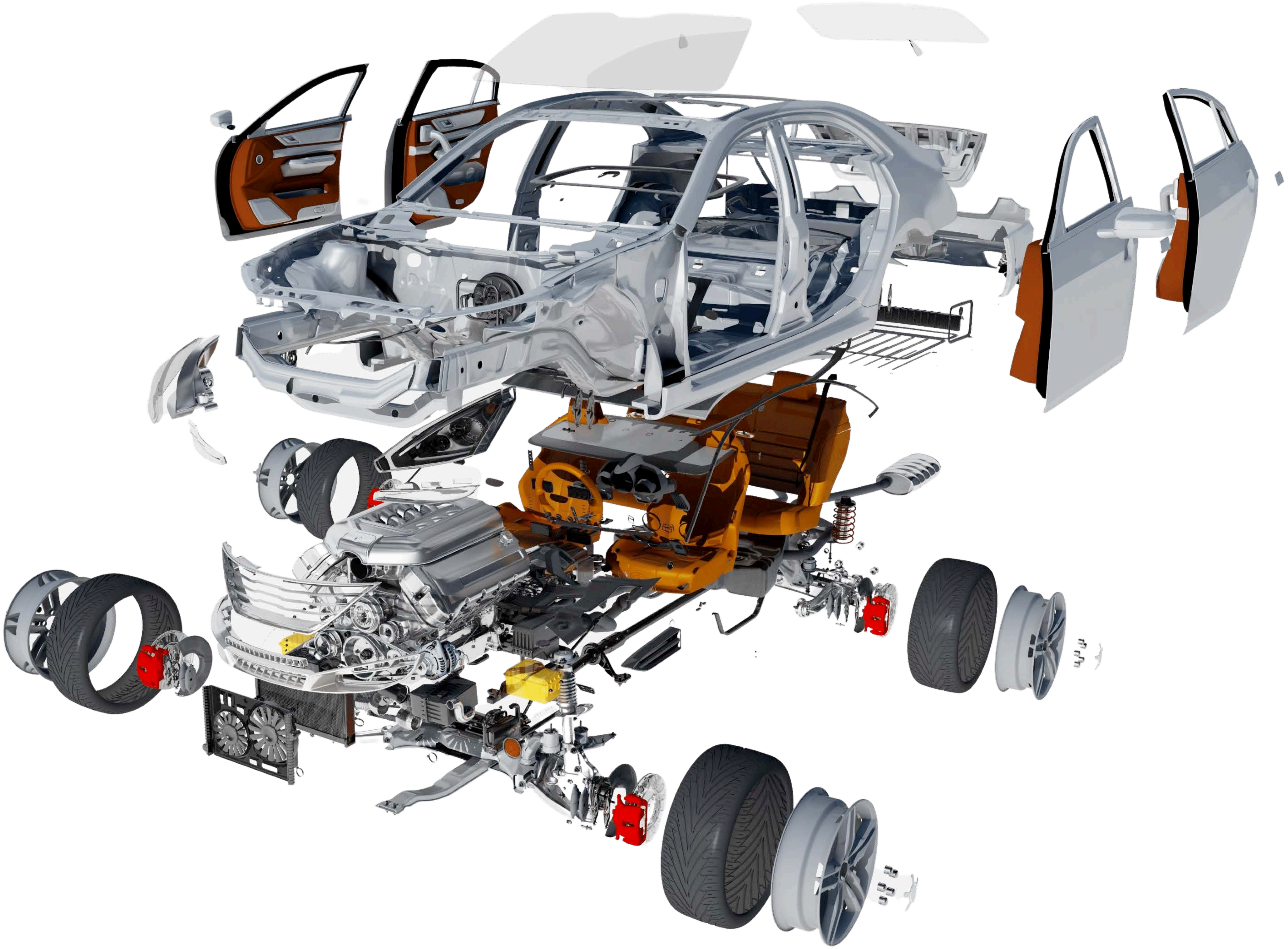
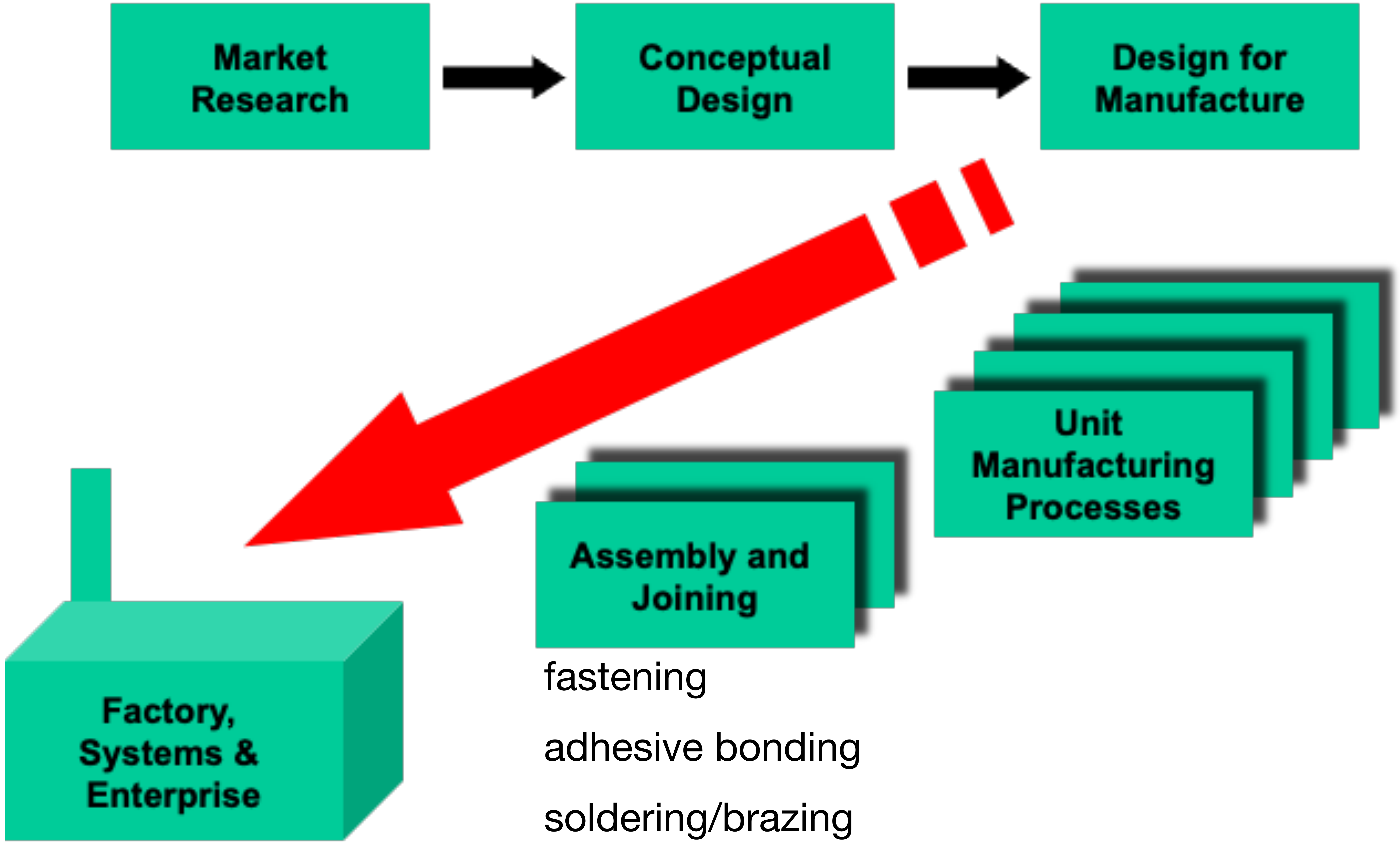
Joining I

Manufacturing Assemblies



Assembly/Disassembly

FISKARS Hand Drill Activity



- injection molding
- thermoforming
- machining

- fastening
- adhesive bonding
- soldering/brazing
- diffusion bonding
- fusion welding

2.008 Coverage of Assembly + Joining

Assembly/Disassembly Activity FISKAR drill

Joining I: Manufacturing Assemblies + Intro to Joining Processes

Joining II: More on Joining Processes

Main Questions

how do engineers utilize multiple processes to manufacture products and packaging?

how are the different parts of a product carefully constrained?

Importance of Assembly and Joining

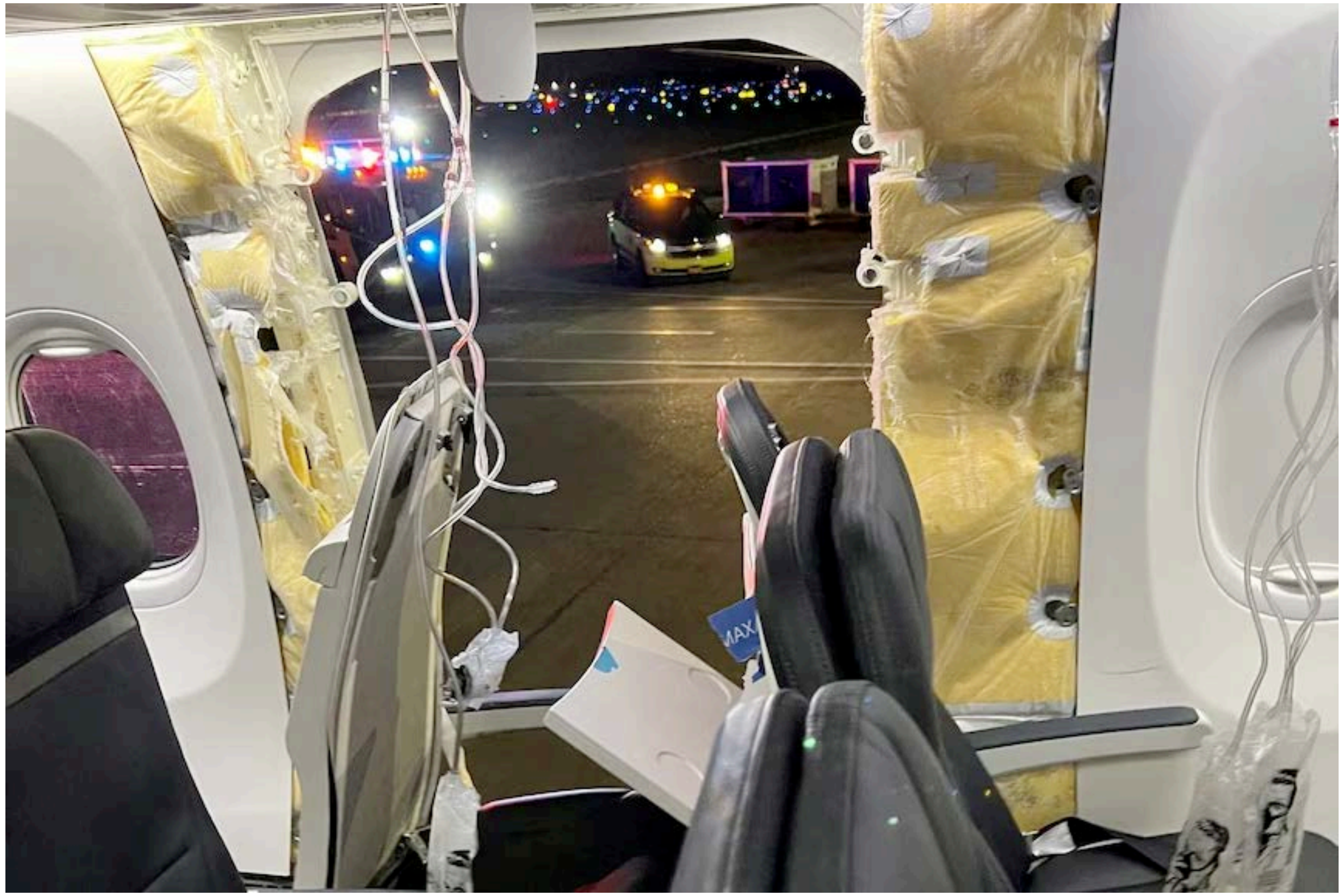
Why focus on Assembly?

parts: 1 4

Approximate Number of Parts in Products	
Common pencil	4
Rotary lawn mower	300
Grand piano	
Automobile	
Boeing 747–400	

Assemblies actually do things customers want

Assemblies sometimes do things customers don't want



Boeing 737 Max 9 door plug blowout

4 bolts missing during assembly

issues happen at the interfaces

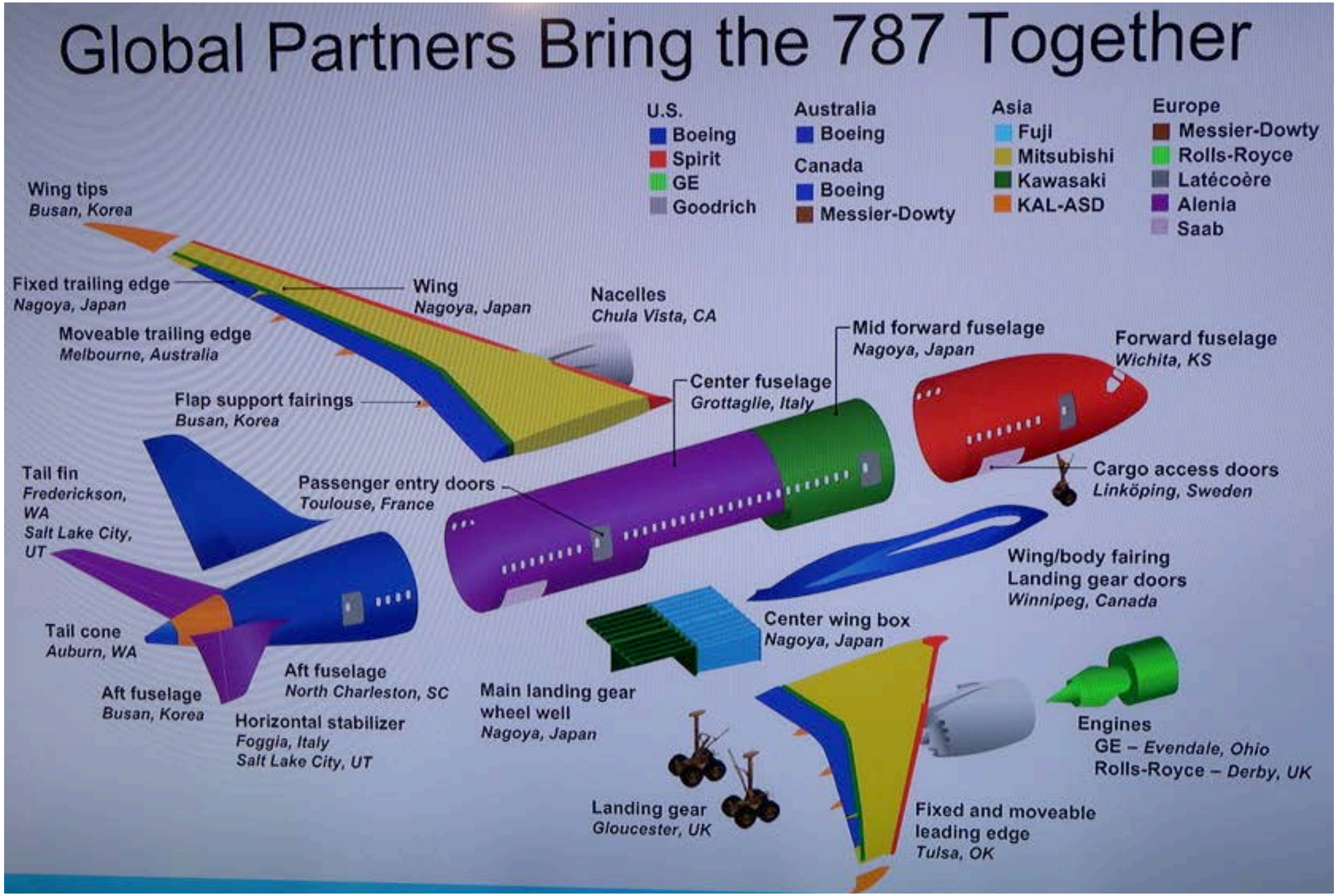
the main engineering requirement for the yo-yo project is an assembly challenge

