CubeSat Project Logbook

Team B

Alex Berresford

# Common part

## Team members

Claudio Vestini

Alex Berresford

Fizza Naqvi

Hani Moussa

## Code of Conduct

This Code of Conduct establishes guidelines for behaviour and collaboration among members of the [Project Name] group. We aim to create a respectful, inclusive, and productive environment for all participants.

Please continue from here.

## Summary of the project and objectives

This project…

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# 2024-21-10 First meeting

Present: Claudio Vestini, Hani Moussa, Alex Berresford, Fizza Naqvi

Apologies: None

Location and time: RSL Study Room 4 at 14:00

Author of minutes: Claudio Vestini

* Discussion of project organisation:
  + File system (GitHub repository, GitHub Projects roadmap (Gantt chart))
  + Google Drive folder
  + Report LaTeX file
  + References (.bib master file)
  + Meetings and WhatsApp group for communications
* Allocation of tasks (initial draft):
  + Claudio:
    - Aerothermal
    - Instrumentation
  + Hani:
    - Electronics
    - Interfaces
  + Fizza:
    - Trajectory
    - Internal heat generation
  + Alex:
    - Mechanical
    - Launch service provider
    - Launch environment
* Discussion of scientific goals:
  + CubeSat constraints dictated by launch service provider (size, weight, centre of mass, electronics, stress response) - Alex
  + Ionospheric disruption due to re-entry impact - Fizza
  + Consideration of Magnus Effect during hypersonic re-entry – Alex
  + Budget analysis - everyone
  + Model Predictive Control for maintaining trajectory attitude (both in orbit and during re-entry). Use of cold gas thrusters as actuators - Claudio
  + Black box (GPS-tracked, ablative-protected) for retaining re-entry data – Alex
  + Materials testing for re-entry – Hani
  + Communications: information transfer during blackout – Claudio
  + Modelling the aerothermal environment in different re-entry stages - Claudio

### References

### Actions

* Discuss scientific goals with supervisors

### Deadlines

# 2024-22-10 Second meeting

Present: Alex, Claudio, Hani, Fizza, Tobias (Supervisor)

Apologies:

Location and time:LR7 at 2:00pm

Author of minutes: Alex Berresford

-Briefing Tobias on our progress, file system, organisation etc

-Mendeley for .bib file for automatically referencing papers

-Briefing Tobias on project ideas

-Ionosphere disturbances

-Feedback: Interesting, but a bit of a secondary goal, not directly related to re-entry

-Materials for re-entry

- Use CubeSat as a test rig for materials and how they demise in extreme flow conditions

-Feedback: On topic, very current bit of research for space industry

-How would you mitigate inequalities in material conditions

-Sample spheres inside sacrificial shell?

-Altitude control using spin

-Magnus effect

-Feedback: Could be used to control material conditions to allow for testing

-Serious control problem

Overall Feedback:

-Find rough bounds to problem through research and rough calculations

-Budget unlimited, but must be justified

-Black box vs Comms system

-Both realistic, depends on specific design choices

Long Term goals

### References

### Actions

### Deadlines

Research Tasks by 29/10/2024

-Hani – sensors for material degradation

-Claudio – Magnus effect, and realism of generating spin

-Fizza – Look into trajectory, expected burn altitude and ideal orbital altitude as well as ionosphere

-Alex - Investigate different CubeSat geometries, costs, pros, cons et. Keep up with Launch provider research.

# 2024-24-10 Launch service provider summary

**Nanoracks**

Ideally 1U, must be 1 by X

Rail Launch system from ISS

Supposedly ~$90,000 per 1U, although source not confirmed

51.6-degree inclination

385-400Km

**SpaceX**

Minimum 300k$ for a rideshare, might be the best option for launching multiple Cubesats as other providers might charge per satellite rather than by a minimum + extra for mass like SpaceX do. – We may need to package them together and plan for separation. Might be ok for larger payloads

**GOMspace**

Offers better integrated packages for 5-year LEO missions with all required hardware – not an option for our mission.

**Rocket Lab**

Various launch locations, and we can deploy from 38 to 120 degrees up to 500km with ~ 1.5 degrees precision.

Mission very flexible.

Provides launch force and frequency information.

Price unclear.

**Endurosat**

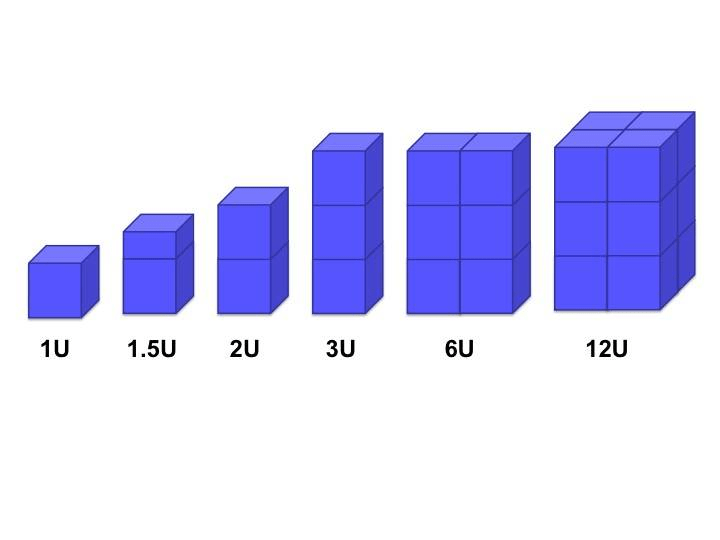
Cost calculator but uses external launch providers. Might be the easiest logistical option, but potentially the costliest if they outsource everything.

<https://www.endurosat.com/configurator/>

**More information on the above in relevant datasheets**

# 2024-26-10 CubeSat geometries

CubeSats measured in terms of “U”, a unit of volume that represents a cube of 10cm x 10cm x10cm.



