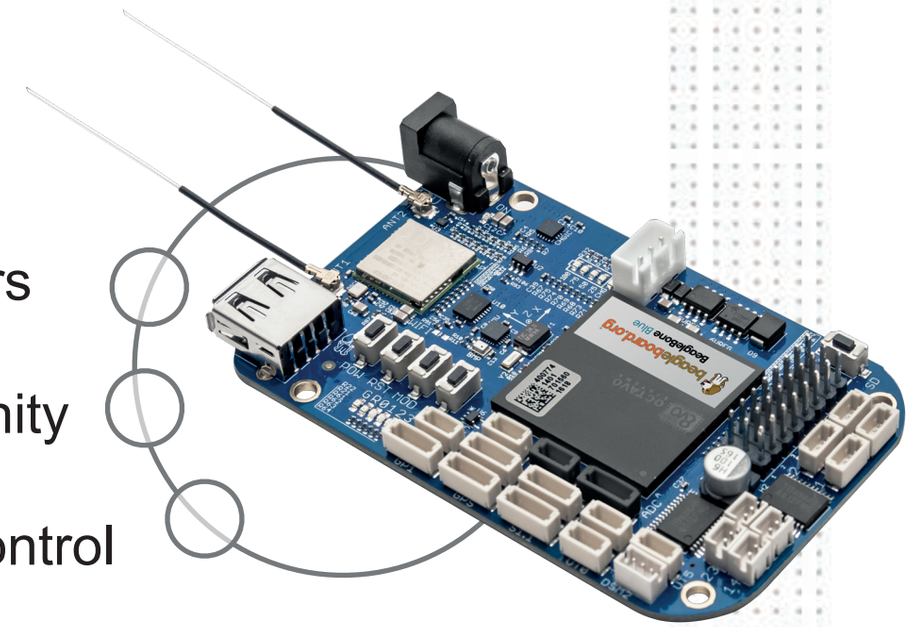
Using Beagle as a Flight Controller



Open-source hardware Linux computers

Proven platform with professional community

Integration for real-time control

Jason Kridner

Co-Founder

BeagleBoard.org

February 5, 2018

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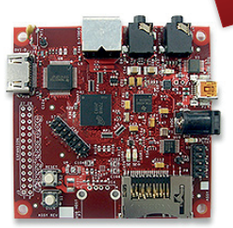
Agenda

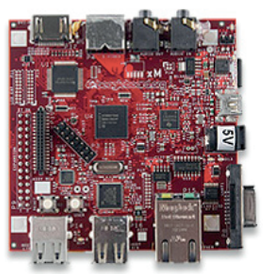
- Introduction to Beagle
- Choosing flight controller hardware
- Flight control software options
- ArduPilot
  - MAVLink
  - APM planner
- Building out a quadcopter
- Installing ArduPilot
- Calibration
- Buying parts
- Mistakes and questions

