Product development & engineering design

ME-320

Prof. Josie Hughes

Lecture 9: 3D Printing & Drawings

Course Content & Topics

Weekly Topics

Date	Week	Topic	Activity
21/09/2022	Week 1	Intro to Design, The project. Design Process, Design Thinking	Tour of the DLL
28/09/2022	Week 2	Brainstorming, Ideation and Concept Selection	3D Printer Tours
05/10/2022	Week 3	Prototyping & Sketching	Introduction to Arduino
12/10/2022	Week 4	Engineering Design: Actuators & mechanisms	
19/10/2022	Week 5	Engineering Design: Sensors + microcontrollers	Design Review 1 (Scheduled 5 minutes with TA)
26/10/2022	Week 6	**Guest Lecturer: Library**	
02/11/2022	Week 7	Engineering Design: Printing + CAD	
09/11/2022	Week 8	Engineering Design: CAD + Drawings	
16/11/2022	Week 9	Engineering Design: Electronics Drawings + Industrial Design	Design Review 2 (Scheduled 5 minutes with TA)
23/11/2022	Week 10	Reverse Engineering/Learning From Mistakes (Extra time for project work)	
30/11/2022	Week 11	IP/Copy Right/Approval/Standards/Ethics (Extra time for project work)	
07/12/2022	Week 12	Course Recap + Exam Info!	Design Review 3 (Scheduled 5 mins with TA)
14/12/2022	Week 13	Very short recap! Time for project work	
21/12/2022	Week 14	Demonstrations/Top Videos/Testing	Competition

Reminders

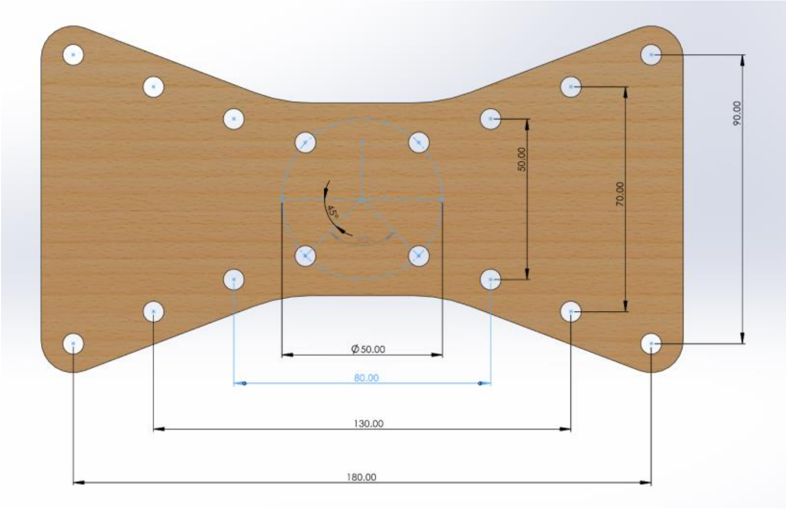
Course Documents & General Information

In this section you will find the main documents relating to the course including de

- Announcements
- Team Sign up List
- Course Schedule
- Parts List
- Project Details
- Final Team List
- Assessment Submission: Functionality diagram, concept selection, Gantt C
- Request Parts/Help
- CAD Files of Parts

1. STEP files of key parts and the mounting point

2. Mounting to Robot (M6 Bolts in SPOT)



3. Request Parts here:

Course Documents & Genera

In this section you will find the main documents rel

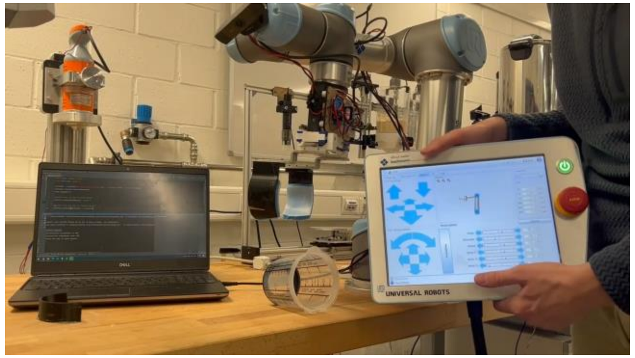
- Announcements
- Team Sign up List
- Course Schedule
- Parts List
- Project Details
- Final Team List
- Assessment Submission: Functionality diagr
- Request Parts/Help
- CAD Files of Parts

4. Demo Video here:

Course Documents & General I

In this section you will find the main documents relatin

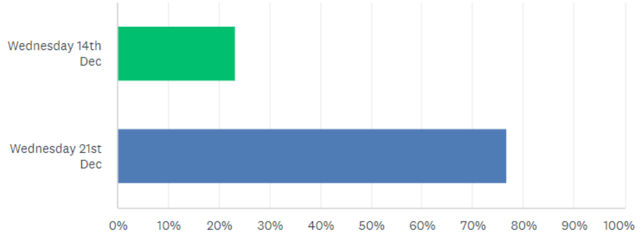
- Announcements
- Team Sign up List
- Course Schedule
- Parts List
- Project Details
- Final Team List
- Assessment Submission: Functionality diagram,
- Request Parts/Help
- CAD Files of Parts
- Demonstration Video of the Process



Final Demonstration/Competition Dates

Which is your preferred competition date

Answered: 30 Skipped: 0



ANSWER CHOICES	RESPONSES	
Wednesday 14th Dec	23.33%	7
Wednesday 21st Dec	76.67%	23
TOTAL		30

Course Documents & General Information

In this section you will find the main documents relating to the course including details of project and als

- Announcements
- Team Sign up List
- Course Schedule
- Parts List
- Project Details
- Final Team List
- Assessment Submission: Functionality diagram, concept selection, Gantt Chart (Due Tuesday 18t

View Insert Format Data Tools Extensions Help Last edit was 2 minutes ago

100% £ % .0 .00 123 Default (Ari... 10 B I S A

Choice of Competition Date (14/21st December)

Name First Name	Sciper	e-Mail	Group Number	Choice of Competition Date (14/21st December)
n	299240	max.aebi@epfl.ch	1	
Pierre Maximilian	297166	carlo.angelini@epfl.ch	1	
ıng Sebastián Giosue	311462	sebastian.schupbachchung@epfl.ch	1	
a	311471	oussama.yazidi@epfl.ch	1	
nder Philipp	325065	alexander.bommer@epfl.ch	2	
e Paul	329055	philippe.gachet@epfl.ch	2	
athieu	330025	niels.jullien@epfl.ch	2	
nitri	329492	this.koster@epfl.ch	2	
ınn Calixte	314867	yohann.dezauzier@epfl.ch	3	

- Confirm names and numbers of team are correct
- Choose your preferred competition date

Deadline: Nov 30th

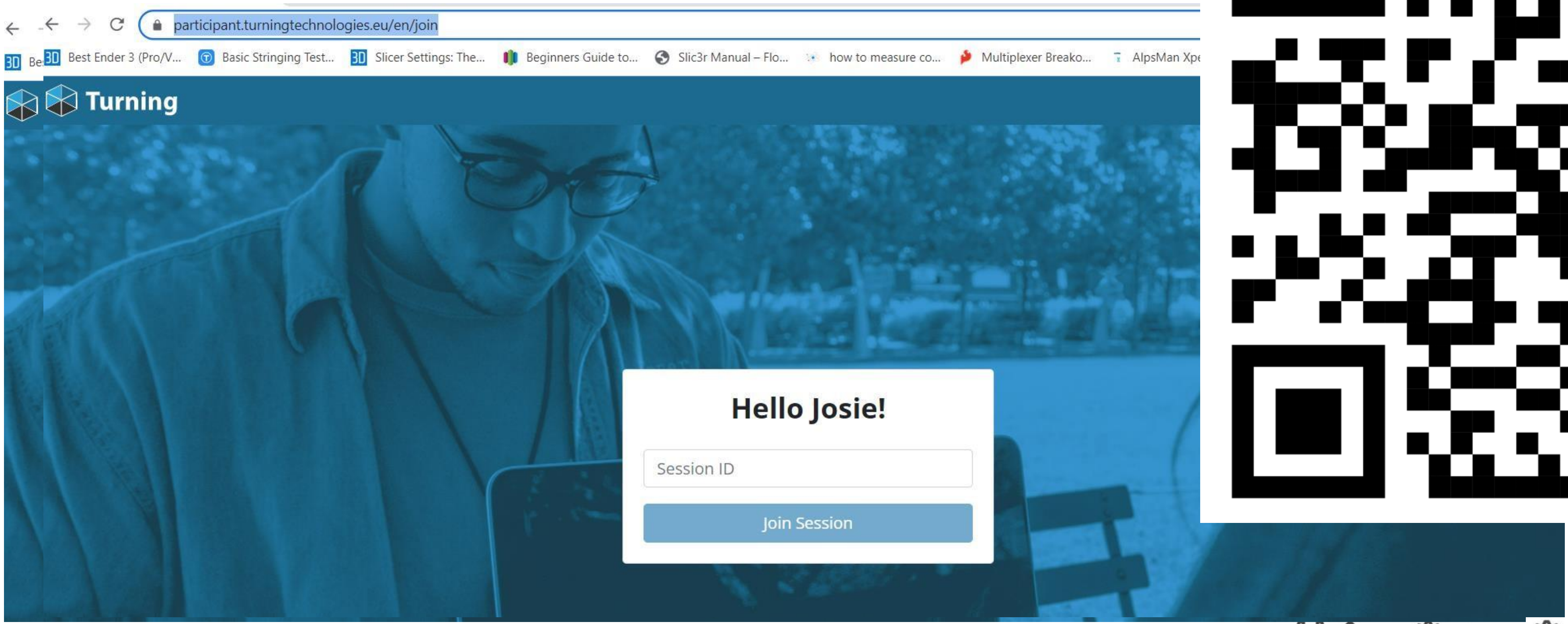
Engineering Drawings Quiz

https://participant.turningtechnologies.eu/en/join

https://participant.turningtechnologies.eu

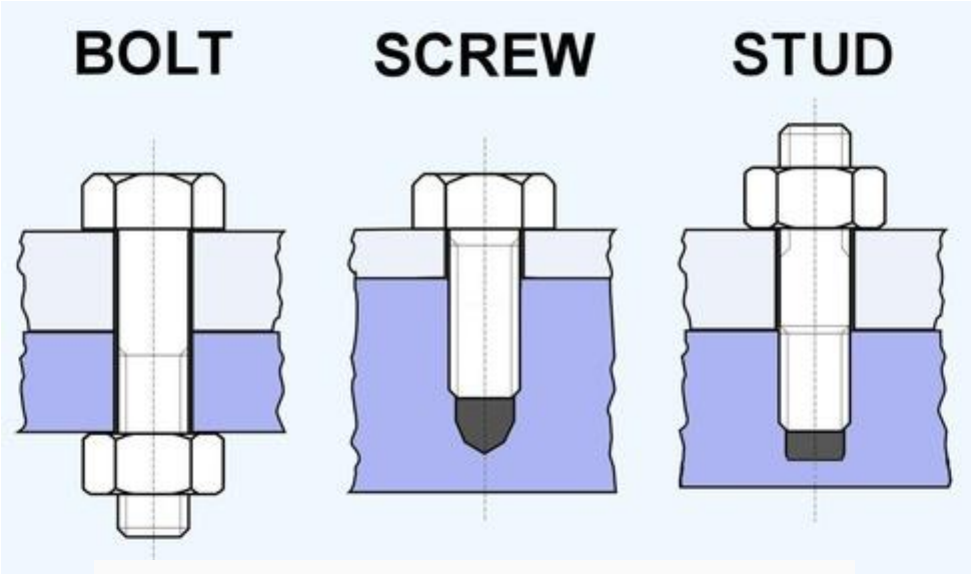
SessionID: datadriven

https://ttpoll.eu/p/datadriven



Fasteners

- Bolts
- Studs
- Cap Screws
- Set screws



Fasteners

Thread Standards & Dimensions

- *Pitch* – distance between adjacent threads. Reciprocal of threads per inch
- *Major diameter* – largest diameter of thread
- *Minor diameter* – smallest diameter of thread
- *Pitch diameter* – theoretical diameter between major and minor diameters, where tooth and gap are same width

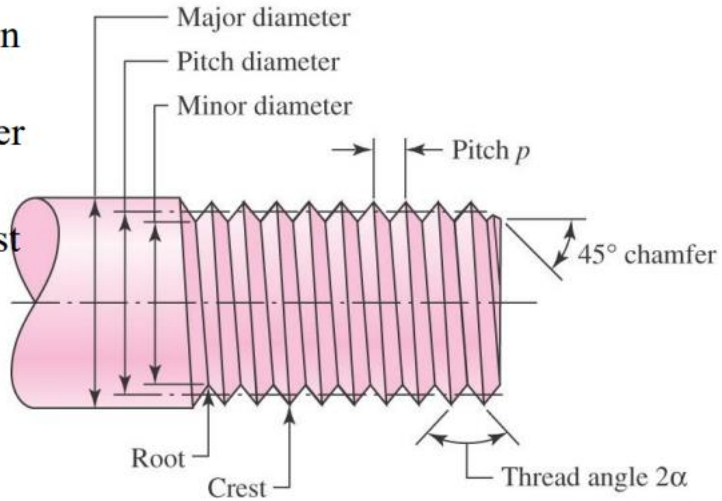
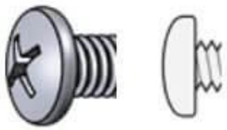
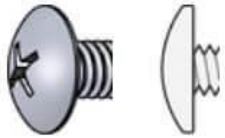
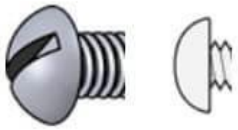
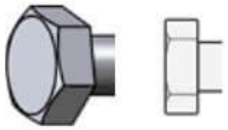
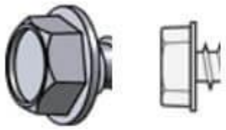
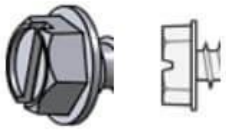
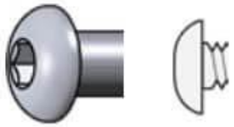


Fig. 8–1

Fasteners
Head Types

Head Styles			
 **Flat** A countersunk head with a flat top. Abbreviated FH	 **Oval** A countersunk head with a rounded top. Abbreviated OH or OV	 **Pan** A slightly rounded head with short vertical sides. Abbreviated PN	 **Truss** An extra wide head with a rounded top.
 **Round** A domed head. Abbreviated RH	 **Hex** A hexagonal Head. Abbreviated HH or HX	 **Hex Washer** A hex head with built in washer.	 **Slotted Hex Washer** A hex head with built in washer and a slot.
 **Socket Cap** A small cylindrical head using a socket drive.	 **Button** A low profile rounded head using a socket drive.		

