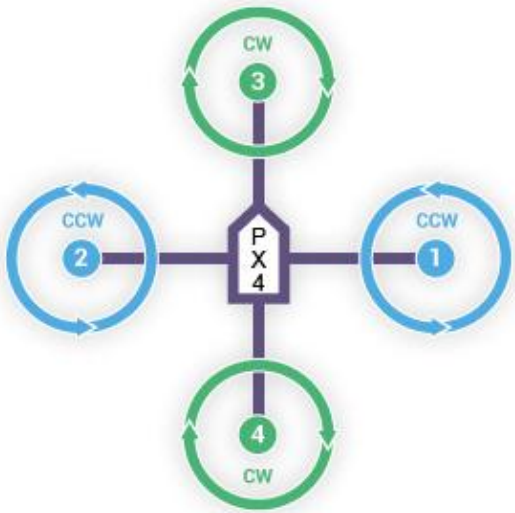
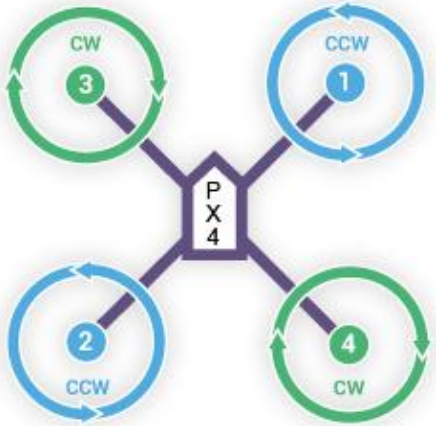
Build Your Own Quad-Copter

Quad-Copter vs Standard Helicopter

- 4 vertical motors are only moving parts (2 CW, 2CCW)
- Control is achieved by independently varying the thrust of each motor (Lift, Pitch, Roll, Yaw)
- Low moment of inertia—extremely agile



QUAD +



QUAD X

Standard Configurations

Quadcopter

- Simple/Easy to build
- High maneuverability/acro
- Light payload (Go-Pro)
- Susceptible to motor failure
- Most fun to fly!

Hexacopter

- Moderate payload
- Moderate maneuverability
- Very stable
- Flyable with loss of 2-3 motors
- Great aerial photography platform

Octocopter

- Very large payload (professional cameras)
- Extremely stable
- Resistant to motor failure
- Extremely intimidating if operating within close proximity to you!!!

Non-Standard Configurations

Tricopter

- Cheap (3 motors)
- 120^{o} between arms
- Great for FPV
- Requires a tilt servo on one motor for yaw stability and control

Y-6

- Tricopter footprint
- No tilt servo required
- Less efficient then the hexacopter

X-8

- Footprint of quadcopter
- Motor redundancy
- Less efficient then the octocopter
- Power hog

LiPo (Lithium Polymer) Batteries

- Driving force behind popularity of RC aircraft
- High energy storage to weight ratio
- High discharge current

- Lipo Safety
  - Never leave unattended while charging
  - Take special precautions if damaged

Battery Stats

Voltage (# Cells)

- 3.7 volt battery = 1 cell x 3.7 volts (1S)
- 7.4 volt battery = 2 cells x 3.7 volts (2S)
- 11.1 volt battery = 3 cells x 3.7 volts (3S)
- 14.8 volt battery = 4 cells x 3.7 volts (4S)
- 22.2 volt battery = 6 cells x 3.7 volts(6S)a
- Charged voltage is 4.2 volts/cell
- NEVER discharge below 3 volts/cell

Discharge Rate

- Called the “C” rating
- Maximum Current load = C x capacity
- 66A = 2200mAh x 30C
- Some batteries have a burst rating

