Air & Land ACE

A.C.E.

AUTONOMOUS CHARGING ENVIRONMENT

TÉCNICO LISBOA

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Motivation:

The deployment of autonomous tools in high-risk missions is increasing. With it, so does the need for a higher degree of autonomy on those very tools.

The manual method of charging a drone or rover normally requires interrupting missions and mandatory human intervention.

An autonomous charging environment would manage each of the drone’s necessities automatically.

Challenge:

CNN Portugal - Marta Coropos Carvalho

1. What weaknesses in telecommunications in Portugal were exposed by Storm Kristin?

Portugal's telecommunications infrastructure - particularly mobile communications - is highly dependent on power supplied by commercial electrical grids. While critical telecommunications infrastructure (such as maintenance and control centers of major operators) has redundancies that enable uninterrupted operation for at least 15 days, mobile customer access networks rely on base stations located near users' terminals.

Instituto de Telecomunicações - António Rodrigues

The battery autonomy of a common drone is limited. In addition, the scenario of certain operations sometimes makes manual charging a risk or a heavy cost to the operator.

As seen during storm Kristin on January 2026, electric power might not be available in certain areas, even if close to an operational power source.

If autonomous means were to be deployed, charging could be a difficult task.

Challenge:

All municipalities and 76% of parishes have 5G stations

There are 5G base stations located in every municipality in Portugal (308 municipalities) and across 2,336 parishes (75.6% of the country's parishes)1.

In general terms, the four operators each have stations in almost all municipalities.

The areas of the country with a higher density of stations also correspond to those areas where population density is higher or where there is a seasonal increase in the number of inhabitants.

63% of 5G stations are located in urban areas

The majority of 5G stations were located in predominantly urban areas (62.8% of the total, or 9,729 stations), compared to approximately 13.9% (2,158 stations) installed in moderately urban areas and 23.3% (3,608 stations) located in predominantly rural areas.

Considering the total number of locations in Portugal where each operator has mobile stations, NOS had the highest proportion of 5G stations in the locations where it was present (94.4% of its locations), followed by Vodafone (92.0%), DIGI (61.6%) and MEO (44.0%).

Portugal has 15,500 installed 5G stations - ANACOM

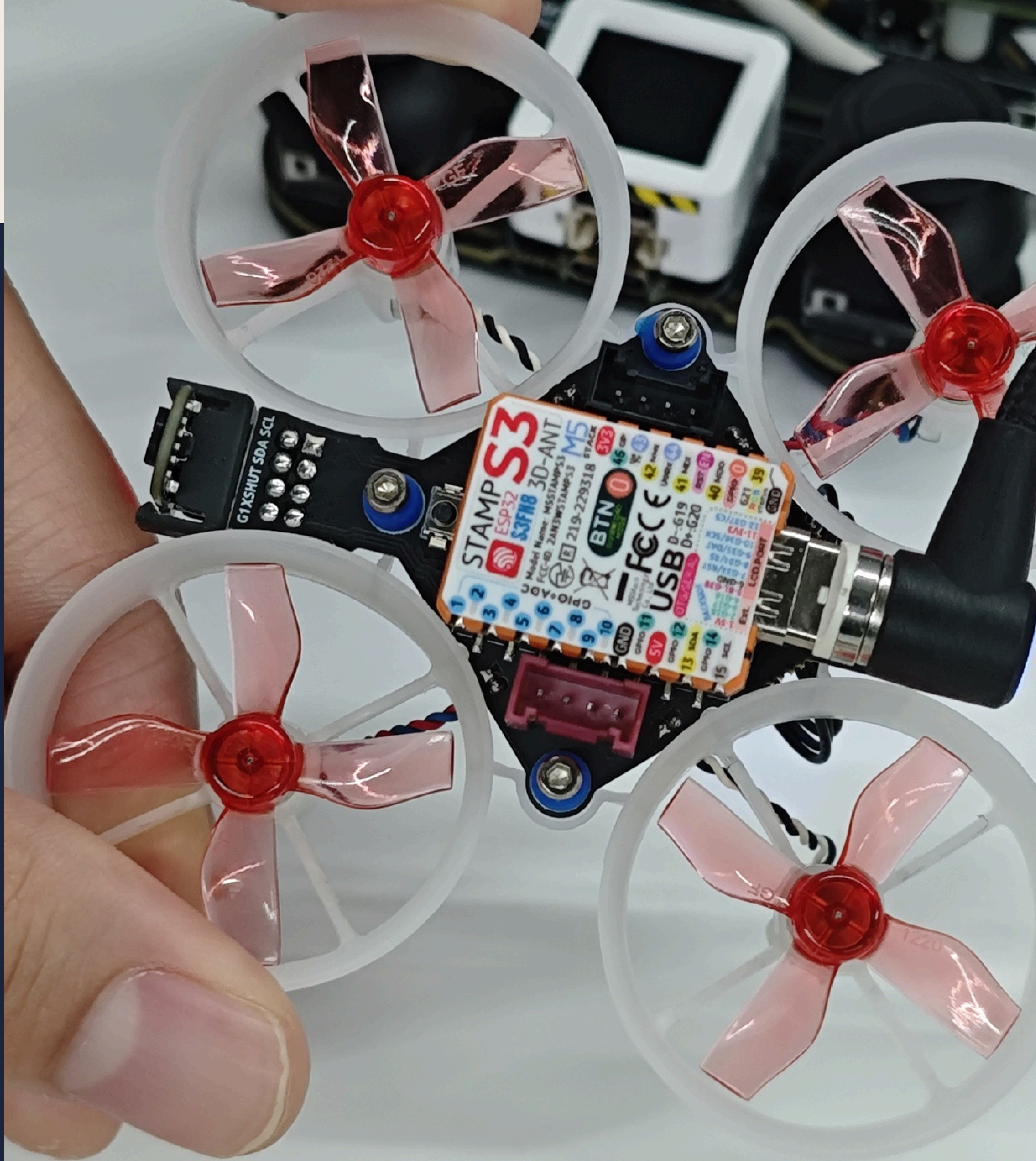
In addition, the signal most IoT devices use to operate, most commonly Wi-Fi, might be unavailable on-site or locally corrupted due to external interferences.