Fasteners
Head Types

- Hexagon head bolt
  - Usually uses nut
  - Heavy duty
- Hexagon head cap screw
  - Thinner head
  - Often used as screw (in threaded hole, without nut)
- Socket head cap screw
  - Usually more precision applications
  - Access from the top
- Machine screws
  - Usually smaller sizes
  - Slot or philips head common
  - Threaded all the way

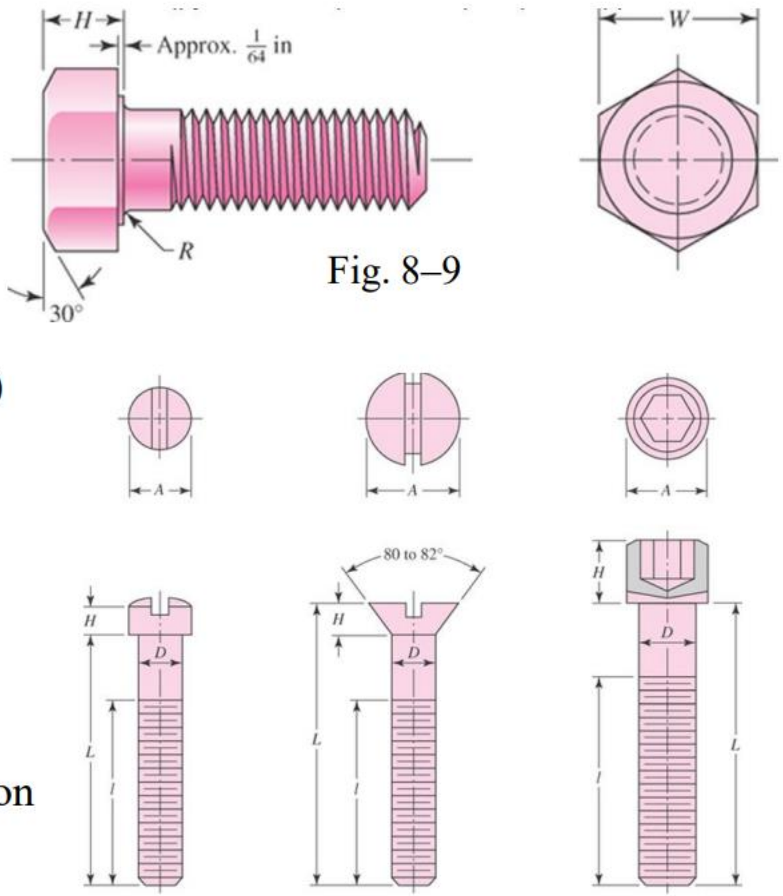
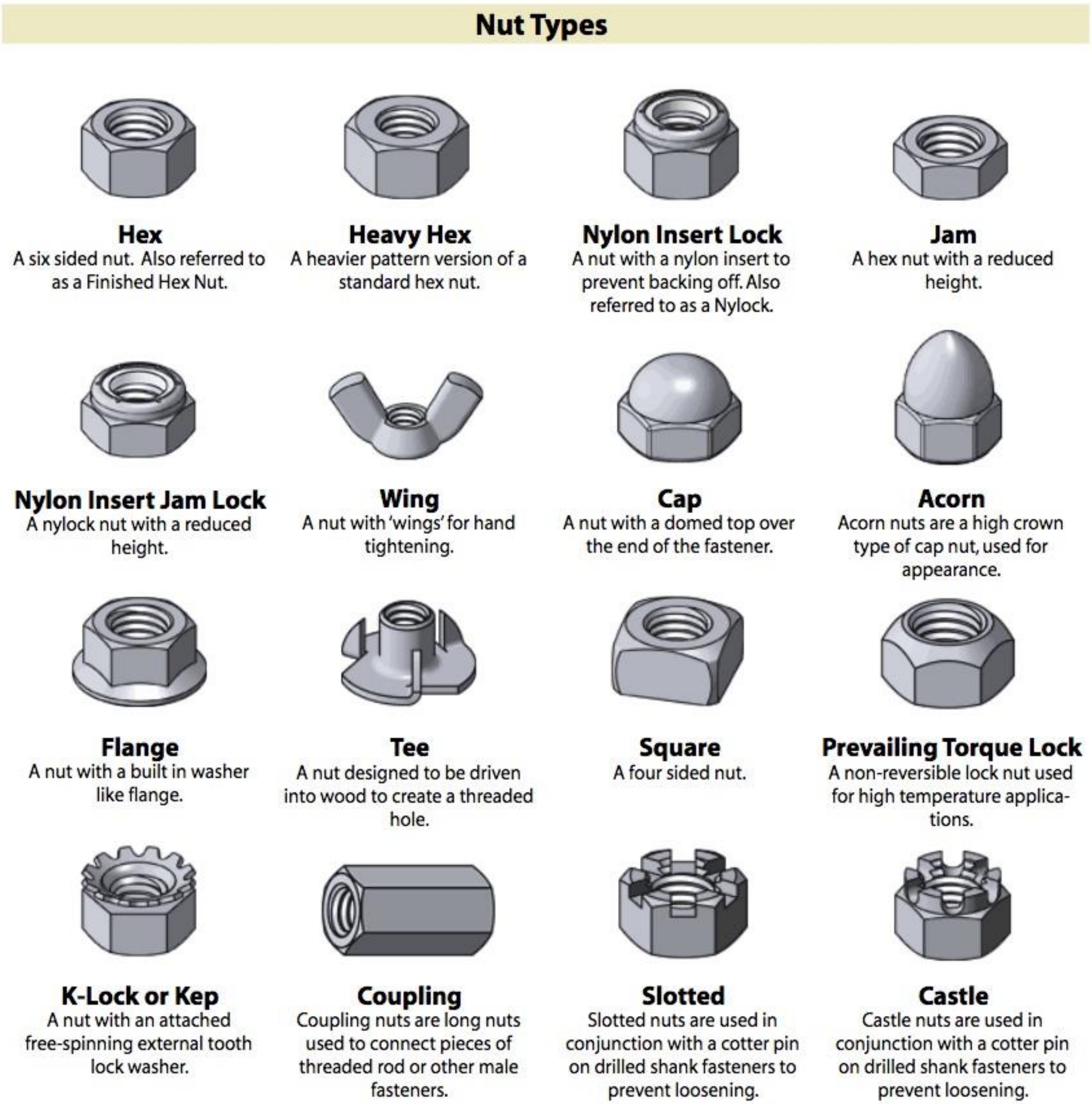
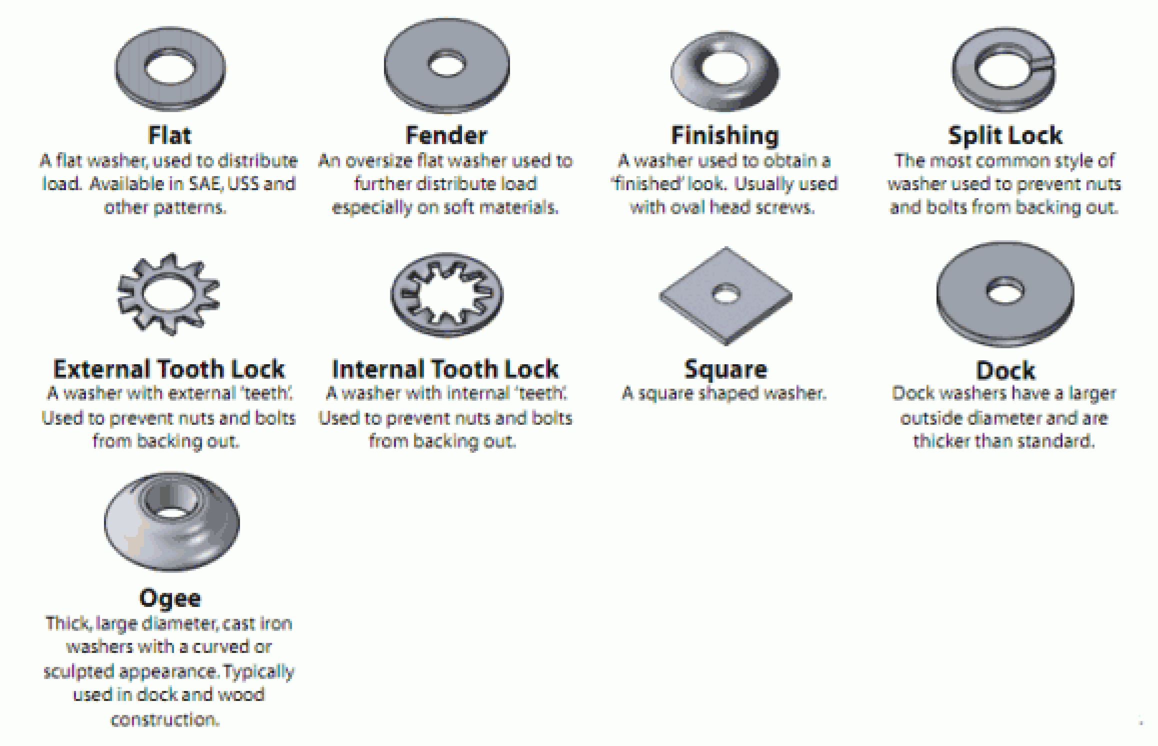
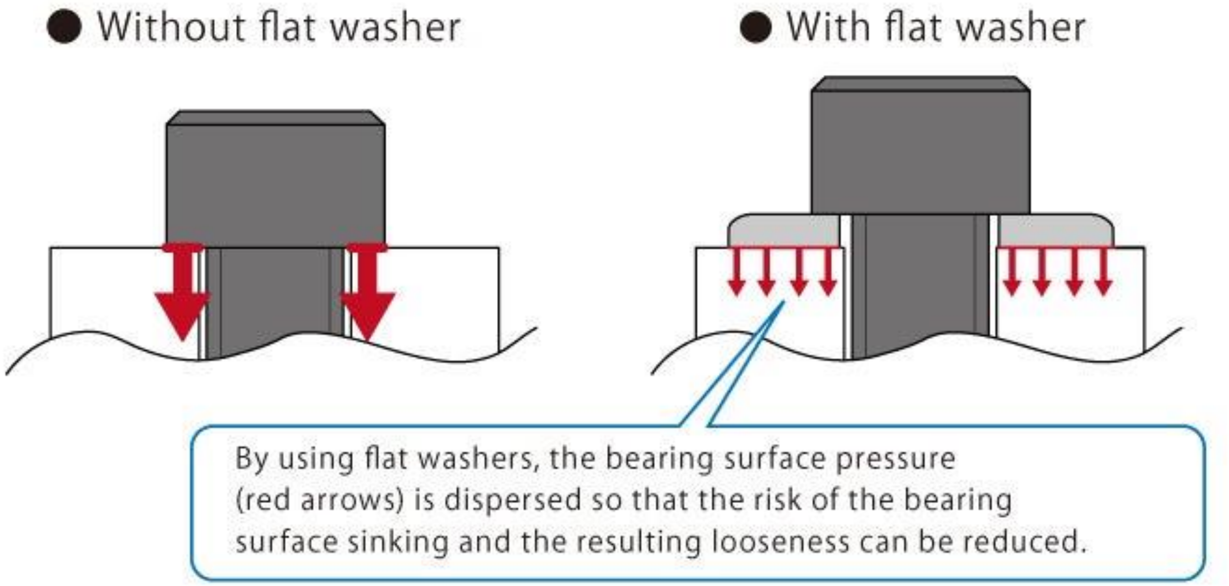


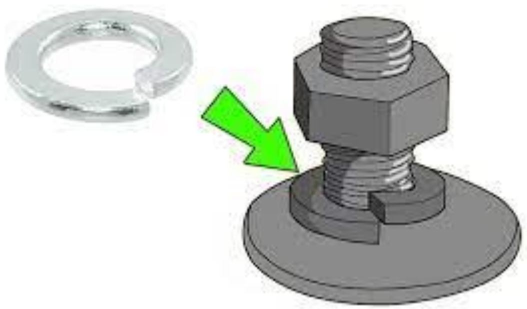
Fig. 8–9


Nut Types
Hex
A six sided nut. Also referred to as a Finished Hex Nut.
Heavy Hex
A heavier pattern version of a standard hex nut.
Nylon Insert Lock
A nut with a nylon insert to prevent backing off. Also referred to as a Nylock.
Jam
A hex nut with a reduced height.
Nylon Insert Jam Lock
A nylock nut with a reduced height.
Wing
A nut with 'wings' for hand tightening.
Cap
A nut with a domed top over the end of the fastener.
Acorn
Acorn nuts are a high crown type of cap nut, used for appearance.
Flange
A nut with a built in washer like flange.
Tee
A nut designed to be driven into wood to create a threaded hole.
Square
A four sided nut.
Prevailing Torque Lock
A non-reversible lock nut used for high temperature applica-tions.
K-Lock or Kep
A nut with an attached free-spinning external tooth lock washer.
Coupling
Coupling nuts are long nuts used to connect pieces of threaded rod or other male fasteners.
Slotted
Slotted nuts are used in conjunction with a cotter pin on drilled shank fasteners to prevent loosening.
Castle
Castle nuts are used in conjunction with a cotter pin on drilled shank fasteners to prevent loosening.

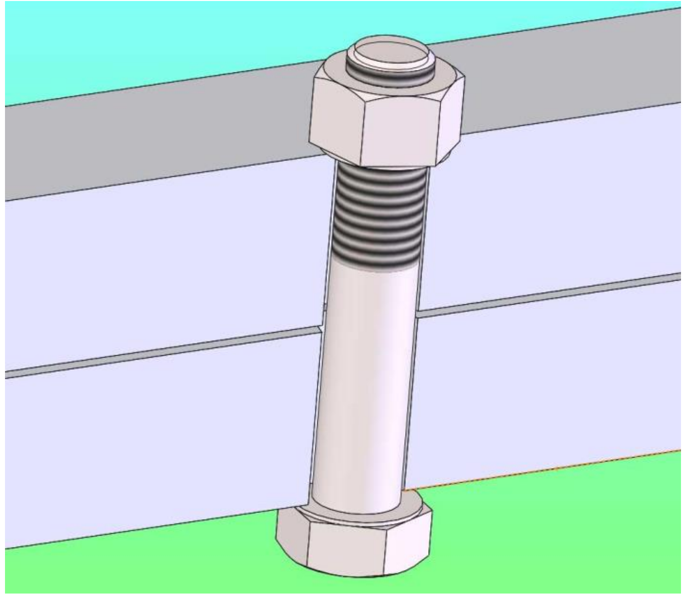

Flat
A flat washer, used to distribute load. Available in SAE, USS and other patterns.
Fender
An oversize flat washer used to further distribute load especially on soft materials.
Finishing
A washer used to obtain a 'finished' look. Usually used with oval head screws.
Split Lock
The most common style of washer used to prevent nuts and bolts from backing out.
External Tooth Lock
A washer with external 'teeth'. Used to prevent nuts and bolts from backing out.
Internal Tooth Lock
A washer with internal 'teeth'. Used to prevent nuts and bolts from backing out.
Square
A square shaped washer.
Dock
Dock washers have a larger outside diameter and are thicker than standard.
Ogee
Thick, large diameter, cast iron washers with a curved or sculpted appearance. Typically used in dock and wood construction.

Washers – why do we use them?

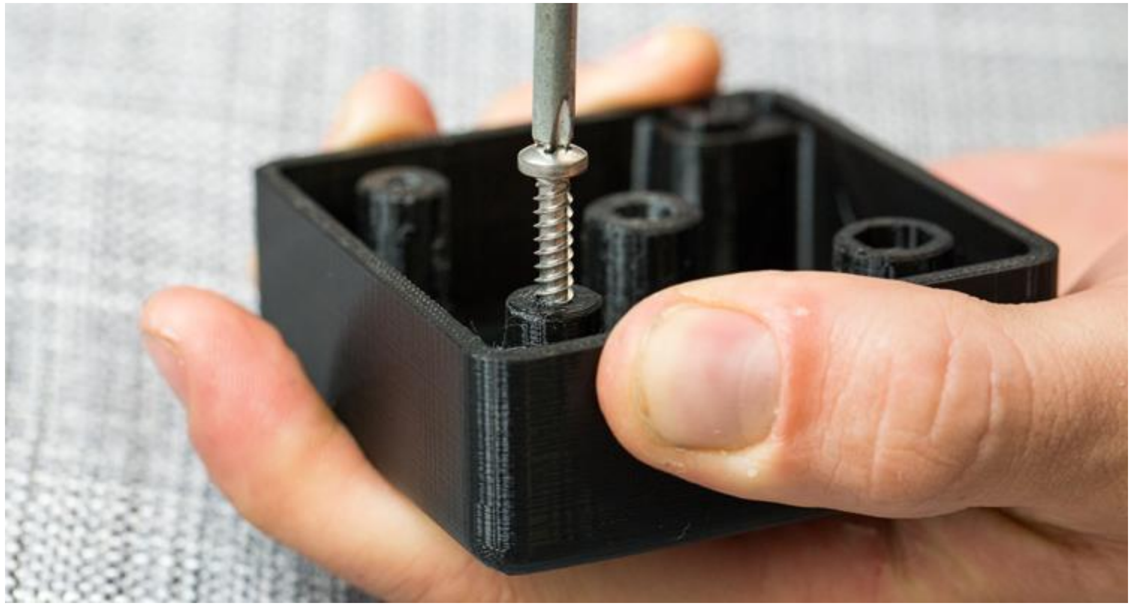




Fasteners & 3D Printing



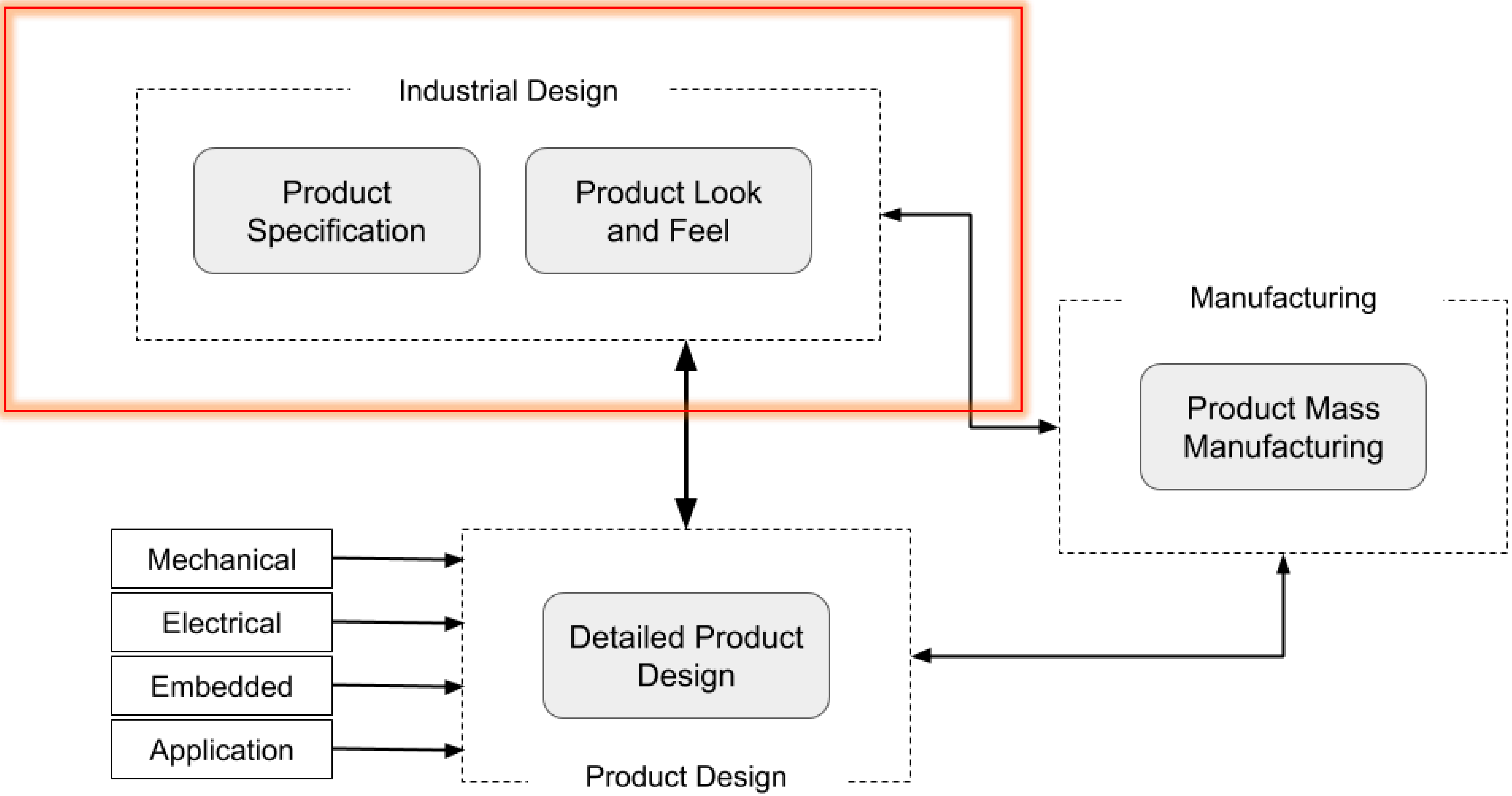
1) Bolt Holes
2) Captured Nut
3) Self-tap



- Finalized concept
- Finalized key engineering concept
- Demonstrated proof-of concept
- Work-like prototype
- Communicated concepts (drawings)

What next?

