TWIND Summer School 2021

Introducing O&M in Marine Energy Technologies

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Operation & Maintenance

Farm Management

Resource Forecast

Maximization of Extraction Efficiency

Avoidance of equipment losses

Reduction of downtimes

Maximization of equipment availability

- ***Reduce LCOE***
- ***Maximize electricity production***

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What is Maintenance?

“the work needed to keep a road, building, machine, etc. in good condition”

in Cambridge Dictionary

“all activities aimed at keeping an item in, or restoring it to, the physical state considered necessary for the fulfillment of its production function.”

by Geraerds, W.M.J. 1985

“the engineering decisions and associated actions necessary and sufficient for the optimization of specified capability.”

by MESA (Maintenance Engineering Society of Australia)

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Reliability Vs. Maintainability Vs. Survivability

Reliability

Reliability is defined as the “probability that an item can perform a necessary function under given conditions for a given time interval”.

Maintainability

Maintainability is defined as the “ability to be retained in, or restored to a state to perform as required, under given conditions of use and maintenance”.

Survivability

Survivability is a measure of the ability of a subsystem or device to experience an event (‘Survival Event’) outside the expected design conditions, and not sustain damage or loss of functionality beyond an acceptable level, allowing a return to an acceptable level of operation after the event have passed.

Highly dependent on adequate Design Development!!!

in FRAMEWORK FOR OCEAN ENERGY TECHNOLOGY, OES 2021

- **These concepts are part of a set of areas that affect the success of a certain technology (i.e. Affordability, Manufacturability, Power Capture, etc.)**

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Why do we need to maintain assets?

- Preserve the functioning of systems
- Reduce or (ideally) eliminate stoppage times of equipment
- Avoid economic losses
- Prevent reputational damage
- Avoid catastrophic failures that may lead to loss of lives (human and others)

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Why do we need to maintain assets?

- For marine energy devices, proven reliability is particularly necessary for **Technology Credibility**
- Wave devices have been particularly prone to premature failures

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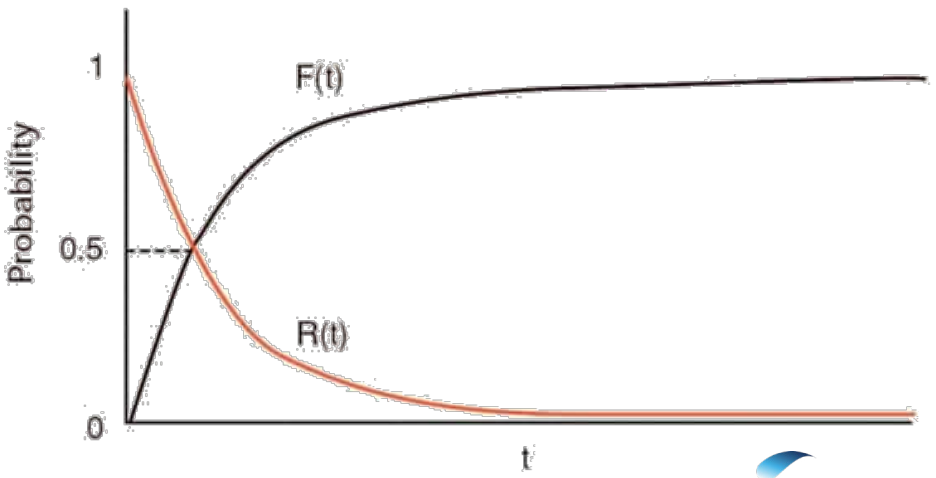
What is a failure?

A phenomenon that causes an equipment or system to be uncapable of performing its intended function in a safely, reliably and cost-effectively manner

For a certain system, the **cumulative probability of a failure** occurring at a certain time **t** (F(t)) is associated with the **reliability** at time **t** (R(t)), such that:

$$\boldsymbol{F(t) = 1 - R(t)}$$



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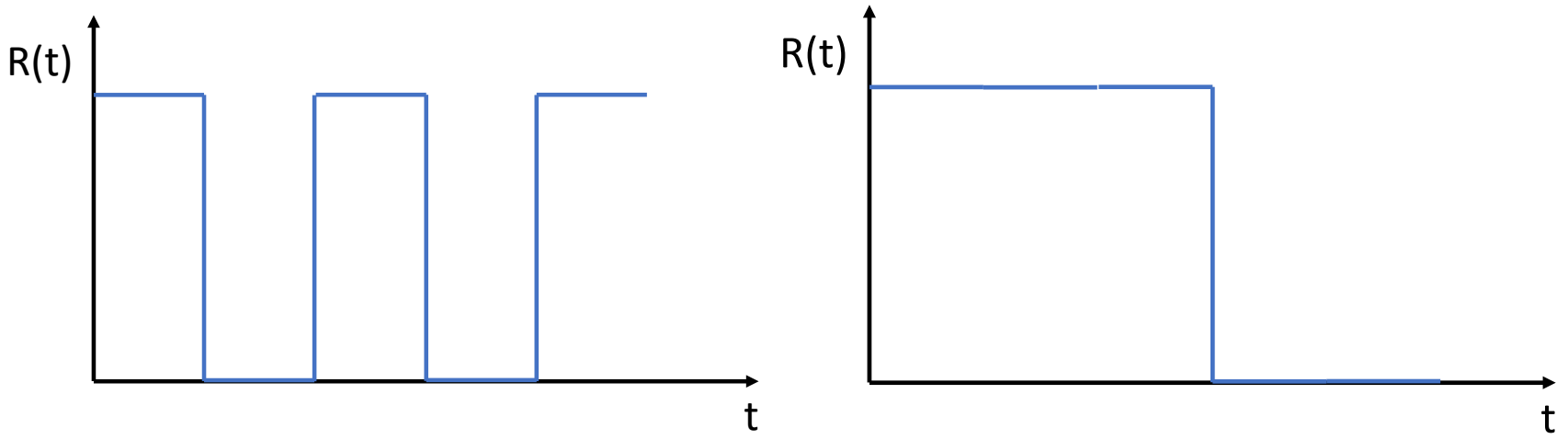
What is a failure?

But we can have different types of failures!!!

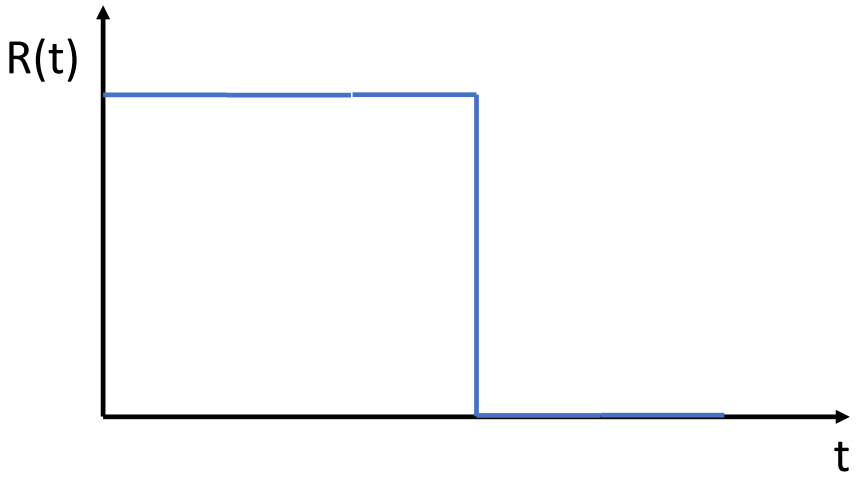
Intermittent vs Extended:

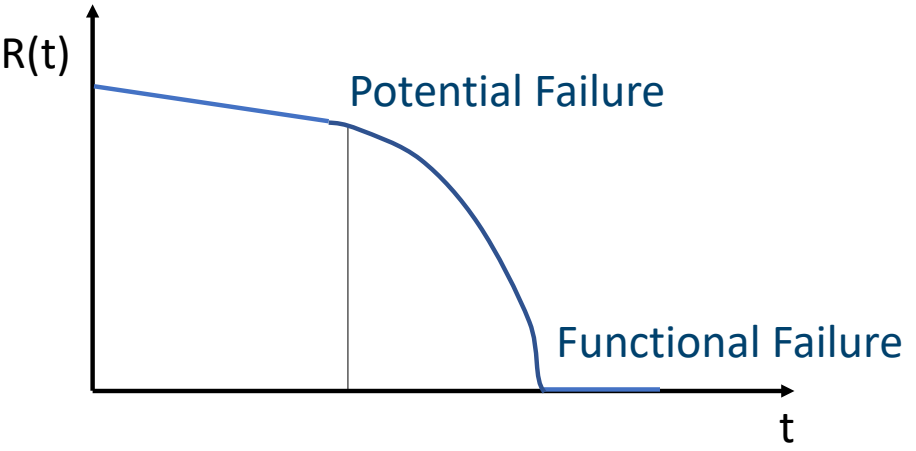


What is a failure?

