# ProtoSat program – A prototype weather cube satellite

## STEM Stage 4

### Summary

This unit provides students with an opportunity to explore the emerging technology of low-cost cube satellites through Arduino (or similar) microcontrollers, sensors, and coding. Students will follow an engineering design process to design, make and evaluate a 1U weather CubeSat for ground testing using industry-inspired processes.

Many of the learning experiences in this unit have been inspired by authentic spaceflight and CubeSat developmental processes outlined by NASA and implemented in Australia by start-up organisations and universities.

The intent of this unit is to address the ‘Inspire’ challenge from the Australian Space Agency’s Advancing Space Australian Civil Space Strategy 2019 – 2028:

* to support Australia’s future space industry, it will be important that the workforce is equipped with the necessary skills and children are engaged in STEM education.

This unit also contributes to achieving the goals and actions of the Education Council’s National STEM School Education Strategy 2016 – 2026.

We acknowledge the support of Thunderstruck Space and the University of New South Wales Canberra Space for their contributions to the development of the ProtoSat unit of work.

### Duration

10 weeks @ 2.5 hours/week

This resource could be used in various contexts, and the outcomes identified below reflect points of connection to the activities.

Teachers are encouraged to select the outcomes that are most appropriate to their context.

## Technology outcomes

**TE4-1DP** designs, communicates and evaluates innovative ideas and creative solutions to authentic problems or opportunities

**TE4-2DP** plans and manages the production of designed solutions

**TE4-3DP** selects and safely applies a broad range of tools, materials and processes in the production of quality projects

**TE4-4DP** designs algorithms for digital solutions and implements them in a general-purpose programming language

**TE4-9MA** investigates how the characteristics and properties of tools, materials and processes affect their use in designed solutions

**TE4-10TS** explains how people in technology related professions contribute to society now and into the future

[Technology Mandatory Years 7-8 Syllabus (2017)](https://educationstandards.nsw.edu.au/wps/portal/nesa/k-10/learning-areas/technologies/technology-mandatory-7-8-new-syllabus) © NSW Education Standards Authority (NESA) for and on behalf of the Crown in right of the State of New South Wales, 2017.

## Science outcomes

**SC4-2VA** Shows a willingness to engage in finding solutions to science-related personal, social and global issues, including shaping sustainable futures

**SC4-7WS** processes and analyses data from a first-hand investigation and secondary sources to identify trends, patterns and relationships, and draw conclusions

**SC4-8WS** Selects and uses appropriate strategies, understanding and skills to produce creative and plausible solutions to identified problems

**SC4-9WS** presents science ideas, findings and information to a given audience using appropriate scientific language, text types and representations

Other relevant outcomes could include: SC4-1VA, SC4-3VA, SC4-4WS, SC4-5WS, SC4-6WS

[Science Years 7-10 Syllabus (2018)](https://educationstandards.nsw.edu.au/wps/portal/nesa/k-10/learning-areas/science/science-7-10-2018) © NSW Education Standards Authority (NESA) for and on behalf of the Crown in right of the State of New South Wales, 2018.

## Mathematics outcomes

**MA4-1WM** communicates and connects mathematical ideas using appropriate terminology, diagrams and symbols

**MA4-2WM** applies appropriate mathematical techniques to solve problems

**MA4-3WM** recognises and explains mathematical relationships using reasoning

**MA4-4NA** compares, orders and calculates with integers, applying a range of strategies to aid computation

**MA4-5NA** operates with fractions, decimals and percentages

**MA4-19SP** collects, represents and interprets single sets of data, using appropriate statistical displays

[Mathematics K-10 Syllabus (2012)](https://educationstandards.nsw.edu.au/wps/portal/nesa/k-10/learning-areas/mathematics/mathematics-k-10) © NSW Education Standards Authority (NESA) for and on behalf of the Crown in right of the State of New South Wales, 2012.

## Learning across the curriculum

General capabilities encompass the knowledge, skills, attitudes and behaviours to assist students to live and work successfully in the 21st century. While there may be others, aspects of these general capabilities have been identified in the following activities.

* **Critical and Creative thinking** – The skills and processes of Design and Production provide critical and creative thinking opportunities as students pose questions, make predictions, engage in first-hand investigations, design projects, solve problems and make evidence-based decisions.
* **Information and communication technology** – Students learn to access information, collect, analyse and represent data, model and interpret concepts and relationships, and communicate scientific and technological ideas, processes and information. ICT, through simulations, provides opportunities to view phenomena, test predictions and visualise designs that cannot be investigated or produced through practical experiences in the classroom,
* **Numeracy** – real-world numeracy connections are formed when numerical data is collected and manipulated and numeracy concepts, such as size, proportion and measurement, are used by students as tools in the design and production process.

These General Capability descriptions are adapted from the Science, Technology Mandatory and Mathematics syllabuses © NSW Education Standards Authority (NESA) for and on behalf of the Crown in right of the State of New South Wales, 2018, 2017 and 2012.

## Unit overview

Students develop knowledge and an understanding of the role of CubeSats in space science and the benefits of space science research for society. Students working in groups follow an engineering design process to design, make and evaluate a 1U weather CubeSat for ground testing using industry-inspired processes.

Students build on their knowledge and skills of coding using a general-purpose programming language to construct and code a FlatSat (CubeSat component ground testing device) designed to measure temperature, humidity and air pressure. Students use the data collected to compare with other published sources of weather data, and deduce possible causes for any differences.

