Trident CanSat Pre-Launch Report

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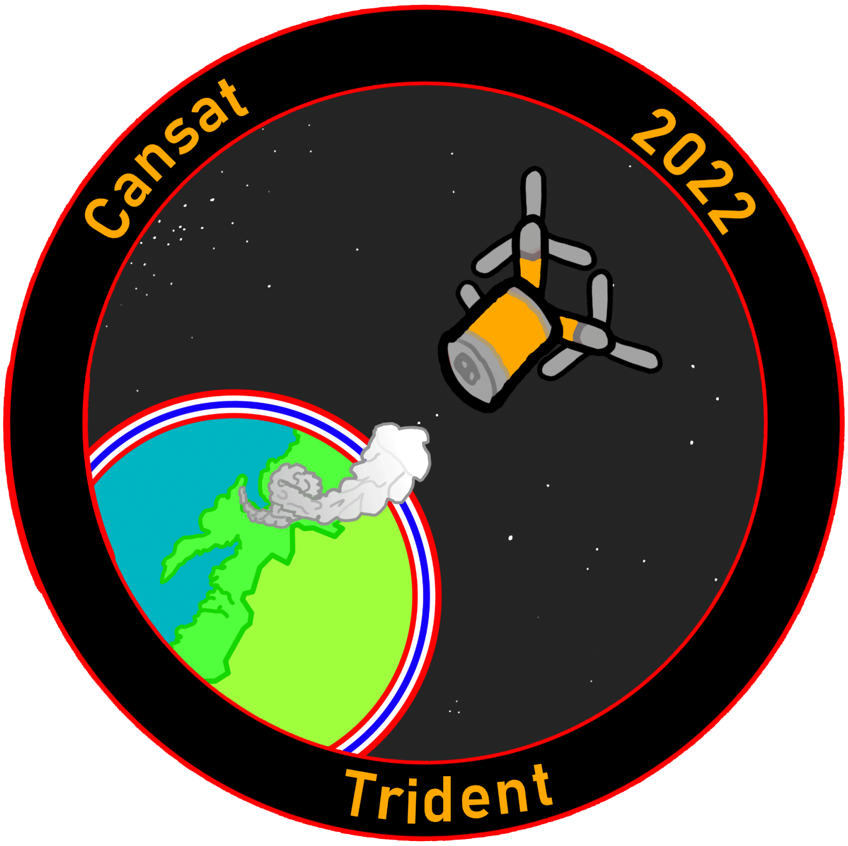

Table of Contents

Summary

This report details Team Trident, its CanSat design and design choices, economy, budget, and advertising. This document provides insight on how the team is operating, what has been done, how and why and by who.

Abstract

Designing a satellite is no easy feat. It requires dedication and a lot of work. Trident came to the conclusion of using a three armed drone with capabilities of guided landing that samples the air for a variety of gasses shortly after the process started.

Proceeding with the tri-copter idea, the team started development. The decision was quickly made to use a Raspberry Pi Compute Module 4 for its fast computing capabilities, and a PID controller was to be implemented in software. This enabled stabilization of the CanSat, and guided navigation. To be able to control all axes of rotation, one of the arms was designed to be able to rotate to vector the force of its propeller.

To promote the project and gather funds, a website was created, and shortly after, merchandise was available to be bought there. The website's objective was to inform interested people of the concept and to provide information and marketing space for potential sponsors. Three sponsor deals were done and the funding was secured. The funding was primarily used to develop prototypes to check what works and what didn’t.

1 Mechanical Design

1.1 Concept

To challenge the competition, a unique and creative way to design the CanSat and complete the assignment set was devised. The idea that struck us was a powered landing from a drone. Due to restrictions with the slamm form factor, the decision to use three foldable arms was made. This is how the CanSat ended up with its three signature rotor arms, which lead to the name 'Trident'.

