Cosmic SOS

Discover particle detectors as you travel through space!

Systems Engineer:	…..……………………………………………..
Mission Safety Officer:	……………………………………………….
Mission Documentation Specialist:	……………………………………………….
Communication Officer:	……………………………………………….

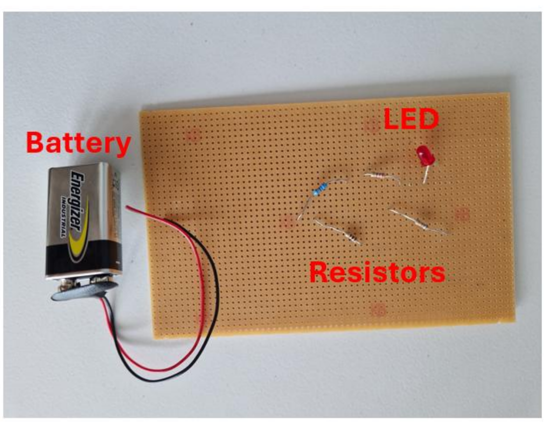
Welcome aboard!

On your table you can find several tools. Please make sure that, before using each tool, you read the relevant safety and operation instructions found in the ***Equipment Instructions Sheet***.

Please put on your safety goggles,
and wear them for the duration of the workshop.

Challenge 1: Find the Damage!

Due to the unknown signal, the spaceship's communication system has failed, leaving you unable to contact mission control back on Earth. We suspect that one of the resistors on its electric circuit board is not connected properly. Your task is to identify the faulty connection to restore the communication system.



See if you can identify the faulty resistor by using either the RGB torch, the UV torch or the infrared camera.

What did you observe? Which of the three tools helped you?

____

____

Explanation

What tool was used to identify the faulty resistor on the circuit board? Choose the correct answer.

- ☐ Our eyes, because they are very good at detecting problems.
- ☐ A torch, to illuminate the circuit board and see finer details.
- ☐ An infrared camera, because it detects temperature variations, revealing that the correctly connected resistors heat up.
- ☐ A UV torch, because it highlights cracks or burns not visible when using the RGB torch.

Did you know? We can feel infrared radiation as heat. In astronomy, we use terrestrial and space telescopes to observe infrared radiation coming from space. The James Webb Space Telescope (called "JWST"), launched in December 2021 is specifically designed to detect infrared radiation. In this way, we can find out how the first galaxies formed after the Big Bang and study the atmospheres of *exoplanets* (planets outside the Solar System).

The JWST, with a diameter of 6.5 meters.

Image taken by the JWST.

Challenge 2: Adjust your sensors!

With the communication system partially restored, the mission control says that, after this malfunction, the ship's sensors must be re-adjusted to detect the signal's origin. To do that, you need to analyze the visible light.

When visible light passes through a prism, it splits into different colors, like a rainbow.

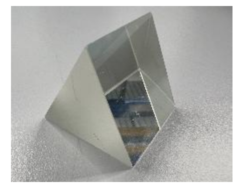
Prediction

Think first! How will these colors (blue, red, green, yellow, violet) be arranged and why? Write your prediction here.

The order of colors is ____

Observation

Now you can observe, using the RGB torch and the prism.



Place the prism on the table and illuminate it with the torch. Try to find the optimal angle in order to produce a rainbow.

The order of colors is ____

Did your observation match your predictions? Yes ❒ No ❒

Did you know that light has energy? Each light color corresponds to a different energy.

Which light color do you think has higher energy? red ❒ green ❒ blue ❒

Explanation: Light dispersion

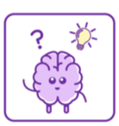
When visible light passes through a prism, it splits into different colors ("light dispersion"). This happens because different colors of visible light have different energies and bend ("refract") by different amounts. Blue light bends more because it has higher energy, and red light bends less because it has lower energy.

Did you know? The cover of the iconic album "Dark Side of the Moon" by the famous band Pink Floyd is inspired by Isaac Newton's light experiments in the 17th century and the phenomenon of light dispersion.

"Every time I listen to it, I feel like I'm be transported... It is just right for what like to be weightless looking out window of a spaceship."
Chris Hadfield, astronaut

The ship's sensors are now adjusted, but you need to fine-tune the ener detection system. By observing how different highlighter colors behave unc different types of light, you will enhance the ship's ability to detect and decode t signal.

Draw one horizontal line with each of the highlighters (orange, yellow, blue and green) inside the box. Make sure that they are separated.



Prediction

Think first! What do you expect to happen to the lines when you shine red, green and blue light on them? Choose the answer that you think is correct.

- ☐ The blue highlighter is visible under blue light, and the green highlighter under green light.
- ☐ All lines will appear the same regardless of the light color.
- ☐ Some lines will appear brighter than others, depending on the light color.

Observation

Observation: Shine the RGB torch on the paper (red, green, blue). What do you observe? Which highlighter colors are brighter each time?

Red: ____

Green: ____

Blue: ____

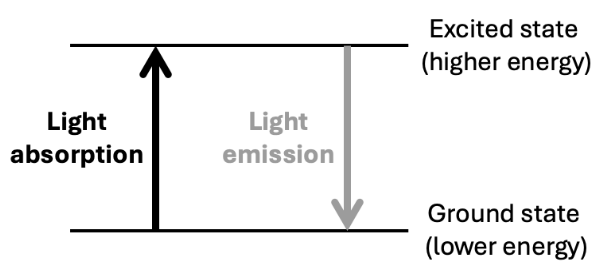
Did your observation match your predictions? Yes ❒ No ❒

What happens if you use the UV torch? _________________________________

Attention! Always wear your safety goggles when you use the UV torch!

Explanation: Fluorescence

When we shine light on a material, the light interacts with the electrons of the material and transfers energy to them. If the energy is high enough, the electrons get "excited" which means that they jump to a higher level of energy, kind of like climbing a step.



After a little while, they fall back down to their original level and release the extra energy in the form of light. For some materials, this light can be in a different color and has less energy than the initial light. This phenomenon is called "fluorescence".

Did you know? Highlighters contain a special dye which can take in high-energy light (like blue or ultraviolet) and then shine back lower-energy light (like yellow or green).

Why isn't a yellow highlighter visible under red light? Choose the correct answer.

- ☐ Because red light is too dim.
- ☐ Because red light doesn't have enough energy to excite the dye in the highlighter.
- ☐ Because yellow light absorbs red light.
- ☐ Because the highlighter only works in the dark.

Did you know? All scorpions will fluoresce under ultraviolet (UV) radiation. They can be easily spotted at night as they glow bright greenish-blue, due to a substance in their skin.

Challenge 3: Explore the Electromagnetic Spectrum!

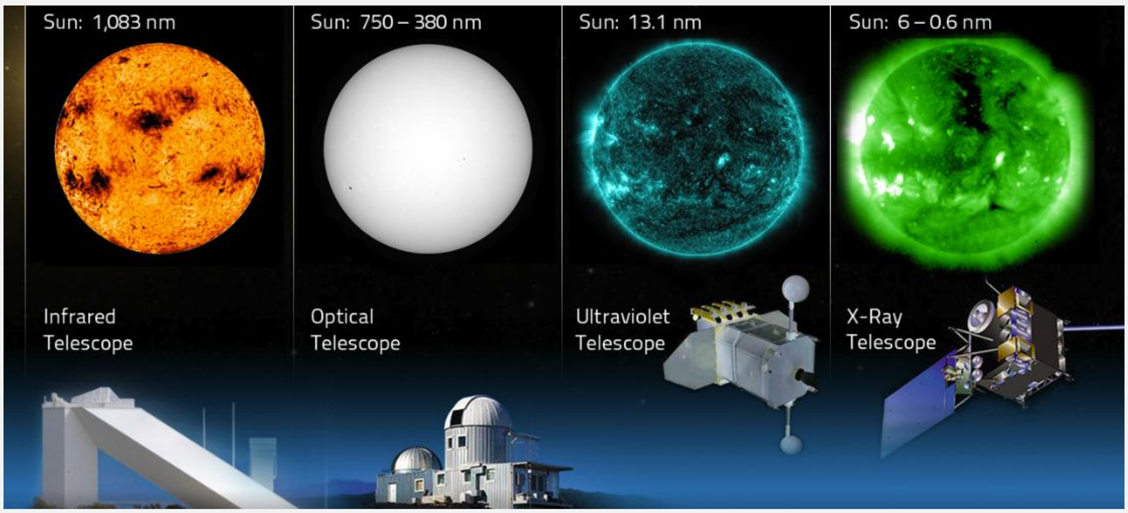
Now that the spaceship's sensors have been adjusted, the signal's origin has been narrowed down, but you need to identify its precise energy. By exploring the electromagnetic spectrum, you will be able to decode the signal's message.

Arrange the cards in the correct order of the electromagnetic spectrum, starting with the region with the lowest energy. What is the correct order?

Match the different applications to the regions of the spectrum, by placing them below the electromagnetic spectrum cards. What matches did you find?

Once you have finished matching the cards, write down the characters that you read on the top left of the cards and call your commander!
The code is ____.

Did you know? The electromagnetic spectrum is composed of radiation of different energies, from radio waves to gamma rays. Without it, you wouldn't be able to watch TV, use your Wifi, send a text message, or use a microwave oven. Humans are able to see only a small part of this spectrum, known as "visible radiation" or "visible light". While in everyday life we use the term "light" to refer to visible light, scientists use "light" to refer to the whole spectrum of electromagnetic radiation.
Stars, planets, black holes and other objects in our Universe emit electromagnetic radiation. By detecting this radiation using specialized telescopes, we can understand cosmic phenomena that aren't visible in the same way through ordinary optical telescopes.



Four images of the Sun captured using different telescopes that are able to detect infrared, visible, ultraviolet and X-ray radiation. Notice the spots that are standing out in these different images! In this way, astrophysicists can better understand the Sun.

Challenge 4: Examine radiation emitted by different objects!

While navigating, the spaceship is getting hit by various small objects. In order to proceed safely, you need to examine them using a Geiger Müller detector.

Did you know? A Geiger Müller detector (simply called a Geiger counter) is a device used to detect and measure radiation that comes from various sources, both natural and artificial. The more clicks you hear, the more radiation is detected by the detector.

You need to examine the different objects (glass beads, rock) by taking measurements with the Geiger counter.

Prediction

Think first! Which object do you expect to emit the most radiation?
The object emitting the most radiation is _________________________________

Observation

Turn on the Geiger counter and follow the instructions on the Equipment Instruction Sheet, in order to set the detector in “counting” mode.

> Attention! Do not take the rock out of the plastic case!

For each object, take a measurement for 30 seconds. Make sure to reset the counter before starting a new measurement. After you have finished all measurements, turn off the Geiger counter and write down your observations:

Emits the most radiation: ___________________________________
Emits the least radiation: ___________________________________

Did your observation match your predictions? Yes ❒ No ❒

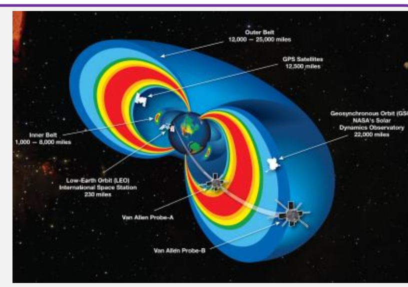
Explanation: Natural Radioactivity

Natural radioactivity is the spontaneous transformation of unstable atomic nuclei found in nature. This process releases energy in the form of radiation, which can be either particle radiation in the form of alpha particles (Helium nuclei) or beta particles (electrons or positrons), or electromagnetic radiation in the form of gamma particles (high-energy photons). Common naturally radioactive elements include uranium, thorium, and radon.

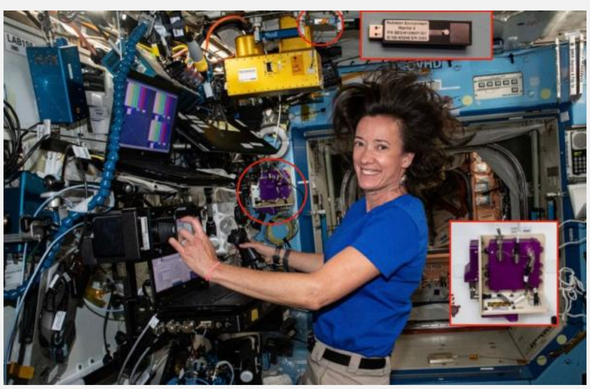
Challenge 5: Build a detector!

As you get closer to the signal's source, you encounter the Van Allen radiation zone. To navigate through this zone, you need to use another type of detector, which is called pixel detector. This will help you detect and identify particles.

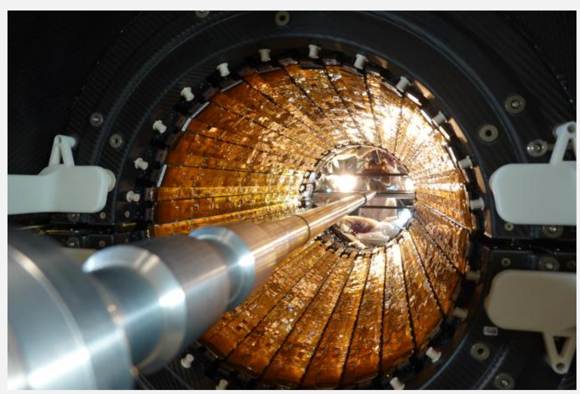
Did you know? The Van Allen radiation belts are regions of high-energy particles trapped by Earth's magnetic field, and they pose significant challenges for space travel, as they can be harmful for both spacecraft and astronauts.



Did you know? The Geiger counters that you used before do not provide detailed information about the energy or type of the particles. In order to be able to identify the type of particles, you will now use a pixel detector.
A pixel detector is a high-tech device that captures images by detecting individual particles. Each pixel in the detector records the energy and position of incoming particles, allowing for precise imaging. Pixel detectors are used in many experiments at CERN. Today we will use the MiniPIX-EDU detector, a compact version used in education, while a more advanced version is at the moment on the International Space Station.



Pixel detector on the International Space Station



ALICE Inner Tracking detector at CERN, consisting of about 12 billion pixels (in gold)

Ask your commander for the LEGO building instructions, and assemble the detector while you explore its different parts.

After you have finished, identify the function of each component by connecting the dots below.

MiniPIX – EDU Parts			**Function**
aluminum layer	●	●	Has extra electrons ready to move, helping to detect particles.
n-type silicon layer	●	●	Connects and collects signals from all the pixels and readout cells.
p-type silicon implantation	●	●	Protects the sensor and conducts electricity.
single pixel readout cell	●	●	Has extra "holes" for electrons to move, helping to detect particles.
electronics chip	●	●	Reads signals from each pixel when a particle hits.

Now, you are ready for the final challenge! Call your commander to give you the state-of-the-art equipment to proceed, in exchange for the LEGO detector!

Challenge 6: Identify particle tracks!

You've made it past the radiation zone, but you now face a final challenge. By taking measurements and identifying particle tracks, you will unlock the coordinates of the signal's base and complete your mission.

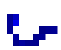
Prediction

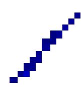
With the pixel detector, you will be able to observe tracks of muons, electrons (or positrons), alpha particles and photons. First, you need to match the different particles to their corresponding tracks.

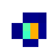
Hints:

- **Alpha Particles:** Alpha particles are Helium nuclei, composed of two protons and two neutrons. As they are very heavy, they interact with atoms strongly and lose their energy quickly, resulting in shorter paths.
- **Muons (or anti-muons):** Muons are much lighter than alpha particles but still heavier than electrons. They interact very weakly with matter, allowing them to penetrate deeply into the detector without losing a lot of energy or getting deflected.
- **Electrons (or positrons):** Electrons/positrons are much lighter than muons. Due to their low mass, electrons are more easily deflected by interactions with the detector, resulting in more swirly movement.
- **Photons:** Photons are neutral particles, so they don't always interact with matter. When a photon enters a detector, it can pass through without interacting, or it can give all its energy to an electron, which can then knock out other electrons.

Write down the particle that each track corresponds to from the list above.







________________ ________________ ________________ ________________

Observation

Follow the steps on the Equipment Instructions Sheet to connect and operate the pixel detector.

Take a new measurement, according to the instructions. What do you observe? Think about where these particles are coming from.

Attention! Do not touch the window of the pixel detector!

Write down the number of tracks that you can see for each particle type.

alpha: _____ electron/positron: _____ muon/antimuon: _____ photon: _____

Click on the “Tracks” tab (above the “Spectra”). Here you can see the exact number of tracks for each particle.
Does your observation match this number? Yes ❒ No ❒ Almost ❒

You can repeat the measurement by placing the rock 5 cm above the pixel detector. What do you observe?

Explanation: Background radiation on Earth

Here on Earth, we are constantly exposed to some radiation that is always present in the environment, which we call ‘background radiation’. This radiation has always been part of our environment, and it's something we are exposed to every day, but it's usually in very small, safe amounts. This radiation is coming from two main sources: materials on Earth (like rocks, soil, bananas, and even the air) and cosmic radiation traveling from outer space towards Earth (like the sun and other stars). At sea level, Earth's atmosphere protects us from most cosmic radiation, but as you climb higher, like on a mountain or in an airplane, there's less atmosphere to block it, so you’re exposed to more cosmic radiation.

Final Challenge

On the three cards you can see some measurements taken with a pixel detector at three different locations: in an office at CERN, on an airplane and onboard a satellite. Can you guess which measurement corresponds to which location?

Place the cards in the correct order from the lowest to the highest radiation level. You will find a number on the top left of the cards.
The code is ____

Now, call your commander to share your findings and combine them with those of the other teams!