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CAPTURING AND DOCKING SPACECRAFT WITH FLUX PINNED INTERFACES

Abstract

Capturing a cached orbiting sample (OS) far from Earth is a delicate rendezvous maneuver with high-stake planetary protection implications that must nevertheless be properly executed in order to enable the significant scientific gains offered by sample return missions. The success of this maneuver will rely on autonomous technologies that can robustly close the distance and orient the OS relative to the sample return orbiter. Most sample capture techniques rely on complex control systems or mechanical capture systems. This paper instead looks at flux-pinned interface (FPI) technology, which leverages magnet-superconductor physics to offer a unique set of advantages for sample capture applications. FPIs generate a contactless, compliant connection between spacecraft which can passively orient the system to a preferred relative attitude, correct for misalignments, and reduce the risk of collision. Because this capture system works using a magnetic potential well, there are bounds on both the energy and relative cone over which the technology will generate a passive, non-contacting capture of the OS. It is essential to establish these bounds in order to assess the range, relative velocity, and alignment errors the sample return orbiter and OS must achieve to successfully engage the FPI.

This paper describes a set of air-bearing experiments and simulations designed to characterize the dynamics of an OS capture by an FPI and determine the bounds over which the interface will generate a successful capture. The experiments were performed with an OS analogue on a 4 degree-of-freedom planar air bearing carriage. This unit was flux pinned to a stationary sample return orbiter analogue, and data was collected over a variety of different capture scenarios, especially over variations in the magnitude of incoming velocity. The simulation models the physics of both the testbed and an on-orbit system and is used to extend these empirical results to a flight FPI. It was determined that slower on-axis velocities (3.5 cm/s) nearly guaranteed capture, but velocities above 6 cm/s did not consistently capture. The experiments also show a sensitivity to variation in the number of degrees of freedom, which suggests a microgravity flight may be a better testing environment.The simulation shows that the existing models of flux pinning physics over-predict the performance of the capture system and need to be modified to take into account various system limitations. The paper concludes with the implications of this research for sample capture applications and paths for future technology development.