Students use computer aided design (CAD) software to design a case for their prototype CubeSat which houses the microcontroller and power supply and complies with the requirements definition. Students use cardboard prototyping and available fabrication techniques, which may include advanced manufacturing processes such as laser cutting or 3D printing (in addition to manual fabrication techniques) to develop prototypes based on their CAD designs and the requirements definition.

Students research, plan and conduct an investigation to test the durability of at least one aspect of their CubeSat design and evaluate the results to make any necessary modifications. Students deploy the final design of their ProtoSat to collect weather data for a location within the school for a period of two weeks.

Students retrieve their ProtoSat to download the collected data and develop their skills in working with data by analysing aggregated datasets and creating visualisations.

## Inquiry question

How do we ensure our satellites work before deploying them on missions into orbit or beyond?

## Resources

* International Space Station (ISS) – [nasa.gov/mission\_pages/station/main/index.html](https://www.nasa.gov/mission_pages/station/main/index.html)
* Earth from orbit 2019: how NASA satellites #PictureEarth – [youtube.com/watch?v=cu4ZvCguhaw](https://www.youtube.com/watch?v=cu4ZvCguhaw)
* Sounding rockets explained – [youtube.com/watch?v=t8G3YPEczqg](https://www.youtube.com/watch?v=t8G3YPEczqg)
* High altitude balloon experiment platform – [rsaa.anu.edu.au/study/potential-projects/high-altitude-balloon-experiment-platform](https://rsaa.anu.edu.au/study/potential-projects/high-altitude-balloon-experiment-platform)
* CubeSats: a satellite small enough to fit in your hand – [youtube.com/watch?v=Z9iAMhaSiE4](https://www.youtube.com/watch?v=Z9iAMhaSiE4)
* Case for space, the need for an Australian space program – [youtube.com/watch?v=tNHpcZ6Ge\_4](https://www.youtube.com/watch?v=tNHpcZ6Ge_4)
* Space UNSW: what is a CubeSat? – [youtube.com/watch?v=Kv1iWteL2ok](https://www.youtube.com/watch?v=Kv1iWteL2ok)
* CubeSats: mini cube satellites – [youtube.com/watch?v=-BGXRGoEnAc](https://www.youtube.com/watch?v=-BGXRGoEnAc)
* This Small Satellite Could Predict the Next Hurricane – [youtube.com/watch?v=nG9lYpWy6KM](https://www.youtube.com/watch?v=nG9lYpWy6KM)
* (Optional) NASA CubeSat to test miniaturised weather satellite technology – [nasa.gov/feature/goddard/2017/cubesat-to-test-miniaturized-weather-satellite](https://www.nasa.gov/feature/goddard/2017/cubesat-to-test-miniaturized-weather-satellite)
* CubeSats in hydrology: ultrahigh‐resolution insights into vegetation dynamics and terrestrial evaporation – [agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2017WR022240](https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2017WR022240)
* Australia's space race has benefits for farmers on planet Earth – [abc.net.au/news/rural/2019-10-30/farmers-look-to-the-stars-for-crop-monitoring/11648496](https://www.abc.net.au/news/rural/2019-10-30/farmers-look-to-the-stars-for-crop-monitoring/11648496)
* CubeSat satellite data make daily crop monitoring possible – [feedstuffs.com/news/cubesat-satellite-data-make-daily-crop-monitoring-possible](https://www.feedstuffs.com/news/cubesat-satellite-data-make-daily-crop-monitoring-possible)
* Case studies of satellite imagery applications – [euspaceimaging.com/category/case-study/](https://www.euspaceimaging.com/category/case-study/)
* Hazards of space: how satellite missions can go wrong – [captechu.edu/blog/hazards-of-space-how-satellite-missions-can-go-wrong](https://www.captechu.edu/blog/hazards-of-space-how-satellite-missions-can-go-wrong)
* Mission patch – [spacecenter.org/docs/Activities-MissionPatch.pdf](http://www.spacecenter.org/docs/Activities-MissionPatch.pdf)
* Australian Bureau of Meteorology – [bom.gov.au/](http://www.bom.gov.au/)
* NASA CubeSat 101 – <https://www.nasa.gov/sites/default/files/atoms/files/nasa_csli_cubesat_101_508.pdf>
* Official CubeSat specification – <https://www.cubesat.org/s/CDS-REV14-2020-07-31-DRAFT.pdf>
* 3D printing a model of a CubeSat – <https://asc-csa.gc.ca/eng/search/images/watch.asp?id=10185&search=cubesat>
* A sample 3D printable CubeSat frame design – <https://www.thingiverse.com/thing:27300>
* General Environmental Verification Standard – [standards.nasa.gov/standard/gsfc/gsfc-std-7000](https://standards.nasa.gov/standard/gsfc/gsfc-std-7000)
* Example of thermal vacuum testing – [lasp.colorado.edu/home/csswe/system/testing/thermal-vacuum/](https://lasp.colorado.edu/home/csswe/system/testing/thermal-vacuum/)
* Testing CubeSats with the Wombat XL – [spaceaustralia.com/news/unsw-canberra-space-gearing-launch-next-cubesat](https://spaceaustralia.com/news/unsw-canberra-space-gearing-launch-next-cubesat)
* National Space Testing Facility – [inspace.anu.edu.au/nstf](https://inspace.anu.edu.au/nstf)
* CubeSat EPS and Battery NASA GEVS Vibration test – [youtube.com/watch?v=y90V0o2\_HHY](https://www.youtube.com/watch?v=y90V0o2_HHY)
* Questacon shake table lesson plan: <https://www.questacon.edu.au/sites/default/files/resources/teacher-resources/file/Shake%20Table%20Lesson%20Plan.pdf>
* Pyroshock test of CubeSat systems <https://youtu.be/SfGjNQZ78Eo>
* Thermal Vacuum Test of CubeSat Subsytems <https://youtu.be/aWNgM58kUas>
* Risks in space from orbiting debris – [orbitaldebris.jsc.nasa.gov/library/sciencemag-risks-in-space-from-orbiting.pdf](https://orbitaldebris.jsc.nasa.gov/library/sciencemag-risks-in-space-from-orbiting.pdf)
* Lifespan of satellites – [euspaceimaging.com/the-lifespan-of-orbiting-satellites/](https://www.euspaceimaging.com/the-lifespan-of-orbiting-satellites/)
* Where do old satellites go when they die? – [spaceplace.nasa.gov/spacecraft-graveyard/en/](https://spaceplace.nasa.gov/spacecraft-graveyard/en/)
* Costs, risks, and benefits: science and the citizen – [astronomy.swin.edu.au/sao/downloads/HET610-M19A01.pdf](http://astronomy.swin.edu.au/sao/downloads/HET610-M19A01.pdf)
* International Space Station Benefits for Humanity – [nasa.gov/connect/ebooks/iss\_benefits\_for\_humanity.html](https://www.nasa.gov/connect/ebooks/iss_benefits_for_humanity.html)
* Societal impact – [nasa.gov/connect/ebooks/historical\_studies\_societal\_impact\_spaceflight\_detail.html](https://www.nasa.gov/connect/ebooks/historical_studies_societal_impact_spaceflight_detail.html)

