POLITECNICO DI MILANO

Centre de recherche sur les Risques et les Crises

Event tree analysis

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Event Tree Analysis (ETA)

- **Systematic and quantitative**
- **Inductive**

AIM:

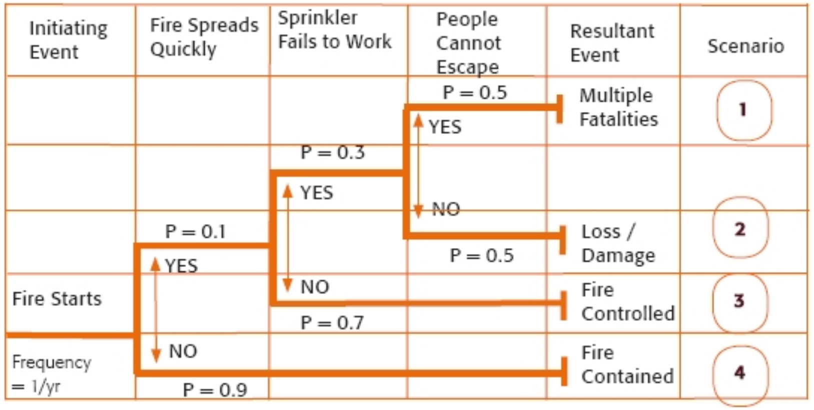
1. **Identification of possible scenarios (accident sequences), developing from a given accident initiator**
2. **Computation of accident sequence probability**

ETs typologies

- **System event tree**

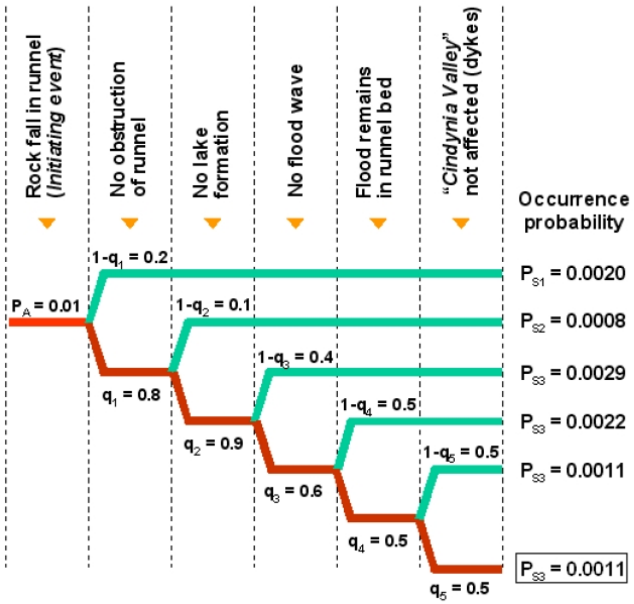
  The accident sequences **in the system/infrastructure** are identified with respect to the protection and safety systems/components involved (valves, pumps, pipes, tanks, etc.)

Quantification of Event Tree for Building Protected by Sprinkler System



- **Phenomenological event tree**

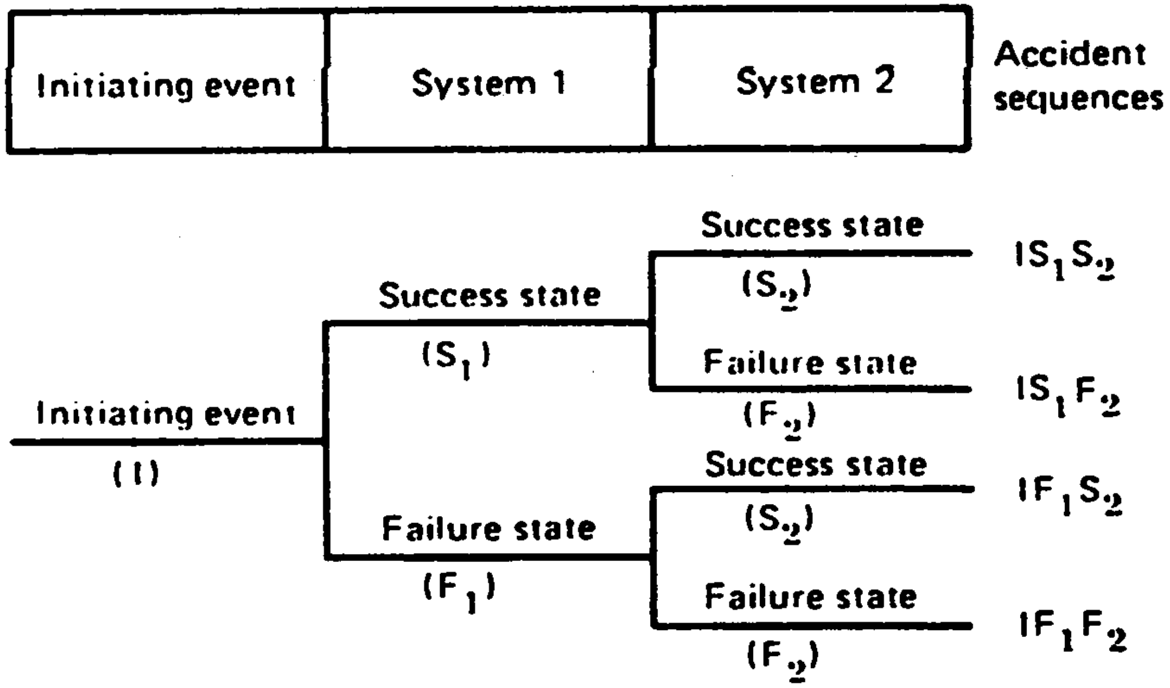
  Description of the accident phenomenological evolution **that affect the system/infrastructure** (winds, sea currents, animals/plants, etc.)