<https://www.nasa.gov/what-are-smallsats-and-cubesats/>

Typically, ~ 1.3kg per 1U

Any 1 by X configuration has more access to rideshare as they can be used in shared deployers, which are typically 1 by Y in dimension e.g. Nanoracks deployer – 1U, 2U or 3U preferred, 1.5U not necessarily supported.

Other configurations may cost extra relative to size as it’s more likely we’ll need to provide our deployer.

# 2024-10-28 Third meeting

Present: Claudio Vestini, Hani Moussa, Alex Berresford, Fizza Naqvi

Apologies: None

Location and time: RSL study room 2 at 13:00

Author of minutes: Fizza Naqvi

* Discussion on how to get Mendeley working for references
* Hani’s research: discussion on the different types of sensors that already exist
  + Accoustic emission sensor
  + Recession sensors (used to measure how thermal protection systems are damaged as they enter the atmosphere); NASA and ESA has used this before so there’s lots of information available
  + Look into what we’re actually going to measure before deciding on what sensors we should use
  + Ensure that our experiment cannot be easily conducted on Earth
* Claudio’s research: magnus effect and MPC
  + Magnus effect at hypersonic speeds works very differently
  + Most research is done on sphere’s but calculations might be able to be manipulated to work with a cube
  + Looking at simulations- the ones that are currently available are limited as it won’t test everything we need
  + Magnus effect can be tested when we have our CAD models
  + For control: our main options are cold gas thrusters
  + Reaction wheels- cheapest, easiest to manufacture, least risk involved but takes up lots of space, quite heavy
  + other forms of thrust such as hypergolic- mainly used in thrust systems in capsules or small satellites; easy however it’s extremely toxic; slightly more expensive
  + MPC
  + Find a company that has architecture already made up for this or make it from scratch
  + We need 2 separate controllers
* Fizza’s research:
  + Burn up altitude is typically 80-120km but depends on size, mass orientation and material composition
  + Design for Design study- use semi-controlled re-entry
  + Trajectory model that simulated CubeSat re-entry trajectory; lots of assumptions are made on the atmosphere calculations and dynamic calculations
  + Ionospheric impact research- the range at which satellite demise occurs overlaps with the “E region” which reflects radio waves and is essential for long distance communication
  + Could monitor atmospheric composition changes because materials from the CubeSat could remain in the ionosphere temporarily- use spectrometers to detect the wavelengths and see how the different material affects the ionosphere composition, therefore radio wave reflection and long distance communication
* Alex’s research:
  + NASA has info on different possible CubeSat sizes- we want to do a 1U size due to how easy the geometry is, but we could expand greater if needed
  + Endurosat- cost calculator; limited to a 1.5U platform

### References

### Actions

* Ask Tobias about what data would be good for our measurements

### Deadlines

# 2024-10-29 Fourth meeting

Present: Alex, Claudio, Hani, Fizza, Luke (Supervisor)

Apologies: None

Location and time:LR7 at 2:00pm

Author of minutes: Hani Moussa

* Discussion of mission (material testing for hypersonic re-entry)
  + Recession sensors/Acoustic emission sensors
  + Experimental use of sensors is viable if well-researched
  + Acoustic environment information could be researched
* Thrust for deorbit
  + Low orbits will be brought in by drag
  + Active re-entry is likely more practical
  + Consider price/how well-established each technology for thrust is
    - Ion thrusters are for longer missions
    - Cold gas thrusters may be more practical/cheaper
* Launch Service Provider
  + Can get in touch with providers/external companies/physics department
    - Be upfront and professional
    - Can get basic information on launch costs
  + Materials not easily comparable between companies
* Model Predictive Control
  + Model needed for cube tumbling into atmosphere
  + Relation to materials testing
    - Initial idea - even tumbling on all sides
    - Speed of trajectory/speed of tumbling need to be considered relatively
* Possible secondary mission objectives
  + Magnus effect in orbit
  + Ionosphere experimentation
    - Difficult to measure through the atmosphere
    - Good to look at environmental effects of satellite demise
* Transmitting data
  + Blackbox/Comms system options
  + Formalise choice process/create spreadsheet and compare qualities
    - Quantity of data
    - Rate of data
    - Likelihood of survivability
    - Price
  + Justification should be in logbook and report
  + Can carry out a similar process for sensors
* Originality of design
  + Use necessary qualities of product to pick items off the shelf
  + Microcontrollers/thrusters etc.
  + Need to be space-certified or need to be tested (legislation side of things)
* Deciding next steps
  + Need to add numbers to decisions
  + Batteries and reaction wheels
  + Comms/Blackbox
  + Mass limit and Budget need to be considered

### References

### Actions

* Alex - Re-entry breakup (Blackbox system), cold gas thruster comparison
* Claudio - Spin rate vs re-entry rate, motors needed for reaction wheels and their weight
* Fizza – Ionosphere measurement specifics, background trajectory information
* Hani - Compare possible options for sensors in more depth
* Long term considerations – get in contact with relevant companies for information

Deadlines

# 2024-1-11 Cold Gas Thruster summary



Notes

100mN HPGP Thruster - 1U possible - need more info for tank dimensions, potential follow up when we have an idea of how much propellant is necessary

Nanosatellite Micropropulsion system - need to request more information - modular and customizable, space certified 1U possible

**UPDATE:16/11/2024 Request for more information declined**

I2T5 Cold Iodine Thruster - Iodine propellant - not pressurised. States 0.5 U footprint. The listed dimensions are approximated. Too large for 1U.

Other less appropriate thrusters were researched and datasheets retrieved.

None provided a standard set of units for easy comparison.

<https://satsearch.co/> source of information

# 2024-3-11 Battery options



Batteries were chosen with small size in mind for potential fit within 1U CubeSat rather than electronic properties.

