Hypervelocity impacts into regolith targets

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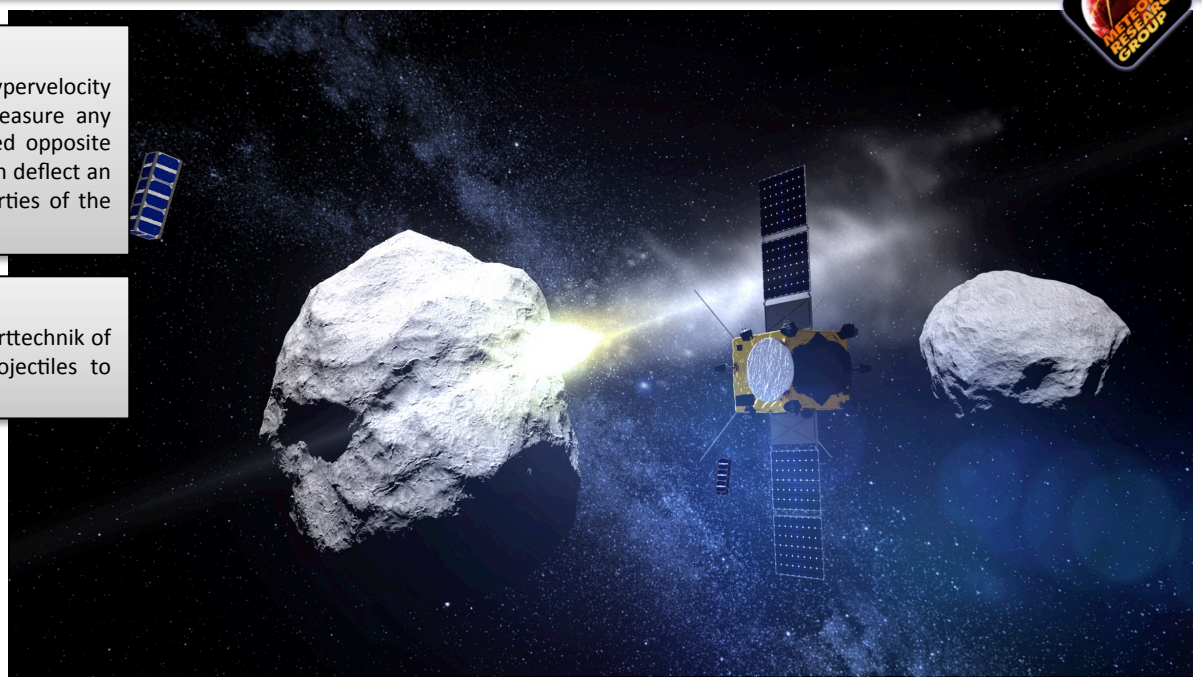
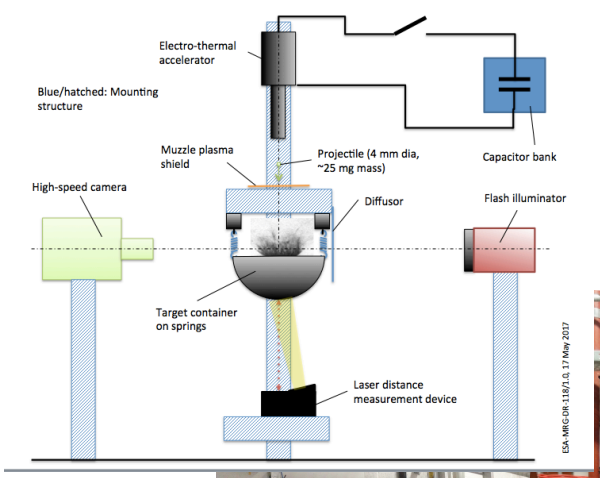
Introduction

