Process Planning

Manufacturing Planning and Cost

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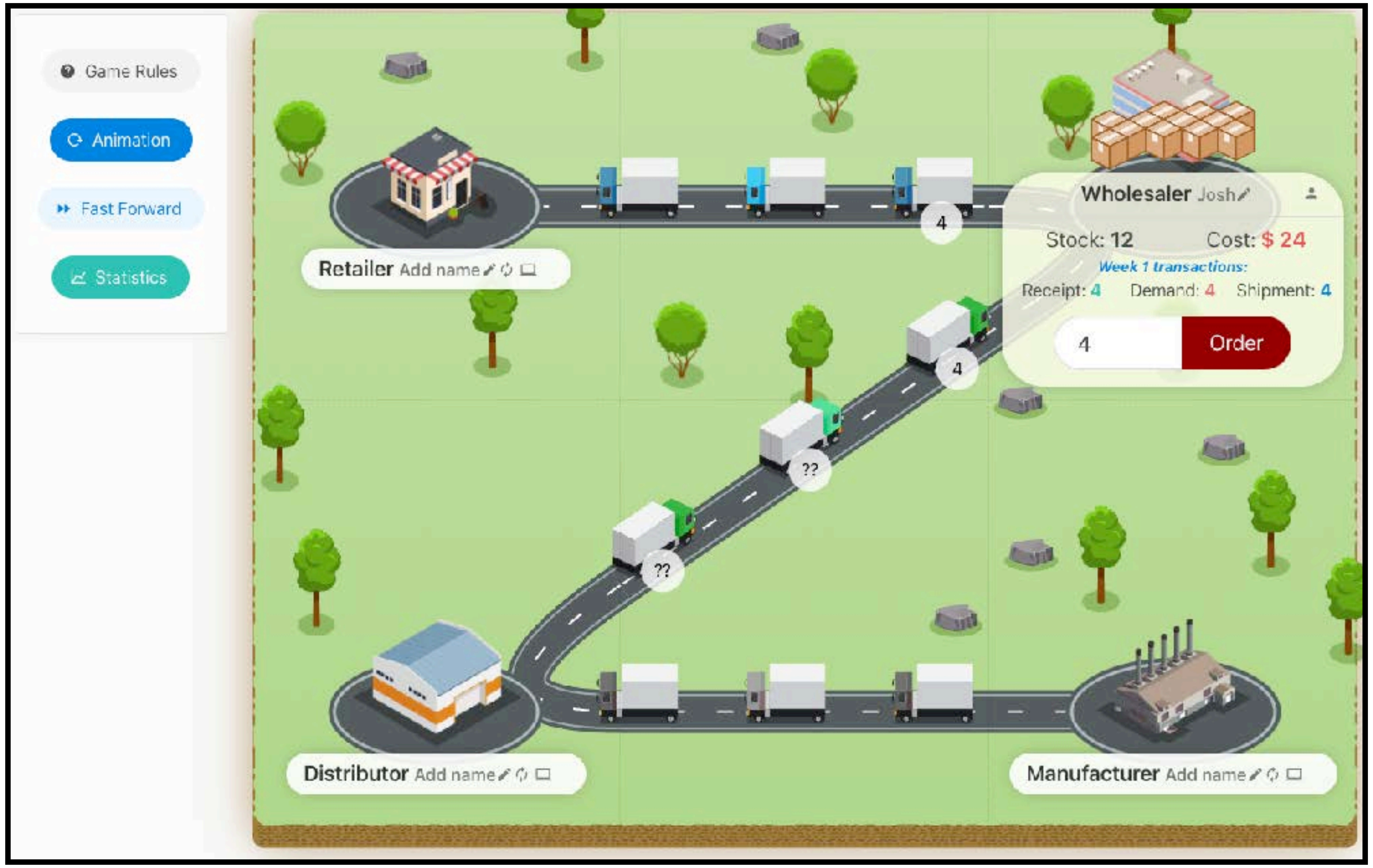
Beer Game Results

Melinda, Kayla, Kimaya, Avani

	Game 1	Game 2
2.008 Team 01	-$8,861.00	-$2,800.00
2.008 Team 03	-$33,227.00	-$1,029.00
2.008 Team 04	-$16,756.00	-$1,325.00
2.008 Team 05	-$2,218.00	-$1,753.00
2.008 Team 06	-$14,616.00	-$1,150.00
2.008 Team 07	-$6,172.00	-$1,239.00
2.008 Team 08	-$16,863.00	-$1,868.00
2.008 Team 09	-$4,696.00	-$620.00

Wren, Tissany, Pau, Keiji



Beer Game Results

$$Improvement = 1 - \frac{Game\ 2\ Cost}{Game\ 1\ Cost}$$

	Game 1	Game 2	% Improvement
2.008 Team 01	-$8,861.00	-$2,800.00	68%
2.008 Team 03	-$33,227.00	-$1,029.00	97%
2.008 Team 04	-$16,756.00	-$1,325.00	92%
2.008 Team 05	-$2,218.00	-$1,753.00	21%
2.008 Team 06	-$14,616.00	-$1,150.00	92%
2.008 Team 07	-$6,172.00	-$1,239.00	80%
2.008 Team 08	-$16,863.00	-$1,868.00	89%
2.008 Team 09	-$4,696.00	-$620.00	87%

S

	Game 1	Game 2	% Improvement
2.008 Team 01	-$6,001.00	-$1,374.00	77%
2.008 Team 03	-$12,370.00	-$1,744.00	86%
2.008 Team 04	-$2,327.00	-$1,109.00	52%
2.008 Team 05	-$41,375.00	-$3,134.00	92%
2.008 Team 06	-$14,402.00	-$1,733.00	88%

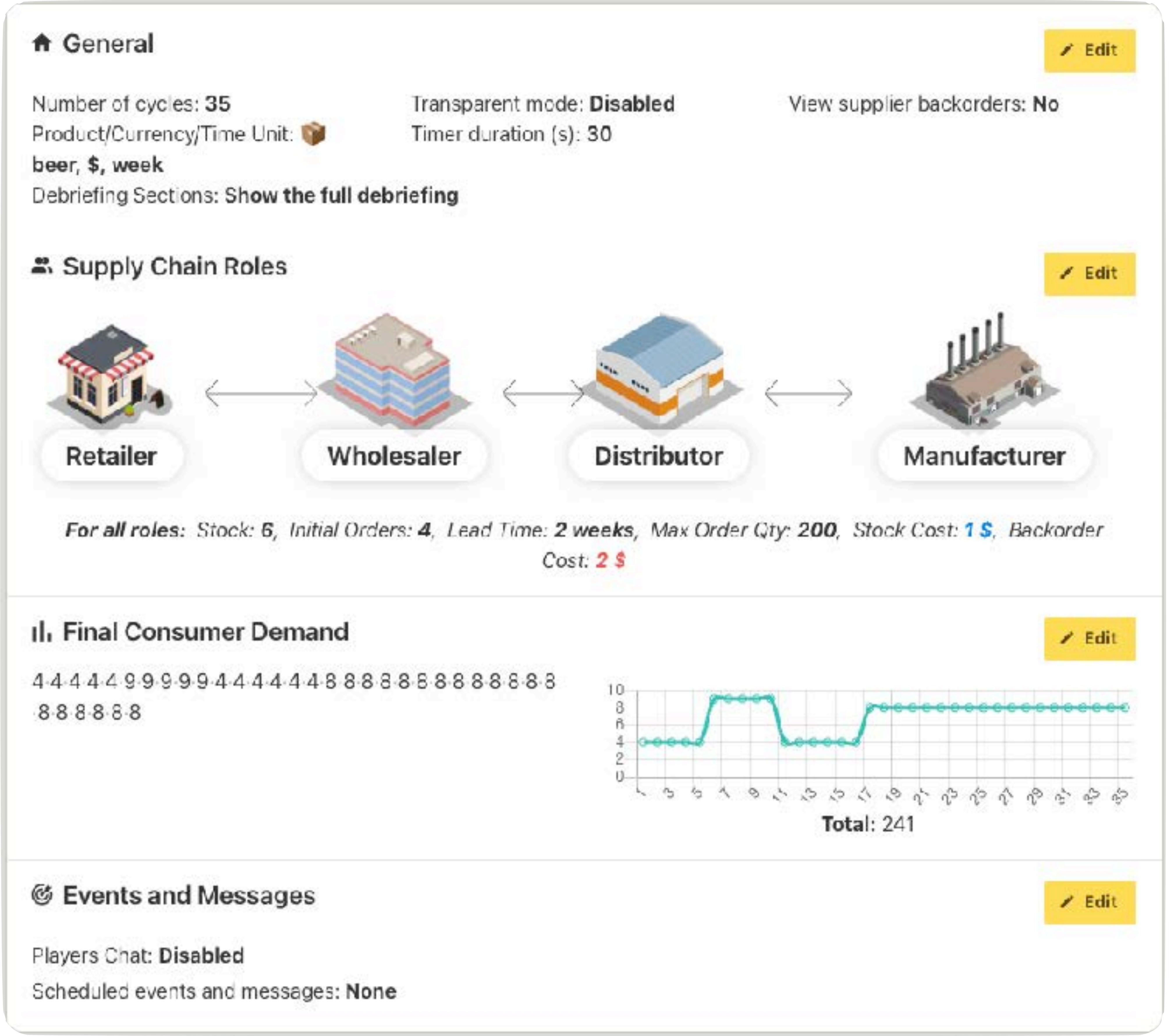
Beer Game Results

	Game 1	Game 2	% Improvement
2.008 Team 01	-$8,861.00	-$2,800.00	68%
2.008 Team 03	-$33,227.00	-$1,029.00	97%
2.008 Team 04	-$16,756.00	-$1,325.00	92%
2.008 Team 05	-$2,218.00	-$1,753.00	21%
2.008 Team 06	-$14,616.00	-$1,150.00	92%
2.008 Team 07	-$6,172.00	-$1,239.00	80%
2.008 Team 08	-$16,863.00	-$1,868.00	89%
2.008 Team 09	-$4,696.00	-$620.00	87%

