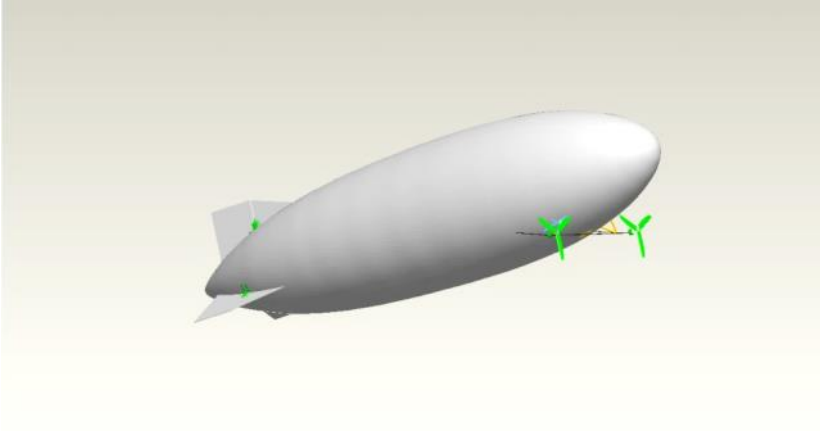
silent_runner

HOW TO

Contact: andreas@windreiter.de, www.windreiter.de

Contributors: Andreas Burkart, Thomas Burkart, Clemens Mayer, André Sobotta, Martin Zobel and Johannes Eißing



silent_runner datasheet	
length:	2.2 m
diameter:	0.5 m
mass:	300 g
motors:	2x Brushless
ESC:	2x 6 A
battery:	LiPo 2S 500 mAh
speed:	4 m/s
endurance:	45 min

Introduction

The silent_runner project is an open project aiming to build a high performance model airship. All building processes are well documented to make it easy to build your own ship. The design of the ship is based on some hundred years of experience of the airship community starting from the old rigid airships, over several blimp designs up to new developments in lighter than air technology and electronics. All components are easy to buy or to build and can even be manipulated to fit your purpose. The actual design of the silent_runner is optimized for speed and maneuverability, but can be adapted to whatever you wish. The size of the airship is with 2.2 m length chosen for, easy transportation in inflated conditions, and a low consumption of lifting gas. An Arduino microcontroller as the central processing unit of the ship is used for flexible attachment of other components, other ways of communication or even autonomous operation. All components are low cost and should be available all over the world.

Airships have, other than planes or helicopter, about the same weight as the surrounding air. This is achieved by the use of a lifting gas like helium or hydrogen inside a large envelope. The principle of being “lighter than air” opens up several advantages, but on the other side has some drawbacks. Airships use very low energy, as they don´t need to waste power for floating. On the other hand, airships are, due to their large size and low density, sensitive to wind. In the past and nowadays, endless efforts were put into the design of efficient airships. The results of these efforts are collected in the simple and straight forward design of the silent_runner, featuring easy assembly and standard components.

Parts

Structure

1. **Depron** for the three fins: 3mm thickness, about 0.5 m²
2. **CFK rods** 3 mm diameter:
   For the motor rig: 1 x 50 cm; 2 x 20 cm
   For the three fins: 3 x 13 cm
3. **Printed Parts**
   For the motor rig: 2x Linkage Connector; 2x Linkage Backup; 2x Motor Mount
   For the three fins: 3x Servo Mount; 3x Rudder Backup; 3x Rudder Adapter
   (see Wiki for the files or http://www.thingiverse.com/thing:31180)

Hull

1. **Latex** airship shaped ballon with at least 200 g of lift/300 L volume.
   OR
2. **Octax** hull welded after silent_runner template (see Construction->Hull)

Electronics

1. 3 x **Servo** 23 mm x 12 mm x 27 mm, 7 g
2. 2 x **Brushless Motor**, 11 g
3. 2 x **ESC 6A**, 6 g
4. 1 x **Receiver+Sender** ≥3 channels, 7 g
5. 1 x **Arduino Pro Mini** (optional)
6. 1 x **Battery** 2S Lipo, 28 g
7. A set of thin **wires**
   (See Appendix for an exemplary shopping list)

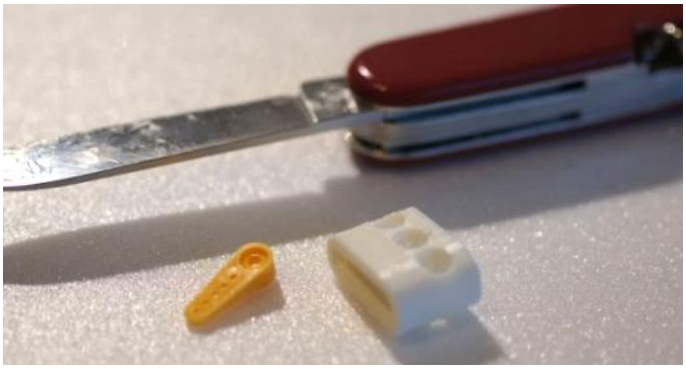
Tools

1. Epoxy Glue
2. Soldering tools
3. Fine saw
4. 3 mm drill
5. Sharp knife
6. Tape
7. Additional tools are necessary for welding an octax hull (see Construction->Hull)
8. Additional tools and software are needed for programming the Arduino

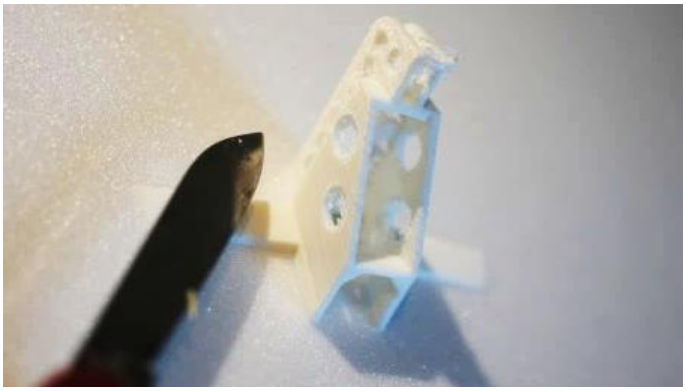
Construction

Rudders

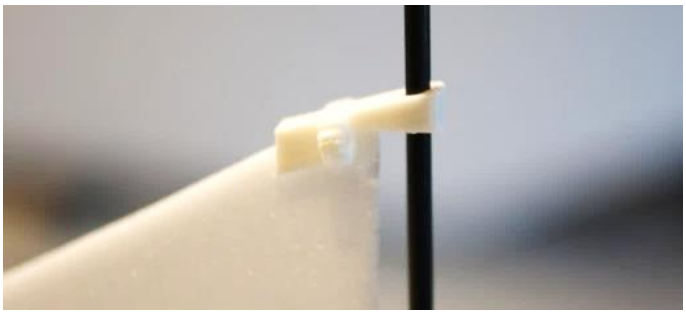
1. Preparing the printed parts:



3x **Rudder adapter**: Use a 3mm drill to open the hole and use a knife to open the slit for the depron. The servo horn should snap fit in the bottom.



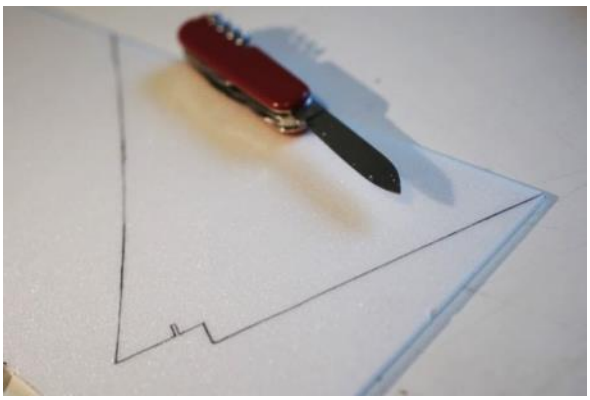
3x **Servo mount**: Use a knife to clean the part from printing remains. Make sure the servo snap-fits in and the depron slides in the back of the part.



