UBC Orbit Info Package

2022 - 2023

Created by the UBC Orbit Satellite Design Team

The University of British Columbia

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INTRODUCTION

The purpose of this document is to outline the team structure of the UBC Orbit Satellite Design Team, and provide a basic description of the team's current operations.

Mission

Our mission is to design, build and operate CubeSats that push the limits of space technology. We provide students with an opportunity to engineer for a harsh space environment, helping them develop the skills they need for a career in the aerospace industry.

ALEASAT

This project, a joint initiative between Simon Fraser University and the University of British Columbia, originated from the fifth Canadian Satellite Design Challenge (CSDC), where teams all around Canada were challenged to build a CubeSat that, when contacted, takes and transmits a picture of the point of contact. In addition to the opportunity for university students to develop and launch a spacecraft, the project will bring real value to the community. Soon, Canadian operators will have a satellite at their disposal for on-demand imagery to assist in disaster monitoring. Web-based modules and live sessions will also be available for those looking for an introduction to satellite communications and what they can expect when interfacing with ALEASAT.

ALEASAT's second payload is a scale-model of a human centrifuge; a ground version of which is currently being built at the SFU Aerospace Physiology Laboratory. Artificial gravity created by centrifugation helps sustain and improve astronaut health. This model will help researchers predict the behavior of the centrifuge in space, and optimize it for long-term space missions. The ALEASAT team looks forward to connecting with schools and youth organizations to provide accessible learning opportunities in STEM, both live and remote, to students of all ages.

ALEASAT is a joint initiative between Simon Fraser University (SFU SAT) and the University of British Columbia (UBC Orbit). Together we are developing an Earth Observation (EO) CubeSat that allows radio amateurs engaged in disaster relief to request and downlink imagery directly. The project involves over 100 members of design teams SFU SAT and UBC Orbit, with support from the Director of the UBC Radio Science Lab, Prof. David Michelson and the Director of the SFU Aerospace Physiology Lab, Dr. Andrew Blaber.

The CSDC

The Canadian Satellite Design Challenge (CSDC) is a two-year competition, in which multiple Canadian universities compete to develop a functional CubeSat. This program is run by the Canadian Satellite Design Challenge Management Society Inc. and is sponsored by the Canadian Space Agency (CSA), with the support of multiple aerospace companies.

The main purpose of the CSDC is to teach university students about the process of designing, building, and testing a satellite in a professional laboratory. To compete in the CSDC, teams must follow a strict design and build timeline. This timeline consists of two design reviews and a final evaluation. This evaluation includes a series of environmental tests to validate the CubeSat's performance in space, including vibration, thermal, and vacuum tests.

UBC Orbit participates in the CSDC because it not only provides a proven framework for developing a functioning CubeSat, the winner of the competition also gets support in launching their satellite into space.

TEAM OVERVIEW

This section will cover the details of what it means to be a part of UBC Orbit.

Team Structure

UBC Orbit has a simple internal structure designed to help reduce the complexity of building a satellite. Each satellite *subsystem* is managed by a *sub-team*. This allows members to focus on manageable tasks without having to worry about the complexity of other elements.

Each sub-team has a *lead* who makes the design decisions and plans the development process for their subsystem. Leads are the primary point of contact for problems and questions from the sub-team members. Leads are NOT there to complete a task on their own, although they may work part-time on a task if time allows. All sub-teams are overseen by the *team captain*, who tracks overall team progress, and enables the integration process.

