Final report-STR-01: Space Team Rocket 01

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I. INTRODUCTION

The first experimental rocket of the Technical University of Vienna Space Team is STR-01. The main goal of this project was to design and manufacture a rocket which implies a type of electronic build in such a way it can be used in further missions without big changes of the layout. From a mechanical point of view the aim was to construct and manufacture a proper lightweight structure made of composite materials.

II. Context of Development

A. Club

The Technical University of Vienna Space Team is a working group of 12 students from various academic disciplines with a shared focus on air and space technology. The Space Team was founded in October 2010 and is currently in its first year after formation. The mission of the Space Team is to provide an intellectual and entrepreneurial platform for the inception and development of air and space technology projects.

Members have the opportunity to experience working in an interdisciplinary environment as they design, manufacture, and test air and space technology projects. Along with the exciting challenges of international competition, there are also a variety of social events planned. It is our goal that the Space Team will become an integral part of the Technical University of Vienna.

Fig. 1 the team

B. Work plan

Since the Team was found at the beginning of the school year 2010/11 we spend a lot of time on setting up a long lasting team structure. We founded an association to have a labor contract so we can handle your budget and open a bank account. Then we had to find a room for meetings and to build and store our projects. Next steps were setting up our homepage, designing a folder and finding sponsors. This work was finished by the end of the winter semester 2010 and some topics like sponsoring are still in progress.

During the start up phase we already discussed what project should be realized during our first year. Since the club founder and current head had been at C'Space 2010 it was logic to participate in C'Space 2011. Soon a mechanic team of 5 persons and an electronic team of 5 persons were found. Each team tried to develop first sketches and how to solve given problems. A work plan with MS Project was written to give team members an overview and a possibility to structure remaining time. Our first schedule envisioned to finish the design phase until February, the fabrication phase until end of May and to have one month of testing in June.

For several reasons but manly structural ones the timetable had to be adapted several times and the fabrication and testing phase had to be postponed.

Never the less we were almost ready on the D-Day.

III. Definition of the Missions

A. Scientific Mission

The main mission of STR-01 was to collect, store and transmit data such as air-pressure, temperature, GPS coordinates, acceleration and cosmic radiation. Furthermore it was a main goal to reduce weight to a minimum and develop a rocket which is made out of composite materials. So finally the main tubes and the ogive were made from GRP and the paddles consist of GRP, balsawood and CRP.

Fig. 2 composite paddles

As a result of lightweight design the rocket with a diameter of 89mm, all electronics and a loaded engine (PRO-54 from Cesaroni) weights only around 8 kg.
The calculated lift off speed was 26,9m/s and STR-01 should have reached an altitude of 1700m.

B. Electrical architecture

The goal of our Flight Measurement System (FMS) was to collect the sensor-data, store it on SD-Card and transmit it to the ground station. Our aim was to develop a system that is small enough to fit in the experimental rocket STR-01 and can also be used in other projects like our first CanSat or in next year's projects. The system should be build up very easy out of standard components that will be also available in the future. Because we don't want do reinvent the whole system every year. To improve the reusability we have full access to all of the important pins of the microcontroller via connectors on the PCB.

Microcontroller:

The core of our system is an Atmega128 from AVR which is clocked by a speed of 16MHz and has 128kBit Memory. We decided to use this microcontroller because it is very easy to program, you get a version in a DIL-package so you can build up a test system on a breadboard, it is very cheap and the software is for free. The Atmega128 has the following digital interfaces: 2x UART, I^2C, SPI and a 1-wire interface.

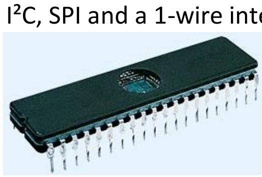

Fig. 3 Atmega128 from AVR

Internal Sensors of the FMS:

To get the position coordinates we use the standard GPS-receiver, NL-552ETTL from Navilock which includes receiver and antenna. The GPS-receiver transmits the data over a serial link to the Atmega128 with a baud rate of 38400 and the standard NMEA-protocol. We only use the GPGGA and the GPRMC strings to get the position, height, speed and direction, four times a second.

Fig. 4GPS-receiver

To measure the air temperature we use the TMP100 sensor which is connected over the I^2C-bus to the Atmega128. The sensor is located directly on the PCB.