ETA: Procedure steps

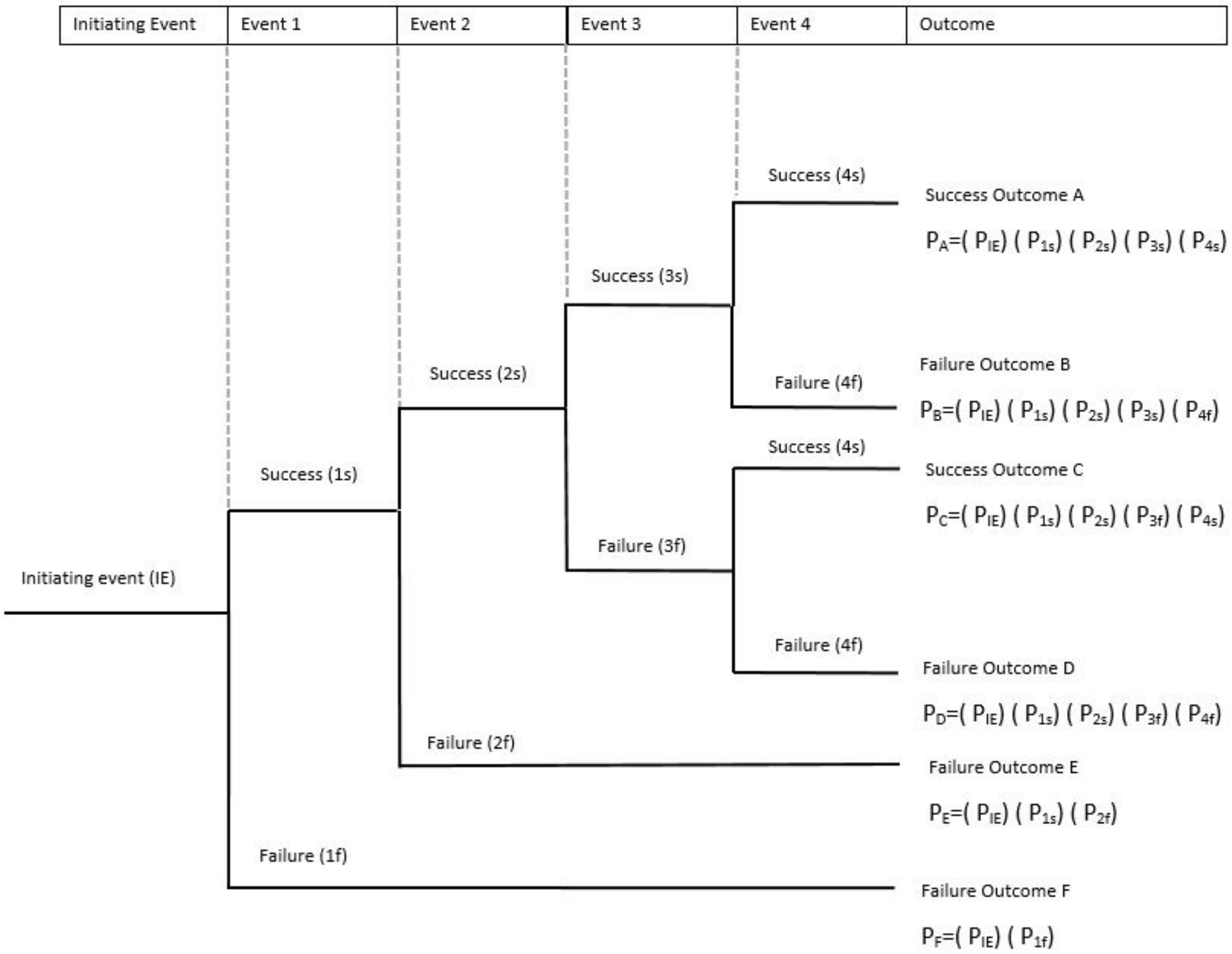
1. Define accident initiator I (system failure);
2. Identify safety/protection systems (S_k) demanded by I
3. Specify failure/success states of S_k
4. Combine the states of all S_k to generate accident sequences

