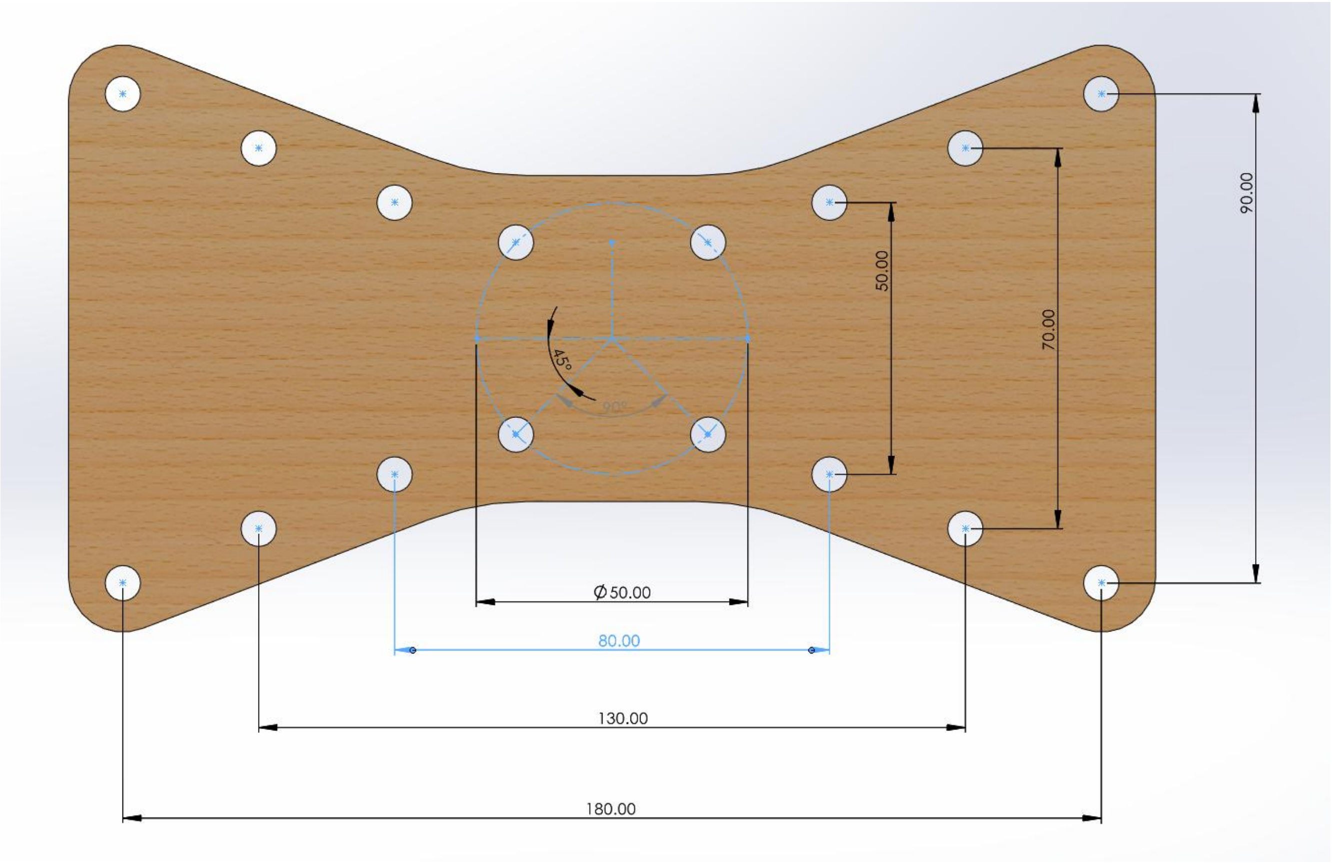
Product development & engineering design

ME-320

PROF. JOSIE HUGHES

Lecture 10: ID + MD + Sustainability

Attachment/mounting point



This is attached to the robot arm. You must attach to this mounting point.

6mm bolts will be given!

A longer USB cable will be provided!

Schedule

Week 7	*22/10/2025*	*Break*	
Week 8	29/10/2025	2nd Design Review with TAs	Review session in SPOT
Week 9	05/11/2025	Electronics & prototyping	Lecture
Week 10	12/11/2025	Engineering Drawings	Lecture
Week 11	19/11/2025	Design for Manufacture, Sustainability	Lecture
Week 12	26/11/2025	3rd Design Review with TAs	Review session in SPOT
Week 13	03/12/2025	Introduction to the robot arm	SPOT
Week 14	10/12/2025	Preparation and testing (competition for anyone wanting to go early)	SPOT
Week 15	17/12/2025	Final Testing/Competition	SPOT

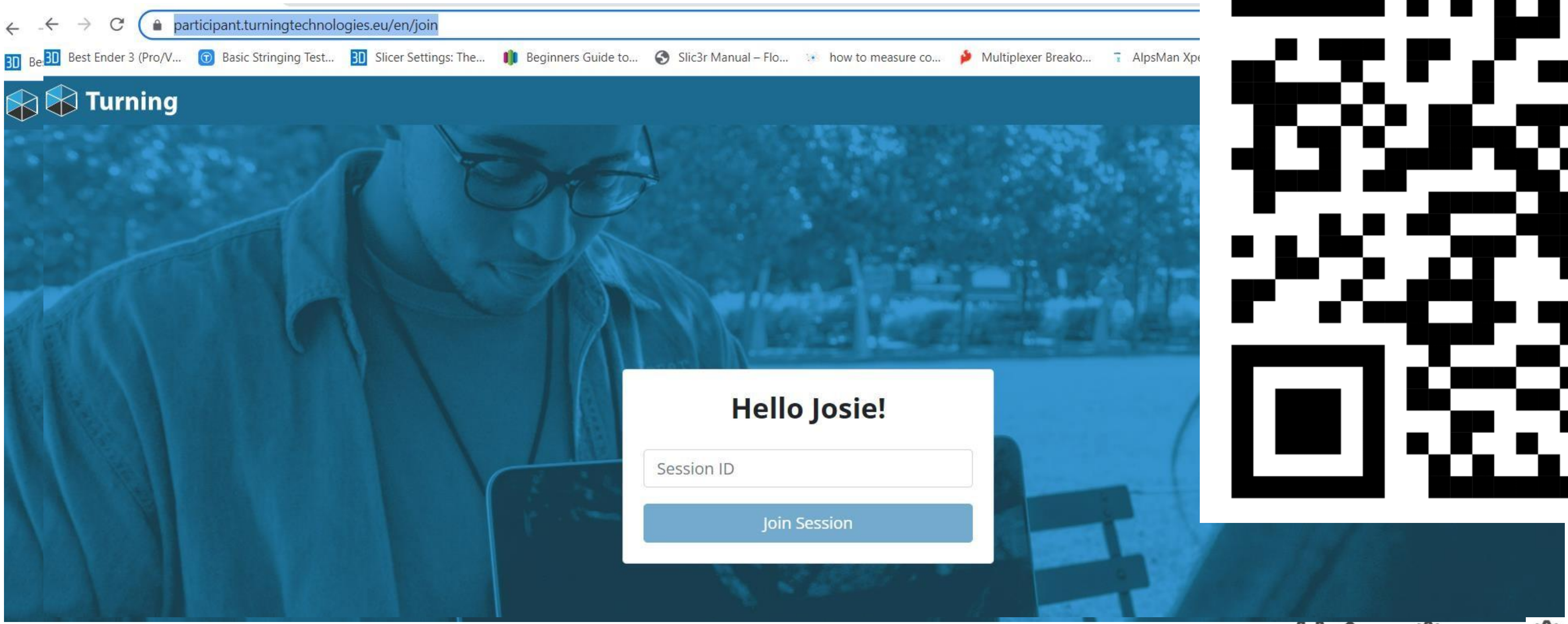
Electronics Prorotyping Quiz

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

https://participant.turningtechnologies.eu

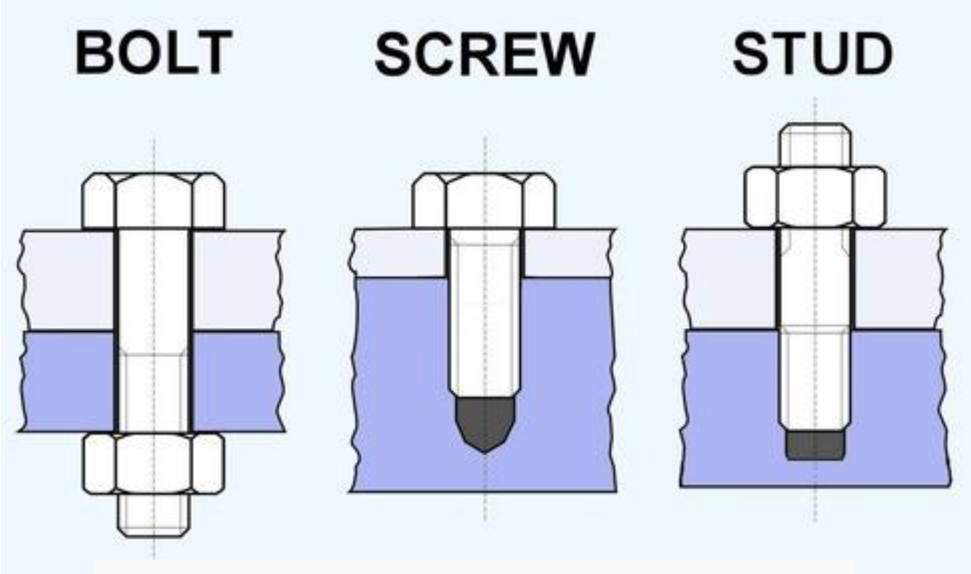
SessionID: datadriven

https://ttpoll.eu/p/datadriven



Fasteners

- Bolts
- Studs
- Cap Screws
- Set screws



www.thomasnet.com

Success or failure of a design can hinge on proper selection and use of its fasteners

University of South Australia

Boeing 747 uses about **2.5 million fasteners**

http://en.wikipedia.org/wiki/Seattle#mediaviewer/File:Boeing_747-8_Test_Planes_in_Assembly.jpg

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

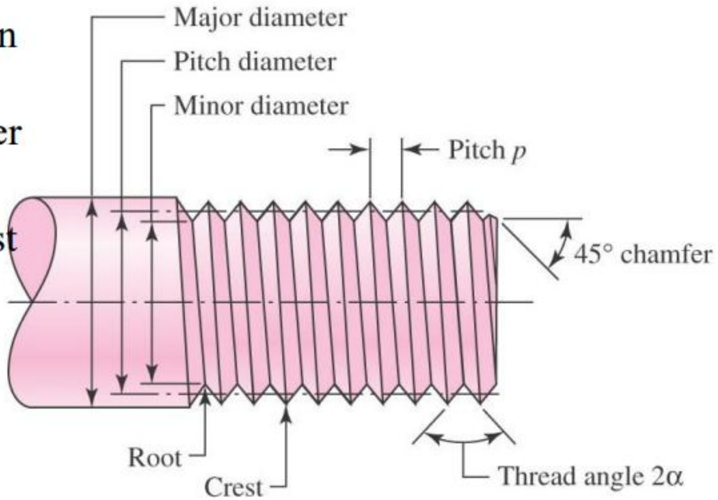
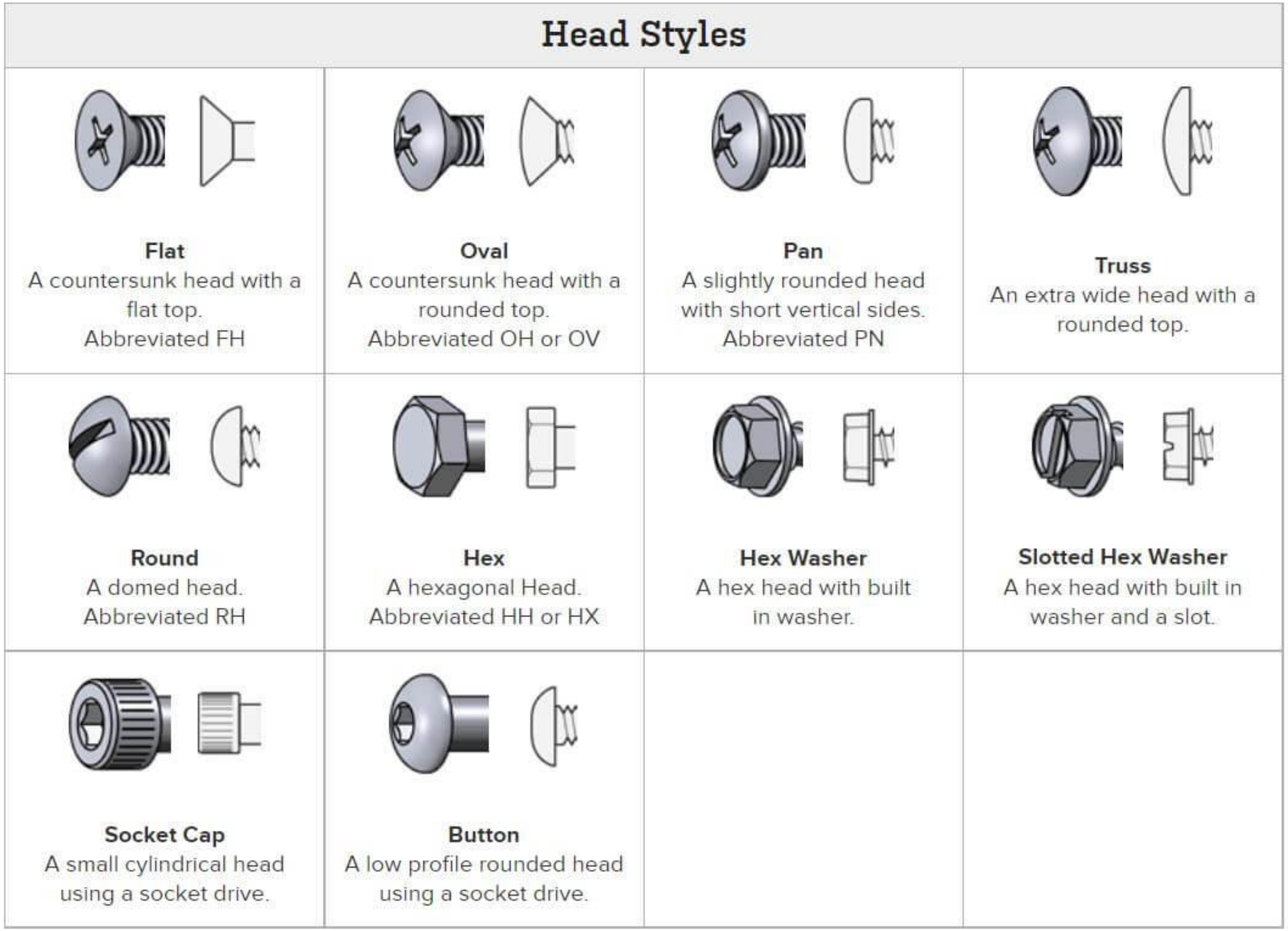


