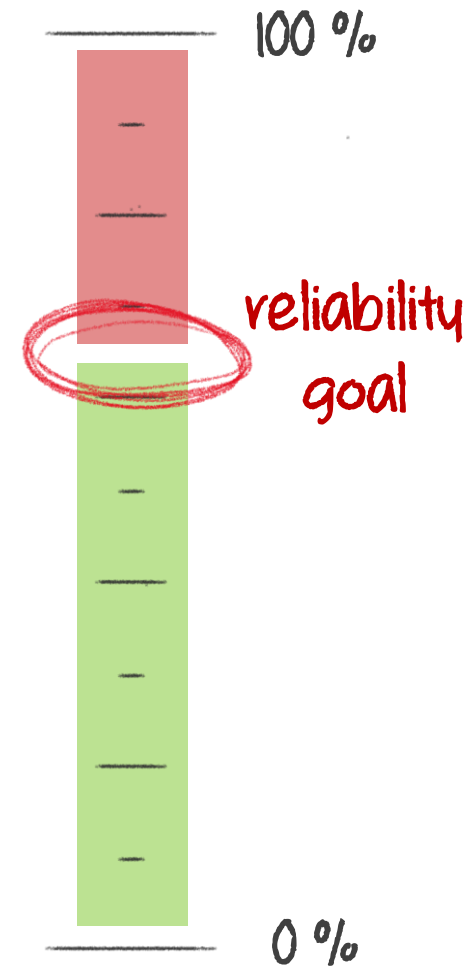
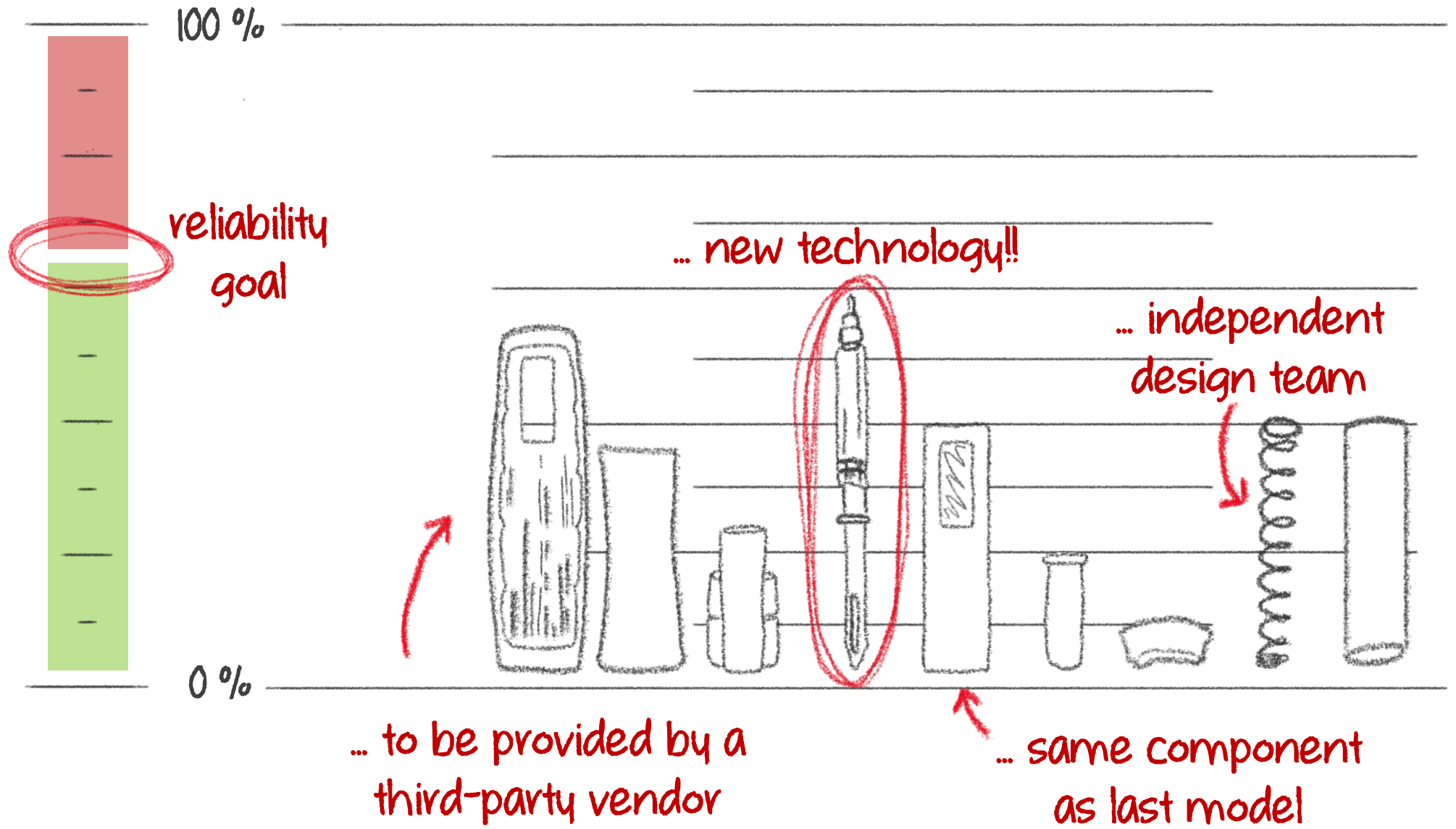
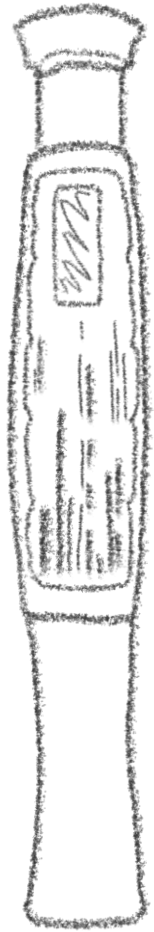
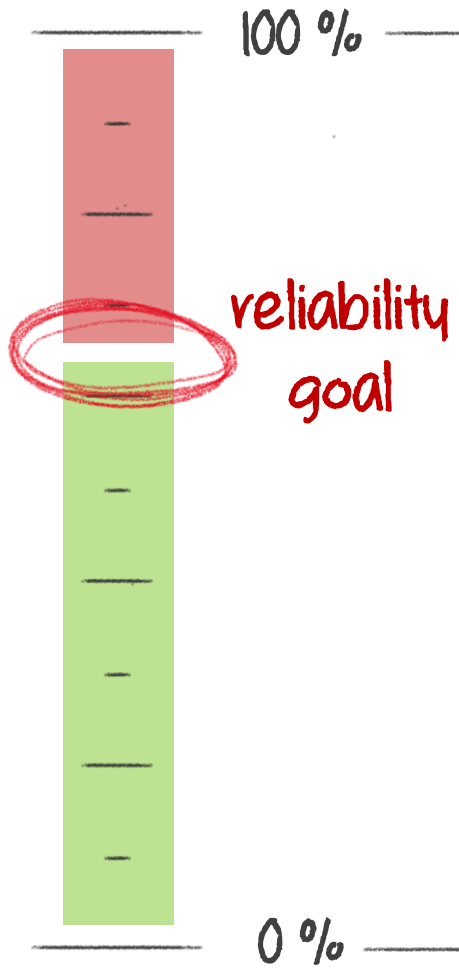
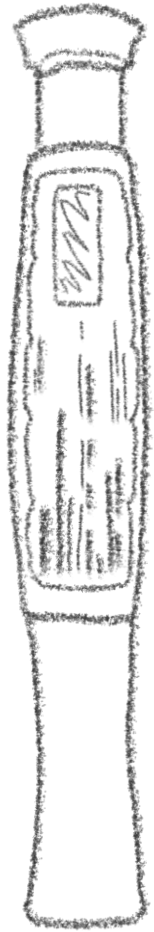


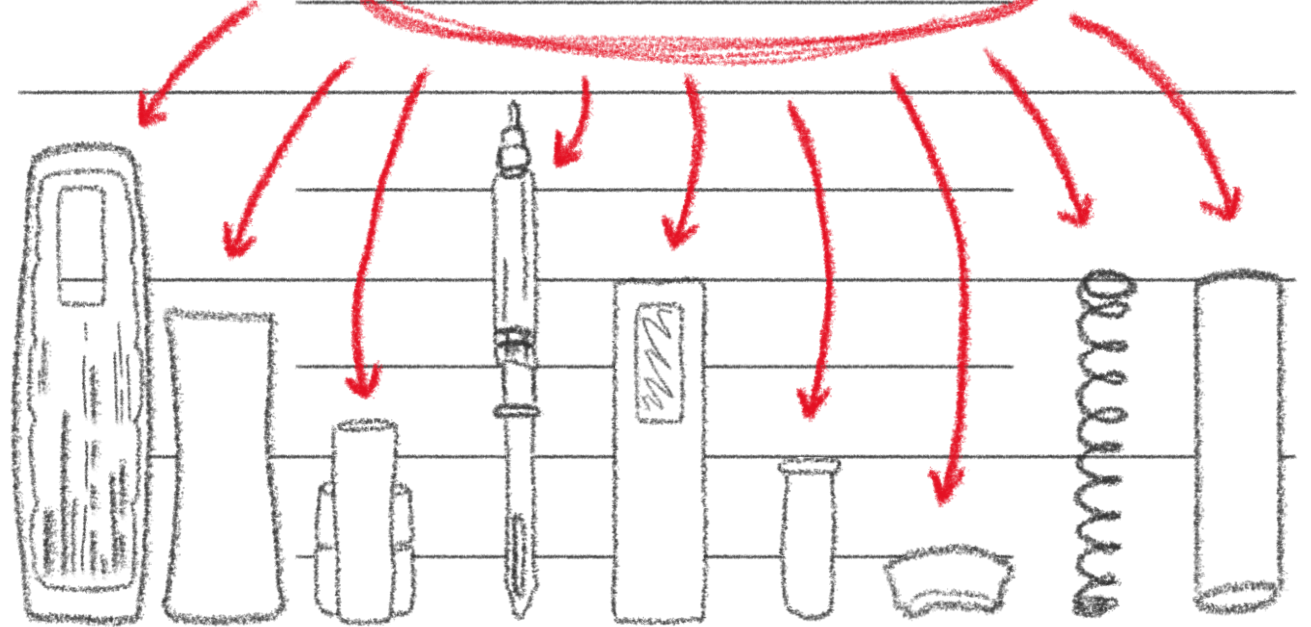
reliability  
allocation



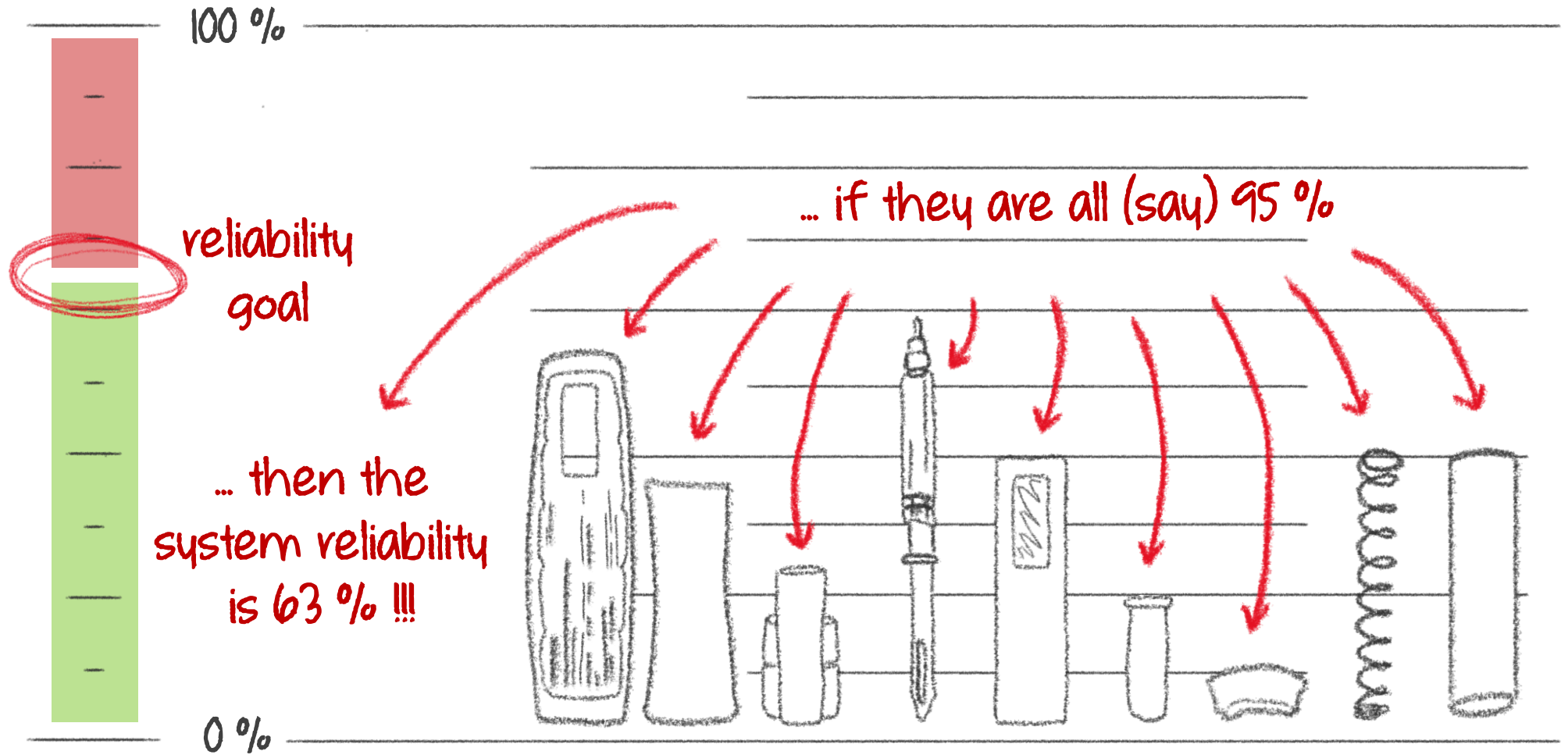
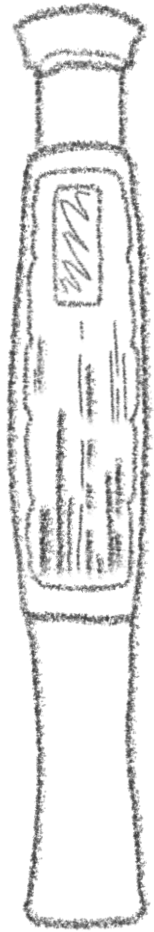




RELIABILITY GOALS???