Event Tree

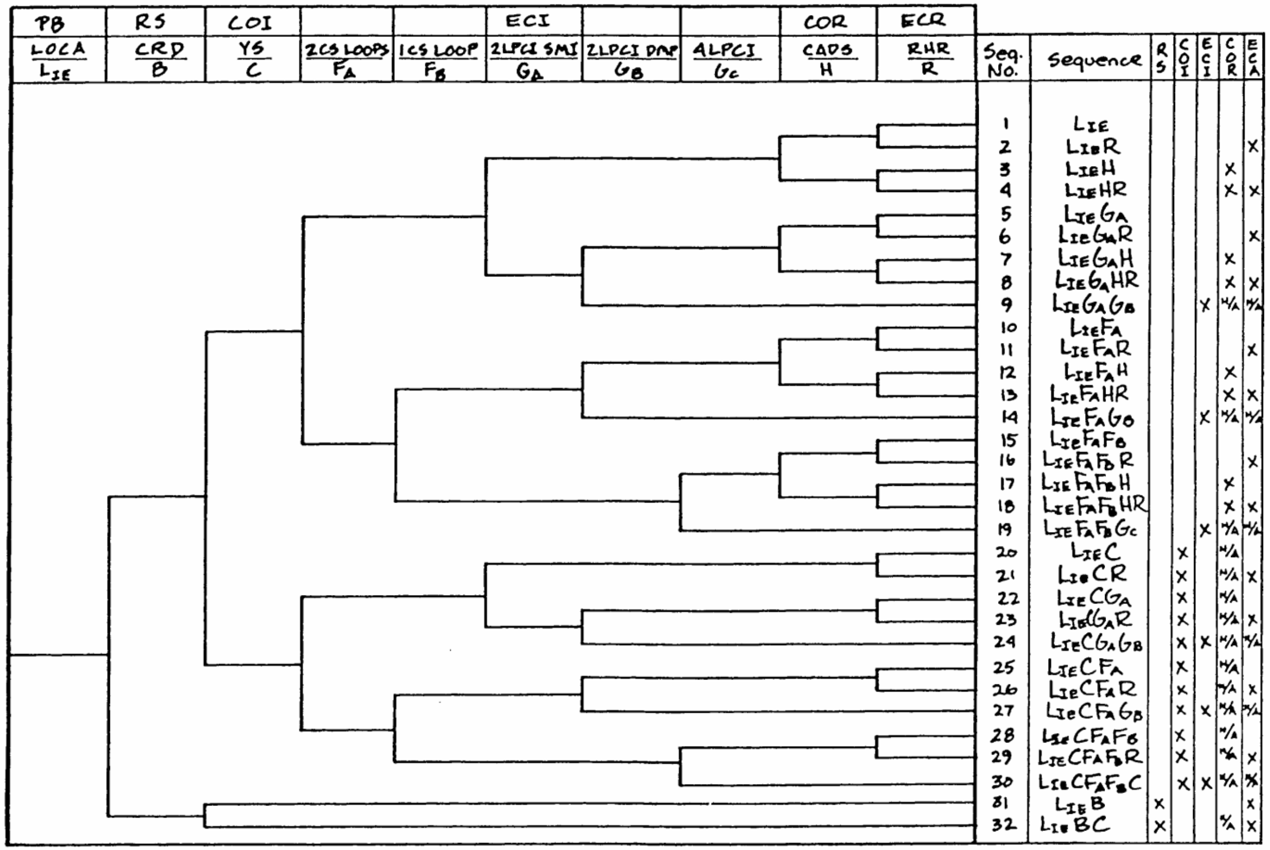


Initiating event
System 1
System 2
Accident sequences
Success state
(S2)
IS1S2
Success state
(S1)
Failure state
(F2)
IS1F2
Initiating event
(I)
Success state
(S2)
IF1S2
Failure state
(F1)
Failure state
(F2)
IF1F2

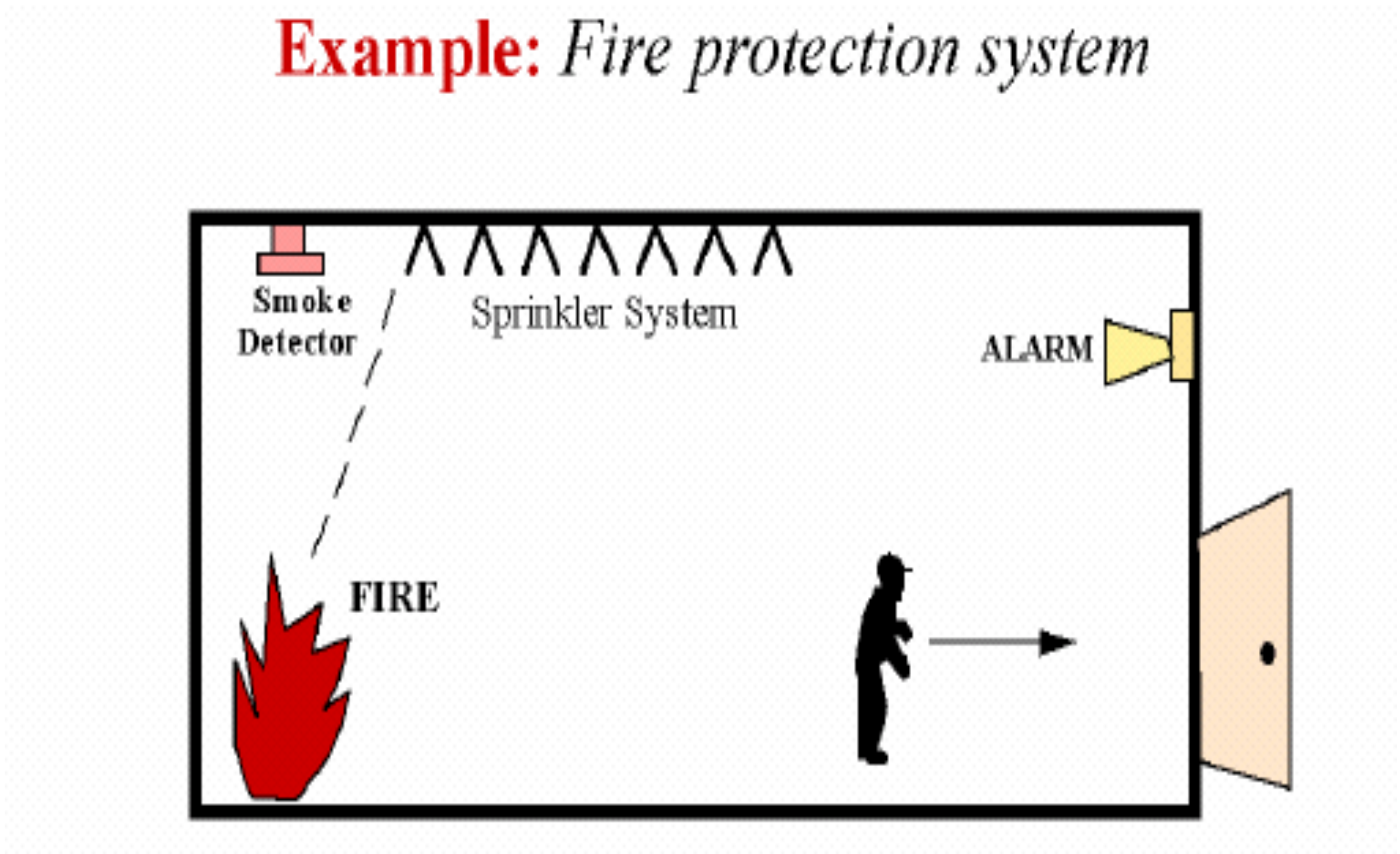
Event Tree (independent events)



