Technische Hochschule Rosenheim
Technical University of Applied Sciences
Fakultät für Ingenieurswissenschaften

Project Report

Water Rocket Experiment

Team:

Piyush Panse

Rejoys Peter

Vaibhav Kumbhar

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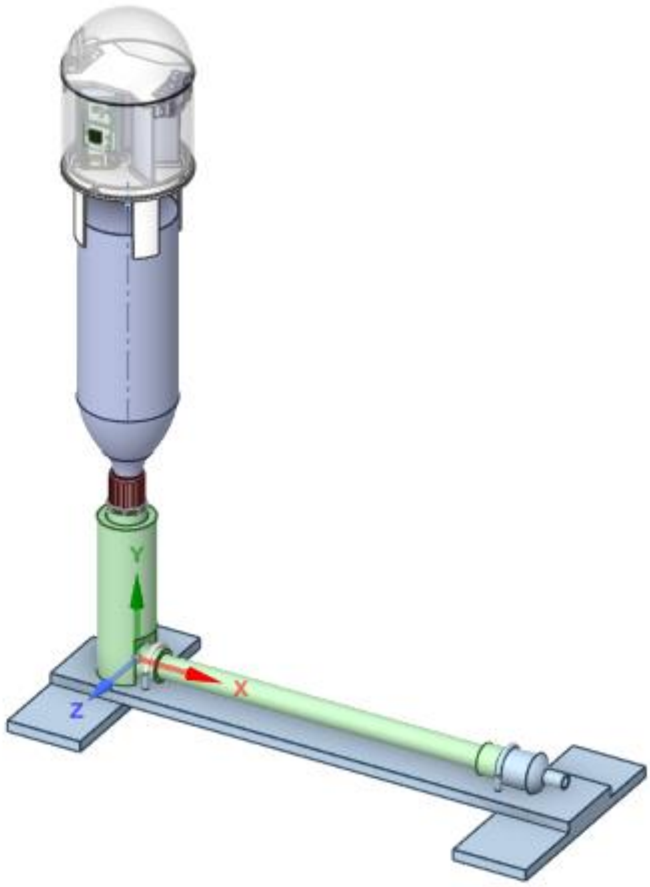
1. Project Description

- The goal of the project is to design a rocket that can be shot high as possible simply by water pressure.
- Before the flight the orbit of the rocket shall be predicted by a simulation model.
- The rocket will be having sensors to measure its orbit and flight will be made observable in the internet.

2.Tasks and Challenges

- Developing a method to determine the inertial position and the attitude of the flight behavior of the rocket
- Implementing the method in a MATLAB/Simulink model and verify the algorithm by backwards computation of a given position and altitude.
- Building the Simulink model with the original water rocket interfaces such that it can run without any changes on the rocket.
- Designing and implementing a method to broadcast the flight with a camera in the internet.



3.The Team

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4.Personal Introduction

Piyush Panse

Hello, My name is Piyush Panse and I come from Pune in India. I have done my bachelor's in mechanical engineering and after 1 year of working I decided to pursue higher education particularly in Germany because of its superior education system. I chose TH Rosenheim as I knew a couple of students here pursuing masters, hence it was easy to get information and know about the university before hand. I was drawn to this project of water rocket experiment as it encompasses all the domains of industry, design conceptualization, manufacturing, testing, sensors, actuators and so on. Also Prof. Zentgraf’s knowledge about rockets is an added advantage. My part in the project was deciding which microprocessor, sensors, actuators to use and helping in designing the mountings for these components and retrieving data from these. Although we were a team of 3 each doing separate task, each of us helped each other in doing our tasks. Sometimes I received help in coding for a particular sensor and sometimes I helped in building a payload assembly or launcher for rocket. As the main moto was to learn as much as possible. The project has not only taught me Technical Stuff but also taught me to work with people as there were lot of people involved. I hope that our project is continued and further improved on by other students and it becomes some sort of custom that ever semester a team betters the rocket of their former team.

Rejoys Peter

Hello,

I am Rejoys Peter currently in the third semester of the master’s Programme in Engineering Sciences specialising in Mechatronics at TH Rosenheim. I did my bachelor’s in mechanical engineering under APJ Abdul Kalam Technological University, Kerala which is in the southern part of India. Migrating to another country for better education was my dream from childhood and like any other tech enthusiast, Germany became my top priority. I came to know more about TH Rosenheim after starting my studies here. And now Rosenheim and the university give me the same feeling as in my home. On March 5, 2020 I landed on Germany (while I am writing this, I am celebrating the first anniversary of arrival!) and after some days everything turned upside down. Lockdown was imposed, classes got extended and then lectures became online. After travelling about 5000 miles, leaving my family, home and friends and then being alone in an apartment which is very next to university, attending online lectures without having a chance to visit at least the classrooms of the university is kind of funny and sad at the same time. ‘Man plans, God laughs.’ Coming to point now, after 6 months first semester came to an end and then I had the choice to apply for master project. Being interested in the subject Model Based Development I was very excited to do the Project under Prof. Peter Zentgraf which had the part of modelling and simulating water rocket. Every meetings and discussions with him gave very good insights about the project and the things to be achieved. He was so kind at the same that he allowed access to the Lab so that we could work and gave contacts and helped to arrange meetings with various people that could contribute to the Project. Through these, things were getting better, got more chances to visit the university, work in the lab, communicate with other people and gain knowledge from everywhere. That is how I started getting exposure that one should get being an international master's student in Germany. Knowing the advantages of obtaining and interpreting the results for varied inputs and environment without doing real life experiments, I was very fascinated in the domain of modelling and simulating processes. That is why I mainly did the conceptual and mathematical modelling, MATLAB simulation of this water rocket experiment. The dependence of height the rocket achieves on the parameters such as launch pressure, weight, nozzle size etc is portrayed in the model. Also to decide on the optimum filling ratio of water which is affected by various factors, this simulation model can be used. I also managed to setup, interface Raspberry Pie, the tiny computer we are using in this Project that is used to receive data from sensors, actuate servo motor for parachute deployment and capture video from pi camera. I am also enjoying the responsibility of maintaining the contents of the Wiki Page of the Water Rocket Experiment. There is immense pleasure of working in this team, by supporting each other in the tasks, sharing knowledge and moving together with a proper aim. The model, the experiment even though not 100 percent perfect now, I believe this could be referred and done in a better way by the future teams.

Vaibhav Kumbhar

Hello,

My name is Vaibhav Kumbhar, I am from India. I did my bachelor's in mechanical engineering and now I am a master Engineering Sciences at TH Rosenheim. Being a mechanical engineer, it was my dream to come to Germany and study in one of the prestigious universities. For our master project we are simulating a water rocket experiment using MATLAB/Simulink and ANSYS. The goal of the project is to compare the practical results from the sensor with the simulations. I am responsible for design and manufacturing of the experiment. The system is developed for the maximum pressure of 15 Bar. There are two main parts first one is the Launcher and second is rocket with payload and parachute assembly. The system is pressurized with bicycle pump through the shredder valve attached to one end of hose pipe and the second end is attached to a release mechanism. Which is main part of the launcher and has stability connector. The high impulsive force is generated during the launch and which can result into failure of the launcher. The stability connector is designed in such way that it will sustain those forces and accommodate release mechanism inside it. We are using the strings attached this part to release the rocket. The second part is the rocket with the payload and parachute assembly. We used coke bottle as pressure chamber where air is pressurized. These four legs of the payload assembly are attached to top of the bottle with little clearance between them. The clearance is provided for better camera angle which is attached at the bottom of the payload assembly. All the electronics components are assembled on the vertical strips and these strips are inserted in respective slots on payload base. The slots are made in radial direction considering the size and shape of the component. Also, this arrangement provides better stability for components and more space for electrical connections. The parachute is placed in top hemisphere of the assembly. The strings of the parachute are attached to the parachute base which is bolted to the outer cover. The mechanism is activated with servo command and spring mechanism is used to open the cap to release the parachute. The project has great potential to explore various dimensions of engineering. Further this project can be developed for, 1. Automatic docking and release mechanism for pressure range up to 50 bar. 2. Design of high-capacity pressure chamber using carbon fibers. 3. Use of multistage rockets. 4. Development of customized nozzles and optimization for perfect shape. 5.

Use of generative design for lightweight construction. 6. Vertical landing using landing gears with the help of parachute. 7. Structural, modal and CFD simulations

5.Science Behind Water Rockets

Taken from [1]: "Water filled in the rocket is pressurised first and when it escapes through a small opening in the bottom of the rocket, thrust force is generated that makes the rocket to propel upwards.

According to Newton's second law of motion, the acceleration depends on mass and force.

So, for the rocket to go faster and higher:

- Weight of rocket must be reduced without affecting stability.
- Pressurize the water to produce higher thrust.

- Faster the water is ejected, greater is the reaction force on the rocket.
  After the thrust phase, rocket propels further in the presence of gravitational and drag force.

Stability of the rocket:

- For the rocket to fly straight, centre of pressure of the rocket must position below the centre of mass.
- For this reason, fins are provided at the rear end of rocket.

Filling ratio of water:

- Water, having greater mass than air contributes to a greater thrust.
- If there is more water, the speed of expulsion must be higher.
- The more time water stays in the rocket, the more instable it will be.

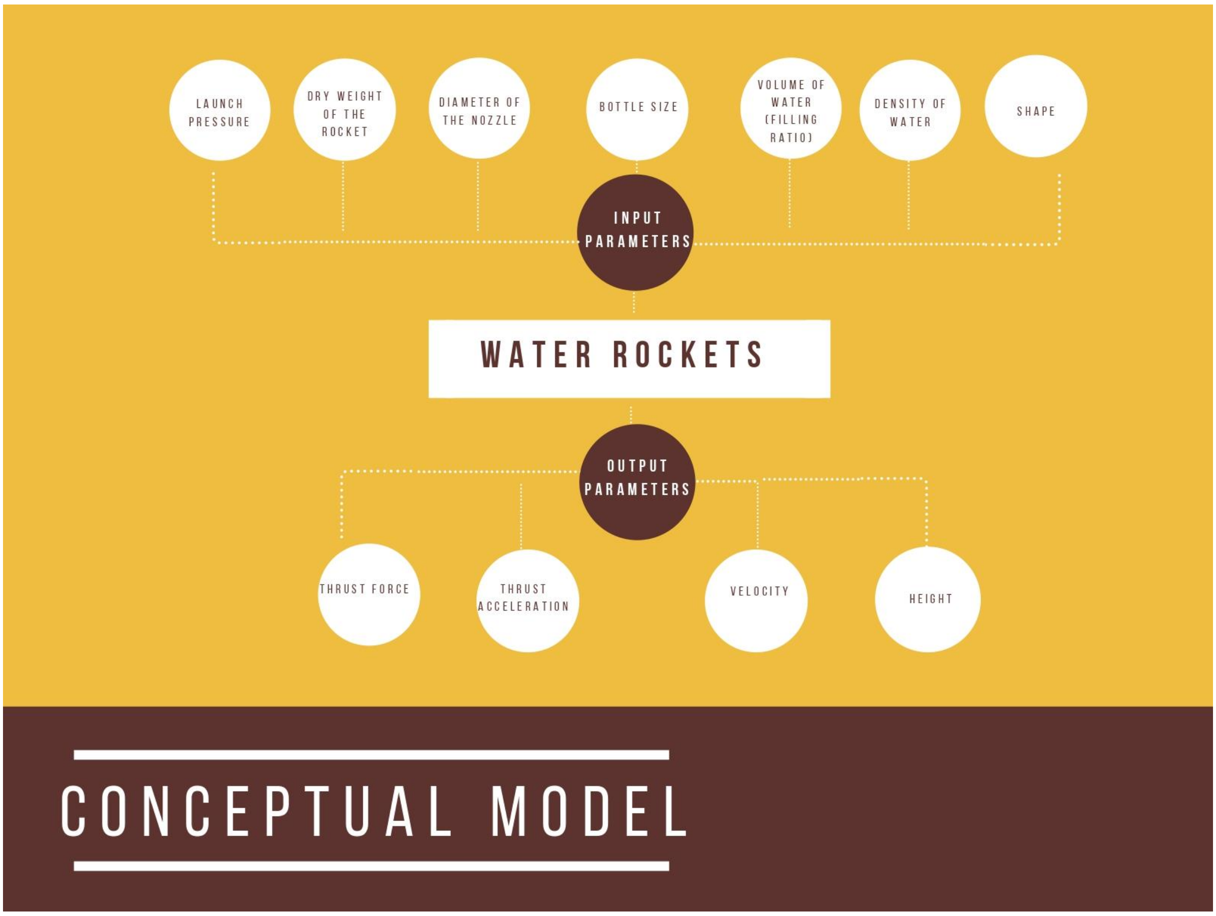
Air drag:

The drag force of air is proportional to the velocity of the rocket. To reduce the air drag, the rocket must have a streamline design and the surfaces should be smooth."

Reference

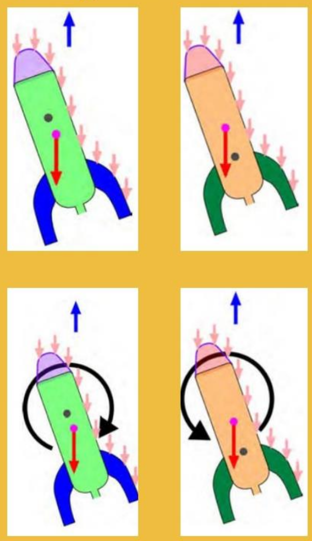
- [1] https://www.scarsdaleschools.k12.ny.us/cms/lib5/NY01001205/Centricity/Domain/330/water_rocket_physics_and_principles_18621.pdf

6.Conceptual Modelling



Design considerations

(Weight distribution, usage of fins)



Positioning centre of mass and centre of pressure

- Relative positions of the centre of mass and the centre of pressure determines a rocket's aerodynamic stability
- For Rocket A (left) the centre of mass lies above the centre of pressure. The drag forces exert a torque which acts about the centre of mass to restore optimal flight attitude
- For Rocket B (right) the centre of mass lies further below the centre of pressure. The extra drag forces therefore act more on the front end of the rocket and tend to push it even further out of line.

CONCEPTUAL MODEL

Design considerations

(Nozzle)

- *Flow impedance* is a parameter used to describe the nozzle
- It is determined by the cross-sectional area of the nozzle
- The larger the area, the quicker water comes out and impedance is low
- The smaller the area, the slower water comes out and impedance is high
- But in the case of a very high impedance, due to overweight, bottle will not leave the ground
- Therefore an optimum nozzle crossection needs to be determined

CONCEPTUAL MODEL

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Optimum filling ratio
(Volume of water in the bottle)

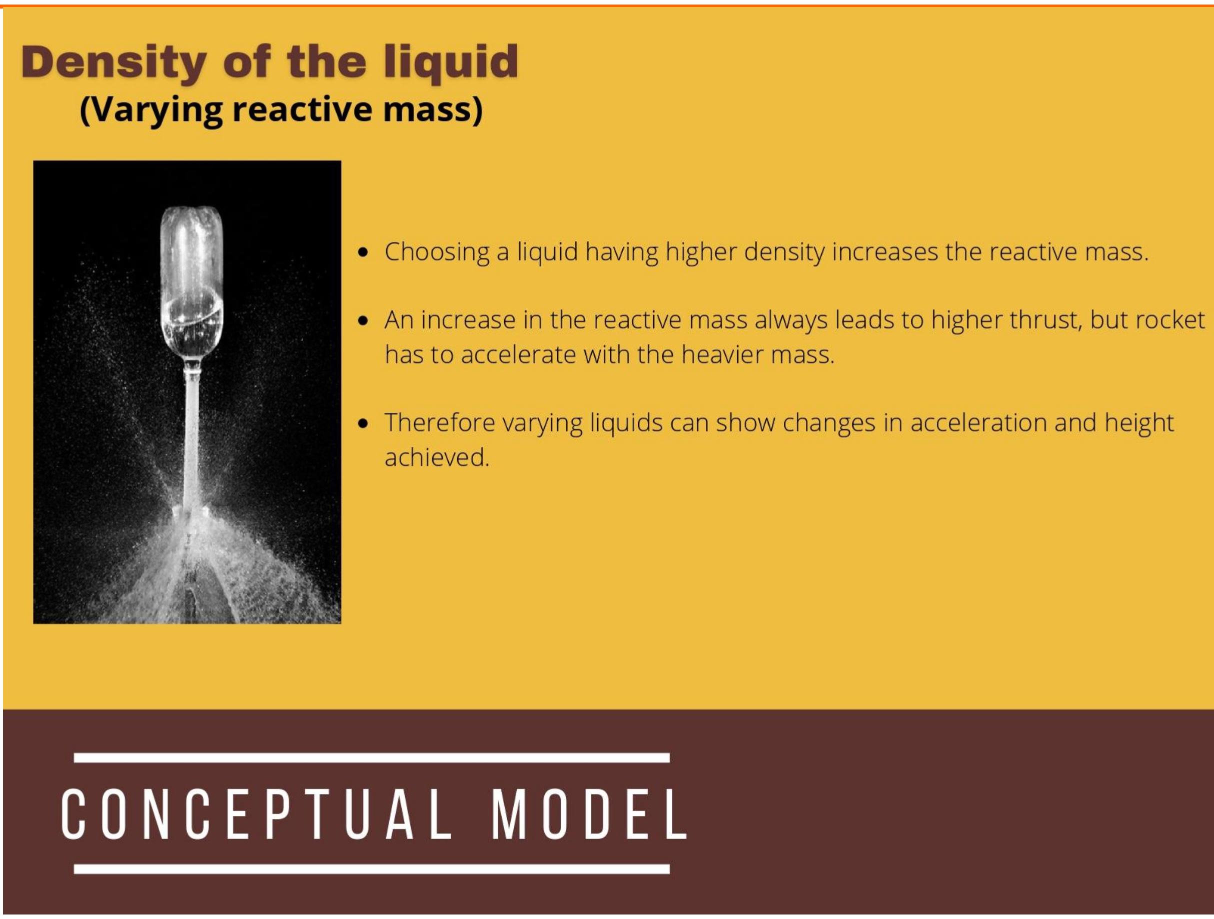
- *Water being incompressible cannot store much energy when it is pressurized. Air on the other hand can store lots of energy when pressurized but is not very heavy and therefore doesn't work well as a reactive mass*
- In a water rocket the air provides the stored energy and the water provides the reactive mass
- Too much water and the rocket is too heavy, and not enough water means there isn't a lot of reactive mass to throw

CONCEPTUAL MODEL

Optimum filling ratio
(Volume of water in the bottle)

- In order to achieve maximum performance a balance needs to be found between the amount of stored energy and the amount of reactive mass the rocket carries
- The optimum amount of water depends on a number of interdependent factors such as weight of the rocket, launch pressure, nozzle size etc.
- Additionally desired goal for the rocket flight also needs to be take into consideration, such as the highest altitude, or carrying a heavy payload, or achieving the highest acceleration

CONCEPTUAL MODEL



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National Physical Laboratory Teddington, Water Rocket Challenge

- www.npl.co.uk/water-rockets

Picture credits

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- http://www.uswaterrockets.com/3D_Printing/3D_Gardena_Nozzle/tutorial.htm
- https://bloximages.chicago2.vip.townnews.com/idahostatejournal.com/content/tncms/assets/v3/editorial/d/49/d49c4781-2898-5938-accb-1b942da145f0/576aef1365686.image.jpg?resize=1200%2C851
- https://media.wired.com/photos/59271797ac01987bf01387d2/master/w_2560%2Cc_limit/GettyImages-128628610-sa.jpg

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7. Mathematical Modelling

Thrust Force

- The thrust force 'F_thrust' from any rocket exhaust is the mass flow rate 'mf' times the exhaust velocity 'u_ex' of the rocket

  F_thrust = mf . u_ex = ρ . A . u_ex^2

  where ρ is the density of the water, and A is the outlet cross section.

