ElectroCap Project Final Pitch

UAV'S SWARM COMMUNICATION

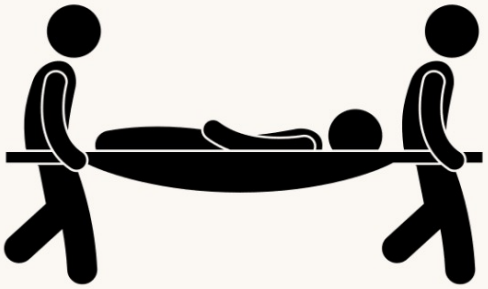
Rafael Major - ist1102647
Maria Rodrigues -ist1102587
Manoel Maio - ist1103109
Afonso Lopes - ist198922
Yeon Su Choi - ist1110547

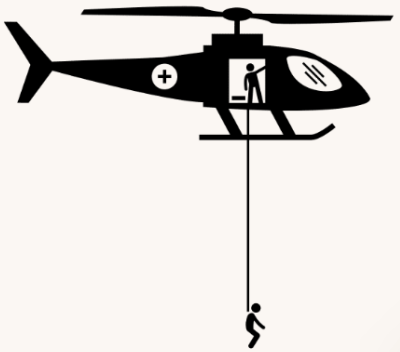
Introduction

Effective communication is critical during emergency response operations.

In remote and challenging environments, maintaining reliable connections is difficult.

New technologies like UAV swarms offer promising solutions to improve coordination and safety in these missions.





Problem

Drone swarms for search and rescue struggle to maintain real-time, low-latency communication over wide areas—especially in remote zones without network infrastructure.

Built-in Wi-Fi offers limited range and high latency, while mesh networks fail in fast-moving, data-intensive scenarios.

+60% **Coastal areas** in search and rescue missions often have limited or no mobile network coverage.

±45% The **area affected by wildfires** often experiences mobile network coverage failures during operations.

Problem

Economic feasibility is a major challenge: each drone costs 1.000€, plus 1.400 € for communication equipment. This makes large-scale deployment costly and hard to scale. We aim to explore low-cost communication solutions that ensure reliable connectivity.

High cost per drone → Not scalable for large swarms → Unsuitable for real rescue missions

💡 **Goal:** Reduce communication costs *without* sacrificing performance

Solution

We propose a communication **algorithm** for UAV swarms that ensures real-time data flow with minimal delay.

It integrates easily with MAVLink and ArduPilot, requiring no deep firmware changes.

Using TDMA, it avoids collisions and improves reliability through redundancy and error correction.

📡 Real-Time Data Layer	🔁 TDMA Scheduling Layer	🧠 MAVLink + ArduPilot Integration	🛡️ Reliability Layer
• Continuous info exchange between drones.	• Smart time-slot allocation to avoid packet collisions.	• Plug-and-play deployment on standard drones.	• Redundancy + error correction to handle interference.

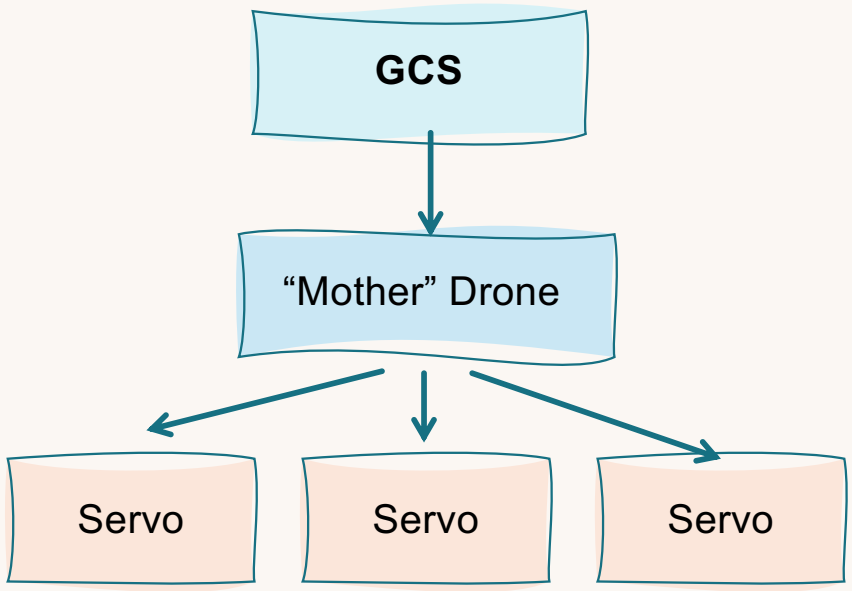
Solution

The project aims to implement a decentralized communication system that operates on three main levels:

- **Ground Control Station (GCS)**
- **"Mother" Drone**
- **"Servo" Drones**

The GCS connects to the Mother, which manages communication with Servos, ensuring efficient data flow.

