INTRODUCTION

This **Introduction** is part of the **SEP 'Sensors' pack**

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Refractometer image provided by the author.
The set of 4 force -time graphs onto various materials on page I02 of the Student Materials is from Lorenz R.D.; Bannister M.; Daniell P.M.; Krysinski Z.; Leese M.R.; Miller R.J.; Newton G.; Rabbetts P.; Willett D.M.; Zarnecki J.C. (1994). An impact penetrometer for a landing spacecraft *Measurement Science and Technology* Volume 5, (9), pages1033-1041
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Science Enhancement Programme

The Science Enhancement Programme (SEP) is part of Gatsby Technical Education Projects. It undertakes a range of activities concerned with the development of curriculum resources and with teacher education. For further information, visit www.sep.org.uk

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SENSORS

INTRODUCTION

Note: *Whilst technically one can distinguish between a sensor and a transducer, it is not a useful distinction at this level, and the term sensor is used throughout these materials.*

The activities in this package have been designed to require very little, if any, knowledge of physics or electronics, and are intended for use with students at Key Stage 4 and post-16.

The activities are intended to show the key features of designing a sensing instrument: the choice of sensor/transducer, the use of signal conditioning and calibration, and the use of a suitable display/recording device.

The 'About sensors' notes for students show that there is often more than one type of sensor which could be used to measure quantities such as temperature or flow rate. The choice of sensor – as well as the choice of display/recording device – will depend on the circumstances in which it is to be used. (Constraints might include range, response times, robustness and reliability as well as cost and how the data is to be used, for example).

Signal conditioning is worthy of comment, as there is little point in having a sensor which provides an output form which cannot be used. In most of the activities the sensors' outputs have been conditioned either through software 'converting' voltages into temperatures, light levels, angles of rotation etc., or by the use of an amplifier or a potential divider to bring the sensor's output within a sensible range. Additionally, such signal conditioning has involved the process of calibration, matching known values of quantities being measured to those being displayed.

The Student materials Introduction: sensors and frontier science introduces these ideas and briefly describes just two of the Surface Science Package's instruments and sensors on the Huygens probe which landed on Saturn's largest moon in January 2005. The use of sensors in space science is an important one and this introduction provides a link to a topic many students find interesting. The example also provides opportunities for broader discussion of how scientists rely on remote-sensing devices to provide data in such a situation and the kinds of decisions they might have to make, not only about what to measure but also about how to obtain these measurements.

USEFUL WEBLINKS

British National Space Centre's Learning Zone Resources
http://www.bnsc.gov.uk/lzcontent.aspx?nid=4852
Provides sensing activities designed for schools based on the Cassini-Huygens mission. Most of these come complete with Teacher's and Technician's Notes, the former with many associated weblinks.

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

ESA: Cassini-Huygens
http://www.esa.int/esaMI/Cassini-Huygens/index.html

Open University Planetary and Space Sciences Research Institute: Huygens Surface Science Package
http://pssri.open.ac.uk/missions/mis-casa1.htm