Joining I

Manufacturing Assemblies

787 Dreamliner Factory, South Carolina

787 Dreamliner Factory




02 WELDING
L2
TOYOTA
TOYOTA
an inspector confirms quality.

Challenges in Assembly

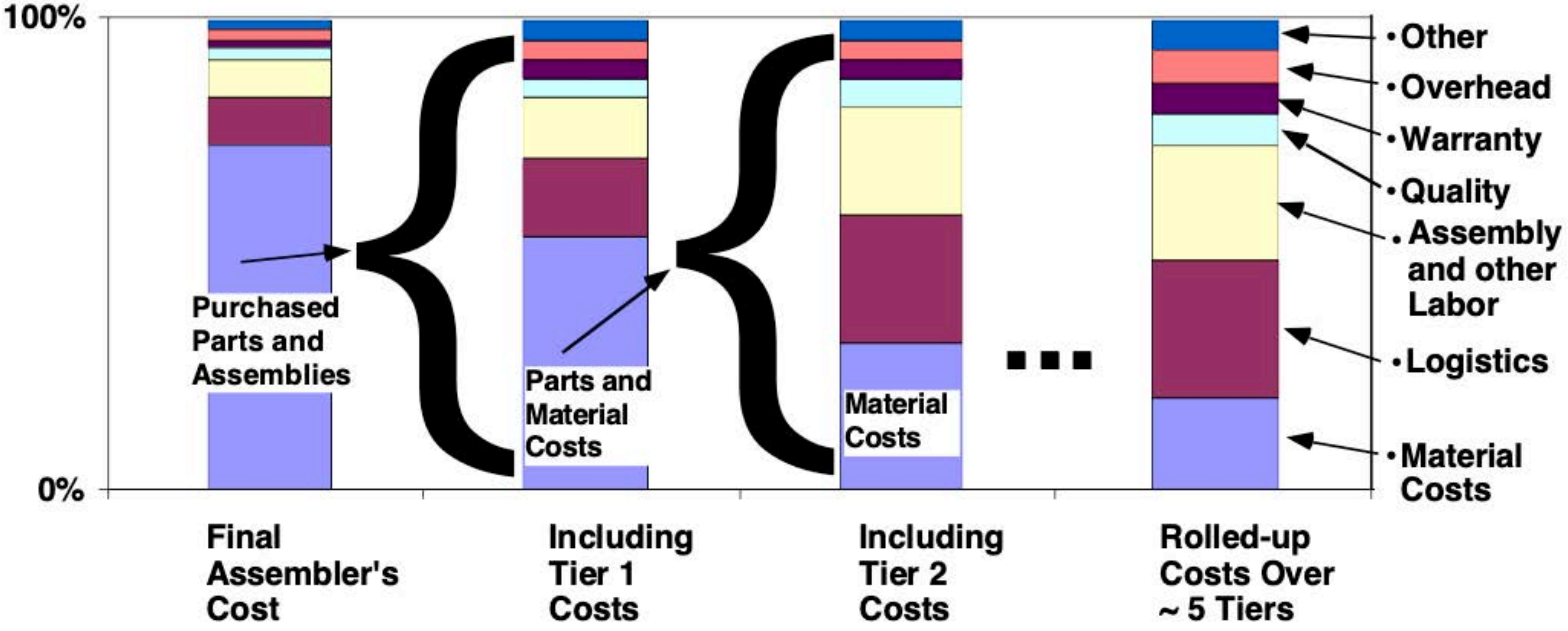
Cost people, machines

Speed rates: transport, alignment, joining

Complexity difficult assembly operations

Flexibility different versions of a product

Manufacturing Cost



Source: Daimler Chrysler via Munro and Associates

Assembling can often account for more than 50% of total costs

but it might appear smaller at the final stages

Get it Right the First Time…

TABLE 1.5

Relative Cost of Repair at Various Stages of Product Development and Sale

Stage	Relative cost of repair
When the part is being made	1
Subassembly of the product	10
Assembly of the product	100
Product at the dealership	1000
Product at the customer	10,000

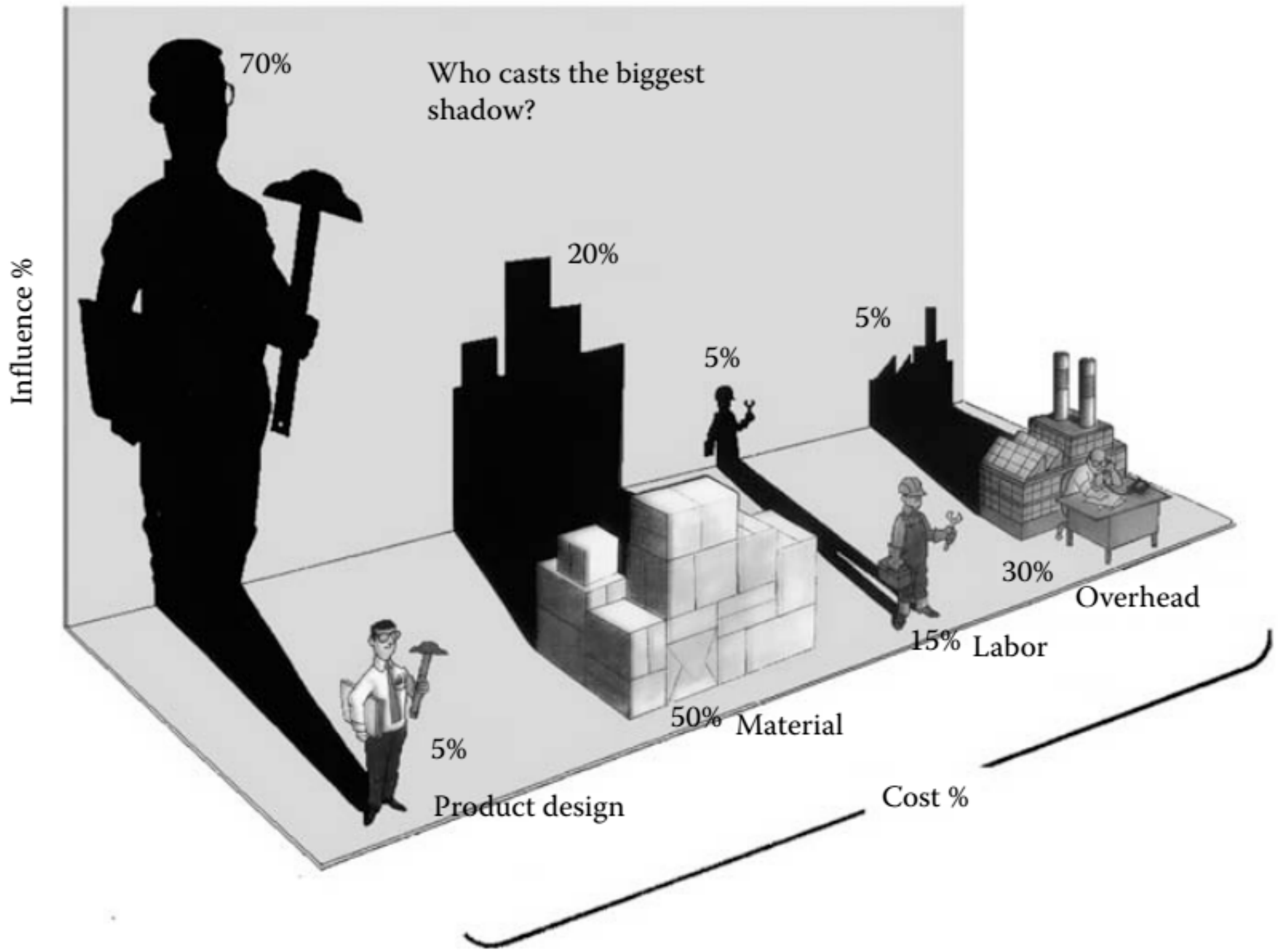
"The Multiplier" According to Ford and GM or: Why Is DFM/DFA Important?

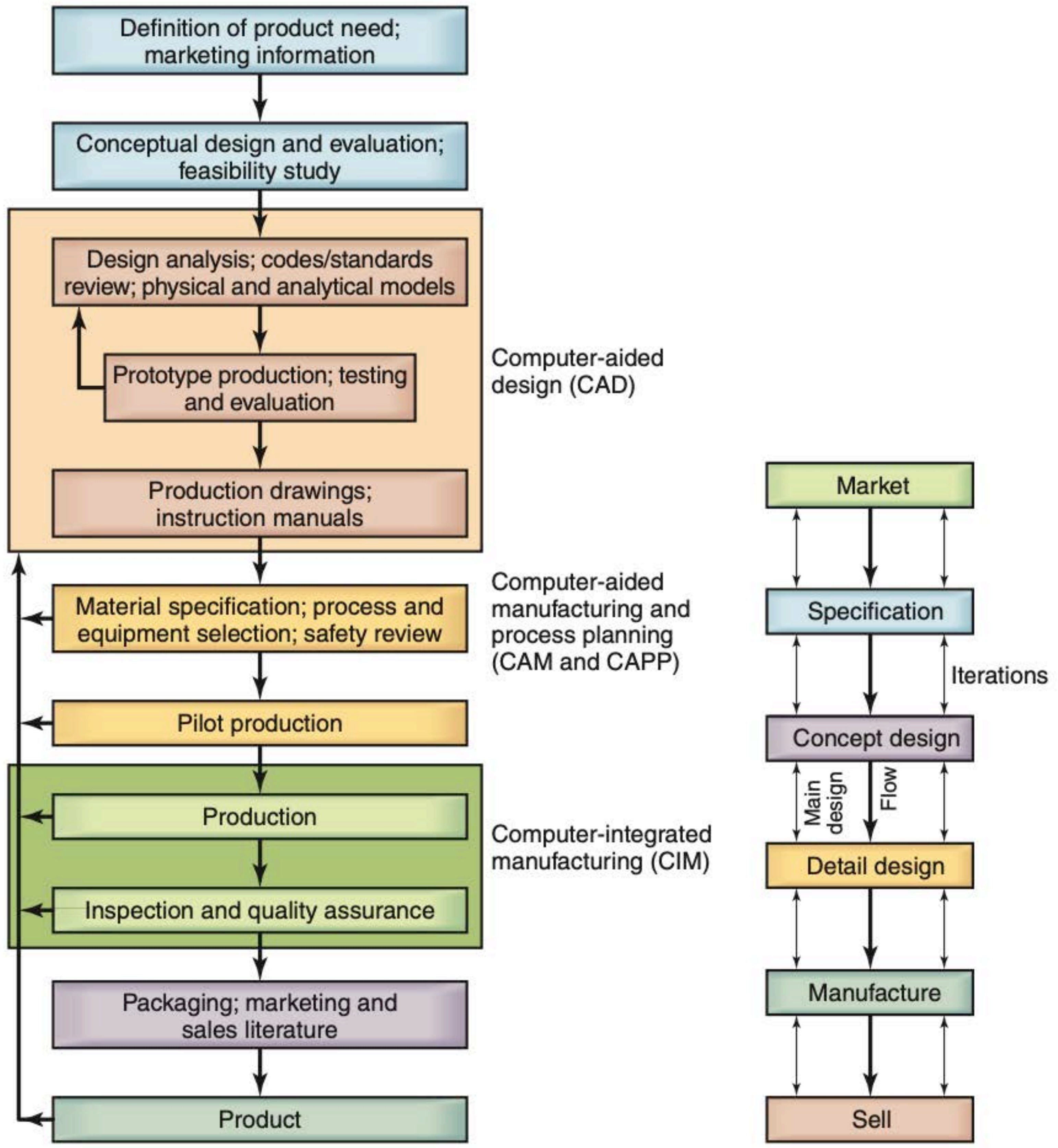
- For every product part, there are about 1000 manufacturing equipment parts*
- Or, for every toleranced dimension or feature on a product part, there are about 1000 toleranced dimensions or features on manufacturing equipment
- Such "equipment" includes fixtures, transporters, dies, clamps, robots, machine tool elements, etc

*Note: Ford's estimate is 1000, GM's is 1800. Both are informal estimates.

MIT Prof. Daniel Whitney

Get it Right the First Time…

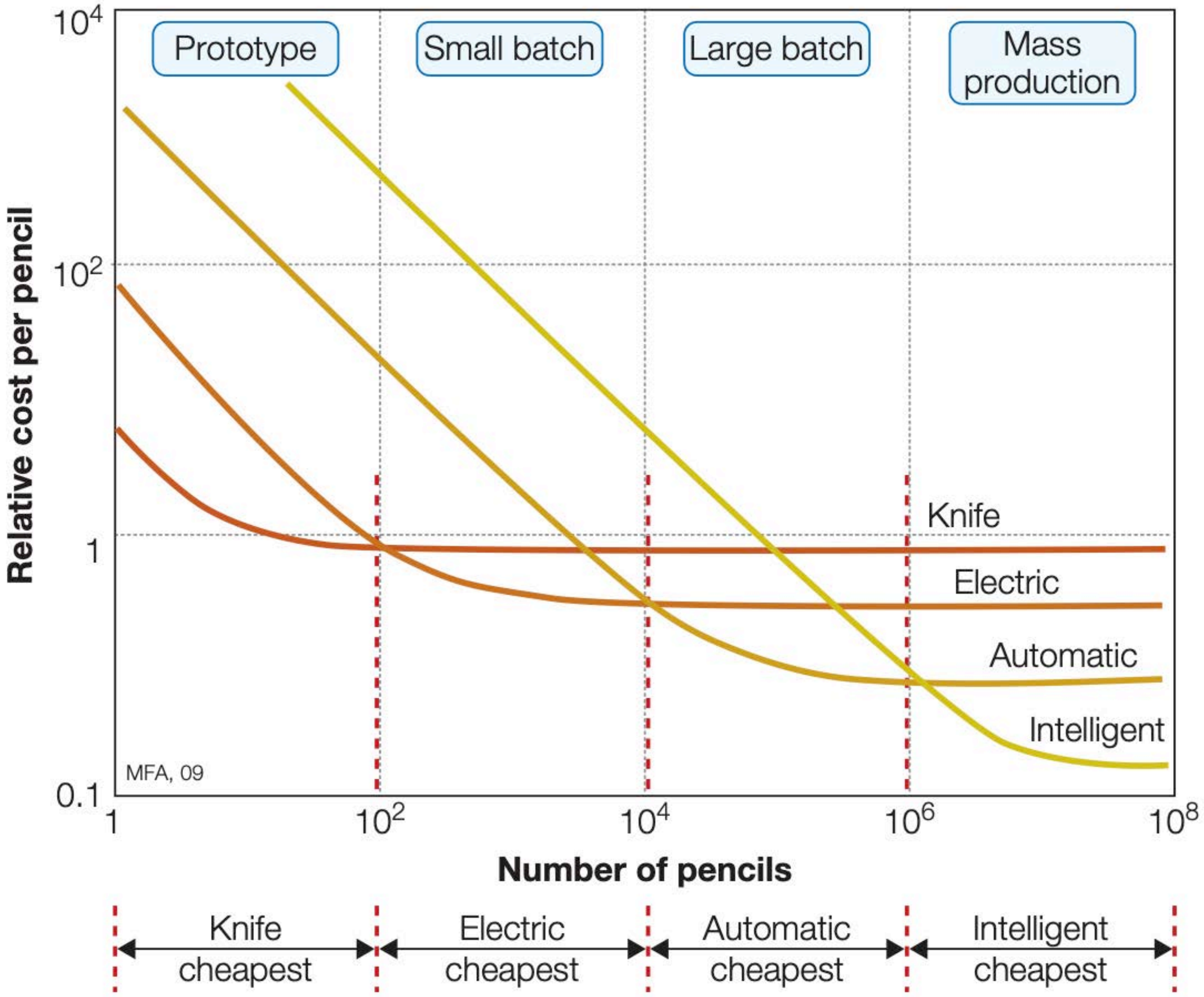


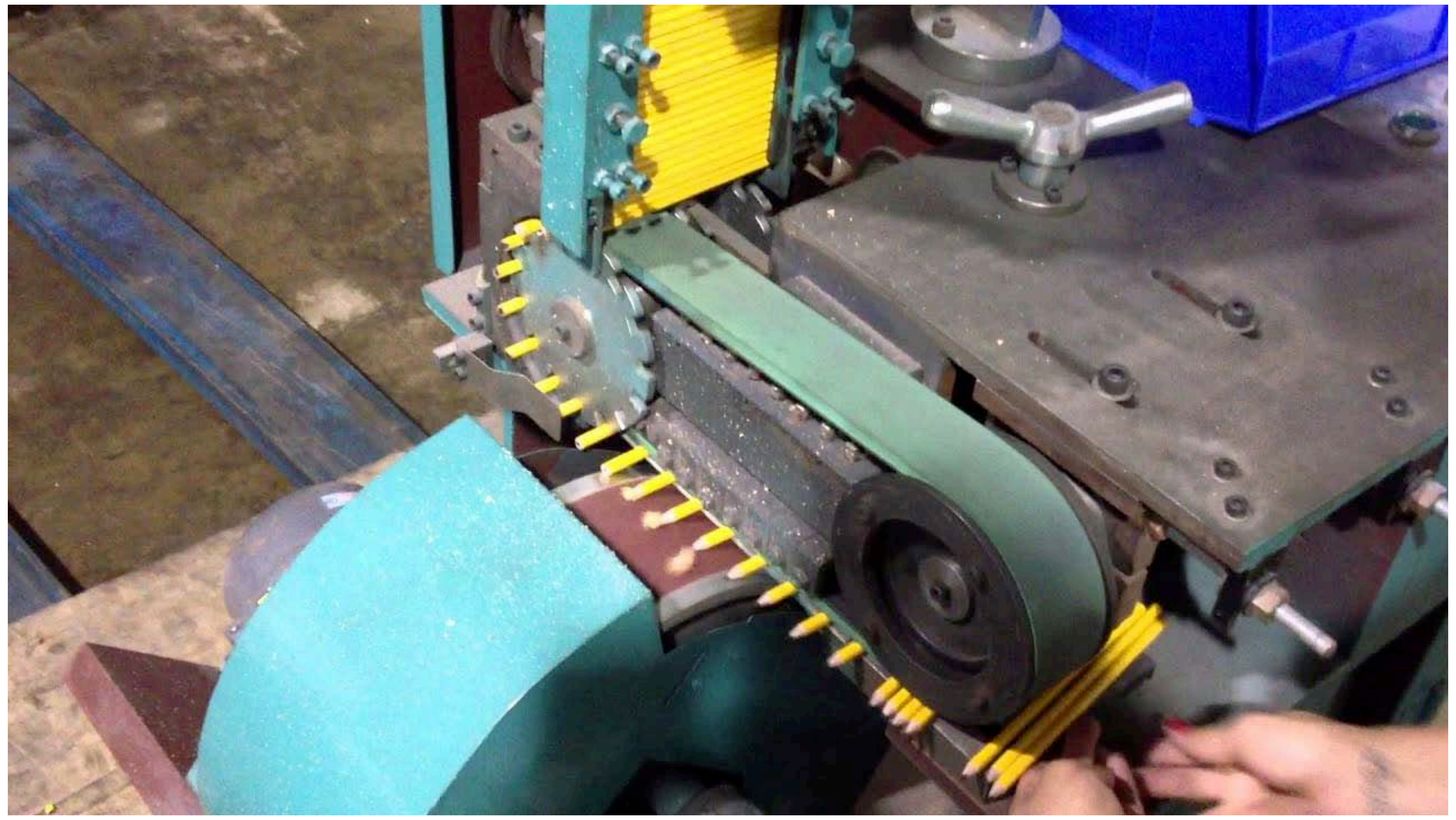


traditional

concurrent

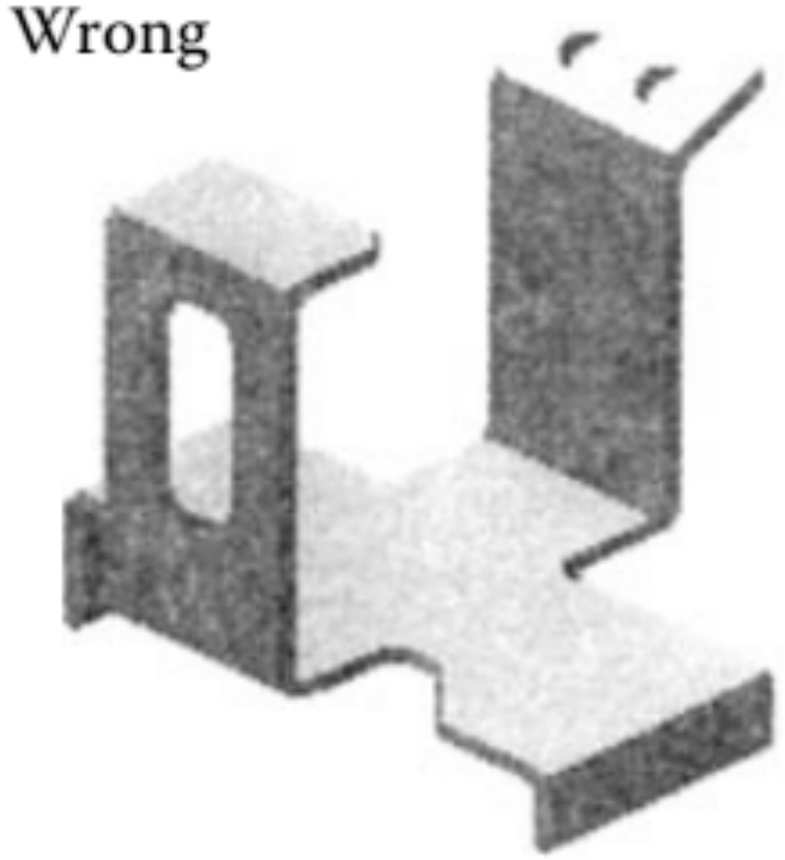
Investing in Automation





DFA History: Design for Assembly

“producibility guidelines” of the 1960s

Guideline	Wrong	Right
Avoid complex bent parts (material waste); rather split and join		

