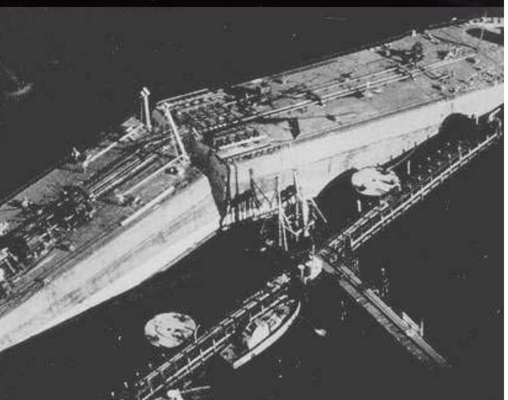

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UCL London

Integrating Monitoring in Risk Based Inspection Planning

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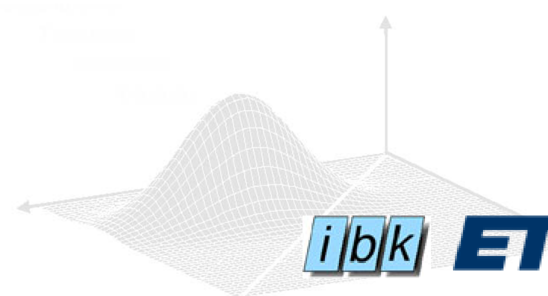
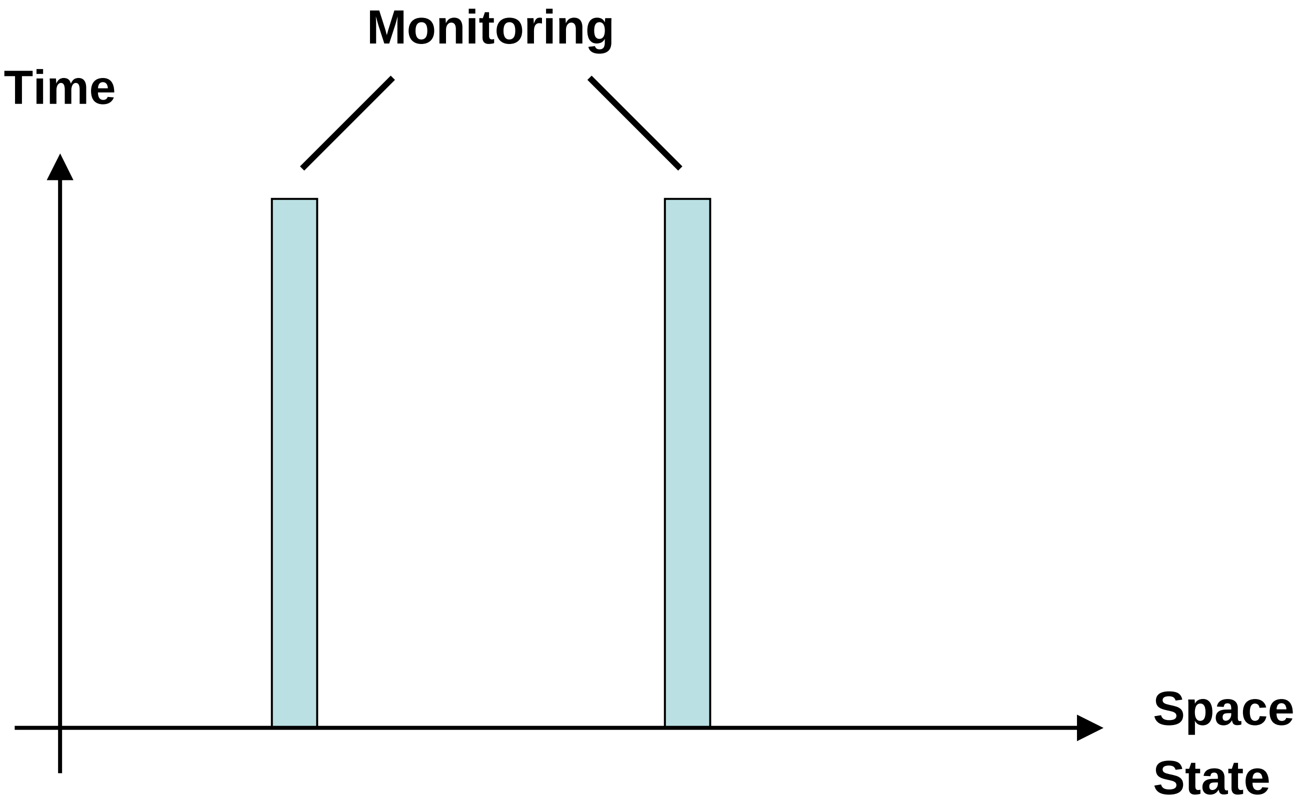
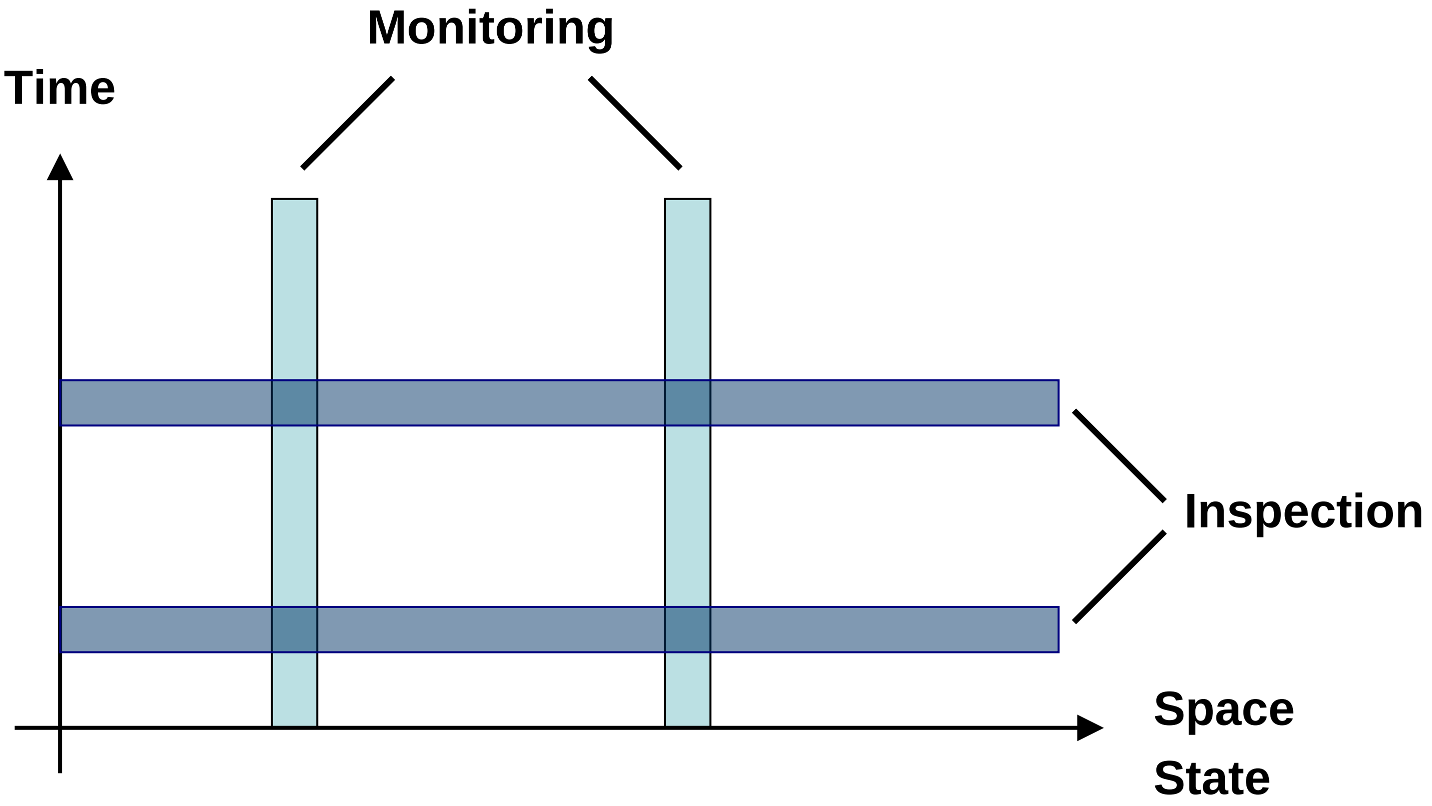


