BirdBox

Technology in the service of nature

Project Name	Connected nesting box
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Group Number	Group N°10
Project Location	ICAM Strasbourg-Europe
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A. Context reminder and expected objectives

A.1 Context reminder

The **connected nesting box** is a project initiated as part of the Icam 4 Technical Project, **in partnership with the Ligue de Protection des Oiseaux d'Alsace LPO**. It responds to **the monitoring and preservation of bird species** in urban and peri-urban environments. The aim is to help preserve two particular species: **the great-tit "Parus major" and the black redstart "Phoenicurus ochruros".**
This connected nesting box will be installed **on the Icam Strasbourg site in early 2025**, contributing to the attractiveness of the campus and raising awareness of biodiversity among students and staff.

The origin of this project comes from **the decline of these species.** It is often due to the loss of their natural housing, the scarcity of their food and the disruption of their breeding cycles by increasing urbanisation. The design of an intelligent nesting box makes it possible **to alleviate some of these problems** by providing a safe shelter while **collecting precise data** on their habits and behaviour.

What	Connected nesting box and instrumentation system
When	2024/2025
Where	Around ICAM Strasbourg-Europe building
Who	LPO, 4th year student, ICAM
How	Ecological way
How much	300€
Why	Collecting data about the behavior of the birds

A.2 Expected objectives

A.2.1 Instrumentation System Objectives

Temperature Measurement

- **Specific**: Measure the temperature inside the nest.
- **Measurable**: Range of -25°C to 45°C with a tolerance of ±5°C.
- **Achievable**: Use appropriate temperature sensors capable of this range and accuracy.
- **Relevant**: Temperature affects bird health and nesting conditions.
- **Time-bound**: Continuous monitoring over the project's duration.

Humidity Measurement

- **Specific**: Measure the humidity inside the nest.
- **Measurable**: Range from 10% to 100% with a tolerance of ±5%.
- **Achievable**: Use humidity sensors capable of covering the entire range.
- **Relevant**: Humidity impacts nesting material and bird comfort.
- **Time-bound**: Continuous monitoring over the project's duration.

Bird Counting

- **Specific**: Count the number of birds inside the nesting box.
- **Measurable**: Accurate within ±2 birds, with a maximum count of 4 birds simultaneously.
- **Achievable**: Utilize infrared or camera-based detection technology.
- **Relevant**: Understanding bird occupancy is crucial for data collection.
- **Time-bound**: Real-time monitoring throughout the day.

Species Identification

- **Specific**: Identify whether the birds are great tits, black redstarts, or neither.
- **Measurable**: Ensure a maximum error margin of 30% by the end of each day.
- **Achievable**: Use image recognition software and bird call analysis.
- **Relevant**: Knowing bird species helps in studying biodiversity and bird behaviors.
- **Time-bound**: Provide species identification results at the end of each day.

Species Identification

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-

Energy Autonomy

- **Specific**: The system must be energy self-sufficient.
- **Measurable**: Operate autonomously for at least one year, with a tolerance of ±2 months.
- **Achievable**: Implement energy-efficient hardware and renewable energy sources (e.g., solar).
- **Relevant**: Ensures continuous operation without manual battery changes.
- **Time-bound**: One-year operational period.

Environmental Durability

- **Specific**: The system should resist weather-related degradation.
- **Measurable**: Show no signs of degradation due to sun or rain for 8 months, withstand winds up to 40 km/h.
- **Achievable**: Use weatherproof materials and robust construction.
- **Relevant**: Ensures system reliability in outdoor conditions.
- **Time-bound**: 8-month weather durability

Weight Variation Measurement

- **Specific**: Measure the weight of the nesting box.
- **Measurable**: Detect changes up to a maximum of 5 kg with a tolerance of ±5 g.
- **Achievable**: Use precision load cells or weight sensors.
- **Relevant**: Weight changes can indicate nest activity.
- **Time-bound**: Continuous monitoring.

Data Transmission and Interface

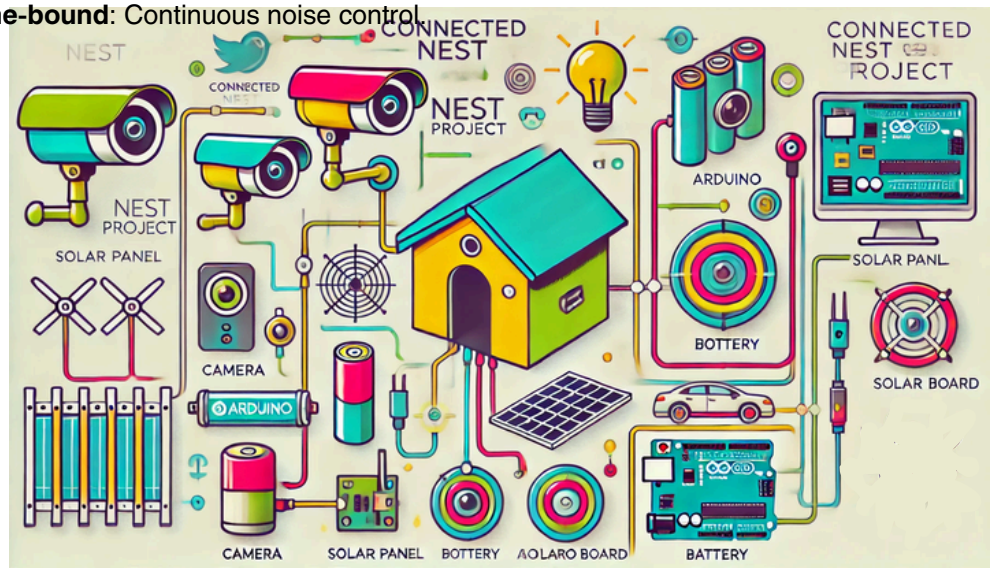
- **Specific**: Transmit data to a user-friendly interface.
- **Measurable**: Display hourly data updates suitable for ages 4 to seniors.
- **Achievable**: Design a simple, intuitive interface with large icons and minimal text.
- **Relevant**: Makes data accessible to a broad audience.
- **Time-bound**: Hourly data updates.

Data Security

- **Specific**: Ensure encrypted data transmission.
- **Measurable**: Zero tolerance for data leakage.
- **Achievable**: Use strong encryption protocols.
- **Relevant**: Protects sensitive information from unauthorized access.
- **Time-bound**: Continuous encryption throughout the project.