“design for manufacturing in a vacuum”

Boothroyd, Dewhurst, Knight (1980s-1990s):

economically, this is very wrong

TABLE 1.1

Estimated Costs in Dollars for the Two Examples in Figure 1.3 if 100,000 are Made

	Wrong	Right
Setup	0.015	0.023
Process	0.535	0.683
Material	0.036	0.025
Piece part	0.586	0.731
Tooling	0.092	0.119
Total manufacture	0.678	0.850
Assembly	0.000	0.200
Total	0.678	1.050

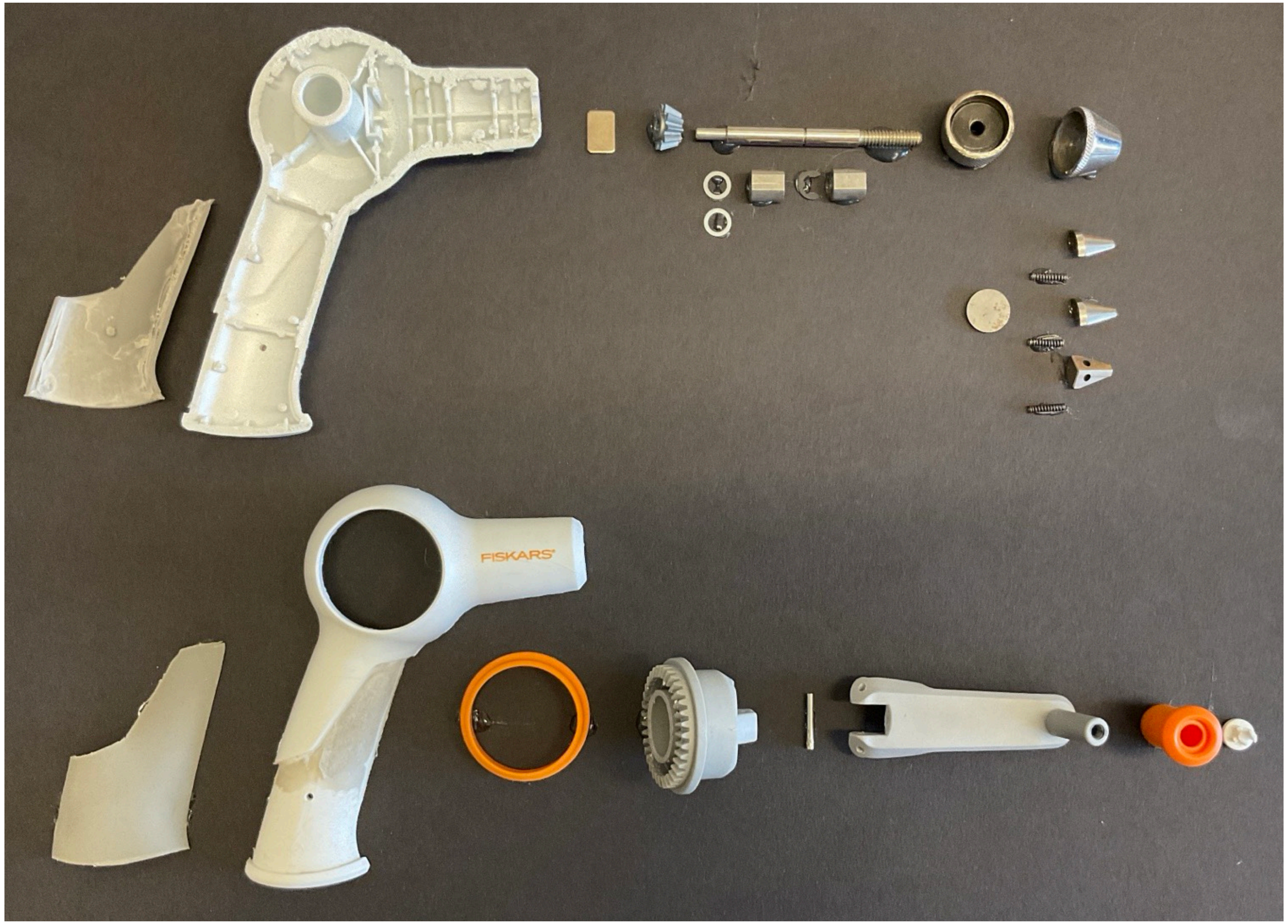
each part is simpler to manufacture, but now you have to deal with joining/assembling more parts…

DFA: Design for Assembly

1. Reduce the Part Count

2. Make Each Part Easier to Assemble

note: parts still need to be manufacturable (DFM still applies: DFMA)



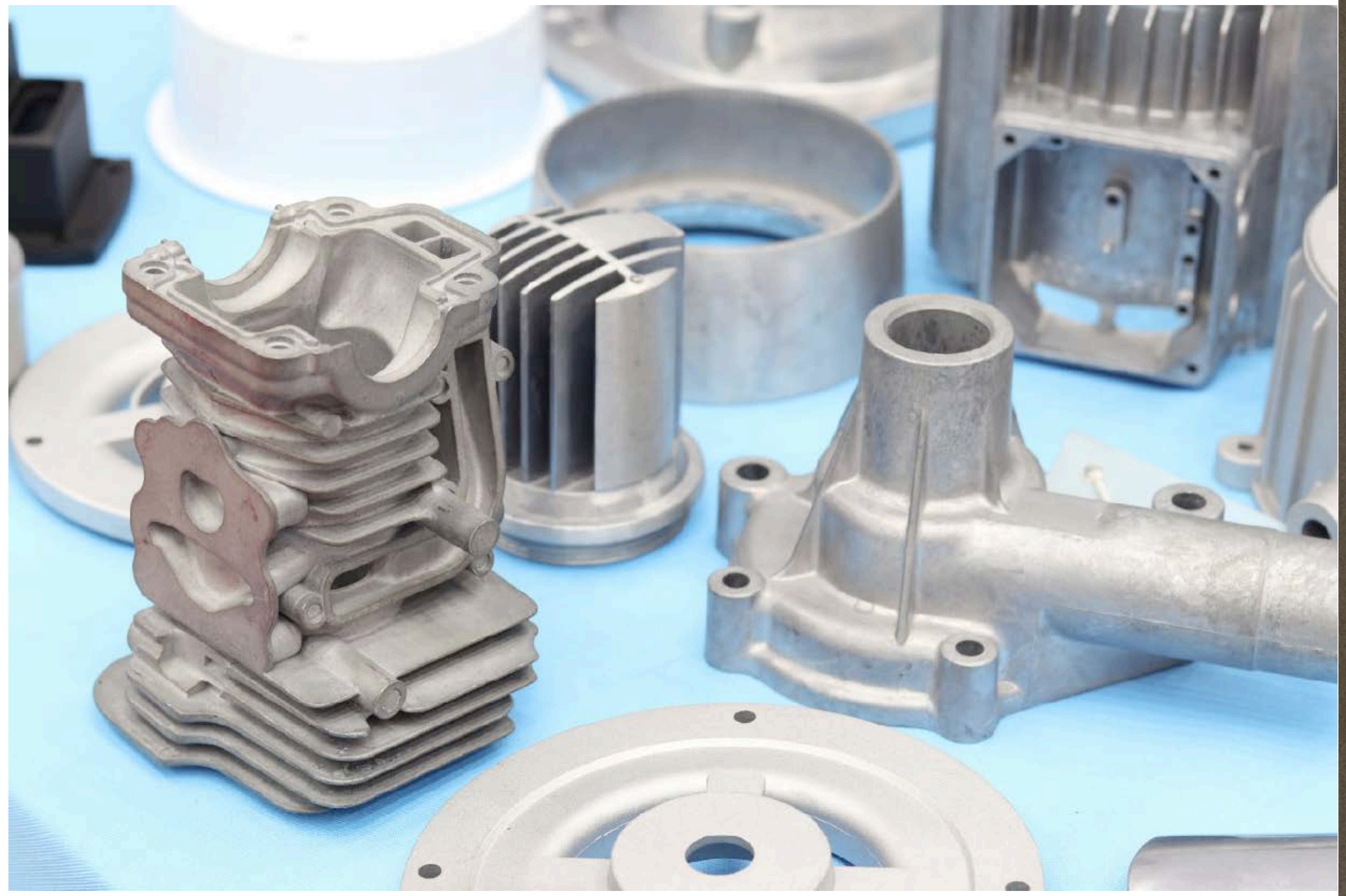
1) Reduce the Number of Parts

start with simplifying the design: make it as simple as possible (remove features, etc.)

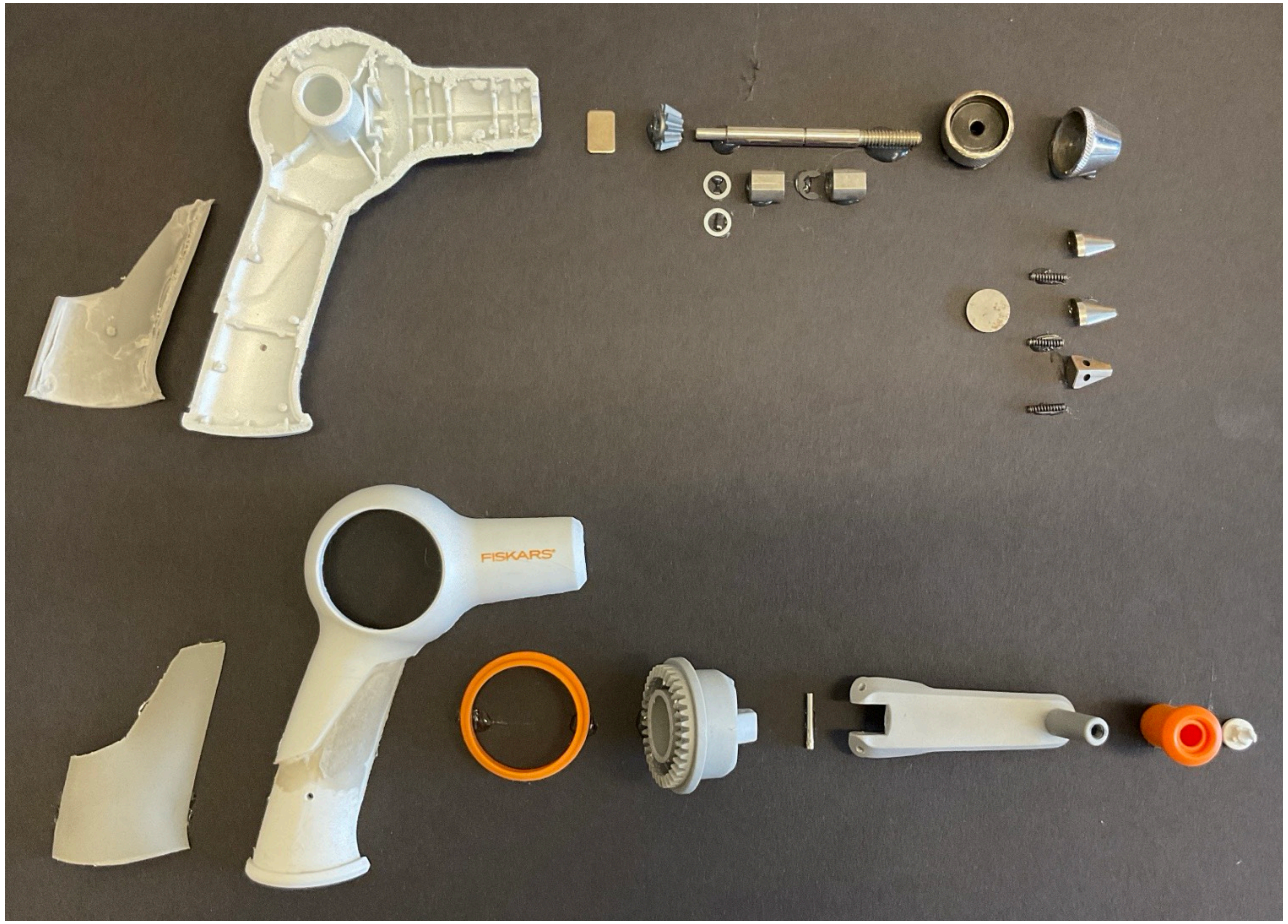
Process Plan: select manufacturing processes, consider part flow, select joining processes

why processes that can make complex parts are popular: push the complexity on the unit process

air intake manifold example



1) Reduce the Number of Parts



When do you need separate parts?

- relative motion
- material properties
- otherwise impossible
- maybe disassembly: for recycling

1) Reduce the Number of Parts

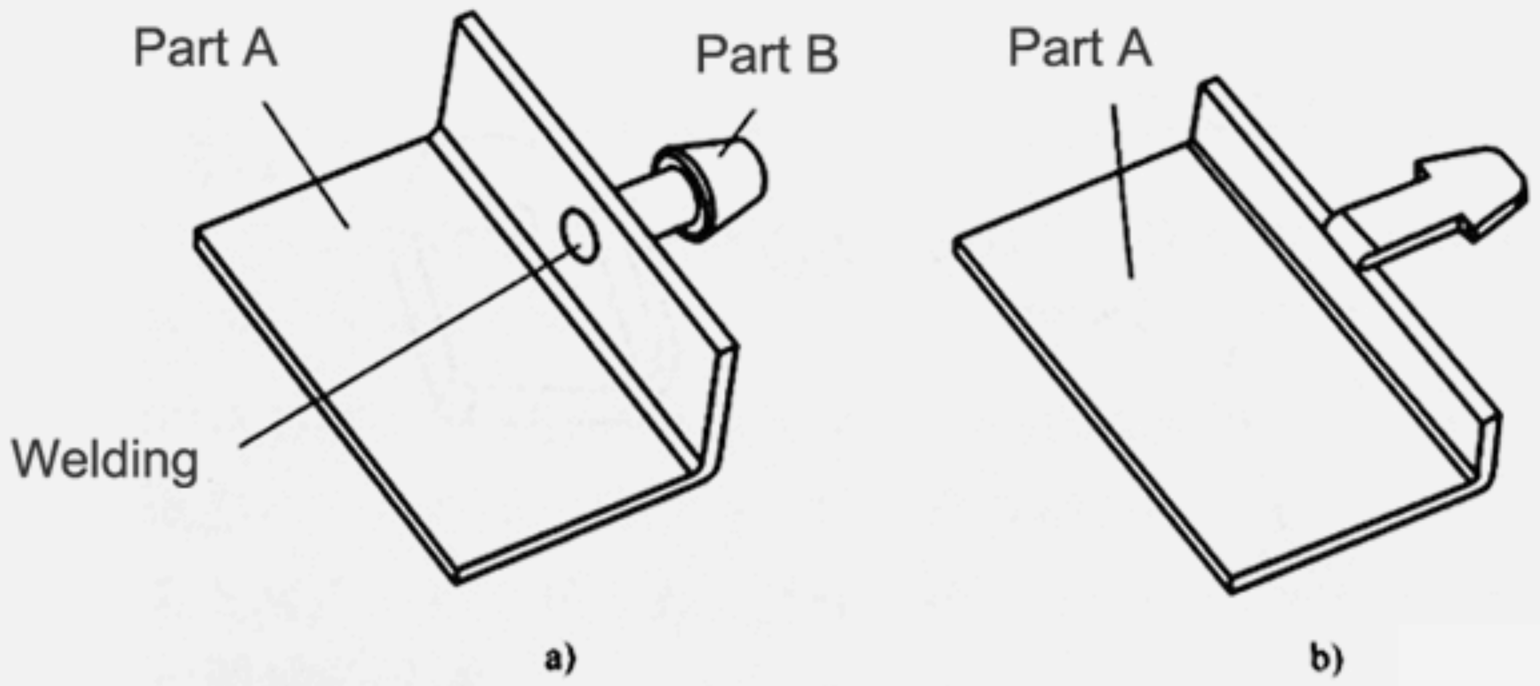


Figure 1-1 Considering the possibility of removing each part

a)Original design
b)Improved design

Figure 1-4 Merges 1 sheet metal part and 3 machined parts into one part.

