# Rockets and Range – Teacher Notes

Earth is only one of the eight planets orbiting our Sun. Many of these have their own moons orbiting them. The distances between them are pretty large so we use the Astronomical Unit (AU) as the base measurement. This unit is the distance from Earth to the Sun (149,596,870.7 kilometres). Some astronomers consider that our solar system stretches out to the edge of the heliosphere where light from the Sun will no longer penetrate into space.

| | Distances from the Sun | Diameter at equator (km) |
|---|---|---|
| Sun | 0 | 1.4million |
| Mercury | 0.387 AU | 4,878 |
| Venus | 0.723 AU | 12,105 |
| Earth | 1 AU | 12,756 |
| Mars | 1.524 AU | 6,786 |
| Between Mars and Jupiter lies the Asteroid Belt | | |
| Jupiter | 5.203AU | 142,984 |
| Saturn | 9.502 AU | 120,536 |
| Uranus | 19.19 AU | 51,118 |
| Neptune | 30.06 AU | 49,528 |

Measurements of planetary diameter are taken from each planet's equator as spinning in space causes flattening at the poles and bulge at their equators.
Beyond these lie the dwarf planets such as Sedna and Pluto, the many small bodies in the Kuiper Belt and the Oort Cloud.

A major misconception of students and space moviemakers is that the Asteroid Belt is closely packed with huge asteroids. This is not so. In this belt lumps of rock less than half a kilometre wide travel thousands of kilometres apart. Most asteroids are the size of a tennis ball. Indeed if all the mass of the objects in the whole asteroid belt was added up it would only be equivalent to one third of the mass of our Moon. NASA estimates that the probes it sends through the Asteroid Belt to reach outer planets and beyond have a one in a billion chance of being hit.

Travelling through space poses many problems. These activities can be done as individual tasks or student groups may cover them and present a report of their findings at the end.
Factors to consider could be:

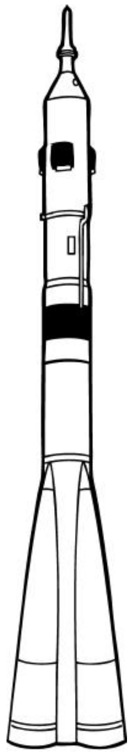
- Distance
- Technology
- Fuel load
- Opposition (Position of planets relative to each other)
- Gravity sling
- Is it necessary to send manned spacecraft at all?

# Rockets and Range – Teacher Notes

1. **Distance**. The further away from Earth the planet lies, the longer it will take. Mars can be reached in between 150 to 300 days. Jupiter takes very much longer, between 4 and 6 years.
2. **Technology**. Improvement in technology and the use of more efficient fuels to reduce load can shorten time. Launching from space would greatly decrease the fuel required.

Firing balloon rockets along string-controlled trajectories can test these two concepts.

**Student Activity**
To investigate differences encountered in sending rockets to Mars and to Jupiter.



- Mars is approximately 0.5AU from Earth
- Jupiter is approximately 4.2AU from Earth
-

What is an AU? An AU is an Astronomical Unit and is the distance from Earth to the Sun
Why do we use AU? We use AU because the distances are immense if measured in other units.

**Materials** per group

- 4m nylon string or fishing line
- Piece of drinking straw (5 – 6cm long)
- Sticky tape
- Marking pen
- Large balloon
- Tape measure
- Stopwatch/mobile/clock with second hand

**Method**

1. Thread straw onto string.
2. Stretch out approx. 4m of taut string between two students.
3. Tie loops at the end of the string as handles.
4. Mark the start at least 20cm from one end. Position the straw at the start.
5. Mark 25cm from start for the distance to Mars and 2.1m for the relative distance to Jupiter.
6. Inflate a balloon and hold it with your fingers round the neck. *It may be advisable to ask students with breathing difficulties to time rockets rather than blow up the balloons.*
7. Attach the straw to the middle of the balloon with sticky tape.
8. Test your setup by releasing your hold on the neck of the balloon. The air from the back of the balloon should drive it forwards along the string.
9. Adjust the equipment for reliable balloon rocket flight.
10. Have a student stationed at Mars and Jupiter to measure the time taken for the rocket to reach these locations.
11. Repeat the experiment to calculate average values.