1) Industrial Design
2) Design for Manufacture


Industrial Design
Product Specification
Product Look and Feel
Manufacturing
Product Mass Manufacturing
Mechanical
Electrical
Embedded
Application
Detailed Product Design
Product Design

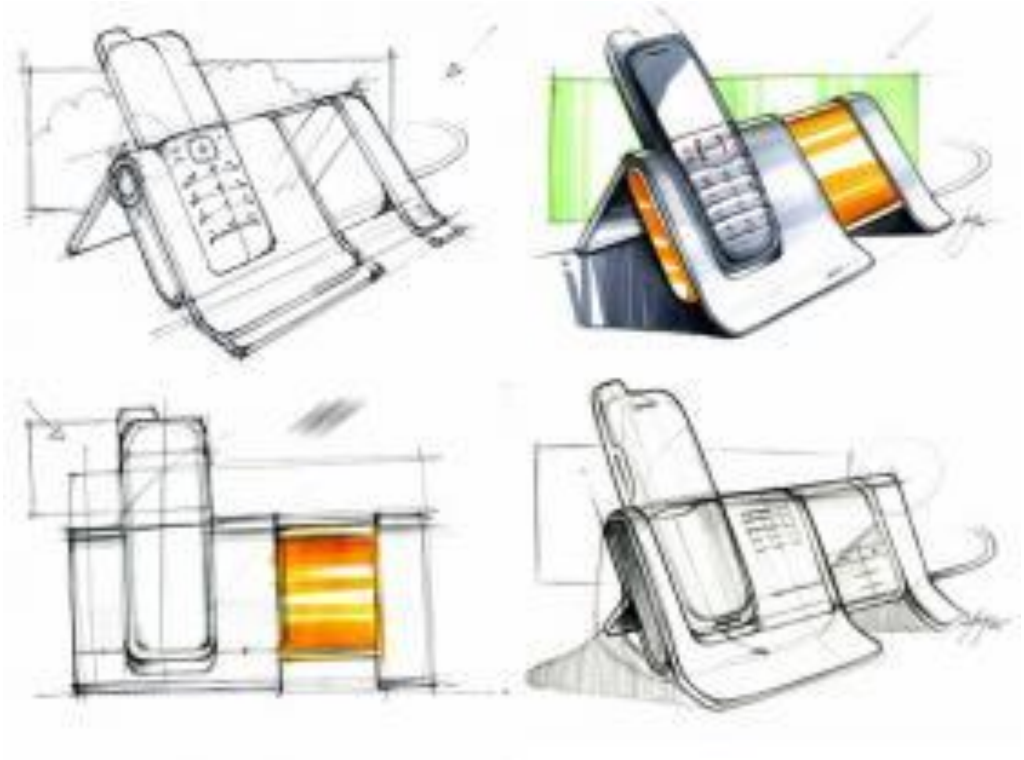
What is Industrial Design?

"(...) the professional service of creating and developing concepts and specifications that optimize the function, value, and appearance of products and systems for the mutual benefit of both user and manufacturer."

Industrial Designers Society of America

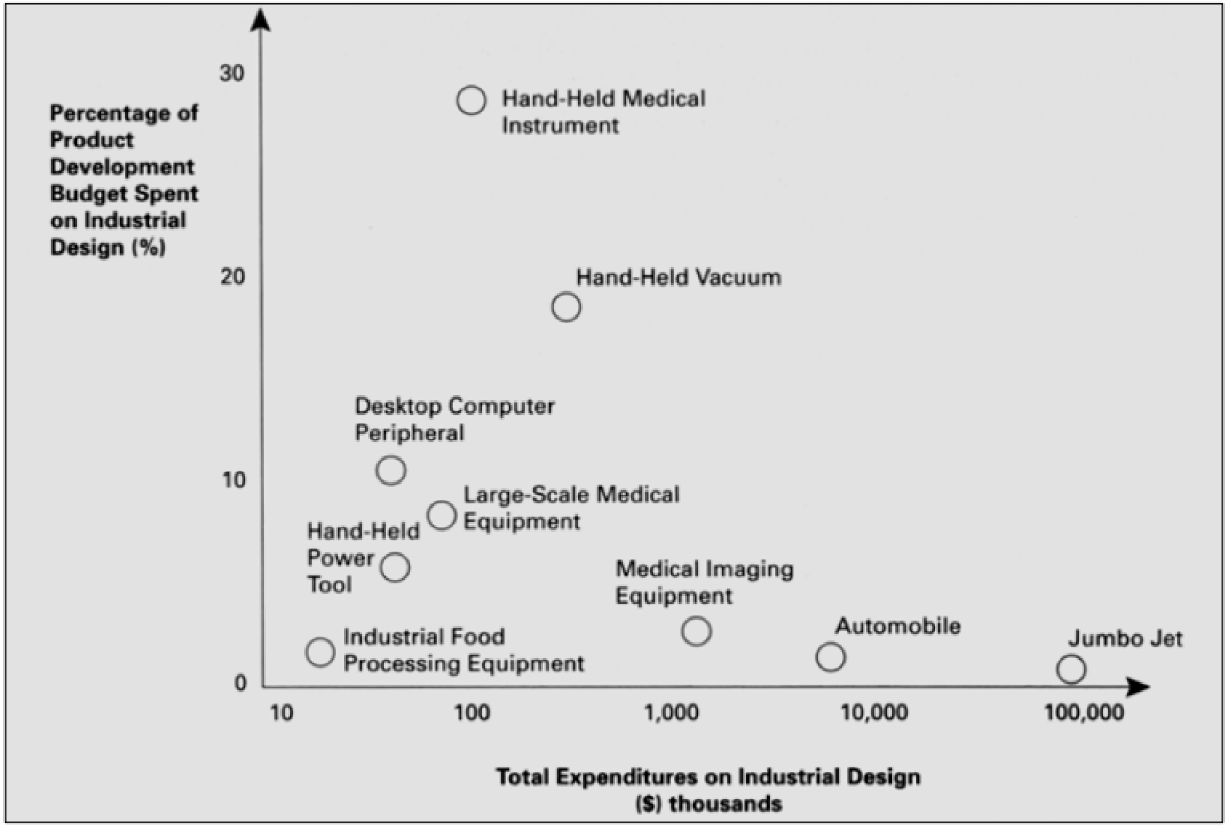
5 Goals of Industrial Design

- Utility
- Appearance
- Ease of maintenance
- Low costs
- Communication



How important is industrial design?

% of Development



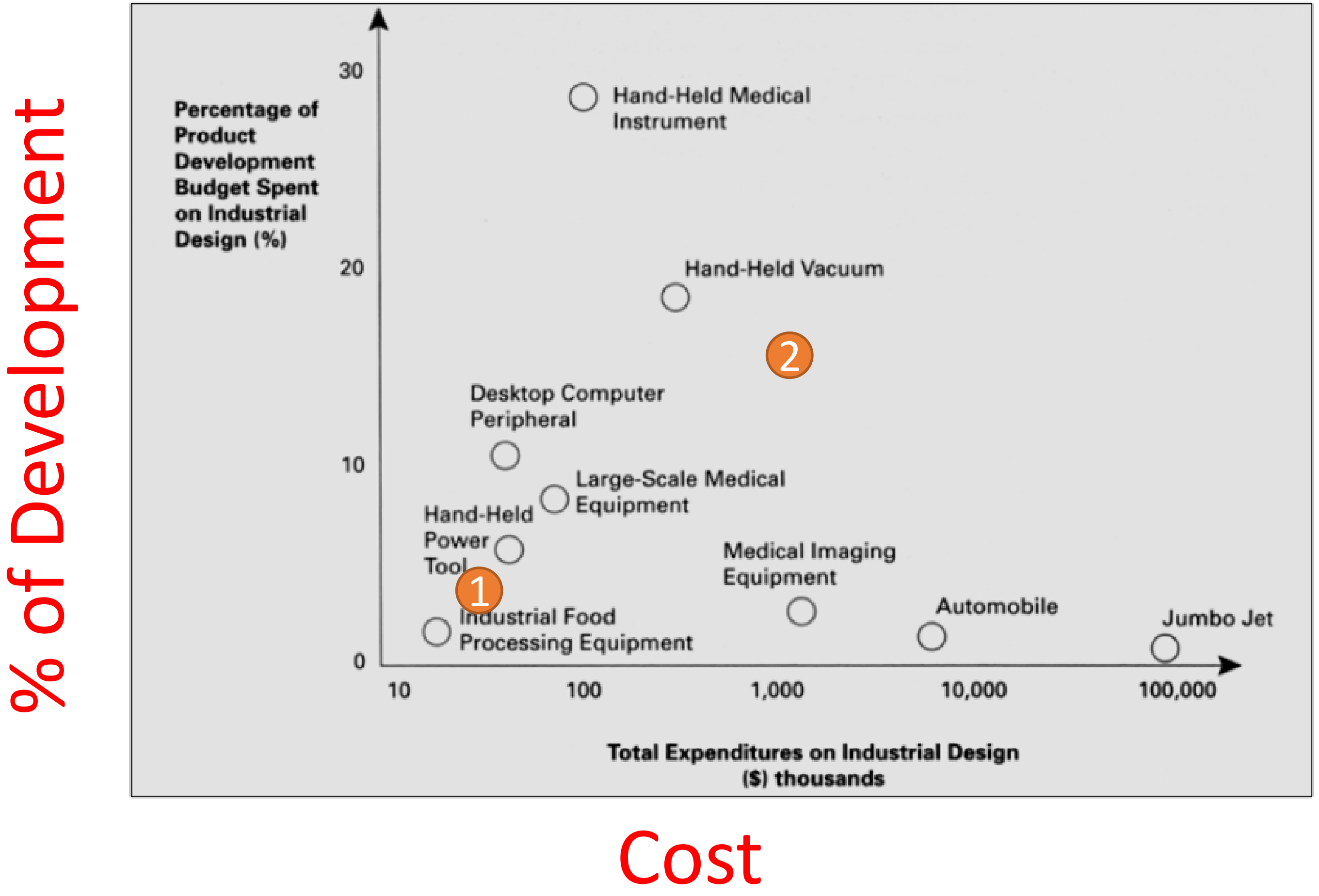
Cost

Where would you put:

1. Robot gripper for item handling
2. Mobile Phone

...varies with task

How important is industrial design?



Where would you put:

1. Robot gripper for item handling in factory
2. Mobile Phone

...varies with task

How important is industrial design?

Ergonomic needs

– How important is ease of use?
– How important is ease of maintenance?
– How many user interactions are required?
– How novel are the user interaction needs?
– What are the safety issues?

Aesthetic needs

– Is visual differentiation required?
– How important are pride of ownership, image and fashion?
– Will an aesthetic product motivate the team?

Needs	Level of Importance (Low / Medium / High)	Explanation of Rating
Ergonomics		
Ease of use		Critical for a portable telephone since it may be used frequently, may be needed in emergency situations, and can be operated by motorists while driving. The product's function must be communicated through its design.
Ease of maintenance		As with many integrated electronics products there is very little maintenance required.
Quantity of user interactions		There are many important user interactions such as: changing the battery, dialing, programming the features, sending and receiving calls.
Aesthetics		
Product differentiation		There were hundreds of models of cellular pones on the market when the StarTAC was introduced. Its appearance (including its size and shape) was essential for differentiation.
Pride of ownership, fashion, or image		The StarTAC was intended to be a highly visible product used by people for business and personal communication in public areas. It had to be physically attractive for everyday use.
Team motivation		The StarTAC's novel form turned out to be an important inspiration to the development team and selling point for senior management.

StarTAC

The First Flip phone

The Impact of ID…

Is ID worth the investment?

- Direct cost
- Manufacturing cost
- Time cost

How does ID establish a corporate identity?

– Apple Computer, Inc.

– Rolex Watch Co.

– Braun AG

– Bang & Olufsen

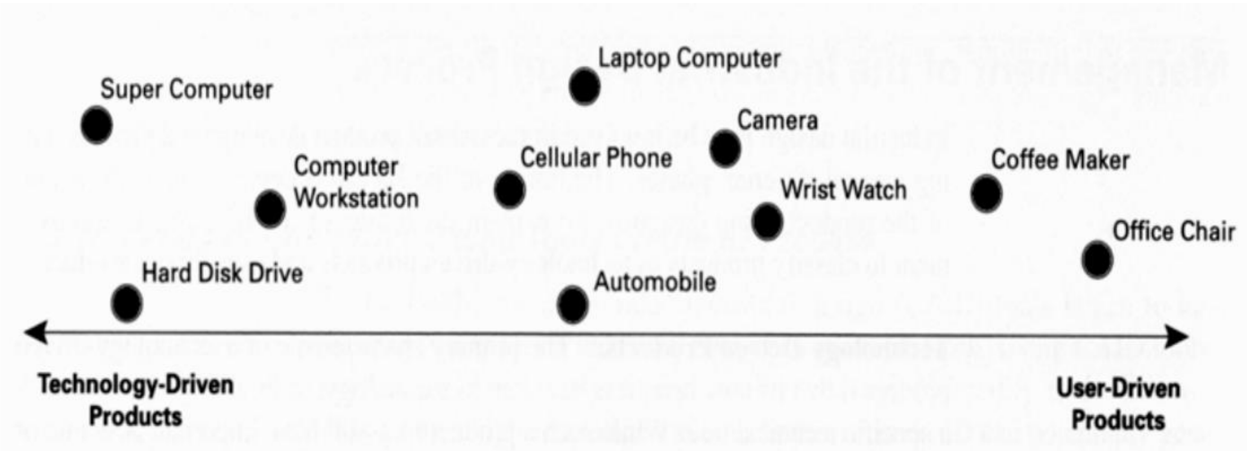
– Motorola, Inc.