BeagleBoard.org Roadmap

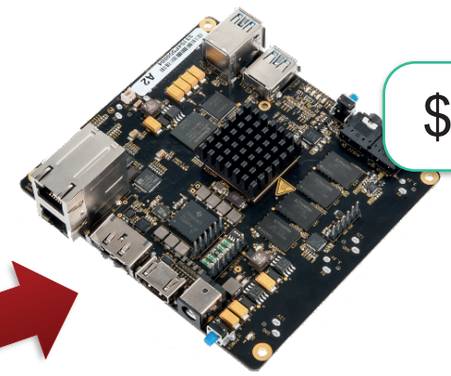
Fanless open computer
BeagleBoard



2008: Personally affordable
BeagleBoard



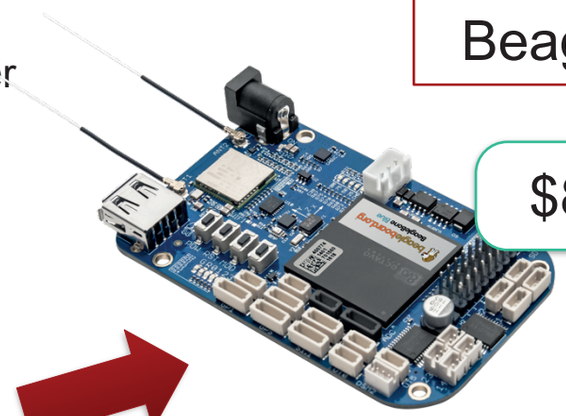
2010: Extra MHz/memory
BeagleBoard-xM



$250

2016: Extreme power
BeagleBoard-X15

Robotics-focused
BeagleBone Blue



$80

2017: Complete robotics controller
BeagleBone Blue

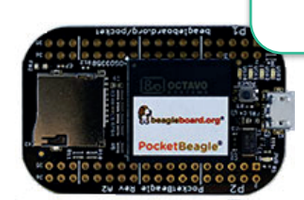
2011: Bare-bones
BeagleBone

$50

2013: Wildly popular
BeagleBone Black

2016: BeagleBone Black Wireless uses
EAGLE, Wilink8 and Octavo SIP

Mint tin sized
BeagleBone



$25

2017: PocketBeagle breaks out even
smaller Octavo SIP

Smalls mint tin sized
PocketBeagle

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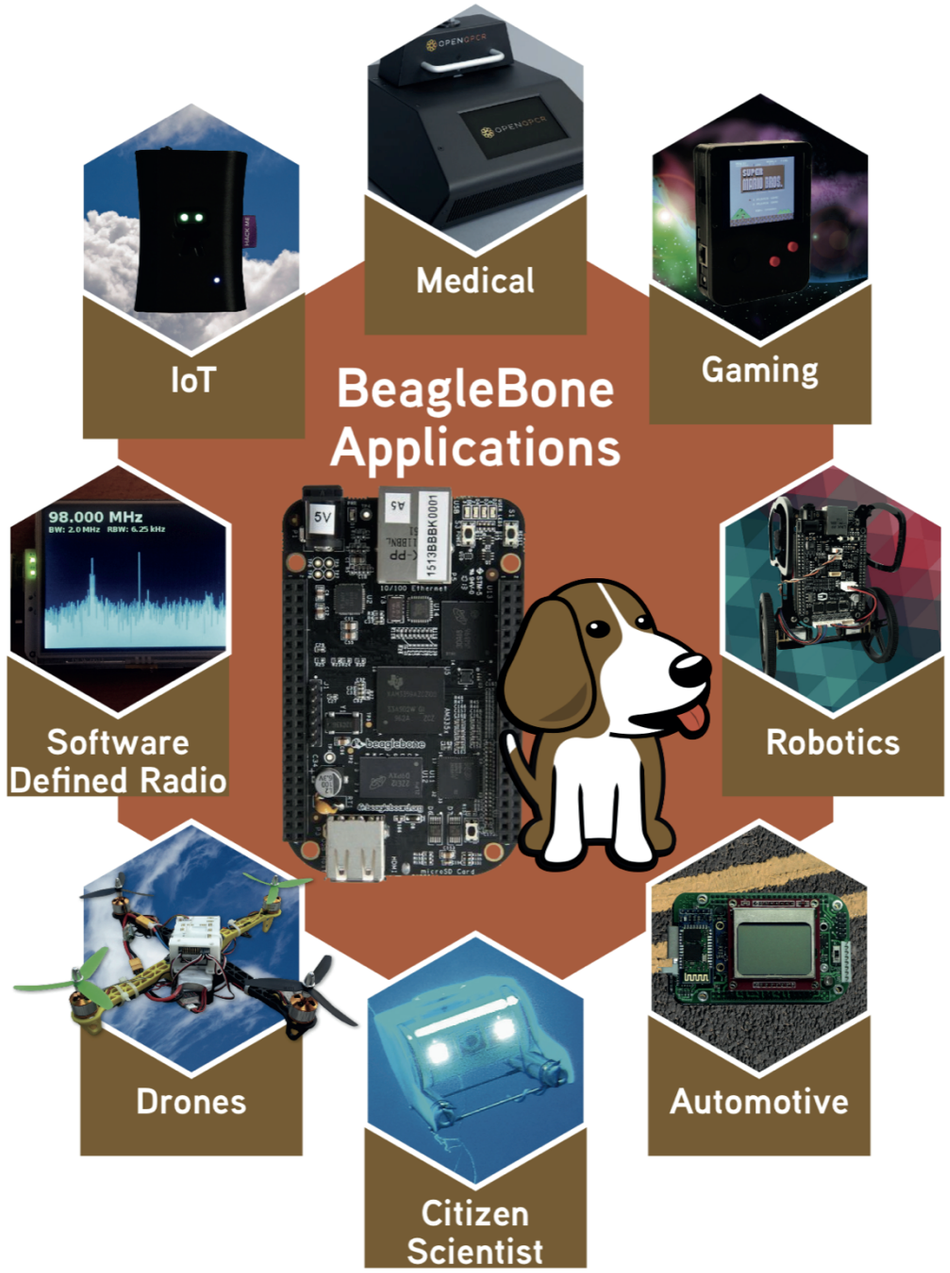
BeagleBone used in many applications



- Simple Mobile Robots
- Industrial Robots
- Network Security
- Medical
- Citizen Science
- Home Automation
- Localizing Information
- Assistive Technology
- LEGO Robotics

