OPEN-SOURCE QUADCOPTER PLATFORM FOR SIMULINK

IACAS-63

Joseph Attias, Yael Marciano, Ruslan Archipov, Daniel Zelazo
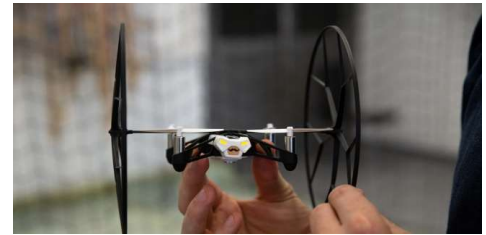
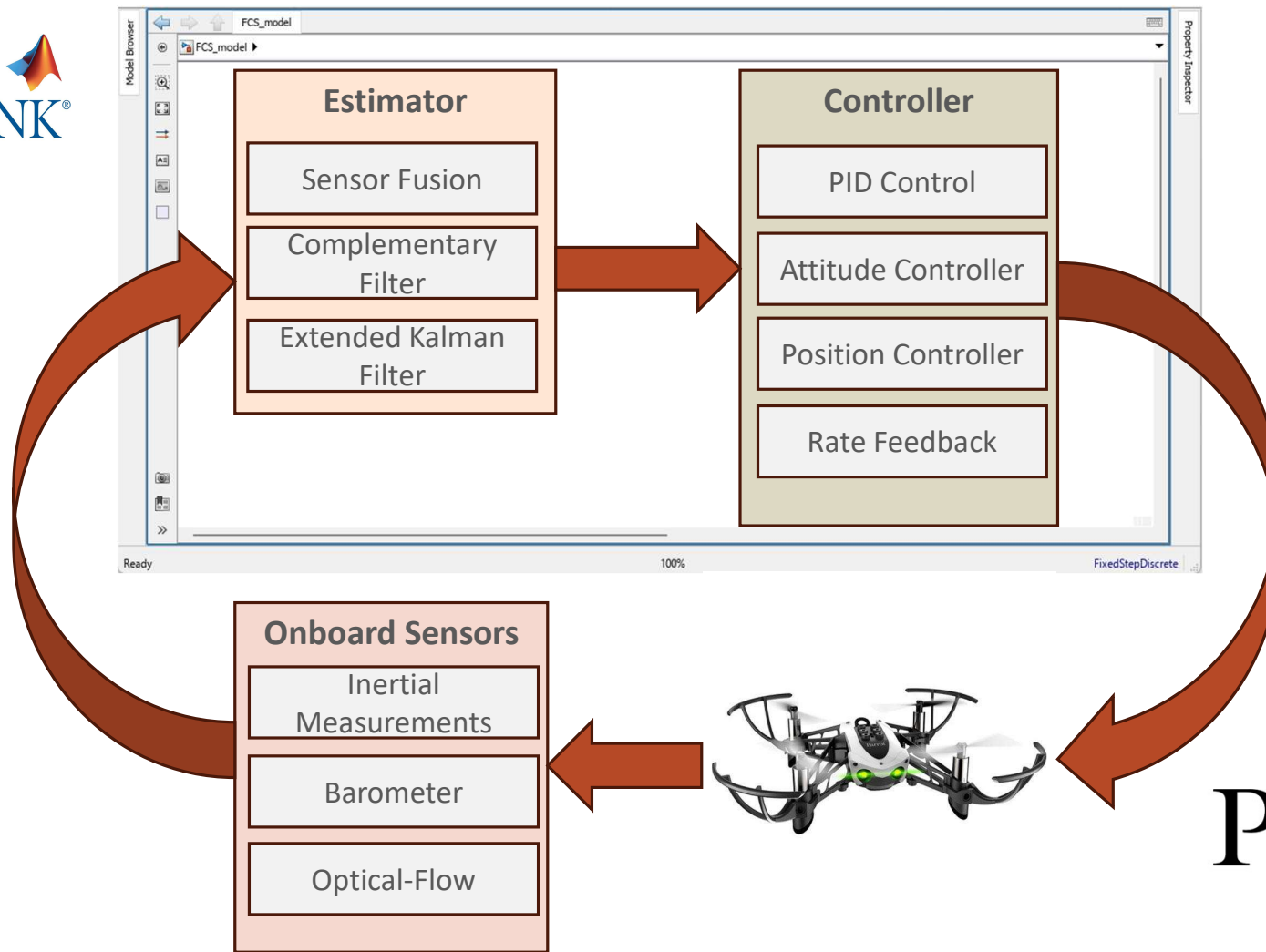May 9 , 2024

DEPARTMENT OF
AEROSPACE ENGINEERING

TECHNION
Israel Institute
of Technology

CoNeCt
Cooperative Networks
and Controls Lab

The Technion's Faculty of Aerospace Engineering's,

Advanced Control Lab (085705)

➢Students build low level estimation and control algorithms.

➢Students deploy their algorithms onto quadcopter drones.

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The Simulink Support Toolbox for Parrot mini-drones is the current backbone of the course.

Parrot

Pros:

➢ Parrot supplies an environment for motor control algorithms

➢ Hardware is cheap

Cons:

➢ Hardware is becoming obsolete and has only 2 years of support left

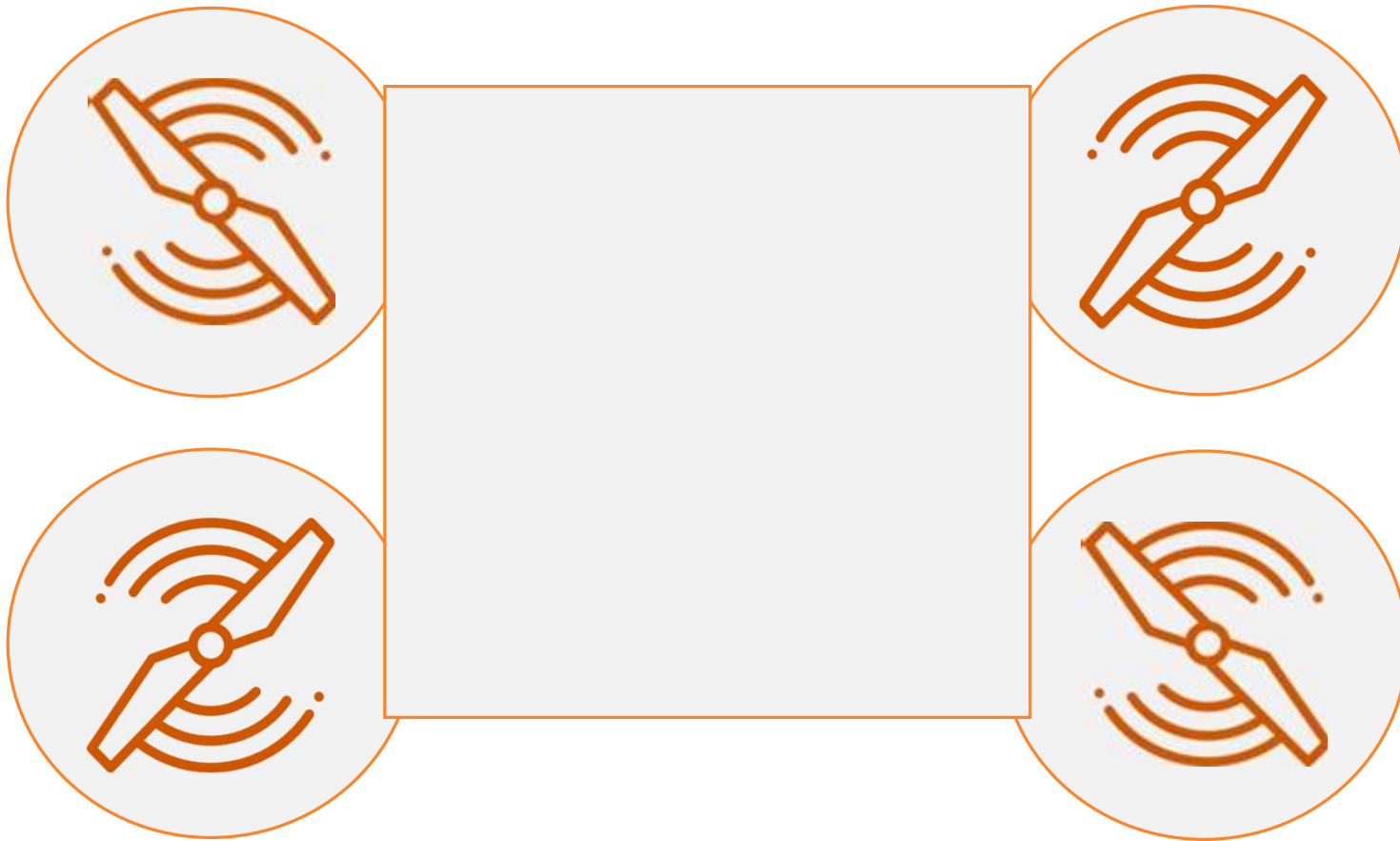➢ Bluetooth connectivity issues

➢ Limited flexibility for other uses

The Parrot platform is not sustainable. We need a new drone.

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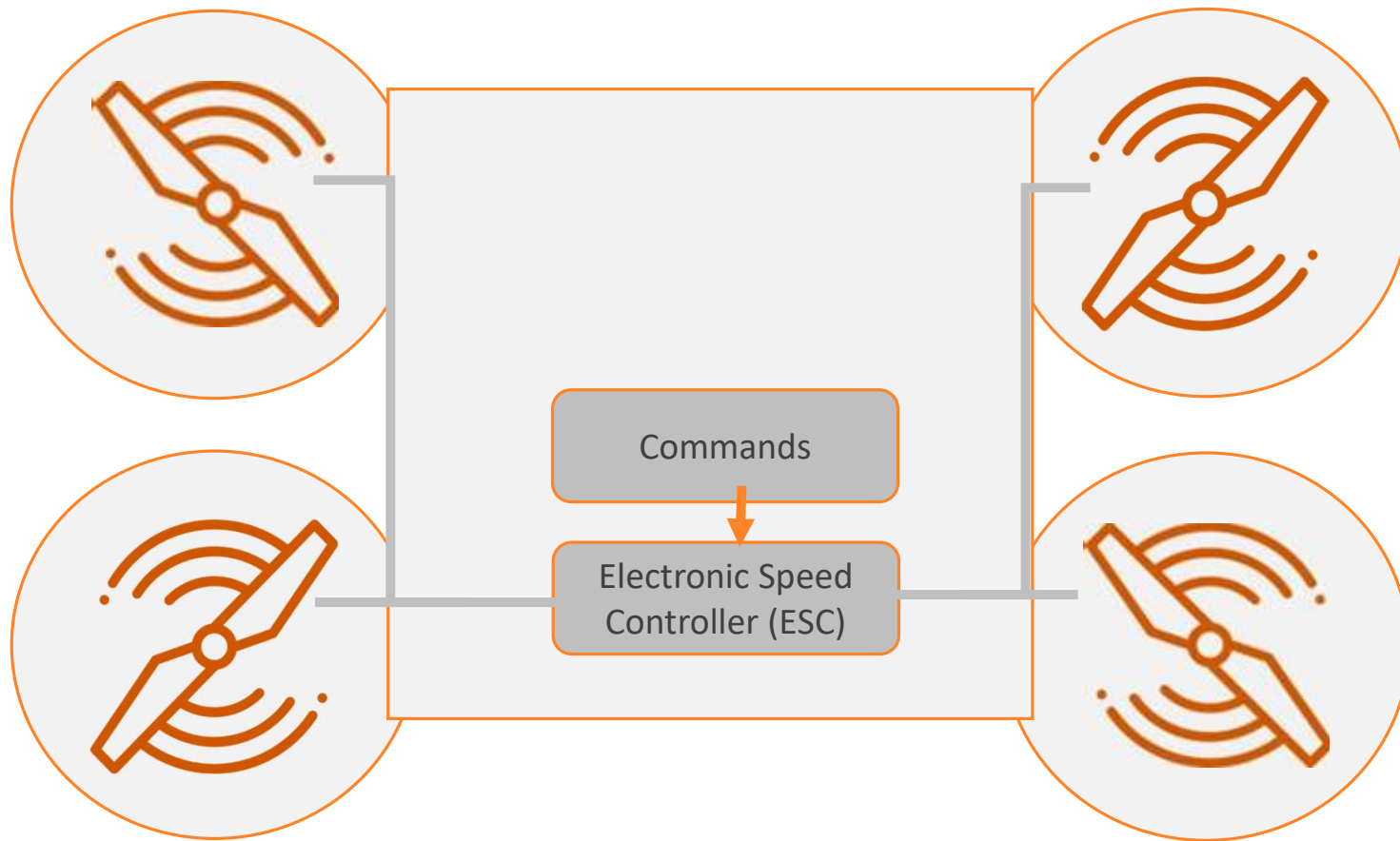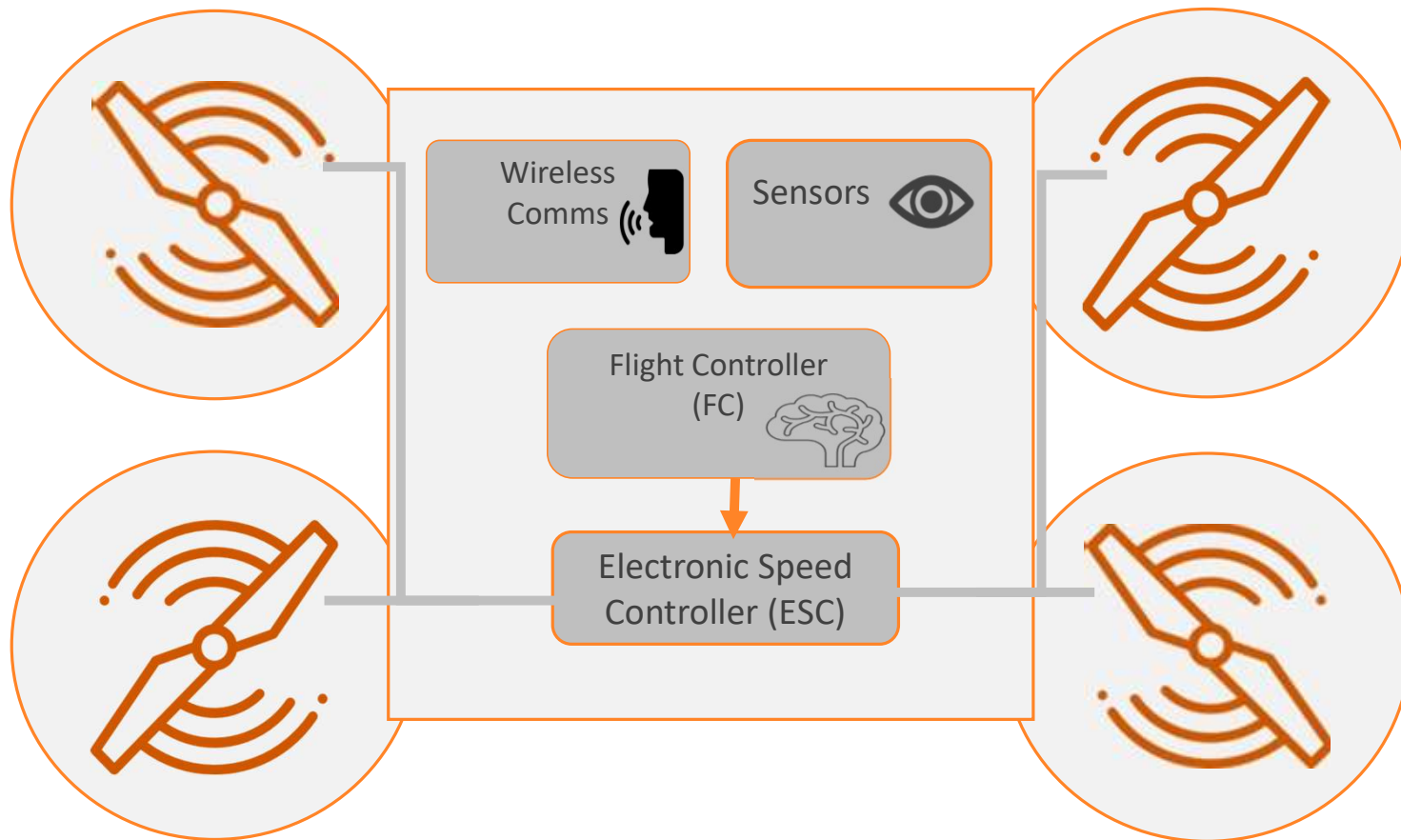# WHAT IS A QUADCOPTER ?