# reliability allocation

... is the assigning of numerical reliability goals to subsystems and components in support of system level reliability performance characteristics.

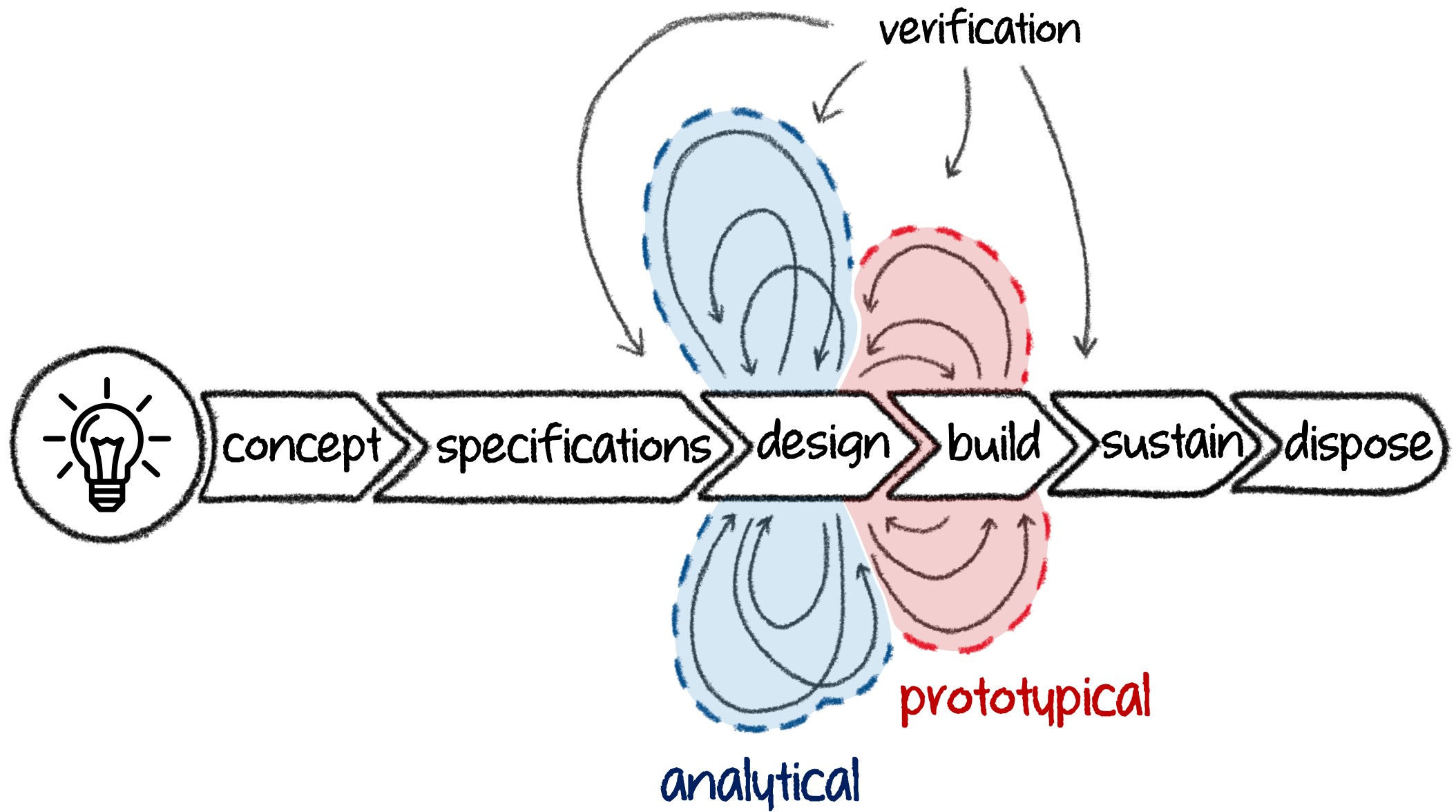
allow smaller design teams to independently work on specific elements of the system with their own reliability goals and targets

# reliability allocation

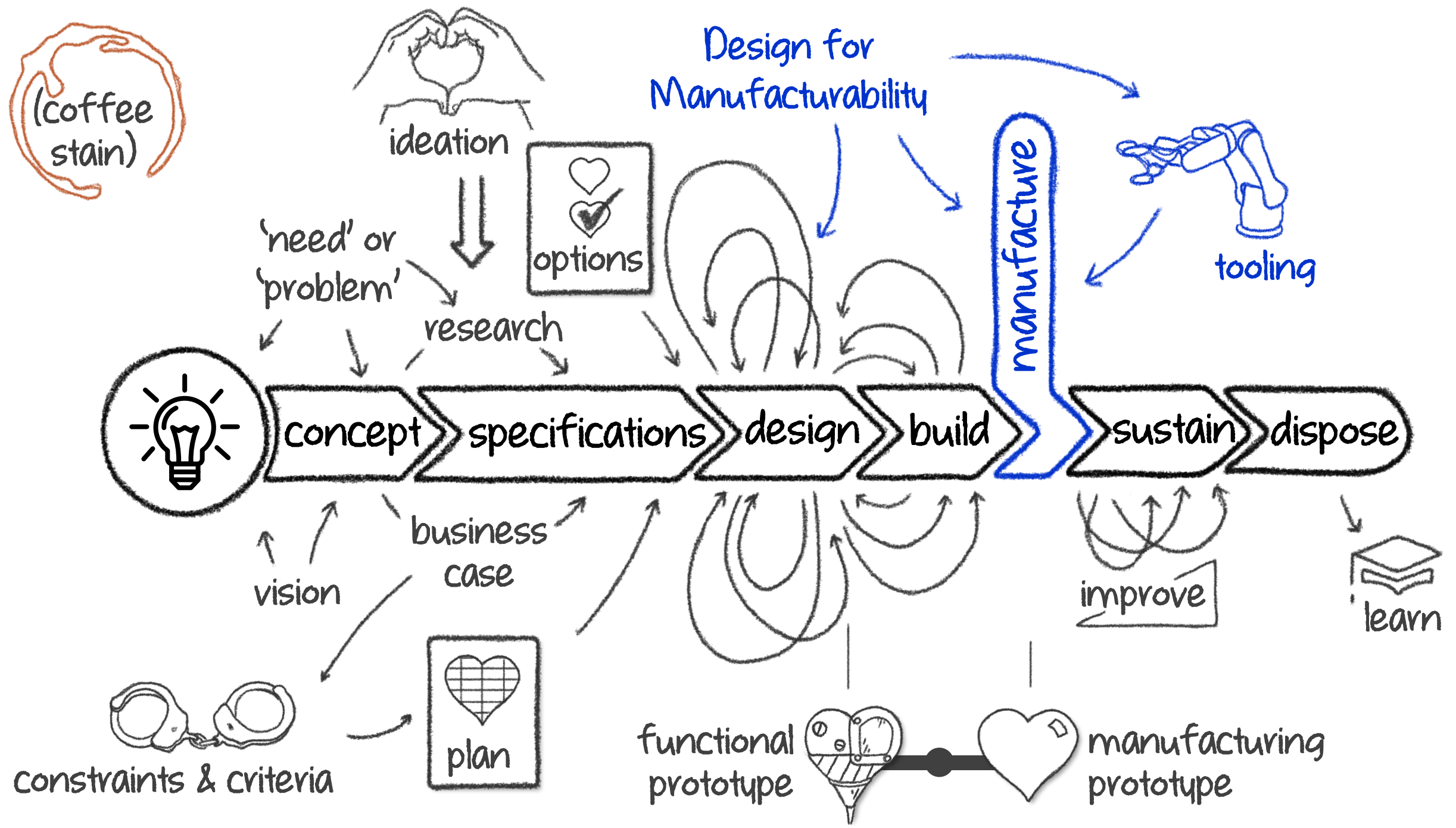
helps allocate money to meet reliability goals

allows trade-offs and other design element feasibility to be investigated

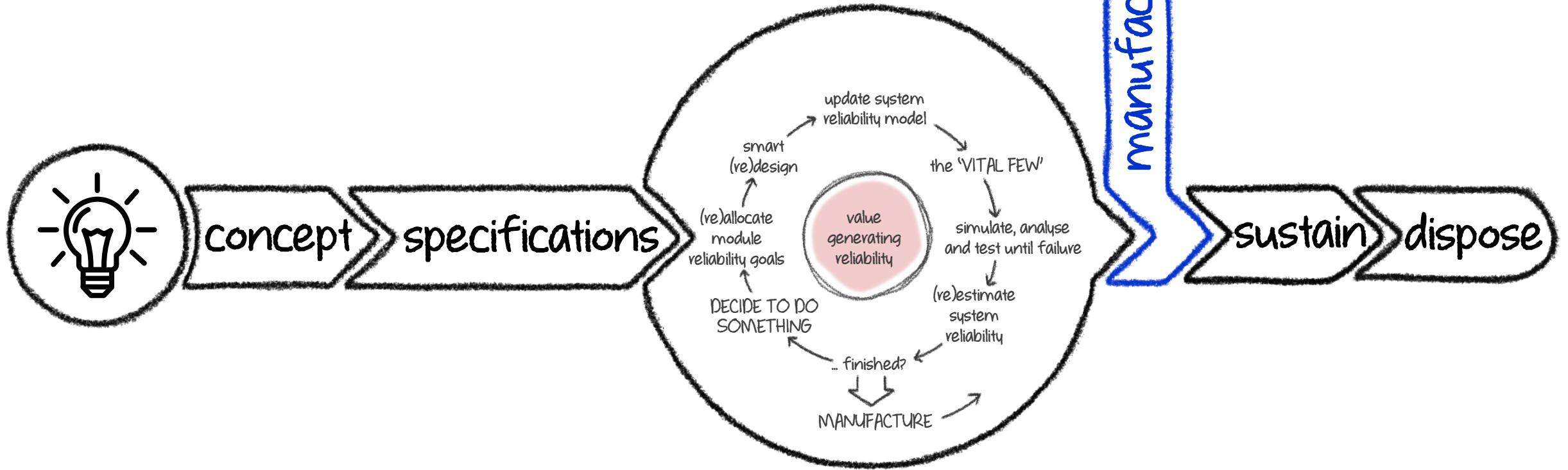
informs the overall design process as it relates to reliability



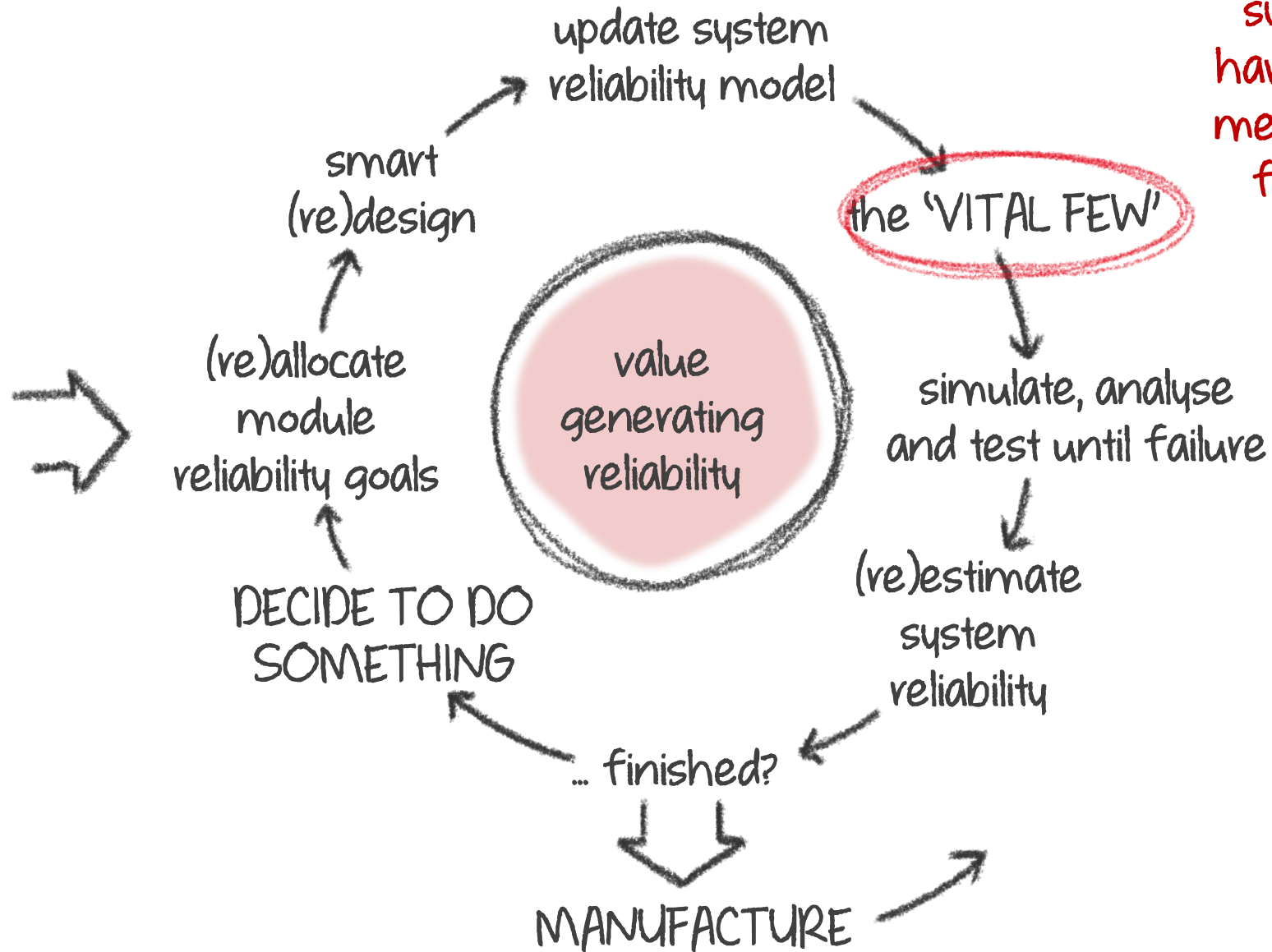
(coffee stain)