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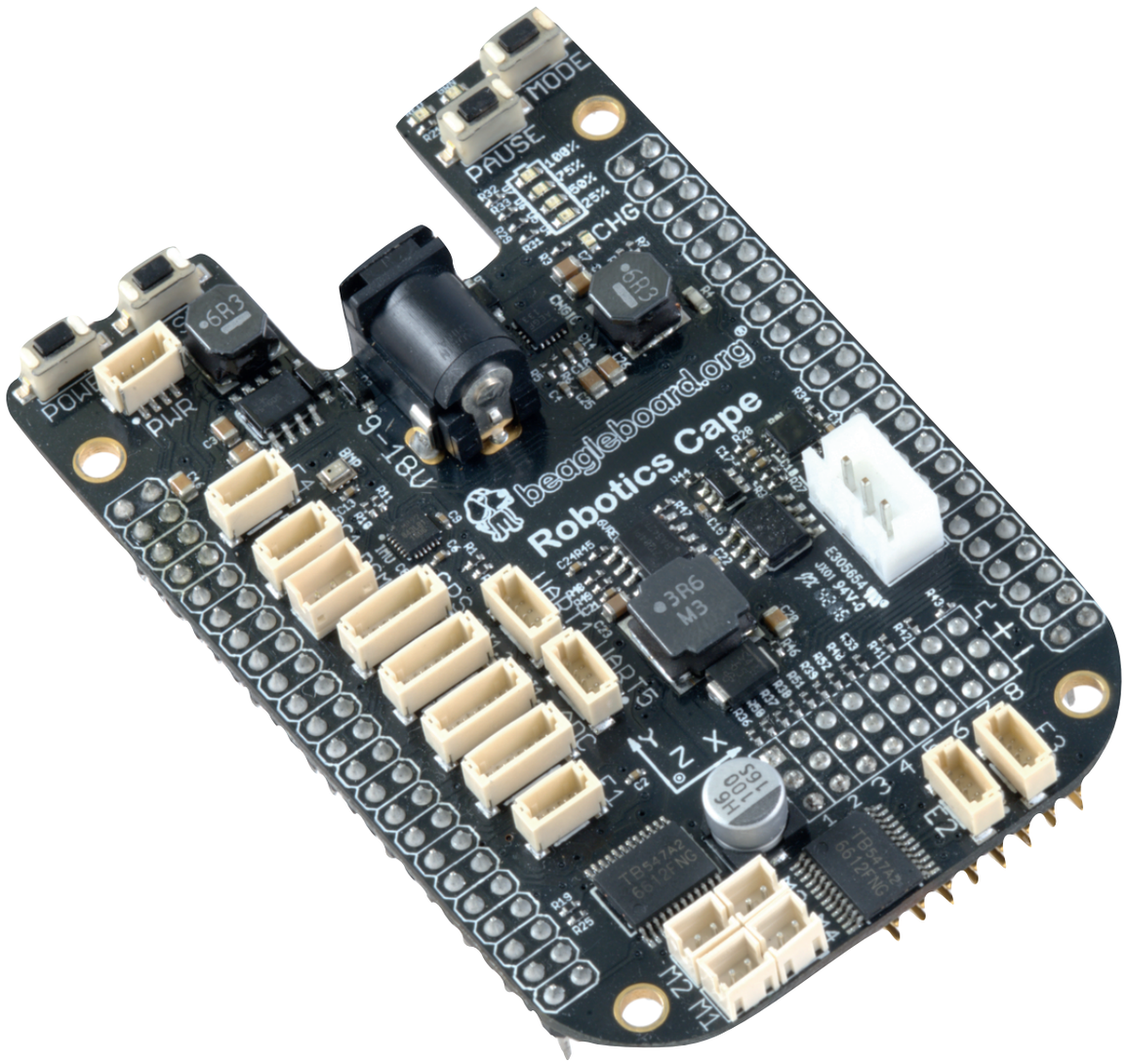
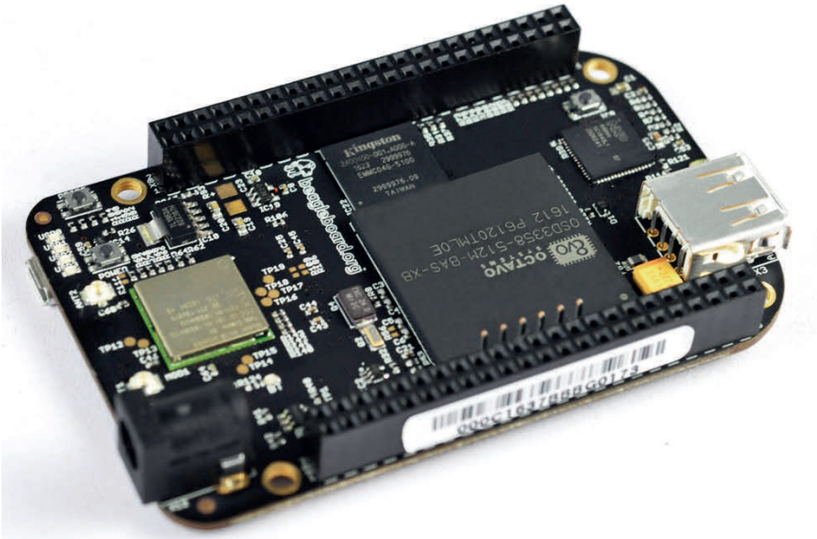
Robotics Cape

