LOPA method: Simplified approaches versus advanced calculation methods

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LOPA and ISO/TR 12489

- ISO/TR 12489:2013 is focused on probabilistic calculations
- LOPA is a widely used method to estimate probabilities
- LOPA requires the use of PFDavg calculation
- Some pillars of LOPA are sometimes disregarded or unknown
- LOPA tends to be more and more quantified with some pitfalls

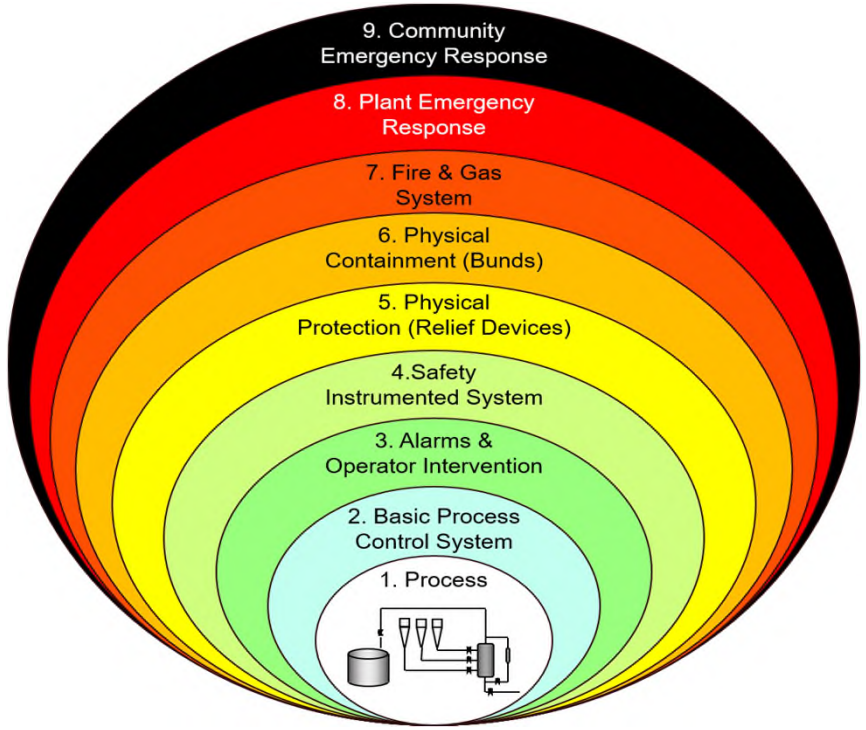
Agenda

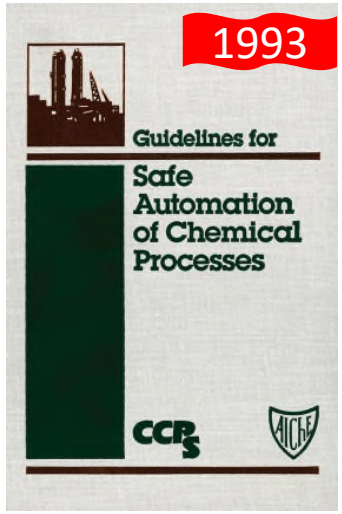
1. Some reminders on LOPA method
2. Implementation of an advanced LOPA approach with GRIF® software
3. Study case
4. Comparison : traditional LOPA versus advanced LOPA approach
5. Conclusion

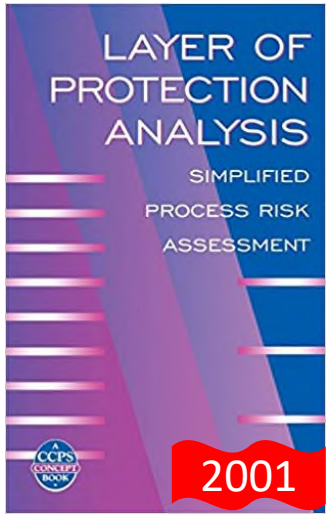
1. Some reminders on LOPA method

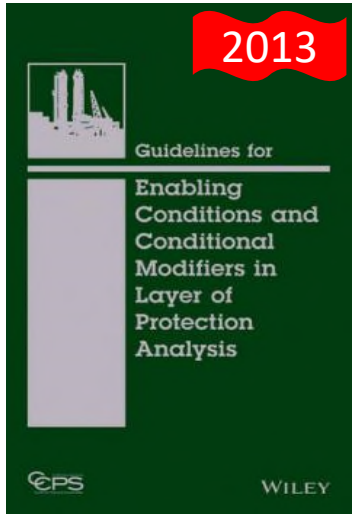
LOPA method

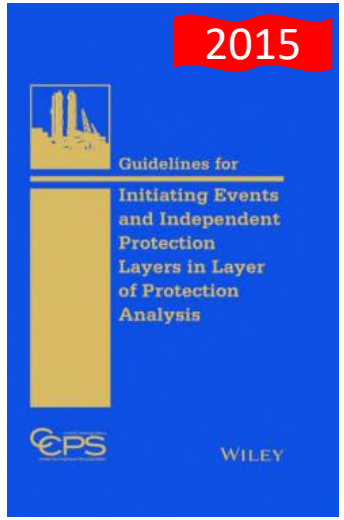
- LOPA = Layer Of Protection Analysis.
- Concept : The reduction of a risk is achieved by several layers of protection --> defence in depth
- Risk reduction is achieved by IPL (Independent Protection Layer) ; RRF (Risk Reduction Factor)
- Single « Cause-Consequence » pair as a scenario