3x **Rudder backup**: Use a knife to clean the part from printing remains in a way that the depron fits in the lower part and a thin cord goes easily through the two holes. Use a 3 mm drill to open the big hole.

2. Cutting the Depron:

Using a sharp knife, cut the two **rudder parts** 3 times. Each after the template found in the appendix.

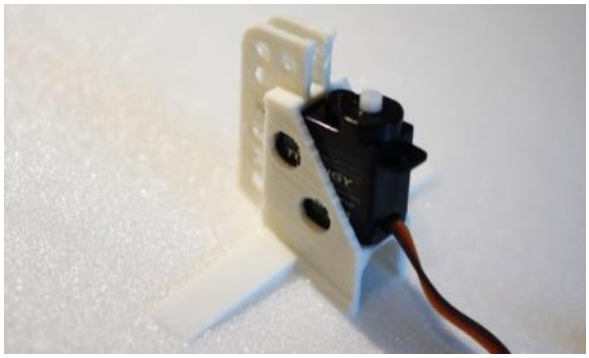


3. Cutting the **CFK rods**:

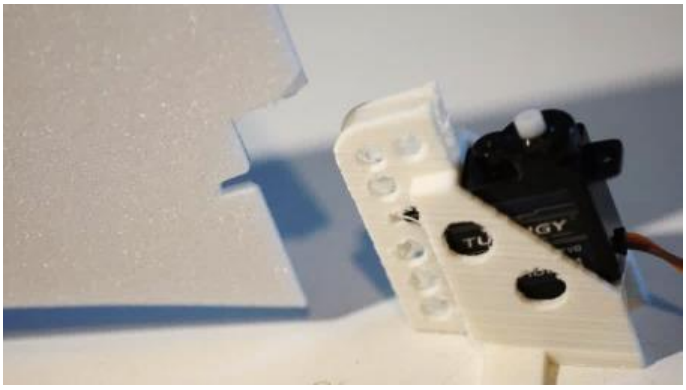
Use a fine saw to cut the three **CFK rods** for the rudders 3x 13 cm. Work clean and make sure to vacuum all CFK dust as it might be harmful when breathed in.

4. Gluing everything together (Use Epoxy):

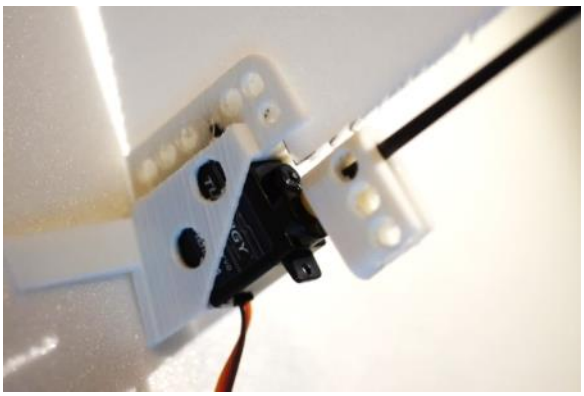
Glue the servo horn into the r**udder adapter**.



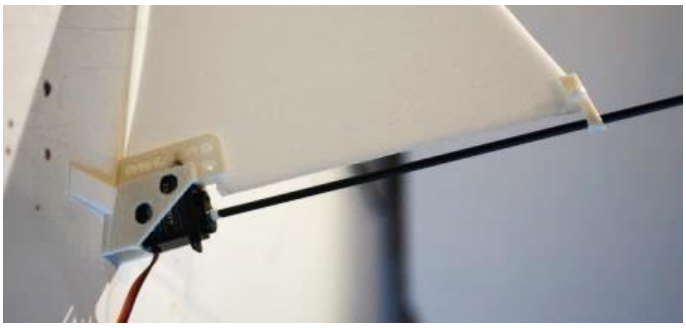
If the snap fit of the servo in the **servo adapter** is not rugged, glue the servo into the **rudder adapter**. Or use just tape, to remove the servo later.



Glue the front Depron part into the Servo Mount.



Glue a CFK rod into the **rudder adaper.**



On the upper edge of this Depron part, glue the **rudder backup**. Make sure the 3 mm hole is vertically above the servo horn.

Glue the rudder part of the Depron into the **rudder adapter** and to the **13 cm CFK rod**. Shape the moveable rudder part as you wish, that´s the individual part of your silent runner and we love to see different shapes. Slow indoor ships should have big rudders (18 cm long) faster ships use shorter rudders.

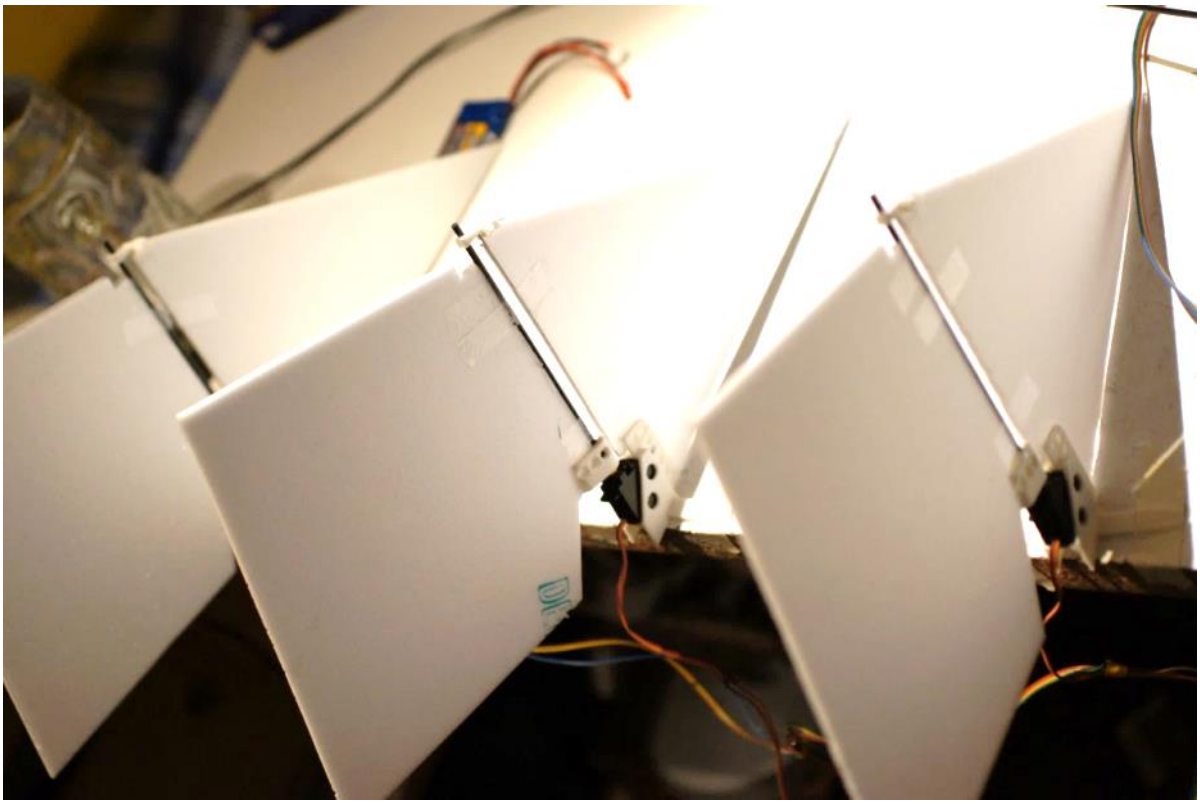
Support by **tape**:

Plug the fixed fin with the servo and the moveable rudder together and attach the servo horn to the servo. Make sure the servo is in neutral position. When the servo is in neutral position, use tape to connect both Depron parts, which prevents vertical movement. To change the servo position later you will have to remove the tape.

Make sure the fins can freely move 90° to the left and right, as the silent_runner code uses the full range of the servo which is way larger than the movement range of common RC sender-receiver combinations.