Fig. 8–1

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

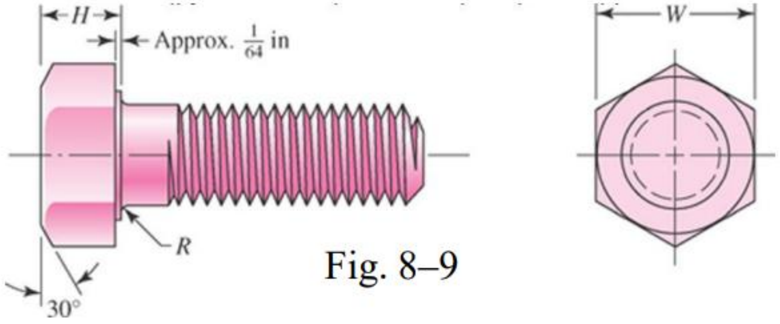
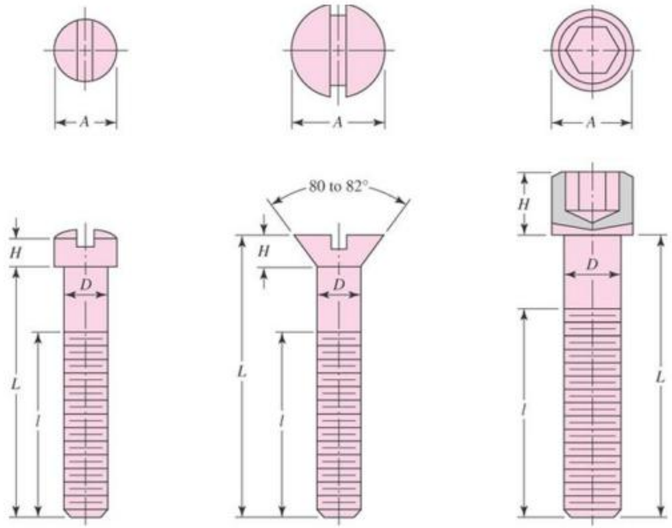
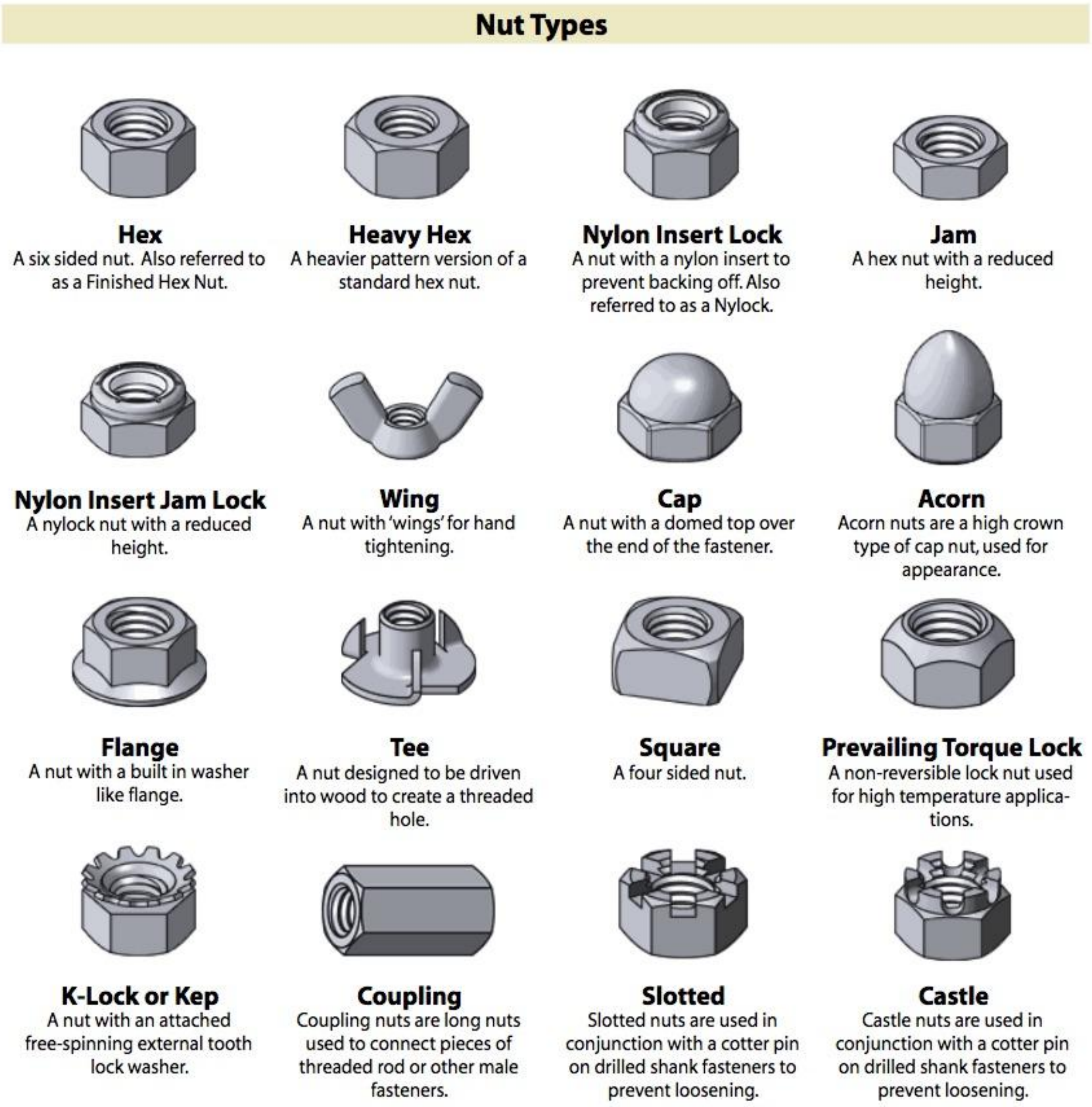
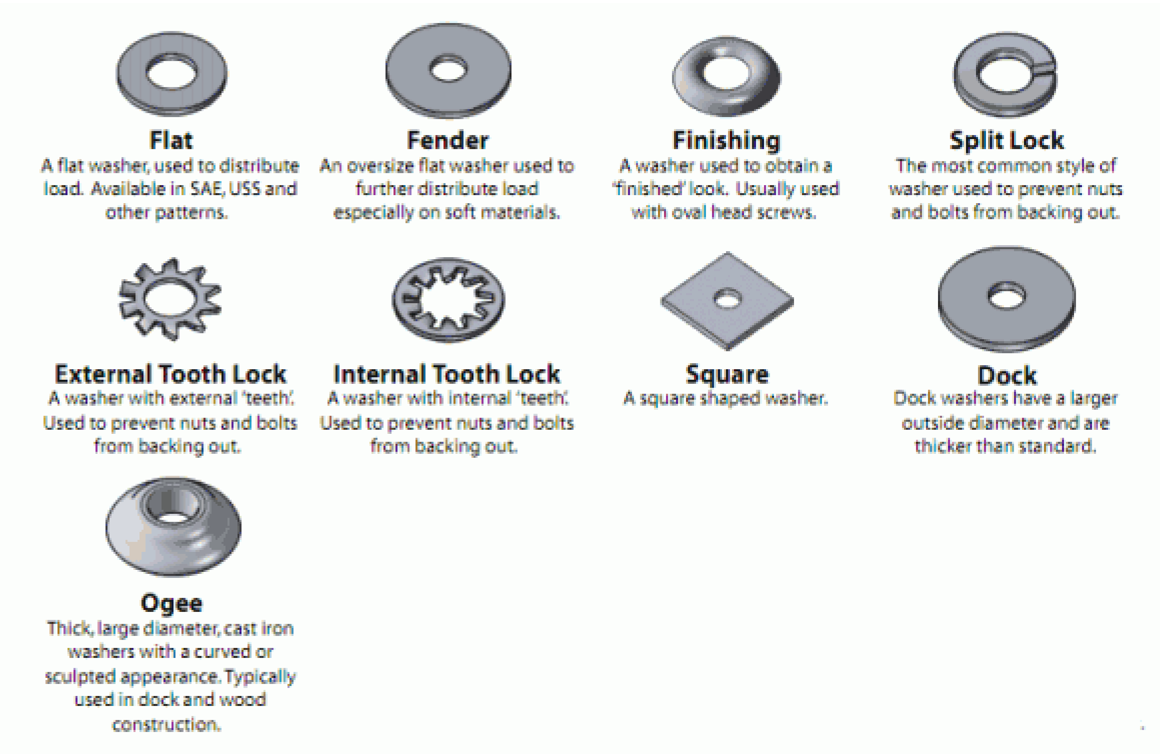


Fig. 8–9

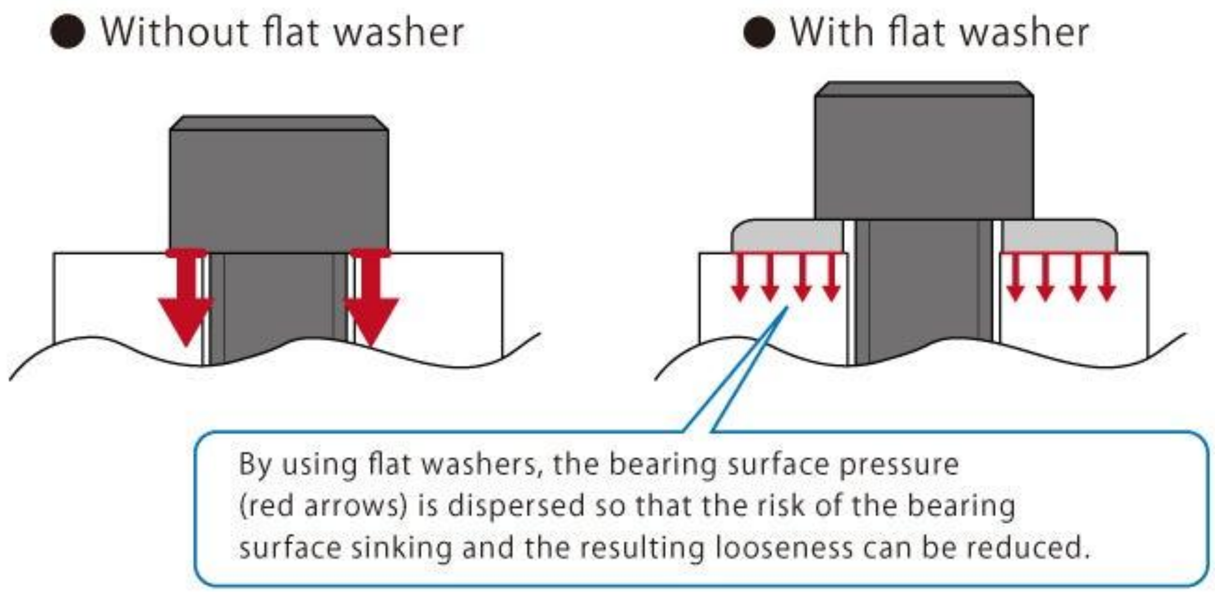


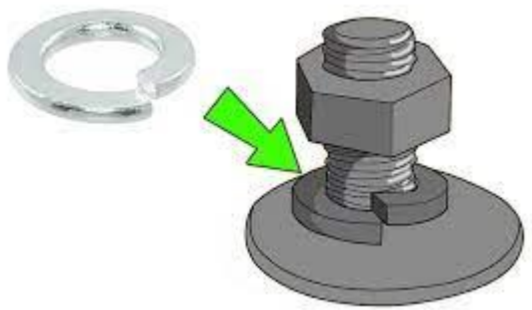

Nut Types
Hex
A six sided nut. Also referred to as a Finished Hex Nut.
Heavy Hex
A heavier pattern version of a standard hex nut.
Nylon Insert Lock
A nut with a nylon insert to prevent backing off. Also referred to as a Nylock.
Jam
A hex nut with a reduced height.
Nylon Insert Jam Lock
A nylock nut with 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.

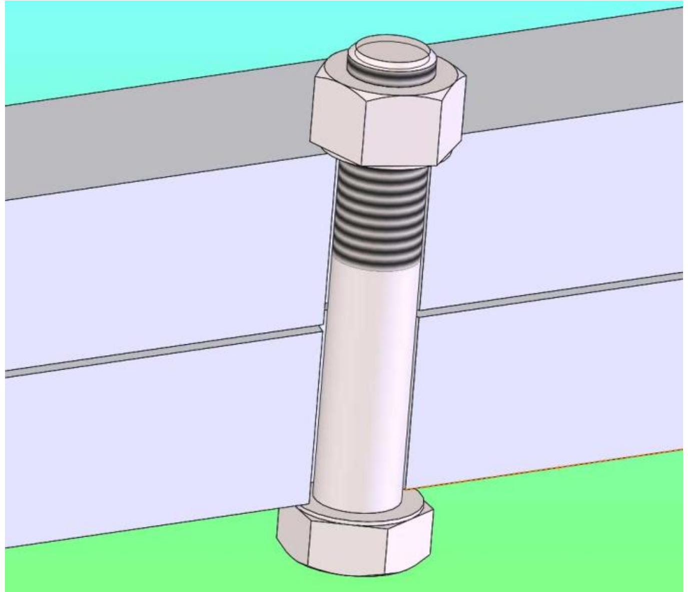
Washers – why do we use them?

Washers – why do we use them?

