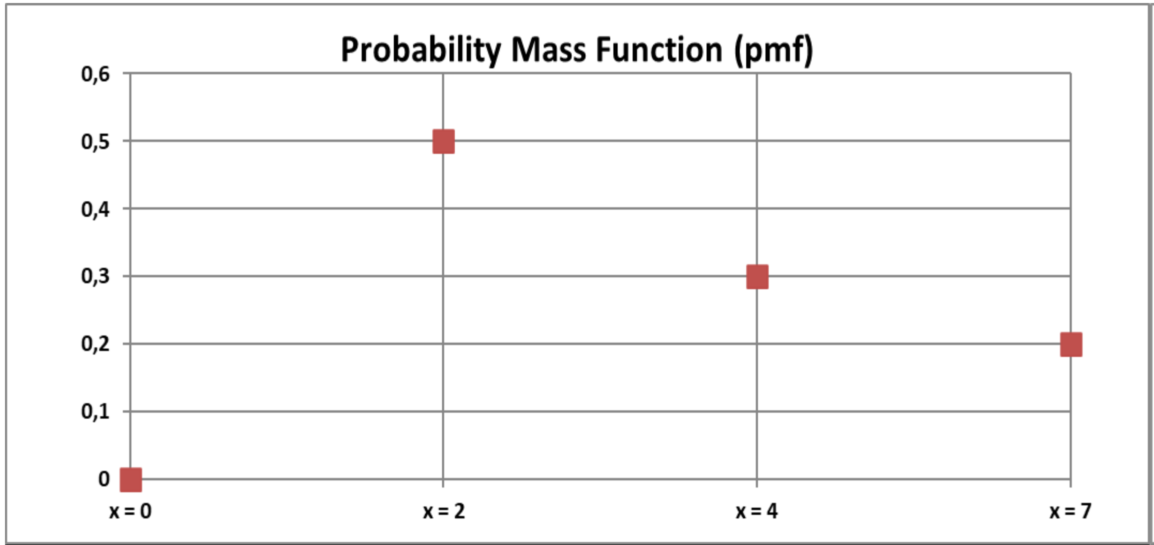
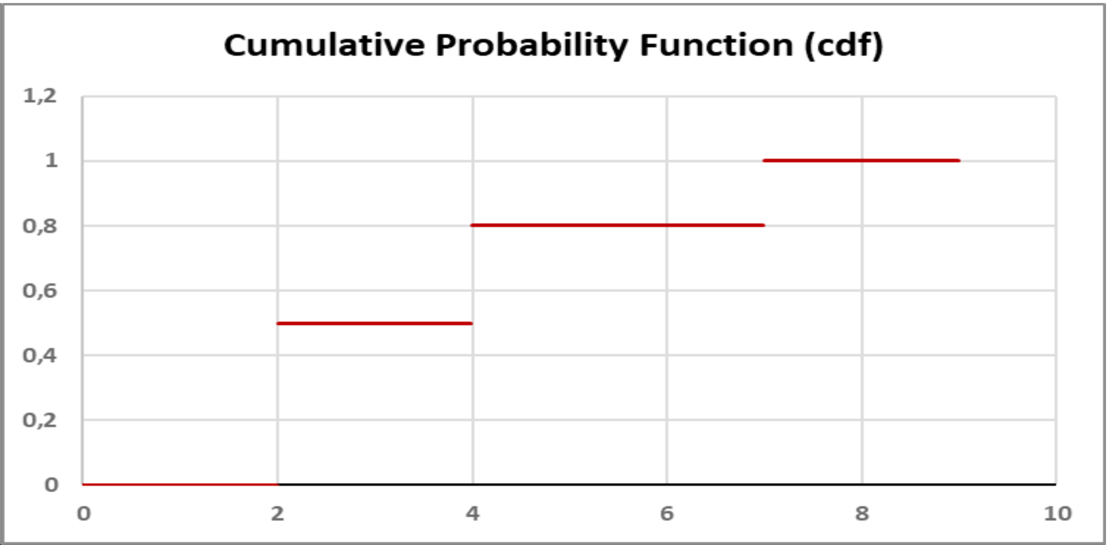
Reliability Basics: Probability Functions