Commands

Electronic Speed Controller (ESC)
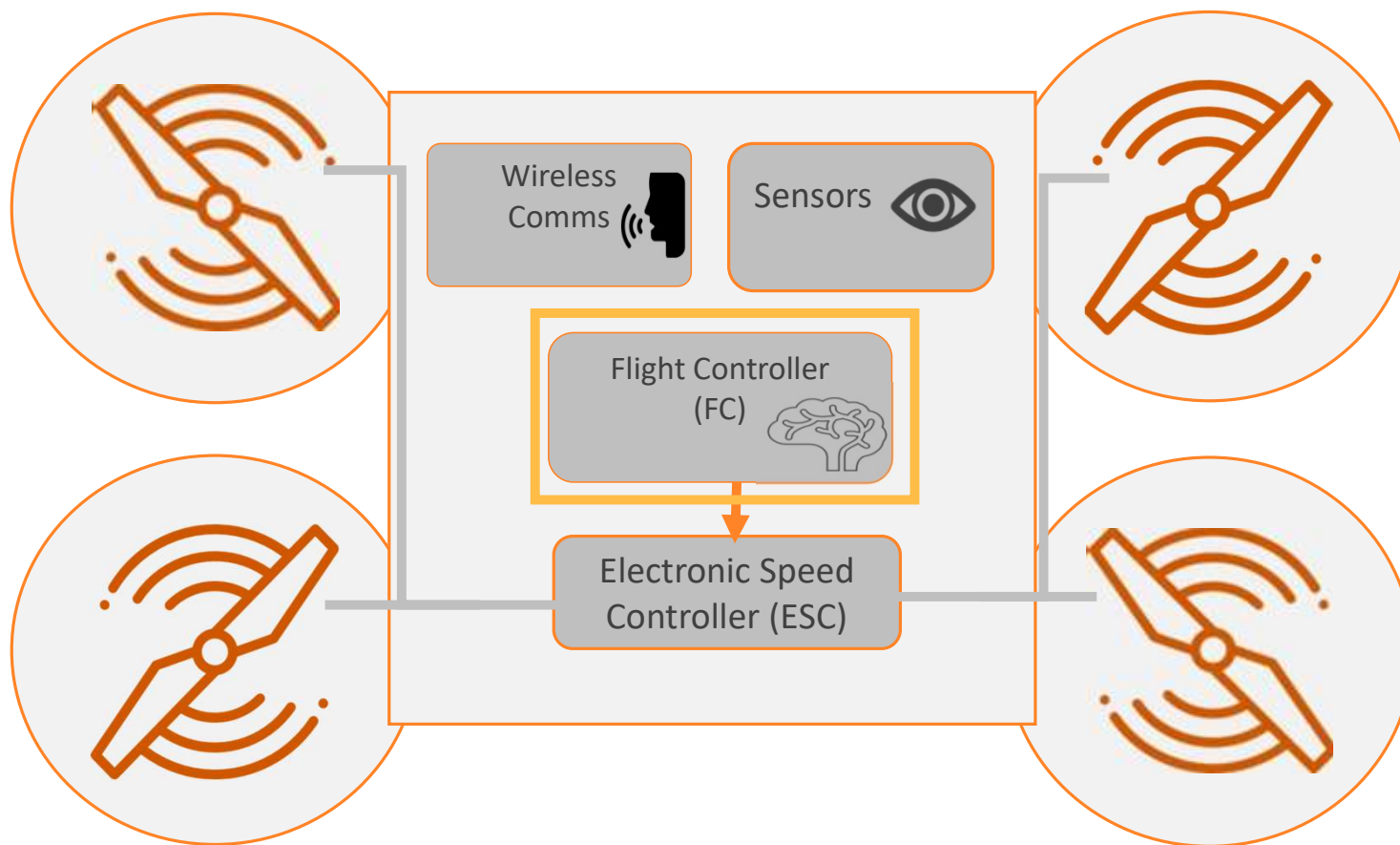
FLIGHT CONTOLLER PACKAGE OPTIONS

Requirements	Flight Controller Firmware			
	Parrot	PX4	Betaflight	Ardupilot
Open-source firmware with accessible documentation.	X			
Support for off-the-shelf parts.	X			
Simulink Toolbox exists.	✓			
Total part cost is less than $100.	✓			

FIRMWARE OPTIONS

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https://ardupilot.org/dev/_images/copter-architecture.pn