Table 1 – ProtoSat 10 week program

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| --- | --- | --- | --- |
| Content | Teaching and learning | Evidence of learning | Adjustments and registration |
| **Week 1**  (T) Evaluate how existing information systems meet needs, are innovative, and take account of future risks and sustainability  (T) Identify social, ethical and cyber security considerations of digital solutions | **Teacher**  Identify the current options available for conducting experiments in space, including:   * [International Space Station](https://www.nasa.gov/mission_pages/station/main/index.html) (ISS) * [satellites](https://www.youtube.com/watch?v=cu4ZvCguhaw) * [sounding rockets](https://www.youtube.com/watch?v=t8G3YPEczqg) * [high-altitude balloons](https://rsaa.anu.edu.au/study/potential-projects/high-altitude-balloon-experiment-platform) (HAB)   Introduce [CubeSats](https://www.youtube.com/watch?v=Z9iAMhaSiE4) and their role in space research and in [developing a space industry in Australia](https://www.youtube.com/watch?v=tNHpcZ6Ge_4).  Outline some [benefits](https://www.youtube.com/watch?v=Kv1iWteL2ok) of using CubeSats over larger traditional satellites.  Describe some examples of current research involving the use of CubeSats, including:   * [space weather](https://www.youtube.com/watch?v=-BGXRGoEnAc) * [terrestrial weather](https://www.youtube.com/watch?v=nG9lYpWy6KM) * [fresh water reservoirs](https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2017WR022240) * [agriculture](https://www.abc.net.au/news/rural/2019-10-30/farmers-look-to-the-stars-for-crop-monitoring/11648496) – [crops](https://www.feedstuffs.com/news/cubesat-satellite-data-make-daily-crop-monitoring-possible) * polar ice caps.   Introduce context-relevant terminology.  **Students (optional)**  Explore the impact of satellites on communication systems, weather forecasting, and [monitoring terrestrial events](https://www.euspaceimaging.com/category/case-study) to improve decision-making. | * Students can describe the role of CubeSats within the broader space research domain. * Students can explain the importance of accurate weather forecasting for society. * Students can explain the impact of satellites on weather forecasting. * Students can provide reasons for collecting weather data and predicting forecasts. * Using case studies on the applications of satellites, students demonstrate understanding and insight into how the use cases build awareness of potentially critical events and improve decision making in responding to current issues and finding solutions to problems. |  |
|  | **Teacher**  Explain the [risks of launching satellites into space](https://www.captechu.edu/blog/hazards-of-space-how-satellite-missions-can-go-wrong), both during and after launch. | Students can describe a range of risks involved in launching satellites and demonstrate further understanding by analysing and assessing these activities’ costs against the proposed benefits. |  |
|  | * Outline the intended outcomes of the project and explain what the students will be trying to create. * Outline essential stages of project management required to plan any space launch, including:   + requirements/deliverables definition/contract (What)   + conceptual planning (How)   + Preliminary Design Review (customer)   + design/prototyping/component selection   + Critical Design Review (customer)   + purchase items/manufacture components/acceptance   + Component and Subsystem Level tests   + Integrated System tests   + Environmental Qualification Campaign (thermal cycling (ambient), thermal vacuum, shock, vibration) “Shake n Bake”   + Flight Acceptance Review (customer)   + **Launch!**   + operations * Outline the range of STEM careers in both the roles/jobs associated with the list above and the space industry in general. * Introduce more terminology relevant to project planning in aerospace, for example:   + launch commit criteria   + mass budget   **Students**   * Begin organising the team, assigning roles where individual students have the opportunity to lead an aspect of the project, for example:   + software engineering lead   + CAD design lead   + experimental design lead. * Setup folio and record relevant information. * Setup shared folders for collaboration. * Examine the weather requirements as part of Launch Vehicle (LV) launch commit criteria.   **Extension (optional):**  Student groups [design a unique mission patch](http://www.spacecenter.org/docs/Activities-MissionPatch.pdf) for their group. | * Students can recall the order of stages required for planning a successful space launch and can demonstrate an understanding of the logical reasons for the sequence. * Students actively participate in class conversations about STEM careers in space. * Students actively participate in the organisation of their assigned team and the equitable distribution of roles/tasks. |  |
|  | **Teacher**  Define requirements/deliverables of the ProtoSat project, for example:   * operating temperatures * ability to withstand environmental conditions * payload is no more than 100g |  |  |
| TE4-7DI  (T) Identify social, ethical and cyber security considerations of digital solutions  (T) Collect and access data from a range of sources, for example:   * using sensors to collect temperature data * downloading public datasets from the internet   (T) Evaluate the authenticity, accuracy and timeliness of data  (T) Interpret and visualise data using a range of software to create information | List sources of weather data and classify them as either predicted or actual.  Define weather elements that will be captured in terms of data items.  Demonstrate how to use a spreadsheet program.  **Students**  Examine different sources of weather data, including:   * [Bureau of Meteorology](http://www.bom.gov.au/) (BOM) * thermometers * weather apps * apps on phones * digital sensors attached to microcontrollers or mini-computers   Establish a spreadsheet for collation and manipulation of defined data.  Take weather measurements, record and compare with BOM published data. | Students produce a spreadsheet for the collation and manipulation of data.  Students can assess the validity of data and subsequently recognise trends. |  |
| TE4-3DP, TE4-4DP, TE4-7DI  (T) Implement and modify programs involving branching, iteration and functions in a general-purpose programming language, for example:   * microcontroller | **Teacher**  Introduce microcontroller and other hardware to be used and explain safety issues. | Students can identify key hardware elements.  Students can articulate safety requirements of each piece of technology to be used. |  |
