Influence of pick & place machines on product quality

The impact of placement quality on SMT manufacturing costs

Assembléon

Introduction

ABOUT ASSEMBLEON

Assembléon Headquarters in Veldhoven (Netherlands)

A-series

AX- Hybrid

iFlex

Assembléon's focus is to provide competitive solutions
for the electronics manufacturing industry
based upon our core strength in **Pick and Place machines**

SMT process quality influencing factors

SMT PROCESS Q CRITERIA

Typical SMT process flow

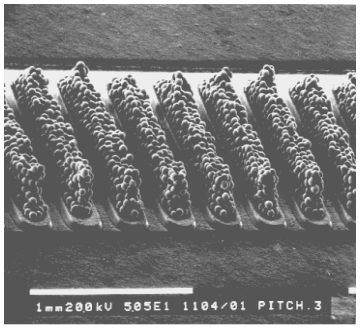
Solder paste printing → Component placement → Reflow soldering →

SMT process requirements

Solder paste printing → Component placement → Reflow soldering →

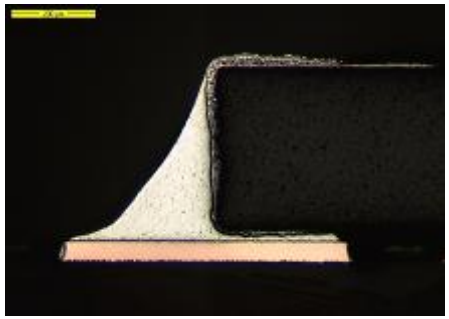
Process requirements

- Right amount
- Right place



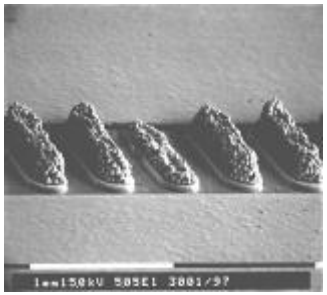
- Right component
- Right place

- Right temperature profile
- Good reflow

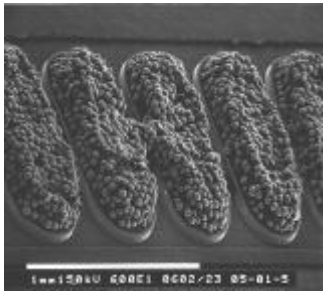


Assessment criteria for stencil printing process

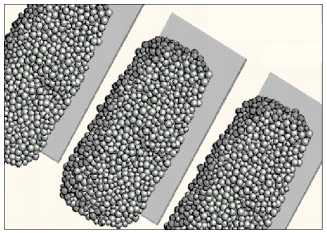
1. Solder paste pattern resolution (paste transfer)



2. Bridging (‘smearing’)

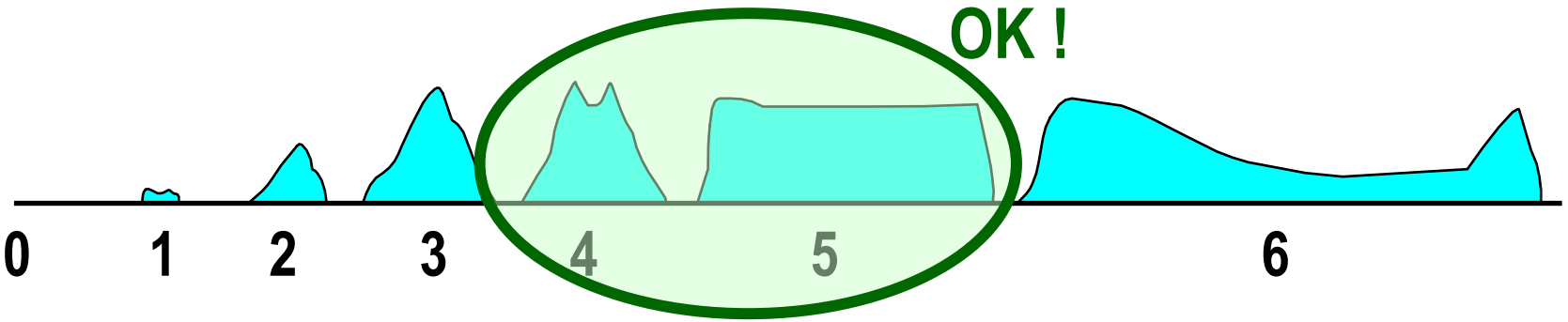


3. Misalignment



Stencil printing

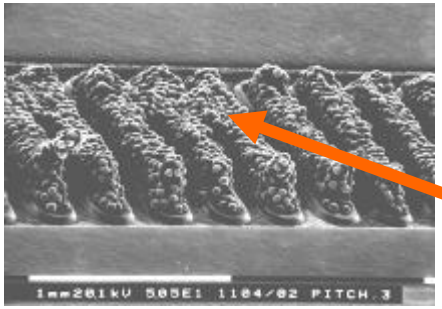
Solder paste pattern resolution



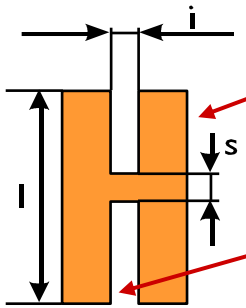
	0	no paste
	1	irregular shape (few balls)
	2	pyramid lower than stencil thickness
	3	pyramid equal to stencil thickness
✓	**4**	**beginning flat top with "dog ears"**
✓	**5**	**flat top side**
	6	scooped-out

Stencil printing

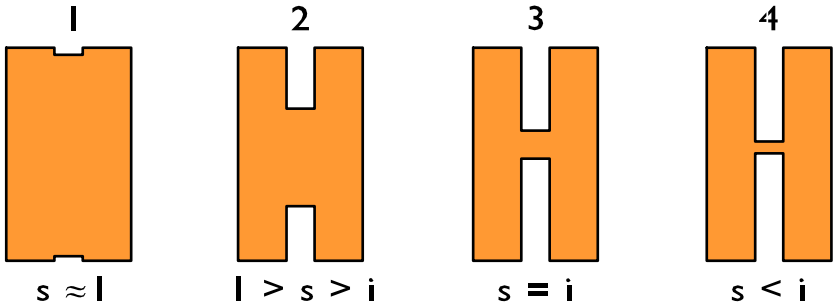
Solder paste smearing



Smearing

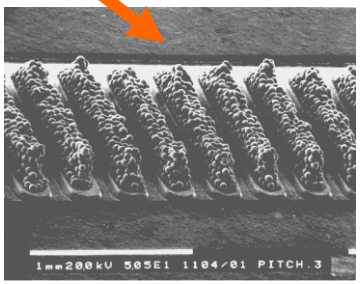


Criterion:
Neighboring pads
May not have contact



OK !

