Development and Implementation of an Unmanned Aerial System for a 5G Vertical Use Case

A thesis presentation in partial fulfillment of the requirements for the degree of Integrated Masters in Electrical and Computer Engineering

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ΠΑΝΕΠΙΣΤΗΜΙΟ ΠΑΤΡΩΝ

Brief Introduction

Use Case Scenario

Ground station unit provides the user with the ability to control a vehicle in real time, through the cellular network with line-of-sight not required

Vehicle should be able to transmit live video feeds to provide the user with appropriate feedback of its course

Application in search and rescue operations, remote takeover of autonomous vehicles or supervision of areas of interest

- Legacy systems utilize alternative radio frequency bands to transmit said video feeds which are prone to interference, low quality and medium to high latency
- By leveraging V2X connectivity, the user stands to benefit from the emerging 5G NR network, as increased coverage, low latency and quality of service are some of its main attributes. Commercial joysticks demonstrated jitter
- Various accessories that can augment the overall experience such as first person view (FPV) goggles and 360o cameras shall be supported in future iterations.

Requirements

- Open source
- Supports x64 platforms
- Easy modifications to conform to each use case
- Lightweight
- Battery autonomy

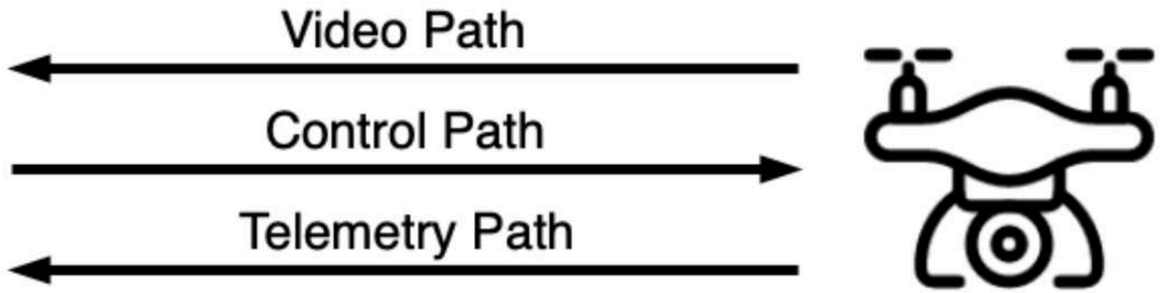
Architecture Overview

Network Slicing

The customizable network capabilities include data throughput, quality, latency, reliability and security.

From a mobile operator's point of view, a network slice is an independent end-to-end logical network that runs on a shared physical infrastructure, capable of providing a negotiated service quality and can be created on demand.

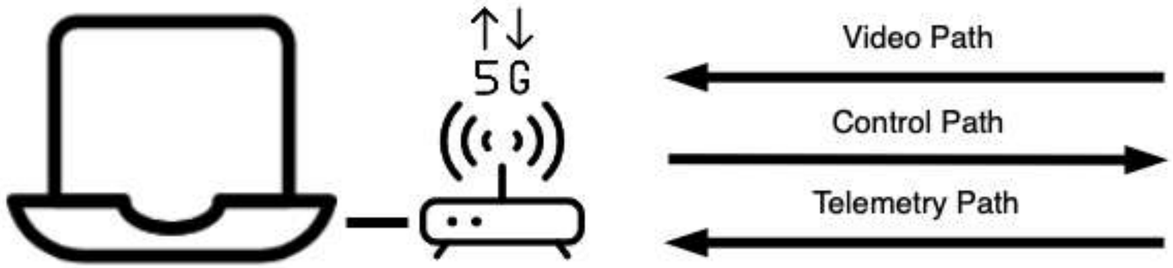
- Video streaming requires a significant amount of data
- Remote-control requires low latency and high reliability for delivery of commands
- To satisfy these requirements, capabilities provided by eMBB and URLLC slices are critical.



User Side

A wireless adapter will be used to relay a traditional two-stick radio controller's commands to the ground station software running on the laptop

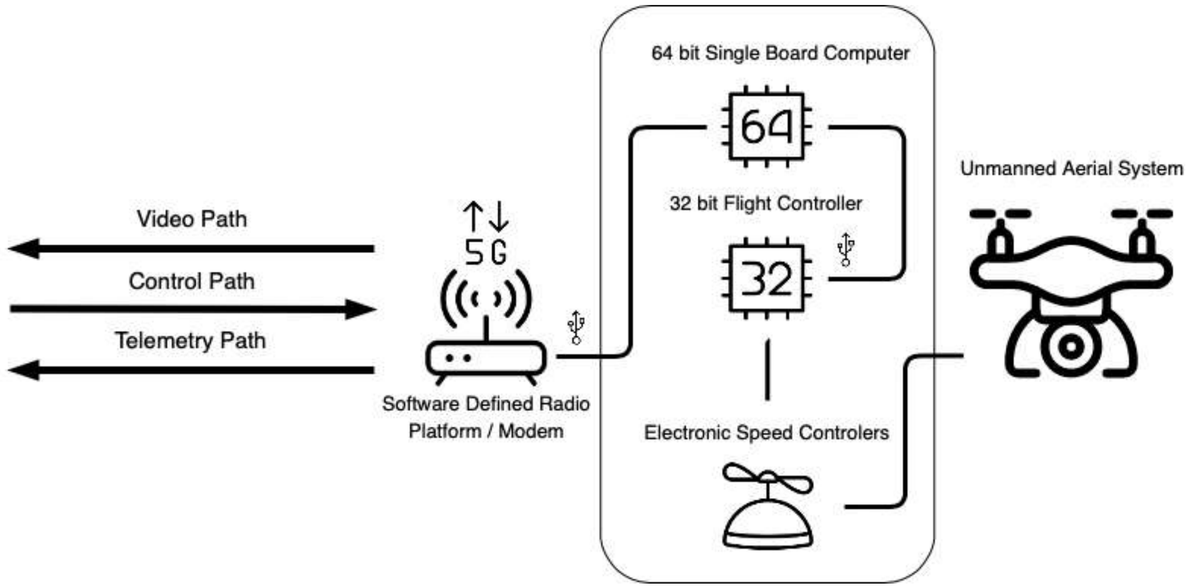
- Laptop keyboard input must be avoided
- Use wireless adapter for included radio remote
- Commercial joysticks demonstrated jitter
- FPV goggles can be added later



Vehicle Side

Workload-intensive tasks such as video encoding and streaming while maintaining timely reaction to received commands are vital to its operation.

Commercial off-the-shelf solutions prove to be severely incapable of conforming to our platform needs



Hardware Architecture

Intel Aero Ready To Fly

Headroom for future expansions, as additional cameras or sensors can easily be mounted

Nominal 20 minutes flight time well

Combined takeoff weight of 1.9kgs.

Intel Aero Compute Board

Comes bundled with Intel’s own flight controller, that connects over a serial port to the companion computer

All signals from the Aero Flight Controller are routed through the MAX10 FPGA to the IO Expansion connector.

