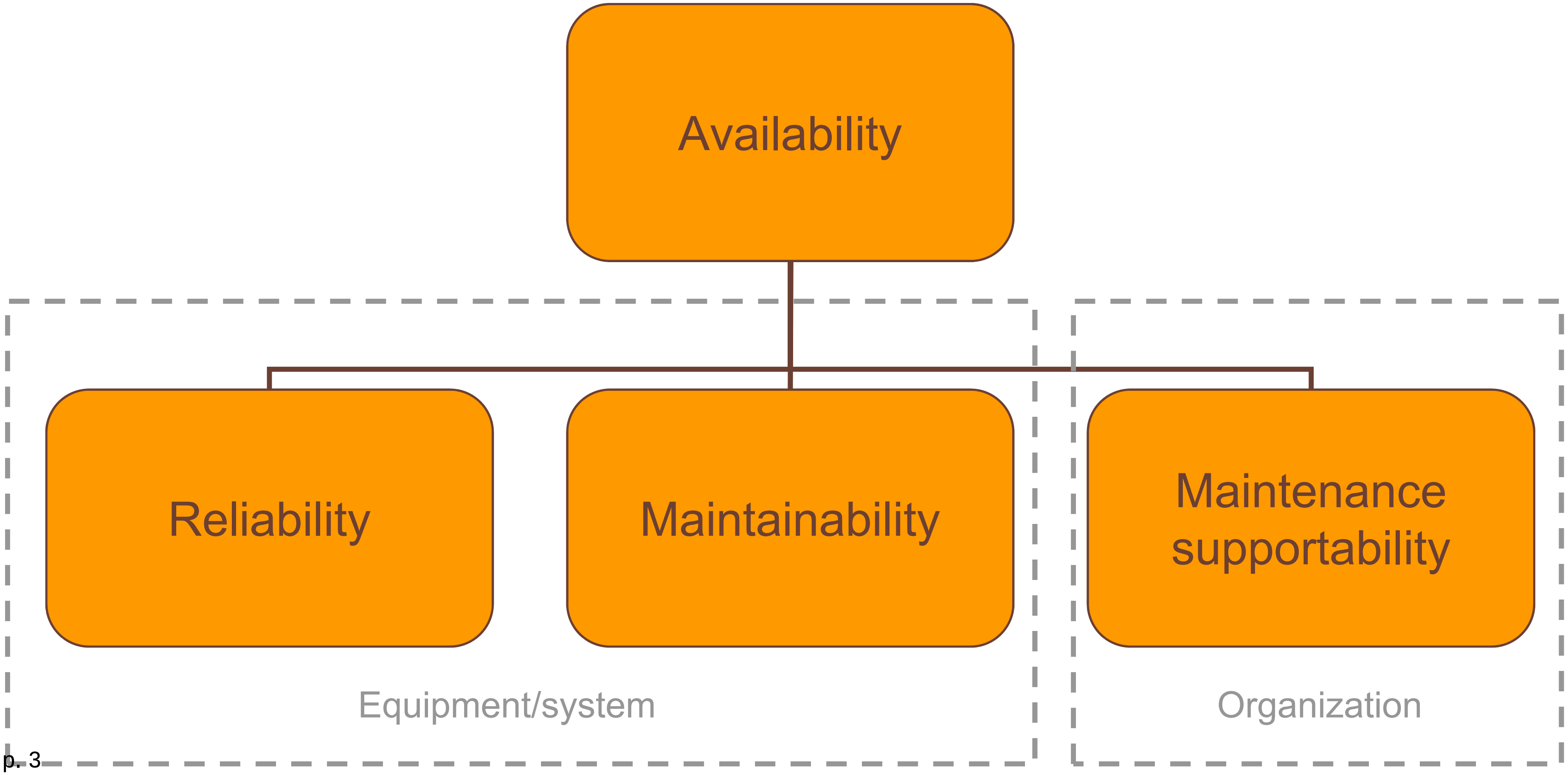
Dependability

Dependability

Collective term used to describe the availability and its influencing factors:

- Reliability
- Maintainability
- Maintenance supportability

Dependability



Reliability

”Ability of an item to perform a required function under given conditions for a given time interval”

(Often calculated as probability instead)

Reliability function

Reliability function – R(t): The probability that an item is functioning after the time t.
Ex: R(1000) = 0,9 means that 90% of the items in a given batch will survive1000 h.