Flux with incidental balls



Perfect

Stencil printing

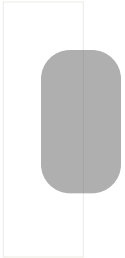
Solder paste pattern misalignment

100% of paste centered on pad

Perfect

< 25% of paste off-pad

Acceptable



> 25% of paste off-pad

Not acceptable

100% of paste on pad

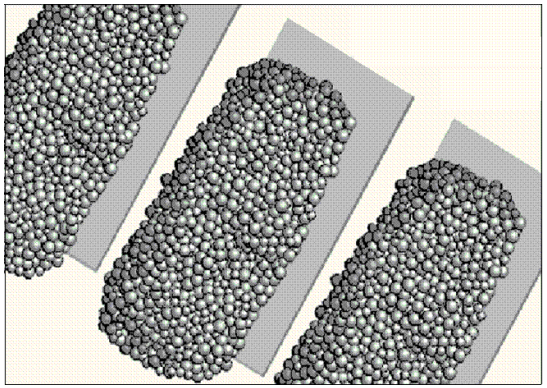
Acceptable

< 25% of paste off-pad

Acceptable

> 25% of paste off-pad

Not acceptable



Remedy:
Board to stencil alignment correction

Stencil printing

Placement defect analysis

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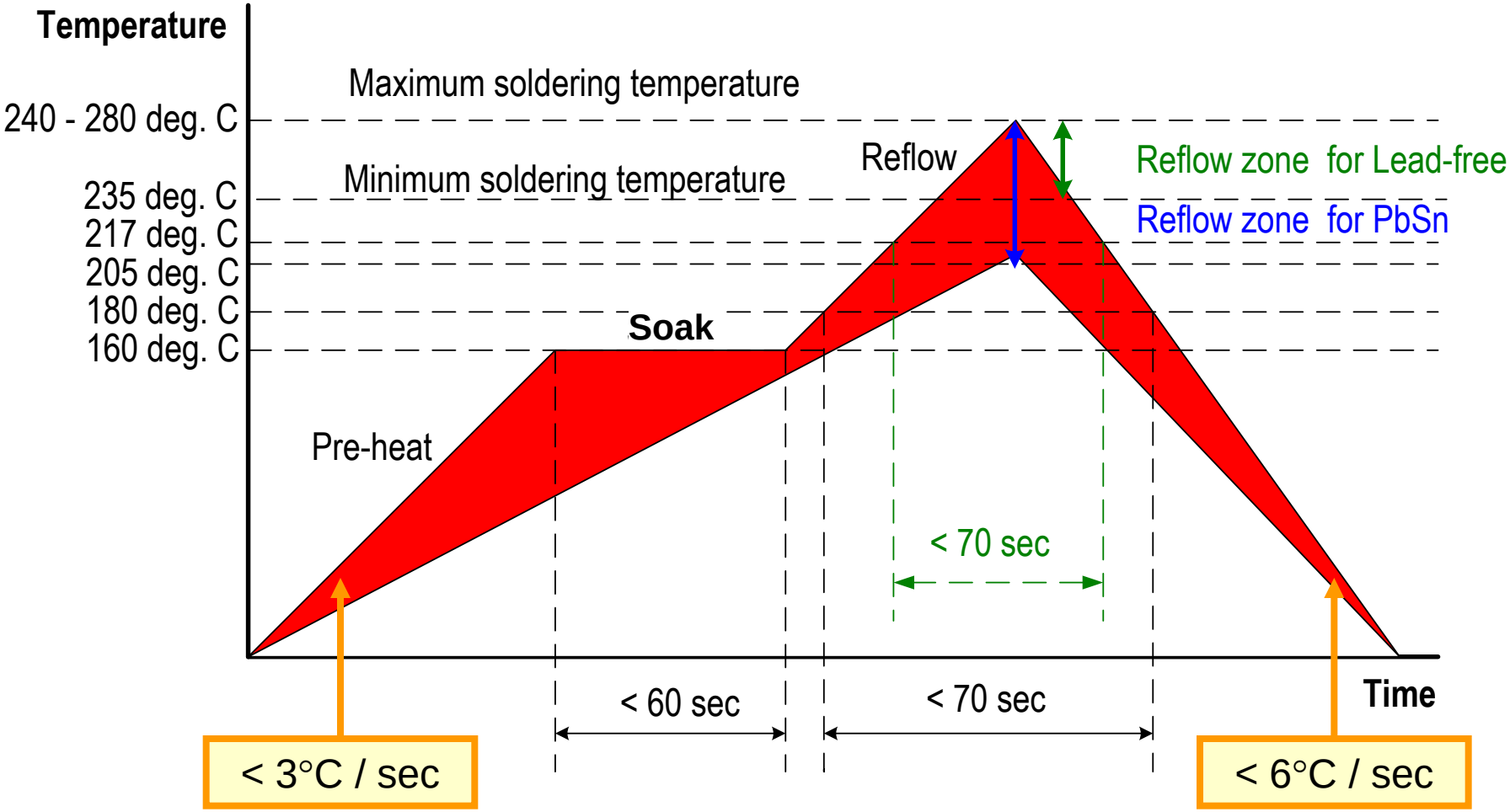
Part misaligned	• Mis read fiducials • Machine needs calibration • Placement error • Alignment error • Part slid off pads	• Misalignment • Solder bridging • Tombstoning
Incorrect part	• Incorrect part reel loading • Tape splice error	•Incorrect part
Part damaged	• Part damaged at supplier • Placement force too high	• Opens • Component cracking • Tilted part
Wrong polarity	• Programming error • Tray rotated	• Wrong polarity
Extra / missing part	• Part lost during pick & place	• Extra / missing part
Symptom (before reflow)	Cause	Defect (end of process)

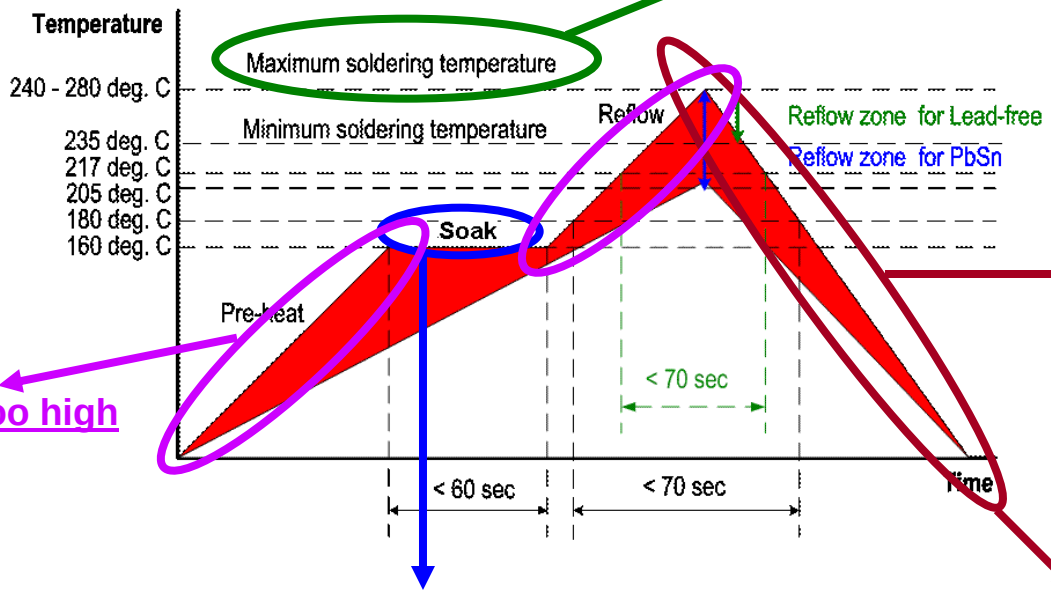
Pick & place

Reflow solder process requirements



Reflow soldering

Reflow process defect analysis



Peak temperature too high:
- Charring
- Delamination
- Intermetallics
- Leaching
- Dewetting
- Voiding

Cooling rate too fast
- Solder detachment
- Pad Detachment

Ramp-up rate too high
- Hot Slump
- Bridging
- Tombstoning
- Skewing
- Wicking
- Opens
- Solder beading
- Solder balling
- Components cracking.

