SUAS Operations Manual

Senior Design April 2012

By

Ryan Jantzen[1] Antwon Blackmon[1] Walker Carr[1]

Brian Roney[2] Eric Prast[2] Alek Hoffman[2]

[1]*Department of Mechanical Engineering*
[2]*Department of Electrical and Computer Engineering*

Project Sponsor

Florida Center for Advanced Aero-Propulsion

Department of Mechanical Engineering

FAMU-FSU College of Engineering

2525 Pottsdamer St, Tallahassee, FL 323

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1. Aircraft Overview

The SUAS is comprised of five subsystems, each of which perform a relavent task of the overall design. The subsystems and their tasks are:

- Aircraft: Provides physical component mounts, and facilitates flight.
- Avionics: Manipulates aircraft control surfaces to control flight.
- Imagery: Feeds video to ground station from aircraft.
- Propulsion: Drives aircraft, and provides thrust for flight.
- Power supply system: Powers all aircraft electronics.

To operate the SUAS, the subsystems are assembled from individual components, and the guidelines in this operations manual are followed prior to, during and after flight. A basic functional diagram of the SUAS is shown below.
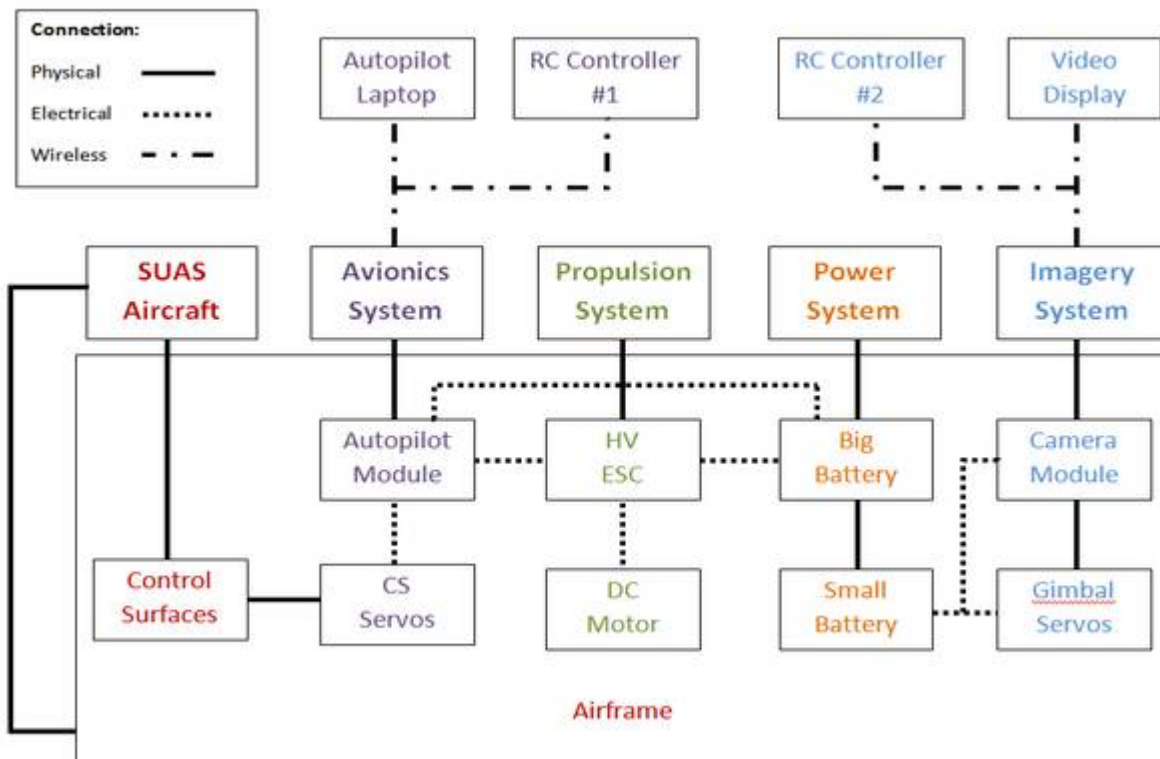
2. Aircraft Assembly

2.1 Airframe Assembly

The SUAS airframe is the platform on which all the other subsystems are mounted. It also contains the aileron, elevator and rudder control surfaces. The airframe is comprised of the following parts:

- Fuselage
- Landing Gear
- Wings (Ailerons attached)
- Horizontal Stabilizer (Elevator attached)
- Vertical Stabilizer (Rudder attached)

To assemble the airframe, the following steps are followed:

1. The horizontal stabilizer is attached to the rear boom of the fuselage.
2. The vertical stabilizer is attached to the horizontal stabilizer.
3. These parts are secured and make up the tail of the aircraft.
4. The landing gear is attached to the underside of the fuselage.
5. The camera gimbal is installed in the fuselage.
6. The wings are connected, then attached to the top of the fuselage.

2.2 Avionics Assembly (Control Surface servos and RC equipment)

The avionics system is comprised of the following components:

- Aileron Servos (2)
- Elevator Servo (1)
- Rudder Servo (1)
- Futaba RC Transmitter (Handset)
- Futaba RC Receiver
- Control Surface control rods

To assemble the avionics system in the aircraft, the following steps should be followed:

1. Install servos in the appropriate servo slots.
2. Secure servos with screws. Make sure they are tight.

3. Adjust control rods so the control surfaces are flush with the wings and stabilizers by twisting in/out the control rod clips.

4. Attach control rods to servo arms by prying open clip with fingernail or small screwdriver. Snap into place and secure with control rod clips.

5. Install Futaba receiver in the receiver cradle.

6. Plug servo wires into the appropriate receiver slots.

7. Install battery pack into the handset.

8. DO NOT connect the throttle lead from the ESC to the receiver.

9. Attach the power source to the receiver in the 'B' slot.

10. Turn on the handset.

11. Turn on the safety switch.

12. Test all the servos by moving the control sticks.

13. Insure all control surfaces respond to the correct input; otherwise switch the incorrect servo wires in the receiver.

14. Turn off the safety switch.

15. Power down handset and connect throttle lead.

16. DO NOT connect ESC power, and stay well clear of prop.

2.3 Propulsion and Power Supply Assembly

The propulsion system is comprised of the following components:

- Power 60 Motor
- Electronic Speed Control (ESC)
- Propeller
- Motor mount
- Propeller mount

The system is assembled by following these steps:

1. Install the motor by securing the motor mount to the motor, then attaching the motor and motor mount to the motor platform on the nose of the aircraft.

2. Attach the propeller by sliding the propeller onto the propeller mount, then sliding the propeller mount onto the motor driveshaft.

3. Tighten the propeller mount.

4. Secure the ESC into the ESC cradle.

5. Plug the ESC wires into the motor wires, black to black, red to blue and blue to red. This is because the motor is backwards mounted.

6. DO NOT plug the ESC into the batteries until aircraft is ready to fly and stay well clear of the prop at all times after the motor is plugged into the ESC. The motor propeller is EXTREMELY dangerous and will cause massive bodily damage if triggered accidentally while handling.

The power supply system consists of the following components:

- Big battery pack (2 8-cell 3850 mAh 29.6 V batteries)
- Small battery pack (3-cell 1300 mAh 11.1 V battery)
- Battery Eliminator Circuit (BEC)

The system is assembled by following these steps:

1. Install both batteries in the battery corral, which is as far forward in the plane as possible. The battery leads should point towards the tail of the plane.

2. Secure batteries with Velcro straps.

3. Attach BEC to Velcro patch.

4. DO NOT plug Batteries into ESC until the aircraft is ready to fly, and stay well clear of the prop.

5. Insure both ESC and video feed power cables reach the battery terminals.

2.4 Video Feed system assembly

The video feed system is comprised of the camera, the video transmitter, the video receiver and a laptop with a video recording interface. The system also contains the camera interface board, the Arduino board, and the secondary RC controller. In order to assemble the system, the following steps should be followed;

