THE UNIVERSITY OF SYDNEY

The University of Sydney

Faculty of Engineering

STEM Winter Workshop 2019

Heavens above!

Developing eyes in the skies

July 14, 2019

Project Outline

During the STEM Winter Workshop, you will have time each day to work on a multidisciplinary project in a team. At the end of the week, your team will pitch your project's end result to Houseparents and Faculty Staff in a "Sharktank" style presentation. Prizes awarded for the most innovative designs, the most convincing business case, and overall teamwork.

1 Your task

You have been tasked to plan, create and pitch Australia's first earth observation CubeSat, ready for launch on the first Australian Space Agency rocket in 2025.

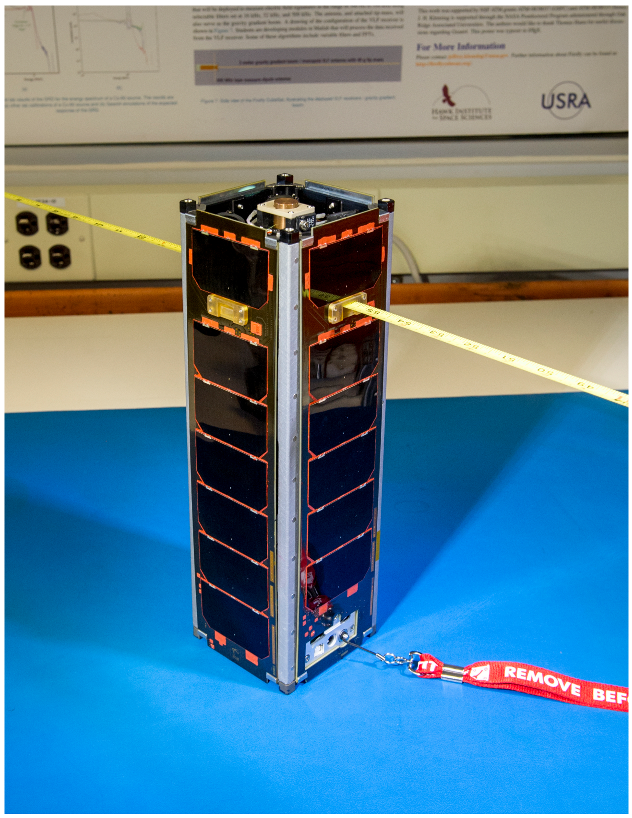

Figure 1: Firefly CubeSat, a small satellite that has as much volume as 3 cans of soft drink (Source: NASA)

2 Project Brief

You are part of a team in the brand new "Spacecraft Development and Operations" division at the Australian Space Agency (ASA). The CSIRO, Geoscience Australia and the Australian Antarctic Division have all asked the ASA to develop a satellite specific to their needs in the leadup to the first launch from Australian soil on the ASA's Silvereye II rocket. The ASA only has the funds however to take on ONE of the following briefs:

1. CSIRO: Monitoring of marine temperatures to determine health of the Great Barrier Reef
2. Geoscience Australia: Imaging of natural disaster prone areas for early warning systems
3. Australian Antarctic Division: Magnetic field changes of the Earth and its effects on ice formation in the Antarctic region

The total group has been split into 3 teams to look at each of these briefs to work out which project is the most pressing and to determine what will go into the CubeSat.

You will be allocated one of the above projects and will need to design/determine the following:

- Size of the CubeSat (in measures of "Units", 1U = 10cm × 10cm × 10cm). The smallest size is 0.5U and the largest the Silvereye II can launch is 3U
- Materials and Weight of the CubeSat structure (e.g. metals, carbon fibre)
- Number of solar panels and batteries to support the systems onboard
- Sensors/imaging equipment to get the data needed by the client
- Communications antennas
- On-board data storage and computers
- Stabilisation systems (if required)

The ASA has a number of components available to them that have all been tested and certified to survive in space, listed in Appendix C.

The total budget for the CubeSat is AU$100,000.

You will need to present two things at the end of the week to the ASA Procurement Division:

1. A scale model of your CubeSat (constructed using skewers, Blu Tack, paper and other provided materials, showing shape size and location of key systems)
2. A poster to convince the Procurement Division to fund your satellite over the other projects

2.1 Your Team

Successful projects rely on great teamwork and cooperation. You will need to determine who is responsible for what during the week before you start your project (i.e. allocate a specific role to each team member). Your team members include:

1. Project Manager(s)
2. Spacecraft Systems Engineer(s)
3. Scientific Liaison Officer(s)

In your team, read the brief carefully, and determine who will be responsible for which role during the week, keeping in mind that you need to collaborate and work as a team to get the best possible product at the end of the week.