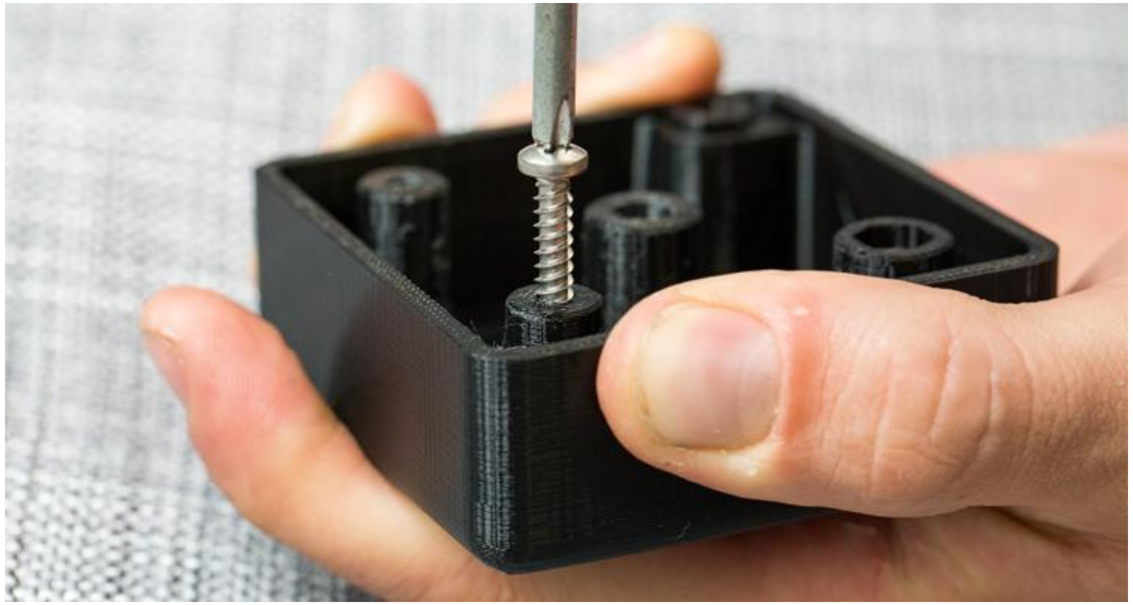




Fasteners & 3D Printing



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

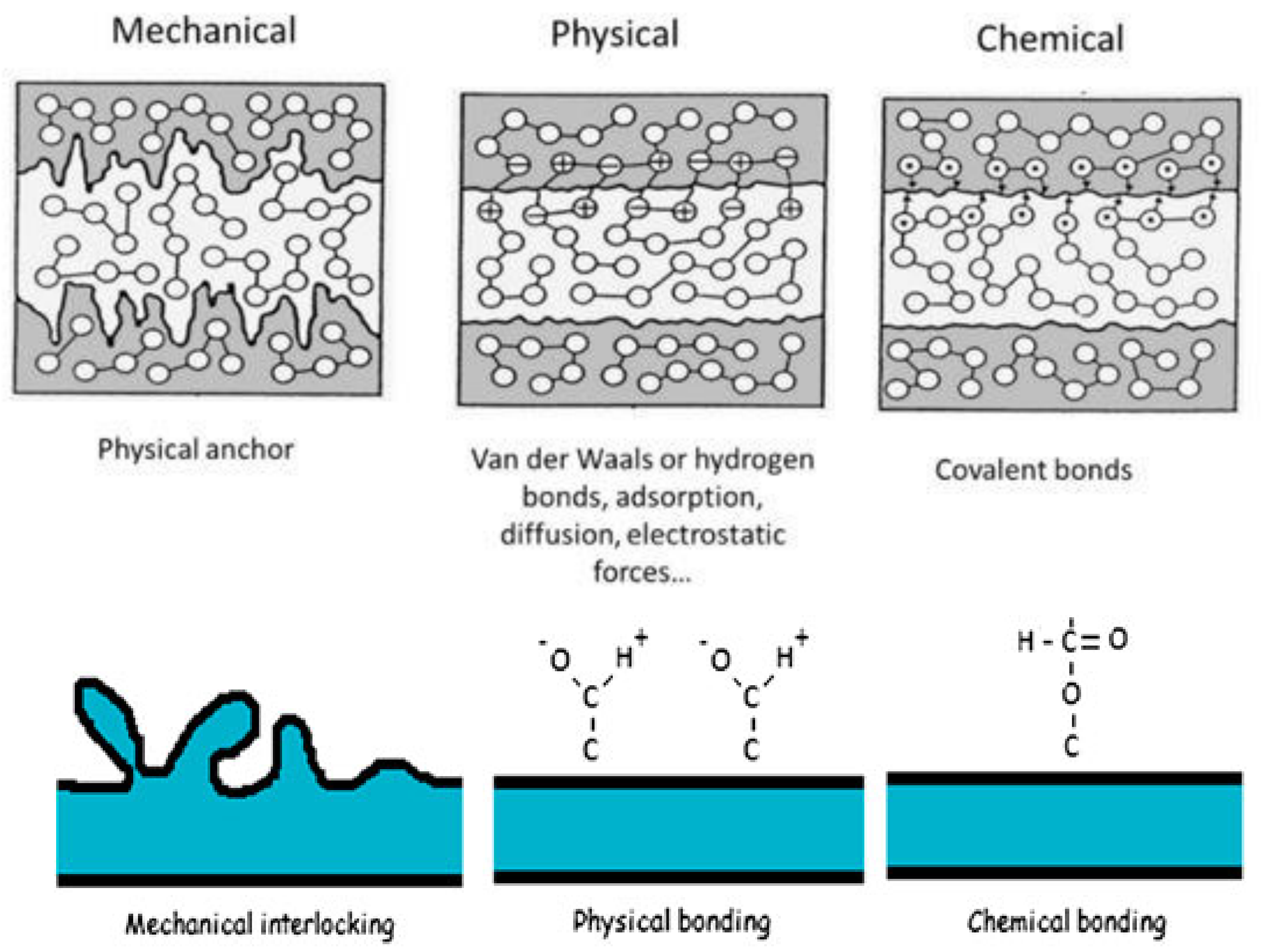


Comparison of Bonding Techniques

Joining procedure	Multi-material design	Rigidity	Crash-resistance	Endurance strength	Media strength	Acoustics	Cycle time	Initial strength	Removability
Bonding	+++	+++	+++	+++	++	+++	+++	-	-
(Spot) welding	-	O	O	O	-	-	-	+++	-
Clinching	-	O	-	+	O	-	-	+++	-
Riveting	O	O	-	+	-	-	-	+++	-
Screwing	O	O	O	O	-	-	-	+++	+++
Laser welding	-	++	++	++	O	+	+	+++	-

Adhesives: How do they work?

Adhesives: 3 Different Mechanism

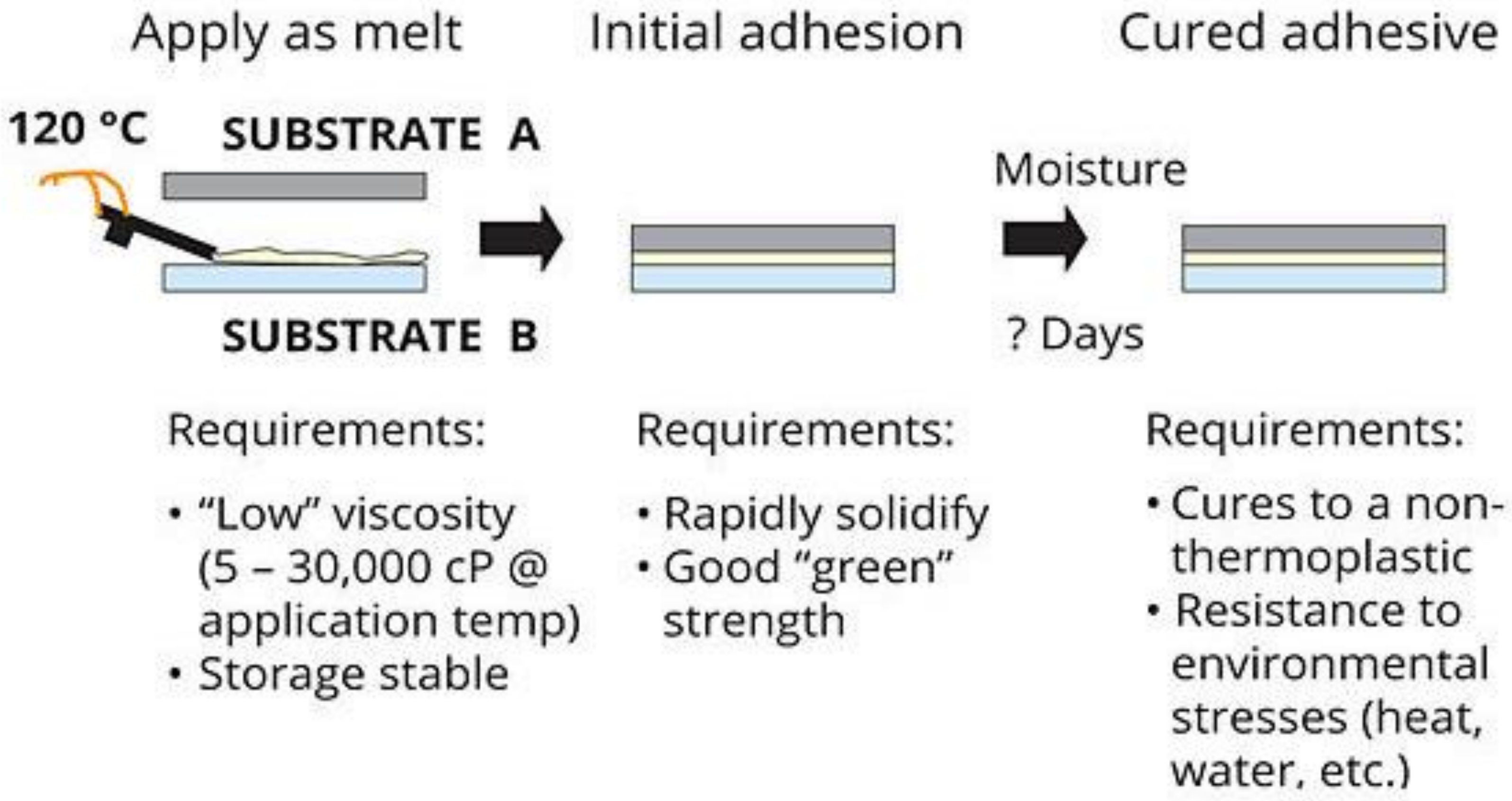


- **Mechanical:** adhesives fill the pores of the surface roughness, resulting in mechanical anchoring between the two surfaces.

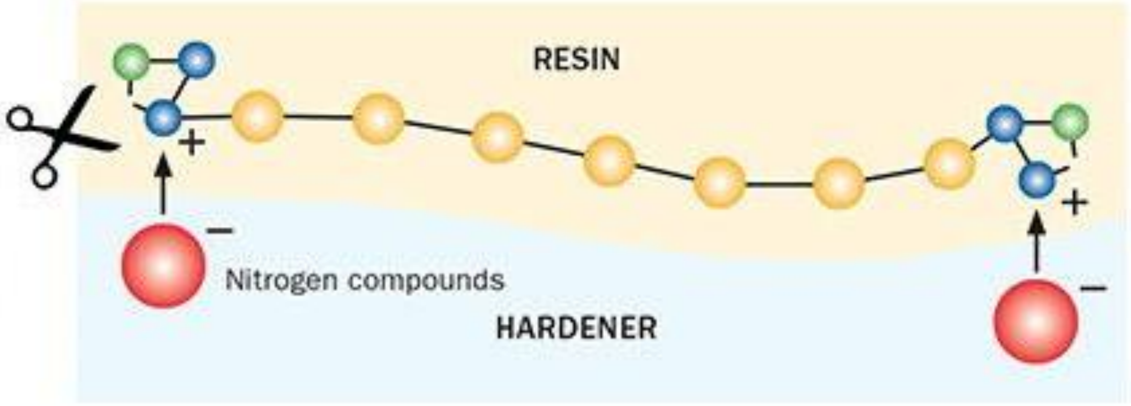
- **Physical:** two materials are held together by Van der Waals forces or hydrogen bonds: the attraction between positively and negatively charged molecules.

- **Chemical:** a chemical reaction between the molecules of the adhesive and the molecules of the substrate surface forms a covalent bond (strongest bond).

Hot Melt Adhesive

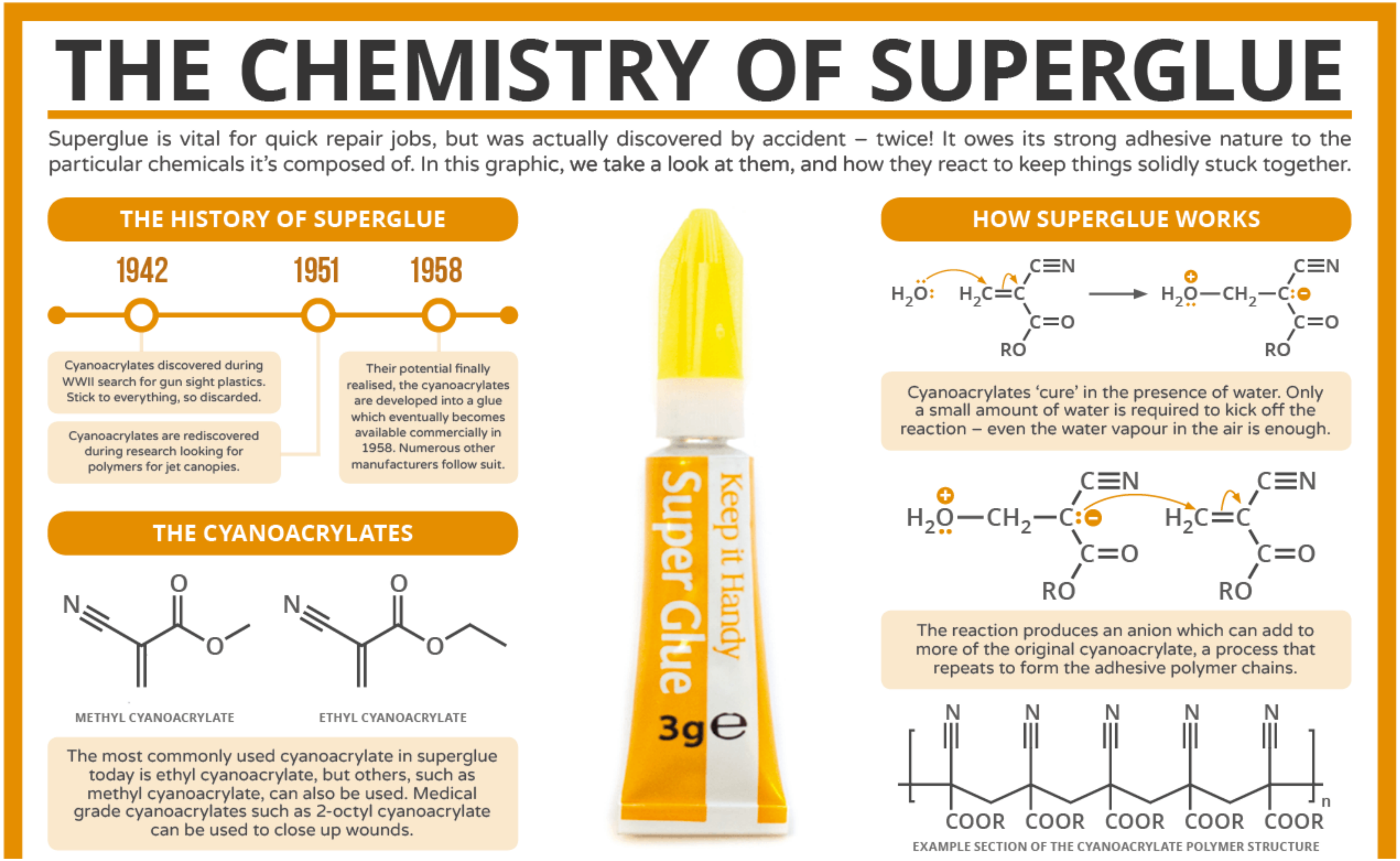


Epoxy Resin



2. When the resin (part A) and the hardener (part B) are combined, the nitrogen compounds in the hardener break apart the epoxide rings.