- For air-water rockets, Bernoulli's equation gives

  u_ex = 2P+ / ρ

  where P+ is the internal over-pressure and ρ the density of water.

MATHEMATICAL MODEL

Enclosed air volume V

The pressure inside the rocket decreases as the water escapes and the air volume V increases.
A reasonably simple model is obtained by assuming the process to be like the adiabatic expansion of an ideal gas

$$P = P_o\,(V_o/V)^{1.4}$$

where the volume and absolute pressure at take-off are Vo and Po

The rate of increase of the enclosed air volume due to the exhaust flow is then

$$u_{ex}A = \sqrt{\frac{2P^+}{\rho_w}}A = \sqrt{\frac{2[P_o(V_o/V)^{1.4} - P_a]}{\rho_w}}A$$

where Pa is the atmospheric pressure and P+ = P - Pa.

The air volume at a slightly later time t+δt can then be calculated as

$$V(t+\delta_t) \approx V(t) + \delta_t u_{ex}A = V(t) + \delta_t\sqrt{\frac{2[P_o(V_o/V)^{1.4} - P_a]}{\rho_w}}A$$

These formulae hold until the water is used up

MATHEMATICAL MODEL

Mass 'm' of the rocket

If the solid parts of the rocket have the mass Ms, and the total volume of enclosed air and water is V_tot ,
the mass of the rocket as function of time is

m(t) = Ms + ρ . (V_tot –V) for V < V_tot

Acceleration 'a' of the rocket

If the rocket is moving vertically upwards against gravity, Newton's Second Law gives its acceleration a by

ma = F_thrust –mg

a=F_thrust/m -g

where g is the acceleration due to gravity, 9.8m/s2

MATHEMATICAL MODEL

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Velocity u and Height h of the rocket

- The acceleration values can be used to calculate speed u and height h of the rocket.
- Starting from u=0 and h=0 at time zero and then updating u and h after each time increment δt using

$$u(t+\delta_t) = u(t) + \delta_t \frac{[a(t) + a(t+\delta_t)]}{2}$$
$$h(t+\delta_t) = h(t) + \delta_t \frac{[u(t) + u(t+\delta_t)]}{2}$$

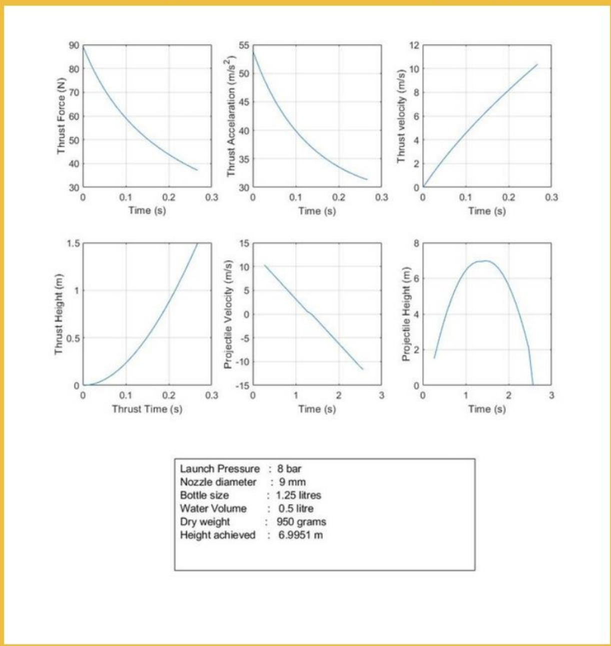
Reference: School of Civil Engineering, University of Queensland, Australia
https://www.civil.uq.edu.au/rocket

MATHEMATICAL MODEL

8.Simulation and Observations

Simulation results

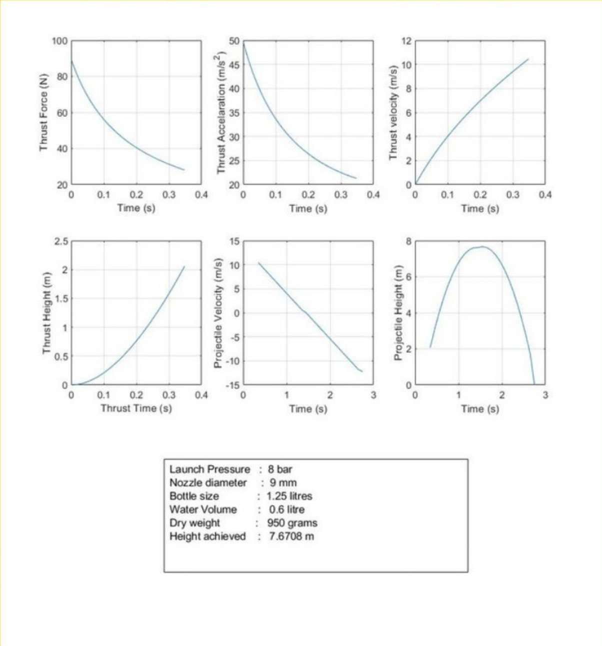
- For a given pressure, nozzle size, dry weight, bottle size and varying filling ratio



SIMULATION

Simulation results

- For a given pressure, nozzle size, dry weight, bottle size and varying filling ratio



SIMULATION

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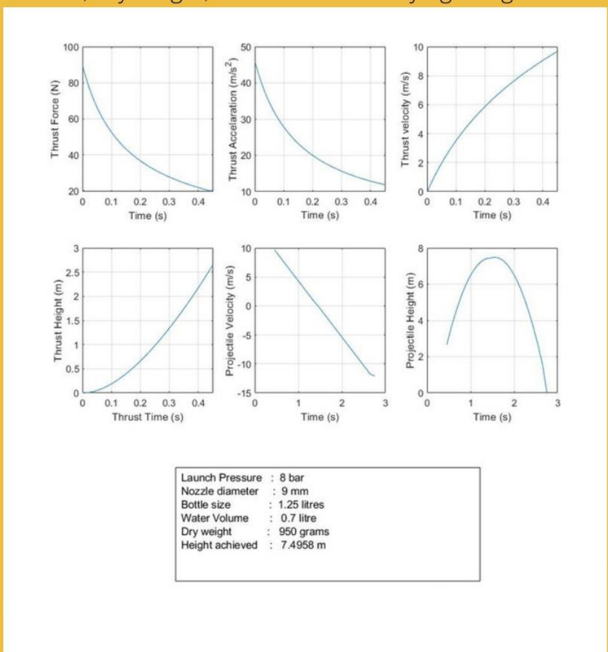
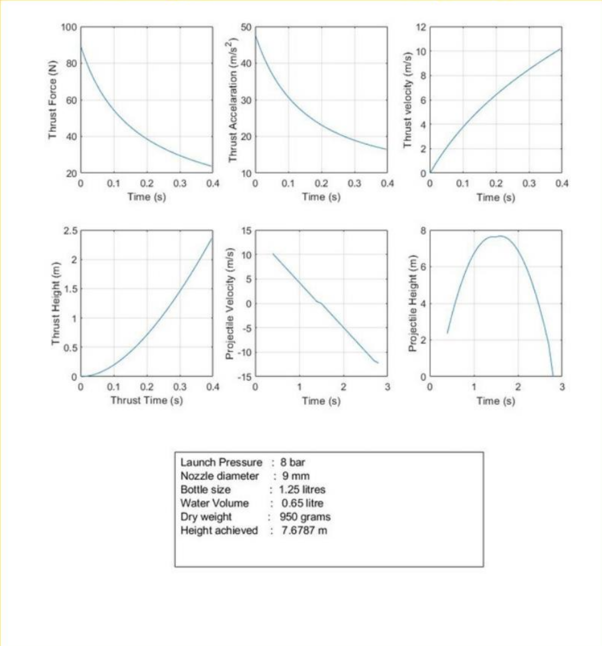


SIMULATION

Simulation results

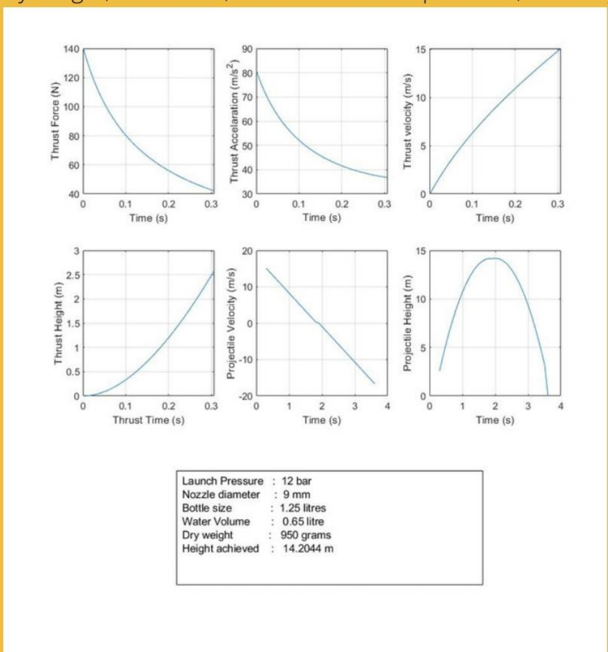
- For a given pressure, nozzle size, dry weight, bottle size and varying filling ratio



SIMULATION

Simulation results

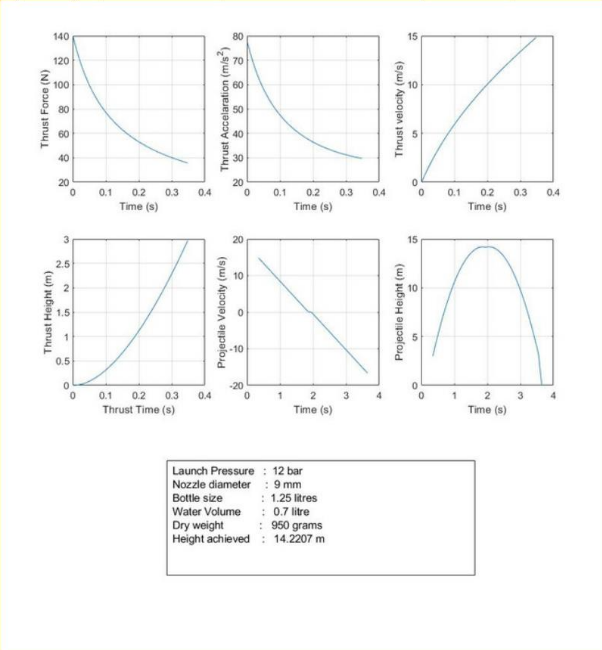
- For a given nozzle size, dry weight, bottle size, increased launch pressure, and varying filling ratio



SIMULATION

Simulation results

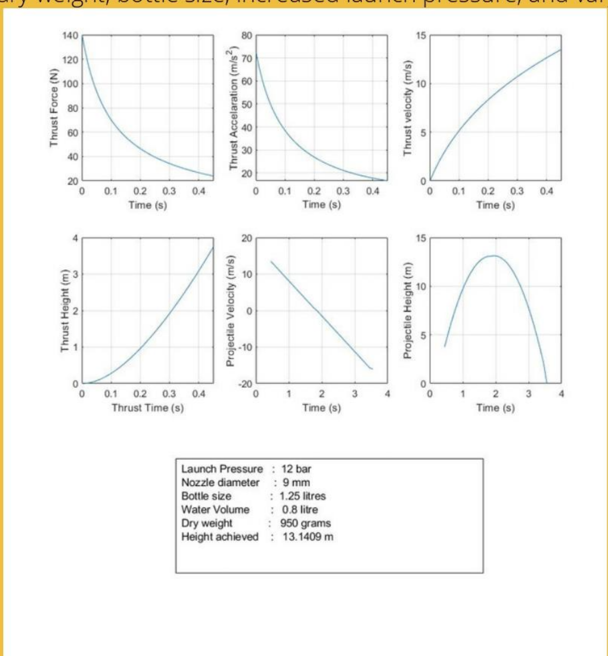
- For a given nozzle size, dry weight, bottle size, increased launch pressure, and varying filling ratio



SIMULATION

Simulation results

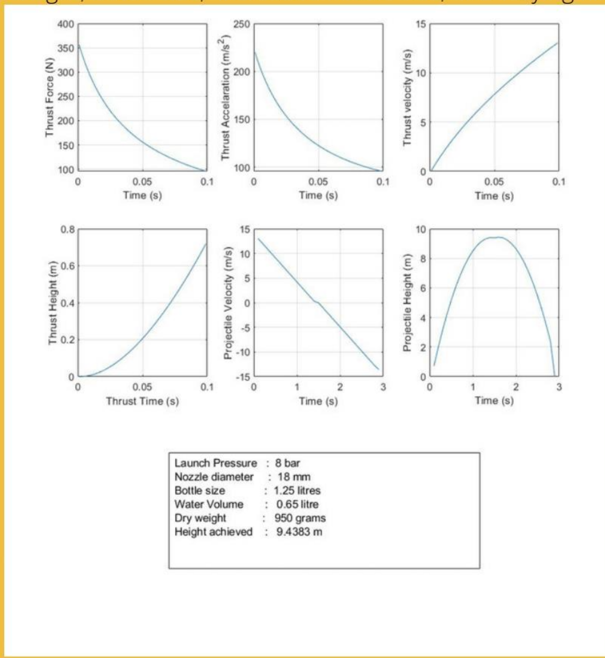
- For a given nozzle size, dry weight, bottle size, increased launch pressure, and varying filling ratio



SIMULATION

Simulation results

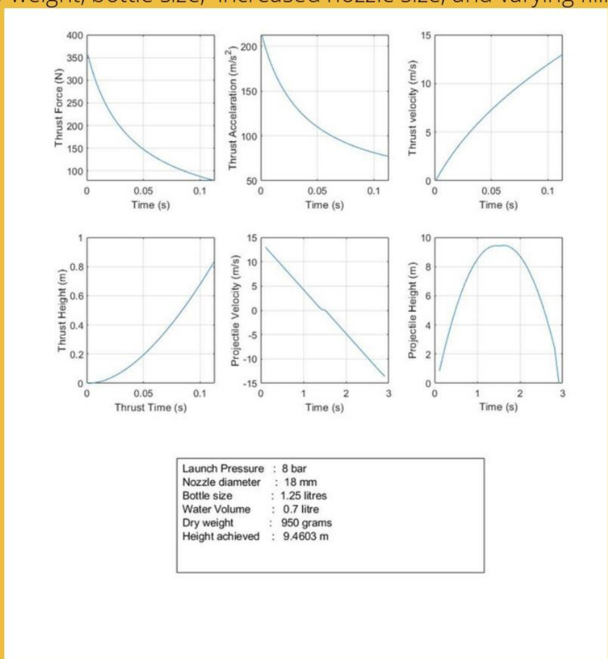
- For a given pressure, dry weight, bottle size, increased nozzle size, and varying filling ratio