(coffee stain)



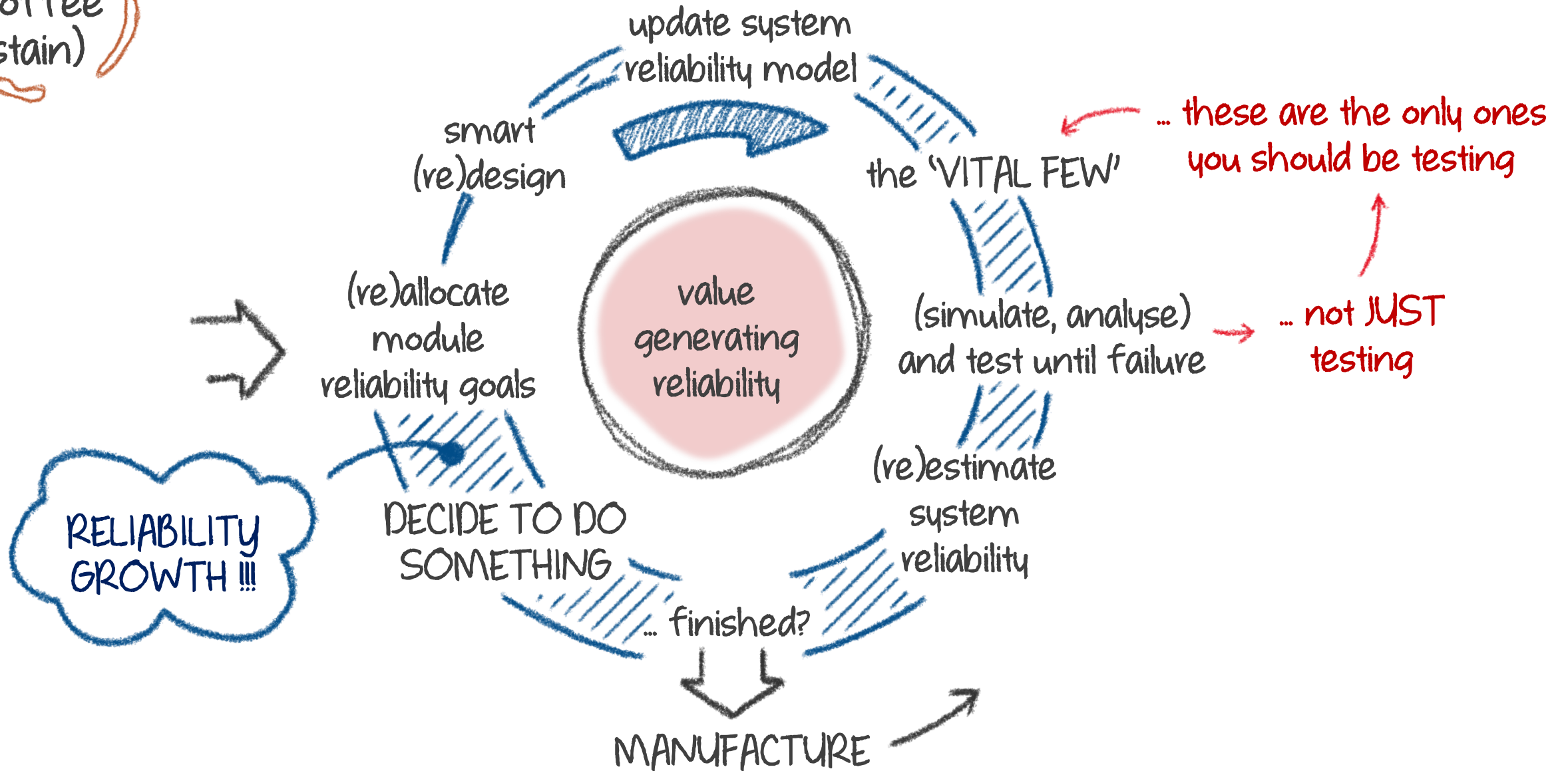
design leadership (& strategy)



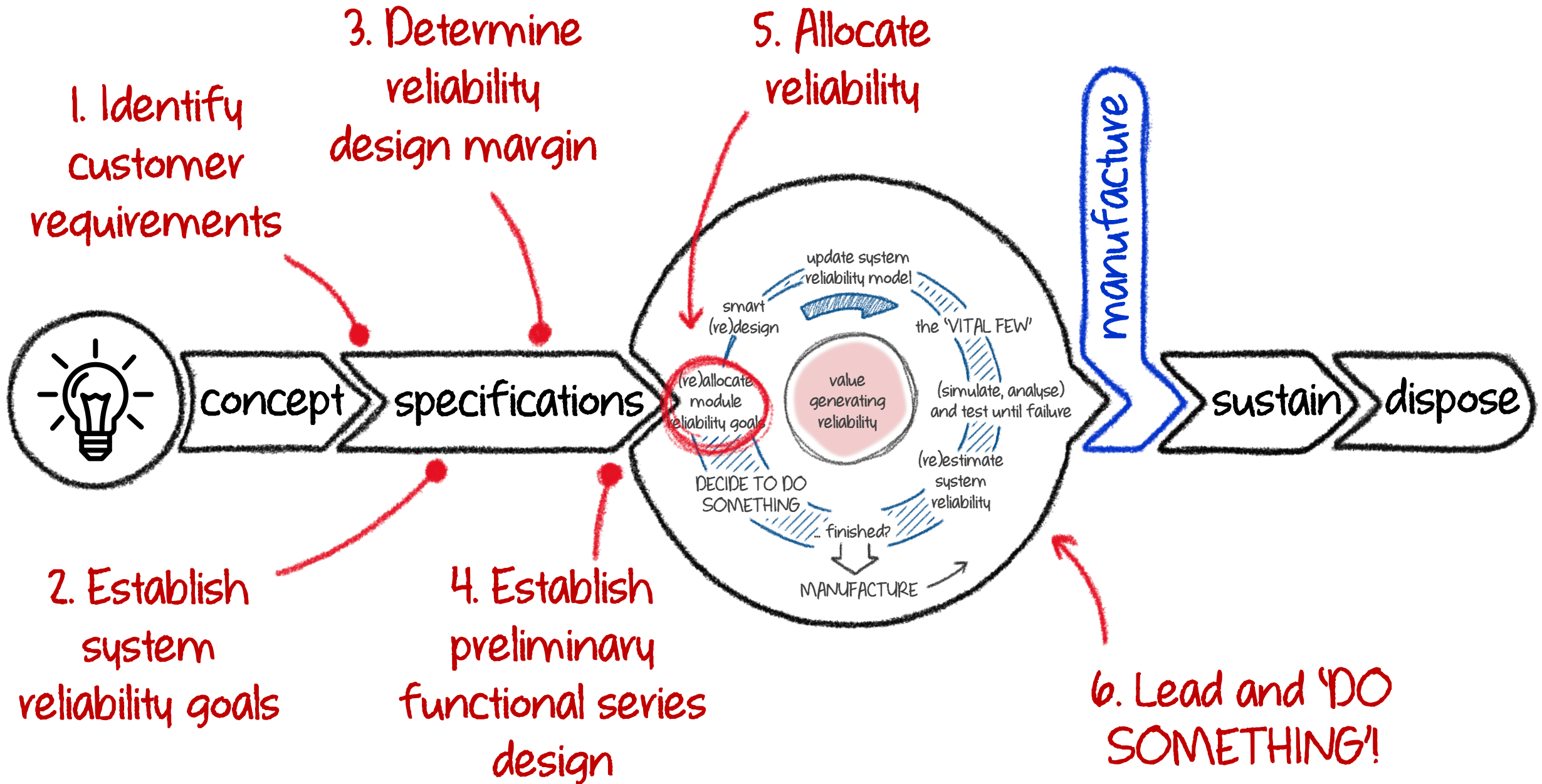
... your product or system will likely only have a couple of failure mechanisms that cause failure **WAY MORE** than all others



(coffee stain)





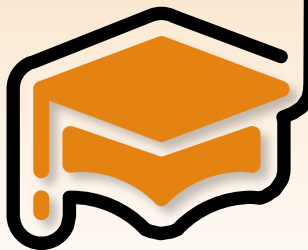


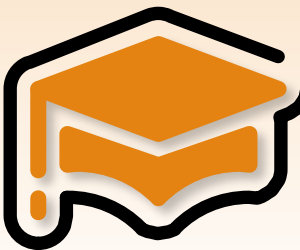
## Step 1: Customer requirements

... go through the FULL (and thoughtful) process of specifying *customer* reliability requirements

... and we define FAILURE

The MEDICAL DEVICE shall have a reliability of no less than 95 per cent after a 3-year service life when used in accordance with specified use cases.





# EXAMPLE



... what we believe the customer 'wants'

... this doesn't mean  
our product can  
*afford* to be this  
(un)reliable

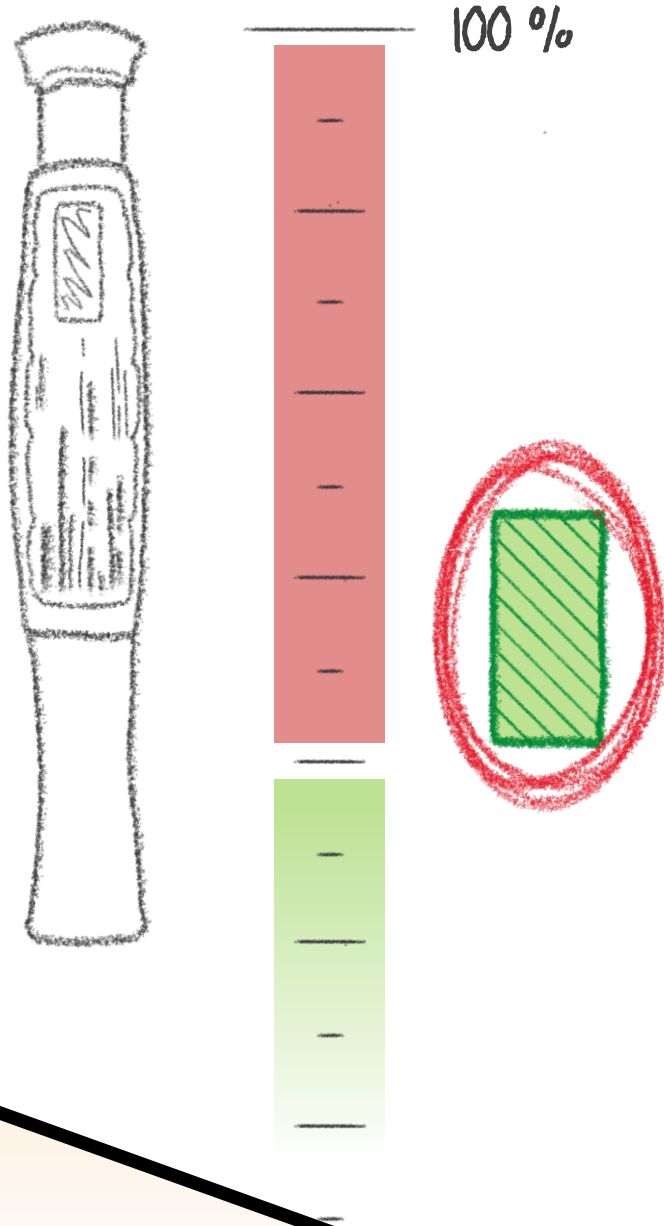
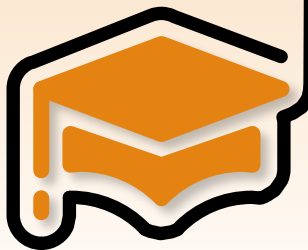


# EXAMPLE



... what we believe the customer 'wants'

# EXAMPLE

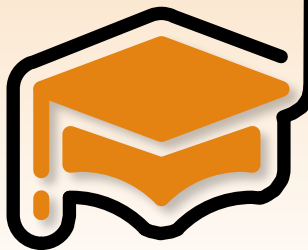


... if we have a **RELIABILITY DEMONSTRATION TEST (RDT)** then the actual reliability needs to have a higher reliability to have a reasonable chance of passing ...

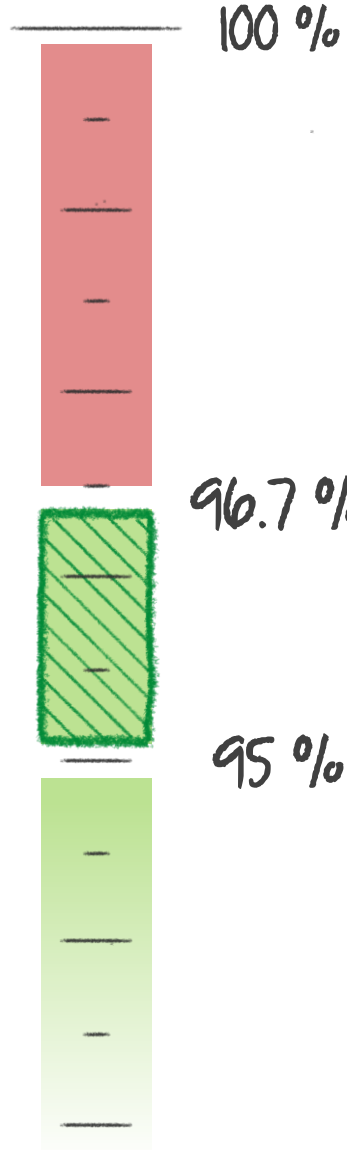
... so we introduce a **DISCRIMINATION RATIO**

... and users will almost certainly use our product in unintended ways – so the **APPARENT** fielded reliability may not meet expectations ...

