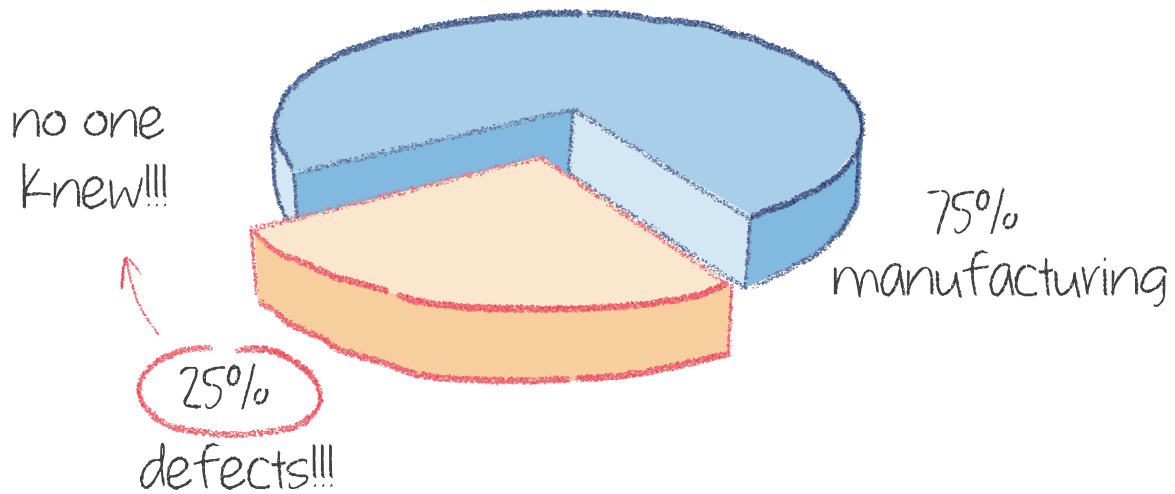




lets start with a story ...

but the CEO had a hunch that
things weren't that good ...
... so he launched an
investigation

manufacturing resources

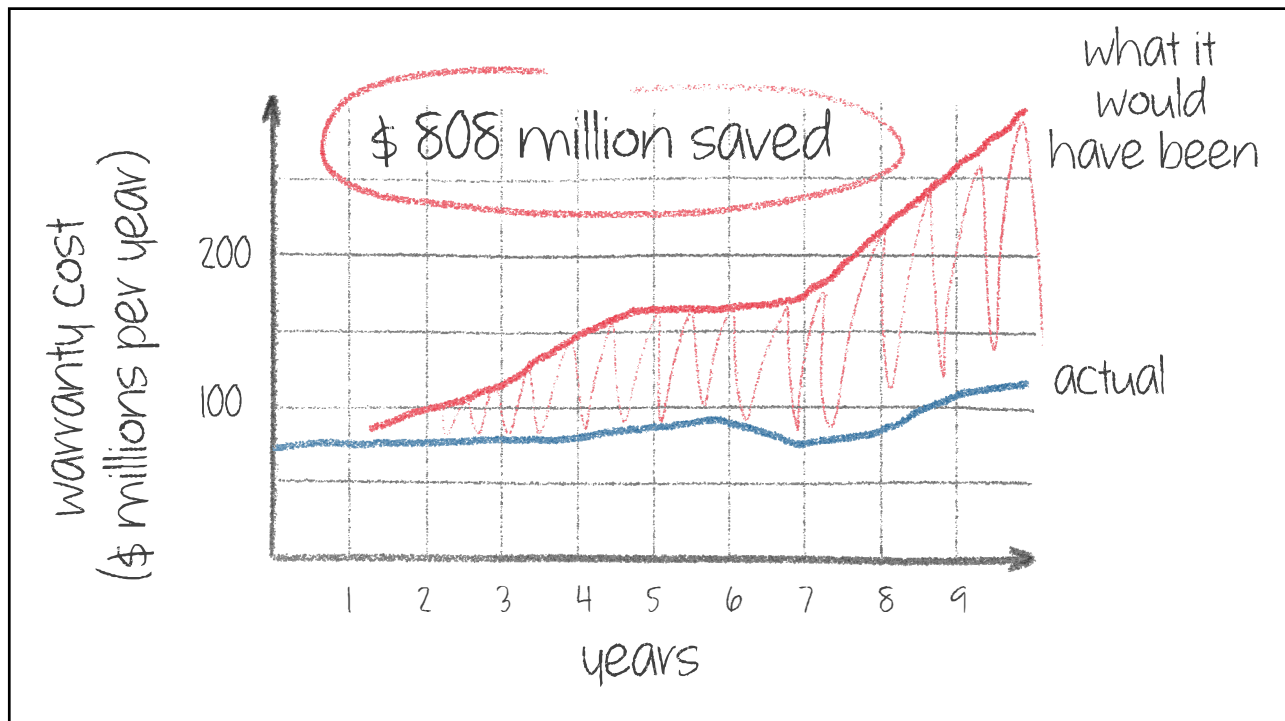
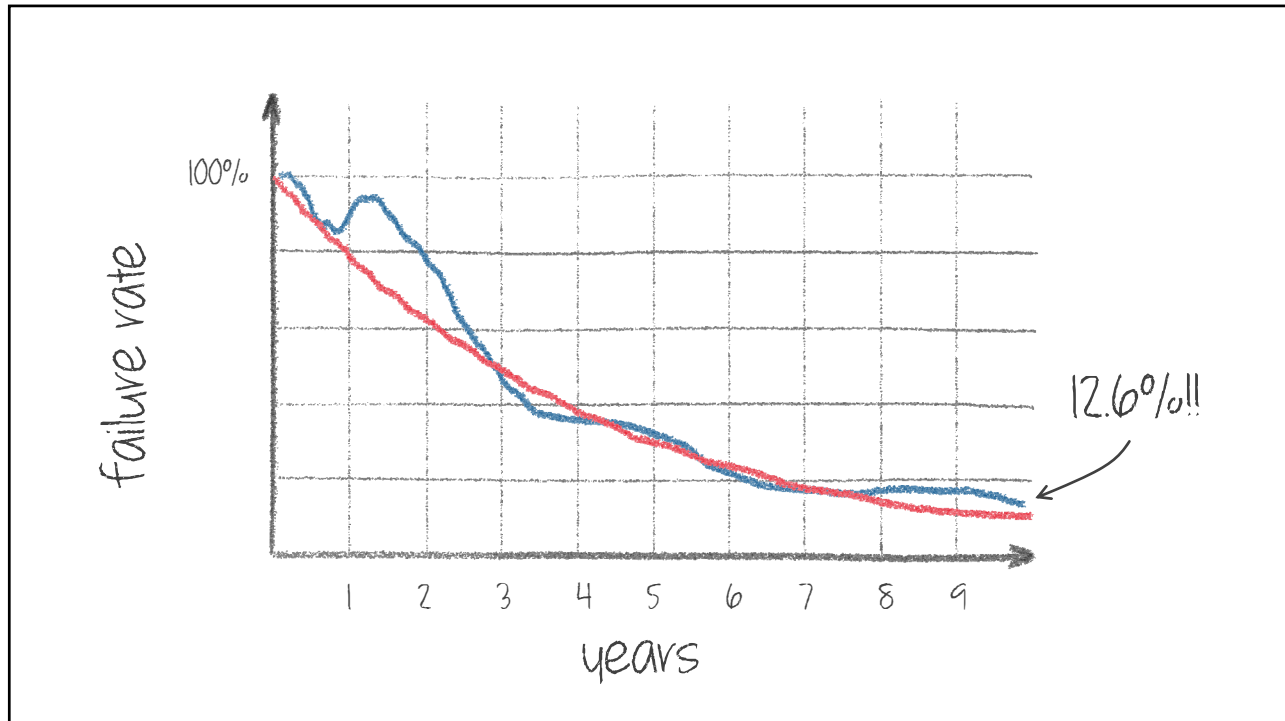