Noise Emission

- **Specific**: Limit noise emitted by the system.
- **Measurable**: Maintain noise levels below 5 dB, with a tolerance of ±2 dB.
- **Achievable**: Use silent components and sound dampening materials.
- **Relevant**: Prevents disturbance to birds and the surrounding environment.
- **Time-bound**: Continuous noise control.



Non-contractual image

A.2.2 Nesting Box Objectives

Mounting Adaptability

- **Specific**: Adapt to various mounting locations.
- **Measurable**: Fit tree diameters from 10 to 40 cm (±5 cm) and mountable on walls at heights of 3 m (±1 m).
- **Achievable**: Use adjustable straps and versatile mounting systems.
- **Relevant**: Ensures the nesting box can be used in diverse environments.
- **Time-bound**: Ready for mounting upon installation.

Environmental Durability (Nesting Box)

- **Specific**: Resist weather-related degradation.
- **Measurable**: Show no signs of degradation for at least 3 months under sun or rain.
- **Achievable**: Use UV-resistant materials and waterproof coatings.
- **Relevant**: Ensures the nesting box remains functional and secure.
- **Time-bound**: 3-month weather durability.

A.2.3 Global objectives

Budget Compliance

- **Specific**: Complete the project within the allocated budget.
- **Measurable**: Do not exceed 300€.
- **Achievable**: Optimize costs for materials and components.
- **Relevant**: Ensures financial feasibility.
- **Time-bound**: Budget tracked throughout the project lifecycle.