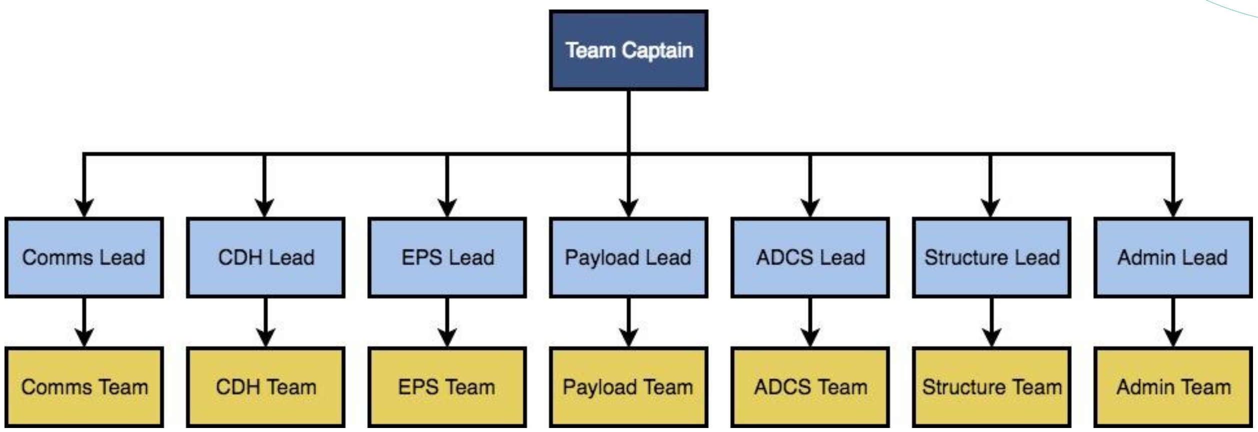

Figure 1: UBC Orbit Team Structure

Time Commitment

Weekly meetings are mandatory and will be held online at the discretion of each sub-team lead. Under usual circumstances we would be holding meetings on Saturdays 11AM-5PM but due to the difficulty of accommodating for members in different time zones that will not be the case. Still, we expect members to put in the same amount of hours.
To become part of the team you must be able to attend the sessions every week. The meetings will be suspended during final exam season but will remain active during midterm season, and attendance is expected.

If you are unable to attend a meeting, let your team lead know as soon as possible. Occasional absences are tolerated, but repeated absences are grounds for expulsion from the team. The same standard goes for showing up late to meetings or having to leave early. Members who are absent for a meeting are expected to take the initiative in catching up on missed work and any missed information. To meet task deadlines, members are sometimes expected to put in extra time over the week. The time commitments for each member are:

- **Technical Team Member**: 8 hours a week (6 Saturday, 2 on own time)
- **Admin Team Member**: 5 hours a week (1 Sunday, 2 own time)
- **Sub-team Lead**: 12 - 16 hours a week (6 Saturday, 2 at lead meetings, 4 - 7 on own time)

Every other week, there is also an integration meeting after the general meeting. The purpose of this meeting is to discuss satellite-wide issues and come up with solutions that involve more than one sub-team. Leads are required to attend these meetings, and it is encouraged that general members stay to participate.

Subteam Breakdown

General team members belong to a particular sub-team. Technical team members are science and engineering students (or individuals with relevant skills) who complete the majority of the technical development for the team. Admin team members are students interested in the management and marketing of the team. Specific skill sets that are used in each sub-team are outlined below (these are not pre-reqs, but having them beforehand is very advantageous).

General Technical Skills

Some skills are useful to most sub-teams, however each sub-team also entails a more specialized list of tools. The relevant skills for most subteams are:

- Embedded C programming
- Serial communication protocols (I2C, SPI, UART, etc.)
- AGI STK
- Electrical test equipment

Administration Team (Admin)

The admin team is responsible for all non-technical management tasks. The team maintains UBC Orbit's public image, relationships, and finances. This includes searching for sponsorships, applying for funding, booking educational and industry outreach events, and managing all of our social media platforms. Relevant skills:

- Marketing and public relations
- Photography and videography skills
- Graphic design skills
- Knowledge of accounting and bookkeeping finances

Attitude Determination and Control System (ADCS)

The ADCS team is in charge of determining and stabilizing the orientation of the satellite. The positioning of the satellite is determined using a variety of sensors. Gathered data is then fed into a control system that triggers actuators to adjust the orientation. Relevant skills:

- MATLAB Simulink
- ANSYS
- Control theory
- Linear algebra & differential equations

Command and Data Handling (CDH)

The CDH sub-system is essentially the brain of the satellite. It deals with carrying out commands from ground station, compiling satellite-wide data, and monitoring and responding to any system failures. Relevant skills:

- Embedded software development tools, JTAG
- FreeRTOS

Communications (COMMS)

The COMMS team creates an interface between the satellite and ground station. This requires dealing with advanced hardware structures, knowing the constraints of radio communication, and deciding how data should be formatted to enter and leave the satellite. Relevant skills:

- Python
- RF simulation tools
- Software defined radio
- Communication protocols (eg. AX.25, continuous wave)
- Modem architecture
- Amateur radio licence (acquired while on the team)

Electrical and Power Systems (EPS)

The EPS team is responsible for planning the power budget of the satellite and ensuring that there is always ample power. To do so, the team must run simulations of our orbit to see if the power intake is sufficient for the satellite's power consumption. Relevant skills:

- MATLAB Simulink
- Linear algebra
- SPICE tools (eg Circuitmaker, PSIM)
- Knowledge of solar power generation

Payload

The payload is responsible for executing the main mission of the satellite. Our payload consists of a camera module that will be able to take images of a specifically requested location on Earth and immediately downlink the photos. Relevant skills:

- Basic / moderate knowledge of optics

Structure

The structure team is in charge of designing, manufacturing and assembling the frame and components of the satellite. The team also runs simulations on the design to ensure it passes the necessary stress and thermal tests. Relevant skills:

- SolidWorks
- ANSYS
- Python
- Excel
- Basic machine shop skills

Hardware

The hardware team handles design, testing, and debugging of all PCBs for the CubeSat.
Relevant skills:

- Component Selection
- Schematic Capture (Altium)
- PCB Layout (Altium)
- Hardware Testing and Debugging
- Bill of Materials and Manufacturing Outputs
- Electrical Test Equipment

SPACE ENGINEERING CONSIDERATIONS

Orbit and Space

An *orbit* is a path that an object takes around another object in space. There are many kinds of orbits, but the two most relevant to satellite development are Low Earth Orbit (LEO) and Geostationary Orbit (GEO). For modern and low-cost satellites, a LEO with altitude between 160 km and 2000 km is selected, with most LEO satellites orbiting below 1000 km. On the other hand, GEO is at 35,786 km above Earth’s equator and orbits at the same speed as Earth rotates. Consequently, the satellite stays at a fixed location above a given spot on Earth.

LEO orbits are defined by their altitude and inclination. The altitude is how high the satellite is from the surface of the earth. The inclination is the angle of the orbit from the equator. This means that if a satellite orbits directly over the equator, it has an inclination of 0 degrees. Contrarily, if it travels over the north and south poles, it has an inclination of 90 degrees.

CubeSats

A CubeSat is a small type of satellite, commonly used by universities to teach students about satellite research and development. A typical one-unit (1U) CubeSat measures 10cm x 10cm x 10cm and can weigh no more than 1 kg. Commonly, CubeSats are developed as 3U whose structure resembles three 1U CubeSats being stacked on top of one another. To further reduce cost, CubeSats make use of commercial off-the-shelf products and materials where possible.

The CubeSat Program was introduced in 1999 by professors from the California Polytechnic University and Stanford University, and was intended to be used as an educational platform. Since then, the CubeSat Program has gained popularity around the world primarily due to its simple design process, low construction cost, low launch cost, use of simple electronic parts, and short development period. Due to mass and space limitations, CubeSat payloads are often those not justifiable of a conventional satellite. This includes basic Earth observation, technological experimentation, and biological payloads.

Space Related Issues for CubeSat Design

A CubeSat, like its larger satellite cousin, is designed to ensure that it will survive and function properly when in space. The challenges for a CubeSat are outlined below.