<https://satsearch.co/> source of information

# 2024-04-11 Fifth meeting

Present: Claudio, Alex, Fizza, Hani

Apologies: None

Location and time: RSL at 5pm

Author of minutes: Claudio

Content goes here

* Alex – re-entry system:
  + Blackbox Idea not going to work due to weight restrictions, 4.0 kg + housing -> 8.6kg
  + Thrusters: factsheets -> possible choices (not clear, contact companies):
    - 300g mass, 100uN to 10mN thrust – hydrazene
    - HPGC thruster – low toxicity, low freeze point, 40g mass (no nozzle),
  + Batteries:
    - Optimus 30: large dimensions, 268g 30wHR
    - B14 modular: 375g, 45Whr, no NASA certification
* Fizza:
  + Ionosphere:
    - studies by ESA, cannot be used as classified
    - Remote sensing – companies:
      * Ground-based: higher resolution, no data storage problem
      * Balloons: difficult, coordination complexity, path complexity, time complexity
    - Justification of secondary objective due to regulations
* Hani:
  + Sensors:
    - Spreadsheet of several sensors for comparison:
    - Recession sensors not readily available – emerging technology, could build ourselves or contact ESA for purchase
    - GENERAL POINT: if price is not available, estimate in report
    - RSComponents website (not made for space, but cheap and used in the past in space applications), could lower price significantly
    - Papers: types of sensors used in projects – thermocouples (light, cheap, use several), mosaic core (infrared camera, not made for space so not certain we can certify it, 21mm largest dimension – viable (used in CubeSats in the past))
    - Can we certify things that have not been certified for space? (ASK TOMORROW). How do we design tests.
    - Could be the case that we do not need to be as rigorous with certification as it is only necessary if you stay in atmosphere for a long time - > our satellite demises so could get away w/o certification if launch company is okay with it -> Ask someone at the company
* Claudio:
  + Book for general understanding of hypersonic regimes, for both trajectory and aerothermal environment – relations can be found nicely displayed in graphs
  + Mass of typical re-entry attitude control system below 200g – very slow rotation rates and very weak forces. Ditched idea of controlling during re-entry but could easily spin up using loads of time to do so before hitting atmosphere
  + Paper on reaction wheels design and modelling -need 3 of them
  + Found a paper on the design of a reaction wheel-controlled CubeSat – very useful as it contains lots of pictures and cad files of the architecture – should use as reference when designing our own satellite (BEESAT)
  + Paper on empirical results of hypersonic testing of CubeSat topologies.
  + Roshko number, Strouhal number, paul bruce -> tumbling objects for re-entry
  + Youtube videos for hypersonics CFD simulations

### References

BEESAT: A Pico Satellite for the On Orbit Verification of Micro Wheels

### Actions

* Alex: document choice of no black box
* Fizza: document choice of ionosphere effects as secondary objective, document choice of ground sensing (why are alternatives not viable?)
* Hani: decide on recession sensors
* Claudio: look at thermal transfer rates for different spin rates

### Deadlines

# 2024-05-11 Sixth meeting

Present: Alex, Claudio, Fizza, Hani

Apologies: Name4

Location and time: 14:00 at IEB LR7

Author of minutes: Alex Berresford

Catching up Tobias on design choices

Rule out Black box

Settled for cold gas for altitude control

Spectroscopy

Use Fibre coupled spectrometer (Thor labs), multiple fibres possible per spectrometer, one on each face is possible.

Ground observation difficult due to range.

Space certification is on launch provider and not strictly legislative. Minimise risk where possible.

Devices that will function in a space environment difficult to find:

Electronics want to be certified to ensure they won’t be damaged by radiation.

Simpler components e.g. thermocouple/mechanical frame are more case by case.

Problem obtaining technical components (e.g. recession sensors)

Make a mock up CAD and reference a paper describing use.

Based on component sizing, 1U design unrealistic.

Possibility of de-orbit using ISS “trash” system – Nanoracks deployment goes via ISS anyway. – solves deorbit issue.

Spin up in vacuum during de-orbit but before colliding with atmosphere to avoid competing with aerodynamic forces.

Dependent on launch provider altitude.

Roshko number – ND group for describing oscillating flow mechanisms.

For electronics, heating needs to be critically considered. Build up models from 0D to having a heating solution.

Shielding should be considered for digital information stream to prevent bit flips, unnecessary for analogue streams.

### References

### Actions

Fizza – Design an orbit to allow for burn at apogee, followed by a spin up in vacuum before reaching atmosphere.

Hani-Background reading on heating for CubeSat electronic, followed by having another look at thermocouple and recession sensor implementation.

Claudio- Roshko number, Strouhal number and CFD hypersonics.

Alex – begin CAD modelling to get idea of internal design.

### Deadlines

# 2024-8-11 Reaction wheels and frame

**Reaction Wheels options**

****

source <https://satsearch.co/> for datasheet

CAD models were unavailable – company to be contacted

**Sample CubeSat frame** – designing our own is an option but should only be explored if commercial options are impractical.

A black and white cube

Description automatically generated

SM01 frame from Spacemind – 1U frame

113.5 x 100 x 100mm

Full structure mass 125.9g

Datasheet doesn’t specify exact material, just mentions of aluminium alloys and stainless-steel inserts.

More details in factsheet – sourced from <https://satsearch.co/> along with CAD model

Also have options in 2U, 3U, 6U and 12U with various options.

**11/11/2024 Black box ruled out for 1U**

Re-entry breakup recorder non – viability for 1U

-No commercially available options suitable for CubeSat sizes

-Designing one would be too technical and a project of its own

-examples of designs from space companies in “Black Box” Folder

-Unrealistic to build one small enough for a CubeSat that will survive re-entry

e.g. ESA design >8kg

-If POSSIBLE, could provide much more data than transmit during burn, as time isn’t a critical factor, a lot could be stored within the satellite which could then be retrieved upon landing or transmitted slowly.