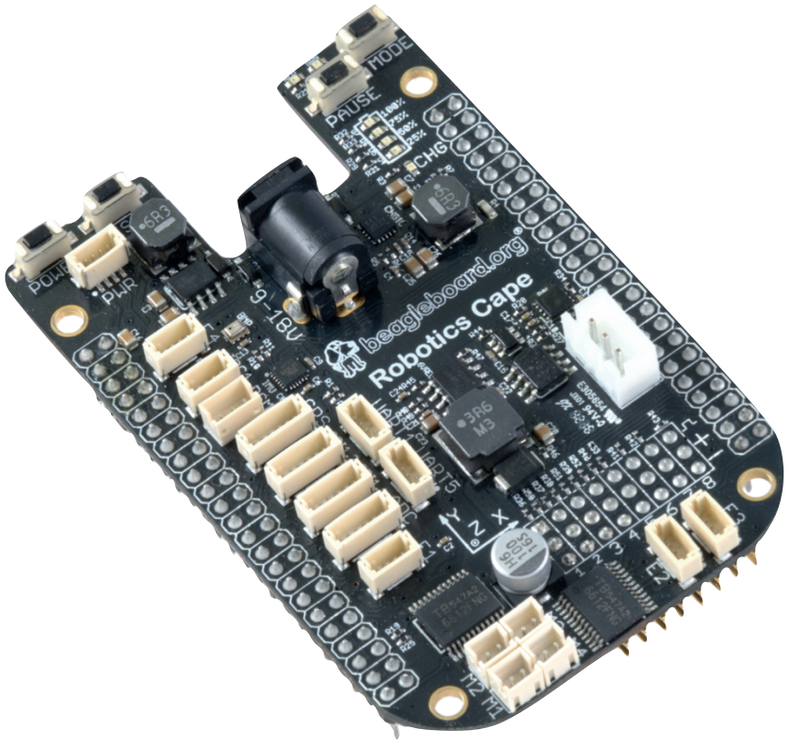


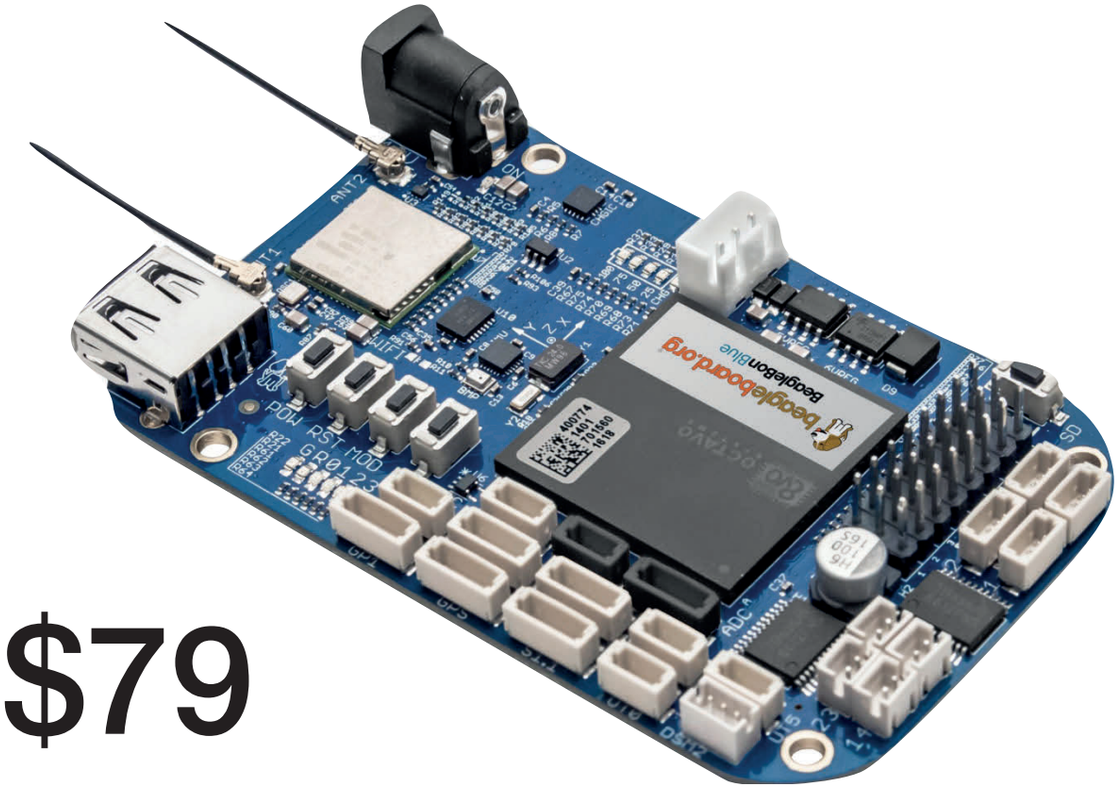
strawsondesign.com

- Designed at UCSD by James Strawson
- Used in hundreds of student projects
- On fourth revision
- Supported by ‘libroboticscape’ software
  - C library
  - Examples for all major functions
- Features
  - 2-cell LiPo support with balancing and LED power gauge
  - 9-18V charger input
  - 4 DC motor & 8 servo outputs, 4 quadrature encoder inputs
  - 9 axis IMU, barometer
  - Easy connect JST interfaces for: I2C, SPI, UART, CAN, GPIOs, GPS, DSM2 radio, power, ADC
  - User-programmable LEDs and buttons

Wireless + Robotics Cape = **Blue**



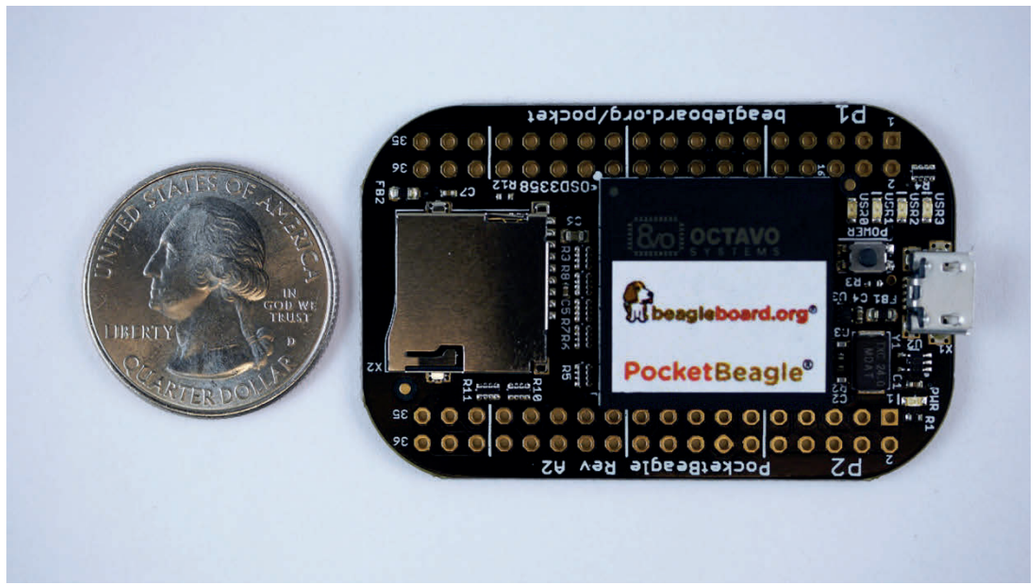




$79

- Combines Wireless and cape
- 4 layer PCB
  - Designed in Autodesk **EAGLE**
- In mass production, lowering cost
- Simplifies system configuration
- Added CAN interface

PocketBeagle



- Based on Octavo Systems OSD3358-SM SiP
  - ARM Cortex-A8 @ 1-GHz
  - 512 MB DDRs RAM integrated
  - ARM Cortex-M3
  - 2×200-MHz RISC Programmable Real-time Units (PRU)
  - Integrated power management

$25

- **Power and develop over USB**
- **Add up to 2 mikroBus Click boards**
  - **Over 300 available today**
- **Runs latest BeagleBone software images**

- Connectivity
  - Bootable microSD card slot
  - High speed USB 2.0 OTG (host/client) control signals
  - Dual 36-pin expansion headers
    - 8 analog inputs (6 @ 1.8V and 2 @ 3.3V)
    - 44 digital GPIOs
    - 3 UARTS
    - 2 I2C
    - 2 SPI
    - 4 PWM
    - 2 QEP
    - 2 CAN

