

The Cassini-Huygens Mission to Saturn and its Moons

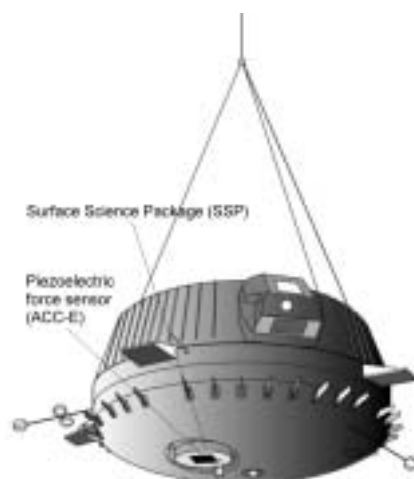
Identifying the type of surface on a model of Titan, Saturn's largest moon.

Introduction



**Figure 1 Artist's impression of the Huygens probe landing on Titan
(Courtesy NASA/JPL-Caltech)**

The NASA/ESA/ASI* Cassini-Huygens mission to Saturn and its moons began back in October 1997 with a launch from Cape Canaveral. Seven years later on Thursday 1 July 2004, having travelled some 2.2 billion miles, the Cassini orbiter with its Titan probe Huygens, went into orbit. On Christmas Day 2004 the 318kg Huygens probe (see Figure 2) was released from the orbiter and entered Titan's atmosphere on 14 January 2005 to land shortly afterwards on this moon's surface.



**Figure 2 Huygens probe (Courtesy Planetary and Space Sciences Research Institute,
The Open University)**

* NASA – National Aeronautics and Space Administration, ESA – European Space Agency, ASI – Italian Space Agency

The Huygens probe, named after the Dutch physicist and astronomer Christiaan Huygens (1629–1695) who discovered Titan in 1655, has been designed to investigate Titan’s atmosphere and surface. Here you will be modelling part of its Surface Science Package (SSP) – the force sensor (ACC-E) – which, on contact with the surface, provides a Force-time graph of this probe’s impact.

Your task will be to use a force sensor to identify the type of ‘mystery’ surface on which a model of Huygens is dropped by comparing the Force-time graph obtained with those produced by impacts with a series of known surfaces. Examples of what might be expected on Titan are shown in Figure 3 and were obtained by Dr Ralph Lorenz (see Figure 4) when working on his PhD thesis back in 1994. He is now Assistant Research Scientist at the Department of Planetary Sciences Lunar and Planetary Laboratory at the University of Arizona, Tucson, USA, and Visiting Research Fellow at the Planetary and Space Sciences Research Institute, The Open University, UK.

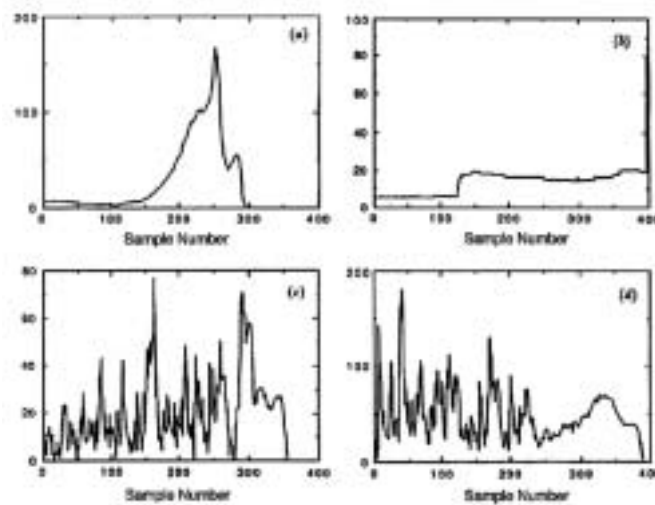


Figure 3 Force-time graphs of drops at 5m/s into (a) sand, (b) clay, (c) fine gravel (8mm particle size) and (d) medium gravel (15mm particle size) (Courtesy: Ralph D Lorenz. Exploring the Surface of Titan. PhD thesis University of Kent at Canterbury 1994)



Figure 4 Dr Ralph D Lorenz at the Paris Air Show in 1995 with the Huygens probe in the background (Courtesy: Ralph D Lorenz)

You might like to see what Ralph has been up to and what his non-space interests are too. Visit his homepage at <http://www.lpl.arizona.edu/~rlorenz/>

Measuring forces

The force sensor on the Huygens probe is acting as a penetrometer and can measure forces in the range 5N to 2000N at a rate of 10000 samples/second. It is made of a piezoelectric crystal of the ceramic PZT-5A (lead zirconate titanate) used in ultrasound imaging for both the production and reception of ultrasound.