ArduCopter

Main Loop (ArduCopter.cpp)
scheduler, fast_loop

Maintainable high-level structures

Copter.cpp
➢ Similar to a main file
➢ Highest level
➢ Often contributed to

Older ■■■■■■■■■■ Newer   Contributors 32

Copter: finished conversion to .cpp files   9 years ago

1   /*

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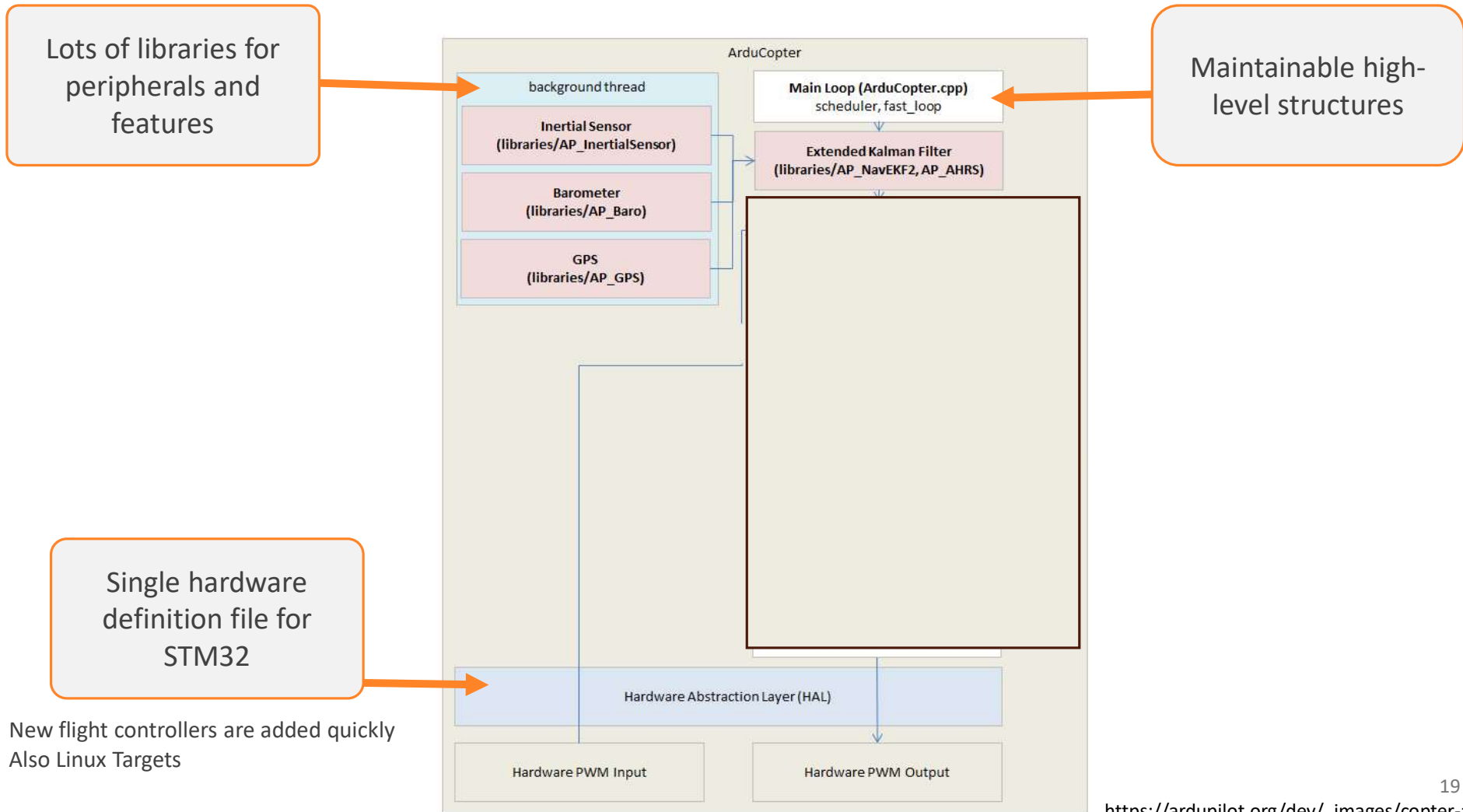https://ardupilot.org/dev/_images/copter-architecture.pn
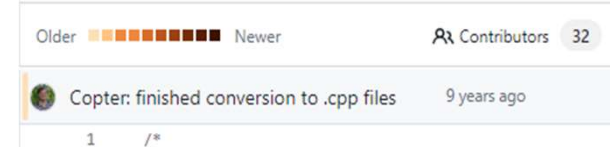
Lots of libraries for peripherals and features

- 121 Ardupilot Libraries
  Not counting varieties
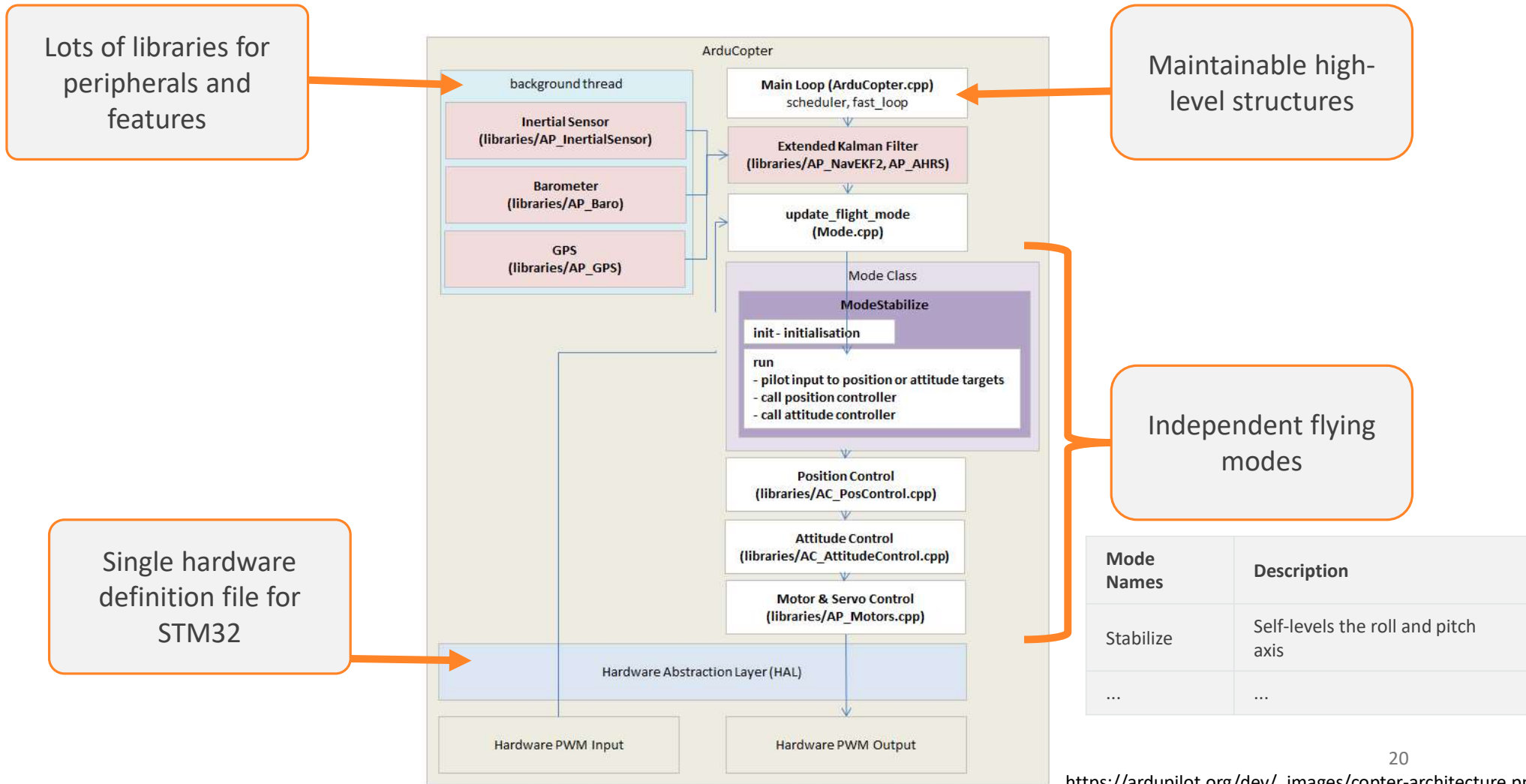- Generalized for any hardware and often contributed by the community