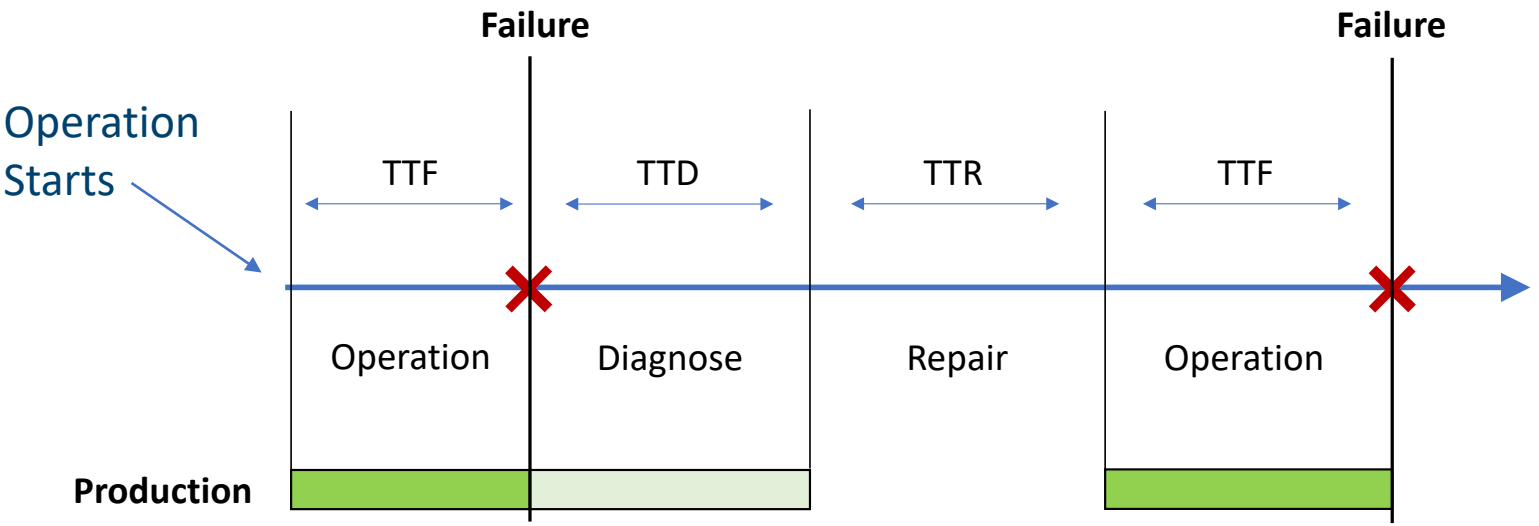
Extended failures may be: Complete or Partial

Extended failures may be: Sudden (Catastrophic) or Gradual (Degraded)





Introduction to Maintenance Concepts



- By averaging TTF, TTD and TTR, we will obtain the MTBF, the MTTD and the MTTR
- Different Maintenance strategies will impact the MTTD, the MTTR, and eventually, the MTBF, as failures may be detected even before occurring!

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Introduction to Maintenance Concepts

- If the MTBF is an average for a failure, then our Failure Rate comes:

$$\lambda = \frac{1}{MTBF}$$

- **However!** The MTBF is usually NOT a fixed variable in the real world

$$\lambda\,(t)$$

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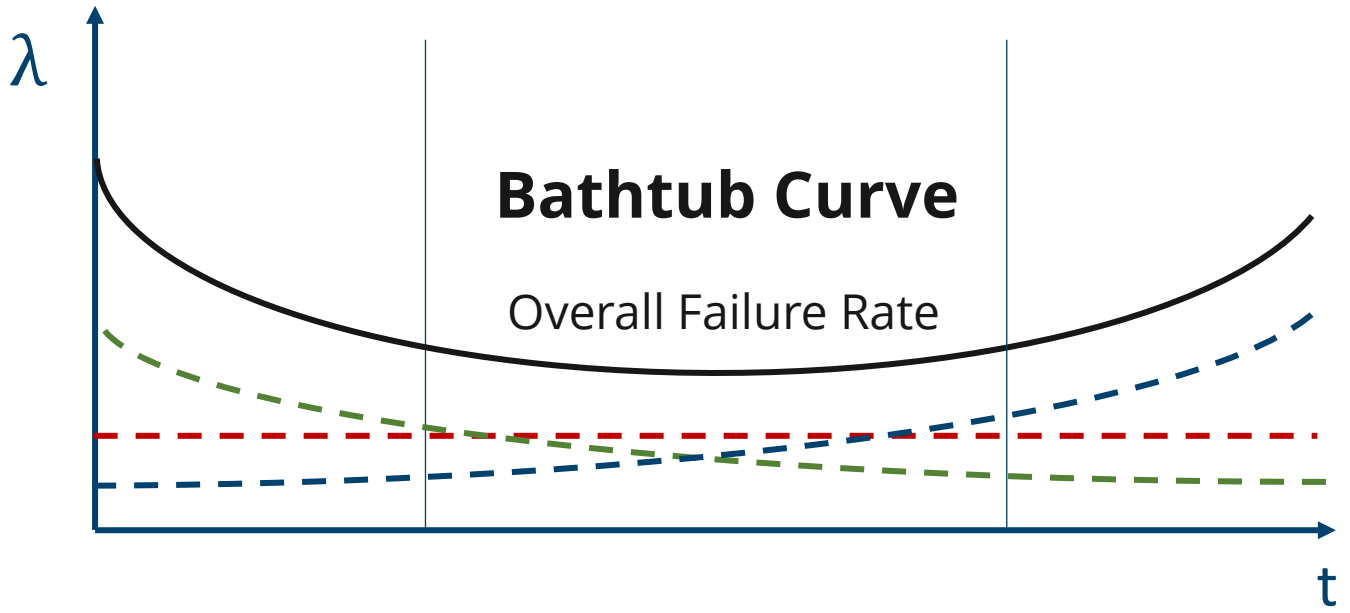
Introduction to Maintenance Concepts



- Constant Failure Rate
- Infant Mortality – Decreasing Failure Rate
- Wear-out effects – Increasing Failure Rate

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Introduction to Maintenance Concepts

- For constant failure rates, an exponential distribution can be used to describe the reliability of a structure

$$\lambda = \frac{1}{MTBF}$$

$$R(t) = e^{-\lambda t}$$

- For time-dependent failure rates, other more complex distributions are used – notably the Weibull distribution

$$R(t) = e^{-\left(\frac{t-\gamma}{\eta}\right)^{\beta}}$$

Maintenance Strategies

- **We may adopt different strategies to maintain our devices**
  - Corrective
  - Predetermined
  - Preventive
  - Condition-based
  - Predictive