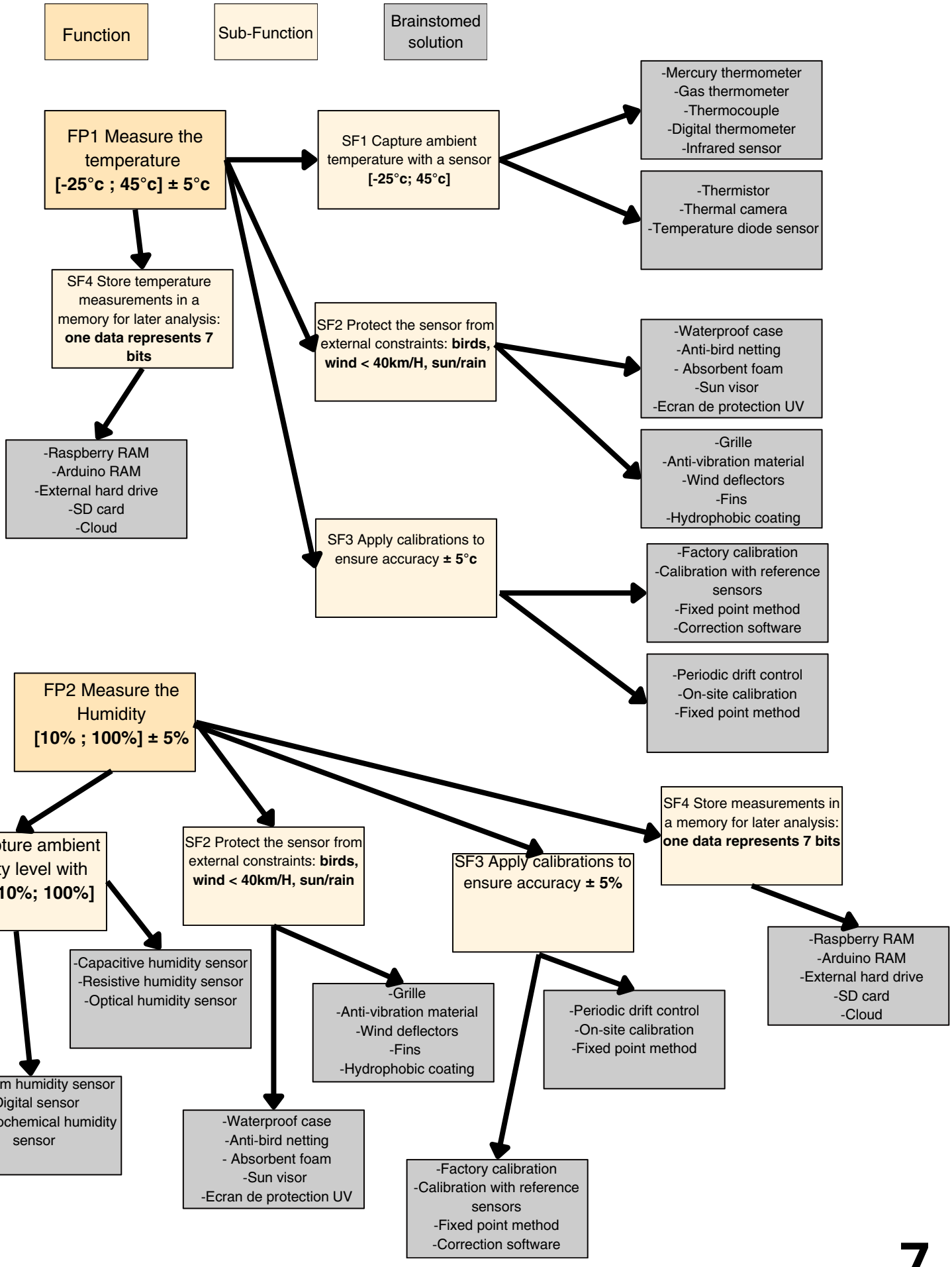
Safety Compliance

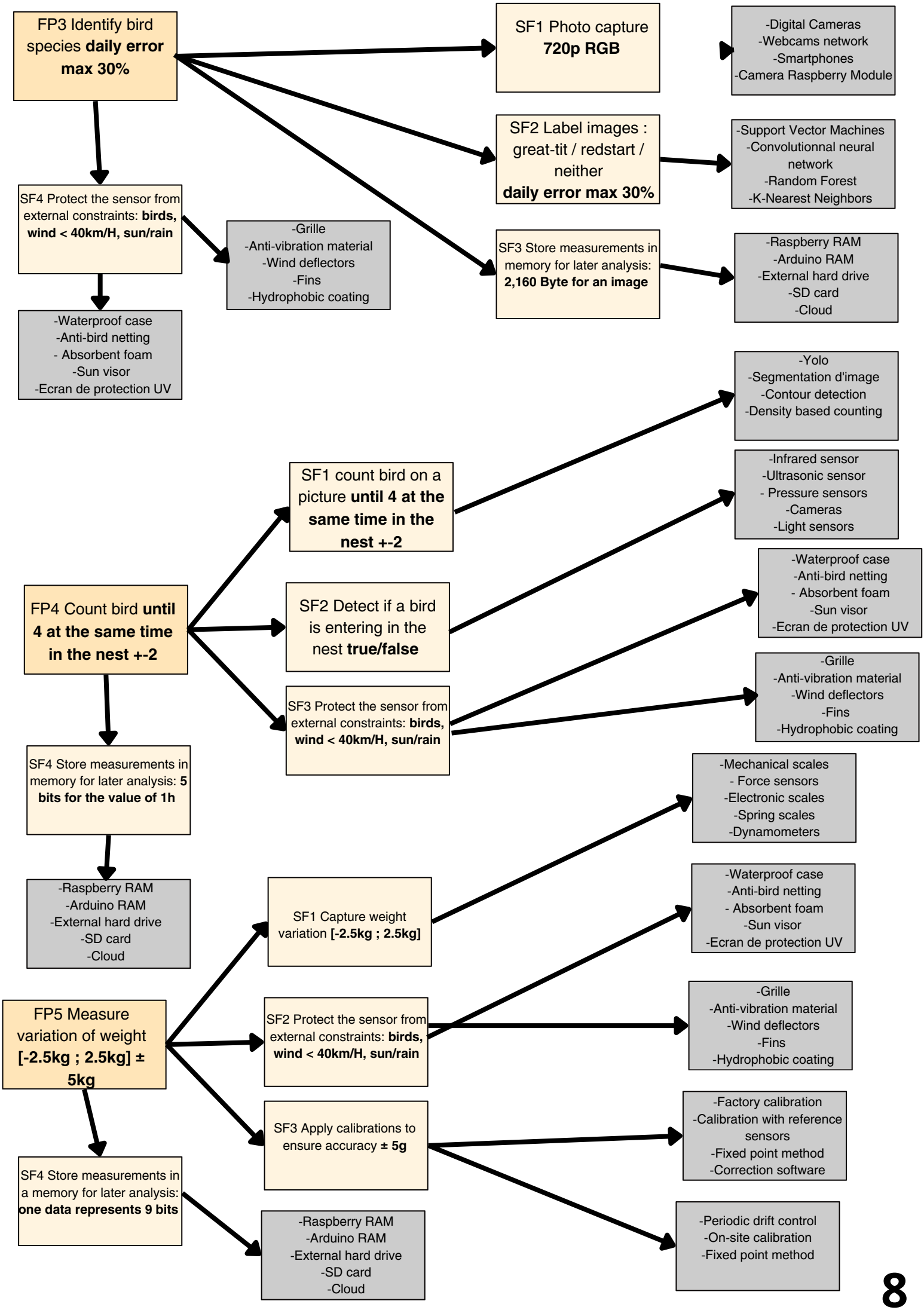
- **Specific**: Ensure safety throughout the project.
- **Measurable**: Zero tolerance for safety violations.
- **Achievable**: Follow safety guidelines for equipment use and mounting.
- **Relevant**: Prevents injuries and ensures the wellbeing of people and wildlife.
- **Time-bound**: Safety maintained from start to project completion.

