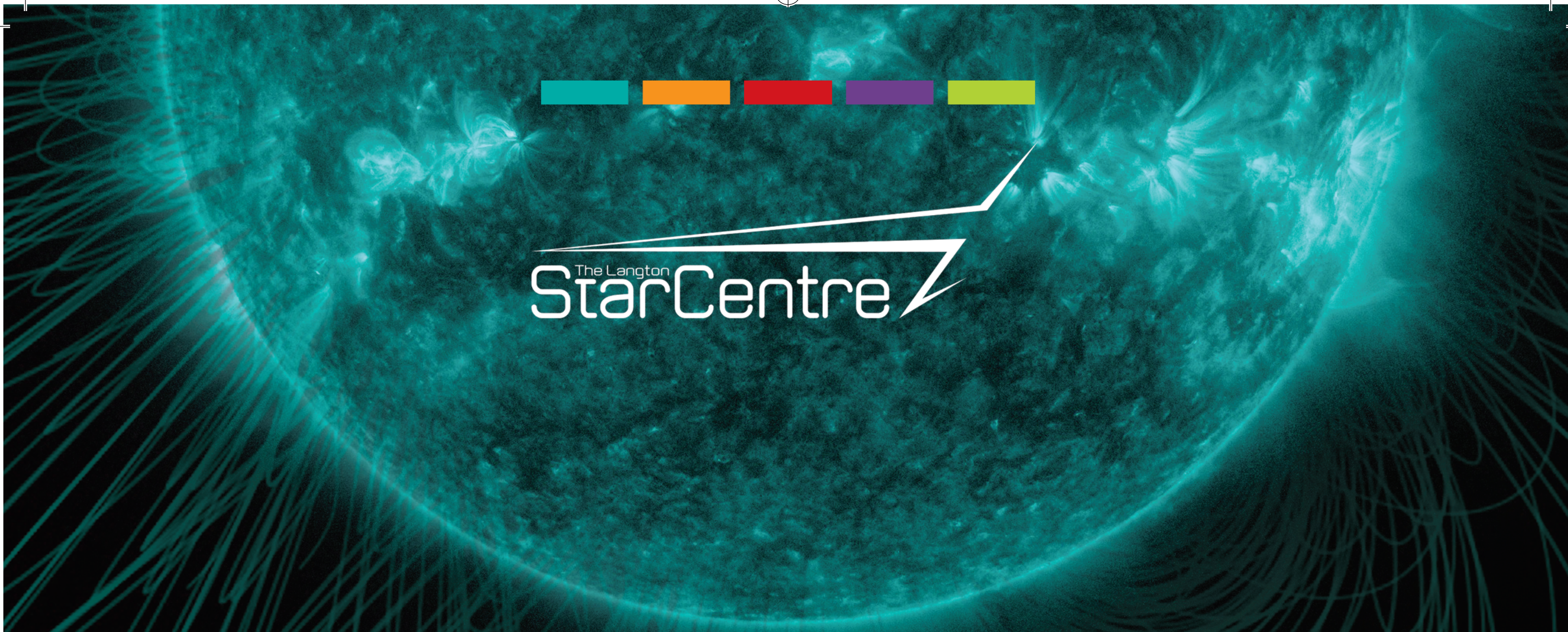


The Langton StarCentre

SUNNY SPELLS & SOLAR STORMS

UNDERSTANDING SPACE WEATHER WITH LUCID

Introduction

This resource contains background information and activities linked to the mission of LUCID, the Langton Ultimate Cosmic ray Intensity Detector on-board the British satellite TechDemoSat-1. Designed by pupils at the Langton School for Boys, it uses technology developed at CERN, the European Centre for Nuclear Research to learn more about space weather.

Space weather has the potential to have a serious impact on our lives. Originating mainly from the Sun, any adverse weather conditions can affect our satellites, airplanes, spacecraft and electricity networks. However, by studying this weather we can better prepare ourselves to protect against it.

This guide is for Primary teachers and provides information on space weather and where it comes from. Three activities are included in this pack, suitable for 8-12 year olds. Each is designed to last around 1 hour. The electronic version of this guide is available to download at http://www.thelangtonstarcentre.org/.