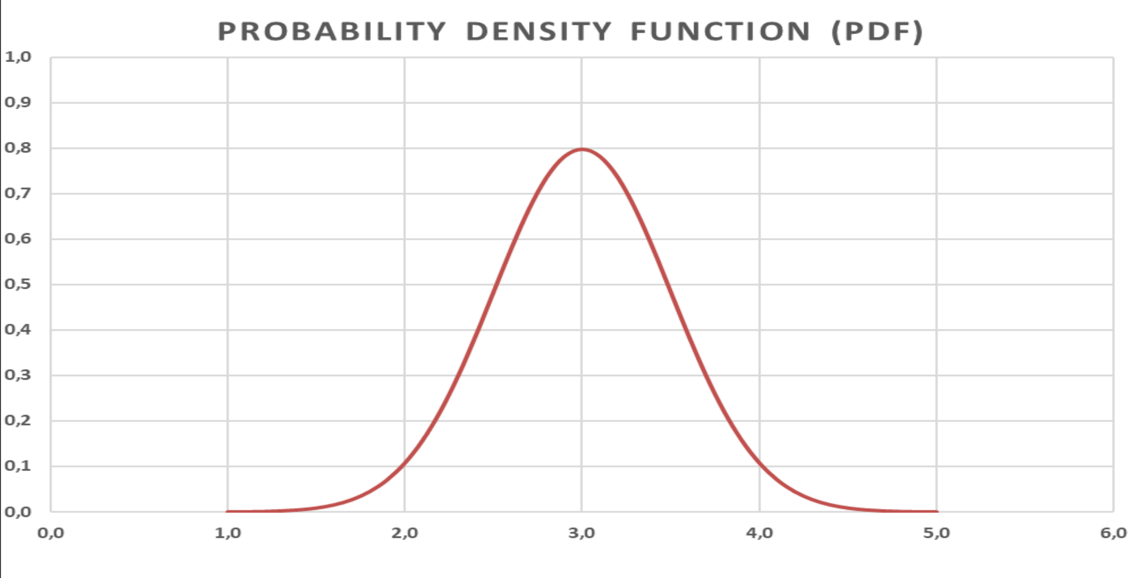
- Support = the set where a probability function is defined.
- Probability functions can be clustered according to their support.
- This helps to identify the class of probability functions which can be used for a specific question.

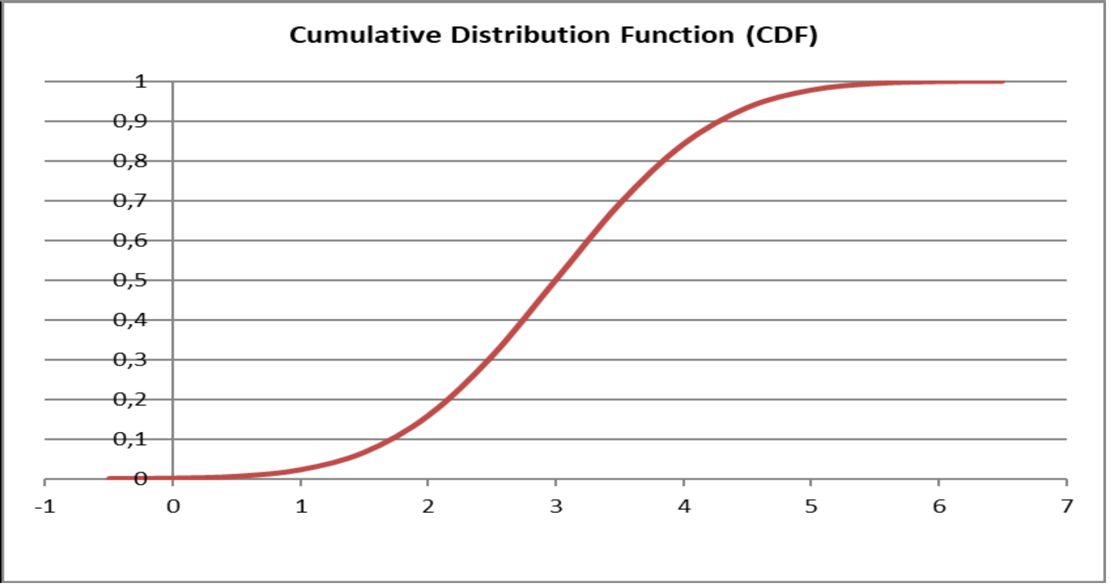
Support		Probability functions
$(-\infty, \infty)$	Whole real axis	Normal distribution, student distribution, logistic distribution, …
$[0, -\infty)$	Positive real axis	χ^2-Distribution, lognormal distribution, exponential distribution, …
$\{0,1,2, 3, \dots\}$	Natural numbers	Poisson distribution, geometric distribution, negative binomial distribution, …

