Highly Efficient DPPM Improvement Programs Depend on Pre-production and Post-probe Data Analysis

Michael Scott, Greg LaBonte
Test Advantage Inc.
June 14, 2006

TEST ADVANTAGE™
SOFTWARE

Toward Zero Defects

- There is an established relationship between Burn-In failures/ELFs and abnormal devices in the "Bin 1" population
- Quality is inversely proportional to ***"variance"***
  - Eliminating classified outlier devices from the Bin 1 population will reduce the number of early life failures

But……………

The Testing environment itself can be a source of "RISK" to measuring actual device "variance"

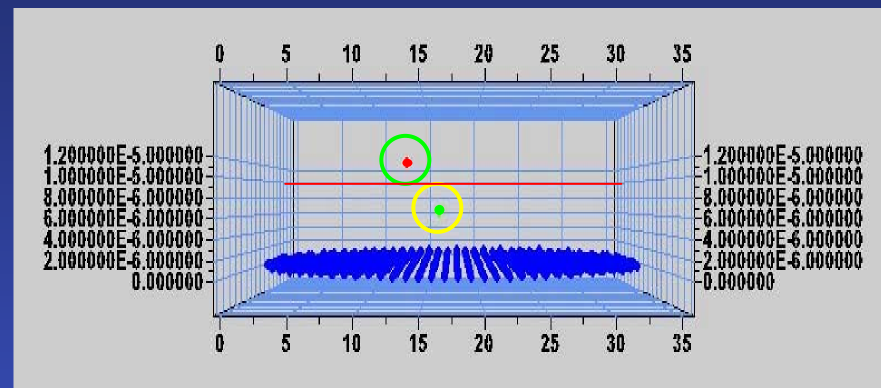
Agenda / Overview

The Keys to Enabling Accurate, Comprehensive, and Efficient DPPM Reduction

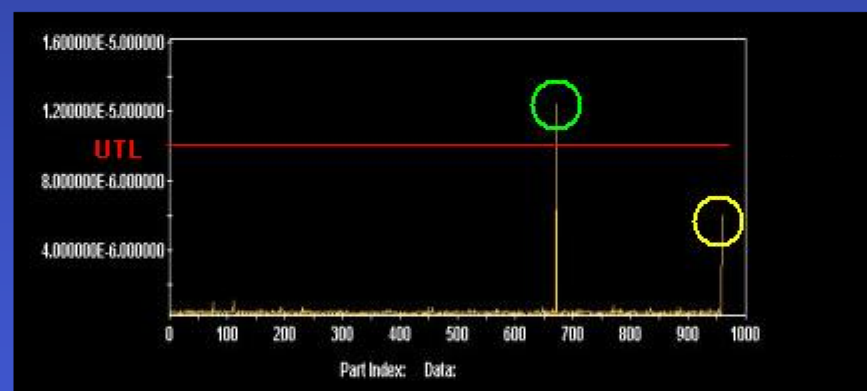
- Parametric and spatial outlier detection
- Quality of measured data
- Pre-production test program development
- Leverage of “hidden” information contained within the test data
- Post-probe outlier detection optimization
- Summary