The arms are spring loaded and will be realized after deployment while in the air. They are connected to the body of the CanSat through bearings which are threaded over a metal rod. Following the deployment, the rotors will keep the CanSat within a vertical velocity of 5 to 12m/s. The flight will end in a soft landing provided by increased thrust of the propellers. Due to limited space, a creative way of making both the rotor arms, and rotor propellers were needed, However, with the sacrifice of the fourth rotor arm comes inherent stability issues.

Three arms meant it was no longer possible to control the yaw. To address this issue, a solution where the third arm had the ability to vector its thrust was put in place.

1.2 Materials

All the mechanical parts are either metal or 3D-printed in resin. The resin gives the opportunity for rapid prototyping as well as a strong frame for the electrical components to connect to.

2 Electrical Design

2.1 Microcontroller

To allow for actively stabilized flight, one is dependent on a plethora of components. The CanSat will have to be aware of its current position, rotation, altitude and track how all of those values change over time. As a result, one needs a lot of computing power, a simple arduino won't be able to keep up with all the computing necessary. This brought the team to use a raspberry pi compute module 4 (RPiCM4).

RPiCM4: This microcontroller allows for many computations to be done, while still keeping a small enough form factor to fit in a CanSat. The RPiCM4 offers plenty of General Purpose Input and Output (GPIO) ports to be used for sensors and outputs. The drawback of using an RPiCM4 instead of a smaller less capable microcontroller is its power consumption. Therefore the team decided to add an additional microcontroller to turn on or off the RPiCM4, for this an ATTINY85 was chosen.

ATTINY85: The ATTINY85 is a tiny microcontroller that consumes very little power while still being able to perform the necessary operations. This microcontroller was chosen due to its small physical size, small power draw, and ease of programming. The task of the ATTINY85 will be to act as a middleman between the team and the RPiCM4. It is connected to the RPiCM4 and the communications module using two separate UART busses, in addition to being connected to the power up and down pin and the RPiCM4. Commands will be sent to the ATTINY85 telling it to power up or down the RPiCM4, as well as commands telling it to pass through data from the RPiCM4 to send back to the ground station.

2.2 Components

RFM96: The choice of antenna module came down to what module has the best reliability, ease of use, power consumption and working distance. The RFM96 passed all of the requirements and seemed a better option than the alternatives.

MPU6500 Gyro/Acc: Compact and versatile sensor which is easy to communicate. Allows for configuration of sensitivity and resolution. I^2C.

L80-M39 GPS: Good GPS module, simple to communicate with, SPI.

GM-402B Methane and Propane: Simple to communicate with, also well-documented. I^2C.

SGP30-2.5K Ethanol and H2 : Changes resistance depending on how much gas it detects. Somewhat complicated to measure with, but well-documented and compact.

MCP3008-I/SL ADC: Used to process analog data, such as measurements of ethanol and H2.

PCF85063AT/AAZ RTC: Recommended by the RPI team.

DS18B20U Temp sensor: Good experience using this sensor, easy to communicate with. Requires only a few GPIO pins.

MS563730BA03-50 Barometer: Compact, simple communication. I^2C.

TH02 SI7005 Humidity: Compact and easy to communicate with. I^2C.

All these electronics need to be controlled via Pulse Width Modulation (PWM), it therefore needs a controller. PCA9685PW,118 PWM Controller was chosen. This is necessary because the RPiCM4 only has two PWM outputs, additionally, the controller is easy to communicate with, using I^2C. The controller possesses data at a high speed and produces accurate PWM signals.

3 Software

3.1 Language

It is common to program the Raspberry Pi family of microcontrollers in Python. This is not an option for Trident as it needs to be efficient in its calculations to be able to perform flight corrections as often as possible. As a result, the programming language chosen is c++. C++ strikes a balance between usability and performance. An additional reason for picking c++ for the code is its community documentation. Libraries are available to interface with GPIO and the file system, something that could be required to write by hand in faster languages like C.

