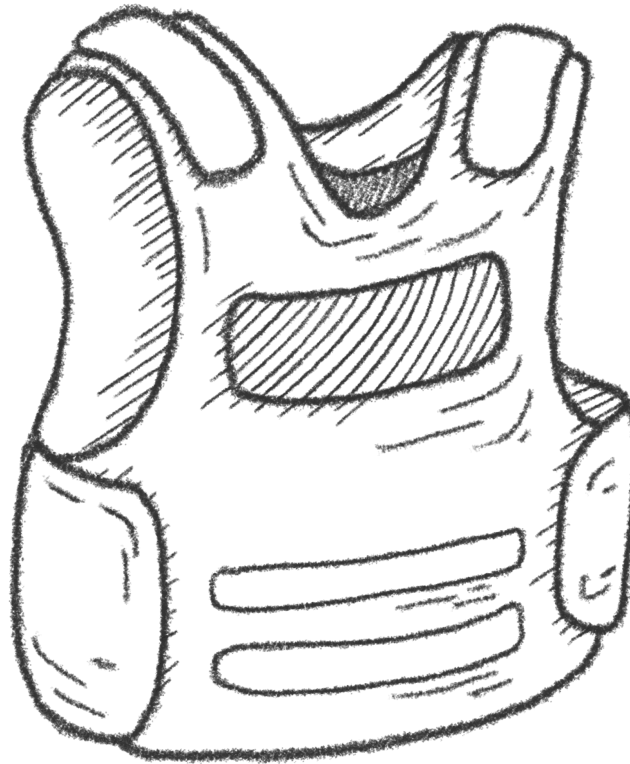


so what is a

ROOT CAUSE

Zylon ® bullet resistant vest

manufactured by
Second Chance
Body Armor



Zylon ® fibers
provided by
Toyobo Co. Ltd

... a 0.40 caliber round
penetrated the vest of
police officer Edward
Limbacher in 2003



... the Zylon fibers
in this vest were
30 % weaker
than brand
new fibers



... **58 %**

were penetrated by
rounds they were
supposed to defeat



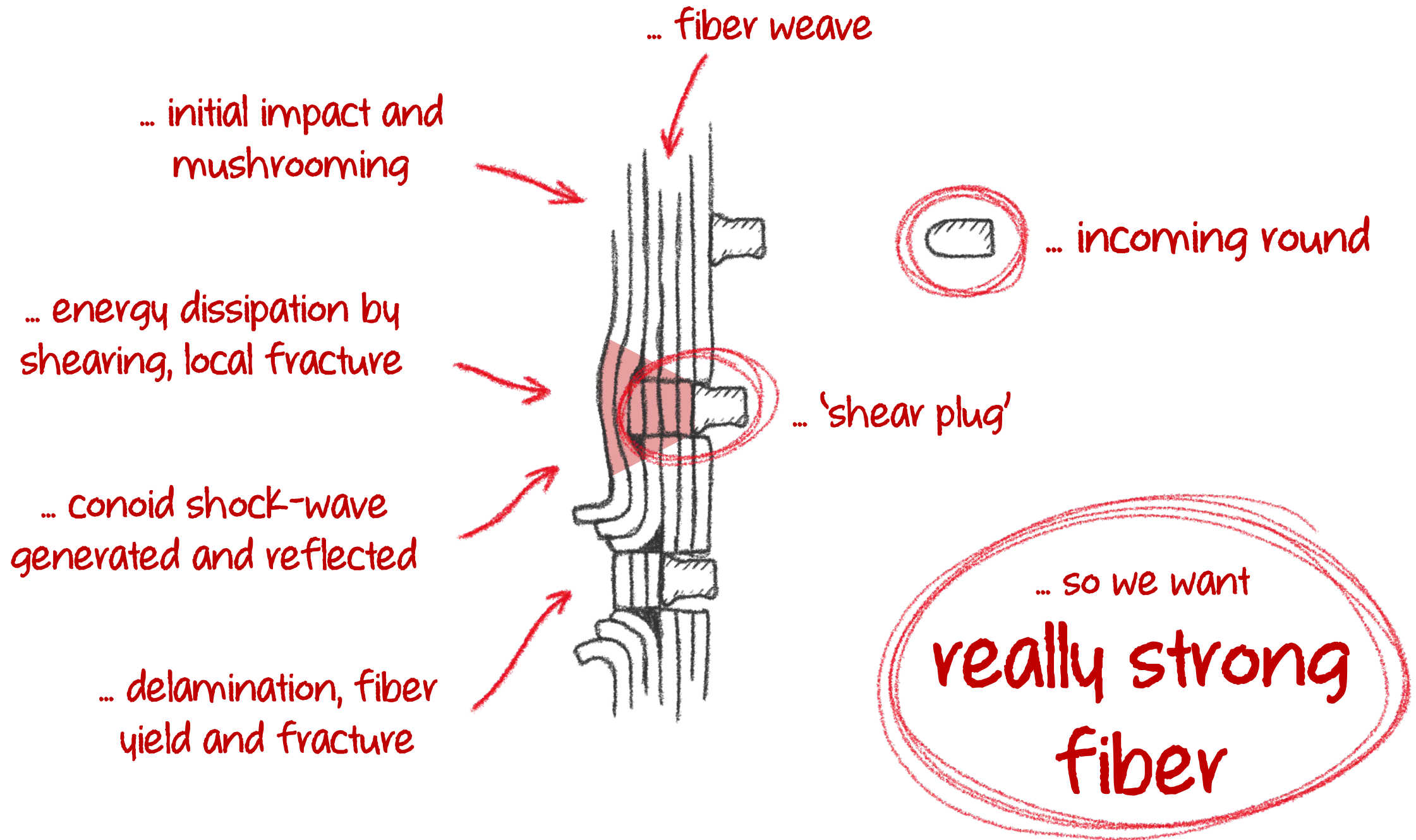
... when other Zylon
vests were tested ...



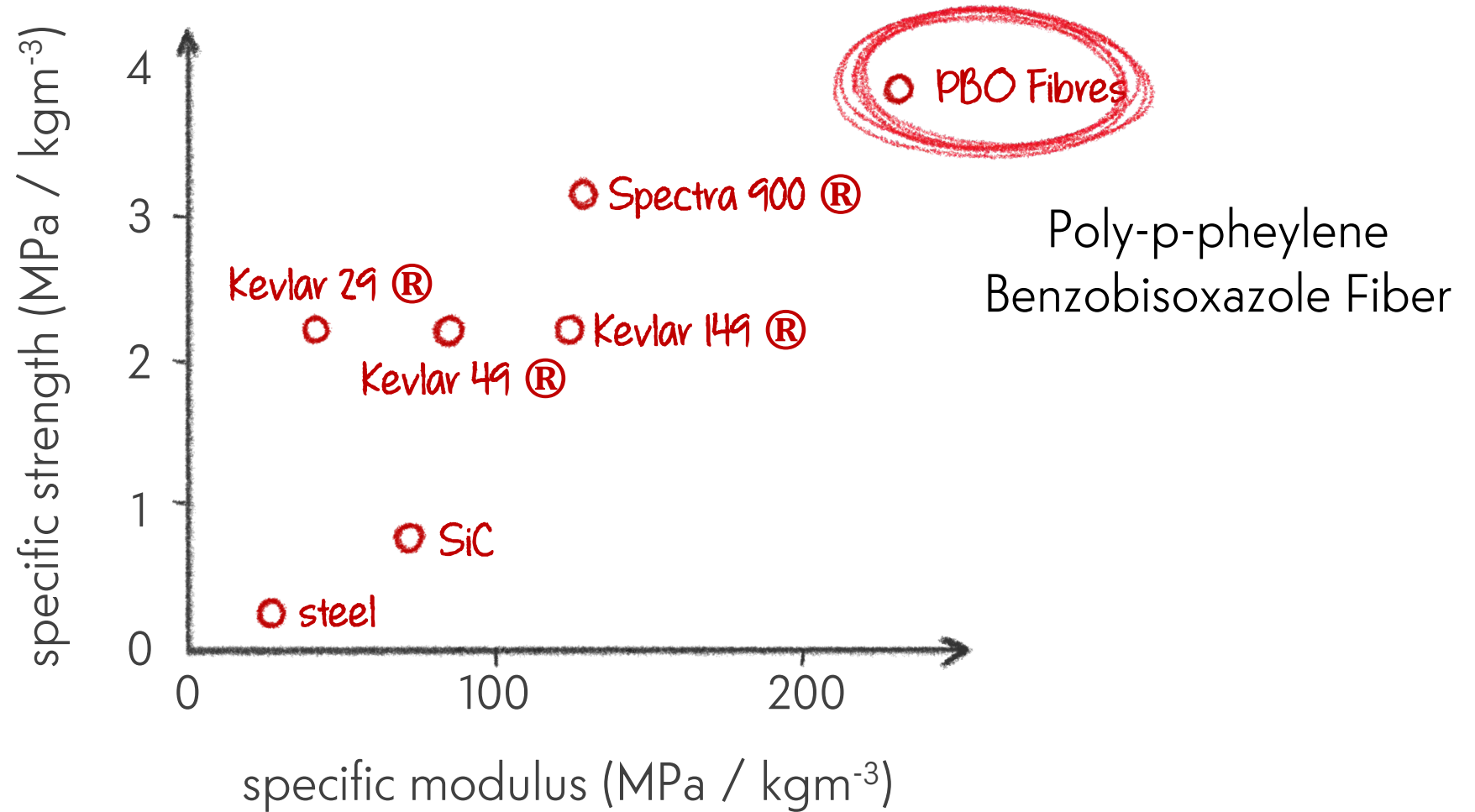
... **38 %**

had excessive
back-face
deformation

... **4 %**
were OK



Zylon®

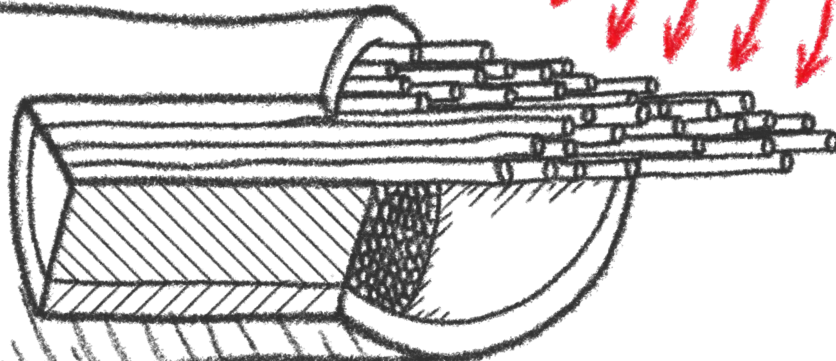


Poly-p-phenylene Benzobisoxazole Fiber

... polymer molecule direction



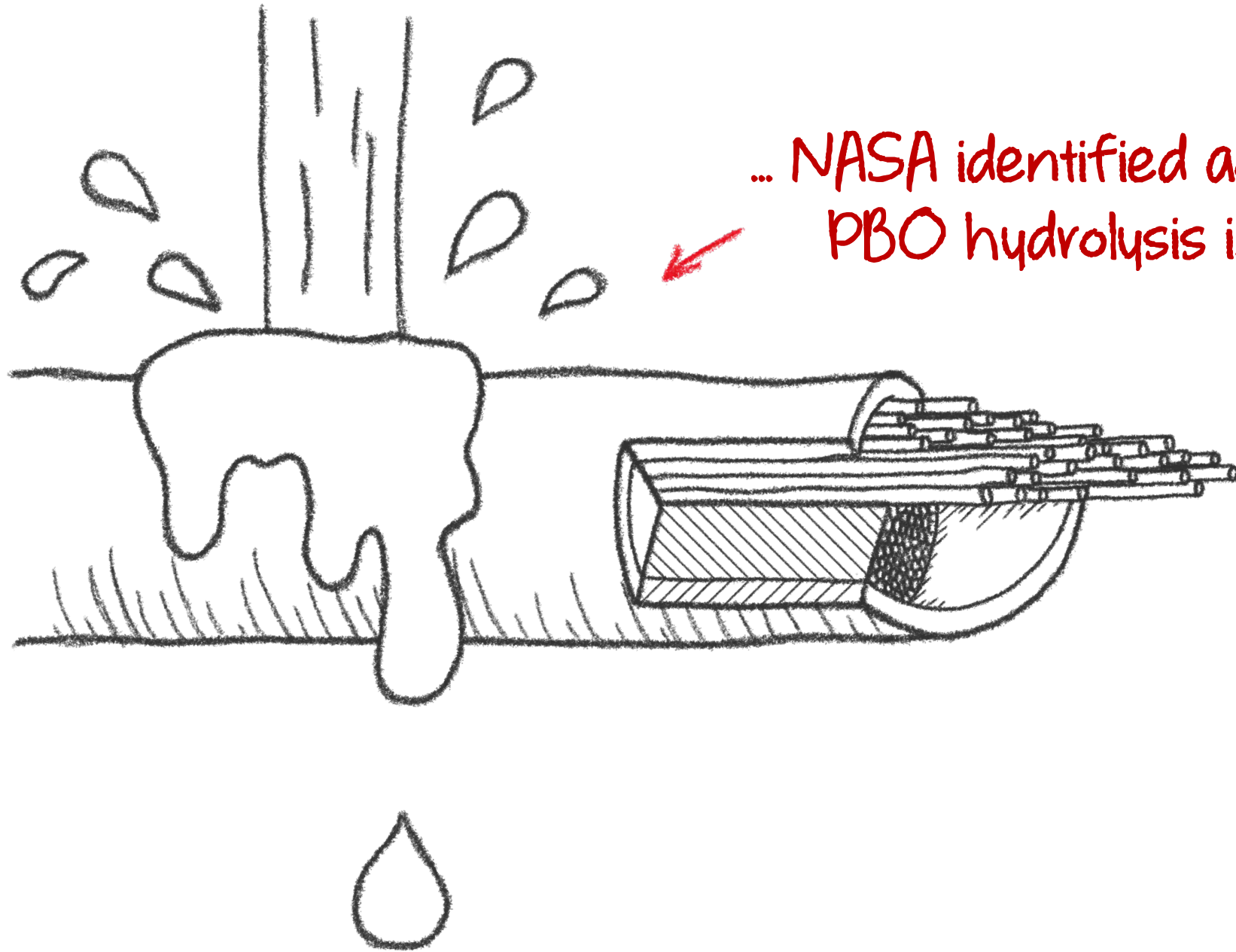
... microfibrils



... surface

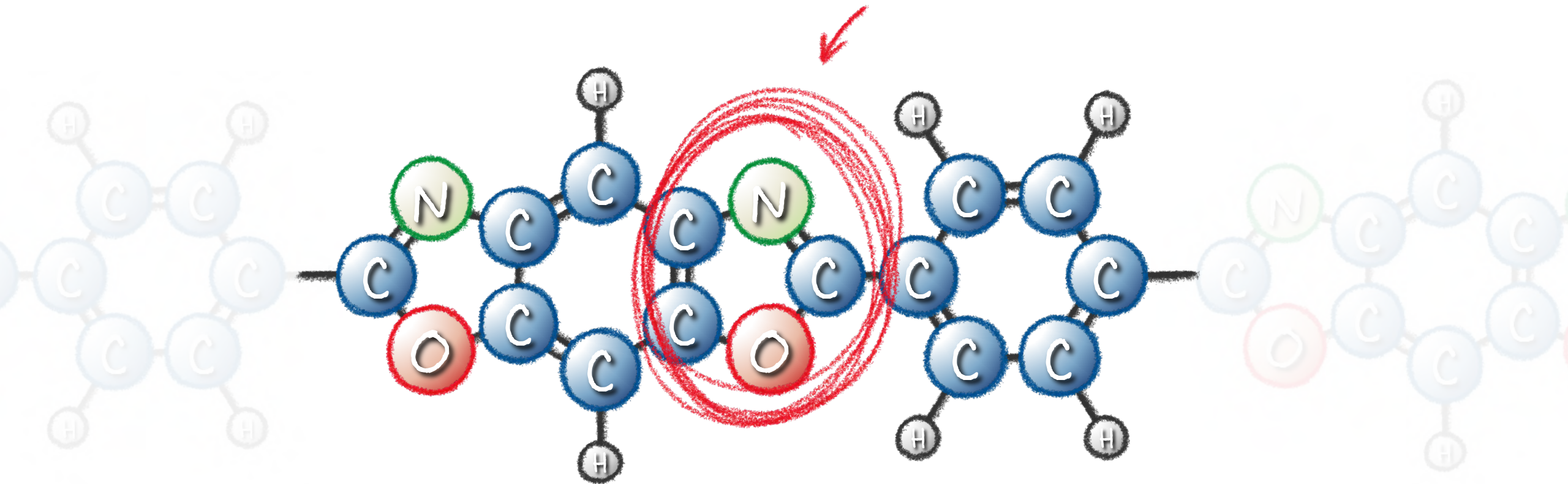
<2 μm thick

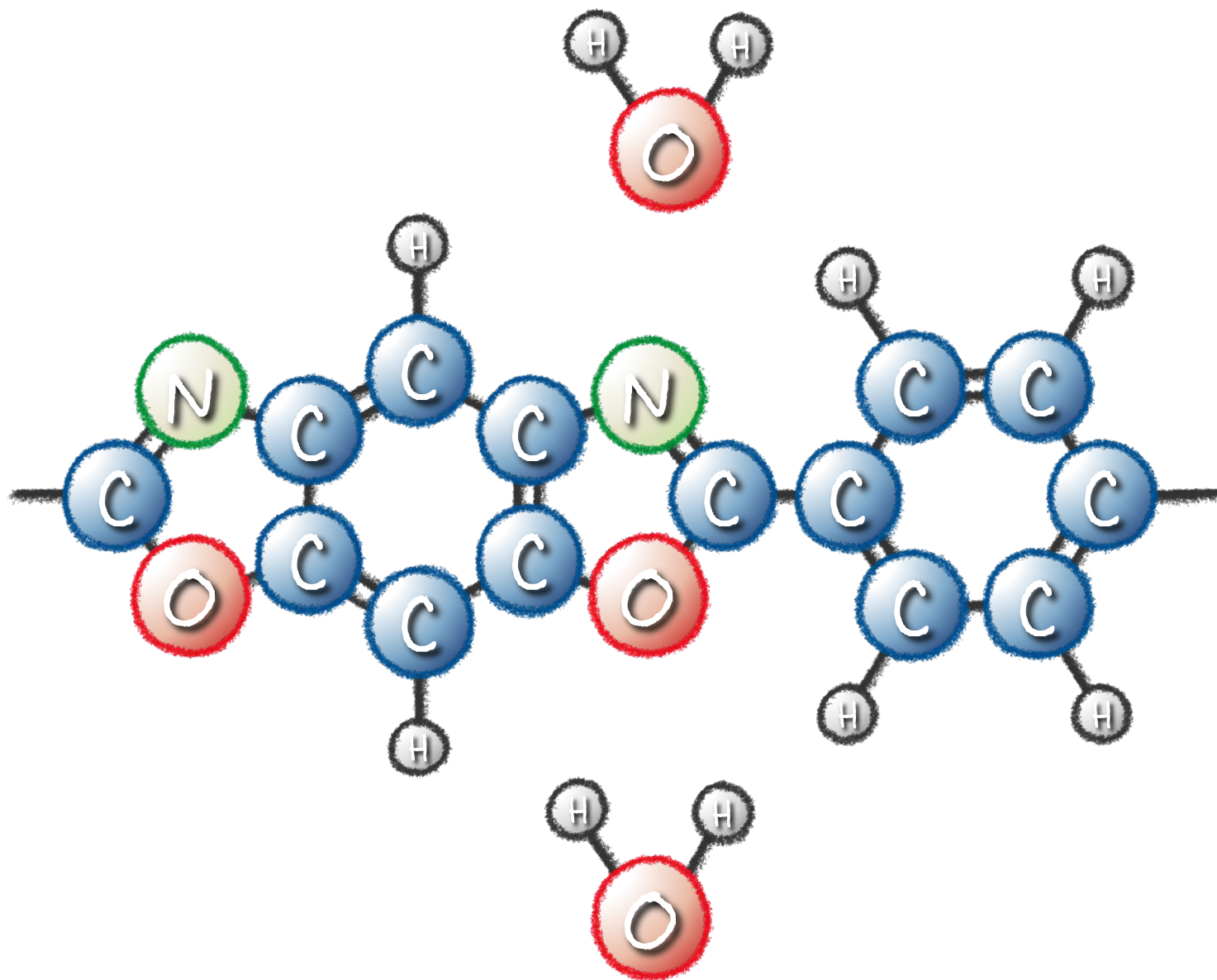


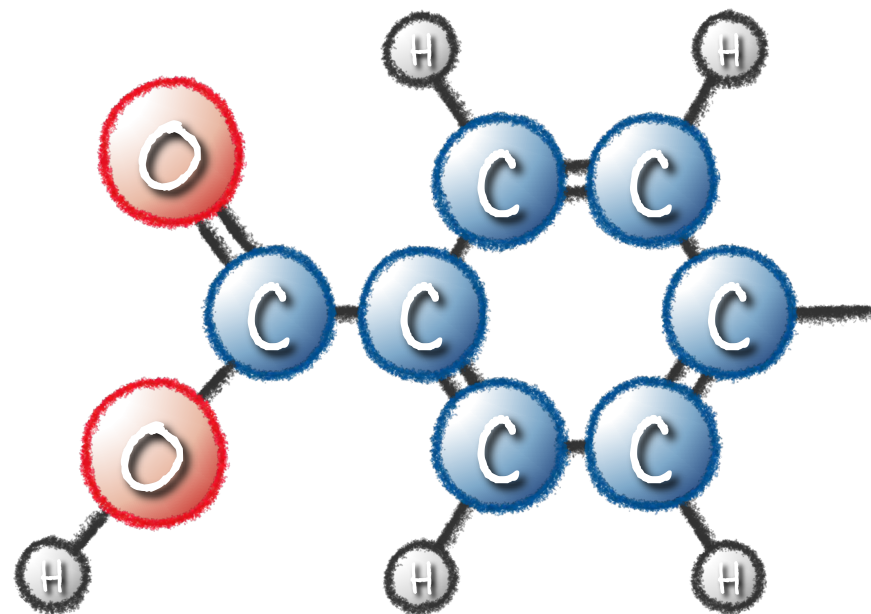
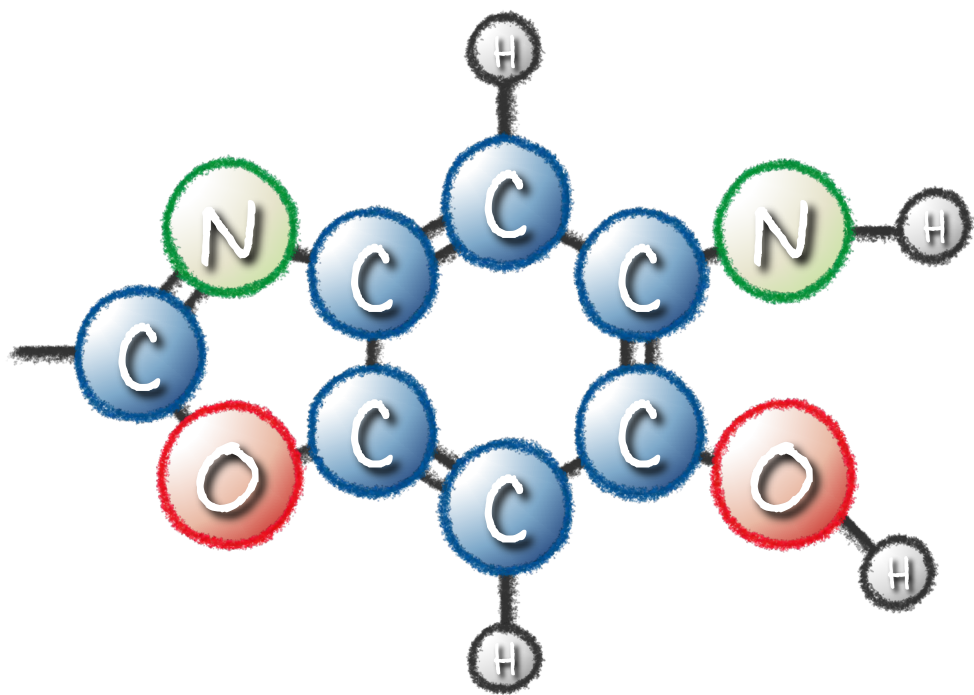