Iconic Examples of Industrial Design

Ergonomics & Aesthetics help make these products stand out

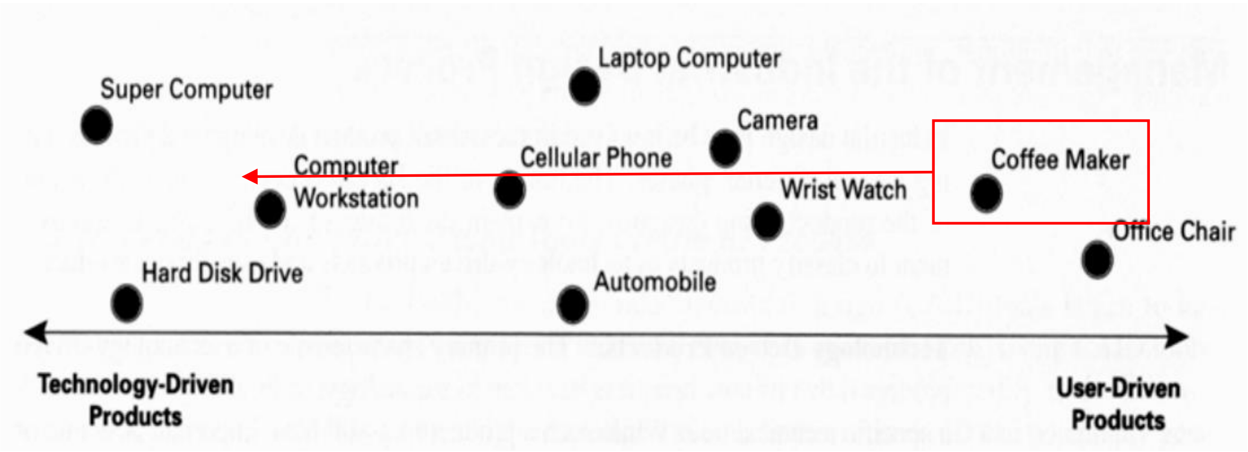
Management of ID Process

- Technology-driven products
- User-driven products



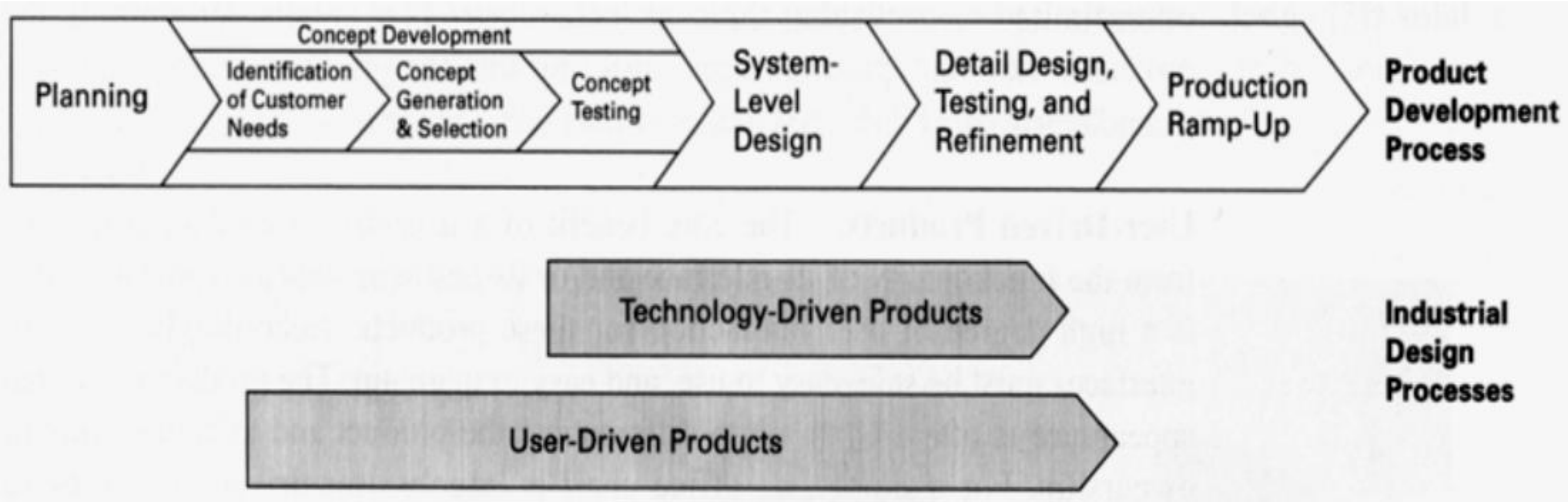
Management of ID Process

- Technology-driven products
- User-driven products



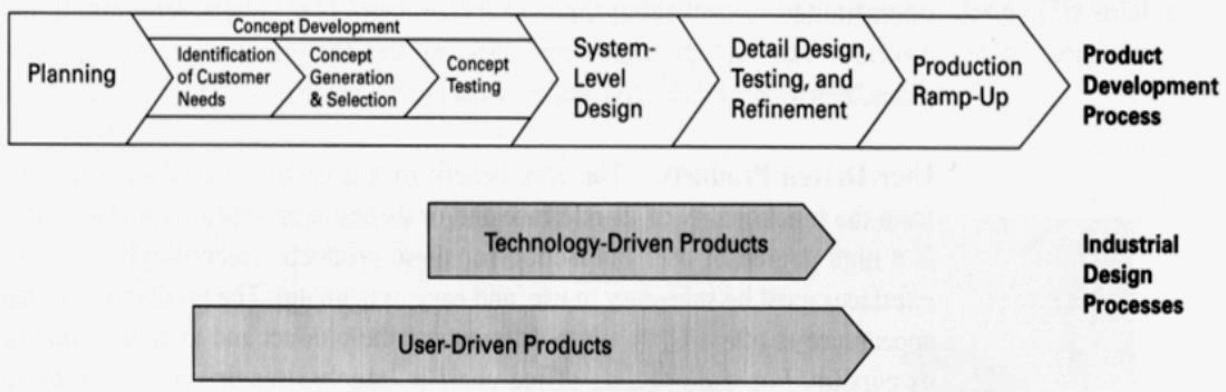
Management of ID Process

When does ID come into play?



- Can have pure product development or industrial design
- Most-likely blend and combine

Management of ID Process



Product Development Activity	Type of Product	
	Technology-Driven	**User-Driven**
Identification of Customer Needs	ID typically has no involvement	ID works closely with marketing to identify customer needs. Industrial designers participate in focus groups or one-on-one customer interviews
Concept Generation and Selection	ID works with marketing and engineering to assure that human factors and user-interface issues are addressed. Safety and maintenance issues are often of primary importance	ID generates multiple concepts according to the industrial design process flow described earlier
Concept Testing	ID helps engineering to create prototypes, which are shown to customers for feedback	ID leads in the creation of models to be tested with customers by marketing
System-Level Design	ID has typically little involvement	ID narrows down the concepts and refines the most promising approaches
Detail Design, Testing and Refinement	ID is responsible for packaging the product once most of the engineering details have been addressed. ID receives product specifications and constraints from enginering and marketing	ID selects a final concept, then coordinates with engineering, manufacturing and marketing to finalize the design

Assessing the quality of ID

Metrics for assessing ID:

- Quality of the user interfaces
- Emotional appeal
- Ability to maintain and repair the product
- Appropriate use of resources
- Product differentiation

Can be subjective…

May not appeal to all

Assessing the quality of ID

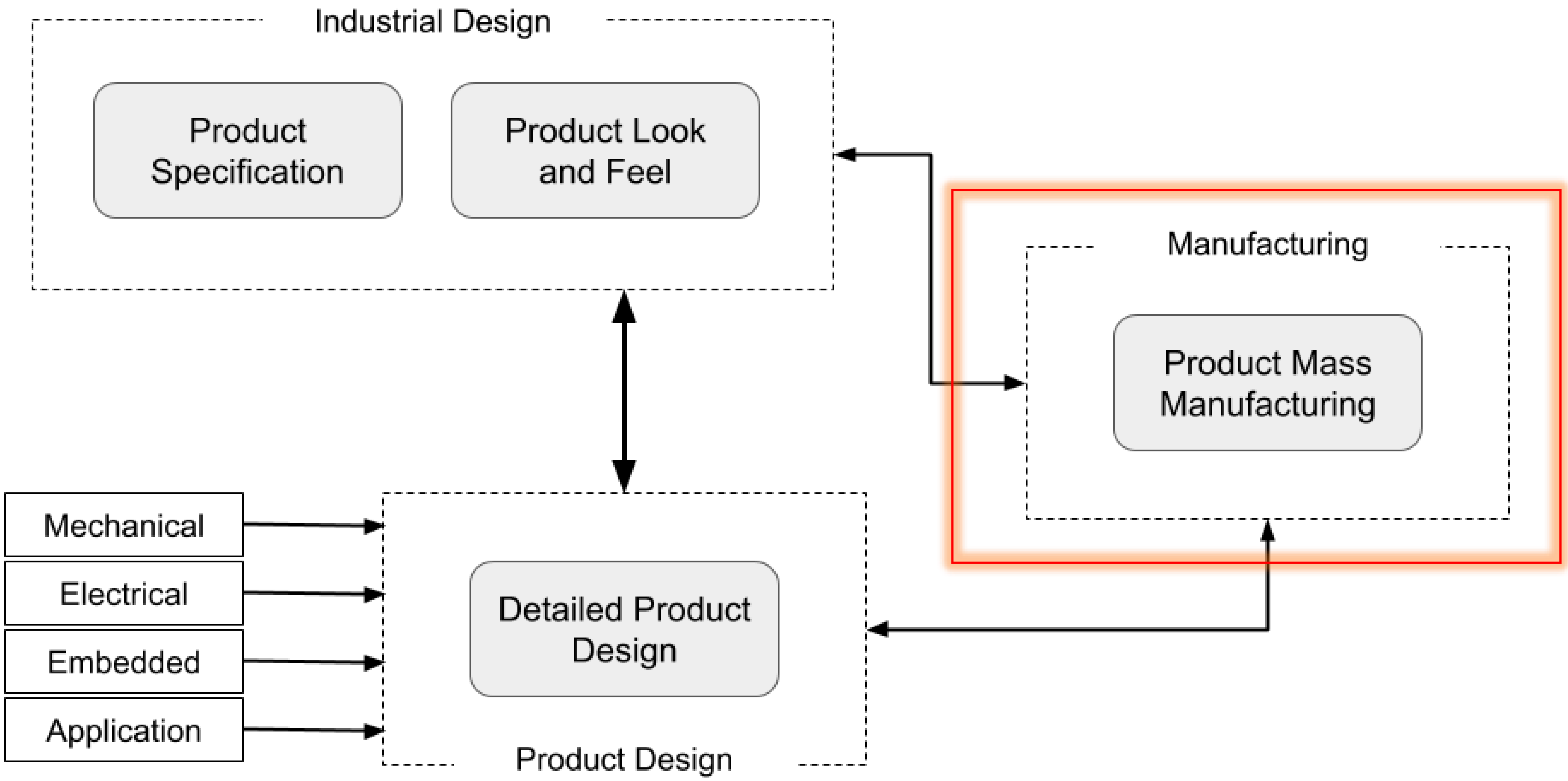
Assessment Category	Level of Importance (Low – Medium – High)	Explanation of Rating
1. Quality of the User Interfaces		In general, the StarTAC is both easy to use and comfortable. For example: calls can be answered by simply opening the keypad cover, numbers can be easily dialed into the keypad, and the functions are readily accessible. The StarTAC's drawbacks include that the visual display can be difficult to interpret because it mixes upper- and lower-case alphabetic characters, and that some users inadvertently remove the battery when attempting to open the phone for the first time.
2. Emotional Appeal		The StarTAC has a high emotional appeal which stems from its sleek appearance and tiny size.
3. Ability to Maintain and Repair the Product		Although maintenance and repair are not of primary importance to the customer, the StarTAC rates high in this category. The battery can be removed and replaced easily. Customers can install various batteries depending on their preference for size, weight, and talk time.
4. Appropriate Use of Resources		The final design includes only those features that satisfy real customer needs. Materials were selected to satisfy manufacturing constraints, to withstand extreme environmental conditions, and to meet strict appearance criteria.
5. Product Differentiation		The StarTAC's appearance is clearly unique. It is easily identified when viewed in a public area or next to a competitor's product.

StarTAC

The First Flip phone

Summary

- The primary mission of ID is to design the aspects of a product that relate to the user: aesthetics and ergonomics
- Most products can benefit in some way or another from ID.
- When the success of a product relies more on technology, ID can be integrated into development process later.



Industrial Design
Product Specification
Product Look and Feel
Manufacturing
Product Mass Manufacturing
Mechanical
Electrical
Embedded
Application
Detailed Product Design
Product Design

Design for Manufacture

- Detail design decisions can have substantial impact on product **quality and cost**
- Development teams face multiple, and often **conflicting**, goals
- It is important to have matrics with which to **compare alternative designs**
- A well-defined method assists the decision –making process

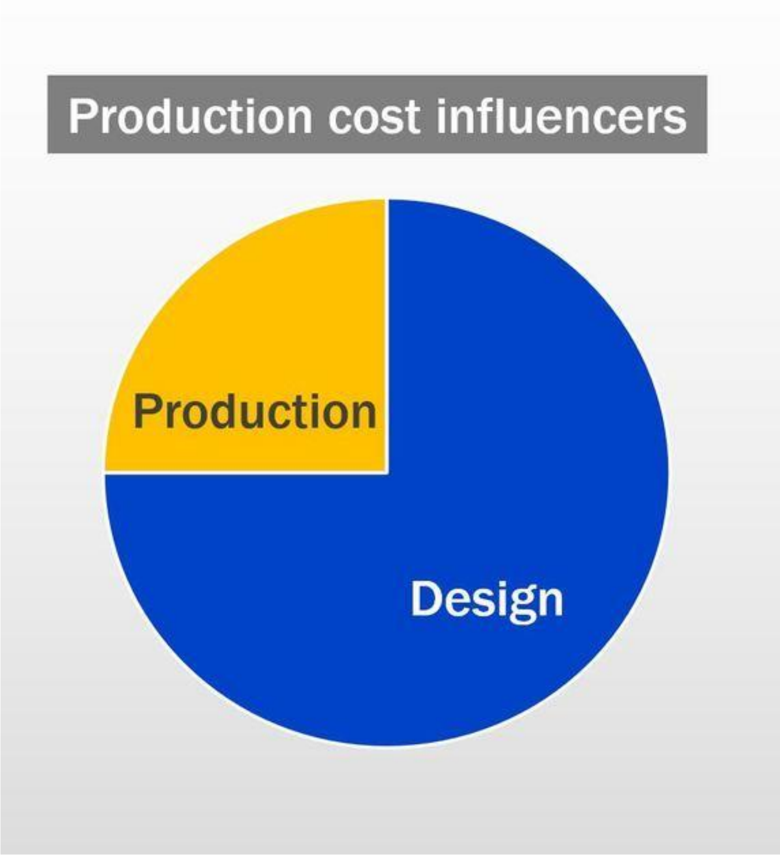
Design for Manufacture

Why not do this in product development?

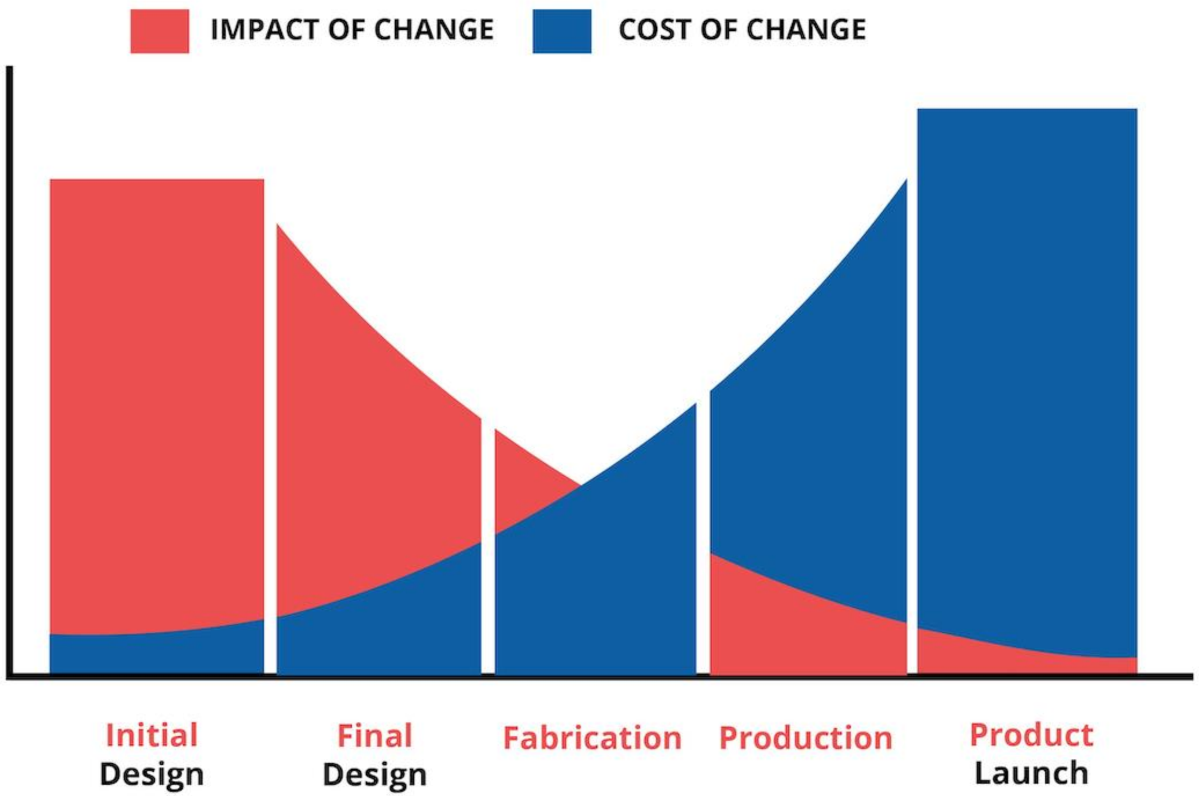
- Customer needs and product specs are hard to link with downstream product development
- Many teams use "design for X" where X means reliability, robustness, environmental impact, manufacturing,...

