6. Shaping Constants Through Simulation

Since adequate test data are not available to establish the Mode-5 shaping constants empirically, other methods are needed for this purpose. It will be recalled that, after vehicle pitchover, any malfunction with the potential to cause a substantial deviation from the intended flight line is, by definition, a Mode-5 failure response. The malfunction need not actually cause a large deviation to be classified as a Mode-5 response. One such class of failures leading to a Mode-5 response has been termed a random-attitude failure. Such responses can result from guidance and control failures that lead to erroneous orientation of the guidance platform or an erroneous spatial target. Another class of failures that can cause sustained deviation away from the flight line is the slow turn, where the engine nozzle, in effect, locks in some fixed position, generally but not necessarily near null. Both types of malfunctions have been investigated in an attempt to estimate numerical values for Mode-5 shaping constants A and B. Basically, the idea is to (1) run a large sample of random-attitude and slow-turn failures, (2) calculate the percentages of impacts in five-degree sectors from 0° to 180°, (3) compare these percentages with those obtained from the Mode-5 impact density function when specific values are assigned to A and B, and (4) assign values to A and B until the best possible fit is obtained between the simulated-turn impacts and the theoretical Mode-5 impacts.

6.1 Malfunction Turn Simulations

6.1.1 Random-Attitude Failures

A guidance and control failure leading to a fixed erroneous direction of thrust is termed a random-attitude failure. Such failures represent a subset of possible Mode-5 failure responses. Random-attitude failures can be used to establish the maximum possible region of impact, given that a vehicle has flown normally for a specified period of time. For this purpose RTI has developed a Random-Attitude Failure Impact Point (RAFIP) program written in Fortran (3900 lines of code) for execution on a personal computer.

Using a Monte Carlo approach, program RAFIP first selects a starting time and then a random thrust direction on the attitude sphere, with all directions having the same chance of being chosen. Each Monte-Carlo run is begun using the nominal vehicle position and velocity at the selected start time, assuming an instantaneous change in thrust direction. Thrust is applied continuously in the selected random direction, and the equations of motion are numerically integrated until one of four conditions is satisfied: (1) final stage burnout occurs, (2) the vehicle impacts while thrusting, (3) orbital insertion occurs, (4) the vehicle breaks up due to aerodynamic forces

For conditions (1) and (4), the trajectory is extended to impact using Kepler's equations. For condition (3), an impact point does not exist. The process just described is repeated