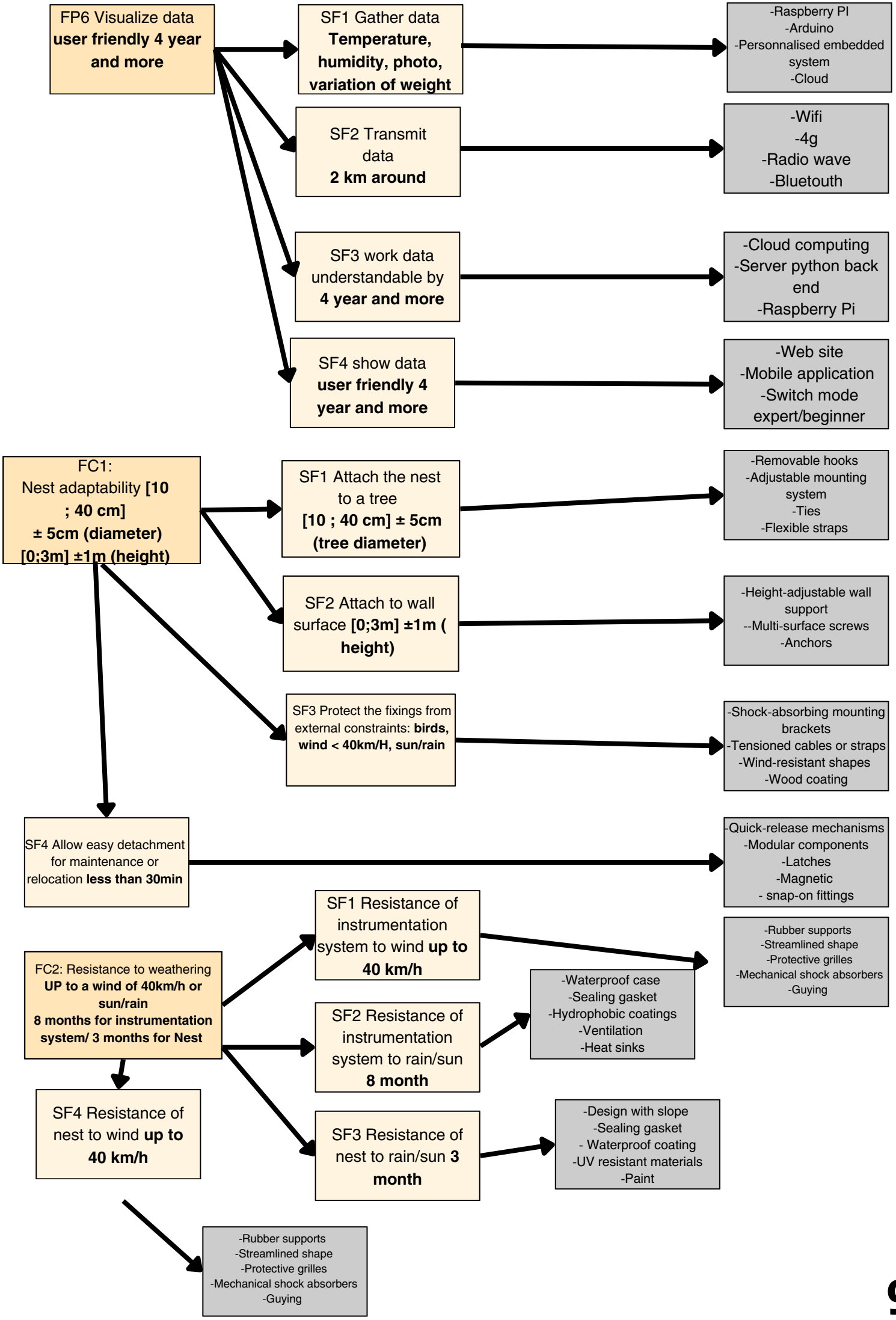
Non-contractual image

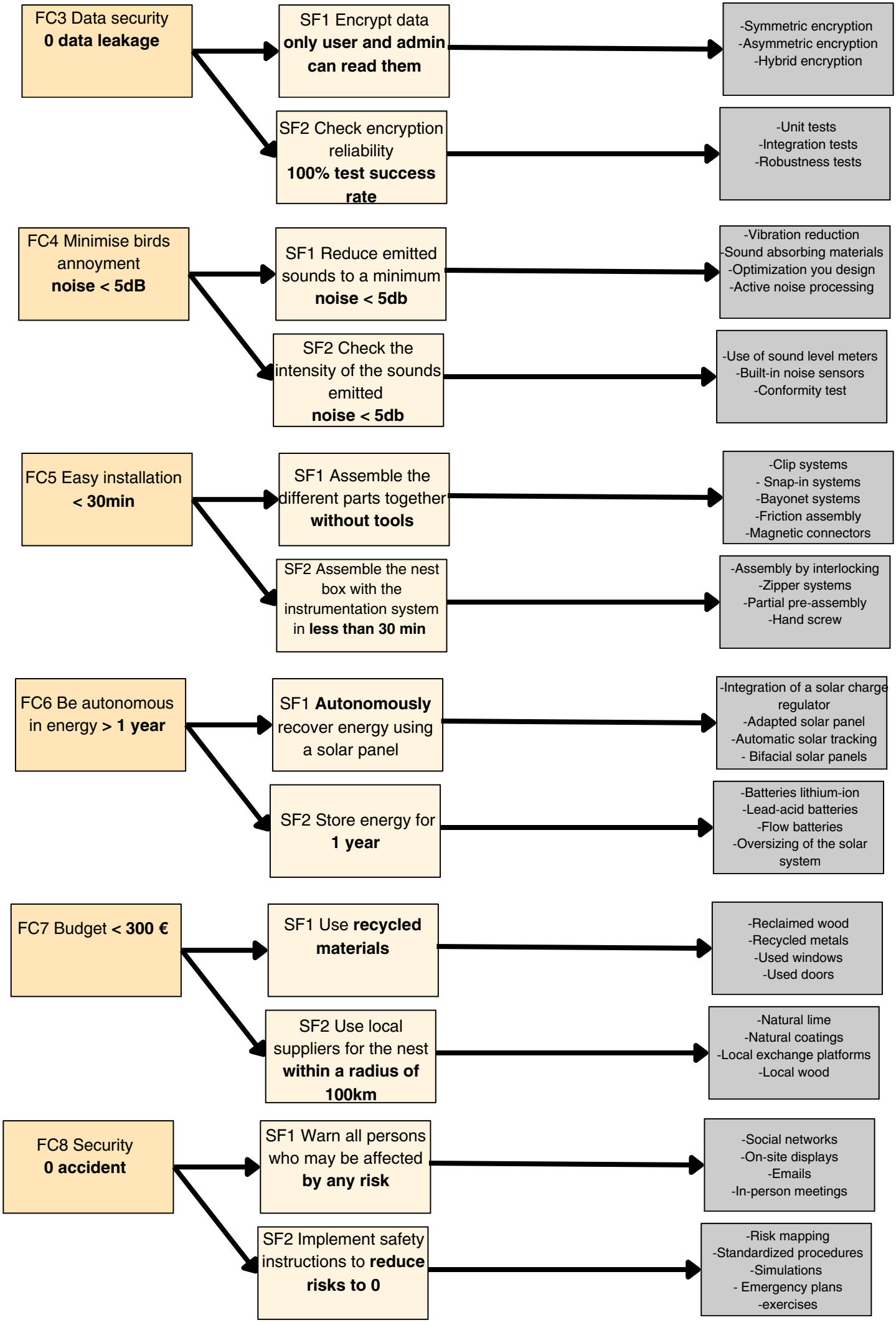
B. All explored solution

Analyse FAST with brainstormed solution




FP3 Identify bird species **daily error max 30%**
SF1 Photo capture **720p RGB**
-Digital Cameras
-Webcams network
-Smartphones
-Camera Raspberry Module
SF2 Label images : great-tit / redstart / neither **daily error max 30%**
-Support Vector Machines
-Convolutionnal neural network
-Random Forest
-K-Nearest Neighbors
SF3 Store measurements in memory for later analysis: **2,160 Byte for an image**
-Raspberry RAM
-Arduino RAM
-External hard drive
-SD card
-Cloud
SF4 Protect the sensor from external constraints: **birds, wind < 40km/H, sun/rain**
-Grille
-Anti-vibration material
-Wind deflectors
-Fins
-Hydrophobic coating
-Waterproof case
-Anti-bird netting
- Absorbent foam
-Sun visor
-Ecran de protection UV
FP4 Count bird **until 4 at the same time in the nest +-2**
SF1 count bird on a picture **until 4 at the same time in the nest +-2**
-Yolo
-Segmentation d'image
-Contour detection
-Density based counting
SF2 Detect if a bird is entering in the nest **true/false**
-Infrared sensor
-Ultrasonic sensor
- Pressure sensors
-Cameras
-Light sensors
SF3 Protect the sensor from external constraints: **birds, wind < 40km/H, sun/rain**
-Waterproof case
-Anti-bird netting
- Absorbent foam
-Sun visor
-Ecran de protection UV
-Grille
-Anti-vibration material
-Wind deflectors
-Fins
-Hydrophobic coating
SF4 Store measurements in memory for later analysis: **5 bits for the value of 1h**
-Raspberry RAM
-Arduino RAM
-External hard drive
-SD card
-Cloud
FP5 Measure variation of weight **[-2.5kg ; 2.5kg] ± 5kg**
SF1 Capture weight variation **[-2.5kg ; 2.5kg]**
-Mechanical scales
- Force sensors
-Electronic scales
-Spring scales
-Dynamometers
SF2 Protect the sensor from external constraints: **birds, wind < 40km/H, sun/rain**
-Waterproof case
-Anti-bird netting
- Absorbent foam
-Sun visor
-Ecran de protection UV
-Grille
-Anti-vibration material
-Wind deflectors
-Fins
-Hydrophobic coating
SF3 Apply calibrations to ensure accuracy **± 5g**
-Factory calibration
-Calibration with reference sensors
-Fixed point method
-Correction software
-Periodic drift control
-On-site calibration
-Fixed point method
SF4 Store measurements in a memory for later analysis: **one data represents 9 bits**
-Raspberry RAM
-Arduino RAM
-External hard drive
-SD card
-Cloud