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

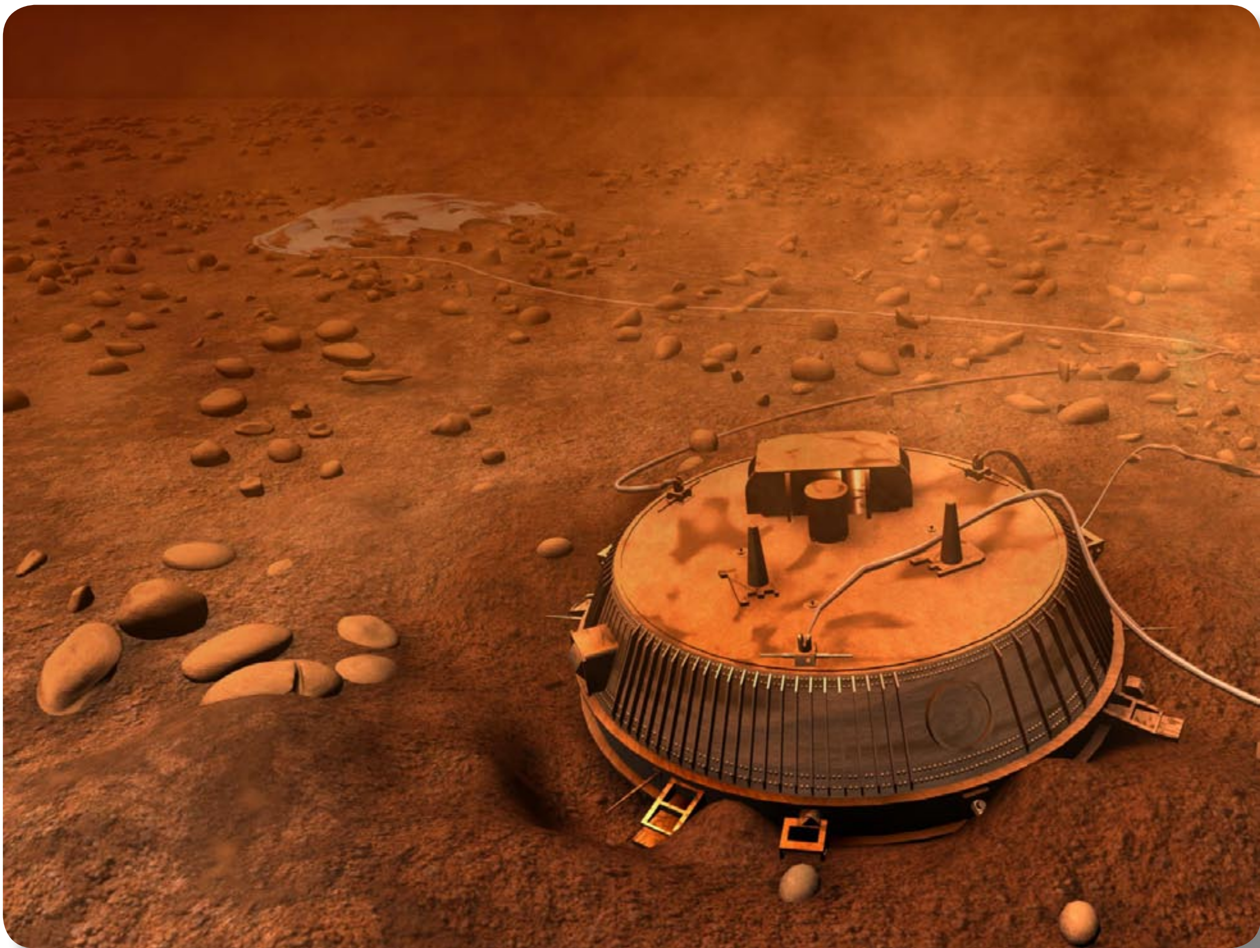
Practical Electronic Sensors. Owen Bishop. Bernard Babani (publishing) Ltd 1991. ISBN 0859342182 £8.50

USEFUL MAGAZINE

Astronomy Now.

Introduction: Sensors and frontier science

The Cassini-Huygens mission to Saturn and its moons began back in October 1997 with a launch from Cape Canaveral aboard a TitanIVB/Cantaur rocket. The Cassini orbiter was as tall as a two-storey house and had a mass of 5700kg, the Huygens probe had a mass of 318kg. At the time they were the most massive combination ever launched into space. Seven years later, on Thursday 1 July 2004, having travelled some 2.2 billion miles, the Cassini spacecraft with the Huygens probe still attached went into orbit around Saturn. On Christmas Day 2004 the Huygens probe was released and entered Titan's atmosphere on 14 January 2005, landing shortly afterwards on the surface of this, Saturn's largest moon.



Artist's impression of the Huygens probe landed on Titan (Courtesy ESA)

So why mention such spacecraft here? Like many space probes of the 20th and 21st century, they were packed full of sensors in the many instruments designed to tell us back on Earth about a vast range of phenomena and conditions on and around the ringed planet and its many moons. Amongst a total of eighteen such instruments, eight had involved UK teams in their development. The **Penetrometer** and the **Refractometer** referred to here are just two of those that formed the Surface Science Package, but the various websites listed later give details of them all, together with some of the latest findings.

