



Up, Up, and Away: *Adventures in Aerial Robotics*



Kimberly McGuire
Robotics Engineer



Introduction



Ramón Roche
General Manager



Some words from Kim

"I'm very sorry I couldn't come to ROScon! I was looking forward to it all year but my health got in the way... I hope you enjoy this talk prepared by us and I really hope to see you at next year's ROScon or at one of the Aerial-ROS meetings!"

Kimberly McGuire

Robotics Engineer, Bitcraze





Where do Drones come from?

Everything went by very quickly

In the last 20 years

We went from this



10 years ago

Selfie?





Today



A studio setup for motion capture. A black metal rig is suspended from the ceiling, holding several cameras. The rig is supported by four black tripods on the floor. The floor is covered with numerous small, blue, circular markers. A grey door is visible in the background. The word "Today" is written in large black letters on the left side of the image. A green vertical bar is on the far left edge.

Today

Today



DroneUp

FAA
CERTIFIED
OPERATION

STAND CLEAR



Today

\$33.7b


Current Drone Market size in 2023

\$54.6b

Drone Market size by 2030



**But the journey to success for many
has been one of multiple challenges**



**We started working together to fix
the frustrations of our own journey's
into Aerial Robotics**

A cautionary tale

The journey of a robotics developer in the aerial space



Introducing Mary

Mary finished her MSc in Robotics

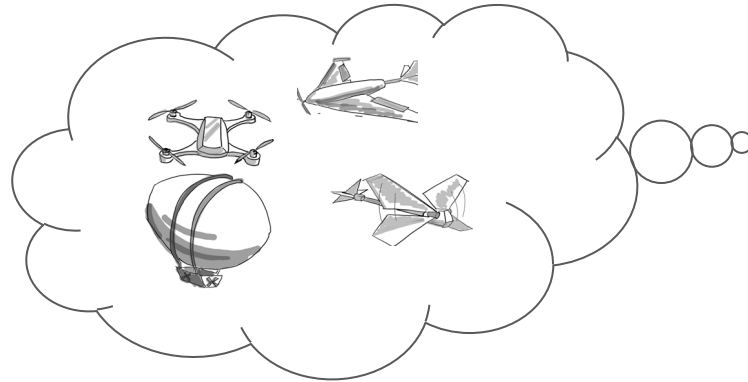
She knows about ROS, simulation, perception,
and has build some ground robots herself.



The quest

She just got hired at a company that wants to build their own *fully autonomous UAV for indoor navigation*.

Mary hasn't worked with UAVs before but *how hard can it be?*



Decisions, decisions

Unmanned aerial vehicle

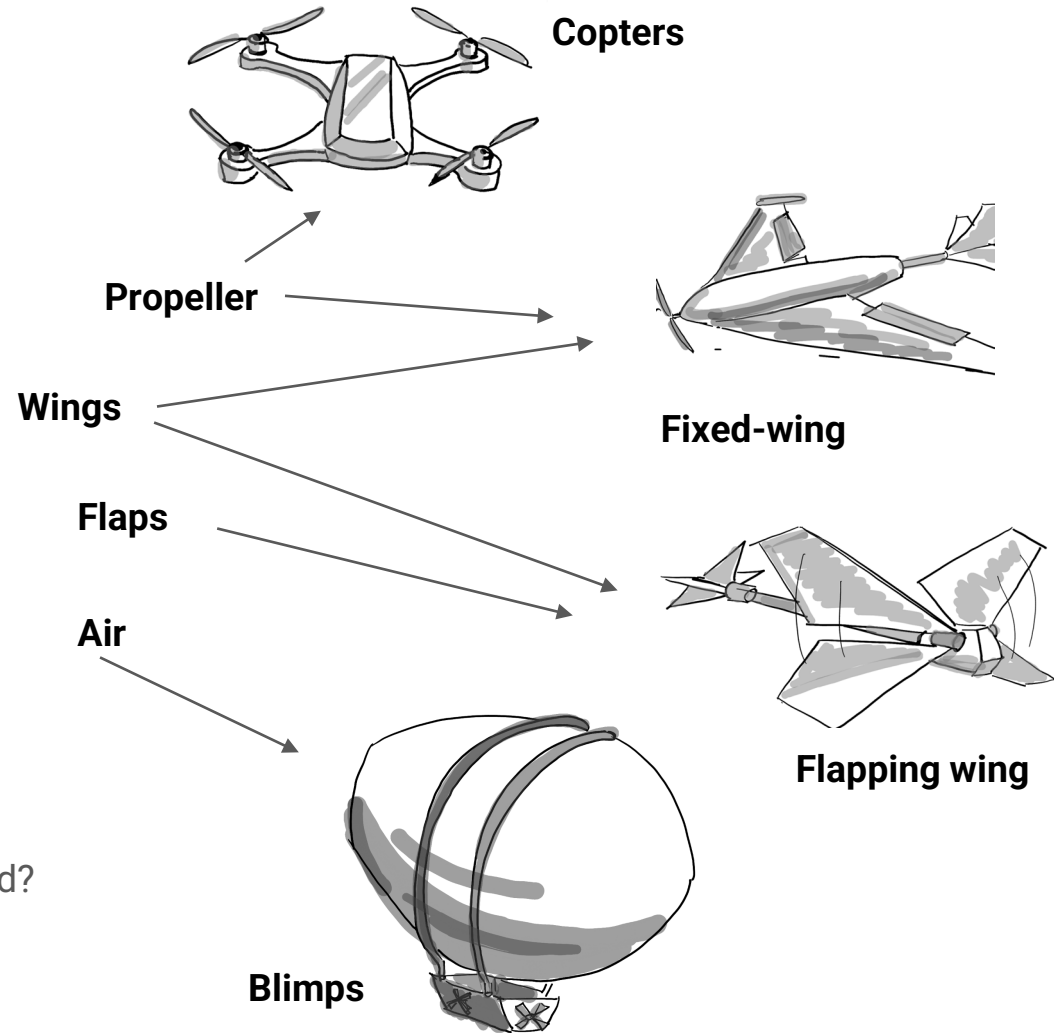
- Needs to be off the ground
- It needs to be controllable
- No human should be on board

It usually consist of

- Motors
- Propellers
- Wings/Flaps/balloons

Many types available

- What type of platform do we need?



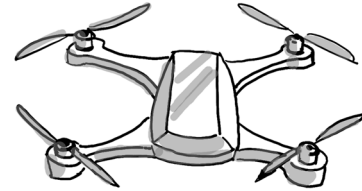
Mary thinks she needs a Multicopter

- Main advantage: Can hold position!