FP6 Visualize data **user friendly 4 year and more**
SF1 Gather data **Temperature, humidity, photo, variation of weight**
-Raspberry PI
-Arduino
-Personnalised embedded system
-Cloud
SF2 Transmit data **2 km around**
-Wifi
-4g
-Radio wave
-Bluetouth
SF3 work data understandable by **4 year and more**
-Cloud computing
-Server python back end
-Raspberry Pi
SF4 show data **user friendly 4 year and more**
-Web site
-Mobile application
-Switch mode expert/beginner
FC1: Nest adaptability **[10 ; 40 cm] ± 5cm (diameter) [0;3m] ±1m (height)**
SF1 Attach the nest to a tree **[10 ; 40 cm] ± 5cm (tree diameter)**
-Removable hooks
-Adjustable mounting system
-Ties
-Flexible straps
SF2 Attach to wall surface **[0;3m] ±1m (height)**
-Height-adjustable wall support
--Multi-surface screws
-Anchors
SF3 Protect the fixings from external constraints: **birds, wind < 40km/H, sun/rain**
-Shock-absorbing mounting brackets
-Tensioned cables or straps
-Wind-resistant shapes
-Wood coating
SF4 Allow easy detachment for maintenance or relocation **less than 30min**
-Quick-release mechanisms
-Modular components
-Latches
-Magnetic
- snap-on fittings
FC2: Resistance to weathering **UP to a wind of 40km/h or sun/rain 8 months for instrumentation system/ 3 months for Nest**
SF1 Resistance of instrumentation system to wind **up to 40 km/h**
-Rubber supports
-Streamlined shape
-Protective grilles
-Mechanical shock absorbers
-Guying
SF2 Resistance of instrumentation system to rain/sun **8 month**
-Waterproof case
-Sealing gasket
-Hydrophobic coatings
-Ventilation
-Heat sinks
SF3 Resistance of nest to rain/sun **3 month**
-Design with slope
-Sealing gasket
- Waterproof coating
-UV resistant materials
-Paint
SF4 Resistance of nest to wind **up to 40 km/h**
-Rubber supports
-Streamlined shape
-Protective grilles
-Mechanical shock absorbers
-Guying


FC3 Data security
0 data leakage
SF1 Encrypt data **only user and admin can read them**
-Symmetric encryption
-Asymmetric encryption
-Hybrid encryption
SF2 Check encryption reliability **100% test success rate**
-Unit tests
-Integration tests
-Robustness tests
FC4 Minimise birds annoyment **noise < 5dB**
SF1 Reduce emitted sounds to a minimum **noise < 5db**
-Vibration reduction
-Sound absorbing materials
-Optimization you design
-Active noise processing
SF2 Check the intensity of the sounds emitted **noise < 5db**
-Use of sound level meters
-Built-in noise sensors
-Conformity test
FC5 Easy installation **< 30min**
SF1 Assemble the different parts together **without tools**
-Clip systems
- Snap-in systems
-Bayonet systems
-Friction assembly
-Magnetic connectors
SF2 Assemble the nest box with the instrumentation system in **less than 30 min**
-Assembly by interlocking
-Zipper systems
-Partial pre-assembly
-Hand screw
FC6 Be autonomous in energy **> 1 year**
SF1 **Autonomously** recover energy using a solar panel
-Integration of a solar charge regulator
-Adapted solar panel
-Automatic solar tracking
- Bifacial solar panels
SF2 Store energy for **1 year**
-Batteries lithium-ion
-Lead-acid batteries
-Flow batteries
-Oversizing of the solar system
FC7 Budget **< 300 €**
SF1 Use **recycled materials**
-Reclaimed wood
-Recycled metals
-Used windows
-Used doors
SF2 Use local suppliers for the nest **within a radius of 100km**
-Natural lime
-Natural coatings
-Local exchange platforms
-Local wood
FC8 Security **0 accident**
SF1 Warn all persons who may be affected **by any risk**
-Social networks
-On-site displays
-Emails
-In-person meetings
SF2 Implement safety instructions to **reduce risks to 0**
-Risk mapping
-Standardized procedures
-Simulations
- Emergency plans
-exercises

Methodology used to generate ideas

During our divergent brainstorming stage, we sought to generate as many ideas as possible without worrying about their quality. The aim was to foster creativity and open-mindedness, encouraging each team member to express his or her thoughts freely. At this stage, no idea was filtered, evaluated or rejected. Every suggestion was noted, even if it seemed unconventional or impractical at first glance.

What's more, when one of the team members proposed modifications, additions or deformations to an initial idea, we took care to record both the original and modified versions. This approach enabled us to follow the evolution of concepts, sometimes leading to unexpected and valuable solutions.

To ensure the effectiveness of this divergent stage, we all adopted and respected certain fundamental rules. Firstly, we avoided censoring ideas, ensuring that each one was expressed and taken into account by the team.

Secondly, we set aside any judgement: at this stage, we weren't trying to determine whether an idea was good or bad, but rather to gather as many as possible. We were also careful to stay focused, as this kind of session can easily drift into off-topic discussions, which would have reduced our productivity.

Finally, we encouraged the visualisation of ideas; drawings and sketches were often used to better illustrate the concepts expressed.

The role of the moderator proved crucial in facilitating this divergent stage. This person, who was either the project manager or another team member, ensured that the rules were respected and set an example by encouraging exchanges.

The moderator was responsible for recording all ideas and keeping the session on track, creating an environment where everyone felt comfortable sharing and building on each other's proposals.

