Engineers Week

Space Debris

Classroom
Resource Booklet

SFI Curious Minds/ESERO Framework for Inquiry

Theme	Space Debris
Curriculum	**Strand>Strand Unit>Curriculum Objectives:** Materials> Materials and change -- examine the changes that take place in materials when physical forces are applied Materials>Properties and characteristics of materials> -- group materials according to their properties and/or composition -- identify how materials are used Energy & Forces>Forces 1st/2nd class -- investigate how forces act on objects -- explore how objects may be moved by pushing and pulling -- observe and investigate the movement of objects such as toys on various materials and surfaces 3rd/4th class -- investigate falling objects -- explore the effect of friction on movement through experimenting with toys and objects on various surfaces -- explore how some moving objects may be slowed down 5th/6th class -- identify and explore how objects and materials may be moved -- explore the effect of friction on movement and how it may be used to slow or stop moving objects **Skills Development:** Working Scientifically: Questioning; Investigating & Experimenting; Analysing. Designing and Making: Exploring; Planning; Making; Evaluating.

Engage

The Prompt	Wondering	Exploring	Considerations for inclusion
Watch this segment from the film Gravity. Watch this video from PAXI about satellites and space debris.	What happens to satellites at the end of their lives? What happens to garbage in space? What kinds of things might be classed as space 'junk'? Teacher sets up the collision demonstration from PR51-Why is there Junk in Space? using marbles. Teacher demonstrates the marble-crisp impact to show how materials can fracture into many pieces. Discuss what the learners have seen and why they think this has happened. How might space agencies reduce the likelihood of space junk impacts?	Read articles about Space Junk from ESA Kids. Learners should explore the marble-crisps impact test to determine the best height and should consider how they might sort the fragments by size into three groups. Use PR52-Cleaning Up Space to describe the features of an active debris removal tool. • What sort of tool do they think would be needed to capture a satellite? • What would the tool be made from? Why? (It should be durable and light weight) • How might it work? Learners may carry out Activity 2 and 3 to explore two processes before they design their own. Use PR53-Coming Back to Earth Safely to carry out the first part 'Satellite Slowdown' with sheets of paper or bedsheets. How might we get satellites back to Earth?	

Investigate: WHY IS THERE JUNK IN SPACE?

Starter Question	Predicting	Conducting the Investigation	Sharing: Interpreting the data / results
How big is space debris? Learners will find out about space debris with uniform size crisps and using marbles as the impactor.	Learners should describe what they expect to happen as they drop the marbles onto the crisps. Different groups may have different heights and their predictions should reflect their chosen height.	Drop the marble three times onto the same crisp. After each drop count according to size.	What did each group/the class notice? Is there a pattern in their results? What happens to the number of pieces as the number of impacts increases? Learners might display their results in a graph or chart.

SFI Curious Minds/ESERO Framework for Inquiry

Investigate: CLEANING UP SPACE			
Explore	Plan	Make	Evaluate
Design a debris grabbing tool so you can help a space agency to design tools to remove space debris.	Learners should choose appropriate materials to design tools to tackle a specific problem and explain their reasoning.	Learners should design and make a prototype tool to pick up Lego blocks.	Each group should share their results and consider possible improvement to their designs. How does their device work? Is it able to capture a piece of space debris represented by pieces of Lego? Compare to ESA's ClearSpace mission designs.

Investigate: COMING BACK TO EARTH SAFELY			
Starter Question	Predicting	Conducting the Investigation	Sharing: Interpreting the data / results
Launch mini-spinners and then consider how to slow them down. Learners should consider possible variables and may make up their own starter question. Possible starter questions: How does changing the material affect the flight time of a spinner? How does changing the length of the wings affect the flight time of a spinner?	Learners should make a prediction of how their chosen change affects the flight time of the spinner. They might refer to forces and how they have changed the properties of the spinner.	Learners should adapt their spinners, test them, and record the new flight times. Learners should be able to explain how they have made their comparisons "fair."	Using the results of their tests, what do they think we should put into the 'satellites' backpacks'? How can slowing down the spinner in this activity be related to how satellites come back to Earth?

Take The Next Step

Applying Learning	Making Connections	Thoughtful Actions

From PR51-WHY IS THERE JUNK IN SPACE?
Learners might…
- change the height of marble drop or drop the marbles from different heights which could be linked to debris colliding at different speeds – the higher the marble is dropped from, the faster it will collide with the crisp
- change the mass of the marble
- use marbles which have different masses which could be seen to represent lighter/heavier pieces of debris colliding with satellites.
- change the material being tested, use a different type of crisp/paper.

Find out about the Zero Debris Charter that was proposed in 2023. View this 13-minute video from 2021 called Time to Act.

Some astronauts think that human spaceflight might become impossible in a few years, due to the risks of space debris. Do you think that is important?

Play the PAXI game https://www.esa.int/kids/en/learn/Technology/Space_debris/Space_Cleanup

Reflection	
Reflection	• Did I meet my learning objectives? • What went well, what would I change? • Were the cross-curriculum opportunities used? • Are the learners progressing with their science skills? • Have you recorded and reviewed any new vocabulary? • What questions worked very well? • What questions didn't work well? • Ask the learners would they change anything or do anything differently

primary | PR51

teach with space

→ WHY IS THERE JUNK IN SPACE?

Teacher guide & student worksheets

TEACH WITH SPACE - Why is there junk in space | PR51
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WHY IS THERE JUNK IN SPACE?

Fast facts

Subject: Mathematics, Physics

Age range: 7-11

Type: student activity

Complexity: easy

Lesson time required: 2 hours and 30 minutes

Cost: low (0 – 10 euros)

Location: indoors or outdoors, classroom, school hall

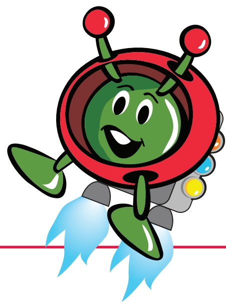
Includes the use of: craft material (cardboard) marbles, small balls, crisps

Keywords: materials, forces, Earth and space, solar system, orbit, forces, contact, collision, friction, impact, debris, gravity

Brief description

In the first activity, the children will investigate how collisions between objects can produce further impacts. In the second activity, they go on to investigate how such impacts can cause some materials to fracture into many particles.

These activities may be taught separately or combined for progressive learning.



Learning objectives

Having completed these activities, students will now...

- Understand that collisions between objects in Earth's orbit can lead to several more collisions
- Understand that satellites burn up upon re-entry to Earth's atmosphere
- Understand that repeated impacts increase the amount of space debris
- Be able to work scientifically by making careful observations, looking for patterns and relationships

Success Criteria

During these activities, students will demonstrate their ability to...

- Collect and record data from their own observations and measurements
- Make predictions based on preliminary results and set up further tests
- Relate their results to the wider scientific issue in question

Summary of activities

Title	Description	Outcome	Requirements	Time
1.Collisions in Space	Students will model collisions between debris and satellites, and observe that one collision can lead to several more.	Students will learn that collisions between objects in Earth's orbit can lead to several more collisions, and that satellites burn up upon re-entry to Earth's atmosphere.	None	1 hour
2.How big are space debris?	Students will investigate how collisions with space debris can cause some materials to fracture into many pieces.	Students will learn that repeated impacts increase the amount of space debris. They will also learn to work scientifically by making careful observations, looking for patterns and relationships	None	1.5 hours

INTRODUCTION

Humans have been sending satellites into space for decades. These missions allow us to gain more information about our Sun, the Earth, and other planets, and look deep into space at black holes, distant stars and galaxies. There are also communications satellites, weather satellites, and the International Space Station. But what happens to a satellite once it has served its purpose? It continues to circle (orbit) around Earth! Space debris, or space 'junk', refers to human-made objects that are orbiting the Earth but no longer serve a useful purpose. Examples include large objects such as non-functioning satellites as well as smaller objects such as flecks of paint.

Space debris is posing an increasingly large threat to spacecraft and functioning satellites - the more debris that accumulates, the more likely a collision is. Scientists are constantly monitoring large pieces of debris (larger than 10cm) using space telescopes to assess the risk the debris poses. If possible, they take action to protect satellites and spacecraft. The International Space Station sometimes conducts 'an avoidance manoeuvre' to prevent damage from debris.