So the management team did something about it

Among the many things they did, they provided absolute commitment to improving reliability and quality

They also set a goal:

*A tenfold factor decrease in failure rate
over a ten year period*



who was this?



**HEWLETT®
PACKARD**

... a company whose marketing plan
relies on the perception of reliability



**Christopher
Jackson**

Reliability and Logistics Engineer
Management Specialist

FMS Reliability
Founder of Acuitas Reliability
Founder of the Center for the Safety
and Reliability of Autonomous Systems
(SARAS) @ UCLA

what is reliability?

reliability/
[ri-lahy-uh-bil-i-tee]

noun

is the **probability** that a system
 has **not failed** in designated
conditions at a particular usage
duration

a form of
arithmetic average
 ... or expected value

... a better word would be '**usage
 duration**' as in equipment life is
 not just measured by time

what is the
mean time
between failure?

... the word is '**between**' and **does**
 not imply a '**failure free**' period

... where the system inherently
ceases to function

mean time between failure/
[meen tahym bih-tween feyl-yer]

noun

is the arithmetic average duration
between successive failures of
repairable systems.

M..T..B..F

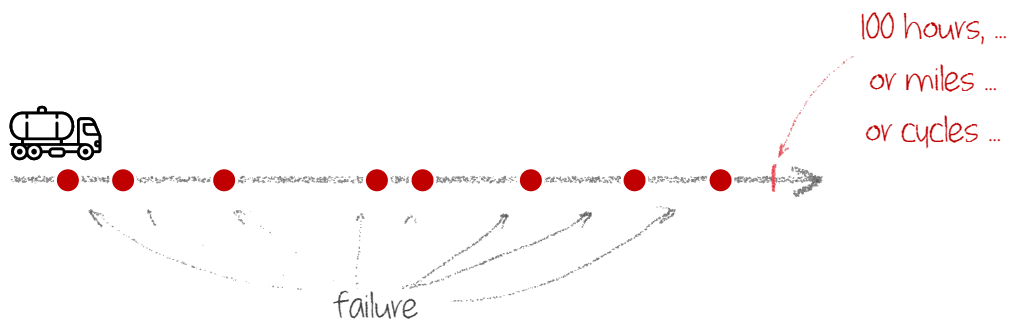
sometimes denoted Greek
letter 'theta' or θ

M..T..B..F

$$\approx \frac{\text{total usage duration}}{\text{number of failures}}$$

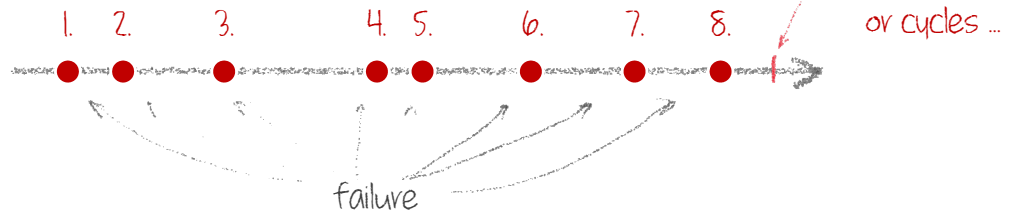
... approximation???

... because failure is a random process, and any observed data is observed **random** data



M.T.B.F

$$\approx \frac{\text{total usage duration}}{\text{number of failures}} = \frac{100}{8} = 12.5$$



but the MTBF (and nothing else) says nothing about whether the rate at which failure is occurring is increasing, decreasing or staying the same

M.T.B.F

$$\approx \frac{\text{total usage duration}}{\text{number of failures}} = \frac{100}{8} = 12.5$$



but the MTBF (and nothing else) says nothing about whether the rate at which failure is occurring is increasing, decreasing or staying the same

M.T.B.F

$$\approx \frac{\text{total usage duration}}{\text{number of failures}} = \frac{100}{8} = 12.5$$



100 hours, ...
or miles ...
or cycles ...

but the MTBF (and nothing else) says nothing about whether the rate at which failure is occurring is increasing, decreasing or staying the same

I am a reliability engineer ...

I am not here to admire a

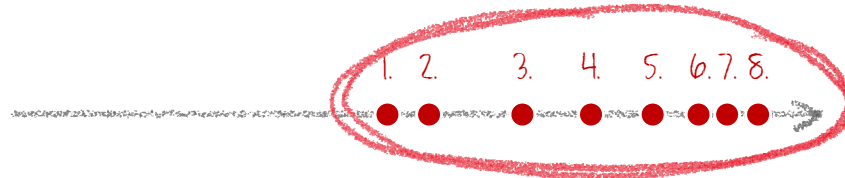
do testing ← problem → do analysis

↓

write a report

M.T.B.F

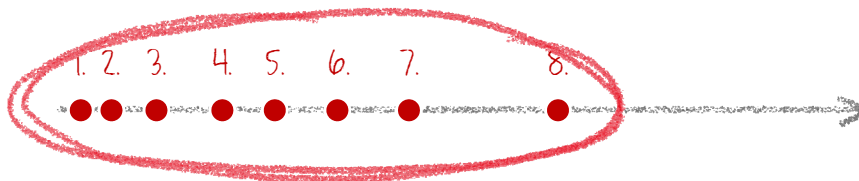
$$\approx \frac{\text{total usage duration}}{\text{number of failures}} = \frac{100}{8} = 12.5$$



... so failure is caused by components slowly **accumulating damage** – and we can make them more robust, introduce servicing, reduce stresses ...