Capacity

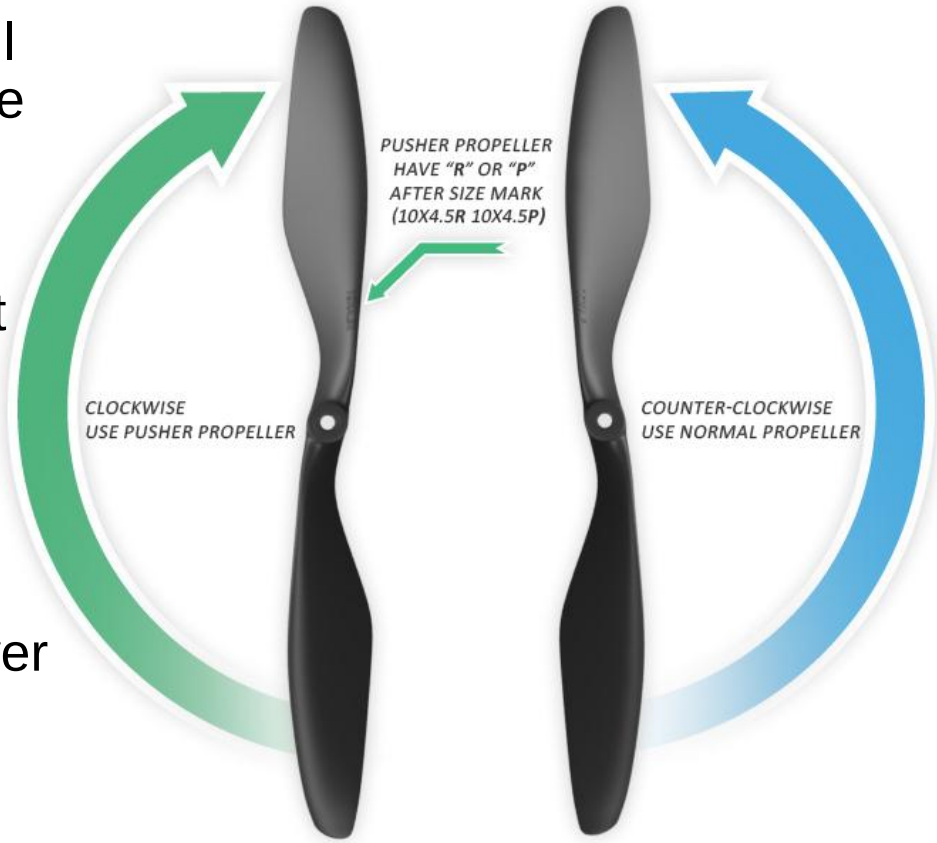
- How much energy the battery can hold
- Measured in mAh (milliamp hours)
- 2200mAh → Can pull 2.2A for 1 hour
- 2200mAh → Can pull 15A for ~9 min
- Higher capacity = longer flight times + weight

Charge Rate

- 1C for long lasting batteries
- Charge 2200mAh @ 2.2A
- Only use LiPo charger

Propellers (Prop)

- Classified by length and pitch
  - Ex: 10x4.5 (10 inches long, will move 4.5 inches forward in one revolution)
- Optimized for one direction
  - CW and CCW require different props
- Choosing a prop
  - Research other quad setups
  - Higher length and pitch values mean more air movement, lower RPM, and higher current draw
  - Trial and error