This structure boosts resilience and creates the perception of real-time transmission, even with limited connectivity.



Solution

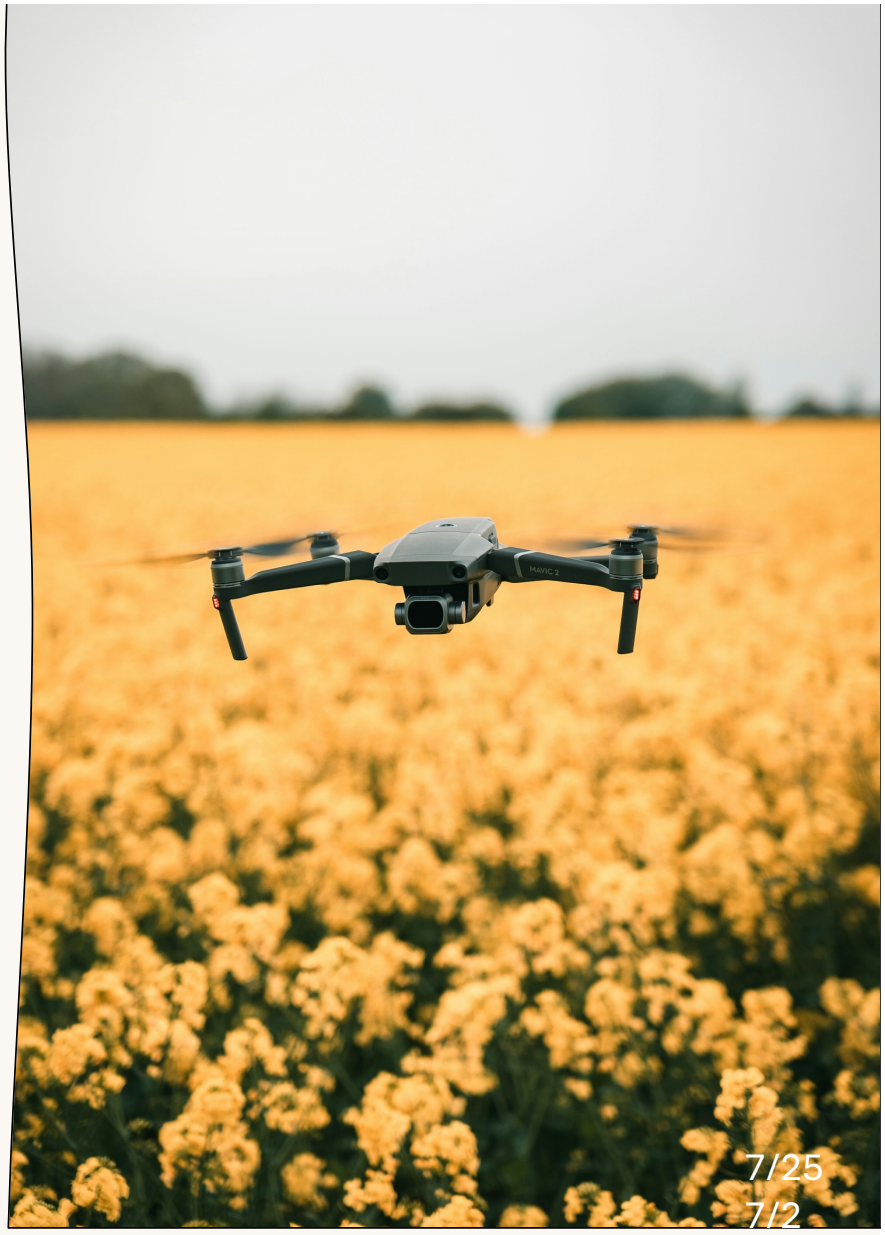
The implementation of this system follows a **decentralized approach**, where a 'Mother Drone' coordinates the communication between the various UAVs ('Servo Drones') and the GCS, enabling **efficient communication**.