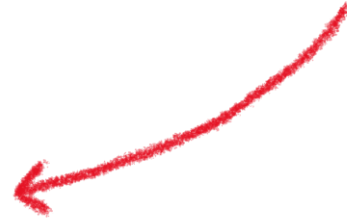
... so we should account for this



# EXAMPLE



## Step 2: System Reliability Goal



96.7 %

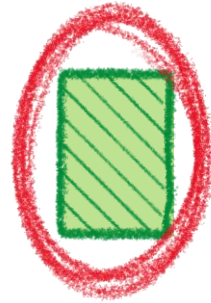
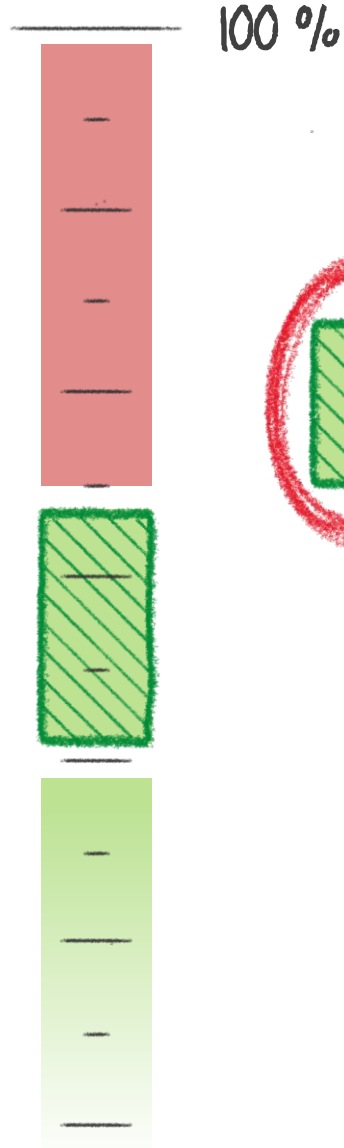
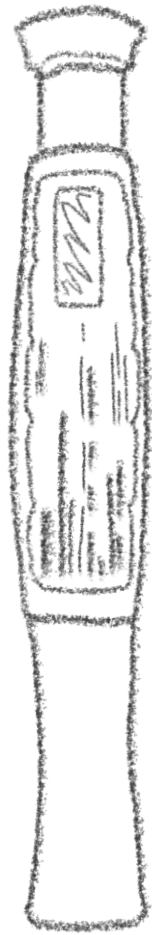
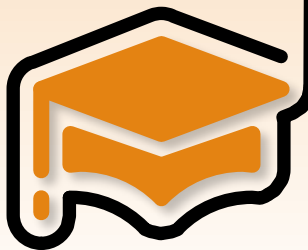
95 %

... customer requirement

... but we still have  
nothing to 'play' with



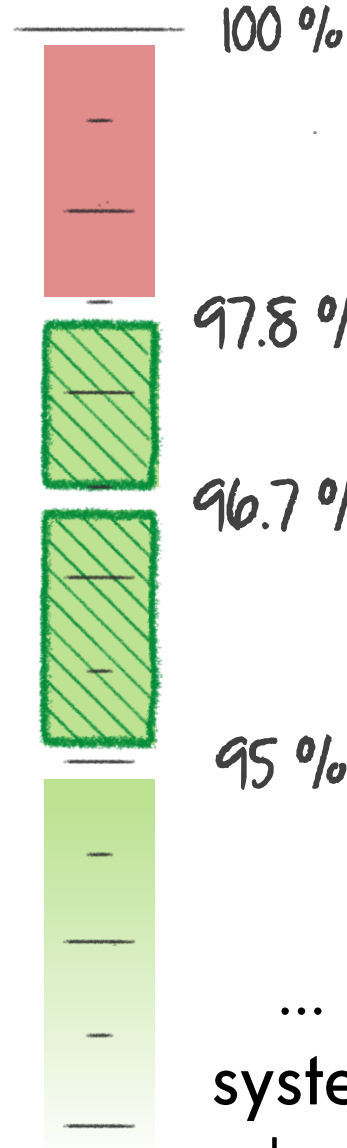
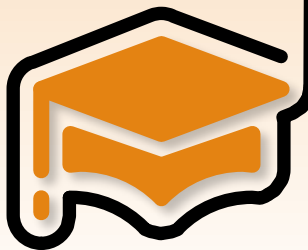
# EXAMPLE



... this represents the RELIABILITY DESIGN MARGIN our lead engineer keeps up his or her sleeve to 'reallocate' during the RELIABILITY DESIGN CYCLE

... in this case this is one third of the remaining UNRELIABILITY ...  
... but you choose what works for you (more design uncertainty should mean bigger margin)

# EXAMPLE



## Step 3: Reliability Design Margin

... system reliability goal

... customer requirement

... the design process involves **developmental systems** with inherent uncertainty regarding actual sub-system and component reliability performance

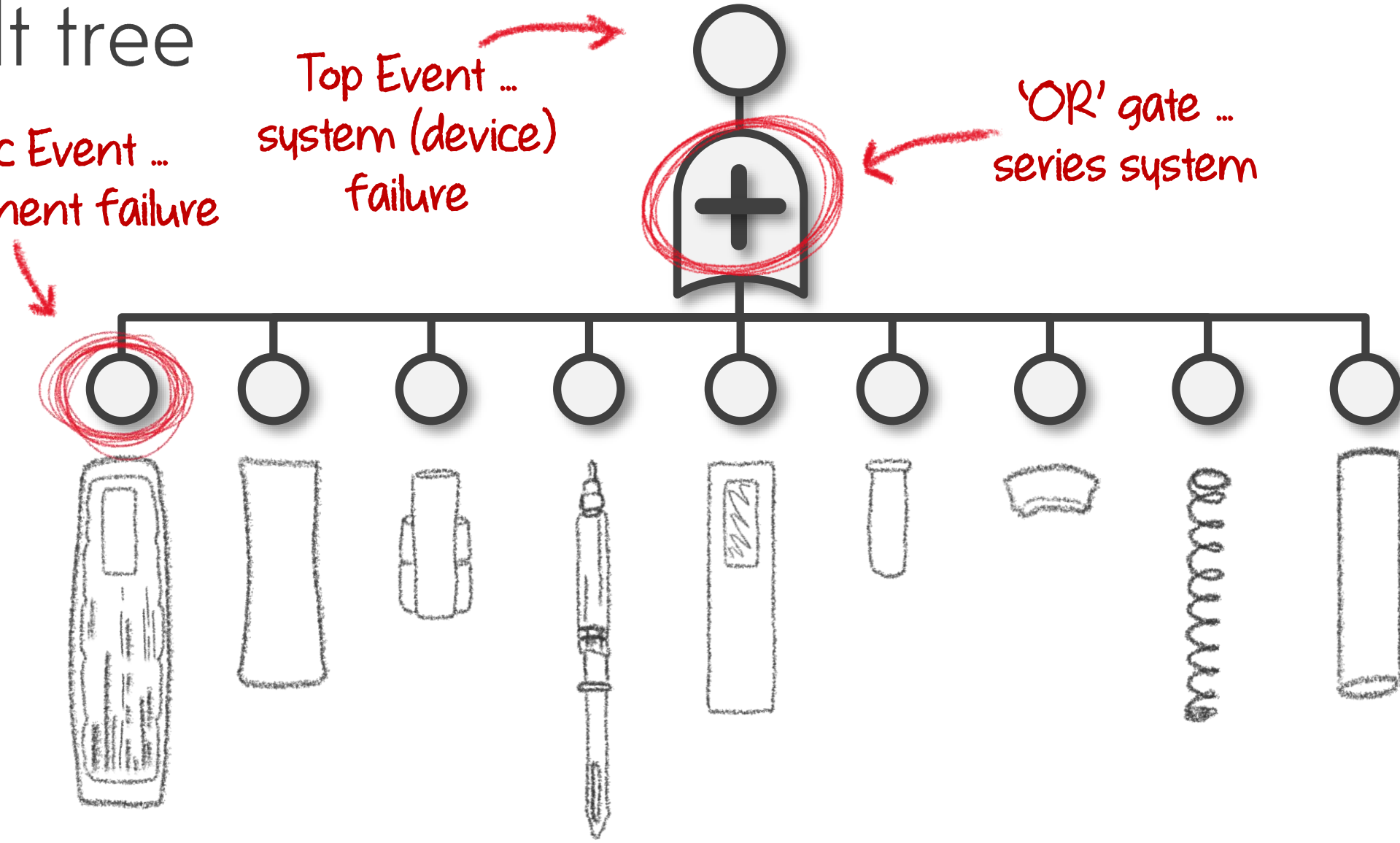


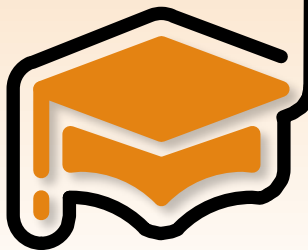
# fault tree

Basic Event ...  
component failure

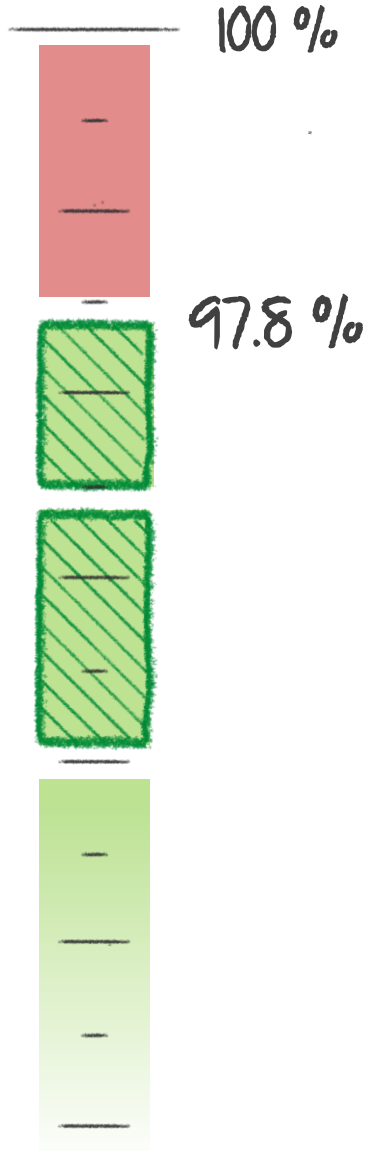
Top Event ...  
system (device)  
failure

'OR' gate ...  
series system

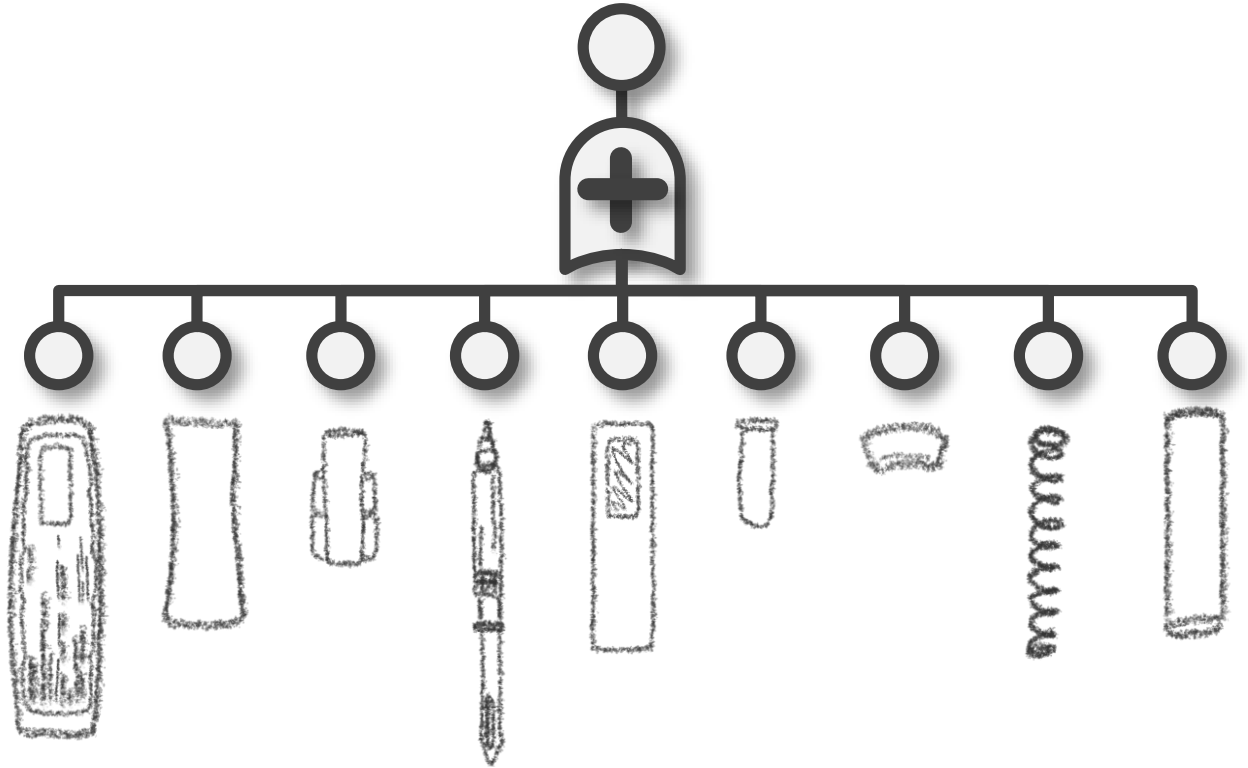




# EXAMPLE



Step 4: Create a *preliminary* functional series design



... so the next thing  
to do is to *allocate*

## Step 5: Allocate Reliability

$$R_{i(DG)} = \frac{\sum a_i}{a_i} \sqrt{R_{Sys(DG)}}$$

... ALLOCATED design reliability goal for the  $i^{th}$  component, module or subsystem