Distribution function – F(t): The probability that an item is not functioning after the time t.
Ex: F(1000) = 0,1 means that 10% of the items in a given batch will not survive1000 h.

Note:

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

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

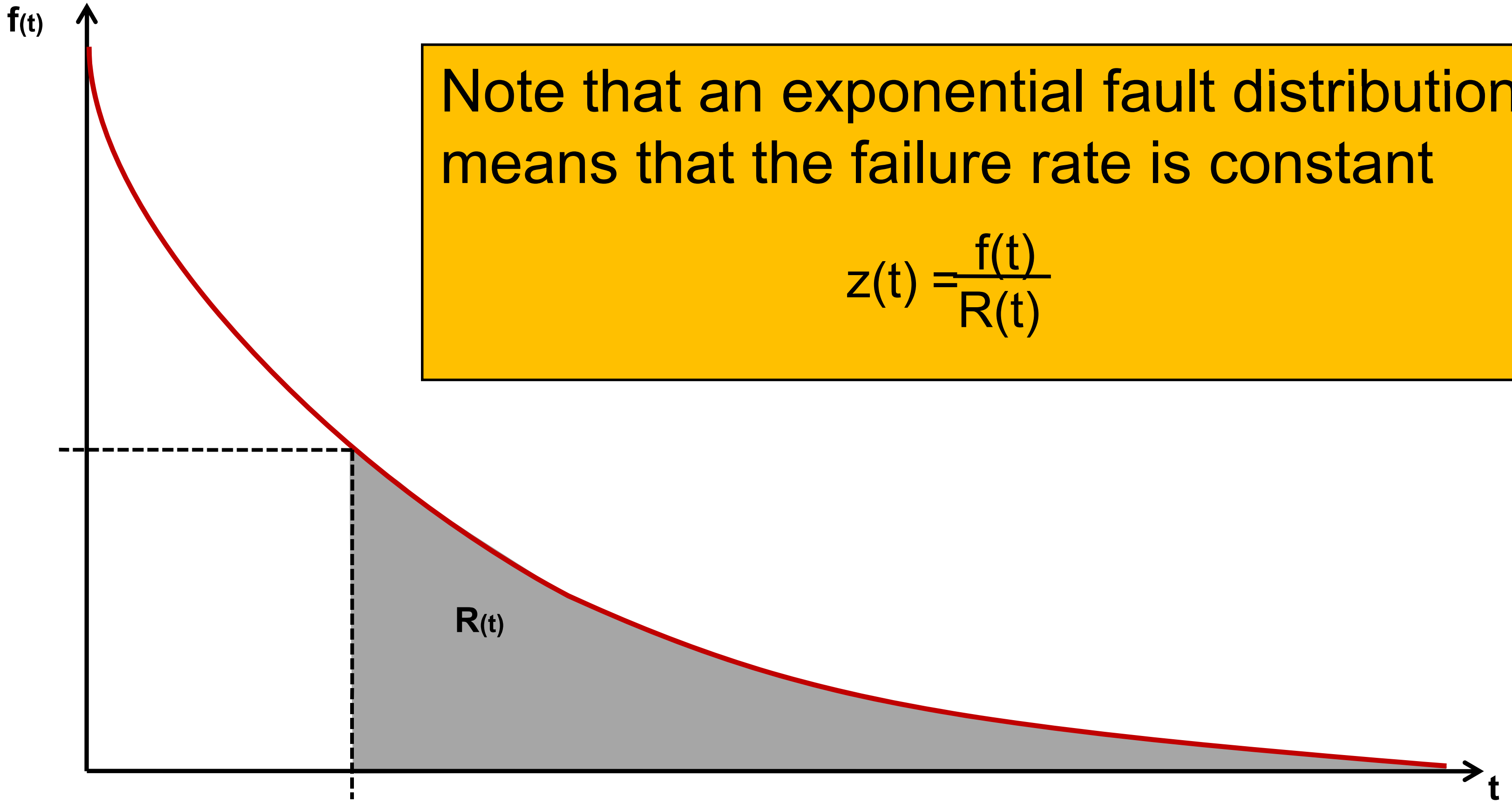
Failure rate

Failure rate – z(t): The number of faults to occur during a given time interval, (faults/h).
Probability density – f(t): The distribution of probability over time.