SIMULATION

Simulation results

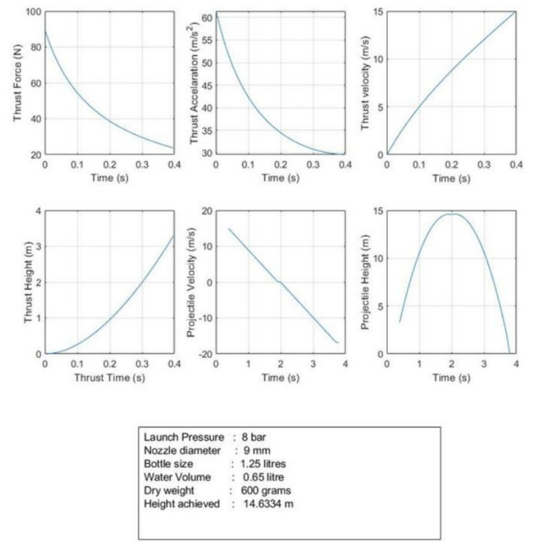
- For a given pressure, dry weight, bottle size, increased nozzle size, and varying filling ratio



SIMULATION

Simulation results

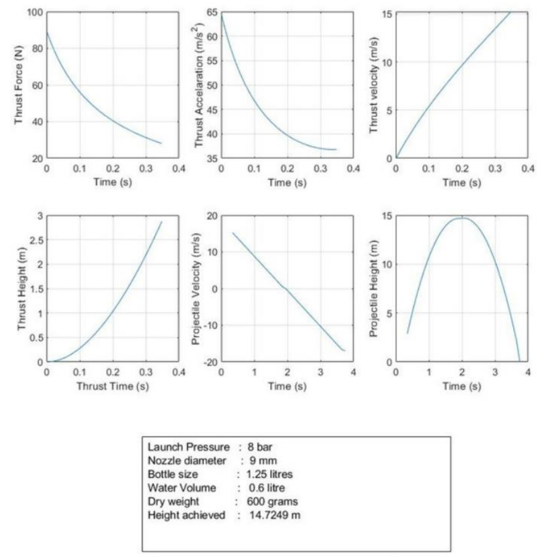
- For a given pressure, nozzle size , bottle size, decreased dry weight, and varying filling ratio



SIMULATION

Simulation results

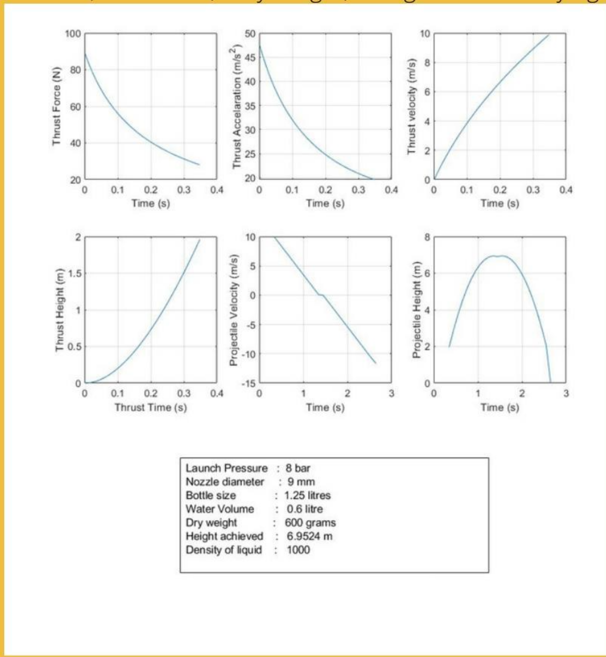
- For a given pressure, nozzle size , bottle size, decreased dry weight, and varying filling ratio



SIMULATION

Simulation results

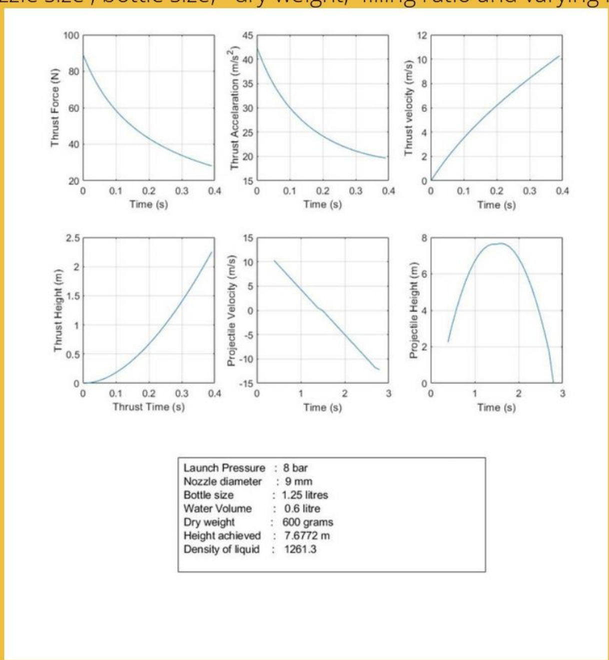
- For a given pressure, nozzle size , bottle size, dry weight, filling ratio and varying liquid density



SIMULATION

Simulation results

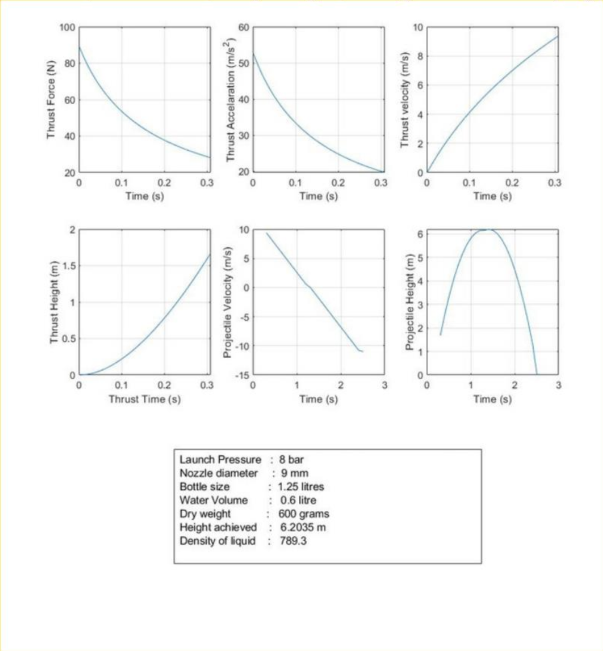
- For a given pressure, nozzle size , bottle size, dry weight, filling ratio and varying liquid density



SIMULATION

Simulation results

- For a given pressure, nozzle size , bottle size, dry weight, filling ratio and varying liquid density



SIMULATION

- For a given pressure, nozzle size , bottle size, dry weight, there is an optimum filling ratio for maximum altitude which is in the range of 45-55%.
- Optimum water volume could be increased when launch pressure increases
- It also increases for increased nozzle size.
- But for rockets with lesser dry weights, optimum water volume gets reduced.
- Altitude increases by using denser liquids to an extent

OBSERVATIONS

After performing the conceptual modelling of water rockets, we came to identify the parameters that could affect the flight of the rocket. From varying the factors such as launch pressure, dry weight of the rocket, weight distribution, shape, diameter of the nozzle, bottle size, water filling ratio etc, the output parameters like thrust force, thrust acceleration, velocity and height achieved vary accordingly.

From the relation between various parameters, mathematical model was created for further simulation studies. The simulation is done in MATLAB and the output of focus is the maximum height achieved. Also, key results such as thrust force, thrust acceleration are obtained.

Some of the main observations after conducting various simulations are as follows:

- For a given pressure, nozzle size, bottle size, dry weight, there is an optimum filling ratio for maximum altitude which is in the range of 45-55%.
- Optimum water volume could be increased when launch pressure increases.
- It also increases for increased nozzle size.
- But for rockets with lesser dry weights, optimum water volume gets reduced.
- Altitude increases by using denser liquids to an extent.

Furthermore, proposals for an achievable height of 100m is made from the simulation. Some of them are:

1. Initial Pressure: 10 Bar
   Diameter of nozzle: 9 mm
   Volume of rocket: 3 litres
   Volume of water: 1.2 litres
   Weight of rocket: 350 grams

2. Initial Pressure: 10 Bar
   Diameter of nozzle: 30mm
   Volume of rocket: 2.5 litres
   Volume of water: 1.2 litres
   Weight of rocket: 350 grams

9.Assembly Procedure

Assembly Procedure for Launcher:

1. Separate the below parts on the ground:
    - Wooden Launcher Base
    - Hose pipe with shredder valve
    - PVC pipe
    - 90° Elbow
    - Stability Connector
    - Gardena quick release Connector

2. Insert the hose pipe (from open end) in the PVC pipe up to shredder valve.
3. Insert the 90° Elbow in hose pipe and connect it to the PVC pipe.
4. Insert the stability connector in the hose pipe and keep it as it is.
5. Connect the Gardena quick release connector to the hose pipe.
6. By rotating the stability connector fit the Gardena quick release connector into it.
7. Pull the excess hose pipe through the PVC pipe. insert stability connector into the 90° Elbow.
8. Mount the PCV pipe into the plastic clamps on the wooden base.
9. Insert the strings of release mechanism through ankers on the wooden board.

Assembly Procedure for Payload Assembly:

1. Separate the below parts:

    Mechanical Parts:
    1. Payload Base
    2. Outer Cover
    3. Parachute base
    4. Mounting Strips (2 mm THK)
    5. Parachute Cap
    6. Springs
    7. Parachute
    8. Screws
    9. Electrical tape, double side tape, Rubber bands

    Electronics Parts:
    1. Air unit with antenna (dji)
    2. Camera (dji)
    3. Battery (dji)
    4. MPU 9250, MPU 6050 (IMU)
    5. BMP (Pressure sensor)

6. Pi W Zero
7. Pi sugar Battery
8. Pi camera
9. Servo motor, Motor shaft
10. Jumper wires

2. Mount raspberry Pi zero with battery on mounting strips.
3. Mount Air unit (dji) on mounting strips.
4. Mount all sensors on the mounting strips.
5. Mount battery (dji) on mounting strips.
6. Mount camera (dji) at specific location on payload base with screws.
7. Mount Pi cam on the outer cover.
8. Mount servo on the outer cover.
9. Attach parachute on the payload base.
10. Insert all the mounting strips on the payload base.
11. Make sure all the connections tight and properly connected.
12. Insert outer cover on the payload base and ensure it is placed in the given gaps.
13. Attach parachute cap to the outer cover with springs in it.
14. Mount parachute base on the outer cover with the screws.
15. Mount the Parachute cap on the servo mechanism.

Some Guidelines and Safety Instructions:

1. Check all the mechanical and electronics component are properly connected.
2. Check payload assembly is properly mounted on the bottle. The ground (dji) camera should be able to capture proper view.
3. Check nozzle is properly connected to the bottle. There should not be any leak.
4. Insert nozzle into the release mechanism. Take 2-3 dry tests and confirm release mechanism is working properly.
5. Connect Air Pump connector to the shredder valve.
6. Check pressure gauge reading before pressurizing the rocket. (it should be zero)
7. In case faulty pressure gauge take proper precautions or change the gauge.
8. Maximum pressure depends on the which bottle and Air pump we are using (in our case Do not pressurize rocket for more than **11 bar** pressure)
9. In case of abort remove the air pump and release air from shredder valve
10. During releasing the rocket launcher should be steady. Don’t pull the strings force-fully.
11. Always do tasting at remote places.

Future Scope:

1. Development of the launcher for pressure range between 15-40 bar.
2. Development of Automatic launch mechanism:
   The system can be developed in such way that, after pressurizing the rocket initial command is given, then:
   - Count down will start (10, 9, 8, ….1) sound effect also can be given
   - Automatic lift off: Servo command
   - Detection of highest altitude: Sound alert at ground station.
   - Parachute deploy: Use Servo Command

3. Further modifications in Payload Assembly, Space optimization, More sensor Integration
4. Development of New pressure chamber:
   Currently we are using PET Bottle which has limited pressure range and volume capacity.
   The new pressure chamber can be manufactured using carbon fibre and resin with high pressure range and volume.
5. Structural, modal and dynamic Simulations of all components.
6. Use of generative design for advanced light weight construction

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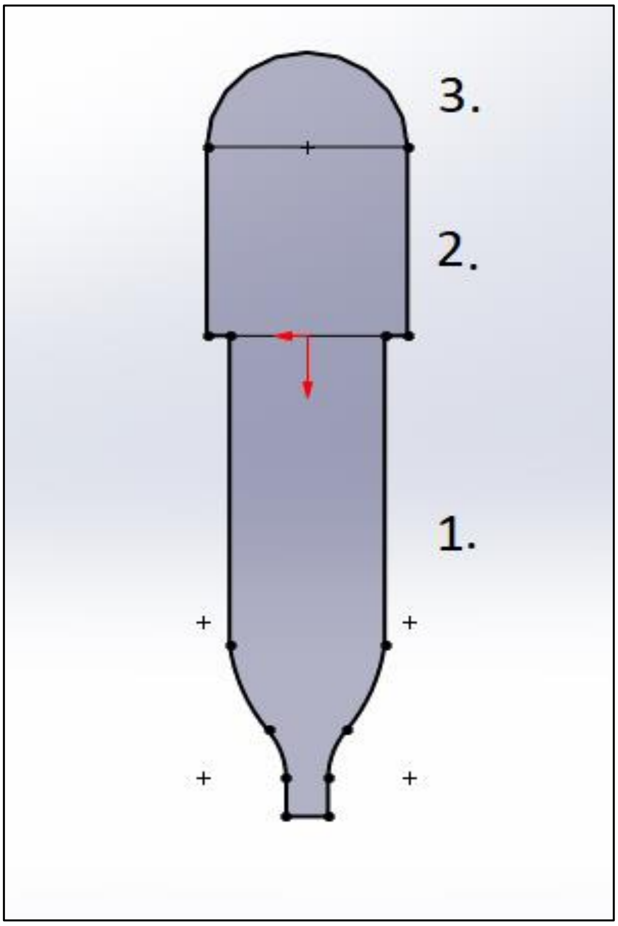
10.Rocket Calculations

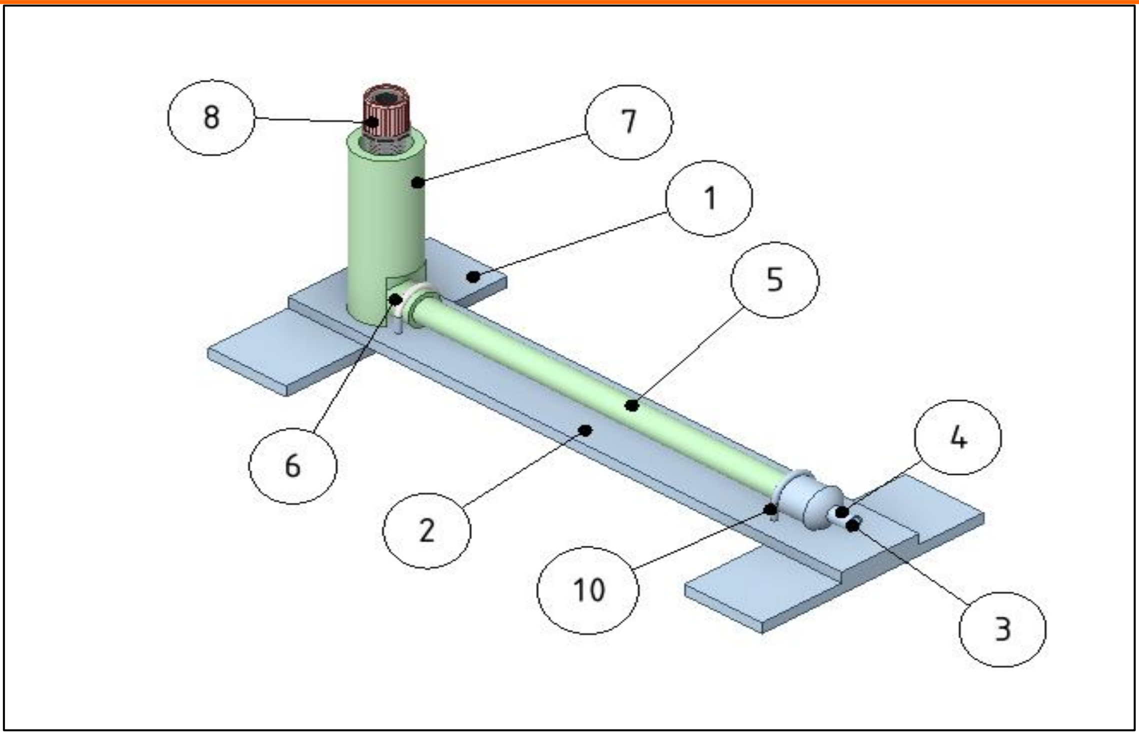
Calculations for Centre of Pressure					
Sl.No	Shape	Area (mm^2)	Location of the axis (mm)	Area Moment of Inertia (mm^3)	Remark
1	Bottle	20100	160	3216000	Location is from the Nozzle end
2	Payload	12100	335	4053500	
3	Parachute	5240	422	2211280	
	Sum of Areas	37440			Sum of all the Areas
			Sum	9480780	Total sum of the Moment of the Inertia
			Distance of centriod	253.226	Distance of the centroid from the Nozzle end