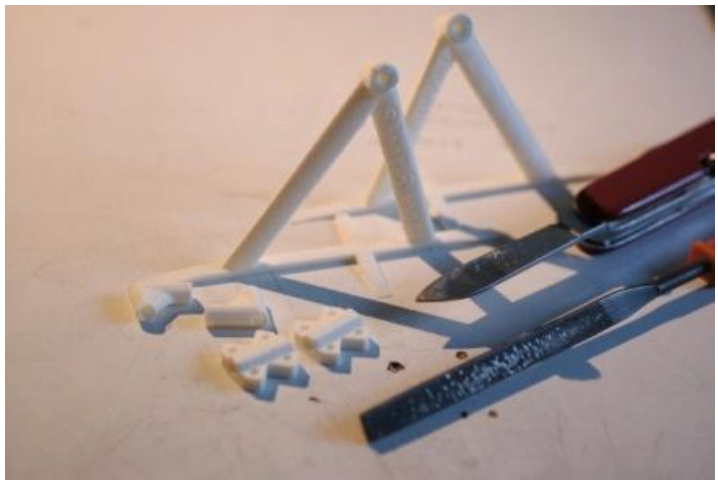
This is how the 3 fins look like in the end. Each weighs about 20 g.

The two small holes at the **rudder backup** will be connected by a thin line once the fins are taped to the balloon. This increases the strength of the fin layout during hard maneuvers.



Motor rig

1. Preparing the printed parts:

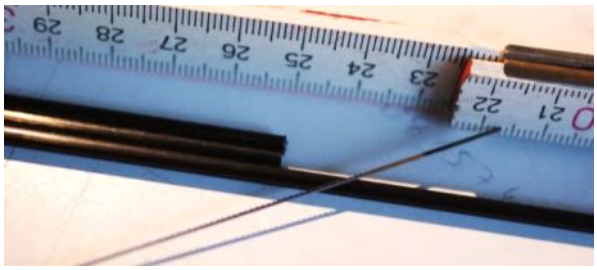


2x **Linkage backup**: Open the hole to 3 mm using a drill.

2x **Linkage connector**: Open both holes to 3 mm using a drill.

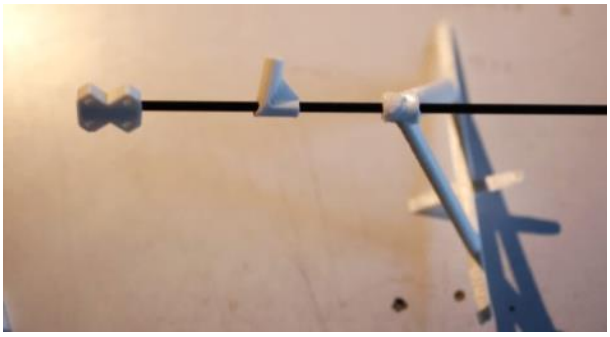
2x **Motor mount**: Open the horizontal hole to 3 mm and depending on the screw diameter you use to fix the motor, open up the screw holes as well.

2. Cutting the **3mm CFK rods**:



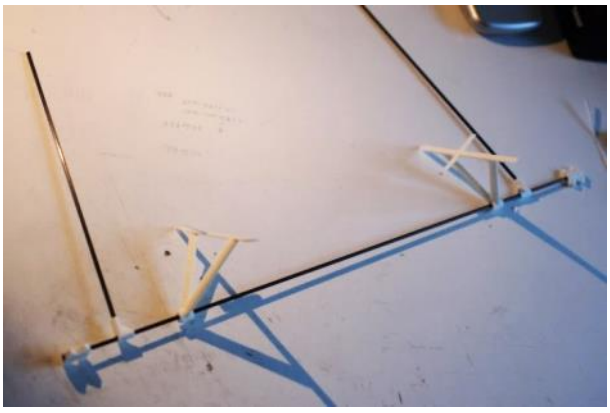
Cut 2 CFK tubes with 20 cm length and 1 CFK tube with 50 cm length. Work clean and make sure to vacuum all CFK dust as it might be harmful when breathed in.

3. Gluing everything together (Use Epoxy):



First put all the parts on the **50 cm tube**. In the center there are the two **linkage backups**, second there come the **linkage connector** and the most outer parts are the two **motor mounts**.

Glue the **motor mounts** first using a good amount of Epoxy to make them tight. Be sure both are facing exactly the same direction.



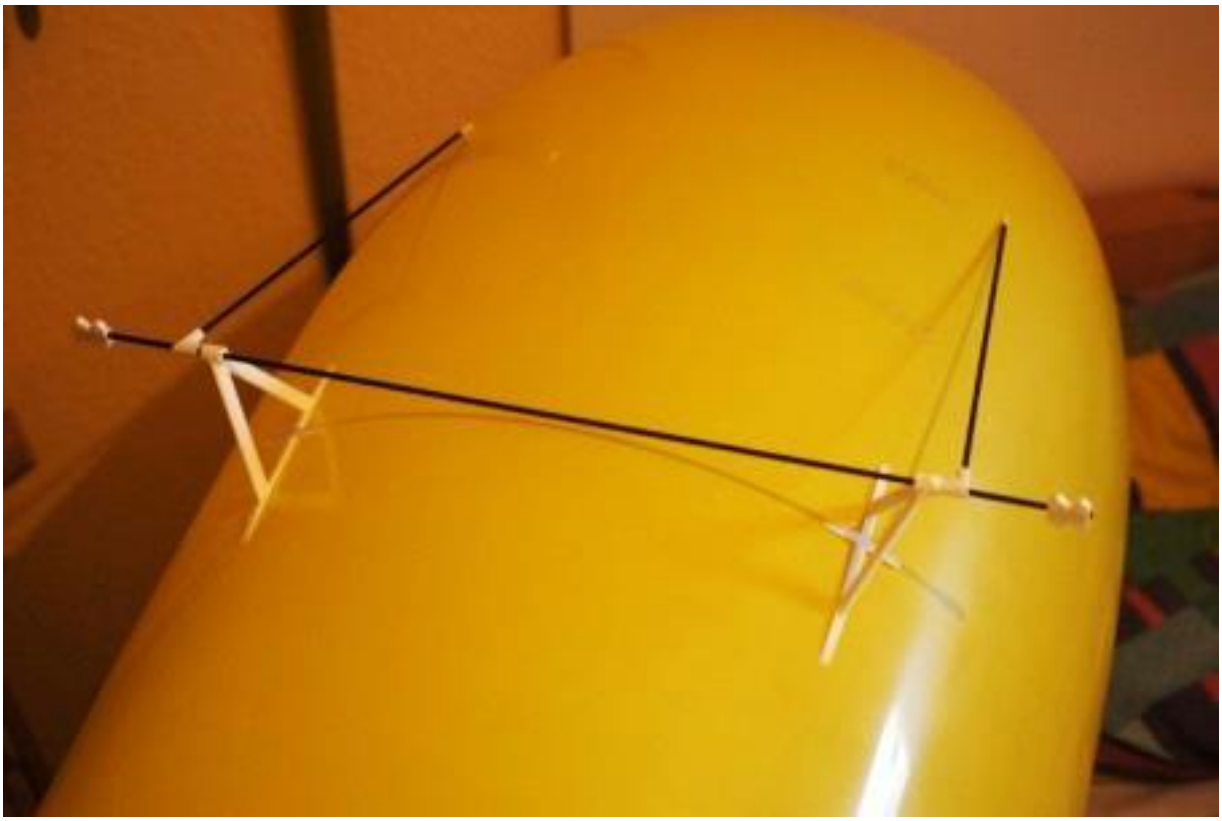
Second glue the **20 cm carbon rods** in the **Linkage connectors**

Then use glue to fix the angle of the **linkage connectors**. The angle must be chosen in a way, that the motors face horizontally backwards when the tips of the 20 cm rods are taped to the **hull**.

Don’t glue the **linkage backup** to the CKF rod, as you might want to adjust the angle of the motors.

You can put shrink tube or tape on the tip of the **20 cm CFK** rods to prevent penetration of the **balloon**.