$$z(t) = \frac{f(t)}{R(t)}$$

Ex: z(t) = 5×10^{-4} faults/h. How many faults during10000h?

$5 \times 10^{-4} \times 10000 = 5$



Note that an exponential fault distribution means that the failure rate is constant

$$z(t) = \frac{f(t)}{R(t)}$$

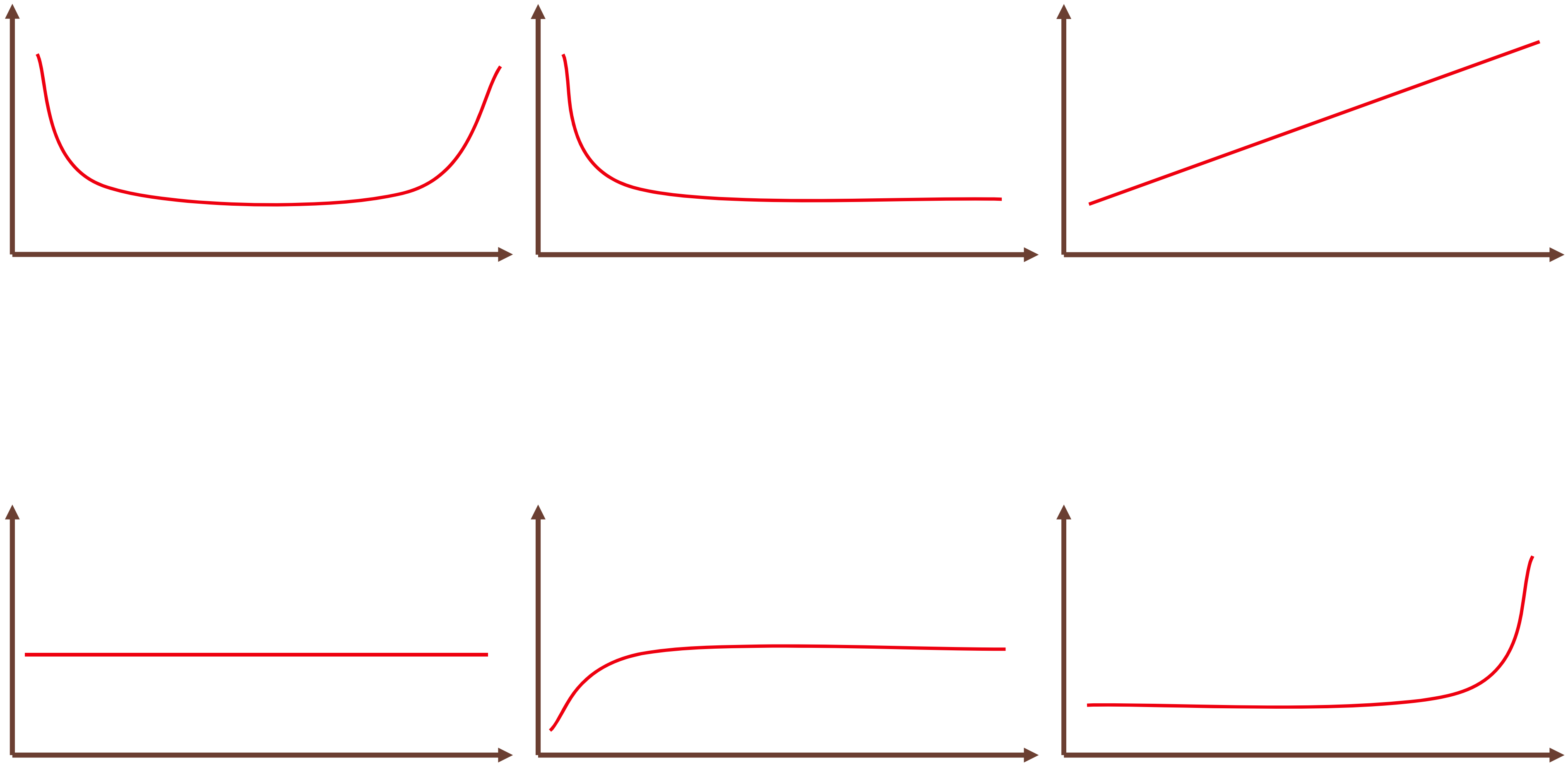
Mathematical models

- Exponential distribution (constant failure rate)
- Normal distribution
- Weibul distribution
- Gamma distribution
- Log normal distribution

Note that an exponential fault distribution means that the failure rate is constant

MÄLARDALENS HÖGSKOLA
ESKILSTUNA VÄSTERÅS

Distribution functions



Constant failure rate

When using exponential distribution the failure rate is denoted: λ.

$Z(t) = \lambda$

When the failure rate is known, it is easy to calculate the reliability function

$$R(t) = e^{-\int_0^t z(x)dx}$$

$$R(t) = e^{-\int_0^t \lambda dx} = e^{-[\lambda x]_0^t} = e^{-(\lambda t - \lambda 0)} = e^{-\lambda t}$$

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

Example

A component has $\lambda = 5 \times 10^{-5}$ h

Calculate the probability that the component will survive 2 months.

MÄLARDALENS HÖGSKOLA ESKILSTUNA VÄSTERÅS

Mean Time Between Failure

$$MTBF = \int_0^{\infty} R(t)\,dt$$

$$MTBF = \int_0^{\infty} e^{-\lambda t}\,dt = \left[-\frac{1}{\lambda}e^{-\lambda t}\right]_0^{\infty} =$$

$$= -\frac{1}{\lambda}e^{-\lambda\infty} - \left(-\frac{1}{\lambda}e^{-\lambda 0}\right) = \{e^{-\infty} \rightarrow 0;\ e^{0} \rightarrow 1\} =$$

$$= 0-\left(-\frac{1}{\lambda}\right) = \frac{1}{\lambda}$$

MTTF - MTBF

- MTTF: Mean Time To Failure (Non-repairable items)
- MTBF: Mean Time Between Failure (Repairable items)

Median time, t_m

Median time, t_m shows aproximately at which time half of the items in a given batch has stopped functioning.

