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To-test or not-to-test:
Balancing costs between testing and quality

Ercan Sengil
Business Development Manager, Philips Micro Devices
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Introduction to Philips Micro Devices

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- **Test Coverage in Electronic (and Photonic) Systems**
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- **Conclusion and Recommendation**

Who are we?

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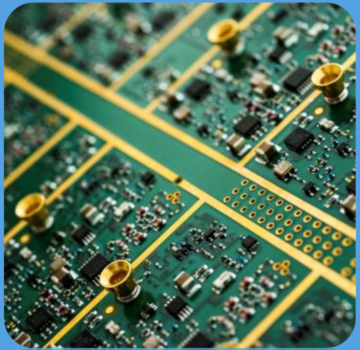
Philips Micro Devices Electronic Manufacturing

Our strategic pillars

PCB Assembly

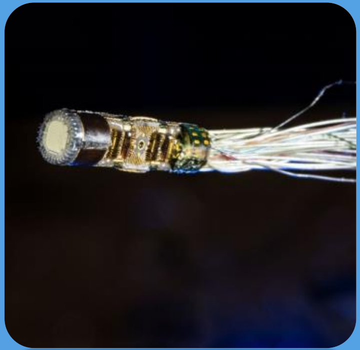


Up to 100k per year PCBA manufacturing

Verification & Validation

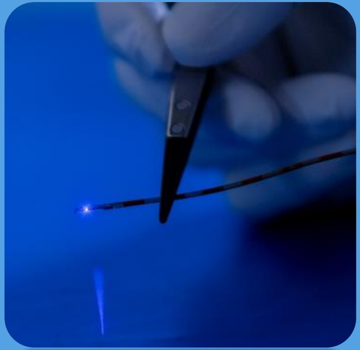
NPI support (production of verification, valid. & application boards

Micro Assembly Medical Devices



Micro assembly of medical devices.

Adjacent (Photonic) Micro Assy



Photonics integration and micro assembly.

Operations, Delivery & Services

Philips Micro Devices (Greenhouse)

Infographic

Philips Micro Devices

~80

Nr. of employees

Total operations area

4.300 m²

Capacity (if fully automated)

100+ k/yr

Customer portfolio internal vs. external

~50/50

Kastanjelaan 400
5616 LZ Eindhoven
The Netherlands

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Micro Devices added value

- Advanced development through structural de-risking of concepts and technologies.
- Design and layout services via Innovation Engineering (IEN).
- Early expert DfX consulting.
- Manufacturing report, with potential suggestions on design and layout improvements.
- (Fast)-Prototyping, with 2-week LT (w/o 3D AOI)

- Low threshold access and communication.
- Fast turnaround.
- Prototyping according ISO13485.
- Sourcing material.
- Well documented assembly flow supported by data, e.g. 3D XRAY/AOI, 3D AOI, Flying Probe.
- Integration of PCB & micro assembly technologies.

- NPI and production of verification and validation batches according to ISO 13485 and IPC-A-610 grade (class 2/3).
- Statistical manufacturing data.
- Processes & component traceability.
- Sourcing material.
- Philips QMS processes, e.g. DMR/DHR.

- High mix, low volume production according to ISO 13485 and IPC-A-610 grade (class 2/3).
- Philips QMS processes (incl. Design History Record, Certificate of Conformity).
- Processes & component traceability.
- Sourcing material.
- Transfer to high volume EMS partners, if needed.

- PCBA manufacturing (incl. prototyping), according to ISO 13485 and IPC-A-610 grade (class 2/3), to support your Service Parts.
- Processes & comp. traceability.
- Philips QMS processes (incl. DHR, CoC, etc.).
- Sourcing, incl. EOL parts.
- Potential PCB redesign due to EOL parts by IEN.

(Fast-) Prototyping → Prototyping → Industrialization (NPI, Engineering runs) → Low-volume, High-Mix Production, Ramp Up → Prototyping, Production of Service Parts

Philips Micro Devices (Greenhouse)

