Teacher Resource Book

Exploring planetary science in the primary classroom

Curtin University

An Australian Government Initiative

Inspiring Australia

WHAT IS FIREBALLS IN THE SKY?

Dramatic meteors are called fireballs

Fireballs in the Sky is a citizen science initiative linked to the research of the Desert Fireball Network (DFN) team at Curtin University. The project aims to record fireballs (meteors or shooting stars) as they enter the Earth's atmosphere in order to calculate where they came from in space and where they landed.

WHAT IS PLANETARY SCIENCE?

Planetary science is the study of planets (incuding Earth), moons and smaller bodies of the solar system and how they were formed. It is a blend of geology and astronomy.

The study of meteorites, or meteoritics, allows us to find out what asteroids, comets and planets are made of, and thus learn more about the origins of the solar system. The project uses cameras stationed in the desert (the DFN) and a smart phone app (Fireballs in the Sky) which people all around the world can use to report a sighting.

HOW DO I USE THIS BOOK?

This book provides experiments and activity ideas to supplement classroom science and maths teaching around the theme of 'Fireballs in the Sky'.

Dissecting playdough meteorites

Experiments can be used individually or as the whole unit to engage students in science and maths.

Resources such as recipes and worksheets are available to photocopy (pages 50 - 69).

There are fact sheets and a glossary at the end of this book to help you out (pages 70 - 89).

HOW WILL THIS BOOK HELP WITH FORMAL LEARNING?

Some of the Fireballs team having a cuppa

The Australian Curriculum emphasises the use of the scientific method and understanding the endeavour of scientists themselves. Each topic in this book is set in Bybee's 5Es model of science learning and comes with a hands-on element.This will allow you to engage, explore, explain, elaborate and evaluate the topic with your students. **Space Rocks** targets students in kindy to year two. The activties in this unit may be scaled up or used as a warm up for the **Origins** unit lessons, designed for years three to six.

The experiments in this book have been written in a 'plan, predict, test, analyse, communicate' format to encourage regular use and familiarity with the scientific method.

Students will enjoy learning about the people behind the projection the website and can follow their field trips and achievements through the online blog. You can sign up for the e-newsletter and social media updates on the website.

A matrix of the relevant curriculum links touched on in each topic can be seen at the start of the **Space Rocks** and **Origins** units (pages 8 and 22 respectively).

WHERE CAN I GET MORE HELP?

You can contact the team on fireballs@curtin.edu.au

These experiments and activities, along with templates and fact sheets are also available on the website:

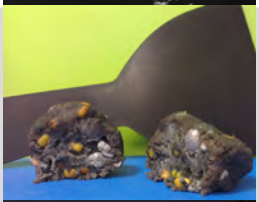
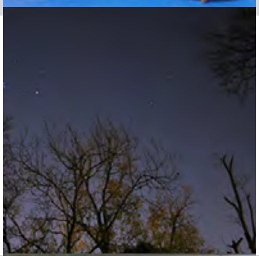
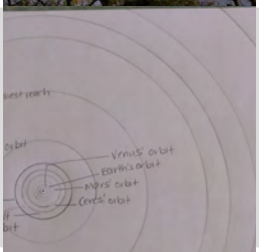
www.fireballsinthesky.com.au

SAFETY

While all of these actvities have been devised to carry out in a school classroom, you will still need to assess the risks related to your activity, with your children, in your venue. It is recommended that you read and plan the session ahead of time to be well prepared to mitigate any forseesable risks.

SPACE ROCKS UNIT
FOR YEARS K - 2

ORIGINS UNIT
FOR YEARS 3 - 6

Stage	**Activities**		**Page**
Curriculum links summary			22
ENGAGE Where do space rocks come from?	Making comets with dry ice and water ice Worksheet		24 60
	Meteorite Dissection Worksheet		29 61
EXPLORE How do we know about space rocks?	Sky Observing Sky Observing frame Worksheet		32 62 63
EXPLAIN Where do they come from? How do we measure space?	Solar Systems Scale Models Worksheet		34 36 64
	Measuring Intangible Heights Inclinometer template Worksheet		40 65 66
ELABORATE What made that?	Making Craters Worksheet		43 67
	Trajectories Worksheet		46 68
EVALUATE	Catapult craters investigation Worksheet		48 69

ABOUT THE DESERT FIREBALL NETWORK

Meteorites are the oldest rocks in existence; the only surviving physical record of the formation and evolution of the solar system. They sample hundreds of different heavenly bodies. Potentially, meteorites offer a direct route to understanding our origins. But to decode that record we need to know where they come from. The Desert Fireball Network (or DFN for short) is designed to provide that data.

Meteorites generate a fireball as they come through the atmosphere – you may even have seen one of these yourself. The DFN is a network of digital cameras in the outback desert of Australia which capture photographs of the night sky. By making networked observations of the fireball we can triangulate its trajectory, track the rock forward to where it lands, and back, to where it came from in the solar system.

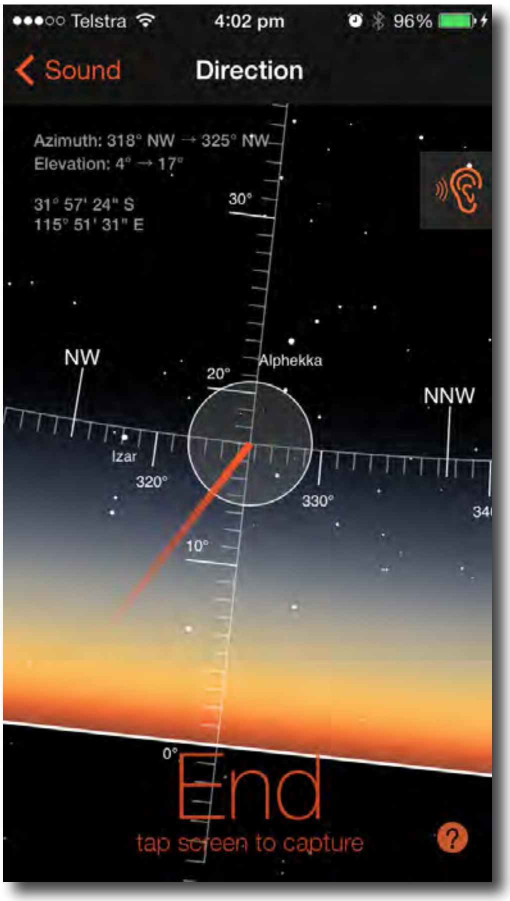
More and more cameras are being added to the DFN as the project expands. The final network will image the night sky over roughly one-third of Australia, and track whatever is coming through the atmosphere. DFN researchers will then go out and recover the meteorites. Knowing where the meteorite came from, and what it is made of, will help us to address some of the biggest questions in planetary science: how our planetary system came into being and how dust and gas produced a planet capable of supporting life – our Earth.

ABOUT THE APP

Download the app for free here:
http://www.fireballsinthesky.com.au/download-app/

You do not need to take a video recording of a fireball. The app displays the celestial sphere (star map) for you to click and drag the path of the fireball from start to end. The app then prompts you to indicate duration, shape, colour, brightness and fragmentation. It also prompts you to make a note whether you heard a sonic boom during or after seeing the fireball.

Enter your details to hear back from the team and find out about developing research on your fireballs!



ABOUT THE TEAM

The Desert Fireball Network team comprises scientists and engineers with qualifications in a range of areas. Geologists, minerologists, physisists as well as software, mechatronics and electrical engineers all work on the project.

The Fireballs in the Sky project is an Inspiring Australian initiative supported by the Australian Government through the Department of Industry.

You can find out more about the researchers and partners on the website.

Stay in touch by signing up to the Fireballs newsletters, like us on facebook, or follow us on twitter. You'll be able to find out about what we're up to and the community events we'll be at in the coming months.

		What is a rock and what's not?	*Shooting star stories*	*Space rocks game*	*Making craters*	*Edible meteorites*
Foundation year curriculum links						
Science as a Human Endeavour	Science involves exploring and observing the world using the senses (ACSHE013)	■	■	■	■	■
Science Inquiry	Explore and make observations by using the senses (ACSIS011)	■	■		■	■
	Engage in discussions about observations and use methods such as drawing to represent ideas	■	■	■	■	■
	Share observations and ideas (ACSIS012)	■	■	■	■	■
Physical Sciences	The way objects move depends on a variety of factors, including their size and shape(ACSSU005)	■		■	■	■
Maths Measuring	Use direct and indirect comparisons to decide which is longer, heavier or holds more, and explain reasoning in everyday language(ACMMG006)	■		■	■	
Maths Shape	Sort, describe and name familiar two-dimensional shapes and three-dimensional objects in the environment (ACMMG009)	■			■	
Year 1 curriculum links						
Science as a Human Endeavour	Science involves asking questions about, and describing changes in, objects and events(ACSHE021)		■	■	■	
Science Inquiry	Respond to and pose questions, and make predictions about familiar objects and events(ACSIS024)				■	■
	Participate in different types of guided investigations to explore and answer questions, such as manipulating materials, testing ideas, and accessing information sources (ACSIS025)		■		■	
	Use informal measurements in the collection and recording of observations, with the assistance of digital technologies as appropriate(ACSIS026)				■	
	Use a range of methods to sort information, including drawings and provided tables(ACSIS027)	■	■	■	■	■
Earth and Space science	Observable changes occur in the sky and landscape (ACSSU019)		■	■	■	
Physical Science	A push or a pull affects how an object moves or changes shape (ACSSU033)			■	■	
Maths Measurement	Measure and compare the lengths and capacities of pairs of objects using uniform informal units (ACMMG019)	■			■	
Year 2 curriculum links						
Science as a Human Endeavour	As for year 1	■	■	■	■	■
Science inquiry	As for year 1	■	■	■	■	■
Maths Measurement	Compare masses of objects using balance scales (ACMMG038)	■			■	■

ENGAGE

WHAT IS A ROCK AND WHAT IS NOT?

DESCRIBING AND CLASSIFYING ROCKS

What makes a rock a rock?

30 MINUTES

SUMMARY

What do rocks from space look like? Actually, not that different from Earth rocks. You know, the samples you have in your back yard, all over the school grounds, and quite possibly in a shoebox under your students' beds. We're going to start with them, and try and work out - what makes a rock, a rock?

Students will use their senses to observe and describe lots of samples and start to use ways of storing and sharing that information.

What's brown, hard, has layers and harder bits in it? A rock? or a frozen Snickers bar? Students will need to use lots of describing words to distinguish between rocks and not-rocks.

OUTCOMES

1. Students will observe, describe, compare and group rocks and 'not-rocks' - using colour, shape, informal measurements of length, mass.
2. Students will create a describing key for their rock collection, providing a library of activities to return to later.

EQUIPMENT

- Student rock collections or class sets
- Magnifying glasses or hand lenses (optional)
- Fun-size chocolate bars of different varieties, roughly chopped, frozen is best
- Describing key worksheets, page 50 - 52
- Other 'not-rocks' e.g. toys, building materials like bricks, wood, metal, fabric, plastic
- Large snap lock bags, takeaway containers or document wallets

THE ACTIVITY

Warm up:
Students pool their rocks and not-rocks together in groups and use their senses to observe and describe them. Have students place the items on the first template - What's a rock and what's not? Why? See worksheet, page 50.

Have students come up with clear descriptions which explain what things are rocks and what are not. If they find this hard without mentioning saying "it's chocolate, it's wood" tell them to pretend to be aliens who have never seen any of those things before. How would the alien describe it?

What is a rock and what's not? Why?

What objects have characteristics that overlap? Have students use the second template to place objects in Venn diagram-like fields, and write down the group describing word (see worksheet, page 51).

Plan:
Students are going to make a key (guide) for someone else to group their rocks. Have each student collect 4 - 6 rocks and think about all of the things that are the same and different about their rocks. Number the rocks 1 - 6.

Predict:
Students make their key using the worksheet (page 52). They need to ask questions about the rocks to be able to single them out.

To provide an answer sheet, you could
a) photocopy the sheet double sided and have students use their key on one side, writing the rock numbers where they fit
b) students take a photo of the rocks in the right places.

Test:
Students pack their rocks and the key sheet together in a bag. Students select a rock kit at random and follow the key to group the rocks. They compare their answer with the maker's answer.

Analyse:
Students share: Did the key work? (ie. did they end up with the rocks groups in the same way to the maker?)
If they didn't, why not? Students might then need to refine their key and re-test.

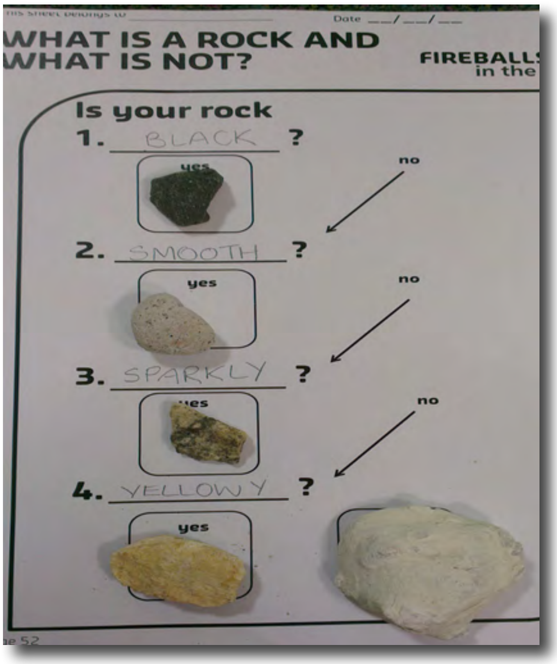
Communicate:
Student rock kits are placed in a box for students to have a go in a spare 5 minutes. Invite parents to try them out too.

SUGGESTIONS FOR THE CLASSROOM

- Example categories of items for learning and practising making describing keys:

  fruits, shapes, cartoon characters, items in a pencil case

- Use post-it notes with rock features to play with how keys are put together and to find the most useful way of sharing information.
- Instead of using words, students could draw or colour in the boxes to describe the rock features
- Add useful describing words to a vocabulary wall or similar to encourage students to continue using these words



Is your rock ...?

EXPLORE

HOW DO WE KNOW THERE ARE ROCKS IN SPACE?

SHOOTING STAR STORIES

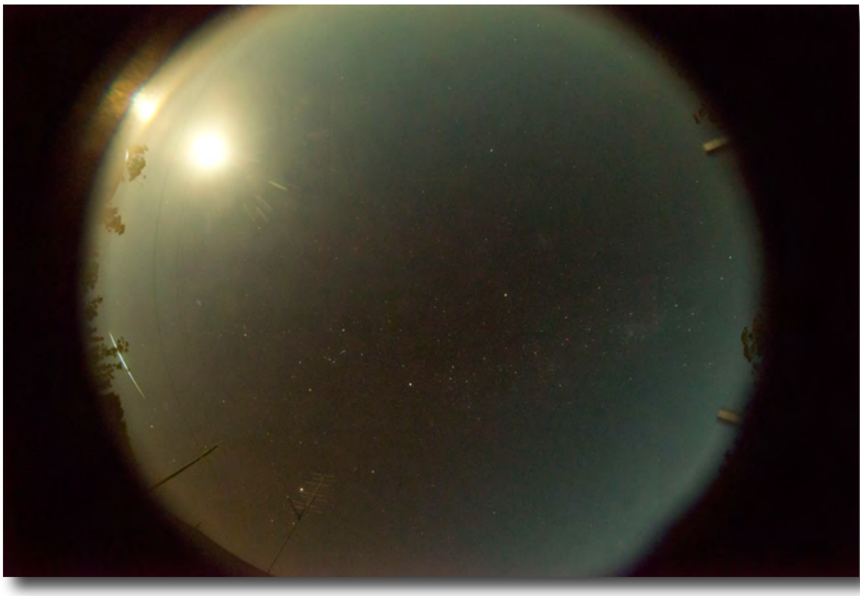
30 MINUTES AND 1 WEEK TO COLLECT STORIES

SUMMARY

In this activity students will interview their family and neighbours about their own observations of the sky: have they ever seen a shooting star?

It is unfortunate that most of us now live in cities where light pollution obscures much of the night sky. Despite this, many of us have seen a meteor, and remember it well. In any case, most of us have seen images of them in movies and on TV. By conducting interviews you'll be able to start conversations about space rocks at home and in the classroom.

Much can be learned from observing. Past Astronomers have determined the shape of the solar system, the distance to the sun, moon and planets and predicted planets and moons, just by observing.



Fireball (near horizon, left) captured by a DFN camera in Northam at dawn

OUTCOMES

1. Students share and engage in discussions about observations, asking questions and describing changes

2. Students explore the world using their senses and use drawings to represent ideas.

3. Students interview others to find out about their family or neighbour's shooting star experiences to discover observable changes in the night sky.

4. Students share their data about shooting stars with the class and discuss why their results might be different

EQUIPMENT

- Shooting Star Stories Worksheet, page 53

THE EXPERIMENT

Plan:

Students will be conducting interviews with their friends, families and neighbours to find out who has seen a shooting star. As a class, students write a list of what information they'd like to know about other people's shooting stars

Predict:

Students use the worksheet or make their own table and fill in the first line as themselves. On the second line students can predict what information they will get from their interviewees

Test:

Over the week, students take home their table and interview their family, friends, neighbours.

Analyse:

Students bring in their table and compare notes. In a teacher led discussion, find out from the class who has seen the most, least, and listen to different people's stories about shooting stars.

Communicate:

Students share the total number of shooting stars recorded by the class with their interviewees.

SUGGESTIONS FOR THE CLASSROOM

- Play music, read poems and find more artwork about shooting stars. Read some picture books about shooting stars and watching the night sky
- Discuss words that could be used to describe shooting stars and contribute these to the vocabulary wall
- Have students share stories about what they have been told about shooting stars and discuss how different cultures give them great importance. Have you ever made a wish on a shooting star?
- Encourage students to ask their interviewees more than just the questions on their table. Students can find out about how it felt to see a shooting star, whether interviewees look out for them etc.
- Download the 'Fireballs in the Sky' app to find out about when the next meteor shower will be and encourage the students to watch out for it.