Intel Realsense R200

Intel® RealSense R200 module implements a long range, stereovision 3D imaging system that implements a variety of capabilities to be used accordingly.

It consists of an infrared laser projection system, two infrared and a full HD color imaging sensors.

Color data is provided by the full HD color imaging sensor.


intel

Cellular Modem

The Intel Aero Compute Board enables LTE modem devices to be installed into the M.2 interface

Future M.2 form-factor modems can be swapped out, thus allowing easier connectivity upgrades and testing

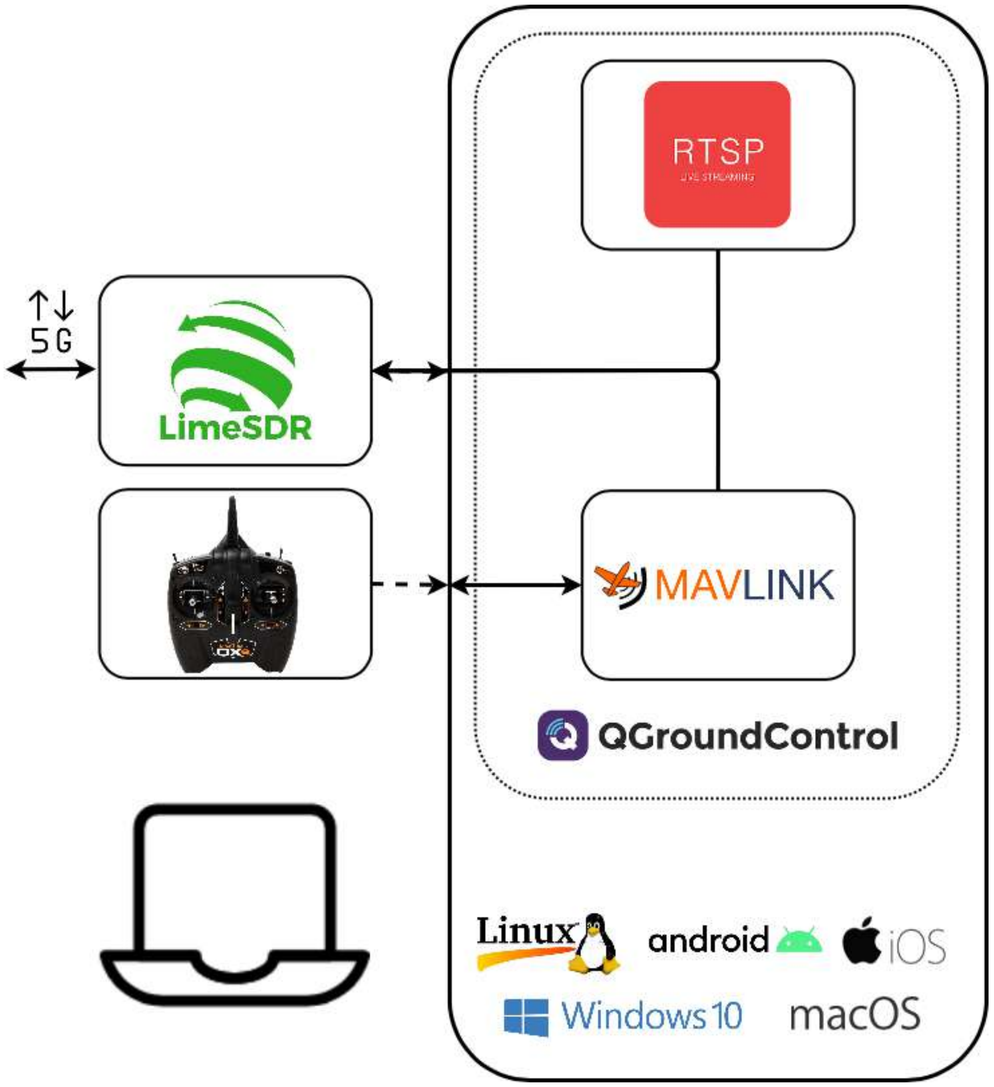

Main
Aux
telit LN930
IMEI:356406060866893
CE 0682
PN:G12Z024.06
MO:5200138549
MODEL:LN930
FCC ID:RI7LN930
IC:5131A-LN930
Made in China

Software Architecture - User

User Side

Base station software that runs on all modern operating systems

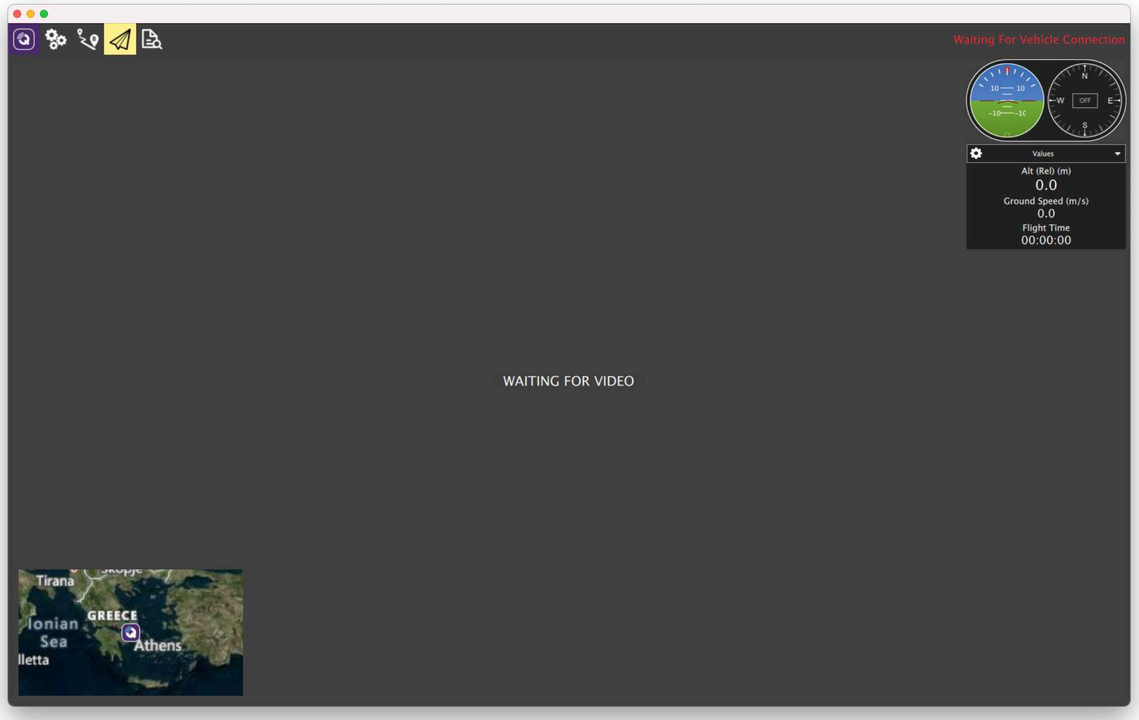
Concentrates all vital aspects of the operation in one platform



QGroundControl

QGroundControl provides full flight control and vehicle setup for PX4 or ArduPilot powered vehicles