... NASA identified aggressive
PBO hydrolysis in 1996

... oxazole link





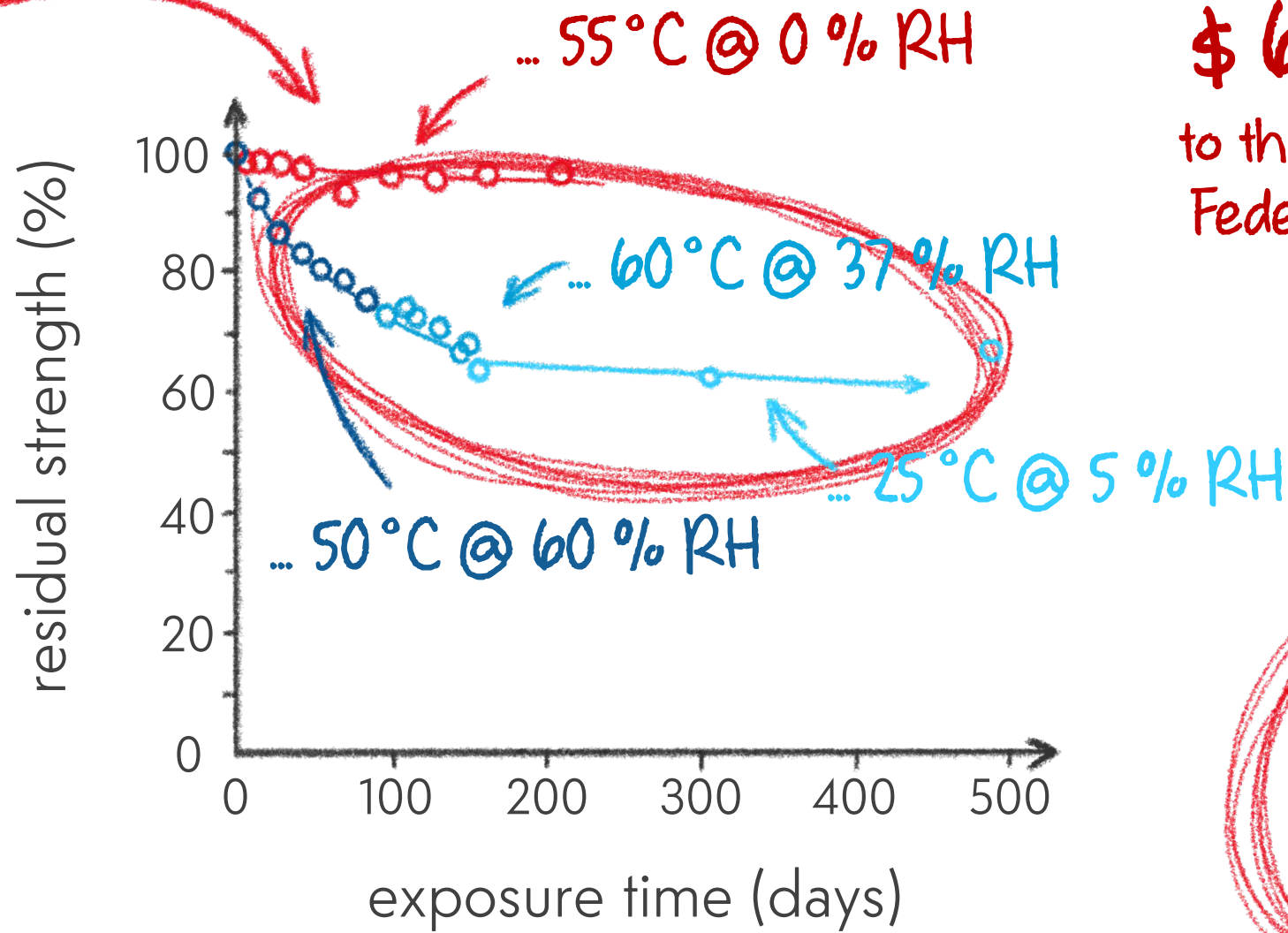


... declared bankruptcy

... Second
Chance
didn't test

for (well
known)
hydrolysis

... and they
ignored
their own
results in
2001

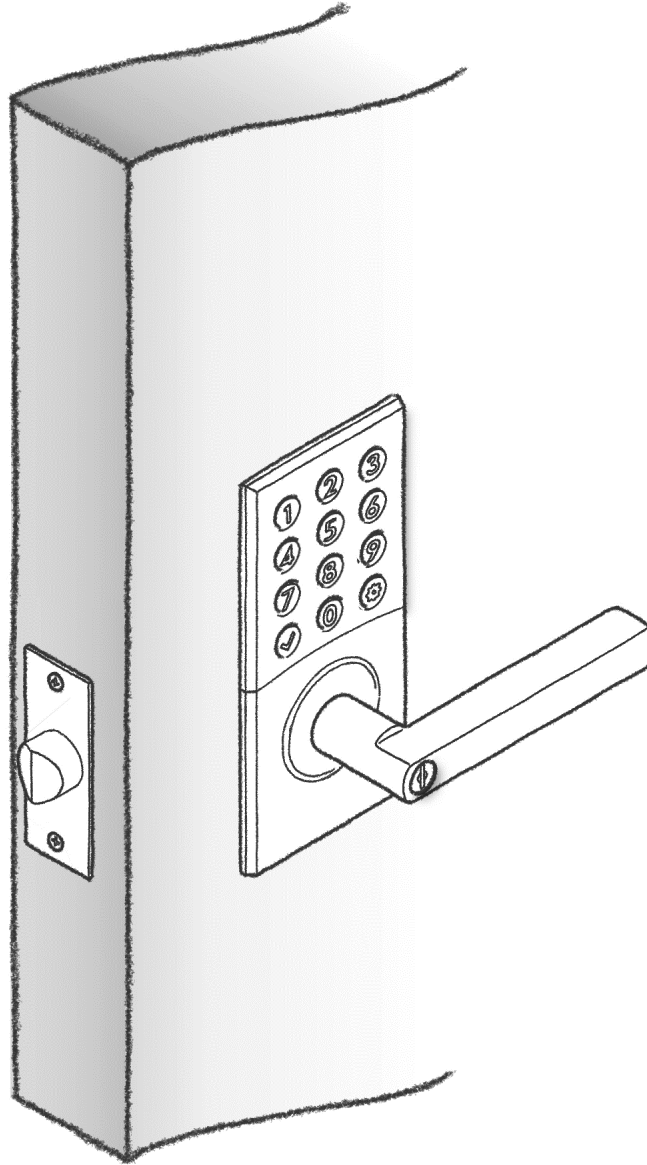


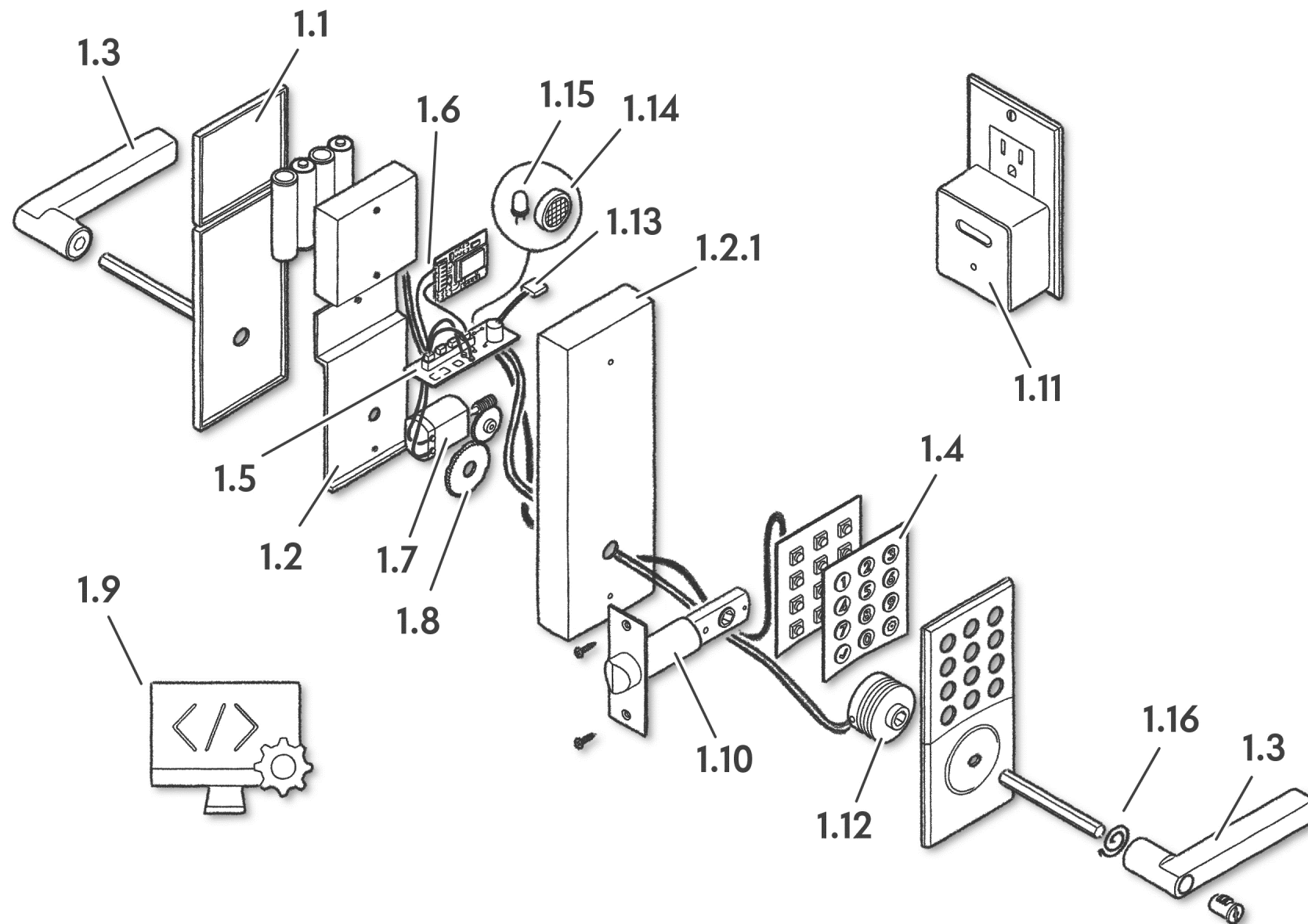
... Toyota paid
\$ 66 million
to the United States
Federal Government

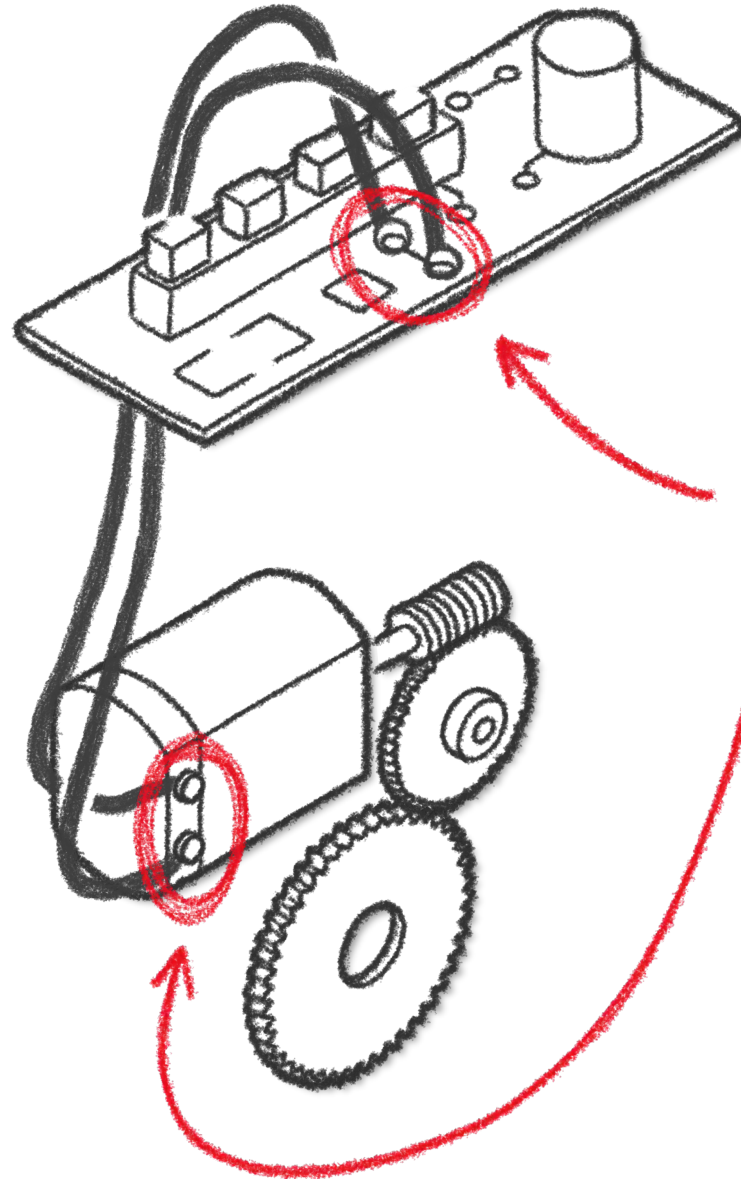
... 1 known
death
from faulty
Zylon vests

understanding the
ROOT CAUSES
of failure would not allow
this to happen

SMART^a LOCK
(to be) manufactured by
Rad Lock Ltd







... think about the
effects of
DOOR SLAMS
on these solder joints

CORRECTIVE ACTION #3

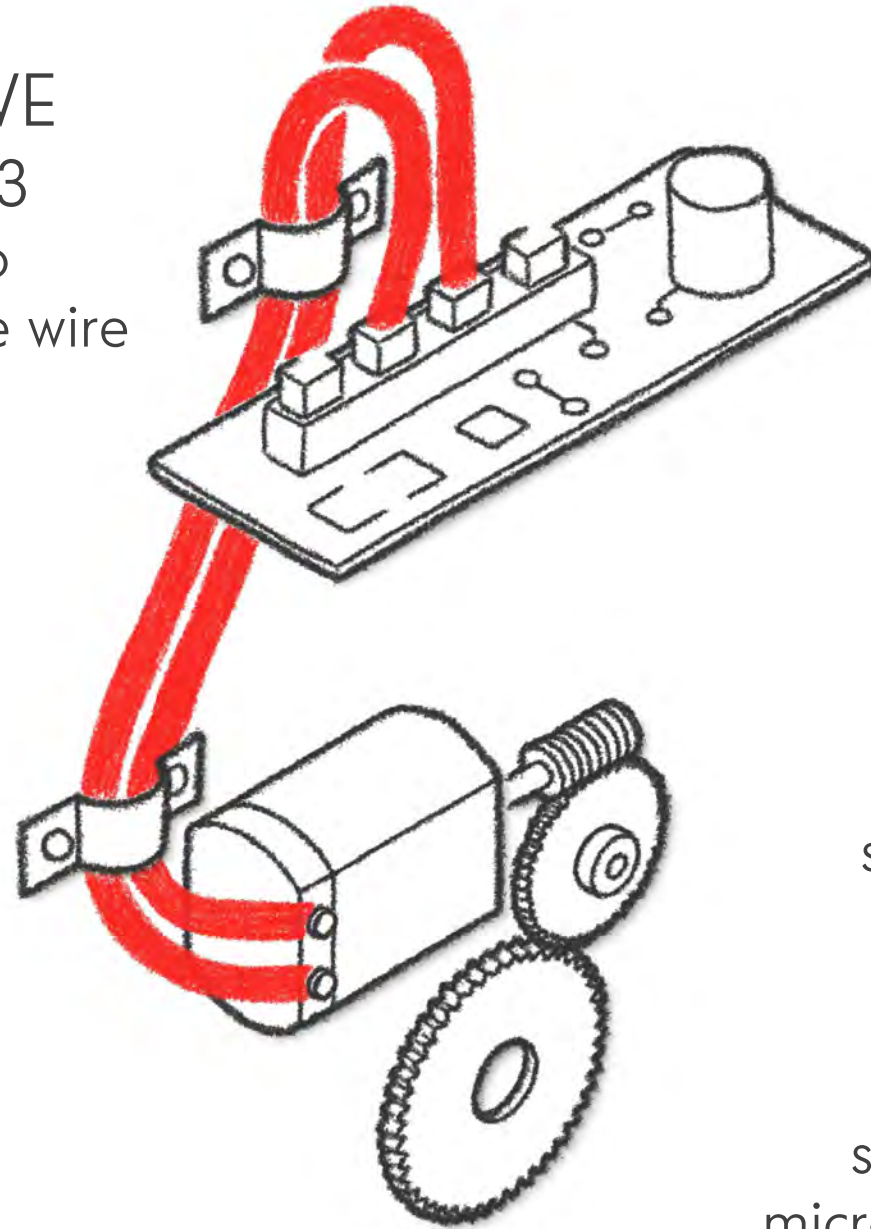
wire clips to
physically secure wire

CORRECTIVE ACTION #2

shorter wire to
accumulate less
momentum

CORRECTIVE ACTION #1

thicker gauge wire
to provide more
contact area with
motor terminal



CORRECTIVE ACTION #4

socket & plug instead of
solder joint on circuit board
... which also makes
assembly MUCH easier

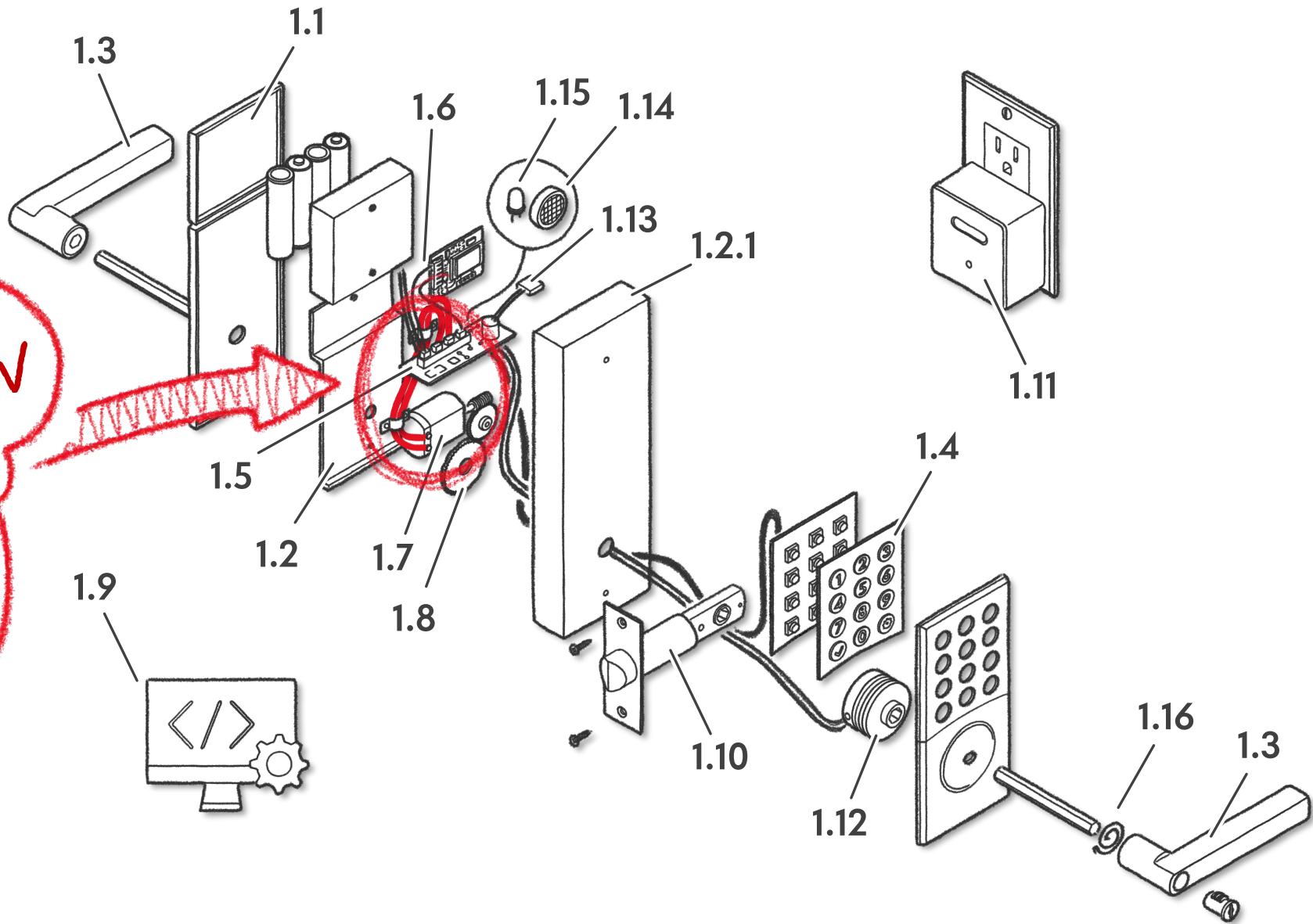
CORRECTIVE ACTION #5

visual inspection of motor
solder joints added to
supplier inspection checklist

CORRECTIVE ACTION #6

surveillance automated
microscopic optical inspection
for 10 % of incoming motors

... this is HOW
we make
reliability
happen



... so what is

RELIABILITY?

RELIABILITY

... is the probability that an item will not FAIL for a designated period under specified conditions.

RELIABILITY is the
probability



that an item will not FAIL for
a designated period under
specified conditions.

