A 2002 Yo-Yo vs. a free gift

Guidelines to Assembly Design
- Minimize parts
- Design assembly process in a layered fashion
- Consider ease of part handling
- Utilize optimum attachment methods
- Consider ease of alignment and insertion
- Avoid design features that require adjustments

Cost of Design Changes

Manufacturing
### Typical Cost Breakdown

<table>
<thead>
<tr>
<th>Component</th>
<th>% of Selling Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selling Price</td>
<td></td>
</tr>
<tr>
<td>Admin, sales</td>
<td>24%</td>
</tr>
<tr>
<td>Profit</td>
<td>19%</td>
</tr>
<tr>
<td>R&amp;D</td>
<td>5%</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>38%</td>
</tr>
<tr>
<td>Engineering</td>
<td>14%</td>
</tr>
<tr>
<td>Indirect labor</td>
<td>28%</td>
</tr>
<tr>
<td>Direct labor</td>
<td>15%</td>
</tr>
<tr>
<td>Manufacturing Costs</td>
<td></td>
</tr>
<tr>
<td>Direct labor</td>
<td>12%</td>
</tr>
<tr>
<td>Indirect labor</td>
<td>26%</td>
</tr>
<tr>
<td>Plant, machinery</td>
<td>12%</td>
</tr>
<tr>
<td>Parts, material</td>
<td>56%</td>
</tr>
</tbody>
</table>

### Assembly business

<table>
<thead>
<tr>
<th>Industry</th>
<th>% Workers in Assembly</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automobile</td>
<td>45.6%</td>
</tr>
<tr>
<td>Aircraft</td>
<td>25.6%</td>
</tr>
<tr>
<td>Telephone &amp; Telegraph</td>
<td>58.9%</td>
</tr>
<tr>
<td>Farm Machinery</td>
<td>20.1%</td>
</tr>
<tr>
<td>Home appliances</td>
<td>32.1%</td>
</tr>
<tr>
<td>Two-wheel vehicles</td>
<td>26.3%</td>
</tr>
</tbody>
</table>

### Optical Connectors

- MT connector

### Initial Quality Study

**IQS:**

Problems experienced after 90 days of ownership per 100 vehicles

- 0 to 100
- 100 to 200
- 200 and over

### The automobile industry, 1980's

- **Design Changes per Week**
- **SOP**

### Good Design

**DFMA (Design for Mfg. & Assembly)**

- Simplicity for both human operators and robots
- Even Kids can do.
DFA guide

- Simplicity is the best DFA. Minimize part numbers, operations, simplify assembly sequence (steps) and set-ups
- Standardize components, use suppliable common parts
- Minimize assembly directions (layered structure)

DFA Guide (cont.)

- Modular design, product families, assembly friendliness
- Use symmetrical parts
- Physical integration
- Minimize sharp, delicate, flexible, slippery part
- Relax tolerances on non-critical locations.
- Approachable, line of sight

DFA Guide (cont.)

- Material for DFA, avoid flexible components
- Concurrent engineering
- Design for disassembly (recycling, repair, retrofit)

DFMA

- Hitachi assemblability evaluation method
- Lucas DFA
- Boothroyd-Dewhurst DFA (BD)

Design for Assembly

Pneumatic Piston Sub-Assembly

- screw
- spring
- cover
- piston stop
- main block

Redesigned
DFA: Examples

- Parts are difficult to assemble
- Changing part geometry allows it to be aligned properly before it is released

DFA for Automation: Examples

- Parts are also difficult to assemble
- Changing part geometry allows it to be aligned properly before it is released

Assembly automation

**Challenges**

- Parts Feeding
- Sorting
- Orienting
- Pick-and-place
- Assembly

Non-vibratory Feeding

Non-vibratory parts feeding includes:

- Groove
- Rotary mechanism with multiple blades
- Hopper
- Rotation axis
- Inclined discharge rail

Vibratory Parts Feeding

**Vibratory Feeding - orientation**

- Second attachment (rejects a and b)
- First attachment (rejects c and d)
- Third attachment (rejects e and f)
- Side view
- Top view
- Discharge hole
Magnetic Parts Feeding

Parts picked up by magnets
Delivery chute
Stationary hopper

DFA for Transporting

Non-functional peg prevents jamming.
Wider edge surface prevents overlap.

Flat end prevents jamming.

Automated Assembly

Transfer
- Transfer lines
- Conveyor
- Automated Guided Vehicle
Positioner
Assembly Operations

Transfer Lines

Work carriers
Fixed rail
Step
Transfer rail
Slide

Rotary Assembly Transfer

Completed pieces
Inspection station
Adhesive-bond applicator

AGV

Pallet load / unload mechanism
Workplace
Pallet
Safeguards against collision
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Pick & Place Positioner

Fixed-length arm
Linear actuator
Rotary actuator
Gripper
Rotary actuator
Fixed base

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Robot

Arm
Hydraulic/electric power unit
Robot controller
Wrist
Elbow extension
Pitch
Yaw
Wrist

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Robots: Components

- Manipulator
- positioning
- power
- stiffness
- control
- End effector
- tooling

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Robots: Applications

- 3 D’s (Dull, Dirty, Dangerous)
- 3 H’s (Hot, Heavy, Hazardous)
  - Materials handling
  - Spray painting
  - Spot welding
  - Arc welding
  - Assembly

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Good Design Principles: DFM Assembly

- Design parts to be self-locating and self-aligning
- Error-proof parts to make incorrect assembly impossible
- Minimize the number of parts.
- Minimize the number and variety tools for assembly
- Minimize the number of axes of insertion
- Ensure clear vision and access for all assembly operations
- Minimize the number and complexity of adjustments
- Eliminate the need to hold down, clamp or fixture parts
- Eliminate special assembly tools

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What assembly process to choose?

- Reasons to avoid assembly
- Reasons that justify assembly
Workholding

- Immobile a workpiece for machining or assembly
- Jigs: locating and holding workpiece, guiding tools
- Fixtures: locating and holding
- Provide maximum accuracy and ease of mounting
- Datum

3-2-1 rule of locating

- 6 dof, \((D_x, D_y, D_z)\) and \((R_x, R_y, R_z)\)
- 3 support Points (1, 2 and 3) eliminate \((R_y)\) and \((-D_z)\); 2 points (4 and 5) eliminate \((R_y)\) and \((-D_z)\); and, 1 point (6) eliminates \((-D_y)\).
- Push or clamp 3 directions, x,y,z.