This is how the **motor rig** looks like in the end, as attached to a latex **balloon**. The motors are pushing and thus facing backwards. The 20 cm rods transfer the force to the hull of the airship.

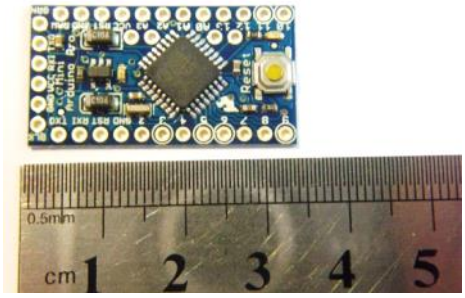


Arduino(optional)

(if you can program your RC-Sender to control the lambda fin layout, skip the Arduino)

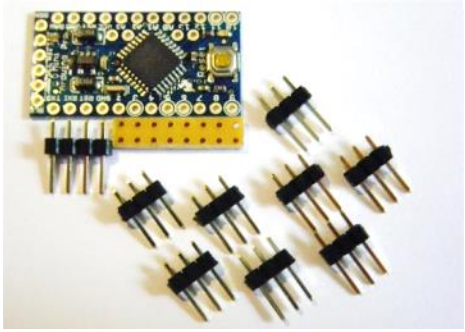
1. Soldering:

To enable the Arduino to control the RC electronics and receive the signals from the RC-Receiver, it is necessary to solder some connectors to it. It is also necessary to solder connectors for programming to the board. This is done as described in the following pictures.



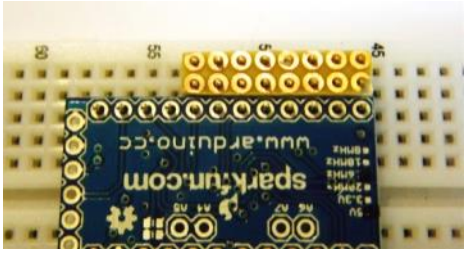
A

The bare Arduino pro Mini 5V board. The lower side of the board provides all necessary pins(2-9, GND-TX)



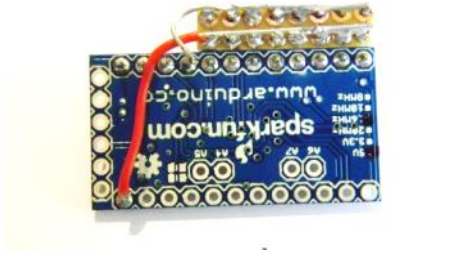
B

Cut a conductor plate to the right size (2x8 holes) and cut the pins as shown in the picture



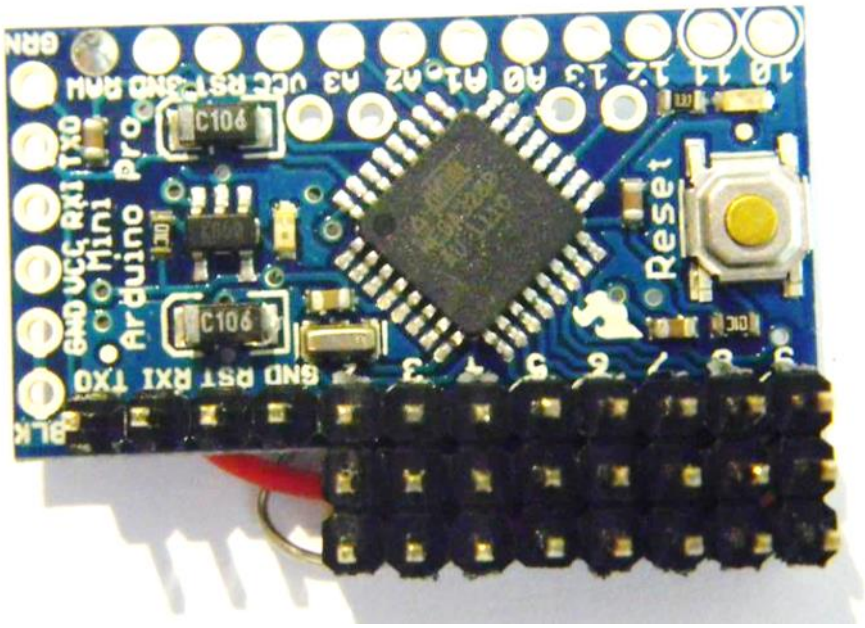
C

For soldering it is easier to place the whole board on a breadboard to fix all the pins.



D

Connect RAW to the middle line of the triple pins and GND to the top line. All other pins are separately soldered to the Arduino board.



The final Arduino looks like this. Note that all the pins on the top are free to use and provide amazing capabilities for advanced functions. Servo cable will be connected with the SIGNAL (white/orange) to the Arduino pins, the middle pin to +5V RED and the lower pin to GND BLACK

2. Programming:

For processing control inputs and output to engines and control surfaces, an Arduino is implemented in the silent_runner configuration. This microcontroller is programmed with a specific code that translates the receiver inputs by formulas to the desired servo outputs. Code development is done in the Arduino environment, which is freely available like the silent_runner code. For the current version of the code visit https://github.com/wemperor/silent_runner. The code consists of very basic parts, which are essential to control the ship, but can be expanded easily. The code is intensively commented for fast understanding. To upload the code on the Arduino pro Mini, a serial connection must be established to a computer running the Arduino software. For more information go to www.arduino.cc.

For more information how to upload the silent_runner code to the Arduino pro Mini, see the following homepage: http://arduino.cc/de/Main/ArduinoBoardProMini

Note that there are other Arduino boards that can be used, such as the Arduino Micro or the Flyduino pro Mini.

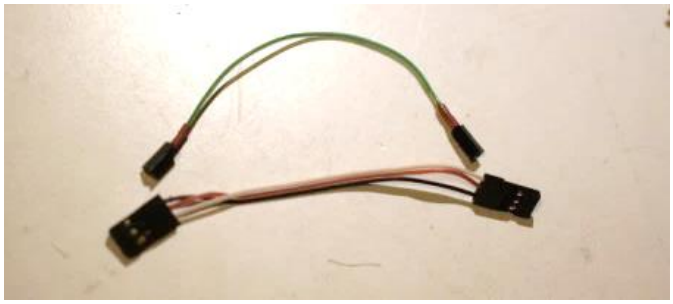
Wiring

1. Cutting the **wires**:

Connection of **Receiver** to **Arduino**:

1x **3-wire** with male Servo plug on both ends, 8cm RED, BLACK, YELLOW

1x **1-wire** with as single female plug on both sides, 8 cm, YELLOW



Connection of **Arduino** to the 3 **Servos**:

This is a complex piece of soldering long wires together. To save weight, we don't use 3 servo wires to control the **servos**, but use 3 signal lines and the two power lines +5V and GND. At the end of the airship the power lines split up to the **servos** again. You need:

1x **+5V**, 2 m, RED

1x **GND**, 2 m, BLACK

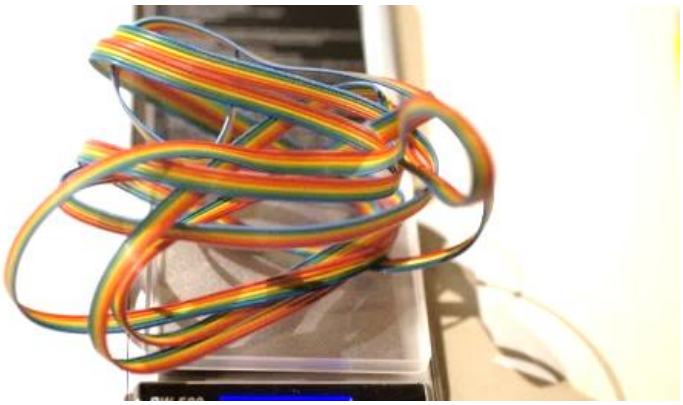
1x **Signal fin up**, 2 m, YELLOW

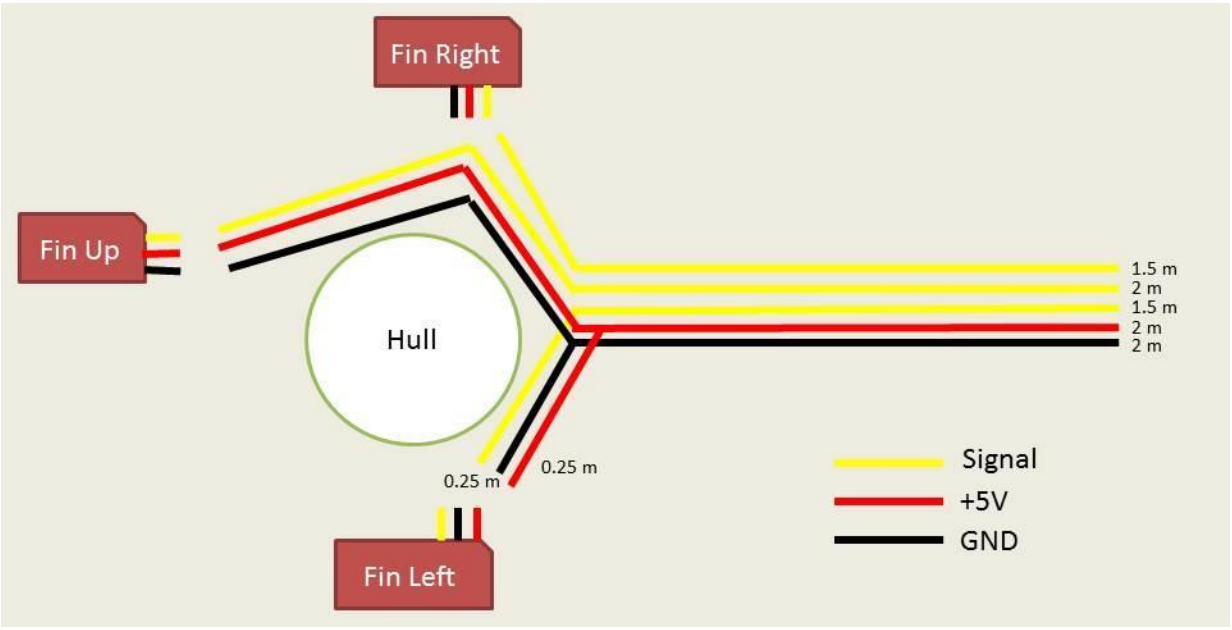
1x **Signal fin right**, 1.5 m, YELLOW

1x **Signal fin left**, 1.5 m, YELLOW

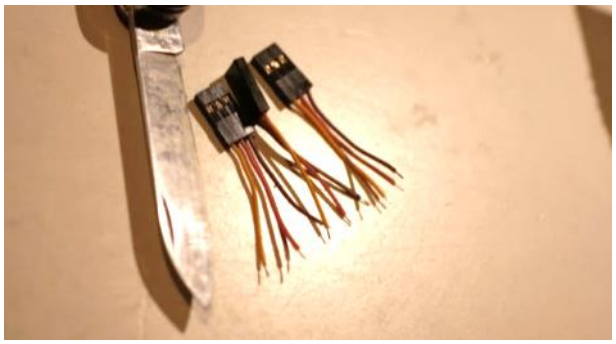
1x +5V left fin, 0.25 m, RED

1x GND left fin, 0.25 m, BLACK



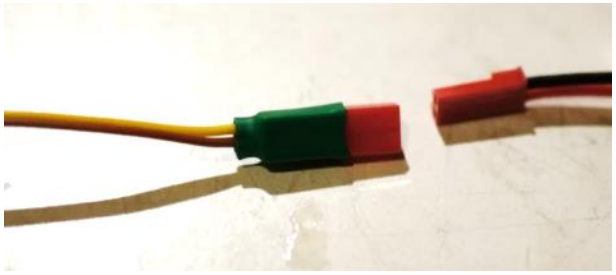


Cut the 3 **servo plugs** of the **servo**, as they will be soldered to the other end of the long wires to establish the connection to the **Arduino**. Keep about 5 cm wire with the plugs.



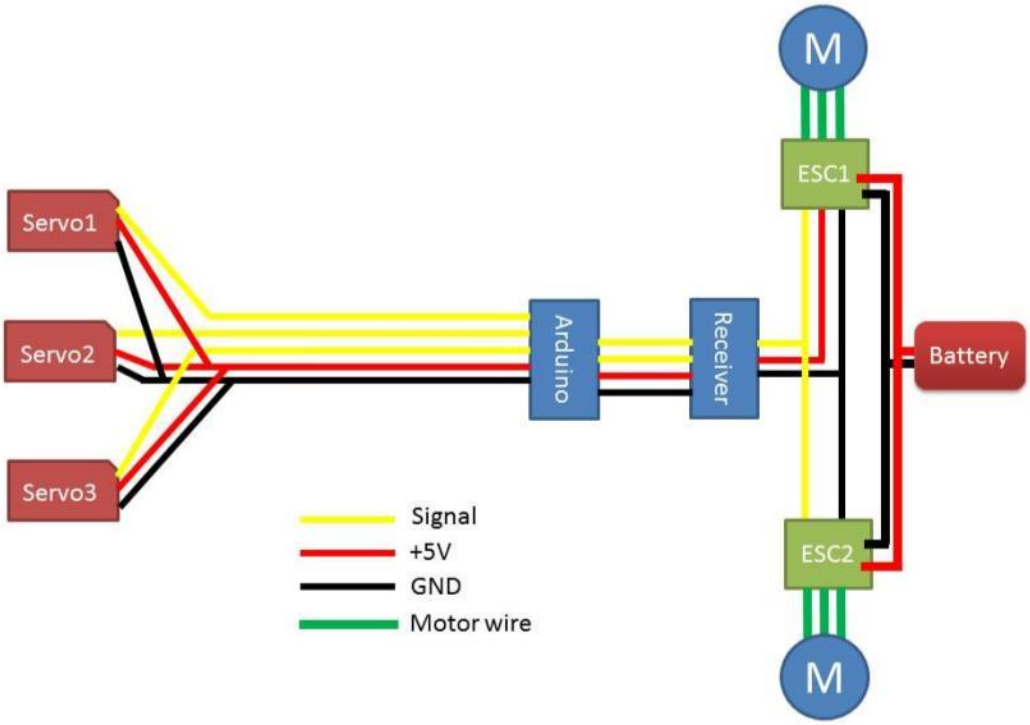
Connection of the **Battery** to the two **ESC**:

1x **two-line wire** with a female battery plug on one end, 30 cm, RED, BLACK. This wire transfers all electrical power, so should not be too thin.



2. Soldering everything together:

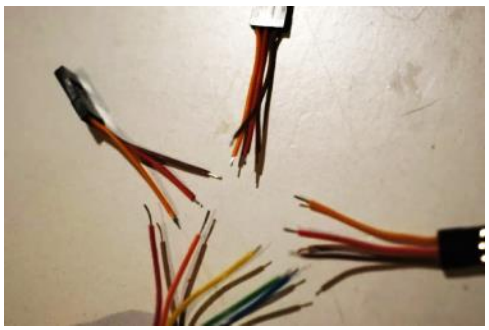
This figure shows schematically all wire connections of the silent_runner. Make sure to fully understand the way of signal and power before soldering the components.



