Flying Penguins

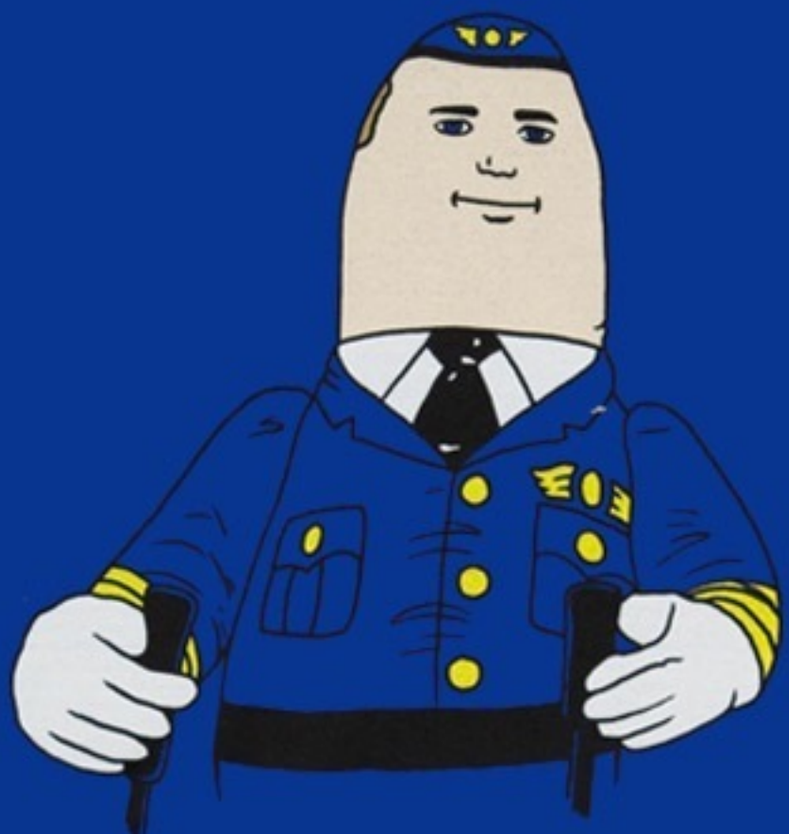
Embedded Linux applications for autonomous UAVs

Clay McClure

twitter.com/claymcclure

github.com/claymation


IKHANA
NASA
NASA
870



OTTO

IS MY CO-PILOT

stabilization

telemetry

missions

failsafes

PX4 autopilot

APM
MULTIPLATFORM AUTOPILOT

AUTO ≠ AUTO

PILOT ≠ NOMOUS

"system finds its own goal positions"

AUTONOMY

"system finds its own goal positions"

where to go

AUTONOMY

"system finds its own goal positions"

where to go

how to get there

AUTONOMY

"system finds its own goal positions"

