CubeSat Project Logbook

Team B

Hani Moussa

# Common part

## Team members

Alex Berresford

Claudio Vestini

Fizza Naqvi

Hani Moussa

## Summary of the project and objectives

This project concerns the demise of a CubeSat upon re-entry to Earth’s atmosphere. We design scientific goals, breakdown mechanisms and CubeSat configuration within this context.

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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, center 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 inequaltities in material conditions

-Sample sphere’s 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.

# Sensors Research

* Background reading
  + [Material Thermal Degradation Under Reentry Aerodynamic Heating (2014) | Deependran Balakrishnan | 17 Citations](https://typeset.io/papers/material-thermal-degradation-under-reentry-aerodynamic-1ug5gzyv1k)
  + [SDC8-paper210.pdf](https://conference.sdo.esoc.esa.int/proceedings/sdc8/paper/210/SDC8-paper210.pdf)
  + [Re-entry Heat Shields: Materials and Design for Spacecraft Protection - Space Voyage Ventures](https://spacevoyageventures.com/re-entry-heat-shields-materials-and-design/)
  + [Webinar 01312023-Final.pdf](https://ntrs.nasa.gov/api/citations/20230001416/downloads/Webinar%2001312023-Final.pdf)
  + [Thermite-for-Demise: Preliminary on-Ground Heat Transfer Experimental Testing | AIAA SciTech Forum](https://arc.aiaa.org/doi/10.2514/6.2023-1778)
* List of potential measuring instruments for material degradation
  + Temperature and heat
    - Thermocouple
      * Voltage across the double-wire depends on temperature
        + [What is a thermocouple and how does it work?](https://www.omega.co.uk/prodinfo/thermocouples.html)
      * Uses the Seebeck Effect
        + [The Seebeck Effect: How Temperature Differences Generate Electricity | Electrical4U](https://www.electrical4u.com/seebeck-effect-and-seebeck-coefficient/)
      * Used in [Advancing spacecraft demisability through a novel composite bolt joint system: a step toward sustainable and safe space environments | CEAS Space Journal](https://link.springer.com/article/10.1007/s12567-023-00531-x)
    - Infrared camera
    - Heat Flux sensors
      * Measure heat transfer through a surface
      * [Heat flux sensors: the latest technologies](https://www.hukseflux.com/library/heat-flux-sensors-latest-technologies)
  + Strain
    - Strain gauge
      * Measures strain via extension of wires and change of resistance
      * [Strain Gauge: Working Principle & Diagram | Electrical4U](https://www.electrical4u.com/strain-gauge/)
    - Optical fibre sensors
      * Can measure strain amongst other variables
      * Fiber Bragg Grating detects shifting in Bragg wavelength/ temperature from change in shift of reflected wavelength
        + [Microsoft Word - 01\_Allil\_final.docx](https://cdn.intechopen.com/pdfs/44684/intech-a_guide_to_fiber_bragg_grating_sensors.pdf)
      * Sources:
        + [Optical Fiber Sensors: Working Principle, Applications, and Limitations - Elsherif - 2022 - Advanced Photonics Research - Wiley Online Library](https://onlinelibrary.wiley.com/doi/full/10.1002/adpr.202100371?msockid=0a55f8df2a8e6e1a0919edfb2bac6f38)
        + [Functional Optical Fiber Sensors Detecting Imperceptible Physical/Chemical Changes for Smart Batteries | Nano-Micro Letters](https://link.springer.com/article/10.1007/s40820-024-01374-9)
        + [Microsoft Word - 01\_Allil\_final.docx](https://cdn.intechopen.com/pdfs/44684/intech-a_guide_to_fiber_bragg_grating_sensors.pdf)
