University of Nottingham
UK | CHINA | MALAYSIA

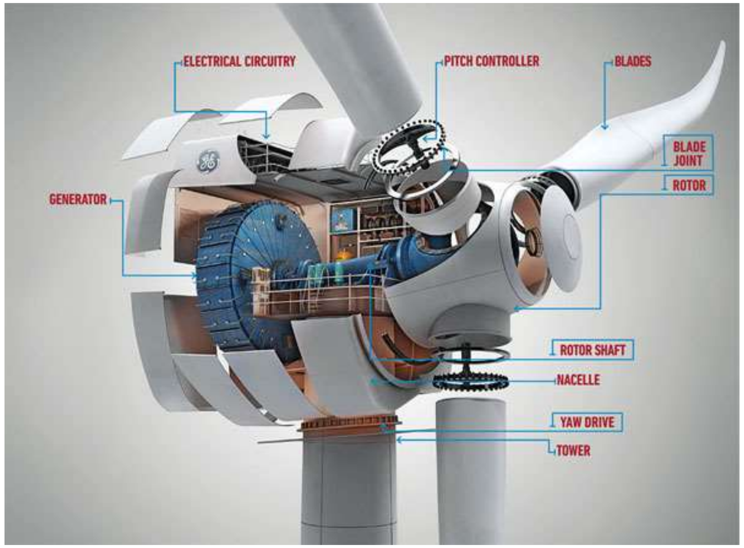
Design, Manufacture and Project Module MMME2044

Design for Manufacture and Assembly (DFMA)

Presented by Dr Khaled Goher
Adapted from the work of Dr Lin Wang and Simon Lawes

Definition: DFA is the method of design of the product for ease of assembly

'…Optimization of the part/system assembly'



- DFA is a tool used to assist the design teams in the design of products that will transition to productions at a minimum cost
- Focusing on the number of parts, handling and ease of assembly.

Definition: DFM is the method of design for ease of manufacturing of the collection of parts that will form the product after assembly.

'Optimization of the manufacturing process…'

- DFM is a tool used to select the most cost-effective material and process to be used in the production in the early stages of product design.
- The goal is to make the manufacturing process as simple and efficient as the product's functionality will allow.

Differences

➢ <u>Design for Assembly (DFA)</u>
- ✓ Concerned only with <u>reducing product assembly cost</u>
- ✓ Minimises number of assembly operations
- ✓ Minimises number of parts
- ✓ Individual parts tend to be more complex in design

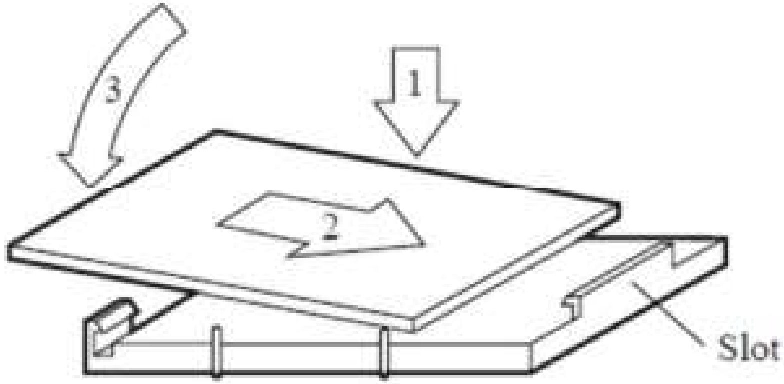
➢ <u>Design for Manufacture (DFM)</u>
- ✓ Concerned with <u>reducing overall part production cost</u>
- ✓ Minimises complexity of manufacturing operations

Similarities

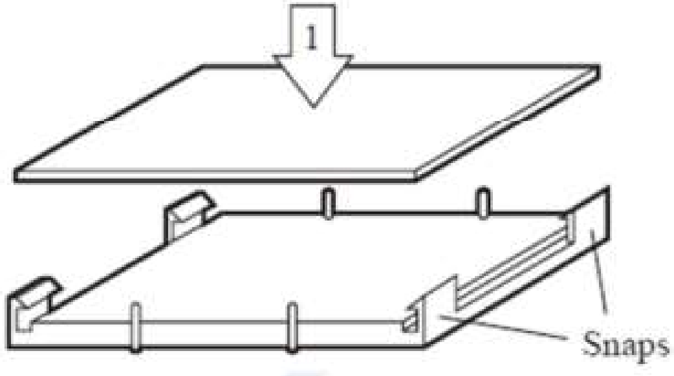
- Both DFM and DFA seek to reduce material, overhead and labor cost
- They both shorten the product development cycle time
- Design for Manufacture (DFM) and Design for Assembly (DFA) are now commonly referred to as a single methodology, Design for Manufacture and Assembly **(DFMA)**.

General Design Principles

Minimising assembly direction



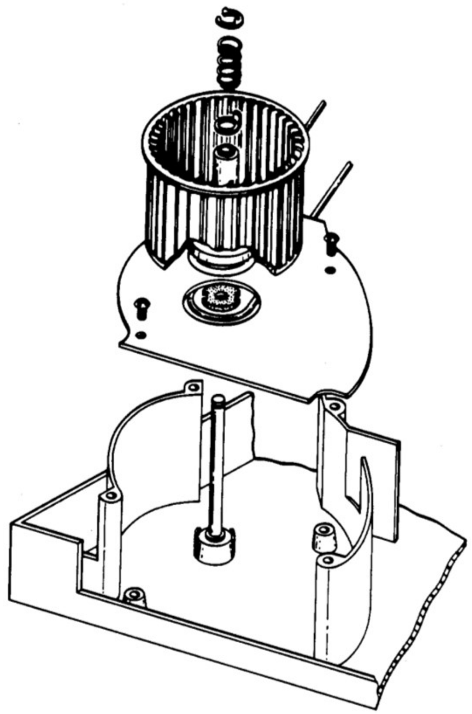
Initial Design: Multi-direction assembly



Improved: one-direction assembly

General Design Principles

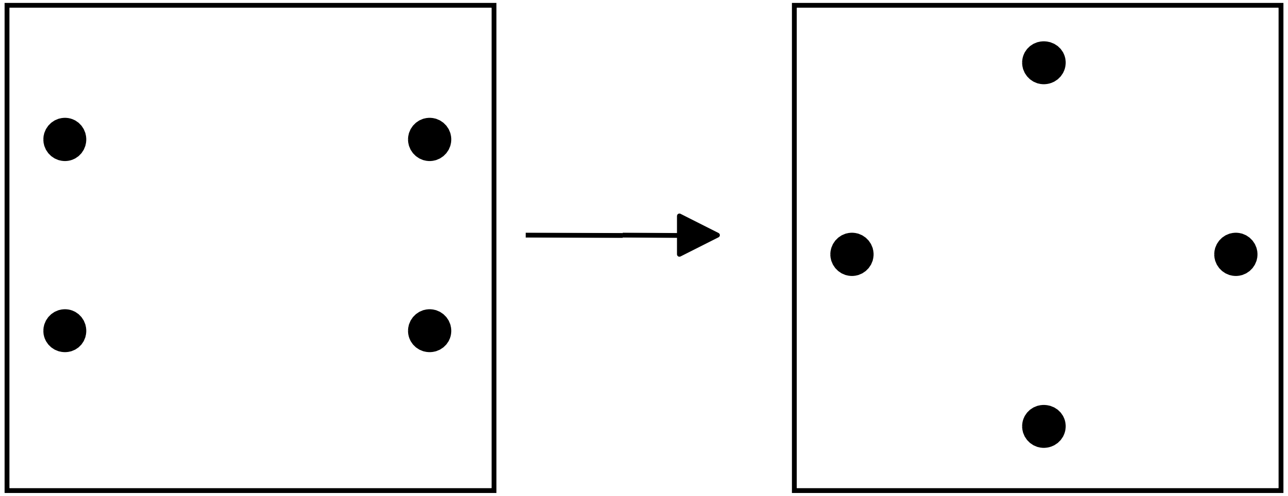
Top-Down Assembly



- All assembly operations are done from above, which allows for maximum visibility and provides no obstructions to the operator.