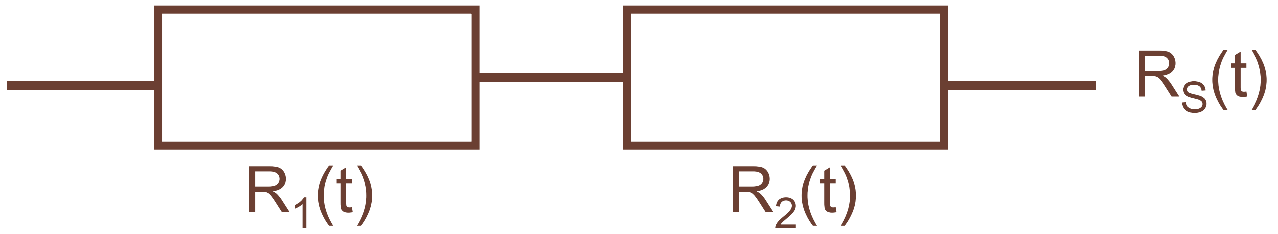
$R(t) = 0,5$

$F(t) = 0,5$

$R(t) = e^{-\lambda tm} = 0,5$

MÄLARDALENS HÖGSKOLA ESKILSTUNA VÄSTERÅS

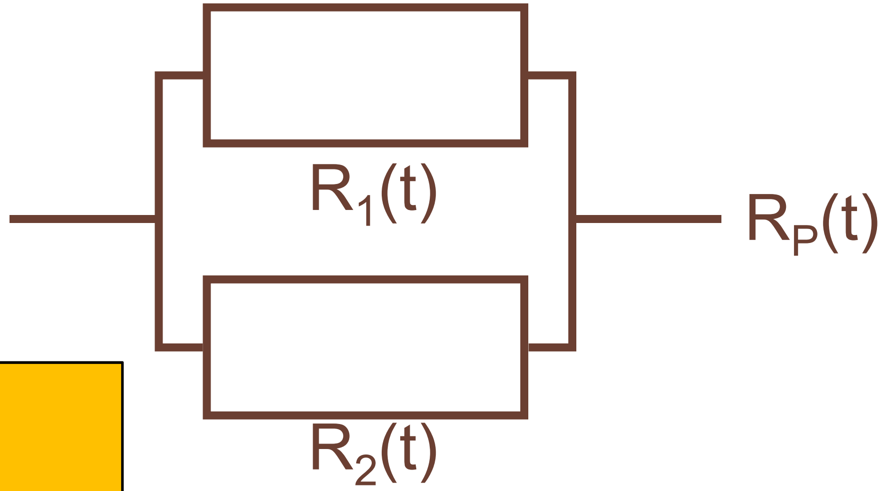
Series systems



$$R_S(t) = \prod_{J=1}^{n} R_j(t) = R_1(t) \times R_2(t) \times,,,\times R_n(t)$$