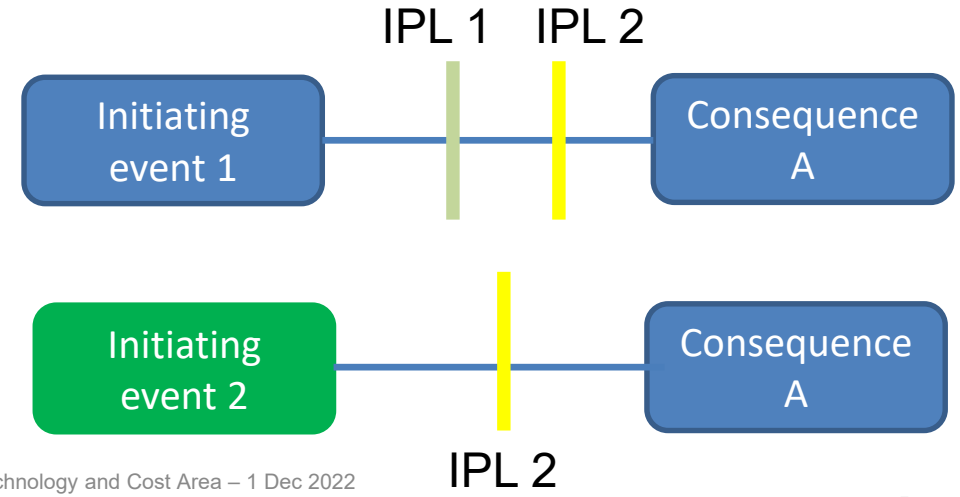








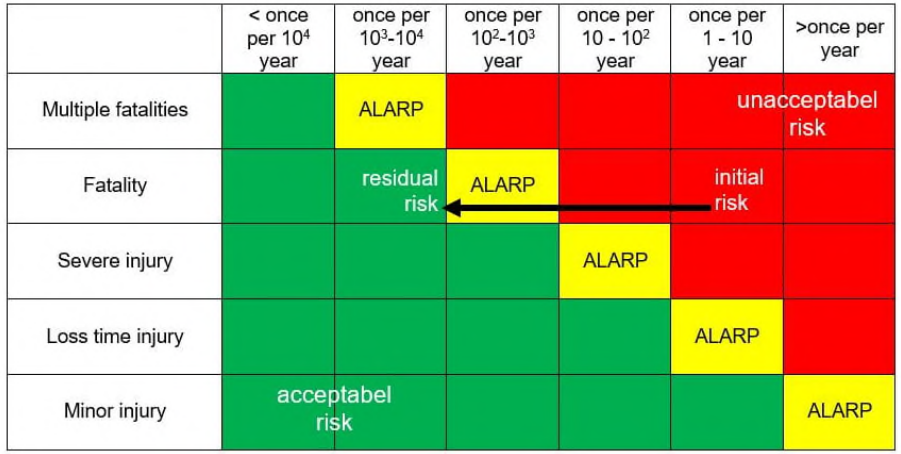




Common applications of LOPA method

- SIL allocation = define the required Safety Integrity Level (SIL) for Safety Instrumented Functions (SIF)

TABLE 1: SAFETY INTEGRITY LEVELS WITH ASSOCIATED PFD_{AVG} AND RRF		
Safety integrity level (SIL)	Average probability of failure (PFD_{avg}), low-demand mode of operation	Risk reduction factor (RRF; $1/PFD_{avg}$)
SIL 4	$\geq 10^{-5}$ to $<10^{-4}$	100,000 to 10,000
SIL 3	$\geq 10^{-4}$ to $<10^{-3}$	10,000 to 1,000
SIL 2	$\geq 10^{-3}$ to $<10^{-2}$	1,000 to 100
SIL 1	$\geq 10^{-2}$ to $<10^{-1}$	100 to 10



- **To investigate in detail selected critical accident scenarios → frequency assessment**

- CEI 61511 "democratised" the LOPA method **BUT** it should not be limited to the SIL allocation - wider use in risk analysis