Soaking Zone too long
- Voiding
- Poor Wetting
- Solder Balling
- Opens

Cooling rate too slow
- Intermetalllics
- Charring
- Leaching
- Dewetting
- Grain Size too large

Reflow soldering

Acceptable part to pad misalignment (IPC-A-610D)

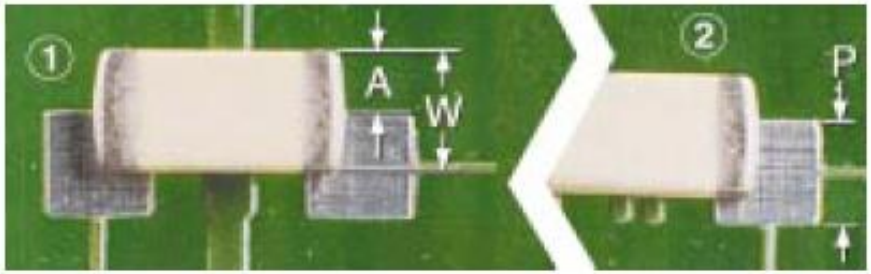


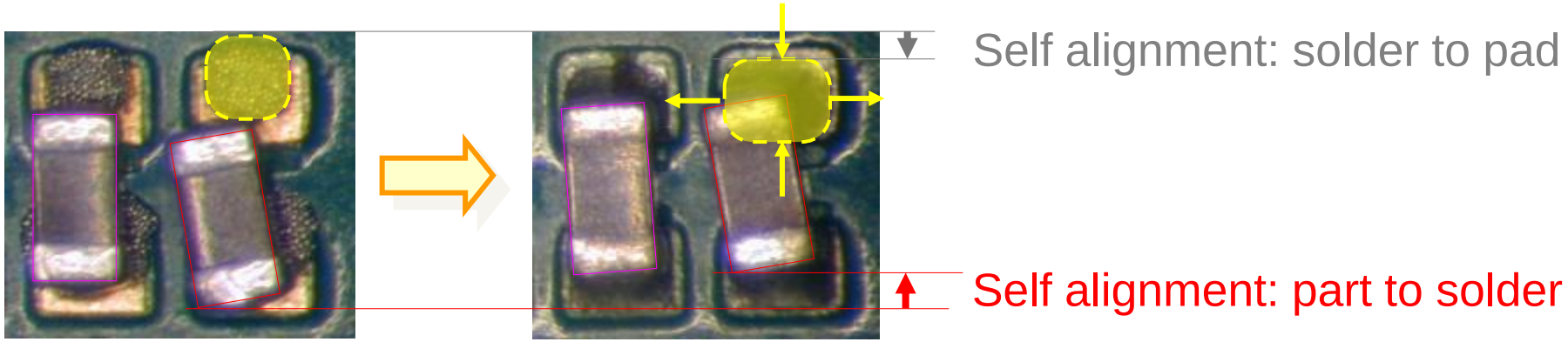
Figure 8-12
1. Class 2
2. Class 3

Acceptable - Class 1,2

- Side overhang (A) is less than or equal to 50% width of component termination area (W) or 50% width of land (P), whichever is less.

Acceptable - Class 3

- Side overhang (A) is less than or equal to 25% width of component termination area (W) or 25% width of land (P), whichever is less.



Before reflow

After reflow

Reflow soldering

Relationship placement machine concept and placement quality control

PICK & PLACE RELATED ERRORS

Possible defects in SMT: defect opportunities

1. Component opportunities (O_C)
   - All parts that need to be assembled on board (incl. PCB)
   - Every **part** counts for **one** defect opportunity
   - Defect example: damaged parts
2. Placement opportunity (O_P)
   - All parts that need to be placed on board, based on bill of materials (excl. PCB)
   - Every **part** counts for **one** defect opportunity
   - Defect examples: misaligned parts, missing parts
3. Termination opportunity (O_T)
   - Any hole, pad or land or other surface to which a component is electrically terminated
   - Every **termination** counts for **one** defect opportunity

     (example: QFP48 → 48 leads → 48 termination opportunities)
4. Assembly opportunity (O_A)
   - An **overall** defect opportunity that is not captured within component, placement or termination opportunity defect classes
   - Defect examples: conformal coating, cleaning

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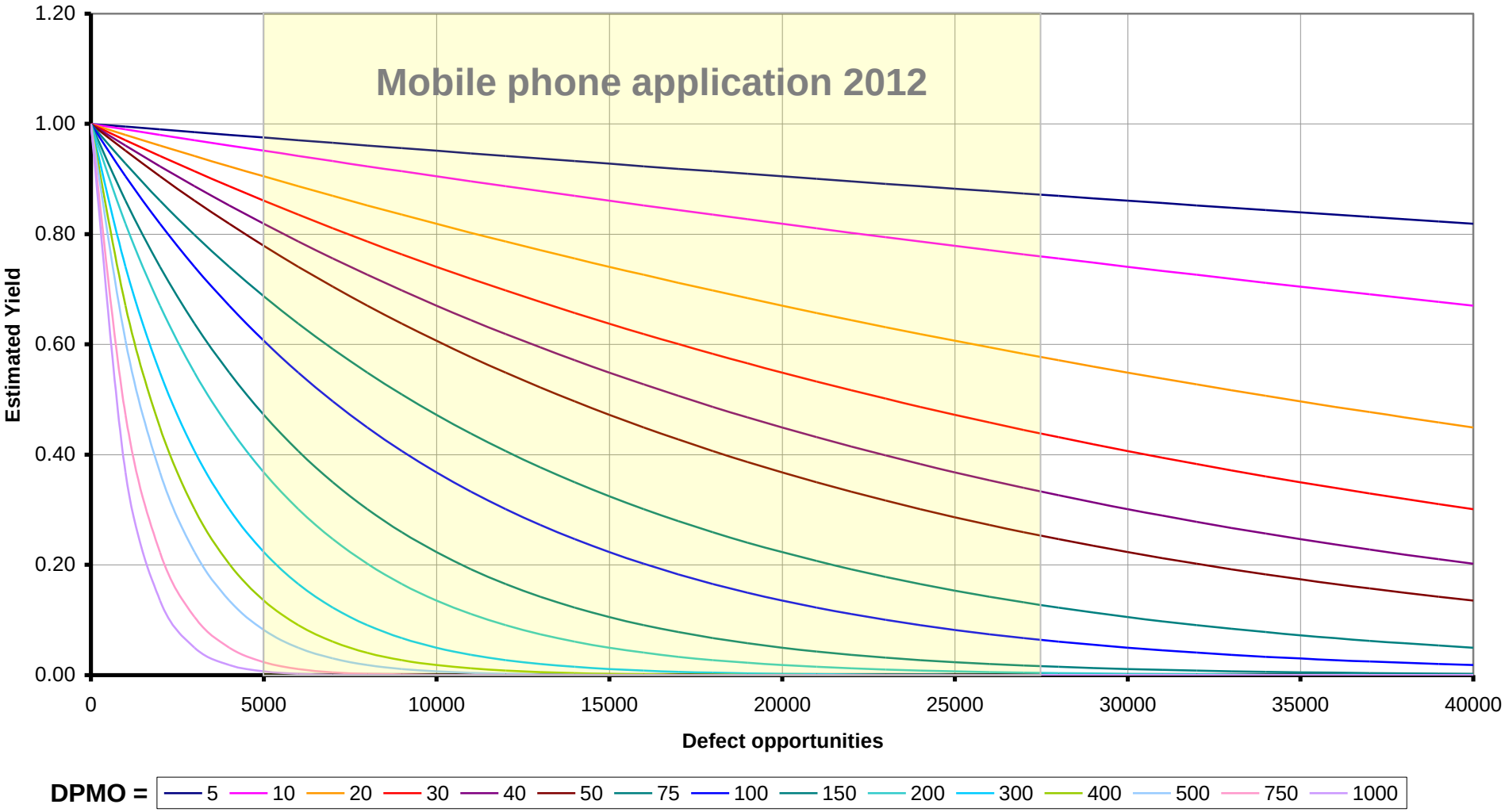
IPC-9261A Defect classification overview

