MATE ROV COMPETITION
WORLD CHAMPIONSHIP

Electronic Control System for an Underwater ROV

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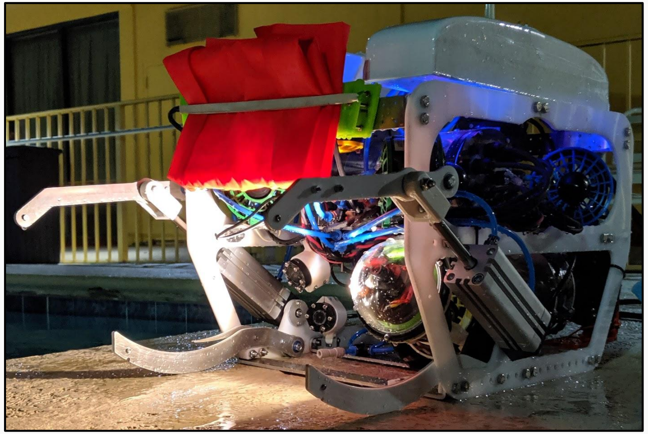
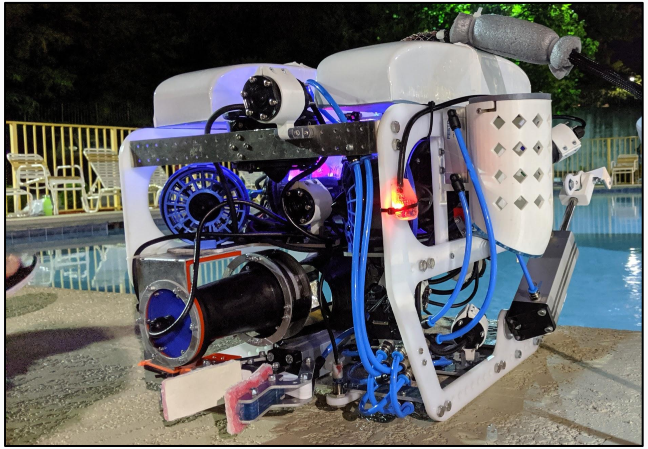
Joe Orford & George Osmond

Introduction - [Henry]

- ➔ Competing in the 2020 Marine Advanced Technology Education (MATE) ROV Competition.
- ➔ Competition held in the USA against universities from around the world (1400 students last year).
- ➔ Design and build an underwater remotely operated vehicle (ROV) to complete a range of underwater tasks within 15 minutes.
- ➔ Tasks include removing plastic debris, autonomous motion, computer vision, picking/placing objects, underwater maintenance etc.
- ➔ 1st in the UK and 11th worldwide in the 2019 competition.

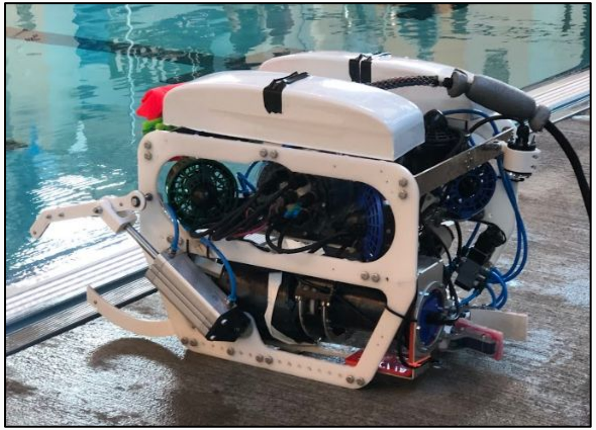




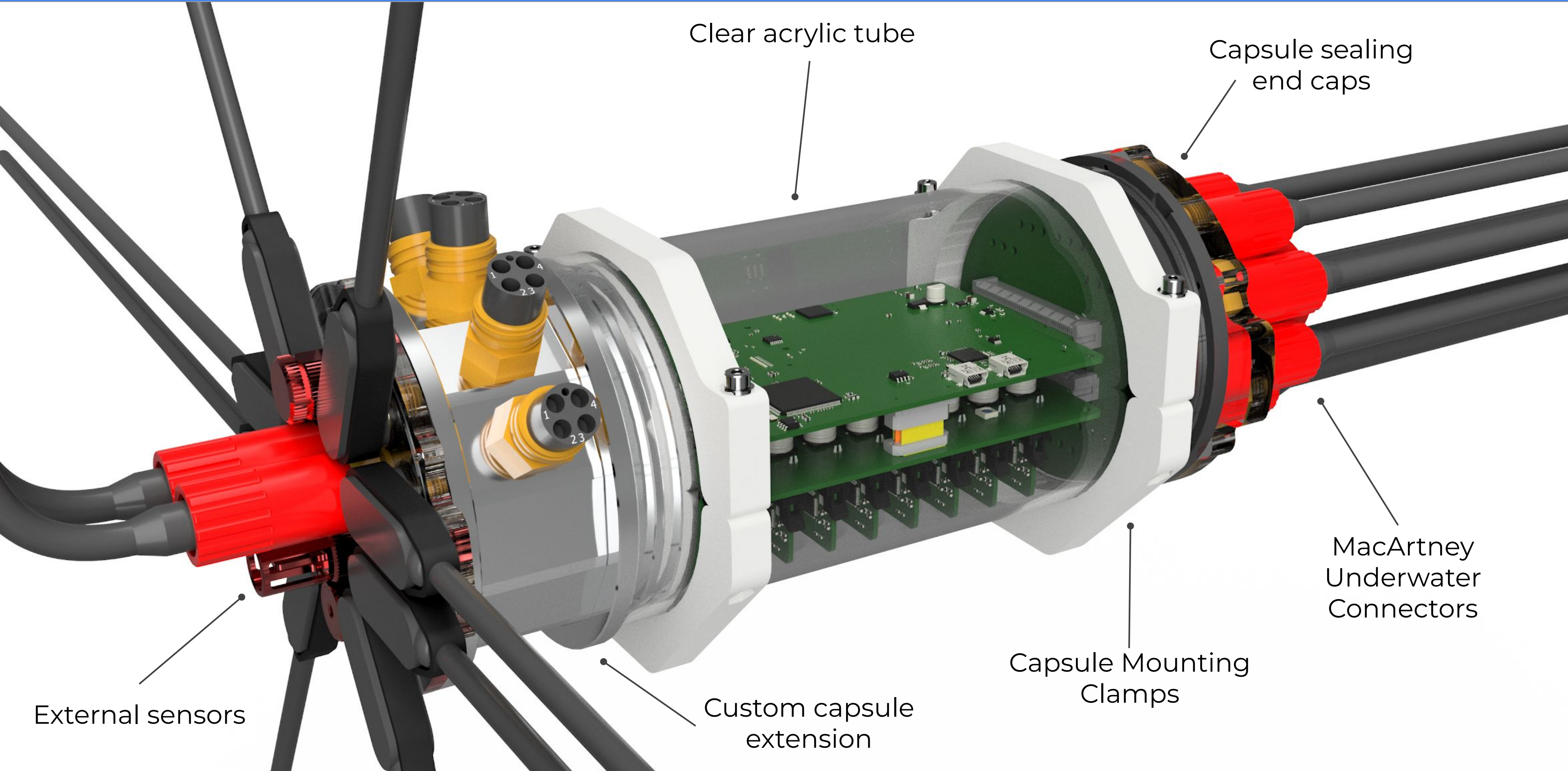
Aims & Objectives - [Joe]