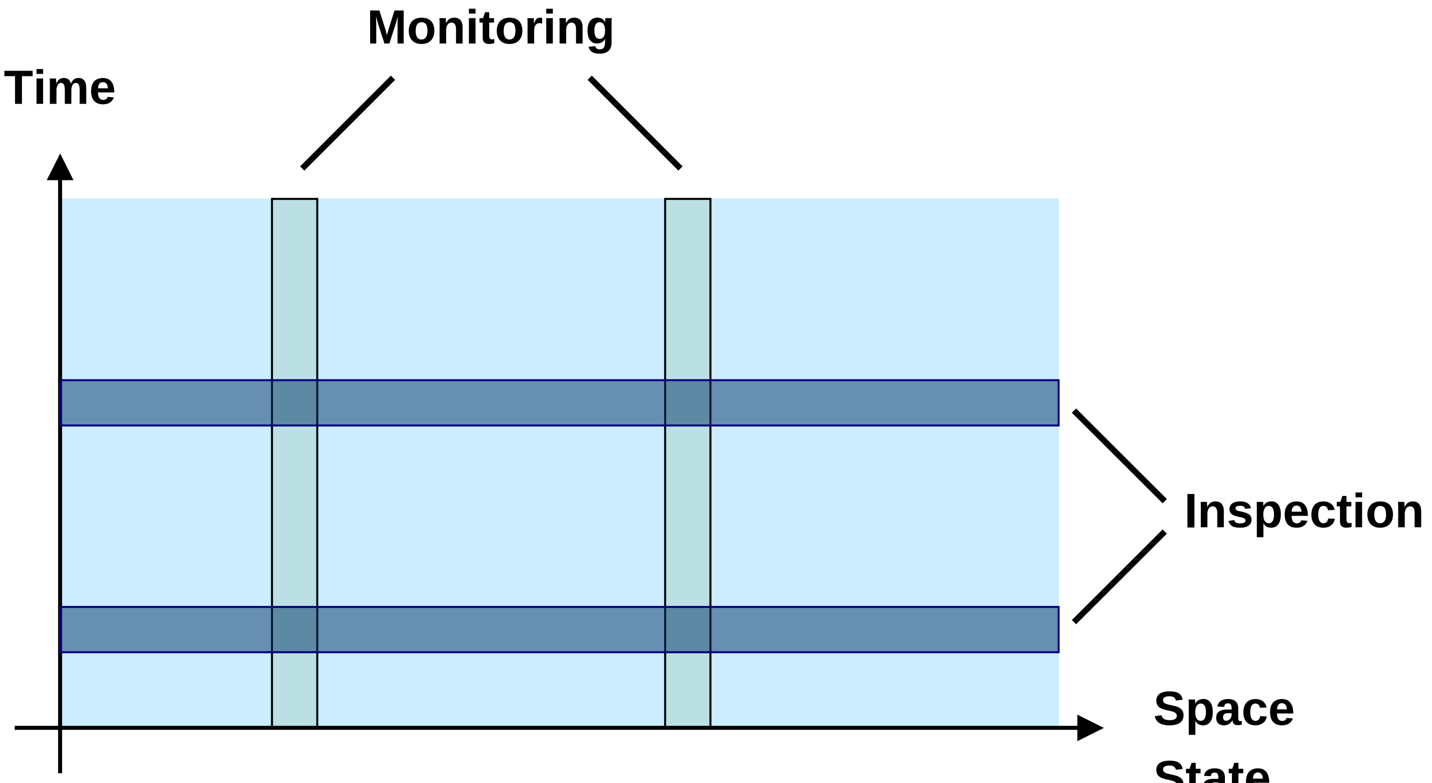
Monitoring & Inspections



Monitoring & Inspections



Monitoring & Inspections



Monitoring & Inspections

- **Monitoring:**
  - Information on the influential parameters,
  - Can be used to update the model parameters
  - Can serve as real-time „alarm system“
  - Does generally not provide direct information on the state of the system

- **Inspections:**
  - Provides (direct) information on the state of the structure
  - Serves as basis for repair decisions
  - Only indirect updating of model parameters (such as stresses, temperature, etc...)

