

Reliability Making  
Money

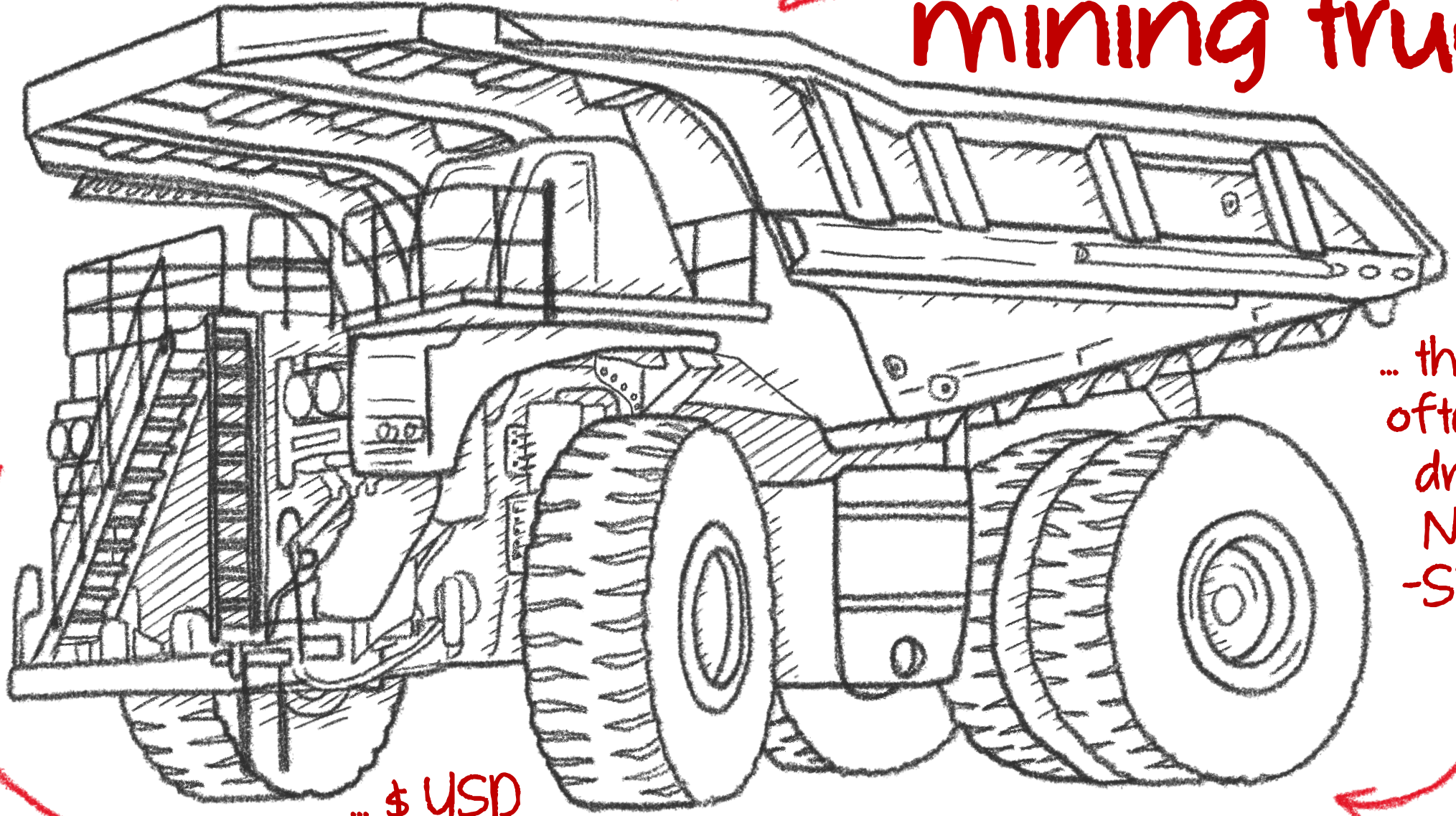
#1

... being DUMB  
is expensive

... 400 tonne payload

... really big

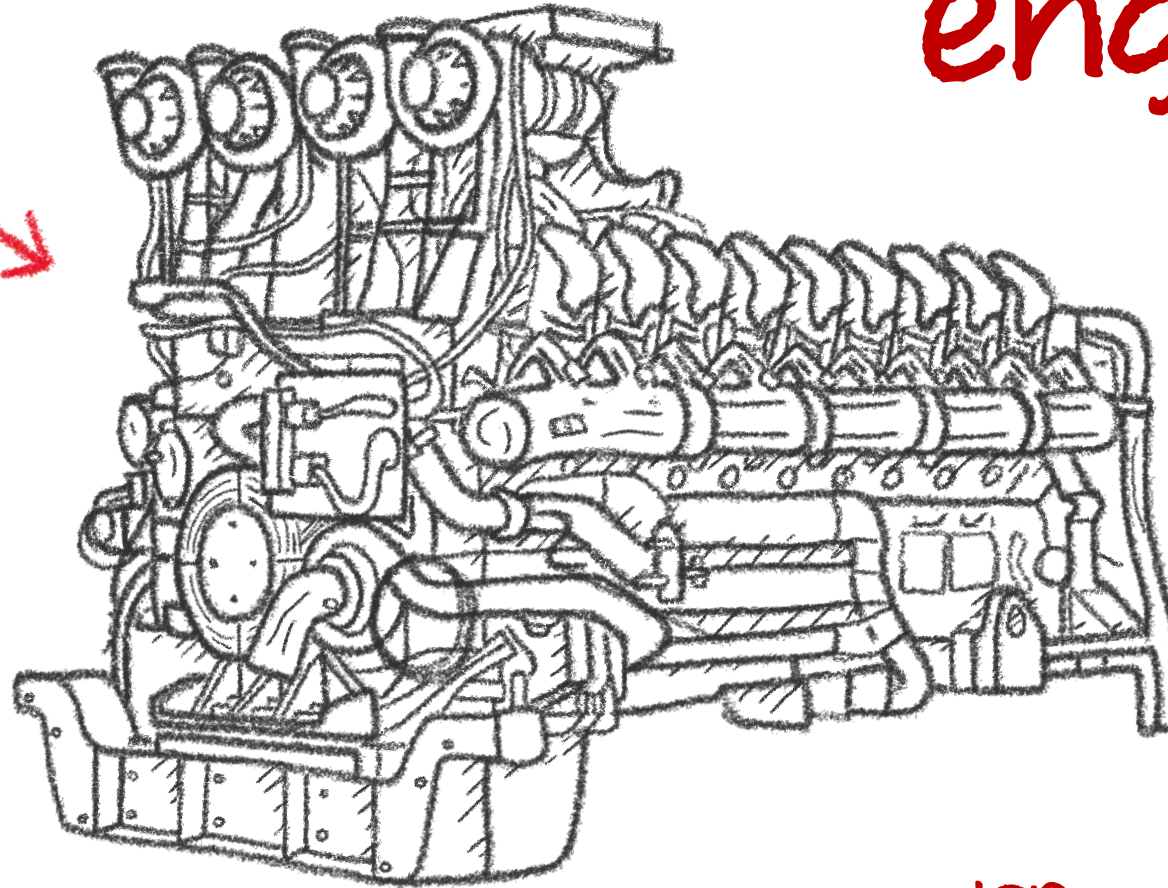
# mining truck



... they will  
often be  
driven  
NON  
-STOP

... \$ USD  
5-6 million

... 20  
cylinder  
engine



... really big  
**engine**

... \$ USD  
700 - 800 thousand



... so how many spare  
engines do I need for a  
**3-year period**  
for 1 truck?