RELIABILITY is the probability
that an item will **not FAIL**
for a
designated period under
specified conditions.

... cycles

... distance

RELIABILITY is the
probability that an
item will not FAIL for a



designated
period

under
specified

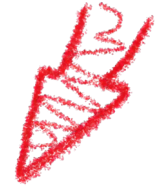
conditions.

... number of units processed

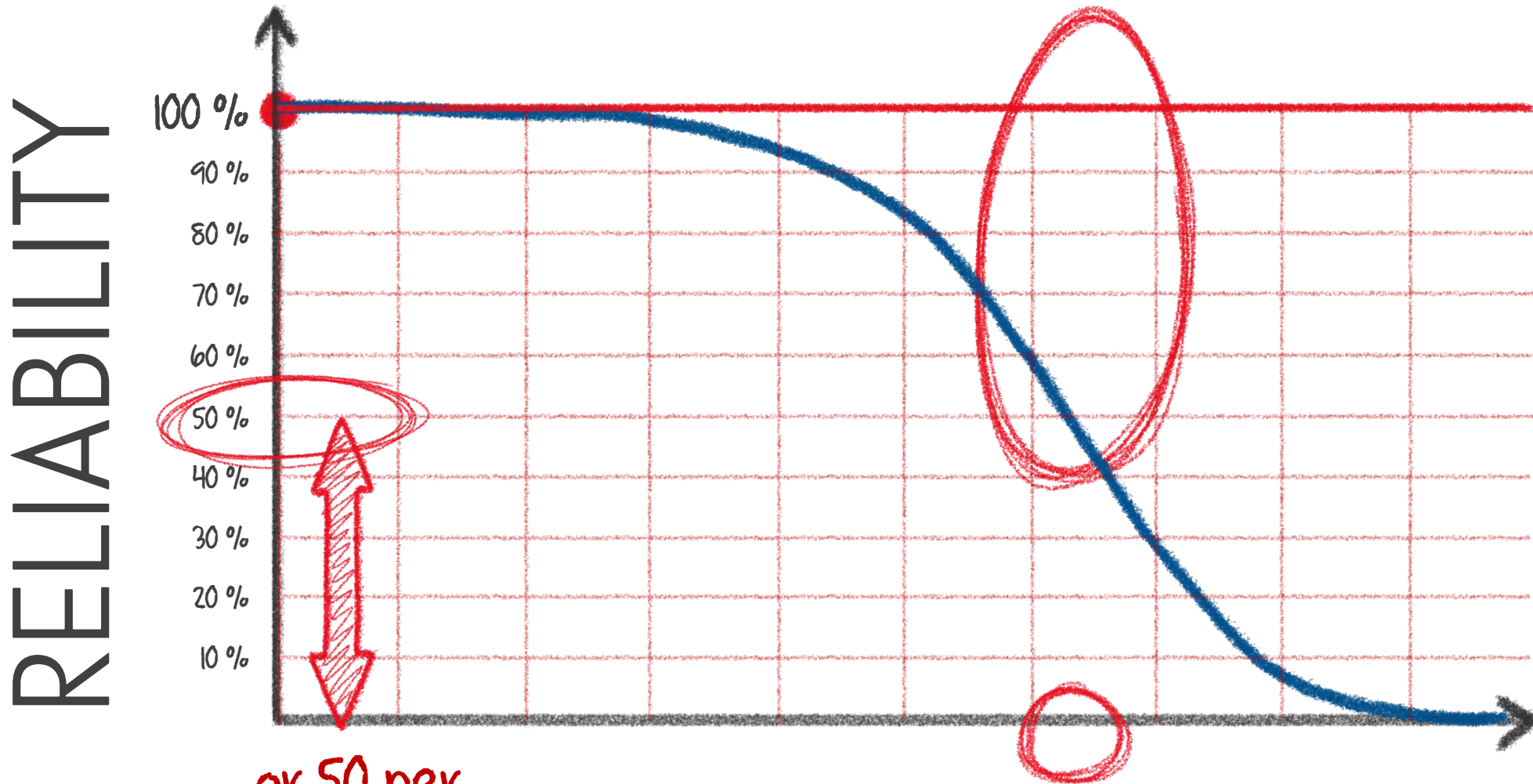
RELIABILITY is the
probability that an
item will not FAIL for a
designated
period
under

specified
conditions.

... based on
USER or
CUSTOMER
INTERACTION



... so we have this probability of failure



... or 50 per cent reliability

time to FAILURE (TTF)

... reliability is a
measure of how often
FAILURE
occurs

... and

FAILURE

is the product of

CAUSALITY

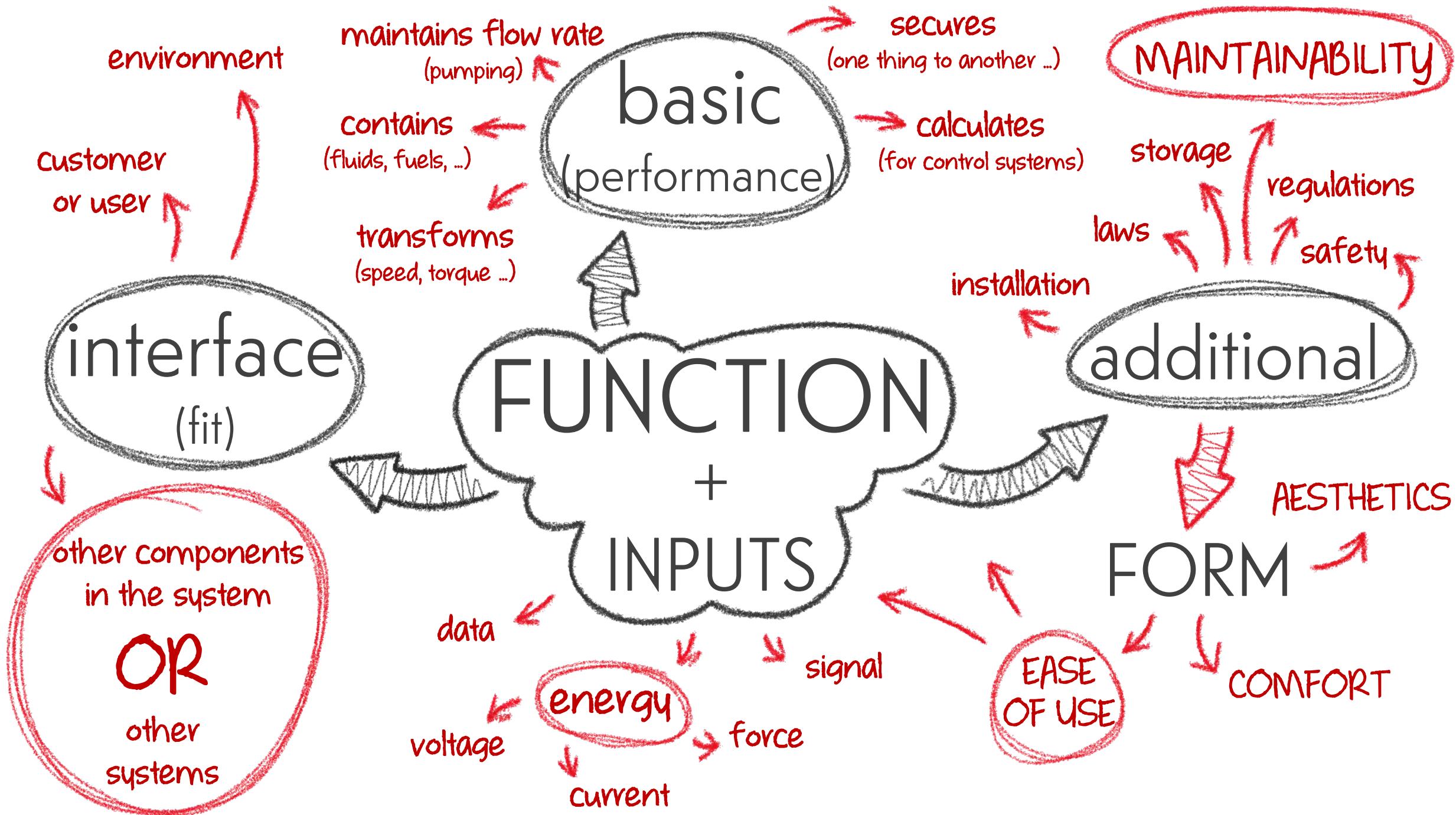
FAILURE

... is the event where a system inherently ceases to perform a specified or required FUNCTION.

FUNCTION

... is a behavior, process
action or task.

... *is what the item is
INTENDED to do*



FAILURE

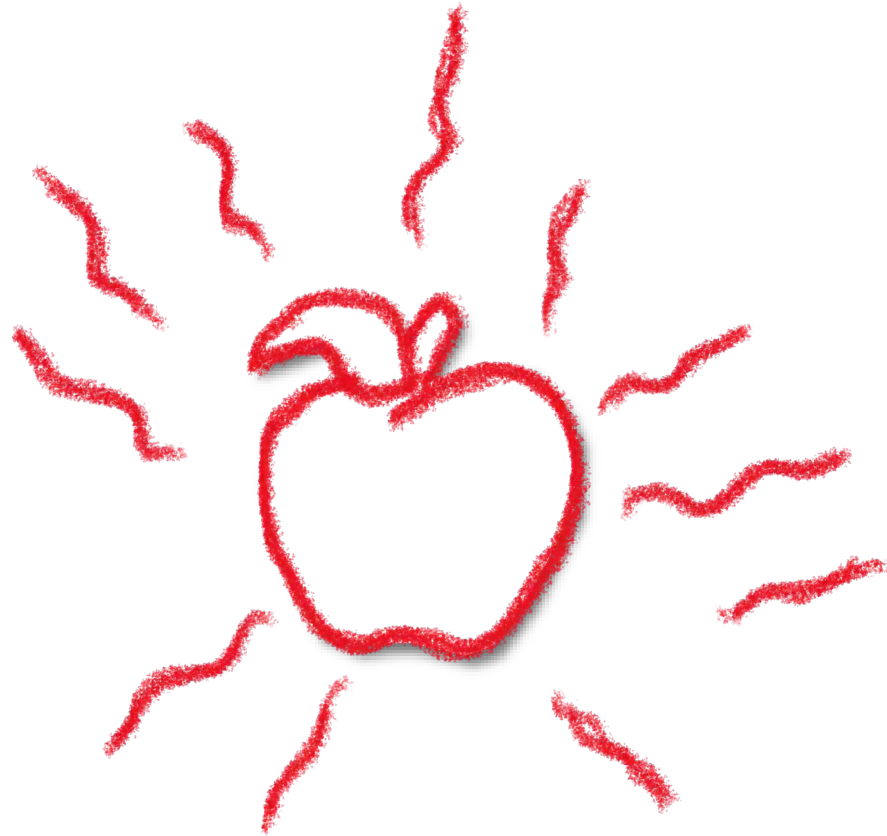
... is the event where a system inherently ceases to perform a specified or required FUNCTION.

... let's say that this
apple represents an

event

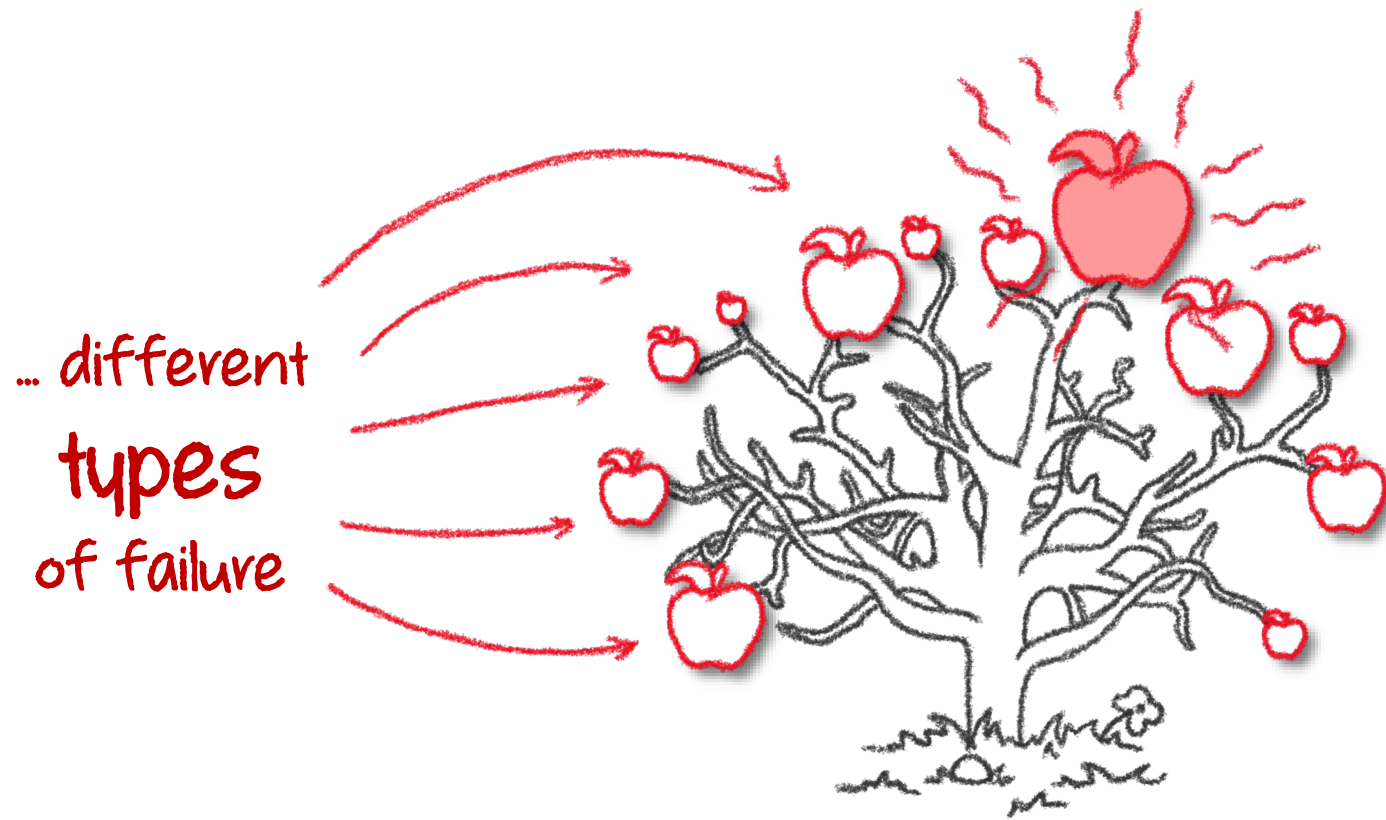
or

outcome of
something



... like

FAILURE

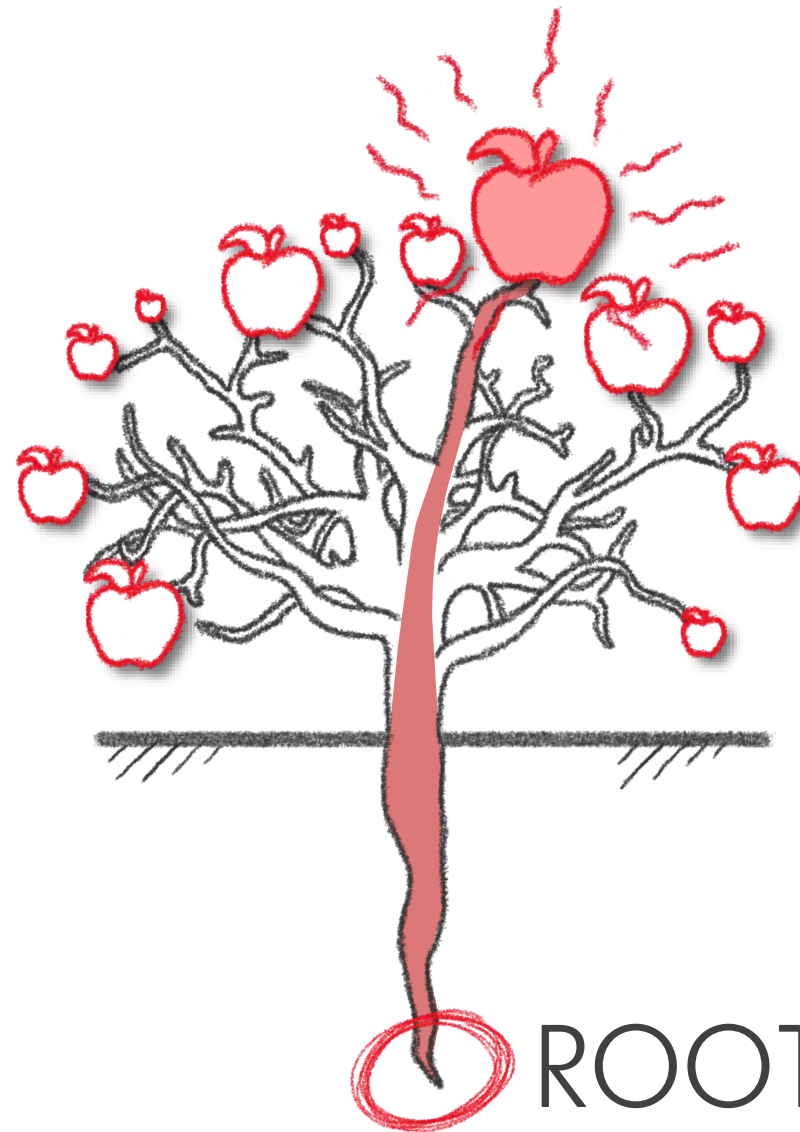


tree of
FAILURE



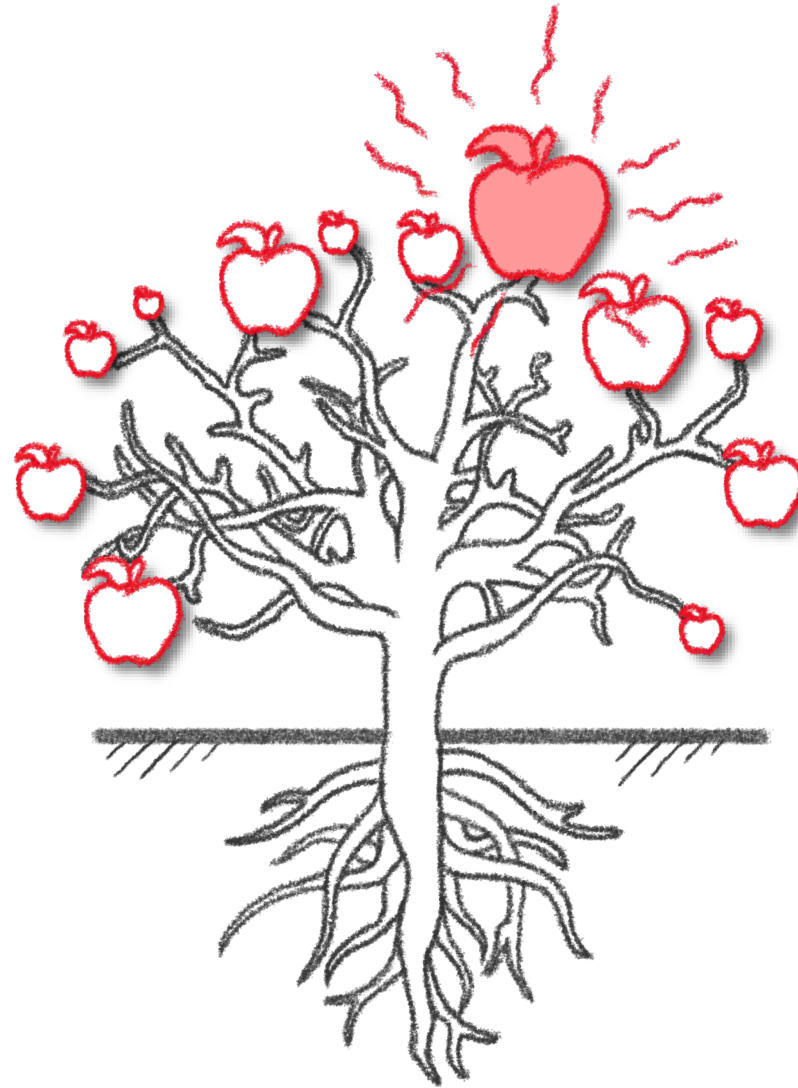
tree of
FAILURE

tree of
FAILURE



ROOT CAUSE

tree of
FAILURE



ROOT CAUSE(s)

... it is a
HUMAN BEHAVIOR(s) OR DECISION(s)
(and not a physical phenomenon)



ROOT CAUSE

... is the initiating cause of FAILURE

... is the
THING we can change
to make sure 'that' failure hardly happens again

... a lot of
ROOT CAUSES
look like these ...