where to go

how to get there

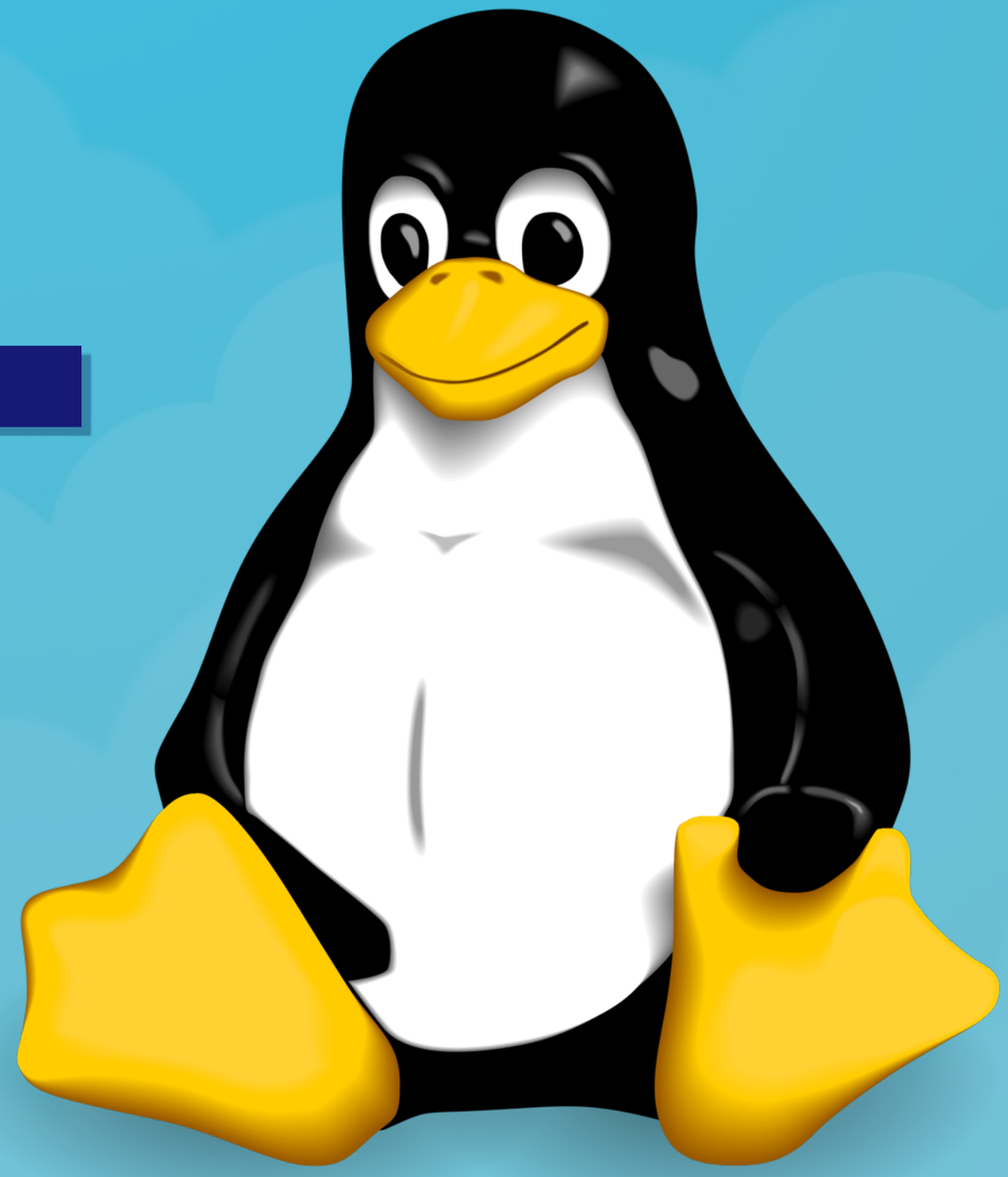
what to do next

AUTONOMY

SO MANY ALGORITHMS,

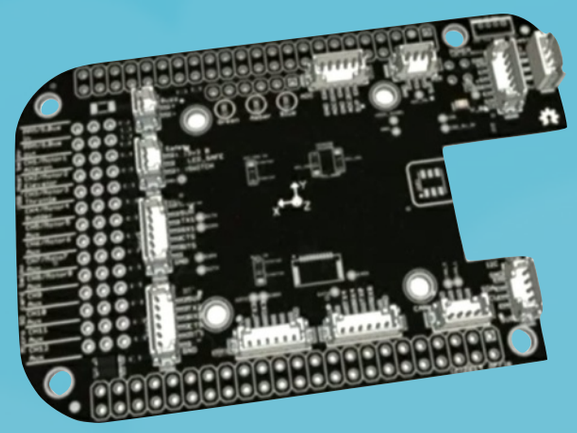
http://ra3ndy.deviantart.com/art/Sad-Panda-69204875

SO LITTLE MEGAHERTZ



Autopilot *runs on* Linux

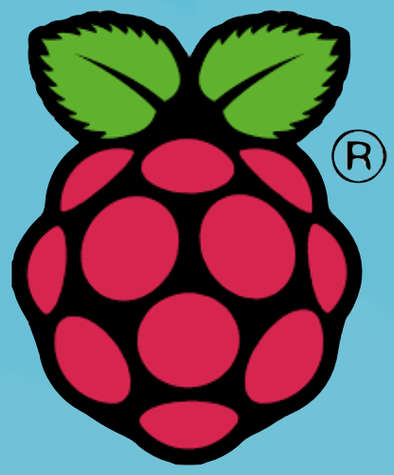
- Real-time kernel
- Hardware drivers (SPI, I2C, CAN, UART)
- Device trees
- Programmable real-time units
- PixHawk Fire Cape
- BeaglePilot project



