EletroCap challenge 14

Low-cost, Versatile, Autonomous UAV Flight Controller

Team

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Operating system department

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Eletronics department

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Mentors

Prof. Alexandra Moutinho
Coordinator

Rafael Cordeiro
Mentor

Prof. Luís Caldas de Oliveira
Scientific advisor

Problem

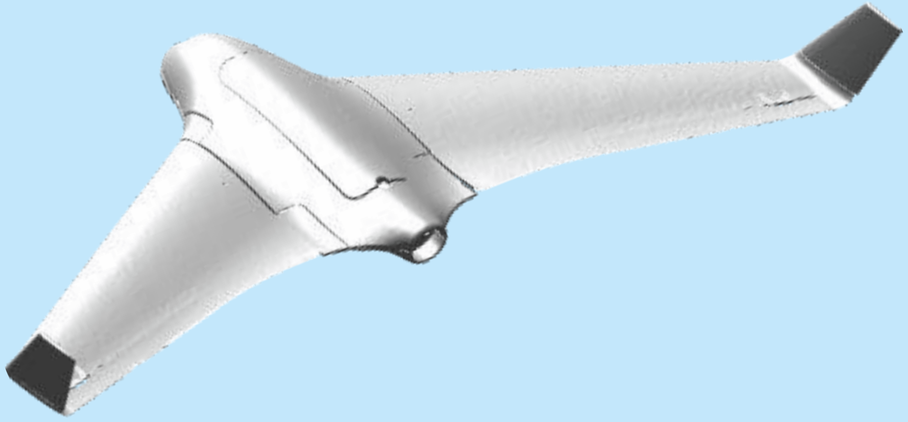
Wildfires, with their unpredictable nature and rapid spread, devastate thousands of hectares annually, threatening wildlife, infrastructure, and communities in rural areas.

The primary challenge lies in the delay between fire ignition, detection, and the alerting of authorities, which often allows fires to escalate uncontrollably.

While active monitoring can significantly reduce response times, it is frequently prohibitively expensive, necessitating highly trained field operators and costly technology.

Solution

- **Versatile & Autonomous System:**
  - Controls small fixed-wing aircraft (radio-controlled model airplanes)
  - Includes both hardware and software components
- **Affordable Solution:**
  - Leverages high availability and low cost of fixed-wing aircraft
  - Facilitates development of a matching low-cost flight controller
- **Enhanced Monitoring:**
  - Deploy multiple UAVs for autonomous high-risk area surveillance
  - Relays critical information to firefighters
- **Operational Efficiency:**
  - Minimizes need for manned interventions
  - Improves response time and firefighting effectiveness



Target audience

This solution can be highly advantageous for firefighters by providing more information about high-risk areas before, during, and after a fire event.

It benefits individuals living in rural areas, as well as wildlife and infrastructure in regions with a high wildfire risk, by reducing the time needed to initiate fire suppression and control operations.

Previous work

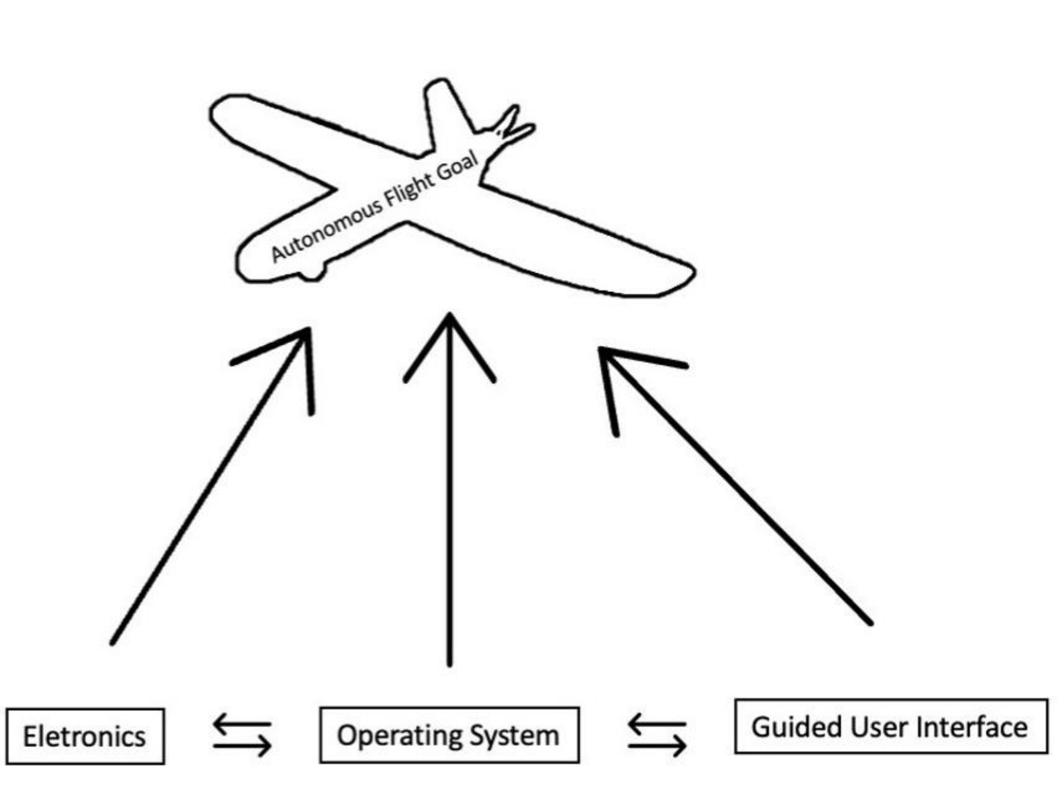
The Portuguese Air Force employs large, internal combustion engine-powered UAVs for forest surveillance.
Currently, they collaborate with firefighters to provide aerial images upon request.