Thus, it’s useful to have a system where information and orders can be exchanged between agents capable of reacting to such changes in a timely manner.

Solution:

- A self-managing autonomous environment.
- The environment is composed of the actors (drones) and support devices (stations).
- The environment changes over time with:
  - Updated information;
  - New devices in the env.;
  - New orders from higher-ups;

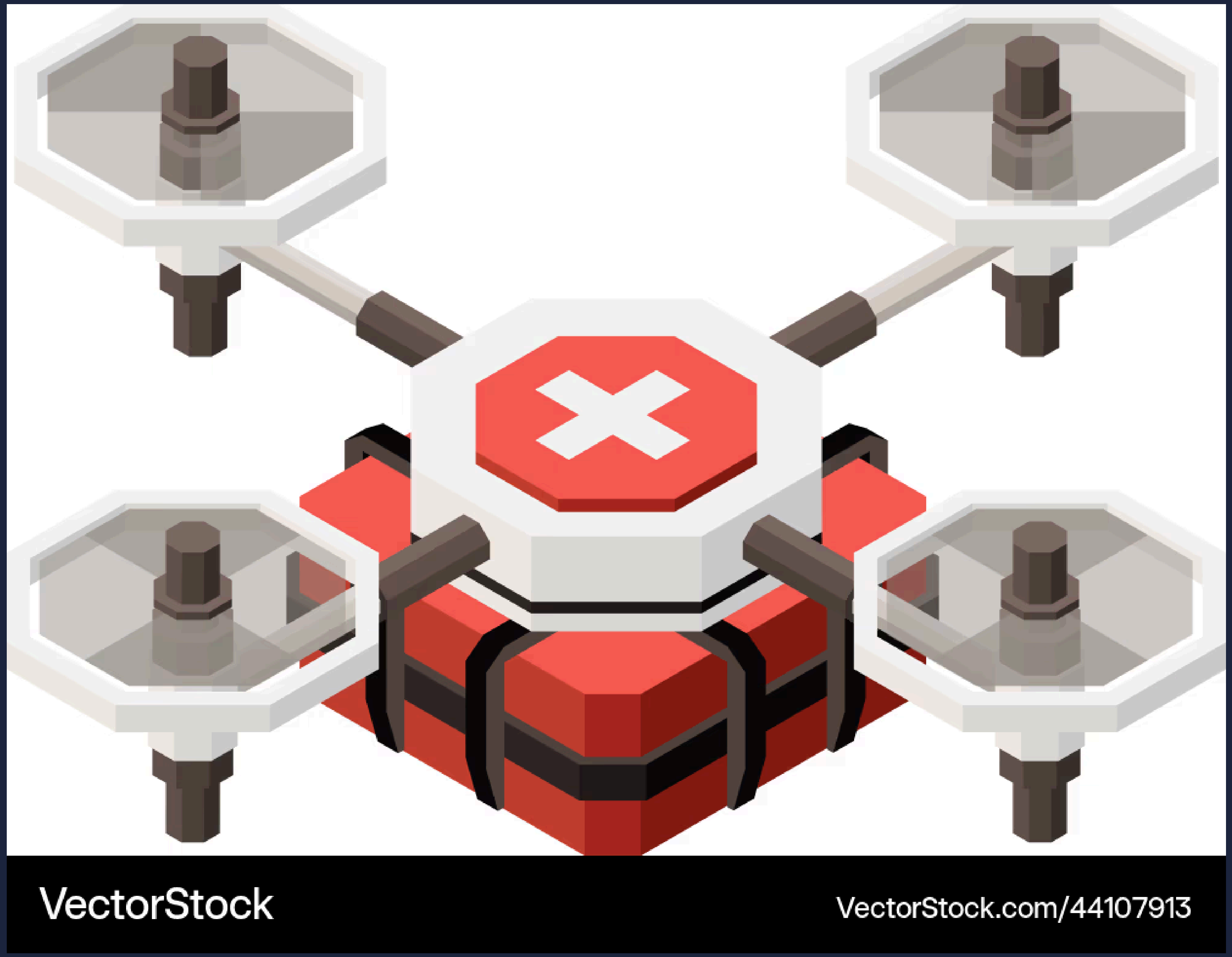
That way, a human operator can trust the environment to <u>self-regulate towards the objective</u>.