- Design, manufacture and test the electronic control system for the ROV.
  - Robust communication system with backup systems in place
  - High resolution and low latency video from multiple angles
  - Monitor all critical system characteristics for performance and fault monitoring
  - Control 9 underwater thrusters to achieve precise control over the ROV’s position
  - High efficiency operation to maintain cool operation
  - Modular system for redundancy in the event of a failure

- Ultimately we aim to win the 2020 MATE ROV competition



The On-Board Electronics Capsule - [George]



Clear acrylic tube

Capsule sealing end caps

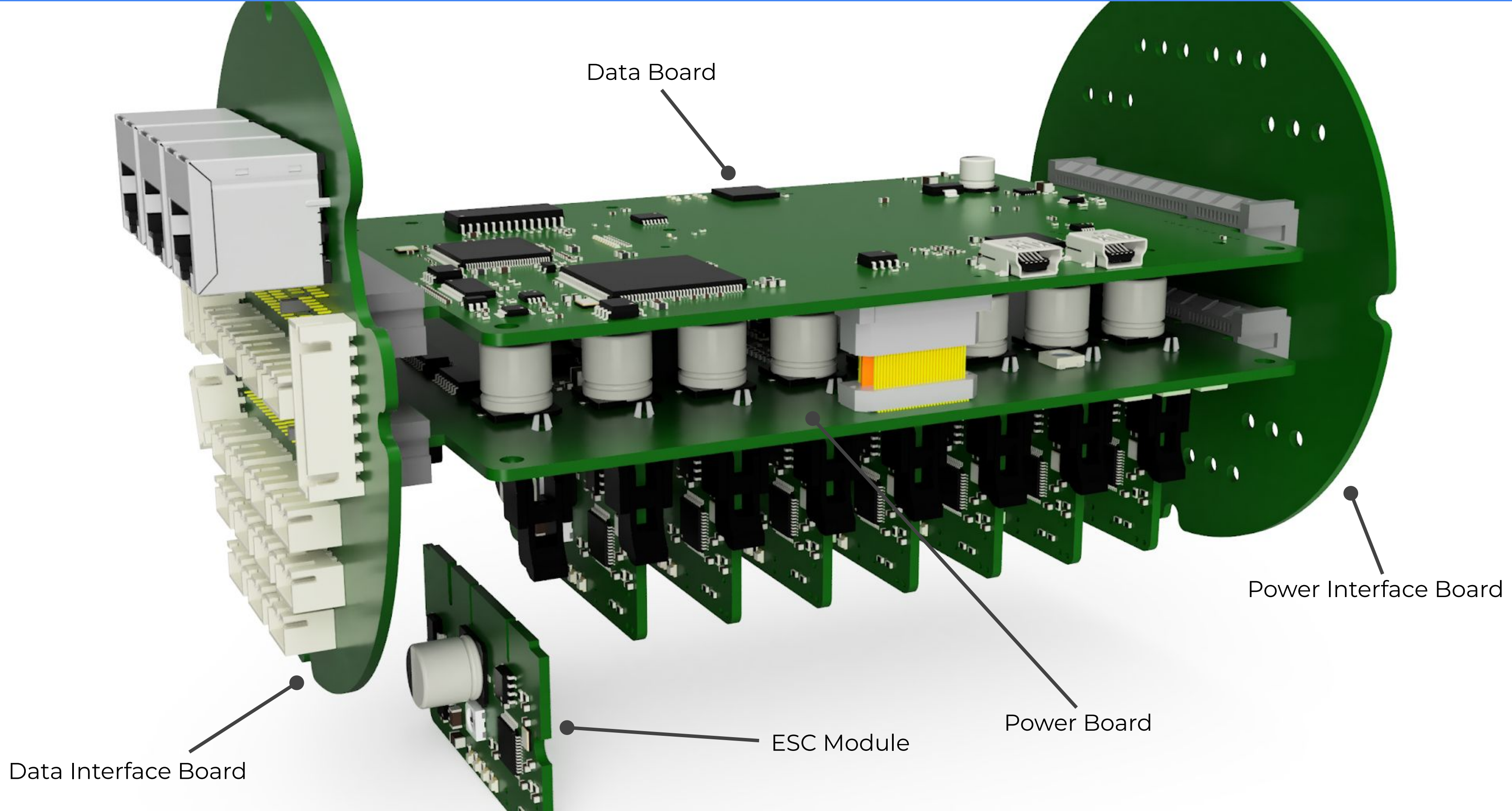
MacArtney Underwater Connectors

Capsule Mounting Clamps

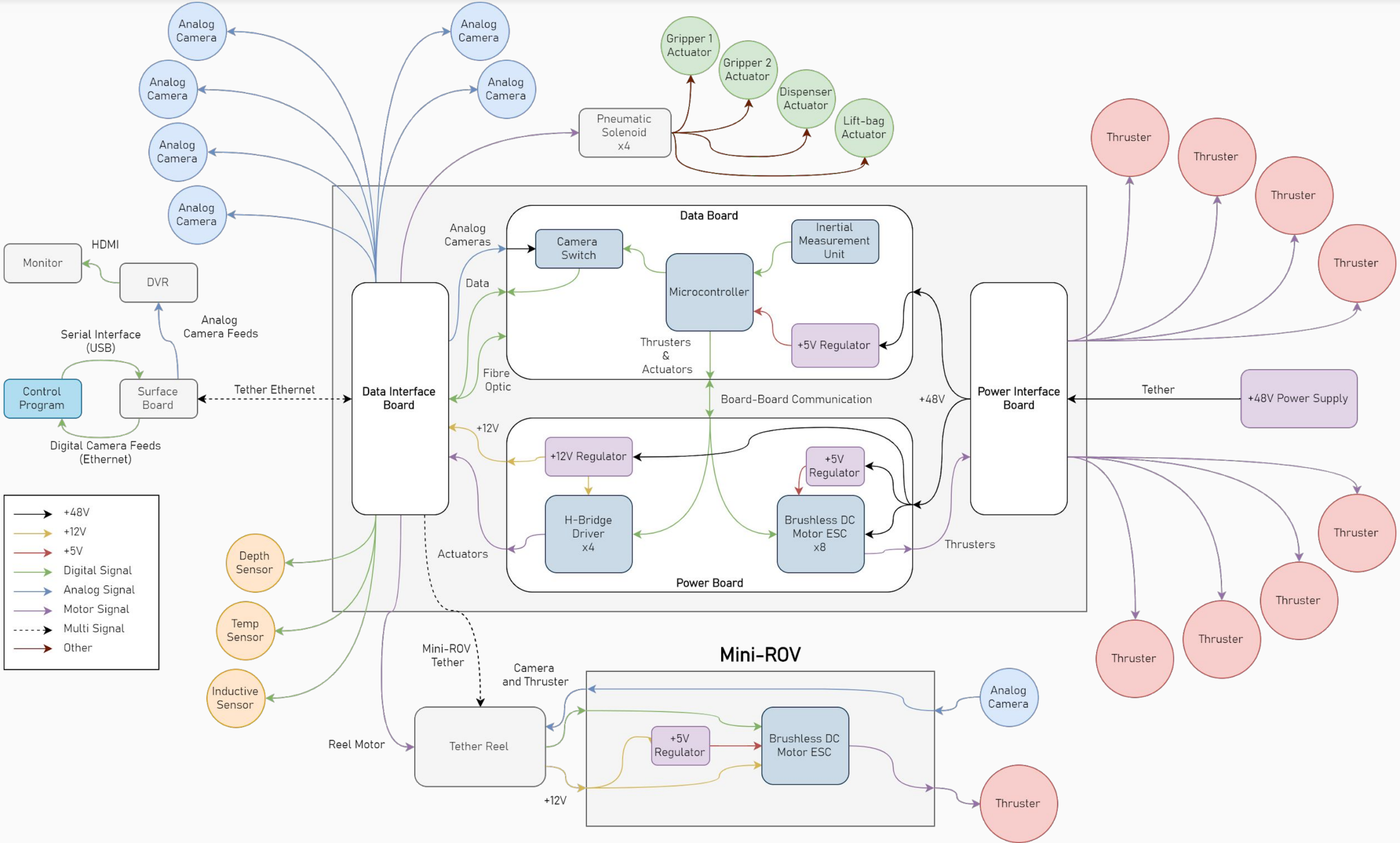
Custom capsule extension

External sensors

The Electronics System - Board breakdown - [Joe]