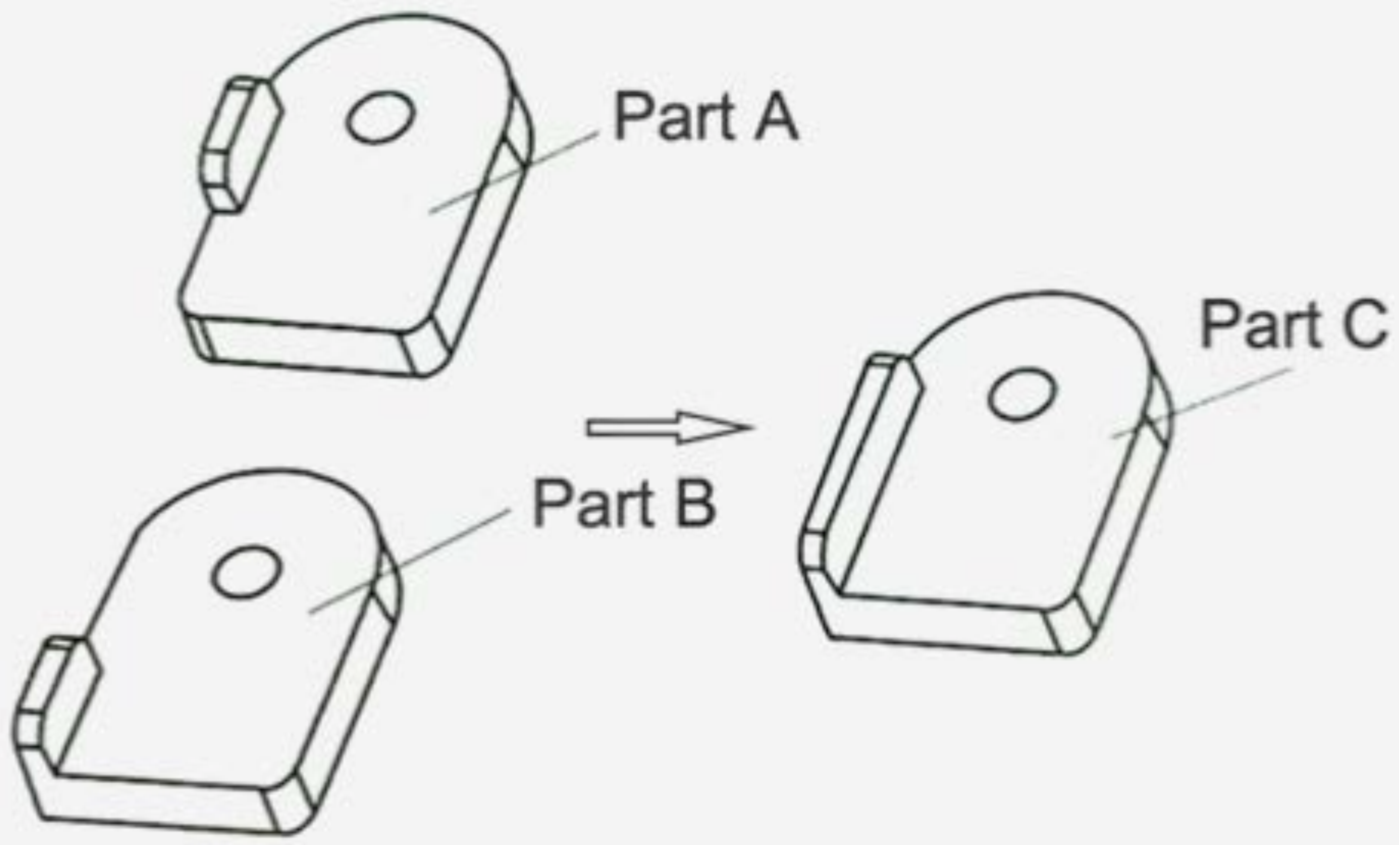


Figure 1-2 Similar parts merge into one part

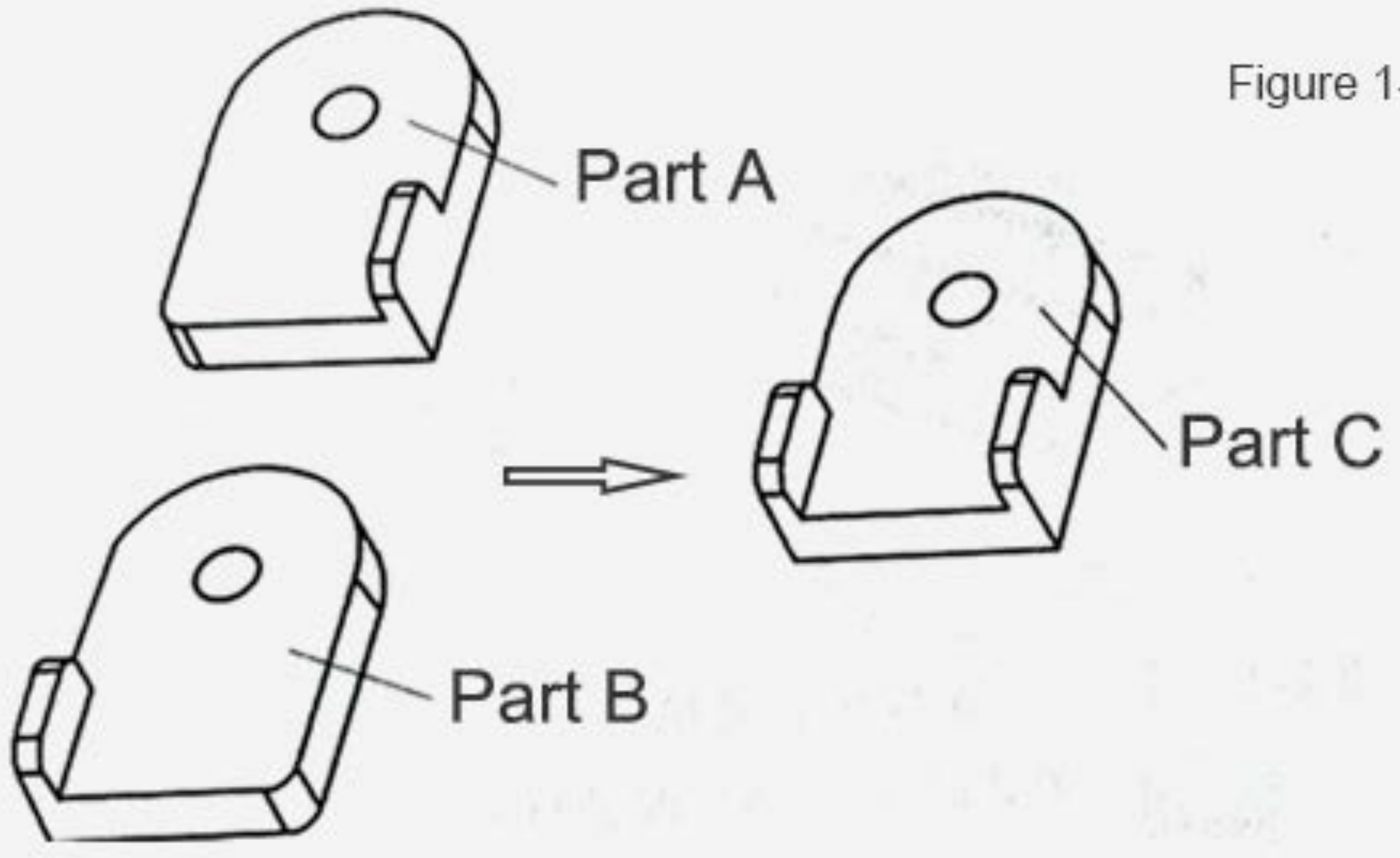


Figure 1-3 Symmetrical parts merge into one part

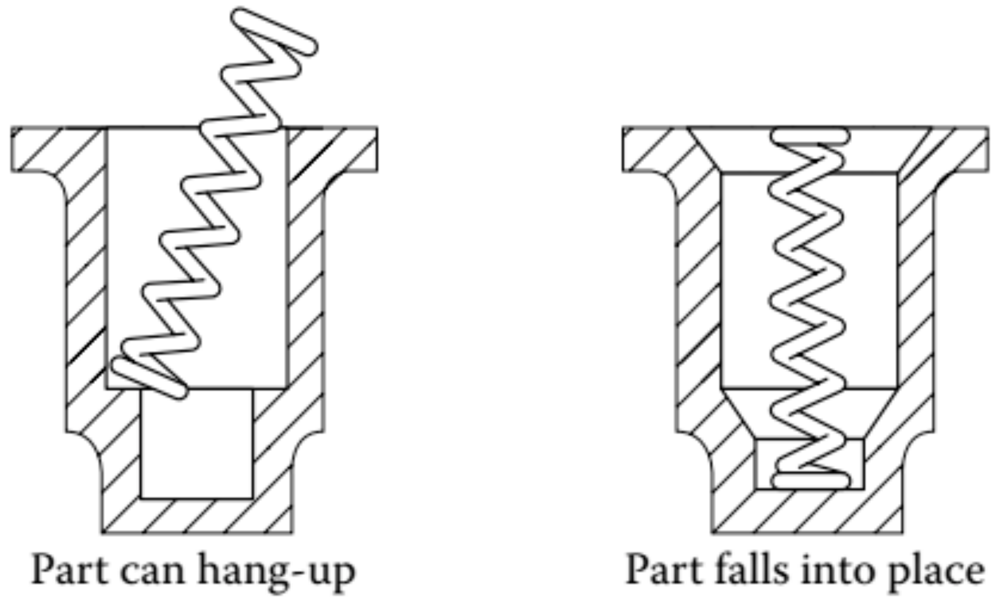
new technology: part reduction
vs user experience…