1	Base material damage	1	Part lead stressed	2	Wire connected wrong
1	Bent lead	1	Plating or other finish problem	2	Wire routing wrong
1	Birdcaged wire	1	Sleeving problem	3	Blow holes
1	Blisters, mealing, peeling	1	Solderability problem	3	Cold solder joint
1	Board warped or bowed	1	Spliced where not permitted	3	Disturbed solder joint
1	Cable made wrong	1	Unprepped part	3	Fractured solder joint
1	Circuitry damaged	1	Wire damage	3	Icicles
1	Connector damaged	1	Wire not tinned where required	3	Insufficient solder
1	Gold not removed	2	Cable connected wrong	3	Lead protrusion wrong
1	Improper stress relief	2	Parts / loose / missing / wrong	3	Part coating meniscus in joint
1	Incorrect terminal flange	2	Crimping wrong	3	Solder bridge
1	Insulation or wire damage	2	Improper mounting	3	Solder wetting unacceptable
1	Lead bend problem	2	Lead / cable routing wrong	3	Unsoldered connection
1	Lead coplanarity out of spec	2	Min. electrical clearance violated	4	Assembly not clean
1	Lead forming wrong	2	Part height wrong	4	Conformal coating absent
1	Lead / cable length wrong	2	Part misaligned	4	Conformal coating peeling
1	Leads bent under	2	Part extra	4	Conform. coat. present unwanted
1	Leads not tinned	2	Part mounted wrong	4	Solder balls / splash
1	Marking incorrect	2	Tilted part		
1	Part damaged	2	Tombstone		

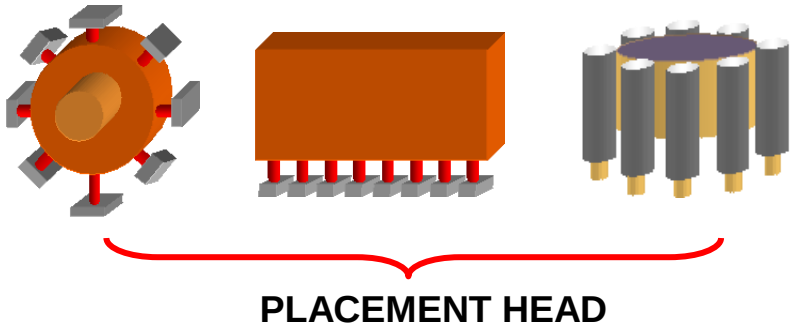
1) Component defects 2) Placement defects 3) Termination defects 4) Assembly defects

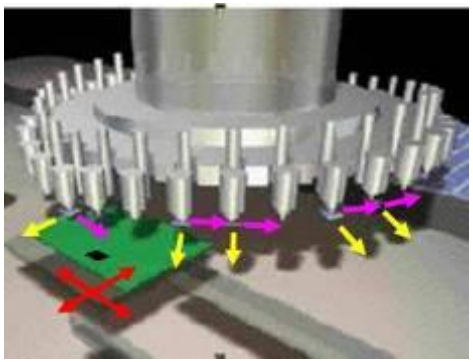
Yield vs. number of defect opportunities

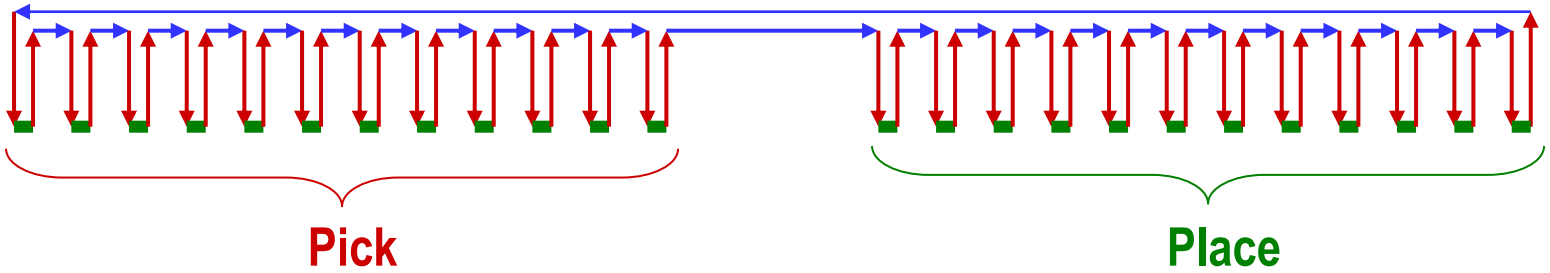


Lower DPMO will increase Yield and thus reduce repair costs

Most pick & place machines are sequential

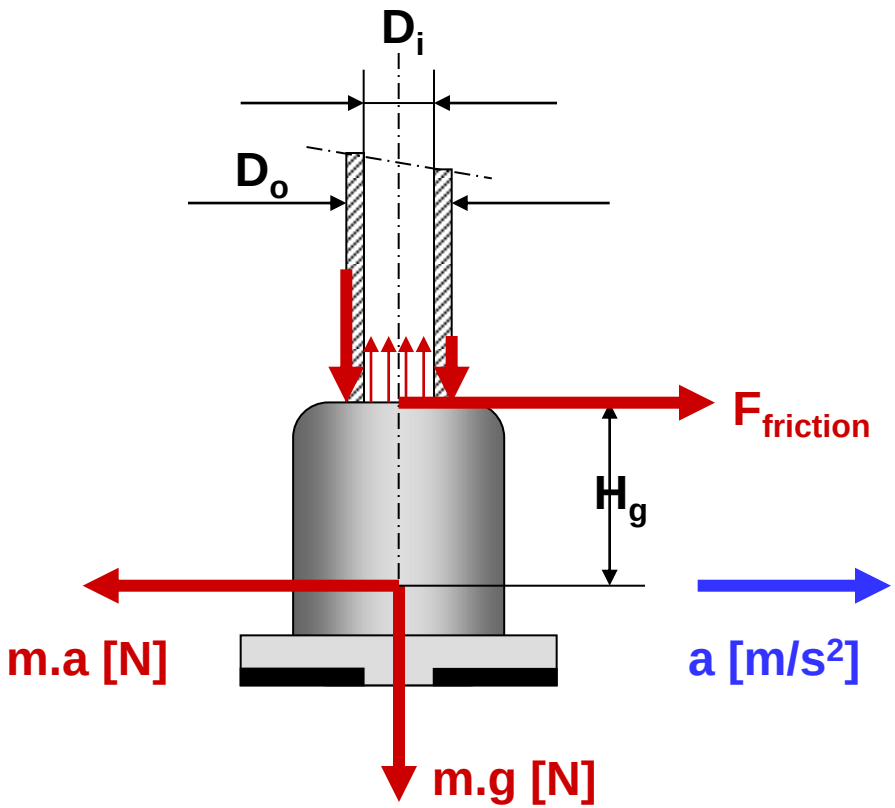






- High accelerations / decelerations
  - High forces acting on components → risk of component shift or loss
- No component position monitoring between component alignment and placement position
- In most cases: no placement force control / no presence check

