IEEE SW Test Workshop
Semiconductor Wafer Test Workshop

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Adaptive test on wafer level

focus on: test-time reduction (TTR)

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Introduction

- **What is Adaptive test?**
  - Modify test content/flow based on results
- **Examples of adaptive test**
  - Dynamic change test limits (DPAT)
  - Reduce amount of tests
  - Make test plan based on PCM data
  - Smart Sample Probe
- **ITRS (Salland Engineering, contributes)**
  - International Technology Roadmap for Semiconductors

Why do we test in the 1st place?

- **What if the wafer-fab would produce 100% perfect product?**
  - No need for testing at wafer level.
  - Most of us would not have a job!
- **Lucky for us; there is enough process variation during wafer fabrication!**
  - This makes wafer test mandatory.

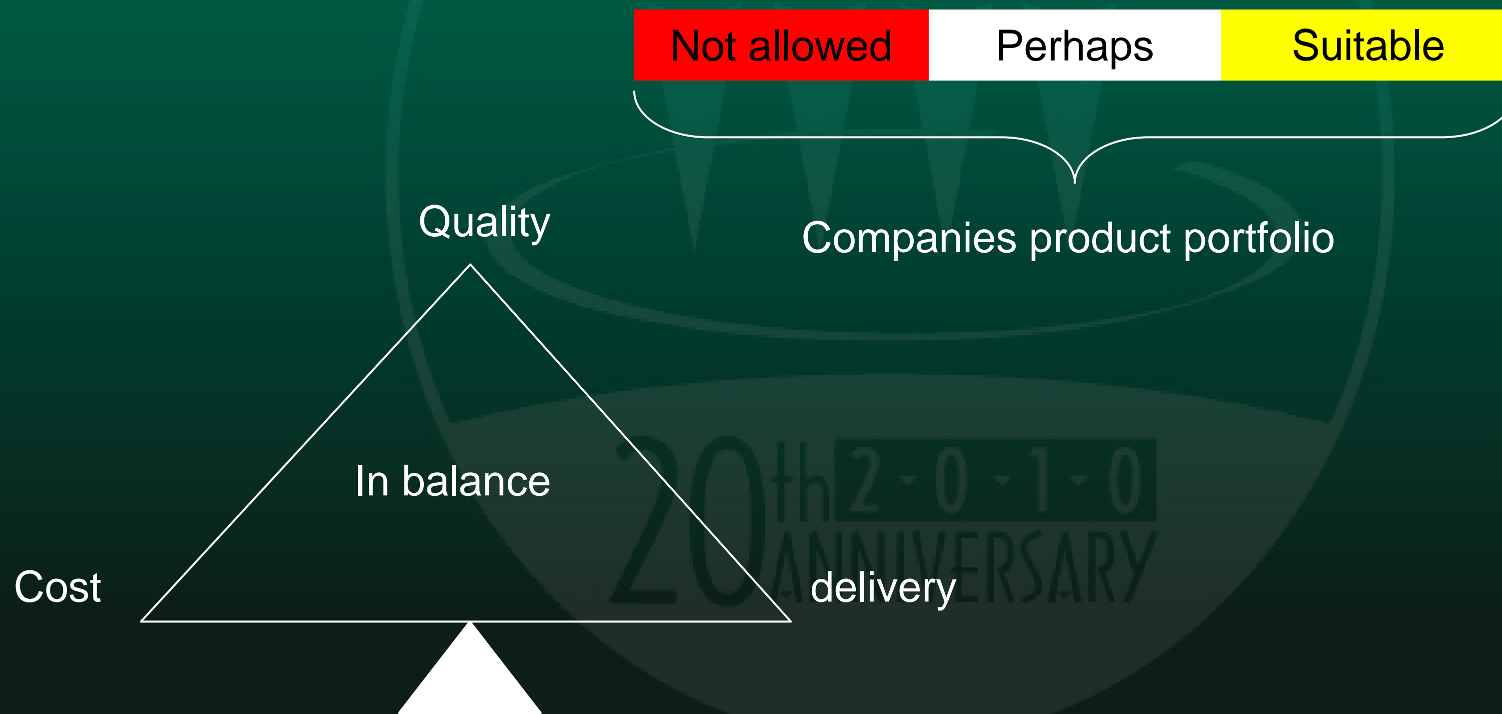
Cost of test

- **Cost of test still grows**
  - More complexity in the devices
  - More pins, higher density
  - More expensive ATE
- **Challenge to reduce cost without concessions to the quality**
  - Invest in Dynamic Test-cell Controller
  - Gain all advantages (not just TTR)