M.T.B.F

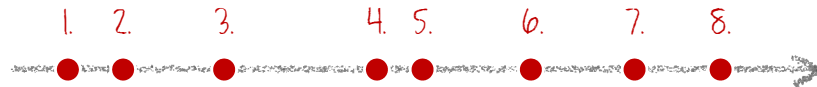
$$\approx \frac{\text{total usage duration}}{\text{number of failures}} = \frac{100}{8} = 12.5$$



... so failure is likely caused by **manufacturing defects**
– so we need to look at manufacturing quality,
improve Design for Manufacturability...

M..T..B..F

$$\approx \frac{\text{total usage duration}}{\text{number of failures}} = \frac{100}{8} = 12.5$$



... so failure is likely caused by **external events** – so we look at human error, the operating environment ...

I am a reliability engineer ...

I am not here to admire a problem

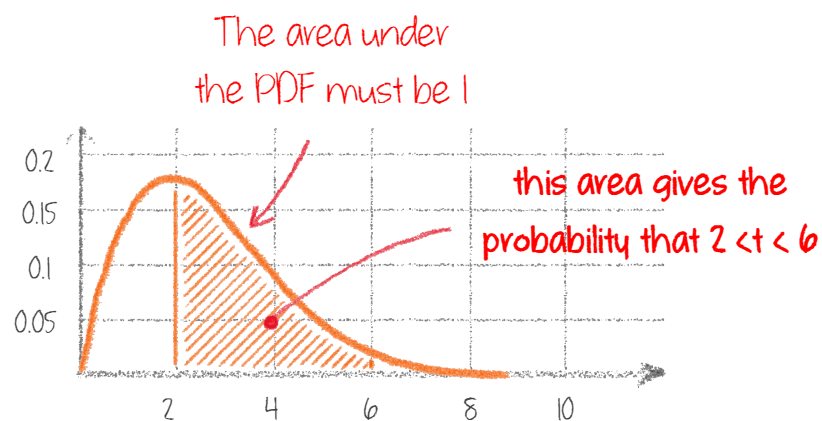
... I am here to **improve the design and make it more reliable**

... and to do this, I need to
know the nature of failure.

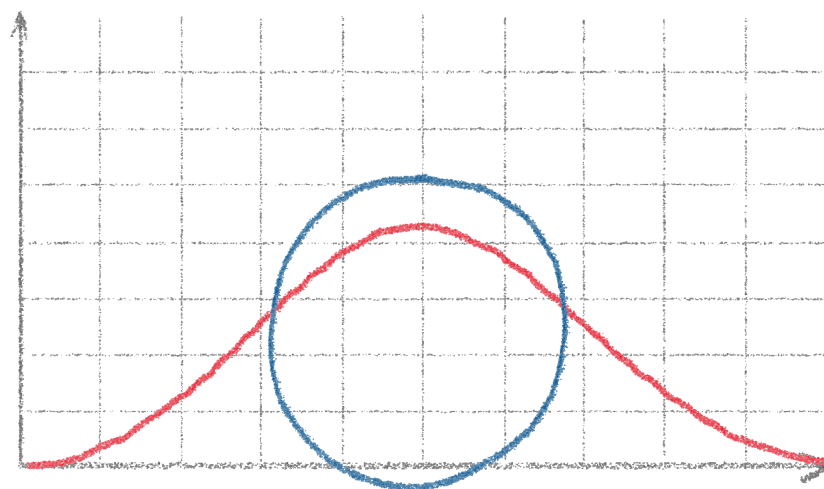
MTBF = 12.5 tells me nothing

So lets talk about
probability density
functions (PDFs)

The PDF gives the relative probability that a continuous random variable is equal to a specific value



