Silent_Runner

Documentation

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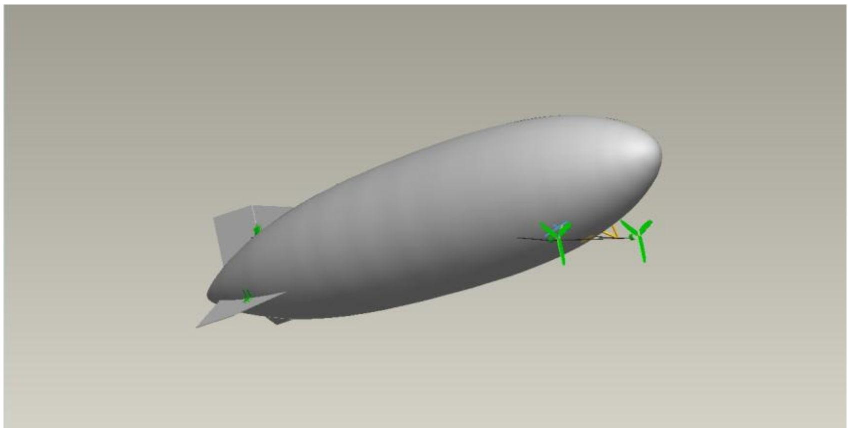

Introduction

The Silent_Runner project is an open project aiming to build a high performance model airship. All building processes will be 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 indoor use, 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 lifting a 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 assemby and standard components.

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Structure

The structure of the Silent_Runner consists out of three kinds of components.

1. The electronics will do all maneuvering and include motors, servos, communication, battery and processing.

2. The hull is the mainframe of the blimp and relies on low internal pressure to maintain the shape of the airship.

3. Further structure parts are the mounts for the motors and the fins. They hold everything together and are fixed to the hull.

For building of these components several methods are used and all of them can be done at home if the specific tools and materials are available. For the electronics, soldering is needed. The hull is usually made by a welding technique and the structure parts are printed by a rapid prototyping machine. For developing the central processing unit some programming is needed to understand and further develop the code.

Components

RC-Electronics

The RC-Electronics consist of two motors, both placed in the lower front of the airship, one on the left (MotorL) and one on the right side (MotorR). Both are brushless outrunner with about 15g weight and a 3 blade propeller. The motors are oversized to gain a high top speed. For other purpose smaller engines can be chosen to save weight. A three-blade propeller is chosen, as the distance between the motor and the hull of the airship is small, thus higher thrust can be reached by larger blade surface. Smaller motors can rely on smaller 2 blade propellers. To reduce the side impulse effect of the propellers, the two motors should go in the opposite direction using counteracting blades. Each motor is controlled by an Electronic Speed Controller (ESC) for brushless motors sized to 10 Ampere. Motors and ESCs are connected by three wires. The direction of rotation can be changed by switching the cables. The ESC itself is only capable of managing forward thrust. If available, bi-directional ESC´s can be considered to even fly backwards or stop the airship. To control the direction of the airship,

Figure 1: Triple-Blade propeller

three servos are used, each placed on one fin. The fins are spread around the stern of the ship in an inverted Y or lambda order with 120° distance to the other fins. We chose 5g servos that are capable of high torque, as high speeds will deliver big forces to the fins. The connection between rc-sender and airship is done by a standard rc-receiver-sender couple with a minimum of 3 channels. We propose a 2.4 Ghz transmitter for a reliable signal, but others will do as well. The most important thing when considering electronics for use in airships is the weight. It was tried to save as much weight as possible by buying small electronics, ripping off not necessary material like stickers, cases and too long or big cables or big plugs. As energy source a 7.4 V 2S Lithium-Polymer battery with 26 g weight is recommended. Higher thrust for the price of less endurance can be reached by using a 3S Lithium-Polymer battery.

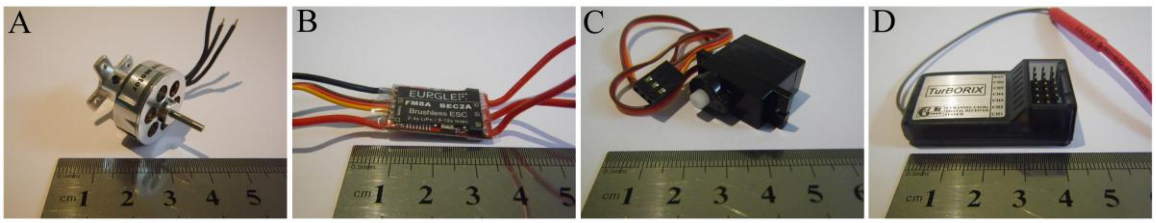

Figure 2: RC electronics used in a Silent_Runner A: Brushless Motor B: Brushless ESC C: Servo D: 6 Channel 2.4 Ghz Receiver

Table 1 Components of the Silent_Runner and the calculated weight.

