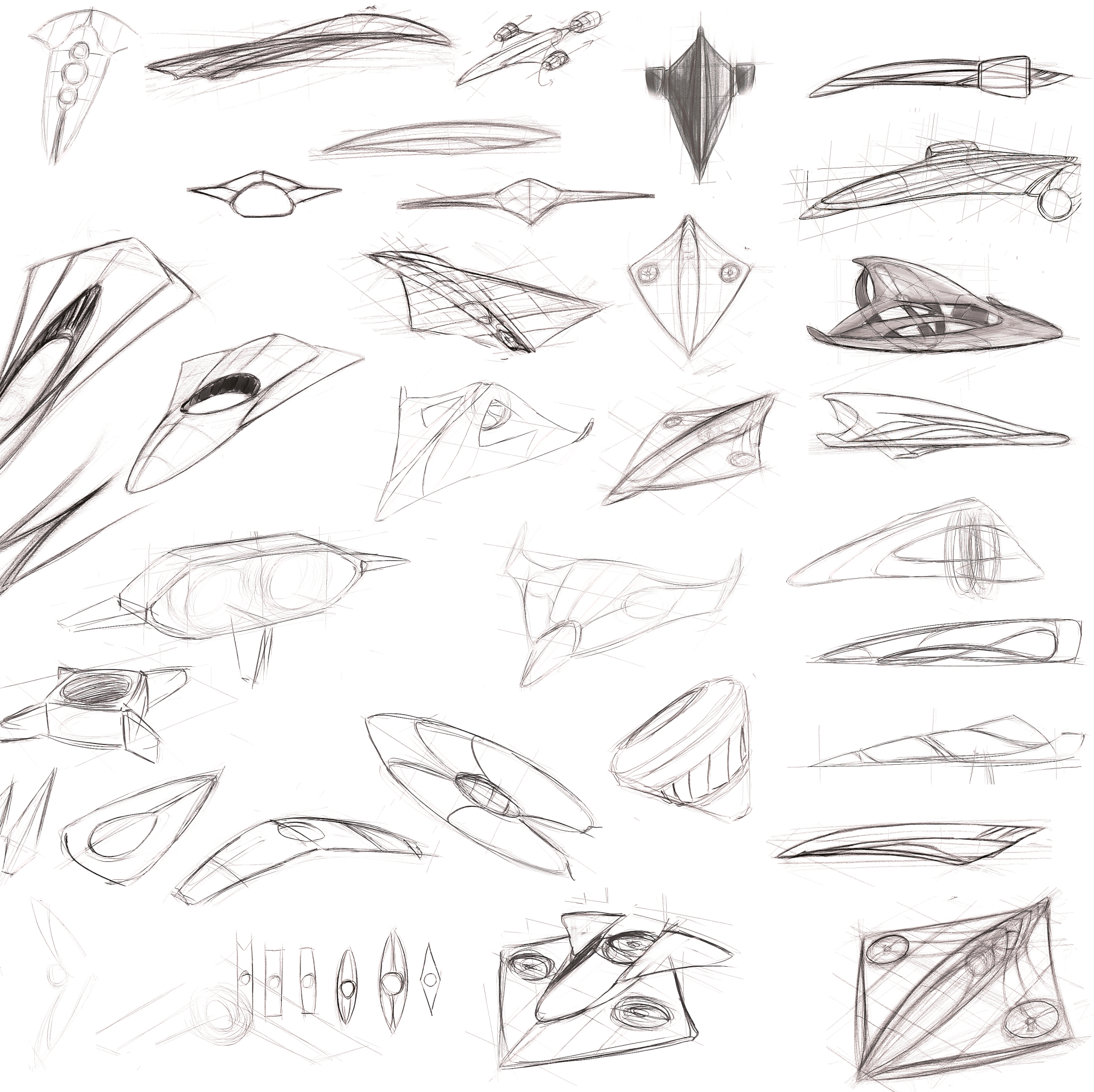


# FIRST SKETCHING PHASE

Early sketches did not include all of the findings from research and were done quite early in process to practice and generate ideas.