Autopilot *talks to* Linux

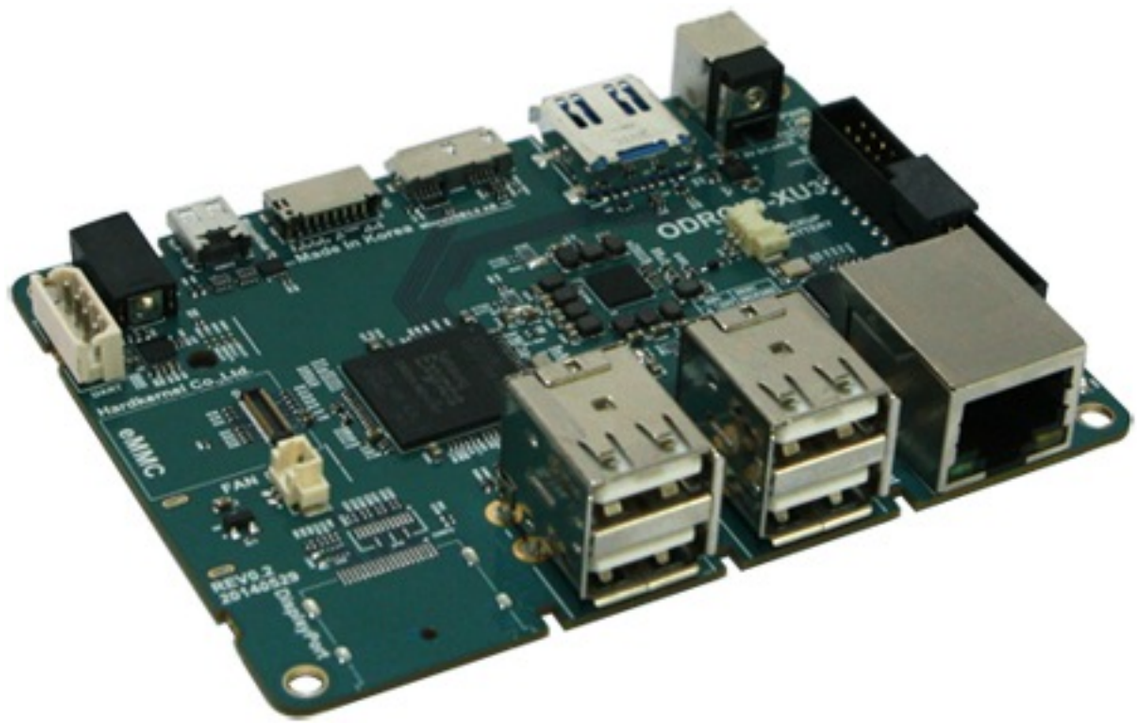
- Linux runs on a companion computer
- RS-232 serial interface to autopilot
- Treat the autopilot as a peripheral
- This is what I'm talking about today

ODROID



ODROID-XU3 Lite

- Samsung Exynos5422 **octa core**
  - 4x Cortex™-A15 2.0GHz
  - 4x Cortex™-A7 1.4GHz
- 2 GB RAM
- 32+ GB flash
- 4x USB 2.0 + 1x USB 3.0