Component	**Weight [g]**	**Quantity**	**Total [g]**
Hull	100	1	89
Motors	15	2	30
Motor Mounts	16	1	16
Propeller	4	2	8
Lipo 2S	26	1	26
Fins	16	3	48
Servo	5	3	15
Receiver	8	1	8
Arduino Pro Mini	5	1	5
Wires	20	1	20
Ballast	10	1	10
ESC	11	2	22
Total weight:			**297**

Arduino Pro Mini

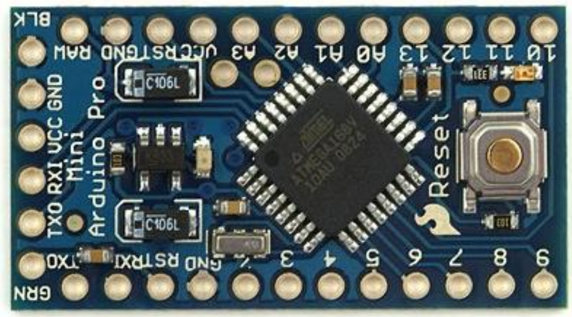

Figure 3: Arduino Pro Mini, designed and manufactured by SparkFun Electronics

The control of the Silent_Runner is in need of some capabilities, standard remote controllers are not able to. Thus a central processing unit was incorporated to include advanced control operation. The Arduino Pro Mini 5V/16Mhz is a microcontroller with a weight of about 2 g, and all features of the widely used Arduino environment (www.arduino.cc). The unit is low cost, robust and simple to use. All signals will be read from the RC-receiver, processed and then delivered to the servos and ESC´s. The controller runs on 5V and is connected to the power source delivered by the ESC´s. It is able to run at least 6 RC-electronics like servos or ESC´s which rely on a PWM signal, thus other functions can be implemented either by using the Arduino or the free channels on the RC-receivers. Secondary it features some more General Purpose Input/Output (GPIO) pins that can be used for powering LED`s connecting to serial devices or whatever is wished. The Arduino needs to be programmed with a specific code designed for the Silent_Runner. If an advanced radio control unit is used, capable of programming and controlling an inverted Y fin layout, the Arduino can be excluded from the design and the Silent_Runner can be controlled just using a stand-alone at least 4 channel RC receiver. This on the other hand will exclude advanced functions.

Hull

The hull of the Silent_Runner is derived from a 4154 Gertler shape, showing a length to diameter ratio of 4:1. This design features low resistance while featuring a high volume. Both are necessary to gain high speed and on the other hand a good lifting capacity to become airborne when filled with gas. As material we recommend Octax, provided by the company aeroIx. This is a lightweight, flexible, gas-tight and weld-able foil, coated with aluminum. By using this material an overall weight of the hull of less than 100g can be achieved, resulting in a lifting capacity of about 200g for electronics and structure parts. For the basic design of the hull, a simple three slice design is proposed which will on the one hand make the exact attachment of the structure parts such as fins easy. On the other hand, this will result in wrinkles, increasing drag. For more sophisticated hulls, six gores (“banana peels”) will make a far better result. Depending on the material available, other techniques can be used, but should be adapted in volume to the properties of the film.