1. Mount camera to camera gimbal.

2. Feed camera wires through slot in camera gimbal.

3. Attach wires to Arduino board and I-Shot interface board.

4. Mount boards in their desired locations.

5. Connect the spektrum receiver to the arduino board.

6. Plug the power plugs from the small battery harness into the arduino board and the video transmitter.

7. Plug the camera RCA output plug into the video transmitter receptacle.

8. Install the harness into the aircraft insuring that it reaches the small battery pack.

9. Insure the harness kill switch is in the "off" position.

10. Plug the harness into the small battery pack.

11. Turn on switch to power entire system.

12. Plug the video receiver into the laptop via the USB converter.

13. Test for video reception.

14. Turn off harness kill switch.

2.5 Autopilot system assembly
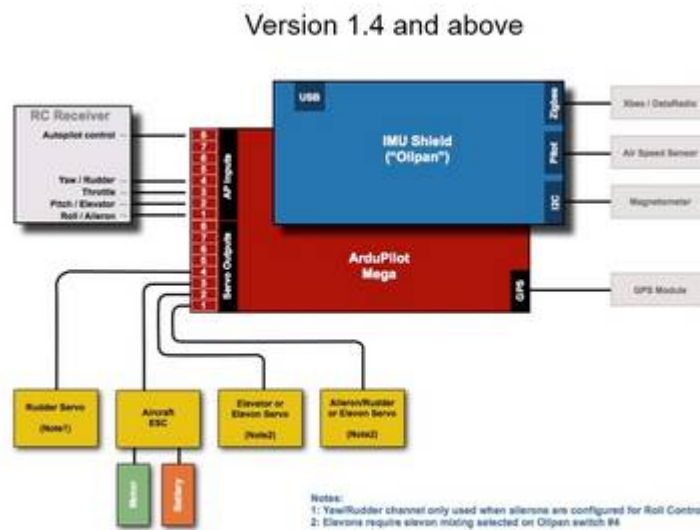
The picture above shows the basic layout of the autopilot system. The servos and RC receiver connections to the APM board are regular 3 pin servo connectors. The GPS module and air speed sensor both have specific connection points on the APM board. The mini USB port is used to directly connect the autopilot to the ground station interface.

3. Pre-Flight

3.1 Pre-Flight Checklist

The following checklist must be completed prior to flight:

1. Is landing gear secured?
2. Is motor secure to fuselage?
3. Is prop secured to shaft?
4. Are motor connections secured?
5. ESC Connected to Receiver?
6. Servos Tight and connected to receiver?
7. Aircraft batteries charged?
8. Camera batteries charged?
9. Is Rudder secured to fuselage?
10. Is elevator secured to fuselage?
11. Check servo Linkage Binding.
12. Visually check for anything loose or play in any control surfaces.
13. Are all electronics secured?
14. Are wind conditions favorable for flight?
15. Connect Batteries.
16. Stay clear of prop.
17. Are wings secured properly and evenly?
18. Is there glitching present?
19. Check rudder Control full deflection.
20. Check Elevator Control full deflection.
21. Check Aileron Control full deflection.
22. Is elevator trimmed neutral?
23. Is rudder trimmed neutral?

3.2 Battery charging instructions

1. Use only a charger approved for lithium batteries.
2. Make certain that the correct cell count is set on your charger.

3. Watch the charger very closely for the first few minutes to ensure that the correct cell count continues to be displayed.

4. Never charge the batteries unattended.

5. Use a safe surface to charge your batteries on so that if they burst into flame no damage will occur. Vented fire safes, pyrex dishes with sand in the bottom, fireplaces, plant pots, are all good options.

6. Do not charge at more than 1 C unless specifically authorized by the pack vendor.

7. If a cell balloons quickly place it in a fire safe place, especially if you were charging it when it ballooned.

8. If you crash with your lithium cells they may be damaged such that they are shorted inside.

9. Charge your batteries in a open ventilated area. If a battery does rupture or explode hazardous fumes and material will spew from the battery.

10. Keep a bucket of sand nearby when you are flying or charging batteries. This is a cost effective way to extinguish fires.

3.3 Rules and Regulations

Source: Academy of Model Aeronautics National Model Aircraft Safety Code
Effective January 1, 2011

A. **GENERAL**: A model aircraft is a non-human-carrying aircraft capable of sustained flight in the atmosphere. It may not exceed limitations of this code and is intended exclusively for sport, recreation and/or competition. All model flights must be conducted in accordance with this safety code and any additional rules specific to the flying site.

1. Model aircraft will not be flown:

(a) In a careless or reckless manner.

(b) At a location where model aircraft activities are prohibited.

2. Model aircraft pilots will:

(a) Yield the right of way to all man carrying aircraft.