The MAVLink "microservices" define higher-level protocols that MAVLink systems can adopt in order to better inter-operate and are used to exchange data

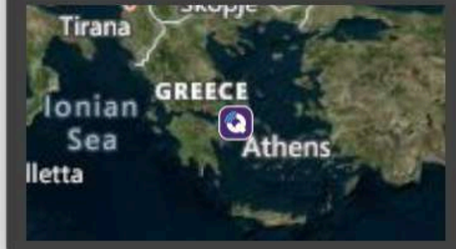


Waiting For Vehicle Connection

Values

Alt (Rel) (m)
0.0
Ground Speed (m/s)
0.0
Flight Time
00:00:00

WAITING FOR VIDEO

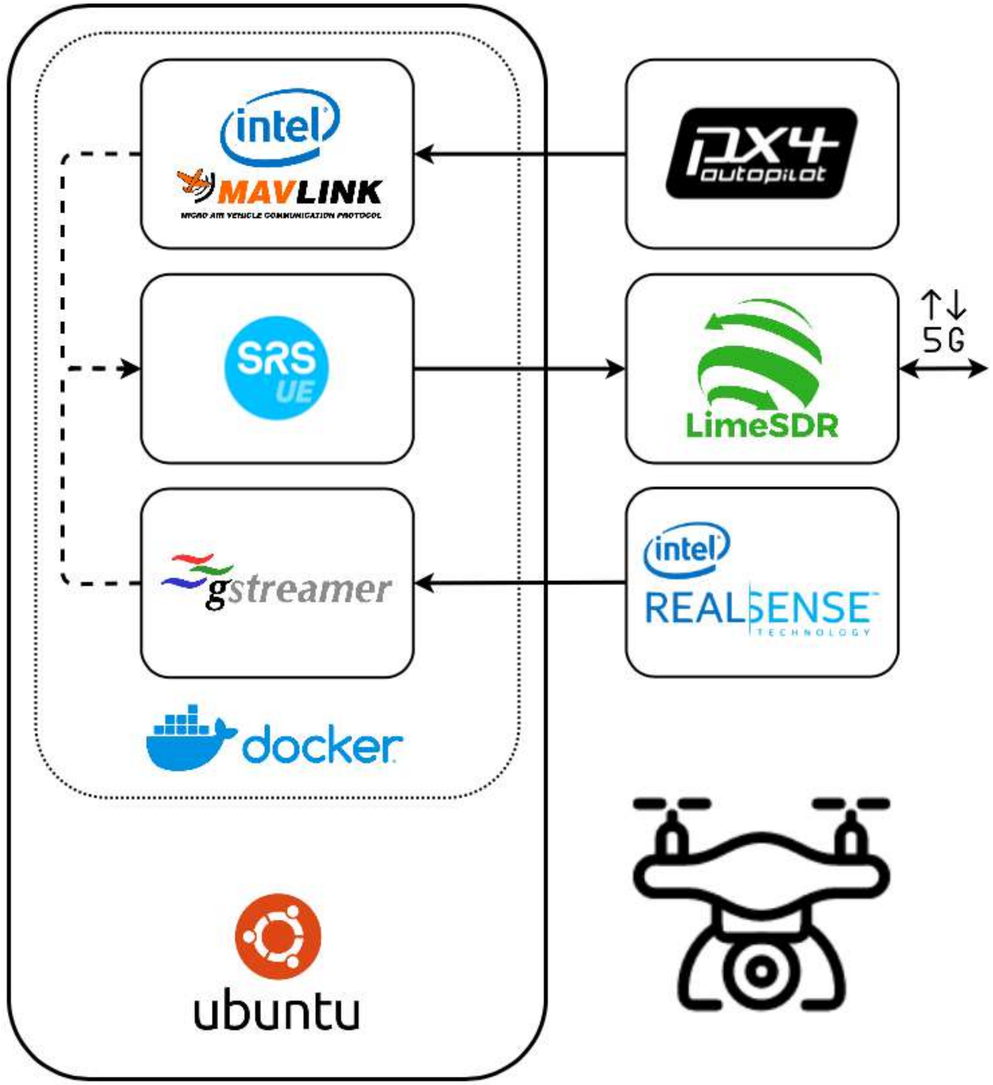


Software Architecture - Vehicle

Vehicle Side

Standalone operation on desktop Ubuntu 16.04.3

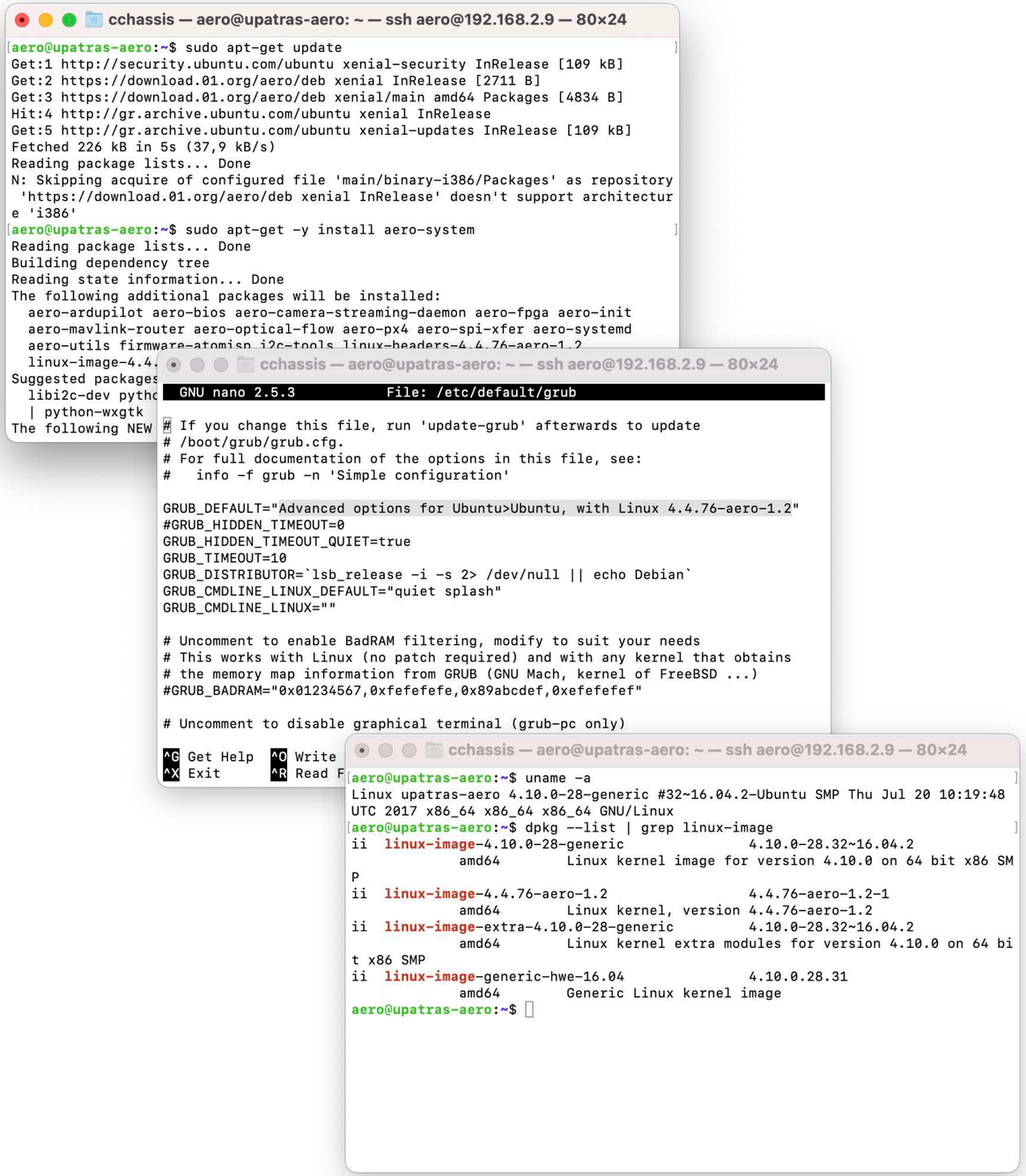
Ability to use Docker to further optimize recourses and availability



