Adaptive Ground Control Station for UAVs

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PROBLEM & OBJECTIVES

Problem Statement:
Most open-source ground control stations (GCS) have static, restricted interfaces aimed at hobbyists, and do not meet professional or defense-grade requirements.

Motivation:
Consultations with defense industry executives and commercial drone startup founders showed that existing open-source solutions lack the interface flexibility and robust multimedia handling needed for professional, high-stakes operations.

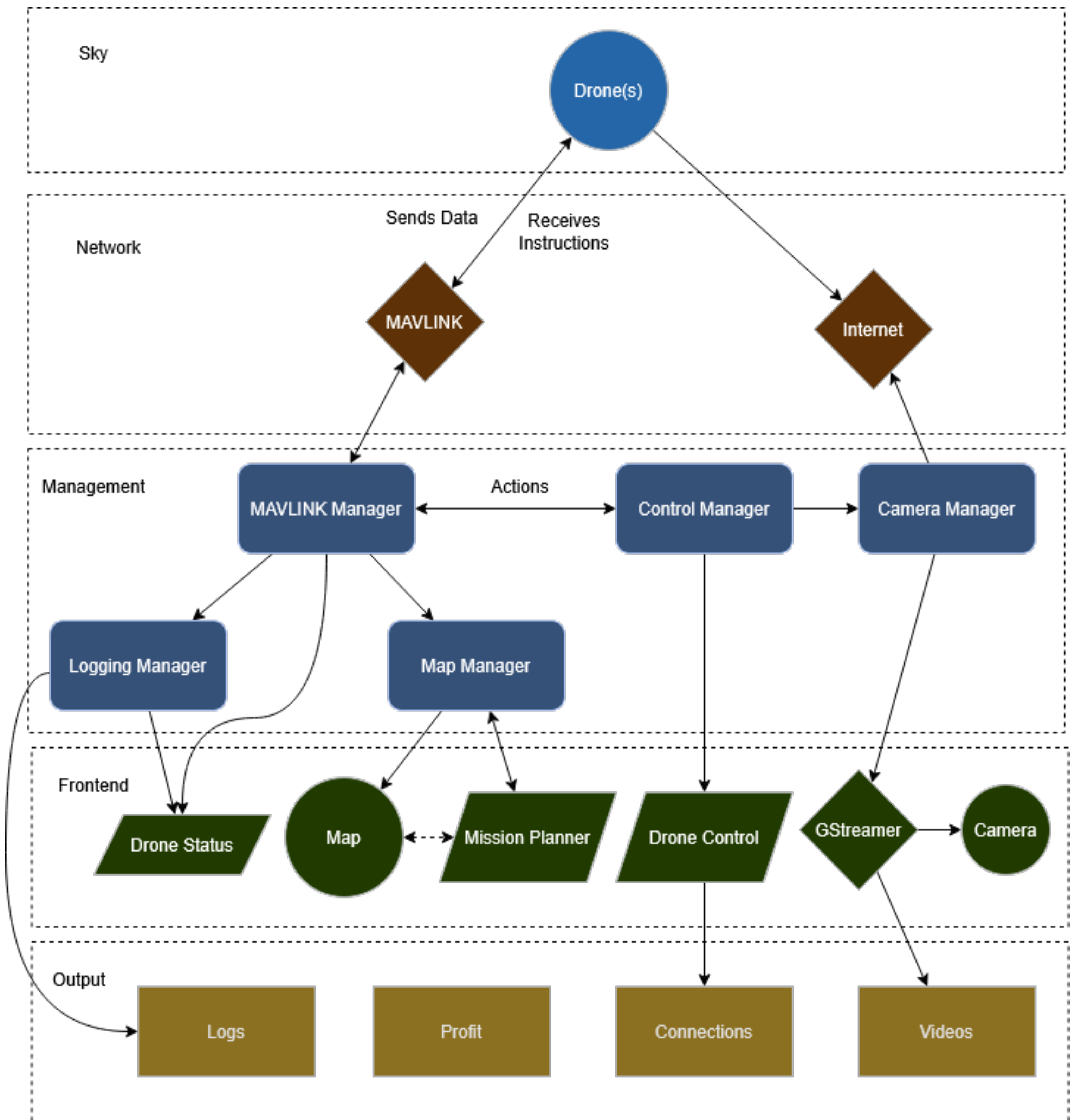
Objectives:
- Adaptive, customizable interface for every use case through a flexible docking system
- Core GCS modules: map with marking, drone tracking, telemetry, real-time video stream, and AI/AR overlays
- Non-blocking communication between the UI and the drone control system
- Integration of all modules into a single seamless Adaptive Ground Station