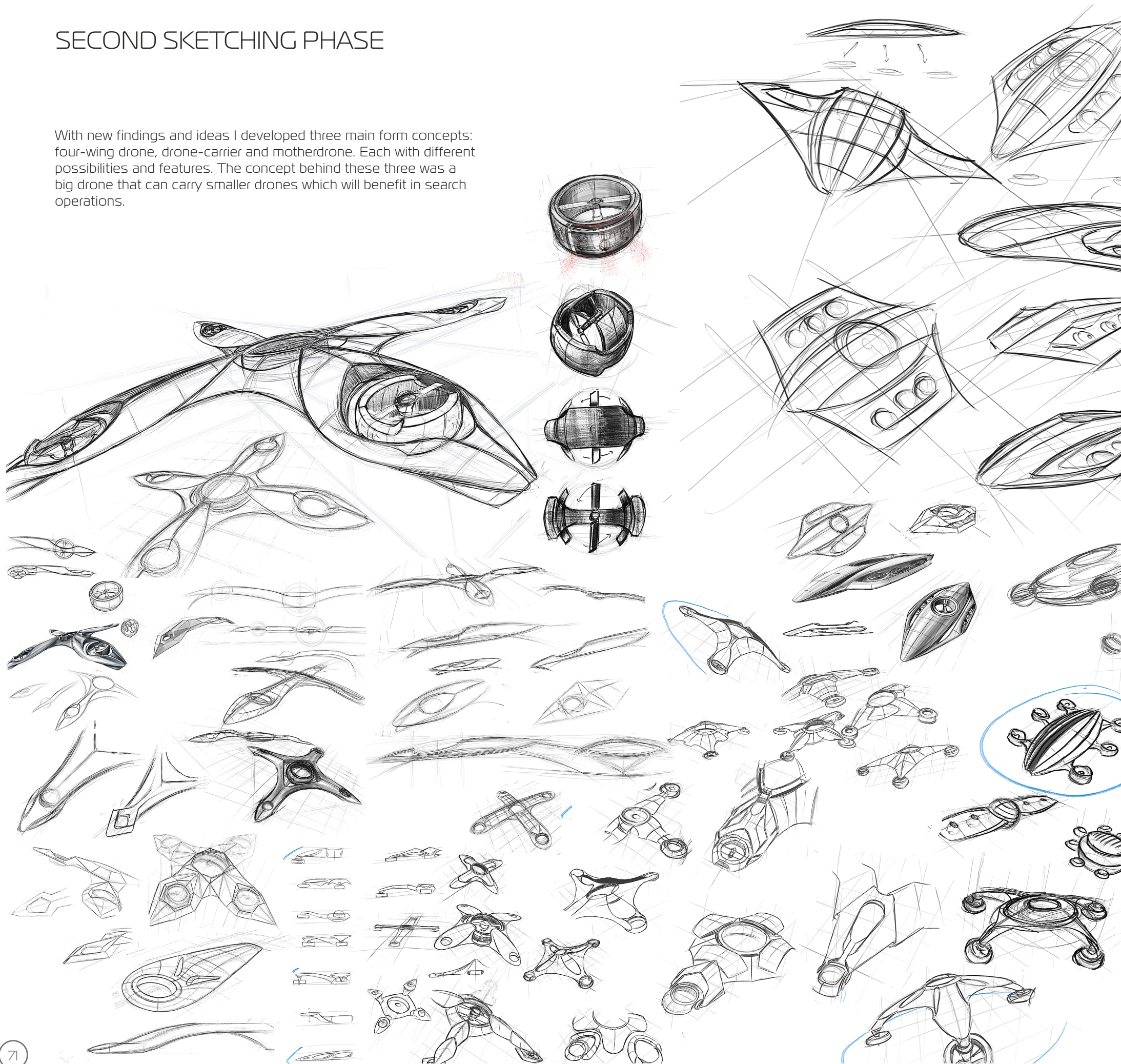




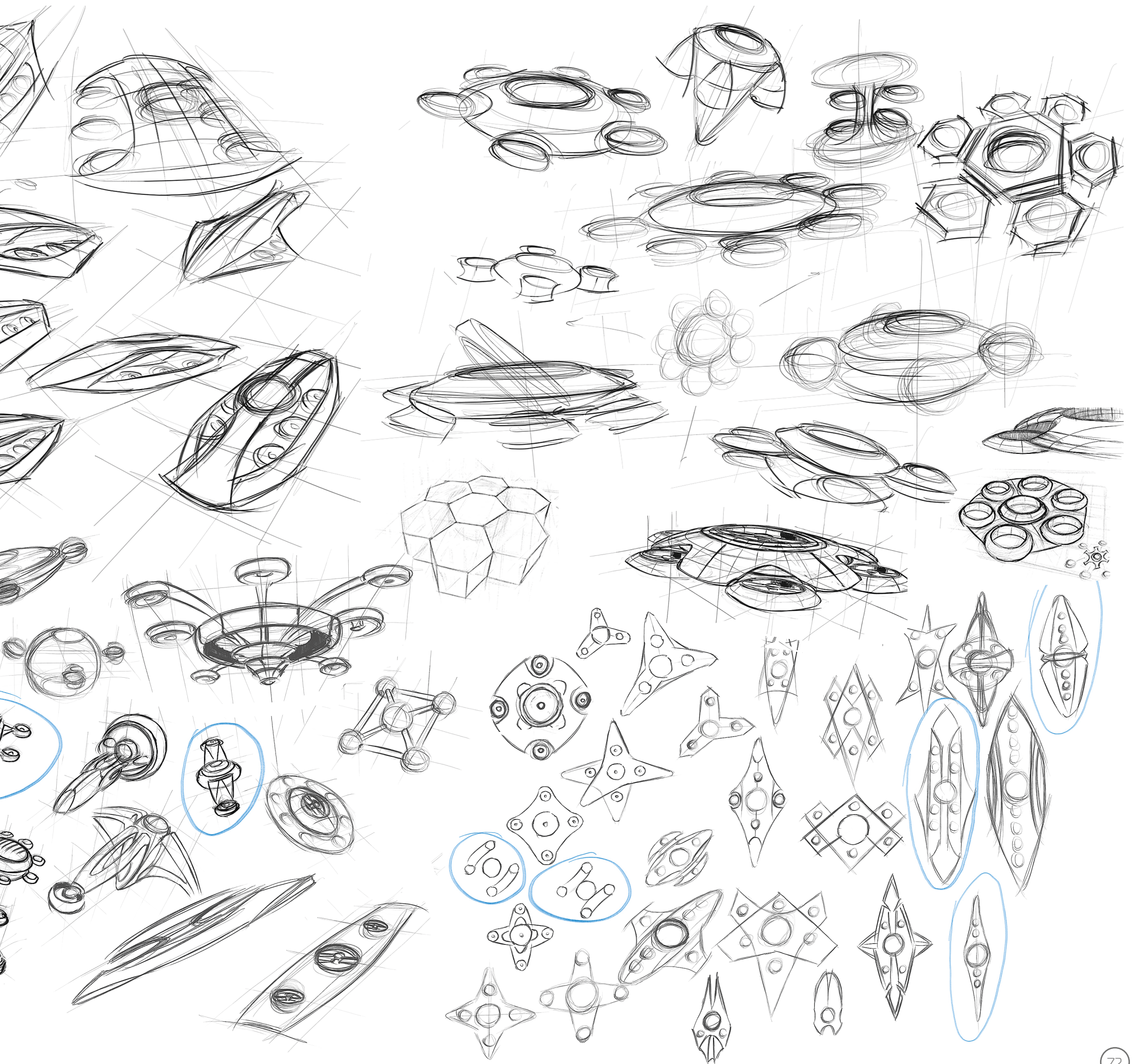


# SECOND SKETCHING PHASE

With new findings and ideas I developed three main form concepts: four-wing drone, drone-carrier and motherdrone. Each with different possibilities and features. The concept behind these three was a big drone that can carry smaller drones which will benefit in search operations.



