Cosmic SOS

Discover particle detectors as you travel through space!

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

Welcome aboard!

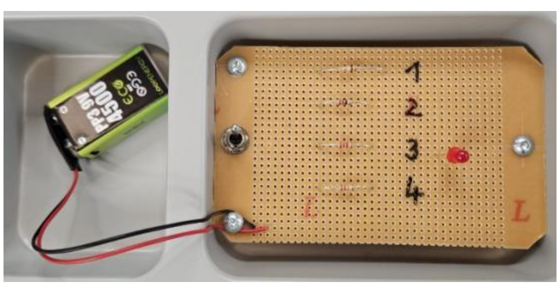
Please put on your safety goggles,
and wear them for the first 3 challenges

Challenge 1: Find the Damage!

There is an issue, the spaceship can't talk to Earth!

Carefully connect the 9V battery (without taking out the board) and switch on the red LED.

Some resistors (1, 2, 3, 4) on your electric circuit board may be broken, even if the red light is on. Use the RGB torch, UV torch or thermal (infrared) camera to find the broken ones that don't allow electric current to go through.



What did you find?

____

____

____

____

Disconnect the battery.

Explanation

What tool did you use to find the bad resistor? Pick one:

- ☐ RGB Torch – shows small details in different colours
- ☐ Thermal (infrared) camera – shows hot resistor (= proof of electric current)
- ☐ UV torch – shows hidden cracks or burns

Did you know? We can feel infrared radiation as heat. In astronomy, we use telescopes on Earth and in space to observe infrared radiation coming from space. The James Webb Space Telescope, 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 planets outside the Solar System.

The JWST, with a diameter of 6.5 meters.

Image taken by the JWST.

Challenge 2: Adjust your sensors!

"This is Mission Control, can you hear us? The sensors must be fixed to find the signal! Use visible light — either through a prism or a diffraction grating — to break it into colours, like a rainbow!"

Prediction

Think first! How will these colours (blue, red, green, yellow, violet) line up? Why?

Order of colours: ____

Observation

Use the RGB torch to shine white light through the small gap of the diffraction grating.

Order of colours observed: ____

Did your observation match your predictions? Yes ❒ No ❒

Explanation: Light dispersion

When white light goes through the diffraction grating, it splits into colours. Each light colour corresponds to a different energy and bends by different amounts: Light with high energy bends less than light with low energy.

Which colour has more energy? red ❒ green ❒ blue ❒

"Mission Control here, the ship's sensors are set but the energy system needs fine-tuning. Watch how highlighter colours act under different lights to help detect the signal!"

Draw one horizontal line with each highlighter (orange, yellow, blue, green) in the left box. Keep the lines separate.

Prediction

Think first! What will happen to the lines under red, green and blue light?

- ☐ Blue highlighter shows under blue light, green under green
- ☐ All lines look the same under any light
- ☐ Some lines look brighter depending on the light

Observation

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

Red: ____

Green: ____

Blue: ____

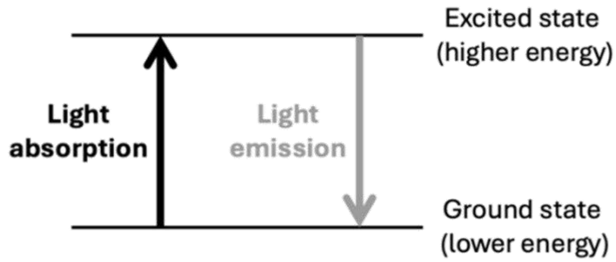
Did your observation match your predictions? Yes ❒ No ❒

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

What happens if you use the UV torch? ___________________________________

Explanation: Fluorescence

When light hits a material, it gives energy to its electrons. The electrons jump up - like climbing a step. Then they fall back and give off light. Sometimes the new light is a different colour and lower energy.



This is called *fluorescence*. Highlighter pens contain a special dye which can take in high-energy light (like blue or ultraviolet) and shine back lower-energy light (like yellow or green).

Why isn't a yellow highlighter colour visible under red light?

- ☐ Red light is too dim
- ☐ Red light doesn't have enough energy to excite the dye in the highlighter
- ☐ The pen only works in the dark

Did you know? All scorpions 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!

"The ship's sensors are ready. We know where the signal comes from, but now we must find its energy. Use the electromagnetic spectrum to decode the message"

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 Wi-Fi, send a text message, or use a microwave. Humans are able to see only a small part of this spectrum, known as "visible radiation" or "visible light".