Parametric Outlier

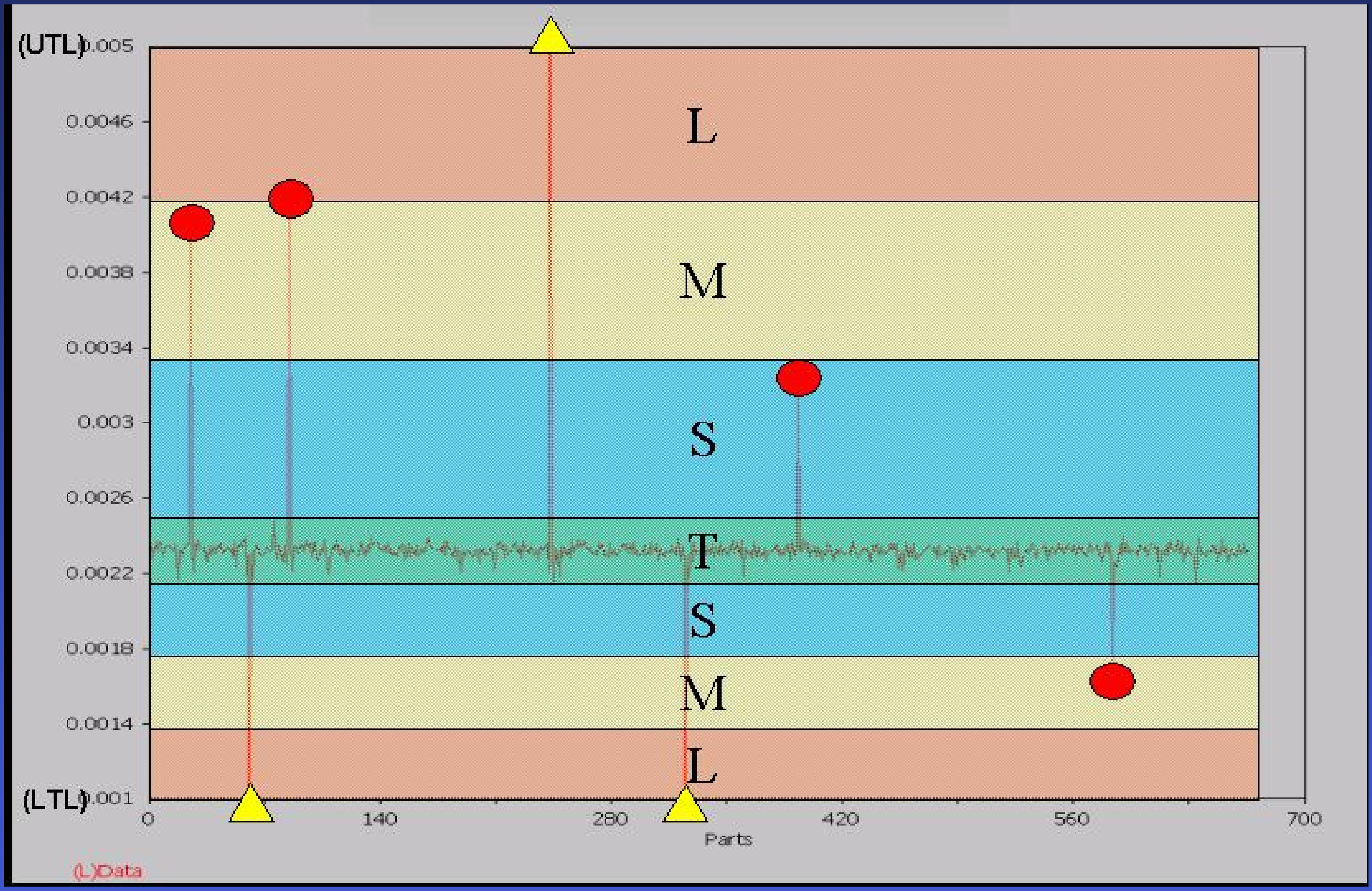
- Test failures – gross outlier removal

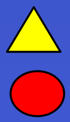


- Parametric Outliers – atypical results in Bin 1 population



Parametric Outlier Classifications





= Test Limit Failure / Outlier

= Bin 1 Outlier

Device Classification

Rules Managed via Recipe

- Outlier Device Classification using Magnitude and Frequency
- Specific Tests may be considered uniquely

Example Classification Rule:

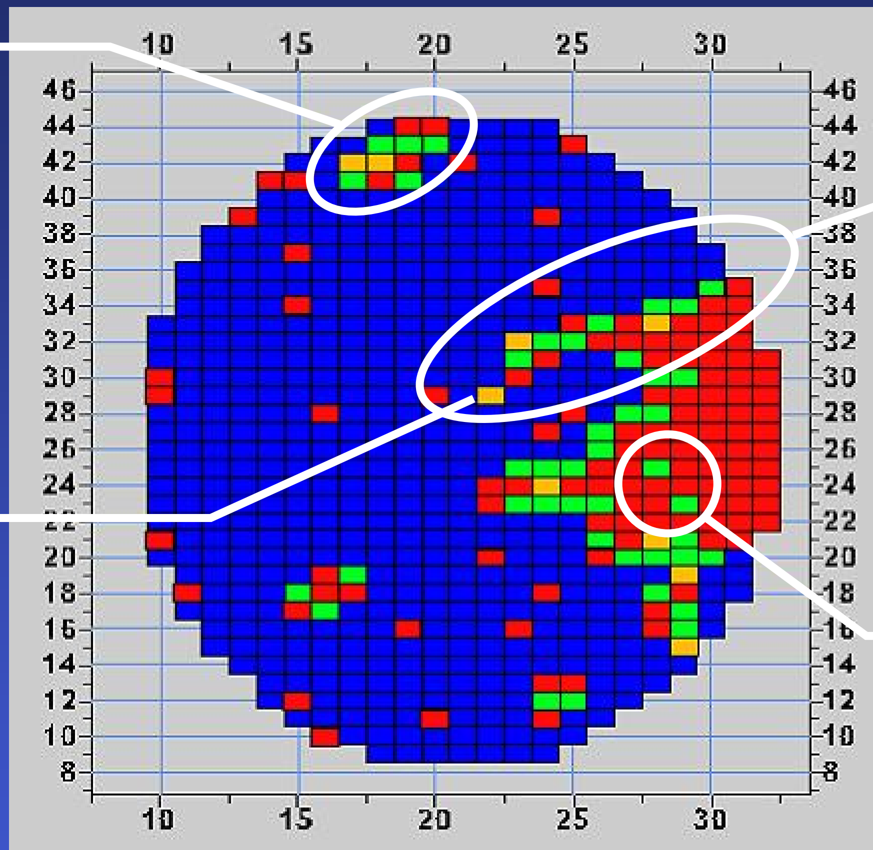
- Critical Device Outlier = L > 0 or M > 2 or S > 3 = Bin 25

A device may exhibit a smaller magnitude of variance but have this occurrence across multiple tests confirming a quality risk device

Spatial Outliers

Proximity weighting with smoothing

Guardbanding with smoothing



Parametric Outlier Devices comprehended in Spatial Analysis

Good Die in a Bad Neighborhood

Highly Efficient DPPM Improvement Programs Depend on Pre-production and Post-probe Data Analysis

Test Data Quality is a Key Requirement !

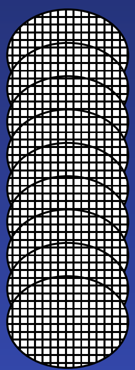
Data analysis automation

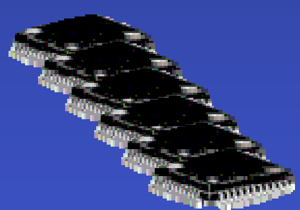
Speeds time to market, focusing Engineering talent on Problem resolution versus manually grinding through data

STANDARDIZED
Repeatable, automated, and objective analysis

Recommendations Report

Corrective Actions
Test Removal Candidates
Test Sampling Candidates



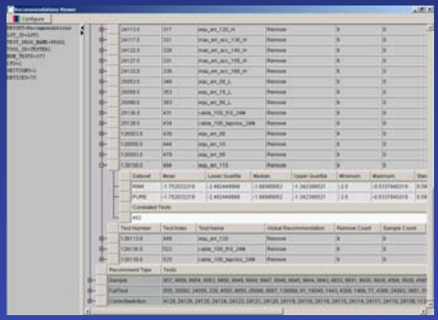


INPUT

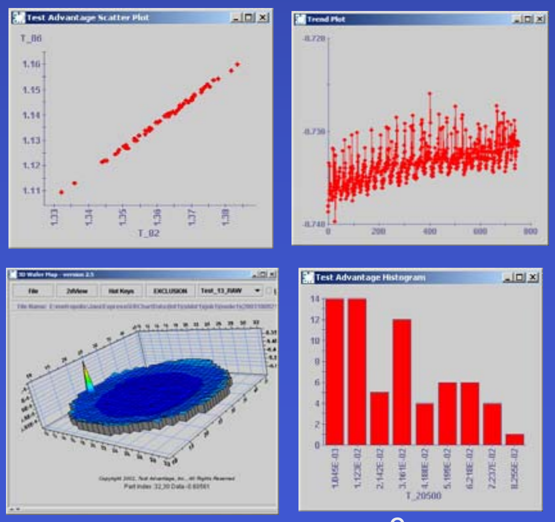
Express™

OUTPUT

INPUT



Recommendations Verification Tools



Non-intrusive, ATE independent – uses industry standard datalog format

Recipe driven approach produces an automated analysis, standardizing test program qualification