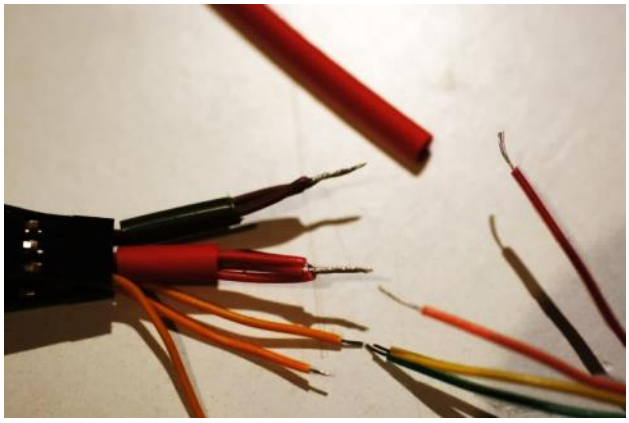
In the following some tricky steps are shown with pictures:

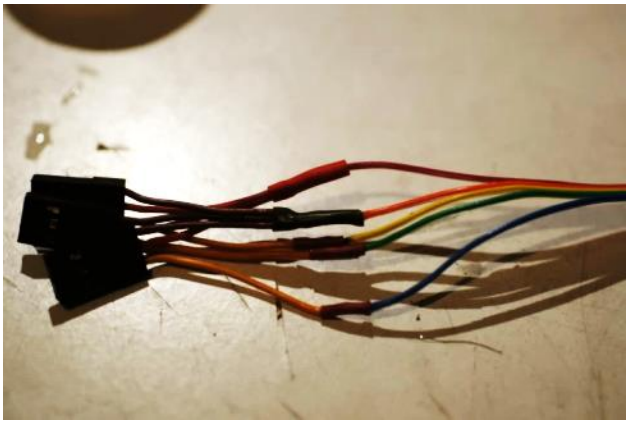
Soldering the 3 **Servo plugs** to the 5 wires from the fins to connect to the Arduino:

Each signal from the fins goes to one signal wire of each plug.



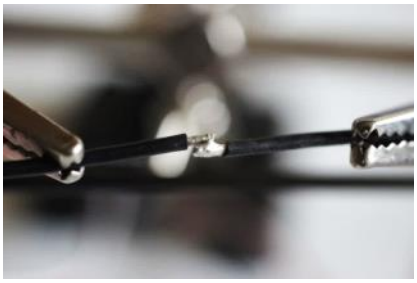
The +5V RED and the GND BLACK from the fins goes to all three plugs at the same time. Remove about one cm isolation from the black and red wire of the servo plugs. Then spin all 3 black wires together. Spin all 3 red wires together too. Then solder this package of wires to the single +5V or GND line coming from the fins. Wrap everything with shrinking tube once it´s firmly soldered.

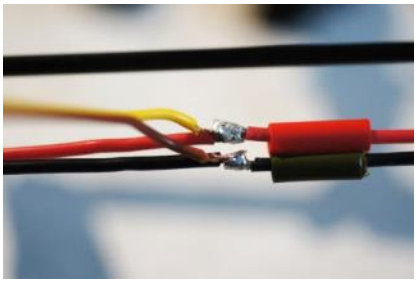


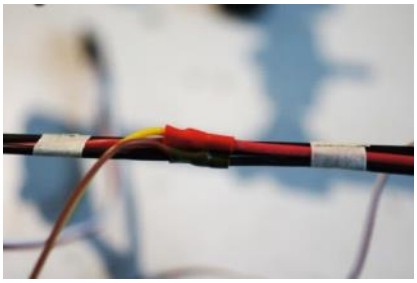


Soldering the battery cable to the **ESC** power input wires:

Solder the thick RED and BLACK wires of the **ESCs** to each other. BLACK to BLACK and RED to RED. Then Solder the BLACK line of the battery cable to the joint of the BLACK **ESC** wires. Do the same with the RED lines.







Soldering the ESCs to the motors:

The three wires of the ESC are soldered to the three wires of the motor. After you´ve soldered everything together make a test run of the motor. If it does not rotate in the right direction, open two of the solderings and switch the motor wires. The motor will then reverse its rotation.

Soldering the servo wires of the ESC together:

Solder the BLACK wires together. Solder the Signal line together as well. You need just one ESC to provide 5V BEC power, so remove one +5V RED wire. 2 BLACK, 2 Signal and 1 RED wire should go into the remaining servo plug that goes into the receiver.

Soldering the long servo lines:

Just make sure to fully understand the wiring as shown in the two wiring figures, and then go for it.

3. Attaching and connecting the electrical components

Attaching components to the **motor rig**:

The motors are screwed to the motor mounts by using M2 screws. Use nuts with rubber inlay to prevent them from getting lose by vibration or put glue/Locktite on the screw. Attach wires and ESC firmly to the 50 cm CFK rod by using tape or cable tie.

Connection of **Servos**, **Arduino** and **Receiver**:

Receiver to **Arduino** (SIGNAL):

Up/Down Channel of the Receiver to:
PIN7 of the Arduino

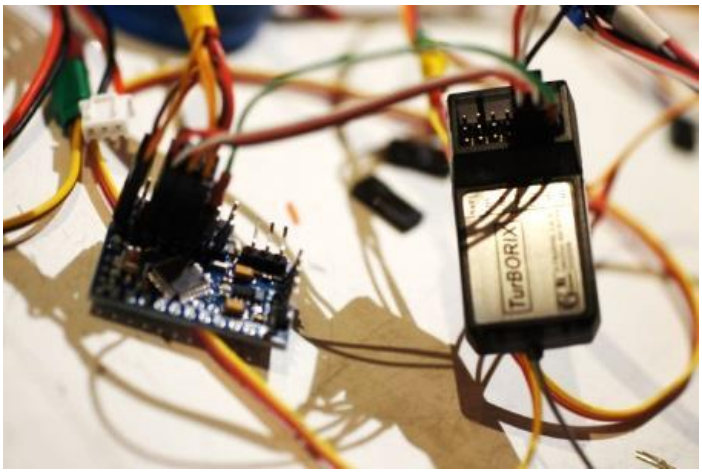
Left/Right Channel of the Receiver to:
PIN4 of the Arduiono

Arduino to **Servos** (SIGNAL):

Servo Up to:
PIN9 of the Arduino

Servo Left to:
PIN5 of the Arduino

Servo Right to:
PIN6 of the Arduino



Hull

1. Using the Latex Ballon:

Using a huge airship shaped latex balloon as hull is pretty straight forward and easy. Balloons of good quality can be inflated several times. To close the vent of the balloon, use a plastic clip as usually used to close freezerbags. The balloon should have 300 L volume and <90 g weight to lift the ship

2. Welding an Octax hull:

Building of an Octax hull can give beautiful results but on the other hand requires huge efforts. Find a full explanation of the building process in the documentation:
http://www.silent-runner.net/index.php/Documentation

Inflation and balancing

1. Setup:

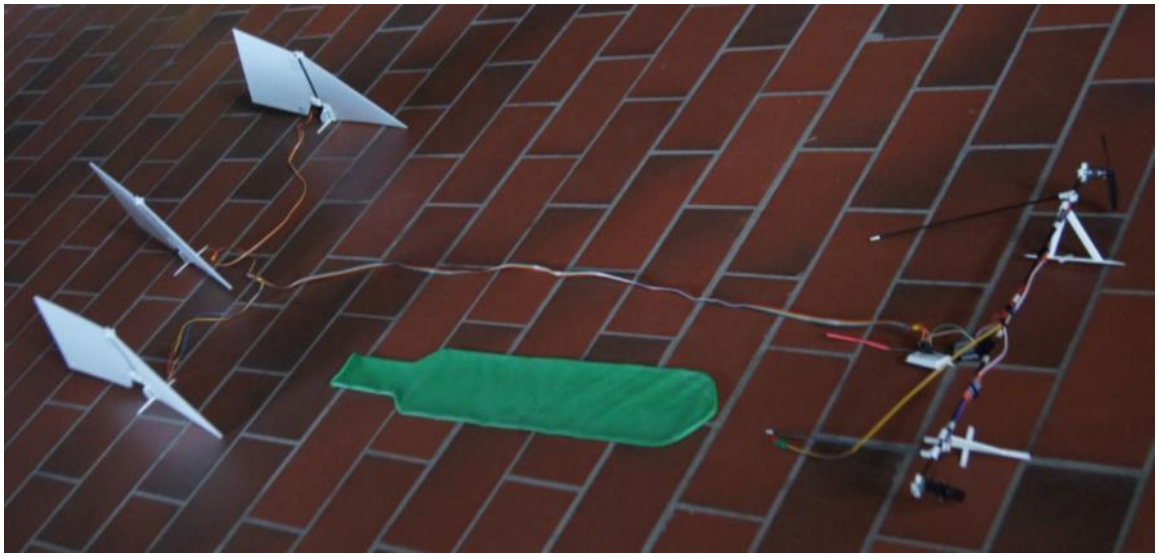
   What you need:

   Lifting Gas (Helium, at least 300 L), probably a compressed bottle with pressure regulator and tube to get the gas inside the balloon.