(b) See and avoid all aircraft and a spotter must be used when appropriate. (AMA Document #540-D-See and Avoid Guidance.)

(c) Not fly higher than approximately 400 feet above ground level within three (3) miles of an airport, without notifying the airport operator.

(d) Not interfere with operations and traffic patterns at any airport, heliport or seaplane base except where there is a mixed use agreement.

(e) Not exceed a takeoff weight, including fuel, of 55 pounds unless in compliance with the AMA Large Model Aircraft program. (AMA Document 520-A)

(f) Ensure the aircraft is identified with the name and address or AMA number of the owner on the inside or affixed to the outside of the model aircraft.

(This does not apply to model aircraft flown indoors).

(g) Not operate aircraft with metal-blade propellers or with gaseous boosts except for helicopters operated under the provisions of AMA Document #555.

(h) Not operate model aircraft while under the influence of alcohol or while using any drug which could adversely affect the pilot's ability to safely control

the model.

(i) Not operate model aircraft carrying pyrotechnic devices which explode or burn, or any device which propels a projectile or drops any object that

creates a hazard to persons or property.

Exceptions:

- Free Flight fuses or devices that burn producing smoke and are securely attached to the model aircraft during flight.
- Rocket motors (using solid propellant) up to a G-series size may be used provided they remain attached to the model during flight. Model rockets
- may be flown in accordance with the National Model Rocketry Safety Code but may not be launched from model aircraft.
- Officially designated AMA Air Show Teams (AST) are authorized to use devices and practices as defined within the Team AMA Program Document (AMA Document #718).

(j) Not operate a turbine-powered aircraft, unless in compliance with the AMA turbine regulations. (AMA Document #510-A).

3. Model aircraft will not be flown in AMA sanctioned events, air shows or model demonstrations unless:

(a) The aircraft, control system and pilot skills have successfully demonstrated all maneuvers intended or anticipated prior to the specific event.

(b) An inexperienced pilot is assisted by an experienced pilot.

4. When and where required by rule, helmets must be properly worn and fastened. They must be OSHA, DOT, ANSI, SNELL or NOCSAE approved or

comply with comparable standards.

B. *RADIO CONTROL (RC)*

1. All pilots shall avoid flying directly over unprotected people, vessels, vehicles or structures and shall avoid endangerment of life and property of others.

2. A successful radio equipment ground-range check in accordance with manufacturer's recommendations will be completed before the first flight of a new or

repaired model aircraft.

3. At all flying sites a safety line(s) must be established in front of which all flying takes place (AMA Document #706-Recommended Field Layout):

(a) Only personnel associated with flying the model aircraft are allowed at or in front of the safety line.

(b) At air shows or demonstrations, a straight safety line must be established.

(c) An area away from the safety line must be maintained for spectators.

(d) Intentional flying behind the safety line is prohibited.

4. RC model aircraft must use the radio-control frequencies currently allowed by the Federal Communications Commission (FCC). Only individuals properly

licensed by the FCC are authorized to operate equipment on Amateur Band frequencies.

5. RC model aircraft will not operate within three (3) miles of any pre-existing flying site without a frequency-management agreement (AMA Documents #922-

Testing for RF Interference; #923- Frequency Management Agreement)

6. With the exception of events flown under official AMA Competition Regulations, excluding takeoff and landing, no powered model may be flown outdoors

closer than 25 feet to any individual, except for the pilot and the pilot's helper(s) located at the flight line.

7. Under no circumstances may a pilot or other person touch a model aircraft in flight while it is still under power, except to divert it from striking an individual.

This does not apply to model aircraft flown indoors.

8. RC night flying requires a lighting system providing the pilot with a clear view of the model's attitude and orientation at all times.

9. The pilot of a RC model aircraft shall:

(a) Maintain control during the entire flight, maintaining visual contact without enhancement other than by corrective lenses prescribed for the pilot.

(b) Fly using the assistance of a camera or First-Person View (FPV) only in accordance with the procedures outlined in AMA Document #550.

C. **FREE FLIGHT**

1. Must be at least 100 feet downwind of spectators and automobile parking when the model aircraft is launched.

2. Launch area must be clear of all individuals except mechanics, officials, and other fliers.

3. An effective device will be used to extinguish any fuse on the model aircraft after the fuse has completed its function.