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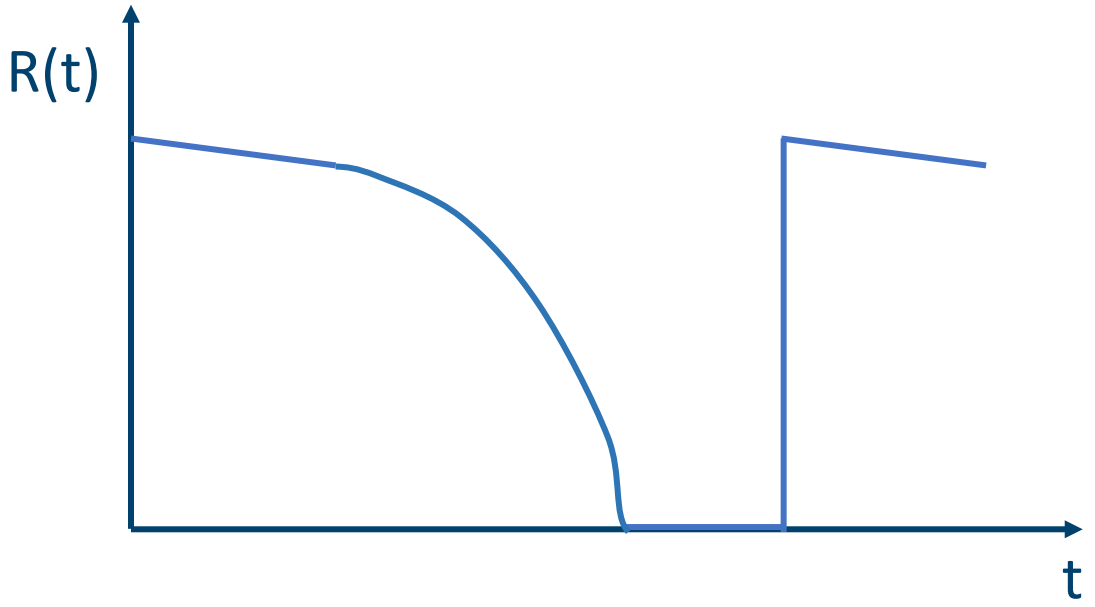
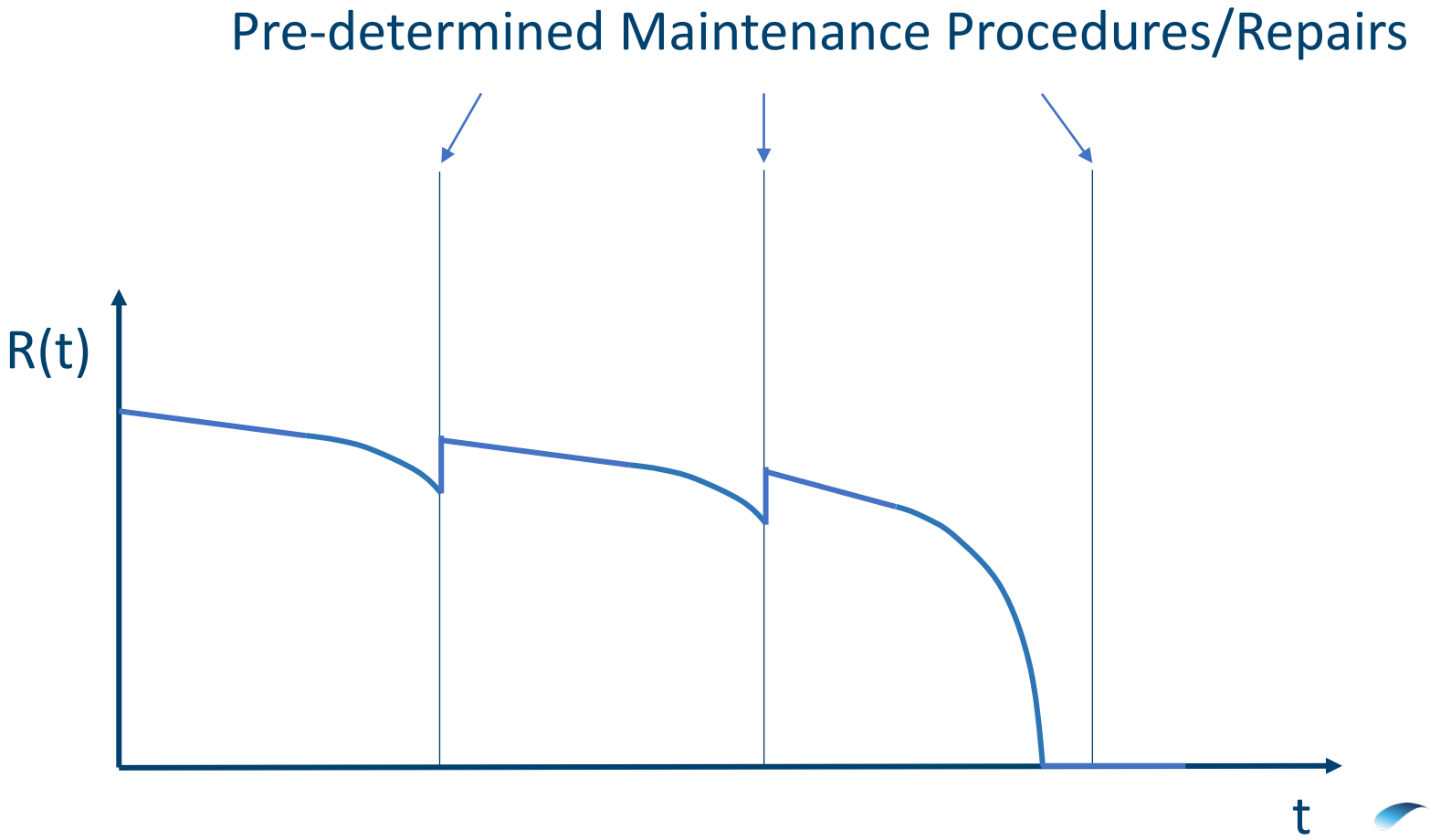
Maintenance Strategies

