School Information

Norwood Morialta High School is a dual campus high school of 1400 students (years 8 to 13) and is located in the Eastern suburbs of Adelaide, the capital city of the state of South Australia in Australia.

It is a world class school accredited by the Council of International Schools (CIS).

The International Baccalaureate Middle Years Program (IBMYP) is offered in partnership with feeder primary schools.

The school has a culturally and linguistically diverse population, which includes a large international student cohort.

Norwood Morialta High School is leading an innovative STEM program from P-12, and is recognised as a leader in the field of STEM.

Norwood Morialta High School is part of the Morialta Partnership, a local network of 12 schools and preschools committed to working collaboratively in developing powerful learners in STEM.

Some of our STEM initiatives include:

- Computer Science and Engineering Pathways from Year 8 – 12
- Environmental Science Pathway from Year 8 - 12, with a focus on STEM for Sustainability
- Student leadership and mentoring of STEMies, a program for students from Years 5-7 from our Partnership schools. Each primary school student is partnered with a secondary school buddy to learn how to design, build and program microcontrollers in response to a real-world problem.
- Academic partnership with UniSA.

Industry Partners and Connections

Background

The safety of astronauts is a paramount consideration when embarking on space travel. Space suit material can protect against short term exposure to radiation for improving the safety conditions in space, particularly to safeguard against long term exposure to radiation. This can support longer voyages into deep space (e.g. Mars) which would allow for greater exploration; supporting a better Earth in the future.

Boron Nitride nanotubes (BNNTs) are novel radiation shielding materials that contain boron and have been used in various industries but have not been tested in space.

"BNNT can be the basis for neutron shielding composites for use in radiation shielding applications due to the presence of boron with its unique high efficiency for absorbing thermal neutrons. BNNT can also be used for ultra violet (UV) shielding applications." [1]

NASA's Langley Institute Research Centre has conducted Phase 1 research with BNNT in a Computational and Experimental Study: *Radiation Shielding Materials Containing Hydrogen, Boron, and Nitrogen: Systematic Computational and Experimental Study* in 2012.[2]

Our team endeavours to test BNNTs in space against prolonged exposure to gamma radiation.

Aim: To investigate whether novel radiation shielding materials will be capable of enduring the impact of gamma radiation over extended periods.

Design and Safety Criteria

All components will be housed within a cylindrical container with a mass less than 300 grams and within a volume less than a one litre milk carton. The container will house one high density material: BNNTs and a control material.

The container will be made of a semi-transparent polycarbonate material which can withstand temperatures up to 155 Degrees Celsius and alpha radiation.

The container will house 100 grams of the test materials, along with the following components:

- Raspberry Pi (Version 3) on-board CPU (31 grams, 5V, 86mm x 56mm);
- Sense Hat add-on (20.4 grams) to collect information such as orientation, pressure, humidity and temperature;
- Camera Board add-on (3.4 grams, 25mm x 23mm x 9mm) to monitor integrity of the internal components and test material;
- Geiger counter add-on (300-600V, 70mm x115mm) to measure the amount of radiation (namely beta particles and gamma radiation) that the test material will be exposed to; and
- Back-up power bank - as a back-up power source.

The 5-volt micro-USB will be used to provide power for the Raspberry Pi console.

[1] BNNT. 2017. BNNT (Boron Nitride Nanotube) radiation shielding applications. [ONLINE] Available at: http://www.bnnt.com/resources/applications/radiation-shielding. [Accessed 2 September 2017].

[2] Sheila Thibeault. 2014. Radiation Shielding Materials Containing Hydrogen, Boron, and Nitrogen: Systematic Computational and Experimental Study. [ONLINE] Available at: https://www.nasa.gov/directorates/spacetech/niac/thibeault_radiation_shielding.html. [Accessed 20 September 2017].

FIGURE 1: Aerogel

Aerogel[3] will be used as a safety precaution to insulate, stabilise and protect the internal components from electrical interference, launching forces (G forces up to 7.5g) and impact forces, as well as extreme temperatures between -20 and +50 degrees Celsius.

Development of the idea through the engineering design process

Students were introduced to the Engineering Design Process[4] early in Stage 1 of the SA School Space Mission.