Operating System

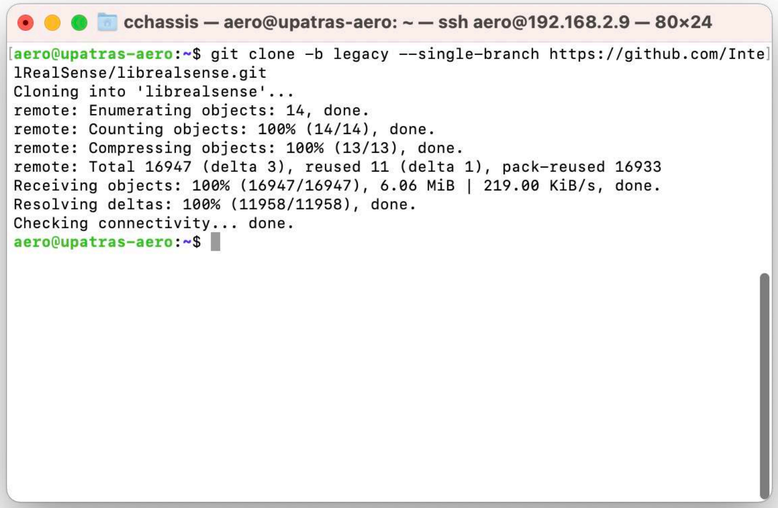
By default, Intel Aero board and Intel Aero Ready To Fly kit are delivered with a Yocto Project build already flashed

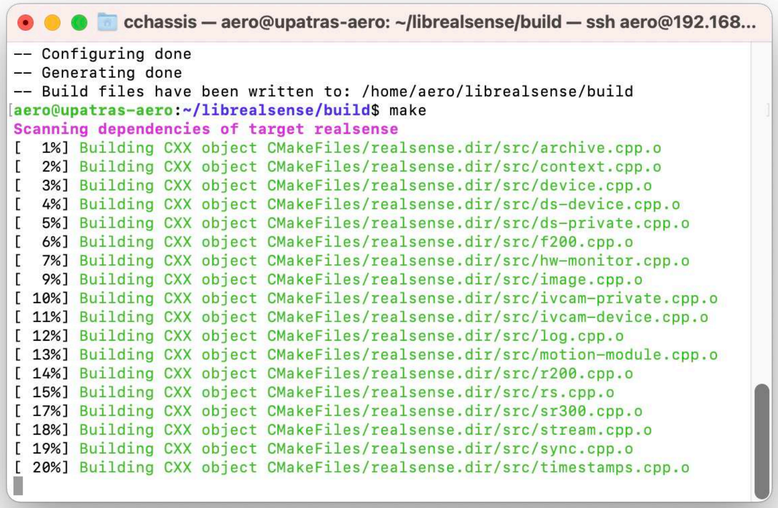
In parallel to this Intel supported Yocto image, full native Ubuntu with Intel drivers is available as user installation