D. **CONTROL LINE**

1. The complete control system (including the safety thong where applicable) must have an inspection and pull test prior to flying.

2. The pull test will be in accordance with the current Competition Regulations for the applicable model aircraft category.

3. Model aircraft not fitting a specific category shall use those pull-test requirements as indicated for Control Line Precision Aerobatics.

4. The flying area must be clear of all utility wires or poles and a model aircraft will not be flown closer than 50 feet to any above-ground electric utility lines.

5. The flying area must be clear of all nonessential participants and spectators before the engine is started

4. Flight instructions

4.1 Autopilot interface

1. Start Ardupilot Mega Planner program
2. In the top right, select the correct COM PORT that the ground station Xbee module is connected to, and select the correct data right.
3. In the top right, select the "Connect" button.
4. On the top left, select the "Flight Planner" tab
5. In the bottom right, select "Home Location" to set the home location.
6. Create a flight plan by creating several waypoints for the aerial vehicle to fly to.
7. On the right, select "Write WPs".

4.2 Takeoff

a. Make sure the autopilot is in manual mode using the RC controller
b. In manual mode, proceed to take off with the aerial vehicle

4.3 Waypoint navigation

a. When stable, use the RC controller and switch the plane to Auto mode.
b. The aerial vehicle should proceed to complete the mission uploaded previously

4.4 Flight Modes

Flight modes are set by utilizing the three position switch labeled channel 6. Through the Autopilot GUI, the positions of the switches can be set to any of these flight modes. This is done through the setup tab in the configuration menu.

- Stabilize – Autopilot stabilizes plane during RC control. When RC controller sticks are released, the autopilot levels the aerial vehicle.
- Fly by wire – The autopilot will hold the current position of the controls of the RC controller. For example, if a stick is held at 5 degrees to the right, the autopilot will turn the aerial vehicle and hold that position. This differs from stabilize because stabilize will continually increase the turn, rather than holding it.
- Autopilot – The autopilot directs the aerial vehicle to previously uploaded GPS waypoints.

- Return to Launch (RTL) – The autopilot directs the aerial vehicle to the launch point and then directs it to circle overhead until further instructions.
- Loiter – The autopilot will circle the location that it is in until further instructions. The radius of the circle can be set using the ground station interface.

4.5 Video Recording

In order to record wireless video the LawMate 1.2 GHz receiver must be connected to a display device capable of running a video recording software. Since the receiver only uses a RCA connector, plug this into the Gigaware converter and attach the converter to a PC via USB. The Gigaware drivers and software are available on the CD, the device includes a video capture suite. This software is very out of date, users may record the wireless video through other software.

One alternative software is ArcSoft Showbiz 5 suite, this demo allows video capture. To do so, select import seen by the red arrow. Select the USB port which the wireless video receiver is connected to.

The video should be visible in the top right hand corner of the player. To record video To record video select the video camera capture button, this is circled in red. The software will capture and record the incoming wireless video signal, and display it as a montage below.

4.6 Landing

1. Once the aerial vehicle completes the mission, use the RC controller and switch the aerial vehicle to manual mode.
2. Land the aerial vehicle.
3. Turn off power to the aerial vehicle

5. Post-flight

5.1 Post flight safety checklist

Even once the aircraft has landed it is extremely important to approach the vehicle carefully. Before doing so the user should quickly perform a Post Flight Safety Checklist. The criteria is necessary to ensure the user or any

1. Leave the handset on with the throttle in the down position.
2. Insure the aircraft has landed and taxied to a safe location clear of other aircraft.
3. Put on eye glasses before working on aircraft.
4. Stay well clear of the prop when approaching aircraft.
5. Turn off RC kill switch.
6. Step away from the aircraft, and have the pilot throttle the plane.
7. If the prop does not move you may approach the aircraft, if not, attempt again to turn off the RC switch.
8. The handset may be turned off if the plane does not react to any input.
9. Walk around aircraft, verify no structural damage.
10. Open front hood and disconnect power, stay away from propeller.
11. Safely move vehicle from the runway, remove wing and check for any electrical shorts.
12. Remove batteries from airplane and store at room temperature in static-free bag.
13. Check all interior and exterior screws, repair and re-fasten any loose ones.
14. Patch any holes in the aircraft and repair any electrical shorts.
15. Save autopilot and ESC data logs and video footage.