... dumb way #1

... *textbook*

... let's say that we know the engine's

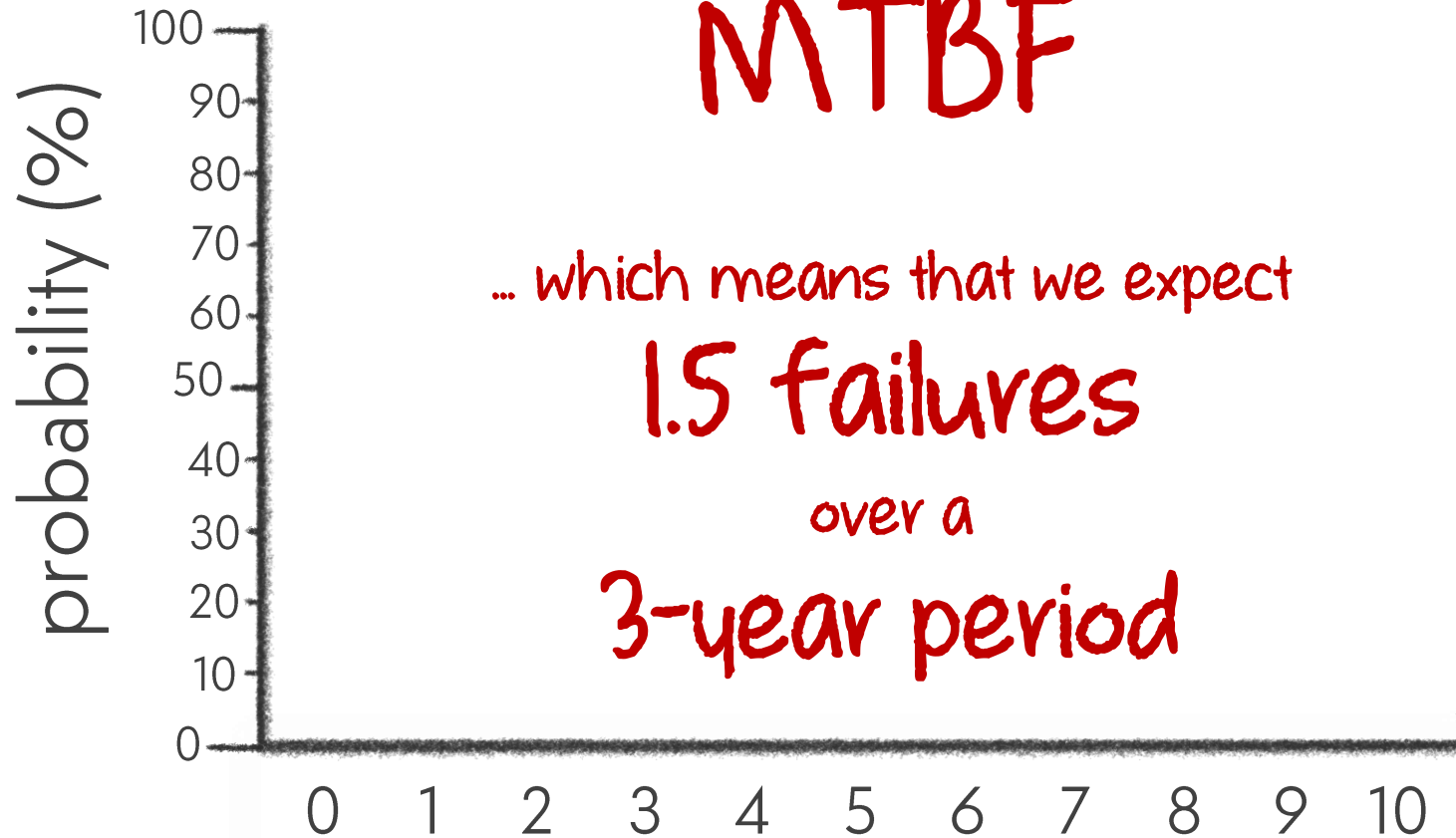
MTBF

... which means that we expect

1.5 failures

over a

3-year period



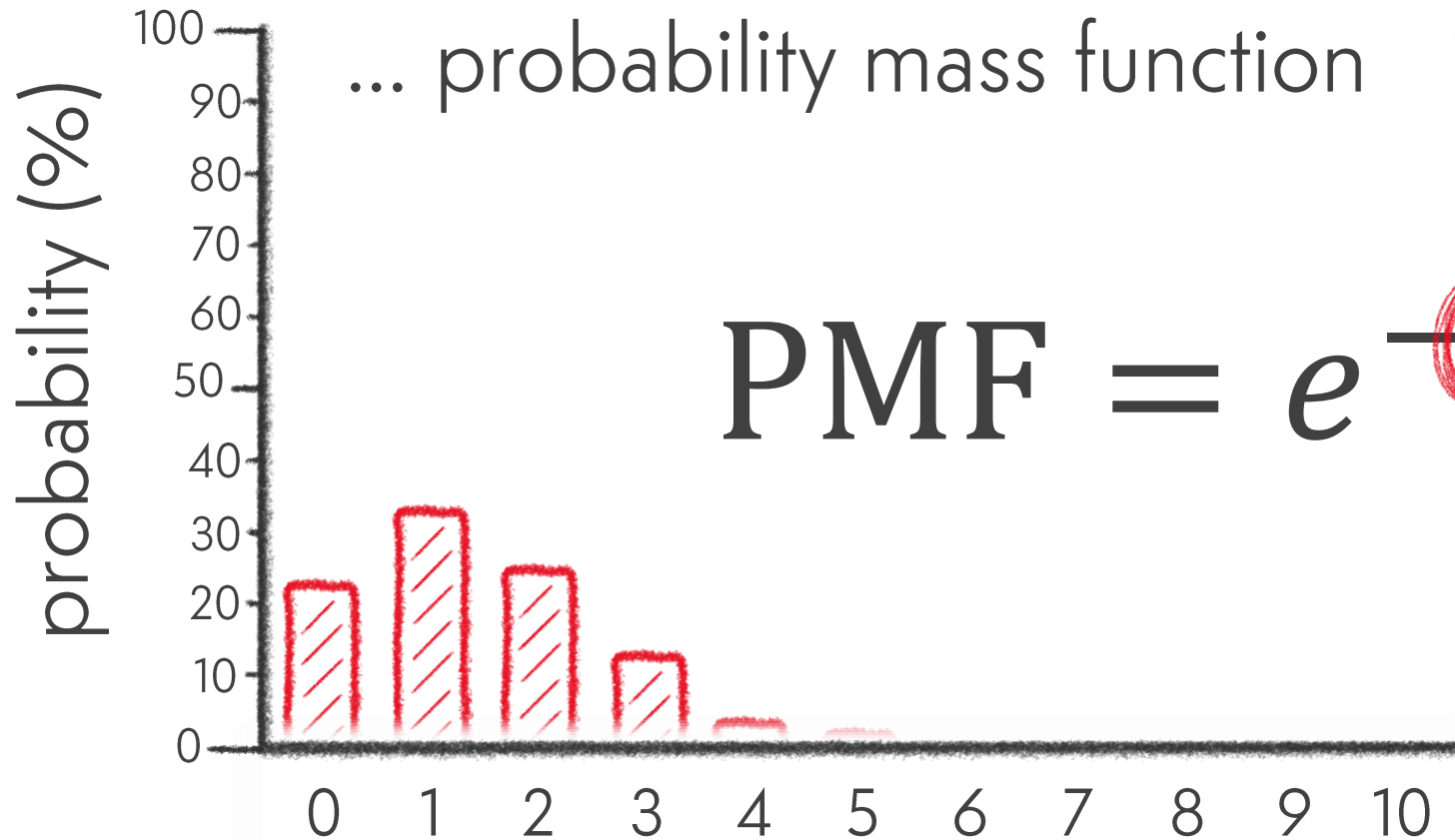
... total # of failures

... the

# Poisson Distribution

... probability mass function

... the  
expected  
number of failures



$$\text{PMF} = e^{-\mu} \frac{\mu^x}{x!}$$

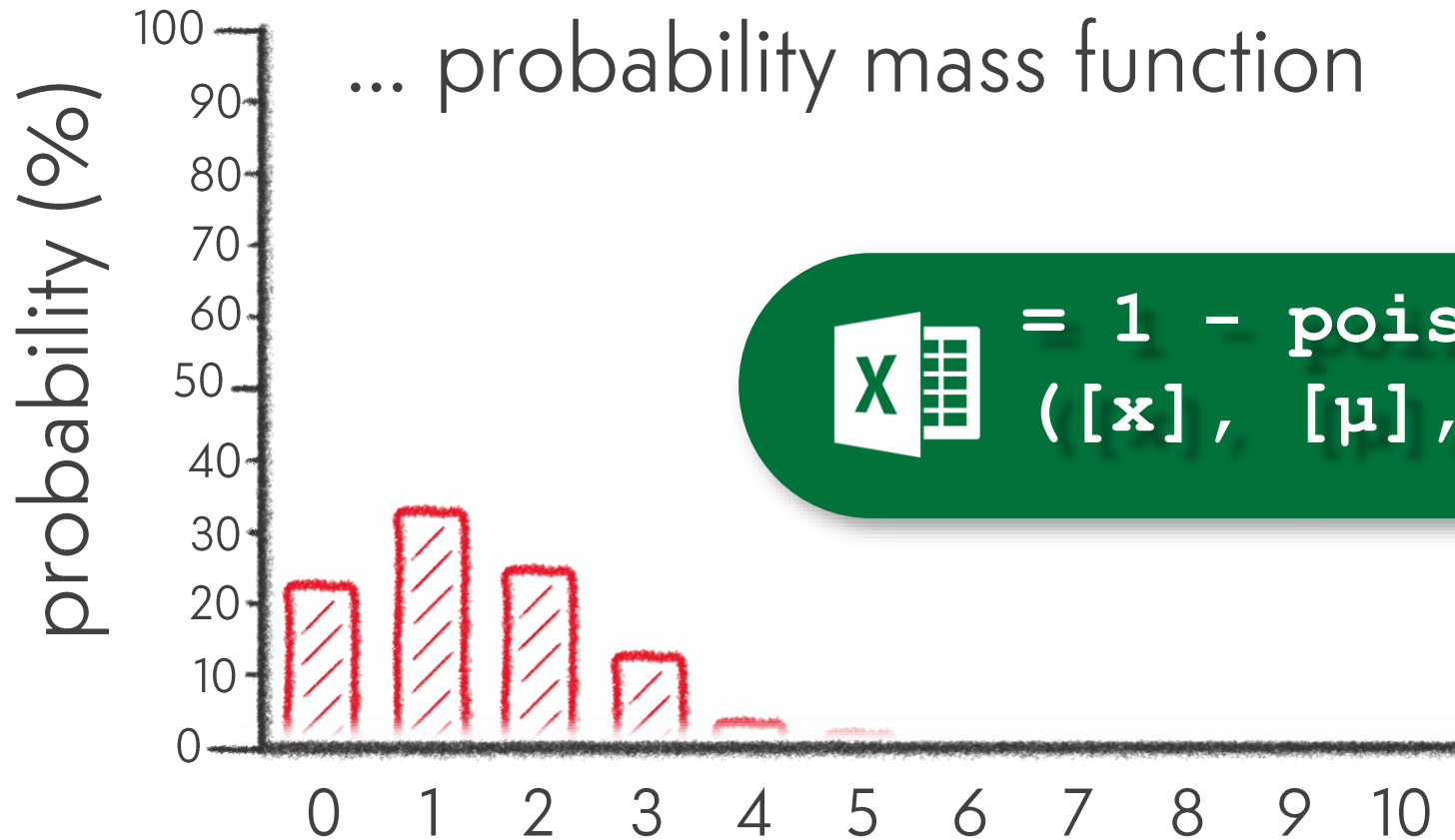
... total # of failures



... the

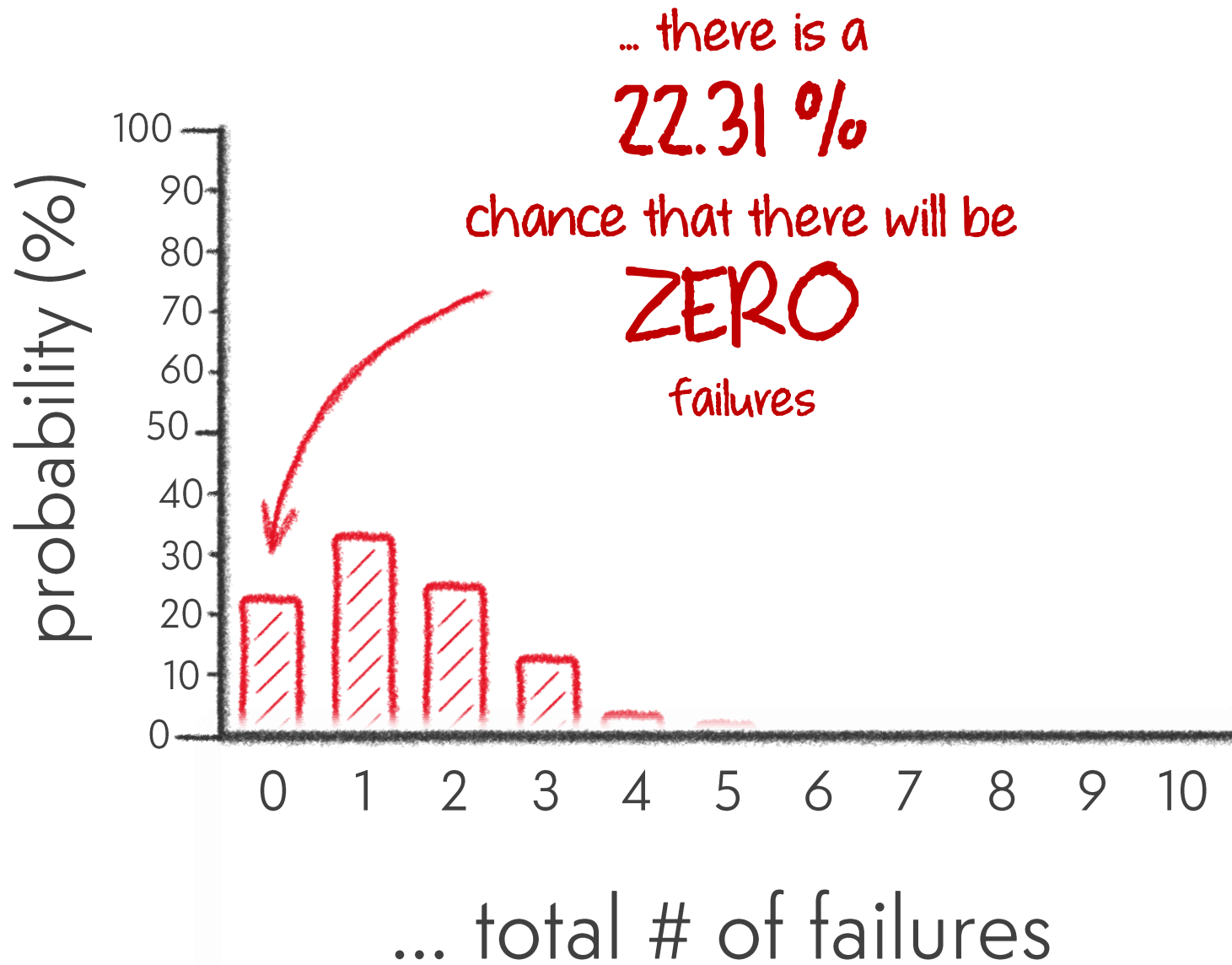
# Poisson Distribution

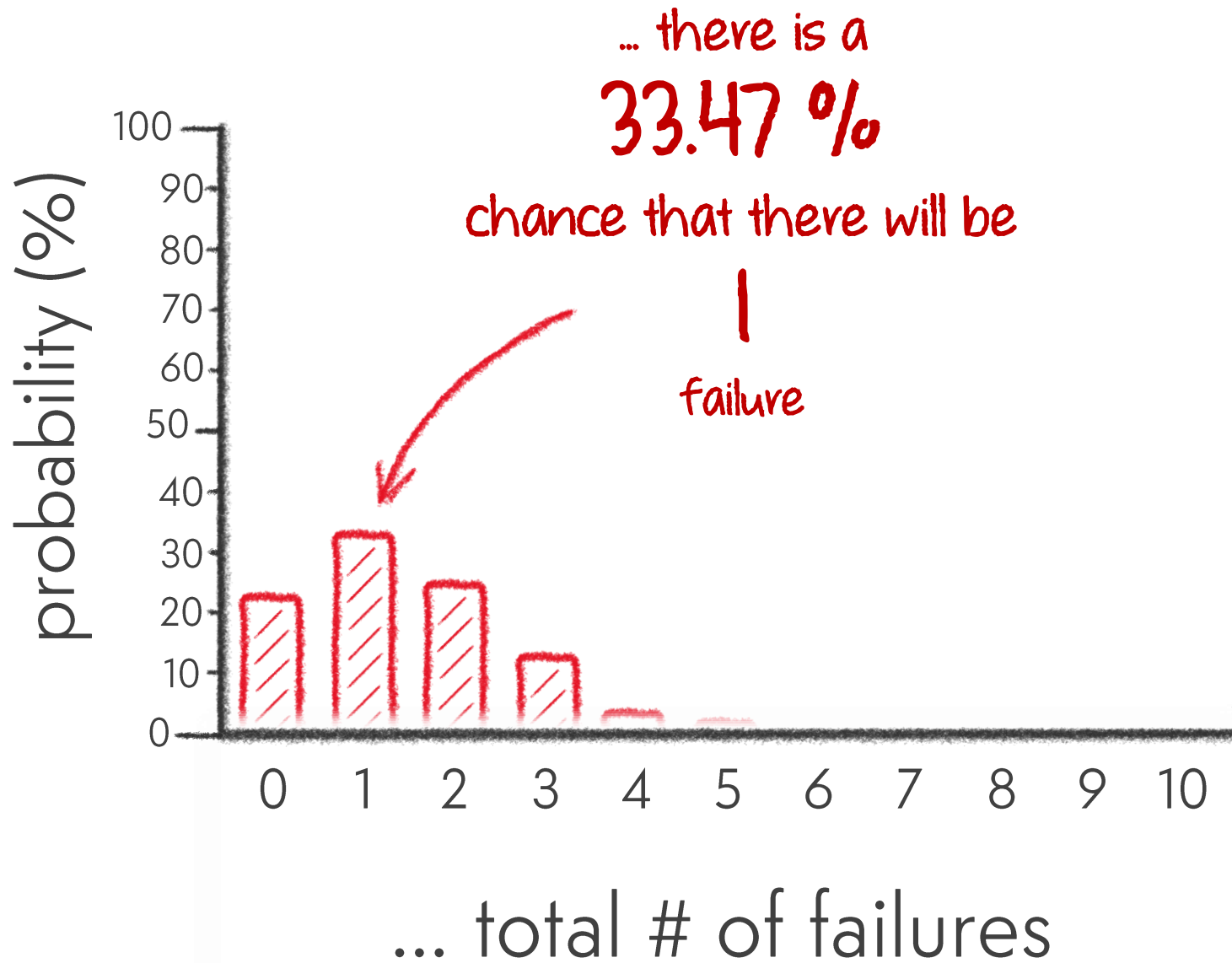
... probability mass function



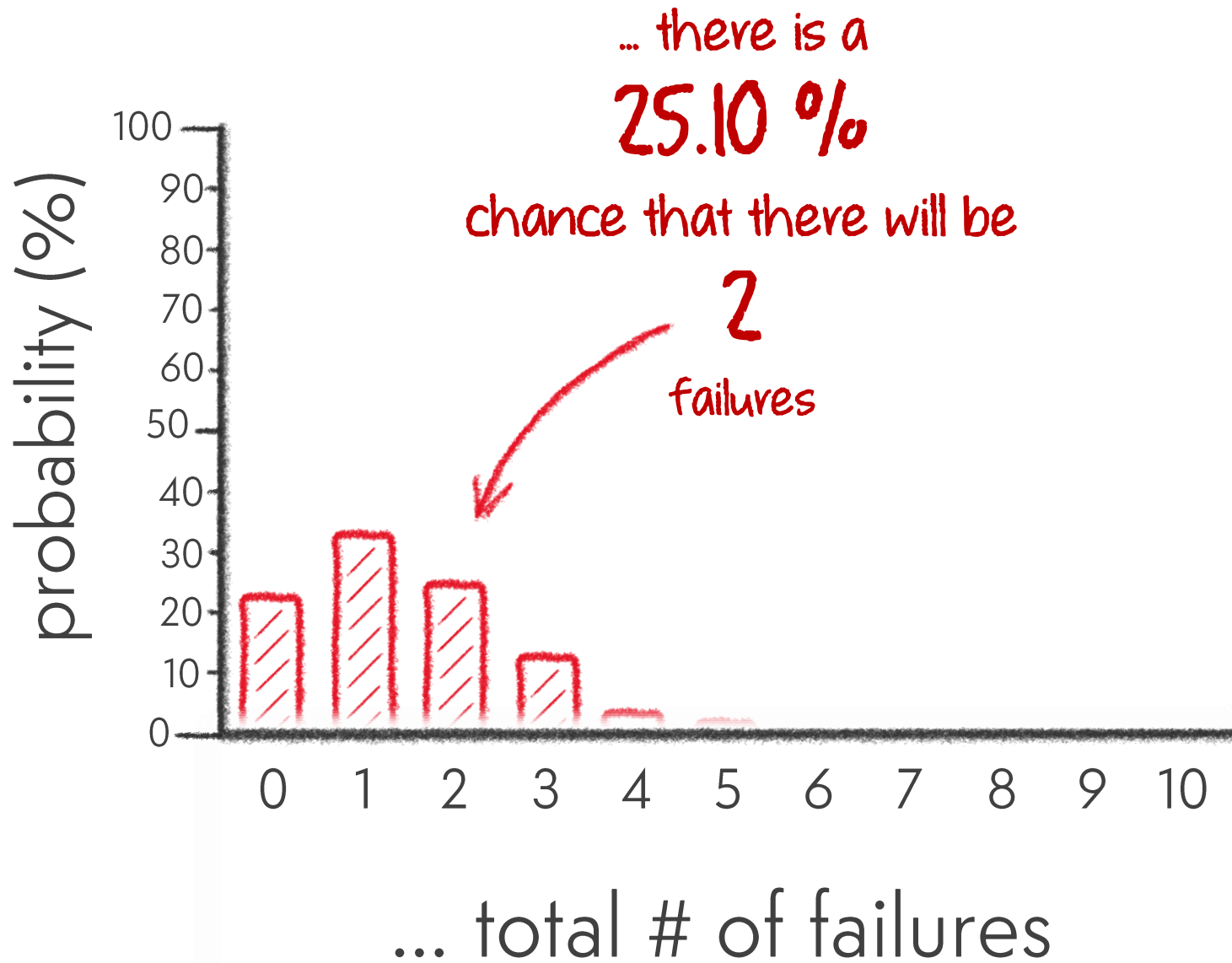
```
= 1 - poisson.dist  
([x], [μ], FALSE)
```