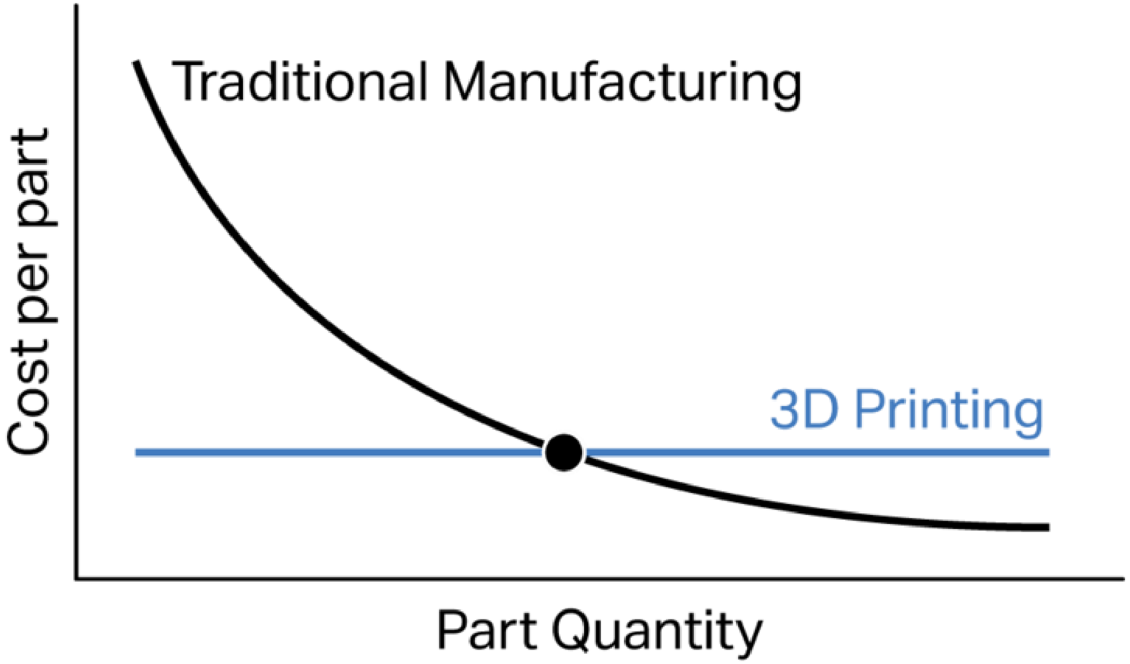
The goal of DFM:

- *Economically successful design is about ensuring high product quality while minimizing manufacturing cost*



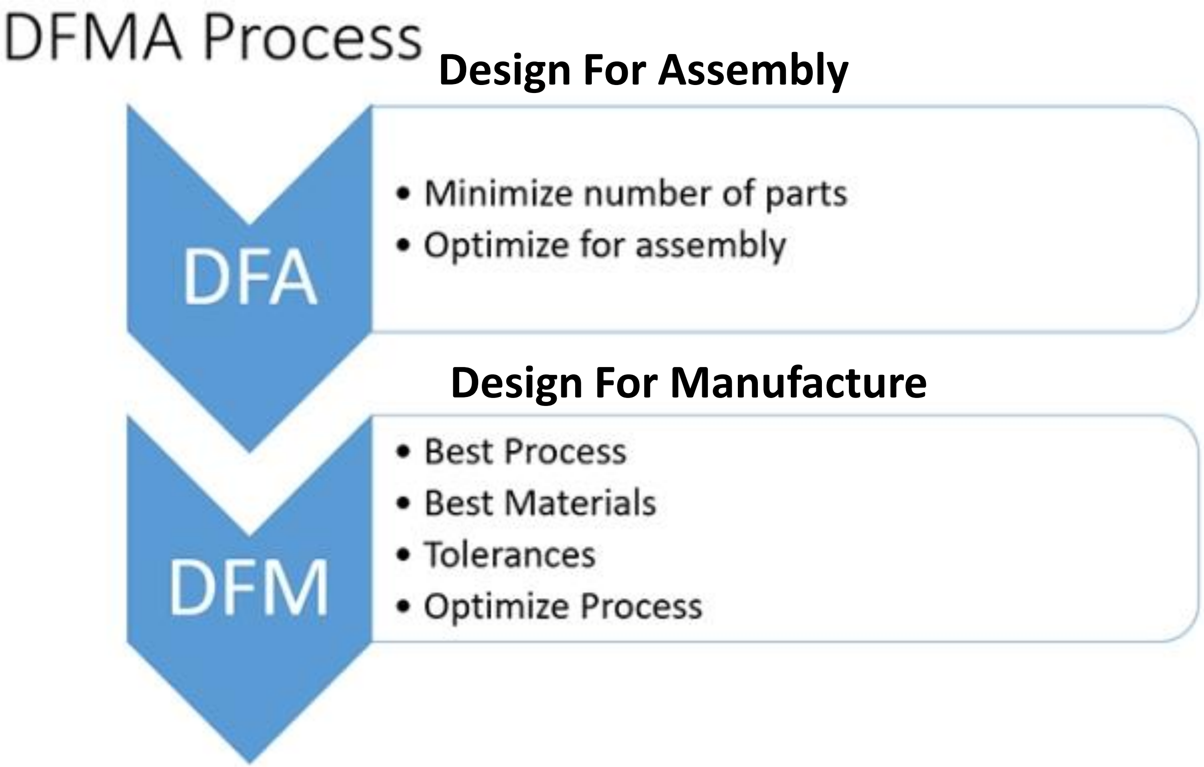
Design for Manufacture





Design for Manufacture

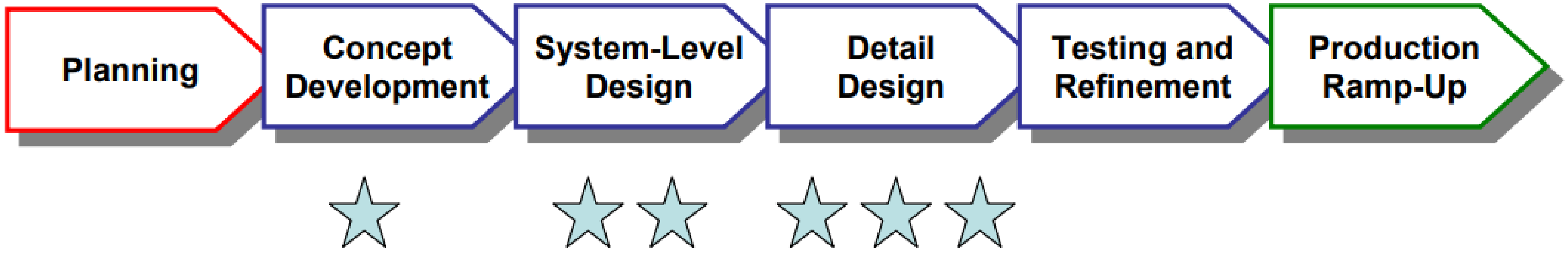
DFM requires a cross-functional team → One of the most integrative practices in PD



Inputs to DFM include:

– sketches, drawings, product specs, design alternatives;
– detailed understanding of production and assembly processes;
– estimates of manufacturing costs, production volumes and ramp-up timing.

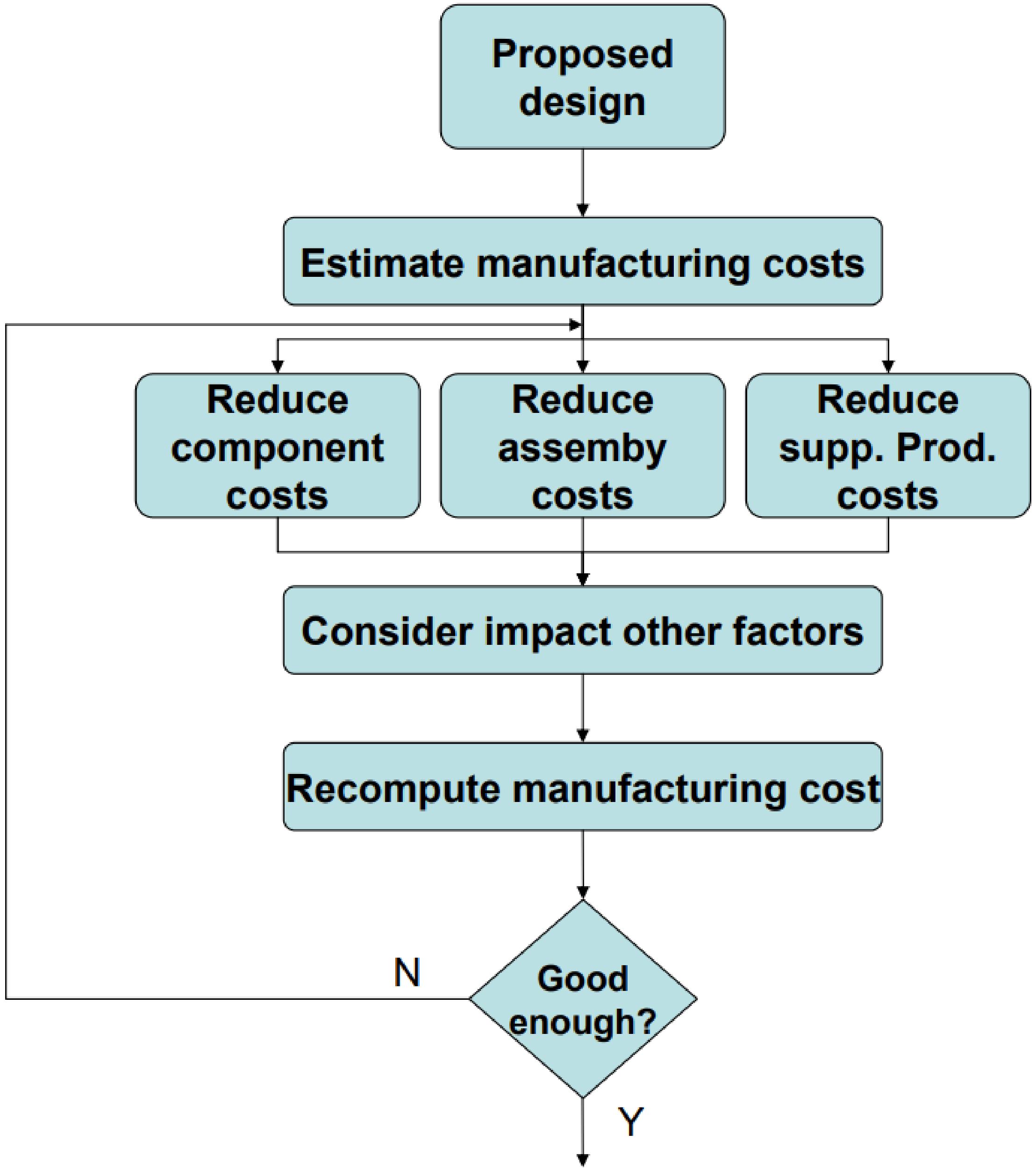
DFM within Product Development Process



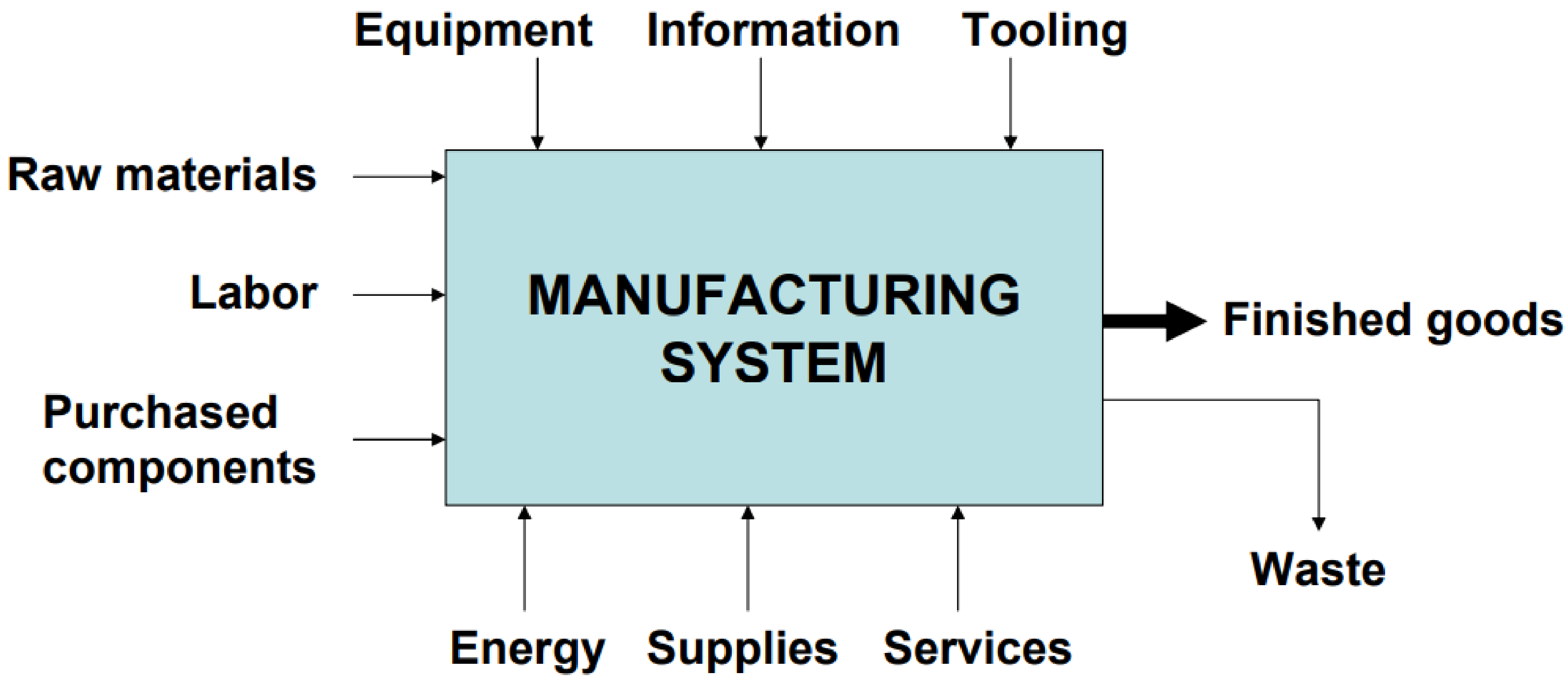
How can we emphasize manufacturing issues throughout the development process?

- Around 70% of the manufacturing costs of a product can be derived from design decisions like materials and manufacturing method.
- The remaining 30% of the costs make up production decisions like process planning and tool selection.
- Focusing on design optimization reduces the cost of manufacturing.