General Design Principles

Symmetry eliminates reorientation

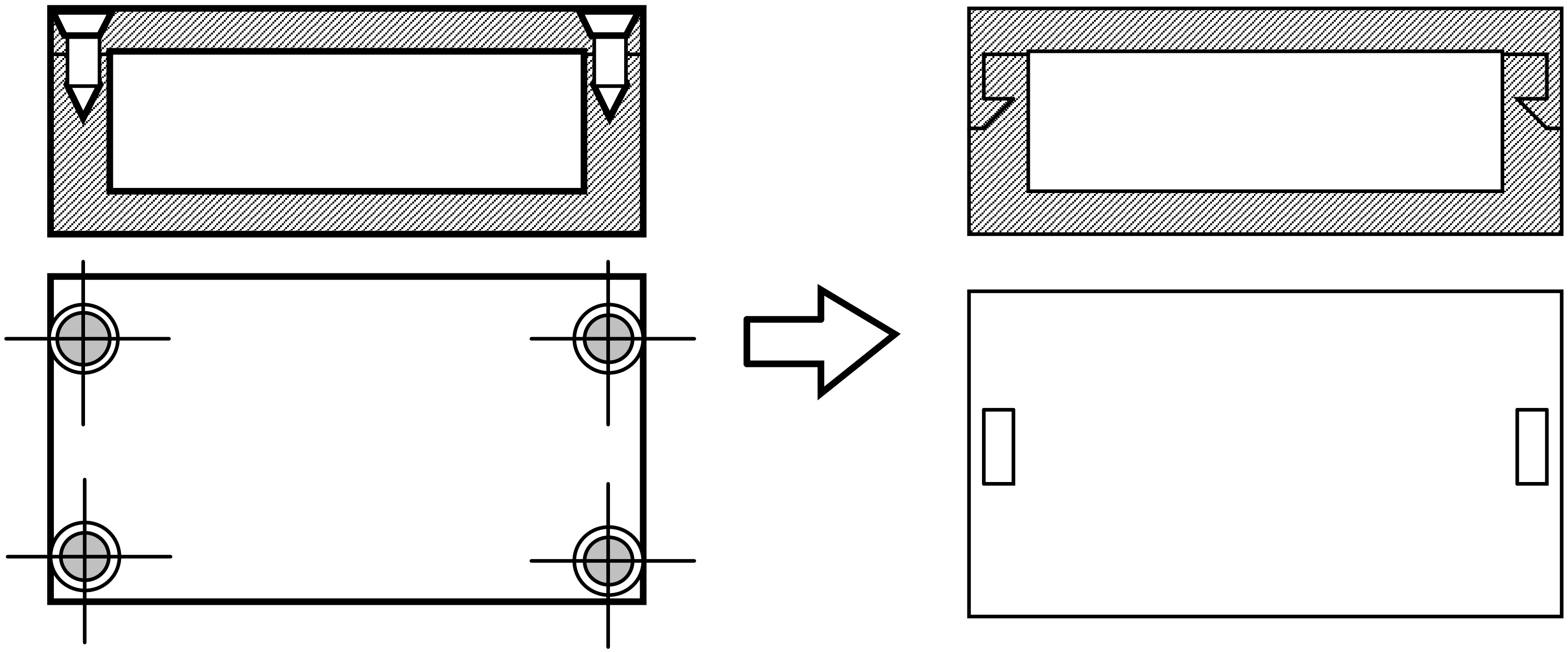


Asymmetric Part

Symmetry of a part makes assembly easier

General Design Principles

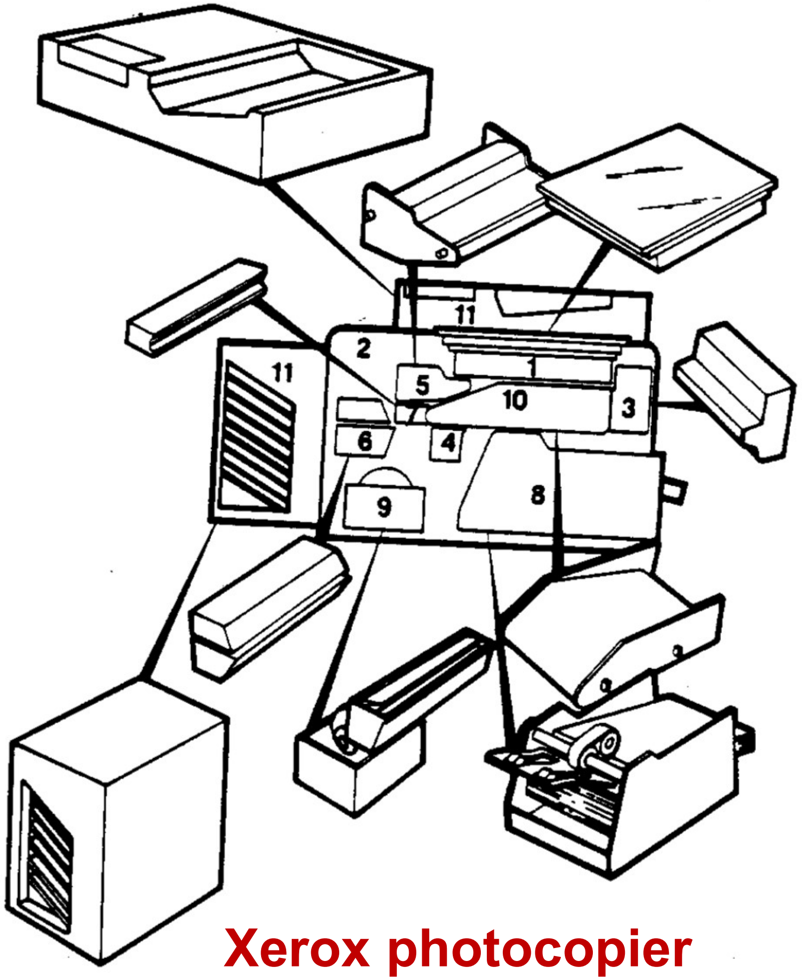
Self-fastening features



General Design Principles

Modular Assemblies

1. Imaging
2. Drives
3. Development
4. Transfer/Stripping
5. Cleaning
6. Fusing
7. Charge/Erase
8. Copy Handling
9. Electrical Distribution
10. Photoreceptor
11. Input/Output Devices



Xerox photocopier

Design, Manufacture and Project
Design for Assembly Process

Step 1
- Product Information: ***functional requirements***
- Functional analysis
- Identify parts that can be standardized
- Determine part count efficiencies

Step 2
- Part count reduction

Step 3
- Identify quality (mistake proofing) opportunities

Step 4
- Identify handling (grasp & orientation) opportunities

Step 5
- Identify insertion (locate & secure) opportunities

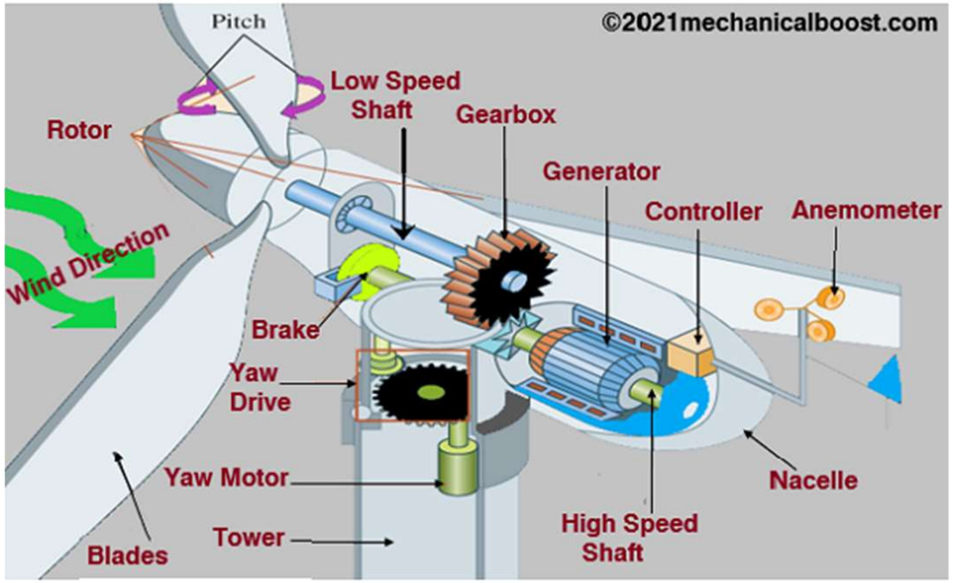
Step 6
- Identify opportunities to reduce secondary operations

Step 7
- Analyze data for new design

Step 1

- Product Information: ***functional requirements***
- Functional analysis
- Identify parts that can be standardized
- Determine part count efficiencies

- Identify essential parts
- Non-essential parts:
  - Fasteners
  - Spacers, washers, O-rings
  - Connectors
- Do not include liquids as parts (e.g. glue, lube, etc.)



➢ The criteria for an essential part

- The part must exhibit motion relative to another essential part
- A fundamental reason to be made of a different material
- It is impossible to assemble or disassemble the other parts unless this part is separate

Parts used only for fastening are prime candidates for elimination.

Equation to evaluate the efficiency of assembly (Design Efficiency)

$$\text{Design Efficiency} = \frac{3 \times \text{min number of parts}}{\text{total assembly time}}$$

where the time taken to assemble a 'theoretical' part is 3 sec

To determine essential or non-essential parts

Ask three questions:

1. Does the part move relative to all other parts already assembled – does it need to?
2. Is the part made of a different material to all other parts already assembled – does it need to be?
3. Is the part separate to allow for its in-service adjustment or replacement – does it need to be?