... total # of failures

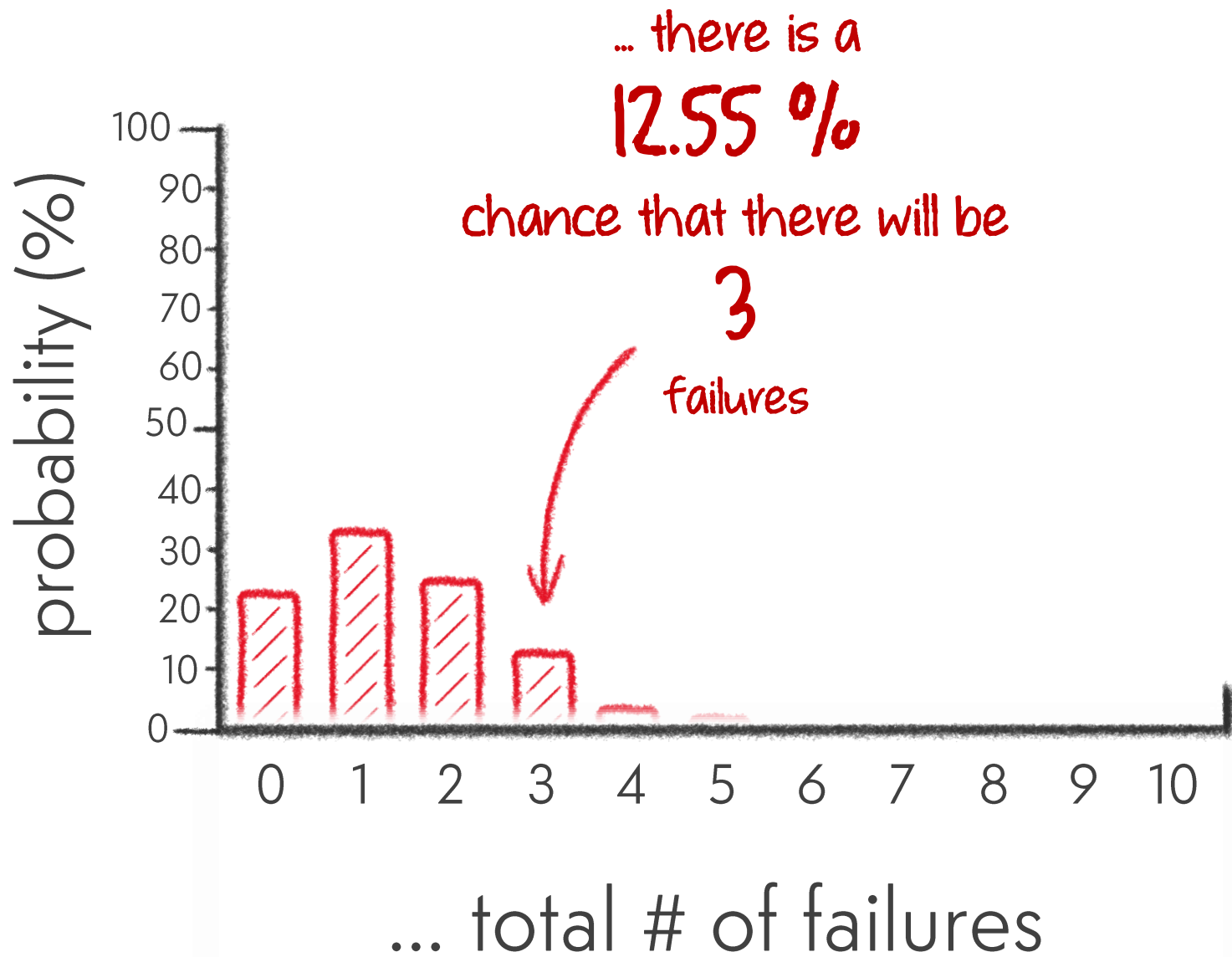


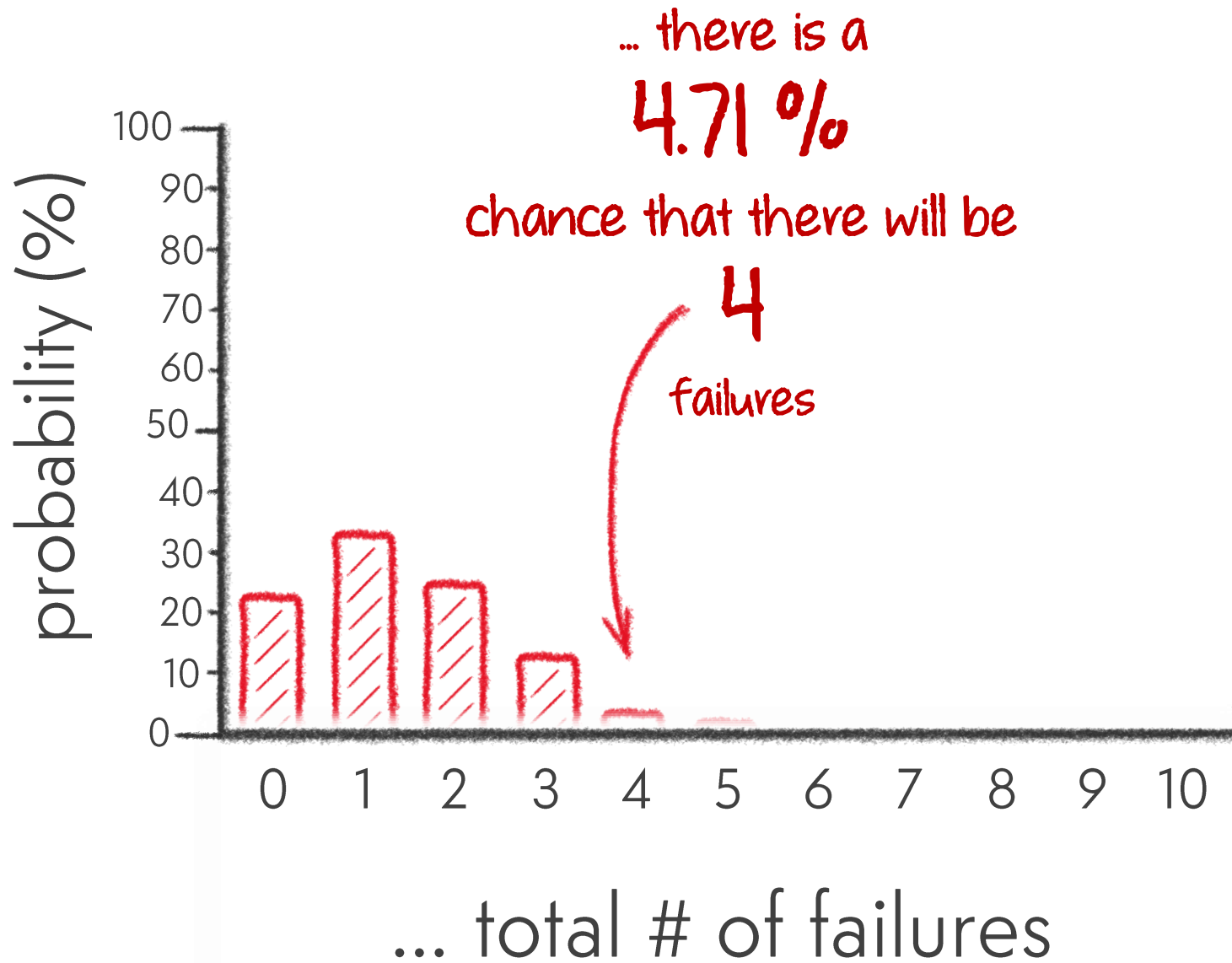


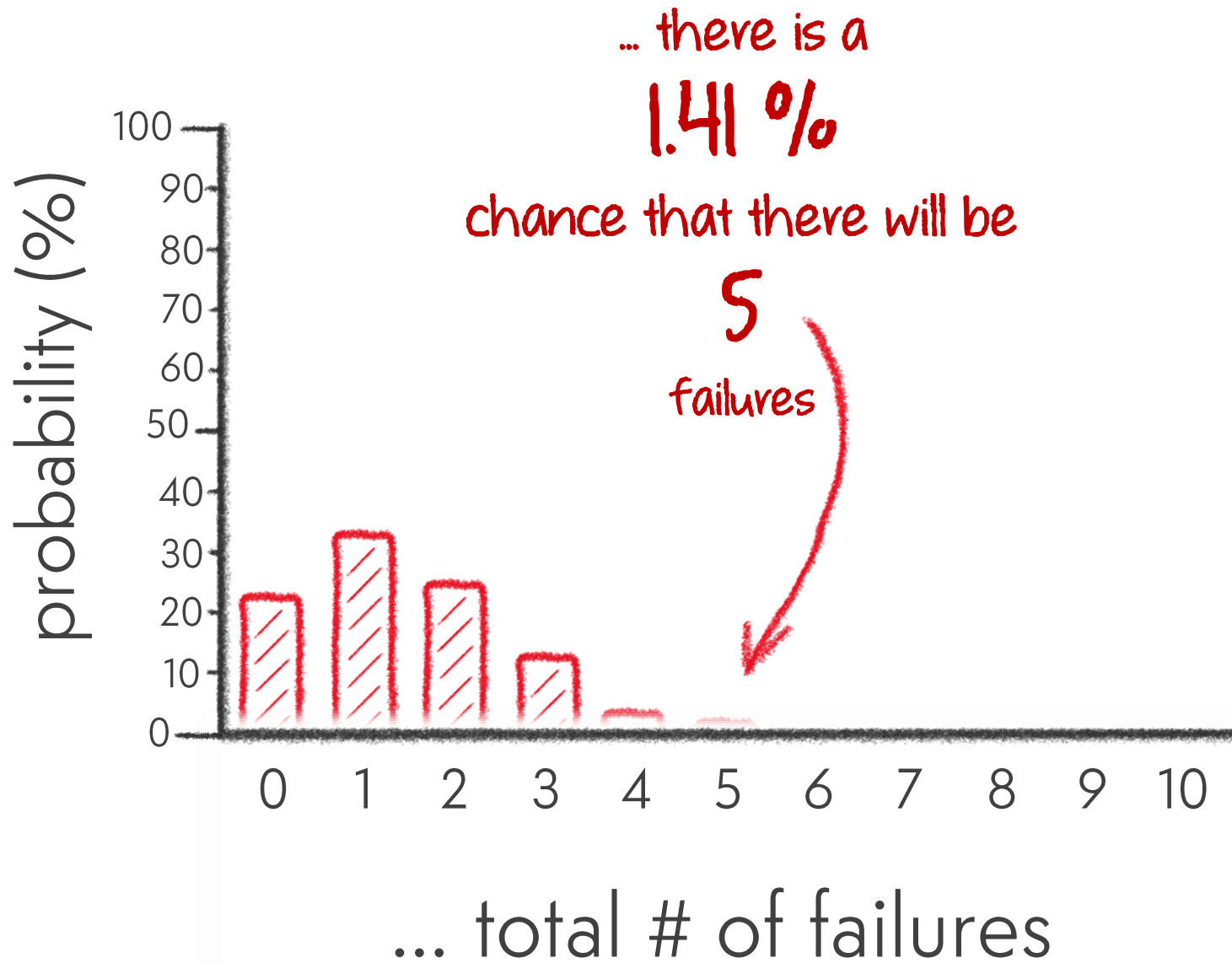
**22.31 %**

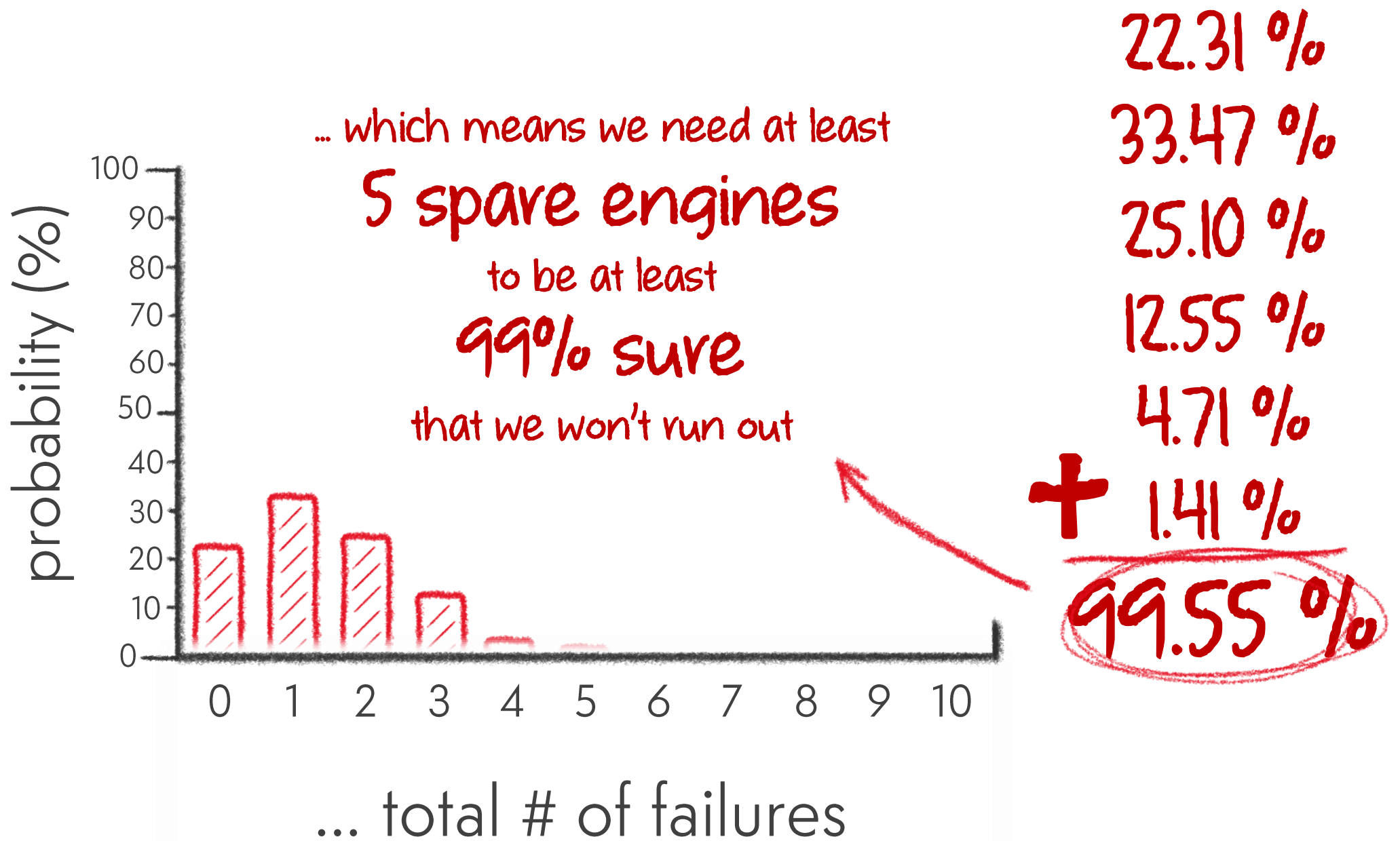








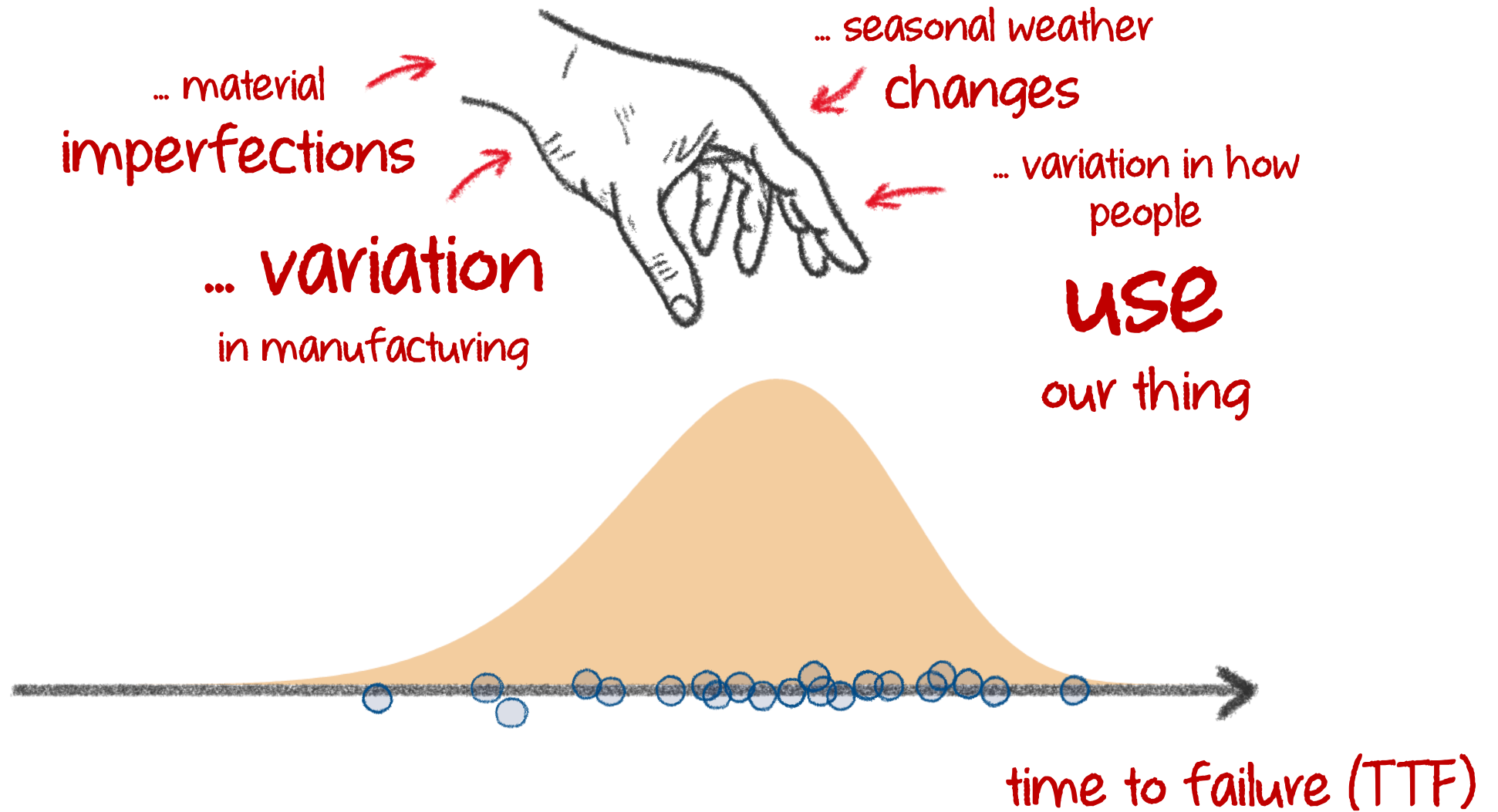




