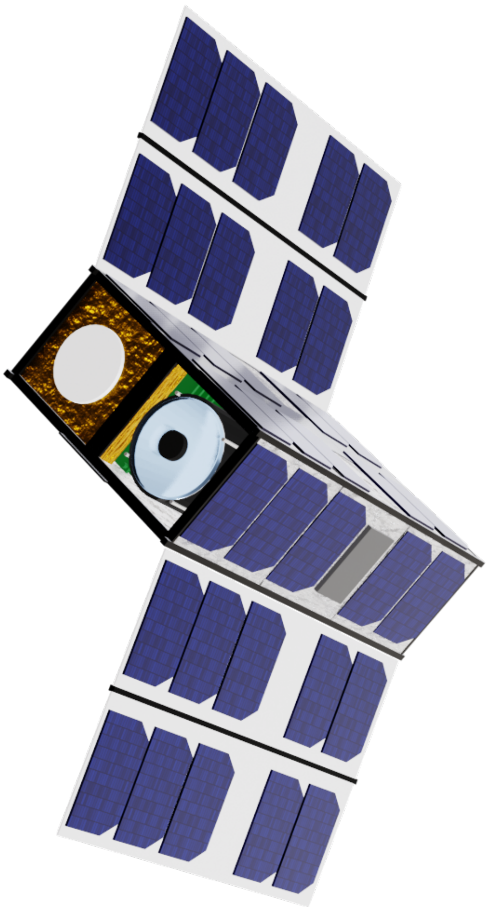
OPEN COSMOS

# Challenge Project



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# Top-Level Summary of Project Technical Approach:

**Project Overview:**
The satellite will be built and designed according to the main requirements established by the client. It will therefore be based on the 6U CubeSat architecture, measuring 20cm x 10cm x 34.05cm and weighing no more than 12kg. As an Earth Observation satellite, it must be equipped with advanced imaging equipment, capable of capturing high-resolution imagery of the Earth's surface.

**Orbit:**
The orbit of choice is defined by the functionality of the satellite and its desired lifetime. For an Earth Observation satellite, the proposed orbit is a sun-synchronous orbit (SSO). This orbit will enable the satellite to pass over the same region at approximately the same local solar time on each orbit, ensuring consistent lighting conditions for optimal image quality and electrical power through the solar panels. The minimum mission lifetime is 2 years, the satellite must therefore orbit at a high enough altitude that the orbit does not decay too quickly while also ensuring it does not stay in space long enough to become space debris. The following graph plots decay times for the CubeSat at different orbital altitudes*:

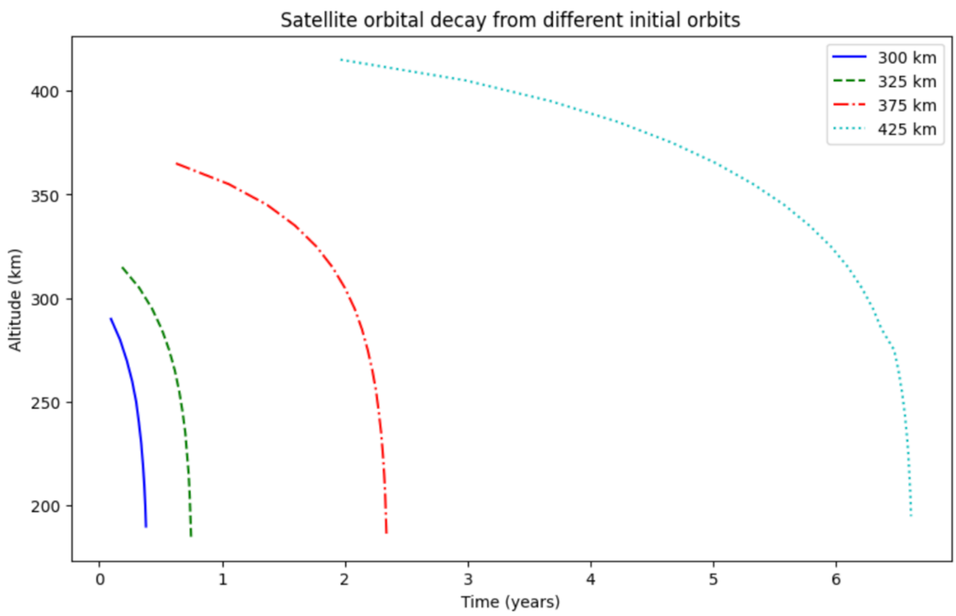



*Figure 1 Orbit decay*

The CubeSat's minimum orbital altitude must therefore be of approximately 375km, and while the final choice depends on the client, satellites of similar characteristics commonly orbit at around 500km. At this range of altitudes, the orbital inclination to achieve SSO is of approximately 97° [1].

* Assumptions: No damaging storms, radiation pressure and magnetic reaction forces negligible. Lifetime likely represents high estimate.

**Main Subsystems:**
The satellite will comprise several key subsystems:

1. **Structure**: A light-weight space-grade structure made of Aluminium 6082 conforming to CubeSat standards will house all of the satellite's subcomponents.
2. **Power System**: It is crucial for the satellite to stay powered throughout its mission. The main source of electric power are solar panels, which take advantage of the designated SSO orbit. Additionally, an electrical power system and batteries are required to manage the power input from the solar panel and to store electricity.
3. **Telemetry & Communications**: A robust communication system will facilitate data downlink to ground stations and uplink for command and control (C&C) operations. The satellite will operate in the S-band frequency. Also, GPS and internet modules can be installed.
4. **Payload**: An imaging system with additional image processing and control will be used for earth observation.
5. **Thermal Control System**: The thermal design will regulate the satellite's temperature to ensure the payload's optimal performance.
6. **Navigation & Attitude Control:** Star trackers and Inertial Measurement Units (IMU) will be used to track the satellites motion. 3 Reaction wheels will be used for attitude control.
7. **Onboard Processing**: A powerful flight computer will coordinate all of the satellite's subsystems to ensure safe and reliable operation in space.

