PENETRATORS ARE NOT A PANACEA : A CRITICAL REVIEW AND REMARKS ON APPLICATION TO THE OUTER SOLAR SYSTEM

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ABSTRACT

Penetrators have been advocated as exploration vehicles for a number of targets, most recently the Galilean satellites in connection with the NASA/ESA Europa-Jupiter System Mission. I briefly review the development and flight history of penetrating vehicles in military and planetary applications (the Tallboy 'earthquake bomb' of WWII, the Vietnam 'Igloo White' air-dropped seismic sensor network and more recent military systems ; the CRAF penetrator ; Mars-96 ; DS-2 [the only vehicles that reached their planetary target] and Lunar-A).

It is noted that penetrators offer modest improvements in seismic vs. wind coupling at Mars, and a more benign thermal environment at the Moon, and may facilitate subsurface sample acquisition in all locations. However, these advantages are modest compared with the challenges in assuring successful deployment, sample acquisition and communication. Furthermore, the burial of the vehicle (obviating conventional thermal control via radiative coatings) introduces severe thermal challenges, especially in polar environments or on outer solar system satellites. I show that heat flow measurements from penetrators are likely to require careful interpretation, and that advantages of burial on airless worlds for seismic measurements are modest.

It is furthermore noted that while at Mars the atmosphere provides both deceleration (from orbital or interplanetary speeds of several km/s to a tolerable impact speed of 50-250 m/s) and stabilization (to point the long axis of the vehicle close to its velocity vector, needed for successful penetration), at large satellites such as the moon or Ganymede, these functions must be provided by propulsion and guidance systems which must decelerate, then rotate, the vehicle. Once these systems are accounted for, the claimed advantages of penetrators are illusory – all that the penetrator vehicle does is provide the last 200 m/s of Delta-V, out of a much larger total (> 1 km/s). This provision seems not worth the price of the thermal challenges, impact shock qualification requirements and sensitivity to an uncertain terrain.

Critical consideration suggests that instead, cost-effective and robust delivery to the surface of large icy satellites may best follow the early Lunar program, wherein a propulsion system delivers a semi-hard lander to within a few tens of meters and speeds of 10-20 m/s of the surface. The original Ranger capsules, and the successful Luna-9 capsule (which sent back the first pictures from the surface of another celestial body), are useful prototypes.

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