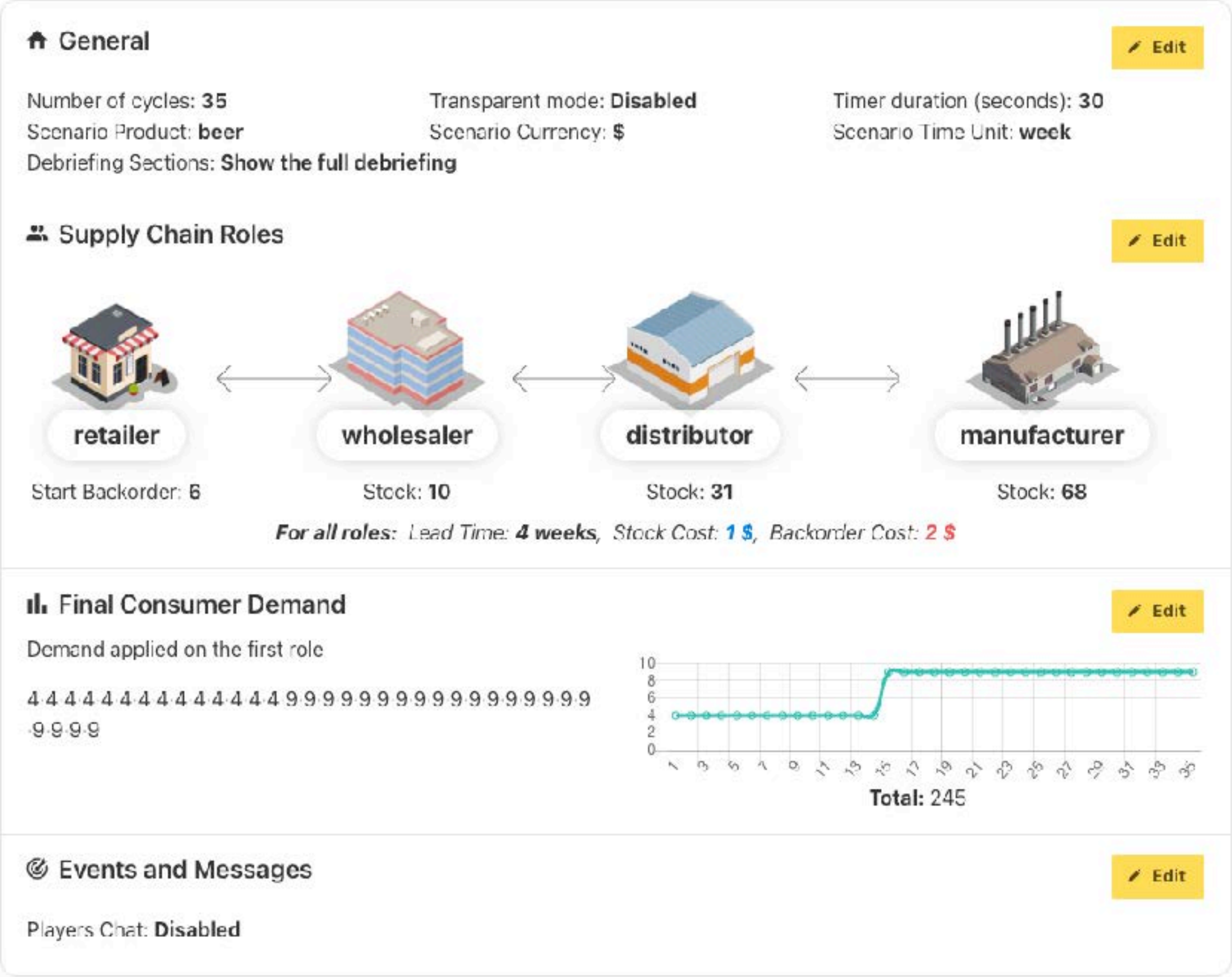
	Game 1	Game 2	% Improvement
2.810 Team 01	-$18,360.00	-$11,270.00	39%
2.810 Team 02	-$6,386.00	-$1,770.00	72%
2.810 Team 03	-$67,406.00	-$3,941.00	94%
2.810 Team 04	-$10,871.00	-$2,348.00	78%
2.810 Team 06	-$26,064.00	-$3,695.00	86%
2.810 Team 07	-$24,552.00	-$12,748.00	48%
2.810 Team 08	-$607,331.00	-$1,414.00	99.8%
2.810 Team 09	-$5,075.00	-$4,544.00	10%
2.810 Team 10	-$13,350.00	-$1,960.00	85%

Beer Game Results

2.008 S25 - Round 2



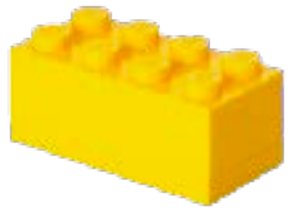
2.810 F23 - Round 2



2.008 Systems Coverage

Systems I: Beer Game

Process Planning and Cost 

Systems II: System Considerations 

Systems III: System Design and Operation

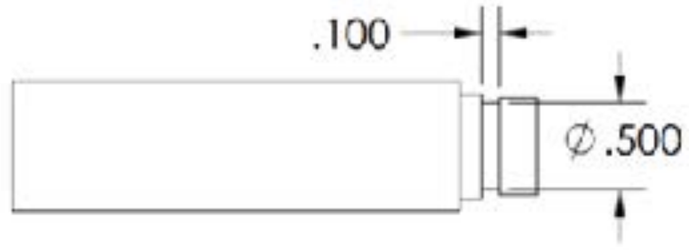
Systems IV: Modeling Transfer Lines

What is Process Planning?

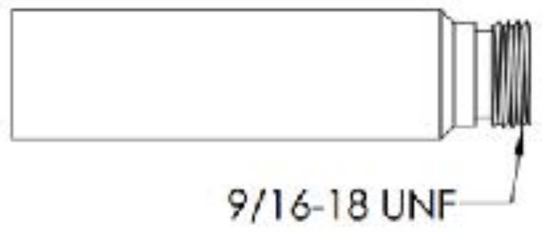
“an engineering activity that determines the appropriate procedures for transforming raw materials into a final product as specified by engineering design, including assembly”

typically senior people in a factory: need to have detailed knowledge of every step

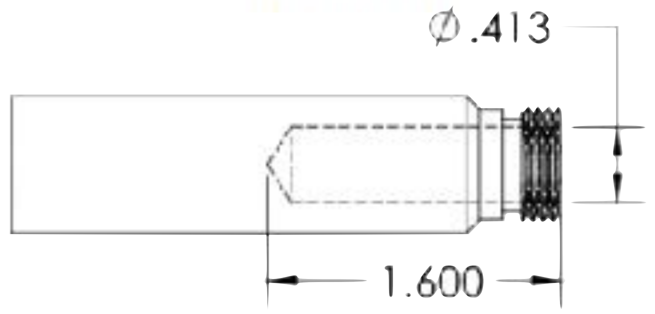
can be at any level of the hierarchy



1. turn features



2. add threads



3. drill hole

4. knurl outside

What is Process Planning? laptop process plan

Maker Bootcamp Process Plan

All process plans (even first attempts/early versions) must be included in Machining Guru notebook for grading.