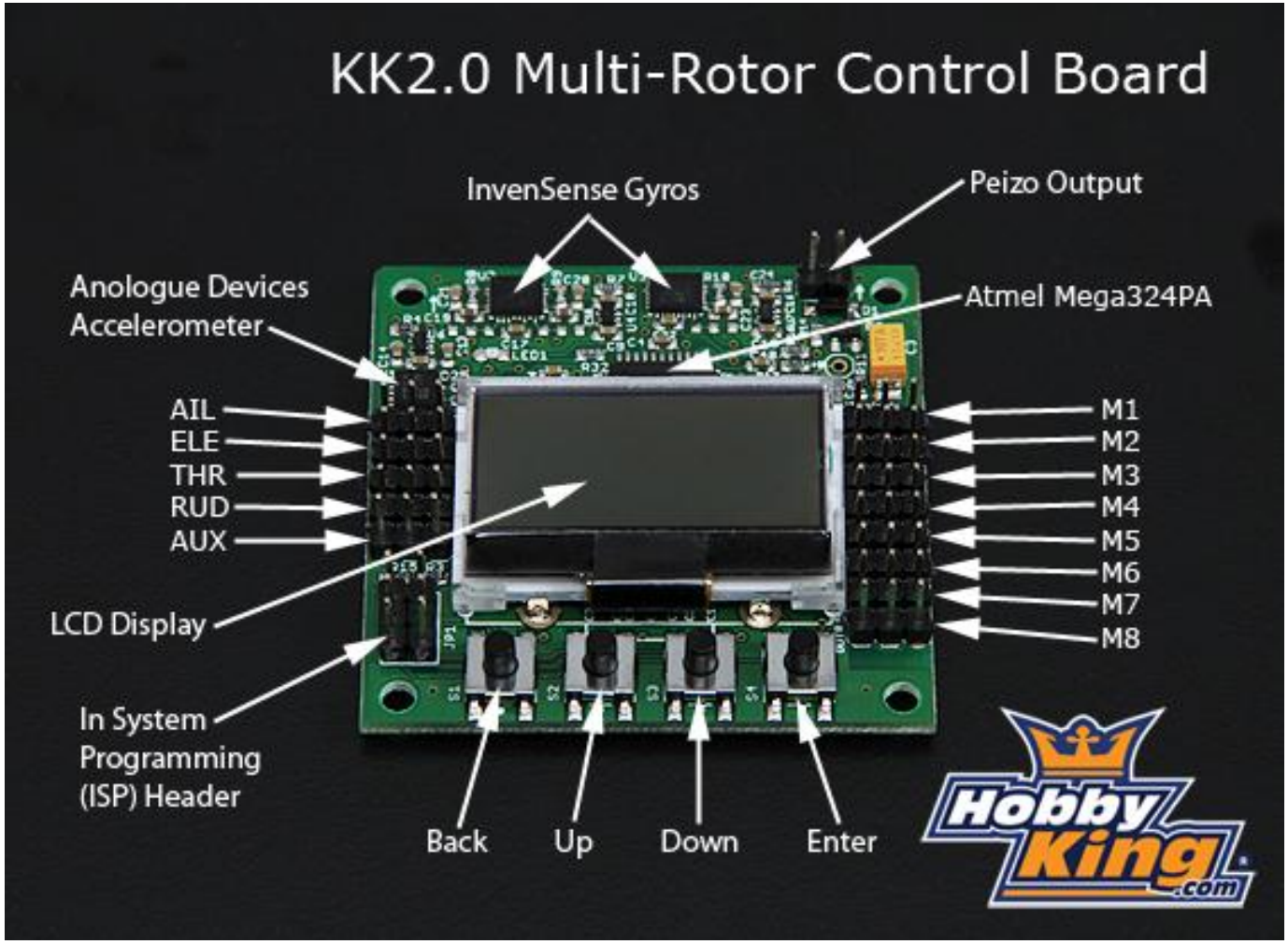
Motors/ESCs

- Brushless Motors
  - Main Spec: KV (RPM/volt)
    - Low KV=Low RPM, High Torque
  - More efficient then brushed motors
  - Require external controller
- ESC (Electronic Speed Controller)
  - Main battery connector (+/-)
  - Motor timing circuitry
  - Driven by PWM signal from flight controller
  - BEC (Battery eliminator circuit)
    - Usually 5 volts to power other electronics