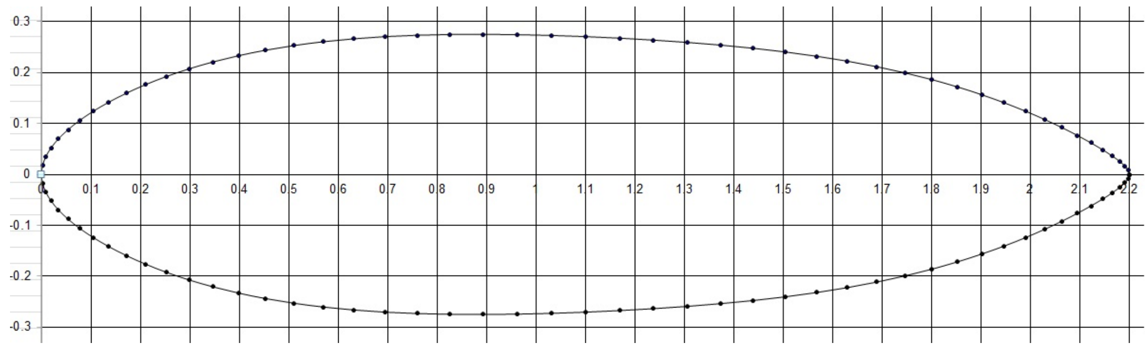

Figure 4: Gertler 4154 Shape with 2.20 m length and 4:1 slenderness ratio, derived from Series-58 4115 Shape tool by Johannes Eissing

Structure Parts

Motor mounts

The motor mounts will deliver the thrust of the motors to the airship and must be strong and on the other hand lightweight. These parts are built with a combination of CFK fibers and 3D printed parts. The parts are attached to the inflated hull by sticky tape like Tesa, Scotch Tape, or the like.

Fins

The fins consist out of stabilizing surfaces and moveable control surfaces (rudder) and they are connected to the hull. The Material for the fin is the lightweight foam material Depron with a strength of 4mm. Epp is also suitable but will may need some reinforcement, preventing flexing of the fins. The rudder is connected to the fin and on the base of the fin to the servo, thus can be controlled for maneuver. Each of the three fins follows the same design, but will be controlled in a different way to make possible all maneuvers. The Inverted Y design is used to maintain stability in curves, in comparison to a V-design, and at the same time lowers the weight in comparison to an X-design. The inverted Y (or "lambda") design was used successfully employed in several Navy Blimps, and is even present in the modern Zeppelin-NT. To build the fins, print the template on paper and cut the parts with a sharp knife from Depron. The fins are then attached to the servo holder and to each other using tape. For the robust and exact attachment of the servo to the fin a lot of effort was put in the design of a structure for that purpose. This servo and fin mounting consists of several printed parts that is optimized for low weight, easy construction and good transfer of forces. The servos arm is directly connected to the fin by a printed part and thus allows the whole movement of the servo transferred to the fin. A small carbon rod

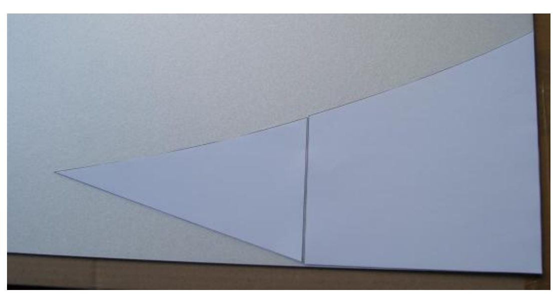

Figure 5 fin template and depron

is used to prevent the fin from flexing, and a top join will connect each fin to both of the other fins of the lambda layout by a 2 mm carbon fiber rod. This provides high stability of the fins even at high speeds. For an indoor application these high efforts may not necessary, and a simpler construction can be chosen. The parts are designed for a specific size of the servo and may need to be fitted for other servo types before use.

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Figure 6 fin control setup of printed parts

Rodding

The rodding is used to connect the Motormounts to each other and to the hull. The rodding includes 3 CFK rods, 2 bar connectors, 2 bar spacer and 1 bar fixing. The bar spacers and bar fixing are mounted directly to the hull. This layout was designed for puller motors with high thrust and will spread the driving force to the ship to several points. For smaller motors, the outer rods can be left out, as well as the center connector. Note that the design is ready for vectored thrust which can easily be implemented by connecting the horizontal rod to a servo.