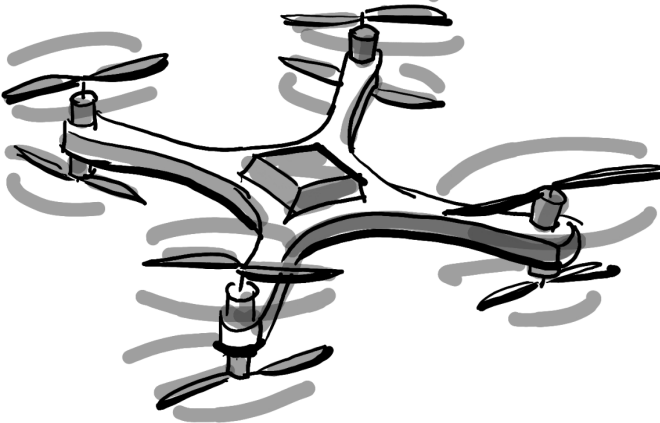
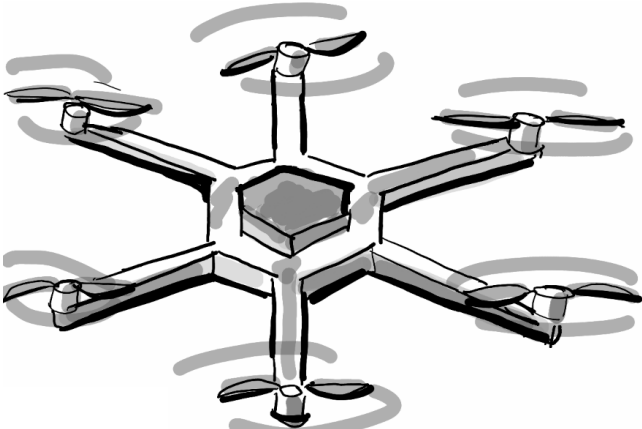
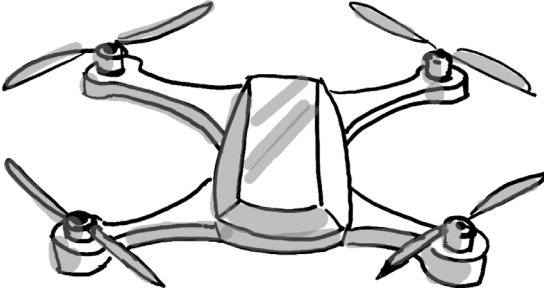
- Allows for precise control

- Very common platform

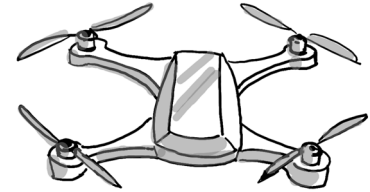
- Many examples available



Multicopter options



Let's go with Quadcopters



Mary picks a quadcopter, as that is a very common vehicle for this type of task.

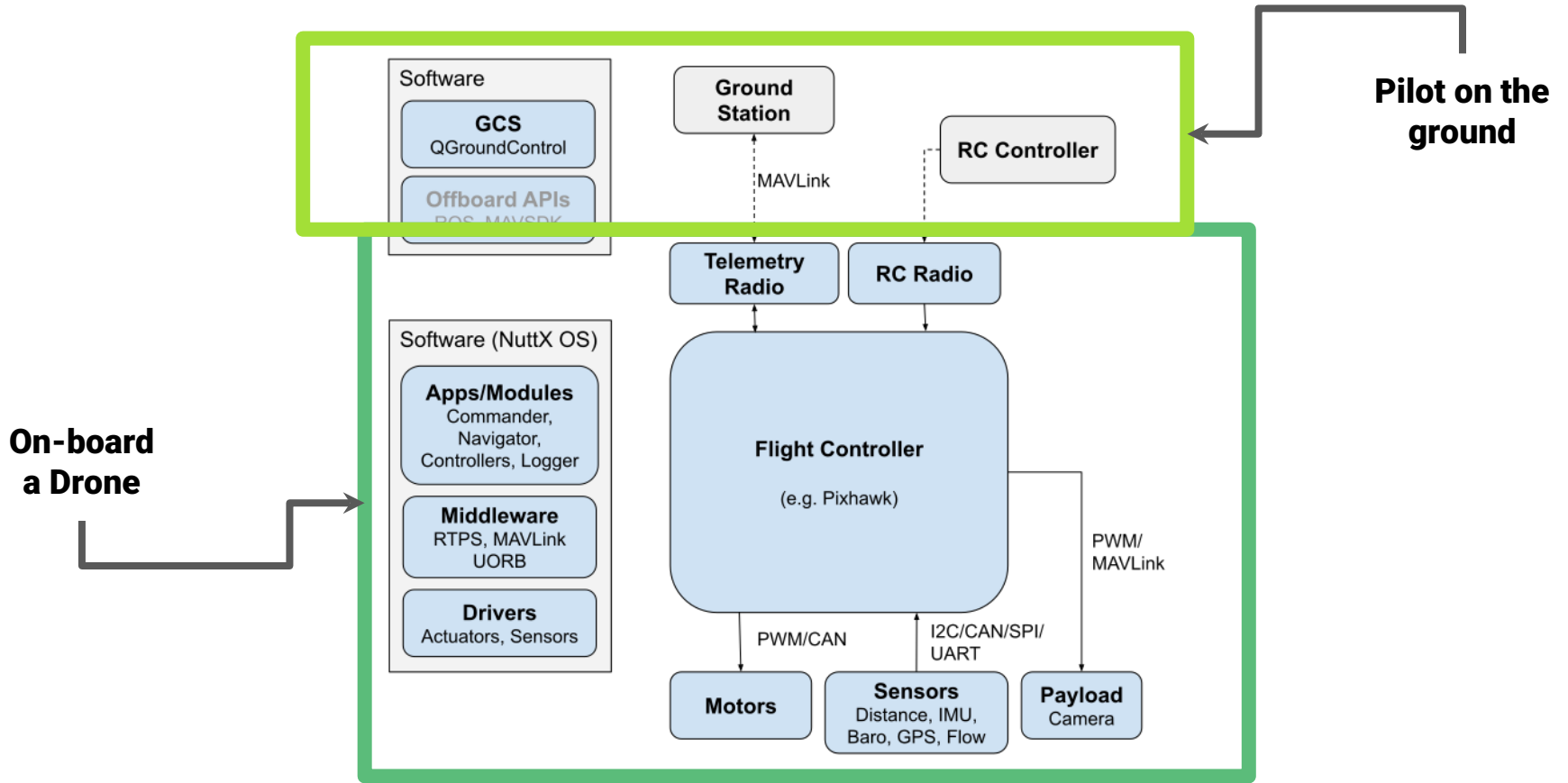
But what is necessary to fly a quadcopter?