A network of two species of agents: Drones and Stations

Drones:

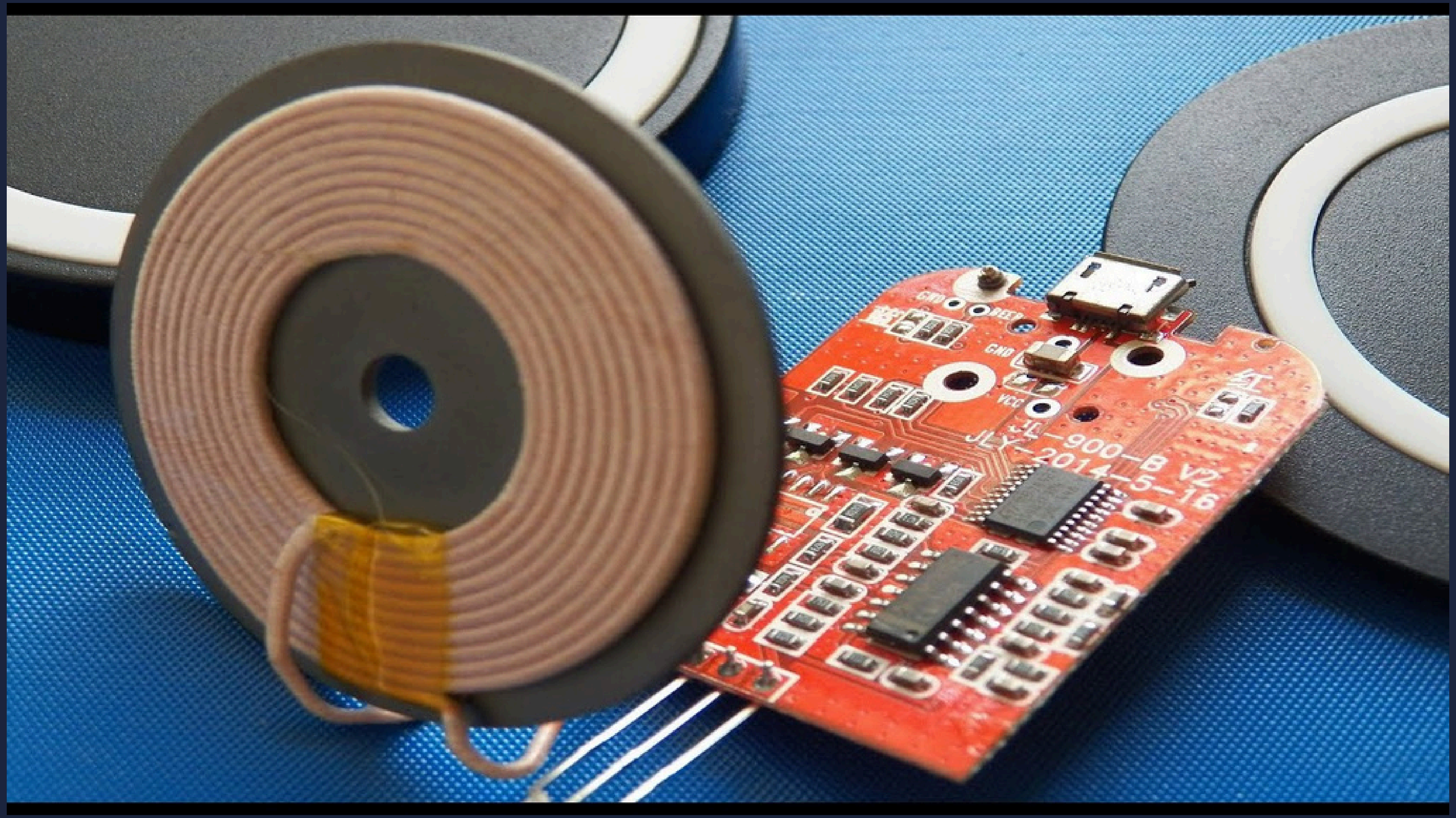
- Perform a mission.
- Updates itself with new info.
- Frequently exchanges with the station:
  - State (distance, battery and health);
  - Rank and Signature;
  - Mission related info.
- Asks a station for permission to land and recharge (and obeys the response).