Next, we will detail the propulsion system of a drone designed to ensure stability, energy efficiency, and autonomy during operations.

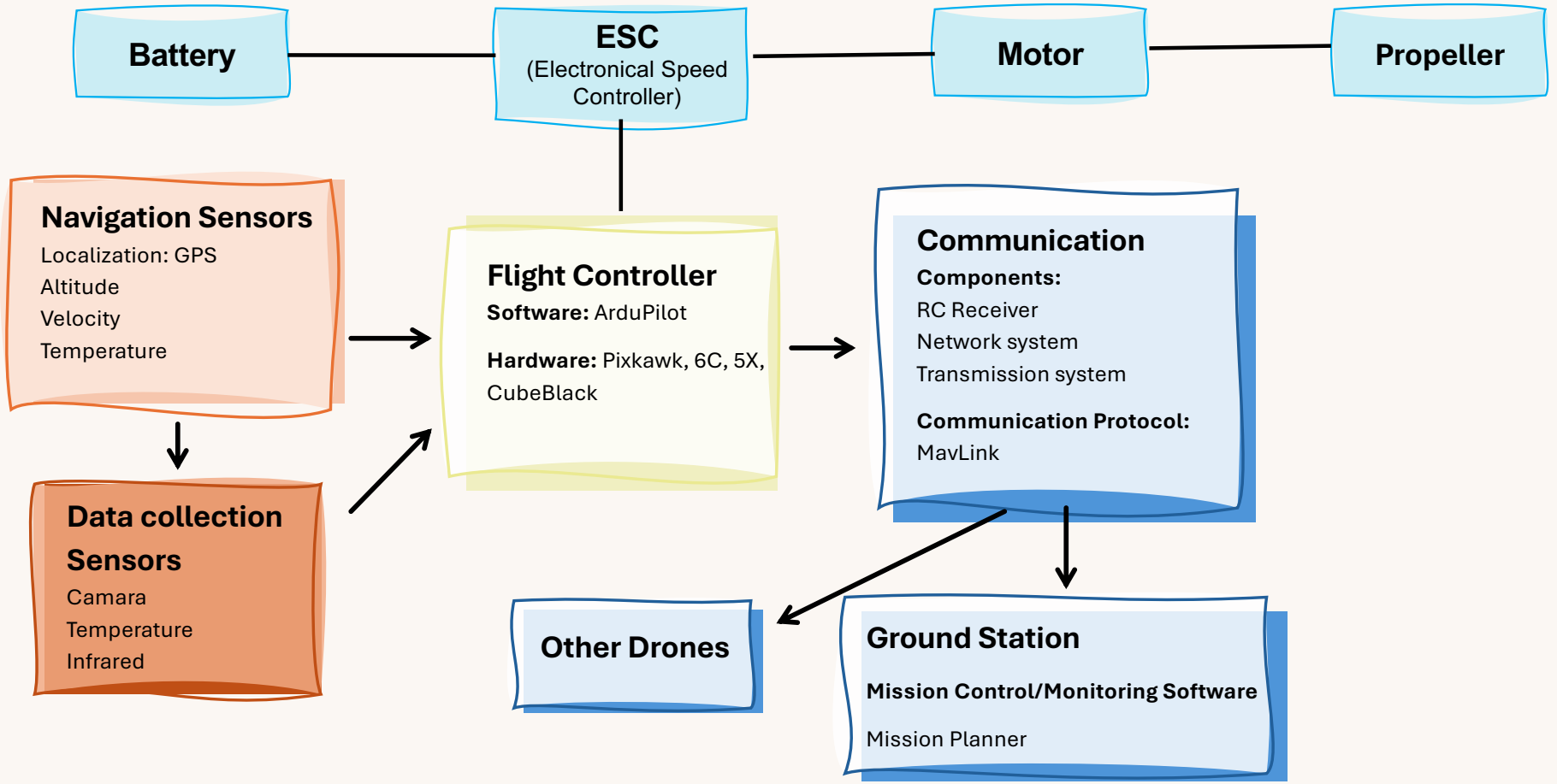
🧠 ***Decentralized Control***

⚙️ ***Efficient Propulsion***

📡 ***Adaptable Communication***



Solution


Battery
ESC
(Electronical Speed Controller)
Motor
Propeller
Navigation Sensors
Localization: GPS
Altitude
Velocity
Temperature
Flight Controller
Software: ArduPilot
Hardware: Pixkawk, 6C, 5X, CubeBlack
Communication
Components:
RC Receiver
Network system
Transmission system
Communication Protocol:
MavLink
Data collection Sensors
Camara
Temperature
Infrared
Other Drones
Ground Station
Mission Control/Monitoring Software