5.2 Disassembly

The disassembly of the aircraft for removal from the flight area is completed as:
1. Insure pilot keeps handset powered on, and throttle stick down.
2. If the pilot has a grudge against you, or hates you, do not approach aircraft.
3. Keep clear of the prop as you approach aircraft.
4. Loosen wing attachments and disconnect aileron servo wire from autopilot.
5. Remove wings from fuselage.
6. Disconnect ESC throttle cable from Autopilot or RC receiver.

7. Disconnect motor batteries from ESC and BEC.

8. Pilot may now power down handset.

9. Disconnect batteries from camera and receiver.

10. Wings and fuselage may now be carried separately off of flight area.

11. Remove batteries once the aircraft is out of the flight area.

12. Store batteries in a safe, cool location and monitor for 30 minutes before stowing.

5.3 Data logging

The ESC features a dynamic logging feature that records voltage current and many other parameters that can be downloaded after a flight. To download the logged data the following steps must be completed:

1. Download the required software onto a computer:

   http://www.castlecreations.com/downloads.html

2. Plug the USB cord into the computer and open the software.

3. Plug the other end of the cable into the throttle lead coming out of the ESC.

4. The USB-throttle lead adaptor should be flashing.

5. Connect power to the ESC.

6. The software should automatically detect the ESC.

7. Go to logging to download the data and follow the prompts.

The castle link cable can also be used to program the BEC output voltage by following the same steps, and using a small jumper to connect the cable to the BEC port.
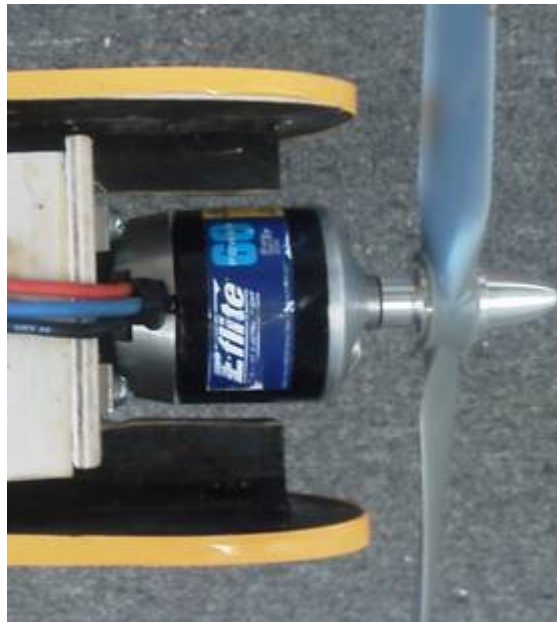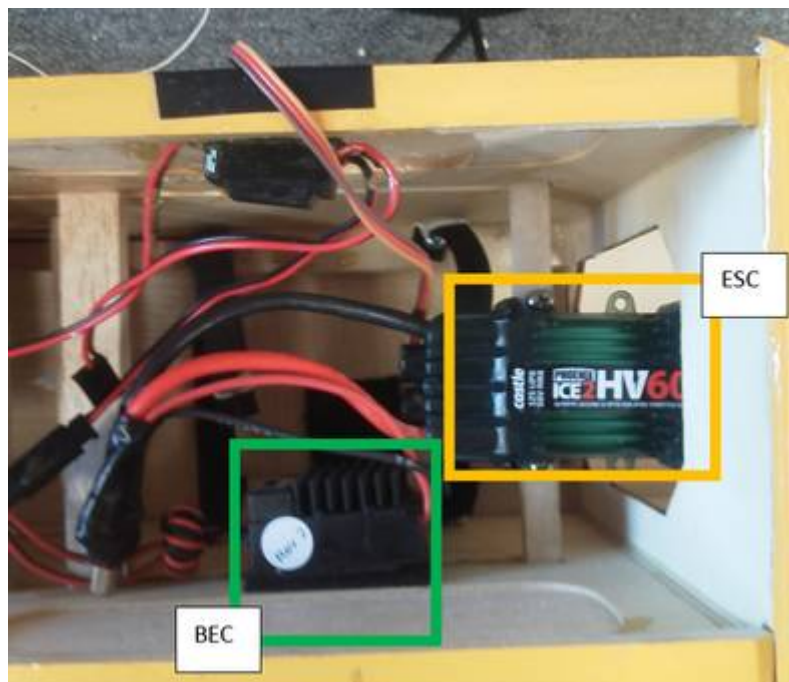
6. Electronic component pictures

