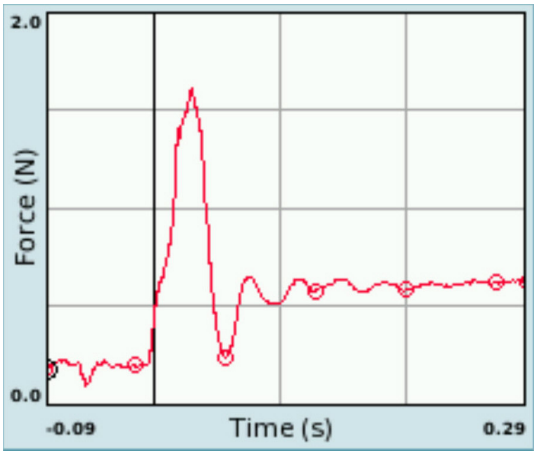
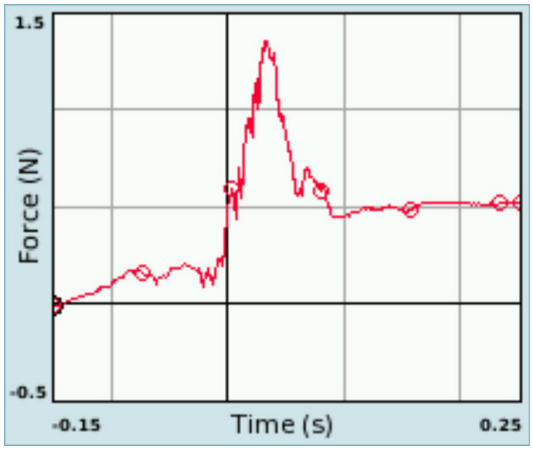
The Cassini-Huygens Mission to Saturn and its Moons –
Identifying the type of surface on a model of Titan - Teachers' Guide

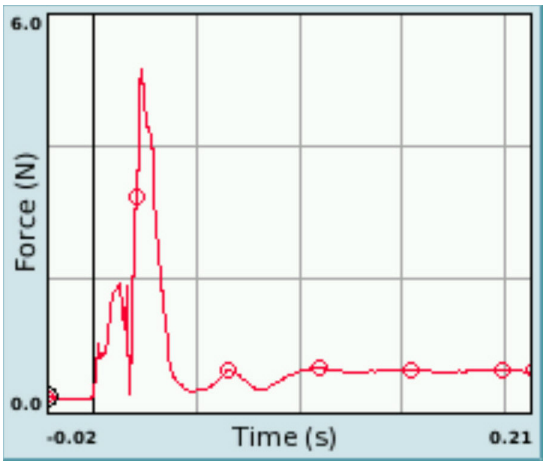
This activity is essentially one of matching what is seen on a Force-time graph with one from a series previously obtained. Typical graphs (expanded) are shown in Figure 1.



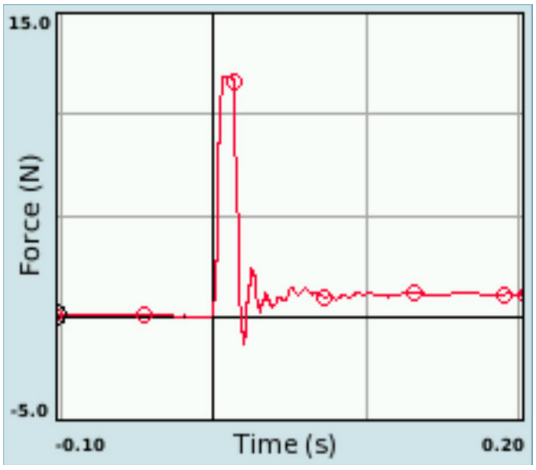
1(a) Sand surface



1(b) Fine grit surface



1(c) Fine gravel surface



1(d) Clay surface

Figure 1 Typical Force-time graphs

The matching exercise is not particularly intellectually demanding but it does illustrate a use for a Force-time graph and how the Cassini-Huygens' Mission scientists set about discovering what the surface of Titan is like. However, if students go on to analyse how the graphs differ and why, and what the real Force-time graph (impact signature) suggests, one has a more demanding task. The model surfaces used are sand, clay, fine grit and fine gravel. It is providing a bit of a mystery puzzle for your students to solve. If only one force sensor is available then the activity could be presented as a student demonstration, with the class being given copies of the specimen Force-time graphs to match with that produced with each 'mystery' Titan surface.

