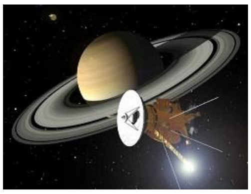


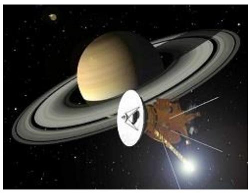
Cassini: Mission Planning Exercise

Teacher notes

The Saturnian System and

Overview of task

Prepared by Laura Thomas, LF Thomas Consulting



The Saturnian System and Overview of Task

Your pupils are being given control of a £2 billion spacecraft for the next seven days. In teams, they need to select targets and decide on the instruments they want to use. Each decision must be backed up by a scientific argument because once each team has made their selection you then need to get agreement between the teams on who has the use of the spacecraft for each time segment. Bear in mind that more than one time segment may want to be used by different teams but not all instruments can be used at once due to the design of the spacecraft.

Your spacecraft

The Cassini spacecraft launched in October 1997. Its journey to Mars took 7 years and on the way it visited the Moon, Venus and Jupiter. However, the process of designing and building the spacecraft started in the 1980s and in general space missions do take a number of years from the initial idea to launch and then normally a while longer as the craft makes its way across the vast distances between planets in the Solar System.

Astrophysics is different to the other sciences in that there aren't a lot of experiments we can do. Instead we need to observe the universe around us and try to draw conclusions from the evidence we find. The Cassini spacecraft is a tool to help us understand more about planetary formation. By studying the interaction of the rings and moons of Saturn (there are over 60) we can perhaps learn more about the formation of the Solar System.

The Saturnian System

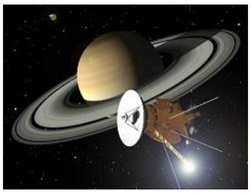
Saturn is a gas giant and is the second largest planet in the Solar System and is the sixth from the Sun. It has an extensive ring system made up of particles of dust and ice. There are a large number of moons orbiting the planet, at last count there were 62. They are all very different. Some interact with the rings and contribute to the mass of the rings, others are strangely shaped and may have been captured by Saturn's gravity as they passed by. The largest of Saturn's moons is called Titan and we are very interested in it because we think it is like what Earth would have looked like 4 billion years ago.

Instruments

The version of the spacecraft you are working with is called "Cassini Lite" and it has four instruments: imaging, magnetometer, dust detector and radar. Each is summarised below. Due to the design of the spacecraft the dust detector is the only instrument that can be used at the same time as imaging, magnetometer and radar. Radar and imaging cannot be used at the same time because they are located on different parts of the spacecraft and to get data on our target, the spacecraft has to rotate into position.

Imaging: The camera system is made up of a charged coupled device (CCD) that is 1024x1024 pixels. It has extremely high resolution and can see a 10p (2.4cm across) at a distance of 4km away. Images aren't just taken in visible wavelengths. The camera system can operate from ultra-violet through to infra-red, allowing intricate details of the planet, rings and moons to be clearly viewed.

http://saturn.jpl.nasa.gov/spacecraft/cassiniorbiterinstruments/instrumentscassiniiss/



Magnetometer: This instrument is essentially a magnetic compass and directly measures a magnetic field. The instrument is extremely sensitive to electric currents and metal components, so it is placed on an 11m boom made of non-metallic material. The boom remained folded during launch and was only deployed two years after launch. It allows study of the inside of planets and moons. By understanding more about the magnetic field of Saturn, more can be learned about the size of the core of the planet. Unlike the Earth, and indeed any other planet in the Solar System, the magnetic north and south pole of the planet lines up exactly with the geographic north and south pole.

http://saturn.jpl.nasa.gov/spacecraft/cassiniorbiterinstruments/instrumentscassinimag/

Dust detector: This instrument gives information on particles found in the Saturnian system. It allows investigation of their physical and chemical properties and also the study of how they interact with the rings, moons and magnetic fields around Saturn. A grid collects the particles for study and the particle is then assessed by other components inside the instrument.

http://saturn.jpl.nasa.gov/spacecraft/cassiniorbiterinstruments/instrumentscassinicda/

RADAR: The RADAR (radio detection and ranging) instrument uses radio waves to investigate the surfaces of the many different moons of Saturn. RADAR is an extremely flexible instrument and can be used for multiple purposes. In some cases normal pictures or a 3D map is created by bouncing pulses of energy off the surface from different angles. However, this cuts through the atmosphere and shows the surface. Instead, to find out more about the atmosphere, the RADAR instrument can be set up to measure the energy that is being emitted naturally by the surface. This gives important information about the moisture in the atmosphere. The microwaves emitted by the instrument are at a frequency of 13.78 GHz. The frequency can be converted to to a wavelength using the following equation:

$$\lambda = \frac{c}{f}$$

$$\Rightarrow f = \frac{c}{\lambda}$$

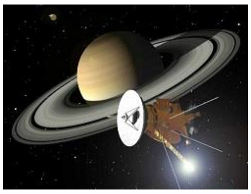
http://saturn.jpl.nasa.gov/spacecraft/cassiniorbiterinstruments/instrumentscassiniiss/

<u>Targets</u>

There are a number of potential targets on Cassini's orbit of Saturn and these are described below. It is recommended that the teams carry out additional research.