Your App

Autopilot

Your App

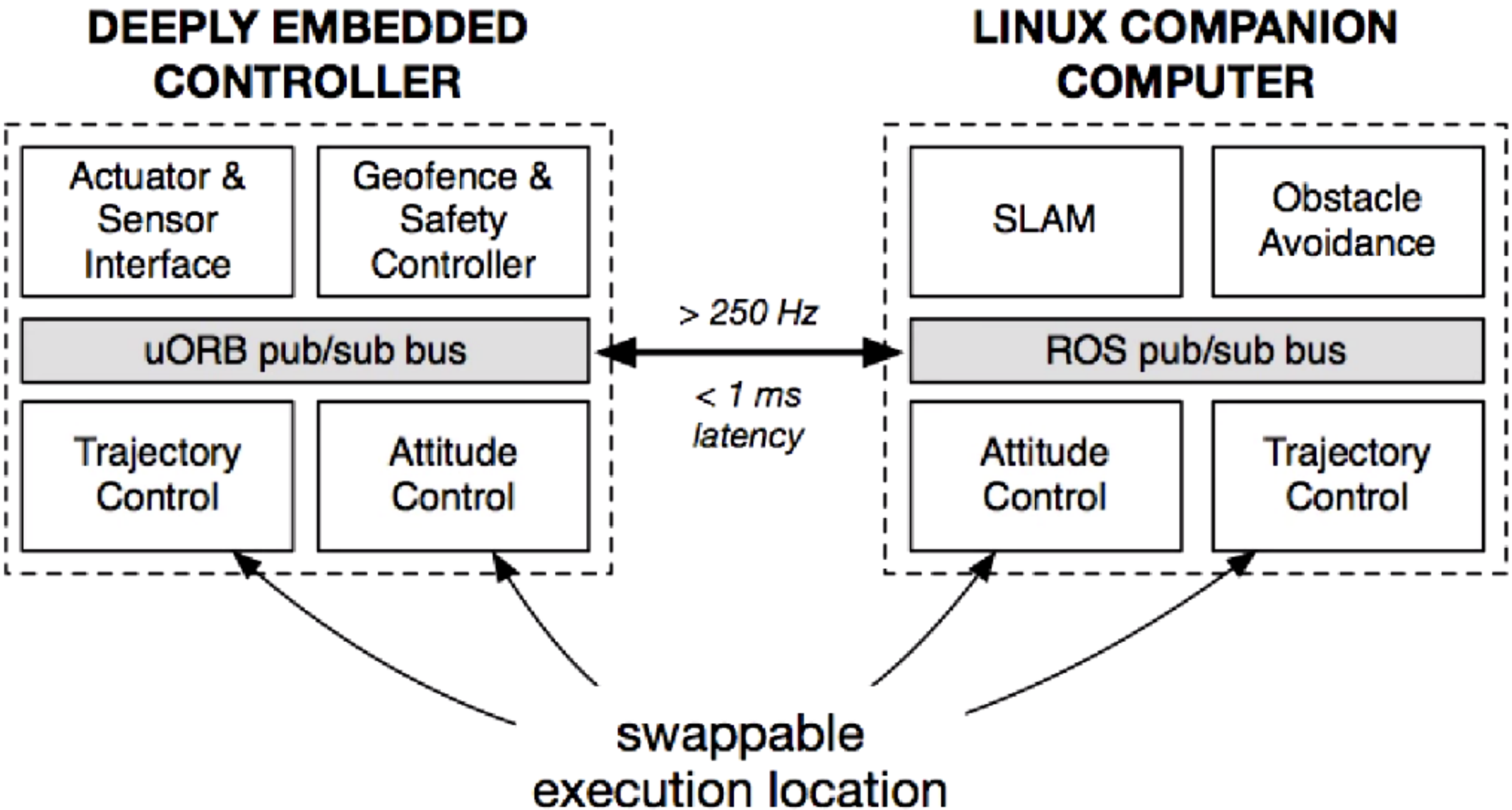
Middleware

Autopilot

Middleware

- **DroneAPI**
  - Python
  - Go to Kevin Hester's talk tomorrow
- **ROS + mavros**
  - Python, C++, Lisp (really)
  - Access to a wealth of robotics research and tools

PX4 + ROS



Credit: Kabir Mohammed

ROS CRASH COURSE

Robot Operating System

"ROS is an **open-source**, meta-**operating system** for your **robot**."

– http://wiki.ros.org/ROS/Introduction

Nodes

- Process / address space
- ROS applications composed of many small nodes
- “Do one thing and do it well”
- Modular
- Reusable
- Separation of concerns

Topics

- Publish / subscribe message bus
- Strongly-typed messages
- Peer-to-peer message passing
- Centralized name registry (master node)

Services

- Similar to topics, but with request / reply semantics
- Think of it as RPC

but that's not all...

parameters

transformations

record/playback

visualization

logging

mavros

Topics

- /mavros/global_position/global
- /mavros/local_position/local
- /mavros/imu/data
- /mavros/state
- /mavros/setpoint_position/local_position
- /mavros/setpoint_velocity/cmd_vel

Services

- /mavros/cmd/arming
- /mavros/cmd/land
- /mavros/cmd/takeoff
- /mavros/set_mode
- /mavros/set_stream_rate