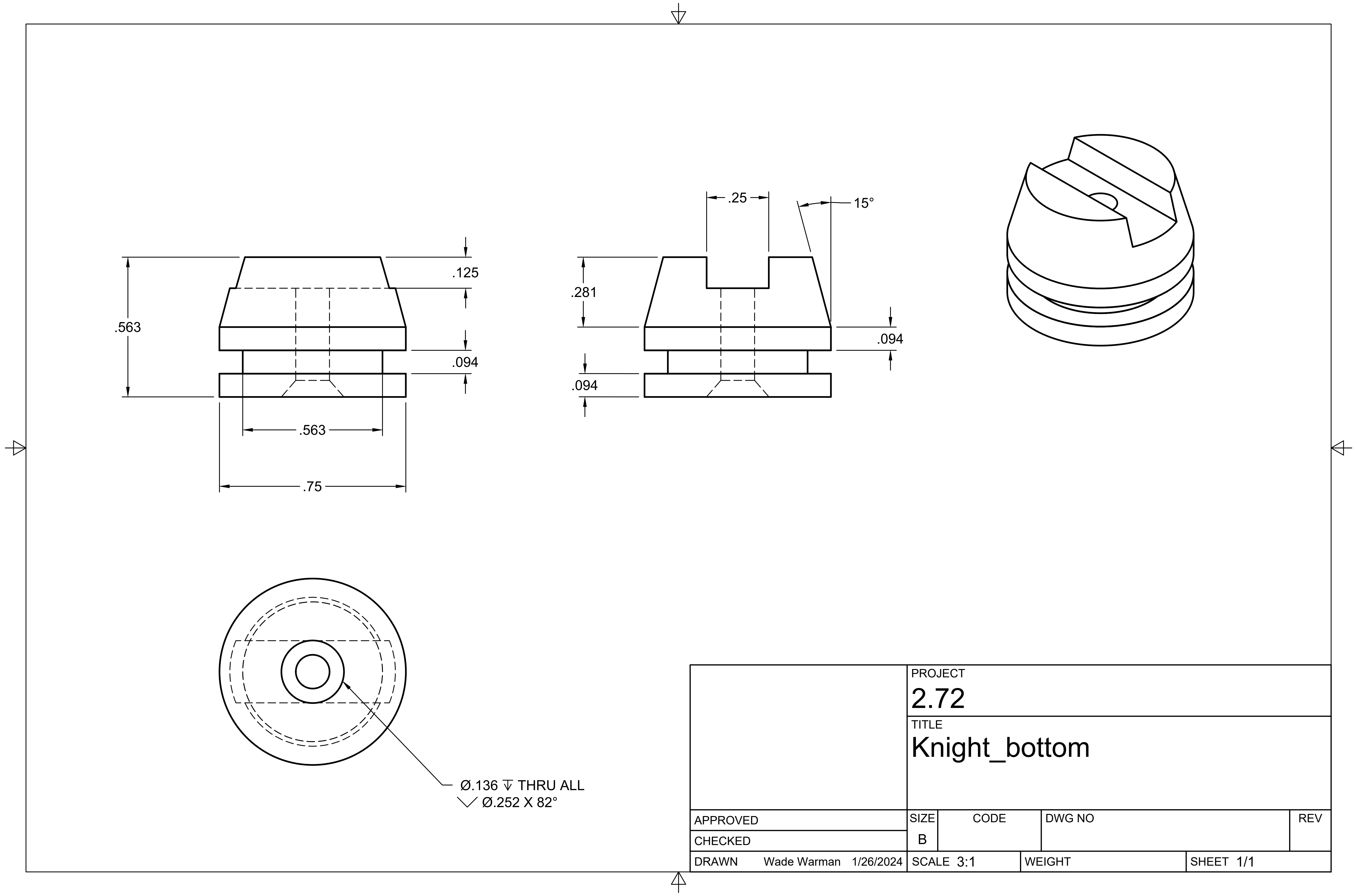
Process Plan	Group #:	Part Name: **Knight Chess Piece (BASE)**	Version: **2**
Revision Date: **1/29/2024**	Group Members in Attendance: **WADE**		
Approval Date:			

Application of previous lessons learned:

Lathe, Mill, Water Jet, Drill, Tap, Fixturing, Calipers, Dial Indicator, Gage Pins

#	Task & Questions	Machine	Tooling	Measurement
00	Cut stock to ~2.000"	Band saw	Band saw	Tape Measure
01	Fixture workpiece (~1.500" length of working material)	Lathe	3 Jaw Chuck	Calipers, dial indicator
02	Face material	Lathe	Facing tool	Visual to confirm facing operation.
03	Center drill	Lathe	Center drill	Visual, Calipers/depth gage (~0.025" depth)
04	Drill, ↓ 1.000" (Close-Fit)	Lathe	#29 Drill, Tailstock	Depth gage/pins, Calipers (1.000" +/- .010")
05	Create Taper, (15 deg)	Lathe	Face/turning tool	Protractor (15 deg)
06	Create Relief cut (0.563" dia.)	Lathe	Parting/groove tool	Calipers (0.563" dia.)
07	Part material (0.563" height)	Lathe	Parting/groove tool	Calipers (0.563" height)
08	Fixture Part for countersinking	Vise	Vise	Visual (level and secure)
09	Counter Sink	Hand drill	Countersink	Fit-Test w/ #5-40 Flathead
10	Fixture & Locate part on Mill	Mill	Soft jaws, edge finder	DRO, calipers
11	Create slot	Mill	1/4" End mill	Calipers, test-fit w/ mating part
12	Assembly	Hand Tools	5/64 Hex	Visual, fit-test
13				

Page 1



Process Planning

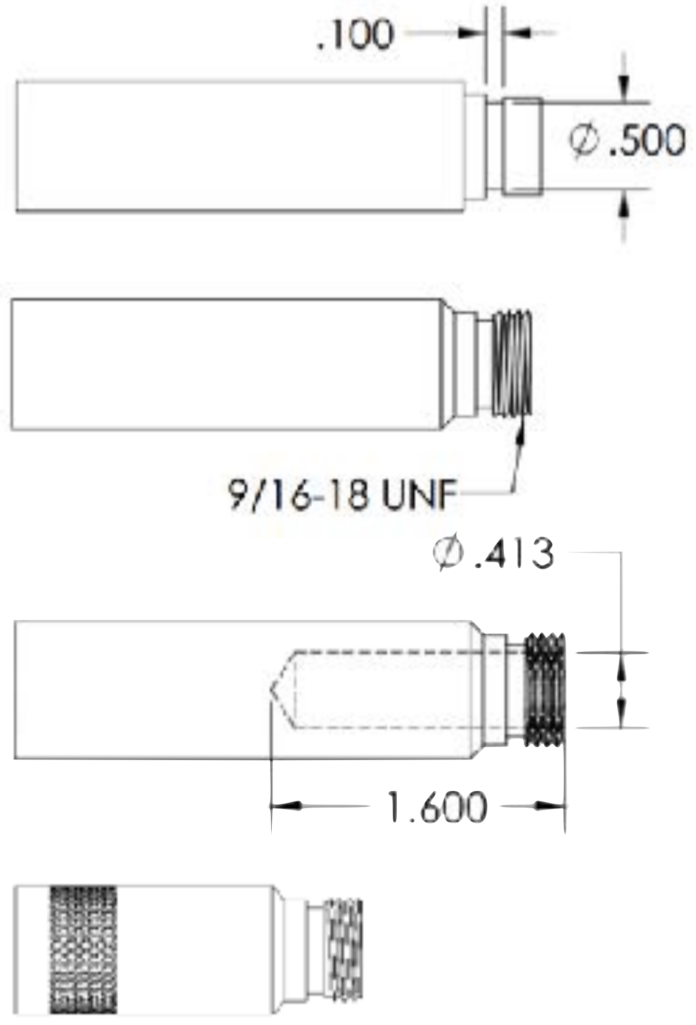
Manufacturing Planning and Cost

What is Process Planning?

“an engineering activity that determines the appropriate procedures for transforming raw materials into a final product as specified by engineering design, including assembly”

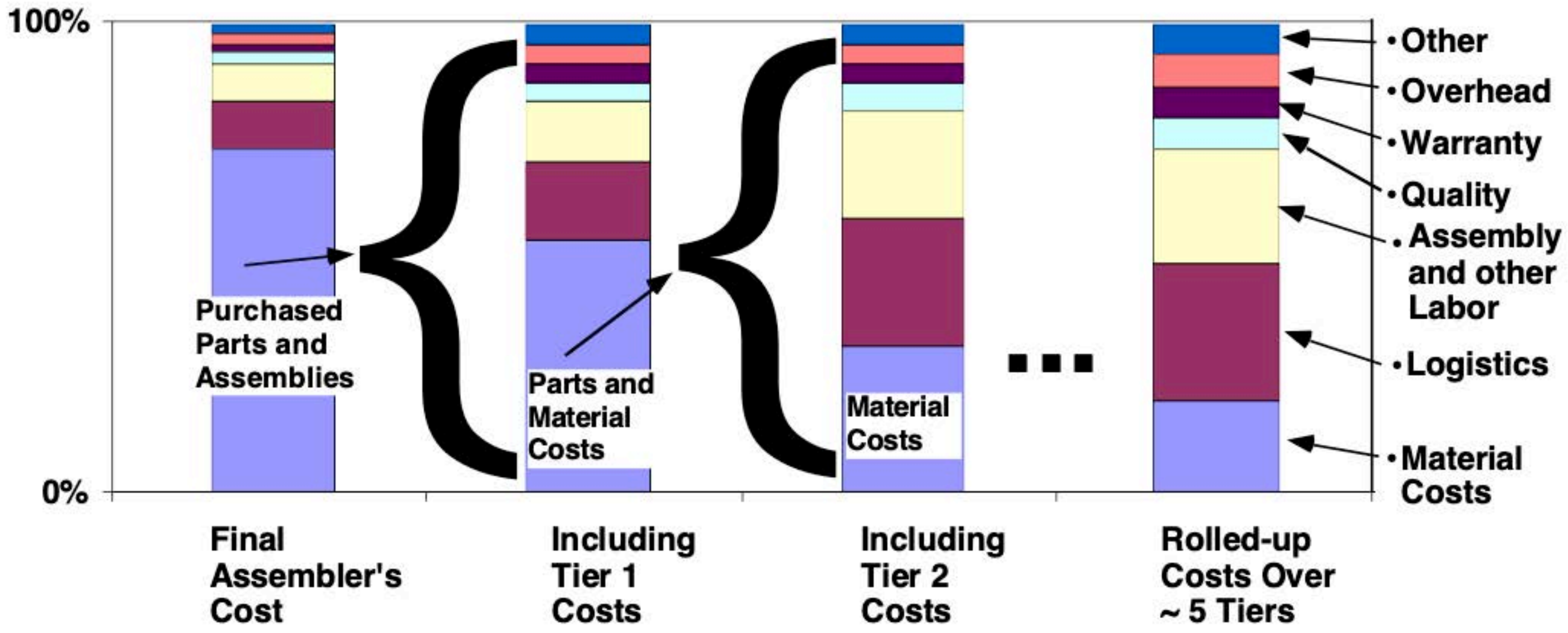
typically senior people in a factory: need to have detailed knowledge of every step