Thermal Cycles

Thermal cycles are extreme temperature fluctuations in space. Due to the large temperature difference between the Sun and an eclipse, the body temperature of a CubeSat undergoes large fluctuations. This causes thermal expansion and contraction of the CubeSat structure and the incorporated electronic hardware. Consequently, CubeSats are designed and launched for a specific orbit where the temperature difference can be kept to a minimum.

Space Debris

Space debris consists of manmade and natural objects. Unused satellites, scattered particles of old spacecraft, and disposed astronautical waste are classified as man-made objects. Natural debris, on the other hand, includes micro- and regular-sized meteoroids. Any collision between the satellite and space debris can cause serious structural harm.

Vacuum

There are two major issues that a vacuum environment poses on a CubeSat:

- *Outgassing* is the process by which certain chemicals evaporate at low pressures, particularly affecting plastics. While the loss of material is not structurally critical, the vapours can coat and damage other components, eventually leading to failure.
- *Cold-welding* is the process by which metals, in the absence of an oxidized layer, fuse together. Prevention is most critical in moving systems, such as deployment mechanisms, where the initial movement removes the oxide layer from the assembly.

Ionized Gases

One unique complication of LEO is the presence of *ionized gases*, particularly highly energized ions of oxygen and other elements. The ionized gases can decompose certain surfaces, over a long period of time. This is of particular concern for electrical connections which can eventually be corroded and lose their conductivity. The sensitive electronic connections are often protected by coating circuit boards in a polymer or epoxy.

Radiation

Ionizing radiation, consisting of high-energy particles, can cause permanent damage to electronic memory. In conventional satellites, special radiation-hardened electronics are used to mitigate this problem. However, this is much too expensive for a CubeSat and it largely limits performance. Some alternate methods to bypass this issue are: aluminum shielding, choosing hardware which is less susceptible to this type of damage, hardware redundancy, and implementing error-handling protocols that account for these upsets.

CURRENT SATELLITE BREAKDOWN

The ALEA Satellite is UBC Orbit’s current 1U CubeSat, developed along with SFU Sat. Its mission goal is to take a photo of any location on Earth when contacted and downlink the image to where it was commanded from. The following sections outline the designs and goals of each sub-team.

ADCS

The ADCS for the satellite determines its orbital position by propagating two-line element data given from Earth. The orientation of the satellite is determined using sun sensors and an Inertial

Measurement Unit (IMU). The gathered data is then fed into a custom control system which uses magnetorquers as actuators. Further testing needs to be done to prove magnetorquers sufficient for our payload. Should they be proven insufficient, reaction wheels will be incorporated into the design to improve mobility. The short-term goal of the ADCS team is to develop and refine the control system. Most hardware components necessary to perform this task have been selected. The team must now use those specifications in their design and simulation of that system.

CDH

CDH is developing an inexpensive on-board computer, known as Trillium, that can self-handle radiation-induced upsets. Implementing the concept of Triple Modular Redundancy (TMR), the system contains three microcontrollers (MCUs) that continuously compare their data with each other. When a comparison among two MCUs goes wrong, it is assumed that the third one holds the correct value and it resets the other two. The system can self-sustain itself as long as arising upsets are detected and corrected early. The short-term goal of the CDH team is to redevelop the Trillium architecture to better utilize the concept of TMR. Furthermore, they plan on implementing FreeRTOS to aid the timing synchronization of all three MCUs.

COMMS

The satellite utilizes an ISM band radio that downlinks at 433MHz, allowing for basic image and on-board telemetry transmission. The uplink frequency is planned to be 144MHz to allow for basic commands to be sent to the satellite. All radio communications from the satellite utilize a programmable transceiver allowing for greater design flexibility. Additionally, the satellite will be operational by any amateur satellite station wanting to downlink images of the satellite's current position in orbit.