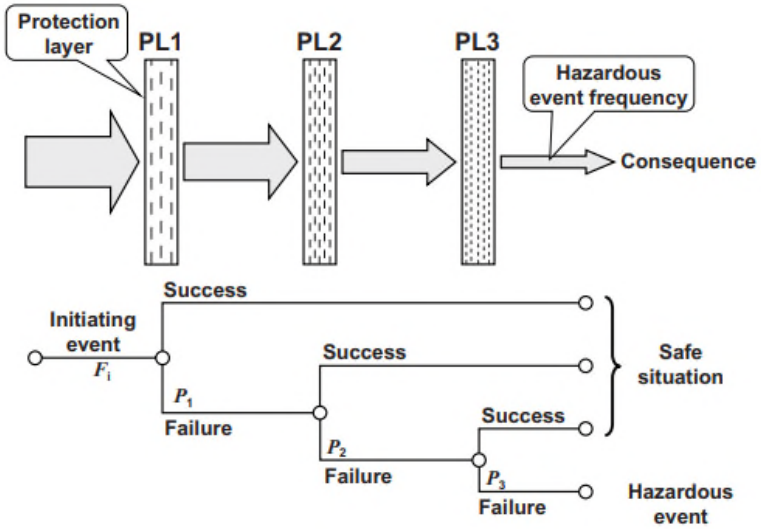
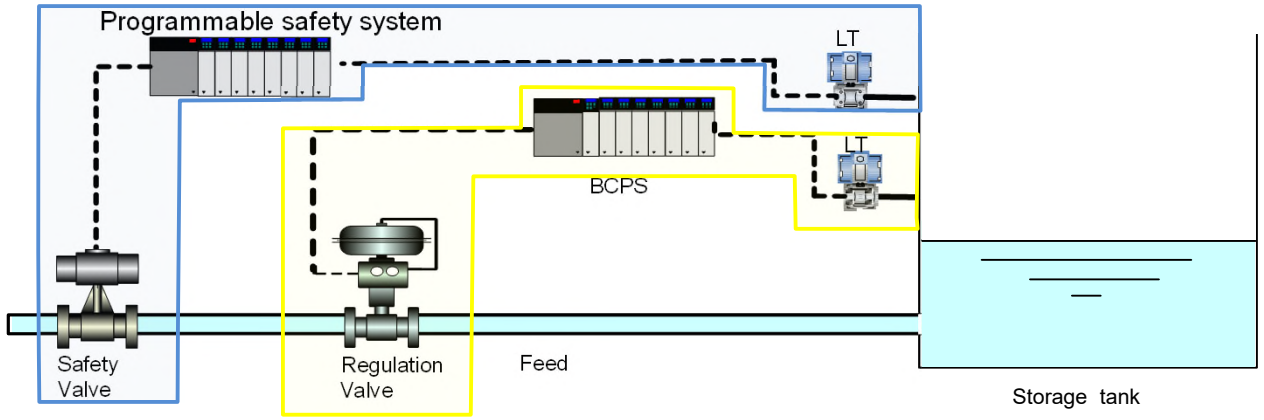
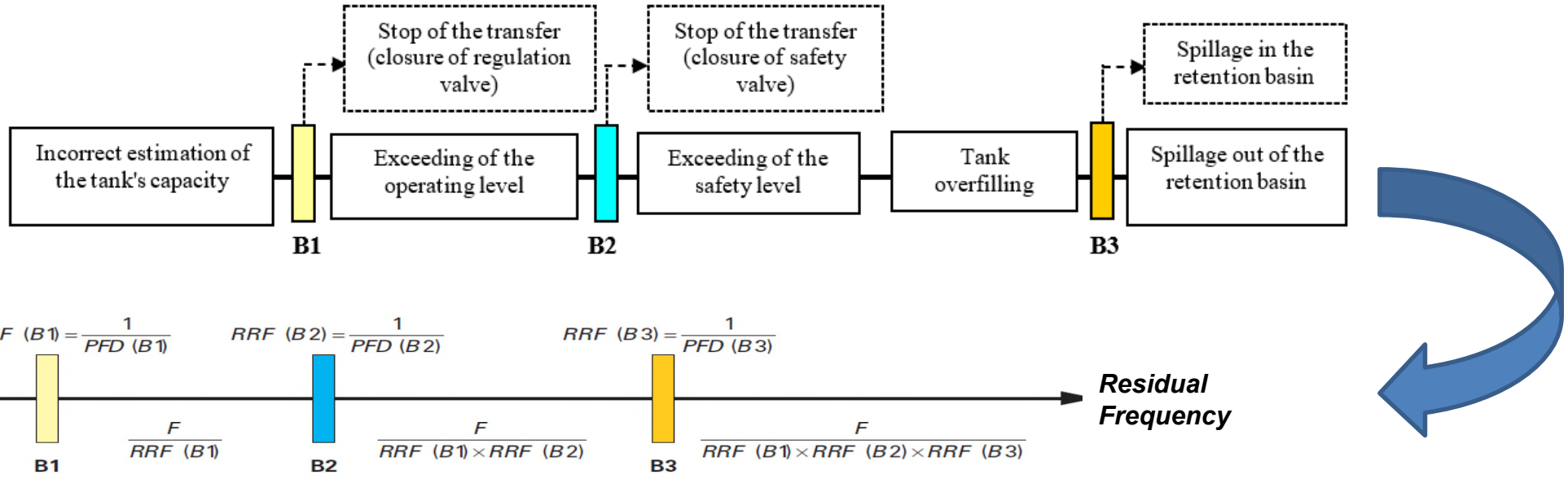


Figure J.4 — Example of LOPA

Traditional LOPA method

- Overfilling of a storage tank





RRF : Risk Reduction Factor

PFD : Probability of Failure on Demand

Residual frequency calculation – *Traditional approach*

- Residual Frequency = F(IE) x P(WFi) x PFD(IPL1) x PFD(IPL2) x … x PFD(IPLi)

Event	Estimated Frequency
Loss of cooling (Standard simplex system)	1/year
Loss of power (Standard simplex system)	1/year
Human error (Routine, once per day opportunity)	1/year
Human error (Routine, once per month opportunity)	1/10 years
Basic process control loop failure	1/10 years
Large fire	1/100 years* 1/1,000 years

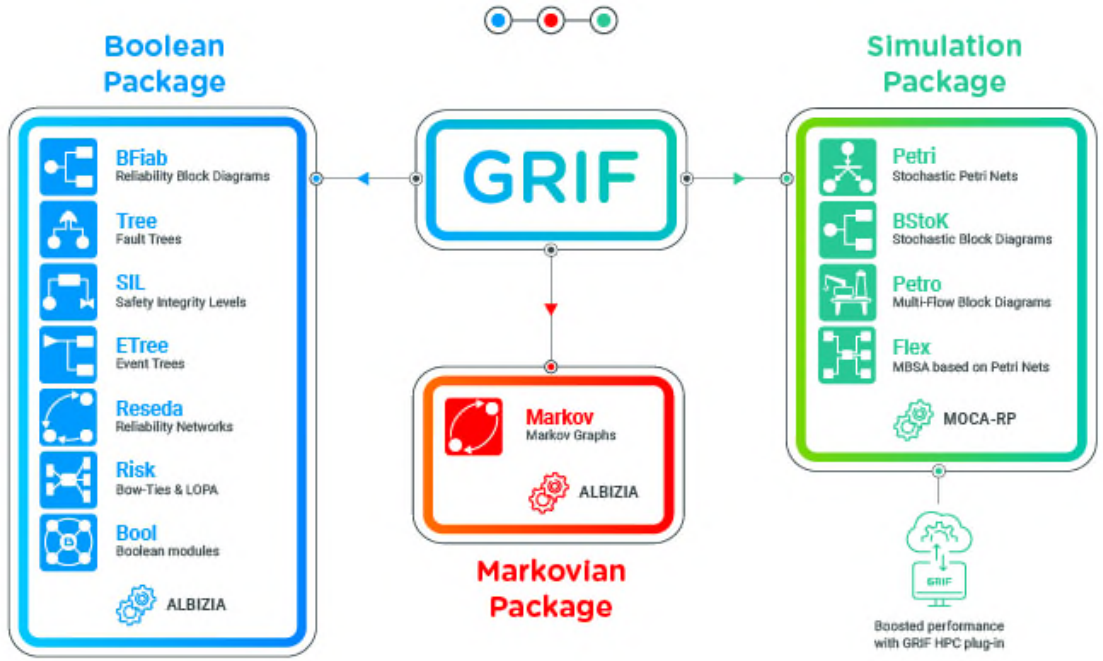
Independent Protection Layer	PFD
Control loop failure	1.0×10^{-2}
Relief valve failure	1.0×10^{-2}
Human Error (trained, no stress)	1.0×10^{-2}
Operator Response to Alarms	1.0×10^{-1}