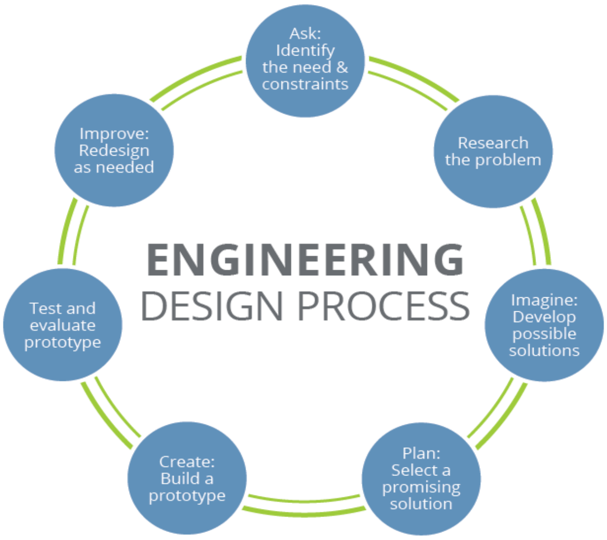

FIGURE 2: Engineering Design Process

<u>Ask: Identify the needs & constraints</u>

Students brainstormed numerous ideas including:

- Learning about Micro-organisms
- Dealing with waste on Earth
- Dealing with Space Junk
- Effects of Radiation

The team looked toward Innovation for a Better Future and narrowed the focus to one idea.

The team focused on the idea of Space suit design against radiation, and begun considering the physical and safety parameters of the experiment.

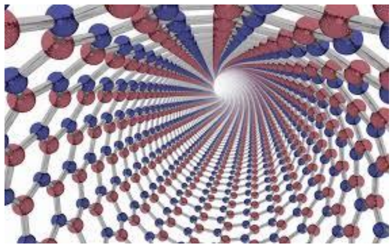

FIGURE 3: BNNT

<u>Research the problem</u>

In smaller groups, students conducted further research around the idea. Students considered answering the following questions:

- What types of radiation are astronauts subject to?
- How do we shield against these types of radiation on Earth?
- What is currently being used to protect astronauts against these types of radiation?

<u>Imagine: Develop possible solutions</u>

Students then considered developing solutions to the problem, and considered the following more specific questions:

- What radiation shielding materials are being used on Earth against gamma radiation?
- Which novel radiation shielding materials are available and haven't been tested for space applications?

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3 See Figure 1: Aerogel, (2017), *aerogel - Google Search* [ONLINE]. Available at: https://upload.wikimedia.org/wikipedia/commons/2/2c/Aerogel_hand.jpg [Accessed 2 September 2017].

4 See Figure 2: Engineering Design Process - www.teachengineering.org, (2017), *Engineering Design Process* [ONLINE]. Available at: https://www.teachengineering.org/images/v-636404169280000000/EDP_WebpageGraphic.png [Accessed 2 September 2017].

Three materials were considered: a thermoplastic from Ecomass, Demron and Boron Nitride nanotubes[5] (BNNTs).

Students developed written correspondence to communicate with the companies that specialise in these three materials. BNNT[6] and Tekna, who produce and distribute BNNT worldwide were very positive in developing a connection with our team and collaborating with our team in this endeavour.

FIGURE 4: BNNT Radiation

Plan: Select a promising solution

Students then considered the physical and safety criteria in regard to housing and testing the radiation shielding materials identified in the previous stage of the Engineering Design Process.

The team decided that radiation and temperature would be the key data to be collected via the Geiger counter, Sense Hat and Camera Board add-ons to a Raspberry Pi micro-computer over a 12-month period.

Students have researched and have sought advice from Technology teachers at Norwood Morialta High School to determine the most appropriate coding platform required to program the Raspberry Pi and collect the data required over the 12-month period.

On-board the Raspberry Pi, there are three programming languages. These are, python, C++, and the block based Scratch. Out of these languages, for the experiment, Python is most suitable. This is because it is a multipurpose dynamic and high level language, while simple and easy to pick up for people who already know programming. It is also much more object-oriented than the other two languages, and used by many companies around the world. The main disadvantage of python is that it is slow in speed because it is an interpreter. However, in this experiment, it will not be a problem due to the fact that we will not be measuring the radiation every millisecond or second. Scratch is the simplest of the languages, as it is very easy to understand and use, however it is not very versatile or high level. It also does not give the user as much freedom to program as Python does. C++ is known as the mother of all languages, but is not object-oriented, so instead another version of C++, VisualC++, could be used. It is based on a compiler and therefore much faster than Python, but the only problem is that it will need bigger resources being the faster language. Python is also much more supported on the Raspberry Pi, and less complicated than C++.