Arrange the cards from lowest to highest energy. Match the applications with the right spectrum region.

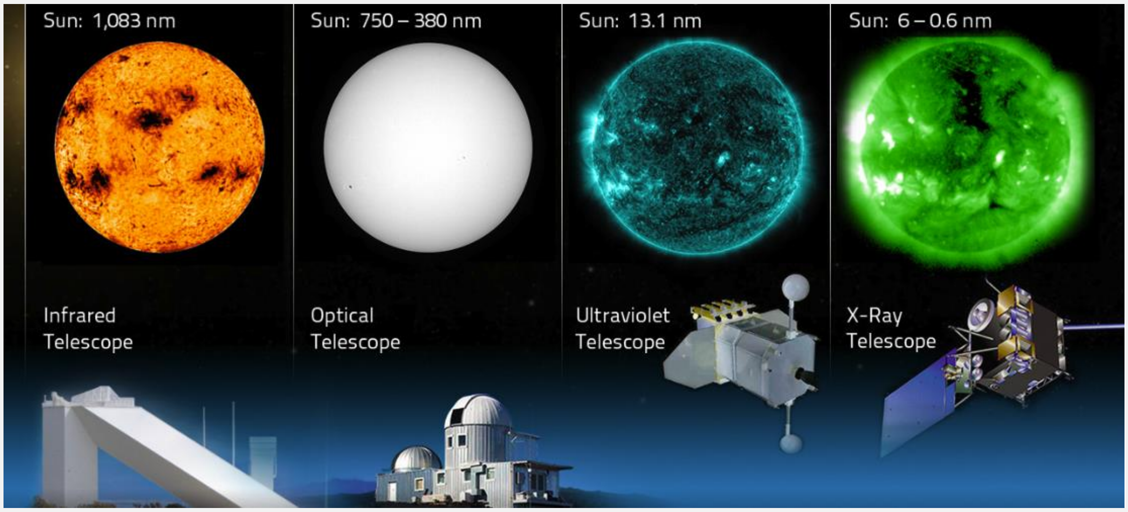
Write the letters from the top left of the cards (first spectrum, then applications)

The code is______________________________

Call your commander to find a box exactly matching this code!

Did you know?

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 which detect infrared, visible, ultraviolet and X-ray radiation. In this way, astrophysicists can better understand the Sun.

Challenge 4: Examine radiation emitted by different objects!

"The ship is hit by small objects; they might emit ionising radiation. To stay safe, check them with a Geiger counter!"

Prediction

Think first! Look at the **glass bead, rock, and LEGO brick**. Which object do you expect to emit the most ionising radiation?

____

Observation

Turn on the Geiger counter. Follow the equipment sheet inside the box of the Geiger counter to set it to *counting mode*.

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

For each object, measure for 30 seconds. Reset the counter before each new test.
TIP: While you are waiting, take out the LEGO instructions and start building!

Glass bead	_____ counts in 30 s
Rock	_____ counts in 30 s
LEGO brick	_____ counts in 30 s

Turn off the Geiger counter.
Did your observation match your predictions? Yes ❒ No ❒

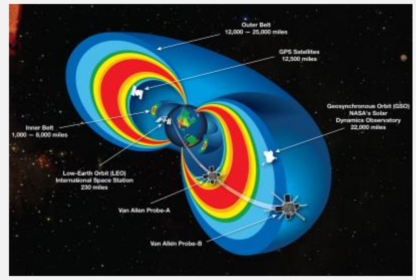
Explanation: Natural Radioactivity

Natural radioactivity is when instable atoms change by themselves and give off radiation (alpha, beta or gamma). Some natural radioactive elements are uranium, thorium, or radon. The rock you studied has some thorium atoms. The glass bead looks a bit greenish, because it has some uranium atoms. The LEGO brick does not have any radioactive atoms. The air around us has a small number of radioactive radon atoms.

Challenge 5: Build a detector!

"You are getting closer to the signal! You are now near the Van Allen radiation zone. To pass safely, use a pixel detector. It will help you find 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.



The Geiger counter that you used before cannot provide detailed information about the energy or type of the particles. To be able to identify the type of particles, we need a pixel detector.

Use the LEGO instructions to build the detector while you explore its different parts.