Work groups

Project Management

In order to optimize task allocation among team members, the project has been divided into three core areas:

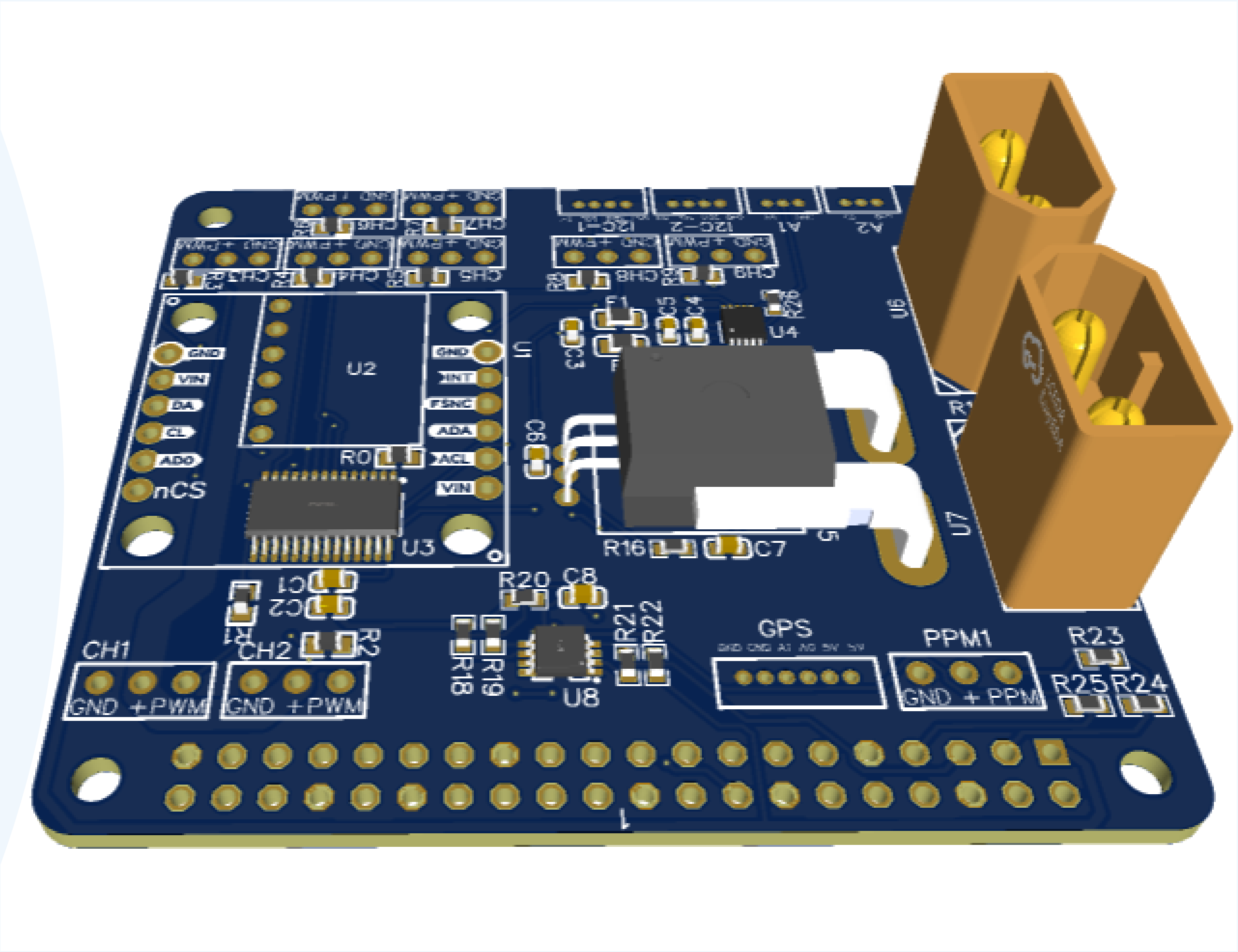
- Electronics
- Operating System
- Guided User Interface