MÄLARDALENS HÖGSKOLA
ESKILSTUNA VÄSTERÅS

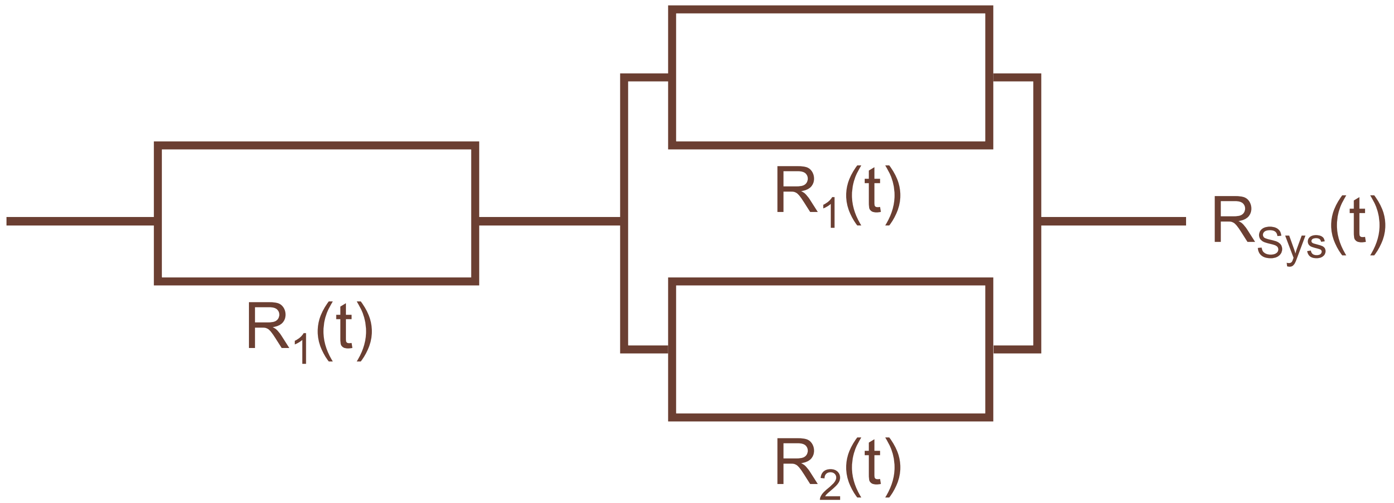
Parallel systems



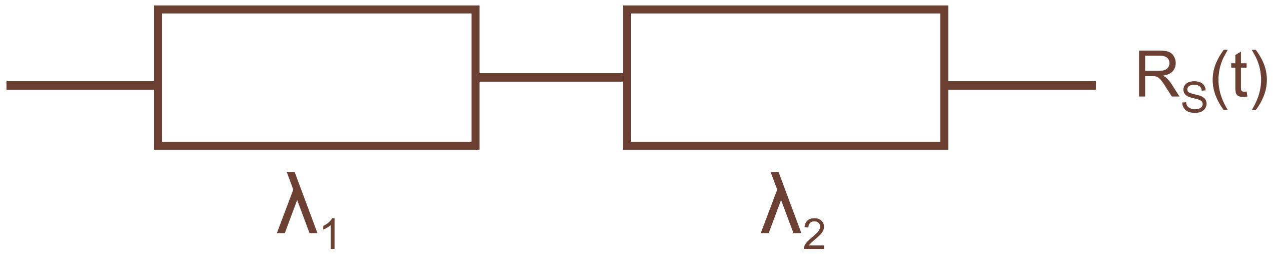
$$R_P(t) = 1 - \prod_{J=1}^{n} (1 - R_j(t)) =$$

$$= 1-(1-R_1(t)) \times (1-R_2(t)) \times,,,\times (1-R_n(t))$$

Mixed systems



Example



λ_1=0,6x10^{-6} h^{-1}

λ_2=0,9x10^{-6} h^{-1}

t=100000 h

Availability

”Ability of an item to be in a state to perform a required function under given conditions at a given instant of time or during a given time interval, assuming that the required external resources are provided”

Availability – Three levels

$$A_i = \frac{MTBF}{MTBF + MTTR}$$

$$A_a = \frac{MTBM}{MTBM + \overline{M}}$$

$$A_o = \frac{MTBM}{MTBM + MDT}$$

A is always a measure between 0-1 (0-100%)

$$A_i > A_a > A_o$$

MÄLARDALENS HÖGSKOLA
ESKILSTUNA VÄSTERÅS

A_i - Inherent availability

$$A_i = \frac{MTBF}{MTBF + MTTR}$$

MTTR = Mean Time To Repair

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

Through history and experiences we know MTTR = 2h.