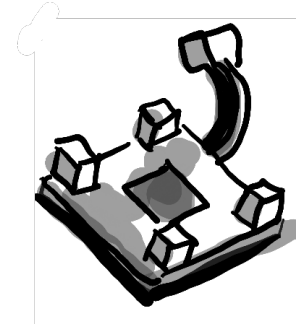
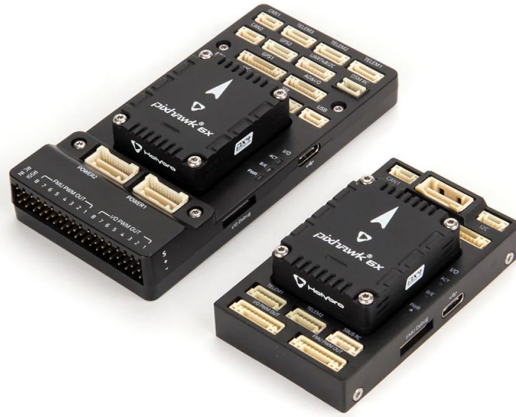


Identifying the required components

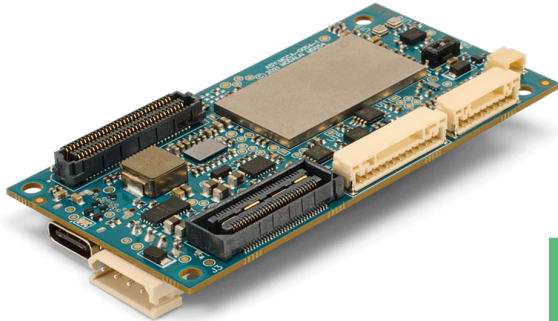
A few hours of google later...



Pixhawk 6X



Flight Management Unit (FMU)



VOXL 2



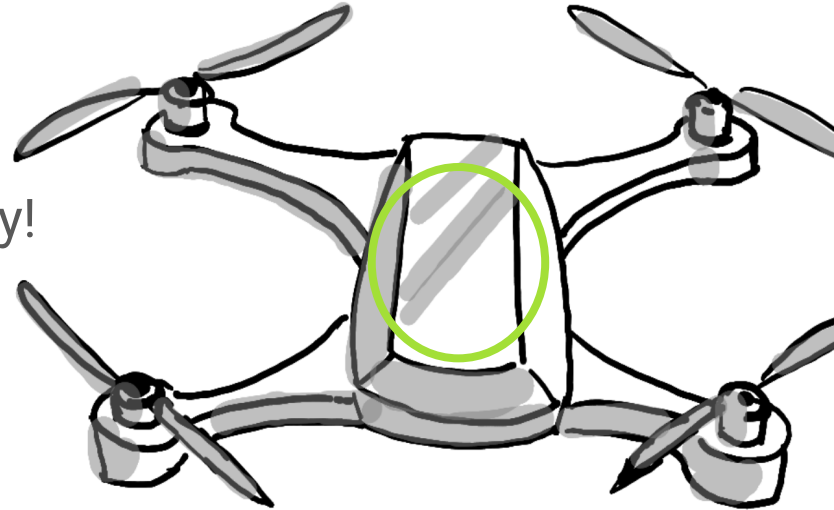
Crazyflie Bolt

Turns out Mary needs a Flight Controller

A flight controller or also flight management unit (FMU) is crucial

It handles the control, navigation and telemetry/communication necessary to fly!

Brains of the operation



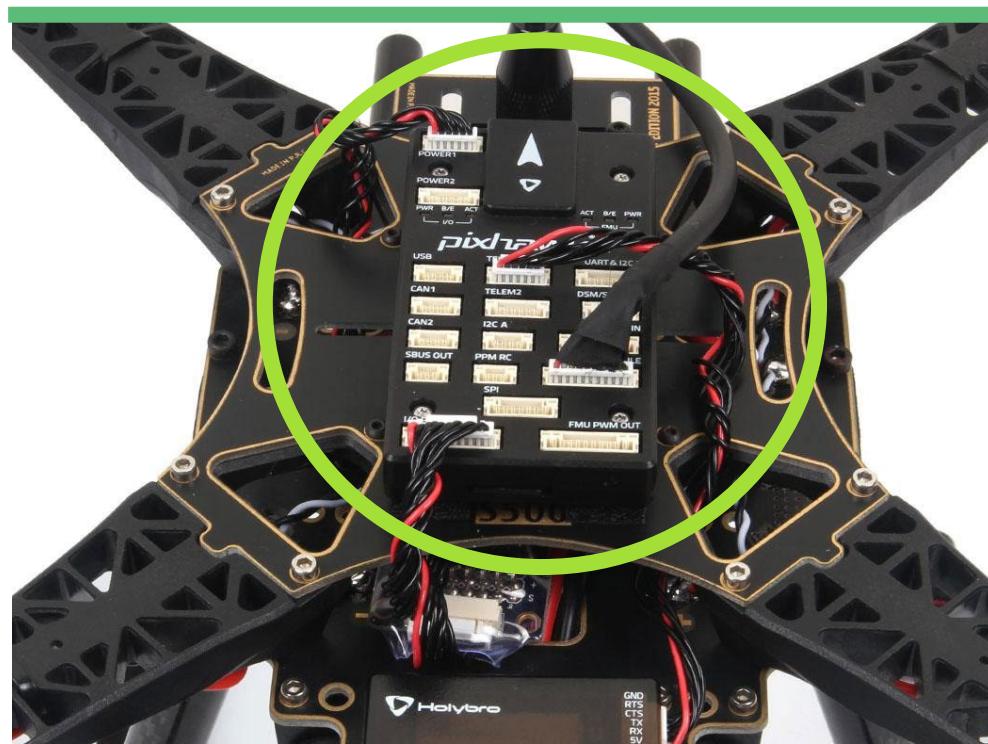
Flight Management Unit (FMU)

Typical components of an FMU (minimum)

- Microcontroller STM32 or similar
- IMU
- Barometer
- Magnetometer

The central unit of a drone

- Usually realtime running an RTOS
- Controls the I/O
- Runs navigation
- Handles telemetry/communication
- And more...



How to choose the right one? Mary isn't sure

Mary made a priority list for her project

1. \$\$\$ Price
2. Capabilities
3. Allow Custom firmware
4. Documentation
5. Well supported by Manufacturer

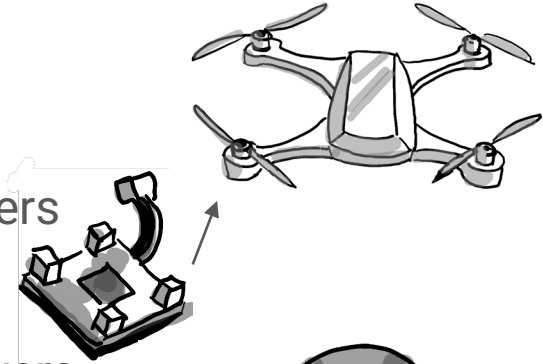
Mary found a manufacturer that had what she was looking for plus shipped to her country at reasonable prices.

Mary needs to decide which firmware to run

She starts to understand the basics of a quadcopter and the necessary components

But compared to the ground robots, quadcopters are *unstable*!