Mission Planner

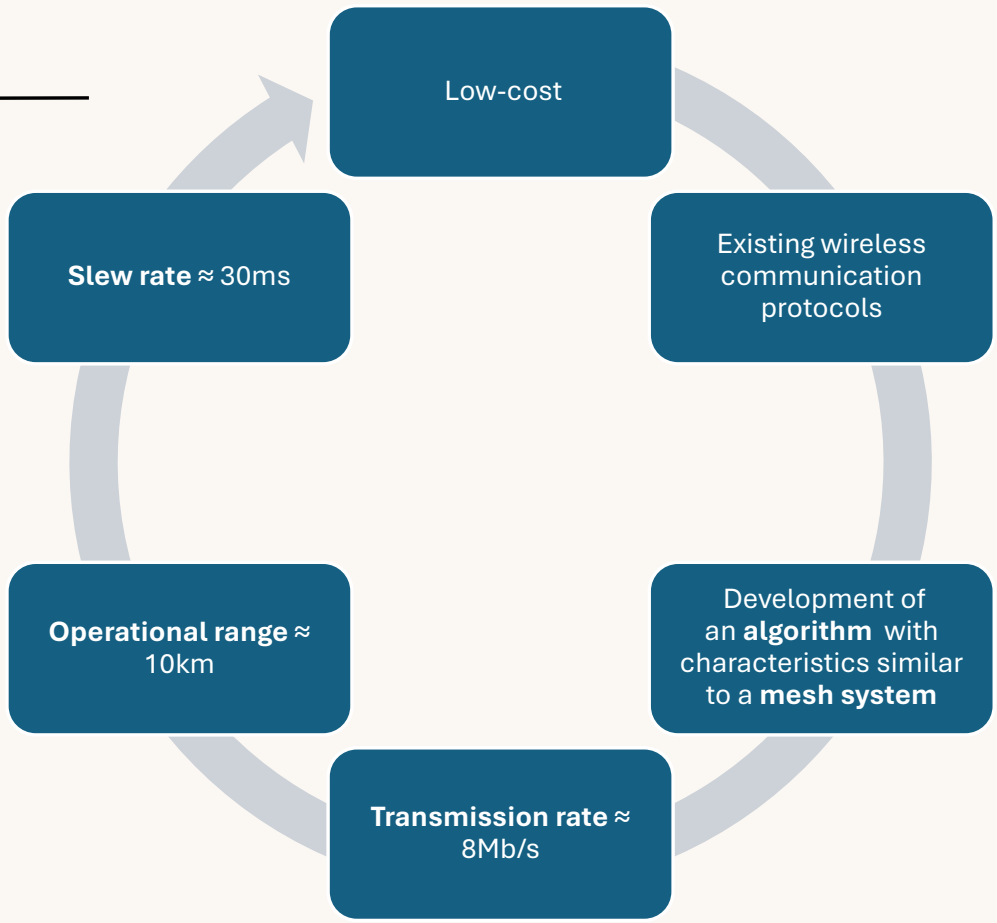
Solution

The proposed solution enables efficient communication among drones.
It combines low-cost hardware and existing protocols with an advanced channel management algorithm.

The goal is to create a mesh-like network using unidirectional devices.

This approach achieves high transmission rates, long range, and low latency.

It enables scalable and reliable operations with multiple UAVs



Solution

We use Sik V3 telemetry radios for transmission—compact, open-source, and fully compatible with ArduPilot and MAVLink.

Ideal for missions requiring robust data links, such as monitoring, rescue, or remote control.

