Leaving mission times backstage and taking repair into account in long term scenarios

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Lloyd's Register

Outline

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- Introduction to *Initiators & All Barriers* (I&AB) methodology
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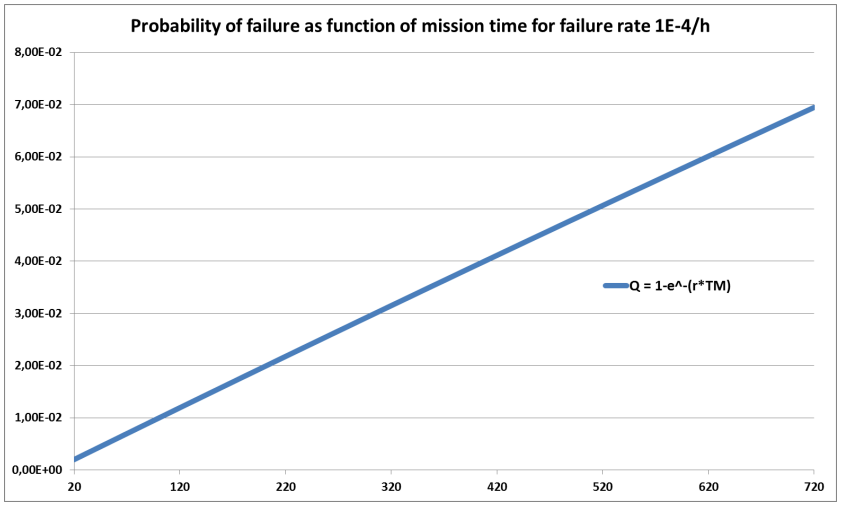
Introduction and objective

What's the driving force behind this paper?

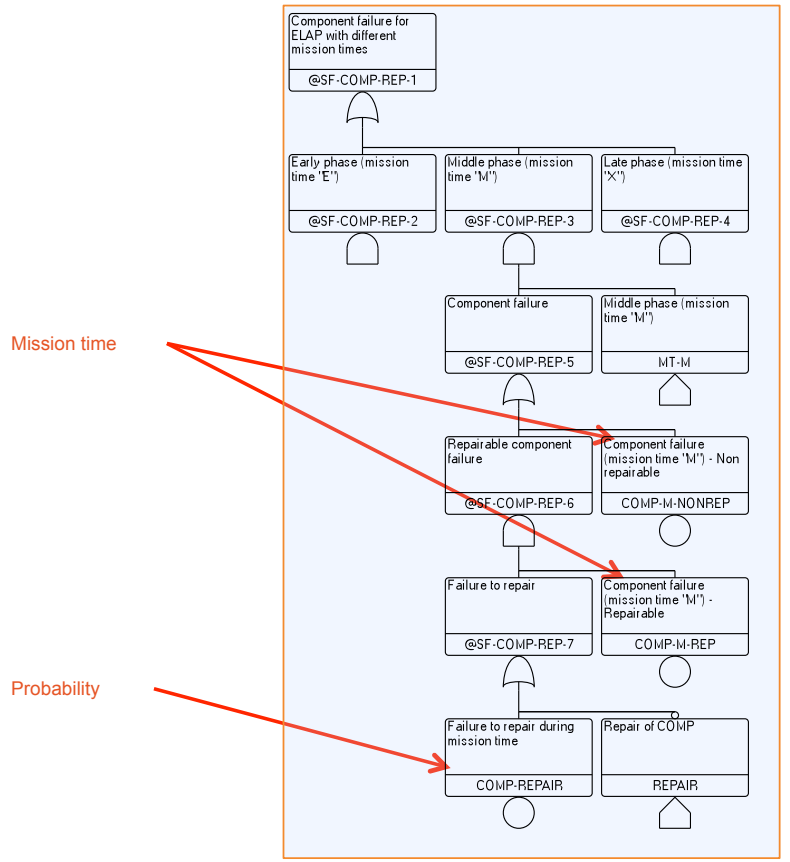
- For non-reactor nuclear facilities a 24 h mission time (Level 1) is often not sufficient.
- In long term scenarios it is reasonable to take repair into account in order to yield realistic results.