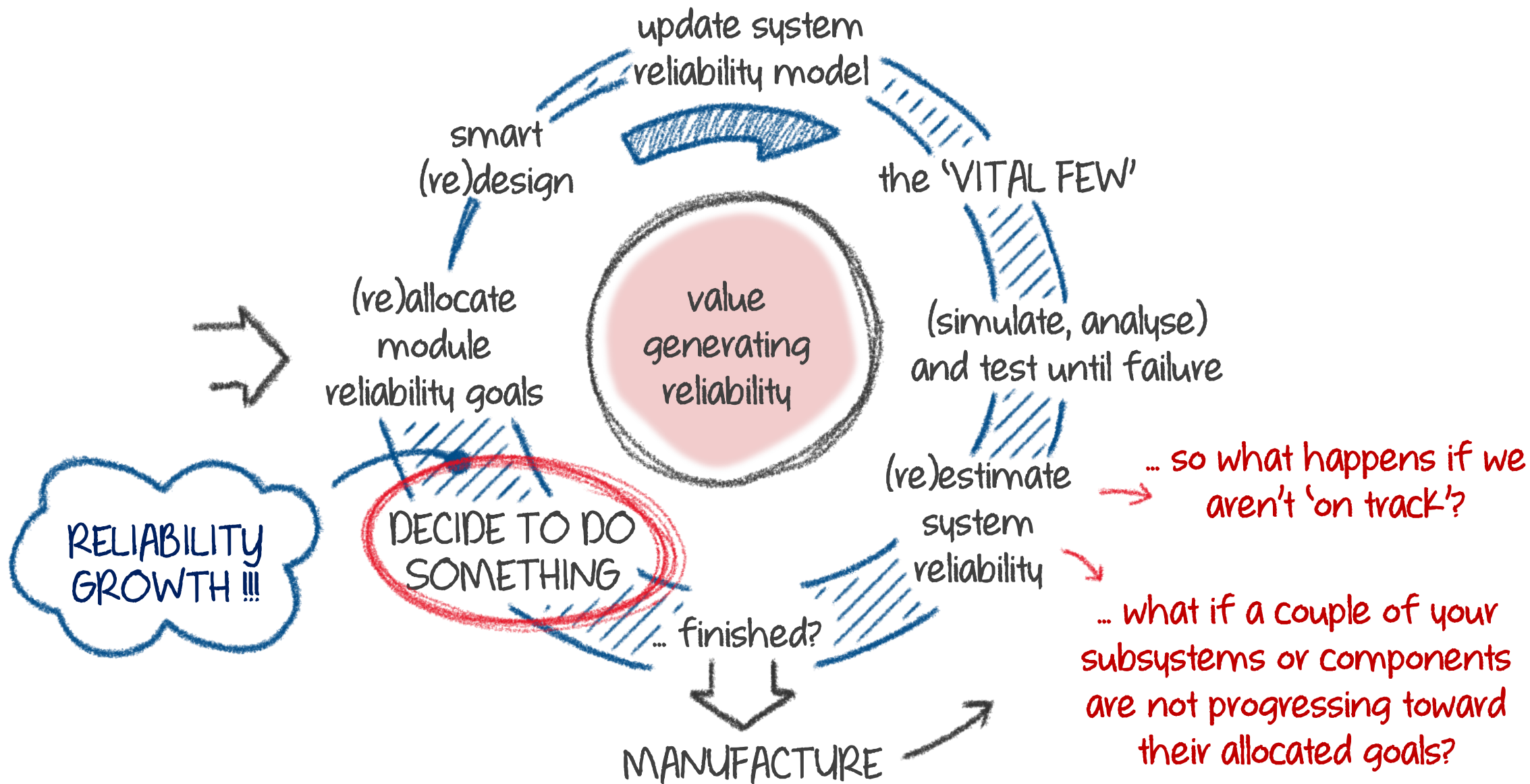
... system design reliability goal (97.8 %)

ALLOCATION FACTORS

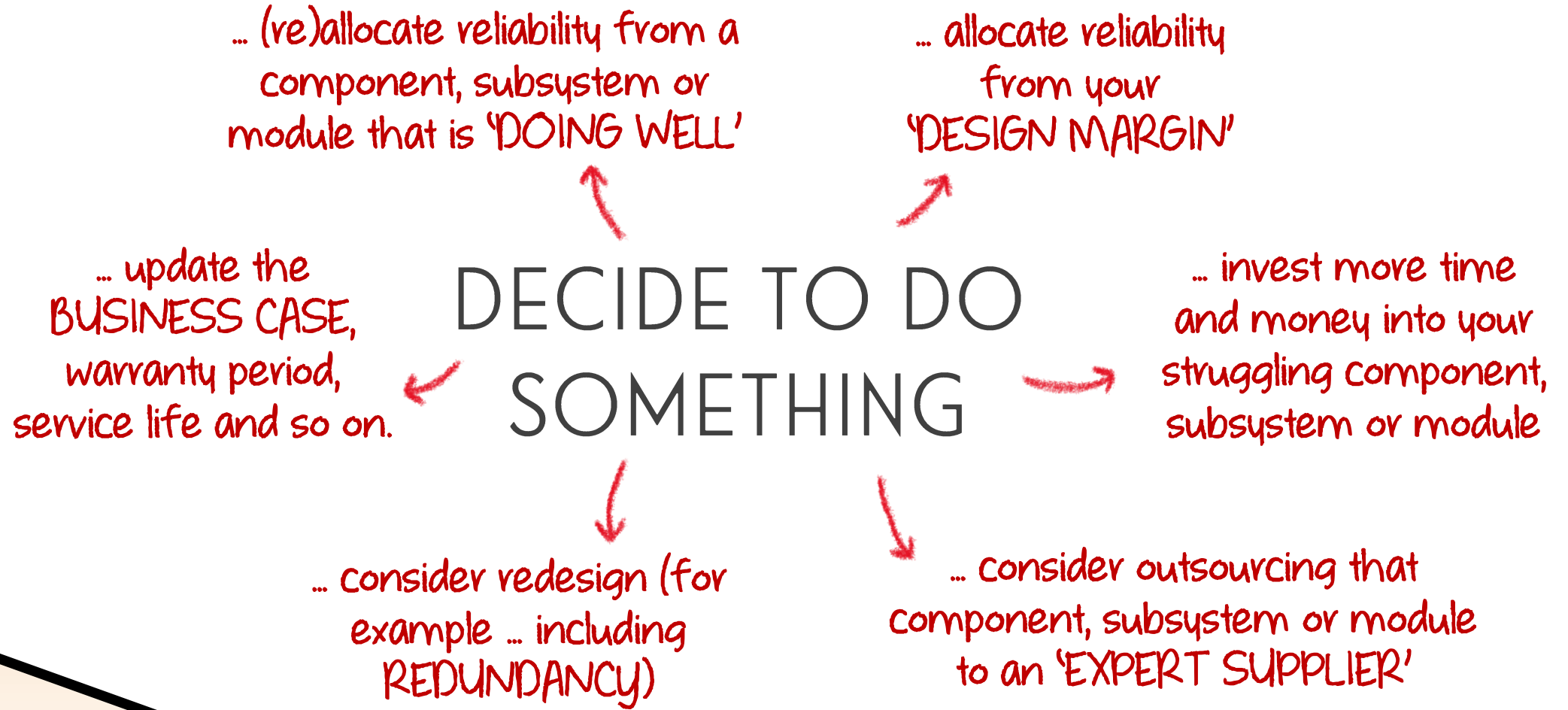


... but this is simply the  
first allocation effort as  
part of a bigger design  
process





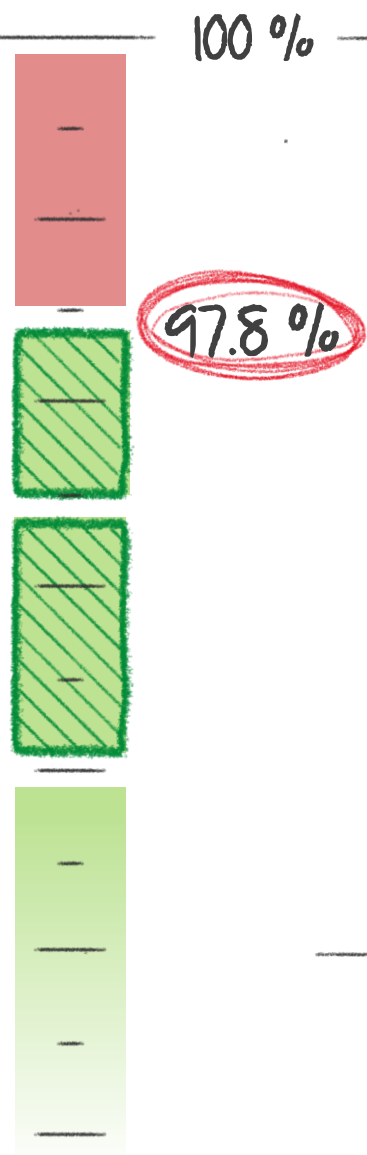
## Step 6: Lead and 'do something'



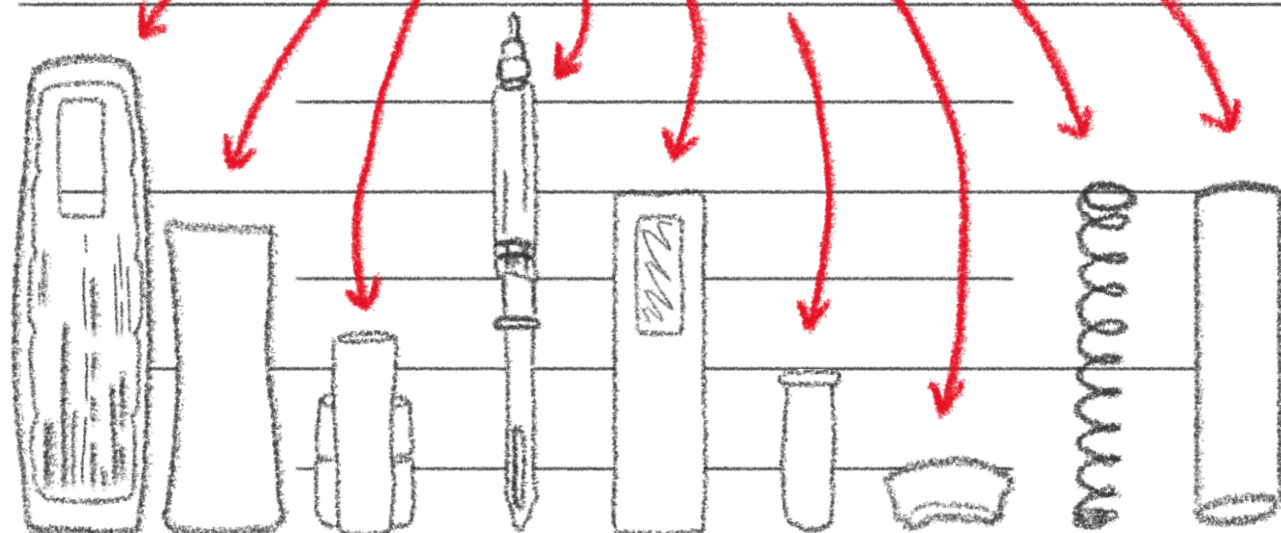
?

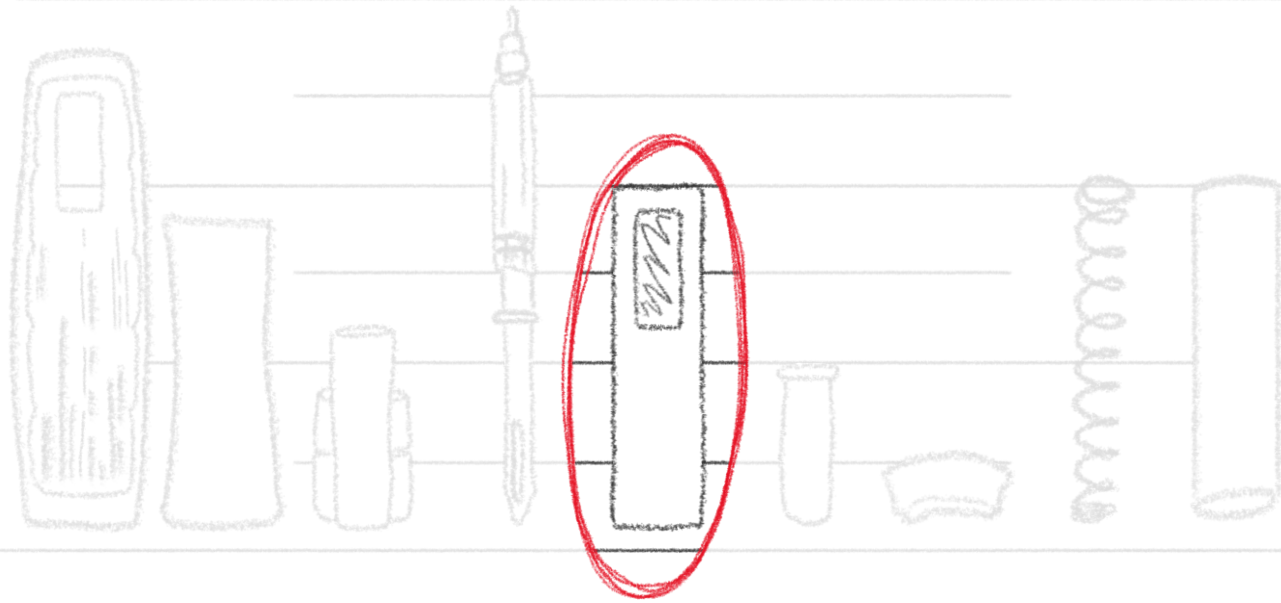
... so far

... so what about  
those *allocation*  
*factors*?