Curriculum links

Scotland:

- Materials: Earth's Materials [SCN 2-17a]
- Topical Science [SCN 1-20a, 2-20a]
- Forces, Electricity and Waves: Forces [SCN 1-08a, 2-08a]
- Planet Earth: Space [SCN 2-06a]

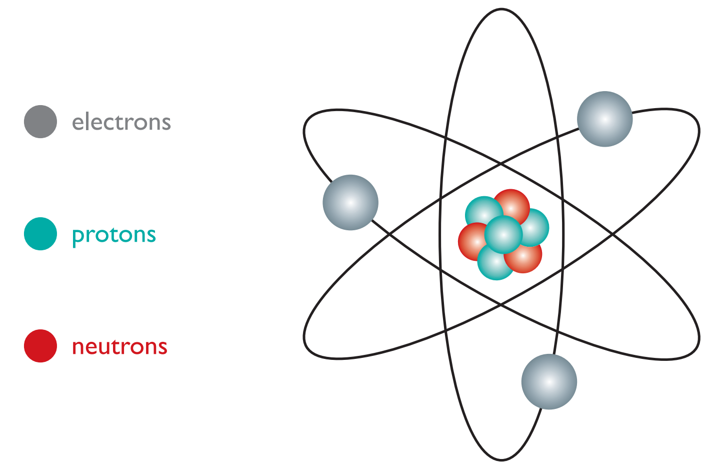
England:

- Years 3 and 4: Rocks, Lights, Forces and Magnets
- Years 5 and 6: Properties and changes of materials, Earth and Space, Forces, Light

Contents:

Atoms

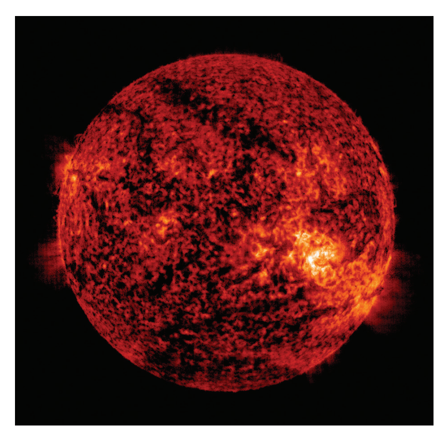
All of the materials we see around us on Earth, the stars in the sky, humans, plants and animals are made from atoms. There are many different types of atoms, called elements. Elements are different from each other because of the particles that make up their atoms: they each have a unique recipe.



Atoms are made from a combination of particles called protons, neutrons and electrons. The number of each will tell us which element they make, for example:

Element	Protons	Neutrons	Electrons
Hydrogen	1	0	1
Carbon	6	6	6
Oxygen	8	8	8
Gold	47	32	47

So far we have discovered more than one hundred elements and these can be found listed in the periodic table. Humans are made up of many different elements, including Hydrogen, Carbon and Oxygen. Stars like the Sun are made from Hydrogen and Helium.



Radiation

Objects all around us, including rocks, buildings and bananas release their own radiation. The water we drink and the air we breathe produces some radiation. So depending on where you live, there will be a different level of background radiation that relies on the make-up of your environment. Radiation from the Sun and elsewhere in space will contribute to the total. The amount you are exposed to, however, will depend on your lifestyle. For example, someone who breaks a leg and has to have an X-ray will receive a slightly higher dose of radiation.

When radiation occurs something is always emitted as part of the process. In some cases particles are released, such as protons and electrons, and in others energy is produced. For example electromagnetic radiation (light) can be released as X-rays or Ultraviolet (UV) light. Photons are the carriers of electromagnetic radiation.

There are different types of radiation:

1. Alpha: this type of radiation means that an atom has changed into a different kind. Release: Two protons and two neutrons – known as a Helium nucleus.

2. Beta: this occurs when a neutron within an atom changes into a proton. This is normally a high energy type of radiation. Release: electron.

3. Gamma: this type is very high energy. There are several ways to produce this type, including changes within atoms. Release: photons.

It is important that we can detect radiation and measure it. This allows us to track how much we are exposed to. In some workplaces - for example in a radiography department in a hospital - staff are required to wear a device that tracks how much radiation they are exposed to. Radiation exposure is monitored on the International Space Station.