  + Vibrations and sound
    - Vibration sensors
      * Layers polarised in opposite directions move when vibrated, causing a current
      * Product example: [RS PRO Vibration Sensor, 100 Hz, -15°C → +55°C | RS](https://uk.rs-online.com/web/p/vibration-sensors/0285784)
      * Sources:
        + [Efficient Structural Damage Detection with Minimal Input Data: Leveraging Fewer Sensors and Addressing Model Uncertainties](https://www.mdpi.com/2227-7390/12/21/3362)
    - Acoustic emission sensors
      * Locates cracks and defects in materials by measuring acoustic waves released by high pressures or temperatures
      * Sources:
        + [What Is Acoustic Emission Testing? A Definitive Guide - TWI](https://www.twi-global.com/technical-knowledge/faqs/acoustic-emission-testing)
        + [Acoustic emission testing (AET) - A Complete Guide](https://www.aendt.com/blog/acoustic-emission-testing.html)
  + Pressure and stress
    - Pressure sensors
      * Measure fluid pressure by the deformation of a diaphragm- like membrane material’s strain
      * Sources:
        + [Advances in high-performance MEMS pressure sensors: design, fabrication, and packaging | Microsystems & Nanoengineering](https://www.nature.com/articles/s41378-023-00620-1)
        + [What Is A Pressure Sensor? Pressure Sensors Working Principle - Piping Technology System](https://pipingtechs.com/what-is-a-pressure-sensor/)
    - Piezoelectric sensors
      * Measure mechanical strain by using crystal that outputs corresponding voltage
        + [What is Piezoelectric Sensor - Construction, Working & Applications](https://www.electricaltechnology.org/2020/05/piezoelectric-sensor.html)
  + Recession sensors
    - Measure erosion of a material in extreme environments, such as that of the Thermal Protection Systems (TPS) of spacecraft re-entry
    - Capacitive recession sensors measure how capacitance changes as dielectric is worn
    - ARAD/HEAT sensors developed by NASA
      * [Microsoft Word Viewer - 60518.docx](https://ntrs.nasa.gov/api/citations/20140005545/downloads/20140005545.pdf)
      * [(1) Current developments in future planetary probe sensors for TPS | Ed Martinez - Academia.edu](https://www.academia.edu/6829841/Current_developments_in_future_planetary_probe_sensors_for_TPS)
      * [(1) MIRKA2: Small Re-Entry Demonstrator for Advanced Miniaturized Sensors | Georg Herdrich - Academia.edu](https://www.academia.edu/63307995/MIRKA2_Small_Re_Entry_Demonstrator_for_Advanced_Miniaturized_Sensors?auto=download)
    - ReWiG sensor developed by ESA
      * Measures resistance change of grid of wires as it is damaged over time
      * [ReWiG: A Resistive Wire Grid TPS recession sensor | Nebula Public Library](https://nebula.esa.int/content/rewig-resistive-wire-grid-tps-recession-sensor)
    - Sources:
      * [IEEE Aero-Conference Big Sky-10192022.pdf](https://ntrs.nasa.gov/api/citations/20220015212/downloads/IEEE%20Aero-Conference%20Big%20Sky-10192022.pdf)
      * [Webinar 01312023-Final.pdf](https://ntrs.nasa.gov/api/citations/20230001416/downloads/Webinar%2001312023-Final.pdf)
      * [Microsoft PowerPoint - 6thAblationWorkshop\_Winter\_seeding](https://ntrs.nasa.gov/api/citations/20190001960/downloads/20190001960.pdf)
      * [Remote Recession Sensing of Ablative Heat Shield Materials - NASA Technical Reports Server (NTRS)](https://ntrs.nasa.gov/citations/20140011534)
      * [251419.pdf](https://eprints.gla.ac.uk/251419/1/251419.pdf)
        + Details number of recession sensor techniques