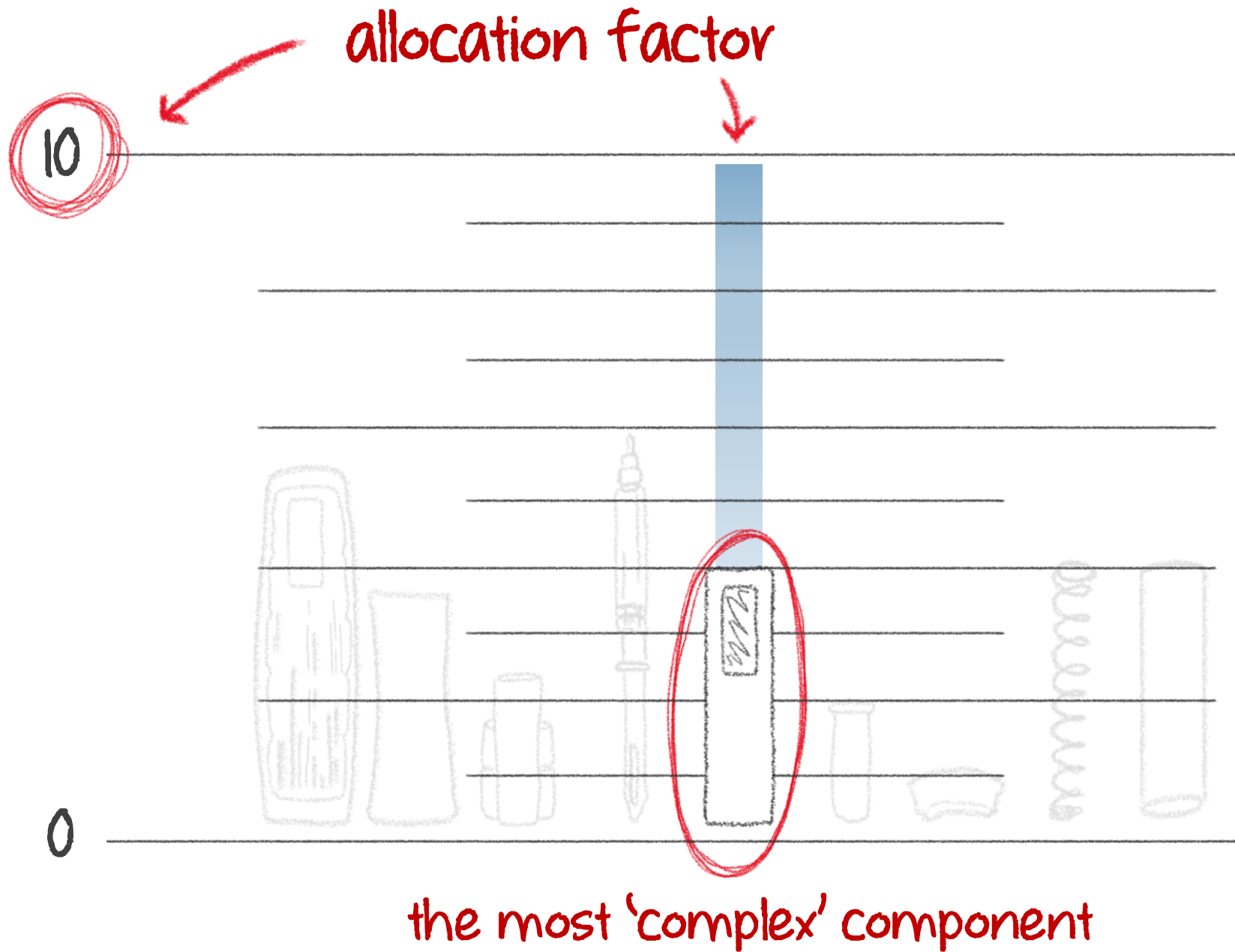


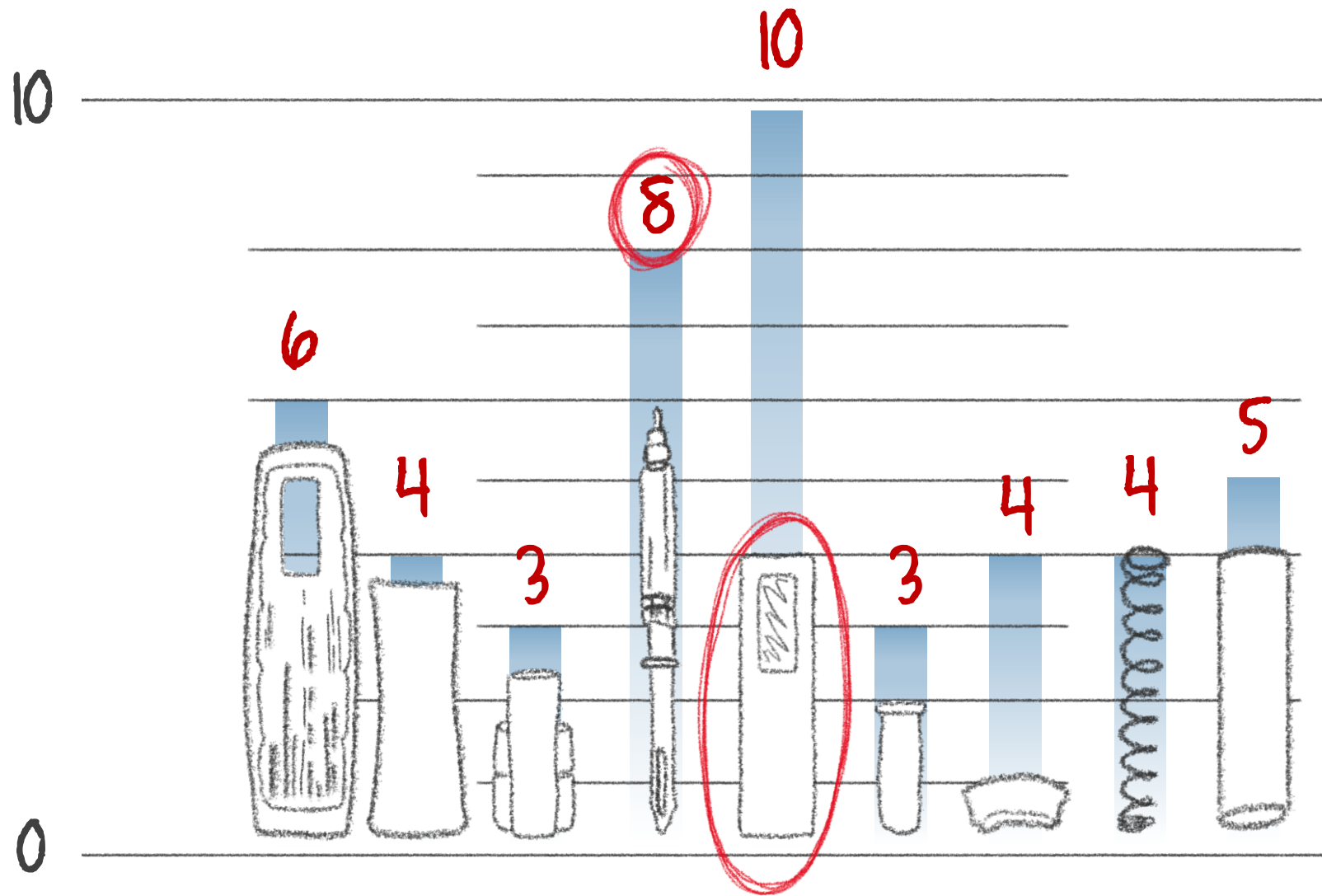
RELIABILITY GOALS???





the most 'complex' component





... sum  
to 49

the most 'complex' component



allocation factor for  
the  $i^{\text{th}}$  subsystem or  
component

sum of all  
allocation factors

$$R_{i(DG)} = \frac{\sum a_i}{a_i} \sqrt{R_{Sys(DG)}}$$

reliability design goal  
for the  $i^{\text{th}}$  subsystem  
or component

system reliability  
design goal

$$R_{i(DG)} = \frac{49}{10} \sqrt{97.8 \%}$$

$$= 99.55 \%$$

$$R_{i(DG)} = \frac{49}{3} \sqrt{97.8 \%}$$

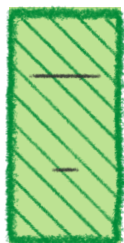
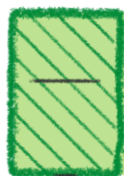
$$= 99.86 \%$$

system reliability goal = 97.8 %

allocation factor = 10 ... 99.55 %

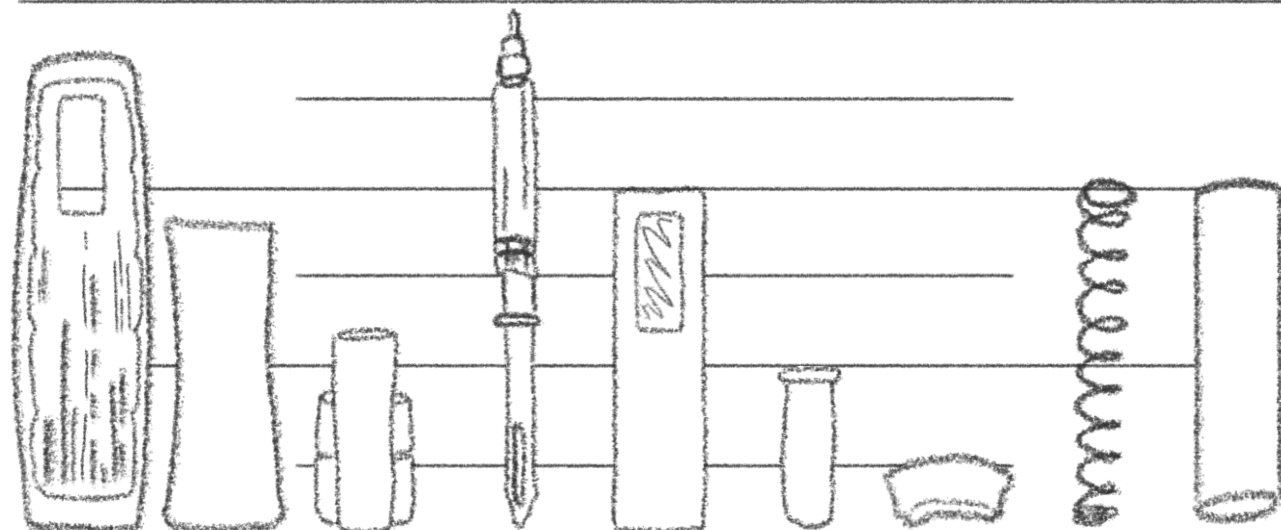
allocation factor = 3 ... 99.86 %

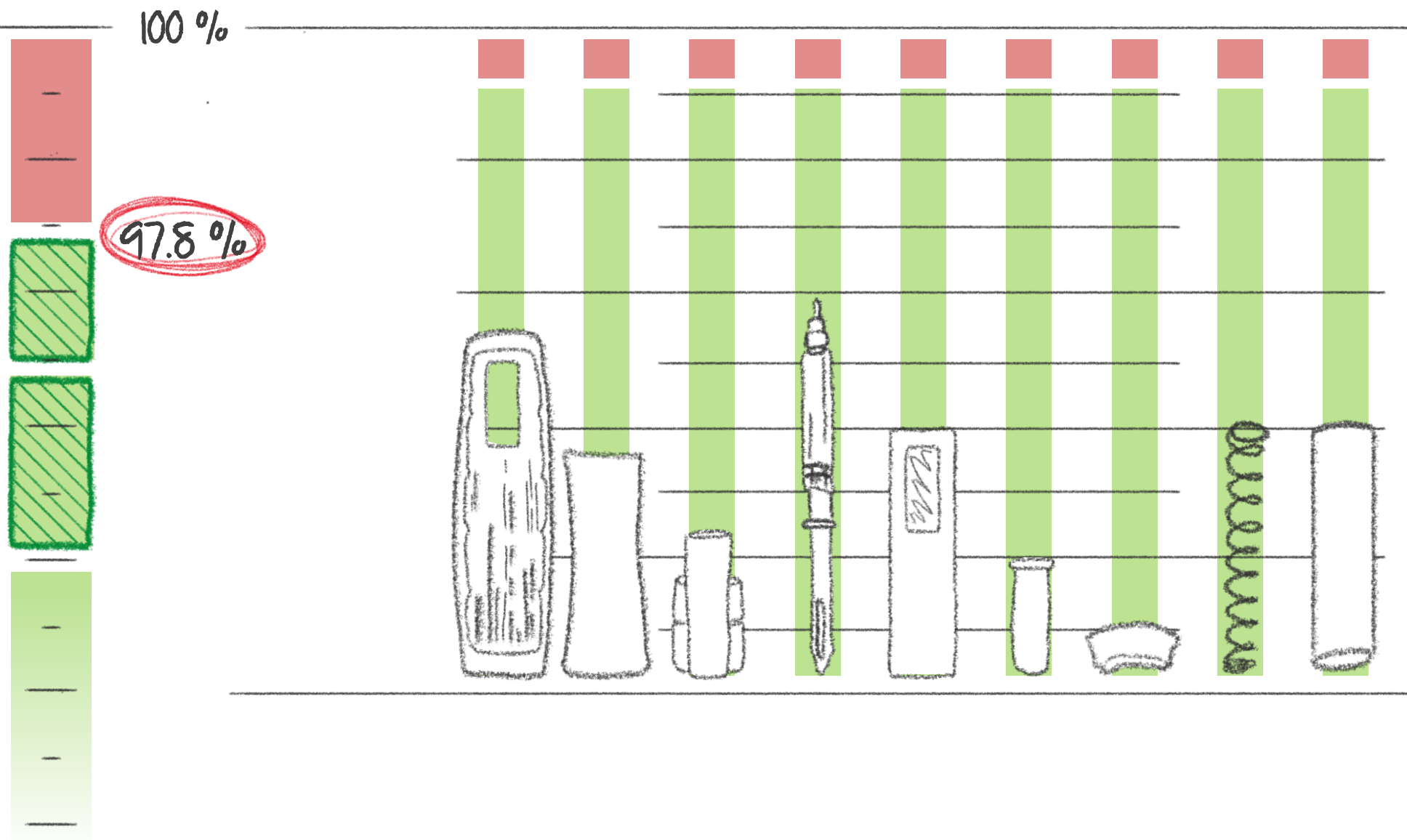
get used to 'high' subsystem and  
component reliability design goals!!!



