Safe Landings in Extreme Terrain

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Following the failure of the Mars Polar Lander and the re-evaluation of the Mars Sample Return mission status, a Safe Landing Tiger team was established on January 7, 2000. The charter of the team was to re-evaluate large scale (1000-2000 Kg) Mars lander designs with the principal objective being the assurance of safe landing in hazardous terrain. The tiger team developed a number of concepts, two of the most notable and promising concepts, are both based on a Mobile Lander paradigm. Unlike the Pathfinder and Surveyor class landers, this paradigm groups all of the landed equipment into one of two categories: EDL only equipment (ie not used after touchdown) and multi-use equipment, those used during and or after touchdown. The objective is to maximize the use of all equipment being brought to the surface by placing the bulk of the avionics and mechanical systems onto a much larger “rover” and leaving only the bare essentials on a “dead-on-arrival” landing system. All of the hardware that the surface roving mission needs is enlisted into performing the EDL tasks. Any EDL specific avionics not used after touchdown are placed on the landing system.

The first concept developed is called the pallet lander and is comprised of a low profile, large footprint mechanical framework which accommodates the descent propulsion system and a minimal set of avionics. The low profile of the pallet and the large scale of the Rover precludes the need ramps to allow rover egress. The basic principal of the pallet is that a lightweight semirigid central core takes the brunt of the primary impact, and in doing so is allowed to sustain irreversible but controlled damage. The rover is suspended above the core on 6 crushable shock struts. A reasonable analogy is that of a passenger car which sacrifices the vehicles integrity in order to protect the occupant (payload). As such, most of the pallet mechanical system is designed only to the levels required to ensure a safe stable landing even though large portions of the structure may be damaged during the landing. To prevent tipover, 6 outriggers are extended horizontally from the cetral core and are stabilized by tension only cables. This combination provides an extremely lightweight tension-compression outrigger system that is used for tipover stabilization but not primary touchdown impact mitigation.

The second concept developed by the tiger team is an airbag concept based on Mars Pathfinder heratige. In this concept an airbag system is wrapped directly around the large rover without the use of an exoskeletal frame such as the Pathfinder tetrahedron. Without the aid of this frame to self-right the rover after touchdown, a soft-goods concept was defined to ensure that the rover would be capable of self righting itself after a random touchdown and rollout. In order to maximize Pathfinder heratige, lobe diameter and inflation pressures were kept the same. The resuling airbag configuration coupled with a liquid propelled descent stage is capable of surviving landings on the required terrains .

The terrain requirements set forth for the tiger team were based on the work done in reference [1]. This study defined 3 representative terrains models described as lightly, moderately and heavily cratered terrains. The models generated combinations of slope, rock size and rock abundance. The program extrapolated from this study that lightly cratered terrains were the most viable landing sites for near term exploration. The touchdown requirement that stemmed from this report represented a 97% worst case. It was a continuum bounded by a 1 meter high rock (2 meter diameter half buried) on a zero degree slope, up to a .5 meter high rock on a 30 degree slope.

Using ADAMS dynamic simulation software, a high fidelity model of the pallet lander has been generated. The airbag system has also been modeled using a gas-bag simulation code developed for Pathfinder. Based on results from these both systems are capable of safe landings on a 30 degree slope with a 1 meter high rock (this excedes the requirement) and touchdown velocities with very large margins.

The team is currently designing a 3/8 test models of the pallet lander and airbag rollover system. The models will be used to validate the concepts to allow the team to make a quantified assesment of which concepet to carry forward into full scale development.

References:

[1] Doug Bernard and Matt Golombek, Preliminary Look at Hazard Models for Mars Landing, JPL IOM 3412-00-020, March 2, 2000.

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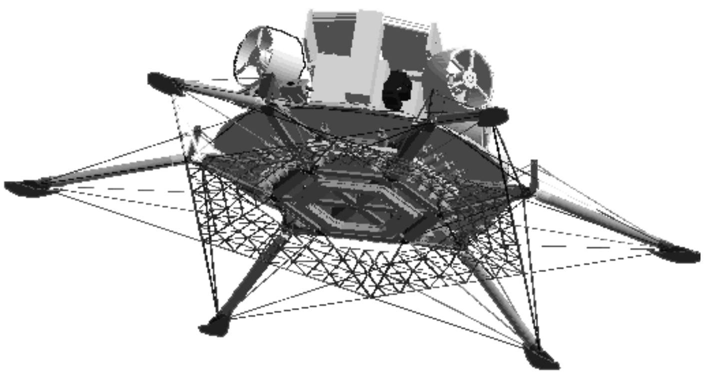

Figure 1: Bottom isometric view of pallet lander.