? *How can long term scenarios be analyzed in a realistic manner and how to define repair?*



Modelling of repair with traditional PSA technique

- Typically, the PSA analyst want to focus on what is driving the result, so in terms of repair:
  - Take it into account most contributing components
  - Consider other components to be non-repairable
- Also need to consider that some failure modes may not be repairable for all components



Introduction to pilot study

PSA for spent fuel facility

- Large fuel pools and low decay heat:
  - Boiling starts after ~1 week
  - It takes another ~3 weeks until boil-off cause fuel element uncovery
- Deterministic requirement that fuel pool cooling must not fail within 30 days after an IE.
  - 30 days mission time.
- **Repair probabilities assessed based upon if repair can be conducted within 7 days or not**
  - **0.01 ≤ Qrep ≤ 0.5**

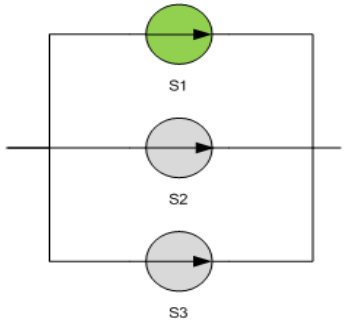
Model summary

Topic	Note
No. Basic Events	>1200
No. Event Trees	>30
No. Fault Trees	>350
Consequences	• Boiling • Fuel uncovery • Mechanical damage
Mission time	30 days (720 h)
No. Basic Events modelling repair	<20 (~1%)


How realistically has repair been considered?
What would the benefits be if a more realistic dynamic method would be applied?

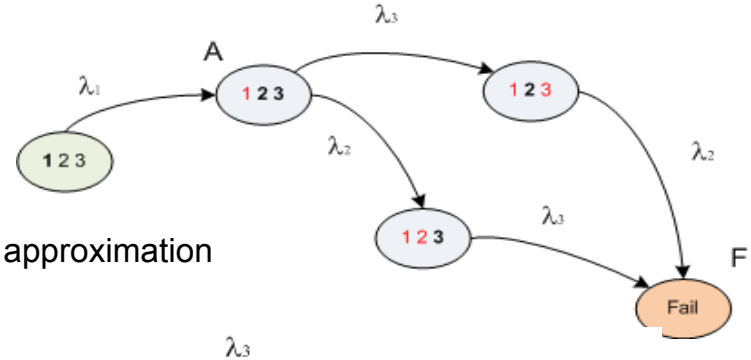
Introduction to *Initiators & All Barriers* (I&AB) methodology

Simplified example of the principle without mathematical formulas

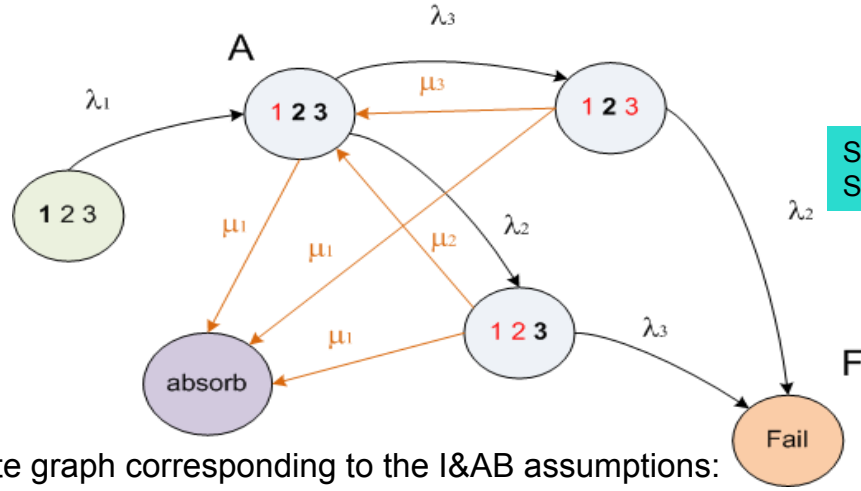


Consider a system of three repairable components where:

- S1 is in operation; S2 and S3 in stand-by
- Failure of S1 require S2 and S3 to start



State graph for PSA approximation



State graph corresponding to the I&AB assumptions:

State A = IE
State F = End state (CD)

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Application of I&AB methodology

Repair rates & Grace time

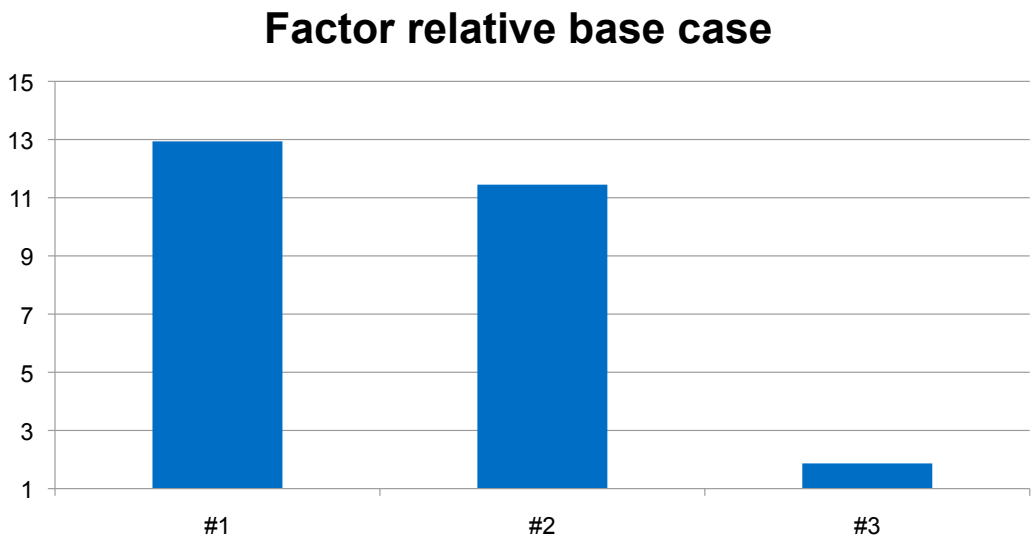
- **Repair rates** (1/[repair time]) instead of Qrep.
  - Mandatory parameter

- **Grace time** defined as available time for repair.
  - Optional parameter

Param.	#	Options
Repair time	A	• 7 days for components where repair is consider in the PSA • Others non-repairable
	B	• 7 days for components where repair is consider in the PSA • Others 30 days
	C	Conversion of Qrep to repair times
Grace time	A	No grace time considered
	B	7 days (time until boiling)
	C	30 days (time until fuel uncovery)

Results obtained with inputs provided in the PSA

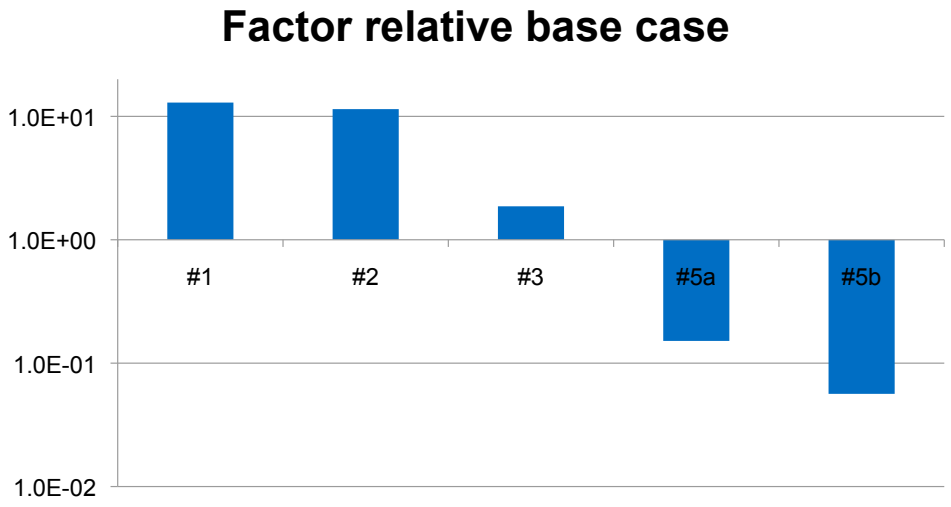
#	Case definition
1	• Repair only for same components as the base case. • 7 or 30 days assumed • Other comp's non-repairable • No grace time
2	• Same as #1 but comp's considered non-repairable are assigned 30 days repair time. • No grace time
3	• As for #2 for repair time • Grace time of 7 days