Micro Devices services

Process Development

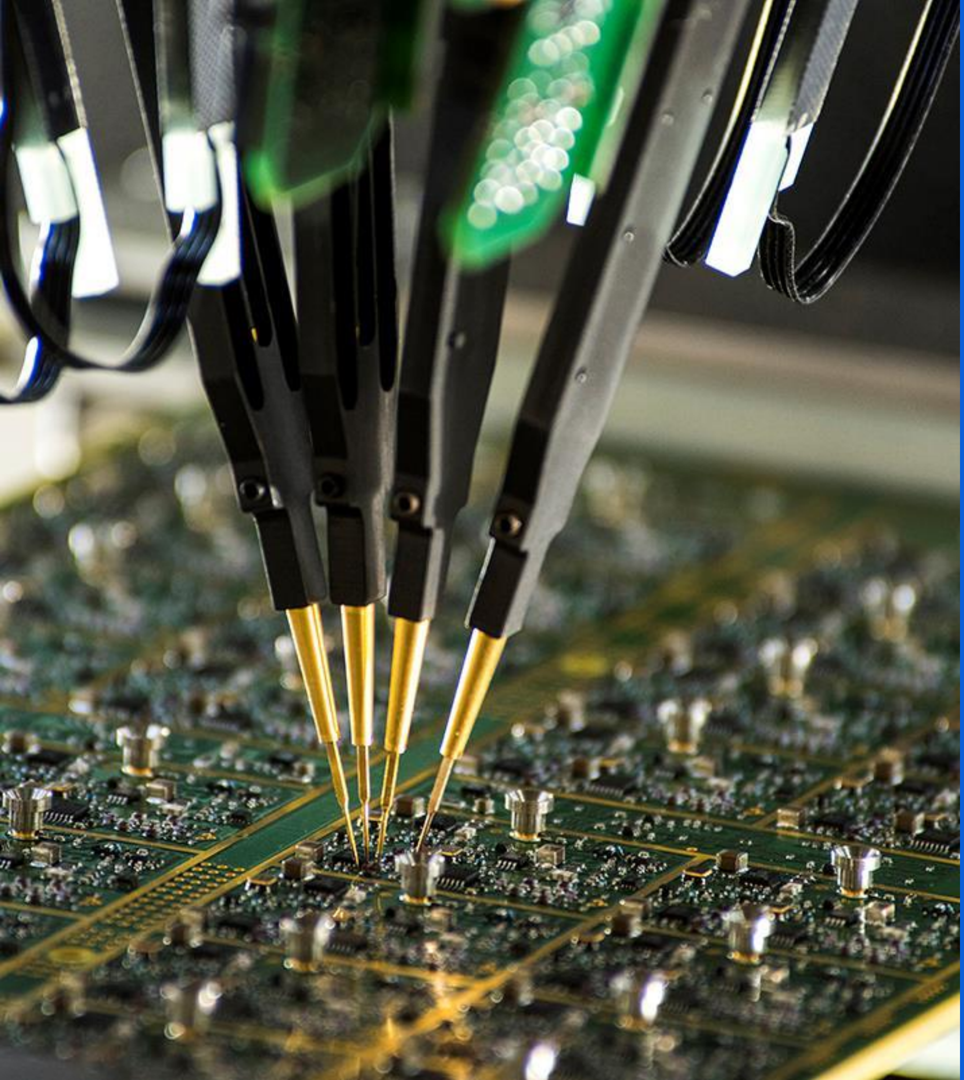
- DfX: Design for eXcellence
- Continuous improvement
- Cpk analysis and yield improvement
- (In line) Inspection and failure analysis: solder paste inspection, 3D automated optical, X-ray
- Risk management, FMEA
- Supply chain management
- TPD/DMR product documentation management
- Verification & validation of process & tooling

Prototyping/NPI

- PCB Assembly
- Micro-assembly: die attach, wire-bonding, stud bumping, ACF bonding, pick & place, soldering
- Project management
- Functional testing
- Inspection & failure analysis: solder paste inspect., 3D AOI/3D X-RAY
- Risk management, FMEA
- DfX: Design for eXcellence

Volume Manufacturing

- ISO13485, ISO9001, ISO14001, ISO27001, ISO45001
- TPD/DMR product documentation management (PTC Windchill)
- Purchasing, Forecasting, MRP
- Quality Management (SAP ERP)
- Routing, Tracking, Traceability (SAP ME)
- Statistical process control (SPC)



To-test or not-to-test: *balancing between costs of testing and quality*

To-test or not-to-test: balancing costs between testing and quality

Salland Test Technology Summit 2025
12-13 February 2025

Abstract

To-test or not-to test, that is the dilemma in electronic manufacturing services (EMS). This narrative poses a critical challenge, especially in the realm of printed circuit board assembly (PCBA).

Comprehensive testing and visual inspections are an integral part of the PCBA process to ensure that boards are free of assembly faults or failures, provided the design itself is error-free. However, the increasing demand from customers for exhaustive testing protocols introduces a complex trade-off. While these additional tests can enhance test coverage, they come with significant costs in terms of time, resources, and incurred expenses. This paradox raises the fundamental question: does the incremental assurance provided by extensive testing justify the associated operational inefficiencies and financial burdens?

Balancing cost-effectiveness, time-to-market, and customer satisfaction is pivotal in determining the optimal testing strategy. Simulation and prediction tools based on statistical analysis, design rules and first product inspection can be beneficial to ensure reliability while remaining commercially viable.

This paper discusses the decision-making process, exploring the need for strategic approaches that align quality assurance with manufacturing efficiency.