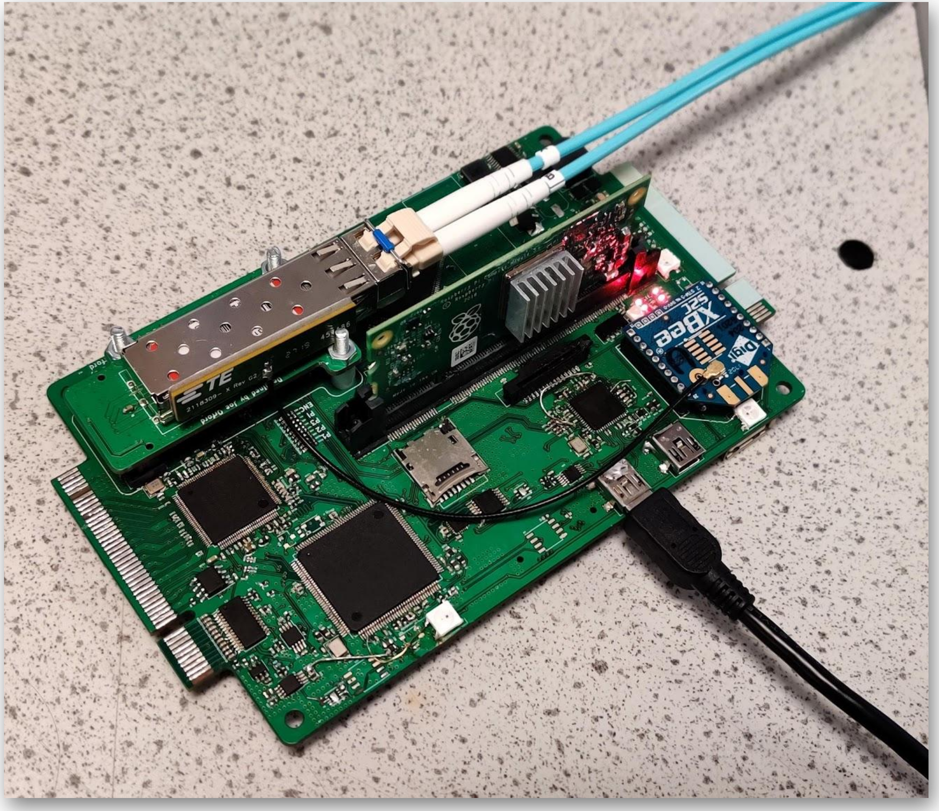


The Electronics System - Basic Diagram - [Ben]



Data Board - [Joe]

- ATSAM3x8E central microcontroller
- Raspberry Pi CM3+ as image processor
- Spartan-6 FPGA for image processing assistance for Raspberry Pi
- KSZ9477s 7 port ethernet switch with gigabit SFP fibre optic module
- Differential communications
- On board PSU with 5 voltage levels
- Wireless programming with XBEE
- USB hub and switching for configurable add ons
- IPS display for debugging
- RGB for feedback
- Multiple environment and positional sensors