If all answers are "Yes": **essential** part

If any answers are "No": **non-essential** part

Example

Tea Set

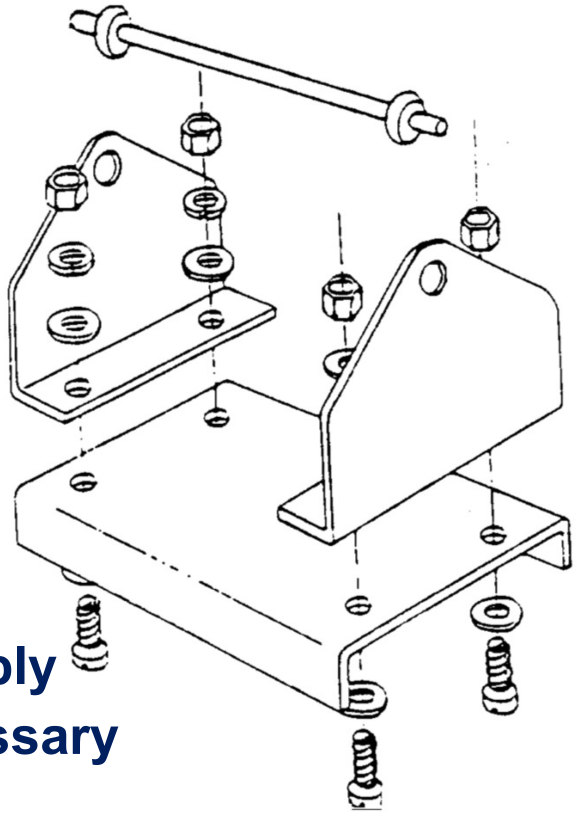
https://www.youtube.com/watch?v=C31RPvtFw6k&t=78s

Step 2 Part count reduction

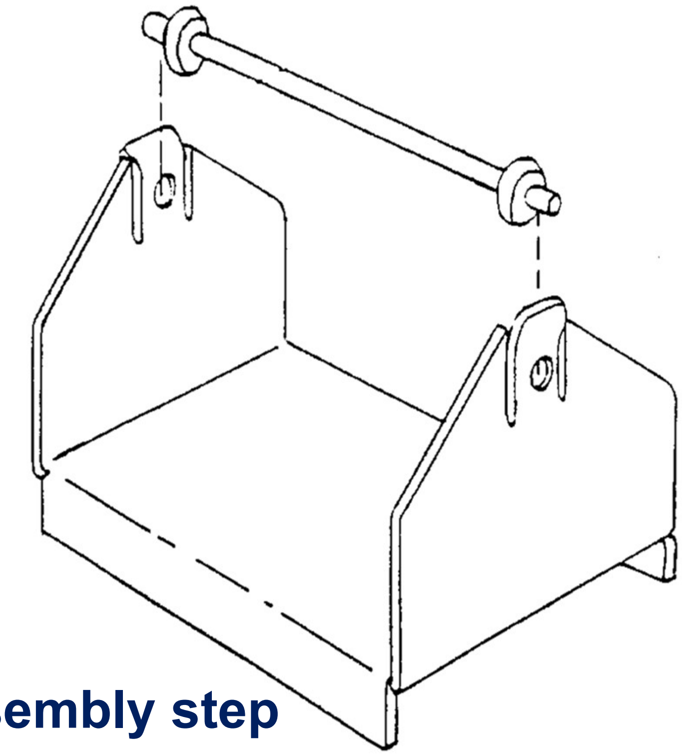
- Identify opportunities to eliminate non-essential parts

Example: Rollbar Redesign

'..If more than 1/3 of the components in a product are fasteners, the assembly logic should be questioned.'



- 24 Parts
- 8 different parts
- multiple assembly processes necessary



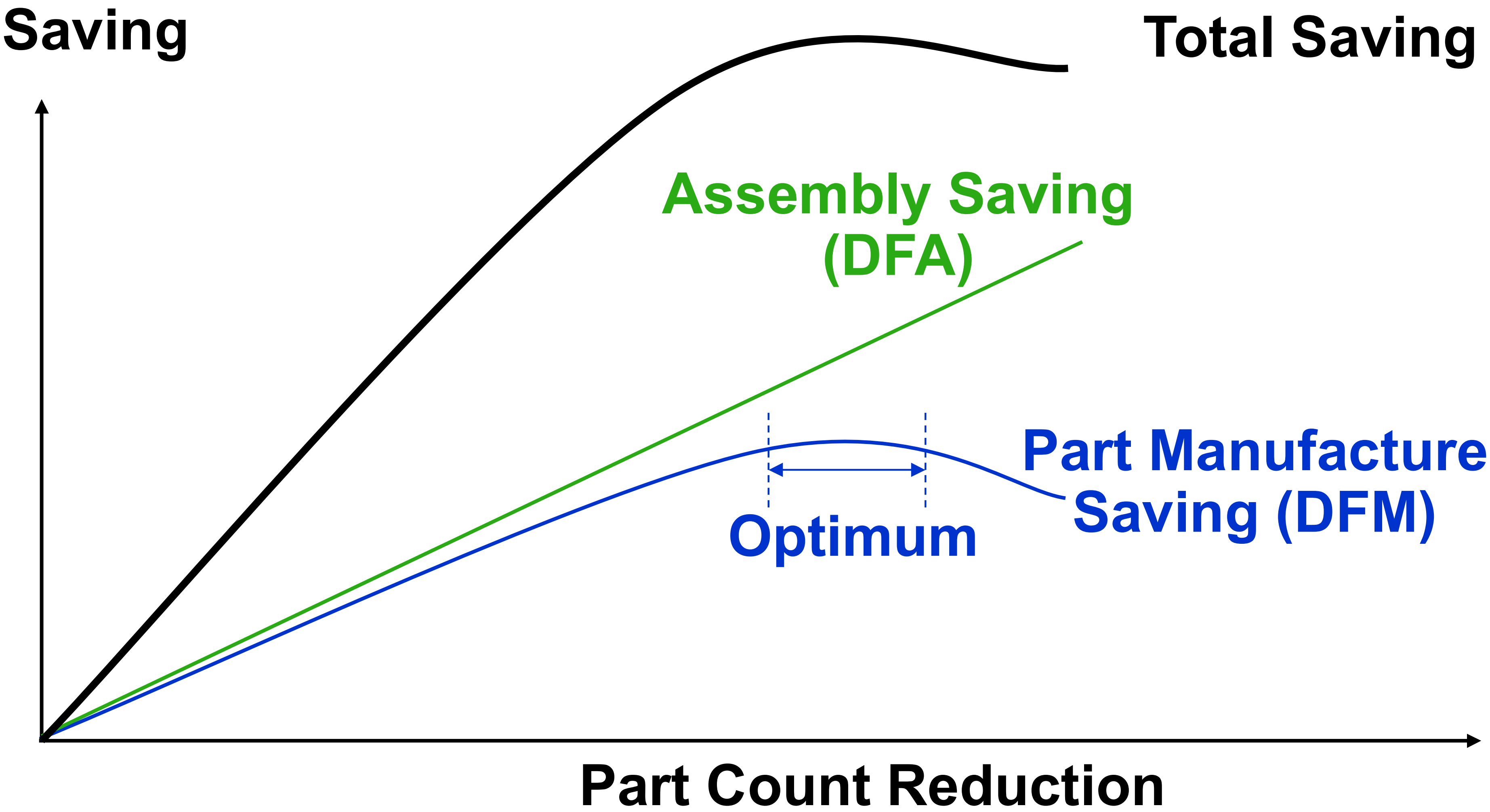
- 2 Parts
- one assembly step

Eliminated parts are NEVER…

- Designed
- Detailed
- Prototyped
- Produced
- Scrapped
- Tested
- Re-engineered
- Purchased
- Progressed
- Received
- Inspected
- Rejected
- Stocked
- Outdated
- Written-off
- Unreliable
- Recycled
- late from the supplier!

