1. Introduction

The debris from most launch vehicles that fail catastrophically tend to impact close to the intended flight line. Typical failures that produce such results are premature thrust termination, stage ignition failure, tank rupture or explosion, or rapid out-of-control tumble. Less likely malfunctions may cause a vehicle to execute a sustained turn away from the flight line. Examples are control failures that cause the rocket engine to lock in a fixed position near null, or failures leading to erroneous orientation of the guidance platform. Such failures should not be ignored, since they may produce nearly all or a significant part of the risks to population centers that are more than a mile or so uprange or many miles away from the flight line. Consequently, RTI has been tasked to estimate the probabilities of occurrence of these less-likely failures, and to determine optimum values for the shaping constants of the associated impact-density function.

RTI has developed a prototype risk-analysis program (1) to analyze the level of risk in the launch area when ballistic missiles and space vehicles are launched, and (2) to provide guidelines for launch operations and launch-area risk management. This program, "facility DAMage and Personnel injury" (DAMP), uses information about the launch vehicle, its trajectory and failure responses, and facilities and populations in the launch area to estimate hit probabilities and casualty expectations. When a missile or space vehicle malfunctions, people and facilities may be subjected to significant risks from falling inert debris, or from overpressures and secondary debris produced by a stage, component, or large propellant chunk that explodes on impact. Although fire, toxic materials, and radiation may also subject personnel to significant danger, these hazards are not addressed in program DAMP. Hazards are greatest in the launch area and along the intended flight line, but lesser hazards exist throughout the area inside the impact limit lines. Small hazards exist even outside these lines if the flight termination system fails or other unlikely events occur.

In computing launch-area risks, DAMP makes no attempt to model vehicle failures per se. A list of possible failures for any vehicle would be extensive, and variations in failures from vehicle to vehicle would complicate the modeling process. Instead, DAMP models failure *responses*. Regardless of the exact nature of the failures that can occur, there are only six possible response modes that affect risks on the ground, five for failure responses, and one to model the behavior of a normal vehicle. The six modes are described in Appendix A. It can be seen from the descriptions that impacts resulting from failure-response Modes 1, 2, and 3 occur at most a mile or two from the launch point, while those from Mode 4 can only occur near the flight line, even though the vehicle may tumble before breakup or destruct. Although the hazards outside the launch area and away from the flight line may be small, vehicle flight tests through the years have demonstrated that finite hazards do exist in these areas. Such hazards are due almost entirely to Mode-5 failure responses, even through the probability of a Mode-5 failure may be only a small part of the total failure probability. The Mode-5 failure-response, theoretical though it is, was developed to reflect the facts that: (1) unlikely vehicle failures