***Reminder* : CCPs presents LOPA as a semi-quantitative method because the frequency and the severity of the consequences are generally based on approximations (using powers of ten for frequencies).**

2. Implementation of an advanced LOPA approach with GRIF® software

Risk : one module of GRIF®

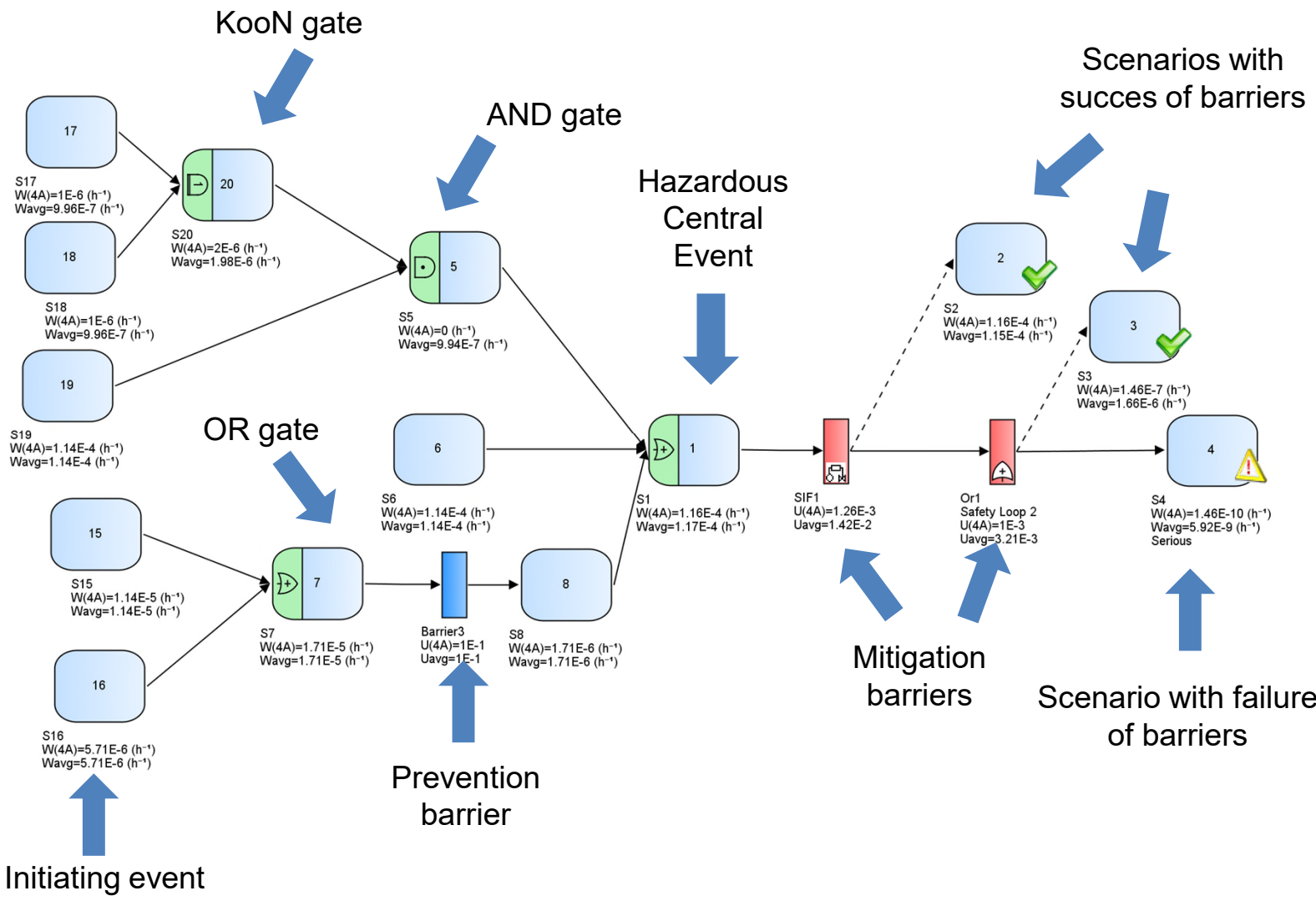
- GRIF includes 3 packages and 12 modules allowing the user to choose the most appropriate modelling technique for the resolution of the studied system (block diagrams, fault trees, Markov graphs, Petri nets...).



- Risk was developped :
  - ✓ To implement easily LOPA approach
  - ✓ To perform « correct » calculations based on reliability models.

Risk capabilities

- Friendly views for LOPA and bow-tie diagrams
- Possible to present scenarios with or without operating barriers
- Possible to link PFDavg calculations (e.g FT) to barriers valorized on the diagram



Risk module advantages

- Provides a "correct" assessment of the RRF (Risk Reduction Factor) resulting from several barriers
- Provides a "correct" assessment of the scenario frequency
- Allows the frequency assessment in single GRIF module
- Allows to focus only on scenarios with failed barriers or to introduce scenarios with barrier success
- Permits also the development of bow tie

3. Study case

Assumptions

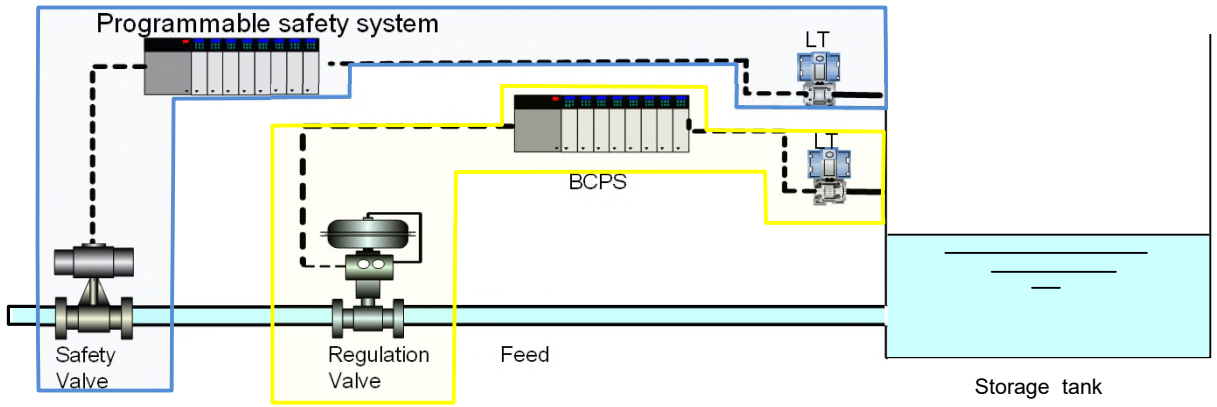
- <u>Case :</u> Overfilling of a storange tank

