WilD

Product report

M.Sc.04 | ID6 | 2018

Title page

Project title
WilD - Wildfire Detection

Type of report
Product report

Time period
01.02.2018 - 31.05.2018

Team
SaF - Save Forest
M.Sc. 04 - ID6

Main supervisor
Finn Schou

Technical supervisor
Erik Appel Jensen

Number of pages
23

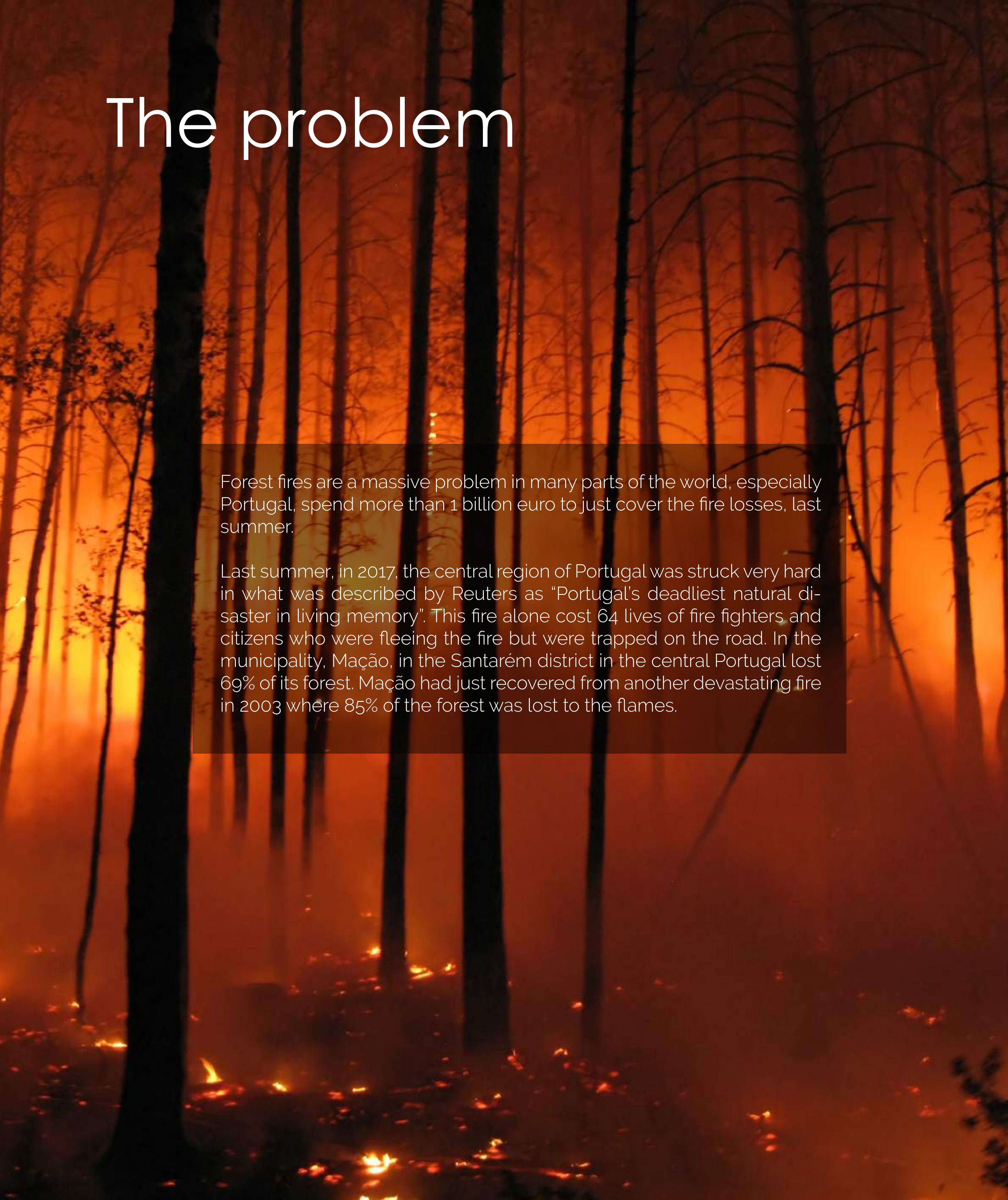
Abstract

The purpose for this project is to make a product that can give the user and authorities knowledge of if a forest fire is about to ignite and the control to act on it.
The product is a scalable smoke detecting system, that allows the user to cover and protect a plantation size of their need. The smoke detecting system will provide safety of the users eucalyptus trees from when they are 2 years and up to the harvest with no maintenance.

Esben Holdt Rude
Esben@rude.net
+45 3028 7717
www.eedk.design

Steffen Aa. Andreasen
Design@steffenandreasen.dk
+45 2654 9561
www.SteffenAndreasen.dk

Table of content



The problem

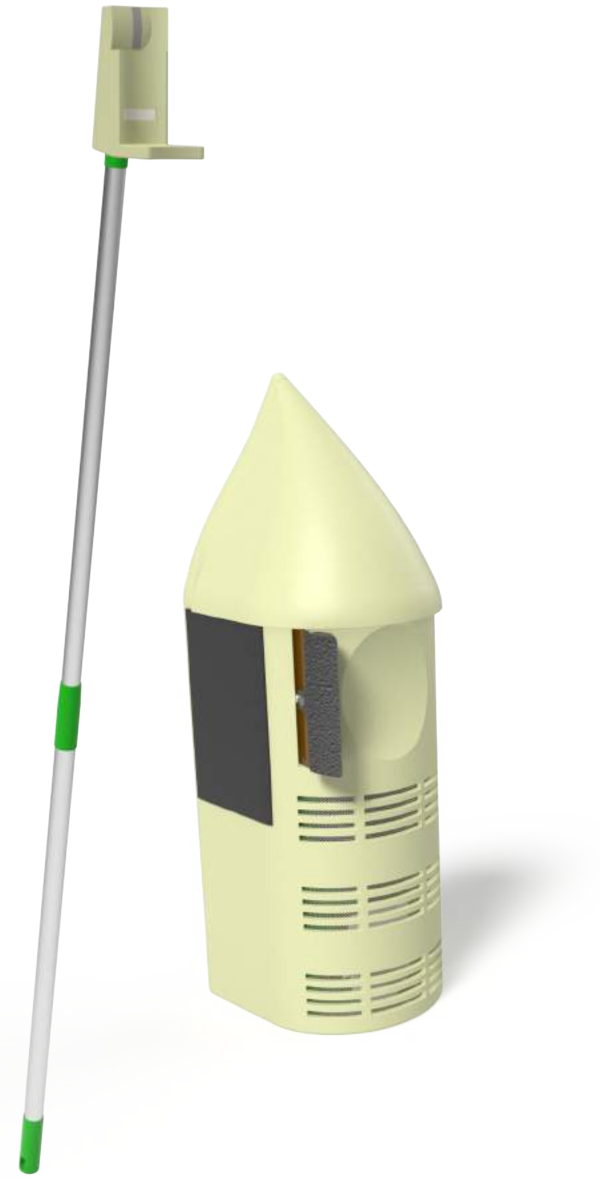
Forest fires are a massive problem in many parts of the world, especially Portugal, spend more than 1 billion euro to just cover the fire losses, last summer.

Last summer, in 2017, the central region of Portugal was struck very hard in what was described by Reuters as “Portugal's deadliest natural disaster in living memory”. This fire alone cost 64 lives of fire fighters and citizens who were fleeing the fire but were trapped on the road. In the municipality, Mação, in the Santarém district in the central Portugal lost 69% of its forest. Mação had just recovered from another devastating fire in 2003 where 85% of the forest was lost to the flames.

WilD

WilD is the fire alarm for the forest. It alarms the fire department and the owner, when a fire is building up, it does this by analyzing the air around it for smoke particles and CO_2. This dual sensor setup reduces the risk of false alarms. The system includes drone coverage, which autonomously will track down any triggered unit and transmit live video to the control center and the plantation owner, who then can make the right decisions.
WilD is faster both to detect the fire, but also faster to provide vision of it, as the first responding fire fighter need before the water carriers arrive.

WilD is easy. Just attach it to the trees using the bundled mounting stick and it will stay as long as the tree. In case that the tree should fall before it is harvested, WilD will tell you. The mounting stick makes the attachment a breeze, just attach it the mounting stick and knock it upon the tree, where the sensor unit will grip around the tree, here it allows the tree to grow freely without any limitation. WilD is built to last, and can endure even the hottest summers and the wettest springs, with a battery life of over 10 years.
WilD is a good solution for both the farmer, the fire fighters, the citizen and the country.



How it works

The WilD system consist of the sensor units, a mounting stick, a camera drone, an app and a computer interface.

The sensor unit are able to cover the size of forest that you want to protect. They are placed in a triangular pattern on the trees for every 15m for the best coverage (76 units per hectare). Here they analyze the air constantly to ensure the safety.

When a fire is detected, the unit sends an alert to the SaF server, which relays to the owner, the local control center and the local fire department through the computer interface and app as well as dispatches the nearest drone.

The drones are placed at fire watch towers, fire stations and other municipal areas. The drone reaches the destination in less than 10 minutes and send the video feed to the fire department and local control center, who can control the drone and its camera to investigate the area, while the fire department is on their way, giving them vision of the area before they arrive.

The app is primarily used when the units are installed. It uses the phones GPS to pair the sensor units with a GPS coordinate, which is used when an alarm is trigged. The app also provides field-access to see where a specific unit is, if it should need replacing or similar.
The sensor units mount are self-adjusting and just need to be primed when put on the mounting stick and then just knocked onto the tree, followed by a tap on the “connect” bottom in the app.

1. The fire is detected by the sensor unit which sends an alarm to the SaF servers

2. The SaF server then relays the alarm to the drone, the plantation owner and national control center

3. The drone autonomously flies to the location of the alarmed unit.

4. The control center then recieves a live feed from the drone and are able to control the drone and camera to take a closer inspection, such he can make the right decision on how to fight the fire.

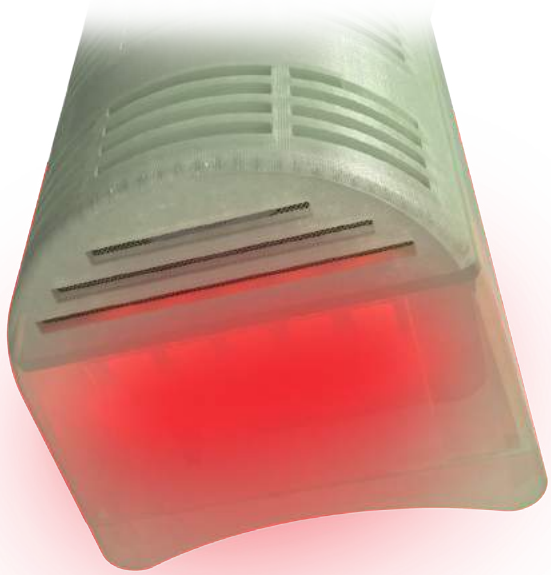
Key functions

The sensor unit analyses for smoke every 30 second, if it senses any smoke it starts up the CO_2 sensor, which also analyses the air. It requires a trigger from both sensors before it sends the alarm to decrease the risk of false alarms, due to smokers and passing cars.

The sensor unit is built to last, it is sealed against both water and dust with an IP 65 rating, it features a metal mesh to keep micro insects out of the sensors. The casing is manufactured from UV resistant recycled PVC such it can resist the sun and even the hottest days. It is shaped to resist a build-up of falling debris, that otherwise could block the sensors.

The unit adapts to the growth of the tree without ever hurting it by using a spring band, which provide tension around the stem. The unit is deployed using the supplied mounting stick, which allow for an easy montage. The unit is put in the mounting unit and the band is pulled to the right where it is locked by the mounting unit. It is then just to slap it onto the tree and the band will swing around and lock itself on the Velcro pad. The mounting stick allow the user to be placed on the ground while placing the units in a height of 2.5m.

The sensor unit is a place and forget unit, after it is placed you will never have to think about it before the harvest, the battery of 19,000 mAh is able to power the device for over 10 years, due to smart power management. If the tree should fall due to storms or illness, the sensor unit will tell you. If the device tilts more than 30 degrees, it will shut off and the servers will alert the owner. To reduce the risk of vandalism, the unit is discretely colored to blend in with the tree, and it is placed out of sight. The unit does not like to be found unless it wants to be found. In case of detected smoke, it will flash bright LED's through the body, to mark its location. The location is roughly known from GPS coordinates, registered during setup.

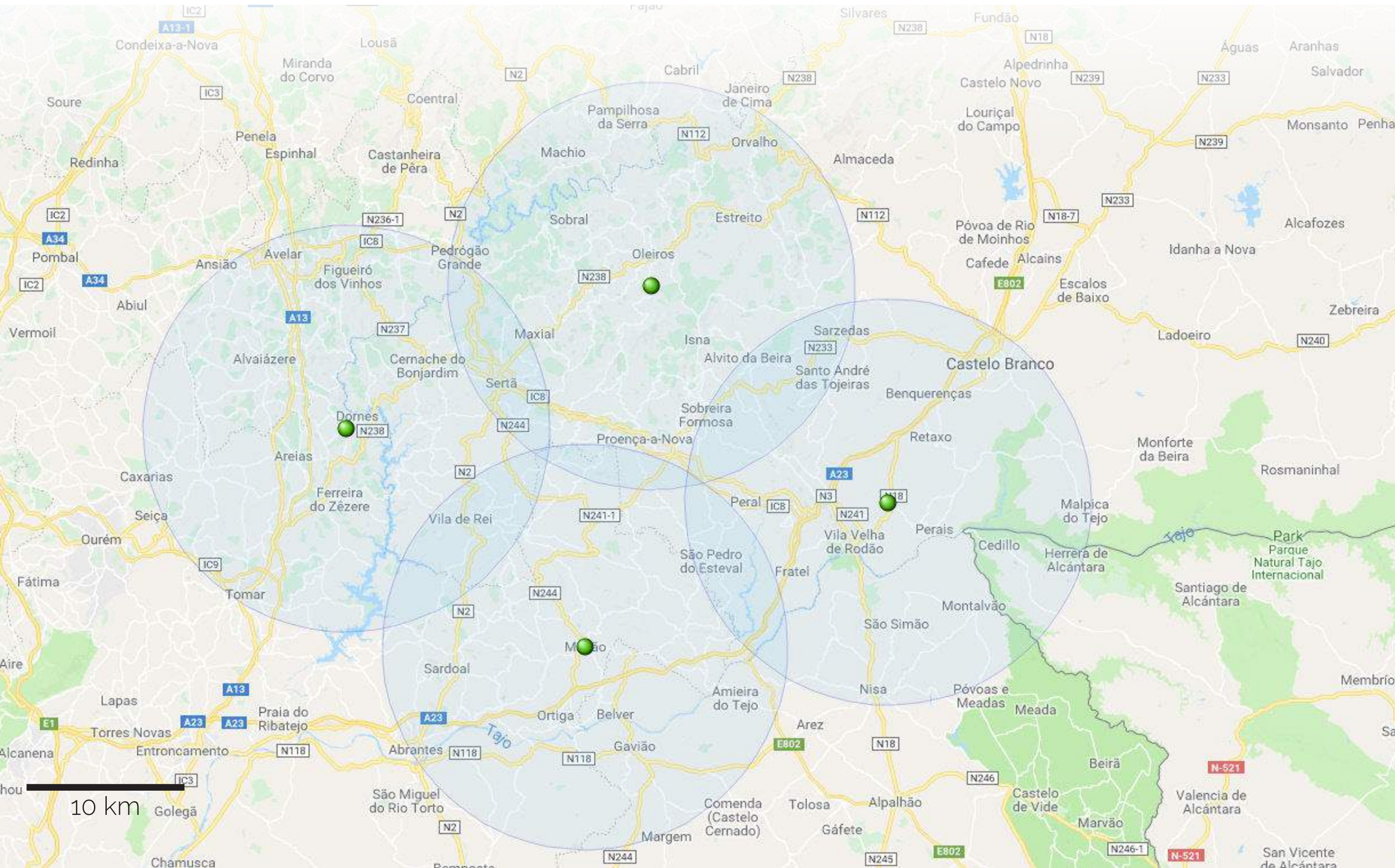


The drone is a shared resource and does not belong to each forest owner. They are placed around the country near the customers plots. There will always be a drone within 13 km, to be able to reach any field in 10 minutes or less. This is much faster than the fire department, who are bound to the twisted roads.

They are placed in pair such it is possible to respond to two simultaneous fires or have one fully charged at all time.

The drone flies autonomously to the site, when the first alarm sends its alarm. The drone is equipped with a 30x zoom camera to allow the operator the best possibility to spot the fire or the smoke. If this is not enough, it is sturdy and small enough to even fly between the rows of trees to get very close to the site. The drone works independently of human interaction and charges itself on its charging pad.

The system comes with the app, which is used during setup to match the units with GPS coordinates, but it can also be used in the field to check up on specific units during a forest inspection.



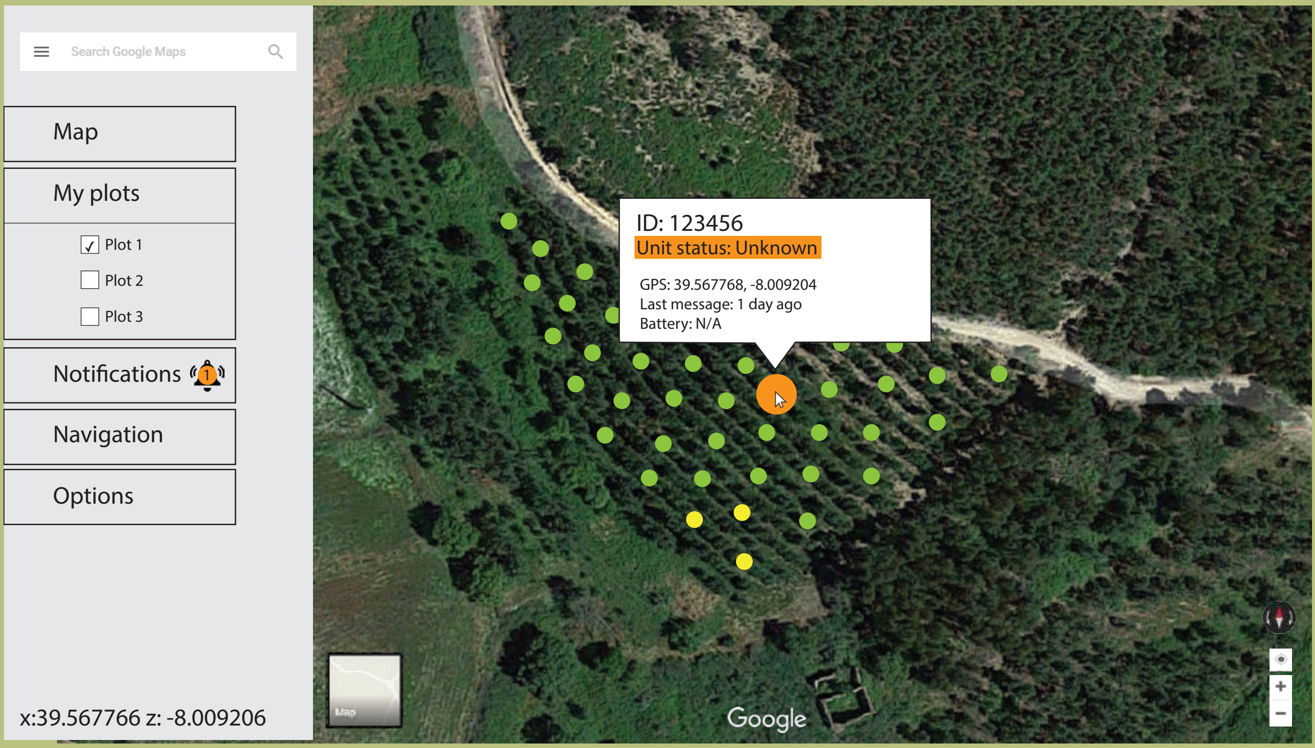
Interface

The computer interface is the main information platform for both the forest owner, the control center and the fire department. The interface is based on Google maps API as it is open source and known by everyone.

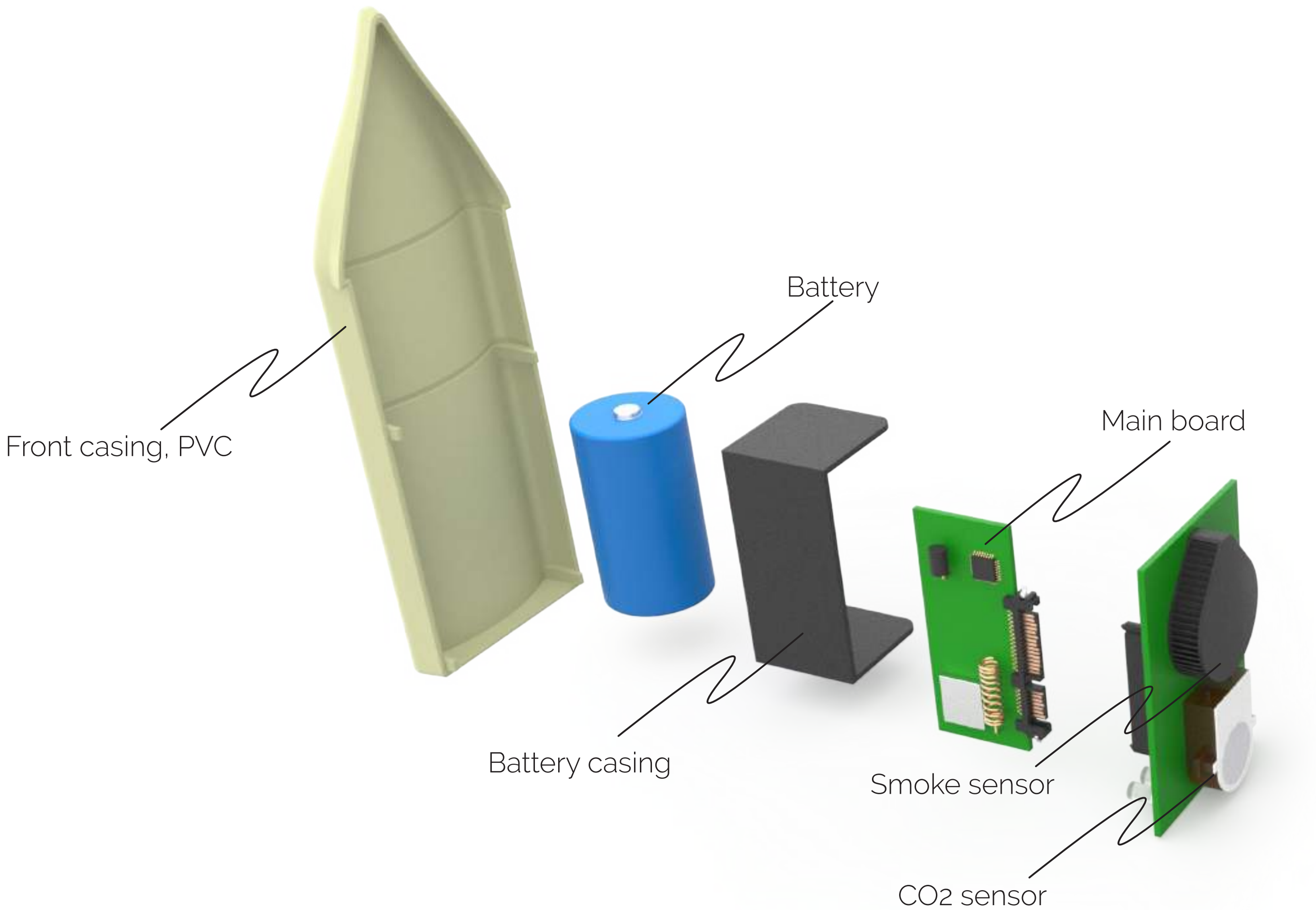
The interface is different between the plantation owner and the authorities.

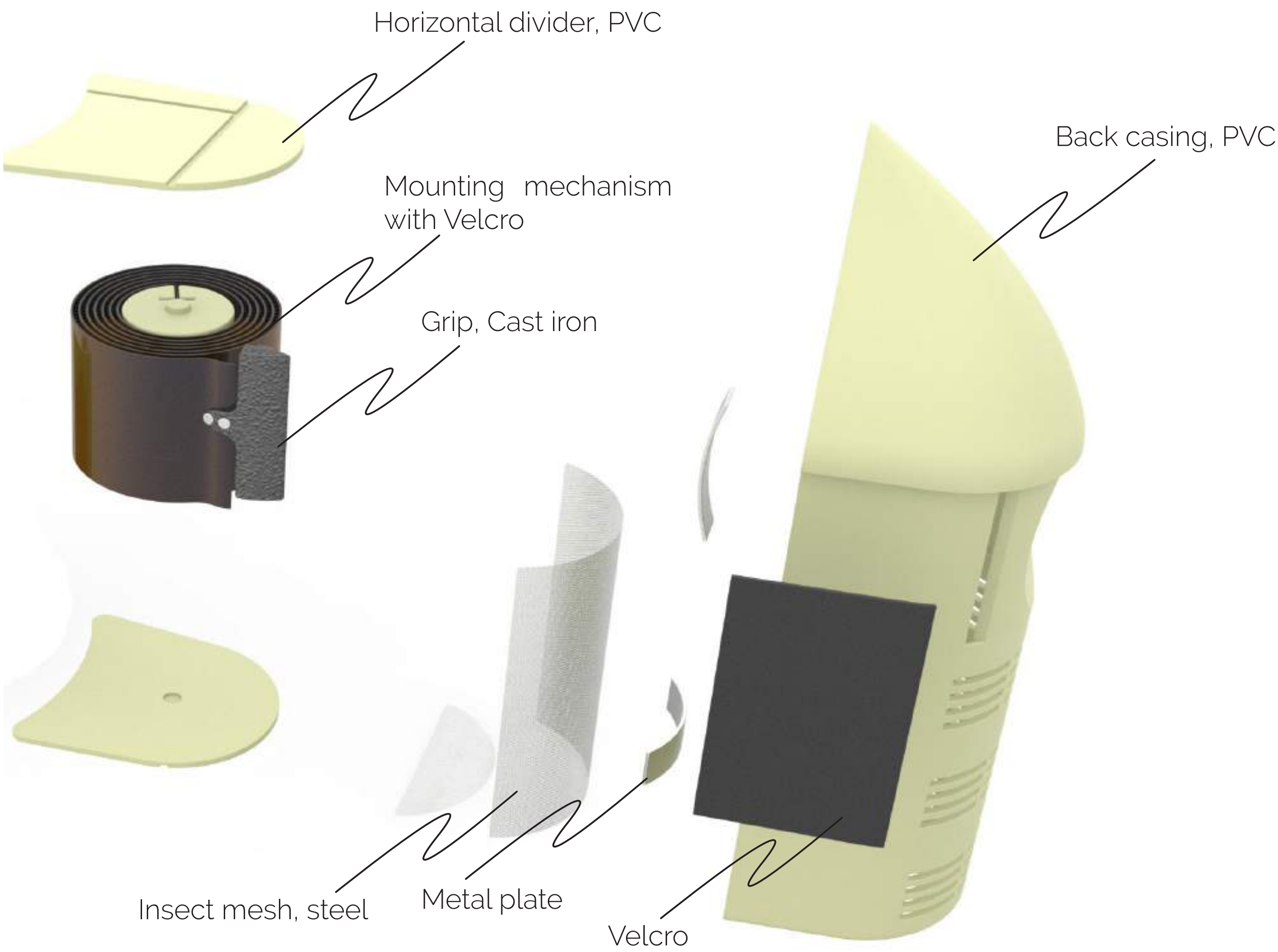
The owner can see information, such as the location, battery status, unit ID and the time of the last message of each individual unit. The owner receives alarms from his own units as well as any unit with 5 km, he can see the drone footage, but not control the drone. The units are reporting once every day to ensure that they are still working, if a unit fails to report, it will be shown on the owner's interface with a notification.

The fire department cannot see the individual unit unless it has triggered the alarm. They see what areas are covered by the system and the location of the drones. An alarm inside the chosen area will pop-up and show which drone is dispatched and the estimated arrival time, The fire department/ control center are then able to abort the flight if necessary and control camera of the drone through this interface, which the camera feed is also seen from.



Component overview



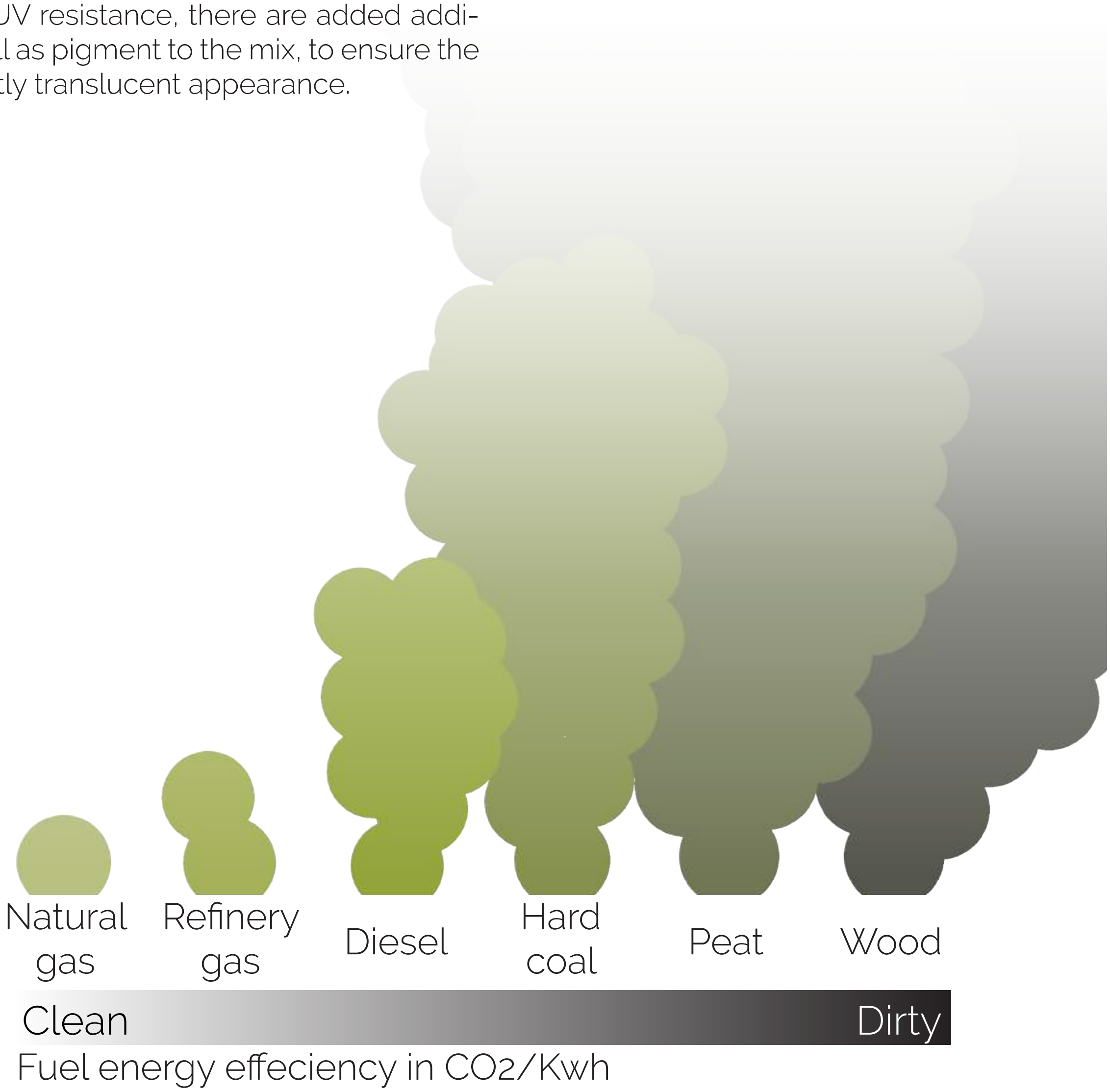

Horizontal divider, PVC
Mounting mechanism
with Velcro
Grip, Cast iron
Back casing, PVC
Insect mesh, steel
Metal plate
Velcro

Environmental impact

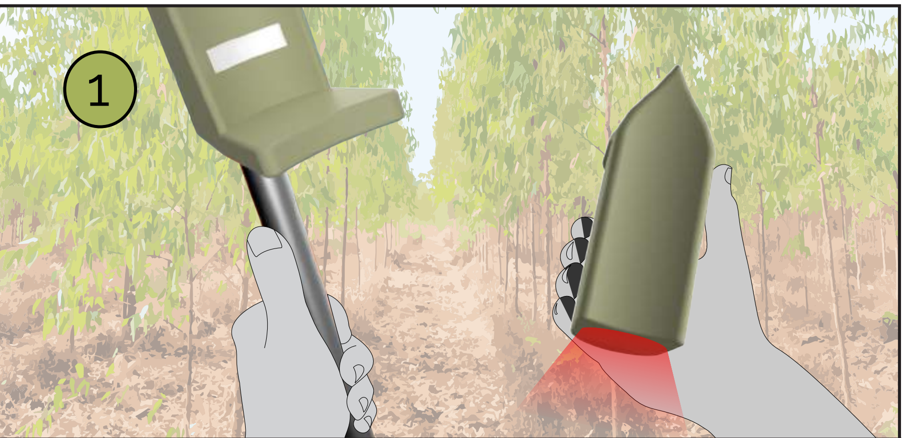
The system is not only saving the material value of the forests, but it is also good for the environment. The first way is by saving trees, which then absorb more CO_2 and emits more O_2. Burning wood is one of the most dirty fuels per amount of energy, so the less burned, the less emitted.

The case and the internal plastic parts are made from recycled PVC, which produces 95% less CO_2 than virgin material. PVC is one of the most commonly used plastics in the world. To boost its UV resistance, there are added additive as well as pigment to the mix, to ensure the right slightly translucent appearance.

The little grip on the edge of the steel band is made from grey cast iron, which is also easily recyclable, which it will be, alongside the casing, after a successful decade in the forest. The unit include other parts that are a little harder to recyclable, these are the electronic components and the lithium battery, which undergo a more elaborate process. The electronics and the battery are a hazard to the environment and to ensure the recycling of these components, therefore SaF will buy back old units in exchange of discounts.

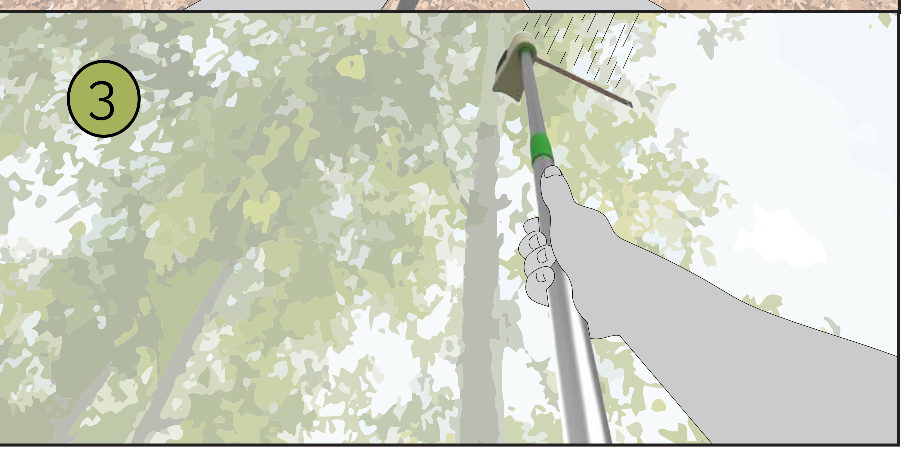


Mounting scenario



The sensor unit is being picked up. When the product is raised, the LED light up indicating the product is on.

The product is placed on the mounting stick and magnets hold it tight while the strap is pulled out.



The product is now knocked onto the stem of the tree

When the product hit the stem, the spring steal, will continue the motion, bend, fold around the stem and lock.

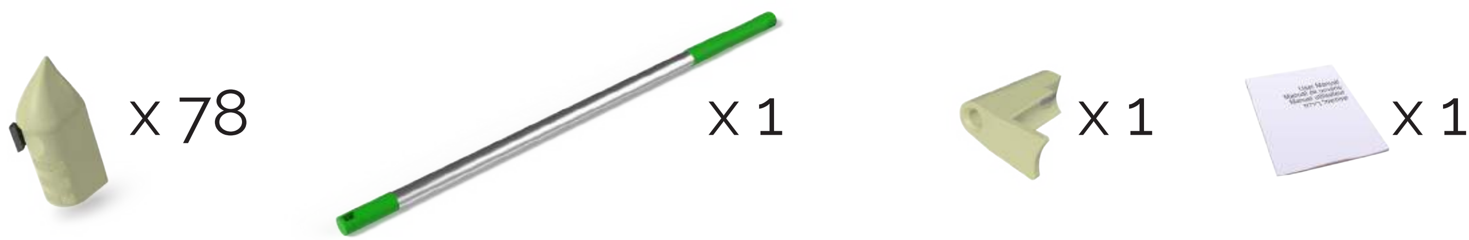
When placed the app is used to connect the unit with GPS coordinates from the phones internal GPS.

The sensor sends its first message, which is reviewed and seen at the web interface. WilD is ready to use.

The kit

The system is available in packets for whole and quarter hectares as well as single units. It is also possible to buy the mounting stick separate, if the one that come with the packets are not enough.

This is packed and shipped in a 60x40x40 cm cardboard box and weighs approx. 25kg.



Business cases

Primary
The first business case it to sell to the plantation owners with economically support from the municipality. The Farmer needs the system to protect his investment in the forest. The municipality want to support the local farmers, since a protection of the forest lowers the risk of fire in the municipality. This means that the municipality save money on fire fighting, rebuilding and reestablishing the landscape and infrastructure, in addition to increasing the safety for the citizens. The municipality are therefore, willing to support with around 75%. The farmer will manage the mounting of the units.

Secondary
The second business case is to sell directly to the municipality, who can distribute it to farmers. By going the way it is possible for the municipality to cover some of the many abandoned forests around the countryside, which creates a big fire hazard due to the lack of maintenance. The municipality also has the option to cover national parts, which are housing rare species of fauna and flora.

The WilD strategy

Stage 1:
(2 months)
- Final development
- Fine tuning components
- Development of the code for sensor unit and system
- Design and coding of the interface
- 3 prototypes
- Intensive testing

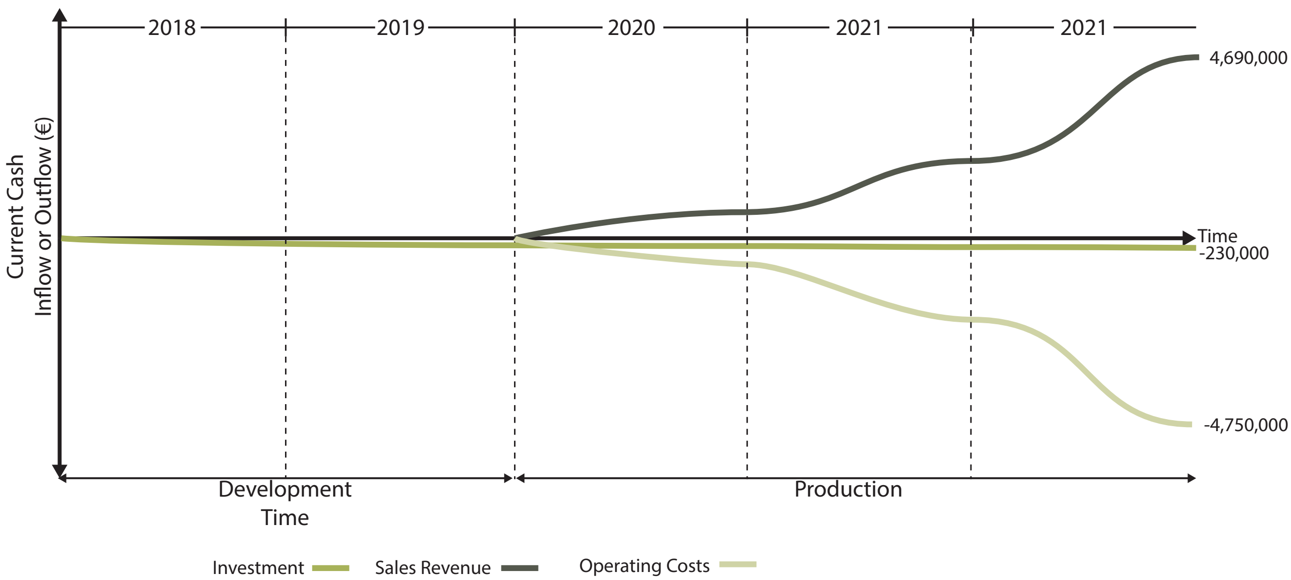
Stage 2:
(1 year)
- Pilot project
- Full scale testing (1 ha)
- Weather rigidity testing
- Third party drone development and testing
- Attending award show to create attention.

Stage 3:
(8 months)
- 10 hectares of full scale user test spread across 3 regions of Portugal

Stage 4:
- Product launch in Macao, Portugal.
- Launching in sectors, due to drone coverage and flight permissions.

Expected sales in the first 3 years of production.

Year		2020		2021		2022
1 ha kits		150		300		600
1/4 ha kits		1200		2400		4800
Single units		2500		5000		10000
Single mounting sticks		10		20		40
Turnover	€	670.200,00	€	1.340.400,00	€	2.680.800,00
Variable Costs	€	680.553,45	€	1.347.106,90	€	2.694.213,80
Fixed Costs	€	18.354,00	€	18.354,00	€	18.354,00
Contribution Margin	€	-28.707,45	€	-25.060,90	€	-31.767,80



Conclusion

WilD is a tough system that can save both lives, land and money for the many affected instances. It eases the mind of the plantation owner and protects his investment, so he doesn't have to worry. The fire department will be able to react faster to the growing fire. Hereby, they can have an smaller fire to extinguish. This will decrease the cost of the fire fighting, the resource loss, the restoration cost and increase the safety of the citizens.

WilD is at the moment a bad business, since it creates a slight deficit. This is partly due to the communication technology is not fully ready for this application, yet. It is from the creators stated that the prices are expected to drop heavily within WilDs two-year development, which can make WilD a much better business.

The market is ready, especially in the recently struck regions, where the people now remember the fire. The product launch comes at the right time, since the recently affected plantation owner are now replanting and the tree will at the launch be big enough to have the sensor unit attached.


Aalborg Universitet | 2018

WilD

Process report

M.Sc.04 | ID6 | 2018

Title page

Project title
WilD - Wildfire Detection

Type of report
Process report

Time period
01.02.2018 - 31.05.2018

Team
SaF - Save Forest
M.Sc. 04 - ID6

Main supervisor
Finn Schou

Technical supervisor
Erik Appel Jensen

Number of pages
90

Abstract

The purpose for this project is to make a product that can give the user and authorities knowledge of if a forest fire is about to ignite and the control to act on it.
The product is a scalable smoke detecting system, that allows the user to cover and protect a plantation size of their need. The smoke detecting system will provide safety of a the users eucalyptus trees from when they are 2 years up to the harvest with no maintenance.

Esben Holdt Rude
Esben@rude.net
+45 3028 7717
www.eedk.design

Steffen Aa. Andreasen
Design@steffenandreasen.dk
+45 2654 9561
www.SteffenAndreasen.dk

Acknowledgment

Special thanks for the extra assistance throughout the project to:

Finn Schou, Main supervisor

Erik Appel Jensen, Technical supervisor

Antonio Luoro, Vice president of Mação

Sónia Oliveire, Senior technician at the forest and civil protection office

Mads Lauritsen, Associate professor at department of electronic systems at Aalborg university

Bent Tindal Pedersen, fire department of northern Jutland

Preface & Reading guide

The problem

The idea for the project started because of the big wildfires in California, that by the time of sending in the project description, were still burning. We realized how big and issue it was and the most striking where how long it lasted and how many homes that was destroyed.

Ill. 01.01: California wildfires

Denmark

Before we went for California, we wanted to investigate the situation in Denmark.
We used about a month researching articles, interviewing stakeholders (firefighters, emergency responders, private forest owners, associations of forest owners, locals and the municipality as well as contacting national companies and experts in the field.
Finally when we reached data from DMI (The Danish meteorological Institute) we decided to abandon the Danish marked. There was a problem, but it was not real demand - thereby it would be a too big "technology push" for us.

At this point we were far into the project timespan, therefore we researched Europe for indication of dealing with same problem.
When we found out about The European Forest Fire Information System (EFFIS) we quickly realized that Spain and Portugal were dealing with great problems like those in California.
In the end we chose Portugal on the language barriers we would experience in Spain.

Reading guide

This project is documented in four reports

- Product
- Process
- Appendix
- Technical.

Before reading

It is recommended to read them in the above listed order, starting with the product report, to get an understanding of the final product, then the process report will give an understanding of the process, with appendix in the appendix folder. This led to the technical folder where drawings of the custom parts can be seen.

The process report

The process report is divided into eight phases: Preface, The Problem, Research, Framing, Solution space, The Product, Business and Closing. Every phase starts with a short intro about the content, and ends with a short summery.

In the report findings is documented and is indicated with a flame (see Ill. 01.02)

Ill. 01.02: Flame

The product report

The product report is a representation of the final product. The report contains a user scenario and renderings of the product in the Portuguese context.

References & Illustrations

The Harvard method is used for references
Illustrations are numbered and listed in the illustrations list.

Table of content

Introduction SaF

This past year several places in the world got hit by megafire, which individual fires that burn more than 40.000 hectares. (Hessburg, S. 2017) Portugal got hit by the biggest megafire, that they have experienced so far consuming more than 5000 km^2. (Bugge, A. 2017) The western United States were next, in December, with megafires consuming more than 1000 km^2 of land (Wikipedia. 2018) and latest this march in Australia.

It is definitely a problem, but fires is nothing new. The new factor is that climate change according to studies (Brändlin, A. 2017), are responsible for the increasing of the megafires intensity, which means that the problems are getting worse.

With firetrucks, firefighters, helicopters, fire planes and so forth, why is it not a decreasing problem? And why does the existing prevention solutions like watch towers and camera surveillance not cope with the problem?

This thesis is trying to understand and research these problematics and, via a study trip to Portugal, collecting data from the Municipality of Mação to understand how they see the problem as authorities, firefighters and the locals. With this data, the product, WilD - Wildfire Detection, have been developed for eucalyptus trees, targeting the Portuguese plantation owner in Mação but with the potential for later expansion.

This project was from the start thought as a project that could be done in collaboration with a company, but it was quickly realized that the simple idea of a smoke alarm for the forest was quite unique and as described in “Market” on page 16, it was difficult to find similar solutions on the marked and thereby companies that we could partner with.
Therefore it was decided to run the project a startup:

SaF - Safe Forest

The idea of starting a company in the first place, were born from our supervisor that have a former experience being an entrepreneur.
As the project became more tangible the idea of starting a business became more realistic.

SaF is pronounced **/seɪf/**, as the word “safe” and means “Safe Forest”.
SaF is a upcoming company, that with the product described in this project is going set a new standard of how quick fires can be detected.

At SaF we will develop products that make it more manageable to guard the forests against forest fires, this will save time, money and in the end precious nature and lives.

Ill. 01.03: Logo

01
THE PROBLEM

What is fire, how does it occur and what is the by-product? In this phase you will get an understanding of the problem, as well as what solutions exist today and what market these products leave untouched.

Ill. 01.01: Steffen and Esben in what is left of the forest near Zimbreira.

What is fire?

Fire is a combination of two types of energy; heat and light, which is released during a combustion process. To create fire, three parameters need to be fulfilled:
Fuel, like wood, oxygen, which is in the air, and heat, like a spark. (See Ill. 1.01)
Once a fire is ignited, a chain reaction will happen because a fire can sustain its own heat by the further release of heat energy, provided there is a continuous supply of oxygen and fuel. (Fire Safety Advice Centre. 2011)

Oxygen

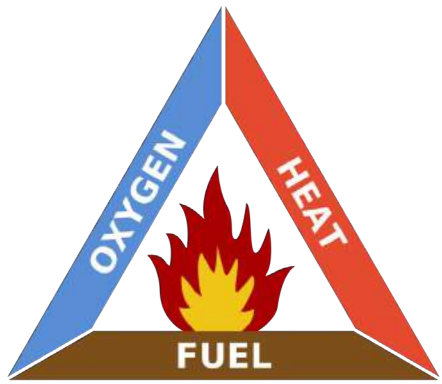
The atmosphere, consisting of ~21% oxygen, is in most natural fires the source of oxygen.
The more surface area of the burning element the more oxygen, meaning a quicker burn. (Harris, T. 2002)

Fuel

Fuel is in most cases referred to as chemical fuel, which is the source of energy that, when combusted, releases gases that when ignited creates heat and light. In this thesis the focus is on chemical fuel which grows from the ground and have captured the energy from the sun.
Elements in the fuel, like water, can prevent or slow the reaction, because water, when reaching the temperature of 100 degrees is changing form from solid to gas. This gas (or steam) does not react with oxygen in the air, meaning it cannot burn. (Harris, T. 2002)

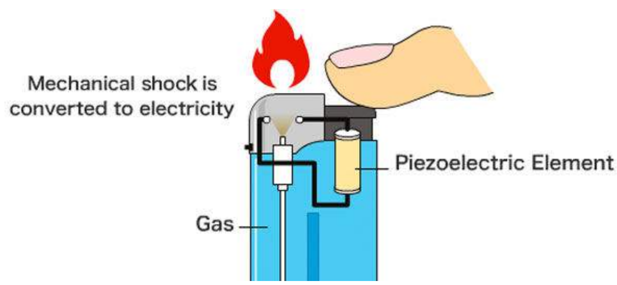
Heat

The fuel element has a specific temperature it must reach before it releases gases, that burst into flames. The combustion temperature for wood is for instance 150 degrees Celsius but it is not before 500 degrees that the gases being made ignite into flames. (Harris, T. 2002)



Ill. 01.02: The fire triangle

Example
A candle is made of wax (the fuel). To light it up you need heat. Often it is lit up by another fire from a lighter. The lighter uses gas as fuel and a spark either made by a spark-wheel and a stone or a piezoelectric element.



Ill. 01.03: How a lighter ignites

Finding 1: The fire can ignite instant with a spark, which is a quick heat build up.

Finding 2: Fuels have different ignition heat and moisture influences that.

What is smoke?

Some of the material released when fuel is being combusted is volatile gases. We know these gases as "smoke".

Smoke from wood is a mix of hydrogen (H2), carbon (C), and oxygen (O). The rest of the material forms char, which is nearly pure carbon and ash, which is all of the unburnable minerals in the wood (calcium, potassium, and more).

When the smoke is hot enough (260 degrees C for wood), the compound molecules break apart, and the atoms recombine with the oxygen in the air to form steam (H2O), carbon dioxide (CO2) and other products. In other words; they burn. (Harris, T. 2002)

Smoke from wood is the most* dirty emission compared to burning oil, coal or any other fuels, regarding particles and CO2 (see Ill. 01.05). (Quaschning, V. 2001)

Smoke behavior

Smoke is described as a fluid, because it, like water, can be made to flow or move. (Hall, N. 2001)

The Navier–Stokes equations are the most used way of getting an understanding for how smoke behaves regarding velocity, pressure, temperature, and density.

The Navier–Stokes equations only operate in free stream and do not account for the boundary layer (see Ill. 01.06) (Hall, N. 2001). Furthermore a lot of other variables are not taken into consideration including obstacles, turbulence, changing wind speeds and -directions. Because of these variables it is not possible to theoretically calculate how smoke will behave.