A network of two species of agents: Drones and Stations

Stations:

- Checks for new orders by the user.
- Verifies, updates and relays new network info. regarding:
    - Network state;
    - Rank updates and signatures;
    - Mission related info.
- Analyses the NW state, new orders and determines a landing priority.
- If asked, the station accepts or rejects the landing.



NW: Network

Target beneficiaries:

- Autoridade Nacional de Proteção Civil:
  - Forças de Segurança: GNR & PSP;
  - Corpos de bombeiros portugueses;
  - Forças Armadas;
  - INEM (Instituto Nacional de Emergência Médica);
  - Autoridade Marítima e Aeronáutica.

Our competitors:

Skydio (Skydio Dock)

Known for industry-leading AI and obstacle avoidance. Their "Dock for X10" uses 5G/LTE for unlimited range and remote operations

Nokia Drone Networks

A leader in industrial-grade drone solutions that utilizes 4G/5G connectivity. Focuses on mission-critical applications and public safety.

Percepto (Percepto Air)

A pioneer in the "Drone-in-a-Box" industry. Their platform provides 24/7 automated inspection for large-scale industrial sites

Tech specifications:

Prototype - Equipment choice:

- The M5Stack K138 (Stamp Fly) operates under a modified ESP32-S3@Xtensa LX7 microcontroller equiped with a Wi-Fi module.

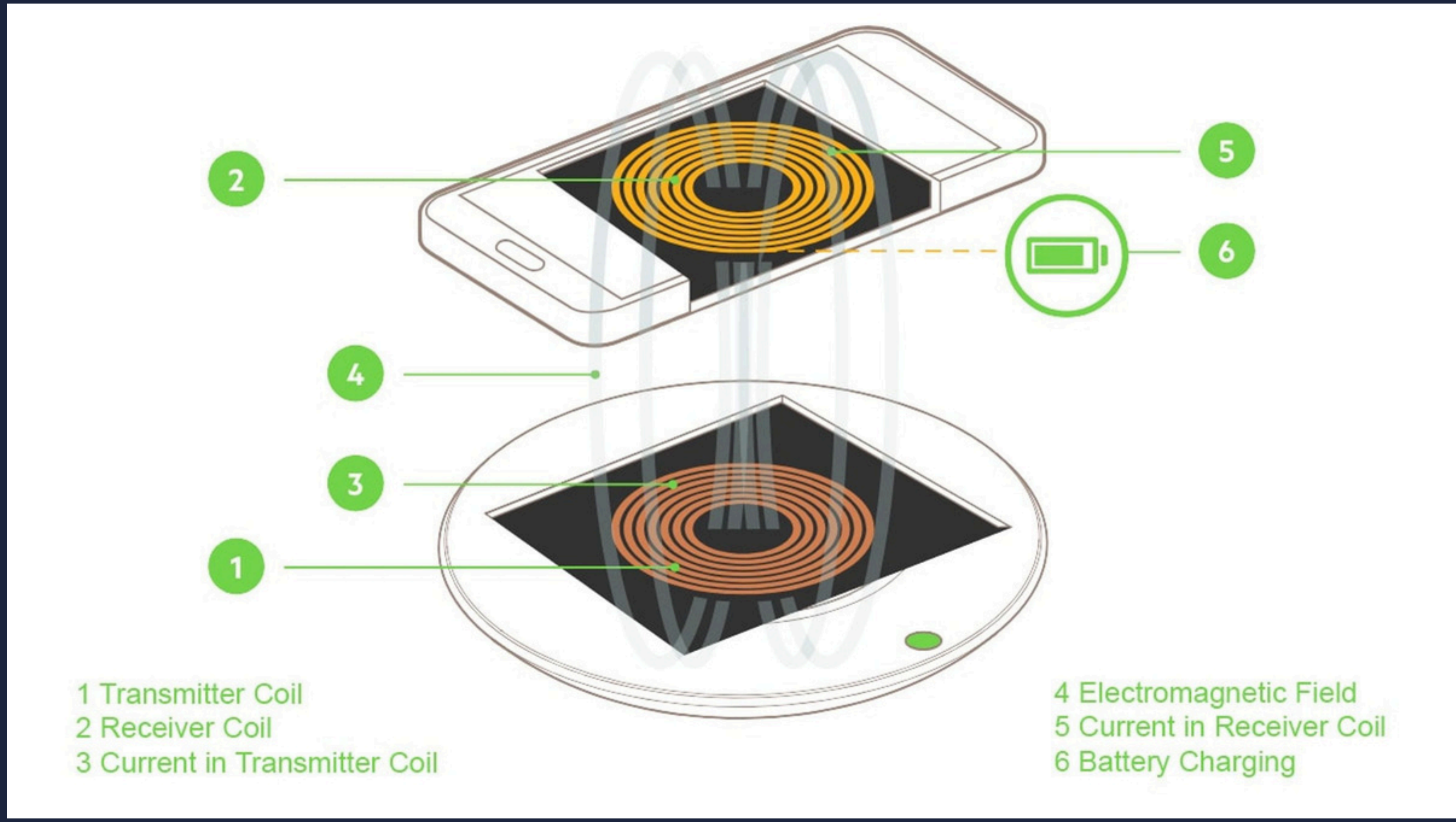
- For adaptability, the M5Stack K137 (Atom Joystick) is used to operate the drone. It enables us to start the drone, activate the autonomous flight and making it return to base at the end of the demonstration.