Although we mainly used brainstorming to explore different solutions, we also complemented our approach with the FAST method (Function Analysis System Technique). This method enabled us to break the project down into sub-problems, tackling elementary questions where simple solutions could be put into competition.

This offered us a structured exploration of the project's complexities, facilitating the identification of practical and innovative solutions from the divergent brainstorming stage.

D. Methodology used to select the concept

OPTIMIZING RESOURCES AND REDUCING WASTE (MUDA):

The Connected Nesting project focuses on **reducing waste (Muda) and optimizing resources to improve efficiency and generate added value**. Using the **Eisenhower matrix**, we can effectively prioritize essential tasks and solutions according to urgency and importance. This enables us to focus our efforts on areas of major impact, reducing wasted time, unnecessary costs and effort.

This prioritization method simplifies technological and operational decisions, reduces delays and ensures optimized investments in appropriate solutions. It also helps to simplify installation and maintenance procedures, avoid complexities and improve the efficiency of field teams.

Integrating the Eisenhower matrix with LEAN principles promotes continuous improvement (Kaizen) by proactively identifying and resolving inefficiencies. This approach ensures effective resource management, improves overall project performance, and upholds the goal of protecting bird species while consistently gathering environmental data.

E. The concept retained

FP1 Measure the temperature

Important & Urgent

- Digital thermometer
- Water resistant case
- Grille
- Raspberry RAM
- On-site calibration
- Cloud

Important but not urgent

- Fixed point method
- Sun visor
- Correction software
- Fins
- Periodic drift control
- Anti-vibration equipment
- Anti-bird netting
- Wind deflectors
- Hydrophobic coating

Not Important but Urgent

- Raspberry RAM
- Arduino RAM
- Thermistor
- Infrared sensor
- SD card

Not Important & Not Urgent

- External hard drive
- Absorbent foam
- Ecran de protection UV
- Anti-vibration equipment
- Factory calibration
- Calibration with reference sensors
- Mercury thermometer
- Thermocouple

FS1
FS2
FS3
FS4
Solution chosen

FP2: Measure the Humidity

Important & Urgent

- Digital sensor
- Water resistant case
- Grille
- On-site calibration
- Raspberry RAM
- Cloud

Important but not urgent

- Periodic drift control
- Calibration with reference sensors
- Correction software
- Resistive humidity sensor
- Optical humidity sensor

Not Important but Urgent

- Fixed point method
- Wind deflectors
- Fins
- Hydrophobic coating
- Sun visor
- Anti-bird netting
- Absorbent foam

Not Important & Not Urgent

- External hard drive
- SD card
- Anti-vibration equipment
- Ecran de protection UV
- Electrochemical humidity sensor
- Thin film humidity sensor
- Capacitive humidity sensor

FS1
FS2
FS3
FS4
Solution chosen

FP3: Identify bird species

FS1
FS2
FS3
FS4
Solution chosen

Important & Urgent

- Camera Raspberry Module
- Convolutionnal neural network
- Raspberry RAM
- Cloud
- Grille
- Water resistant case

Important but not urgent

- Arduino RAM
- Absorbent foam
- Sun visor
- Ecran de protection UV
- Support Vector Machines
- Webcams network

Not Important but Urgent

- Digital Cameras
- K-Nearest Neighbors
- Anti-vibration equipment
- Wind deflectors

Not Important & Not Urgent

- Fins
- Hydrophobic coating
- Anti-bird netting
- External hard drive
- SD card
- Smartphones
- Random Forest

FP4: Cound bird

FS1
FS2
FS3
FS4
Solution chosen

Important & Urgent

-Yolo
-Segmentation d'image
-Infrared sensor
-Cloud
-Raspberry RAM
-Water resistant case
-Grille

Important but not urgent

-Wind deflectors
-Fins
-Hydrophobic coating
-Arduino RAM
-External hard drive

Not Important but Urgent

-Cameras
-Light sensors
-Contour detection
-Density based counting
-Sun visor
-Ecran de protection UV
-Anti-vibration material

Not Important & Not Urgent

-SD card
-Ultrasonic sensor
- Pressure sensors
-Anti-bird netting
- Absorbent foam

FP5: Measure variation of weight

Important & Urgent

-Dynamometers
-On-site calibration
-Grille
-Water resistant case
-Raspberry RAM
-Cloud

Important but not urgent

-Factory calibration
-Mechanical scales
- Force sensors
-Calibration with reference sensors
-Fixed point method

Not Important but Urgent

-Hydrophobic coating
-Anti-bird netting
- Absorbent foam
-Sun visor
-Ecran de protection UV
-Electronic scales
-Spring scales

Not Important & Not Urgent

-Arduino RAM
-External hard drive
-SD card
-Fixed point method
-Correction software
-Periodic drift control
-Anti-vibration material
-Wind deflectors
-Fins

FS1
FS2
FS3
FS4
Solution chosen

FP6: Visualize data

Important & Urgent

-Raspberry PI
-Cloud
-Mobile application
-Switch mode expert/beginner
-Web site
-4g
-Cloud computing
-Server python back end
-Raspberry PI

Important but not urgent

-Radio wave

Not Important but Urgent

-Wifi

Not Important & Not Urgent

-Arduino
-Personnalised embedded system
-Bluetouth

FS1
FS2
FS3
FS4
Solution chosen

FC1: Nest adaptability

Important & Urgent

-Removable hooks
-Magnetic
-Snap-on fittings
-Anchors
-Height-adjustable wall support
-Wind-resistant shapes
-Wood coating

Important but not urgent

-Shock-absorbing mounting brackets
-Tensioned cables or straps

FS1
FS2
FS3
FS4
Solution chosen

Not Important but Urgent

-Multi-surface screws

Not Important & Not Urgent

-Quick-release mechanisms
-Modular components
-Latches
-Adjustable mounting system
-Flexible straps

FC2: Resistance to weathering

Important & Urgent

-Rubber supports
-Water resistant case
-Ventilation
-Heat sinks
-Paint
-Design with slope
-Rubber supports
-Guying

Important but not urgent

-Sealing gasket
- Waterproof coating
-UV resistant materials
-Streamlined shape
-Protective grilles