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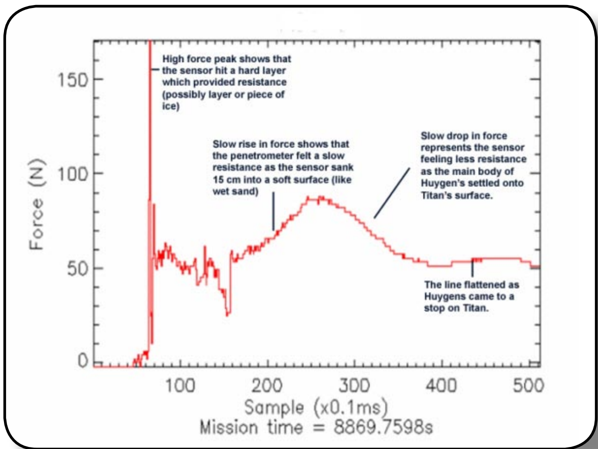
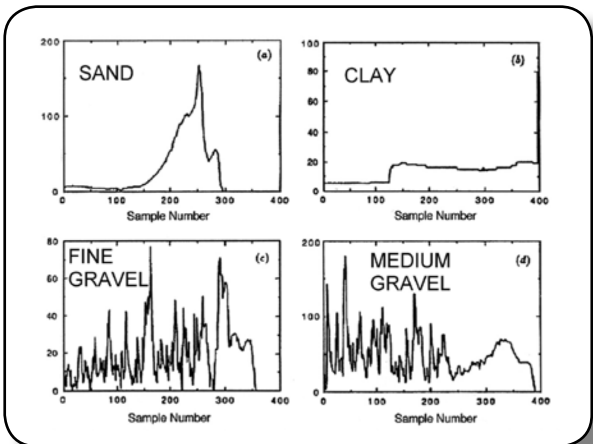
Piezoelectric force sensor on the Huygens probe (Courtesy Planetary and Space Sciences Research Institute, The Open University)

A **piezoelectric sensor** formed the basis of the **Penetrometer** which, when impacting with Titan's surface, produced a varying voltage. The larger the voltage, the greater the impact force. Some gas-lighters that you squeeze to produce a spark work on the same principle.



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 Institute at the Open University)

The resulting Force-time graph of the impact with the moon's surface is shown.



Force-time graphs of drops at 5m/s into various materials, from 'An impact penetrometer for a landing spacecraft' by RD Lorenz et al (1994).

Research prior to launch involved dropping the penetrometer onto different surfaces to see the nature of the Force-time graphs obtained. Four of these graphs are shown here.

This is a similar matching task to the activity on investigating crispness using sound that is included in the SEP **Sensors** package.