Reliability Basics: Distributions









Reliability Basics: Binomial distribution

- **Cumulative Distribution Function (cdf)**:
  - **Cumulative distribution function cdf** determines the probability for X to take smaller or equal values of x

$$F(x) = P\,(X \leq x)$$

- **Probability Density Function (pdf):**
  - **PDF** is the first derivative of the **cumulative distribution function** (**cdf**):

$$f(x) = F'(x);$$

- **Binomial distribution**
  - It is a discrete probability distribution that describes the number of failures in a series of independent trials with repetitions.

- **Probability mass function (pmf)**

$$p(k, n) = \binom{n}{k} p^k \,(1 - p)^{n-k}$$

  - **p =** the probability of a device to fail
  - **1 – p =** the probability that a device will not fail
  - **n** = the number of trials/experiments
  - **k** = the number of failures, sometimes also called “successes”

Reliability Basics: Reliability Function

- **Reliability function R(t)**
  - **R(t)** gives the probability that a device will operate for a certain time:

$$R(t) = P(T > t)$$

    - **T** – random variable, time-to-failure
    - **t** – a particular time point
    - **P(T > t)** – the probability that the failure will not occur before the time **t.**

$$R(t) = 1 - F(t)$$

    - **F(t)** – cumulative distribution function

- Exponential Distribution

  CDF: $F(t; \lambda) = 1 - e^{-\lambda t}$

  PDF: $f(t; \lambda) = \lambda e^{-\lambda t}$

- Weibull Distribution

  CDF: $F(t) = 1 - e^{-\left(\frac{t}{\eta}\right)^{\beta}}$

  PDF: $f(t) = \frac{\beta}{\eta^{\beta}} t^{\beta - 1} e^{-\left(\frac{t}{\eta}\right)^{\beta}}$