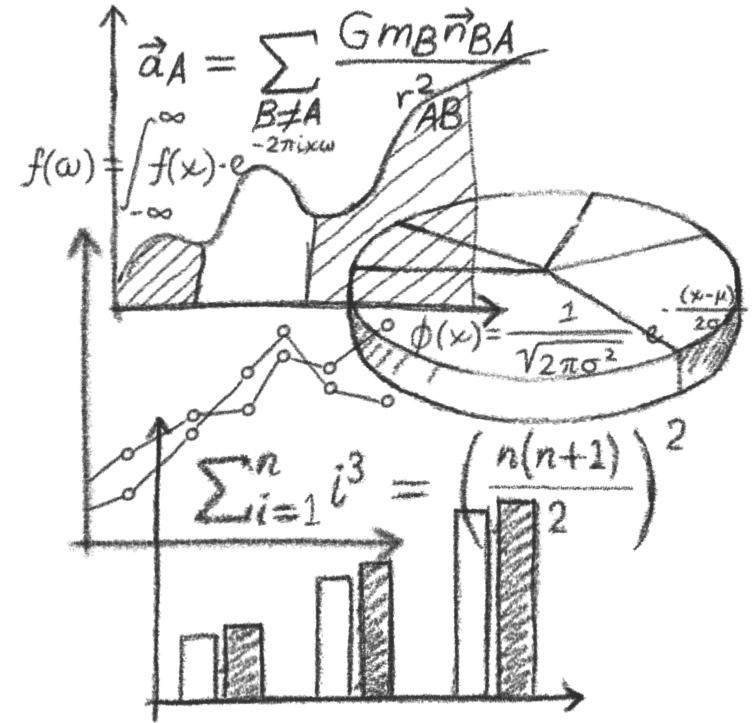
infant manager

Wrong

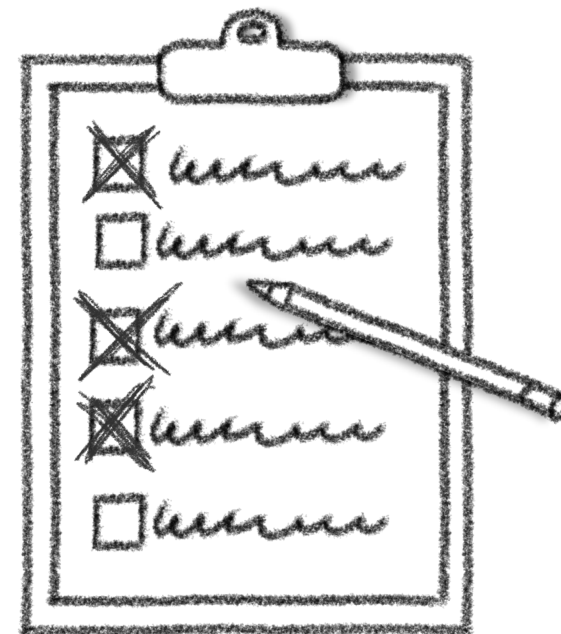
Thing

Fast

$$\begin{aligned}
 \rho \cdot \left(\frac{\partial \mathbf{v}}{\partial t} + \mathbf{v} \cdot \nabla \mathbf{v} \right) &= -\nabla p + \nabla \cdot \mathbf{T} + \mathbf{f} \\
 + \frac{7}{2c^2} \sum_{B \neq A} \frac{G m_B \vec{a}_B}{r_{AB}} + O(c^{-4}) \\
 \vec{a}_A &= \sum_{B \neq A} \frac{G m_B \vec{r}_{BA}}{r_{AB}^2} \\
 + \frac{7}{2c^2} \sum_{B \neq A} \frac{G m_B \vec{a}_B}{r_{AB}} + O(c^{-4})
 \end{aligned}$$



ponderous professor



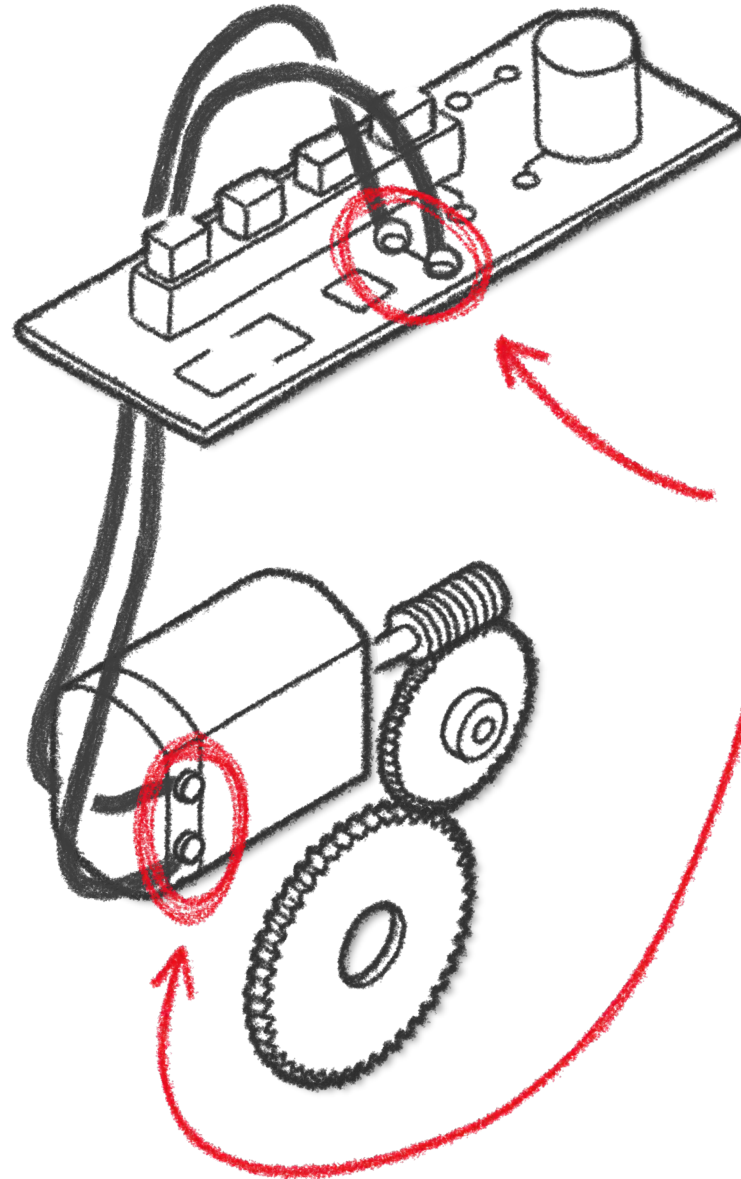
process zealot

... a

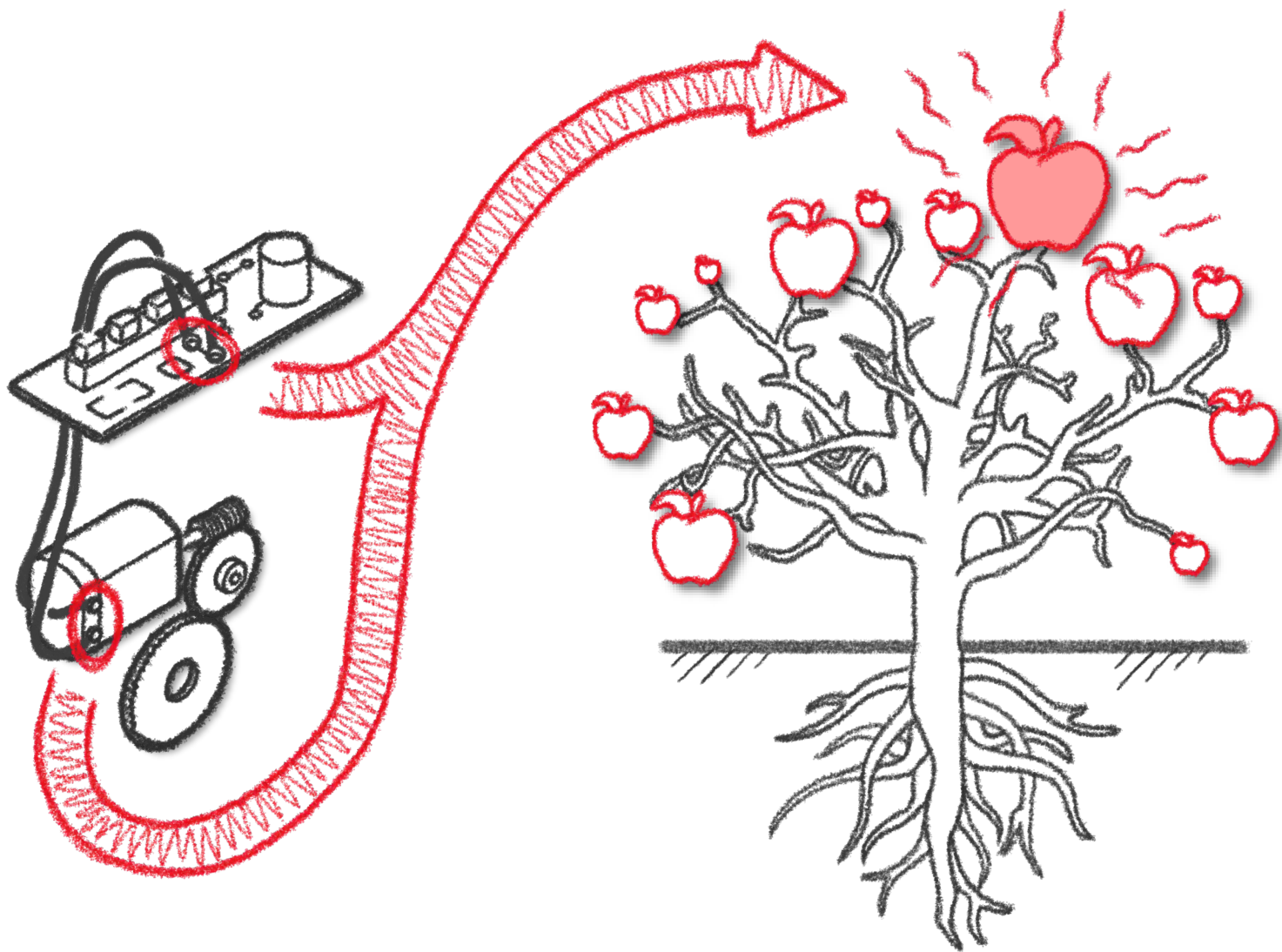
ROOT CAUSE

is (in a way) always

YOUR FAULT!

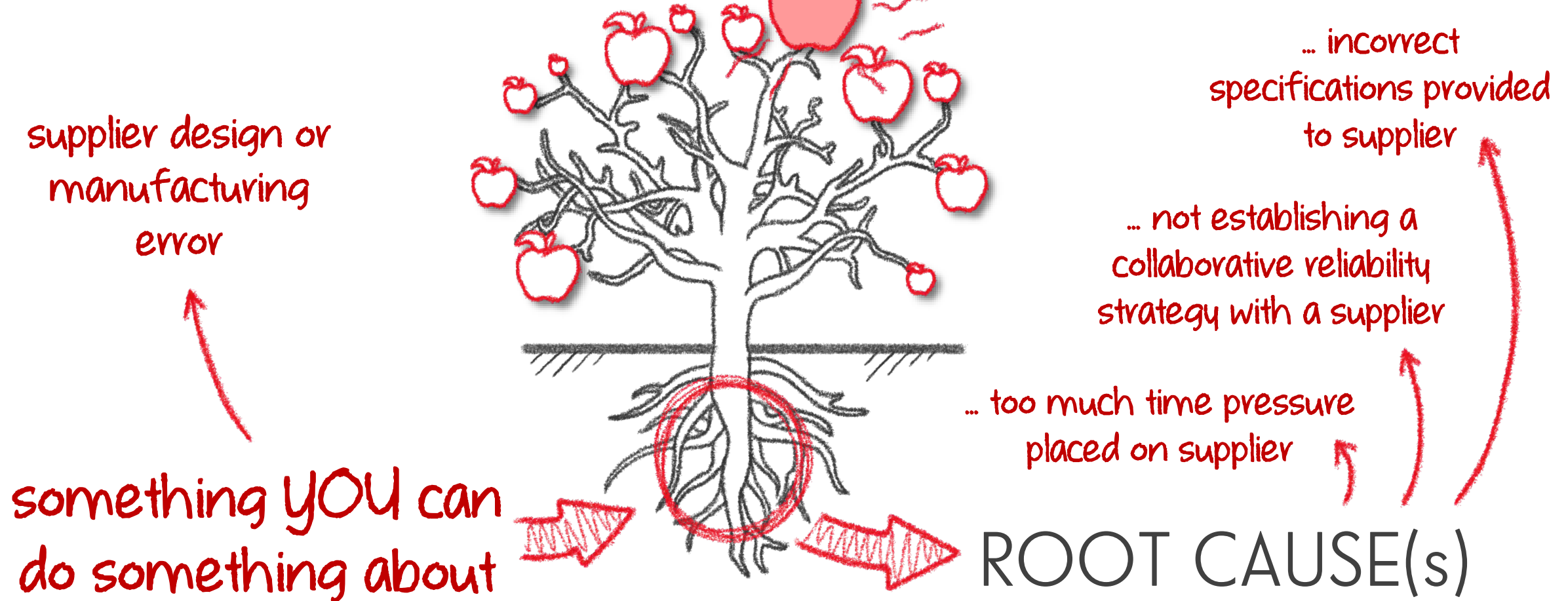


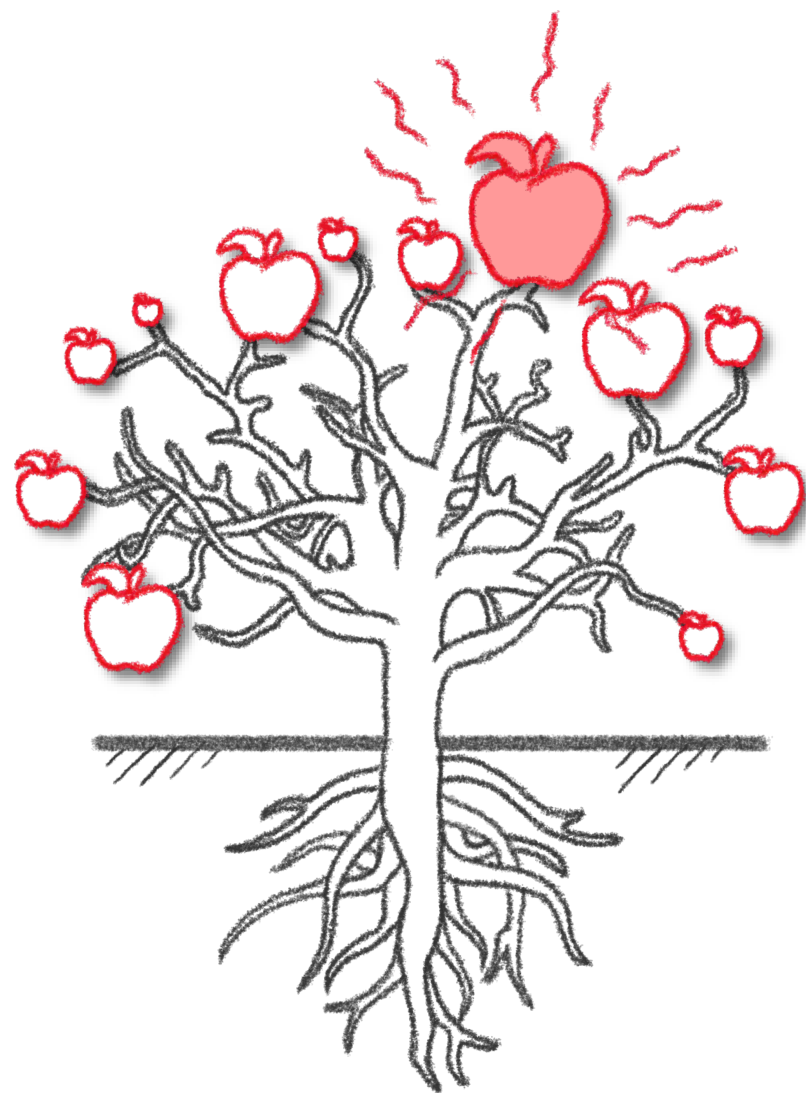
... think about the
effects of
DOOR SLAMS
on these solder joints



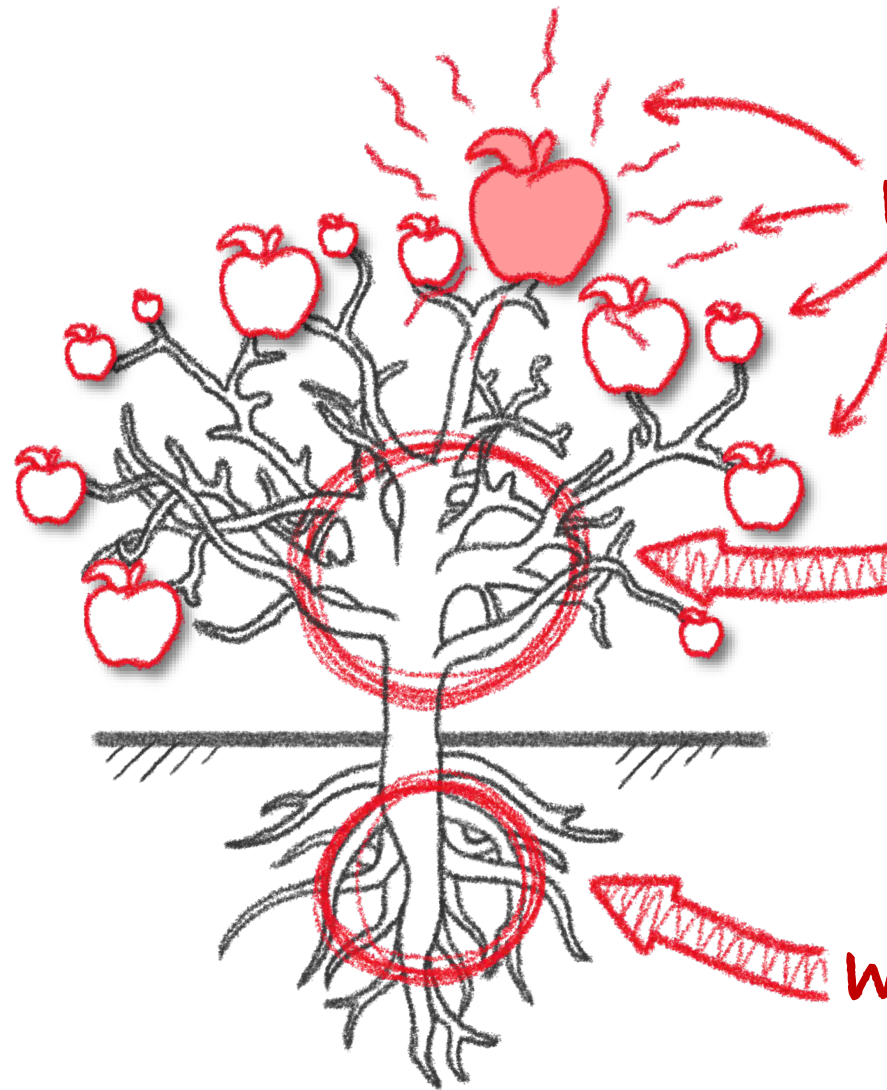
blame / avoiding
responsibility

improving
reliability





and a really, really easy way
of finding out a
ROOT CAUSE
is by asking yourself a set
of questions



what is my ^{NOT} SYSTEM [^] DOING?

why DID THIS HAPPEN?

1. what BROKE?

2. HOW did it break?

3. what STARTED it?

what DID WE DO WRONG?

... what DO WE NEED TO DO?