Superglue


THE CHEMISTRY OF SUPERGLUE
Superglue is vital for quick repair jobs, but was actually discovered by accident – twice! It owes its strong adhesive nature to the particular chemicals it's composed of. In this graphic, we take a look at them, and how they react to keep things solidly stuck together.
THE HISTORY OF SUPERGLUE
1942
1951
1958
Cyanoacrylates discovered during WWII search for gun sight plastics. Stick to everything, so discarded.
Cyanoacrylates are rediscovered during research looking for polymers for jet canopies.
Their potential finally realised, the cyanoacrylates are developed into a glue which eventually becomes available commercially in 1958. Numerous other manufacturers follow suit.
THE CYANOACRYLATES
METHYL CYANOACRYLATE
ETHYL CYANOACRYLATE
The most commonly used cyanoacrylate in superglue today is ethyl cyanoacrylate, but others, such as methyl cyanoacrylate, can also be used. Medical grade cyanoacrylates such as 2-octyl cyanoacrylate can be used to close up wounds.
Super Glue
Keep it Handy
3g
HOW SUPERGLUE WORKS
Cyanoacrylates 'cure' in the presence of water. Only a small amount of water is required to kick off the reaction – even the water vapour in the air is enough.
The reaction produces an anion which can add to more of the original cyanoacrylate, a process that repeats to form the adhesive polymer chains.
COOR
COOR
COOR
COOR
COOR
EXAMPLE SECTION OF THE CYANOACRYLATE POLYMER STRUCTURE

Choosing an Adhesive

Odour/VOC emissions

Colour

Environment protection / Occupational safety

Substrate
Material
Surface quality
Surface pre-treatment
Dimensions

Economics
- Material costs
- Process costs
- Investment costs
- Personnel costs

Quantities
Component size
Cycle time

Strength characteristics
Elastic/rigid

Adhesive choice

Application technique
- Spray application
- Bead application
- Extensive coating

Stress
Temperature
Mechanical
Moisture
Chemicals
Radiation
- static / dynamic
- short-term / long-lasting
- one-time / repeatedly

processes upstream and downstream from the adhesive processing

Stabilising conditions
- Room temperature
- Heat accelerated
- Heat curing
- Light curing

Process safety

Additional properties,
such as thermal or electrical conductivity, density

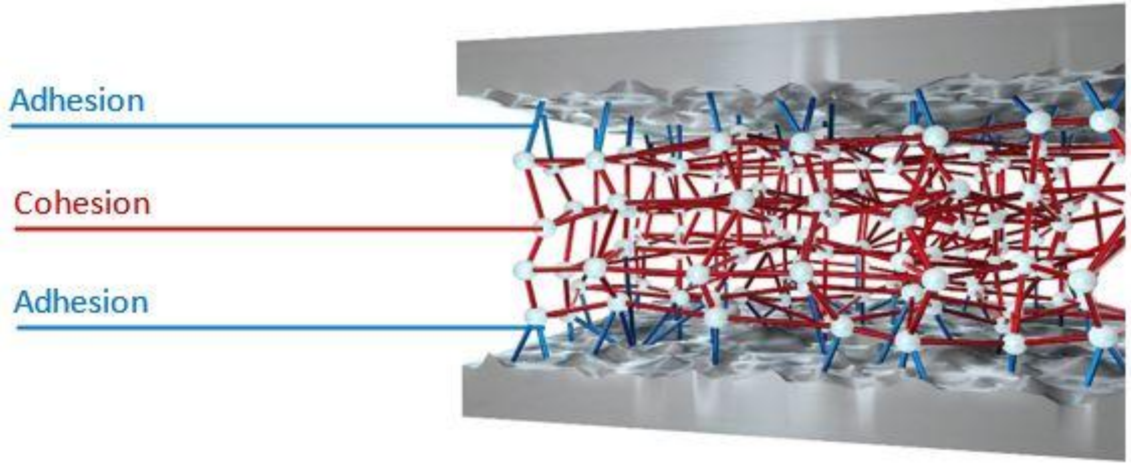
Flow properties,
e.g. viscosity, flow limit, self-levelling/stable

Adhesive technology
- Physically hardening
- Chemically hardening
  - 1C-/2C-
- Hard adhesive

Adhesives: Avoiding Failure

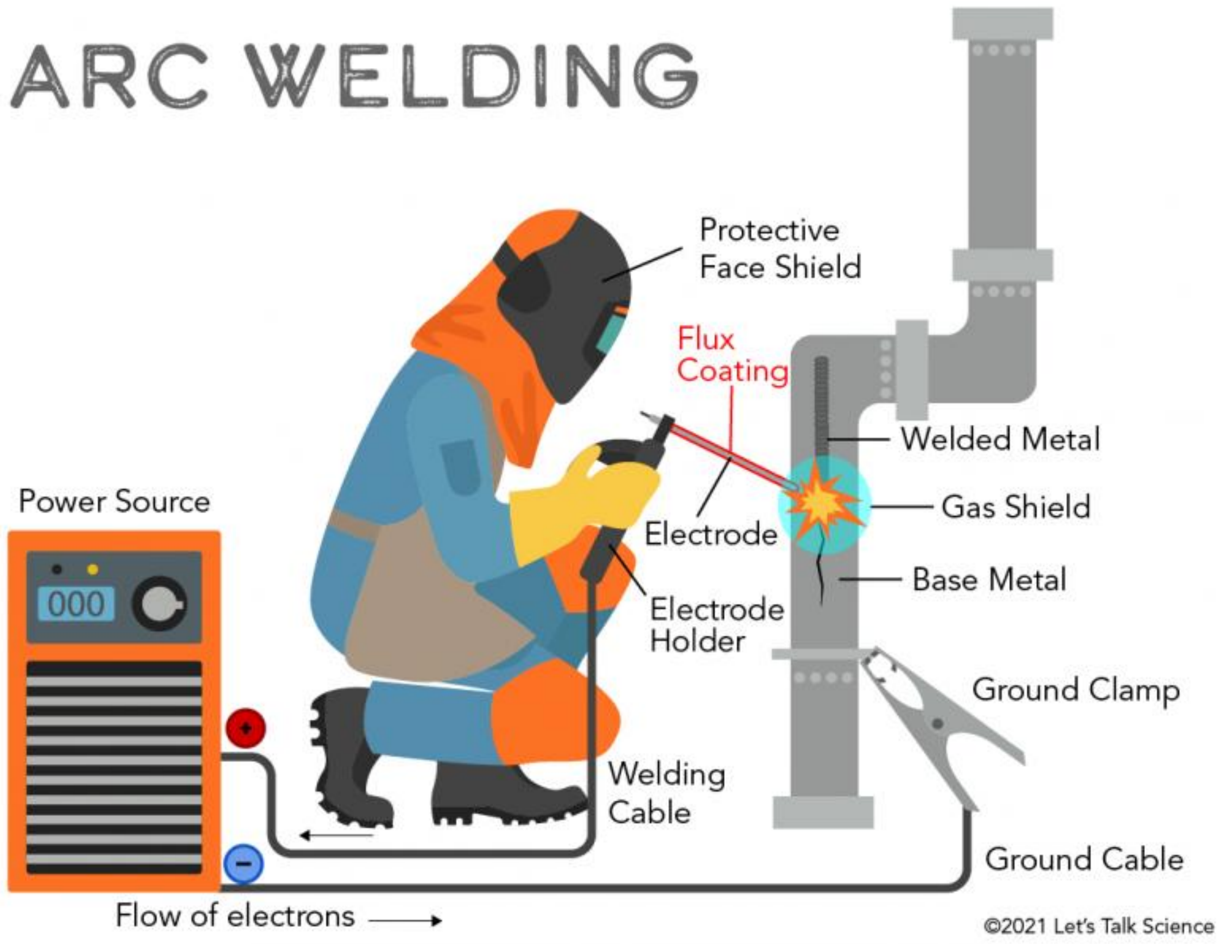
Industrial adhesives are made from polymers that join materials by two phenomena:

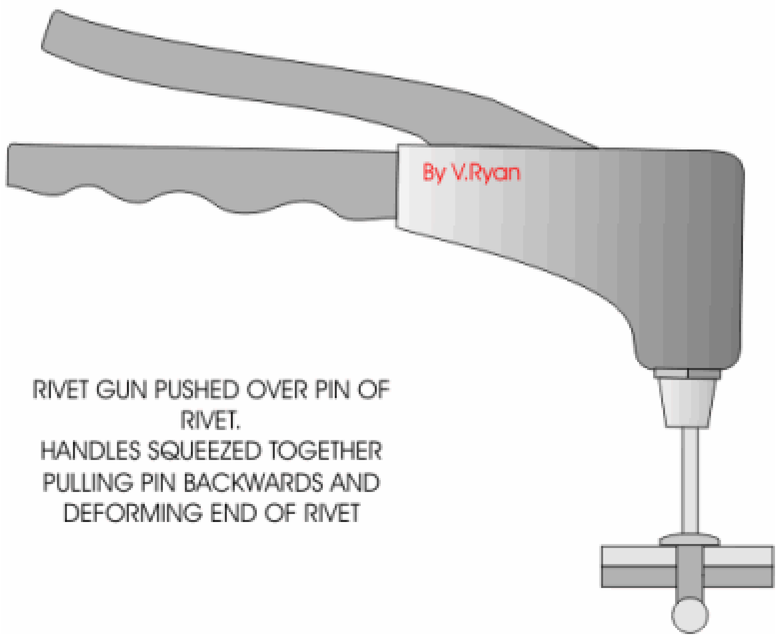
- Adhesion of the adhesive on both substrates
- Cohesion of the adhesive with its internal strength



The combination of adhesion and cohesion determines bonding effectiveness.
Both must be considered when choosing the right adhesives and surface treatments.

Alternative 'Fastening' Methods

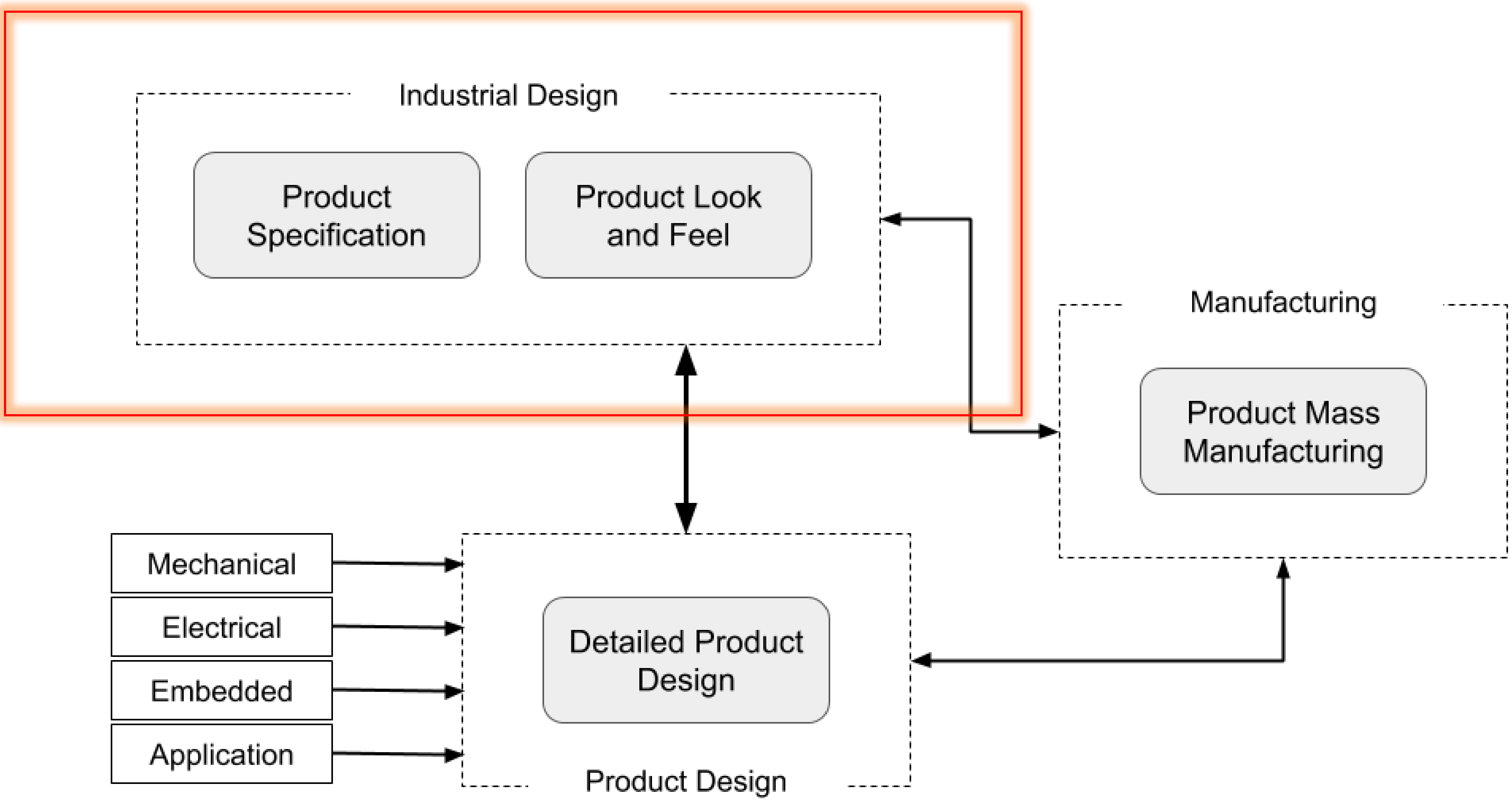




- Finalized concept
- Finalized key engineering concept
- Demonstrated proof-of concept
- Work-like prototype
- Communicated concepts (drawings)

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

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

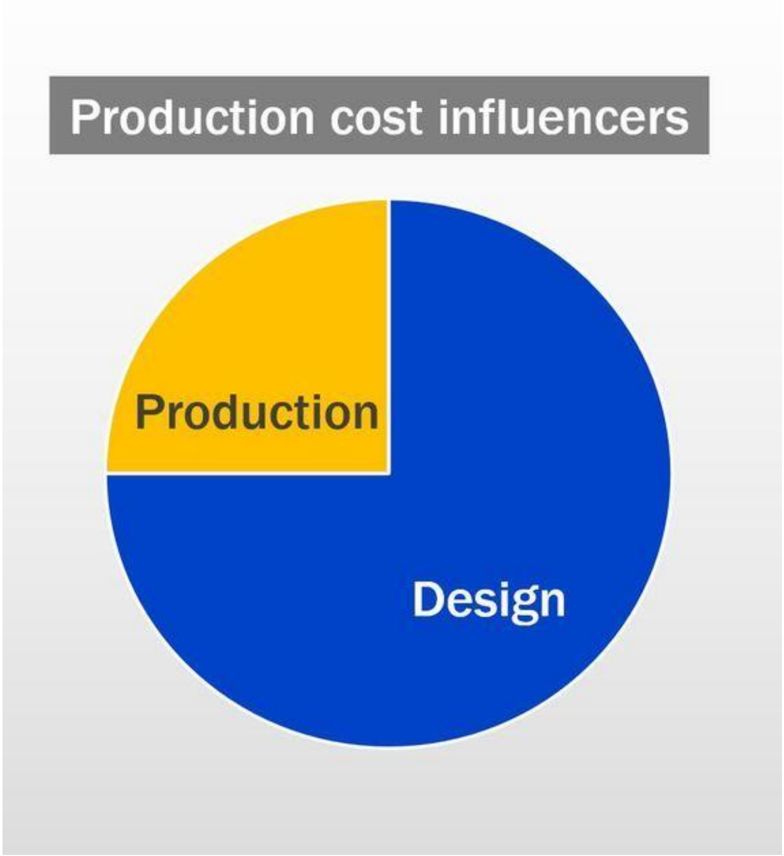
Design for Manufacture

Why not do this in product development?