Our problem findings lead to the making of a smoke test that is described in phase 4

* Some types of lignite can be worse

Heated wood releases gases

$$6C_{10}H_{15}O_7 + \text{Heat} \rightarrow C_{50}H_{10}O + 10CH_2O$$

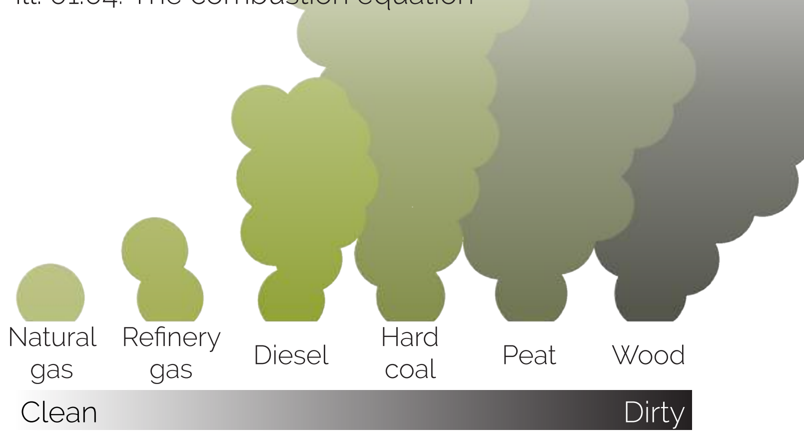
(Wood) (Charred wood) (Gas)

Gases react with oxygen in atmosphere

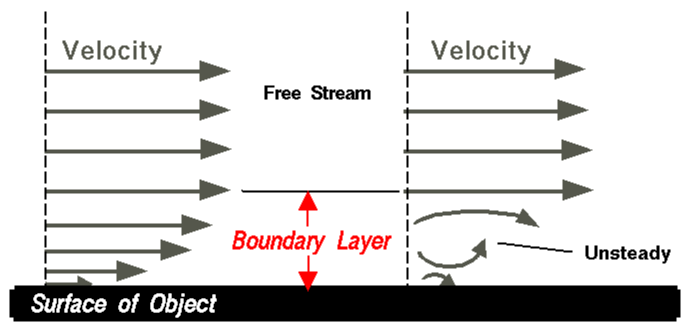
$$CH_2O + O_2 \rightarrow H_2O + CO_2 + CO + C + N_2$$

(Gas) (Oxygen) (Water) (Carbon dioxide) (Carbon monoxide) (Carbon) (Nitrogen

Ill. 01.04: The combustion equation



Ill. 01.05: Various fuels compared regarding kg CO2/kWh



Ill. 01.06: The Boundary Layer affect both Laminar and turbulent fluids. (Velocity is zero at the surface)

Finding 3: When burning wood, the smoke consist of e.g. charred wood and CO2

Finding 4: The behavior of smokes is affected by several variables, making prediction difficult.

What is wildfire?

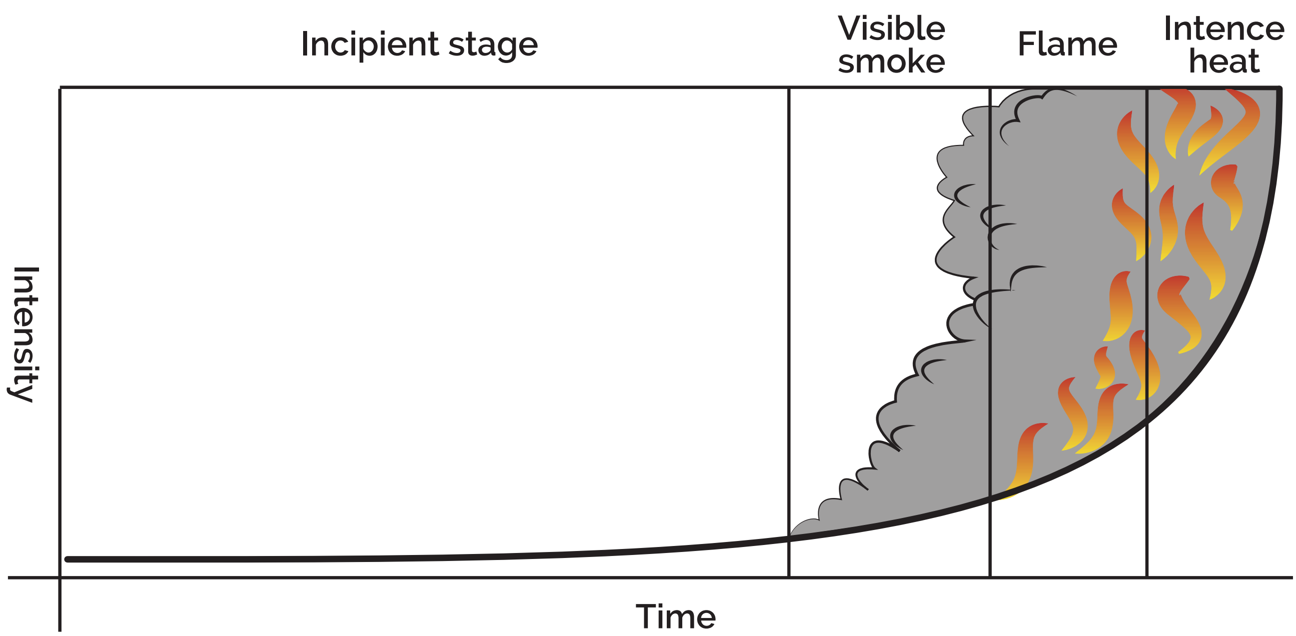
On a hot summer day, when drought conditions peak, something as small as a spark from a brush cutter, a lightning, a cigarette or the heat from the sun magnified trough a shattered piece of glass can ignite a fire in the nature.
Different aspects cause the fire to increase in intensity. These are weather conditions and fuel.

Fuel
Wildfires spread based on the type and quantity of flammable material that surrounds it, called fuel load. Fuel load can include everything from trees, underbrush and dry grassy fields to homes.
A small fuel load will cause a fire to burn and spread slowly, with a low intensity. If there is a lot of fuel, the fire will burn more intensely, causing it to spread faster. The faster it heats up the material around it, the faster those materials can ignite. The dryness of the fuel can also affect the behavior of the fire. When the fuel is dry, it is consumed much faster and creates a fire that is much more difficult to contain.

Small fuel materials, also called flashy fuels, such as dry grass, pine needles, dry leaves, twigs and other dead brush, burn faster than large logs or stumps.

On a chemical level, different fuel materials have different ignition time than others. But in a wildfire, where most of the fuel is made of the same sort of material, the main variable in ignition time, is the ratio of the fuel's total surface area to its volume. Since a leafs surface area is much larger than its volume, it ignites quickly. By comparison, a tree's surface area is much smaller than its volume, so it needs more time to heat up before it ignites.

Wind
Wind also has a huge impact on wildfire's behavior. It adds the unpredictable factor. Winds supply the fire with additional oxygen, dry up potential fuel and accelerate the fire across the landscape at a faster rate.
(Bonsor, B. 2001)



Ill. 01.07: Development of fire

Finding 5: Early detection is very important because of the factors: fuel load and wind.

The problem in Portugal

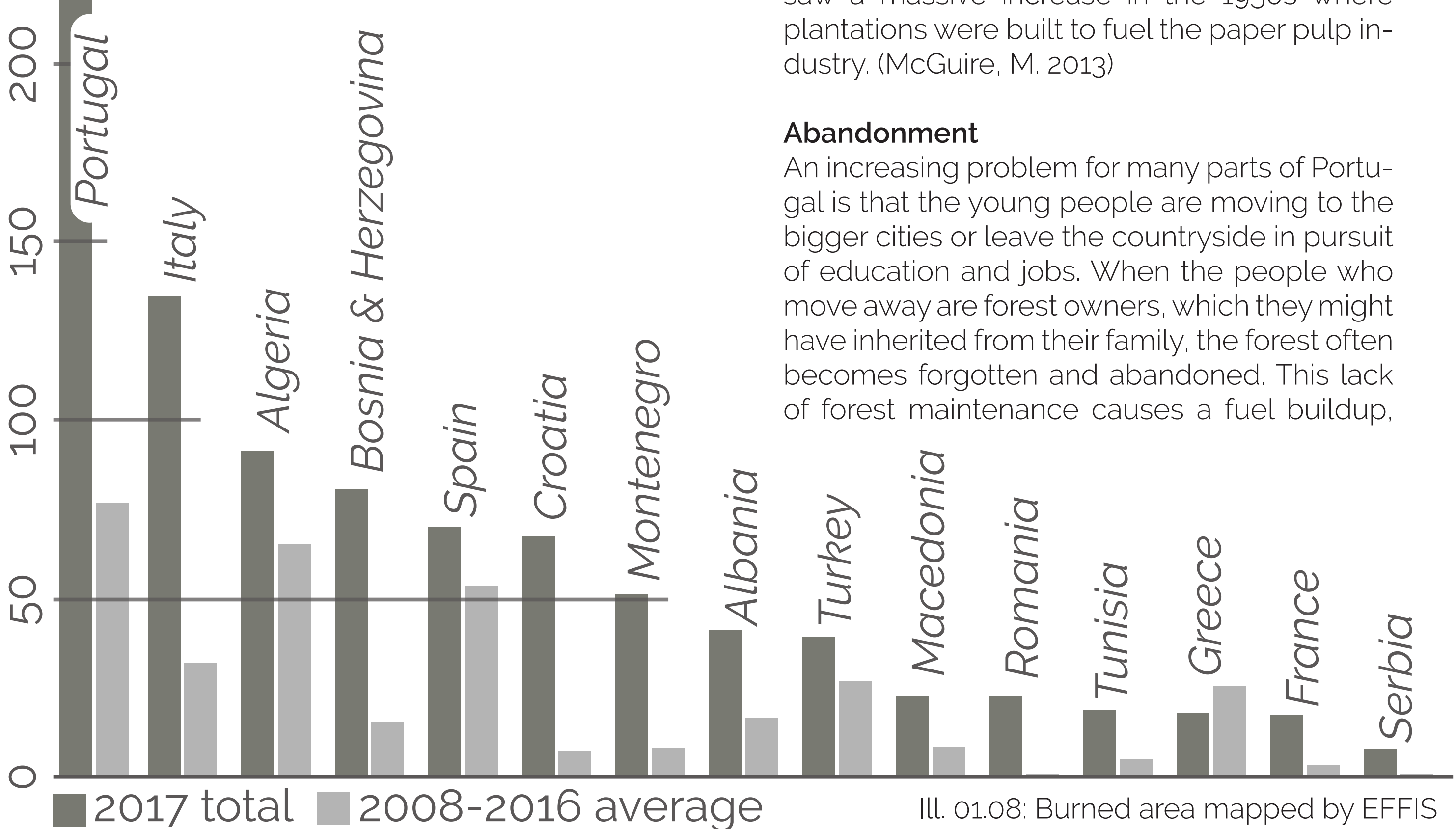
Last summer sixty-four people died to the fires Reuters describes as, “Portugal’s deadliest natural disaster in living memory”, the fire costed more than 1 billion euro in fire losses alone. (Bugge, A. 2017) Portugal usually spends just €70 million on its firefighting budget and €20 million on fire prevention (López, A. 2016)

Even though Portugal only represents about 2.1 percent of Europe’s total landmass, it makes its mark on the map regarding wildfire. In 2017, 520,000 hectares of Portugal’s forest were burned which account for about 60% of the total burnt area in Europe. (Bugge, A. 2017)

What is the reason?
There are three additional reasons to the ones described in ‘What is wildfire’ (See p. 9). The first one is the eucalyptus tree, the second is abandonment and the third is the aging of the population.

The eucalyptus tree
As described on the previous page the flashy fuels and undergrowth is very dangerous, and among firefighters there is no doubt: The root cause of the rapid spread of fires is rampant undergrowth. (Bugge, A. 2017)
But especially eucalyptus adds to these flashy fuels because it lets go of its bark every year, to get rid of illness and fungal (see Ill. 01.10). (Carroll, J. 2018) They are also highly flammable and can even explode when on fire. (George, Z. 2016)
The Eucalyptus tree is not a native species in Portugal, it was imported in 18th century, but saw a massive increase in the 1950s where plantations were built to fuel the paper pulp industry. (McGuire, M. 2013)

Abandonment
An increasing problem for many parts of Portugal is that the young people are moving to the bigger cities or leave the countryside in pursuit of education and jobs. When the people who move away are forest owners, which they might have inherited from their family, the forest often becomes forgotten and abandoned. This lack of forest maintenance causes a fuel buildup,

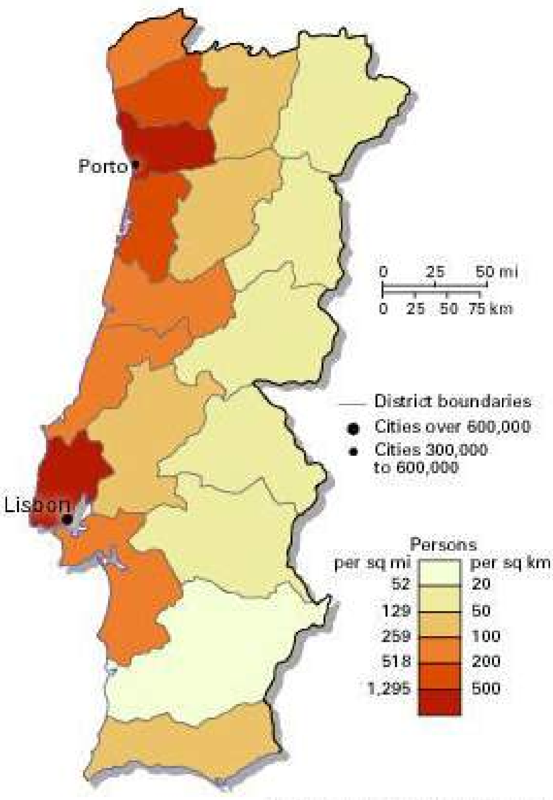


Ill. 01.08: Burned area mapped by EFFIS
Top 15 countries, thousands of hectares

creating a serious fire hazard. (Appendix 01)

People become older

When the young people leave the area, it raises the average age, which is increasing in general due to better healthcare. The guardian has estimated that in 2030, 27% of the population will be above 65 years. (Faiola, A. 2013) When this is compared to the young people moving away, the rural areas are left with a higher degree of elderly who can struggle with both health and sight, which can make it difficult to detect and fight fires.



Ill. 01.09: Population density in Portugal

Finding 6: The population in the countryside is decreasing.

Finding 7: Eucalyptus is a big fire hazard

Ill. 01.10: Undergrowth between eucalyptus trees. Bark is pealing of the tree.

Existing products

There is no direct competitors on the European market, but there have been projects like the WilD project. There are multiple companies e.g. NarrowNet, who have put their project on full stop, due to “complications” that, in their eyes, make the project unable to proceed. (NarrowNet, 2018) When looking in a broader view there are products that operate in different areas and thereby offer similar types of solutions but in a different way regarding the detection and coverage.

Video smoke detection

This solution makes use of a camera mounted on high point, typically on a tower on a hill, where the camera slowly rotates, for example with 6 revolutions per minute. An example of a system could be where the camera feed is analyzed for plumes of smoke down to 10x10 pixels or fire if parts of the images brightness suddenly change. If the automated system detects a smoke plume, it notifies an operator. The operator can control the camera to zoom-in to study the smoke or look for the source. (DDS, 2013, OOR, 2018). The camera needs to be connected to the power grid, but often has a backup battery. The system is limited to surveying above the trees but can see great areas. (Appendix 02) Some systems are non-automated and require an operator to monitor the camera feed at all time.

Ill. 01.11: Automated smoke detection system

Thermal cameras

Thermal cameras are also used to detect the fires by seeing the fire itself. An example of the system could be from Insight robotics which can detect a fire of 2m2 within a range of 5 km. This system is often installed together with a wind turbine and/or solar panels to supply the power. It also has a backup battery with a capacity of running the system for five days (Insight robotics, 2015). The general advantage over the smoke detecting cameras is that they can see through fog and other plumes. The thermal cameras are mounted similar to the smoke detecting cameras and require an operator to control it. (Insight robotics, 2015). Both

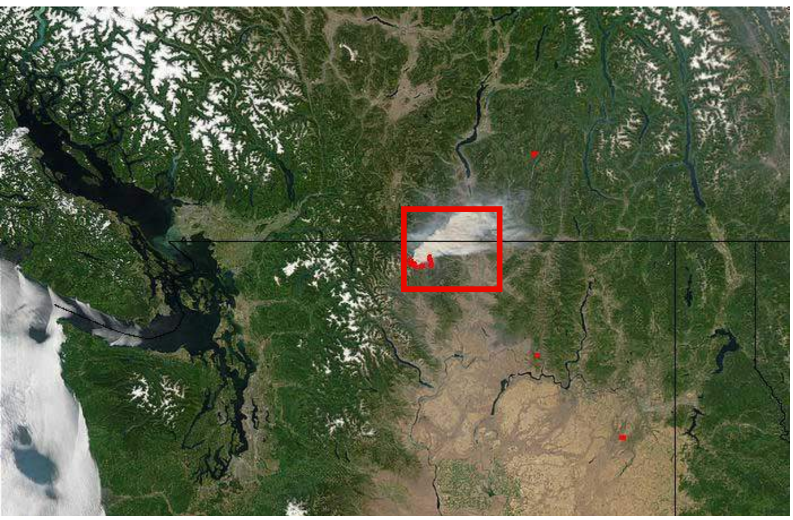
Ill. 01.12: Automated thermal detection system

camera systems can trigger false alarms based on vibrations of the cameras moving in the wind. (Cetin et al., 2013).

Detection by aircraft

To detect wildfire, there is the possibility to use aircraft which are manned or unmanned, these cover a great area and can quickly move to scout another area. They can, however, be limited by vision due to low hanging clouds. Airplanes are expensive to have running because of the pilot and fuel while drones have a limited flight time. Because of this, the aircrafts are more often used to track existing wildfires than to detect them. (Cetin et al., 2013)

Ill. 01.13: Automated drone detection system



Ill. 01.14: Automated smoke detection system

Satellites

In the highest-flying end of the spectrum there are satellites. They orbit the earth and can cover great areas. They can be used for fire detection but are mostly used for fire tracking and post fire assessment, since they only pass by every four hours or more. Their costs are low, but the initial cost is very high. (Cetin et al., 2013) A research project is experimenting with mounting thermal cameras on a satellite, making it able to spot fire of 0,1 ha (e.g. 31x31m) every three minutes. (Carpenter, 2015). This accuracy is very poor since a fire of that size is big, but it can scan entire regions at once.

Finding 8: The fires has to be of a bigger size to be detected by the existing solutions

Market

There are a few solutions on the market and they excel in different parameters. The different types of solutions are graded using Blue ocean canvas. (Chan Kim, W. 2005) They are rated from a buyer's point of view, by the SaF team. Some of the rating are based on assumptions since data is not publicly available. It is important to note that multiple parameters are rated according to attractiveness e.g. a low price rated highly, and a short detection time is best.

The video smoke detection system is the cheapest option available on the market, it requires an operator to watch the cameras, when the alarm is triggered as well as maintenance. It can detect when the smoke is thick enough and rises above the tree tops (Alkhatib, 2014). They often cover an area of 5-10km in radius per unit but can be unreliable in cases of low hanging clouds, fog or other vision impairing phenomenon's.

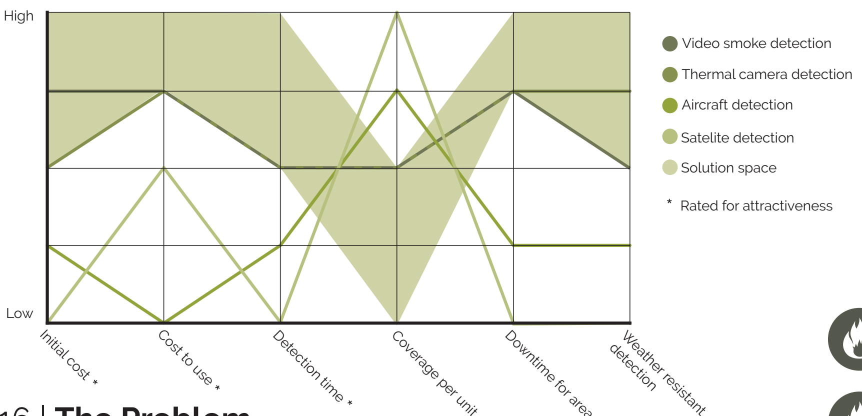
The thermal detection system is mostly similar to the smoke detection system and are often paired together. It can see through clouds, fog and other low-density vision impairing objects, but at a higher cost of. (Insight robotics, 2015)

Aircraft detection systems (mostly airplanes) cover great areas, since they are moving fast across the land. This also results in more downtime of vision on a specific area. They are more impaired by low hanging clouds and fog since they fly higher than where the camera-based systems are located. Aircraft detection is more expensive due to the price of the aircraft and camera system, and more expensive to use since it requires a pilot and fuel. (Cetin, et al.)

The satellite detection system is the most expensive to launch since it needs to be transported to the outer atmosphere by a space ship. It can cover a band across the globe but can only survey an area every 4-5 hour since it is orbiting. Due to the high flight height it can be impaired by a thicker cloud cover. It has the worst detection time since the fire needs to be of greater size before it is possible to detect from space. (Cetin, et al.)

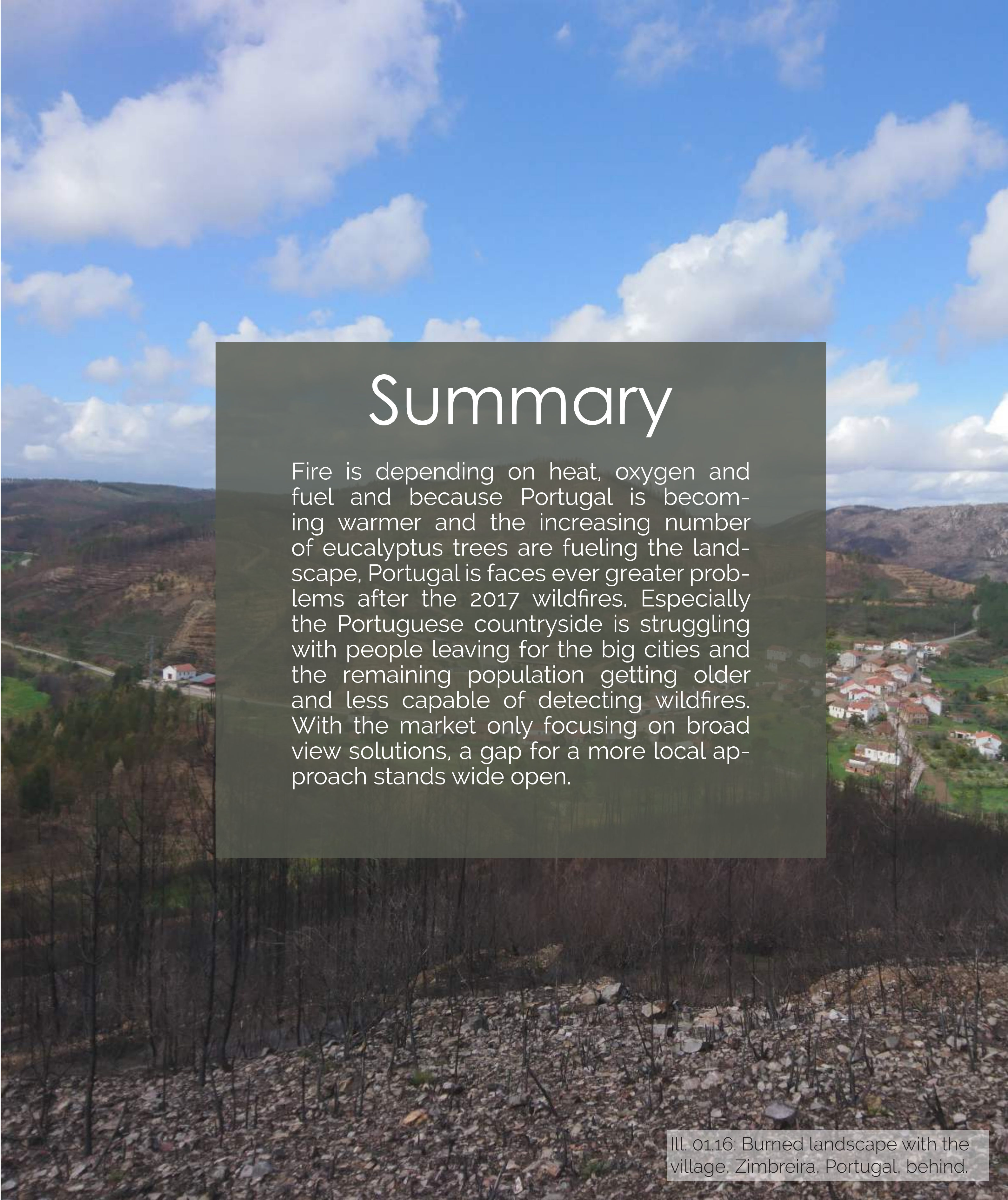
Comparing the solutions on the market in the Blue Ocean Canvas, there is a gap regarding the detection time, which the SaF teams sees as the most important factor, knowing the potential exponential spread of wildfires. It is also aimed to provide a relatively moderate-cheap solution that works disregarding of the weather. To detect the fire earlier than the other solutions the SaF team is aiming towards a solution placed under the tree top resulting in a lower coverage per unit.

Ill. 01.15: Blue ocean canvas



Finding 9: The existing solutions are expensive but cover a large area.

Finding 10: Most solutions have visibility problems in certain situations



Summary

Fire is depending on heat, oxygen and fuel and because Portugal is becoming warmer and the increasing number of eucalyptus trees are fueling the landscape, Portugal is faces ever greater problems after the 2017 wildfires. Especially the Portuguese countryside is struggling with people leaving for the big cities and the remaining population getting older and less capable of detecting wildfires. With the market only focusing on broad view solutions, a gap for a more local approach stands wide open.

Ill. 01.16: Burned landscape with the village, Zimbreira, Portugal, behind.

02
RESEARCH

A study trip to Portugal formed the foundation for the following section where the research is presented from the focus area, with context description, the problem owners and their existing coping strategies.

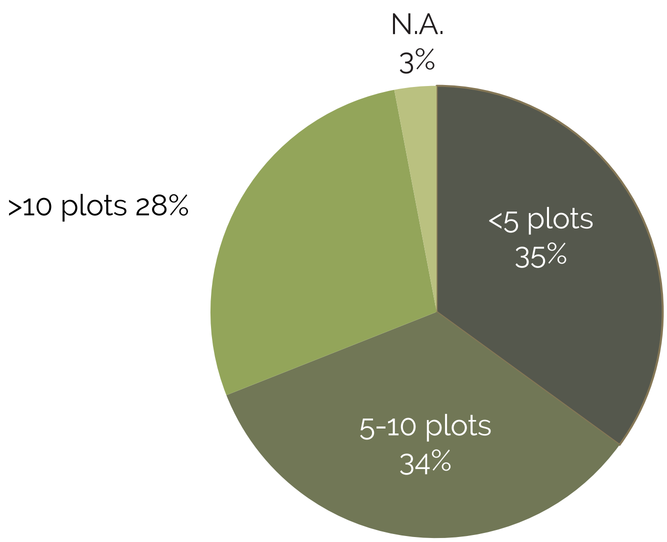
Ill. 02.01: Steffen and Vice president of Mação, António Louro

Mação, Central Portugal

More or less all the municipalities are battling the fire every year, especially Santarém District in the central region that lies between the warm south and the wooded north.
The Santarém District contains the municipality of Mação that was struck heavily in 2003 and with around 85% of the municipals forests burned down (AFN, 2010) and again in the last fire season (2017) where only four fires destroyed 69 % of the remaining 39.997,99 ha forest in the municipality (Appendix 01)
The fight against windfires is often a joint fight, since the surrounding fire brigades are called in when a forest fire occurs, because the fire is spreading too fast for one department to get it under control. The big fires, which are out of control also often cross the municipal borders and continues through the entire district. (Appendix 02).

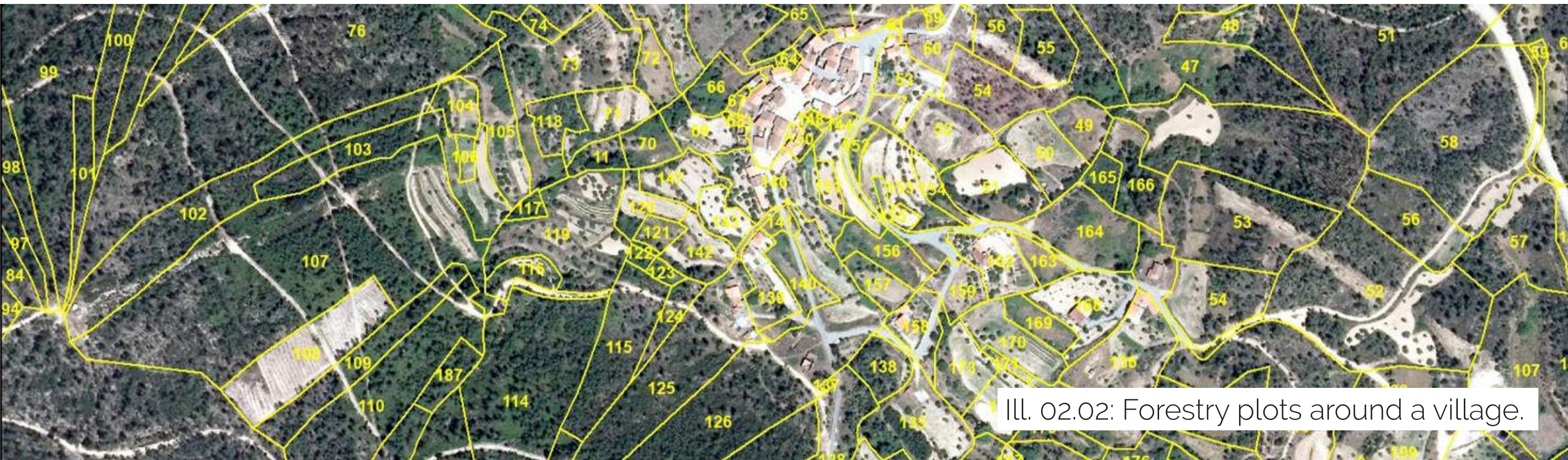
One of the problems in the central region of Portugal is that the land was in the 70's was very agricultural, but now the active agriculture is primarily located in the southern region. The land in the central region is now converted into forestry with the bloom in eucalyptus plantations.
The abandonment described on page 12 is also a huge problem for Mação, where only 10% of the municipals forest owners live within the municipality. (Appendix 01).
The forest plots in Mação are very small with an average size of 0,5ha, (Ill. 02.02) but the owners often have multiple plots (Ill. 02.03). (Valente et.al, 2015)

"This was an area where families had their small properties and they lived off the land. That ended in the 1970s, they left, and the owners of the land now live in the cities [...] The landscape we now have is the result of abandonment." - Louro, Vice President f Mação.



Ill. 02.03: Distribution of forestry plots

Finding 11: Maçãos many small plots are in average 0,5 ha.

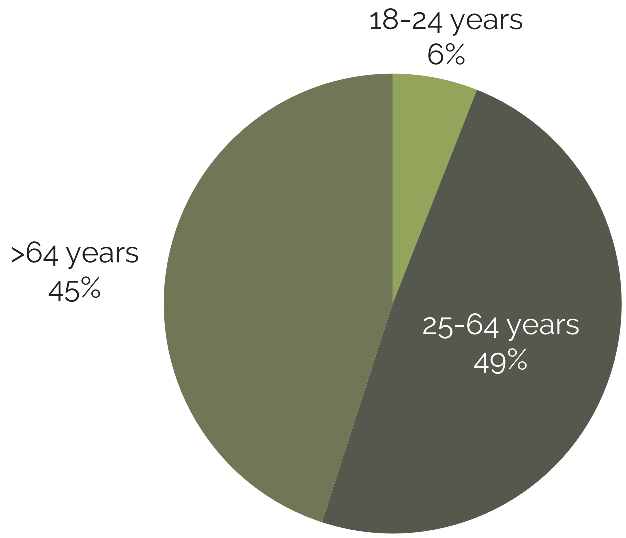


Ill. 02.02: Forestry plots around a village.

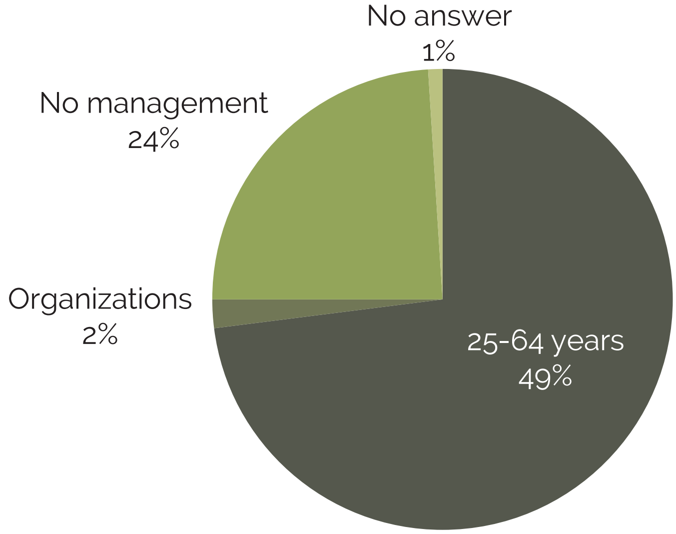
The average age of the farmers in forestry are higher than in the rest of the population. A survey among a sample group consisting of 64% forest owners and 36% other citizens in Mação shows that almost half are more than 64 years old. It also shows that 73% of the forest owners manage their forest individually, while nearly a quarter admit to not taking care of their forest.(Valente et.al, 2015). This abandonment is a huge fire risk due to the buildup of fuel from when the tree shed their skin and change their leaves.

The municipality of Mação is the forerunner in fire prevention, e.g. they are clearing the vegetation under power lines, which now has become a national requirement for power suppliers. To fight the trend of abandoned plots, they are attempting to redistribute the land to make proper forestry more attractive to what they call "village companies". They are also improving the firefighting by creating fire fighting kits, which they are distributing to selected villages across the municipality. These kits consists of a 1000l tank with a pump and a nozzle. This kit can be mounted on a pickup truck that are able to get to the fire much quicker than the fire department because of its proximity. (Appendix 01) Last but not least, they have been very open toward the SaF team in assistance with the development of this project. The fire protection initiatives as well as how badly they have been hit was the reason for the SaF team to choose this exact municipality as research case.

Ill. 02.06: Local fire fighting kits



Ill. 02.04: Age distribution of the sample group on Mação



Ill. 02.05: Forest management distribution

Finding 12: Many forests are managed individually.

Finding 13: 45% of forest owners are more than 64 years old.

Problem owners

Every time there is a fire several people are in one or more ways involved physically, mentally or financially. In other words they are problem owners. In this section the five most important problem owners are described.

Local
The local is retired and is taking care of the home, visiting family and meeting with the other citizens in the small village of Carvoeiro.
He spends the most time in the garden that he uses to be as self-sustainable as possible. He loves to be able to supply himself, with his own bread, meat from his chickens and wine he trade with his neighbors.
This summer he experienced the wildfire at first hand:
"The fire came, so quickly! I went out to the neighbors, to help them protect their houses and land
When I came back my garden was destroyed!
I had cloth hanging on the door, it [had] burned from just the heat in the air." (Appendix 04)

Plantation owner
It is a problem that many poor people have no insurance so after a wildfire nobody can afford to replant. (Appendix 04) Those who can afford do replant, tend to prefer Eucalyptus because of the faster growth rates and thereby the fast turnover. (Silva, J. 2016)

During the study trip to Portugal such a plantation owner was visited. He is responsible for several plots that he buys, and then businesses can pay him to grow trees that they provide.
He described that he would like a fire protection if its not too expensive, but he questioned whether the technology would harm the trees. (Appendix 05)
Eucalyptus trees from a 1 ha plantation can give a profit of up to ~25.000 euro. (Tree Plantation. 2000)

Ill. 02.07:
Local
Living in Carvoeiro, Mação

"The fire came so quickly! I went out to the neighbors, to help them protect their houses. When I came back my garden was destroyed." - Local

Ill. 02.08:
Plantation owner
Working in Vergão, Mação

Finding 14: The plantation owner care for the trees wellbeing.

Ill. 02.09:

Fire fighter
Working in Mação municipality

Ill. 02.10:

Municipality
Of Mação

Ill. 02.11:

Government
Of Portugal

Fire fighter

In the fire season the fire fighters are understaffed. To keep the fire under control they often have to work 24 hours straight. Their manager express that 8 hour shifts would be preferable, but that is not an option, with the fire intensity and their current crew size.
"In big fires, coordination sometimes is a problem" the fire fighter expresses.
Another of their big problems is false alarms which happens "very often" (Appendix 02)

Municipality of Mação

António, the Vice President of Mação, is frustrated: "Nothing is happening on a national scale, since they and the citizens quickly forget about the fires, if it didn't happen in their area", (He is thinking of the huge fire in Mação in 2003, where 60 people died.).
Last summer, huge fires hit again. It started 20 km north of the municipality, spread quickly and burned half of the municipality's land. That summer approx. 75% of Mação burned.
Mação spends approx. 300.000 Euro on fire intervention per year. (Appendix 01)

Government

As described in 'The Problem in Portugal', phase 1, Portugal spends a lot of money on *fighting* and prevention and still it keeps happening. The Portuguese people are not satisfied resulting in questioning whether the Portuguese government is fit for its role. (Khalip, A. 2017)
The fires were not a problem in the 1970-80's, because of the agricultural land and higher population. Now things have changed with the global warming giving them drier periods more often and for longer time. (Appendix 01)
In 2014 Portugal spent 100 mill. Euro on fire-fighting and prevention. (López, A. 2016)

Finding 15: The firefighters get a lot of false alarms.

The context

As described in the previous section, the central region is just between the warm south and the wooded north. Mação is in the lower end of the region, more precise in the subregion, Pinhal Interior Sul.

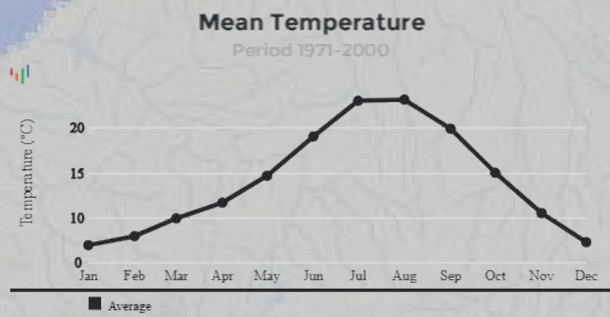
Climate

In general Pinhal Interior Sul have two seasons regarding precipitation, Where the winter is rain season, with a lowest avg. temperature on 7˚C, and the summer is dry season, with highest temperature avg. being 22,3 (max 47,4 (IPMA, 2017.)), is dry season (see Ill. 02.12) The illustrations show how much the average amount of precipitation drops in May which also indicate the start of the fire season (mid May). From there it starts to dry up the landscape until July where it rains less than 1 mm. From mid October is the fire season officially over and the rain season is starting again. (Appendix 02)
The wind speeds is in average lowest in October (3,3 m/s) and highest in July (4 m/s) and August (3,9 m/s). These numbers seem fairly low when compared to Denmark (avg. 5,8 m/s) (Portal Do Clima. 2018); (Cappelen et Al. 2011)

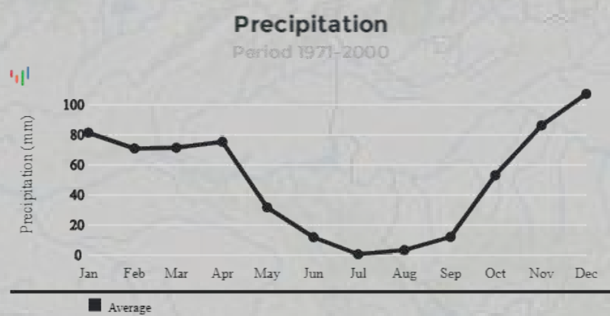
Terrain

In Portugal Eucalyptus is the single most dominant tree specie, but if we combine the different sorts of pine we end up with ~30% Pines 26% Eucalyptus Globules. (ICNF. 2013)
Because the Eucalyptus trees grows fast (10-12 years (Appendix 05), they are the preferred sort regarding a fast turnover. (Silva, J. 2016)
That is very visible when you travel around in the municipality of Mação, where a lot of plantations are Eucalyptus Globules planted in patterns of 3 meters between the trees and 1,8 meters between the rows. (Appendix 06)

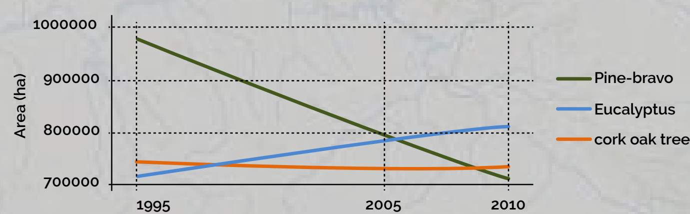
Ill. 02.15: Map of Portugal showing placement of Pinhal Interior Sul. (Background)



Ill. 02.12: Diagrams showing mean temperature from the neighbor subregion, Médio Tejo.



Ill. 02.13: Diagram showing the average precipitation from the neighbor subregion, Médio Tejo



Ill. 02.14: Diagram showing the area of pine-bravo trees becoming less than eucalyptus in 2006

Finding 16: It rains all winter season and is very hot and dry in the summer season.

Finding 17: Eucalyptus is the dominant specie in Portugal.

Vegetation (context continued)

In general as described in the previous section, "Mação, Central Portugal", most of the plots of the land are in general abandoned. This means that the vegetation is growing freely and that it in most cases is impossible to walk in these areas outside dedicated roads.

Regarding pine or eucalyptus plantations, the ground is very clean under eucalyptus trees where as pines have more and larger vegetation with a hight up ~2 m. (0,45 m. in average) (See Ill. 02.16 and Ill. 02.17). (Appendix 06)

Ill. 02.16: Eucalyptus ground clearance

Ill. 02.17: Pine ground vegetation

Finding 19: The trees are planted in patterns of 3 x 1,8 meters.

Finding 18: Eucalyptus plantations have less ground vegetation than pine, but a lot more of its bark, leaves, branches etc. falls off.

Coping

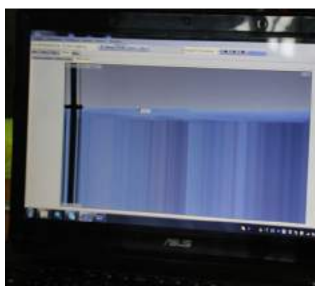
Since the problem of wildfires is not a new problem as described in phase 1, Portugal has following existing coping strategies:

Cameras

To detect the fire, the authorities are having video cameras mounted on towers on top of the largest hills. These are not automated and are therefore, manned by operators located at a central station in Lisbon. These operators monitor the camera feed from all the municipalities. In the municipality of Mação they are having five of these cameras, but the cameras seem unreliable, for example, one camera was malfunctioning at the time we visited (see Ill. 02.08). The cameras are connected to the power grid and are having large backup batteries capable of powering the system for 1-3 years. (Appendix 02)

Watch towers

In addition to the cameras they are also having fire watch towers placed on the hill-tops - some even right next to a camera. Which can indicate that the authorities do not trust in the camera system. There is a total of 236 manned towers in Portugal. (Rego et Al. 2004) Both the towers and the cameras have a great view of the sur-



Ill. 02.18: Malfunctioning surveillance camera video feed. (Left)

Ill. 02.19: Fire watch tower with camera. (Right)

Finding 20: Existing solutions works regardless of power grid failure.

strategies

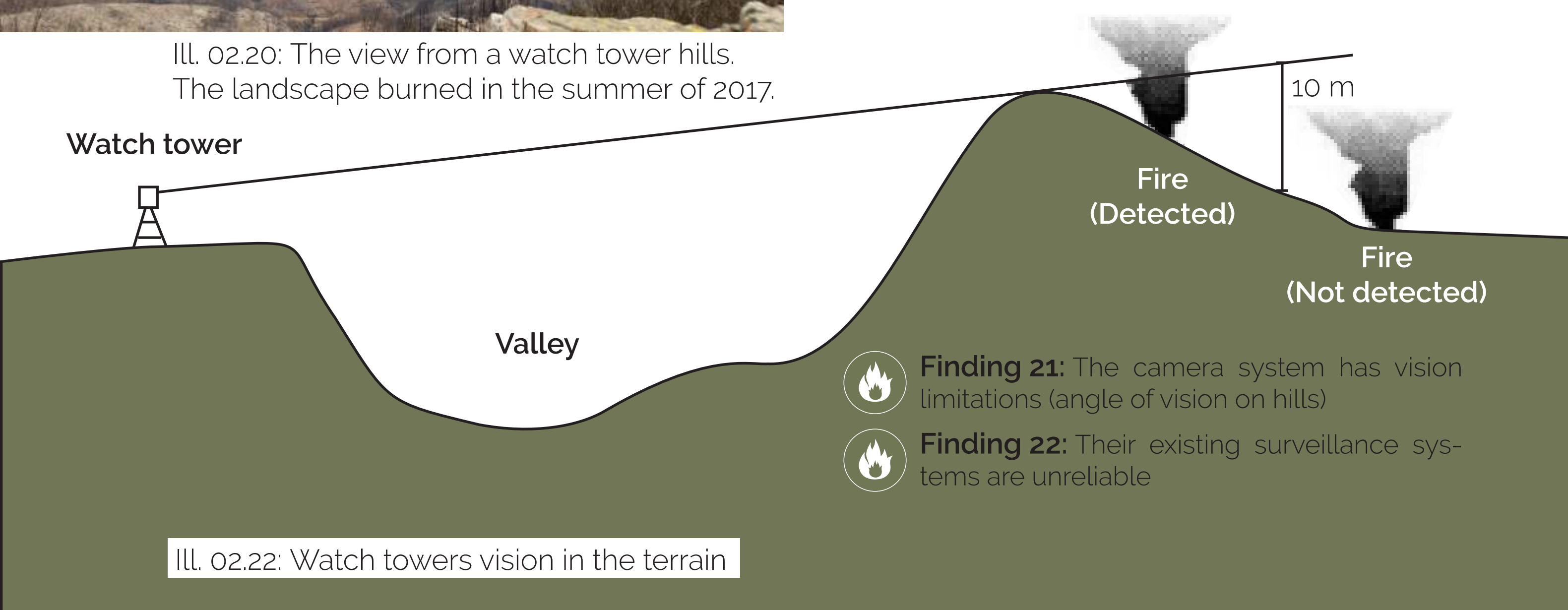
rounding land, but cannot see on the away-facing slopes, meaning that the smoke sometimes must rise above the hills to be spotted.
In some occurrences the fire is closing in on the fire watch towers while they are manned, the crew is therefore evacuated using helicopters.
During the fire season, the municipality has people driving around the country side to spot for fires.
It cost 2,5 million euro pr year, to operate the watch towers (Catry et Al. 2007)

The locals
Even though the authorities have these method for detecting the fire, the most fires are spotted by locals, who often are closer to the situation when it happens and are then able to report it in to the emergency line.

Ill. 02.20: The view from a watch tower hills.
The landscape burned in the summer of 2017.

Pump kits
To speed up the reaction time of the fire fighters, the municipality have donated fire pump kits to many villages. It consists of a 1.000 liter tank with a pump, hose and a spray nozzle, which can be loaded onto a pickup truck. This allows the locals to start the fire fighting and possibly extinguish the fire before the fire fighters arrive.
Since the fires are spreading rapidly because of the very dry vegetation the fire alarm is send to all the nearby municipalities, who then each send fire fighters to aid. This is an expensive solution, but they need to act fast.
During the fire season it is illegal for anybody to start fire and use tool as metal brush cutters (Ill. 02.09), since these can create sparks by hitting small rocks.

Ill. 02.21: Examples of periodically illegal tools.



Finding 21: The camera system has vision limitations (angle of vision on hills)

Finding 22: Their existing surveillance systems are unreliable

Ill. 02.22: Watch towers vision in the terrain

Warning scenarios

Today there is basically to ways of reporting a fire. The most common is locals reporting the fire, the second is the watch towers.

Ill. 02.23:

The Local - Primary

The vast majority of responds is from locals near the location. As described earlier, the locals, in the remote areas where the fires usually starts, are elderly persons. (Appendix 03)

When a local sees the fire, the required actions to get help is as following:

1. The local pick up the phone and call the national emergency line on "1-1-2".
2. The national emergency center redirects the call to the regional commander.
3. The regional commander redirects the information the local commander.
4. The local commander sends out a responder car to determine where the fire is exactly and how bad the situation is. Simultaneously other fire fighters are on their way.
5. The responder car reports back to the local commander that uses the information to determine how to handle the situation.

Ill. 02.24:

Watch tower - Secondary

The watch towers is used to cope with the problem about the fewer and elderly locals regarding detecting of fire as described in 'The problem in Mação'

When the watch tower detects a fire the procedure is shorter since they report directly to the regional commander central:

1. The crew at the tower informs the regional commander central about the fire.
2. The national commander redirects the information the local commander and if possible checks the towers' video feed.

The following steps is the same as step 4 and 5 for the local.

Finding 23: The local commander needs to analyze the situation with his own eyes.

Finding 24: The watchtowers are a way of detecting fires with fewest steps.

Ill. 02.25:

Summary

The Portuguese population is becoming older and that is also a trend in Mação that is placed in the sub-central-region, Pinhal Interior Sul. The region experiences rain all winter and drought in the summer where temperatures can reach up to 47,4 ˚C. The elderly citizens are primarily the owners of the many small plots in Mação, which in most cases are not insured because of the cost. They are also often the first ones to detect a forest fire (before the watch towers).

Ill. 02.26: Walk in the forest near the village, Vergão, Portugal.

03
FRAMING

To get a common understanding of the purpose of the thesis, a re-framing were done several times throughout the project, consisting of rephrasing the project focus, vision, mission, metaphors and requirements.

Ill. 03.01: Burned street sign in Mação municipality

Focus

The following vision, mission, metaphor and problem statement are made upon several iterations in each of the 11 re-framings done in this project. (Appendix 07)

Note: The vision and mission is a company mission and vision for the SaF start-up .

Vision & Mission
Every one wants to be in control, whether it is the small things as what is being played on the stereo or bigger things as what personal data is shared with whom.
To control something, you have to know it.

With the start-up company Safe Forest (SaF), the company will roll out products that when covering an specific area, will make the plot owner or the municipality be able to determine if a fire should start or not.
Until now wildfires have ignited without anyone being in control of whether was about to happen or not, simply because they did not know it was going to happen before it happend.

SaFs vision is to make it possible for the plot owners to "control the ignition of wildfires".

At SaF we know that to get control you have to know about the situation soon enough to make a decision.
Therefore SaFs mission it to deliver the "First detection and localization of fires in forest before the flames occur."

Metaphor
To understand what the first product from SaF is going do to the detection of forest fires, a metaphor was made which can be seen below.

Problem statement
The problem statement was used as well as the other parts of the framing, to keep the project on track.
The problem statement is a statement of what that is aimed to solve. It is in this project used to narrow down the solution space. Meaning that earlier it was attempted to solve wildfires but now with the current problem statement it is narrowed down to forest fire. See below:

Vision

"Control the ignition of wildfires"

Mission

"First detection and localization of fires in forests before the flames occur"

Metaphor

"The seismograph of the forest"

Problem statement

"How is it possible to design a system, using low cost units, that by detecting and localizing upcoming forest fires on an early stage, can reduce the damage and cost of a forest fire?"

Target price

A target price were setup to get a direction for the price of the unit. The price were used both internally and externally when the project were described to potential customers and other important stakeholders.
The price were based upon research of existing products as the indoor smoke alarm as well as crucial components as the battery and sensors. The prices were gathered from Alibaba as Alibaba is a marketplace for b2b. It was an easy way of quickly get a overview of the prices for mass production.

The price were first given pr unit, for a unit that would work for 10 years.

It was quickly realized to determine i price for covering of one hectare, to give the potential costumer a easier number to relate to.

Target price of one sensor unit

1 €

Target price of coverage for one hectare

1000 €

Requirements

The requirements is a tool to measure relevance and priorities in a product development process, based on Ulrich and Eppingers model (Ulrich, et al.. 1995), with a brush-up at each of the re-framings. It contains following values below;

Requirement number
The requirement number is used for identifying the requirement, especially in The Productdevelopment phase.

Finding number
The Finding number is used to get an easier direct understanding for where the requirement come from e.g. theory or collected data.
The findings are often a result of a stakeholder.

Stakeholder
The stakeholder is the person or organization that is affected by the requirement.

Requirement
The actual requirement is the result of re-framings where each requirement were evaluated.

Importance
The importance column shows the importance from 1-5 of a requirement, where 5 is highly important and 1 is less important.

Ideal or marginal value
The ideal value is what is strived for, while the marginal value is the acceptable value.