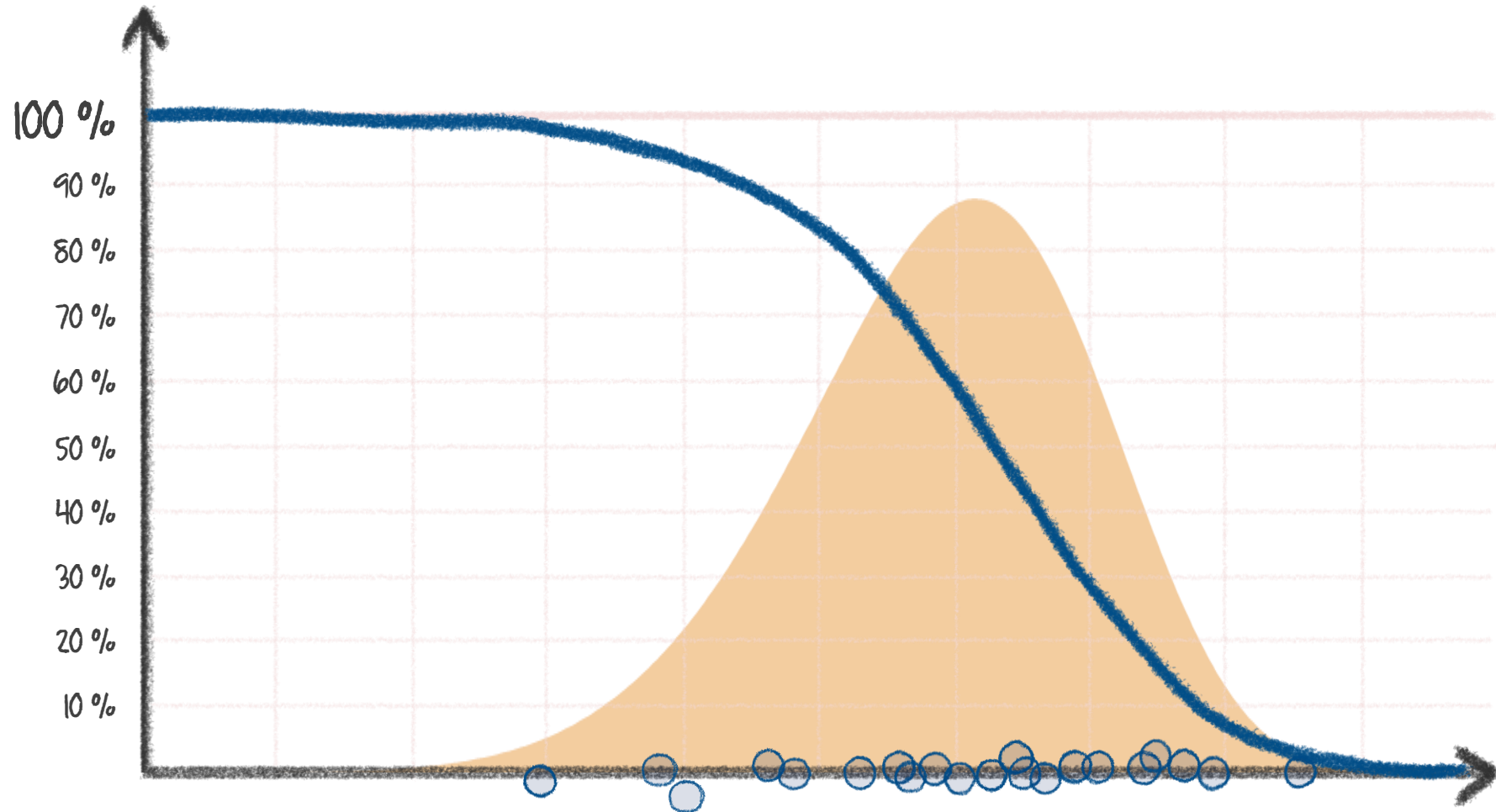


... why is this dumb?

the (random) hand of failure

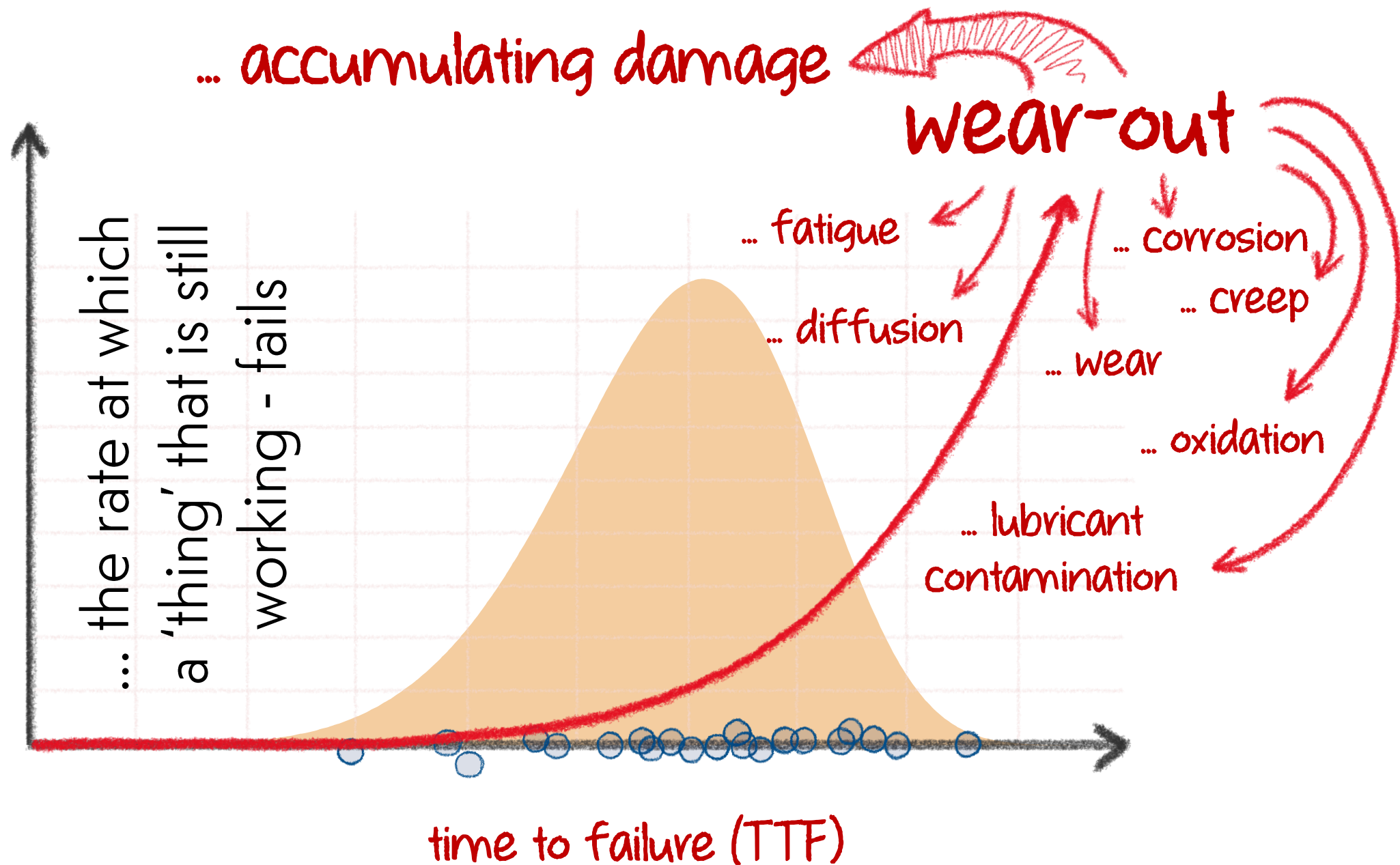


# reliability



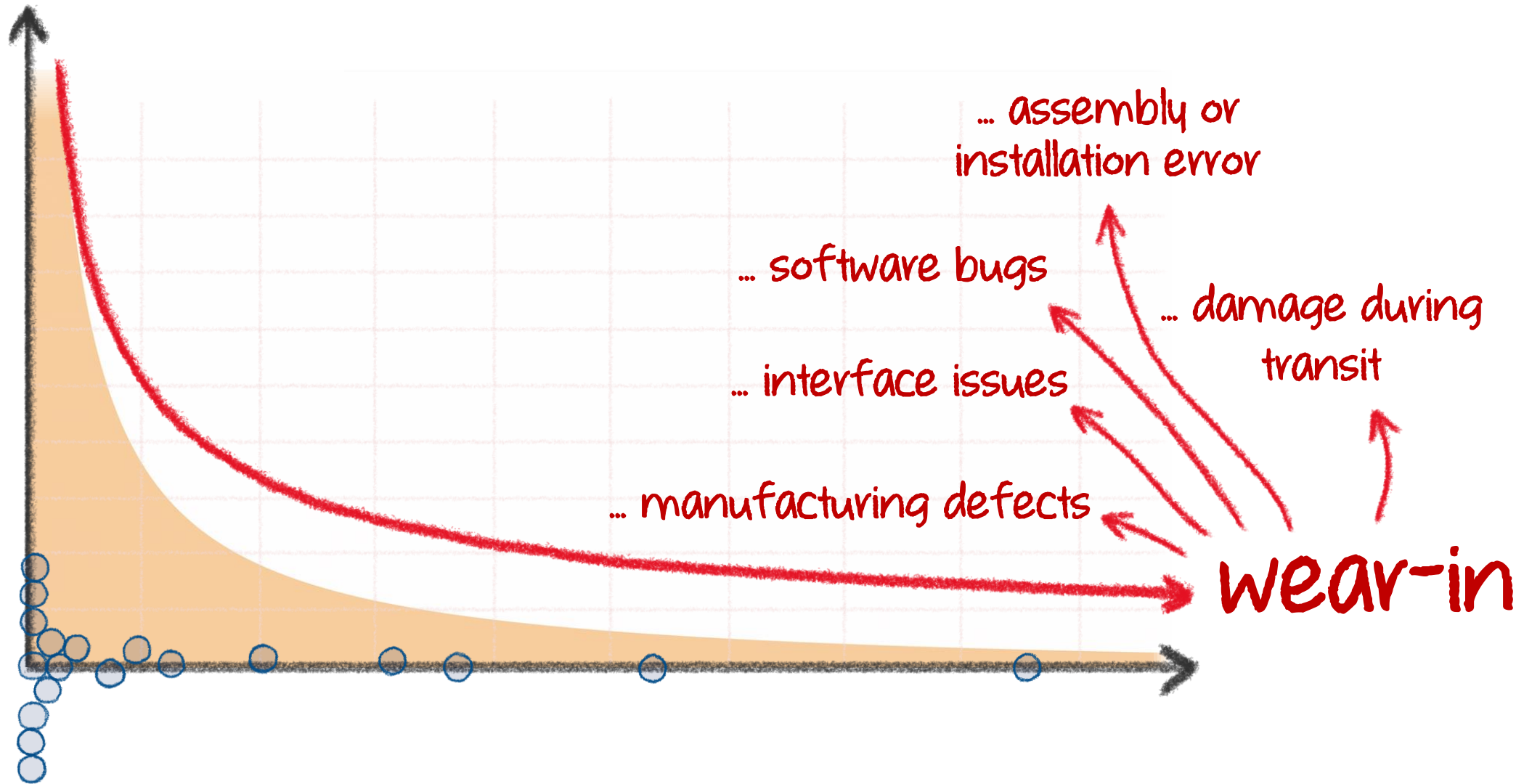
time to failure (TTF)