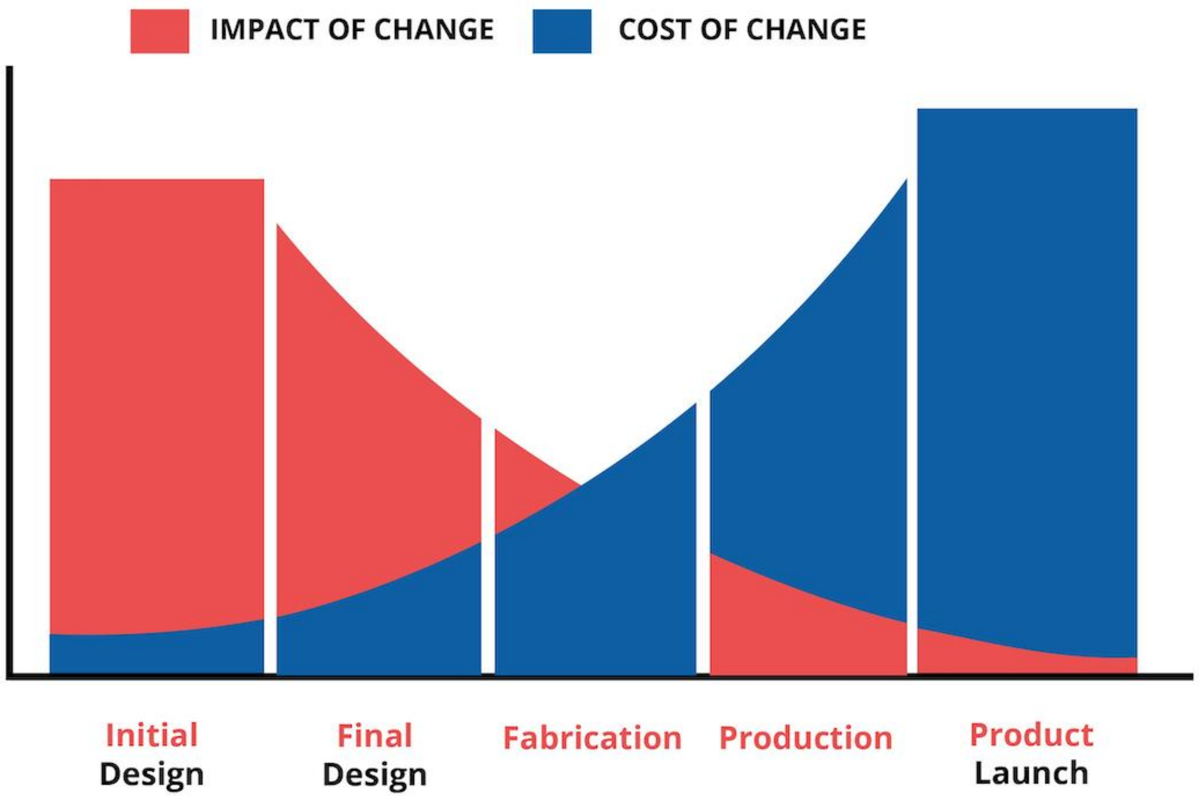
- Customer needs and product specs are hard to link with downstream product development
- Many teams use "design for X" where X means reliability, robustness, environmental impact, manufacturing,...

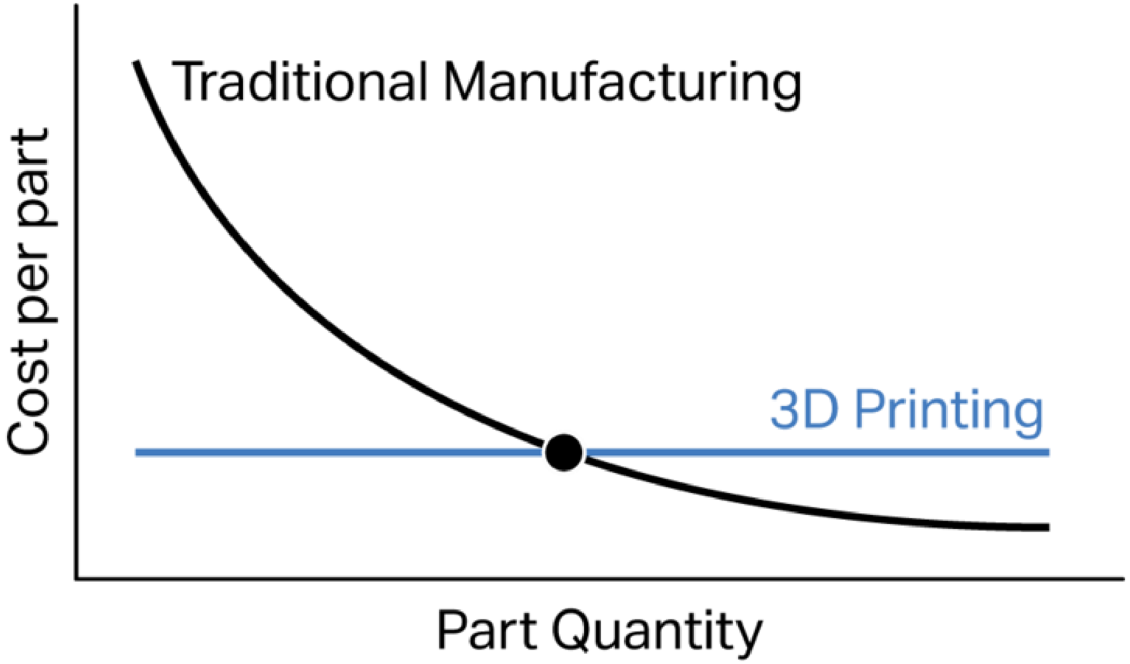
The goal of DFM:

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



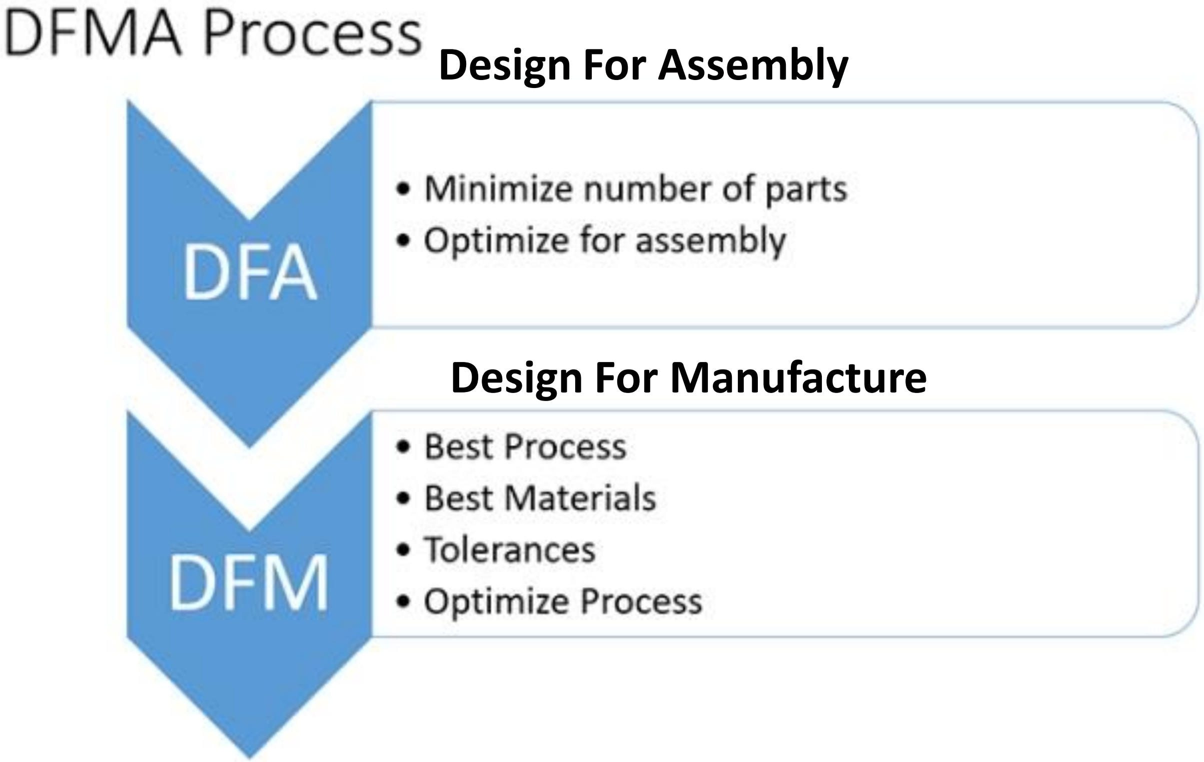
Design for Manufacture





Design for Manufacture

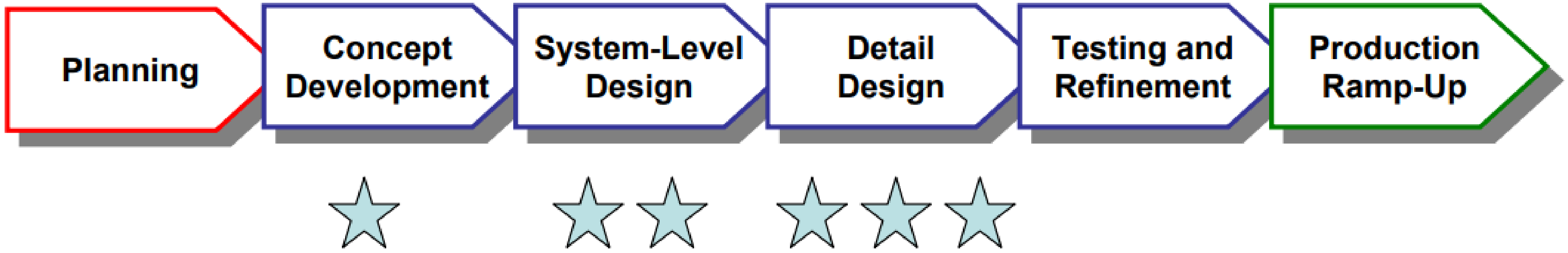
DFM requires a cross-functional team → One of the most integrative practices in PD



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.

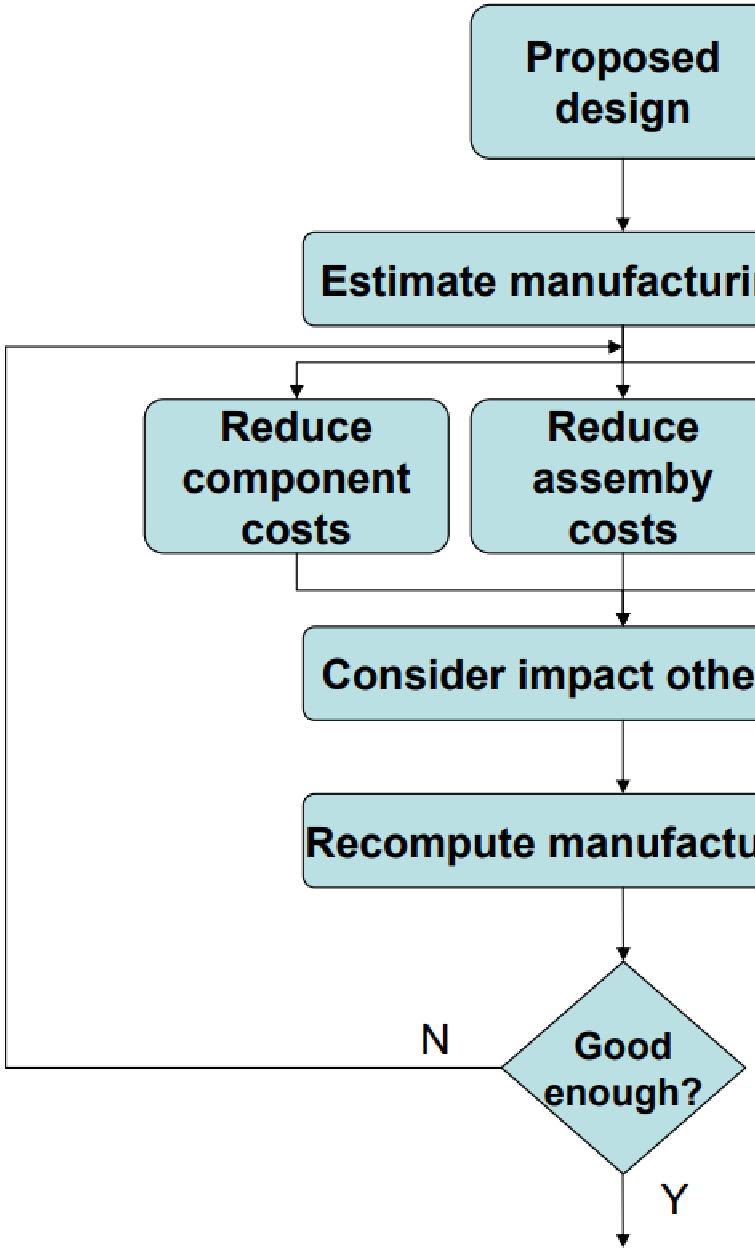
DFM within Product Development Process



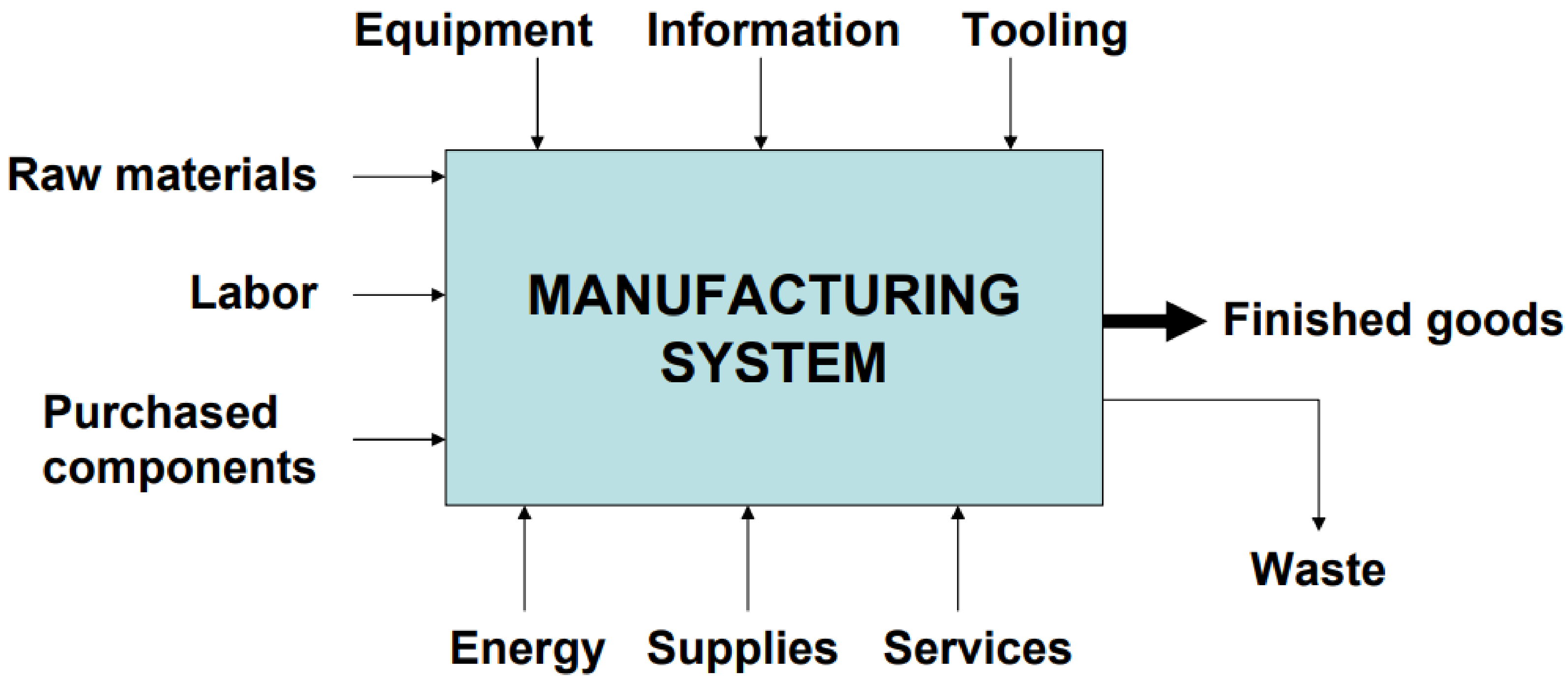
How can we emphasize manufacturing issues throughout the development process?

- 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.

