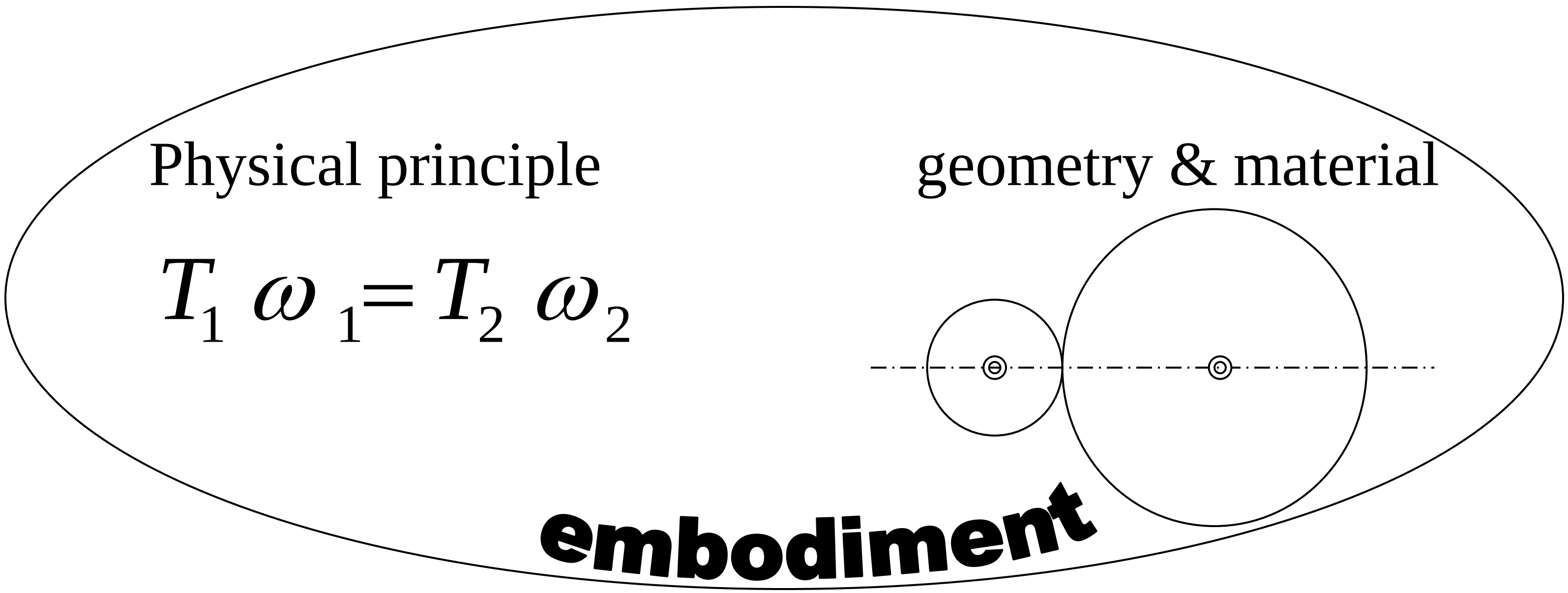
Configuration Design

- What is a product configuration?
- What is a part configuration?
- Product architecture design
- Part configuration design

What is configuration design?

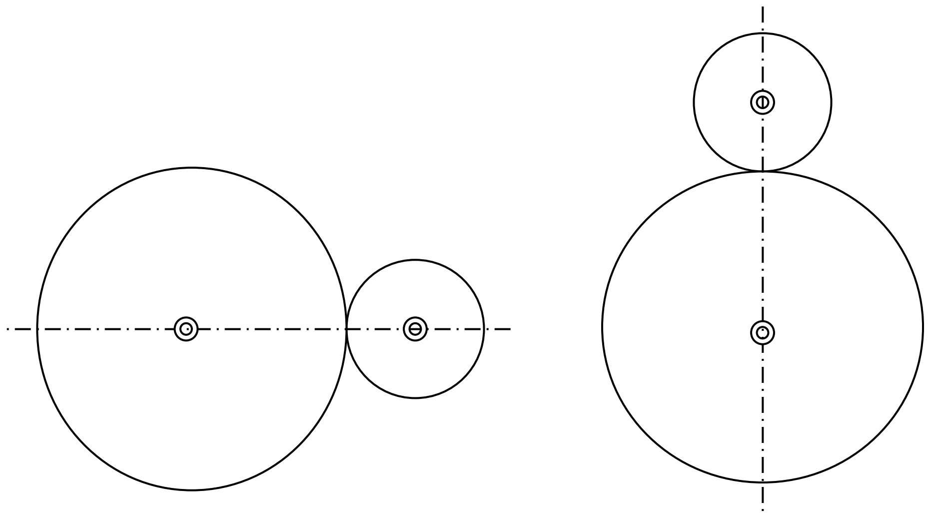
For example:

Design problem: *reduce speed* ---- Concept: *gear pair*



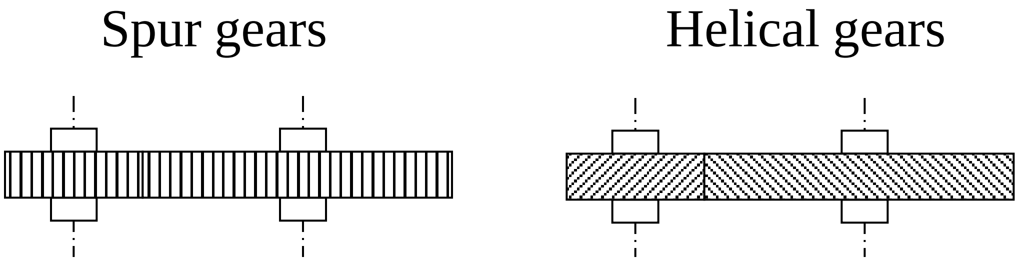
What are some possible “configurations” for a gear pair?

Alternative configuration #1



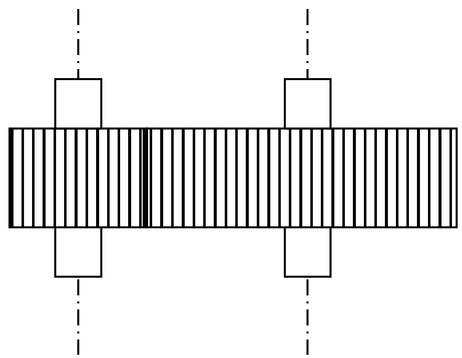
arrange
parts
differently

Alternative configuration #2

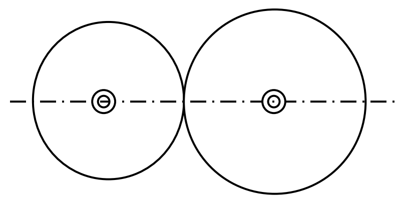


use different
features or parts

Configuration #3 and #4



wide teeth



similar diameters

use different
relative dimensions

What is a part configuration?