2.2 Requirements

1. Each member will need to take responsibility for a specific role for the week's project
2. Team members must together to bring all elements of the project together
3. A group presentation will take place at the end of the week, where each member will need to explain their contribution and role in the project
4. Effective time management to meet the deadline

2.3 Product-specific Requirements

1. End product must meet the needs of the client
2. System choices and designs must be innovative
3. Satellite must be aesthically pleasing
4. Must be cost effective and within budget
5. Your team will need a good case for why your project should go ahead, and motivation for system choices
6. Excellent team work required, with a great pitch at the end of the week
7. Other factors should be considered such as environmental impacts and the design and manufacturing process of your satellite.

3 Monday

Start thinking about the project:

1. Familiarise yourself with the project: As a team, read the brief and understand the client's needs. Start planning ideas, based on the client's needs.
2. Role allocation: Think who in the team might have the interests or skillset to deliver on certain areas. Consider who might be able to lead the project. Give your team (or company) a name.
3. Budget: Start thinking of what materials you might need, and work out what will be most cost effective, and whether you'll be in budget. Remember, the client will take into account which design is most cost-effective to determine the winner. Also factor in what costs your team might incur (e.g. hourly wage).
4. Design ideas: As a team, start thinking of your design. You can only start building your prototype CubeSat on Wednesday.
5. Project Case: Think how and why your project might be better than other projects, and why the client should choose your project at the end of the week. Set a timeline, keeping in mind you are presenting on Friday to the Procurement Division!

4 Tuesday

Today you need to do the following:

1. Plan the design. Think of:
   - Sensor Needs
   - Client Requirements
   - Costs Involved
   - System Efficiency
2. Produce a budget to present to the client.
3. "Run the numbers": which components are the most efficient and are the best value for money? Negotation may be needed and you may need to compromise between power, weight and data requirements.
4. Outline the case you will present to the client. Think of:
   - Possible solutions to the problem
   - Describe the shape and size for your design
   - List the factors that may impact the budget such as manufacturing costs, time to produce, testing etc and how you plan to save on these costs
   - Think of potential risks/problems you might encounter while developing the product, and possible solutions
5. A representative from the CSIRO, Geoscience Australia and the Australian Antarctic Division (the houseparents) will be present to help with clarifying any project needs.

5 Wednesday

In testing the Silvereye II, the ASA experienced a catastrophic misfire! It turns out that the Silvereye II cannot handle the added weight of a 3U CubeSat and is now only certified to carry a 2U CubeSat or below.

The misfired Silvereye II crashed into one of the main manufacturers of silicon wafers in Australia, so all solar cells are now 3x the price!

Your job for today:

1. Manage the crisis! Revise your budget and design to mitigate the effects on your project outcomes.
2. You can now start building your scale model CubeSat. Remember to show the location of all systems on board, particularly the sensors.
3. Think of the sort of tests you might need to put a CubeSat through to send it into space (what sort of temperatures could it be exposed to, what sort of forces/vibrations, will it experience drag in a LOW Earth Orbit (LEO)
4. List your products strengths and weaknesses
5. How will you convince the ASA to choose your project?

6 Thursday

Today you need to do final testing and tweaking. Keep in mind you are pitching your project to the client tomorrow. Ensure you have a great pitch to win over the client. As a team, explain your product, what the steps were that you followed, and why they should pick your product. Ensure each team member explains their role, and how they fit into the project. Practice your pitch! You have 5 minutes tomorrow as a group to present to your client,

and convince them why your product is the best product on offer. Your team might like to keep the following in mind when putting together your pitch:

1. Outline your brief and what the client needed
2. Outline why your clients problem is of extreme importance to Australia and needs to be funded
3. What is your proposed CubeSat?
4. What engineering/science has gone into your design?
5. What testing methods were used?
6. What are the products strengths and weaknesses? (design-wise, budget-wise etc)
7. How is the clients needs met?
8. What is the carbon-footprinst of the CubeSat?
9. Were you within budget? What costs did you have in addition to materials?
10. What obstacles did you face?
11. Anything else to convince the ASA to choose you

You will be judged on the following criteria:

- Teamwork
  - Did each team member have a role and took ownership of this?
  - Good teamwork (keep in mind each team member will need to explain their contribution)
  - Was the deadline met?
  - The team was able to identify possible risks & how to manage them
- Client Needs
  - The product is innovative & aesthetically pleasing
  - The product is cost effective and within budget
  - Care was taken to ensure the patient's comfort
  - The team presented a good business case, with good motivation behind design
  - Good testing methods used to test the product
  - The design chosen is well justified
- Presentation
  - Each member presented

  - Well thought through pitch & good presentation skills

- General
  - The team thought of external factors, such as whether the product is environmentally friendly
  - Good testing methods used
  - The team sought the client's advice throughout the week / asked relevant questions

Appendix A: Equations

- Power Supply

$$P = Vi$$

  Where V = voltage and i = current.