Does she need to write the controllers and drivers from scratch?





Imposter syndrome kicks in...

Back to google...

So many options

And more...



How to choose?

Mary made another helpful list to help her decide. The firmware needed to have:

1. Support my Hardware
 - a. After the huge expense
2. Friendly License
 - a. Mary needs to get to market
3. Maintainer Activity
 - a. Active Open Source Community
4. ROS Support
 - a. Mary has a Masters she really wants to be able to use in this project

...The list narrowed down...

??





**Mary saw a youtube
video and chose PX4**

Short Commercial

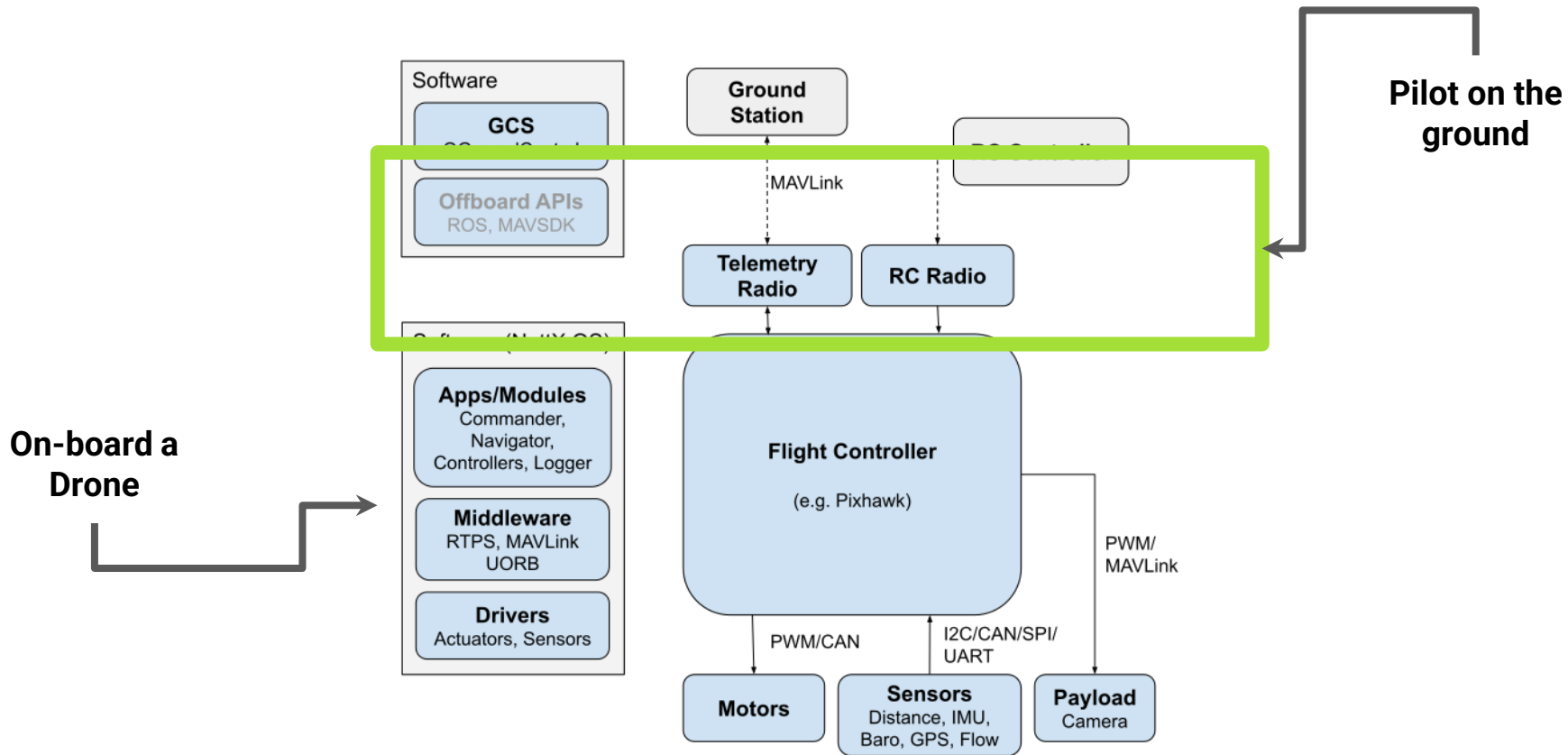
Mary is able to fly manually with
RC control

Not super easy but it's fun!

But... it's not really autonomous

She needs telemetry





Communication

Telemetry: the real-time transmission of data collected on-board a drone about its flight dynamics, status, and operating environment.

Control: Either RC attitude control, or high level commands like waypoint navigation

Messaging protocol options:

MAVlink (ardupilot, PX4, ROSflight)

Pprzlink (Paparazzi UAV)

Multiwii Serial Protocol (Betaflight)

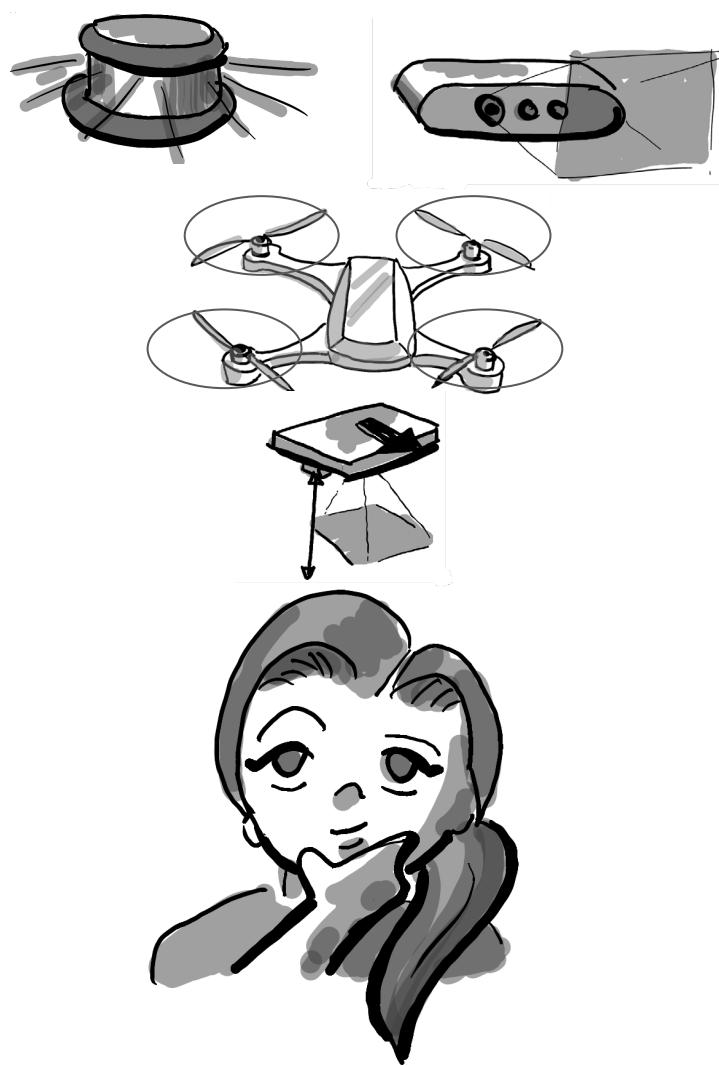
Crazy Real-Time Protocol (Crazyflie)



Back to google...