To-test or not-to-test: balancing costs between testing and quality

- **Test Coverage in Electronic (and Photonic) Systems**
- **Cost vs. Quality**
- **Impact of Small Increases in Test Coverage**
- **Conclusion and Recommendation**

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Carlos Gonzalez Avelino

- Production Test Development Engineer, MD Process Development, Philips Innovation Engineering

Paul van Bakel

- Senior Architect – Quality & Reliability, Philips Innovation & Engineering

Introduction:
The dilemma of '*To-Test or Not-to Test*'

Key cost factors in manufacturing

- Materials, personnel, equipment, and other factors, with effectiveness often measured by yield, which directly impacts costs.

Costs beyond manufacturing

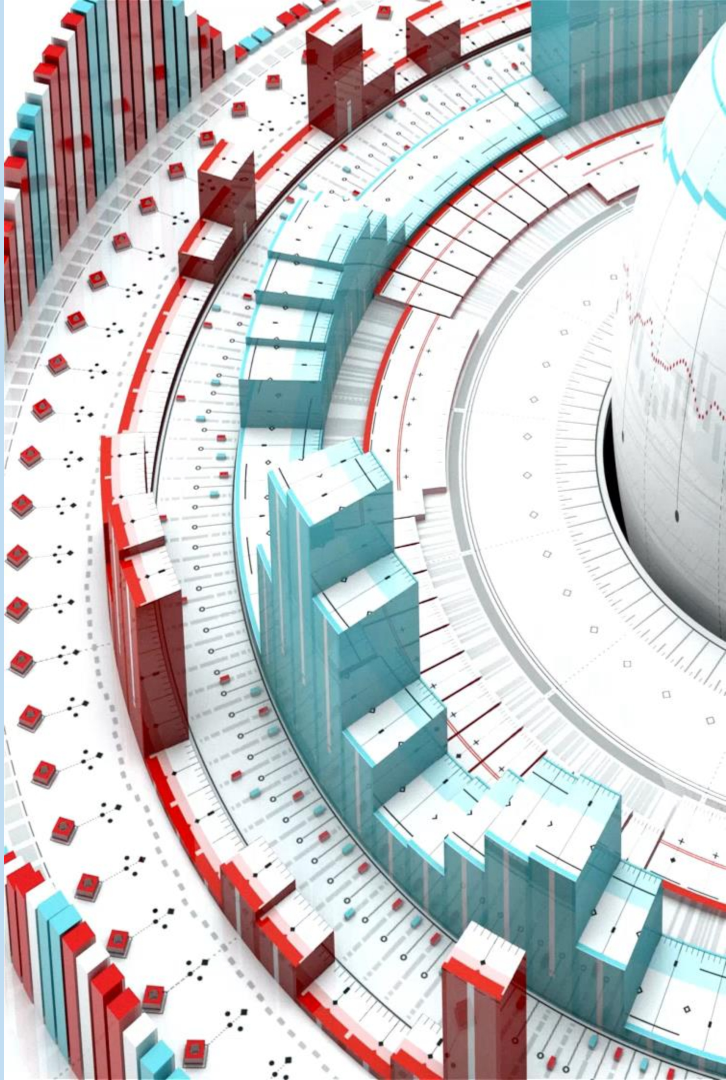
- Warranties, service plans, repairs, callbacks, reimbursements.