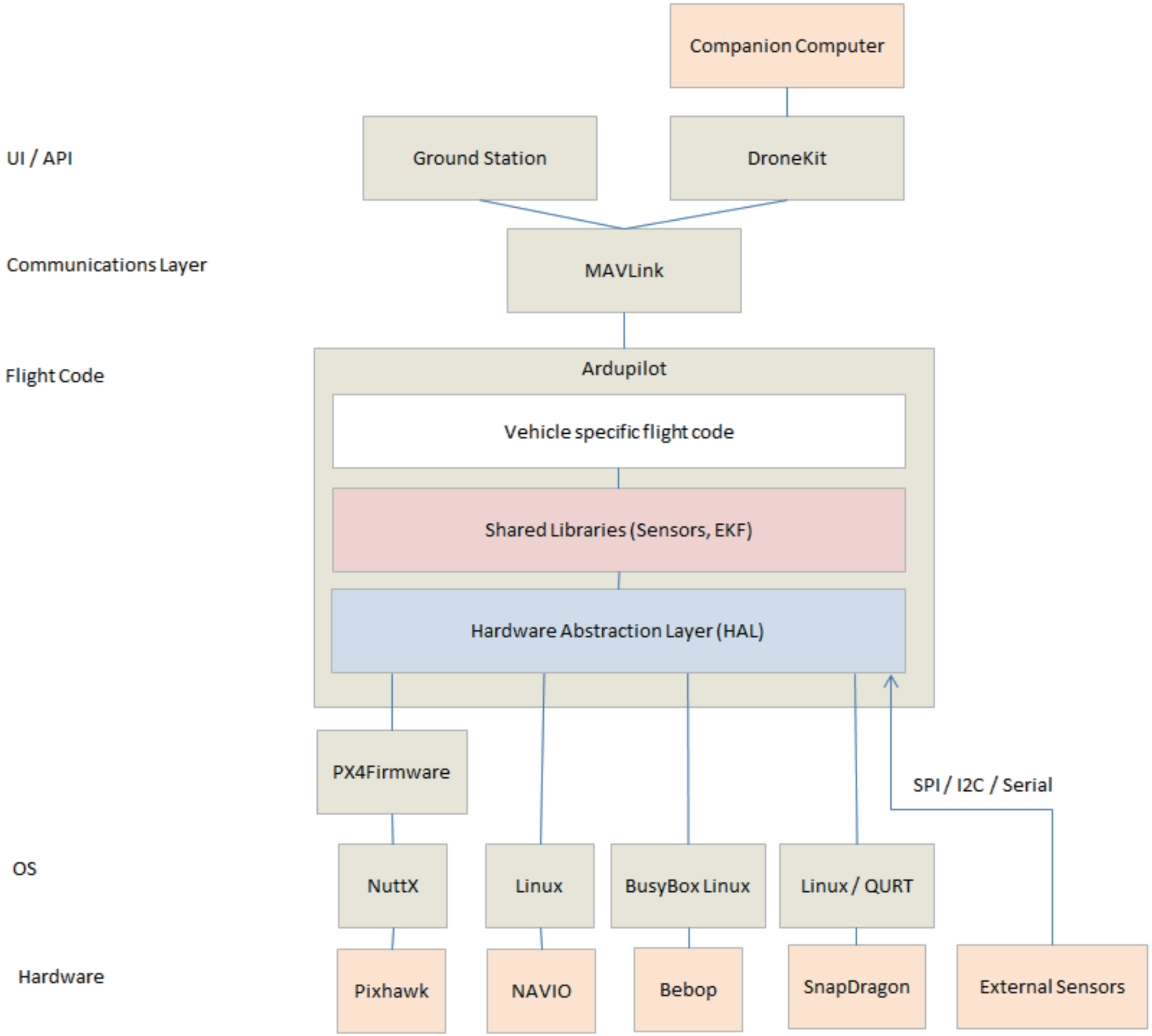
Choosing flight controller electronics

- Are you looking to do autonomous flight?
- Will you utilize on-board computing?
- What type of connectivity do you require?
- How will you power it?
- What do you need in terms of motor drive?

BeagleBone Blue flight control options

- ArduPilot is the way to go to get the most working the quickest
- UCSD has developed its own controller software
- Papparazzi
- PX4

ArduPilot



ArduPilot on BeagleBone Blue

- BeagleBoard.org mentored the original port of ArduPilot to Linux in 2014 as part of Google Summer of Code
  - BeagleBone Black + Erle Cape or Pixhawk Fire Cape
- Mirko Denecke and ArduPilot community continued work
  - 2015: BBBmini Cape for BeagleBone Black and SeeedStudio BeagleBone Green
  - 2017: Support for BeagleBone Blue
  - 2018: PocketPilot PocketCape for PocketBeagle
- Pre-built ‘ardupilot-copter-blue’ in the package feeds
- Requires some edits to the system configuration (/boot/uEnv.txt, /lib/systemd)
  - Needs a start-up script to configure and run on boot
  - Uses PRU eCAP on BeagleBone Blue software-based quadrature encoder input, E4, as radio controller input
  - Uses UIO to load PRU firmware
  - Uses RT kernel for reliable timing, which may break the USB gadget function, but WiFi works fine

Micro Air Vehicle Protocol (MAVLink)

- Protocol for communicating with an autopilot
- Can be sent over serial or network packets (UDP/TCP)
- Can be communicated over ROS

Out of Box

- Click “Getting Started” https://beagleboard.org/getting-started
- Three Easy Steps
  - Download Latest Software Image and burn onto your microSD card
  - Insert your card, power your Beagle
  - Browse to the IP address for your PC OS and add :3000
    - For WiFi, SSID is ‘BeagleBone-*XXXX*’ and password is ‘BeagleBone’