Wishes were also made, which were not directly required to be fulfilled, but they were made to strive for. Less important requirements or wishes for the product, that were not directly required to be fulfilled, were also formulated. They have been kept in mind as goals to strive for. (See Appendix 07)

No.	Finding no.	Stake-holder	Requirement	Impor-tance 1-5	Unit	Ideal val.	Marginal val.	Fulfill-ment
1	1, 5, 8, 23	Investor/ buyer	Must in average detect the fire quicker than exist-ing solutions	5	Binary	Yes	Yes	Test
2	21	Buyer/lo-cals/ mu-nicipality	Chance of the fire getting detected	5	%	100	90	Test
2	6, 23	Firefighter command-er	All sensor units must be able to communicate with National controller (direct or indirect)	5	Binary	Yes	Yes	Ideal
3	8, 15	User/fire command-er	Limit false positives (% alarms are true)	4	%	100	50	Test
4	21	User/buy-er	Inform about malfunction (destroyed, low battery, vandalism, moved etc.)	5	Amount of info	Details	Basic info	Margin-al
5		Setup	Sensor units must be wireless (connection, power)	4	Binary	Yes	Yes	Ideal
6	6, 13	User	No battery failure	5	Years	10+	10	Ideal, test
7	11	Investor/ user	Must be scalable (as needed (ongoing))	4	Binary	Yes	Yes	Ideal
8	12, 13	Setup	Setup time for sensor unit (incl. Walk between trees	4	Sec.	<20	60	Ideal
9	12	Setup	Must be able to be mounted by one person	4	Binary	Yes	Yes	Ideal, test
10		Developer	Mounting height interval (unobstructed)	4	m	2-3	2-2,5	Ideal
11	10, 16	User/buy-er	Must be weatherproof (rain, wind, snow, dust)	4	IP. rating	65	53	Test
12	10, 16	Investor/ developer	Particles must be able to enter detecting sensor(s)	5	Binary	Yes	Yes	Ideal, test
13	10	User	Must work in all weather conditions	5	Binary	Yes	Yes	Test
14	7	User/buy-er	Product lifetime	4	Years	10+	10	Ideal, test

No.	Finding no.	Stake-holder	Requirement	Impor-tance 1-5	Unit	Ideal val.	Marginal val.	Fulfill-ment
15	14	User	Not kill the tree	4	Loss of trees	0%	5%	Test
16	14	User	Hinder the trees growth	4	Binary	No	No	Ideal, test
18	21	Investor, developer	Sensors not getting blocked by dirt, dust, insects etc.	5	% blocked over lifespan	0%	1%	Test
21		User/buy-er	Fireproof	4	Binary	Yes	No	Margin-al
24		Buyer	Price per ha (sales price)	4	Euro	<1000	1000	No
26		Firefighter command-er/user	System should indicate where the fire is	5	Preci-sion, radius [m]	Area (within 10)	Area (within 50)	Ideal test
27		Firefighters	Firefighters should be able to find triggered unit (where the fire is)	5	From given area [sec]	15	60	Test
28	22	User/fire command-er	The drone must be able to be piloted	4	Binary	Yes	Yes	Ideal
30	16	Buyer/ User/de-veloper	Weatherproof (tempera-ture)	5	Degrees Celsius	<-20 - < 60	0-50	Ideal, test
30		Govern-ment	Limiting the drone to a specific area + height (law)	5	Binary	Yes	Yes	Ideal
31		Firefight-ers/user/ buyer	Drone response time	4	Minutes	<10	10	Margin-al
32		Fire com-mander	Drone size	5	Dimen-sions [mm]	500 x 500	1000 x 1000	margin-al
33		Investor/ User/ drone-op-erator	Drone should be able to overcome or evade tiny branches (dry eucalyptus branch up to Ø5mm)	4	Binary	Yes	Yes	suppli-er-test

Summary

The continuous framing of the project throughout the development phase, kept it on course, resulting in the final SaF vision, mission and a clear definition of the purpose, by the creation of the metaphor and problem statement.

The final requirement specification shown on p. 29 & 30 is showcasing that a lot needs to be tested in order to fully determine whether the requirements is fulfilled.

Ill. 03.02: Investigation of the burned landscape in Zimbreira, Portugal

04
SOLUTION SPACE

Phase 4 describes the development of the product. From very early sketches, through several concepts and user feedback to the final scenario, proof of concept test and lastly the development of the setup mechanism.

Ill. 04.01: Initial sketching (Quick & Dirty and sub-problems)

Ideation

Quick & dirty
The first sketching round in February, was a way to empty the head by getting the ideas, from the problem description phase down on paper. (See Ill. 04.01).

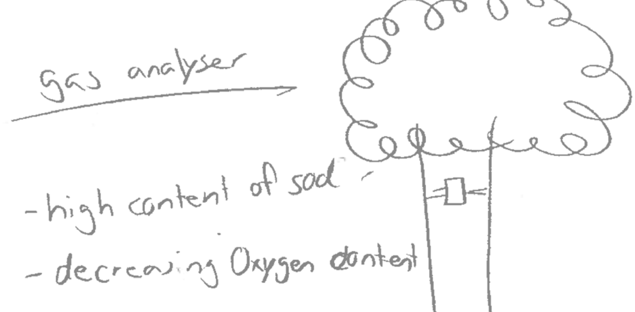
Systematic sketching
To get a understanding of the possibilities we used the brain-pool method. The subjects were as following;

- Detection method
- Warning Method
- Power supply
- Placement
- Montage

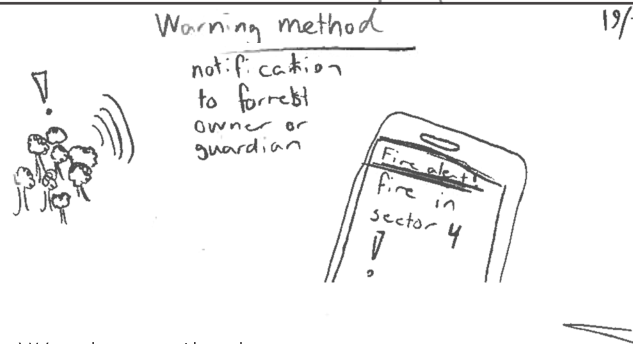
This resulted in broad and wild ideas which were good because now was the time for these. Regarding the "detection method" both the existing airplane and satellite were suggested but also autonomous robots, laser and the normal gas sensor as seen on Ill. 04.02.
The sketches on warning method were also as expected the sounding alarm, the blinking, but also fireworks and notifications on a cellphone (see Ill. 04.03)
The "power supply" sketches were around hydro, chemical, bio, and of cause solar which became the most popular. (Ill. 04.04)
When it comes to placement both a drone and an air balloon were drawn but also placement on the tree. (See Ill. 04.05)
For the last theme, "Montage" (how to mount the device).
The principles were inspired by knocking it up with a stick, to using a hook or magnet and lastly the principles from the slap-on reflective band, used for keeping clothes, close into your body when biking (see Ill. 04.06)

Early ideas

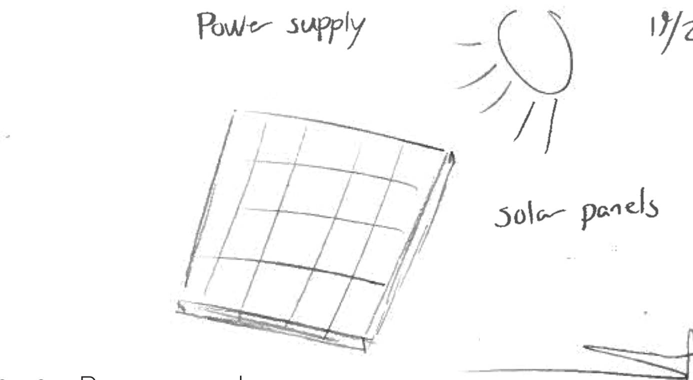
* Autonomous = Self controlling



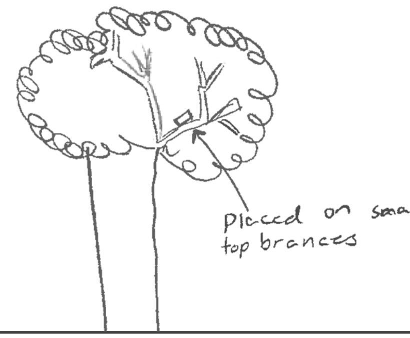
Ill. 04.02: Detection Method



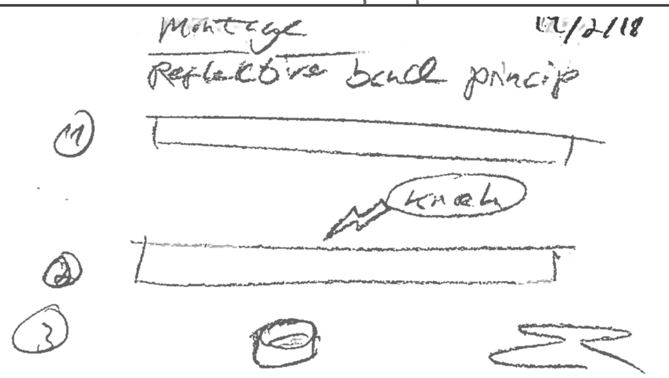
Ill. 04.03: Warning method



Ill. 04.04: Power supply



Ill. 04.05: Placement



Ill. 04.06: Montage

After the brain-pool, additional framing was done and the requirements were updated with the problems that we now faced from some of the previous ideas. This process resulted in the first real ideation on future concepts.

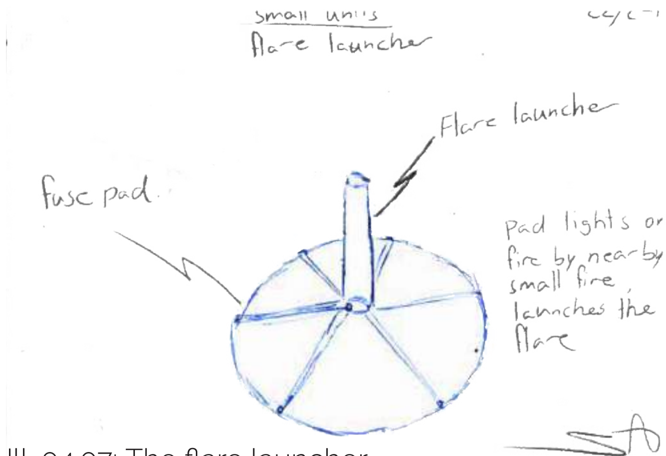
The sketching round were divided into themes that derived from detected patterns in the previous round. The themes were as following.

- Coverage
    - Small - many units
    - Medium
    - Large - few units
- Removable

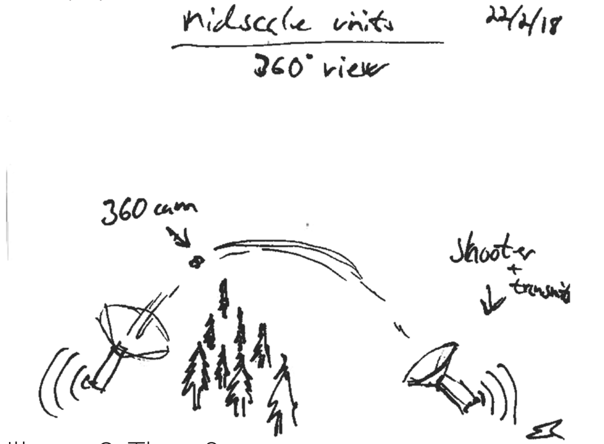
The theme "coverage" helped to ideate on how few units could cover a large area, how many units with a small coverage, combined could do the same and lastly, the medium scale.
The small coverage, many units could be "Ill. 04.07: The flare launcher" that triggers by the flame reaching the ignition pad. Locals would then be able to see the light from far away.
The medium scale theme was for instance "Ill. 04.08: The 360 camera" that contains two stations shooting a 360 camera ball back and forth and sending the pictures to the fire station.
The large coverage, few units theme came up with the hot air balloon principle where a camera were held up by a hot air balloon looking down over the forest (Ill. 04.09)

The removal was how the solution could solve easy set up/removal e.g. the idea with a "build in seed" (Ill. 04.10)

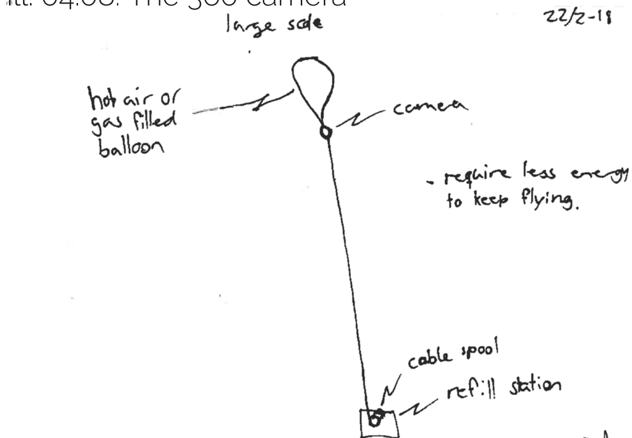
This gave us a feeling for what is possible: Units with large coverage can have an expensive unit prize, where-as many units with small coverage have to be cheap. as you need more of them.



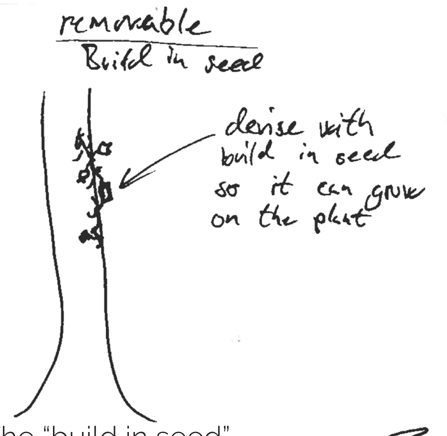
Ill. 04.07: The flare launcher



Ill. 04.08: The 360 camera



Ill. 04.09: The hot air balloon



Ill. 04.10: The "build in seed"

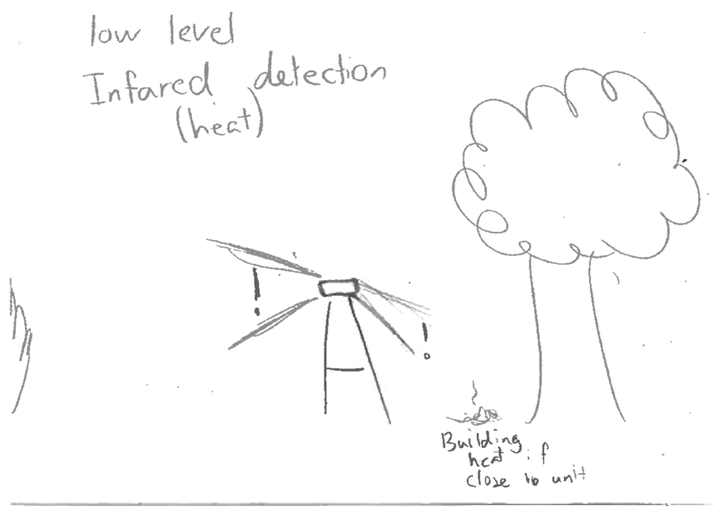
The three directions

After the first initial sketching rounds and the first framings with initial requirements, it was possible to sort out the sketches, and find three directions that could be presented at the first status seminar.

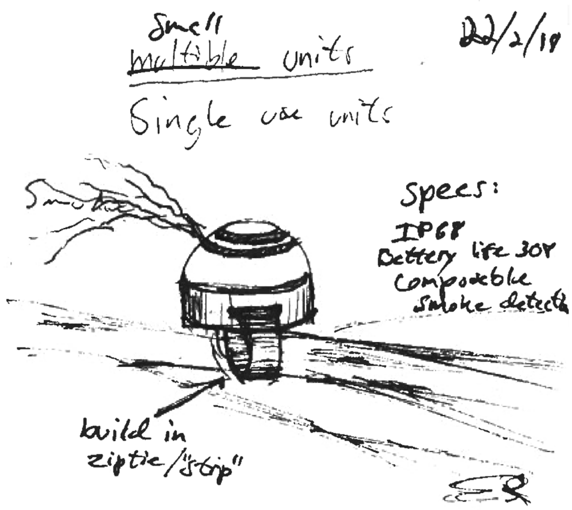
The sketches from the different categories, described at the previews page, were rated based on the requirements where a green label were given the idea that fulfilled the requirement the best and a red were given to the idea that fulfilled the requirement the least. On the label the requirement numbers were written so discussions about the ideas could happen on a constructive level. (Ill. 04.11)
On Ill. 04.11 we see the two winners, but the one in the top right, (see Ill. 04.14) was close to being the best of many requirements, so it passed on. The three sketches that made it further where:

- A camera that use the idea of infrared heat detection to detect fire. (Ill. 04.12)
- A very small smoke detector based on the single use principle. (Ill. 04.13)
- An idea based on damage detection (Ill. 04.14)

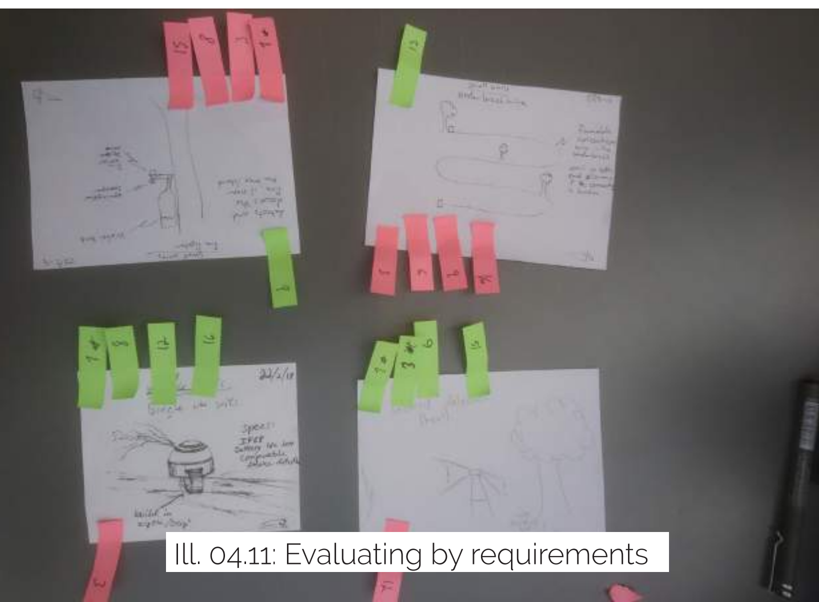
This led to creation of 3 concept directions: A vision based, an air based and a damage based.

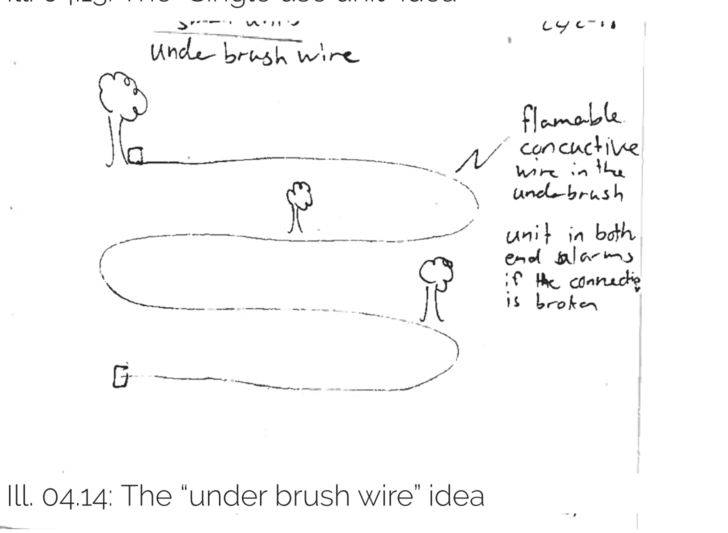


Ill. 04.12: The "Infrared detection" idea



Ill. 04.13: The "Single use unit" idea


Ill. 04.11: Evaluating by requirements



Ill. 04.14: The "under brush wire" idea

Detection by vision
The first concept was developed from the existing solutions as seen on page 24 but with the knowledge from Finding 5 that early detection is crucial.
This concept is therefore a unit placed in the forest, to be able to see what happens underneath the crown of the tree. Its key features, were the following:

- Approx. 4 units/ha (assumption)
- Accurate detection - since human validation is possible.
- Visual of the fire
- Radio waves grid relay
- Solar powered

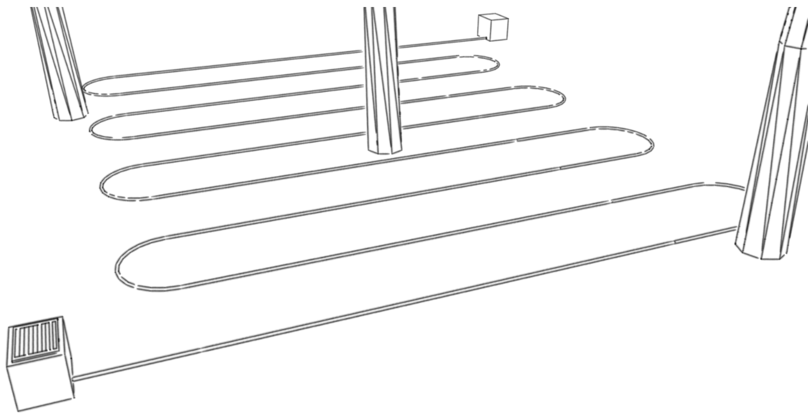
Detection by damage
The second concept was developed with the inspiration from a similar indoor solution, for the storage halls of companies. The concept is a cord with two wires inside, when the fire would reach the cord the insulation would melt at the system would short circuit coursing the alarm to go off. The key features were as following:

- Detects heat damage to the wire
- Approx. 2 unit/ha
- Sector alarm (eg. 50x100m)
- Radio waves grid relay
- Solar powered

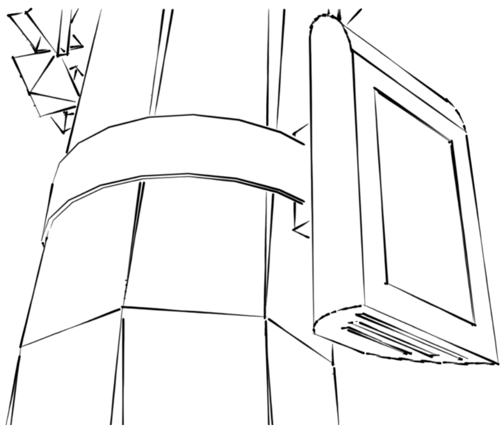
Detection by air
The last concept was basically a smoke alarm for outdoor usage, that would trigger if smoke were detected. The key features were as seen:

- Smoke detection
- Many units (up to 250 units/ha)
- Accurate detection
- Very low cost / unit (1$)
- Battery powered
- Low energy usage
- Radio waves grid relay

Ill. 04.15: Camera detection



Ill. 04.16: Damage detection



Ill. 04.17: Air detection

Concept evaluation

The three concepts were brought to a status seminar to get external feedback and afterwards the concepts evaluated internally guided by the early requirements.

The status seminar

At the status seminar the three concepts (camera detection, damage detection and air detection) were presented. This led to a lot of suggestions like: why not use satellites and if we had considered how the wildlife would react to devices like this. A suggestion about a drone were also brought up two times through out the seminar.
Moreover the feedback for the wire concept was mostly negative where-as the feedback of the sensor unit was more positive.
A to look into invisible smoke, as part of the early detection was also highlighted.

Early detection

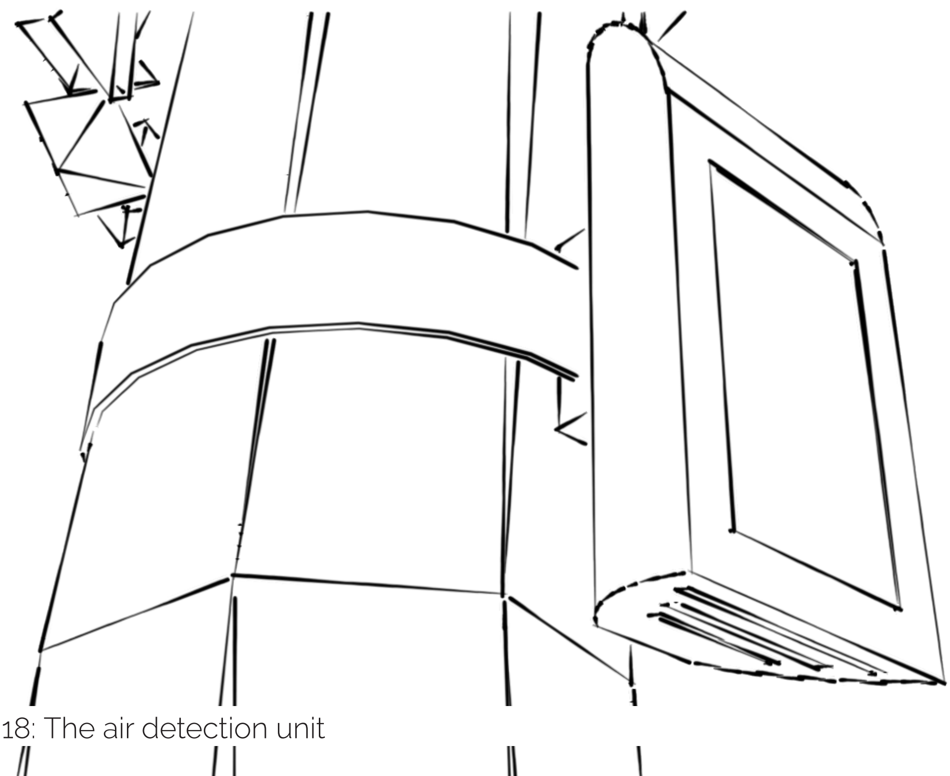
Early detection is at this point still the fundamental element of the project based on the research on page 11 which also were presented at the status seminar.

Internal evaluation

Based on the feedback, the requirements and our focus of early detection the wire concept was abandoned because would be to difficult to install, it would first trigger when fire was already happened and the wire could be cut by animals or falling trees/branches etc.

The camera concept was abandoned because of the visibility problems it would get if it was standing in the woods. The dense undergrowth described in “The context” on page 23, would be difficult to see through.

Therefore we decided to go with the air detection.
The air detection units are able to be placed all around the forest and the smoke will be blown to the sensor by the wind.
This concept will now be developed further.



Ill. 04.18: The air detection unit

Concept development

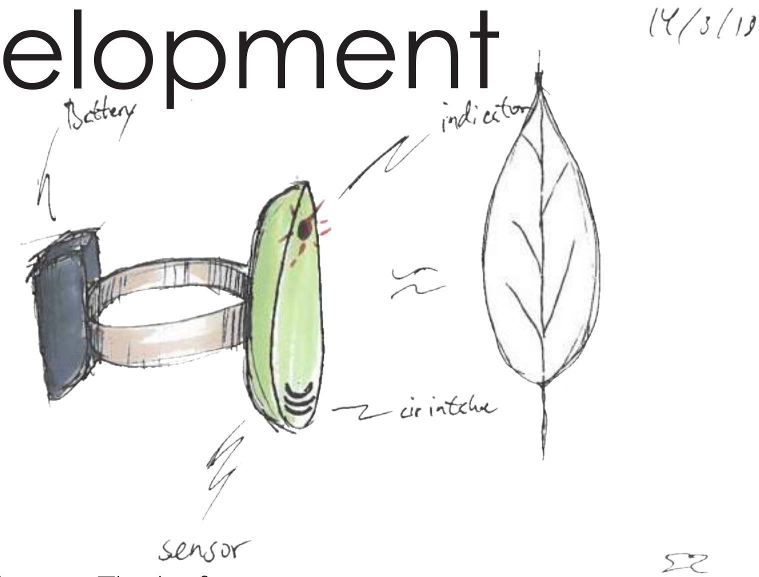
Now that the direction with many small units were chosen to be developed, two categories were developed to streamline the development. Two directions were: on the tree and beside the tree.

On the tree
In this category the context was taken highly into consideration to make the product able to blend into the context.

The leaf were the first design with a more curved look. It was, as the name suggests, meant to look like a eucalyptus leaf and had a indication LED on top and air intake in the bottom. The battery was placed outside the main body to balance weight around the tree. The band around it should be an elastic rubber and the initial idea was that the plantation owner stretched it on to the sapling and that the tree would then lift it up as it grew. (see Ill. 04.19)

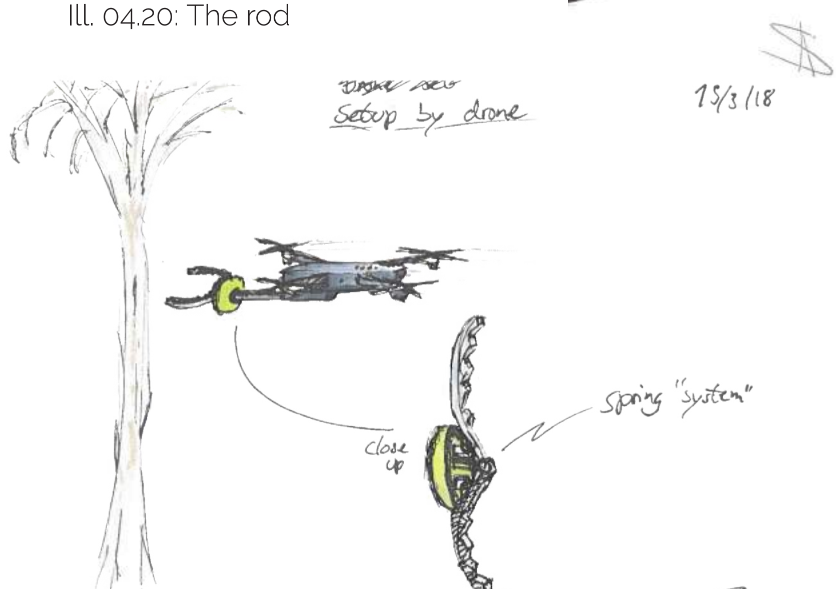
The rod was built on the principle of the carabiner, making it very simple to put up on branches, just under the crown. The shape of the rod fitted a standard battery cell and the sensor part was placed facing down and a bright LED indicator was placed on the side. (Ill. 04.20)

The “slap on” concept were based on the principle from a bear trap as seen on Ill. 04.21 where the idea primarily were to let a drone setup the sensors, to save labor salary the drone could do i automatically.
But it was the spring “system” that were adobted and after some iterations led back to the reflective “slap on” band as seen earlier on “Ill. 04.06: Montage” on page 35 (Ideation).



Ill. 04.19: The leaf

Ill. 04.20: The rod



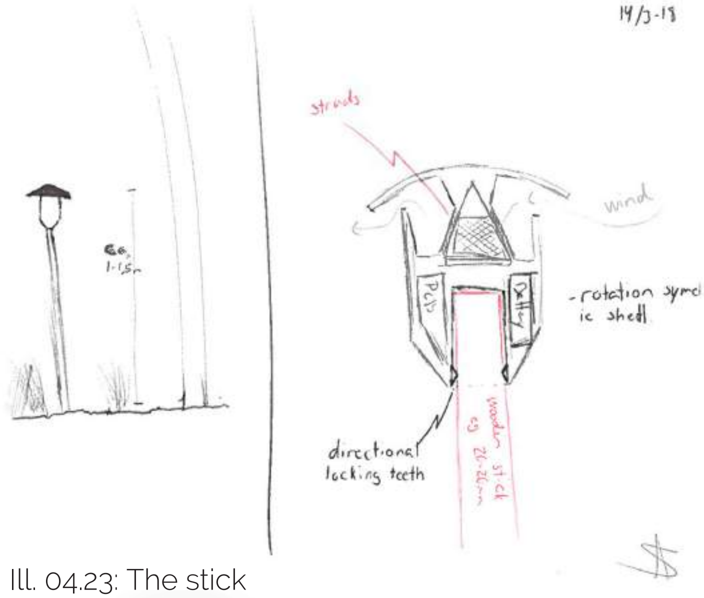
Ill. 04.21: The drone and early “slap on” concept

Beside the tree

The other category was beside the tree. At this point the idea was that this would be an easier and more diverse concept as it would be able to work i several contexts.
The idea was that the sensor was the top part of a standard pole and that they could be placed in-between the trees on the plantation. The product would then be levitated above the under growth (Ill. 04.23)

Moch-up's

It was decided to make moch-up's of the products to get a feeling of the scale of the products, an idea of the weight and how the mechanism would actually work.
The moch-up's were made during the trip to Portugal with what we were able to find in local stores. (It worked out well and especially the rod and the "slap on" were a pleasant surprise of how easy it was to setup, where as the leaf was flimsy but had a more organic feel to it.
The stick was very big, heavy and thereby clumsy to maneuver around.



Ill. 04.23: The stick


Ill. 04.24: Mock-up of the stick and "slap on"


Ill. 04.22: The making of "The leaf" in Vergão


Ill. 04.25: Moch-up of the leaf and the rod

User feedback

To get a better understanding of the user, it was decided to setup a meeting with first the fire coordinator, Sonia and the firefighter commander and afterwards, Antonio Louro, vice president of Mação, to discuss and test the concepts

Feedback from the fire coordinator and the firefighter commander
At the department of civil and forest protection, the commander and Sonia listened very concentrated to the description of the current solution principle and elaborated with questions and knowledge about the situation. (Ill. 04.26)
Sonia were very interested in the solution principle and requested a picture of it.
Afterwards the concepts were described with the key aspects of how to set them up, and the small details such as how to find the sensor if a malfunction happened (first by GPS coordinates, and then by the product blinking with an LED. Then the moch-up's were presented to give the physical impression.
The last thing, was letting the fire commander try to set the different concepts up, one by one.
When sitting up the rod, the firefighter suggested just to use a zip-tie instead, because it was difficult to find a fitting branch. Then the slap on concept resulted in the question of how to reach the hight of the placement. There were no comments to the stick. (Appendix 08)

Feedback from the vice president of Mação
The meeting started with describing the current solution principle, then the different moch-up's were presented and finally the different deployment scenarios and our potential business models were described. (Appendix 09)

Antonio really liked the moch-up's and saw a great potential in the concepts. In fact he called in the president of Mação to describe especially the "slap on" concept.
Antonio thought that all the concepts were good in each of their scenarios.
He suggested that the concept could fit very well in national parks with special nature.


Ill. 04.26: Meeting with the fire commander


Ill. 04.27: Meeting with Antonio Lorou

The final concept

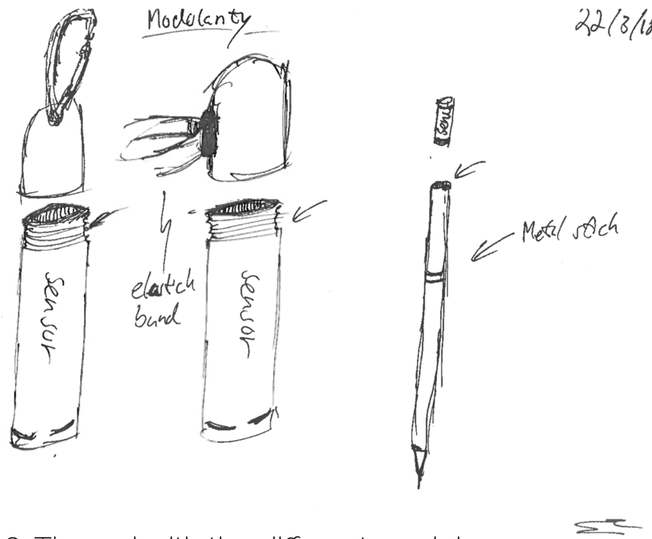
From the feedback i was noticed that the user saw the possibility of the product in many different scenarios, but a conclusion was quickly drawn: The final solution would not be with much variation, but the possibility of modularity was brought up.

Modularity
The cylindrical shape of the rod quickly gave birth to the idea of a thread in the top where the components could slide in under production, and different tops could be added depending on the use case: The carabiner for the branches, the rubber band to the tree and also the possibility of the rod to be attached directly on a stick.

In the end it was discovered by Finding 18 on page 24 that the rod would fall down because the branches would brake.
The rubber band solution would not work since trees does not lift the product up while growing. (Forsite. 2016)
The stick solution was abolished because of a wish from the user that it would withstand vandalism (Appendix 07)

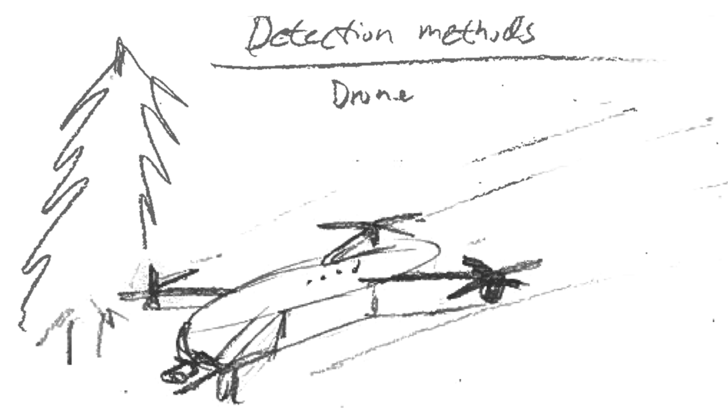
This led to the final concept ended up being the "slap-on" concept. But from the feedback at the status seminar, feedback from the users and the "Finding 23: The local commander needs to analyze the situation with his own eyes." on page 26, it was decided to adopt the drone principle to the concept.

The drone
Beside the sensors, a drone would make it possible to solve one of the biggest issues so far: False alarms. With the drone the user would be able to verify the validity of a fire.
This will be showcased in the following section.



Ill. 04.28: The rod with the different modules

Ill. 04.29: The "slap on" moch-up in context



Ill. 04.30: Drone sketch

The solution principle

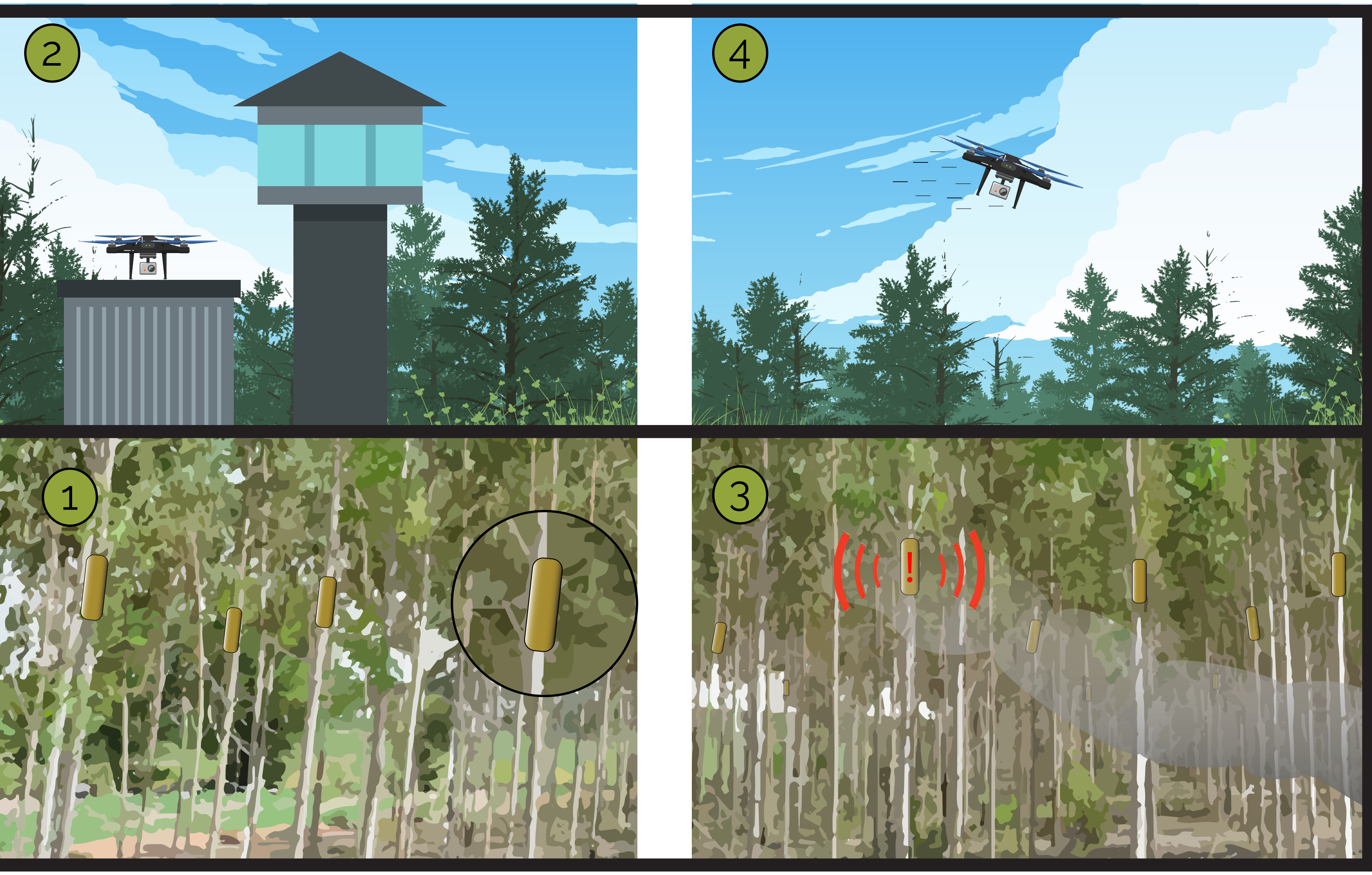
The solution principle consists of two key elements, A Sensor Unit that consists of a smoke sensor and an autonomous drone with a camera.

1. The sensor units are placed on the trees in the forest just under the crown, to let the breeze reach them

2. Just beside the watch tower the drone is placed, and charging, ready to respond to a situation.

3. The first sensor have detected some smoke!
It immediately sends an alarm to the systems servers, that determines the coordinates to the sensor and thereby the fire. This is sent to the drone and at the same time to the firefighters.

4. The drone has at this point already reviewed the coordinates and is automatically flying to the location of the fire



Ill. 04.31: The solution principle

Delimitation

5

Now the drone has reached the dissemination and will with the camera start transmitting a live feed of the fire directly to the fire station.
Here they are now able to control the drone to get a better view of the situation before they are able to get to it by car or truck.
In this way the firefighters are able to determine how the situation is, how it should be handled and in the end stop wildfires much faster.

Context
Even though wildfires happens in many contexts and many types of forests, research in "The problem in Portugal" on page 12, indicates that the eucalyptus tree is one of the worse contributers to the problem. Therefore it is, in this project, decided to focus only on Eucalyptus plantations trees
Furthermore the focus was limited to Mação municipality, Portugal, to get a more narrow solution space and a more focused result.

Fire season
In Portugal data from "The context" on page 23 shows that the fire season is approximately half a year and in that period it is not allowed to make any open flames as "controlled fire cleaning", at campfire or use bush cutter machines.
The product that is attempted to be made, is relying on these rules and will not work if these rules were to change.

No wind = no detection
As shown in previews section with the solution principle, the solution is relying on wind to blow the smoke to the sensors. This project it is made able to detect smoke on days with no wind. Unless they are started right under a sensor. In situations with no the watch towers (described in "Coping strategies" on page 24), will have optimal conditions for detecting with this project is relying on.

Drone
The drone market is right now very large and varied, with the Chinese DJI in the lead, both in the consumer and professional sector, and because of that, the development and construction of the drone is outsourced.

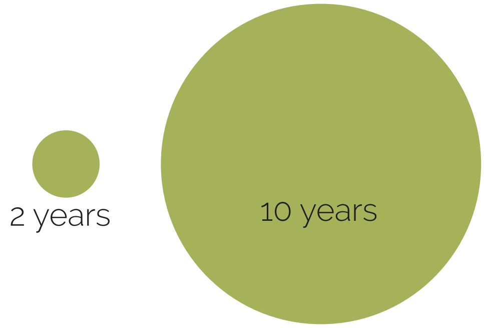
The mounting mechanism

The rod concept (see the concept development section) was a solution, for a long time until the discovery that the lower branches break off over time because the sunlight stop reaching them. (Appendix 06)
This led back to the "slap on" concept from the concept development section.

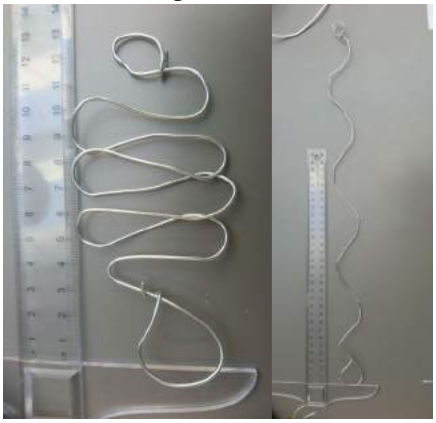
The two main problems with the attachment to the tree was how to get the connector part around the tree and how to lock it in place, when it comes around. The tree grows a lot. It grows from a diameter of 45 mm at age 2 to 214 mm at age 10 (Hay et Al. 1999). Which is a circumference of 141-672mm. This means that the solution must be able to stretch to 5 times its starting length.
The "slap on" had a problem of being non-expandable, therefore, it was attempted to find other solutions.

The first thought was to use an elastic band as they are known for expanding a lot, but they cannot last for much more than two years. (Appendix 10)

The second idea was to use a string loop system, where it can expand by pulling the string. This was limited to a 2-times expansion and created a lot of friction as the entire string had to move.



Ill. 04.32: Tree growth in scale 1:5.


Ill. 04.33: Elongation of the metal spring


Ill. 04.34: The friction locking string

The third idea was using the elasticity of metal. It is a flat spring wrapped around the tree, it can then be pulled and deformed, as the tree grows, since the tree does not shrink again. (Ill. 04.33) This expand heavily but had a problem to get mounted.

The forth idea was inspired by rappelling where friction is used to lock their ropes. This was mimicked by looping a string through a metal guide multiple times until the friction were sufficient to keep it tight, but not too tight. (Ill. 04.34) This had no limit to the expansion but had a problem of how to get around the tree and lock onto the sensor unit.

The fifth idea were inspired by a measuring tape, as also have the spring-like ability. The idea is to have a coil with extra band and then still use the spring steel bands feature of swinging around the tree, but only from one side. The loose end was covered with Velcro in addition the side of the unit, such it could hook on.

As a way of getting fresh idea, we challenged a group from the second semester master students to a quick ideation after presenting the problem. (Ill. 04.35) This freshened up the pot with an idea of having one big stiff ring that would tilt on the tree, since the weight is uneven distributed. As the tree grows it will level the ring. The problem here is to get it onto the tree.
A mock-up was build to test the principle of the steel spring band and if it could lock onto the Velcro. It worked, but it was hard to start as it required a sideways knock on the tree.

The band were then moved such it faced perpendicular to the tree. It was an improvement, but the band were a little light to start on its

Ill. 04.35: The mounting mechanism challenge

Ill. 04.36: First mock-up on a tree.

Ill. 04.37: Later mock-up with perpendicular band.

own momentum, therefore a weight was added to the tip, which lowered the speed that the unit needed to hit the tree to spring the band.

The band were made to exit the casing and go around the device to make the mounting stick able to hold the band in place, since the band must be able to be pulled back when mounted, but not during mounting.

The mounting stick

The mounting stick holds the sensor unit inside its curve with magnets, an upper and a lower. The upper pulls the spring steel band onto it as well as a metal plate on the inside of the casing, this magnet is enclosed behind a shaped silicon rubber pad to increase friction to restrict the band from retracting. The band is locally held in its stretched position by the holder's shape.

Ill. 04.40: Mounting stick with magnets.

Ill. 04.39: Test on Eucalyptus tree in Væksthuset, Århus.

Ill. 04.38: Early mock-up of setup mechanism.

Ill. 04.41: Test of the mounting stick

The sensors

Several tests were done on the projects to verify consumptions and to get a better understanding of the smoke as well as technologies.

Smoke test 1

As described in Ill. 04.47 on page 50, it was not a possibility to calculate smokes behavior from a theoretical standpoint because of variables in the formulas that Navier stokes did not count for. (See "What is smoke?" on page 10)
Therefore is was decided early in the process, after the arrival back from Portugal, to conduct a smoke experiment. This was done with a smoke machine and gave an understanding of how smoke behaves.
But, the day of the experiment had temperatures near zero ˚C and the wind was very calm, which is usually not the case when a wildfire ignites as "What is wildfire?" on page 11) describes.
The weathers impact on the steam from the smoke-machine resulted in a fast chill down, keeping it near the ground and the data was therefore determined invalid. (Appendix 13)

Smoke alarm

It was then investigated what was inside indoor fire alarms, the most common types are Ionization, photoelectric and hybrids. The photoelectric are best for smoldering fires while the ionization type is best to detect flames. (WCCO - CBS Minnesota. 2014) Both of these where found unsuited for use in the forest since they can be falsely triggered by water vapor and dust. There was therefore investigated other ways of detecting fire.

2. Smoke test

Since wood and other organic materials break down into gases during combustion (as described in "What is fire?" on page 10, it was investigated whether Violate Organic Compounds (VOC's), CO_2 or CO would be the best gases to determine a fire. This was done by a test, both with a professional CO sensor from Dräger and a home-made Arduino setup, consisting of a MQ-135 VOC-sensor and a MQ-7 CO-sensor. The weather was this time around 22 ˚C but still calm wind.
The test was done in two rounds:
A round with smoke from smoldering biofuel (leafs and small sticks) and another by a trafficated road to measure the influence of cars. (Ill. 04.43
The test showed that CO would not fit the product, but indicated that Smoke combined with CO_2 might be the sensors to go for.

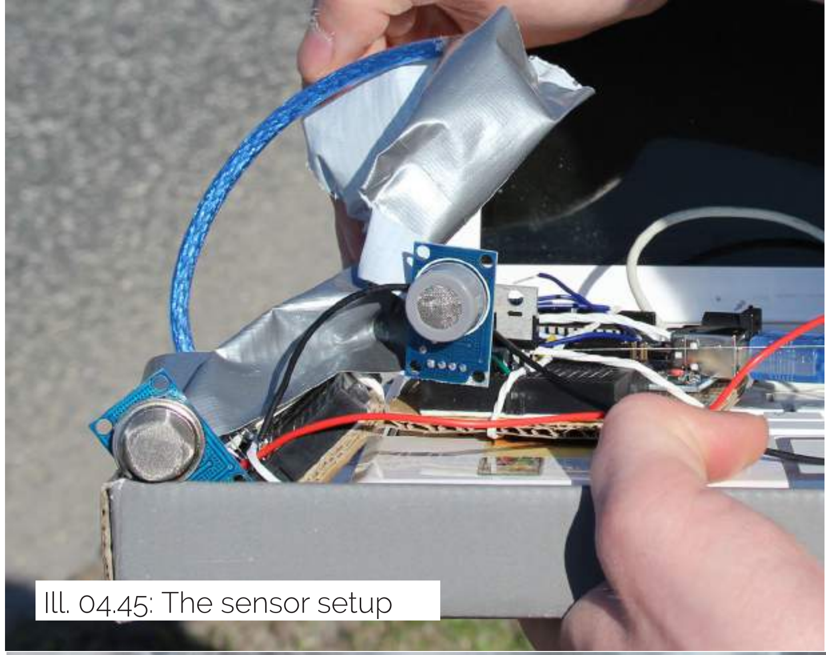
As it was unclear whether the sensor was triggered by smoke or CO_2 in the second smoke test more research was done. According to re-

Ill. 04.42: The test setup

Ill. 04.43: Sensor form Dräger at road-test.

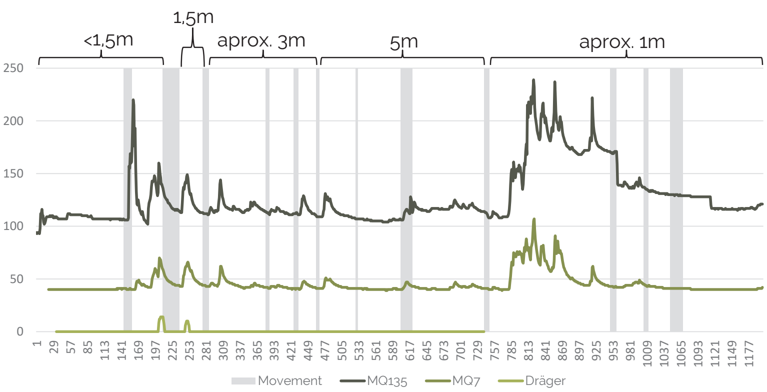
search done by Yan et al. it is best to use multiple sensors as they tested a smoke sensor in conjunction with respectively a CO_2- and a temperature sensor. Their test showed that the smoke sensor alone had a 75% detection rate for smoldering fires, while adding a CO_2 sensor increased the rate to 95%. Combining the smoke sensor with a temperature sensor had only a 82,5% detection rate. By having all three sensors together resulted in a 97,5% detection rate. (Yan et al. 2016.)

Their test (Ill. 04.47) also showed that when the fire starts to smolder at the time, 7.25, it gives high peaks for smoke, CO_2 CO and a decrease in humidity, where after they all dip for a bit before rising steadily. The smoke rises significant faster than the others. As the fire evolves it decreases the production of smoke as the combustion becomes more complete, instead it produces a lot more CO_2. The temperature is rising throughout the test until the fire dies out. Based on this and the second smoke test, it was chosen to use both a smoke sensor as well as a CO_2 sensor. The temperature sensor was discarded because of the added power consumption with little gain in detection rate.