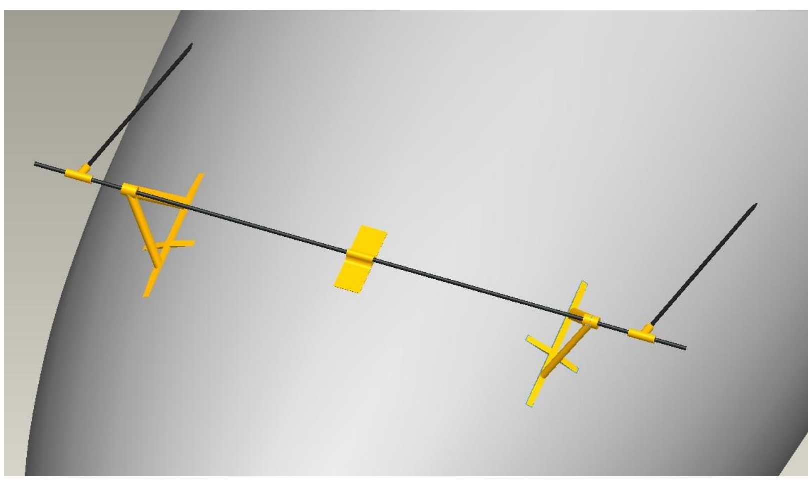

Figure 7 CFK rod, rod connector, rod spacer, rod fixing

Balancing

The airship´s balance is an important part, and before flight, the ship should be balanced to a perfect horizontal level. This allows a straight forward flight. For a good balance the parts of the airship must, regarding to their weight, be placed in a way the weight is spread over the whole ship with the center of gravity below the center of buoyancy. The center of buoyancy can be found with the Series58 Shape Generator http://www.airshipworld.info/software/2009/08/generator-v06-available/

Further stability is gained by placing the parts in the lower area of the ship, thus the center of gravity is low. For placement of the parts see the following table. When finally balanced, make sure the airship is a little heavier than air, to make it smoothly floating down if there´s any problem.

Table 2: Weight and position of the electronic and structure parts

Part	**Weight[g]**	**Position [m from nose]**
Motors	30	0.4
Mounts	32	0.4
Propeller	8	0.4
ESC	22	0.45
Battery	26	0.6
Receiver	8	1
Arduino	5	1
Fins	48	1.9
Servo	15	1.9
Ballast	10	2
Center of gravity from nose [m]:		**1.01**
Total weight [g]:		**204**

Methods

Soldering

Soldering is needed to prepare the Arduino and to fit all the cables to the correct length. When soldering for airship, special attention must be put in not using too much solder to keep a low weight. All solder joints must be isolated using tape or shrinking tube, as the hull is coated with aluminum and therefore can short circuit when touched by wires or even be destroyed.

Assembling of the Arduino Pro Mini 5V

Enabling 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 very useful to solder connectors for programming to the board. This is done as described in the following pictures.

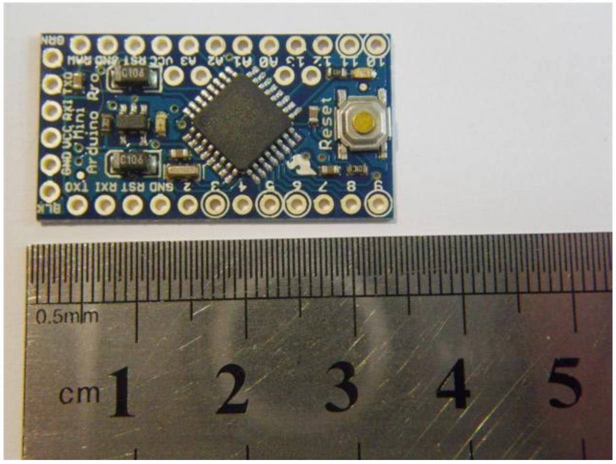

Figure 8: The bare Arduino board. The lower side of the board provides all necessary pins(2-9, GND-TX)

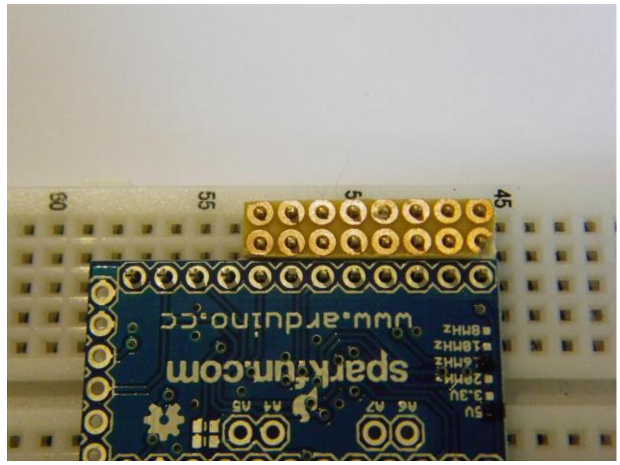

Figure 10: for soldering it is easier to place the whole board on a breadboard to fix all the pins.