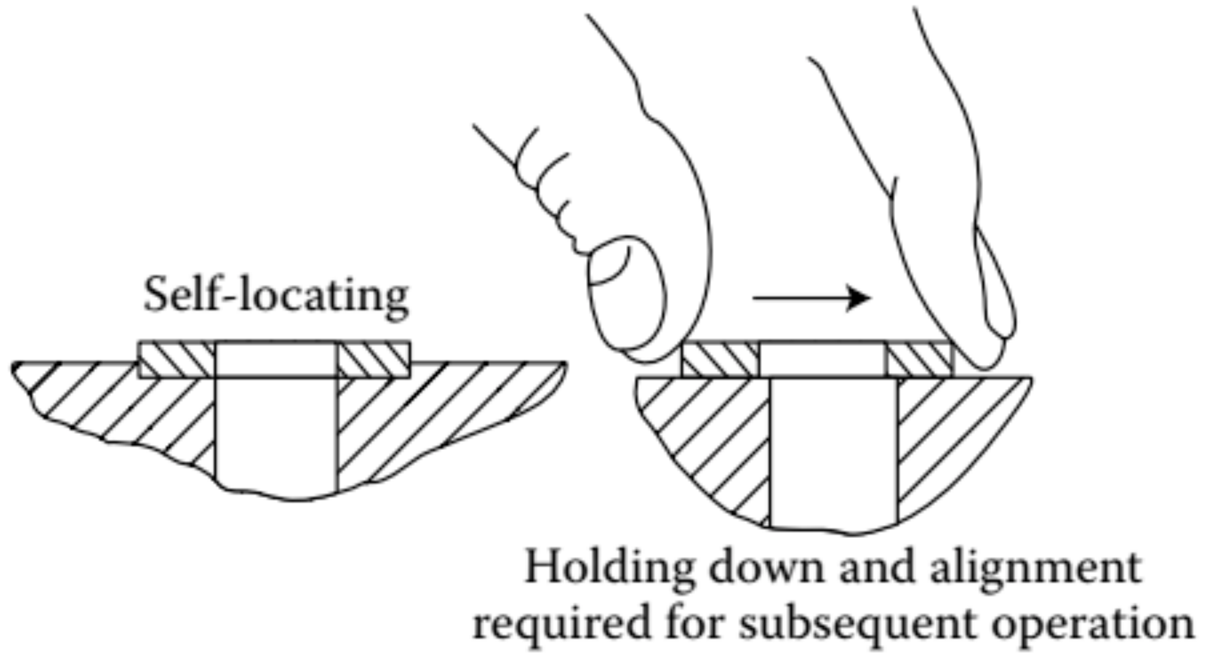
Figure 1-7 Evolution of mobile phones

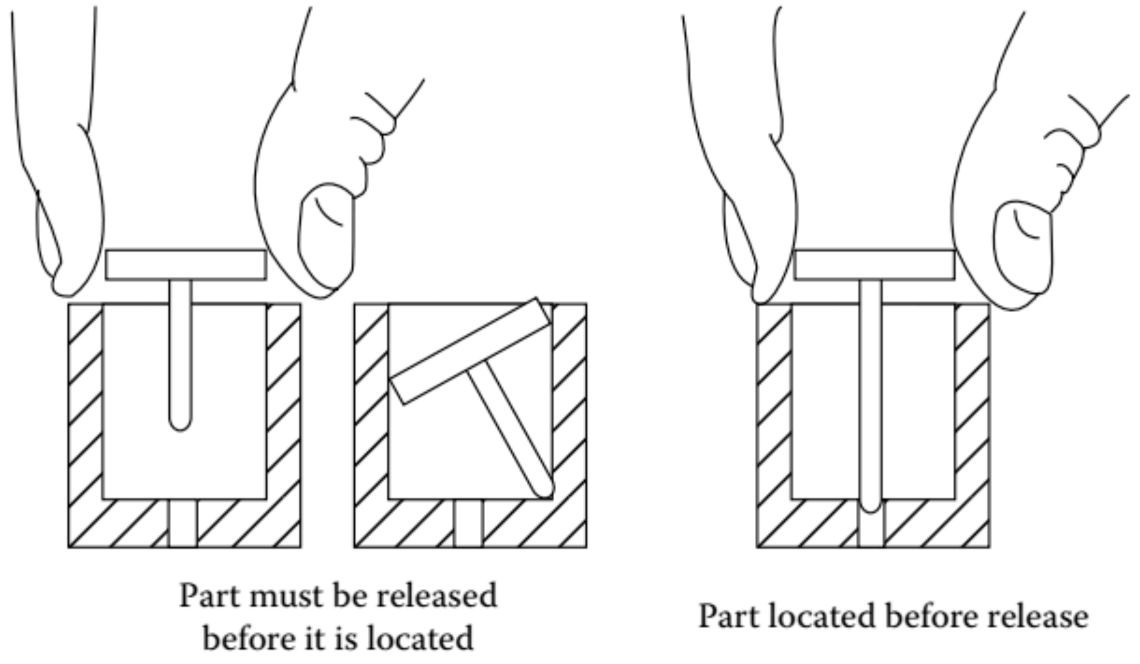
2) Make the parts easier to assemble

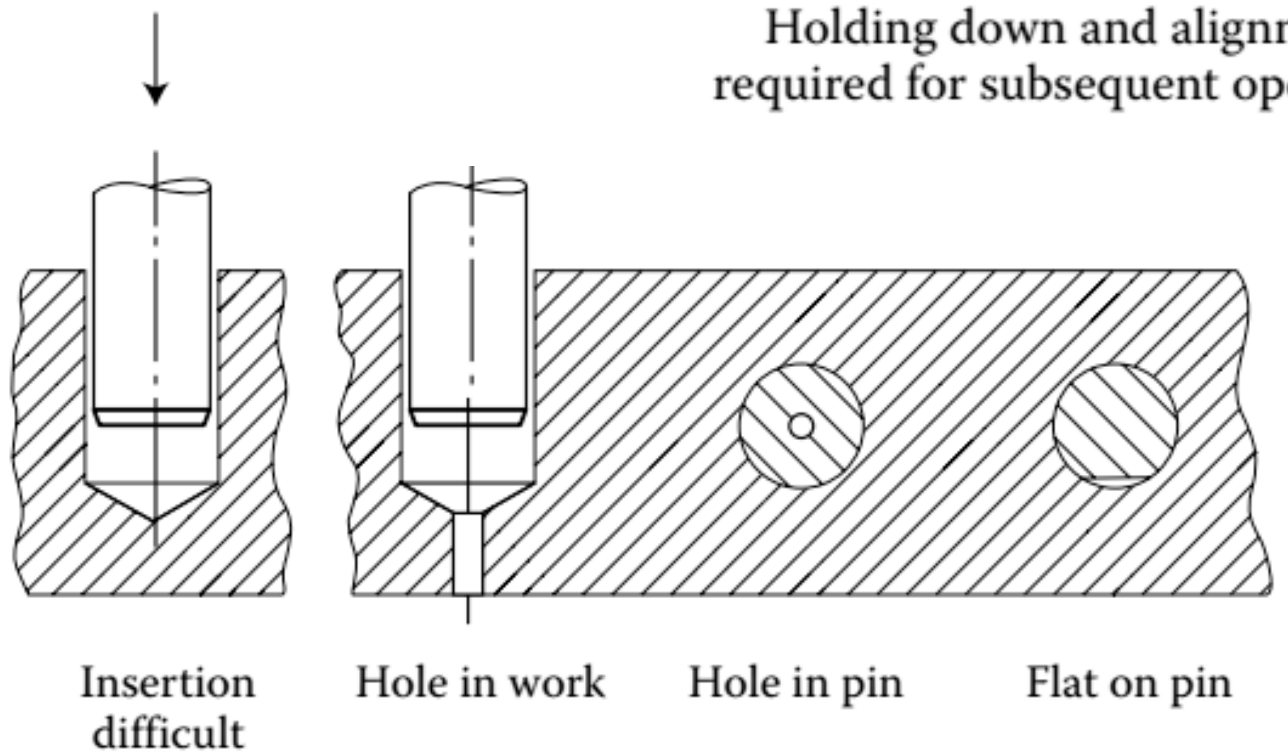
consider

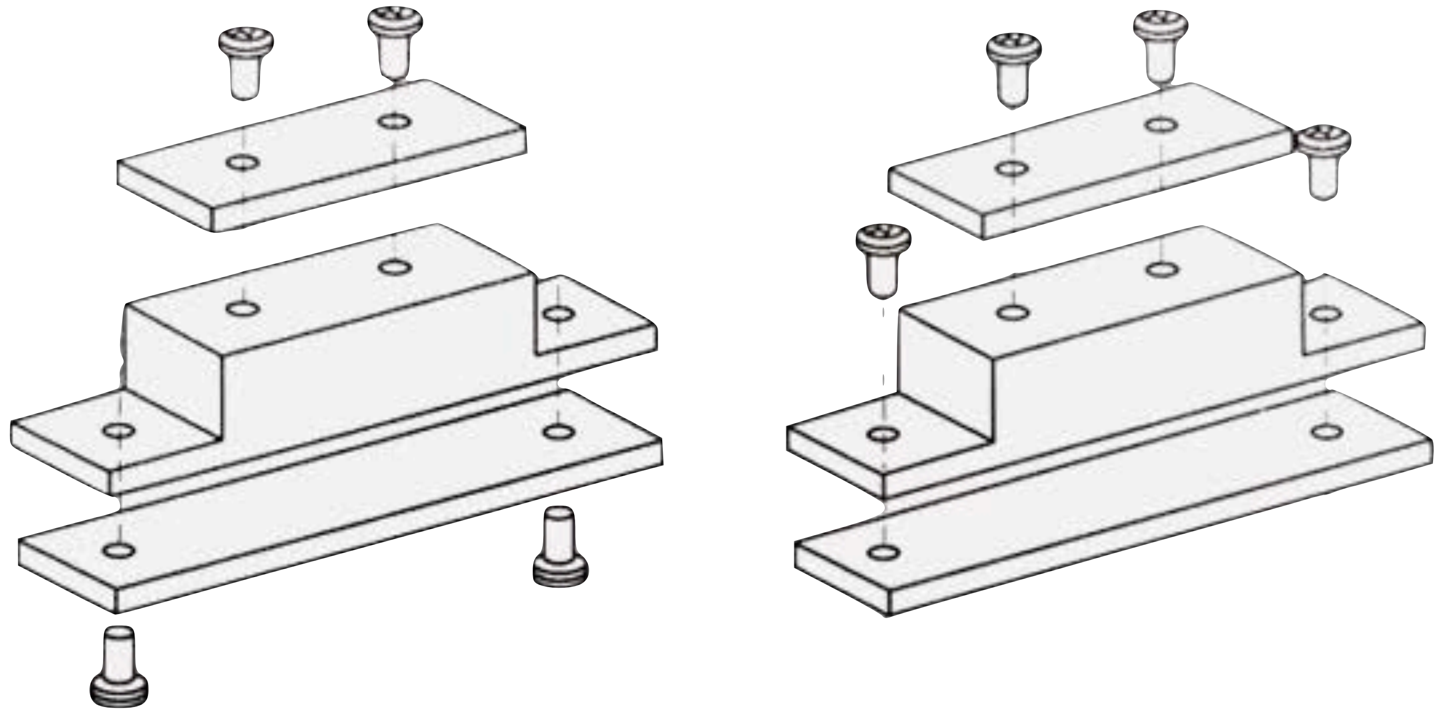
- fixturing
- ergonomics
- dexterity
- health and safety
- automatability







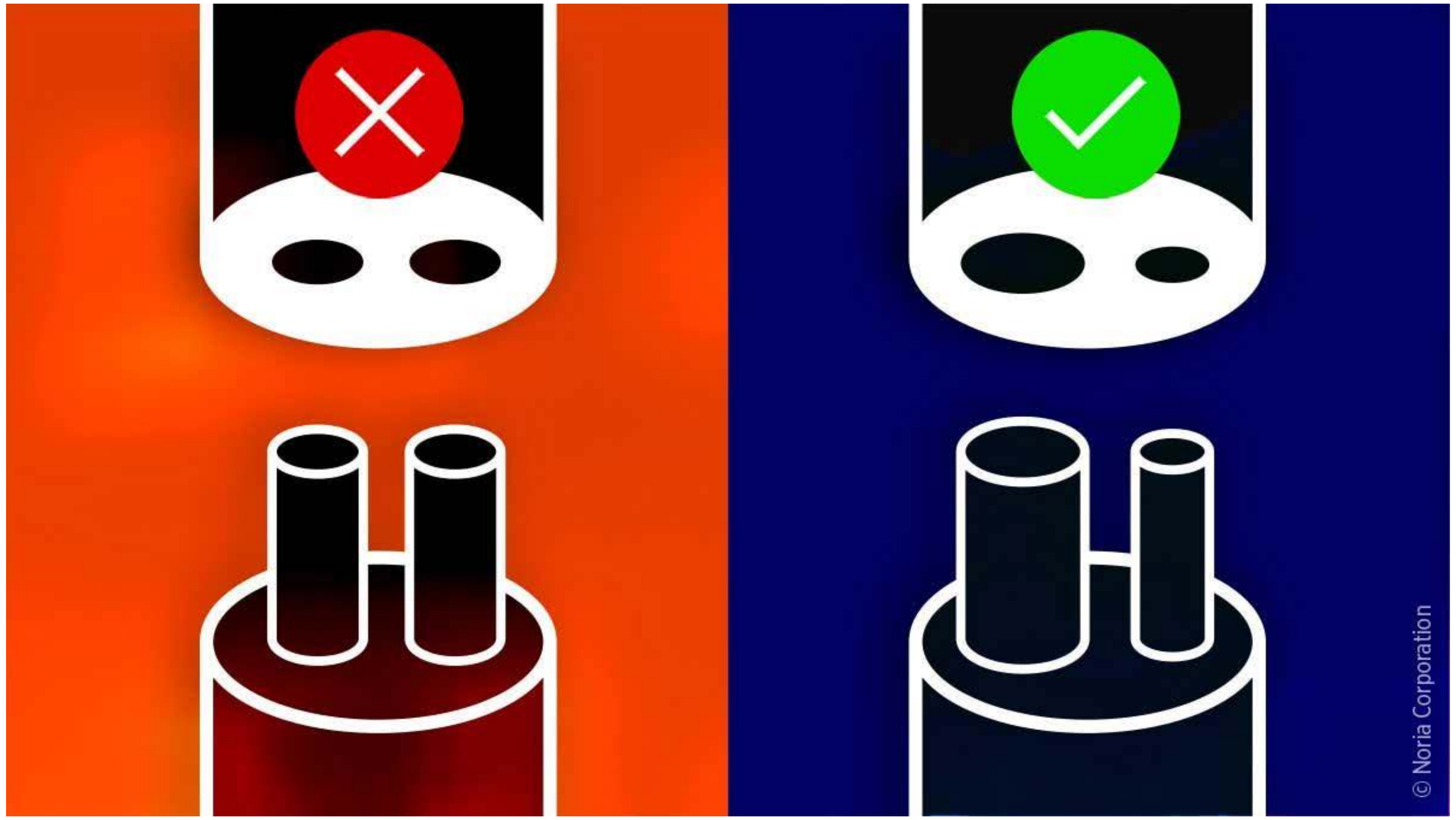


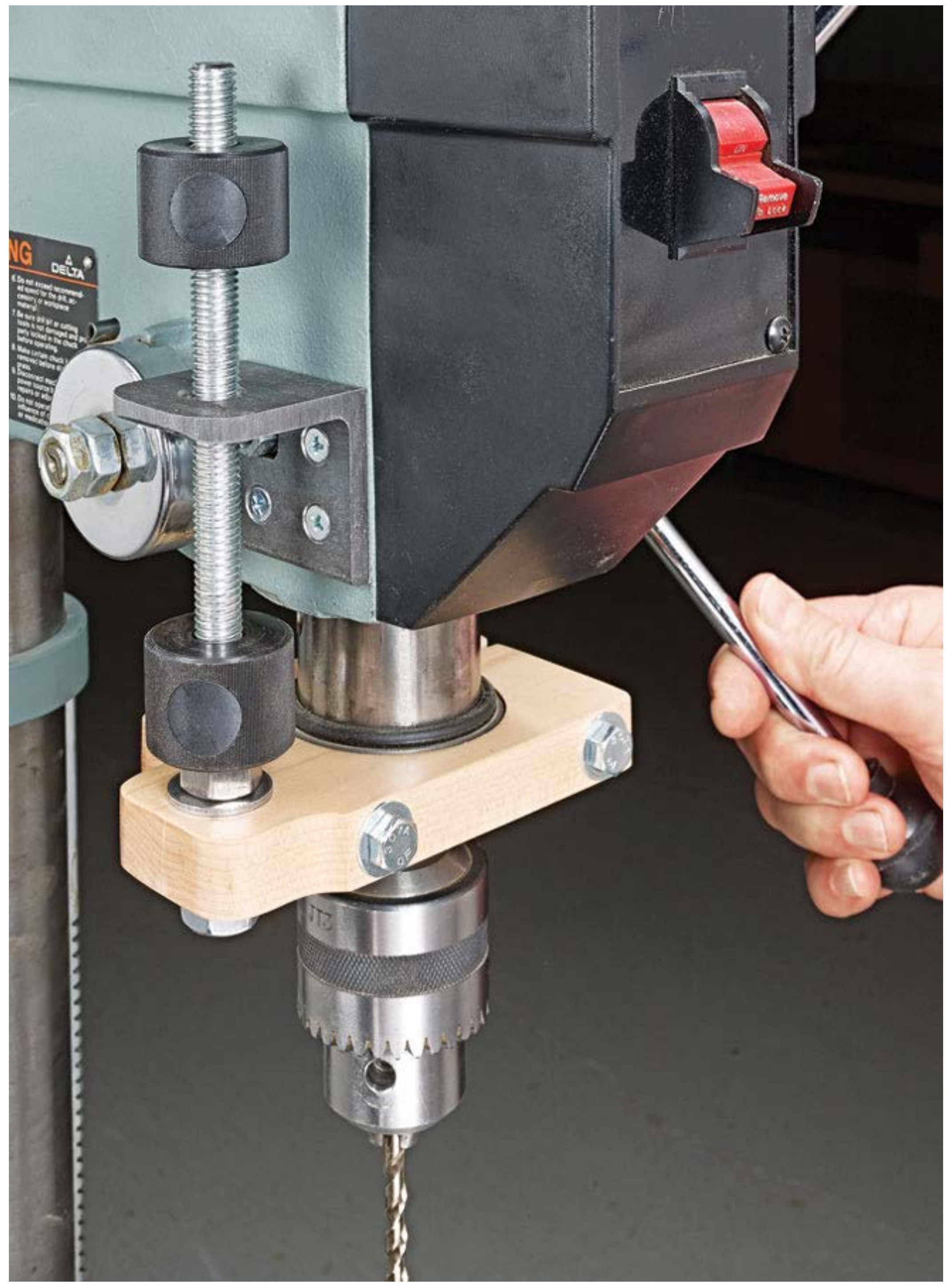


minimize assembly directions

2) Make the parts easier to assemble

Poka-yoke or "mistake proofing"





different levels: can't do it wrong/get a warning if it's wrong/looks obviously wrong

Manufacturing Systems

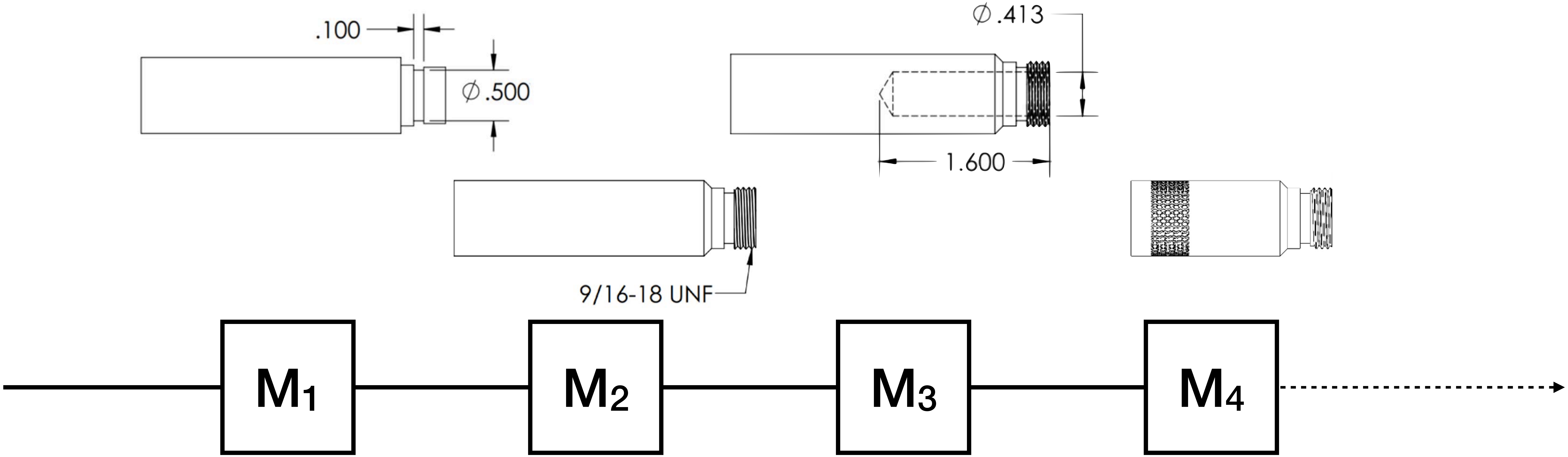
not just making parts from raw materials, but the context of bringing them all together

factories, plants, supply chains, material flow, efficiency and economy of scale

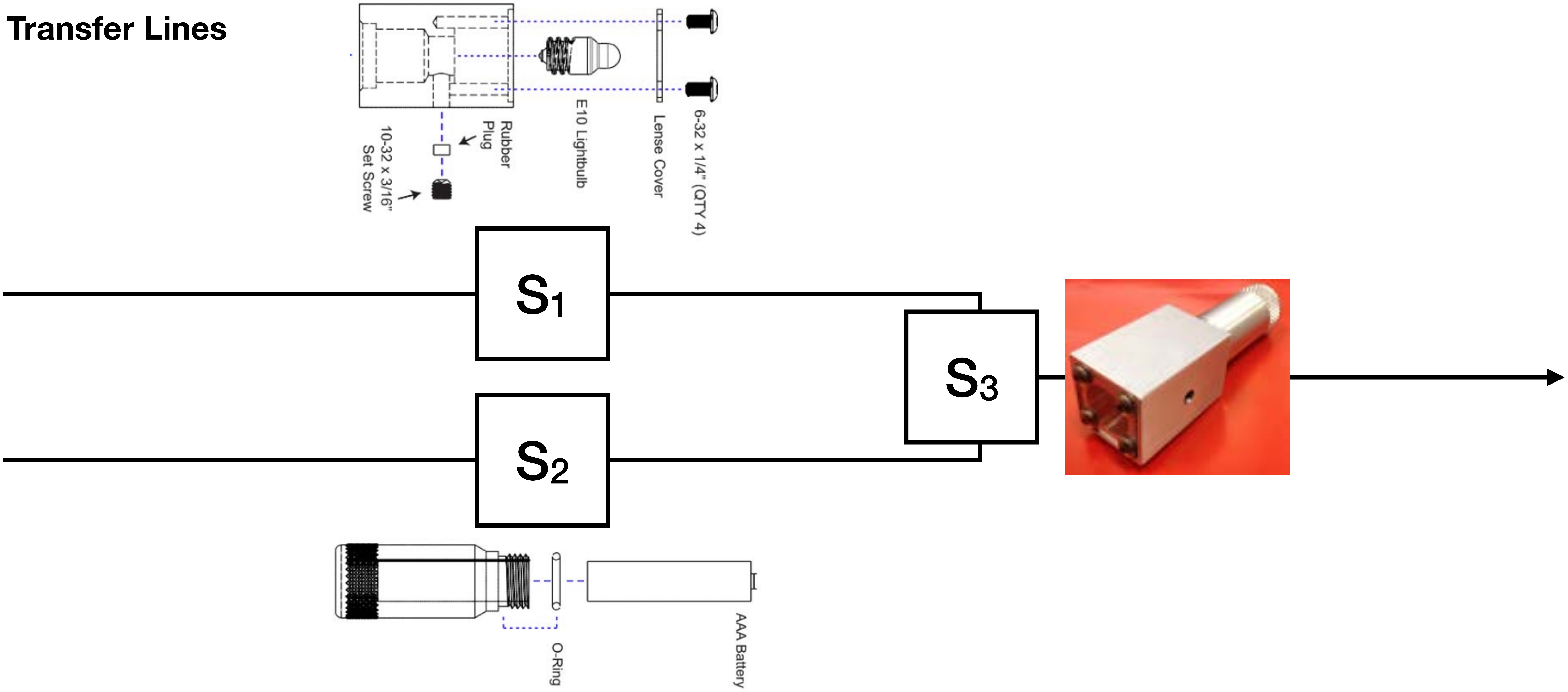
“well orchestrated dance”