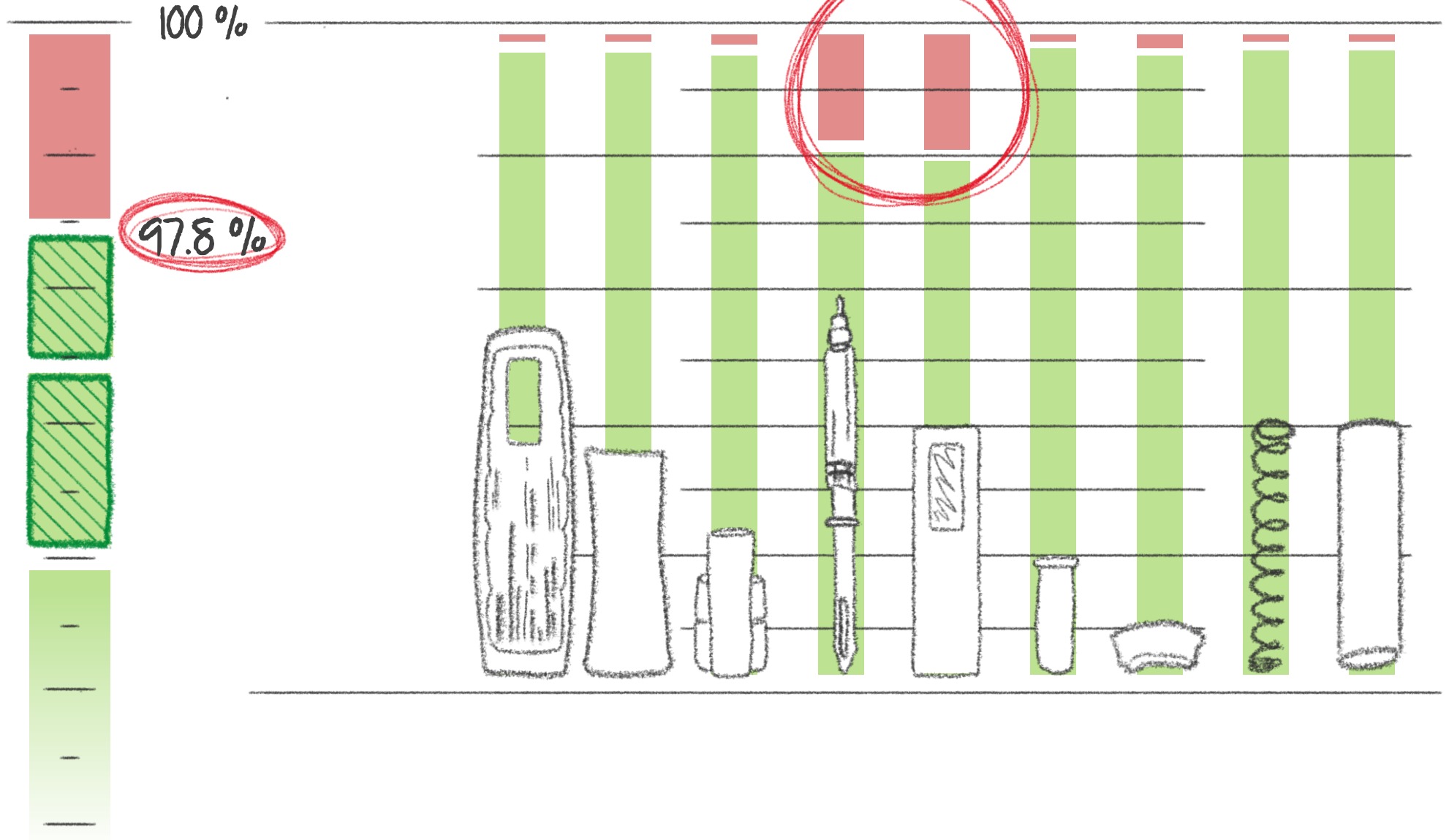
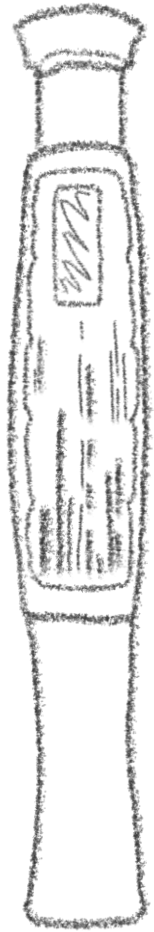
100 %

97.8 %





more 'COMPLEX'  
subsystems



?

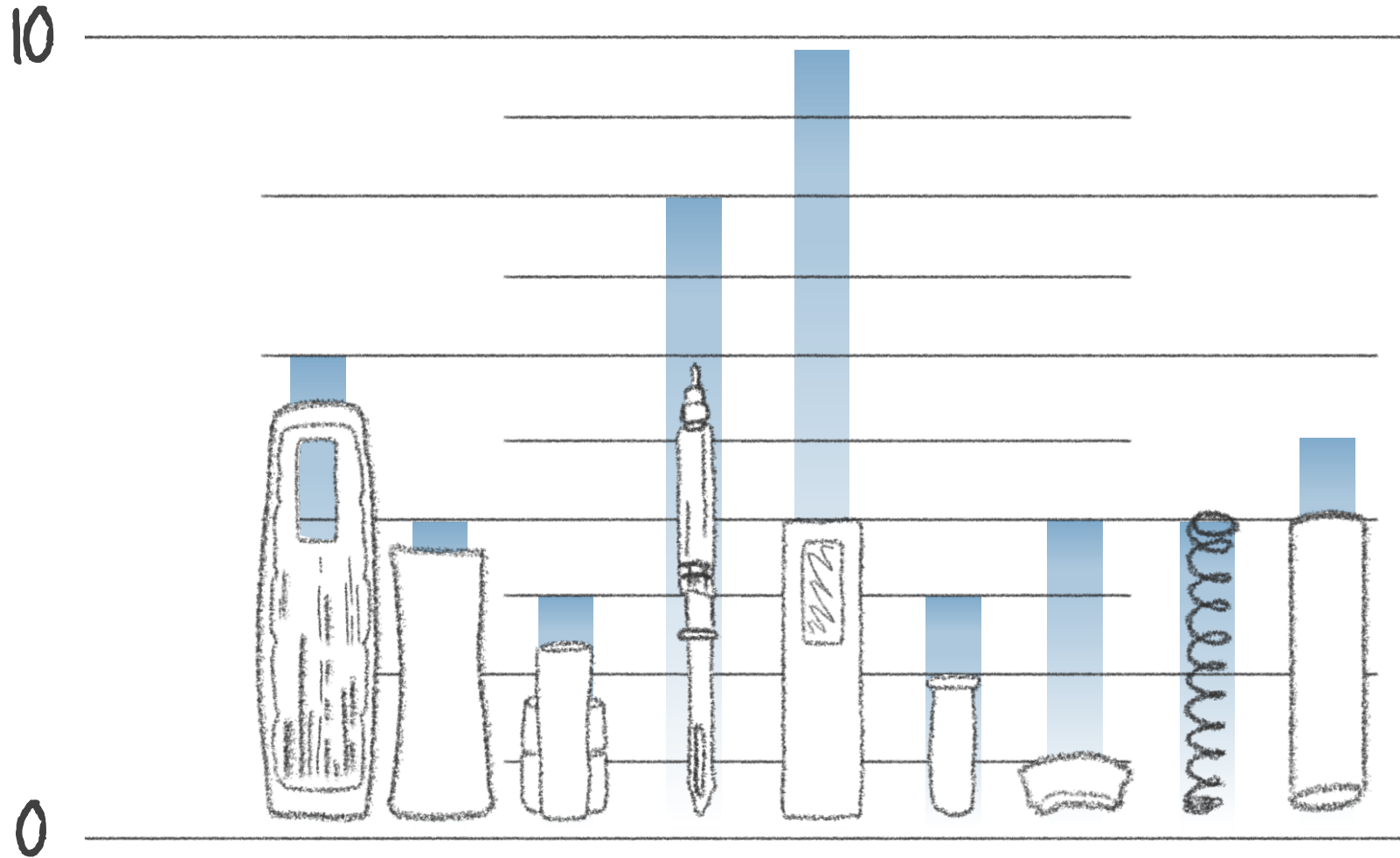
... so far



... so what are the  
**3** ways to do  
reliability  
allocation?

**#1** ... based on  
complexity

# #1 ... based on complexity

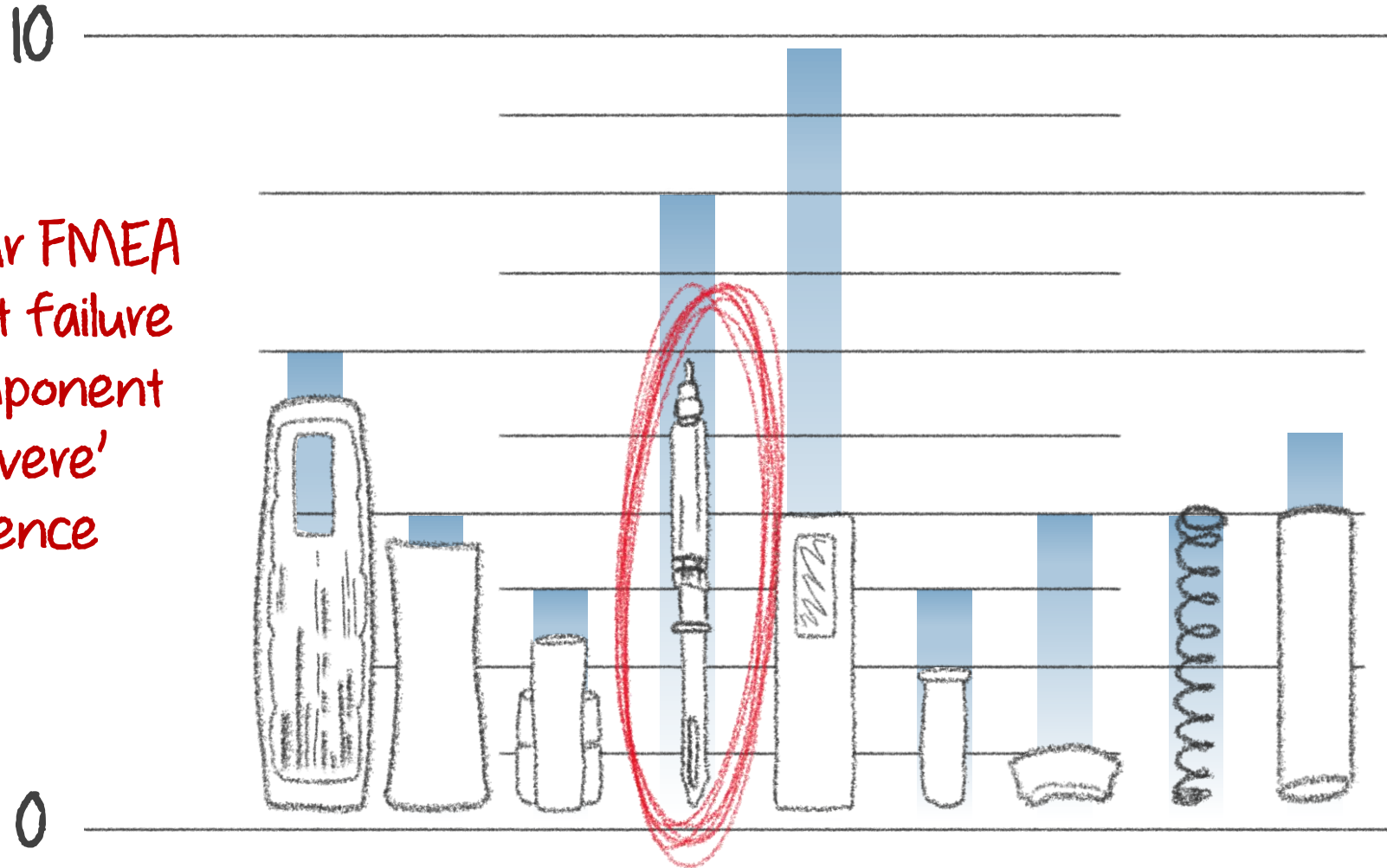


... the  
approach  
we just  
looked at

**#2** ... based on  
complexity & risk

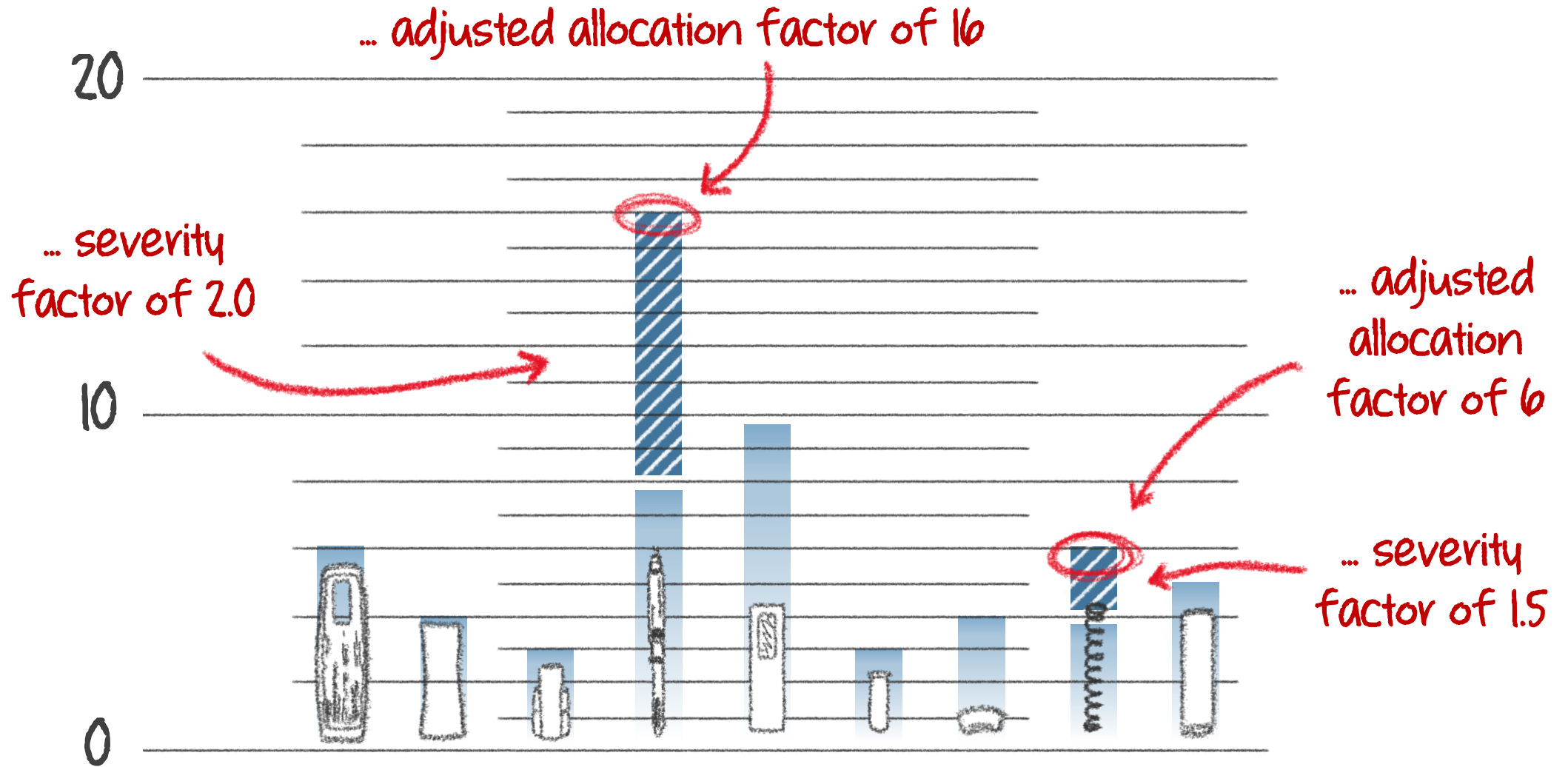
# #2 ... based on complexity & risk

... let's say our FMEA suggest that failure of this component has a 'severe' consequence



