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AIRBORNE SIMULATION OF LAUNCH VEHICLE DYNAMICS

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In this paper we present a technique for approximating the short-period dynamics of an exploration-class launch vehicle during flight test with a high-performance surrogate aircraft in relatively benign endoatmospheric flight conditions. The surrogate vehicle relies upon a nonlinear dynamic inversion scheme with proportional-integral feedback to drive a subset of the aircraft states into coincidence with the states of a time-varying reference model that simulates the unstable rigid body dynamics, servodynamics, and parasitic elastic and sloshing dynamics of the launch vehicle. The surrogate aircraft flies a constant pitch rate trajectory to approximate the boost phase gravity-turn ascent, and the aircraft's closed-loop bandwidth is sufficient to simulate the launch vehicle's fundamental lateral bending and sloshing modes by exciting the rigid body dynamics of the aircraft. A novel control allocation scheme is employed to utilize the aircraft's relatively fast control effectors in inducing various failure modes for the purposes of evaluating control system performance. Sufficient dynamic similarity is achieved such that the control system under evaluation is optimized for the full-scale vehicle with no changes to its parameters, and pilot-control system interaction studies can be performed to characterize the effects of guidance takeover during boost. High-fidelity simulation and flight test results are presented that demonstrate the efficacy of the design in simulating the Space Launch System (SLS) launch vehicle dynamics using NASA Dryden Flight Research Center's Full-scale Advanced Systems Testbed (FAST), a modified F/A-18 airplane, over a range of scenarios designed to stress the SLS's adaptive augmenting control (AAC) algorithm.

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