can be at any level of the hierarchy



1. turn features
2. add threads
3. drill hole
4. knurl outside

Manufacturing Cost

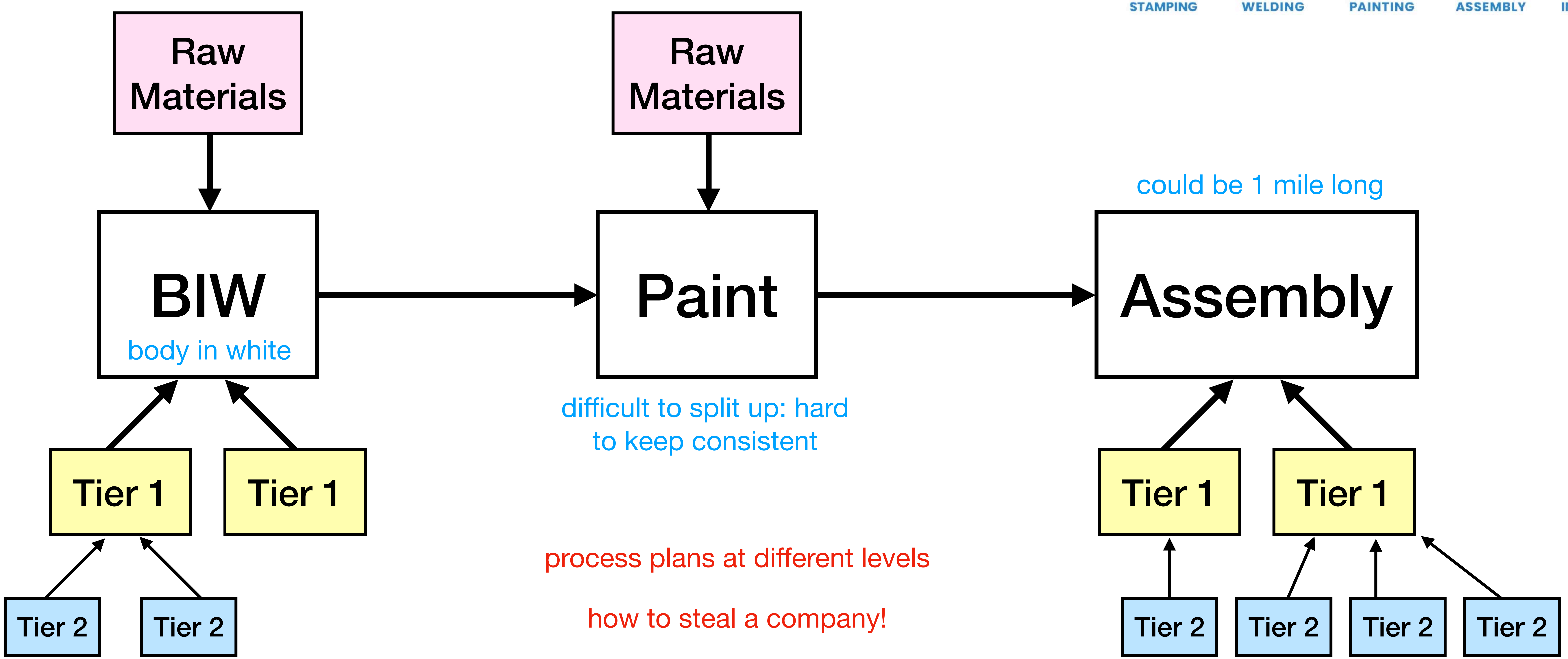


Source: Daimler Chrysler via Munro and Associates

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

but it might appear smaller at the final stages

Manufacturing Hierarchy



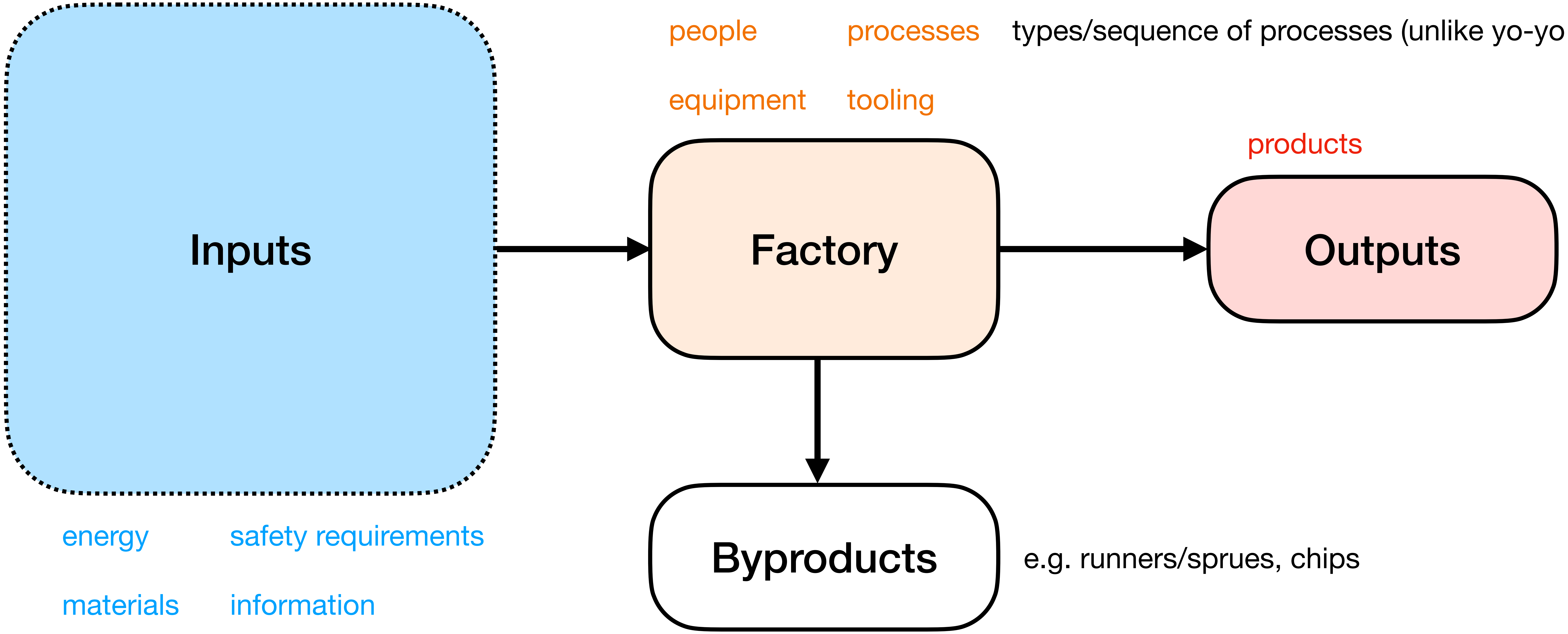
Process Planning

Manufacturing Planning and Cost

people processes types/sequence of processes (unlike yo-yo project)

