Appendix E

Event Tree Analysis (ETA)

E.1 Introduction

An event tree is a logical diagram which displays possible event sequences following a specified critical event in a system. An event tree analysis (ETA) is a method for systematic analysis of a system after a critical event has occurred. The result of an ETA is a list of possible event sequences that follows the initiating event. The critical, initiating event may be a technical failure or some human error. In the development of the event sequences, the effects of possible barriers and safety functions, which are designed to prevent the occurrence of the critical event or reduce the consequences of this event, are taken into account. The analysis is both qualitative and quantitative. The qualitative content is primarily a visualisation of different scenarios (the event tree) with corresponding end consequences, while the quantitative analysis gives frequencies for the different end consequences. Figure **??** shows an ETA example. The initial event could be for example SPAD = Signal passed at danger (obtained from for example an FTA), and then the various barriers are shown as B_1, B_2 etc. Each barrier has a Y=Yes output and a N=No output.

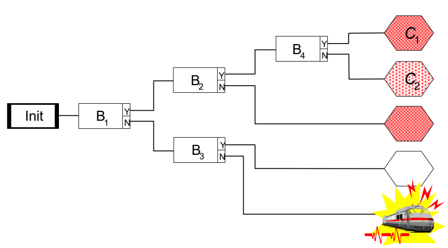

Figure E.1: ETA example

E.2 Procedure

The event tree analysis is usually carried out in six steps:

1. Identification of a relevant initiating event (which may give rise to unwanted consequences).
2. Identification of the barriers and safety functions which are designed to prevent the occurrence of the initiating event, or to reduce the consequences of this event.
3. Construction of the event tree.
4. Description of the resulting event sequences.
5. Calculation of probabilities/frequencies for the identified consequences.
6. Compilation and presentation of the results from the analysis.

E.3 Identification of a relevant initiating event

As for the fault tree it is important to define an unambiguous initiating event, use the “what”, “where” and “when” keywords to structure the definition of the initiating event. How early in the course of event the initiating event should be placed depends on the scope and available resources for the analysis. As a starting rule we often define the initiating event as the first significant deviation from normal operations.

E.4 Identification of the barriers and safety functions

Usually, a number of measures are taken to prevent accidents or limit their consequences These measures are referred to by different names, e.g. “barriers”, “security functions” or “protection layer” (defence in depth). The measures are modelled in the event tree. Other factors related to the physical course are also modelled, e.g.,

- Whether a leak ignites or not
- Whether the fire is large or small
- Whether it’s day or night
- and so forth

E.5 Construction of the event tree

The event tree is constructed by thinking logical sequences by answering Yes/No questions. The questions should be formulated systematically. Either one uses consistent questions where the "Yes" answer is "success", or Then the "Yes" answer is systematic failure or error in barrier/safety function The branches corresponding to "Yes" must either systematically go "upwards", or systematically go "down" in the event tree.

If we adopt the convention that the "No" branch ("barrier fails to hold") is the down-hand branch from the barrier symbol. The most severe consequences will then normally be located to bottom right corner of the consequence spectrum. Note that in some presentations "Yes" is used to describe that the barrier fails. This will then give a different interpretation of the most critical events.

If we consider a SPAD event, the first barrier, B_1, could be {Automatic train protection (ATP) OK}. When constructing the event tree the output from a barrier symbol may lead to another barrier symbol. The development is continued to the resulting consequences, illustrated by consequence symbols, C_1, C_2 etc in Figure **??**. We should aim at identifying the barriers in the sequence they are expected to be activated. In this way, there will be an implicit time line from left to right. However, in some situations this is demanding because it is not always easy to say which barriers are activated first.

E.6 Description of the resulting event sequences

The qualitative analysis of the event tree is typically to list the events leading up to the most severe end consequences, and discuss barriers and other circumstances that influence the course of events.

E.7 Calculation of probabilities/frequencies for the identified end consequences

In order to carry out the quantitative analysis we need the frequency of the initiating event, and the barrier probabilities. During construction of the event tree, we enter the probability that the various barriers fails, i.e., the "No" results. For each barrier, i, we need:

- q_i = probability that barrier i fails ("No"), and similarly
- $p_i = 1 - q_i$ probability that barrier i functions as intended ("Yes")

In addition to the barrier probabilities, we enter the frequency of the initiating event:

- f = frequency of initiating event

When establishing the barrier probabilities and the initiating frequency it might be required to perform separate analyses, e.g., FTA. Also for the barrier probabilities we usually need separate analyses like FTA for the ATP system, failure statistics and "load/strength" methods.

To calculate the frequencies of the various consequences we may multiply the frequency of the initiating event by the barrier probabilities for each barrier along the path leading to the actual consequence . Now, consider consequence C_j, and assume that S = is the set of barriers in the path leading to consequence C_j, and that represents "success" of the barrier (Yes-terminal), and further F = is the set of those barriers on the path leading to consequence C_j, and that represent "the barrier fails" (No-terminal) we have that the frequency of consequence C_j is given by:

$$F_j = f \prod_{i \in S} p_i \prod_{i \in F} q_i$$

This formula is only valid if the barriers are "independent". This is not always the case, and to overcome the problem of "stochastic" dependent barriers, we should in principle specify the barrier probabilities as conditional probabilities given the course of events up to the current barrier. This is not always easy.