The aerodynamic sabot discard process is crucial to the success of hypervelocity testing using less than ideal projectile launch properties or sub-caliber projectiles in smooth bore launchers. Achieving efficient sabot separation is integral to both reaching extreme velocities and capturing distinguishable impact phenomena during testing. In this paper, the conical-cup discard technique is investigated for four-petal sabot packages carrying 2-8 mm diameter spherical projectiles launched with the state-of-the-art 2-stage light gas gun located in the Texas A&M University Hypervelocity Impact Laboratory. Empirical models relating both environmental and launch parameters to the degree of sabot separation at a fixed distance from the muzzle are developed. Image processing techniques are employed to convert images of sabot petal impacts to coordinate entities. The degree of separation for each entity is then characterized by the distance travelled in the radial direction away from the axis of penetration. Simulations using computational fluid dynamics (CFD) code are conducted to model the discard motion during projectile flight. The present models show close agreement with the computational results, validating the accuracy of the simulation software in predicting separation in the HVI Lab’s 2-stage light gas gun. Computational agreement promotes streamlined sabot design for various new payloads, such as penetrators.