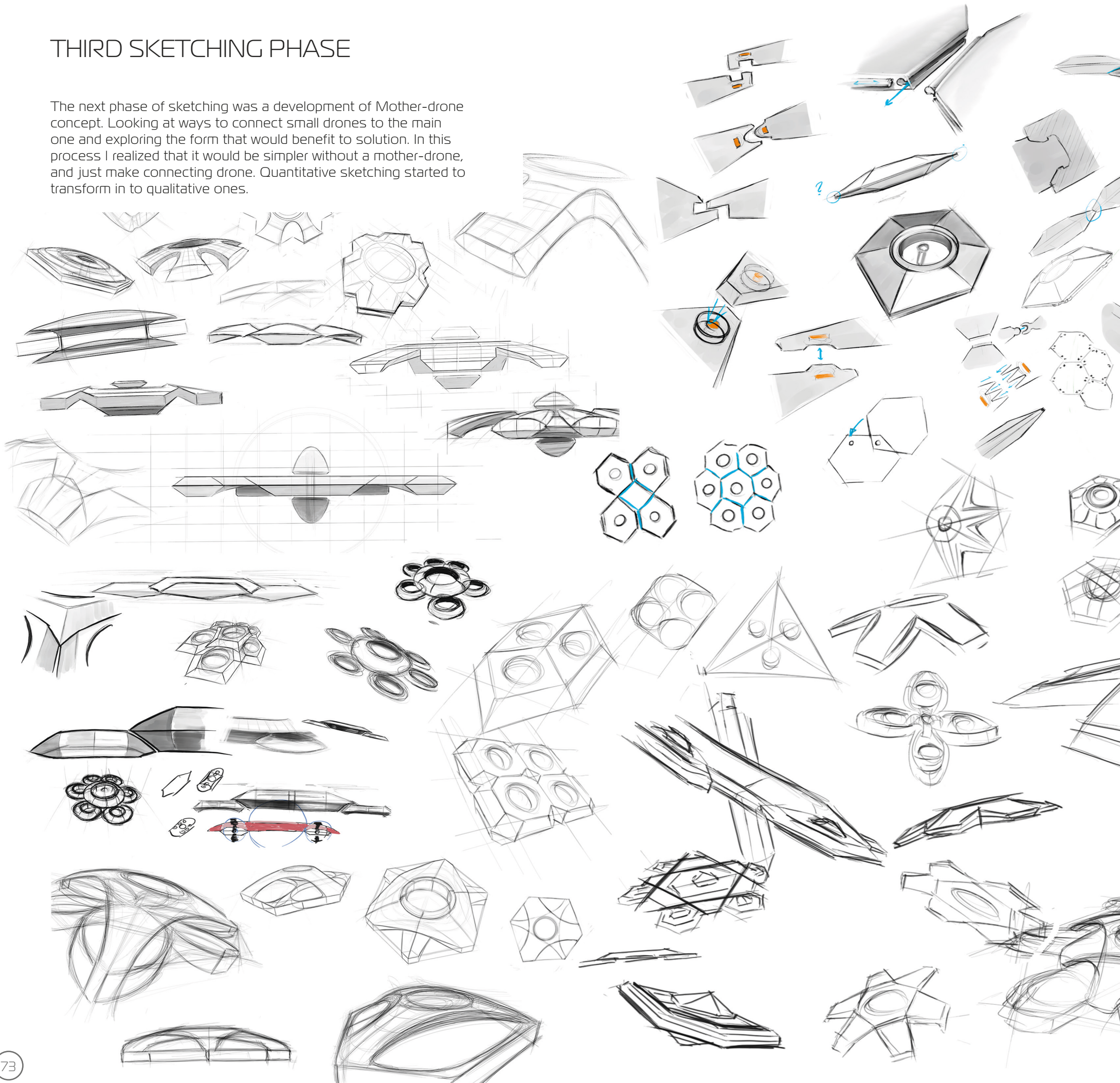




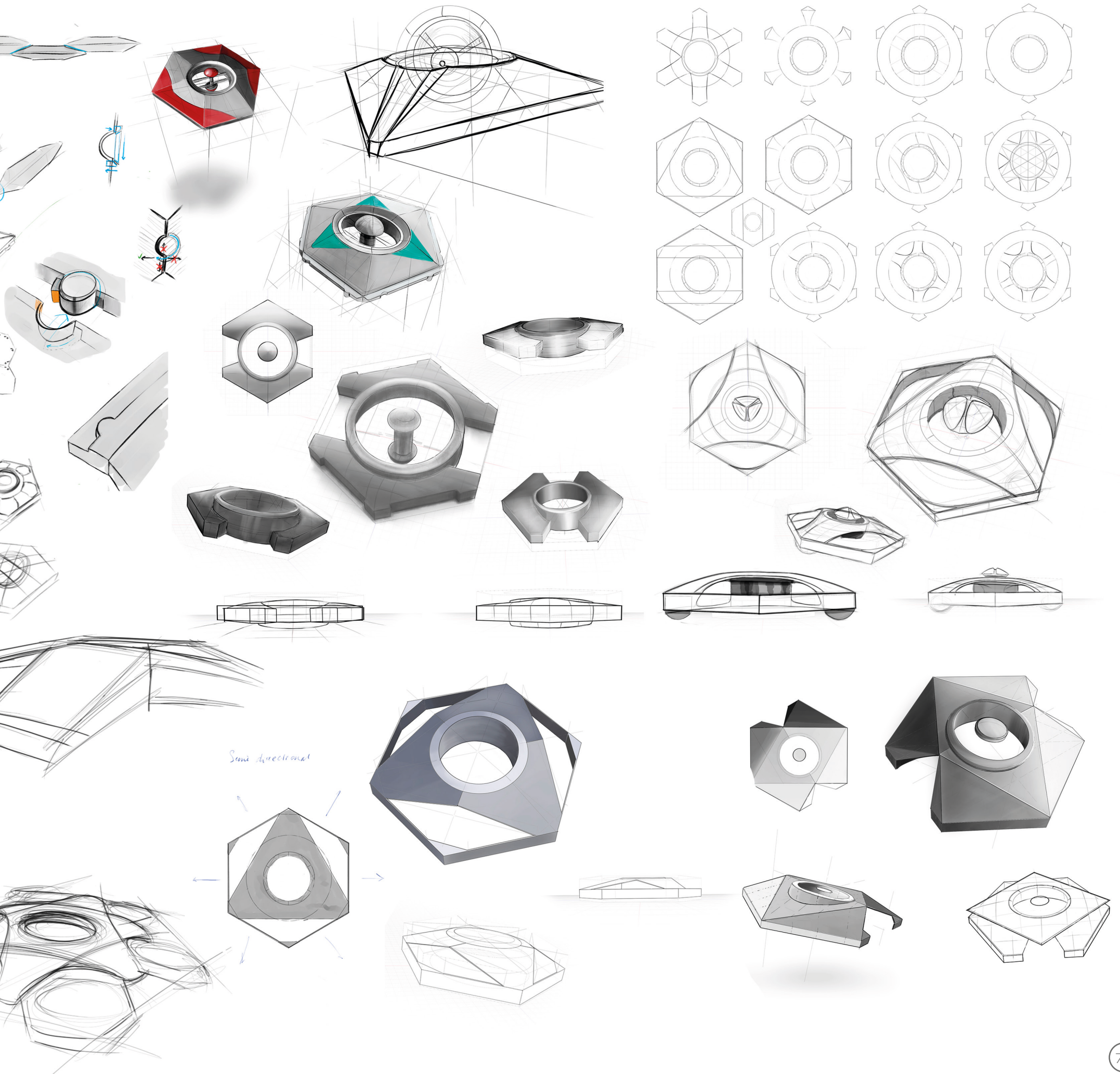


## THIRD SKETCHING PHASE

The next phase of sketching was a development of Mother-drone concept. Looking at ways to connect small drones to the main one and exploring the form that would benefit to solution. In this process I realized that it would be simpler without a mother-drone, and just make connecting drone. Quantitative sketching started to transform in to qualitative ones.