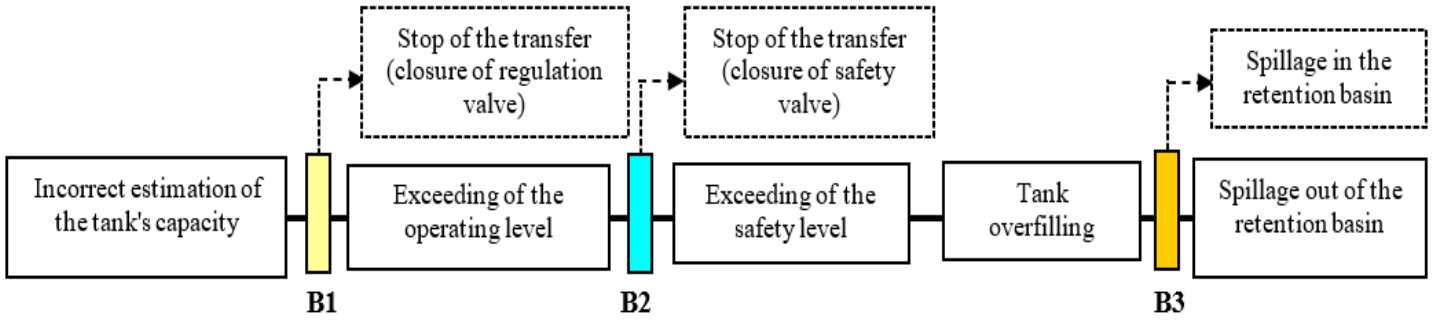
I. Initiating event frequency « Incorrect estimation of the tank capacity » : F(IE) = 0.2/year

II. Test periods :
   - T = 2 years for safety barrier 1 (B1)
   - T = 1 year for safety barrier 2 (B2)

   Note : PTC ≠ 100% for B2

III. Equipment failure rates :
   - Extracted from SINTEF data base





3 compared approaches

1. **Traditional LOPA**

→ All the data used are extracted from databases (or Company golden rules)

2. **Upgraded traditional LOPA**

→ Traditional LOPA including accurate PFDavg calculations

3. **Advanced LOPA**

→ Chained calculations with Risk module

Appproach 1 : Traditional LOPA

- Typical orders of magnitude :

	RRF	PFD
Barrier B1 (operating level + regulation valve)	10	1E-1
Barrier B2 (safety level + safety valve)	100	1E-2
Barrier B3 (retention basin)	100	1E-2

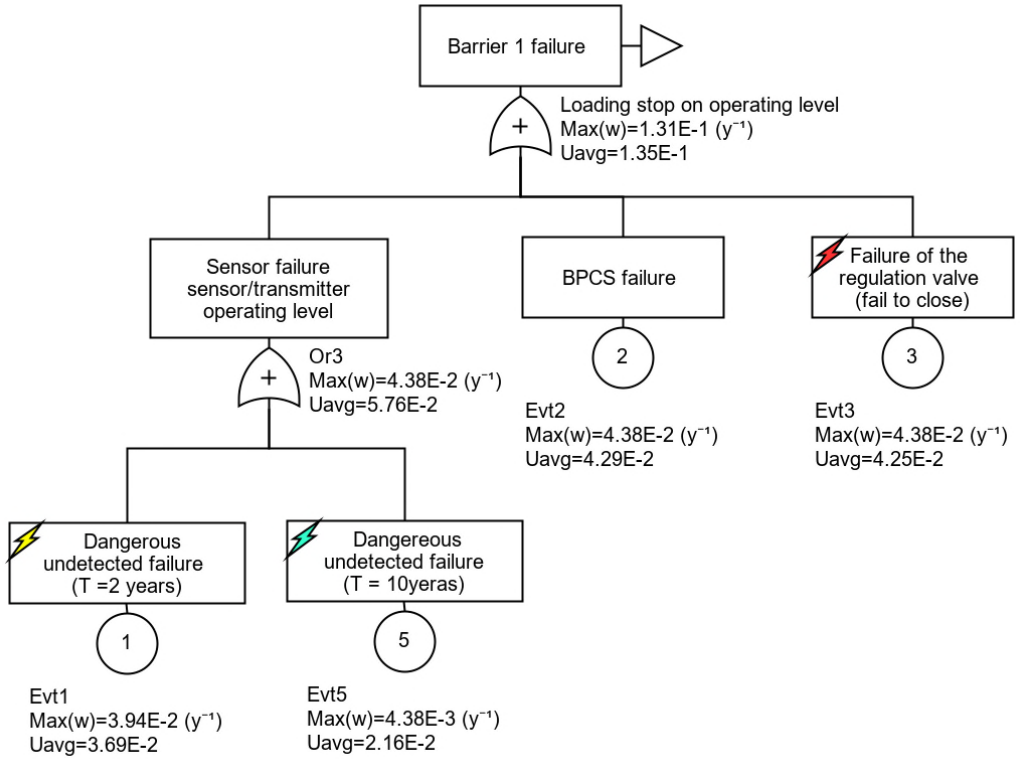
F(spillage out of the retention basin) = F(IE) × PFD (B1) × PFD (B2) x PFD (B3)