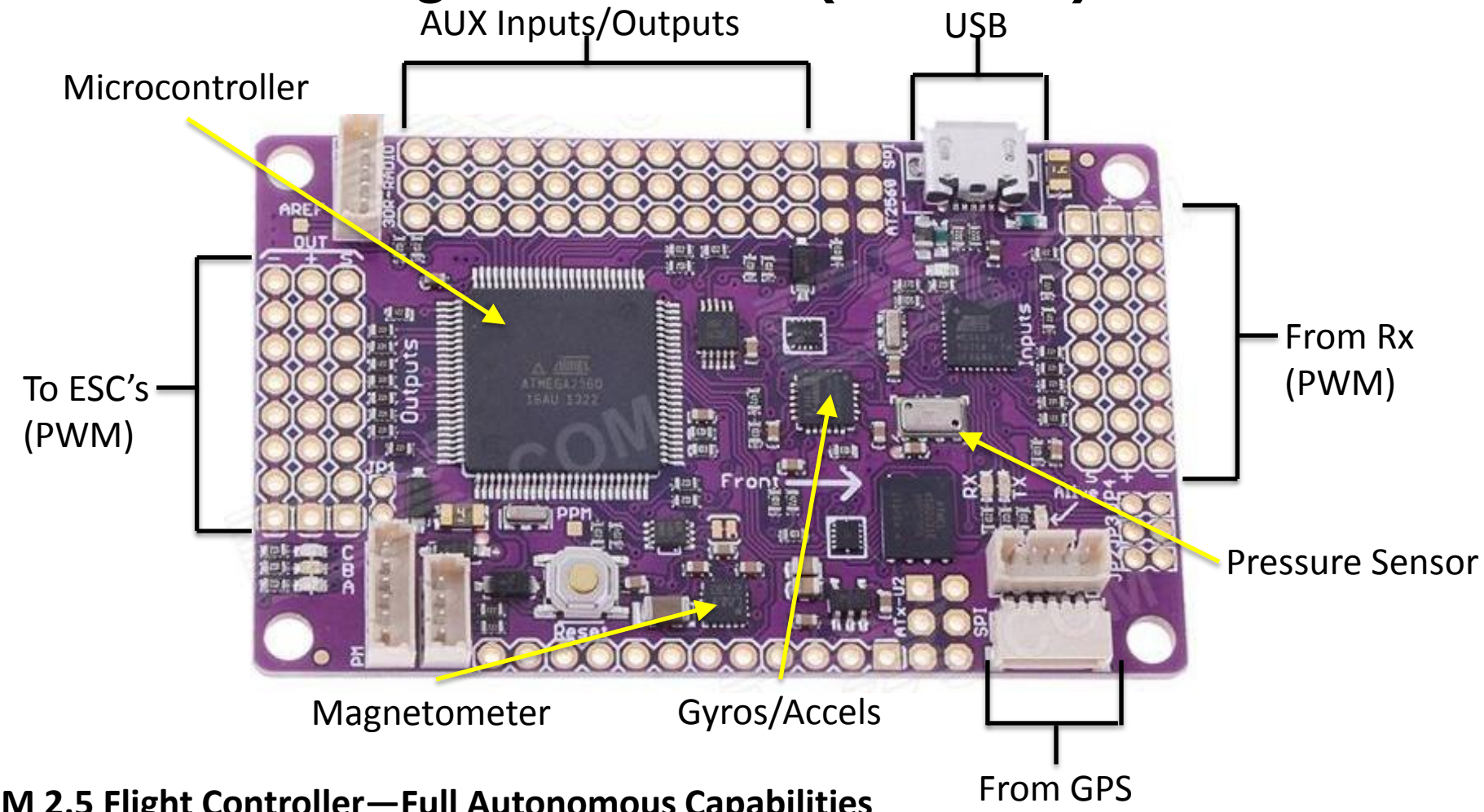
Flight Controller

- Multi-copters are inherently unstable and require computer control for stable flight. Fly-by-wire
- Functions
  - Input: Desired movement from remote user or navigation routines
  - Output: Update all ESC control signals in real-time to control motor speeds
  - Aux: Camera Stabilization, Payload Operations, Lighting
- Sensors
    - (R) 3-axis Gyro (angular rotation about axis)
    - (R) 3-axis Accelerometer (acceleration along axis)
    - Pressure Sensor (altitude)
    - GPS
    - 3-axis magnetometer
- Microcontroller
  - Sensor fusion
  - Feedback control loop ~200-1000Hz
  - Typically reprogrammable via PC interface

KK 2.0 Multi-rotor Control Board



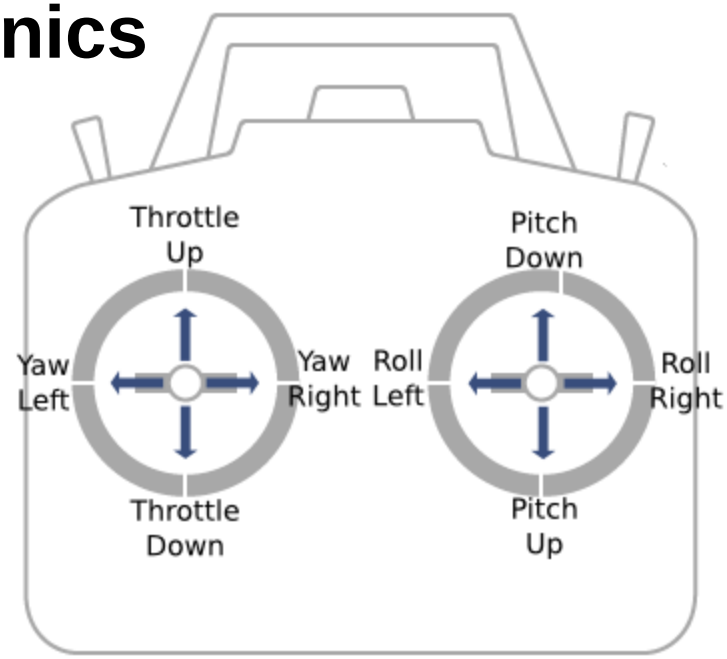
Flight Controller(APM 2.5)