Spectrometer options info link <https://www.thorlabs.com/thorproduct.cfm?partnumber=CCS100/M#ad-image-0>

# 2024-11-12 Seventh meeting

Present: Alex, Claudio, Fizza, Hani

Apologies: None

Location and time: 13:30 in Holder Building

Author of minutes: Fizza Naqvi

Fizza

- How far out we need to be to generate enough spin to get into the atmosphere

- spawning the CubeSat too far out burns a lot more energy from getting the ‘spawn’ place to the atmosphere

Claudio

- Looking at the Knudsen number and mean free path; how the interactions of particles can affect the trajectory

-CFD examples that could be used when we have CAD files

-Strouhal number

Hani

- reading on cooling electronics; dealing with heat generation from electronics; some CubeSat’s have heat pipes linked from components themselves to the other components to deal with the heat

-phase-change material – stores lots of energy; commonly used for CubeSats

- looked into recession sensors; what materials work best (nickel)

Alex

-Start making CAD files

-Used some existing components and made some files

-Found some reaction wheels of various sizes

Discussion with Luke:

Treat the trajectory simulations as separate to the spin calculations

Look at steady state models, perform calculations

If flow speed and spin speed time scales are equal, the system isn’t into steady state

Validity of the steady state calculations/analysis

To consider the thermal environment of the electronics, create a heat transfer flow analysis to consider how heat transfer affects each component

Obtain a set of equations to solve what the steady state temperature would be

Discussion with Tobi:

You would need time-accurate simulations to resolve some of the terms, but this is beyond our scope

Use a matrix method to do the heat transfer analysis

-grid convergence study- typically done with FEA and CFD simulations

In the report, include flow charts to represent complex code instead of directly incorporating the code into the report

### References

### Actions

Hani- look at what temperatures the electronics can deal with; what does the heating scenario look like when simply being in orbit; look further into certain components such as battery choices and microcontrollers

Alex- email manufacturers for necessary CAD file components; work on CAD design

Fizza- Modelling and simulation of aerospace vehicles by Peter Zipfel; do some calculations on the required spin, distance, time, impulse of thrusters etc.

Claudio- look at the requirements for systems to be in steady state, quasi steady state, etc; continue CFD analysis

### Deadlines

# 2024-15-11 Enquiries on various CAD files (sent 15/11) and mock up CAD model

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<https://www.aac-clyde.space/what-we-do/space-products-components/cubesat-batteries>

A close-up of a text

Description automatically generated

A screenshot of a computer

Description automatically generated

**Example CAD model**

A 3d model of a machine

Description automatically generated

**22/11/2024 Model updated to replace placeholder box with battery model**

Mock up for 1U model made up of a set of reasonable components.

The red boxes represent a pair of reaction wheels I haven’t been able to obtain the CAD models for, currently measured at the most extreme dimensions listed on the datasheet, with a central COM and the component set to the correct weight.

This model currently contains an OBC, 2 reaction wheels and a battery. With the limited space available we would still need to fit:

-A cold gas thruster for de-orbit burn

-sensors to collect data

-internal structures to hold components in place

-communications equipment to transmit data

-ablative material to be tested at a useful thickness

This kind of packing would be costly, increase the risk of early equipment failure and loss of data due to components going out of operational temperature range too quickly.

-high chance of data loss and mission failure. This also removes any potential of attempting secondary objective as spectrometer has no chance of fitting.

# 2024-18-11 Eighth meeting

Present: Alex, Claudio, Fizza, Hani

Apologies: None

Location and time: 14:30 at RSL

Author of minutes: Hani Moussa

* Timeline discussion
  + Logbook review next week – clean up
  + Speaker tomorrow
* Hani’s Microcontroller/Battery choice
  + List of common processors on CubeSats
  + Many possible OBCS
  + Specific decisions dependant on mission requirements
  + Battery material Types
* Alex’s Communication with suppliers
  + Rejected information request for propulsion system
  + Modular, customisable component dependant on customer requirements
* Possible collision
  + Avoidable with reaction wheels/planning/thrust
* Fizza’s Trajectory Calculation
  + Starting at 400km (ISS level), spinning until Deorbit burn (250km)
  + Altitude control could be done with thrusters – would not require high mass (~1 gram)
    - Harder to design than reaction wheels
      * Research available for mathematics of reaction wheel use
  + Stability requires low frequency (1Hz order of magnitude)
  + Thruster required not to affect spin
    - Deorbit thrust could occur before spin
    - If spin thrust comes first, timing makes a harder problem
* Magnus effect
  + spin is slow for magnus effect
* Re-entry timeline and Sizing Considerations
  + re-entry burn, Attitude activation, Burn up
  + Control for 3U CubeSat
    - Stable re-entry aided by positioning of centre of mass
    - Entry surface can be one of the smaller faces if spinning around longer axis
    - Alternative re-entry surface and slightly misaligned centre of mass causes unintended spin
    - Thermal equilibrium not reached for Materials testing
  + Larger satellite Considerable?
    - 8U would benefit the material testing experiment
    - Larger satellite may require higher budget
  + Split 3U into 1U detachment for material testing experiment
    - Advantages
      * Simplifies design for 1U section
    - Disadvantages
      * Detachment is difficult (wiring/batteries/Side of 1U)
      * Positioning of components is difficult
      * Trajectory will be affected
  + 1U CubeSat
    - theoretically possible, but fitting everything may be possible
    - Launch may be expensive
    - Layered design as in BEESAT
* Claudio’s Research on Aerodynamics situation
  + Thermal load/velocity stream on example satellite
  + CFD runs
  + Strouhal Number has a low order of magnitude with low frequency
    - Time to go between steady states is very low
    - allows assumption of constant steady state