Event-driven programming

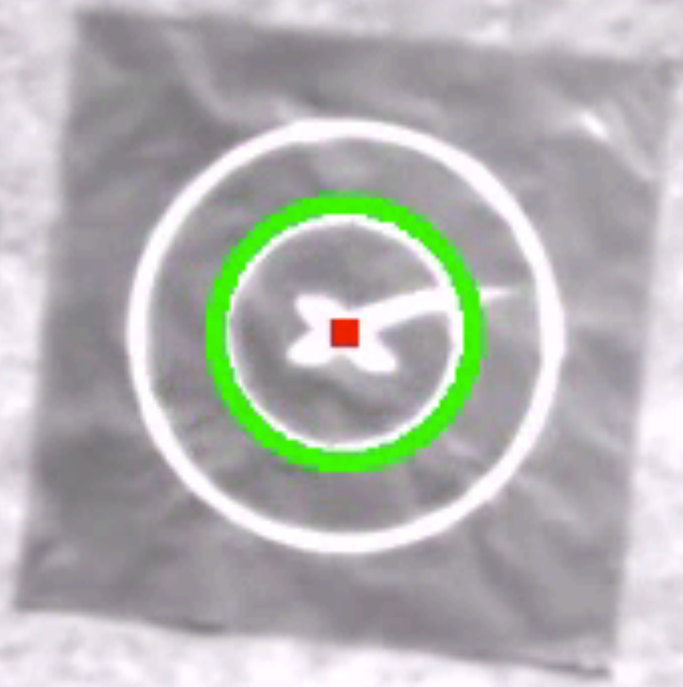
- “Don’t call me, I’ll call you”
- Your application code responds to events
  - Message arrival
    - “my position is *(x, y, z)*”
  - Timer expiry
    - “it’s time to run the control loop”

Example Application

Yet Another Precision Lander

Nodes

- **Tracker**
  - Processes video stream, looking for landing pad
  - Publishes target position/velocity messages
- **Commander**
  - Subscribes to vehicle state and position messages
  - Controls vehicle velocity



(TODO: code snippets)