# fatigue life

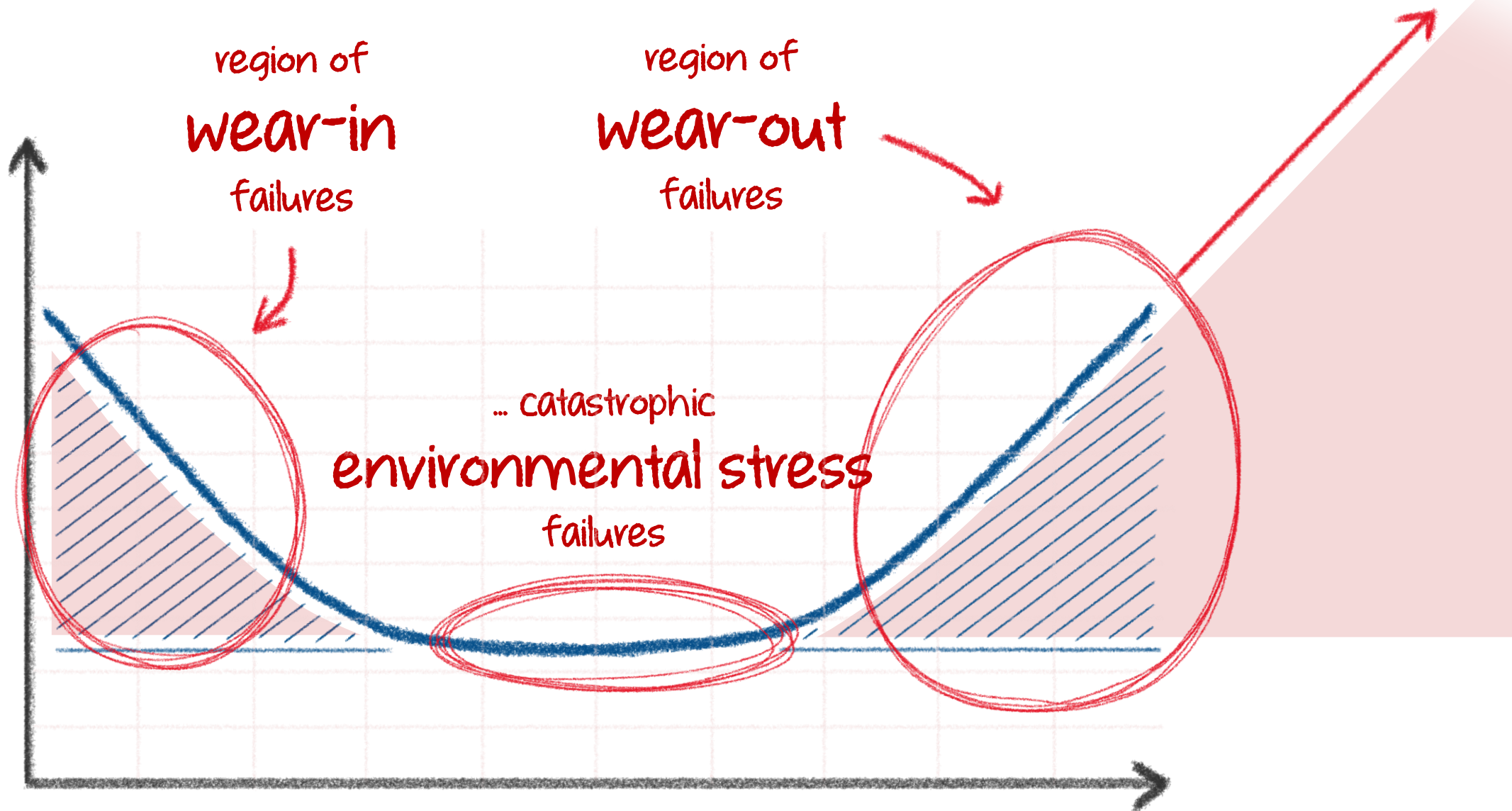




# failure rate



# failure rate

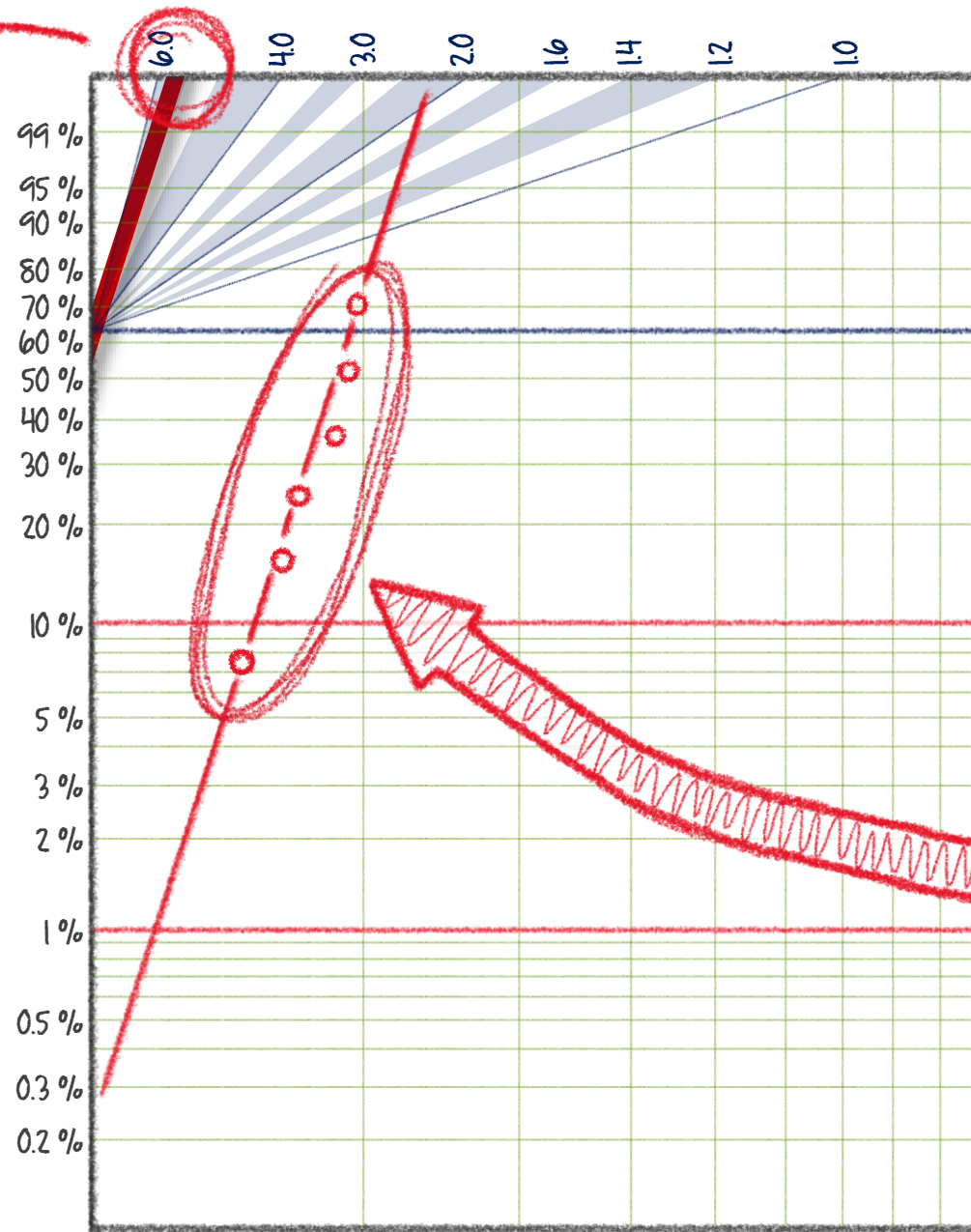


... and our  
engine?

... shape  
parameter of  
about

6

... so  
everything is  
wearing out!



Weibull  
Plot

... failure  
data

... the

# Poisson Distribution



... only models things with constant hazard rates

... NOT our engine

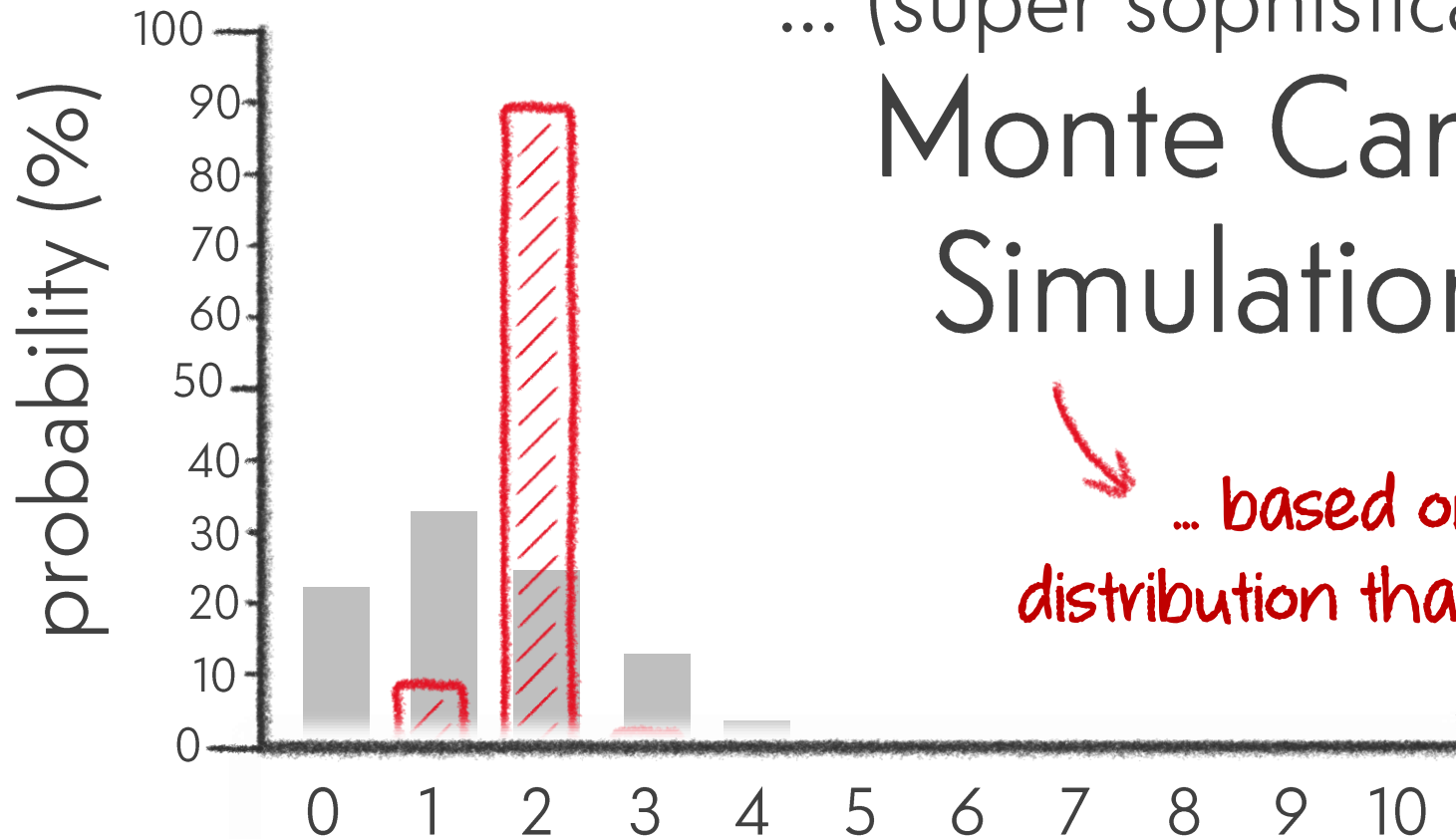
... total # of failures

... includes starting with engines at random points in their service life

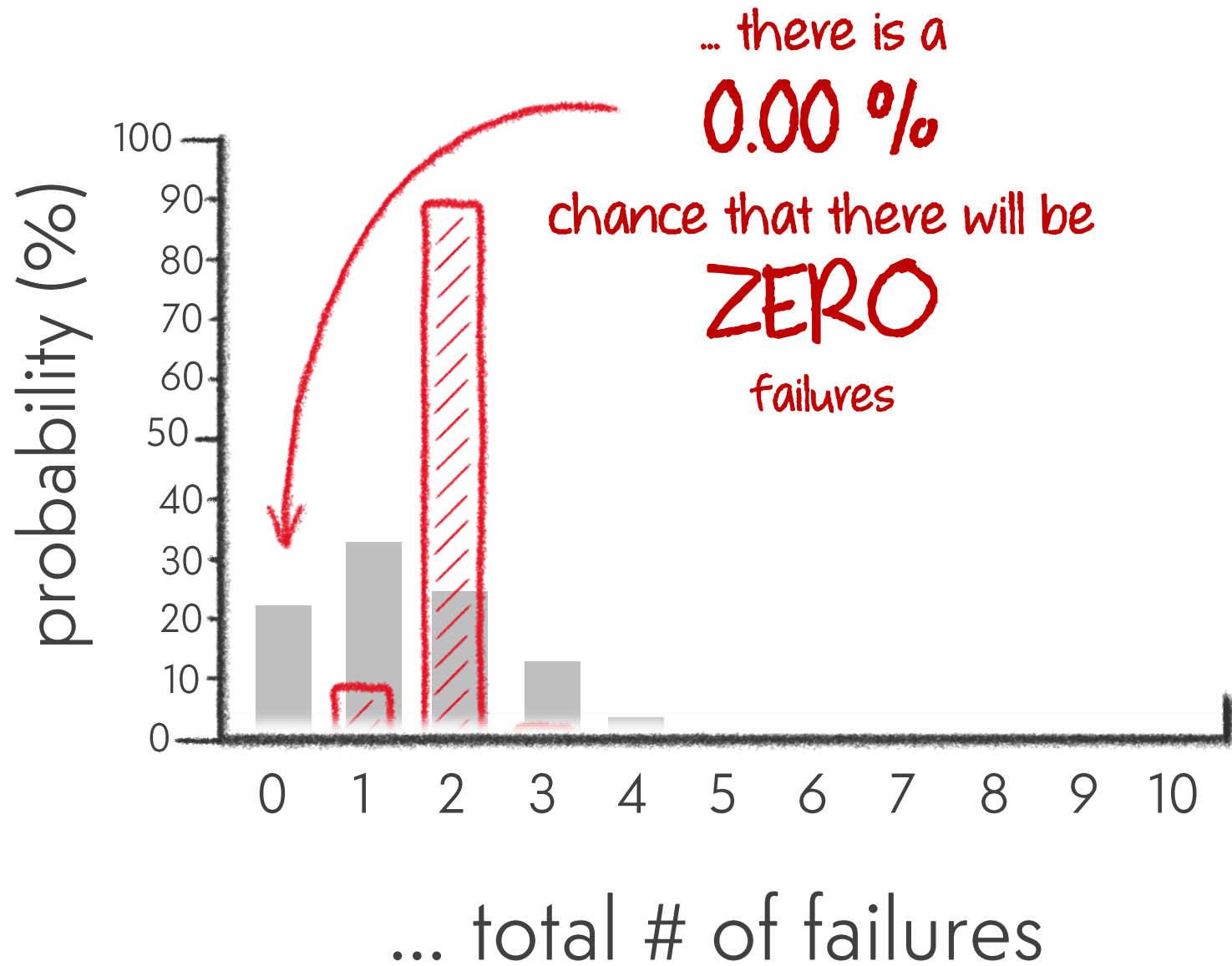
... (super sophisticated!)

## Monte Carlo Simulation

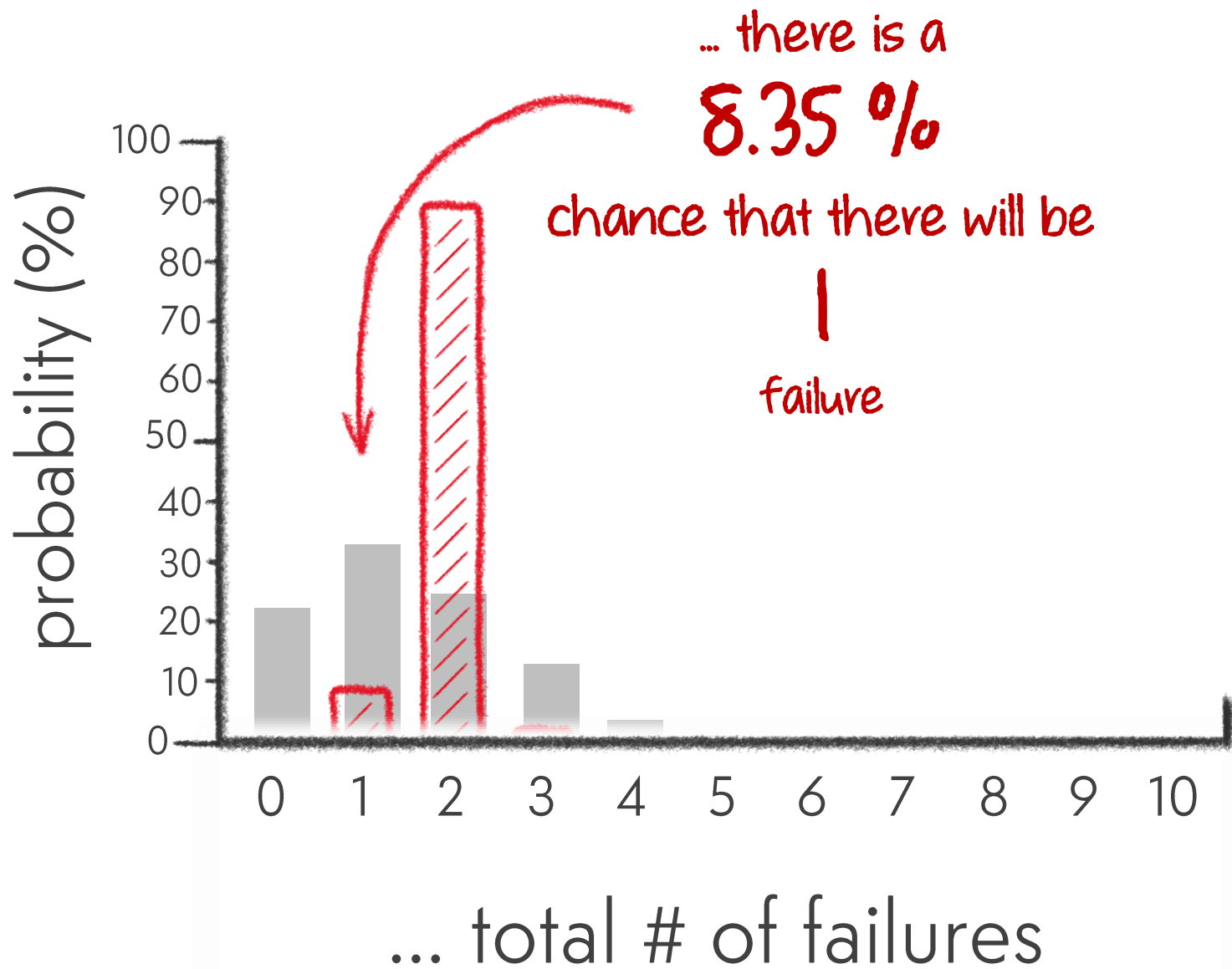
... based on our Weibull distribution that models wear-out