For example:

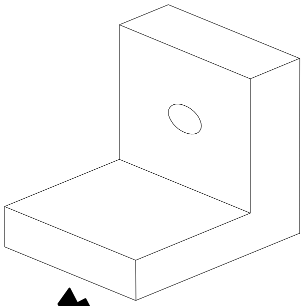
Design problem: *support vertical load* ---- Concept: *wall bracket*

Physical principle

Force Equilibrium

$$\sum F = 0$$

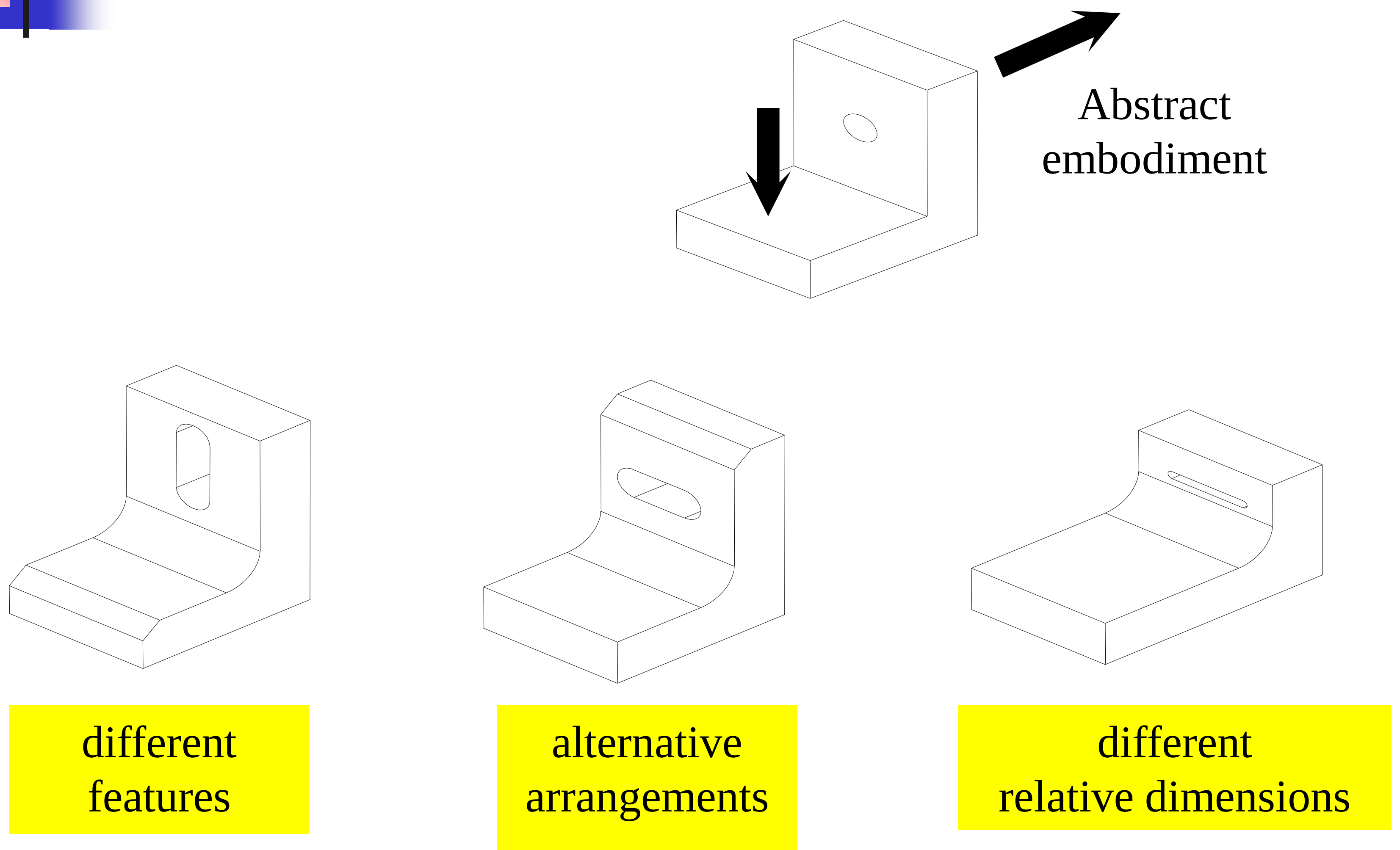
geometry & material



embodiment

What are some possible “configurations” for a wall bracket?

Wall bracket configurations



Configuration decisions

Configuration Problem	Required Decisions
Product	Types of component Number of components Arrangements / connectivity Relative dimensions
Special purpose part	Geometric features Arrangements of features Relative dimensions Design variable / Parameter list
Standard part, or Standard subassembly	Type of component Relative dimensions Design variable / Parameter list

How do we create different configurations?

Change one or more of these…

Obtaining the “best” configuration

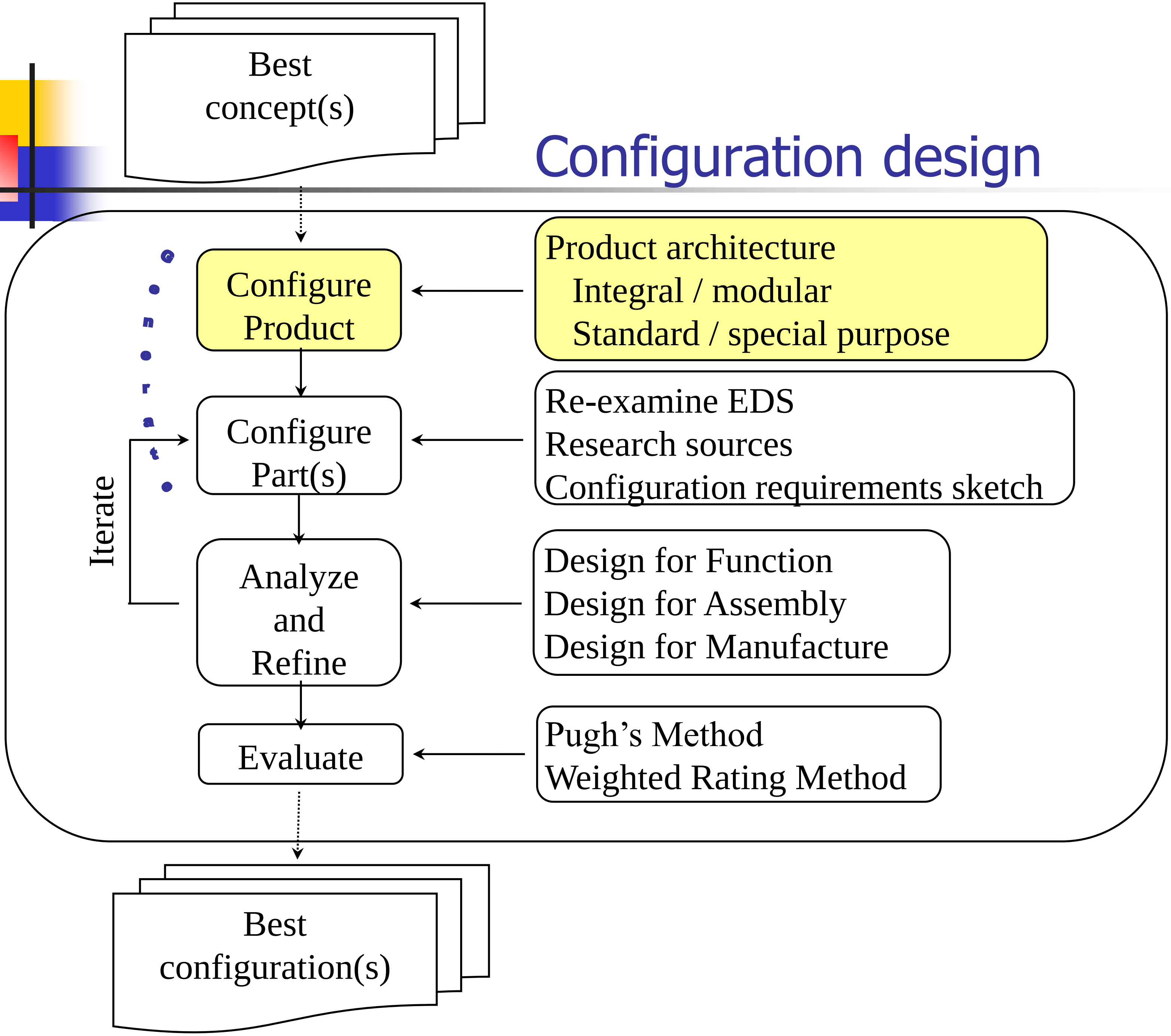
To choose the “best” alternative….