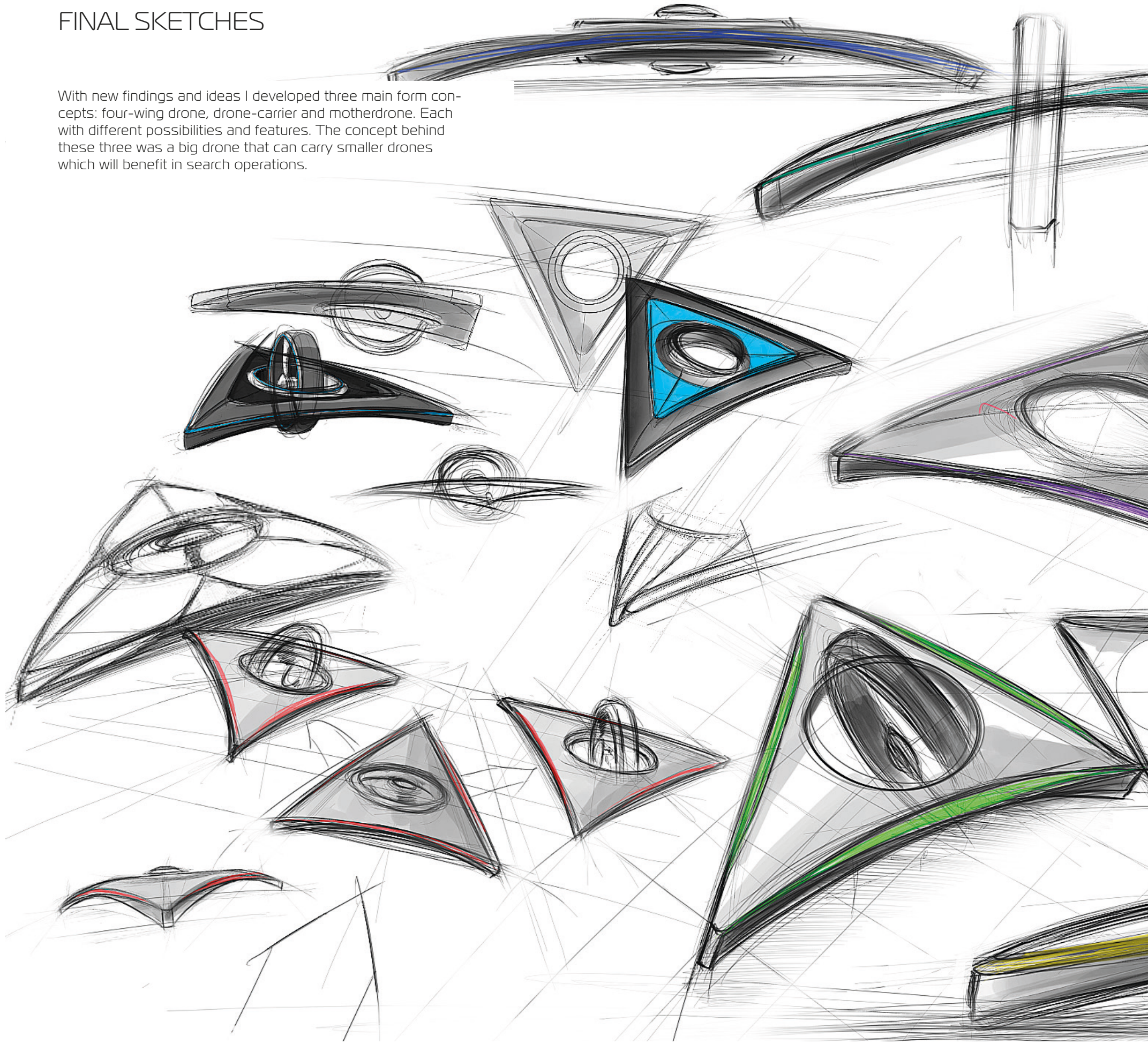




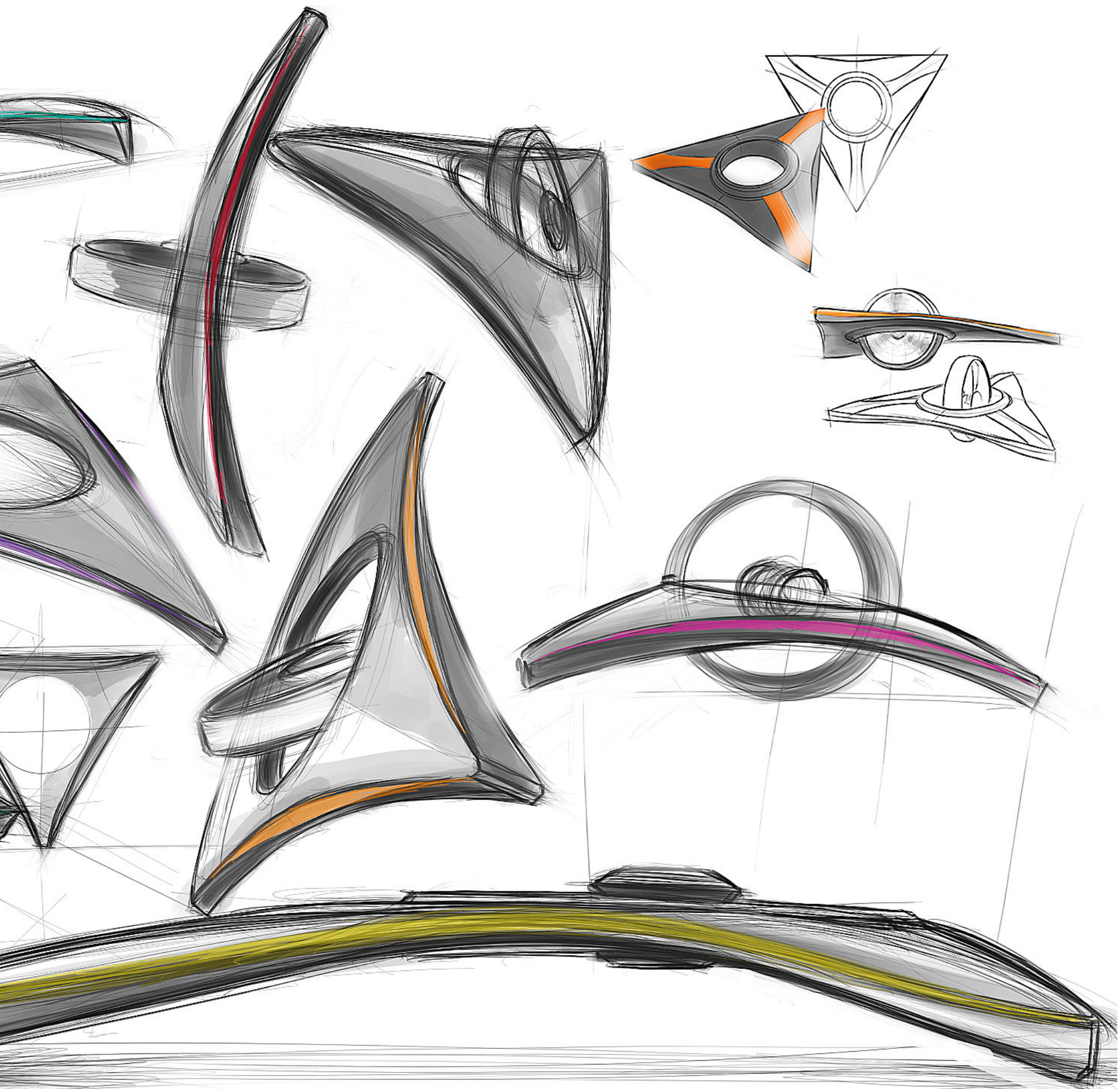


## FINAL SKETCHES

With new findings and ideas I developed three main form concepts: four-wing drone, drone-carrier and motherdrone. Each with different possibilities and features. The concept behind these three was a big drone that can carry smaller drones which will benefit in search operations.