### References

### Actions

### Deadlines

# 2024-11-19 Ninth meeting

Present: Alex, Claudio, Fizza, Hani

Apologies: None

Location and time: 14:00 at IEB LR7

Author of minutes: Hani Moussa

**Belstead Re-entry Talk**

* Destructive re-entry
  + Some debris can survive
* Uncertainties
  + Aerothermodynamics
    - Thin parts get hot first (titanium bipod test)
    - Calculations are not necessarily strong predictors, testing required
  + Fragmentation
    - Electronics box
      * Housing fails
      * aluminium warps under oxide layer influence
      * steel pins survive longer
      * electronics card survives past metals
  + Material Response
    - Liquid droplets, oxide layers on stainless steel
* Knowns
  + Demise qualities
  + Continuum heating dependant on length scale
* Unknowns
  + Rarefied heating
  + Structure failure mode in re-entry
  + Materials responses to failure
    - Metals
    - Ceramics
    - Composites
* QnA
  + Predictions
    - Speed/air density/size define drag/heating
    - Use literature
    - High up for CubeSats
    - Box of doom
  + Tumbling
    - Tumble-averaging heat flux, thermal approximation
    - Numerical extrapolation

**Experiment assessment**

* Fragmentation causes casualty risk
* Experiments to this end
  + EntrySat
  + Qarman
* Flight recorder
  + Transmits after blackout
  + Parachutes/buoyant
  + Difficult to apply to CubeSat
* Dedicated vehicles
  + Qarman survives blackout
    - Heatshield
    - Aerodynamically stable
  + VAST + VASP
    - Large vehicles
    - Thermally insulated electronics
    - Not applicable to 3U
* Measurements
  + Images and video are very helpful
    - Not necessarily high resolution
    - High number of low res >> low number of high res
  + Thermocouple/pressure traces aren’t helpful by themselves
  + Images are data hungry, however
  + Thermocouple data high priority
    - Doesn’t require high data rates
* Repeatability
  + Demise behaviour may vary from CubeSat to CubeSat
  + Repeatable CubeSat is very valuable – allows consistent scientific results
* QnA
  + Blackbox idea
    - Great in theory
    - Issue is lack of volume in a CubeSat
  + Difficulty of transmitting data
    - Transmit through radar-transparent material
    - Spherical sat (e.g. iball) has wide ability to transmit
    - Aerodynamically stable sat allows simple transmit direction
    - IRIDIUM satellite network

**Discussion with Luke**

* Don’t expect us to solve every problem
  + >=50% expectation of working
* Transmitting information
  + No spin allows transmitting out the back of the satellite
  + Tumbling could use multidirectional antenna
* Size
  + Smaller = simpler
  + Size decision (1U) allows boundaries for power/size/cost
* Materials not possible on every side due to size constraint
  + Could have material for testing on not every side/on 80% of sides
* Timeline
  + Current idea as described in yesterday’s meeting
  + Transmission requires radio-transparent materials
* Transmission
  + Tumbling limits window of transmission for single-direction antenna
  + Side panel with unidirectional antenna not part of material experiment
  + Choice comes down to data-rate required/instrumentation
* Mission objective
  + Secondary objective is beneficial to materials testing customers – track environmental impact
  + Spectrometer is large for 1U, would work for 8U
* Sensor on outside
  + Glue – easy to take off
  + Solder – wire will be broken down
  + Bore-hole – measure under the surface, but doesn’t measure true surface temperature
* Logbook review next week
  + Go over logbooks
  + Tidy up logbooks till then
  + Not examinable till end of project

# 2024-11-26 Tenth meeting

Present: Alex, Claudio, Fizza, Hani

Apologies: Name4

Location and time:LR7 at 15:00

Author of minutes: Alex Berresford

Presentation sum up from Tobias

-Total 20-minute presentation

~ 5 minutes each

-cohesive, not 4 individual presentations

-Give enough detail so the audience knows what’s going on and can make a judgement

-In general pitch to audiences understanding

-For undecided options, present both and give a conclusion to how that decision will be made.

-Referencing

-Ideally on the slide, abbreviation ok

-Sum up references on final slide alongside abbreviated on slide referencing

-Not formally assessed, purely for feedback

-OK to present work done, not based on pure calculations e.g. for mechanical/electrical

-Present on work done

How detailed should trajectory calculation be after re-entry?

Velocity and force balance every ~ 0.5km

Google slides vs Beamer vs PowerPoint Online

-Beamer decided as it will develop useful Latex skills

1U vs 8U

-1U is simpler and far cheaper for materials testing rig

-1U has very limited volume limitations

Diagonal OBC and battery?

-8U still cube for tumbling

-8U allows space for secondary objectives, e.g. Ionosphere

-No packing problem

Sum up chosen components in spreadsheet for mass estimate of prototype

Presentation for next Tuesday 2nd Dec – meeting Friday 29th Nov

-Begin with primary objectives

-Give cohesive, continuous presentation

-1U vs 8U “debate” heavily featured

More detailed plan below

Presentation plan


### References

### Actions

Everyone to prepare content for their assigned slides by the next meeting 29/11/24

### Deadlines

# 2024-11-28 Notes for presentation

Notes for my assigned slides.

Introduction

-CubeSat for testing materials during re-entry

-Provide this service for space companies to test their materials in a consistent manner

-Affordable repeatability is ideal to allow for multiple materials to be tested

Component masses for current proof of concept prototype

* COMAT RW20 142g x2 – Reaction wheel
* SM01 CubeSat frame 125.9g – most likely, we should get in contact with manufacturers for exact properties.
* Battery options

AAC Clyde Space Optimus 30 - 268g

Ibeos B14-M45 14V Modular SmallSat Battery – 375g

* OBC CUBE Polar 80g

-Unaccounted for

-Shell

-Internal mechanical

-Wiring

-Deployer interface

-Comms system

-Thruster mass

1U vs 8U

Only cube-shaped configurations – allowing for more smooth tumbling and even coverage

Estimated mission cost\*

-1U ~£46,500

-8U ~£318,000

\*Estimated using endurosat cost calculator <https://www.endurosat.com/configurator/> with the broadest parameters. Likely an underestimate. Not including component costs.

