Space Propulsion Project - Group 2

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***Abstract*—This report is part of the Space propulsion course by Jäger Markus Hendrik. The main objective of this course is to provide an overview of space propulsion systems and to describe the basic design principles of propulsion systems. The aim of the project is to develop a 1.5 stage launcher based on liquid propulsion. This report responds to the fourth exercise of April 26, 2022: verification plan.**

I. Verification of the main requirements

A. Boosters separation

To ensure a nominal separation of the boosters and the center core, we firstly design and compute the burn time of the boosters in order to have a bigger thrust and a shorter burn than the main core. Secondly, the attachment of the boosters on the center core are designed to disconnect by itself (only by gravity) after the end of the burn.

B. Parachute deployment

The parachute deployment will be verified by triggering an impulsion of the Servo motor with the Raspberry, i.e. by sensing the increase of pressure after the apogee and with a backup timer. This way, the correctness of the opening and the deployment of the parachute will be verifiable in an elevator, or running up and down stairs for example (Yes it works very well, the EPFL Rocket Team is an expert with this testing process, particularly at 3am!).

C. Electronic systems

Each of the electronic systems (Raspberry Pi, Barometer, Accelerometer) will be isolated for testing. The Raspberry Pi is assumed to work as intended since we use it to verify the other systems.
The Servo motor will be verified to work correctly by simply triggering the rotation of the axis, to do that it will be connected to the Raspberry Pi.
The accelerometer can be verified for example by programming the Raspberry to log the data collected by the accelerometer every seconds, try to run or ride a bike and check the collected logs afterward.
The barometer can be tested by doing the same log system and try it in different altitudes or environment with different pression.

D. Safe-landing

First simple test:
We will take the main parts of our rocket, mainly the core stage, so the rocket without the electronic system to avoid breaking it. We will replace the weights of the electronic system by small dummy mass. Then we will deploy manually the parachute, just open the head of our rocket. Therefore to test the safe-landing, we will throw the rocket from a specific height. This test will also verify if the parachute opens correctly during the descent phase. To prevent damaging the rocket we will stand below the rocket with a bed sheet to recover the rocket as firemen. Moreover, by calculation the main core will have a terminal velocity less than 5m/s, which is the requirement for a reserve parachute for human.

Second test:
In this test, we will add the raspberry in the rocket and record the rocket's acceleration. Then we will throw again the rocket and check that the velocity stay constant a certain time before touch the ground. And that this velocity is below the threshold given by: $\sqrt{\frac{2 \cdot M_{tot} \cdot g}{\rho \cdot S_{eff} \cdot C_d}}$

E. Maximal altitude (below 200m)

This test will be check by calculation. We will run a new simulation with our Matlab program with the precise mass of the rocket before the launch. And, we will also test it during the trial launch by analysing the data of the accelerometer and the pressure sensor.

F. Pressure test

This test just verifies if our vessel can support the pressure. We will test the pressure at 1.5x the nominal launch pressure.

G. Vertical Lift-Off

The vertical lift-off will be estimated by the calculation of the center of mass and the center of pressure with the software *Open Rocket*.

Items	Weight in g.
2L soda bottle x2	53 x2
1.5L soda bottle x2	40 x2
Raspberry pi pico	3
Barometer	TBD
GPIO header	TBD
Servo Motor	9
3D printed pins	TBD
Nylon Rope Ø5 mm (0.013 kg/m)	13
Parachute	28
Epoxy glue	TBD
Rubber band x2	2.8 x2
Portable battery	77
Total	326.2

Table I
UPDATED ESTIMATION OF THE DRY MASS OF THE ROCKET.

Ref	Description	Verification method
MS-01	The launch vehicle shall reach an apogee between 10 m to 200 m (AGL)	On-board altitude measurement
MS-02	The launch vehicle shall deploy a parachute	Ground test of deployment
MS-03	The launch vehicle shall have a safe landing, such that it can be reused without any modification	Visual inspection after landing
MS-04	The launch vehicle shall be aerodynamically stable at launch rail exit and during flight	Design
FCT-01	All propulsion systems shall initiate at lift-off	Design
FCT-02	All propulsion systems shall exclusively use water and either air or nitrogen for pressurization	Design, visual confirmation during launch pad operations
FCT-03	If applicable, booster stage shall be discarded at "burnout" (i.e. as soon as no more thrust is generated)	Design
FCT-04	Maximum pressure allowed for COTS pressure vessels at launch is [7] bar	Design, will be regulated by GSE operators
FCT-05	Max pressure for modified COTS or SRAD pressure vessels at launch is [16] bar	Design, will be regulated by GSE operators
FCT-06	If applicable, core stage and booster stage shall be pressurized at the same pressure value	Design
DGN-01	Avionics shall be powered only once the launch vehicle is sitting on the launch pad	Design
DGN-02	Parachute shall be attached/detached to/of the rocket using a metal ring	Design
DGN-03	If applicable, all booster and core stage shall have their nozzle/water exit at the same height	Design
CONF-01	The launch vehicle shall be either single stage or 1.5 stage, i.e. 1 core stage or 1 core stage + booster(s)	Design
CONF-02	If applicable, booster total number shall not be greater than [3]	Design
CONF-03	If applicable, booster shall be uniformly spread around the core stage	Design
PHY-01	Airframe/pressure vessels shall possess a standard thread	Design
PHY-03	The maximum dry mass of the launch vehicle shall be [1.5] kg	Measurement
PHY-04	The maximum height of the launch vehicle shall be [120] cm	Measurement
SAF-01	No pyrotechnics (e.g. black powder) shall be used	Design
INT-01	Launch vehicle shall fit on the launch rail profile	Design, possibility to test-fit beforehand
INT-02	Propulsion systems shall fit on the GSE pressurization fitting	Design, possibility to test-fit beforehand
VF-01	All propulsion systems (core stage + boosters if applicable) shall perform at least [one] successful static fire	Test, measurement
VF-02	All modified COTS pressure vessels shall pass a hydrostatic pressure test at 1.1x the nominal launch pressure	Test, measurement
VF-03	Calculation/simulation of thrust generated by each stage shall be provided prior to lift-off	Calculation and analysis
VF-04	Calculation/simulation of flight trajectory of the launch vehicle shall be provided prior to lift-off	Calculation and analysis

Table II
TECHNICAL REQUIREMENTS TO FOLLOW. A GREEN LINE MEANS THAT IT HAS BEEN VERIFIED.