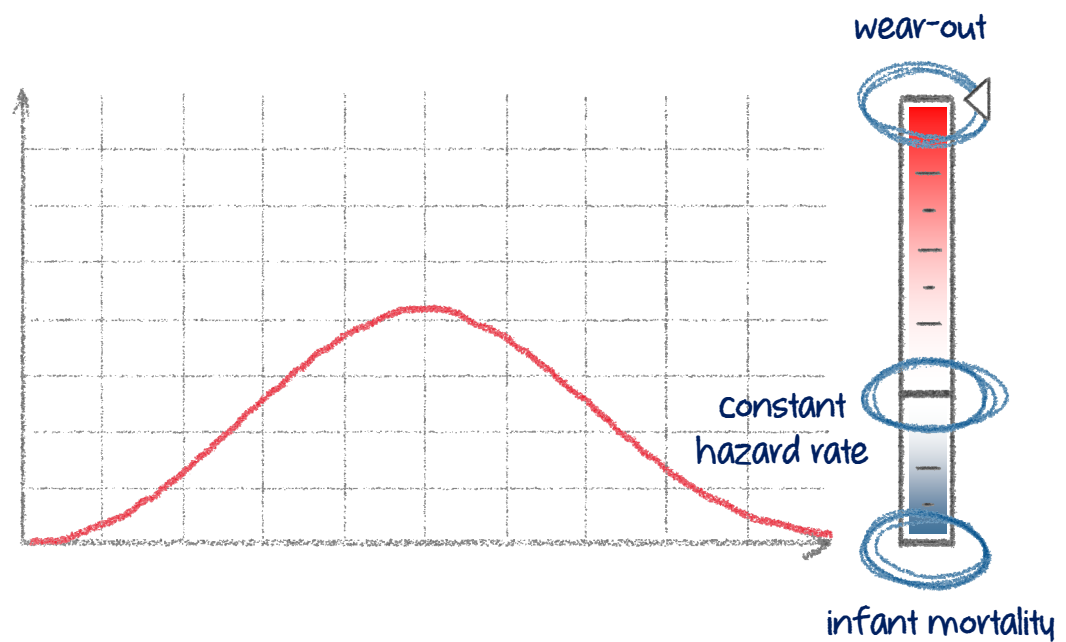
... lets look at an example

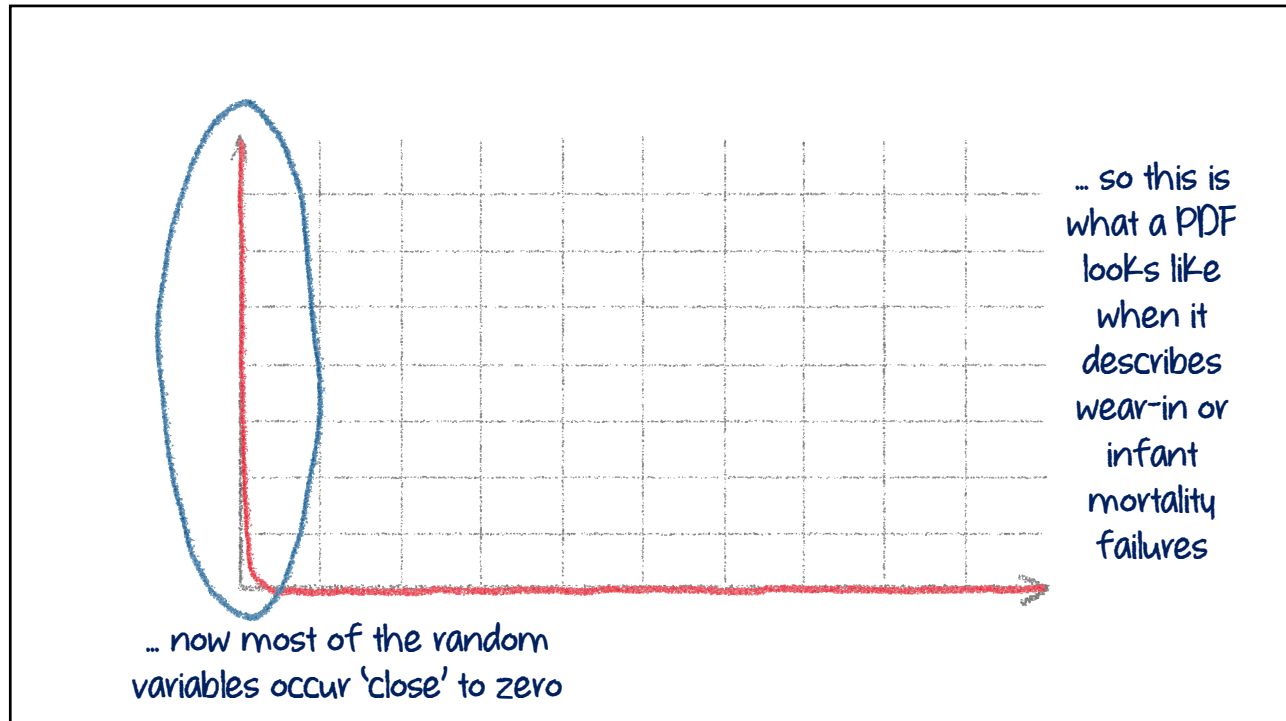


... so this is what a PDF looks like when it describes wear-out failures

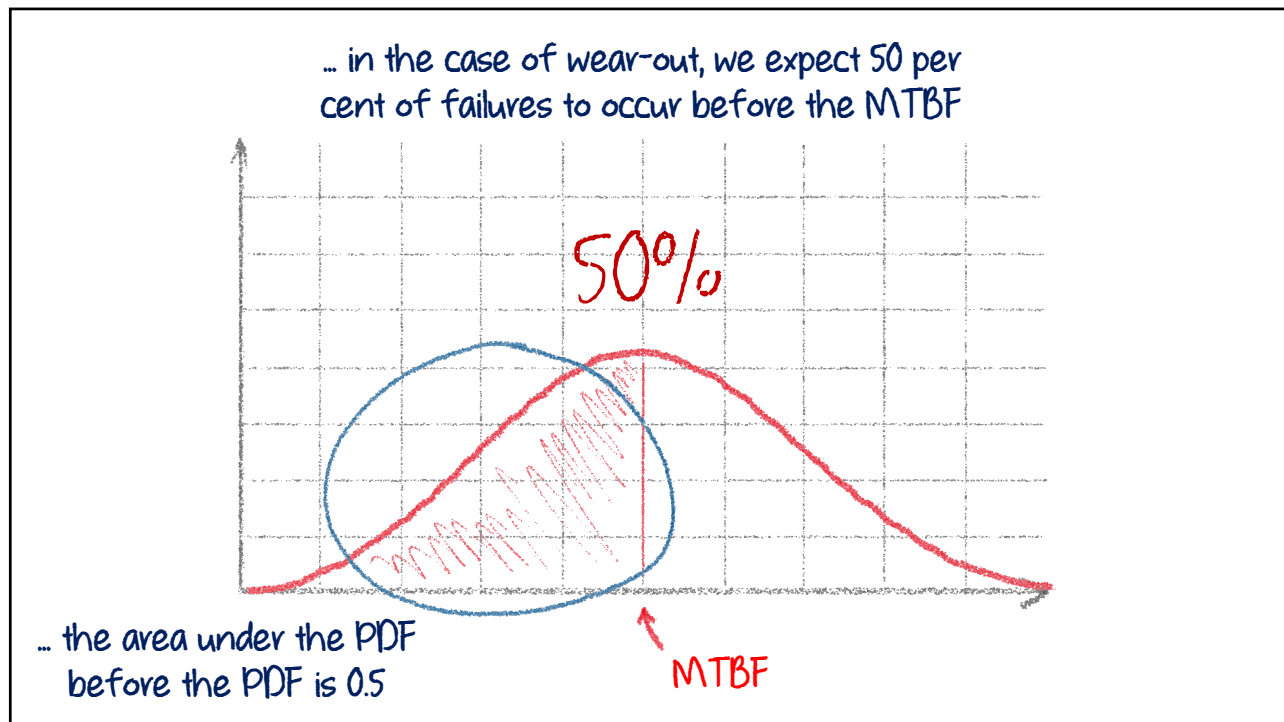
... most of the random variables occur 'away' from zero