|  | Explain programming concepts, including:   * control structures:   + sequence   + selection (branching)   + repetition (iteration) * relevant data types:   + text   + numbers   + boolean * functions (as necessary) | Students can identify key features of a program written in the selected general-purpose coding language. |  |
|  | Demonstrate how the coding environment operates and how to upload code to the microcontroller.  **Students**  Learn to use selected coding environment to program microcontroller to perform some tasks which may include:   * blinking LEDs * reading values. | Students can enter instructions or code into the coding environment and successfully upload it onto the microcontroller.  Students can demonstrate success with properly functioning code as intended by the set task.  If the code is not functioning properly, they are working on debugging syntax errors.  If the code is functioning, but not as intended by the task, they correct the code’s logic errors. |  |
| **Week 2**  TE4-2DP, TE4-3DP, TE4-4DP, TE4-7DI  (T) Implement and modify programs involving branching, iteration and functions in a general-purpose programming language, for example:   * microcontroller | **Teacher**   * Demonstrate a pre-assembled temperature sensor [FlatSat](https://www.nasa.gov/sites/default/files/atoms/files/nasa_csli_cubesat_101_508.pdf) (page 23) and explain its functions. * Show how to access and view the captured data.   **Students**   * Build the temperature sensor FlatSat according to instructions or specifications and test its operation. Modify as necessary to achieve a functioning unit. * Copy and upload provided sample temperature code onto microcontroller or create and upload original code using a general-purpose coding language. Test and modify as necessary. * Collect data from the Bureau of Meteorology (BOM website or app) and compare it to data from FlatSat, suggest reasons for any discrepancies. * Evaluate functions. | Students produce a functioning temperature sensing FlatSat comprising:   * microcontroller (for example, Arduino Uno or micro:bit) * data logging shield and RTC * temperature sensor * battery pack/power supply   Students can demonstrate how the unit operates and how to view and collect the data.  Students can troubleshoot code and resolve syntax errors. |  |
| TE4-1DP, TE4-2DP, TE4-4DP, TE4-7DI  (T) Evaluate how student solutions address defined functional requirements and constraints  (T) Implement and modify programs involving branching, iteration and functions in a general-purpose programming language, for example:   * microcontroller   (T) Trace algorithms to predict output for a given input and to identify errors | **Teacher**   * Outline the extra functionality required, including:   + humidity   + pressure   + altitude (calculated from temperature and pressure)   + UV exposure (optional) * Outline the conditions the FlatSat and student CubeSat unit will operate under and guide students in developing an algorithm to measure, calculate and record the weather elements listed above. This will also include the rate of measurements (for example measurements per hour and length of time record data), the required precision and the formatting of the collected data.   **Students**   * Develop an algorithm for the ongoing operation of the Flatsat as defined by the class. * Translate the algorithm into a general-purpose coding language. Upload and test for syntax and logical errors. * Evaluate function (ongoing) and record details in student folio. | Students produce and test an algorithm to measure and record temperature, humidity and pressure.  Students will have assessed the operation of the unit and recorded any changes in their design folio. |  |
| TE4-1DP, TE4-2DP, TE4-4DP, TE4-7DI  (T) Implement and modify programs involving branching, iteration and functions in a general-purpose programming language, for example:   * microcontroller   (T) Evaluate how student solutions address defined functional requirements and constraints  (T) Trace algorithms to predict output for a given input and to identify errors  MA4-1WM, MA4-2WM  MA4-3WM, MA4-19SP  (M) Identify and investigate issues involving numerical data collected from primary and secondary sources   * identify the difference between data collected from primary and secondary sources   (M) Collect and interpret information from secondary sources, presented as tables and/or graphs, about a matter of interest  (M) Use spreadsheets or statistical software packages to tabulate and graph data | **Students**   * Continue writing code and testing for reliable data capture. * Evaluate function (ongoing) and record details in student folio. * Collect data from the BOM website or app (or similar source) and compare it to data from FlatSat (sensor rig). Analyse and provide reasons for any discrepancies. | Students will have produced code and performed troubleshooting in a general-purpose coding language.  Students will be able to describe what parts are working properly and what parts need further improvement. Students should be articulating how they know whether their code is working properly or not.  Student folios should clearly display some observations of feedback from the coding environment and whether/how they responded to address any identified issues.  Students should be able to identify any notable differences in data between the two sources and propose the cause(s). |  |
| **Weeks 3-4**  TE4-1DP, TE4-2DP, TE4-7DI  (T) Evaluate how student solutions address defined functional requirements and constraints | **Teacher**   * Lead class discussion on where weather data is collected around the school. Apart from obvious issues like WH&S, exposure to the elements, and the security of the devices, the criteria may focus on selecting various conditions to obtain an interesting range of data. * Establish a FlatSat within the classroom/staffroom to operate from the beginning of week 3 to the end of the unit, to provide baseline data for class.   Note: This FlatSat could be connected to a computer for regular access to data by students.  **Students**   * Identify test locations around the school and evaluate suitability. * Continue collecting and recording data from BOM source and compare them to the data from FlatSat (and eventually student CubeSats). Collate and store for the duration of the unit for use in later exercises and the folio. * Using the data collected over a longer time period, analyse and suggest reasons for any discrepancies. | Students can justify/provide reasons for selected locations based on agreed criteria.  Students collate and compare weather data from different sources, checking for FlatSat system error. |  |