Saturn

Discovered	Diameter	Composition	Appearance	Orbit
First observed through a telescope in 1610 by Galileo Galilei	116,500 km	Hydrogen and Helium but it is thought to have a rocky core.	It is a gas giant. Complex weather systems can be observed in the atmosphere of the planet.	It orbits the Sun once every 30 years and is the sixth planet from the Sun.



Rings

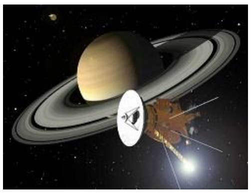
Discovered	Diameter	Composition	Appearance	Orbit	
1659 Christiaan Huygens	E ring extends to 480, 000 km from the centre of the planet. There are 20 rings or features identified at Saturn.	Dust, water ice, rock.	The rings are thought to be made up of pieces of asteroids, comets or moons that broke up before reading Saturn.	Each of the rings orbits at a different speed.	One of the mission aims is to find out how the rings formed and how they keep in their orbit.

Mimas

Discovered	Diameter	Composition	Appearance	Orbit	
1789	396 km	Water/ice, small amount of rock	There are many different sizes of craters on the surface of the moon. Due to tidal forces, the moon is not spherical but slightly egg-shaped.	The moon orbits in the "Cassini gap" the space between the A and the B rings of Saturn.	Known as the "Death Star" due to an 130 km wide impact crater. Shock waves from this impact can be seen on the other side of the moon.

Enceladus

Discovered	Diameter	Composition	Appearance	Orbit	
1789	500 km	Rocky core, ice/liquid water surface	It has any icy surface but cryovolcanoes at the south pole shoot out jets of water into space. There are smooth and cratered sections of surface, the smoother areas being younger. In addition to the craters normally found on moons, there is evidence of tectonics with long fractures, rifts and grooves in the surface.	It orbits in the E ring and is thought to be the source of the particles in that ring.	There is the possibility that life may exist in the oceans of Enceladus.



Tethys

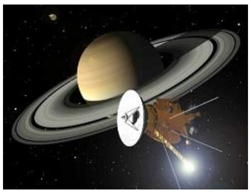
Discovered	Diameter	Composition	Appearance	Orbit	
1684 Giovanni Cassini	1060 km	Rock (6%), water/ice	Like other moons, the surface is made from water ice with some rock. It is one of the brightest moons of Saturn and is neutral in colour. There are a large number of craters, the largest is 400 km in diameter. Other large features can be found including a valley 100km wide and over 2000km long.	The location of the orbit of Tethys is 295000 km from Saturn (4.4 Saturn's radius). It is constantly bombarded with energetic (electrons and ions) particles.	Tethys has now been studied by four different spacecraft: Pioneer 11 (1979), Vooyager 1 (1980), Voyager 2 (1981) and Cassini (since 2004 to present). Just like our own moon, Tethys is tidally locked with Saturn. This means it always shows the same face to the planet.

Dione

Discovered	Diameter	Composition	Appearance	Orbit	
1684 Giovanni Cassini	1122km	Mainly water ice, but its high density implies there is a large proportion of rock (almost 50%) inside the moon	Its leading hemisphere is heavily cratered and its trailing hemisphere has an unusual surface feature of ice cliffs.	Dione orbits Saturn at a distance of 377,400 km which is roughly the same distance that the Moon orbits the Earth.	It is thought that a relatively recent large impact has spun Dione 180 degrees as the most heavily cratered areas are expected on a trailing hemisphere – this is not what we see with Dione. Just like our own moon, Dione is tidally locked with Saturn. This means it always shows the same face to the planet.

Rhea

Discovered	Diameter	Composition	Appearance	Orbit	
1672 Giovanni Cassini	1528 km	75% ice, 25% rock. Observations suggest that it does not have a rocky core and instead is a large, dirty	Rhea is more heavily cratered than the similar moons of Dione and Tethys.	At 527,040 km it is further away from Saturn than Dione and Tethys and therefore does not experience heating that the other moons do. The heating on the other	This is the second largest moon of Saturn. It is similar to Dione and Tethys. Just like our own moon, Rhea is tidally locked with Saturn.



		snowball as the rock is spread equally through the moon.		moons melts water which results in flatter surfaces.	This means it always shows the same face to the planet.