**Figure 5 Force sensor ACC-E on the Huygens probe
(Courtesy Planetary and Space Sciences Research Institute, The Open University)**

This device behaves in a similar way to a piezoelectric gas-lighter which, when its 'trigger' is squeezed, generates a large electric charge. This charge in turn produces an electric field and a voltage across the crystal resulting, in the case of the gas-lighter, of a spark jumping a small gap to light the gas but, with Huygens, voltages which relate to the impact forces. The crystal pick-up on a gramophone record player used the same principle, as does a crystal microphone.

Most of the force sensors available to schools and colleges to use with dataloggers are based on the use of strain gauges. A common form of strain gauge consists of very thin metal foil bonded to a slightly flexible surface as shown in Figure 6. They can vary in size from less than a millimetre to 10cm long.

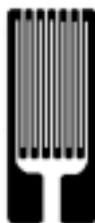


Figure 6 Strain gauge

As a force is exerted on that surface making it bend, so the metal foil stretches and increases in resistance. Incorporated in an electronic circuit this change of resistance produces a change of output voltage which is measured by a datalogger.

Setting up your investigation



Figure 7 Setup of *Xplorer GLX* with Huygens Titan lander

You will have been provided with a large pipe in which an unknown material - sand, clay, fine grit or slightly coarser gravel - has been poured to a depth of 10cm. This is to represent the surface material on Titan. Attached to the threaded rod sticking out of the lid attached to the pipe, but hidden from view, is a force sensor. You can see the set up of this system in Figure 7. Do **not** take the lid off to look inside the pipe, it will spoil the puzzle.

You will also have been given a set of Force-time graphs which have been previously obtained by dropping the force probe onto the materials mentioned. Your task is to suggest which material you think is in the base of your pipe. There will not be a perfect match, so look for particular features and values to help you decide which material is most likely. If there is time you might be able to exchange your pipe for one that a colleague has been investigating and see what you think is inside that.

In this investigation you will need to set a 'trigger level' to start the datalogger collecting data as the penetrometer force sensor first makes contact with the unknown material. A fairly fast rate of sampling will be needed to collect data whilst the penetrometer head goes into the material. The Huygens probe sampled at a rate of 10000 samples/second (10kHz), but rates over 1kHz should be fine. A suitable time to collect data over is also required, so think about how long such a probe might take to come to rest after contact with sand, grit, gravel or clay.



If mains power is available connect the power adaptor to the *Xplorer GLX* and then switch ON by pressing the **ON/OFF** key  at its bottom right-hand corner. Press the **GLX Home** key  to go to the GLX Home Screen as shown in Figure 8 if that has not already been displayed.



Figure 8 GLX Home screen



If necessary, use the arrow keys to navigate to the Data Files icon  and press the  key to open the Data Files screen as shown in Figure 9.



Figure 9 Data Files screen


You should see that an untitled new file has been opened for use. Press the **GLX Home** key  to return to the Home Screen shown previously in Figure 8. If it has not already been done, hold down the lid on the large pipe containing the model Titan surface and raise the rod to which the Force Sensor is attached to its highest point. Anchor the rod in place with the clothes peg just above the white plastic tube and plug the Force Sensor into one of the *GLX* ports as shown in Figure 10.



Figure 10 Force sensor plugged into the GLX

Press **F1** to display the Sensors screen similar to that shown in Figure 11.

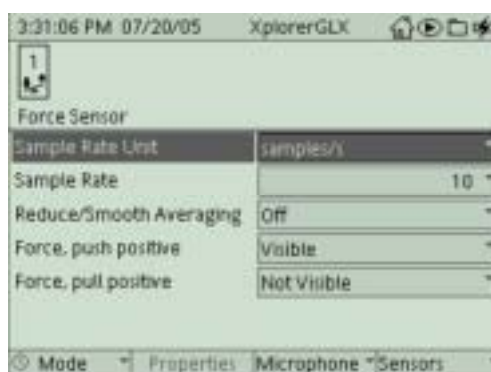


Figure 11 Sensors screen

This screen should indicate that the Force sensor is connected. 'Sample Rate Unit' should be displayed as highlighted, use the **checkmark** key and alphanumeric key **10000** to set it to 'Samples/s' if that is not already the case. Now press the **down-arrow** key to highlight 'Sample Rate' and repeatedly press the **+** key until a Sample rate at '5000' is displayed. Again press the **down-arrow** key to highlight 'Reduce/Smooth Averaging' and use the **checkmark** key and the alphanumeric key **0000** to set it to 'OFF'. Similarly press the **down-arrow** key again to highlight 'Force, push positive' and use the **checkmark** key to set it to 'Visible'. Finally press the **down-arrow** key again to highlight 'Force, pull positive' and use the **checkmark** key to set it to 'Not visible'. The screen display should now be as shown in Figure 12.