Simulations

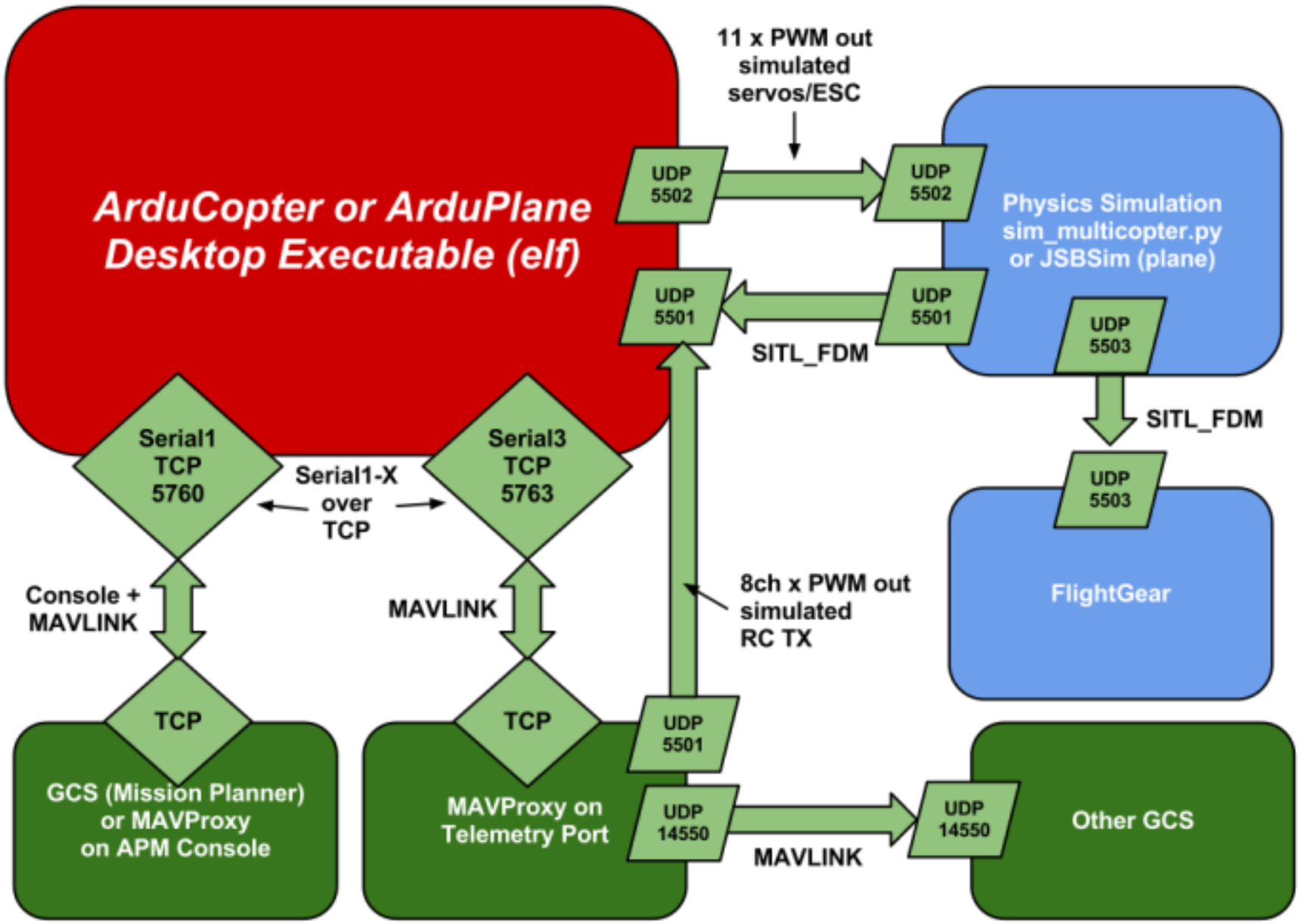
HITL

- Hardware in the loop
- Flight software runs on flight hardware
- Simulated sensor and control inputs

SITL

- Software in the loop
- Flight software runs on (Linux) desktop
- Simulated sensor and control inputs and HAL

ArduPilot SITL



Terminal

5:28 PM

rqt_console__Console - rqt

Console

Displaying 1 messages

Fit Columns

#	Message	Severity	Node
#1	STATE TRANSITION: INIT --> PENDING	Info	/commander

trusty

clay@trusty: ~/ardupilot/ArduCopter

```
POSHOLD>
POSHOLD>
POSHOLD>
POSHOLD>
POSHOLD>
POSHOLD>
POSHOLD>
POSHOLD>
POSHOLD>
POSHOLD>
POSHOLD>
POSHOLD>
POSHOLD>
POSHOLD>
POSHOLD>
POSHOLD>
POSHOLD>
```