As the dynamic approach is more realistic the results obtained indicate that the repair times of 7 and 30 days are too conservative

Estimation of less conservative repair times

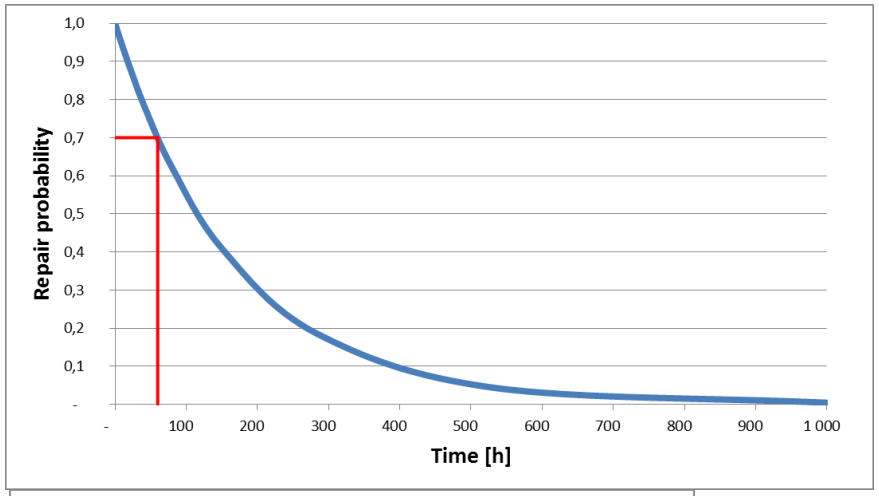
- New repair times defined based on ”eng. judg.” for components that where assigned 7 or 30 days in case #1-3
- Repair time ranging between 8 h to 15 days.
- **#5a:** Other comp’s 30 days repair time
- **#5b:** other comp’s 7 days repair time

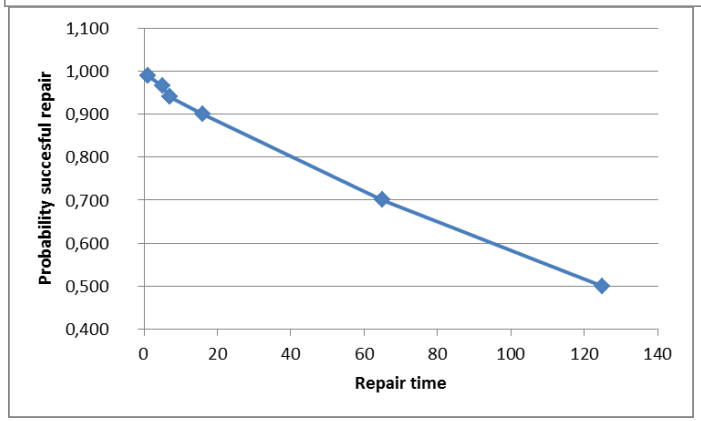


Verification of repair times used in case #5 is of great importance for the utility, not only in terms of “PSA result”.