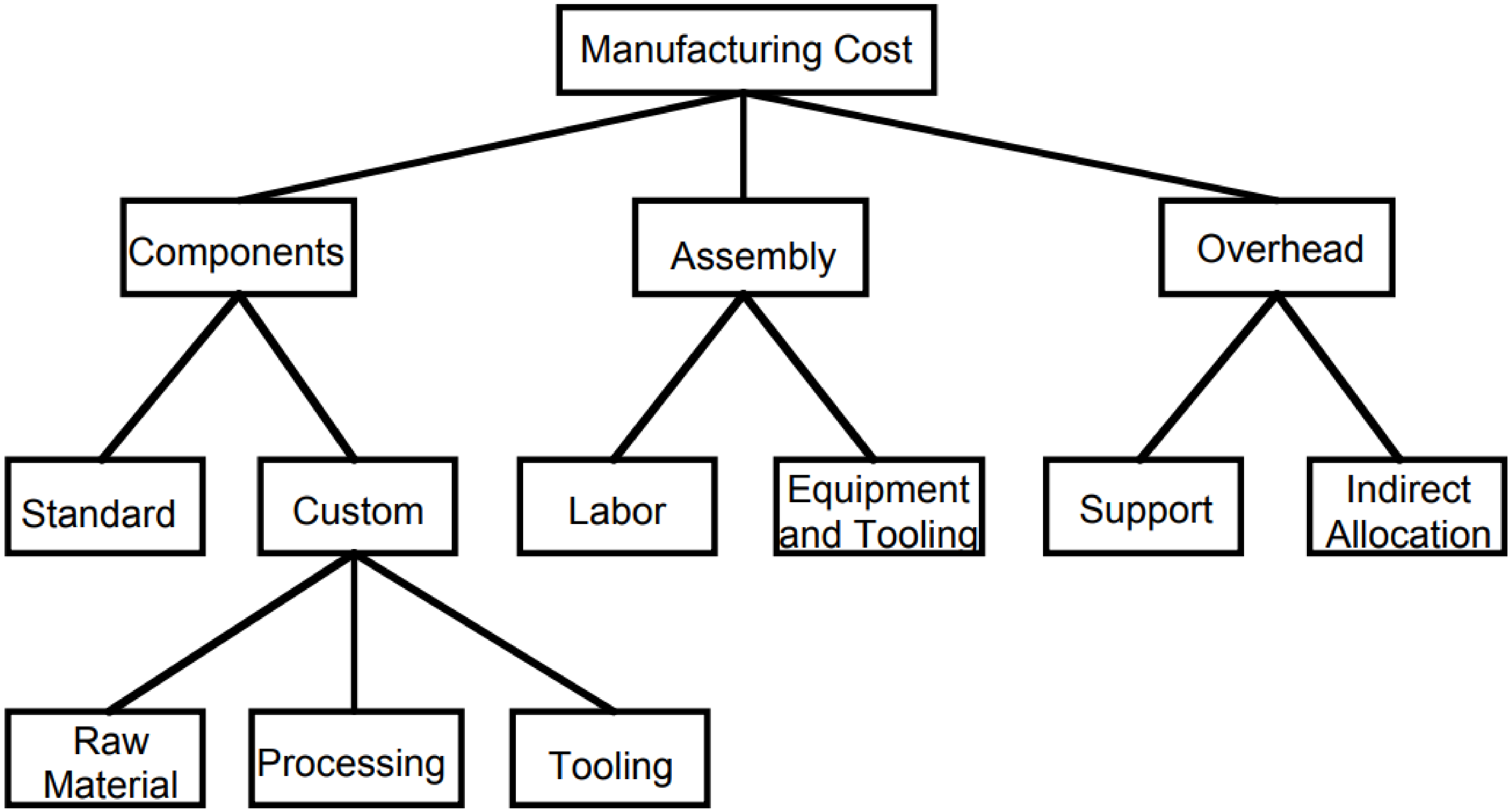
DFM Approach



Step 1: Estimate Cost



Step 1: Estimate Cost

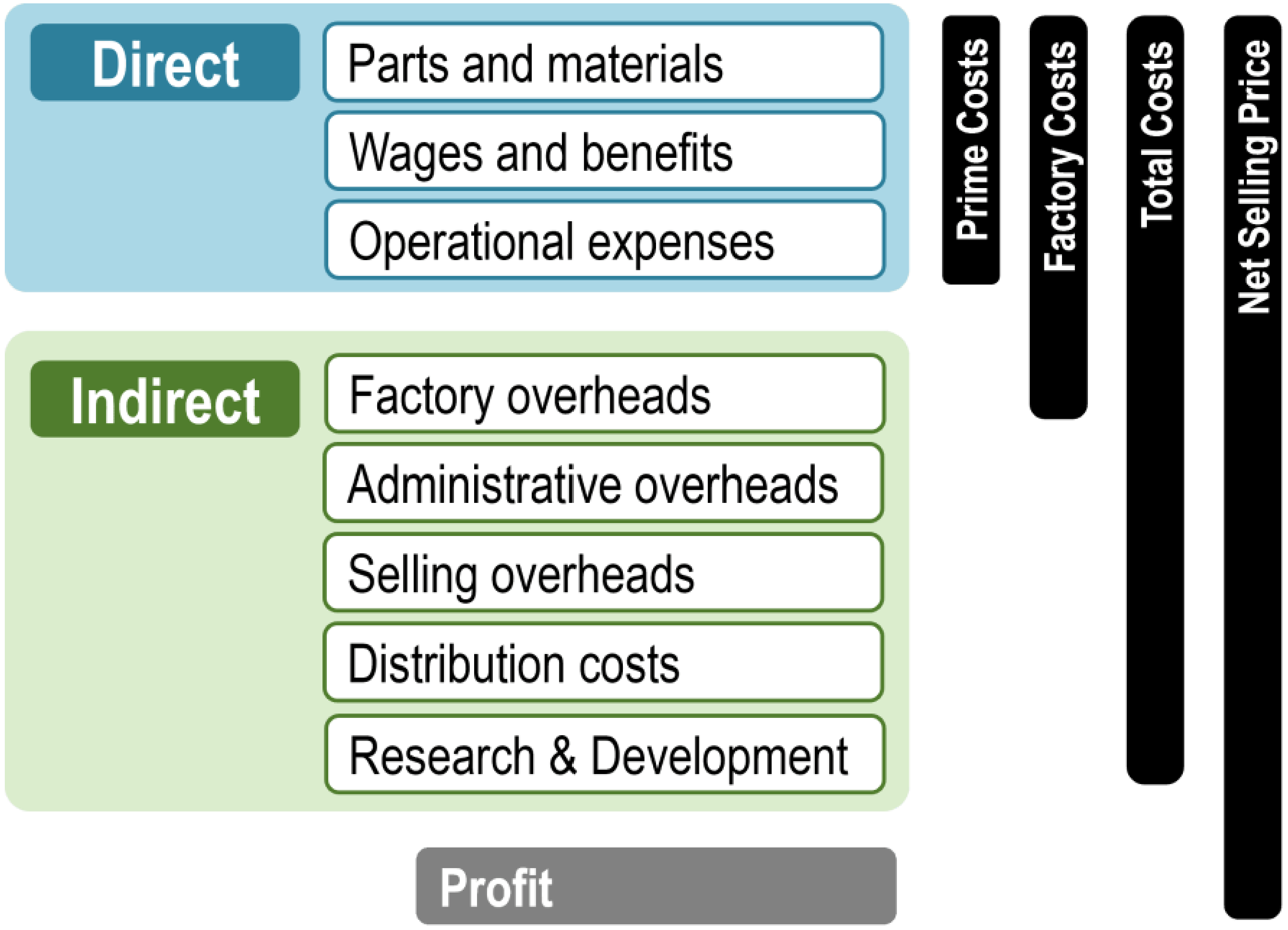


What affects the manufacturing cost?

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



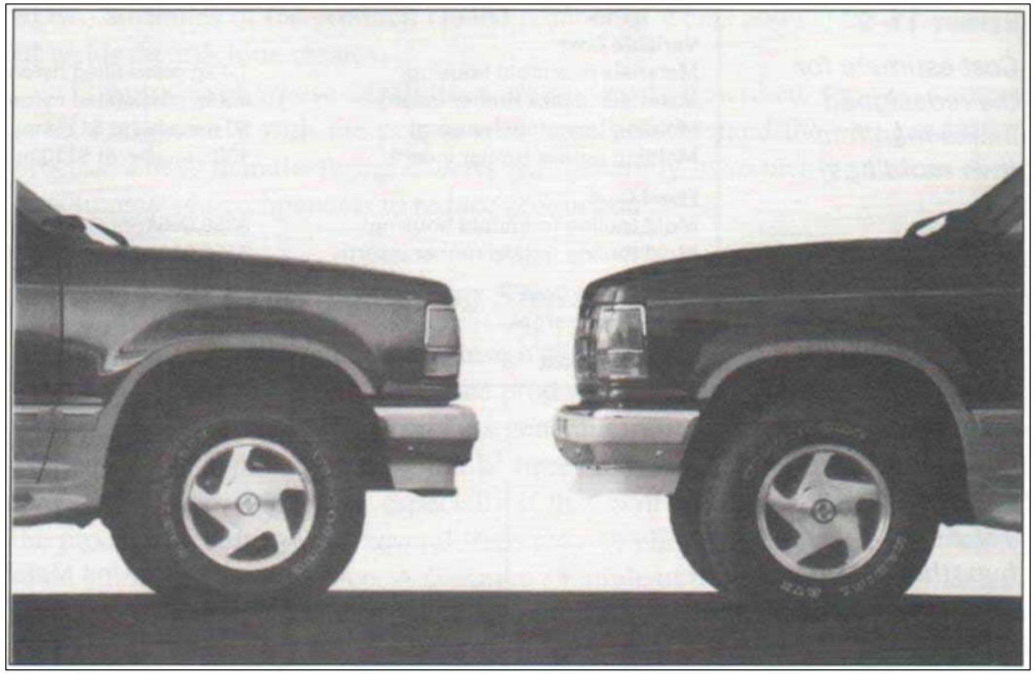
Step 1: Estimate Cost

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

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

- 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

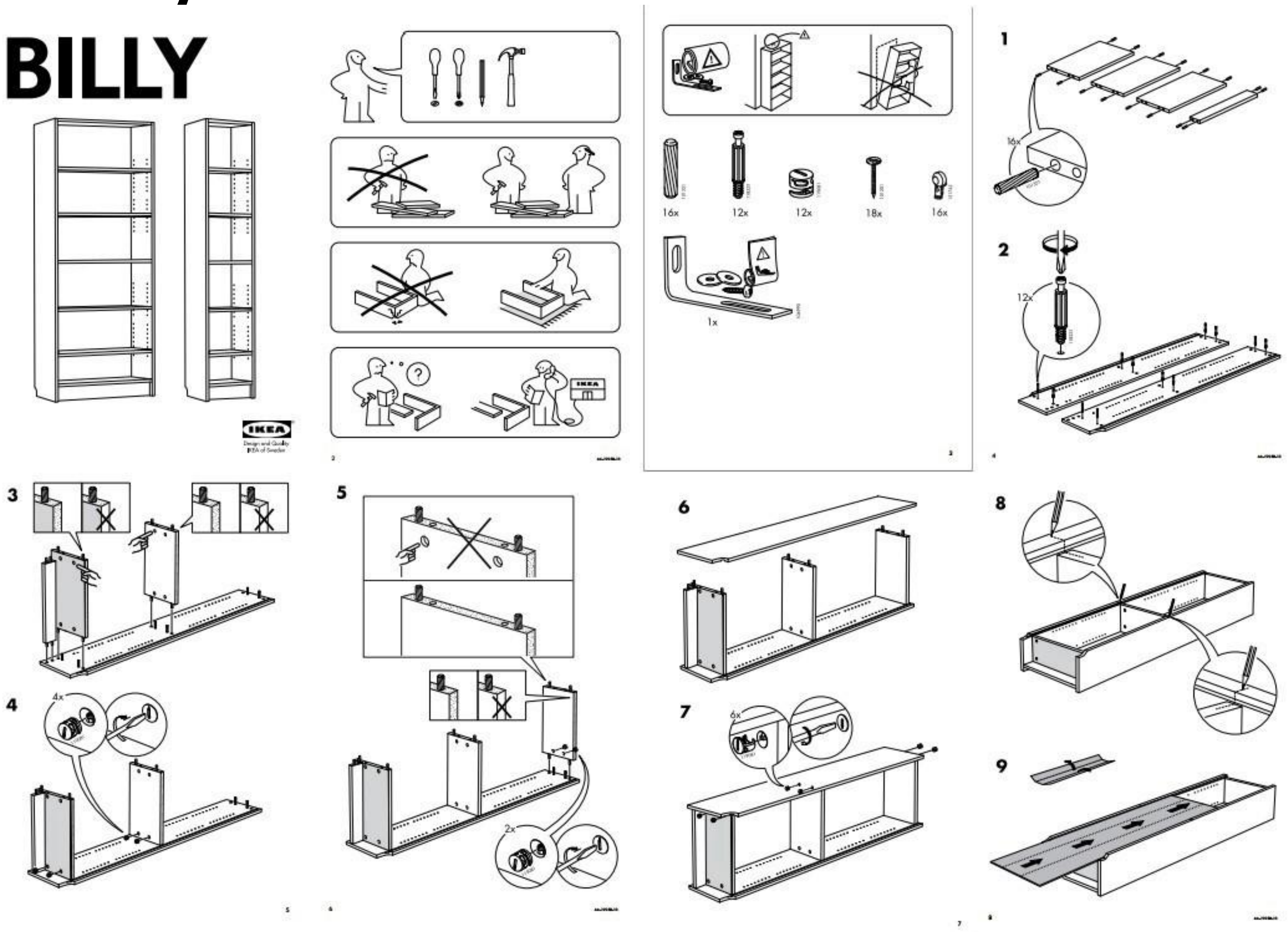
– Part is inserted from the top of the assembly
– Part is self-aligning
– Part does not need to be oriented
– Part requires only one hand for assembly
– Part requires no tools
– Part is assembled in a single, linear movement
– Part is secured immediately upon insertion