equipment tooling

products



e.g. runners/sprues, chips

energy safety requirements

materials information

process planning is **intensive**

outcomes need to be **repeatable**

save time and money by avoiding **waste**

communication is critical: everyone on the same page

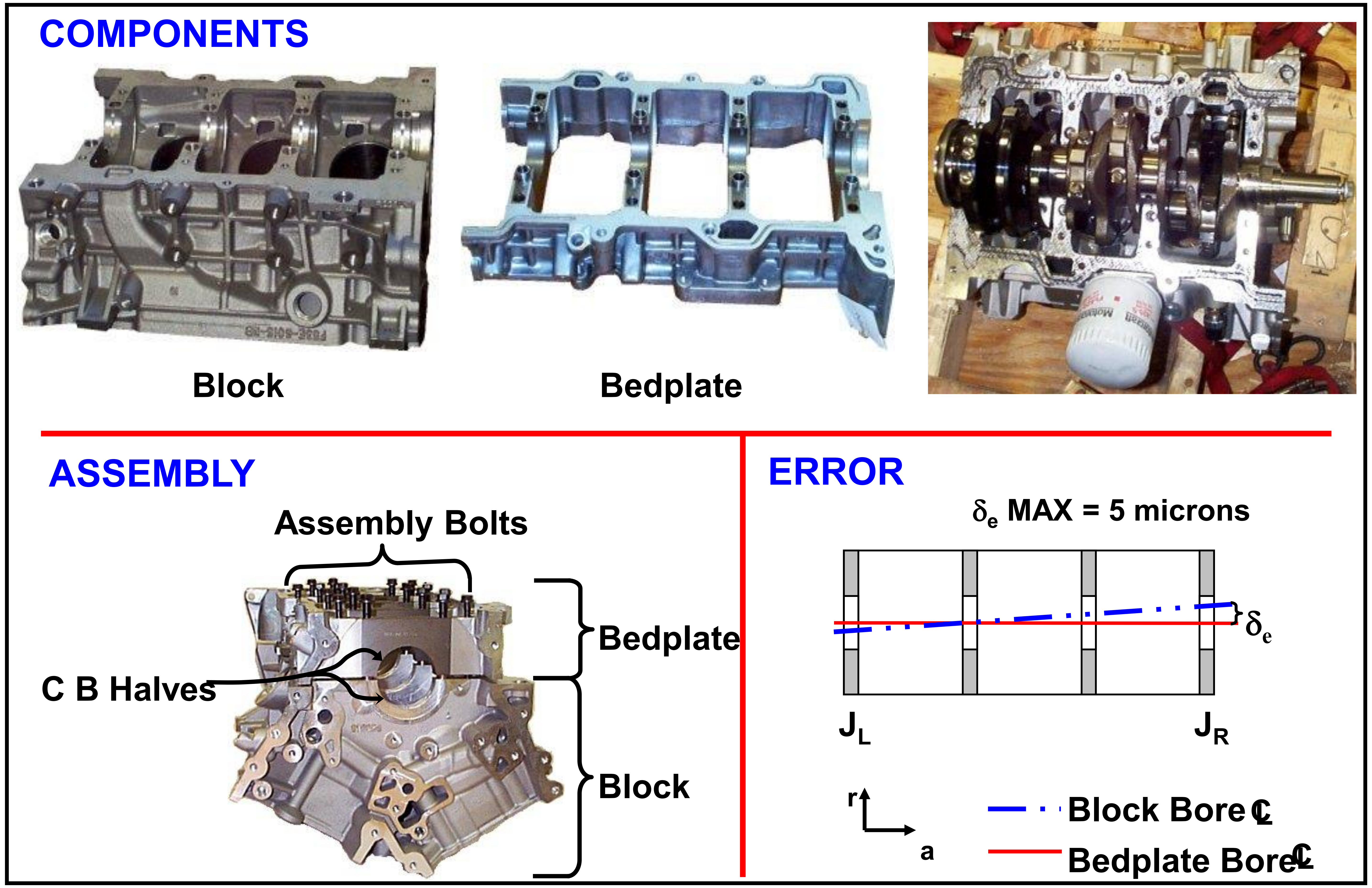
optimize/troubleshoot/**improve**

Example: Ford Duratec Engine

engine has to be split into halves to allow for crank shaft assembly

misalignment between halves: < 5 µm

process plan for producing the engine?



Prof. Marty Culpepper

Example: Ford Duratec Engine

define everything: process, sequence, machines, tooling (100s of steps)

if one station has to stop, everything has to stop

Partial plan to form geometry for 2.3L Ford Duratec / 3.0L Jaguar engine:

Note some steps/operations are missing, I've included the steps we will need for the example

Operation. #10
- Mill Joint Face
- Drill/Bore **16 Holes**
- Drill Bolt Holes

→

Operation. #30
- Drill Bolt Holes

→

Operation. #50
- Press in **8 Dowels**
- Assemble
- Load Bolts
- Torque Bolts

→

Operation. #100
- Semi-finish crank bores
- Finish crank bores

- **300,000 Units / Year** ➡ engine finished every 30s

Requirements

meet design specifications

meet the manufacturing schedule   meet demand or else…

Constraints

can you meet the specifications: capability $C_p = \dfrac{USL - LSL}{6\sigma}$

training, skill, expertise

timing for a new car: ~3 years

designing the car is the easy part!

