National Aeronautics and Space Administration

SHIELD: A Small, High Impact Energy Landing Device for Low-Cost Access to the Martian Surface

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Program: FY21 R&TD Strategic Initiative **Strategic Focus Area: Hard Lander for Low-Cost Access to the Martian Surface**

Objectives

In FY2021, the specific objective for the SHIELD proposal was to reach TRL 5 with the impact deceleration mechanism. The impact deceleration mechanism will reach TRL-5 using impact testing done at up to half the speed (≤ 25m/sec) of the predicted flight impact (≤ 50 m/sec).

Background

The Mars science community and JPL's Planetary Science Directorate have expressed a need for a method to deliver low-cost (<$50M) landers to the surface of Mars. Satisfying this need will enable a broad suite of potential missions that can complement "flagship class" Mars missions such as Mars Sample Return. The goal of the SHIELD effort is to develop a new entry/descent/landing (EDL) technology compatible with mission concepts that could investigate questions within all four Mars science goals: Life, Climate, Geology, and Preparing for Human Exploration. The missions thus enabled could range from single small landers to multiple landers carried as supplemental "piggyback" landers on larger Mars orbiters (for example, the ICE-SAG mission concept). SHIELD has no parachute system, no propulsive landing or airbag landing system, and no ground detection system. Instead, SHIELD relies on a low ballistic coefficient and the impact attenuator to limit landing decelerations to < 2000 g (19,600 m/sec^2).

Approach and Results

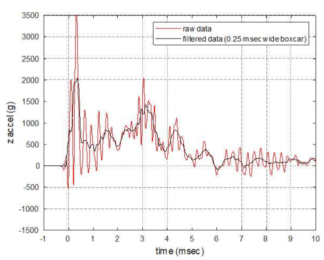
The primary function of the impact attenuator is to absorb and dissipate the kinetic energy of the landing while limiting payload deceleration to < 2000 g (19,600 m/sec^2). In order to reduce cost during this early stage of hardware development, half-speed testing (testing at ≤ 25 m/sec) was implemented because this speed could be achieved by lifting the test article 50m in the air with a crane and then letting the test article free fall to the ground. In order to accommodate the half-speed test, the test article needed to "crush" only 25% as much as a comparable full-speed impact attenuator. The impact speed was determined via high speed imagery of the test, and an accelerometer and data logger package was included on the test article to record accelerations during impact.

On March 5, 2021, two identical test articles were tested as described above. The first test article impacted a roughly 1" thick steel trench plated placed on the parking lot surface: this was considered representative of a "worst case" surface to land on with regards to a non-compliant surface. The test article responded as anticipated based on LS-Dyna simulations. The impact attenuator was "crushed" as expected: in this case, the surface was "harder" than the impact attenuator, and so the attenuator was "crushed." The accelerometer data (when filtered with a 0.25 msec boxcar filter) peaked at 2000 g, and the test article "bounced" approximately 0.5m into the air after the initial impact.

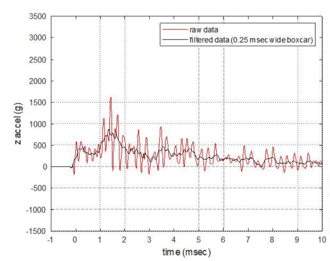
The second test article was dropped onto a cylindrical tub approximately 0.6m tall and approximately 2.4m in diameter that was filled with dry playa and then covered with sandstones approximately 35mm thick (the sandstones were painted black to help visually distinguish the sandstones from the playa): this was considered a "more realistic" approximation of a "typical" landing surface relative to the previous "worst case" test. In this case, the test article broke through the sandstone and compressed the underlying playa, with negligible "crushing" of the impact attenuator itself. In other words, in this case, the surface was "softer" than the impact attenuator, and so the surface was "crushed." The accelerometer data (when filtered with a 0.25 msec boxcar filter) peaked at less than 1000 g in this test, and no "bounce" was observed.

Significance/Benefits to JPL and NASA

This R&TD work has demonstrated the fundamental function of the SHIELD impact atenuator and has paved the way to further develop the SHIELD conept into a low cost method for delivering science payloads to the surface of Mars. Alow cost method for delivering science payloads to the surface of Mars benifits JPL and NASA by increasing the rate of new opportunities for scientific investigations.



Drop 02A, March 5, 2021
Test article was dropped onto 1" thick steel trench plates at approximately 25 m/sec
Peak deceleration was approximately 2000 g (19,600 m/sec²)
Moderate bounce of the test article (roughly 0.5m bounce height)



Drop 02A, March 5, 2021
Test article was dropped onto 1" thick flag stones on top of playa at approximately 25 m/sec
Peak deceleration was approximately 800 g (7,840 m/sec²)
No bounce of the test article

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