You could, additionally, discuss the shapes of such Force-time graphs with students, what might have caused them to be of such shapes. You also might

like to get across ideas of high forces over short times for hard impacts and lower forces over longer times for more spongy impacts. Concepts of acceleration and deceleration could also be broached, as could Impulse and Momentum change, and how Impulse can be determined from the area under a Force-time graph. You might also like to get your students to suggest what the Force-time might look like if Huygens landed in a liquid like water. Do not, however, do this for real as your probe would most likely be ruined. It is thought that there may be liquid areas on Titan made up of combinations of ethane, methane, propane, argon and nitrogen. Liquid water is unlikely as the surface temperature is very low.

An annotated Force-time graph (impact signature) that was obtained on impact is shown in Figure 2 below and unannotated as Figure 17 in the student activity.

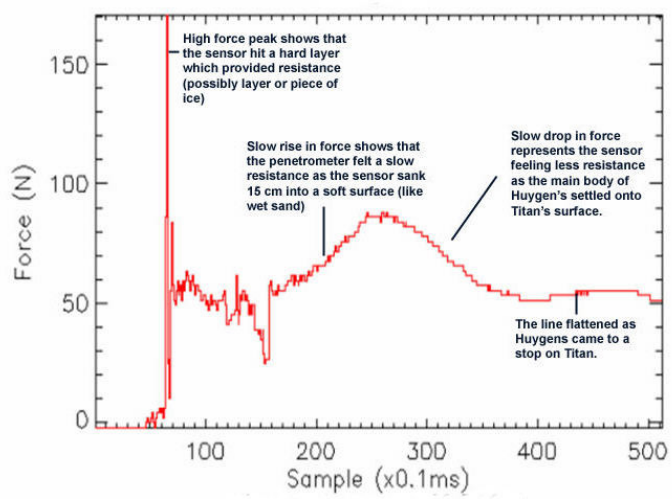


Figure 2 Annotated impact signature from the landing of Huygens on Titan (Courtesy Rutherford Appleton Laboratory Space Electronics Group and the Planetary and Space Sciences Research Institute at the Open University)

It is recommended that students should analyse this graph, discuss key features, and suggest, with reasons, what they think the surface of Titan on which Huygens landed may be like. Professor John Zarnecki, Principal Investigator for the Surface Science Package, on seeing the impact signature, said: "A crust and a pebble will give you an initial peak, but the match looks better with a pebble and, if we're seeing lots of them in the ground image it's hardly fanciful that we've bashed one of them". So he appears to think that the force probe hit a pebble, knocking it out of the way, and then penetrated a surface of 'sand' made up of ice grains. His comments are based on the tests scientists at the Planetary and Space Science Research Institute at the Open University did subsequent to the landing, trying to reproduce the Force-time graph with various combinations of materials. If the force sensors available to schools and colleges had been identical to that on Huygens then a nice activity would have been for students to try different materials, and combinations of them, to see how best to reproduce the impact signature. Unfortunately such a sensor is not available. However, it may be of interest to investigate the effect of a fairly hard but thin crust on top of a softer surface and this could be achieved with a thin layer of wax placed on top of sand. The wax layer can easily be made by pouring liquid wax onto the surface of water, let it harden, lift

it off and embed this layer into the surface of sand or clay where the force sensor is to impact.

Vernier Logger Pro 3 software gives access to a Fourier Transform (FFT) and so it is possible, by transferring the file into *Logger Pro 3*, to go further than just plot a Force-time graph. You can analyse the frequencies, and amplitudes or intensities of such frequencies, of the variations in force on impact. It would be interesting to see if, or how, this extra technique provides a clearer means of identification than a Force-time graph alone. It was a technique researched in the 1990s to identify the freshness of lettuces by snapping their leaves in front of a microphone and analysing the frequency spectra produced. The Salters Horners Advanced Physics course suggested using the technique to investigate biscuits and wafers in its *Good Enough To Eat* unit.

A sampling rate of 1kHz should prove adequate to gather enough data from the impact and penetration of the sample materials. Impact times appear to be between 0.1s and 0.2s. It would be useful to discuss the sort of time that impacts with the materials provided might take, and why fast sampling speeds are useful. Likewise it is helpful to discuss and explain the need for a 'trigger' to start off the data recording. I found a trigger of '0.5N' satisfactory.

The sensor used on Huygens was designed to measure forces in the range 5 to 10000N at a sampling rate of 10 kHz providing a depth resolution of 1mm at the nominal impact speed expected of 5 m/s. Its working is based on the same piezoelectric ceramic material (PZT-5A) as is found in the ultrasound generators/detectors used for imaging. On impact an electric charge is generated which is transferred into a capacitor. In being charged this capacitor has a voltage across it which is then amplified, digitised, and stored in a First In First Out (FIFO) buffer which can store 512 samples.

