Design Review PLR

Team Name: VegaSat

Country: Slovenia

Ljubljana, 9. June 2023

1. INTRODUCTION

1.1. Mission objectives

Our secondary mission is to attempt a guided landing, record all the flight data like acceleration, position, and location, and use said data to create an animation of the flight later. We've selected this mission as we thought it would be quite a challenging task and could be applied to other space exploration missions. The flight's animation would also prove a useful resource for analysis and improvements of the guided landing system.

Our objectives are

1. to make the CanSat land as close to the middle of the landing zone determined by three radio beacons,
2. to record flight data such as acceleration, position, and location and create an exact flight animation from the data.

Our research will help us to determine the performance of the guiding system and make possible improvements.

We have researched how similar tasks were performed by teams in the past. One of the most notable designs included four "arms" that would open from the CanSat when it descended out of the rocket. Here is the final report of the Austrian team mentioned before. Each arm had a motor and propeller, and the CanSat ended up acting as a drone. It was, like many others, guided using GPS. This differs from our system in many ways. Our system uses the propellers only as a means of directing the CanSat and the parachute to slow down to the appropriate vertical velocity. It also does not use GPS. We have constructed three transmitters, which will be placed in a triangular shape around the landing zone. Using their signals, the CanSat will be able to find the centre of the triangle, which is our landing spot.

2. CANSAT DESCRIPTION

2.1. Mission outline

Our mission is to design and build a CanSat to be launched and deployed from a rocket at an altitude of about 1000 metres. The CanSat should not descend faster than 11 m/s and slower than 9 m/s. During its descent, it will measure air temperature and pressure, and attempt to guide itself towards the landing zone, determined by three ground transmitters (beacons). Each beacon transmits pulses of different frequencies by which we determine its ID. The launch will be considered successful if the CanSat lands within 25 metres from the middle of the triangle, composed of the three transmitters.

Our guidance system was already described in our CDR, but here is a short overview. In advance of the launch, we place 3 transmitters (beacons) on the ground. Since they are not colinear, each beacon can represent a corner of a triangle. All beacons' radio frequencies are the same (433,862 MHz in our case). With the ASK modulation that our beacons use, we can only "hear" one beacon at a time. We assume that's the closest one since it's "heard" with the highest power. Each beacon transmits pulses of different frequencies. With ESP32's internal pulse counter, we can detect the frequency and decide which beacon we are currently receiving. When we are the closest to one beacon, we know roughly in what direction to move to get to the centre of the triangle (that direction is away from the beacon toward the centre). To more easily comprehend the idea we also made a GeoGebra simulation, at https://www.geogebra.org/m/pfsmeetn. An example simulation is visible in Appendix 1.

To collect the temperature and pressure data, a BMP280 sensor module is used. To achieve our secondary mission of guided landing, we will need three ground transmitters, a separate receiver on the CanSat, and an MPU9250 gyro sensor and compass. Data will be stored on two separate SD cards as well as transmitted to ground stations to assure redundancy.

The connection diagram is in Appendix 2.

2.2. Mechanical/structural design

The structure of our CanSat will be almost entirely 3D printed using PLA filament since that's what we have on hand and because it's both inexpensive and lightweight. To secure parts together we will use three M3 threaded rods. To secure the motor holder to the parachute attachment plate an M6 screw is used. The parachute will be tied to the ends of the M3 threaded rods on top of the CanSat. The PCBs are sandwiched on the M3 threaded rods on the bottom of the CanSat.

2.3. Electrical design

We have decided to use the ESP32 microcontroller as it is powerful enough and has enough I/O. All sensors such as the BMP280 and the MPU9250 are connected to it using I^2C communication, SD cards are connected using the SPI bus and the APC220 radio transceiver module uses a UART connection. The L293D motor driver and SYN480R radio receiver are connected directly to ESP32 GPIO pins.

Schematic in Appendix 3.