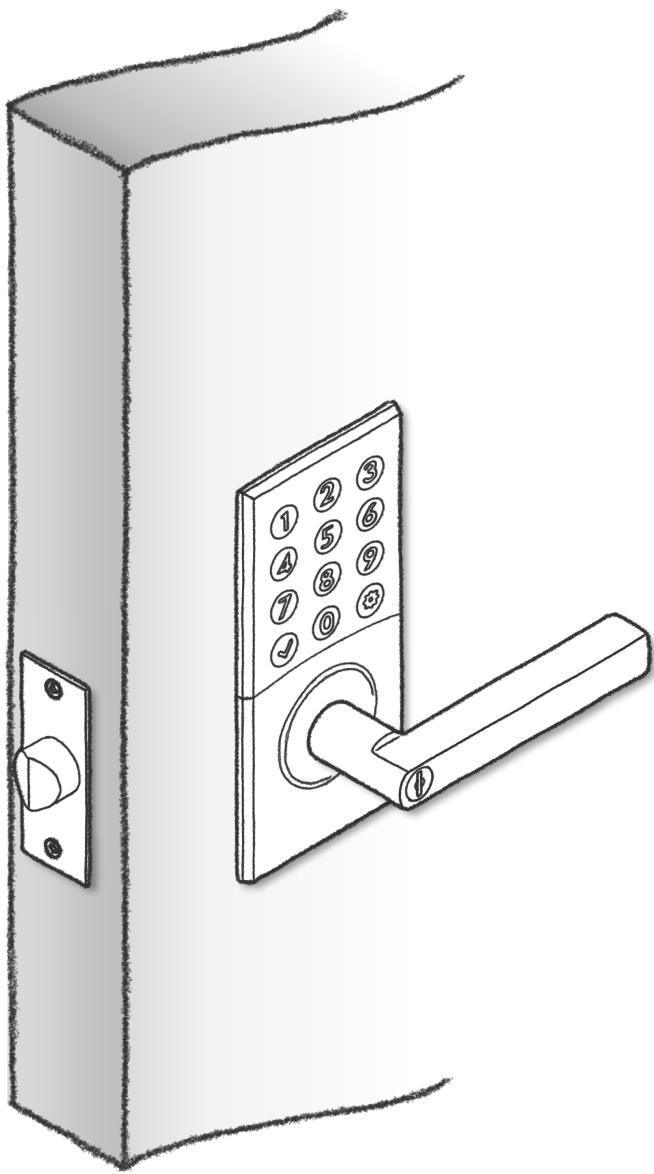
EXERCISE

the
amazing
F•M•E•A
or
R•C•A
facilitator



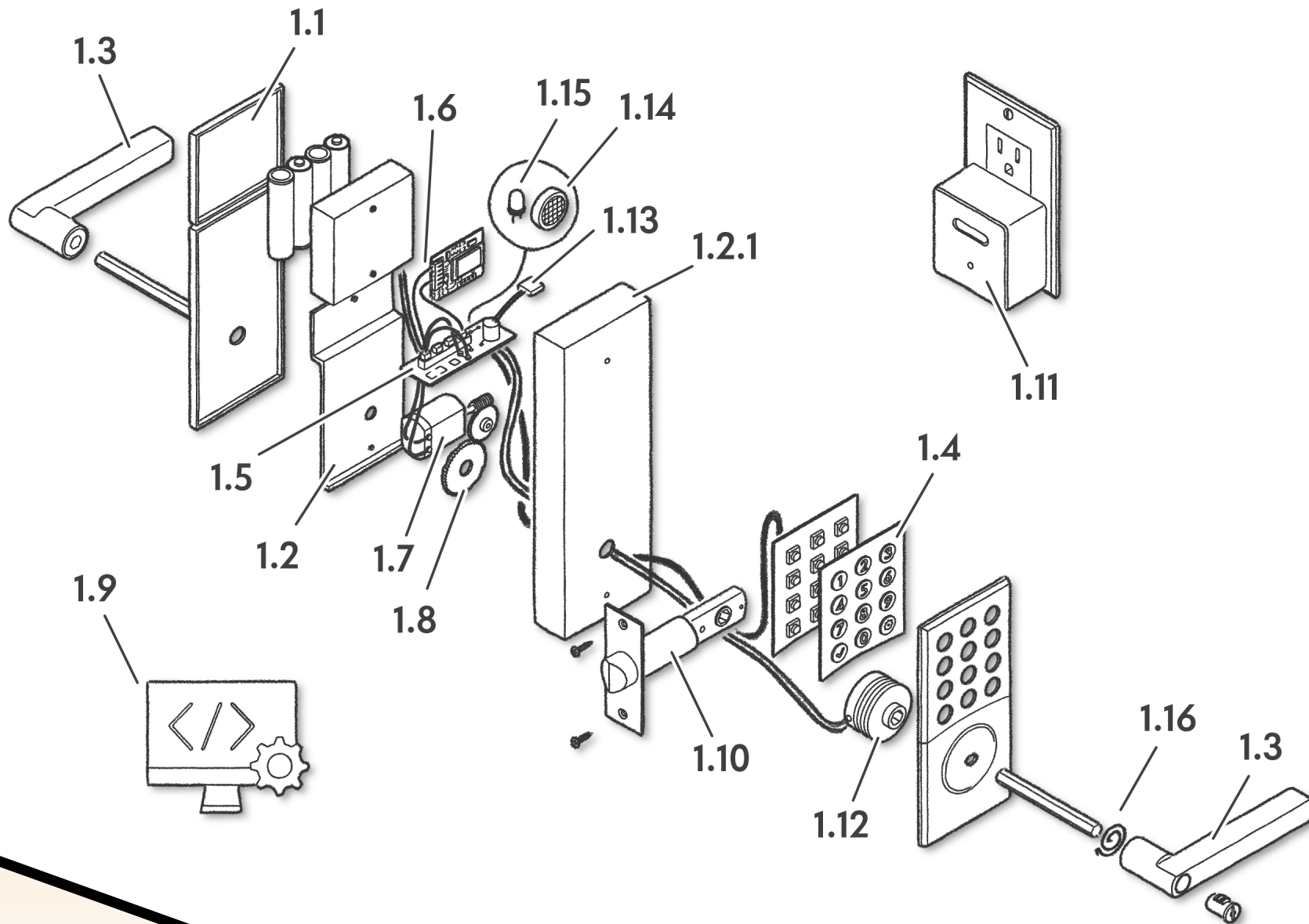


EXERCISE



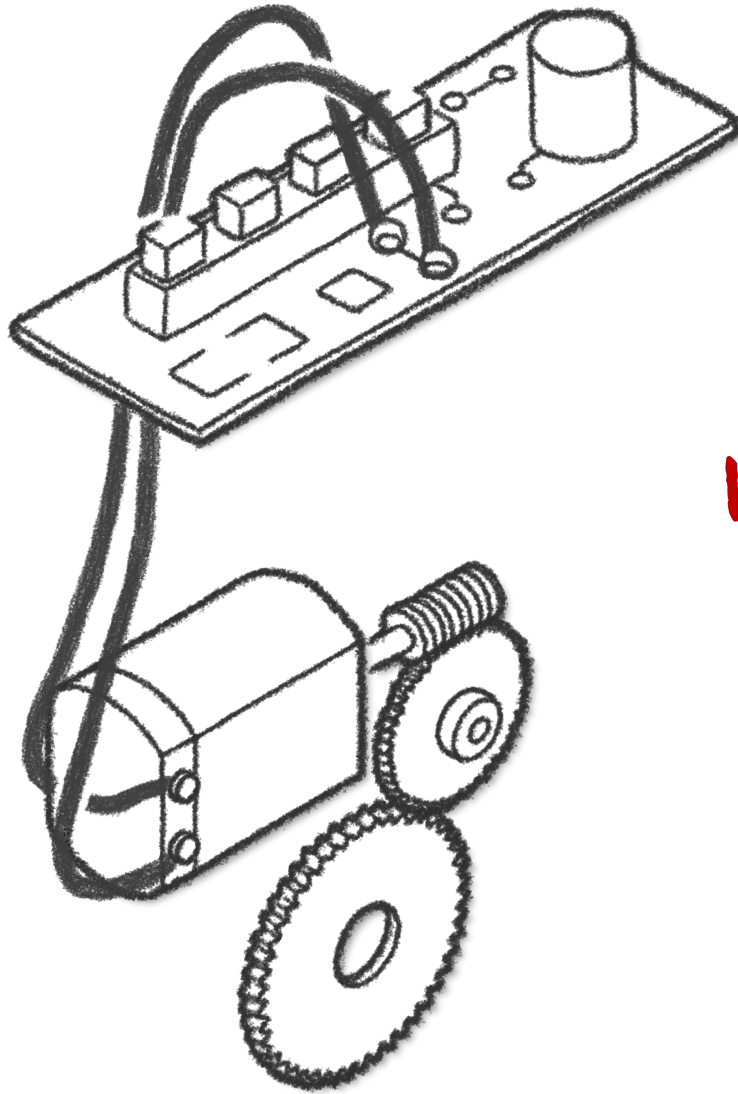


EXERCISE





EXERCISE

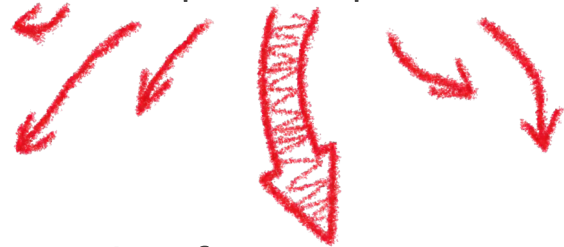


what could go
WRONG?

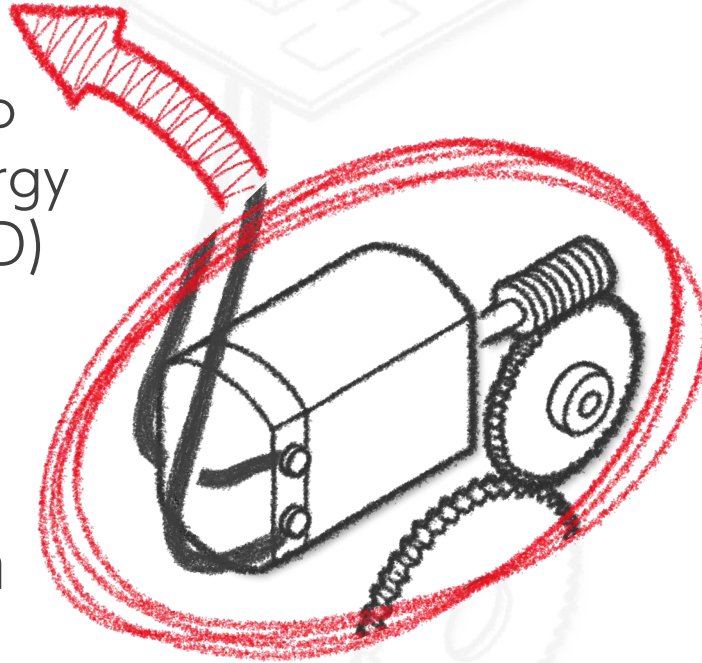
EXERCISE

FUNCTION

to convert
6 V / 100 mA DC to
rotational kinetic energy
(torque & speed TBD)



shaft won't turn



what is my SYSTEM ^{NOT} DOING?



EXERCISE

why DID THIS HAPPEN?

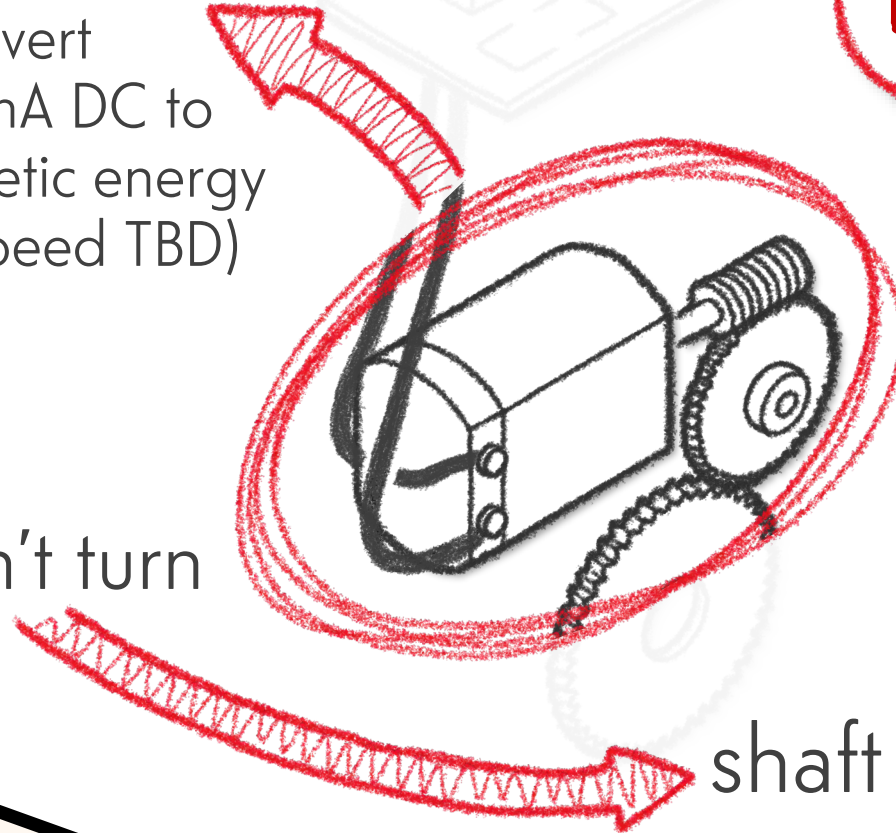
FUNCTION

to convert
6 V / 100 mA DC to
rotational kinetic energy
(torque & speed TBD)

1. what BROKE?

shaft won't turn

shaft fracture



EXERCISE

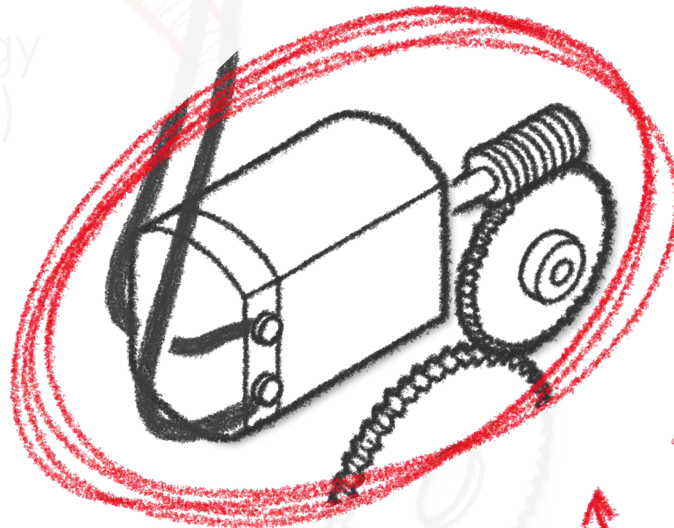
why DID THIS HAPPEN?

FUNCTION

to convert
6 V / 100 mA DC to
rotational kinetic energy
(torque & speed TBD)

2. HOW did it break?

shaft won't turn



fatigue

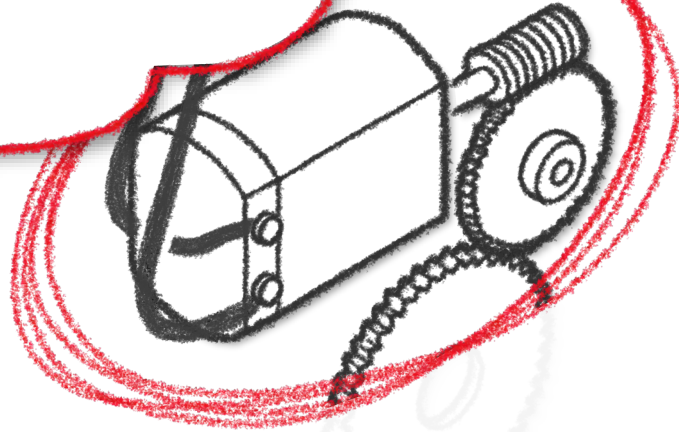
shaft fracture



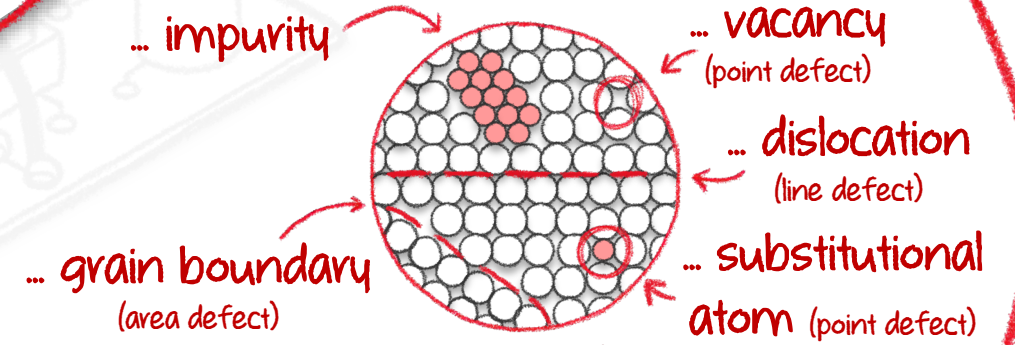
EXERCISE

why DID THIS HAPPEN?

3. what STARTED it?



misaligned bearings/gears



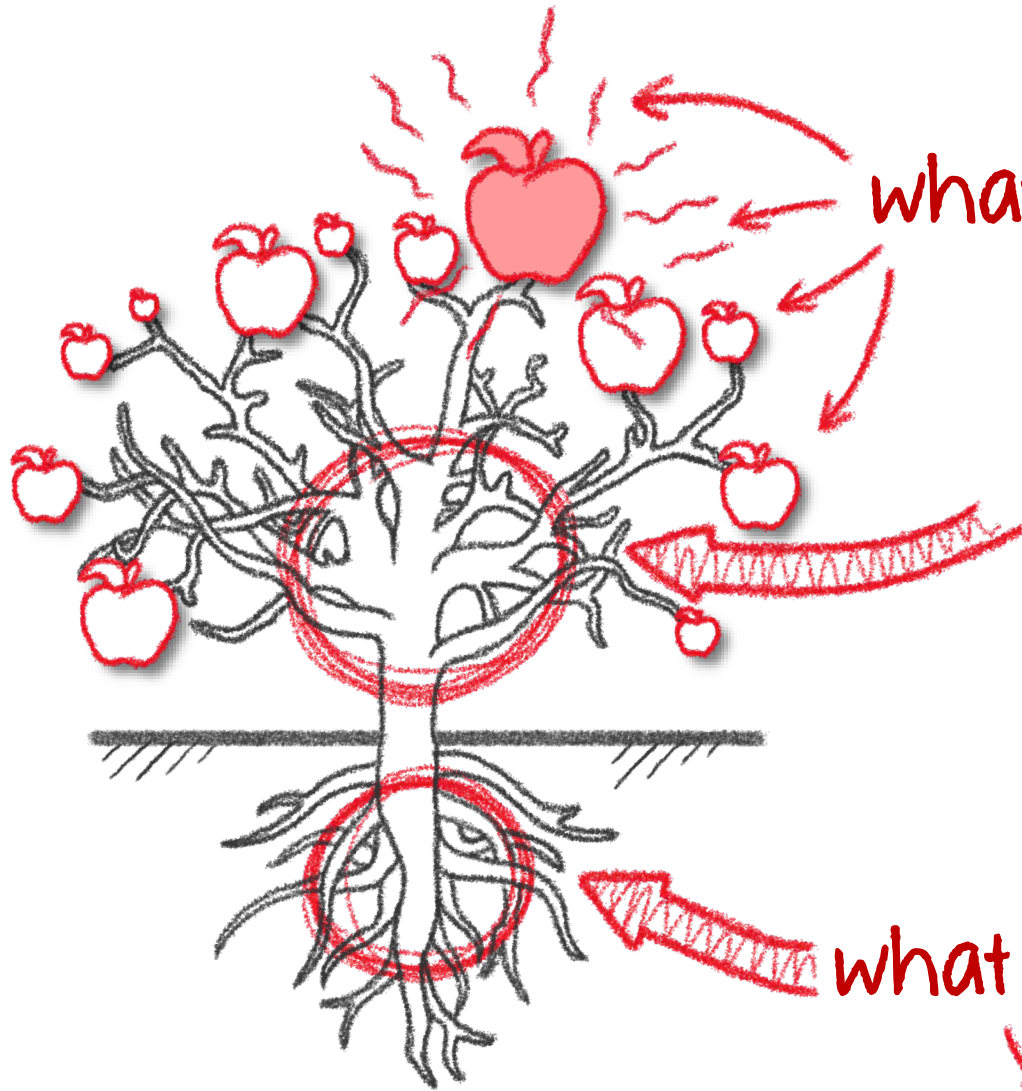
surface imperfections

fatigue

shaft fracture



EXERCISE



what is my ^{NOT} SYSTEM [^] DOING?

why DID THIS HAPPEN?

1. what BROKE?

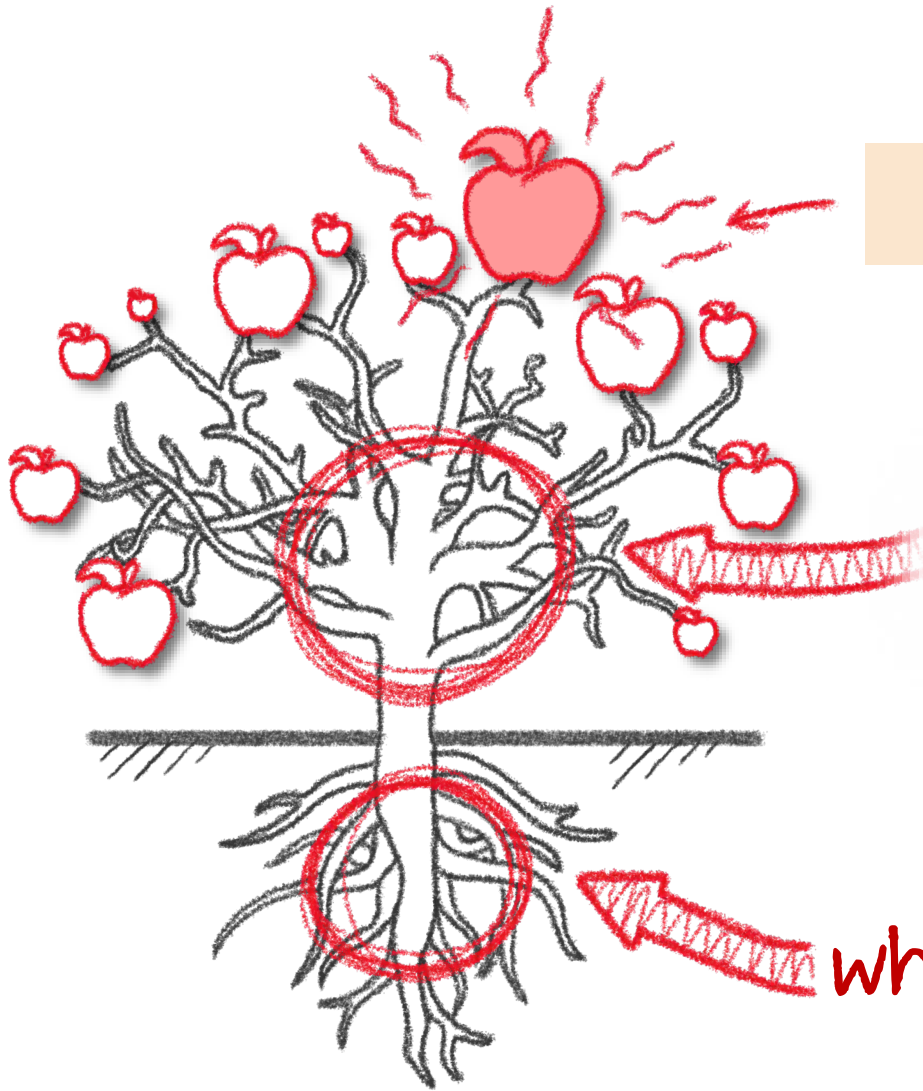
2. HOW did it break?

3. what STARTED it?

what DID WE DO WRONG?

... what DO WE NEED TO DO?

EXERCISE



shaft won't turn

... *due to* shaft fracture

... *from* fatigue cracking

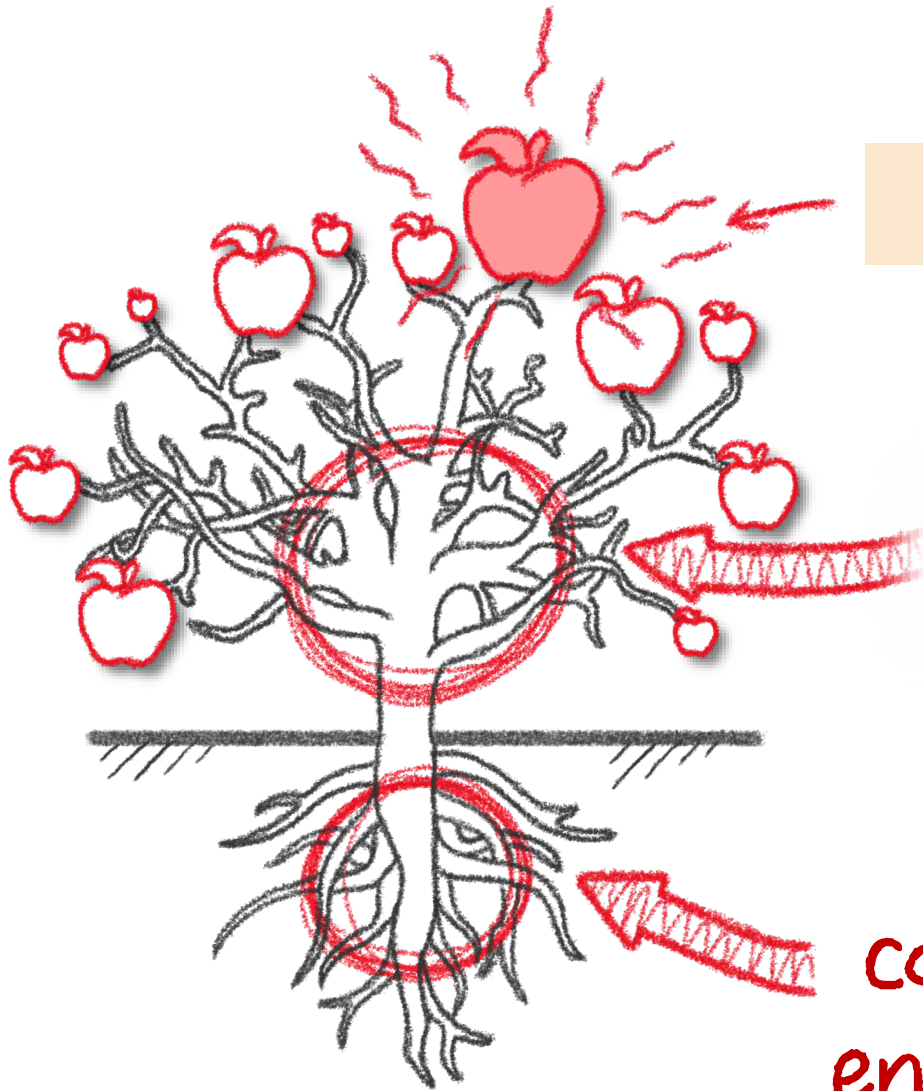
... *caused by* surface imperfections

what DID WE DO WRONG?

... *what* DO WE NEED TO DO?