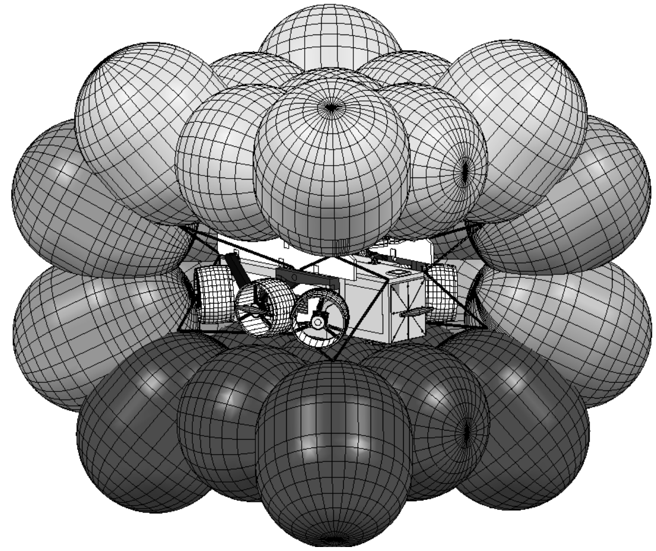

Figure 2: Isometric view of airbag landing system (2 bags removed for clarity).

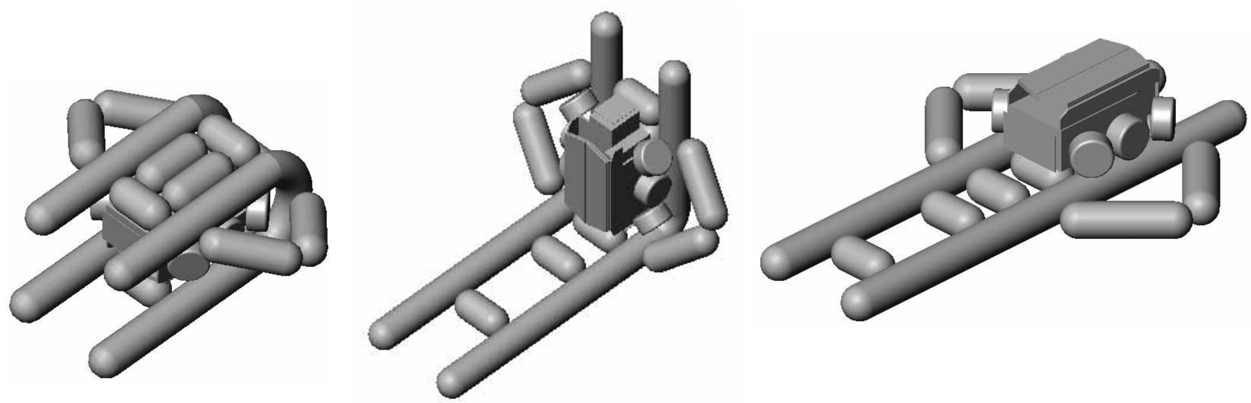

Figure 3: Inflatable self-righting system for the airbag lander (deflated impact bags not shown for clarity).

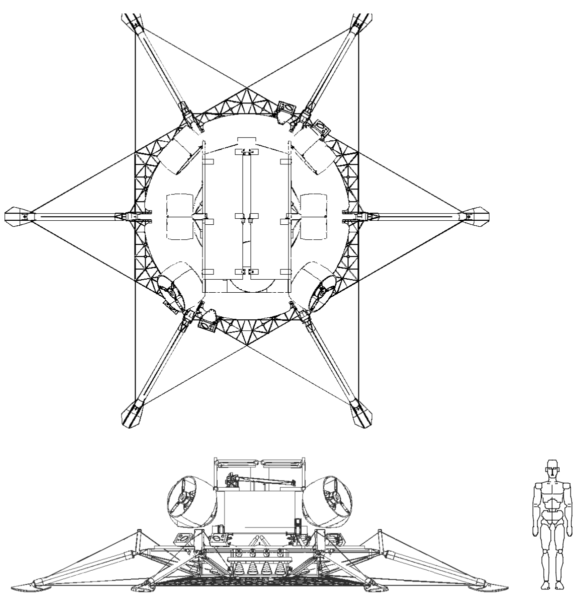

Figure 4: Top and front view of pallet lander.

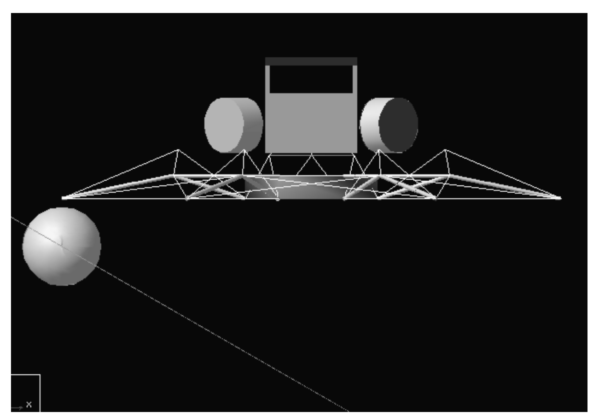

Figure 5: ADAMS simulation of pallet lander on a 30 degree slope with a 2 meter diameter rock half buried.