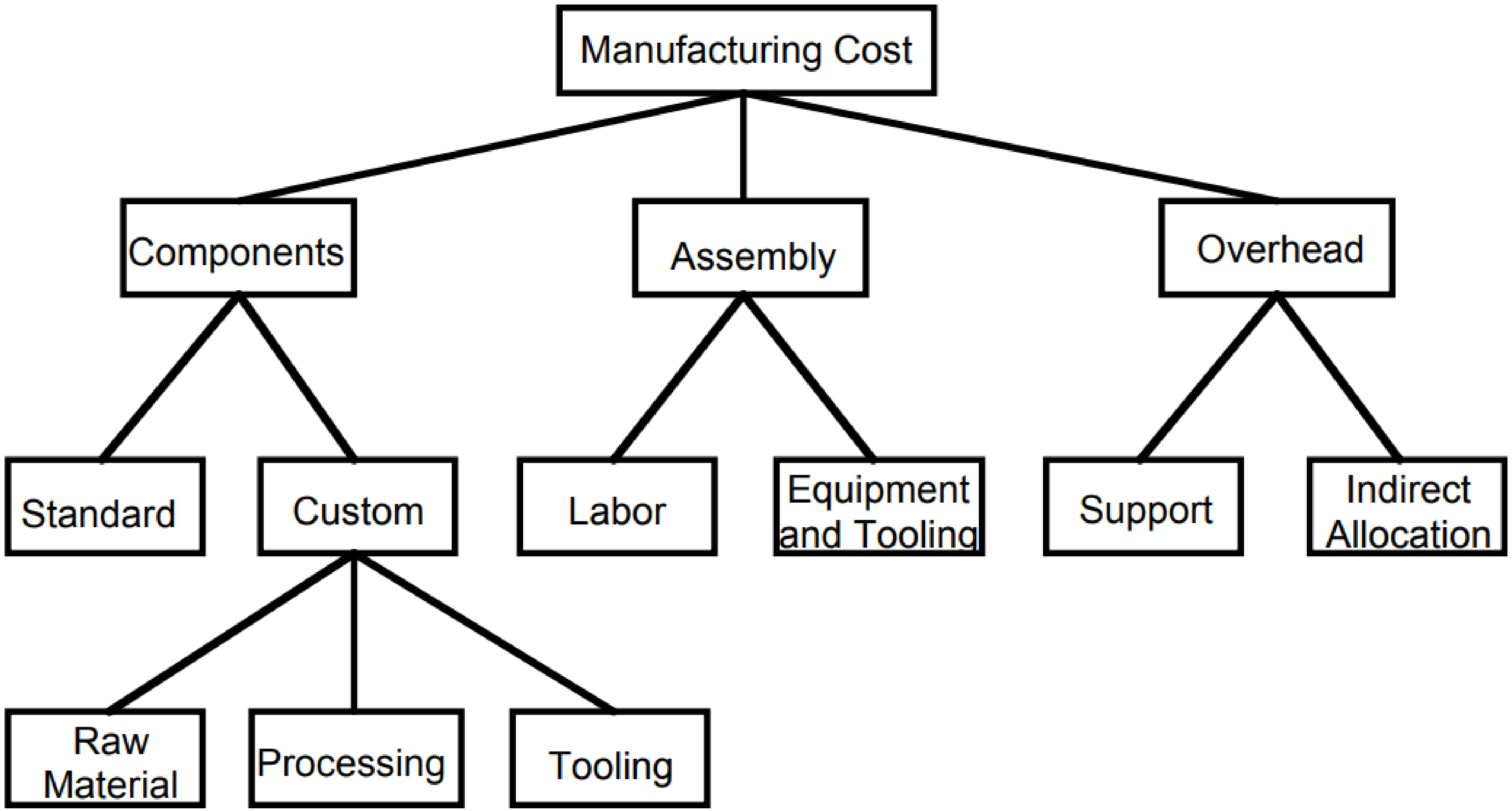
DFM Approach



Step 1: Estimate Cost



Step 1: Estimate Cost

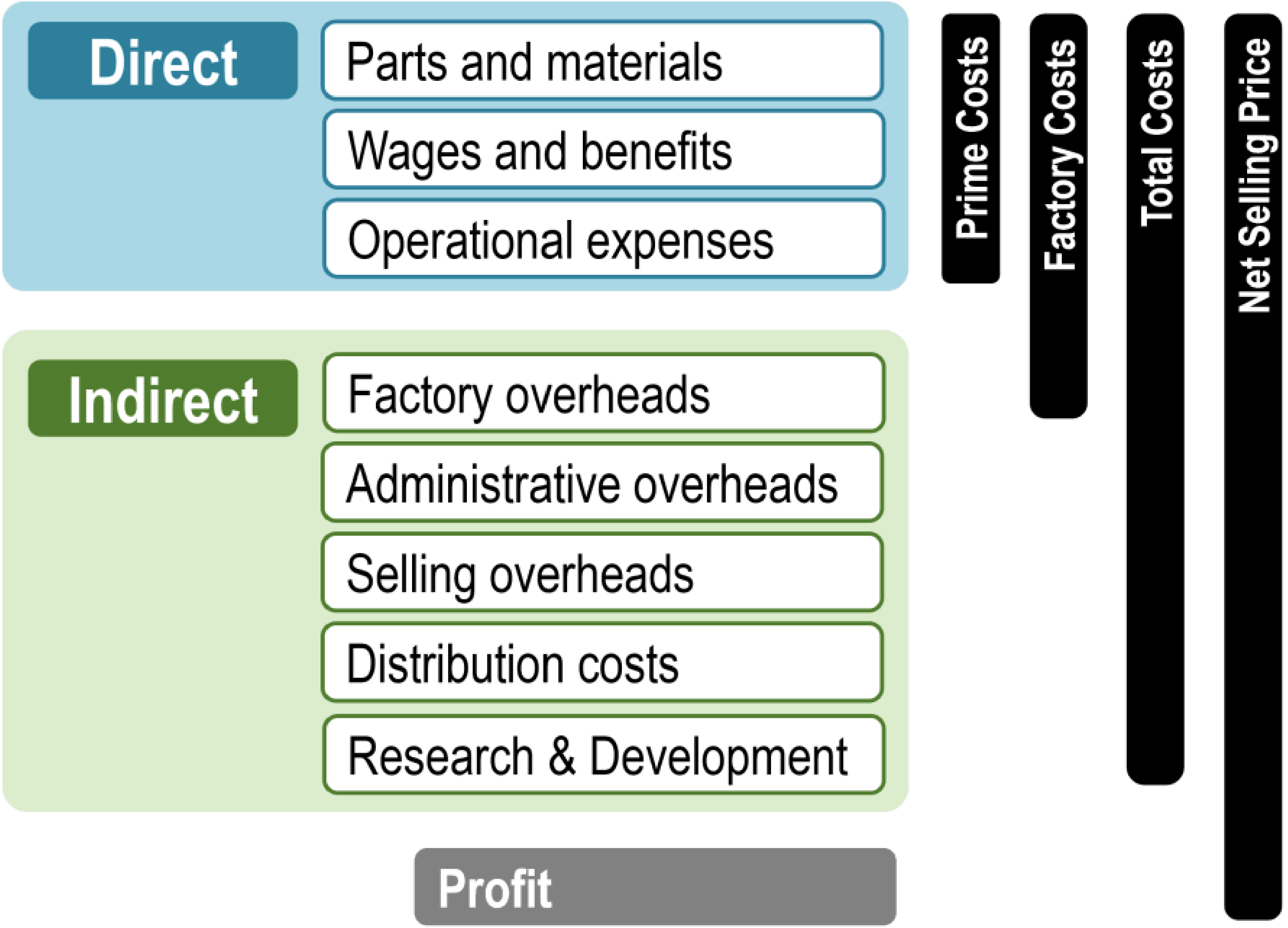


What affects the manufacturing cost?

Step 1: Estimate Cost

Estimating manufacturing cost:

- Fixed costs versus variable costs
- Estimate the costs of standard components
- Estimate the costs of custom components
- Estimate the cost of assembly
- Estimate the overhead costs



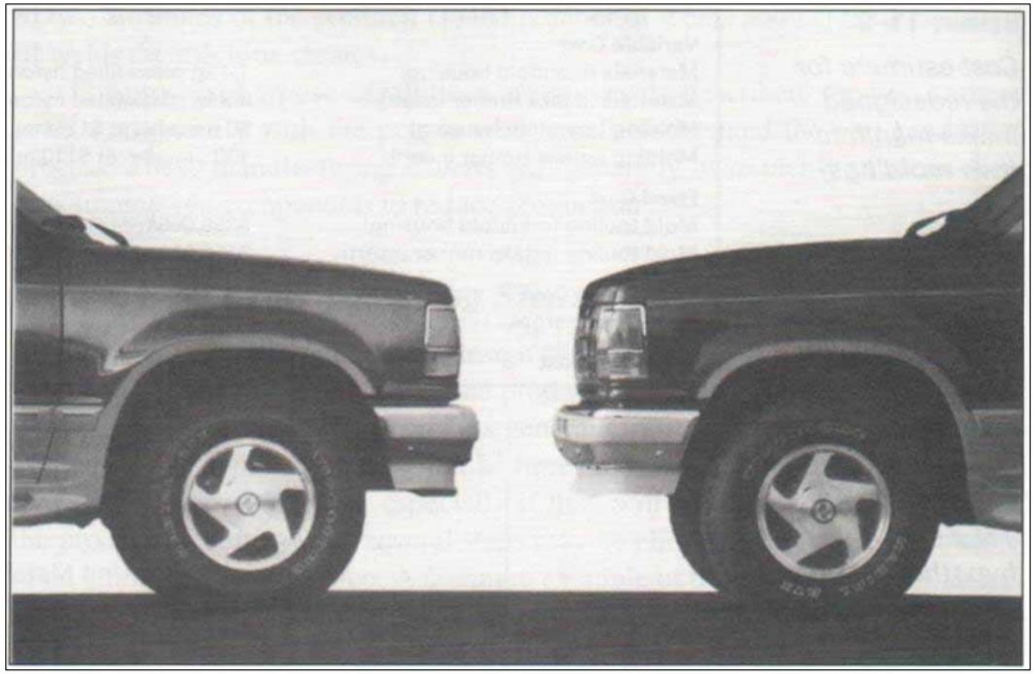
Step 1: Estimate Cost

Variable Cost		
Materials	5.7 kg aluminum at $2.25/kg	$12.83
Processing (casting)	150 units/hr. at $530/hr.	3.53
Processing (machining)	200 units/hr. at $340/hr.	1.70
Fixed Cost		
Tooling for casting	$160,000/tool at 500K units/tool (lifetime)	0.32
Machine tools and fixtures	$1,800,000/line at 10M units (lifetime)	0.18
Total Direct Cost		**$18.56**
Overhead charges		$12.09
Total Unit Cost		**$30.65**

Variable Cost		
Materials (manifold housing)	1.4 kg glass-filled nylon at $2.75/kg	$ 3.85
Materials (intake runner insert)	0.3 kg glass-filled nylon at $2.75/kg	0.83
Molding (manifold housing)	80 units/hr. at $125/hr.	1.56
Molding (intake runner insert)	100 units/hr. at $110/hr.	1.10
Fixed Cost		
Mold tooling (manifold housing)	$350,000/tool at 1.5M units/tool	$ 0.23
Mold tooling (intake runner insert)	$150,000/tool at 1.5M units/tool	0.10
Total Direct Cost		**$ 7.67**
Overhead charges		$ 5.99
Total Unit Cost		**$13.66**

Step 2: Reduce Cost of Components

- Understand the process constraints
- Redesign the components to eliminate processing steps
- Choose the appropriate economic scale for the part process
- Standardize components and processes
- “Black-box” component procurement



Step 3: Reduce Cost of Assembly

- Design for assembly (DFA) is a subset of DFM
- Keeping score

$$DFA\ index = \frac{(Theoretical\ minimum\ number\ of\ parts) \times (3\ seconds)}{(Estimated\ total\ assembly\ time)}$$

- Ask of each part in a candidate design:
  1. Does the part need to move relative to the rest of the device?
  2. Does it need to be of a different material because of fundamental physical properties?
  3. Does it need to be separated from the rest of the device to allow for assembly, access, or repair?
- Parts satisfying one or more of the questions should theoretically be separate.

Have can we reduce **assembly** costs?

Integrate parts: Integrated parts do not have to be assembled

- Integrated parts can be less expensive
- Integrated parts allow for the geometrical dimensions and tolerances to be more precisely controlled

Maximize ease of assembly

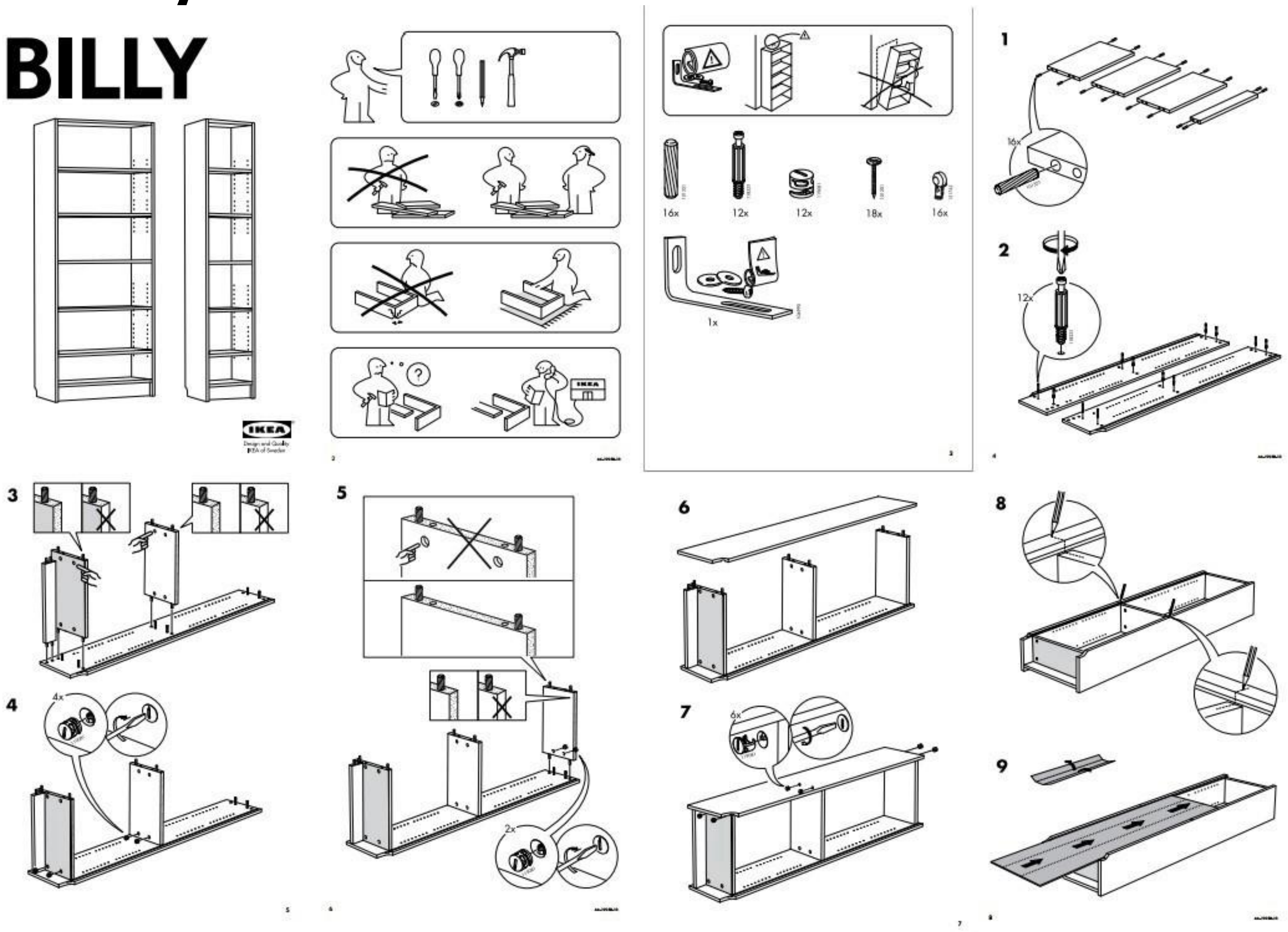
– Part is inserted from the top of the assembly
– Part is self-aligning
– Part does not need to be oriented
– Part requires only one hand for assembly
– Part requires no tools
– Part is assembled in a single, linear movement
– Part is secured immediately upon insertion

Have can we reduce **assembly** costs?

Consider customer assembly

– Look into it if purchasing and handling by the customer are substantially easier

– Substantial challenge to design a product to be assembled by the most inept customers, many of whom will ignore directions

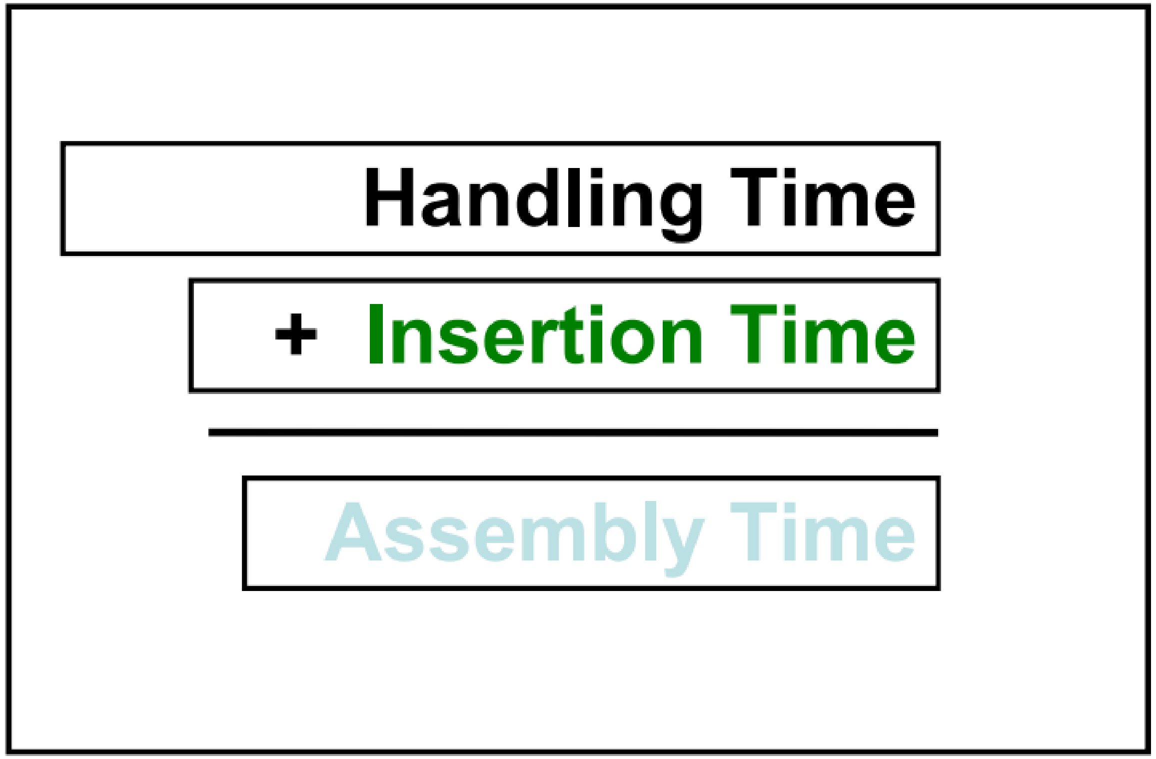


Design for Assembly Rules

Example set of DFA guidelines from a computer manufacturer:

1. Minimize parts count.
2. Encourage modular assembly.
3. Stack assemblies.
4. Eliminate adjustments.
5. Eliminate cables.
6. Use self-fastening parts.
7. Use self-locating parts.
8. Eliminate reorientation.
9. Facilitate parts handling.
10. Specify standard parts.