if **everything** is not in place, the whole line might stop

Transfer Lines



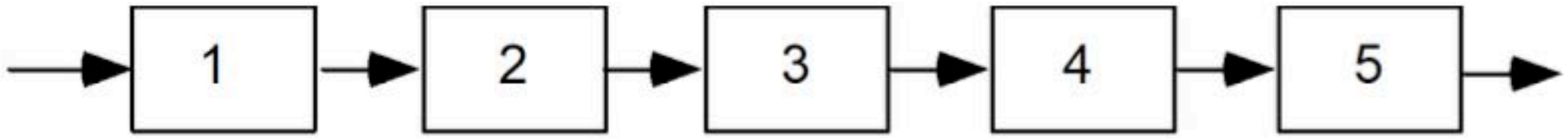
Transfer Lines



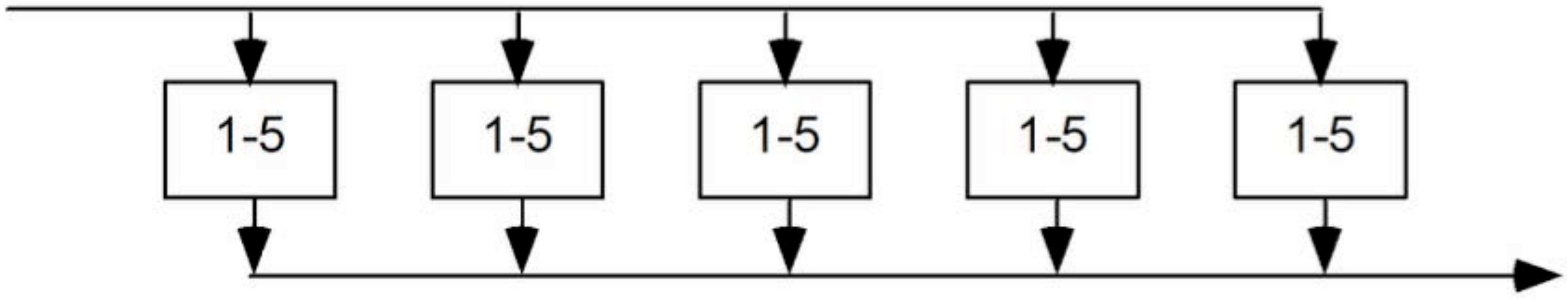
Line Architectures

serial line

parallel line



Series Task Arrangement



Parallel Task Arrangement

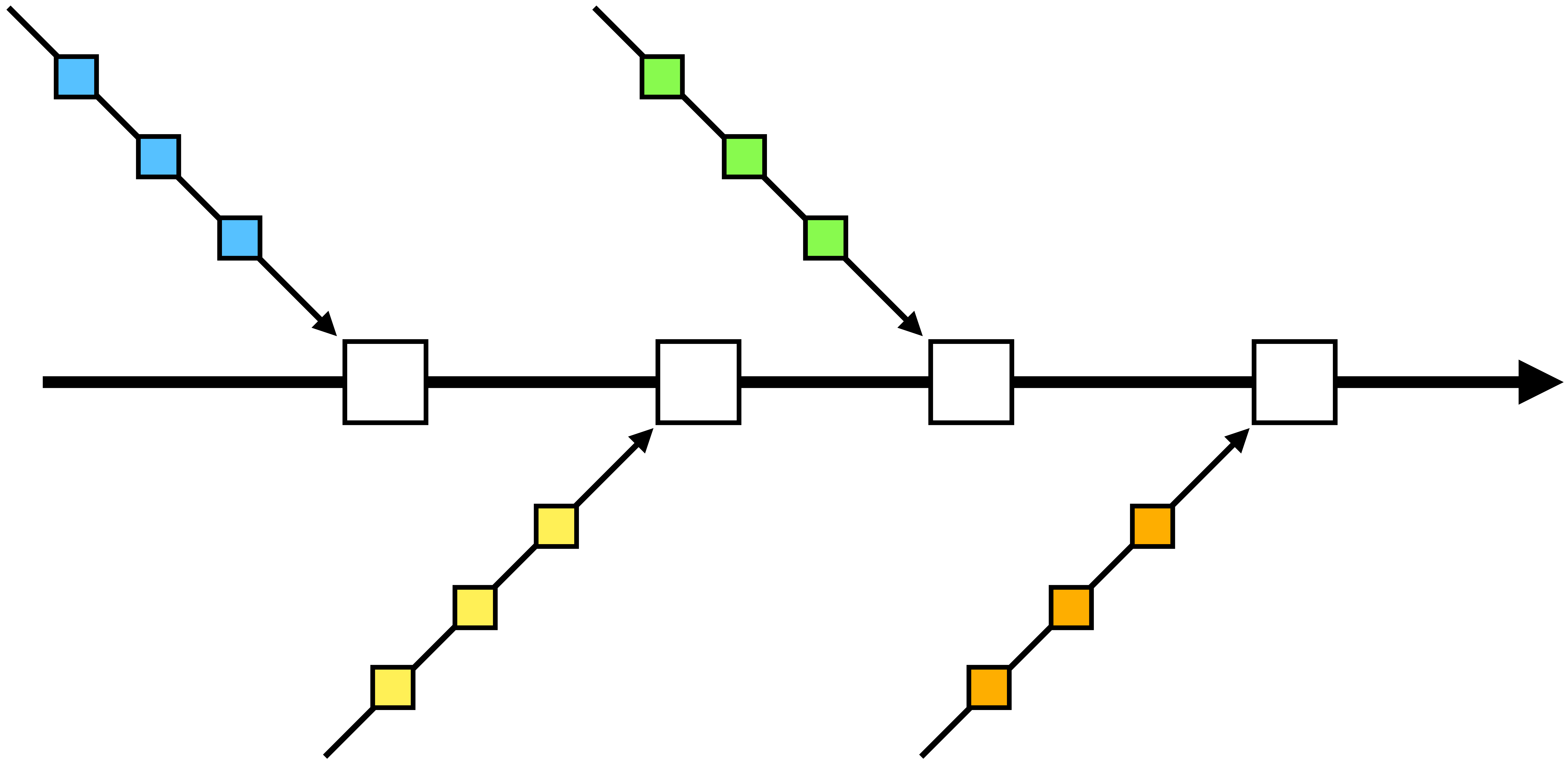
How do they compare on tool cost, reliability, time, flexibility?

Line Architectures

serial line

parallel line

fishbone line



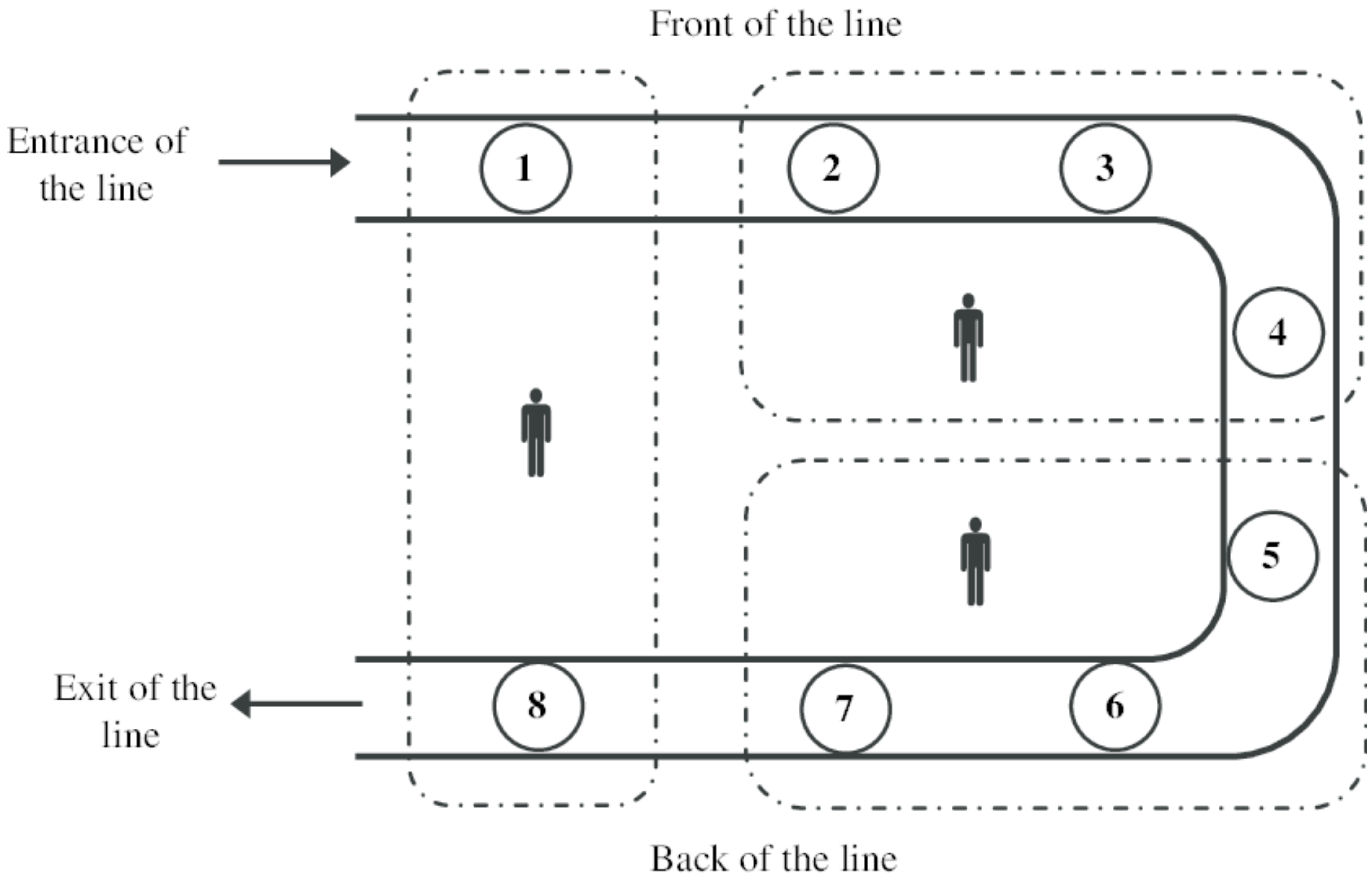
Line Architectures

serial line

parallel line

fishbone line

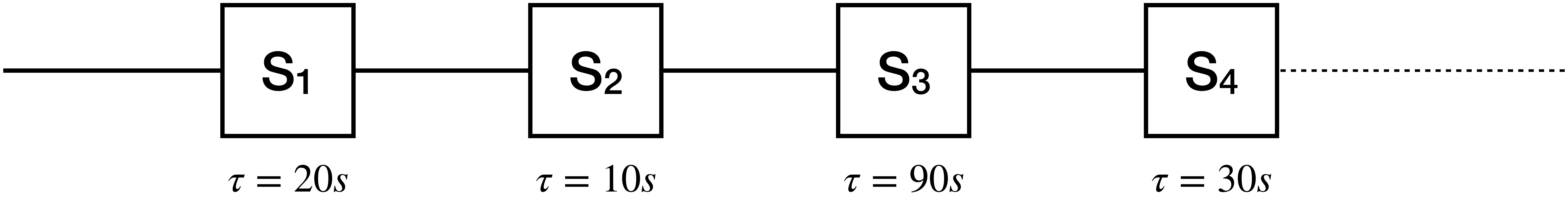
U-shaped line
or “cell"



Line Balancing

parts are flowing from station to station to be assembled…

what if the assembly processes take different amounts of time?



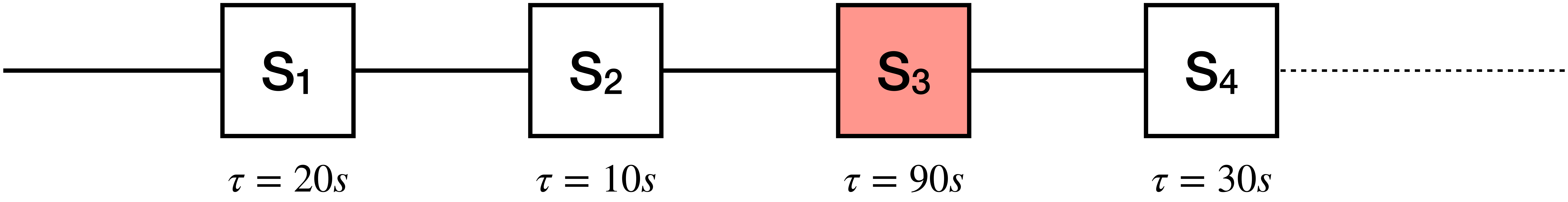
τ: operation time (time per part)

Bottlenecks

overall production rate is determined by the bottleneck - you always want it to be utilized!

slow stations make fast stations wait

what can you do to fix this problem?

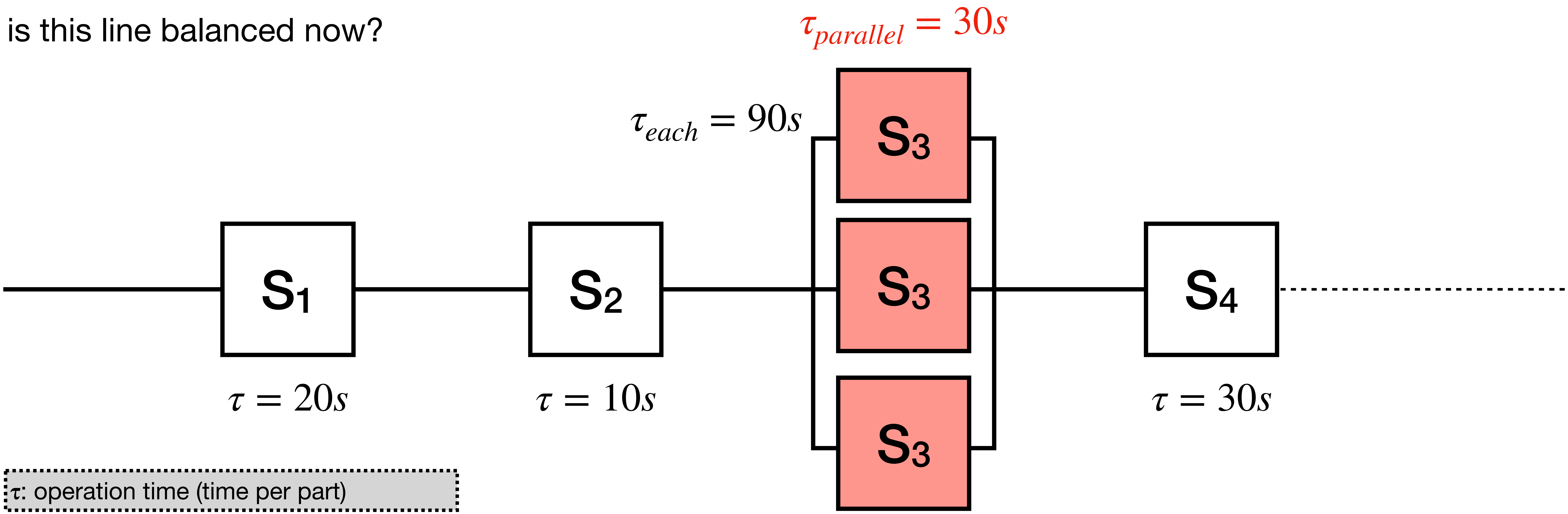


τ: operation time (time per part)

Line Balancing

you might need extra stations for slower operations

is this line balanced now?



τ: operation time (time per part)

Product Line Strategies

Subaru Crosstrek

Subaru Impreza

same platform

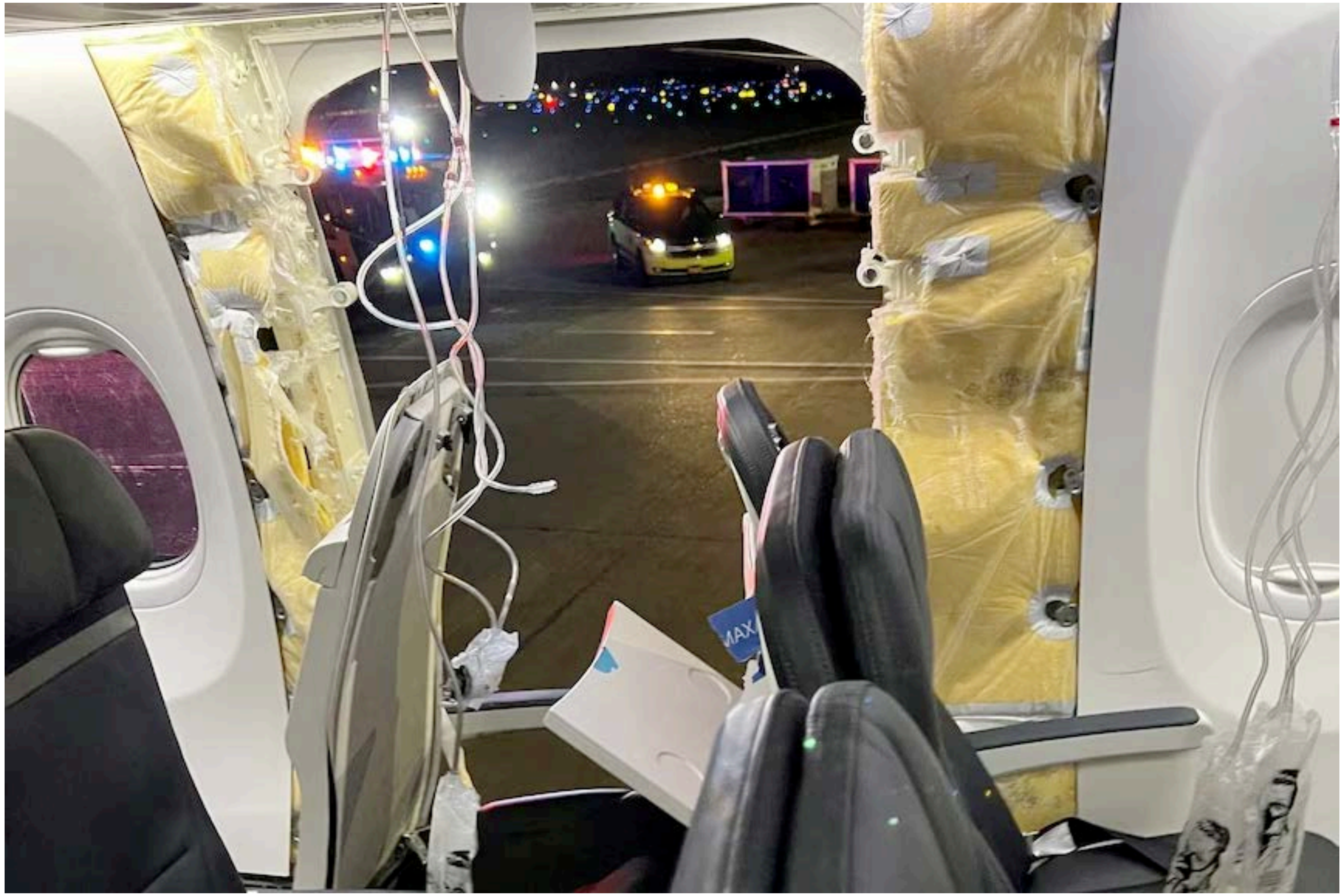
Subaru WRX

where is the “decoupling point”?

how do you create the right “mix” to match demand?