- The ESP-NOW protocol allows the drone to share telemetry information and exchange flags that determine what mode it’ll fly in.

Tech specifications:

Prototype - Equipment choice:

- A LiHV battery powers the system. The system does not support concurrency between the charging and the workload, so hardware modifications are required.
- To power the drone, we chose the QI induction protocol, common in smartphones.
- To integrate it, we'll build a module that provides and rectifies the current.



Tech specifications:

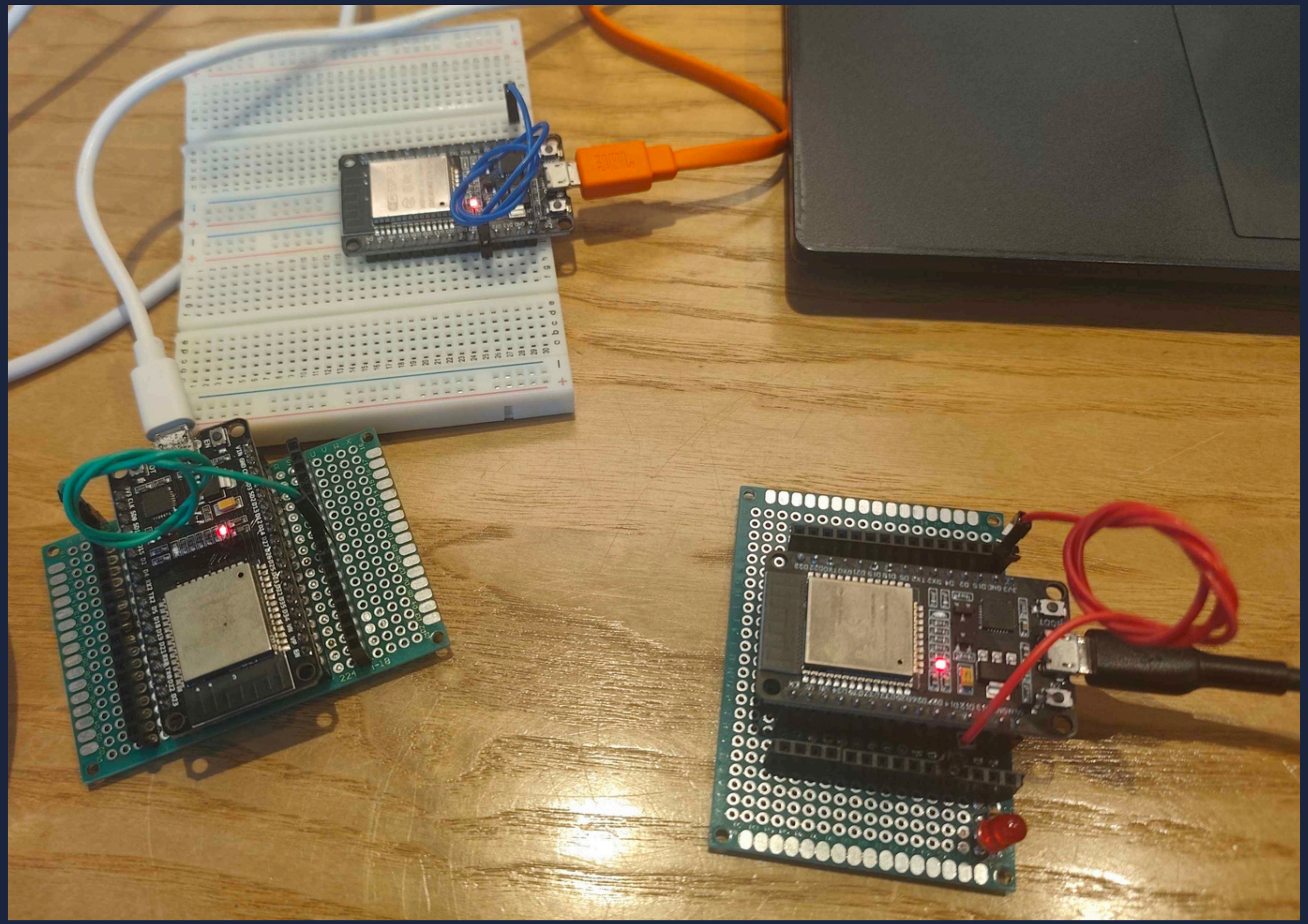
Prototype - Equipment choice:

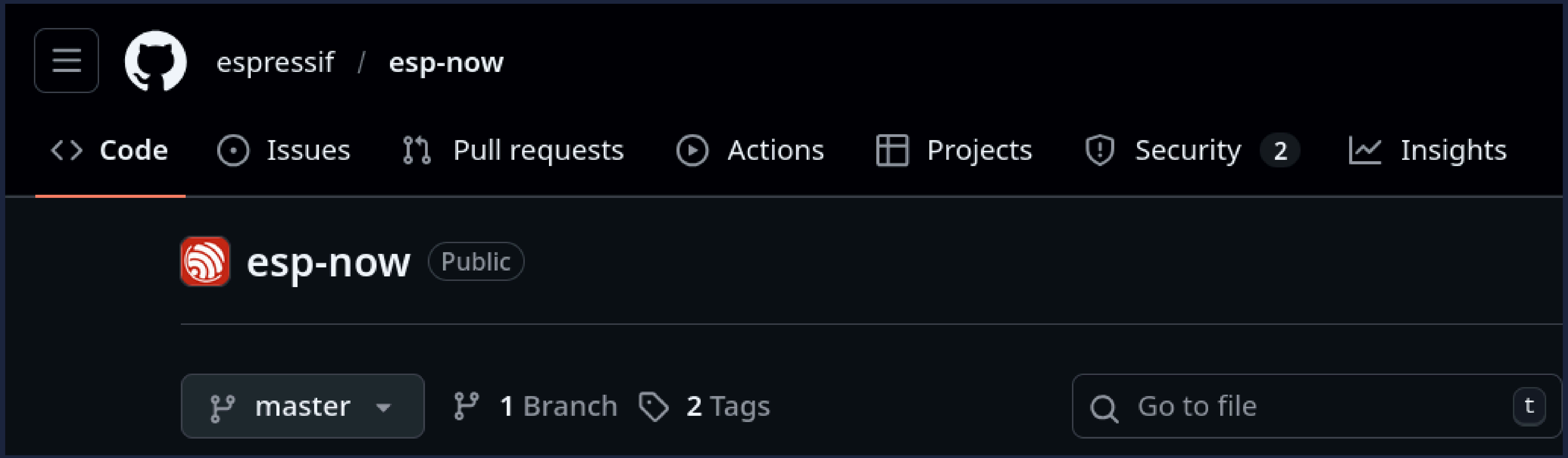
- The Station will both interact with the Network and provide power to the charging station.

- For data processing and actuation, an SBC-NodeMCU-ESP32-C will be used.

- The ESP in the station will manage which and when the theoretical multiple drones will land and charge.