EPS

The power system for the satellite is a commercial product purchased from Clyde Space. The system consists of a 30Wh battery and a module used to interface with the battery and control the distribution of power through switches. In the coming term, the team will develop a primary model for power intake and consumption of the satellite, and selecting the solar panels needed to generate sufficient power.

Payload

The payload module consists of an image sensor PCB, lens and filter assembly, and a microcontroller for processing the sensor output and communicating with the other subsystems. Over the next term, the payload team will be writing firmware to interface with our camera sensor.

Structure

The structure for the Aspectu satellite is a standard 1U aluminum CubeSat frame, custom-designed by UBC Orbit to support the payload module. The short-term goal of the structure team is to re-design several components and sub-assemblies to improve functionality, durability, manufacturability, and assembly time. The old design had deployable wing panels to increase the surface area for solar panels. As the power requirements are now less demanding, the need for deployable wing panels is gone.

Hardware

The hardware team has created the OBC (On Board Computer) PCB and is currently working on testing and debugging. Our current goals are to confirm functionality of the board and begin designing revision 2 to meet new requirements and fix any issues.

Mission Operations

The mission operations team is involved in designing our mission. Current work involves building an user interface that will communicate with our satellite once launched and performing orbital analysis.

SatNOGS

satnogs

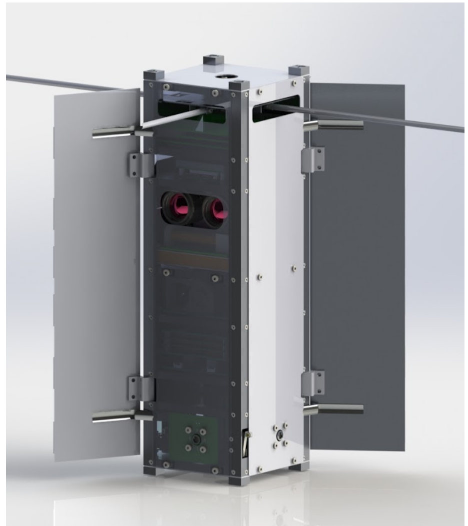

Figure 4: Previous Satellite Structure

FAQ

Balancing school and an engineering team?

The time commitment required by most teams is very much manageable. In fact, the two experiences can be mutually beneficial. An engineering design team offers means of applying theoretical knowledge in a practical way. We will always suspend team meetings during exam season as we are aware of the importance of proper studying. That being said, midterms and homework are not excuses to miss meetings or slack off on work.

Can I be a member of more than one design team?

You can be a member of more than one design team, although being a student and committing your time to one student team is already a fair amount of work. Regardless, if you are sure that you can commit the time to UBC Orbit and another team without it interfering with your school work, then you are welcome to join. However, we strongly recommend that you start off with just one team so you get a sense of the time commitment.

Should I be a part of the Admin team?

Your suitability for a management role is in no way determined by your past experiences. While experience is good to have, we are looking for individuals who are interested in marketing, management and educational/industrial outreach. We are an engineering team, so being also interested in STEM would go a long way to communicate with our partners and other team members. If you are comfortable with communicating with individuals, managing social media, creating marketing content, handling finances and expanding our business relationships, then we would be happy to consider you for a position.

I am not pursuing a science or engineering degree, can I still join UBC Orbit?

We expect that technical team members have some sort of technical background, thus most of our team members are in engineering, computer science or a general science degree. If you don’t have a technical background but are interested in space and still want to join the team, you are welcome to join as a member of the admin team. If you have technical skills that are not in engineering or science you can still apply through general member methods so we can determine whether or not you would be a good fit for the team.

Do I need to be in Vancouver to join?

Integration meetings between the subteams will be held in discord, however there will be meetings held in person especially for the technical subteams. The admin sub-team holds most of its meetings online, however there will be in-person events that admin members will be required to attend. Note that absences from a single meeting must be approved in advance by your team lead and should not be a regular occurrence. A large number of absences will result in your expulsion from the team.