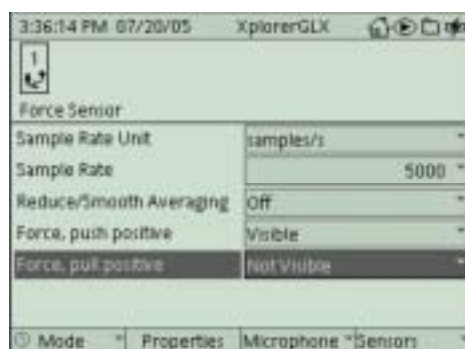



Figure 12 Sensors screen with settings required

Press  to return to the Home screen.

A high rate of sampling is useful here, think why. The Huygens probe's force sensor was able to sample at a rate of 10000 samples/second (10kHz). The GLX with this force sensor connected can sample at rates up to 5000 samples/second.

Now press the **Graph** key  to display the Graph screen shown in Figure 13.

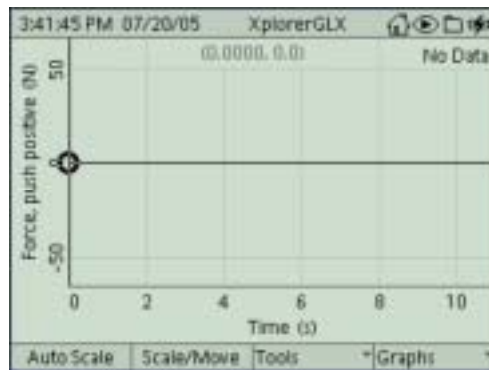



Figure 13 Graph screen

Now press the **Graphs** key  to display its pop-up menu as shown in Figure 14.

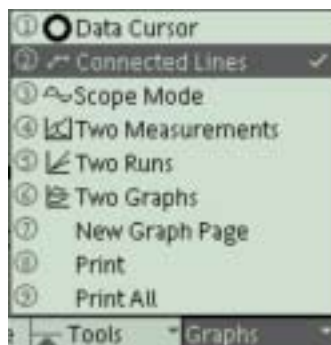




Figure 14 Graphs screen pop-up menu

Use the **up/down-arrow** keys to highlight 'Connected lines' only and, if no tick is shown alongside this, press the  key. Use the  key also to deselect items from this menu. Leave all the other options in this menu unticked – you may need to highlight some of these in order to change their settings.

After a moment or two the screen should revert to that shown in Figure 13.


The datalogger now needs to 'know' when to start logging from. In this case from as soon as the sensor's plunger first makes contact with the modelled Titan surface material at the base of the large pipe. Until it hits this material the force sensor will register 0.0N but, on impact, this force will rise sharply. So, to make datalogging start on impact, a Trigger setting is used which is just a little above 0.0N, say 0.2N. Press the **Tools** key  to reveal its pop-up menu shown in Figure 15.



Figure 15 Tools screen pop-up menu

Now press the alphanumeric key **Tab** to set up this trigger. Press **F3** again and then **Del** to display the Trigger Settings screen shown in Figure 16.



Figure 16 Trigger Settings screen

Use the **up/down-arrow** keys to highlight 'Trigger edge' and, if necessary, use the **✓** key to set this to 'Rising' to indicate a start to data collection as the force rises. Now use the **down-arrow** key to highlight 'Trigger level'. Press the **✓** key and type in a value of '0.2' using the alphanumeric keys. Now press the **OK** key **F1**. This setting will cause datalogging to begin when the impact force has risen to 0.2N.

All is now ready to go. Press the **Record/Stop recording** key **▶** to start the datalogging and, holding the lid firmly, remove the clothes peg from the rod attached to the force sensor and let the force sensor drop down into the modelled Titan surface. Quickly press the **Record/Stop recording** key **▶** to stop the datalogging. Very little will be seen on screen at this time.

Press the **Autoscale** key **F1** to display a slightly expanded trace as shown in Figure 17.

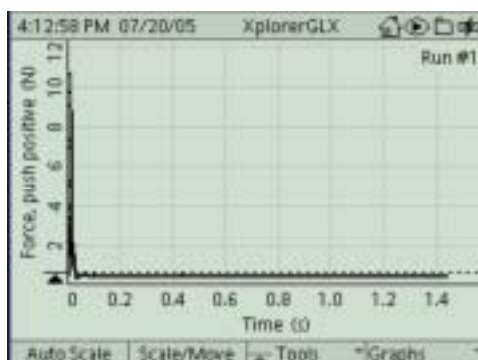


Figure 17 Slightly expanded trace following use of Autoscale

To attempt to match the impact trace (known by the Huygens investigators as an impact signature) with known sample materials, more detail needs to be shown. To do this the trace needs to be expanded further using the **Scale/Move** key **F2** in conjunction with the arrow keys. In Scale mode pressing the left and right-arrow keys produces expansion and compression of the graph horizontally. Pressing the up and down-arrows produces expansion and compression vertically.