2.4. Software design

Cansat communicates with ground stations via APC220 radio transceiver modules. Data is collected into packets which are then transmitted to the ground. In order to assure the reliability of packets we calculate the packet's CRC (cyclic redundancy check) checksum on the Cansat and then send it with the packet. The same CRC checksum is then calculated on the ground station and compared. Corrupted packets are then dumped. A flowchart can be seen in Appendix 4.

For redundancy, we also store data on SD cards on the Cansat itself. Data is stored twice, as hex files and as CSV files. For added redundancy, we store files on two separate SD cards, so we theoretically have four copies of collected data on board.

To recognize the beacon, we use the ESP32 microcontroller's internal pulse counter (ESP PCNT). Since beacons are differentiated by the frequency of their pulses we count 20 of the pulses and together with time we calculate frequency and with frequency the position of the beacon. Based on the detected beacon and cardinal direction acquired from the MPU9250 sensor we determine at which power to run which of our motors.

2.5. Recovery system

The CanSat will be equipped with a single hexagonal parachute. It will also have a spill hole in the centre for better stability, as air can escape from the parachute. Parachutes without the spill hole tend to tip, which could lead to unexpected consequences for our task. The spill hole in the parachute provides an opening for airflow from the high-pressure upper surface to the lower-pressure lower surface. Airflow creates an upward force that counters the downward force of gravity. When the parachute descends through the air, the airflow through the spill hole helps redistribute the forces acting on the parachute, resulting in better stability of the CanSat.

The parachute is made from non-tear nylon fabric and attached to CanSat with braided nylon string. We used the quadratic law of drag to calculate the area of the parachute.

The surface of the parachute will be around 530 cm^2 and the CanSat is expected to descend for 100 s. The spill hole of the parachute represents 5 % of the total surface area, resulting in 505 cm^2 of the actual area. To calculate parachute parameters, we used the force of gravity of g = 9,81 m/s^2, the drag coefficient of c_x = 1,4 and a descent velocity of v = 9 m/s. We used $S = \frac{2mg}{\rho v^2 c_x}$ to calculate the parachute's area where m is the mass of our CanSat and ρ is the density of the air. The drawing is found in Appendix 5.

In case we fail to land in the target zone, we will use an LPDA antenna in order to retrieve the CanSat. With it, we can find a general direction and then we listen to the buzzer attached onboard.

2.6. Ground support equipment

Our ground support equipment is composed of two laptops, each connected to an APC220 transceiver with a different antenna, one will be omnidirectional QFH and one will be directional LPDA. Both of them are running the same software. Such a setup enables us to minimise data loss caused during transmission and have a backup already running should one of the ground stations malfunction. The software running on the laptops visualises received data in real-time and saves it to a CSV-formatted file.

We also have three transmitters spread across the landing zone in a triangular shape. They enable the CanSat to find its designated landing spot. They require their own transmission frequency of 433,862 MHz.

3. Project Planning

3.1. Time schedule of the CanSat preparation

Gantt chart in Appendix 6.

4. Resource estimation

4.1. Budget

In Appendix 7.

4.2. External support

Organisations that support us so far are listed in Appendix 8. We also contacted the Slovenian Police to carry out another "drop test" but they told us they aren't able to drop things out of a helicopter.

5. Testing

We have multiple plans for testing the CanSat. First, we will test every component of the system by itself. We have made multiple testing plans once we assemble all the components. We have already arranged a test drop from a helicopter with the Slovenian air force. We will also test the parachute in a wind tunnel provided by the Faculty of Mechanical Engineering and/or Aerodium.

To test visualisation components we made a Dummy Data Generator or DDG for short. It generates random numbers for all metrics transmitted from the CanSat to the ground. Besides using Excel to analyse the CSV data, we are also designing Godot-based visualisation software that will help us evaluate system performance mid- and post-flight.

6. Outreach program

Our outreach program consists of a website, an Instagram account, and presentations.

In our sponsorship program, we reached out to ARNES (Academic Research Network of Slovenia). This government institution manages the Slovenian internet backbone and supplies educational institutions and other eligible organisations with internet services. They supplied us with the domains cansat.si and vegovasat.si. We host our website on those domains (https://vegovasat.si and redirected to https://cansat.si it). We write blog posts after big achievements like meeting with the ESA crew or after hitting a major milestone.