- There is always a tradeoff between DFA and DFM.
- Taken to it's extreme, DFA would recommend that you make one very complex part that requires no assembly. This can make that one part very difficult to manufacture.
- Taken to it's extreme, DFM would recommend that you make big chunks off with hammers and saying "close enough". However, this would make it really hard to put the parts together into an assembly that functions.
- The optimum is somewhere in between

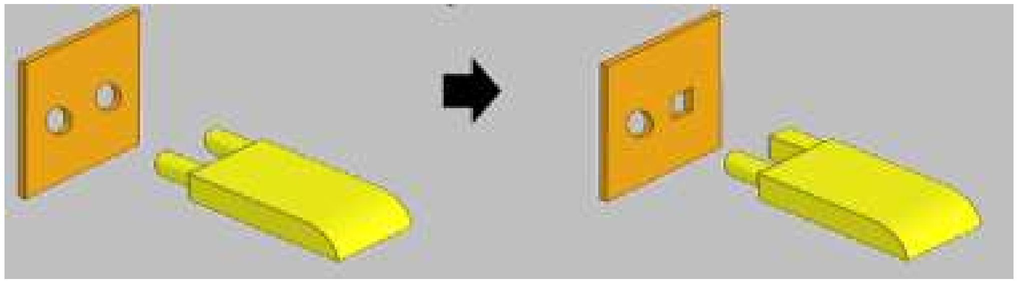
Cost of Assembly Vs Cost of Part Manufacture

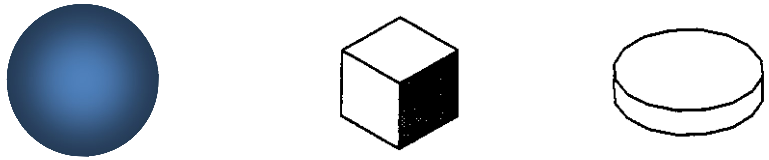


Step 3 □ Identify quality (mistake proofing) opportunities

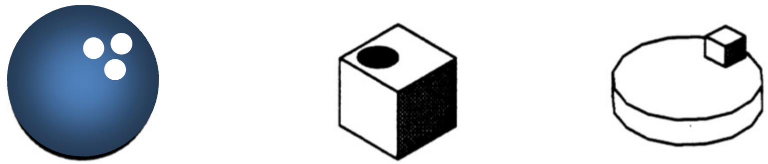
Design for mistake-proofing assembly to prevent

- wrong parts being assembled
- assembling parts in the wrong orientation





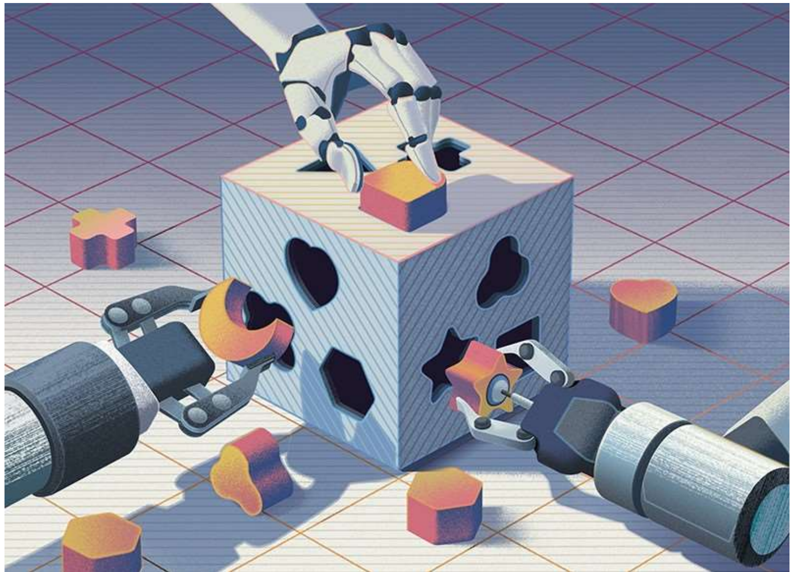
symmetrical parts



asymmetrical parts

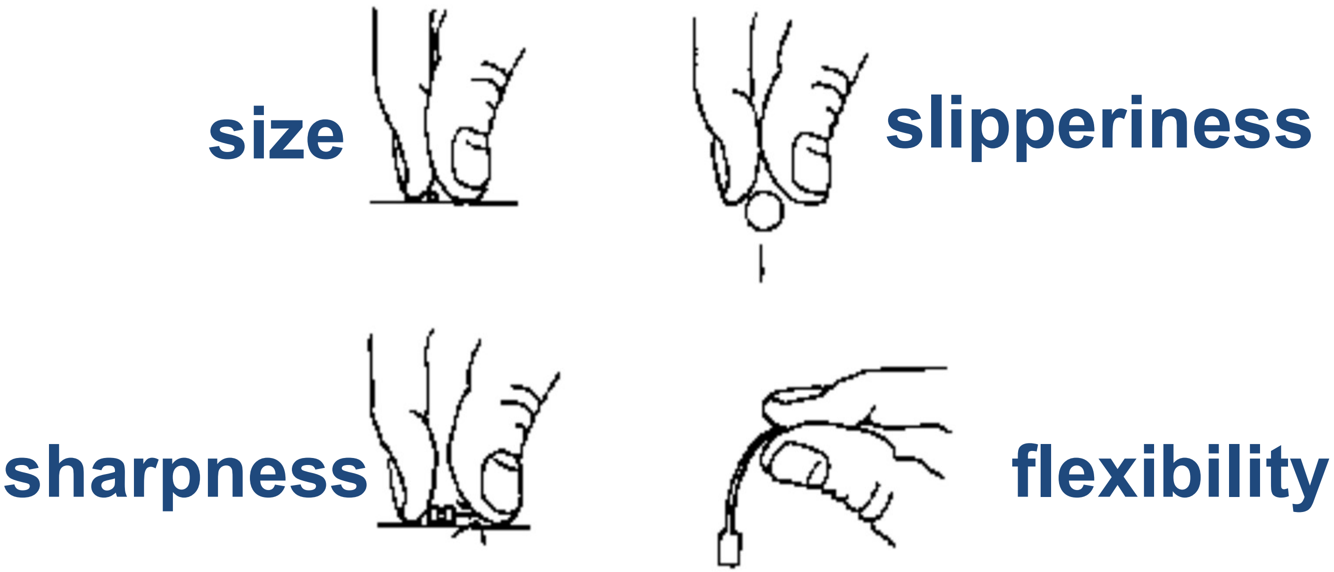
Step 4 Identify handling (grasp & orientation) opportunities

- **Handling Time:** based on assembly process and complexity of parts
  - How many hands are required?
  - Is any grasping assistance needed?
  - What is the effect of part symmetry on assembly?
  - Is the part easy to align/position?

