ABSTRACT

Store separation may be defined as the process in which an aircraft's stored payload, carried externally on the aircraft body, or internally within a bay, is released from a parent aircraft. The term store usually implies weapon systems but can also include fuel tanks, countermeasures, and secondary aircraft. For bomber-class and stealth fighter-class aircraft, internal carriage of stores is strictly necessary to achieve sufficient carrying capacity, decrease aerodynamic drag, and/or reduce radar cross-section.

The fundamental issue encountered during internal store separations is the aerodynamic interactions between the store and the highly unsteady flowfield of the aircraft bay. Such flowfields are often characterized by an intense, flow-induced resonance caused by coupling between the separated flow grazing the bay and acoustic waves propagating away from the rear wall of the bay. At supersonic speeds, up to about Mach 4, many studies have demonstrated that the strength of this aeroacoustic resonance is striking for uncontrolled, canonical cavity models of aircraft bays. The resonance can be powerful enough to fatigue structures within the bay, including stores fixed in a carriage position and supporting pylons, damage mission-critical electronics onboard internally carried stores, and even give rise to unexpected trajectories of released stores. These issues can have extremely dangerous consequences but are not completely understood due to the complexity of the resonance process. The recent trend towards fielding hypersonic aerospace vehicles has highlighted additional deficiencies in the current understanding, with very limited investigations being conducted at hypersonic speeds. Furthermore, few studies have investigated more complex aircraft bay configurations that support multiple stores, despite such an arrangement being standard in the majority of modern tactical aircraft. Therefore, there is a need for further investigation into high-speed store separations from aircraft bays that are designed to carry multiple stores.

The objective of this dissertation is to further the understanding of the carriage and release of stores from an aircraft bay at supersonic and hypersonic speeds using a relevant bay configuration involving multiple stores. The rectangular cavity model used is analogous to any specific aircraft bay geometry to isolate the effects of carrying and releasing multiple stores. Two identical store models may be installed in the cavity side-by-side to obtain a representative multi-body bay configuration. These stores are generic in design, with a tangent-ogive nosecone, cruciform fins, and a boat tail. Wind tunnel tests are conducted at nominal freestream Mach numbers of 2, 3, 4, and

5, and numerous experimental diagnostic techniques are employed to understand the associated flow physics. Measurements of the boundary layer approaching the cavity model are presented first, as several studies have revealed the sensitivity of the cavity mean flow and resonance to the boundary layer properties. A description of the cavity flowfield topology follows, using the qualitative flow visualization methods of shadowgraphy and surface oil flow visualization. The steady and unsteady pressure distributions within the cavity and on the stores are then presented, which were measured using both discrete transducers and pressure-sensitive paint (PSP). An extensive aerodynamic database of forces and moments is then built with 6DOF force balance measurements, which captures the effects of the store in the cavity, passing through the shear and shock layers, and in free flight outside of the influence of the cavity flow. Subsequently, the fundamentals of flight dynamics and the aerodynamic database are applied to simulate six-degree-of-freedom (6DOF) store separation trajectories. Finally, experimental store separation trajectories are obtained from high-speed recordings of free drop tests and the results are compared with simulation results.

The baseline results for the empty cavity echo the findings of many other studies incorporating similar cavity geometry and flow conditions. The signature of the cavity resonance is observed, consisting of noise levels exceeding 160 dB and large-amplitude tones in the pressure spectra that are predicted reasonably well by models in the literature. The surface oil flow visualization results of the baseline cavity mirror those of similar studies, exhibiting the footprints of a counter-rotating vortex pair within the cavity near the upstream wall. In addition, oil flow results clearly indicate that the presence of stores near the cavity sidewalls can involve significant interactions with the sidewall spillage vortices, and single-store configurations give rise to strong asymmetry in the recirculating flow within the cavity. Results corresponding to the force and moment measurements, trajectory simulations, and dynamic drop test trajectories all conclude that asymmetries related to the off-center position of a store within the cavity lead to the generation of roll and yaw during separation. At hypersonic speeds, the unsteady pressure measurements determined that the strength of the cavity resonance is significantly diminished and, coupled with the dynamic drop test results, it is apparent that problems with adverse roll and yaw, as well as time-of-release effects, become much more benign.