2.008 Design & Manufacturing II

Spring 2004

Assembly & Joining

Dexter's Plastic Can

-cool ?

-gas leakage ?

-recycling?

# A 2002 Yo-Yo vs. a free gift

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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

Manufacturing

Market Research → Conceptual Design → **Design for Manufacture**

Contributions on the final cost?

Factory, Systems & Enterprise

Assembly and Joining
- Welding
- Bolting
- Bonding
- Soldering

Unit Manufacturing Processes
- Machining
- Injection molding
- Casting
- Stamping
- Chemical vapor deposition
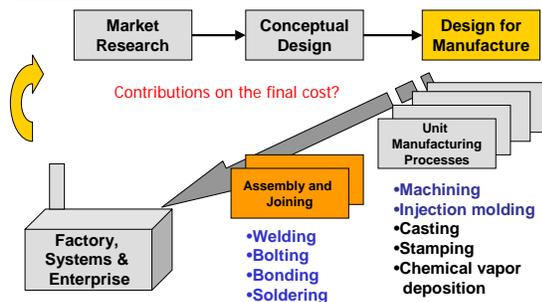
Cost of Design Changes

$$$$ time

CONCEPT X

DESIGN 10X

TOOLING 100X

Assembly 1000X

RELEASE 10,000X

WHO CASTS THE BIGGEST SHADOW?

Typical Cost Breakdown

Selling Price

- Engineering 14%
- R&D 5%
- Admin, sales 24%
- Manufacturing 38%
- Profit 19%

Manufacturing Costs

- Plant Machinery 12%
- Parts, Material 50%
- Indirect labor 26%
- Direct labor 12%
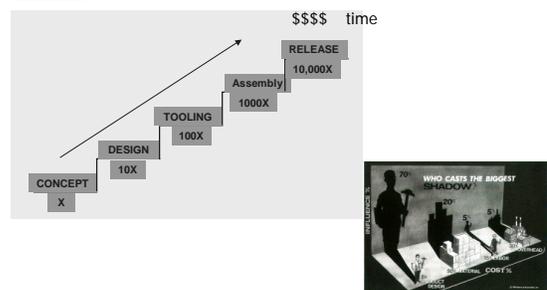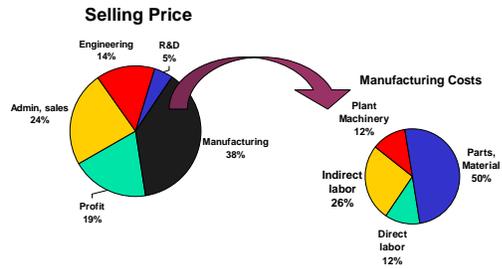
Assembly business

Industry	% Workers in Assembly
Automobile	45.6%
Aircraft	25.6%
Telephone & Telegraph	58.9%
Farm Machinery	20.1%
Home appliances	32.1%
Two-wheel vehicles	26.3%

M. Culpepper

Optical Connectors

MT ferrule, fiber ribbon, Alignment pin, clamp

Fig. 2 Mini-MT connector

MT connector

- Lateral offset
- Axial offset
- Tilt
- Mode mismatch
- Scattering/reflections

Alignment errors

Initial Quality Study

2002 J.D.POWER AND ASSOCIATES
INITIAL QUALITY STUDY
We Shouldn't Call Them Luxury Vehicles. A Luxury Is Something You Can Live Without.
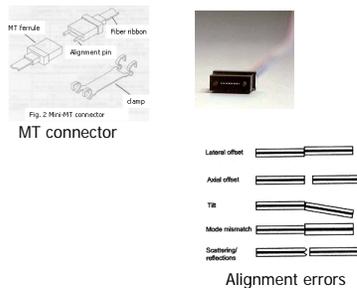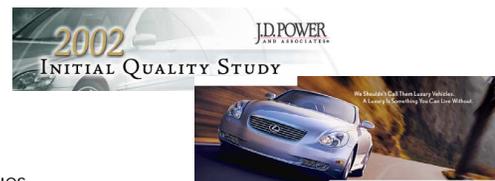
IQS:

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

- Problem "find and fix" (US company)
- Problem prevention (Japanese company)
- Product Launch
- SOP

Months Relative to Product Launch (-20, -10, 0, +10)
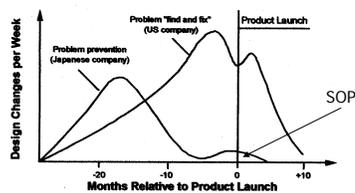
Sullivan, 1986

Good Design
DFMA (Design for Mfg. & Assembly)