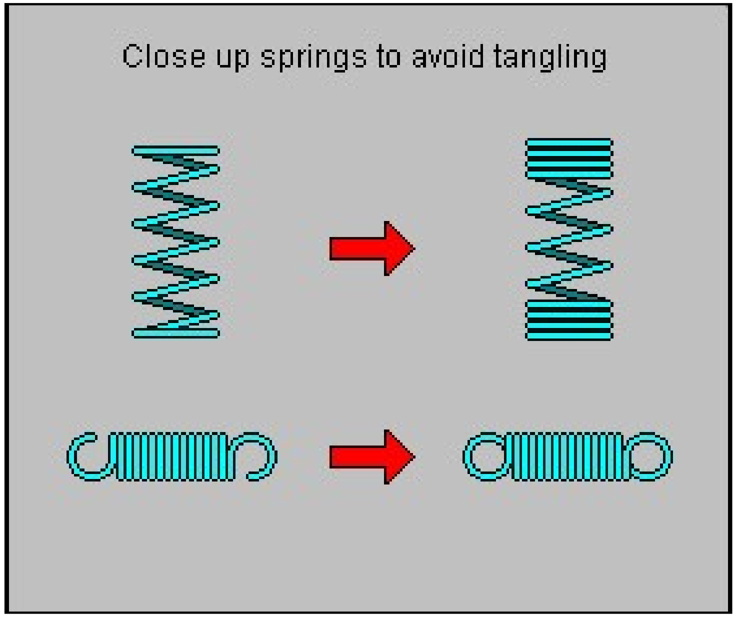


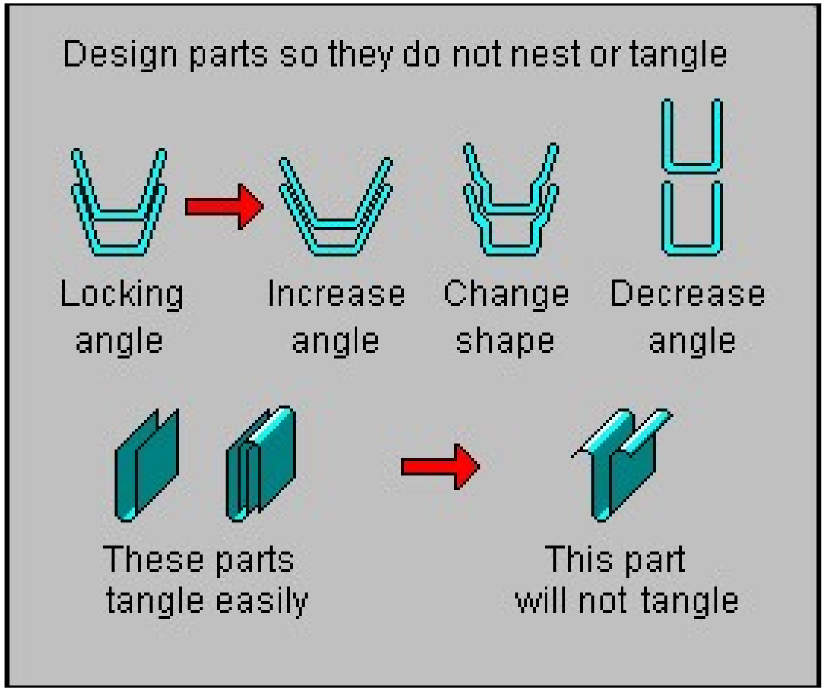
Handling Difficulty

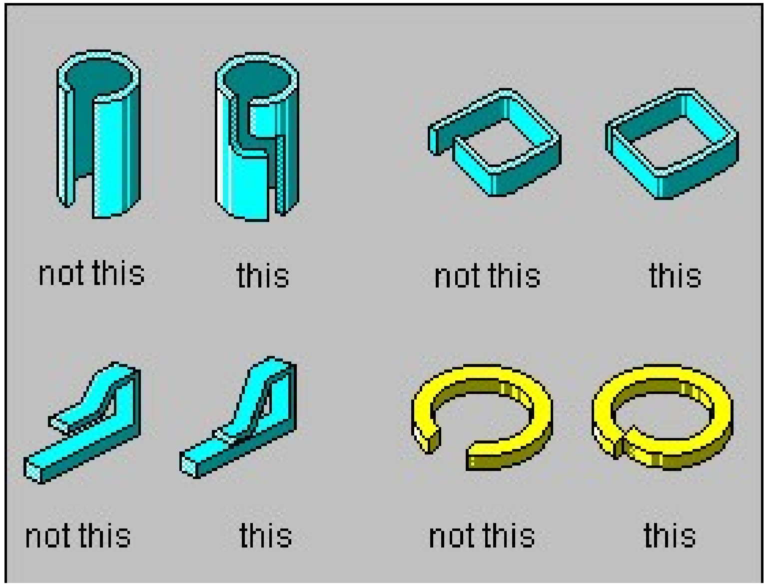
- Size
- Thickness
- Weight
- Fragility
- Flexibility
- Slipperiness
- Stickiness
- Necessity for using
  - two hands,
  - optical magnification, or
  - mechanical assistance



Eliminate Tangling/Nesting



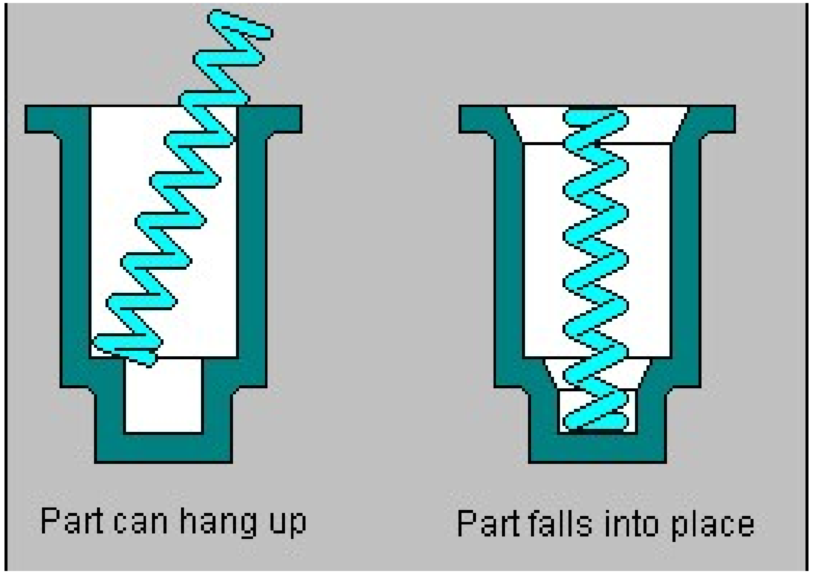


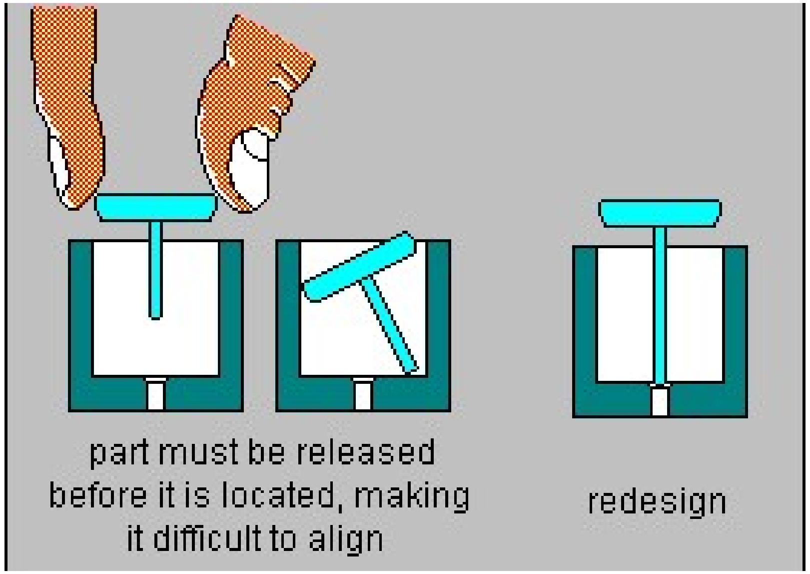


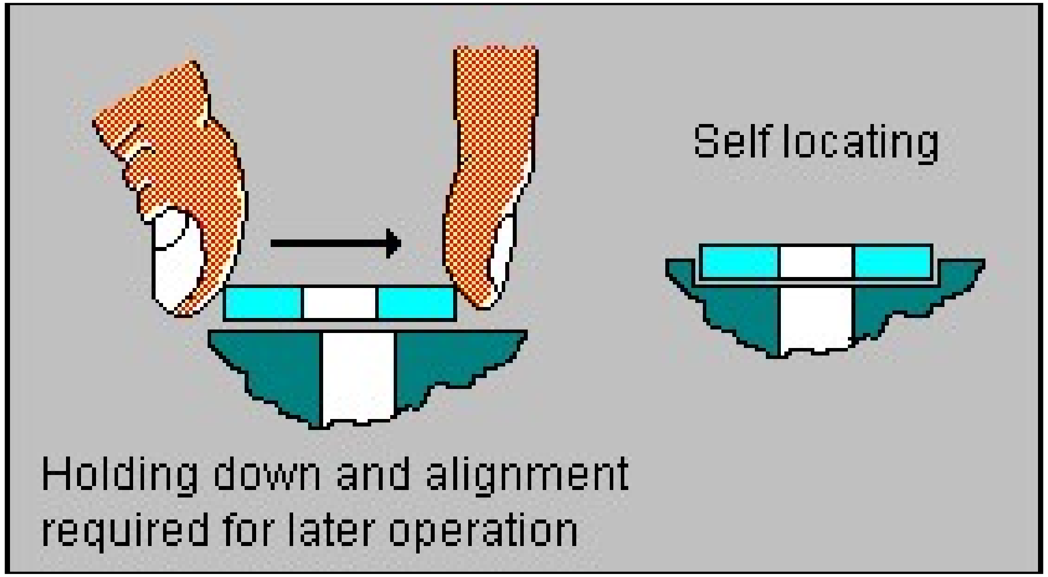
Step 5 □ Identify insertion (locate & secure) opportunities

- **Insertion time:** based on difficulty required for each component insertion
  - Is the part secured immediately upon insertion?
  - Is it necessary to hold down part to maintain location?
  - What type of fastening process is used?
  - Is the part easy to align/position?