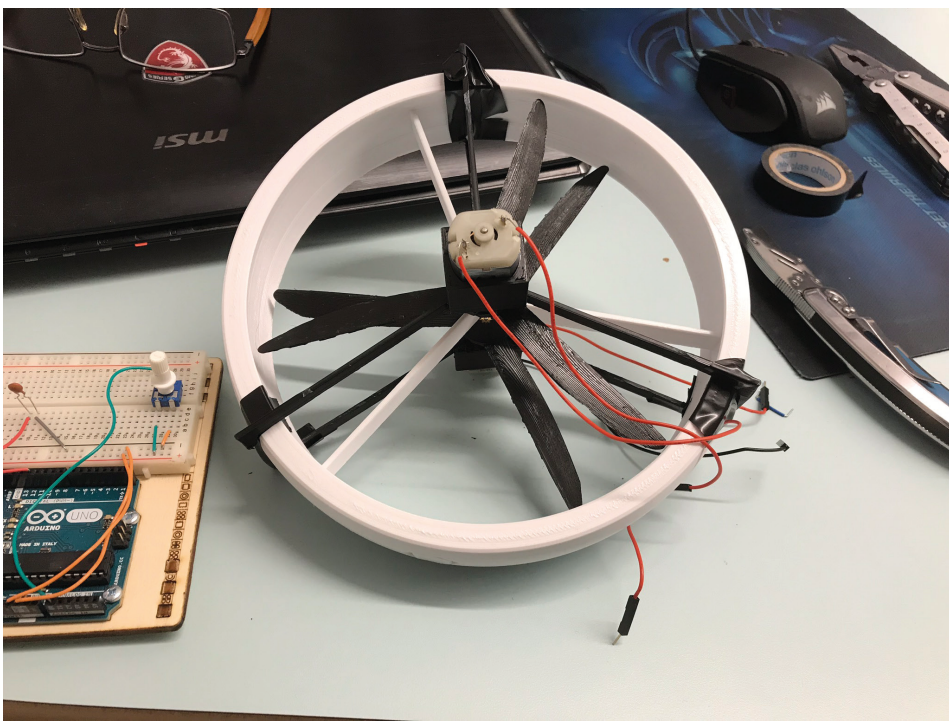
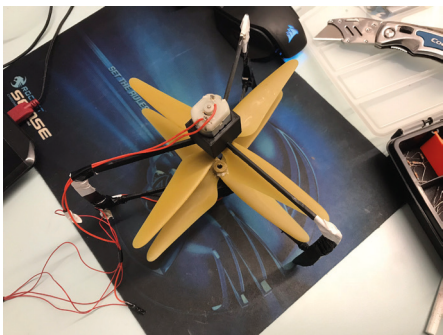
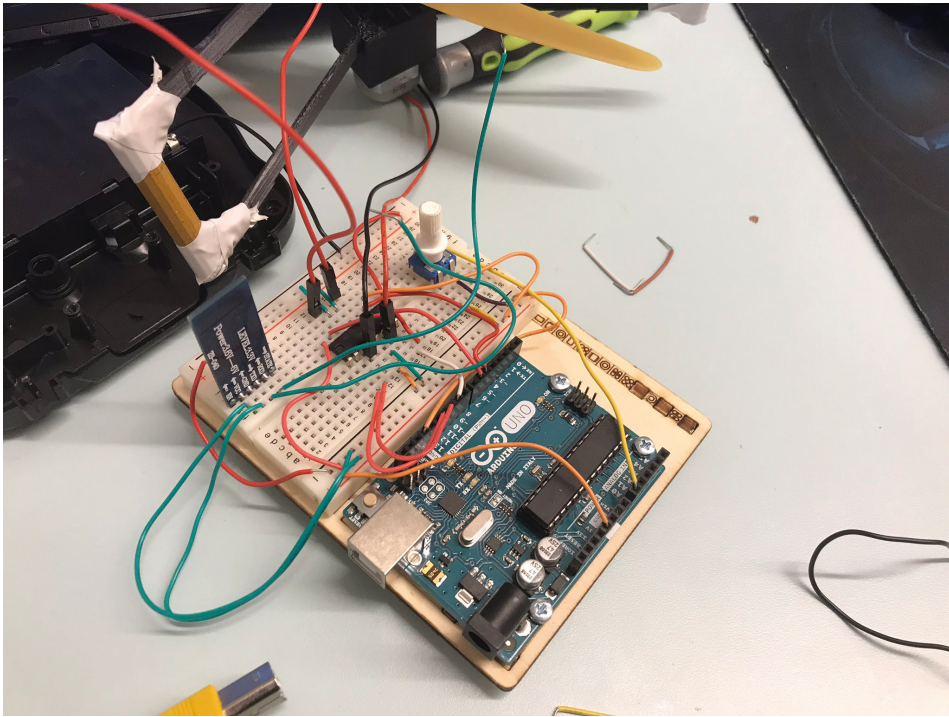




PROCESS PICTURES

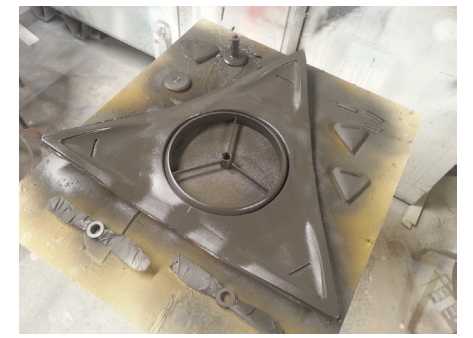
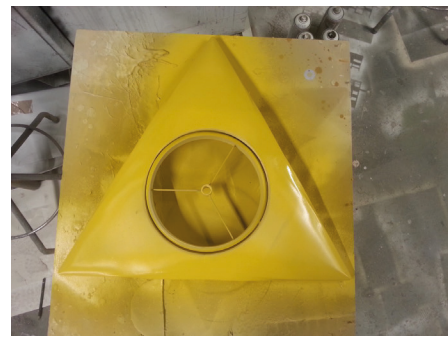