Implies that we have a number of feasible alternatives!

To be selective, we need a selection!

How should we start our configuration design efforts?

Configuration design



Part configuration design

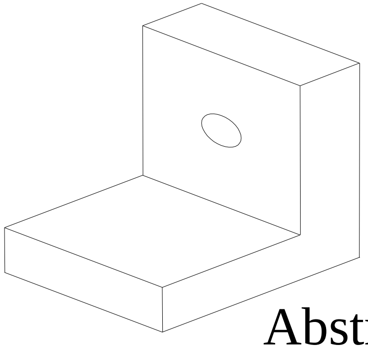
Configuration Problem	Required Decisions
Special purpose part	Geometric features (type & no.) Arrangements of features Relative dimensions Design variable / Parameter list

geometric features include:

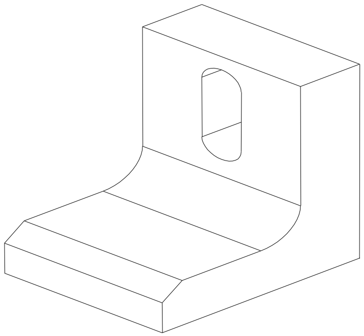
walls	rounds	cubes	notches
ribs	bosses	spheres	chamfers
projections	cylinders	holes	grooves
fillets	tubes	slots	

How can we "generate" alternative part configurations?

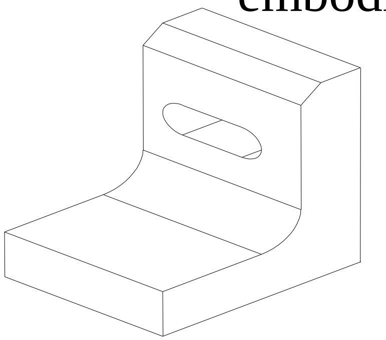
Recall bracket configurations



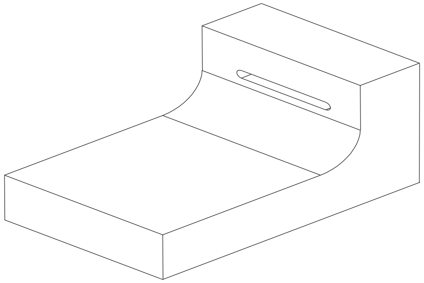
Abstract embodiment



different features



alternative arrangements

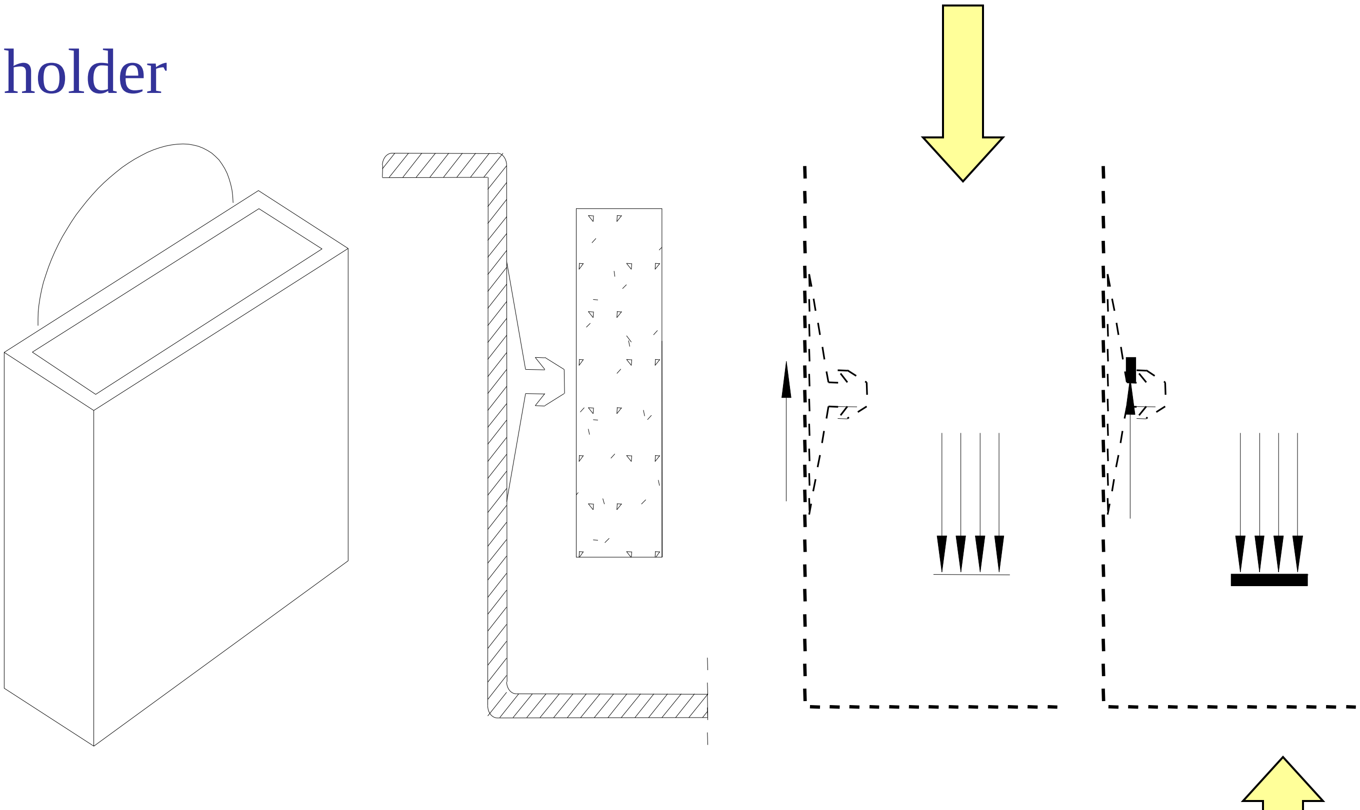


different relative dimensions

Dixon & Poli Method using "configuration requirements"
Example: configuring a sponge holder