EXPLAIN

ARE ALL SPACE ROCKS THE SAME?

MAKE A SPACE ROCKS GAME

30 MINUTES

SUMMARY

Comets, asteroids and meteorites are the main types of space rocks. They are all different but how can students learn about and remember them? By making up their own game!

In this activity students will be able to contribute what they know and sort new information in a variety of ways, culminating in them creating a class game much like the traditional 'knights, mounts and cavaliers'.

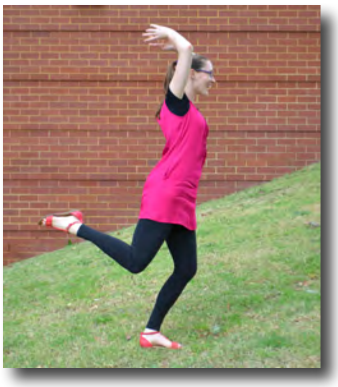
OUTCOMES

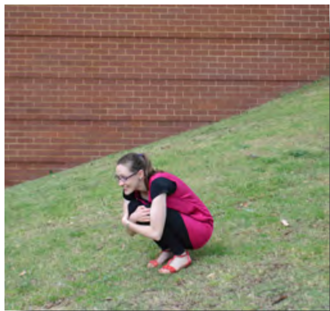
1. Students formulate and construct explanations about space rocks and use a range of methods to sort information.

2. Students consider how objects move depending on factors such as size, shape and conditions (e.g. atmoshere vs vacuum)

EQUIPMENT

- Space Rocks Game Worksheet, page 54
- Fact sheets, page 70 - 79; books, video





Possible asteroid, comet and meteorite poses

THE ACTIVITY

Plan:

Facillitate a student discussion about types of space rocks. Together, compile the information they know about comets, asteroids and meteorites and find out what they need to research. You could use a KWL chart.

Students find out about what is the difference between comets, asteroids and meteorites?

Students collect information as a list, Venn diagram, table or mind map

Predict:
Students think-pair-share ways to represent each of the objects using their whole body and try them out.

Have the class agree on three body movements (one each for comet, asteroid, meteorite) to test out for the game.

Test:
Outside or in an empty room, have the leader call out one of the objects. The aim of the game is for students to assume the right position. To increase the competition, have the last two people to get into position elimated each round.

Analyse:

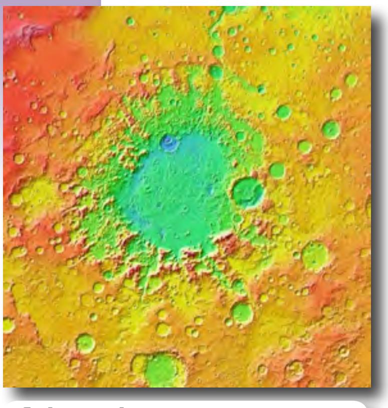
Does the game work? Why or Why not? are the actions to similar? Can everyone explain what each movement means?

Communicate:

Students explain the game - and the meaning behind the movements - to another class and play it together.

SUGGESTIONS FOR THE CLASSROOM

- Students invent a game for meteoroid, meteors, meteorites



False colour moon crater

ELABORATE

WHAT MADE THAT?! CRATER MAKING

60 MINUTES

SUMMARY

What happens when a space rock hits Earth? Sometimes they make a crater. In this activity, students will drop 'meteorites' onto a soft surface to experiment with making craters.

Students will be running their own experiments and testing different variables but it will be important to start with some free investigation. This will let students experiment with all of the variables randomly, for them to get the idea of the experiment. Afterwards, you can discuss how to make it a fair test? For example, discuss the difference when students drop or throw the meteorite down.

OUTCOMES

1. Students respond to and pose questions, make predictions about craters and explore answers by experimenting with materials to make craters

2. Students make informal or formal measurements and sort information

3. Students investigate how force moves or changes the shape of the impacted surface and relate it to changes that occur in our landscape

EQUIPMENT

- Crater making surfaces, in desk trays, such as:

loose earth	sawdust	flour
sand pit	dirt	

- Range of 'meteorite' samples,of different weights/sizes such as:

tennis balls	marbles	ping pong balls	dice
bouncy balls	sinkers	playdough	building blocks

- Recording and measuring equipment:

rulers	pencils
tape measure	camera

- Circle sizes template, page 55
- Results table worksheet (younger students - page 56, older students - page 57)
- Broom, dust pan and brush for smoothing surface and tidying up
- Safety glasses

SAFETY

This experiment requires dropping/throwing objects and loose sand etc. Discuss safety considerations with the students. Safety glasses are recommended and extra adult helpers would be advised.

THE EXPERIMENT

Plan:
A student will drop a 'meteorite' onto the surface in order for the group to find out what kind of crater it makes. What are the things that can be changed?

Choose what things you will keep the same, and what you will change. e.g. Keep the surface (sand pit), height of hand (50 cm), the same and test all of the different meteors.

This is very important in science experiments and makes it a fair test. Discuss what's fair when running a race, or doing a maths test. Things that can change in an experiment are called varibles. Things that are kept the same are constant variables.

Predict:
Each student predicts how big (diameter) the crater will be, using 'greater than, less than' terminology


Craters in flour

Test:
Student drops each meteorite in a fresh patch of the sand pit/other surface

Analyse:
Students measure the impacts, comparing them to the meteorite that made them, and other craters. Measuring can be with formal (metric) units or informal units (finger depth, counting blocks, which number circle?). Take some photos to record the data. Were the predictions correct?

Communicate:
Students share their findings with other groups and draw pictures of their craters.

As a class, graph the results: what size crater comes from different objects? You could repeat the experiment with different variables, for example, changing the surface and compare the findings across experiments.

SUGGESTIONS FOR THE CLASSROOM

- Watch the video 'Kandimalal - Aboriginal and Scientific views on Wolfe Creek Crater on the Fireballs in the Sky website
- Use Google Earth, Google Moon and Google Mars to observe craters visible from space. How are they similar and different to the ones you have made?
- Discuss how the angle of approach changes the crater. Can an object coming from space hit at any angle?
- Using a hand sifter, spread a thin layer of cocoa over the flour. This will make the impact craters more visible.
- At the impact calculator online you can choose the size, angle, velocity and density of your meteorite to see what kind of crater it will make:

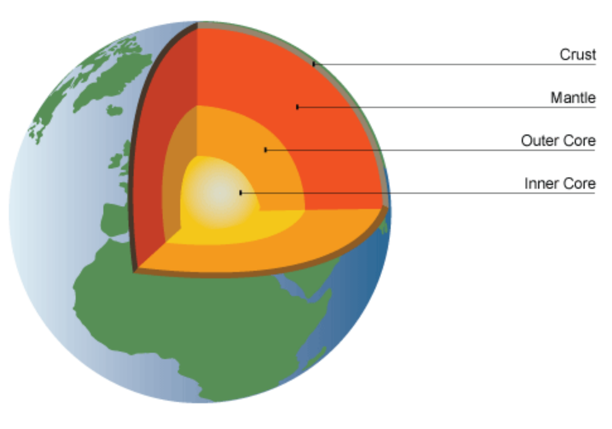
http://education.down2earth.eu/impact_calculator

EVALUATE

WHAT'S INSIDE SPACE ROCKS?

EDIBLE METEORITES

30 MINUTES (CREATING)
30 MINUTES (ANALYSING)



Asteroids, like Earth, can have a crust, mantle and core too (image: BBC GCSE Bitesize)

SUMMARY

Rice crispy slice and rocky road have quite a lot in common with meteorites. They're made of different bits and pieces that we can pick out. In this activity we'll have some fun making and dissecting meteorites. It's also a chance for students to reflect on all that they have learnt, and continue to ask more questions about space and rocks.

Scientists study what's in meteorites because they tell us about the planet, asteroid or comet they are from. Much like on Earth, solid iron forms at the core of planetary bodies, olivine crystals are found at the core-mantle boundary and mixed up rocky patterns are found closer to the crust.

OUTCOMES

1. Students learn about different types of meteorites and make observations using their senses to discuss, describe and draw representations of meteorites
2. Students test ideas and sort information about meteorites and their shapes and sizes
3. Students create and analyse edible meteorites that resemble a particular type of meteorite

SAFETY

Remember to check for any student allergies or food intolerances when preparing for this activity.

EQUIPMENT - CREATING

- Recipes for rocky road, rice crispy slice, page 58
- Ingredients required for above recipes
- Baking equipment - spoons, microwave safe bowls,baking paper, trays, teatowels and mits
- Microwave
- Fact sheets and Types of meteorite table, pages 70 - 85

THE EXPERIMENT - CREATING

Plan:

After investigating types of meteorite and discussing the differences between rocky road and marshmallow rice bars, students plan how they will make a sample of each of four types of meteorite (chondrite, achondrite, iron meteorite, pallasite).

Predict:

Students help make the meteorites by predicting how much of the important inclusions to add to each type of meteorites.

Have adults make the mixtures in a large bowl by following the instructions on page 58.

Test:

To make individual meteorites, students collect a 'slice' of their meteorite type and mould it into a shape.

Using tongs, students dip their shape into melted chocolate and leave to cool.

Analyse:

After the meteorites have been left to set, students give their samples to other groups to dissect - see describing experiment

Communicate:

Have students design an advert for their meteorite treat explaining what it is made from, and what those things represent.

Rocky road pallasite meteorite

EQUIPMENT - DESCRIBING

- Pre-made edible meteorites of different varieties
- Clean work area or placemats
- Butter knives or dough cutting spatulas
- Camera/digital tablet for recording images

THE EXPERIMENT - DESCRIBING

Plan:

Students revise the different types of meteorites they have learnt about and decide what they will look for when dissecting the edible meteorites

Predict:

Students 'discover' their meteorite and before disecting it, predict what kind it is. Normally scientists have to do this and it may be many months, if at all before they can look inside their meteorite

Test:

Students make a single careful incision in their meteorites to divide it in half. They create a labelled sketch of what they see. They could also take photos of the sample.

Analyse:

Students hypothesise the type of meteorite they have and explain why. They may need to make another cut - make sure to do it carefully!

Communicate:

Students share with others what they found out about their meteorite and discuss their hypothesis with the student who made it. They also tell them how delicious it was!

SUGGESTIONS FOR THE CLASSROOM

- Read about meteorites and types of meteorites and have a look at real samples. Describe the different pictures. Create a simple table to explain the differences between chondrites, achondrites, iron meteorites and pallasites.
- Use a defined cooking space that is clean and ensure students wash hands and maintain good hygiene while creating meteorites. Remind them that they won't be able to sample the meteorites if they have not been hygeinically made.
- After modelling the known types of meteorites, students will enjoy creating their own, and being able to explain its make-up to the class.
- As another finishing activity, check out Space Rocks! A giant Meteorite Board Game from the Lunar and Planteary Institute: http://www.lpi.usra.edu/education/space_days
- Introduce the difference between the words 'chondrite' and achondrite' by comparingthem with 'symmetry' and 'asymmetry'

Rocky road chondrite

Rice crispy achondrite

		Make a comet	Meteorite dissection	Star gazing	Solar systems	Intangible heights	Making craters	Trajectories	Crater investigation
year 3									
Science as a Human Endeavour	Science involves making predictions and describing patterns and relationships(ACSHE050)	■	■	■	■	■	■	■	■
	Science knowledge helps people to understand the effect of their actions (ACSHE051)						■	■	■
Science In-quiry	With guidance, identify questions in familiar con-texts that can be investigated scientifically and predict what might happen based on prior knowl-edge (ACSIS053)	■	■	■			■	■	■
	Suggest ways to plan and conduct investigations to find answers to questions(ACSIS054)		■	■		■	■	■	■
	Safely use appropriate materials, tools or equip-ment to make and record observations, using formal measurements and digital technologies as appropri-ate (ACSIS055)		■	■		■	■	■	■
	Use a range of methods including tables and simple column graphs to represent data and to identify patterns and trends (ACSIS057)		■	■		■	■	■	■
	Compare results with predictions, suggesting possi-ble reasons for findings (ACSIS215)		■	■		■	■	■	■
	Reflect on the investigation, including whether a test was fair or not (ACSIS058)		■	■		■	■	■	■
	Represent and communicate ideas and findings in a variety of ways such as diagrams, physical rep-resentations and simple reports (ACSIS060)	■	■	■		■	■	■	■
Earth and Space	Earth's rotation on its axis causes regular changes, including night and day (ACSSU048)			■				■	■
Maths Measuring	Measure, order and compare objects using familiar metric units of length, mass andcapacity (ACM-MG061)		■		■	■	■	■	■
Maths Geom-etry	Identify angles as measures of turn and comparean-gle sizes in everyday situations (ACMMG064)					■	■	■	■

		Make a comet	Meteorite dissection	Star gazing	Solar systems	Intangible heights	Making craters	Trajectories	Crater investigation
Year 4									
Science as a Human Endeavour	As for year 3	■	■	■	■	■	■	■	■
Science Inquiry	As for year 3	■	■	■	■	■	■	■	■
Earth and space	Earth's surface changes over time as a result of natural processes and human activity(ACSSU075)	■		■			■		■
Physical science	Forces can be exerted by one object on another through direct contact or from a distance(ACSSU076)				■		■	■	■
Maths Mesuring	Use scaled instruments to measure and compare lengths, masses, capacities and temperatures (ACMMG084)				■	■	■	■	■
Maths Geometry	Compare angles and classify them as equal to, greater than or less than a right angle(ACMMG089)					■		■	■
Year 5									
Science as a Human Endeavour	Science involves testing predictions by gatheringdata and using evidence to develop explanations of events and phenomena (ACSHE081)	■		■	■	■			
	Important contributions to the advancement of science have been made by people from a range of cultures (ACSHE082)			■		■	■		
	Scientific understandings, discoveries and inventions are used to solve problems that directly affect peoples' lives (ACSHE083)			■			■		
Science Inquiry	With guidance, pose questions to clarify practical problems or inform a scientificinvestigation, and predict what the findings of aninvestigation might be (ACSIS231)		■			■	■	■	■
	With guidance, plan appropriate investigation methods to answer questions or solve problems(ACSIS086)			■			■	■	■
	Decide which variable should be changed and measured in fair tests and accurately observe, measure and record data, using digital technologies as appropriate (ACSIS087)	■					■	■	■
	Use equipment and materials safely, identifying potential risks (ACSIS088)	■	■			■	■	■	■
	Construct and use a range of representations, including tables and graphs, to represent and describe observations, patterns or relationships in data using digital technologies as appropriate(ACSIS090)		■	■		■	■	■	■

		Make a comet	Meteorite dissection	Star gazing	Solar systems	Intangible heights	Making craters	Trajectories	Crater investigation
Year 5 (continued)									
	Compare data with predictions and use asevidence in developing explanations (ACSIS218)	■		■		■	■	■	■
	Suggest improvements to the methods used to investigate a question or solve a problem(ACSIS091)	■					■	■	■
	Communicate ideas, explanations and processes in a variety of ways, including multi-modal texts (ACSIS093)					■	■	■	■
Earth and Space	The Earth is part of a system of planets orbiting around a star (the sun) (ACSSU078)	■	■	■	■	■	■		
Maths Measuring	Choose appropriate units of measurement for length, area, volume, capacity and mass(ACMMG108)			■		■	■	■	■
Maths Geometry	Estimate, measure and compare angles using degrees. Construct angles using a protractor(ACMMG112)								
Year 6									
Science as a Human Endeavour	As for year 5	■		■	■	■	■		
Science Inquiry	As for year 5	■	■	■	■	■	■	■	■
Earth and space	Sudden geological changes or extreme weather conditions can affect Earth's surface (ACSSU096)						■		
Maths Geometry	Convert between common metric units of length, mass and capacity (ACMMG136)				■	■	■	■	■
Maths Geometric reasoning	Investigate, with and without digital technologies, angles on a straight line, angles at a point and vertically opposite angles. Use results to find unknown angles (ACMMG141)					■			■

ENGAGE

WHERE DO SPACE ROCKS COME FROM?

MAKE A COMET WITH DRY ICE AND WATER ICE

TWO 30 MINUTES AND OVERNIGHT

SUMMARY

Meteorites, asteroids, comets – they're all kinds of space rocks aren't they? The terminology can be confusing and often is confused – by journalists and scientists as well! Use this lesson to chat about what the different terms mean and ways to remember them, and to pique the curiosity of your students.

The fact sheets on pages 70 - 85 are very useful for understanding the differences. A meteorite is called a meteor (shooting star, fireball) when it's entering the atmosphere. Before it enters, it's called a meteoroid. Most meteorites are rocks that have come off asteroids or comets and landed on Earth. Asteroids are rocks with a stable orbit around the sun, such as those in the asteroid belt between Mars' and Jupiter's paths. Comets are more complex than asteroids because they have unusual orbits and aren't all rock. Comets are mostly water ice and other kinds of ice including frozen CO2 (dry ice) and other frozen liquids and gases such as methane and ammonia. They are sometimes called "dirty snowballs"

Dry ice, or solid Carbon Dioxide, can be picked up from a supplier in most towns quite cheaply but it is dangerous if not handled correctly. Read all of the safety information and be prepared well in advance for this demonstration. Make the dry ice comet as a class demonstration – have a look at NASA's video demonstration (see suggestions).

While that's slowly melting, students will make their own comet mixes with water, and stick them in the freezer to inspect the following day.

Comet 67P
http://www.esa.int/rosetta

OUTCOMES

1. Students understand that Earth is part of a system of planets (and other things!) orbiting our sun, and their motions are controlled by a force called gravity
2. Students experiment with changing variables, handle equipment safely, compare data with predictions and suggest improvements for making comets.