... lets change it

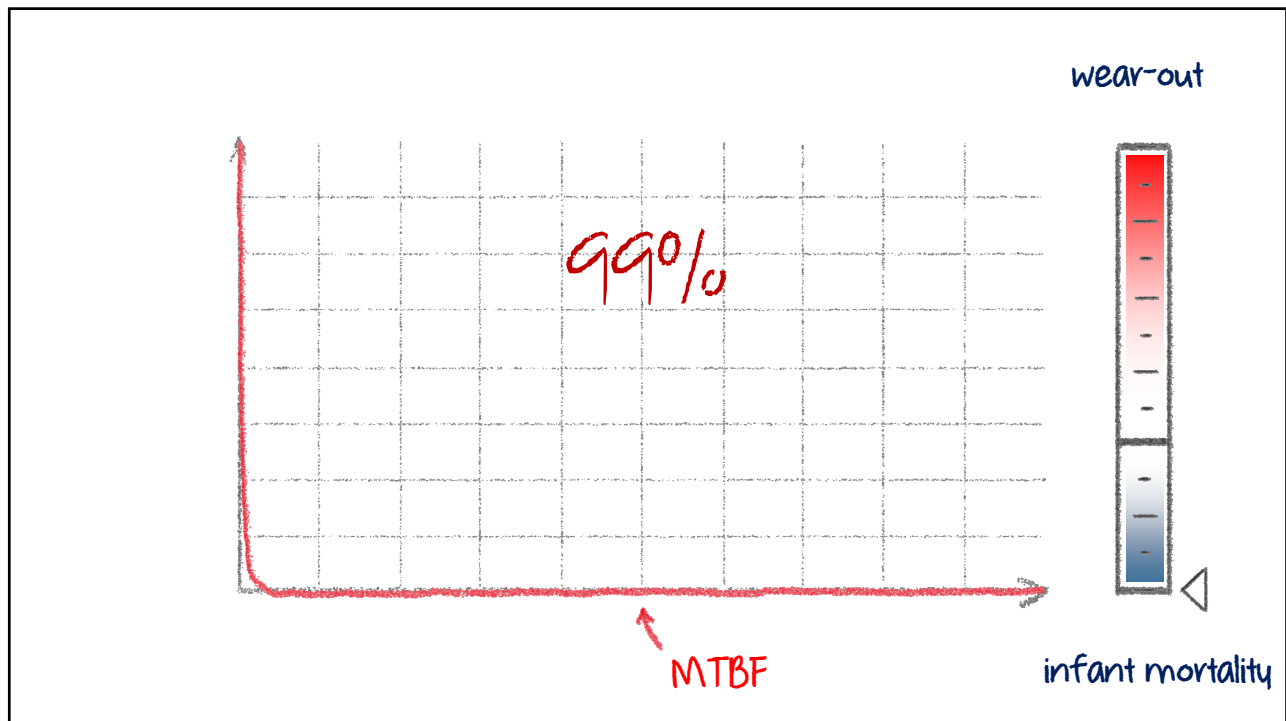
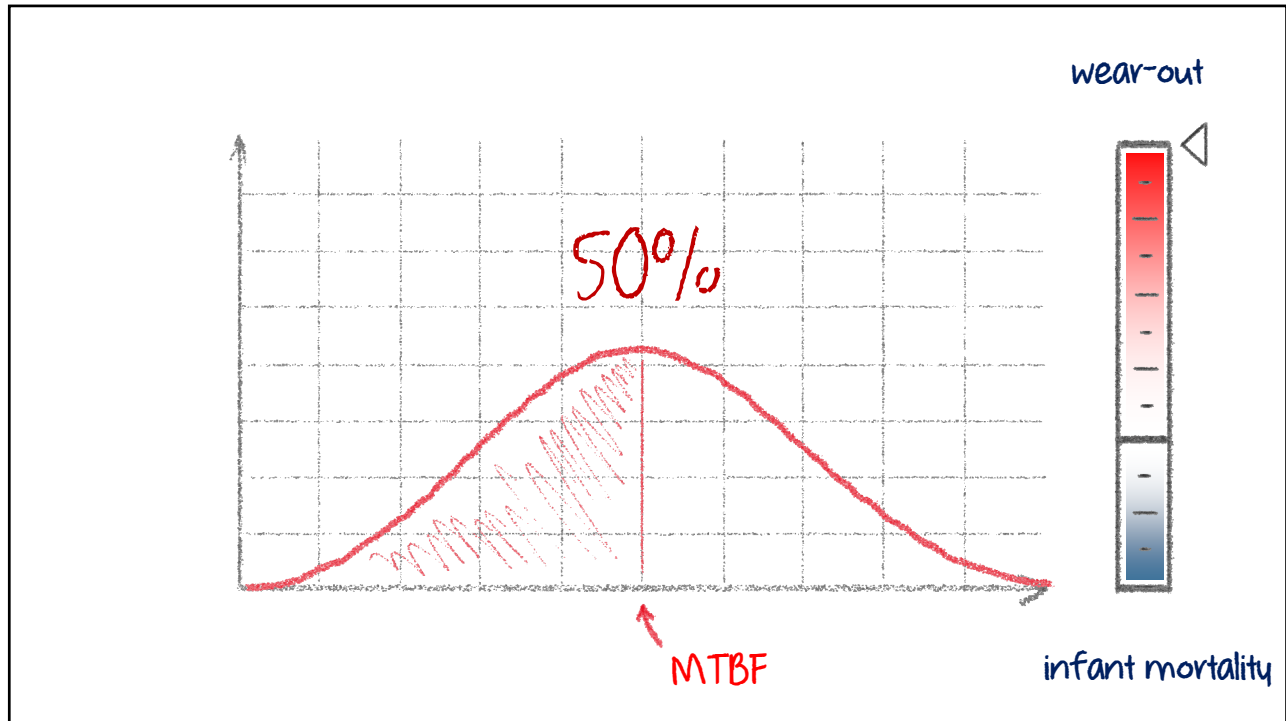




they have the same mean (or MTBF if we are talking about failure)

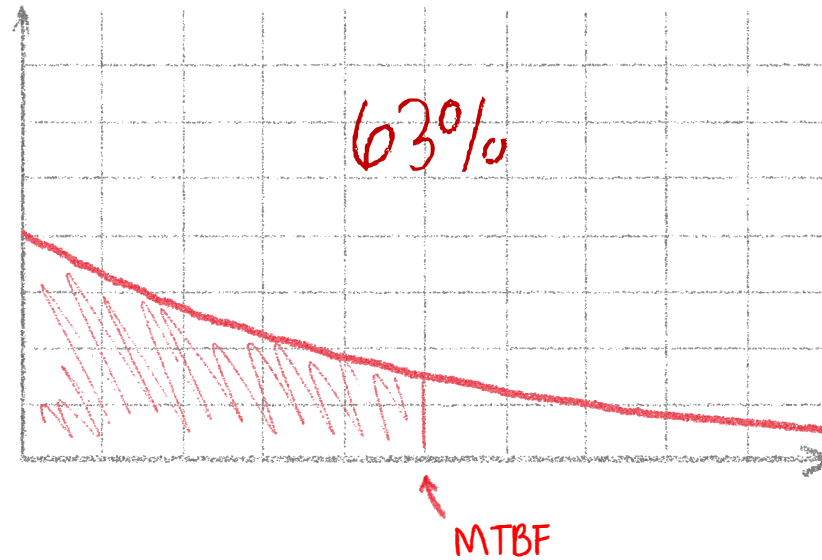


... lets change the PDFs
and see what happens
to the probability
failure occurs before
the MTBF



so anywhere between
50 and 100 per cent of
failures will occur
before the MTBF

... and which one of
these had a constant
hazard rate?



exponential distribution


[ek-s poh-nen-shuh l dis-truh-
byoo-shuh n]

... time to or between events (failure) for a
constant hazard rate

exponent/
[ek-spoh-nuh nt]

noun

is the number that denotes the power to
which another number is raised.