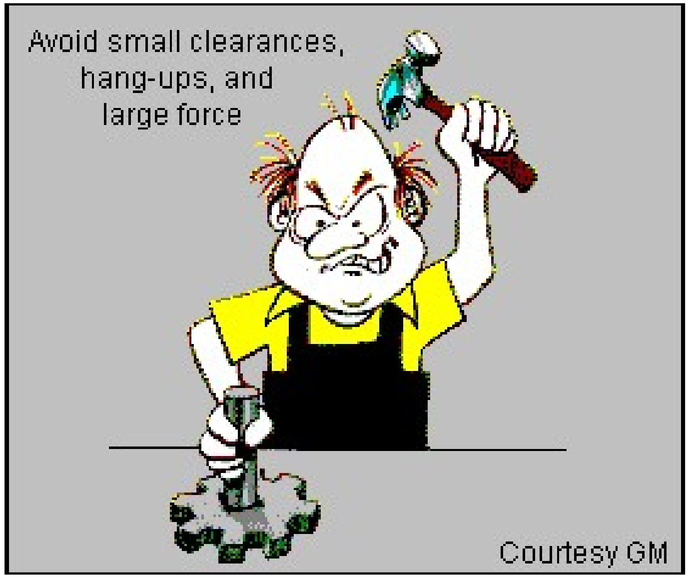
Step 5 □ Identify insertion (locate & secure) opportunities

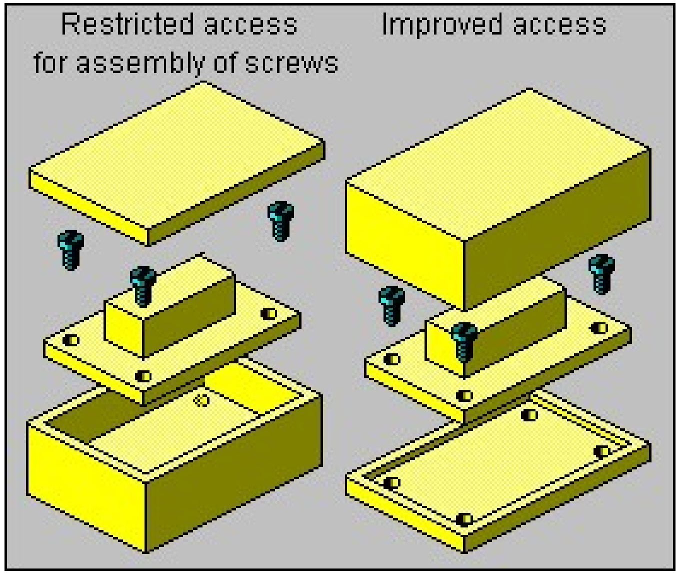


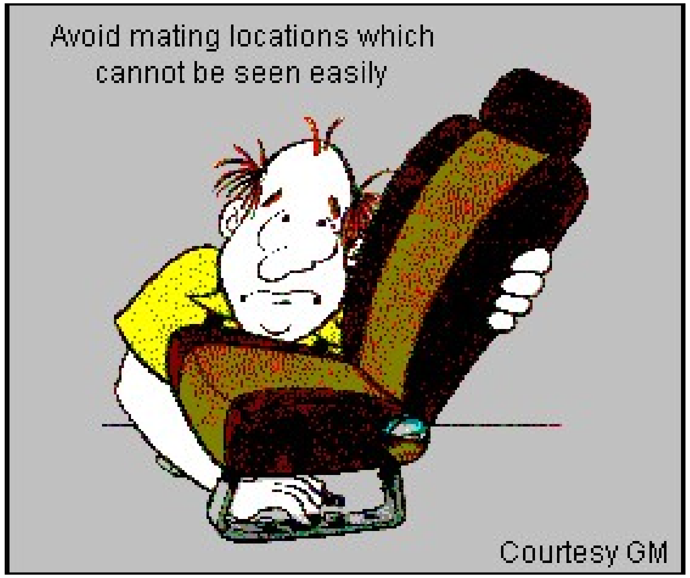




Step 5 □ Identify insertion (locate & secure) opportunities

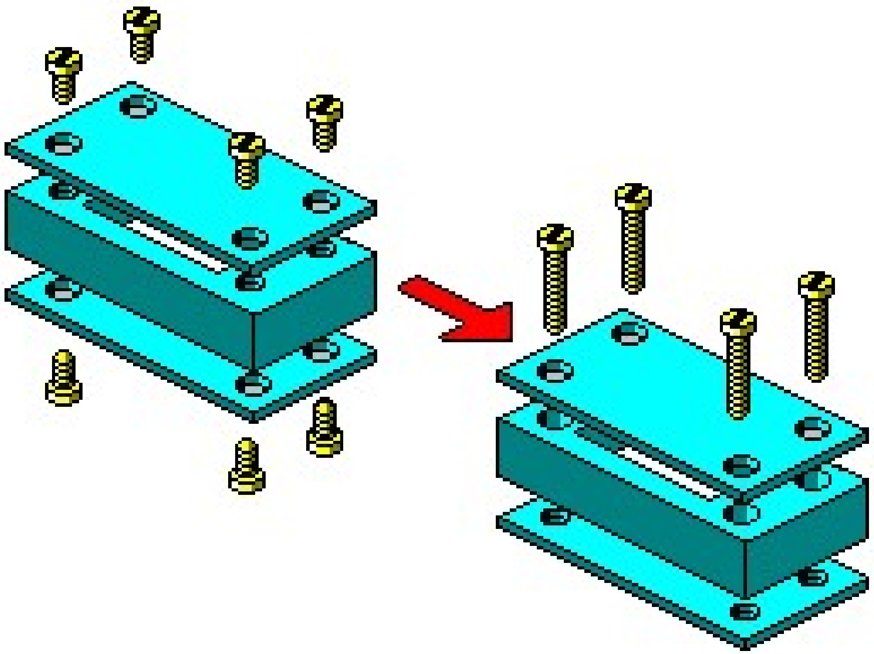


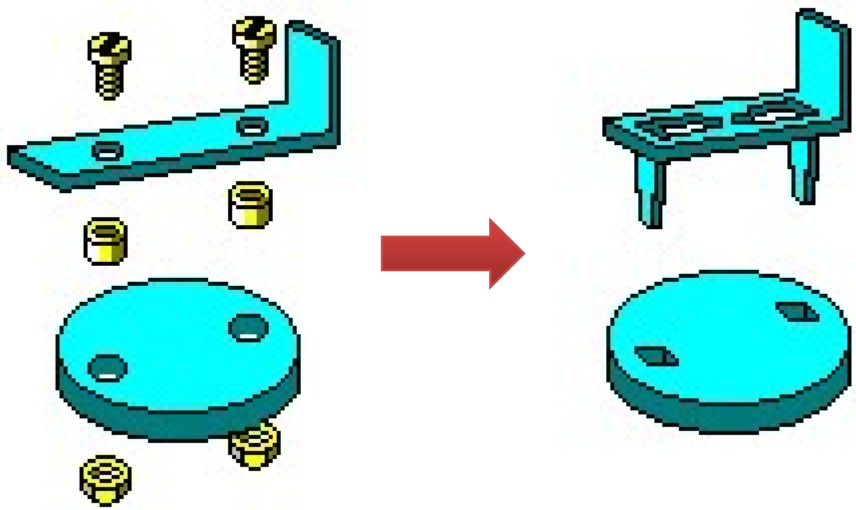




Step 6 □ Identify opportunities to reduce secondary operations

- Re-orientation (assemble in Z axis)
- Screwing, drilling, twisting, bending, crimping.

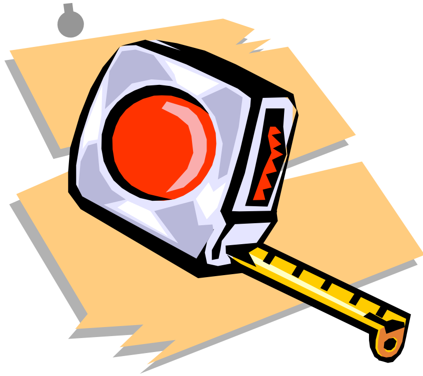


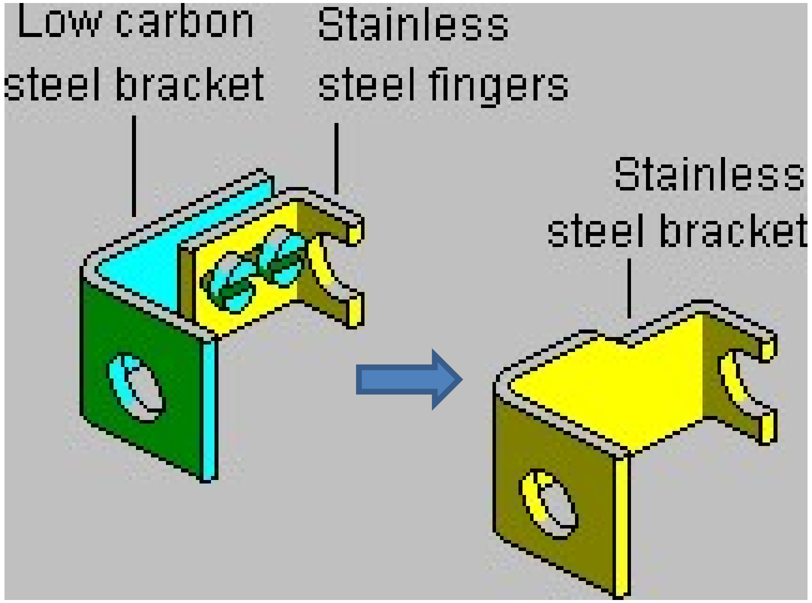


Design, Manufacture and Project
Design for Assembly Process

Eliminate Secondary Operations

- Welding, soldering, gluing.
- Painting, lubricating, applying liquid or gas.
- Measuring, adjusting.