Impact of post-market activities

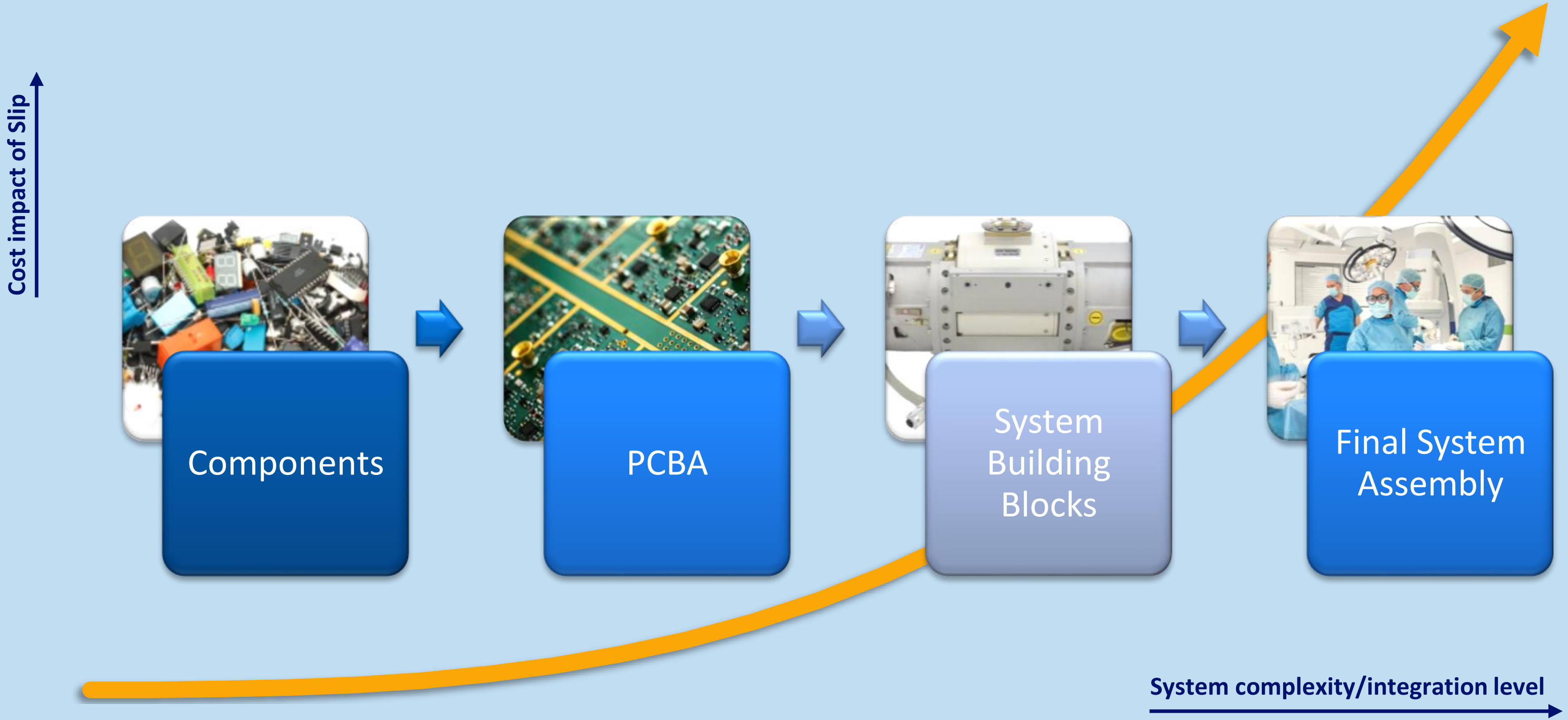
- Repairs and callbacks, can significantly affect company finances;
- Callbacks could harm both revenue and customer trust, and negatively impact brand image;

Importance of reliability

- In order to mitigate risks, reliability must be prioritized, that starts with design and followed by rigorous testing.



Cost impact of *Slip* throughout the System Integration



Test Coverage in Electronic (and Photonic) Systems

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Why *Test Strategy*?

Goals

The goals for PCBA manufacturing test are

- Provide evidence that the PCBA is assembled according to DMR (customer requirements document)
- Provide evidence the safety (CtS) functions meet the design specifications
  - Provide evidence that the PCBA meets the CtQ design specification
- *Support the PCBA manufacturing with continuous improvement processes by pin-pointing to the failure*

By implementing the goals, this results in

- Integral cost-effective solution for the entire value chain by:
  - Quality improvements by closing the feedback loop within the EMS
  - Efficient product build @ Philips assembly line
  - Low reject rates and field call figures
- Sustainable and even improving Quality of PCBA over production years

Two *types of tests*

And the combination there of…

Structural test: ICT, BST, FPT, AOI, XRAY, BIST

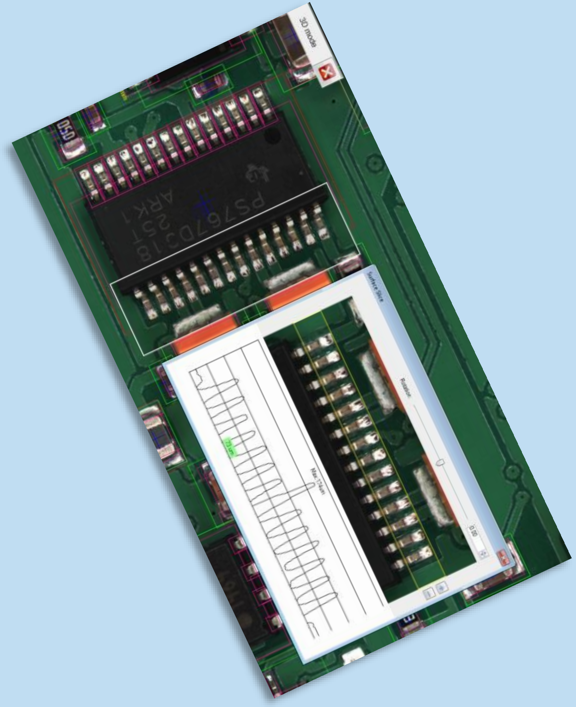
- Checks if the product structure is according to the DMR. By covering:
  - Are all components placed including orientation
  - Are all electrical connections present (solder joints as well as the tracks in PCB)
  - Have the separate component on the board the right “value”
  - Is the right solder paste volume present

The structural test covers our fault model! Evidence: Product is built according DMR!