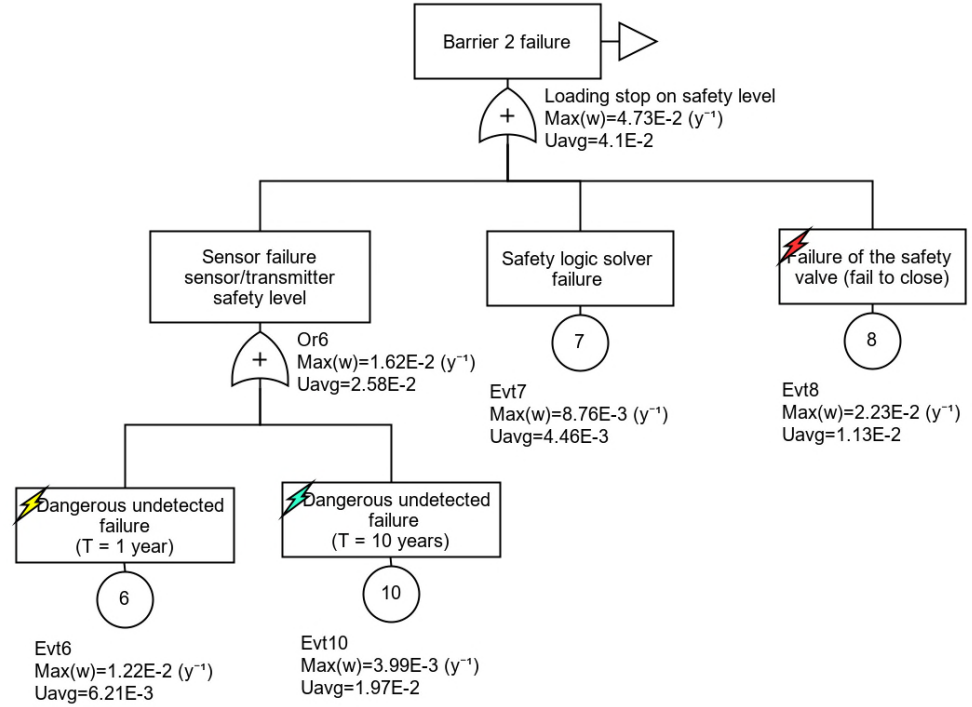
Method Ref.	F(IE) (/h)	PFD (B1)	PFD (B2)	PFD (B3)	F(spillage) (/h)
A1	2.28E-5	1E-1	1E-2	1E-2	2.28E-10

0.2/year

2E-6/year

Approach 2 : Upgraded traditional LOPA





F(spillage out of the retention basin) = F(IE) × PFDavg (B1) × PFDavg (B2) x PFD (B3)

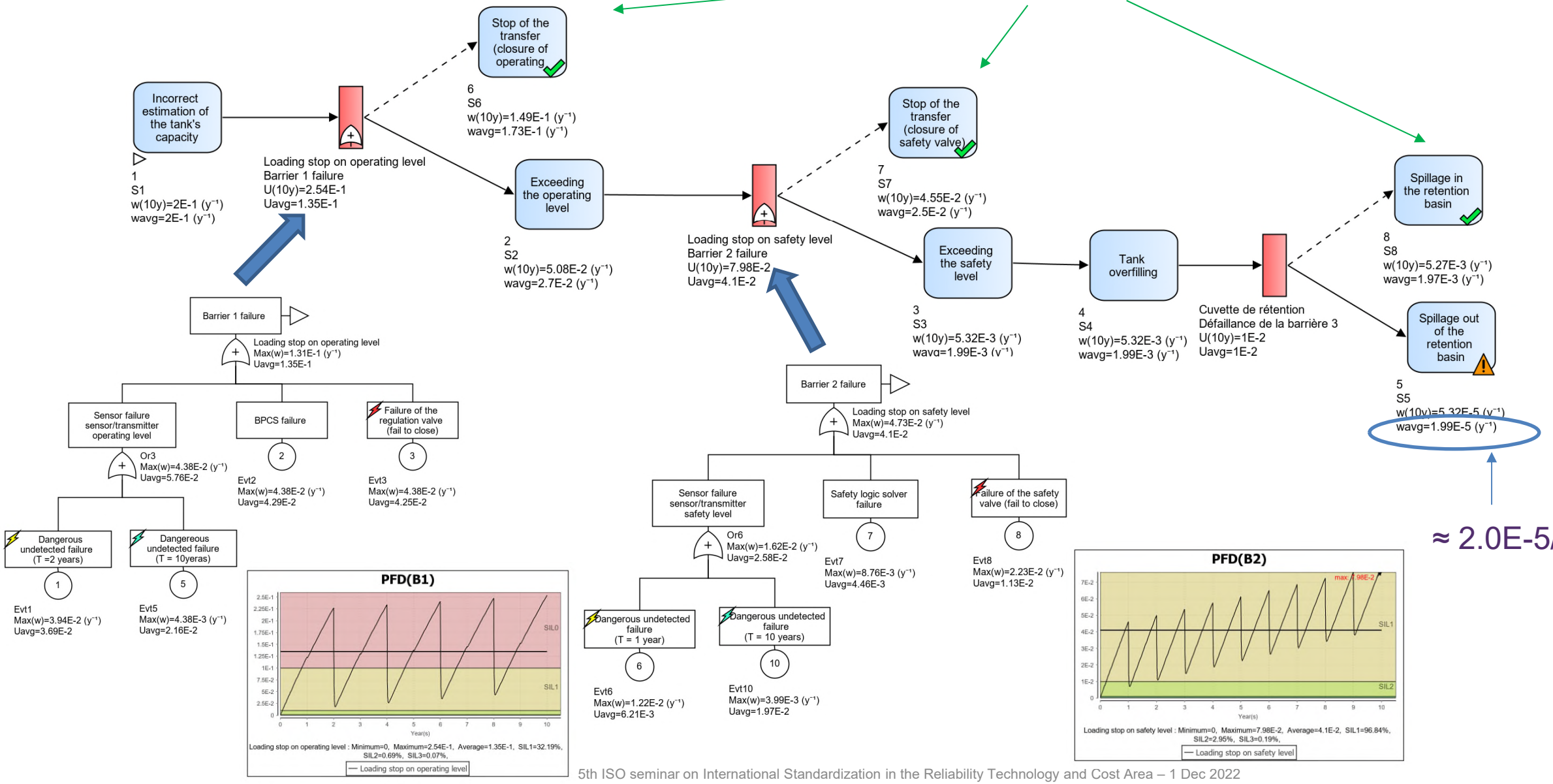
Method Ref.	F(IE) (/h)	PFD (B1)	PFD (B2)	PFD (B3)	F(spillage) (/h)
A2	2.28E-5	1.35E-1	4.1E-2	1E-2	1.26E-9