| (T) Develop criteria to evaluate design ideas, processes and solutions, the functionality, aesthetics and a range of constraints, for example, accessibility, cultural, economic, resources, safety, social, sustainability, technical  (T) Investigate needs or opportunities for designing an engineered system and investigate and select from a range of materials, components, tools, equipment and processes  (T) Select and use a variety of critical and creative thinking strategies to generate innovative design ideas, for example:   * brainstorming * sketching * 3-D modelling * experimenting | **Teacher**  Present the [official CubeSat specifications](https://www.cubesat.org/s/CDS-REV14-2020-07-31-DRAFT.pdf) and reference [websites](https://www.nasa.gov/sites/default/files/atoms/files/nasa_csli_cubesat_101_508.pdf) for students to begin researching 1U CubeSats.  Alternatively, outline any modifications to dimensions, payload constraints and construction materials or establish the modified criteria with the class.  **Students**  Research external and internal dimensions for CubeSats and construction materials.  Identify and assess known relevant constraints, which may include:   * construction materials * power requirements/power sources * heat dissipation * mass.   Measure dimensions of internal hardware components, including mass.  Generate a design solution for how FlatSat components can be reconfigured to fit within pre-defined dimensions.  **Extension:**  Students measure heat dissipation and/or derive methods of determining heat dissipation and explore cooling strategies. | Students identify maximum sizes for a 1U CubeSat.  Design ideas demonstrate student understanding of the requirements and constraints, including size, mass, and materials.  Students conduct a SWOT and/or PMI analysis to determine and justify their most suitable design. |  |
| TE4-1DP, TE4-3DP  (T) Select and use a variety of critical and creative thinking strategies to generate innovative design ideas  (T) Develop models, prototypes or products using a range of tools, materials and equipment to test the functionality of design ideas and consider innovative applications of advancing technologies | **Teacher**  Check that students understand the required criteria, project deliverables and timelines.  **Students**  Apply the design process to develop a cardboard prototype CubeSat casing for housing the hardware components, including:   * microcontroller * sensor(s) * data logging shield and RTC * power source.   Test fit components to demonstrate success. | Students produce a cardboard development prototype to test fit internal hardware components.  Students demonstrate and record an iterative prototyping process until a workable design is achieved |  |
| TE4-1DP, TE4-3DP  (T) Select and use a variety of critical and creative thinking strategies to generate innovative design ideas | **Teacher**  Demonstrate how to use suitable CAD software and save a variety of formats for any of the following purposes:   * printing * [3D printing](https://asc-csa.gc.ca/eng/search/images/watch.asp?id=10185&search=cubesat) (.STL files) * laser cutting * reference images for folio   Demonstrate examples of [3D printed CubeSat frames](https://www.thingiverse.com/thing:27300), laser cut models or cardboard prototypes.  **Students**  Begin to generate designs on CAD software.  Evaluate and modify as necessary. |  |  |
| TE4-1DP  (T) Produce products or systems that apply engineering principles, for example:   * aeronautical vehicles designed according to the principles of flight * structures designed according to statics and properties of materials | **Teacher**  Organise and facilitate safe fabrication processes, which may include:   * cardboard prototyping * 3D printing * laser cutting.   **Students**  Continue with CAD design work.  Continue refining prototypes considering flight-ready materials informed by design. Evaluate and modify as necessary. |  |  |
| TE4-1DP  (T) Develop models, prototypes or products using a range of tools, materials and equipment to test the functionality of design ideas and consider innovative applications of advancing technologies, for example:   * developing computer-aided design (CAD) files to automate manufacturing technologies | **Teacher**  Organise and facilitate safe fabrication processes, which may include:   * cardboard prototyping * 3D printing * laser cutting.   **Students**  Continue refining prototypes considering mounting points for payload informed by design, evaluate and modify as necessary. |  |  |
| **Weeks 5-6**  In groups students plan and conduct (an) independent investigation(s) to:   * determine a fair and reasonable testing regime able to demonstrate compliance with the specified requirements and deliverables * design and construct any required test apparatus * test the structural integrity of their CubeSat design, and/or * test the continued operation of the CubeSat unit under normal (or expected) operating conditions.   **Note:** Depending on the students’ ability and constraints like available time, a group might only perform one of the four tests listed. The results from other groups’ tests could be shared (see weeks 7-8) to allow for a more efficient use of time and provide the data to assist in making any necessary modifications. | **Teacher**  Outline the purpose of an Environmental Qualification Campaign and refer to the [GEVS standard](https://standards.nasa.gov/standard/gsfc/gsfc-std-7000).  Describe the “Shake n Bake” tests relevant to this project, for example:   * vibration * shock (or impact) * thermal cycling (ambient) * [thermal vacuum](https://lasp.colorado.edu/home/csswe/system/testing/thermal-vacuum/).   For thermal cycling and thermal vacuum, describe the [operation of the Wombat XL](https://spaceaustralia.com/news/unsw-canberra-space-gearing-launch-next-cubesat) thermal vacuum testing structure at the [National Space Testing Facility](https://inspace.anu.edu.au/nstf) (ANU).  Organise the class into suitable groups and provide guidance to groups on managing tasks. Supervise groups that may be planning and conducting investigations/experiments.  Facilitate the use of tools and equipment by the students while providing active supervision.  Advise student groups on planning and selecting tasks (project management).  **Note:** 3D printing and laser cutting previous week’s designs could still occur while students are researching for upcoming planned tests. |  |  |