Work groups

Electronics

- Responsible for:
- Selection and testing of sensors
- System prototyping
- PCB design
- PCB assembly
- System testing

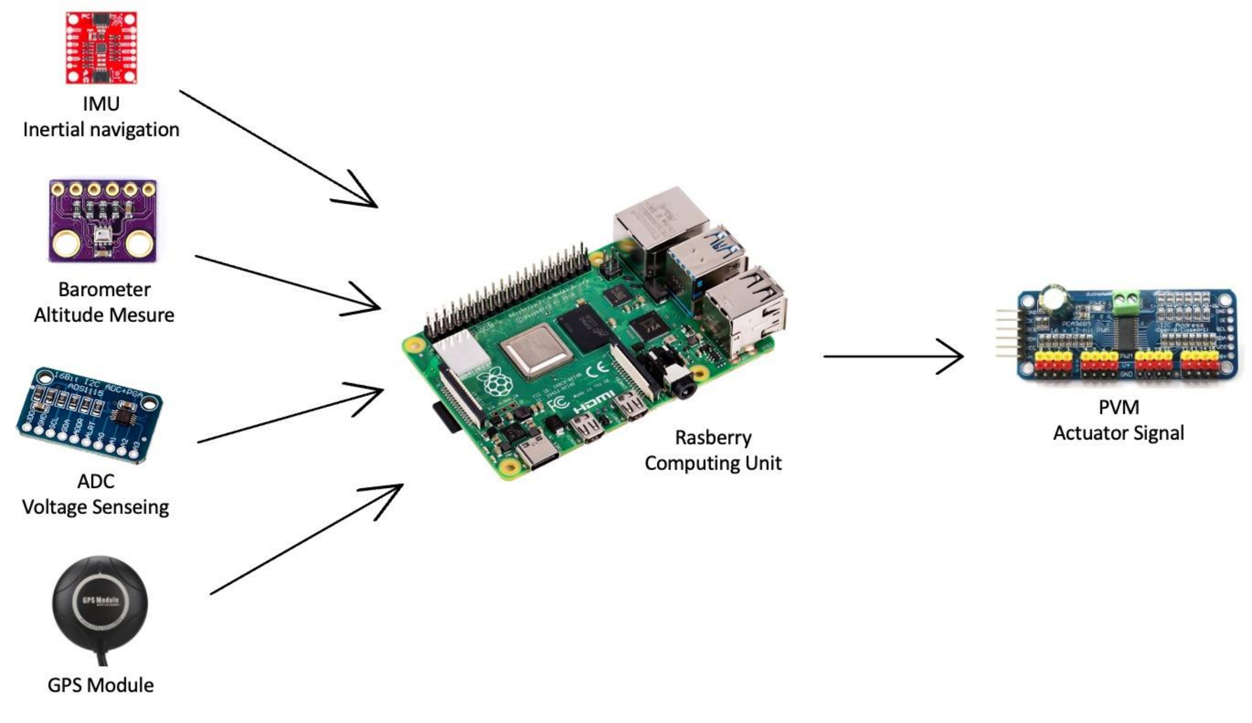


Work groups

Electronics

Why design a printed circuit board from scratch?