Stabilising and protecting the sensitive equipment were also important considerations. The semi-polycarbonate outer casing was researched to withstand appropriate forces and temperatures without adding a significant amount of mass to the 300g limit. Due to advice from Neumann Space, Aerogel, the world's lightest solid material will be used instead of styrofoam due to an outgassing problem. Aerogel will be used to keep the Raspberry PI, sensors and test materials in place over the 12-month period.

Create: Build a prototype

In preparation for Stage 2 of the Mission, our team has initiated consultation of Industry in building and developing connections and partnerships. BNNT and Tekna have been very supportive in the process of starting to develop a prototype. Tekna will supply our team with a sample amount of BNNT at no charge to test, if our team is successful in being chosen to develop a prototype in the next stage. BNNT has offered technical expertise in the particular type of BNNT that could be beneficial in space. Aerogel Australia has been supportive in helping us source Aerogel overseas and providing some technical details regarding the best Aerogel to be used for our experimental purposes.

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[5] See Figure 3: BNNT - Tekna, (2017), *Boron Nitride Nanotubes | Tekna* [ONLINE]. Available at: http://www.tekna.com/boron-nitride-nanotubes [Accessed 2 September 2017].

[6] See Figure 4: BNNT Radiation Shielding. BNNT. 2017. *BNNT (Boron Nitride Nanotube) radiation shielding applications*. [ONLINE] Available at: http://www.bnnt.com/resources/applications/radiation-shielding. [Accessed 2 September 2017].

Norwood Morialta High School has an academic partnership with UniSA. Bruce White from UniSA has offered support to our team.

Links to Australian Curriculum and/or SACE

Our experiment, which we are conducting, is linked to many different aspects and subjects of our school's curriculum. Our school, Norwood Morialta High School, currently follows the ACARA and SACE curriculums.

In **Year 4**, the Australian curriculum covers a topic regarding the Earth's surface. This leads to them also learning on how to make predictions, relationships in results and describing patterns. (ACSSU076, ACSIS064 ACSHE061 and ACSHE062)

In **Year 5**, students learn about the world around us on a different level with them expanding on the topic of matter. They also learn how to take educated guesses and test their predictions and use evidence to develop explanations. (ACSSU077, ACCSSU078, ACSHE081 and ACSHE083)

In **Year 6**, students learn about how changes are classified in various ways and the transfer and transformation of electricity. They also continue their learning about testing predictions by gathering data and using evidence to develop explanations. (ACSSU094, ACSSU097, ACSHE098 and ACSHE100)

In **Year 7**, our experiment links to Science. Our experiment reflects on the aspect of Science as a Human Endeavour as well. Scientific knowledge has changed peoples' understanding of the world and is refined as new evidence becomes readily available. With our experiment, we could have a potential result with the radiation shielding material, which could be used in space suits to withstand the amount of gamma radiation in space. In Year 7, space and phenomena outside Earth is also covered as an aspect. Moreover, because our experiment is going to be in space, it is best to know whether conditions in space could have an effect on our experiment or not. (ACSSU115, ACSSU117, ACSHE119 and ACSHE121)

In **Year 8**, one aspect of Year 8 science is Chemical Sciences wherein atoms, elements, compounds, mixtures and atomic structures are discussed and can be described at a particle level. Properties of the elements and different states of matter are explained. Radiation is also discussed in small detail, which has significant ties to our experiment. (ACSSU151, ACSSU152, ACSSU155, ACSHE134 and ACSHE135)

In **Year 9**, our experiment links to Science. In Year 9 Science, we learn about radioactivity and atoms. In our experiment, we are measuring how much gamma radiation can pass through a piece of material. In Year 9 Science, we learn about alpha, beta and gamma radiation and the decay of the nucleus of an atom. We also learn about how radiation can occur and how it is released from an unstable atom. (ACSSU177, ACSSU178, ACSSU179, ACSSU182, ACSHE157, ACSHE158, ACSHE160 and ACSHE228)