IP Address	Connection Type	Operating System(s)	Status
192.168.7.2	USB	Windows	Inactive
192.168.6.2	USB	Mac OS X, Linux	Inactive
192.168.8.1	WiFi	all	Inactive
beaglebone.local	all	mDNS enabled	Inactive
beaglebone-2.local	all	mDNS enabled	Inactive

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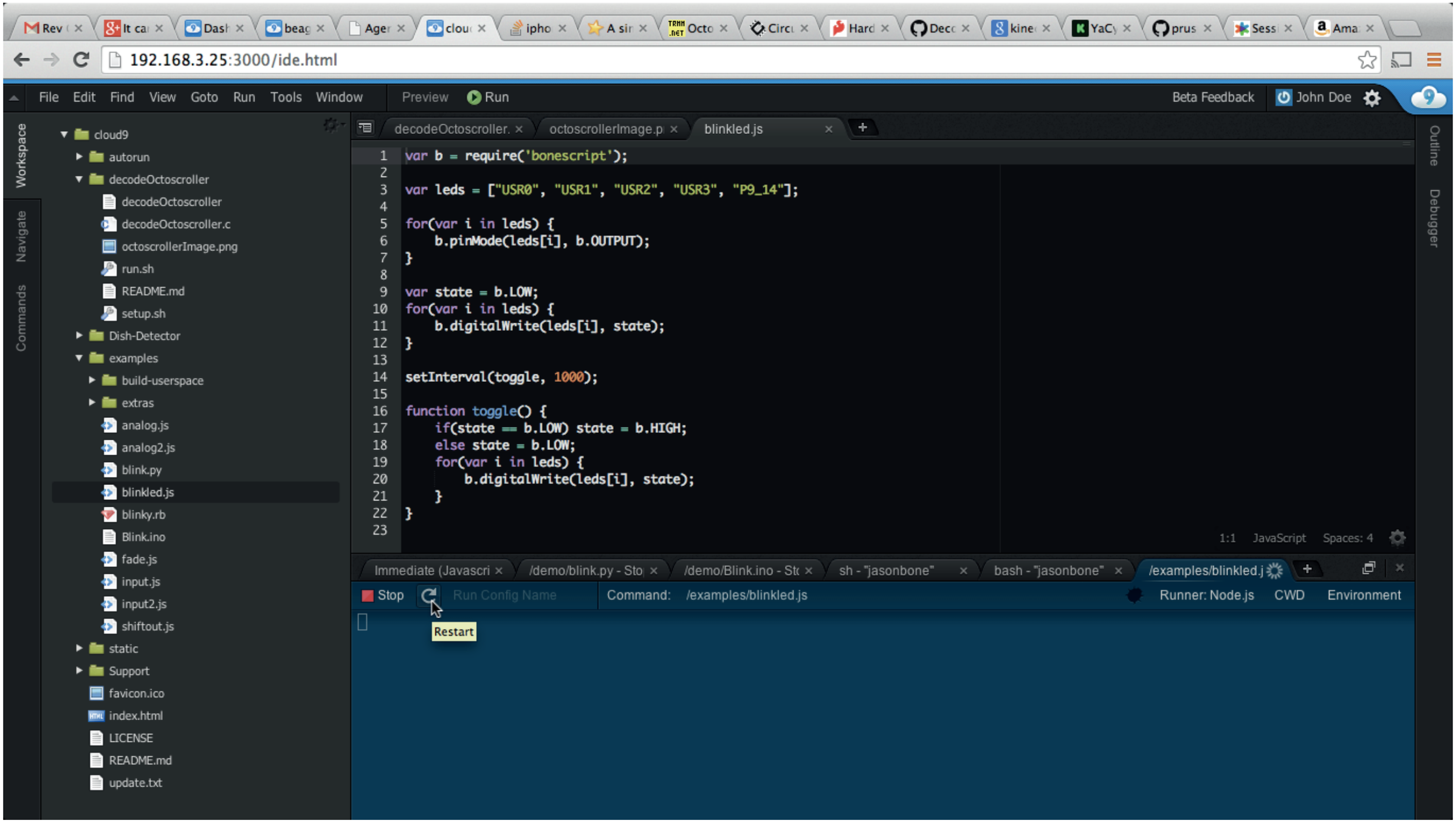
Cloud9 IDE over USB/browser (no host install)

- Zero-install integrated development environment
- Go to http://192.168.8.1:3000



Installing ArduPilot (1/3)

https://gist.github.com/jadonk/6080ca92d6e225eb89d33ad7744e1775

```
#!/bin/bash

cd /opt/scripts/tools

git pull

./update_kernel.sh --ti-rt-channel --lts-4_4

yes | developers/update_bootloader.sh

# Be sure to not try to run "apt-get upgrade" from within Cloud9. "dpkg --configure -a" to fix.

apt-get upgrade -y

apt-get install -y ardupilot-copter-blue
```

Installing ArduPilot (2/3)

https://gist.github.com/jadonk/6080ca92d6e225eb89d33ad7744e1775

```
sed -i 's/GOVERNOR="ondemand"/GOVERNOR="performance"/g' /etc/init.d/cpufrequtils
echo "uboot_overlay_pru=/lib/firmware/AM335X-PRU-UIO-00A0.dtbo" >> /boot/uEnv.txt
echo "enable_uboot_overlays=1" >> /boot/uEnv.txt
mkdir -p /var/APM/logs
mv /etc/rc.local /etc/rc.local.bak.$RANDOM
cat <<EOX > /etc/rc.local
#!/bin/sh
echo pruecapin_pu > /sys/devices/platform/ocp/ocp\:P8_15_pinmux/state
sleep 10
echo 4a334000.pru0 > /sys/bus/platform/drivers/pru-rproc/unbind
echo 4a338000.pru1 > /sys/bus/platform/drivers/pru-rproc/unbind
/usr/bin/ardupilot/blue-arducopter -A udp:10.0.0.10:14550 -l /var/APM/logs 2>&1 > /var/APM/logs/blue-arducopter.log &
exit 0
EOX
chmod +x /etc/rc.local
```