Suitable device types

- **Not all devices are suitable for adaptive test**
  - Test coverage needed at all times (Automotive)
  - New product or new technology
    - (not enough data available yet)
  - Effort is higher then profit
  - Low volume production

All about balance



Test

- **When do you recognize the picture?**
- **In total 80 boxes**
  - 1st ; 5 boxes; 94% reduction
  - 2nd ; 9 boxes; 89 % reduction
  - 3rd ; 13 boxes; 84% reduction

Objectives / Goals

- **Reduce test-time**
  - Have at least 20% TTR
- **No concessions towards quality**
  - Less then 20 PPM difference in yield
- **Recipe controlled;**
  - All adaptive TTR instructions are stored in a TTR-Recipe
- **Useable over wide range of products**
  - Mixed signal & analog
- **Traceability of how each die is tested**
  - Special identifiers (adaptive test-flow pass bins)
  - Know values used for switching

Methods

- **Detect redundant tests/data**
  - In order to create reduced test-flow's
- **Have multiple decision criteria (recipe-content)**
  - Validation towards the lot
  - Tests to monitor (used for switch decisions)
  - Area's over the wafer
  - Watch-dog test
- **Real-time analysis and decisions**
  - Activate the "switch"
  - Real Time data analysis (test-data validation)

Preparation

- **Redundancy analysis required (on historical data)**
  – Results will vary over the wafer surface
    - (geographical connected)
- **Reduce number of tests**
  – Which are suitable?
- **Test-flow creation**
  – Multiple test flows
- **Correlation analysis**
  – Remaining tests should correlate with full flow

Redundancy

- **When is a test redundant?**
  - When it does not contribute by it self, to the end result.
- **Why are there redundant tests in the first place?**
  - Creating a test-program is to cover all specified parameters.
  - for new product it is not clear yet, how tests are “connected” (and could end-up as being “redundant”)
- **How to detect redundant tests?**
  - Use a redundancy analysis software tool
  - Output is: a list with “skip-candidates”

Test-flow creation

- **Create reduced test-program (s) "TTR Test Flows"**
  - Use skip candidates list
- **Not all tests can just be skipped**
  - Waiting loops (for the DUT to stabilize)
  - Set-up information (to bring the DUT in a certain condition)
  - Essential test coverage ("must be" test, used also for switch indicator)
  - Watchdog test
- **Correlate each test in the "TTR Flow" to the Full-Flow**
  - To make sure no quality impact
  - Should bring same reading regardless the "Flow" (TTR or Full)

Watchdog test

- **Monitor the stability of the product & process**
- **Should be a representable test**
  - To validate the measured values (good contact)
  - Real time SPC
- **Secure the quality of process**
  - Watch for “Trend”
  - Guard band value’s set by historical data
- **Can never be switched off!**
- **When out of control;**
  - Return to full test flow