# 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 radiowaves 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

# Sensors Comparison

A screenshot of a computer

Description automatically generated

A screenshot of a web page

Description automatically generated

# 2024-10-05 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 use 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.

### 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

# Electronics Heating Research

* Temperature control for electronics
  + θJC is thermal resistance between Junction and Case1
    - Lower thermal resistance is better to prevent overheating
  + Passive systems
    - Coatings/tapes2
      * Absorptivity and Emissivity controlled
      * Optical Solar Reflectors (OSRS)
      * MLI Blankets
      * Flexible OSR Tapes
      * Radiators can also be coated
    - PCB embedded heat pipes2
      * Rely on phase change
      * Part of the electrical design
    - Thermal straps2
      * Copper or graphene
      * Used commonly in CubeSats due to its flexibility in transferring heat
    - Radiators
  + Active systems
    - Cryocoolers2
      * Very effective, but very heavy (~4kg)
    - Thermal Storage2
      * Phase Change Materials (PCMS) store energy with minimal temperature change

### References

* 1 [Junction-to-Case Thermal Resistance in Thermal Design - Technical Articles](https://www.allaboutcircuits.com/technical-articles/junction-to-case-thermal-resistance-in-thermal-design/)
* 2 Young, J. A. C. (2023). **Next-generation CubeSats and SmallSats thermal control subsystem**. In *Thermal Systems Engineering*. Blue Canyon Technologies, Lafayette, CO, United States.

# 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

# Microcontroller and Battery Choice

* Processors and Microcontrollers
  + MSP430 Series
    - Low power, efficient microcontrollers frequently used for small satellites3
    - MSP430FR59694
  + STM32 Series5
  + RISC-V Series
    - OBC-Cube-Polar6
* Battery Choice
  + Ni-Cd Batteries
    - Nickel cathode, Cadmium Anode
    - Electrolyte: Potassium hydroxide
    - Advantages: Lightweight, cheap
    - Disadvantages: Overcharging/overheating risk
  + NiH2 Batteries
    - Advantages: Safe overcharging/discharging, higher specific energy
    - Disadvantages: High self-discharge rate, low volumetric energy density, high-pressure storage needed
  + Li-ion Batteries
    - Advantages: Dense energy, long lifetime, wide operating temperatures
    - Disadvantages: Internal resistance at low temperatures

### References

3 **Candidate Cubesat Processors** Steven M. Guertin, JPL NASA

4 [N7 Space](https://n7space.com/index.php/msp-taste-toolchain/)

5 [Microcontroller for Cubesat: STM32F407 and More 2022 Embedded Technology Information EmbedIc](https://www.embedic.com/technology/details/microcontroller-for-cubesat--stm32f407-and-more-2022)

# 2024-11-18 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

# Logbook Tidy-Up + Review

Review with Nafiz

14:00 IEB LR7

* Doesn’t need to be too structured
  + Expected times on actions
  + Can have dummy variables if not done
* Include all information – update + add, don’t replace
* Add name to file next to screenshots (YYYYMMDD)
  + Make consistent for all minutes
* Add all ideas, not clean necessarily like report
  + Used for own planning/activities
  + Don’t judge info’s value when adding
* Links fine in logbook
* List options
  + Pros + cons
  + Summary
* Paper referencing
  + Add summary (2-3 lines)
  + Information in logbook
  + Supervisor shouldn’t have to read paper directly
  + Logbook helpful for going over things to put in report
* Higher frequency sensing required
  + Will require high bandwidth comms
  + Pick sensors on bandwidth capacity – maximise data (possible compromise)
* Add ideas and day-to-day
* flir space cameras
* Heat flux sensors may be quicker than thermocouples
* Presentation
  + 5 minutes each
* Boundary conditions
  + Space rated?
  + Temp
  + Power requirements
  + Data rate
* Electronics prove it’ll work

# 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 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 – see plan by the next meeting – 29/11/24

### Deadlines

# 29-11-2024 Presentation Preparation Session

* 11:00 RSL SR1
* Session to work collaboratively on MT presentation
* Used BEAMER and saved on a second GitHub repository