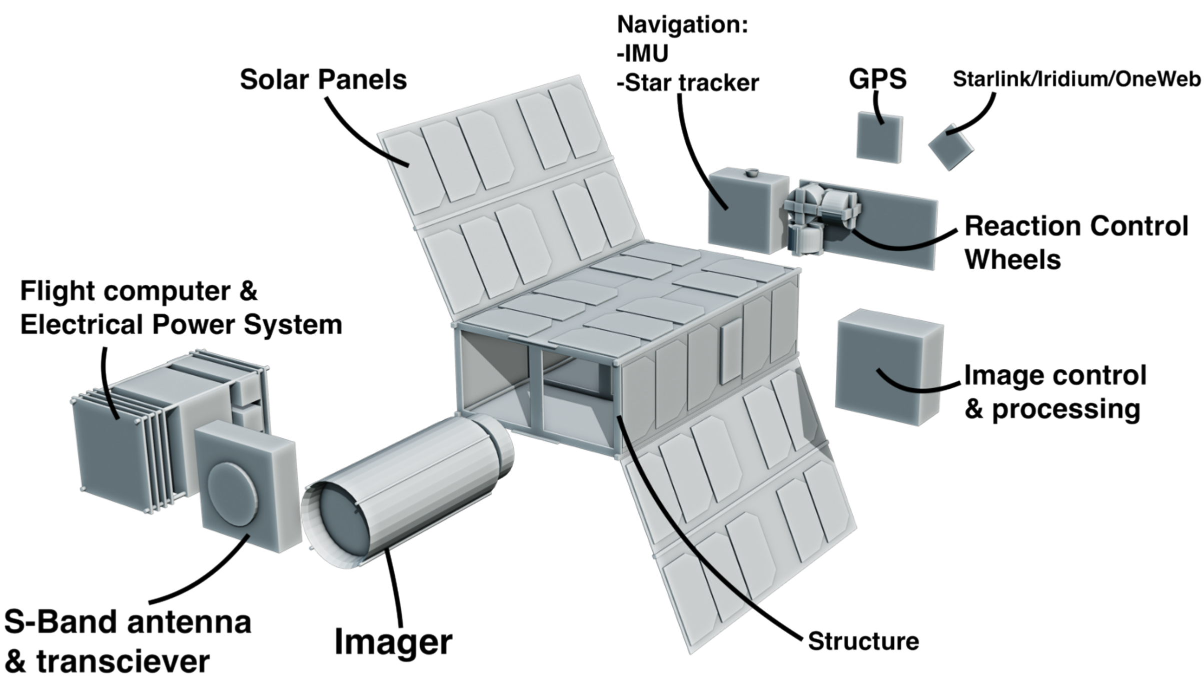



*Figure 2 CubeSat subsystem arrangement.*

**Payload:**
Earth Observation can involve various applications such as environmental monitoring, weather forecasting, disaster management, and natural resource assessment among many other things. The client is yet to specify their desired approach to Earth Observation, meaning that the optimal resolution and field of view of the imaging system remains to be specified. Nevertheless, powerful commercial off-the-shelf (COTS) imaging systems such as the Chameleon Imager by Dragonfly Aerospace [2] cover a wide range of applications. The Chameleon is a lightweight (1.6kg) and compact (2.5U) device capable of taking high-resolution pictures using RGB, Multispectral, or Hyperspectral imaging techniques.

**TT&C (Telemetry, Tracking, and Command):**
The satellite's communication system will support telemetry and tracking through its S-band antenna and GPS module, providing information about the satellite's health, status, and position. Command capabilities will allow operators to remotely control the satellite and its imaging capabilities, ensuring it is at the right attitude for imagining and data relay.

**Launch Segment:**
As stated in the main requirements, the launcher for the CubeSat must be procured as part of the project. When choosing a launch provider, the main aspects to be considered are cost, available launch windows, payload capacity and criteria, as well as regulatory compliance. The main launch providers currently available are:

- **SpaceX**: Through its rideshare program, SpaceX allows for multiple small payloads to be launched simultaneously on a *Falcon 9* rocket. Their quoted price for a 6U CubeSat to SSO at 500km is of approximately $280,000. Their next launch windows are in January 2024, June 2025, and Q4 2025 [3].
- **Rocketlab [4]**: Their *Electron* small satellite launch vehicle is commonly used to launch CanSats and other smaller payloads. While not as much information regarding their services is publicly provided, their launch cost for a 6U CubeSat at SSO orbit can be estimated to be around $500,000].
- **NanoRacks [5]**: This company offers CubeSat deployments from the International Space Station (ISS); However, the ISS' orbit does not match the established criteria for the satellite and is therefore not an adequate option.
- **ISRO [6]**: The Indian space agency has excelled throughout the last decade in providing cost effective launch options. Their PSLV rocket is designed for polar and SSO orbits and is launching evermore CubeSats such as the 3U DemoSat by the American based company *Astranis*.

Integration with the launch vehicle is essential, testing and integration of the satellite must be done in coordination with the launch supplier. Furthermore, a functional dispenser sized for 6U must also be procured to safely detach the CubeSat from the launch vehicle. Companies such as Rocketlab and ISISpace provide COTS dispensers at a price of around $45,000 [7].