In **Year 10**, apart from Science, another subject that relates to our experiment is Programming for real life applications. In this subject, students learn how to use coding, programming and how to use Raspberry Pi and Python. The Raspberry Pi system/Python is crucial in our experiment, as it has to record the data of our measurement. In Year 10, radiation is taught in further advancement and atoms as well. Space and its surroundings is also discussed further in Year 10, as the conditions could affect our experiment. The fact that we are testing materials, which could withstand gamma radiation in order to be used as part of a space suit, comes under one main aspect of Science as Human Endeavour in Year 10. This aspect is that 'Advances in science and emerging sciences and technologies can significantly affect people's lives, including generating new career opportunities'.[7] (ACSSU186, ACSSU187, ACSSU190, ACSHE194, ACSHE191 and ACSHE192)

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7 ACARA. 2017. Science / Year 9 / Science as a Human Endeavour / Use and influence of science / ACSHE161. [ONLINE] Available at: http://v7-5.australiancurriculum.edu.au/science/curriculum/f-10?layout=1#cdcode=ACSHE161&level=9. [Accessed 19 September 2017].

In **Stage 1 (Year 11) and Stage 2 (Year 12)**, Chemistry 1 and 2 and Physics A and B are the main subjects our experiment targets. In Stage 1 and 2 the aspects our experiment focuses on broadens a lot more. Physics focuses on Atoms and Nuclei and Light and Matter. Atoms and Nuclei relate to radiation and therefore are a part of our experiment. Stage 1 Physics B thoroughly focuses on nuclear models and radioactivity therefore meaning that it is a crucial aspect/subject. Stage 1 Chemistry 1 also focuses on Atoms (materials and their atoms and the combination of atoms) and Molecules. In addition, most of the Science as Human Endeavour aspects are expanded on in these years, which also reflect on our experiment. (ACSES048, ACSES049, ACSES104, ACSPH106, ACSPH028, ACSPH030, ACSPH136 and ACSPH137)

This information was sourced from the Australian Curriculum website.

Therefore, as it can be clearly seen, our experiment links up to a vast majority of subjects and aspects throughout the Australian Curriculum and can be linked to most years of schooling.

Experimental diagram

Through using a Computer Aided Design program branded Sketch Up, our team has designed a 3D model prototype of the experiment. (**See Figure 5**). The main structure consists of an outer casing of semi-transparent polycarbonate and hollow columns within, making it drop proof. The entire structure can fit into a 1 litre milk carton in volume and will have a mass less than 300g. It will also be able to survive extreme temperatures up to -90ºC and 90ºC and forces up to 9g. Through this, the structure will meet the design and safety requirements specified by Neumann Space for the SA School Space Mission.