Standard range: 300 m, extendable with a patch antenna for more stable and reliable communication.

Solution requirements

For an **effective communication system** in UAV swarms, several **technical requirements** must be met to ensure **stability, efficiency, and scalability**. These requirements include:

Transmission rate

5 Mb/s link ensures real-time data and decisions across nodes.

Number of nodes

The swarm must scale efficiently, managing 5–10 UAVs with dynamic networking.

Communication frequency

UAVs use 2.4/5 GHz ISM bands, with UHF/VHF for long-range, all under MAVLink.

Solution requirements

Latency

Low latency (<70 ms) is crucial for swarm coordination and collision avoidance.

Network Topology

The system uses a hybrid mesh: drones communicate directly while staying linked to the ground station.

Energy Efficiency

Energy-aware protocols with adaptive power ensure efficient UAV operation.

Error Management & Redundancy

The system includes packet loss recovery, automatic rerouting, and failover for reliable networking.

Security & Encryption

Due to cyberattack risks, all communications must use AES-256 encryption with authentication to block unauthorized access.

Target Audience

- **Portuguese Navy** developing this technology for various operational scenarios.
- **Portuguese Air Force** advancing this technology for diverse operational scenarios.
- **Portuguese Army** actively developing this technology for multiple operational scenarios.
- I**ntelligent Robots and Systems Group** (IRS) of the Institute of Systems and Robotics (ISR).
- **Portuguese Civil Protection** Authority.

Competitors

Competitors	**Lockheed Martin, Boeing, Northrop Grumman, Thales, Saab, Turkish Aerospace, Anduril**

↓

Previous Work	These organizations specialize in autonomous navigation, swarm coordination, real-time communication, and military UAVs, focusing on scalable, autonomous, and fast-deployable solutions.

Team

Maria Rodrigues

Manoel Maio

Rafael Major

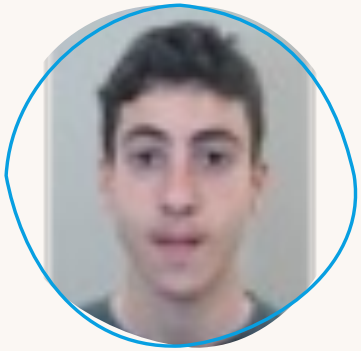
Afonso Lopes

Yeon Su Choi

Advisors and Mentors

Scientific Advisor

João Felício



Mentor

João Gonçalves

Scientific Co-Advisor

Afonso Vale

Scientific Co-Advisor

Prof. Alexandra Moutinho

Scientific Co-Advisor

Emanuel Rodrigues Marante

Results

We developed a distributed communication algorithm, HMAV-LoRa, enabling drone connectivity without relying on external infrastructure.

Communication is layered, with a mother drone coordinating multiple servo drones to ensure real-time data sharing.

MOTHER DRONE:

- Air network central node
- Receives commands from the GCS
- Manages communication and coordination between drones and forwards critical data
- High computational autonomy

SERVO DRONE:

- Mission operational units
- Perform scanning, detection, and monitoring
- Send data to the Mother Drone
- Adapt to failures and network changes

GROUND CONTROL STATION

- Mission ground system
- Does not control the servo drones
- Sends initial commands and receives telemetry
- Communicates with the Mother Drone