A 3d model of a machine

Description automatically generated

1U

-Packing problem, limited by certain components due to size.

-Reaction wheels won’t fit on central axis

-Might be difficult to achieve central COM

-Limited to certain components due to size, might have to use more expensive or sub-optimal components

-Limited shell thickness – may not last long enough to transmit.

-Cost allows 1 CubeSat per material, making it thermally symmetric and no extra considerations for COM necessary based on test material.

-COM wants to be central as possible

-Simpler for rideshares as 1U is a more standard size

-£43,000 estimated from endurosat

8U

-Much more expensive per launch

-Cost would imply multiple material tests at once

-thermally asymmetric, materials may affect each other’s results

-Rideshare would be more difficult

-Would likely need our own deployer

-Rocketlab ideal?

£318,000 estimate from endurosat

-Size Opens the door to a black box approach, still needs consideration

-Larger size would allow a thicker shell, both increasing breakup time, giving more data

-More available components as less physical constraint

-e.g. battery can be selected due to electrical properties rather than physical size

-Gives enough space for secondary objectives – ionosphere study

Project risks

At this stage lots of things uncertain, no clear risks to discuss – omit?

Outro

What we need to do now

-Contact providers and get a more realistic cost estimation

-Decide on 8U vs 1U

-Design/ find a suitable thrust system

# 2024-12-13 Eleventh Meeting

Present: Alex, Claudio, Fizza, Hani

Apologies: None

Location and time: Teams (online), 13/12/2024 at 10am

Author of minutes: Fizza Naqvi

Decision made to go with 8U

* allows us more freedom to do “more engineering”
* easier to design/fit components in
* materials on the outside can be thicker

Decision needs to be made on which materials to use

* look at ablatives typically used by other companies
* think about how long it would take certain materials to break down

Communication

* Look at where we can and can’t communicate properly
* Potentially reconsider blackbox idea
* With the ablatives on the outside, it may be difficult to communicate through the materials
* Potentially have an antenna on most of the faces
* Biggest project risk- not getting data

Power

* Number of batteries/type of battery depends on how much power we will consume

### Actions

Alex

* Look at the vibrational model

Fizza

* GMAT simulation

Claudio

* Look at the materials

Hani

* Look at the comms and what can be done

2025-1-21 Twelfth Meeting

Present: Claudio, Hani

Apologies: Fizza, Alex

Location and time: RSL GSR3, 14:00

Author of minutes: Hani Moussa

* Spoke with Luke on Logbook layout, conclusions below:
  + Make references clearer
    - i.e. just the title doesn’t help
    - Need to say downloaded, or full citation
  + Make your own conclusions separate from the paper summary
    - Currently confusing as to which bullet points are from paper vs my own thoughts
  + Behind on design at the moment
    - Can rectify this by making decisions in net group meeting
  + Turn into a pdf before submitting logbook
  + Meant to be continuable by someone else
* Meeting with Nafiz
  + Decided on 8U, CAD Model in progress
  + Need models and numbers
    - Model needs to be validated against experimental data, not just algebraic model
  + Sensors + Data
    - Bit rate and sampling frequency
      * Consider Nyquist, natural frequency (2x)
    - Example sensor layouts, then propose them (pros + cons, e.g. cost)
    - Redundancies for data – otherwise useless experiment
    - Encrypted? Existence previous space missions
    - Email people who have done this previously
    - Ground station, how is it collected + who?
  + Flow + rotation
    - Currently considering reaction wheels

Aerodynamically unstable allows small spin rate which causes spin to keep going

# 2025-1-27 Thirteenth Meeting

Present: Alex, Claudio, Fizza, Hani

Apologies: None

Location and time: RSL GSR3, 14:00

Author of minutes: Hani Moussa

* Claudio
  + List of known materials for calculations exist
    - In actual design, clients decide on final materials to test
  + Finite volume method to solve aerothermal
    - 1D, then 2D
    - Verify results with similar literature
    - Temperature, pressure, sheer stress distribution across line/surface
  + Model predictive control possible
  + Milan papers on thermite to ensure demise of CubeSat, hypersonic re-entry can start the reaction
  + Report writing is upcoming work
* Alex
  + Matlab code for vibrational analysis
    - Modelled in time
    - Small vibrations resulted
    - Companies have PSD for vibration for each frequency, used to make model
    - Requires finishing work (small errors)
* Hani
  + Comms background research
    - Types of antennae
    - CubeSat comms in the past
  + Plasma sheath
    - Relection/Absorption of material increases with speed
    - Needs unpractically high Gain to get through
    - QARMAN transmitted back to iridum from back of CubeSat
  + Omnidirectional antennae could allow comms backward to iridum
    - Surpasses plasma sheath, but low gain
    - Materials need to allow transmission
  + Solutions
    - Blackbox can be reconsidered with increase in size
    - Idea to direct antenna backward?
      * Low frequency of rotation, so this may be possible
* Fizza
  + Simulation for trajectory
    - Changed perigee
    - Elliptical orbit, but essentially circular for calculations due to low eccentricity
  + Research atmosphere model
    - Current simulation capped at 180km, cannot go below
  + Secondary objective
    - Spectrometer detects lines of elements -> intensity/concentration approximations
    - Mass Spectrometer more specific, but requires more power/storage
    - Equations/method found to assess impact with spectrometer data
      * Conc over altitude –> GPS required, unless barometer can be used?
    - Pressure/temperature sensors may be needed

# 2025-01-28 Fourteenth meeting

Present: Alex, Claudio, Fizza, Hani

Apologies: None

Location and time: RSL GSR3, 14:00

Author of minutes: Fizza Naqvi

Logbook review:

* Ensure that references are clearer (need to change the format) so it’s not just the link
* Include code or description of code in the logbook, especially next to images

Discussion:

Hani

* We are thinking about checking about what side the plasma sheath is on to orientate the receiver during re-entry/tumbling
* This will help solve one of the communication issues
* This hasn’t been done before for this specific purpose

Alex

* Increase samples in the vibrational model to avoid aliasing
* The vibrational model needs to be compared to existing research to ensure that the model is suitable
* All models should be compared to existing data or an analytical model

Claudio

* Verifying the solution for a flat plate
* Tried a 1D and 2D model
* 1D model works fine for smooth solutions
* Start with a simple, subsonic model
* Finite difference doesn’t work well with Navier-Stokes equations
* Discretisation has limitations- must satisfy Fourier number etc.