Acceleration forces acting on pipettes



Risk of components shift:

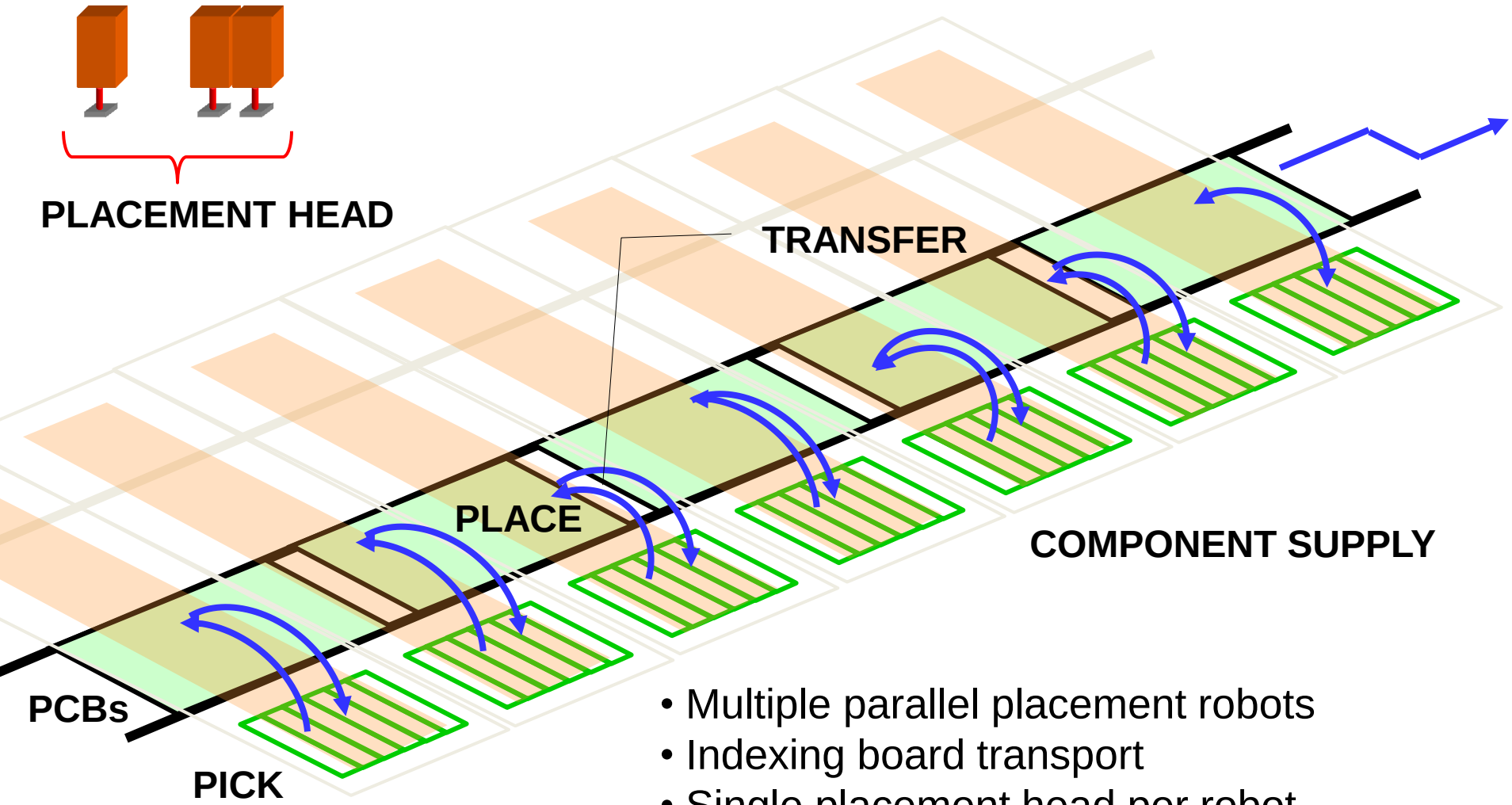
- Acceleration force (= m.a) > friction force

Risk of components break loose:

- $m.a.H_g > F_{vacuum}.(D_o/2)$

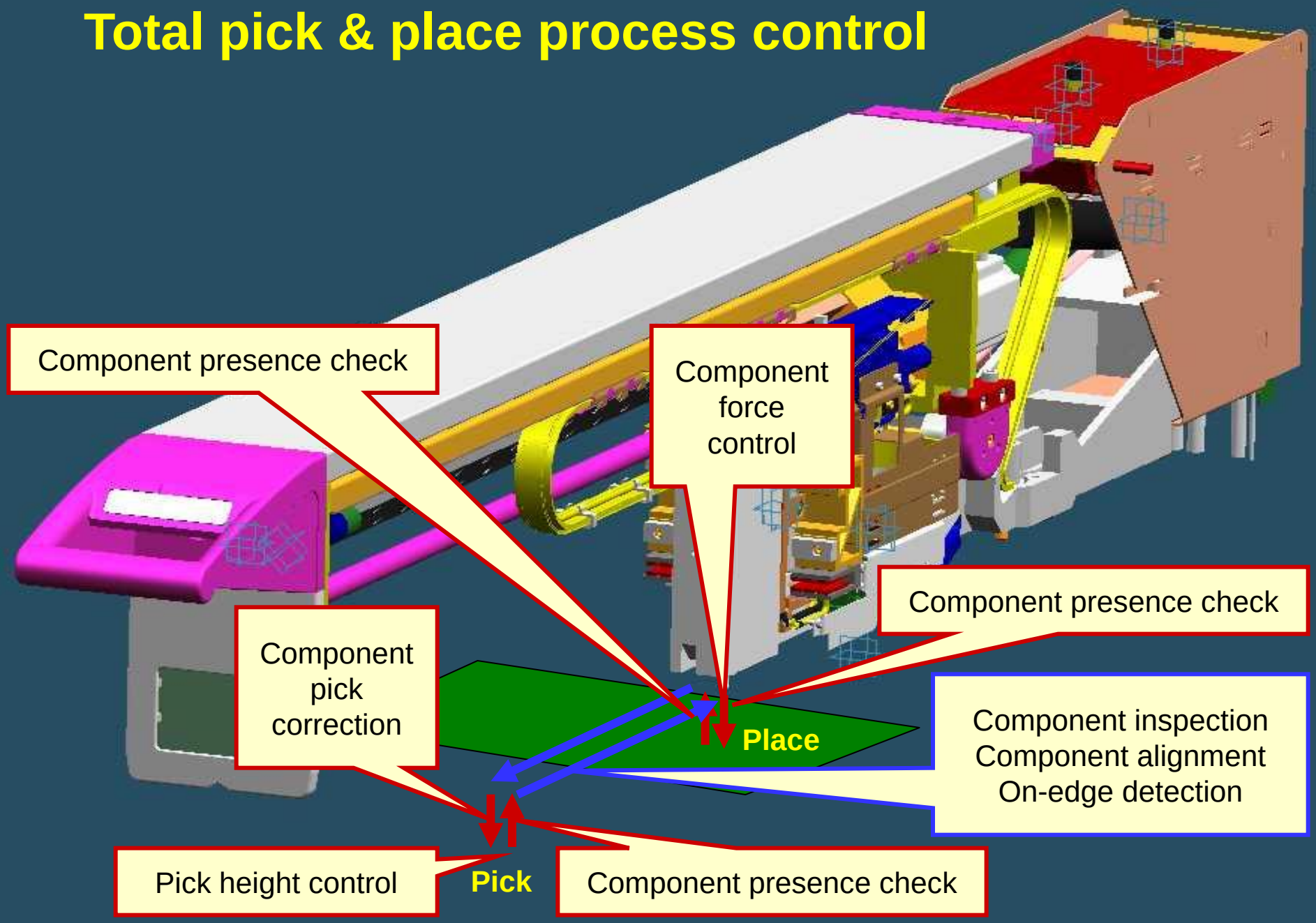
Revolver & turret heads add extra acceleration forces