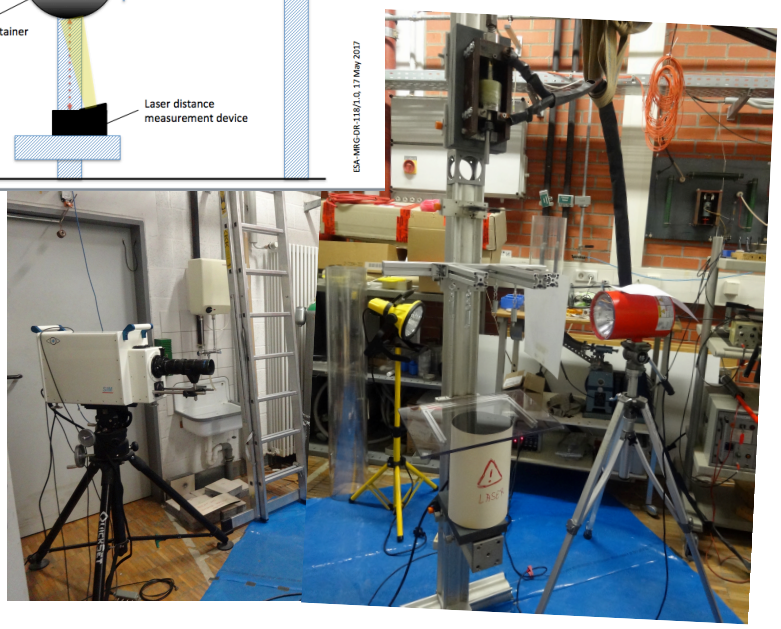
With support of the ESTEC Science Faculty, we have performed hypervelocity impact experiments into regolith targets. The main goal was to measure any potential momentum transfer enhancement by the ejecta accelerated opposite the impact direction. This is relevant for determining how much we can deflect an asteroid by a kinetic impactor. It is expected that the surface properties of the target will affect the momentum enhancement.



Measurement setup

The so-called electro-thermal accelerator of the Lehrstuhl für Raumfahrttechnik of the TU Munich was used to accelerate 4-mm diameter Nylon projectiles to velocities up to 2.7 km/s.

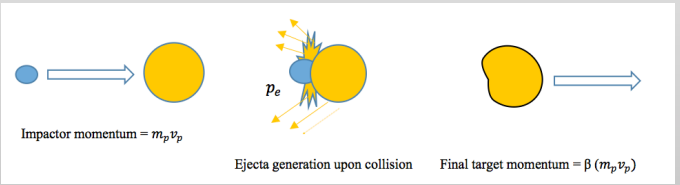




Measurement setup - II

The target is suspended on four springs. We use a laser distance measurement system to record the oscillation of the target after the impact. Knowing the spring parameters, we can compute the momentum transferred to the target. The community uses the term 'momentum enhancement factor β', defined as the ratio of the momentum of the projectile to the target after impact. Because of material being ejected opposite to the impactor flight direction, a momentum increase is possible.

$$\beta = \frac{M_t V_t}{m_p v_p} = \frac{m_p v_p + p_e}{m_p v_p}$$



Experiments

We used four different target types: glass beads (diameter 100 um to 200 um), quartz sand (grain size 100 um to 200 um), lunar regolith simulant JSC-1 in loose form and compressed form. A typical impact crater in sand is shown on the left. The impact was recorded with a high-speed camera giving up to 16 images. They show the evolution of the ejecta cloud. Note the projectile being reflected back out again, visible in the last 5 images.

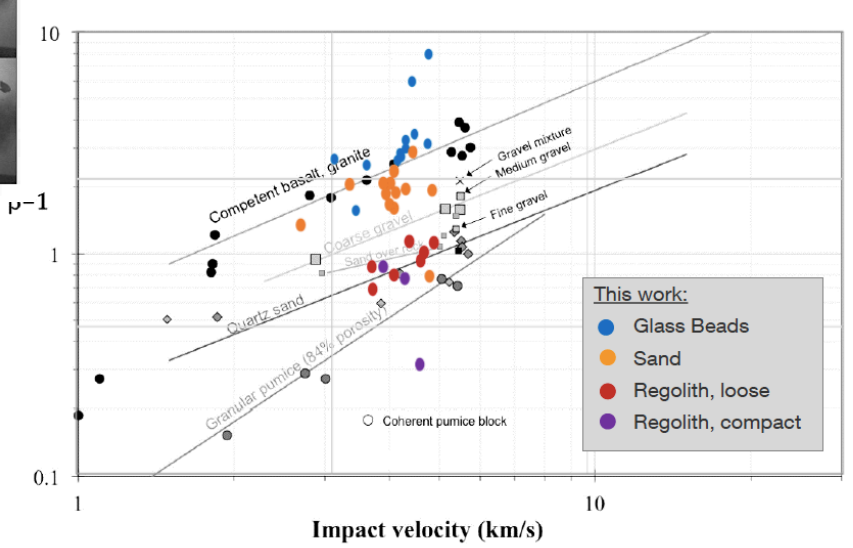
A total of 57 shots were performed.

Shot #2
v_{impact} = 2.4 km/s

Results

Glass beads resulted in the largest impact craters. Most of the ejecta was flying in a direction opposite to the impactor. Quartz sand gave intermediate results. The lunar regolith simulant resulted in the smallest impact craters, with regolith ejected at shallow angles. This means the momentum enhancement is smallest in this case.

The plot to the right shows the measured momentum enhancement factors (in color) over literature results (in black and white, Housen & Holsapple 2015). (β – 1) > 1 means that there is an actual momentum enhancement. No significant enhancement was observed for the lunar regolith simulant.



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