EQUIPMENT

- 500g Dry ice (see info sheet) - in styrofoam esky
- Temperature resistant safety gloves
- Safety glasses
- Water
- Dirt (solar system dust particles)
- Honey (organic molecules)
- Methylated spirits (methanol)
- Vinegar (amino acids)
- Cloth bag
- Hammer
- Large bowl
- Plastic bag
- Large plastic tray
- What is a comet fact sheet, page 78-79
- Worksheet, page 60
- Freezer bags

SAFETY

Dry ice is frozen carbon dioxide

Dry ice can be dangerous if not handled correctly. Make sure you:

- Wear temperature resistant gloves
- Wear safety glasses
- Maintain student distance from ice at all times

Dry ice can be obtained from BOC gases shops. You will need less than 1 kg of ice for this experiment. In a polystyrene esky, 5 kg of ice can sublime or 'disappear' in 8 hours on a warm day.

Sublimation is the process of a solid going directly into a gas phase, without melting. Dry ice sublimes at temperatures above -78 degrees celcius. This means that at room temperature it will be turning from solid to a gas.

Gases take up more space than their solid form. Do not trap dry ice in a container with a screw-on lid. When transporting in a car, ensure windows are open to allow for excess Carbon Dioxide to escape.

SET UP

This activity is best done in an outdoor courtyard.
Have equipment ready, including your safety gear, and establish where you are going to use dry ice and where the students will stay sitting down.
We suggest you run your demonstration like this:

What's out in our solar system?
Planets, sun, moon, moons, asteroids, comets, space, satellites, dust, rocks, ice, aliens?

What do we call rocks in space?
Asteroids, meteoroids, comets, rings on Saturn

What's the difference?
Orbit, size, etc.
Asteroids= regular orbit, whole rocks, between mars and Jupiter, and further out
Comets = more icey balls of rock and dust, eccentric orbits – come in close to sun, but also out with Pluto

Today we're making a comet. What will we need? What's in them?

ın comets	Notes	To make comet:
• Water ice	water is very common in the solar system, but it's almost always solid, except on Earth	2 - 3 cups water
• Dry ice	solid carbon dioxide is also common on comets	500 g dry ice
• Dirt/rock	dust and rock left over from the beginnings of the Solar System	1 cup dirt
• Organic molecules	there is evidence of carbon-hydrogen containing molecules on comets. These provide a hint that perhaps life on Earth and other planets has been initiated by comet impacts	see below
• amino acids	these are the building blocks of proteins	1 tbs vinegar
• nucleic acids	these are the building blocks of DNA	1 tbs honey
• methyl acohol	this is a very simple organic molecule	1 tbs methylated spirits

Mix these ingredients (except dry ice) well, then add:
(Put on safety gloves!) about 500 g dry ice (doesn't need to be exact), crushed into small pieces. Use the plastic bag to mould the dry ice and ingredients into a rough lump (hands outside the bag, have a look at the video).

What happens when a comet comes near the sun? what would happen to an icecube?
Melt – vapourise CO_2, water, dust all stream off in direction away from sun because of direction of travel and solar winds

What happens when Earth passes through this stream? – *meteor shower!*

You will be able to feel when all the ingredients are frozen into a solid "comet" lump, which can now be handled with gloved hands. If you like, you can sprinkle some more dirt over the top, most real comets are very dark.

Analyse:
Study the comet as it melts. What is happening? You might like to use a hair dryer and a fan to simulate the heat and solar winds from the sun.

The comet model will shoot out "jets" of gas as it solidifies, just like a real comet. The "gas" we see here is actually water vapour from the air around us, which is turned into tiny ice crystals when it comes into contact with the cold dry ice.

Real comets are much bigger than our model – the nucleus of a comet (the "dirty snowball") can be from 1-10km across. As comets approach the sun, they develop a dust tail and a plasma tail (containing gas particles) which are visible from Earth as comets go past.

Scientists can tell what comets are made of by studying the light reflected from a comet. Different substances reflect light in different ways. Some space missions have also taken samples from comets.

THE EXPERIMENT - WATER ICE COMETS

Students will make their own water ice comets in a bag and freeze it. The aim of the experiment is to find out how each of the components affects the whole while using representations to understand what comets are made from.

Plan:
Students discuss what a comet looks like and why a comet might create a meteor shower on Earth.
Students plan variables – what will make an awesome tail/ meteor shower, but stick together enough to still be a comet?
Make predictions and divvy up the variables. See the worksheet for recipe details

There are five variables so five different groups can test each ingredient to see how it affects the comet as a whole.

Predict:
Make the equipment available to students. Students predict what the comet will look like when its first made and how it will hold together (see worksheet).

Test:
Pour all the ingredients into the plastic bag and mix by massaging mixture from the outside. Twist the loose bag up tightly, squeeze out air and put in a freezer.
Are students' predictions the same as when they started?

- Leave overnight -

Analyse:
Take the bags out of the freezer and examine – what held together best? Worst?
Allow comets to warm up for about 10 minutes before examining. Students will enjoy 'testing' their integrity by throwing them across a clear grassed area. Do they crumble? How would you make it differently?

A dry ice comet

Communicate:
Students answer questions on worksheet and discuss:
Why do comets have tails?
What would happen to comet tail remnants falling towards the moon?

SUGGESTIONS FOR THE CLASSROOM

- Have a look at different images of comets and discuss how we have the photographs.
- The recent ESA space mission Rosetta landed a probe on comet 67P. Check out videos and images on the website:

  http://rosetta.esa.int/

- See NASA JPL video on comet making:

  http://www.jpl.nasa.gov/video/details.php?id=945

The students might have some good ideas how to find out the answers of these questions if you have some left over dry ice You will need to be their experimenter, but let them lead the experiment by following their instructions, where safe to do so

- What would happen if we had dry ice icebergs on Earth? (e.g. stick some in a clear bowl or cup of water)
- How much gas does one pellet give off? (e.g. insert a pellet into a balloon)
- What sound would dry ice glaciers make against rock? Other glaciers?

Rosetta mission on Comet 67P - http://www.esa.int/rosetta

ENGAGE

WHAT ARE METEORITES MADE FROM?

METEORITE DISSECTION

30 MINUTES

SUMMARY

Sure, meteorites are rocks from space. But from what kind of rocks? Studying the rocks themselves can tell us a lot about what kind of planet or asteroid it might be from. Dissection and x-ray style techniques on meteorites can reveal how much upheaval it's had on it's journey and the kinds of minerals it's made from.

We can also compare their composition to that of Earth: iron nickel meteorites are very similar to what we anticipate at Earth's core, so they're probably from the core of another planet that didn't quite make it, or a large asteroid.

In this investigation students will need to be familiar with different types of meteorites in order to make their own models. Borrow some meteorites from your museum, or check them out online. They can be surprisingly varied in looks, texture, density, not to mention size. See the 'Types of Meteorites' fact files for example images.

In this activity students will create a model meteorite using playdough and other household items. The class group will work to a standard system of representation for all the meteorite inclusions (e.g. bead = crystal, see equipment below). Using the key and dissecting the meteorite, students should be able to accurately identify the type and origin.

OUTCOMES

1. Students make, dissect and identify model meteoirtes by following a key
2. Students provide evidence to communicate their process and result
3. Students learn about different types of meteorites, their make-up and where they come from

What type of meteorite do you have?

EQUIPMENT

- 500 g - 1Kg Playdough or clay
- 50 - 100g of each of the following items in equipment column (or something similar)

Equipment	Representing
Pebbles/gravel	Rocky
Dried mung beans	Organic molecules
Sinkers	Chondrules
Yellowish beads	Olivine crystals
Magnets	Iron

- 15 plastic knives or plastering paddles
- Newspaper, placemats or tablecloths
- 'Types of meteorites' fact files, page 85
- Black crepe paper
- Worksheet, page 61

SET UP

1. Provide Types of Meteorites sheets to student groups and note books/worksheets for rough work
2. Set class up in group tables so that they can share resources – provide each group of 6 with 1.5 cups of playdough, a small bowl each of the inclusions, ¼ sheet of black crepe paper
3. Protect desks from playdough with newspaper/tablecloths/ placemats if desired

THE EXPERIMENT

Plan:

Students study their meteorite fact files, and get familiar with 'what represents what'.

Students make a meteorite true to one of the types – about the size of a billiard ball and put them all in a box (you may want to designate certain people certain types so that you don't have 30 of one kind)

Predict:

Students take a meteorite to study and predict what theirs is without unwrapping or cutting (see worksheet)

Test:

After careful dissection (slice in two, exposing a flat inner surface), students measure, sketch, label and carefully describe the meteorite. Students make a hypothesis about the origin of the meteorite

Analyse:

Students share their results with a partner to see if they agree.

Communicate:

Students complete the worksheet to create information panels for their meteorite. These can be displayed in the classroom 'museum', grouped by type or suspected origin.

SUGGESTIONS FOR THE CLASSROOM

- Read about types of meteorites together in the fact sheet and online and summarise the information in a table to help students break down the important points.
- See 'edible meteorites' in junior section for more ideas about making meteorites
- Encourage students to use new words from the vocabulary activity when describing the meteorites, after they have used their own language to describe the objects.
- Find out about local area meteorites and what types they are

Imitation carbonaceous chondrite
Students will find it easier to cut meteorites after removing the 'ablation crust' layer

ORIGINS

EXPLORE

HOW DO WE KNOW ABOUT SPACE ROCKS?

SKY GAZING

30 MINUTES SET UP, THEN 5 MINUTES/NIGHT (OR AS CLOSE AS POSSIBLE) FOR 5 WEEKS

SUMMARY

How do we know so much about space if only a handful of astronauts have ever left the planet? Most of our space knowledge comes from standing on the ground and looking – with our eyes, through optical telescopes and by measuring the energy waves we can't see as visible light with radio telescopes

Nicolaus Copernicus worked out that the Earth went around the sun and Galileo Galilei found out that other planets have moons too just by looking. There's some wonderful stories to be read about the human endeavours behind astronomy. In this activity, we're going to do the looking ourselves.

Since you can't see much of space in the day time, the data collection for this experiment will need to be done as homework. If students are invested in their predictions and prompted regularly to complete their chart, they'll have their own data to interpret at the end of the month.

OUTCOMES

1. With guidance, students plan investigation and acurately observe and record data to plot the month's sky
2. Students compare data with predictions and use evidence for forming explantations.
3. Students understand tha Earth is part of a system orbiting a star and that it's rotation causes day and night.
4. Students understand that scienc einvolves making predictions and describing patterns and relationships

What can you see from your backyard?

EQUIPMENT

- Weekly sky observing chart for each student, for five weeks, page 63
- Sky observing frame, page 62

THE EXPERIMENT

Plan:

Students will record the patterns in the sky for one month. What should they be looking for? When will they need to be doing it? Agree on 3 sky diary foci (e.g. moon shape, Star patterns, sunset time, general notes) How will they keep the data 'fair'? (e.g. draw star patterns at the same time each night, standing in the same position at home)

Lead discussions in the difficulties of data collection – before starting and then at the end of week 1 once students have had a go.

How will they know they're always looking at the same area? (choose location, facing, make frame, line up frame with a close object (window, fence, tree trunk, not a star!)
Will they always see the moon? Always at night?

Predict:

Discuss with students what they think they will find out by making a sky gazing chart. What do they already know about patterns in the sky?

Test:

Students take home their sky diary on Monday and record what they see each night for a week. This can be a combination of written notes and drawings. Regularly discuss the sky diary to keep students on task and solve any problems early.

Analyse:

Each student examines their own diaries over the month and identifies patterns, then checks with a partner whether these patterns exist elsewhere. Have students predict what they would see in another week, month and 2 months.

Communciation:

Students write about what happened over time in the sky first as scientific notes and explanations, then creatively as a story to make it memorable. Discuss other cultures' stories about day and night.

SUGGESTIONS FOR THE CLASSROOM

- Build up to it – get the students excited by the activity in advance and send a note home to parents about what the students will be required to do. For younger students, try a practise night and have students all bring in their sheets to discuss their results and their questions.
- Use this activity to help students understand Earth's rotation on its axis causes night and day. Discuss before and after the month of data collection why the stars move and where the sun goes each night. Model the earth's rotation with a ball while students play out the places of the sun and the moon.
- Have a practise night where students go home and find a good viewing spot and time that they can go back to each night, for example from the back door, just before bed time. Have students define the area they look at each night using land

ORIGINS

EXPLORE

WHERE DO METEORITES COME FROM?

SOLAR SYSTEMS

30 MINUTES

Milo looks a bit like the beginnings of a solar system.

SUMMARY

Most of us are familiar with the planets and the order they are in from the sun out to Pluto. But what does that look like? and why do they stay there? And what else is there? Here's a few ways of 'viewing' the solar system before we get onto calculating the scale.

Things in space spin. Most scientists agree the initial energy for this came from a massive explosion called the Big Bang. A spinning top on a table slows down and falls over because it rubs with air and drags along the table – causing friction and energy transfer from movement to sound and heat. There's very little resistance in space because there's no air or table, so things keep spinning.

Gravity is an attractive force. Everything with mass has gravity and the bigger it is, the stronger pull it has. In our solar system, the big player is the sun, but every other planet, moon and rock has it's own gravity which does it's best to pull anything smaller in. When there's two objects with a decent sized gravity (such as the Earth and the moon), they don't crash into each other, they keep each other at arms length because they're also caught up in the Sun's stronger pull and that ever-present spin.

What's often forgotten in model solar systems is all the meteoroids, asteroids and comets out there too, so let's include them.Use the table on page 64 to get approximate positions of each object in our solar system. We will look more closely at the objects in our solar system and their scale in the next activity, but for this activity, we are making a 'standard issue' solar system - estimates put them at over 100 billion solar systems in our galaxy alone!

OUTCOMES

1. Students explore the forces exerted on objects in a solar system
2. Students get familiar with the parts of the system of which Earth is a part

EQUIPMENT - BOWL SOLAR SYSTEM

- Deep bowls and spoons – 1 between 3 (or you can do it one each with milk and every students gets a Milo drink afterwards)
- Water (or milk)
- Dirt, (or Milo)

THE ACTIVITY - BOWL SOLAR SYSTEM

1.Students stir the water with a spoon until they've created a vortex – this is establishing the 'spin energy' given to the solar system from the original explosion
2.Add a (dry) spoon of milo directly to the centre vortex and observe what happens

Analyse:
Why does the spinning stop?

EQUIPMENT - OVAL SOLAR SYSTEM

- 1 x biggest ball you can find (representing the sun)
- Up to 10 x various sized balls (representing planets of different sizes)
- Up to 10 x buckets (representing different sized asteroids, meteoroids)
- Up to 10 streamers/fabric strips (representing comets)
- Have enough props for every person in the class

THE ACTIVITY - OVAL SOLAR SYSTEM

1. Explain to students that they're going to make a solar system on the oval, with each person representing either a planet, an asteroid (or bucket full of asteroids) or a comet.

2. Discuss how and where each person will need to move to complete the solar system,

3. Introduce the various objects (people) jogging their orbit one at at time:
- leave the sun as a ball at the centre of the oval/playground.
- inner rocky planets,
- outer gas planets - all orbiting the sun,
- then asteroids - chose a belt area, and then some asteroids can have a different orbit, then the
- comets will come in from out at the edge of the oval, doing a quick fling past the sun before heading back out again.

4. Have a student film the whole group moving to watch back later, or rotate students out of the system so they can see it from a distance.

Analyse:
How were the two models like the solar system? how were they different?
How many different bodies colided (or almost collided)?
How many would have caused meteor showers on earth?
Meteors come from comet trails, asteroids, loose meteoroids floating about in space, and chips off planets now and in the past.

EXPLAIN

WHERE DO METEORITES COME FROM?

SOLAR SYSTEMS - SCALE MODELS

30 MINUTES

SUMMARY

Now that the students have a grasp of all the types of objects present in a solar system and their orbiting habits, it's time to take a look at the actual distances between them. In this activity students will calculate scale models of the solar system, and it's suggested that they try it out on a sheet of paper, then work it up to the school oval.

The vast size of the solar system introduces a new unit of measure – the Astronomical Unit (AU). The AU is equal to the mean distance between the Sun and the Earth. It was used by early astronomers before they could accuratley calculate the individual distances between planets, to compare the distances within our system. For example, Jupiter and Pluto are 5.2 and 39.5 AU from then sun respectively. One AU is equal to 149,597,871 km. Some other comparison measurements we use commonly are the height of Mt Everest (Olympus Mons on Mars is three times the height of Mt Everest) or Olympic Swimming pools (the volume of Sydney Harbour is equal to 200 000 Olympic swimming pools).

With the following resources your students will sketch a scale model on an A4 sheet of paper - but wait! Does it all fit with the first scale we try? How can we fix the problem? Once everyone's got an A4 version, it's time to test our estimating technique by up-scaling to the school oval. The A4 version should help, but there's nothing like pacing it out to get a feel for it. With some flags and prior warning to the sports classes, You'll be able to demonstrate the scale solar system to other classes too.

OUTCOMES

1. Students create scale models of the solar system, and its components, inside and outside the classroom
2. Students use scale instruments such as rulers, tape measures and trundle wheels to measure and compare lengths choosing appropriate metric units and converting between cm/m/Km/AU

EQUIPMENT

- Solar system distances resource and worksheet, page 64
- Rulers, measuring tapes, trundle wheels

- Calculators and compasses
- Flags, markers or various sized balls (for outside solar system)
- 3 plain A4 sheets of paper (per student), coloured pens

THE EXPERIMENT

Set up:

Students will create a scale model of the solar system. Discuss what kinds of things are in our solar system, and what's outside. Our solar system contains one star, 8 (or 9 with Pluto) planets, comets, asteroids, moons, an asteroid belt, the Kuiper belt, the Oort Cloud. To start our making a scale model, students will need to measure the greatest area they have available – i.e. the maximum radius of their piece of paper/school oval.