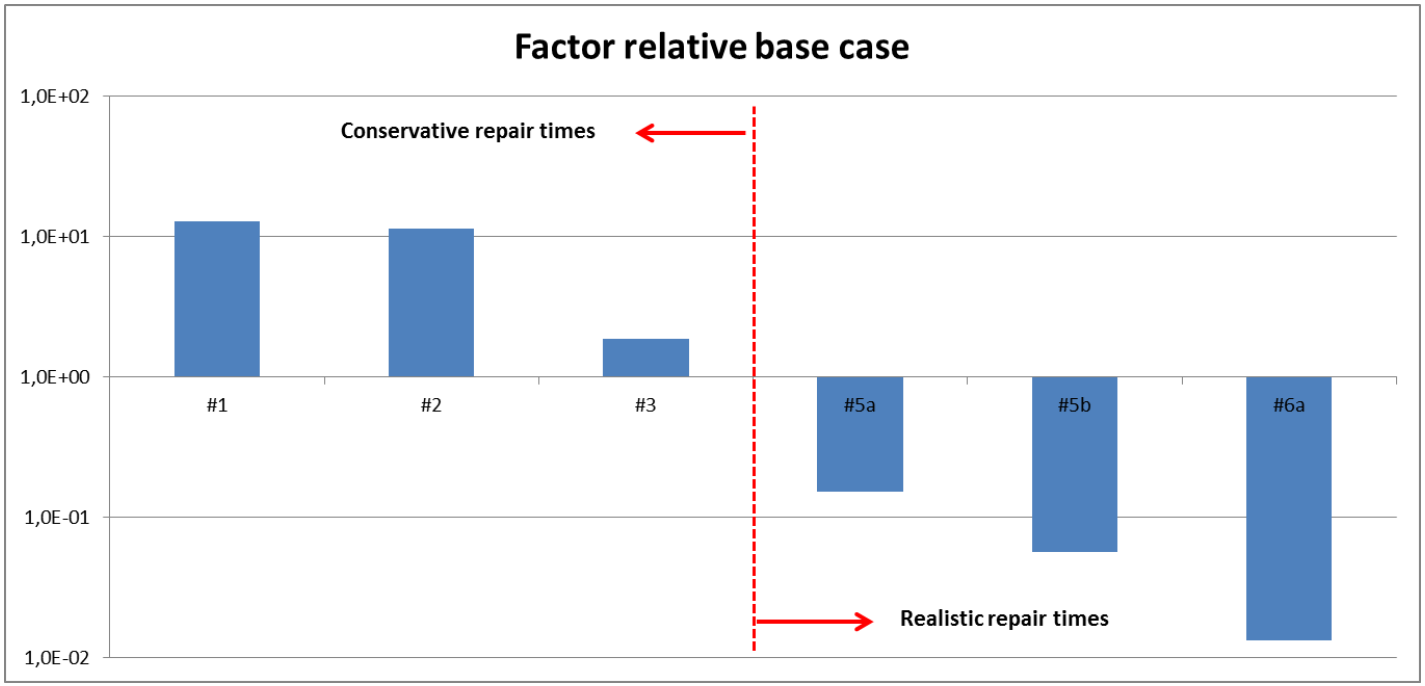
Conversion of Qrep to repair times

- What repair times do defined Qrep's represent?
- Conversion possible using reliability model for ***repairable*** components assuming they are failed at time T=0.
- 0.01 ≤ Qrep ≤ 0.5 corresponds to 1 h ≤ RT ≤ 125 h (~5 days)





Results achieved with Qrep converted to repair times



Case #6a – "Converted repair times" used only for components where repair is considered in the base case, other comp's are assumed to have a repair time of 30 days. Grace time of 7 days taken into account.

Conclusions and final remarks

- A refined methodology require refined & realistic data
  - Traditional PSA technique can use more ”qualitative” information in order to define repair probabilities.
- Conversion of repair probabilities to repair times yields interesting results
  - Repair times are easier to communicate and get acceptance for.
  - Requirements on maintenance personnel and procedures can be defined.
- Impact on results can be significant.
  - Would enable the utility to focus on what is truly risk significant.

Thank you

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