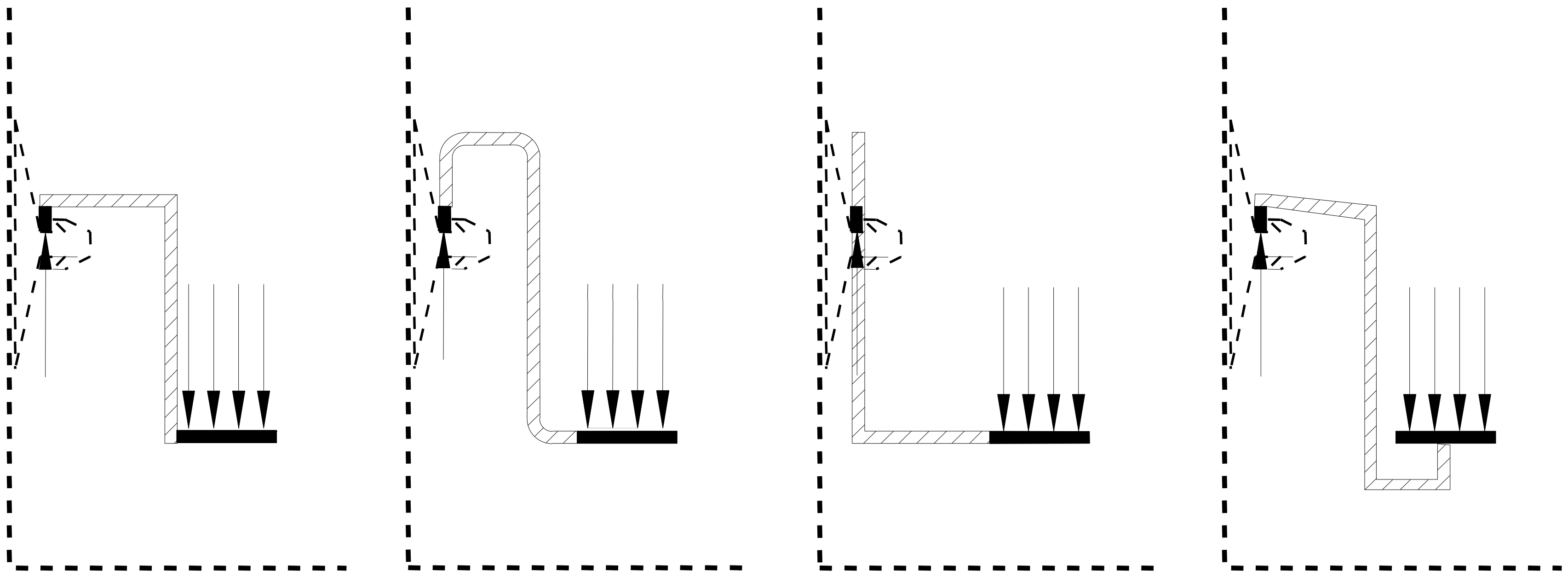
Step 1. Prepare <u>configuration requirements sketch</u>

sponge holder

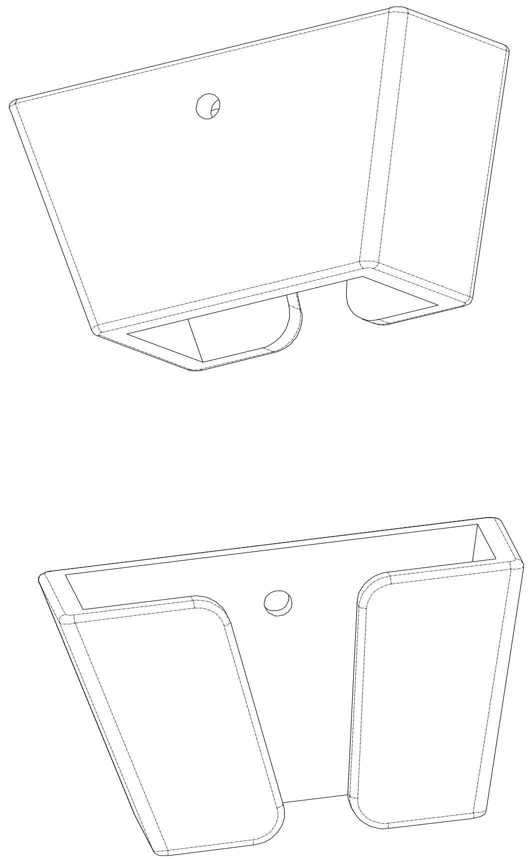


Step 2. Prepare <u>non-contiguous config. requirements</u> sk ch

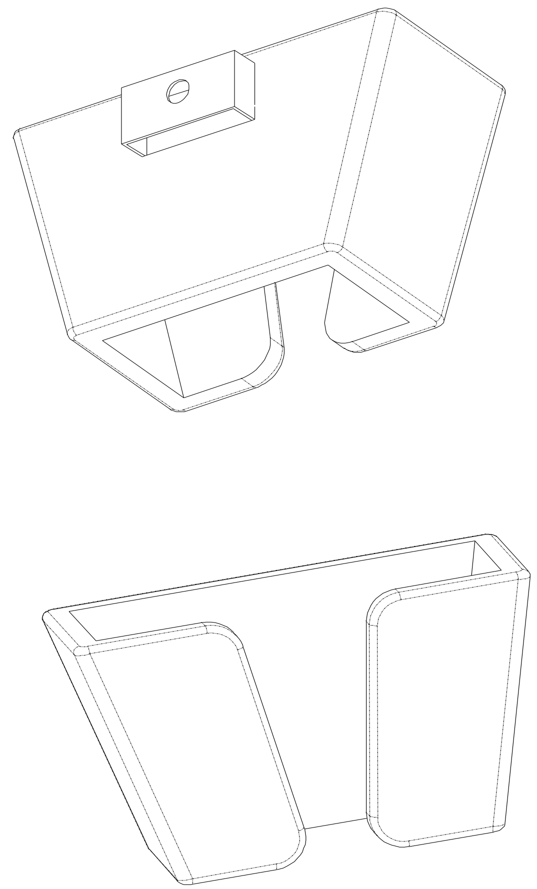
Step 3. Prepare alternative contiguous configuration sketches