Plan:

Students calculate the scale of their solar system, based on:

distance from edge of the solar system to sun ÷
distance from edge of model to middle

= distance outer edge of Oort cloud to sun ÷
distance outer edge of A4 paper to centre (lengthways)

= 100 000 AU ÷ 148 mm

= 676 AU / mm

i.e. 1 mm = 676 Astronomical Units (AU)

(see worksheet)

Predict:

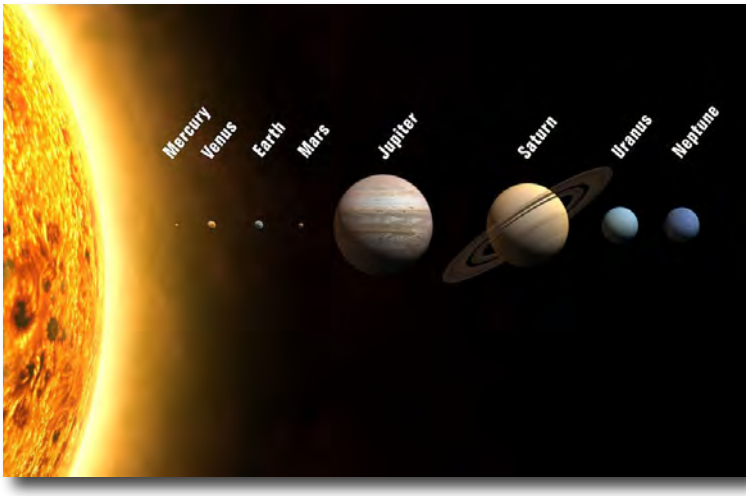
Now that we have an outer perimeter for the system, students can estimate where the rest of the objects will go and sketch a few points in to record their predictions.

Test:

Now calculate the rest of the objects' mean orbit, using the table and the same scale from before, e.g.

distance from Pluto to the sun on model =
acutal distance from Pluto to the sun ÷ scale

= 39.5 AU ÷ 676 AU / mm



Another not-to-scale solar system image

= 0.058 mm

Oh no! That's ridiculously close to the sun, how will the rest of the planets fit in? This scale just won't work without a micrscope. Brainstorm with the students how to rectify the problem, without discounting the true size of the solar system, or losing the scale.

Your best option will be to use three separate pieces of paper and three different scales - a chance to experiment further with scale! This shows how truly big our solar system is, and explains why we rarely see images of the whole thing to scale.

See images on page 39.

For A4 paper, you should be able to fit the following onto each sheet:

1. The outer edge of the Oort cloud to the inner edge of the Oort cloud (with the sun in the middle)

   scale is 1 mm = 676 AU
2. The inner edge of the Oort cloud to the span of the Kuiper belt (with the sun in the middle)

   scale is 1 mm = 67.6 AU
3. The rest of the planets, asteroids, Halley's comet's reach to the inner edge of the Kuiper belt

   scale is 1 mm = 0.338 AU

The next bit of fun is to expand it out - to the size of the oval, using the same steps as follows here - see 'communicate'

Analyse:

Not all scientists agree on what the 'edge' of the solar system is - you may have noticed that the probe Voyager has passed the edge of the solar system multiple times, as the years go on and we find out more about where we live. What do the students think constitutes the edge of the solar system? Is it how far the sun's gravitational influence extends? Is it measurable by temperature? By the last known object?

Commmunicate:

Using the same process as before, establish a scale for the whole solar system (including Oort cloud) to fit the school oval. Will it work? (ie, is there enough space to mark out the objects closest to the sun?) Have the students decide on the scale you should use, and mark with flags or balls the objects that you can. Invite another class to come out and see it and get the students to explain how they worked out the scale.

SUGGESTIONS FOR THE CLASSROOM

- This activity, while stressing the importance of the scale of distance has neglected a bunch of important points - can the students identify what is wrong?
    - No planet's orbit is perfectly circular, they are ellipses
    - The scale size/volume of each planet and rock has not yet been considered
    - While the planets orbit relatively close to the same plane (imagine the horizontal layer of jam in a layer cake), most comet orbits are out of the plane (imagine a diagonal cut through the cake)
    - What about moons?
- Check out an online interactive that lets you zoom in and out of the universe: http://scaleofuniverse.com/
- Find out more about the Voyager mission:

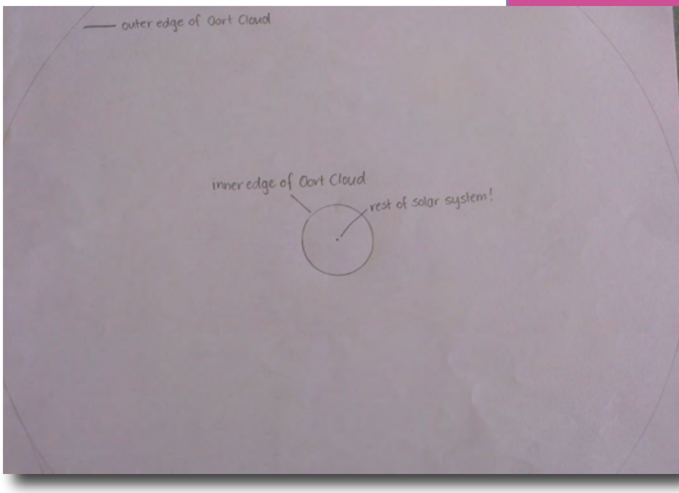
http://voyager.jpl.nasa.gov/

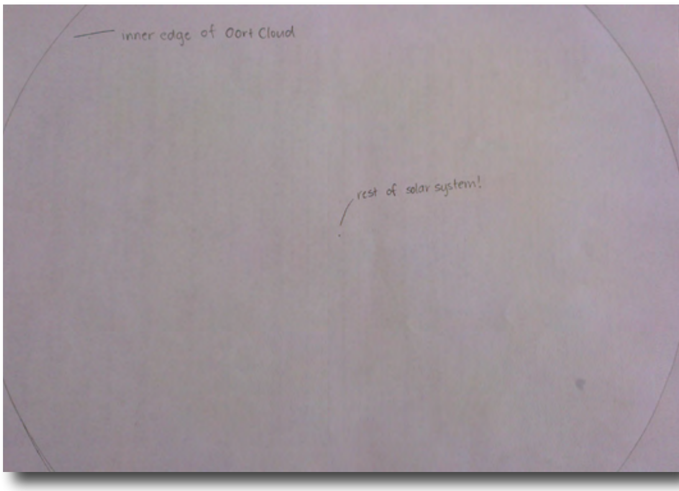
More information about the solar system:

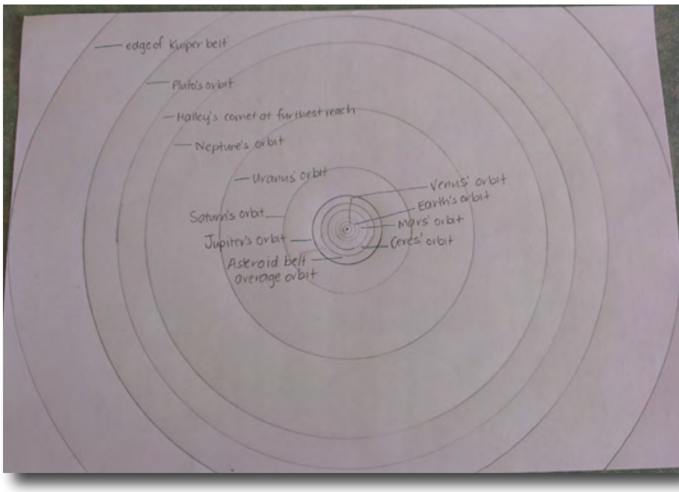
http://umanitoba.ca/observatory/outreach/solarsystem/

http://www.universetoday.com/15462/how-far-are-the-planets-from-the-sun/

http://www.space.com/18584-dwarf-planets-solar-system-infographic.html







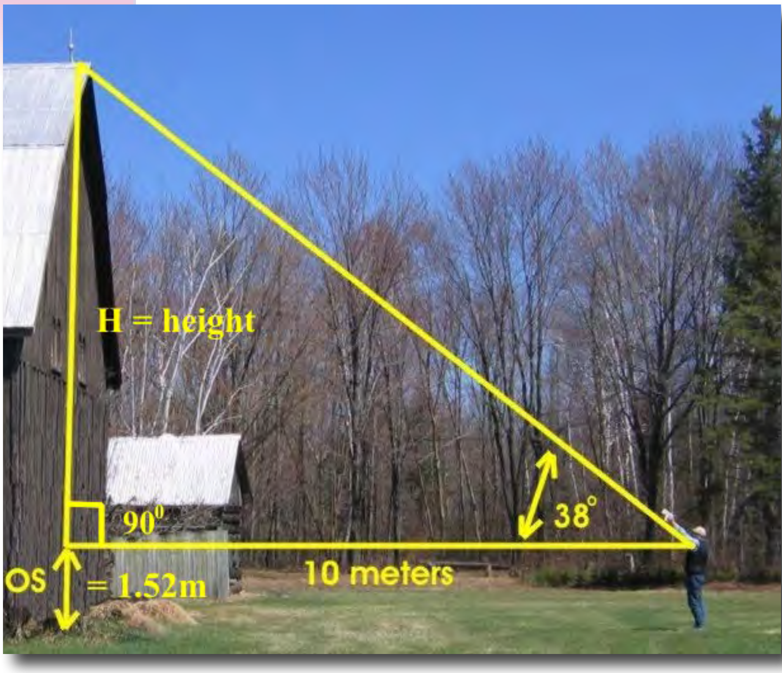
Scale solar system - the first includes the entire Oort Cloud, the second page zooms into what's inside the oort cloud, the third shows what's inside the Kuiper belt's radius.
In other words, the third picture fits into the tiny dot at the centre of the 2nd picture, which fits into the tiny dot at the centre of the 1st picture.
(Note, while the average distance from the sun is to scale, the perfect circular shape of the orbits is not true to reality)

EXPLAIN

HOW CAN WE MEASURE THINGS IN SPACE?

MEASURING INTANGIBLE HEIGHTS

30 MINUTES



Using an inclinometer to measure an intangible height

SUMMARY

How do you measure something if it's out of reach? Whether it's a tall tree, a meteor or a far away star, a longer ruler just won't do. We use geometry and what we know about angles to measure intangible heights.

In this activity, we'll measure the angle to the top and the distance to the bottom of some tall things around the school grounds and draw a scale model. This will allow us to determine the object's height, and is a simple demonstration of how angles and geometry are used.

The Fireballs in the Sky team are 'teaching' the DFN software to determine the distance to a meteor by analysing the angle from the ground and known distances to other cameras.

To measure the distance to other stars, astronomers use parallax. This is a more complex version of trigonometry than we will use here, but it is based on the fact that the Earth moves in space faster than stars do. At opposite ends of the Earth orbit (e.g. mid summer vs mid winter), we can measure the angle that the star in question has appeared to have moved, relative to the other stars. This is the same as when you focus on a point with one eye, then close it and open the other - you can use the apparent shift and the distance between your pupils to calculate the distance to the point.

OUTCOMES

1. Students create and use an inclinometer to calculate heights of objects around the school grounds
2. Students identify, estimate, measure and compare angles in everyday situations
3. Students draw a scale model with a protractor, using measured angles to determine an unknown

EQUIPMENT (PER PERSON/PAIR)

- Inclinometer template, page 65
- Intangible heights worksheet, page 66
- Protractor
- Ruler
- Grid paper
- Sticky tape
- 30cm lengths of String
- Weight with a hole in the middle e.g.20mm nut
- Thumb tacks

THE ACTIVITY

Set up:

Students discuss ways of measuring the height of a tall tree, building or flagpole. Introduce the idea of using right angle triangles by drawing two triangles:

1. Draw a large right-angle triangle on the board and measure the horizontal side (x) and one of the other angles.
2. Have students draw a scale model of the triangle on grid paper to determine the height of the triangle (y):
    - draw a horizontal line (a)
    - measure the angle from one end of the line
    - draw the hypotenuse line (b)
    - complete the triangle and measure the vertical line (c)
    - calculate the scale of small triangle

    (x ÷ a = y ÷c)

    - calculate y (y = x ÷ a x c)
    - check your calculations by measuring the height of the triangle on the board. Were you close?

Alternatively, make the task simpler by using a 1m:1cm scale.

To measure the height of any tall object, we only need to know the angle to the top and the distance from the base to the measuring point.

Plan:

Students build an inclinometer, following the instructions on template.

Predict:

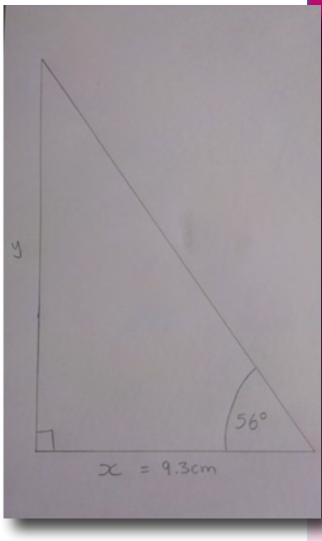
Students create a table for collecting the data they will need and estimate the height of various trees and buildings in the school grounds (see worksheet)

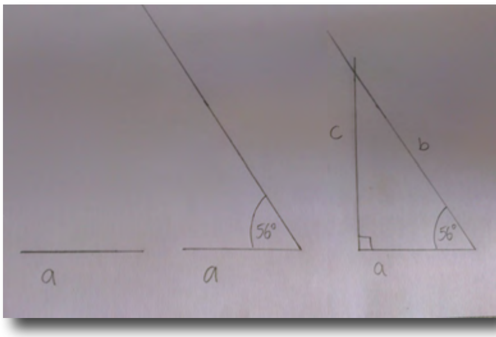
Test:

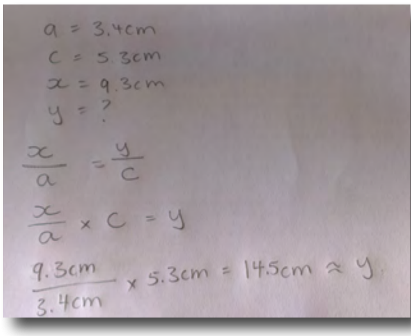
To use the inclinometer, hold it steady on the ground and sight the top of the object through the sight. Have a friend read and record the angle. Measure the distance from the base of the object to the recording point.

Because you are not measuring the angle from the ground, you will need to measure the distance from the object at the same height (e.g. at measurer's shoulder height). See the detailed instructions at the Hila Road centre for more information:

http://hila.webcentre.ca/projects/inclinometer/inclinometer3.htm







Calculating the height of a triangle

Analyse:

Students calculate the height of the objects using their recorded data and drawing scale images:

1. Calculate the scale distance for horizontal line (e.g. 15 m = 15cm)

2. Mark the angle on one end of the line, and draw the (hypotenuse) line to intersect with the vertical grid line

3. Complete the triangle and measure the vertical line

4. Calculate the actual height using the scale

5. Compare with estimate

6. Measure the perpendicular line to the edge of the triangle

Students determine how accurate their method is by using it on something for which they can measure the height (e.g. to the window sill).

Communicate:
Students discuss how they can use their inclinometer to measure the stars or moon – what useful information can be obtained? Students take home their inclinometer to measure the angle of the moon at e.g. 7 pm and explain the concept to someone at home.

SUGGESTIONS FOR THE CLASSROOM

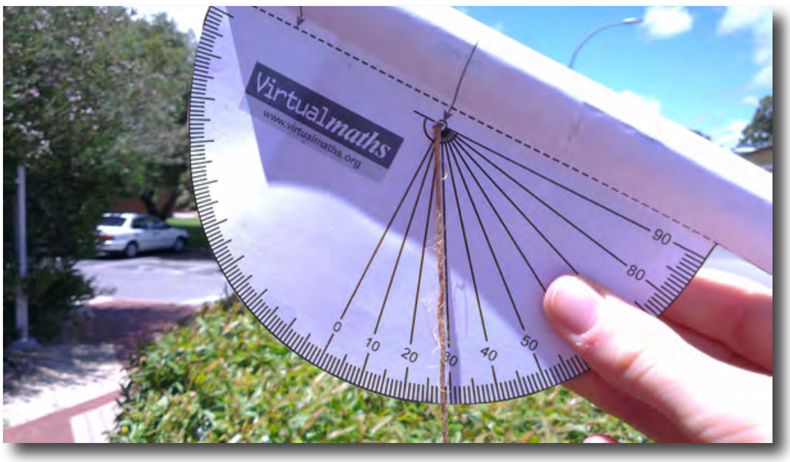
- Inclinometers are available on some compasses and there are many free as a smart phone or ipad app.Compare your own creation with this. What kinds of applications are there for this technology?
- The Fireballs in the Sky app uses the accelerometer in smart phones for exactly this purpose – to measure the angle a meteor was seen.
- More information on parallax can be found here:

http://science.howstuffworks.com/question224.htm

- More information, activities and instructions on using inclinometers can be found here:

http://www.virtualmaths.org/activities/shapes/theod2

http://hila.webcentre.ca/projects/inclinometer/inclinometer3.htm



Using an inclinometer

ELABORATE

WHAT MADE THAT?!

MAKING CRATERS

30 MINUTES

SUMMARY

If something hits the Earth hard enough, it makes a dent. While it's not often seen, rocks do fall from the sky and can create large impact craters. This experiment is an upscaled version of that in the 'Space Rocks' unit. You might like to start there for extra ideas, or work with a buddy class.