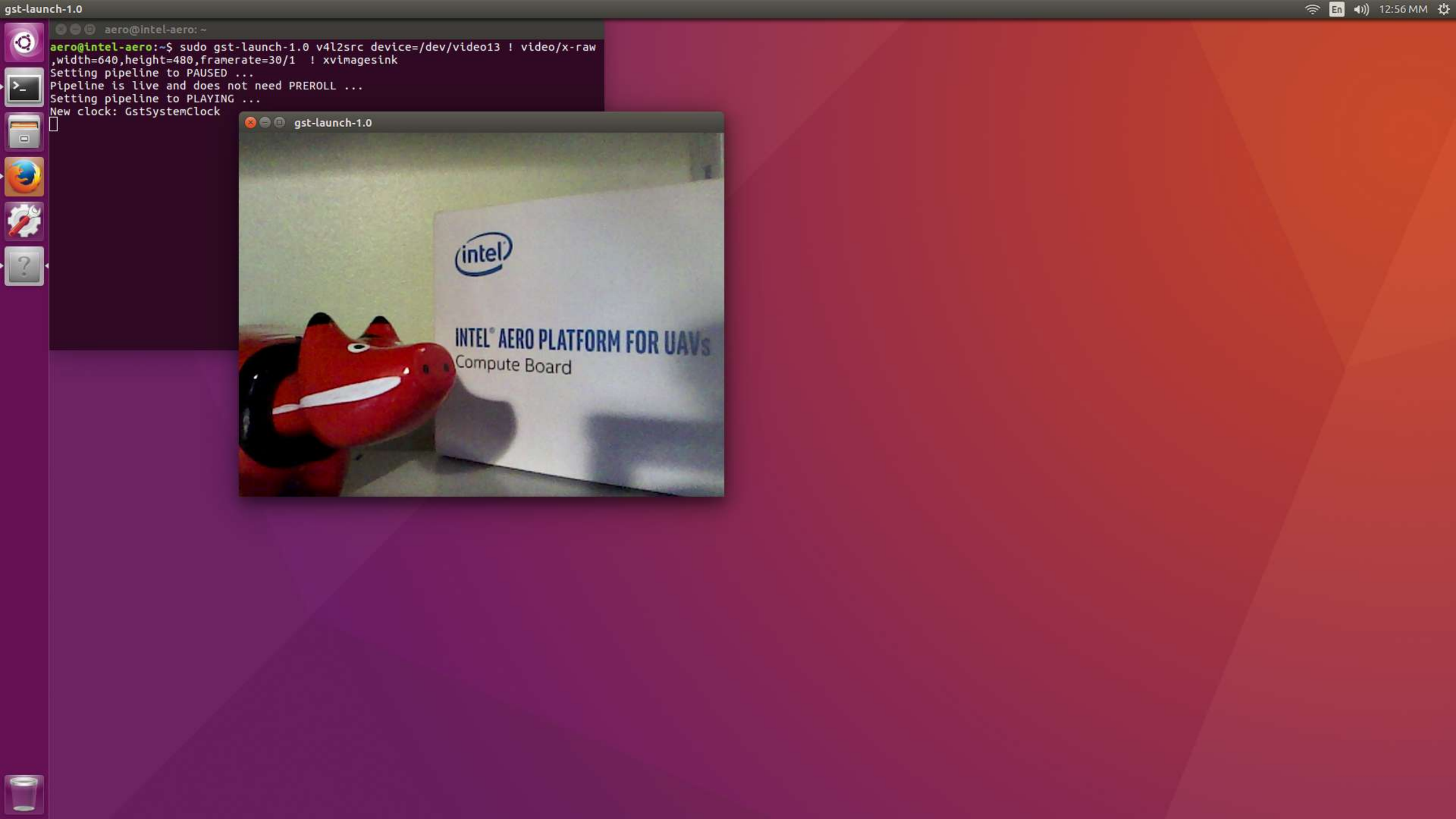


librealsense

Intel developed library specifically for interfacing with RealSense cameras



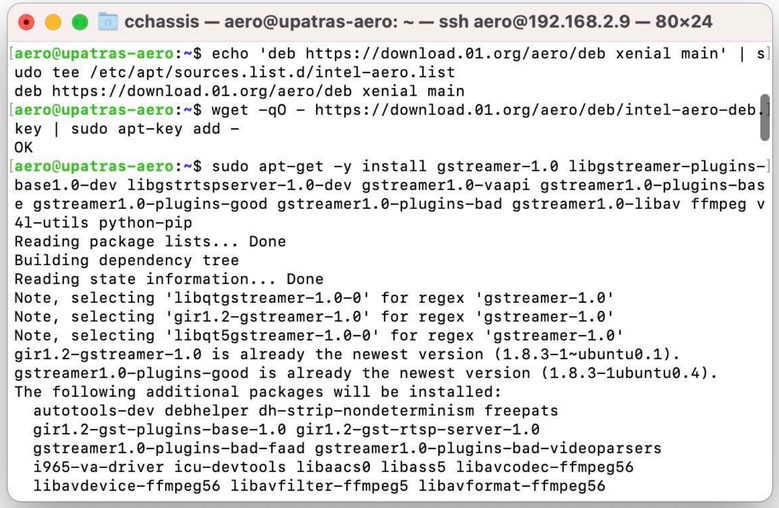


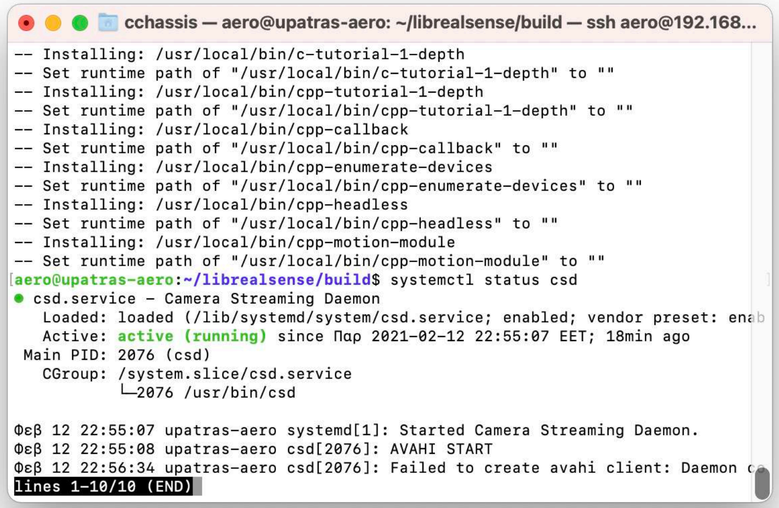

aero@intel-aero: ~
aero@intel-aero:~$ sudo gst-launch-1.0 v4l2src device=/dev/video13 ! video/x-raw
,width=640,height=480,framerate=30/1 ! xvimagesink
Setting pipeline to PAUSED ...
Pipeline is live and does not need PREROLL ...
Setting pipeline to PLAYING ...
New clock: GstSystemClock
gst-launch-1.0
intel
INTEL® AERO PLATFORM FOR UAVs
Compute Board

csd & gstreamer

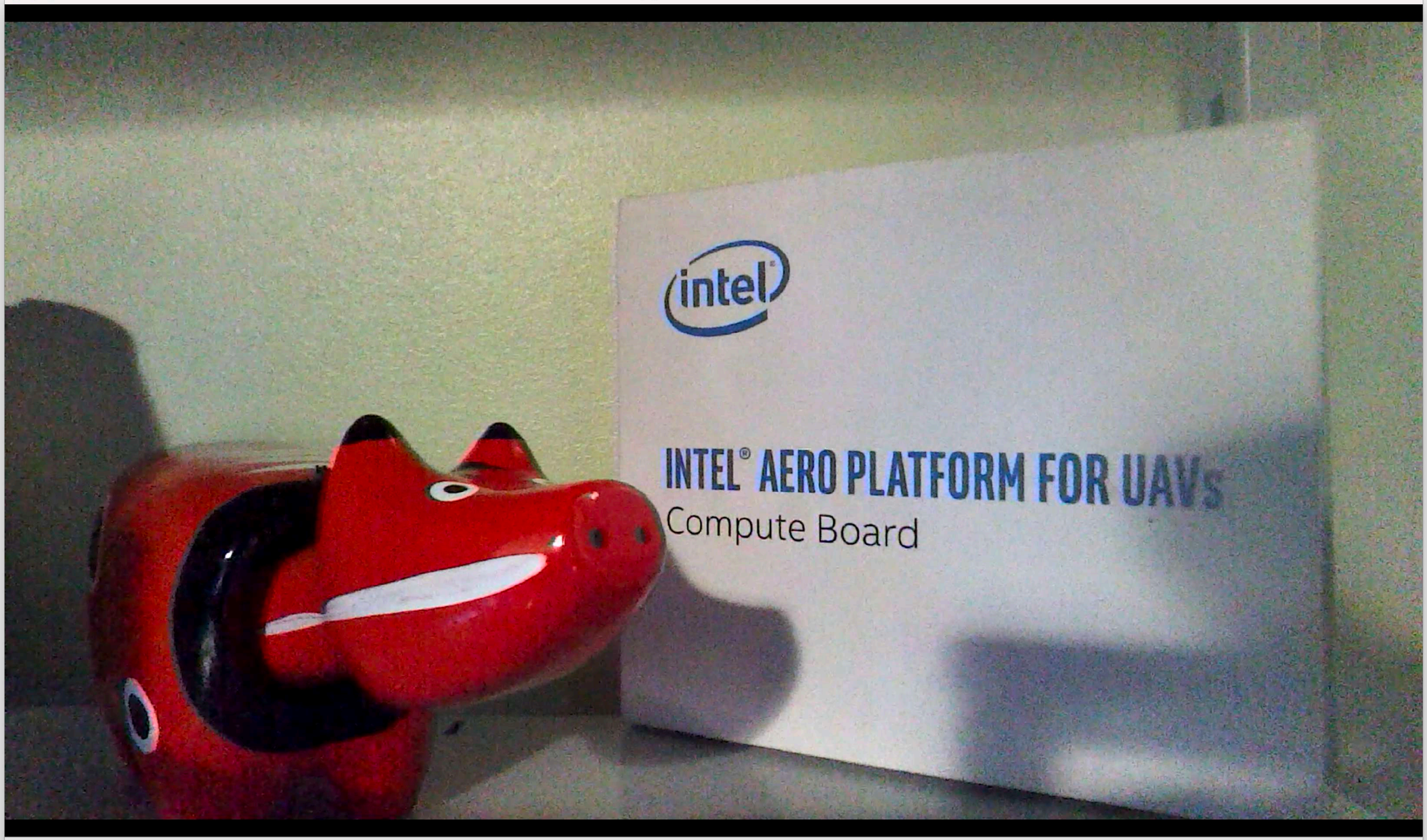
Runs as a daemon proposing network streams of the cameras