Titan

Discovered	Diameter	Composition	Appearance	Orbit	
1655	2575 km	Water ice, rock.	Titan has a thick atmosphere. Mountains, volcanoes and lakes have been found on the surface.	It takes Titan 16 days to complete one orbit of Saturn and it sits 1,200,000 km from the planet.	Titan is the second last moon in the Solar System and is even larger than the planet Mercury.

Hyperion

Discovered	Diameter	Composition	Appearance	Orbit	
1848	270 km	Water ice, small amount of rock.	This was the first non-spherical moon to be discovered. It looks very like a natural sponge.	Hyperion orbits at 1,481,100 km but is affected by Titan.	Hyperion could be what is left after a larger moon was destroyed by an impact.

<u>The task</u>

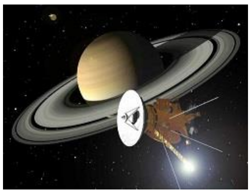
There are four scientific disciplines: rings, atmospheres, surfaces and fields & particles. Depending on the size of your class, you can decide to split them evenly across the four areas or have more than one group covering a discipline.

Three presentations are supplied. One which allows you to introduce the topic using the information above, the second has details of the targets and the third is to be used when bringing the task to a conclusion.

Once you have introduced the information and the groups have been set, they should begin research into their area of interest. This means understanding the task overview, identifying targets of interest to their group and agreeing what instruments on the spacecraft they should use. The research aspect is probably best carried out as a homework exercise or in time where the students can access the web to do further research.

When they have gathered all of their information as a group, they can then take a look at their observations spreadsheet. For each time segment they need to decide what target and instrument they want to use (if any!). They must be careful not to exceed the memory limit for that period. For example, the message "*SSR OVERLOAD!*" will show in Column G if the memory capacity has been exceeded. This means that the number of observations or the type of instrument used must be changed until no error message appears.

As soon as they have filled in their spreadsheet –a short time limit for this task is recommended! – they should submit their spreadsheets to you. They do not need to complete every single time step with an observation. Ideally this should all be done electronically.



You should then collate the spreadsheets into one. You will then see that there are multiple memory overloads as there will be clashes between the different groups. You should take one spreadsheet back to show the class and the last task is for them to negotiate over the time slots where there are clashes. It is always interesting to see the groups negotiate!

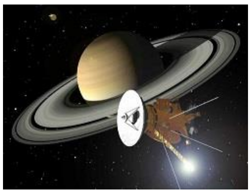
The nature of the task is such that it breaks down into several segments which can be run across different lessons and homework or as one as part of science week activities. It can break down into:

1. Introduction of the task
2. Group research
3. Observation decisions
4. Group negotiation over observations

Once the groups have agreed on who gets what time slot, you can show them what was actually observed that day. The images can be found in the “Concluding the task” presentation. The spacecraft took pictures of Titan and Enceladus, here is a summary:

- The Titan image uses our special filters to "see" through to the surface. Note the "dust doughnut" on the middle right, caused by a speck of dust on the lens.
- The close-up of Enceladus has lots of alternate lines part-missing at the right. This is caused by the lossless data compression running out of time before the line is read out and the length of the missing line is a measure of the entropy of the image line being compressed - the noisier the line the longer it takes to compress and so the more likely it is to be missing.
- The last Enceladus image is a long exposure one at high phase showing the material being emitted from the south polar region. The camera tracks Enceladus which is why you get the long star trail at lower right.

These are comments relating specifically to the photographs from the spacecraft but this would be a good opportunity for the pupils to show what they have learned about the different targets. Both Titan and Enceladus are extremely interesting objects.



Resources Provided

1. Introductory presentation (overview of task)
2. Task overview for the groups
3. Subject discipline introductions
   a. Surfaces
   b. Atmospheres
   c. Fields and particles
   d. Rings
4. Target information: powerpoint and spreadsheet
5. Observation spreadsheet: teacher version and group version
6. Concluding powerpoint (details of the actual observations)

These can all be downloaded from www.lfthomas.co.uk/defyinggravity.

Useful Links

- http://www.ciclops.org/ The official imaging laboratory for the Cassini mission.
- http://saturn.jpl.nasa.gov/ The Cassini spacecraft website, includes recent discoveries and data on the Saturnian system.

This resource was written, edited and compiled by Laura Thomas, LF Thomas Consulting. If you would like advice on any of the aspects of this topic, please don't hesitate to contact Laura Thomas on laura@lfthomas.co.uk

Acknowledgements

The resource is based on a task written and designed by Professor Carl Murray, the only UK member of the Cassini Imaging team and he is based at Queen Mary, University of London. Laura would like to thank Professor Murray for making all of his notes and data available for use and for taking the time to review this resource.

The observations spreadsheet was designed and created by Dr Kevin Beurle. Without this, managing the observations would be impossible.

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