In this activity, students experiment with different objects and dropping heights to determine a relationship between object and crater. They will then extrapolate that data to a crater the size of the school oval. This will be a wild estimate, since it's not going to take into account a multitude of factors affecting a real meteor. Discuss the limits of extrapolation with students and check out the online impact crater simulator - where you can much more accurately estimate the size of the object that could take out the school oval!

Invesitigate the other affects a large meteorite will have on the Earth's surface and systems. It's widely suspected that a meteorite wiped out some of the dinosaurs and it's impact crater takes up a relatively small part of the Gulf of Mexico. How, then, did it massacre dinosaurs across the globe?

The infamous Peekskill meteorite car - the only known manmade object to be hit by a meteorite

OUTCOMES

1. Students experiment with crater making and use their results to extrapolate data for an oval-sized impact crater
2. Students use scaled instruments to order, estimate, measure, and compare objects and impacts
3. Students investigate how forces exerted on the Earth's surface can change it's shape and affect the atmosphere, hydrosphere, biosphere and lithosphere

EQUIPMENT

- See 'crater making' in junior section for ideas
- Plasticine
- Rulers
- String
- Tape measures
- Measuring scales
- What made that?! Worksheet,page 67

THE EXPERIMENT

Plan:
Using data collected in sand pit experiments, students will calculate the mass of a meteorite required for an impact crater the size of the school oval (or similar).

Students will need to establish a relationship between size/ weight of object and size (diameter) of crater. To maintain the same size/mass for each object, use something uniform and changeable, such as plasticine or clay for students to compare different sized objects. This is the independent variable, with the diameter of the crater being dependent.

Discuss - what else needs to be kept the same in this experiment? (controlled variables - e.g. height, speed, angle of drop, 3D shape of object, surface material)

Predict:
Students predict the mass of the object big enough to make a school oval sized crater. We will be estimating this, based on the experiments.

Students also predict impact crater size for the smaller object bombardments used in the data gathering phase (see worksheet).

Test:

Students experiment with crater making - they will need to repeat each set of conditions at least three times to get an average crater size. - see worksheet.
Ensure that the controlled variables are kept the same.

Analyse:
Students discuss the results of their experiments. Can they see a pattern? What kind of graph would best represent this data? Students will turn their data into a line graph showing size of impact crater (dependent variable) against the mass of the object.
Can you draw a relationship between these two? Using a very large sheet of paper, or chalk on the cement, extend the axes out to reach the size of the oval and extend the line graph. The generally agreed on distance to space is 100km from sea level (although this doesn't include the exosphere).
Is this a reliable interpretation? Why not? What is the greatest size of crater/object that you could extrapolate on the graph to be a reliable estimate?

Craters in the sand

Communicate:
Discuss what happens when an object makes a crater. How does it affect the 'land'? Many scientists think that the extinction of lots of dinosaurs at the end of the Cretaceous period was caused by a large meteorite impact. How could the impact affect animals and plants on the other side of the planet?

How do meteorite craters on Earth differ to those on the moon? Why?

SUGGESTIONS FOR THE CLASSROOM

Location of the Chicxulub crater, where a 10 - 20 km asteroid is thought to have put an end to a great many dinosaurs

http://www4.nau.edu/meteorite/meteorite/book-glossaryc.html

- In this experiment we have ignored the influences of some variables that would affect real meteor impacts, such as: angle of descent, atmospheric friction, velocity of meteor, shape of meteor. What other factors would be important? How could we simulate these variables in our experiment?
- Students will enjoy the Impact Crater simulator online when they have finished this activity to compare their class calculation to a real simulator:

    http://simulator.down2earth.eu/

This allows you to choose the object size and density, the angle of trajectory, speed and the target area (on google maps) and impact the Earth!

- Explore Google Earth looking for craters such as Chicxulub crater in Mexico or Wolfe Creek crater in Western Australia.
- Explore Google Moon or Google Mars looking for more craters - where is the biggest?

ELABORATE

HOW CAN WE MAKE THAT?

TRAJECTORIES

30 MINUTES

SUMMARY

Humans have highly developed minds which can estimate the trajectory of an object flinging through the sky. This helps us catch balls, hunt animals and anticipate fireworks. In this activity we'll look at impact craters from a different angle - the path the object takes to get there.

The Fireballs in the Sky team can extrapolate a meteor's path from original orbit in space to its final resting place on Earth from just a few seconds flash. This requires a great understanding of trajectories.

A trajectory is the path followed by a flying object, or an object under force. We'll experiment with different objects being launched in different ways to compare trajectories. We can't organise test drops from space, so these items will have to go up before they come down. Get the students immersed in the activity to learn the terminology and think about applying it to space.

Water balloon launcher, available in online shops: 'Wild Sling Solo'

OUTCOMES

1. Students learn about trajectories and experiment with force required to make a crater
2. Students measure, order and compare objects and distances using scaled instruments, choosing appropriate units and converting between units.
3. Students identify, compare, estimate and measure angles of different sizes in everyday situations.

EQUIPMENT

See if you can obtain some of these more unusual launchers:

- Water balloon launcher and water balloons (check you have an appropriate tap fitting)
- T-ball stand, bat and ball
- Nerf dart gun or other foam bullet toy guns and darts
- Water pistols, super soakers and bucket
- Construction equipment – cardboard, glue, sticky tape, pop sticks, paper, elastic bands, plastcine to make launch pads and:
    - home made pea shooter
    - home made sling shots
- Inclinometers, graph paper, calculators
- Rulers, tape measures
- Worksheet, page 68

SAFETY

It is important to establish clear safety rules and consequences for failure to be safe. It is suggested that you enlist extra adult help for supervision so that students can spread out to do their tests. In all cases, establish a countdown to launch and for each device establish a safety distance for spectators to stay away from launchers. If you have mulitple objects, students won't need to run into the line of fire to measure/retrieve until the end.

THE EXPERIMENT

Set up:
Students will use various devices to investigate trajectories and angles. They will need to fully understand and follow the safety measures required. They will need to measure and compare angles and distances between devices and within the same device

Predict:
Students predict the best angle for launching from each device, and the corresponding best distance and best height an object will reach under those conditions (see worksheet).

Test:
In small groups, students undergo a comprehensive analysis of their device to determine th best angle of launch for highest and furthest trajectory. They may need to make launch pads for their devices in order to change the angle of launch. To measure the height of objects at the top of their curve, students will need their inclinometers and to choose a measuring point perpendicular to the launch zone.

For repeat experiments by a different launch team, have groups swap their devices and repeat the investigation.

Analyse:
Students discuss the differences between their prediction and the findings. Students discuss negative factors that contribute to the experiment – e.g. wind, human error, inaccuracies when measuring

Students create two graphs per launcher:
1. Distance travelled for their object against angle of launch
2. Height reached against angle of launch

Communicate:
Students share their graphs with the class and compare the findings with predictions and outliers and discuss reasons for discrepancies

Students devise statements that describe the relationship between angle/height and angle/distance travelled.

SUGGESTIONS FOR THE CLASSROOM

- Discuss what sciences would use the study of trajectories: e.g. Astronomy, aeronautics, toy-making industry, weapons, studying migratory birds, sports science

EVALUATE

CRATER INVESTIGATION:

CATAPULTS UNDER SUSPICION

60 MINUTES

SUMMARY

Now that we've experimented with trajectories and impact craters, we're going to put those two together to investigate which crater came from which catapult.

First up is building a catapult or trebuchet and testing it out. Then comes the investigation. The machines will be all lined up randomly like an identity parade, separate to the craters. Using their knowledge of trajectories, craters and their experience building a trebuchet, their challenge is to determine which crater belongs to which machine.

OUTCOMES

1. Students make their own catapult and investigate craters to determine which trebuchet made them.

2. Students choose appropriate units of measure for length and measure, order and compare craters and their object's trajectories

3. students estimate, measure and compare angles in everyday situations to identify an unknown.

EQUIPMENT

- Construction materials such as paper, cardboard, sticky tape, glue, elastic bands, cardboard boxes,
- Sand pit, trays of flour or similar
- Rake or similar for smoothing out sand
- Objects for launching - e.g. marbles, plasticine balls
- Flags or notes and pins
- Worksheet (page 69)

THE EXPERIMENT - CATAPULTS

Plan
Students in small groups research and build a trebuchet (or catapult) using the materials provided, and taking care to make theirs work differently from other groups (such as a different launch angle), so it's impact crater is identifiable. Students need to understand the challenge: they will be matching up craters to trebuchets. What is important to look for in the design of the machine with respect to the crater it makes?

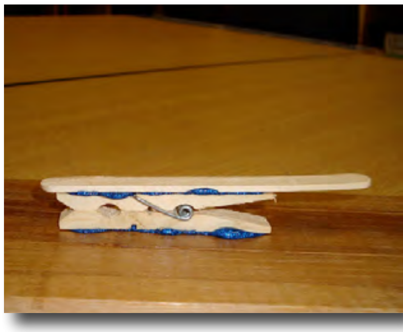
With a small group of students the teacher will line up each of the trebuchets in a launch zone facing the sand pit. Make impact craters in the sand pit by activating each of the catapults. If each group used a different launch object, remove that too. Don't forget to take a photo of the culprits!

Then line the machines up randomly like an identity parade for each of the student groups to investigate the scene.

Predict:
Students will enter the 'crime scene' with their group to investigate. Their job is to predict which catapult made which crater, without testing the trebuchets. Students measure and record the crater size, distance from launch record and their guesses for trebuchet culprit.

Test:
As a class, or in groups, it's time to test out each of the catapults to get an idea of their range and impact. Follow the template to gather repeat data to create an average.

Analyse
Students make an informed prediction as to which trebuchet made which crater, based on the test results. Reveal the photo of each trebuchet lined up with it's crater. Were the students right? Why or why not?



Communicate:
Students turn their catapults into an exhibit for a classroom gallery for visitors. They'll create an engaging poster that explains:

- Furthest height and length range
- Average crater impact
- Affect of changing the angle of launch
- Compare and contrast their trebuchet with others

Various trebuchet and catapult ideas - see suggestions for weblinks

How are the catapult craters similar to and different from a meteorite impact crater?

SUGGESTIONS FOR THE CLASSROOM

Here are some links to catapult and trebuchet ideas:

http://cooltrebuchets.weebly.com/trebuchets-vs-catapults.html

http://www.teachwithfergy.com/popsicle-stick-catapult/

http://mrsmclennan.blogspot.com.au/2010/10/catapults.html

http://www.instructables.com/id/Mini-Siege-Engines/

This sheet belongs to ______________________ Date __/__/__

WHAT IS A ROCK AND WHAT IS NOT?

FIREBALLS in the sky

These are not rocks

because

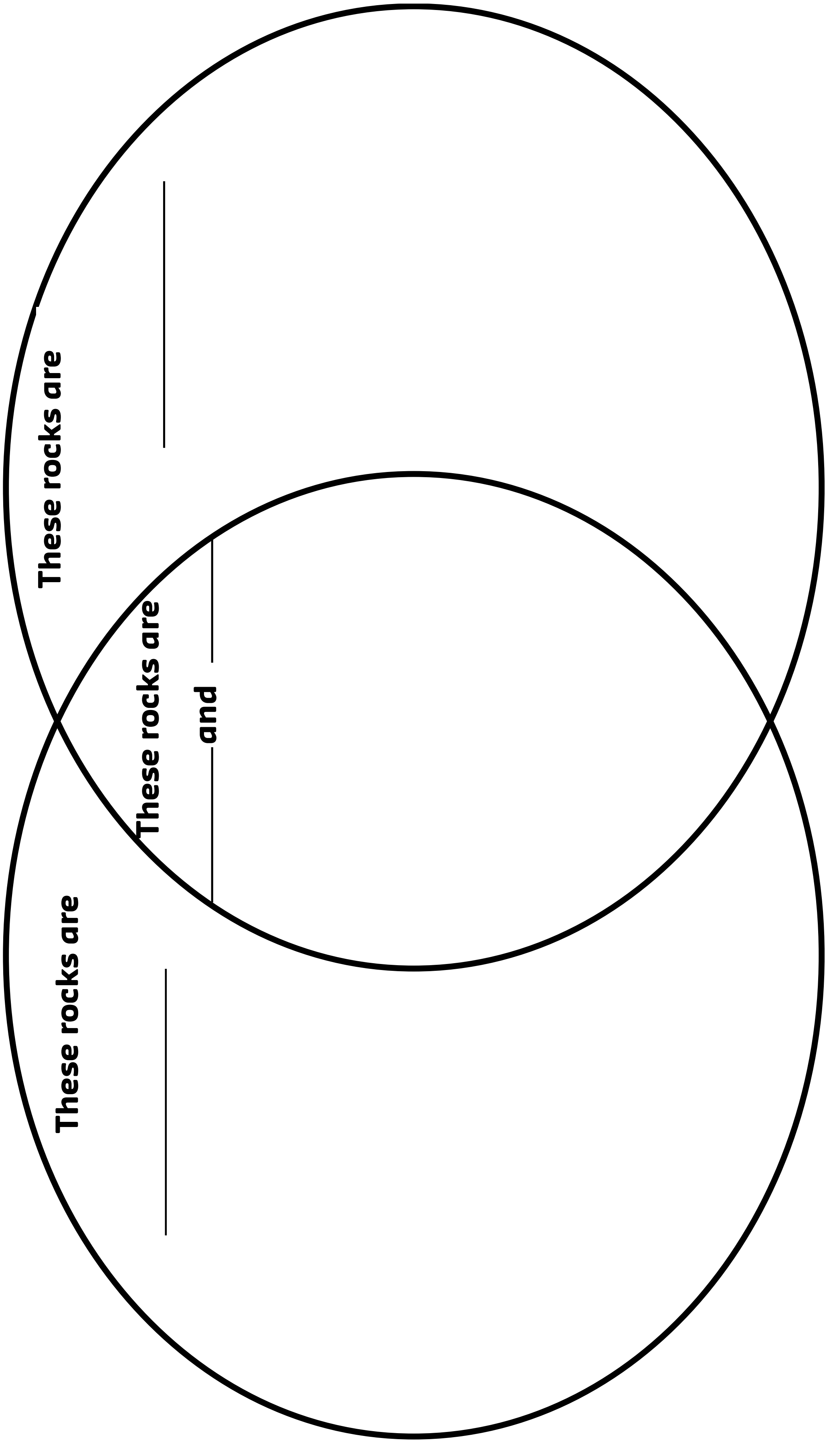
These are rocks

because

This sheet belongs to ______________________ Date __/__/__

WHAT IS A ROCK AND WHAT IS NOT?

FIREBALLS in the sky



This sheet belongs to ____________________ Date __/__/__

WHAT IS A ROCK AND WHAT IS NOT?

FIREBALLS in the sky

Is your rock

1. ______________ ?

yes

no

2. ______________ ?

yes

no

3. ______________ ?

yes

no

4. ______________ ?

yes

no

This sheet belongs to ______________________ Date __/__/__

SHOOTING STAR STORIES

FIREBALLS in the sky

Sometimes we call meteors shooting stars or fireballs. They are rocks from space that are falling very fast to Earth.
Please help me fill in my observation table about shooting stars

Name	Age	How many shooting stars have you seen?	Where have you seen them?	What did it look like?	Drawing

This sheet belongs to ______________________ Date __/__/__

SPACE ROCKS GAME

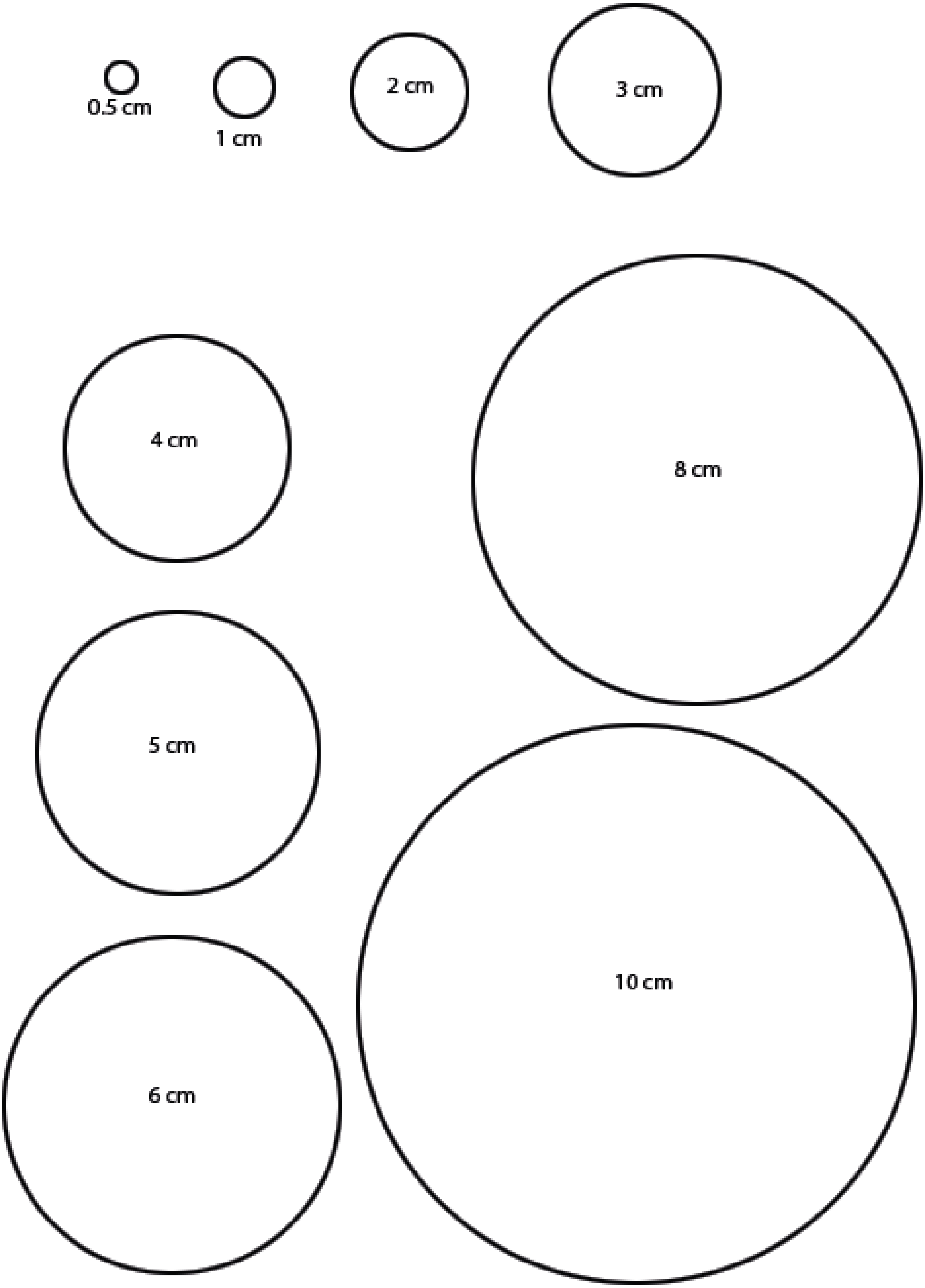
FIREBALLS in the sky

Asteroids	• • • • •	action for asteroids:	
Comets	• • • • • •	action for comets:	
Meteorites	• • • • • •	action for meteorites:	

This sheet belongs to ______________________ Date __/__/__

WHAT MADE THAT?!