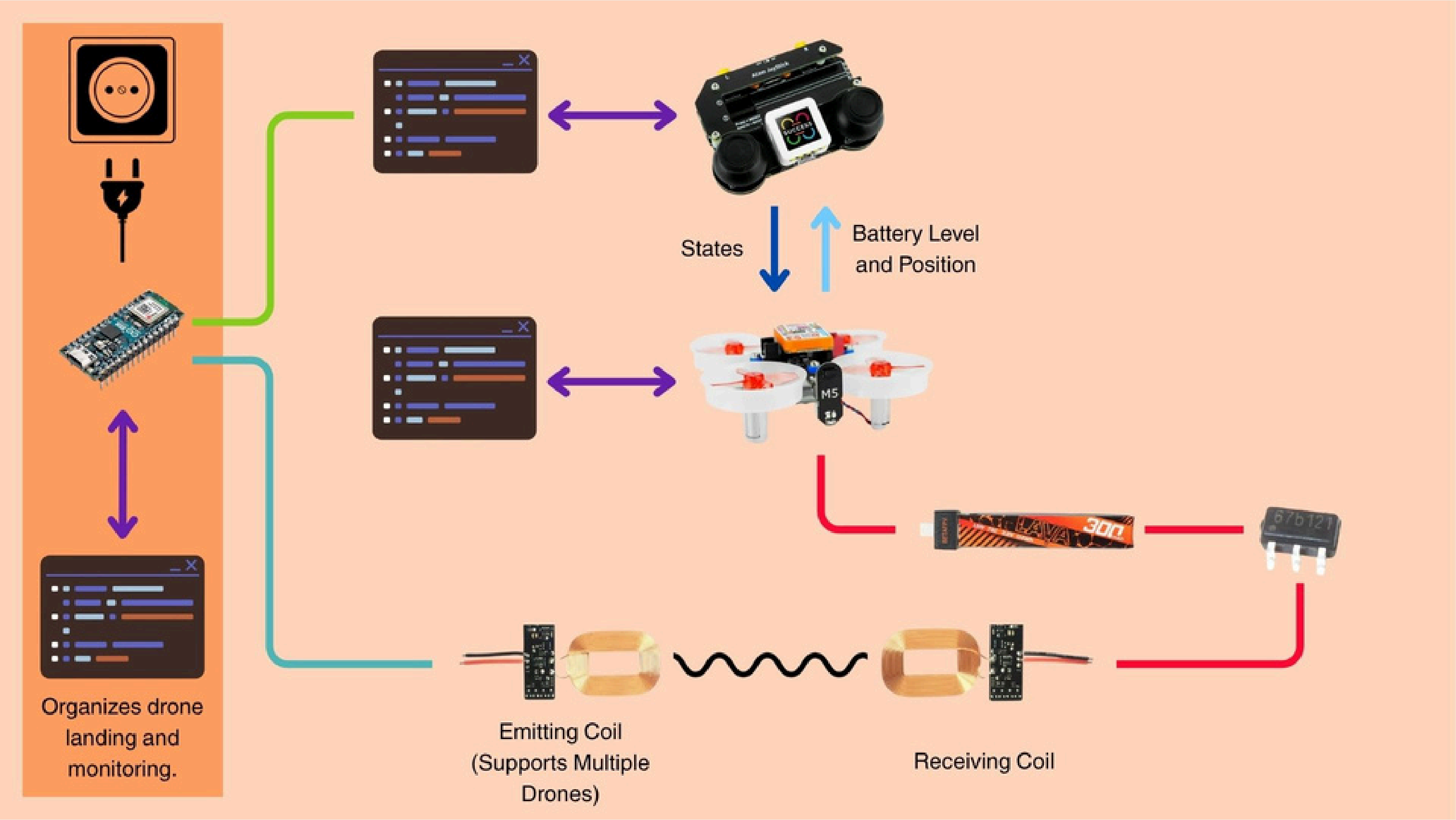
- The ESP-NOW communication protocol will transmit information between the drone and the controller and between the drone and the station.





Tech specifications:

- This technology will be scalable. It will be possible to have a swarm of drones managed by multiple charging stations with capacity to charge multiple drones.
- A drone will request permission to land on the closest station and the station will evaluate the request, taking into account the priority system and the drone's battery.
- Should the drone be given permission to land it will be inductively charged at the station.



Drone

- **Power Source:** LiHV battery
- **Telemetry & Control:** Transmits real-time position and battery status to the controller while receiving mission commands.
- **Charging Module:** Equipped with a TP4067 charging IC and a wireless receiving coil.

Charging Station

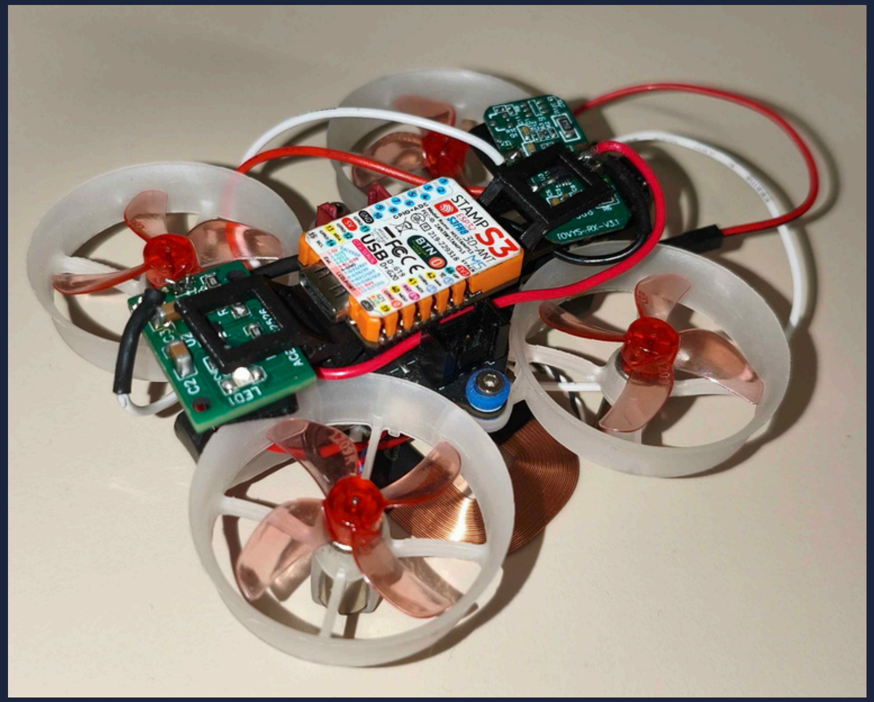
- **Hardware:** Features an emitting coil, a USB-C power adapter, and an ESP32 microcontroller.
- **Management:** Has an ESP32 that hosts the core software responsible for autonomous drone landing coordination and system monitoring.