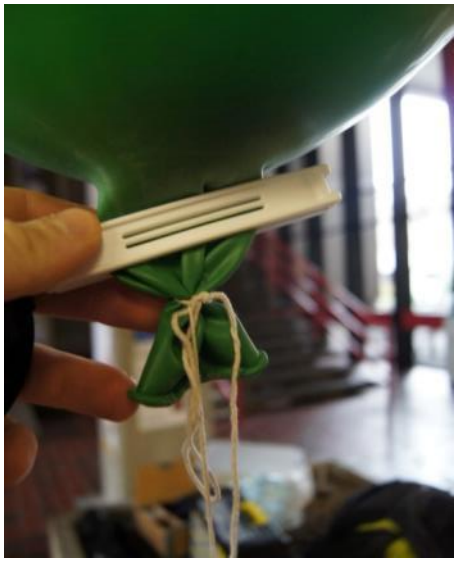
   Weights, some heavy weights to keep the airship tethered to the ground and some light ones (coins) to balance it.

   Strings to hold the balloon to the ground and to connect the rudders

   Tape to fix the components to the hull



Inflation:

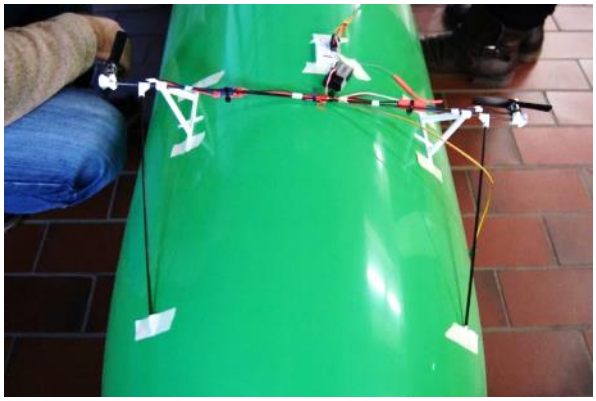


Fill the balloon slowly with helium. If you use an **Octax hull**, fill it up to good tension, but don´t put too much pressure.
If you use a **Latex balloon**, you should prepare a weight with the same weight as the electronics plus some ballast. Then fill the balloon until it lifts the weight. Close the Latex Balloon with a clip and double check if the valve is closed properly (see appendix for some notes on handling a latex balloon).

2. Attachement of the parts:

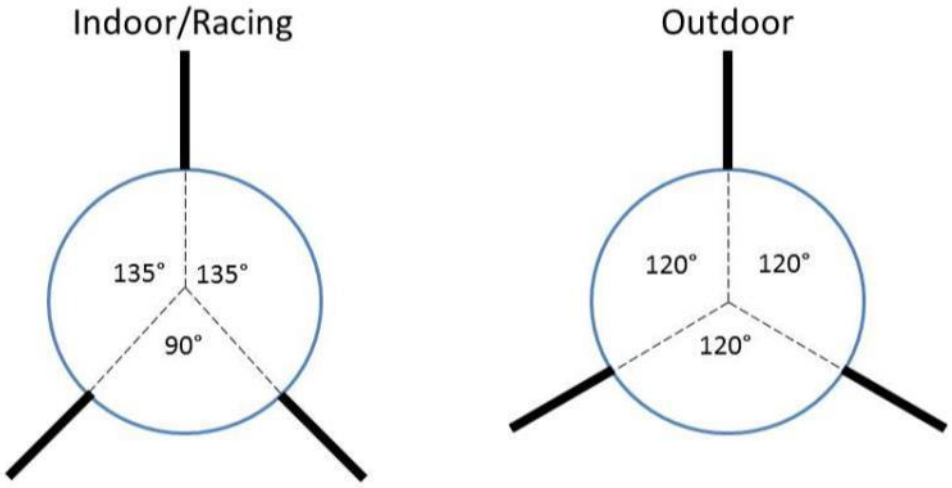
Usually parts are attached like this (measured in distance from the nose):

Motor Rig:	60 cm
Arduino+Receiver:	65 cm
Fins:	200 cm
Battery:	30-90 cm, use the battery to level the ship



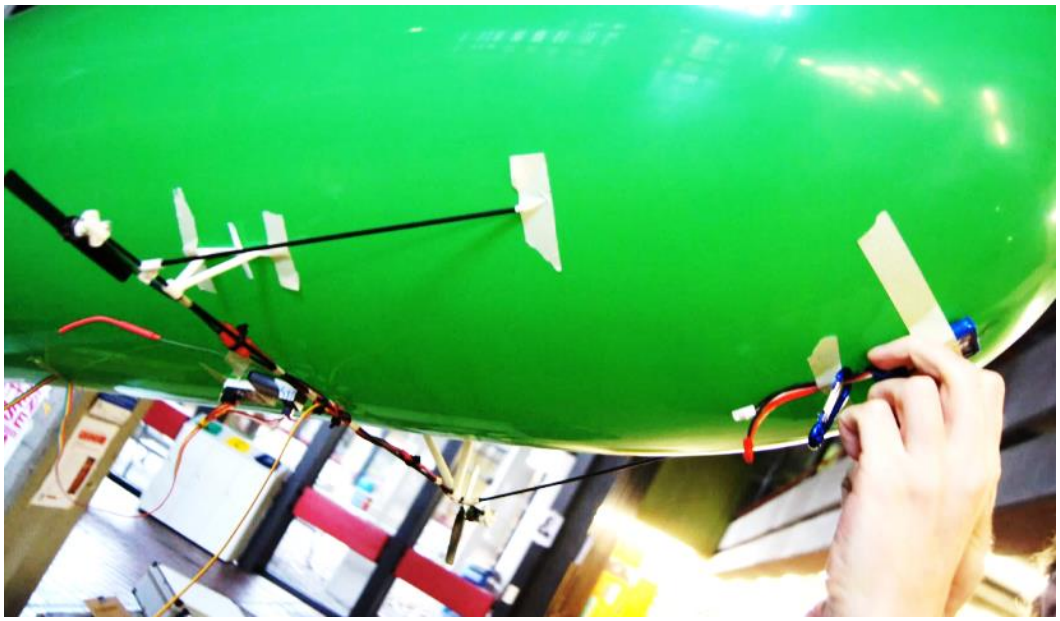
Attaching the **lambda fin** layout:

Depending on the flight situation the angles of the lambda layout can be adapted. If you want to fly indoor or you have a racing track with sharp turns, the agility for horizontal turns can be increased by sacrificing agility in the vertical up and down. If you fly outdoors you will need good control of the altitude, so keep the angle between the fins at 120°. Follow the layout in the figure below to attach the fins to the hull.



3. Balancing:

   Once all components except the battery is connected, put the battery on the top of the balloon and move it from nose to stern until the ship is perfectly horizontal. Tape the battery to the lower side of the balloon at exactly that position. Fine tune the balance of the ship with some coins taped to the stern or nose.
   Attach enough ballast to make the ship gently coming down, in other words fly it heavy.



Flying

Flying the silent_runner is easy, just give it a try and have fun. But there are two critical things you should be aware to not lose the ship:

1. **Fly it heavy**
   Put enough ballast on the ship to make it a bit heavier than air. If you fly indoor 1-2 g is enough. Outdoors you can fly fast and add more weight to make it come down quick if it´s blown away.
2. **Attach everything firmly**
   If something falls of the ship, it will become lighter than air and goes to the ceiling or even worse, to the sky. Attach everything nicely to the hull using a good amount of tape and make sure everything stays in place during flight.

