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SPACE SYSTEMS SYMPOSIUM (D1)
Innovative and Visionary Space Systems Concepts (1)

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HIGH PRECISION PENETRATORS FOR EUROPA

Abstract

There are targets for penetrators in the solar system where the location to be sampled lies in a concentrated area, and a certain shallow depth under the surface. Such targets include, among others, water ice within permanently shadowed regions of the Moon (cold traps), the gully features observed on the surface of Mars, and terrain features in Europa marking possible recent transport of ocean material to the surface. Particularly in the case of Europa, there are various interesting geological characteristics. Chaotic terrain, lenticulae, and smooth plains form above water lenses at a depth of 3 km. Impact craters are geologically recent features that could have potentially resulted in the transport of material from the ocean to the surface. Linear tectonic features might represent regions of material exchange between the surface, ice shell, and ocean. These interesting features range in size, from 10 km to under 1 km. Due to severe chemical degradation from the radiation environment, samples acquired from the very surface will not compositionally represent the ocean. Planetary penetrators would thus be ideal for subsurface sampling of these interesting areas. Penetrators proposed up to now however have a landing accuracy in the order of 20 km and therefore do not satisfy the accuracy requirements to reach the above interesting areas.

In this paper we investigate the accuracy requirements for a penetrator design able to reach these areas. Focusing on guidance, navigation, and trajectory control, we start by assessing the accuracy achievable by current penetrator designs. We then work from there to derive the requirements for increasingly accurate penetrators, with landing ellipses from 10 km to under 1 km. We take into consideration disturbing forces and sources of navigation uncertainty, both inherent to the system (e.g. sensor biases, actuator disturbances) as well as environmental (e.g. gravitational field uncertainties). Finally, we investigate the cost-to-benefit ratio of the generated penetrator designs, and compare it to that of the current low-cost, high-risk penetrator designs.