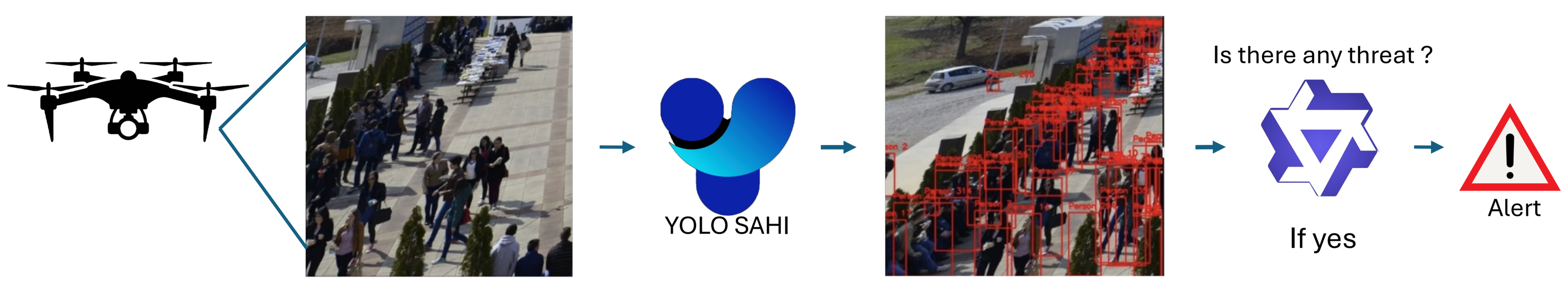
METHODOLOGY & DESIGN

A high-performance desktop application built with modular, event-driven, multi-threaded C++ and the Qt/QML framework for real-time responsiveness and modularity.

Tools & Technologies:
- MAVLINK protocol for UAV communication (hardware-agnostic; compatible with PX4 and ArduPilot)
- Qt/QML for the modular user interface
- Multi-threading for high-bandwidth HD video and telemetry
- GStreamer for video encoding/decoding/routing (target latency under 30 ms)
- Flexible docking architecture (KDDockWidget) for customizable panels

System architecture or design diagram:





IMPLEMENTATION & RESULTS

Key steps: modular docking UI (add / remove / reposition panels), real-time telemetry (X / Y / Z position and altitude), live UAV camera streaming, a UI-to-drone connection layer, and two physical UAVs built to validate both target markets.

Stack: C++ with Qt / QML, MAVLink, GStreamer, KDDockWidget.

Industrial / military VTOL (NADA): Lightweight PLA with aluminum supports, Pixhawk Orange Cube, Here3 GPS, T-Motor motors and ESCs, military-standard APM module, onboard cameras.

Hobby quadcopter (ALPHA): Aluminum frame with TPU prints, carbon-fiber propellers, DJI 2212 920kv motors, Matek F405 flight controller, SpeedyBee GPS.

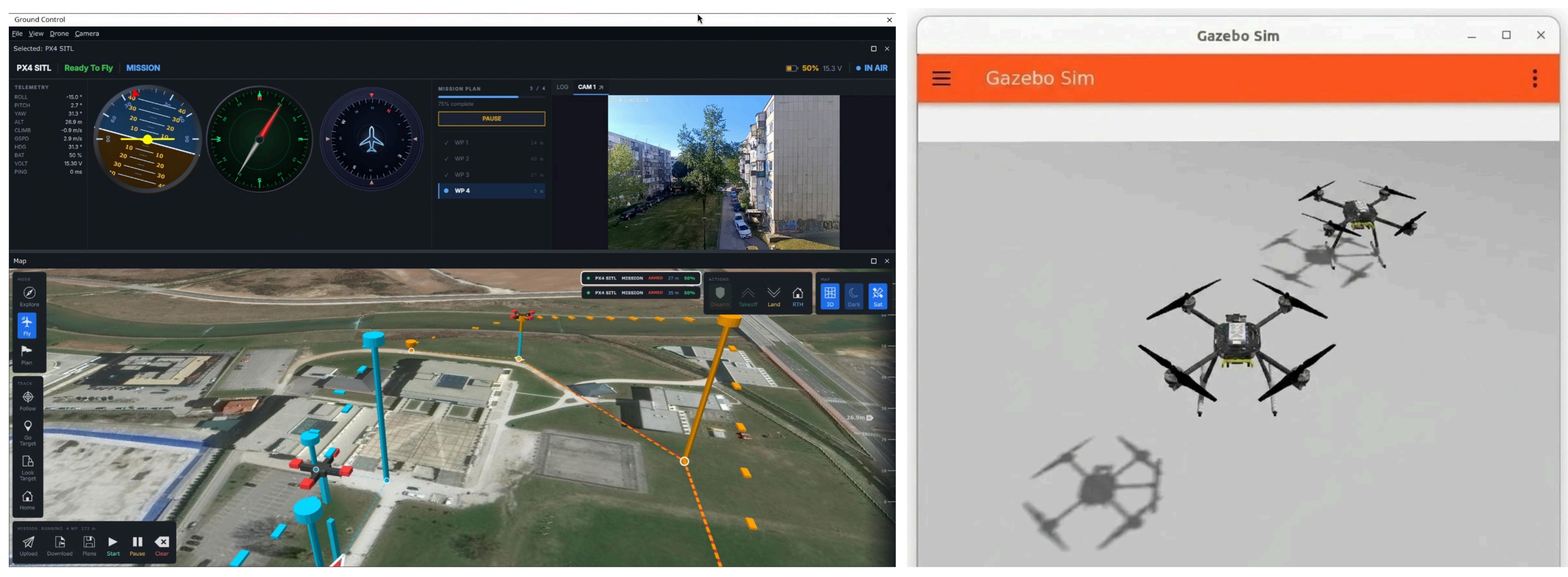
FPV Drone (BETA): Aluminum frame, 920kv motors racing propellers and ArduCopter.