FIREBALLS in the sky



This sheet belongs to ______________________ Date __/__/__

WHAT MADE THAT?!

FIREBALLS in the sky

We kept __________ and __________ the same.

We changed the __________

Object	Crater width

This sheet belongs to ______________________ Date __/__/__

WHAT MADE THAT?!

FIREBALLS in the sky

Variable that we changed: object

Variables that we kept the same: surface - ____________________

drop height - ____________________

Diameter of object	Mass of object	PREDICTION: Crater width	PREDICTION: Crater depth	Crater width	Crater depth

Variable that we changed: surface

Variables that we kept the same: object - ____________________

drop height - ____________________

Surface	PREDICTION: Crater width	PREDICTION: Crater depth	Crater width	Crater depth

This sheet belongs to ____________________   Date __/__/__

WHAT'S INSIDE SPACE ROCKS?

FIREBALLS in the sky

Rocky Road

Ingredients
200g cooking chocolate
1/2 cup rice bubble cereal
1/4 cup yellow jelly lollies (e.g. snakes, chopped)
1 cup extra cooking chocolate, dark
splash of milk

For iron meteorites
1. Line a large baking tray
2. In bowl melt chocolate in microwave. Stir through rice bubbles.
3. Pour mixture onto tray. Allow to cool and harden.
4. Melt chocolate in microwave, stir in splash of milk at a time until dipping consistency.
5. Cut into rough 2 cm pieces. Use tongs to dip in chocolate. Leave on clean tray to cool and harden.

For pallasites
After step 2, allow mixture to cool (enough to stay liquid but not melt marshmallows)
Mix through coconut and jelly lollies.
Continue to step 3.

(makes a bar about 15cm x 10cm x 2cm, about 30 small pieces)

Rice Crispy Slice

Ingredients
1/2 cup butter
300g marshmallows
6 cups rice bubble cereal
200g shredded coconut
100g clinkers/jelly beans/chunky lollies
1 cup dark cooking chocolate
splash of milk

For achondrites
1. Grease or line a large baking tray
2. In bowl or jug, melt butter and marshmallows in microwave . Stir and cook until melted. Stir through coconut.
3. Pour mixture over rice bubbles in a large bowl, stir to coat
4. Press mixture into tray, allow to cool and harden.
5. Melt chocolate in microwave, stir in splash of milk at a time until dipping consistency.
6. Cut slice into rough 2 cm pieces. Mould each piece into an uneven shape, use tongs to dip in chocolate. Leave on clean tray to cool and harden.

For chondrites
At step 4, pour half of mixture into tray then sprinkle clinkers over mixture, press in and cover with rest of mixture. continue as for achondrites.

(makes a bar about 20cm x 20cm, about 30 pieces)

This sheet belongs to ______________________ Date __/__/__

WHAT'S INSIDE SPACE ROCKS?

FIREBALLS in the sky

Drawing of meteorite cut in half:

Features	Represented by	Tick what you find
Ablation crust	chocolate coating	
Rocky	rice bubbles	
Chondrules	clinkers	
Olivine crystals	jelly lollies	
Iron	plain chocolate	

My meteorite is a

Play dough

Ingredients

2 cups plain flour
2 cups warm water
1 cup salt
2 tbs cooking oil
1 tbs cream of tartar
food colour

Method

1. Mix all ingredients in medium saucepan.
2. Warm over low heat and stir continuously.
3. Keep stirring until mixture forms a dough and comes away from the sides. If not cooked long enough, the playdough will be sticky, so don't give up early!
4. Tip dough out onto workbench, allow to cool
5. When dough is ok to touch, add a few drops of food colour and knead through.

(makes about 600g playdough, enough for 30 meteorites)

This sheet belongs to ______________________ Date __/__/__

WHERE DO SPACE ROCKS COME FROM?

FIREBALLS in the sky

To make up a 100mL comet try this standard recipe:

60mL water,
5mL methanol,
5 ml vinegar,
5mL honey,
25mL dirt

Add ingredients to a plastic bag and mix from the outside with your hands. Squeeze air out of bag and twist ends closed. Place in freezer overnight.

Our group is testing the variable: ____________________

The constants will be: ____________________ ____________________
____________________ ____________________

	Comet 1	Comet 2	Comet 3	Comet 4	Comet 5	Comet 6
Water (mL)						
Methanol (mL)						
Vinegar (mL)						
Honey (mL)						
Dirt (mL)						
Maker's name:						

Predictions: ____

____

Observations: ____

____

From our evidence, the best amount of________________ is ____________________.

Why do comets appear to have tails? ____

____

When do comets have tails?

____

This sheet belongs to ______________________ Date __/__/__

WHERE DO SPACE ROCKS COME FROM?

FIREBALLS in the sky

1. Initial observations

Features	Tick or make notes
Unusually heavy	
Magnetic	
Clues through the ablation crust?	

2. Prediction

Based on initial observations, I think this is a ______________________________

3. Cross section – sketch & label

Features	Represented by	Tick and/or make notes
Ablation crust	black paper	
Rocky	pebbles	
Chondrules	sinkers	
Olivine crystals	crystal beads	
Iron	magnets	
Organic molecules	seeds	

4. Based on cross section information, I think this is a ______________________________

5. This meteorite is likely to have come from ______________________________

This sheet belongs to ______________________ Date __/__/__

SKY OBSERVING FRAME

FIREBALLS in the sky

To make a Sky Observing Frame

1. Cut out this shape (including square window)

2. Glue shape to piece of cardboard and cut the cutboard to be the same shape

3. Find a spot outside or at a window where you can see some stars through your observing frame and that you'll be able to come to every night

4. Line the observing frame up with something on the ground that won't move, e.g. a big tree trunk, a window frame, the edge of a fence

5. Use plasticine or blu-tak to install the frame in the same spot for a month

It might be good to take a photo of the frame's position, or of you using the frame in case it gets bumped.

This sheet belongs to ______________________ Date __/__/__

SKY OBSERVING CHART

FIREBALLS in the sky

At the same time each night, use your Sky Observing Frame to view the same patch of sky.
Record what it looks like, what has changed and what has stayed the same.

Features	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Star pattern							
Moon shape							
Sunset time							
Notes							

This sheet belongs to ______________________ Date __/__/__

SOLAR SYSTEMS

FIREBALLS in the sky

1. Calculating scale

distance from edge of the solar system to sun ÷ distance from edge of model to middle

=

=

=

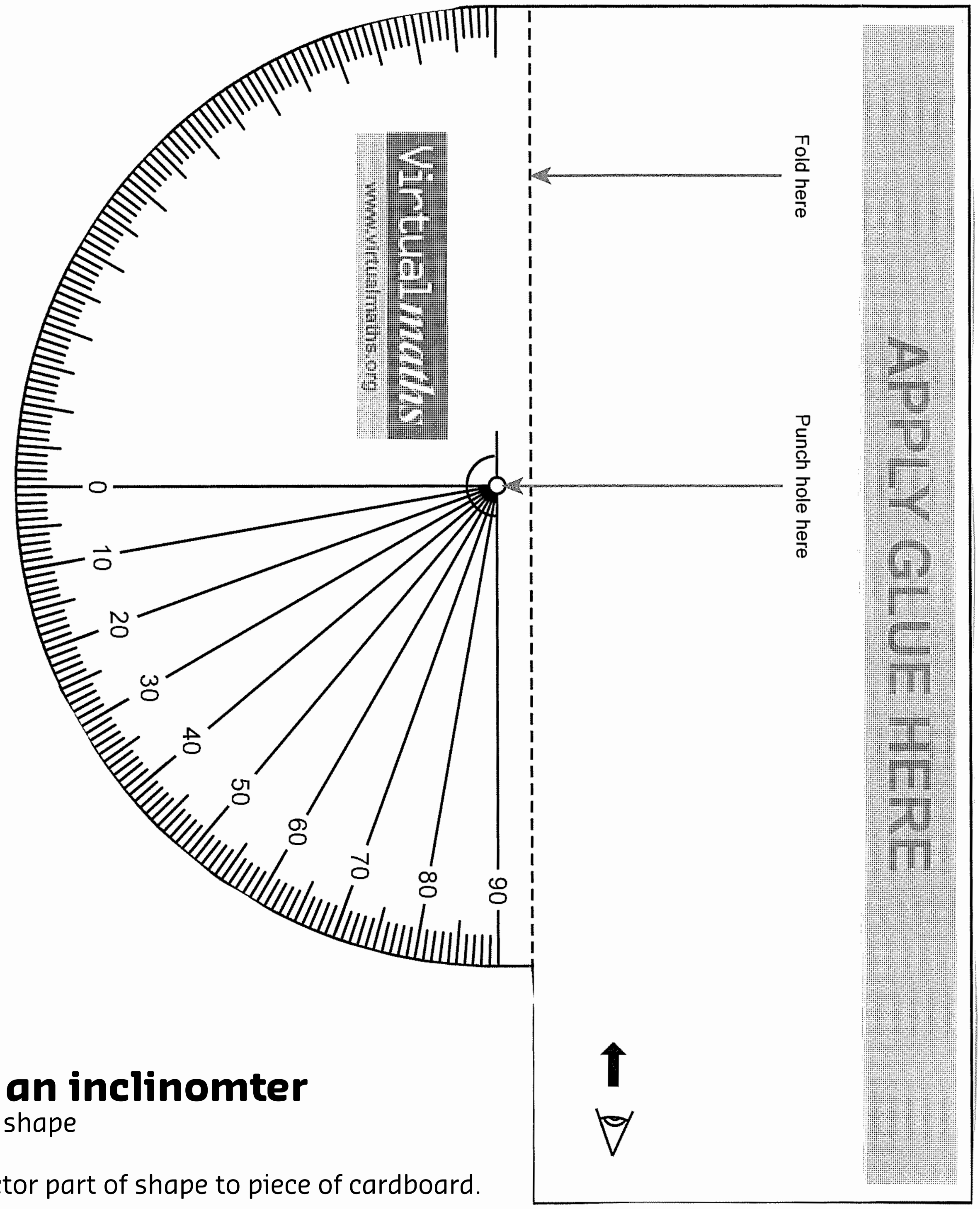
= _______ AU / mm (1 mm in this scale = _______Astronomical Units)

Object	Average radius from sun	Estimate distance from centre on scale model	Distance calculated for scale model
Outer edge of oort cloud	100 000 AU		
Inner edge of oort cloud	10 000 AU		
Outer edge of Kuiper belt	50 AU		
Pluto	39.5 AU		
Halleys comet at furthest reach	36 AU		
Inner edge of Kuiper belt	30 AU		
Neptune	30.1 AU		
Uranus	19.2 AU		
Saturn	9.58 AU		
Jupiter	5.2 AU		
Ceres	2.8 AU		
Asteroid belt	2.7 AU		
Vesta	2.36 AU		
Mars	1.52 AU		
Earth	1 AU		
Venus	0.722 AU		
Mercury	0.387 AU		
Sun	0 AU		

This sheet belongs to ____________________ Date __/__/__

INCLINOMETER

FIREBALLS in the sky



To make an inclinomter

1. Cut out this shape

2. Glue protractor part of shape to piece of cardboard.

3. Make a pin hole at centre of protractor just big enough to thread string through.

4. Thread string through hole, leaving about 20cm dangling before tying on a nut or other heavy item. Tie a knot or tape the other end of string onto back of inclinometer to secure.

5. Roll the rectangle away from the protractor to form a looking tube.

6. Glue or tape down the looking tube.

This sheet belongs to ______________________ Date __/__/__

INTANGIBLE HEIGHTS

FIREBALLS in the sky

Object	Estimated height	Distance to inclinometer	Angle to top of object	Height to inclinomter reading	Calculated height from scale drawing	Measured height of object (if possible)

This sheet belongs to ____________________ Date __/__/__

WHAT MADE THAT?!

FIREBALLS in the sky

Independent Variable (we change): ____________________

Dependent Variable (is changed by the independent variable): ____________________

Constant Variables (we keep the same): ____________________ ____________________

____________________ ____________________

Independent variable:	How the dependent variable changed:				
	Prediction	Trial 1	Trial 2	Trial 3	Average

Independent Variable (we change): ____________________

Dependent Variable (is changed by the independent variable): ____________________

Constant Variables (we keep the same): ____________________ ____________________

____________________ ____________________

Independent variable:	How the dependent variable changed:				
	Prediction	Trial 1	Trial 2	Trial 3	Average

This sheet belongs to ______________________ Date __/__/__

WHAT MADE THAT?!

FIREBALLS in the sky

TRAJECTORIES PREDICTIONS

Launcher	**Best angle for launching highest trajectory** (independent variable)	**Best height achieved** (dependent variable)	**Best angle for launching furthest trajectory** (independent variable)	**Best distance achieved** (dependent variable)

This sheet belongs to ______________________ Date __/__/__

TREBUCHET INVESTIGATION

FIREBALLS in the sky

SCENE INVESTIGATION

Crater number	Distance from launch line	Crater diameter	Crater depth	Suspected trebuchet number
1				
2				
3				
4				
5				
6				

EXPERIMENTAL RESULTS - TREBUCHET NUMBER:

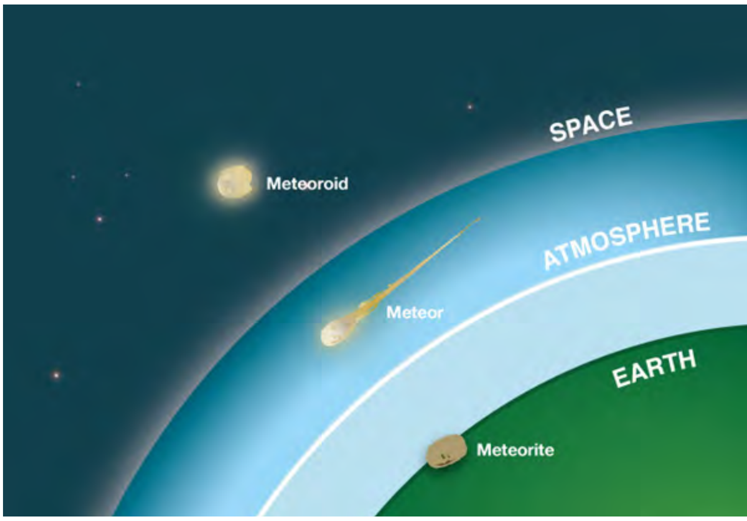
Test launch	Distance from launch line	Crater diameter	Crater depth	Crater number?
1				
2				
3				
average				

EXPERIMENTAL RESULTS - TREBUCHET NUMBER:

Test launch	Distance from launch line	Crater diameter	Crater depth	Crater number?
1				
2				
3				
average				

FIREBALLS in the sky

WHAT IS A METEORITE?



A meteorite is a rock from space that has fallen to Earth.

Meteorites are some of the oldest rocks in existence and have remained untouched since the formation of our solar system. Most meteorites are believed to be broken fragments of asteroids, comets and even planets. Meteorites vary in size; the smallest can weigh just a few grams while the largest of meteorites can weigh several tonnes.

METEROID? METEOR? OR METEORITE?

While a meteorite is still in space it is called a meteoroid. Meteoroids are fragments from asteroids, comets or planetary bodies which are travelling through space. They can travel for billions of years before hitting anything. Some meteoroids come from the Moon or Mars after being knocked loose by other large objects impacting their surfaces.

When you see bright streaks of light or shooting stars in the sky, you are actually looking at rocks burning up through the Earth's atmosphere. These bright lights are called meteors. Most meteors enter the Earth's atmosphere travelling 40 times faster than the speed of sound. Because they are travelling so fast, they become superheated by the atmosphere and start to melt on the outside. The bright fireball that we see is caused by the melted surface being torn away and changing its shape. This process of melting away the hot surface is called ablation and keeps the inside of the meteor cold.

FIREBALLS AND BOLIDES

Meteors can explode on their way down to Earth, breaking into fragments in a bright flash, or they can survive the entry in one piece. Extremely bright meteors are called bolides or fireballs. These meteors are much larger than normal and can sometimes be brighter than the sun.

WHAT DO THEY LOOK LIKE?

When a meteor has hit the ground it is called a meteorite. The outside of a meteorite is normally covered by a thin black fusion crust. The fusion crust forms when the molten surface becomes solid, leaving the inside untouched. Contrary to what you may think, meteorites are not hot when they hit the ground – in fact, they cool down very quickly after landing because they are still cold on the inside.