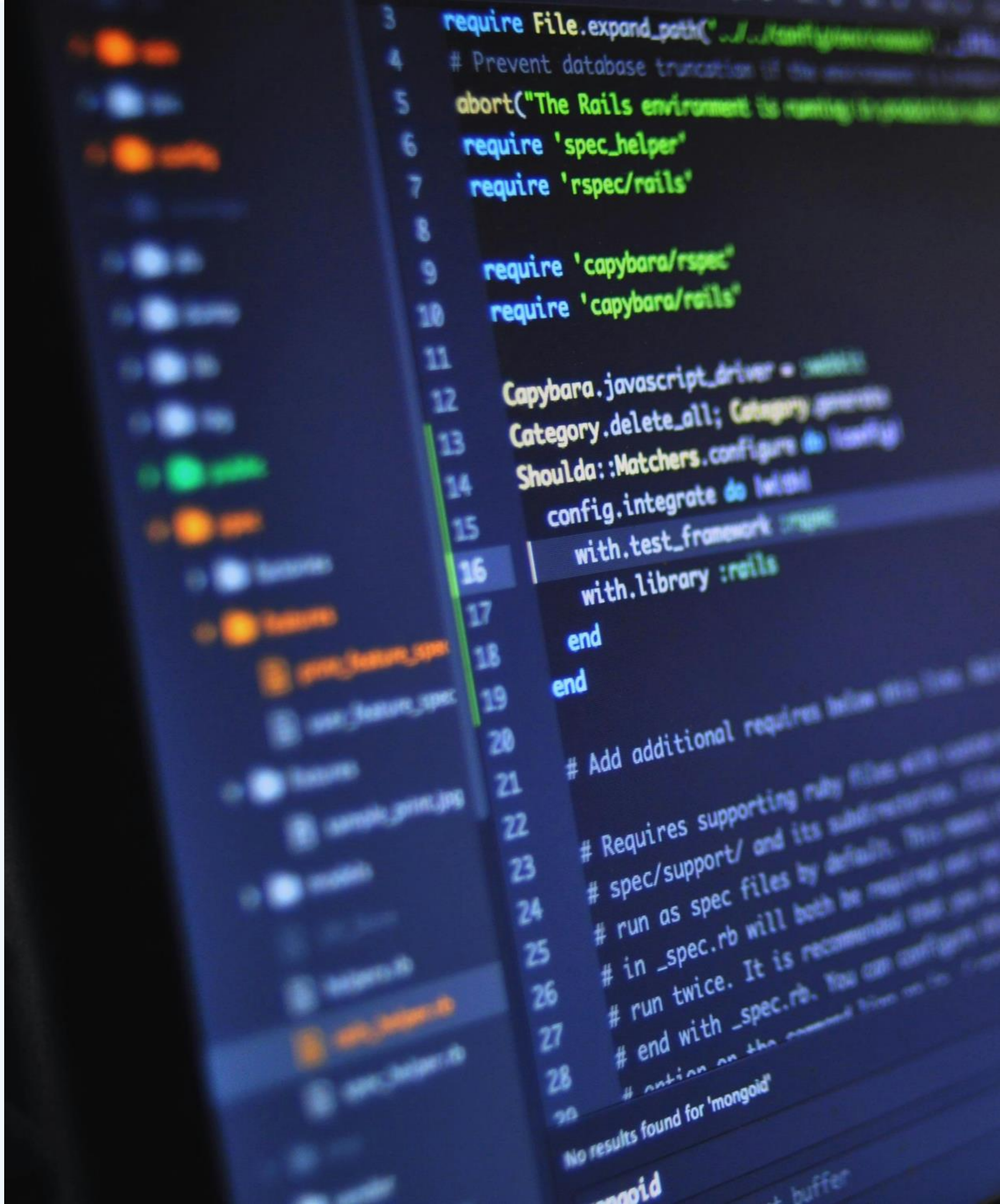
- Limitations of Off-the-Shelf Components:
  - Adds unnecessary weight
  - System bulkiness
  - Unstable connections
- Benefits of Custom PCB Design:
  - Tailored to specific needs
  - Optimized layout and components
  - Minimizes size and weight
- Enhanced Aircraft Performance
  - Improved overall efficiency
  - Better system stability



Work groups

Operating System

- Responsible for:
- Real-Time Kernel patching and compilation
- Autopilot software patching and compilation
- Custom Kernel deployment
- Custom Autopilot software deployment
- Operating System testing