In addition, you can find us on Instagram @vega.sat. We share posts about all those little victories that come together to create something bigger. We post approximately once every 14 days and reach about 80 accounts each month. About 25 % of those Instagram considers engaged. Our account also has 55 followers.

We present our activity in school events like the so-called “Informativni dan” where primary school students visit their future high schools. It was hosted on the 17th and 18th of February and our team made quick presentations of the competition and our mission. Similar activity was carried out on the 8th of June for students of our school, with a view to grabbing the attention of potential future team members.

Infodrom is an informational TV show focused on reaching children and teenagers that airs once weekly on national TV. For technical reasons, we weren’t able to contribute to *Infodrom*, but the competition, ESA, and the team were mentioned in another show called *Osvežilna fronta*, which aired on the 29th of April at 10.50 CEST.

7. Requirements

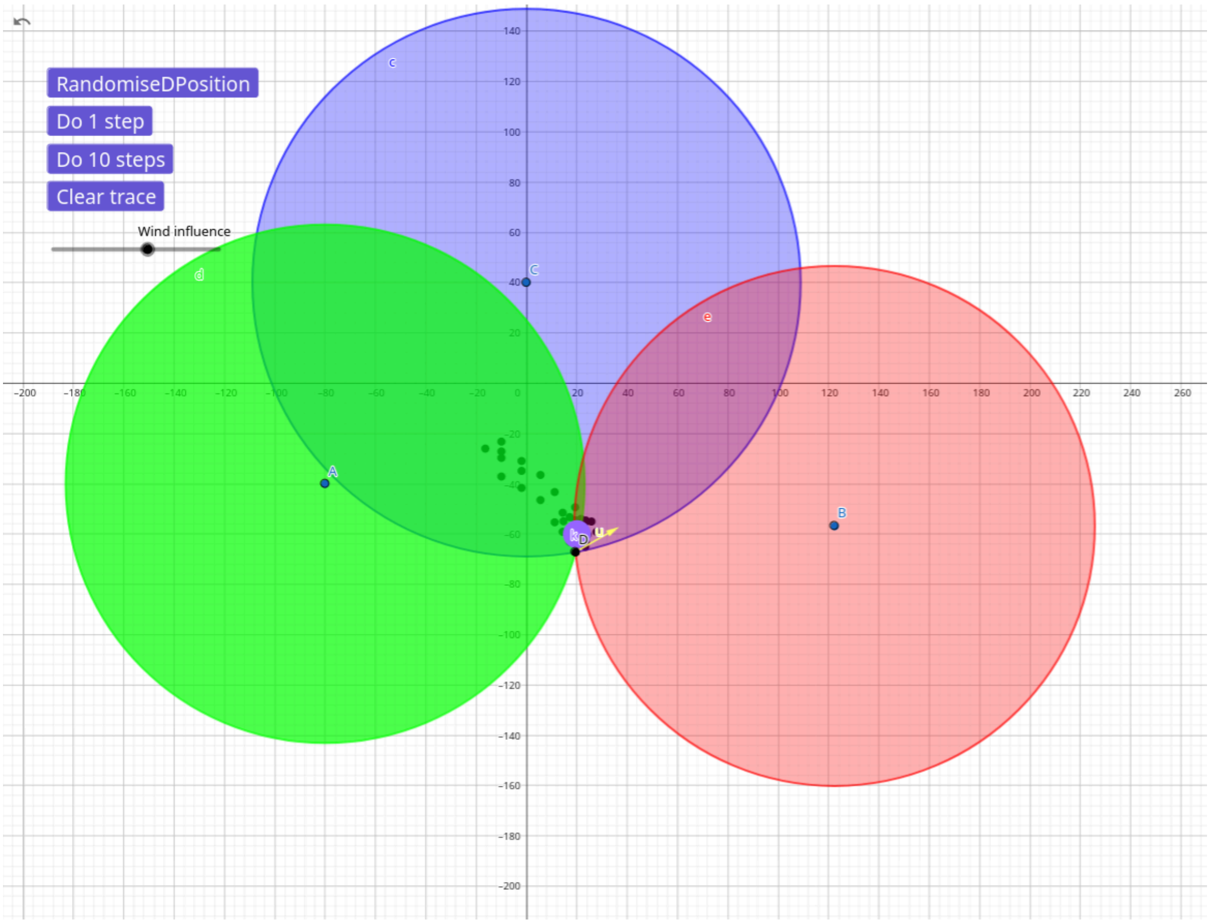
7.1. Characteristics

In Appendix 9.

7.2. Power budget

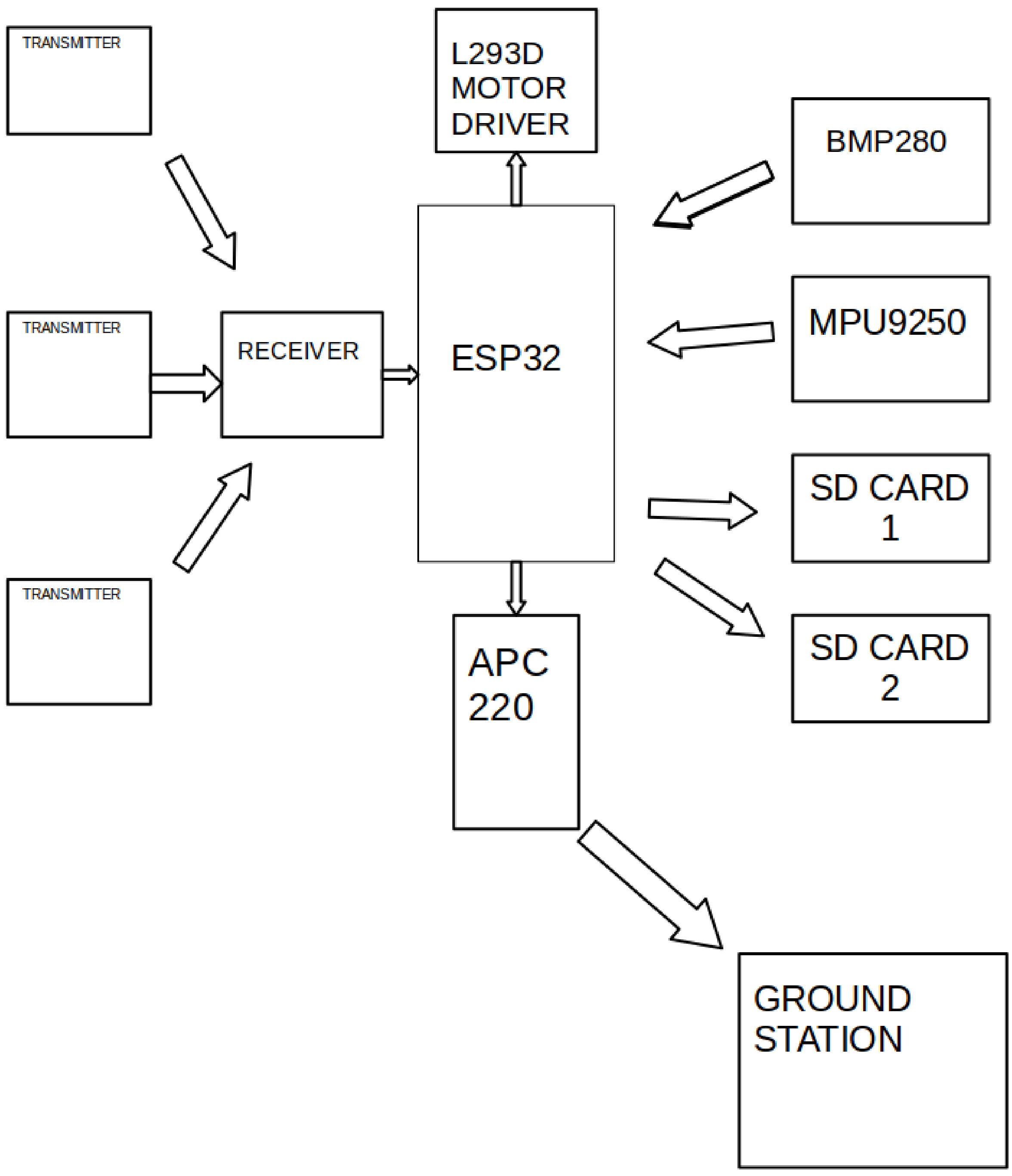
In Appendix 10. Note that not all of the motors run at max power at the same time, they should never run with more than 50 % of max power due to overheating of the motors.