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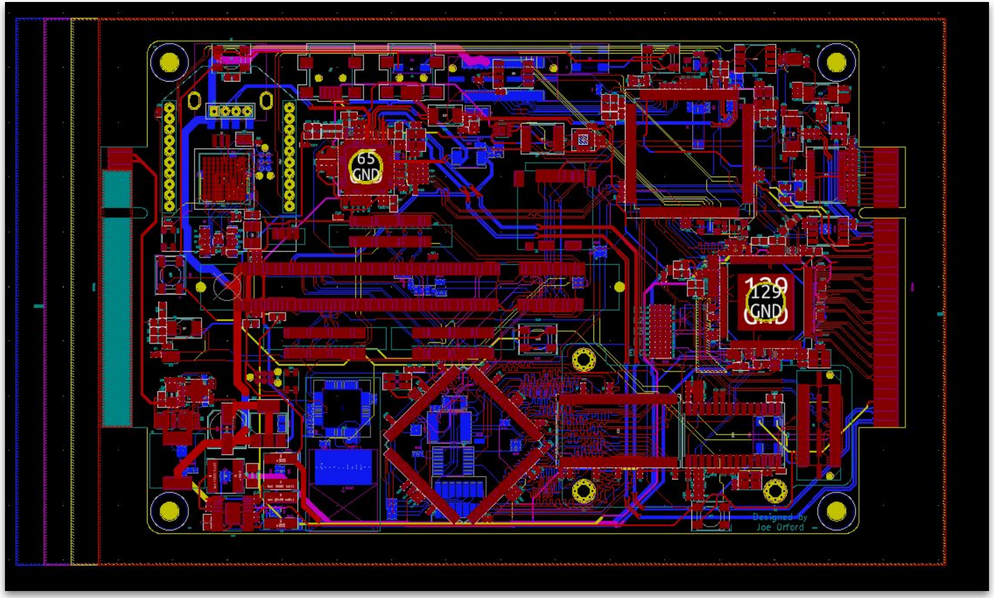
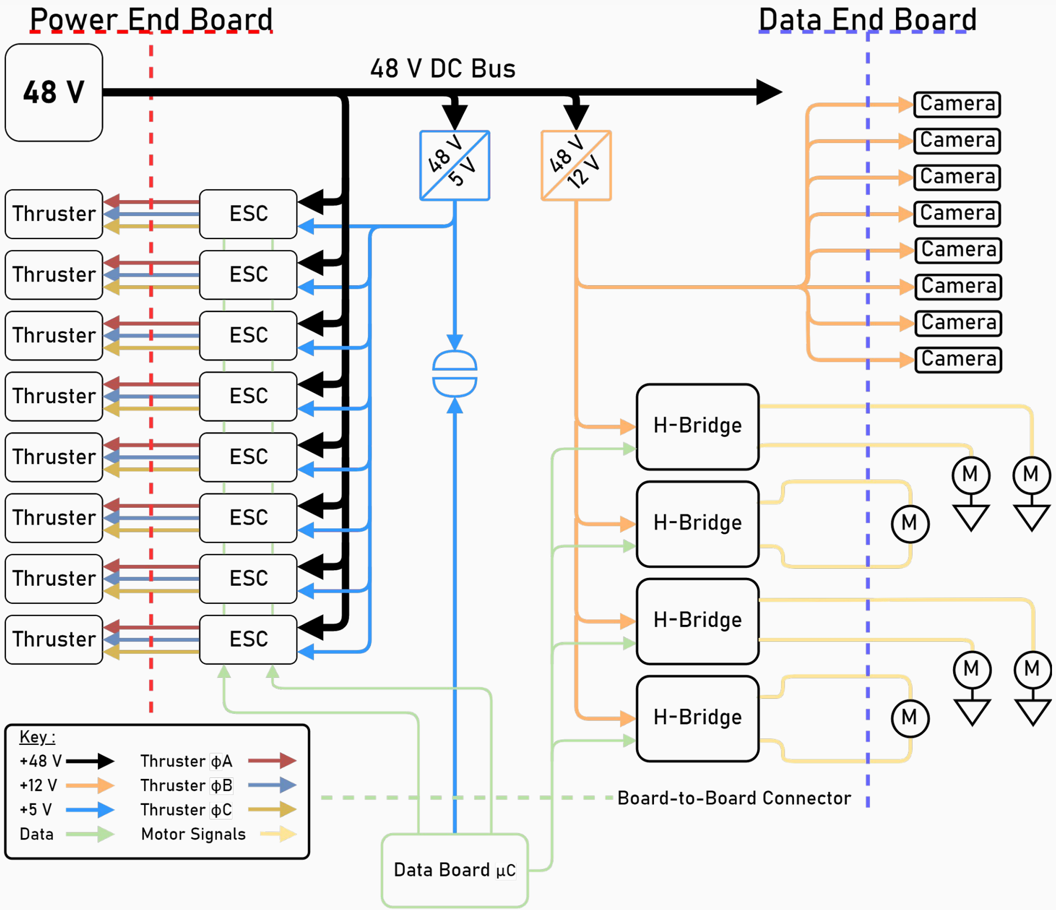
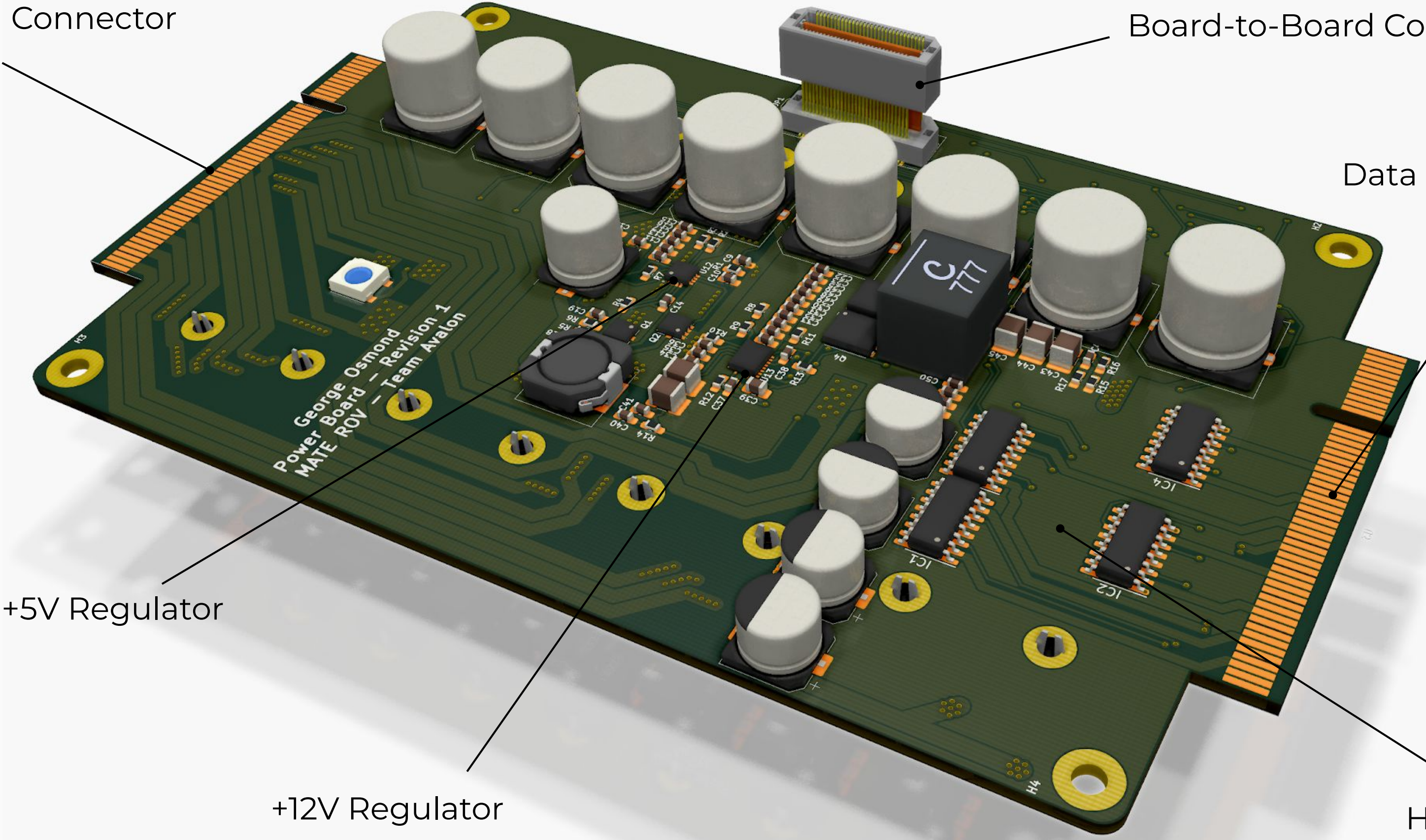


Power Board - System Diagram - [George]



- ➔ Designed to handle all of the ROV's power components and voltage regulators
- ➔ +48 V to +5 V regulator
  - ◆ Used by ESC for 3V3 level shifter and slot allocation
- ➔ +48 V to +12V Regulator
  - ◆ Supply for Cameras and H-Bridges
- ➔ H-Bridge Configuration
  - ◆ 8x Solenoid Valve Controls
    - ○ <u>or</u>
  - ◆ 4x Motor Controls

Power Board - Circuit Design - Revision 1 - [George]