designing a reliable production system is harder

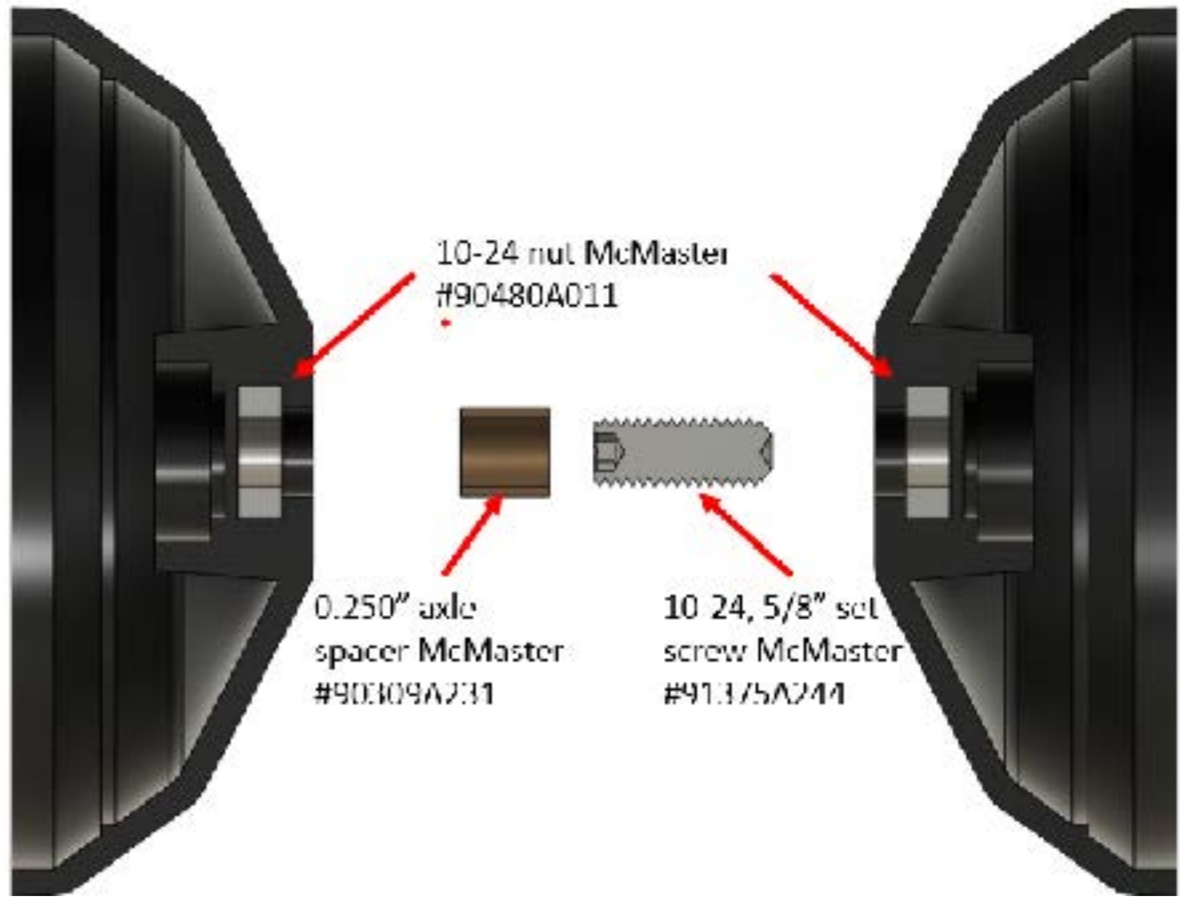
Industry vs Class Projects

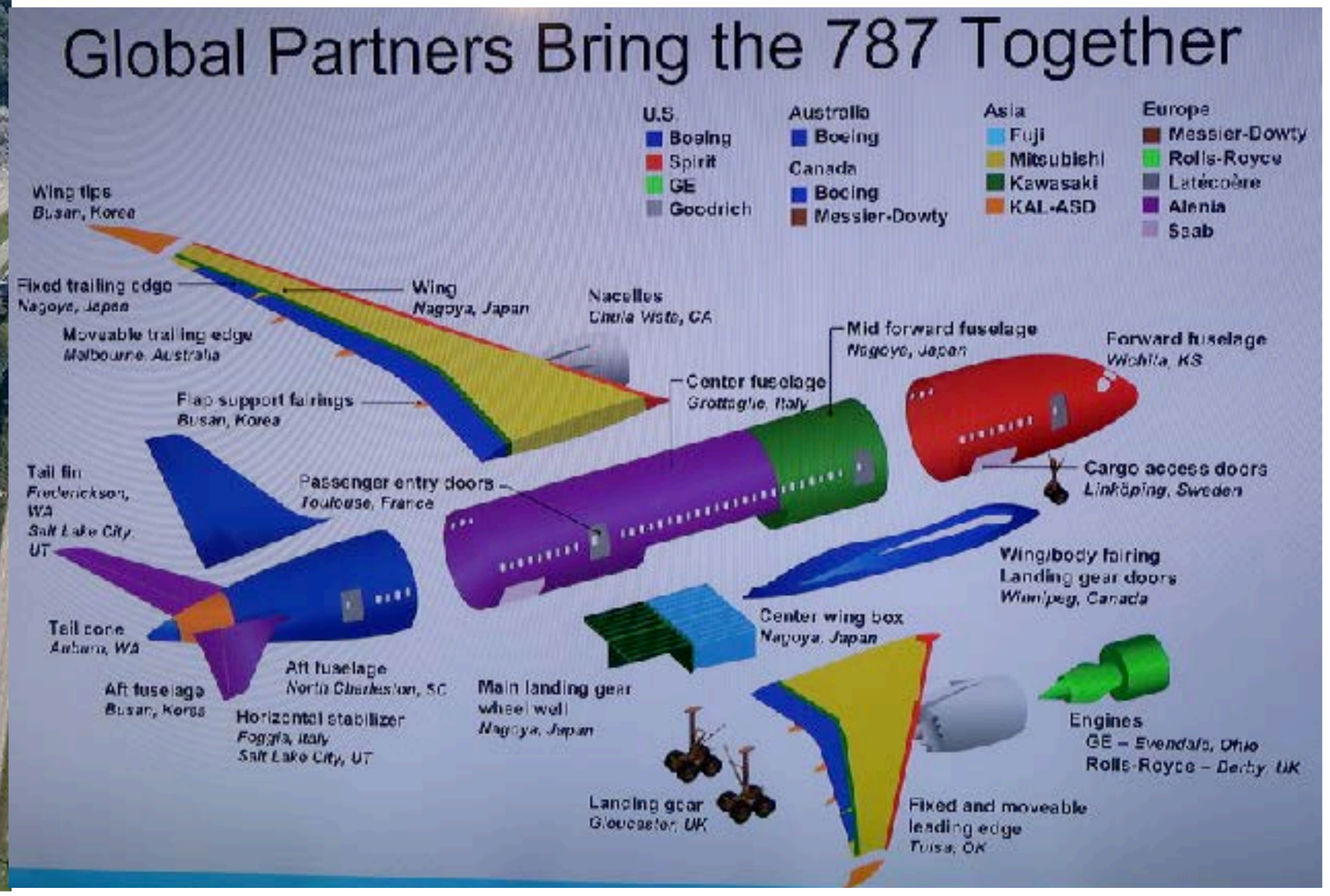
complexity of parts, number of parts

large (huge) teams spanning multiple plants/countries

can’t do things “on the fly”

you can get by making a yo-yo without a detailed plan (it’s just a bit messier)





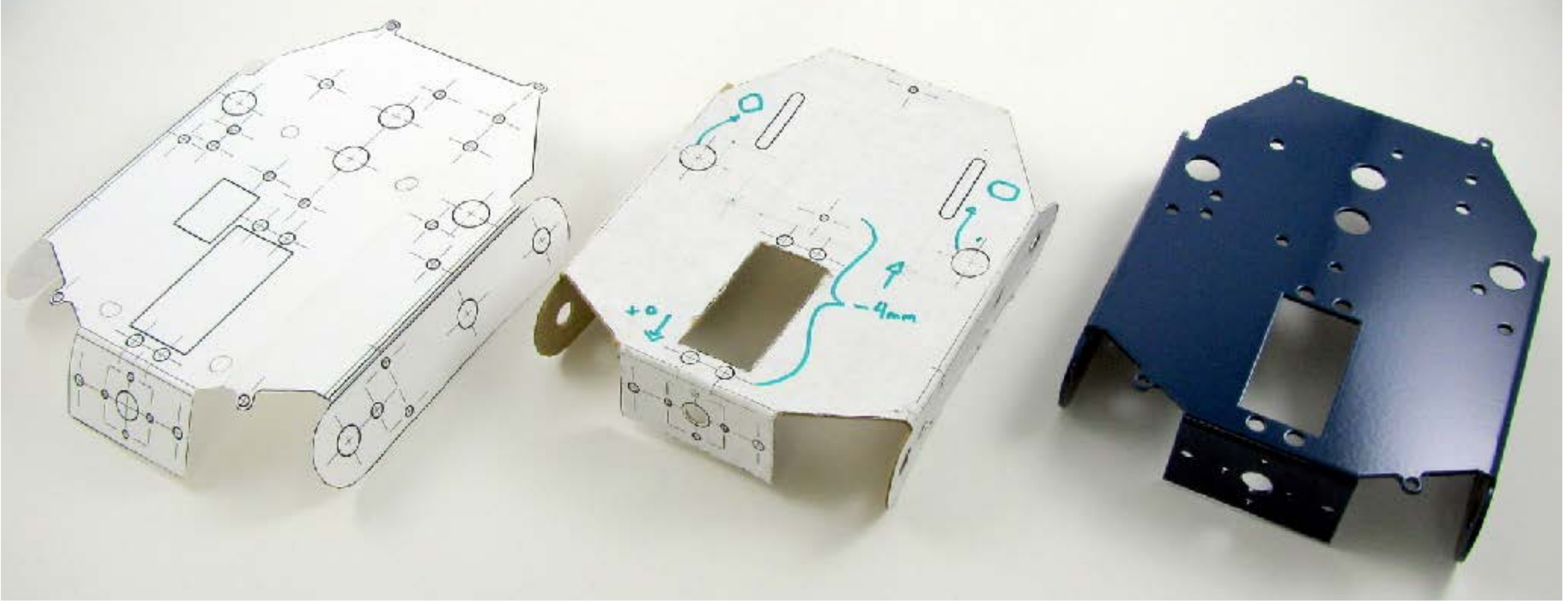
How to Get Started

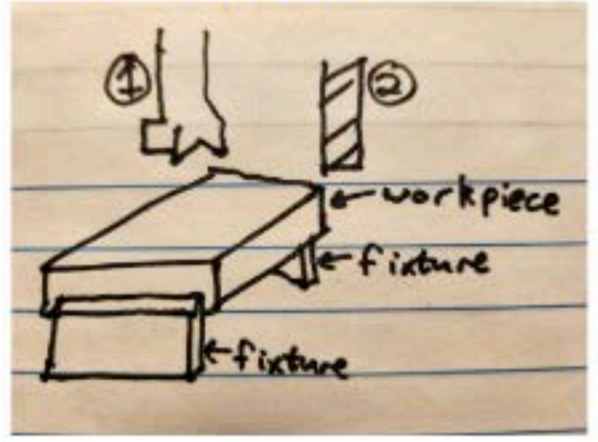
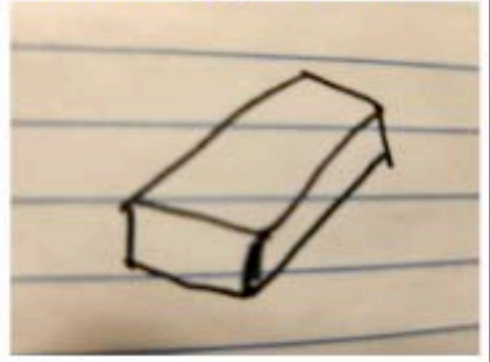
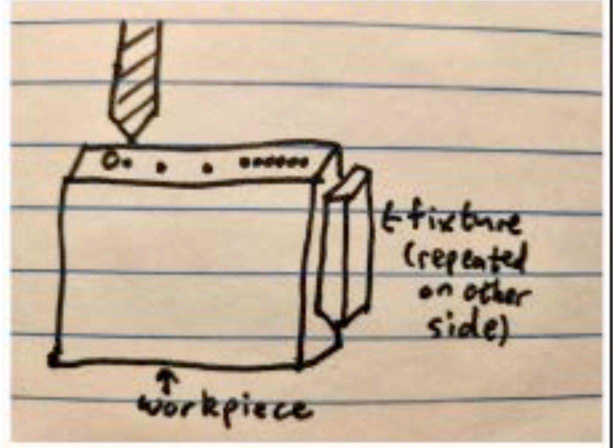
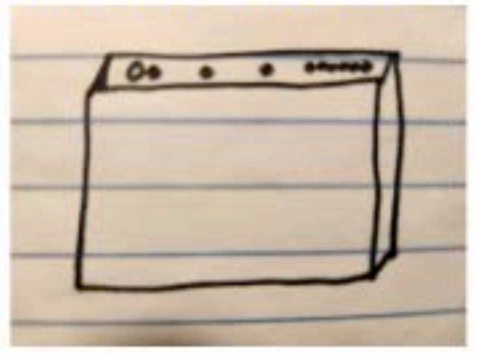
“play the movie in your head” or “be the machine”

make sketches at different stages of the process

create representations of your part/assembly at different stages

can your equipment do it (possible) well (capable)?



Description/ Feature	Tool Choice	Sketch of setup (orientation of the phone, fixture or how it is held, and direction of the tool)	Sketch of part after this step
0. Stock preparation	Face cutter (1) + End mill (2)	Mill back face + Sides 	Show rectangular blank 
1. Drilling holes on bottom	Drillbit	Show iPhone fixtured vertically with the drill coming down 	Show rectangular blank with holes in the bottom 

Include bottom holes and slot

Human Resources

humans are highly flexible

✅ visual identification

✅ dexterity and manipulation

✅ knowledge retention: skill reservoirs

⚠️ cost

- salary (2-3x for benefits, overhead, etc.)
- training
- health: repetitive stress injuries - OSHA
- reliability
- generally not repeatable

hazard avoidance (heavy weight, sharp edges, hazardous materials) are part of the plan: not just reacting to them!

repeatability is necessary for consistency: quality

automation sometimes is slower, but more repeatable!