Adaptive Test Flow

TTR

Recipe

Test

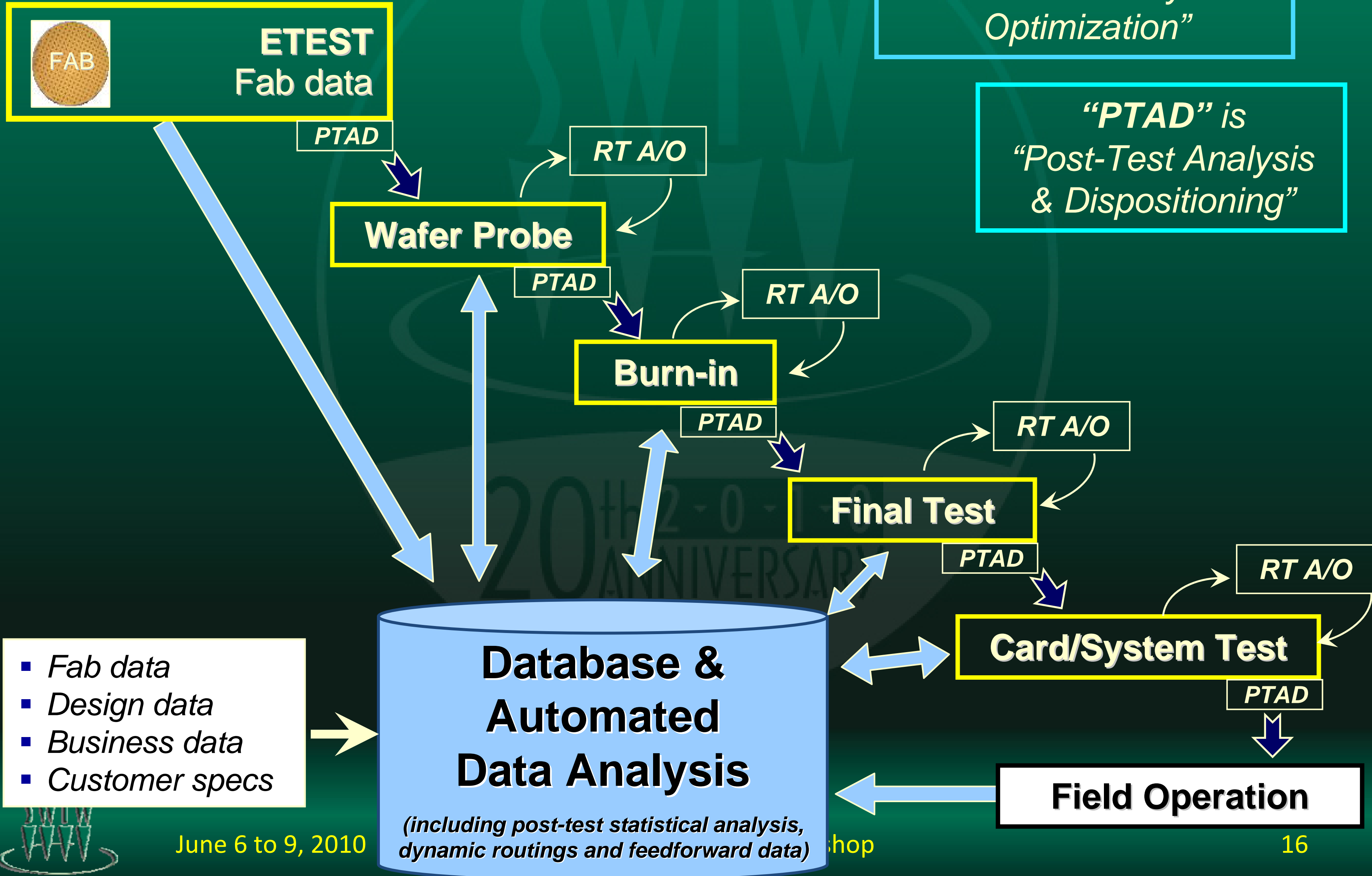
Post-Test Analysis & Dispositioning

Presented at IEEE 2009 International Test Conference