FS1
FS2
FS3
FS4
Solution chosen

Not Important but Urgent

-Sealing gasket
-Hydrophobic coatings
-Mechanical shock absorbers
-Guying

Not Important & Not Urgent

-Streamlined shape
-Protective grilles
-Mechanical shock absorbers

FC3: Data security

Important & Urgent

-Symmetric encryption
-Robustness tests
-Unit tests

Important but not urgent

-Asymmetric encryption

FS1
FS2
Solution chosen

Not Important but Urgent

-Integration tests

Not Important & Not Urgent

-Hybrid encryption

FC4: Minimise birds annoyment

Important & Urgent

-Vibration reduction
-Sound absorbing materials
-Optimization you design
-Conformity test

Important but not urgent

-Active noise processing

FS1
FS2
Solution chosen

Not Important but Urgent

-Built-in noise sensors

Not Important & Not Urgent

-Use of sound level meters

FC5: Easy installation

FS1
FS2
Solution chosen

Important & Urgent

-Clip systems
- Snap-in systems
-Bayonet systems
-Magnetic connectors
-Assembly by interlocking
-Zipper systems
-Partial pre-assembly
-Hand screw

Important but not urgent

-Friction assembly

Not Important but Urgent

Not Important & Not Urgent

FC6: Be autonomous in energy

FS1
FS2
Solution chosen

Important & Urgent

-Adapted solar panel
- 1 year autonomous batteries

Important but not urgent

-Automatic solar tracking
- Bifacial solar panels

Not Important but Urgent

-Batteries lithium-ion
-Lead-acid batteries
-Integration of a solar charge regulator

Not Important & Not Urgent

-Flow batteries
-Oversizing of the solar system

FC7: Budget

FS1
FS2
Solution chosen

Important & Urgent

-Reclaimed wood
-Recycled metals
-Local exchange platforms
-Local wood

Important but not urgent

-Used windows
-Used doors

Not Important but Urgent

-Natural lime

Not Important & Not Urgent

-Natural coatings

FC8: Security

FS1
FS2
Solution chosen

Important & Urgent

-Social networks
-On-site displays
-Emails
-Risk mapping
-Standardized procedures

Important but not urgent

-In-person meetings

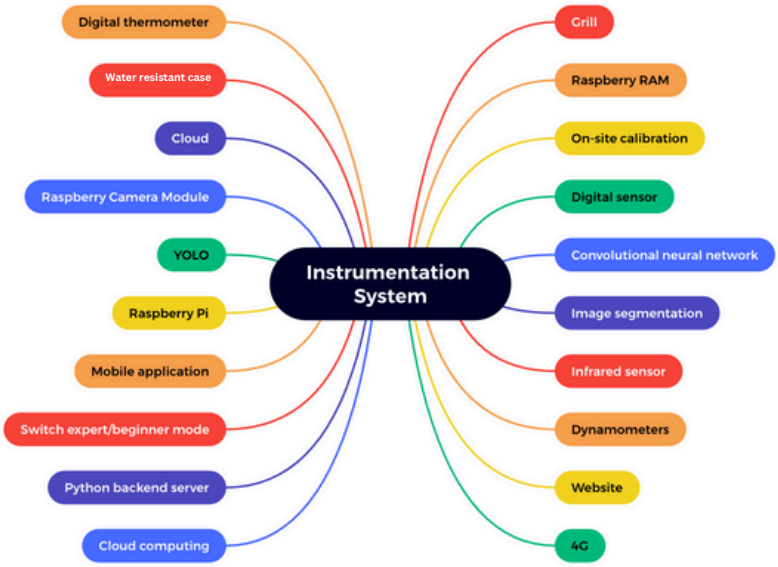
Not Important but Urgent

-Exercises

Not Important & Not Urgent

-Simulations
- Emergency plans

E.1 Final solutions for Instrumentation System



E.2 Final solutions for Nesting Box

F. Preliminary calculations which allowed the concept to be selected

- **FP1 SF4** : On veut mesurer un intervalle de température allant de -25°c à 45°c. Il est nécessaire de pouvoir représenter 70 températures différentes. 7 bits permettent de représenter 2^7 = 128 valeurs. 7 bits seront suffisant pour représenter et mémoriser les différentes valeurs de température.

- **FP2 SF4** : On veut de mesurer le pourcentage d'humidité dans un intervalle de 10% à 100%. Il est nécessaire de pouvoir représenter 90 pourcentages différents. 7 bits seront suffisant pour représenter les différentes valeurs d'humidité.

- **FP3 SF3** : On veut prendre des photos d'une qualité de 720p en couleur RGB avec 1 octet par pixel. Cela représente 720*1*3=2160 Octets.

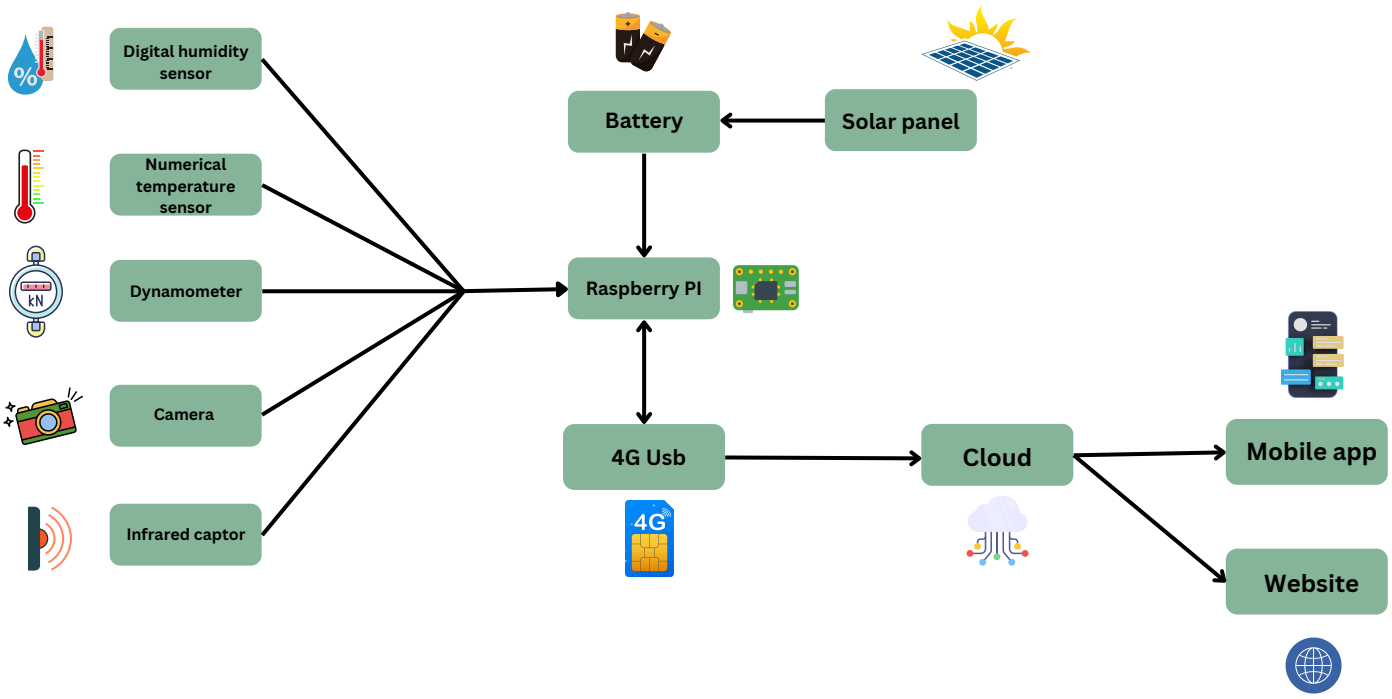
- **FP4 SF4** : On fait l'hypothèse qu'il y aura une fréquence de passage d'oiseau dans le nest <= 30 par heure. On veut donc pouvoir représenter 31 valeurs. 5 bits permettent de représenter 2^5 = 32 valeurs. 5 bits seront suffisant pour représenter et mémoriser les différentes valeurs de fréquence de passage.