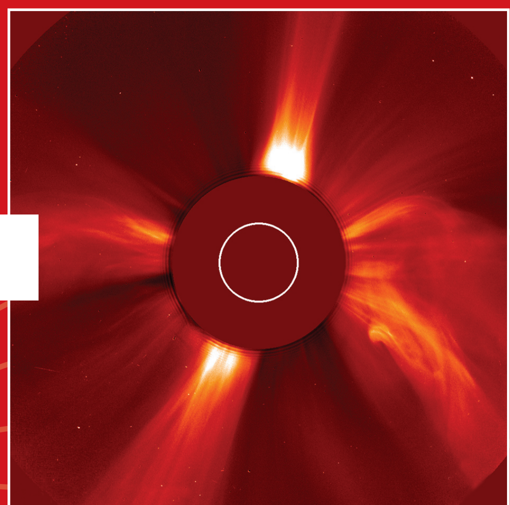
Astrophysicists use telescopes and other instruments to measure radiation from different places in the universe. Radiation comes from stars, galaxies and other unknown sources. By looking at X-rays and radio waves we can find out more about the universe.

Space Weather

The Sun is the Earth's source of heat and light. Without it life would not be possible. To produce heat and light the Sun turns Hydrogen into Helium in a process called nuclear fusion.

The Sun is a massive object and the forces affecting it include gravity and its own magnetic field. The interaction of these forces can result in the Sun releasing radiation. This sometimes comes in contact with the Earth and we call this space weather.

1



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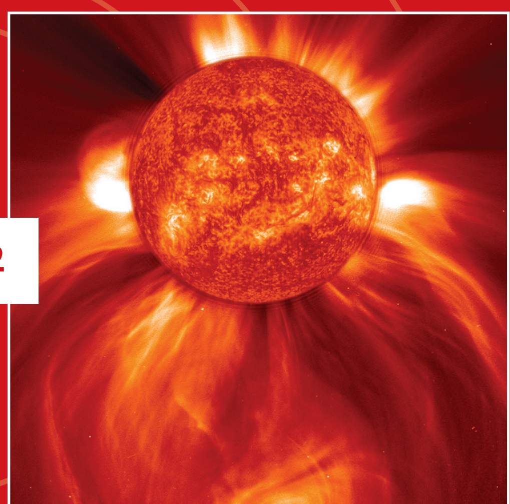

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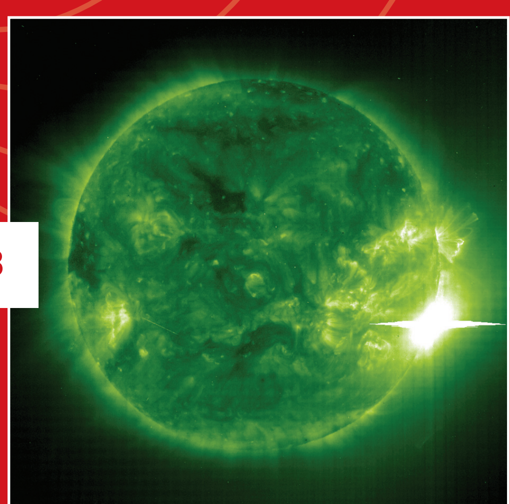


Sources of Space Weather:

1. The Solar Wind is a stream of particles made up of electrons and protons that the Sun releases in all directions. This is a constant stream, but its strength can vary depending on what is going on inside the Sun. If the Solar Wind increases in strength then this could have an effect on Earth. We often see the effect of the Solar Wind as the Northern Lights.

Frequency: Constant, but varies in strength depending on the Sun's activity.
Time to travel to Earth: 2-3 days

2. A Coronal Mass Ejection (CME) is the name given to an explosion of material from the Sun. If the radiation and particles (normally electrons, protons and photons) produced by the Sun come in contact with the Earth, then the effects can be seen. Large CME events usually result in the Northern Lights being visible in the sky quite far south. Normally they are only visible in the north of Scotland and in places such as Canada, Norway, Iceland.

Frequency: A few per day when the Sun is most active, once a week when it is quiet.
Time to travel to Earth: 2-3 days