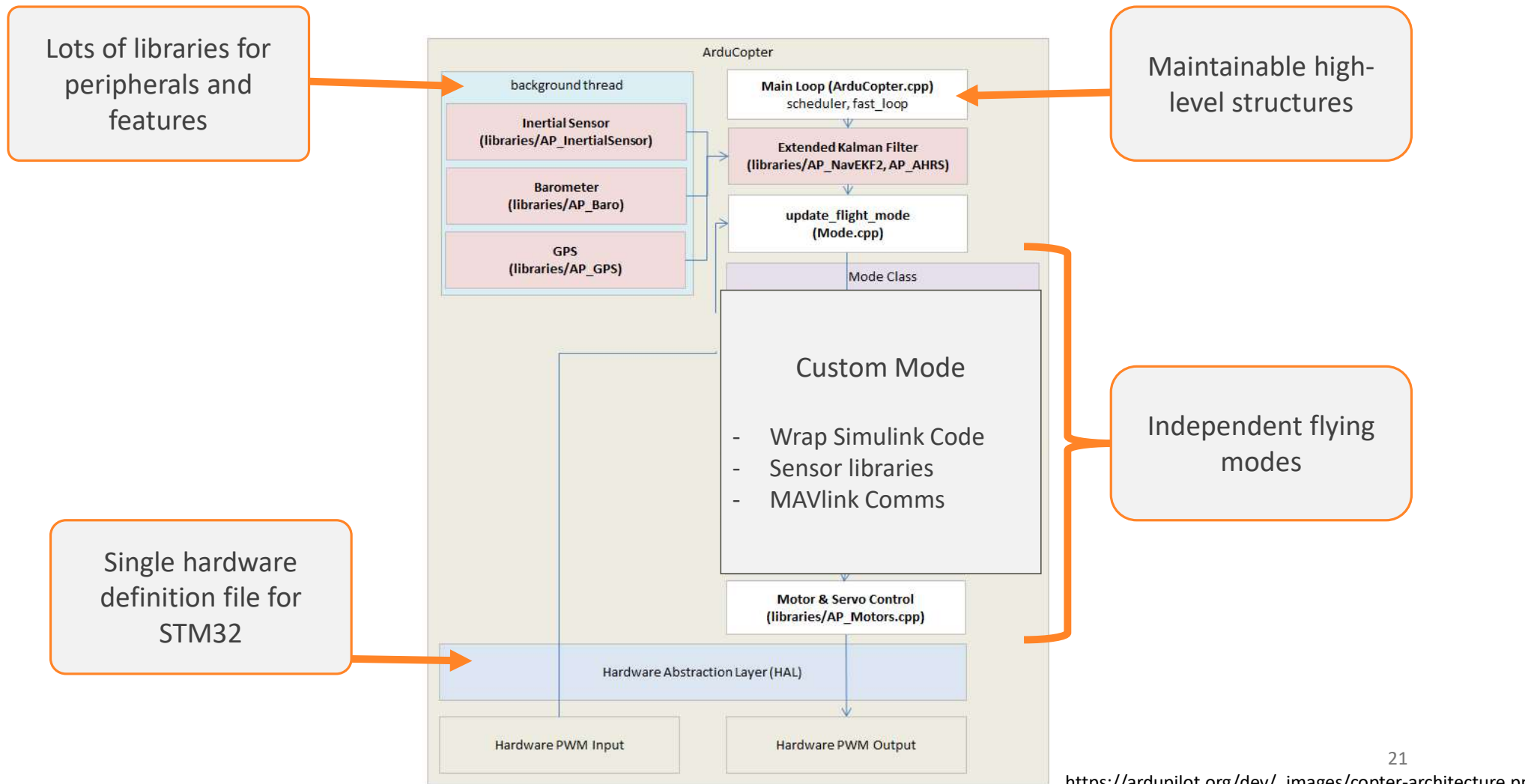Maintainable high-level structures

ArduCopter

background thread

Inertial Sensor
(libraries/AP_InertialSensor)

Barometer
(libraries/AP_Baro)

GPS
(libraries/AP_GPS)

Main Loop (ArduCopter.cpp)
scheduler, fast_loop

Extended Kalman Filter
(libraries/AP_NavEKF2, AP_AHRS)

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https://ardupilot.org/dev/_images/copter-architecture.pn

Lots of libraries for peripherals and features

Maintainable high-level structures

Single hardware definition file for STM32

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(libraries/AP_NavEKF2, AP_AHRS)

Hardware Abstraction Layer (HAL)

Hardware PWM Input

Hardware PWM Output

➢ New flight controllers are added quickly
➢ Also Linux Targets

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https://ardupilot.org/dev/_images/copter-architecture.pn

Lots of libraries for peripherals and features

Maintainable high-level structures

Single hardware definition file for STM32

Independent flying modes

Mode Names	Description
Stabilize	Self-levels the roll and pitch axis
...	...

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https://ardupilot.org/dev/_images/copter-architecture.png

Lots of libraries for peripherals and features

Maintainable high-level structures

Single hardware definition file for STM32

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(libraries/AP_NavEKF2, AP_AHRS)

update_flight_mode
(Mode.cpp)

Mode Class

Custom Mode

- Wrap Simulink Code
- Sensor libraries
- MAVlink Comms

Motor & Servo Control
(libraries/AP_Motors.cpp)

Hardware Abstraction Layer (HAL)

Hardware PWM Input

Hardware PWM Output

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https://ardupilot.org/dev/_images/copter-architecture.pn

Time

MATLAB Project Button

Matlab script

Builds with Simulink Embedded Coder

Align message definitions

- Extracts logging array length
- Modifies dashboard common.xml
- Generates dashboard mavlink dialect
- Copies common.xml to wsl

Starts wsl build script

WSL build.sh

Copies generated code to ardupilot library directory

Standard ardupilot waf process

- Configure hardware
- Build and **upload**

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Windows

Student's MATLAB Project

Flight Control System (FCS)

Dashboard

Windows Subsystem for Linux (WSL)

Modified Ardupilot Source Code

Custom Mode

MAVLink

Hardware definitions

Copter.cpp
mode.h
mode_lab.cpp
libraries/AC_Simulink/
libraries/GCS_MAVLink/
extra_hwdef.dat

FIRMWARE OPTIONS

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Support for off-the-shelf parts.	X	✓	✓	✓
Simulink Toolbox exists.	✓	✓	X	✓
Total part cost is less than $100.	✓	X	✓	✓

Wireless Comms

Sensors

Flight Controller (FC)

Electronic Speed Controller (ESC)

Current Platform

Future Platform

➢Students encounter major interference issues when connecting at the same time

Students spend more time here than studying

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Current Platform

➤Students encounter major interference issues when connecting at the same time

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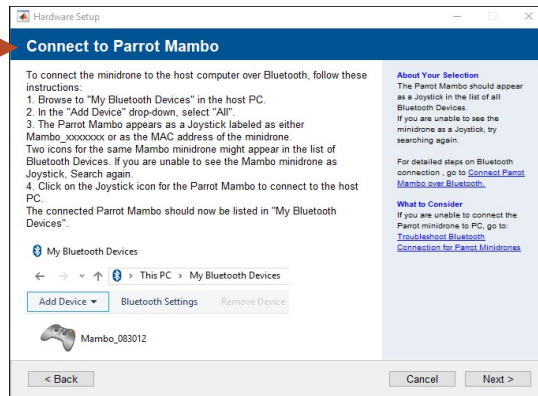
Future Platform

➤WIFI channels can be specified to reduce radio interference

➤MAVLink Messages include system ID to target independent drones
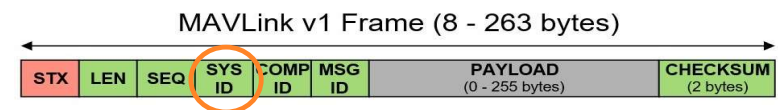
MAVLink v1 Frame (8 - 263 bytes)

STX	LEN	SEQ	SYS ID	COMP ID	MSG ID	PAYLOAD (0 - 255 bytes)	CHECKSUM (2 bytes)