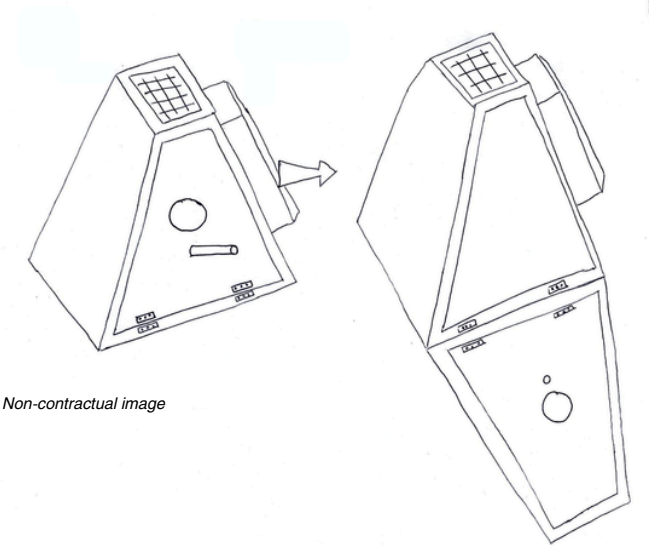
- **FP5 SF4** : On veut mesurer un intervalle de variation de poids allant de -2,5kg à 2,5kg. Il est nécessaire de pouvoir représenter 500 valeurs différentes. 9 bits permettent de représenter 2^9 = 512 valeurs. 9 bits seront suffisant pour représenter et mémoriser les différentes valeurs de variation de poids.

- **FP6 SF2** : L'intervalle approximatif de quantité données totales qui seront transmit chaque heure est entre 2160 + 1 + 1 + 1 + 2 octets et 30* 2160 + 1 + 1 + 1 + 2 octets

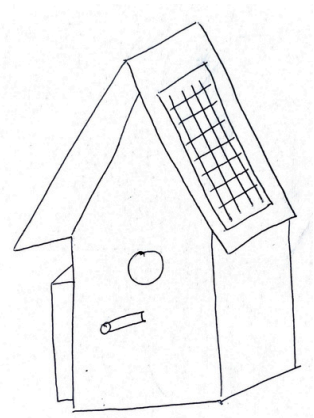
- **FC6 SF2** : Le système de mesure fonctionnera sur 1 mode ON et 1 mode veille. Le mode ON sera actif 1 fois par heure pour la température, la variation de poids, l'humidité et la transmission des données. Il sera aussi actif 30 fois maximum par heure pour prendre une photo à chaque passage d'oiseau détecter. Le reste du temps il sera en mode veille avec pour seul activité la détection des oiseaux et la ventilation. Le mode ON se fait toujours en addition du mode veille. Partant de là nous pouvons calculer une consommation journalière/annuelle approximative sans prendre en compte le mode veille pour avoir une bonne marge d'erreur :
  - Raspberry PI 5Watt/h
  - Capteur température numérique 5Watt/h
  - Capteur humidité numérique 5Watt/h
  - Dynamomètre 5Watt/h
  - Ventilation 5Watt/h
  - Clé USB 4g 10Watt/h
  - Capteur infrarouge 5Watt/h
  - Module caméra Raspberry 5Watt/h

  Total 110Watt/h pour un fonctionnement à plein régime continu sans mode veille
  45 Watt/h / 5V = 9 A/h.





Non-contractual image



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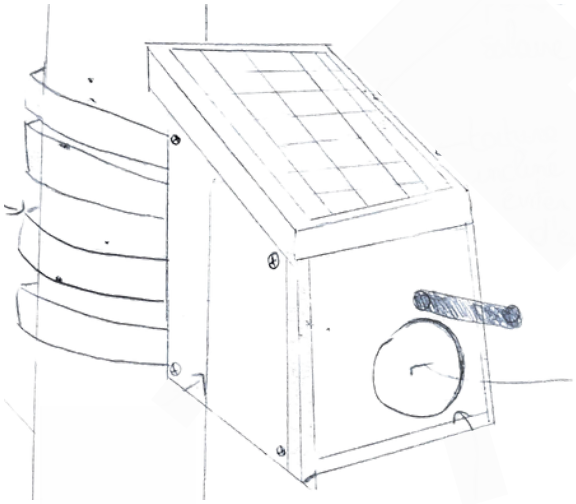

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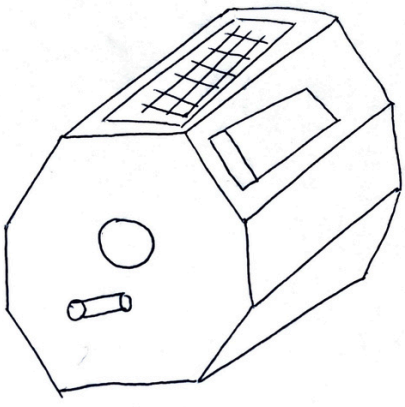

Non-contractual image