/tracker/image

Console

POSHOLD GPS: OK (10) Vcc 5.00 Radio: – INS MAG AS RNG AHRS FEN TERR

Batt: -31%/12.29V 22.4A Link 1 OK (97129 pkts, 0.00s delay, 0 lost) 100%

Hdg 12/92 Alt 44 AGL 44/44 AirSpeed 0 GPSSpeed 0 Thr 43 Roll 0 Pitch 0 Wind —/—

WP 0 Distance 0 Bearing 0 AltError 0H AspdError 0.0H FlightTime 0:02 ETR 0:00

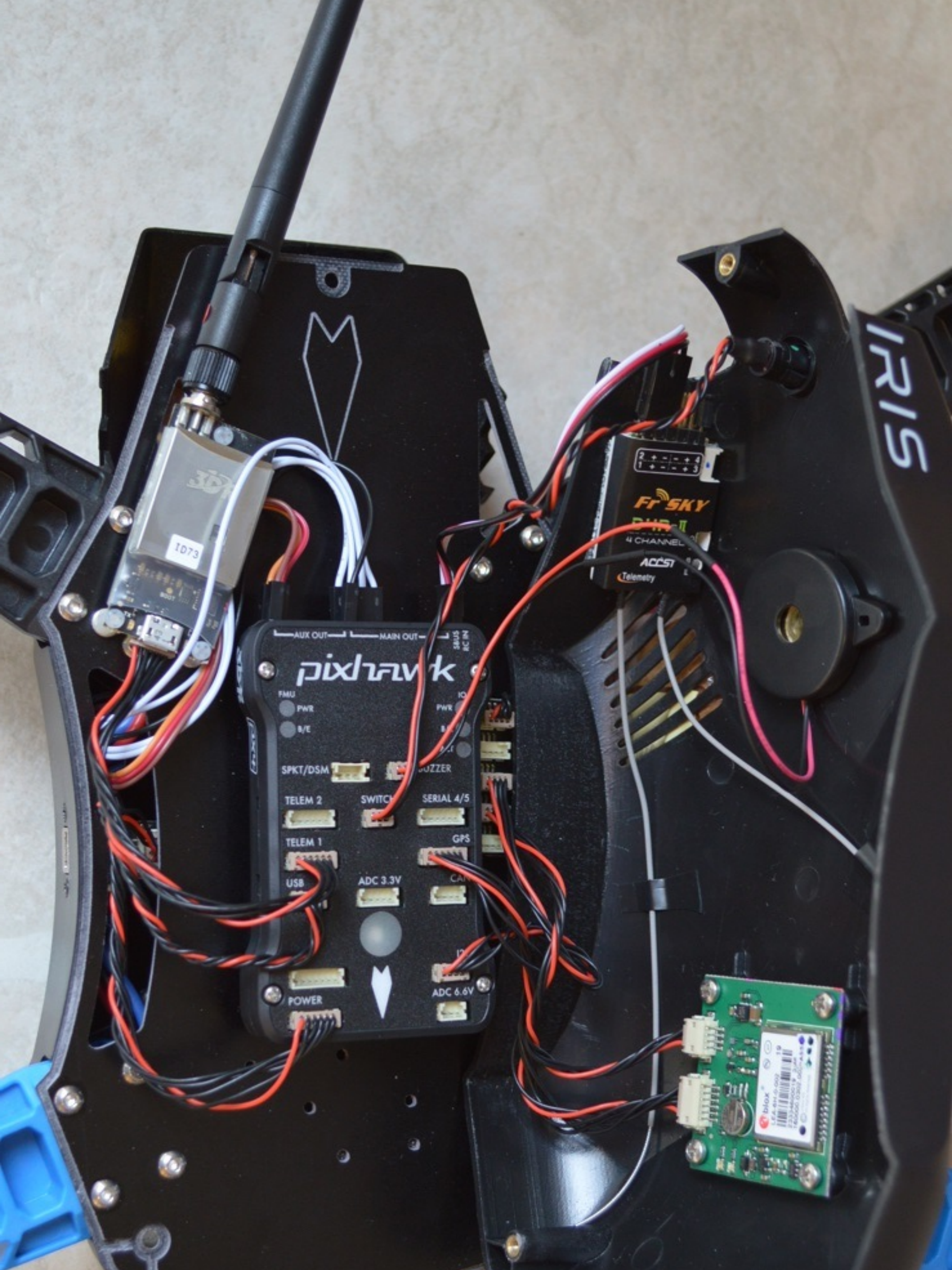
```
Mode GUIDED
Flight battery 0 percent
Flight battery warning
height 20
Got MAVLink msg: COMMAND_ACK {command : 11, result : 0}
Mode POSHOLD
Flight battery -10 percent
Flight battery warning
Flight battery -20 percent
Flight battery warning
height 30
height 40
```

Map

PX4 SITL

- 3D simulation with Gazebo
- TODO

Practical Considerations


IRIS
FrSKY
4 CHANNEL
ACCST
Telemetry
AUX OUT
MAIN OUT
pixhawk
FMU
PWR
B/E
SPKT/DSM
TELEM 2
SERIAL 4/5
TELEM 1
GPS
USB
ADC 3.3V
POWER
ADC 6.6V

Connections

- UART recommended
- USB works for development

Power

- UBEC
- ODROID + USB camera + WiFi + 3S LiPo = 5 hours

Launch files

- ROS feature that makes it easy to start and manage multiple nodes and their parameters

- `roslaunch mavros apm.launch`

- `rosparam load ~/tracker.yaml /tracker`

Startup

- use ubuntu's upstart to launch ROS + mavros + application nodes

- robot_upstart

Telemetry

- MAVLink + radio
- WiFi
  - Ad-Hoc mode (man wireless)
  - sudo apt-get remove wpasupplicant
- GSM

Coordinate Frames

- Global / Local
  - NED
  - NEU
  - ENU
- Body-fixed
- tf library


search and rescue
real estate
law enforcement
cinematography
3D mapping
inspection
delivery
disaster relief
pipeline monitoring
atmospheric research
agriculture
conservation

What will you make?

ardupilot.com

pixhawk.org/start

ros.org

github.com/mavlink/mavros

github.com/claymation/lander