for a suitably large sample so the distribution of resulting impact points will, for all practical purposes, represent all possible impact points, irrespective of the actual nature of the failure.

Depending on vehicle breakup characteristics and failure time, a vehicle that experiences a random-attitude failure may break up at the instant of failure, or after a few seconds into the turn, or not at all. In making the calculations, three separate breakup thresholds and a no-breakup case were investigated. With respect to vehicle breakup, the assumption was made that the vehicle would break up if $q\alpha$ exceeded a specified constant limit, where q is the dynamic pressure and α is the total angle of attack. Although the breakup $q\alpha$ may well be a complicated function of Mach number and other parameters, this simplistic approach was taken.

Random-attitude-failure calculations were made individually for Atlas, Delta, Titan, and LLV1 starting shortly after pitchover and continuing to some convenient time such as a stage burnout when the vehicle could no longer endanger the launch area. Theoretically, the Mode-5 impact density function extends downrange until the instantaneous impact point vanishes. Since this study is concerned with evaluation of density-function parameters for launch-area risk analysis, the random-attitude calculations were stopped at a staging event when the vehicle no longer had sufficient energy to return the impact point to the launch area. Using trajectory data for each vehicle, program RAFIP was run to generate 10,000 impact-point samples at each starting time. Calculations were made at ten-second intervals.

6.1.2 Slow-Turn Failures

Certain types of guidance and control failures can cause the thrusting engine to gimbal to null or a near-null position. Such failures can produce what is herein called a slow turn. For various reasons, after an engine is commanded to null it may not thrust precisely through the center of gravity, e.g., structural misalignments, shifting center of gravity, canted nozzles. Since, like random-attitude failures, slow turns constitute a subset of Mode-5 failure responses, they have been investigated using RTI program RAFIP. The following assumptions have been made in making the calculations:

(1) The effective thrust offset of a "nulled" engine is normally distributed with a zero mean and a standard deviation of 0.1°.

(2) A fixed thrust offset results in a constant angular acceleration of the airframe, and thus a constant angular acceleration of the thrust vector.

(3) For small thrust misalignments, the angular acceleration of the airframe is proportional to the angular thrust misalignment.

At each time point, the angular acceleration produced by small thrust offsets was estimated from the malfunction turn data provided to the safety office by the range user. Malfunction turns for the Atlas IIAS were provided for three gimbal angles, the smallest being one degree. For each gimbal angle, the results were plotted as