# EXPERIMENTAL AND ANALYTICAL TECHNIQUES FOR EXTRACTING THE AERODYNAMIC DAMPING-IN-PITCH PARAMETER FOR ORBITAL RE-ENTRY VEHICLES

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Oscillatory motion is a dynamic phenomenon experienced by space capsules upon re-entry to the earth's atmosphere. Proper characterization of aerodynamic damping for stability evaluation can allow drogue chute deployment at lower Mach number. Such findings may permit smaller drogue chute designs, thus enabling a payload volume and weight increase as well as a vast decrease in drag penalties.

Aerodynamic damping is investigated in the subsonic, transonic and supersonic flight regimes for the Apollo and Expert orbital re-entry vehicles by inducing forced oscillations on models. Oscillations are induced to match reduced frequencies of flight vehicles based on natural frequency. These frequencies are determined by performing static moment measurements. Processing methods are developed to evaluate aerodynamic damping. In conjunction with this, methods are explored for previously obtained free-to-tumble test results. It was found for free-to-tumble test results that aerodynamic damping is most accurately predicted using an outer-extremity envelope distribution, which assumes a constant damping from one peak of pitch attitude to the next. The most accurate prediction for the forced oscillation methods surveyed was found using energy conservation based on hysteresis loops of pitching moment against pitch attitude.

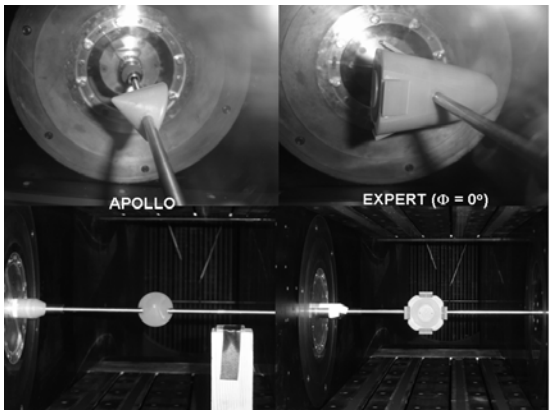


*Figure 1: Model installation in the VKI-S1 supersonic-transonic wind tunnel*

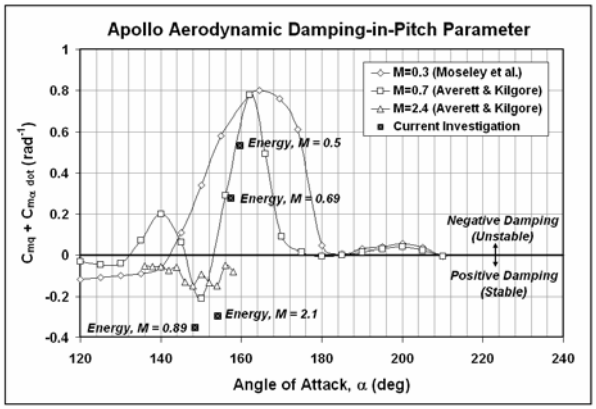


*Figure 2: Forced oscillation damping results using hysteresis loops for Apollo compared with published data*