Fizza

* Verification of simulations:
* Initial velocity should be higher and then decrease
* Consider what it would look like if it was straight or if it was spiralling for example
* Quantify by looking at the angles for example
* Think about the resolution of the spectrometers- may be significantly impacted by the high velocities
* Shock waves can affect the pressure/velocity too

Short discussion with Toby:

* The spectrometer itself needs to be protected from heat so it should be placed sort of near the centre of the cubesat
* The fibre optic cable that is attached to the spectrometer faces a small hole in the heat shield, but is slightly further back at the beginning of the hole rather than at the end so it’s more protected
* The fibre optic cable itself is quite sturdy so his shouldn’t be a problem
* It can then take measurements on the radiation around the CubeSat

### Actions

Hani:

* Create a system diagram to help visualise the comms system

Alex:

* Validate simulations

Fizza:

* Look into verifying simulations
* Look into the spectrometer

Claudio:

* Work on python solver

# 2025-01-30 Vibrational analysis

This is a model to predict the vibrational behaviour of the CubeSat during launch. This model is simple and doesn’t include damping to show the worst-case scenario and simplify calculations.

The model was written in MATLAB with parameters that can be easily altered to match design decisions down the line e.g. material choice, number of layers, support geometry etc.

A whiteboard with math formulas and equations

Description automatically generatedA whiteboard with writing on it

Description automatically generatedA white board with red writing

Description automatically generated

Ideally, we design natural frequencies to be in low power areas of the vibrational PSD to reduce the chance of large vibrations causing damage to the structure.

Vibrational PSD for RocketLab Electron launch


A white board with math equations

Description automatically generated

A whiteboard with math equations

Description automatically generated

A diagram of a flowchart

Description automatically generated

A diagram of a graph

Description automatically generated

**Validation**

To test the model a base case of 2 floors with a single sinusoidal input signal was tested and simulated over a period of 1 second-, or 4000-time steps.

A screen shot of a graph

Description automatically generated

The output displacement graph shows a steady state oscillating response, which is what we would expect with no damping, unless the input signal was at natural frequency.

Next, the same parameters were tested using a signal at the natural frequency, for which we expect a growing response – which is what we found. These oscillations are much larger than the random frequency case, up to a few mm over 1 second.

A screenshot of a graph

Description automatically generated

Simulating over 10 seconds showed harmonic behaviour, peaking at 5mm displacement.

A green lines on a white background

Description automatically generated

This is a beating effect due to the input signal not quite being the same frequency as the natural frequency.

Readjusting for a more precise natural frequency gave the same shape over double the period, reaffirming this idea.

A green and white background

Description automatically generated with medium confidence

Matching the frequency to 6 decimal places gave this response.

A green triangle with a white background

Description automatically generated

This matches the expected model for an undamped system at resonant frequency eventually growing to infinite amplitude. See graph below from HLT page 160 indicating infinite amplitude responses at natural frequency in an undamped system.

A diagram of a function

Description automatically generated

# 2025-02-04 Fifteenth meeting

Present: Alex, Fizza

Apologies: Claudio, Hani

Location and time: 14:00 LR7

Author of minutes: Fizza Naqvi & Alex Berresford

Updates

Alex

Qualitative validation of vibrational model using base case and natural frequency testing.

Supervisor Feedback

Tobi

Do Quantitative analysis for validation of the vibrational model using an analytical model for the “2 floor” base case.

Actions

Alex -do an analytical model of the 2-floor vibrational model to validate base case simulations.

-Formalise material selection for primary structure.

# 2025-02-18 Seventeenth meeting

Present: Alex, Fizza, Hani, Claudio

Apologies:

Location and time: 14:00 LR7

Author of minutes: Alex Berresford

Alex

-Analysed various Reaction wheels for estimated 8U geometry and inertia to maximise momentum storage for minimum size and weight. Decided on **Granstal GS-RW10**.

Hani

-Researched OBCs and directional Comms systems. Decided on an OBC with a software defined radio which turns data into a comms signal without the need for an external system. **ICEPS Spacecraft System Core: All-in-one.** It also includes 3 axis accelerometer attitudes.

-Directional comms system involves several flat antennae adjacent in plane along with phase shifters to change phase of each antenna to control directionality. Rotman lens can be used to generate phase of each array automatically. Using a 2x3 array of **L-band Path1L-R from Space Antenna.**

-Type K thermocouples have highest temperature range, which will be ideal for our goals.

Thermal conditions:

Cube shaped allows even heating – orientation to sun doesn’t matter.

Concerned by lower temperature range, as there will be large losses when passing through Earth’s shadow. Tobias suggested a 0d heat simulation.

Internal heat generation will be dominated by reaction wheels, so they should be kept external to comms, which we expect to be the temperature critical system. If ablatives are sufficiently insulating, internal heat should be fairly constant.

Altitude determination:

Using multiple sensors we can estimate altitude:

Radar altimeter uses radio waves reflected off the earth to measure altitude.

Magnetometer measures the size and direction of the Earth’s magnetic field to estimate altitude.

