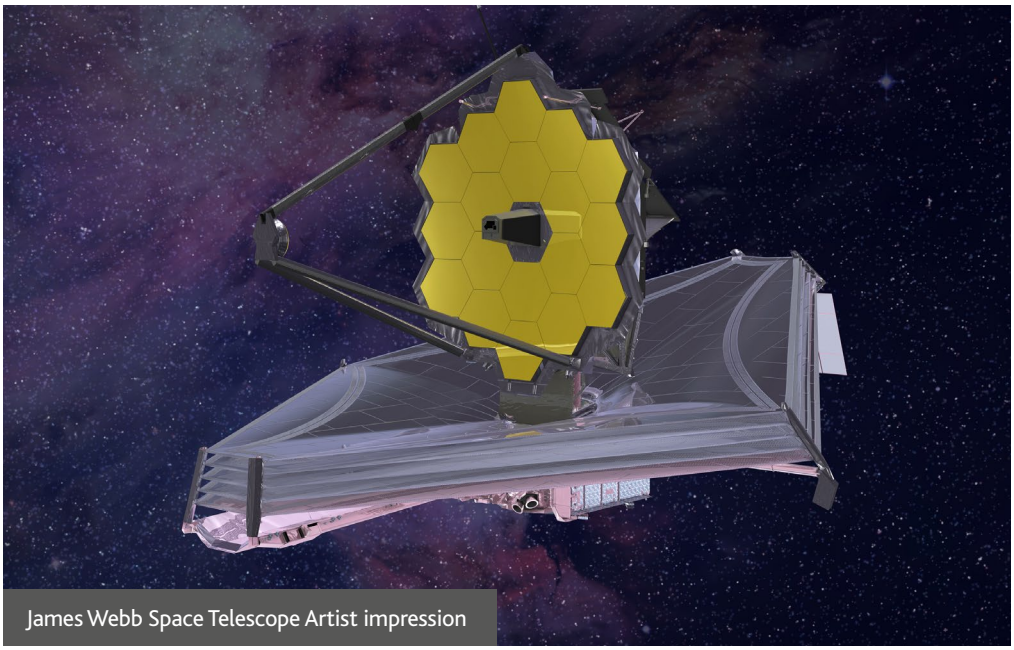
Designing the Primary mirror

Overview

This activity explores the primary mirror of the James Webb space telescope. It explores why it is designed to be the size and shape that it is. Children investigate the rotational symmetry of regular hexagons and explore why hexagons have been chosen to create the mirror rather than other regular shapes.



James Webb Space Telescope Artist impression

Background information

The James Webb Space Telescope's primary mirror is not a circular shape, like the Hubble space telescope. The Webb telescope needs to be much larger than the Hubble, so it can see further into space. If it were the same design as the Hubble it would be too heavy to launch into orbit. The Webb team had to find new ways to build the mirror so that it would be large and strong but also light and able to fit inside a rocket to be launched. Working to solve these design problems the team created a mirror composed of 18 hexagons made out of a light weight metal called beryllium and coated with gold, which is very reflective. The mirror is over 6.5m in diameter and is too large to fit inside the rocket during launch. Because of this it is mounted on a folding framework, so that it can be folded up to be sent into space. The structure will unfold as it nears its destination.

The 18 regular hexagons that make up the primary mirror are arranged so that there are 3 sets of 6 hexagons which are positioned the same distance from the centre of the mirror structure. Tiles located at a specific distance from the centre of the mirror are manufactured with exactly the same optical properties.

Curriculum areas

- D&T
- Science
- Mathematics

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Big questions?

What do space telescopes do?

How do teams find solutions to challenges in the design of products?

Resources

- Designing the Primary Mirror PowerPoint
- Soft balls
- A large golf umbrella
- A small child's umbrella
- Children's worksheets for activity 2

Safety

Take care with the opening mechanisms of the umbrellas and make sure children stand still when holding them open.

Introduction

Using the presentation to show children the pictures of the James Webb and Hubble Space telescopes. Ask them: "What is the same and what is different about them?" Take feedback from the children.

Similarities: they are both space based telescopes. They both collect the light from far away stars and planets and produce images that are sent back to Earth.

Differences: The Hubble is in a near-Earth orbit, the James Webb will be 100 million miles away from the Earth. The Hubble Space Telescope is in space now, the James Webb is due to launch in 2020. Children will notice that the shapes are very different too and will hopefully notice the large primary mirror of the Webb. The Webb Telescope will be able to produce images of galaxies that are further away than Hubble because it has a larger mirror that collects more light.

Look at slide 4 and explain that these are the mirrors that collect the infrared light (heat), from distant stars. Ask them to talk to a partner and find differences between the two mirrors and think about why they may be different. Take their feedback and explain that they are going to do an activity to show why the Webb needs a larger mirror.

Activity

This activity is best carried out in a hall or playground, but can also be done in class. Split the class in two and give each group a large and small umbrella and 30 soft balls. Tell them that the balls represent the infrared light that is given off by stars and planets and small umbrella represents the Hubble mirror, the large one the James Webb mirror.

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Children need to find out which mirror collects the most infrared light at different distances. One child can hold the umbrella upside down and pointing towards the other children, whilst the children stand in the middle of the classroom and throw the balls towards the umbrella. The umbrella stood be keep relatively still. Once all the balls have been thrown then count how many are in the umbrella. Repeat this using the large umbrella and see which collects more of the balls. Then ask children to stand at the very back of the classroom and repeat the exercise with each of the umbrellas.

Ask them if there was a difference? Which umbrella collected the most balls at a close distance? Which umbrella collect the most balls from a further distance? If necessary test this out at an even greater distance.

Ask children which umbrella/mirror collected the most balls/infrared light when they were thrown from further away? If we were designing a telescope that was collecting light from very far away, would we want a large or small mirror? Ask them why the mirror is not even bigger? Is it to do with the rest of the structure? Would we be able to send an even bigger mirror into space?

After listening to their ideas tell them that the Webb has a much larger mirror because it is designed to look very far into space, over 13 billion light years away from us. How much detail a telescope can see, is related to the size of the mirror that collects light from the objects. A larger area collects more light, just like a larger umbrella collects more balls than a small one. Slides 5-7 explain the gold coating of the mirror segments and how such a large mirror will be launched into space.

Activity

Show them slide 8 on the presentation. Ask the children what shapes is the mirror made from? How can they show the hexagons are regular? Ask what is the word when 2D shapes fit together exactly leaving no gaps? Tessellation.

Tell the children they are going to explore the rotational symmetry of regular hexagons to see why they were chosen to create the mirror, rather than other shapes. Show them slide 9 and explain that this is the pattern of the primary mirror. Demonstrate how to measure from the centre of the mirror to the centre point of one of the hexagons.

Tell the children they are going to measure the distance from the centre of the mirror to the centre of each of the 18 hexagons and use colours to show hexagons the same distance from the centre. Children can work in pairs using the worksheets provided.

They should come up with a pattern like the one shown on slide 11.

Look at the pattern made by each colour. What is the order of rotational symmetry for each pattern? Rotational symmetry, order 6 for each pattern.

To provide an extra challenge children may wish to explore the use of different tessellating shapes for building the mirror. Slides 12 and 13 look at squares. If using square mirrors then more different types of mirror are required. The advantage to using hexagonal mirrors is that fewer types are needed.

Further links

James Webb Space Telescope, NASA:	https://jwst.nasa.gov/index.html
James Webb Space Telescope, ESA:	http://sci.esa.int/jwst/