# 02-12-2024 General Research and MT Presentation Slides Finalisation

* Research
  + QB50
    - international network of 50 CubeSats
    - measurements in the lower thermosphere and re-entry research
    - initiative by the Von Karman Institute, funded by the European Commission under the 7th Framework Programme (FP7)
    - Design
      * 2U CubeSat – science block, communications block
    - References
      * [An international network of 50 CubeSats for multi-point, in-situ measurements in the lower thermosphere and re-entry research | QB50 | Project | News & Multimedia | FP7 | CORDIS | European Commission](https://cordis.europa.eu/project/id/284427/reporting)
  + Blackboxes in satellites
    - * Nearspace Launch has several black box designs to be attached to the outside of satellites
        + [NearSpace Launch Black Box](https://nearspacelaunch.com/blackbox/)
        + [NSL unveils new Black Box - SpaceNews](https://spacenews.com/nsl-unveils-new-black-box/)

# 3-12-2024 MT Presentations

* Group A
  + rtd
  + consider cost for company (feasibility)
  + biggest risk?
* Group B
  + Timing – will clock change thermal/time conditions
* Us
  + Are thermocouples good sample rate?
  + Battery choice?
  + Example materials? How long to ablate?
* Overall
  + Timing
  + Too many slides (a slide 1-2mins) – reduce info put in
  + Describe plots shown – make visible font
  + Logical chain
  + Do not assume technical knowledge
  + What doing, why you should care in first 30s
  + Cost, Timeline, Risk
  + Make all graphs, plots readable
  + Less dense text

# 2024-12-13 Online 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

# 2024-12-20 Personal Goal Setting

* Comms
  + Tumble mechanism disallows simple directional communication
  + Blackbox requires larger
  + Actions:
    - Background Comms research
    - Common mechanism research
    - Suggest solutions to tumble situation
* Lack of calculation
  + Research + logbook thus far has had a lack of calculation
  + Will change once design decisions are made
  + Future necessary calculations
    - Heat Dissipation (suggested method by Tobias between components)
    - Power use
    - Sensor design (e.g. ReWiG dimensions and details)
* Report Writing
  + Can be started once meeting is organised to decide on design decisions

# 2024-12-28 Initial Comms Research

My aim here is to get a background look into comms systems in cubesats, before trying to tackle the problem in our particular context

* Introduction to CubeSat Communication System – Teikyo University
  + UHF/VHF common for simple projects, s-band or x-band for actual missions
  + Architecture of system is important
    - Component types and numbers
    - A diagram of a network

      Description automatically generatedEg:
  + Data telemetry and control are common objectives of comms systems
    - GPS/GNSS can give distance info
  + Process of design
    - Identify requirements
    - Frequency selection
    - Hardware choice based on the above
    - Data Protocol Choice
    - Link budget calculations
  + Priorities when considering comms systems:
    - Simplicity
    - Low power
    - Demonstrated to work
    - Compatibility
    - Redundancy
    - Bit rate
  + Antennae
    - A diagram of different antenna components

      Description automatically generatedSeveral types:
      * Omnidirectional antenna also exist (requires more research on my part)
    - Deployment may be required for antennae
      * Space efficient and increase modularity
      * Increases complexity, however, as well as introducing risk
  + Rx/Tx Hardware considerations (ground station)
    - Tx: Transmit power, bitrate, efficiency
    - Rx: Sensitivity, RSSI (received signal strength intensity)
  + Signal Processing
    - Various modulation methods
      * GMSK is commonly used, gets a lot of data transmitted
    - Packets designed to be space efficient, can use error checking etc
* PLASMA SHEATH CHARACTERIZATION FOR TELEMETRY IN HYPERSONIC FLIGHT- University of Arizona
  + Hypersonic flight can cause plasma sheath formation, leading to telemetry blackout
  + This layer absorbs and reflects radio signals, preventing communications
* CubeSat Communication Subsystems: A Review of On-Board Transceiver Architectures, Protocols, and Performance
  + Lists architecture and background, needs closer looking at

# 2025-1-3 Comms Research – Plasma Sheath

More needs to be researched about the plasma sheath and how to allow telemetry to circumvent it