| TE4-1DP  (T) Develop and apply testing procedures to evaluate an engineered system  (T) Evaluate the effectiveness and suitability of choices made during the development and production of the engineered solution  (T) Assess the solution against the predetermined criteria | **Teacher**  Provide examples of [vibration testing](https://www.youtube.com/watch?v=y90V0o2_HHY) experiments, such as a [student made shake table](https://www.questacon.edu.au/sites/default/files/resources/teacher-resources/file/Shake%20Table%20Lesson%20Plan.pdf), to initiate student research.  **Students**   * Research CubeSat launches and identify a typical duration of launch to determine the duration of a vibration test. * Design investigation to test the CubeSat casings durability to withstand vibrations. | * Students plan a vibration test of their prototype CubeSat. * Students safely perform investigation and record findings. * Students evaluate findings and make adjustments to their group’s design. |  |
| TE4-1DP  (T) Develop and apply testing procedures to evaluate an engineered system  (T) Evaluate the effectiveness and suitability of choices made during the development and production of the engineered solution  (T) Assess the solution against the predetermined criteria | **Teacher**  Provide examples of [impact testing](https://youtu.be/SfGjNQZ78Eo) experiments to initiate student research.  **Students**   * Research how the payload is securely attached in the casing and the velocity of CubeSats (and other launch vehicles) in launch and operation. * Design investigation to test the durability of component anchor points to the CubeSat to ensure the payload is not dislodged during operation. | * Students plan an impact test of their prototype CubeSat. * Students safely perform investigations and record findings. * Students evaluate findings and make adjustments to their group’s design. |  |
| TE4-1DP  (T) Develop and apply testing procedures to evaluate an engineered system  (T) Evaluate the effectiveness and suitability of choices made during the development and production of the engineered solution  (T) Assess the solution against the predetermined criteria | **Teacher**  Provide examples of [thermal testing (operating temperatures)](https://youtu.be/aWNgM58kUas) experiments to initiate student research.  **Students**   * Research the operating temperature conditions of CubeSats. * Design investigation to test the functionality of electronics under expected temperature conditions during the operations phase. | * Students plan a temperature test of their prototype CubeSat. * Students safely perform investigation and record findings. * Students evaluate findings and make adjustments to their group’s design. |  |
| TE4-1DP  (T) Develop and apply testing procedures to evaluate an engineered system  (T) Evaluate the effectiveness and suitability of choices made during the development and production of the engineered solution  (T) Assess the solution against the predetermined criteria | **Optional:**  Students research material testing, including extreme impact tests. Students design investigation to test the CubeSat casings durability to withstand impact (either from space debris or return to earth in the event of launch failure) | Students plan a materials test relevant to the design of their prototype CubeSat.  Students safely perform investigations and record findings.  Students evaluate findings and make adjustments to their group’s design. |  |
| TE4-1DP  (T) Develop and apply testing procedures to evaluate an engineered system  (T) Evaluate the effectiveness and suitability of choices made during the development and production of the engineered solution  (T) Assess the solution against the predetermined criteria | **Optional:**  **Teacher**  Provide examples of low gravity experiments to initiate student research.  **Students**  Research the effects of low gravity in space environments. This should inform how hardware is mounted inside CubeSat. | Students plan a low gravity investigation relevant to the design of their prototype CubeSat.  Students safely perform investigations and record findings.  Students evaluate findings and make adjustments to their group’s design. |  |
| TE4-1DP  (T) Develop and apply testing procedures to evaluate an engineered system  (T) Evaluate the effectiveness and suitability of choices made during the development and production of the engineered solution  (T) Assess the solution against the predetermined criteria | **Optional:**  **Teacher**  Provide examples of power supply testing experiments to initiate student research.  **Students**  Map out a sequence of events for a CubeSat launch (or mission) and identify environmental conditions CubeSat is exposed to. This determines how long a power supply must last for a typical mission and under typical conditions. | Students identify relevant findings and record these.  Students make adjustments to their group’s design |  |
| **Week 7-8**  TE4-1DP  (T) Generate and communicate the development of design ideas, plans and processes for various audiences using appropriate technical terms and technologies including graphical representation techniques, for example:   * engineering reports * digital presentations   SC4-9WS  (S) Presenting ideas, findings and solutions to problems using scientific language and representations using digital technologies as appropriate. | **Students**  Present the findings of their investigations, carried out in weeks five to six, to share data that were obtained and the implications this may have on their prototype design.  **Teacher**  Guides discussion and helps students summarise relevant findings. | Students present findings and articulate the impact of the results on the design of CubeSat. |  |
| TE4-1DP  (T) Evaluate the effectiveness and suitability of choices made during the development and production of the solution  (T) Assess the solution against the predetermined criteria | **Students**  Review and discuss findings within groups and decide what further modifications may need to be made.  Present an update of design/changes to the teacher. | Students record a review of findings and provide clear reasons why changes, if any, should be conducted. |  |
|  | **Students**  Perform necessary modifications to casings and assemble hardware components and power supply |  |  |