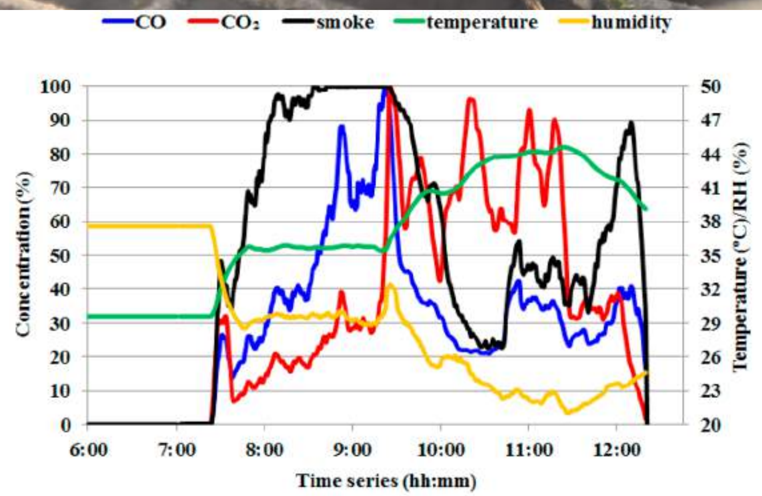


Ill. 04.45: The sensor setup

Ill. 04.46: The fuel (glowing coal with dry sticks an pine cones)



Ill. 04.44: Smoke Measurings indicating when



Ill. 04.47: Measurements during a controlled fire.

Summary

From a wide ideation process with sketching on the different problems it was possible to narrow down to 3 directions based on the vision, damage and air detecting principle.
Based on external feedback, internal framing and work with requirements, the air principle was developed further as four different concepts found their way to the final concept. Now test of components began and finally the setup mechanism was developed.

Ill. 04.48: Early smoke-test with a smoke machine. (Smoke = steam)

05
THE PRODUCT

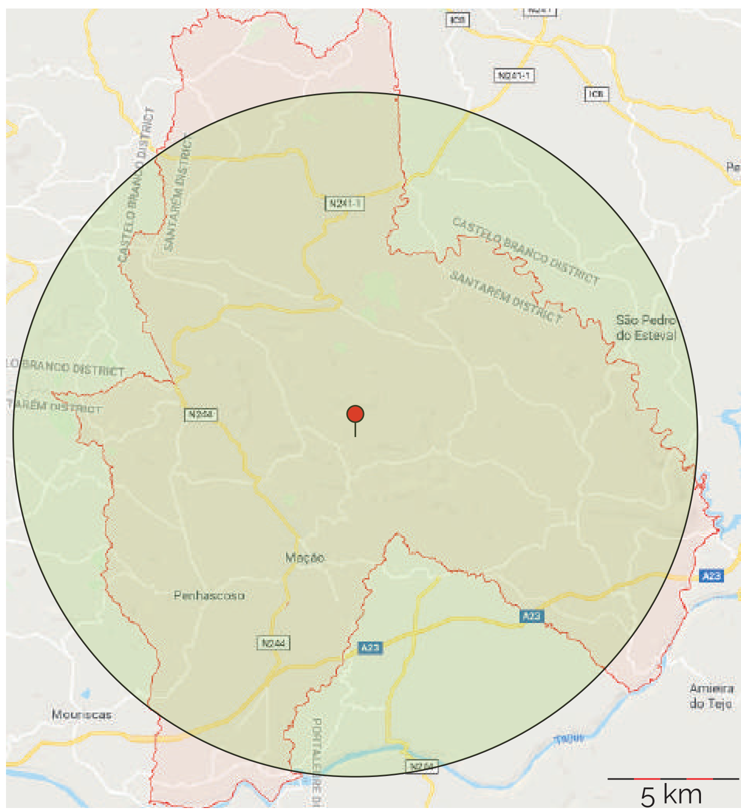
In this phase, the product will be developed and presented in details. It also houses the choice of materials and what effect this has in the environment.

Ill. 05.01: Steffen painting moch-up's in Vergão

Key functions

Dual sensors
The sensor unit is fitted with two sensors for added reliability (Ill. 05.05), a smoke sensor that detects particles in the air and a CO_2 that measures the amount of CO_2. The smoke sensor has a low power consumption and is used as the primary sensor. A downside of the smoke sensor is that it can be triggered by other particles such as dust and water vapor. If the smoke sensor is triggered, the secondary sensor, the CO_2 sensor, will start up and do the measurements. Since the sensor needs to warm up to conduct reliable measurements, there is a slight delay of 10 seconds. Then the CO_2 sensor will measure the amount of CO_2 and compare it to a calibrated baseline for that specific area, which is done upon activation of the unit and a few times per week. The sensor unit will only make an alarm if both sensors are triggered. The alarm is send through the Sigfox module to the SaF servers, which notify the nearest command central as well as launch the drone.

The drone
The drone provides an extra level of reliability, since it is possible for an operator to investigate the situation that have triggered the sensors. It also provides the camera feed to the fire fighter commander, who otherwise had to drive to the site. Now he can get the information he needs before he is on the spot. Since the drones are distributed across the covered areas it is most often much closer than the nearest fire department, and since it is flying it does not have to follow the gnarly twisting roads, which otherwise sets the speed limit. The proposed drone, the DJI Matrice 200 is a powerful mid-sized drone, it features a gimbal stabilized camera with 30x zoom to allow the operator to focus on what he wants (DJI, 2018.). It has a flight time of up to 38 minutes and a top speed of 82,8 km/h (DJI, 2018.), Which gives it a range of 13 km while having 18 minutes on site, This is enough to cover most of Mação municipality Ill. 05.02., but there should be more drones to cover for each others downtime, due to charging or being able to react to multiple alarms at the same time. DJI drones features some degree of autonomous flight and obstacle avoidance, but it needs to be a bit better to be able to fly between the rows of trees and to automatically set course for the triggered sensor unit. In addition it must also be able to connect itself to charging (wireless or touch points.



Ill. 05.02: Range of the drone.

Long lasting

The sensor unit is designed to use as little power as possible while carrying an efficient non-rechargeable lithium primary battery. Which can power the device for over 10 years (see calculations in (Appendix 14) since it uses as little as 8,73 mAh per day of normal operation . The unit saves power by measuring every 30 seconds, instead of continuously. The device is only active during the fire season, since there are many controlled burnings while out of season, these fires would trigger the sensors and drain their batteries quickly. Therefore, it is in sleep mode during the off-season.

Proximity lights

When it detects a fire and it has send the alarm, it automatically flashes with a series of built-in LED's to allow the firefighter or owner to find the unit, in case that they cannot find the fire. The device is roughly located by the GPS coordinates, which is registered during the setup process. This coordinate is, depending on the used device, accurate to with 10 m. This means that there are a total of 11 trees where the unit could be, but the flashing LED's should make it easy.

Montage

To makes the setup process easy the sensor is delivered with a mounting stick, that allow the user to place the device in the wanted height of 2,5m without the risk and hassle of using a ladder or similar. (Ill. 05.03) The mounting stick feature a telescopic pole, such it can be retracted and fit in a car. It secures the sensor unit with magnets, which also locks the steel spring band in its deployable configuration by attracting the band up against a shaped silicone pad (Ill. 05.04), which stops the band from retracting and flexes the band into its straight position.
The only action required to mount the unit is

Ill. 05.04: The mount to hold the sensor unit during the setup process.

Ill. 05.03: The mounting stick in extended position

now just to smack it onto the tree. This will activate the steel spring band which will wrap around the tree and lock onto a Velcro patch on the side of the device. The steel band is coiled up inside the device and will slowly unroll as the tree widens, and therefore neither hurt or limit the tree.

Self activating

The unit features a tilt switch, which is connected to the battery. This makes the unit cut the power when its not upright, this will happen during storage, to activate the unit is as simple as turning it upright, it will then respond with sustained light from the LED's for 10 seconds.

Self-diagnosing

The units will send a status message to the SaF server once a day, during the fire season, the message contains battery status the units ID number. This is used to detect failed units, since an area with failed units can result in catastrophic damages.

If the unit should happen to fall of the tree or that the tree falls, e.g. during a storm, the tilt switch cuts the power, which makes the unit unable to send the status message. When the system lacks a message from a unit its position will be marked on the interface map. (see Ill. 5.11)

The users interface

The user can check the operation of the units via the SaF website (Ill. 5.11) or in the SaF app. The owner can watch detailed information about every sensor units which he is registered as the owner to. This information includes battery level, notifications if any unit is running low on battery and if any unit haven't reported to the SaF server for the last 24 hours. The owner can then go out and check up on the device and remount or replace the problematic unit.

The interface is based on Google maps, which offer a good map as well as search functions and directions. In addition to these features it is possible to sort in the visible units for self-registered groups e.g. for each plot. The units are marked on the map with a colored dot, representing their status. When the dot is green, the unit is in good condition with more than 10% battery left (approx. 1 year), when it changes to orange there is something wrong, this happens when the units fall under 5% power or when it have failed to reported to the server. This is most likely due to the units tilt switch which is shutting the device off (see "Self-diagnosing"). The change to yellow and orange will also be reported in the 'notification' tab, where the owner can get an easy overview of the problematic units. If the unit is represented with a red dot, it has detected signs of fire from both the sensors. This will pop up and show the status and location of the nearest dispatched drone. When the drone gets to the location it turns on the video feed, which the owner have access to, the owner cannot control the drone.

The fire departments and the national control station also have access to the system, but their interface is different (Ill. 5.12). They do not have access to see the unit or their battery status, but a marking of what plantations are covered by the units. They do also have an overview of all the drones with their battery status and approximate range. The departments will only receive the fire pop-ups and see the unit(s) which have triggered it. The fire departments have, in addition to the camera feed from the drone, also the possibility to control it by designating a course and directly control the camera allowing them to see and zoom on anything. This gives the fire fighter commander the opportunity to plan the attack before he gets to the site.

Components

Sensors
The main sensor is a photoelectric smoke sensor. This type is chosen for its good detection of smoldering fires, its simplicity, low power consumption and widespread use, which makes them cheap. It uses only 15mA when operating and has no warm up time. It works shining an infrared LED inside a dark chamber, the chamber has a special construction that allows the smoke to pass while blocking all light, both internal and external, the lack of light is registered by a photo-resistor. The two components are placed such the LED cannot shine directly onto the photo-resistor. When smoke enters the chamber, it is hit by the light and the light then scatter, which allow it to hit the photo-resistor. (Today I Found Out, 2015.)

The second sensor is a Cozir A CO2 sensor from Gas Sensing Solutions. This is chosen since it uses very low power and has a short warm-up time, this is important since the sensor has to be on longer, the longer the warm-up time is. (Appendix 09) The sensor is used as the secondary sensor, since it is the most power consuming of the two. Which means than it only run after the first (smoke) sensor has been triggered.

Communication
When the sensor units senses the presence of smoke it needs to send the alarm wireless, this is done through a new radiofreqency platform called Narrowband, this is a small section of the radiofrequency spectrum that is free to all by law. There are some suppliers on this band to manage the network and sell modules. During the development there were investigated in the two major providers: Sigfox and LoRa. They both manages the network, but in different ways. Sigfox builds the transmission towers and handle the servers, where as LoRa allow you to build the transmission towers yourself. Sigfox requires a subscription of approx. 1$/year, but this is highly dependable on the number of messages and the size of them.
It is chosen to use the AX-FEU module as it is the least power consuming and the cheapest (1,65$) (Appendix 16). Sigfox is expecting its suppliers to deliver modules that include a battery for only 0,2$ in a year (Sayer, 2017.).

Microcontroller
The microcontroller (MCU) is the brain of the device, it controls the power to all the compnents and gathers the data from the sensors. This data is compared to a baseline which is

Ill. 05.05: Cozir A CO 2 sensor and photoelectric smoke detector.

Ill. 05.06: AX-SFEU sigfox module

calibrated upon start up of the device and a few times each week. The chosen MCU is a RL78/G12 (Appendix 17) which is a cheap low power MCU, which is often used in IOT devices. It is an 8 bit processor, which determine how much it can handle at a time (8 is the lowest possible) with 8kb of internal memory and 20 Input/Output pins. The code will approximately take up half of the storage and the rest is saved as future proofing in case they have to be updated later on, this will require the unit to be shipped back and partly disassembled. The entire system will only use 11 pins on the 20 available pins on the MCU and the rest will be left unconnected (Appendix 18).

LED's

The device features 5 high brightness LED's that can shine through the casing, which is thinner on that spot. They are flashing for an hour after the units first alarm trigger, such the firefighters and owner can find it in case the fire has gone out or it is a false alarm.

Battery

To power the sensor unit for 10+ years, A big battery was needed, There where mostly looked at standard batteries, since this will result in a lower price. The standard battery used in fire alarms are 9V and only holds around 500 mAh, which is way too little. A type commonly used in power banks and electric cars are the 26650 Lithium ion battery, which is a D cell. It was found that this type could hold up to 5000mAh and where researchable as an added bonus. During the calculation of the power consumption (Appendix 14) it was found that there should be 4 of these batteries to power it for 10 years, due to internal degradation of the battery. The last class was the Lithium primary. This class outperforms any of the other types in energy density and where found to hold 19000mAh while still being the size of a D cell battery (Ø34x61,5mm (Appendix 20). This type degrades by less than 1% annually and increases its performance during high temperatures, where many other types often struggle. (Appendix 20)

Ill. 05.07: Flat top LED

Ill. 05.08: ER34615 Battery

Materials

The product is made from a variety of materials. This section will look at the custom made items of the product. These are the outer shells, the inner horizontal dividers, and the pulling handle from the sensor unit as well as the mount of the mounting stick.

All of the outer shells and the horizontal dividers are made from recycled PVC (PolyVinyl Chloride). PVC is one of the most commonly used plastics and it can be injection molded, which these parts will be. (Zerma, 2018.) it is commonly used in pipes, gutters and plastic roofing for outhouses.
Recycled PVC produces 95% less CO2 than virgin PVC without losing quality.
During the recycling process the raw waste PVC is sorted into quality classes before it is ground into granulate, which is then sorted by color. and can be made into any color. Hereafter it can be melted and used just like fresh pellets. (Clarke, A, 2009.),(Hanlon, C., 2014.)
Since the product is placed outdoors and for many years it is important that the plastic has additives to increase its UV resistance, without it, the PVC would discolor, lose strength and create micro cracks
Since the Portuguese summers can be quite hot (record of 47,4 degrees) (IPMA, 2017.) it is important that the plastic wont get soft or melt, PVC has a heat deflection temperature of 92 degrees (IPMA, 2017.), this makes PVC able to withstand even the hottest places in the world which is 56,7 degrees(Guinness world records, 2018.).
Recycled PVC is three times cheaper than virgin PVC and the current price is 0,5529 euro/kg (Guinness world records, 2018.)
PVC is available in both opaque, translucent and transparent versions and for the product there is used heavily pigmented clear or almost clear granulate such the product appear opaque against the darkness inside it, but still lets the LED's shine through and illuminate the casing.

The grip located on the spring steel band is both there to avoid the end of the band getting pulled into the closed casing, to give the user something to get a grip on and it is a weight to start the spring bands twisting. It is therefore important that it is a heavy material, for this it was investigated whether it should be steel or iron. Due to its complex shape it was chosen to use iron, since steel is harder to cast(Plasticnews, 2018.). Cast iron (grey) has a density of 7.15 g/cm3 which makes the grip weigh approx. 15g.
Grey cast iron was chosen since it is the most widely used type of cast iron and the cheapest, (Reliance foundry, 2017.) but there needs to be mixed some nickel in it to increase its corrosion resistance. By doing this, it is not needed to paint or otherwise protect the piece.
Since the iron is not used for its strength, it is possible to use to lowest quality iron which is HT100 (Reliance foundry, 2017.).

Ill. 05.09: One appearance of translucent PVC.

Ill. 05.10: The appearance of grey casted iron.

User scenario - Setup

1. The sensor unit is being picked up. When the sensor unit is raised, the LED lights up indicating the product is now on.

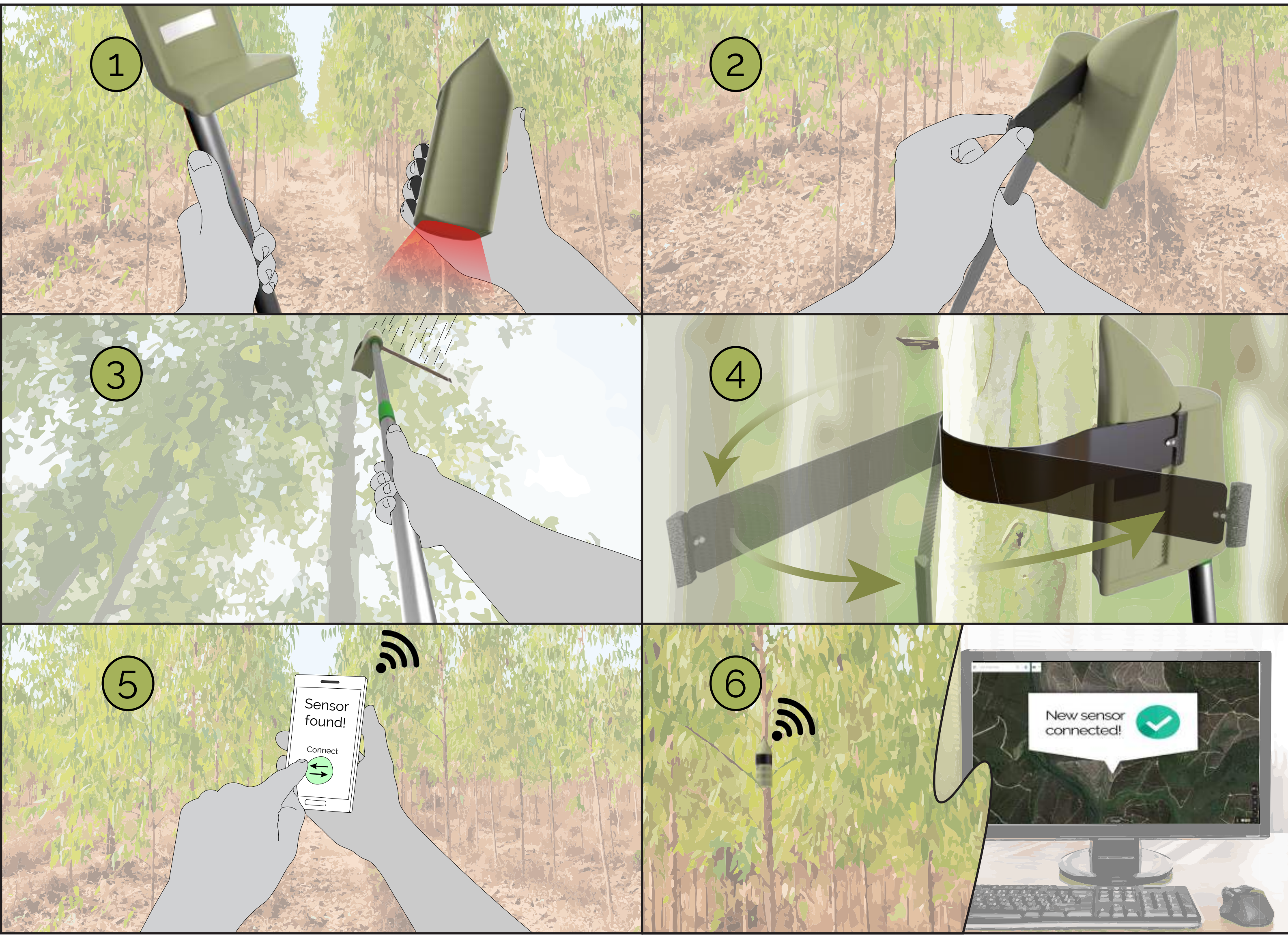
2. The sensor unit is placed on the mounting stick and magnets hold it tight while the strap is pulled out.

3. The sensor unit is now knocked onto the stem of the tree.

4. When the sensor unit hits the stem, the spring steel, will continue the motion, bend, fold around the stem and lock.

5. When placed, the app is used to connect the unit with GPS coordinates from the phones internal GPS.

6. The sensor sends its first message, which is registered at the web interface. WiLD is now ready to use.



Ill. 05.11: Setup scenario

User scenario - Alarm

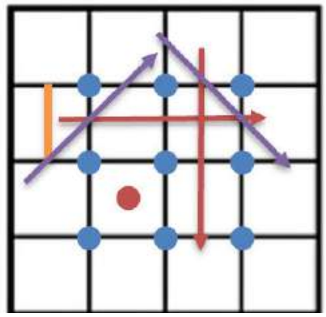
1. The fire is detected by the sensor unit and it sends an alarm to the SaF servers
2. The SaF server then relays the alarm to the drone, the owner and the national control center.
3. The drone autonomously flies to the location of the alarmed unit.
4. The operator can then control the drone and zoom the camera to take a closer inspection, such he can make the right decision on how to fight the fire.

Ill. 05.12: Alarm scenario

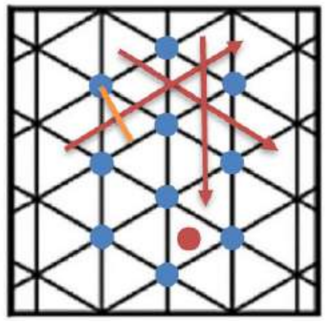
Setup pattern

Since there is needed very many units across a huge area it is important that the space in between is used optimal. It was tested how effective it was possible to fill out at hectare. It was investigated using regular patterns, which is patterns consisting of uniform shapes of the same size. The most basic patterns that were discovered is a square, triangle and hexagon. Each have their pros and cons.
The square grid (Ill. 05.13) has the least amount of major gabs, but have two additional minor corridors, where the smoke could pass through without triggering the sensors, but it also has the worst coverage per unit.
The triangular pattern (Ill. 05.14) had one more major corridor, but none minor, it produced small gaps than the square, and what therefore scaled up to compare them on the same terms.
The hexagon pattern (Ill. 05.15) have the most and the biggest gaps, but have the best coverage per unit .

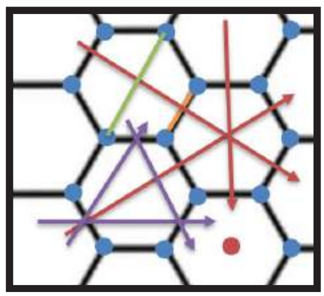
The triangular pattern was chosen since it has the bests compromise between the number of gaps, size of the gaps and unit coverage (see Ill. 05.16) (Appendix 23). The distance between the units where later changed to only 15 m instead of 25.



Ill. 05.13: Square grid pattern.



Ill. 05.14: Triangular grid pattern.

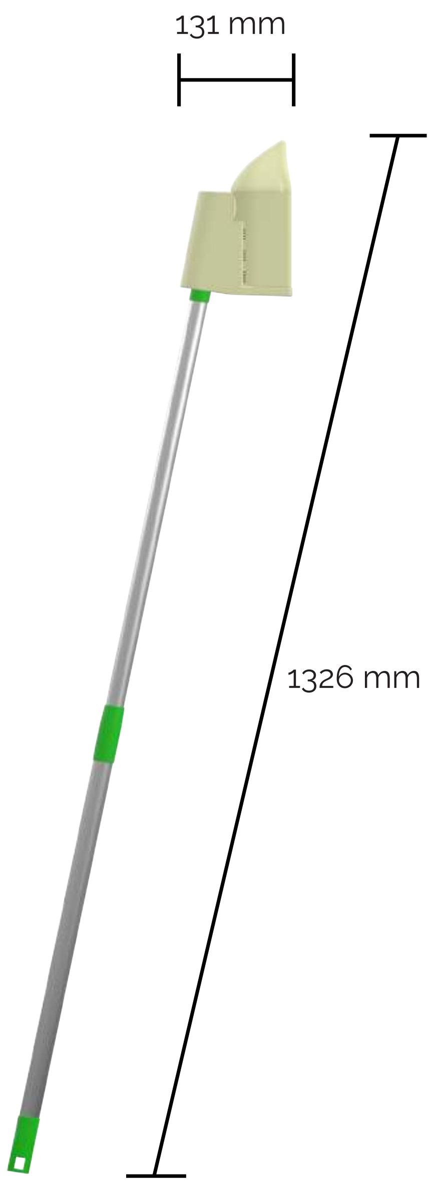


Ill. 05.15: Hexagon grid pattern.

Shape	No. major gaps	Gap size (major) [sensor distance]	No. minor gaps	Gap size (minor) [sensor distance]	Coverage (m/ unit) (25m between units)
Square grid	2	1x	2	0,707x	312,5
Triangular	3	0,866x			360,33
Hexagon	3	1-2x	3	0,866x	541,25
Adapted triangle	3	1x			481,16

Ill. 05.16: Pattern shape comparison chart.

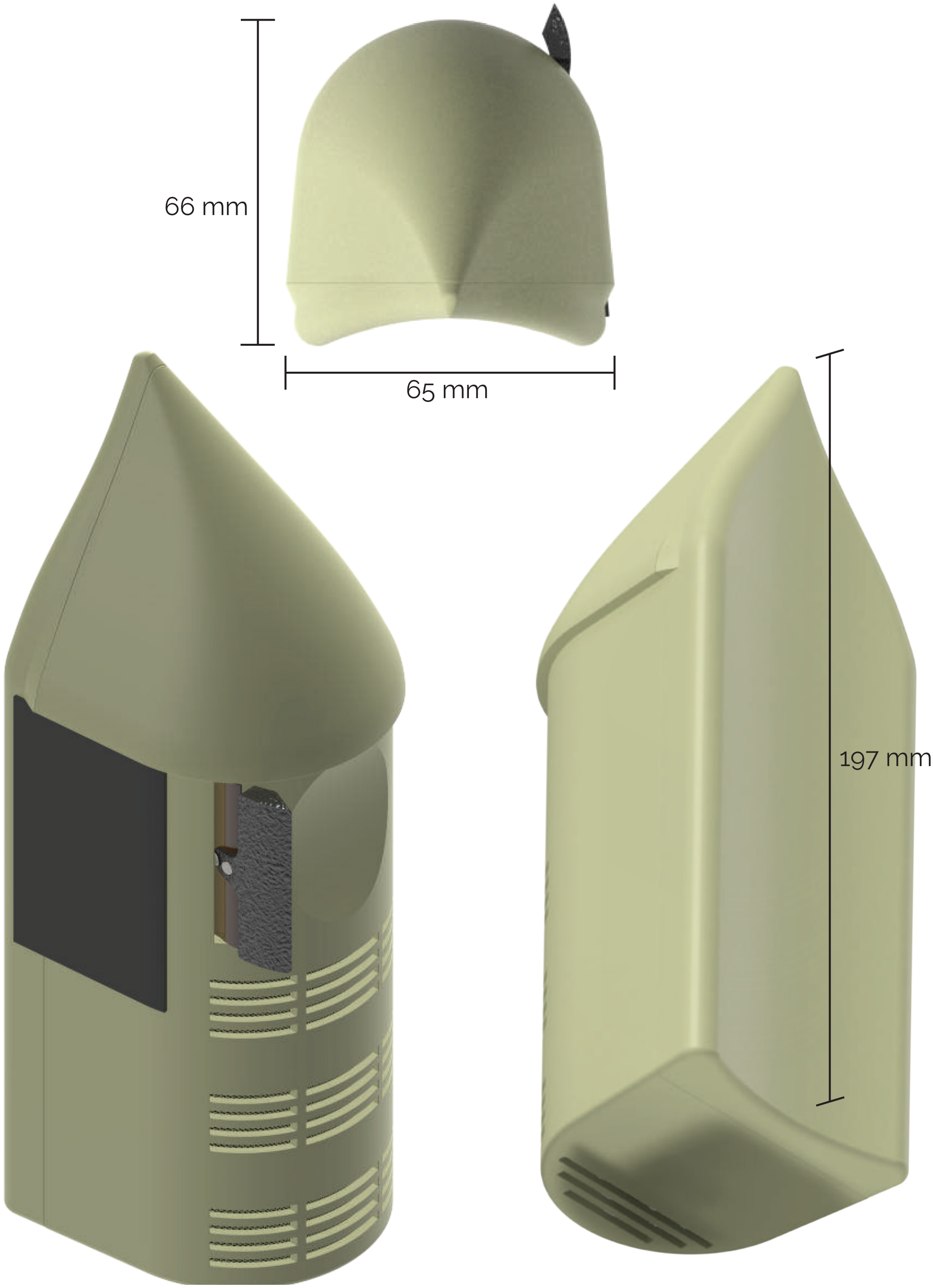
The size



Ill. 05.17: Main dimensions of the mounting stick.

The unit is a slim and long unit with a curved front toward the tree, this ensures a good contact to the tree even though it grows. The spring steel band is coiled up but has a total length if 90 cm, which is enough both to get around a 10 year old tree, but also to expand a bit further in case that the tree is left for a a bit longer.

The mounting stick features a telescopic pole that can extend from 70 – 120 cm. This is enough extension for person of most heights to mount the unit in 2,5m without hassle. The extension pole is short such it is hard to mount the unit too high in addition to being easier to transport in vehicles.

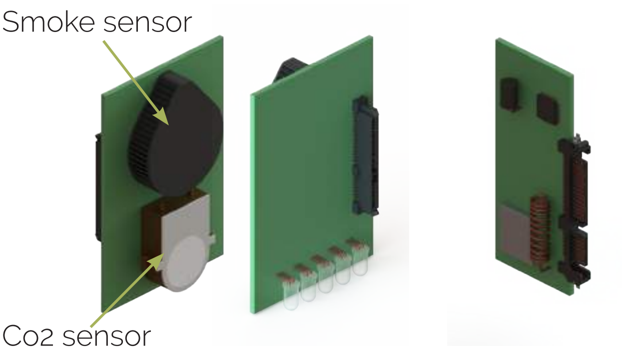


Ill. 05.18: Main dimensions of the sensor unit.

Production

To start the business out small the SaF will be starting as an assembly factory. This means that most of the parts will be produced and partly assembled by sub-contractors, this is the example with the two circuit boards. The first board (sensor board) is fitted with the smoke sensor and the Cozir A Co2 sensor which are soldered through the board, in addition to the sensors, it also receives a row of five LED's in the lower part, a female SATA connector and all the minor components that the sensors need (resistors capacitors etc.) to the opposite side of the board, after these are soldered.
Lastly the board is spray coated on the sensors side to block out moisture from corroding the connections (Humiseal., 2018.).

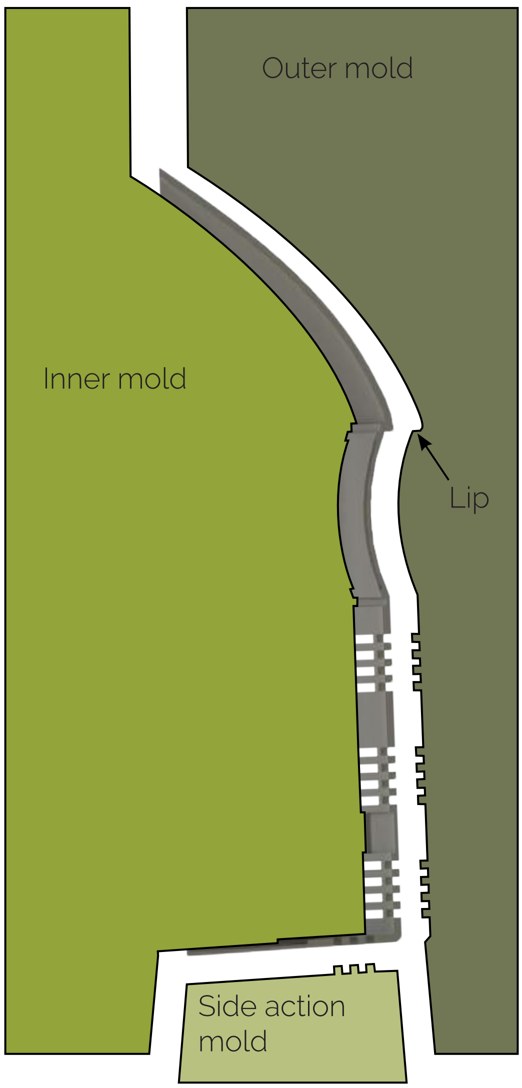
The second board (main board) is housing the microcontroller (MCU), Sigfox module, antenna, tilt switch and male connector. These are all soldered to the same side of the board in addition to minor components. The boards are now ready to be packed and shipped to the SaF factory.



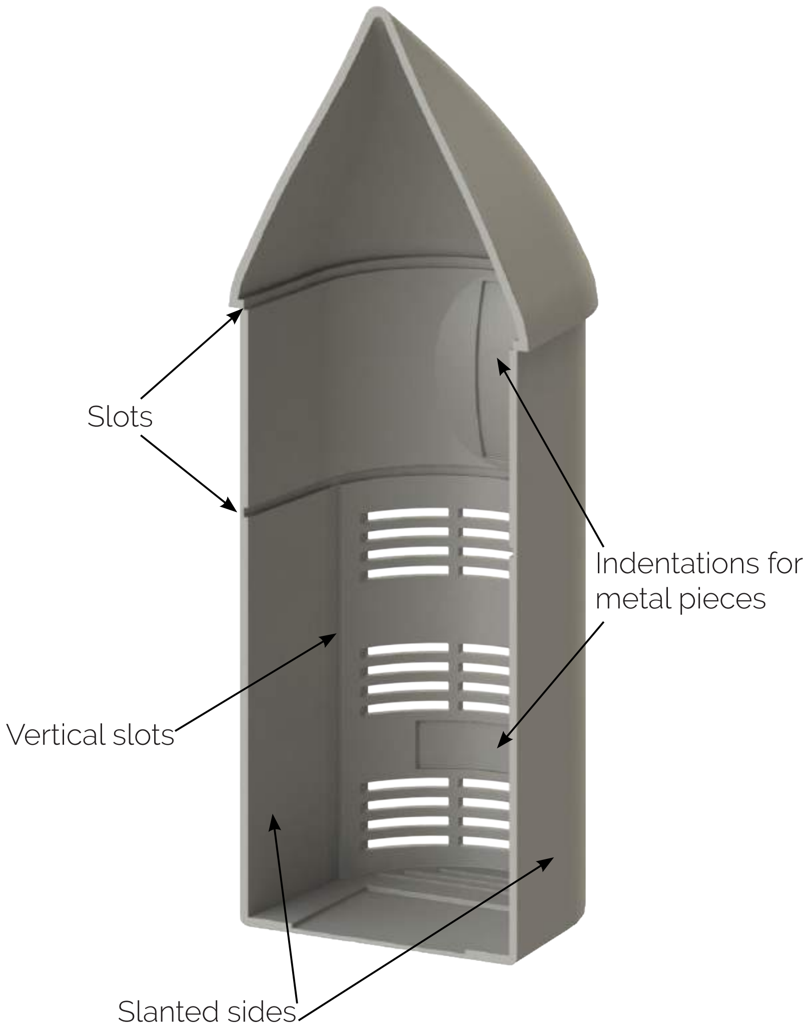
Ill. 05.19: Front and backside of the sensor board and front of the main board (backside is empty)

The outer PVC shell of the sensor unit is divided into two parts for manufacturing, but there are two version of the "frontside" part. All the injection-molded parts will come from the same supplier.

The first part, "the backside", is the biggest part of the entire unit. It shields all the components from the weather. This part is injection-molded with slight draft angles to avoid it getting stuck in the mold (see. Ill. 05.20). These draft angles include the bottom edge which is slanted two degrees outward (see Ill. 05.20) and the sides are slanted by five degrees (see Ill. 05.21). This part has a few slots on the inside that goes all the way around, these are located just above and below the cutout which will be used for the steel band (Ill. 05.21). The entire model is slanted inside the mold by two degrees to allow for easy draft of the bigger lip extending from the top third of the shell (Ill. 05.20), this reduces the drag upon the part during extraction from the form. The air intake holes in the back of the shell and hole for the steel band are made as a fixed part of the mold while the bottom air intake hole need side-action mold. To ease the later assembly there are indentations in the inside part of the back end. These are for metal plates, which are used for holding the unit to the mounting stick. There are long vertical indentations too, which are used to fix the sensor board at a later stage.



Ill. 05.20: Section cut of the 3 Part mold for "the backside"



Ill. 05.21: The "backside" model

Both versions of the “frontside” are also injection molded and has many of the same features in the mold such as the slots. This mold is both smaller and much simpler than the “backside” mold. This one can consist of an inner and outer mold part.

The horizontal plates are also injection molded and feature an indentation on the one side and a T shaped cutout on the other, these are all made within the mold and does only dent half-way through the plate. There are produced two of these plates for each sensor unit.

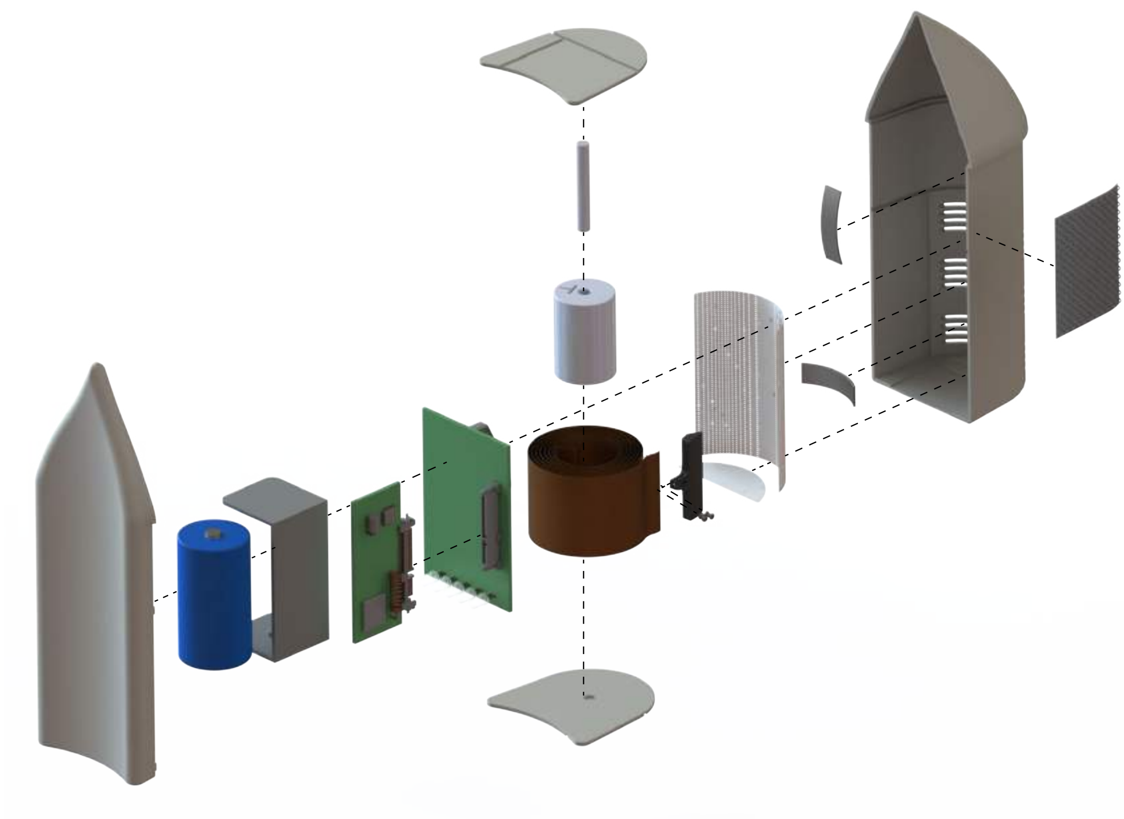
The last part that is injection-molded is the mount for the mounting stick. It is molded using a top and bottom part mold, the bottom part has a side-action with thread, which unscrews when the casting is complete.
The spruces, risers and other production necessities are removed, the molds are a packed and shipped of the SaF factory.
The grip which is made from grey cast iron is molded in a small permanent mold, this provides a higher surface finish right out of the mold, but comes at higher initial cost, since the mold has to be machined. This is better for higher quantities and there can easily be multiple cavities inside the mold, which allow for a quick production.
(Meteor foundry co. 2012.)
The core which holds the steel spring band is machined from a round stock of PVC. It needs a T shaped slot to mechanically hold the steel spring band, the lower part of the T is cut using a cutting blade, while the horizontal part of the T is cut using a T-slot milling cutter. Lastly a hole is drilled through the piece to make way for an axle.

Ill. 05.22: (left) The two versions of the frontside
Ill. 05.23: Top and bottom of the horizontal plate

Assembly
The assembly start by placing the “backside” in a fixture, such it is resting on its front side. First the metal plates are secured with a drop of glue to their respective insert slots. The metal mesh is fastenened in a similar way. The spring band assembly is made by attaching Velcro to the band before putting the axle through the coil core, sliding the steel spring band in place and loosely attaching the two horizontal divider plates (Ill. 05.23). Feed the steel band through the slot and apply a seal of silicon glue to the lower indentation ring before the sub-assembly is slit into place in the “backside” casing, in the indented rings. The silicon glue acts as seal to keep moisture and micro-organisms out of the electronic components. The grip is attached by inserting two pins, such the band cannot retract.

Ill. 05.24: T-slot cutter for milling

Grab the sensor board and apply silicon glue to the sides and bottom before sliding it onto its vertical slots. Set the fixture aside for drying for a few minutes.
When the glue is dry, fasten the battery holder and slide in the main board into the SATA connector on the sensor board. Attach the two wires from the battery holder to the main board and insert the battery. The unit's connectivity and sensitivity is now tested by putting the unit upright inside a small smoky chamber, if the unit sends an alarm, it passes the test and are now ready to receive its frontside. The frontside is, in the development phase, glued in place and held by small tabs while drying. In the production phase it is ultrasonic welded. As a finishing touch a patch of Velcro is attacked to the side of the assembled product.
The unit is now finish and ready for packing.
The mounting stick is assembled by gluing magnets in their indentations and the silicon patch over the top one. It is then threaded on its stick and tested if the stick can lock in extended and retracted position as well as if the magnets can hold the sensor unit perpendicular to the ground. This is now packed on its own.
The sensor units are packed in batches of 1, 20 and 80 pieces, the units are placed flat on their front to avoid unnecessary battery waste during storage and transport.



Ill. 05.25: Exploded view of the sensor unit

Durability

Since the sensor units are outdoor products they need to withstand a lot of things.

The first is the weather itself, Portugal sees both very rainy and very dry and hot seasons as mentioned in 'The context' on p. 21. To withstand the rain, most of the electronic components are sealed behind the sensor board with a silicon glue as mentioned on the previous page. It is likewise sealed from the top using the same procedure on the horizontal plate. The front-side panel is ultrasonic welded shut to make it air tight all the way around, but also to discourage the disassembly of the product. This results in a rating of IP 65, which is "protection from dust that may harm the equipment" and water sprays from all directions (The enclosure company 2018.).
The area of the sensor cannot be sealed air tight since it needs air circulation to analyze the air. To protect this area, the board itself is sprayed with Humiseal, to avoid short circuits and corrosion to the board. The sensors themselves are not sprayed. All the air ports in the casing are covered by a fine metal mesh from the inside (Ill. 05.26). This acts mainly as an insect blocker, as the area could be attractive for small bugs as a hive. It secondly stops the rain from entering as it is very fine, if any water should enter, it will have no force and it will simply run down the mesh and slowly seep out of the bottom. There is a danger that the water might block the mesh due to surface tension, but it is expected that the water will evaporate as the landscape dries. As mentioned in the context section, it rains very little during the fire season.

The summers can get very hot in Portgual, up to 47,4 degrees, (IPMA, 2017.) but the casing is capable of handling it without compromising its strength and abilities. As described in 'Materials' the plastic is mixed with additives, which improve its UV resistance to be able to withstand 10 years of sun, this is most likely to happen to a few units in the outer edge of a fields, as the tree provide shade for the rest, most of the time.

Since the units are mounted in the forest and eucalyptus tree shed their bark annually it is important that the unit can handle the weight as the bark peel off in long strands (Ill. 05.27), and the band might hold on to a bit of it. The top of the device is heavily slanted, and the surface finish is smooth to encourage the bark and leaves to slide of it with ease. The top forms a point since if it was flat the ever changing tree diameter would create gaps, where the thin leaves and bark could get stuck. The steel spring band is extra strong to accommodate for the added weight in the bark and leaves.


Ill. 05.26: Metal mesh to keep bugs out.
Ill. 05.27: Bark peeling off the trees.

Environmental impact

It is impossible to estimate how much forest will be saved by using the system, but any decrease in the amount of burned land is an improvement as the burning of wood is the most 'dirty' emission source of particles and have the emit tons of CO_2 (see "What is smoke?" on page 10). The system will not only save the environment, but also a lot of money for the government, municipalities and fire departments as they currently spent 600 Euro/ha in fire management and 3500 Euro/ha in fire restoration. (Fernandes, 2014,).

When the units have spent a decade in the forest they are bought back by the company in exchange for discount on the new model. This will ensure that the product get reused as much as possible. The shell is cut open and the inner parts can be pulled out with some force, due to the silicon glue used in the production.
The PVC is recyclable as mentioned in the Materials section and the product is originally made from recycled PVC, which produces 95% less CO_2 than virgin material. It is also possible to reuse the casing if it is cut open with accuracy, but since the device is 10 years old at this point it will be reshaped into a newer version, which will have some changes. These changes could be improvement on the design or simply to symbolize that it is another version. (Hanlon, C., 2014.) The silicone, used for sealing the electronic compartments is reusable, if it can be pulled out. (Recycle now, 2010)

The electronics are more difficult to recycle but it can be done by recycling plants where the electronics are shredded to tiny pieces before they under go a complicated sorting process. The sorted materials will then be sold and be transformed into new products. (Recycle now, 2010).

The lithium primary battery is non-rechargeable and must be dealt with correctly. If it is thrown in landfills and crushed, while it still holds charge, it can burst into flames. (Battery university, 2009) To recycle it is cryogenic frozen to make it less reactive before it is crushed under a liquid solution to prevent emissions from escaping (Retriev, 2018). The metal can be reused, e.g. the lithium is used in military equipment, watches, hearing aids etc. (Battery university, 2009). The lithium enriched solution undergo a chemical process to generate Lithium Carbonate that is used in many industrial applications (Battery university, 2009).

Since the sensor unit is in the forest there is a risk that it will catch fire after it has alarmed the fire departments and national control center. The risk is with the current average rates of fire approx. 3,39% that a specific hectare will burn. (Appendix 21).
The burning of the sensor units are very bad for the environment and people, burning PVC releases a dangerous toxins including dioxin, which can land on crops and in water. When it enters the human body it can cause carcinogenic (cancer) and hormone disruptions. (WECF, 2018) The electronics consist of a lot different plastics and heavy metals. the heavy metals are lead, barium, mercury and lithium, these can seep into the ground water until it surfaces in streams or ponds. Here it can kill animal and plant life. If the water is consumed by animals or humans it can cause lead poisoning and cancer (E-TERRA technologies, 2017).

The final product

The system is a help for everybody in the fire prone areas and increases the safety in the regions. It eases the fire fighters job by allowing them to act faster against the blazing fire. Since the fire has a better chance of getting douches earlier it also decreases the damages. This means that the forest owners, the municipality, government, house-owners and insurance companies will save money.

The sensor unit is easy to deploy and clings on to the tree from age 2 and until harvest at age 10-12 using the self-winding steel band that does not hurt the tree. When the tree is cut it is easy to remove the unit again. It is placed up high were the smoke spreads out and where vandals cannot reach it. To resist vandalism, it is colored as the tree stem and placed out of sight. It is easy to mount using the mounting stick such the farmer does not need to balance on a ladder in the soft ground. The unit is resistant to anything that happens in the forest, be it rain, sun, animals and falling debris. The unit is easily assembled and shipped in packs.

The sensor unit is primarily mounted on the trees by using the spring steel band, but it can also be mounted on pole for areas where the security is wanted before the trees are sturdy enough to hold the unit. This is done by exchanging the frontside during production, this edition feature a loop on the top, where a nail or screw can be driven through and into the pole, here after the steel band is wrapped around for the added stability.

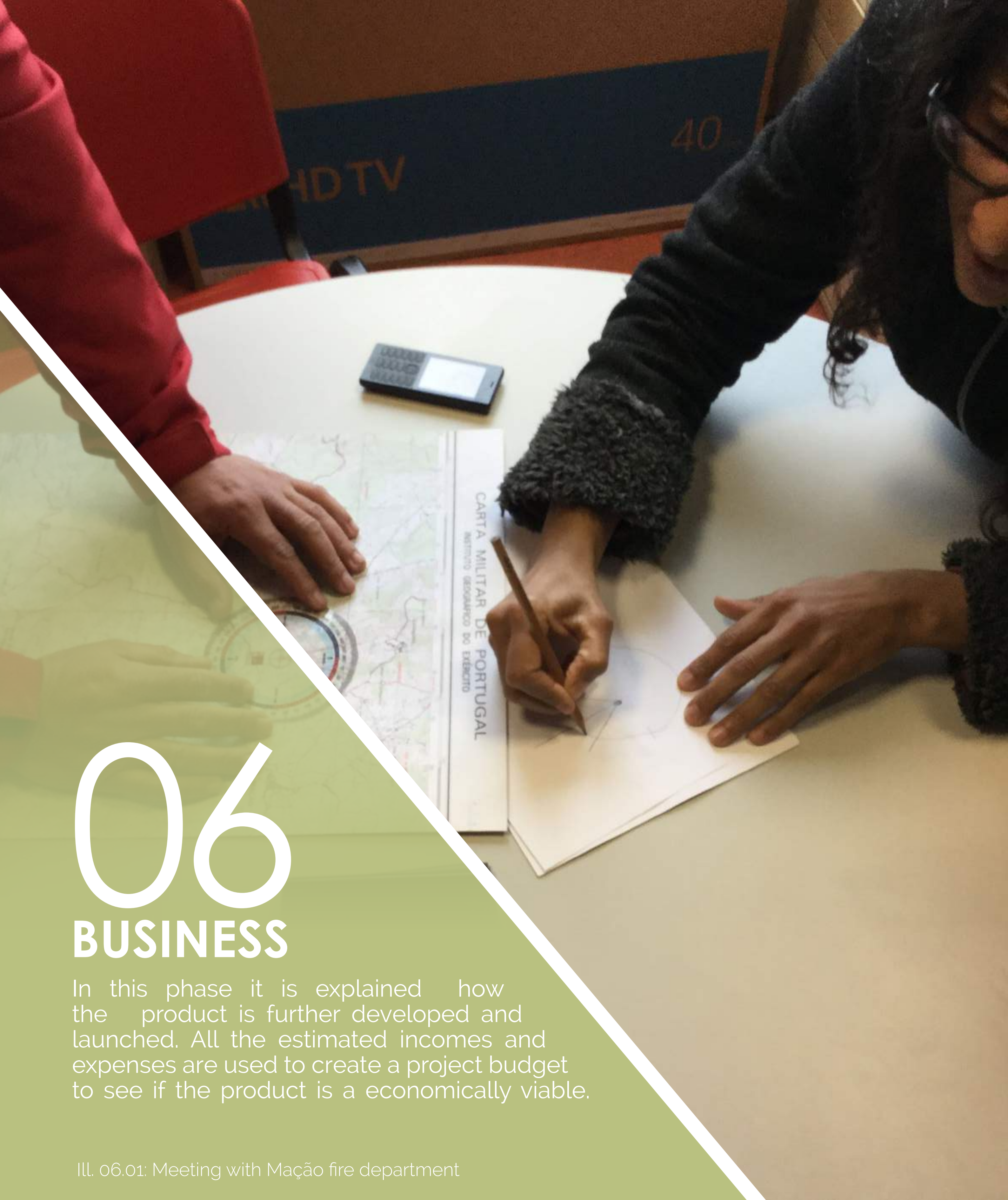
Ill. 05.28: Sensor unit with slightly unrolled band

Ill. 05.29: Version for pole-mounting

Summary

It has now been identified how the final system works, what specific components the sensor unit include and why they are chosen. Furthermore, it was decided which materials the custom made components should be made of. As well as how the items are manufactured and assembled and what effect these choices have on the environment.

Ill. 05.30: Early smoke-test with a smoke machine. (Smoke = steam)



06
BUSINESS

In this phase it is explained how the product is further developed and launched. All the estimated incomes and expenses are used to create a project budget to see if the product is a economically viable.

Ill. 06.01: Meeting with Mação fire department

Business cases

The product is part service part product.
The user pay one price up front, that cover the cost of the physical unit and mounting stick. Beside that, it is also covering the cost of getting the units on the SigFox net and for the drone coverage.

