This paper describes a methodology to determine probabilities of occurrence of seismically initiated event sequences, considering event occurrence probabilities and performance of structures, systems, and components (SSCs). The methodology can be used to assess safety of the pre-closure facility for the seismic hazard at the proposed geologic repository at Yucca Mountain, Nevada, and to demonstrate compliance with the risk-informed, performance-based regulations in the U.S. Code of Federal Regulations, Title 10, Part 63. The probability of occurrence of an event sequence leading to an SSC failure is determined by convolution of the seismic hazard curve with the conditional failure probabilities (i.e. fragility) of the SSCs. The methodology is illustrated using examples of potential event sequences. The methodology described in the paper shows how the safety of a facility during a seismic event can be determined using the performance-based regulations. The scope of the paper is limited to estimating the probabilities of occurrence of potential event sequences leading to failure of SSCs and potential release of radioactivity; it does not discuss dose or risk estimates.