Work groups

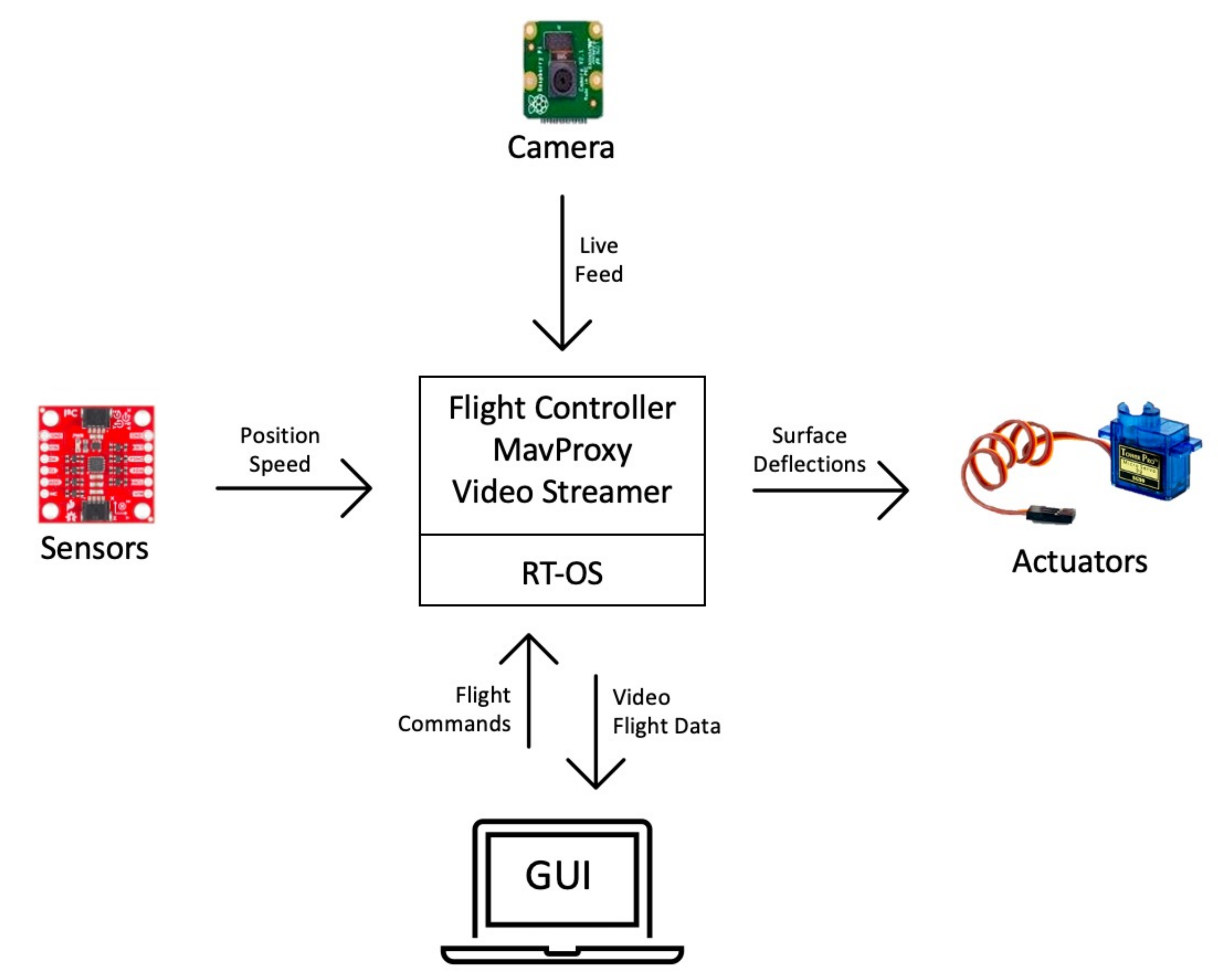
Operating System

Why use an Operating System? And why a real-time one?