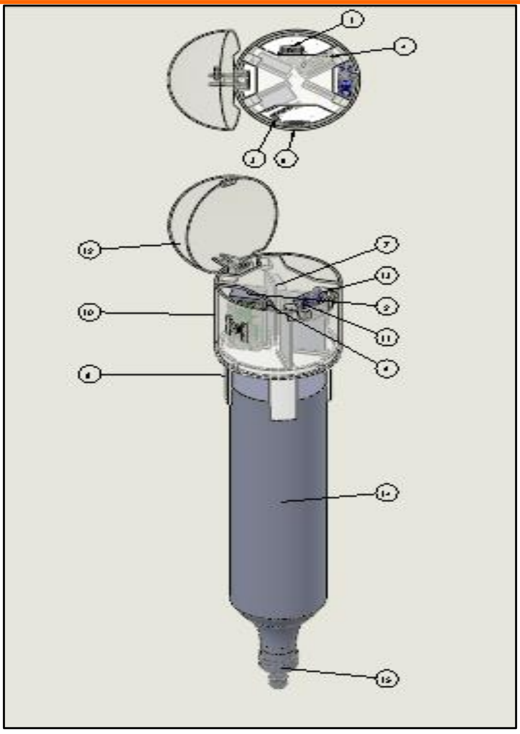


Calculations for Area of the Parachute				
Sl.No	**Parameter**	**Value**	**Unit**	**Remark**
1	Terminal Velocity	2.72	m/s	Desired Speed of the System
2	Density of the Air()	1.225	kg/m^3	Standard density of the Air
3	Coefficient of Drag (Cd)	0.7		Value varies beween 0.5 - 1.2
4	Weight of the System	10	N	Mass of the system 1 Kg
	Area	0.7881	m^2	Required area of the Parachute
	Diameter of the Parachute	1.0020	m	

Pressure Calculation			
Sl. No	**Pressure (N/mm2)**	**Area (mm2)**	**Force (N)**
1	0.2	5671.625	1134.325
2	0.4	5671.625	2268.65
3	0.6	5671.625	3402.975
4	0.8	5671.625	4537.3
5	1	5671.625	5671.625
6	1.2	5671.625	6805.95
7	20	5671.625	113432.5

Bill of Material (Launcher)				
ITEM NO.	**PART**	**DESCRIPTION**	**QTY.**	**REMARK**
1	WOODEN STRIPS		2	OBTAINEND FROM HOLZTECHNISCHE
2	WOODEN STRIPS		1	OBTAINEND FROM HOLZTECHNISCHE
3	SHREDDER VALVE		1	https://www.amazon.de/-/en/RMENOOR-snap-rubber-valves-motorcycle/dp/B08K44BXVV/ref=sr_1_8?dchild=1&key
4	GARDENA HOSE PIPE		2 m LONG	AVAILABLE IN TOOM
5	PVC PIPE		1	AVAILABLE IN TOOM
6	90° ELBO	REFER THE DRAWING	1	USE 3D PRINTING OR ORDER ONLINE
7	STABILITY CONNECTOR	REFER THE DRAWING	1	MANUFACTURED IN THE MACHINE LAB
8	GARDENA QUICK RELEASE CONNECTOR		1	AVAILABLE IN TOOM/ OBI, ORDER ONLINE
9	NYLON ROPE		4 m LONG	AVAILABLE IN TOOM
10	MOUNTING CLAMPS		3	AVAILABLE IN TOOM

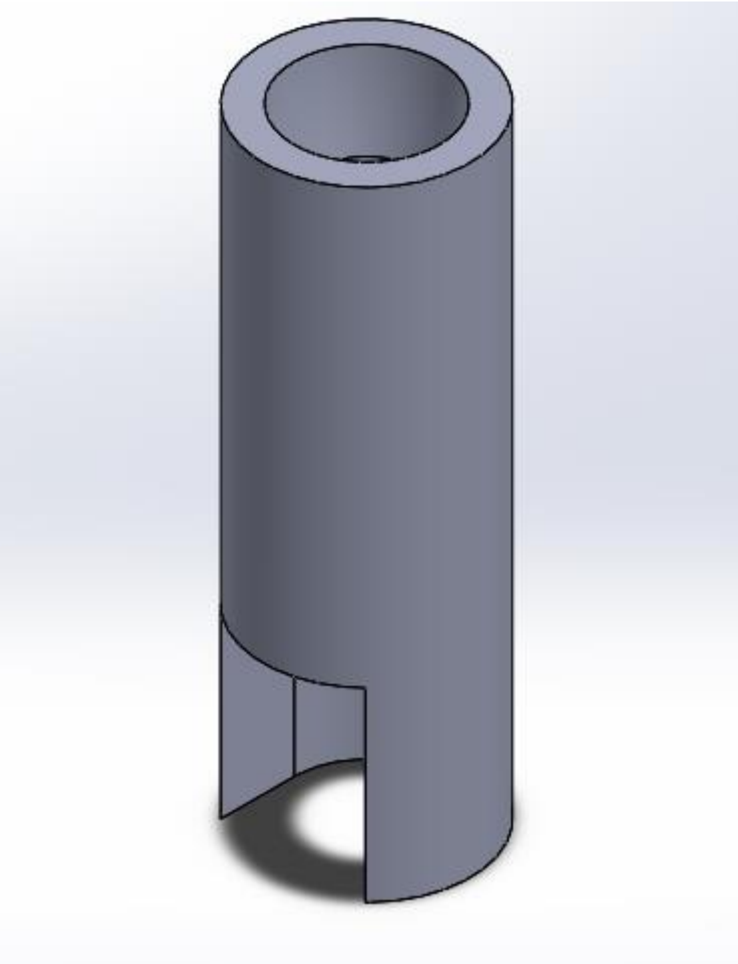

8
7
1
5
4
6
2
10
3

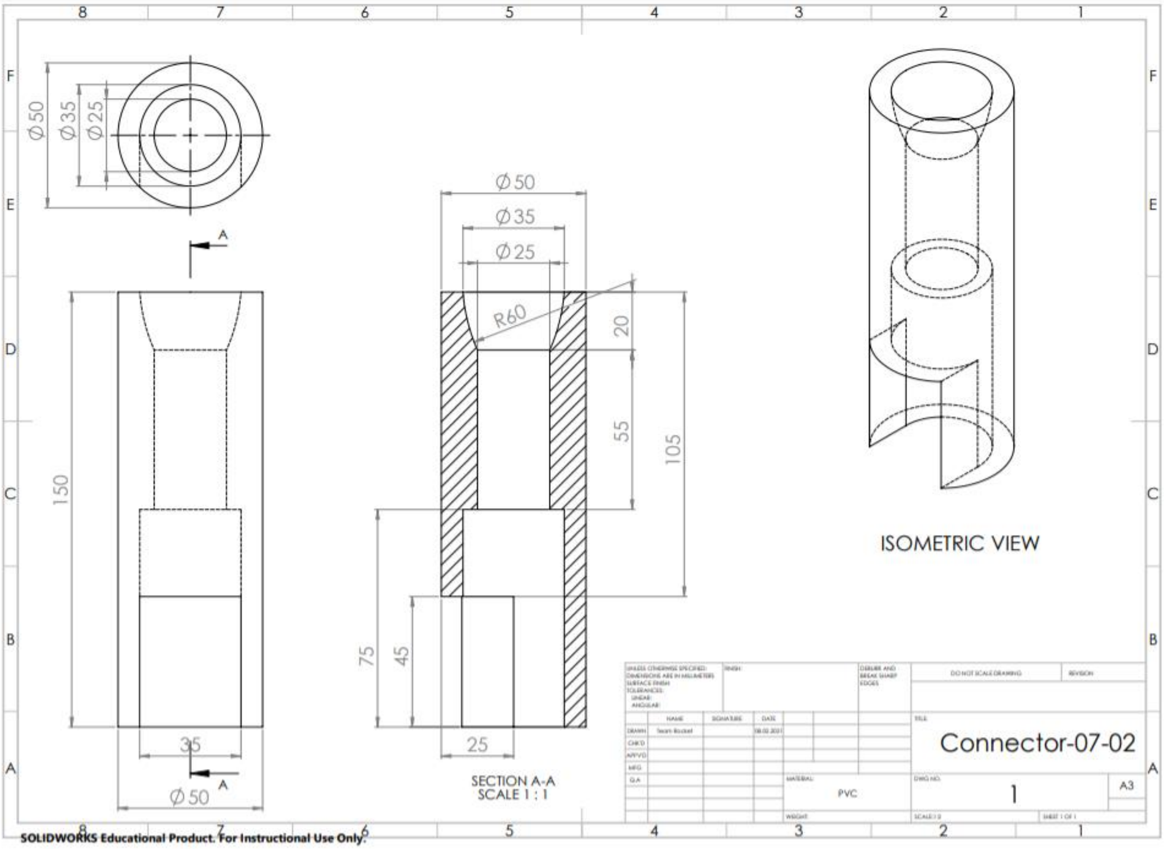


Bill of Material (Rocket)				
ITEM NO.	PART	DESCRIPTION	QTY.	REMARK
1	DJI FPV SYSTEM CAMERA	STANDARD PART	1	https://www.globe-flight.de/DJI-FPV-Lufteinheit?curr=EUR&gclid=CjwKCAiAm-2BBhANEiwAe7eyFGvjUudQa8584hVaxy3jKJaENRj9iBYrPPhKbs6_DVMC2vQCXsEgEhoCA8oQAvD_BwE#false
2	BATTERY PiSugar	STANDARD PART	1	https://www.amazon.de/-/en/Pisugar-Portable-Lithium-Raspberry-Accessories/dp/B07RK17BGN
3	RASPBERRY PI ZERO W	STANDARD PART	1	https://www.conrad.de/de/search.html?search=RASPBERRY%20PI%20ZERO%20W
4	DJI FPV SYSTEM AIR UNIT	STANDARD PART	1	https://www.globe-flight.de/DJI-FPV-Lufteinheit?curr=EUR&gclid=CjwKCAiAm-2BBhANEiwAe7eyFGvjUudQa8584hVaxy3jKJaENRj9iBYrPPhKbs6_DVMC2vQCXsEgEhoCA8oQAvD_BwE#false
5	BATTERY CAM DJI	STANDARD PART	1	https://www.conrad.de/de/p/gens-ace-modellbau-akkupack-lipo-7-4-v-450-mah-zellen-zahl-2-30-c-softcase-jst-syp-2316806.html?gclid=CjwKCAiAm-2BBhANEiwAe7eyFBhBvvBCl-N0ziFdBv6kdP3btFdf_B72fKUBKmkFGBKtf0xIJgsfvBoCTkwQAvD_BwE&hk=SEM&WT.srch=1&WT.mc_id=google_pla&s_kwcid=AL%21222%213%21442300016857%21%21%21g%21%21&ef_id=[illegible]
6	RSP CAMERA MIA	STANDARD PART	1	https://www.conrad.de/de/search.html?search=RASPBERRY%20PI%20camera
7	PARACHUTE BASE	DRAWING AVAILABLE	1	USE 3D PRINTING
8	PAYLOAD BASE	DRAWING AVAILABLE	1	USE 3D PRINTING
9	MOUNTING STRIP	DRAWING AVAILABLE	4	
10	OUTER COVER	DRAWING AVAILABLE	1	USE 3D PRINTING
11	SG90 SERVOMOTOR	STANDARD PART	1	https://www.conrad.de/de/search.html?search=SG90%20SERVOMOTOr&category=%1Ft15%1Fc14743
12	CAP	DRAWING AVAILABLE	1	USE 3D PRINTING
13	MOTOR SHAFT	DRAWING AVAILABLE	1	USE 3D PRINTING
14	BOTTLE	STANDARD PART	1	1,5 Liters Coca Cola Bottle
15	NOZZLE	DRAWING AVAILABLE	1	USE 3D PRINTING