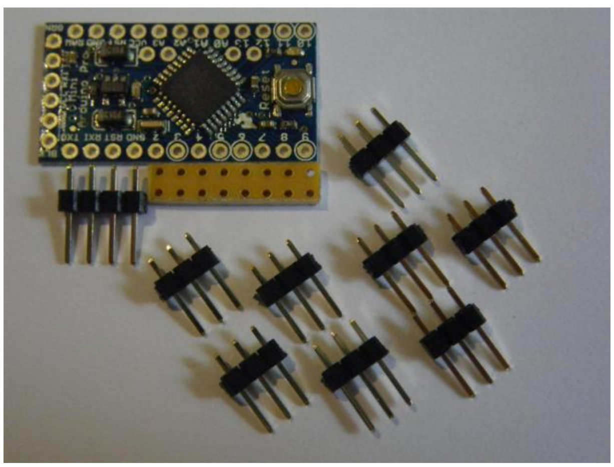

Figure 9: Cut a conductor plate to the right size (2x8 holes) and cut the pins as shown in the picture

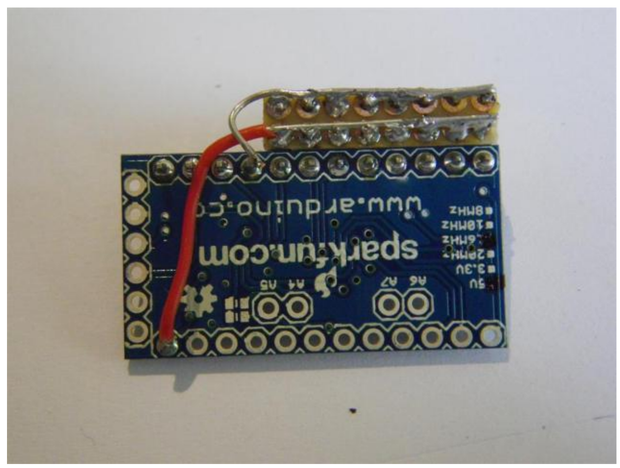

Figure 11: Connect RAW to the middle line of the triple pins and GND to the top line. All other pins are separately soldered to the Arduino board.