Why were 25 cm and 2.1m chosen to represent the distances from Earth to Mars and Jupiter?
They are proportional to the distances to Mars (0.5AU) and Jupiter (4.2AU)

*An initiative supported by Woodside and ESWA*

# Rockets and Range – Teacher Notes

**Observations**

| TEST | Time to Mars (seconds) | Time to Saturn (seconds |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |
| Average time | | |

What did the results of your tests tell you? It takes longer to reach Jupiter. The balloon started slowly, so the speed measured at Mars was slower than the speed measured at Jupiter. Spacecraft launched from Earth also start slowly as they must overcome Earth's gravity.

Was this a fair test? No we couldn't control the amount of air blown into the balloon and consequently the air pressure powering it.

**More ideas to consider and perhaps test**

Would increased air pressure in the balloon make it travel faster and further? YES

Does the rocket travel at the same speed along the string? No, it is slow at the beginning and at the end (fastest in the middle).

Does adding a weight to the rocket affect speed? Yes

Would the increased fuel load required for travel to Jupiter affect travel time? Yes

What adjustments could be made to your balloon rocket to make it work better? Options include: Larger balloon, stronger balloon, different shapes of balloon, fins, tube attached to neck to control direction of air drive.

## Opposition

Planets circle the Sun at different rates. This means that sometimes they are close to each other. When planets are at the closest point to each other, they are said to be "in opposition".

How often does Jupiter come into opposition to the Earth? Every 13 months

If you want to minimise travel time and fuel use, how often would it be in between launches of spacecraft bound for Jupiter? 13 months

Every 26 months Mars and Earth are in opposition and these times are selected for Mars launches. Why do you think we chose to investigate the surface of Mars before the surface of Jupiter? List your answers.

Mars is closer than Jupiter.
Travel to Mars is cheaper and takes less time than to Jupiter.
Jupiter is further away from the Sun, so its surface temperature is -145°C. Temperatures on Mars range from 20°C in summer at the equator to -153°C near the poles at night in winter. The average temperature of -80°C is more tolerable than Jupiter.

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# Rockets and Range – Teacher Notes

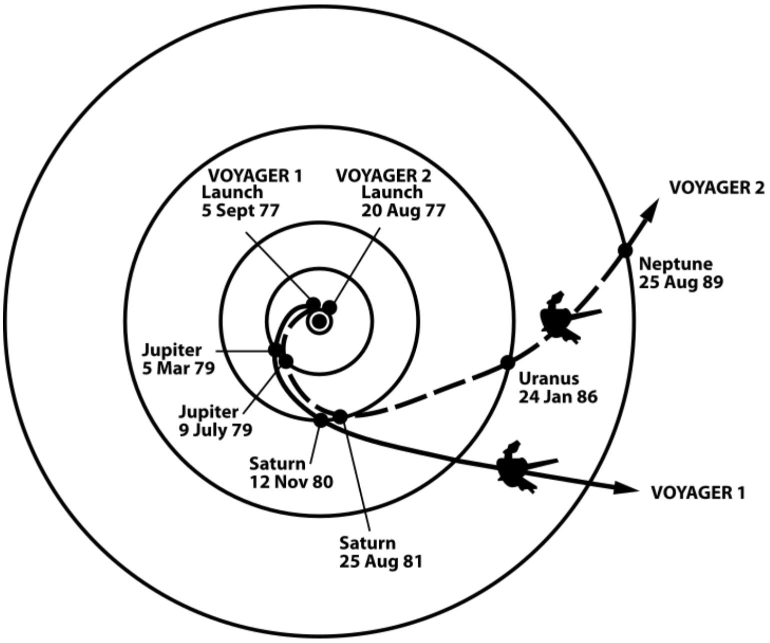
**Gravity Slingshot Effect**

Most of a rocket's energy supplies are required to get it out of Earth's orbit and into space. The speed necessary to escape Earth's gravity is about 11.2km/s or 40,320km/h. After the rocket reaches space, all excess weight, such as booster rockets and fuel tanks for the rockets, is jettisoned. Once a rocket is moving in space there is little to slow it down. However, it still needs some energy to move forward, to adjust its path and to slow down if it is to survive the impact of landing.

Many probes sent into our solar system are not sent in a straight line towards their target. Instead, they pass by other planets to pick up energy from the gravity of those bodies. This is called "gravity assist" or "the slingshot effect". As the largest planet in the solar system, Jupiter is often used for a gravity assist when probes travel to the outer solar system.

If planets were stationary, passing them would have no effect on the speed of a spacecraft. However, planets are moving very fast in their orbits. Spacecraft gain energy from being dragged along by the gravity of a planet and this gives them a kick of speed as they leave the planet's gravity. You may have seen something similar when watching a tennis player serve the ball. The ball is travelling relatively slowly through the air when it is tossed up by the player. When the ball is hit by a fast-moving racquet, it gains a lot of speed. Fortunately, spacecraft do not have to collide with a planet to speed up.