EXERCISE



shaft won't turn

... *due to* shaft fracture

... *from* fatigue cracking

... *caused by* surface imperfections

conduct a PROCESS FMEA to
ensure that there are no surface
cracks deeper than 0.05 mm



EXERCISE



we call this a ROOT CAUSE STATEMENT

shaft won't turn

... due to shaft fracture

... from fatigue cracking

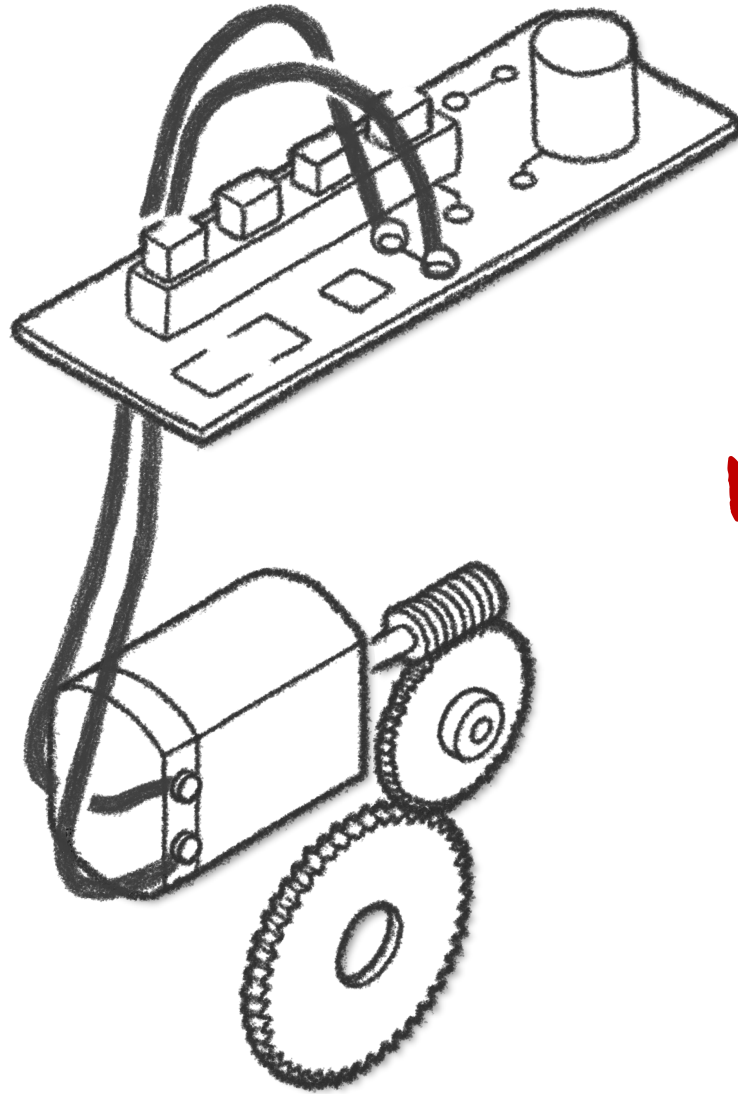
... caused by surface imperfections

... get the ROOT CAUSE
STATEMENT right and you
WILL find the ROOT CAUSE

... but it is **SOMETIMES** OK
to do a **SHORTCUT**



EXERCISE

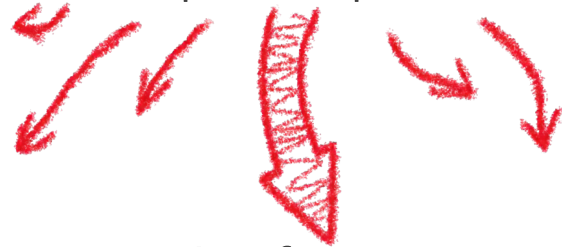


what could go
WRONG?

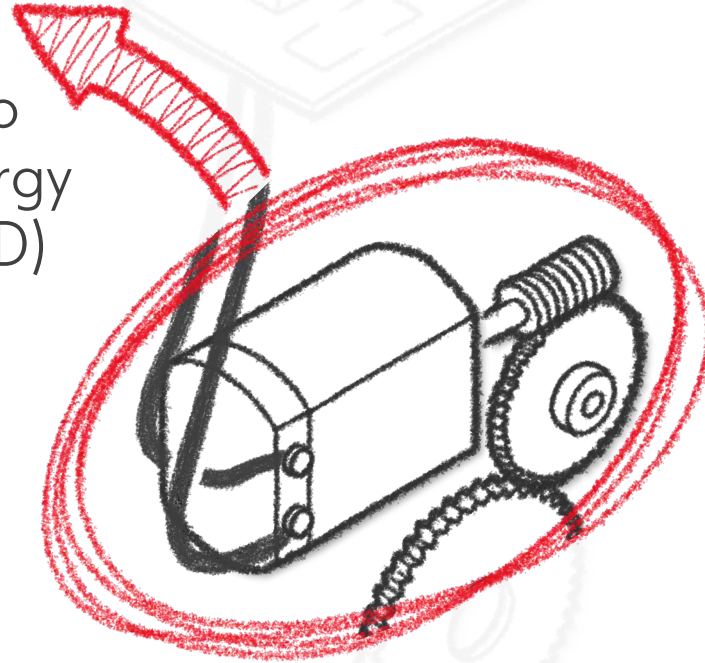
EXERCISE

FUNCTION

to convert
6 V / 100 mA DC to
rotational kinetic energy
(torque & speed TBD)



shaft turns
too slowly



what is my SYSTEM ^{NOT} DOING?



EXERCISE

why DID THIS HAPPEN?

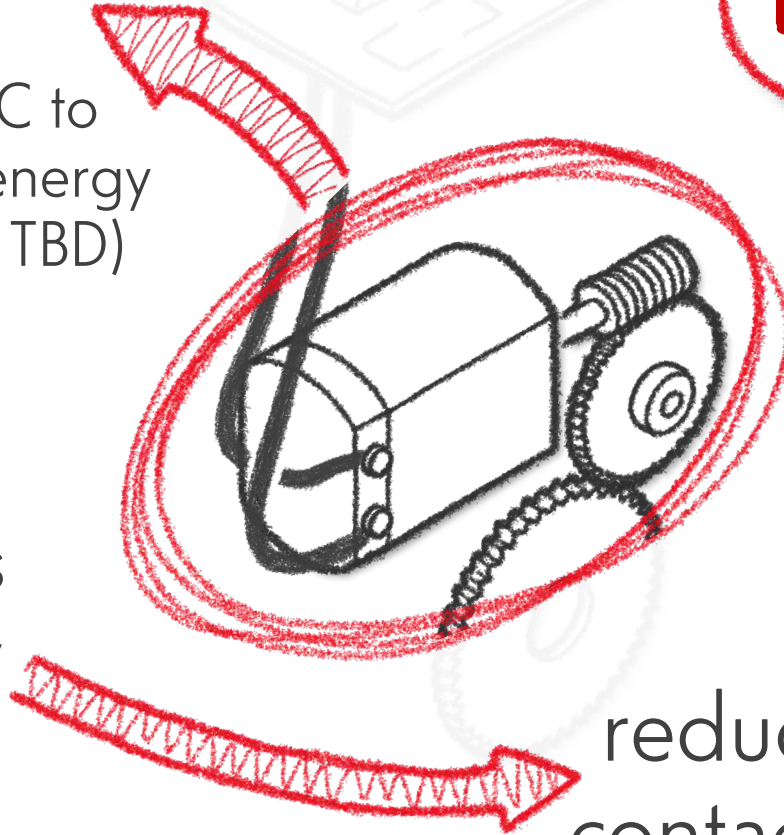
FUNCTION

to convert
6 V / 100 mA DC to
rotational kinetic energy
(torque & speed TBD)

1. what BROKE?

shaft turns
too slowly

reduced electrical
contact conductivity



EXERCISE

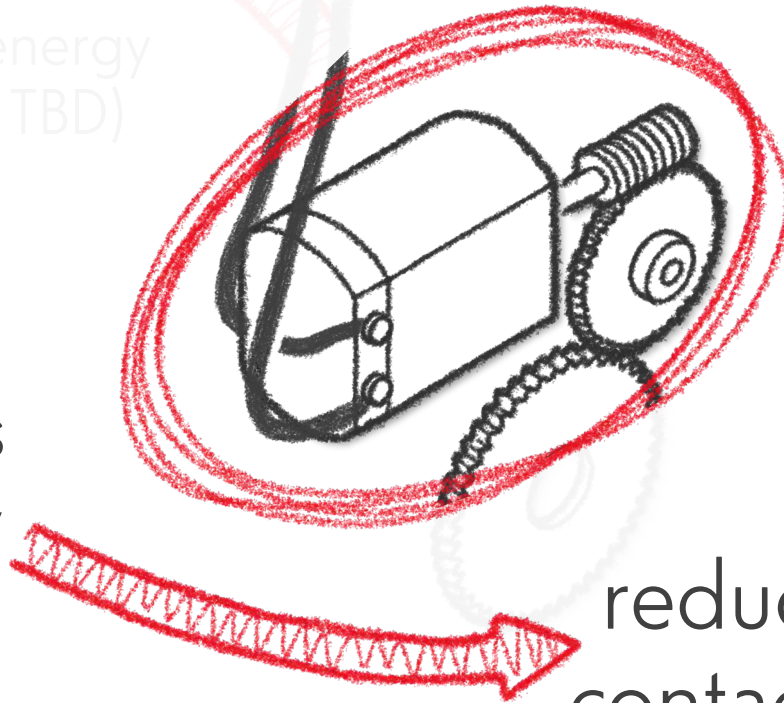
why DID THIS HAPPEN?

FUNCTION

to convert
6 V / 100 mA DC to
rotational kinetic energy
(torque & speed TBD)

2. HOW did it break?

shaft turns
too slowly



corrosion

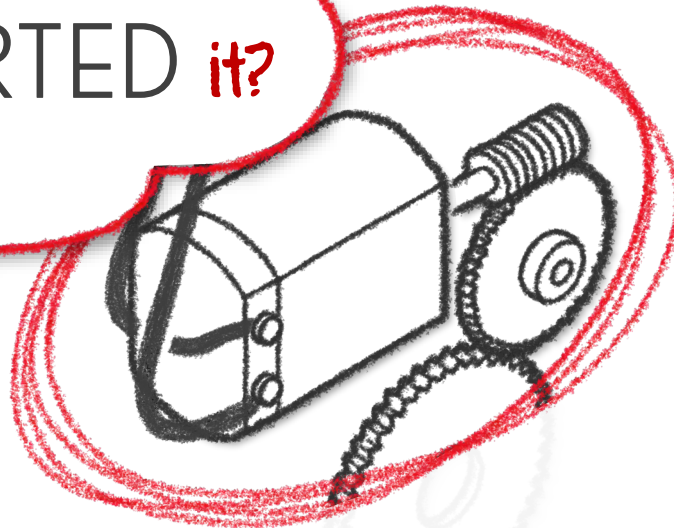
reduced electrical
contact conductivity



EXERCISE

why DID THIS HAPPEN?

3. what STARTED it?



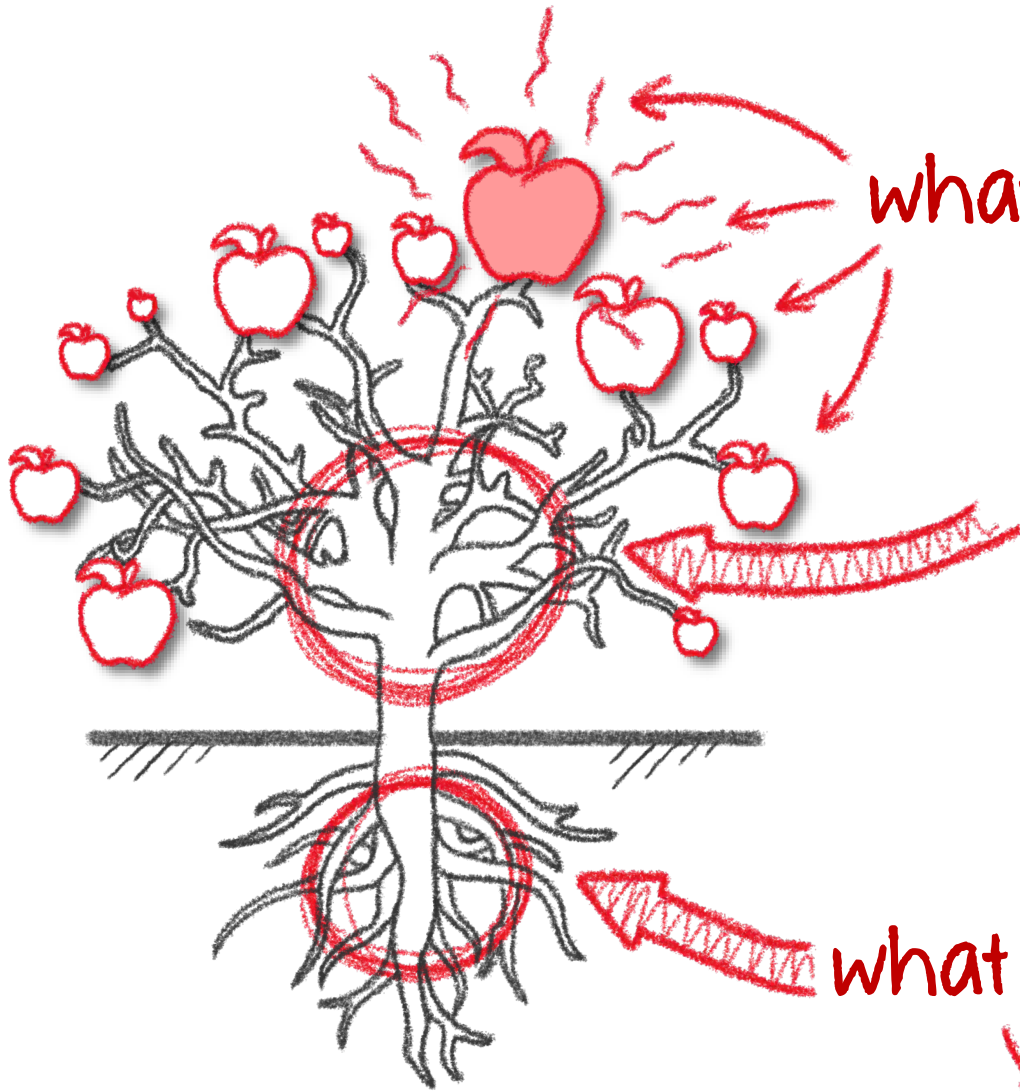
?

corrosion

reduced electrical
contact conductivity



EXERCISE



what is my ^{NOT} SYSTEM [^] DOING?

why DID THIS HAPPEN?

1. what BROKE?

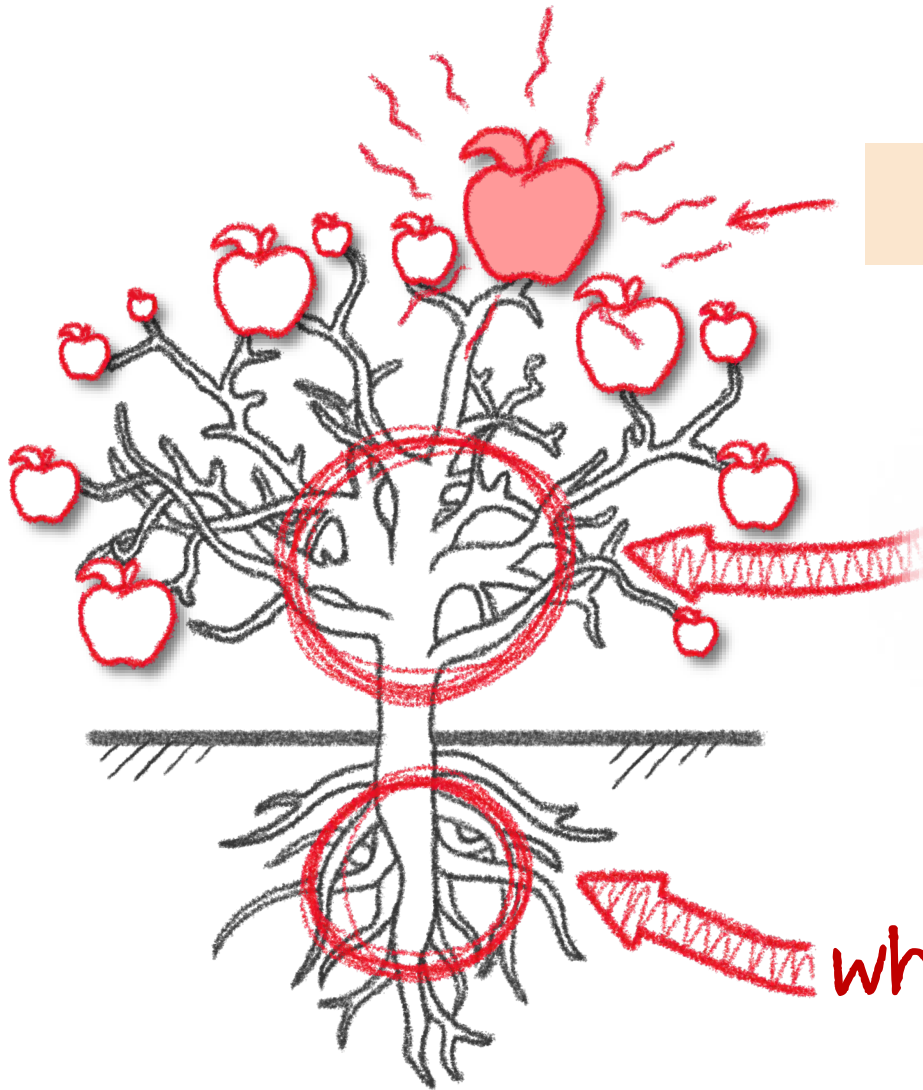
2. HOW did it break?

3. what STARTED it?

what DID WE DO WRONG?

... what DO WE NEED TO DO?

EXERCISE



shaft turns too slowly

... due to reduced electrical contact conductivity

... from corrosion

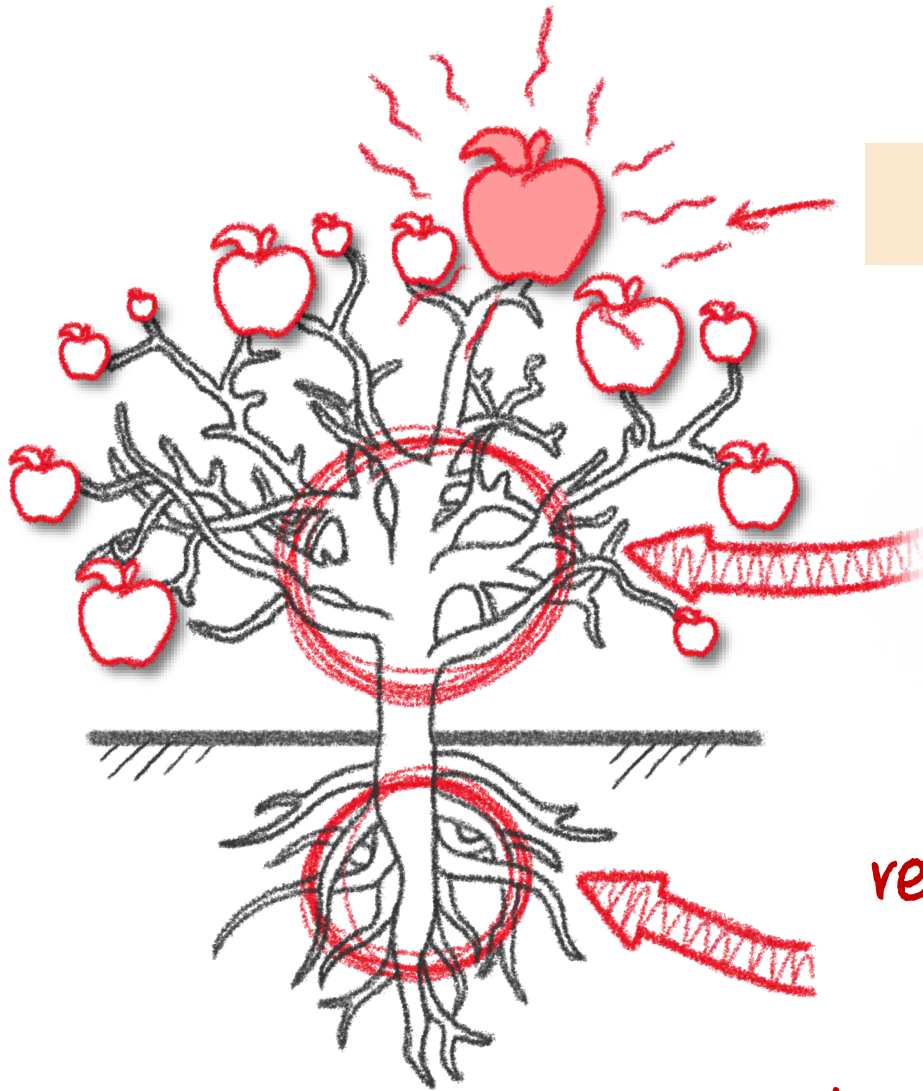
?

what DID WE DO WRONG?

... what DO WE NEED TO DO?



EXERCISE



shaft turns too slowly

... due to reduced electrical contact conductivity

... from corrosion

?

review USE CASE humidity extremes
and include in motor specification

... and conduct a DESIGN FMEA
on the housing seal



EXERCISE



our 'shorter' ROOT CAUSE STATEMENT

shaft turns too slowly

... *due to* reduced electrical contact conductivity

... *from* corrosion

EXERCISE

the
amazing
F•M•E•A
or
R•C•A
facilitator



EXERCISE

stops the
brainstorming
at ...
'HOW
did it break?'



EXERCISE

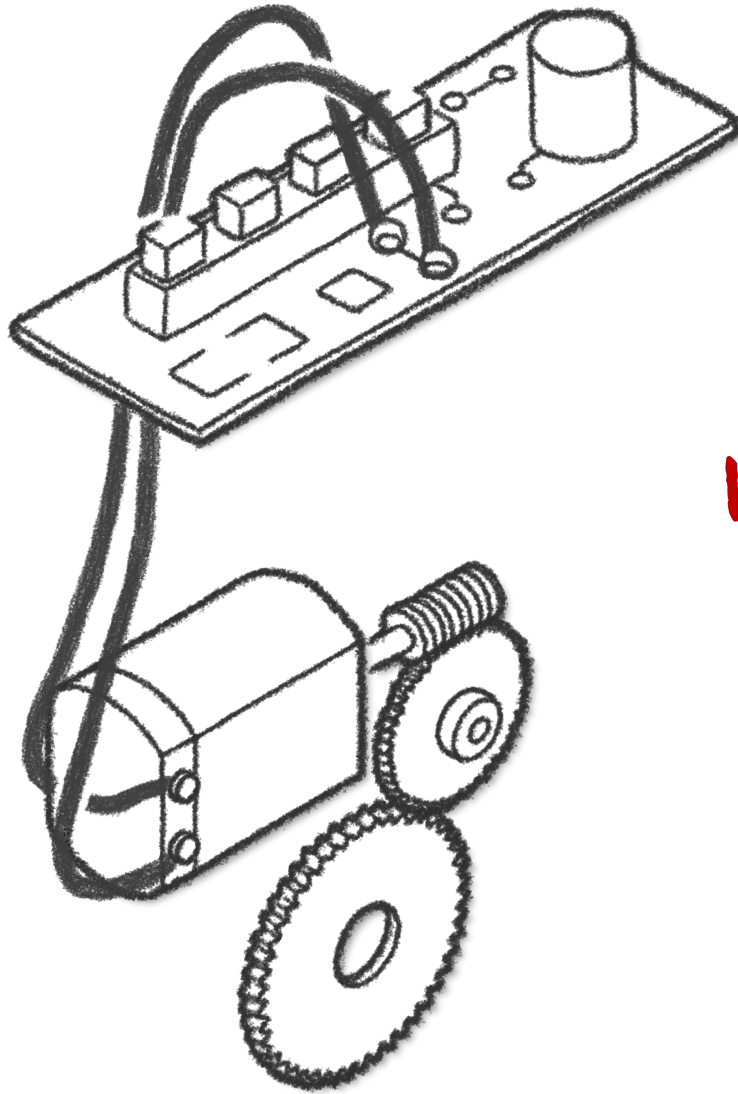
... because she
judged that
her team
really KNOWS
HOW
CORROSION
HAPPENS



... but it is **SOMETIMES OK**
to do an **EVEN SHORTER**
SHORTCUT



EXERCISE

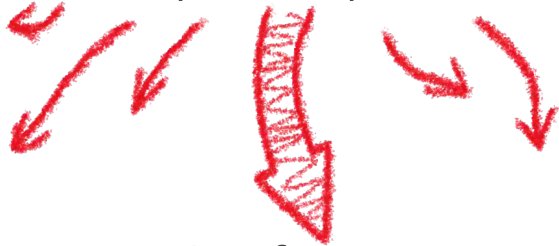


what could go
WRONG?