Functional test

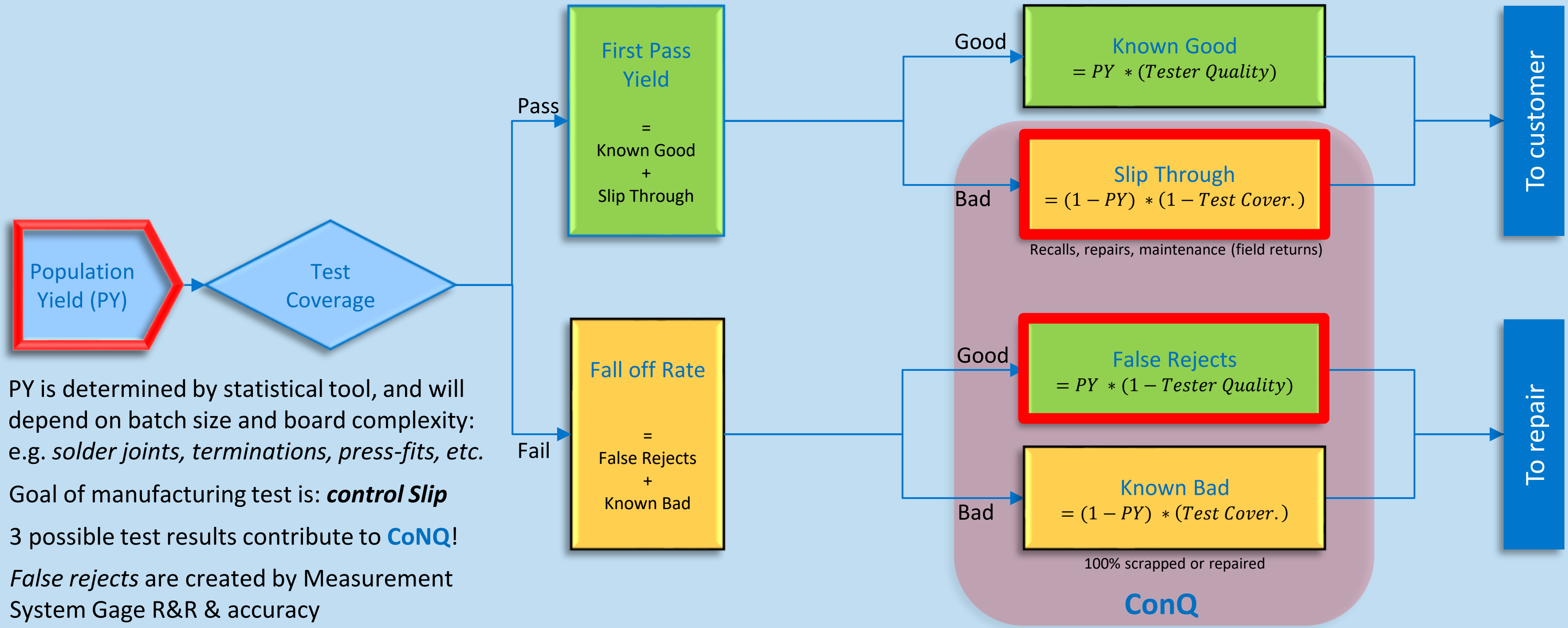
- Checks if the PCBA meets its function in other words covers the CtQs

The functional test shall demonstrate that a product build according to DMR is working @ speed