To measure the g-forces (± 16g), the coriolis -force and the absolute orientation of the rocket we use the 9DOF-measuresystem from sparkfun. It includes an accelerometer (ADXL345) a gyroscope (ITG-3200) and a magnetometer/compass (HMC5843) on a simple PCB that is connected to the Atmega128 with the I^2C bus.

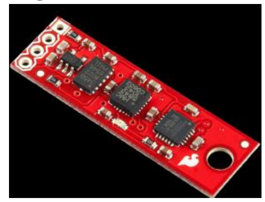

Fig. 5 9DOF-measuresystem

For g-forces beyond 16g we use the MMA2204 that can detect g-forces up to ± 100g. The MMA2204 is connected to the 16 Bit ADC (ADS1115). The ADC is also connected to the microcontroller with the I^2C-bus.

To get the air-pressure we use the MPXA6115A that is also connected to the 16 Bit ADC (ADS1115).

In the rocket we use a Geiger-counter (SEN-09848) from sparkfun, to measure cosmic radiation during the flight. The system includes an also an own microcontroller (Atmega328) that also is connect with the I^2C bus to the FSM.

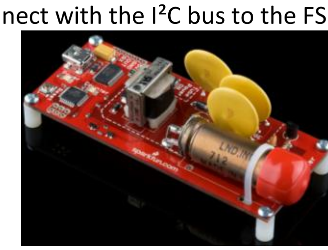

Fig. 6 Geiger-counter from sparkfun

Voltage supply:

We use two standard LiPo accumulator-packs with 2x 3,7V and two voltage regulator to provide 3,3V and 5V for the FMS. This voltage supply is also used to power the external sensors. The FMS runs with 3,3V, some sensors need the 5V. We also measure the accu-voltage to get the charge state of them and protect the accu-pack from total discharge.

SD-Card:

We implement a mass-storage in form of a µSD-Card. The SD-Card is connected over the SPI-bus with the Atmeag128. Here we use a Fat16 file system and create a log-file to save the data in it. The log-file can simply be read out by a PC's. We save most of the measured data 200 times a second only the temperature, pressure and the status information of the FMS are saved once a second.

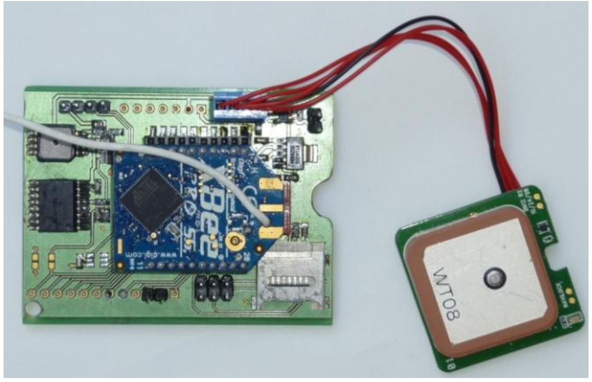

Fig. 9 FMS with GPS & XBee

C. *Mechanical parts*

Main Structure:

Since this STR-01 was our first experimental rocket we mainly orientated to Reinhard Raths experience and knowledge. He has launched already several rockets and therefore he suggested building a separation type of rocket. This system implies a lower and an upper tube which are connected with a couple tube. This tube is glued to the lower tube and the upper tube is put over the couple tube without any fixation. With a mechanical spring system the two tubes will be separated and the parachute will be ejected. -> *see page 6 for detail drafting & pictures*

Mechanical Ejection:

To assure a nice separation we designed a separation system consisting of three springs (each with a force of 100 N) two plats and a simple locking mechanism. The locking mechanism was made of a rod and a trident as shown in Fig. 9. The trident was connected to a servo which should have released the rod and the upper plate at the right moment. The force of the springs was transferred via the upper plat to the couple tube and so the two parts of the rocket could separate.