Results

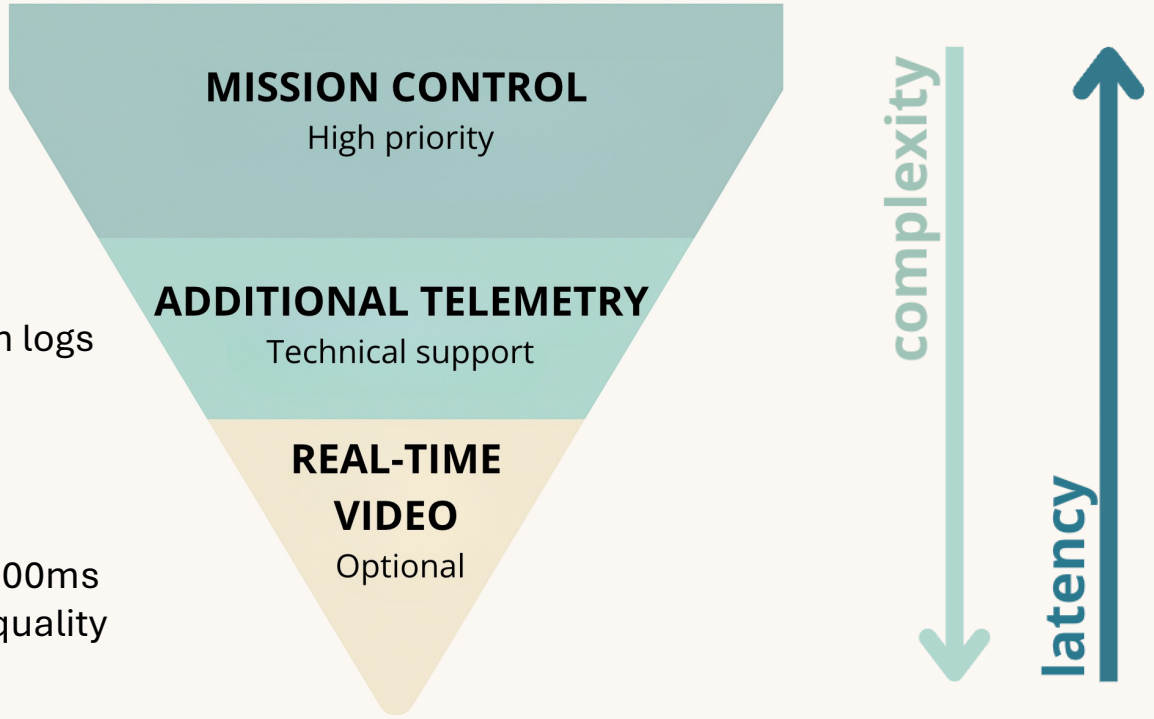
TÉCNICO LISBOA

The drone communication system is divided into **three functional layers**. Each layer manages different types of data based on priority and latency requirements.

Takeoff and landing
Status data (battery, position, etc.)
Swarm task coordination

Environmental sensors and mission logs
Hardware diagnostics

Video transmission – latency under 100ms
LoRa used to ensure efficiency and quality



Team members contributions

Team Leader
Manoel Maio

- ✓ Radio Firmware
- ✓ Software and firmware integration
- ✓ Overall System performance
- ✓ Prototype development
- ✓ Video development

System Integration and Performance Manager
Afonso Lopes

- ✓ One-way communication systems
- ✓ WebApp development
- ✓ Website development

Data and Content Manager
Maria Rodrigues

- ✓ One-way communication systems
- ✓ Content Management
- ✓ Prototype development
- ✓ Website development
- ✓ Poster Development

Team members contributions

Algorithm Developer
Rafael Major

- ✓ Dynamic node connectivity
- ✓ Algorithm Development
- ✓ Firmware Data collection
- ✓ Air to Air Communication
- ✓ WebApp development

Algorithm Developer
Yeon Su Choi

- ✓ Dynamic node connectivity
- ✓ Algorithm Development
- ✓ Firmware Data collection
- ✓ Air to Air Communication
- ✓ WebApp development

Costs and benefits

TÉCNICO LISBOA

Costs

- **Radio Sik V3**
  - Specific communication modules increases hardware costs. Although it remains cheaper than competitors options.