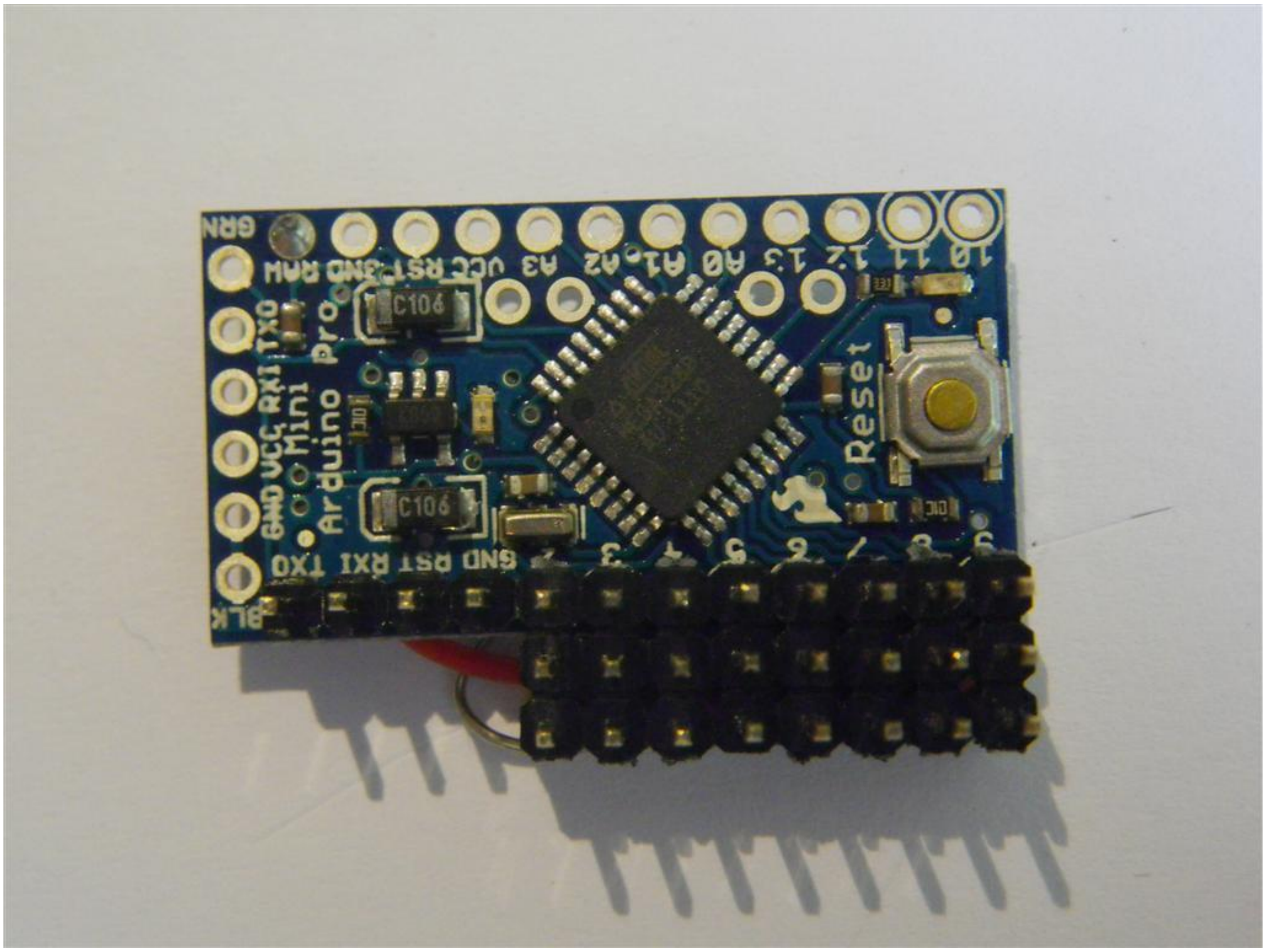

Figure 12: The final Arduino looks like this. Note that all the pins on the top are free to use and provide amazing capabilities for advanced functions. Servo cable will be connected with the signal (white/orange) to the Arduino pins, the middle pin to 5V (red) and the lower pin to Ground (black)

Hull Construction

The construction of the hull is the trickiest part of building the Silent_Runner and needs a lot of skills, large clean surfaces and very accurate working. The hull should be absolutely airtight and withstand internal pressure to establish the shape of the ship. We recommend visiting a training on welding a hull or ask experienced people for building a hull. In the following there is a brief overview on how to weld a hull.

The principle of welding the hull or envelope is based in the following description on using Octax, developed and distributed by aeroIx. The technique for this way of building hulls is mastered by the AirTrek Airship student workshop at the TU Berlin. Octax is probably the best material which is available for this purpose and was used in countless projects for lighter than air models. One of the main feature of the material is the different coating of both sides which makes one side – the blunt- weldeable and prevents the other side –the shiny one- from being welded. This allows us to fold the foil prior to welding in a way that all slices are welded at the same time. The hull of the Silent_Runner consists of three identical parts as seen in the following figure.