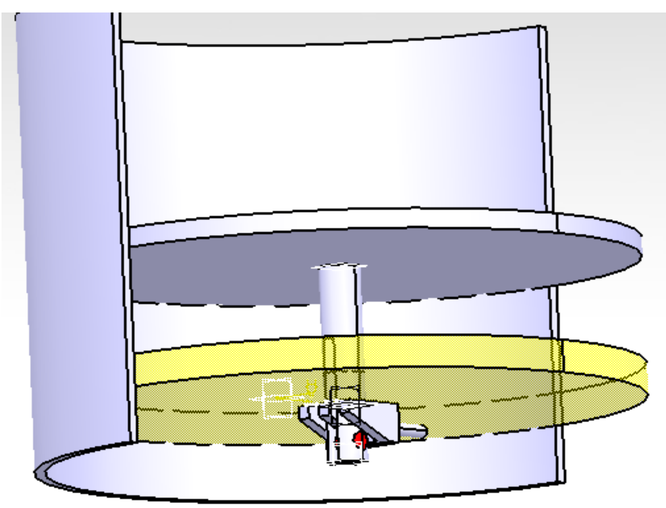

Fig. 7 simplified drawing of the locking mechanism

Parachute:

A parachute of 3,35 m^2 is used to slow STR-01 down to approximately 6 m/s to assure a soft landing.

$$S = \frac{2.M.g}{v_d^2.C_x.R} \quad (3)$$

$$S = 3{,}35\ m^2$$

M = 8000 g; g = 9,81 m/s^2; v_v = 6 m/s; C_X = 1; R = 1,3 g/l

D. *Telemetry*

To send the telemetry-data to the ground station we used the standard XBee-PRO® 868 OEM RF Modules. The XBee-PRO works in the free ISM 868 MHz frequency band (SRD g3 Band: 869.525 MHz) with an power output up to 500mW. The baud rate is 9600 and the possible distance is up to 40km.

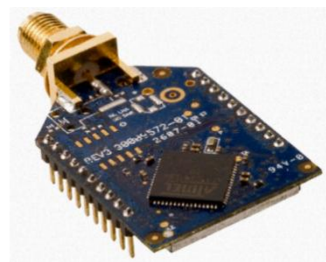

Fig. 10 XBee-PRO® 868 OEM RF Modules

For transmission we used a modified NMEA-protocol from the GPS-receiver. The $PGRMC and the $GPGGA strings were direct forwarded from the GPS-receiver and we add the following two strings: $DOF9 that includes the information from the DOF9-measuresystem and the high-g-sensor. §STATE that includes the other measured data and the status-bits. Both strings have the same CRC-bytes as the NMEA-Protocol. We didn't want to change the NMEA-protocol to use the GPS-Data directly with standard programs so we simply added new strings with the same type of strings.

To analyze the data live at the ground station we used matlab und labview on a standard windows PC. The XBee-Pro module was connected to PC via USB and was also powered over the USB-interface. It was also possible to switch on or off all the functions of the rocket, like the RF-Module, the SD-Card or the Sensors, like shown in Fig. 11.