Based on the response from the stakeholders (Appendix 05 and Appendix 09), two customer segments have shown interest which led to the development of the following business cases.

Case 1 - The plantation owner
The main business case is building on the incentive principle, where the plantation owner will get incentives on the investment of fire prevention.
The plantation owner will thereby cash out the payment to SaF and after receiving the invoice be able to get a re-bait from the municipality.
This scenario is a positive situation for both the plantation owner and the municipality, because the plantation owner will get his primary way of income protection with a great discount and the municipality will get protection of its citizens and nature.
How much incentive the municipality are willing to give is up to them, but at an interview with Antonio (Appendix 09) where the suggestion with a re-bait of 75% of the target price where brought up, did not seem to scare him.
And when the same suggestion were presented for the plantation owner (Appendix 05), he was equally satisfied with a solution like that.
This would all not include installation of the sensor units, that the plantation owner would need to manage himself.

Case 2 - The Municipality
The other case is where the municipality is the buyer, and will give them to the plantation owners to put them up or put them up, them self.
Furthermore Antonio stated that the sensor units would suit National parks very well.

Ill. 06.02: The plantation owner

Ill. 06.03: The municipality

Business strategy

The following strategy is divided into 2 year development phase and a 3 year production phase.
Alongside the development in the first phase, SaF will attend in award shows e.g. Red Dot award, to draw some attention so when fairs are attended in the same period, it would be easier to raise the funds needed to get to the production phase.

The development
To make the product ready for production. A three step plan have been developed.

Step 1 (Final development) - Period: 2 months
In this stem, we are still in development of the product with the following tasks:

- Fine tuning the components.
- Design & development of code and interface.
- 3 prototypes.
- Intensive testing.

First the components will be evaluated by a expert in the field which will led to refinement of the BOM (Build Of Materials), and samples of the components will be gathered to make a experimental setup. If the components work at in theory, the optimization of placement and the connection in between the components.

While the above mentioned is happening, the coding is being engineered by a hired software engineer.
First of all he will develop the coding of the sensor unit. Second, the architecture of the data handling on the servers and third, in collaboration with a designer, develop the web interface and the app to the user.

When the two above mentioned tasks are done, the sensor will be made with 3D printed casing and proof-of-concept components. (Preferably the final components)
The purpose of these units is to get an understanding of the product and see the different functions and features work together.

Now actual intensive testing of the prototypes will happen with fine tuning the code of the MCU on how it reads the sensors regarding sensitivity and reliability. The construction will be tested regarding strength and ability to keep dirt and rain out of the internals and the mounting mechanism regarding the ability to support the product in different scenarios e.g. regarding weather.

Step 2 (pilot project) – Period: 1 year
In this step, we are in the final stage of development with following milestones:

- Drone development and testing by a third party.
- Large scale testing.

The development of the drone will be put out to tender, and a company will be selected for the job. The drone will then be developed by a third party and tested afterwards in relation to the prototypes from last step.

At the same time as the drone is being developed a large scale test of units covering one hectare is taking place. This will help gain an understanding for how the units cover a hectare, and how they together handle a plume. The test have to happen over a timespan of a year to experience the sensors under different stresses coursed by the different seasons (summer with heat and autumn and spring with moist and wet weather). The project will not continue to next phase before a year has passed.

Step 3 (0 series) - Time period: 8 months
In this step we do the final large-scale testing/ early role out of units for 10 hectares.

- Large-scale testing with multiple drones.
- Feedback from users.

The final large scale test is deployed at different areas to cover different scenarios.
The purpose of the test is primarily a reliability test to see how it react to the different scenarios but also to have working setups spread all over Portugal which will be used as showcase to potential customers .

The feedback from the partners that have the 0-series installed will primarily be used for version 2, unless the changes is easy to fix and the feedback is not to late in the period.

The production
In this phase the national roll out will happen over a 3 year period.
The product is now ready for commercial release. The deployment will happen exponential as the awareness of the solutions spread, and as sales begin in more regions.

The roll out will be graduate, starting with Mação, because it at the time of deployment will be tree years after the great fires in summer 2017. This means that the eucalyptus trees have the demanded hight. Furthermore the demand would be high because the 2017 fires is still in the plantation owners thoughts.
After Mação, the further area of roll out depends on where the demand is greater and if it possible to gain permit to fly the drone(s).

To make it feasible the product is only made possible to acquire if the costumer is in an area with high demand, because of the high drone cost. The reference drone from DJI, described in "Key functions" on page 53 is estimated to cover an area of 53093 ha. To make the system more redundant and failsafe, it is decided to use two drones, pr covered area, meaning that each drone in theory are covering 26546,5 (in practice they share the total area).
This means that the sales in an area of the above mentioned need to cover the cost of the drone.

To cover the investments from the development phase and the expenses of the drones and the subscriptions to SigFox, it is decided to sell 4 types of products, consisting of 2 zises kits baced on the research in "Mação, Central Portugal" on page 19. The kits combine the sensor units and the mounting stick and are as following:

- A "One hectare kit"
- A "1/4 hectare kit"

Besides the kits, it is decided to make it possible for the costumer, to buy the unit and mounting stick separately.

Besides the production and sale of WilD which in the 3 years will cover an area of approximately 2500 ha, the development of "WilD Too" will start

In the next section the final budget will be presented.

Budget

As described in the previews section the strategy is divided into two phases, and so is the budget. Furthermore the development phase is divided into the two years and the production phase is visualized in the break-even analysis on page 78.

The development
In the development several investments is necessary to get to the production phase. The main investment is the post "Testing" which is primarily due to the salary of the industrial designers and the production of the 3 prototypes.
Furthermore the outsourced development of the drone and the development of the code.

The operating costs covers the production of units for the different large scale tests as well as SigFox subscription.
Also in the operating costs the fixed costs is presented, including server and website subscriptions and office rental.

The total cost of the development phase sums up to 211.674,74 euro.

See the full budget in (appendix XX)

Investments

Project costs (€)		
Testing (development)	€	30.100,00
Development of drone	€	25.000,00
Development of coding	€	18.200,00
Fairs	€	6.390,00
Awardshow	€	4.960,00
Designing website	€	2.800,00
Development of marketing	€	2.590,00
Development of Mounting stick	€	2.240,00
Development of manuals	€	1.190,00
Printboard layout architecture	€	910,00
Software licenses	€	1.000,00
Fundraising site	€	350,00
Buffer	€	7.500,00
Total	€	73.130,00

Operating costs year 1

Variable costs (€)/unit	Count	Cost pr unit	
Drone(s)	1	€	7.000,00
Mounting stick(s)	1	€	2,78
Sensor unit(s)	76	€	65,82
Manual kit	0	€	1,00
Shipment (inkl. packaging)	1	€	7,25
Sigfox subscribtion/unit	79	€	0,70
Total		€	12.067,44

Fixed costs (€)		cost/period	
Server		€	120,00
Website		€	84,00
Office		€	15.000,00
Total		€	15.204,00

Operating costs year 2

Variable costs (€)/unit	Count	Cost pr. Unit	
Drone(s)	2	€	7.000,00
Mounting stick(s)	10	€	2,78
Sensor unit(s)	780	€	65,82
Manual kit	10	€	1,00
Shipment (inkl. Packaging)	10	€	7,25
Sigfox subscribtion/unit	859	€	0,70
Total		€	65.447,77

Fixed costs (€)		cost/unit	
Server		€	120,00
Website		€	84,00
Office		€	15.000,00
Total		€	15.204,00

Budget - Development phase

Expences (€)	Year 1		Year 2	
Variable costs				
Drone(s)	€	7.000,00	€	14.000,00
Mounting stick(s)	€	2,78	€	27,75
Sensor unit(s)	€	5.002,11	€	51.337,50
Shipment	€	-	€	10,00
Sigfox subscribtion/unit	€	55,30	€	601,30
Fixed costs				
Server	€	120,00	€	120,00
Website	€	84,00	€	84,00
Office	€	15.000,00	€	15.000,00
Variable Costs	€	12.004,89	€	65.375,25
Fixed Costs	€	15.259,30	€	15.805,30
Contribution Margin	€	-27.264,19	€	-81.180,55

Breakeven analysis

Investments	€	-103.230,00	€	-130.494,19
Constribution	€	-27.264,19	€	-81.180,55
Remaining	€	-130.494,19	€	-211.674,74

The production

The deployment of the product is happening over a three year period, as described in the previews section.

The production of the parts for the sensor units and the mounting stick as well as the production of the drone is outsourced. The assembly and programming of the sensors are done by the SaF team.

The prices in the budget is including both the production cost by the partners and the in-house assembly.

The operating cost shown beneath this text, is devided into the kits and the single units and shows that the production cost of a sensor unit is beyond the estimated target price of 1 euro. The cost of one WilD sensor unit is 9,65 at mass production (5000+ units)

The biggest cost in the WilD unit is the circut boards, that have a production start fee of 718 euro for each of the two circuit board which means that the main board end up having a production cost of 3.12 euro.

As described in the "Business strategy" on page 74, the SigFox subscription is a very big post. As seen on the next page, the SigFox subscriptions is 38.26% of the total expenses (production cost, fixed cost and variable cost.

Operating costs		
Variable costs (€)		
one ha kit [1 kit]	**Count**	**Cost pr unit**
Mounting stick(s)	1	€ 1,28
Sensor unit(s)	78	€ 9,65
Manual kit	1	€ 1,00
Shipment	1	€ 20,15
Total (pr. kit)		€ 775,24
1/4 ha kit [1 kit]		
Mounting stick(s)	1	€ 1,28
Sensor unit(s)	20	€ 9,65
Manual kit	1	€ 1,00
Shipment	1	€ 13,08
Total (pr. kit)		€ 208,39
Sensor unit [Single sale]		
Sensor unit	1	€ 9,65
Manual kit	1	€ 1,00
Shipment	1	€ 5,24
Total (pr. unit)		€ 15,89
Mounting stick [Single sale]		
Mounting stick	1	€ 1,28
Manual kit	1	€ 1,00
Shipment	1	€ 5,28
Total (pr. unit)		€ 7,56
Fixed costs (€)		
Name	**Count**	**cost/period**
Storage	1	€ 150,00
Server	1	€ 120,00
Website	1	€ 70,00
Office	1	€ 18.000,00
Total		€ 18.340,00

Budget - Production phase

Expences (€)	Year 1	Year 2	Year 3
Variable costs			
Sigfox subscribtion (10 years)	€ 267.400,00	€ 534.800,00	€ 1.069.600,00
Drones	€ 7.000,00	€ -	€ -
Fixed costs			
Storage	€ 150,00	€ 150,00	€ 150,00
Server	€ 120,00	€ 120,00	€ 120,00
Website	€ 84,00	€ 84,00	€ 84,00
Office	€ 18.000,00	€ 18.000,00	€ 18.000,00

Sales revenue (€)			
Single sale			
Sensor unit (one)			
Products sold	2500	5000	10000
Sales Price	€ 40,00	€ 40,00	€ 40,00
Production cost pr. Unit	€ 15,89	€ 15,89	€ 15,89
Mounting stick (one)			
Products sold	10	20	40
Sales Price	€ 20,00	€ 20,00	€ 20,00
Production cost pr. Unit	€ 7,56	€ 7,56	€ 7,56
Kits			
1 ha kit			
Kits sold	150	300	600
Sales Price	€ 1.000,00	€ 1.000,00	€ 1.000,00
Production cost pr. Kit	€ 775,24	€ 775,24	€ 775,24
1/4 ha kit			
Kits sold	1200	2400	4800
Sales Price	€ 350,00	€ 350,00	€ 350,00
Production cost pr. Kit	€ 208,39	€ 208,39	€ 208,39

Turnover	€ 670.200,00	€ 1.340.400,00	€ 2.680.800,00
Variable Costs	€ 680.553,45	€ 1.347.106,90	€ 2.694.213,80
Fixed Costs	€ 18.354,00	€ 18.354,00	€ 18.354,00
Contribution Margin	€ -28.707,45	€ -25.060,90	€ -31.767,80

Breakeven analysis

Investments	€ -181.574,74	€ -210.282,19	€ -235.343,09
Constribution	€ -28.707,45	€ -25.060,90	€ -31.767,80
Remaining	€ -210.282,19	€ -235.343,09	€ -267.110,88

Summary

The two business cases, with the plantation owner and the municipality is used when the production phase is initiated. But before this WiLD is ready it has to go through a two year development phase where e.g. coding, mounting stick and interface is developed and the product is going through intensive and large scale testings.
Finally the production starts and the biggest costs are the circuit boards in the physical product, but especially the drone service and SigFox subscriptions are

Ill. 06.04: Investigation of healthy forest in Vergão, Portugal.

07 CLOSING

This phase sums up the project as a whole, starting with the conclusion, that describes the efficiency of WiLD, then the reflection dives into the flaws and finally the perspectivation describes use cases in other contexts

Ill. 7.01: Investigation of burned forest in in Zimbreira, Portugal

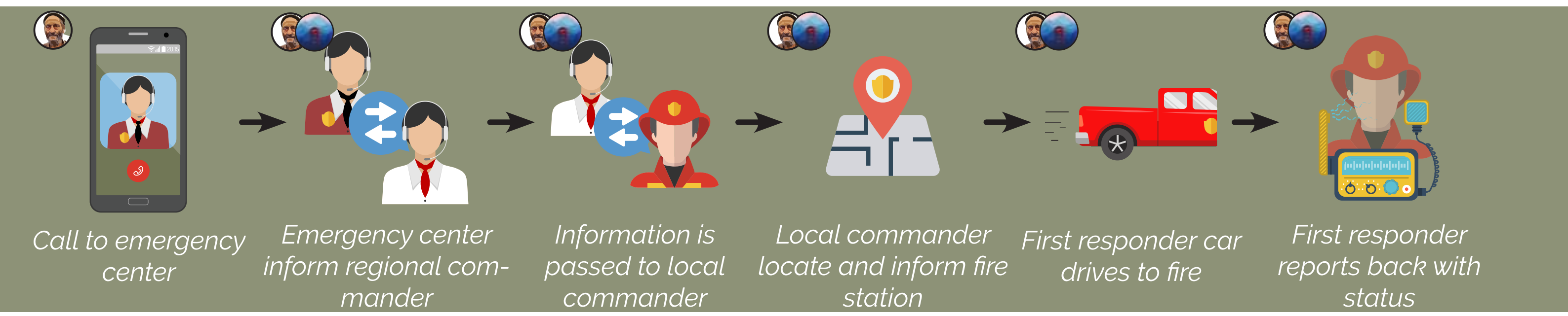
Conclusion

WilD became a reality through the previous eight phases. WilD is going to cope with the problems of ever greater problems after the 2017 wildfires. Fires that especially Mação struggle with.

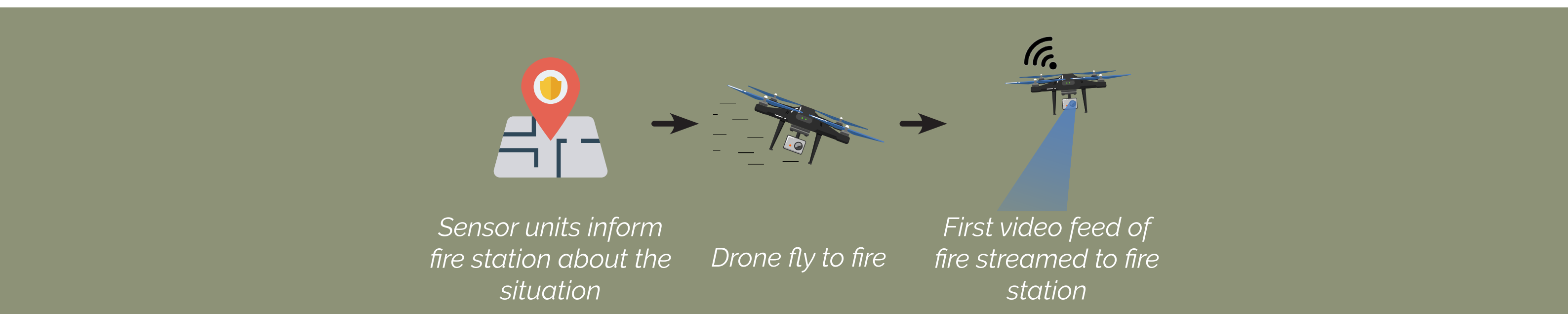
The fire is depending on heat, oxygen and fuel and because Portugal is becoming warmer and warmer and the increasing number of eucalyptus trees is fueling the landscape, meanwhile is Portugal and especially the municipalities in the center of the country like Mação, struggling with people leaving for the big cities or other countries and the rest getting elderly.
Because of all these factors are only making the problem worse for every year, they really need a solution to be faster. In Portugal they have the camera towers, but WilD is even faster., both in detection, transport and by shortening the alarm sequence. WilD is faster where speed means everything, where the situation can escalate exponentially. The market only focusing on broad-view solutions, this leaves an opportunity for a more autonomous and local approach wide open, which can be filled by WilD.

The system is a very useful tool for the fire department, which can lead to great savings in fire fighting, rebuilding and replanting. But the farmer also gains a good advantage, which is heavily needed, since he is partly paying for it. He reduces the risk of fire starting on his land to destroy all his trees and spread to the neighboring fields before, it comes for his home or village.

Even though that they really need this product, most farmers are poor, and the target price during the development where set low. This target price resulted in a deficit, which seems to fix itself as the communication technology matures a bit more, since it is brand new on the market.



Ill. 7.02: Warning scenario as of today



Ill. 7.03: Warning scenario with the WilD system

Reflection

As described in the business phase and the conclusion there is a lot of problems with the outcome of the thesis, that needs to be solved.

Eucalyptus banned
Right before hand in of this thesis, a law were passed, banning establishment of new eucalyptus plantations. (TPN/LUSA, 2017) This will have a direct impact on the product as it was thought. The law does not make it illegal to utilize existing plantations only not to establish new. Since the amount of eucalyptus plantations are already high, the problem of emptying the market will not occur in the near future.
This is a theme to look into.

The price (CO2 sensor),
One of the biggest flaws in the current solution is the use of the COZIR sensor. The COZIR sensor is very good, but also much more expensive than was thought in the first place.
The mass production price were found at Alibaba in the start of the project and were not verified until the very end, when the budget were being made and the sensor should be found for the development phase (a lower amount of sensors is needed in that phase.
The company were contacted, and told a completely different price. Therefore this is one of the high priority tasks after the defense of this thesis.

Budget
The project is a cost driven project, meaning that the price is very important for the costumer in business case 1.
As described in the "Budget" on page 76, the budget does not return a positive result. The variable cost is simply an many things is involved in the reason.
The different parameters that could be adjusted, could be the drones regarding how many that would be deployed, the sales price on the sensors and who pays the subscription for SigFox.

Interface
The interface is one of the points where the project lacks details resulting in a unclear understanding of how the product is used, but as seen in the budget this is a priority the get solved in the development phase.

SigFox and LoRa
In the developed solution, SigFox is used as the provider. This was, in the situation, thought as the best solution, since the majority of the plots in Portugal is privately owned. This meant that to accomplish business case 1 the solution should be easily scalable and should not require a large setup to establish connection to the sensor unit. Since then the drone have been added to the solution, requiring the potential costumers to be within its radius.
Because of this the alternative and much cheaper, in this context, solution LoRa, would be a theme to look into.

Ild fra nabo-marken
"It is a big problem when the fire spreads from other municipalities, since they are big and out of control when they arrive. Also the other municipalities has a focus on saving their own area." - Antonio Louro (Appendix 01) .
The current solution is not fire resistant and will not be able to last a fire. Therefore the fires coming from the neighbor municipalities are one of the greater challenges in this project. The sensor units will detect it, but the fire is already noticed by the authorities who is already put it out.

Perspectivation

WilD has been developed for use in eucalyptus plantations with its swift growth and challenges with falling debris. The system will be able to be deployed on other tree species that shares similarities like few branches, 10 year lifespan and within a circumference of 80cm. This could for example be bamboo trees.

The system is easily extended to areas with similar climate as Portugal, such as the mid and west USA, Australia and China. There might be complications in areas like Alaska, where low winter temperatures might drain the battery faster and the trees grow slower.

To adapt to the conditions of other areas the sensor unit will need further development of the mounting mechanism if there are branches that can interfere with the band. It also need development to its components and especially the battery to last for a longer time without being replaced.

Bibliography

Bugge, A. 2017. *Scorched earth of Portugal fires may hold seeds of a renewal*. Reuters. Available at: https://www.reuters.com/article/us-portugal-fire/scorched-earth-of-portugal-fires-may-hold-seeds-of-a-renewal-idUSKBN1CA0U5 (Accessed 17. May. 2018)

López, A. 2016 . *Portugal's response to forest fires undermined by austerity*. Defend Democracy Press. Available at:
http://www.defenddemocracy.press/portugals-response-forest-fires-undermined-austerity/ (Accessed 17. May. 2018)

McGuire, M. 2013*. The eucalypt invasion of Portugal.* The Monthly. Available at: https://www.themonthly.com.au/issue/2013/june/1370181600/michaela-mcguire/eucalypt-invasion-portugal (Accessed 17. May. 2018)

AFN, 2010.*Apresentação do Relatório Final do 5° Inventário Florestal Nacional.*
Autoridade Florestal Nacional, Ministério da Agricultura, Desenvolvimento Rural e
Pescas, Lisboa.

Valente et.al, 2015. *How much management is enoguh? Stakeholder views on forest management in fire-prone areas in central Portugal.* Elsevier.

Harris, T. 2002. *How Fire Works.* How Stuff Works. Available at: https://science.howstuffworks.com/environmental/earth/geophysics/fire.htm (Accessed 18. May. 2018)

Bonsor, B. 2001. *How Wildfires Work.* How Stuff Works. Available at: https://science.howstuffworks.com/nature/natural-disasters/wildfire.htm (Accessed 18. May. 2018)

Quaschning, V. 2001. *Statistics - Specific Carbon Dioxide Emissions of Various Fuels.* Volker Quaschning. Available at: https://www.volker-quaschning.de/datserv/CO2-spez/index_e.php (Accessed 18. May. 2018)

Hall, N. 2001. *Boundary Layer.* NASA. Available at: https://www.grc.nasa.gov/www/k-12/airplane/boundlay.html (Accessed 18. May. 2018)

Faiola, A. 2013. *Portugal suffers from a plummeting birthrate on top of economic woes.* The Guardian. Available at: https://www.theguardian.com/world/2013/jul/02/portugal-low-birthrate-eurozone-crisis (Accessed 18. May. 2018)

George, Z. 2016. *The Burning Question in the East Bay Hills: Eucalyptus Is Flammable Compared to What?.* Bay Nature magazine. Available at: https://baynature.org/article/burning-question-east-bay-hills-eucalyptus-flammable-compared/ (Accessed 25. May. 2018)

Carroll, J. 2018. *Eucalyptus Tree Bark – Learn About Peeling Bark On A Eucalyptus.* Gardening Know How. Available at: https://www.gardeningknowhow.com/ornamental/trees/eucalyptus/peeling-bark-on-eucalyptus.htm (Accessed 18. May. 2018)

Fire Safety Advice Centre. 2011. *Information about the Fire Triangle/Tetrahedron and Combustion*. The Fire Safety Advice Centre. Available at:
https://www.firesafe.org.uk/information-about-the-fire-triangletetrahedron-and-combustion/ (Accessed 18. May. 2018)

Catry et Al. 2007. *Forest Fires Prevention in Portugal - Using GIS to Help Improving Early Fire Detection Effectiveness*. Conference Paper.

Rego et Al. 2004. *Análise da Rede Nacional de Postos de Vigia em Portugal*. Relatório Final do Projecto. ADISA/CEABN – INESC/INOVAÇÃO. Iniciativa Incêndios Florestais, COTEC Portugal.

Cappelen et Al. 2011. *Danmarks Klimacenter rapport 05-03 - DMI's bidrag til Danmarks 4. nationale afrapportering til FN's klimakonvention UNFCCC*. Danmarks Meteorologiske Institut. pp. 11

Portal Do Clima. 2018. *Climate*. Portal Do Clima. Available at:
http://portaldoclima.pt (Accessed 20. May. 2018)

ICNF. 2013. *6.º Inventário Florestal Nacional*. Instituto da Conservação da Natureza e das Florestas. pp. 11

Silva, J. 2016. *Tasmanian blue gum (Eucalyptus globulus) in Portugal*. The Fire In-Tree Conference. Lisbon: University of Lisbon, pp.1-10. Available at:
http://www.in-tree.org/uploads/images/conference/presentations/Silva.pdf (Accessed 20. May. 2018)

Khalip, A. 2017 . *Portuguese protest over deadly forest fires, government pledges aid*. Reuters. Available at:
https://www.reuters.com/article/us-portugal-fire-government/portuguese-protest-over-deadly-forest-fires-government-pledges-aid-idUSKBN1CQ0TO (Accessed 20. May. 2018)

Tree Plantation. 2000. *Eucalyptus*. Tree Plantation. Available at:
https://www.treeplantation.com/eucalyptus.html#foo (Accessed 21. May. 2018)

Hay et Al. 1999. *Monthly Diameter And Height Growth Of Young Eucalyptus Fastigata, E. Regnans, And E. Salign*. New Zealand Journal of Forestry Science, 29, pp. 263-273.

Forsite. 2016. *How a Tree Grows*. The Forestry Out Reach Site, Available at:
http://dendro.cnre.vt.edu/forsite/hdtg2.htm (Accessed 25. May. 2018)

WCCO - CBS Minnesota. 2014. *What Type Of Smoke Alarm Is Best For Your Home?*. [Online video], Available at:
https://www.youtube.com/watch?v=J9zEi1otL88

Hessburg, S. 2017. *Why wildfires have gotten worse -- and what we can do about it*. [Online video], Available at:
http://www.ted.com/talks/sheryl_sandberg_why_we_have_too_few_women_leaders.html (Accessed 29. May. 2018)

Bugge, A. 2017. *Portugal fires burn 520,000 hectares, nearly 60 percent of EU total*. Reuters. Available at:
https://www.reuters.com/article/us-portugal-fire-area/portugal-fires-burn-520000-hectares-nearly-60-percent-of-eu-total-idUSKBN1CN2F4 (Accessed 29. May. 2018)

Wikipedia. 2018. *December 2017 Southern California wildfires.* Wikipedia. Available at: https://en.wikipedia.org/wiki/December_2017_Southern_California_wildfires (Accessed 29. May. 2018)

Brändlin, A. 2017. *How climate change is increasing forest fires around the world.* Deutsche Welle. Available at: http://www.dw.com/en/how-climate-change-is-increasing-forest-fires-around-the-world/a-19465490_wildfires (Accessed 29. May. 2018)

Chan Kim, W. 2005. *Blue Ocean Strategy: How To Create Uncontested Market Space And Make The Competition Irrelevant*. Harvard Business Review.

Ulrich, et al.. 1995. *Product Design and Development*. McGraw-Hill, New York.

Yan et al. 2016. Cheng, H, Zhao, Y., Yu, W., Huang, H. and Zheng, *Real-Time Identification of Smoldering and Flaming Combustion Phases in Forest Using a Wireless Sensor Network-Based Multi-Sensor System and Artificial Neural Network* , MDPI.

DJI, 2018. *DJI zenmuse Z30 camera.* Available at:
https://www.dji.com/zenmuse-z30/ (Accessed 22. May. 2018)

DJI, 2018. *DJI Matrice 200 series.* Available at:
https://www.dji.com/matrice-200-series (Accessed 22. May. 2018)

DJI, 2018. *DJI Matrice 200 series.* Available at:
https://www.dji.com/matrice-200-series (Accessed 22. May. 2018)

Today I Found Out, 2015.*How smoke detectors work.* Available at:
https://www.youtube.com/watch?v=pcn7MDpoZrY (Accessed 24. May. 2018)

Sayer, 2017.*Sigfox shows 20-cent IOT wireless module.* Available at:
https://www.pcworld.idg.com.au/article/627814/sigfox-shows-20-cent-iot-wireless-module/ (Accessed 24. May. 2018)

Zerma, 2018.*Plastic recycling.* Available at:
http://www.zerma.com.au/recycling_plastics_injection_moulding.asp (Accessed 21. May. 2018)

Clarke, A, 2009. *PVC recycling.* Available at:
https://www.youtube.com/watch?v=m6DfNUSqeAA (Accessed 21. May. 2018)

Hanlon, C., 2014. *How recycled material is remoulding the plastic industry.* Available at:
https://waste-management-world.com/a/how-recycled-material-is-remoulding-the-plastics-industry (Accessed 21. May. 2018)

Vinidex, 2016.. *Weathering and Aging of PVC pipes.* Available at:
http://www.vinidex.com.au/technote-parent-page/weathering-and-aging-of-pvc-pipes/ (Accessed 21. May. 2018)

IPMA, 2017.. *Extremos Climatológicos - Introdução.* Available at:
https://www.ipma.pt/pt/oclima/extremos.clima/ (Accessed 21. May. 2018)

Creative mechanisms., 2018.. *Everything you need to know about PVC plastic.* Available at:
https://www.creativemechanisms.com/blog/everything-you-need-to-know-about-pvc-plastic (Accessed 21. May. 2018)

Guinness world records, 2018.. *Highest recorded temperature.* Available at:
http://www.guinnessworldrecords.com/world-records/highest-recorded-temperature/(Accessed 21. May. 2018)

Plasticnews, 2018.. *Current resign pricing.* Available at:
http://www.plasticsnews.com/resin/recycled-plastics/current-pricing (Accessed 21. May. 2018)

Reliance foundry, 2017.. *Cast iron vs cast steel.* Available at:
http://www.reliance-foundry.com/blog/cast-iron-vs-cast-steel#gref (Accessed 21. May. 2018)

Borui casting international ltd., 2018.. *China grey iron castings.* Available at:
http://www.iron-foundry.com/china-gray-iron-castings.html (Accessed 21. May. 2018)

Humiseal., 2018.. *What is conformal coating.* Available at:
http://www.humiseal.com/conformal-coating/ (Accessed 21. May. 2018)

Meteor foundry co. 2012. . *Casting Competition: Sand Castings vs. Permanent Mold Castings.* Available at:
http://www.meteorfoundry.com/blog/casting-competition-sand-castings-vs-permanent-mold-castings/ (Accessed 21. May. 2018)

The enclosure company 2018.. *IP rated enclosures explained.* Available at:
www.enclosurecompany.com/ip-ratings-explained.php (Accessed 23. May. 2018)

Fernandes, 2014,*Forest Fires in Portugal: Dynamics, Causes and Policies*. ResearchGate

Plastic is Rubbish, 2017. *What is silicone* . Available at:
http://plasticisrubbish.com/2012/05/17/what-is-silicone/ (Accessed 24. May. 2018)

Recycle now, 2010 . *Waste electronics - How they are recycled* . Available at:
https://www.youtube.com/watch?v=RaKLgovVkJQ (Accessed 24. May. 2018)

Battery university, 2009. *BU-705: How to Recycle Batteries.* Available at:
http://batteryuniversity.com/learn/article/recycling_batteries (Accessed 24. May. 2018)

Retriev, 2018. *Primary Lithium.* Available at:
http://www.retrievtech.com/recycling/primary-lithium (Accessed 24. May. 2018)

WECF, 2018. *Dangerous Health Effects of Home Burning of Plastics and Waste.* Available at:
http://www.wecf.eu/cms/download/2004-2005/homeburning_plastics.pdf (Accessed 24. May. 2018)

E-TERRA technologies, 2017. *Impacts of E-Waste on the environment.* Available at:
http://www.eterra.com.ng/articles/impacts-e-waste-environment/ (Accessed 24. May. 2018)

TPN/LUSA, 2017. *Eucalyptus ban is "huge lost to the economy".* The Portugal News Online. Available at:
http://www.theportugalnews.com/news/portugal-bans-new-eucalyptus-forests/42431 (Accessed 29. May. 2018)

Illustrations


Aalborg Universitet | 2018

WilD
Appendix

Index

Appendix 01

Title: Interview with municipality of Maçaõ	**Worksheet no.:** 17 page 1 of 4
Responsible: Steffen & Esben	**Date:** 05/03-2018

What and how?

(What is it we are going to do and how are we going to do it?)

Semi structured interview with a primary and secondary interviewer. The secondary will take notes/pictures and provide 'fresh to the mind' questions. The interview will be recorded for later use and quotation.

Purpose:

(What is the purpose of this research, task, experiment - what do we want to get out of it)
We want to get an understanding of how the municipality sees the problem with wildfires. What they do about it, what they want to do about it and what they think about our solution. Furthermore, what can they explain about the new low proposal and what do you think about it?

Results:

(What are the results?)
Interview with Antonio Luoro, Vice president of Macao and president of the forestry forum

- How long time do we have for this meeting?
- As long as we need (took 2 hours + lunch 😉)

- Can you explain about your department, and what you are doing?
  - Who do you have influence on?
- (no real answer), but administering firefighting and land
- Do you administrate any land/forest around here or how does it work?
  - For instance, abandoned lands?
- They do not administer any lands, they are owned by privates. They administer fire prevention, e.g. fire breaks
- Is this region especially effected by wildfires?
- The middle region of Portugal is hard hit, mostly cause by the lack of agriculture (= more trees, more fire)
- Do you see the problem as increasing?
- The problem has been increasing since the 50's since the population is leaving the villages to go to the bigger cities. This leaving makes the land go from agricultural to forest. The forest lands have bigger risk of fire and bigger fires.
- Do you know of any fire detection systems?
  - Do you know if any is in use in your municipality?
- Portugal has installed hill top cameras all over the nation, this municipality has 5. The camera was tested on the highest point of the municipality (visited afterward)
- Earlier they had 4 people each manning towers on high points 24/7 for the summer period
- How many € do you in your municipality spend on firefighting and how many do you spend on prevention
- Approx. 300.000 Euro for fire intervention per year,
  - Who pays for the fire fighting? Municipality or state?
- The state distributes the money to the fire departments
  - What types of preventions do you have in use? (Fire breaks)
- Fire breaks and 50m clearing zone around villages, and the roads are some places (2000km) structured with 60m of thin tree cover on both sides, instead of dense vegetation.
- We heard about a suggestion of the municipality economically supporting people who do fire reducing initiatives.

  - Can you tell more about it?
  - Do you know if people will use it?
  - Where does the inspiration come from?
  - Would you be interested in supporting them to get a detection system?
- Are there any other similar initiatives?
- The state has previously issued a fund, the municipality applied for fire prevention and got rejected. (2 years ago)
- Who do you see as a buyer for a fire detection system? The forest owner or municipality?
- The municipality with some funding from the state
  - What about the abandoned areas?
- What is done after a forest fire, and who is doing it?
- The municipality is clearing the nearest 50 m of villages (for fire safety) and the roads.
- Is there any place where we can find statistics?
- Antonio will send later.

- Which fire station do you propose we interview?
- We got a meeting set up tomorrow :D
  - We have mailed a lot fire stations, without answer, how do we get in contact with them?

Bonus info /wild notes:
The fires were not a problem 30-40 years ago 1970-80's, because of the agricultural land and higher population, also the global warming are giving them drier periods for longer and more often.
There are very little agriculture in the middle region of Portugal now, they moved to the southern region.
There were no eucalyptus trees here 100 years ago, there were agriculture.
All the other municipalities and government is talking about how to fight the fire, not how to prevent it, but it is changing now.
The land is divided a lot, the municipality's 42.000 ha is owned by 80.000 persons and only 10% of them are living in the municipality, the rest has moved out. This often happens when the children inherit the land from their parents (e.g. 4 children has split ownership)
Nothing is happening on a national scale, since they and the citizen quickly forget about the fires, if it didn't happen in their area.
There was a huge fire in Macao in 2003, where 60 people died.
The national government are more ready for change now than earlier.
In the 23. Juli of 2017 there was started a fire 20 km north of the municipality, the fire reached the municipality after 5 hours, and spread quickly and burned half of the municipality's land. There were multiple fires that year that crossed municipal border and In total they burned approx.. 75% of the land. Only 1 of the fires started in Macao.
Eucalyptus trees are tall and provide almost no ground vegetation making them good against small fires, but if the crown catches fire, it's leave flies off while on fire and spreading the fire very very quickly since they fly ahead and start new fires.
In the 50's they nationally thought the solution was to increase the capacity of fire fighting. (more men and vehicles)
The small villages got a small fire kit, with a tank and a pump to mount on a truck, such they could take the initial fight with the fire.
Macao has a mobile command center vehicle, were the fire fighting is coordinated from, this is the obnly municipality with such.
The fire department usually arrive in 10 mins.
It is a big problem when the fire spreads from other municipalities, since they are big and out of control when they arrive. Also the other municipalities has a focus on saving their own area.
They use bldozers a lot to cut off the fires path, this is their best tool. (the cleared 70 km of land for one of the fires)

Title: Interview with municipality of Maçaõ	Worksheet no.: 17 page 3 of 4
Responsible: Steffen & Esben	**Date:** 05/03-2018

The 2017 fire destroyed 15 houses, where 2-3 were insured, the rest wasn't. Many houses were damaged, but no one died.
The second fire of 2017 was stopped 2-3 times, but reignited.
When the fires are spread across multiple municipalities, there is bad coordination between the municipalities.
The municipality owns very little land <100 ha.
Portugal ran 3 fire detection project previously with smoke and IR detection, the smoke system got triggered by wildfires in other municipalities. And the systems had many false alarms.
There is a project called MacFire
The municipality of Macao has an online map of the fires, but it require login.
It could be usefull for the fire department to know the coordinates of the fire, instead it is from the point were the fire was spotted.
The National fire fighting department have helicopters and planes, which are adjesent to Macao.
The small forest road are made for easier access for fire fighters.
The state is distributing the money for the fire departments
2/3 of the fire fighters are part time, voulentiers.
The Government want more professional fire fighters and better air coordination.1
The Bombeiros are both fire figher department and medical (ambulances)
In the big fire of 2017 there were fire fighting in 200 villages using 800 men and 200 fire vehicles.
Macao was the first to clear the land under the power lines, now it is required by the state to suppliers.
Human detection takes longer during nighttime, also for the towers. (fires still happen at night)
In 2012 the nation had 20501 fires which burned 104.125 ha, 50% of the burned area was caused by 0,4% of the fires.
The don't know how to fight fire on an extreme scale.
Many fires are started by arson, e.g. a men of age 40-50 years, who is drinking, unemployed and bad family and social relations. (maybe to get attention)
Most fires are caused by accidents and some by lightning either overcharging (destroying) power lines or directly igniting the land. Trains can also cause fire, when they are braking (sparks) (maybe 4-5 cases/year, hear interview)
The big fire of 2003 was started by a lightning striking a power line.
During the big fire of 2017 they were fighting the fire in the north, but 2 other fires started from lightning hitting power lines and 3 from direct lightning, meaning they had to manage 6 fires.
Approx.. 70% of the fires are frim accidents.
In the fire of 2003, 60 people died, 30 of these were on the road, getting trapped by the fire.
Big birds can ignite when sitting on power lines, which then fall down and spread to the land (also why they cleared the vegetation under the lines.) (maybe causing 3-4 cases each year, hear interview, late part)
The municipality can put up things in the land and on private property for fire prevention.

Conclusion:

(What are the conclusion regarding the purpose? What can we use from this in our project?)
There were tons of great stuff
There are definatly a huge problem in this municipality
Many big fires cross over from other municipalities.
The municipality can mount stuff on private property.
Macao is a great place to run a pilot project, since they are willing to do new stuff.
The population is dropping, meaning less people to spot fire.
They have the camera system already

Title: Interview with municipality of Maçaõ	**Worksheet no.:** 17 page 4 of 4
Responsible: Steffen & Esben	**Date:** 05/03-2018

Evaluation:

(Did we get the results we were looking for? What should we do next?)
We got more information than we expected, we also got a meeting with the fire command center (center for civil and nature protection). We also got a meeting with the fire department set up through this interview.

Reflection:

(If not, why. Should anything had been different? Are there anything else we maybe should take into consideration?)

Appendix 02

Title: Interview with Civil and forest protection office	**Worksheet no.:** 18 page 1 of 2
Responsible: Steffen & Esben	**Date:** 8/3-2018

What and how?

(What is it we are going to do and how are we going to do it?)
This was not planned in advance, but we got the opportunity and took it, it became a tour of the building, their equipment and vehicles. We also got the opportunity to see a fire spotting camera up close on the municipality's highest point.

Purpose:

(What is the purpose of this research, task, experiment - what do we want to get out of it)
The purpose was to see their existing equipment and the fire detection camera system, to see what we are up against.

Results:

(What are the results?)
The mobile command vehicle
They have a mobile command vehicle for the coordination of the fire fighters plan of attack, the vehicle is equipped with multiple sets of radios and screens, some of the screens are used for the fire detection camera. The team tracks and manages the fight from there. They print out maps for the other districts and supply the strategy to the tablet of the fire fighters. They got the vehicle in 2005 after the big fire in 2003.
The vehicle is equipped with a weather station, such the fire fighters has a local weather report (wind speed, direction humidity etc.
They designed the interior of the vehicle and got it made by some company (she can find it in the files) the interior systems are produced by multiple manufacturers (the gps system, the camera systems, the weather station.

Our sensors
Sonja is concerned about the number of sensors that is needed to cover the municipality, and the cost of the sensors.

Fire fighting
When they are fighting on an extreme scale, the district commander comes to use their vehicle, coordinating from there.

Fire spotting
They have 5 cameras in the municipality on high points, such as the highest point. In addition, they have the older fire watch tower, which are manned 24/7 during the high-risk periods (summer, fall)
The men are watching alone for 8 hours a day.

The existing camera system
The camera is operation on a national level and is manned 24/7, the camera rotates slowly and transmits images. The operator manually watches for signs of fire. In case of fire, he is finding the location from the angle on the camera.
The camera seemed buggy and ran with 0,1 fps at the moment we saw the footage.

Visiting the tower
The camera is surprisingly small and located on a small tower. They can see very far (including into Spain), but not into the away pointing slopes of the hills/mountains. The tower has a triple power line running all the way up the mountain to supply the camera, it also has a shed with backup batteries, in

Title: Interview with Civil and forest protection office	**Worksheet no.:** 18 page 2 of 2
Responsible: Steffen & Esben	**Date:** 8/3-2018

the case that the power line breaks or is destroyed. The battery shed has two large batteries which can keep the camera running for at least 1 year (he claimed, also said maybe 2-3 years…)
All the forest on the mountain side were burnt, but the immediate area around the tower was cleared of vegetation.

Conclusion:

(What are the conclusion regarding the purpose? What can we use from this in our project?)
The camera is unstable and not automatic as expected.
They don’t appear to believe in the camera, since there are 24/7 manning in towers during the summer.
The smoke sometimes needs to rise above a hill/mountain for it to be seen.
The need the local weather report (from their command vehicle) to be most effective.
Macao is leading the technological progress of all the municipalities.

Evaluation:

(Did we get the results we were looking for? What should we do next?)
We saw some flaws In the existing camera system, the blind spots, unreliability, etc.
Also we found some things that would be nice to have such as weather information (wind speed and direction and humidity)
Since the meeting wasn’t planned in advance, we didn’t expect anything. But it provided usefull information and insights.

Reflection:

(If not, why. Should anything had been different? Are there anything else we maybe should take into consideration?)
It would have been good to have prepared questions beforehand.

Appendix 03

Title: Interview with Firefighters of macao	**Worksheet no.:** 19 page 1 of 3
Responsible: Steffen & Esben	**Date:** 7/3

What and how?

(What we are going to do and how are we going to do it?)

Semi structured interview with a primary and secondary interviewer. The secondary will take notes/pictures and provide ‘fresh to the mind’ questions. The interview will be recorded for later use and quotation.

Purpose:

(What is the purpose with this research, task, experiment - what do we want to get out of it)

We want to know the following to see if we can gather the data they want through our product:
What is the standard procedure when they get an alarm regarding nature fires?
What do they need to know?
What would they like to know?

Results: (Translate later if necessary)

(What are the results?)

- How often do you respond a fire call?
  Often every day and sometimes 1-2 days - 233 from mid May – mid okt (fire season) the season becomes longer and longer.

- What is the normal procedure when you receive a call?
  First the local call in the call to 112 (the national emergency line) they redirect the call to the regional commander that command a car from the nearest fire station to the fire to analyse what needs to be done – then the first car report back what is needed and then all the municipalities send trucks and men to the fire.

- What do you know about the fire before you drive out? (Placement, size, Wind direction?)
  They know the approximate location of the fire (the fire is near a town or area etc) Then they use the cameras to verify and pinpoint the exact location with help from men that is located at a tower with the camera.

- What would you like to know?
- *The weather (wind) the vegetation (how much fuel) to predict fire movement.*

- Why do you think some forest fires become so big? (Were they detected to late?)
  Abandoned forests that can grow freely. Sometimes the fire is not spottet close up meaning it is more difficult to locate.
  If it is spotted quickly it doesn’t make that big a difference because the it takes
  Biggest problem is that the young people moves to the coast leaving only the elders

Title: Interview with Firefighters of macao	**Worksheet no.:** 19 page 2 of 3
Responsible: Steffen & Esben	**Date:** 7/3

- What are the main reason for the wildfires?
  Almost all is unknown
  Handheld machines that makes sparks is next biggest
  And then criminals

- How early are the fires typically detected (by the Camera system and people)?
  5-10 minutes
  Cameras work good in summer but in winter there is problems
  There is people with all the cameras 24/7 in the summer

- ~~How much time does it take from you receive the call to you start fighting it?~~
  ~~10-15 minutes~~

- ~~Is there any other people you think could be good for us to talk to? (Police, andre beredskabsafdelinger)~~

- What is your biggest problem when fighting the fire? (The heat, water, coordination, overview, find the fire,)
  Shiftes for 24h – ideal is 8 hours
  (https://www.facebook.com/pedro.bras.90/posts/1444195448956591)
  In big fires there is coordination sometimes is a problem

- What do you think we should be aware off when making the product?
  The cost
  The fire resistance

- ~~What would you say a product like this should do?~~

Bonus info:
The firefighters of one municipality help another municipality but there will always be one to two fire trucks left at the fire station.
In winter/spring it is legal to burn nature waste
60 firefighters at the station in Mação (17 active (24/7) in summer) – 5-6 in winter
Young people move to the city (away from the places that is in risk of fires)
The firefighters (of Mação) know the area (not the fire fighters from the other municipalities)
Dust from machines is confused for smoke – it is a problem because the fire trucks go out. It happens very often.
2/3 of the firefighters is volunteers
Two stations in Macao municipality (40 minutes between)
Drones and helicopters share same airspace – dangerus to use at same time.
Big fires hit every 10-15 year.
Last year more than 70% of the municipality burned
Deal breaker is the fires from the other municipalities.

Title: Interview with Firefighters of macao	**Worksheet no.:** 19 page 3 of 3
Responsible: Steffen & Esben	**Date:** 7/3

Conclusion:

(What are the conclusion regarding the purpose? What can we use from this in our project?)

Evaluation:

(Did we get the results we were looking for? What should we do next?)

Reflection:

(If not, why. Should anything had been different? Are there anything else we maybe should take into consideration?)

Appendix 04

Title: interview with local	Worksheet no.: 20 page 1 of 2
Responsible: Steffen & Esben	**Date:** 10/03-2018

What and how?

(What is it we are going to do and how are we going to do it?)

Situated interview, not prepared

Purpose:

(What is the purpose of this research, task, experiment - what do we want to get out of it)

To get a understanding of the magnitude of the fire seen from the locals perspective. What was lost, how it felt like and how fast it was.

Results:

(What are the results?)
Ludwig is living in the small town, Carvoeiro, where of the summer fires hit in summer of 2017 ran trough.

You saw the fire?
Yes, the fire came, so quickly. I want out to the neighbors to help them protect their houses and land
When I came back my garden was destroyed.
All the trees lost all the leaves only from the heat in the air
I measured the temperature to be 70 degrees C
The next day it was still 60 degrees C
The

How fast were the fire?
The fire was very fast because of the wind the heat were enormous
From when I saw the fire to the village were in a inferno it took only five minutes.
Many many people were very very afraid.
I had cloth hanging on the door, it burned from just the heat in the air.
Internet and telephone was destroyed for approx. 12 hours

Have you experienced fire before?
I have experienced fire at other places but only one time here.

Nobody have money to plant.
The smallest one is tree hectors. Some have 10-20
A new tree cost 30 cents (then you also need fertilizer)
Many poor people have no insurance. (House)
All the trees that were burned were planted by Salazar (previous president of Portugal) to harvest resin for color production.

Title: interview with local	**Worksheet no.:** 20 page 2 of 2
Responsible: Steffen & Esben	**Date:** 10/03-2018

Conclusion:

(What are the conclusion regarding the purpose? What can we use from this in our project?)

Evaluation:

(Did we get the results we were looking for? What should we do next?)

Reflection:

(If not, why. Should anything had been different? Are there anything else we maybe should take into consideration?)

Appendix 05

Title: Interview with Portuguese forest owner	**Worksheet no.:** 25 page 1 of 2
Responsible: Steffen & Esben	**Date** 18/3-2018

What and how?

(What is it we are going to do and how are we going to do it?)
Interviewing a forest owner in Portugal using a semi structured interview. Sketches

Purpose:

(What is the purpose of this research, task, experiment - what do we want to get out of it)
The purpose is to get an understanding of what they do to maintain the forest, when they are not abandoned.

Results:

(What are the results?)

- What trees do you have and how much area?
  Eucalyptus forest – many plots, some small some bigger. Some fields are 4 ha. He buys the lands for eucalyptus (not rental)

- How close are they planted?
  *3*1,8*

- How often do you clean out the forest? (for underbrush, thinning the trees)
  Once a year

- How old are they when you cut them?
  8-10 years

- Do you cut them all at once or in sequence?
  All cut down at once after ~10 years.
  Most of the time its people who have small businesses who buy the trees to the plantation owner and then they sell to another business (intermediary) that then sell to the tree business

- How do the trees grow?
  from small plant

- Does it affect the tree having anything hanging on it?
  Is it streachable?
  It will not hurt the tree or anything.

- Would you invest in keeping your forest safer against forest fire?
  If the municipality pays some of it, it would be nice – it would be too expensive if he should pay for everything himself (1000 euro/ha)
  If the municipality pays 75-80% it would be nice!

- Would you let the municipality hang things on your trees, if it protects the forest?
  He thinks the a product that could do this would be really nice because the problem is that it is not detected earlier [today] so when it is detected it is already a wildfire. He like the idea of a device in his area because [today] there is a lack of communication between the population and the entities (firefighters/emergency)

Bonus info

Title: Interview with Portuguese forest owner	**Worksheet no.:** 25 page 2 of 2
Responsible: Steffen & Esben	**Date** 18/3-2018

He also has pines on his plantations.
Before he had almost only pines, because the area was primarily pine, but now there is also eucalyptus.
He thinks we should be careful about the winds blowing the product down. (with the tube concept)

Conclusion:

(What are the conclusion regarding the purpose? What can we use from this in our project?)

Evaluation:

(Did we get the results we were looking for? What should we do next?)

Reflection:

(If not, why. Should anything had been different? Are there anything else we maybe should take into consideration?)

Appendix 06

Title: Healthy forest walk	Worksheet no.: 21 page 1 of 2
Responsible:	**Date:** 12/3-2018

What and how?

(What is it we are going to do and how are we going to do it?)
A walk in the healthy forest, taking many pictures of the landscape and interesting points. Also taking measurements of trees distances etc.

Purpose:

(What is the purpose of this research, task, experiment - what do we want to get out of it)
We want to see how the forest is organized, are the trees planted in lines? How dense is the forest? What is the visibility? How much underbrush is there? What height should our product be in to have vision/airflow, how wide is the trees?

Results:

(What are the results?)
The areas are often having both pine and eucalyptus trees, but on each their plots. There is no structure to what kind of tree there is on the plots. (no sectioning), the pine trees are sometimes surrounded by a row of eucalyptus, which could be to provide cover from the wind while the pine is growing up. Both kind of trees are most often planted on slopes (up to approx... 30-40 degrees)

Pine forest:
Most of the pine plots appear to be abandoned, but few are well kept. The pine plots often have a tall underbrush of small bushes (up to 2m, most common at 45cm covering around 50%) apart from few, very dense, plot with almost unpassable bushes. In the common pine plot there is lots of fuel in the underbrush, the ground is covered with a 6-7 cm layer of dead needles. The smallest tree suitable for our alarm is 4 cm in dia. and a circumference of 100-130mm in a height of 3m.
The typical tree has a dia. of approx. 13 cm in a height of 2m.
The trees are often located with a typical distance of 95cm (160 – 60cm) except for offspring of the trees which is approx. 10-40 cm from the parent.
The well-kept pine plantation had a thick layer of small cut down trees, which was left behind, possibly to decompose and give nutrition to the ground.
The pine trees appear to get around 15m tall.
The typical middle-aged wood has very few branches left under a height of 2 m.