Original design

Revised design

Design for Assembly Process

Step 1

- Product Information: *functional requirements*
- Functional analysis
- Identify parts that can be standardized
- Determine part count efficiencies

Step 2

- Part count reduction

Step 3

- Identify quality (mistake proofing) opportunities

Step 4

- Identify handling (grasp & orientation) opportunities

Step 5

- Identify insertion (locate & secure) opportunities

Step 6

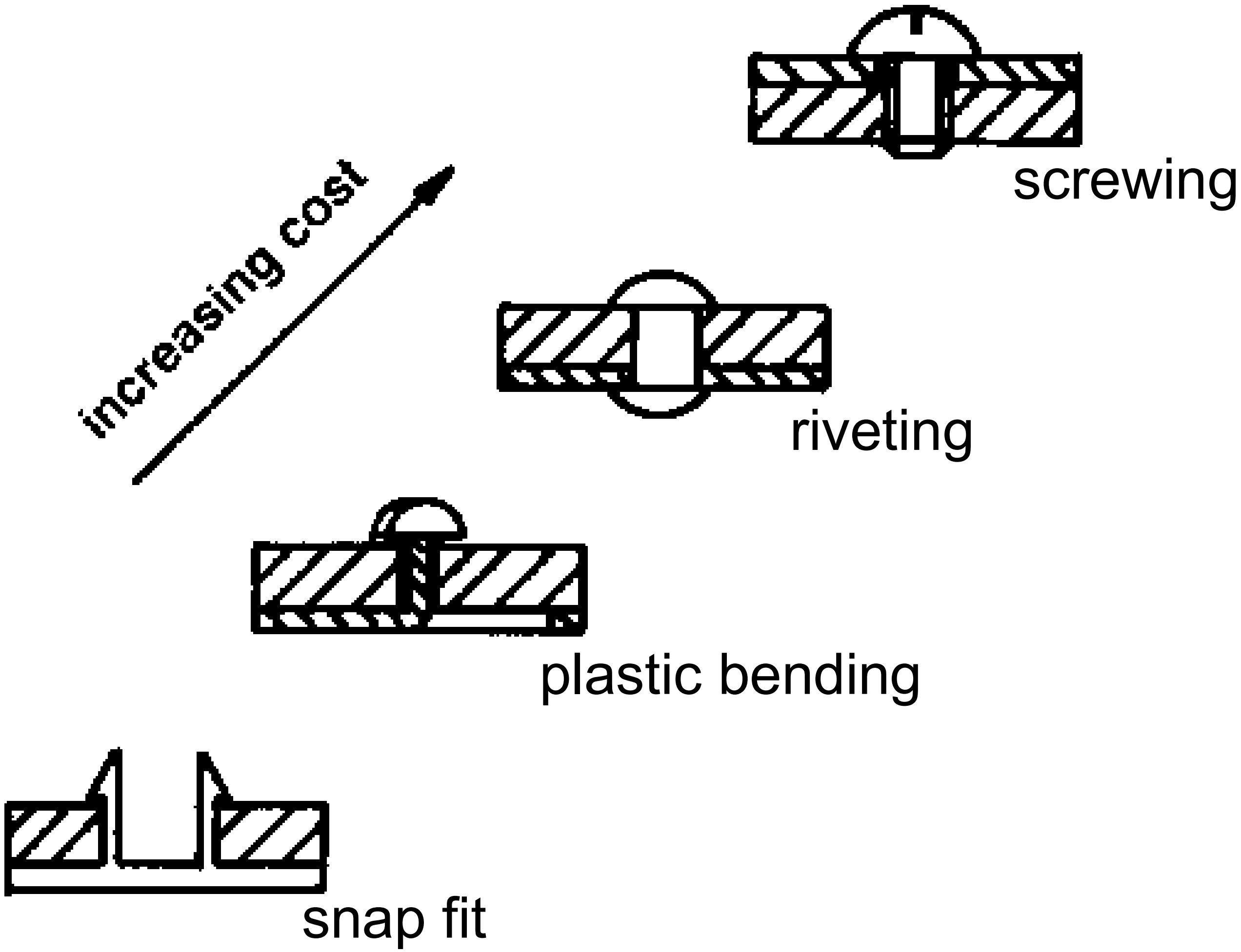
- Identify opportunities to reduce secondary operations

Step 7

- Analyze data for new design

Fastener Cost

- Select the most inexpensive fastenir method required



In order of importance:

- Reduce part count & types
- Ensure parts cannot be installed incorrectly
- Strive to eliminate adjustments
- Ensure parts self-align & self-locate
- Ensure adequate access & unrestricted vision
- Ensure parts are easily handled from bulk
- Minimize reorientation (assemble in Z axis) & secondary operations during assembly
- Make parts symmetrical or obviously asymmetrical

Design for Manufacture (DFM)

- ✓ Optimises the manufacturing process
- ✓ Reduces the manufacturing cost
- ✓ Allows manufacturing problems to be fixed in design phase

Typical Guidelines

- Use standard commercially available components (reduced design time; avoid custom-engineered components)
- Design for ease of part fabrication (simplified part geometry; avoid unnecessary features & unnecessary surface finish requirements)
- Design parts with tolerances that are within process capability (avoid tolerances tighter than the process capability)

Selection of Manufacturing Method

Have we selected the appropriate Technology or Process to fabricate the parts?

Selection of Material

Have we selected the appropriate Material needed for function and cost?

Wind turbine blade

Wind turbine tower

https://www.youtube.com/watch?v=jpRudTUIyfM

Selection of Manufacturing Method

Has the Design Addressed Automation Possibilities?

Is the Product configured with access for and the parts shaped for the implementation of automation?

https://www.youtube.com/watch?v=PaXMzhKCTiY

Understanding Component Features

Part Features that are Critical To the Products Functional Quality

- **Avoid unnecessary surface finish requirement;**
- **Avoid unnecessary features**

Key DFMA Principles

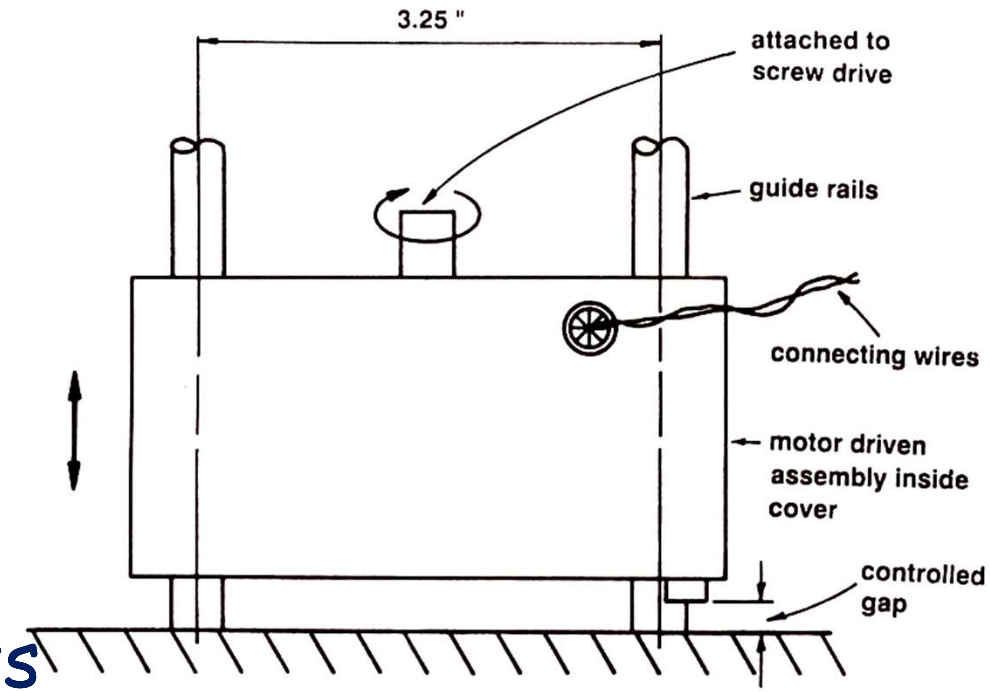
- Minimize Part Count
- Standardize Parts and Materials
- Create Modular Assemblies
- Design for Efficient Joining
- Minimize Reorientation of parts during Assembly and/or Machining
- Simplify and Reduce the number of Manufacturing Operations
- Specify ‘Acceptable’ surface Finishes for functionality

Exercise Session (motor-drive assembly)