Risk Based Inspection Planning

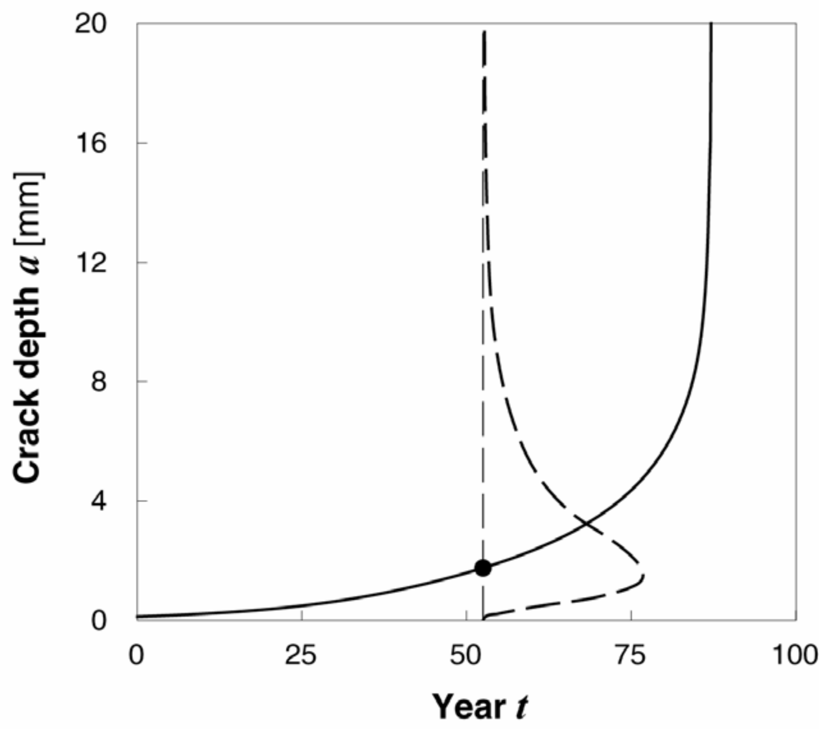
- **Based on probabilistic deterioration model and inspection model**

- **Deterioration model:**
  - containing physical parameters
  - e.g. Paris-Erdogan law

$$\frac{\mathrm{d}a}{\mathrm{d}t} = C_P \cdot \Delta K_{eff}^{\;\;m_{FM}} \cdot \nu$$

  - e.g. deWaards-Milliams

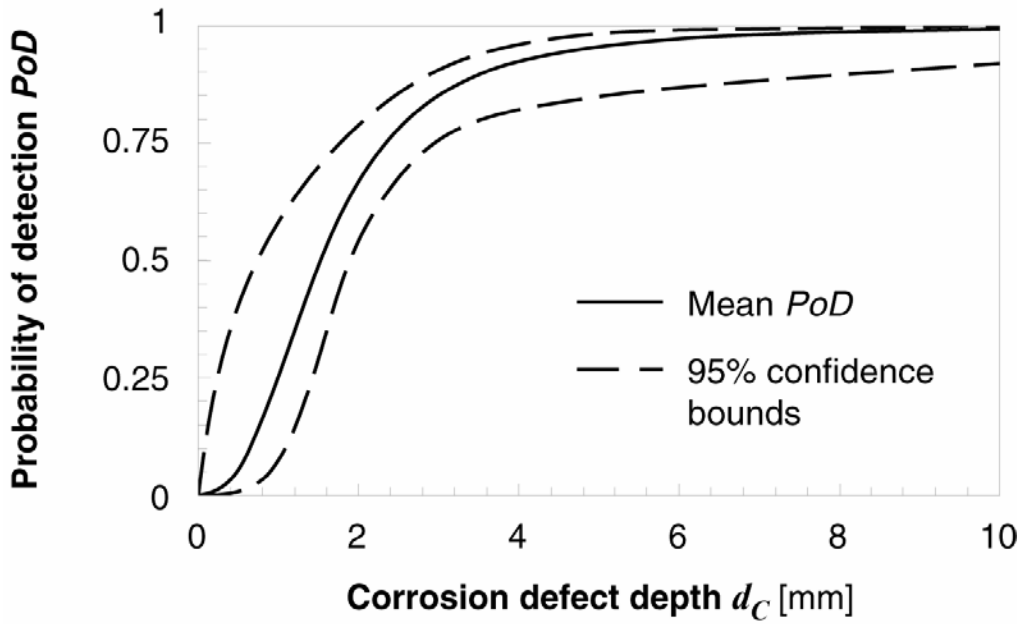
$$r_{CO_2} = 10^{\left(5.8 - 1710/T_o + 0.67 \cdot \log_{10} f_{CO_2}\right)}$$



Risk Based Inspection Planning

- **Based on probabilistic deterioration model and inspection model**

- **Inspection model:**
  - e.g. PoD



Risk Based Inspection Planning

Reliability evaluation and updating:

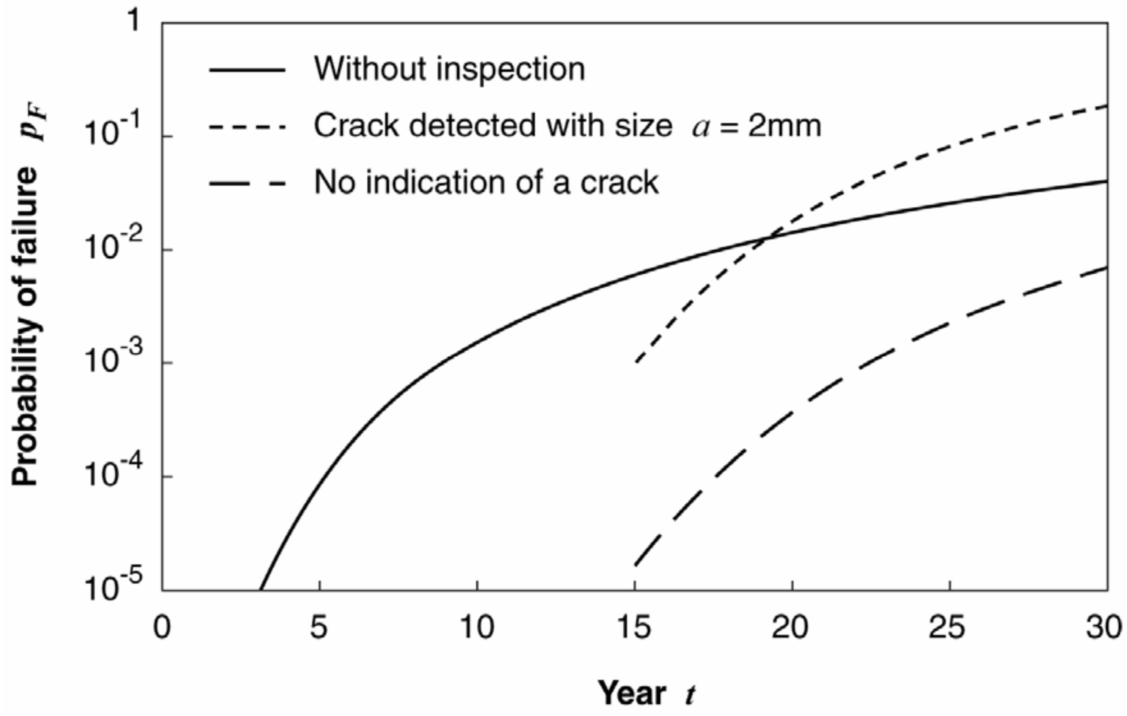
(by simulation techniques or Structural Reliability Analysis)

Reliability:

$$P(F) = P(g(\underline{\mathbf{X}}) \leq 0) = \int_{g(\mathbf{x}) \leq 0} f_{\underline{\mathbf{X}}}(\underline{\mathbf{x}}) \mathrm{d}\underline{\mathbf{x}}$$

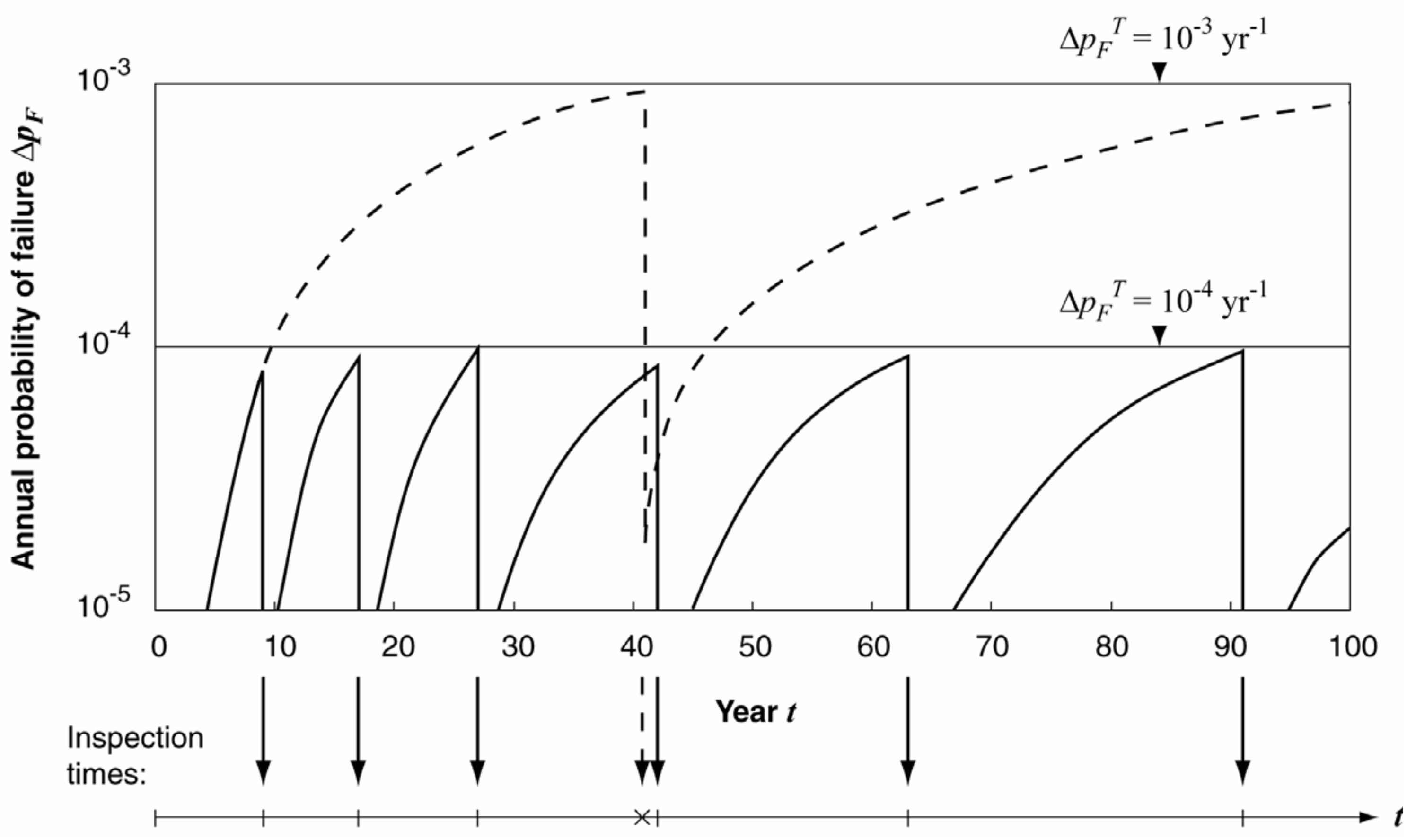
Updating:

$$P(F|O) = \frac{P(O \cap F)}{P(O)}$$



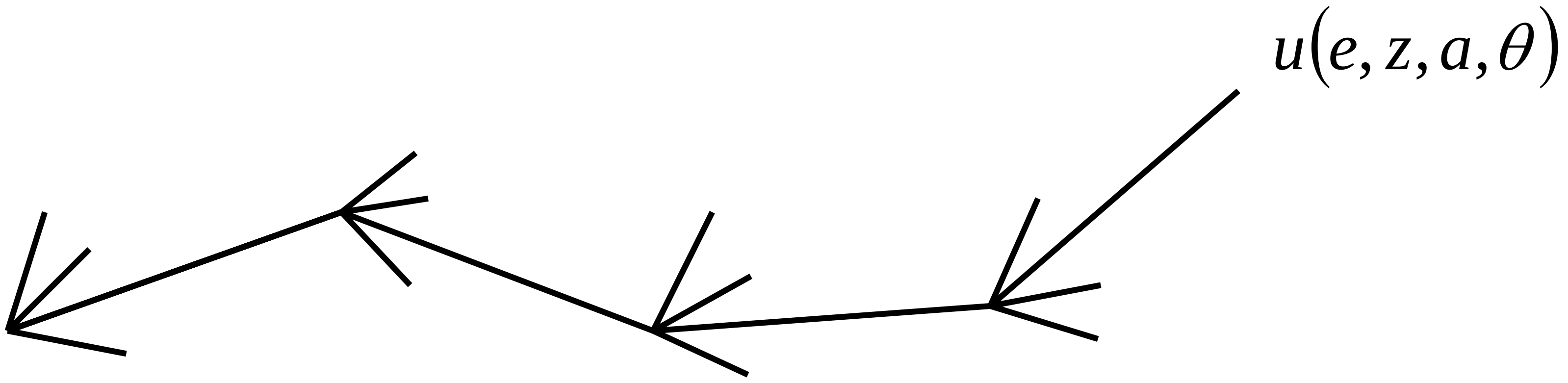
Risk Based Inspection Planning

– **Inspection times:**



Risk Based Inspection Planning (RBI)

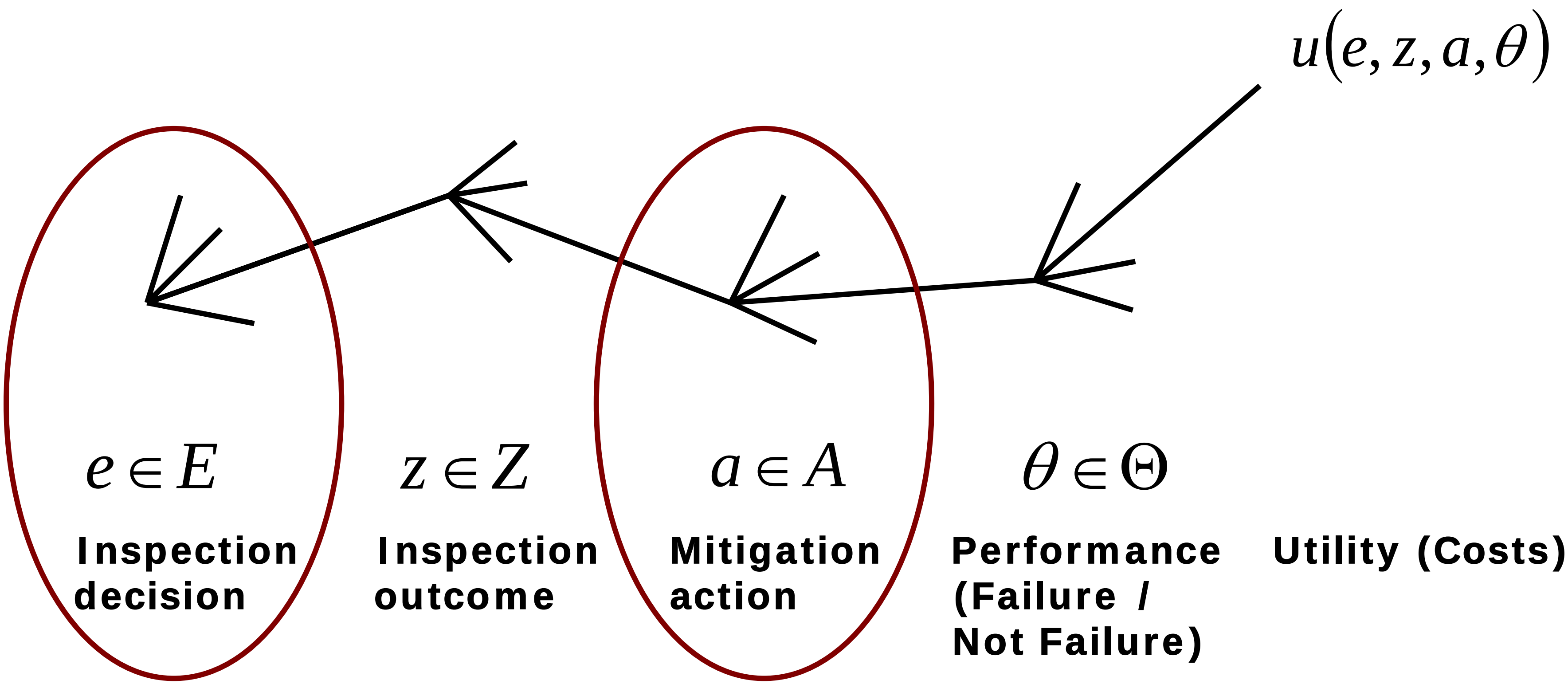
– Decision tree:



$e \in E$	$z \in Z$	$a \in A$	$\theta \in \Theta$	
Inspection decision	**Inspection outcome**	**Mitigation action**	**Performance (Failure / Not Failure)**	**Utility (Costs)**

Risk Based Inspection Planning (RBI)