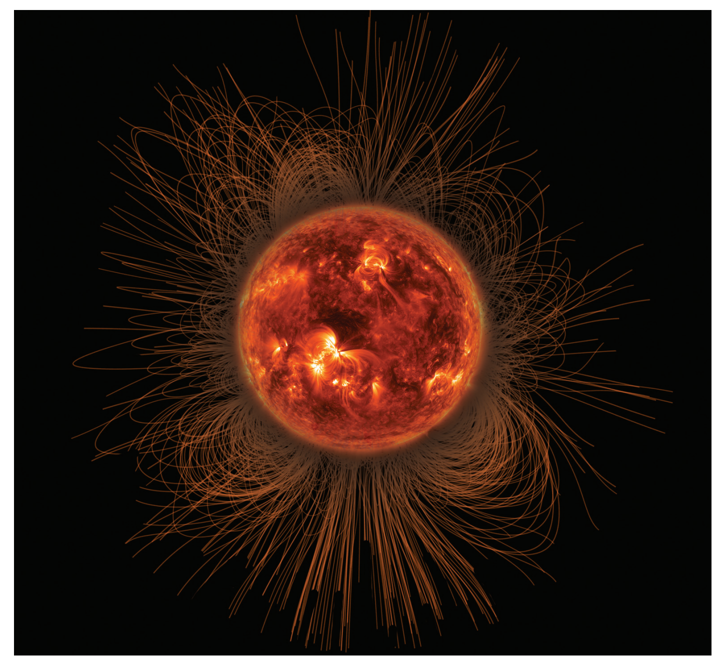
3. A Solar Flare is a very brief but large flash from the Sun. This throws high energy photons, electrons and atoms out into space.

Frequency: A few per day when the Sun is most active, once a week when it is quiet.
Time to travel to Earth: 1-2 hours

4. Cosmic Rays are an alternative source of space weather. They are made up of extremely high energy photons and particles but we don't know where they come from. These rays hit our atmosphere and start off a burst of particles that we can sometimes detect on the ground.

Frequency: Constant
Time to travel to Earth: Origin unknown, therefore time to travel unknown.

The Earth's magnetic field protects us from a lot of space weather. The Earth has a north and south pole, just like a bar magnet. The magnetic field is invisible to us but it can act over a distance and we can see its effects in other ways. However, sometimes the solar wind, a CME or solar flare is so powerful it breaks through our protective barrier.



The effect of the space weather depends on the strength of the release from the Sun. The Sun's magnetic field doesn't stay still, it moves around. The north and south poles switch over every eleven years or so and this marks the time of maximum activity for the Sun, so we find that some years are much quieter than others.

Effects of Space Weather:

1. Electricity network: Damage to electricity lines and other equipment could occur if a large solar storm were to hit the Earth. It would be difficult to replace this equipment quickly so wherever the storm hits there could be electricity blackouts for a long period.

2. Aircraft: The radio frequency used by aircraft to communicate can be interrupted by space weather, particularly if the route of the aircraft is near one of the magnetic poles. This could mean delays as planes are re-routed or even cancelled.

3. Spacecraft: The computer systems on a spacecraft could be affected by the radiation thus endangering its operation. In addition, the astronauts on board would be vulnerable to receiving much higher than normal doses of radiation

4. Satellites: The photons and particles from the Sun can interfere with signals to and from satellites meaning that connections could be lost. This could affect us in different ways:

a. navigation systems used by cars, trains and ships

b. personal, business and government communications around the world could be interrupted if they are routed through affected satellites

c. television signals routed through satellites may also be lost

Aurora

The Aurora Borealis (the Northern Lights) or Aurora Australis (the Southern Lights) can be viewed around the north or the south pole respectively. When viewed from above the Aurora is a ring of light around the pole and is green, pink or red in colour. Electromagnetic radiation such as ultraviolet (UV) has been recorded. This light is produced when electrons from the Sun are pulled into the Earth's magnetic field and interact with our atmosphere.

Langton Ultimate Cosmic ray Intensity Detector

(LUCID)

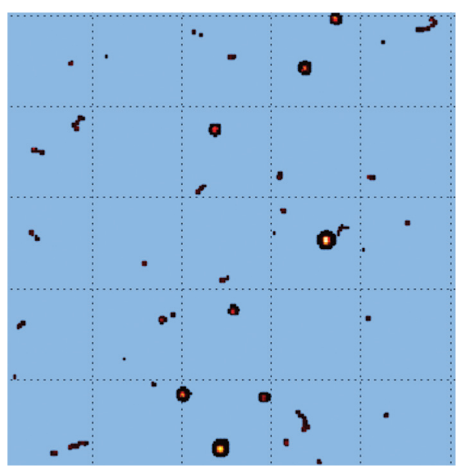
Being able to understand and protect against the effects of space weather is a very important area of research and there are many experiments around the world.