0.2/year

1.1E-5/year

Approach 3 : Advanced LOPA

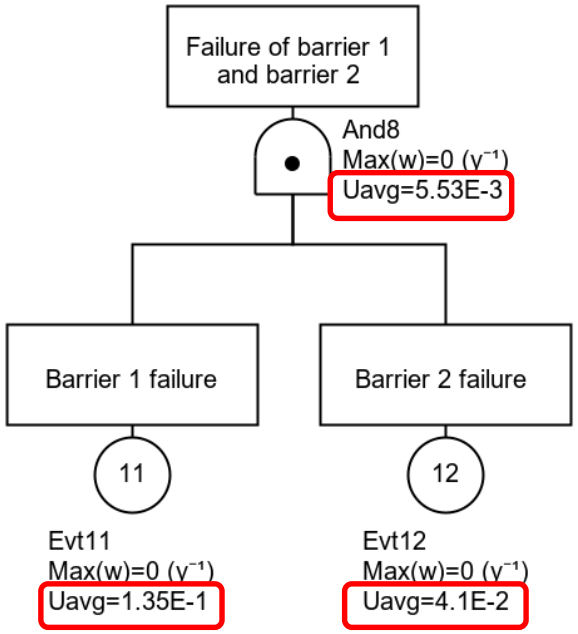
Scenarios resulting from success of safety barriers



≈ 2.0E-5/year

Approach 3 versus approach 2 : what is the difference ?

Approach 2



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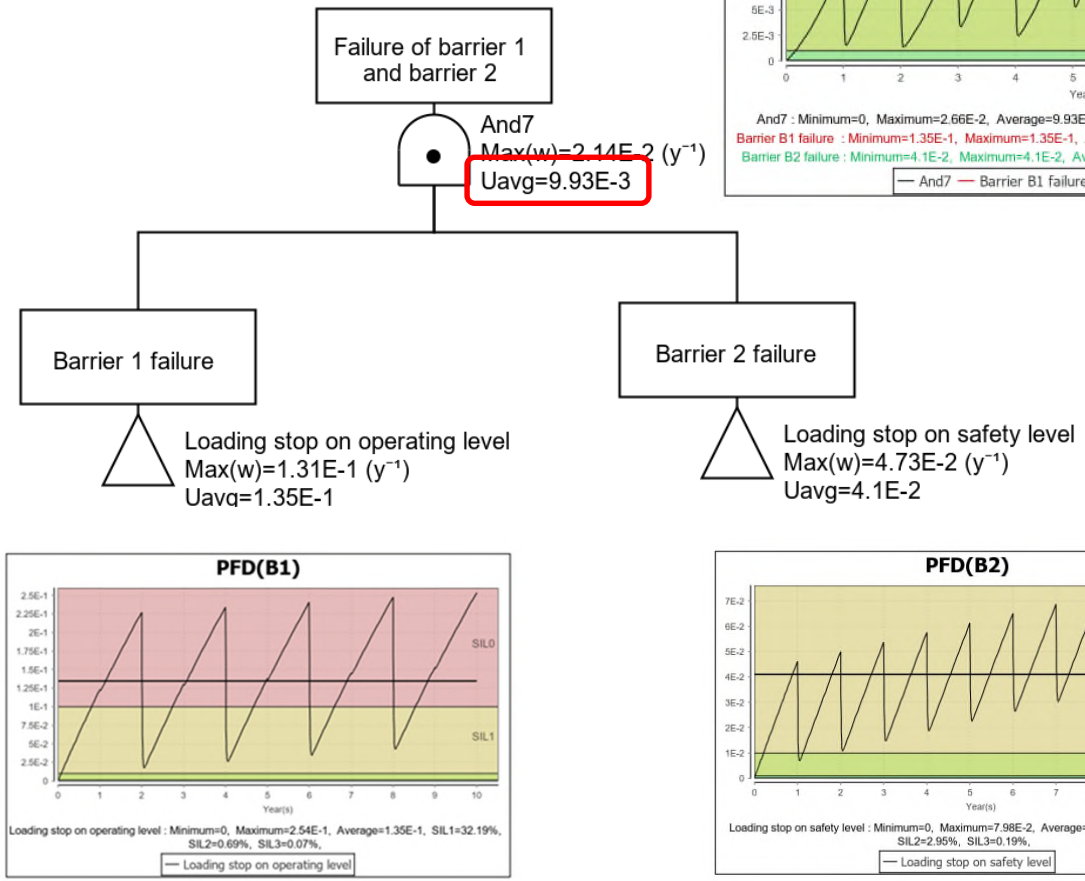
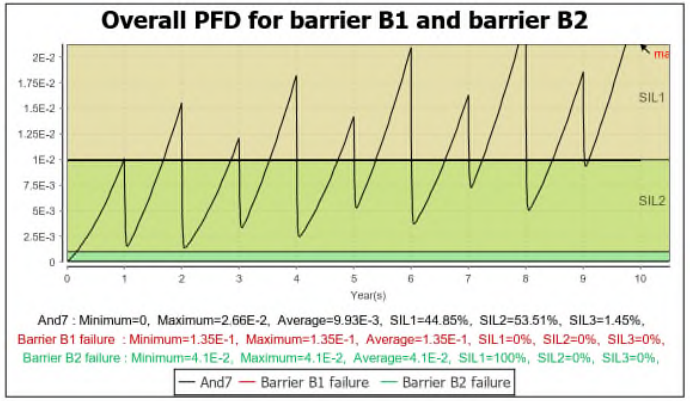
Approach 3