Eucalyptus forest:
The eucalyptus plots seem more organized. They are planted from sprouts in a grid pattern with 1,6 m between the plants and 3m between the planted rows. The ground is waved (might be plowed) and very rocky with three high grounds between the planted rows, the plants are planted in the valleys of the wave pattern. The eucalyptus often has little underbrush, but other times have lots of small bushes (50cm). The ground is covered by a 5-7cm layer of dead leaves and small dry branches that had been broken off. The tree had a lot of creaks assumable from these branches.
The typical tree is approx. 10 cm thick, but the thickest tree found had a dia. of 119 cm. The average tree has a height of approx.10 m, while the highest might be 20 m. The young trees (approx. 3-4 m) has the lower 1,8 m covered with thin branches with smaller leaves, while above that point has the typical elongated leaves. The long leaves cover a lot more effectively the vision. The vision in these woods are decent, allowing us to see Esben at up to 33 m, but you can’t see the ground after 10 m. (these tests are done from a height of 1,6m)

Conclusion:

(What are the conclusion regarding the purpose? What can we use from this in our project?)

Title: Healthy forest walk	**Worksheet no.:** 21 page 2 of 2
Responsible:	**Date:** 12/3-2018

There is a problematic visibility since there is a decent amount of underbrush, especially in pine woods. The ground is covered in both forests. The visibility is much better in eucalyptus forests than pine. If the device is mounted on trees, it should span between Ø 4-119cm, and between 4 - ~15cm (age unconfirmed) for a 5-year period.
If the device should use vision, it needs to be able to see through thin vegetation in addition to either seeing through trees or move to see around them.
The device must be able to adjust for slopes (up to 30-40 degrees).

Pictures:
Pictures can be found here: https://photos.app.goo.gl/6EtEwRc5QYQhrFUP2

Evaluation

(Did we get the results we were looking for? What should we do next?)
It was hard to estimate the age of the forests and find the average forest, since they were very different, both in density, visibility, underbrush and wildness.

Reflection:

(If not, why. Should anything had been different? Are there anything else we maybe should take into consideration?)
It could be nice to have expert knowledge (or owners) to figure out what has been done to the plot and how old they are etc.

Appendix 07

Framing 1 (12/2-18)

Definition of "WIldfire"
any large fire that spreads rapidly and is hard to extinguish.
http://www.dictionary.com/browse/wildfire

Project focus:
Detection of wildfires as early as possible

Vision:
V. 1 Detection of wildfires before they occur
V. 2 Reduce amount and spreading of wildfires
V. 3 Make it easier accessible to detect wildfires
V. 4 Make it easy and precise to detect upcoming wildfires
V. 5 Detection and localization of wildfires before they occur
V. 6 Extinguishing of wildfire before it starts/occur
V. 7 Prevent wildfires from happening

Mission:
V. 1 Make a product that detects the fire early enough for the fire department to get the fire under control before any major damage occurs

Metaphor
The all-seeing eye of the forest
The protector of the forest/land
Should detect a upcoming wildfire like a seismograph detect a upcoming tsunami.

Problem statement
V. 1 How to detect wildfires before they occur
V. 2 How can a detecting device reduce wildfires?
V. 3 How can we create a device, which can alarm the fire department early enough for them to get the fire under control, and therefore limit the damages to the land, structures and wildlife.
V. 4 Is it possible to design a device that, by detecting wildfires on a early stage, can reduce the damage and cost of a wildfire?
V. 5 Is it possible to design a device that, by detecting and localize wildfires on a early stage, can reduce the damage and cost of a wildfire?

Requirements
- Should detect fires
- Detect fire with X minutes of the start
- Should only trigger when the fire is a actual wildfire
- Must be scalable (as needed (ongoing))

Framing v. 4 (23/2)

Project focus:
Detection of nature fire in remote areas to allow them to be suppressed at an early stage

Vision:
Detection and localization of wildfires before they occur

Mission:
Make a product that detects the fire early enough for the fire department to get the fire under control before any major damage occurs

Metaphor
The all-seeing eye of the forest
The protector of the forest/land
Should detect an upcoming wildfire like a seismograph detect a upcoming tsunami.

Problem statement
Is it possible to design a device that, by detecting and localize wildfires on a early stage, can reduce the damage and cost of a wildfire?

Requirements:

No.	Need no.	Requirement	Importance 1-5	Unit	Ideal val.	Marginal val.
1	Designer	Must detect the fire before the fire department is necessary (at 10 points) (their definition is coming later)	5	Points	<=5	<=10
2	Designer	At least one unit should be able to communicate with controller (e.g. forest owner)	5	Binary	Yes	Yes
3	user	Limit false positives (% alarms are true)		%	100	?
4	user	Inform about malfunction (burning, low battery, vandalism etc.)		Action	Active	Inspection
5	Setup /user	Slave units must be wireless (connection, power)		Binary	Yes	Yes
6	user/designer	System should should be working and maintenance free	???	Years		
7	desig	Must be scalable (as needed (ongoing))		Binary	Yes	Yes

	ner/user					
8	setup/ user	Easy setup/removal (service could be a solution)		min./ha		
9	designer/fire department	Must not make the fire worse (per slave unit)		%	0	??
9	designer/fire department	Must not make the fire worse (per master unit)		%	0	??
10	Designer	Must be weatherproof (rain, heat, wind, snow, dust)		IP rating	76	64
11	designer/user	Must be vandal resistant		???		
12		System must be able to be off-grid		hours	Product lifetime	24
13	designer	Product lifetime		Years	30+	15+
14	user	No damage to trees		Loss of trees	0	1%???

Wishes:

- Should blend in (styling)
- Master unit should be able to run off grid if required
- Estimate the size/stage of the fire
- Extinguishing the fire/ decreasing the fire

Framing v. 7 (9/3)

Project focus:
Detection of nature fires in remote areas to allow them to be suppressed at an early stage

Vision:
Detection and localization of wildfires before they occur

Mission:
Make a product that detects the fire early enough for the fire department to get the fire under control before any major damage occurs

Metaphor
The all-seeing eye of the forest
The protector of the forest/land
Should detect an upcoming wildfire like a seismograph detect a upcoming tsunami.

Problem statement
How is it possible to design a device that, by detecting and localize wildfires on a early stage, can reduce the damage and cost of a wildfire?

Requirements:

No.	Need no.	Requirement	Importance 1-5	Unit	Ideal val.	Marginal val.
1	Designer	Must detect the fire before the fire department is necessary (at 10 points) (their definition is coming later)	5	Points	<=5	<=10
2	Designer	At least one unit should be able to communicate with controller (local or fire department)	5	Binary	Yes	Yes
3	user	Limit false positives (% alarms are true)		%	100	?
4	user	Inform about malfunction (burning, low battery, vandalism etc.)		Action	Active	Inspection
5	Setup /user	Slave units must be wireless (connection, power)		Binary	Yes	Yes
6		No battery failure		years	5+	
7	designer/user	Must be scalable (as needed (ongoing))	4	Binary	Yes	Yes

8	setup/ user	Easy setup/removal (service could be a solution)		min./ha		
9	designer/fire department	Must not make the fire worse (per slave unit)		%	0	??
10	designer/fire department	Must not make the fire worse (per master unit)		%	0	??
11	Designer	Must be weatherproof (rain, heat, wind, snow, dust)		IP rating	76	64
12	designer/user	Must be vandal resistant		???		
13		System must be able to be off-grid		Days	Product lifetime	31
14	designer	Product lifetime		Years	30+	15+
15	user	Not kill the tree		Loss of trees	0	1%???
16	animals/fire fighter / user	Should not endanger living creatures	2	Subjective		
17		Sensor reliability	???	Years	5+	3-5
18		Sensors not getting blocked by dirt, dust, insects etc.		years	5+	3-5
19		Component lifetime (reliable)		years	5+	3-5
20		Communication/connection keeps being established.		years	5+	3-5
21		Heat resistant		minutes/fire	???	0
22		Max internal temperature within the time		degre		solder/c

		limit		es		ompone nts melting point
23		Heat resistant (700 degrees)		numb er of expos es	10+	1
24	user/ muni	Price per covered area (sales price)		Euro	(che ap)	
25	User/ muni	Sales price < savings over the products lifetime	5	Binary	Yes	Yes
26		Slave unit should indicate where the fire is	5		Direc tion + dista nce	Area
27		Firefighters should be able to find triggered unit (where the fire is)	5		Light/ soun d/tra cker	GPS

Wishes:

- Should blend in (styling)
- Master unit should be able to run off grid if required
- Estimate the size/stage of the fire
- Extinguishing the fire/ decreasing the fire

Framing v. 9 (21/3)

Project focus:
First detection of forest fires using a system of a drone, a master unit, and cheap battery driven air analysers placed on the tree, under the crown, that combined can detect and localize a forest fire, and therefore, reduce the damages.

Keyword(s)
Smouldering Combustion

Vision:
First detection and localization of fires in forests before they occur

Mission:
Make a system that detects and inform about an upcoming forest fire early enough for the fire department to get the fire under control before any major damage occurs

Metaphor
Should detect a upcoming wildfire like a seismograph detect a upcoming tsunami.
Protecting as a mother to hear baby
Reliable as a LED bulb.

Problem statement
How is it possible to design a system, using low cost units, that by detecting and localizing upcoming forest fires on an early stage, can reduce the damage and cost of a forest fire?

Requirements:

No.	Need no.	Requirement	Importance 1-5	Unit	Ideal val.	Marginal val.
1	Designer	Must detect the fire before the fire department is necessary (at 10 points) (their definition is coming later)	5	Points	<=5	<=10
2	Designer	At least one unit should be able to communicate with National controller (NAME????)	5	Binary	Yes	Yes
3	user	Limit false positives (% alarms are true)	4	%	100	?
4	user	Inform about malfunction (destroyed, low battery, vandalism, moved etc.)	5	Action	Active	Inspection
5	Setup /user	Slave units must be wireless (connection, power)	4	Binary	Yes	Yes

6	User	No battery failure	5	years	10+	10
7	designer/user	Must be scalable (as needed (ongoing))	4	Binary	Yes	Yes
8	setup/ user	Easy setup/removal (service could be a solution)	4	min./ha	???	
11	Designer	Must be weatherproof (rain, wind, snow, dust)	4	IP rating	76	64
12	designer/user	Must be vandal resistant	3	Subjective	100 %	???
13		System must be able to be off-grid	5	Days	Product lifetime	31
14	designer	Product lifetime	4	Years	10+	10
15	user	Not kill the tree	4	Loss of trees	0%	1%
16	user	Hinder the trees growth	4	Binary	No	No
16	animals/fire fighter / user	Should not harm living creatures	3	Subjective rating	100 %	???
17		Sensor reliability	5	Years	10+	10
18		Sensors not getting blocked by dirt, dust, insects etc.	5	years	10+	10
19		Component lifetime (reliable)	5	years	10+	10
20		Communication/connection keeps being established.	4	years	10+	10
21		Fireproof	4	Binary	Yes	No
24	user/ muni	Price per covered area (sales price)	4	Euro	(cheap)	1000?
25	User/ muni	Sales price < savings over the products lifetime	5	Binary	Yes	Yes

26		System should indicate where the fire is	5		Direc tion + dista nce	Area (within x m)
27		Firefighters should be able to find triggered unit (where the fire is)	5	Time to find it	???	???
28	User	The drone must be able to be piloted	4	Binary	Yes	Yes
30		Weatherproof (temperature)	5	Degre e celciu s	???	0-50
30	Gover ment	Limiting the drone to a specific area + height (law)	5	Binary	Yes	Yes
31		Drone flight time	4	Minute s		
32	User	Drone size	5	Dimen sions	50x5 0x?? ?	100x10 0x??? cm
33	User	Drone should be to overcome tiny branches (dry eucalyptus branch up to Ø5mm)	4	Binary	Yes	Yes

Wishes:

- Should blend in (styling) [Buyer]
- Estimate the size/stage of the fire [Fire department]
- Inform about wind speed + direction [Fire department]
- Extinguishing the fire/ decreasing the fire [Municipality + Fire department]
- Modular [Buyer]
- Operate with existing system (the interactive map fire planning)
- Automatic avoidance of helicopter + firefighting planes)

Framing v. 11 final version (20/5)

Project focus:
First detection of forest fires using a system of a drone, a master unit, and cheap battery driven air analysers placed on the tree, under the crown, that combined can detect and localize a forest fire, and therefore, reduce the damages.

Keyword(s)
Smoldering Combustion

Vision:
First detection and localization of fires in forests before they occur
Controlling the flame of the future
Be in control of the (wild)fire
Be in control of whether a fire should ignite or not
Calming the embers of tomorrow
Be in control of the natures blaze
Be in control of the natures embers
Be in control of the embers
Control the fire
control if a nature fire should ignite or not
Control the ignition of wildfires
Control the wildfire

Mission:
Develop a system that detects and inform about an upcoming forest fire early enough for the fire department to get the fire under control before any major damage occurs
Eliminate forest fire through early detection
First detection and localization of fires in forests before the flames occur

Metaphor
Should detect a upcoming wildfire like a seismograph detect a upcoming tsunami.
Protecting as a mother to hear baby
Reliable as a LED bulb.

protector/guardian of the forest
The seismograph of the forest
Natures seismograph
Watchdog of the nature
Watcher of the nature
Fast -
Reliable
Long lasting
embracing
coverage

Problem statement

How is it possible to design a system, using low cost units, that by detecting and localizing upcoming forest fires on an early stage, can reduce the damage and cost of a forest fire?

Requirements:

No.	**Finding no.**	**Stakeholder**	**Requirement**	**Importance 1-5**	**Unit**	**Ideal val.**	**Marginal val.**	
1	1, 5, 8, 23	Investor/buyer	Must in average detect the fire quicker than existing solutions	5	Binary	Yes	Yes	test
2	21	Buyer/locals/municipality	Chance of the fire getting detected	5		100	90	test
2	6, 23	Firefighter commander	All sensor units must be able to communicate with National controller (direct or indirect)	5	Binary	Yes	Yes	Ideal
3	8, 15	user/firefighter commander	Limit false positives (% alarms are true)	4	%	100	50	test
4	21	user/buyer	Inform about malfunction (destroyed, low battery, vandalism, moved etc.)	5	Amount of info	Details	Basic info	Marginal
5		Setup	sensor units must be wireless (connection, power)	4	Binary	Yes	Yes	Ideal
6	6, 13	User	No battery failure	5	years	10+	10	Ideal, test
7	11	investor/user	Must be scalable (as needed (ongoing))	4	Binary	Yes	Yes	Ideal
8	12, 13	setup	Setup time for sensor unit (incl. walk between trees	4	sec	<20	60	Ideal

9	12	Setup	Must be able to be mounted by one person	4	Binary	Yes	Yes	Ideal, test
10		developer	Mounting height interval (unobstructed)	4	m	2-3	2-2,5	Ideal
11	10, 16	user/buyer	Must be weatherproof (rain, wind, snow, dust)	4	IP rating	65	53	test
12	10, 16	investor, developer	Particles must be able to enter detecting sensor(s)	5	Binary	Yes	Yes	Ideal, test
13	10	user	Must work in all weather conditions	5	Binary	Yes	Yes	test
14	7	user/buyer	Product lifetime	4	Years	10+	10	Ideal, test
15	14	user	Not kill the tree	4	Loss of trees	0%	5%	test
16	14	user	Hinder the trees growth	4	Binary	No	No	ideal, test
18	21	investor, developer	Sensors not getting blocked by dirt, dust, insects etc.	5	sensors getting blocked	0%	1%	test
21		user/buyer	Fireproof	4	Binary	Yes	No	Maginal
24		buyer	Price per ha (sales price)	4	Euro	<1000	1000	No
26		firefighter commander/user	System should indicate where the fire is	5	precision, radius [m]	Area (within 10)	Area (within 50)	ideal test
27		Firefighters	Firefighters should be able to find triggered unit (where the fire is)	5	Time to find	15	60	test

					unit from given area [sec]			
28	22	User /fire com man der	The drone must be able to be piloted	4	Binar y	Ye s	Yes	Ideal
30	16	Buy er/U ser/d evel oper	Weatherproof (temperature)	5	Degr ees celciu s	<- 20 - < 60	0-50	Ideal, test
30		Gov ern ment	Limiting the drone to a specific area + height (law)	5	Binar y	Ye s	Yes	Ideal
31		firefi ghte rs/us er/b uyer	Drone response time	4	Minut es	<10	10	Magin al
32		fire com man der	Drone size	5	Dime nsion s [mm]	500 x50 0	1000x 1000	margi nal
33		inve stor/ User /dro ne oper ator	Drone should be able to overcome or evade tiny branches (dry eucalyptus branch up to Ø5mm)	4	Binar y	Ye s	Yes	suppli er devel opme nt/- test

Wishes:
- Should blend in (styling) [Buyer]
- Estimate the size/stage of the fire [Fire department]
- Inform about wind speed + direction [Fire department]
- Modular [Buyer]
- Operate with existing system (the interactive map fire planning)
- Automatic avoidance of helicopter + fire fighting planes)
- Vandal resistant
- Should not harm living creatures

Appendix 08

Title: Feedback from Division of Forest and Civil Protection	**Worksheet no.:** 24 page 1 of 1
Responsible: Steffen & Esben	**Date:** 16/03-2018

What and how?

(What is it we are going to do and how are we going to do it?)

Purpose:

(What is the purpose of this research, task, experiment - what do we want to get out of it)
We need to get feedback on how the Division of Forest and Civil Protection

Results:

(What are the results?)
Description of what we have been doing since last meeting:
We have been meeting with two locals that have been experienced the fire – the heat in the air when a fire is going; that people forget about the problems of fires when they don't happen; and that the fire is very fast.
Sonia describes that they knew about the fire 30 minutes before the fire came.
Esben describes about the research we have been doing in areas of unburned area.
Sonia describes that in Macao they use bulldozers in every fire.
Esben describe the solution principle
Sonia takes a picture (15:10) "[it is] very interesting"

We need a license to use drones in Portugal
Drones can only fly to a certain height.

Esben describes the principle about the sensors can measure wind speed

Steffen: Is it allowed to use autonomous drones in Portugal?

Sonia: "We indicate the grid the drones is allowed to be within"

Esben describes what we know about how eucalyptus grows and are planted and cleaned in the period.

Sonia: Why did you choose eucalyptus. (26:02)

Conclusion:

(What are the conclusion regarding the purpose? What can we use from this in our project?)

Evaluation:

(Did we get the results we were looking for? What should we do next?)

Reflection:

(If not, why. Should anything had been different? Are there anything else we maybe should take into consideration?)

Appendix 09

Title: feedback from Vice President of Mação	**Worksheet no.:** 23 page 1 of 1
Responsible: Steffen & Esben	**Date:** 18/03-2018

What and how?

(What is it we are going to do and how are we going to do it?)
Getting feedback from the Vice President of Mação as a possible buyer of the solution, by describing the developed solution principle and show concrete concepts

Purpose:

(What is the purpose of this research, task, experiment - what do we want to get out of it)
It is very important that we understand our target groups need, to make the product as good as possible.
By describing the status of the project as well as showing the concepts

Results:

(What are the results?)
Antonio listened and committed that the product shouldn't be just one model, but different models, would be great for different places.
Antonio told that he had much more confidence in the project now and he described different scenarios where he thought the product would make sense eg. National parks with specific trees or animals.
Antonio also told that he thinks the government could be interested to invest in the project.

Conclusion:

(What are the conclusion regarding the purpose? What can we use from this in our project?)
Antonio was much more into the project this time = we have our buyer!

Evaluation:

(Did we get the results we were looking for? What should we do next?)
We are now ready for implementing Antonio's feedback by eg. Make the product somehow modular and then we should test the solution by making a Funktion model and then to detailing.

Reflection:

(If not, why. Should anything had been different? Are there anything else we maybe should take into consideration?)
Prepare the interview

Appendix 10

Title: Rubber bands	**Worksheet no.:** xx page 1 of 1
Responsible: Steffen	**Date:** xx/xx-2018

What and how?

(What is it we are going to do and how are we going to do it?)
Desk research and calculations

Purpose:

(What is the purpose of this research, task, experiment - what do we want to get out of it)
Figure out if we can use rubber bands

Results:

(What are the results?)
Natural rubber is biodegradable, which can't work in our solution because it is hanging for 10 years. Rubber is destroyed by ozone and UV light, the sun gives out massive amount of UV light.
https://www.scienceabc.com/eyeopeners/why-do-rubber-bands-lose-their-elasticity.html

EPDM is a UV resistant synthetic rubber, which could be useful.
https://www.aerorubber.com/all-weather-rubber-bands/

EPDM rubber bands are pretty cheap
https://www.alibaba.com/product-detail/packaging-elastic-band-factory-Custom-underwear_60717940665.html?spm=a2700.7724838.2017115.22.48074e98SKvUJL 2,65-4,5 $/kg
https://www.alibaba.com/product-detail/Wholesale-Black-EPDM-Outdoor-Rubber-Band_169057845.html?spm=a2700.7724838.2017115.66.48074e98SKvUJL 0,1-0,5 $/piece
https://www.alibaba.com/product-detail/Black-High-Heat-UV-Resistant-32_60747223721.html?spm=a2700.7724838.2017115.31.3fed3d5ayrHPit 2-4 $/kg

The lifetime of a rubber band is varying a lot, 2 years is expected to be long time for a rubber band. This is nowhere near the lifespan we need.

Conclusion:

(What are the conclusion regarding the purpose? What can we use from this in our project?)
Rubber cannot be used for our solution since they cannot last long enough.

Evaluation:

(Did we get the results we were looking for? What should we do next?)
Look for other elastic soultions

Reflection:

(If not, why. Should anything had been different? Are there anything else we maybe should take into consideration?)
There can be special types of rubber which can last long enough that we haven't found in this research.

Appendix 11

Title: Interview with forest owner	**Worksheet no.:** 4 page 1 of 3
Responsible: Steffen & Esben	**Date:** 13/2

What and how?

(What we are going to do and how are we going to do it?)

Semi structured interview with a primary and secondary interviewer. The secondary will take notes/pictures and provide 'fresh to the mind' questions. The interview will be recorded for later use and quotation.

Purpose:

(What is the purpose of this research, task, experiment - what do we want to get out of it)
We want to know more about our stakeholders. If they value a product like a detector to protect their ground and what features the product should contain in that case or to convince them.

Results:

(What are the results?)

How many forest(s) do you own and where?

Hedeselskabet ejer en stor del skov – ejer en skov I nærheden?

How large are they? (hectares)

Hedeselskabet passer omkring 6000 hektar I Nordjylland
På landsplan passer de ? Og 30-40000 hektar løst

How are they managed? And how often?

Drift: tynding, rydning, genbeplantning, plejning + alt muligt andet som rendes søer, grøfter lave stiger og veje
Nogle skove kommer man kun 1 gang om året hvor man I andre skove der kræver meget tilsyn og pleje kommer man oftere.

Are you concerned about forest fire?

Brand fylder meget I tankerne, når de benytter maskinerne. De udstyret I orden, så de kan slukke det med det samme
Hedeselskabet har intet fokus på påsat eller natur brande, som sker uden hedeselskabets bevidsthed. Dvs. Skovbrande de ikke er direkte eller indirekte skyld i.

Do people live near your forests? Are they concerned?

Skovfoden har boet I skoven. Så var det skovarbejdere. Nu er det mest udlejningsboliger. Det er få steder hvor det stadig er skovfoden der bor

Do you have plans in case of fire?
Nej, det burde vi og det kan være vi får det hvis der kommer endnu en stor brand.

How are the forests organized? (firebreaks, sectors etc)
Der er større fokus mht. Hedeflader hvor de har etableret brandbælter og branddaskere.

Title: Interview with forest owner	**Worksheet no.:** 4 page 2 of 3
Responsible: Steffen & Esben	**Date:** 13/2

Man vedligeholder brandbælter og andre sikkerhedsvern som løvtræerbælter.

Are the forests insured? What is the cost of that on yearly plan
Hedeselskabet anbefaler sine medlemmer at få sin skov forsikret
Det plantageforsikring (6 DKK pr. Hektar)
Hedeselskabet synes 35000 er meget rimeligt I forsikringssum pr. Hektar

What will it cost to loose a forest in a fire?
Jo ældre skoven er, jo mere værdi (hvis skoven har groet optimalt)
Gennemsnit 150.000,- pr. Hektar ekskl. Genetablering (35.000,-)

Would you like to pay for setting up sensors around in the forest to get a cheaper monthly price of the incurrence?
Det kunne være aktuelt I nationalparker (grundet publikumspres) nogle nationalparker er mere hedepræget

Is there any requirements for setting up equipment on trees or in the woods in general
Skader man træet (under Bakken) er det et indløbsted for svampe og det kan også medvirke til at træet kan knække ved en eventuel storm.
Man kan sætte noget om stammen, der kan give sig.

Would you like to get noticed if a fire was under development or would you rather the alarm went directly to the firefighters?
Ejeren bør få meldingen, da hank ender skoven men brandvæsnet bør også få den, så de også kommer frem

Bonus info
Lovtræer er mest fremherskende her mod vest.

Martin ser større potientiale I udlandet.

Ofte holder de specielle arter till I løvtræsbevoksning

Martin anbefaler at snakke med Aalborg kommune.

Martin anbefaler stenbaksskov ved jyskeås flavnskjold – ejer (Else) kunne interessant at snakke med.
Tolleskov (anpartsskov) Lars Fogh – plantageforsikringen

Conclusion:

(What are the conclusion regarding the purpose? What can we use from this in our project?)
Martin lynggaard Jørgensen tells that HedeDanmark recommends its members to get insurance but that customers are probably not interested in paying more to reduce the damage, since the sum insured is already quite reasonable.
He therefore advises us to search abroad to find a more open market.
He, however, reminds us to talk to both customers and plantation insurance, which we have also thought for themselves.A last thing to notice is that he adviced us to look at national parks because they are depended on the audience.

Title: Interview with forest owner	**Worksheet no.:** 4 page 3 of 3
Responsible: Steffen & Esben	**Date:** 13/2

Evaluation:

(Did we get the results we were looking for? What should we do next?)
Of cause we hoped that HedeDanmark as spokesperson of most forest owners in Denmark would be more open to the idea, but since forest fires in very rare in Denmark. Martin thereby support Bent from Beredskabscenter Nordjylland who also advised us to look away from Denmark, which we should take into consideration!

Reflection:

(If not, why. Should anything had been different? Are there anything else we maybe should take into consideration?)
We should have printed out the questions, so we didn't had to look at the same device as we writing notes on.

Appendix 12

Title: Development of the setup mechanism	**Worksheet no.:** 49 page 1 of 5
Responsible: Esben & Steffen	**Date:** 02-08/05-2018

What and how?

(What is it we are going to do and how are we going to do it?)
Broaden the solution space regarding the mounting mechanism.

Purpose:

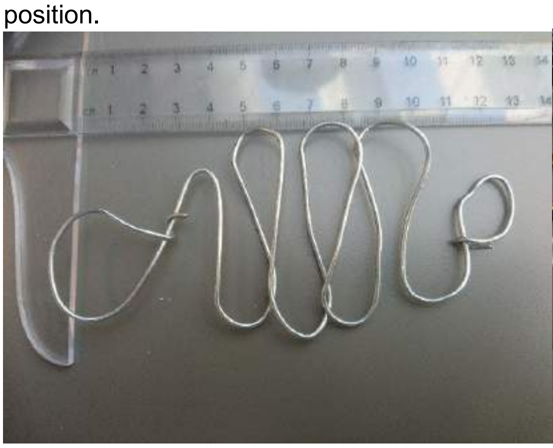
(What is the purpose of this research, task, experiment - what do we want to get out of it)
To be able to choose the right solution for mounting mechanism and mounting stick

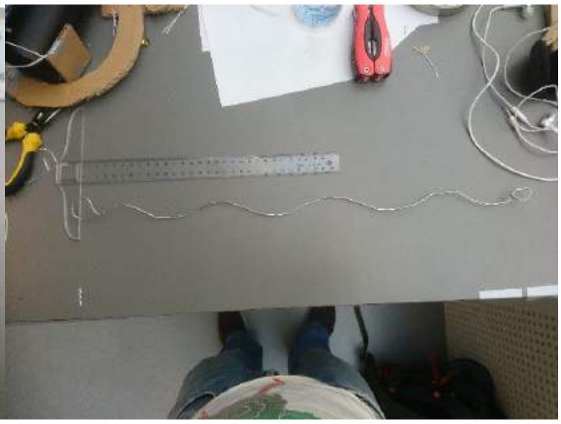
Results:

(What are the results?)
It was discovered that the product had to be placed on the stem because the branches fall off over time.
Different iterations were done regarding the mounting mechanism and the mounting stick.

Several principles were tried out:
Folded steel wire
This idea is based on the knowledge of steel deforms when the "right" force is added.
This were teste by folding a steel wire, force is then needed to unfold it again

The wire are tested on how much force is needed to extended from the folded position to the unfolded position.

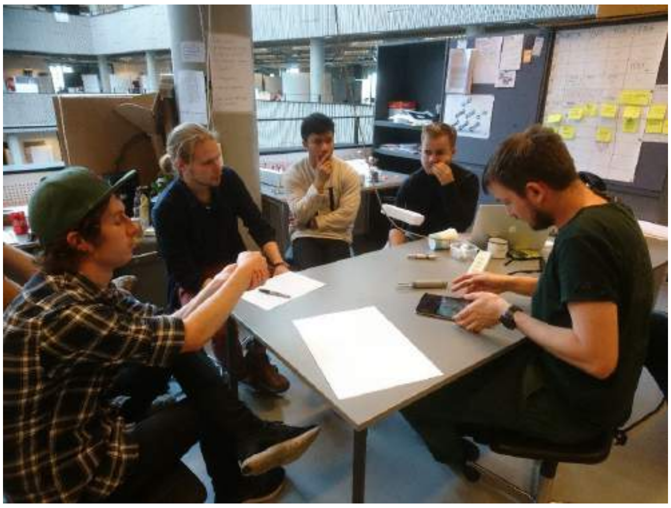




Leash principle
The principle is that the leash has to run through a knot which result in a resistance, which could be able to hold the sensor unit.

This were also tested as seen below.

To gain additional ideas, other design students, where presented for the problem to get fresh eyes and different solutions to the subject. At this session observation were used to make sure none of the barriers we had ran into were an obstacle for their ideas to occur. When they had no ideas information's were given to help new ideas occur.



A idea were born: combining the spring steal with a rubber band:
https://photos.app.goo.gl/hyqA6zjYkg5vS3jk9

The idea solved two aspects that the original "slap on" concept did not.

1. That it was able to lock with the hooks – giving it a great security.
2. It is stretchable.

But since the rubber band will degrade in UV from the sun, the idea was rejected.

Title: Development of the setup mechanism	**Worksheet no.:** 49 page 3 of 5
Responsible: Esben & Steffen	**Date:** 02-08/05-2018

The spring steel came back to the drawing board because the steel would be better in the outdoor environment.

The solution where further developed

Velcro was found as the solution for the locking problem and were tested:
https://photos.app.goo.gl/tlVnQgt2WZAWkely1

We realized that it needed a mechanism to release the spring steel. It where made and tested:
https://photos.app.goo.gl/5bKoq9LyqmxjCf973

It was realized that it did not work from that angle, that band was tested placed flush to the side that would hit the tree but shifted to right, so the band was only sticking out of one of the sensor unit's sides. A weight was also added, to see if the spring steel would be released easier because of that. This was tested with a new mounting stick that was holding the unit tight, also with Velcro:
https://photos.app.goo.gl/CmB4ypL4wn3Alhol2

As the video show the method "acting out" was used to test how long the process would take to set up. This was also documented by how many times a setup was a success and how many times it was a fail.
The weight made the setup much easier

At this point the idea of having it as a coil in the sensor unit came up. It was tried to glue spring steel bands together to see and it was tested. Because of how the spring steel works it had to come out angled. At this point we thought it was important the band came out close to the front. (towards the tree). This was tested in Væksthuset in Aarhus. This was also tested with a new mounting stick that could push the product off the velcro:
https://photos.app.goo.gl/bqmQuwUnnwh8Az9U2

Title: Development of the setup mechanism	**Worksheet no.:** 49 page 4 of 5
Responsible: Esben & Steffen	**Date:** 02-08/05-2018

Because the spring steel were coming out of the side, it was difficult to make it release, so the spring steel band were moved to the back, which made it possible for the band to exit the casing perpendicular to the tree direction. This was tested to make sure it would still work, this time with a new mounting stick that hold the sensor unit tight with magnets: https://photos.app.goo.gl/Gsf4530z9Gg4PzJd2

It worked very well and decided to contact Erik J. Petersen from Lesjöfors A/S, to verify that it is possible to get at spring steel in longer variants than the "slap on" reflective band. He described that Lesjöfors actually invented the reflective "slap on" band and the band only exist in one length. (but he would return with an answer – never did)

After some research Yoyomats were discovered. They make self rolling yoga mat which was a proof of concept

This concluded the development

The look

Inspiration:


Early render:

Title: Development of the setup mechanism	**Worksheet no.:** 49 page 5 of 5
Responsible: Esben & Steffen	**Date:** 02-08/05-2018

Magnets
http://www.motors-biz.com/item/1018978/Permanent-Free- Motor-Generators-.html
: https://www.alibaba.com/product-detail/Customized-shape-Grade-N52-Neodymium-Magnet_60627934095.html?spm=a2700.7724838.2017115.153.54a520e1ylhZbn

Conclusion:

(What are the conclusion regarding the purpose? What can we use from this in our project?)

Evaluation:

(Did we get the results we were looking for? What should we do next?)

Reflection:

(If not, why. Should anything had been different? Are there anything else we maybe should take into consideration?)

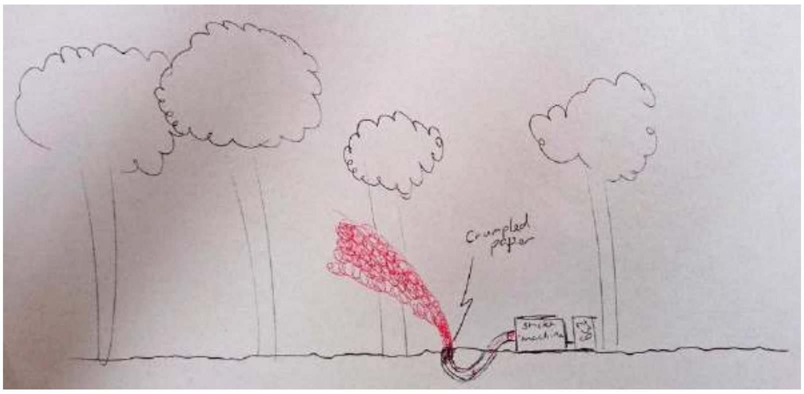
Appendix 13

Title: Smoke dispersion test	**Worksheet no.:** 27 page 1 of 2
Responsible: Steffen	**Date:** 21/3-2018

What and how?

(What is it we are going to do and how are we going to do it?)
A test of how the smoke moves and thins out.
The test will be done using a smoke cannon to simulate the smoke, without creating fire.
It should be done in a forest that is similar to eucalyptus forests regarding density and tree thickness.
The smoke exits the machine at some speed that needs to be braked, to do this we will dig a pipe in the ground from the machine underground to an opening, which is filled with crumpled paper. This should stop the momentum from the machine and release the smoke at ground level at a steady pace. (see drawing)
If it doesn't work with the smoke machine, the test will be replicated using a smaller fire, producing real smoke.
The smoke machine will be powered by Esbens 230V power bank. (Update: Power Bank did not work out – we used extension cords)
The wind speed and direction should be known, we need a wind measurer. (Update: We were not able to get one in time because of Easter)

It should be recorded how wide the smoke cone is and spreading evenly and in specific paths. The smoke will only be noted where it is visible to the human eye. The smoke cones distance to known object. E.g. the ground. If It is possible to measure without affecting the movement of the smoke.



The location is yet unknown. It is also unknown where we get a wind measurer.

Purpose:

(What is the purpose of this research, task, experiment - what do we want to get out of it)
The purpose is to see how the smoke behaves, how fast does it rise, how wide does it spread and how fast.

Results:

(What are the results?)
We were unable to use the smoke sensor, since we ran into problems with the coding of it.
From observing and taking pictures and video of the smoke we were able to measure how long the smoke traveled before it was at the necessary height level.
But we were not able to measure if the smoke would be dense enough for the sensor to register it.

På video:

Title: Smoke dispersion test	**Worksheet no.:** 27 page 2 of 2
Responsible: Steffen	**Date:** 21/3-2018

13 m løber røgen
4,8m fra vinkelret til træ som røgen ramte
Længde til vinkel: 11,2

Conclusion:

(What are the conclusion regarding the purpose? What can we use from this in our project?)
The smoke took a lot longer time to rise than we had thought. Also, it was very difficult to measure because the wind was unstable.
The smoke was running far before it had reached the correct height.
Also it was discovered that the width of the smoke were not that wide.

Evaluation:

(Did we get the results we were looking for? What should we do next?)
Because we the Arduino did not work, we did not get the results the way we hoped but never the less we got some results we came for. Now we should try to find a formula for calculation the behavior of the smoke. Someone else must have made this test before.
We also need to find out what the wind speeds was when the fire were getting out of control in Portugal.
We need to look at the pattern of the sensor grid to make it more failsafe

Reflection:

(If not, why. Should anything had been different? Are there anything else we maybe should take into consideration?)
Error sources:
The smoke might behave different than real smoke.
The ambient temperature will affect the smokes behavior
The forest is not eucalyptus and might affect the smoke by having a lower crown, therefore, slowing the wind more.
The wind are unpredictable in strength and direction and may change during the test.
The windspeed might not be as it will be when the risk of a fire getting out of control is biggest.

Appendix 14

Power consumption

Battery ER34615		LED		Messages		Average fire risk	
Voltage	3,7	Timespand (hours)	1	Size (bit)	32	Days in fire season	0,1
Battery capacity (mAh)	19000	Delay (sec)	0,5	Send time (sec)	1,47	Timespand (hours)	1
Battery capacity (mWh)	70300	Time (sec)	0,5				
Battery drainage factor	0,90					Days of operation	182,5

Measurements							
CO2 (fire)		**Smoke (fire)**		**CO2 (Normal)**		**Smoke (Normal)**	
Timespand (hours)	1	Timespand (hours)	1	Timespand (hours)	3	Timespand (hours)	23
Delay (sec)	15	Delay (sec)	29,8	Delay (sec)	165	Delay (sec)	29,8
Time (sec)	5	Time (sec)	0,2	Time (sec)	5	Time (sec)	0,2
Heat time (sec)	10	Heat time (sec)	0	Heat time (sec)	10	Heat time (sec)	0

		Measurements/day		Work time (hours)				
Senario	**Messages/day**	**CO2**	**Smoke**	**LED**	**CO2 sensor**	**Smoke sensor**	**SigFox**	**MCU**
Normal	1,00	79,35	2745,10	0	0,36	0,15	0,00	0,52
Fire	115,38	124,30	2745,10	0,5	0,57	0,20	0,05	0,81

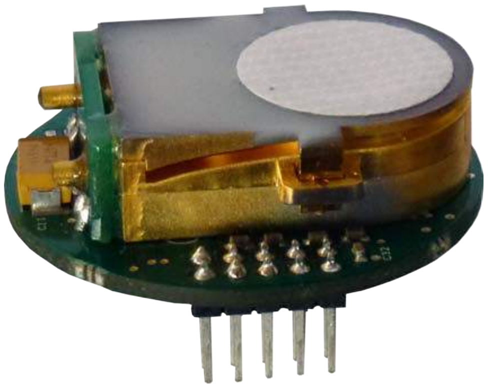
Name	Type	Power stop (mA)	Power idle (mA)	Power work (mA)	Normal idle time (mAh)	Normal work time (mAh)	Fire idle time (mAh)	Fire work time (mAh)
COZIR Ambient Sensor	Sensor	0,00	0,00	1,33	0,00	0,75	0,00	0,75
Smoke	Sensor	0,00	0,00	15,00	0,00	2,29	0,00	3,00
RL78/G12	MCU	0,00	0,22	0,97	5,14	0,50	5,13	0,79
AX-SFEU	SigFox modul	0,00	0,00	48,00	0,02	0,02	0,02	2,27
5x 5 mm red LED	LED	0,00	0,00	150,00	0,00	0,00	0,00	75,00
Total		0,00	0,22	215,30	5,17	3,57	5,15	81,80

Power consumption	mAh pr. day	Years on battery
Normal	8,73	10,78
Fire	86,96	1,08
off season	0,000005	20160470,49
combined	8,77	10,73

Appendix 15

COZIR-A *(2000 ppm, 5000 ppm, 1% CO_2)*

Ultra Low Power CO_2 Sensor For OEM Applications



Key Features

The COZIR is a CO_2 module for OEM applications that represents a breakthrough in low power gas detection making it ideal for battery powered, energy harvesting or wireless applications with tight energy budgets requiring long operating life. This Infrared LED based sensor offers a number of distinctive features over conventional CO_2 sensors.

Key features of the COZIR-A CO_2 sensor include:

- Continuous power consumption of 3.5 mW. With reasonable duty cycling (e.g. 15 min) battery life can be extended to 5+ years.
- Measurement ranges of 0-2000 ppm, 0-5000 ppm and 0-1% (10,000 ppm).
- 10 second warm up time.
- Shock and vibration resistant.
- Built in auto calibration feature.
- Options for on-board temperature and humidity measurement and extended temperature operating range of -13 to 131ºF (-25 to 55ºC).
- Simple, closed contact initiation of ambient or zero calibration.
- Runs cool, there is no heat generated that can interfere with temperature or humidity measurements
- Other models can measure up to 100% CO_2.

The Breakthrough…

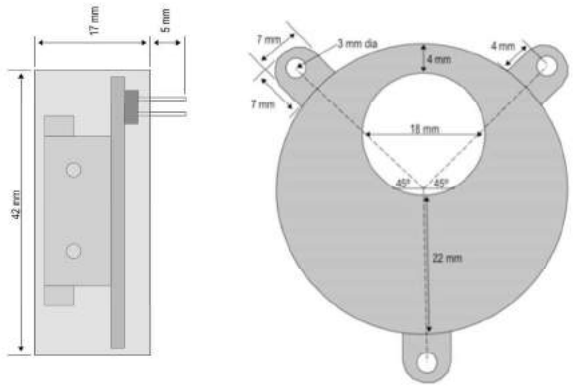
Conventional CO_2 sensors utilize a small incandescent bulb that generates a lot of heat and light energy in addition to the infrared energy used for the gas measurement. Instead of a light bulb, the COZIR uses a small light emitting diode (LED) that generates infrared energy only at the wavelength needed to measure CO_2. This is the reason for the dramatically reduced energy use of the COZIR.

LED sensors have always been recognized as idea for low power gas detection but their development has been a great technical challenge. The COZIR developed by a Scotland based company called Gas Sensing Solutions is the very first infrared LED product on the market that is stable enough and economical enough to be sold into measurement and control products.

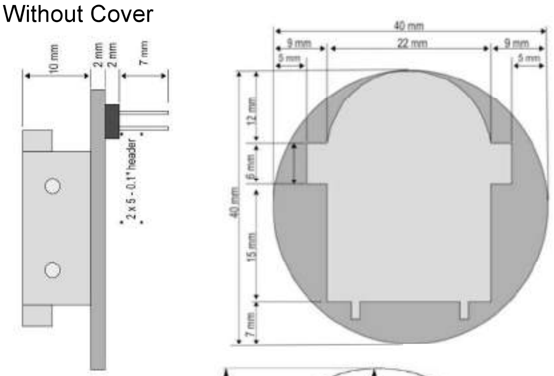
The photo to the right shows the inside of the sensor with the LED emitter and photo detector at the top of the sensor. The yellow line shows the path of the infrared energy inside the sensor. The LED only emits infrared energy at the wavelength that is absorbed by CO_2. As a result any decrease in light getting to the detector relates to how much CO_2 is in the air. Under normal operation the LED flashes 2 times per second but can be made to flash up to 20 times per second.

Dimensions

With Cover



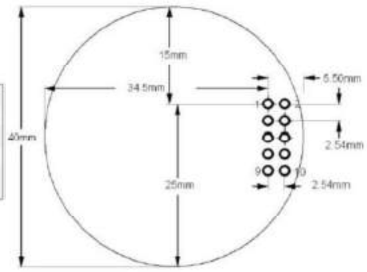
Without Cover



Wiring Connections

1	GND	2	N/C
3	3.3V (Nominal)	4	N/C
5	Rx	6	N/C
7	Tx	8	Nitrogen Zero
9	Analog out (0.1 to 3.3V)	10	Fresh Air Zero

Note: view from connector side with connectors on right



For larger copies of these diagrams use this link:
www.AirTest.com/support/datasheet/COZIR-Adrg.pdf

COZIR Order Codes

Model	ppm Range	Options
COZIR-A	-2000	-X = Standard
	-5000	-V = CO2 Voltage Output (0.1 to 3.3V)
	-1%	-H = Temp & RH (serial output only)
		-E = Extended Temp Range -13 to 131°F (-24 to 55°C)

Example: COZIR-A-2000-V-H-E

Note: The **COZIR-W** will measure up to: 5%, 20%, 60%, 100% CO2
Order the **COZIR-Kit** to connect to a PC (usb cable & software)

Specifications

General

CO_2 Detection Method: Non-Dispersive Infrared Optical Sensor with patented gold plated optics and patented solid-state source and detector.
Sample Method: Diffusion
Transmitter Rated Life: minimum 15 years
Operating Conditions: 32 to 122° F (0 to 50°C), 0 to 95% RH (Standard), -13 to 131°F (-25 to 55°C) (extended range)
Storage Conditions: -22 to 158° F (-30 to 70° C)

Performance

CO_2 Measurement Range: 0-2000 ppm, 0-5000 ppm, 0-1%.
CO_2 Accuracy: +/- 50 ppm +/- 3% of reading.
Non Linearity: < 1% of full scale
Calibration: Automatic calibration built in.
Response Time: 30 seconds to 3 minutes (user configurable via filter type and application. Reading updated twice a second.
Pressure Dependence: 0.13% of reading per mm Hg.
Operating Pressure Range: 950 to 1050 bar.
Minimum Run Time: 10 Seconds on duty-cycle operation

Optional Temperature & Humidity Sensor

Note: Only available as a serial output
Method: RH – Capacitive, Temp – Band-gap
Range: -13 to 131°F (-25 to 55°C), 0 to 95% RH
Resolution: 0.08°C, 0.08% RG
Temp Accuracy: ±1.8°F (1°C) @ 0 to 55°C, ±3.6°F (±2°C) full range,
RH Accuracy: ±3%RH @ 68°C to 131°F (20°C to 55°C), ± 5% full range

Power

Input: 3.25 to 5.5 VDC
Peak Current: 33 mA
Average Current: < 1.5 mA
Power Consumption: 3.5 mW
Wiring Connection: 2 x 5 - 0.1" header

Outputs

Pin Designation: See chart to left
Serial Output: For further details on the serial interface use this link:
www.AirTest.com/support/datasheet/COZIRSerialInterface.pdf
Optional Analog Output: 0-3.3 VDC (CO_2 only). For further details on the serial interface use this link:
www.AirTest.com/support/datasheet/COZIRVout.pdf

Further Reference:

1) EnOcean guide on using a PV cell to power the COZIR and a wireless transmitter off of indoor ambient light.
www.AirTest.com/support/datasheet/EnOceanGSS.pdf

2) Chart showing battery operating life of the COZIR powered on 3 AA batteries based on number of sampling periods per hour. www.AirTest.com/support/datasheet/COZIRBatteryLife.pdf

Distributed By:

2/23/12

AirTest™ Technologies Inc. specializes in the application of cost effective, state-of-the-art air monitoring technology to ensure the comfort, security, health and energy efficiency of buildings.

Sensors That Make Buildings Smart!

Appendix 16

AX-SFEU, AX-SFEU-API

Ultra-Low Power, AT Command / API Controlled, Sigfox® Compliant Transceiver IC for Up-Link and Down-Link

ON Semiconductor®

www.onsemi.com

OVERVIEW

Circuit Description

AX−SFEU and AX−SFEU−API are ultra−low power single chip solutions for a node on the Sigfox network with both up− and down−link functionality. The AX−SFEU chip is delivered fully ready for operation and contains all the necessary firmware to transmit and receive data from the Sigfox network in Europe. It connects to the customer product using a logic level RS232 UART. AT commands are used to send frames and configure radio parameters.

The AX−SFEU−API variant is intended for customers wishing to write their own application software based on the AX−SF−LIB−1−GEVK library.

Features

Functionality and Ecosystem

- Sigfox up−link and down−link functionality controlled by AT commands or API
- The AX−SFEU and AX−SF−API ICs are part of a whole development and product ecosystem available from ON Semiconductor for any Sigfox requirement. Other parts of the ecosystem include
  - Ready to go development kit DVK−SFEU−[API]−1−GEVK including a 2 year Sigfox subscription
  - Sigfox Ready® certified reference design for the AX−SFEU and AX−SFEU−API ICs
  - AX−SF10−MINI21−868−B1 and AX−SF10−ANT21−868−B1, Sigfox compliant SMT modules based on AX−SFEU with 50 Ω pads or chip antenna. Not available for AX−SFEU−API

General Features

- QFN40 5 mm x 7 mm package
- Supply range 2.1 – 3.6 V
- −40°C to 85°C
- Temperature sensor
- Supply voltage measurements
- 10 GPIO pins
  - 4 GPIO pins with selectable voltage measure functionality, differential (1 V or 10 V range) or single ended (1 V range) with 10 bit resolution
  - 2 GPIO pins with selectable sigma delta DAC output functionality
  - 2 GPIO pins with selectable output clock
  - 3 GPIO pins selectable as SPI master interface
  - Integrated RX/TX switching with differential antenna pins

Power Consumption

- Ultra−low Power Consumption:
  - Charge required to send a Sigfox OOB packet at 14 dBm output power: 0.28 C
  - Deep Sleep mode current: 100 nA
  - Sleep mode current: 1.3 μA
  - Standby mode current: 0.5 mA
  - Continuous radio RX−mode at 869.525 MHz : 10 mA
  - Continuous radio TX−mode at 868.130 MHz
19 mA @ 0 dBm
49 mA @ 14 dBm

High Performance Narrow−band Sigfox RF Transceiver

- Receiver
  - Carrier frequency 869.525 MHz
  - Data−rate 600 bps FSK
  - Sensitivity
−126 dBm @ 600 bps, 869.525 MHz, GFSK
  - 0 dBm maximum input power
- Transmitter
  - Carrier frequency 868.13 MHz
  - Data−rate 100 bps PSK
  - High efficiency, high linearity integrated power amplifier
  - Maximum output power 14 dBm
  - Power level programmable in 1 dBm steps

Applications

Sigfox networks up−link and down−link.