Meteorites have many types of internal structures and compositions. They can be made out of metal, rocky minerals or a mixture of both. Once a meteorite has landed and been found, we can study its internal structure and learn about how it was formed.

WHAT CAN WE LEARN FROM METEORITES?

Meteorites are extremely useful in order to better understand the formation and evolution of orbiting bodies and their minerals.

Most meteorites contain minerals that have been frozen in place for billions of years. Others come from fragments of asteroids, the Moon, or even Mars, and contain samples of the minerals of those planets.

By studying the internal structure of a meteorite, we can find out what kind of asteroid it belonged to, learn how asteroids and planets were made and determine the composition of the early solar system.

COLLECTING METEORITES FOR STUDY

Traditional methods of recovering samples from asteroids involve sending robotic spacecraft to asteroids and comets and returning with a sample capsule. These sample return missions cost billions of dollars, take decades to complete and only return limited samples from a small number of asteroids.

FREE SAMPLES

Instead of sampling asteroids in space directly, we can analyse the insides of meteorites that are found here on Earth. These "free samples" from space contain a wealth of information about the asteroids that they came from. There are many different kinds of meteorite and we are able to classify those meteorites into distinct groups. This gives us some indication of which type of asteroid they came from. However, they can't tell us exactly which asteroid they came from.

DESERT FIREBALL NETWORK

The Desert Fireball Network aims to photograph meteors as they fall and calculate the orbit they were in before hitting Earth. By tracking the meteorite's orbit and analysing the internal composition of recovered meteorites we can find out what their parent asteroids are made of.

By combining the mineral data with the orbital data we can create a geological map of the solar system.

GLOSSARY

Mineral: A naturally occurring solid substance with a regular atomic structure. Minerals are different from rocks – rocks are made of many different minerals.

Asteroid: A small orbiting body of rock which does not have the features of a comet and is not large enough to be a planet.

Orbit: The motion of an object around a gravity point in space, such as the motion of a moon around a planet or the motion of a planet around the sun.

TYPES OF METEORITES

FIREBALLS in the sky

There are many different types of meteorites that come from different regions of the solar system and have formed in different ways.

To make it easier to categorise meteorites, scientists have split them into the three main groups; stony meteorites, iron meteorites and stony-iron meteorites.

IRON METEORITES

Iron meteorites are made up of pure nickel and iron metal with some impurities such as graphite and the mineral troilite which may have originated from within the metallic cores of asteroids.

Iron meteorites fall very rarely, but are easier to find because they can survive re-entry relatively intact, are very resistant to weathering and look very different to normal rocks. The largest meteorites ever discovered are iron meteorites. Ancient cultures used to use metal from these iron meteorites to make tools and jewellery.

When an iron meteorite is cut, polished and exposed to nitric acid it is possible to see the nickel-iron crystals in banded patterns on the exposed surface known as Widmanstätten patterns. By studying Widmanstätten patterns we can learn how quickly the meteorite crystallised and how the concentrations of nickel and iron changed as the meteorite cooled down.

STONY METEORITES

Stony meteorites are meteorites made of rock, but can also contain small amounts of iron. There are two types of stony meteorites; chondrites and achondrites.

CHONDRITES

Chondrites are the most common type of meteorite. These are meteorites which have not undergone any alteration or changes since they were formed. They are made up of circular mineral blobs called chondrules that formed in space billions of years ago and became clumped together over the years.

Chondritic meteorites represent the oldest rocks that we know of, and so it is necessary to study them if we want to learn more about how the solar system and the planets were formed.

ACHONDRITES

Achondrites are meteorites that contain minerals which have been melted, changed and altered since they were formed, which makes them different to chondrites. This process of change happens because they are formed on bodies with enough mass to support a molten interior. These can include large asteroids, the Moon and even Mars.

Achondrites are much younger than chondrites and have a variety of different textures and mineral compositions which can teach us about the formation history of their parent body.

STONY-IRON METEORITES

Stony-Iron meteorites are almost even mixes of both metallic and rocky material. They probably formed by mixing between metal cores and the rocky magmas within asteroids. This makes them extremely rare because there is only a small region inside asteroids where metallic and stony material can mix.

FIREBALLS in the sky

TYPES OF METEORITES

There are two types of stony-iron meteorites; pallasites and mesosiderites.

PALLASITES
Pallasite meteorites have solid metallic bodies of nickel and iron but also contain large translucent crystals of olivine within a metallic body.

Pallasites represent the boundary between the metallic core of an asteroid and the surrounding rocky magma which makes them very rare but extremely interesting. They are some of the most visually striking meteorite specimens ever discovered.

MESOSIDERITES
Mesosiderites are meteorites with an equal amount of metallic elements and silicate minerals. Unlike pallasites, the crystals within mesosiderites are made of pale silicate minerals and are not very large, giving the meteorite a speckled and irregular appearance.

Because of the presence of silicate minerals and the small size of the crystals, scientists believe that mesosiderites probably form when magma mixes with the core during a collision.

GLOSSARY
Chondrules: Spherical grains that formed during the early accretion of the solar system and are the building blocks of the solar system. Chondrules formed by the crystallisation of molten droplets and accreted together to from asteroids and planets.

Graphite: A material made of many layers of atomic carbon sheets, commonly used as pencil lead.

Troilite: An iron-sulfide mineral. Troilite is rare on Earth but very common in meteorites and other astronomical bodies such as the Moon, Mars and the moons of Jupiter.

Widmanstätten pattern: A unique pattern found within iron meteorites formed by the slow crystallisation of nickel rich and nickel poor minerals at high temperature over millions of years.

FIREBALLS in the sky

METEORITE SPOTLIGHT

Every now and then an interesting meteorite falls to Earth which catches the attention of scientists and the public.

These famous meteorites stand out because of their interesting stories and the lessons we learn from studying them.

MUNDRABILLA
In 1966 two geologists, Wilson and Cooney, discovered a number of large pieces of iron around 200 metres apart from each other in the middle of the Nullarbor Plain. These iron pieces were fragments of a large meteorite that had fragmented on re-entry. The largest of these pieces weighed 12.4 tonnes and is one of the largest iron meteorites ever discovered.

These meteorites were carried to Perth, Western Australia and now reside in the West Australia Museum on permanent display.

MURCHISON
In 1969, residents of town of Murchison, Victoria were shocked to see a super bright fireball passing over their town and lighting up the night. The meteor exploded in the air causing a tremor and scattered into hundreds of smaller pieces.

The Murchison meteorite has been extensively studied because it contains evidence of fluid alteration and organic molecules which formed before landing on Earth. Some of the molecules found in the Murchison meteorite include amino acids which are necessary for the creation of proteins and even nucleobases which are vital components of DNA.

PEEKSKILL
The Peekskill meteorite fell in 1992 over the East Coast of the US at 7.50 pm. The fireball was seen by thousands of people and filmed by 16 different cameras. A fragment of the meteorite collided into a red Chevy Malibu in Peekskill, New York. The owner of the car, 18 year old Michelle Knapp, had only just purchased the Chevy for $300 and was able to sell the crushed car to a meteorite collector for $10,000.

The meteorite was well documented on amateur film because many people were recording high school football games when the fireball appeared. Using multiple recordings it was possible for scientists to triangulate the orbit of the fireball, and find out that the Peekskill meteorite had originally come from the inner asteroid belt.

The Peekskill meteorite itself is a common type of meteorite – an ordinary chondrite. What made this event very special is the fact that so many people recorded it, meaning scientists could use the footage to calculate its origin. This is the idea behind the Desert Fireball Network.

BUNBURRA ROCKHOLE
The Bunburra Rockhole meteorite is the first meteorite to be recovered in Australia based off of remote camera data and the first meteorite to be recovered using the Desert Fireball Network (DFN). The DFN was able to photograph the meteor as it burned through the atmosphere which made it possible to calculate its original orbit and recover the fragments that survived re-entry.

Bunburra Rockhole is a unique meteorite because it has a eucrite composition which indicates that it is from the asteroid 4-Vesta . However the oxygen isotope composition does not match other eucrite rocks making the Bunburra Rockhole truly one of a kind.

CHELYABINSK
On the 15th of February 2013 a 17 metre wide rock entered the Earth's atmosphere over the Chelyabinsk Oblast region of Russia. The meteor was travelling at nearly 60 times the speed of sound when it entered the atmosphere causing a super bright fireball that exploded over the city of Chelyabinsk with 20 times the energy of the Hiroshima bomb.

The shockwave from the blast was powerful enough to shatter glass windows all over the city causing injury to over 1,500 people. The event damaged windows in over 7,000 buildings and destroyed the roof of a local factory.

The entry of the meteor itself was recorded on multiple cameras and news of the event rapidly spread worldwide. Shortly after the blast a number of small meteorites were recovered by locals throughout the region.

A large hole was also discovered in the frozen surface of nearby Lake Cherbakul which was the result of an impact with a fragment weighing over half a tonne, but it wasn't until October 2013 that the larger pieces were recovered from the lake.

The meteorite fragments show that Chelyabinsk is an ordinary chondrite but also contains 10% iron. Analysis of the fireball footage revealed that the meteor originally had an orbit that crossed between Earth and Mars, making it an Apollo asteroid.

Using the orbital data it was possible to find the parent asteroid, known as 2011EO40. It may be possible to estimate what the parent asteroid is made of by studying the composition of the surviving Chelyabinsk fragments.

GLOSSARY
Apollo asteroid: A near earth object that spends part of its orbit between the Earth and the Sun, and the rest of its trajectory beyond Earth. Apollo asteroids do cross the Earth's orbit and are a potential hazard to our planet.

Eucrite: Meteorites which are believed to come from the surface of the large asteroid Vesta. There are some examples of eucrites that may come from other asteroids or even V-type asteroids which were once part of Vesta itself.

Fluid alteration: Changes in a rocks chemical composition through exposure to water. Fluid alteration is common on Earth but much rarer in outer space, and can give us an insight into the presence of water in the early solar system.

Nucleobases: Nitrogen bearing molecules that are found in DNA. Nucleobases are able to link together in pairs which is why DNA forms a double helix structure. There are four bases that link DNA together but there also exist other nucleobases which have special uses within the body.

WHAT IS AN ASTEROID?

Asteroids are large rocks that have accreted together over millennia but never became large enough to form into a planet.

Asteroids can come in a variety of shapes and sizes from as small as ten metres to hundreds of kilometres across. It is estimated that nearly two million asteroids exist in the main asteroid belt between Mars and Jupiter, but there are other asteroid groups such as the Jupiter Trojans that orbit next to Jupiter and near Earth asteroids which orbit closer to the Earth.

TYPES OF ASTEROIDS
There are many different types of asteroid, but there are three main categories which scientists use to distinguish them.

CARBONACEOUS ASTEROIDS
C-Type or carbonaceous asteroids are the most common type of asteroid. The materials inside C-type asteroids are very similar to the kinds of materials found in chondritic meteorites, which suggests that chondritic meteorites may have originally come from the C-type asteroids.

Chondritic materials are incredibly old and represent the primitive materials which may have been around since the formation of the Sun.

STONY ASTEROIDS
S-Type or stony asteroids are made of stony minerals such as silicates but can have a variety of compositions, including iron and magnesium bearing minerals. It is likely that most stony achondrite meteorites would have originally come from stony asteroids. In 2010 the Hayabusa space probe returned samples from the stony asteroid 25143-Itokawa, making this the first asteroid to be directly sampled by a spacecraft. Pictures of the asteroid revealed that it was less of an asteroid and more of a rubble pile loosely held together by gravity.

METALLIC ASTEROIDS
M-type or metallic asteroids are incredibly dense asteroids with high concentrations of nickel and iron. They are thought to be the broken iron cores of larger asteroids which have been torn apart by ancient collisions. It is believed that nickel-iron meteorites probably come from M-Type asteroids or from the interior of much larger stony meteorites.

VESTA
4 Vesta is the second largest asteroid in the asteroid belt and is the source of HED meteorites which are a very rare type of achondritic meteorite. In 2011 NASA's Dawn spacecraft visited Vesta and discovered two enormous craters over the north and south poles which were probably formed in a massive collision billions of years ago. This collision generated a large number of secondary asteroids called V-Type asteroids as well as a large number of the HED meteorites which we can find on Earth.

CERES
The Dawn spacecraft is also scheduled to visit the asteroid Ceres in 2015. Ceres is the largest asteroid ever discovered and has a total surface area of 2.8 billion square kilometres which means that if it was laid flat it would be even larger than Western Australia. The asteroid is so large it has been called a dwarf planet and may contain water ice or other hydrated minerals on its surface.

FIREBALLS in the sky | Curtin University | An Australian Government Initiative | Inspiring Australia

WHAT IS AN ASTEROID?

GLOSSARY

1-Ceres: The largest asteroid ever discovered. Its status has recently been upgraded to dwarf planet, putting it in the same category as Pluto. As Ceres is too far away to be directly observed by space telescopes, we still don't know much about it.

Achondritic meteorite: Stony meteorite that doesn't contain any chondrules. These meteorites have been melted or recrystallised while they were part of a planet, moon or large asteroid, much like igneous rocks on Earth.

Chondritic meteorite: Stony meteorites that contain chondrules, circular grain structures that formed during the early solar system. These are the most common meteorites that fall to Earth.

Chondrules: Round grains in rocks from space. Chondrules were formed when molten droplets of minerals at very high temperatures hardened quickly as the solar system was being formed.

Dawn spacecraft: The Dawn spacecraft is a space probe on a mission to explore the two largest objects in the asteroid belt; the protoplanet Vesta and the dwarf planet Ceres. The Dawn spacecraft uses ion-propulsion engines to move between the asteroids making it the first spacecraft to orbit two different astronomical bodies.

Hayabusa space probe: Hayabusa was a Japanese space probe designed to rendezvous with an asteroid and collect sample to return to Earth. Hayabusa also had a mini lander named MINERVA which was supposed to land on Itokawa, but the lander detached too early and was thrown into deep space.

HED meteorite: HED meteorites are a rare subgroup of meteorites. The HED stands for Howardites, Eucrites and Diogenites. All HED meteorites are believed to have originally come from the asteroid Vesta or from the V-type asteroids.

Hydrated mineral: A mineral which has been altered by the presence of water to create a hydrated from of the original mineral. It is rare to find hydrated minerals outside of water bearing planets such as Earth and Mars because of the lack of liquid water in space.

25143-Itokawa: Itokawa is a near Earth asteroid and is also the first asteroid to be successfully sampled by a spacecraft.

Silicates: Silicates are rocks that are formed of minerals that contain an oxygen and silicon structure. Silicates are very light rocks and so they mostly occur on bodies with enough gravity to separate heavy and light minerals.

4-Vesta: the second largest asteroid in the asteroid belt. Vesta has two large craters named Rheasilvia and Veneneia on its south pole and a variety of other interesting surface features including several strange troughs that may have formed from large collisions.

V-type Asteroid: V-Type asteroids are large fragments of Vesta that may have been knocked off in the collision which created the Rheasilvia crater. These asteroids share the same composition as Vesta and are also a source of HED meteorites.

WHAT IS A COMET?

Comets are small clumps of dust and ice with eccentric orbits.

Comets spend most of their lifetimes in the outer solar system but periodically fly close to the Sun. Comets are normally frozen solid when in the outer solar system but as they come closer to the Sun, solar radiation vaporises the ice into gases which rapidly escape from under the surface. These gas jets form a thin atmosphere called a coma made of small particles and vapour.

COMET TAILS

As the comet comes closer to the Sun the solar winds become stronger and blow away the coma to form a distinctive comet tail. A comet's tail will always point away from the Sun because the solar wind exerts a force on the dust and gas particles. The tail itself is often split into two; a bright dust tail which curves slightly behind the comet and the faint gas tail which always points directly away from the sun. This occurs because the dust particles are less affected by the solar wind than the lighter gas particles.

HOW BIG ARE COMETS?

The solid core of a comet is called the nucleus and is actually rather small, with the largest being only 60 kilometres across (the biggest asteroids are up to 500 kilometres wide). However, comet tails can stretch over thousands of kilometres. Some tails can even become longer than the distance between the Earth and the Sun.

HOW DOES A COMET MAKE A METEOR SHOWER?

When the Earth passes through the remnants of a comet's tail, the floating dust and meteoroids enter the atmosphere and create spectacular meteor showers. Meteor showers can have hundreds of meteors shooting through the sky every hour but these meteors are usually incredibly small and very few survive re-entry.

Meteor showers are associated with a parent comet that crossed the Earth's orbit, meaning that meteor showers occur at regular times every year. For example, the Orionid meteor shower which regularly peaks in October is made of debris from Halley's Comet.

HALLEY'S COMET

Halley's Comet is perhaps the most well-known comet in the world. It returns to the inner solar system once every 76 years and has been recorded many times throughout history. The last time it visited the inner solar system was in 1986, and it won't be visible again until 2061. Spacecraft that visited Halley's Comet in 1986 were able to find out that the nucleus is only 15 kilometres long and is shaped like a peanut. The nucleus itself was very dark and made mostly of dust with only small amounts of ice and other gases under the surface. Most other comets have a very similar "dirty snowball" composition.

GLOSSARY

Coma: The thin atmosphere of vaporised gas and dust that forms around a comet when it flies near the Sun.

Comet tail: The tail is formed by pressure from the solar wind pushing the coma into a long stream. The tail is often split into two parts; a gas tail and a dust tail. Sometimes there is a third tail called an antitail which is actually the dust tail curving around the comet due to our viewing angle.

WHAT IS A COMET?