Power End Connector

Board-to-Board Connector

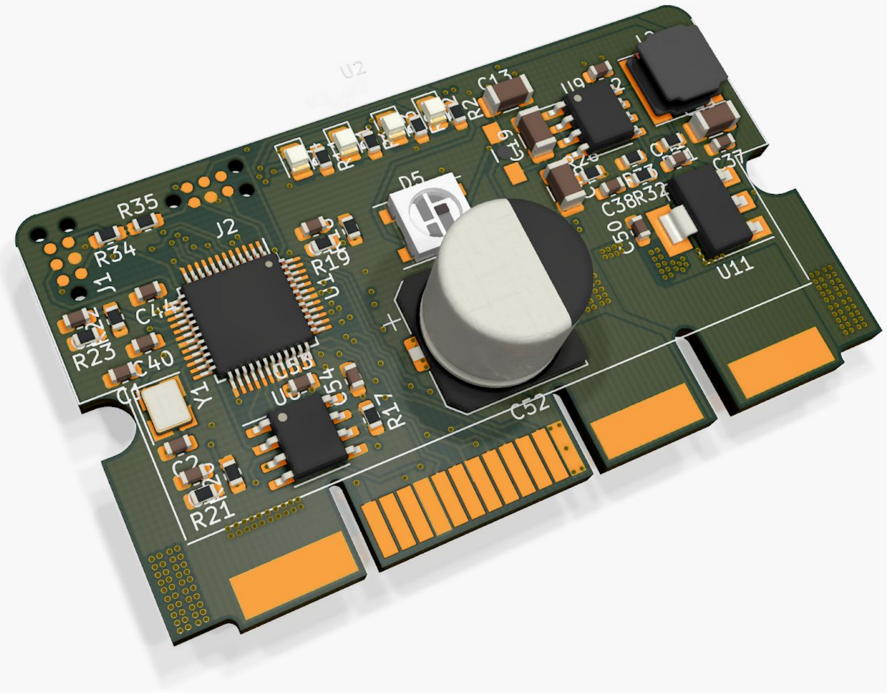
Data End Connector

+5V Regulator

+12V Regulator

H-Bridges

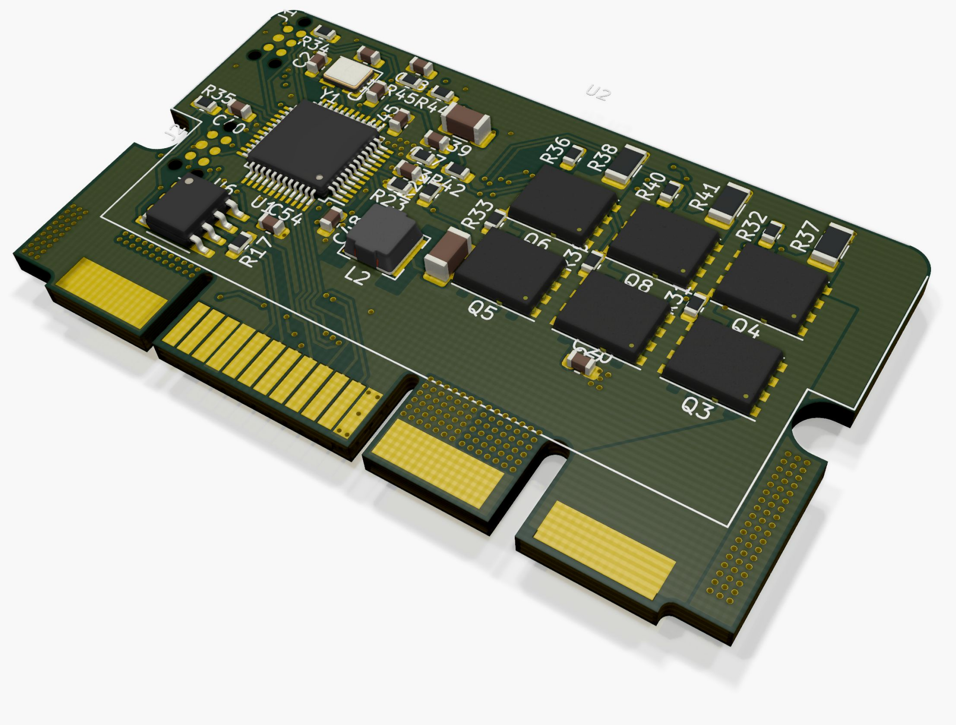
GaN ESC Module - [Henry]



- ➔ 3-Phase PMSM / BLDC Motor Driver
- ➔ 10 A @ 48 V
- ➔ Switchable control schemes
- ➔ Dual-Core microcontroller
- ➔ GaN MOSFETs - fast, efficient switching
- ➔ Easily replaceable design
- ➔ BLDC - Simple, reliable
- ➔ PMSM - Efficient, Quiet operation
- ➔ Many Comms protocols:

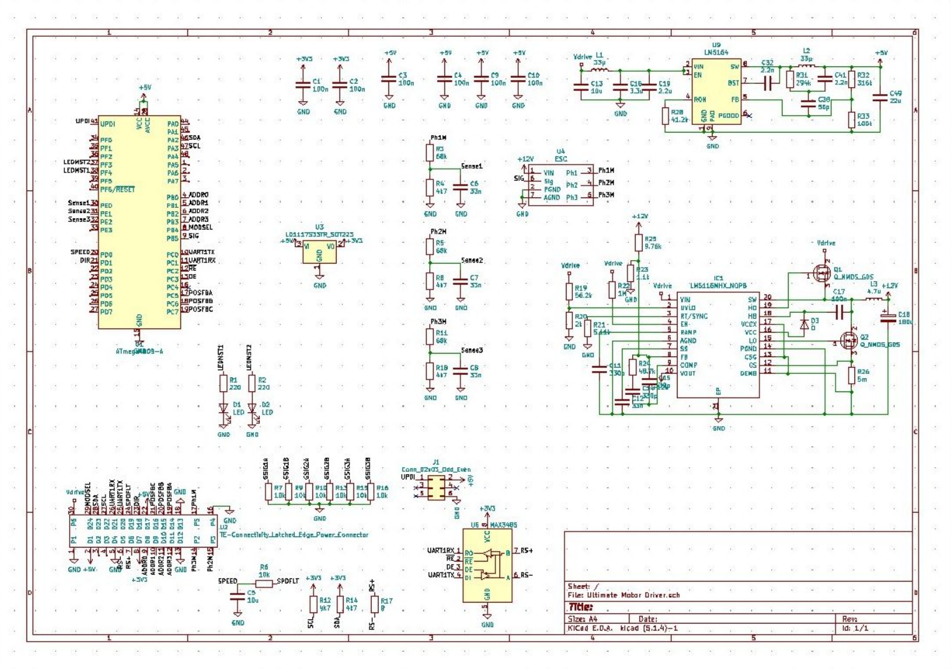
  RS-485
  UART
  Speed/Dir Analogue
  I2C
  Servo PPM

Si ESC Module - [Henry]



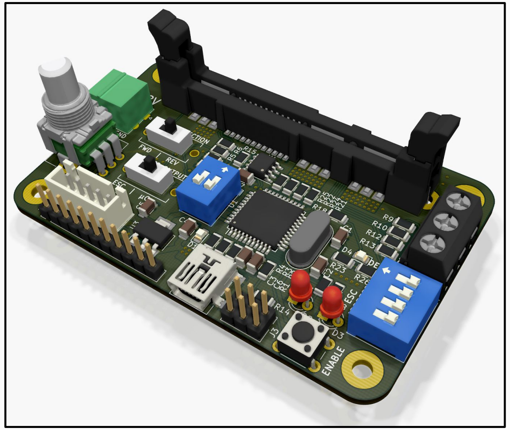
- 3-Phase PMSM / BLDC Motor Driver
- 16 A @ 48 V
- Switchable control schemes
- Dual-Core microcontroller
- Si MOSFETs - powerful, lower losses at slower switching frequency
- Easily replaceable design
- BLDC - Simple, reliable
- PMSM - Efficient, Quiet operation
- Many Comms protocols:
  RS-485
  UART
  Speed/Dir Analogue
  I2C
  Servo PPM

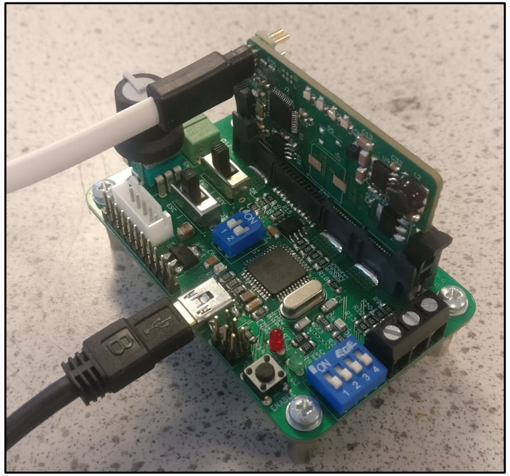
Backup ESC Module - [Henry]