Ford: “you can have any color you want, as long as it’s black” - 12 hr to 90min moving assembly line

Product Line Strategies



Boeing 737 Max 9: why are there door plugs anyway?

same fuselage for multiple seating configurations: better than making more plane models!

Tolerances

all processes have variation: some you can influence and some you cannot

designers specify how much variation can be tolerated while the design goals can still be achieved

manufacturers specify the achievable tolerances based on the variation of a process they control

tolerances stack in assemblies, combining the effects of individual part variations

$h_5 \pm tol_5$

$h_4 \pm tol_4$

$h_3 \pm tol_3$

$h_2 \pm tol_2$

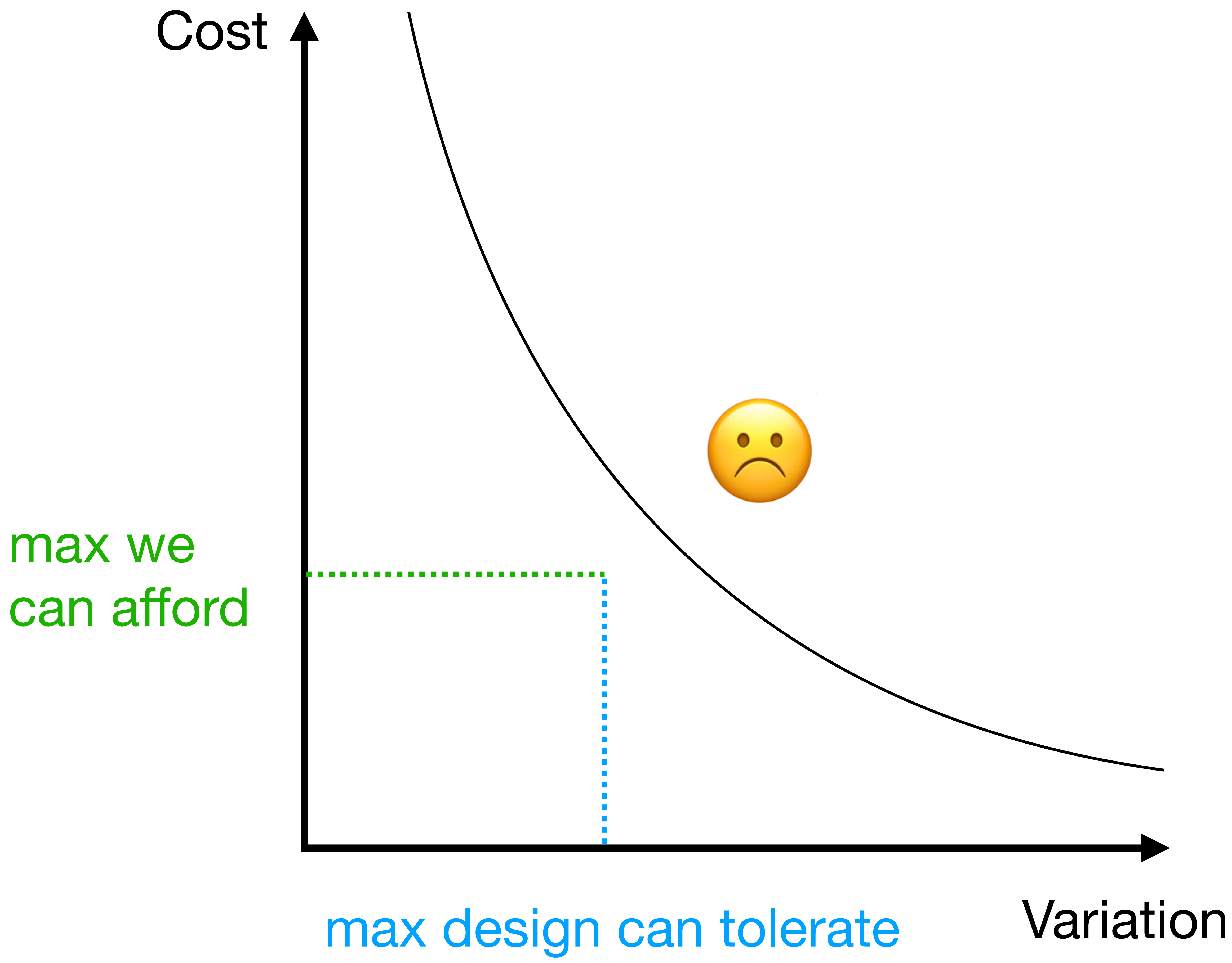
$h_1 \pm tol_1$

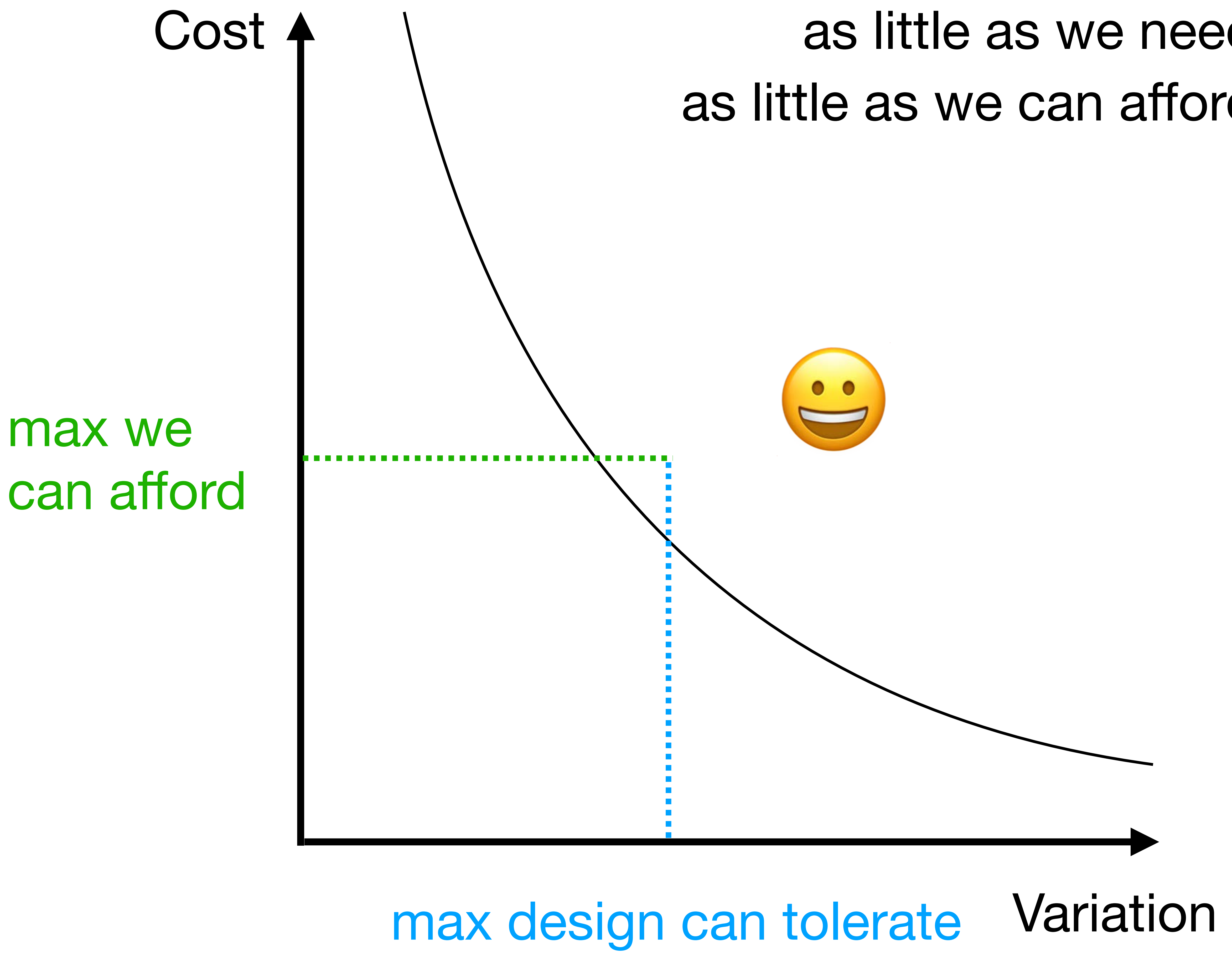
tolerance of final height depends on tolerances of each layer

use statistics to characterize variation of final height σ_{final}

Variation vs Cost

how much variation is acceptable?
as little as possible?
as little as we need?
as little as we can afford?





Tolerances

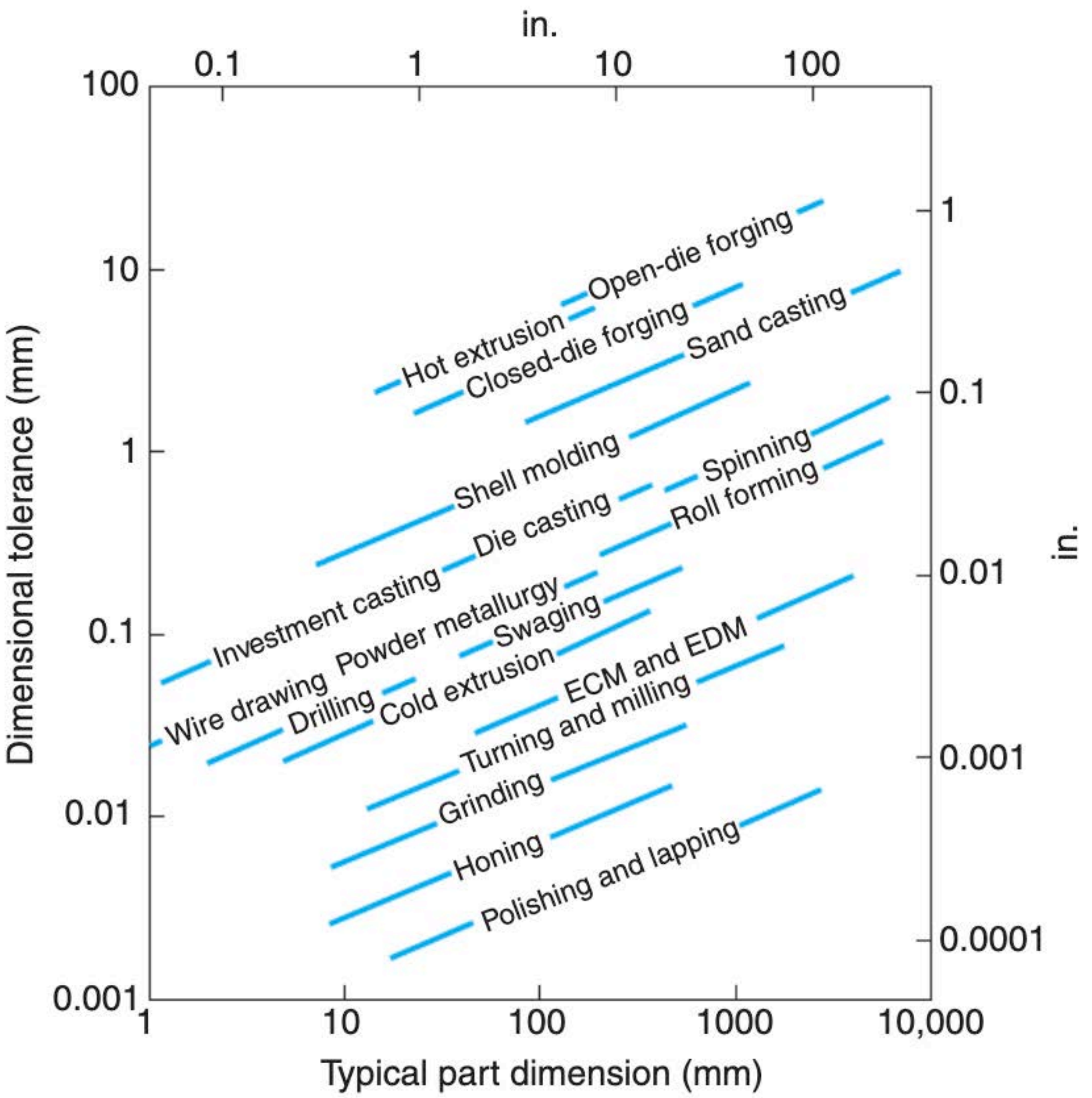
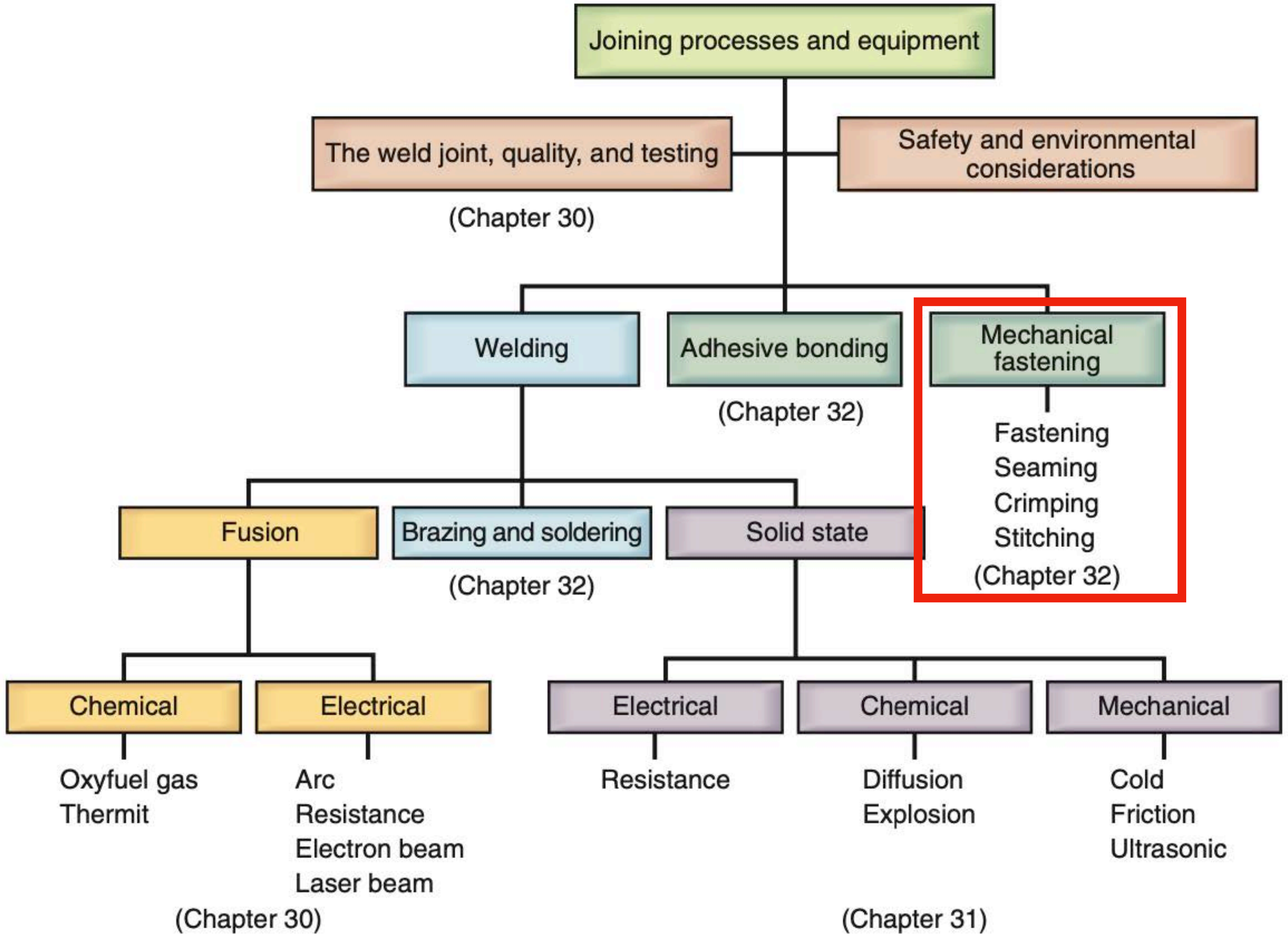


FIGURE 35.20 Dimensional tolerances as a function of part size for various manufacturing processes; note that because many factors are involved, there is a broad range for tolerances.