3.2 PID Control

The standard way of controlling drones, and the one trident uses, is using a Proportional-Integral-Derivative (PID) controller. The basic working principles of a PID controller is the summation of three control signals, a difference (P), derivative (D) and integral (I) of the device's position. It produces an output steering signal that is capable of knowing what reaction the device has on the steering, and applying that as gain or dampening of the steering.

$$u(t) = K_{\rho} e(t) + K_i \int_0^t e(\tau) d\tau + K_d \frac{de(t)}{dt}$$

The K values are the weights of the P, I and D, and each term is summed to produce an output. Each weight will need to be tuned to produce the desired output, where the drone is reactive but does not over-correct.
One PID controller is required for all axes of steering. Three motors and one servo requires separate control. This will all be achieved in software. Rotation and rotational velocity will be read by an IMU. Instead of feeding the inputs directly into the controller, the difference between the value and the desired value is fed into the formula.

3.3 Data Encoding

Sending and storing the data collected alone would make it challenging to process the data post flight. Therefore it will use a standardized format for both the communication and data storage. The formats used are described in table 3.1 and 3.2. Data will be stored both at the receiver and in the cansat as a csv .log file.

3.4 Sensor Interface

The majority of trident's sensors use the Inter-Integrated Circuit (I^2C) interface, a two wire protocol for serial communication. This, in addition to extensive library support makes the software to interface with them easier. The majority of interfaces that do not use I^2C use the Universal Asynchronous Receiver/Transmitter (UART) protocol. The advantage to UART over I^2C is the configurable interface speed, which allows for dynamic CPU usage and dynamic throughput.

4 Public Relations

4.1 Website

A website was created to advertise the project to people interested, as well as bringing something concrete to sponsors to convince them to sponsor Trident. The website started simple with a homepage but grew very quickly as new ideas came to mind. The website can now be found at https://cansat-trident.space/.

On the website you can find everything, from info on the members of the team, to sponsors and merchandise. The website also brings the latest information on mechanical design and 3D models of current versions.

4.2 Logo Design

The Logo depicts a soda can with propellers being launched to the edge of space, the soda can is the Trident and the three propellers are the reason it is named Trident.
On the earth you can see Andøya and around the earth there are colored stripes meant to represent the Norwegian flag.

5 Economy & Budget

Trident’s design is costly, from the sensors to the control components. Trident has had two main sources of income; sales and sponsors. This, combined with contributors have raised the team 1300 eur, which is for the budget of the cansat, ground station and the purchase of merchandise.

5.1 Sponsors

From an early stage, sponsorships were set on the agenda. Realizing that sponsors were necessary to secure funds for prototyping and development of the CanSat. A standardized email was created and together with personalization for each company which were contacted, many emails were sent.

5.1.1 Andøy Bok- & Papirhandel AS

The first sponsor of CanSat Trident came through the family of one member. This made early development and parts gathering possible.

5.1.2 Joker Bleik

Joker Bleik was Trident's second sponsor. The sponsorship from them made the purchases of electronics possible.

5.2.3 Polyalkemi

Polyalkemi was the third sponsor of CanSat Trident. The sponsorship made it possible to gather stronger resin for our 3D printed parts. This allows for thinner walls and a smaller mass CanSat body.

5.2 Sales

Both as a source of income and advertisement, the decision was made to start selling t-shirts with Tridents logo on. After sourcing t-shirts for cheap we realized we could also sell the t-shirts for cheap to people who may not have enough money to buy an expensive t-shirt to support us. Therefore a dynamic pricing system was put in place where you have to pay a minimum fee for the t-shirts with the option of paying more for each t-shirt.

6 The Trident Team

6.1 Overview

The Trident Team consists of six members from different parts of the country. The team members include Team Leader Gabriel Røer (19), Team Manager Mats Haugerud (20), Economy Manager Lukas André Bendiksen (19), PR Chief Max (18), Graphic Designer Becker Wiktor (18), Secretary Felix Andreassen Jørgensen (19), additionally, Hallgeir Solstad Klæboe (27), is the teams' Guardian Teacher for this project.