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

http://order.tupperware.com:8080/coe-images/items/10044822000_detail.jpg

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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)
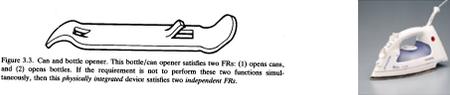
Figure 3.3. Can and bottle opener. This bottle/can opener satisfies two FRs: (1) opens cans, and (2) opens bottles. If the requirement is not to perform these two functions simultaneously, then this *physically integrated device satisfies two independent FRs.*

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

Symmetry

α	0	180	180	90	360	360
β	0	0	90	180	0	360

Size Fragile/Sharp

Slippery/Flexible
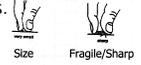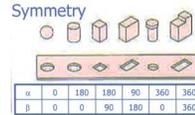
DFA Guide (cont.)

- 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

1)

2)

48 mm

Annual production volumes :
robotic - 200,000
automatic - 2,400,000

Assembly cost ($)

1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

24   8   4   2

Number of parts
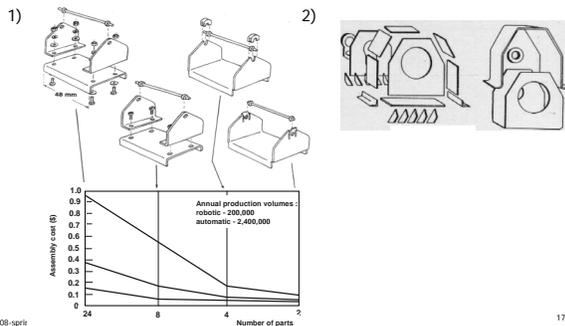
Pneumatic Piston Sub-Assembly

screw

spring

piston

cover

piston stop

main block

1 – snap on cover and stop (plastic)

2 – spring(steel)

3 – piston (aluminum)

4 – main block (plastic)

Redesigned

3

DFA: Examples

Alignment

self-locating

Part can jam when inserted into hole.

Tapering the hole facilitates part insertion.
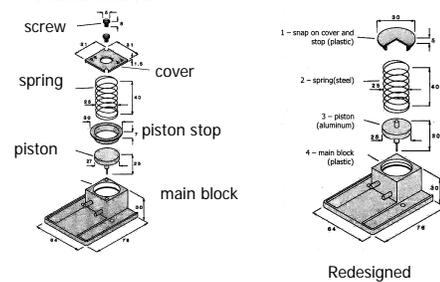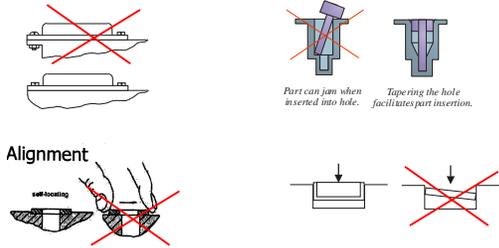
DFA for Automation: Examples

Parts are difficult to assemble.

Chamfers assist assembly.

Parts are difficult to align properly; jamming can occur.

Changing part geometry allows it to be aligned properly before it is released.
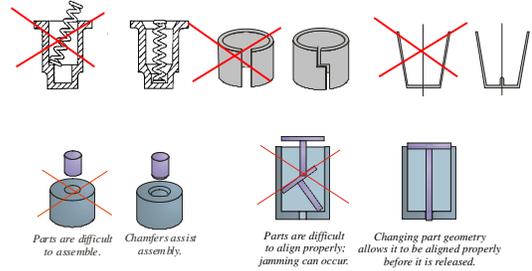
Assembly automation

Challenges
- Parts Feeding
  Sorting
  Orienting   PCB assembly?
- Pick-and-place
- Assembly

Non-vibratory Feeding

Rotary mechanism with multiple blades

Groove

Hopper

Rotation axis

Inclined discharge rail
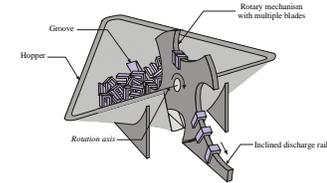
Vibratory Parts Feeding

Track

Outlet

Bowl

Electromagnet

Leaf springs

Base

Translational vibration

Torsional vibration
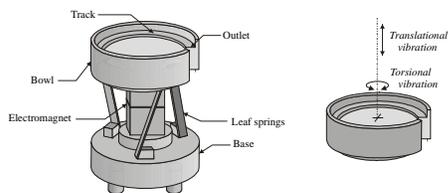
Vibratory Feeding -orientation

Second attachment (rejects *c* and *d*)

First attachment (rejects *a* and *b*)