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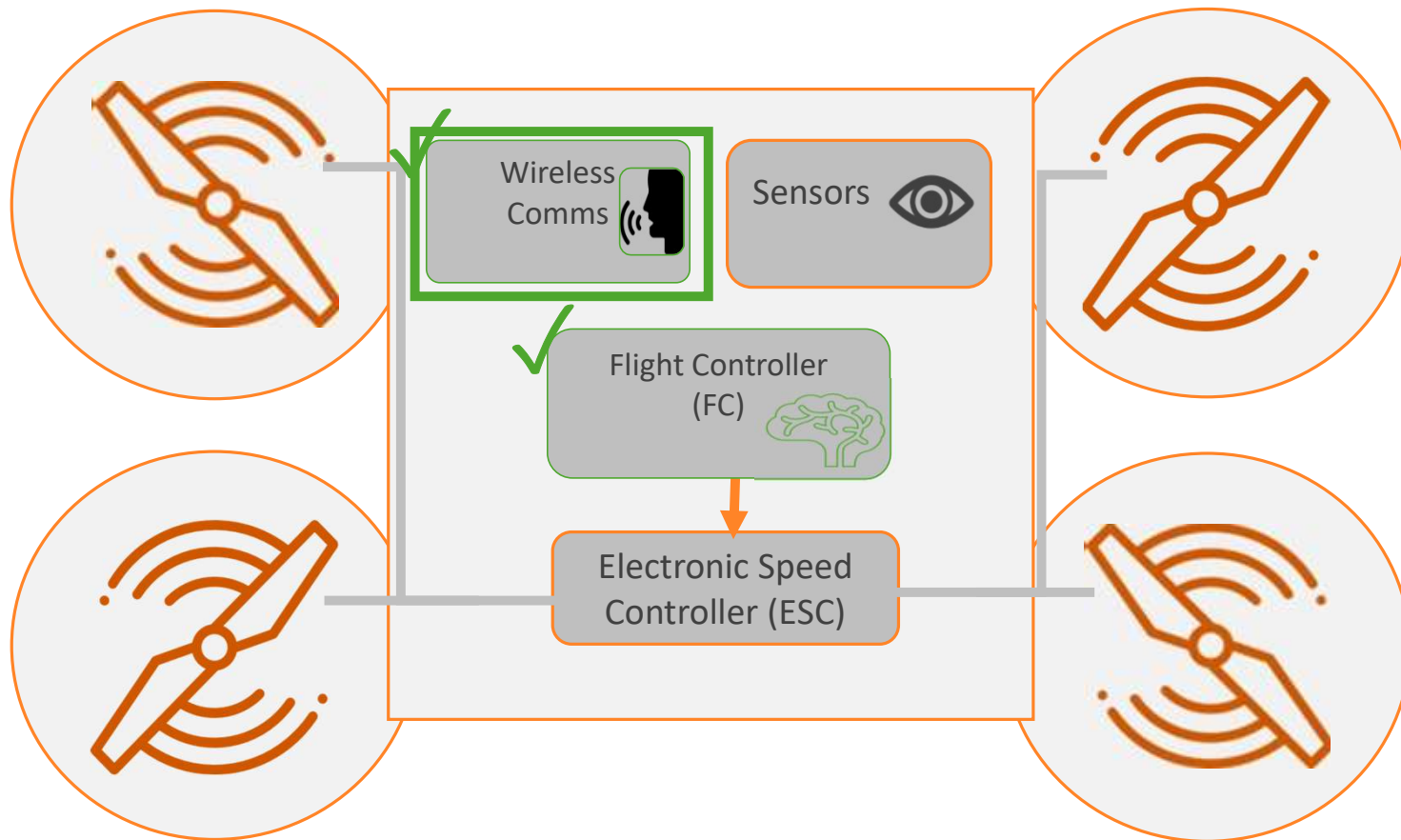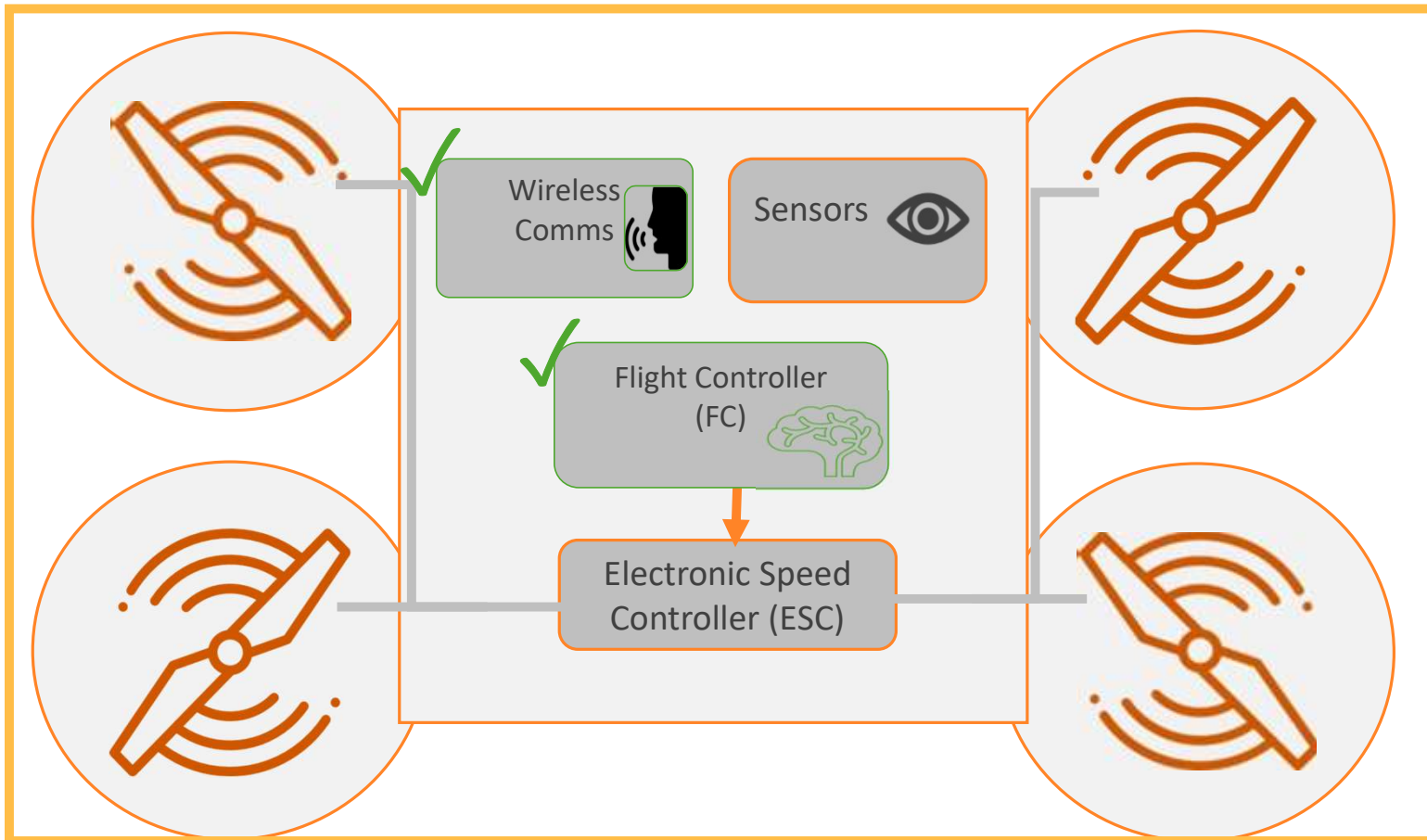
➢Easy replacement and integration of new parts
- Sensors, radio, battery, etc.
- Future proof design for long-term maintenance

➢Control over the physical properties of the drone
- Moment of inertia, center of mass, etc.

