Space Propulsion Project - Group 2

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June 26, 2022

***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 final exercise of May 24, 2022: Trial Launch.**

I. Trial Launch Result

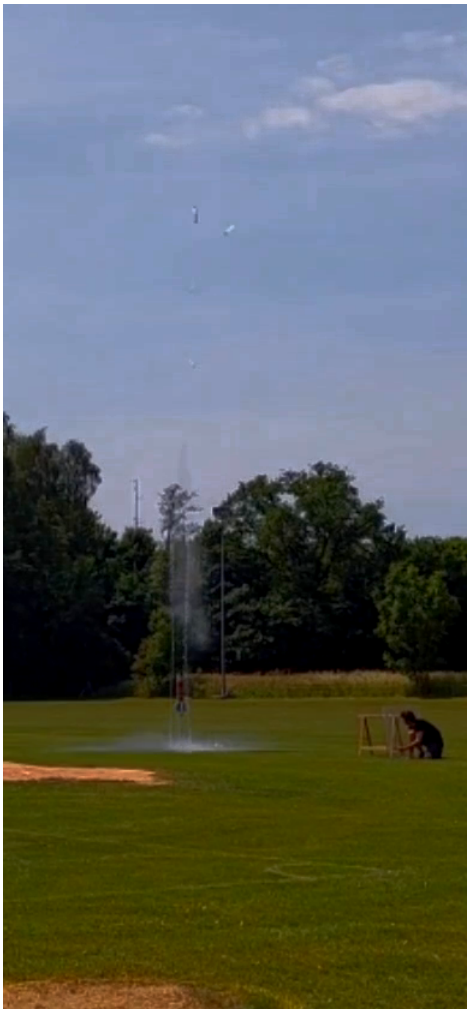

Figure 1. Lift off.

In Figure 1, we can see the start of the lift-off. In the sky, we can distinguish the two boosters and the core stage still on the launch rail. Thus the main problem in this part of the launch is the booster separations. Indeed, the booster's thrusts were too powerful and then the boosters detached themselves from the core stage. Thus the core stage remains alone and even if it succeeds to lift off, it could not achieve the desired vertical trajectory and altitude targeted.

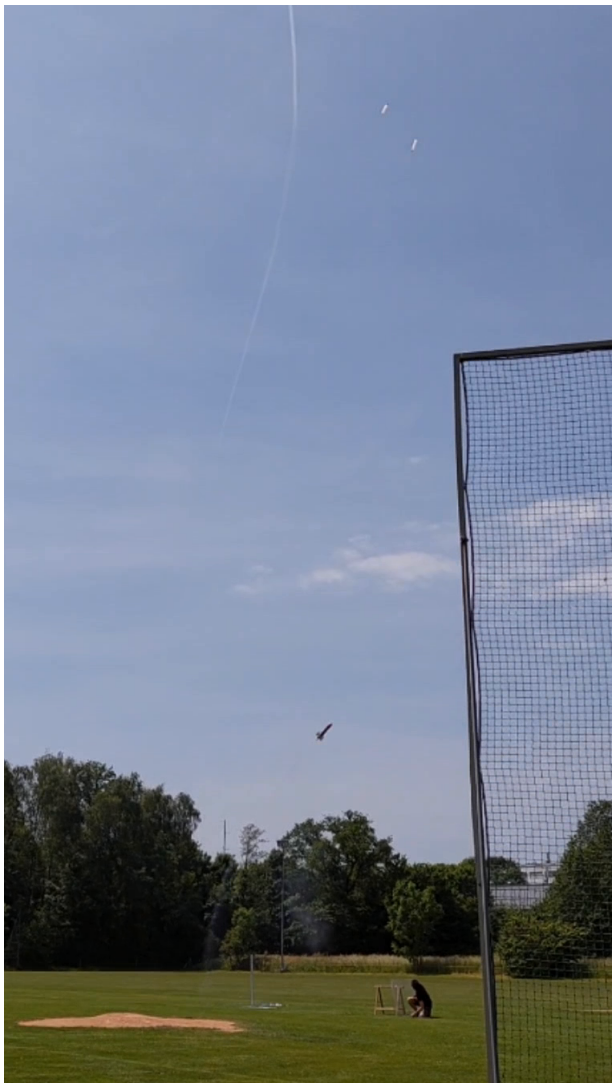

Figure 2. Core stage leaving the launch rail.

Another problem the rocket faced is after leaving the launch rail (Figure 2). We can see that the core stage is not

going vertically. This must be a problem with the center of pressure and mass. We did not want to add too much weight to the nose cone because we feared that the parachute would not be deployed as in our current design the whole nose cone is pulled on the side of the rocket to free the parachute.

Finally, before lift-off, the elastic of the parachute deployment system detach by itself on the launch pad. We however accepted to launch knowing this problem, because we did not want to loose a lot of time to refill all the bottles.

II. Modifications On The Rocket

- Boosters problem:
  The pins attachment system should be more resistant. In fact, the gluing surface was small and the male pins were too weak to withstand the force due to the difference of thrust of the booster and the central core. To address this problem, the final version will be a full crone around the center core to get more gluing surface and the pins will be made bigger.
- Stability problem: To mitigate this problem, we will add for the final launch around 100g of sand in the nosecone to move forward the CG and getting more stability.
- Parachute deployment modification: The parachute deployment mechanism was not robust enough to hold the thrust and instability of the rocket while remaining reliable. So the team is working on a new, more solid system: with spring and PVC cylinder instead of elastics and plastic bottles. In addition, a radial deployment system is constructed. This second system would allow us to put more weight on the nose cone.

III. Positive result

From this launch trial, we get validation on different aspects. First of all, the choice in the quantity of water, air pressure, and the nozzle were right, during the launch booster's burns were much faster than the core stage. Therefore if the boosters were stay attached to the rocket, they would have greatly helped the core stage before getting separated.

The fins were of the right size. They kind of succeeded to keep a small stability even if the nose cone of the rocket were really too light and the exiting rail velocity were too low.

The raspberry worked correctly and recorded some information about the flight.

The rocket was strong enough to ensure a "hard landing", only the nose cone was crushed. The core stage and hardware section of the rocket were not damaged at all.

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