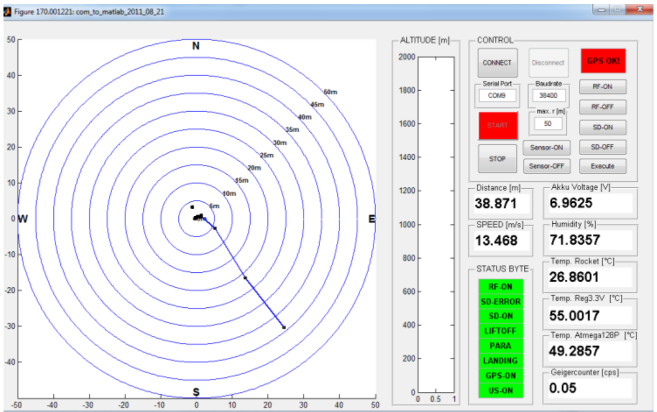

Fig. 11 Matlab control window

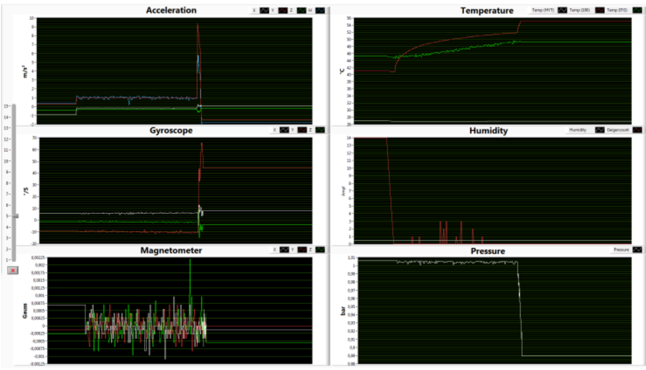

Fig. 12 LabView live window

IV. First flight of STR-01

In Fig. 11 and 12 the real flight data from the first flight on the 25th of August 2011 is shown. As can seen there is just a small spike in acceleration and gyroscope graph that indicates the liftoff and the short time of acceleration during flight. Due to a mechanical failure of the rocket separation mechanism the parachute opened after about 5.5 seconds and the power supply was disconnected from the FMS. There is just a small amount of the recorded data displayed, because we only send once a second to the ground station. We have to reduce the data rate because of the limit in bandwidth and duty cycle by the XBee module.

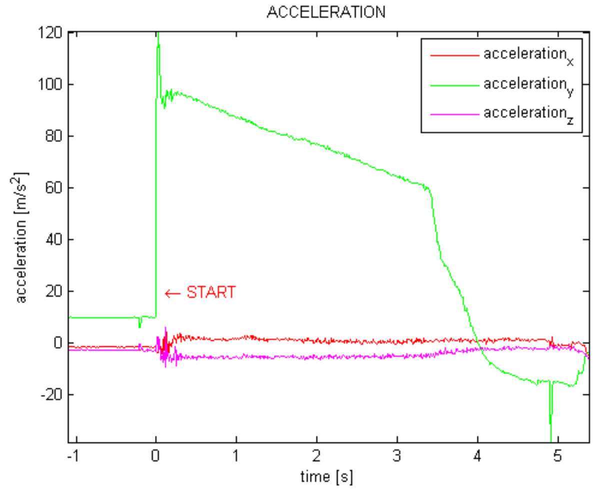

Fig. 13 Acceleration during flight

The acceleration during flight (Fig. 13) shows the liftoff impulse and then the burning of the engine for 3.5 seconds, like specified in the datasheet of the Pro54-5G. After the engine was completely burned out, at around 4 seconds, the rocket starts to decrease the speed (Fig. 14), because of the air resistance. The negative peak just before 5 seconds of flight shows the separation of the rocket and the deployment of the parachute. This takes place at a speed of about 900 km/h and only took 0.5 seconds to fully open the parachute.

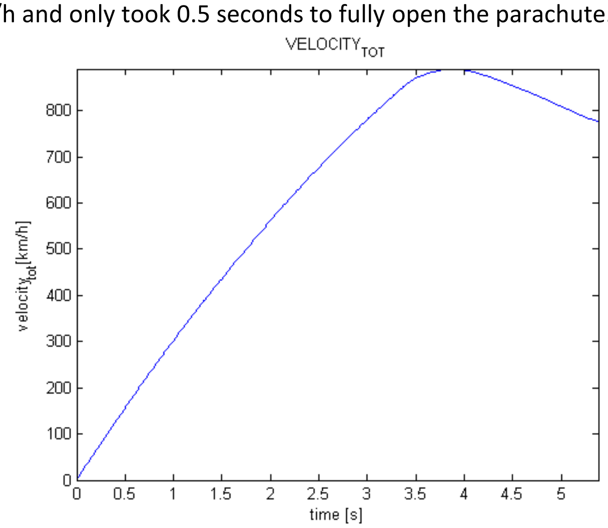

Fig. 14 Speed graph

Because of the high speed the parachute tears off and also the electronic was disconnected from the power supply because of the high forces that occur at this moment.

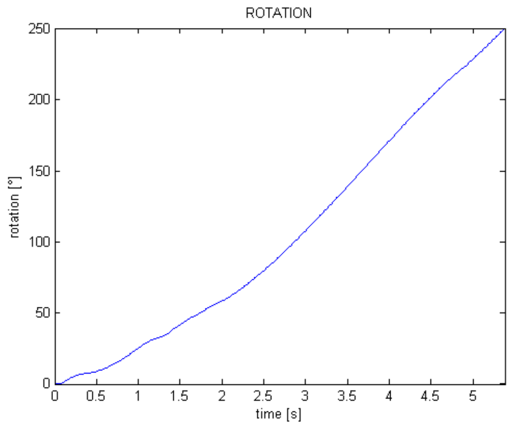

Fig. 15 rotation graph

In Fig. 15 the result of the gyroscope is displayed we integrated the measured value to generate the absolute rotation of the rocket. With less than a complete rotation during the flight, the rocket was stabile and gives us a good estimation for our next year's project, a rotation stabilized rocket.

