SPACE SYSTEMS SYMPOSIUM (D1)
System Engineering Tools, Processes & Training (I) (3)

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LAUNCH VEHICLES SEPARATION DYNAMICS AN END-TO-END SOLUTION

Abstract

To attain the best performance, launch vehicles are often designed to discard the spent stages. For a successful mission, the separations must occur as per the predicted sequence of events with minimum changes in the attitude and tip-off errors of the continuing stage. There must be no re-contact, no shock transmission and no flying debris between the separating bodies. A separation mechanism, which does not meet these requirements, can produce attitude errors and tumbling rates to the continuing body, that are too large for its attitude control system to operate on, can damage its structure and critical instrument and can cause failure or degradation of the mission. In designing separation mechanisms following factors must be considered: adequate clearance between the separating bodies, minimum shock transmission to the payload or structure, less damage or contamination of the continuing stage by debris and the ability of the mechanism to withstand the natural and induced environments encountered during its service. Appropriate severance and jettisoning mechanisms are employed depending upon the stage inert mass and tip off rates specification. Selection and design of suitable separation mechanisms for a launch vehicle needs mathematical modelling and simulation. The state vectors of the separating bodies (viz., burnt out stage and functional stage) are evaluated through integration of the governing equations of motion in the body frame. Each individual body has twelve state variables (namely three displacement of point fixed in the body, three orientation angles, three components of velocity vector and three components of angular velocity vector). Critical points on separating bodies and the relative distance between these points, velocity, attitude angles and attitude rates of the bodies are the basic input to examine the occurrence of collision. The traces of the points together with body attitude angles are used to predict contact free separation and build-up of tip off errors on the ongoing stage. Perturbation studies were attempted where ever required to account for the various off-nominal dynamic parameters. In this manuscript, the state-of-the art tool developed based on object oriented methodology and the test cases analyzed for strapon motors lateral separation in the dense atmosphere, stage pull out from a functional stage, spacecraft separation in the vacuum and reentry vehicle separations are addressed. It is observed from the studies that the predicted results are in very close match with flight observed results. This implies the accuracy of mathematical model developed.