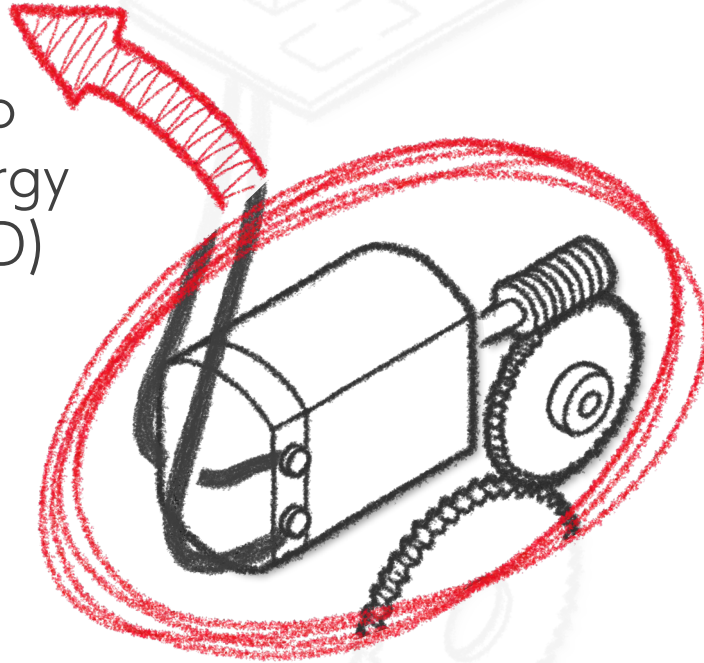
EXERCISE

FUNCTION

to convert
6 V / 100 mA DC to
rotational kinetic energy
(torque & speed TBD)



shaft turns
too slowly



what is my SYSTEM ^{NOT} DOING?



EXERCISE

why DID THIS HAPPEN?

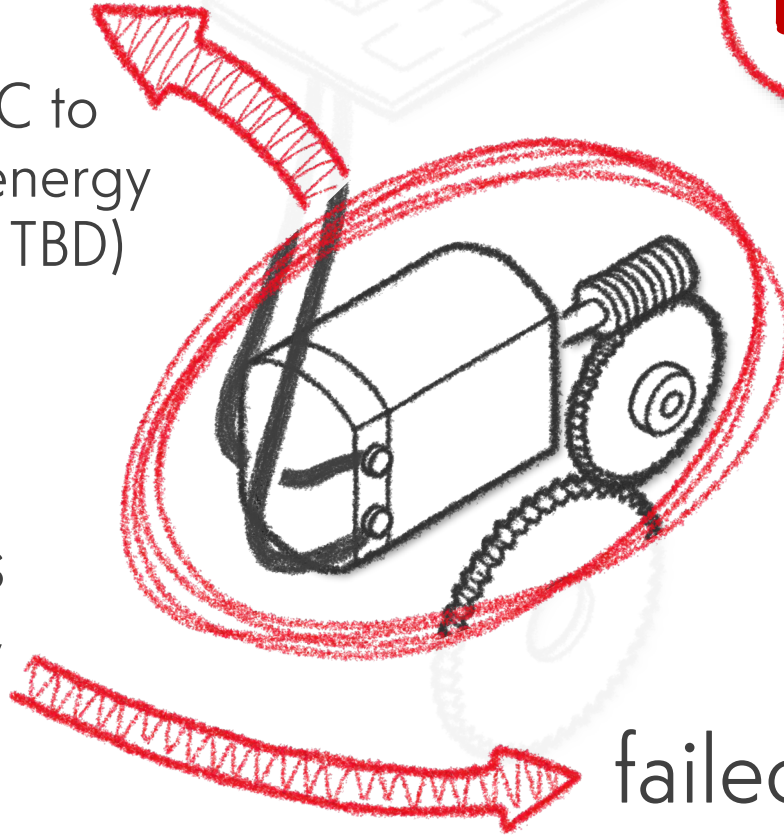
FUNCTION

to convert
6 V / 100 mA DC to
rotational kinetic energy
(torque & speed TBD)

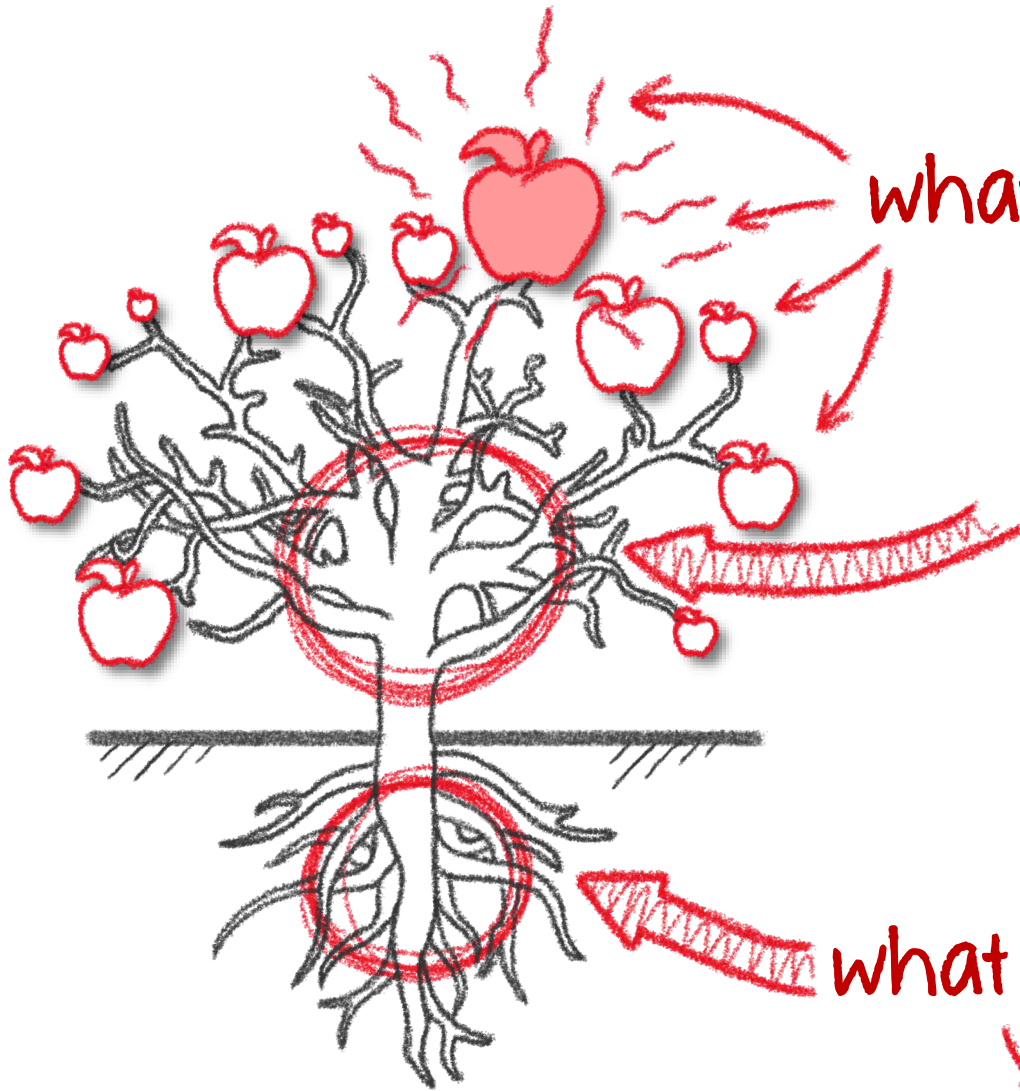
1. what BROKE?

shaft turns
too slowly

failed bearing



EXERCISE



what is my ^{NOT} SYSTEM [^] DOING?

why DID THIS HAPPEN?

1. what BROKE?

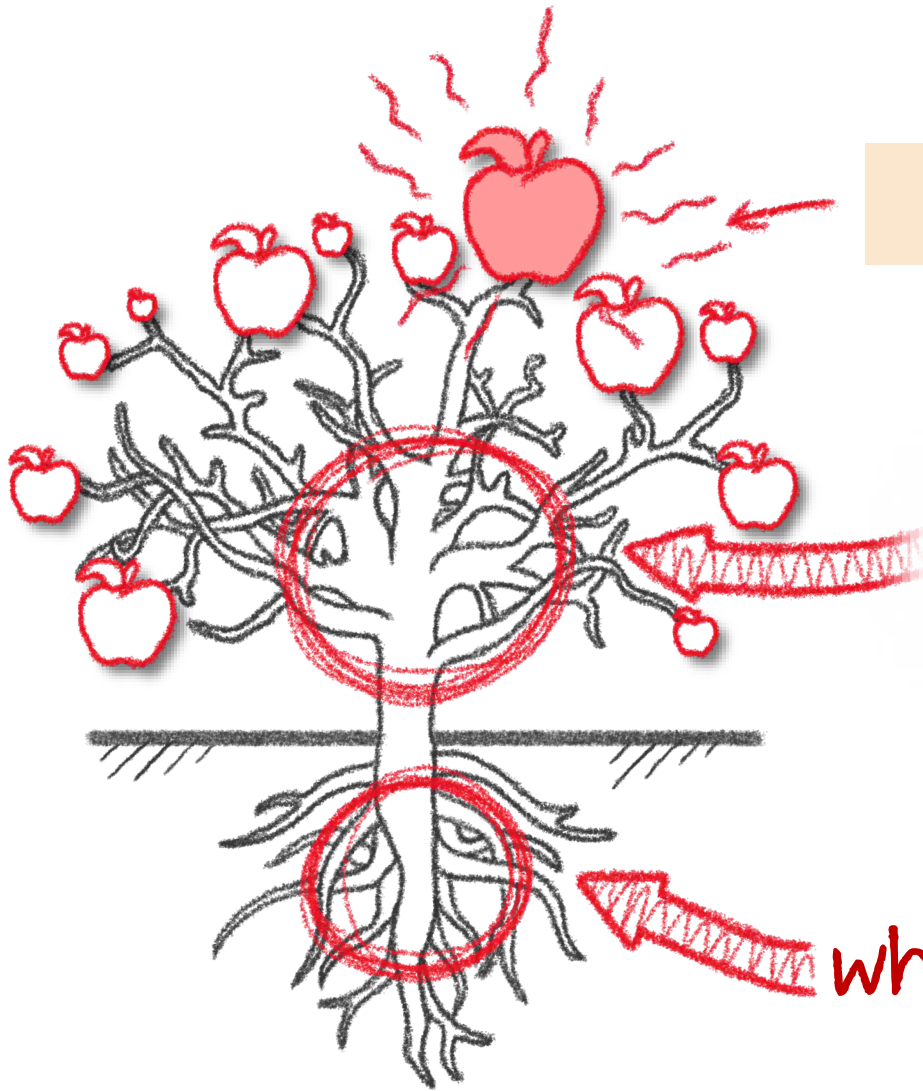
2. HOW did it break?

3. what STARTED it?

what DID WE DO WRONG?

... what DO WE NEED TO DO?

EXERCISE



shaft turns too slowly

... due to failed bearing

?

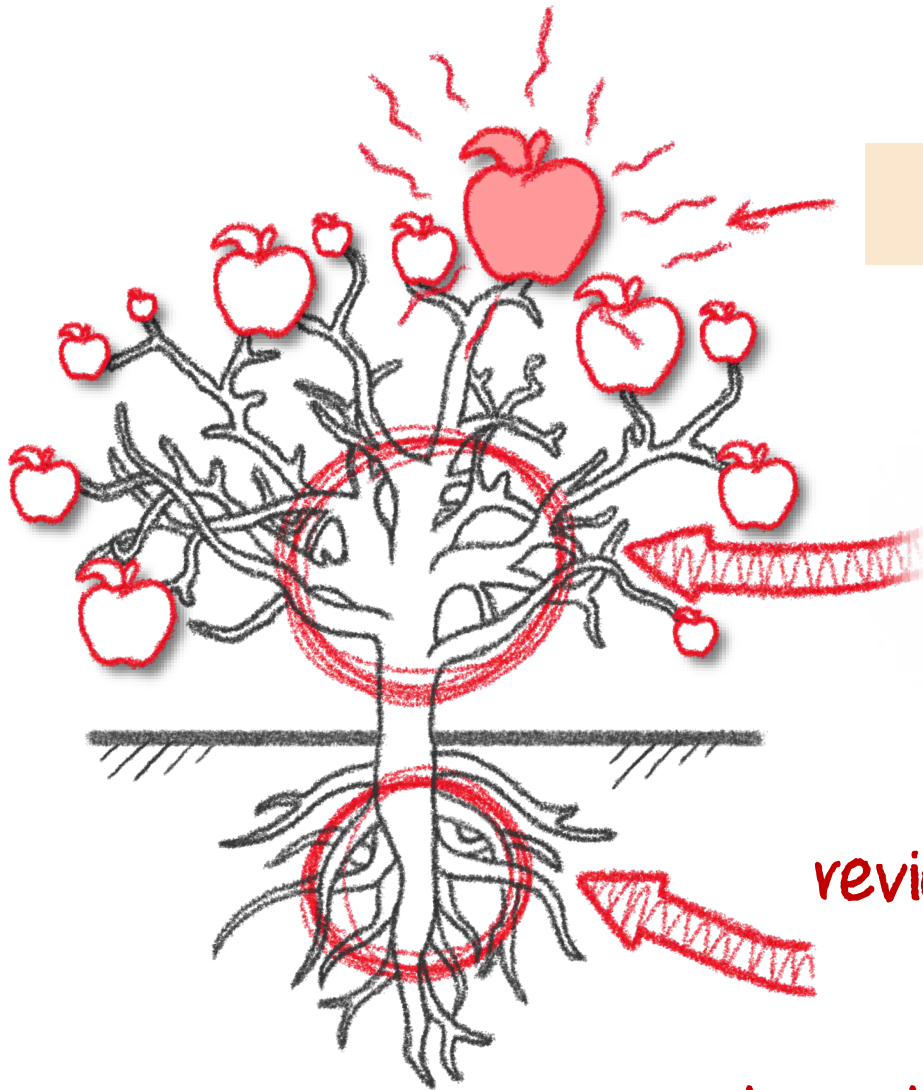
?

what DID WE DO WRONG?

... what DO WE NEED TO DO?



EXERCISE



shaft turns too slowly

... due to failed bearing

?

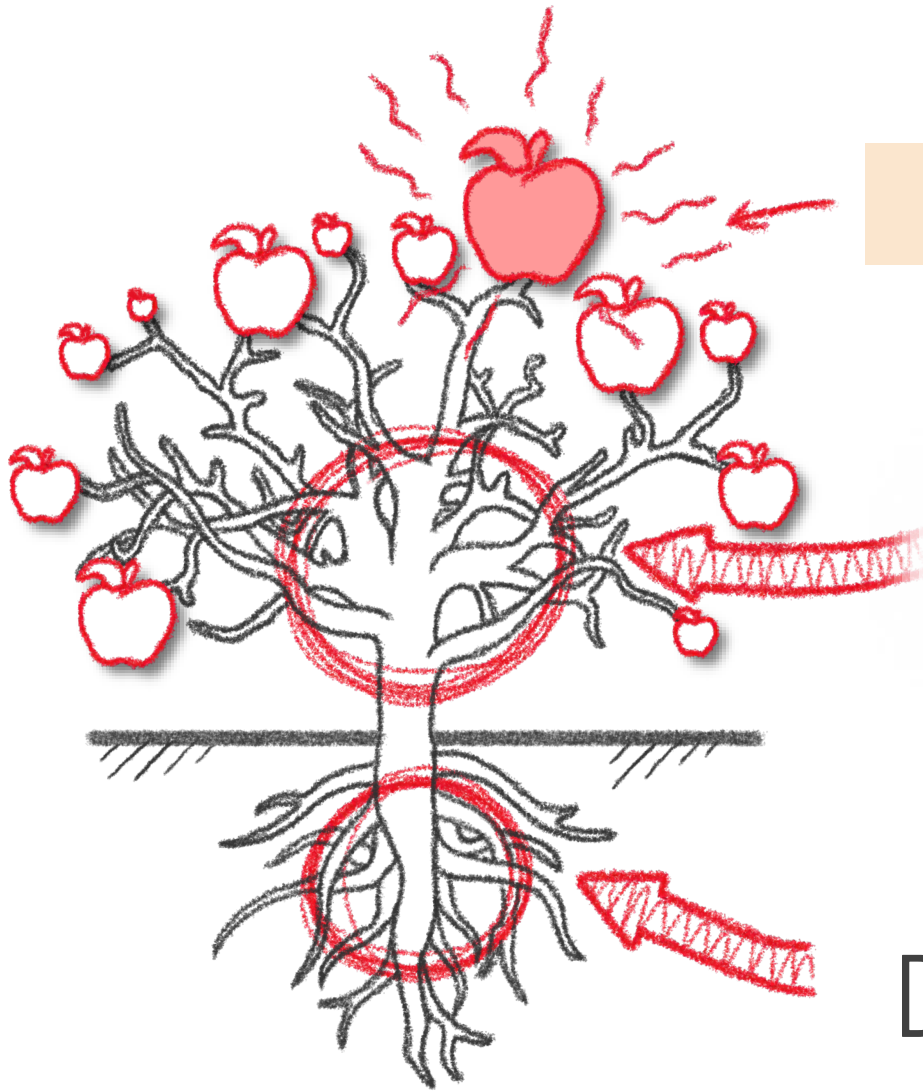
?

review USE CASE and include anticipated cycles in bearing specifications

... and conduct INCOMING ALT on 5 % of all incoming motors



EXERCISE



shaft turns too slowly

... due to failed bearing

?

?

conduct a
DESIGN FMEA
on the bearing



EXERCISE



our even 'shorter' ROOT CAUSE STATEMENT

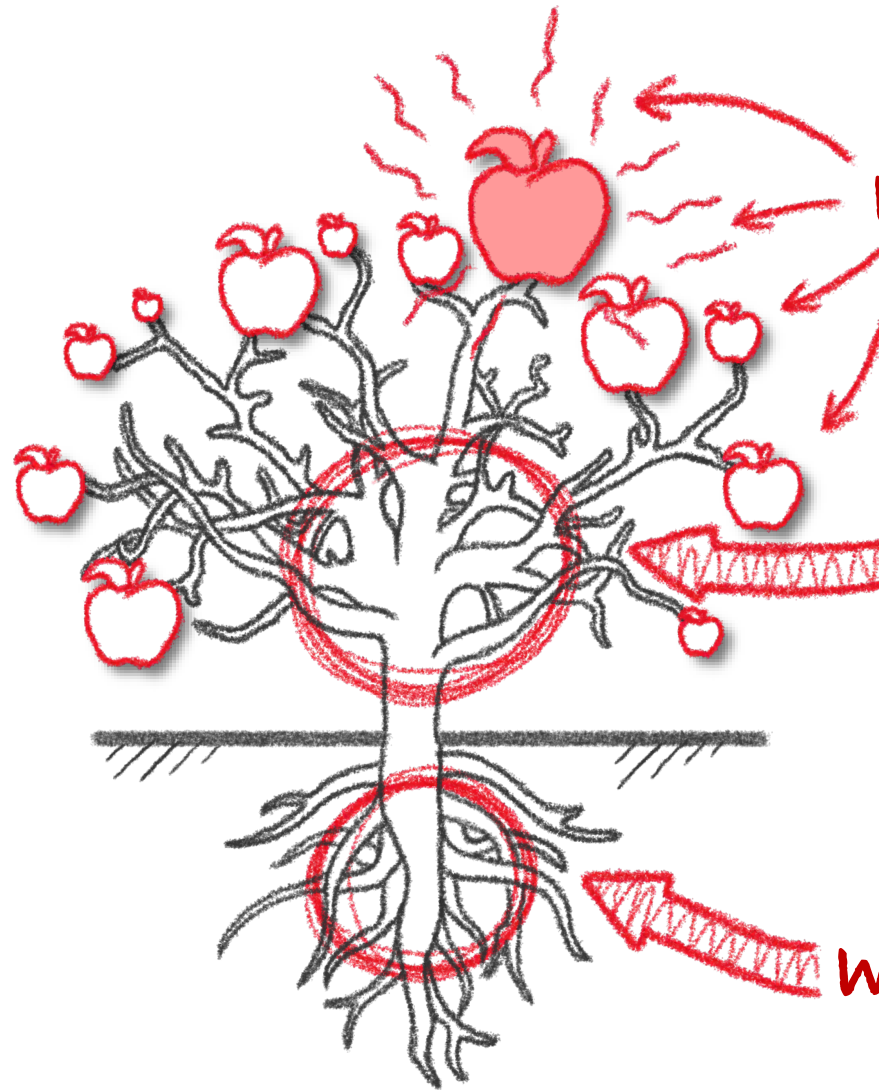
shaft turns too slowly

... *due to* failed bearing

... so how do we 'MEASURE'
how good our root cause
'TAXONOMY' is?

... through the
COVERAGE and
QUALITY of our
CORRECTIVE
ACTIONS





NOT
what is my SYSTEM [^] DOING?

why DID THIS HAPPEN?

1. what BROKE?