Our supplier guarantees $\lambda = 2 \times 10^{-3}\ h^{-1}$ and an exponentialy distributed time to failure.

Calculate A_i

A_a - Achieved availability

$$A_a = \frac{MTBM}{MTBM + \bar{M}}$$

MTBM = Mean Time Between Maintenance

$\bar{M}$ = Mean Maintenance Time

MÄLARDALENS HÖGSKOLA ESKILSTUNA VÄSTERÅS

A_a - Achieved availability

$$MTBM = \frac{1}{\frac{1}{MTBM_{CM}} + \frac{1}{MTBM_{PM}}}$$

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

$MTBM_{PM}$ = Mean Time Between Preventive Maintenance

$$MTBM_{PM} = \frac{1}{f}$$

f = frequency of PM-tasks

$$MTBM = \frac{1}{\lambda + f}$$

A_a - Achieved availability

$$\overline{M} = \frac{\lambda \overline{M}_{CM} + f \overline{M}_{PM}}{\lambda + f}$$

$$\overline{M}_{CM} = MTTR = \frac{\sum_i \lambda_i M_i}{\sum_i \lambda_i}$$

$$\overline{M}_{PM} = \frac{\sum_j f_j M_j}{\sum_j f_j}$$

A_a - Achieved availability

MTBF = 500h, $\lambda = 2 \times 10^{-3}\ h^{-1}$, MTTR = 2h

The supplier only guarantees the low failure rate if we perform preventive maintenance every 200 h. Through experience we know $\bar{M}_{PM}$ = 1.5h.