- Real-Time Operating System (RTOS)
  - Manages tasks with precise timing requirements
  - Enables microcomputers (e.g., Raspberry Pi) to execute programs like a microcontroller

- Benefits for UAV Flight Controller
  - Ensures critical flight tasks (e.g., stabilization, navigation) are executed without delay
  - Runs essential tasks alongside less urgent ones (e.g., camera image capture) efficiently

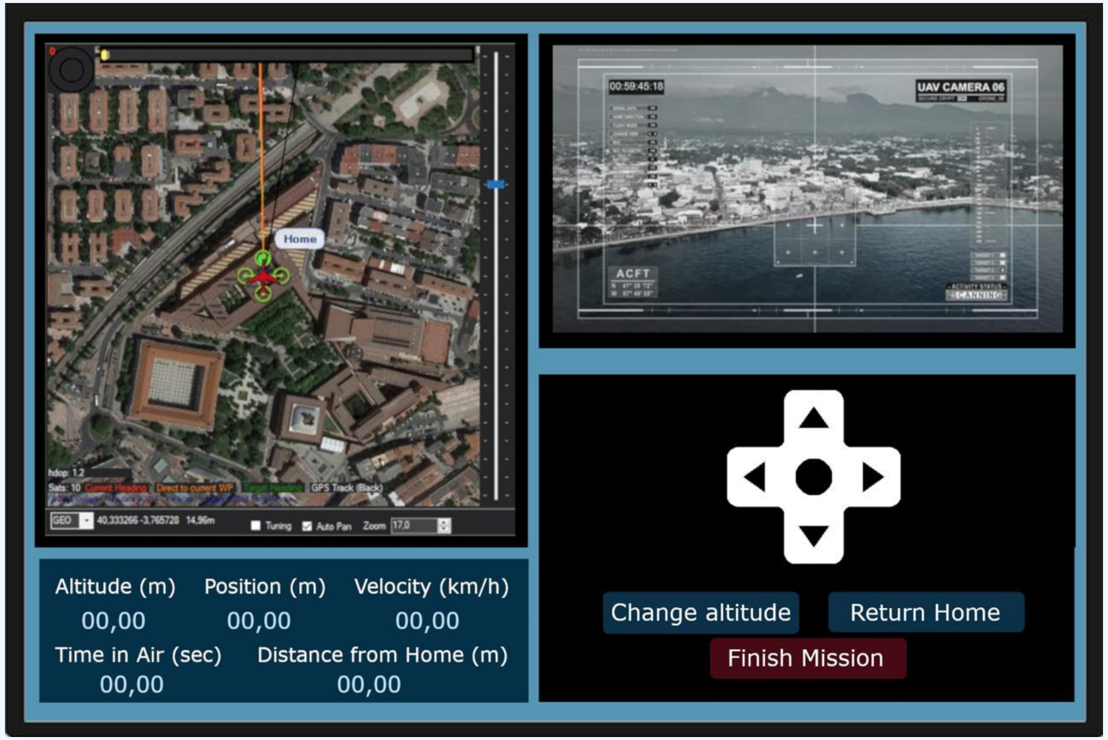
- Improved Flight Performance and Safety
  - Prioritizes essential functions
  - Efficient resource management
  - Enhances overall flight performance and safety



Work groups

GUI (Guided User Interface)

- Responsible for:
- Website development and update
- Air to ground communication
- User interface development
- Interface system integration
- Interface System testing