However, there are millions of pieces of space debris that are too small to be tracked by scientists, and the number is rapidly increasing. The amount of space debris within Earth's orbit is now at a point that we can no longer ignore, and the situation is only going to get worse if we do not act. The European Space Agency's (ESA) Clean Space programme is attempting not only to minimise the debris produced by future space missions, but to actively reduce the debris already in orbit.

DID YOU KNOW?

As more collisions occur, debris is broken into smaller and smaller pieces. This means that small pieces of space debris are more common than large pieces. Statistical models estimate the amount of space debris orbiting Earth to be:

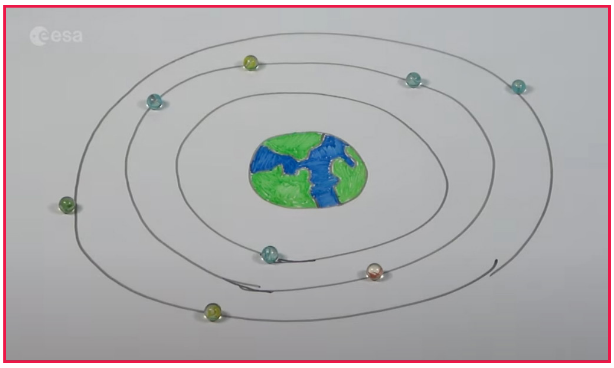
As of November 2021:
36500 objects greater than 10 cm
1000000 objects from 1 to 10 cm
330 million objects from 1 mm to 1 cm

ACTIVITY 1 – COLLISIONS IN SPACE

In this activity, students will model collisions between debris and satellites, and observe that one collision can lead to several more. You can watch the video of the activity here.

Equipment

- Marbles or balls (up to 100)
- Large sheet of paper
- Marker pens or chalk
- Activity sheet 1 (optional)



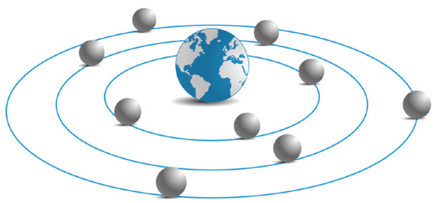
ADVANCE PREPARATION

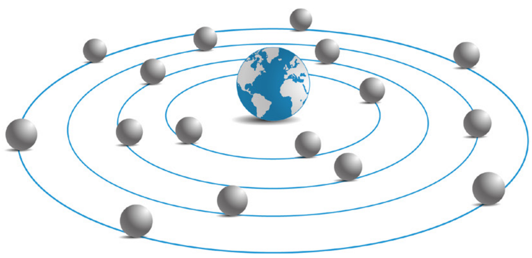
Draw 5 concentric circular orbits on a large sheet of paper. Draw Earth in the centre. Alternatively, chalk the orbits on the floor of the hall or on the playground.

Exercise

Hold a class discussion around the following points:

- *What happens when you throw something into the bin? Where does it end up? You may choose to show the class an image of landfill.*
- *What happens to garbage in space? What kinds of things might be classed as space 'junk'?*
- *You may choose to show the class the image at the beginning of this resource of space debris orbiting Earth.*





Encourage the class to think about how garbage is created here on Earth – when people are finished with something they throw it away and, unless they recycle it, it ends up in a large pile of landfill. Explain that a similar thing happens in space – unless space junk is removed, it stays in orbit around the Earth, littering the space around us.

Watch the Paxi animation. *The video shows why we need to tackle the space debris problem. Paxi guides the children into Low Earth Orbit (LEO), 500-2000 kilometres from Earth! There, he finds there is a traffic jam of (anthropomorphised) satellites, which are sometimes colliding with each other. The situation is chaotic.* ***Pause the video once you have seen the satellites arguing.***

Next, gather the class for the collision demonstration. Place marbles or balls in small groups onto your pre-prepared circular orbits. Explain that the marbles or balls represent satellites and items of space debris. It may be useful to use one colour of marbles for the space debris, and another for the active satellites. If this is not possible, you might like to draw small circles around the marbles that are 'satellites'. Demonstrate that pushing a marble (this represents a piece of space debris) into the groups causes impacts that produce secondary impacts.

Encourage the children to participate in launching the marble, predicting where collisions might occur when the direction or force of the launch is changed.

Discussion

Gather the students and hold a discussion about what they learned from this activity. Points to consider may include:

- *In this activity, the marbles were able to pass over the picture of the Earth. What do the students think would happen if an actual satellite or piece of space debris started falling towards Earth? Do they think this would be a good or a bad thing?*

Explain that satellites are designed so that they burn up on re-entry to the Earth's atmosphere. The Earth's atmosphere can be thought of as a bubble of 'air' that surrounds us – because we live inside this bubble, we are able to breathe. This 'air bubble' has a lot more friction than outer space, and it is this friction that causes debris to burn up upon re-entry. Explain that debris falling through the atmosphere is generally a good thing because if it burns up, it will not impact life on Earth.

- *Each time the students push a marble in this activity, what could this represent in terms of space debris?*

Explain that a 'push' could represent the piece of debris falling out of its orbit. In reality, this would be caused by the low levels of friction experienced in Low Earth Orbit (the outer edges of the 'air bubble').

- *What do they notice when a piece of 'debris' hits a 'satellite'?*

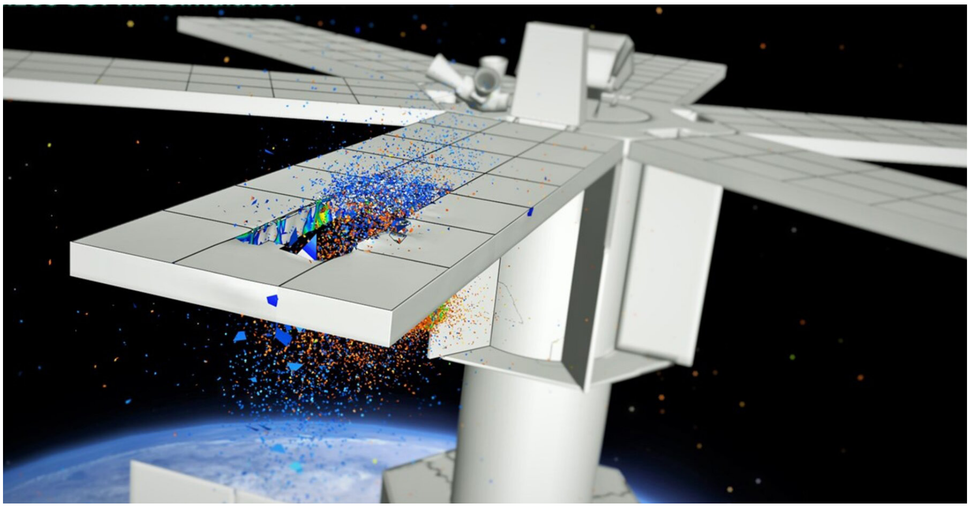
The students should observe that the satellite is knocked out of its orbit. Explain that it would take a large piece of debris to cause this to happen in real life, which is why space scientists monitor debris larger than 10cm. More commonly, debris causes parts of satellites to break off, as will be demonstrated in Activity 2.

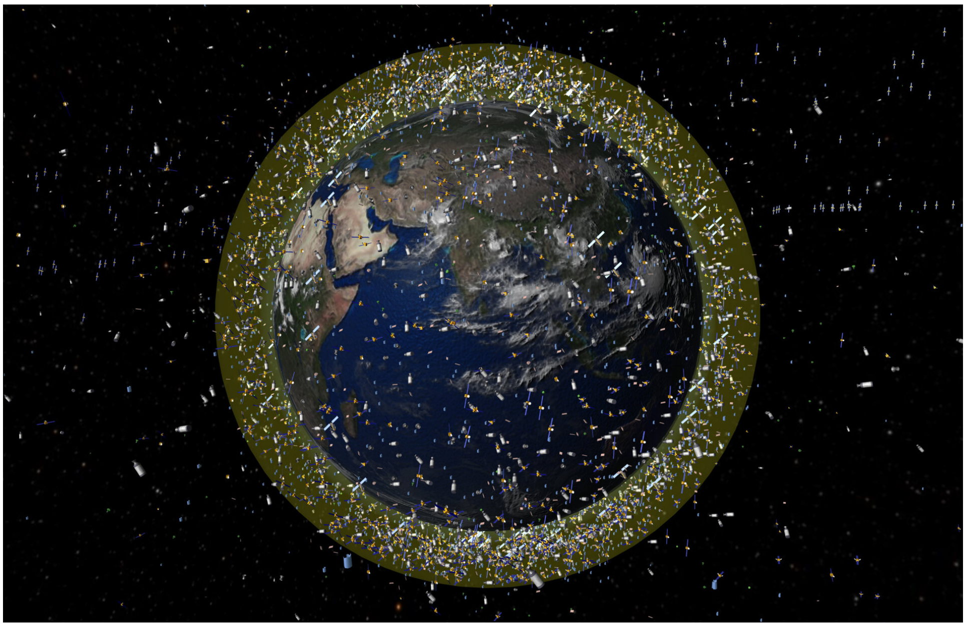
Conclude that an isolated collision generally leads to further collisions which can have varying effects.

Explain that scientists investigate the effect of collisions between objects using computer simulations and by physical impact tests. ESA has a test facility where scientists investigate the effects of impacts on materials used for spacecraft or satellites, to make sure that they can meet the strict standards required for space missions.

DID YOU KNOW?

With this activity we try to simulate the Kessler effect. It is a theory proposed by' NASA debris expert Donald Kessler. Successive collisions can cause chain reactions involving satellites and other objects in orbit around Earth – this is the Kessler effect. But the Kessler effect can be stopped if enough debris items are removed from key orbits.

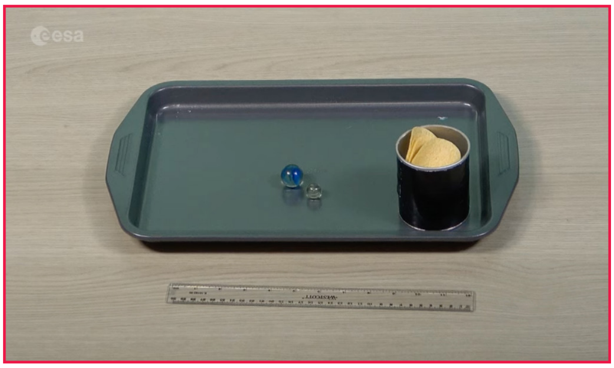




ACTIVITY 2 – HOW BIG ARE SPACE DEBRIS?

In this activity, the students will investigate how collisions with space debris can cause some materials to fracture into many pieces. You can watch the video of this activity here.

Equipment



- Marble
- Crisps
- Deep sided tray or box
- Ruler
- Activity sheet 2

Exercise

Instruct the students to set up their testing station. This should involve clearing an area in which to conduct the tests and placing newspaper sheets on the floor to minimise post-experiment clean-up. The groups should predict what they think will happen and why. They should try a couple of test drops before starting the investigation in order to decide on the most appropriate height of drop. Encourage them to think of a way of sorting or separating the fragments of crisp into three groups.

Instruct the students to drop the marble three times onto the same crisp. After each drop, the students should count according to size (<1cm, 1-5cm, >5cm) the number of pieces of crisp produced and record them. The students can choose their own method of recording or they may like to use the table provided on Activity sheet 2.

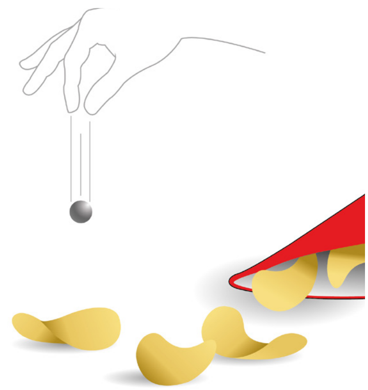


Table 1 shows example data collected from impact testing.

Number of pieces after each drop				
Drop from 25 cm	<1cm	1-5cm	>5cm	Total
1	2	2	1	5
2	10	2	1	13
3	13	3	1	17

Discussion

Display each group's drop test results and ask the class to compare them. Some points to consider in the discussion may include:

- *What did each group/the class notice? Is there a pattern in their results?*
- *What happens to the number of pieces as the number of impacts increases?*
- *Explain that the more collisions that take place, the more pieces of debris will be created. Furthermore, the more particles produced, the greater the risk of collisions.*
- *What advice would they give to the scientists and engineers designing satellites and spacecraft?*
- *What kind of materials do they think would be suitable? Why?*

Watch the first minute of this animation

Extension

The students could extend the impact tests by

- changing the height of marble drop
- dropping the marbles from different heights could be linked to debris colliding at different speeds – the higher the marble is dropped from, the faster it will collide with the crisp.
- changing the mass of the marble
- using marbles which have different masses could be seen to represent lighter/heavier pieces of debris colliding with satellites.
- changing the material being tested
- using a different testing material could emphasise that some materials fracture more easily than others, therefore scientists need to be careful when choosing materials to build their satellites with.
- changing the number of layers of material or number of crisps
- using multiple layers of the testing material could be a good way of showing why layers are used in the engineering of satellites – what happens when they have a sturdier layer on top of a more fragile layer?
- designing a new way of impact testing
- scientists and engineers are always looking to test their designs in many different ways, as different tests can highlight different strengths/flaws.

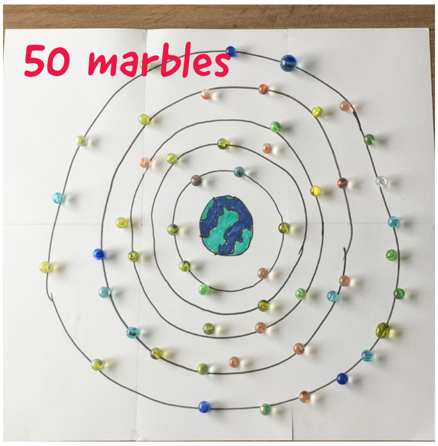
When investigating each of the above variables, students should consider how these changes could relate to space debris.

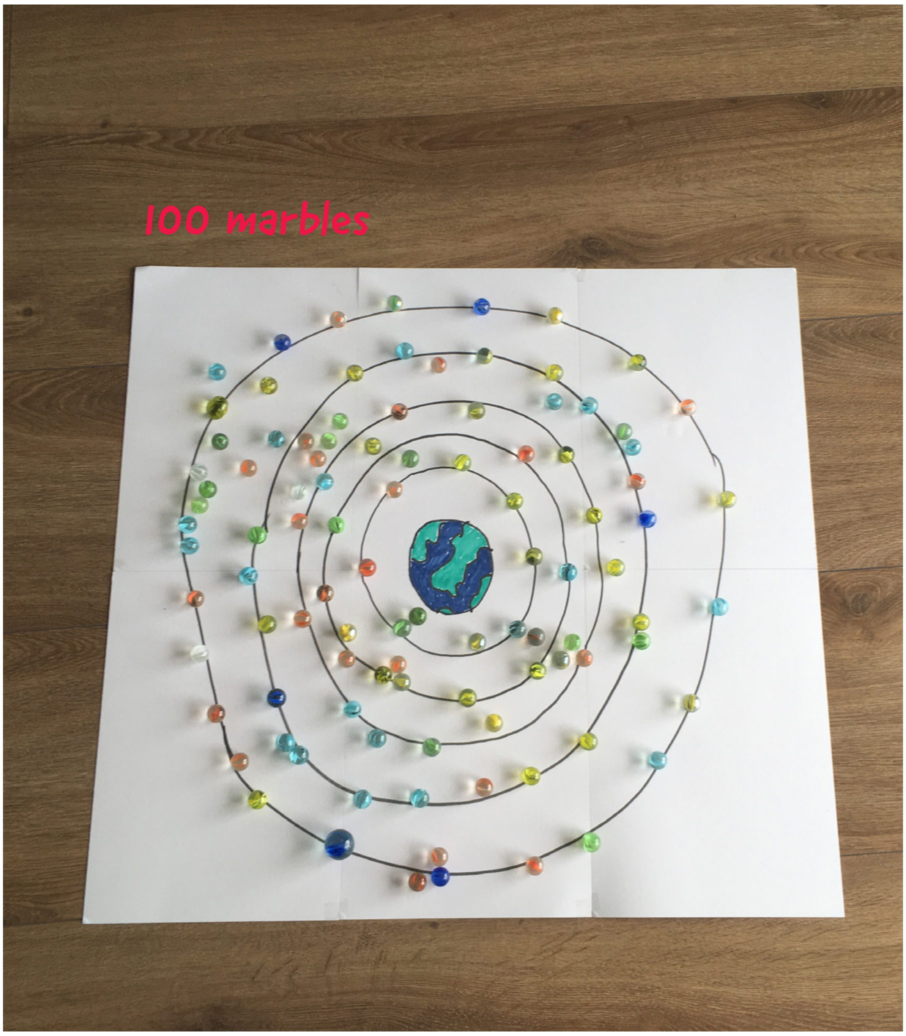
STUDENT WORKSHEET

ACTIVITY 1

You will be rolling 'debris' (a marble) towards Earth to investigate chain-reaction collisions. Take before and after pictures for 3 impact tests: one with 10 marbles in orbit, one with 50 and one with 100 and add your results to the table below.

Note: *if you do not have enough marbles, adjust the numbers in the table and use what you have. Be aware that the difference in number of collisions will not be as obvious when using less marbles.*





Number of satellites (marbles) in orbit	Picture before	Picture after
10		
50		
100		

1. What do you notice about the amount of collisions compared to the number of satellites in orbit?

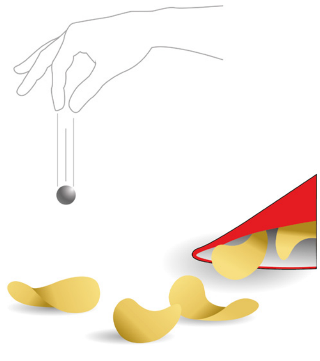
2. Use your knowledge from this activity to explain why space junk is a problem.

ACTIVITY SHEET 2

Drop a marble onto the same crisp three times. After each drop, count the number of pieces of each size. Record the results in the table below.

Number of pieces after each drop				
Drop from __ cm	<1cm	1-5cm	>5cm	Total
1				
2				
3				

1. Did you see a pattern in your results?

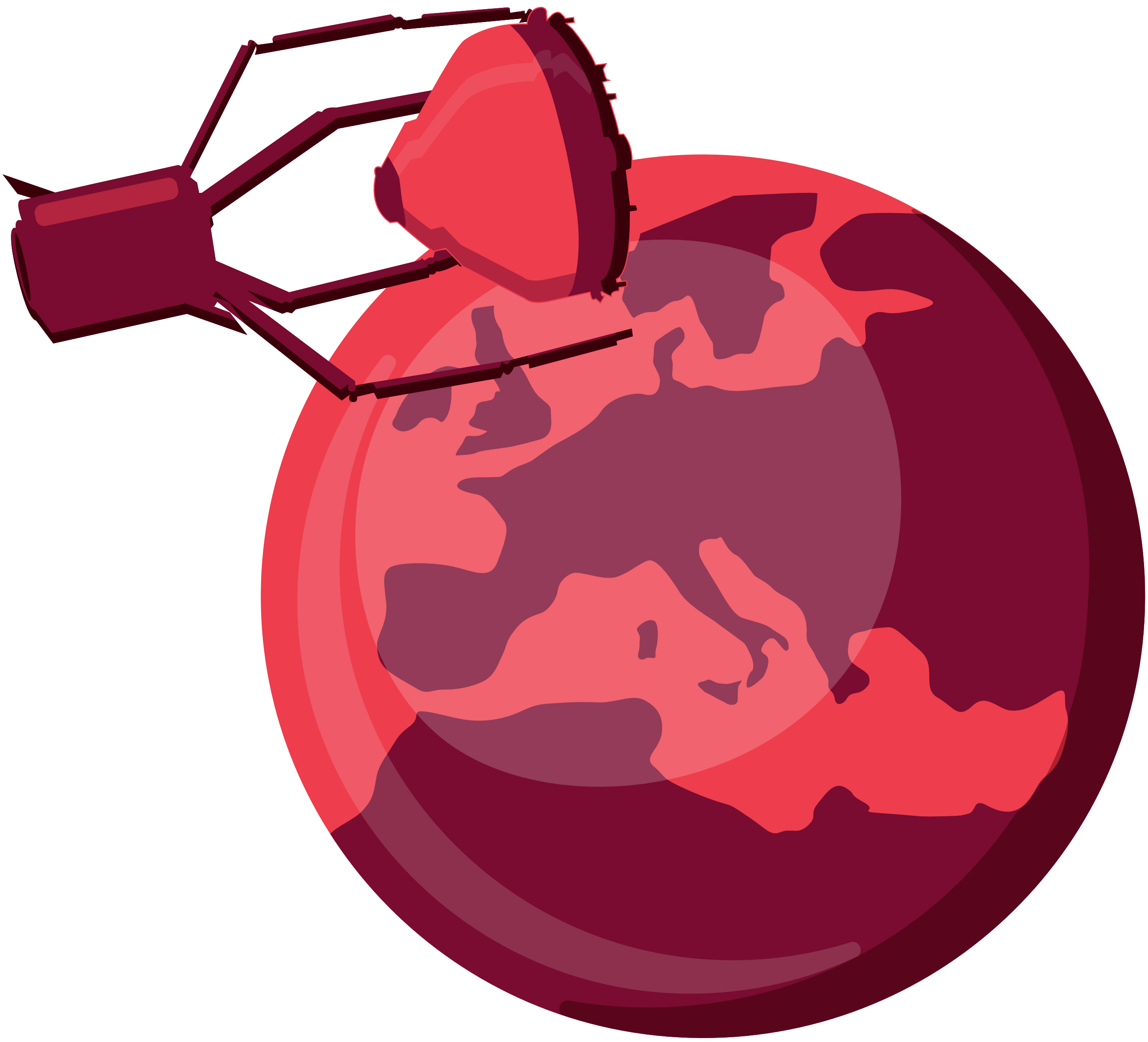


2. What conclusions can you make? Think about what happens to the number of pieces as the number of impacts increases.

primary | PR52

teach with space

→ CLEANING UP SPACE



Teacher guide & student worksheets

TEACH WITH SPACE - Cleaning up space | PR52
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CLEANING UP SPACE

Fast facts

Subject: Engineering, Design, Technology, Science

Age range: 7-11

Type: student activity

Complexity: easy

Lesson time required: 5.5 hour

Cost: low

Location: Classroom

Includes the use of: computers or iPads (optional), sticky materials, glues

Curriculum area/keywords: Design Technology, Science: Earth and Space

Vocab: satellite, orbit, forces, spin, contact, grab, capture, debris

Brief description

In this set of activities, students will start by discussing their initial ideas for helping ESA and Paxi to remove space debris; then go on to plan initial designs for a debris capturing tool. They will investigate the implementation of unfurling 'tentacles', as well as comparing the effectiveness of various sticky materials. The students will then amend and enrich their designs, based on what they have learned.

Activities 1-3 can be done individually or as part of a set. Activity 4 is designed to build upon the knowledge gained in Activities 1-3.

Learning objectives

Having completed these activities, students will now...

- Understand what satellites are and how they help life on Earth
- Be familiar with different methods of debris removal, and have a basic understanding of their mechanisms
- Be able to draw inspiration from the world around them to approach scientific problems
- Be able to recognise when and how to set up comparative and fair tests, and explain which variables need to be controlled and why
- Understand that there can be multiple ways to approach the same problem, and that each method should be tested before implementation

Success Criteria

During these activities, students will demonstrate their ability to...

- Choose appropriate materials to design tools to tackle a specific problem, and explain their reasoning
- Use relevant scientific language and illustrations to discuss, communicate and justify their scientific ideas
- Design and build a prototype tool with a specific purpose
- Take repeated measurements where appropriate
- Decide how to record data and results of increasing complexity from a choice of familiar approaches: scientific diagrams and labels, tables and graphs

Activities 2 and 3 of these classroom resource are illustrated in the "Grab the space junk" video.

Summary of activities

Title	Description	Outcome	Requirements	Time
1. Grab that Space junk!	Students will model collisions between debris and satellites, and observe that one collision can lead to several more.	Students will learn that collisions between objects in Earth's orbit can lead to several more collisions, and that satellites burn up upon re-entry to Earth's atmosphere.	None	1 hour
2. Reaching the debris: Unfurling Tentacles	In this activity, students will explore the concept of unfurling tentacles, and how these might be utilised for space debris retrieval. They will first consider how such a mechanism might work, and will then go on to build their own unfurling tool.	Students will become familiar with different methods of debris removal, and have a basic understanding of their mechanisms.	None	1.5 hours
3. Grabbing the debris: Sticky Surfaces	In this activity, the students take on the role of space scientists to compare the effectiveness of various materials, sticky surfaces and glues in attracting and collecting 'space debris' represented by pieces of Lego.	Students will develop their ability to draw inspiration from the world around them to approach scientific problems, recognise when and how to set up comparative and fair tests and explain which variables need to be controlled and why.	None	1.5 hours
4. Design your own debris removal tool	In this activity, the students incorporate their experiences from all the activities to amend or improve their original designs. They go on to build a simple debris grabbing tool.	Understand that there can be multiple ways to approach the same problem, and that each method should be tested before implementation.	Designs from Activity 1, knowledge from Activities 2&3	1.5 hours

INTRODUCTION

A satellite is an object that orbits (circles around) a planet. There are several hundred natural satellites, or moons, in our Solar System. Thousands of artificial (human-made) satellites have also been launched since 1957. These have many different uses, including taking pictures of the Sun, Earth, and other planets, and looking deep into space at black holes, distant stars and galaxies. There are also communications satellites, weather satellites, and the International Space Station.

However, when satellites are no longer useful there is no simple way to retrieve or dispose of them, so they stay in orbit around Earth. This means that there is a buildup of space 'junk' around Earth, and this buildup is becoming an increasingly concerning issue – the more debris that accumulates, the more likely a collision is. Scientists and engineers are designing and testing technology to actively capture and remove space debris in search of the best ways to clean up space.

ESA is currently working on ideas to capture non-functioning satellites, using various capture methods including robotic arms, nets and harpoons. One of ESA's active debris removal projects involves using tentacle-like mechanical arms to capture dead satellites and drag them out from their orbits. The device would then plummet back towards Earth, and both will burn up when re-entering the atmosphere. Scientists are also taking inspiration from the world around them to develop debris-grabbing tools.

Grabbing things in space can be very difficult but a new robot that uses grippers, based on an amazing method inspired by gecko feet, might just be the solution to the problem. The robot can manoeuvre around in the microgravity of space, gripping and holding onto objects that have flat, smooth surfaces and even those that are curved.

Any concepts that scientists come up with need to be tested in various ways to judge their effectiveness and ensure they will work in microgravity. This set of activities challenges students to complete these tests, and use their findings to design their own debris-grabbing tool.

ACTIVITY 1 - GRAB THAT SPACE JUNK!

In this activity, students will discuss and describe the features of an active debris removal tool; they will go on to plan initial designs for a debris capturing tool.

Equipment

- Sheets of drawing paper
- Pens
- Pencils
- Felt tip pens
- Photos of satellites
- Access to computers or IPads if wished

Exercise

In this exercise, we will ask the students to draw what they think a tool to remove debris should look like.

In order to motivate them with this challenge, show the students the following Paxi animation**:** We see Paxi trying to help the satellite that appeared come back to Earth. Paxi asks the children of Earth to help him create a tool in order to grab this dangerous satellite and bring it back. Can the children think of any way to help Paxi?

Show the students the image of a satellite on **Activity sheet 1** and describe some of the important types of satellites and how they help us. Make a note of their shape and the materials from which they are made.

Ask the class:

- *What sort of tool do they think would be needed to capture a satellite?*
- *What would the tool be made from? Why?*
- *How might it work?*

Debris removal tools should be made from durable materials that can withstand high and low temperatures in space. It is also desirable for the materials to be lightweight because the heavier the load, the more fuel would be needed to carry the device into orbit by the launch vehicle. Satellites are usually made of a shiny metal (often even gold-plated) to reflect sunlight.

Allow time for discussion and designs. The students could use a design program on computer or iPad if available.

ACTIVITY 2 – REACHING THE DEBRIS: UNFURLING TENTACLES

Equipment per group of four

- Straws
- Crafts paper
- Sticky tape
- Scissors
- Ruler
- Elastic bands
- Lego blocks

Preparation

Introduce the lesson by showing this short gif that shows the unfurling of Clean Space tentacle-like arms.

1. *Ask the pupils if they can think of other examples of things that are coiled or curled that can be uncurled?* They might suggest examples from nature, such as the tongues of frogs, geckos or chameleons, octopus arms, a fern uncurling or a butterfly proboscis. See the Useful Links section for videos showing the above examples.

2. Split the class into groups and provide each group with party blowers. Encourage the pupils to discuss how party blowers work. Ask them to test the party blowers and explain the principle of inflation by air: when they blow into the party blower, the air will fill the paper causing it to straighten; when they stop blowing, there is no longer any force straightening the party blower, so it returns to its curled shape. Explain that the unfurling of the blower represents the uncurling of the debris capture tentacles shown in the video clip.

3. Challenge the students to follow the instructions on Activity Sheet 2 to construct their unfurling tentacle device. Their goal should be to create an unfurling arm to reach the debris, though it need not grab the debris at this stage. They can use photos, video or diagrams to record ideas and final design.

Discussion

The groups should demonstrate the effectiveness of their space debris 'tentacle' devices. Each group should describe their design and explore the following points:

- *What worked well?*
- *What did they find most difficult?*
- *What would they change to improve their prototype?*

Explain that space engineers would design, test, improve and retest their models many times before being satisfied with the final product – some designs may work well, some designs may not work at all, it is all part of the process.

ACTIVITY 3 – GRABBING THE DEBRIS: STICKY SURFACES

In this activity, the students take on the role of space scientists to compare the effectiveness of various materials, sticky surfaces and glues in attracting and collecting 'space debris' represented by pieces of Lego.

Equipment per group of four

- Glue sticks
- Sticky tape, duct tape, masking tape, double sided tape
- Magnetic Tape
- Velcro
- Lego pieces
- Activity Sheet 3

Introduction

Today the students will be space scientists, testing suitable materials or surfaces that could be used to capture space debris. They will be using Lego pieces rather than real space debris.

Exercise

Ask students to follow the instructions in activity sheet 3 (cardboard device) to make their own testing devices (one per sticky surface) in order to grab the debris. Once they have build their grabbing device, ask them to test the glue sticks, sticky tape, duct tape, masking tape, magnetic tape, and velcro to try to grab the lego pieces that represent the debris. Ask the students to annotate their findings (how sticky the materials are) in the table below in activity sheet 3.

Discussion

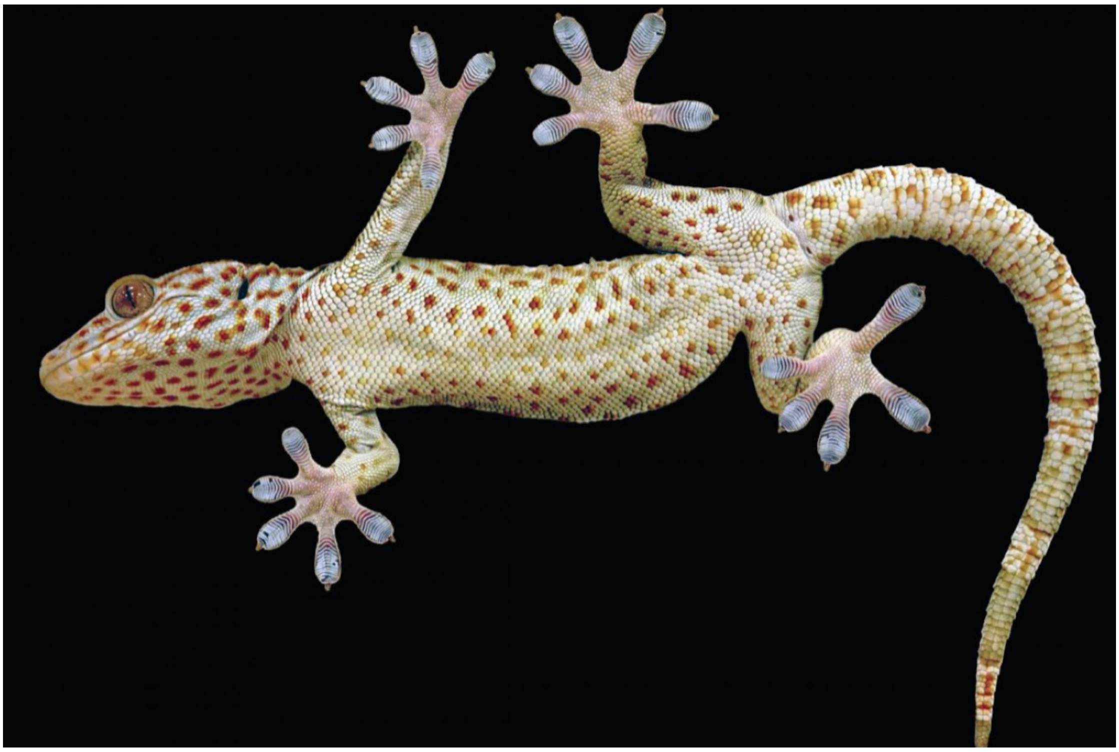
Collate the investigation results from each group and display them for the class to see. Ask the groups:

- Which coating or surface did they find most effective at capturing the debris? Which was the least effective? Can they put the materials into order of stickiness?
- Which materials would they recommend?
- How would they improve their test next time?
- Explain that sticky materials can behave very differently in space. Can they think why?
- Which of their testing materials do they think would work best in space?

Explain that methods used on Earth to grab things don't work in space. Normal adhesives stop being sticky in the cold vacuum of space, and even sticking down a piece of tape requires enough force to make the object you're adhering it to float away! Scientists can test how materials behave in space in planes being flown by trained pilots at high speed and performing parabolic flights.

DID YOU KNOW?

- Scientists have tested sticky surfaces inspired by geckos feet for collecting space debris. Geckos have lot of tiny hairs on the soles of their feet – these provide grip because there are so many of them in contact with the surface of the wall.



ACTIVITY 4 – DESIGN YOUR OWN DEBRIS REMOVAL TOOL

This activity builds upon Activity 1-3 that challenged the students to use their creativity to design a tool to capture space junk. Here, the students incorporate their experiences from all the activities to create their original designs. They go on to build a simple debris grabbing tool.

Equipment

- Thick/thin cardboard
- Paper
- Cardboard tubing
- Straws
- Glue
- Brass fasteners
- Paper clips
- Sticky tape
- Stapler
- Activity sheet 4A and 4B

Exercise

After reading the letter, ask the students to prototype their own reaching and grabbing debris device, which should have both functions (reaching and sticking the lego piece). Points to consider may include:

- What changes, if any, would they make to their designs using information learned from latest space debris capturing missions or techniques tried in activities 2 and 3?
- Would they like to combine aspects of their designs?

Explain that they are going to take on the role of space engineers. Challenge them to work together to build a space junk grabbing device. They should amend and enrich their designs and consider the materials they will need. Allow time for the students to build and test their prototypes. Encourage the students to take photographs or videos of their work at different stages of construction.

Discussion

Gather the students and ask them to describe and demonstrate their prototypes. Some points to consider during the discussion may include:

- *How does their device work? Is it able to capture a piece of space debris represented by pieces of Lego or other suitable objects?*

- *Show the class images of ESA's ClearSpace mission designs, what are the basic differences between their designs and ESA designs?*

Remind the students that engineers expect to test and improve a prototype many times before a final product is agreed; this is called the engineering process. End the lesson by encouraging the students to upload their designs and models onto the ESAKids website.

Useful links

ESA resources:

ESA classroom resources: www.esa.int/Education/Classroom_resources ESA Kids homepage: www.esa.int/kids

Useful information about satellites and their uses can be found on ESAKids website here: https://www.esa.int/kids/en/learn/Technology/Useful_space/Satellites

Videos of unfurling tentacles in nature:
Gecko tongue unfurling: https://www.youtube.com/watch?v=E76YBF3PoKo

Octopus moving: https://www.bbc.co.uk/newsround/32335519

Fern timelapse: https://www.youtube.com/watch?v=9c9Zi3WFVRc

Read more:
https://www.newscientist.com/article/2139071-gecko-inspired-robot-has- grippers-that-could-clean-up-space-junk/#ixzz6Ar1Ghx44

STUDENT WORKSHEETS:

ACTIVITY SHEET 1

Paxi needs your help to create a tool to grab the dangerous inactive satellites orbiting Earth. Consider the artist's impression of the Envisat satellite above. After discussing ideas with your classmates, use the box below to draw your idea for a satellite grabbing tool.

ACTIVITY SHEET 2

Complete the following steps, using the graphic to help you. You will need a piece of paper measuring 7x30cm.

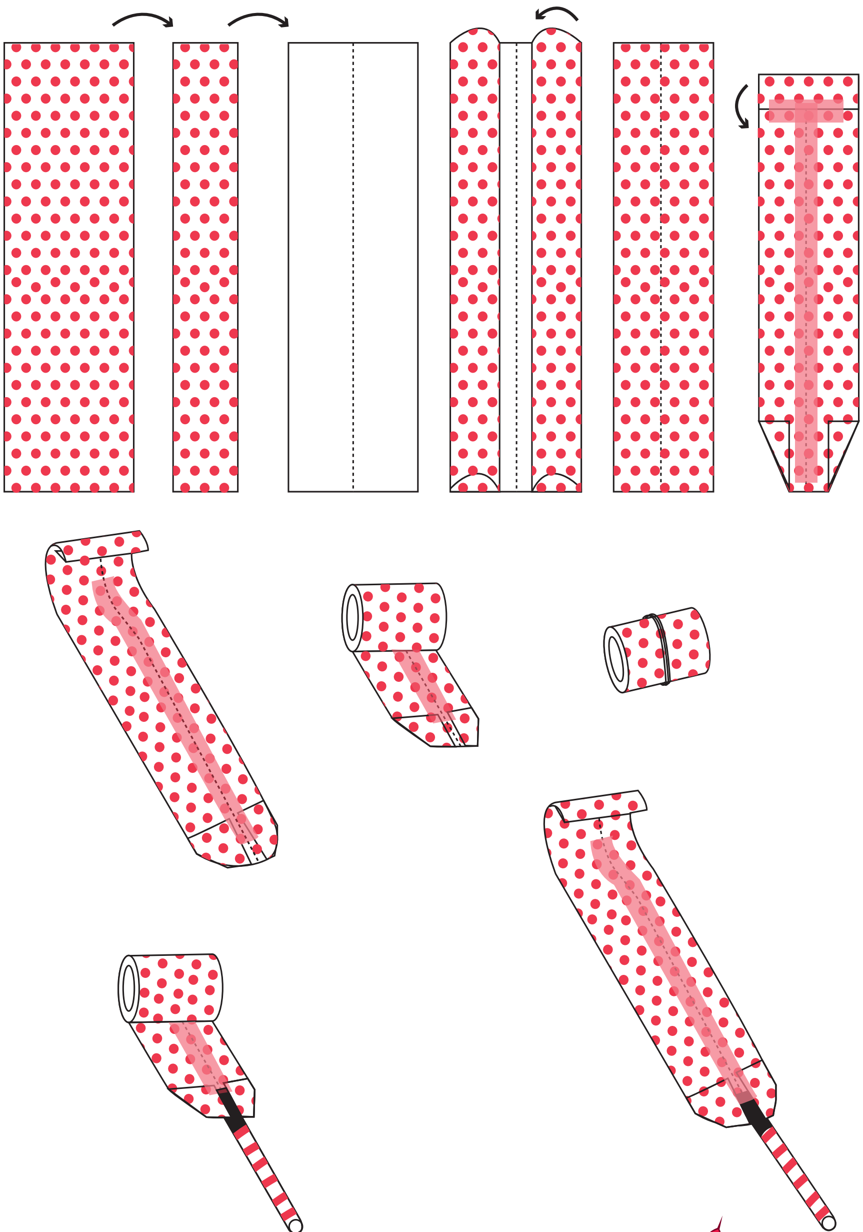
1. Fold the paper in half lengthways.

2. Unfold the paper then fold the edges into the crease in the middle.

3. Fold over about 1cm at one end and tape down.

4. Tightly roll up the paper starting at the taped end, secure with an elastic band and leave for a few hours.

5. Insert the straw into the device and secure it with tape.



ACTIVITY SHEET 3

Prepare a testing device from a rectangle of thick cardboard with a handle stapled in the centre. The example shown in the Teacher Information measures 10cm x 15 cm, its handle 15cm x 2cm. Make four per group, each with a different sticky surface.

1

2

3

Images show 1.an example of a space debris grabbing device, 2.its sticky surface and Lego debris before and after capture

Hint: start with the setup as in the photos above with 20 lego pieces laid out. Press your sticky surface on the lego then lift to see how many lego pieces were collected. Record your results in the table below and repeat 2 more times.

Stickiness (number of lego pieces collected out of 20)				
Testing Material	1st test	2nd test	3rd test	Average

ACTIVITY SHEET 4A

Email from European Space Agency

To: Pupil Space scientists
From: ESA

Subject: We need help to remove the debris!

Dear Space Scientists

We are a team of engineers and scientists working for the European Space Agency. As you know, there are lots of satellites spinning around in space, orbiting our planet Earth. They are very important and help us here on Earth in many ways, such as helping us to use our mobile phones or in weather forecasting. Unfortunately, when satellites stop working, they can become a danger to other satellites and spacecraft.
We think that it might be possible to grab the old or broken satellites in some way but we are not sure which tools would be most effective. We have heard that you are excellent scientists and we are writing to ask whether you would like to help us by doing some investigations.
Would you design a debris grabbing tool so you can help us design our tools to remove space debris?
We look forward to receiving your recommendations. Thank you for your help.

The European Space Agency

ACTIVITY SHEET 4B

You could use this to help you plan your investigation of debris removal tool.

Group Name
These are our ideas
This is our chosen design
We will use these materials
How well did it work?
We could improve our design if we...

primary | PR53

teach with space

→ COMING BACK TO EARTH SAFELY

Teacher guide & student worksheets

TEACH WITH SPACE - Coming back to Earth safely | PR53
www.esa.int/education

The ESA Education Office welcomes feedback and comments at teachers@esa.int

An ESA Education production, collaboration with ESERO UK

COMING BACK TO EARTH SAFELY

Fast facts

Subject: Science, Design Technology, Engineering, Maths

Age range: 7-11

Type: pupil activity

Complexity: moderate

Lesson time required: 2 hours and 15 minutes

Cost: Low- spinners widely available from internet suppliers

Location: classroom, playground or hall

Includes the use of: two bladed helicopter spinners and/or Frisbee style spinners

Curriculum area/keywords: Materials, forces, measures

Vocab: satellite, orbit, friction, air, area, re-entry, atmosphere

Brief description

In these activities, the students are introduced to the idea of controlled or uncontrolled re-entry for satellites. They are challenged to devise a way of reducing space debris by designing alterations to satellites so that they bring themselves back to Earth. In the first activity, the students pretend to be satellites in orbit and experience how increasing the surface area of an object moving in air can cause it to slow down. They go on to discuss and test their own ideas using spinning helicopter 'satellites', before deciding what could be packed in a satellite's 'backpack' and used for a controlled re-entry or slow down.

(These activities may be taught separately or combined for progressive learning.)

Learning objectives

Having completed these activities, students will now...

- Understand that drag is a type of friction that can exist between objects and air
- Understand that increasing the surface area of an object increases the amount of drag it experiences
- Understand that space debris such as satellites can be slowed down by drag, and this can be utilised for space debris removal techniques

Success Criteria

During these activities, students will demonstrate their ability to...

- Identify the effects of drag that acts between moving objects and air
- Collect and record data from their own observations and measurements
- Make predictions based on preliminary results and set up further tests
- Relate their results to the wider scientific issue in question
- Give reasons for the particular uses of everyday materials, based on evidence from comparative tests

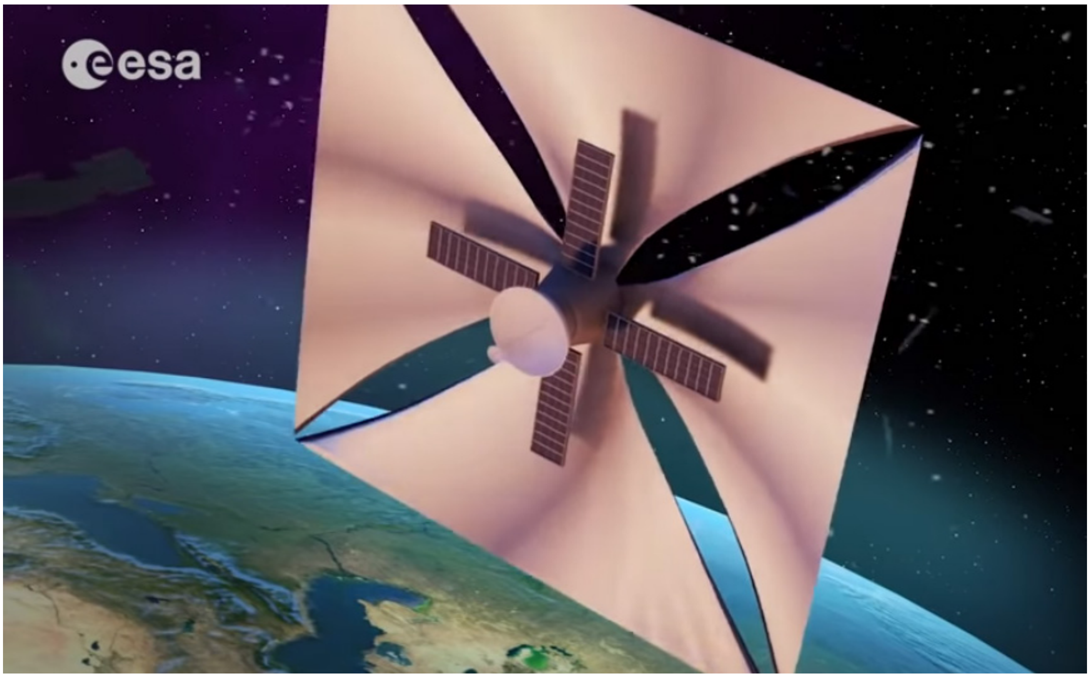
Summary of activities

Title	Description	Outcome	Requirements	Time
1.Satellite Slowdown!	Students pretend to be moving satellites and explore how increasing the surface area of an object moving in air can cause it to slow down.	Students will learn that drag is a type of friction that can exist between objects and air, and that increasing the surface area of an object increases the amount of drag it experiences.	None	45 mins
2.The satellite Backpack Challenge	Students will test ideas for slowing a spinning satellite and then decide what the satellite needs in its 'backpack' to deorbit.	Students will learn that space debris such as satellites can be slowed down by drag, and this can be utilised for Clean Space debris removal techniques.	None	1 hour

INTRODUCTION

The amount of space debris, or space 'junk', surrounding Earth is now at a point that we can no longer ignore, and the situation is only going to get worse if we do not act. The European Space Agency's (ESA) Clean Space program is attempting not only to minimise the debris produced by future space missions, but to actively reduce the debris already in orbit. However, the Clean Space team intend active debris removal (where other vessels are sent to retrieve the debris) to be only a temporary solution to remove the satellites that are currently inactive in space; ideally, the permanent solution would be to design the satellites so that they fall towards Earth themselves, as this is much more sustainable then sending other vessels to retrieve the debris.

Debris that is orbiting the Earth needs to be slowed down so that Earth's gravity can pull it through the atmosphere. Drag – a type of friction that acts between moving objects and air – can be utilised to slow down debris. One of the methods, being used in a mission called Icarus-1, which is currently being tested, involves deployment of a drag sail to increase the surface area of a satellite at the end of its mission, slowing it down and causing it to burn up on re-entry. As the satellite moves away from the thin air that exists in Low Earth Orbit and towards the thicker air that humans breathe, the friction that the debris experiences rapidly increases, which leads to a large buildup of heat until eventually the debris starts to burn up.



ACTIVITY 1: SATELLITE SLOWDOWN!

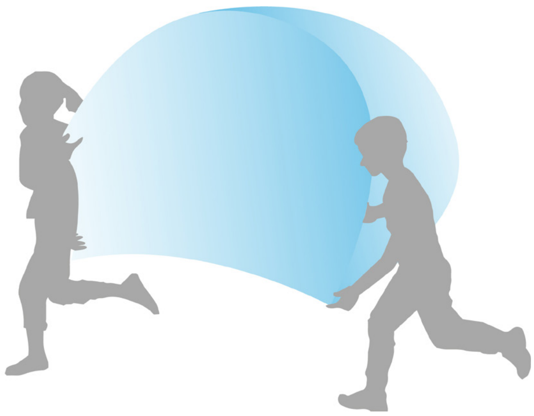
In this activity, students pretend to be moving satellites and explore how increasing the surface area of an object moving in air can cause it to slow down.

Equipment

- Bedsheets
- Paper (varying sizes - A5, A4, A3, A2)
- Umbrella

Exercise

Explain that the students are going to pretend to be satellites. Let the students investigate the effects of air resistance by running across the hall or playground. They should then try running whilst holding sheets of paper of various shapes and sizes at either side of them. They could even try running with a partner whilst holding a large bedsheet between them, or with an opened umbrella carried behind or in front of them.



Discussion

In class, lead a discussion about what the students learned from the activity:

- *What did they notice when they ran with increasingly large pieces of paper?*
- *How would they compare the paper, bedsheet, and umbrella in terms of how fast they were able to run?*

Increasing the surface area of objects causes them to move more slowly through air. This is because of something known as drag. Drag is a type of friction caused by air that creates resistance against movement, and the amount of drag a moving object experiences is related to the object's surface area.

ACTIVITY 2: THE SATELLITE BACKPACK CHALLENGE

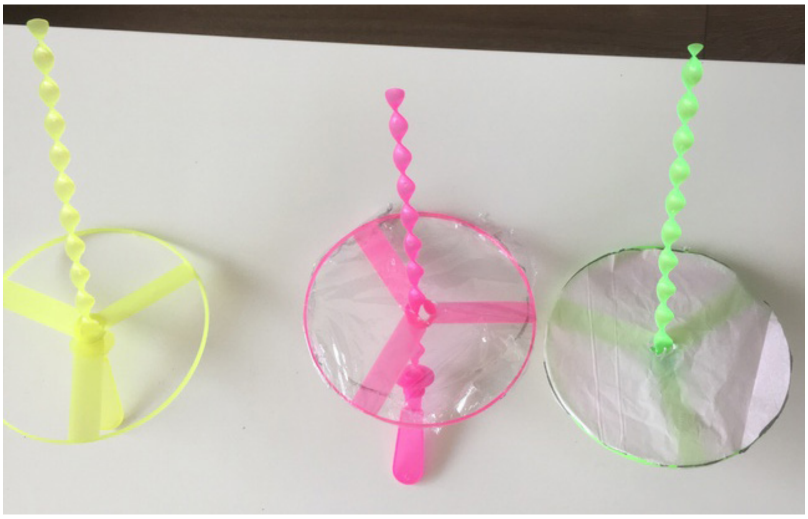
In this activity, students pretend to be moving satellites and explore how increasing the surface area of an object moving in air can cause it to slow down. The video of this activity can be found here.

Equipment

- Plastic two bladed helicopter spinner and/or Frisbee style spinner
- Sugar paper
- Cling film
- Sticky tape
- Stopwatches

Exercise

Give each group a two bladed helicopter spinner and/or a Frisbee style spinner, which will be used to represent satellites in orbit around Earth.



The students should build 3 prototypes of spinners: One without additions, one sticking sugar paper on the surface, and one sticking cling film on the surface, as shown in the picture on the right. Note that It is very important to use very lightweight materials (cling film and sugar paper, and a minimal amount of film) to add on top of the spinners, otherwise they will become too heavy and this won't allow the spinners to stay in the air for long.

Outside or in a hall, the students should launch the spinners and record the flight times.

The groups might come up with their own method of recording the flight times, such as tables or charts, or use the format in Activity Sheet 2.

Once each group has at least 3 flight times recorded, get them to consider how they might slow down the spinners. They may wish to consider what they learned from
Activity 1.

They should discuss ideas and may wish to draw their designs before trying to implement them. For the helicopter spinner, suggestions might include extending the length, width, angle or shape of the wings by attaching paper, balloons or other materials to the wings. For the Frisbee style spinner, they may wish to add materials between the propellers.

The groups should adapt their spinners, test them, and record the new flight times.

Discussion

Lead a discussion surrounding each groups' findings. Points to consider may include:

- *How can slowing down the spinner in this activity be related to to how satellites come back to Earth?*
- *Which ideas did they think worked well/not so well? Why?*
- *Using the results of their tests, what do they think we should put into the satellites' backpacks?*
- *What advice would they give to ESA?*

Conclusion

Adding materials to a spinner slows down how the speed at which they spin – this makes them fall back to Earth faster. Dragsails slow down the spinning of satellites around Earth, leaving more opportunity for Earth's gravity to attract those satellites and fall to Earth faster.

DID YOU KNOW?

ESA is testing many different ideas for slowing down satellites to bring them back to Earth, including dragsails. Using everyday materials to slow down the spinners works in a similar way to how dragsails would slow down debris. The materials increase the drag that the spinners experience, which mean they spend less time in the air and come quickly back to 'Earth'. For satellites, the dragsails are used to increase the drag they experience, slowing them down and allowing the Earth's gravity to pull them through the Earth's atmosphere, where they burn up as a result of friction.

Watch togetherr with the students the following [Paxi animation:]

STUDENT WORKSHEET

ACTIVITY 2: THE SATELLITE BACKPACK CHALLENGE

1. Launch your spinning 'satellite'. Time how long it stays in the air. Repeat twice. Add up the three results and divide by three to find the average (mean) spin time.

2. Then try a way of slowing your satellite. Time how long it stays in the air this time.

3. Find another way to slow the satellite and time how long it stays in the air.

Time spinner stays in the air (seconds)				
	Test 1	**Test 2**	**Test 3**	**Mean time**
1. Spinner without modification				
2. Spinner with cling film				
3. Spinner with sugar paper				

Which idea worked best to make the spinner spin more slowly (and therefore fall more quickly)?
What should Paxi pack in the satellite's backpack bring it back to Earth?
Using your knowledge from this experiment, how do you think dragsails would work to bring debris back to Earth?

Useful links

ESA resources:

ESA classroom resources: www.esa.int/Education/Classroom_resources
ESA Kids homepage: www.esa.int/kids

Extra notes on ESA space projects:

The following video link is an excellent demonstration of the sail developed by the University of Surrey, used to create drag during debris capture.

https://youtu.be/3DYYHiW6x44

Curious Minds ESERO

Framework for Inquiry - Promoting Inclusion

SPECIAL EDUCATION SUPPORT SERVICE
building on ability

When planning science activities for students with Special Educational Needs (SEN), a number of issues need to be considered. Careful planning for inclusion using the framework for inquiry should aim to engage students in science with real purpose. Potential areas of difficulty are identified below along with suggested strategies. This list is not exhaustive, further strategies are available in the Guidelines for Teachers of Students with General Learning Disabilities (NCCA, 2007).

ENGAGE

POTENTIAL AREA OF DIFFICULTY	STRATEGIES
Delayed language development/poor vocabulary/concepts	• Teach the language of science demonstrating meaning and/or using visual aids (material, property, strong, weak, textured, dimpled, absorbent, force, gravity). • Have the student demonstrate scientific phenomena, for example gravity —using 'give me, show me, make me,' as much as possible. • Assist the student in expressing ideas through scaffolding, verbalising a demonstration, modelling. • Use outdoor play to develop concepts.

INVESTIGATE

POTENTIAL AREA OF DIFFICULTY	STRATEGIES
Fear of failure/poor self-esteem/fear of taking risks	• Model the speculation of a range of answers/ideas. • Repeat and record suggestions from the students and refer back to them.
Understanding Time and Chronology	• Practice recording the passing of time, establish classroom routines that draw the students' attention to the measurement of time. • Teach and practice the language of time.
Fine/Gross Motor Difficulties	• Allow time to practice handling new equipment. • Allow additional time for drawing diagrams, making models etc. • Give students the option to explain work orally or in another format.
Short Term Memory	• Provide the student with visual clues/symbols which can be used to remind him/her of various stages of the investigation.

TAKE THE NEXT STEP

POTENTIAL AREA OF DIFFICULTY	STRATEGIES
Developing Ideas	• Keep ideas as simple as possible, use visuals as a reminder of earlier ideas. • Discuss ideas with the whole group. • Repeat and record suggestions from students and refer back to them. • Encourage work in small group and in pairs.
Communicating Ideas	• Ask students to describe observations verbally or nonverbally using an increasing vocabulary. • Display findings from investigations; sing, do drawings or take pictures. • Use ICT: simple written or word-processed accounts taking photographs, making video recordings of an investigation.

REFLECTION

- Did I take into account the individual learning needs of my students with SEN? What differentiation strategies worked well?
- Did I ensure that the lesson content was clear and that the materials used were appropriate?
- Was I aware of the pace at which students worked and the physical effort required?
- Are there cross curriculum opportunities here?
- Are the students moving on with their skills? Did the students enjoy the activity?

More strategies, resources and support available at **www.ncse.ie**

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