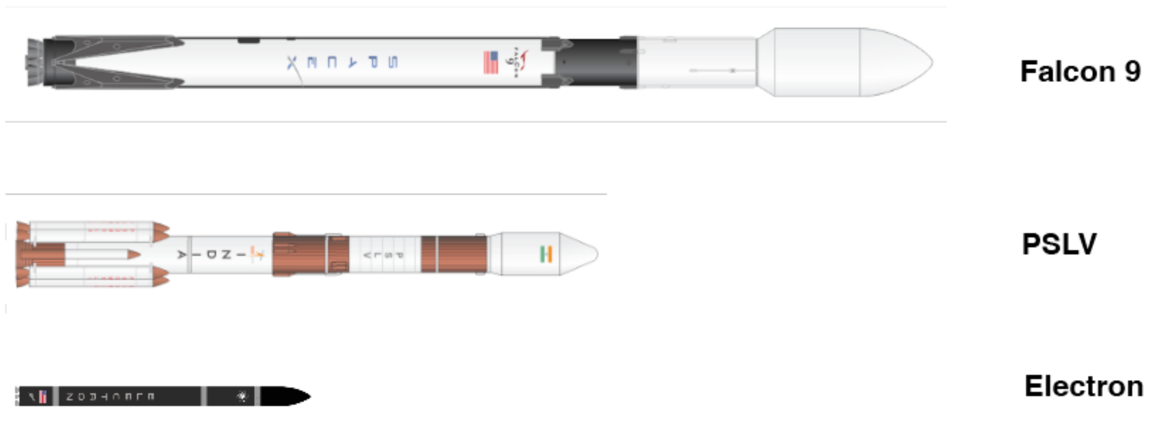



*Figure 3 Launch vehicles.*

**Ground Segment:**

In order to communicate with the satellite from the ground, a radio frequency licence must be acquired from a regulating authority (the FCC in the US or the CAA in the UK). A ground station can then be set up consisting of a Yagi or/and parabolic antenna operating in S-band frequencies. While very cost effective, such a system would only allow the satellite to relay and receive data as it flies over the ground station, meaning that there would be no constant feed of data and communications. If the client were to need constant communication and tracking with the satellite, ground stations can be leased all over the globe, thus increasing the satellite's coverage area.

The day-to-day operation of the satellite and data processing are also to be run from the ground, suitable facilities must be put in place with all required resources to ensure the smooth operation of the CubeSat once it is in space.

# Project Management Plan Outline:

**Cost Estimation:**

Sending a satellite to space is no cheap endeavour, and large costs are associated with such a mission. A table is provided with a detailed breakdown of the project's estimated costs, where the satellite component prices are taken from readily available Commercial Off-The-Shelf options. It must be noted, however, that this is an approximate breakdown and therefore very likely to be a lower estimate of the costs:

*Table 1 Cost Estimation Breakdown*

| Category | Item | Provider | Quantity | £/Unit | Total |
|---|---|---|---|---|---|
| **CubeSat** | 6U Structure | Endurosat | 1 | £5,956.12 | £5,956.12 |
| | Reaction Control Wheel | CubeSpace | 3 | £6,771.17 | £20,313.00 |
| | 6U Solar Panels | Endurosat | 3 | £11,133.39 | £33,400.17 |
| | Electrical Power System | Endurosat | 1 | £27,439.30 | £27,439.30 |
| | Flight Computer | Endurosat | 1 | £3,683.83 | £3,683.83 |
| | Flight Computer SDK | Endurosat | 1 | £4,797.55 | £4,797.55 |
| | GPS Module | EXA | 1 | £1,455.91 | £1,455.91 |
| | IMU | Omni instruments | 2 | £413.56 | £827.12 |
| | Iridium Module | NearSpace Launch | 1 | £6,901.88 | £6,901.88 |
| | Payload (Imaging Device) | Dragonfly Aerospace | 1 | (Estimated)£50,000 | £50,000.00 |
| | S-Band Patch Antenna | EXA | 1 | £8,050.30 | £8,050.30 |
| | S-Band Transciever | Endurosat | 1 | £9,591.85 | £9,591.85 |
| | Star Tracker | CubeSpace | 1 | £13,798.05 | £13,798.05 |
| **Launch** | Launch Provider | SpaceX | 1 | £300,000.00 | £300,000.00 |
| | 6U Dispenser | ISISpace | 1 | £41,130.83 | £41,130.83 |
| **Ground** | Estimated Ground Segment Setup | - | - | £500,000 | £500,000 |
| **Other** | Testing, Transport, Mission Operations, etc | - | - | £200,000 | £200,000 |
| **TOTAL** | | | | | **£1,227,345.91** |

**Timeline:**

Aiming for the late 2025 or early 2026 launch windows provided by SpaceX, the following Gantt chart showcases a possible operations timeline for the development, construction, and integration of the satellite, along with other aspects such as license acquisitions, funding, and readiness reviews. This chart was made with information provided by the SpaceX *Rideshare Payload User's Guide* [8], NASA's *CubeSat 101* [9], and the *Spaceflight Mission Planning Guide* [10].