After you have finished, put the layers in the right order from bottom to top:

p-type silicon, n-type silicon, electronics chip, aluminium layer

Top

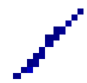
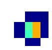
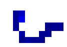
Bottom

Challenge 6: Identify particle tracks!

"You passed the radiation zone. Now the last challenge: measure and find the particle tracks. This will give you the signal's coordinates and finish the mission"

Prediction

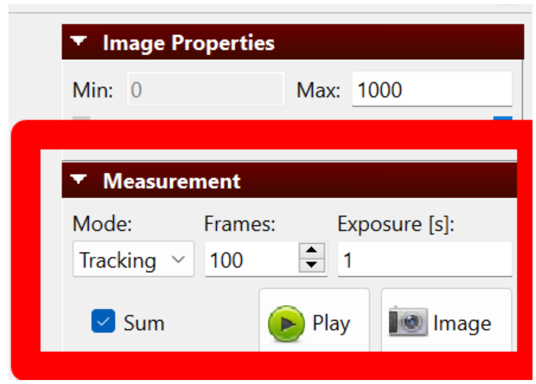
With the pixel detector you can see tracks of these particles: muons, electrons, alpha particles and photons. What kind of track do you think they would leave? **Connect the dots between particles and tracks:**

Electrons ● Bounce around	●	
Muons ● Move straight and far	●	
Alpha Particles ● Stop quickly with big effect	●	
Photons ● Barely leaves a mark	●	

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!

Observation: What particles can we measure?

Follow the instructions inside the pixel box to connect the pixel detector. Open the lid of the detector. **Keep it open only when you are measuring. Do not touch the window of the detector.**



In the Measurement box, set:

- Mode to "Tracking": this means particle tracks are measured
- Frames to 100: this means the detector will take 100 photos
- Exposure to 1 s: this means it takes 1 s to take one photo
- Check "Sum": this means the software will put all photos together into one
- Click "Play" to start a new measurement. Wait until the number of frames is completed (shown at the bottom right corner).
- Click "Stop" to end your measurements.

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

alpha: ______ electron: ______ muon: ______ photon: ______

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

Explanation: Background radiation on Earth

Background radiation is always around us. It comes from Earth (e.g., radioactive elements in rocks) and from space (e.g., cosmic radiation from star explosions). At sea level, the atmosphere blocks most cosmic radiation, but higher up, like on a mountain or in a plane, more reaches us.

Final Challenge

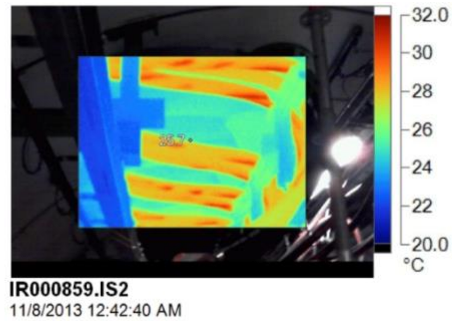
You have three cards showing pixel detector measurements: office at CERN, airplane, and satellite. Can you guess which is which?
Place the cards in the correct order: office, airplane, satellite.
You will find a number on the bottom left of the cards.

The code is ____

Debriefing of challenges 1 and 2

Challenge 1: Find the damage!

Using the IR (Infrared) camera you can see, that only 1 of the 4 resistors (number 1) gets warm. That means only this resistor has electric current going through. The other resistors are not connected to the battery, maybe a cable got lose? At CERN, technicians use IR cameras to check electric circuits and to find faulty electrical cables.



Challenge 2: Adjust your sensors!

Similar to a prims, a diffraction grating will separate white light into the different colours that make up white light. This also happens when sunlight passes through rain drops and we can observe rain bows. Red light has the lowest energy, blue light has the highest energy.

When you shine the RGB torch on the paper with the 4 lines drawn with the 4 highlighter pens, you can observe that red and green light do not have enough energy to excite the electrons in the highlighter dye to higher energy levels. This means the lines do not appear bright under red or green light (they do not fluoresce). Only blue light and UV light have enough energy to produce fluorescent colours.

You might get confused by what you have learned about colours before. E.g. red things are red, because they absorb light of all colours except red, which they reflect. In this challenge, fluorescence is the dominant effect.

There are similar experiments at CERN in the antimatter factory. We shine laser light on anti-atoms to excite anti-electrons to higher energy levels. Then we measure the energy of the light they emit when falling back to the ground level. We compare this with normal atoms to understand the differences between antimatter and normal matter.