➢Interface with test rigs
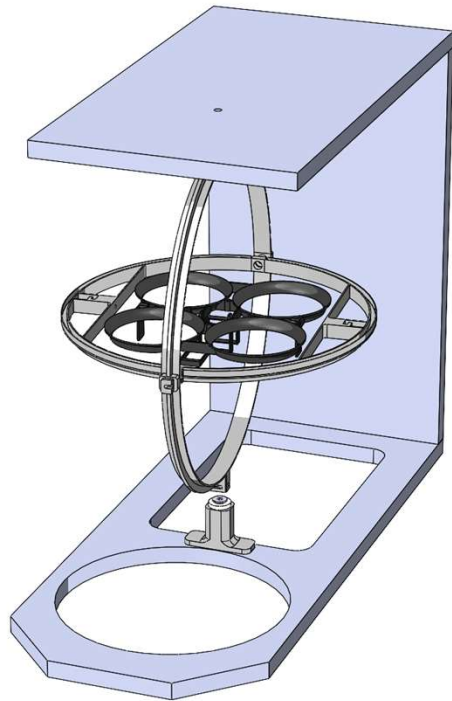
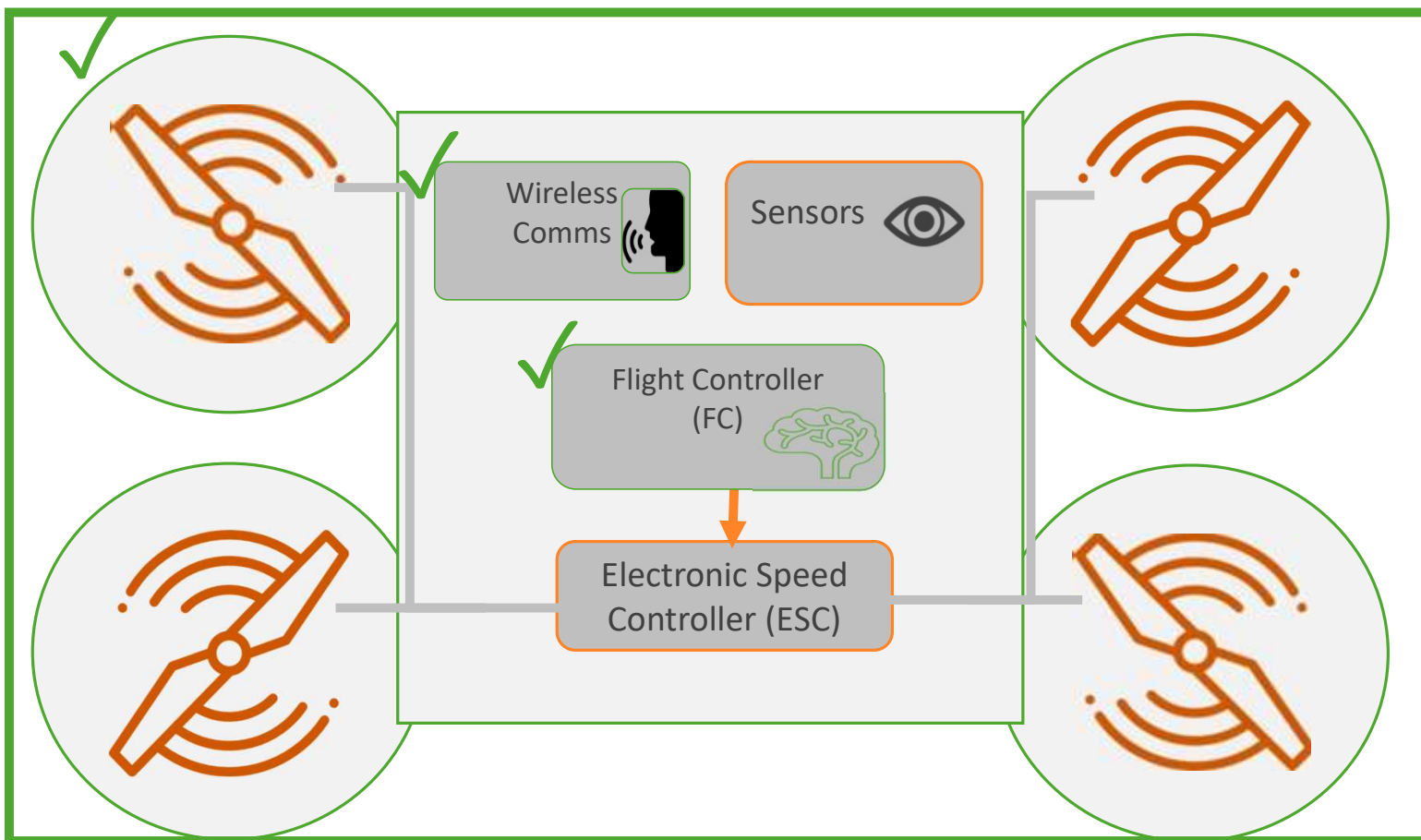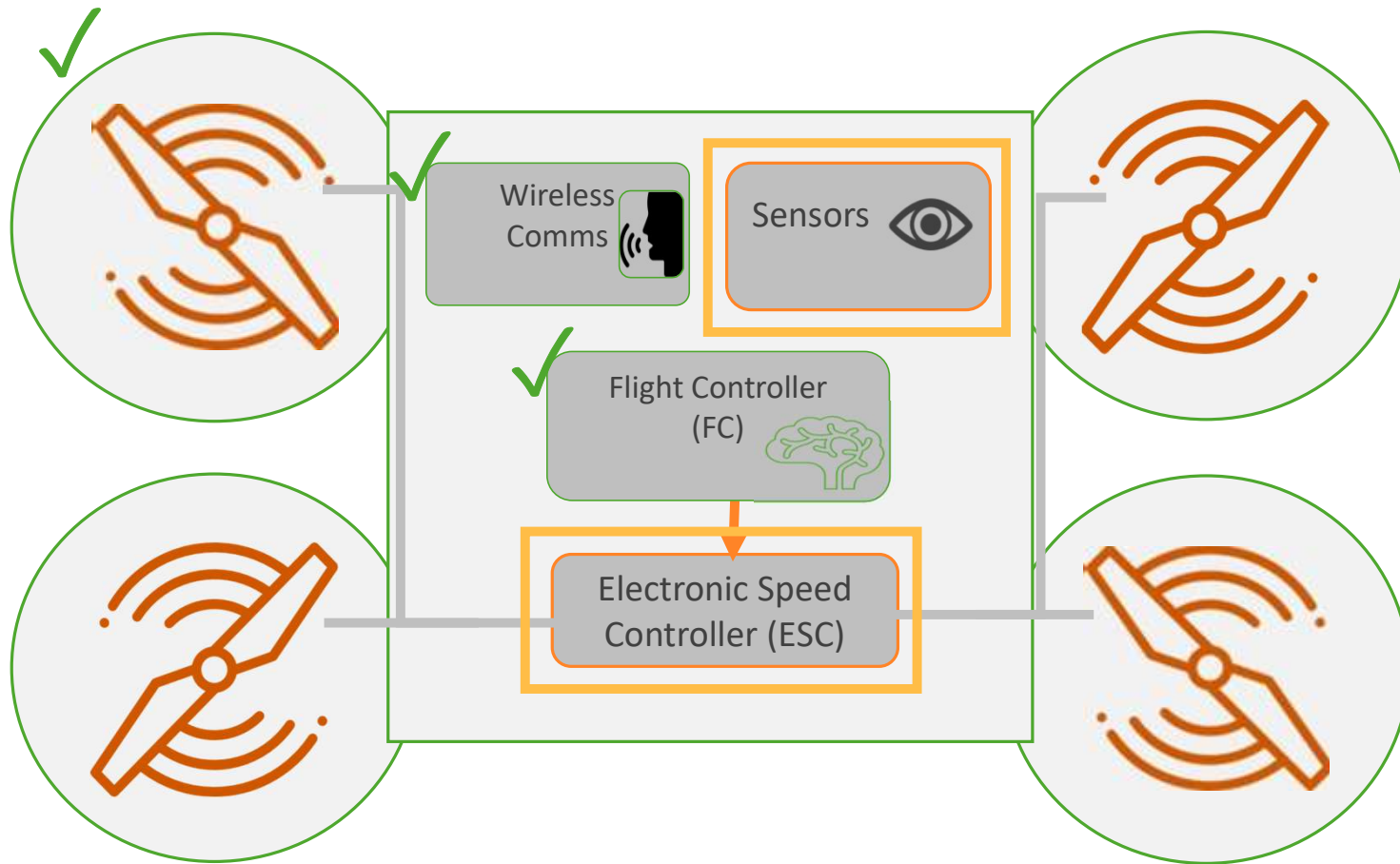*Gimble for yaw/pitch/roll control tuning.*
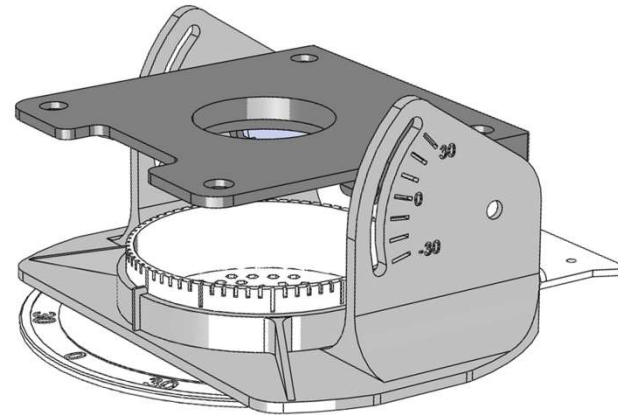
Adjustable platform for estimator calibration.

