3. Understanding the Mode-5 Failure Response

Unlike failure response Modes 3 and 4, response Mode 5 (and also Mode 2) is not a direct function of time from launch. For Modes 3 and 4, the mean point of impact (MPI) for each debris class is fixed, once the failure time is established. At each instant there is only one possible location for the MPI for each debris class. On the other hand, the Mode-5 impact-density function for each debris class consists of a primary part and a secondary superimposed part. The primary impact-density function accounts for impact variability due to the erratic flight of the vehicle. It is used to determine the probability that the mean piece in a debris class resulting from vehicle breakup falls in a given area (say on a building or open field). The secondary density function accounts for debris dispersion due to vehicle breakup and to aerodynamic effects during free fall. It is used to determine the probability that fragments from the class actually hit a building or field. In other words, the primary impact-density function is used to compute the probability that the secondary function is centered in some specified area; the secondary function, which describes the distribution of class pieces about the mean point, is then used to compute the probability that one or more class pieces impacts on the specified population center or area.

The primary part of the Mode-5 impact density function, which was presented as Eq. (9.5) in Ref. [1], is reproduced here as Eq. (1):

$$f(R,\phi) = \frac{Ce^{A\phi} + \dfrac{D}{R}}{2(T_B - T_P)\left[\dfrac{C}{A}\left(e^{A\pi} - 1\right) + \dfrac{D\pi}{R}\right]R\dot{R}} \qquad (1)$$

where R is the range from the launch point in miles, ϕ* is the angle in radians between the uprange direction and a line from the pad through the impact point, $\dot{R}$ is the impact-range rate in miles per second. A and C are dimensionless shaping constants, and shaping-constant D is in miles. For a Mode-5 response, there is by definition an earliest time of occurrence T_P (pitch-over time) and a latest time of occurrence T_B (burnout, orbital injection, or some other specified termination time). The specific time in this span at which a Mode-5 response manifests itself is of no consequence, although the duration of the span must be considered in assigning a probability of occurrence for a Mode-5 response.

Given that a Mode-5 response has occurred, the probability that the center of the secondary function lies in some region or on some building (population center) is determined by integrating the primary impact-density function for the class over the region or building. The primary function depends on range (R) and direction (ϕ) from the launch point to the population center, but not directly on time from launch. The primary function does,

---

* As an aid to understanding, the supplement of ϕ, designated as θ, is used in plots and tables in this report.