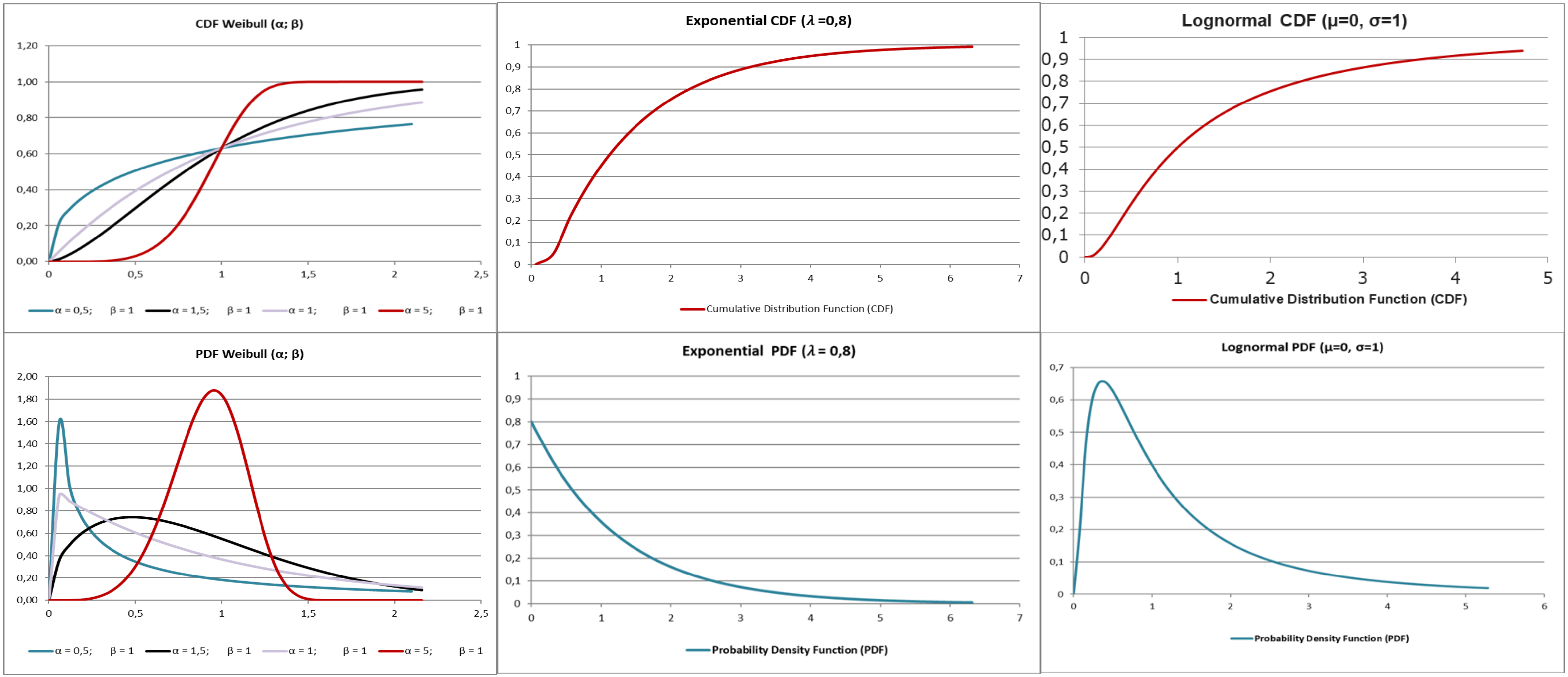
- Lognormal Distribution

  CDF: $F(t) = \Phi\left(\frac{ln(t) - \mu'}{\sigma'}\right)$

  PDF: $f(t) = \frac{1}{t \cdot \sigma' \cdot \sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{ln(t) - \mu'}{\sigma'}\right)^2}$

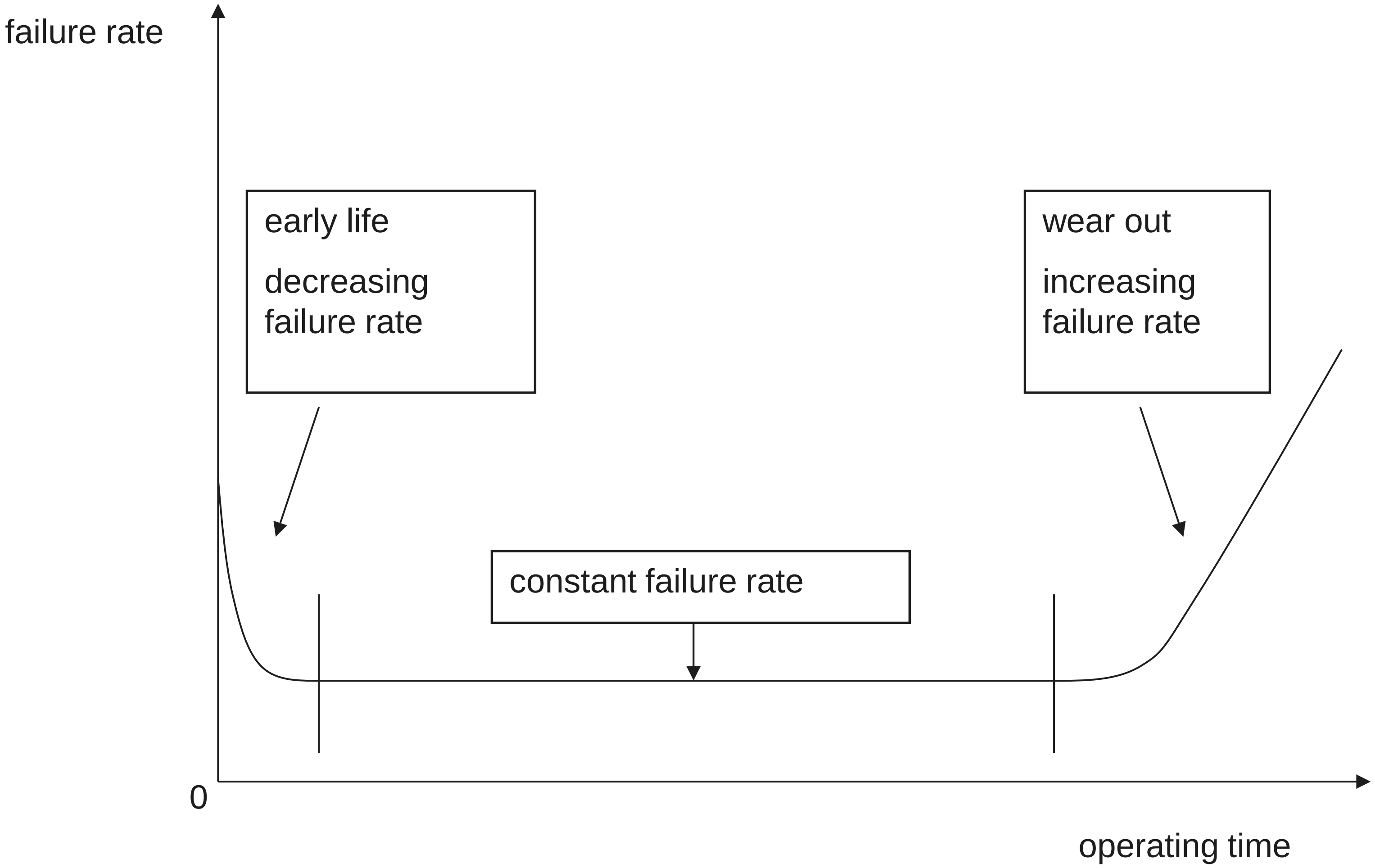
Reliability Basics: Lifetime Distribution Functions