- ➔ 3-Phase BLDC Motor Driver
- ➔ 30 A @ 12 V - apparently
- ➔ DC/DC converter 48 V - 12 V onboard
- ➔ ATmega based
- ➔ Off-the-shelf ESC attached
- ➔ Easily replaceable design
- ➔ Many Comms protocols:
  - RS-485
  - UART
  - Speed/Dir Analogue
  - I2C
  - Servo PPM

ESC Breakout Board - [Ben]

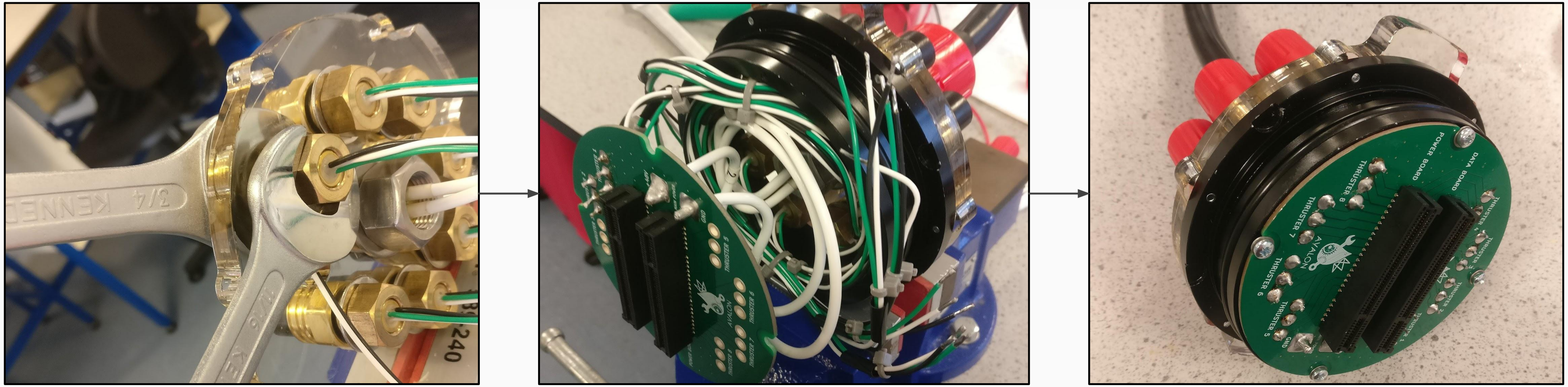




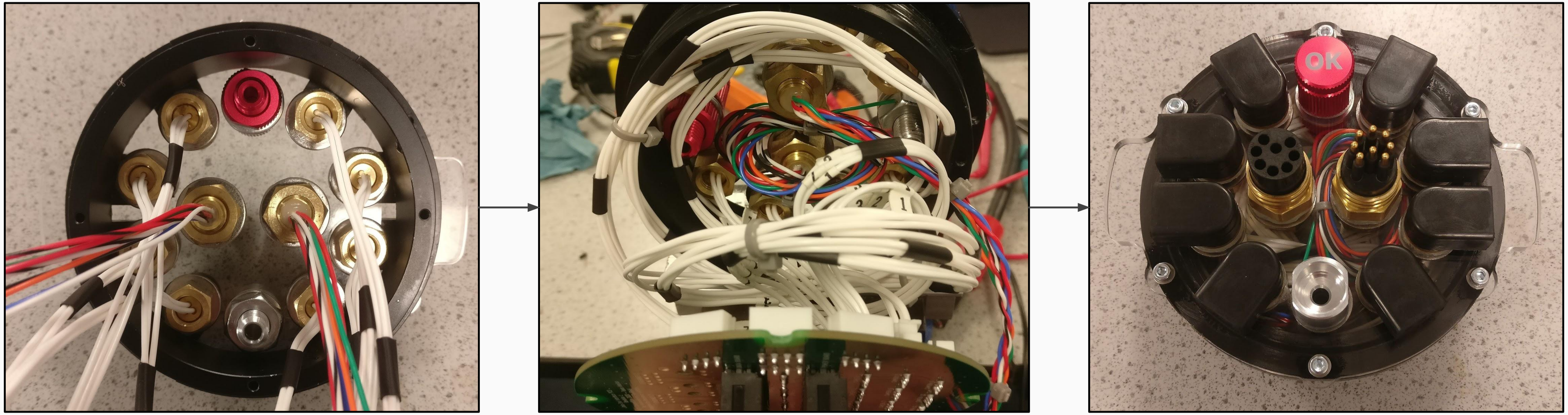
- ➔ Allows ESC modules to be programmed and tested quickly and easily.
- ➔ Allows development of the ESC modules to be isolated from the rest of the electronics system.
- ➔ Based on the ATmega 32u4.
- ➔ Controlled over a USB serial interface.
- ➔ Contains a range of switches, buttons, potentiometers and LEDs to enable full functionality testing.

Interface Boards - [Ben]

Power End



Data End



Software - [Ben]