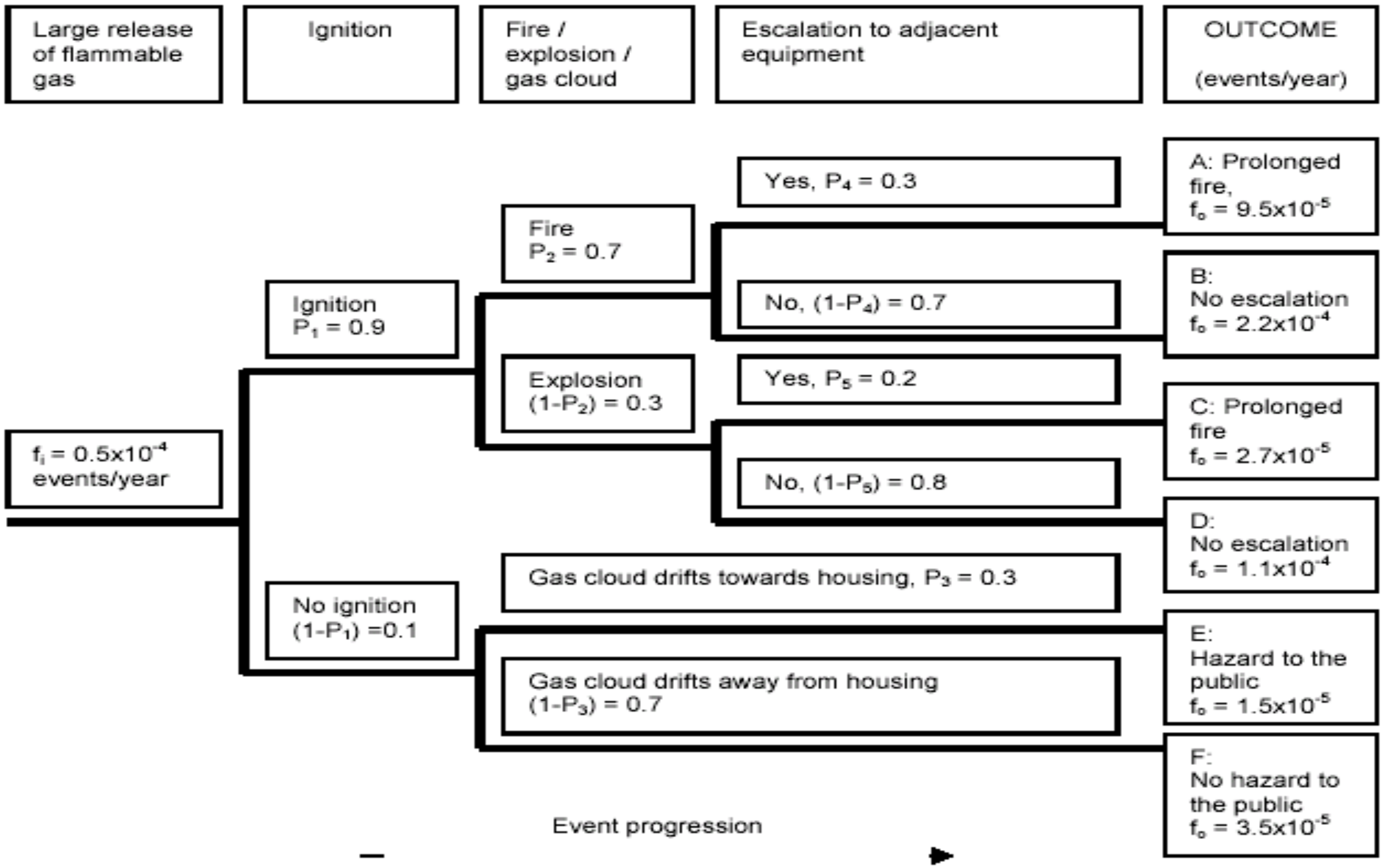
Event Tree


PB
LOCA
LIE
RS
CRD
B
COI
YS
C
2CS LOOPS
FA
1CS LOOP
FB
ECI
2LPCI SMI
GA
2LPCI DMP
GB
ALPCI
GC
COR
CADS
H
ECR
RHR
R
Seq. No.
Sequence
RS
COI
ECI
COR
ECA
1 LIE
2 LIER
3 LIEH
4 LIEHR
5 LIEGA
6 LIEGAR
7 LIEGAH
8 LIEGAHR
9 LIEGAGB
10 LIEFA
11 LIEFAR
12 LIEFAH
13 LIEFAHR
14 LIEFAGB
15 LIEFAFB
16 LIEFAFBR
17 LIEFAFBH
18 LIEFAFBHR
19 LIEFAFBGC
20 LIEC
21 LIECR
22 LIECGA
23 LIECGAR
24 LIECGAGB
25 LIECFA
26 LIECFAR
27 LIECFAGB
28 LIECFAFB
29 LIECFAFBR
30 LIECFAFBC
31 LIEB
32 LIEBC