Calculate A_a

MÄLARDALENS HÖGSKOLA ESKILSTUNA VÄSTERÅS

A_o - Operative availability

$$A_o = \frac{MTBM}{MTBM + MDT}$$

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

MDT = Mean Down Time = $\overline{M}$ + $MTW_{(A)}$ + MLDT

$MTW_{(A)}$ = Mean Time Waiting (Administrative)

MLDT = Mean Logistics Down Time

$$MDT = \frac{\lambda(MTW_{(A)CM} + MLDT_{CM} + \overline{M}_{CM}) + f(MTW_{(A)PM} + MLDT_{PM} + \overline{M}_{PM})}{\lambda + f}$$

A_o - Operative availability

Example (continue):

MTBM = 142,9h

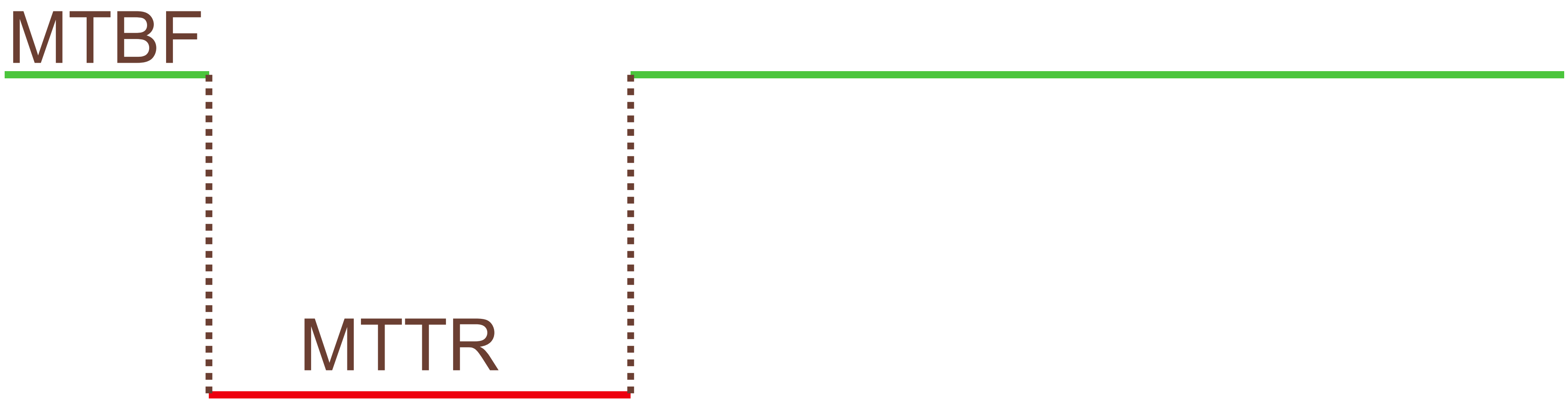
$\bar{M}$ = 1,64h

Outsourced maintenance with $MTW_{(A)}$ = 1,5h

and MLDT = 2,5h

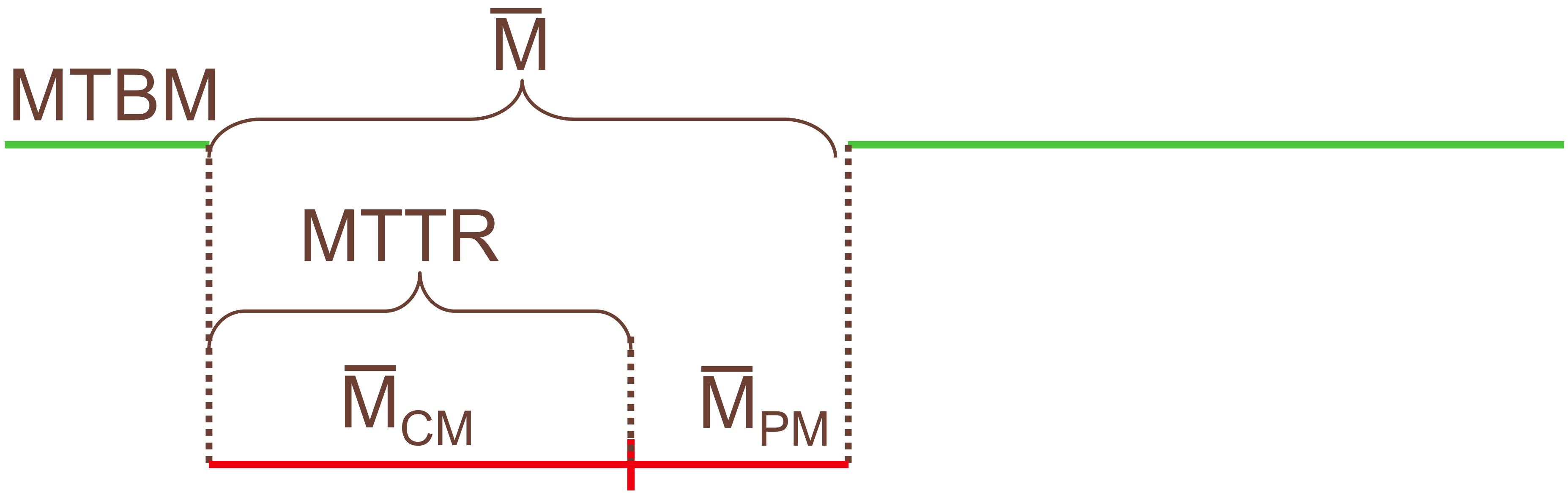
Calculate A_o

Inherent availability A_i

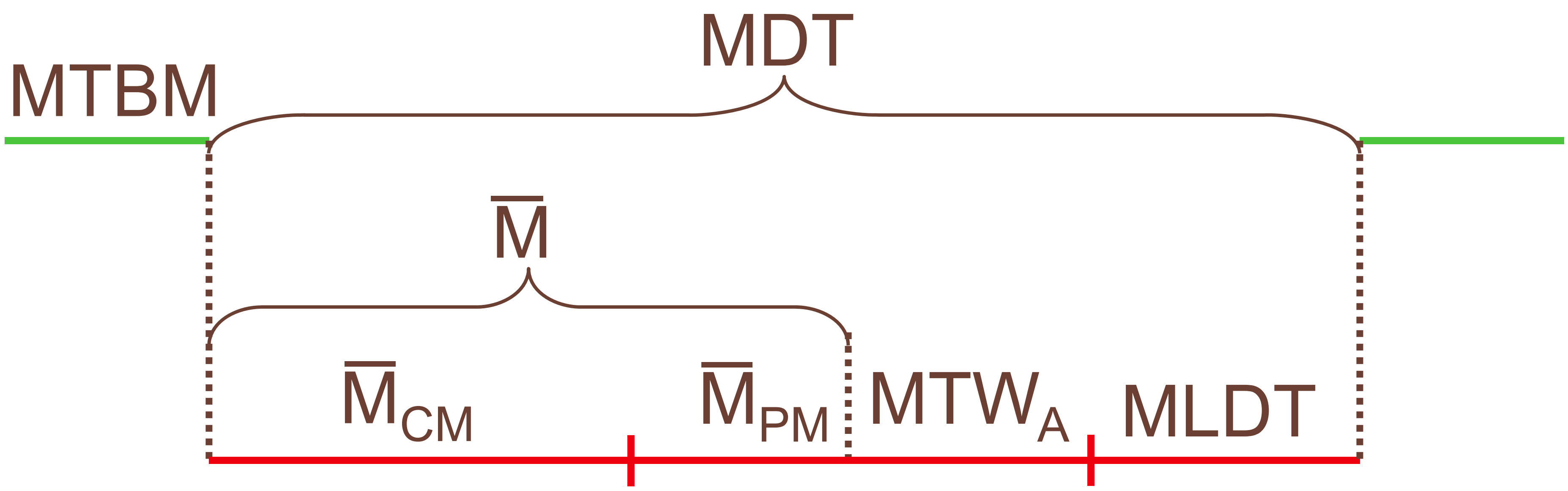


MÄLARDALENS HÖGSKOLA
ESKILSTUNA VÄSTERÅS

Achieved availability A_a



Operative availability A_o



Exercises

Dependability

Recomended examples:

1, 2, 3, 6, 12, 18, 19, 23, 24, 25, 28