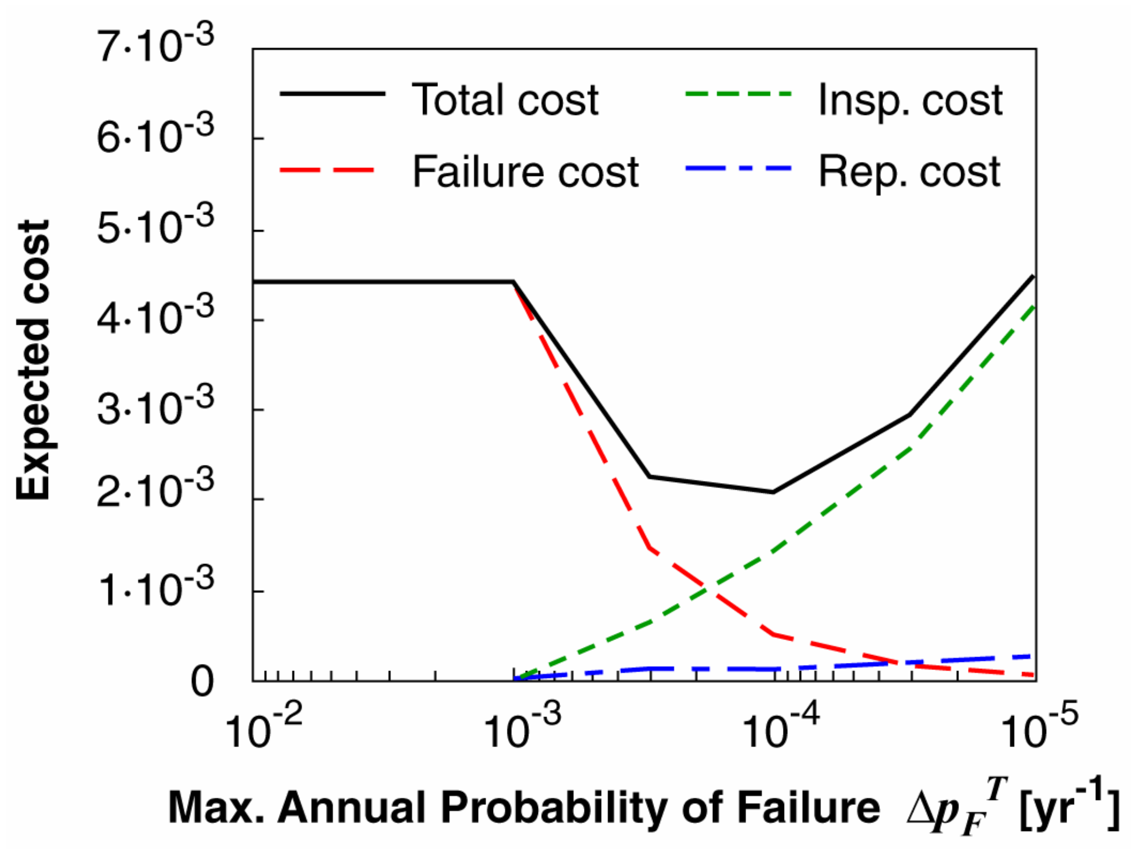
– Decision tree:



The expected utilities of any combination of e and d are calculated by integration over Z and Θ

Risk Based Inspection Planning (RBI)

– Optimizing the inspection effort:



Generic approaches to RBI

- **Inspection plans are obtained very efficiently using the generic approach to RBI**
- **as a function of the main influencing parameters**

- **e.g. for fatigue:**
  - Detail type
  - Environment
  - Geometrical properties (thickness)
  - Loading characteristics
  - Fatigue Design Factor *FDF*
  - Quality of fatigue calculations
  - Initial quality control

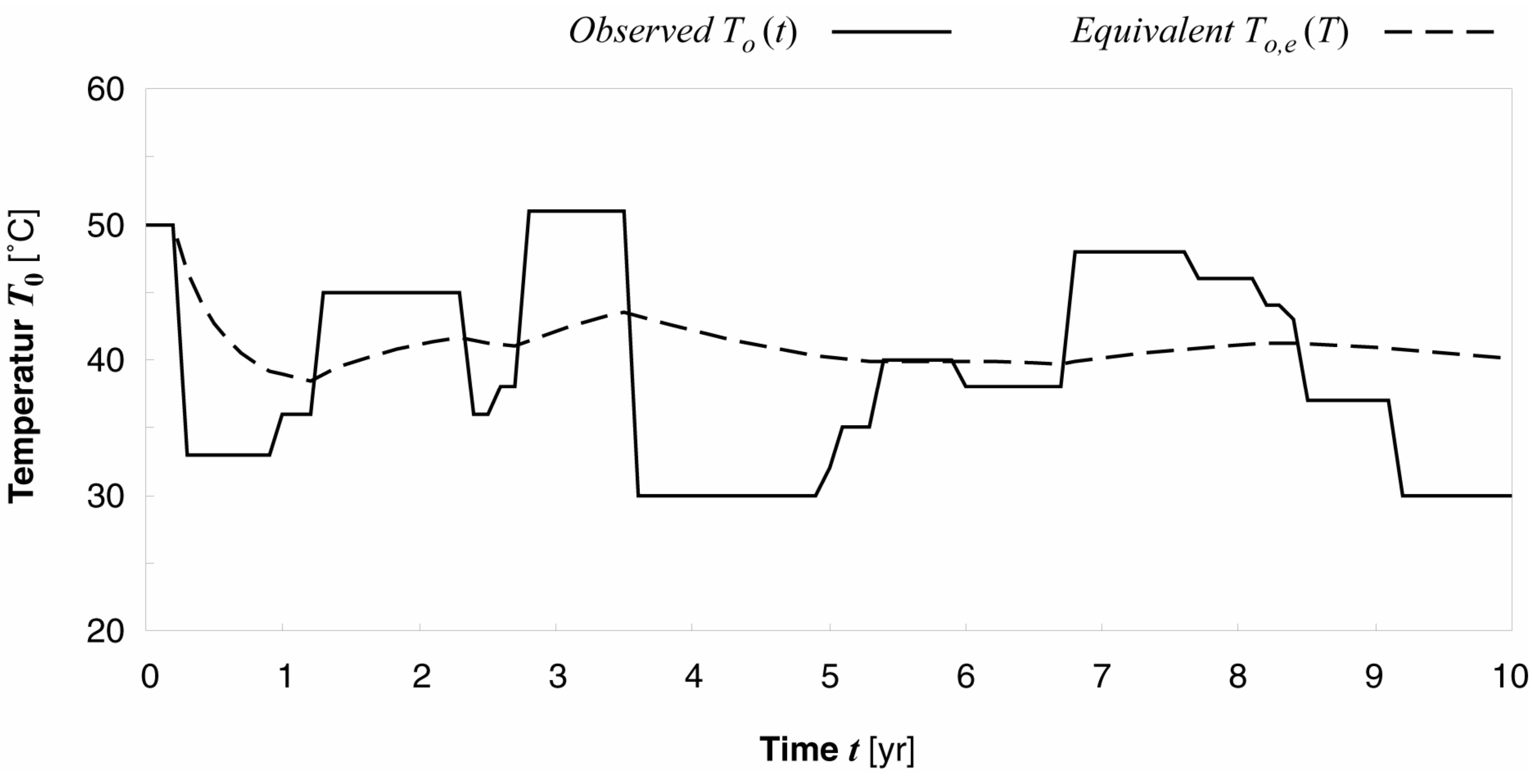
- **for CO_2 corrosion:**
  - temperature
  - pressure
  - model uncertainty
  - and others…