Results: built and flight-tested the hobby quadcopter on low-cost hardware, completed assembly of the professional-grade VTOL, and demonstrated that a single system adapts across both hobby and defense use cases.

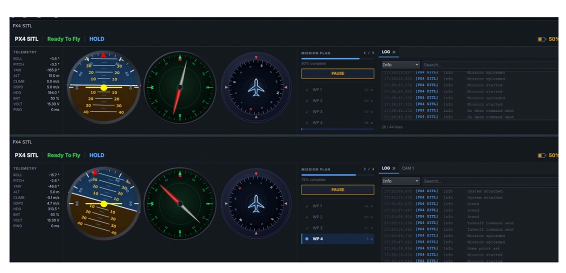
Validation: UI / connection latency <200 ms, camera stream <999 ms, telemetry <100 ms, and connection setup <200 ms on stable Wi-Fi; flight-tested for stability and control with verified map-path accuracy and logging.

UAV's

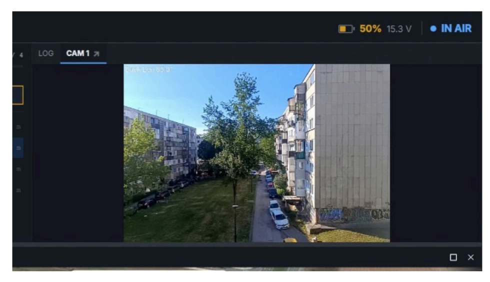
APPLICATION INTERFACE



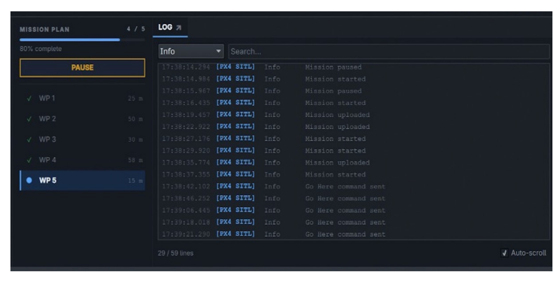
Map & Mission Planner
Satellite map with live waypoints



Live Telemetry
Real-time attitude, heading & compass



Live Video Stream
Real-time YOLO object detection



Logging
Follow the logs

CONCLUSION

Main takeaways:
By building a professional-grade VTOL quadcopter, an FPV drone, and a hobby-grade, the project proves the Adaptive Ground Station serves a single, unified platform across hobby, FPV, commercial, and defense use cases something existing open-source solutions do not offer.

Was the objective achieved?
Yes, the core software was built and validated on real hardware. Three UAVs were produced: a hobby-grade quadcopter and an FPV drone (both flight-tested), and an industrial/military-grade VTOL assembled with professional-standard components, demonstrating the platform across all target markets. Full performance validation against the target indicators is the final remaining step.

References

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3. A. Koubaa et al., "Micro Air Vehicle Link (MAVLink) in a Nutshell: A Survey," IEEE Access, vol. 7, pp. 87658–87680, 2019.
4. X. Nie and Q. Wu, "A Real-Time Video Detection Algorithm for UAV Based on YOLOv8," IEEE ICISCAE, pp. 1238–1243, 2024.

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