... total # of failures

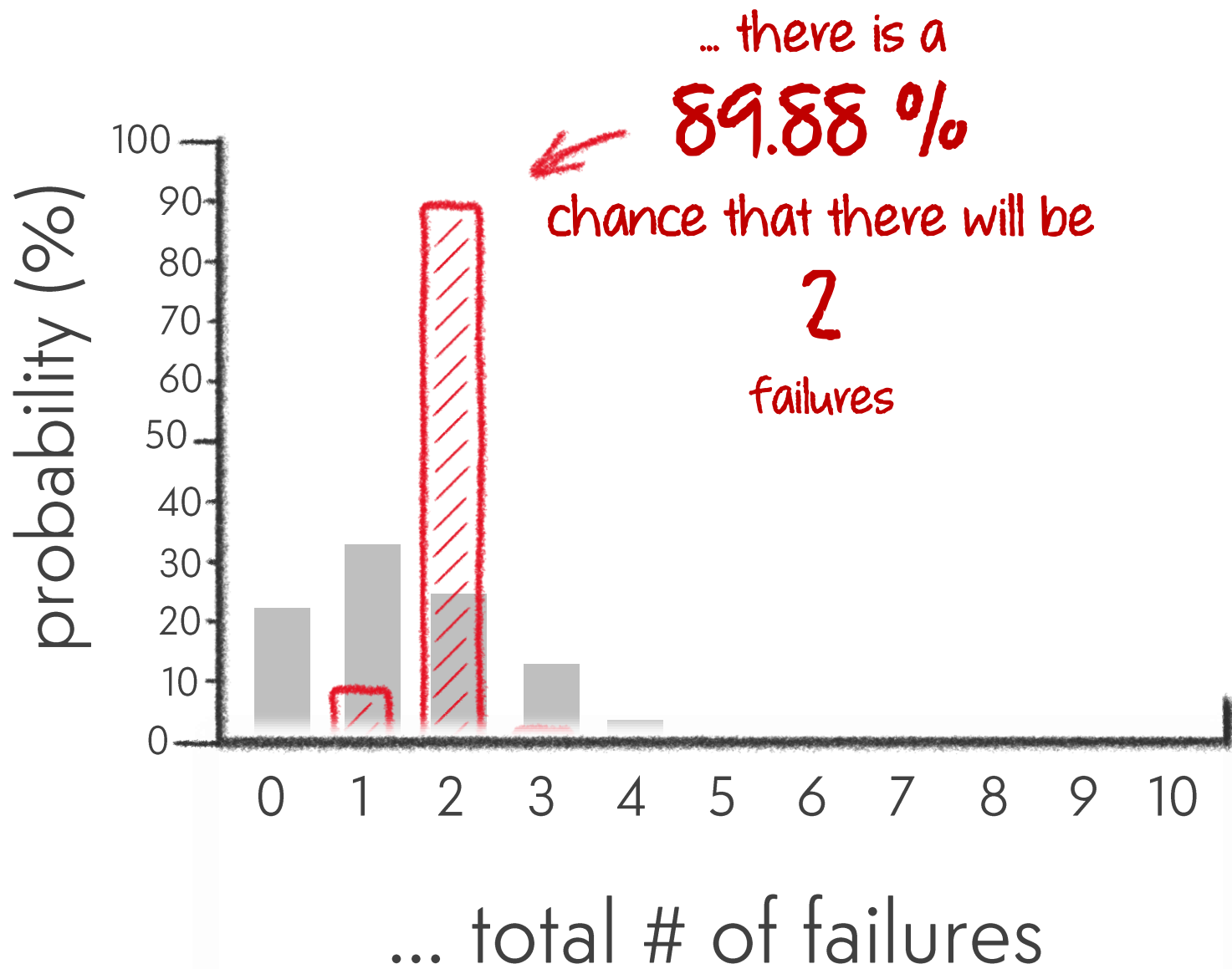


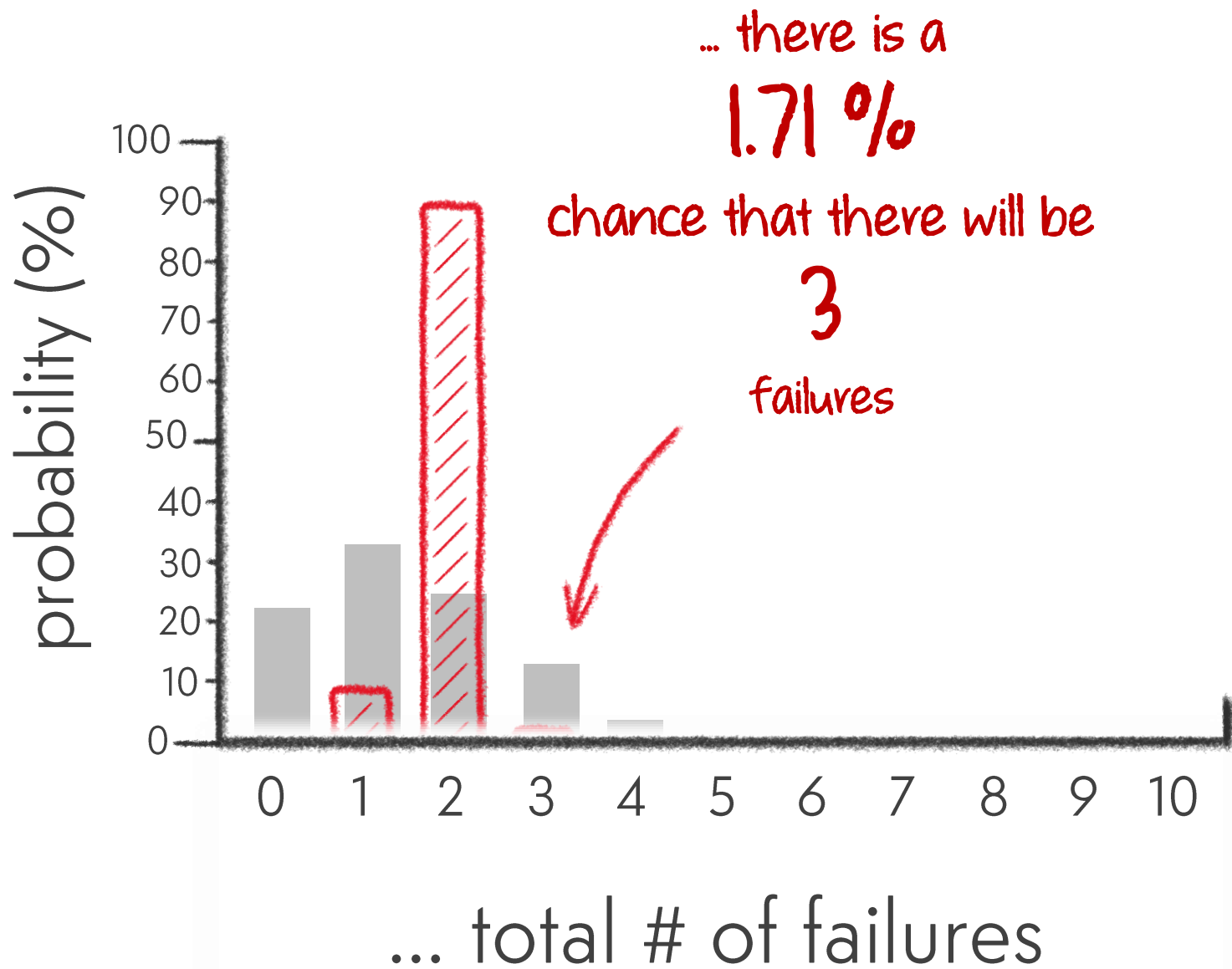




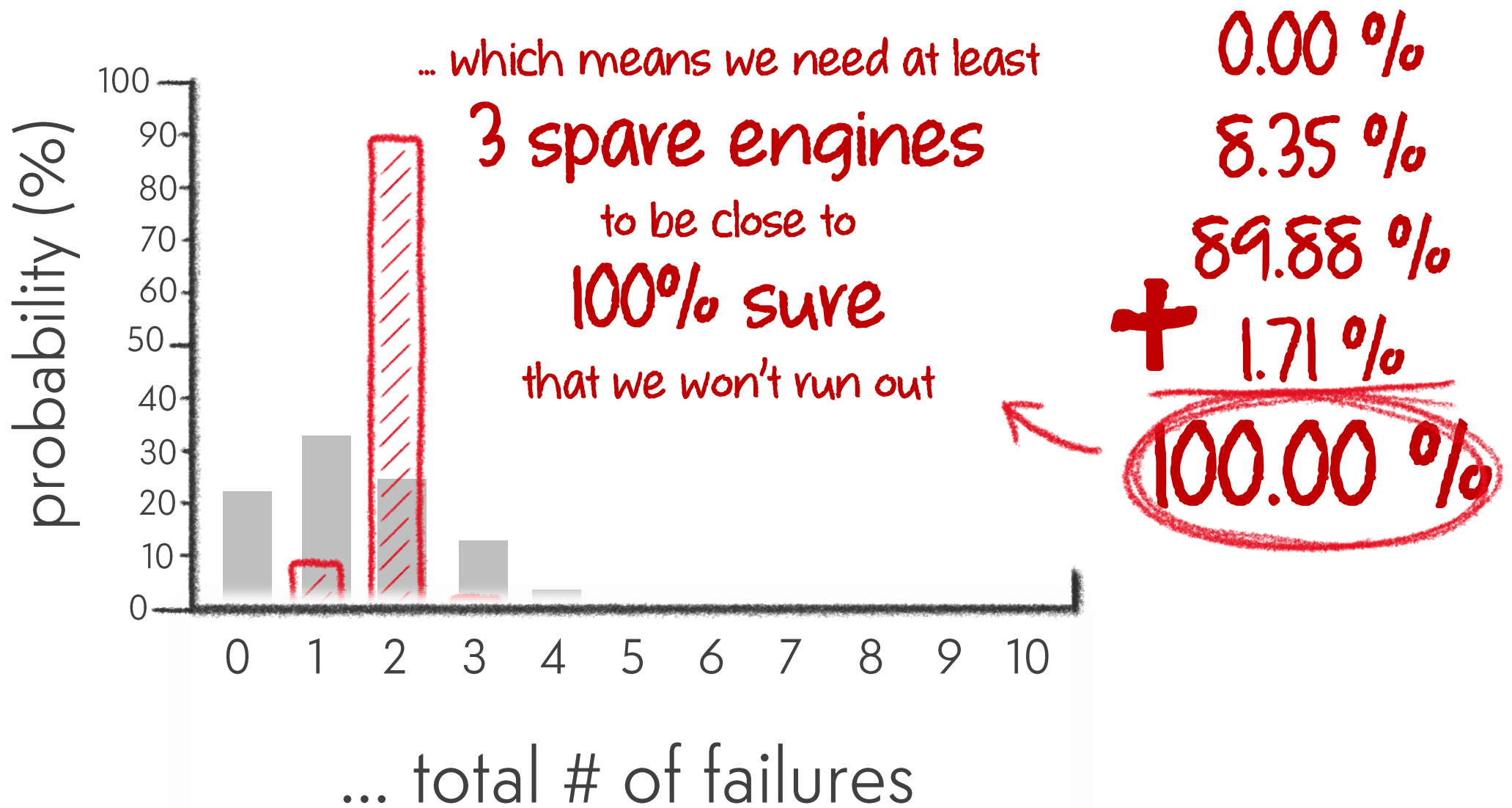
**0.00 %**







**0.00 %**  
**8.35 %**  
**89.88 %**



... \$ USD 1.4 – 1.6  
million



... what will happen to the

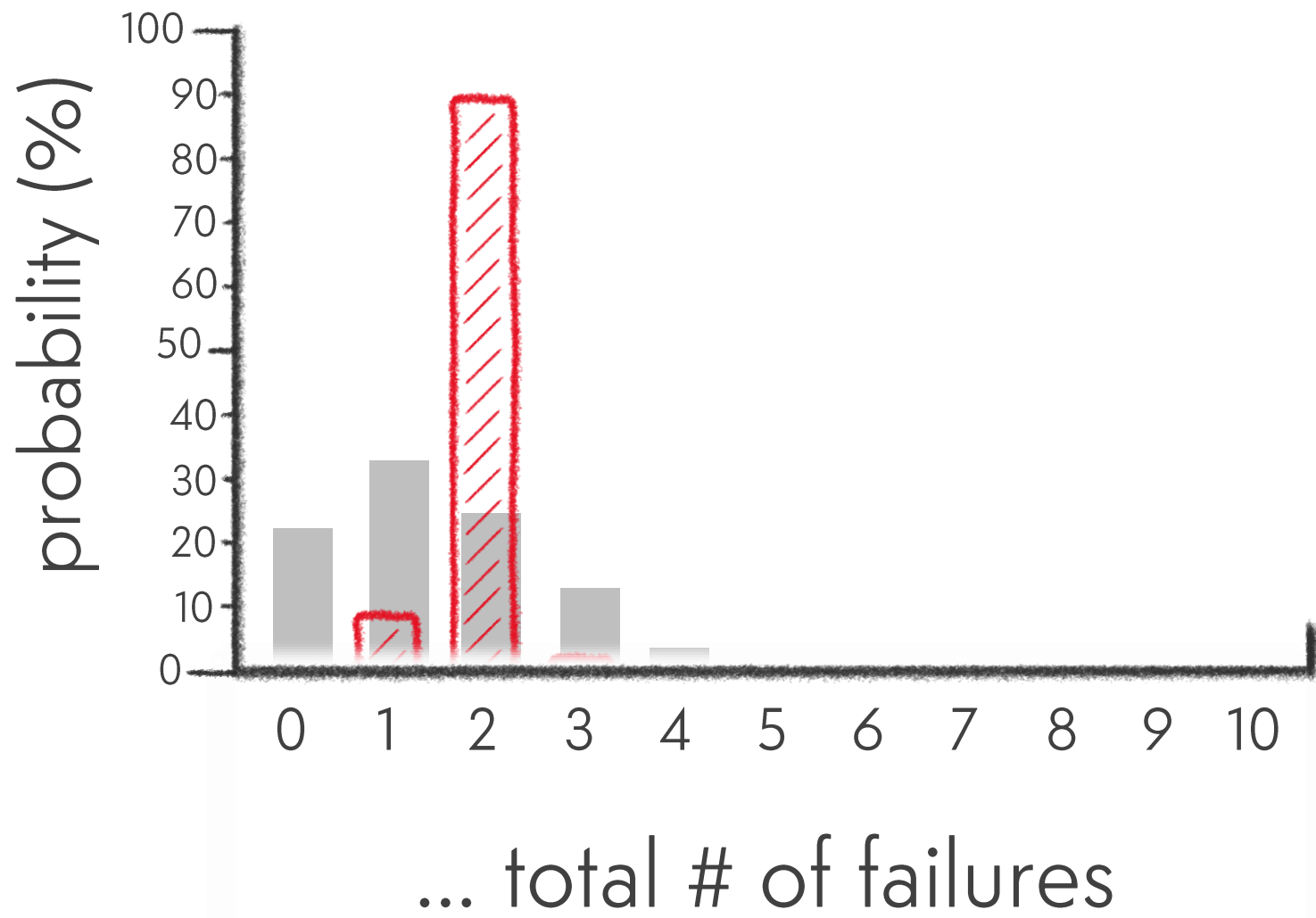
2 (of the 5)