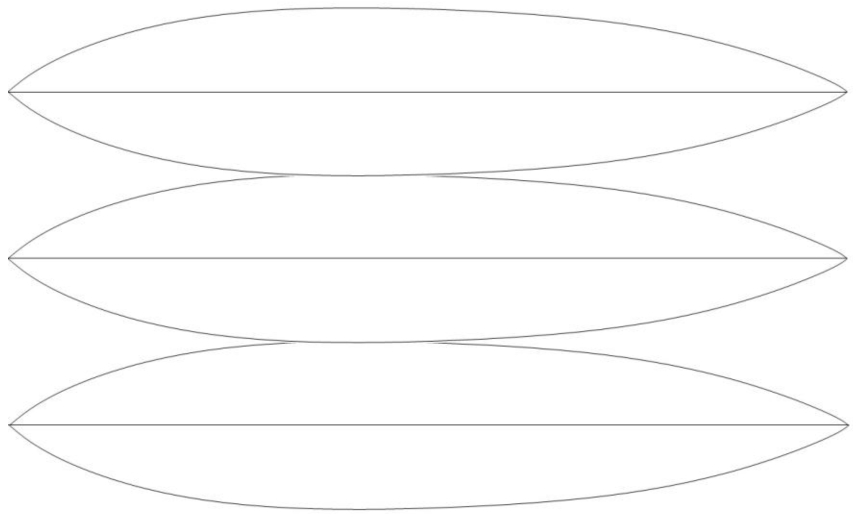

Figure 13: Parts of the film as needed to form the envelope of the Silent_Runner

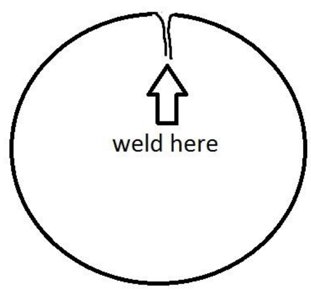

Figure 15: Scheme of the tube vent, the weld-able side of the foil is outside

Figure 14 welding with an iron

These parts are welded to the next part by using a flat iron on a flat table and a large paper with gore geometry printed on it. In the following the procedure is explained step by step. First get used to welding with a flat iron and experiment with the temperature, the speed of moving the iron and the pressure applied to the slice. This can perfectly be done by building the tube vent for the hull. This tube vent is just a tube formed by one layer of Octax welded on one side. This tube will later be inserted between two slices and be used as vent. Take care that the weld-able (the blunt) side is outside of the tube. For welding, heat the iron to maximum. Fold the foil in a way that it lays on a perfect clean and flat surface. Attach the foil by adhesive tape to the table and finally put a layer of normal paper over the foil and mark the path that shall be welded. Backing paper works fine too and is even transparent. Make sure that the paper will not move while welding, by putting heavy things on it, or tape it again to the ground. When these preperations are done, use the iron carefully and slowly - but not to slow - drive over the line that should be welded. Generate a narrow welding line by using the iron in an angle of about 45°and thus just welding by the edge of the iron. Do several tests with pressure, speed and heat of the iron, and check how strong the welding line is. If you have welded in a good way, the welding line won´t break when rip on both sides: Octax first will stretch a little and then break at some other place. When the vent is fine, prepare the welding of the hull.

Place the film on a clean and flat table. Tape it with sticky tape to the table, and stretch it in a way all wrinkles are removed and the film lays absolutely flat. Always double check the correct side of the film is facing upwards. The first layer should face the soldable – the blunt – side upwards. The second layer is then folded in a way, that half of the first layer is covered. The third layer is not folded and lies on the top of the other layers with the weld able side facing downwards.

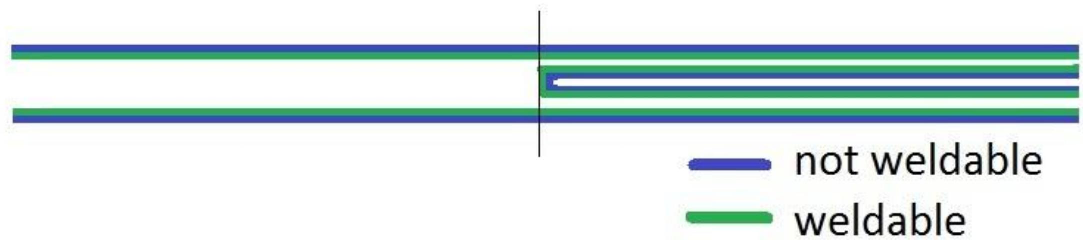

Figure 16: Placing of the film layers to build the three gore hull

Secure all the layers by tape and don't forget to place the tube vent. Now place the prepared pattern of the gores of the envelope on the top of the film layers. This pattern should be printed on a large piece of paper and is the template for the way of the iron (see Gertler4154_Silent_Runner.xls). Fix the paper well by placing heavy things on it, heat the iron, and start welding the hull, by carefully driving with the edge of the iron over the seam. Be aware on one side you will weld to seams at one time, thus move the iron a little slower. After finishing the seams, weld again, now with the flat tip of the iron an area of about 1 cm outside of the seams to have a save weld. If the first weld was perfect, you won´t need this second weld. Remove the paper, and cut the envelope out of the film layers. Be aware of not cutting the vent. Fill it with air, and check if it is tight. Don´t forget to weigh it for later calculations.

3D Printing

For the construction of the Silent_Runner, 3D printing is used for easy replication of all parts. The design of the parts is optimized for the open source rapid prototype system Prusa Mendel, but will probably work on any 3D printing machine. For more information visit http://reprap.org. The Material of choice is PLA due its light weight and good strength. The newest iteration of the parts can be found under (Thingiverse Link). Of cause all structural parts can be done on conventional ways by using balsa wood, or similar lightweight materials. This could even save weight as compared to the rapid prototyping parts. For shape and dimension refer to the CAD files.

Code

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 inputs by formulas to the desired 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 update and develop the code on the Arduino, a serial connection must be established to a computer running the Arduino software. For more information go to www.arduino.cc.