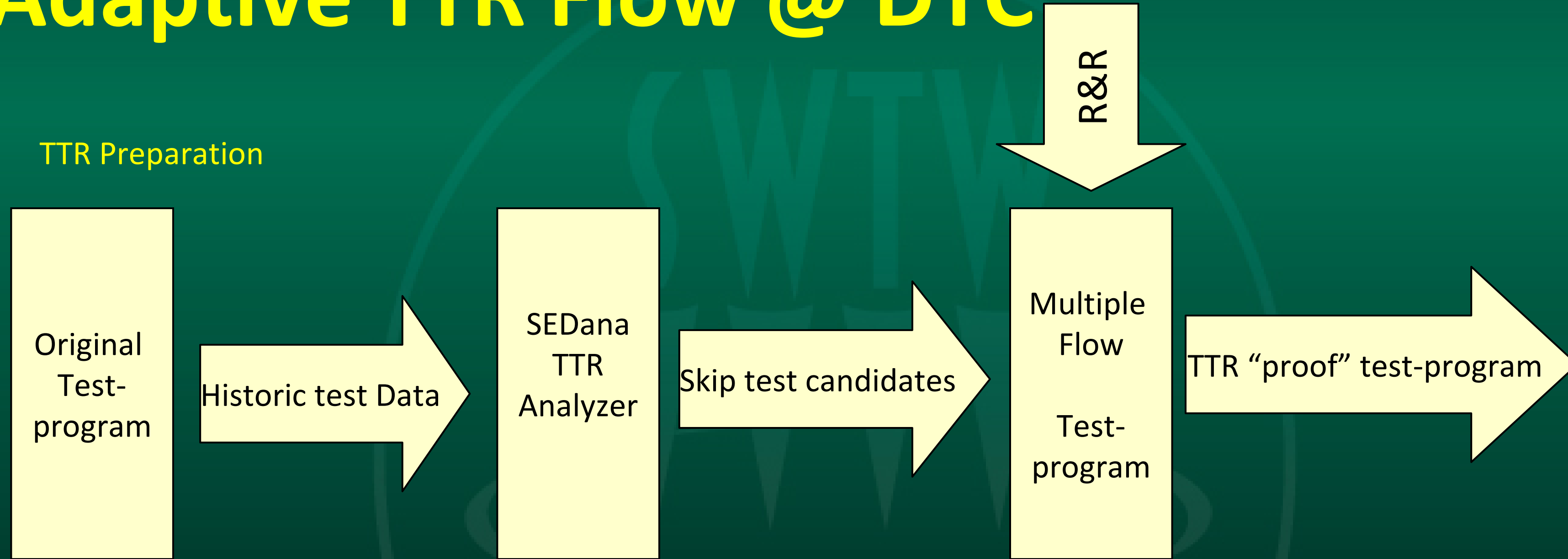
Adaptive Test Data Flow

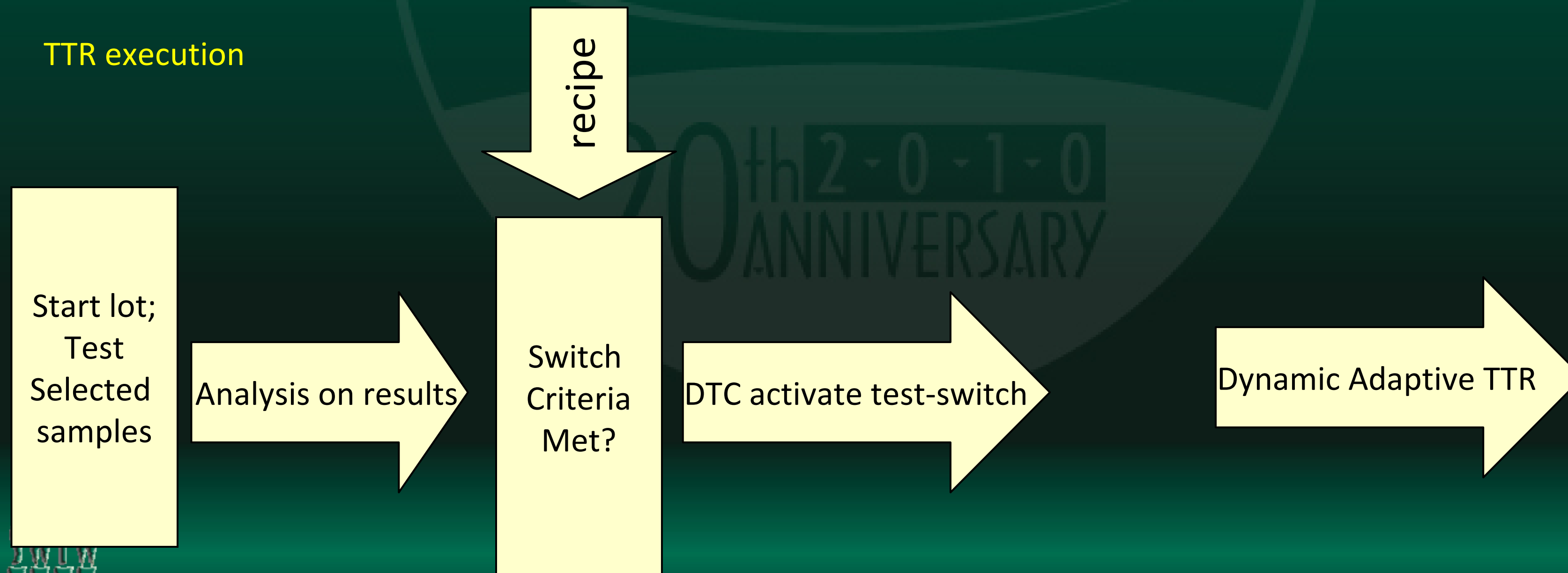
"RT A/O" *stands for "Real-Time Analysis & Optimization"*