User definable, leveraging existing data analysis libraries

Determination of Poor Test Data "Quality"

- Automatically determine key elements contributing to Poor Quality Data
  - Multimodal distributions due to multisite variation
  - Clamping or poor resolution due to incorrect force/measurement ranges
  - Tester alarms due to incorrect configuration
  - Invalid test limits can allow bad devices to pollute the good device statistics
  - Etc
- Provide explicit feedback of ***Corrective Actions***

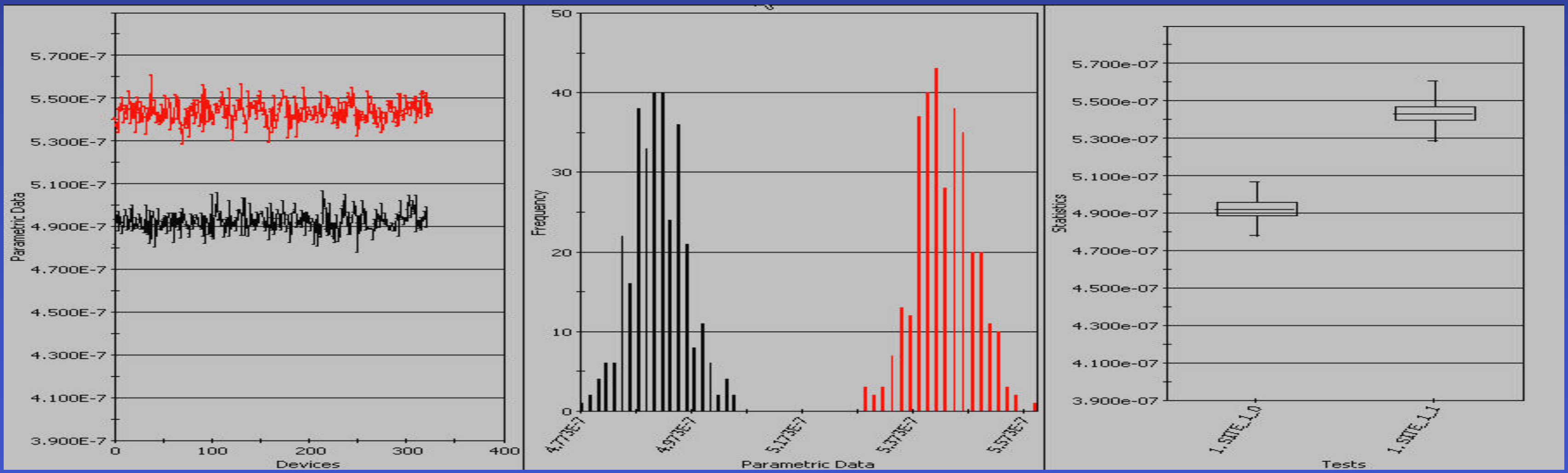
Multisite Variation

Test Index	Test Number	Test Name	Type	Recommendation	Information	Executed	Fails	Unique Count	UTL
165	165	Test_00165	P	Corrective	MultisiteVariation	652	0	647	1.500e-06

DataSet	Num	Cpk	Pci	Minimum	Q1	Q2	Mean	Q3	Maximum	STD Dev	IQR	Skewness	Kurtosis	L
RAW_ALL	650.0	4.067	7.740	4.780e-07	4.921e-07	5.307e-07	5.181e-07	5.431e-07	5.605e-07	2.608e-08	5.094e-08	-0.008998	-1.857	-