$$x^a$$


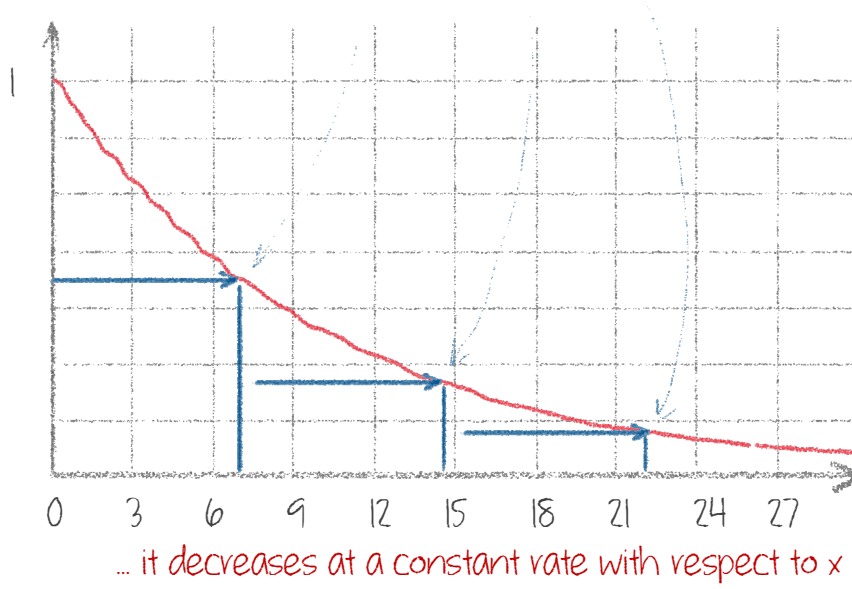
... in this case, 'a' is the **exponent** to
which 'x' is raised

$$x^a$$

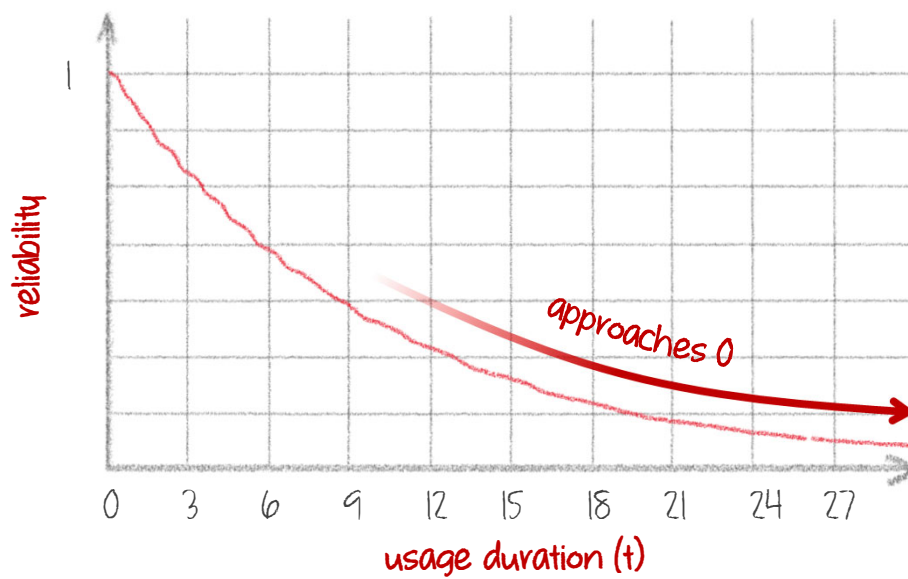
... so for every **unit increase in x**, the value
'x^a' will increase by a factor of 'a' ...

... noting that if 'a' is negative, 'x^a' will go
down by a factor of **a**

... the 'height' of this curve halves over the same interval step of time



$\lambda = 0.1$ failures per unit duration



OBSERVATION



the **exponential distribution** can be used to model failure where the probability of failure does not change with respect to time or usage ...

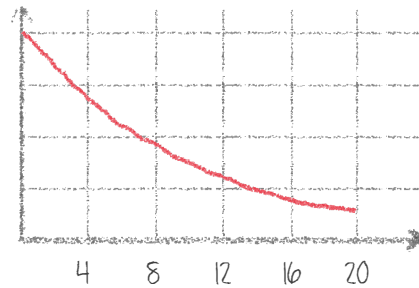
... there is no scope for **wear-in** or **wear-out**

... the exponential distribution is **simple** ... and is often used (with assumptions) to reduce complexity

so lets look at some
common mistakes
people make about
failure and MTBFs

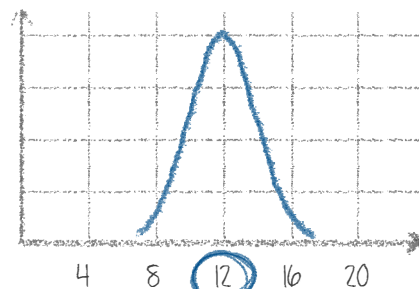
EXAMPLE

a lot of people do not 'imagine' the exponential PDF
when the MTBF is measured ...



EXAMPLE

a lot of people do not 'imagine' the exponential PDF
when the MTBF is measured ...



... they think of
this 'bell curve'
PDF instead

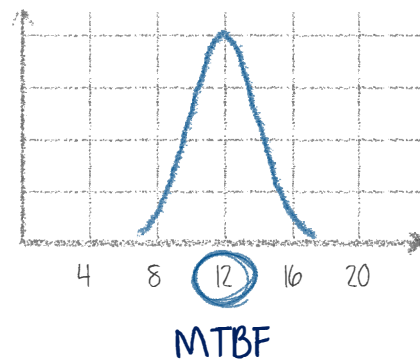
MTBF



but it gets
much worse ...

EXAMPLE

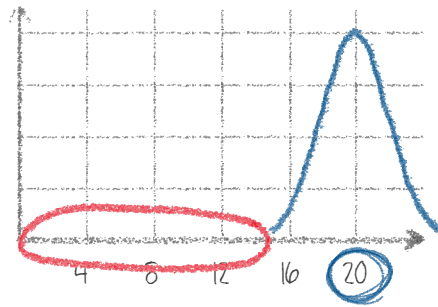
some people equate the MTBF with a
'failure free period' ...



EXAMPLE



some people equate the MTBF with a
'failure free period' ...



... the 'failure free'
period is not the MTBF

MTBF

EXAMPLE



some people equate the MTBF with a
'failure free period' ...

... yet time and time again, we see
things like servicing intervals set
to a system's MTBF

... which essentially means that
people are assuming the MTBF
to be a 'failure free' period

... the 'failure free'
period is not the MTBF

MTBF

and there are other
things people often
get wrong...

EXAMPLE



consider a 'fleet size problem'
a transportation company needs to have 8 trucks
available all the time.