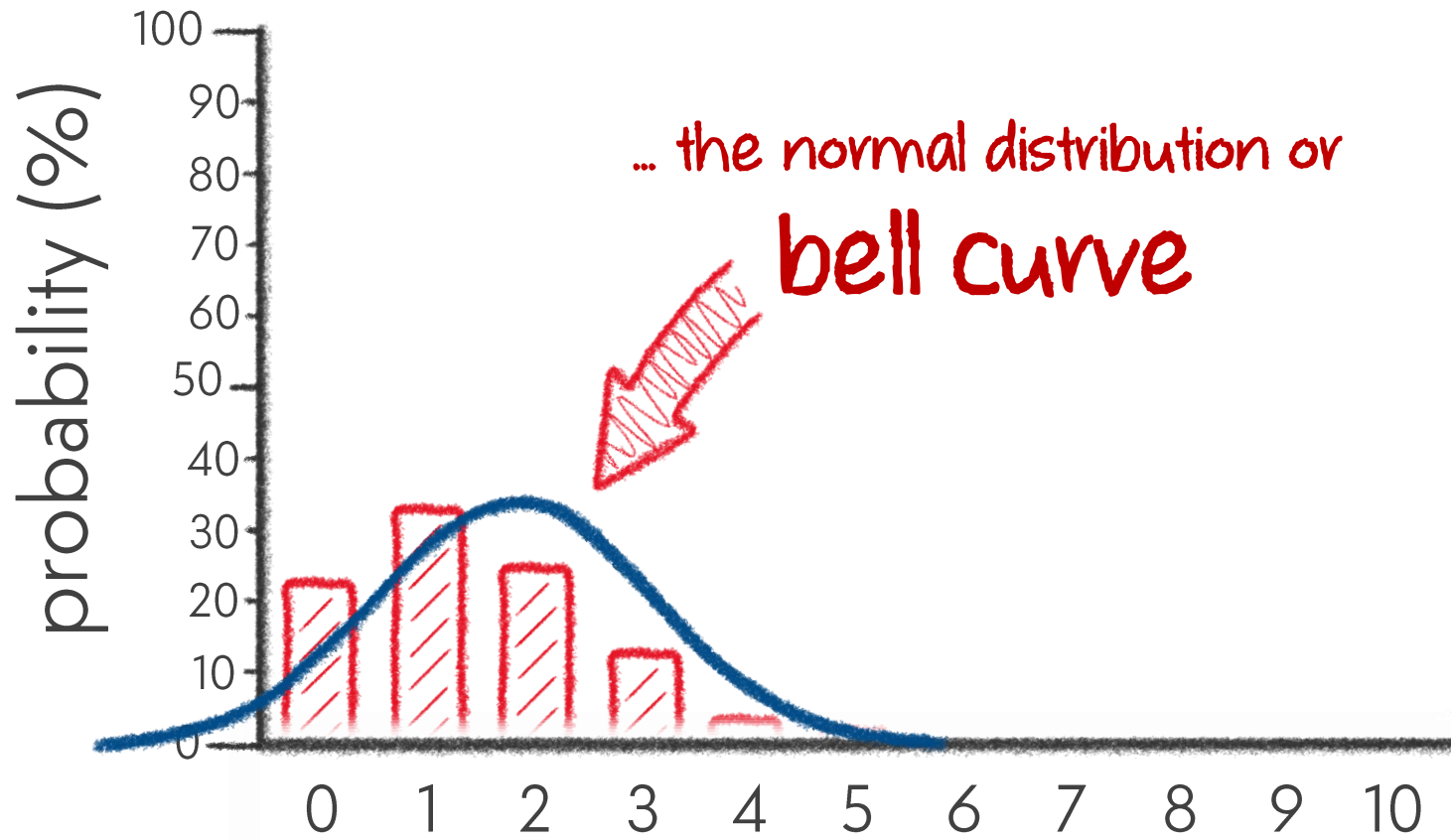
engines that are all but  
guaranteed to be left over  
after 3 years?

... and how  
much does it  
cost to  
PROPERLY  
warehouse  
these two  
engines?

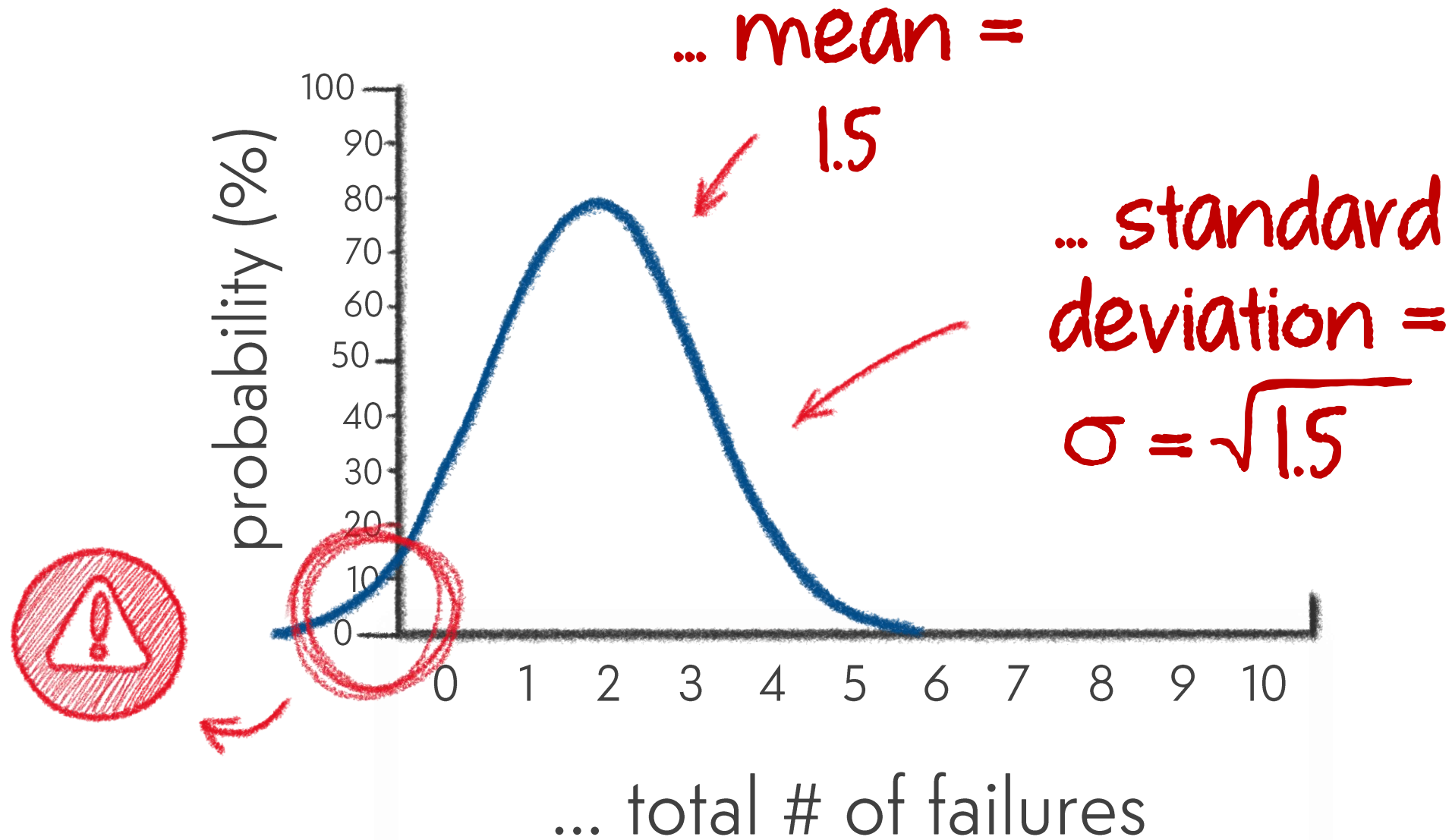
... dumb(er) way #2

... *OLD textbook*



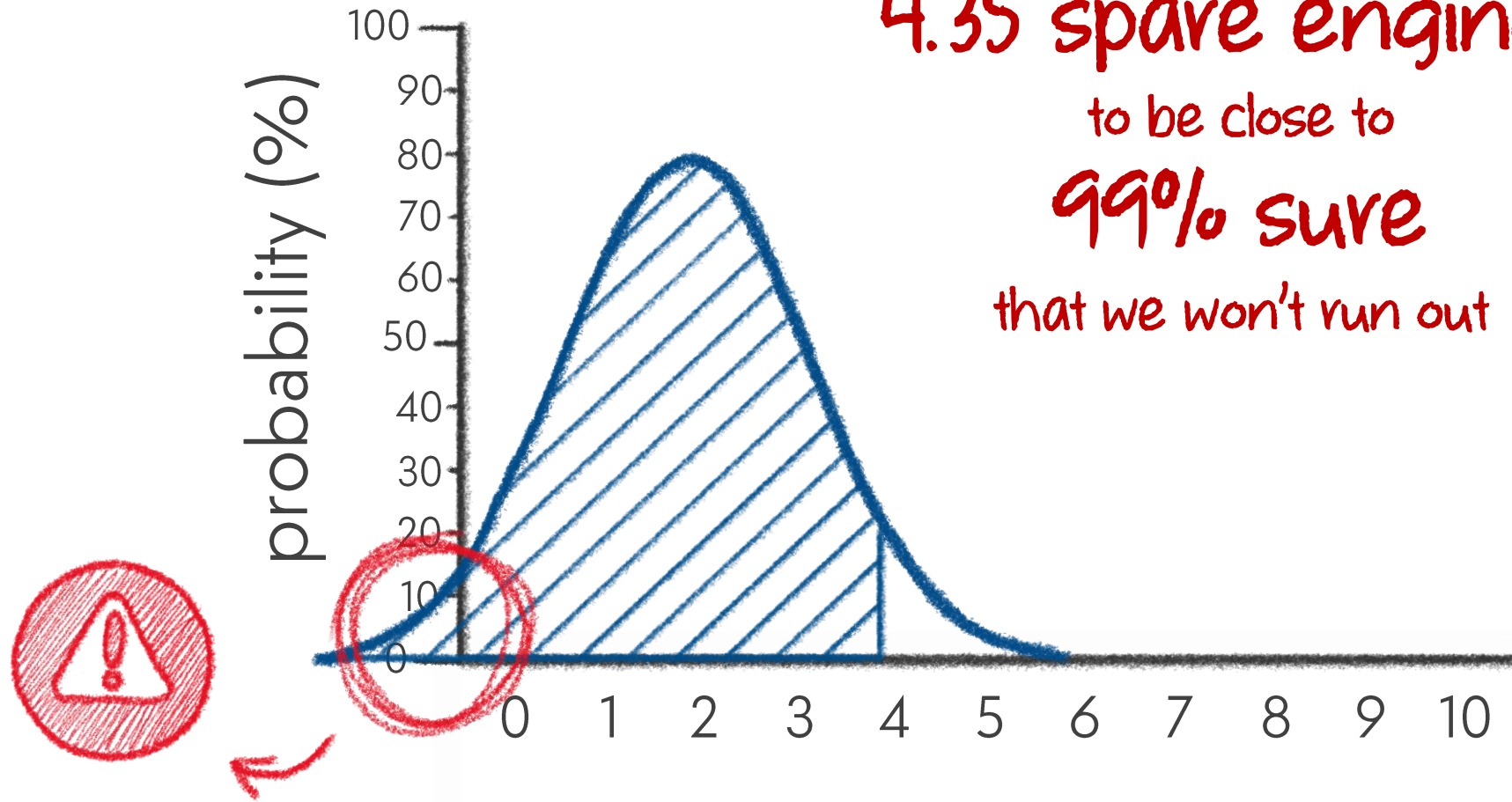


... total # of failures





... which means we need at least  
**4.35 spare engines**  
to be close to  
**99% sure**  
that we won't run out



... total # of failures

... failure  
rate

... interval

# of spares

$$= \lambda t + z_{CL} \sqrt{\lambda t}$$

... standard normal  
variable

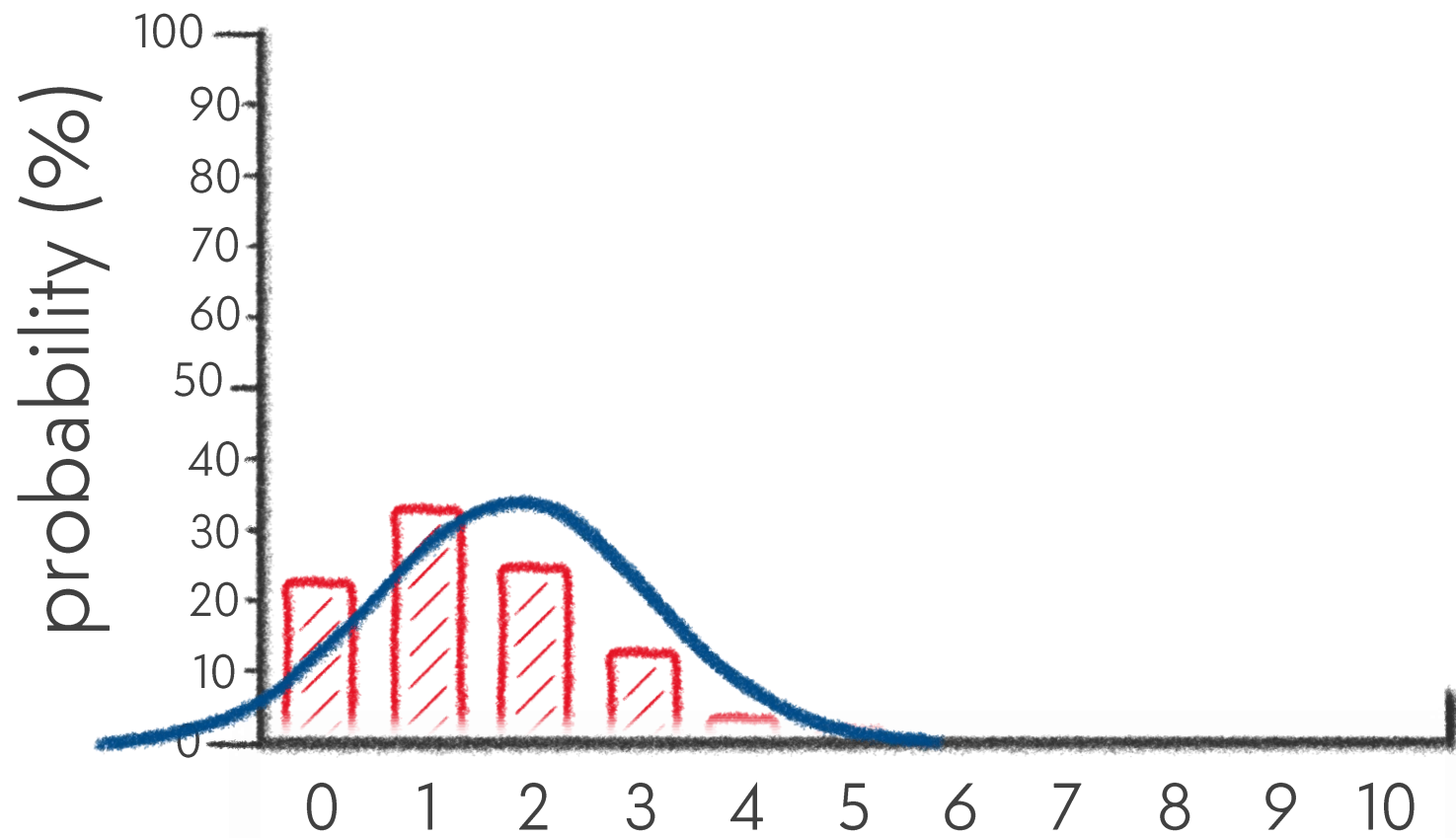
... for this level  
of confidence

... this approximation was used back when the only way to solve statistical problems was through a *normal distribution table* in the back of textbooks.

