# CONSTRAINTS ON THE HUYGENS LANDING SITE TOPOGRAPHY FROM THE SURFACE SCIENCE PACKAGE ACOUSTIC PROPERTIES INSTRUMENT.

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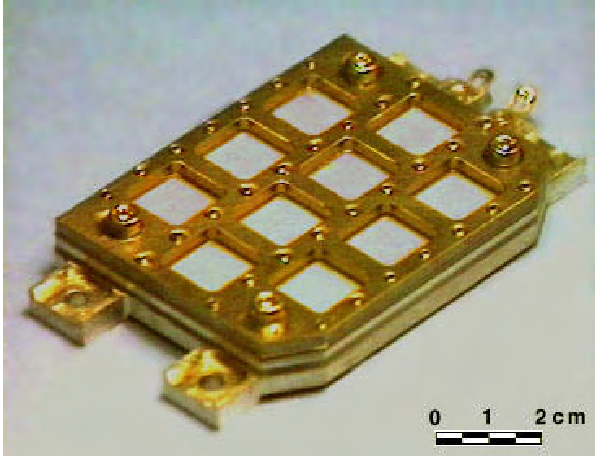
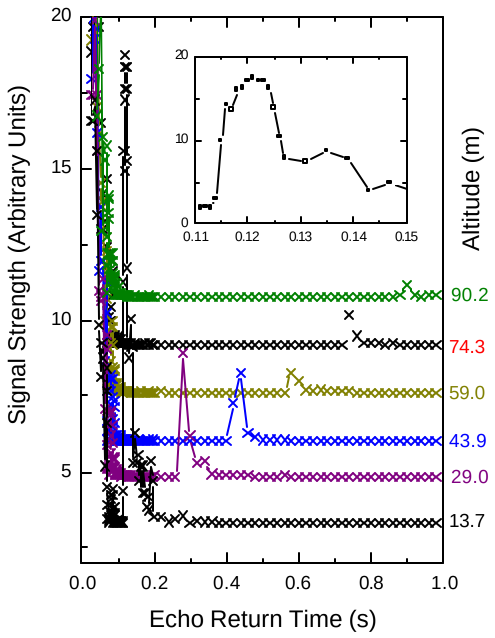
**Introduction:** On 14th January 2005 the Huygens probe landed on the surface of Titan, a culmination of many years work. There were six major instruments onboard, designed primarily for atmospheric measurements. Further details of the Huygens Probe and the instruments can be found in the ESA publication SP-1177. Initial results and interpretation from the mission can be found in [1] and companion works in the same journal issue.

One of the sub-sensors included in the Surface Science Package (SSP) is an acoustic ranging sonar, called the Acoustic Properties Instrument-Sonar (API-S). This sensor had two major science goals – in the event of a liquid landing, it was to measure the depth of the liquid body, and secondly it was designed to measure probe speed and also infer surface properties during the last few seconds of Huygens' descent before impact. A third, opportunistic goal was to look for possible reflections and scattering off cloud layers during the descent. [2] contains a more detailed description of the sensor's operating principle and design. In the event the actual landing of Huygens was on a solid surface, and no liquid investigations were required. Here we present results and interpretation of the final descent phase measurements.

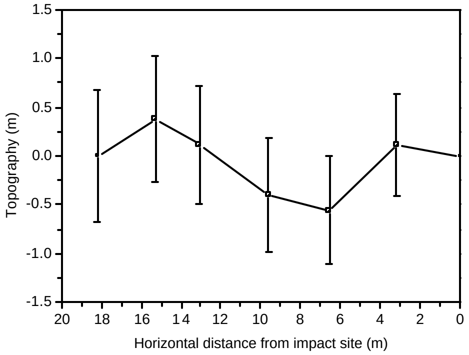


The API-S sensor carries out both send and receive operation through a single transducer array. The transducer array is driven by a 10ms long pulse of 20V peak to peak 1MHz square waves, resulting in a transmitted acoustic power of about 104dB (with respect to 20µPa as is conventional in terrestrial acoustic work). Then, after a short blanking period to prevent detection of structural acoustic ringing, the transducer is switched to a listening mode. If a signal is detected above a certain threshold, the peak time is logged, and the peak is sampled at 1ms resolution to generate a peak profile. This cycle is repeated approximately every 2 seconds during final descent, with the precise timing dependent on overall processor load. The 3db beam width has a half angle of approximately 20degrees, resulting in a variable size ground footprint during final descent. As can be seen from the figure, the transducer is also not axially symmetric, resulting in an elliptical rather than circular footprint.