They know that (on average) each truck is
available 80 per cent of the time

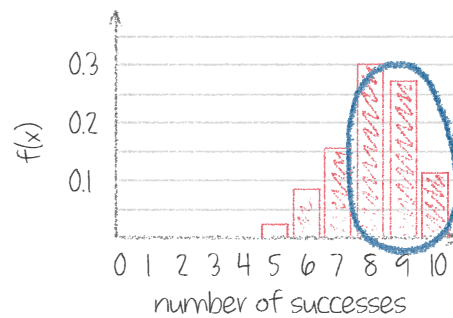
... or in other words the truck's availability is 80
per cent

so they need to have a fleet size of 10? ...
right?

EXAMPLE



here are the probabilities of certain numbers of trucks being available

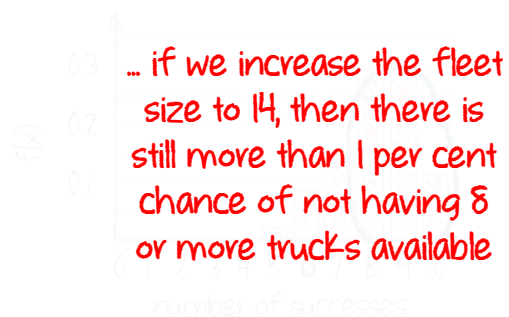


... there is only a 68 per cent chance of having 8 or more trucks available

EXAMPLE



here are the probabilities of certain numbers of trucks being available



... if we increase the fleet size to 14, then there is still more than 1 per cent chance of not having 8 or more trucks available

... there is only a 68 per cent chance of having 8 or more trucks available

OK... so I am a boss ...
what do I need to do?

RELIABILITY IS
OUR #1
PRIORITY!



... you often tell
your staff how
important
reliability is.



Reliability Hero
of the Month

... and you provide annual
bonuses to your staff who ...
(1) are on budget; and
(2) are on schedule

Engineer #1



focuses on schedule
focuses on budget

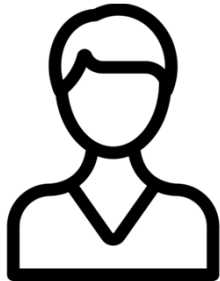
Engineer #2



... does some reliability stuff
schedule increases by 2 %
budget increases by \$ 150 000

saves
\$ 2 million
later

Engineer #1



focuses on schedule

focuses on budget



... it is irrational
for this person to
do 'reliability
stuff' and save
your company
\$1.85 million

Engineer #2



saves
\$ 2 million
later

... does some reliability stuff
schedule increases by 2 %
budget increases by \$ 150 000

... your job (as a boss) is to not
check your engineer's work ...

you should have already hired
smart people ...

... this is your job ...



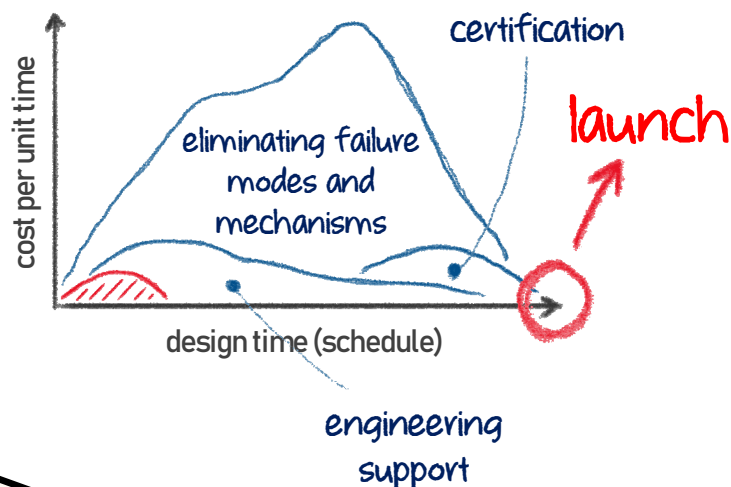
... but I don't care how
reliable it is for the
customer ...