Material Handling

material balancing act:

- run out: lose time, money, customers
- storing material: costs money, space, time

input material also has variance, quality affects your processes

- know your supplier
- redundancy in supply chain
- manage lead times (proper ordering strategies)

Material Handling: The Circulatory System

manage the flow of material

- carts
- pallets
- robots
- people
- conveyors
- cranes
- etc.

the “well orchestrated dance”

Information Management: The Nervous System

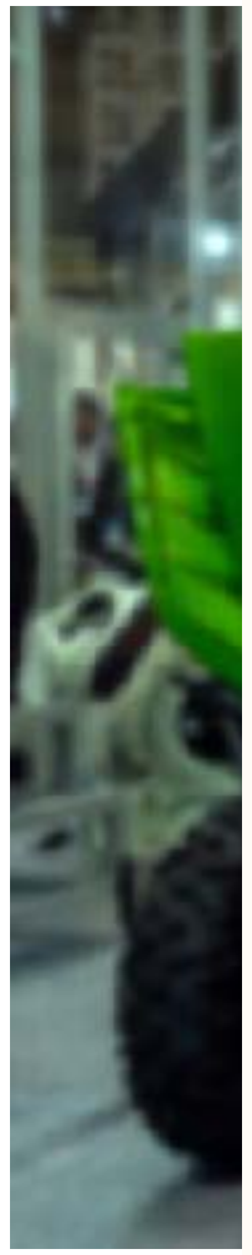
need the right info at the right place and time

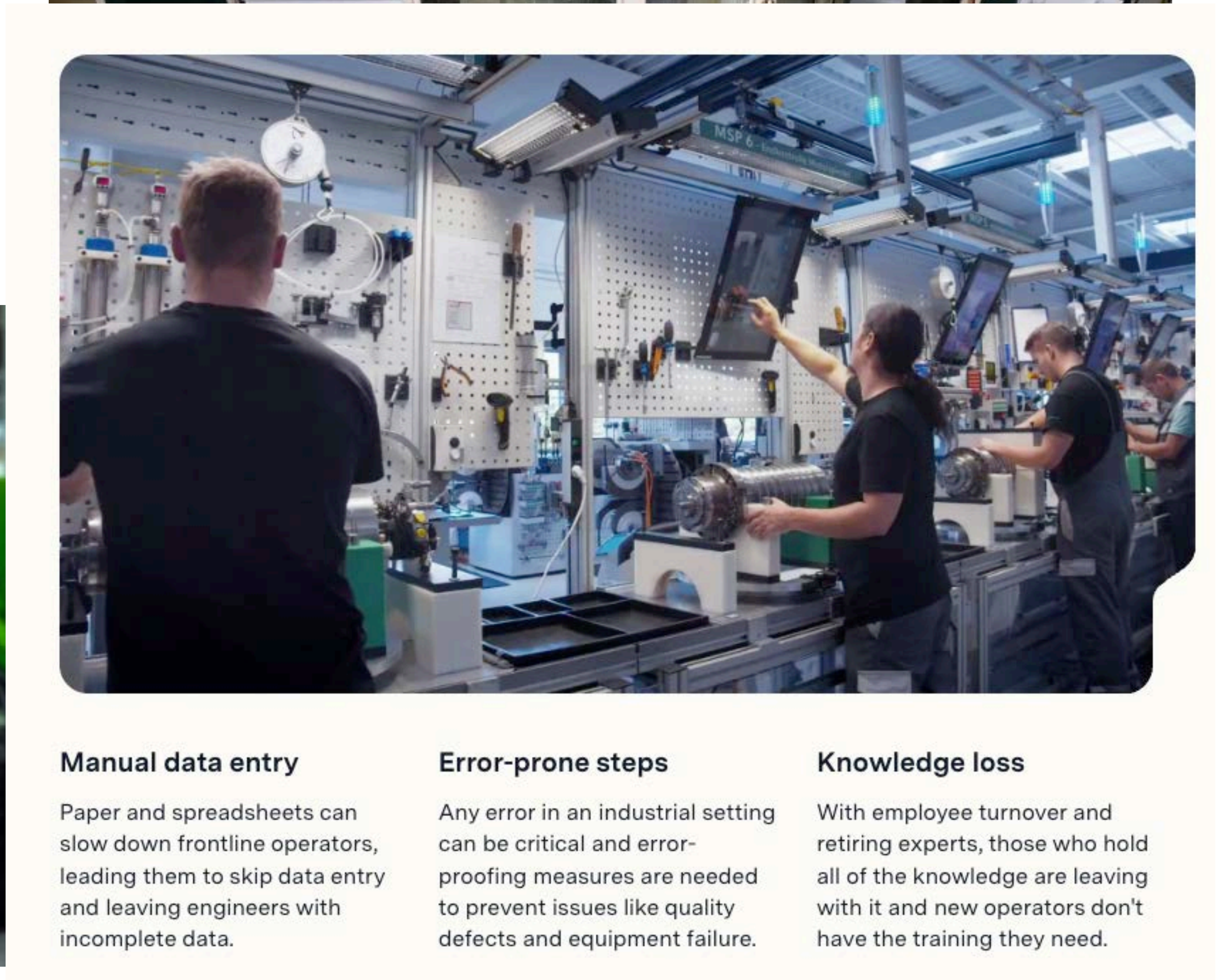
database management + communication

becoming more automated with better sensor technology

tracking: RFID tags, QR code scanning

multiple software platforms





Evaluation and Measurement

do you satisfy the requirements? meeting the USL and LSL?

you only know as much as you can measure

without measurement, it is impossible to control any process


gom
gom
gom

Process Planning

Manufacturing Planning and Cost

Example: Ford Duratec Engine

a process plan allows you to identify pain points

where to invest time and money

Engine Manufacturing Process With Pinned Joint

Op. #10
- Mill Joint Face
- Drill/Bore 16 Holes
- Drill Bolt Holes

→ **Op. #30**
- Drill Bolt Holes

→ **Op. #50**
- Press in 8 Dowels
- Assemble
- Load Bolts
- Torque Bolts

→ **Op. #100**
- Semi-finish crank bores
- Finish crank bores

Modified Engine Manufacturing Process Using Kinni-Mate Coupling

Op. #10
- Mill Joint Face
- Drill/Bore 3 Peg Holes
- Drill Bolt Holes & Form 3 Conical Grooves

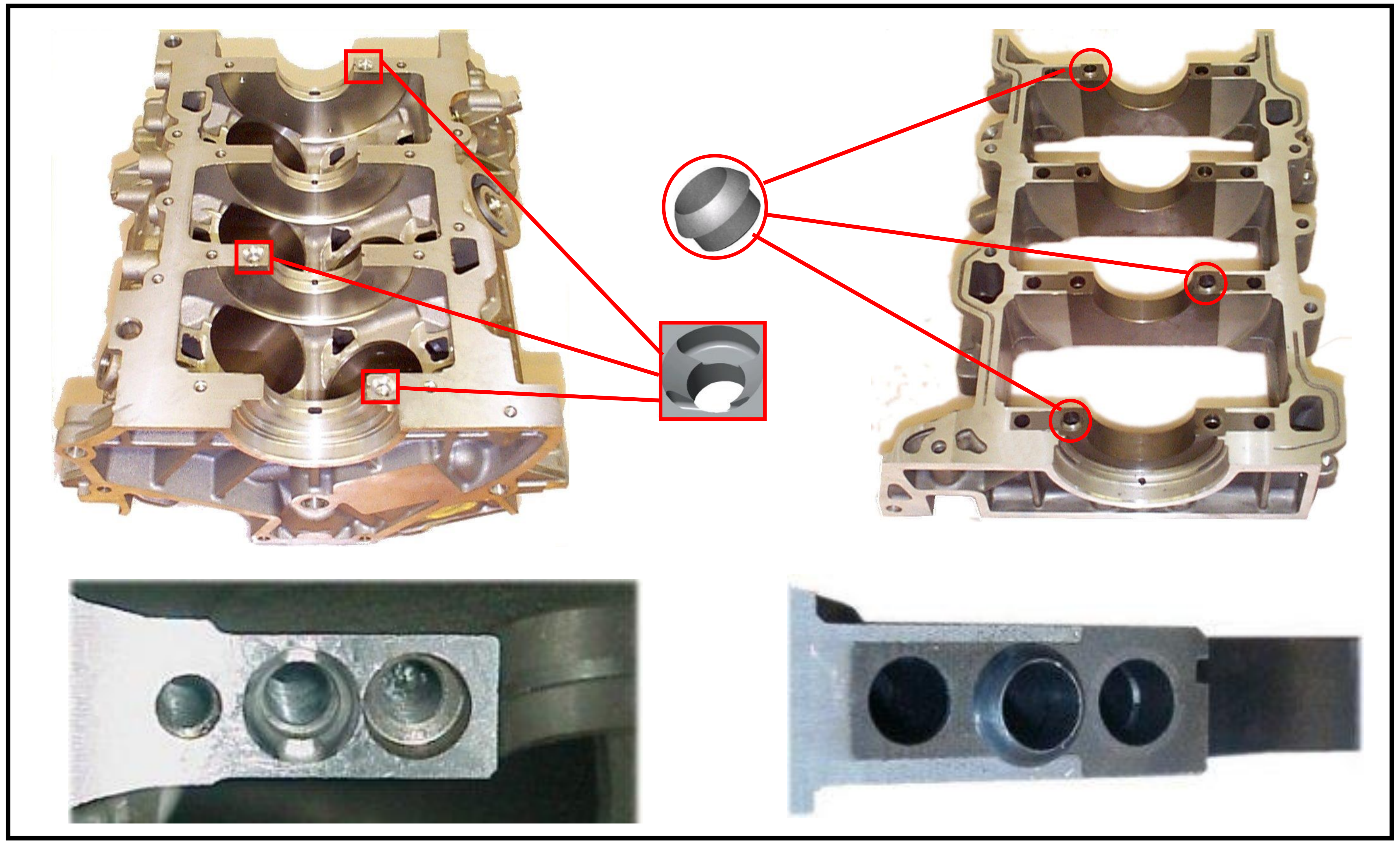
→ **Op. #30**
- Drill Bolt Holes

→ **Op. #50**
- Press 3 Pegs in BP
- Assemble
- Load Bolts
- Torque Bolts

→ **Op. #100**
- Semi-finish crank bores
- Finish crank bores

DESIGN:

ITEM	QKC	Pinned Joints
# Precision Pieces	3	8
# Precision Features	3	16
Feature Placement Tolerance	+/- 0.08mm	+/- 0.04mm
Average Centerline Repeatability	0.65 μm	4.85 μm
Normalized $/Engine	0.64	1



DFA: Design for Assembly

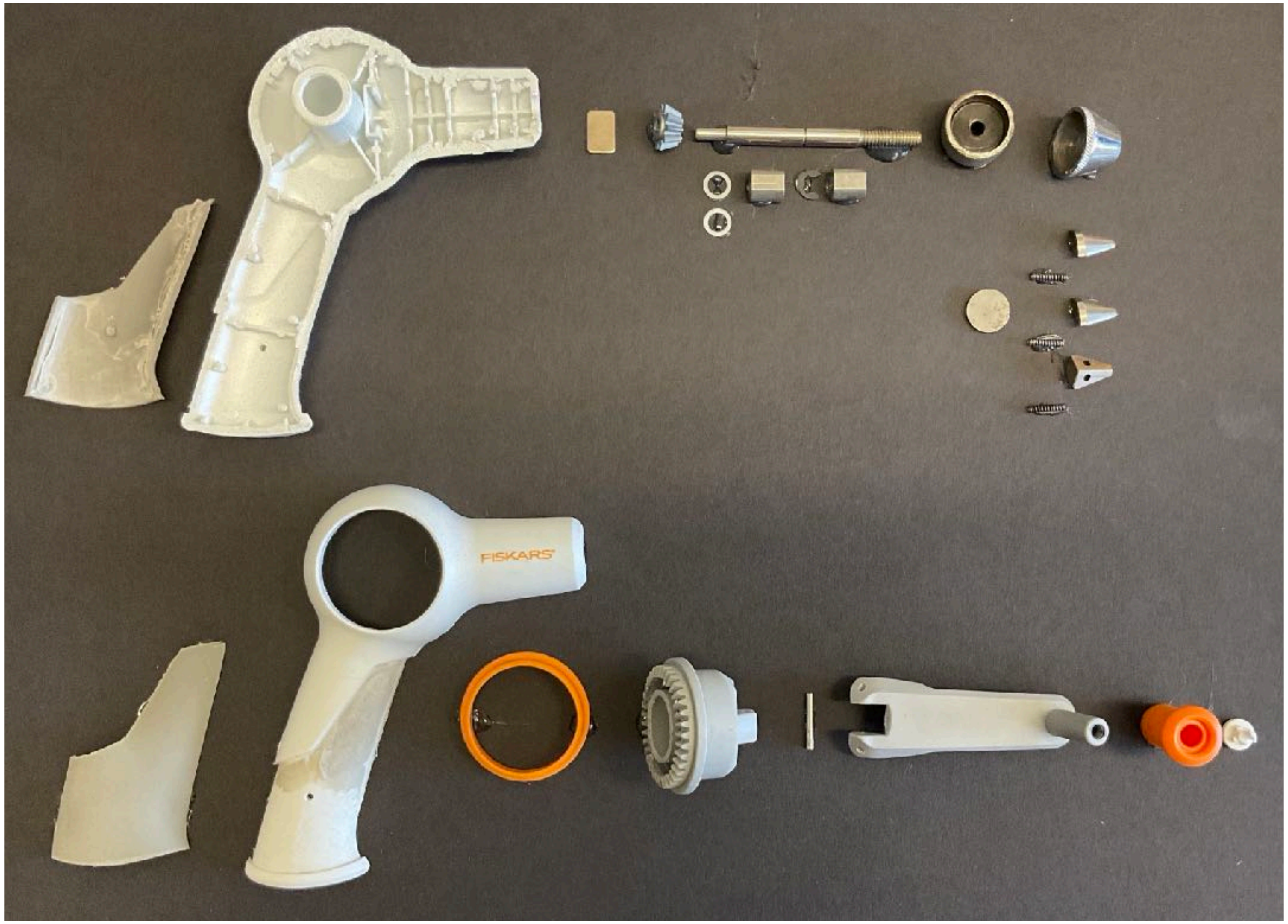
1. Reduce the Part Count

2. Make Each Part Easier to Assemble

(Duratec Engine)

Snowball Effect:

- fewer drawings/documentation
- fewer specifications to meet
- less material to handle
- less design time
- fewer vendors
- less inventory to manage
- reduced overhead



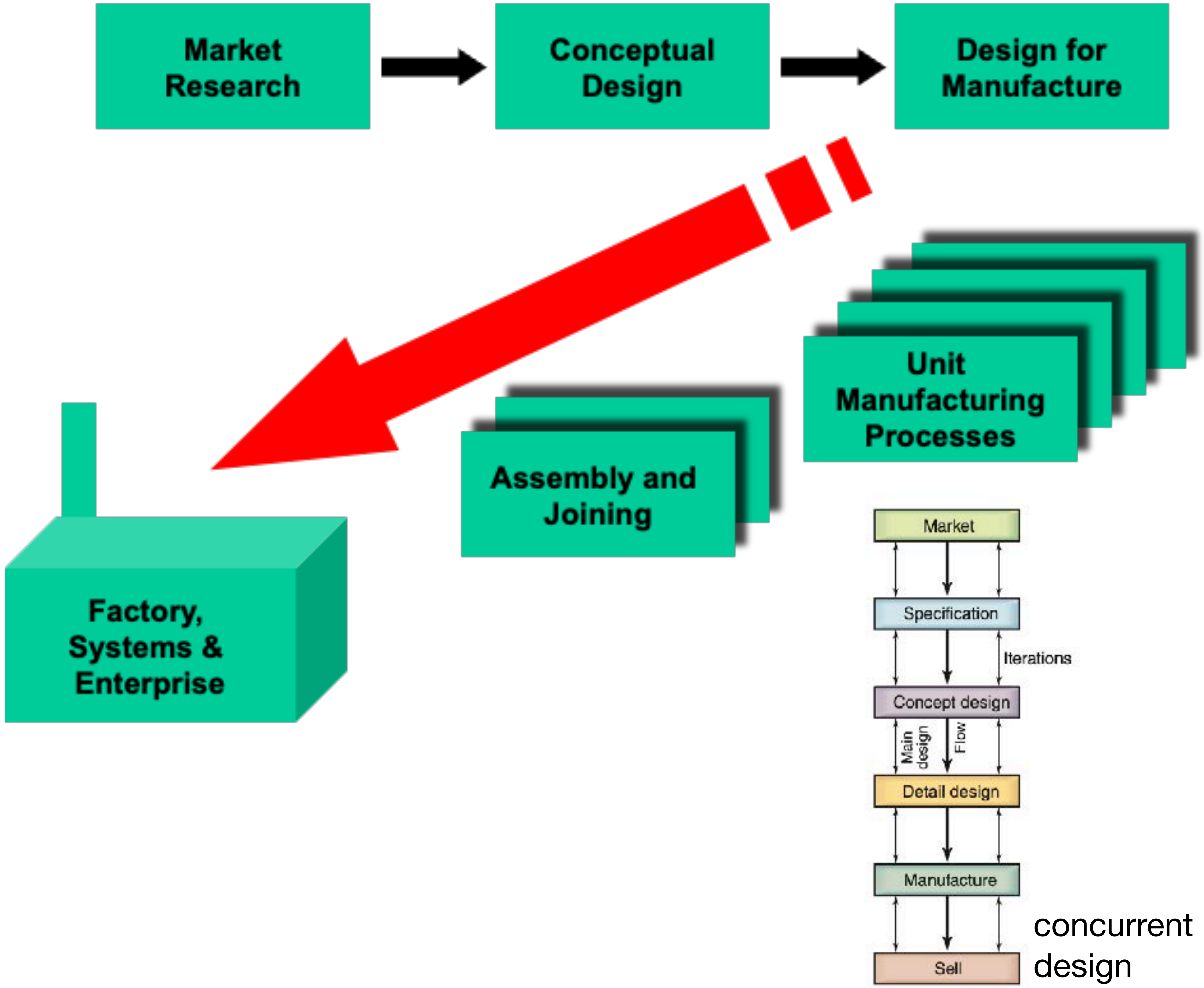
Yo-yo Process Plan?

how would you scale up a yo-yo process?

generating a plan helps you think about scale

upcoming: simulating and modeling systems

- yo-yo is a simple starting point: few parts and processes



Knowledge Multiplier

unit ➡ assembly: need process plan

feed information back: design with process plan in mind

- now better designed for upcoming stages
  - now it's easier to capture information and feed it back to design

car company making a new car

vs a new company making a new car…

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