4. Results comparison

Gap between approaches

- Approach 3 provides a "correct" assessment of the RRF (Risk Reduction Factor) resulting from several barriers

Ref.	Approach	F(IE)(/y)	PFDavg (B1)	PFDavg (B2)	PFD (B3)	F(spillage out of retention basin) (/y)
A1	Traditional (*PFD extracted from [2]*)	0.2	1E-1	1E-2	1E2	≈ 2E-6
A2	Upgraded traditional LOPA (*PFDavg assessed with Fault trees - GRIF®*)	0.2	1.35E-1	4.1E-2	1E-2	≈ 1E-5
A3	Advanced (*Risk module calculation GRIF ®*)	0.2	1.35E-1	4.1E-2	1E-2	≈ 2E-5

[2] CCPS, Guidelines for Initiating Events and Independent Protection Layers in Layer of Protection Analysis, February 2015. ISBN: 978-0-470-34385-2.

- The traditional approach (A1) significantly reduces the accident frequency by a factor of about 10 compared to the advanced approach [A3].
- The upgraded approach (A2) compared to the advanced approach (A3) reduces the accident frequency by a factor of about 2.

How significant is this?

- Overlfillings have generally significant consequencies

→ The frequencies assessment must be accurate

→ A focus must be done on the safety barriers : performances, independence, common cause of failure

Adanced LOPA can help

5. Conclusion

In Brief

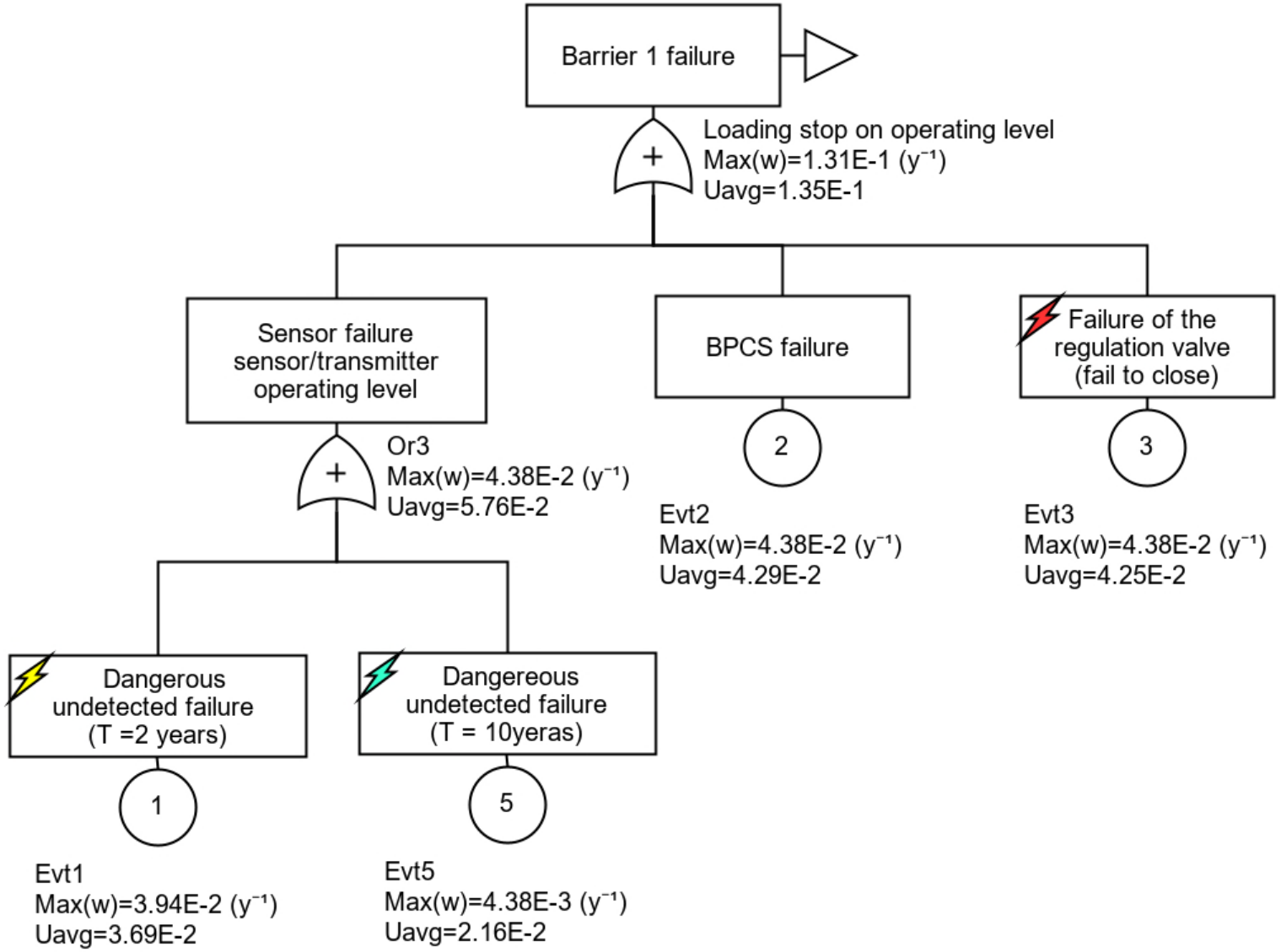
- The advanced LOPA method allows :
  - ✓ To have a better traceability in the demonstration
  - ✓ To ask relevant questions (testability of barriers, coverage of test, common cause of failure existence, ….)
  - ✓ To make management aware of the limits of what is done (assumptions)

- Main obstacles to implementation of the advanced :
  - ✓ How implement this method during a working group ?
  - ✓ Time to devote to it ?

- Wayforward :
  - ✓ Promote the advanced approach for high severity level scenario
  - ✓ Raise management awareness of the issues involved in quantified risk analysis

Thank You

Fault tree for B1



Fault tree for B2