© Semiconductor Components Industries, LLC, 2017

April, 2018 − Rev. 8

Publication Order Number:
AX−SFEU/D

BLOCK DIAGRAM

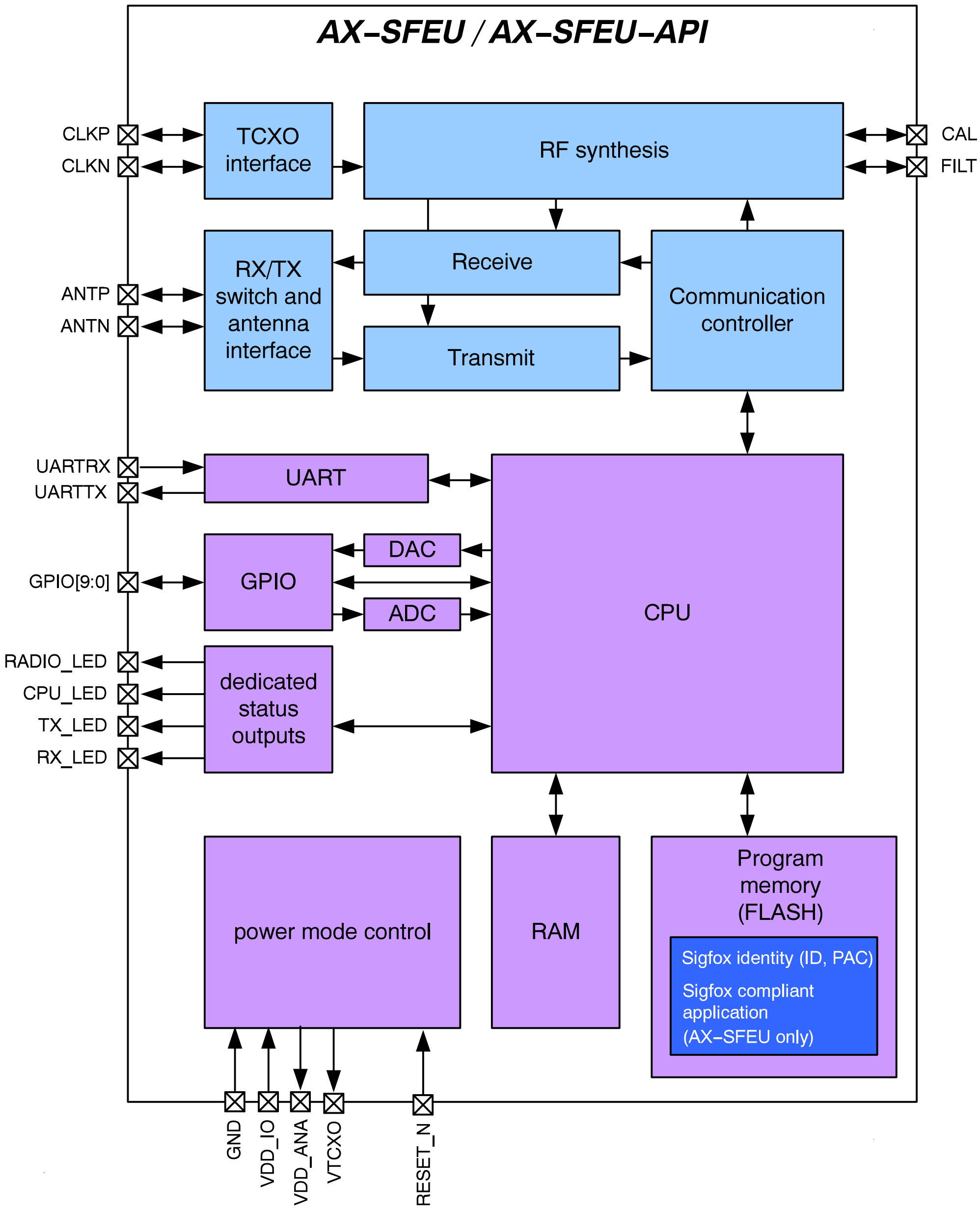


Figure 1. Functional Block Diagram of the AX–SFEU / AX–SFEU–API

Table 1. PIN FUNCTION DESCRIPTIONS

Symbol	Pin(s)	Type	Description
VDD_ANA	1	P	Analog power output, decouple to neighboring GND
GND	2	P	Ground, decouple to neighboring VDD_ANA
ANTP	3	A	Differential antenna input/output
ANTN	4	A	Differential antenna input/output
NC	5	N	Do not connect
GND	6	P	Ground, decouple to neighboring VDD_ANA
VDD_ANA	7	P	Analog power output, decouple to neighboring GND
GND	8	P	Ground
FILT	9	A	Synthesizer filter
L2	10	A	Must be connected to pin L1
L1	11	A	Must be connected to pin L2
NC	12	N	Do not connect
GPIO8	13	I/O/PU	General purpose IO
GPIO7	14	I/O/PU	General purpose IO, selectable SPI functionality (MISO)
GPIO6	15	I/O/PU	General purpose IO, selectable SPI functionality (MOSI)
GPIO5	16	I/O/PU	General purpose IO, selectable SPI functionality (SCK)
GPIO4	17	I/O/PU	General purpose IO, selectable ΣΔ DAC functionality, selectable clock functionality
CPU_LED	18	O	CPU activity indicator
RADIO_LED	19	O	Radio activity indicator
VTCXO	20	O	TCXO power
GPIO9	21	I/O/PU	General purpose IO, wakeup from deep sleep
UARTTX	22	O	UART transmit
UARTRX	23	I/PU	UART receive
RXLED/ DBG_DATA	24	O I/O	Receive activity indicator in AX-SFEU Debugger data line in AX-SFEU-API
TXLED/ DBG_CLK	25	O I	Transmit activity indicator in AX-SFEU Debugger clock line in AX-SFEU-API
NC/ DBG_EN	26	PD PD	Do not connect in AX-SFEU Debugger enable line in AX-SFEU-API
RESET_N	27	I/PU	Optional reset pin. Internal pull-up resistor is permanently enabled, nevertheless it is recommended to connect this pin to VDD_IO if it is not used
GND	28	P	Ground
VDD_IO	29	P	Unregulated power supply
GPIO0	30	I/O/A/PU	General purpose IO, selectable ADC functionality, selectable ΣΔ DAC functionality, selectable clock functionality
GPIO1	31	I/O/A/PU	General purpose IO, selectable ADC functionality
GPIO2	32	I/O/A/PU	General purpose IO, selectable ADC functionality
NC	33	N	Do not connect
NC	34	N	Do not connect
GPIO3	35	I/O/A/PU	General purpose IO, selectable ADC functionality
VDD_IO	36	P	Unregulated power supply
CAL	37	A	Connect to FILT as shown in the application diagram
NC	38	N	Do not connect

Table 1. PIN FUNCTION DESCRIPTIONS

Symbol	Pin(s)	Type	Description
CLKN	39	A	TCXO interface
CLKP	40	A	TCXO interface
GND	Center pad	P	Ground on center pad of QFN, must be connected

A = analog
I = digital input signal
O = digital output signal
PU = pull−up
I/O = digital input/output signal
N = not to be connected
P = power or ground
PD = pull−down

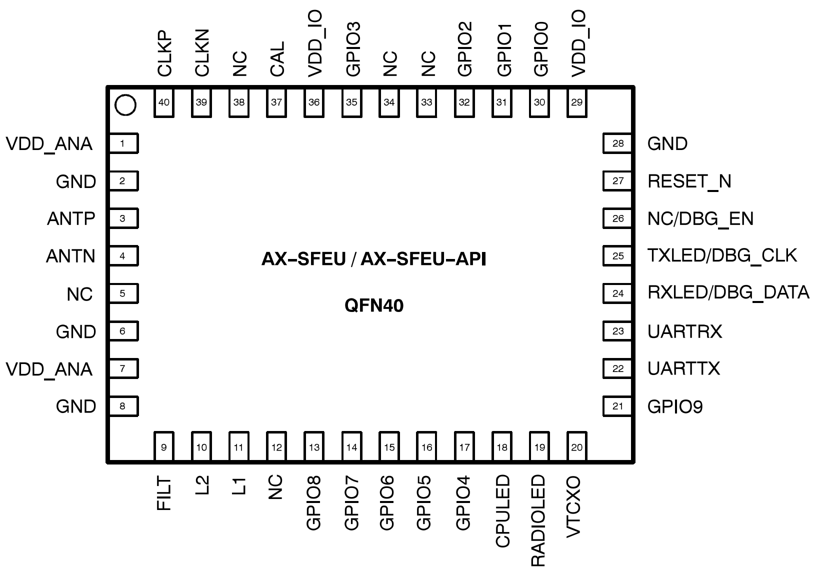
All digital inputs are Schmitt trigger inputs, digital input and output levels are LVCMOS/LVTTL compatible. Pins GPIO[3:0] must not be driven above VDD_IO, all other digital inputs are 5 V tolerant. All GPIO pins and UARTRX start up as input with pull−up. For explanations on how to use the GPIO pins, see chapter “AT Commands”.

Table 2.

Pin	Possible GPIO Modes
GPIO0	0, 1, Z, U, A, T
GPIO1	0, 1, Z, U, A
GPIO2	0, 1, Z, U, A
GPIO3	0, 1, Z, U, A
GPIO4	0, 1, Z, U, T
GPIO5	0, 1, Z, U
GPIO6	0, 1, Z, U
GPIO7	0, 1, Z, U
GPIO8	0, 1, Z, U
GPIO9	0, 1, Z, U

0 = pin drives low
1 = pin drives high
A = pin is analog input
T = pin is driven by clock or DAC
U = pin is input with pull−up
Z = pin is high impedance input

Pinout Drawing



NOTE: Pins 24−26 have different functionalities in AT command and API versions, so for these pins AX−SFEU/AX−SFEU−API explanations are shown respectively.

Figure 2. Pinout Drawing (Top View)

SPECIFICATIONS

Table 3. ABSOLUTE MAXIMUM RATINGS

Symbol	Description	Condition	Min	Max	Units
VDD_IO	Supply voltage		−0.5	5.5	V
IDD	Supply current			200	mA
P_{tot}	Total power consumption			800	mW
P_i	Absolute maximum input power at receiver input	ANTP and ANTN pins in RX mode		10	dBm
I_{I1}	DC current into any pin except ANTP, ANTN		−10	10	mA
I_{I2}	DC current into pins ANTP, ANTN		−100	100	mA
I_O	Output Current			40	mA
V_{ia}	Input voltage ANTP, ANTN pins		−0.5	5.5	V
	Input voltage digital pins		−0.5	5.5	V
V_{es}	Electrostatic handling	HBM	−2000	2000	V
T_{amb}	Operating temperature		−40	85	°C
T_{stg}	Storage temperature		−65	150	°C
T_j	Junction Temperature			150	°C

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.

1. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

DC Characteristics

Table 4. SUPPLIES

Conditions for all current and charge values unless otherwise specified are for the hardware configuration described in the AX−SFEU Application Note: Sigfox Compliant Reference Design.

Symbol	Description	Condition	Min	Typ	Max	Units
T_{AMB}	Operational ambient temperature		−40	27	85	°C
VDD_{IO}	I/O and voltage regulator supply voltage		2.1	3.0	3.6	V
VDD_{IO_R1}	I/O voltage ramp for reset activation	Ramp starts at VDD_IO ≤ 0.1 V	0.1			V/ms
VDD_{IO_R2}	I/O voltage ramp for reset activation	Ramp starts at 0.1 V < VDD_IO < 0.7 V	3.3			V/ms
I_{DS}	Deep sleep mode current	AT$P=2		100		nA
I_{SLP}	Sleep mode current	AT$P=1		1.3		μA
I_{STDBY}	Standby mode current Note 2			0.5		mA
I_{RX_CONT}	Current consumption continuous RX	AT$SE		10		mA
$Q_{SFX\_OOB\_0}$	Charge to send a Sigfox out of band message, 0 dBm	AT$S0		0.12		C
$Q_{SFX\_BIT\_0}$	Charge to send a bit, 0 dBm	AT$SB=0		0.08		C
$Q_{SFX\_BITDL\_0}$	Charge to send a bit with downlink receive, 0 dBm	AT$SB=0,1		0.27		C
$Q_{SFX\_LFR\_0}$	Charge to send the longest possible Sigfox frame (12 byte) , 0dBm	AT$SF=00112233445566778899aabb		0.14		C
$Q_{SFX\_LFRDL\_0}$	Charge to send the longest possible Sigfox frame (12 byte) with downlink receive, 0 dBm	AT$SF=00112233445566778899aabb,1		0.27		C
$Q_{SFX\_OOB\_14}$	Charge to send a Sigfox out of band message, 14 dBm	AT$S0		0.28		C
$Q_{SFX\_BIT\_14}$	Charge to send a bit, 14 dBm	AT$SB=0		0.20		C
$Q_{SFX\_BITDL\_14}$	Charge to send a bit with downlink receive, 14 dBm	AT$SB=0,1		0.35		C
$Q_{SFX\_LFR\_14}$	Charge to send the longest possible Sigfox frame (12 byte) , 14 dBm	AT$SF=00112233445566778899aabb		0.39		C
$Q_{SFX\_LFRDL\_14}$	Charge to send the longest possible Sigfox frame (12 byte) with downlink receive, 14 dBm	AT$SF=00112233445566778899aabb,1		0.46		C
$I_{TXMOD0AVG}$	Modulated Transmitter Current, Note 1	Pout=0 dBm; average		19.0		mA
$I_{TXMOD14AVG}$	Modulated Transmitter Current, Note 1	Pout=14 dBm; average		49.0		mA

1. The output power of the AX−SFEU / AX−SFEU−API can be programmed in 1 dB steps from 0 dBm – 14 dBm. Current consumption values are given for a matching network that is optimized for 14 dBm output. 0 dBm transmission with typically 10 mA can be achieved with other networks that are optimized for 0 dBm operation.
2. Internal 20 MHz oscillator, voltage conditioning and supervisory circuit running.

Appendix 17

Datasheet

RL78/G12

RENESAS MCU

R01DS0193EJ0210
Rev.2.10
Mar 25, 2016

True Low Power Platform (as low as 63 µA/MHz), 1.8V to 5.5V operation,
2 to 16 Kbyte Flash, 31 DMIPS at 24MHz, for General Purpose Applications

1. OUTLINE

1.1 Features

Ultra-low power consumption technology
- V_{DD} = single power supply voltage of 1.8 to 5.5 V which can operate at a low voltage
- HALT mode
- STOP mode
- SNOOZE mode

RL78 CPU core
- CISC architecture with 3-stage pipeline
- Minimum instruction execution time: Can be changed from high speed (0.04167 µs: @ 24 MHz operation with high-speed on-chip oscillator) to ultra-low speed (1 µs: @ 1 MHz operation)
- Address space: 1 MB
- General-purpose registers: (8-bit register x 8) x 4 banks
- On-chip RAM: 256 B to 2 KB

Code flash memory
- Code flash memory: 2 to 16 KB
- Block size: 1 KB
- Prohibition of block erase and rewriting (security function)
- On-chip debug function
- Self-programming (with flash shield window function)

Data flash memory Note
- Data flash memory: 2 KB
- Back ground operation (BGO): Instructions are executed from the program memory while rewriting the data flash memory.
- Number of rewrites: 1,000,000 times (TYP.)
- Voltage of rewrites: V_{DD} = 1.8 to 5.5 V

High-speed on-chip oscillator
- Select from 24 MHz, 16 MHz, 12 MHz, 8 MHz, 6 MHz, 4 MHz, 3 MHz, 2 MHz, and 1 MHz
- High accuracy: +/- 1.0 % (V_{DD} = 1.8 to 5.5 V, T_A = -20 to +85 °C)

Operating ambient temperature
- T_A = -40 to +85 °C (A: Consumer applications, D: Industrial applications)
- T_A = -40 to +105 °C (G: Industrial applications) Note

Power management and reset function
- On-chip power-on-reset (POR) circuit
- On-chip voltage detector (LVD) (Select interrupt and reset from 12 levels)

DMA (Direct Memory Access) controller Note
- 2 channels
- Number of clocks during transfer between 8/16-bit SFR and internal RAM: 2 clocks

Multiplier and divider/multiply-accumulator
- 16 bits x 16 bits = 32 bits (Unsigned or signed)
- 32 bits x 32 bits = 32 bits (Unsigned)
- 16 bits x 16 bits + 32 bits = 32 bits (Unsigned or signed)

Serial interface
- CSI : 1 to 3 channels
- UART : 1 to 3 channels
- Simplified I^2C communication : 0 to 3 channels
- I^2C communication : 1 channel

Timer
- 16-bit timer : 4 to 8 channels
- 12-bit interval timer : 1 channel
- Watchdog timer : 1 channel (operable with the dedicated low-speed on-chip oscillator)

A/D converter
- 8/10-bit resolution A/D converter (V_{DD} = 1.8 to 5.5 V)
- 8 to 11 channels, internal reference voltage (1.45 V), and temperature sensor Note

I/O port
- I/O port: 18 to 26
  (N-ch open drain I/O [withstand voltage of 6 V]: 2, N-ch open drain I/O [V_{DD} withstand voltage]: 4 to 9)
- Can be set to N-ch open drain, TTL input buffer, and on-chip pull-up resistor
- Different potential interface: Can connect to a 1.8/2.5/3 V device
- On-chip key interrupt function
- On-chip clock output/buzzer output controller

Others
- On-chip BCD (binary-coded decimal) correction circuit

Note Can be selected only in HS (high-speed main) mode.

Remark The functions mounted depend on the product. See 1.7 Outline of Functions.

*** There is difference in specifications between every product. Please refer to specification for details.**

Downloaded from Arrow.com.

2.3.2 Supply current characteristics

(1) 20-, 24-pin products

(T_A = –40 to +85°C, 1.8 V ≤ V_{DD} ≤ 5.5 V, V_{SS} = 0 V) **(1/2)**

Parameter	Symbol	Conditions					MIN.	TYP.	MAX.	Unit
Supply current[Note 1]	I_{DD1}	Operating mode	HS(High-speed main) mode[Note 4]	f_{IH} = 24 MHz[Note 3]	Basic operation	V_{DD} = 5.0 V		1.5		mA
						V_{DD} = 3.0 V		1.5		
					Normal operation	V_{DD} = 5.0 V		3.3	5.0	mA
						V_{DD} = 3.0 V		3.3	5.0	
				f_{IH} = 16 MHz[Note 3]		V_{DD} = 5.0 V		2.5	3.7	mA
						V_{DD} = 3.0 V		2.5	3.7	
			LS(Low-speed main) mode[Note 4]	f_{IH} = 8 MHz[Note 3]		V_{DD} = 3.0 V		1.2	1.8	mA
						V_{DD} = 2.0 V		1.2	1.8	
			HS(High-speed main) mode[Note 4]	f_{MX} = 20 MHz[Note 2], V_{DD} = 5.0 V		Square wave input		2.8	4.4	mA
						Resonator connection		3.0	4.6	
				f_{MX} = 20 MHz[Note 2], V_{DD} = 3.0 V		Square wave input		2.8	4.4	mA
						Resonator connection		3.0	4.6	
				f_{MX} = 10 MHz[Note 2], V_{DD} = 5.0 V		Square wave input		1.8	2.6	mA
						Resonator connection		1.8	2.6	
				f_{MX} = 10 MHz[Note 2], V_{DD} = 3.0 V		Square wave input		1.8	2.6	mA
						Resonator connection		1.8	2.6	
			LS(Low-speed main) mode[Note 4]	f_{MX} = 8 MHz[Note 2], V_{DD} = 3.0 V		Square wave input		1.1	1.7	mA
						Resonator connection		1.1	1.7	
				f_{MX} = 8 MHz[Note 2], V_{DD} = 2.0 V		Square wave input		1.1	1.7	mA
						Resonator connection		1.1	1.7	

Notes 1. Total current flowing into V_{DD}, including the input leakage current flowing when the level of the input pin is fixed to V_{DD} or V_{SS}. The values below the MAX. column include the peripheral operation current. However, not including the current flowing into the A/D converter, LVD circuit, I/O port, and on-chip pull-up/pull-down resistors and the current flowing during data flash rewrite.

2. When high-speed on-chip oscillator clock is stopped.

3. When high-speed system clock is stopped

4. Relationship between operation voltage width, operation frequency of CPU and operation mode is as follows.

HS(High speed main) mode: V_{DD} = 2.7 V to 5.5 V @1 MHz to 24 MHz
V_{DD} = 2.4 V to 5.5 V @1 MHz to 16 MHz

LS(Low speed main) mode: V_{DD} = 1.8 V to 5.5 V @1 MHz to 8 MHz

Remarks 1. f_{MX}: High-speed system clock frequency (X1 clock oscillation frequency or external main system clock frequency)

2. f_{IH}: high-speed on-chip oscillator clock frequency

3. Temperature condition of the TYP. value is T_A = 25°C.

Downloaded from Arrow.com.

(1) 20-, 24-pin products

(T_A = –40 to +85°C, 1.8 V ≤ V_{DD} ≤ 5.5 V, V_{SS} = 0 V) **(2/2)**

Parameter	Symbol	Conditions				MIN.	TYP.	MAX.	Unit
Supply current [Note 1]	I_{DD2} [Note 2]	HALT mode	HS (High-speed main) mode [Note 6]	f_{IH} = 24 MHz [Note 4]	V_{DD} = 5.0 V		440	1210	μA
					V_{DD} = 3.0 V		440	1210	
				f_{IH} = 16 MHz [Note 4]	V_{DD} = 5.0 V		400	950	μA
					V_{DD} = 3.0 V		400	950	
			LS (Low-speed main) mode [Note 6]	f_{IH} = 8 MHz [Note 4]	V_{DD} = 3.0 V		270	542	μA
					V_{DD} = 2.0 V		270	542	
			HS (High-speed main) mode [Note 6]	f_{MX} = 20 MHz [Note 3], V_{DD} = 5.0 V	Square wave input		280	1000	μA
					Resonator connection		450	1170	
				f_{MX} = 20 MHz [Note 3], V_{DD} = 3.0 V	Square wave input		280	1000	μA
					Resonator connection		450	1170	
				f_{MX} = 10 MHz [Note 3], V_{DD} = 5.0 V	Square wave input		190	590	μA
					Resonator connection		260	660	
				f_{MX} = 10 MHz [Note 3], V_{DD} = 3.0 V	Square wave input		190	590	μA
					Resonator connection		260	660	
			LS (Low-speed main) mode [Note 6]	f_{MX} = 8 MHz [Note 3], V_{DD} = 3.0 V	Square wave input		110	360	μA
					Resonator connection		150	416	
				f_{MX} = 8 MHz [Note 3], V_{DD} = 2.0 V	Square wave input		110	360	μA
					Resonator connection		150	416	
	I_{DD3} [Note 5]	STOP mode	T_A = –40°C				0.19	0.50	μA
			T_A = +25°C				0.24	0.50	
			T_A = +50°C				0.32	0.80	
			T_A = +70°C				0.48	1.20	
			T_A = +85°C				0.74	2.20	

Notes 1. Total current flowing into V_{DD}, including the input leakage current flowing when the level of the input pin is fixed to V_{DD} or V_{SS}. The values below the MAX. column include the peripheral operation current. However, not including the current flowing into the A/D converter, LVD circuit, I/O port, and on-chip pull-up/pull-down resistors and the current flowing during data flash rewrite.

2. During HALT instruction execution by flash memory.

3. When high-speed on-chip oscillator clock is stopped.

4. When high-speed system clock is stopped.

5. Not including the current flowing into the 12-bit interval timer and watchdog timer.

6. Relationship between operation voltage width, operation frequency of CPU and operation mode is as follows.

HS(High speed main) mode: V_{DD} = 2.7 V to 5.5 V @1 MHz to 24 MHz
V_{DD} = 2.4 V to 5.5 V @1 MHz to 16 MHz

LS(Low speed main) mode: V_{DD} = 1.8 V to 5.5 V @1 MHz to 8 MHz

Remarks 1. f_{MX}: High-speed system clock frequency (X1 clock oscillation frequency or external main system clock frequency)

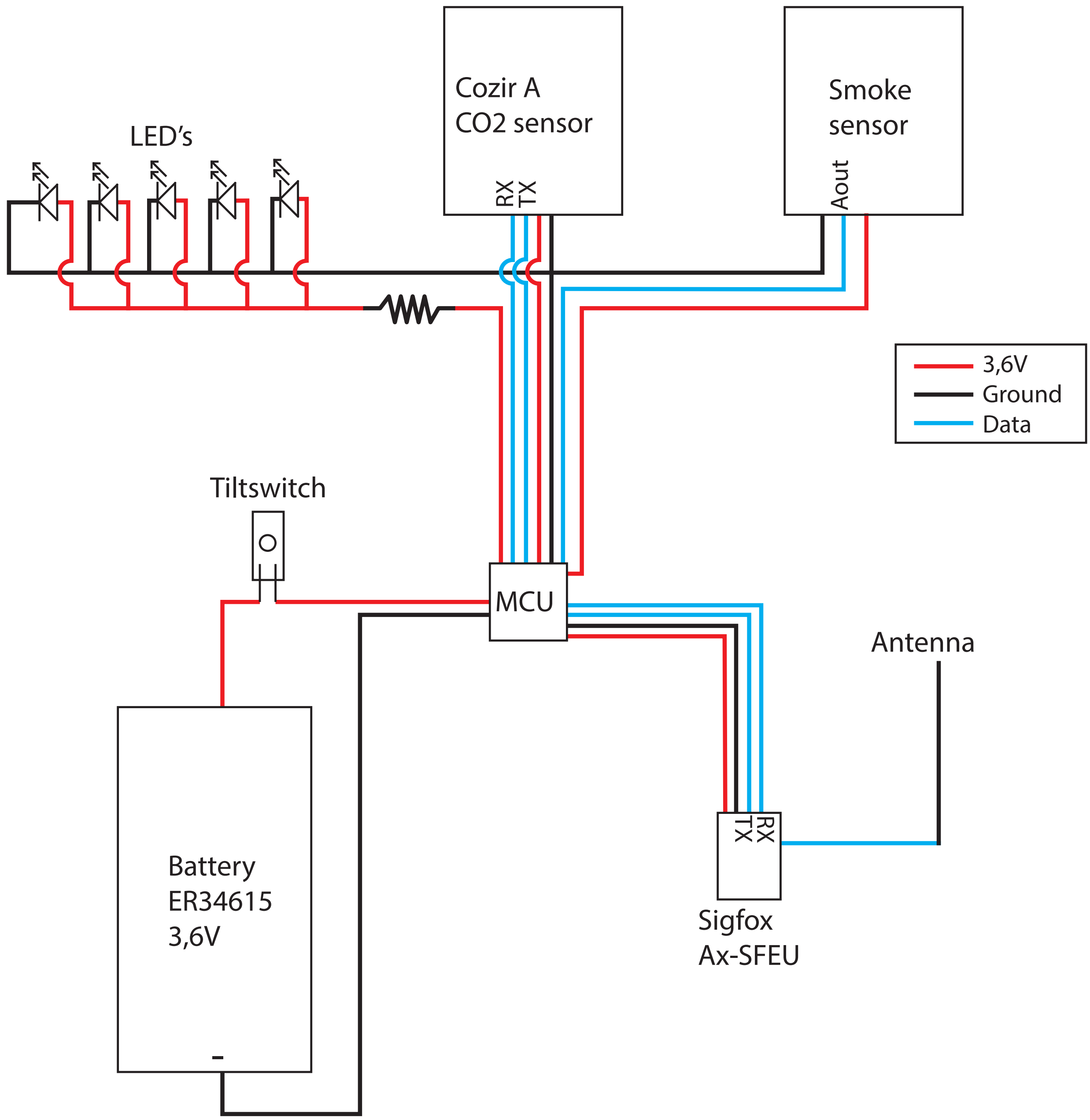
2. f_{IH}: high-speed on-chip oscillator clock frequency

3. Except temperature condition of the TYP. value is T_A = 25°C, other than STOP mode

RENESAS

Downloaded from Arrow.com.

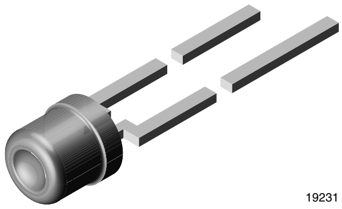
Appendix 18



Cozir A
CO2 sensor
RX
TX
Smoke
sensor
Aout
LED's
3,6V
Ground
Data
Tiltswitch
MCU
Antenna
RX
TX
Battery
ER34615
3,6V
-
Sigfox
Ax-SFEU

Appendix 19

Backlighting LED, Ø 3 mm Tinted Non-Diffused Package



19231

DESCRIPTION

The TLV.420. series was developed for backlighting. Due to its special shape the spatial distribution of the radiation is qualified for backlighting.

To optimize the brightness of backlighting a custom-built reflector (with scattering) is required. Uniform illumination can be enhanced by covering the front of the reflector with diffusor material.

This is a flexible solution for backlighting different areas.

PRODUCT GROUP AND PACKAGE DATA

- Product group: LED
- Package: 3 mm backlighting
- Product series: standard
- Angle of half intensity: ± 85°

FEATURES

- High light output
- Wide viewing angle
- Categorized for luminous flux
- Tinted clear package
- Low power dissipation
- Low self heating
- Rugged design
- High reliability
- Material categorization: for definitions of compliance please see www.vishay.com/doc?99912

APPLICATIONS

- Backlighting of display panels, LCD displays, symbols on switches, keyboards, graphic boards, and measuring scales
- Illumination of large areas e.g. dot matrix displays

PARTS TABLE

PART	COLOR	LUMINOUS FLUX (mlm)			at I_F (mA)	WAVELENGTH (nm)			at I_F (mA)	FORWARD VOLTAGE (V)			at I_F (mA)	TECHNOLOGY
		MIN.	TYP.	MAX.		MIN.	TYP.	MAX.		MIN.	TYP.	MAX.		
TLVH42N2Q2	Red	35.5	-	112	15	612	-	625	10	-	2.4	3.0	20	GaAsP on GaP

ABSOLUTE MAXIMUM RATINGS (T_{amb} = 25 °C, unless otherwise specified)
TLVH42N2Q2

PARAMETER	TEST CONDITION	SYMBOL	VALUE	UNIT
Reverse voltage (1)		V_R	6	V
DC forward current	$T_{amb} \leq 60$ °C	I_F	30	mA
Surge forward current	$t_p \leq 10$ µs	I_{FSM}	1	A
Power dissipation		P_V	90	mW
Junction temperature		T_j	100	°C
Operating temperature range		T_{amb}	-40 to +100	°C
Storage temperature range		T_{stg}	-55 to +100	°C
Soldering temperature	t ≤ 5 s, 2 mm from body	T_{sd}	260	°C
Thermal resistance junction/ambient		R_{thJA}	400	K/W

Note

(1) Driving the LED in reverse direction is suitable for a short term application

For technical questions, contact: LED@vishay.com
THIS DOCUMENT IS SUBJECT TO CHANGE WITHOUT NOTICE. THE PRODUCTS DESCRIBED HEREIN AND THIS DOCUMENT ARE SUBJECT TO SPECIFIC DISCLAIMERS, SET FORTH AT www.vishay.com/doc?91000

OPTICAL AND ELECTRICAL CHARACTERISTICS (T_{amb} = 25 °C, unless otherwise specified) **TLVH42N2Q2, RED**						
PARAMETER	**TEST CONDITION**	**SYMBOL**	**MIN.**	**TYP.**	**MAX.**	**UNIT**
Luminous flux	I_F = 15 mA	ϕ_V	35.5	-	112	mlm
Dominant wavelength	I_F = 10 mA	λ_d	612	-	625	nm
Peak wavelength	I_F = 10 mA	λ_p	-	635	-	nm
Angle of half intensity	I_F = 10 mA	φ	-	± 85	-	deg
Forward voltage	I_F = 20 mA	V_F	-	2.4	3.0	V
Reverse voltage	I_R = 10 μA	V_R	6	12	-	V
Junction capacitance	V_R = 0 V, f = 1 MHz	C_j	-	50	-	pF

LUMINOUS FLUX CLASSIFICATION		
GROUP	**LUMINOUS FLUX (mlm)**	
STANDARD	**MIN.**	**MAX.**
N2	35.5	45
P1	45	56
P2	56	71
Q1	71	90
Q2	90	112

Note

- Luminous flux is tested at a current pulse duration of 25 ms and an accuracy of ± 11 %.
  The above type numbers represent the order groups which include only a few brightness groups. Only one group will be shipped on each bag (there will be no mixing of two groups in each bag).
  In order to ensure availability, single brightness groups will not be orderable.

TYPICAL CHARACTERISTICS (T_{amb} = 25 °C, unless otherwise specified)

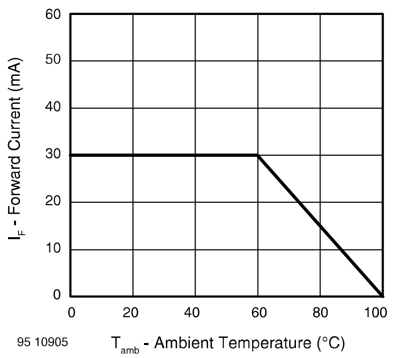


Fig. 1 - Forward Current vs. Ambient Temperature

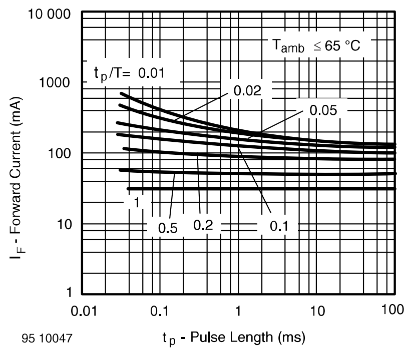


Fig. 2 - Forward Current vs. Pulse Length

THIS DOCUMENT IS SUBJECT TO CHANGE WITHOUT NOTICE. THE PRODUCTS DESCRIBED HEREIN AND THIS DOCUMENT ARE SUBJECT TO SPECIFIC DISCLAIMERS, SET FORTH AT www.vishay.com/doc?91000

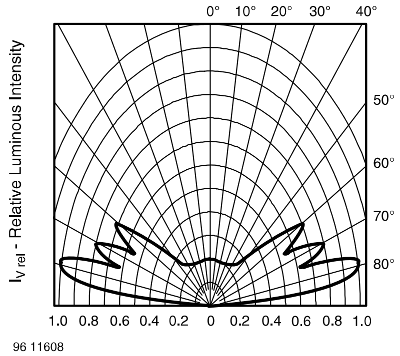


Fig. 3 - Relative Luminous Intensity vs. Angular Displacement for 90° Emission Angle

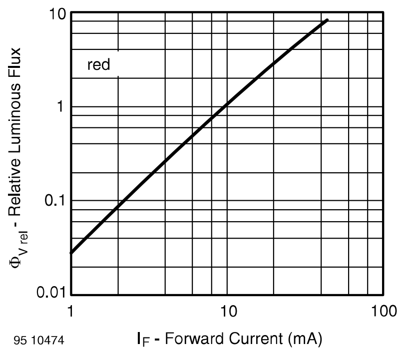


Fig. 6 - Relative Luminous Flux vs. Forward Current

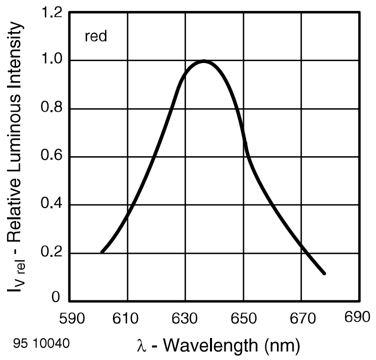


Fig. 4 - Relative Intensity vs. Wavelength

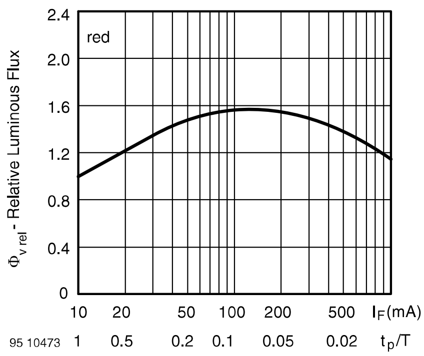


Fig. 7 - Relative Luminous Flux vs. Forward Current/Duty Cycle

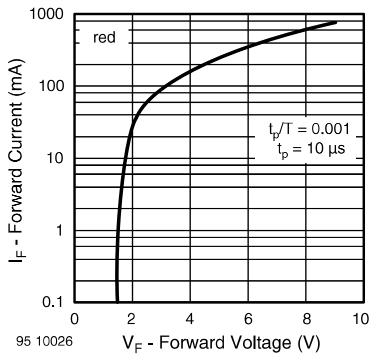


Fig. 5 - Forward Current vs. Forward Voltage

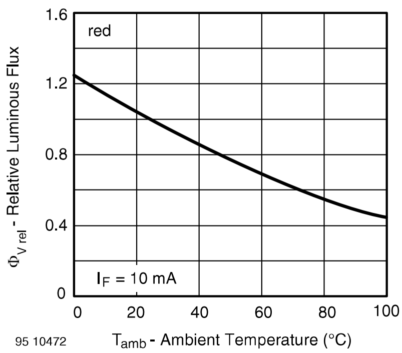
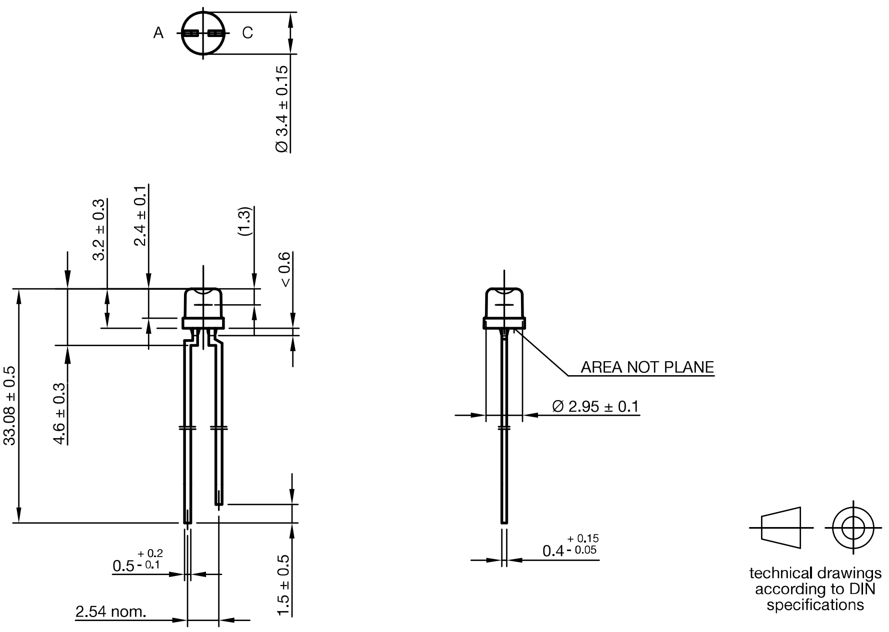


Fig. 8 - Relative Luminous Flux vs. Ambient Temperature

THIS DOCUMENT IS SUBJECT TO CHANGE WITHOUT NOTICE. THE PRODUCTS DESCRIBED HEREIN AND THIS DOCUMENT ARE SUBJECT TO SPECIFIC DISCLAIMERS, SET FORTH AT www.vishay.com/doc?91000

PACKAGE DIMENSIONS in millimeters



Drawing-No.: 6.544-5268.01-4
Issue: 3; 28.07.14

THIS DOCUMENT IS SUBJECT TO CHANGE WITHOUT NOTICE. THE PRODUCTS DESCRIBED HEREIN AND THIS DOCUMENT
ARE SUBJECT TO SPECIFIC DISCLAIMERS, SET FORTH AT www.vishay.com/doc?91000

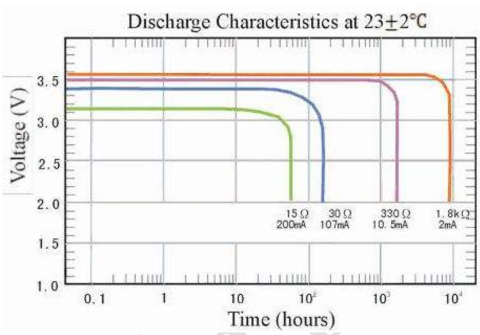
Appendix 20

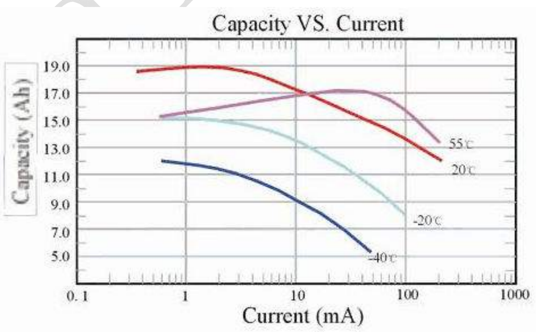
蓝泰阳
BLUE TAIYANG

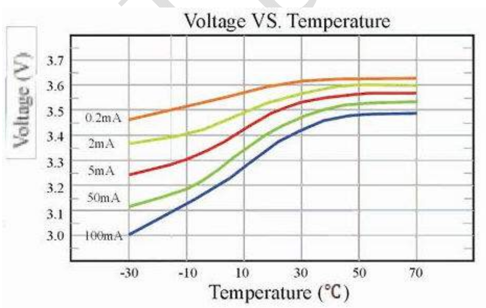
BASIC SPECIFICATIONS:

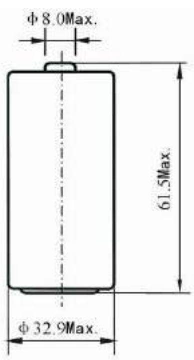
No.	Item	Specifications
1	Model	ER34615H
2	Nominal voltage	3.6V
3	Nominal capacity	**19000mAh**(At 1.0mA, +25℃ 2.0V cut off. The capacity restored by the cell varies according to current drain, temperature and cut-off,For more severe conditions,consult Blue Taiyang.)
4	Max. constant current	230mAh
5	Max. pulse current	400mAh
6	Operating temperature range	-60℃~+85℃(-76℉~+185℉)
7	Nominal weight	105.0g
8	Dimension(Φ*H*Φ1)	Φ34.0*61.5*8.0mm

ELECTRICAL CHARACTERISTICS:









www.bluetaiyang.com

Appendix 21

Risk calculation

Risk of burning a specific hectare, national

129,9	m2/sensor unit
converting to ha/unit	
129,9 m2/unit /10000	
0,01299	ha/unit
107.717,65	ha average burned in Portugal
3.182.000,00	ha forest in Portugal
107717/3182000	
3,39%	Anual risk of burning a hectare, national average

Number of sensors

1 ha/0,01299 ha/unit	
76,98	unit per hectare
76,98… * 3182000 ha	Sensors pr ha * ha in Portugal
244.957.659,74	Units to cover all the Portuguese forest (optimal placement)
245 mil. units	

Risk of burning a sensor

3,39%/ha * 76,98 sensors/ha	risk of burning 1 ha * sensors / ha
2,61	average sensors burned per hectare per year (national avg.)
2,61 burned/ha /76,98 sensors	
3,39%	sensors burned per year

Risk of a sensor burning over 10 years

1-3,39%	
96,61%	Chance of NOT burning
96,61%^10	
70,9%	Chance of NOT burning over 10 years
29,1%	**Risk that the sensor will burn in its 10 year lifespan**
3,39% * 245 mil. units	
8.292.351,58	**Average number of burnerd units each year**

Appendix 22

Development phase

Information about the company

Workers	Number	Salary/hour		Total hours in period pr. year
Production worker	2	€	27,00	3848,00
Developers	2	€	70,00	3848,00
Software engineer	1	€	70,00	1924,00
Marketing/spokes person	1	€	70,00	1924,00
Accountant	1	€	70,00	962,00
Total	7	€	350,00	12506,00

Expenses

Inhouse

Marketing/spokes person	1	€	70,00
Accountant	1	€	70,00
Total	7	€	350,00

Expenses

Inhouse

Assembly

Sensor unit

Name	Time (sec)	Cost (€)/unit	
Upload code to MCU	8	€	0,06
Insert metal plates	8	€	0,06
Insert steel mesh	15	€	0,11
Fill in Mounting mechanisem	6	€	0,05
Insert Sensor board	15	€	0,11
Insert Main board	10	€	0,08
Insert battery casing	16	€	0,12
Insert battery	2	€	0,02
Close casing	15	€	0,11
Cut velcro	2	€	0,02
Attach velcro to case	10	€	0,08
Mounting mechanism			
Cut velcro	3	€	0,02
Attach velcro	15	€	0,11
Attach grip to spring steel	10	€	0,08
Insert axle into coil	2	€	0,02
Attach spring steel to coil	30	€	0,23
Attach axle to plates	4	€	0,03
Total	171	€	1,28

Mounting stick

Name	Time (sec)	Cost (€)/unit	
Attach magnets to mount	10	€	0,08
Total	10	€	0,08

Quality testing for every: 1 unit

Sensor unit

Name	Time (sec)	Cost (€)/unit	
Mounting mechanism	10	€	0,08
Connectivity	10	€	0,08
Sensors	13	€	0,10
Total	33	€	0,25

Mounting stick

Name	Time (sec)	Cost (€)/unit	
Pole	12	€	0,09
Mount	10	€	0,19
Total	22	€	0,28

Packaging

System

Name	Time (sec)	Cost (€)/unit	
Mounting stick	10	€	0,19
Sensor units	3	€	0,06
Total	13	€	0,25

Packaging

System

Name	Time (sec)	Cost (€)/unit
Mounting stick	10	€ 0,19
Sensor units	3	€ 0,06
Total	13	€ 0,25

Development

Marketing

Name	Time (hours)	Cost (€)
Flyers	8	€ 560,0
Posters	5	€ 350,0
T-shirts	4	€ 280,0
Hats	2	€ 140,0
Catificate	2	€ 140,0
Stickers	2	€ 140,0
Keynote	14	€ 980,0
Total	37	€ 2.590,0

Codeing

Name	Time (hours)	Cost (€)
The sensor unit	20	€ 1.400,0
The server	80	€ 5.600,0
Interface		
Webcontroller	80	€ 5.600,0
Setup-app	80	€ 5.600,0
Total	20	€ 18.200,0

Print board layout architecture

Name	Time (hours)	Cost (€)
Sensor board	5	€ 350,0
Main print boar	8	€ 560,0
Total	13	€ 910,0

Mounting stick

Name	Time (hours)	Cost (€)
Telescope hand	8	€ 560,0
Mount	24	€ 1.680,0
Total	32	€ 2.240,0

Packaging

Name	Time (hours)	Cost (€)
Mounting stick	5	€ 350,0
Sensor unit	5	€ 350,0
System (1 ha)	7	€ 490,0
System (1/4 ha)	3	€ 210,0
Total	20	€ 1.400,0

Manuals

Name	Time (hours)	Cost (€)
Quick guide	5	€ 350,0
Manual	10	€ 700,0
Guarantee pape	2	€ 140,0
Total	25	€ 1.190,0

Marketing

Fair (3)

Name	Time (hours)	Cost (€)
Attending fee	N/A	€ 450,00
Food/hotel/trans	N/A	€ 900,00
Salery	24	€ 5.040,00
Total	24	€ 6.390,00

Awardshow (2)

Name	Time (hours)	Cost (€)
Attending fee	N/A	€ 1.000,00
Food/hotel/trans	N/A	€ 600,00
Salery	24	€ 3.360,00
Total	24	€ 4.960,00

Website

Name	Time (hours)	Cost (€)
Build/Design	40	€ 2.800,00
Total	40	€ 2.800,00

Fundraising sites

Name	Time (hours)	Cost (€)
Setup	5	€ 350,00
Total	5	€ 350,00

Testing

Sensor unit		
Name	**Time (hours)**	**Cost (€)**
Salery	320	€ 22.400,00
Travel	N/A	€ 6.000,00
Prototypes (3)	N/A	€ 1.500,00
Materials	N/A	€ 200,00
Food/hotel/tra	N/A	€ 800,00
Total	320	€ 30.100,00

Outsourced

Production

Casing			
Name	**Description**	**Amount**	**Cost**
Injection molding front (pvc)	0,05kg	1	€ 0,50
Injection molding back (pvc)	0,02 kg	1	€ 0,50
Injection molding plates (pvc)	0,004 kg	3	€ 0,25
Metal plate 1	Cut and bend	1	€ 0,05
Metal plate 2	Cut and bend	1	€ 0,05
Velcro (1000 mm)	Cut	1	€ 3,00
Steel Mesh top	0,1 mm thick	1	€ 0,08
Steel Mesh bottum	0,1 mm thick	1	€ 0,01
Total			€ 4,86

Main circuit board			
Name	**Description**	**Amount**	**Cost at 1+ units**
Fixed costs pr. unit			
Initial start fee		1	€ 718,00
fee pr. unit	Salary	1	€ 2,00
Components pr. unit			
N/A	Circuit board	1	€ 1,00
RL78/G12	Microcontroller	1	€ 0,50
Ax-SFEU	SigFox transmitter	1	€ 1,63
SW520	Tilt swich	1	€ 0,02
SOZ-0918V-3S	Antenna	1	€ 0,45
N/A	Resistors, wiring, etc.)	1	€ 0,40
Total (ekcl. Start fee)			€ 6,00

Sensor circuit board			
Name	**Description**	**Amount**	**Cost at 50+ units**
Fixed costs pr. unit			
Initial start fee		1	€ 718,00
fee pr. unit	Salary	1	€ 2,00
Components pr. unit			
N/A	Circuit board	1	€ 1,00
COZIR A	CO2 sensor	1	€ 35,00
N/A	Smoke sensor	1	€ 1,00
HB 510HR3C	LED	5	€ 0,08
N/A	Resistors, wiring, etc.)	1	€ 0,20
Total (ekcl. Start fee)			€ 39,60

Spring steel band			
Name	**Description**	**Amount**	**Cost at 50+ units**
Spring steel band (1000 mm)		1	€ 1,00
Grip		1	€ 4,00
Velcro (900 mm)		1	€ 3,00
Coil core		1	€ 0,07
Axle (plastic)		1	€ 0,004
Total			€ 8,07

Battery for Sensor Unit			
Name	**Description**	**Amount**	**Cost at 1+ units**
ER34615	Battery	1	€ 5,00
N/A	Casing	1	€ 1,00
Total			€ 6,00

Drone			
Name	**Description**	**Amount**	**Cost at 1+ units**
Drone	From DJI	1	€ 6.000,00
Charging pad	From DJI	1	€ 1.000,00
Total			€ 7.000,00

Mounting stick				
Name	**Description**	**Amount**	**Cost at 1+ units**	
Pole		1	€	2,00
Magnets top	Holding the spring steel	1	€	0,10
Magnets bottum	Holding the Sensor unit	1	€	0,10
Mount		1	€	0,50
Total (pr unit)			€	2,70

Marketing material				
Name	**Description**	**Amount**	**Cost/unit at 200+ units**	
Flyers	For the Fairs	20	€	10,00
Posters	For the Fairs + awardshows	2	€	20,00
T-shirts	fundraising campaign	250	€	10,00
Hats	fundraising campaign	250	€	10,00
Certificate	fundraising campaign	1000	€	0,10
Stickers	fundraising campaign	500	€	0,01
Total			€	5.345,00

Manuals				
Name	**Description**	**Amount**	**Cost at 1 units**	
Manuals (all)		1	€	1,00
Total (pr unit)			€	1,00

Packaging (one ha kit)				
Name	**Description**	**Amount**	**Cost/unit at 40+ units**	
Cardboard box		1	€	6,00
Dividers		8	€	0,10
Tape		1	€	0,10
Other		1	€	0,10
Total (pr unit)			€	7,00

Development

Drone			
Name	**Description**	**Cost**	
Drone	DJI	€	20.000,00
Charging pad	DJI	€	5.000,00
Total		€	25.000,00

Casing			
Name	**Description**	**Cost**	
Mold back	Price is for two	€	6.600,00
Mold front	Price is for two	€	3.000,00
Mold plates	Price is for two	€	2.400,00
Total		€	12.000,00

Grip			
Name	**Description**	**Cost**	
Mold	price for one	€	2.400,00
Total		€	2.400,00

Mount			
Name	**Description**	**Cost**	
Mold	Price for two	€	3.000,00
Total		€	3.000,00

Production phase

Information about the company

Workers	Number	Salary/hour	
Production worker	2	€	27,00
Developers	2	€	70,00
Software engineer	1	€	70,00
Marketing/spokes person	1	€	70,00
Accountant	1	€	70,00
Total	7	€	350,00

Expenses

Inhouse

Assembly

Sensor unit

Name	Time (sec)		Cost (€)/unit	
Upload code to MCU	8		€	0,06
Insert metal plates	8		€	0,06
Insert steel mesh	15		€	0,11
Fill in Mounting mechanisem	6		€	0,05
Insert Sensor board	15		€	0,11
Insert Main board	10		€	0,08
Insert battery casing	16		€	0,12
Insert battery	2		€	0,02
Close casing	15		€	0,11
Cut velcro	2		€	0,02
Attach velcro to case	10		€	0,08
Mounting mechanism				
Cut velcro	3		€	0,02
Attach velcro	15		€	0,11
Attach grip to spring steel	10		€	0,08
Insert axle into coil	2		€	0,02
Attach spring steel to coil	30		€	0,23
Attach axle to plates	4		€	0,03
Total (pr. unit)	171		€	1,28

Mounting stick

Name	Time (sec)		Cost (€)/unit	
Attach magnets to mount	10		€	0,08
Total (pr. unit)	10			0,075

Quality testing for every: 25 unit

Sensor unit

Name	Time (sec)		Cost (€)/unit	
Mounting mechanism	10		€	0,08
Connectivity			€	-
Sensors			€	-
			€	-
Total (pr. unit)	10			0,075

Mounting stick

Name	Time (sec)		Cost (€)/unit	
Pole	12		€	0,09
Mount	10		€	0,19
Total	22		€	0,28

Packaging

System

Name	Time (sec)		Cost (€)/unit	
Mounting mechanism	2		€	0,02
Sensor units	2		€	0,02
Total (pr. unit)	4			0,03

Outsourced Production

Casing

Name	Description	Amount	Cost	
Injection molding front (pvc)	0,05kg	1	€	0,50
Injection molding back (pvc)	0,02 kg	1	€	0,50
Injection molding plates (pvc)	0,004 kg	2	€	0,25
Metal plate 1	Cut and bend	1	€	0,01
Metal plate 2	Cut and bend	1	€	0,01
Velcro (100)	Cut	1	€	0,10
Steel Mesh top	0,1 mm thick	1	€	0,0008
Steel Mesh bottum	0,1 mm thick	1	€	0,0001
Total (pr. unit)			€	1,62

Main print board

Name	Description	Amount	Cost at 5000+ units	
Fixed costs pr. unit				
Initial start fee		1	€	718,00
fee pr. unit	Salary	1	€	1,00
Components pr. unit				
N/A	Circuit board	1	€	1,00
RL78/G12	Microcontroller	1	€	0,62
Ax-SFEU	SigFox transmitter	1	€	0,20
SW520	Tilt swich	1	€	0,01
SOZ-0918V-3S	Antenna	1	€	0,09
N/A	Resistors, wiring, etc.)	1	€	0,20
Total (pr. unit)			€	3,12

Sensor print board

Name	Description	Amount	Cost at 5000+ units	
Fixed costs pr. unit				
Initial start fee		1	€	718,00
fee pr. unit	Salary	1	€	1,00
Components pr. unit				
N/A	Circuit board	1	€	1,00
COZIR A	CO2 sensor	1	€	0,10
N/A	Smoke sensor	1	€	0,10
HB 510HR3C	LED	5	€	0,08
N/A	Resistors, wiring, etc.)	1	€	0,20
Total (pr. unit)			€	2,80

Spring steel band

Name	Description	Amount	Cost at 5000+ units	
Components pr. unit				
Spring steel band (1000 mm)		1	€	0,10
Grip		1	€	0,05
Velcro (900 mm)		1	€	0,10
Coil core		1	€	0,07
Axle (plastic)		1	€	0,004
Total (pr. unit)			€	0,32

Battery for Sensor Unit

Name	Description	Amount	Cost at 5000+ units	
Components pr. unit				
ER34615	Battery	1	€	0,20
N/A	Casing	1	€	0,30
Total (pr. unit)			€	0,50

Drone				
Name	**Description**	**Amount**	**Cost at 1 units**	
Components pr. unit				
Drone	From DJI	1	€	6.000,00
Charging pad	From DJI	1	€	1.000,00
Total (pr. unit)			€	7.000,00

Mounting stick				
Name	**Description**	**Amount**	**Cost at 1 units**	
Components pr. unit				
Pole		1	€	0,50
Magnets top	Holding the spring steel	1	€	0,10
Magnets bottum		1	€	0,10
Mount		1	€	0,50
Total (pr. unit)			€	1,20

Marketing material				
Name	**Description**	**Amount**	**Cost**	
Parts			**Cost at 200+ units**	
Flyers	For the Fairs	20	€	10,00
Posters	For the Fairs	2	€	20,00
T-shirts	fundraising campaign	250	€	10,00
Hats	fundraising campaign	250	€	10,00
Catificate	fundraising campaign	1000	€	0,10
Stickers	fundraising campaign	500	€	0,01
Total (pr. bundle)			€	5.345,00

Manuals				
Name	**Description**	**Amount**	**Cost at 1 units**	
Manuals (all)		1	€	1,00
Total (pr unit)			€	1,00

Packaging (one ha kit)				
Name	**Description**	**Amount**	**Cost/unit at 40+ units**	
Cardboard box		1	€	4,00
Deviders		8	€	0,10
Tape		1	€	0,10
Other		1	€	0,10
Total (pr unit)			€	5,00

Packaging (1/4 ha kit)				
Name	**Description**	**Amount**	**Cost/unit at 40+ units**	
Cardboard box		1	€	2,50
Dividers		8	€	0,05
Tape		1	€	0,05
Other		1	€	0,10
Total (pr unit)			€	3,05

Packaging (1 sensor)				
Name	**Description**	**Amount**	**Cost/unit at 40+ units**	
Cardboard box		1	€	0,10
Dividers		0	€	0,01
Tape		1	€	0,01
Other		1	€	0,10
Total (pr unit)			€	0,21

Packaging (1 Mounting stick)				
Name	**Description**	**Amount**	**Cost/unit at 40+ units**	
Cardboard box		1	€	0,10
Dividers		0	€	0,01
Tape		1	€	0,05
Other		1	€	0,10
Total (pr unit)			€	0,25

Appendix 23

Title: Pattern analysis	**Worksheet no.:** 34 page 1 of 3
Responsible: Steffen	**Date:** 5/4-2018

What and how?