- **Corrective Maintenance**



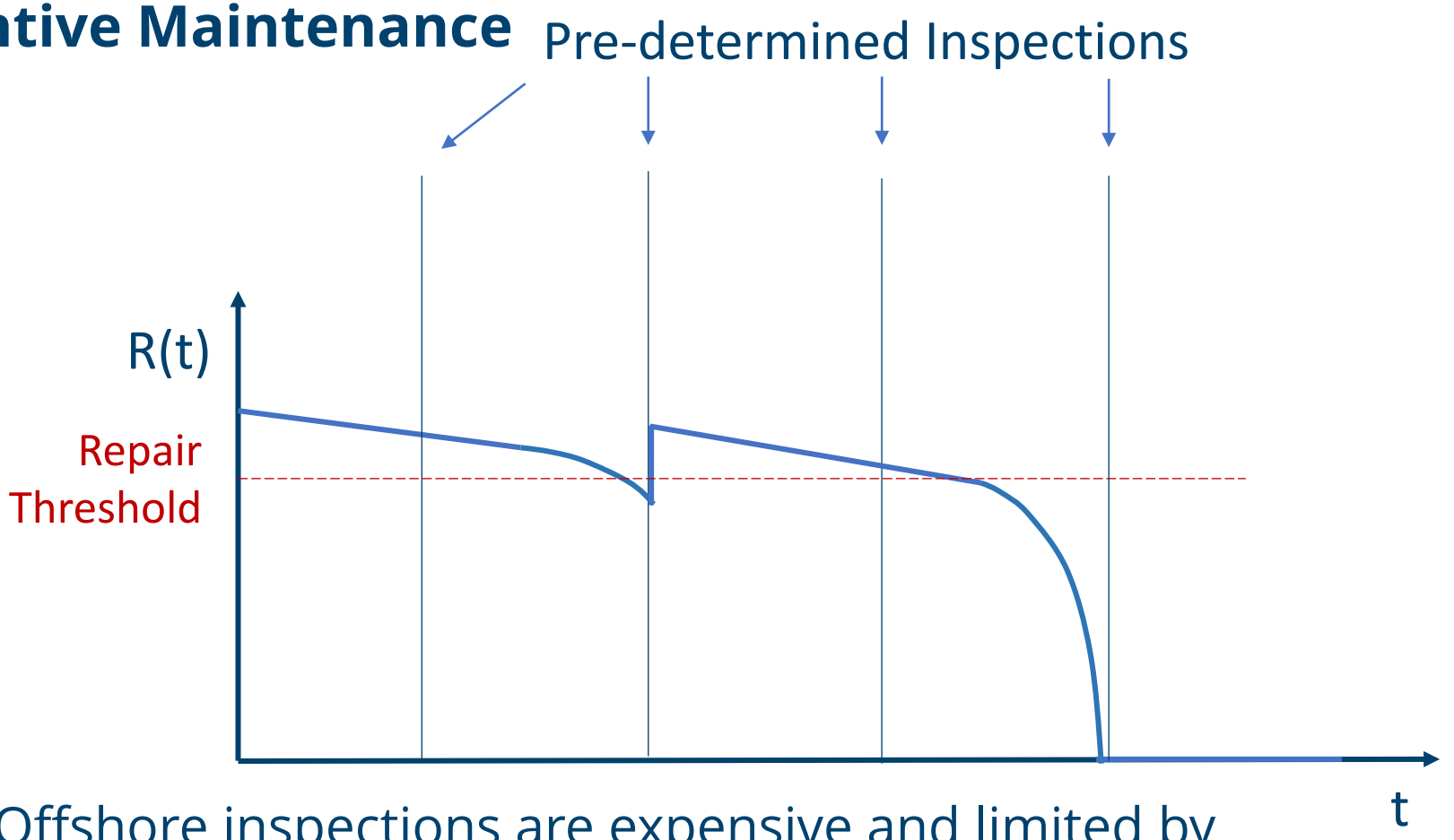
Maintenance Strategies

- **Predetermined Maintenance**



Maintenance Strategies

- **Preventive Maintenance**



  - Offshore inspections are expensive and limited by weather windows!!