Appendix 1

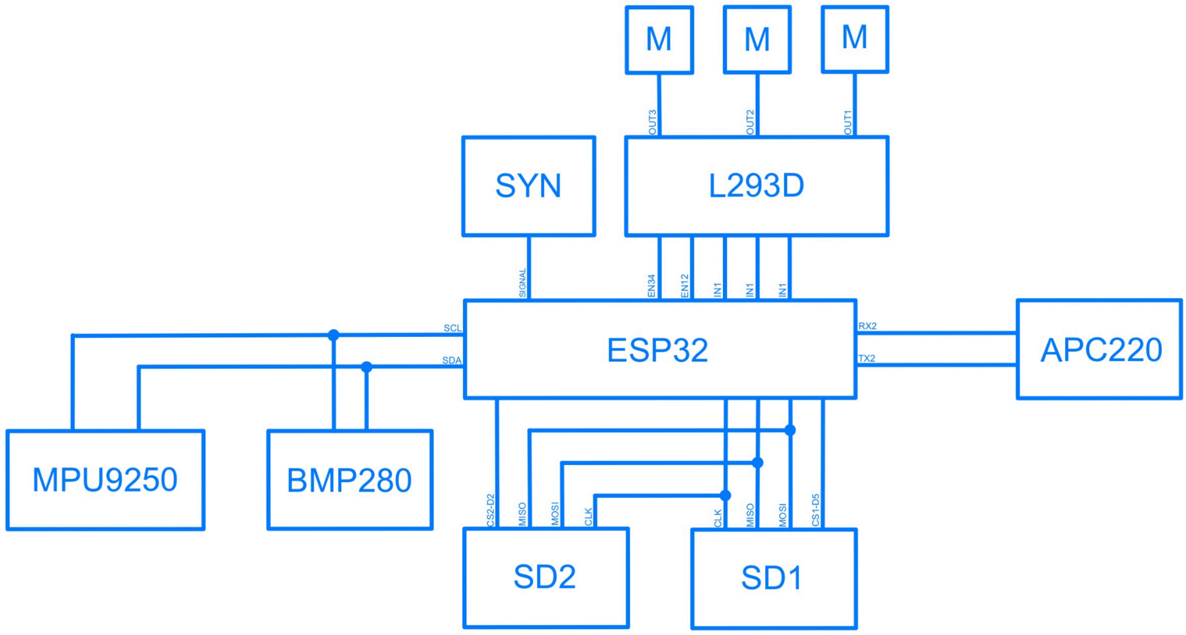


RandomiseDPosition
Do 1 step
Do 10 steps
Clear trace
Wind influence

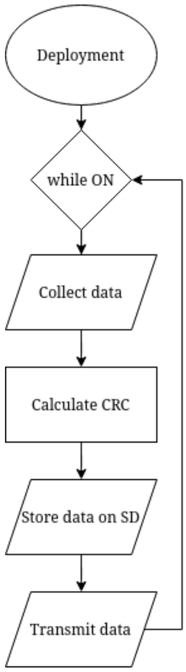
Appendix 2


TRANSMITTER
TRANSMITTER
TRANSMITTER
RECEIVER
L293D MOTOR DRIVER
ESP32
APC 220
BMP280
MPU9250
SD CARD 1
SD CARD 2
GROUND STATION