Wiring

The Electronics of the Silent_Runner are connected by three wire types. Most of the RC components, except the battery and the motors, are connected by standard 3 wire (Signal, 5V, ground) servo cables. Both ESC`s are receiving the same control signal from the receiver and can be connected just to one pin. The Battery is connected via a 2 wire Y cabel with large diameter to both ESCs. This cable will face the most current and must therefore be thick to lower resistance. Both motors are connected to the ESCs, using three wires each. Wiring of the electronic components is described in the following figure. To save weight, a little wiring trick can be applied on the 3 long servo wires going to the stern of the airship. The 5V and Ground cables (red and black) can be wired to the stern by just one cable each, which then splits to the three servos. This saves 4 cables and therefore a lot of weight.

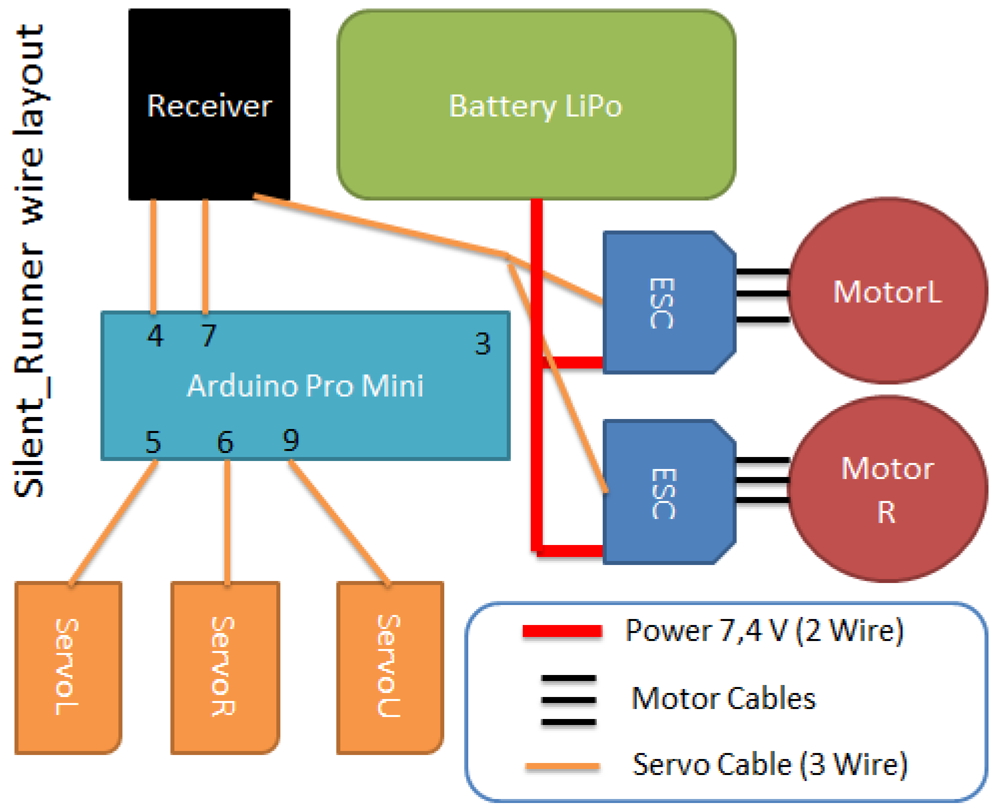

Figure 17: Layout of the wiring of the electronic components

Construction

The construction and setup of the Silent_Runner is done in this order:

1. Welding the hull and checking for tightness by test inflating with air
2. Assembling the electronics by soldering it all together.
3. Uploading the code to the Arduino, while disconnected from the ships system, and testing the whole electric setup.
4. Construction of fins, motor mounts and other spare parts.
5. Inflating the hull with air and attachment of all parts to the ship. Again test of the setup, trimming the rudders.
6. Deflating the hull completely. It is important to extract all air from the hull to have the full lifting force after filling with lifting gas.
7. Inflating the hull with lifting gas, pay attention to keep it well tethered.
8. Trim of the airship to nice horizontal balance. And keep in mind to make the ship slightly heavier than air.
9. Fly!
10. After the flight, either store the airship inflated till the next flights, but consider the loose of lifting gas over the time. For longer storage, deflate the hull carefully, a vacuum cleaner can help quite good. Depending on your way of storage, detach all the parts of the ship, and carefully fold the hull. By this method you can store all parts in a very small box.

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