Parallel pick & place principle

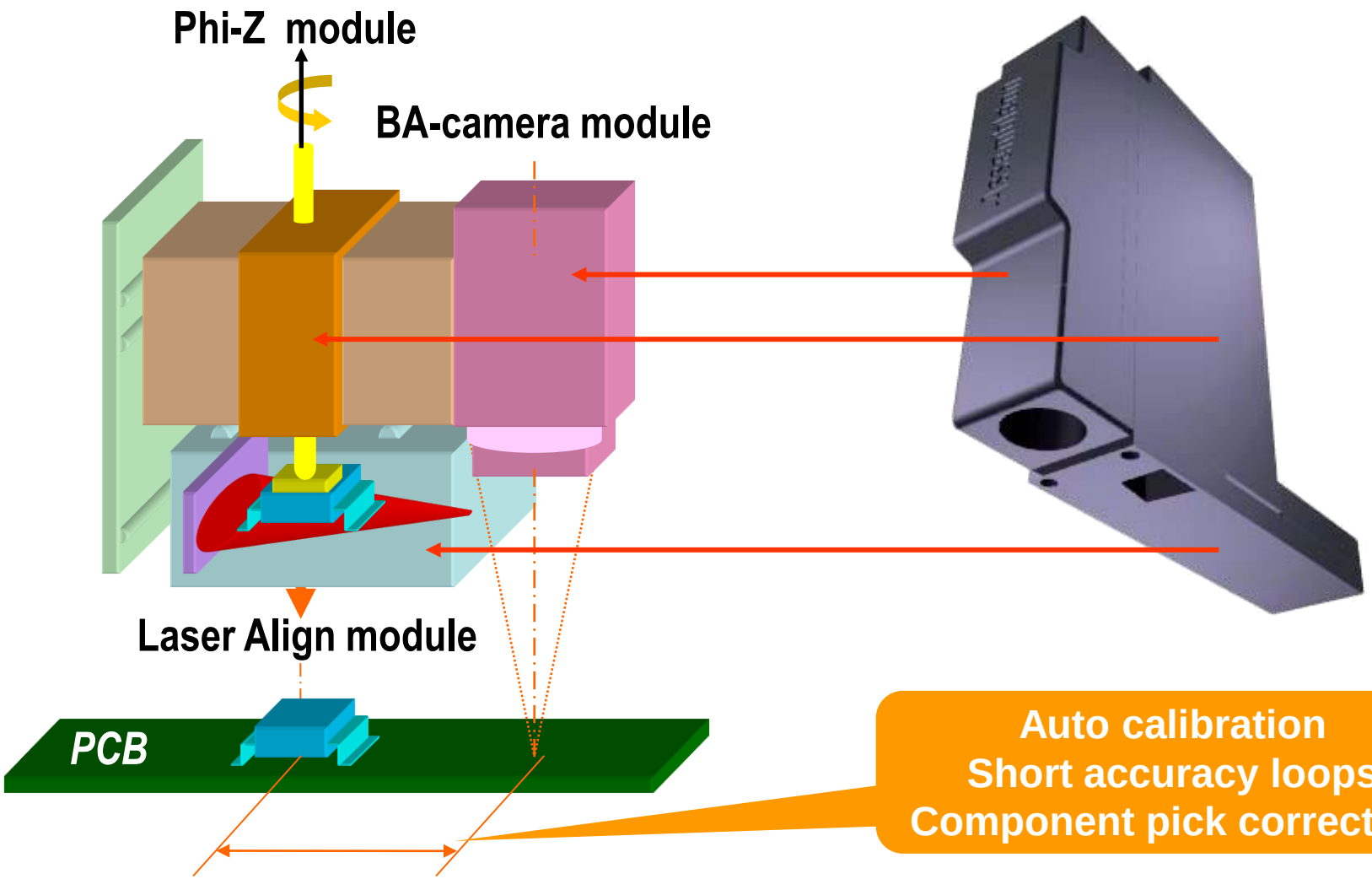


- Multiple parallel placement robots
- Indexing board transport
- Single placement head per robot