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

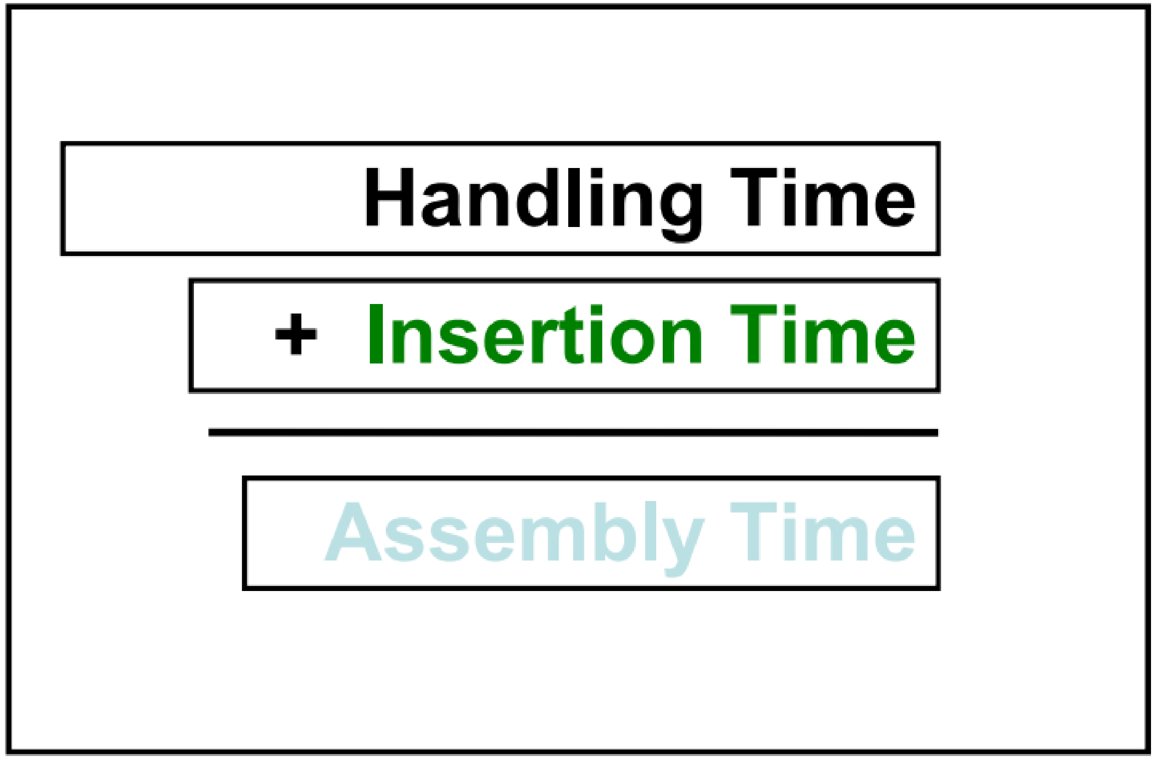


Design for Assembly Rules

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

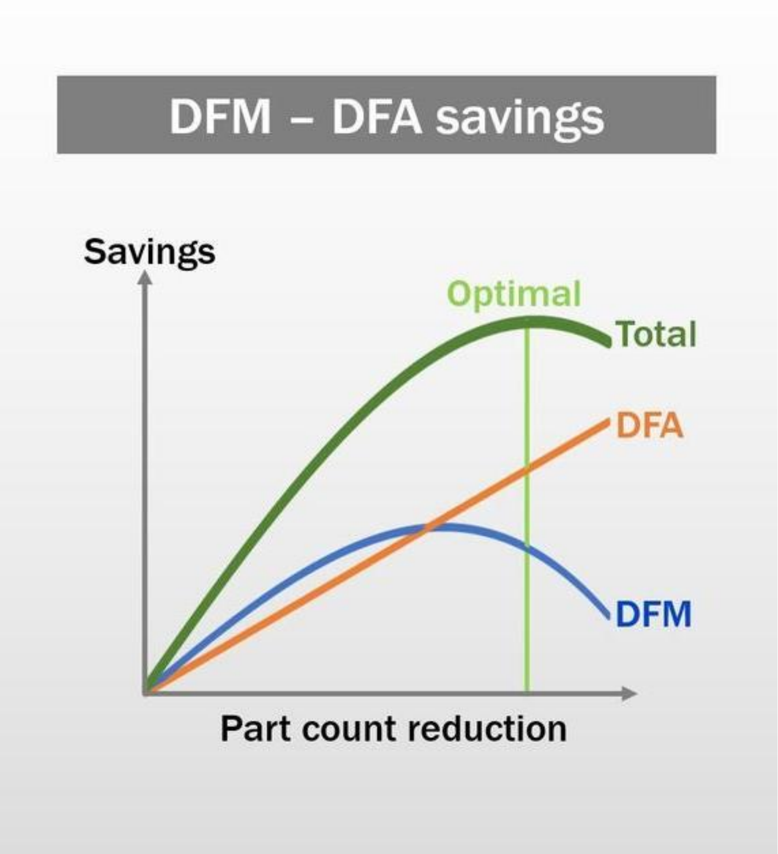
– Maximize the ease of inserting parts

- Benefits of DFA

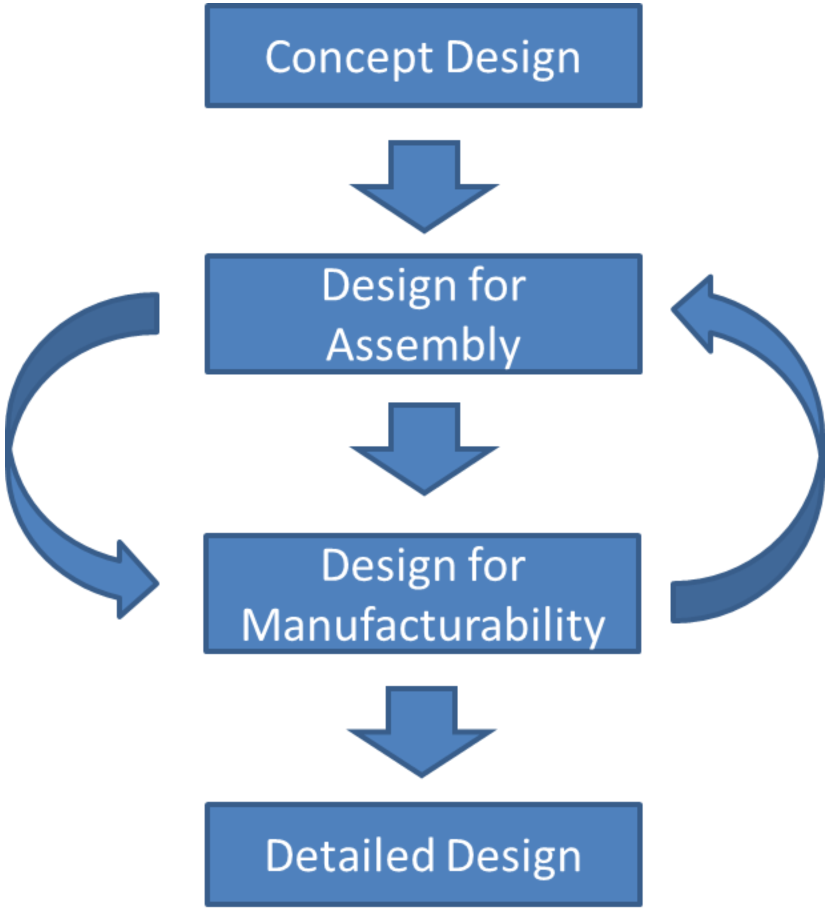
– Lower labor costs

– Other indirect benefits

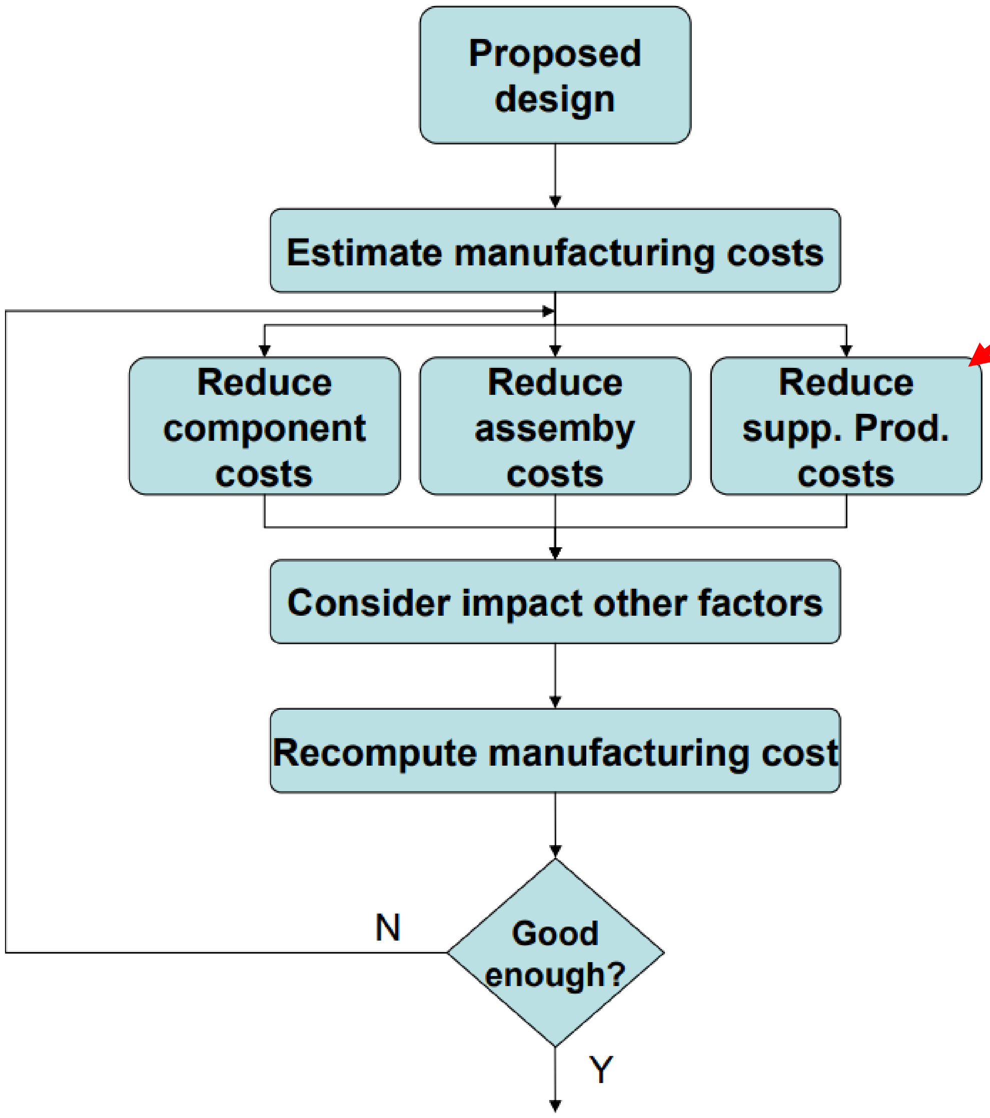
DFA and DFM



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

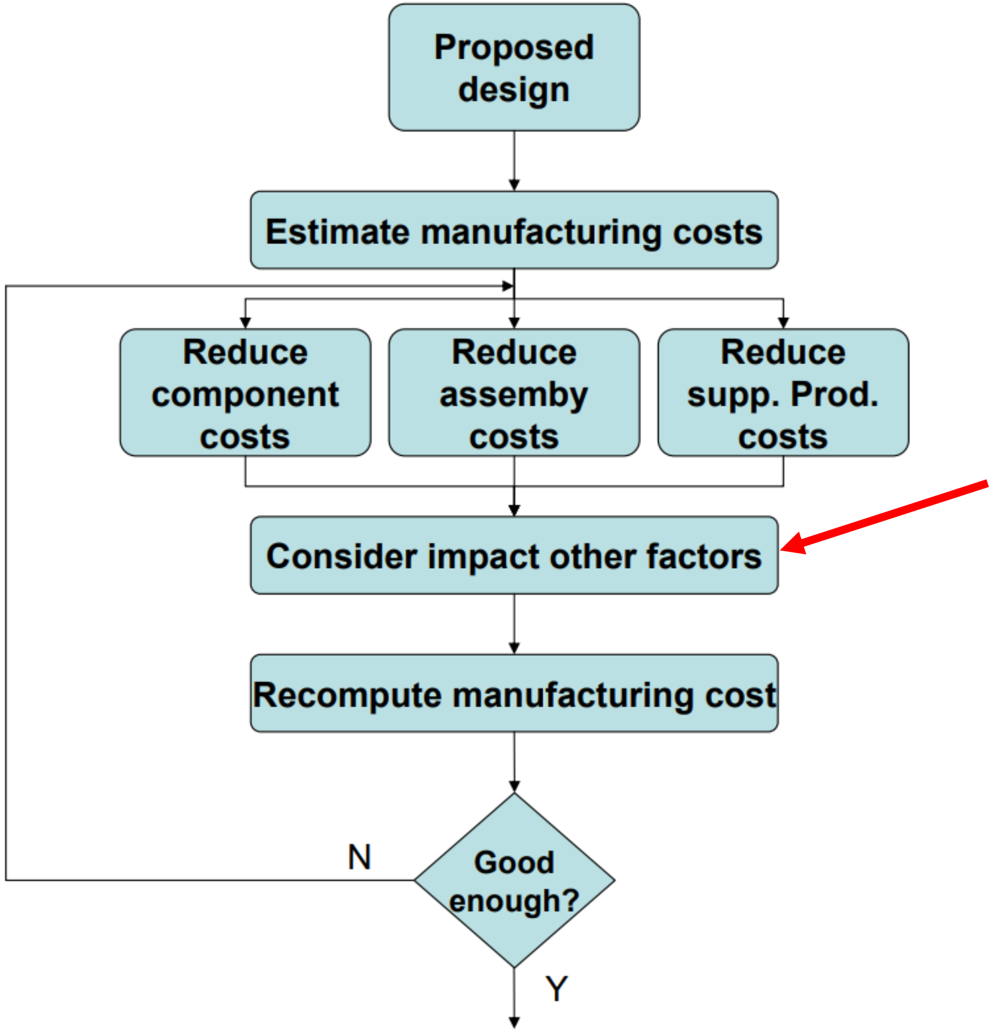


Step 4: Reduce Cost of Supporting Manufacture



- 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

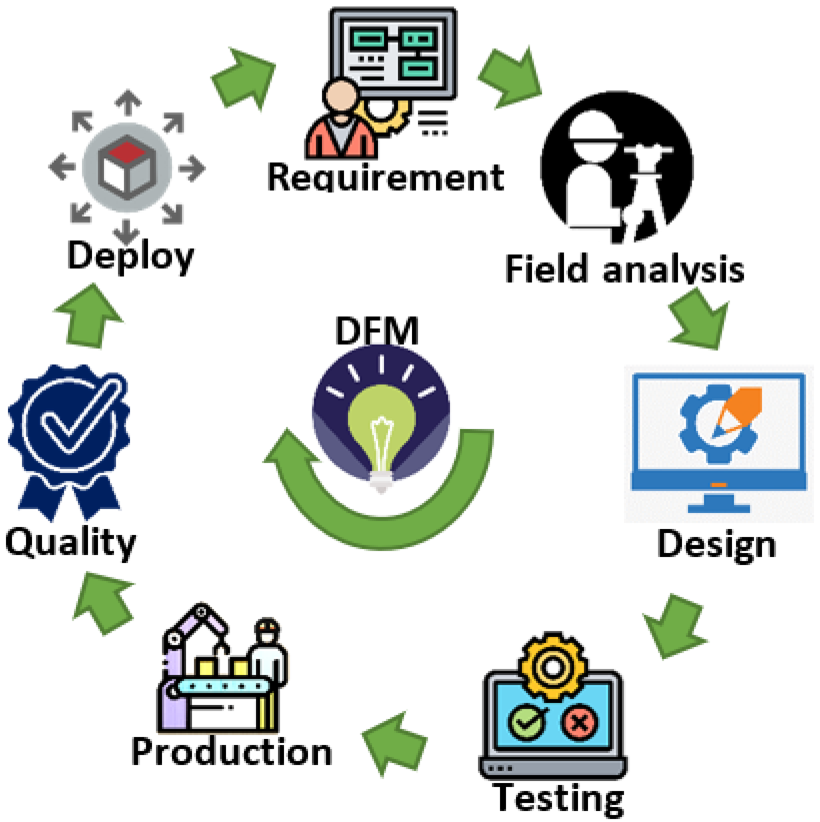
- **Impact of DFM on external factors**

– 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?