6.2 Meetings & Organization

Meetings are held to organize the team's efforts, responsibilities and also acts as a way to receive in-person updates on the status of work relating to the project. The meetings are not held on any specified, regular schedule, but are instead prepared, announced, and held as needed. This is usually when there is a major design decision to be made, updates are needed, or at the request of the Team Leader.

Meetings are announced on the application 'Discord', usually, a Microsoft Word .docx file is uploaded onto Discord which details when and where the meeting is to take place. Additionally, information about the different subjects to be discussed, or decisions to be made will be listed in the document. Sometimes, all of this information is written just as plain text, this is done to inform the team as quickly as possible and this only happens when there is an urgent need to hold a meeting, usually due to uncertainty in design, or to propose a new solution or suggest changes to one.

At the conclusion of a meeting, another document which details what was discussed and which decisions were made, gets approved by all of the members present in the meeting. This document is then subsequently uploaded to the teams' group on Discord in a separate category exclusively reserved for such files. This is done to organize the team, and also acts as a way for members who were sick, or could otherwise not attend the meeting to still get updated information about the decisions made, or what to do as decided during the meeting.

Due to the members of the group attending the same school, there are usually some extra discussions and conversations on topics related to, or directly concerning the project held during breaks. These talks do not usually result in major overhauls or decisions being made, and therefore meetings are not required in their place. This has the benefit of freeing up additional time which can be spent on working on the different areas of the project. The team has a largely decentralized structure, so outside of the meetings, members work on what they want to, when they want to. This makes sure that members are always motivated to do what they are doing, and prevents burnout.

6.3 Members

6.3.1 Team Leader: Gabriel Røer (19)

Responsibilities: Physics Theory, General Design, Organization, Secondary and Primary Mission, CAD/CAM.

School: Andøy Upper Secondary School – Space technology.
E-mail: NorgeSkiFollo@gmail.com
Phone: +47 46910340

Biography: For as long as I can remember, I have always had an interest in finding out how things work. Picking things up and pulling them apart and putting them back together just to see what they are made of and how they work. That is why electronics and technology quickly became a natural topic of interest, just like space technology later in life. That is also why my first reaction when I heard about this competition was "this is something I need to participate in", and why I started this CanSat team.

Contribution to the team: As the team leader, my job is to guide the team towards a common goal. I have also had a hand in both the mathematical design, and the math behind the electronics.

6.3.2 Team Manager: Mats Haugerud (20)

Responsibilities: Mechanical Design, Website Design, CAD/CAM, Software design.

School: Andøy Upper Secondary School – Space Technology.
E-mail: haugerudmats@gmail.com
Phone: +47 95040971

Biography: Since the first time I picked up an Arduino, I have been amazed. The endless possibilities it creates have been something I have sought to explore for the past three years. To be able to continue my journey as a part of a team is something I could not say no to. Sharing experiences and thoughts on problem-solving is something I look at as a good opportunity to develop my skills further and learn new things.

Contribution to the team: My job at Trident is to do the mechanical design, make the website, help with electronics and write the software for the CanSat and ground station.

6.3.3 Accountant and Designer: Lukas André Bendiksen (19)

Responsibilities: Hardware, Mechanical, and Electrical Design, CAD/CAM, Economy, Account management, Secondary and Primary Mission.

School: Andøy Upper Secondary School – Electronics and Computer Technology
E-mail: Lukas.bendiksen@gmail.com
Phone: +47 90532258

Biography: I am greatly interested in everything considered STEM. I actively do stuff within electrical, and mechanical engineering and a little programming. I joined the project since it sounded like a challenge. I wanted to solve problems, and contribute to the project succeeding.