LUCID was launched in July 2014 on board the satellite TechDemoSat-1 and was designed by pupils at Simon Langton School for Boys. The LUCID project began in 2007 when pupils from the school visited CERN, the European Centre for Nuclear Research. They met with members of the Medipix2 Collaboration and found out about their technology designed for use in X-ray imaging. Pupils investigated other uses of the detector technology and this resulted in the design for the LUCID experiment.

The detectors on board the satellite will tell pupils about the radiation that strikes it, including its type. The results will help build a picture about the space weather at the orbit of the spacecraft, which is around 635 km above the surface of the Earth.

The Detector:

- a square grid made up of 256 by 256 pixels
- when struck by a type of radiation, each pixel accurately measures the energy of the radiation
- results can be viewed as a picture and computer software can identify the different types of radiation (alpha, beta or gamma) based on the pattern on the grid and energy recorded by the pixels



Other applications of the detectors include in X-ray imaging and they can be found on board the International Space Station where they are used to measure the amount of radiation that the astronauts are exposed to.

Activity 1 - Atoms and Particles

Pupils learn about the building blocks we are made from and build models of different atoms.

Equipment required: Building blocks of some kind (for example LEGO) or round pieces of paper or stickers of different sizes, for example:

The Session:

A suggested script is available below. Slides are available for use but are not required if you have access to a board or flip chart to draw the diagrams. Content for this activity is linked to the "Atoms" section on page 3.

1. Introducing the topic (15 minutes)

- Ask children what they think we are made from and make a note of their responses on a board/flip chart. Typical responses will include skin, flesh, bone, blood, particles, stardust or building blocks.
- Using the content from the "Atoms" section explain that we are made from "atoms". Ask the pupils if they have heard this word before. Pupils may have come across the term elements but not atoms, so it is important to mention both. Write up/display the words "Atoms and Elements"
- Display or draw a diagram of an atom (found on page 3), labelling the protons, neutrons and electrons, emphasising that the electrons travel around the nucleus of protons and neutrons. Or ask pupils to draw their ideas themselves.
- Ask pupils if they can name any elements. You could offer some leading questions or examples, including "take a deep breath, what are you breathing in?". Responses include "air" and "gas". You can ask them what they are made from before going on to mention Oxygen.
- Ask them to name other examples of atoms. Common responses include "CO2" and "H2O". Let them know what they are made of (Hydrogen, Oxygen and Carbon) and ask them what stars are made of (Hydrogen and Helium).
- Display or draw table:

Element	Protons	Neutrons	Electrons
Hydrogen	1	0	1
Carbon	6	6	6
Oxygen	8	8	8
Gold	47	32	47

- Ask them how many elements they think there are. So far we have discovered more than one hundred elements and these can be found listed in the periodic table. Show them the periodic table.

2. Completing the task (25-30 minutes)

- Establish with the children what building blocks/materials correspond to the different particles.
- Based on the atoms that make up our bodies, split the children into groups and ask them to make a model of the different elements. For example, one group can make oxygen, another carbon, etc. Give them a time limit to see how many models they can make of each type.
- Wander around and talk to them as they are doing it to make sure they understand that the protons and neutrons go in the middle and that the electrons go around the outside.

3. Conclusion (10 minutes)

- At the end of the available time, ask each group to count up how many elements they have made and report back to you. Write the numbers up on a board/flip chart. Now ask how many of each they think we have in the body before writing up the actual number from the table below.

Element	Number in the body
Hydrogen	4,700,000,000,000,000,000,000,000,000
Oxygen	14,000,000,000,000,000,000,000,000,000
Carbon	42,000,000,000,000,000,000,000,000,000

- Once they realise how many atoms are in the body ask them what this implies about the size of an atom. They will realise that atoms are very small!

Activity 2 – Radiation

Pupils learn about the different kinds of radiation, what they are used for, where they come from and how we track them. Equipment required: particle grid (on page 11), pencils/pens for colouring in.

The Session:

As in Activity 1a suggested script and slides are available but using them is not mandatory. Content for this activity is linked to the "Radiation" section on page 3.

1. Introducing the topic (10 minutes)

- Write up the word "radiation" on the board and ask pupils what it means/have they heard or seen the word before. If yes, collate their responses and comment on them. Commonly pupils will say "light".

- Using the content from the "Radiation" section explain what it is and when they experience it.