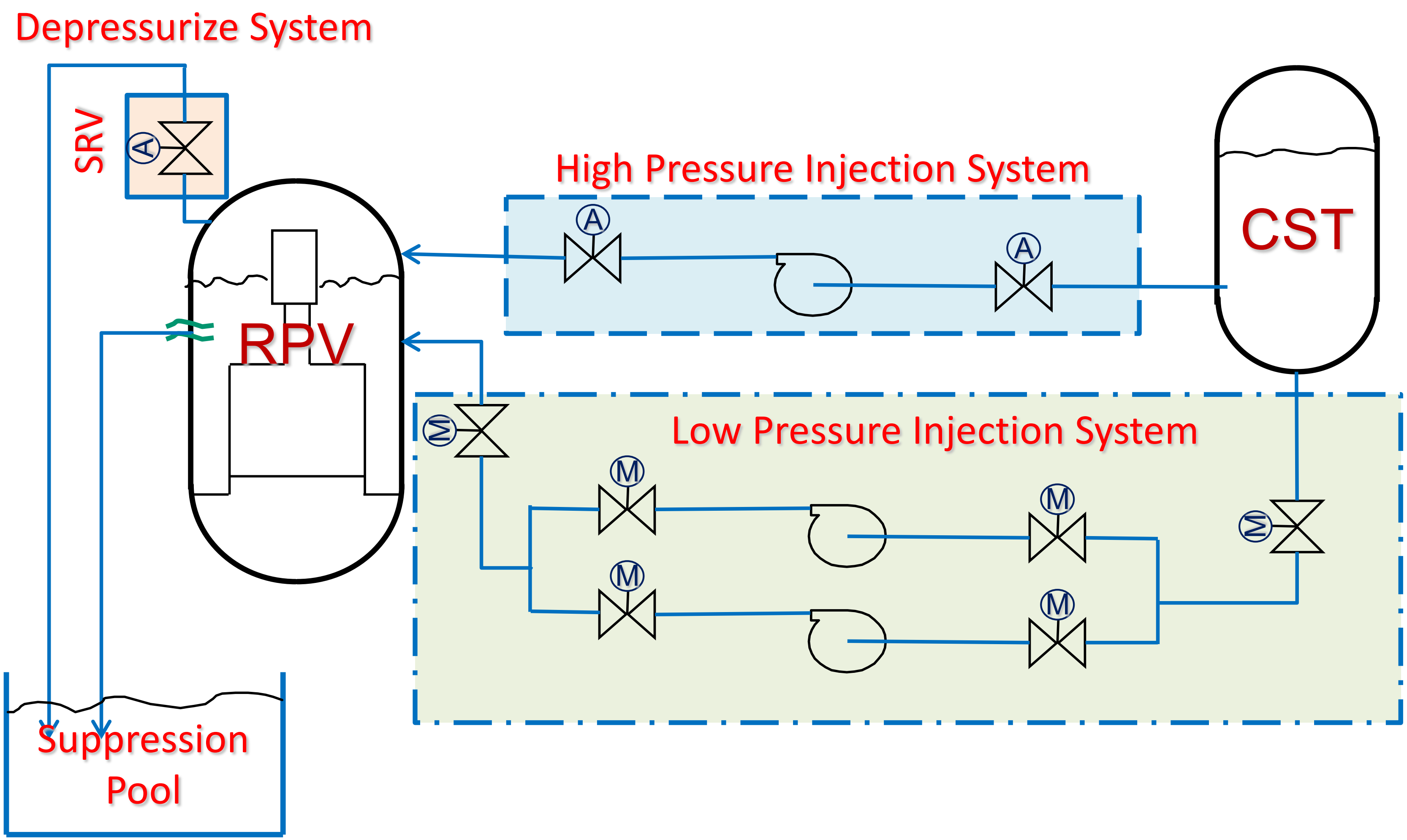
Event Tree Example 1: Fire protection system



Event Tree Example 2: Release of flammable gas



Event Tree Example 3 Loss of coolant accident

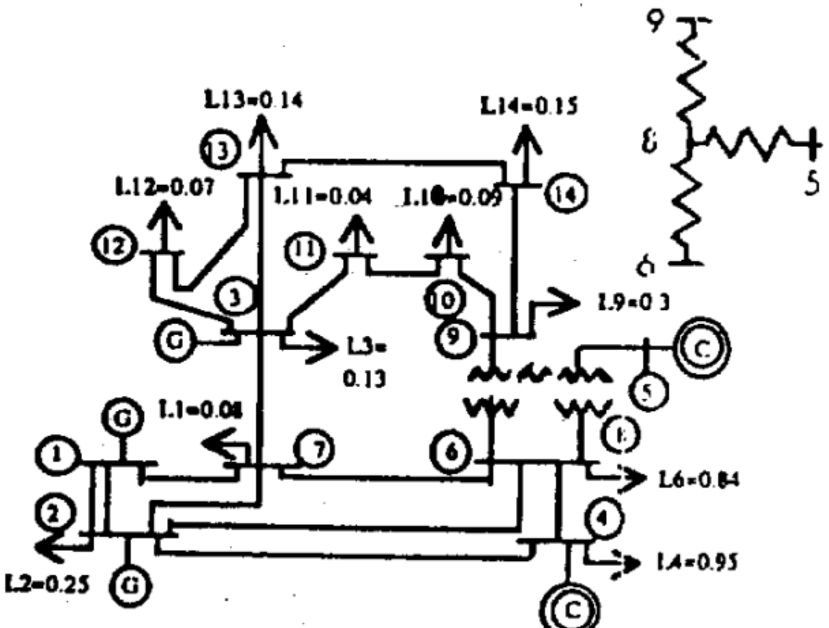


Event Tree Example 3 (cont.)

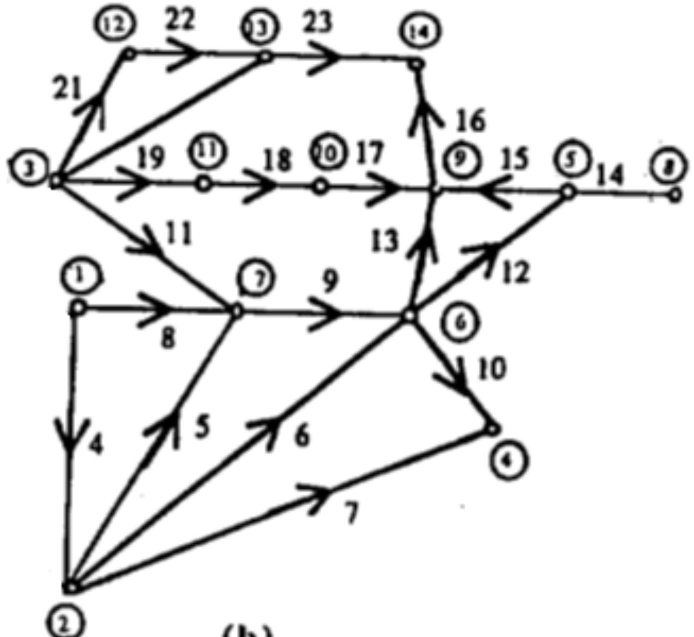
- A small pipe crack can induce the loss of coolant of the reactor pressure vessel (RPV). The frequency of this event is 5.0E-4.
- Under the small loss of coolant accident (SLOCA) condition, the RPV water level drops due to the crack and decay heat. When it drops to a certain low level, the high pressure injection system (HPIS) starts to pump water into the core.
- In case that the HPIS works properly, the RPV can be depressurized under control and low pressure injection system (LPIS) will take care of long term heat removal to bring the core to safe status.
- If HPIS fails (at probability of 2.0E-3), the water level goes down to another setting level and trigger-starts LPIS. Then the operator has to open the safety relief valve (SRV) to relief the RPV pressure in order to keep LPIS pumping the water into the core.
- In case either the operator fails to open SRV (at probability of 5.0E-3) or LPIS fails (at probability of 5.0E-4), the core will be damaged.