➢FC is compatible with Ardupilot

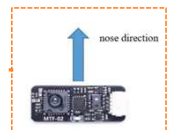➢ESC is all-in-one (AIO), built into the FC

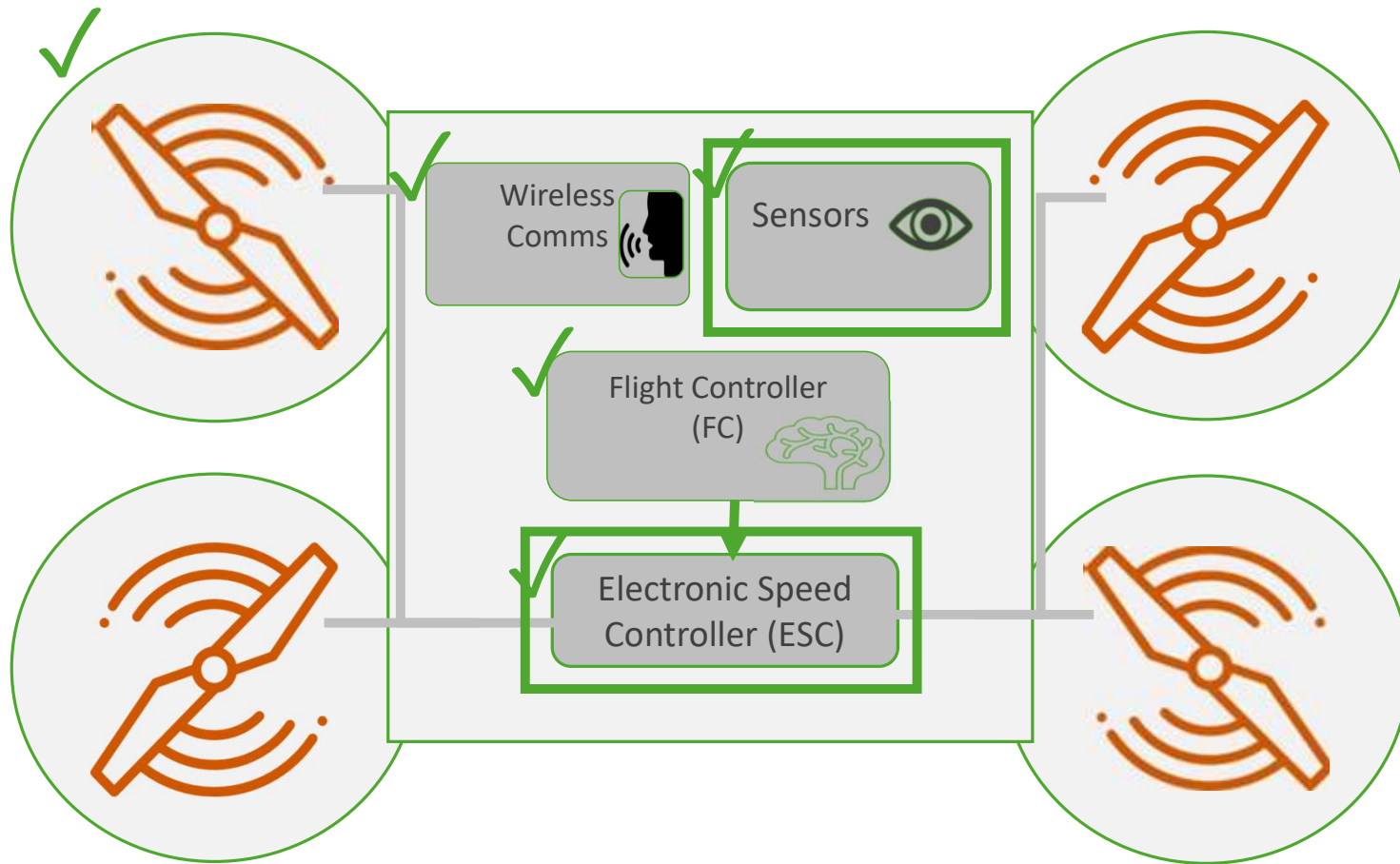➢ESC powers brushless motors

BOTTOM FRONT
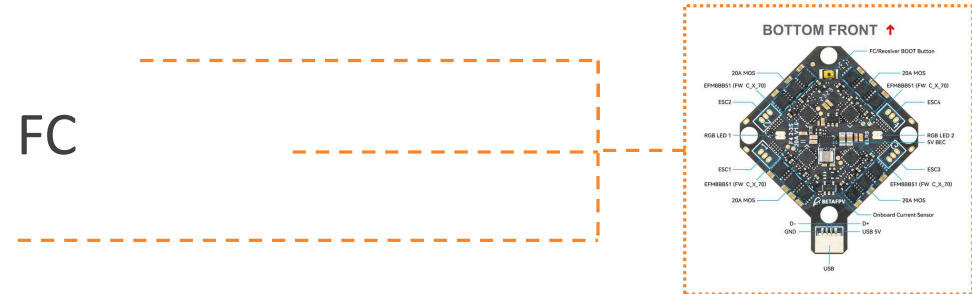
➢FC has 2 accessible serial connections,
   wireless module and yaw sensor

➢Yaw sensor uses one MAVLink serial connection

nose direction

Remark: Many Optical Flow modules separate camera and rangefinder connections.

NEXT STEPS

➢ Development
➢ Potential

➢Not flying with course control system:
- Complementary filter tuning
- Controller gain tuning

➢Wrapper issues:
- Integrating optical flow sensor with position estimation

➢Debugging pymavlink dashboard
- Technion firewall issues with WIFI

Closeup at drone prototype


Drone with test stand prototype 39

➢Ardupilot is built around messy library instance references

➢PX4 is build with uorb:

  ▪ Subscribes and publishes like ROS topics.

➢We have two options for future toolbox:
  ▪ Build a uorb (or similar) messaging structure
  ▪ Build wrappers for common variables as simulink blocks

Current Implementation:

```
// '<Root>/accel' ------------------------------------
Vector3f accel_vals = ahrs.get_accel();
float arg_accel[3]{ accel_vals.x, accel_vals.y, accel_vals.z };

// '<Root>/gyro' ------------------------------------
Vector3f gyro_vals = ahrs.get_gyro();
float arg_gyro[3]{ gyro_vals.x, gyro_vals.y, gyro_vals.z };
```
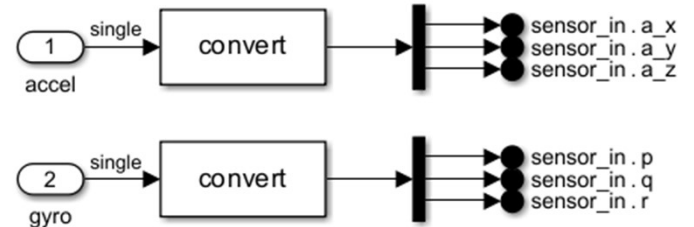
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MAVLink

Hardware definitions

Remark: The educational platform can be used as a template for research projects.

THANK YOU!
QUESTIONS?