Integrating Monitoring in RBI

- Monitoring provides information about influencing parameters
- Inspection plans (and related risks) are constantly actualised as a function of these parameters (their changes)
- Aditionally the monitoring also reduces the uncertainty on the model parameters which are the basis of RBI
- Example: temperature in a pipeline subject to CO_2 corrosion

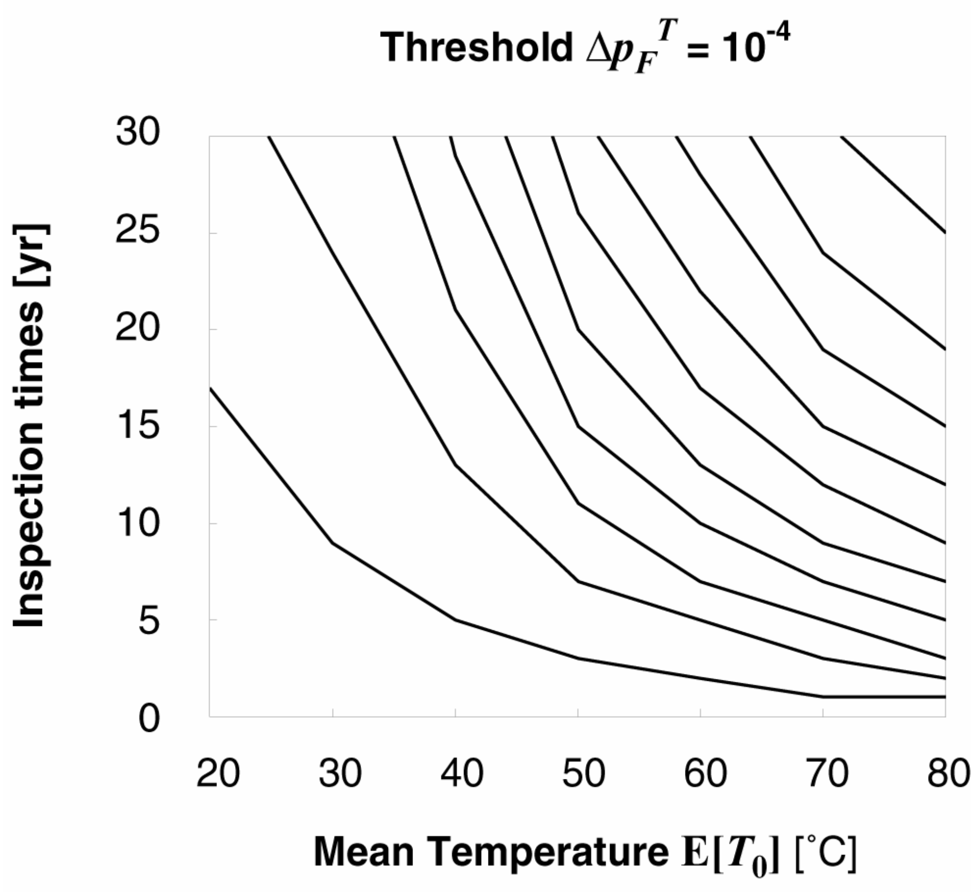
Integrating Monitoring in RBI

– **Equivalent temperature as a function of time:**



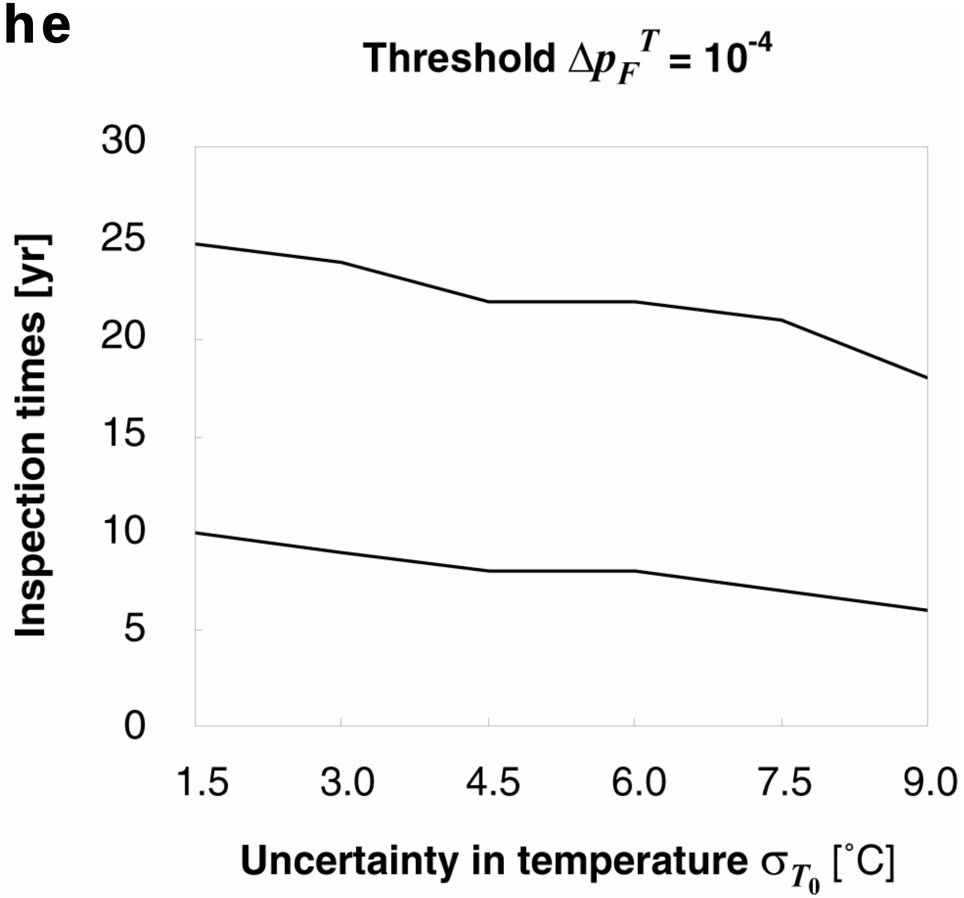
Integrating Monitoring in RBI

– **Inspection times as a function of mean temperature:**

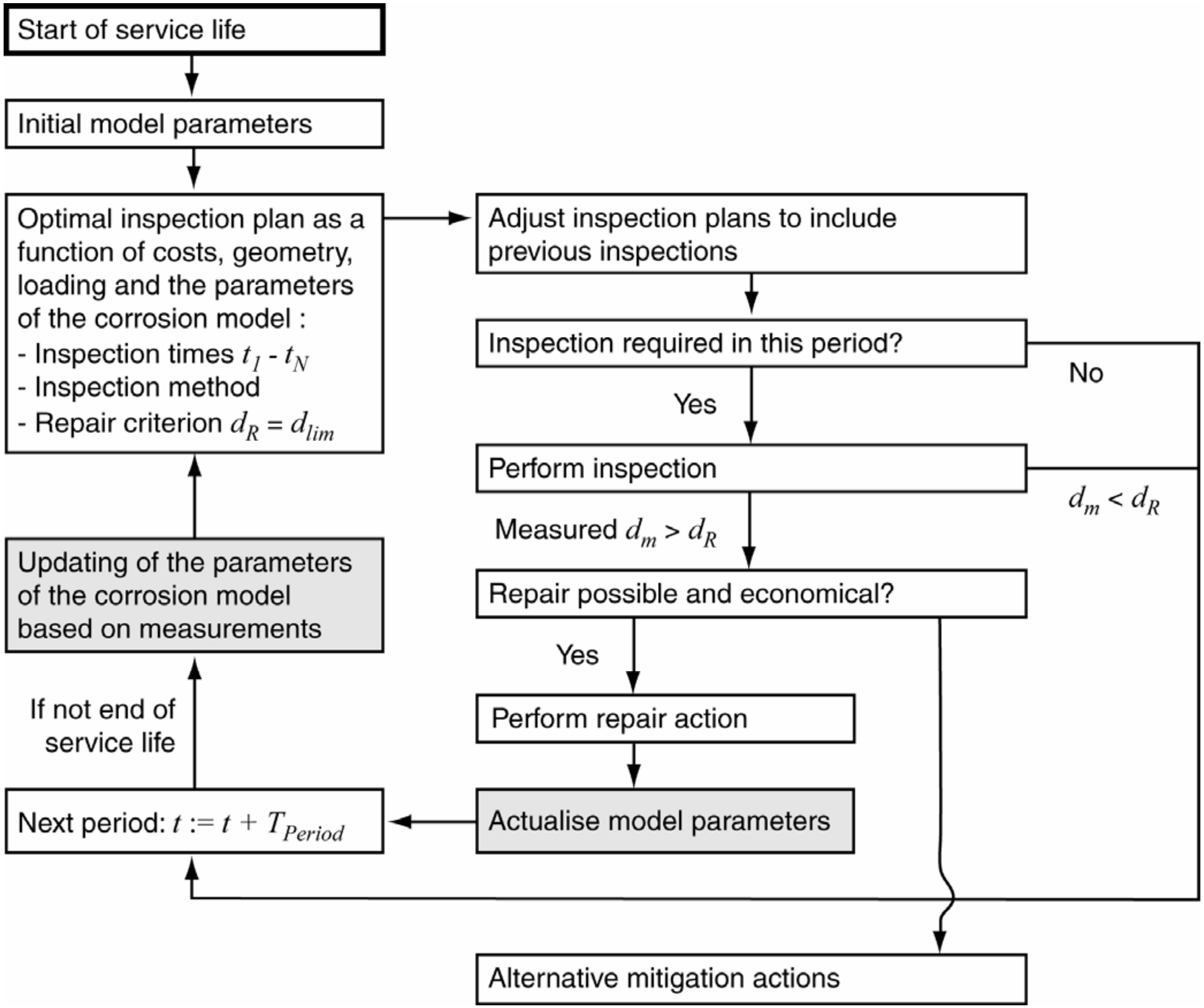


Integrating Monitoring in RBI

– **Inspection times as a function of the uncertainty on the temperature:**



Integrating Monitoring in RBI



Conclusions

– Monitoring outcomes should be used as a basis for the inspection planning

– State of the art RBI procedures provide the means for applying fully quantitative models of the deterioration and the inspection performance

➢ Fully consistent integration of monitoring and RBI

– Requires an integral asset integrity management strategy

References

Straub D. (2004). *Generic Approaches to Risk Based Inspection Planning for Steel Structures*. VdF Verlag, Zürich.

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