Installing ArduPilot (3/3)

https://gist.github.com/jadonk/6080ca92d6e225eb89d33ad7744e1775

```
xxd -r -a - /var/APM/ArduCopter.stg <<EOF

0000000: 5041 0600 0002 0000 7800 0602 f303 0f00  PA......x.......

0000010: 0601 0415 000b 4401 0000 0000 000b 8400  ......D.........

0000020: 00bd 7a76 442a 0200 0000 0003 c500 006c  ..zvD*.........l

0000030: 095f bc4e c2a7 3c02 2463 bd03 8307 0011  ._.N..<.$c......

0000040: 6824 0003 c501 0000 0000 0000 0000 0000  h$..............

0000050: 0000 0003 c307 0000 0000 0003 8502 0000  ................

0000060: 0000 0000 0000 0000 0000 0003 0308 0000  ................

0000070: 0000 0006 0313 0000 0000 0006 0323 0094  ............#..

0000080: 5604 0006 0333 00ea 74ea 0249 c100 0001  V....3..t..I....

0000090: 7102 0000 fc00 06c1 0300 0195 0100 0001  q...............

00000a0: 9345 0000 0000 6fc3 0000 bcc2 0080 c643  .E....o........C

00000b0: 93c3 0300 110c 0400 0345 0300 3ea1 b53d  .........E..>..=

00000c0: 71d4 8e3d 6b17 6bbf 0305 0300 c606 803f  q..=k.k........?

00000d0: 6ca3 7f3f bccb 7f3f 0343 0800 1168 1600  l..?...?.C...h..

00000e0: 0383 0800 0000 0000 03c5 0300 0000 0000  ................

00000f0: 0000 0000 0000 0000 0385 0300 0000 0000  ................

0000100: 0000 0000 0000 0000 03c3 0800 0000 0000  ................

0000110: 0345 0400 0000 0000 0000 0000 0000 0000  .E..............

0000120: 0305 0400 0000 0000 0000 0000 0000 0000  ................

0000130: 9f05 0200 9bd7 133b d2d9 043c 0000 0000  .......;...<....

0000140: 0642 1408 db05 ffff 3f00 0000 0000 0000  .B......?.......

0000150: 0000 0000 0000 0000 0000 0000 0000 0000  ................

*

0000600: ae65 0000 0000 0000 0000 0000 0000 0000  .e..............

0000610: 0000 0000 0000 0000 0000 0000 0000 0000  ................

*

0003ff0: 0000 0000 0000 0000 0000 0000 0000 0000  ................

EOF
```