Design for Assembly



Key ideas of DFA:

– Minimize parts count

– Maximize the ease of handling parts

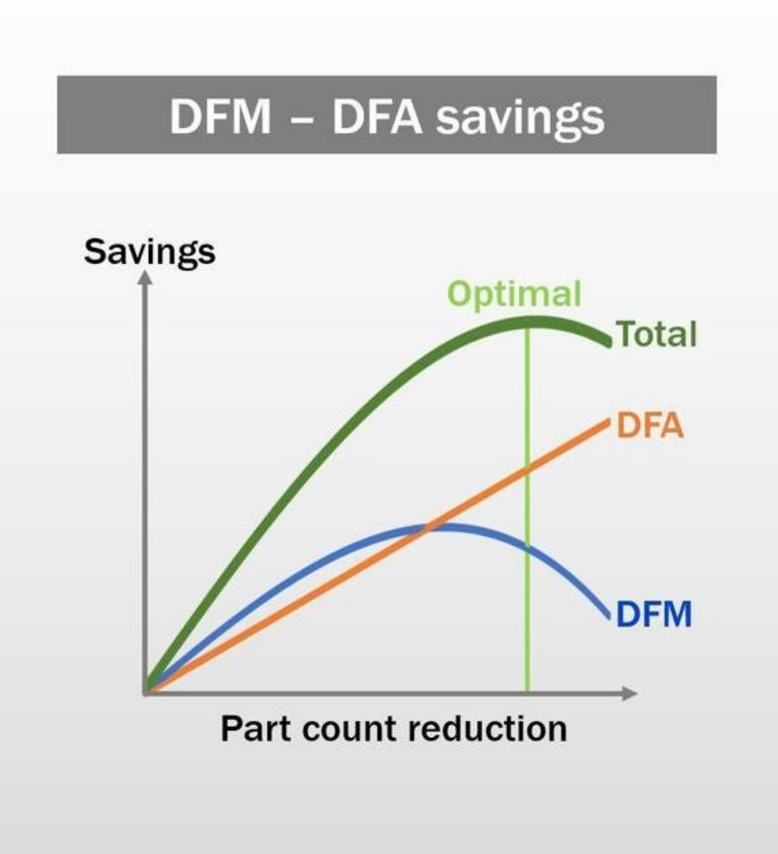
– Maximize the ease of inserting parts

- Benefits of DFA

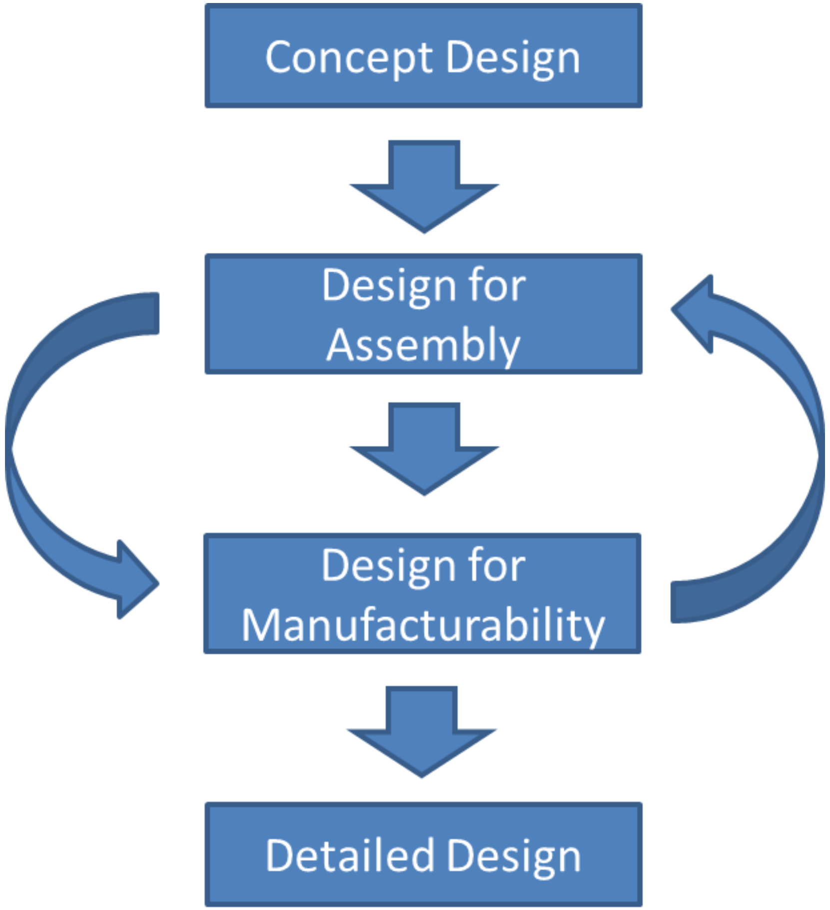
– Lower labor costs

– Other indirect benefits

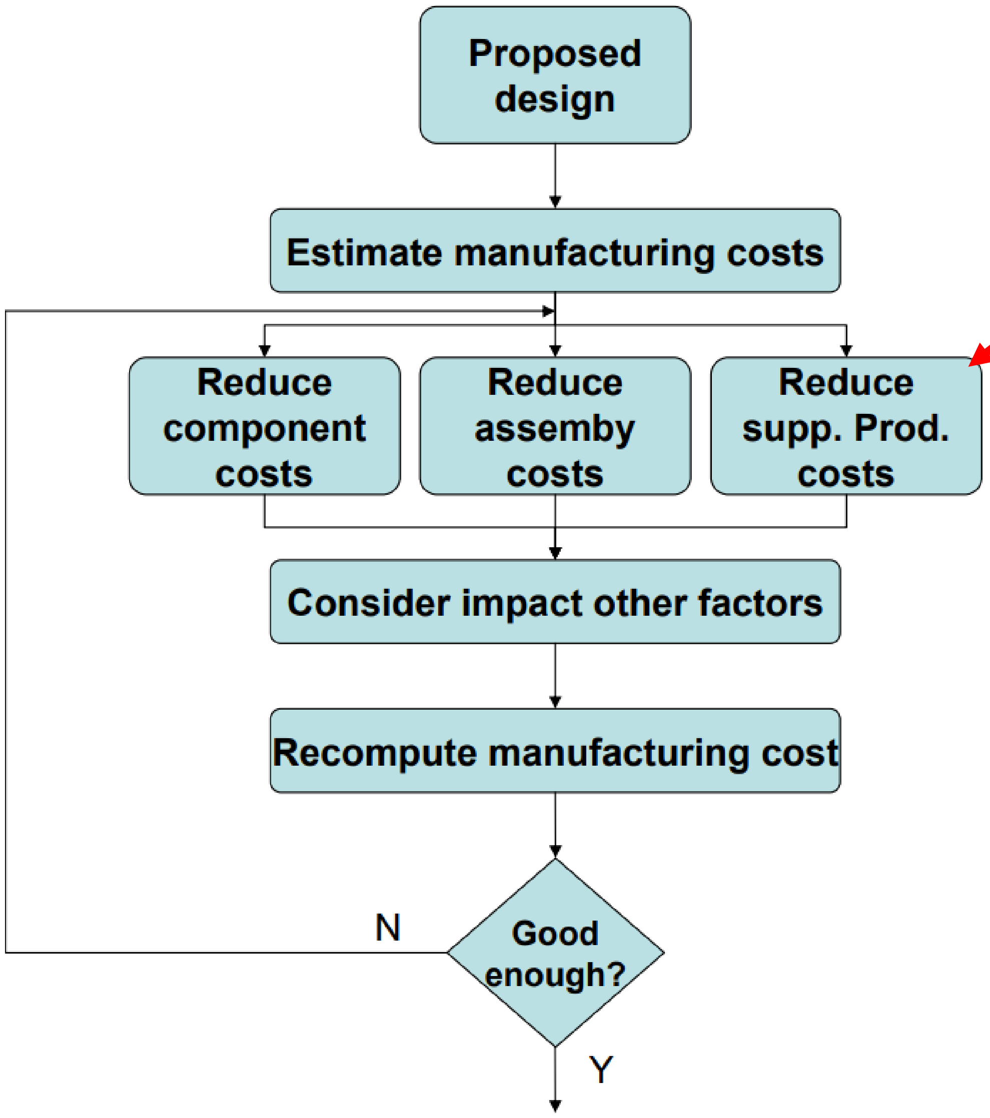
DFA and DFM



- DFA increases linearly with part count
- DFM non-linear with part count

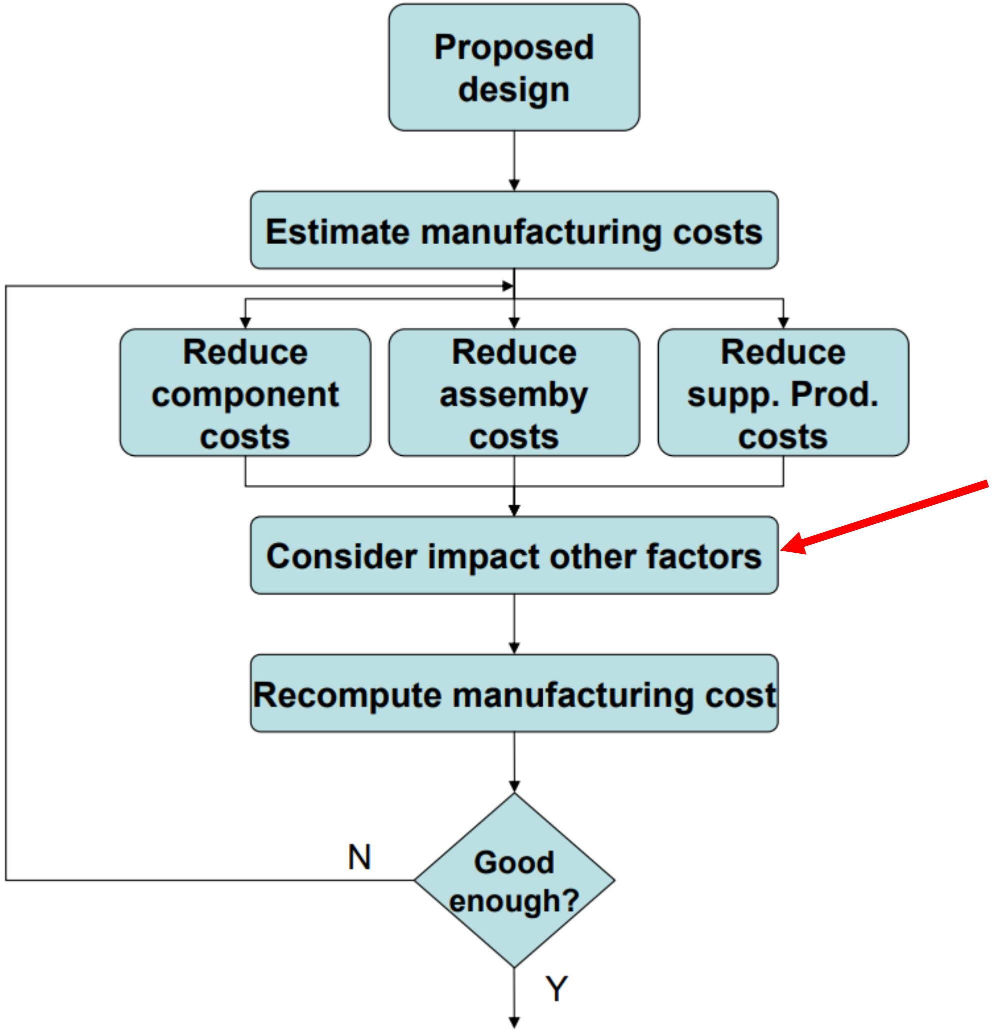


Step 4: Reduce Cost of Supporting Manufacture



- Minimize systemic complexity
- Error proofing

Step 5: Consider impact of DFM decisions on other factors



Impact of DFM on development time

– Reduction of $1 on each manifold would be worth $1 million in annual cost savings, but would not be worth a six-month delay in the project

- **Impact of DFM on development cost**

– If properly integrated in product development, extra cost is meaningless

- **Impact of DFM on product quality**

– Usually DFM results in improved serviceability, ease of disassembly, and recycling

– Can cause adverse effects in product reliability and robustness

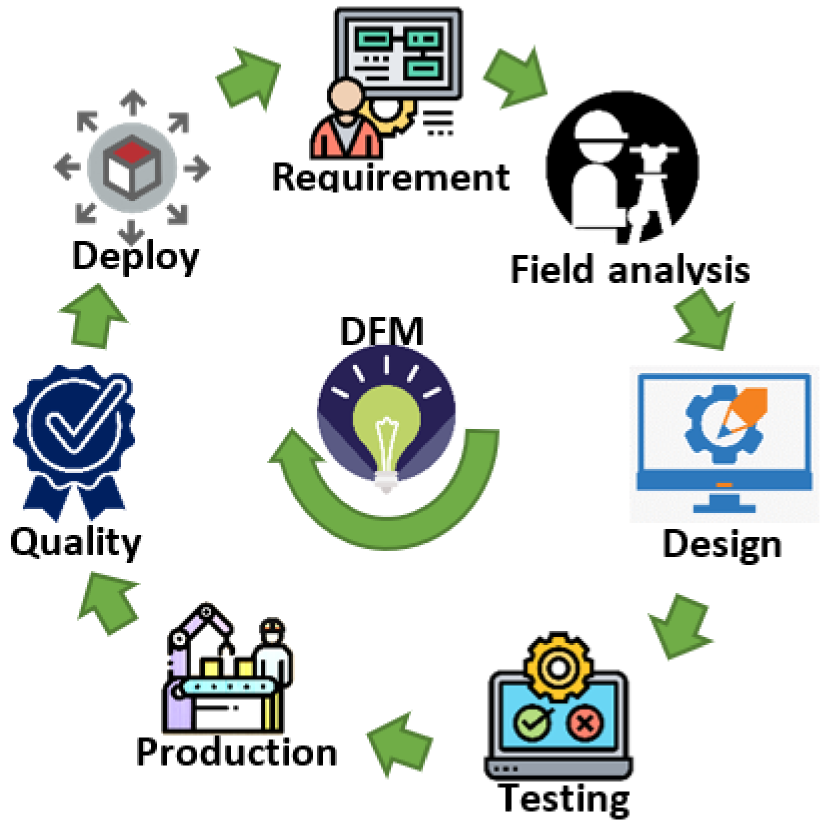
- **Impact of DFM on external factors**

– Component reuse

– Life cycle cost

Design For Manufacture

- DFM begins with the concept development phase and system-level design phase
- DFM utilizes estimates of manufacturing cost to guide and prioritize cost reduction efforts
- DFM practice involves making decisions in the absence of detailed data



What percentage of ecological impacts of a product are locked in at the design phase?