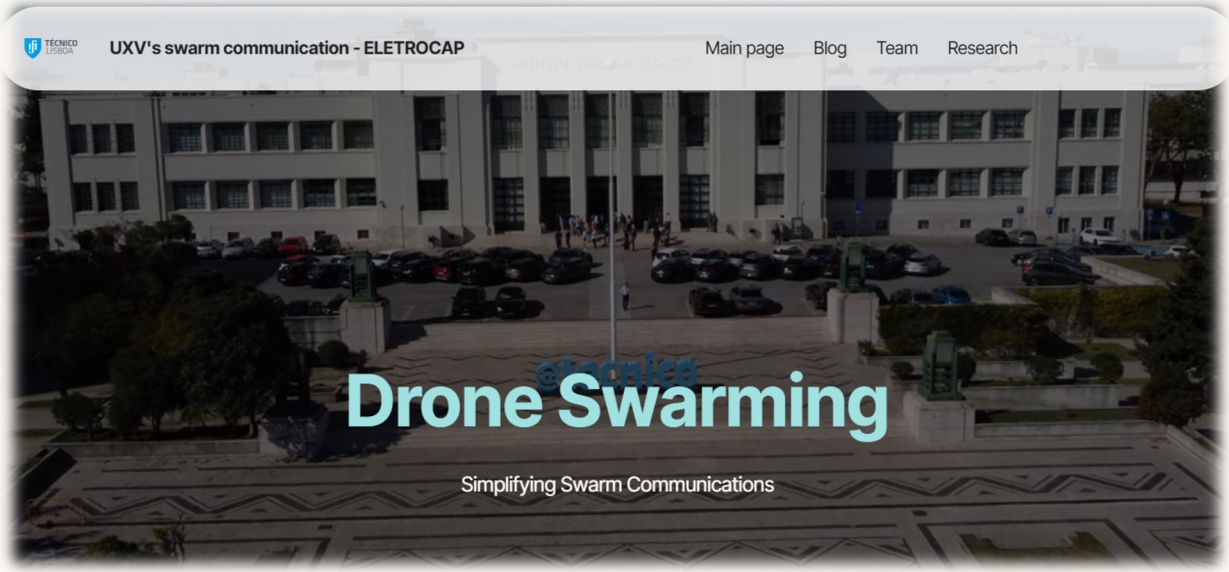
Benefits

- **Scalability**
  - Easily adaptable to larger swarms without significant redesign.
- **Robustness**
  - Fault-tolerant communication ensures system resilience.
- **Versatility**
  - Can be integrated into diverse drone platforms and mission types.
- **Modularity**
- **Open Protocol Compatibility**

Landing page

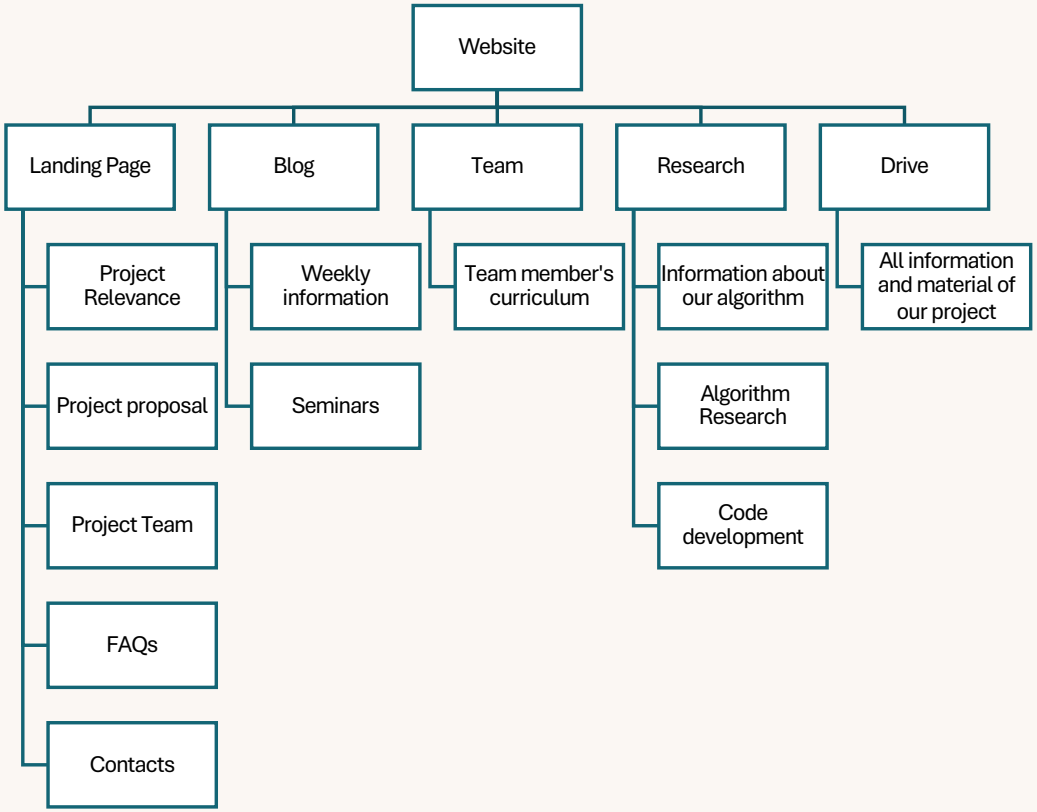
TÉCNICO LISBOA

Our landing page offers a clear project overview, context, team info, objectives, and links to additional resources.