Open-source multimedia framework, is able to provide the granularity that’s required in our use-case

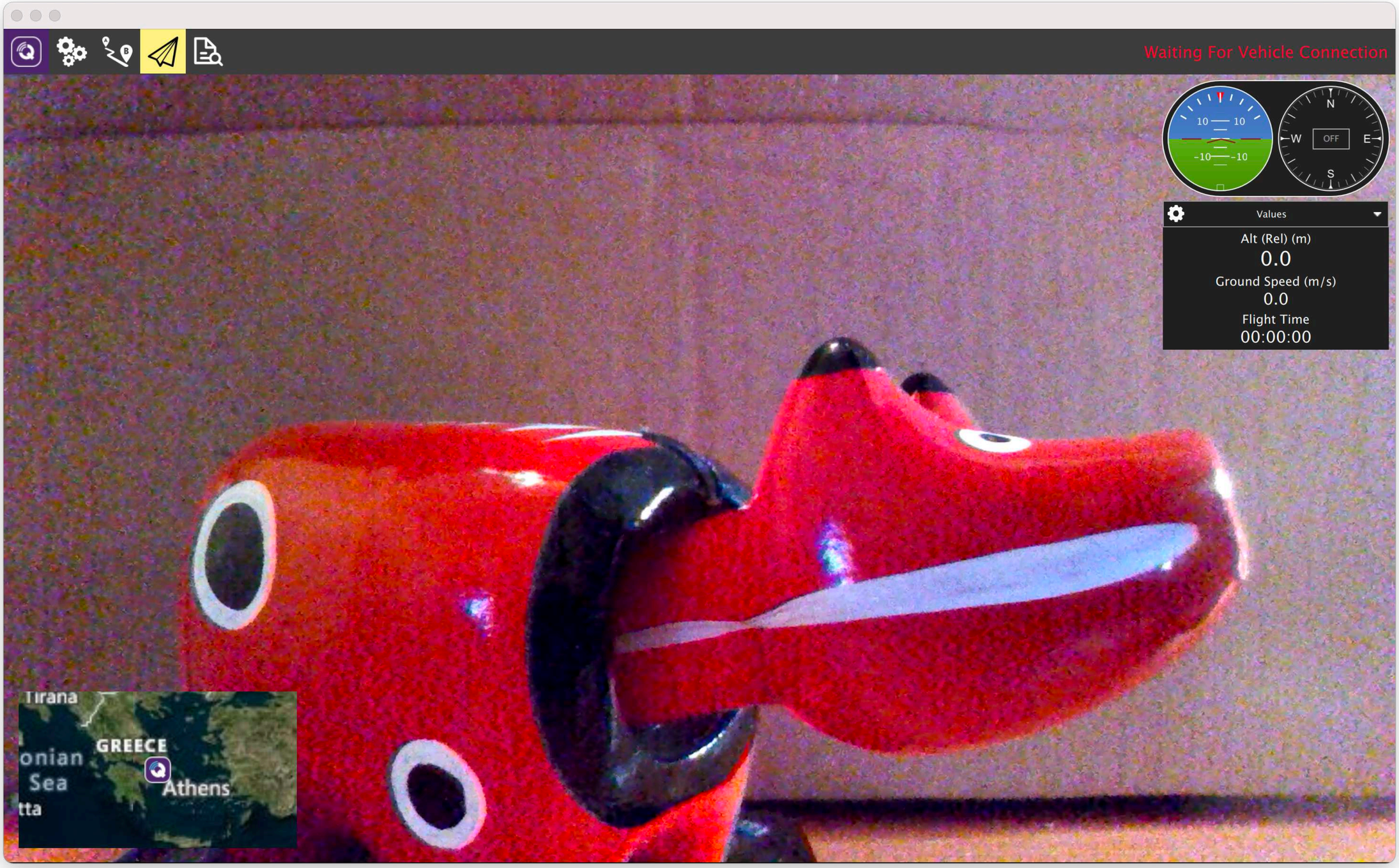




rtsp://192.168.2.8:8554/video13



00:04


Waiting For Vehicle Connection
10
10
-10
-10
N
W
OFF
E
S
Values
Alt (Rel) (m)
0.0
Ground Speed (m/s)
0.0
Flight Time