Also the thermal situation of our board was an interresting result before and during our flight. We includet three temperature sensors. One measures the temperature inside the rocket, one next to the voltage regulator und a third one on the processor. As shown in Fig. 16 the before lunch, the board was in standby and already heats the voltageregulator up to 41°C and the processor up tp 45°C. About two minutes bevor lunch we switch on the RF-Module with standart transmission of basic information once a second. Because of the high powerconsumption of the XBee module the temperature increased to about 52°C before lunch. The integrated lunch detection sets the Datarate of the RF-Module to a burst mode, where the measurementdata of the accelerometer and the gyroscope were transmittet four times a second. This also increases the power consumption and therfore the temperature of the voltageregulator. In future missions the thermal design has to be improved to prevent the electronic from overheating.

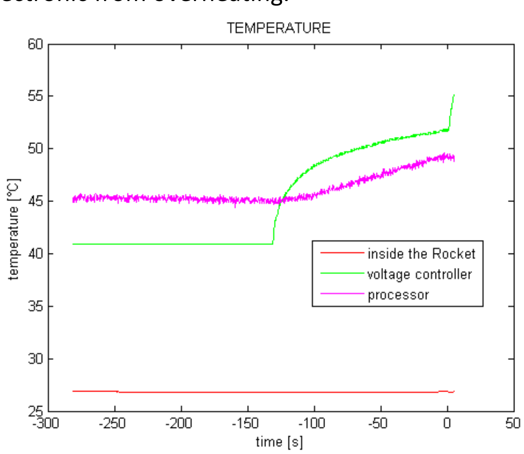

Fig. 16 Temperature graph

V. Conclusion

Although our first rocket STR-01 couldn't reach the calculated altitude and we couldn't save all the data it was a big success for our team. We always knew that the ejection system was the weakest part of our rocket and so we will try to improve this part as much as possible.

We learned a lot at C'Space 2011 and we could see how other teams work and what solutions they have for the same problems. With all this new knowledge we will try to improve our rocket to take part in C'Space 2012 with a brand new system.

Acknowledgment

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Last but not least we want to thank DGA-EM to welcome us on their military base for the flights demonstration in 2011.