Design of a motor-drive assembly that moves vertically on two steel guiderails

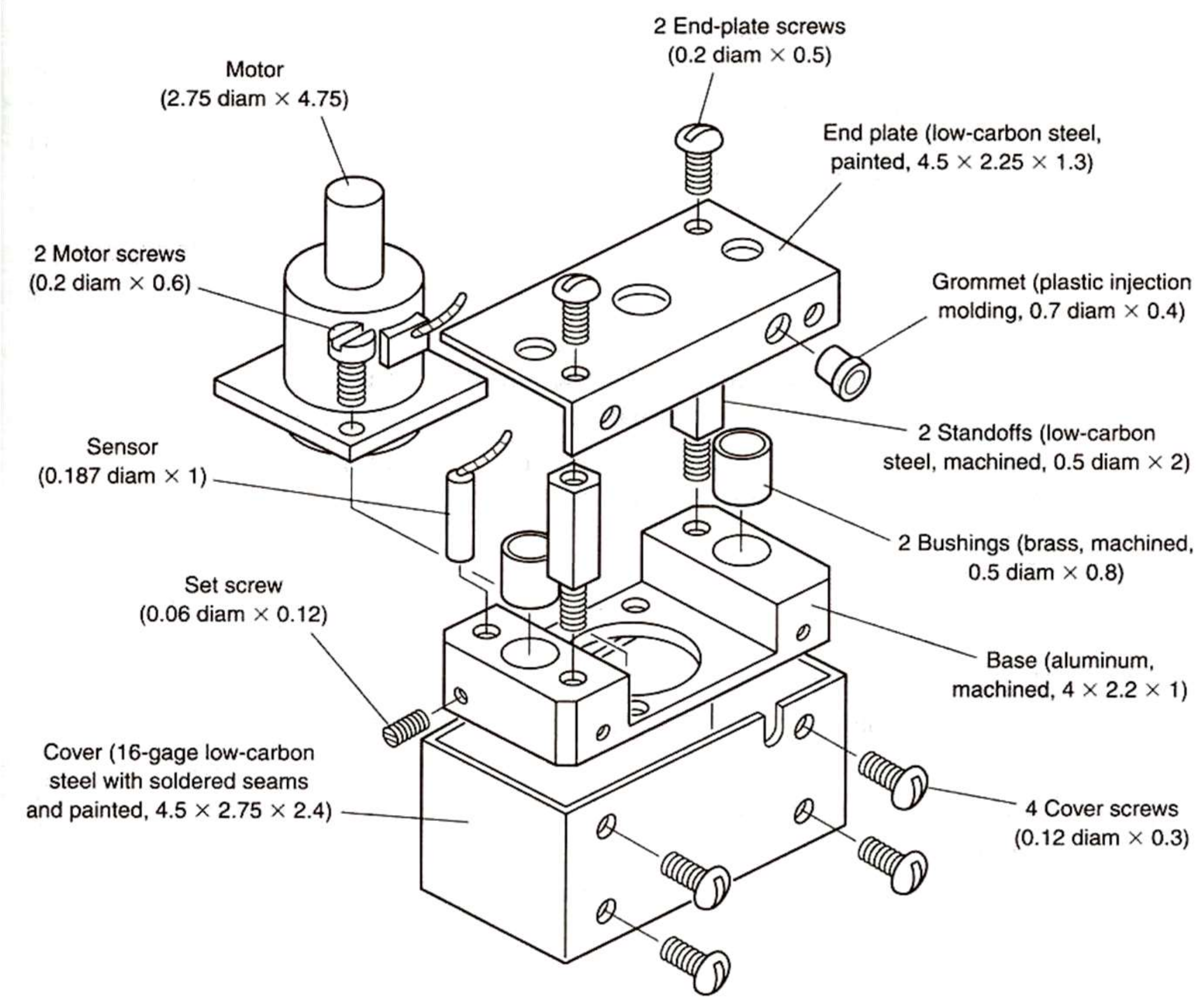
Requirements:

- the motor must be fully enclosed & have a removable cover for access to the sensor;
- a rigid base which supports the motor & sensor, move up & down on the rails.



From Ref [1]

Exercise Session (motor-drive assembly)



Initial design of the motor-drive assembly

Answer the following questions:

- How many parts are there in the initial design?
- Which are the essential parts to be kept?
- Which are the non-essential parts to be eliminated?
- What are the areas for redesign?

From Refs [1, 3]

Design, Manufacture and Project
Design for Assembly Exercise

Results of DFA analysis for the motor-drive assembly (initial design)

Part	No.	Theoretical part count	Assembly time, s	Assembly cost, ¢ *
Base	1	1	3.5	2.9
Bushing	2	0	12.3	10.2
Motor subassembly	1	1	9.5	7.9
Motor screw	2	0	21.0	17.5
Sensor subassembly	1	1	8.5	7.1
Setscrew	1	0	10.6	8.8
Standoff	2	0	16.0	13.3
End plate	1	1	8.4	7.0
End-plate screw	2	0	16.6	13.8
Plastic bushing	1	0	3.5	2.9
Thread leads	. . .	. . .	5.0	4.2
Reorient	. . .	. . .	4.5	3.8
Cover	1	0	9.4	7.9
Cover screw	4	0	31.2	26.0
Totals	19	4	160.0	133.0

Design efficiency for assembly = (4 × 3)/160 = 7.5%

* The labour rate is $30/hour.

From Refs [1, 3]

$$\text{Design Efficiency} = \frac{3 \times \text{min number of parts}}{\text{total assembly time}}$$

Design efficiency for assembly =(4x3)/160=7.5%

Design, Manufacture and Project
Design for Assembly Exercise

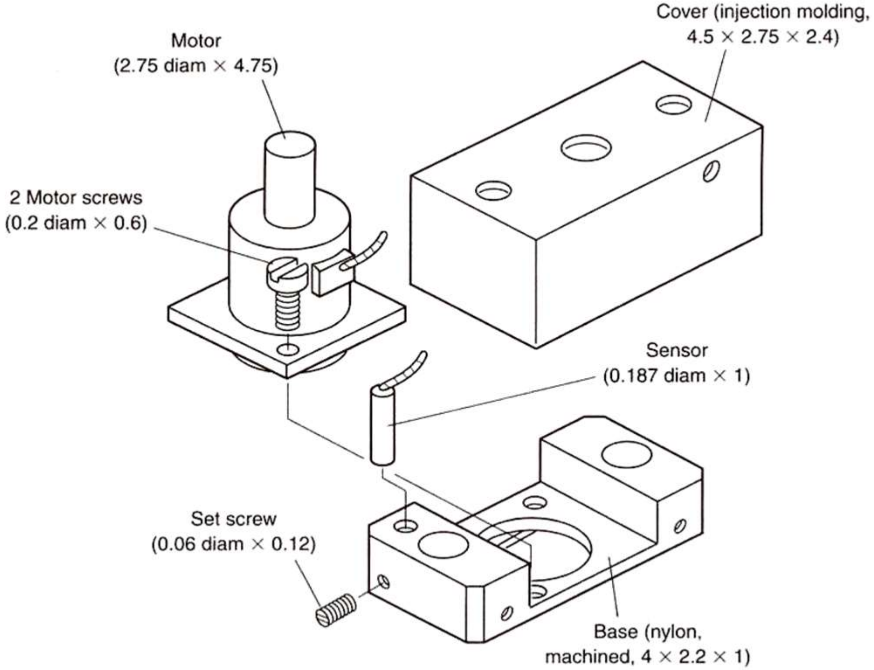


TABLE 9.6
Results of DFA analysis for motor-drive assembly after redesign

Part	No.	Theoretical part count	Assembly time, s	Assembly cost, ¢
Base	1	1	3.5	2.9
Motor subassembly	1	1	4.5	3.8
Motor screw	2	0	12.0	10.0
Sensor subassembly	1	1	8.5	7.1
Setscrew	1	0	8.5	7.1
Thread leads	. . .	. . .	5.0	4.2
Plastic cover	1	1	4.0	3.3
Totals	7	4	46.0	38.4

Design efficiency for assembly =(4x3)/46=26%

Redesign of the motor assembly based on DFA analysis

From Refs [1, 3]

Further reading

1. "Product design for manufacture and assembly," Geoffrey Boothroyd, Peter Dewhurst, and Winston Knight. Marcel Dekker Inc. 1994. ISBN 0-8247-9176-2

2. "BI 7000-2 2008: Guide to managing the design of manufactured products," BSI, ISBN 978 0 580 58521 0

3. "Engineering Design," George E. Dieter, McGraw Hill. 2000. ISBN 0-07-116204-6

4. "The Mechanical Design Process," David G. Ullman, McGraw Hill. 1992. ISBN 0-07-112871-9

5. "Engineering Design: A systematic approach," G. Pahl, W Beitz, J Feldhusen, K.H. Grote, Springer, 2007. ISBN 085072239X

Design for Manufacture and Assembly (DFMA)

End of Session