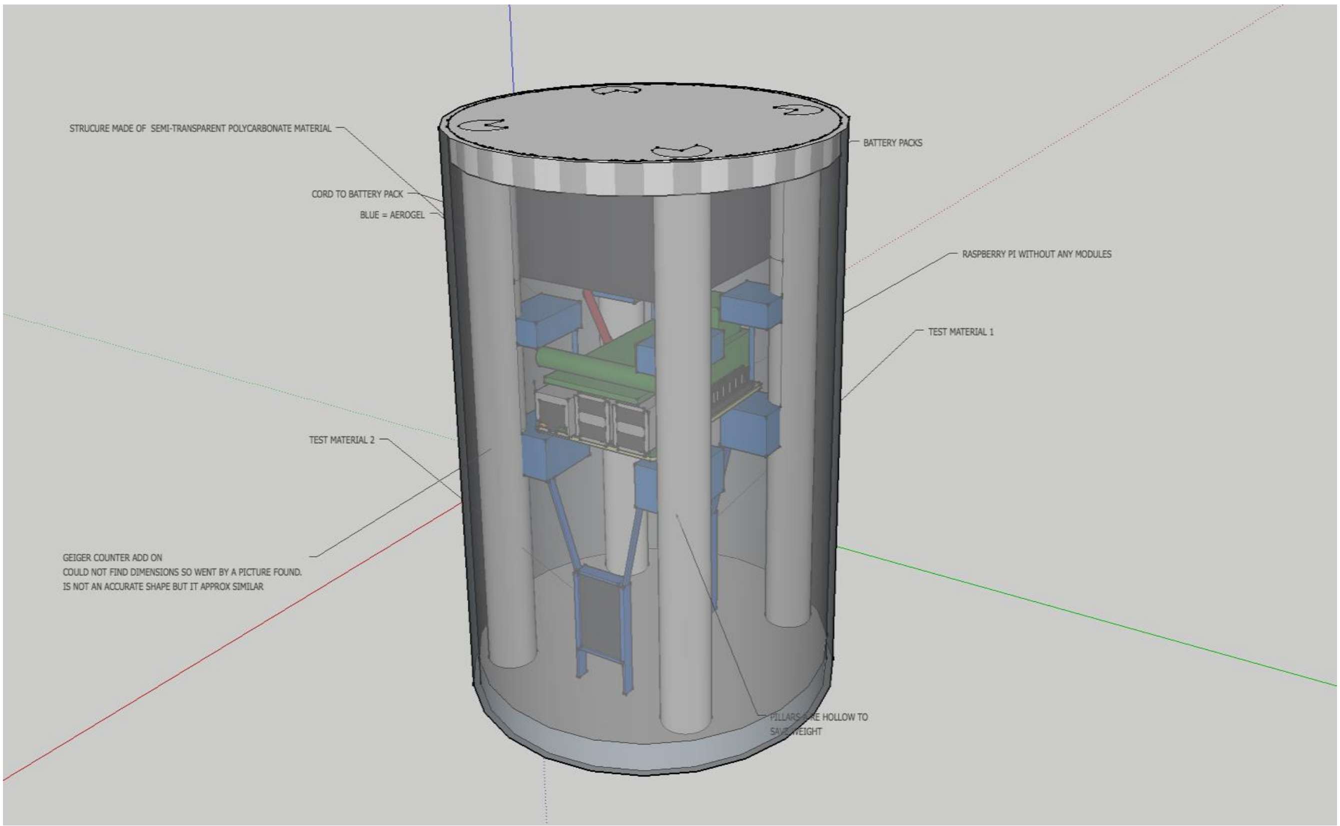

Figure 5: Experimental Diagram as conceptualised using Sketch Up

In the centre of the structure is a Raspberry Pi, though the modules are not shown, we will have them present. The Raspberry Pi is surrounded by Aerogel (In Blue) which will be used as a shock absorber to protect the sensitive and critical instrumentation namely the Sense hat, the Geiger counters to record data, Raspberry Pi and other sensitive collection materials. There is a battery pack attached to the top of the structure, which is linked to the Raspberry

Pi via the (red) cable. (**See Figure 6 and 7**) At the bottom of the container we have 2 tests materials: the BNNTs and the control which will be tested against gamma radiation. For these reasons we will have 2 separate Geiger counters, of which will be separately recording data for one of the 2 test materials, allowing us to compare data.

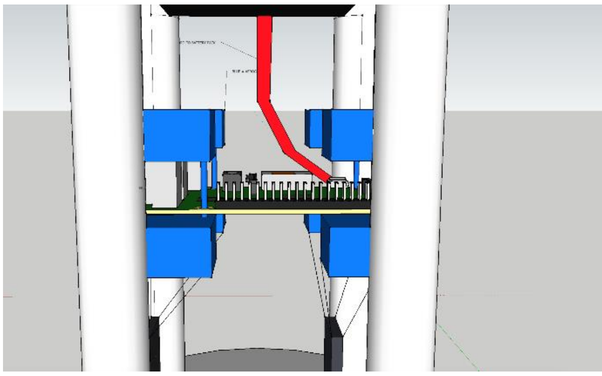

Figure 6: Closeup of Aerogel (FRONT)

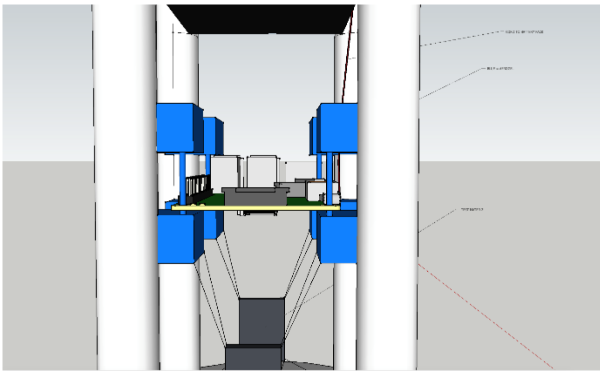

Figure 7: Closeup of Aerogel (SIDE)

Accessibility and usefulness of data to experimental hubs and industry partners

Our research will set the foundation and provide the basic information that experimental hubs and industry partners need to develop their products for space travel. These partners will build onto our work and take our experiment to the next level of research and development. This potentially may enable Tekna to supply radiation shielding materials to research institutions, and other interested organisations directly to conduct larger scale tests.