Step 4. Refine configurations



with hole in back wall

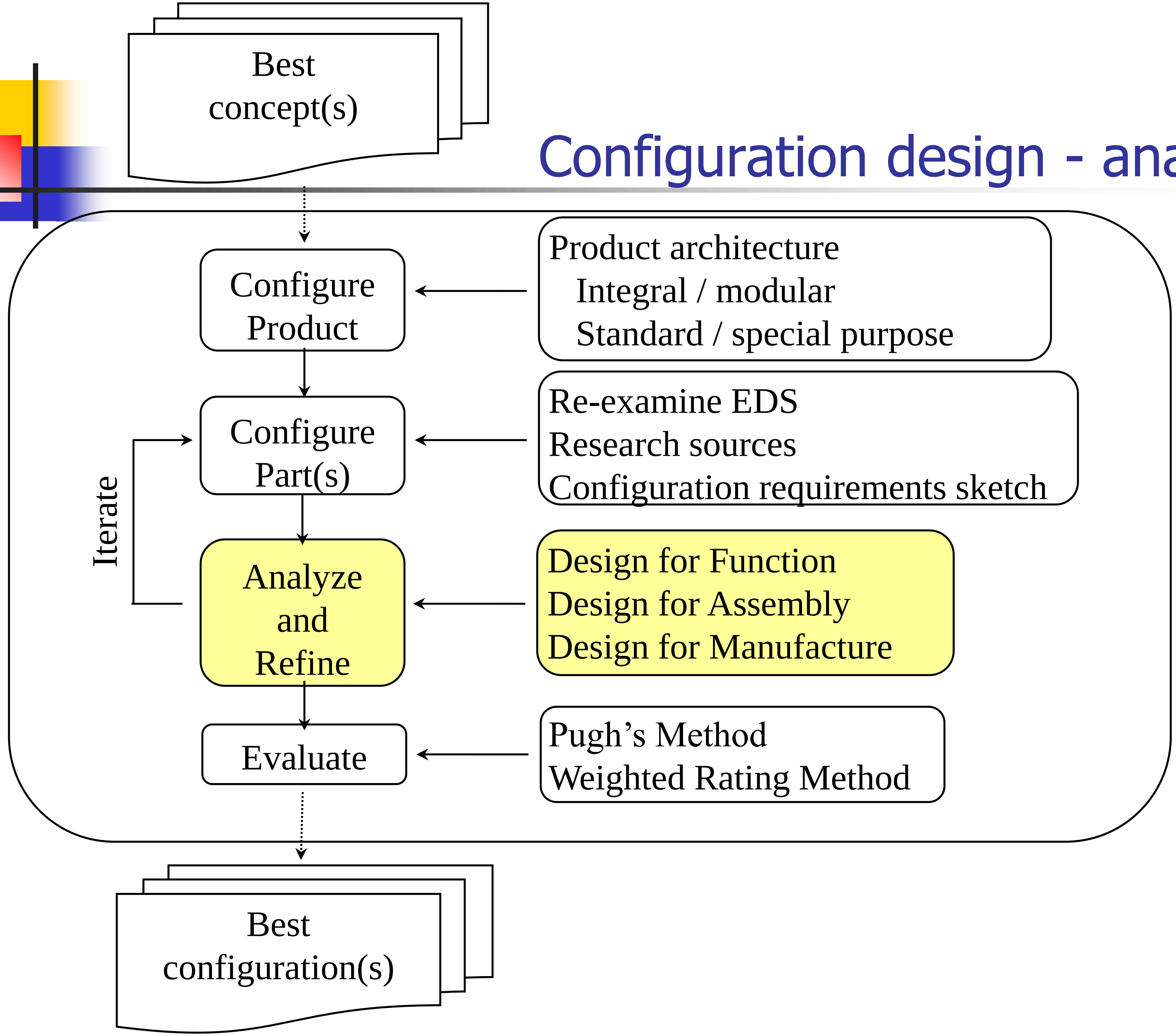


with hole in offset wall

Configuration Design

- Analyzing configurations
- DFA
- DFM
- Evaluating Configurations
- CAD
- Solid modeling

Configuration design - analysis



Analyzing Configurations

- Design for Function
- Design for Assembly
- Design for Manufacture

To analyze configurations, we ask…

Will it function?

Will it assemble?

Will it be manufacturable?

Design for function

Will the part or product perform its function(s)?

1. Strong
2. Stiff or flexible
3. Buckle
4. Thermal expansion
5. Vibrate
6. Quiet / Noise
7. Heat transfer
8. Fluids transport / storage
9. Energy efficient
10. Stable
11. Reliable
12. Human factors/ergonomics
13. Safe
14. Easy to use
15. Maintain
16. Repairable
17. Durable (wear, corrosion)
18. Life-cycle costs
19. Styling/aesthetics

Will it assemble?

What do we mean by assemble?

Assembly - a process of *handling* components to bring them together (*inserting*) and then *fastening* them.

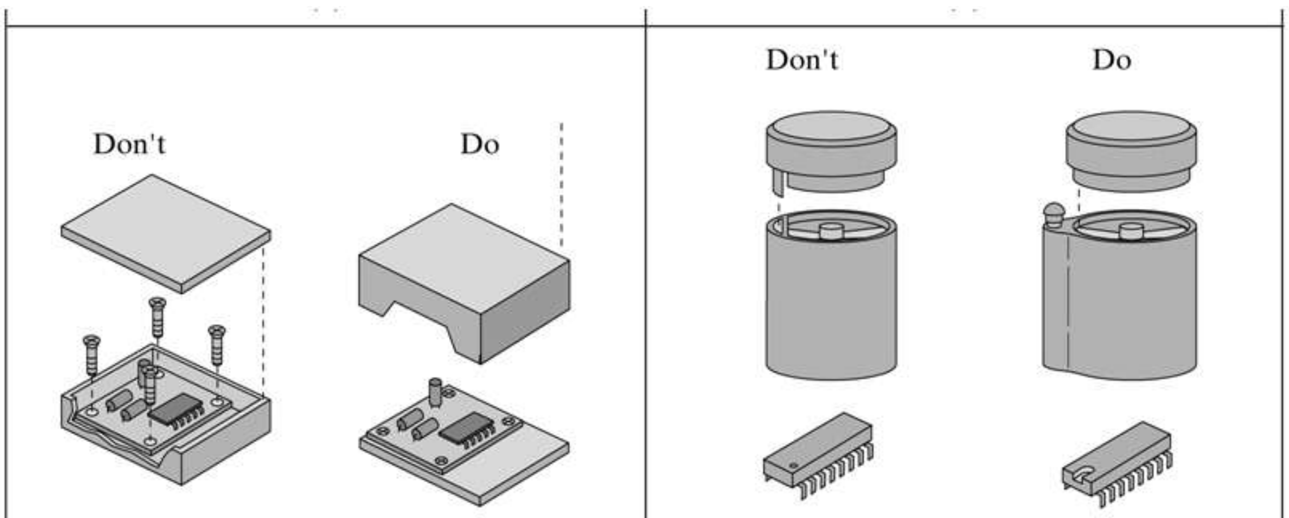
DFA

Design for Assembly - a set of design practices which reduce the manpower time required to *handle, insert and fasten* components of a product.

(designing part features for a more effective assembly of the parts)

1. Design Guidelines (written and graphical)
2. Cost estimating methods

Example of DFA Graphical



Design open enclosures to permit assembly in open space, not in confined spaces. Never bury important components.
(c)

Parts should easily indicate orientation for insertion.
(d)

Design for Assembly Guidelines from SME

- minimize part count
- minimize levels of assembly (number of assemblies)
- encourage modular assembly
- use standard parts
- stack sub-assemblies from the bottom up
- design parts with self-fastening features (snap-fits, press-fits)
- facilitate parts handling (grasp, orient, move)
- design parts with self-locating features (e.g. chamfers, aligning recesses/dimples)
- eliminate reorientation (i.e. insertion from 2 or more directions)
- eliminate (electric) cables