Figure 6.3: Control Surface Servo and control arm

Figure 6.4: Autopilot Board connected to servos

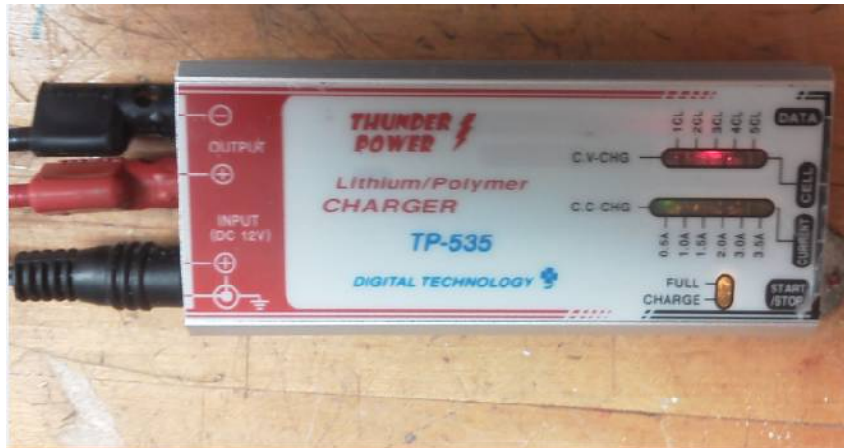**Figure 6.5: Futaba Transmitter**

Figure 6.6: Futaba Receiver

Figure 6.7: Battery Charger

Figure 6.8: Video Receiver

Figure 6.9: Bottom of Video Rec. With correct pin settings

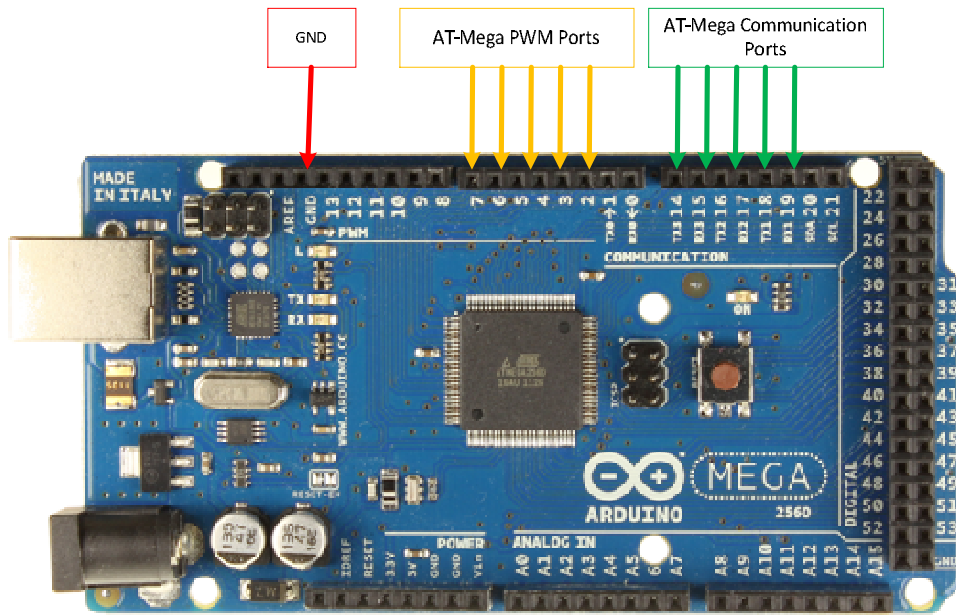**Figure 6.10: Lawmate Video Transmitter**

Figure 6.11: Arduino Mega Board

Figure 6.12: I-shot Block camera Interface board

Figure 6.12: Sony Block Camera

Figure 6.13: Sony CCD Test Camera

Figure 6.14: Large Battery

Figure 6.15: Small Battery