Autonomy

- Mary also implements on her quadcopter:
 - Lidar
 - RGB Camera
 - Flow sensor and height sensor
- She is experienced with several autonomy packages in ROS
- But she can't use those out-of-the-box as easily...
- Does she:
 - Write something completely from scratch?
 - Try to fit existing ROS packages to aerial vehicles
 - Look for Aerial Autonomy stacks?

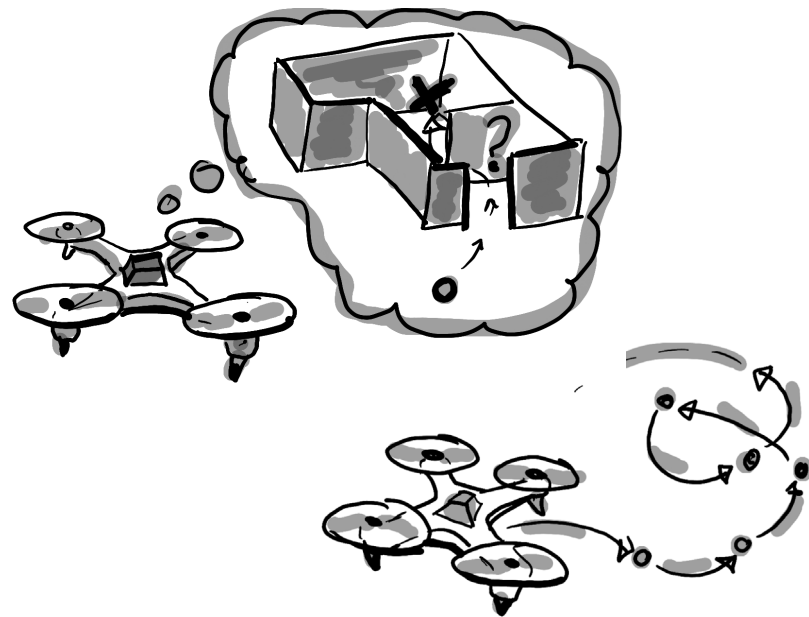


ROS Autonomy stacks for aerial vehicles

ROS packages examples

- Aerostack(2)
- Aerial Core
- Kumar Robotics
- Crazychoir
- Crazyswarm(2)
- And many more..

**Don't miss
the talk
today!**



Adapted from M. Fernandez-Cortizas, M. Molina, P. Arias-Perez, R. Perez-Segui, D. Perez-Saura, and P. Campoy, 2023, "Aerostack2: A software framework for developing multi-robot aerial systems", ArXiv DOI 2303.18237.

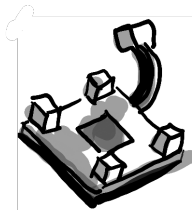
https://github.com/ROS-Aerial/aerial_robotic_landscape/blob/main/aerial_autonomy_stacks.md



How does ROS talk to the FMU?

ROS and FMU communication

Flight management Unit (FMU) to ROS Running on Laptop



FMU

Intercommunication



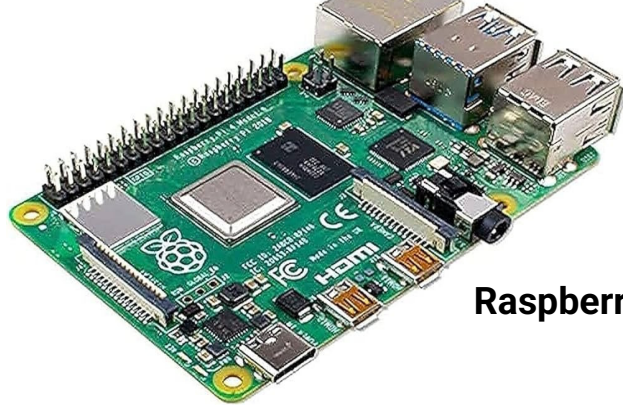
Laptop

Intercommunication options:

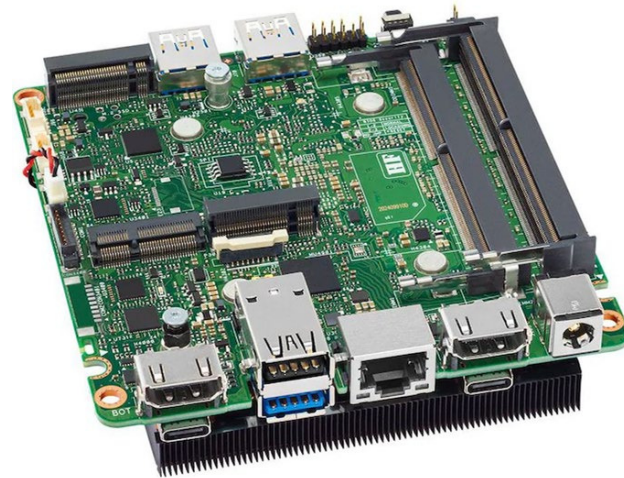
- FMU <-> **MAVlink** <-> MAVros <-> ROS packages
- FMU <-> **DDS / Zenoh** <-> ROS packages
-



But running ROS in a laptop is not the end goal we need an additional companion platform on board the vehicle