Event tree Example 4:
IEEE14 Bus Power Distribution System

Generators (G1, G2 , G3)
Loads (2, 3, 4, 6, 7, 9, 10, 11, 12, 13, 14)
Power delivery paths: lines (L) and buses (B).



(a)



(b)

FT Example 4: IEEE14 Bus Power Distribution System

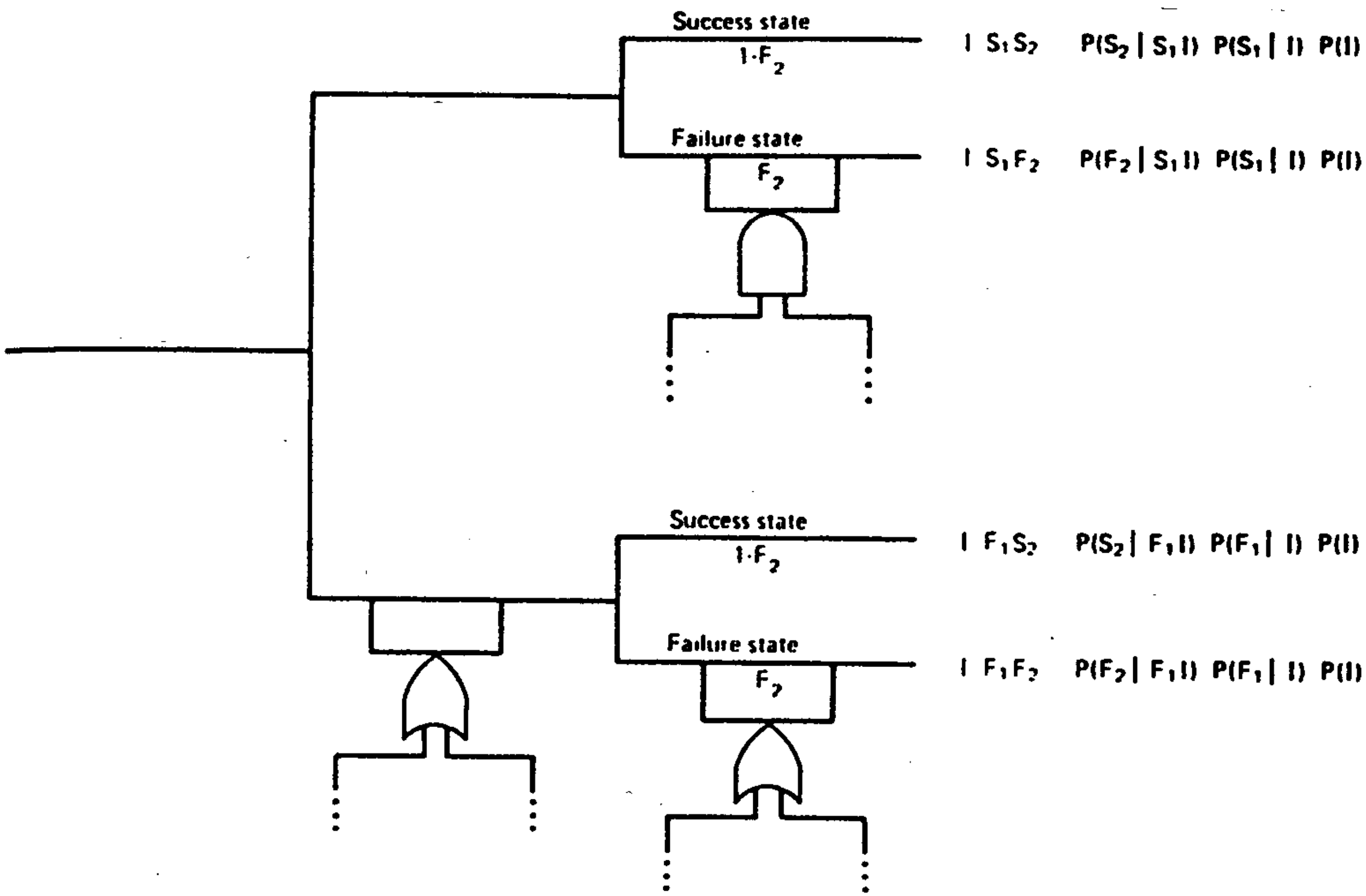
Draw the ET and calculate the probability of “failure to supply power to bus 2” (Load2)