**Results:** During the final descent, there are six API-S echo returns which show peaks that represent surface reflections, below 90.2m, as shown below. During this time the probe traversed approximately 20m across the Titan surface.

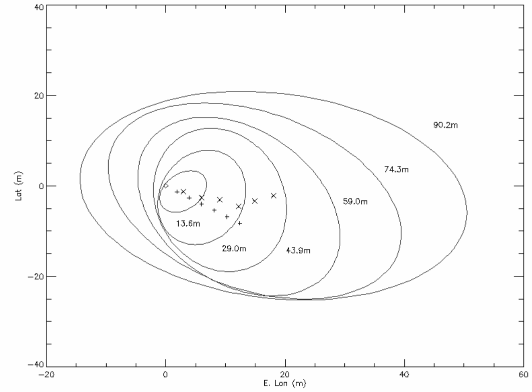


From these data it is possible to derive a series of values for the probe ranges to ground. Since the probe moves significantly during the travel time of the sound pulse, one must consider consecutive pairs of returns, and then solve a pair of simultaneous equations to derive speed and range, using a speed of sound for the medium. (Speed of sound is measured by API-V, one of the other SSP sub-sensors.) However, it is important to note that these simultaneous equations require assumptions of constancy of probe velocity and terrain between the consecutive returns under consideration. In reality it is expected that there will be a very slight drop in speed as the probe descends, as pressure (and hence density) of the atmosphere increases by about 6hPa (~0.4% change), but this effect is well within experimental errors. From a derived probe descent velocity, one can in theory further infer a possible topography transect under the probe, by noting the small deviations from straight line fits to the ranges, based on the assumption that in reality the probe descended at a constant speed over the last 100m, as shown below:



The terrain derived indicates a terrain height variation of 1-2m over 20m or so, in agreement with DISR imagery. Such a terrain is geologically plausible given the descent and surface imagery as seen in [4] figures 3 and 4, and may represent hummocks or channels (the wavelength seen is comparable with terrestrial analogues)– however it is important to note that vertical variation in values derived are within the error estimates for the sensor, and should not be over-interpreted. Additionally the fitting results in the end points both being at height of 0, implying no underlying terrain slope. Such a slope could very well be present, but would only result in a slightly different value for the average descent speed derived from the straight line fit.

In the lower atmosphere the probe experienced horizontal winds of approximately $1\,ms^{-1}$ [4,5]. By combining API-S peak ranging information with probe positional and attitude information from the SSP tilt sensors and the descent trajectory reconstruction [1,6], it is possible to plot the sensor footprints sampled by API-S in a Titan coordinate frame relative to the landing site as the probe descends, below. The API-S sensing acoustic beam is not circularly symmetric, and the probe tilt and azimuth varies during descent, resulting in elliptical rather than circular sensor footprints.



The images of the surface taken by the Huygens camera ([4], figure 3), show predominantly NW-SE channels, which would run close to parallel to the descent. In light of this the possible transect over channels as shown may represent a very oblique cut across the channels, such that the wavelength from the figure is significantly larger than the true wavelength.

**Peak shape modelling:** To investigate further the peak shape, we have constructed a computer model that simulates the 10ms transmit pulse, onto a defined terrain, and integrates over sensor angles and calculates a time of flight and signal strength for each ray path to assemble a peak, given the probe altitude and attitude. A topography description (arbitrarily varying surface height and reflectance) can be applied to the simulated ground, as input to investigate what peak shape is generated.

This work is currently underway and will be presented. Preliminary results indicate that the surface acts more as a specular reflector, rather than a Lambertian surface: such a surface might be expected if the ground is effectively smooth at scales comparable to the acoustic wavelength (1.3cm). If one discounts the larger rocks seen in the surface images, this is a not unreasonable description of the remaining surface. This is also compatible with the results from the SSP ACC-E penetrometry sensor [6], which indicated grain sizes of *c.*8mm diameter or less, with no indication of larger grains.

**References:** [1] Lebreton, J-P. et al, Nature, 438, 758-764, 2005. [2] Zarnecki et al, Space Science Reviews 104: 593-611, 2002. [4] Tomasko M., et al, Nature, 438, 765-778, 2005 [5] Bird, M. et al, Nature, 438, 800-802, 2005 [6] Zarnecki, J.C. et al, Nature, 438, 792-795, 2005.