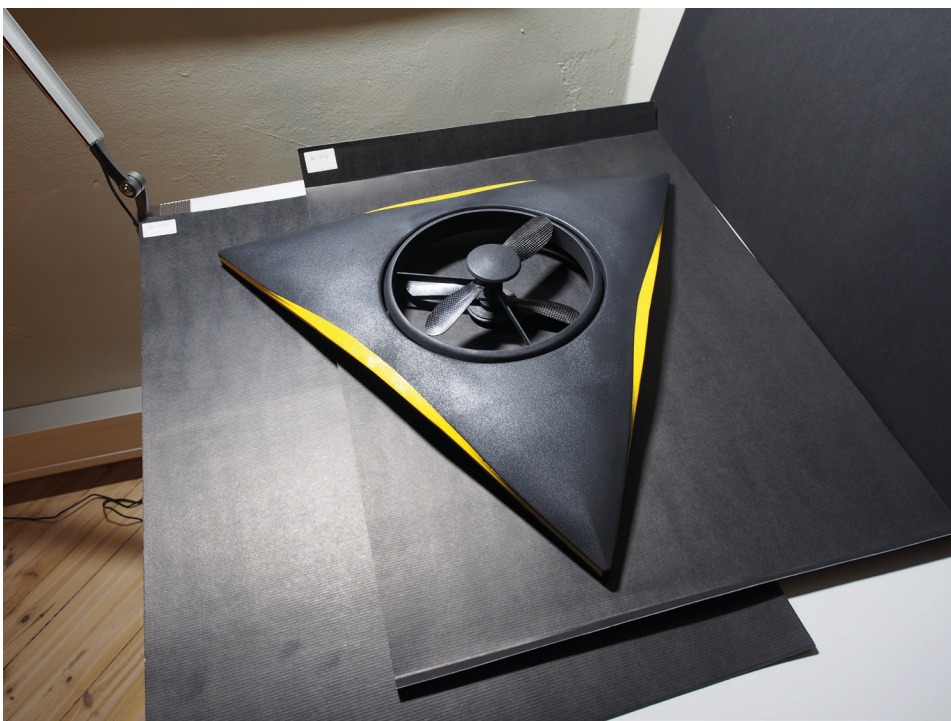
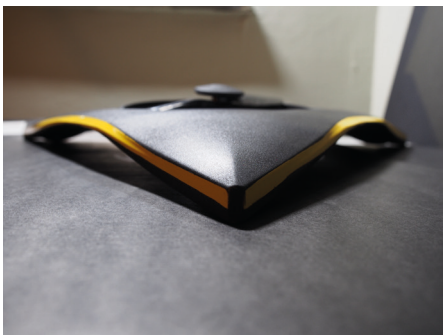
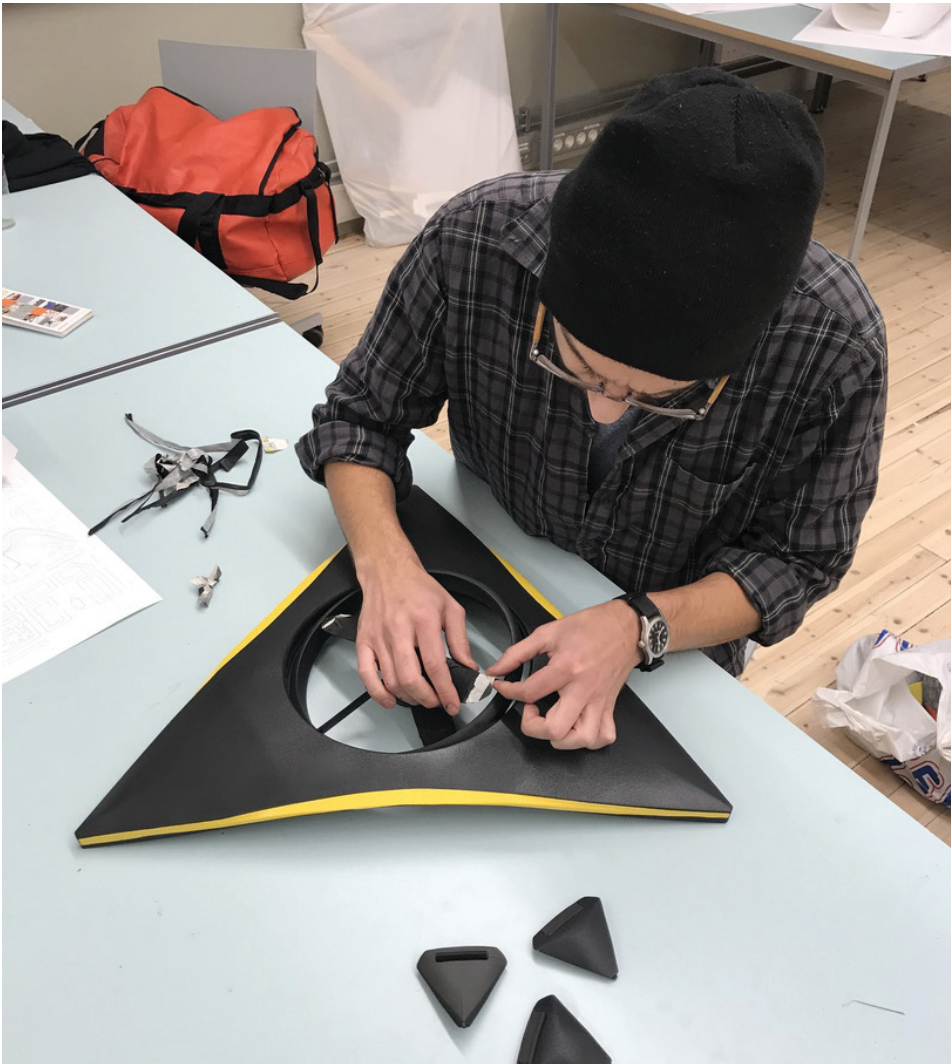




# MODEL DEVELOPMENT PICTURES











# REFLECTIONS

## OVERALL

It is known that industrial design has roots in handicraft and engineering. To some extent, this project reflects the very traditional industrial design, where form follows function and, where possibly, the solution is not extraordinary and extremely innovative, but rather an evolutionary one. In the sense that the proposed concept does not turn over the view on the stated problem, but complements it, allowing us to look at the solution from a different angle, perhaps opening new doors or inspiring someone to something even more ambitious

To achieve the desired result, I used both methods of design thinking and an analytical approach. The combination of those, in my opinion, is the advantage of a modern industrial designer, since the designer is an interdisciplinary profession. Designer is the link that connects engineers, entrepreneurs, customers and users with creative approach. And this approach is one of those that is able to generate ideas and solutions based on user experience, as well as on logical inferences

Looking at my own process I realize that sometimes I get stuck with an idea and adapt findings to this idea. Or the idea influences the research topics. It's suppose to be other way around. This happened in the beginning of the project. Taking a step back and rethinking process helps me to get around this problem. Remembering that purpose of a design project is to gather insight and create solutions on this basis, not designing for the sake of the design

As probably most designers do, I don't feel hundred percent satisfied with the project. The result can never be perfect and one cannot think through every possible detail. In this project I did my best to cover all necessary aspects and through that show my level of understanding and professionalism. I have

tried to organize the process closest possible to a real life project, where designer dives in to all relevant topics, extracts important findings, refines them and adapts the design to it. I wished to show the diversity of knowledge and skills in I have gained as a design thinker

Since the topic of the thesis is open, I, like other students, had to first find and define the scope of activities in which I would like to dive. This, in my opinion, is also a responsible choice, since in this way we are trying to show the world that we are not indifferent and we want to do something useful. Choosing a thesis theme, we make a definite statement about what kind of designer we want to be. This is a rare chance and fortune that we can create something for an overall well-being, and not for profit. With great pleasure and enthusiasm, I was engaged in this work. In this regard, this project has helped me understand myself a little better and in what way I can make my contribution to the development of society



## PROJECT

The process of designing an aerial vehicle was a very complicated task. I had to dive in many new fields and study them thoroughly. Systemic approach to the problem played an important role in this matter. Any findings were immediately noted on the mind-map. This allowed me to constantly have an overview of the process and findings. Analytical and creative processes were constantly mixed, where all new discoveries were applied. Typical broad start eventually has been narrowed down into a set of requirements. Finally I could see what findings were the most important. User insights have influenced the decisions and again I had to look at the problem more broadly. This has resulted in several concept reconsiderations until the final concept was defined. Further, findings made in the beginning were applied to develop the actual product.

The result product partly satisfies set requirements, and hypothetically meets aimed goal. Implementation of such product would definitely improve conventional situation in SAR field. Both from user perspective and systemic.