G1	B1	L4	G2	B2

ETA: comments

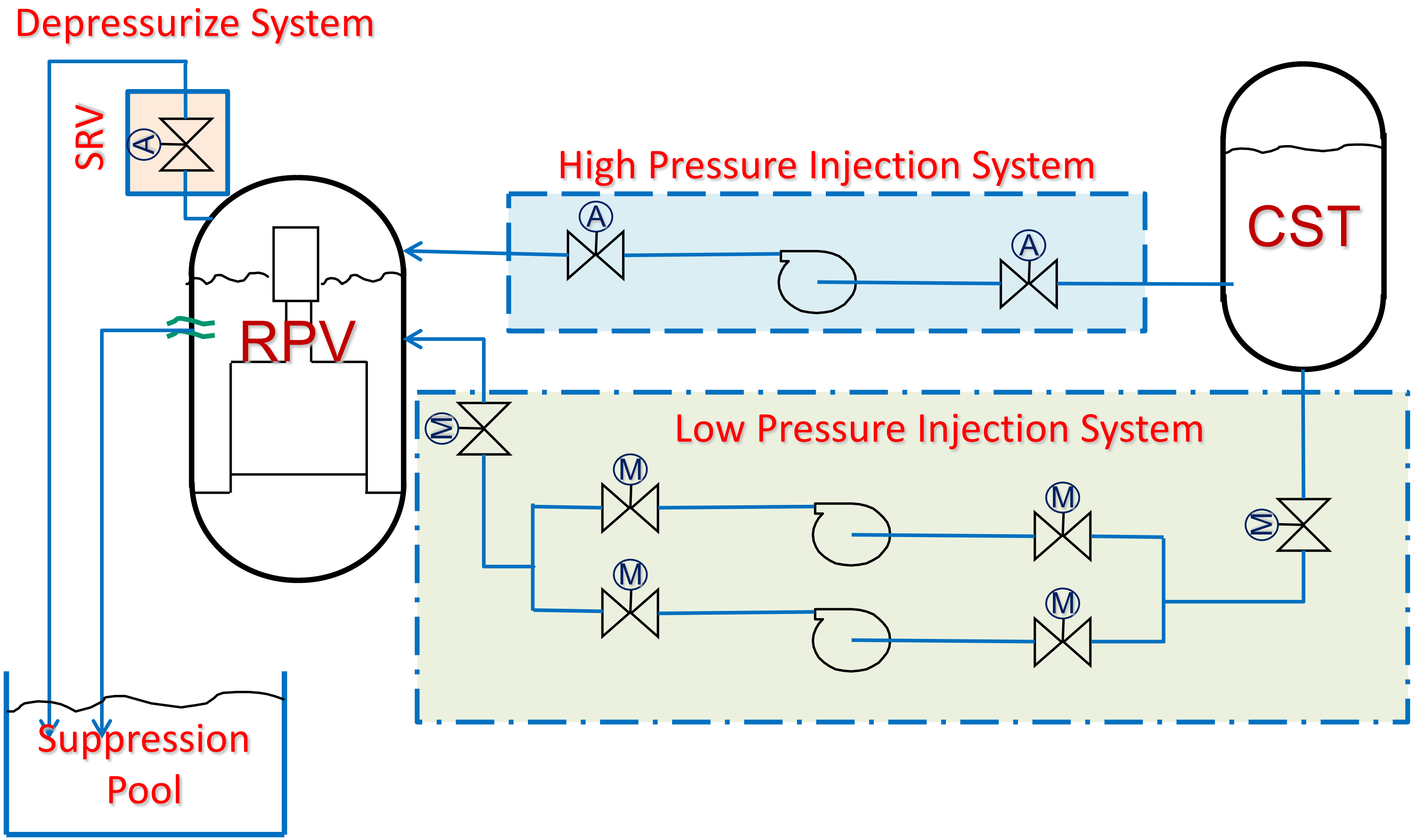
1. One ET for each accident initiator
2. Time and logic of S_k interventions important for the tree structure (simplifications possible)
3. S_k states conditional on accident initiator and previous S_j's
4. Conditional probabilities of S_k states (FTA)