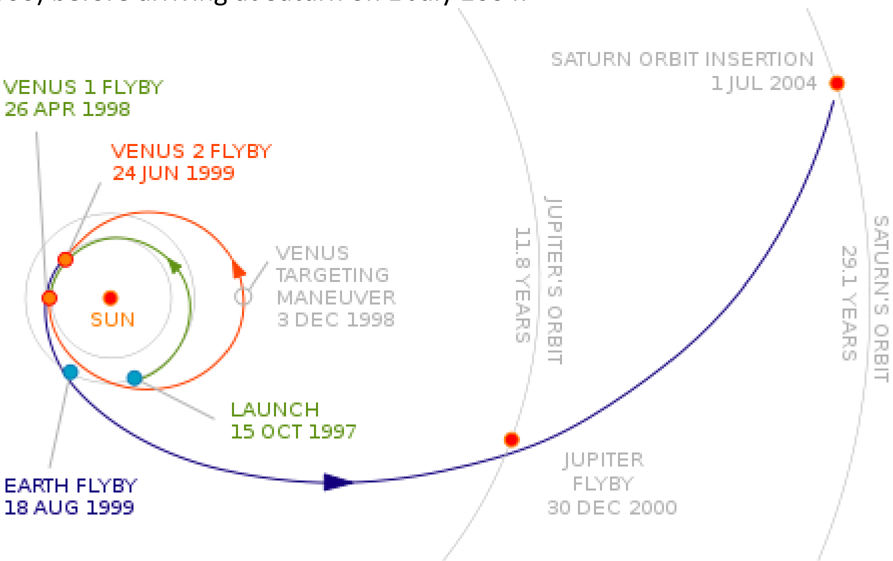
The two Voyager spacecraft launched in 1977 only had enough energy to get to Jupiter. However, a rare alignment of Jupiter, Saturn, Uranus and Neptune allowed the Voyagers to go much further. As they reached Jupiter, the slingshot effect from Jupiter's gravity allowed them to reach Saturn and further gravity assistance. Voyager 2 gained more information and gravity assistance from Uranus and Neptune on its journey. Both craft have continued beyond the orbit of Pluto into interstellar space.




*Pathway of the Voyager missions (NASA 2012, public domain)*

# Rockets and Range – Teacher Notes

The Cassini-Huygens probe was launched for Saturn in 1997 and arrived in 2004. It received gravity assistance from Venus (26 April 1998 and 21 June 1999), Earth (18 August 1999) and Jupiter (30 December 2000) before arriving at Saturn on 1 July 2004.



*Cassini's interplanetary trajectory (NASA 2009, public domain)*

***ASIDE*** - In Scotland, folk dancing is sometimes treated as a polite form of warfare. The pull and added speed from the more stationary dancers could be greatly increased by them dipping as they linked arms and spun the traveller round before releasing them. By lowering the centre of gravity of the individuals in the line the moving dancer ended up travelling extremely fast though not always in the direction they wished.

**Activity - Manned spacecraft or not**

Students are asked to suggest:
**Positive** (PLUS) aspects of manned spacecraft:
**The ability to respond to occasions not programmed**
**A human perspective of what happens**
**The chance to experience what no human has done before**
**The capacity to change programs to meet new challenges**
**Recognise opportunities to learn new things**
**Collect unknowns for testing**

**Negative (MINUS)** aspects are:
**Extra load of fuel for human support**
**Effect of human loss on public perceptions and funding**
**Extra expense required for high needs load**

**INTERESTING** aspects are**:**
**The challenge of meeting and overcoming totally new experiences**
**The development of new materials required**

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# Rockets and Range – Teacher Notes

**Rocket Science - Teacher Demonstration**

If the school owns a bicycle pump driven bottle rocket, teachers and selected students can test to find the optimum pressure (number of pumps) and volume of water in the bottle to produce the farthest flight. Perhaps the Laboratory Technician in the nearest secondary school might even lend you theirs.

Care must be taken not to put cool drink bottles under too much pressure or they will explode. Modern bottles are very much thinner than their predecessors.
The experiment should be done outside, preferably in an open grassed area.

Bottle kits can also be bought from game shops or through the Internet. Adventurous teachers will also find do-it-yourself directions for constructing these rockets and suggestions for class activities on the Internet

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