Silver Arrow

Team 420

Basic parameters

We have chosen 3D printing as the main method of manufacturing our rocket because it allows us to create more complex structures and at the same time can produce them quite accurately. We chose ASA as the material for the rocket's construction because it has the lowest density of all the materials considered, as well as a good
temperature and mechanical resistance.

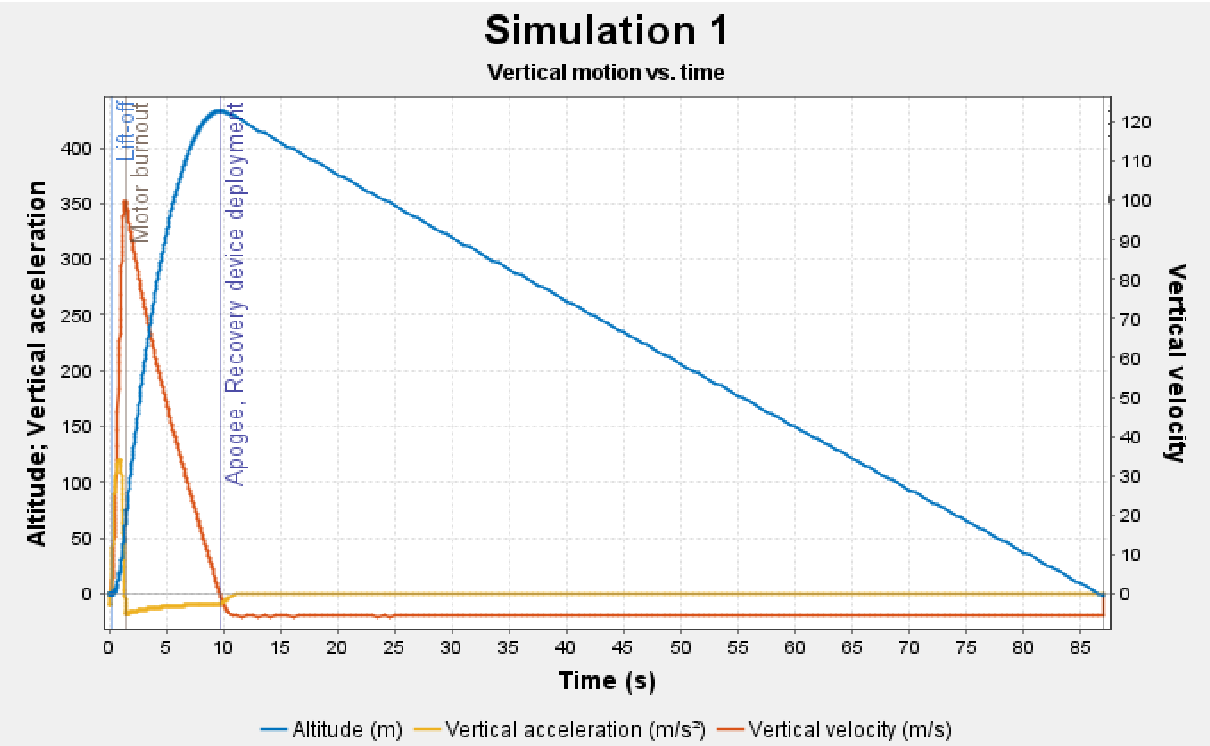
We decided to divide the actual body of the rocket into two independent parts - the lower part, which contains the motor and stabilizing ailerons, and the upper part, which carries the control electronics, the rescue system and the payload in the form of a camera. This division allows us good access to the internal systems of the rocket and also simplifies the 3D printing of the individual parts. The lower and upper sections are threaded together. We chose the Haack type as the shape of the rocket tip because of the lowest aerodynamic drag.

Inside the upper part of the rocket we have created a system of rails into which modules with different contents can be inserted. One of the modules could be avionics, a rescue system or cargo. This solution allows us good access to the internal components and at the same time increases the strength of the entire rocket.

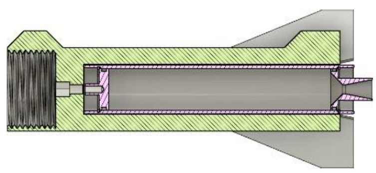
The parachute is attached to the rocket by a flexible rope, on which the tip is also atta to prevent the rocket from free-falling after the parachute is deployed.

We performed basic strength tests on the printed parts, in which the parts passed. Finally, we tried to simulate an impact with the bottom of the rocket at around 8 m/s, which the rocket withstood.

Total weight	1028 g
Max. accessibility	433 m
Total flight time	87,1 s
Length	70,4 cm
Width	50 mm upper part and 60 mm lower part
Stability	1.84 cal



Engine storage



The motor is inserted into the bottom of the rocket, where it is inserted into the prepared hole from the bottom and screwed onto the screw. The motor is thus secured against sideways movement and at the same time firmly attached to the thread. The motor protrudes from the bottom of the rocket by 10 mm for better handling in preparation for launch.

Avionics

The main task of the avionics in this rocket is to detect the apogee and fire the rescue device. This is provided by the Cimrman Mini flight computer developed by us. The processor uses data from the barometric altitude sensor and accelerometer to evaluate the moment of rocket launch and also the appropriate moment for parachute deployment. It then triggers the launch system by switching on the power output. The entire avionics system is powered by a small LiPo dual-cell aerospace battery.