Contribution to the team: I have taken a look at budget, mangaging our accounts and helping with mechanical design, ele

6.3.4 Secretary: Felix Jørgensen (19)

Responsibilities: Documentation, Writing, Editing, Organization.

School: Andøy Upper Secondary School – Space Technology.
E-mail: felixandreassenpost@gmail.com
Phone: +47 94261638

Biography: I have always been interested in both space and technology, especially how the two interact with one another. Even though I do not work with the actual design of the CanSat itself, my interest in both fields were my primary reasons for joining the team. Additionally, I thought the competition seemed interesting, and I wanted to take part in a bigger group project and hopefully gain valuable experience from participating in it.

Contribution to the team: Primarily, I have been assisting with writing and the organization of the team's meetings.

6.3.5 PR Chief: Max (18)

Responsibilities: Graphic Design.

School: Andøy Upper Secondary School – Space Technology.
E-mail: maximilian.christoffer.olsen@gmail.com
Phone: +47 45844217

Biography: Not much to say, I enjoy being a part of this and I design logos and whatever else is requested of me.

Contribution to the team: I made the logo for the Trident CanSat.

6.3.6 Graphic Designer: Wiktor Becker (18)

Responsibilities: Graphics and PR.

School: Andøy Upper Secondary School – Space technology.
E-mail: beckerwiktor@gmail.com
Phone: +47 96801127

Biography: Me? I've been interested in space roughly since I was 13, and always dreamt of differing myself from standard society. I'm mostly a gamer, but I'm a positive guy with lots of ideas, and I like making decisions on the spot. Therefore I took four minutes, made up my mind, and joined the team. I like working with people, and helping them when they're in need, but the real reason I joined the team was actually because of the people and community. There are a bunch of clever students here in Andøya, so when they announced the project I was sure I wanted to get a good look at it, and to hopefully learn a thing or two along the way.

Contribution to the team: I've come with suggestions, design suggestions, translations, wording and positivity.

6.3.7 Guardian Teacher: Hallgeir Solstad Klæboe (27)

Responsibilities: Official communications and guidance.

School: Andøy Upper Secondary School – Teacher
Email: halkle13@vgs.nfk.no
Phone: 482 65 911

Biography: For as long as I can remember I have been interested in the universe, especially the planets in the solar system. This interest led me to study science in high school and, some years later, take a bachelor's degree in Satellite

Technology at UiT. After I finished my degree, I was lucky enough to get a job within this field as a teacher of Space Technology at Andøy High School. I decided to join the team as the guardian teacher because I had never heard of this competition before and thought it sounded fascinating, and I was severely impressed by the team's plan and was interested in seeing how they would fare in a competition such as this.

Contribution to the team: Communication between the team and Andøya Space, as well as giving the team hints and tips when asked.

8 Conclusion

Through hard work and dedication, the team has been able to develop a concept and make the CanSat real. Facing challenges, the team has been dynamic and been able to overcome what is needed to be able to create and fly a CanSat tricopter.
Professional documentation and working methods has ensured that everyone in the team is updated and knows what they need to do after a meeting. In addition it has allowed the team to communicate easier.

Appendix

Tables

Table 3.1: Communication format

Frame	1	2	3	4	5	6	7	8
Data	FC	Temp	P	Latitud e	Long	Altitud e	IMG1	IMG2

Table 3.2: Communication format

Frame	1	2	3	4	5	6	7	8	9
Data	FC	Time	Vel	Lat	Long	Alt	Temp	P	Hum

10	11	12	13	14	15	16	17	18	19	20
Ax	Ay	Az	Gx	Gy	Gz	S1	S2	S3	S4	S5

Temp = Internal Temperature
P = Pressure
IMG1 & IMG2 = Pixels from live images
Vel = Velocity
Lat = Latitude
Long = Longitude
Alt = Altitude
Hum = Humidity
Ax, Ay and Az = Acceleration
Gx, Gy and Gz = Rotational Velocity
S1, S2, S3, S4 and S5 = Gas Sensors