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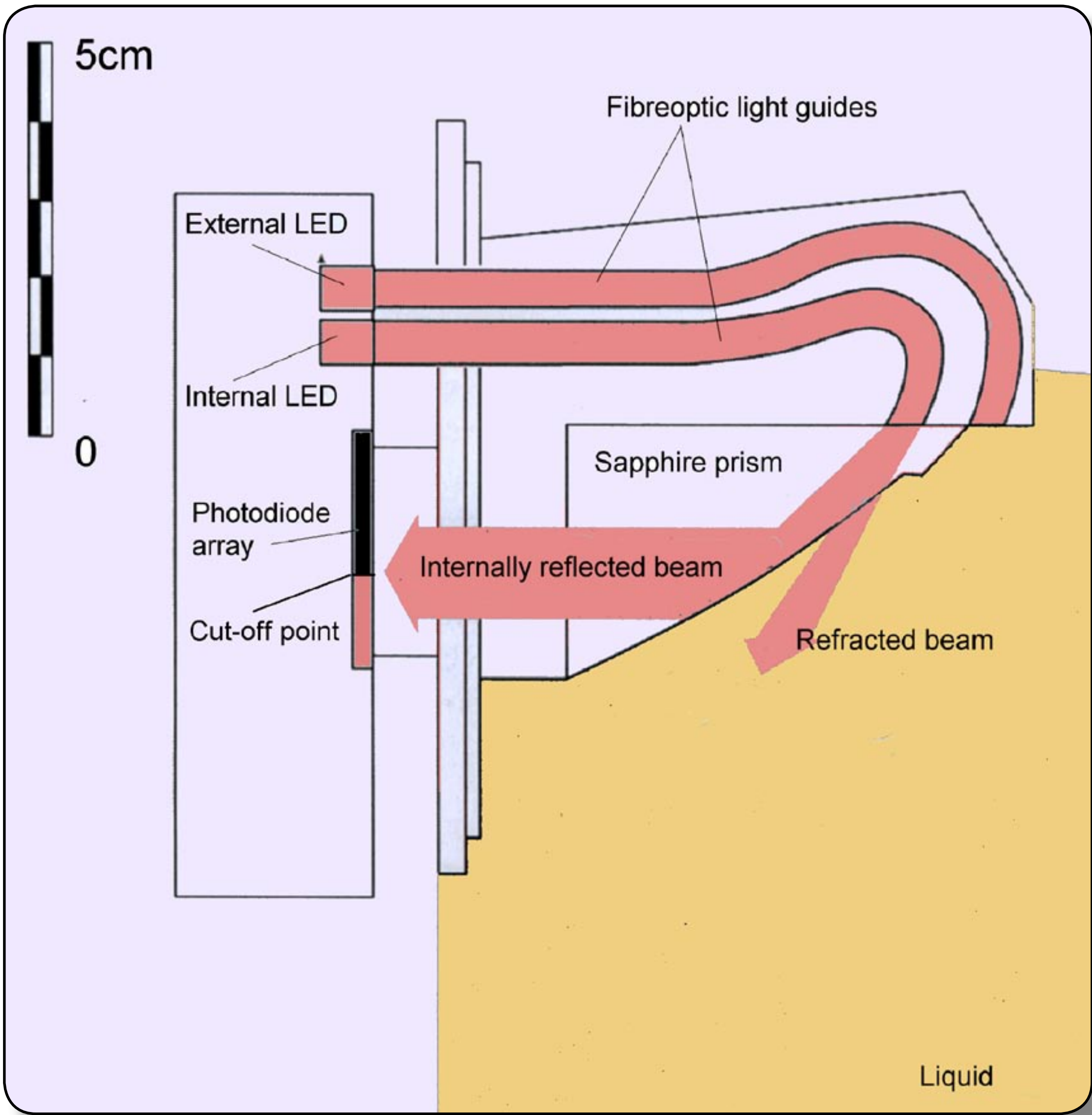

The Refractometer

Also on board the Huygens probe was a **Refractometer**, an instrument to measure the Refractive Index of any liquids that it landed in. It had been hoped that the probe might land in an ocean or sea made up of liquid methane and ethane and, by measuring its refractive index, the percentage mix of these two substances could be determined. This instrument detected the extent that a totally internally reflected beam of light from a light emitting diode (LED) was incident on a photodiode array sensor. The position of the 'cut-off' point on the array depended on the refractive index of the liquid. The above diagram shows the principles involved.

It was tried out before launch with a series of known combinations of liquid methane and ethane.

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Both of these prior testing processes can be looked upon as **calibration**. This is not just something that happens in research settings: it applies to all sorts of everyday equipment, too. Measuring instruments which need to be accurate in their measurement often have Calibration Certificates attached to them to show that their accuracy and reliability has been checked. Calibration would be done at regular intervals and all certificates would be dated, as shown in the photograph.

Calibration certificate

Your measurements of the voltage outputs for various **known** temperatures, light intensities, weights etc. in the **Sensors** activities will be a combination of **calibration** and **signal conditioning**. Signal conditioning is the process of 'converting' a voltage output (or some other quantity) into the type of measurement required and within the range required. Very often a potentiometer is the means of signal conditioning, though sometimes amplification is needed, as in the **Percentage Reflectance** activity.

Introduction: Sensors and frontier science

If you would like to find out more about the Cassini-Huygens Mission or about sensors, you could try some of the publications and websites listed below:

Useful websites

NASA Jet Propulsion Laboratory: Cassini-Huygens Mission to Saturn and Titan
http://saturn.jpl.nasa.gov/home/index.cfm
ESA: Cassini-Huygens
http://www.esa.int/esaMI/Cassini-Huygens/index.html
Open University Planetary and Space Sciences Research Institute: Huygens Surface Science Package
http://pssri.open.ac.uk/missions/mis-casa1.htm

Useful books

Lifting Titan's Veil. Ralph Lorenz and Jacqueline Mitton. Cambridge University Press 2002.
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Practical Electronic Sensors. Owen Bishop. Bernard Babani (publishing) Ltd 1991.
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Useful magazine

Astronomy Now