# Prediction of the Probability of an Event by the Comparative Experience Method

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## Abstract

This paper describes the Comparative Experience Method used to estimate the probability of an event, $P_e$. This method can be employed to facilitate the initial safety reviews of proposed flight scenarios during the early design stages of a launch vehicle when limited reliability analyses or empirical data exist to support more rigorous predictions of $P_e$. The authors present a detailed description of the seven steps of the Comparative Experience Method and cite how this method was used to predict $P_e$ for a NASA reusable launch vehicle.

## Introduction

One of the most challenging analytical decisions facing safety professionals in this country involves the assessment of the predicted failure rates for a new launch vehicle at one of our National Ranges. Malfunction events are analyzed and the probability of these events ($P_e$) becomes a very important parameter, which can directly affect the acceptability of a given launch or system, and the safety of the public. The selection of $P_e$ can become technically challenging and politically contentious. Although failures can occur at any time (and Murphy's Law has shown many times that they do), the state of the art in launch vehicle design is ever improving. To presume a failure with a probability of $P_e = 1$ at every worst-case point along a planned flight is overly pessimistic. Moreover, as our launch industry moves from an era where the government sponsored all launches to one where our industry must compete internationally, it becomes an imposing burden to demonstrate extremely high reliability rates before launch. This paper identifies several proven methods used to determine $P_e$ and then describes the Comparative Experience Method, another approach for predicting failure rates for new systems at national or commercial ranges.

## Background

Range facilities around the world use a variety of methods to provide for the safety of the public. These methods can be grouped into two general categories. The first is commonly called *containment*, where a launch is conducted from such a remote location that there are no people nearby to be hazarded. Potential hazard areas are defined and monitored to assure that people don't stray into the area at the time of launch. This approach provides for positive protection, and it is feasible as long as there is sufficient area under control. The second method is a *quantitative risk assessment* (QRA) that is used when there is insufficient area to contain the potential hazard. The QRA estimates the overall risk to the surrounding population. It is in the conduct of this risk assessment that the prediction of failure rates becomes important. Safety professionals at our National Ranges use an 8-step QRA process as documented in the RCC Commonality Standard 321 (ref. 1). Steps 2 and 3 of this process identify potential malfunctions and estimate their probability of occurrence, $P_e$. Subsequent steps define the hazard and risk that results from these malfunctions, but are not the subject of this paper.

## Methods to Determine Probability of Event

In determining probability of undesired events for launches at National Ranges, safety professionals have traditionally used one of three methods that may be identified as the conservative method, mathematical predictions method, or the flight experience method.

Conservative Method: The most conservative method is to use a probability of $P_e = 1$ for all critical failures. This worst-case, time-honored approach precludes debate about reliability and is the clearest path to positive protection. While keeping with the containment philosophy, it never underestimates $P_e$ and helps safety professionals achieve their goal of minimizing risk. This method is always a good choice from a purely safety perspective; however, it results in unreasonably large hazard areas.

Mathematical Predictions: Another commonly used method to determine $P_e$ is to use reliability


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