Inverting Comet Acoustic Surface Sounding Experiment (CASSE) touchdown signals to measure the elastic modulus of comet material

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The landing of Philae on comet 67P/Churyumov-Gerasimenko is scheduled for November 11, 2014. Each of the three landing feet of Philae house a triaxial acceleration sensor of CASSE, which will thus be the first sensors to be in mechanical contact with the cometary surface. CASSE will be in listening mode to record the deceleration of the lander, when it impacts with the comet at a velocity of approx. 0.5 m/s. The analysis of this data yields information on the reduced elastic modulus and the yield stress of the comet's surface material.

We describe a series of controlled landings of a lander model. The tests were conducted in the Landing & Mobility Test Facility (LAMA) of the DLR Institute of Space Systems in Bremen, Germany, where an industrial robot can be programmed to move landers or rovers along predefined paths, allowing to adapt landing procedures with predefined velocities.

The qualification model of the Philae landing gear was used in the tests. It consists of three legs manufactured of carbon fiber and metal joints. A dead mass of the size and mass of the lander housing is attached via a damper above the landing gear to represent the lander structure as a whole. Attached to each leg is a foot with two soles and a mechanically driven fixation screw ("ice screw") to secure the lander on the comet. The right soles, if viewed from the outside towards the lander body, house a Brüel & Kjaer DeltaTron 4506 triaxial piezoelectric accelerometer as used on the spacecraft. Orientation of the three axes was such that one of the axes, here the X-axis of the accelerometer, points downwards, while the Y- and Z-axes are horizontal. Data were recorded at a sampling rate of 8.2 kHz within a time gate of 2 s. In parallel, a video sequence was taken, in order to monitor the touchdown on the sand and the movement of the ice screws.

Touchdown measurements were conducted on three types of ground with landing velocities between 0.1 to 1.1 m/s. Landings with low velocities were carried out on the concrete floor of the LAMA to determine the stiffness of the landing gear based on the deceleration data measured with the accelerometer. Landings on fine-grained quartz sand and on a Mars soil simulant (brand names WF34 and MSS-D, respectively) allow quantifying the changes of the deceleration data due to interaction with the soil. The elastic moduli of the soils that were inverted from the accelerometer data agree well with data obtained by ultrasonic time-of-flight measurements, provided an effective contact area is used. To this end, the lander structure was viewed in a simplified way as a mass-spring-damper system coupled to the soil by a contact spring, whose stiffness is determined by elastic moduli of the soil and the contact radius. Analytical expressions allow a rapid inversion of the deceleration data to obtain elastic data. It is expected that the same procedure can be applied to the signal measured when landing on comet 67P.