Breaking down ***reject*** and ***good*** parts

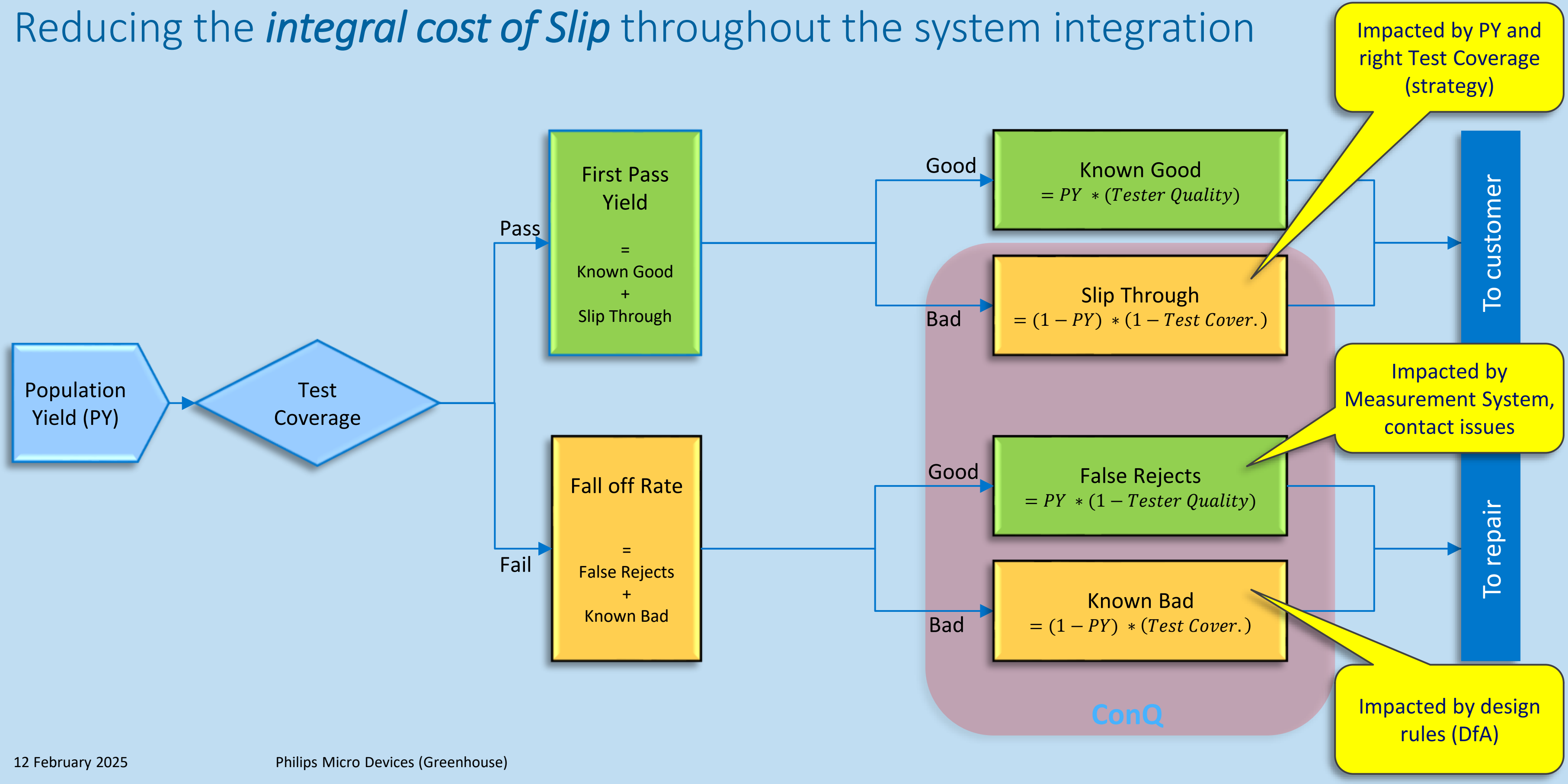
Reducing the ***integral cost of Slip*** throughout the system integration



- PY is determined by statistical tool, and will depend on batch size and board complexity: e.g. *solder joints, terminations, press-fits, etc.*
- Goal of manufacturing test is: ***control Slip***
- 3 possible test results contribute to **CoNQ**!
- *False rejects* are created by Measurement System Gage R&R & accuracy

Breaking down *reject* and *good* parts

Reducing the *integral cost of Slip* throughout the system integration



Quality vs. Cost

Importance of Test Coverage in Electronic (and Photonic) Systems

Reliability and Quality Correlation

- Linked to quality, can be measured using the IPC-7912, that defines defects per million opportunities (DPMO) across categories: Component, Placement, Termination, and Assembly

Predictive Analysis and Risk Mitigation

- Statistical data from previous runs can predict errors, allowing preemptive mitigation strategies to reduce risks in future batches.

Test Coverage (*C*) and Slip Through (*S*)

- ***C*** aims to reduce false positives (slipped-through products) and improve first-pass yield (functional products after testing).

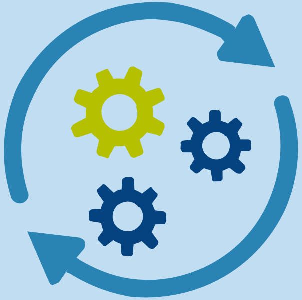
Design for Manufacturability (DFM):

- Maximize population yield and test coverage by standard processes, component packages, and DFM rules.

Testing Techniques and Overlap:

- Test coverage depends on structural or functional testing methods.

$$S = 100 \cdot (1 - PY) \cdot (1 - C) \quad [\%]$$



Finding the ***right balance between coverage***, ***quality***, and ***cost***

Test Coverage:

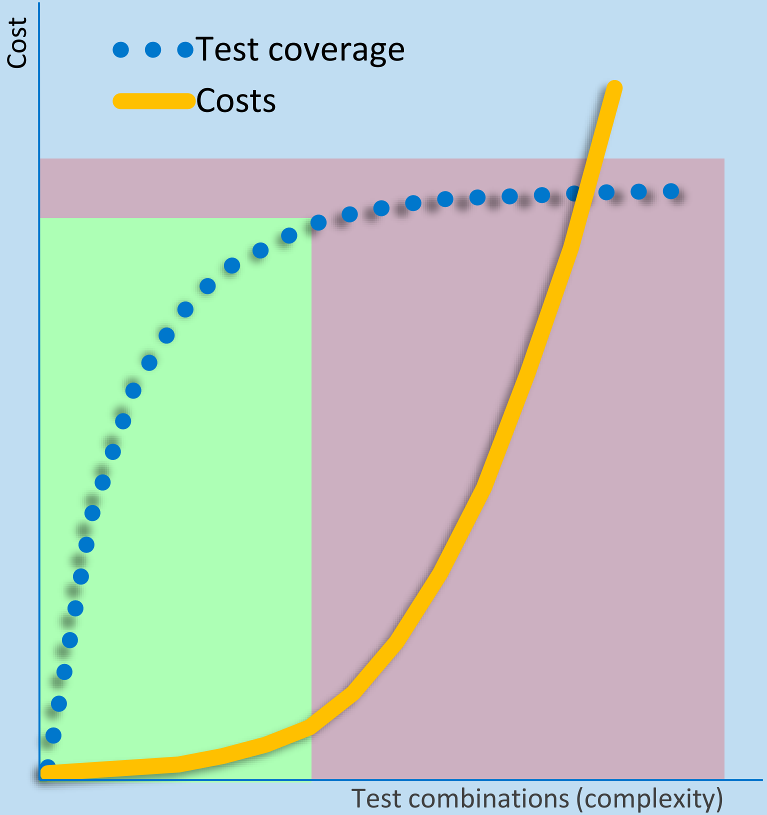
- 3D AOI provides relatively high coverage (> 50% in 3D mode) with low overhead costs, making it a strong default starting point“
- Flying Probe could help increase test coverage, but this one comes at relatively higher NRE costs.
- 3D AOI drastically reduces NRE for configuration and debugging while maintaining adequate coverage

Quality

- Reduced Slip means improved reliability, less callback and repairs.
- This benefits both customer, but certainly the EMS.
- At some point costs increase rapidly for marginal test coverage increase.

Cost

- As increased test coverage reduces Slip, it is not a linear function.
- At some point costs exponentially increase for marginal coverage increase.



Electronic PCBA testing

SPI (Solder Pate Inspection)

3D AOI (Automatic Optical Inspection)

FP (Flying Probe)

3D X-RAY

FT (Functional Testing)

Photonics testing

Beam quality characterization (wave front sensor):

- Aberration are measured and corrected accordingly

Measurement beam power

Measurement of coupling efficiency (joint quality measurement)

Impact of Small Increases in Test Coverage

Impact of *Small % Increase in Test Coverage*

Limitations of Testing

- 0% slip-through or 100% test coverage is impossible
- Overlap b/w test techniques means coverage increases only from (marginal) added value.
- Slip-through reduction is non-linear, combined tests yield non-linear coverage.

Cost Considerations

- Adding extra tests increases manufacturing costs, so a balanced and thoughtful approach is essential to optimize testing strategies

Design for Testability (DFT)

- Aim is to reduce the non-quality to below customer target (5.000 units).

Types of Structural Testing

- Structural tests include optical (e.g., X-Ray) and electrical inspections (e.g., flying probe, boundary scan, in-circuit testing).

Functional Testing Costs:

- Dedicated fixtures and software, significantly increases costs, but might be justified by the reduction in risk.

Impact of *Small % Increase in Test Coverage*

Putting it into perspective

Client requirements/targets:

- Batch size: 1,000,000 units
- Yield: >95%
- Slip through (S) <0.5% (<5,000 units)

Population yield (dpmo = defect per million opportunity, ppm): **97.752%**

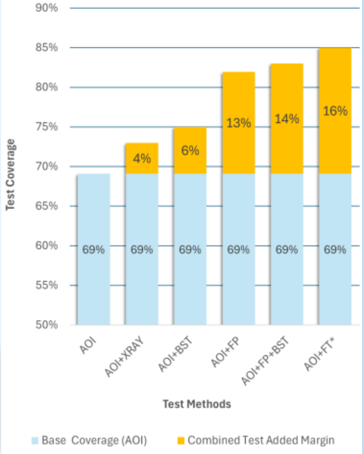
- Non-quality (NQ = slip through w/o test): 2.248% (= 1-PY → 22,480)
- We apply testing to reduce this number as much as we can.

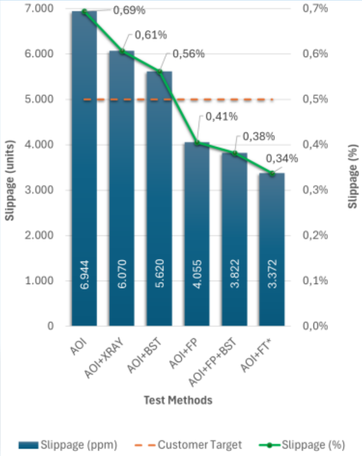
Testing will address, or will reduce, the non-quality

- Aim is to reduce the non-quality to below customer target (5.000 units).