Process Planning: Your “Well Orchestrated Dance” Plan

which manufacturing methods + joining methods (plus all of the logistical details to make it happen)



Mechanical Fastening

Type of Fasteners

- bolts/screws
  - disassembly/reassembly
  - cross threading
- rivets
  - when disassembly not required
- dowel pins
- cotter pins
- snap fits

Mechanical Fastening

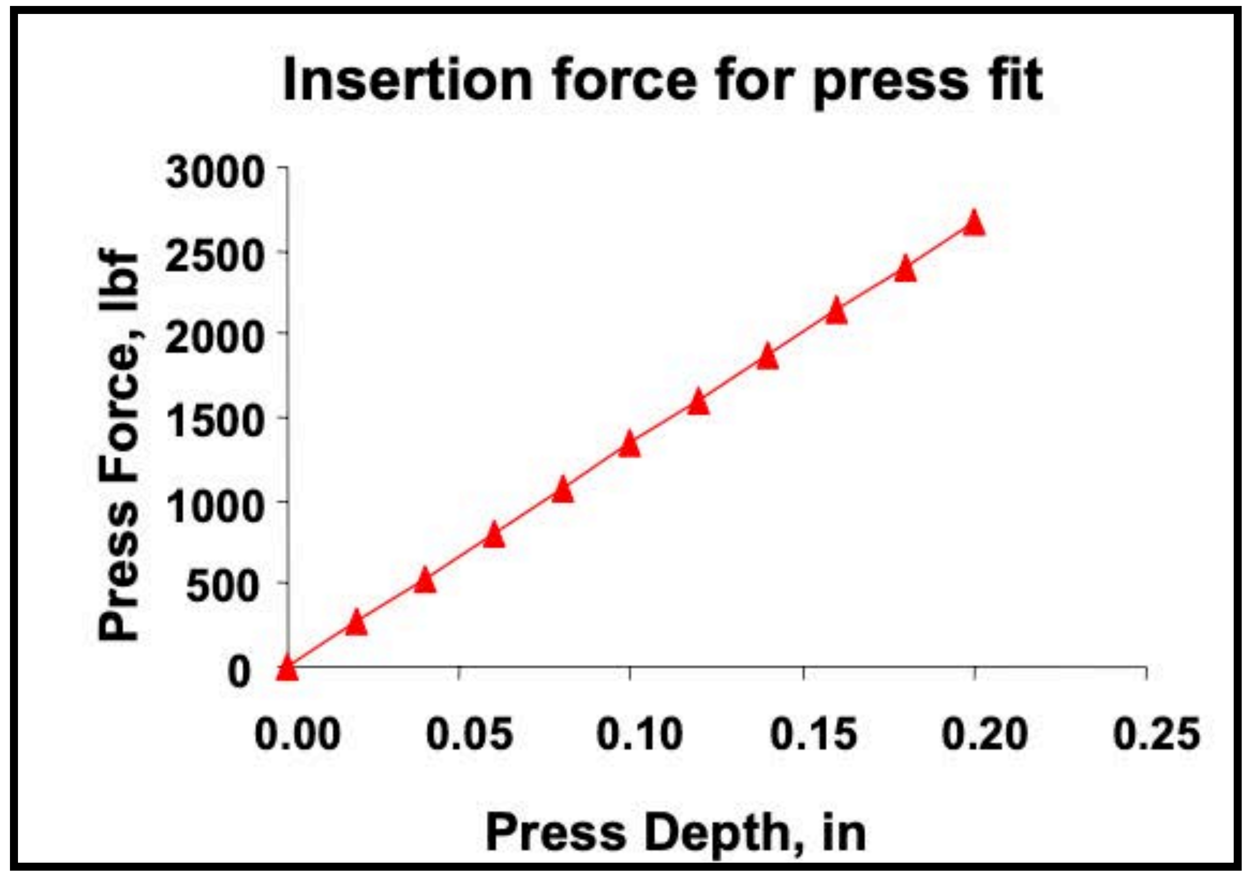
Considerations

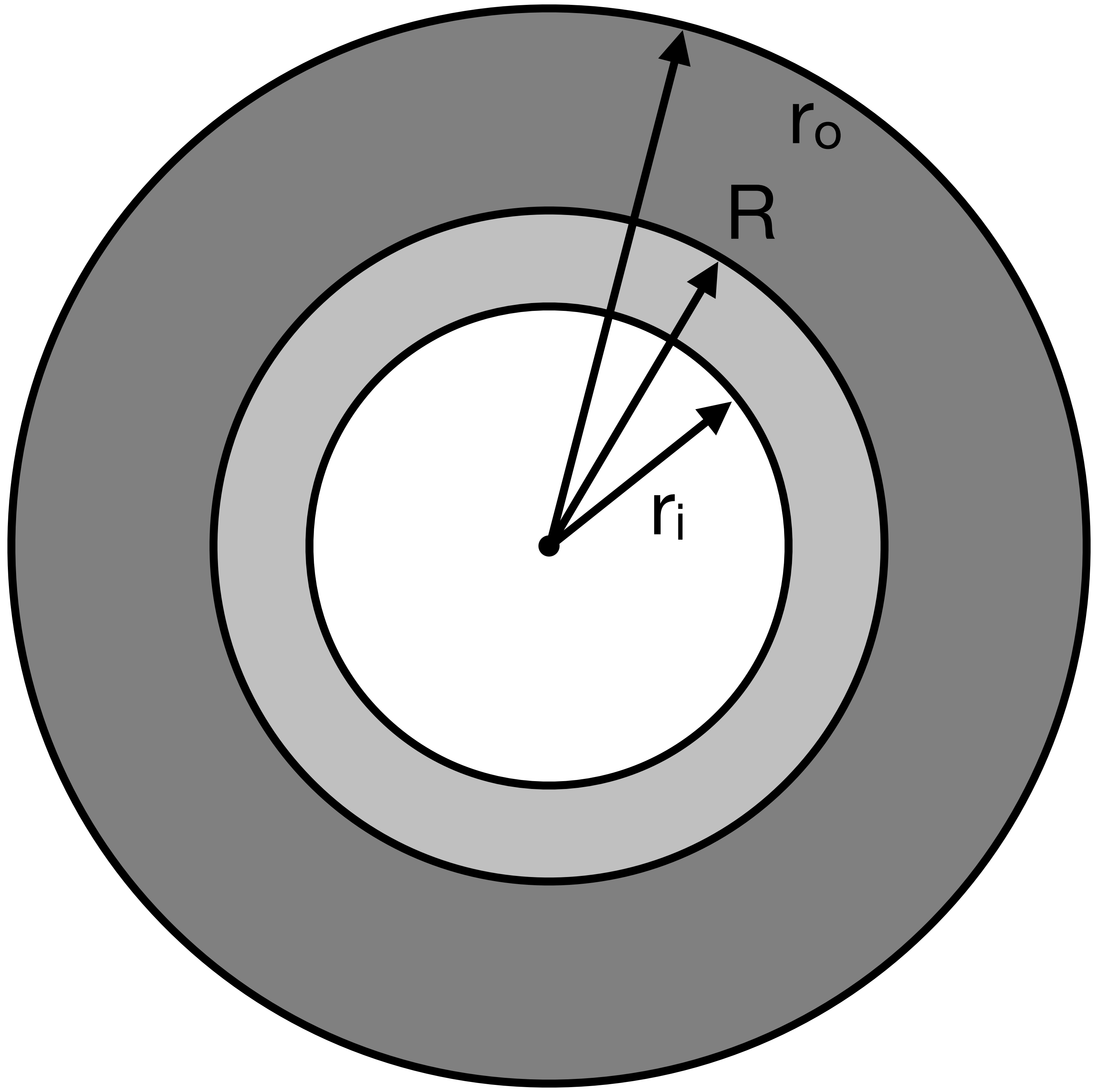
- any shape and material
- semi-permanent
- least expensive for low volume
- limited strength and sealing
- increases part count
- assembly can be challenging
- loosen over time

Mechanical Fastening: Press/Shrink Fits

two cylinders of the same length pressed to interfere

or, one body is heated to expand, and then allowed to cool over the other part





$$p = \frac{E}{R}\delta\left(\frac{\left(r_0^2 - R^2\right)\left(R^2 - r_i^2\right)}{2R^2\left(r_0^2 - r_i^2\right)}\right) \rightarrow F_{insert} = \mu p 2\pi R x_{insert}$$

$$\delta_{thermal} = \alpha R \Delta T$$

p: interface pressure, [Pa] or [psi]
E: Young's Modulus, [Pa] or [psi]
δ: radial interference [m] or [in]
α: coefficient of thermal expansion [deg^{-1}] ⚠️
ΔT: temperature change [deg]
x_{insert}: length of engagement [m] or [in]

Mechanical Fastening: Press/Shrink Fits

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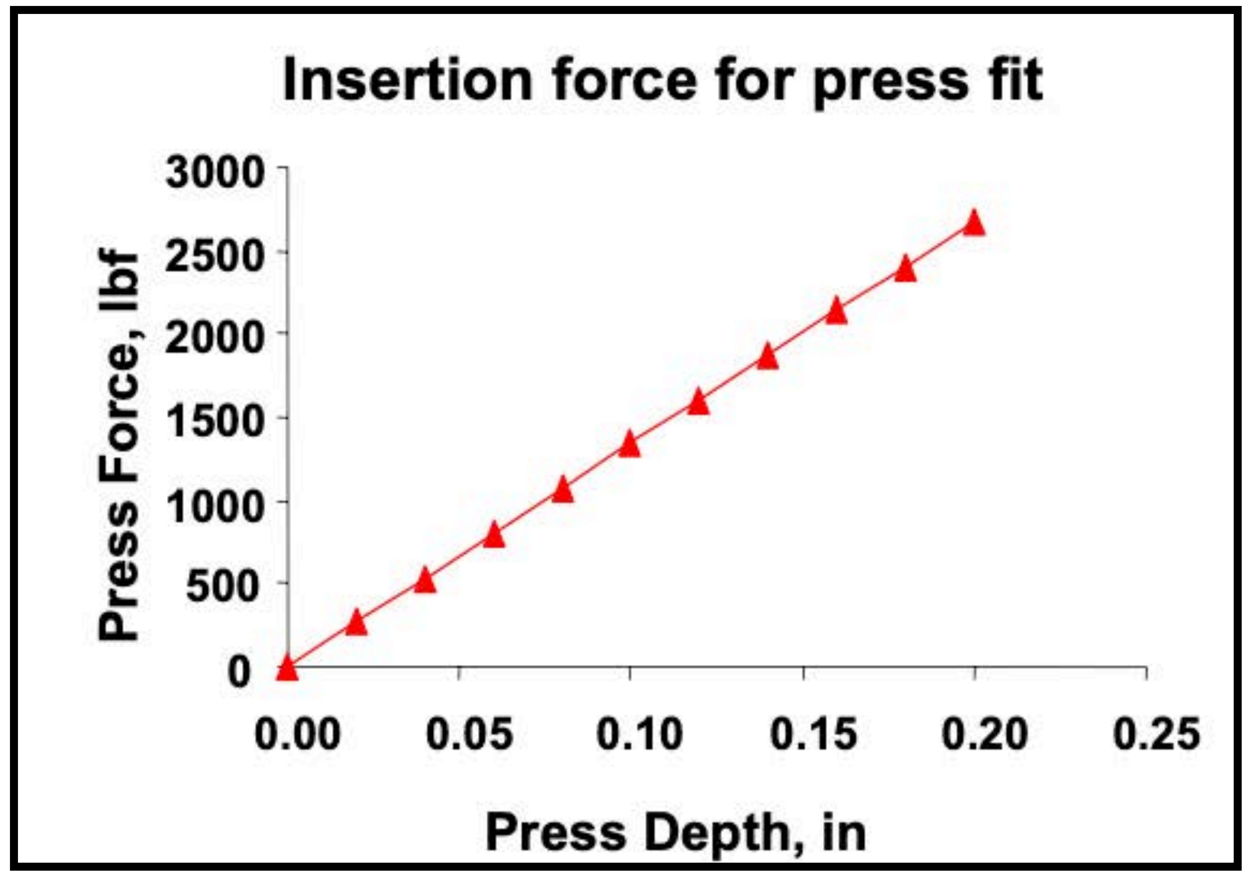

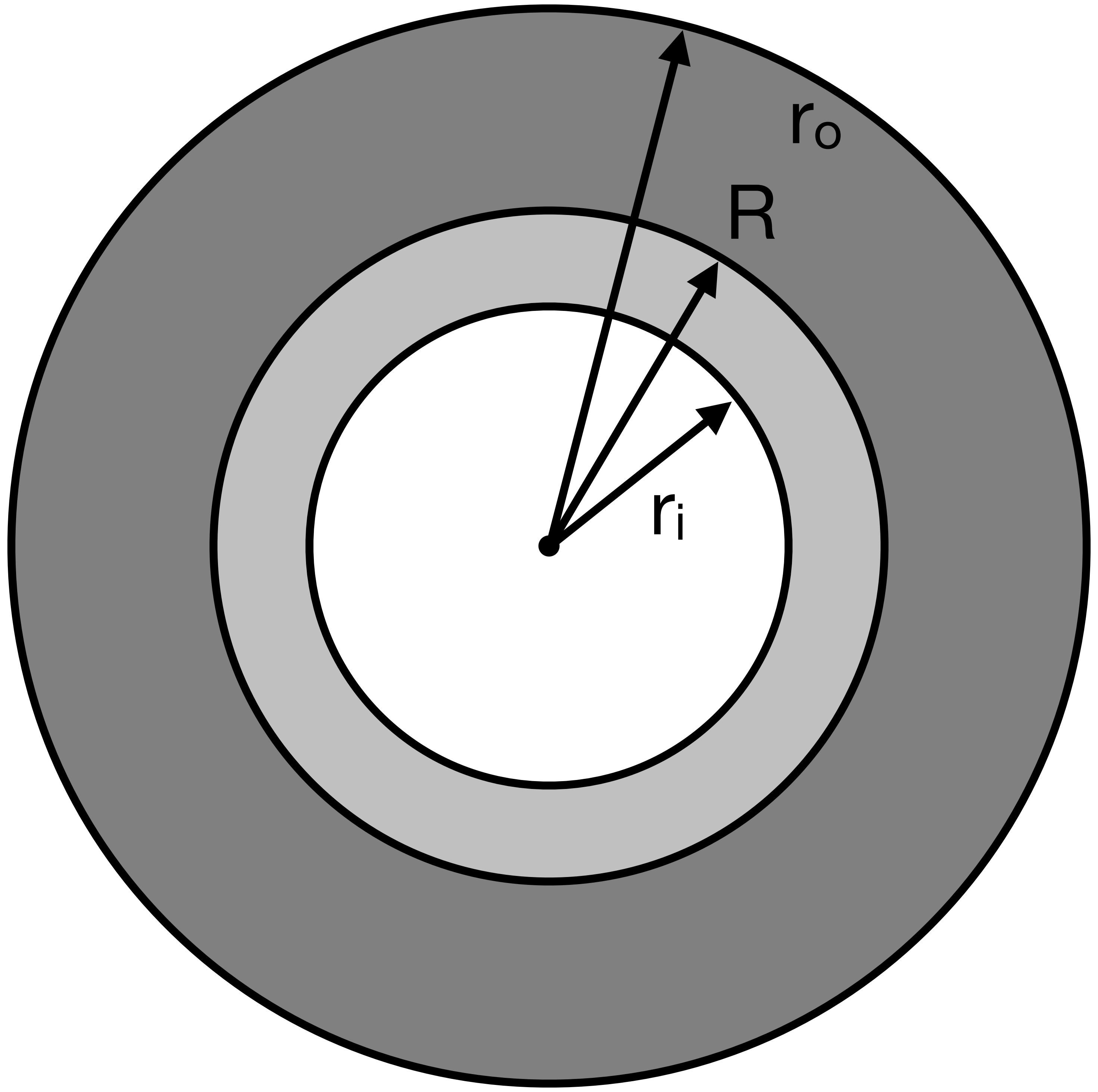

$$p = \frac{E}{R}\delta\left(\frac{\left(r_0^2 - R^2\right)\left(R^2 - r_i^2\right)}{2R^2\left(r_0^2 - r_i^2\right)}\right) \rightarrow F_{insert} = \mu p 2\pi R x_{insert}$$

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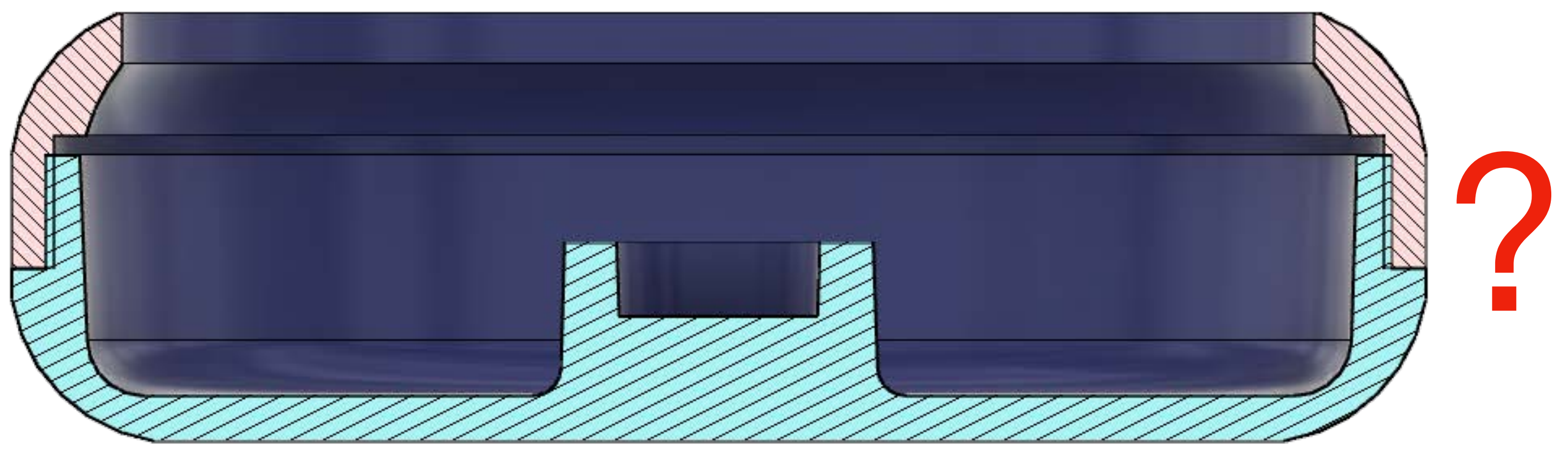

p: interface pressure, [Pa] or [psi]

E: Young's Modulus, [Pa] or [psi]

δ: radial interference [m] or [in]

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ΔT: temperature change [deg]

x_{insert}: length of engagement [m] or [in]

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