Appendix

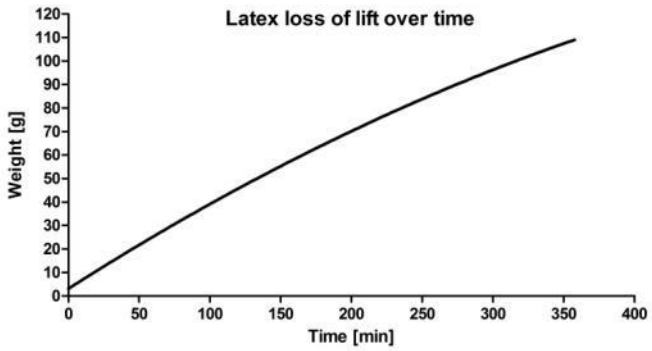
Bill of material, exemplary, cheap and light:

Electronics	**Count**	**Name**	**Weight [g]**
Motor	2	Turnigy 1811 Bruhless Motor	11
ESC	2	Turnigy Plush 6A	6
Battery	1	Zippy Flightmax 500 mAh Lipo	28
Sender + Receiver	1	Hobby King 2.4 Ghz 6CH V2 Mode 2 + receiver	7
Servo	3	Turnigy 1800A Servo	7.05
Wiring		Ribbon-cable and plugs	
Arduino	1	Arduino Pro Mini	2.2
Structure			
CFK	2	Tube 3 mm diameter, 1m length	4
Depron	1	3 mm thickness, 0.5 m²	
Latex Balloon	1	300 l Volume	82

Handling a huge Latex Balloon

The Latex balloons are tempting as they are easy, robust and cheap. Additional they have the advantage that the flexible material keeps the aerodynamic shape of the envelope even if a lot of gas is lost. This makes the Latex balloon perfect for a beginner and half a day of nice flying. On the other hand there are quite a few things to bear in mind when using this kind of balloons.

1. Latex is very permeable for helium. That means the balloon will continuously lose lift with the time. If you have closed the valve of the balloon properly it will lose about 20 g of lifting capacity per hour. So either you fill additional helium in the balloon after some time, or you detach ballast. (A good Octax hull loses about 10 g lift per day)



2. Sometimes the balloons come due to fabrication not perfectly straight. They are formed a bit like a banana. This will affect the flying. The best is, to put the bending in the vertical, so your ship will by its shape go up or down.

3. Whatever tape you use, the longer it stays on the balloon the tighter it will adhere to the Latex. If you leave the tape (sticky / masking tape) longer than 4 hours, it might will rupture the balloon when ripped off. This is even worse when the balloon is deflated. So detach everything before opening the valve and do it straight after the flight.

A comment on the robustness of the silent_runner

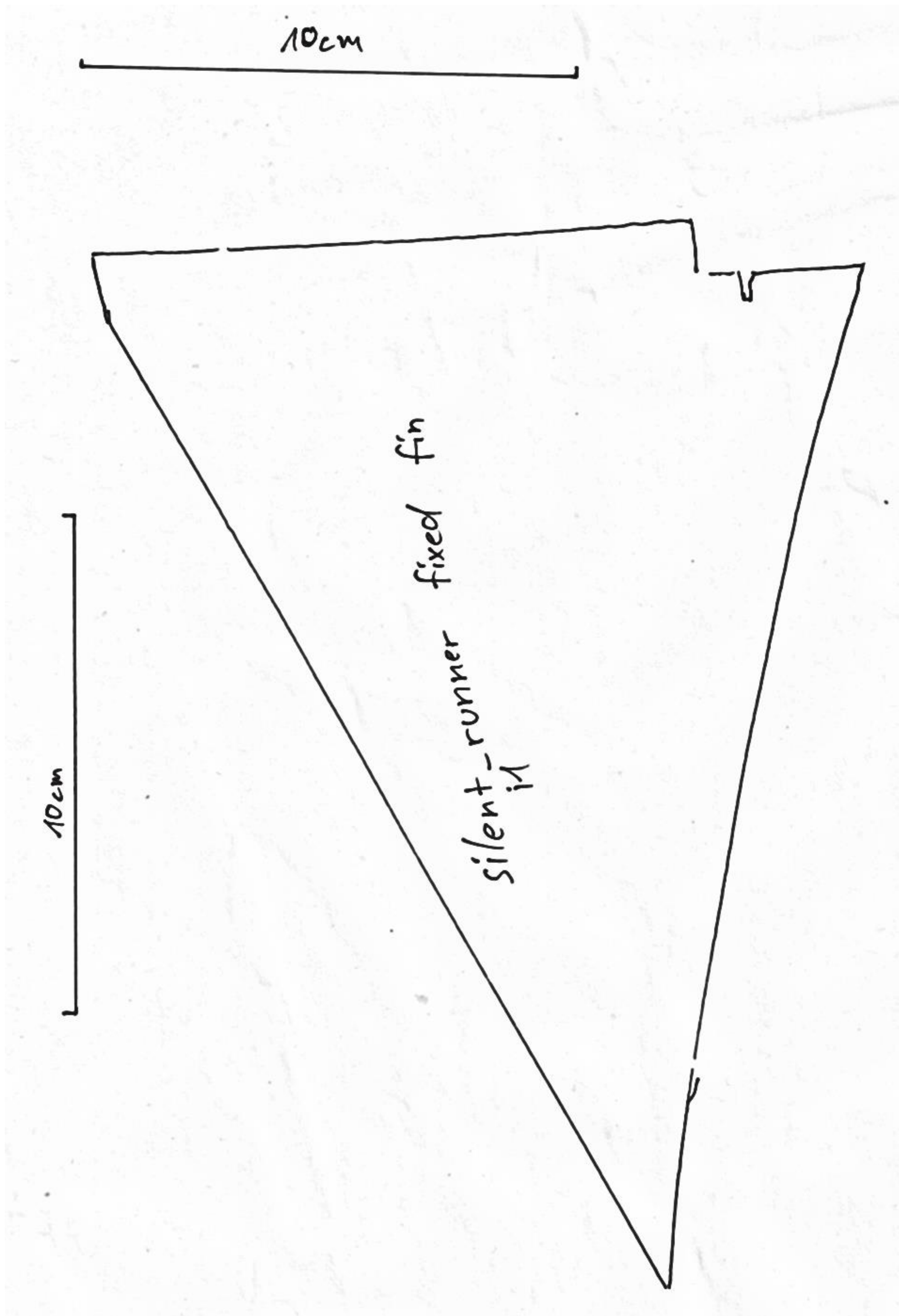
Even though airships seem to be the most fragile aircrafts ever, you will find that the silent_runner is pretty tough. If built properly, the structure components can withstand heavy crashes such as smashing the fins to the wall or scraping the ground with the motor rig. The Latex balloons are incredible robust as well, actually you can sit on it when inflated. Bumping the silent_runner with the front to a wall to stop it or make a sharp turn is a legal maneuver. Nevertheless handle the airship with care to make it last long. And finally keep your ship away from sharp or hot items.

A comment on the lifting gas

We recommend Helium (He) as lifting gas for the silent_runner airship. However as He is quite expensive you might be tempted to go for hydrogen (H2) as lifting gas. H2 is way cheaper, easily available but at the same time easily flammable. Be sure to use hydrogen only outside. Make sure to use pure hydrogen and don´t mix it with air to prevent an explosive mixture of H2 and oxygen. By diffusion oxygen will leak into the hull with time, this effect is fast in Latex hulls and slow in Octax hulls. So after a couple of hours an explosive mixture of H2 and Oxygen will develop inside the Latex balloon. After flying release the H2 from the balloon far away from persons and any source of sparks.

Contacts:

andreas@windreiter.de | www.silent-runner.net | www.windreiter.de |
rc_airship_regatta@yahoogroups.com


10cm
10cm
silent_runner
fixed fin