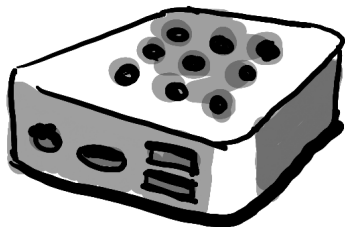


Raspberry pi 4

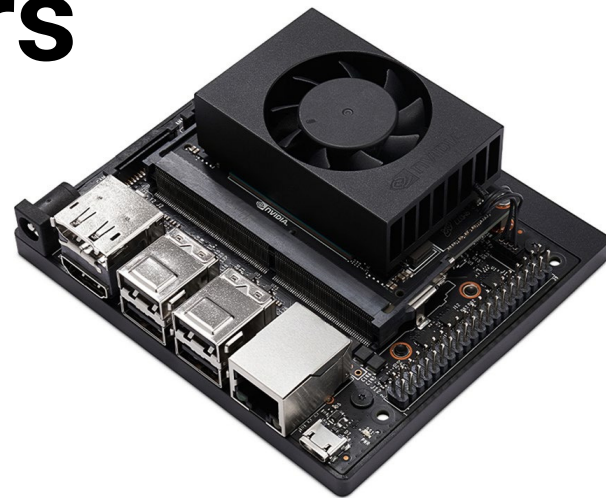


NUC

Companion Computers



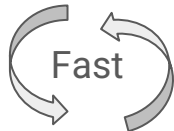
Nvidia Jetson Xavier



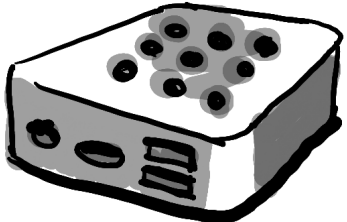
Mary breaks down levels of control



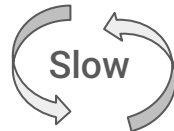
FMU



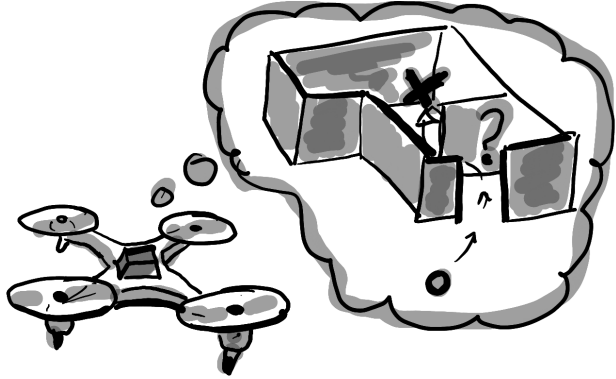
Attitude control



Companion



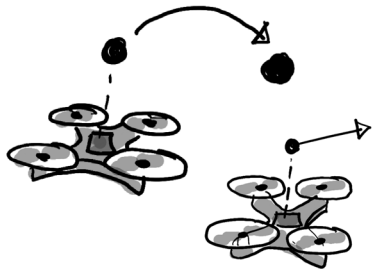
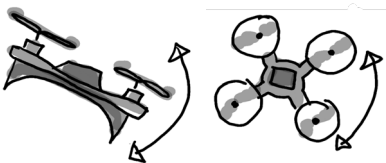
Position control



High level goals



Trajectory control



As many of us Mary had a RPi4 in her desk collecting dust and she's going to try that for now

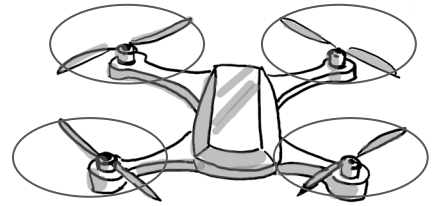


Let's not forget the assignment Mary!

Mary implements an additional:

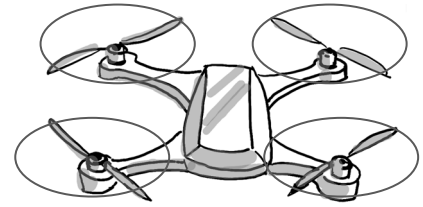
- Companion computer (Raspberry Pi 4)

So now... finally... Mary is able to use some of her past expertise in robotics!



Safety and simulation

- Mary has spent close to **\$5k USD** in her project
- The drone is a bit heavy now... **2 kg**..
- Mary finds it a bit scary to fly, specially when crashing is a real possibility.
- Mary decides to start using a simulator first!
- It needs to be able to simulate the drone in a more or less realistic way



Back to google...

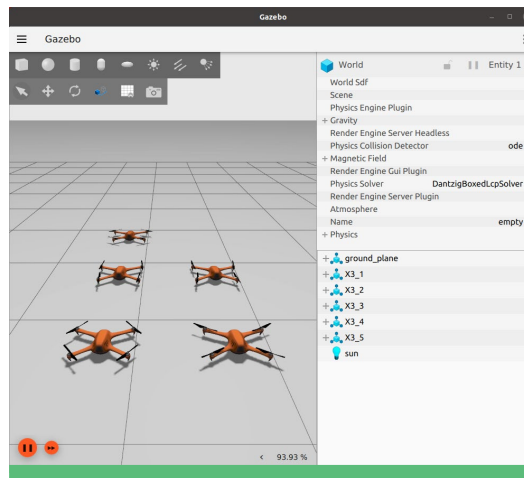
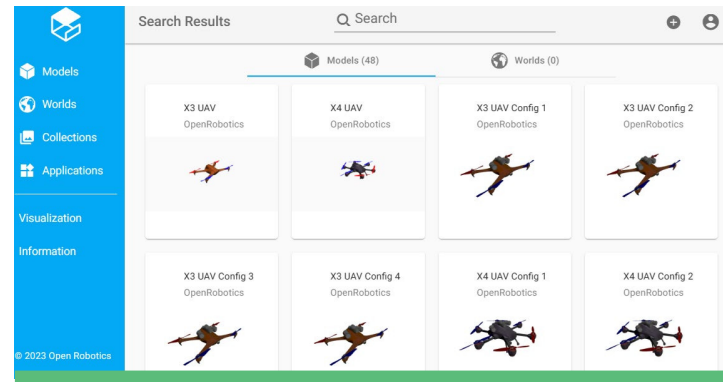
Aerial Robotics Simulation

Simulators

- Gazebo (new and classic)
- Webots
- Microsoft AirSim
- Nvidia Isaac Sim
- And more...

Choices??

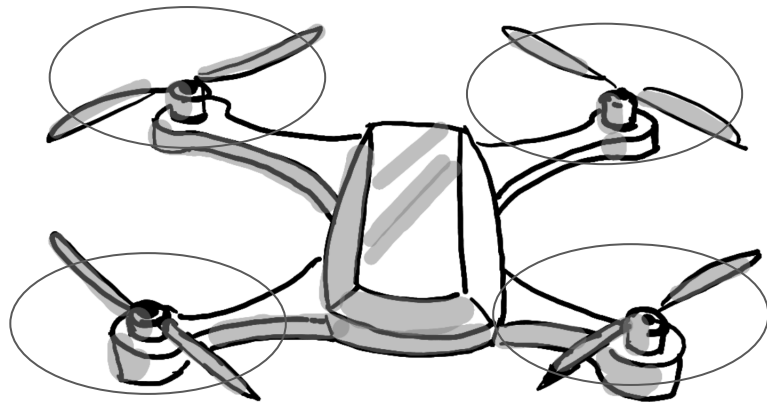
- Dynamics versus vision rendering?
- Hardware or software in the loop?
- Collision models?





**Mary saw another youtube
video and chose Gazebo**

Now the real fun begins (?)



Now Mary is ready to try out things!

She'll use the simulator to initial development

And implements it to the real drone, tries it out in the lab, and iteratively develops the autonomous drone.

But...