ETA+FTA

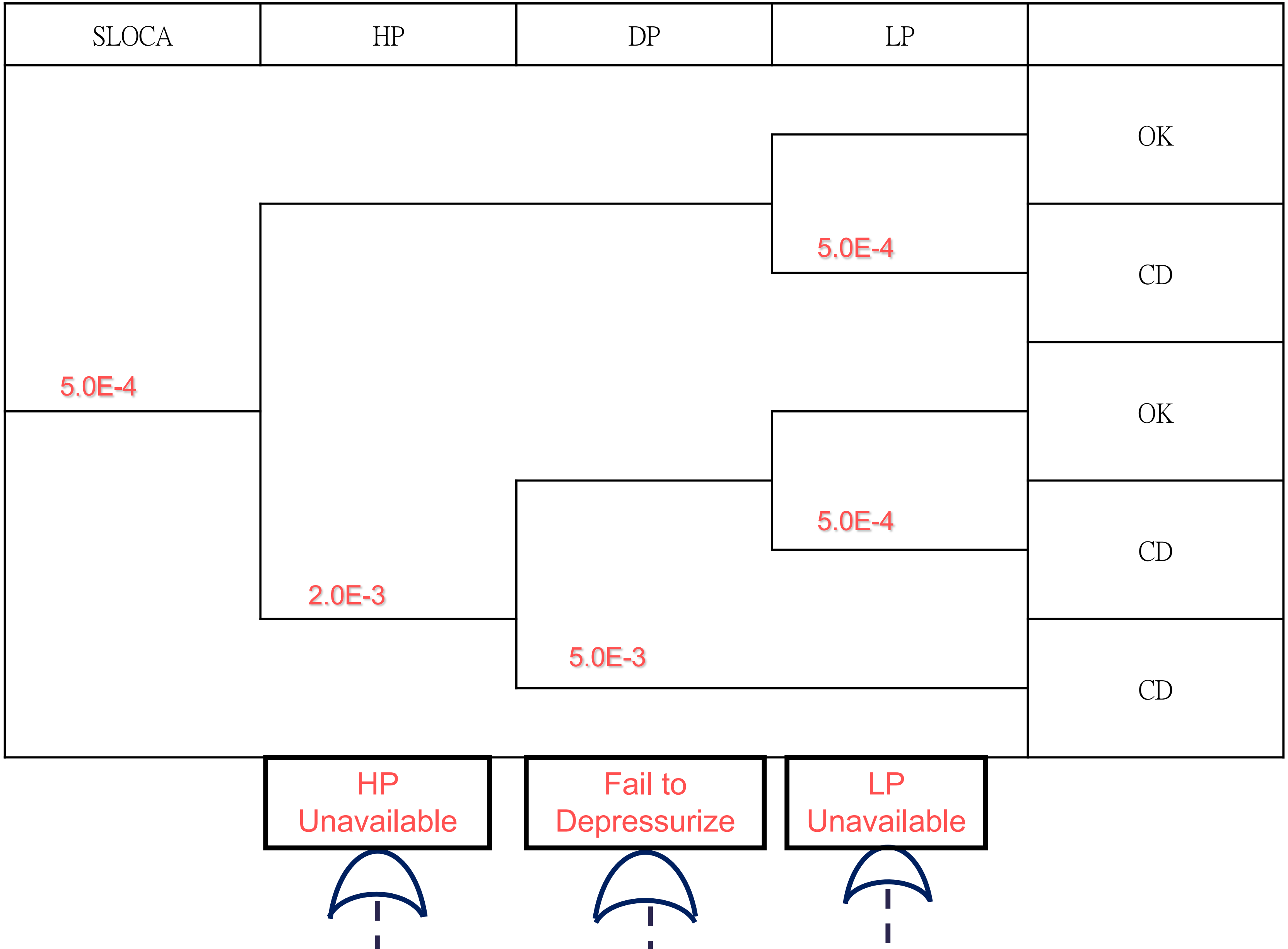


Success state
1-F2
Failure state
F2
Success state
1-F2
Failure state
F2
I S1S2 P(S2 | S1 I) P(S1 | I) P(I)
I S1F2 P(F2 | S1 I) P(S1 | I) P(I)
I F1S2 P(S2 | F1 I) P(F1 | I) P(I)
I F1F2 P(F2 | F1 I) P(F1 | I) P(I)

Event Tree Example 3 Loss of coolant accident



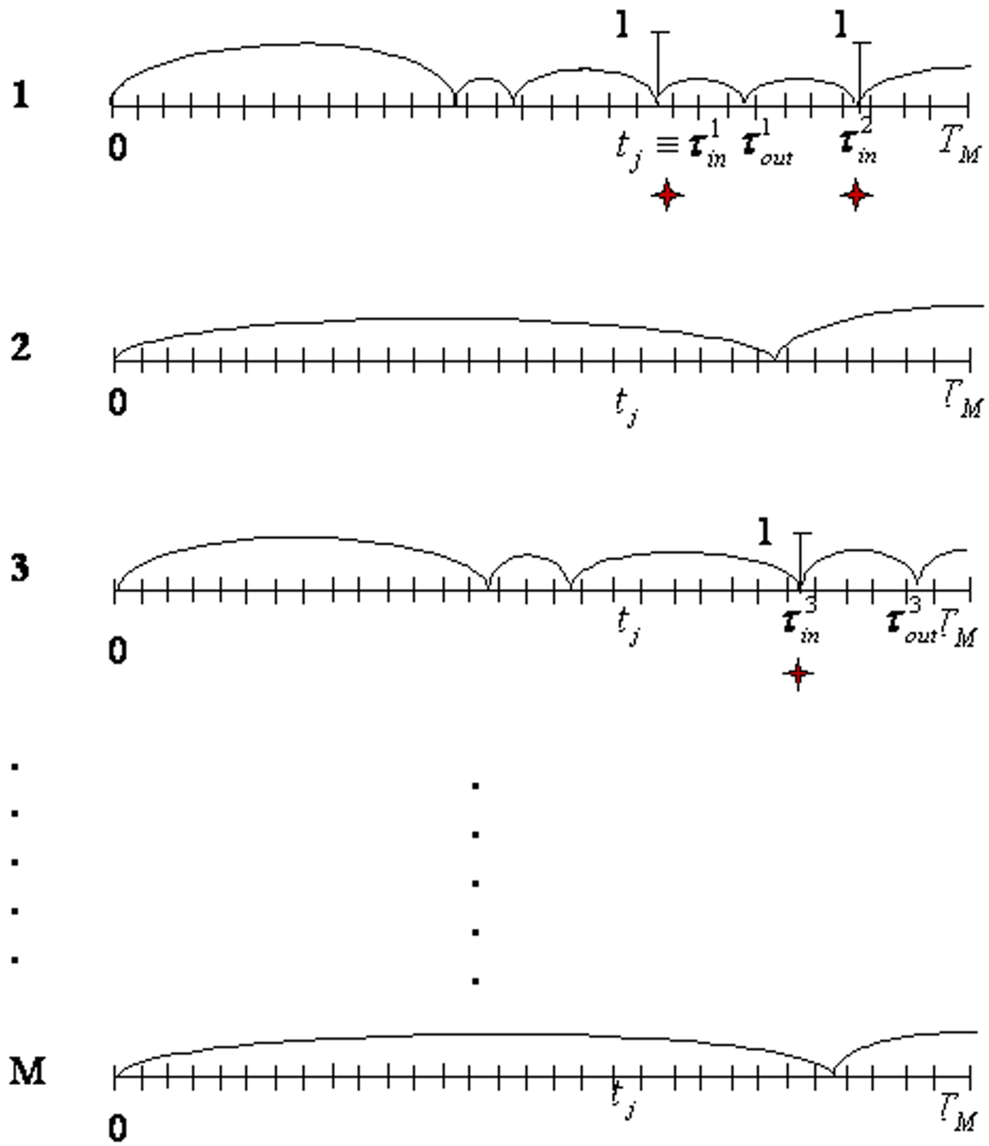
Event Tree Analysis



MONTE CARLO SIMULATION

- Perform many simulations (trials or histories) of the system life during its mission time
- Each trial is a random walk of the system from one stochastic configuration to another, at stochastic times.
- For each piece of walk, starting from a given system configuration k' entered at t', we need to determine when the next transition occurs and which new configuration is reached by the system.
- When the system enters in a failure configuration, we record the event realization
- Perform statistical estimates on the failure events to compute system failure probabilities

MONTE CARLO SIMULATION



$$c^R(t_j) = c^R(t_j) + 1$$

$$c^R(t_j) = c^R(t_j)$$

$$c^R(t_j) = c^R(t_j)$$

$$G^R(t_j) = \frac{c^R(t_j)}{M}$$