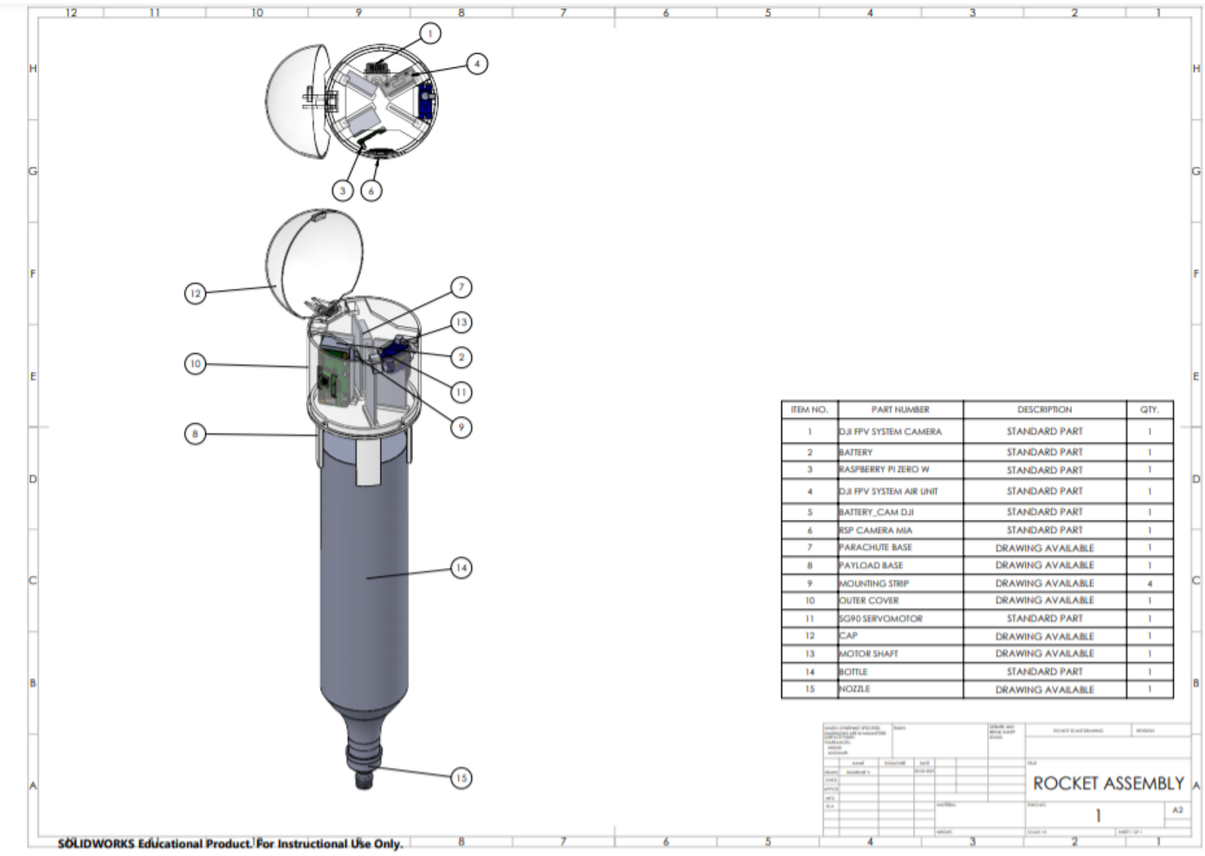
11.Designs

Stability Connector



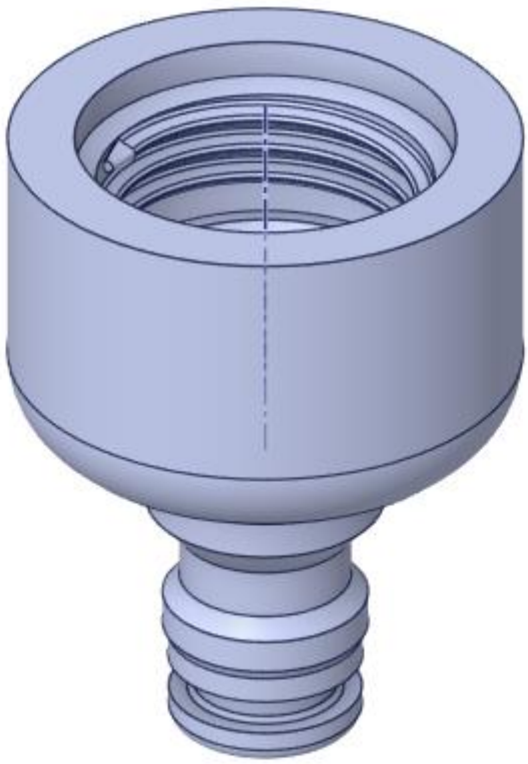


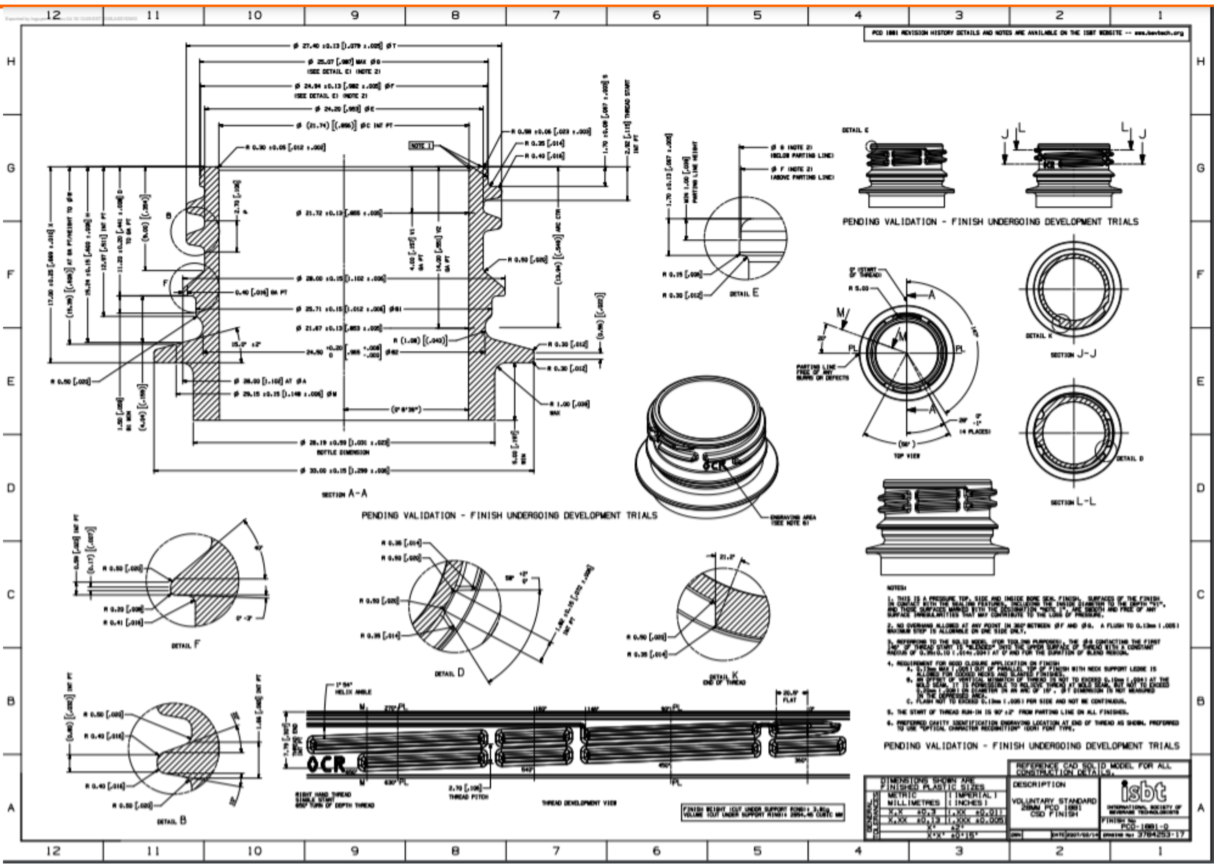
Payload Assembly



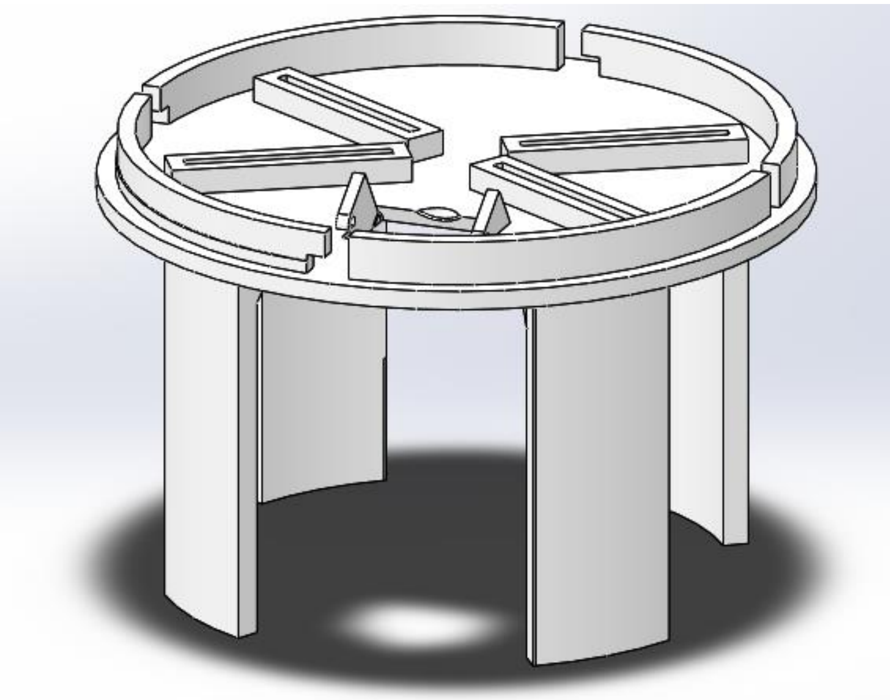
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	DJI FPV SYSTEM CAMERA	STANDARD PART	1
2	BATTERY	STANDARD PART	1
3	RASPBERRY PI ZERO W	STANDARD PART	1
4	DJI FPV SYSTEM AIR UNIT	STANDARD PART	1
5	BATTERY_CAM DJI	STANDARD PART	1
6	RSP CAMERA MIA	STANDARD PART	1
7	PARACHUTE BASE	DRAWING AVAILABLE	1
8	PAYLOAD BASE	DRAWING AVAILABLE	1
9	MOUNTING STRIP	DRAWING AVAILABLE	4
10	OUTER COVER	DRAWING AVAILABLE	1
11	SG90 SERVOMOTOR	STANDARD PART	1
12	CAP	DRAWING AVAILABLE	1
13	MOTOR SHAFT	DRAWING AVAILABLE	1
14	BOTTLE	STANDARD PART	1
15	NOZZLE	DRAWING AVAILABLE	1

Nozzle

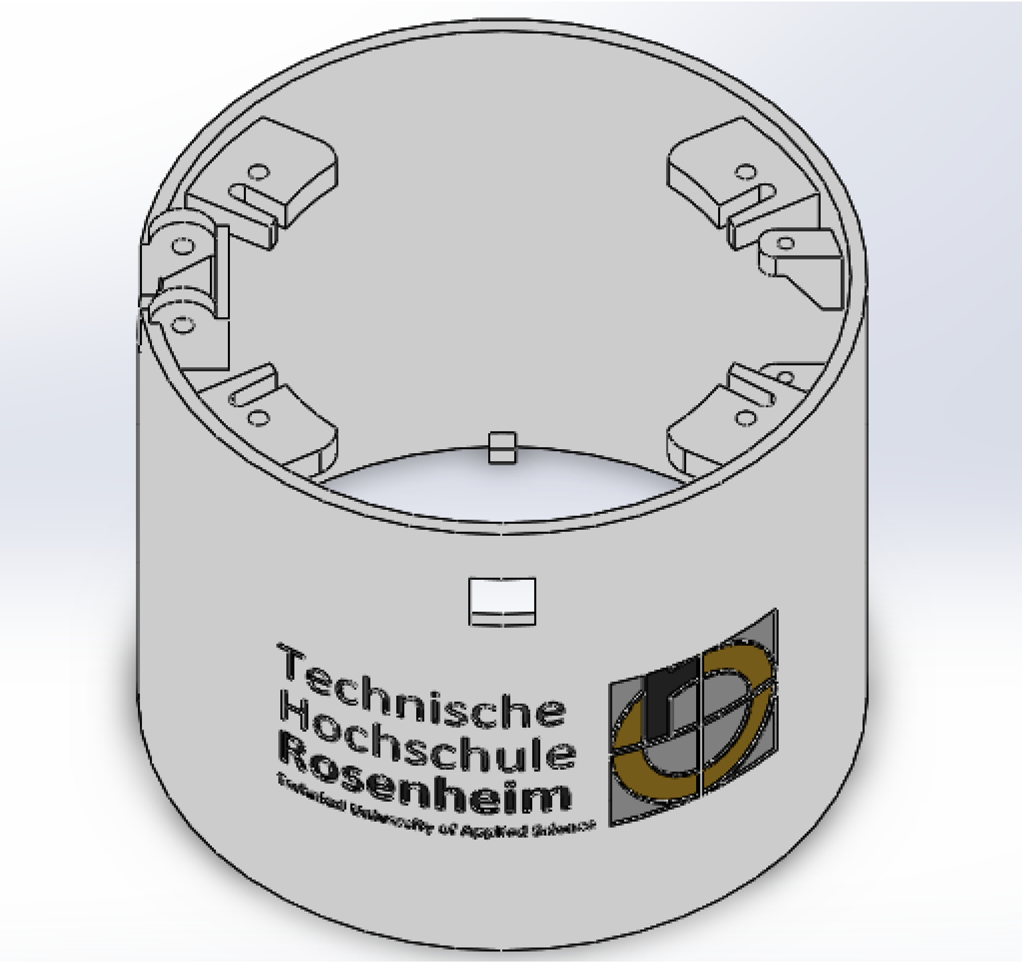




PayloadBase



Outer Cover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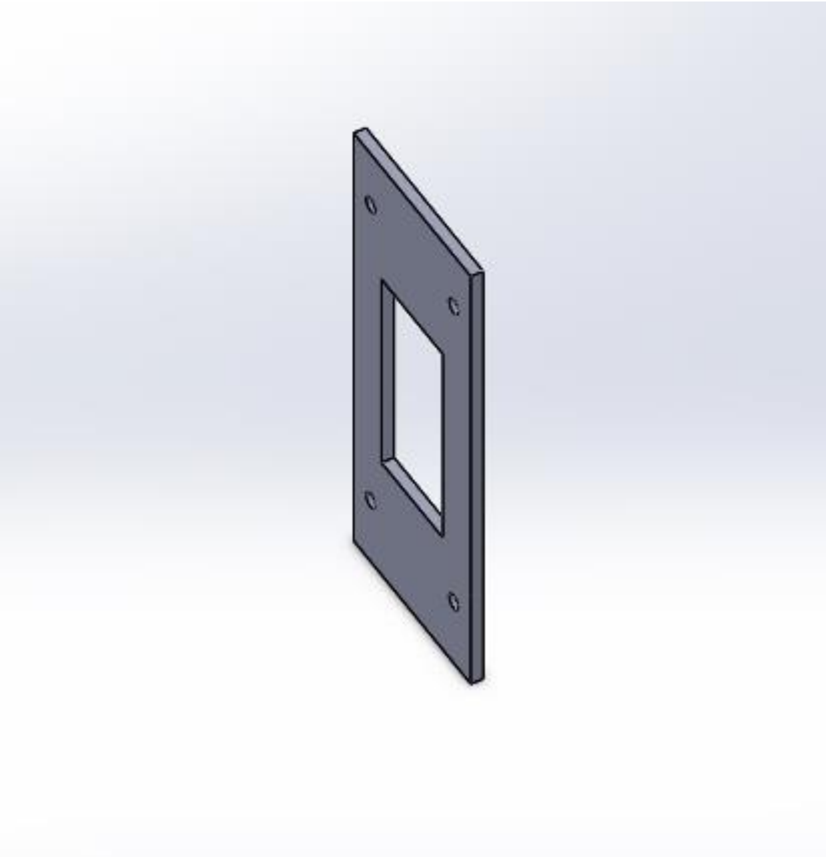
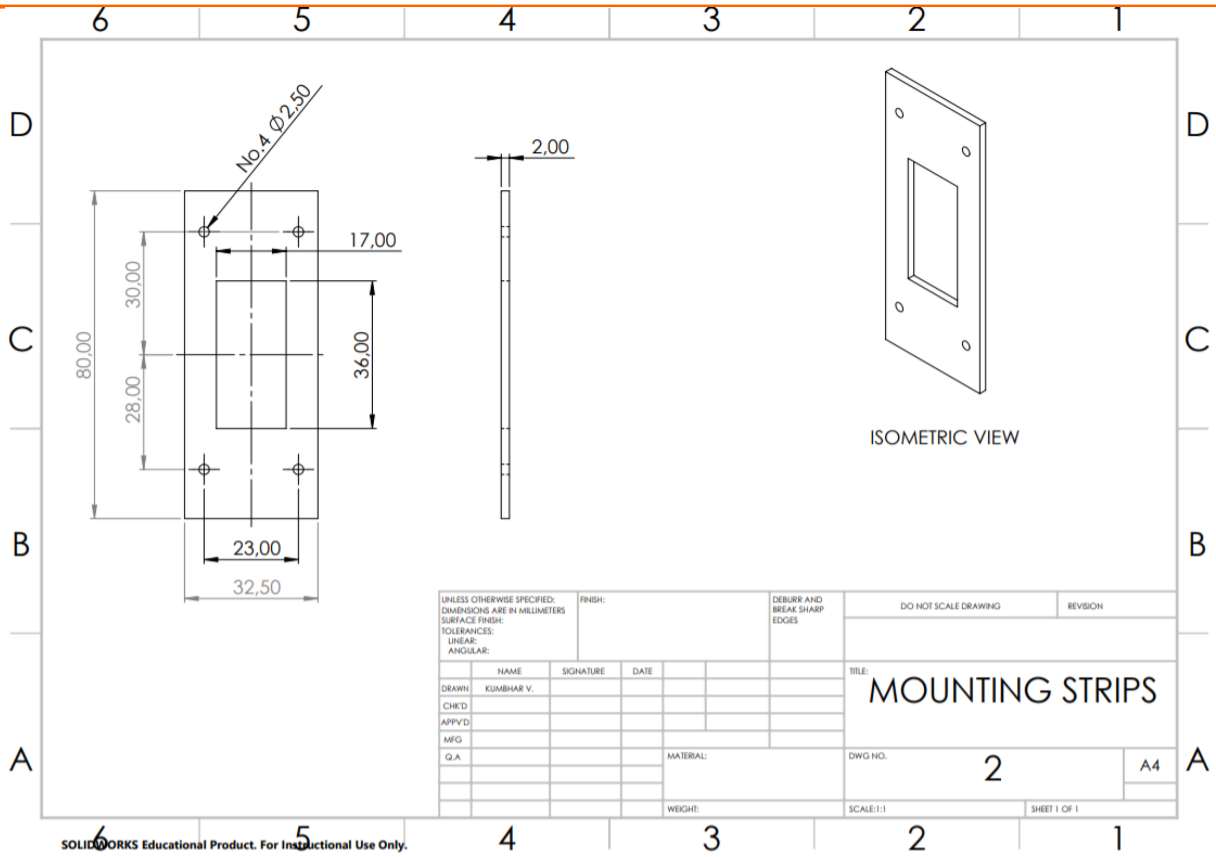
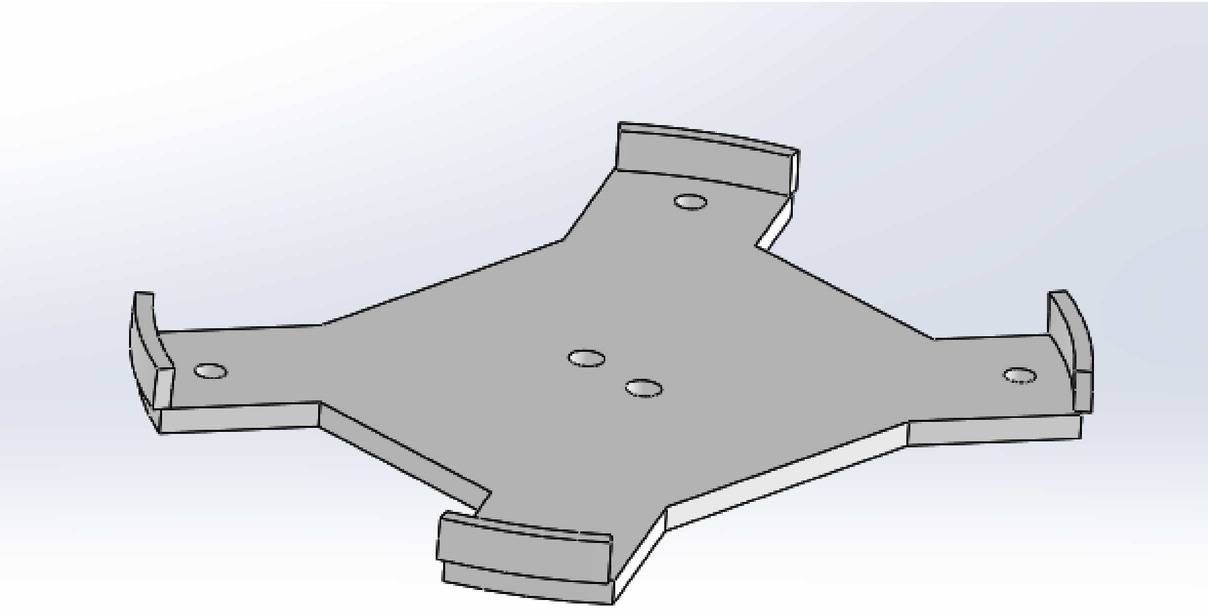
Hochschule
Rosenheim
Technical University of Applied Sciences