Another objective of our experiment is to conclude on whether the material that we use is robust enough to withstand high temperatures and pressure as seen in space transit.

BNNTs are designed to withstand extreme conditions such as those in space.

The data that we record can be used to test whether the chosen material is robust enough to withstand high temperatures and other extreme conditions. This data can be useful to Industry Partners as it can lead to further experimentation with our test materials.

If the tests prove that the material we have used is able to shield against long term exposure to radiation, experimental hubs could benefit from this as they may need such information for further research and study. For example, NASA and other organisations are already conducting research with developing BNNTs as they see the potential in BNNTs with space applications.

If our tests are good, the material can be used to make thin, ultra-light-weight space suits- that could even be used for more advanced expeditions, for example: transit to Mars.

Innovative potential to support a better Earth in the future and practicality of the idea and usefulness to society

This experiment will help further an understanding of the many dangers space has to offer. The experiment will test whether novel radiation shielding materials will be able to endure the impact of radiation over long periods. This is beneficial in many fields of science such as the production of space suits so astronauts can stay in space for longer periods at a time.

When embarking on space travel, safety of the astronauts is a matter of utmost importance. The materials used in current spacesuits only allow for short term exposure to the various outer space radiations, so proving that BNNTs can protect against galactic cosmic radiation and other radiation for extended periods of time will allow for their integration into space travel allowing for longer periods of travel in space. This is especially useful for extremely long journeys into parts of space such as in trips to mars as when away from the magnetic field of earth, the amount of radiation that the space ships and the astronauts will be bombarded with will exponentially increase. Therefore, integration of these materials into space suits may allow for astronauts to space walk or walk on celestial bodies such as on the ISS where the thin atmosphere will block almost no radiation with next to no issues regarding being exposed to radiation. This is important as measured by the Mars rover 'Curiosity', the average dose of radiation received when simply getting to Mars is equivalent to 24 CAT scans, solidifying why better methods of radiation shielding are of paramount importance in order to ensure the safety of astronauts.

The potential to reinvent space travel is astronomical and a major step forward in the advancements of space travel and the hope to find a new sustainable planet. The material being tested could also be used to line space crafts, thereby further enhancing space safety as a whole.

Summary of Costs to develop a prototype:

Item	Cost	Links
Aerogel	**Disk** (26 x 7 mm approx.): US$35 =~AU$44.47 **Tile** (50 x 75 x 7mm approx.): $200 =~AU$254.13 *Subject to bulk buying discounts*	http://www.buyaerogel.com/
Raspberry Pi Console (v3)	AU$56.40	https://core-electronics.com.au/raspberry-pi/boards.html
Raspberry Pi Sense HAT	£24.99 = ~AU$41.11 (8 Aug. 2017)	http://uk.rs-online.com/web/p/interface-development-kits/8949310/?searchTerm=raspberry+pi+sense+hat&relevancy-data=636F3D3126696E3D4931384E53656172636847656E65726963266C753D656E266D6D3D6D61746368616C6C7061727469616C26706D3D5E2E2A2426706F3D31333326736E3D592673743D43415443485F414C4C5F44454641554C542673633D592677633D4E4F4E45267573743D726173706265727279207069207365736520686174267374613D72617370626572727920706920736E73652068617426
	AU$55.10 ($60.61 inc. GST) *Australian Supplier: Free delivery*	http://au.rs-online.com/web/p/interface-development-kits/8949310/?sra=pmpn
Raspberry Pi Camera v2	£20.99 = ~AU$34.63 (8 Aug. 2017)	http://uk.rs-online.com/web/p/processor-microcontroller-development-kits/9132664/?sra=pmpn
	AU$39.88 ($43.87 inc. GST) *Australian Supplier: Free delivery*	http://au.rs-online.com/web/p/processor-microcontroller-development-kits/9132664/?sra=pmpn
Geiger Counter Kit	£97.50 = ~ AUS $218.59 (22 Aug. 2017)	https://thepihut.com/products/adafruit-geiger-counter-kit-radiation-sensor