00:00:00
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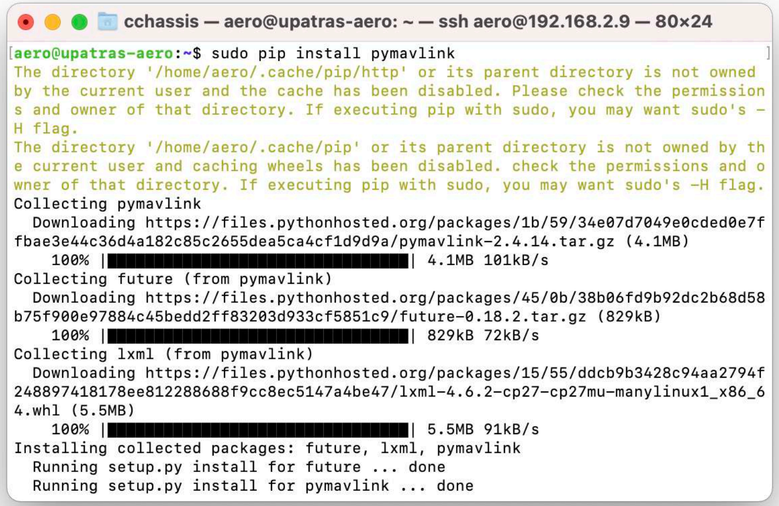
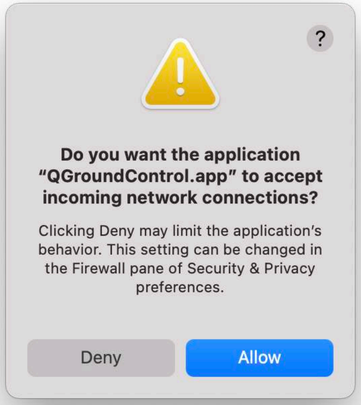
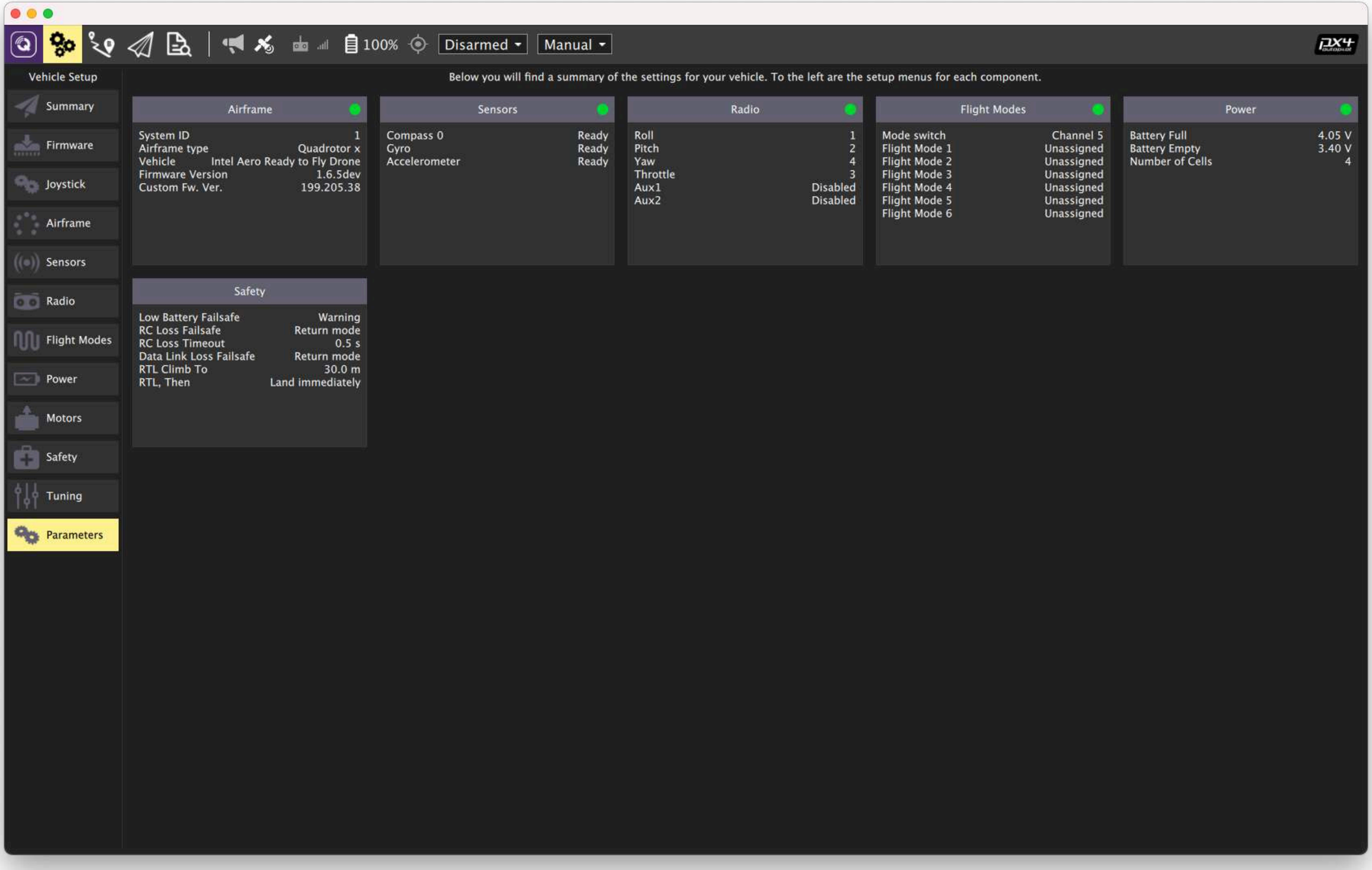
MAVLink-router

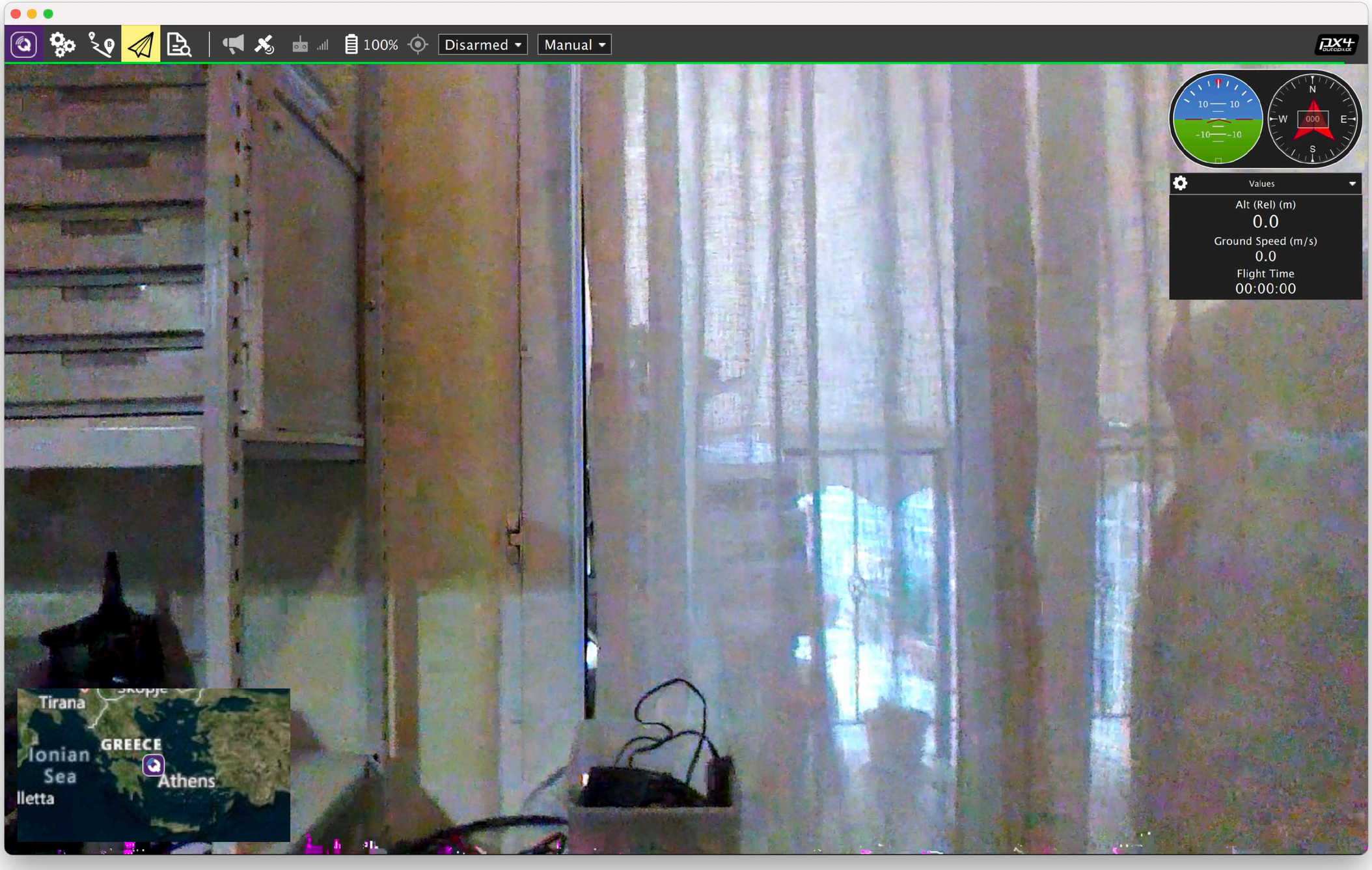
Encapsulation method for MAVLink packets to traverse the IP network