One of the requirements I have set was simplicity, which I didn't manage to satisfy. It was uncovered in the process that an aerodynamic aerial vehicle is an extremely complex system, design of which implies a high level of complexity process. Consciously I have taken that challenge and did my best to reach the set goal. On the other hand, simplicity in use is achievable and I have shown in the report how it can be done.

Summing up I would say this was a hard but a fun and engaging task!



# REFERENCES

## BOOKS

Banner, J. M., & Cannon, H. C. (2005). The elements of learning.

Belker, H., Burg, S., Clyne, J., Goerner, M., Page, N., Pugh, N., ... Coppola, F. F. (2003). Concept design:

Hopia, H., Barth, B., & Wilfried Martens Centre for European Studies. (2015). Dawn of the drones: Europe's security response to the cyber age.

Koskinen, I. K., & ProQuest (Firm). (2012). Design research through practice: From the lab, field, and showroom.

Milne-Thomson, L. M. (1979). Theoretical aerodynamics.

Robertson, S. (2010). Lift off: Air vehicle sketches & renderings from the drawthrough collection

Smith, M. D. (2015). Quadcopters and drones: A beginner's guide to successfully flying and choosing the right drone.

## WEB-PAGES / ARTICLES

Attack angle and lifting power. (n.d.). Retrieved from <http://avia-simply.ru/ugol-ataki-ad-sili/>

Commercial Drones Are Revolutionizing Business Operations. (n.d.). Retrieved from <https://www.toptal.com/finance/market-research-analysts/drone-market> [11]

Corrigan, F. (2018, December 2). What Are Drones Used For From Business To Critical Missions. Retrieved from <https://www.dronezon.com/drones-for-good/what-are-drones-used-for-and-best-drone-uses/> [5]

Drone market research. (2018, February 9). Retrieved from <https://blog.dti.team/issledovanie-rynka-dronov/>[12]

Drones and Energy-Efficiency - Army Technology. (n.d.). Retrieved from <https://www.army-technology.com/contractors/surveillance/smartplanes-army/pressreleases/drones-energy-efficiency/>

eCalc - the most reliable electric Motor Calculator on the Web for RC Pilots [Video file]. (n.d.). Retrieved from <https://www.ecalc.ch>

Elementary aerodynamics. (n.d.). Retrieved from <http://avia-simply.ru/category/aerodinamika-elementarno/>

Everything about propellers. (n.d.). Retrieved from <http://avia-simply.ru/vozdushnij-vint/>[3]

How drone works. (n.d.). Retrieved from <https://iot.ru/gadzhety/kak-ustroen-dron/>[13]

International Search and Rescue Advisory Group. (2018, May 3). Retrieved from [https://en.wikipedia.org/wiki/International\\_Search\\_and\\_Rescue\\_Advisory\\_Group](https://en.wikipedia.org/wiki/International_Search_and_Rescue_Advisory_Group)[6]

NTB. (2018, July 13). Over 100 wildfire in 2018. Retrieved from <https://www.nettavisen.no/nyheter/innenriks/over-100-skogbranner-i-sr-norge--de-neste-to-dagene-blir-kritiske/3423513674.html>

Search and Rescue Optimal Planning System. (2018, July 29). Retrieved from [https://en.wikipedia.org/wiki/Search\\_and\\_Rescue\\_Optimal\\_Planning\\_System](https://en.wikipedia.org/wiki/Search_and_Rescue_Optimal_Planning_System)[14]

Search and Rescue. (n.d.). Retrieved from [https://en.wikipedia.org/wiki/Search\\_and\\_rescue](https://en.wikipedia.org/wiki/Search_and_rescue)



Significant Facts and Statistics on Missing Persons - Trackimo. (2018, August 28). Retrieved from <https://trackimo.com/facts-statistics-on-missing-persons/>

Study of Contra-rotating Coaxial Rotors in Hover, A Performance Model Based on Blade Element Theory Including Swirl Velocity. (n.d.). Retrieved from <https://commons.erau.edu/cgi/viewcontent.cgi?article=1174&context=db-theses> [2]

Turbulence - Wikipedia. (n.d.). Retrieved from <https://ru.wikipedia.org/wiki/Турбулентность>

Turbulence. (n.d.). Retrieved from <http://evgars.com/turbo.htm>

UAV Factory – Unmanned Platforms and Subsystems [Video file]. (n.d.). Retrieved from <http://www.uavfactory.com/product/21>

UAV Octocopter V1000 Drone | Aretas Aerial | Aerial Monitoring. (n.d.). Retrieved from <http://www.aretasaerial.com/products/uav-octocopter-v1000-drone>

UAV Wildfire Drones | Aretas Aerial | Aerial Monitoring. (n.d.). Retrieved from <http://www.aretasaerial.com/products/uav-wildfire-drones>

Wildfire drone in New York. (2016, September 16). Retrieved from <https://apparat.cc/news/fire-department-drones/>

DJI Mavic Pro & Mavic Pro Platinum ? Every Creative Moment ? DJI. (n.d.). Retrieved from <https://www.dji.com/mavic> [1]

Dozor 600. Surveillance drone techs. (n.d.). Retrieved from <http://avia.pro/blog/dozor-600-tehnicheskie-harakteristiki-foto> [4]

Causes, Effects and Solutions to Wildfires - Conserve Energy Future. (2016, December 25). Retrieved from <https://www.conserve-energy-future.com/causes-effects-and-solutions-of-wildfires.php>[7]

Aerodynamics. (2018, November 29). Retrieved from <https://en.wikipedia.org/wiki/Aerodynamics>[8]

James Wallace Black | Boston, as the Eagle and the Wild Goose See It | The Met. (n.d.). Retrieved from <https://www.metmuseum.org/art/collection/search/283189>[9]

Unmanned aerial vehicle. (2018, December 13). Retrieved from [https://en.wikipedia.org/wiki/Unmanned\\_aerial\\_vehicle](https://en.wikipedia.org/wiki/Unmanned_aerial_vehicle)[10]