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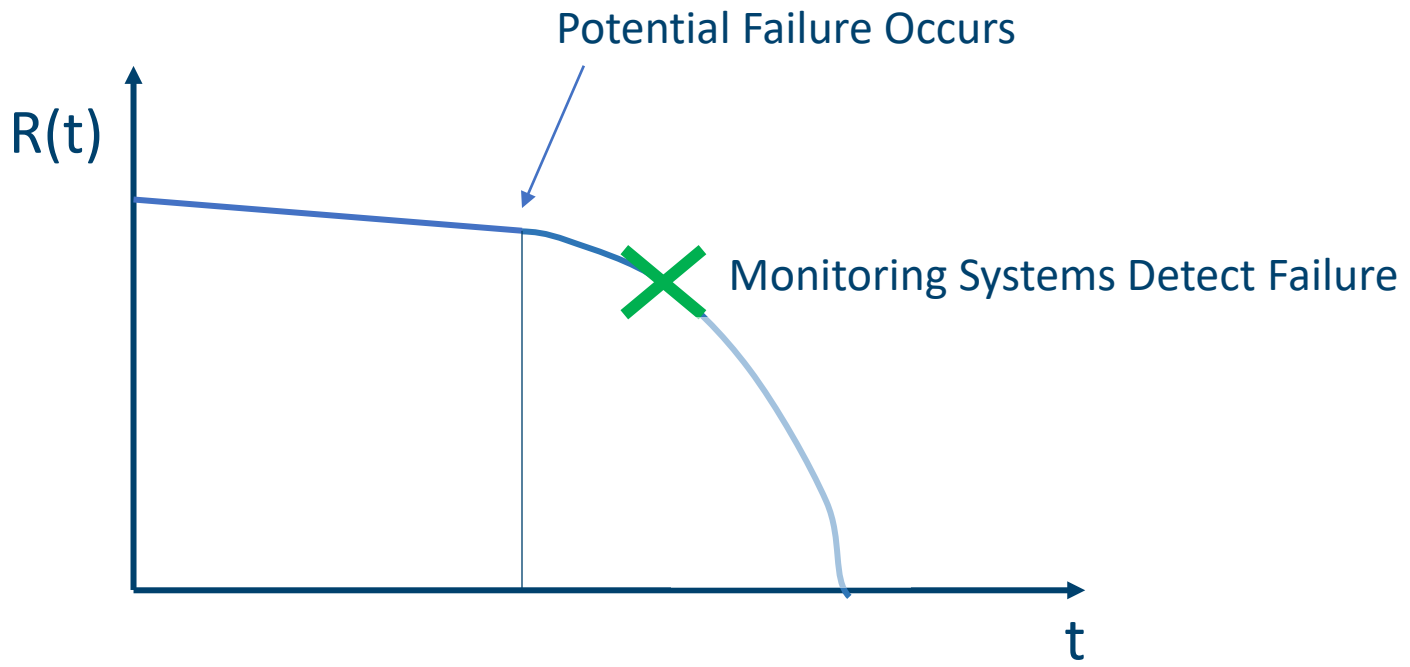
Maintenance Strategies

- **Condition-based Maintenance**



  - Monitoring systems may not detect all the possible failure modes….

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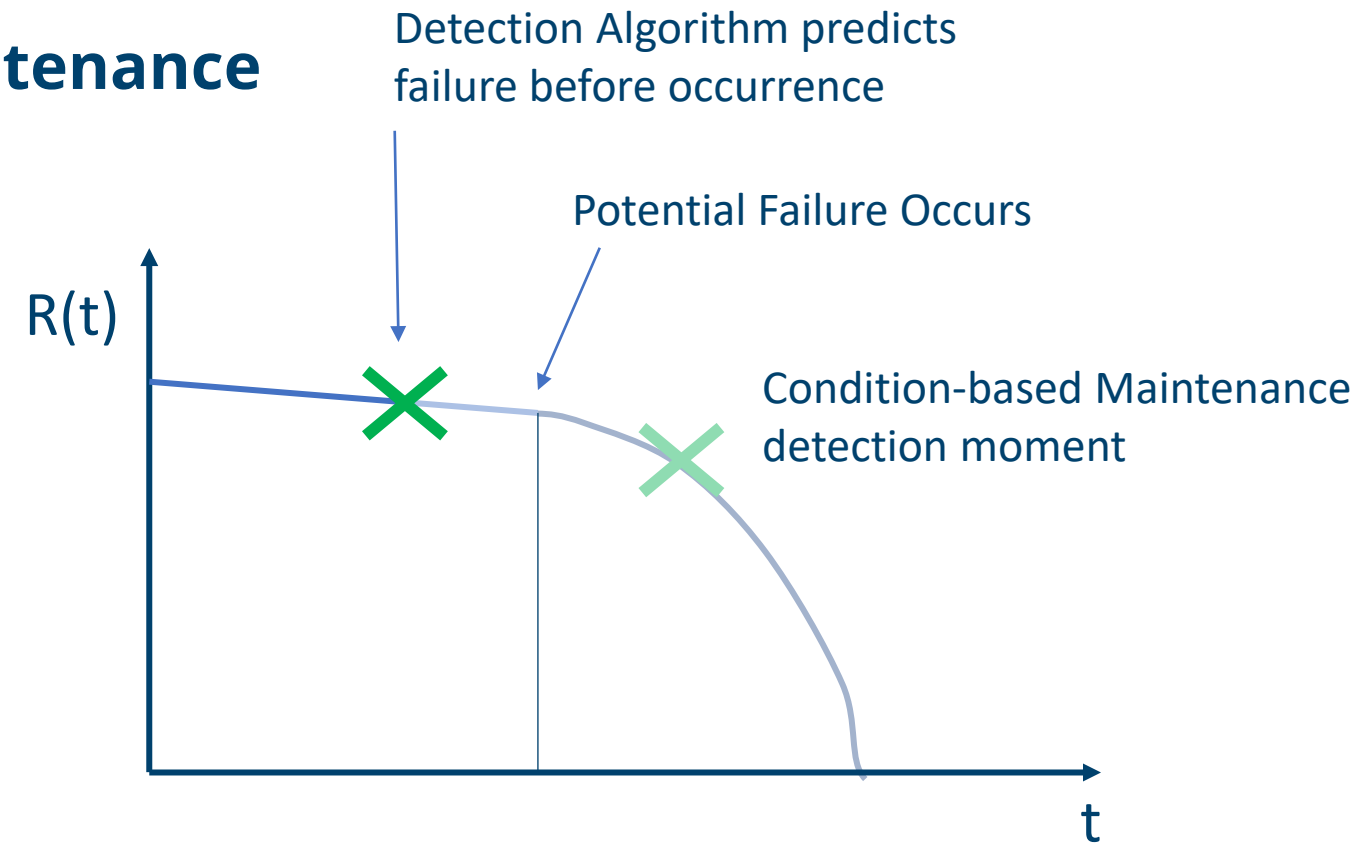
Maintenance Strategies