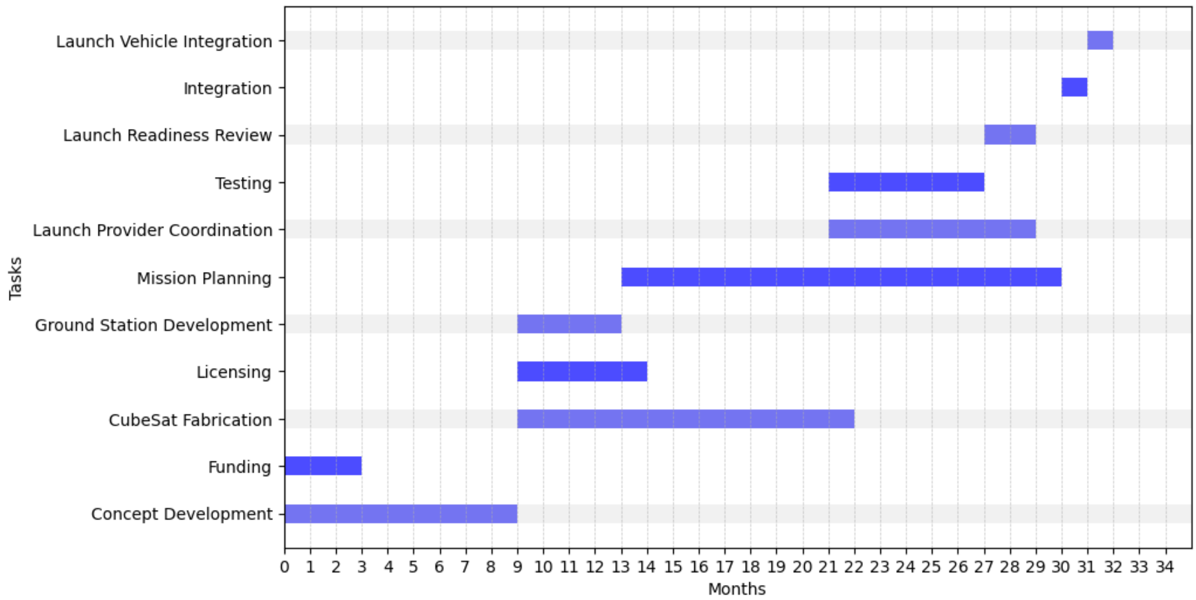



*Figure 4 Timeline Gantt chart*

Overall, the entire process from development to launch would take 2 years and 8 months. Meaning that if work were to start immediately, the CubeSat could be expected to fly in early 2026. The mission operations post-launch is not included in the Gantt chart, but if everything goes as planned this section of the project would last a minimum of 2 years as was decided by the client.