Work groups

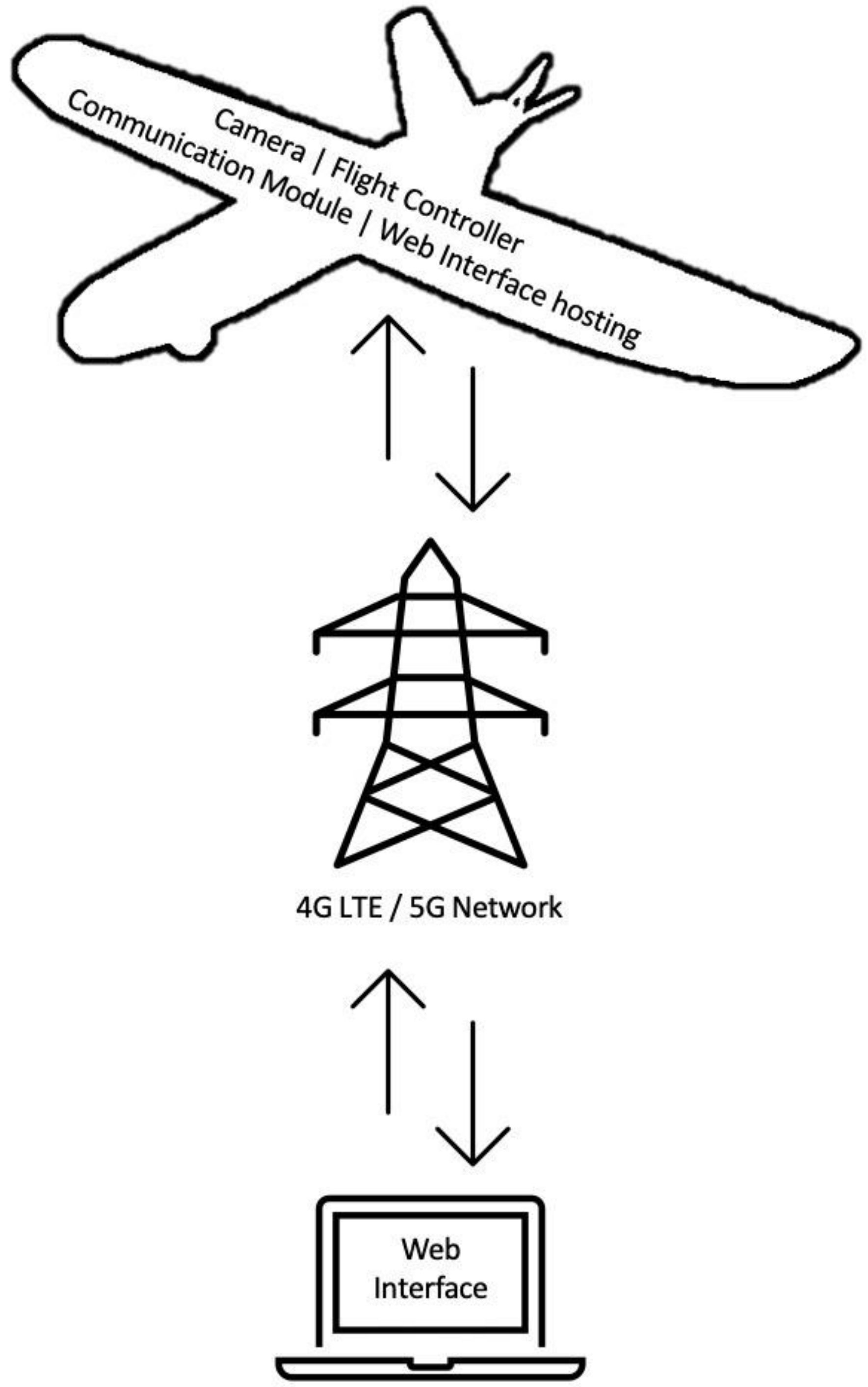
GUI (Guided User Interface)

Why design a user interface from scratch?

- **Simplicity for Intuitiveness:**
  - Simplicity for users with limited flight operations experience
  - Enabling multi-tasking

- **Prioritizing Essential Elements:**
  - Decision to focus on core elements
  - Map display
  - Altitude control
  - Camera management

- **Task Specific Design:**
  - Ability to transfer decision making to the UAV
  - Ability to add more functionalities on demand



Results

Flight Controller System

➢ Versatile Flight Controller System:

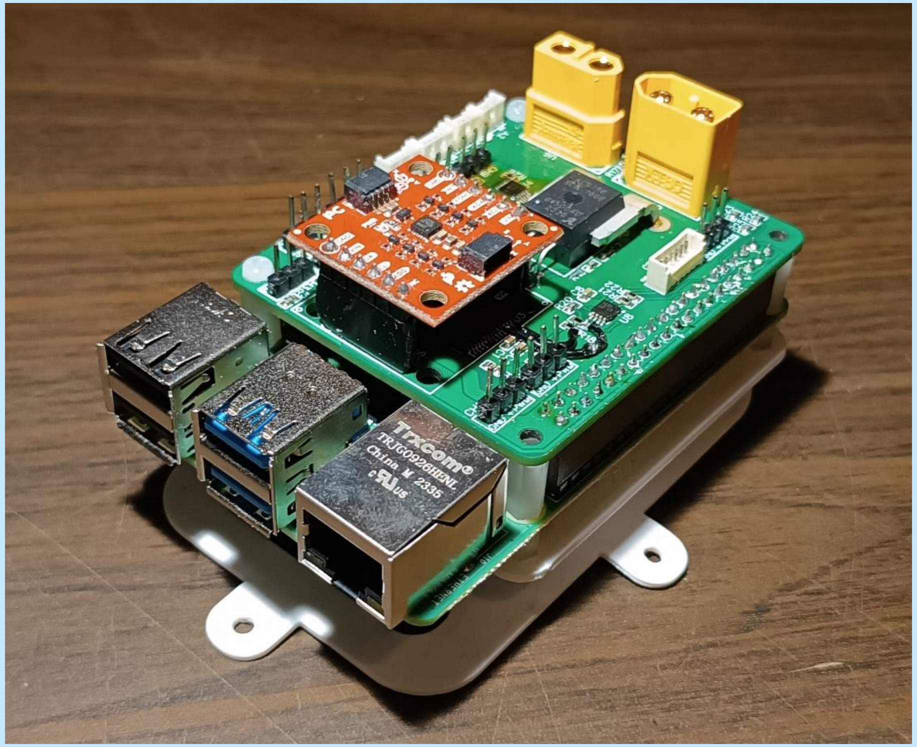
- Developed for various aerial autonomous vehicles: fixed-wing aircraft, helicopters, and multicopters
- Flexibility to adapt to different vehicle types, ensuring compatibility and versatility