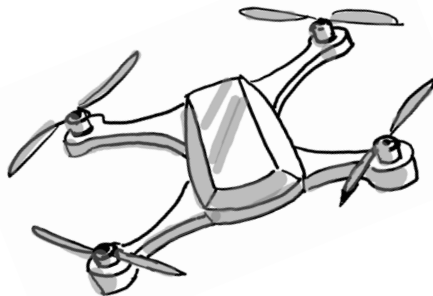
Now the real fun begins (?)

Now Mary is ready to try out things!

She'll use the simulator to initial development

And implements it to the real drone, tries it out in the lab,
and iteratively develops the autonomous drone.

But...





Mary ran out of time

The project was supposed to be finished in 3 months... she only has a week left now to finish her assignment...

What went wrong for Mary, and many others?

- The learning curve is still too steep
- You almost need to be an expert in everything
- Many need to custom build their own drone
- Too many choices in software and hardware
- Mary's story is very common for many starting in aerial robotics, both in academia and industry!

NOT MARY'S FAULT!

Mary could be you

A common frustration

- We have personally been through this experience
- Almost everyone we meet has gone through a similar experience
- If we are going to complain we should at least do something to help
- No group for aerial vehicles?
- Let's start one!
- **First meeting @ ROSCon 2022**







Let's document everything and make a landscape



Our goals

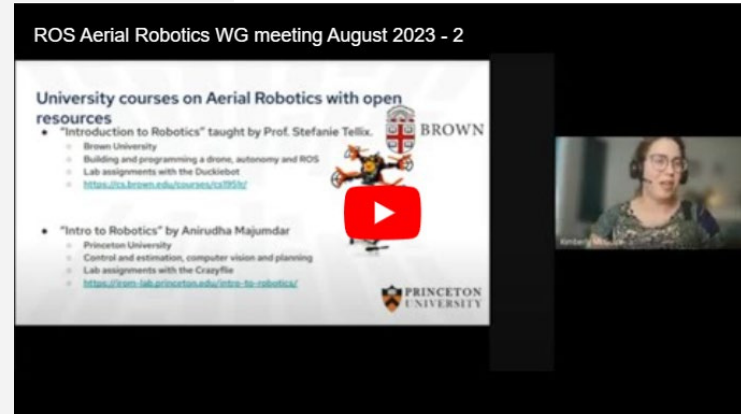
The Journey so far

6 x Scientific meetings

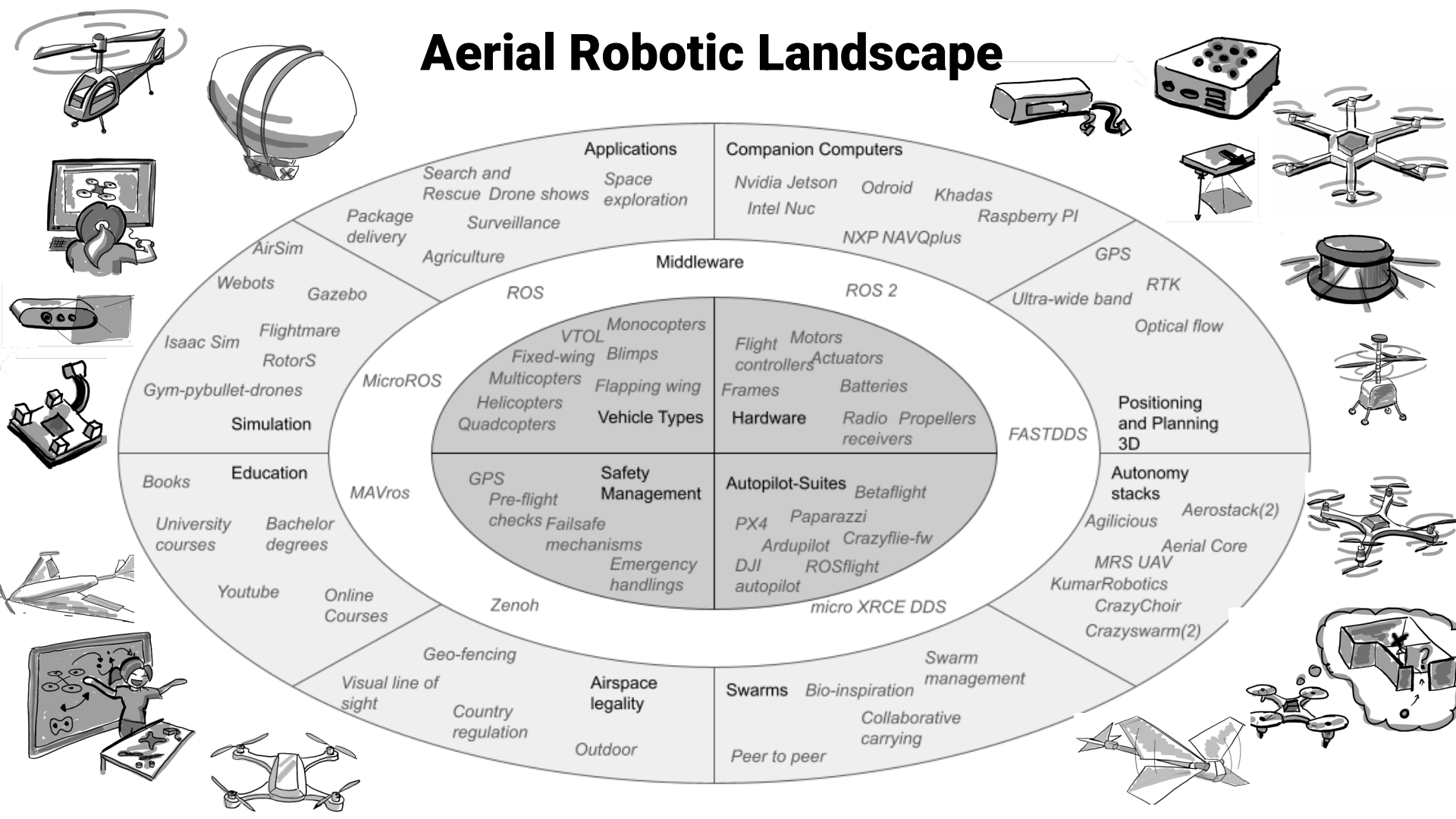
- Aerostack2
- Drone2bets
- Vehicle Gateway
- Duckietown's Duckiedrone
- Education overview
- NXP Semiconductors

6 x discussion meetings

- Hardware, components and dev kits
- Message standards
- Swarm management
- Tutorial and education
- Aerial autonomy stacks
- Simulation

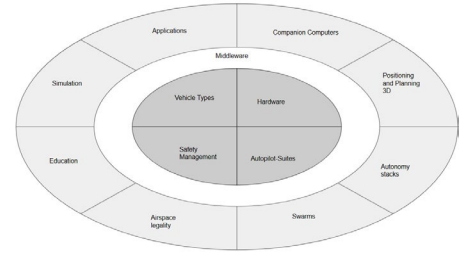


Aerial Robotic Landscape



It's not yet complete

WE NEED YOUR HELP



Conclusions of our meetings so far

Education

Simulation

Standardized drone

Autonomy packages



Aerial Robotics in ROS

First exploratory meeting!