Total pick & place process control

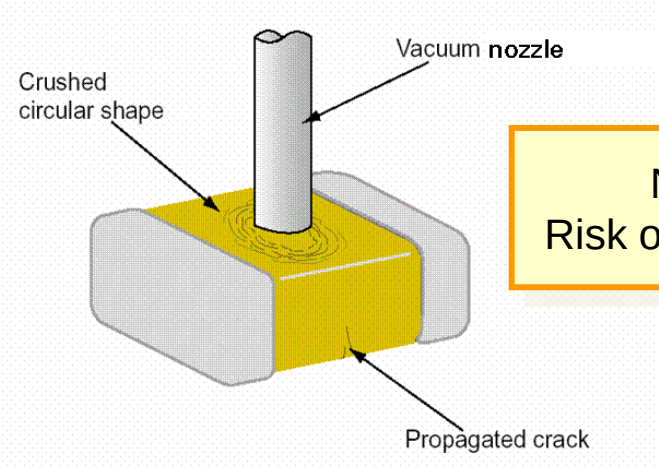


Placement head with integrated P&P process feedback

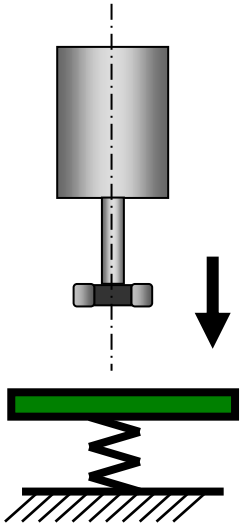


Auto calibration
Short accuracy loops
Component pick correction

Force control



No force control:
Risk of component cracking



Placement head

PCB

Contact stiffness

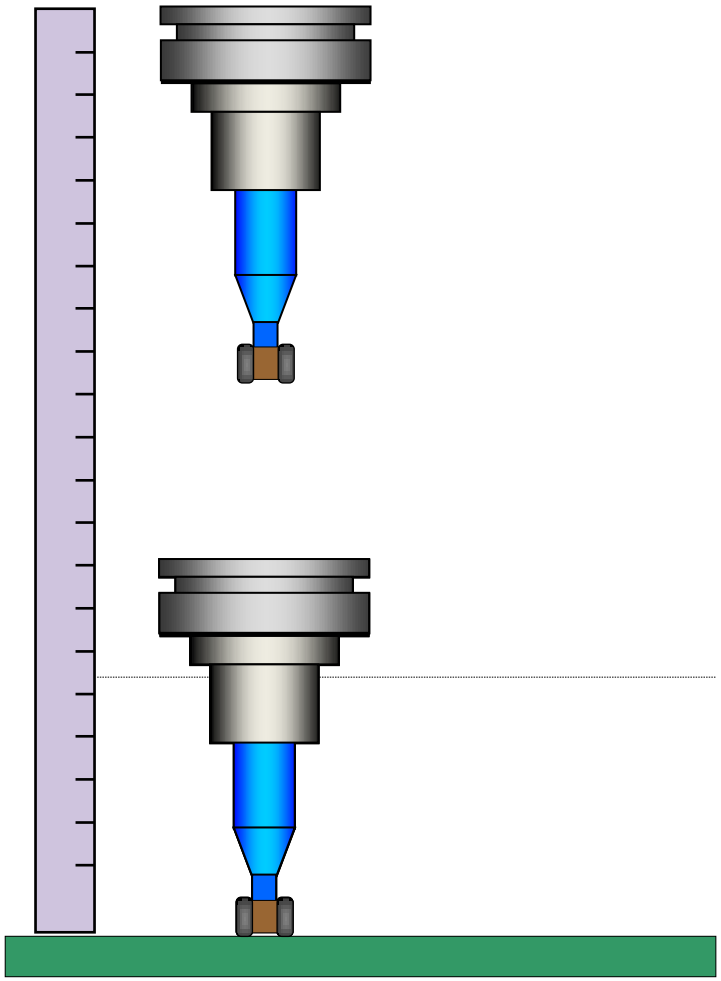
Impact force is determined by :

- Velocity
  - High velocity → high impact force
- Contact stiffness
  - High stiffness → high impact force
- Impact mass
  - High mass → high impact force

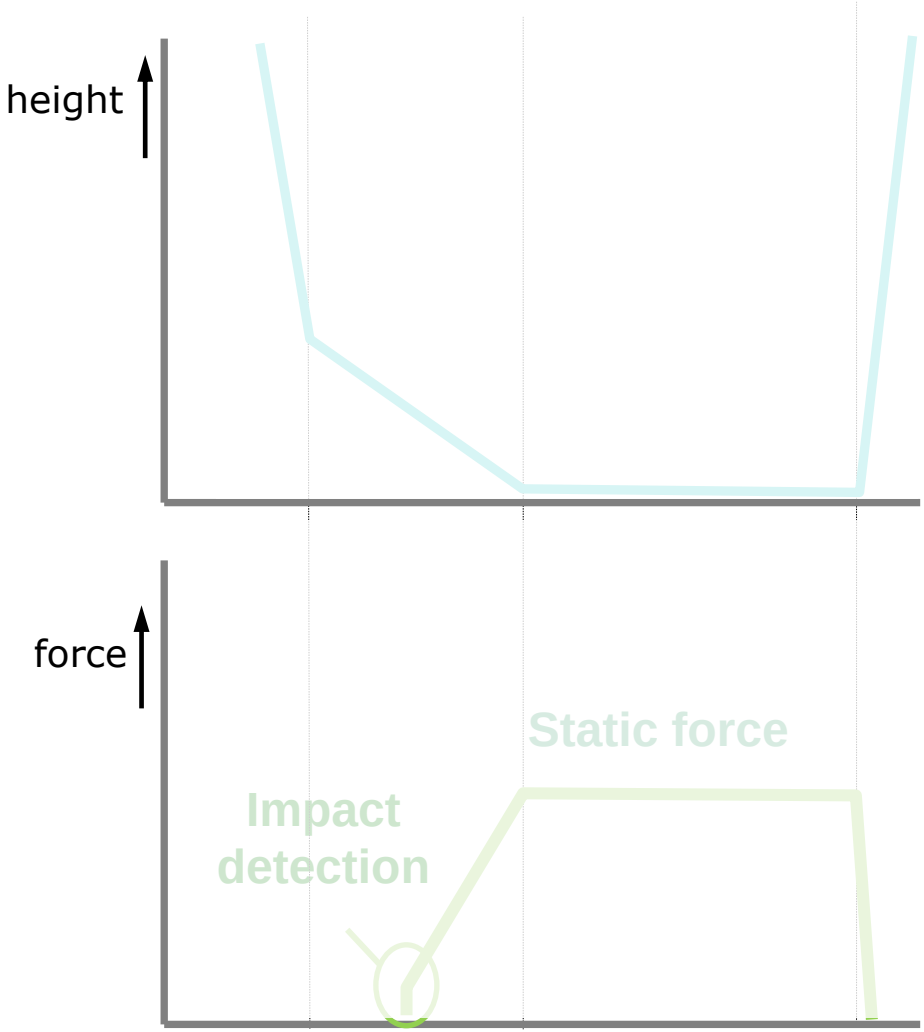
$$F_{placement} = F_{impact} + F_{static}$$

$$F_{impact} = v * \sqrt{m * k_{contact}}$$

Impact force control



PCB / Substrate



Placement defect prevention

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Auto calibration
Short accuracy loops

Low accelerations
Servo Z movement
On edge detection
Pick correction

Splice detection

Setup verification

Force control

Presence check

Symptom (before reflow)	Cause	Defect (end of process)
gned	• Mis read fiducials • Machine needs calibration • Placement error • Alignment error • Part slid off pads	•
art	• Incorrect part reel loading • Tape splice error	• Incorrect part
d	• Part damaged at supplier • Placement force too high	• Opens • Component cracking • Tilted part
Wrong polarity	• Programming error • Tray rotated	•
Extra / missing part	• Part lost during pick & place	• Extra / missing part

Pick & place

Relationship DPMO and rework costs

RESULTS

DPMO results for parallel placement

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WORK MONTH	08-30	08-31	09-01	09-02	09-03
INSPECTION(output)	1030	2332	2940	2850	2136
PASS	993	2302	2919	2801	2136
FAILED	37	30	21	49	
TOTAL DEFECT	112	96	49	142	52
DPU	0.109	0.041	0.017	0.050	0.024
DPMO					
DPU control level	0.094	0.094	0.094	0.094	0.094
DPMO control level					

DEFECT BREAKDOWN	QTY	QTY	QTY	QTY	QTY
COMPONENT RELATED					
Bend lead					
PROCESS RELATED DEFECT					
Wrong Direction					
Wrong Component					
Missing Component	1	1	7	6	6
Extra Component		3	2	1	
Damaged Component					
Misalignment		4		5	5
Tombstone	10	16		17	9
Component reversal			1	4	
Component incline					
Component high					
total defect	11	24	10	33	20
DPM	14	13	4	15	12

WORK MONTH	08-28	08-29	08-30	09-01	09-02
INSPECTION(output)	628	104	420	120	1610
PASS	612	92	394	110	1574
FAILED	16	12	26	10	36
TOTAL DEFECT	126	221	147	190	144
DPU	0.201	2.121	0.349	1.584	0.090
DPMO					
DPU control level	0.094	0.094	0.094	0.094	0.094
DPMO control level					