| TE4-1DP  (T) Generate and communicate the development of design ideas, plans and processes for various audiences using appropriate technical terms and technologies including graphical representation techniques, for example:   * engineering reports. | Prepare Flight Acceptance Review report for customer, confirming:   * requirements and deliverables have been achieved * component and subsystem are operational (coding and output) * Integrated System Tests (payload operational in CubeSat casing) * successful environmental qualification   + vibration   + impact   + temperature. | Students will have produced the required documentation in a suitable format and with appropriate detail. |  |
| **Week 8** | **Teacher**  Sign-off of Flight Acceptance Review and give “Go/No go” status confirmation to launch crews.  **Students**  Deploy finished CubeSat to the identified location in the school. Initiate power and begin monitoring.  If it appears the ProtoSat stops functioning, students retrieve the unit and determine likely causes of any failures. | Students diligently monitor the operation of the ProtoSat and confirm it is functioning through regular observations.  Students are able to deduce the cause(s) of malfunctions and provide reasons to justify their inference. |  |
|  | **Teacher and students**  Discuss the history and development of space exploration, especially issues such as manned versus unmanned space exploration, spacecraft design, launch and navigation, imaging and remote sensing. | * Students can recognise some social implications of space science. They can present arguments around the costs, risks & benefits of space exploration. |  |
| (T) Identify social, ethical and cyber security considerations of digital solutions | **Teacher and students**  Discuss the [impact of space junk](https://orbitaldebris.jsc.nasa.gov/library/sciencemag-risks-in-space-from-orbiting.pdf) on operational satellites and missions.  **Students**  Research the [lifespan](https://www.euspaceimaging.com/the-lifespan-of-orbiting-satellites/) of a satellite.  **Extension (Optional):**  Debate the value (or impact) of [space exploration and research on society](http://astronomy.swin.edu.au/sao/downloads/HET610-M19A01.pdf), for example:   * [Scientific](https://www.nasa.gov/connect/ebooks/iss_benefits_for_humanity.html) * Economic * [Societal](https://www.nasa.gov/connect/ebooks/historical_studies_societal_impact_spaceflight_detail.html). | * Students actively participate in classroom discussion * Students produce a report on the life of the satellite. * Students can recognise some social implications of space science. They can present arguments around the costs, risks & benefits of space exploration. |  |
| **Week 9** | **Students**   * Monitor the operation of the deployed CubeSat and confirm continued functioning. * If it appears the ProtoSat stops functioning, students retrieve the unit and determine likely causes of any failures. |  |  |
| SC4-7WS  (S) WS7.1a Students process data and information by summarising data from students’ own investigations and secondary sources.  (S) WS7.1b Students process data and information by using a range of representations to organise data.  (S) WS7.2b Students analyse data and information by constructing and using a range of representations.  MA4-1WM, MA4-3WM  MA4-19SP  (M) Use spreadsheets or statistical software packages to tabulate and graph data | **Teachers**  Demonstrate how to use data to create visualisations.  **Students**  Use computer software to enter data from original FlatSat or provided sample data and create charts and simple visualisations. | Students can construct charts and simple visualisations from provided test data (in preparation for loading real data into charts) |  |
| **Week 10** | **Teachers and students**  Retrieve CubeSats and download data to place in a shared drive. |  |  |
| SC4-7WS  (S) WS7.1a Students process data and information by summarising data from students’ own investigations and secondary sources.  (S) WS7.1b Students process data and information by using a range of representations to organise data.  (S) WS7.1c Extracting information from tables and graphs, including column and line graphs  MA4-1WM, MA4-3WM  MA4-19SP  (M) Use spreadsheets or statistical software packages to tabulate and graph data  (M) Graph more than one line on the same set of axes using digital technologies and compare the graphs to determine similarities and differences | **Students**  Use spreadsheets or statistical software packages to tabulate and graph data from their CubeSat.  Graph more than one dataset on the same set of axes using a spreadsheet or graphing software and compare the graphs to determine similarities and differences.  Evaluate collected data according to agreed criteria. |  |  |
| MA4-1WM, MA4-2WM  MA4-3WM, MA4-20SP  (M) Explore the practicalities and implications of obtaining data through sampling using a variety of investigative processes.   * identify issues that may make it difficult to obtain representative data from either primary or secondary sources * investigate and question the selection of data used to support a particular viewpoint   (M) Identify and investigate issues involving numerical data collected from primary and secondary sources   * discuss ethical issues that may arise from collecting and representing data   (M) Calculate mean, median, mode and range for sets of data and interpret these statistics in the context of data  (M) Investigate the effect of individual data values, including outliers, on the mean and median   * analyse collected data to identify any obvious errors and justify the inclusion of any individual data values that differ markedly from the rest of the data collected   (M) Describe and interpret data displays using mean, median and range   * draw conclusions based on the analysis of data displays using the mean, median and/or mode, and range   SC4-7WS  Students analyse data and information by:   * checking the reliability of gathered data and information by comparing with observations or information from other sources * identifying data which supports or discounts a question being investigated or a proposed solution to a problem * using scientific understanding to identify relationships and draw conclusions based on students’ data or secondary sources | **Teacher and Students**  Discuss the value of data.  Some questions to consider:   * Which data is more accurate, the ProtoSat or the BOM? * Which data is more reliable, the ProtoSat or the BOM? * What is the quality of this data? * What are the dimensions of this data? * How well does the information from this data reflect reality? * What is the value of weather data? * What are the implications of this captured data? | Students actively participate in classroom discussion |  |

