

## Objectives

In this unit students will:

-  Explore the James Webb Space Telescope (JWST) and understand its mission.
-  Understand the restrictions placed on the design of the JWST due to space flight.
-  Be able to identify the key parts of the spacecraft that will carry the JWST.
-  Understand the work of Aerospace Engineers.

## The big questions

- What is the James Webb Space Telescope (JWST)?
- What are some of the parts of JWST?
- How can it be transported into space inside a spacecraft that smaller than JWST?

## Background

The James Webb Space Telescope will be launched into space, to eventually reach a point 930,000 miles away from Earth known as L2. The launch itself, the first stage of the journey, will take place on board an Ariane 5 Rocket, where JWST will be housed in the nose of the rocket, the payload fairing. Ariane 5 produces a range of different sized payload fairing, however, none are as large as JWST is overall.

To combat this JWST has been designed to be folded and to gradually unfold once it is released from the payload fairing. One of the larger parts of JWST is a large mirror panel, which is made of hexagonal sections, this is the primary mirror of the telescope itself which reflects light back into the various sensing devices that allow the telescope to operate.

## Curriculum Links

Design & Technology KS3 PoS

- Design
  - develop and communicate design ideas using annotated sketches, detailed plans, 3-D and mathematical modelling, oral and digital presentations and computer-based tools
- Evaluate
  - investigate new and emerging technologies
- Technical knowledge
  - understand and use the properties of materials and the performance of structural elements to achieve functioning solutions
  - understand how more advanced mechanical systems used in their products enable changes in movement and force

## 1 Resources

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Per Student:

- Mirror Mechanism Worksheet

Optional Demo / Extension Task, per team of 3 students:

- |                                      |                       |
|--------------------------------------|-----------------------|
| ➤ JWST Primary Mirror Model Template | ➤ A3 Sheet Thick Card |
| ➤ A3 Mirrored Sheet / Card           | ➤ Heat Resistant Glue |
| ➤ Nitinol Wire                       | ➤ Heat Gun            |
| ➤ Heat Resistant Tape                |                       |

## 2 Starter

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Slide 1:

Students are asked what the picture (of JWST) shows? They may require some prompting – try asking them to identify what the different parts of the satellite might do and talk about where it is located (in space).

## 3 Introduction

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Slide 4 & 5:

To check previous knowledge of JWST show the telescope again now it has been identified through the session objectives. Some of the basic facts about JWST and its mission can then be shown and discussed.

Slide 6:

Introduce the role of an Aerospace Engineer, and ask students to research the role online – this comes up in Slide 22.

Slide 7 & 8:

Ask students why they think JWST is needed, what will it do? Discuss the images taken by Hubble, and the fact that Hubble although similar in purpose is much smaller and was launched in 1990. How might JWST improve on this work?

## 4 Activity

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Slide 9-13:

Students are introduced to JWST's mode of transport into space, the Ariane 5 Rocket. They need to be questioned on what the problem in fitting JWST inside an Ariane 5 will be, by considering the size data given. It should be explained that the payload fairing is located in the end of the nose of a rocket and that it contains the rocket's cargo. Also further detail on the main parts of JWST are shown to give context to where the primary mirror the students are focusing on is located and what the function of some of these parts are, discuss with them what they think the functions of the different parts could be, how might they be used, what might they be able to tell us about space?

A short video clip showing the JWST unfolding is included to help students visualize how JWST unfolds in space and how the primary mirror unfolding fits into this sequence.

It should be pointed out that this animation is not in real time, and the actual points where these things happen are shown on slide 13. More able students may be able to match points in the video clip to the launch / deployment timeline to reinforce understanding.

#### Slide 14-17:

Students are introduced to their own design challenge, to take the place of an aerospace engineer and design the mechanism that will allow JWST's primary mirror to unfold in space.

Using the worksheet provided they should add drawings and annotation to show how the mirror can unfold. They can use ideas from simple mechanisms they may have learnt about in Design & Technology, including motors (including pulleys and gears), pneumatics, hydraulics or any alternative methods. This should relate to prior learning of the individual students, however, they need to apply their knowledge of mechanisms considering any effects space may have on their choices (i.e. power supplies from batteries being finite for motors, leakage and pressure issues on pneumatic systems within the vacuum of space, and suitability of different liquids when dealing with temperature extremes in space on a hydraulic system).

Individual ideas for students system should be shared and reviewed.

Students should then consider how their chosen system might be controlled autonomously, again their prior knowledge in areas such as sensors, timers and smart materials will enable supporting the students to pick an appropriate system from prior or guided learning. Students need to consider why the system might need to be autonomous, why communication difficulties to JWST may occur due to its distance from Earth.

Students then feedback on their final complete system.

## 5 Plenary

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#### Slide 18-19:

After presentation of ideas students will compare their own ideas to the actuators that are used to control the unfolding and then flatness of JWST's primary mirror. Actuators are introduced as a means of movement, the students should consider that as JWST will use motors that it will be important to not waste power making excessive adjustments.

## 6 Follow up session

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#### Slide 22-31:

As an extension, students can model their own mechanism and/or control system. They should work in teams of approximately 3 students. A base to build this system around is included on templates, the templates are at an approximate 1:50 scale.

An example solution is provided using smart materials, in this case Nitinol wire, students can be guided through this example, and either recreate to allow for experimentation to take place under different conditions (temperature).

Alternatively students should be encouraged to use appropriate materials to model their own system design, and evaluate the reliability of these systems against each other.

### Unfolding JWST's Primary Mirror - Design Ideas

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JWST needs to sit inside the payload fairing (this is the nose part of the Ariane 5 rocket where JWST will be held while it is launched). It opens up in space to allow JWST to be released and carry on its journey into deeper space. To allow it to fit inside the payload fairing some parts need to be folded up so that it fits, this include the Primary Mirror.

Produce a design for how JWST's Primary Mirror can be unfolded when it is in space, include:

- A sketch showing details of the parts that allow this to happen.
- Annotations to explain how the mechanism would work.
- An evaluation of how successful you think your system would be.

### Evaluation:

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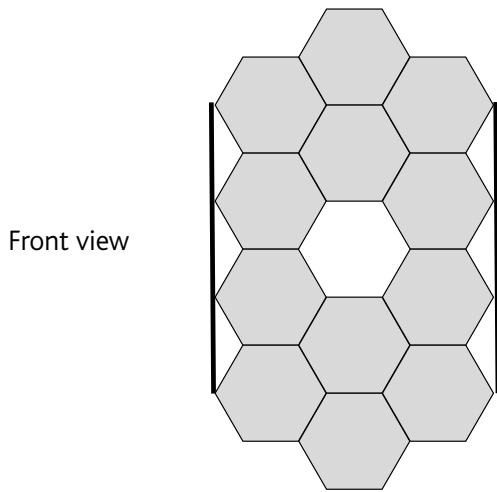
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Produce a design for how JWST's Primary Mirror can be unfolded when it is in space, include:

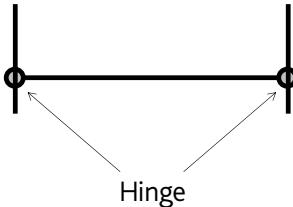
- A sketch showing details of the parts that allow this to happen.
- Annotations to explain how the mechanism would work.
- An evaluation of how successful you think your system would be.

**Primary Mirror folded**

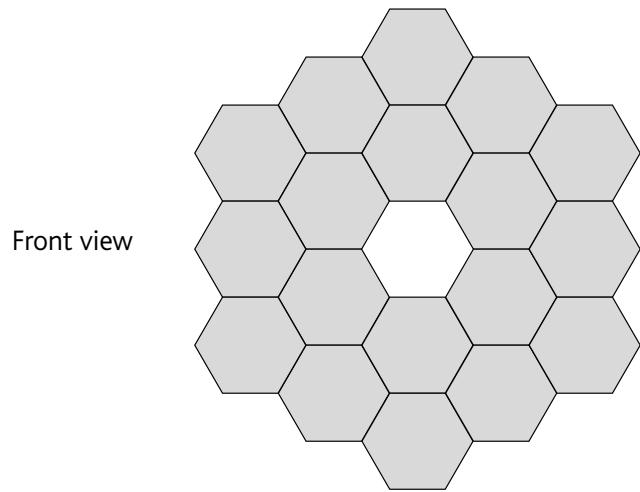


Front view

Top view

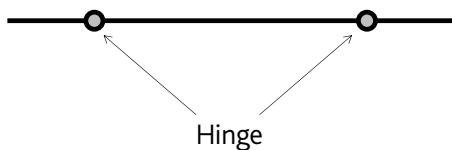


**Primary Mirror Unfolded**



Front view

Top view



### Evaluation:

### JWST's Model Primary Mirror Template

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