Conclusion

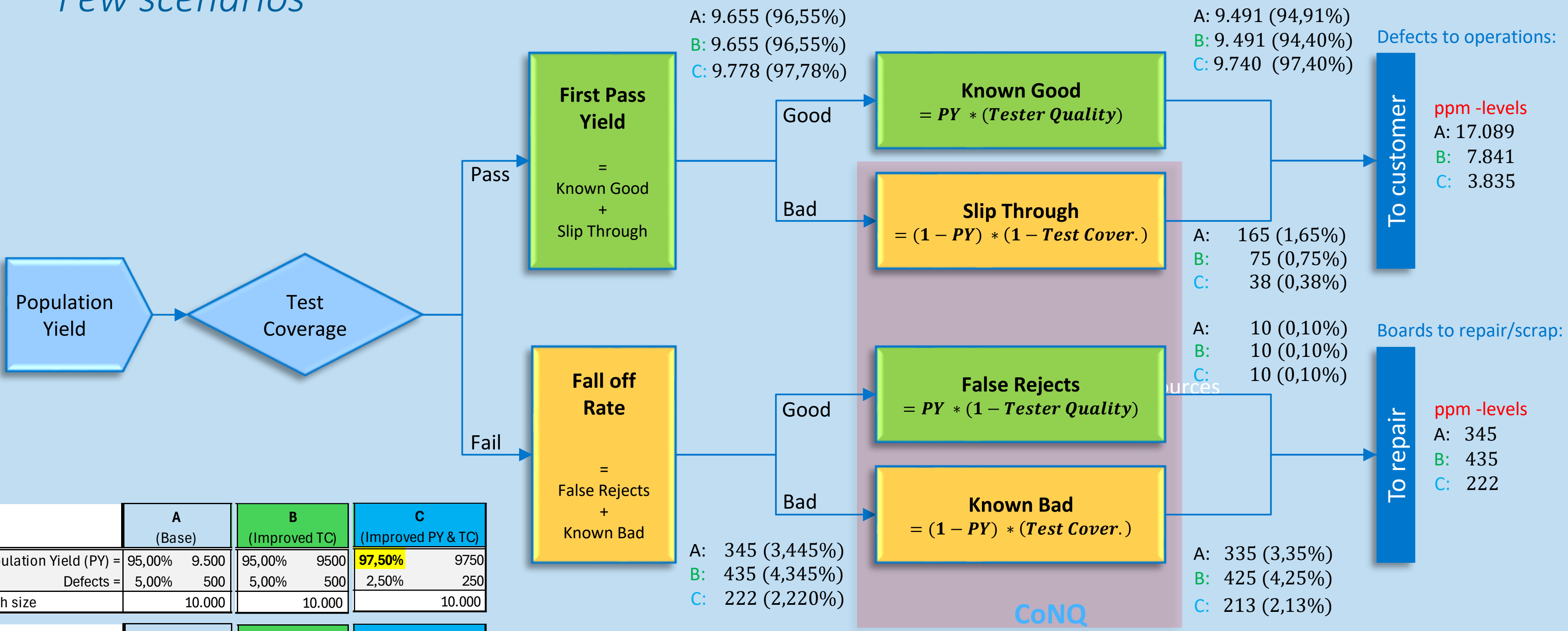
- In order to meet customer requirement, Flying Probe is required on top of 3D AOI.
- Further improvement is possible with additional investment in BST/FT or FT.





Breaking down ***reject*** and ***good*** parts

Few scenarios



	A (Base)		B (Improved TC)		C (Improved PY & TC)	
Population Yield (PY) =	95,00%	9.500	95,00%	9500	**97,50%**	9750
Defects =	5,00%	500	5,00%	500	2,50%	250
Batch size		10.000		10.000		10.000

	A (Base)	B (Improved TC)	C (Improved PY & TC)
Test Coverage (TC) =	67,00%	**85,00%**	**85,00%**
Tester Quality (TQ) =	99,90%	99,90%	99,90%

Conclusion and Recommendations

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Conclusion and *Recommendations*

Testing will never solve q-issues, and coverage will never reach 100%

Proactive Design for Efficiency

- Optimizing manufacturing processes requires a proactive approach (incl. DfM, DfT) to increase PY and achieve high test coverage.

Simulation and Prediction Tools

- Statistical analysis and simulation tools can support DFM/DFT efforts, help select best test strategy that balances quality and costs.

Improve design rules to prevent defects pro-actively

- The more design rules are used, the more one can leverage on learnings.
- Improved population quality will result in reduced warranty cost and improve reliability.

Apply appropriate test strategy to reduce Slip through

- Aim is to reduce the non-quality slipping through.

Test coverage >85% will require huge efforts & large amount of investments

- In order to meet customer requirement, Flying Probe is required on top of 3D AOI.
- Further improvement is possible with additional investment in BST/FT or FT.

Facing manufacturing challenge?

Ercan Şengil

Business Development Manager
Mobile: +31 6 81 03 95 16
E-mail: ercan.sengil@philips.com

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