... and technological advances in medicine allowed us to eradicate SMALLPOX in 1979

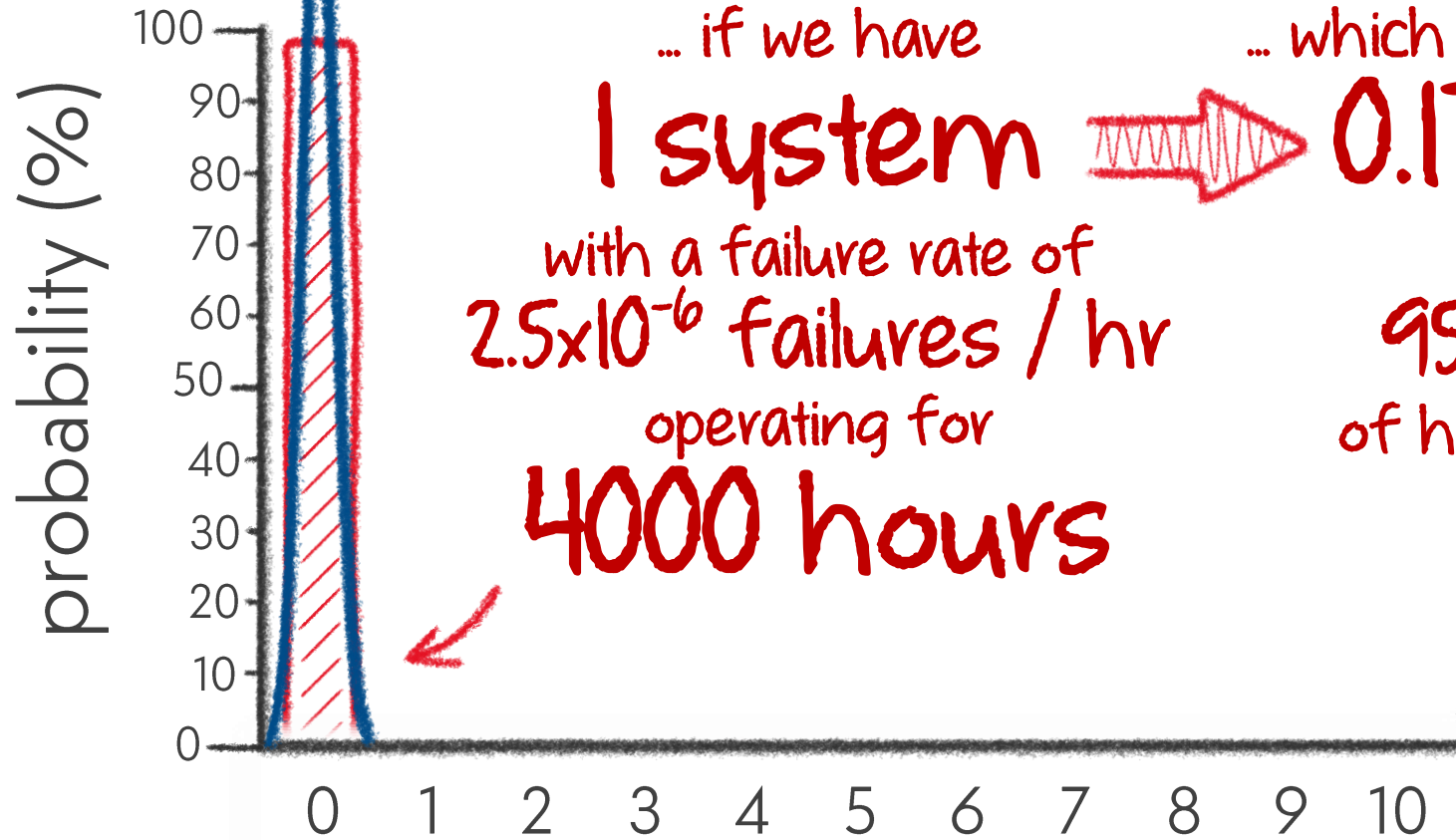
... (next level) dumb way #3

... *several BOKs*



... total # of failures

... here is the  
normal  
approximation

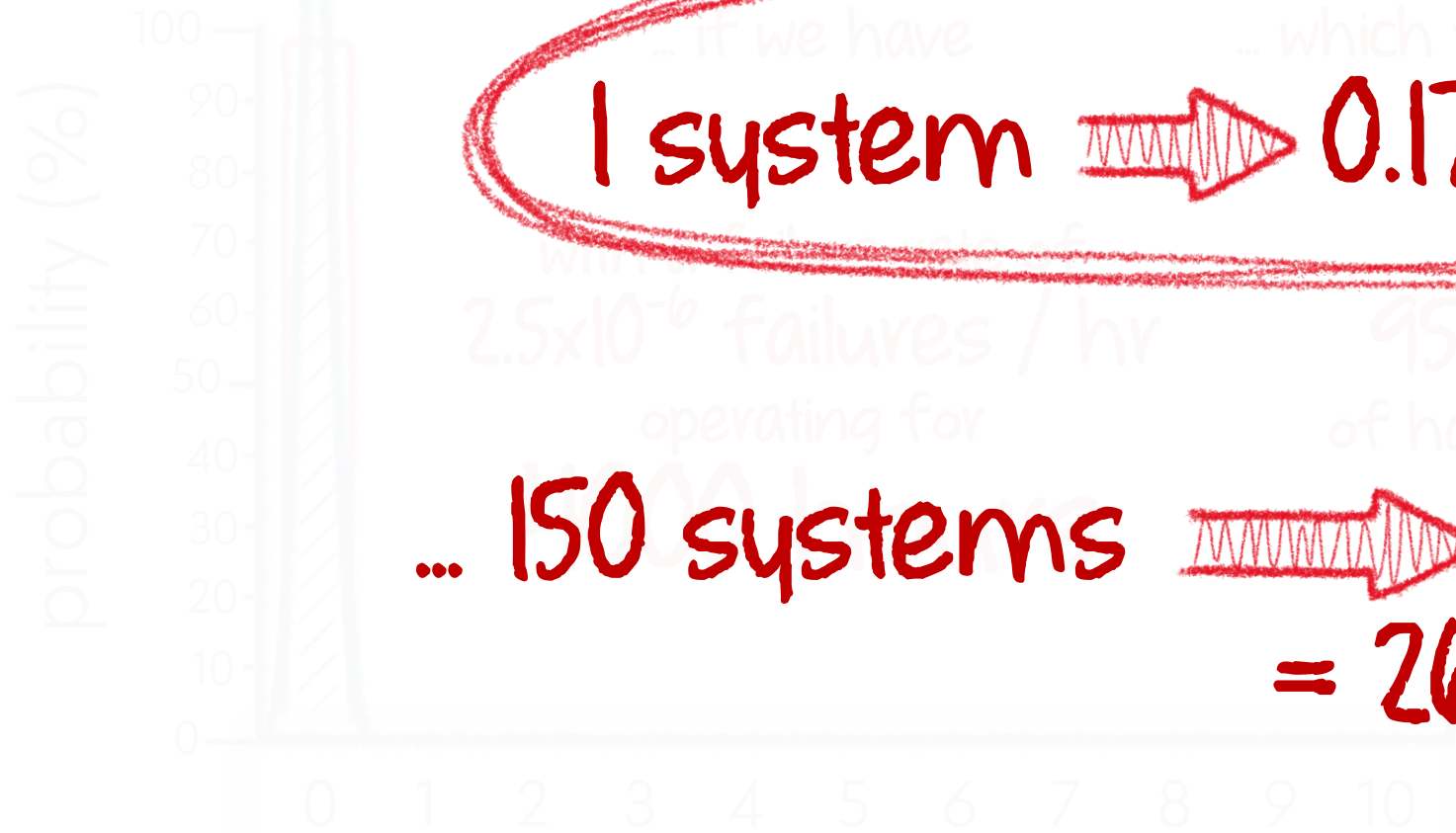


... if we have  
**1 system**  
with a failure rate of  
 $2.5 \times 10^{-6}$  failures / hr  
operating for  
**4000 hours**

... which tells us we need to have  
**0.1745 spares**  
to be  
**95% confident**  
of having enough spares  
for 4000 hours

... total # of failures

... here is the  
normal  
approximation



1 system  $\Rightarrow$  0.1745 spares

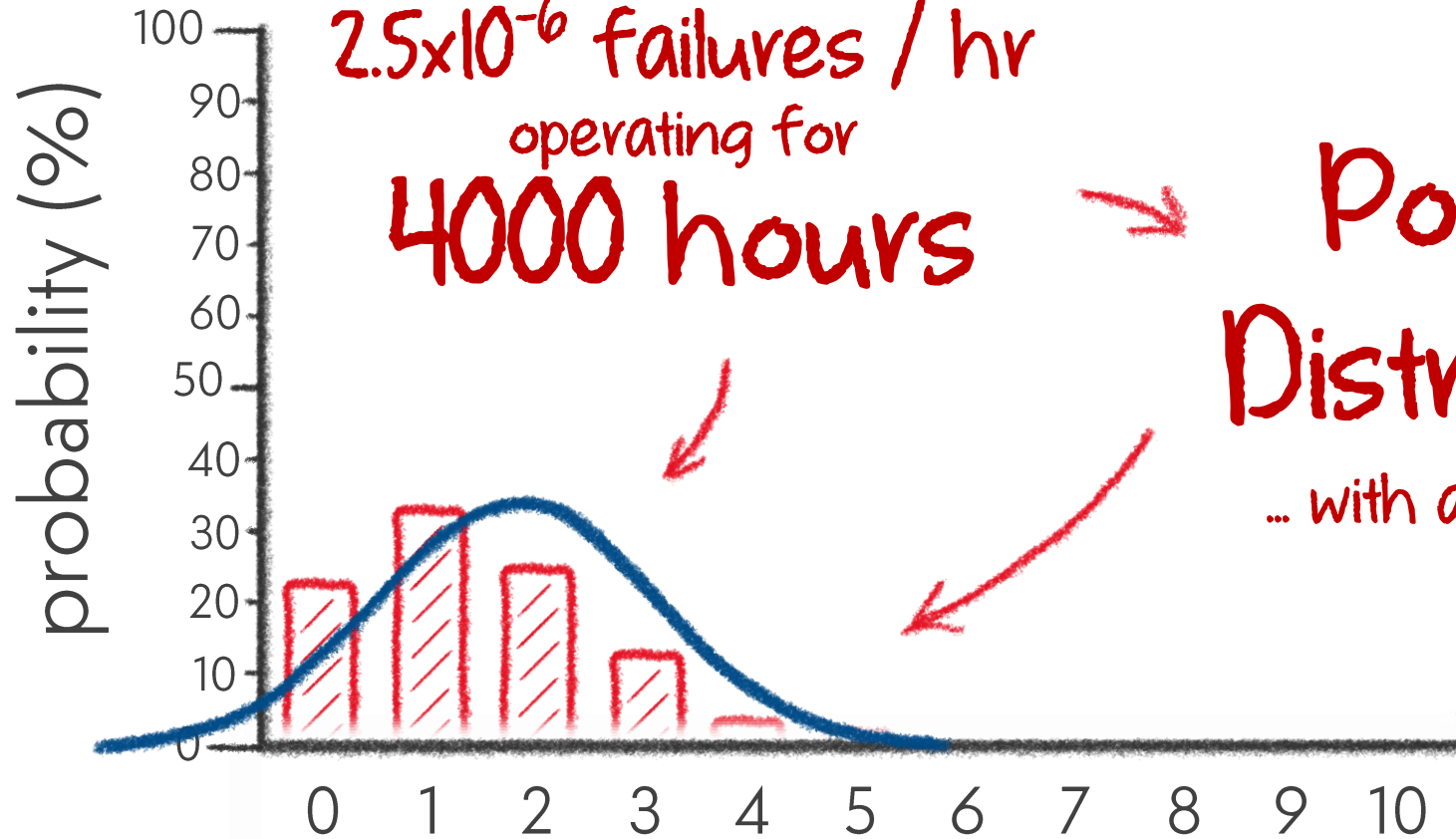
... 150 systems  $\Rightarrow$  x 150  
= 26.2 spares

... but remember the  
example we just  
went through?



150 systems

with a failure rate of  
 $2.5 \times 10^{-6}$  failures / hr  
operating for  
4000 hours



... the  
**Poisson  
Distribution**  
... with a mean of 1.5

... we need  
4 spares

... for a fleet of 150 ... total # of failures

4 spares ... fleet

27 spares ... dumb

... truly dumb way #4

... *old guy guesses*

... assuming a  
series system

... number of  
each component  
in the system

$$\lambda_{\text{equip}} =$$

$$N_1 \lambda_1 + N_2 \lambda_2 + \dots + N_n \lambda_n$$

... generic component failure rates from some book  
(like MIL-HDBK-217F)

$$\lambda_{\text{equip}} =$$

$$N_1 \pi_{Q1} \lambda_1 + N_2 \pi_{Q2} \lambda_2 + \dots + N_n \pi_{Qn} \lambda_n$$

... these are called  
**quality factors**  
which we get from ... witchcraft?

$$\lambda_{\text{equip}} =$$

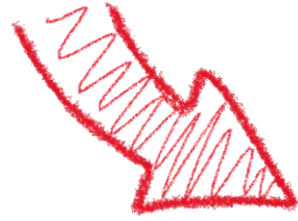
$$N_1 \pi_{Q1} \pi_{e1} \lambda_1 + N_2 \pi_{Q2} \pi_{e2} \lambda_2 + \dots + N_n \pi_{Qn} \pi_{en} \lambda_n$$

... these are called

**environmental stress factors**

which we get from ... the same witch?

... which means we are not even pretending to use reliability engineering to get this



$$\lambda_{\text{equip}} =$$

$$N_1 \pi_{Q1} \pi_{e1} \lambda_1 + N_2 \pi_{Q2} \pi_{e2} \lambda_2 + \dots + N_n \pi_{Qn} \pi_{en} \lambda_n$$

... these are called

environmental stress factors

which we get from ... the same witch?

... economic  
order quantity

... annual  
failure rate

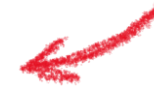


EOQ

=

$$\sqrt{\frac{2\lambda s}{ic}}$$

... setup  
costs



... interest and  
carrying costs  
(percentage)



... unit  
cost





# EOQ

... and this might not align  
with Poisson distribution  
spare part analysis

... but this is only a

rule

and not an  
optimized figure  
or formula

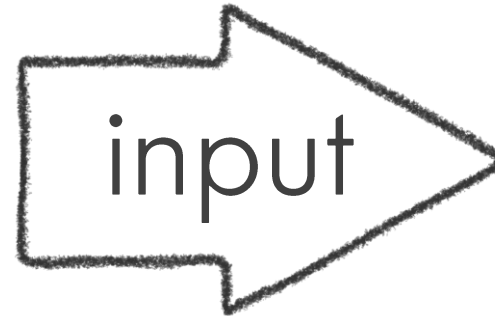
... how do you  
do yours?

**maintainability**



**logistics  
engineering**

**maintainability**



**logistics  
engineering**