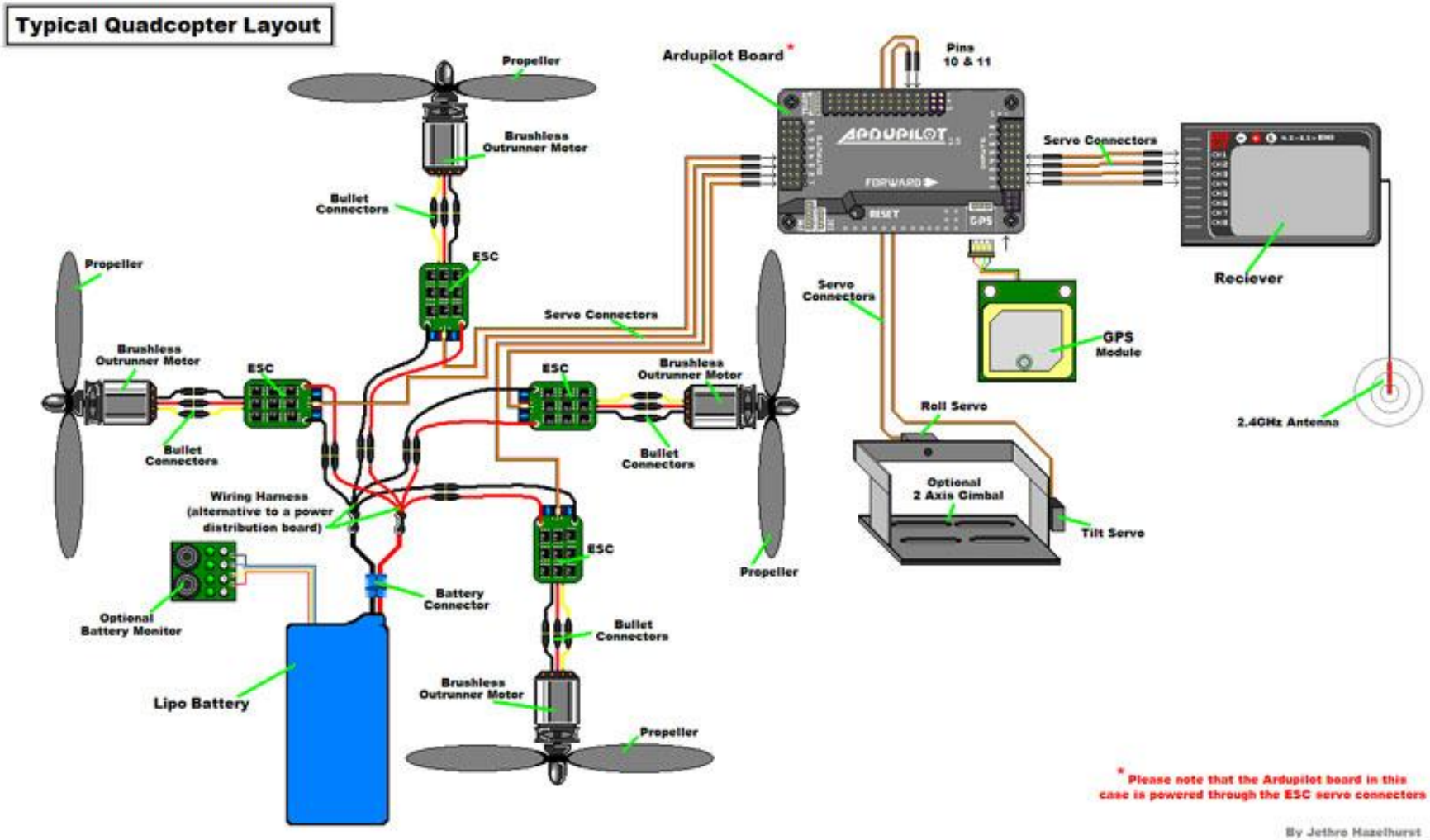
APM 2.5 Flight Controller—Full Autonomous Capabilities

Other RC Electronics

- Transmitter
  - Minimum 4 channels (roll, pitch, yaw, throttle)
  - Extra channels desired for mode selection
  - KK2.0 5th channel used for auto level
- Receiver
  - Wirelessly communicates with transmitter
  - Provides PWM signals to flight controller that represent transmitter stick positions