Versatility in terms of addressing as it can route streams to and from multiple devices independently at the same time






100%
Disarmed
Manual
Vehicle Setup
Summary
Firmware
Joystick
Airframe
Sensors
Radio
Flight Modes
Power
Motors
Safety
Tuning
Parameters
Below you will find a summary of the settings for your vehicle. To the left are the setup menus for each component.
Airframe
System ID 1
Airframe type Quadrotor x
Vehicle Intel Aero Ready to Fly Drone
Firmware Version 1.6.5dev
Custom Fw. Ver. 199.205.38
Sensors
Compass 0 Ready
Gyro Ready
Accelerometer Ready
Radio
Roll 1
Pitch 2
Yaw 4
Throttle 3
Aux1 Disabled
Aux2 Disabled
Flight Modes
Mode switch Channel 5
Flight Mode 1 Unassigned
Flight Mode 2 Unassigned
Flight Mode 3 Unassigned
Flight Mode 4 Unassigned
Flight Mode 5 Unassigned
Flight Mode 6 Unassigned
Power
Battery Full 4.05 V
Battery Empty 3.40 V
Number of Cells 4
Safety
Low Battery Failsafe Warning
RC Loss Failsafe Return mode
RC Loss Timeout 0.5 s
Data Link Loss Failsafe Return mode
RTL Climb To 30.0 m
RTL, Then Land immediately

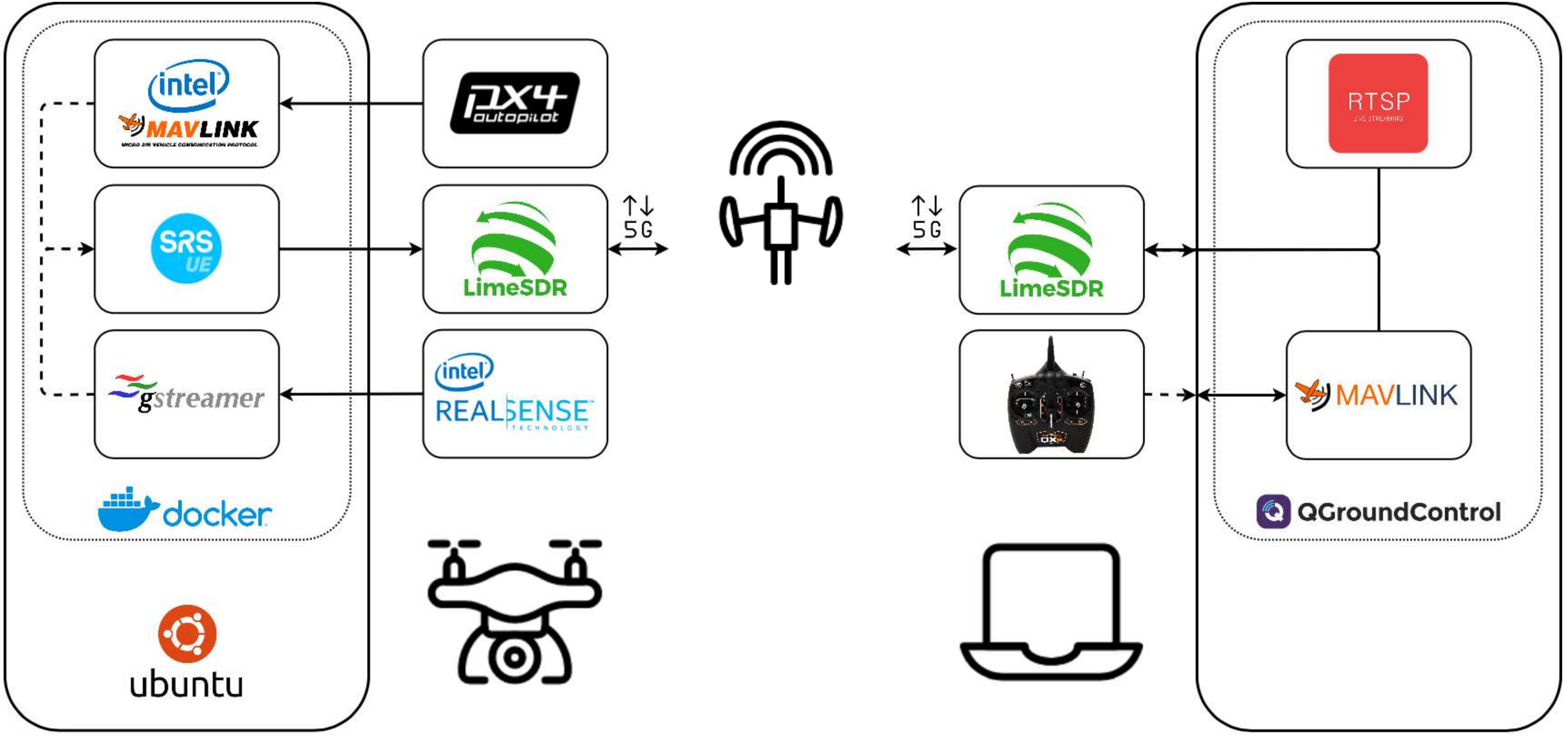

100%
Disarmed
Manual
10
10
-10
-10
N
W
E
S
000
Values
Alt (Rel) (m)
0.0
Ground Speed (m/s)
0.0
Flight Time
00:00:00
Tirana
GREECE
Ionian
Sea
Athens
lletta

Docker Containers

Each process can be installed, updated and run independently

Evolution to interact with the next-generation capabilities of 5G Core

Load balancing and fault tolerance


intel
MAVLINK
MICRO AIR VEHICLE COMMUNICATION PROTOCOL
PX4 autopilot
SRS UE
LimeSDR
5G
gstreamer
intel
REALSENSE
TECHNOLOGY
docker
ubuntu
5G
LimeSDR
RTSP
MAVLINK
QGroundControl

Conclusions

A fully operational platform was proposed and implemented, fully operational on a wireless IP network

Evolution possible on many aspects

- Flexible
- IP forwarding
- Ease of modification

- Streaming latency
- Compliance with other network protocols
- Automation & Provisioning

Thank you