DEFECT BREAKDOWN	QTY	QTY	QTY	QTY	QTY
COMPONENT RELATED					
Bend lead					
PROCESS RELATED DEFECT					
Wrong Direction					
Wrong Component					
Missing Component	24	2	6	9	16
Extra Component					1
Damaged Component					
Misalignment	6		11		3
Tombstone	1	12	10	5	29
Component reversal					
Component incline					
Component high					
total defect	31	14	27	14	49
DPM	64	193	87	161	39

Product: LCD television (Shenzhen, China) (790 parts / board)

Line A: **Parallel** placement
DPU_{total} (5 days) = 0.0399 → **Y = 96.1%**

Line B: **Sequential** placement
DPU_{total} (5 days) = 0.2873 → **Y = 75%**

Difference in first pass yield: 21.1%

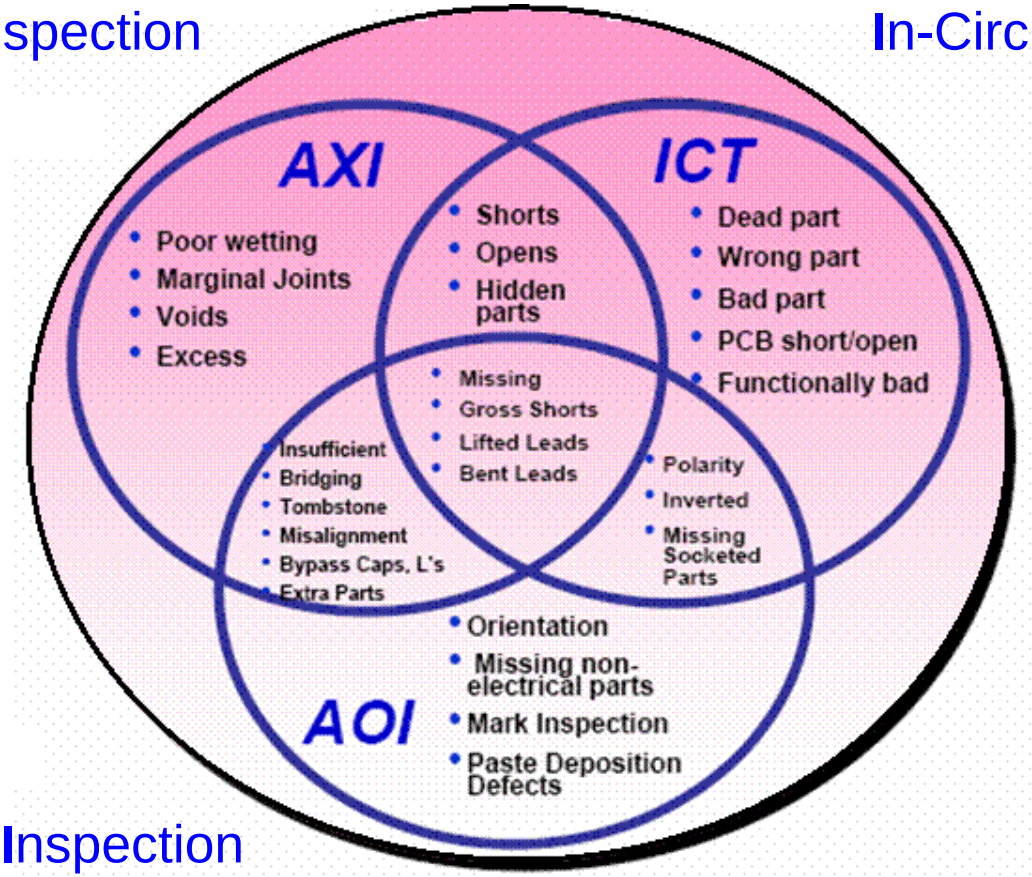
Example: Rework cost savings for LCD television

Item	Parallel line	Sequential line
# Productive hours per year	7800	7800
Real output per line [cph]	100000	100000
# Components per board	790	790
# Defect opportunities per board	5700	5700
DPMO	7	50
DPU	0.04	0.29
First pass yield [%]	96%	75%
Average BOM cost per part [€]	0.07	0.07
Line cycle time [s]	28.44	28.44
# Repairs per hour (board level)	5	31
Average rework per hour [s]	2674	16951
# Rework operators (3 shifts)	2	14
Annual labor cost per operator [k€]	3	3
Total annual labor cost [k€]	7	45
# Rework stations needed	1	5
Annual station costs (excl. labor) [k€]	20	100
Annual BOM rework costs [k€]	3	17
Total repairs per line per year [-]	38619	244847
Total repair costs per line (per year) [k€]	30	162
Average defect coverage [%]	90.00	90.00
# Boards needing second order rework (per year)	3862	24485
Average second order rework per hour [s]	267	1695
# Rework operators (3 shifts)	0	2
Total annual labor cost [k€]	1	5
# Rework stations needed	1	1
Annual station costs (excl. labor) [k€]	20	20
Annual BOM rework costs [k€]	0.26	1.66
Second order repair costs (per year) [k€]	21.2	26.5
Total repair costs per line (incl. defect recov. per year) [k€]	**51.2**	**188.6**

Quality inspection methods

AXI
Automatic **X**-ray **I**nspection

ICT
In-Circuit **T**est



AOI
Automatic **O**ptical **I**nspection

Defect coverage estimates

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Defect		HVI	ICT	AOI	AXI	BSCAN
1.1	Bridge	80 %	90 %	70 %	90 %	90 %
1.2	Insufficient	60 %	0 %	90 %	80 %	0 %
1.3	Open	50 %	80 %	80 %	90 %	90 %
1.4	Excess	60 %	0 %	90 %	80 %	0 %
1.5	Residue	80 %	0 %	0 %	20 %	0 %
1.6	Grainy	60 %	0 %	50 %	70 %	0 %
1.7	Other	0 %	0 %	0 %	0 %	0 %
2.1	Missing	80 %	80 %	90 %	80 %	100 %
2.2	Wrong	50 %	80 %	0 %	10 %	100 %
2.3	Misaligned	70 %	0 %	90 %	90 %	0 %
2.4	Tombstone	50 %	80 %	90 %	90 %	20 %
2.5	Inverted	30 %	80 %	30 %	10 %	100 %
2.6	Other	0 %	0 %	0 %	0 %	0 %
3.1	Dead	0 %	30 %	0 %	0 %	100 %
3.2	Tolerance	0 %	30 %	0 %	0 %	20 %
3.3	Other	0 %	0 %	0 %	0 %	0 %

Source: Nokia & University of Oulu, Finland, 2005

HVI: Human Visual Inspection
ICT: In Circuit Testing

AOI: Automatic Optical Inspection
AXI: Automatic X-ray Inspection
BSCAN: Boundary Scan

A combination of different test methods is needed for optimal test coverage

Approximate test coverage: 90% (→ 10% of all defects is not detected)

Conclusion

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- Prevention is better than cure…
  - Solder paste printing
    - Selection of optimal stencil & aperture definition
    - Selection of optimal printing parameters
    - Process monitoring (stencil cleaning, paste replenishment, etc.)
  - Component placement
    - Monitoring of every pick & place process step
    - Selection of optimal P&P parameters ('Take it easy')
  - Reflow soldering
    - Selection of optimal reflow temperature profile
    - Reflow process control
- Parallel placement principle gives intrinsically better placement quality
  - Continuous process monitoring
  - More time available per process step → less risks
  - Result: Typical DPMO ≤ 10 → Considerable savings on rework cost !

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Sjef van Gastel

October 3rd 2012