Press the **Scale/Move** key **F2** to display 'Scale' just above the **F2** key and then press the right-arrow key a number of times to expand the trace until just before it goes off-screen. See Figure 18.

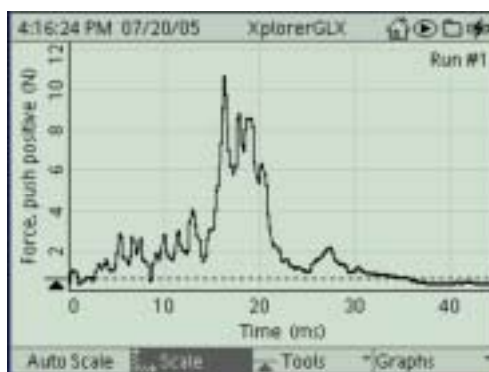


Figure 18 Expanded trace just about to go off-screen

If you press the **Scale/Move** key **F2** again to display 'Move' just above the **F2** key then, pressing the **left or right-arrow** keys a number of times would move the trace to the left or right. Similarly pressing the **up or down-arrow** keys would move the trace up or down the screen. Repeated use of the **Scale/Move** key **F2** and the arrow keys allows almost indefinite expansion and movement of the trace. It provides a Zoom function. Unless already done, expand the trace until it fills the screen.

With the landing on Titan there was just one chance of collecting data and, fortunately, this was successful. However, if you **did not** get a satisfactory impact trace in this simulation, you can make a further run. As before, raise the rod to which the force sensor is attached to its highest point and anchor it with the clothes peg. Press the **Record/Stop recording** key **F2** and, holding the lid firmly, let the force sensor drop into the modelled Titan surface. Quickly press the **Record/Stop recording** key **F2** again to stop the datalogging. This trace will be displayed as Run#2 and your first trace will be overwritten. Again expand the trace to fit the screen as detailed previously.

Analysing the data

Compare the graph displayed, your impact signature, with the specimen Force-time graphs you have been given.

Reporting your findings

- (a) Note down which 'Titan surface' label is on the pipe you have been using. Report which material you suspect is at the bottom of the pipe and why – note the key features of the graph which affected your choice.
- (b) Figure 19 shows the actual Force-time graph (impact signature) obtained by the Huygens probe.

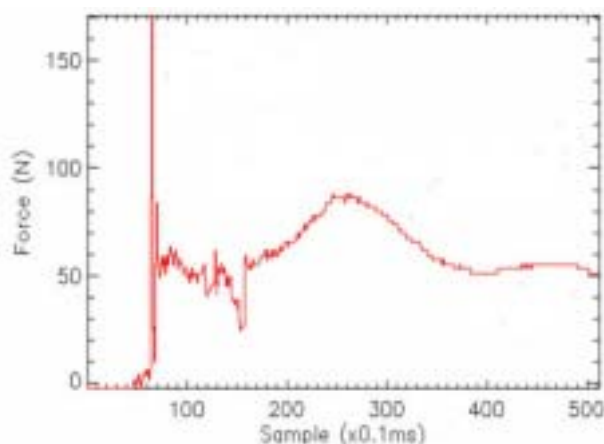








Figure 19 Force-time graph obtained by the Huygens probe on landing on Titan (Courtesy Rutherford Appleton Laboratory Space Electronics Group and the Planetary and Space Sciences Research Institute at the Open University)

With reference to the Force-time graphs shown in Figures 3 and 19 comment on how the impact force changed with time, how fast the changes were, and so suggest what might be the nature of the surface of Titan that Huygens impacted on.

Deleting data sets and finishing

To leave things set up for other users it is best to delete the data that you have collected. To do this press the **GLX Home** key  to return to the GLX Home screen. If necessary, use the arrow keys to navigate to the Data Files icon  and press the  key to open the Data Files screen as shown in Figure 9. Highlight, if necessary, the file you have been using (most likely the only one shown) and press the **Delete** key  and then the **OK** key . Now press the **GLX Home** key  to return to the GLX Home screen and then press the **ON/OFF** switch at the bottom right-hand corner of the *GLX Explorer*. Finally unplug the force sensor.

Acknowledgements

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