- As an alternative to describing alpha, beta, gamma in terms of changes in an atom, you can instead highlight their uses

  - Alpha radiation is used in smoke detectors. If smoke gets into the alarm this absorbs the radiation (like when water is absorbed by a towel) and this change is detected by the alarm and a sound is produced.

  - Beta radiation can be used to measure the thickness of materials like paper, plastic and aluminium. The thicker the material the more radiation it will absorb.

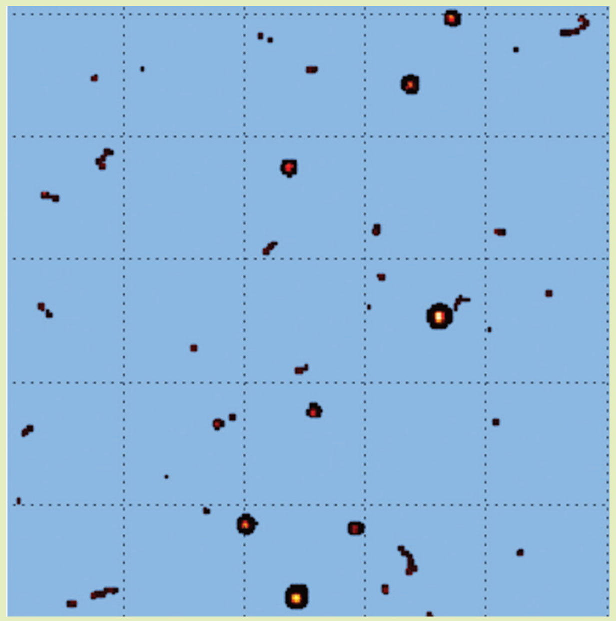
  - Gamma radiation is used widely in medicine. For example it can be used as part of cancer treatment and to sterilise instruments by killing viruses and bacteria.

- When radiation occurs something is always emitted as part of the process. In some cases particles are released, such as protons and electrons, and in others energy is produced, for example electromagnetic radiation can be released as X-rays or Ultraviolet (UV) light.

- Radiation is often thought to be dangerous but it is only dangerous in high doses. This means that it is important that we can detect radiation and measure it. This allows to track how much we are exposed to.

- We can use technology to track radiation and one method uses a detector, a bit like what you find inside a digital camera. It is made up of a square grid of pixels. When struck by radiation each pixel records how much. Different types of radiation appear as a different pattern on the detector.

- The results can be viewed as a picture and we can identify which areas are alpha, beta or gamma:



2. Completing the task (25-30 minutes)

- The challenge is for the pupils to make a radiation picture from either a cup of water, a banana, potato or brazil nut. Once everyone has finished their pictures they will swap with someone and try to work out what their picture is of.

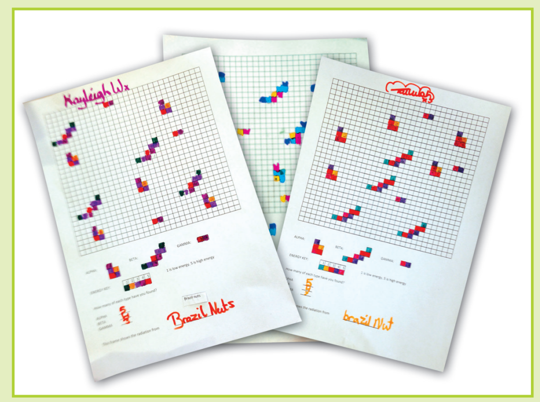
- Hand out the grid templates. The first task is to ask each pupil to choose 5 different colours to work with. They then allocate a colour to 1-5 on the energy scale. Using their now defined scale ask them to colour in the alpha, then beta and gamma in the key above. It is useful for you to do one at the same time as the pupils to show what you mean.

- Once the energy key and example particles are coloured in, randomly allocate each pupil a source from the table below to draw. You should reinforce that they are not allowed to tell anyone else which they got.

- Some pupils will ask if they can flip the alpha and betas around and that is fine. They can also colour them in clusters. In reality the alphas and betas appear in different orientations and can be grouped together. There are different approaches that the pupils will take to colouring in. Some will go ahead and use their coloured pens or pencils immediately. Others will write out the numbers and lay out the different particles before colouring them in.

Item	Alpha	Beta	Gamma
Water	4	4	2
Banana	3	5	5
Potato	3	5	2
Brazil nuts	4	4	3

- Once pupils start to finish pair them up for them to swap, count each type and write down which one they think it is. Their partner can then confirm whether or not they are correct. Examples of completed grids are below:



3. Conclusion (10 minutes)

Once pupils have finished their radiation pictures explain why these objects are radioactive:

- Water: certain rocks are naturally radioactive and through these, small amounts of radiation can get into our water.

- Banana: contain potassium-40 which is naturally radioactive

- Brazil nuts: come from trees with deep roots which carry the radiation into the plant.

- Potatoes: come from potatoes in the ground grown with water and near naturally occurring radiation in rocks.

Using the content from the "LUCID" section in the guide, explain the purpose of the detector.

Activity 3 – Space weather

Pupils learn about the different kinds of radiation and how we track them.

Equipment required:
white paper discs (diameter of 9cm), black A4 card/paper, pencils, colouring pens/pencils, glue sticks, magnets, model Earth and Sun

The Session:

As in Activities 1 and 2 a suggested script and slides are available. It is recommended that the slides are used as they contain key diagrams and images. Content for this activity is linked to the "Space weather" section on page 4.

1. Introducing the topic/completing the task (40 minutes)

- Review the relative position of the Earth and the Sun, including concepts such as day/rotation and year/orbit.

- Hand out the white discs. Ask pupils to choose to draw either the Sun or the Earth. Once they have finished their colouring, ask them to stick the disc to the centre of an A4 black piece of paper and then set it aside.

- Hold up some magnets and ask if they know what they are. Encourage the pupils to describe them and where they find them. Pass out the magnets to each group and ask them to put them together and pull them apart in different orientations. They should notice a difference when they turn poles to face each other.

- Ask them to describe magnetism. Magnetism is an invisible force that is a push and a pull. Next ask them to think about how they would draw a magnetic field if they could see it. Ask for volunteers to come to the board to show you. Pupils will often draw parallel lines. Draw a bar magnet and show that it has a North and South pole. Ask what happens when two Norths come together.

- Explain that the Earth has a magnetic field and so does the Sun – show diagrams of both (in slides).

- The Sun's magnetic field isn't stable like the Earth's. Its North and South poles flip every 11 years and this affects how it behaves. Sometimes it is more active than others.

Activity 3 – Space weather continued

- At this stage ask the pupils to add the magnetic field to their Earth or Sun. They may want to use chalk for this. Once they have finished return to the board and move onto discussing the Sun's activity.

- The Sun is active in different ways, these include: solar wind, coronal mass ejection and solar flare. For full details please refer to the "Space weather" section of the guide on page 4.

- In the main we observe this activity on Earth as the Aurora or the Northern Lights. The Aurora Borealis (the Northern Lights) or Aurora Australis (the Southern Lights) can be viewed around the north or the south pole respectively. When viewed from above the Aurora is a ring of light around the pole and is green, pink or red in colour. Electromagnetic radiation such as ultraviolet (UV) has been recorded. This light is produced when electrons from the Sun are pulled into the Earth's magnetic field and interact with our atmosphere.

- Pupils should now add some solar activity to their Sun or the Aurora to the north and south poles of the Earth. Once finished, get them to show them to the rest of the class. Example pictures are below:

2. Conclusion (10 minutes)
Unfortunately the effects of the Sun's activity don't just appear as the Aurora. If the space weather is very powerful then there can be other effects. These include:

A. Electricity network
Damage to electricity lines and other equipment could occur if a large solar storm were to hit the Earth. It would be difficult to replace this equipment quickly so wherever the storm hits on Earth could experience electricity blackouts for a long period.

B. Aircraft
The radio frequency used by aircraft to communicate can be interrupted by space weather, particularly if the route of the aircraft is near one of the magnetic poles. This could mean delays as planes are re-routed or even cancelled.

C. Spacecraft
The computer systems on a spacecraft could be affected by the radiation thus endangering its operation. In addition, the astronauts on board would be vulnerable to receiving much higher than normal doses of radiation

D. Satellites
The photons and particles from the Sun can interfere with signals to and from satellites meaning that connections could be lost. This could affect many different aspects, including:

a. navigation systems used by cars, trains and ships

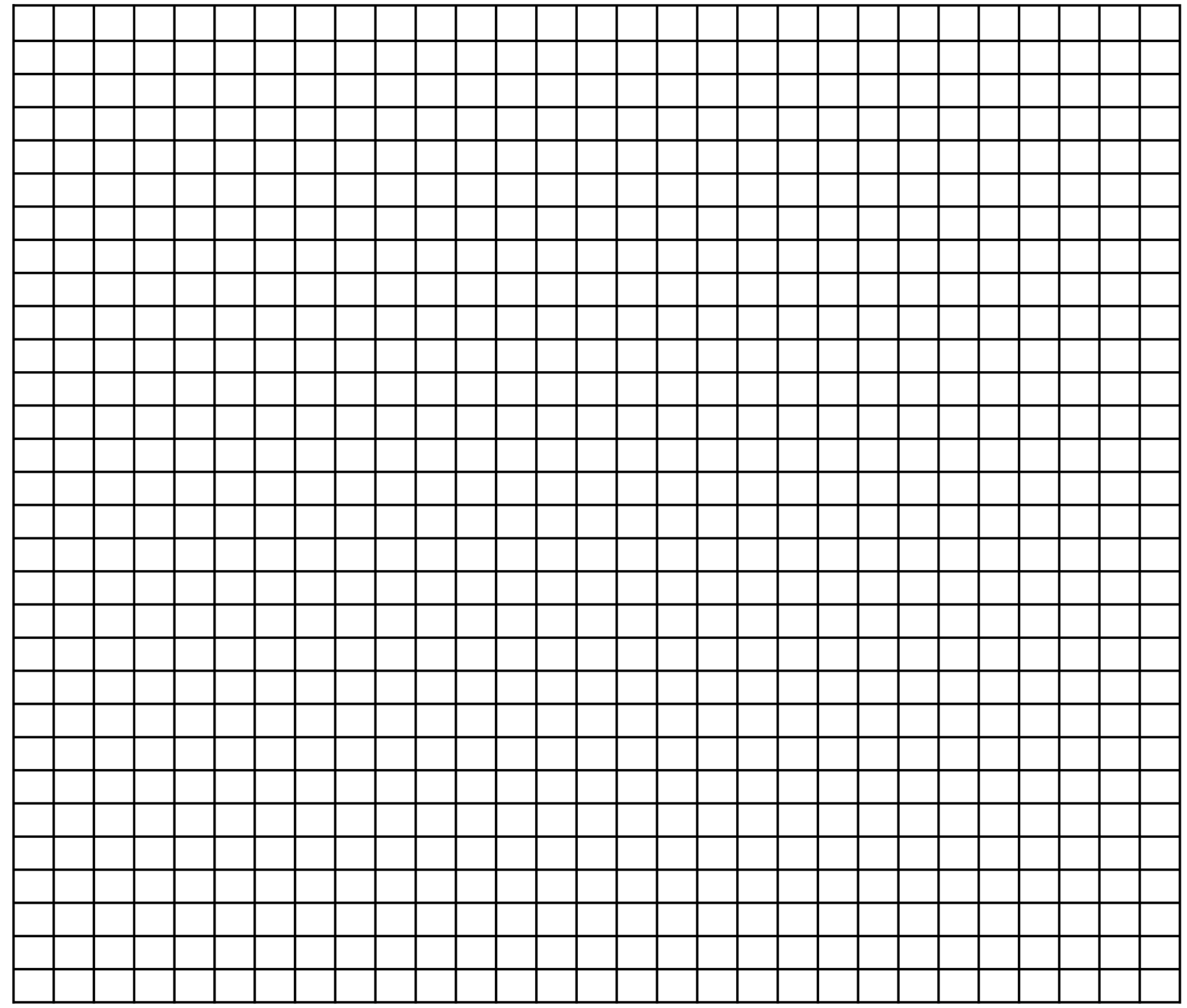
b. personal, business and government communications around the world could be interrupted if they are routed through affected satellites

c. television signals routed through satellites may also be lost

Being able to understand and protect against the effects of space weather is a very important area of research. There are many experiments around the world trying to do just that.

Using the content from the "LUCID" section in the guide, explain the purpose of the detector.

Particle Grid



ALPHA:

	3	
2	4	2
3	5	3

BETA:

				1
			3	3
		5	4	
1	3	4		

GAMMA:

5	4

ENERGY KEY:

1	2	3	4	5

1 is low energy, 5 is high energy

How many of each type have you found?

ALPHA ______
BETA ______
GAMMA ______

This frame shows the radiation from ____________________

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CERN & Society

CERN@school

The Langton StarCentre

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