Gyroscope measures acceleration, which can be integrated twice to estimate distance travelled.

Fizza

-Investigated spectrometers but hasn’t found an acceptable one yet. Thor labs one doesn’t have electrical requirements listed and has a very small acceptable temperature range.

Actions

Hani- Look into the maths of the comms system.

Claudio – Do a worst-case external heat balance model over an orbit.

Alex – Contact Rocket Lab and SpaceX, try and find examples of minor sensors (pressure sensor, thermocouples).

Fizza – Continue looking into spectrometers and atmosphere models.

# 2025-02-24 Magnetometers and Pressure Transducers

Magnetometer to be used as one of the methods for approximating altitude by measuring the Earths magnetic field. Choosing the MM20 due to its small size.



Pressure Transducer to be used as one of the methods of estimating altitude by measuring the pressure perpendicular to direction of travel – one on each side, taking the average of the 2 middle readings for the estimate of pressure, then comparing these to an atmospheric model to approximate altitude. Choosing Antrix absolute pressure transducer due to its small size and wide thermal operating range.



# 2025-03-04 Nineteenth Meeting

Present: Alex, Fizza,Claudio

Apologies: Hani

Location and time: 14:00 LR7

Author of minutes: Fizza Naqvi & Alex Berresford

Updates

Claudio

Has completed initial modelling for heating during orbit, with a steady state temp of ~120oC while exposed to Sun. Assuming area illuminated is constant and is average area of projection, temp of space assumed to be 0K, ignoring transient behaviour of satellite during illuminated phase. Conduction ignored to find steady state satellite surface temperature.

On shadow side, conduction is considered towards centre of CubeSat. Goal is to keep electronics above a set value. Upper bound of thickness to be determined during demise phase to maximise operating time for sensors.

Fizza

Decided on AvaSpec-Mini2048CL spectrometer.

Discussion with Nafiz:

Consider Aerodynamic loading for designing structure.

Actions

Hani – For next meeting find minimum electronics temp range.

Fizza – Long Term goal, complete collision risk model.

Everyone: prepare slides for presentation practice on Saturday 8th March

# 2025-04-12 Frame material selection

<https://asm.matweb.com/search/SpecificMaterial.asp?bassnum=MA2014T6> 2014 shear

<https://asm.matweb.com/search/SpecificMaterial.asp?bassnum=ma2024t4> 2024



Common Al alloys were assessed qualitatively across a variety of properties, with an emphasis on ease of manufacture, strength and low thermal conductivity. Low thermal conductivity is important to slow the passage of heat to the core electronics, keeping them functioning within acceptable temperature range Ultimately the decision came down to 2014 and 2024 as they both had low conductivity, and the highest strength characteristics. However, 2014 can be welded and is easy to machine making it the preferable material.

# 2025-04-16 Final components for CAD Mock-up

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Component** | **Count** | **L(mm)** | **W(mm)** | **H(mm)** | **Mass(g)** | **Total Mass(g)** |
| GS-RW10 Reaction wheel | 3 | 50 | 50 | 60 | 250 | 750 |
| Vacco Cold Gas Thruster | 3 | 100 | 100 | 30 | 542 | 1626 |
| AvaSpec-Mini2048CL Spectrometer | 1 | 95 | 68 | 20 | 175 | 175 |
| ICEPS Spacecraft System Core All-In-One: EPS/OBC/Radio | 1 | 96 | 96 | 25 | 100 | 100 |
| CC-UV/VIS/NIR-8MM  Cosine Corrector | 6 | 12(diameter) |  | 29 | Unknown |  |
| FC6-  UVIR400-2 Fibre Optic Cable | 1 | Splitter 18 (diameter) | Cable 6 (diameter) | Splitter 42 | Unknown |  |
| BA06 A/S Battery | 1 | 90 | 96 | 9 | 209.45 | 209.45 |
| HXDC16010 SA00 Iridium SBD | 4 | 14(diameter) |  | 41.5 | 22 | 88 |
| EPB-25PS-C20004 Pressure Transducer | 6 | 6.98(diameter) |  | 5.84 | Unknown |  |
| MEAS 410 Thermocouple | 6 | Negligible | Negligible | Negligible | Negligible |  |
| MM 200 magnetometer | 1 | 33 | 20 | 11.3 | 12 | 12 |

[https://tpsx.arc.nasa.gov/Material?id=46#](https://tpsx.arc.nasa.gov/Material?id=46) example carbon phenolic

**Costs**

Launch ~ £318,000 estimation from EnduroSat – lower bound

Graduate Engineer Salary~ £30,687 per annum

4 Graduate Engineers until Jan 2027 (December 2026 launch + ~1 month for mission time)

~ £215,000 on Salary

~£100,00 on components and materials (better estimate to come)

Total £633,000 conservative budget.

~£700,000 Best estimate so far

# 2025-04-18 FEM of Frame under extreme loading

Solidworks FEM used to observethe displacement and stress of the frame with total estimated cubesat mass (12kg) distributed on top of the CubeSat and under gravitational loads to represent extreme points of the electron acceleration MPE.

A graph of a graph

AI-generated content may be incorrect.

-1g,7.5g with lateral perp to side

A blue and green wireframe with a red arrow

AI-generated content may be incorrect.A blue and green metal frame

AI-generated content may be incorrect.

Stress displacement

-1g,7.5g with lateral at 45deg to side

A blue and green wireframe with a red dot

AI-generated content may be incorrect.A blueprint of a metal frame

AI-generated content may be incorrect.

Stress Displacement

2g,3g with lateral at 45deg to side

A blue and red wire frame

AI-generated content may be incorrect.A blue and red structure with a graph

AI-generated content may be incorrect.

Stress Displacement

2g,3g with lateral perp to side

A blue and green wireframe

AI-generated content may be incorrect.A blueprint of a metal frame

AI-generated content may be incorrect.

Stress Displacement