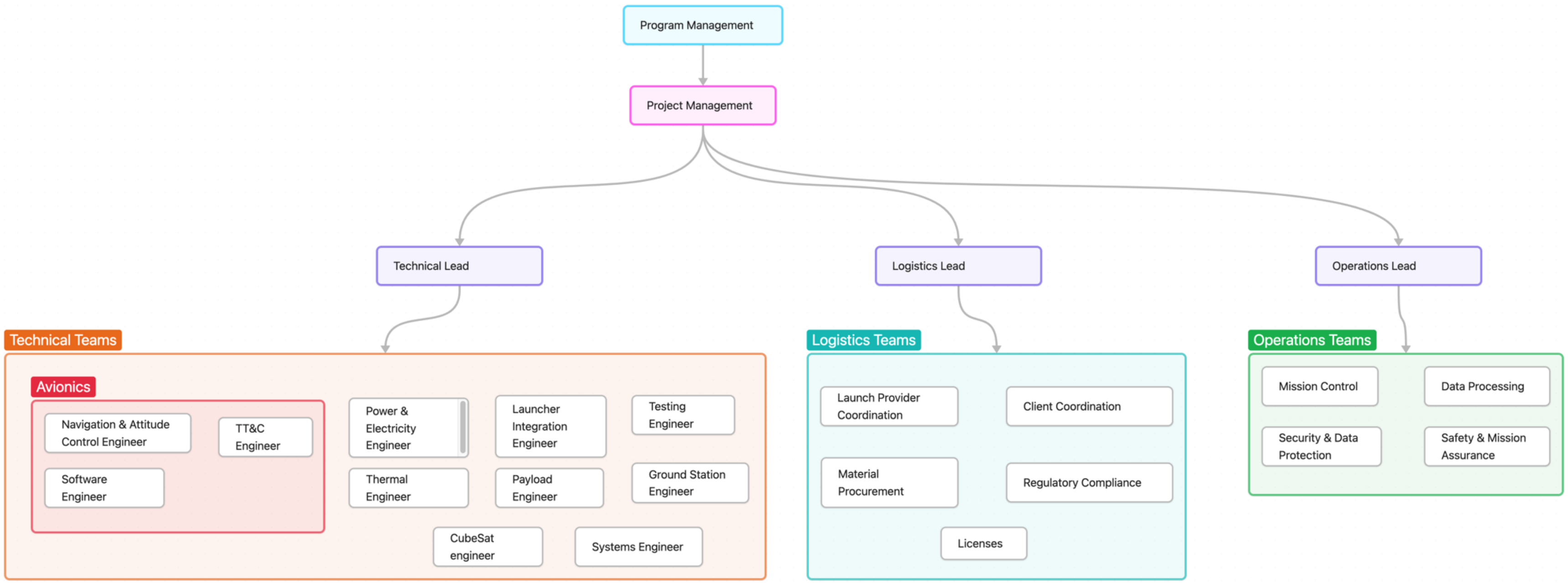
**Project Structure:**

This project will require a great variety of people with expertise in a wide range of fields. The following structure, divides the project in three sections:

- **Technical**: in charge of the design, assembly, and integration of the satellite with all its required teams.
- **Logistics**: this section handles all the logistical aspects of the project, such as procuring components, communicating with the client and launch providers, and ensuring regulatory compliance.
- **Operations**: handling the day-to-day operation of the CubeSat once it is in space, this mainly involves handling the data captured by the satellite and mission operations.

Each section will have a designated lead in charge of organising all its sub teams and departments. The leads themselves will be coordinated by the project manager:

# Project Structure



**Regulatory Compliance:**

Regulatory compliance is a core aspect of the planning of this mission, if the satellite does not meet regulations, it might not be allowed to fly. The following is an overview of some of the main regulations the project might face:

- **Licensing and Permits:** Necessary licences and permits might be required by government institutions, especially given the Earth Observing capabilities of the CubeSat. This will require communication with national entities such as NASA, ESA, and the UK Space Agency.

- **International Treaties and Agreements:** The CubeSat must comply with international treaties. The regulations established by the United Nations Office for Outer Space Affairs (UNOOSA) must be carefully studied.

- **Frequency Allocation:** As previously mentioned, a radio frequency must be licensed, this can be done through entities such as the American Federal Communications Commission (FCC) or the British Civil Aviation Authority (CAA).

- **Orbital Debris Mitigation:** Mitigation measures must be established to prevent the satellite to become the cause of space debris. It must be placed in an orbit that will decay with time and where the chances of collision with other satellites are minimal.

- **Coordination with Launch Providers:** Each launch provider provides extensive documentation on requirements and regulations for their payloads, it must be ensured that out CubeSat meets these requirements for a safe launch and deployment of the satellite.

- **End-of-Life Disposal:** A plan for the Cubesat's end-of-life disposal must be prepared, ensuring the satellite will deorbit in a calculated timeframe and if possible, ensuring re-entry does not take place over highly populated areas.

# References:


[1]. Smallsat. (2013, April 11). *Sun-Synchronous Circular Orbit, Inclination vs Altitude (LEO,J2 perturbed)*. Small Satellites. https://smallsats.org/2013/04/11/sun-synchronous-circular-orbit/

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