Calibration

- Must do it!
- Sometimes, ESCs must be calibrated separately

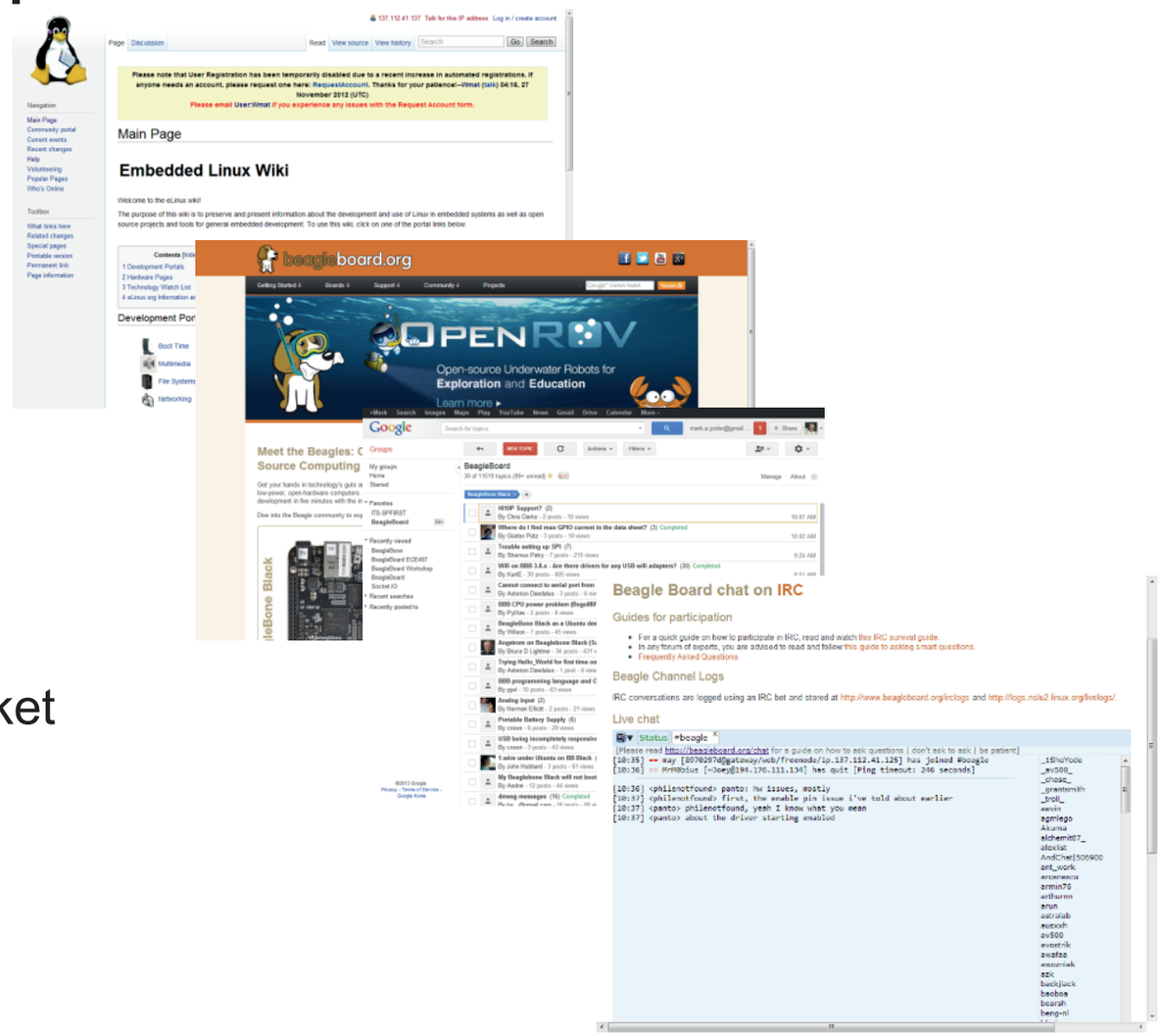
Buying parts

- Hobby King
- Horizon Hobby
- Banggood

- BeagleBoard.org/blue
- github.com/beagleboard/beaglebone-blue/wiki/Accessories

The Community

- Google Group support forum
  - beagleboard.org/discuss
- IRC or Riot.IM live chat
  - beagleboard.org/chat
- Newsletter
  - beagleboard.org/newsletter-subscribe
- References
  - beagleboard.org/getting-started
  - beagleboard.org/blue beagleboard.org/pocket
- Projects
  - beagleboard.org/p
- Related communities
  - eLinux.org
  - diydrones.com



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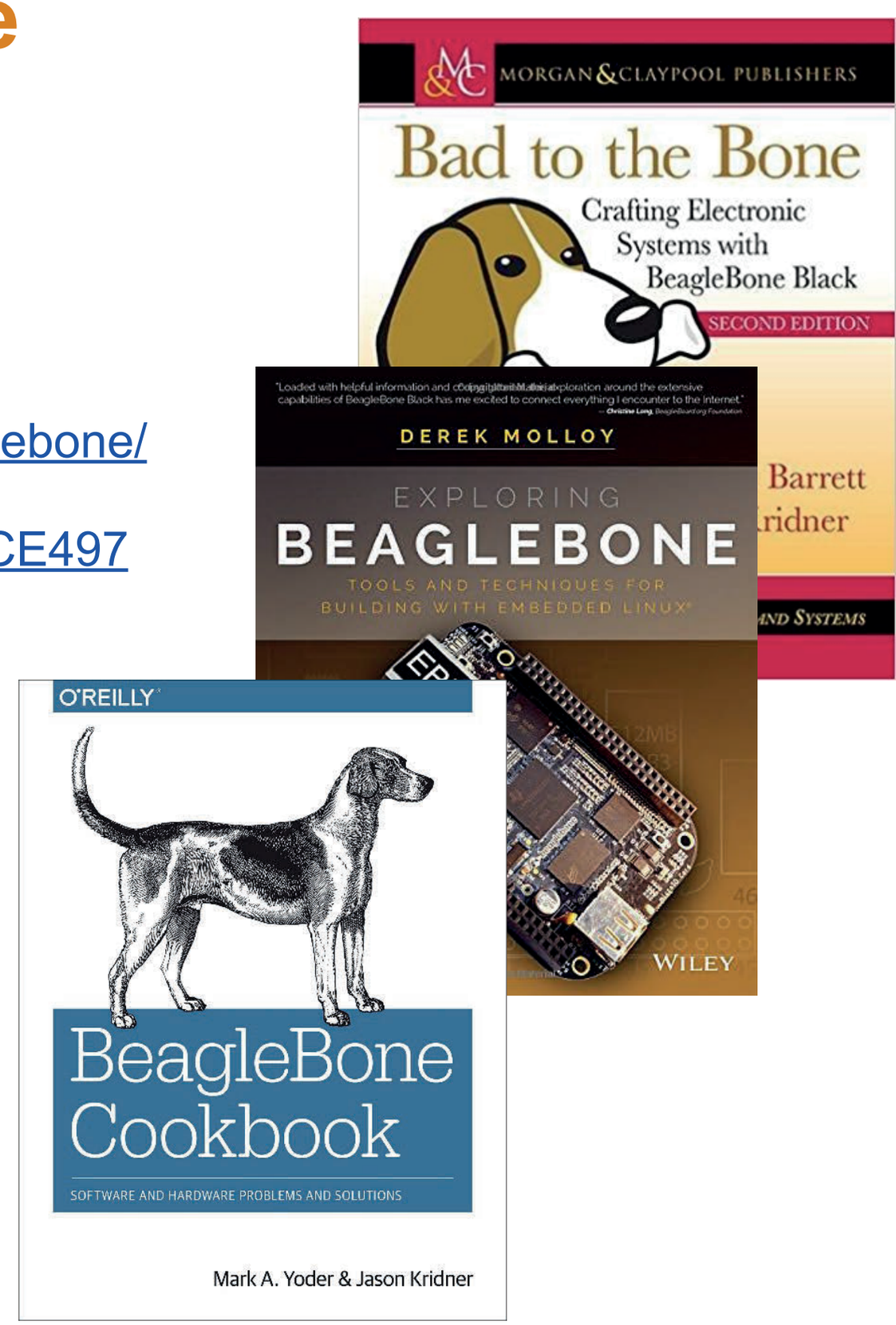
Teaching with BeagleBone

- How do you get going?
- Attend a tutorial
- Derek Molloy http://derekmolloy.ie/beaglebone/
- Yoder's wiki http://elinux.org/Category:ECE497
- Barrett/Kridner Book
- 30+ Books bbb.io/books
- univ@ti.com
- bbb.io/asee



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Mistakes and Questions

- ESC/prop orientation
- Pre-flight check

- beagleboard.org/discuss
- beagleboard.org/chat