https://web.tecnico.ulisboa.pt/ist198922/index.html

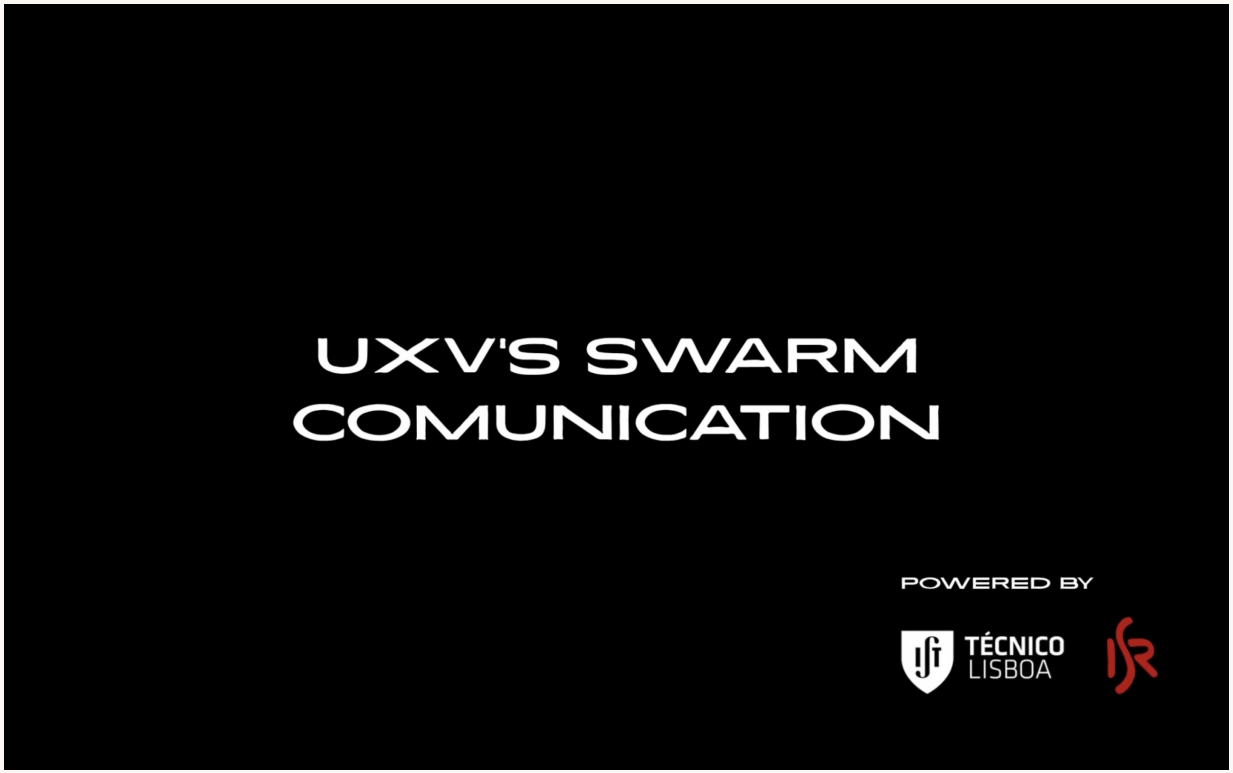
Website



This website serves as a **blog** and invitation for anyone interested, showcasing our research, team, and presentations to explain our approach to the problem.

Demo Video

Discover our project!



Partners

The Portuguese Navy

Provides expertise in maritime operations, defence applications, and integration of UAVs into naval missions.

Instituto Superior Técnico (IST):

Supports the project through research in autonomous systems, control algorithms, and communication protocols for UAV applications.

Institute of Systems and Robotics (ISR):

Focuses on the development of collaborative technologies for drone swarms, including AI-based coordination, trajectory planning, and real-time communication algorithms.

Industry & Startup Collaborators:

iStartLab supported us by 3D printing the physical mockups of the project, enabling us to better visualizethe concepts during development.