Kimberly McGuire Ramon Roche

MORE VIDEOS  

Kimberly McGuire

ROS Aerial Robotics WG meeting August 2023 - 2



University courses on Aerial Robotics with open resources

- "Introduction to Robotics" taught by Prof. Stefanie Tellex.  BROWN
 - Brown University
 - Building and programming a drone, autonomy and ROS
 - Lab assignments with the Duckiebot
 - <https://ics.brown.edu/courses/cs395b/>
- "Intro to Robotics" by Anirudha Majumdar
 - Princeton University
 - Control and estimation, computer vision and planning
 - Lab assignments with the Crazyflie
 - <https://sem.lab.princeton.edu/intro-to-robotics/>

Anirudha Majumdar

Conclusions about Simulation

Feedback: Many use Gazebo but not yet the new one

Many are confused about choices for dynamics models, vision engines and the differences between them

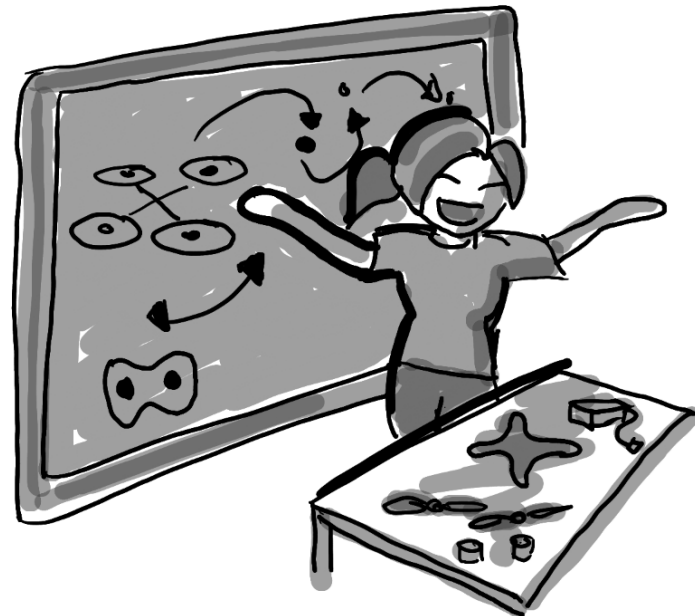
There are just so many simulators out there!

Also, don't miss the talk on '**Multi-drone simulation with deep q-learning**' 3:30 PM today



Conclusions about Education

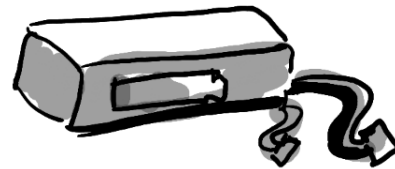
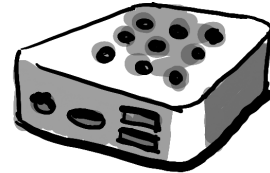
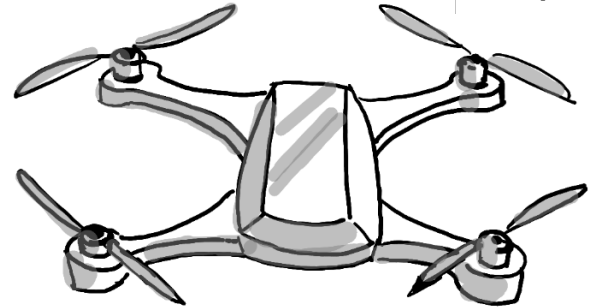
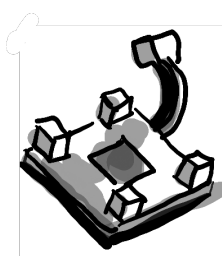
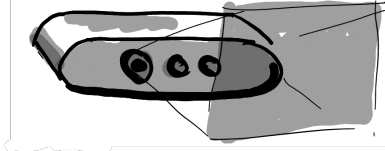
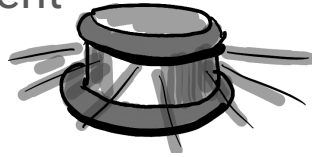
- A lot of education available for aerial robotics
- Only a handful that also cover ROS, even less ROS 2
- The “Duckiedrone” by duckietown
- **Feedback:** better docs, more tutorials



Conclusions about Standardized Drone

We are missing a Turtlebot equivalent

The 'Turtledrone'



Conclusion Autonomy packages

Aerostack2 will present their work today as well at 10 AM today!

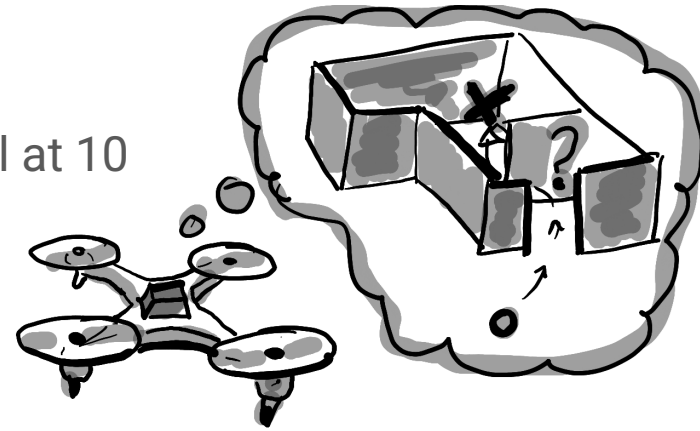
Many Autonomy packages that exist

But unclear for many which to use?

And should there be an specific aerial autonomy package?

What is missing from those for ground robots?

Feedback: Better visibility, and end-to-end integration



Help us map the aerial robotics landscape

— Aerial Robotics community working group meetings every 2 weeks

— Soon we will be starting with specific development goals!

— Let's make it easier for all the Mary's to get started in Aerial Robotics!

— **Feedback:** Your participation!



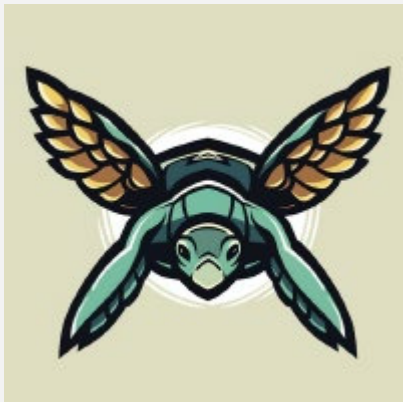
Thanks for your time!

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kimberly@bitcraze.io

Ramón Roche - [@mrpollo](#) (X prev Twitter)

rroche@linuxfoundation.com



Aerial Robotics Work Group



www.github.com/ros-aerial