- Total Data Transferred

$$D = rt$$

  Where D = data, r = transfer rate and t = time.

- Power stored

$$\text{SP} = CVi$$

  Where SP = stored power and C = capacity. Watch the units!

- Mass from density

$$m = \rho Al$$

  Where m = mass, ρ = density, A = cross-sectional area of structural member and l = length of structural member.

Appendix B: Reference Images

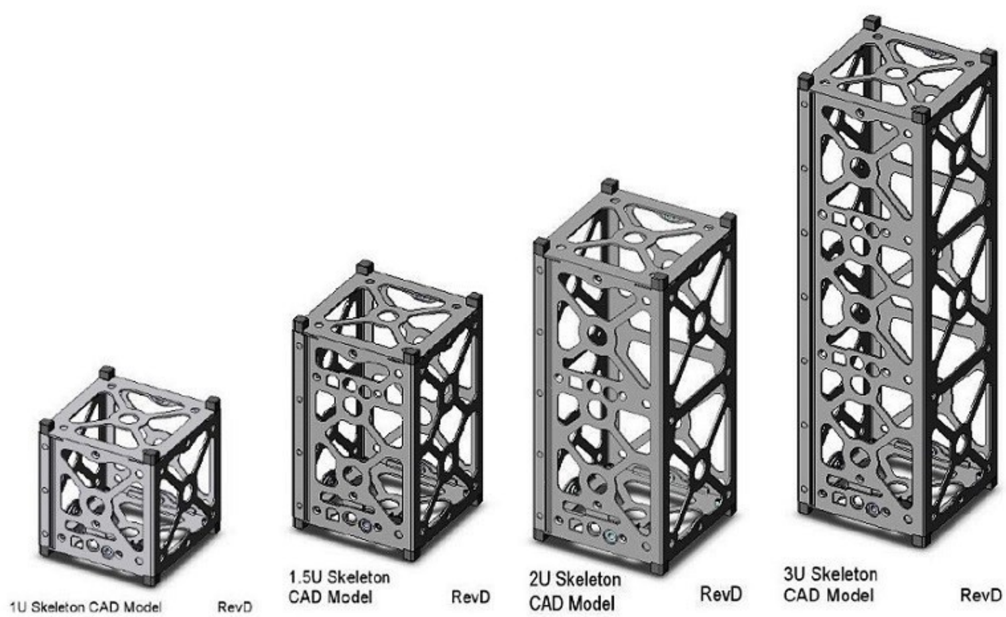

Figure 2: The Structure of a CubeSat - simplify to suit your needs!