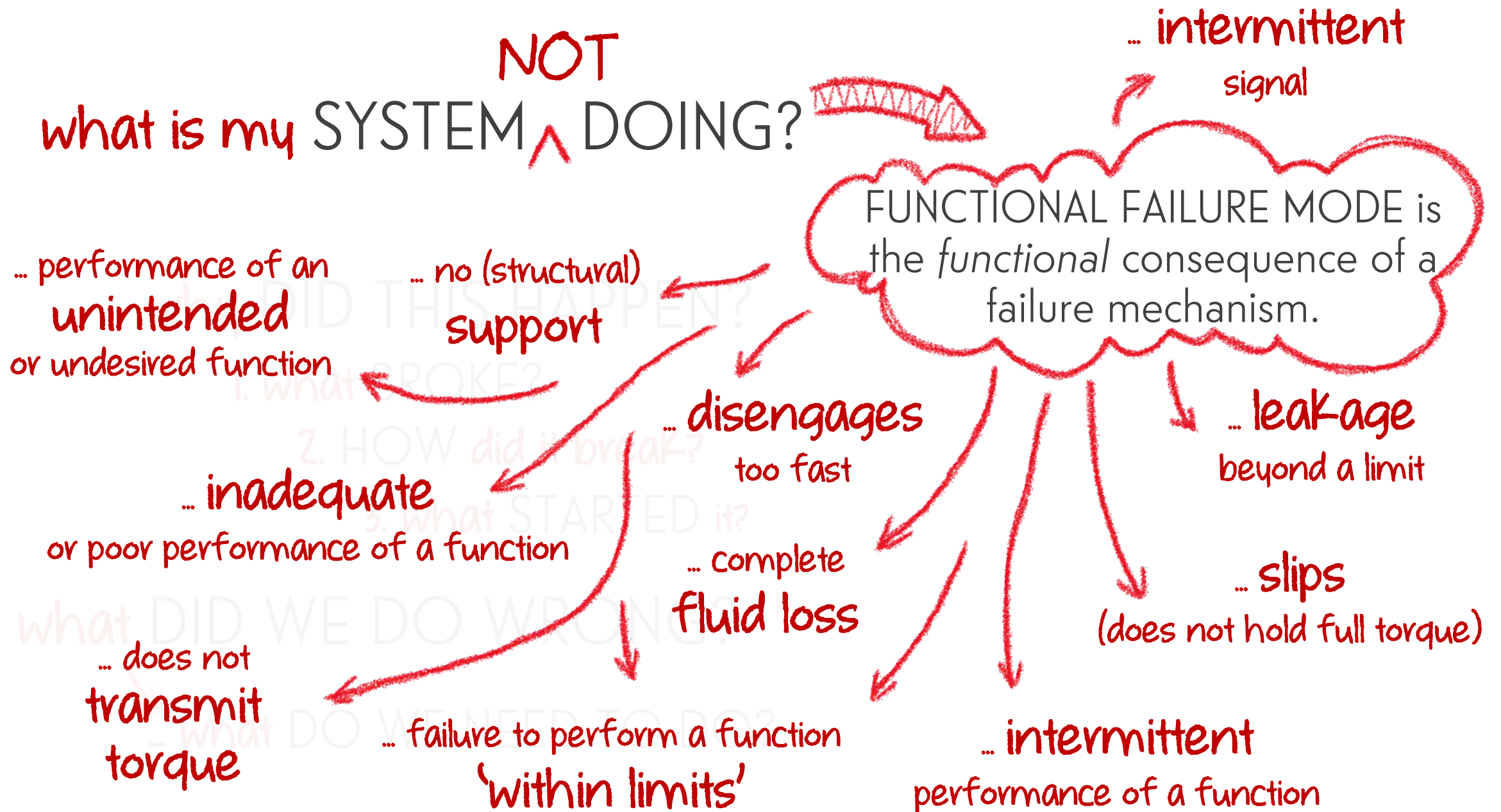
2. HOW did it break?

3. what STARTED it?

what DID WE DO WRONG?

... what DO WE NEED TO DO?

what is my **NOT** SYSTEM **DOING?**



NOT
what is my SYSTEM [^] DOING?

why DID THIS HAPPEN?

1. what BROKE? →

2. HOW did it break?

3. what STARTED it?

what DID WE DO WRONG?

↙
... what DO WE NEED TO DO?

PHYSICAL FAILURE MODE is
the *physical* consequence of
a failure mechanism.

... sticking

... oxidized

... deformed

... loose

... cracked

... fractured

NOT
what is my SYSTEM [^] DOING?

why DID THIS HAPPEN?

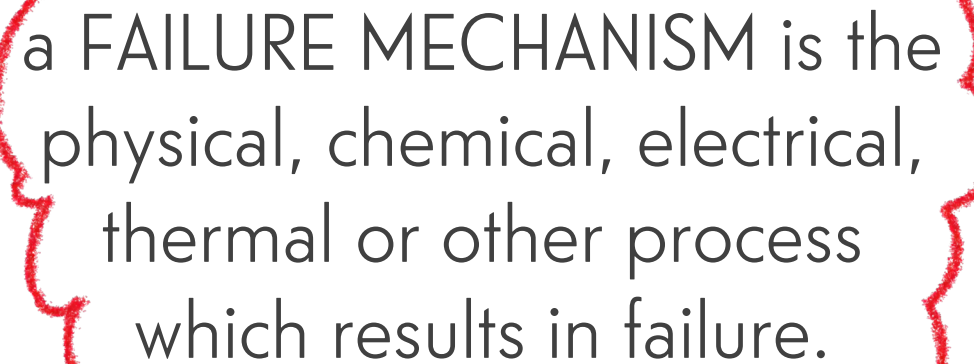
1. what BROKE?

2. HOW **did it break?** 

3. what STARTED it?

what DID WE DO WRONG?

 ... what DO WE NEED TO DO?



a FAILURE MECHANISM is the physical, chemical, electrical, thermal or other process which results in failure.

TIN WHISKER



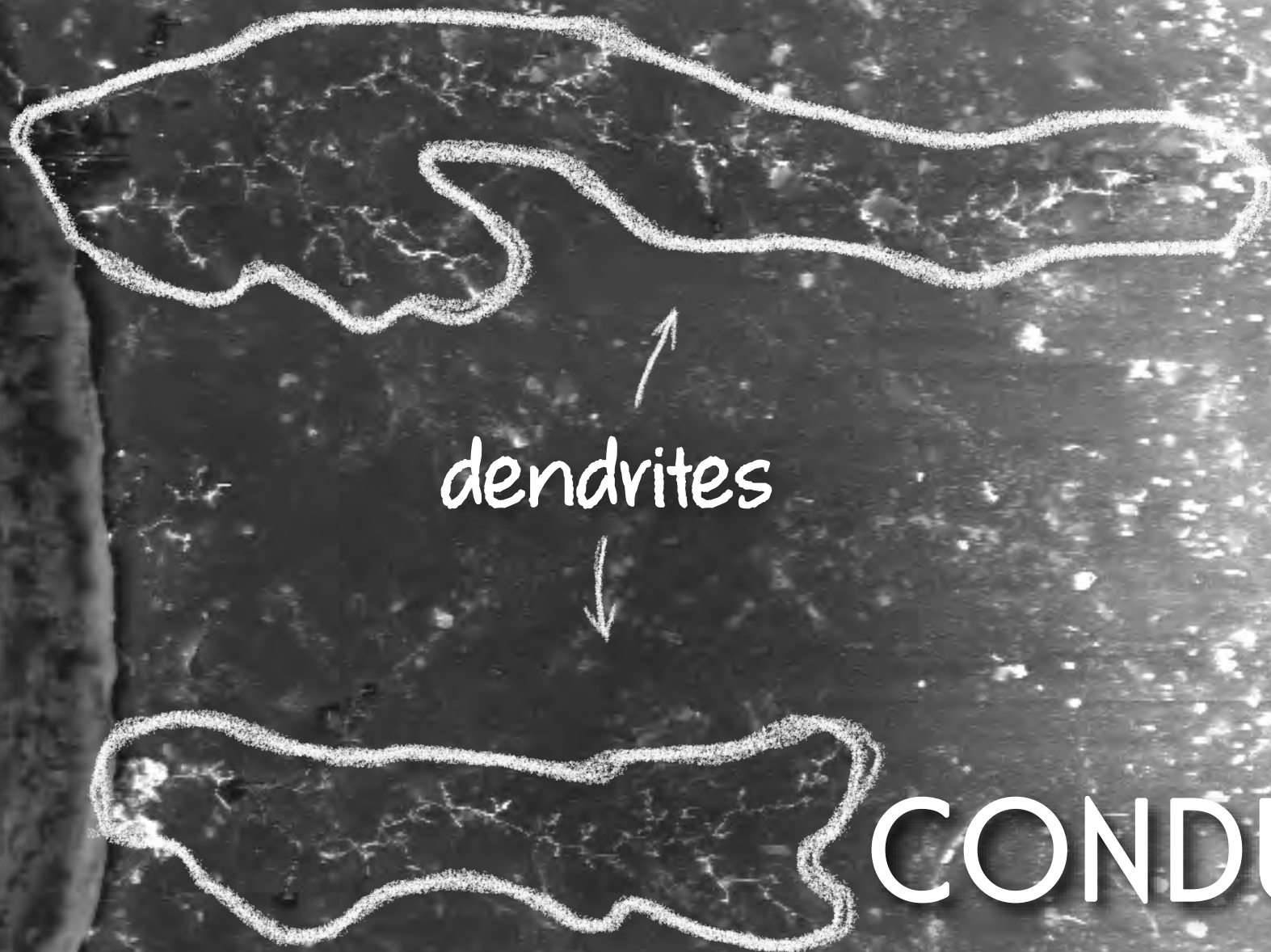
tin-plated terminals of an
electromagnetic relay

cathode

anode

dendrites

SEMI-
CONDUCTORS





CORROSION

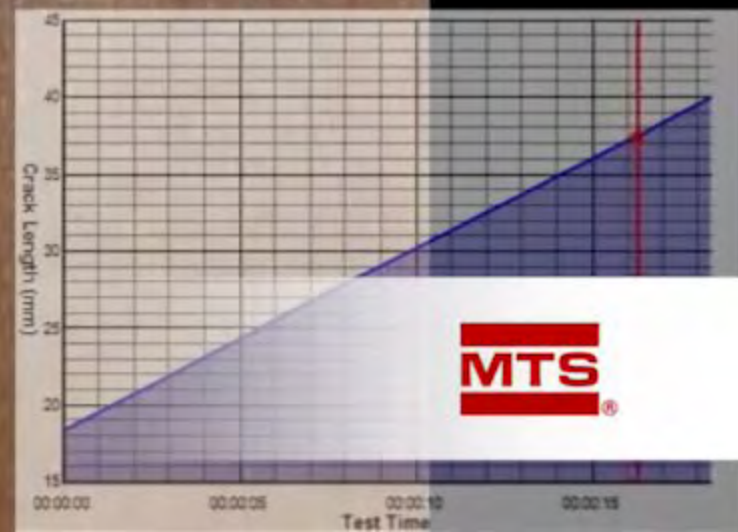
Cycles

96585

Crack Size (mm)

37.545

FATIGUE



NOT
what is my SYSTEM [^] DOING?

why DID THIS HAPPEN?

1. what BROKE?

2. HOW did it break?

3. **what** STARTED it?



a FAULT is the
'immediate' cause of
failure

what DID WE DO WRONG?



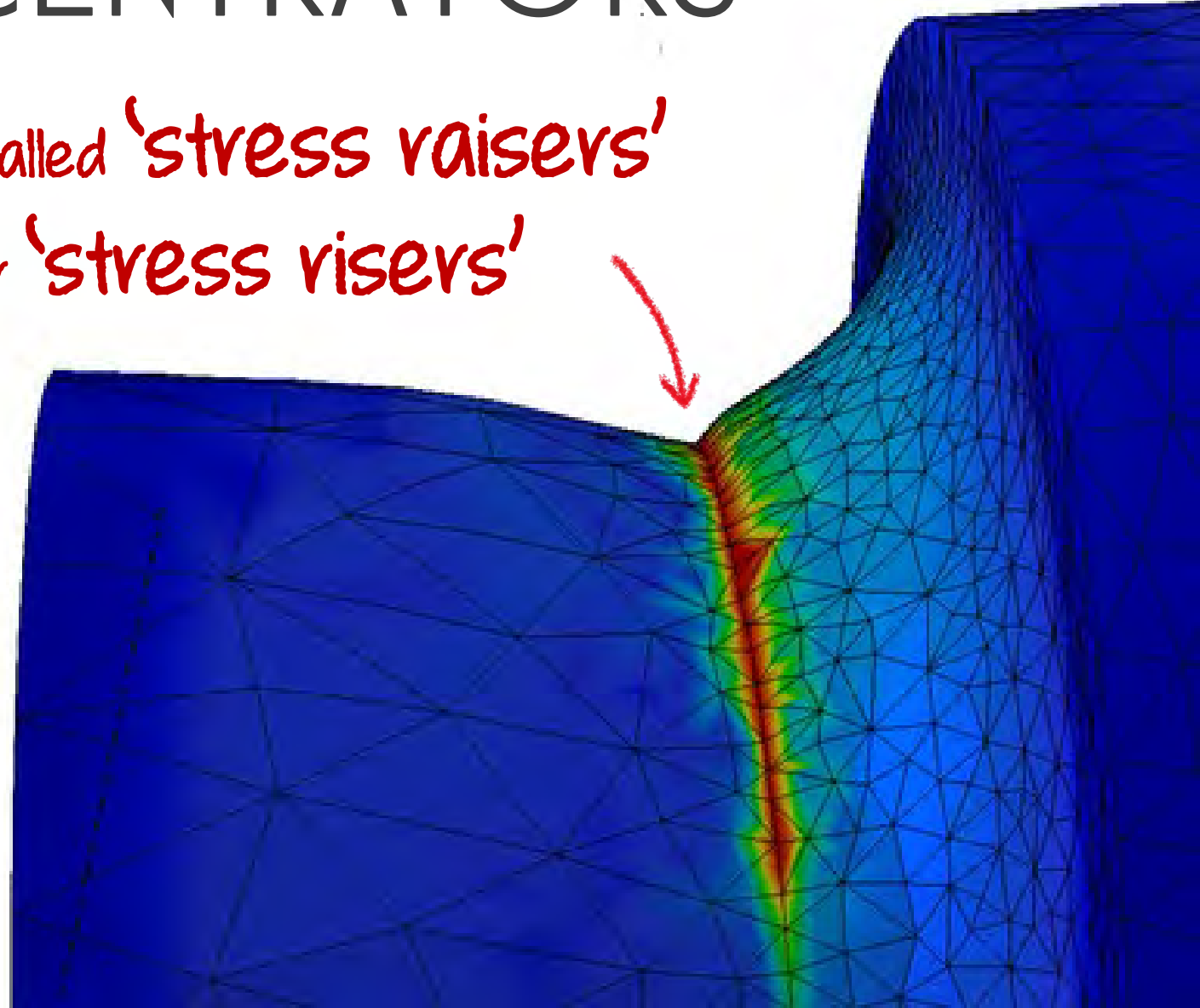
... what DO WE NEED TO DO?

STRESS CONCENTRATORS

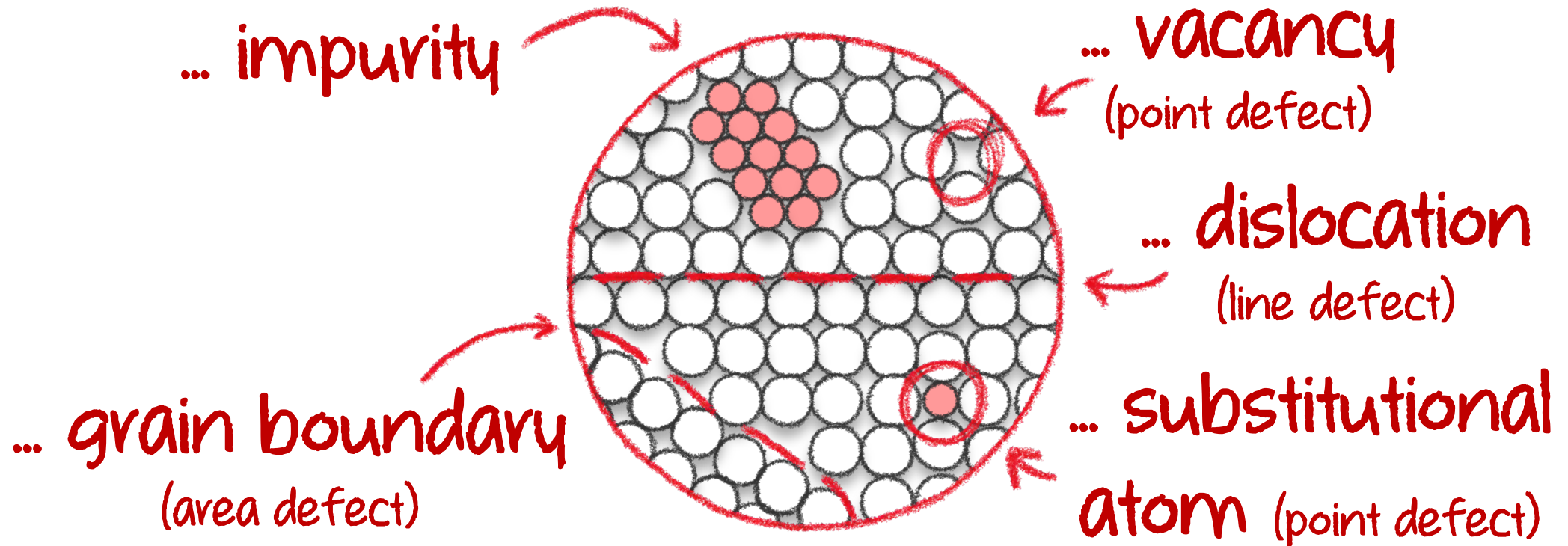
... also called 'stress raisers'
or 'stress risers'

points of a component where
stress is increased, primarily
due to geometry.

usually the failure site for
fracture (both overstress and
fatigue)



DEFECTS



NOT
what is my SYSTEM [^] DOING?

why DID THIS HAPPEN?

1. what BROKE?

2. HOW did it break?

3. what STARTED it?

what DID WE DO WRONG? 

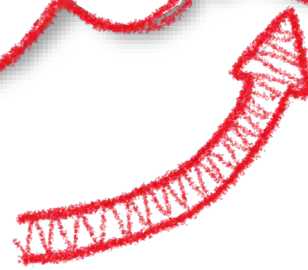
ROOT CAUSE

 ... what DO WE NEED TO DO?

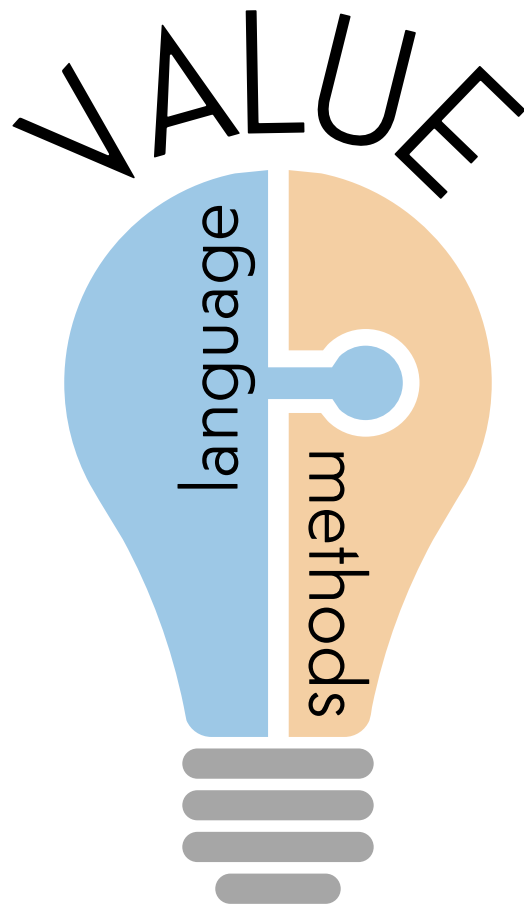
CORRECTIVE ACTION (CA)

or fix is an action that involves a change to a system design, operation, maintenance procedures, or the manufacturing process of the item for the purpose of improving its reliability.

... **what** DO WE NEED TO DO?



... the RELIABILITY
MINDSET



VALUE

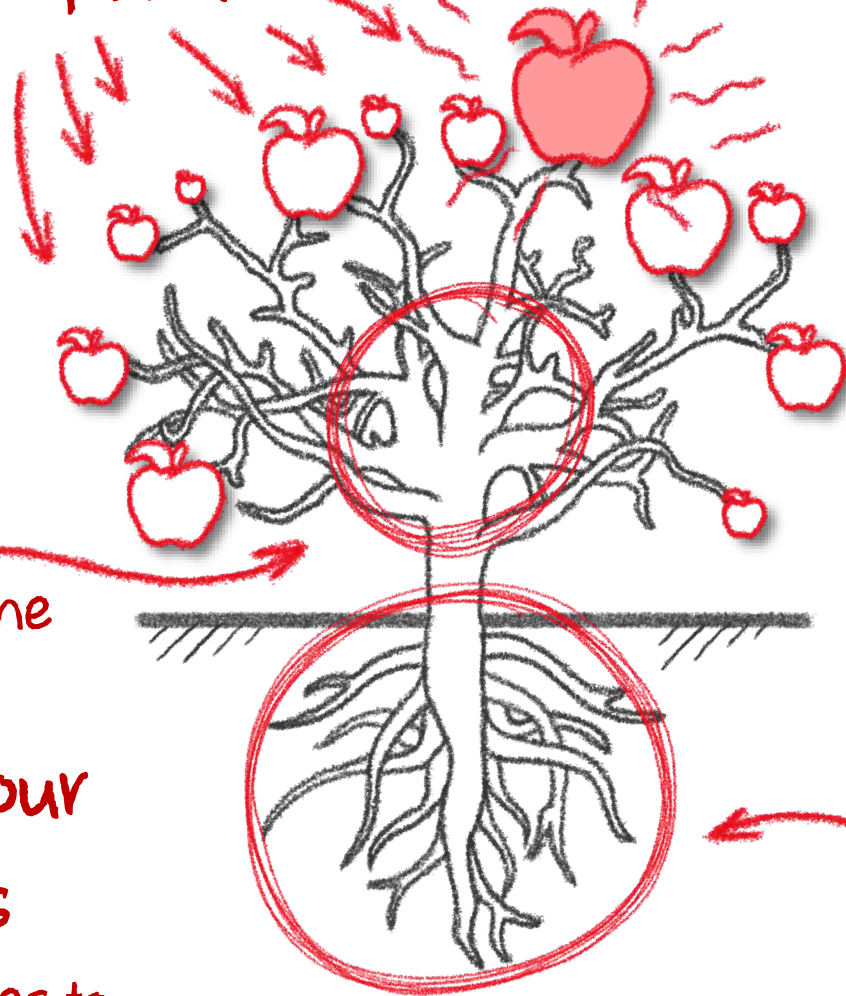
... Knowing how
failures destroy value

... and by how much

... to create
value

language

... giving you the
terms to
organize your
thoughts
to connect failures to
root causes



... which means you
know the
vital few
root causes or
causal factors you
need to address

methods