– **Weibull, Exponential, and Lognormal CDFs and PDFs**



Reliability Basics: Failure Rate Function

- **Failure rate**
  - Also, the term hazard rate, *h(t),* is used for the failure rate.
  - $h(t) = \frac{f(t)}{R(t)} = \frac{f(t)}{1-F(t)}$
  - The failure rate function of semiconductors typically follows the so-called bathtub curve.



Reliability Basics: FIT-Rate

- FIT-Rate
  - The communicated FIT-rate typically represents the constant part of the bathtub curve.
  - FIT-rate gives the number of failures per 10^9 operating hours
  - Mean time between failures (MTBF) = 10^9 / FIT-rate

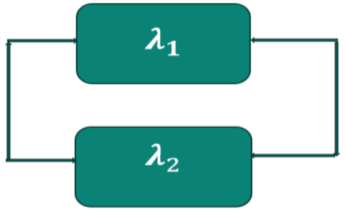
- FIT-rates can be given as
  - Point estimators
  - Interval estimators at a certain confidence level (CL), e.g., at 90% CL.

- The FIT-rate is temperature dependent.
  - Typically, the acceleration factor follows the Arrhenius law.
  - $Acceleration\ Factor\ (T) = e^{\frac{\Delta E}{k}\left(\frac{1}{T_{use}}-\frac{1}{T_{reference}}\right)}$
    - $T_{reference}$ = temperature at which the FIT-rate is given
    - T_{use} = usage temperature
    - k = Boltzmann constant.
    - ΔE = activation energy. A typical value for semiconductors is, e.g., 0.7 eV.

Reliability Basics: Reliability of systems

- Reliability block diagram
  - Represents the reliability of a system, like semiconductors mounted on a PCB
  - The total failure rate λ_{total} depends on redundant and not redundant structures
  - Reliability block diagram pictures the reliability structure
    - Serial system

      - For exponential distribution: $\lambda_{total} = \lambda_1 + \lambda_2$
    - Parallel system



      - For exponential distribution: $\frac{1}{\lambda_{total}} = \frac{1}{\lambda_1} + \frac{1}{\lambda_2}$

Reliability Basics: Event Evaluation

- **Event evaluation**
  - An event evaluation is a performance and reliability assessment, typically on delivered devices.
  - Based on available data, the likelihood of deviations = events at our customers is assessed.
  - Results can be regularly reviewed and updated.

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