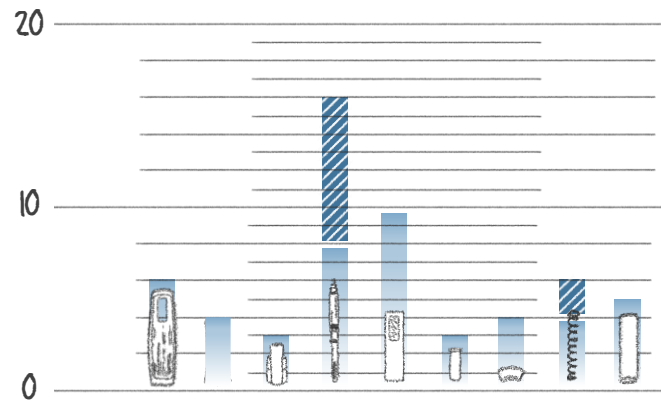
... and we introduce a CONSEQUENCE FACTOR such as 2 (most severe) down to 1 (least severe)

# #2 ... based on complexity & risk

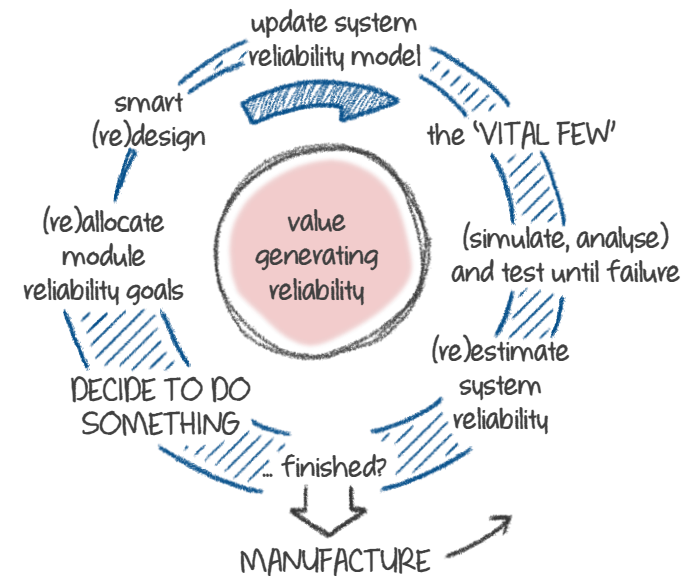


**#3** ... any way  
you want

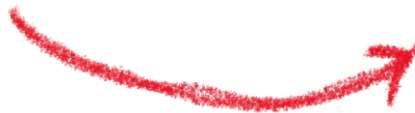
# #3 ... any way you want



... remembering that  
your first, allocated  
goals are GUIDES only



... that are not as  
important as this





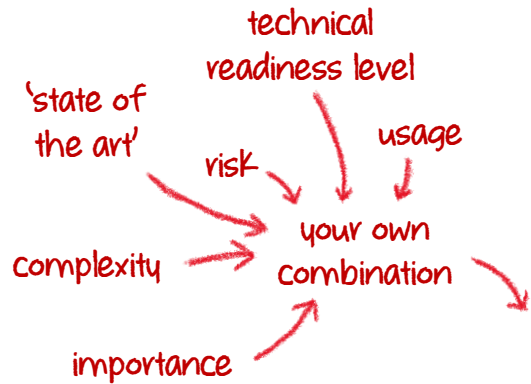
# #3 ... any way you want

$$R_{i(DG)} = \frac{w_i - 1 + \frac{\sum a_{ij}}{a_i} \sqrt{R_{Sys(DG)}}}{w_i}$$

... the probability of product or system failure if the  $i^{th}$  subsystem, component or module fails

$w_i$

Advisory Group on Reliability of Electronic Equipment (AGREE) approach



... component, subsystem or module reliability estimate based on historical data

$\hat{R}_i$

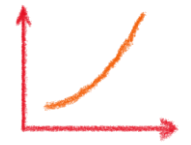
Aeronautical Radio Incorporated (ARINC) approach

$a_i$

$$a_1 = a_2 = a_3 = \dots$$

... or equal allocation / apportionment

The aim is to find the set of component reliability improvements ( $x_i$ ) to minimise total cost  $C = \sum c_i(x_i)$



$c_i(x_i)$  ... cost of reliability improvement in the  $i^{th}$  subsystem

$$R_{Sys(DG)} \leq \prod (R_{i(DG)} + x_i)$$

... reliability improvement in the  $i^{th}$  subsystem

... which is almost impossible to 'meet system goals' - so you may as well go straight to allocation factors

$$R_{Sys(DG)} = \prod R_{i(DG)}$$

... simple expert judgment

?

... so far

single  
supplier? ← so how far  
PCB? ← down should I  
assembly? ← allocate?

... (typically) a single  
person who is  
accountable

... allocate based on  
what makes sense from  
a *human accountability*  
perspective

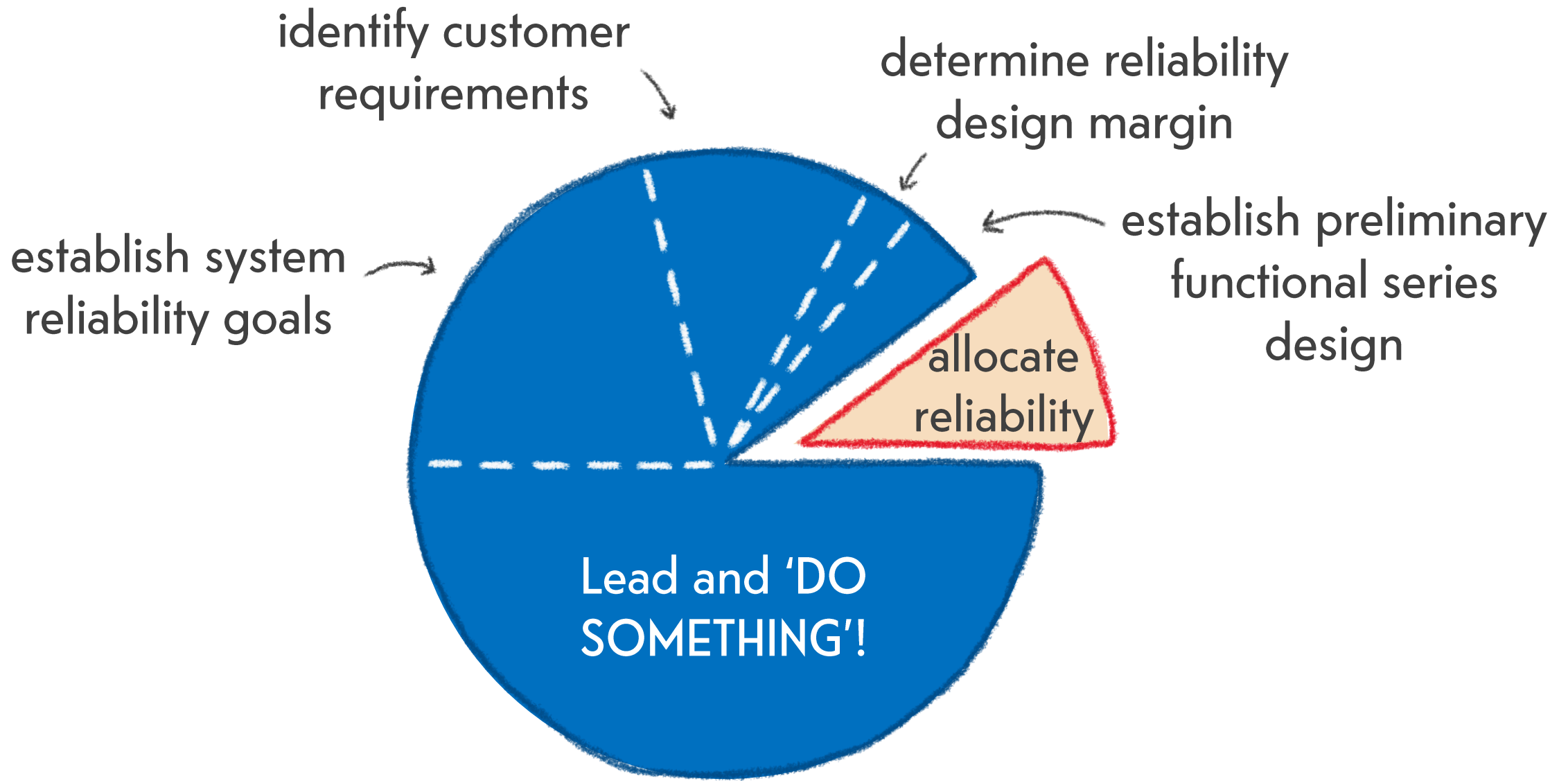
... not spread across  
disciplines (such as  
electrical and hydraulic)

... what 'makes  
sense' to the  
design lead

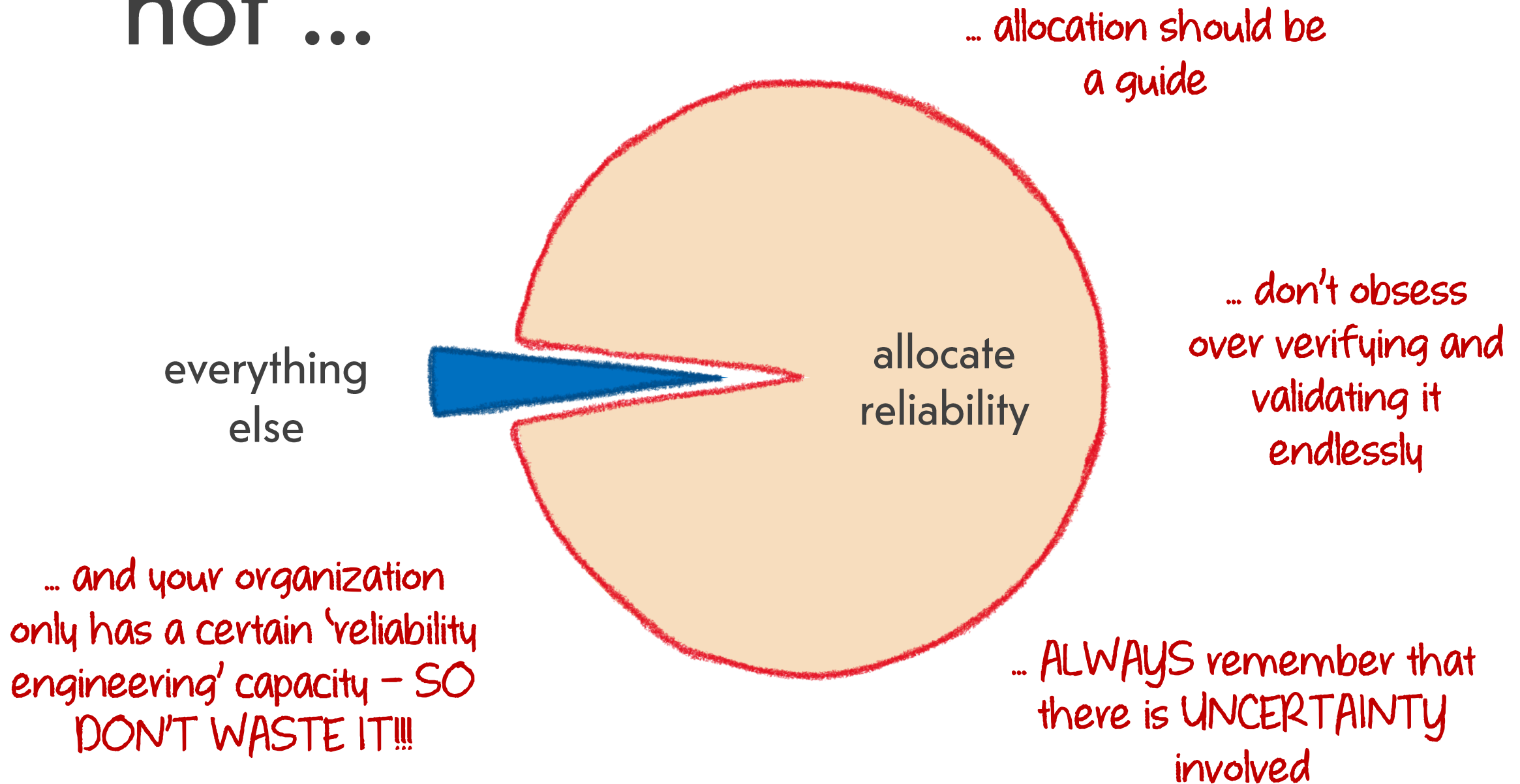
?

... so far

how much effort do I  
invest in getting the  
first allocations *right*?



# not ...





~~over-  
engineering~~