Third attachment (orients *e* and *f*)

Discharge hole

Side view

a   b   c   d   e   f

Top view
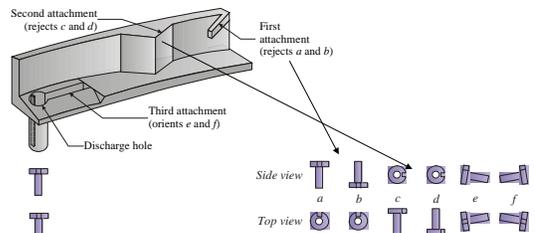
4

Magnetic Parts Feeding

Parts picked up by magnets
Delivery chute
Stationary hopper
Magnets
Parts

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DFA for Transporting

Non-functional peg prevents jamming.

Flat ends prevent jamming.

Wider edge surface prevents overlap.
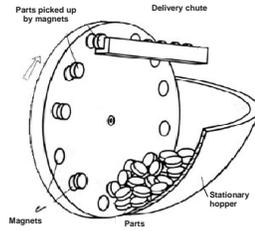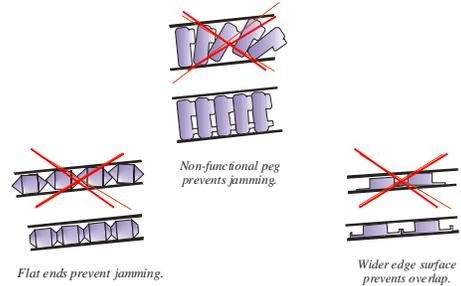
B. Benhabib
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Automated Assembly

Transfer
- Transfer lines
- Conveyor
- Automated Guided Vehicle

Positioner

Assembly Operations

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Transfer Lines

Work carriers
Fixed rail
Stop
Step
Piston
Transfer rail
Slide
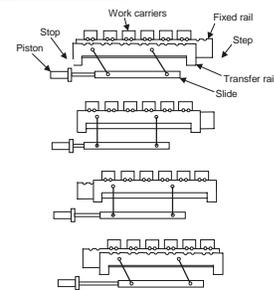
J. Chun
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Rotary Assembly Transfer

Positioning unit
Riveter
Feedtrack
Vibratory bowl
Completed pieces
Inspection station
Adhesive-bond applicator

B. Benhabib
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AGV

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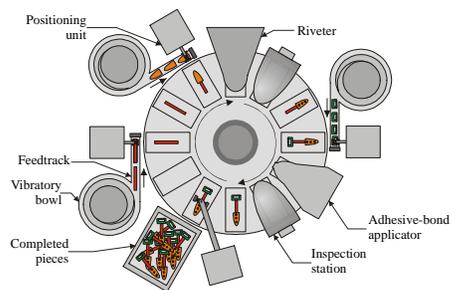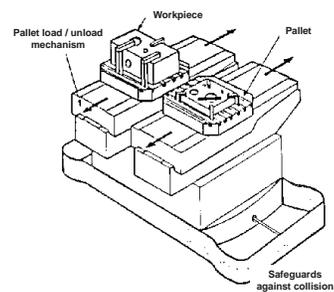
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Pick & Place Positioner

Fixed-length arm

Linear actuator

Rotary actuator

Gripper

Rotary actuator

Fixed base

Robot

Arm

Elbow extension

Hydraulic/electric power unit

Shoulder swivel

Body-in-White solutions

Yaw

Wrist

Robot controller

Arm sweep

Pitch

Roll
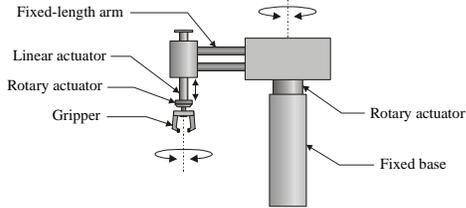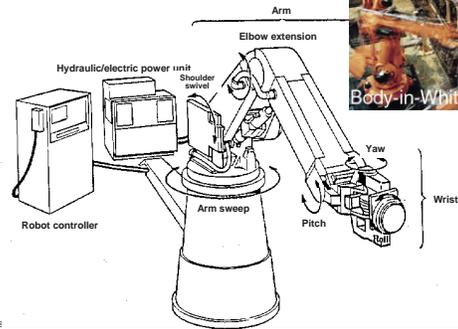
Robots: Components

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

Robots: Applications

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

J. Chun

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

Alignment

self-locating
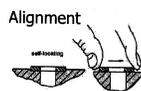
What assembly process to choose?

- Reasons to avoid assembly
- Reasons that justify assembly

Workholding

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