Whilst a little information has been provided on force sensors, much more detailed information is available on the *National Instruments* and *PCB Piezotronics* websites listed.

There are lots of useful weblinks to information on the Cassini-Huygens mission. Already they give access to a host of pictures of Saturn, its rings and moons, close-ups of Titan itself, and detailed information on the spacecraft and their sensors. There are also two card models for students to make. Ralph Lorenz' homepage is interesting for students to look at, showing him working on space projects, his background and his other interests. It's the human face of a scientist!

The three books listed provide lots of information on the Cassini-Huygens mission, the spacecraft and Titan itself. The magazines mentioned, and their back issues, have many articles on this mission and will undoubtably update readers subsequent to a successful landing and feedback of data.

Useful weblinks

An impact penetrometer for a landing spacecraft
http://www.lpl.arizona.edu/~rlorenz/acce.pdf

British National Space Centre (BNSC) – Cassini-Huygens
http://www.bnsc.gov.uk/default.aspx?nid=4395

Cassini-Huygens card models to make
http://www.nasa.gov/pdf/59402main_model_simple.pdf
http://www.nasa,gov/pdf/59403main_model_challenging.pdf

CCLRC Rutherford Appleton Laboratory Space Science & Technology – Huygens
http://www.sstd.rl.ac.uk/Features/Huygens.htm

ESA Cassini-Huygens
http://www.esa.int/SPECIALS/Cassini-Huygens/

Huygens Surface Science Package
http://www.rssd.esa.int/SB/HUYGENS/docs/SP1177/zarnecki.pdf

Huygens SSP: Experiment to Archive Interface Control Document (OU PSSRI)
http://pds.jpl.nasa.gov/documents/pag/sspeaicd.doc

Mission: Cassini-Huygens
http://www.uk2planets.org.uk/m_cassini.htm

NASA Cassini-Huygens Mission to Saturn and Titan
http://saturn.jpl.nasa.gov/home/index.cfm

National Instruments – Measuring Strain with Strain Gauges
http://zone.ni.com/devzone/conceptd.nsf/webmain/C83E9B93DE714DB08625686600704DB1?OpenDocument

Open University , Planetary and Space Sciences Research Institute
http://pssri.open.ac.uk/missions/mis-casa1.htm
http://pssri.open.ac.uk/missions/mis-cas.htm

PCB Piezotronics
http://www.pcb.com/techsupport/tech_force.aspx
http://www.pcb.com/techsupport/tech_gen.aspx

PPARC Cassini-Huygens School Resources
http://www.pparc.ac.uk/Ed/ch/Home.htm

Ralph Lorenz's Homepage
http://www.lpl.arizona.edu/~rlorenz/

The Planetary Society
http://www.planetary.org

The Planetary Society Interview with John Zarnecki
http://www.planetary.org/news/2004/conversation_zarnecki_john_huygens_1129.html

The Society for Popular Astronomy
http://www.popastro.com

Titan's Rotation Reveals an Internal Ocean and Changing Zonal Winds
http://www.sciencemag.org/cgi/content/full/319/5870/1649?ijkey=KlvSlOBKSenaU&keytype=ref&siteid=sci

UK Cassini-Huygens Press Conference
http://pssri.open.ac.uk/missions/UK%20C-H%20Press%20Conf/UK%20C-H%20Press%20Conf%203%20June%2004.pdf

Useful books

Lifting Titan's Veil. Ralph Lorenz and Jacqueline Mitton. Cambridge University Press 2002. ISBN 052193483 £19.99

Mission to Saturn: Cassini and the Huygens Probe. David M Harland. Springer-Verlag 2002. ISBN 1852336560 £19.38

Titan Unveiled. Ralph Lorenz and Jacqueline Mitton. Princeton University Press 2008. ISBN 978 0 691 12587 9 £17.05

Useful magazines

Astronomy Now. Local newsagents.

Frontiers. Free magazine on UK particle physics, astronomy and space science. Available from Strategic Planning and Communications, Particle Physics and Astronomy Research Council (PPARC), Polaris House, North Star Avenue, Swindon SN2 1SZ.

ESA Bulletin. Free magazine from the European Space Agency (ESA). Available from ESA Publications Division, c/o ESTEC, PO Box 299, 2200 AG Noordwijk, The Netherlands.

Popular Astronomy. The quarterly magazine of The Society for Popular Astronomy (also contains Prime Space for younger readers) – see their website listing.

The Planetary Report. The bi-monthly magazine of The Planetary Society – see their website listing.

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