Mounting Strips

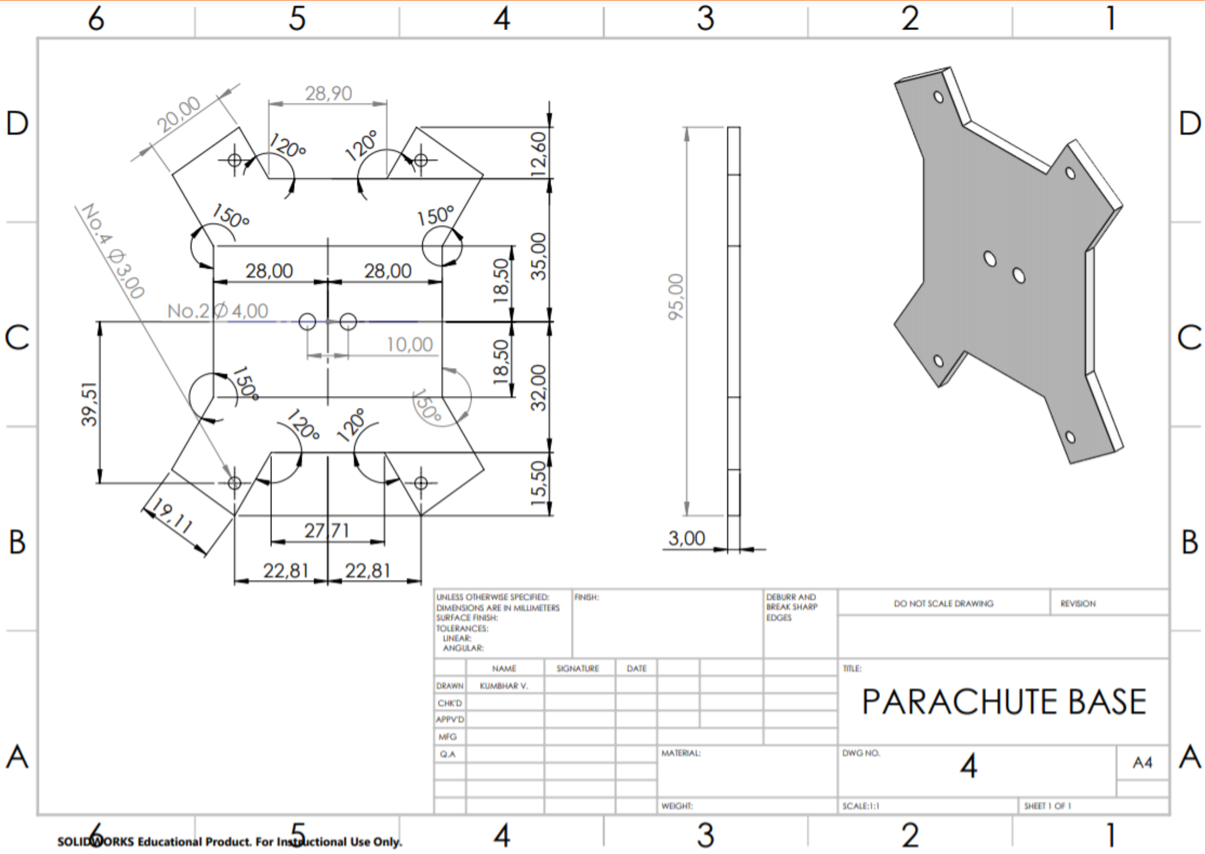




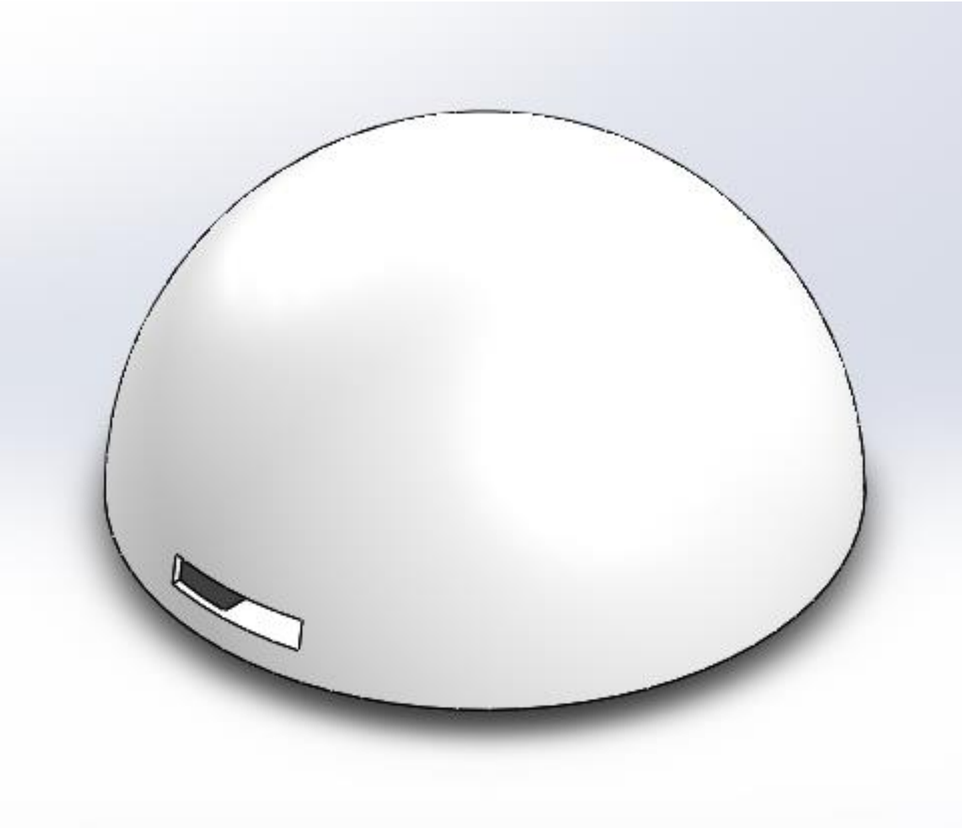
Parachute Base



Technische Hochschule Rosenheim
Technical University of Applied Sciences
Fakultät für Ingenieurswissenschaften



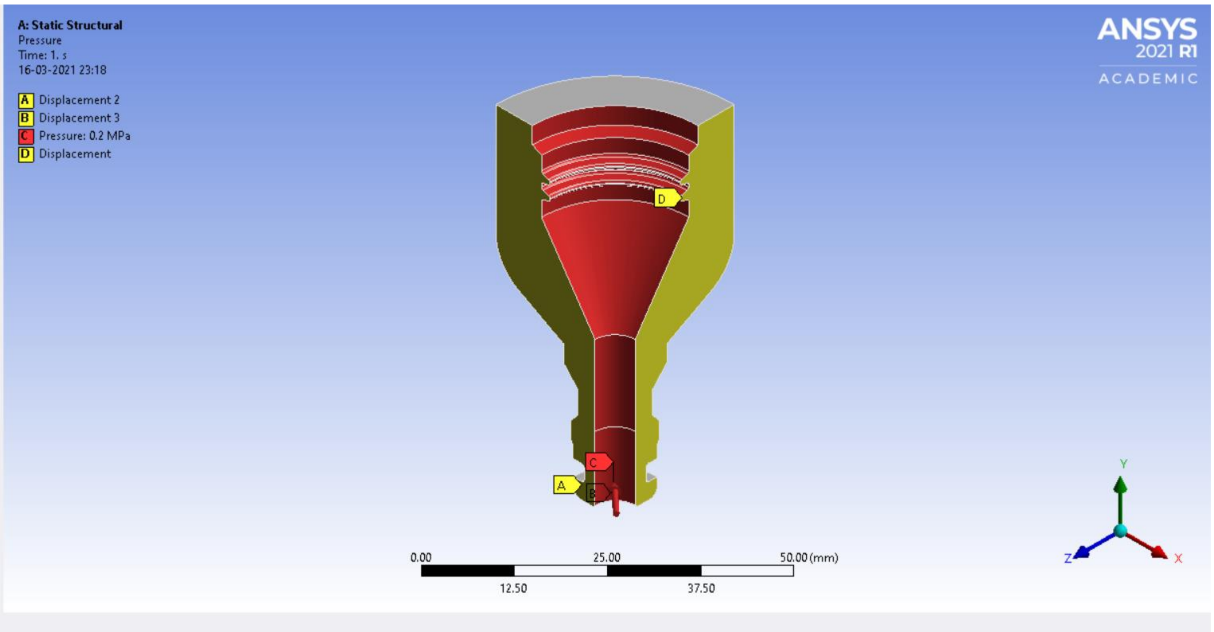
Parachute Cap



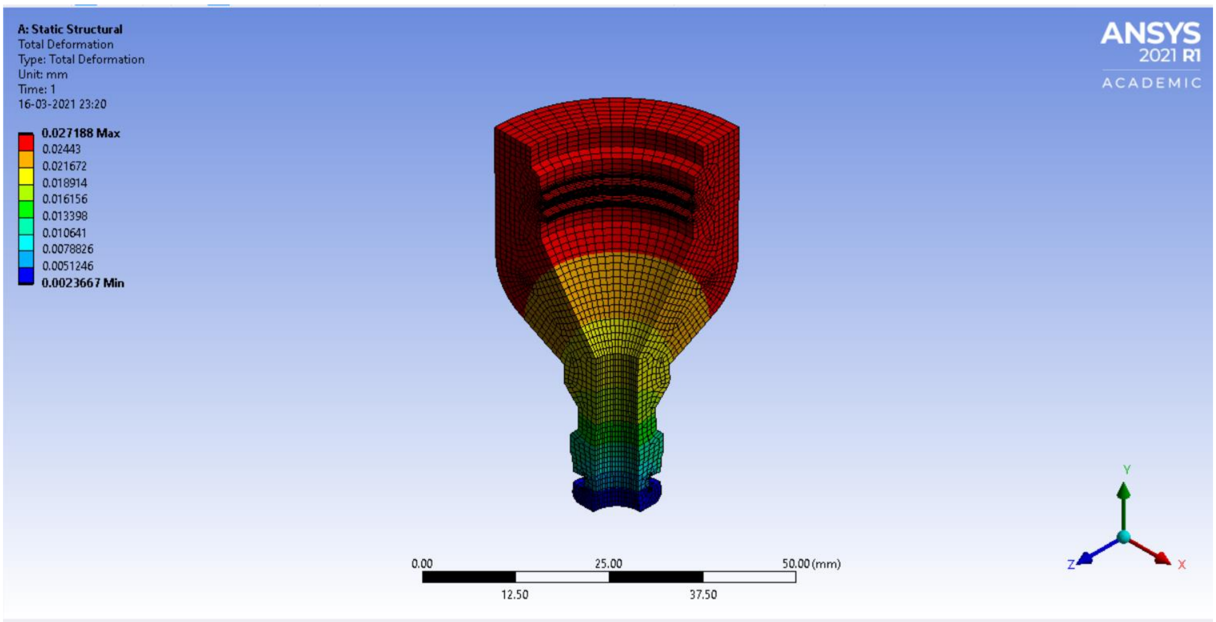
12.Ansys Simulation

Structural Simulation of Nozzle

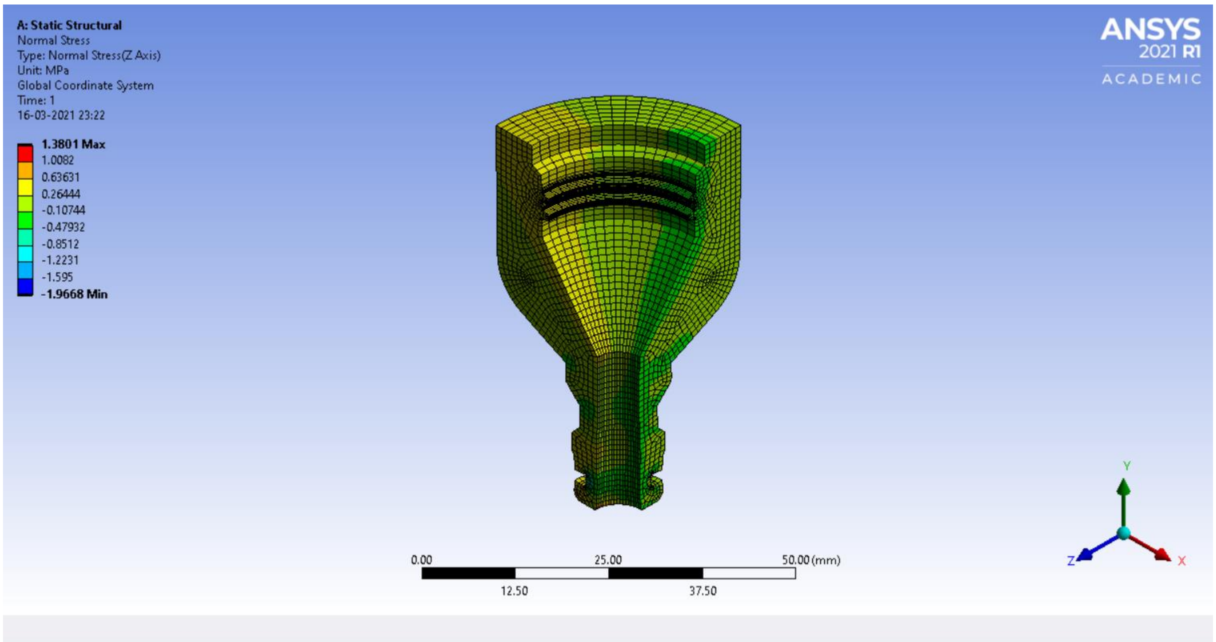
Boundary Conditions:



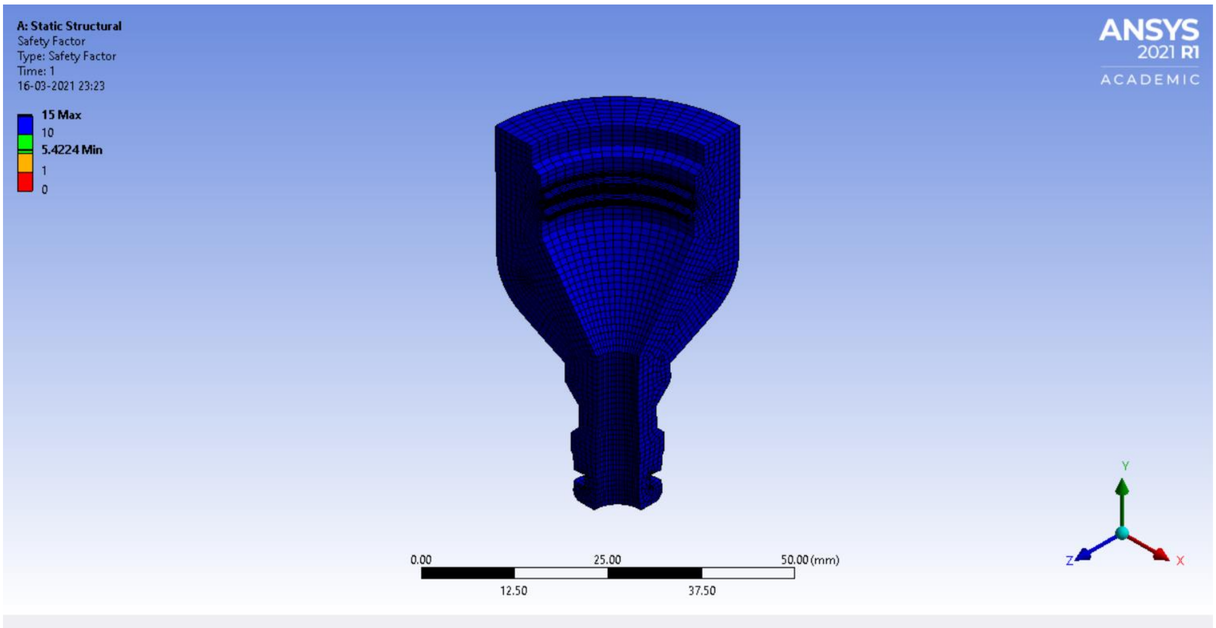
Total Deformation:



Normal Stress



Factor of Safety:



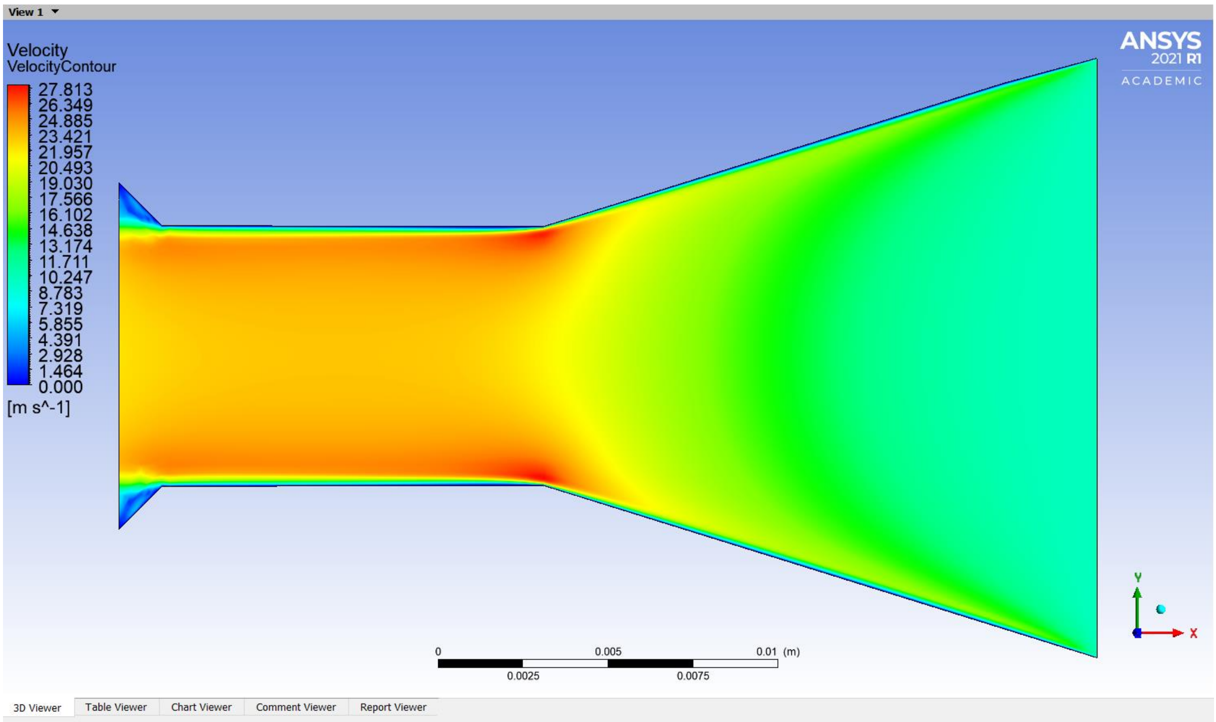
Parameter Set:

Table of Design Points

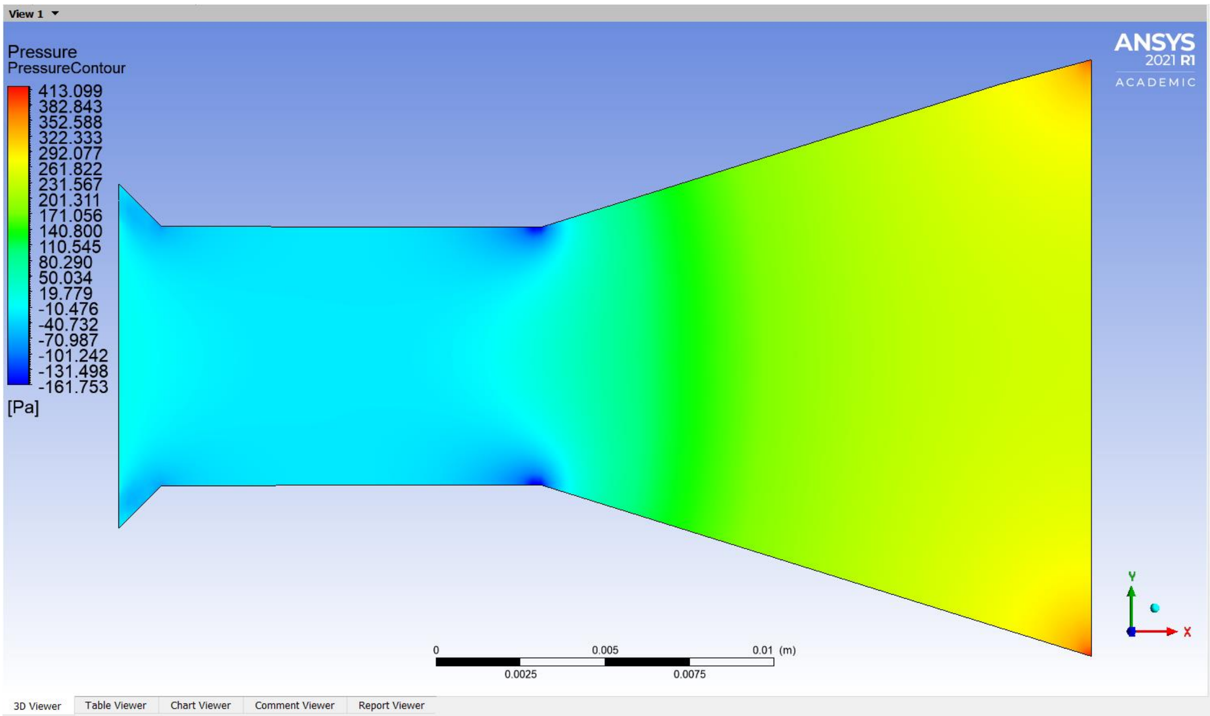
	A	B	C	D	E	F	G	H
1	Name	P1 - Pressure Magnitude	P3 - Total Deformation Maximum	P4 - Safety Factor Minimum	P5 - Normal Stress Maximum	Ret...	Retained Data	Note
2	Units	MPa	mm		MPa			
3	DP 0 (Current)	0.2	0.027188	5.4224	1.3801	☑	✓	
4	DP 1	0.4	0.054376	2.7112	2.7601	☐		
5	DP 2	0.6	0.081565	1.8075	4.1402	☐		
6	DP 3	0.8	0.10875	1.3556	5.5203	☐		
7	DP 4	1	0.13594	1.0845	6.9003	☐		
8	DP 5	1.2	0.16313	0.90373	8.2804	☐		
*						☐		

Nozzle Internal Flow Simulation

Velocity Contour:

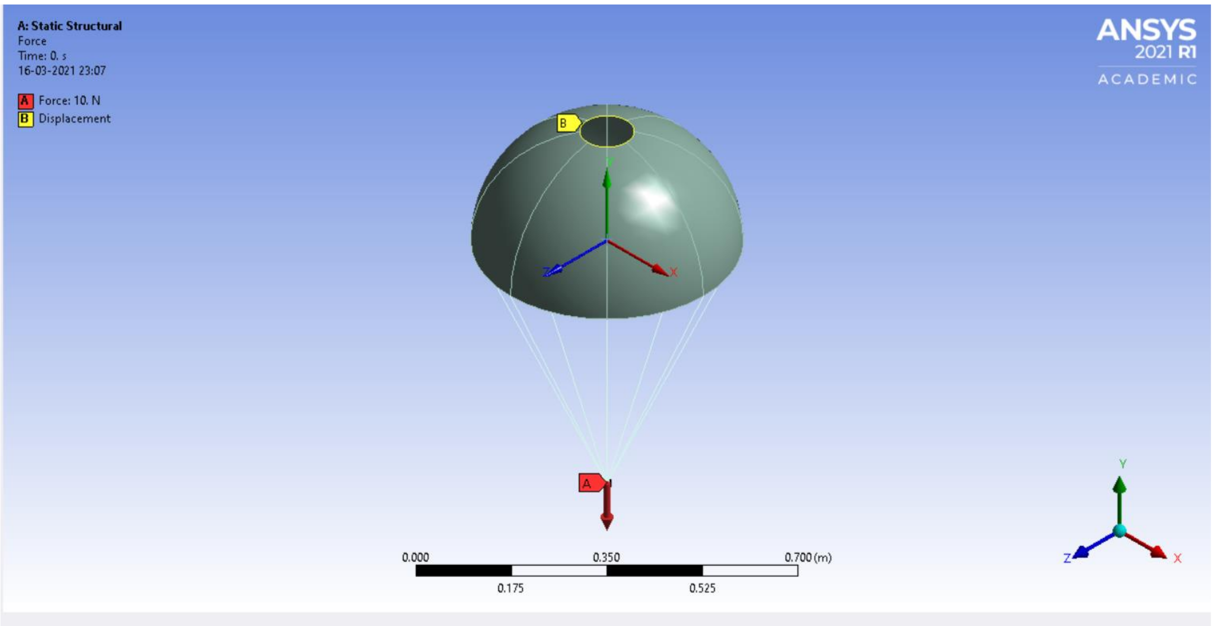


Pressure Contour

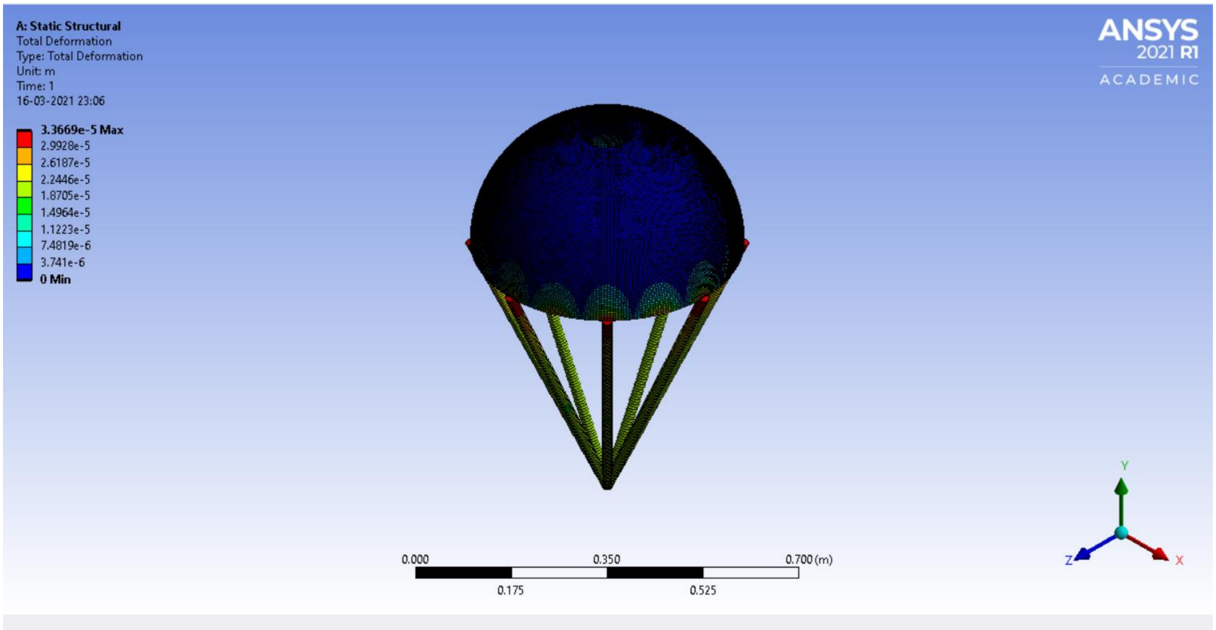


FSI Parachute Simulation

Boundary Conditions:

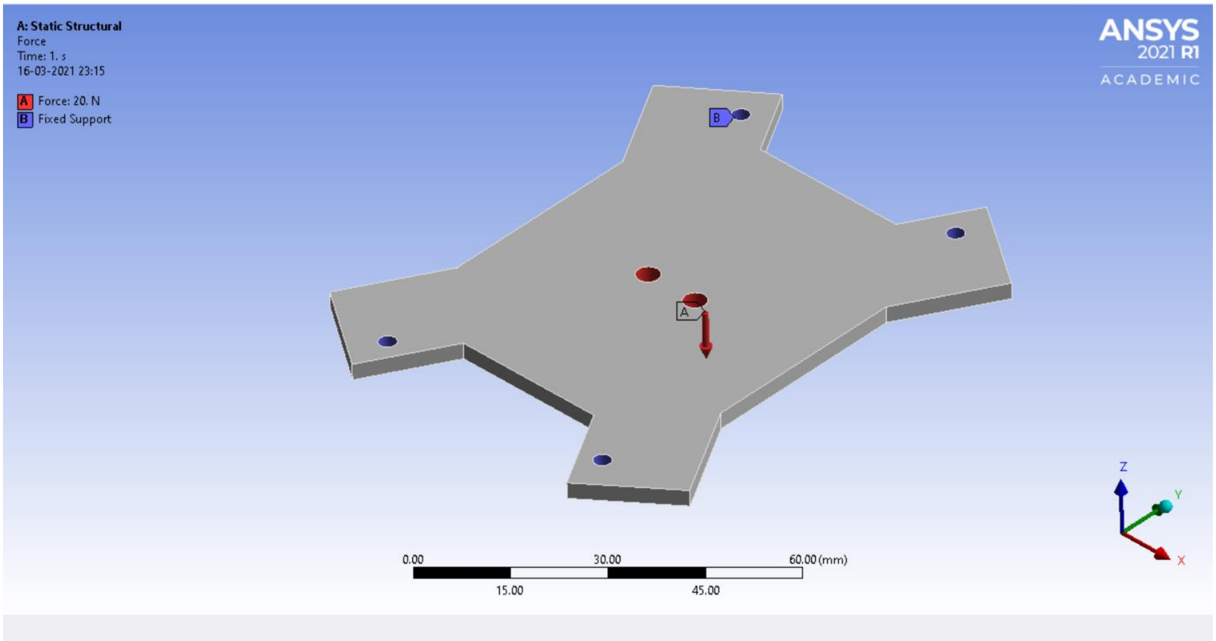


Total Deformation:

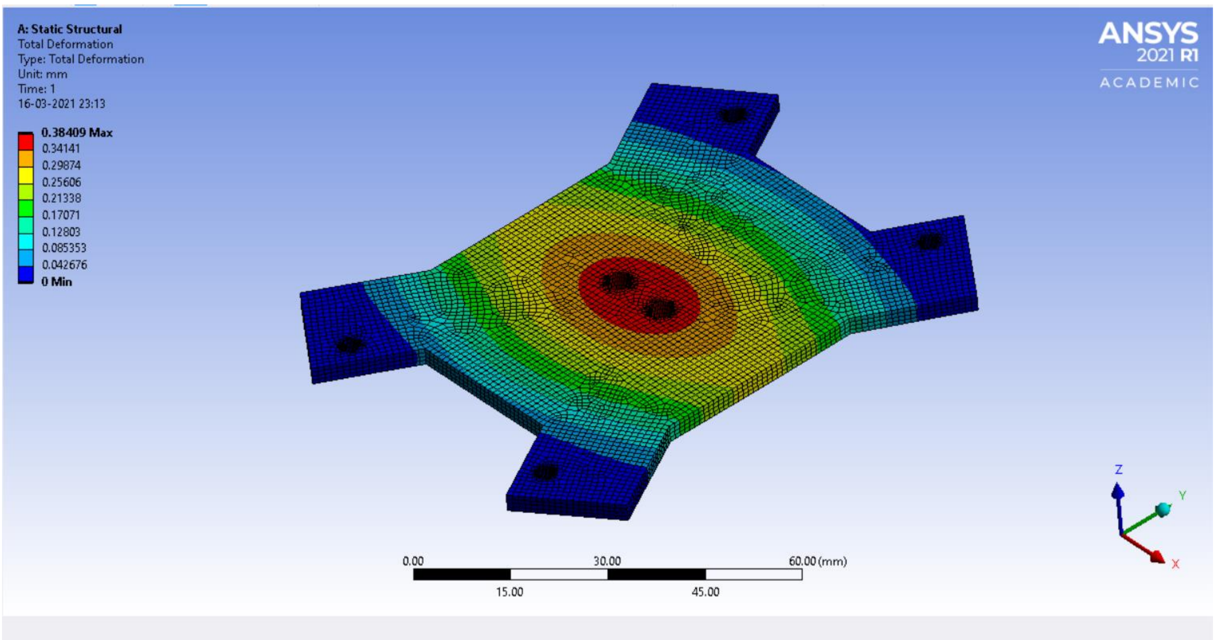


Parachute Base Structural Simulation

Boundary Conditions:

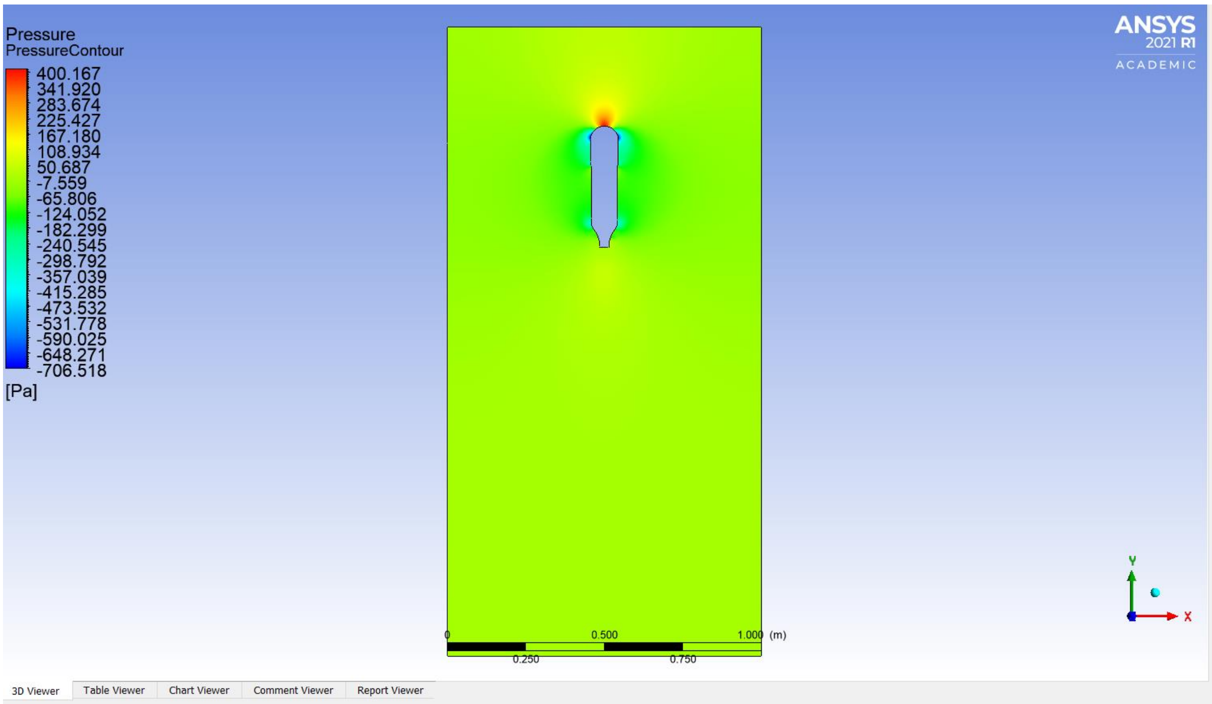


Total_Deformation:

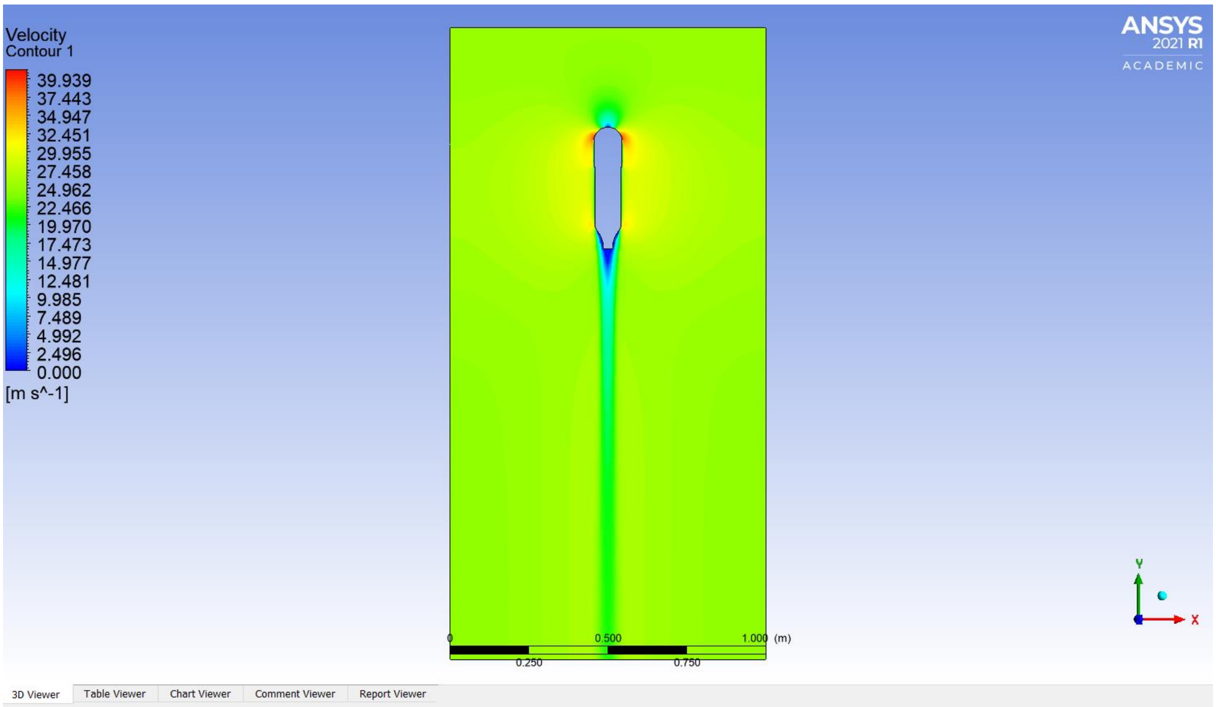


External Flow Simulation

Pressure Contour:



Velocity Contour:



13.Matlab Codes

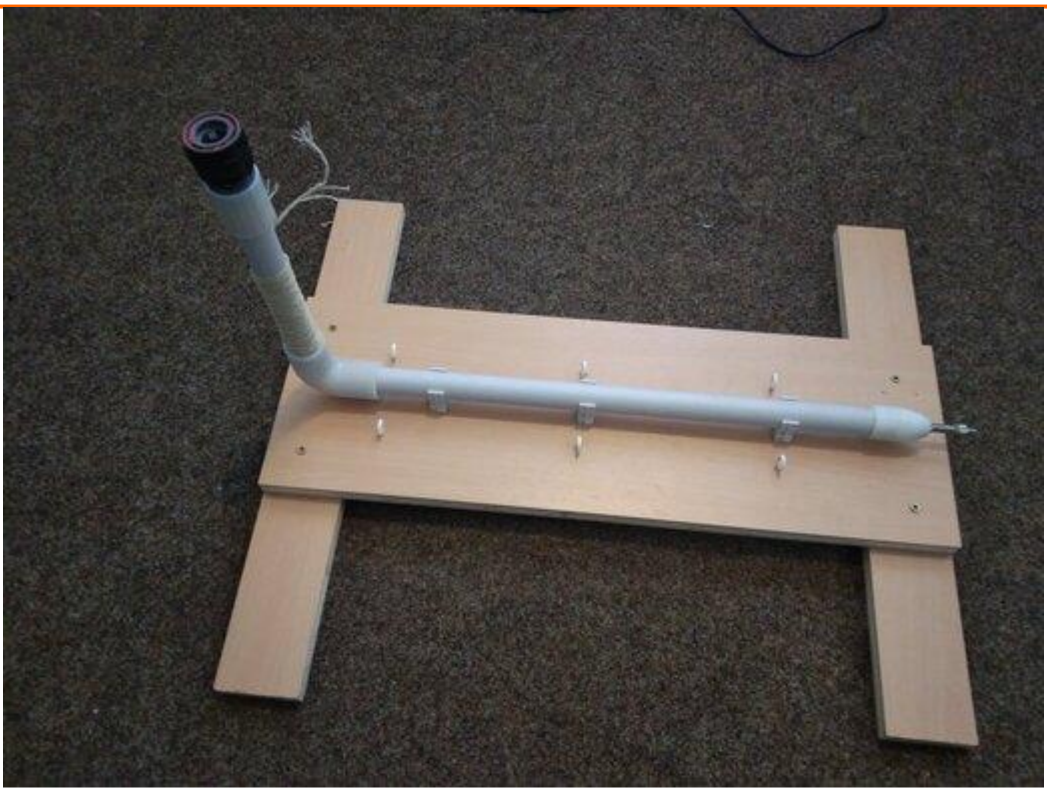
Simulation Code

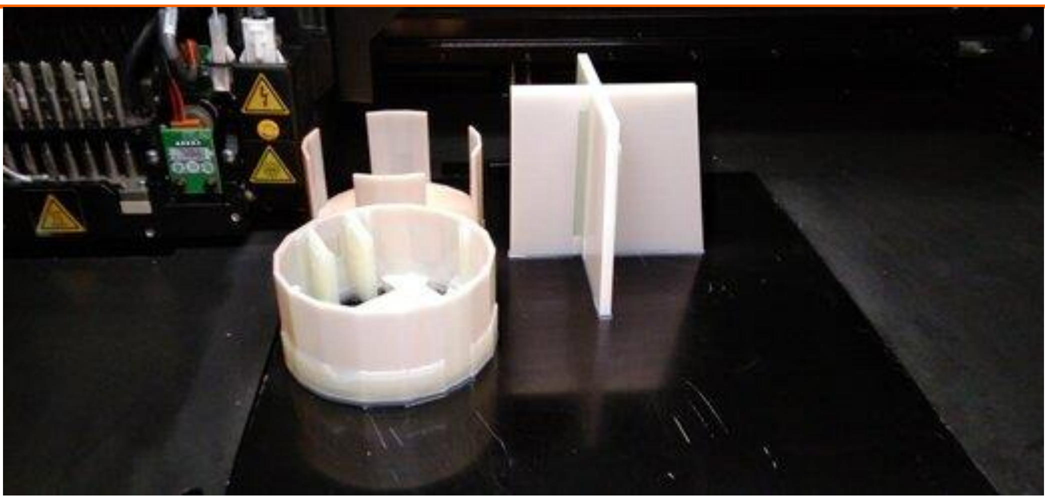
https://inf-git.fh-rosenheim.de/water-rocket/waterrocket-test/-/wikis/uploads/161f58756c2331e4bfb6073ec5df1fad/Water_Rocket_Mathematical_Model.m

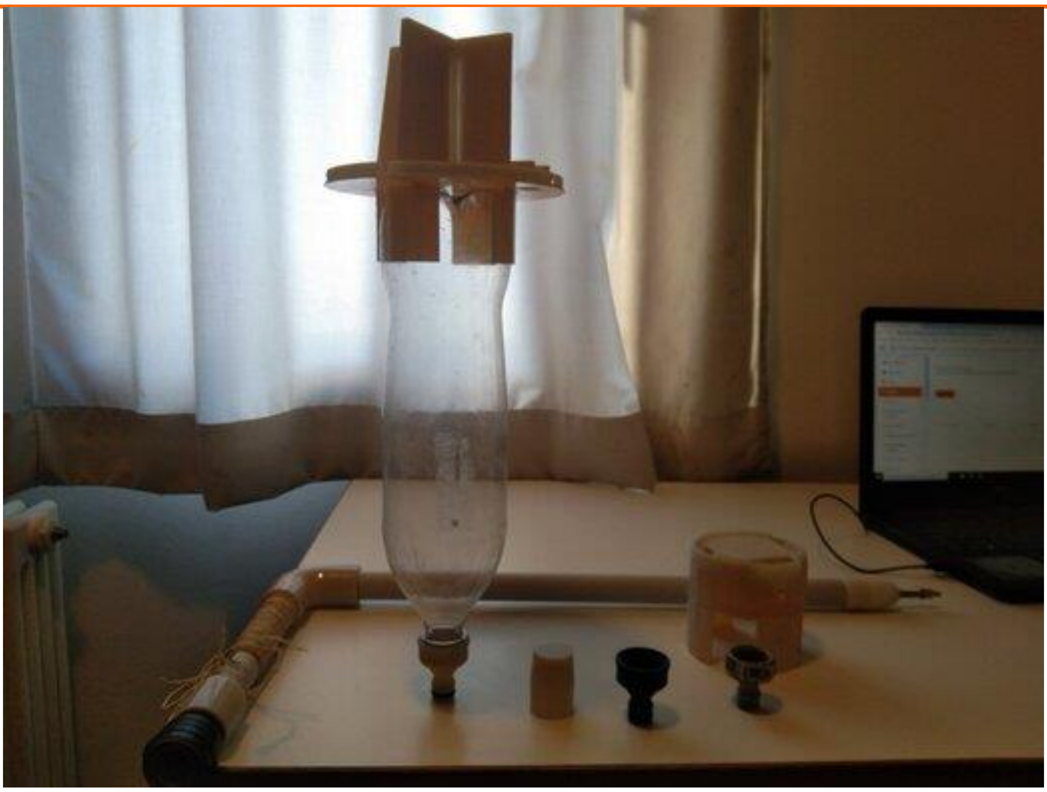
Final Flight Code

https://inf-git.fh-rosenheim.de/water-rocket/waterrocket-test/-/wikis/uploads/d61e31b3637f80d9a44280cff46b4cfa/Final_Flight_Code.m

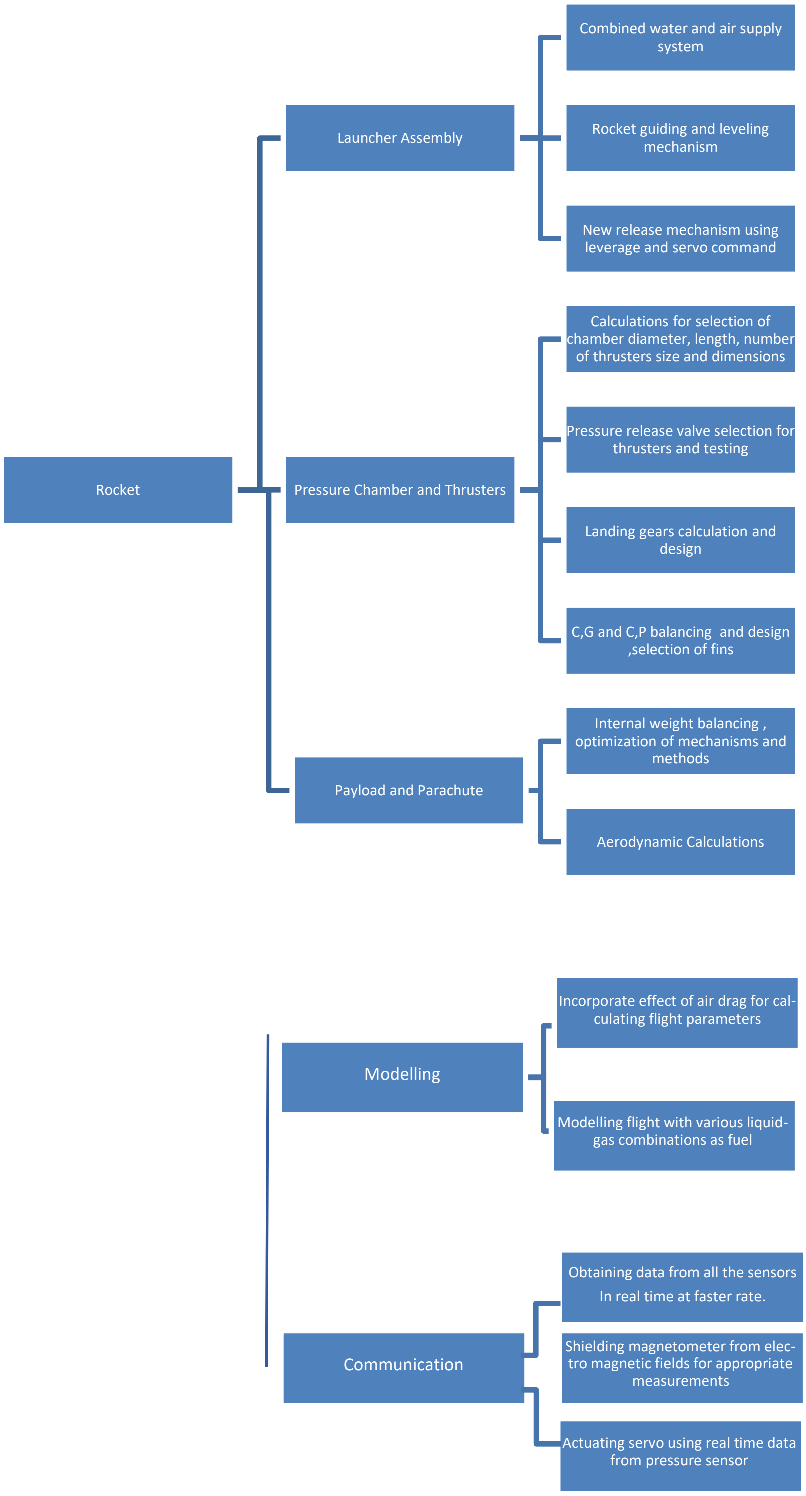
14.Manufacturing and Testing







15.Further Modifications Possible



16.Future Scope

Hardware-

- The hardware selected for the prototype project is BMP280 pressure sensor MPU6050 accelerometer plus gyro and GY 521 Magnetometer. These modules of sensors follow I2C communication protocol and hence only one reading can be measured at one instance of time this reduces the number of readings in fixed time. An appropriate sensor keeping the cost not high can be based on SPI communication protocol for e.g. MPU 9250. Currently with these sensors and MATLAB as software approximately 15 readings per second can be recorded at 9600 baud-rate.
- Currently two strings attached to the gardenia ½ inch hose connector. These strings are manually pulled by a person and then the program is started. This has a major drawback as there is human error between the time one person pulls string and the other person starts the timer. The manual ejection of the water rocket can be replaced with appropriate actuator and a feedback system can be used to have accurate control over the timing of parachute actuation. This will ensure that the parachute ejects at appropriate time – not too early to reduce maximum height and not too late so that the parachute does not open properly.
- For the prototype the launcher base is only a simple ply. However there and launching location is not perfectly flat. Hence addition of 2 levelling meters and levelling screw will increase the maximum vertical height gained by the rocket.
- Increase in No. and types of sensors for filtering data. Currently only single sensors for reading, more sensors of different sensors can be used to get accurate date particularly for position and attitude

Software-

- The current code written is in sequential order with data reading and timer to control servo to actuate parachute in same code and sequence. However, it is not safe to have such a code. There was one instance where the communication between sensors and MATLAB halted and the servo actuation being next in the line of code too failed to execute and there was a crash landing. An appropriate solution will be to have priority to timer and servo in the code so that even if other sensors fail the servo and timer will still get priority and will prevent crashing of rocket in such case. Another method that can be tried is parallel computing where the sensor readings and the servo actuators and two separate blocks of logic codes to prevent halting of each other's functionality in case one fails.

Design and manufacturing-

- Development of Release mechanism- Currently the release mechanism is an OEM part Gardenia hose connector which has Maximum pressure limitation to 16 Bar. This can be redesigned for custom requirements to sustain more pressure.

-

- Development of Pressure Vessel/Chamber- A custom Pressure vessel with light weight materials like carbon fibres can be used instead of PET bottle used in the experiment when trying the experiments at higher bar pressure (>20bar).For example a custom pressure vessel made from Carbon Fibre and Epoxy resin can withstand pressure up-to 100 bar as well.

- Customised nozzle development according to simulation data for optimised performance. An ideal solution will be to manufacture in metal as it is seen in experiment that this component comes under maximum mechanical stress.

- Design of Fins and their mounting for minimum drag. Present model uses fins for the said model itself but change in any parameter will affect fin calculation. (See references for Fin Calculation)

- Development of quicker parachute release mechanism or space optimisation for release mechanism.

Modelling-

- From conceptual modelling of water rockets, the parameters that could affect the flight of the rocket are identified. From varying the factors such as launch pressure, dry weight of the rocket, weight distribution, shape, diameter of the nozzle, bottle size, water filling ratio etc, the output parameters like thrust force, thrust acceleration, velocity and height achieved vary accordingly.
- In the mathematical model and in the further simulation studies, only the parameters like launch pressure, dry weight of the rocket, diameter of the nozzle, bottle size, water filling ratio could be varied, and the results obtained are thrust force, thrust acceleration, velocity and height achieved. The air drag factor is also not considered in the modelling.
- The model becomes more realistic when it includes the drag factor, so that the effect of weight distribution, position of centre of pressure and mass, shape etc could be studied. Also, there are possibilities of predicting not just altitude but also attitude through further modelling. Studies can also be conducted not just with water-air as fuel but also other liquid-gas combination.

17.Conclusion

- The objective of the project was to develop a Mathematical model and a physical model of water propelled rocket and receive data about position and orientation of rocket and compare results practical model with mathematical model of the same.

- The difference in the theoretical and practical results is due to following reasons-
- The mathematical model does not account for air drag, wind speed and hence overestimates the height
- The Mathematical model considers perfect straight launch and uniform pressure distribution and hence does not account for displacement in x and y direction
- The Launcher has unaccounted frictional losses in release mechanism hence the thrust force developed by the launcher is over-estimated in mathematical model
- There is a processing time in between the software timer and the time when the readings are taken and hence an offset occurs between real readings and recorded readings.
- All sensors have bias and this bias when integrated over a long period results to error accumulation this is particularly seen for data for distance in x and directions.