* High Altitude Re-entry Plasma Emulation Experiment (HARPEE), NASA Glenn Research Center
  + Uniform Plasma Sheath may lead to easier comms
* The propagation characteristics of low frequency radio waves in magnetized hypersonic plasma sheaths
  + Low frequency radio waves could get through the plasma unperturbed
  + Antenna Positioning
    - Gaussian distribution of electron density along the surface of the re-entering spacecraft
    - Transmission coefficient increased further from the head as a result
    - Collision frequency of plasma (rate of electrons hitting other particles) was largely irrelevant
  + A graph of a graph of a plane

    Description automatically generated with medium confidenceFlight speed impact
    - A,b,c show 100kHz signal , with speed as independent variable
      * Higher speed => lower absorption/transmission, but higher reflection
      * Tail of vehicle has higher transmission generally
      * 5650 m/s is aapproximately boundary between hypersonic near-space and re-entry
    - D,e,f show 5650m/s, with wave frequency as independent variable
      * Higher frequency => higher A, lower R/T
  + Using magnetic fields to reduce electron density
    - Magnetic window method – increases transmission coefficient dramatically
    - This is true for all frequencies, helps especially with high frequencies
    - Polarisation becomes important at high frequency radio
* QARMAN
  + [QARMAN (QubeSat for Aerothermodynamic Research and Measurements on Ablation) - eoPortal](https://www.eoportal.org/satellite-missions/qarman#qarman-qubesat-for-aerothermodynamic-research-and-measurements-on-ablation)
  + [Qarman beacon telemetry information released | AMSAT-UK](https://amsat-uk.org/2020/01/09/qarman-beacon-telemetry-information-released/)
* Potential ideas to look into:
  + Omnidirectional antennae
  + Multiple antennae
  + Do as QARMAN did, transmit to iridium
  + Rotating Antenna
  + HIGH power transmitters, low frequency, magnetic window, just try to force signal through the plasma sheath
  + Remove tumbling
* Other sources to look into:
  + [Prediction Performance of Blackout and Plasma Attenuation in Atmospheric Reentry Demonstrator Mission | Journal of Spacecraft and Rockets](https://arc.aiaa.org/doi/full/10.2514/1.A32880)
  + [Examination of Radio Frequency Blackout for an Inflatable Vehicle During Atmospheric Reentry | Journal of Spacecraft and Rockets](https://arc.aiaa.org/doi/full/10.2514/1.A32539)

# 2025-1-18 Comms Research – Solution Listing

Comms has many problems – I will list options here and next week begin to compare them once these have been communicated to the rest of the team, maybe they have some ideas

* Omnidirectional Antennae
  + Will allow transmission to overcome the tumbling issue previously described
  + Examples to look into:
    - [AS-48915 Series Omnidirectional Conical Spiral Antenna | L3Harris® Fast. Forward.](https://www.l3harris.com/all-capabilities/48915-series-omnidirectional-conical-spiral-antenna)
    - [SUTRON Antenna, Full Wave OMNI-Directional Satellite | OTT HydroMet](https://www.otthydromet.com/en/p-sutron-antenna-full-wave-omni-directional-satellite/5000-0021-1)
  + Performance Characteristics of Omnidirectional Antennas for Spacecraft Using NASA Networks
    - Describes positioning of antennae and discusses their use
    - Quite old (1987), but science still seems relevant
* Antenna types
  + [Satellite Antenna Types: Advantages, Disadvantages, Applications](https://www.rfwireless-world.com/Terminology/satellite-antennas.html#:~:text=Some%20satellites%20use%20multiple%20antennas%20for%20different%20purposes,UHF%20band%2C%20Helix%20station%20for%20ground%20station%20applications.)
* Materials may block antennae, blocking transmission
  + I need to investigate types of materials and how to combat this
  + Possible solutions:
    - Ensure all test materials allow signal transmission
      * Might limit options for potential customers
      * Further information on material effect on transmission may mean this is not an issue, however
    - Transmit after material is gone (with ablative to allow time for data to be sent)
    - Reconsider Blackbox now that 8U is considered
    - Could use comms and Blackbox for redundancy? Depends on budgeting

# 2025-1-21 Logbook Review + Supervisor Meeting

* 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 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