➢ Future-Proof Design:

- Capability to accommodate new software deployments on the on-board computer
- Seamless integration with new or different hardware configurations

➢ Simple Operation:

- Autonomous flight capability based on a pre-planned route
- Easy and real-time operation through a user interface

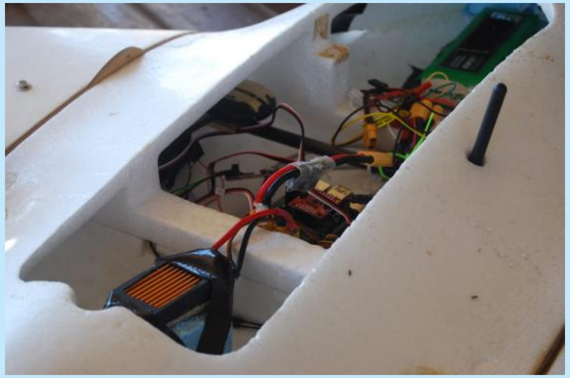


Results

Flight System Integration

UAV characteristics:

- Flying wing
- Wingspan 2.12m
- Flight endurance 1h (50Km)
- Hand launch
- Belly landing



On board system:

- Our flight controller
- GPS
- Other critical external flight sensors
- Electric propulsion system
- Full HD camera

Results

Full System

Mission start:

- Assisted hand launch
- Automatic home loiter pattern
- Follow pre-planed rout or wait for commands

Mission command (User Interface):

- UAV position monitoring
- Camera data monitoring
- Commands to change route and altitude

Flight mission end:

- Automatic landing
- Ability to land in unprepared pavement
- Compatible with parachute landing system

Team members contributions

Francisco Loureiro	João Matos	Manuel Dias
Electronics supervisor and Team Leader	**Code Review and Compiling**	**Real-Time OS Patching**
Rev1 PCB design	Creating a repository for the autopilot code	Creating a repository for the Linux kernel
Rev2 PCB design	Modifying code for new sensors	RT-pathing the Linux kernel
PCB Design	Ardupilot code compilation	RT-kernel compilation
PCB assembly	Video editing	RT-kernel testing

Team members contributions

Inês Santos	Ana Pinto	Marina Nóbrega
Electronic circuits design and testing	**Back-end development**	**Front-end development**
Individual sensor testing	Website back-end development	Website front-end development
Rev1 schematic design	Website updating	Website updating
Rev2 schematic design	Setting up a Mav Proxy for communication	Creating GUI layout
Airplane system integration	Setting up camera stream	Implementation of video stream in the GUI

Costs and Benefits

System cost breakdown:

- Our flight controller – (≈180€)
- Camera – (≈ 30€)
- Communication modules – (≈ 60€)
- Flying wing – (≈ 300€)
- Propulsion system – (≈ 120€)
- Miscellaneous parts – (≈ 50€)

Total: ≈740€

Benefits:

- Reduced delay time of aerial image support
- Increased user independence
- Reduced risk compared to land-based monitoring
- Reduced cost compared to manned and other unmanned aerial monitoring
- Low maintenance
- Simple to operate

Links

Website:
https://web2.tecnico.ulisboa.pt/ist1102949/home_blog.html#

Blog:
https://web2.tecnico.ulisboa.pt/ist1102949/updates.html

Video:
https://youtu.be/QMtTFQzuqGo?si=-mNFl_oNIMoiMf0Y