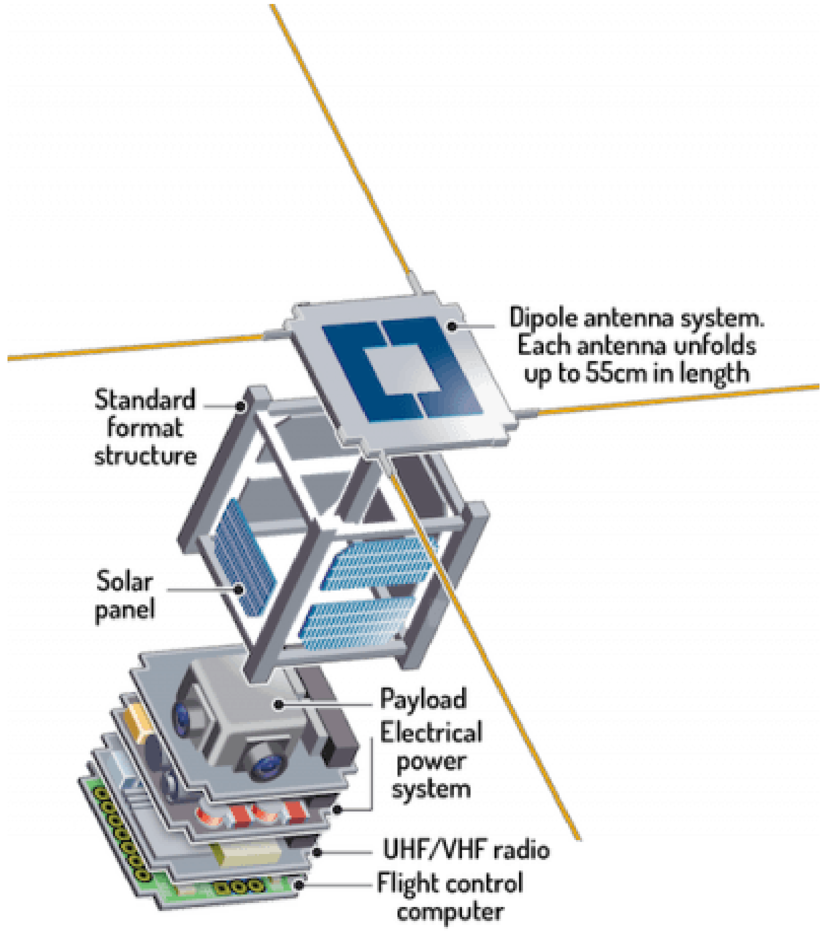

Figure 3: An example CubeSat setup

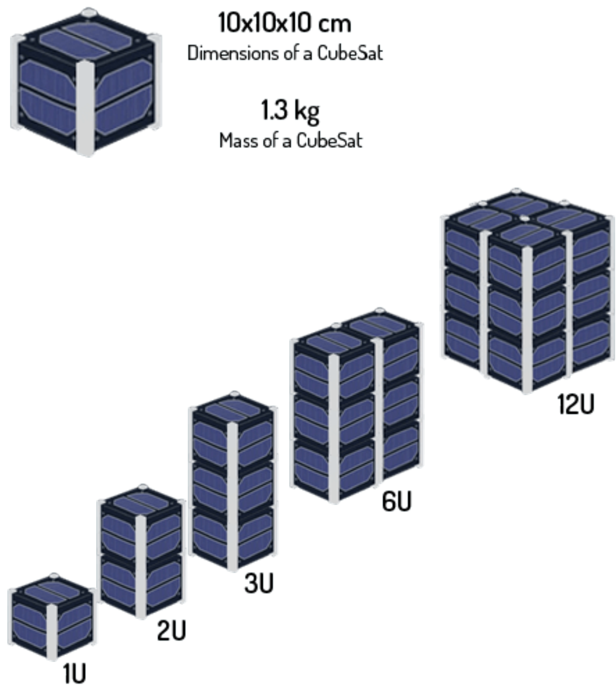

Figure 4: Sizes of CubeSats

Appendix C: Parts List

Launch costs are $20000 per 500g.

Table 1: Structural Material Choices

Materials for Structure	Cost	Unit	Density	Min. Cross Sectional Area
6061 Aluminium	$500	per cm^3	$2.7g/cm^3$	1 cm^2
IMI829 Titanium	$1,000	per cm^3	$4.5g/cm^3$	0.5 cm^2
Carbon Fibre	$1,800	per cm^3	$2g/cm^3$	0.4 cm^2
17-4PH Steel Alloy	$200	per cm^3	$7.8g/cm^3$	1 cm^2

Table 2: Energy Supplies

Energy Supplies - Solar Cells	Cost	Size	Max Power Out	Mass
AusSat PV-3A	$800	5cm x 5cm panels	10 W	20g
AusSat PV-64D	$1,800	10cm x 10cm panels	50 W	50g
SunSeeker 2	$400	2.5cm x 5 cm panels	6 W	15g
SunSeeker 7	$900	7.5cm x 5cm panels	15 W	40g

Table 3: Energy Storage

Energy Supplies - Batteries	Cost	Capacity	Max Current Out	Mass
AusSat B-600	$600	5000mAh	1 Amp	500g
AusSat G-50	$900	7500mAh	0.75 Amp	300g

Assume 12V output to satellite systems.

Table 4: Sensors

Sensors	Cost	Type	Power Needed	Mass	Data Capture Rate
XWu Industries Infrared Imager	$9,000	Thermal	50 W	200g	50 MB/s
XWu Industries Magnetometer*	$11,000	Magnetic	40 W	100g	20 MB/s
XWu Industries Hi-Def Camera	$13,000	Visual	60 W	220g	60 MB/s

*Unable to use magnetorquer stabilisation.

Table 5: Communications

Communications	Cost	Data Transfer Rate	Power Needed	Mass	Downlink Time Per Orbit
NBN "S" Range Antenna	$5,000	800 MB/s	80 W	20g	100s
NBN "X" Range Antenna	$6,000	700 MB/s	60 W	75g	150s
NBN "K" Range Antenna	$8,000	650 MB/s	30 W	100g	175s

Table 6: Stabilisers

Stabilisation	Cost	Mass	Power
Magnetorquers	$2,000	60g	40 W
Reaction Wheels	$1,000	200g	60 W
Gravity Gradient*	$0	0g	0 W

*Only to be used if you can work it out. Hint: Which end of the CubeSat has the greatest gravity force?

Table 7: Data Storage

Storage	Cost	Mass	Power
50 GB Computer/Storage	$8,000	500g	20 W
80 GB Computer/Storage	$14,000	800g	20 W

Table 8: Orbital Data

		Inclination
Time over Australia	900s	20 Deg
Time over Great Barrier Reef	300s	10 Deg
Time over Antarctica	1500s	80 Deg