Pros and Cons of DFA methods

1. Design Guidelines
   pros: fast, easy, non-coupled
   cons: non-quantitative, can't compare alt. designs

2. Assembly Efficiency (Boothroyd & Dewhurst)

   $$\text{Efficiency} = \frac{\text{theoretical min. assembly time}}{\text{estimated assembly time}}$$

   pros: systematic, comparative
   cons: takes time to code & calculate

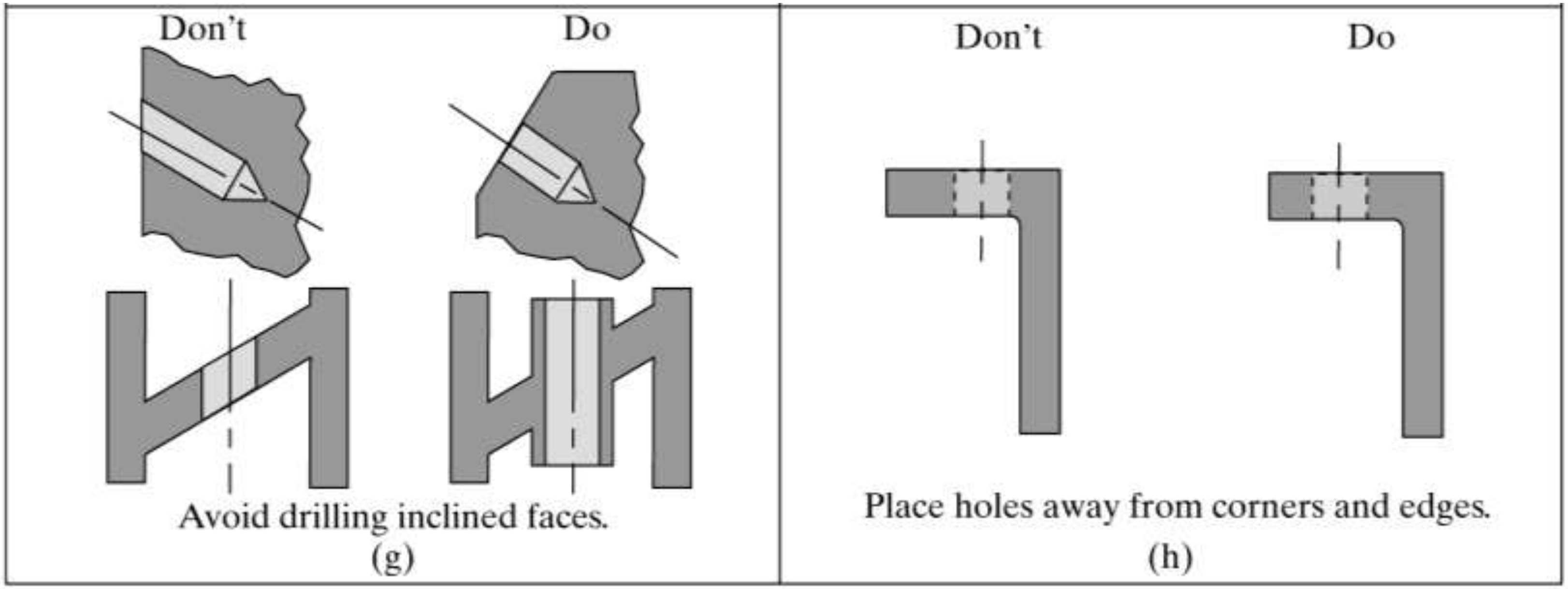
DFM

Deign for Manufacture (manufacturability) - A set of practices that aim to improve the fabrication of individual parts

1. Design Guidelines (written and graphical)
2. Cost estimating methods

(designing parts for less costly fabrication)

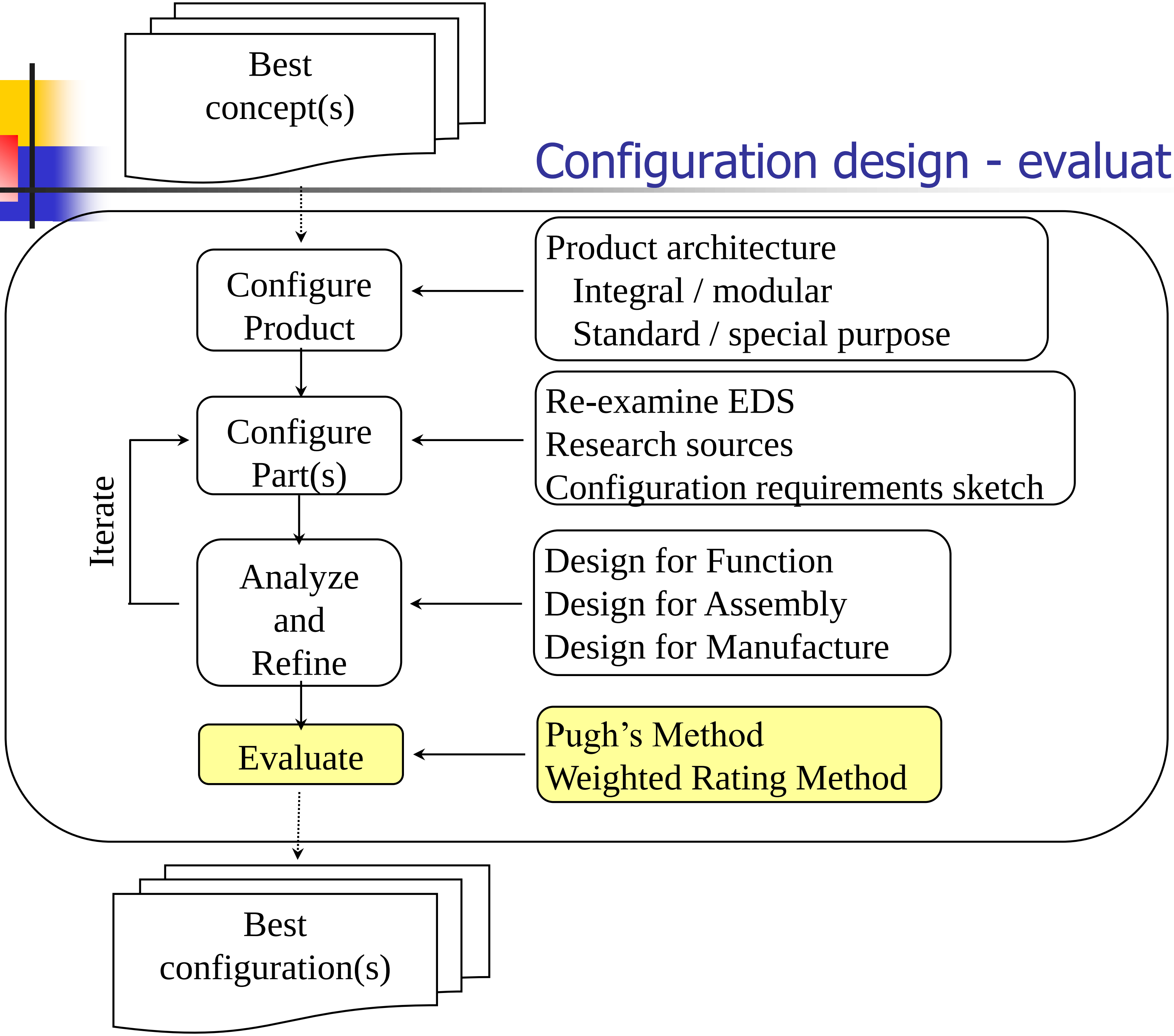
DFM Graphical – machining examples



DFM Guidelines – Example: Sheet metalworking

- avoid designing parts with narrow cutouts or projections
- minimize manufactured scrap (cut-off versus blanking)
- reduce number of bend planes
- keep side-action features to a minimum or avoid completely

Configuration design - evaluation



Evaluation using Weighted Rating Method

1. List evaluation criteria (in a column).
2. Determine importance weights (in an adjacent column)
3. List alternatives (along the top row)
4. Rate each alternative on each criterion
5. Compute the weighted rating for each criterion
6. Sum the ratings to produce the Overall Weighted Rating