Eccentric orbit: A non-circular (oval shaped) orbit around a larger body (the Sun for example). The nature of the orbit means that the comet accelerates as it flies close to the sun, and decelerates as it flies away and so only spends a brief amount of time in the inner solar system. Most comets have eccentric orbits. Other bodies with eccentric orbits include the dwarf planet Pluto, some robotic spacecraft and many near earth asteroids.

Halley's Comet: A short period comet which completes its orbit every 75-76 years. Halley's Comet is named after Edmund Halley who calculated the comet's return in 1758.

Orionid meteor shower: A meteor shower that occurs in mid-October from the debris of Halley's Comet. During the Orionids it is possible to see up to 70 meteors an hour. These meteors appear to radiate from between the constellations of Gemini and Orion, which is why they are named the Orionids.

Outer Solar System: The region of the solar system beyond the orbit of Jupiter. The solar radiation is less intense in this region so most objects are able to hold on to gaseous materials such as ammonia, methane and water without it being vaporised away.

Solar radiation: Energy emitted by the Sun in the form of light. As objects move closer to the Sun, the intensity of the radiation increases and they become hotter.

Solar wind: Waves of charged particles and plasma released from the surface of the sun. The solar wind interacts with comets, blasting away loose bits of dirt and gas particles into a tail. Planets are protected from the solar wind by their magnetic fields; however, the solar wind still affects Earth by producing the aurora or Northern lights effect near the poles.

AUSTRALIAN ABORIGINAL INTERPRETATIONS OF THE NIGHT SKY

Australian Aboriginal culture has its own astronomy with its own stories and traditions which has survived for over 60,000 years, making it the oldest astronomy using cultures in the world.

For many thousands of years, the night sky has intrigued people from all over the world. Different societies around the world created their own interpretations, stories and meanings for the things they observed in the night sky.

Aboriginal culture is massively diverse with over 400 different language groups in different regions of Australia. Different cultural groups have formed their own explanations of the sky and these have different meanings and importance. While not every story is the same across the country, some stories are common to many different Aboriginal groups.

METEORS

Meteors have been seen as omens, tools, beginnings, endings, weapons and rewards. Shooting stars were seen by some as 'fiery demon eyes' and were omens for death and disease. The Warlpiri people from an area in the Northern Territory also believed that the Tjukurrpa was brought to earth by wise men travelling as falling stars and bringing stories to the people. An Arrernte and Luritja Tjukurrpa of central Australia tells the story of the beginnings of life being brought to Earth by the animal Kulu:

> All the animals had a big meeting. Who was going to carry the egg of life up to the universe? The Kulu was chosen. When you see where the egg of life was carried. Meteorite has landed and dropped, split three ways. This is our memory of the Kulu. And life began (Hamacher, D. 2011)

CONSTELLATIONS

Cultures around the world have used stories about constellations - pictures in the stars - to help interpret and make use of what we can see in the night sky. Some Aboriginal constellations are constructed by looking for the spaces between stars, rather than the stars themselves.

ORION

The well-known constellation of Orion the hunter was also observed by Aboriginal people. The Yolngu people of the Northern Territory called the same constellation Djulpan. In Djulpan, the three stars we know as Orion's Belt represent three brothers fishing in a canoe. The Djulpan brothers are chasing a group of sisters - represented by the Pleiades constellation. This is surprisingly similar to the European story of the hunter Orion chasing the Seven Sisters.

CALENDAR SKY

The night sky was also important as a calendar for Aboriginal Australians. The movement of constellations was connected to

AUSTRALIAN ABORIGINAL INTERPRETATIONS OF THE NIGHT SKY

the changing of the seasons and the availability of food sources. The Boorong people knew that mallee-fowl would build their nests at the same time when the star Lyra appeared in the sky. For the Yolngu people, the rising of the Scorpius constellation heralded the arrival of Macassan fishermen from Indonesia and the Pitjantjatjara people knew that winter began when Pleiades rose in the dawn sky.

Some of the information in this fact sheet has been collected by Ray Norris and Duane Hamacher.

Thanks to Simon Forrest, Elder in Residence at Curtin University for his contributions.

GLOSSARY

Arrernte: The Arrernte are the traditional owners of the Arrernte lands in Central Australia which includes the town of Alice Springs.

Boorong: The Boorong people are an Aboriginal Australian group whose traditional lands are near Lake Tyrell in North-West Victoria.

Djulpan: Djulpan is the name given to the constellation of Orion by the Yolngu people. The constellation depicts the three stars in Orion's belt as three brothers fishing in a canoe who were banished into the heavens for eating king-fish which was against the law in the king-fish clan.

Luritja: The Luritja lands border the lands of the Arrente people to the West and are South of Alice Springs.

Macassan: The Macassan are Indonesian fishermen who regularly landed on the northern coast of Australia to trade with local Aboriginal people.

Pitjantjatjara: The Pitjantjatnara are the aboriginal people of the Central Australian desert. The rock formations of Uluru and Kata Tjuta are some of their sacred sites.

Tjukurrpa: Tjukurrpa is the central Australian Aboriginal word for the understandings, laws and explanations of the spiritual and natural world.

Warlpiri people: The Warlpiri people are traditional owners of lands north of the Luritja country in the Northern Territory.

Yolngu people: The Yolgnu people are the traditional owners of lands in the northeast of the Arnhem shelf in the Northern Territory. Their proximity to the Northern coastline meant that these people were able to trade locally found sea cucumber with Indonesian fishermen.

WHAT IS THE DESERT FIREBALL NETWORK?

FIREBALLS in the sky

The Desert Fireball Network (DFN) is a project designed to find out where meteorites come from in the solar system.

The DFN consists of a series of satellite monitored cameras in the Nullarbor Plain constantly watching the night sky for any incoming meteors. There are currently 30 cameras in the network, and this number is increasing each month as new cameras are installed.

WORKING TOGETHER

The DFN is a collaborative effort between Imperial College, London, Ondrejov Observatory in the Czech Republic, Curtin University in Western Australia and the Western Australian Museum. The DFN team involves specialists from multiple disciplines including geologists, planetary scientists, astrophysicists, petrologists, mineralogists, mechatronic engineers, software engineers and science communicators.

THE CAMERAS

The DFN cameras capture pictures of meteors as they fall, and accurately measure the speed and direction of the meteor. Using this data it is possible to calculate the landing zone of the meteorite as well as the original orbit of the meteorite and possibly the parent body where it came from.

After recovering and analysing the fallen meteorite it will be possible to determine its composition, and by extension, the composition of the parent body. Using the DFN, scientists can find out valuable information about meteorites and their origins within the solar system.

OTHER FIREBALL NETWORKS

The establishment of a dedicated sky survey facility has been attempted in other countries over the last 50 years. However, most attempts met with limited success because of the use of clunky and out of date camera equipment, and poor recovery environments such as heavily forested areas or hilly terrain. This makes it difficult to maintain the network in an environment where recovery is almost impossible.

The Australian Desert Fireball Network aims to utilise the unique environment of the Australian outback which makes it easier for researchers to photograph, track down and recover incoming meteorites. The DFN is set up in the Australian Nullarbor Desert where the sky is clear almost all year round, and the ground is flat, white limestone.

The Nullarbor is an ideal location for the DFN because there is little human or animal activity to disturb the meteorites and the pale white landscape makes it easy to spot the darker meteorites once they have landed. These unique conditions make tracking and recovery much easier.

SUCCESS!

In July 2007, the DFN tracked and located its first meteorite. Using precise measurements obtained from the DFN

FIREBALLS in the sky | Curtin University | An Australian Government Initiative | Inspiring Australia

WHAT IS THE DESERT FIREBALL NETWORK?

cameras it was possible to triangulate the landing zone and successfully recover the meteorite. The Bunburra Rockhole meteorite, as it came to be known, is an achondritic eucrite which was originally in a strange orbit that carried it between Venus and Earth.

Over the next three years, the DFN researchers successfully photographed and recovered a second meteorite, Mason Gully, as well as recording and tracking the orbits of over 150 smaller meteorites. Most other networks would take decades to gather this much data.

EXPANDING THE NETWORK

Recently the Desert Fireball Network has been upgrading its cameras to be smaller, cheaper and easier to use in the hopes of expanding the network beyond the Nullarbor.

The Nullarbor is extremely hot and dry, but modern technology makes it possible for the cameras to survive in the harsh Australian outback. The cameras use an assortment of 3D printed parts to streamline the production process and reduce costs. To protect against extreme weather the cameras are housed within a waterproof container with an inbuilt fan cooling system to protect the camera during the day.

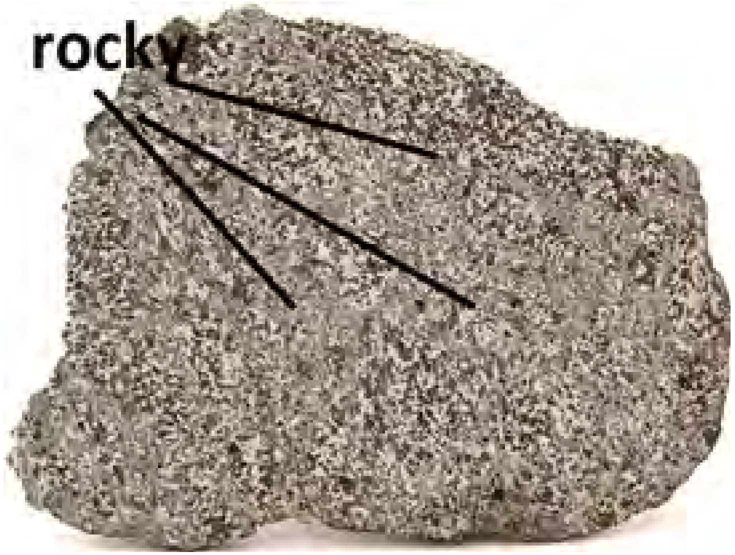
IMPROVING THE CAMERAS

The next generation of cameras in development are being designed to use more advanced computers and waste less power, and include a number of backup programs in case of a malfunction.
With these improvements the DFN will be able to extend the camera network from the Nullarbor into the West Australian wheat belt and beyond. The DFN aims to expand throughout the Australian outback in the hopes of monitoring one third of the Australian night sky.

TYPES OF METEORITE

FIREBALLS in the sky

Achondrite



Features
Ablation crust
99% Rocky

Likely origin
Crust of an asteroid

Chondrite

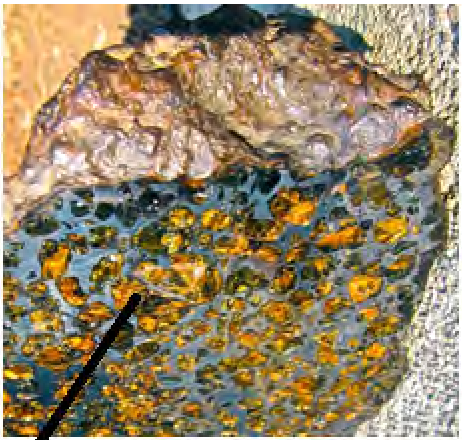
Features
Ablation crust
Chondrules
Rocky

Likely origin
Asteroid

TYPES OF METEORITE

FIREBALLS in the sky

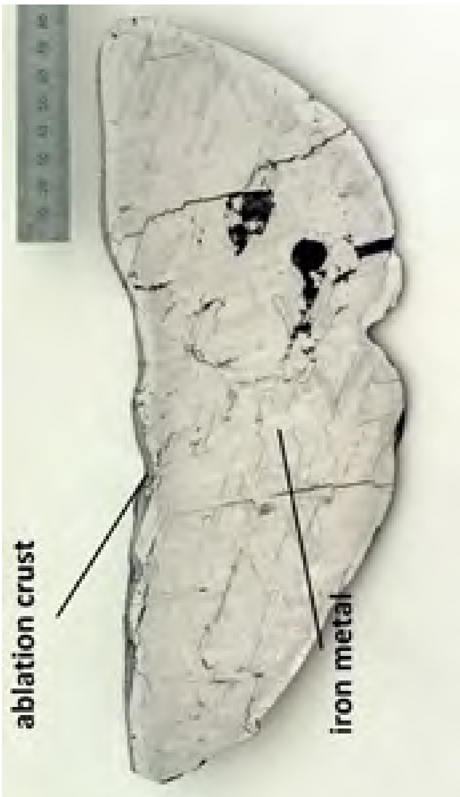
Pallasite



Features
Ablation crust
Olivine crystals
50% Rocky, 50% Iron

Likely origin
Core/mantle boundary of asteroids

Iron meteorite



Features
Ablation crust
Magnetic
99% Iron

Likely origin
Core of older and larger asteroids

TYPES OF METEORITE

FIREBALLS in the sky

Type	Percent rocky	Percent iron metal	Characteristics and formation
Chondrites	80	20	• Contain chondrules • After coming together (accretion), chondrites have never melted again, which makes them some of the oldest objects in the solar system.
Carbonaceous Chondrites	80	20	• Chondrites that contain traces of organic molecules. • These may be catalysts for life on Earth and other planets
Achondrites	>99	<1	• Igneous rocks that formed from the lavas that compose the crust of asteroids, or as material remaining inside asteroids to form their mantles • These look a lot more like earth rocks, such as granite or basalt
Iron Meteorites	<1	>99	• Most are from solidified cores of asteroids that have melted, similar to the core of Earth
Pallasites	50	50	• Mostly the crystals of the mineral olivine surrounded by metallic iron-nickel, • Formed at the boundary between an asteroid core and mantle • Olivine crystals are also found at the core-mantle boundary of Earth

GLOSSARY

Ablation: The removal of the surface of a re-entering body by vaporisation. The process of ablation prevents the interior of the meteor from being heated but also removes a large amount of the meteor's mass.

Accretion: Process of growth due to gradual build-up of material. In astrophysics this is due to gravity attracting more matter.

Amino acids: Molecules made of an amine and carboxylic acid. They can be combined into long branching chains to form proteins which are necessary for life. There are 20 different amino acids which are used to build all life as we know it.

Angle: The amount of turn between two lines that meet at a common point (vertex) Predict: Making an educated guess about an outcome.

Asteroid: Large rocks that have accreted together over millennia but never became large enough to form into a planet.

Bolide: An extremely bright meteor or fireball that is the result of a large meteoroid entering the atmosphere.

Catapult: A machine for hurling objects.

Chondrules: Spherical grains that formed during the early accretion of the solar system and are the building blocks of the solar system. Chondrules formed by the crystallisation of molten droplets and accreted together to from asteroids and planets.

Controlled: Factors that are kept the same in an experiment so they do not influence results so the test is 'fair'. Examples are duration of experiment, type of plant, soil used, water given, place of light exposure, measuring instruments used.

Comet: small clumps of dust and ice with eccentric orbits.

Constellation: A constellation is a defined region of the celestial sphere (night sky) that can be interpreted to form a shape when viewed from the Earth. They are often constructed like a dot-to-dot picture in the stars. Stars within constellations are not actually related, as they are at varying distances from the Earth, but are useful for identifying regions of the night sky.

Crater: A depression or cavity on the Earth's surface caused by the impact of a celestial body.

Density: Mass per unit volume of a substance where density equals mass divided by volume. Indicates how tightly matter is packed in a substance.

Dependant: Responds to changes in the independent variable and changes in its value are observed in an experiment. Example is amount of plant growth in cm

DNA: Deoxyribonucleic acid. These molecules contain the genetic code necessary for the construction and function of all known forms of life.

Dwarf planet: Smaller than normal planets and orbit the sun with objects at a similar distance from the sun. Planets can clear their orbital path of other objects.

Estimate: Roughly calculate or judge the value

Fireball: Extremely bright meteors. These meteors are much larger than normal and can sometimes be brighter than the sun.

Fusion crust: Smooth, shiny black surface of a meteorite formed by the flash cooling of the molten exterior after ablation has stopped.

Hypothesis: A proposed theory about the natural world that could explain natural phenomena. A proposal based on incomplete evidence that sets up the opportunity for further investigation.

GLOSSARY

FIREBALLS in the sky

Inclinometer: An instrument used to measure an angle of elevation (height) of an object.

Inclusion: A particle that is a part of something else.

Independent: Factor changed in an experiment (usually singular) to see how it impacts upon the dependant variable. Example is amount of light a plant is exposed to.

Intangible: Incapable of being perceived by the senses.

Kuiper belt: A disc shaped region of icy objects beyond the orbit of Neptune (30-55 AU). Comets which take less than 200 years to orbit the sun originate here.

Meteor: The bright light given off by a meteoroid as it burns through the atmosphere.

Meteor showers: A regularly occurring rain of meteors that radiate from a point in the sky. These meteors are the remnants of a comets tail.

Meteoroid: A small rock that is currently travelling through space. Once it has landed on a planet it is called a meteorite.

Meteorite: A rock from space that has survived re-entry and landed on the Earth's surface.

Mineral: A naturally occuring, inorganically produced crystalline solid with a fixed chemical composition.

Oort cloud: A disc shaped region of icy objects beyond the orbit of Neptune (5-100,000 AU). Comets which take more than 200 years to orbit the sun originate here.

Orbit: The motion of an object around a gravity point in space, such as the motion of a moon around a planet or the motion of a planet around the sun.

Organic molecules: Molecules made of carbon chains and other organic elements such as oxygen or nitrogen. Organic molecules are not necessarily biological in nature and can be from

Parallax: An apparent change in the position of an object due to a change in position of the observer.

Proteins: Long chains of molecules that serve a number of different functions within life forms from cell walls to respiration. They are made of amino acid chains and can form incredibly complex structures.

Rock: A naturally occuring solid made up of minerals or mineral like matter

Scale: The ratio of length in a model to the length of the real object.

Solar system: A star and all the objects that travel in orbit around it.

Trajectory: Path of a moving object in air or space influenced by factors such as thrust, gravity and wind resistance.

Trebuchet: A counterweight machine for hurling objects.

Variable: Any factor that can be controlled, changed or measured in an experiment that will influence results.