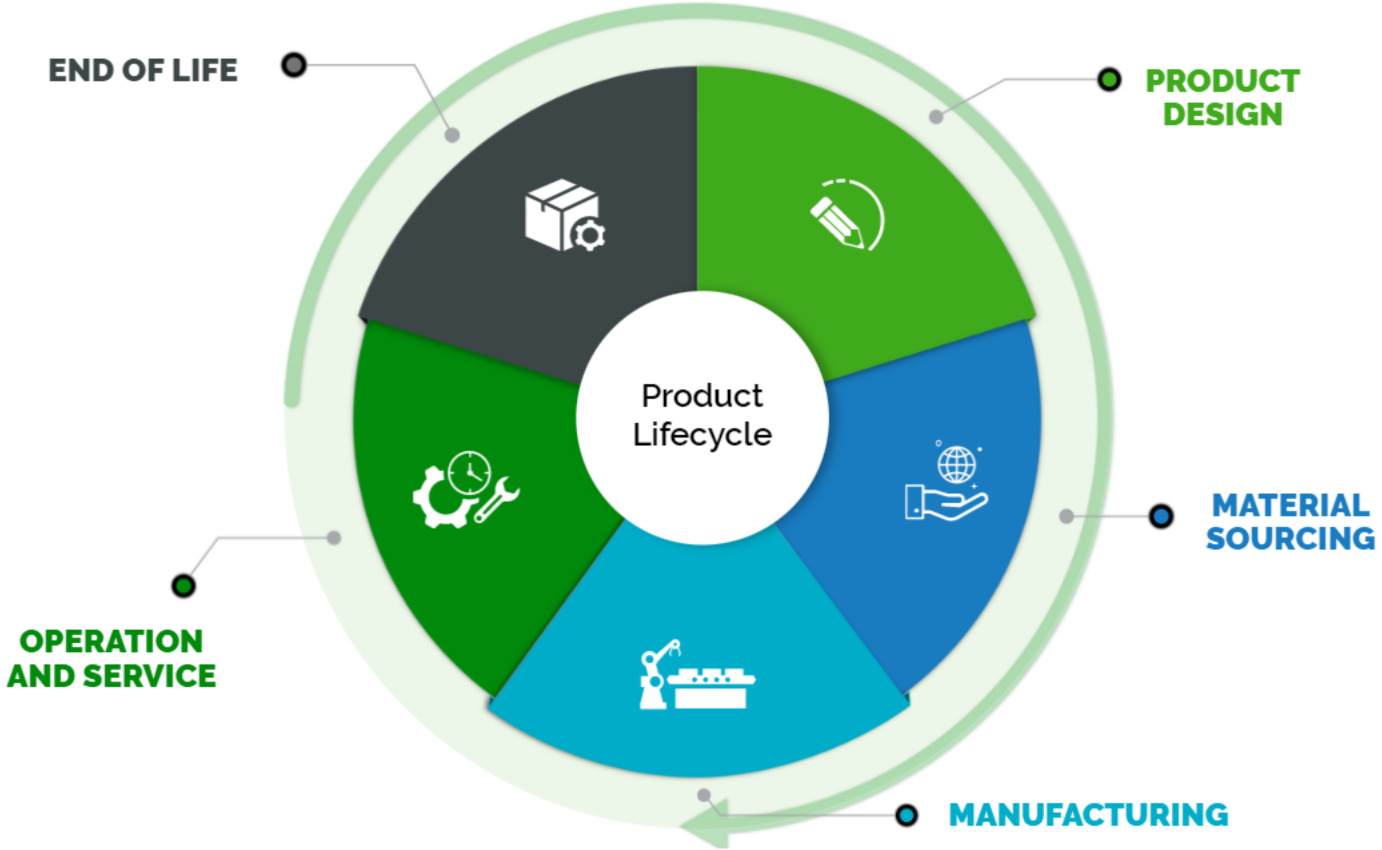
How can we increase sustainability during product design?

What does sustainability mean in terms of product design?

? ?

What does sustainability mean in terms of product design?

- Every product goes through the product design, material sourcing, manufacturing, operation and service, and end of life stages.
- Following a **circular economy model**, products should be designed to be reused and recycled.
- During the engineering and design phase, a sustainably informed team follows the circular economic model.



What does sustainability mean in terms of product design?

During product design, ideation, create prototype, make **sustainable adaptations**, from reducing emissions to making consumables recyclable and more efficient.

By addressing how efficiently a product progresses through its lifecycle, designers and engineers are dictating how a product will impact the environment.


most favourable
least favourable
Waste hierarchy
PREVENTION
PREPARING FOR RE-USE
RECYCLING
RECOVERY
DISPOSAL
PRODUCT
(NON-WASTE)
WASTE

What does sustainability mean in product design?

Beginning of Life (BOL)

Product Development & Manufacture

Middle of Life (MOL)

Connected Assets & Digital Twin

End of Life (EOL)

Driving Circular Processes

The circular economy model guides a product through its entire lifecycle. Product lifecycle management (PLM) solutions help aid and organize the vast amount of product information.

Why is sustainable product design important?

Much of a product's CO_2 footprint is determined during the design phase. Considering that, product design's role should be front and center in any manufacturer's sustainability strategy.

1. **Global Regulations**
   - Manufacturers need to meet specific requirements to be approved and/or certified as a green organization.

2. **Consumer and Investor Demands**
   - 62% of consumers now say they're willing to change their purchasing behavior to help reduce negative impacts on the environment

3. **Staying Competitive**
   - 2021 survey shows that companies with the most embedded sustainability practices outperformed their peers by 21% on both profitability and positive sustainability outcomes.

4. **Reduce Impact, Improve Sustainability (Environmental, Economic & Societal)**

Executing Sustainable Product Design

Source sustainably produced or recycled materials for environmental good

Sustainable materials refer to materials that don't negatively impact the environment during production, use, or disposal.

What to think about:
Where am I getting these materials from?
Can I source locally?
Does the sourcing company have a sustainability focus?
Can I use recycled materials?

Executing Sustainable Product Design

Design products for reuse and recycling
Can we shift a product's life-span by re-using or recycling?

What to think about:

- ***Consider the type of materials*** *– can they be recycled or reused? Materials like steel, aluminum, PET plastic, and HDPE plastic, are good for recyclability.*
- *Is your product made up of* ***multiple types of materials or one material****? A product made up of one standard material is easier to recycle or reuse compared to blended/mixed.*
- *Is your product* ***built to be easily taken apart****? If your product is made from a wide array of materials, it should be designed so that it can be easily disassembled and the materials sorted, recycled, and reused.*

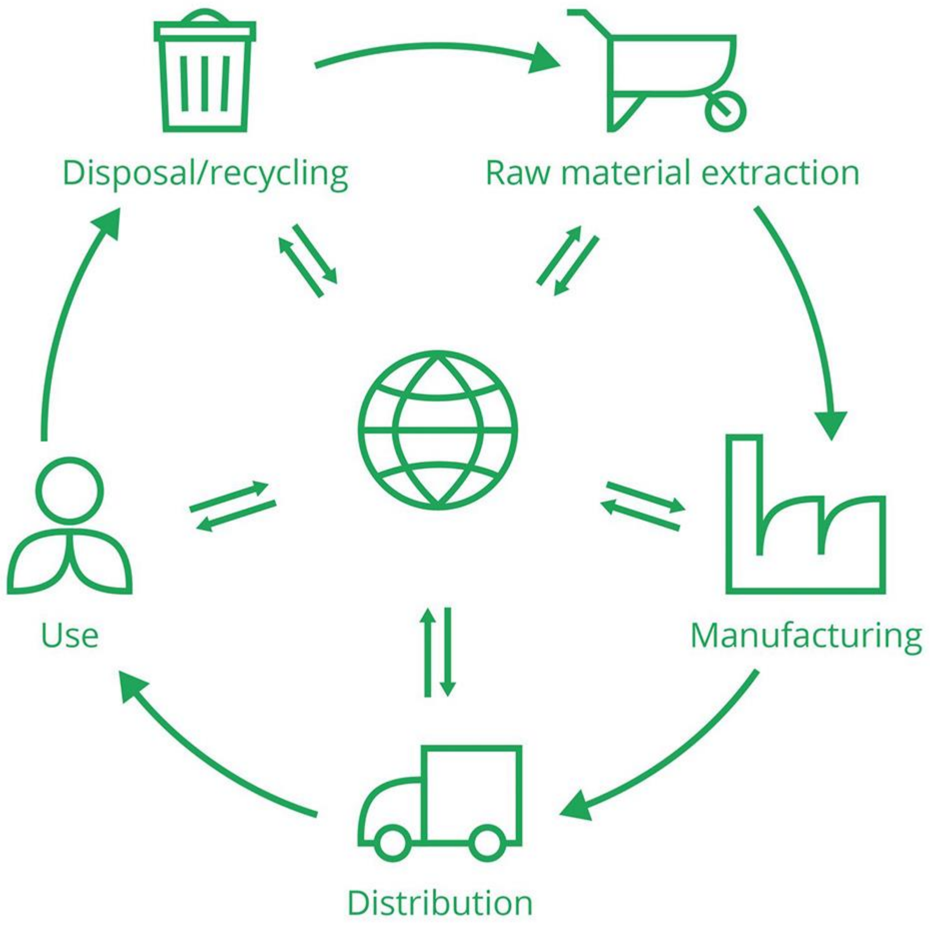
Executing Sustainable Product Design

Track sustainability efforts with Product Lifecycle
Track usage data and feedback when creating the next generation of products.

Product lifecycle management (PLM) solutions are helpful when it comes to organizing, sharing, and drawing meaningful conclusions out of complex data.

Gather data on CO_2 emissions, average time until product retirement, and how sustainable the materials/suppliers are.

PLM helps designers and engineers build a better, more sustainable product for generations to come.



Executing Sustainable Product Design

Build premium products that last longer

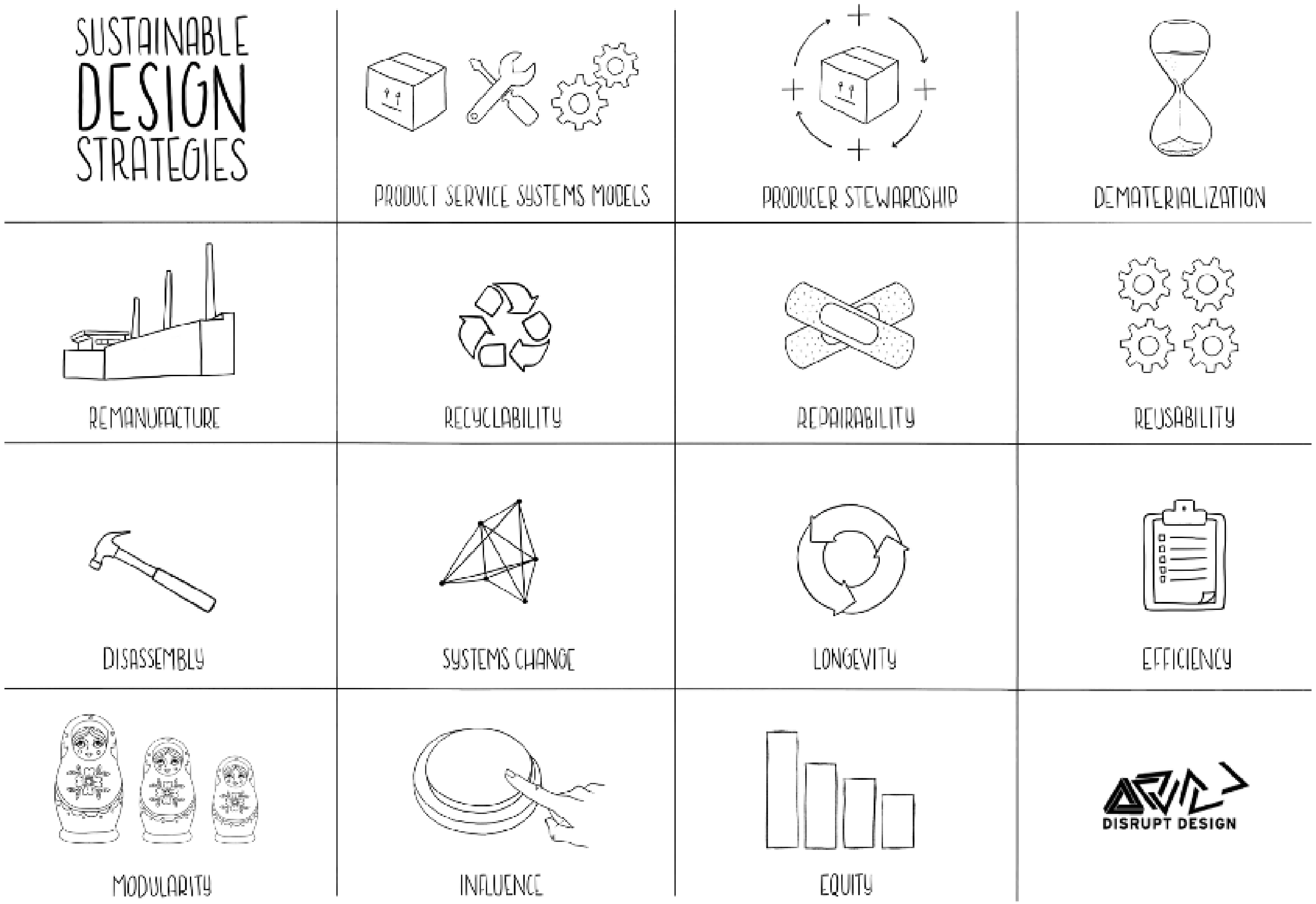
Designing for durability significantly extends a product's lifecycle. Product durability, in turn, lessens the need for replacements, repairs, or waste. The result is a higher-value product and brand equity.

Build products that are easier to repair

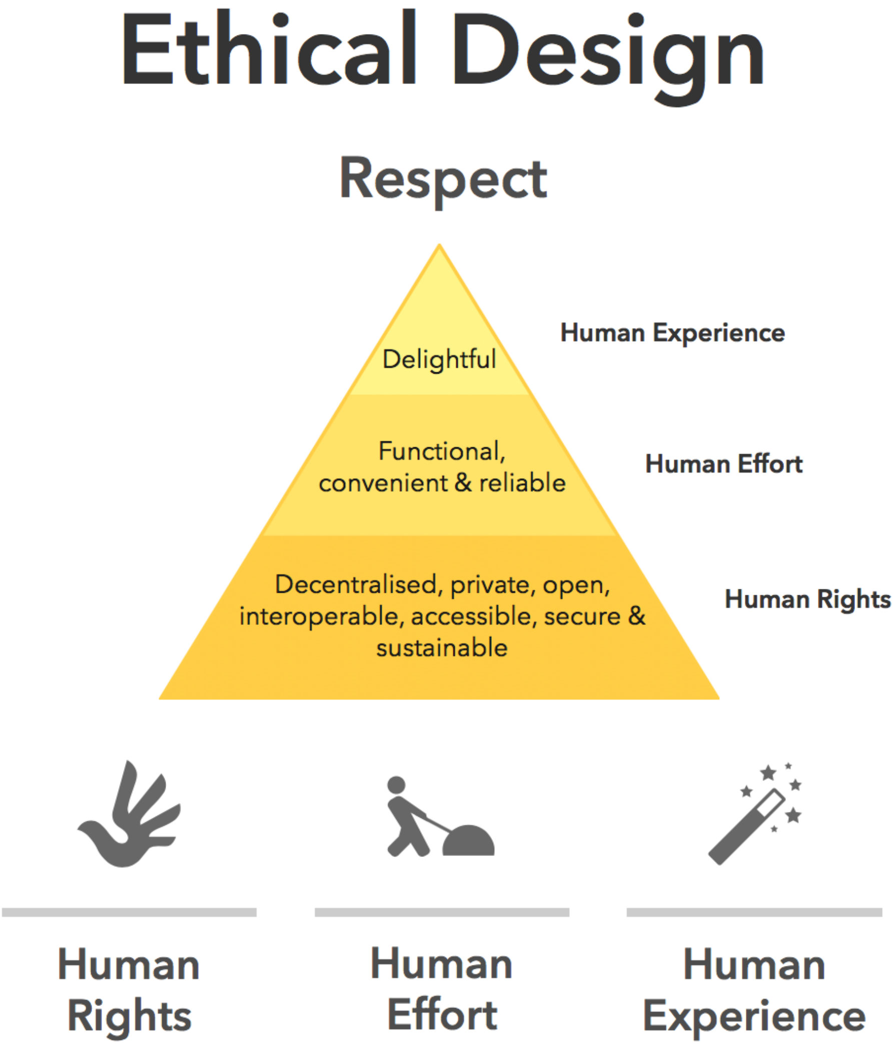
Products can be renewed or refreshed, limited short term waste.


most favourable
least favourable
Waste hierarchy
PREVENTION
PREPARING FOR RE-USE
RECYCLING
RECOVERY
DISPOSAL
PRODUCT
(NON-WASTE)
WASTE

Executing Sustainable Product Design



Ethics of Product Design



- Developing products that is inclusive
- Manufacturing and product design that considers the welfare of workers (human rights)
- Product is positive for humans

Project

The timeline…

Date	Week	Topic
16/11/2022	**Week 9**	**This Week**
23/11/2022	Week 10	W1
30/11/2022	Week 11	W2
07/12/2022	Week 12	W3
14/12/2022	Week 13	Time for project work/ Competition W4
21/12/2022	Week 14	Competition W5

4-5 Weeks left