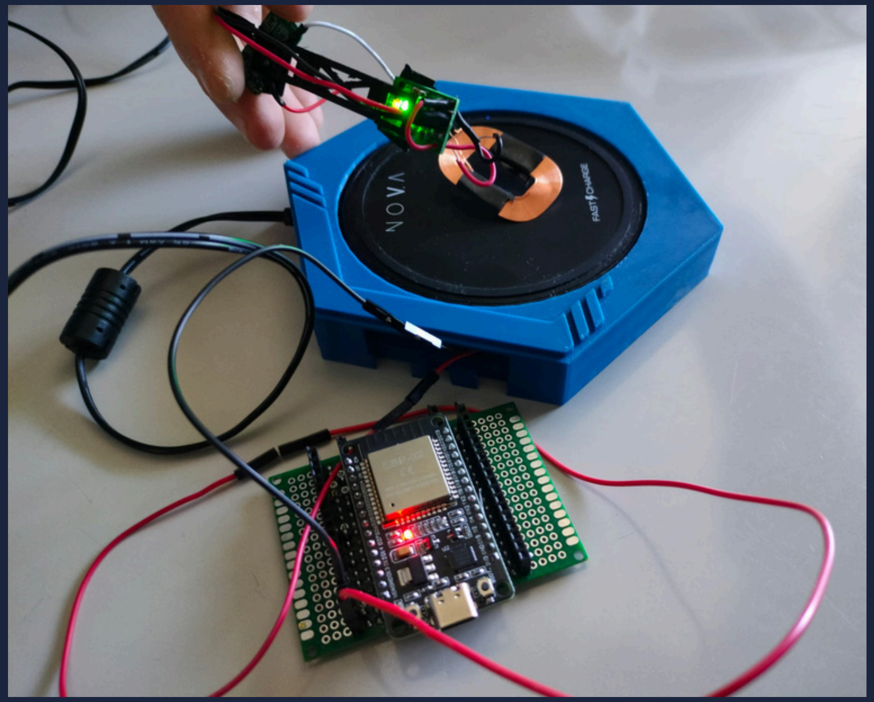
Achieved results

- **Autonomous Flight Optimization:** The drone's original code was modified to achieve a stable, fully autonomous mission execution.

- **Hardware:** A charging module was designed and integrated to solve power concurrency issues between the charging circuit and the operational workload.

- **Networked Charging Infrastructure:** An induction charging station capable of wireless power transfer and interaction with the central network was developed.





Achieved results

- **Scalability Simulation:** A multi-agent simulation was developed to validate the environment's framework and demonstrate system scalability across larger drone fleets and multiple stations.

- **Green squares:** Forest
- **Grey squares:** Burned area
- **Blue squares:** Stations

- **White lines:** Communication between stations and drones

- **Dots:** Drones
  - **Green:** Directly connected to stations
  - **Yellow:** Indirectly connected to stations
  - **Red:** Not connected to stations (try to connect to a station as quickly as possible so there are no offline drones)

Costs and Benefits

- **Costs:**
  - **Drone:**
    - Drone & Controller: ≈120€ or more
    - Batteries: ≈8€/pc
    - Charging module (induction coils, TP4067): ≈8€/pc
  - **Networked Charging Station:**
    - Base materials (induction coils, power adapter, casing): ≈30€/pc
    - ESP32 microcontroller: ≈8€/pc

- **Benefits:**
  - **Continuous 24/7 monitoring -** Fully automated flight and charge, reducing operational down time;
  - **Zero human exposure -** Removed the need for human operators to enter high-risk or hazardous mission zones;
  - **Fleet scalability -** A single operator can oversee multiple drones and stations via network coordination.

Our contributions:

- **Sara Viegas:**
  - Flight controller & Station firmware dev.
- **Rodrigo Oliveira - TEAM LEADER:**
  - Flight controller SW main designer
- **Francisco Gonçalves:**
  - Drone and Station SW/HW designer
- **Ricardo Maurício**
  - Main website dev./maintainer, NetLogo Simulation main dev.
- **Pedro Nantes:**
  - Video-Production and human resources
- **Lena Wang:**
  - Human resources and Main Artistic Designer

Online Resources & Media

For more information visit our website:

To watch a solution demo video check: