DESIGNING A TELESCOPE

Astronomy is driven forward by always asking new questions. When we get to a question that we can't answer, it usually means that we don't have the technology, or the knowledge, to get to the bottom of the problem. This drives technology forward, and there are constantly new telescopes in development.

When deciding upon what new telescope to build, the primary driver is the science – what questions are we trying to answer and what technology do we need to answer them?

In this session you will work in groups to design a new telescope to try and detect sources of gravitational waves!

In 2015 the first detection of a gravitational wave was recorded. A gravitational wave is a ripple which travels through the fabric of space (often called space-time) much the same as a ripple travels through water when you drop a stone. They were first predicted by Einstein in 1916 with his theory of relativity. They are made when very massive objects move quickly in space. For the ripples to be strong enough to be detected on Earth, the movement of these objects must be very fast. The following events are likely to lead to gravitational waves:

- Black holes colliding together
- Huge supernova explosions
- Neutron stars colliding together
- Neutron star merging with a black hole

Gravitational wave detectors on Earth 'listen' out for these events. They can measure the size of the waves and then try to figure out what event caused them. To learn more about this new area of astronomy it is useful to also 'see' the events with telescopes. If the source of the waves includes a neutron star or a supernova explosion, then we should be able to see an optical source alongside the gravitational wave detection. This will help scientists to answer questions like:

- Where did the event take place?
- Do gravitational waves travel at the speed of light?
- What is going on inside a neutron star?
- How do stars actually explode?

Your budget for your telescope is **£160 million** and you must decide:

- Where to build it
- What mirrors to use
- What material to build the telescope structure from

Name your telescope: ________________________________

OBSERVING SITE SELECTION

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To detect the maximum number of gravitational wave sources it is important for the observing site to be close to the equator, from which both the northern and southern hemispheres can be observed.

Use the map of potential observing sites and locations fact files to choose a first-choice site for your telescope and a backup. Fill in the pros and cons for each site below:

Primary choice location: ___________________________________

Pros	Cons

Budget required: £_______________(cost per square metre)

Back-up choice location: ___________________________________

Pros	Cons

Budget required: £_______________(cost per square metre)

MIRROR SELECTION

Gravitational wave sources can come from very distant objects. In order to be able to see these distant sources, astronomers must use telescopes with as large a mirror as possible. The bigger the diameter of the mirror, the more light can be collected, enabling you to see fainter objects. The **minimum diameter** of mirror which can **detect** gravitational wave sources is **8 metres**.

Use the mirror information page to decide upon the mirror setup for your telescope. You can combine several mirrors of different sizes. Draw the design for your Primary and Backup mirror choice below and note the mirror diameter, weight and cost of each choice.

Primary Mirror:

Design:

Effective diameter: __________

Widest diameter: __________

Weight: __________

Cost: ___________

Back-up Mirror:

Design:

Effective diameter: __________

Widest diameter: __________

Weight: __________

Cost: ___________

TELESCOPE STRUCTURE MATERIAL SELECTION

Gravitational wave sources are also likely to emit flashes of optical light, which appear and then fade very quickly. This means that the telescope needs to move very quickly to see the light before it disappears. The materials need to be strong enough to support the mirror, but light enough to move at speed.

Use the Material Selection table provided to decide upon which material to use to build your main telescope structure. You need to consider the weight of your mirror in your decision.

Your material MUST be strong enough to hold up the mirror.

Fill in the pros and cons for each selected material below:

Primary choice material: ___________________________________

Pros	Cons

Budget required: £____________ Weight limit: __________

Back-up choice material: ___________________________________

Pros	Cons

Budget required: £____________ Weight limit: __________

THE SCHOOLS' OBSERVATORY

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REACHING A DECISION

Total up the cost of your **primary telescope choices**:

Site (cost per square metre x mirror diameter): £___________

Mirror: £______________ Material: £____________ Total: £______________

It's usually not possible to build the absolute best telescope for your science. There are often compromises which need to be made to ensure that you stick to your given budget. Considering your budget of £150 million, you must now choose between your primary and backup choices for each aspect of your telescope design to reach a final decision on your set up:

Final build: £____________________

Site (cost per square metre x mirror diameter): £___________

Mirror: £______________ Material: £____________ Total: £______________

Telescopes are expensive to build. Below are of some of the best telescopes in use today, or soon to be launched. The costs skyrocket if astronomers want to put the telescope in space!

Telescope	Location	Mirror Size (m)	Cost	First Light
Hubble Space Telescope	Space (low Earth orbit)	2.4	£3.4 billion	1990
Very Large Telescope	Paranal, Chile	4 x 8.2	£300 million	1998
Subaru Telescope	Hawaii, USA	8.3	£275 million	1999
Liverpool Telescope	La Palma, Canary Islands	2	£7 million	2003
James Webb Space Telescope	Space (Lagrange Point 2)	6.5	£7.5 billion*	2022
New Robotic Telescope	La Palma, Canary Islands	4	£24 million*	2026*
Extremely Large Telescope	Cerro Armazones, Chile	39	£1.1 billion*	2025*

The year of 'First Light' refers to the first time it is used to take an astronomical image. For space telescopes we have used their year of launch.

*These telescopes have not yet been completed and the costs and first light dates might change.