"PTAD" *is "Post-Test Analysis & Dispositioning"*



Adaptive TTR Flow @ DTC





Switch criteria, recipe based

- **Validation towards the lot**
  - Test 1 (or more) wafers to detect if the lot is “good”
  - Run full-flow and monitor:
    - Overall wafer yield
    - Not containing more then X bin-Y
- **Tests to monitor on:**
  - Cpk, Cp, mean/median, sigma on parametric level
  - Yield on bin level
- **Area’s on the wafer with corresponding sample die**
- **Watch-dog test**

TTR-Control map

Full Flow

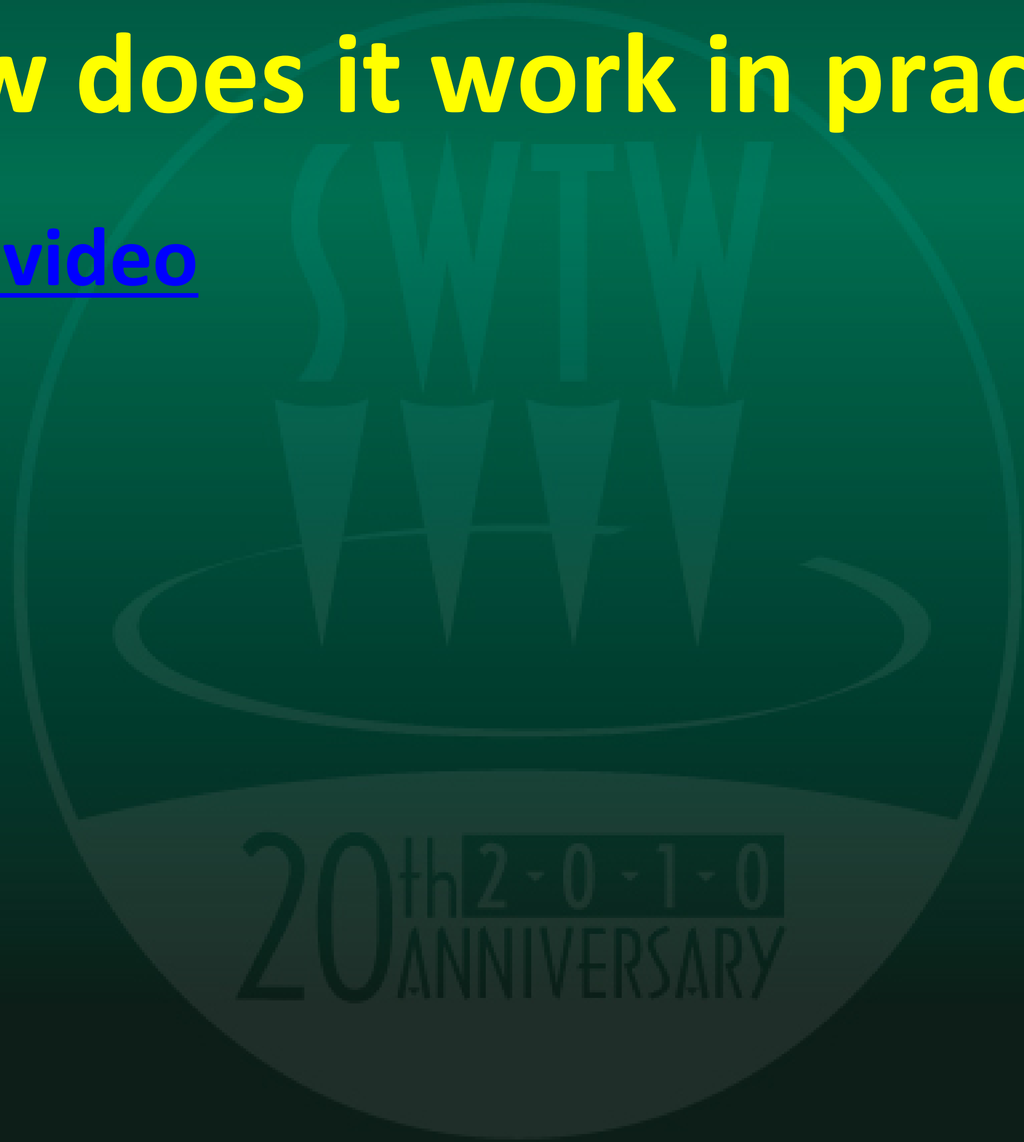
Area 0

Sample 0

Area 1

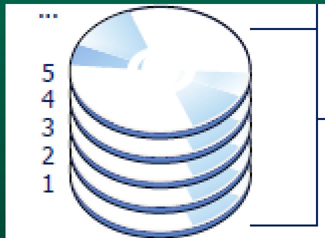
Sample 1

How does it work in practice

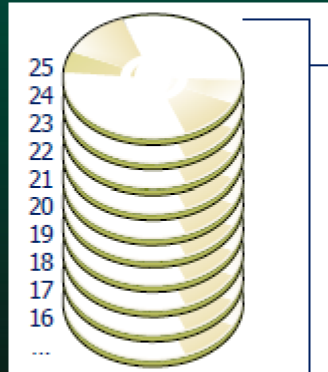


- Screen video

Results

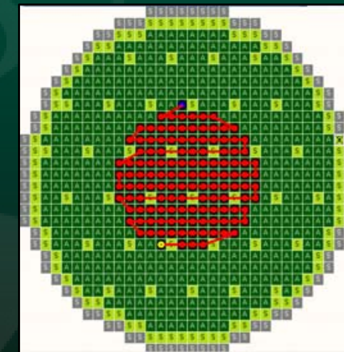


Validation wafers (lot level)



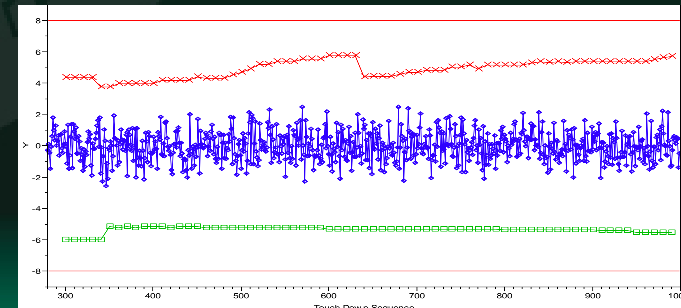
TTR candidate (wafer level)

Multi-layers TTR



Watchdog (die level)

By trend module



Adaptive TTR is triggered

Multi-layers TTR

Skip items

Reference dice

Trig events

Type Name	Test time saving	Remark
Type A	15 %	yield increase ~0.5% at WT with full detected by FT
Type B	16 %	yield increase ~0.6% at WT with full detected by FT
Type C	26 %	yield increase ~0.7% at WT with full detected by FT

Summary / Conclusion

- **Customers targets are not fully reached**
  - Average yield increase 0.6% (compared to 100% testing of same wafer)
    - final-test catches the "Slip-through" parts
  - Average test time reduction 19%
- **Adaptive TTR is definitely a solution to reduce cost of test.**
- **Maturity of the product**
  - More data to be used for analysis
  - Different TTR test-flows over time.
  - The better you understand the "connection" between tests, more reduction can be offered
  - Automatic test program optimization
- **Next to adaptive test time reduction, also additional tests can be activated for higher test coverage.**

Prediction

- **Within the next 2 years; adaptive TTR will be used for at least 30% of all semiconductor test.**

Follow-On Work

- **Improvements**
  - Analysis algorithms
  - Automatic recipe generation tool
  - Extend functionality to PCM-data processing
  - Extend supported platforms
  - Reporting functionality
- **Benefit overview IDM/Fab-less/OSAT**

Special thanks

- ITRS adaptive test committee
- Thijs Haarhuis SE (screen movie)