Evaluating alternative configurations

Criteria	Importance Weight	Sponge Holder Configuration Ratings			
		With hole		With bracket	
		Rating	Wt. Rating	Rating	Wt. Rating
Function					
drains well	15	3	0.45	3	0.45
dries quickly	10	3	0.30	3	0.30
stays clean	10	2	0.10	3	0.15
sponge inserts easily	15	2	0.40	4	0.80
Manufacture					
material usage	10	3	0.30	2	0.20
tooling costs	15	3	0.45	2	0.30
processing costs	5	3	0.15	3	0.15
Assembly					
handling	5	3	0.15	3	0.15
insertion	5	3	0.15	3	0.15
number of parts	10	3	0.30	3	0.30
	100%				
Weighted rating			2.75		2.95

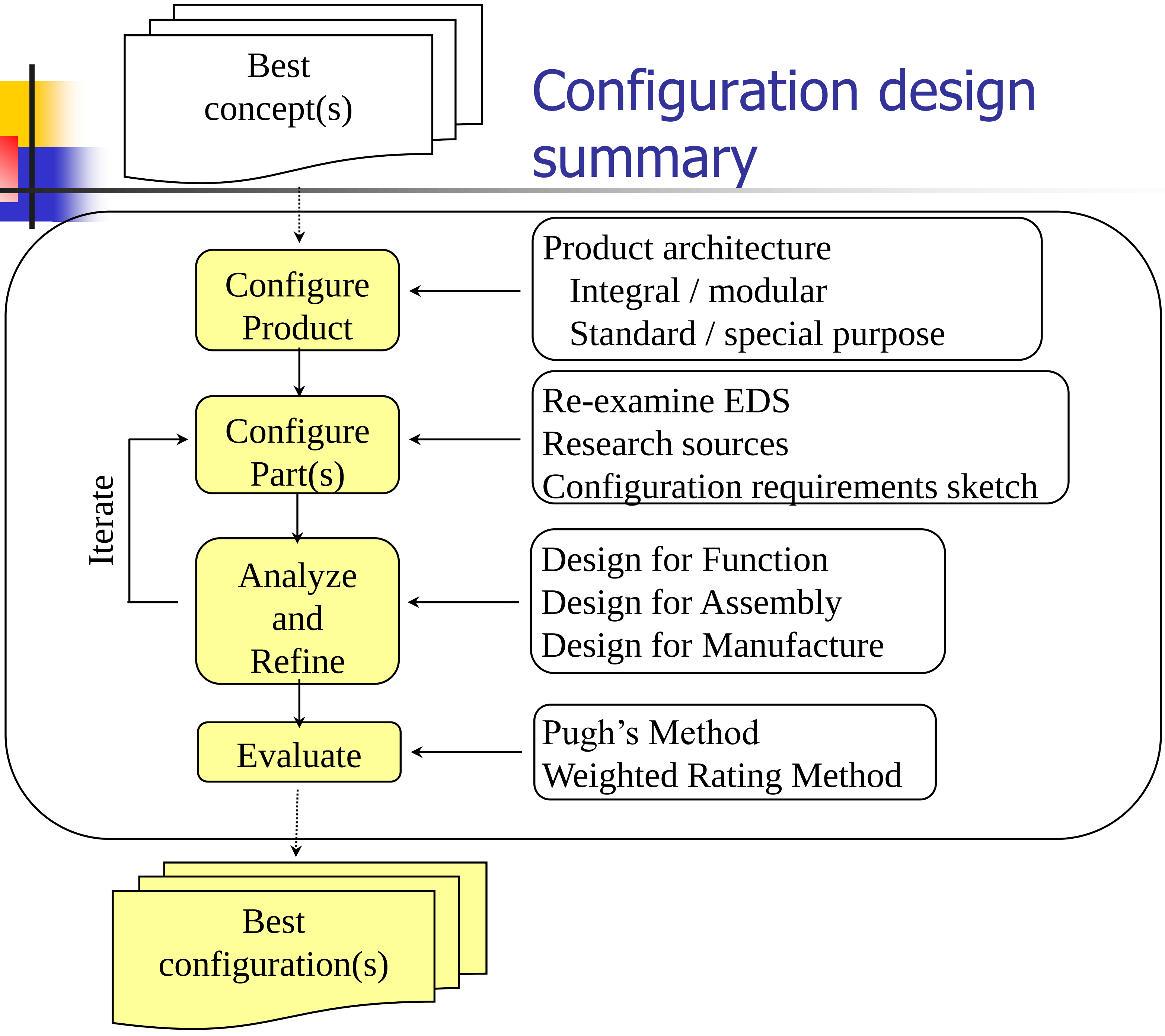
Graphics during Configuration Design

- Sketches are used a lot in configuration design
- Sketches assist creativity
- Sketches are not typically used to “document” the “design”
- CAD Drawings need sizes (e.g. H, W, L, D)
- CAD Takes time
- 2-D model
- Wireframe model
- Surface model
- Solid model

Advantages of solid modeling

- *Design intent is captured*- such as holes moving with bosses
- *Feature-based modeling*– automating with features such as chamfer, fillet, flange-bolt
- *Constraint-based*– geometric relations
- *Parametric*- dimensions are placeholders
- *Fully Associative*- one model controls all views
- *Assemble-ability check*– interference, motion
- *Downstream benefits*- CAE, FEA, CAM, rapid prototyping