Launch detection occurs when the minimum acceleration threshold is exceeded and the minimum altitude above the ground is exceeded. The flight computer then switches to flight mode and monitors sensor data for apogee detection. Apogee detection occurs when the vertical velocity of the rocket is negative for 1s. At that point, the parachute is deployed and the computer switches to landing mode. After landing, which the computer detects by zero vertical velocity, it switches to post-landing mode, where it starts beeping and waits to be picked up.

Circulation

The launch vehicle will be used for two different missions. The main mission is to test several sensors and a wireless communication system that could be used in other rockets. The sensors will record readings during the flight and the data will be evaluated after landing. According to the data obtained, the algorithms for combining data from different sensors or for evaluating the course of the flight will be tuned. At the same time, part of the measured data will be sent to the ground station using a wireless communication system with LoRa modulation. This will allow us to realistically verify the reliability of the communication and thus evaluate the possibilities of further use for sending telemetry.

The secondary mission is commercial in nature and consists of filming the flight with a camera for a video production company. A camera loaned by the sponsor and placed in the nose of the rocket will record the flight and will be handed over to the sponsor with the footage after landing.

Rescue device - parachute

A parachute is used to rescue the rocket when it returns to the ground. To estimate its size, we used the following
Formula:

$$A = \frac{2 \cdot m \cdot g}{\rho \cdot vT^2 \cdot C_D}$$

where m is the mass of the rocket, g is the gravitational acceleration, ρ is the air density, vT is the required final
velocity and C_D is the air resistance coefficient.

We chose a rocket mass of 1 kg for the calculation, as this is close to the modelled rocket mass. The calculation was performed for a terminal velocity of $4.5\ ms^{-1}$ with an air drag coefficient of 1.75, which is a typical value for a large parachute. With these values, the required surface area comes out:

$$A = \frac{2 \cdot 1 \cdot 9.81}{1.225 \cdot 4.5^2 \cdot 1.75} = 0.45\ m^2$$

Using the following equation, we determined the required parachute diameter:

$$D = \sqrt{\frac{4 \cdot A}{\pi}} = \sqrt{\frac{4 \cdot 0.45}{\pi}} = 0.76\ m$$

That is why we chose a parachute with a diameter of 76 cm made of nylon and weighing 37 g.

Then we tested the real characteristics of the selected parachute. We measured the aerodynamic drag coefficient by dropping the rocket with the parachute from a height (see video https://youtube.com/shorts/MrjfeVrgBfI). The parachute reduced the falling speed of an object with a mass of 350g to 3.5m/s, from which we used the equation above to determine the real drag coefficient:

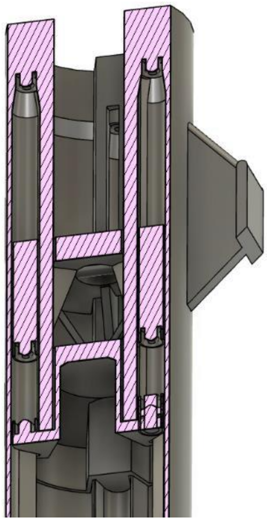
$$C_D = \frac{2 \cdot 0{,}35 \cdot 9.81}{1.225 \cdot 3.5^2 \cdot 0.45} = 1.02$$

With the realistic drag coefficient of the parachute, we finally determined the final rate of descent for the entire mass of the rocket:

$$vT = \sqrt{\frac{2 \cdot 1 \cdot 9.81}{1.225 \cdot 0.45 \cdot 1.02}} = 5.9\ m/s$$

This velocity is still low enough and the selected parachute meets the conditions for use in our rocket.

Launching the rescue device



The ejection of the parachute is provided by a piston pushed by springs. This plunger moves in the previously described rails and its release is controlled by a system working on the principle of overheating the holder by heat. Before take-off, the springs are compressed and the holder is snapped into place. When it is time to deploy the parachute, a current is switched on by a resistance wire which burns out the holder, the springs move the piston and eject the parachute. For a basic functional test, see the attached video (https://youtube.com/shorts/ZLcCtQzlM90).

Pre-start procedures

- **Preparation the day before**
  We will prepare all parts of the rocket - the lower part including the screw for the motor, the upper part, the tip, the ejection system, the avionics and the parachute with ropes. Check the flight computer and battery charge. We will add spare filaments and resistance wires to the launching system. We'll take the payload for both missions - sensor board and camera. Tools needed will be a Phillips screwdriver, pliers and a multimeter. A computer and a receiver with an antenna will be needed to test the wireless communications.
- **Preparation of the launch**
  Insert new filament into the parachute launch system and check the resistance wire. Tie the parachute line to the launch system. Insert the entire launch system into the rocket and connect to the flight computer. Insert the battery into the avionics holder and plug it in. Run a continuity test on the flight computer. Test the functionality of the sensor payload and wireless communications. After a successful test, insert the avionics mount and sensor payload into the rocket. Check the motor attachment screw at the bottom. Then we screw the top part into the bottom part and insert the camera payload into the tip and turn on. Add the competition altimeter. Push the ejection system plunger into place. Tie the parachute and tip to the prepared rope, fold the parachute and insert into place in the launch system. Insert the tip into the rocket.
- **Move the rocket to the ramp and launch**
  After completing the rocket, Lukáš and Matěj will go to the launch pad and add the motor. Through the hole in the rocket, they press the button to activate the computer. The flight computer will beep to indicate readiness for flight. The launch pad operator will insert the ignition device. This makes the rocket ready for launch.
- **Cleaning**
  After landing, the parachute will be folded first and then we will carry the rocket. After that, the rocket will be released
  download the measured data.