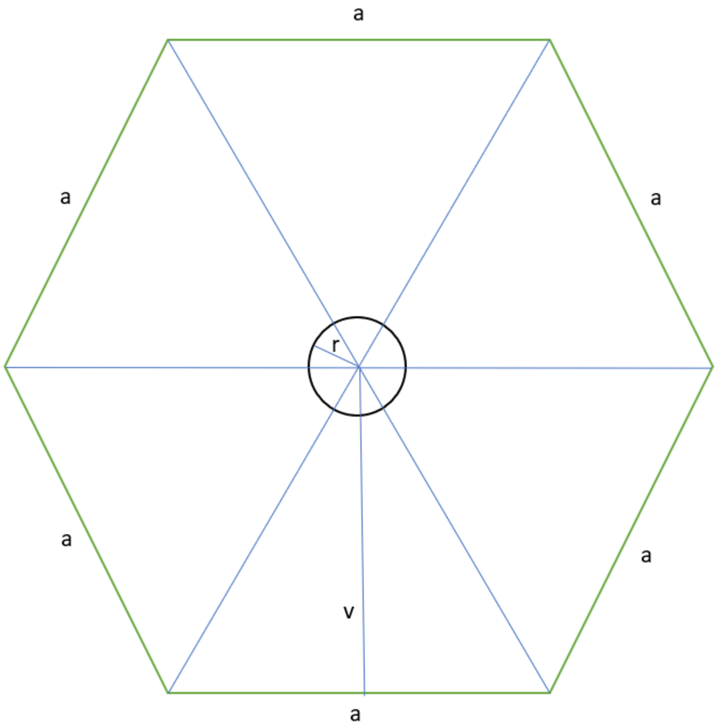
Appendix 3


M
M
M
OUT3
OUT2
OUT1
SYN
L293D
SIGNAL
EN34
EN12
IN1
IN1
IN1
SCL
SDA
ESP32
RX2
TX2
APC220
MPU9250
BMP280
CS2-D2
MISO
MOSI
CLK
CLK
MISO
MOSI
CS1-D5
SD2
SD1

Appendix 4


Deployment
while ON
Collect data
Calculate CRC
Store data on SD
Transmit data

Appendix 5



Appendix 6

9. 6.	12. 6.	15. 6.	23. 6.	26. 6.	30. 6.	July
PLR						
CanSat assembled						
		Helicopter test drop				
	CanSat optimisation					
				Launch campaign		
					Mission analyzations	
						Final report

Appendix 7

Component	Price [€]
ESP32	11
BMP280	15
APC220	20
3,3 V MOTOR 3-times	3
L293D	7
MPU-9250	12
MicroSD Card adapter + MicroSD Card 2-times	12
100 g PLA filament	2
SYN480R	1
Battery	6
SUM	89

Appendix 8

Name	Website	Manner of support
VEGOVA Ljubljana	https://www.vegova.si	
ARNES (Academic and Research Network of Slovenia)	https://www.arnes.si/en	Merch T-Shirts and domains
RTVSlo	https://www.rtvslo.si	Help with outreach program
Faculty of Mechanical Engineering	https://fs.uni-lj.si/en	Use of their (horizontal) wind tunnel
Aerodium	https://www.aerodium.si/Home	Use of their vertical wind tunnel
General Staff of the Slovenian Armed Forces	https://www.slovenskavojska.si/en/about/scope-and-structure/general-staff/	Drop test of our CanSat before the competition

Appendix 9

Characteristics	Figure (units)
Height of the CanSat	115 mm
Mass of the CanSat	approx. 320 g
Diameter of the CanSat	65 mm
Additional length of external elements (along axial dimension)	approx. 45 mm
Flight time scheduled	100 s
Calculated descent rate	9 m/s
Power consumption	2 W
Total cost	89 €

Appendix 10

Device	Voltage [V]	Current [mA]	Power [mW]
ESP32	3,3	20	66
BMP280	3,3	1,2 peak	4
MPU 9250	3,3	4	13
Motors 3x	3,7-4,7	360	1690
L293D driver	4,5	60	270
Total power (sum of all)			2040