... I need my equipment
developed fast and cheap

EXAMPLE



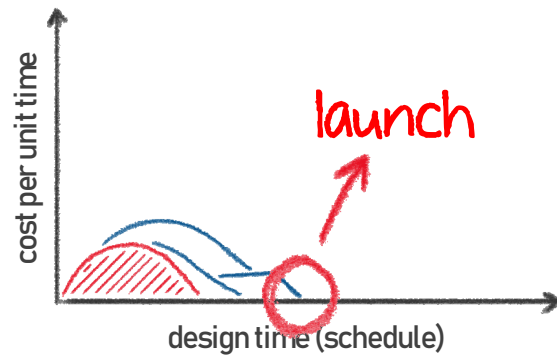
a common or traditional design process



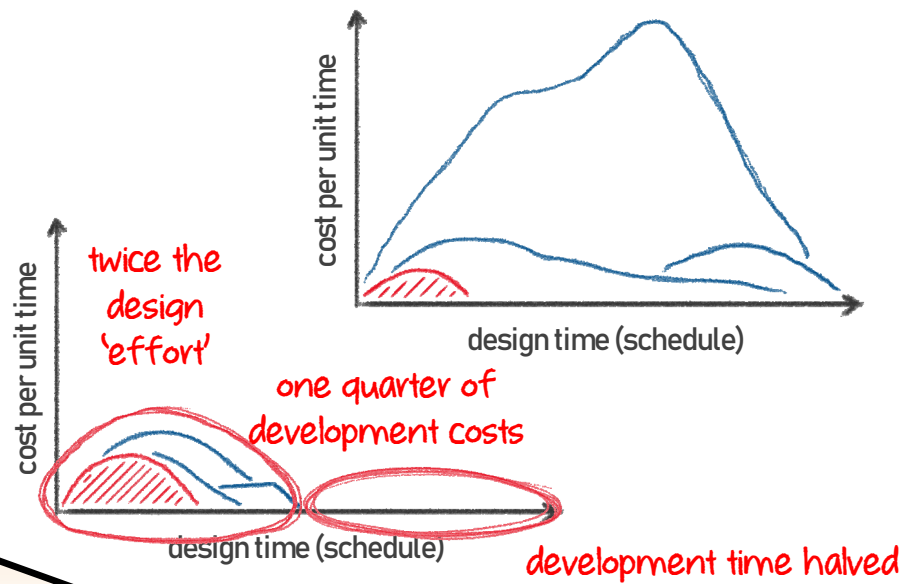
EXAMPLE



a 'more advanced' design process



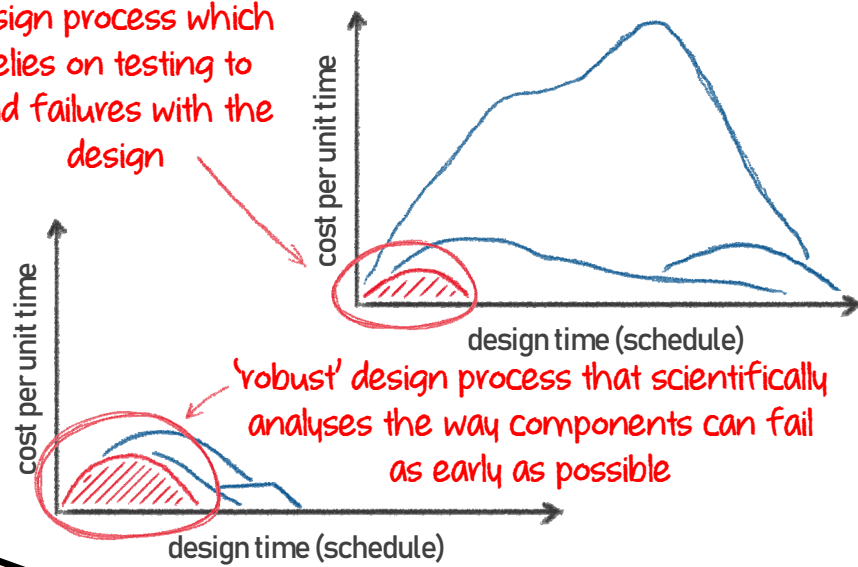
EXAMPLE



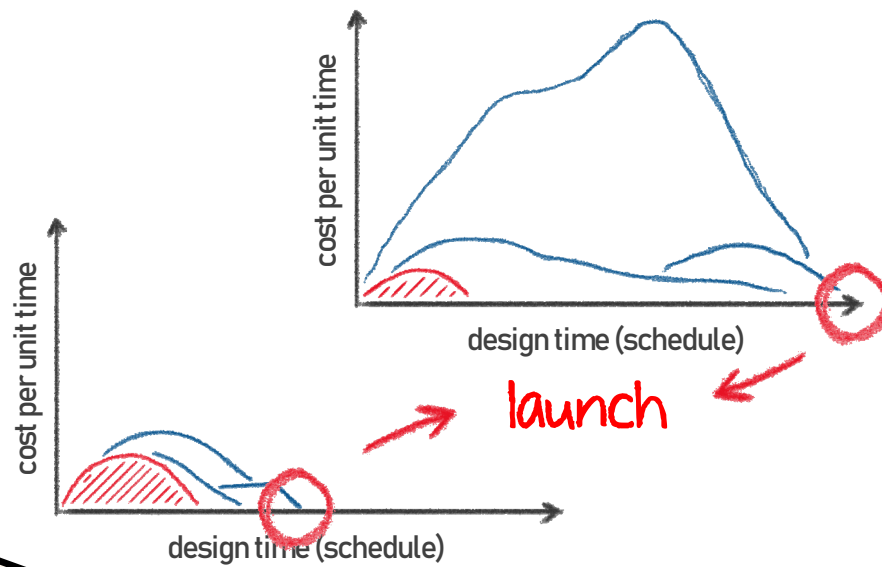
EXAMPLE



design process which
relies on testing to
find failures with the
design



EXAMPLE



EXAMPLE

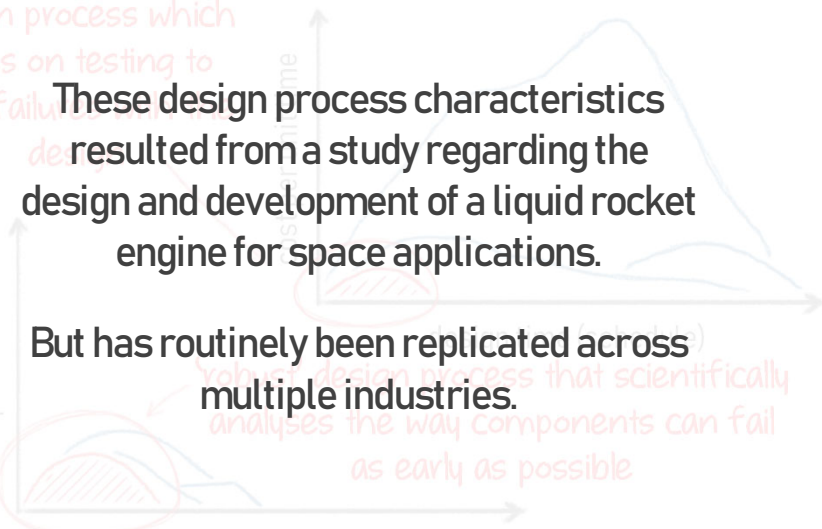


design process which
relies on testing to
find failure

These design process characteristics
resulted from a study regarding the
design and development of a liquid rocket
engine for space applications.

But has routinely been replicated across
multiple industries.

cost per unit time



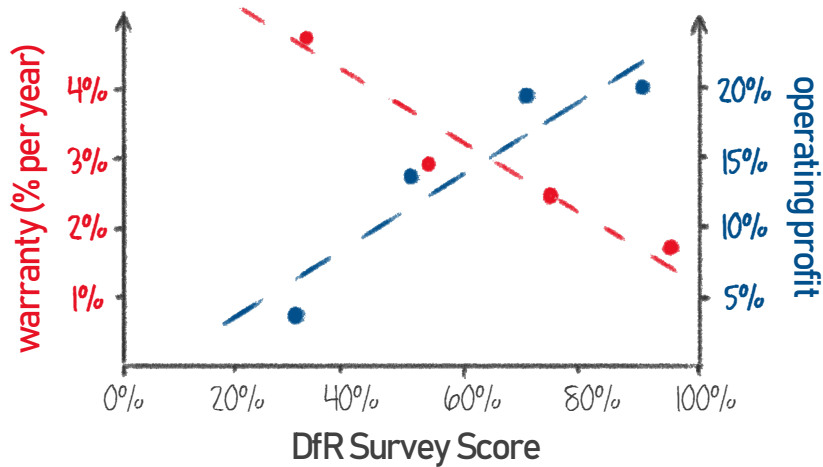
Rajagopal, K., An Industry Perspective on the Role of Nondeterministic Technologies in Mechanical Design, Engineering Design Reliability Handbook (Niolaids, E, Ghiocel, D.M, and Singhal S Editors), CRC Press (2005)

And returning to ...



**HEWLETT®
PACKARD**

They conducted multiple Design for Reliability (DfR)
surveys across all its divisions to measure the 'extent' to
which reliability was formalized within its processes



DO NOT USE THE MTBF ...

... and always, always seek to understand the nature of the probability distribution before making any important decision.

... and perhaps learn about the Weibull distribution

