Stability Statistics: The Effect of Incremental Stability Deviations on Rocket Flight Optimization and Precision

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NASA has pioneered space exploration by paying exceptional attention to stability and precision. This experiment evaluates how the distance between the Center of Gravity and Center of Pressure affects the average and standard deviation of altitudes and flight times. This investigation analyzes six distances: 0 calibers, 0.5 calibers, 1 caliber, 1.5 calibers, 2.0 calibers, and 2.5 calibers (independent variable) and how they respectively impact the altitude and flight time achieved by model rockets (dependent variable). It was hypothesized that if the distance between the center of gravity and center of pressure within a rocket increasingly deviates beyond one caliber, then the precision of the rocket's altitude and flight time, as well as the actual altitude and flight time, will progressively decrease because an imbalance among the forces acting on the rocket cause instability, which will increase the standard deviation of the sample simulation values. OpenRocket was used to perform this experiment, with additional real launches done to verify simulation results. This simulator allowed for isolation of variables, creating a more controlled environment as opposed to physical launches. The rockets were based on previously designed models, which ensures viable architecture of rocket designs. The independent variable was manipulated through the location of mass components that change the distance between the CP and CG, yet maintain the same aerodynamic characteristics. The analysis of the resultant data from OpenRocket shows a difference with both the average altitude achieved and standard deviation. These results can be applied to aerospace studies in the future of space exploration.