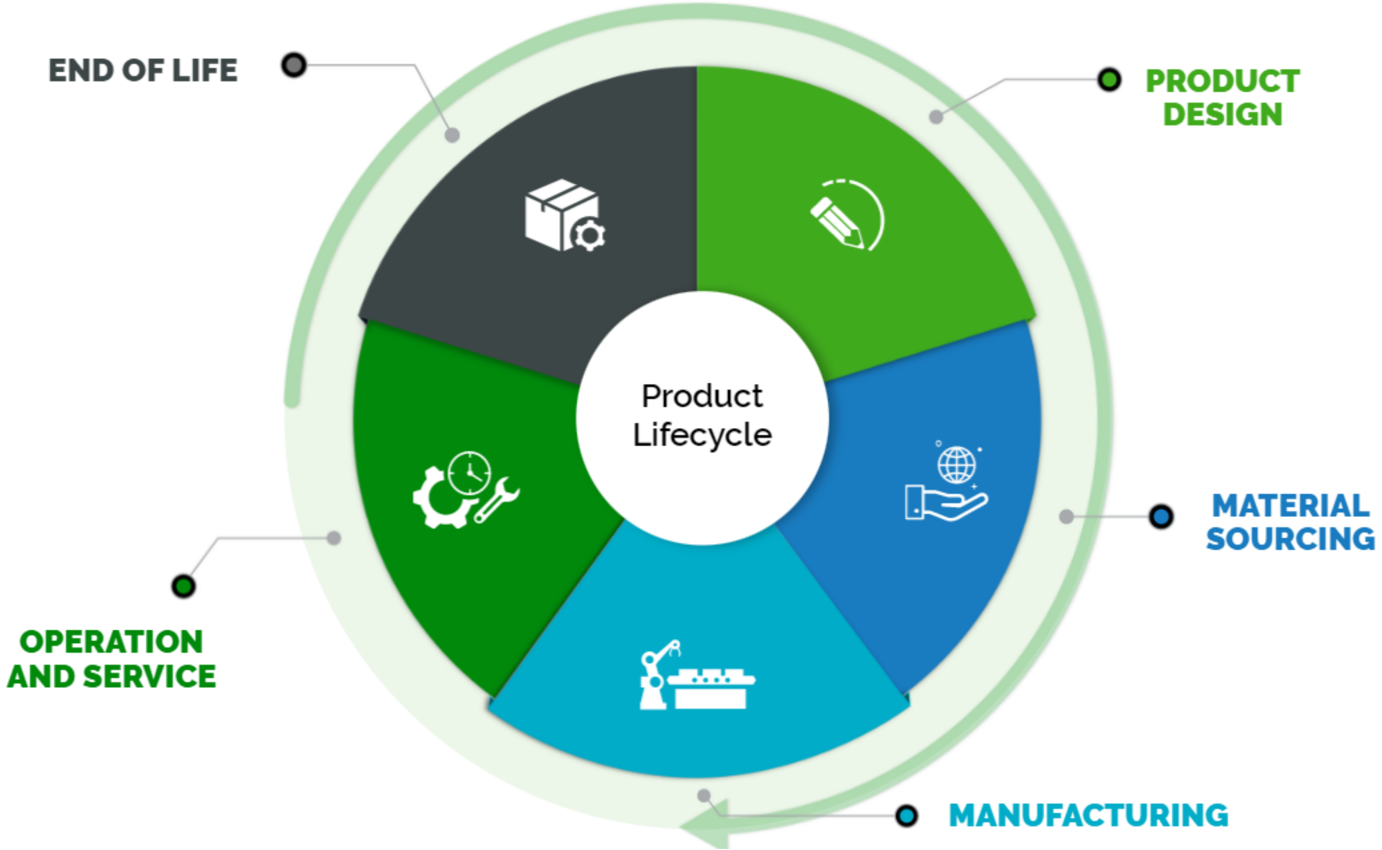
How can we increase sustainability during product design?

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.



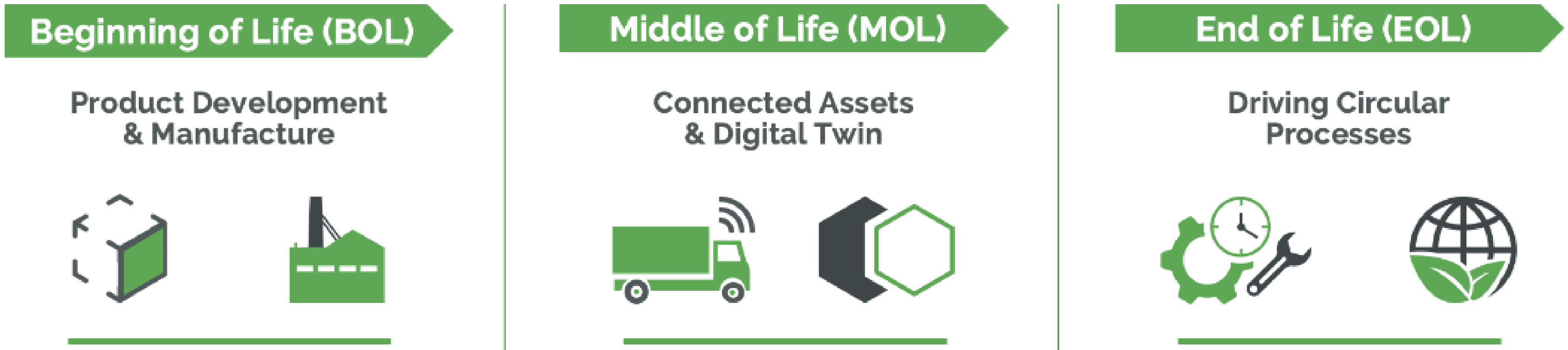
What does sustainability mean in terms of product design?

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?



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.*

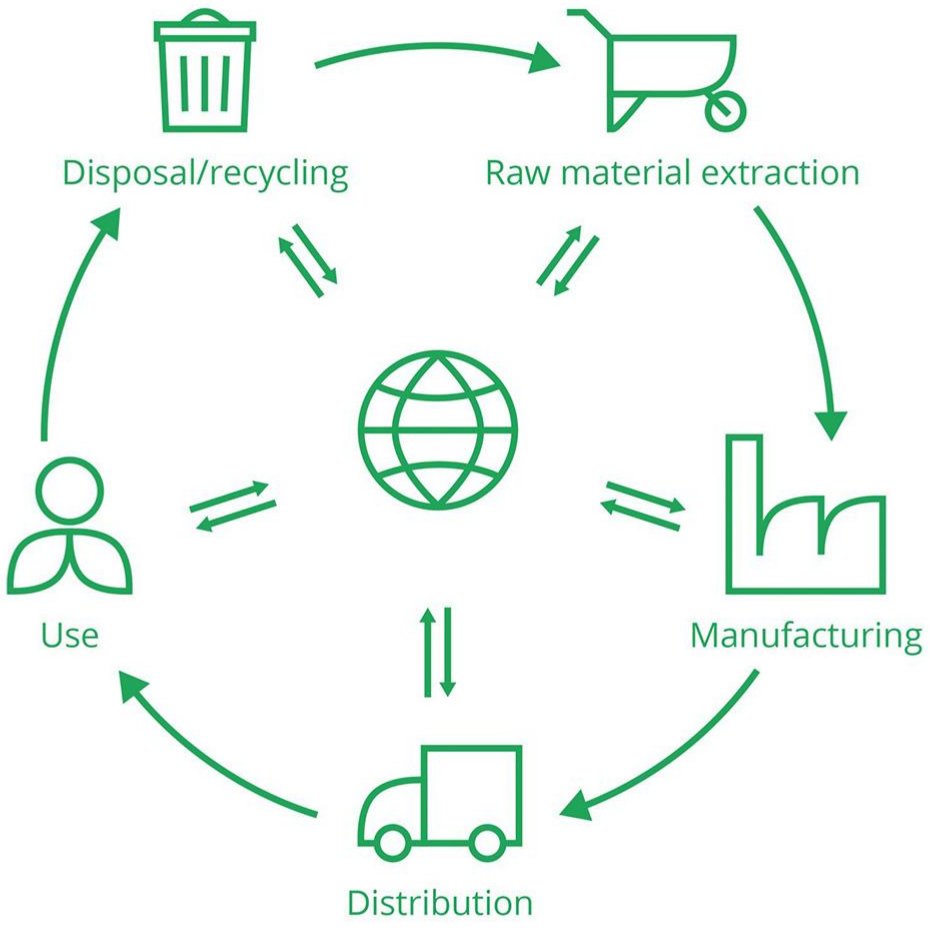
Executing Sustainable Product Design

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 CO2 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
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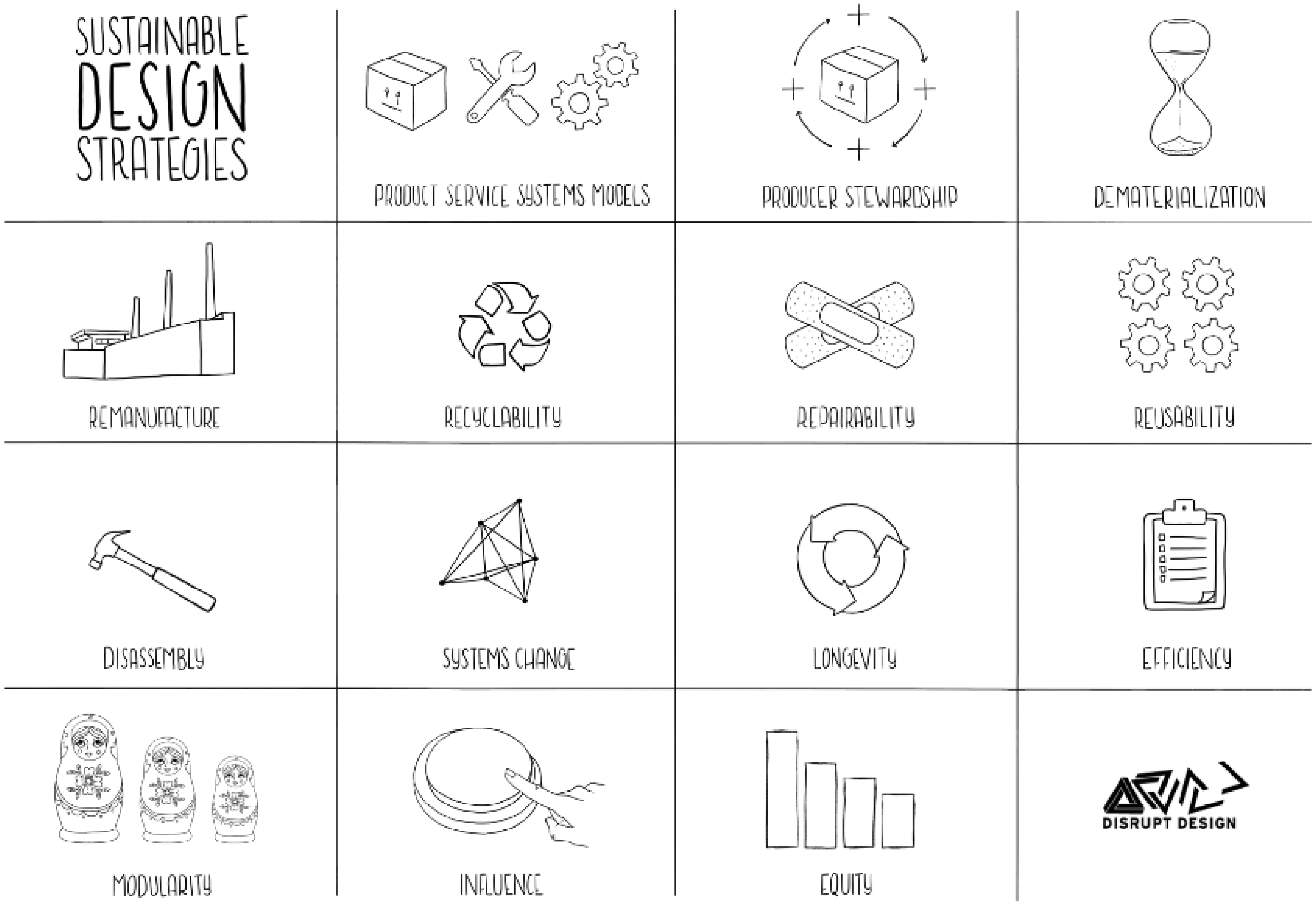
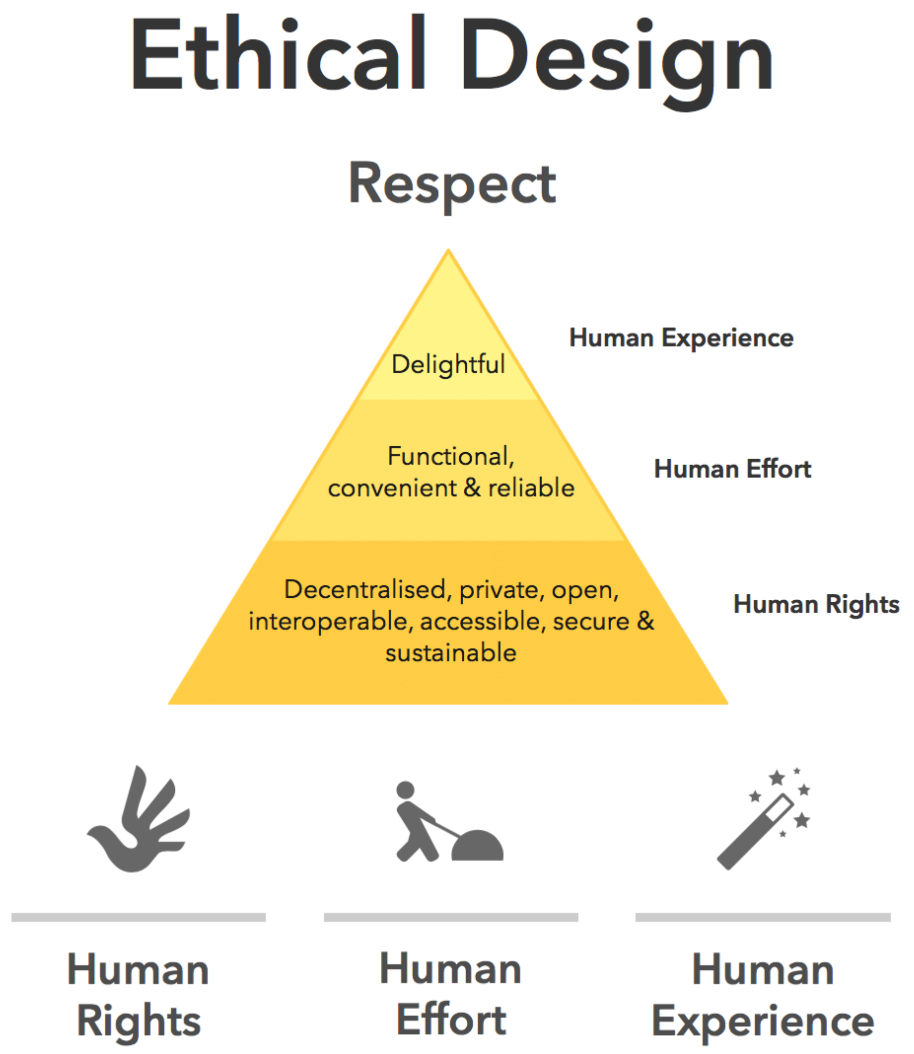
Executing Sustainable Product Design



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