Configuration design summary



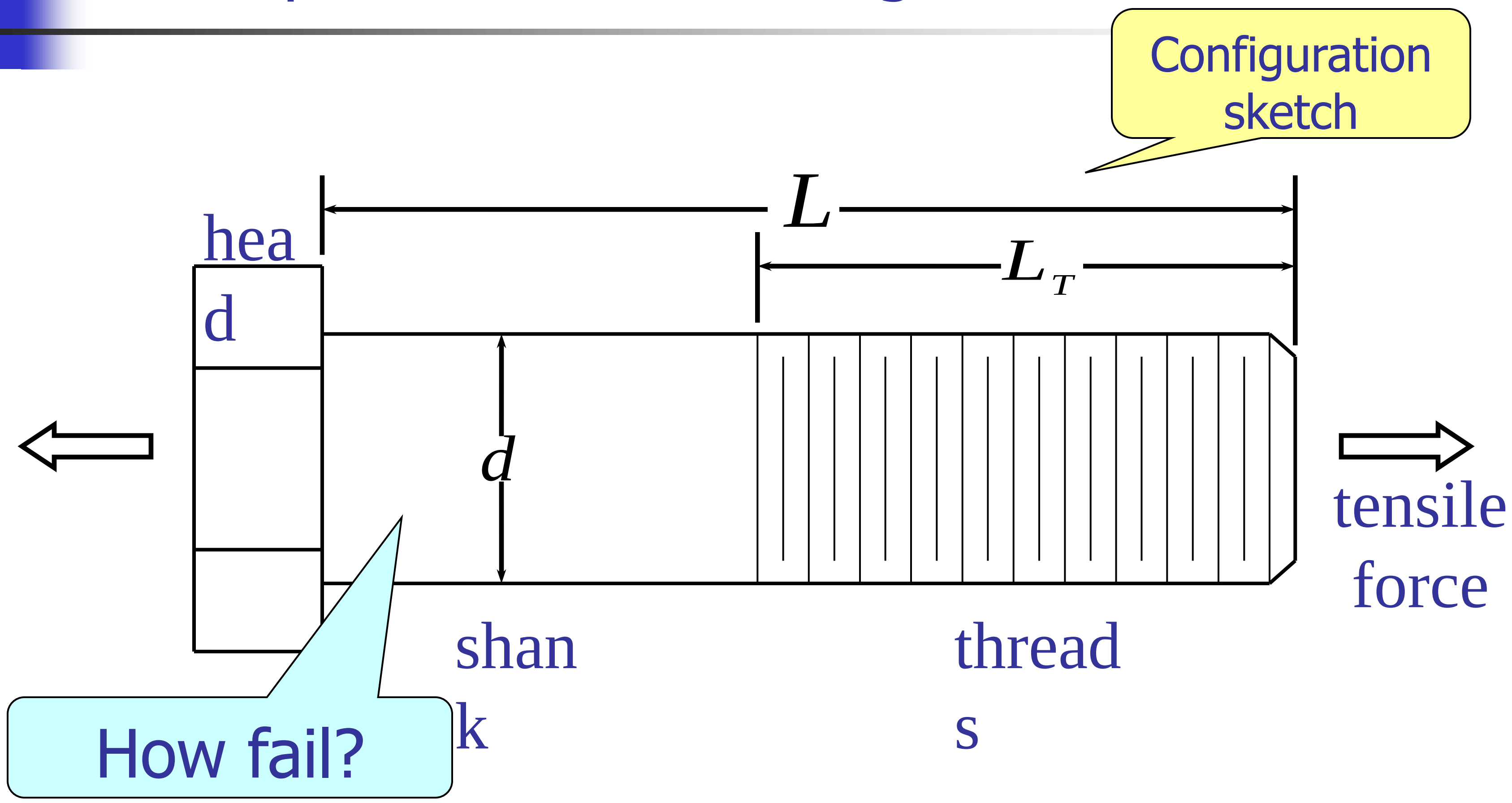
Summary

- Product architecture design determines the type and number of components, their arrangement, and their relative dimensions.
- Part configuration design determines the type and number of geometric features, their arrangement, and their relative dimensions.
- Standard part configuration design involves determining part type and relative dimensions.
- Part features include: walls, ribs, projections, fillets, bosses, rounds, cylinders, tubes, cubes, spheres, holes, slots, notches, chamfers, and grooves.
- Configuration requirements sketches can be used to develop alternative part configurations.
- Configuration analysis includes considerations of function, assembly and manufacture.
- Alternative configurations may undergo significant revision during successive iterations.
- Solid-modeling CAD systems can be useful during configuration design as well downstream in parametric design and or manufacturing.

Parametric Design

- Information flow thru phases
- Parametric design of a bolt
- Systematic parametric design
- Summary

Example: Parametric Design of a Bolt



Mode of failure under investigation: tensile yielding

What steps did we just take to "solve" the problem?

- Reviewed concept and configuration details
- Read situation details
- Examined a sketch of the part – 2D side view
- Identified a mode of failure to examine – tensile yield
- Determined that a variable (proof load) was "constrained"
- Obtained analytical relationships (for F_p and A)

Equation "juggling" is not always possible in design, especially ***complex design*** *problems. (How do you "solve" a system of equations for a complex problem?)*

Formulating the parameters

- Determine the type of parameter
  - Solution evaluation parameters SEPs
  - Design variables DVs
  - Problem definition parameters PDPs
- Identify specifics of each parameter
  - Name (parameter/variable)
  - Symbol
  - Units
  - Limits

Example SEPs

Select one or more "engineering characteristics"….to measure performance … i.e. Solution Evaluation Parameters

Pong ball launcher – SEPs
Distance (ft/sec, init velocity)
Accuracy (points for 10 balls)
Launch rate (balls/min)
Cost of system ($)

“Formulating” the formulas (constraints)

- Recall from sciences:
  physics, chemistry, materials
- Recall from engineering:
  statics, dynamics, fluids,
  thermo, heat transfer, kinematics,
  machine design, circuits
  mechanics of materials
- Conduct experiments

Example Constraints

Ball launcher
Max motor power available? Human factors (user, mfr, repair)? Size (H, W, L)?

Analytical relationships

$$F = ma \qquad \Sigma F = 0 = ma$$

$$T = r \times F \qquad \Sigma M = 0 = I\alpha$$

$$F_f = \mu N \qquad V_t = \omega r$$

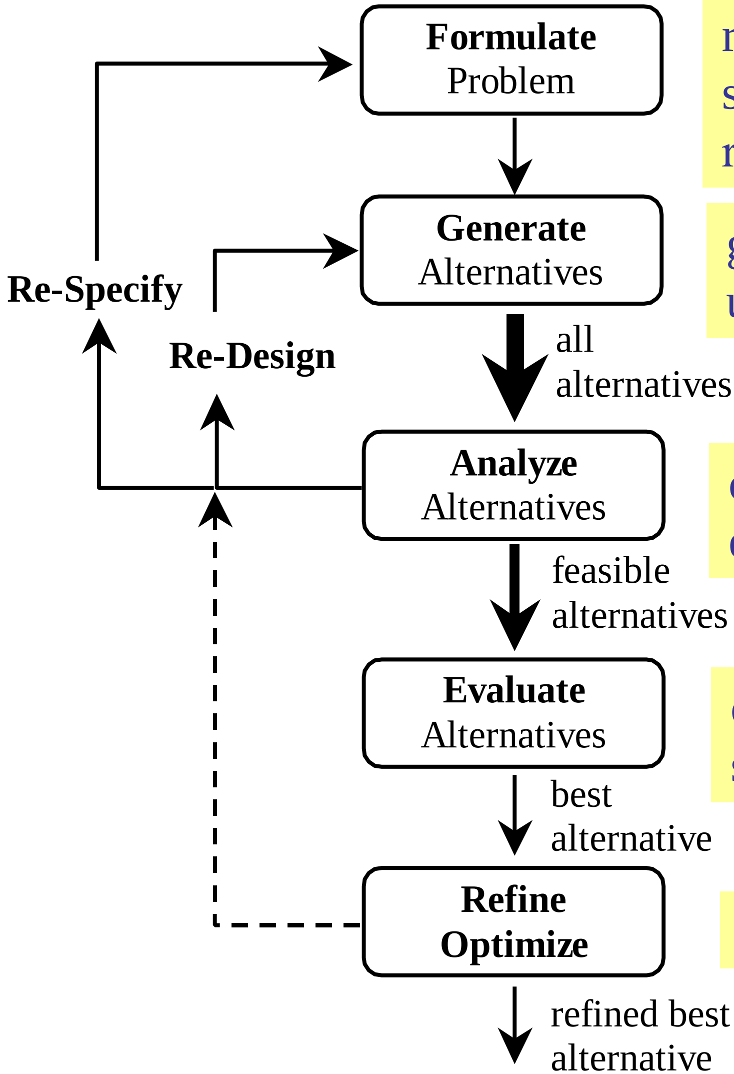
$$P_i = P_o$$

$$SR = d_o / d_i = N_o / N_i$$

Assess Satisfaction

- Determine satisfaction
- Multiply by importance weight
- Does “form” satisfy “function?”
- Is “design” the best?

Systematic Parametric Design



read, interpret
sketch
restate constraints as eq'ns

guess, ask someone
use experience

calculate
experiment

calculate/determine satisfaction
select Qmax alternative

improve "best" candidate