- **Predictive Maintenance**



  - Best approach for marine energy devices probably includes a hybrid maintenance strategy of predetermined, preventive and predictive

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Economics of O&M

- **O&M decisively impacts the viability of renewable technologies**
  - One of the most relevant indicators for viability is LCOE:

$$LCOE\left(\frac{€}{MWh}\right) = \frac{CAPEX + \sum \frac{OPEX_t}{(1+r)^t}}{\sum \frac{E_t}{(1+r)^t}}$$

    - For Offshore Wind, OPEX account for 20 – 25% of the LCOE
      - Note that OPEX is highly discounted in the final operational years

- Note that if Maintenance is successful in maintaining equipment (raising availability), more electricity will be produced throughout the operational period – decreasing LCOE

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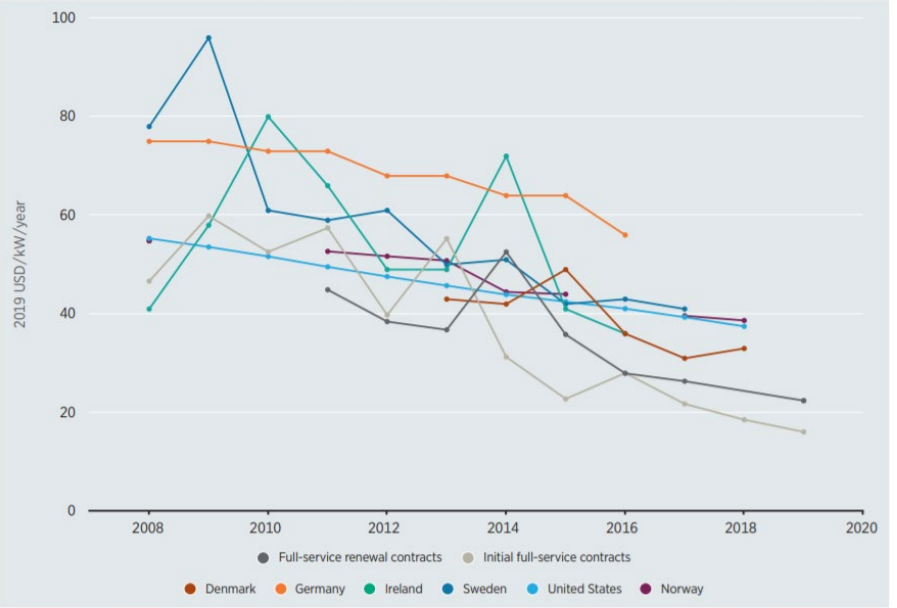
Economics of O&M

- OPEX is not only related with Maintenance, but also administration and management, renting and licences, insurance and other financial costs

- For a certain technology, OPEX are expected to decrease (per unit of energy produced) with time, as scale and learning effects take place



Source: BNEF, 2019b and IEA Wind, 2020.

Example for decreasing OPEX in onshore wind; similar trends are expected for marine technologies

In: RENEWABLE POWER GENERATION COSTS IN 2019, IRENA

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Thank you for your attention! ☺

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