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VI. ATTACHMENT

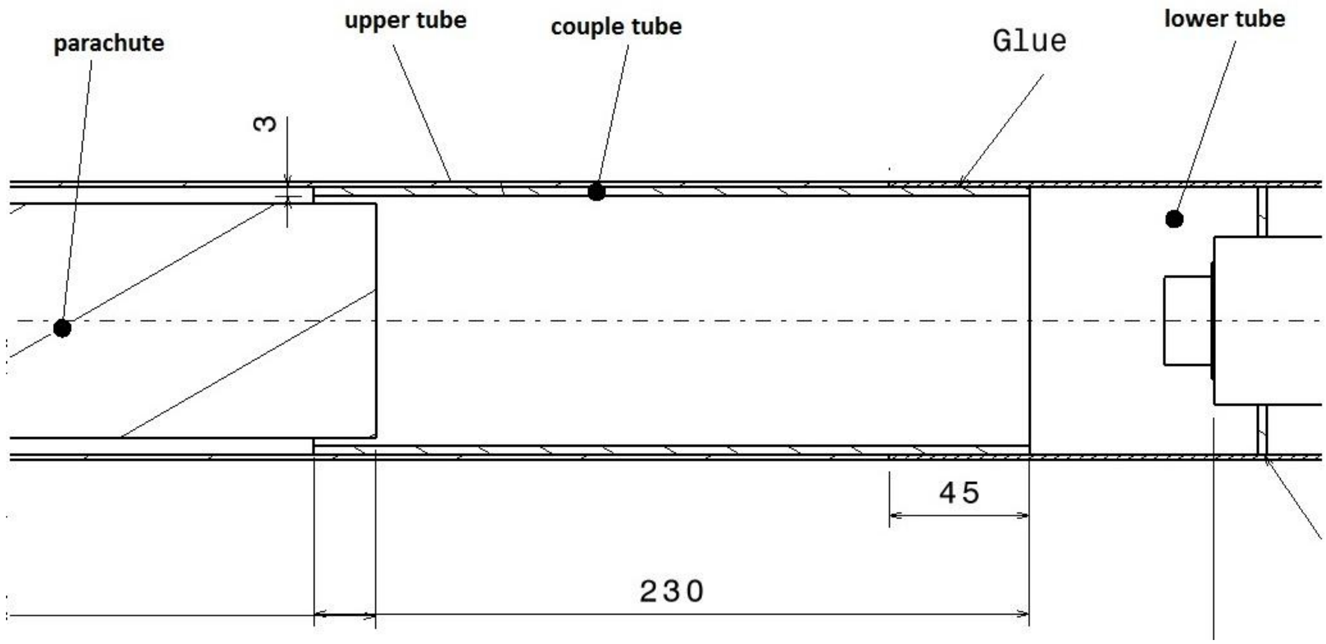
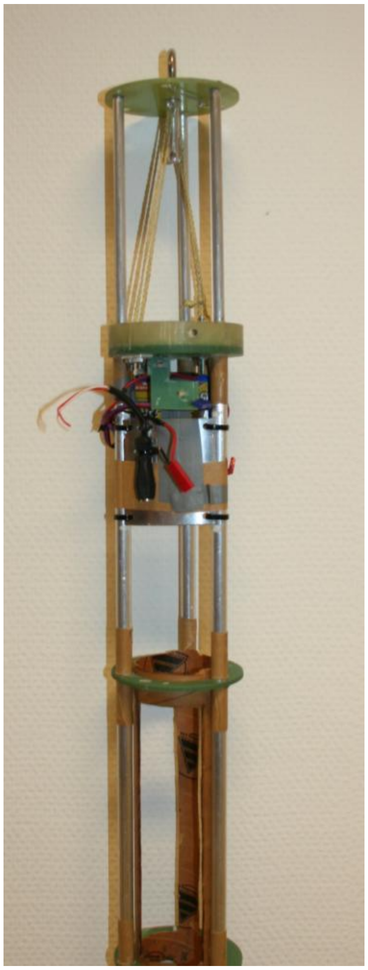


Fig. 1 couple tube, lower and upper tube



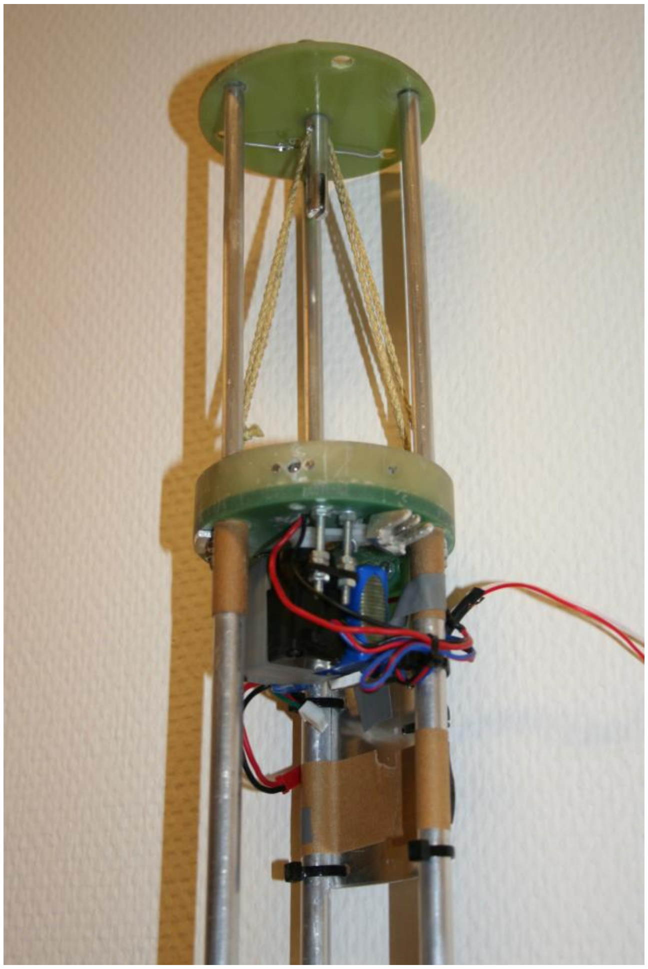


Fig. 2 ejection system