## Evaluation

Evaluation of learning activities should be an ongoing process that happens throughout the delivery of this unit. Teachers should document their evaluation of learning activities throughout the program. The space provided below is to evaluate the overall unit of work.

## Interesting but not essential links

* CubeSats explained by NASA – [youtube.com/watch?v=yGUWTxV0r8c](https://www.youtube.com/watch?v=yGUWTxV0r8c)
* CubeSats: a satellite small enough to fit in your hand – [youtube.com/watch?v=Z9iAMhaSiE4](https://www.youtube.com/watch?v=Z9iAMhaSiE4)
* Crazy Engineering: CubeSats – [youtube.com/watch?v=7RrWZJHkREI](https://www.youtube.com/watch?v=7RrWZJHkREI)
* Tiny satellites that photograph the entire planet, every day – [youtube.com/watch?v=UHkEbemburs](https://www.youtube.com/watch?v=UHkEbemburs)
* The new nano satellite companies looking at everything – [youtube.com/watch?v=xfD5cvwOdO4](https://www.youtube.com/watch?v=xfD5cvwOdO4)
* SciTech Central Short Cubesat – [youtube.com/watch?v=y5QEhk8\_bGA](https://www.youtube.com/watch?v=y5QEhk8_bGA)
* Build a CubeSat satellite that actually works, part 1: make it resilient – [rs-online.com/designspark/build-a-cubesat-satellite-that-actually-works-part-1-make-it-resilient](https://www.rs-online.com/designspark/build-a-cubesat-satellite-that-actually-works-part-1-make-it-resilient)
* Build a CubeSat satellite that actually works, part 2: make it reliable – [rs-online.com/designspark/build-a-cubesat-satellite-that-actually-works-part-2-make-it-reliable](https://www.rs-online.com/designspark/build-a-cubesat-satellite-that-actually-works-part-2-make-it-reliable)
* The CubeSat era in space – [jpl.nasa.gov/cubesat/](https://www.jpl.nasa.gov/cubesat/)
* Canadian Space Agency: what is a CubeSat – [asc-csa.gc.ca/eng/satellites/cubesat/what-is-a-cubesat.asp](https://asc-csa.gc.ca/eng/satellites/cubesat/what-is-a-cubesat.asp)
* NASA EDGE CubeSat Launch Initiative – [youtube.com/watch?v=q38k0RRmOKk](https://www.youtube.com/watch?v=q38k0RRmOKk)
* XinaBox powered CubeSat – [youtube.com/watch?v=Z6hUoMEkjTk](https://www.youtube.com/watch?v=Z6hUoMEkjTk)
* Sixty years of Australia in space – [royalsoc.org.au/images/pdf/journal/153-1-Dougherty.pdf](https://royalsoc.org.au/images/pdf/journal/153-1-Dougherty.pdf)
* Sounding rockets: cutting-edge science, 15 minutes at a time – [youtube.com/watch?v=KkeCXrgrKuY](https://www.youtube.com/watch?v=KkeCXrgrKuY)
* Sounding rockets launch playlist – [youtube.com/watch?v=6fqyX3p7Qdk&list=PLpGTA7wMEDFjRg8yeHzPr1-dFwfKAiO-L](https://www.youtube.com/watch?v=6fqyX3p7Qdk&list=PLpGTA7wMEDFjRg8yeHzPr1-dFwfKAiO-L)
* The history of sounding rockets and their contribution to European space research – [esa.int/esapub/hsr/HSR\_38.pdf](http://www.esa.int/esapub/hsr/HSR_38.pdf)
* High altitude ballooning tools hub – [habhub.org](http://habhub.org/)
* What’s the lifespan of a satellite? – [youtube.com/watch?v=BvKon9BH9XM](https://www.youtube.com/watch?v=BvKon9BH9XM)
* NASA Edge CubeSat workshop – [youtube.com/watch?v=wTvaU24BZMA](https://www.youtube.com/watch?v=wTvaU24BZMA)
* Insights into successfully designing, building and launching a CubeSat – [youtube.com/watch?v=TOE1t\_vyuCE](https://www.youtube.com/watch?v=TOE1t_vyuCE)
* How are small satellites changing the earth observation industry? – [youtube.com/watch?v=vd4oecayaMk](https://www.youtube.com/watch?v=vd4oecayaMk)
* Climate CubeSat co-build – [assets.pubpub.org/a6vi4w5y/51553649627460.pdf](https://assets.pubpub.org/a6vi4w5y/51553649627460.pdf)
* Weather balloon design guidelines – [festorage.blob.core.windows.net/weatherballoon/files/weatherballoon-DesignGuidelines.pdf](https://festorage.blob.core.windows.net/weatherballoon/files/weatherballoon-DesignGuidelines.pdf)
* (Check links to datasets)
* UK student-built satellite sends data back from space – [youtube.com/watch?v=\_3YFJhAWFk4](https://www.youtube.com/watch?v=_3YFJhAWFk4)
* 2019 CubeSat Developers Workshop – [youtube.com/watch?v=O7iokwtpZlU](https://www.youtube.com/watch?v=O7iokwtpZlU)