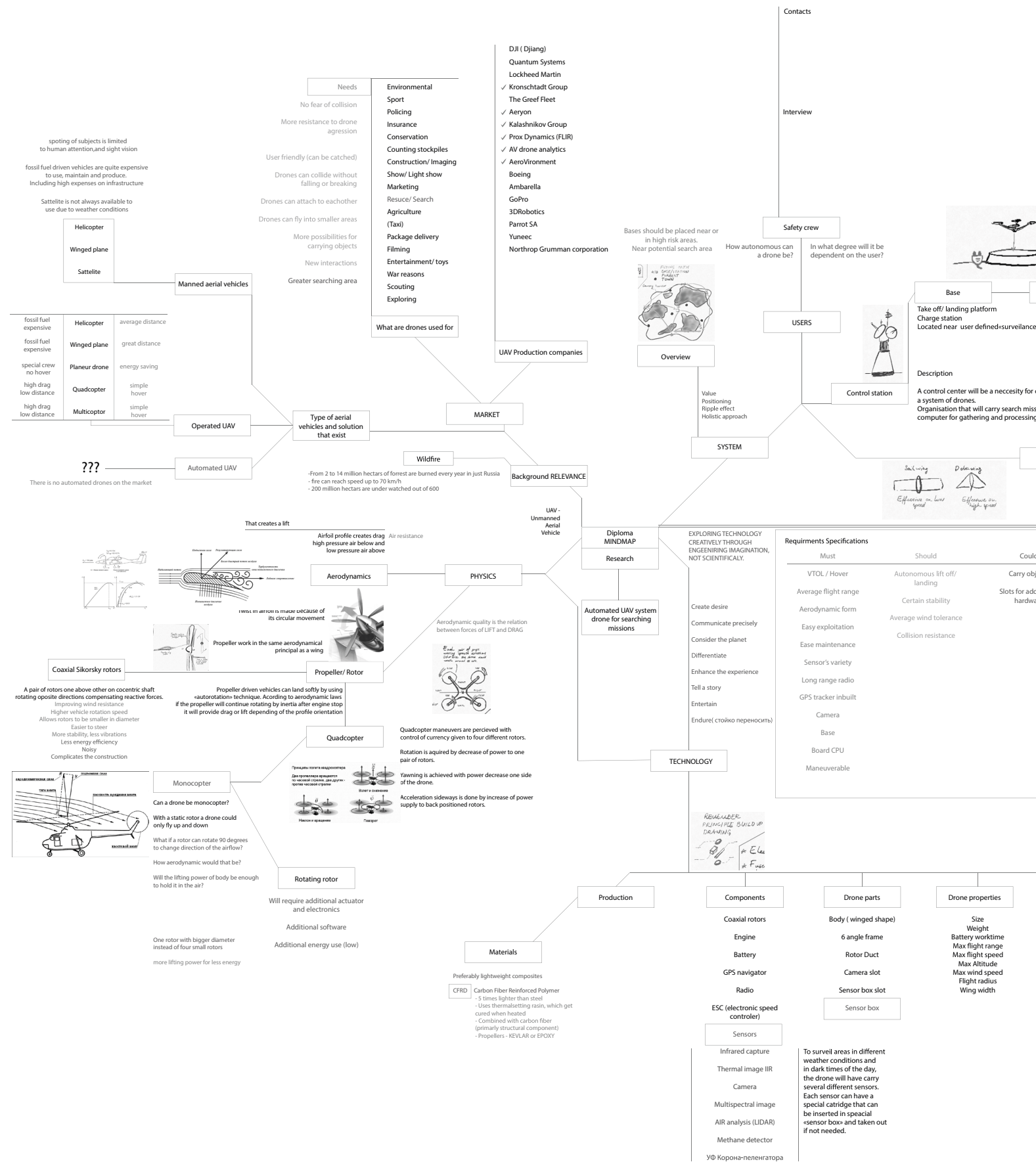
## VIDEOS

Drone against wildfire [Video file]. (2016, June 3). Retrieved from <https://www.youtube.com/watch?v=Yf6i-OHOPZc&feature=youtu.be>

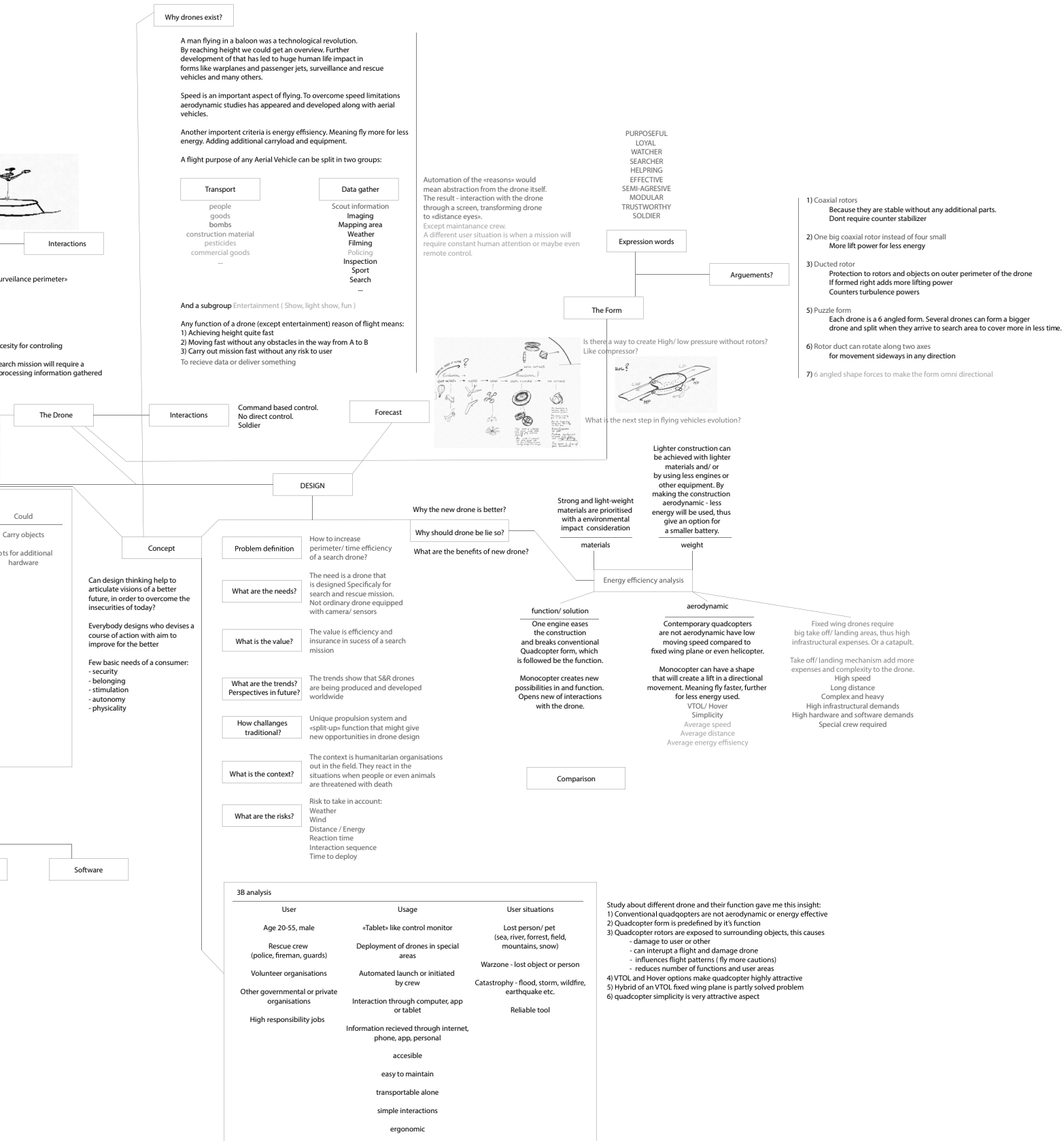
How ducting a propeller increases efficiency and thrust [Video file]. (2015, July 22). Retrieved from <https://www.youtube.com/watch?v=Cew5JF8q6eY>

# APPENDIX GIGA-MAP

Follow link for better quality  
<https://adobe.ly/2BgNvIZ>











## ACKNOWLEDGMENT

I want to use the opportunity to thank for the support, guidance and supervision all my teachers and mentors during five years of study. Thank to all my classmates and designer friends for valuable experience exchange, help and support.

Special thanks to my family and close one's for tremendous support and assistance during all these years.

Thank you!