Putting It All Together



Aerial Photography

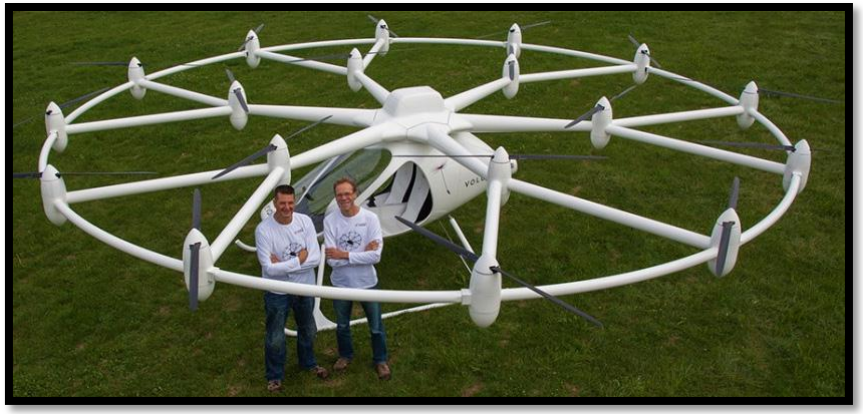
- Search and Rescue
- Examine Pipe/Power-line/Fence/Etc
- Film Making
- FPV (First Person View)
- Exploration
- Situational Awareness
- Surveillance

Video

- Play aerial video we took since I never put it on Youtube

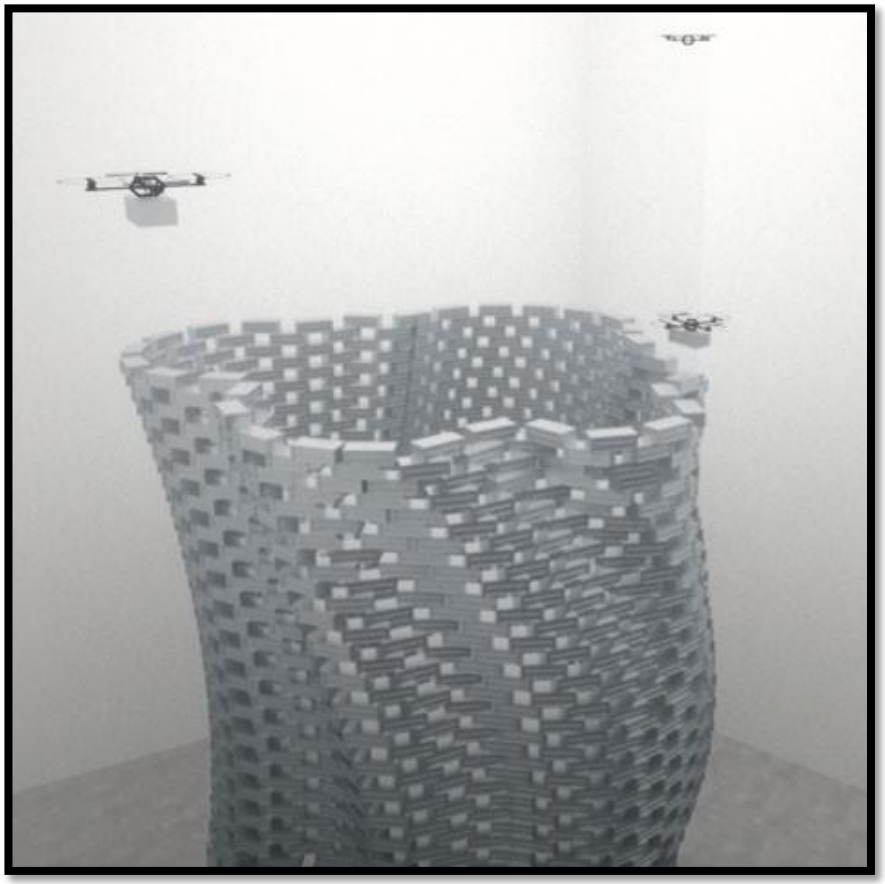
Other Applications

- Transportation
  - Delivery to hard to reach places
  - Small manned aircraft
- Communications
  - Emergency communications
  - Mesh networking



Cooperative Flying Robots

- Multiple copters working together



Regulations

- Nobody is really sure!!!!
- FAA has “stated” that sUAS (small unmanned aerial systems) are illegal for commercial purposes based on interpretation of other laws
  - FAA made an aerial photography company cease and desist
  - Decision was overturned by federal court
- AC 91–57 Model Aircraft Operating Standards (1981)
  - < 400ft
  - Line of sight
  - AC (Advisory Circulars) are guidance and not enforceable by law
- However, Regulations are coming (Sept. 2015)
- Be safe and don’t do anything stupid!!!