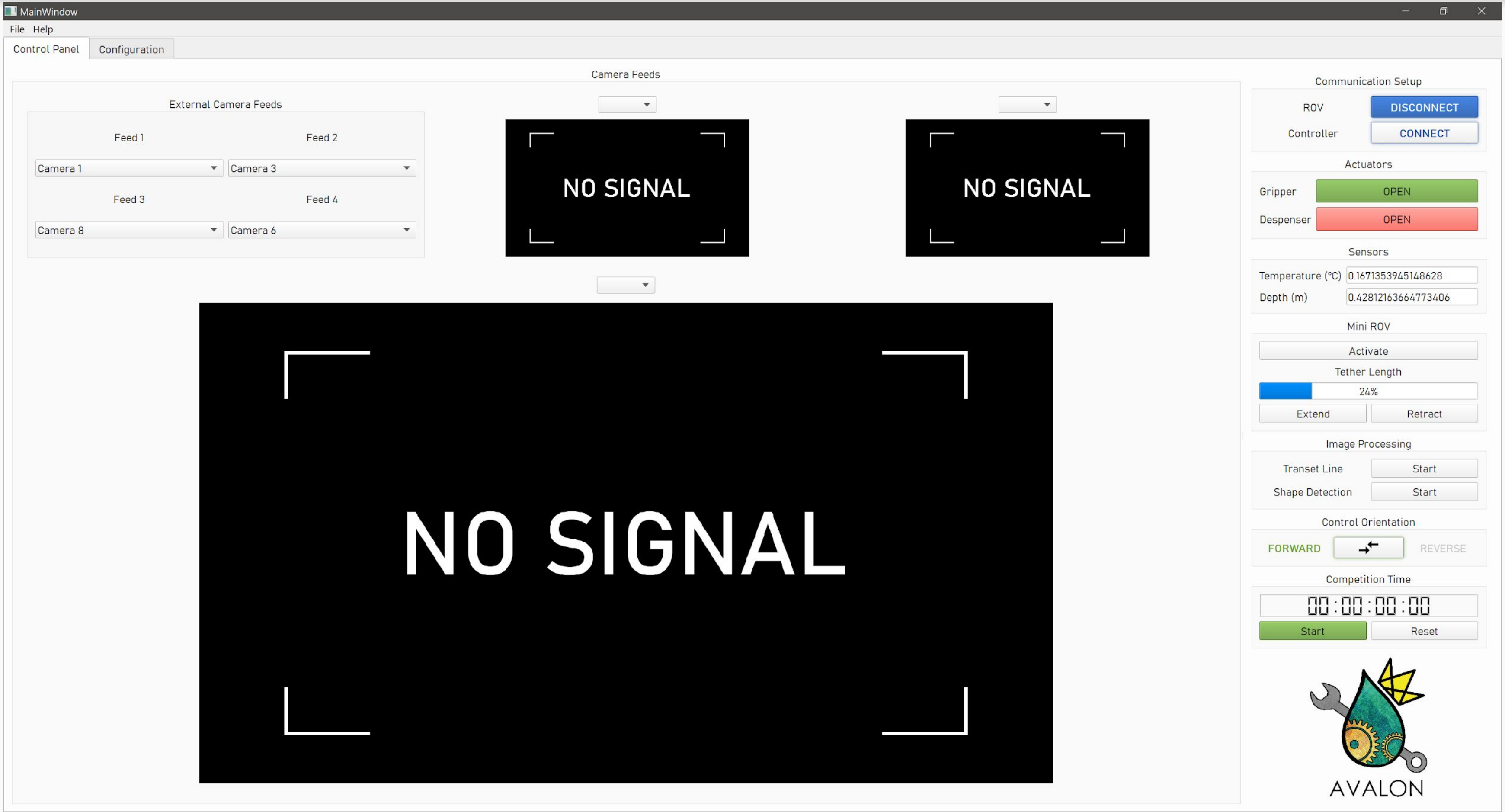
GUI

- ➔ Program runs on a computer at the base station.
- ➔ Used by the pilot to control the ROV and all its functions.
- ➔ Uses XBOX controller for user inputs.
- ➔ Developed in Python and PyQt5.
- ➔ Highly configurable for future ROV designs / different pilots.

ROV

- ➔ Runs on the Atmel microcontroller on the ROV.
- ➔ Developed in C++ in the Arduino Environment.
- ➔ Receives data from the control program over a serial interface.
- ➔ Controls thrusters, actuators, sensors and cameras.

Software - GUI Control Panel - [Ben]



Feed 1: Camera 1

Feed 2: Camera 3

Feed 3: Camera 8

Feed 4: Camera 6

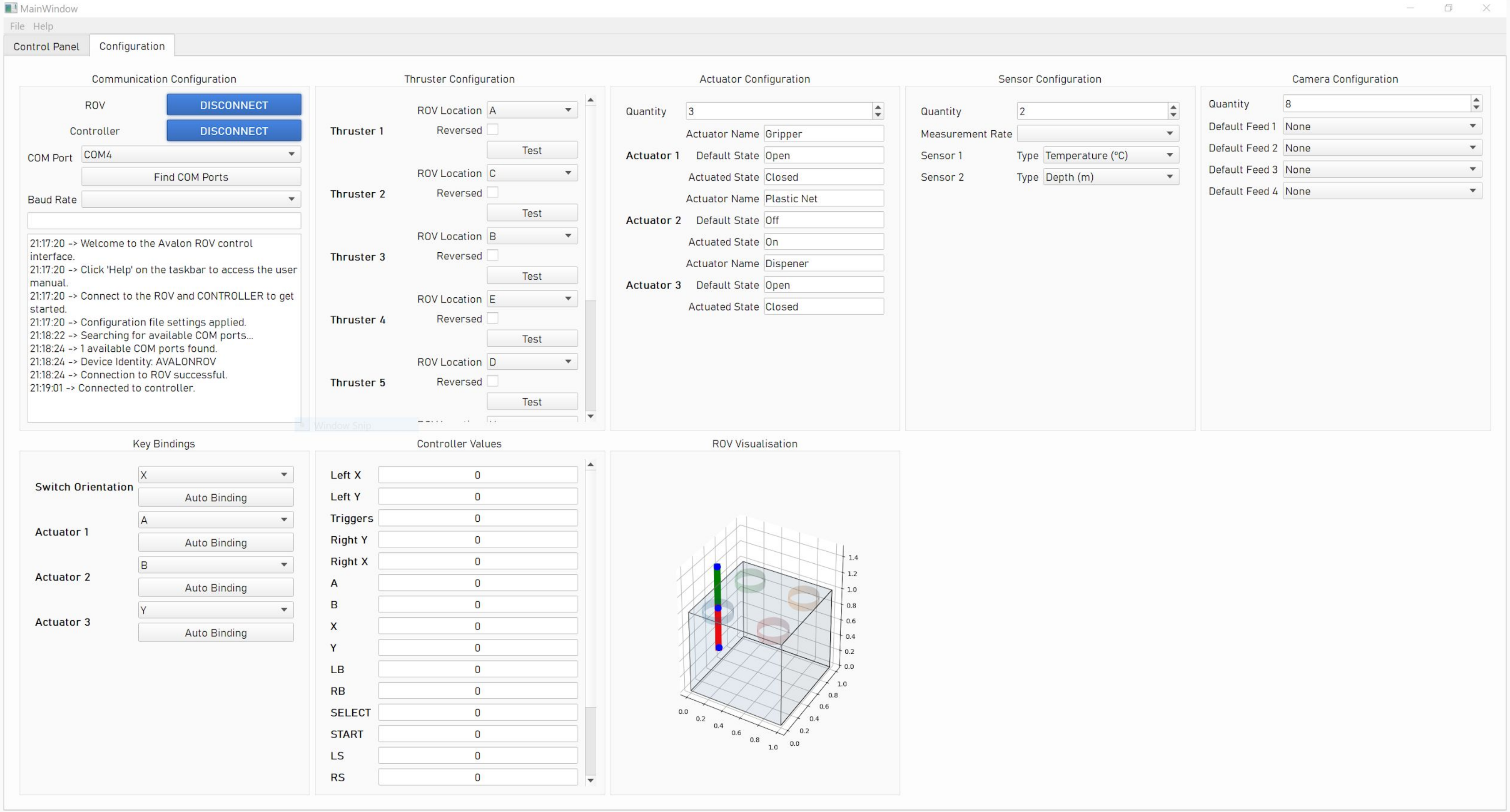
Temperature (°C) 0.1671353945148628

Depth (m) 0.42812163664773406

Tether Length 24%

Competition Time 00:00:00:00

Software - Control GUI - [Ben]



Communication Configuration

ROV DISCONNECT

Controller DISCONNECT

COM Port: COM4

Baud Rate:

```
21:17:20 -> Welcome to the Avalon ROV control interface.
21:17:20 -> Click 'Help' on the taskbar to access the user manual.
21:17:20 -> Connect to the ROV and CONTROLLER to get started.
21:17:20 -> Configuration file settings applied.
21:18:22 -> Searching for available COM ports...
21:18:24 -> 1 available COM ports found.
21:18:24 -> Device Identity: AVALONROV
21:18:24 -> Connection to ROV successful.
21:19:01 -> Connected to controller.
```

Thruster Configuration

	ROV Location	Reversed
Thruster 1	A	□
Thruster 2	C	□
Thruster 3	B	□
Thruster 4	E	□
Thruster 5	D	□

Actuator Configuration

Quantity: 3

	Actuator Name	Default State	Actuated State
Actuator 1	Gripper	Open	Closed
Actuator 2	Plastic Net	Off	On
Actuator 3	Dispener	Open	Closed

Sensor Configuration

Quantity: 2

Measurement Rate:

Sensor 1 Type: Temperature (°C)

Sensor 2 Type: Depth (m)