(What is it we are going to do and how are we going to do it?)
Desk research searching for scientific theory on effective patterns for different parameters. The patterns will also be analyzed for flaws and their coverage.

Purpose:

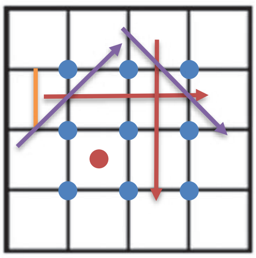
(What is the purpose of this research, task, experiment - what do we want to get out of it)
We want to find the most efficient and best covering pattern to place our sensors in, since a basic grid pattern can allow the smoke/gas to pas right between the sensors if we are very unlucky.
The goal is to find a pattern that can have approx.. 25 m between the sensors while limiting the amount of paths where the smoke can pass though without hitting any sensor.

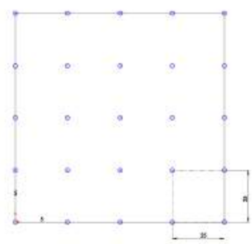
Results:

(What are the results?)

Regular patterns (patterns consisting of uniform shapes):
https://www.livescience.com/50027-tessellation-tiling.html

Basic grid

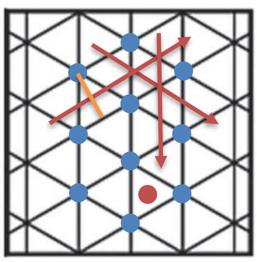


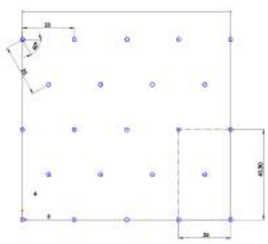


Allows the smoke to pass in two directions (red), creates gaps of **1***sensor distance (orange), the two corridors are **90** degrees apart. This patterns also has minor corridors with a width of **0,707** * sensor distance
The maximum distance from fire source (red dot) to the nearest sensor is **0,707** * sensor distance

In the rightmost illustration a hectare is shown with 25m between each sensor. The dotted line shows one repeated pattern filling 25*25m=625m^2 using 2 sensors = **312,5m^2/unit**.

Triangular



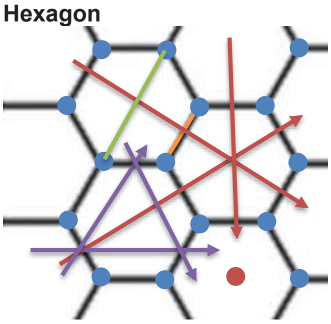


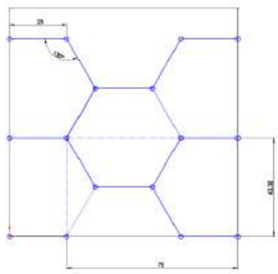
This pattern creates gaps in 3 directions (red), but the gaps are smaller than the square grid, **0,866** * sensor distance (orange). The corridors are **60** degrees apart. The maximum distance from the fire

Title: Pattern analysis	**Worksheet no.:** 34 page 2 of 3
Responsible: Steffen	**Date:** 5/4-2018

source (red dot) to the sensor is **0,433** * sensor distance.
This pattern fills 43,3*25m per repeated pattern using 3 units = **360,33**m^2/unit

Hexagon

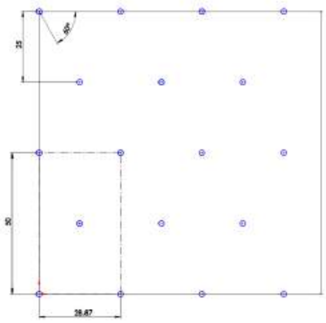




The honeycomb pattern creates 3 major corridors similar to the triangular pattern, but the width of it is going from **1***sensor distance (orange) up to **2***sensor distance (green)

It also has 3 minor corridors (purple) these are identical to the triangles biggest corridors at **0,866** * sensor distance
The major corridors are 60 degrees apart, while the minor is similar, but are shifted 30 degrees.

The maximum distance possible from fire source (red dot) to sensor **1** * sensor distance
This pattern takes 75*43,3m per repeated pattern with 6 units, which results in **541,25**m^2/unit
Adapted triangular



Since the previous triangular pattern had smaller gaps than the other two, it is attempted to scale it up accordingly creating this adapted triangular pattern. It is identical to the triangular except the gap size is now 1* sensor distance. The increase in distance between the sensors makes it use 50*28,87m per repeated pattern still with 3 sensors resulting in **481,16**m^2/unit

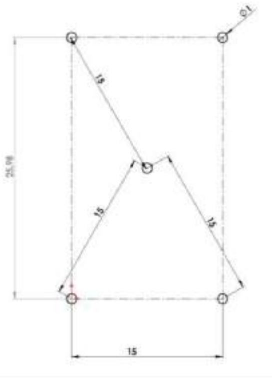
Recap comparison chart

Shape	No. major gaps	Gap size (major) [sensor distance]	No. minor gaps	Gap size (minor) [sensor distance]	Coverage (m/unit) (25m between units)
Square grid	2	1x	2	0,707x	312,5
Triangular	3	0,866x			360,33
Hexagon	3	1-2x	3	0,866x	541,25

Title: Pattern analysis	**Worksheet no.:** 34 page 3 of 3
Responsible: Steffen	**Date:** 5/4-2018

Adapted triangle	3	1x			481,16

Adapted triangle with 15m radius can cover 389,7m^2 per 3 units = **129,9m^2**



Conclusion:

(What are the conclusion regarding the purpose? What can we use from this in our project?)
Each shape has its pro's and con's. The square has least amount of major gaps, while the triangle have the smallest gap. The hexagon is the most space efficient, but have many gaps where the smoke can escape through. The best pattern with the best compromise between the number of gaps, the size of the gaps and coverage is the adapted triangle, giving much better coverage with the same gap size, while raising the number of major gaps by 50%, while eliminating minor gaps.

Evaluation:

(Did we get the results we were looking for? What should we do next?)

Next we should adapt it to fit the planted lines in the forest (3x1,6-1,8m)

Reflection:

(If not, why. Should anything had been different? Are there anything else we maybe should take into consideration?)

We could have looked into more pattern, e.g. the semi-regular patterns (using 2 sizes of patterns) but these would create uneven gaps between the sensors, and while having uneven gaps, the space might not be used optimal.

WilD
Technical drawings

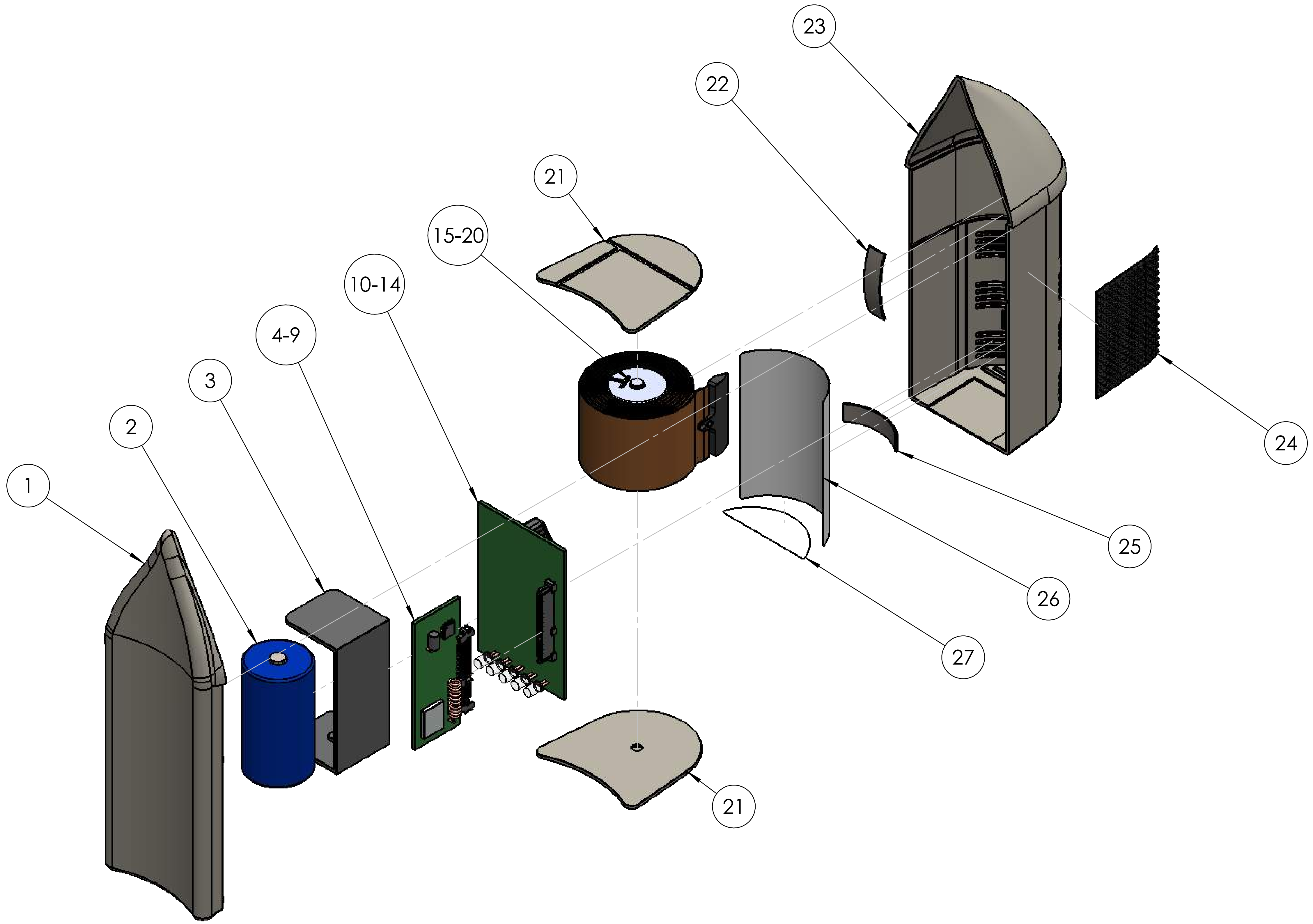
Index

Sensor unit

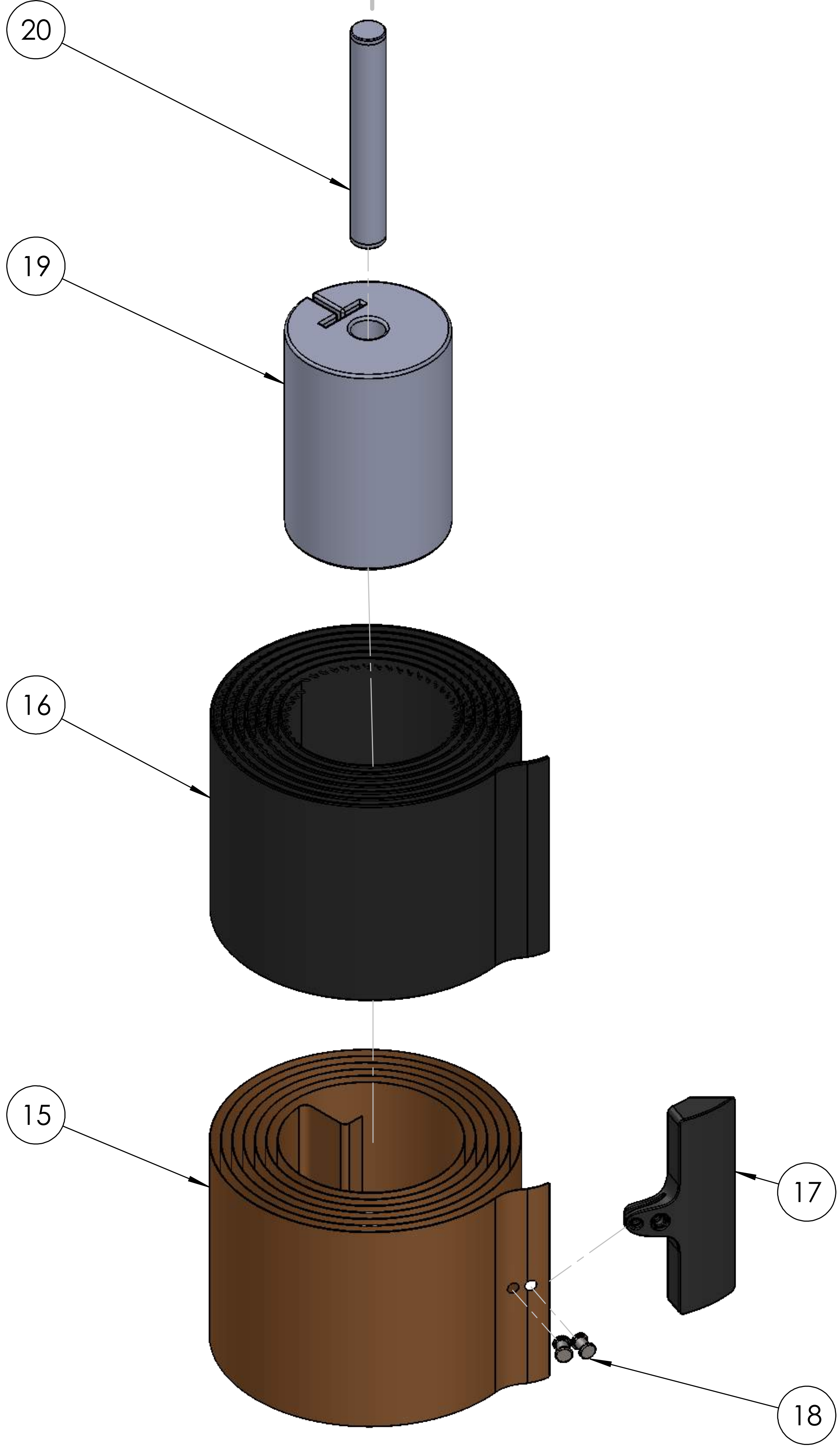
Mounting stick

Bill of materials

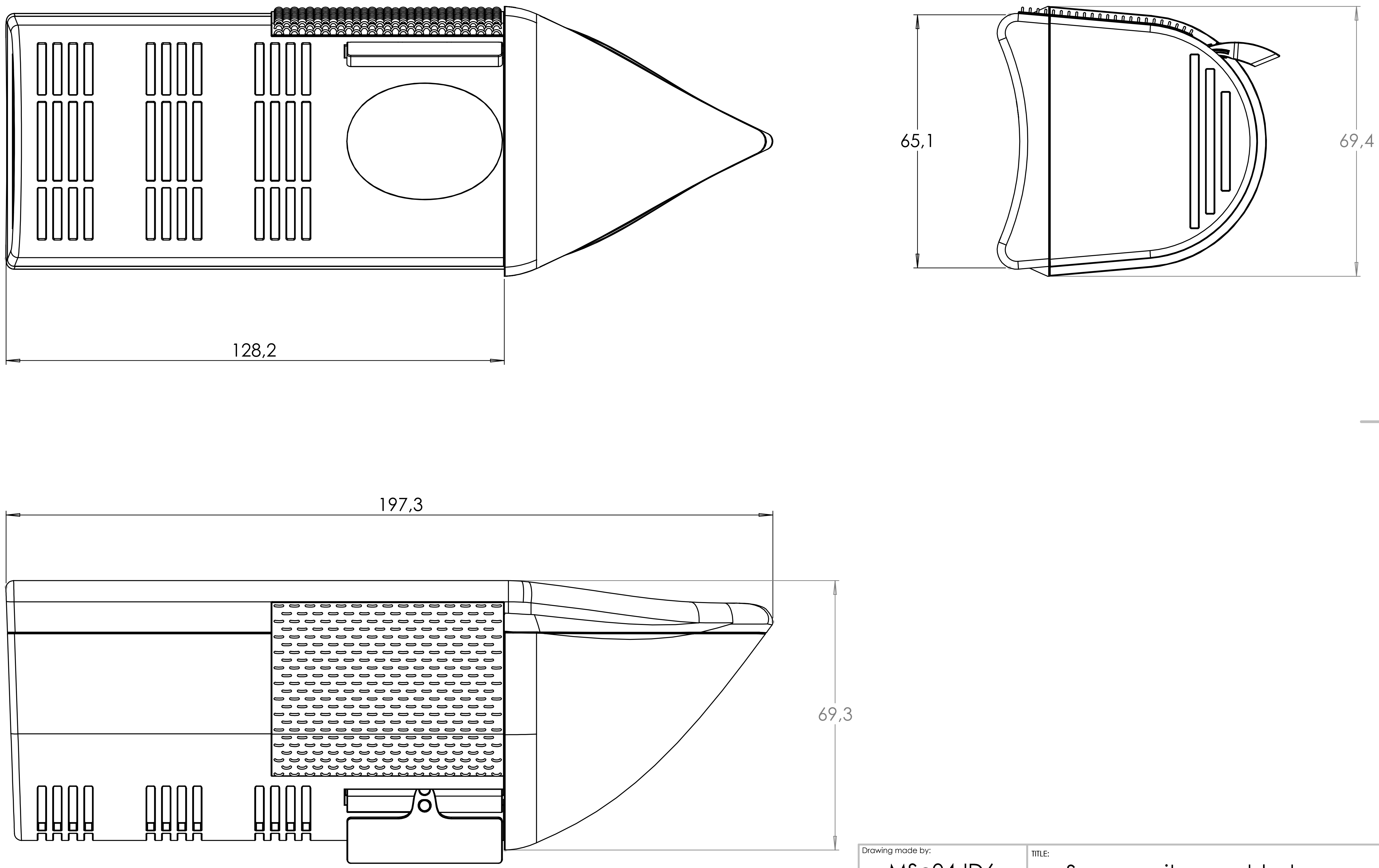
ITEM NO.	PART NUMBER	QTY.
1	Casing front	1
2	ER34165 Battery	1
3	Battery holder	1
4	Main circuit board	1
5	Tilt sensor	1
6	RL78/G12 MCU	1
7	Ax-SFEU Sigfox	1
8	Antenna	1
9	Connector male	1
10	Sensor circuit board	1
11	Smoke sensor	1
12	Cosir A CO2 sensor	1
13	5mm Flat top LED	5
14	Connector female	1
15	Steel spring band	1
16	Velcro band 90 cm	1
17	Grip	1
18	Pin	2
19	Coil core	1
20	Coil axle	1
21	Horizontal divider plate	2
22	Metal plate upper	1
23	Casing back	1
24	Velcro on casing	1
25	Metal plate lower	1
26	Steel mesh back	1
27	Steel mesh bottom	1



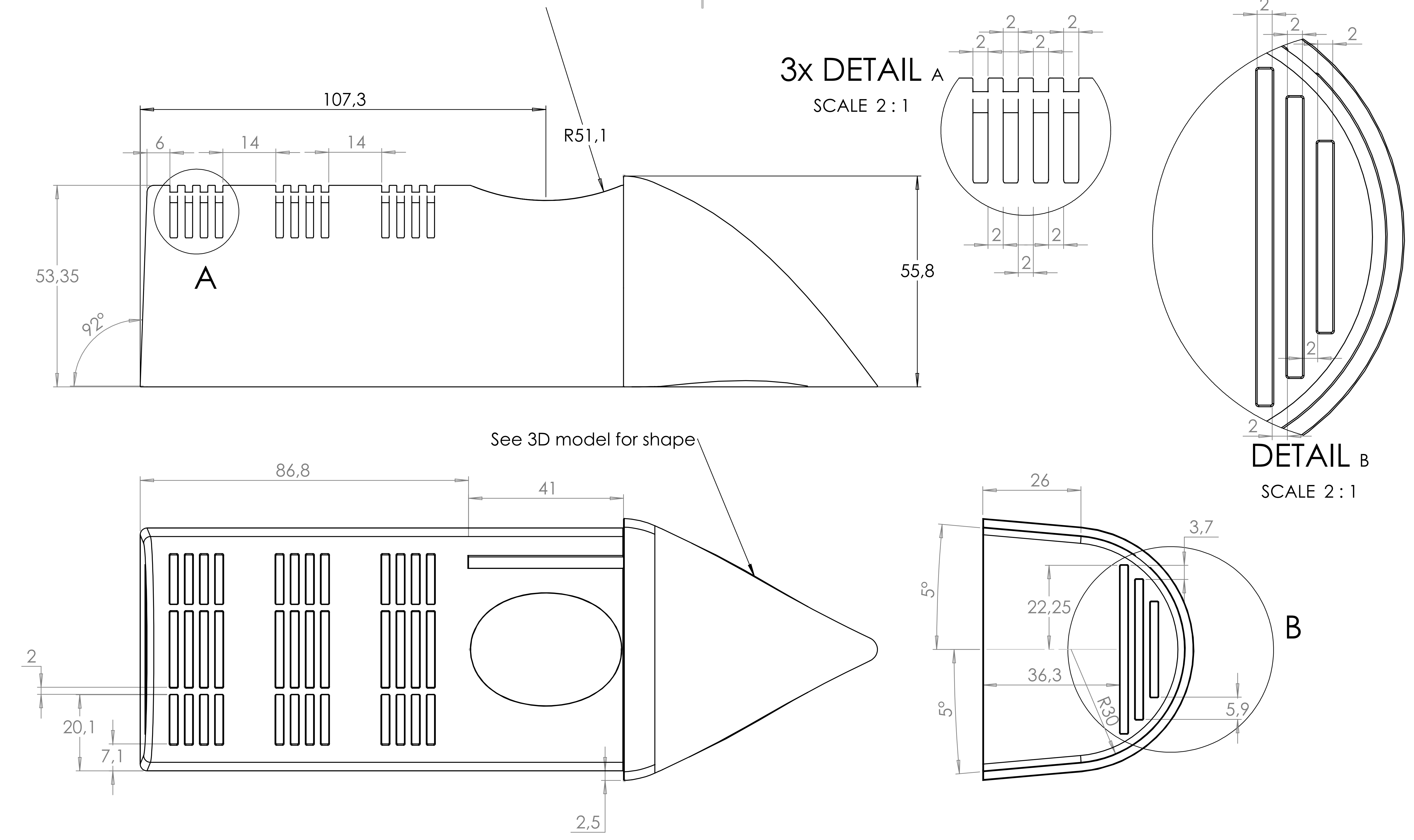
Drawing made by: MSc04-ID6	TITLE: Sensor unit exploded overall	
DO NOT SCALE DRAWING	PART: 20 assem	SHEET NO.: 1
	DS/ISO 128 · SCALE:1:2 · SHEET 1 OF 1	SHEET FORMAT A3



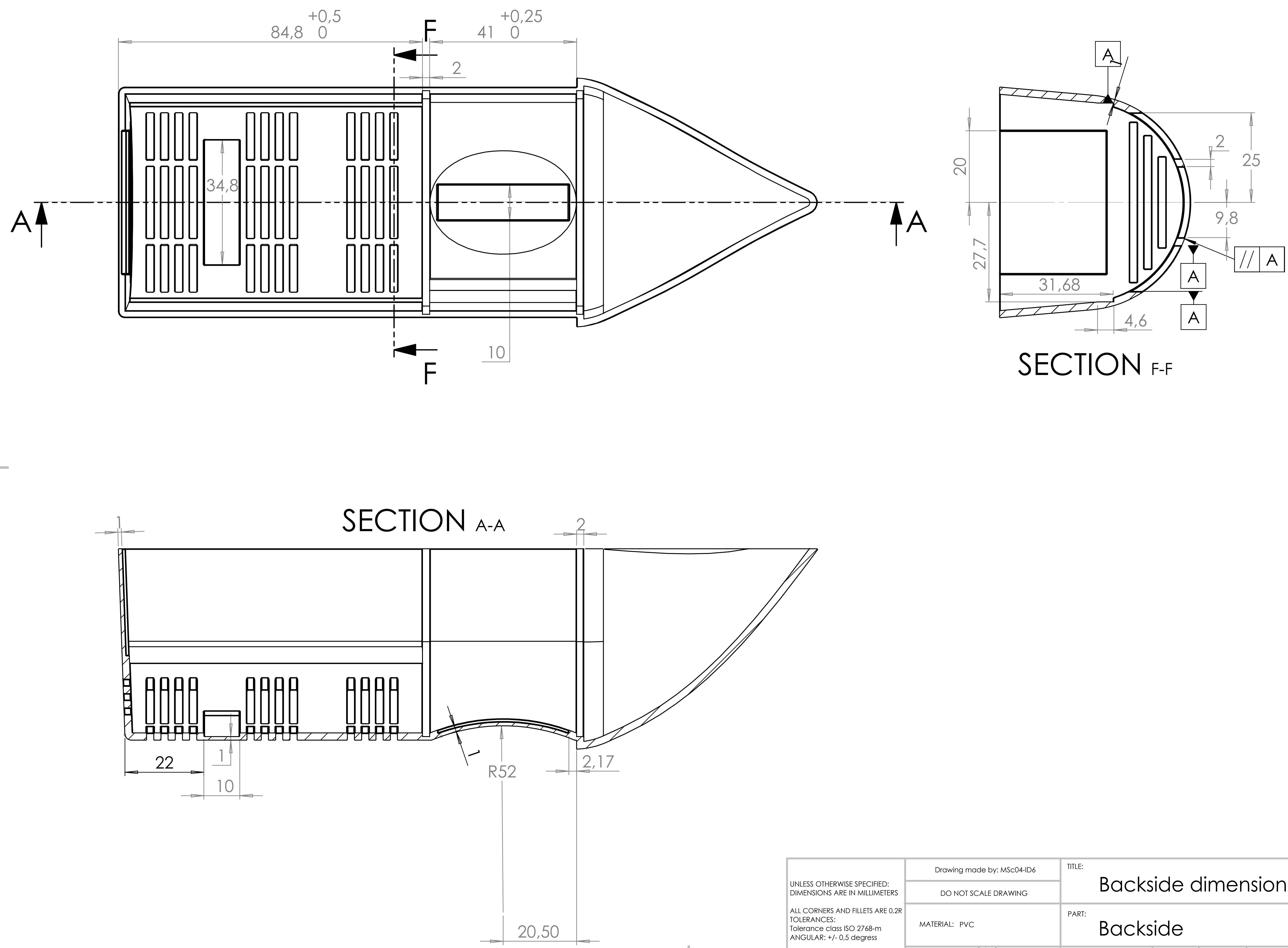
Drawing made by: MSc04-ID6	TITLE: Mounting mechanism exploded			
DO NOT SCALE DRAWING				
	PART: Mounting mechanism			COMPONENT NO.: 15 - 20
		SCALE:1:1	SHEET 1 OF 1	SHEET NO.: 2	FORMAT: A4



Drawing made by:	TITLE:			
MSc04-ID6	Sensor unit assembled			
DO NOT SCALE DRAWING	PART: 20 assem			SHEET NO.: 03
	DS/ISO 128	1:1	SHEET 1 OF 1	SHEET FORMAT A3



UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS	Drawing made by: MSc04-ID6	TITLE: Backside dimensions		
	DO NOT SCALE DRAWING			
ALL CORNERS AND FILLETS ARE 0.2R TOLERANCES: Tolerance class ISO 2768-m ANGULAR: +/- 0.5 degrees	MATERIAL: PVC	PART: Backside	COMPONENT NO.: 23	
			SHEET NO.: 4	FORMAT: A3
	SURFACE FINISH: 0.4 micro m on outer surfaces	SCALE:1:1	SHEET 1 OF 2	

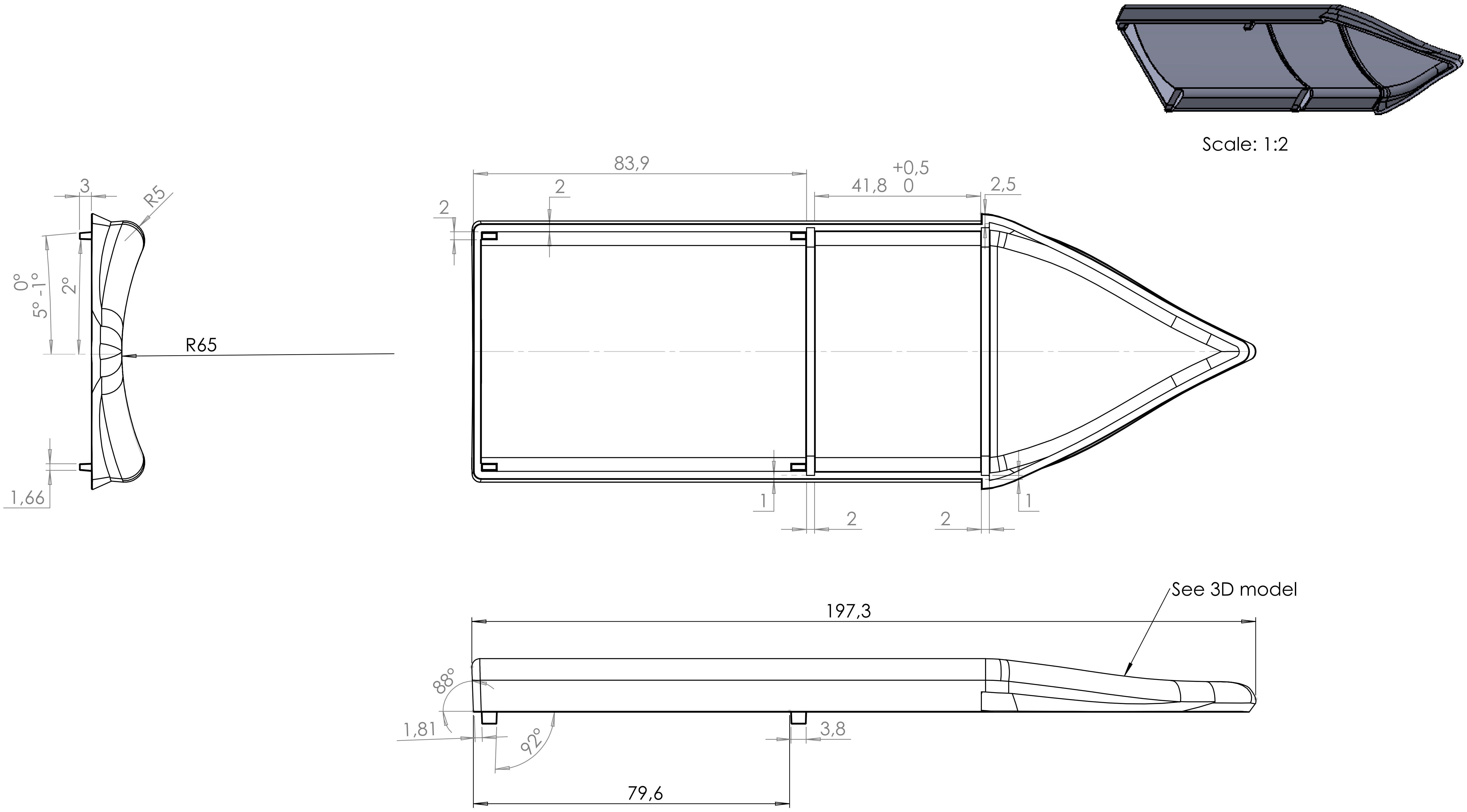


UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS	Drawing made by: MSc04-ID6	TITLE: Backside dimensions 2
ALL CORNERS AND FILLETS ARE 0.2R TOLERANCES: Tolerance class ISO 2768-m ANGULAR: +/- 0,5 degress	DO NOT SCALE DRAWING	
	MATERIAL: PVC	PART: Backside
	SURFACE FINISH: 0.4 micro m on outer surfaces	SCALE:1:1 / SHEET 2 OF 2

COMPONENT NO.: 23

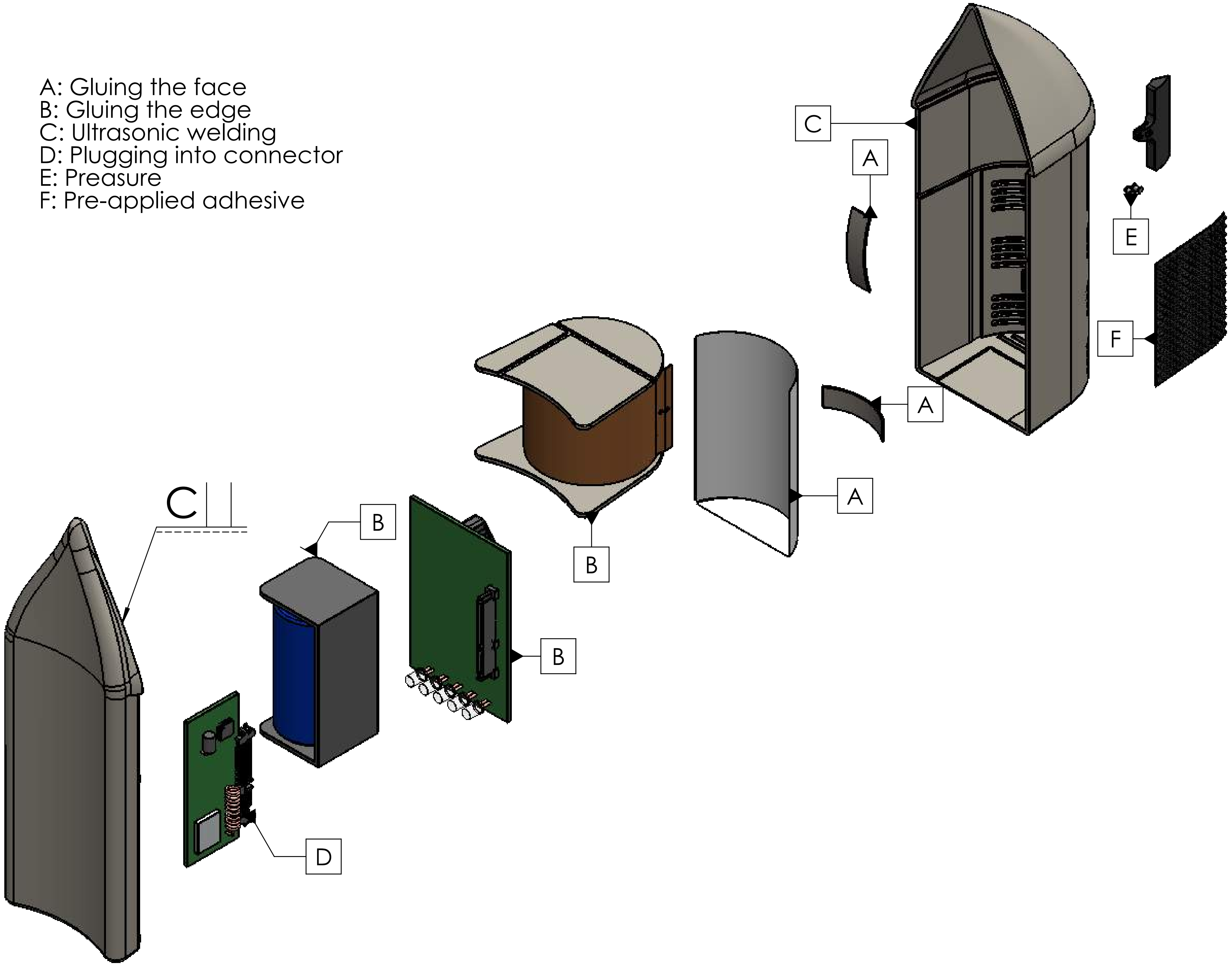
SHEET NO.: 4

FORMAT: A3



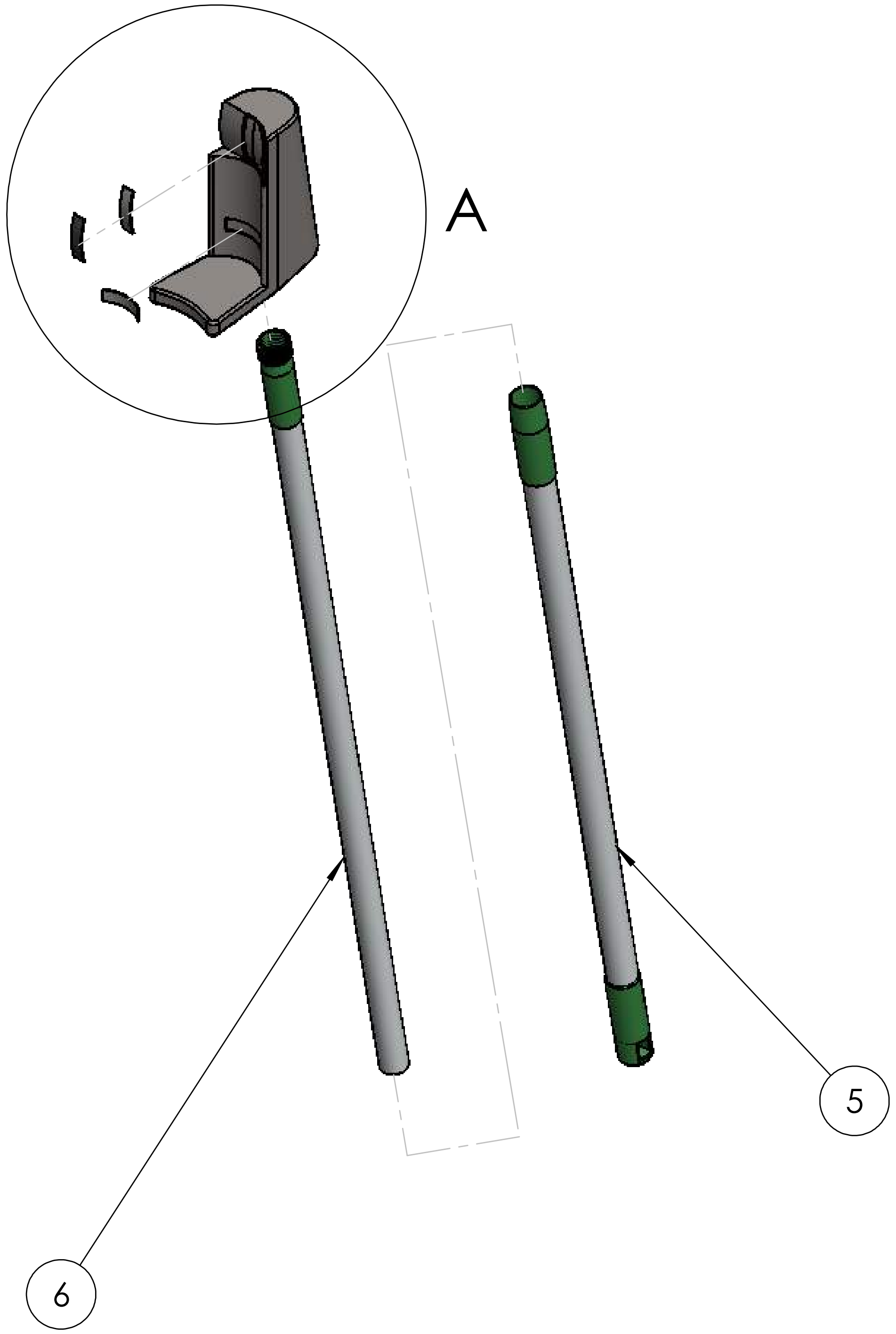
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS	Drawing made by: MSc04-ID6	TITLE: Frontside	
ALL CORNERS AND FILLETS ARE 0.2R TOLERANCES: Tolerance class ISO 2768-m ANGULAR: +/- 0,5 degrees	DO NOT SCALE DRAWING	PART: Frontside	COMPONENT NO.: 1
	MATERIAL: PVC	SCALE:1:1	SHEET 1 OF 1
	SURFACE FINISH: 0,4 micro m on outer surfaces	SHEET NO.: 5	FORMAT: A3

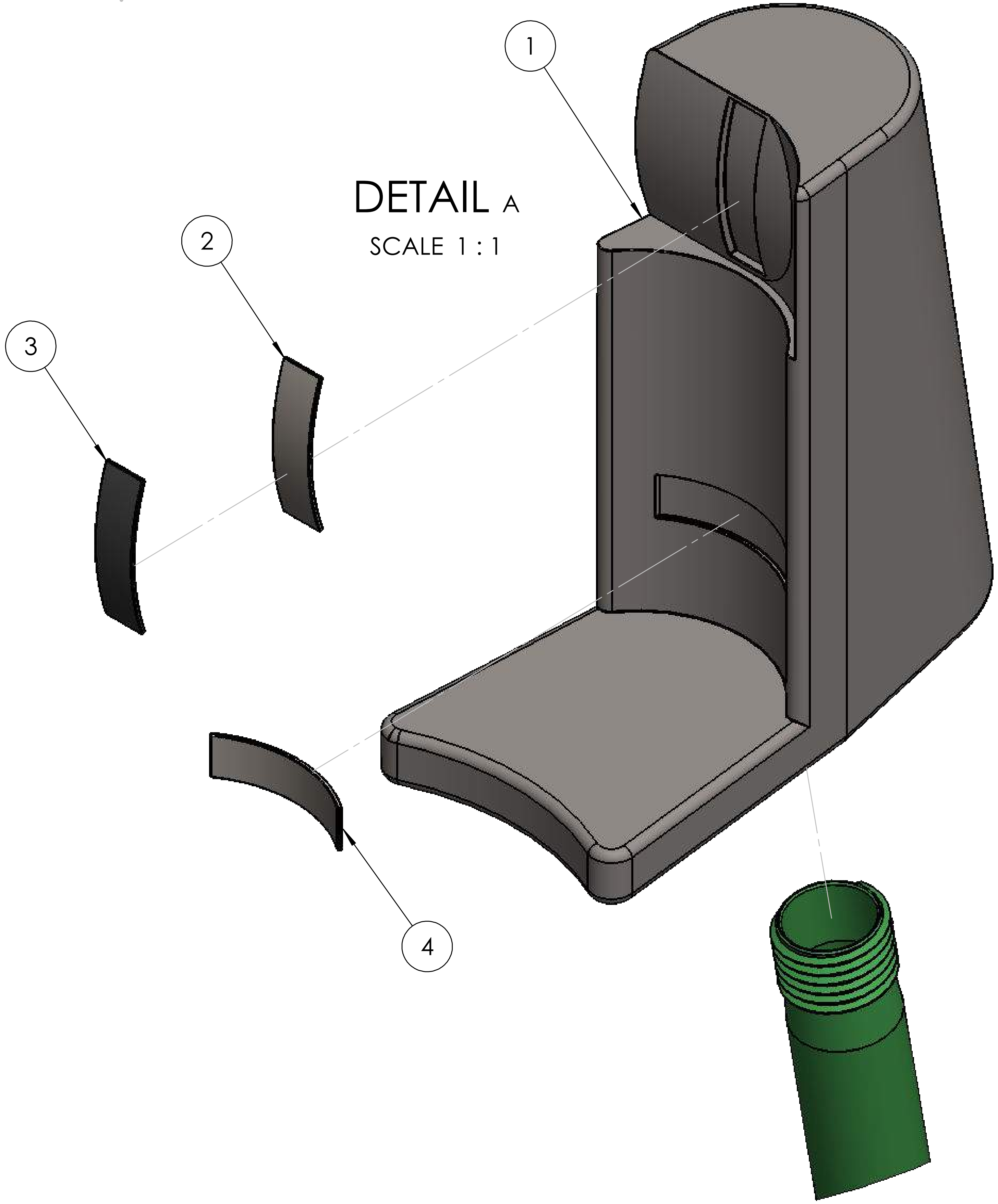
A: Gluing the face
B: Gluing the edge
C: Ultrasonic welding
D: Plugging into connector
E: Preasure
F: Pre-applied adhesive



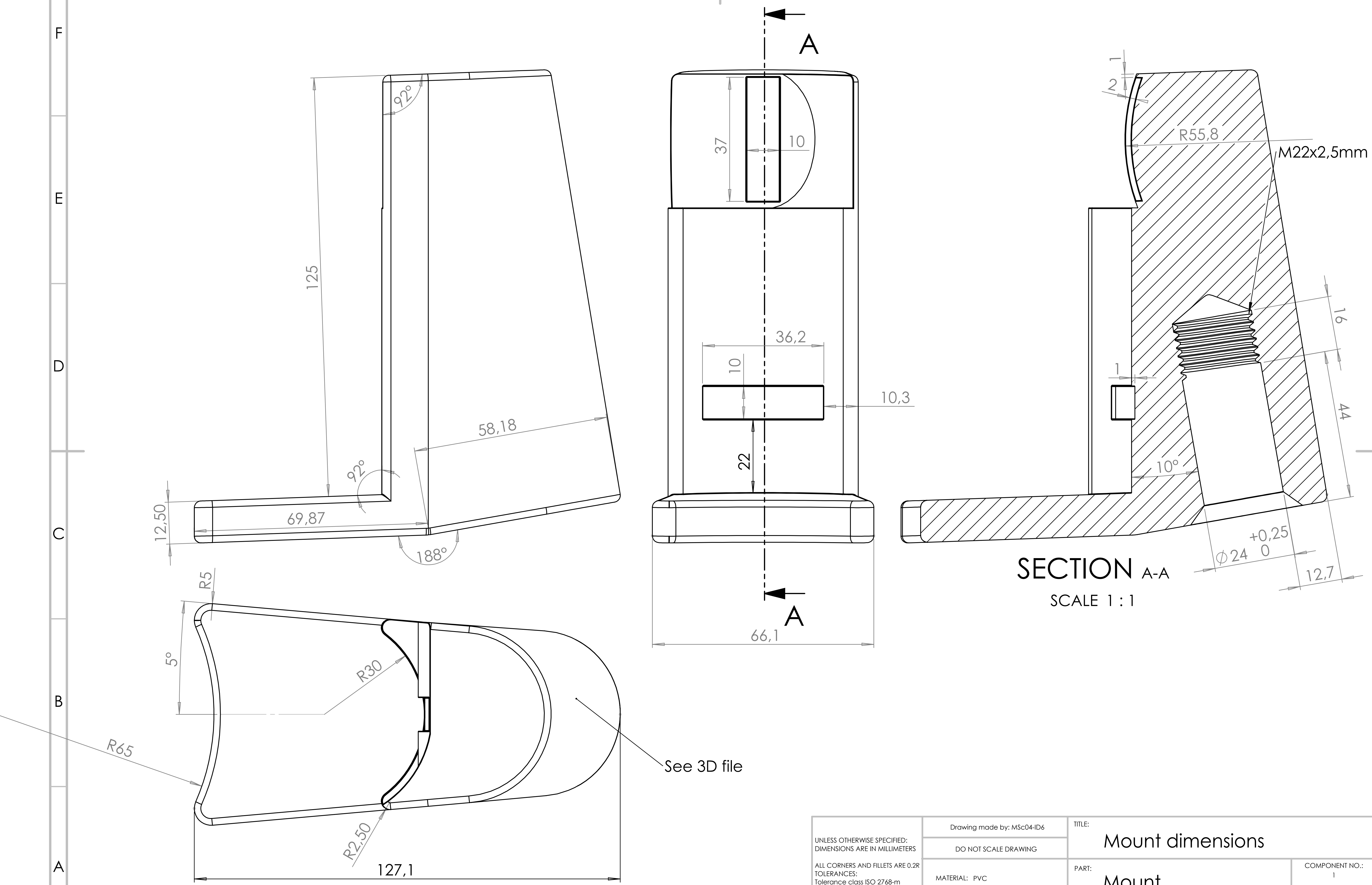
Drawing made by: MSc04-ID6	TITLE: Sensor unit assembly		
DO NOT SCALE DRAWING	PART: assem 20		SHEET NO.: 6
DS/ISO 128	SCALE:1:2	SHEET 1 OF 1	SHEET FORMAT A3

ITEM NO.	PART NUMBER	QTY.
1	Mount	1
2	Magnet 1	1
3	Silicon plate	1
4	Magnet 2	1
5	Telescopic stick pt 1	1
6	Telescopic stick pt 2	1





Drawing made by: MSc04-ID6	TITLE: Mounting stick exploded			
DO NOT SCALE DRAWING	PART: Mounting stick			SHEET NO.: 7
	DS/ISO 128	SCALE:1:10	SHEET 1 OF 1	SHEET FORMAT A3



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS

ALL CORNERS AND FILLETS ARE 0.2R
TOLERANCES:
Tolerance class ISO 2768-m
ANGULAR: +/- 0,5 degrees

Drawing made by: MSc04-ID6

DO NOT SCALE DRAWING

MATERIAL: PVC

SURFACE FINISH: 0,4 micro m

TITLE:
Mount dimensions

PART:
Mount

COMPONENT NO.: 1

SCALE:1:1 | SHEET 1 OF 1 | SHEET NO.: 8 | FORMAT: A3