Camera Configuration

Quantity: 8

Default Feed 1: None

Default Feed 2: None

Default Feed 3: None

Default Feed 4: None

Key Bindings

Switch Orientation: X

Actuator 1: A

Actuator 2: B

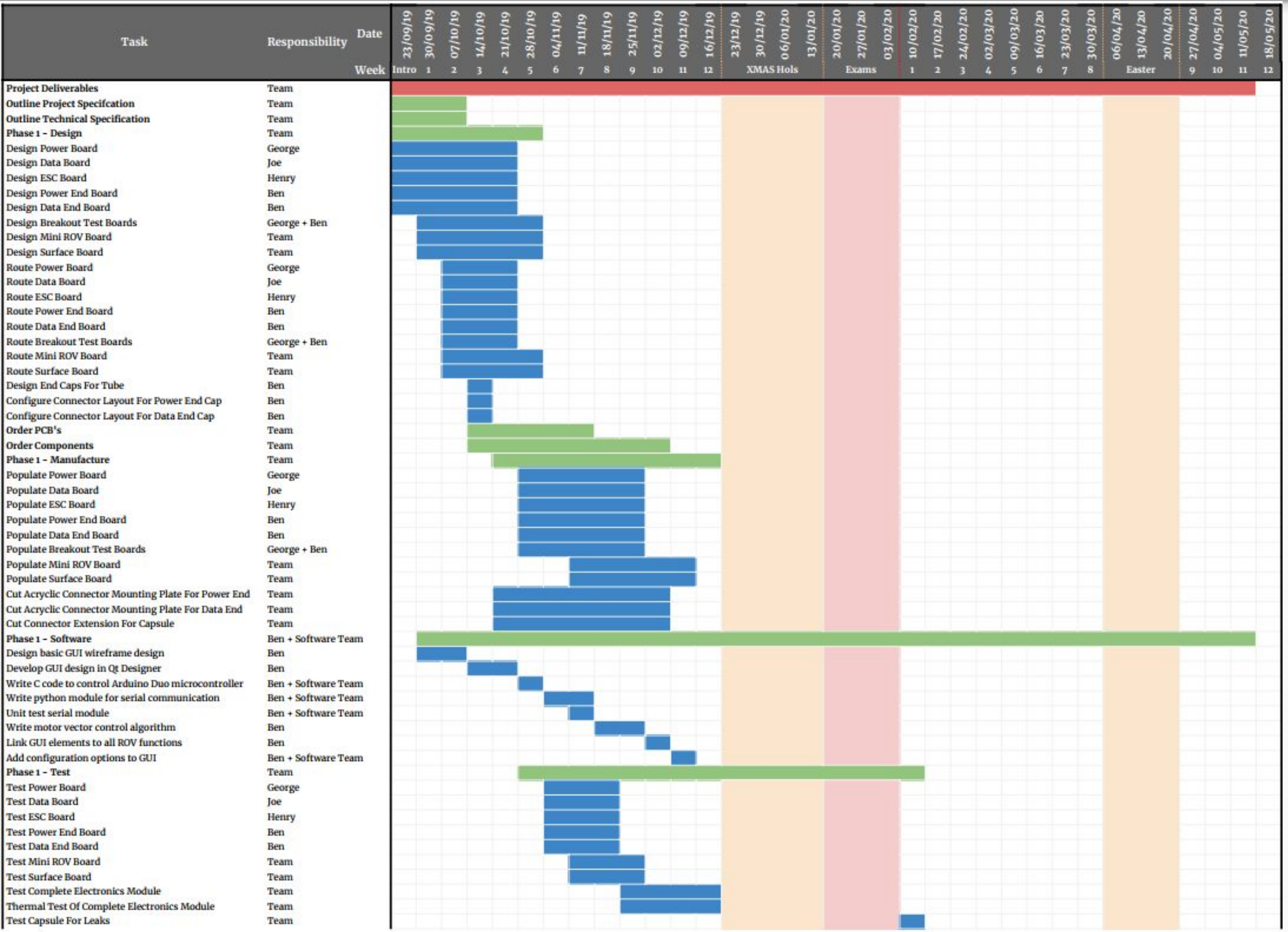
Actuator 3: Y

Controller Values

Left X	0
Left Y	0
Triggers	0
Right Y	0
Right X	0
A	0
B	0
X	0
Y	0
LB	0
RB	0
SELECT	0
START	0
LS	0
RS	0

ROV Visualisation

Project Progression and Future Work - [George]



Date	23/09/19	30/09/19	07/10/19	14/10/19	21/10/19	28/10/19	04/11/19	11/11/19	18/11/19	25/11/19	02/12/19	09/12/19	16/12/19	23/12/19	30/12/19	06/01/20	13/01/20	20/01/20	27/01/20	03/02/20	10/02/20	17/02/20	24/02/20	02/03/20	09/03/20	16/03/20	23/03/20	30/03/20	06/04/20	13/04/20	20/04/20	27/04/20	04/05/20	11/05/20	18/05/20
Week	Intro	1	2	3	4	5	6	7	8	9	10	11	12	XMAS Hols				Exams			1	2	3	4	5	6	7	8	Easter			9	10	11	12

Task	Responsibility
Project Deliverables	Team
Outline Project Specifcation	Team
Outline Technical Specification	Team
Phase 1 - Design	Team
Design Power Board	George
Design Data Board	Joe
Design ESC Board	Henry
Design Power End Board	Ben
Design Data End Board	Ben
Design Breakout Test Boards	George + Ben
Design Mini ROV Board	Team
Design Surface Board	Team
Route Power Board	George
Route Data Board	Joe
Route ESC Board	Henry
Route Power End Board	Ben
Route Data End Board	Ben
Route Breakout Test Boards	George + Ben
Route Mini ROV Board	Team
Route Surface Board	Team
Design End Caps For Tube	Ben
Configure Connector Layout For Power End Cap	Ben
Configure Connector Layout For Data End Cap	Ben
Order PCB's	Team
Order Components	Team
Phase 1 - Manufacture	Team
Populate Power Board	George
Populate Data Board	Joe
Populate ESC Board	Henry
Populate Power End Board	Ben
Populate Data End Board	Ben
Populate Breakout Test Boards	George + Ben
Populate Mini ROV Board	Team
Populate Surface Board	Team
Cut Acrylic Connector Mounting Plate For Power End	Team
Cut Acrylic Connector Mounting Plate For Data End	Team
Cut Connector Extension For Capsule	Team
Phase 1 - Software	Ben + Software Team
Design basic GUI wireframe design	Ben
Develop GUI design in Qt Designer	Ben
Write C code to control Arduino Duo microcontroller	Ben + Software Team
Write python module for serial communication	Ben + Software Team
Unit test serial module	Ben + Software Team
Write motor vector control algorithm	Ben
Link GUI elements to all ROV functions	Ben
Add configuration options to GUI	Ben + Software Team
Phase 1 - Test	Team
Test Power Board	George
Test Data Board	Joe
Test ESC Board	Henry
Test Power End Board	Ben
Test Data End Board	Ben
Test Mini ROV Board	Team
Test Surface Board	Team
Test Complete Electronics Module	Team
Thermal Test Of Complete Electronics Module	Team
Test Capsule For Leaks	Team

- ➔ Project currently on track with initial Gantt chart plan
- ➔ Currently in testing and redesign phase of timeline
- ➔ Next step is to modify circuits if required then start final and full system tests
- ➔ Revision 2 of PCBs will improve circuit design
- ➔ Improve performance and functionality
- ➔ Increase reliability

Thank you for listening!