Section	Num	Cpk	Pci	Minimum	Q1	Q2	Mean	Q3	Maximum	STD Dev	IQR	Skewness	Kurtosis
SITE_1_0	322.0	19.83	20.24	4.780e-07	4.889e-07	4.921e-07	4.923e-07	4.957e-07	5.069e-07	4.915e-09	6.784e-09	0.1751	0.2142
SITE_1_1	328.0	21.76	21.53	5.285e-07	5.398e-07	5.430e-07	5.434e-07	5.471e-07	5.605e-07	5.260e-09	7.254e-09	0.06589	-0.02661

DataSet	Num	Cpk	Pci	Minimum	Q1	Q2	Mean	Q3	Maximum	STD Dev	IQR	Skewness	Kurtosis	L
PURE_ALL	650.0	4.067	7.740	4.780e-07	4.921e-07	5.307e-07	5.181e-07	5.431e-07	5.605e-07	2.608e-08	5.094e-08	-0.008998	-1.857	-

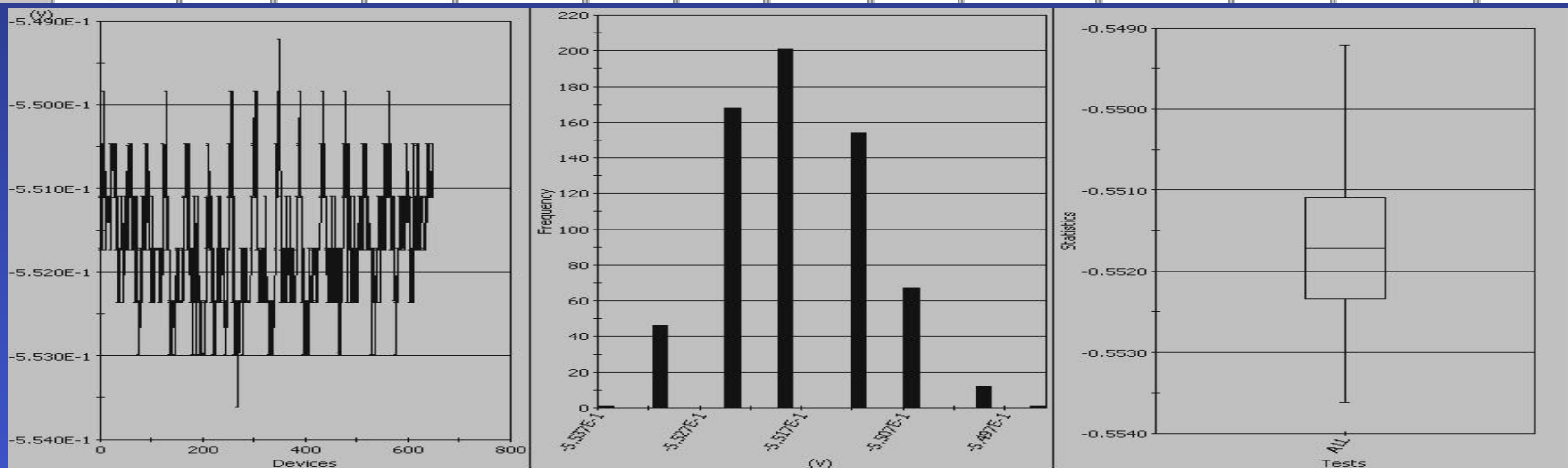


A measurement offset between two test sites has resulted in the detection of multisite variation, which requires engineering analysis into a possible hardware, software or calibration issue.

Poor Measurement Resolution

Test Index	Test Number	Test Name	Type	Recommendation	Information	Executed	Fails	Unique Count
183	183	Test_00183	P		Categorical, VeryHighCapability	652	0	13

DataSet	Num	Cpk	Pci	Minimum	Q1	Q2	Mean	Q3	Maximum	STD Dev	IQR	Skewness	Kurtosis
RAW_ALL	650.0	66.75	67.50	-0.5536	-0.5523	-0.5517	-0.5517	-0.5511	-0.5492	0.0007408	0.001251	0.2331	-0.3523
PURE_ALL	650.0	66.75	67.50	-0.5536	-0.5523	-0.5517	-0.5517	-0.5511	-0.5492	0.0007408	0.001251	0.2331	-0.3523



A low number of unique values, which result in a discontinuous (categorical) distribution histogram, may be as a result of a measurement resolution problem.

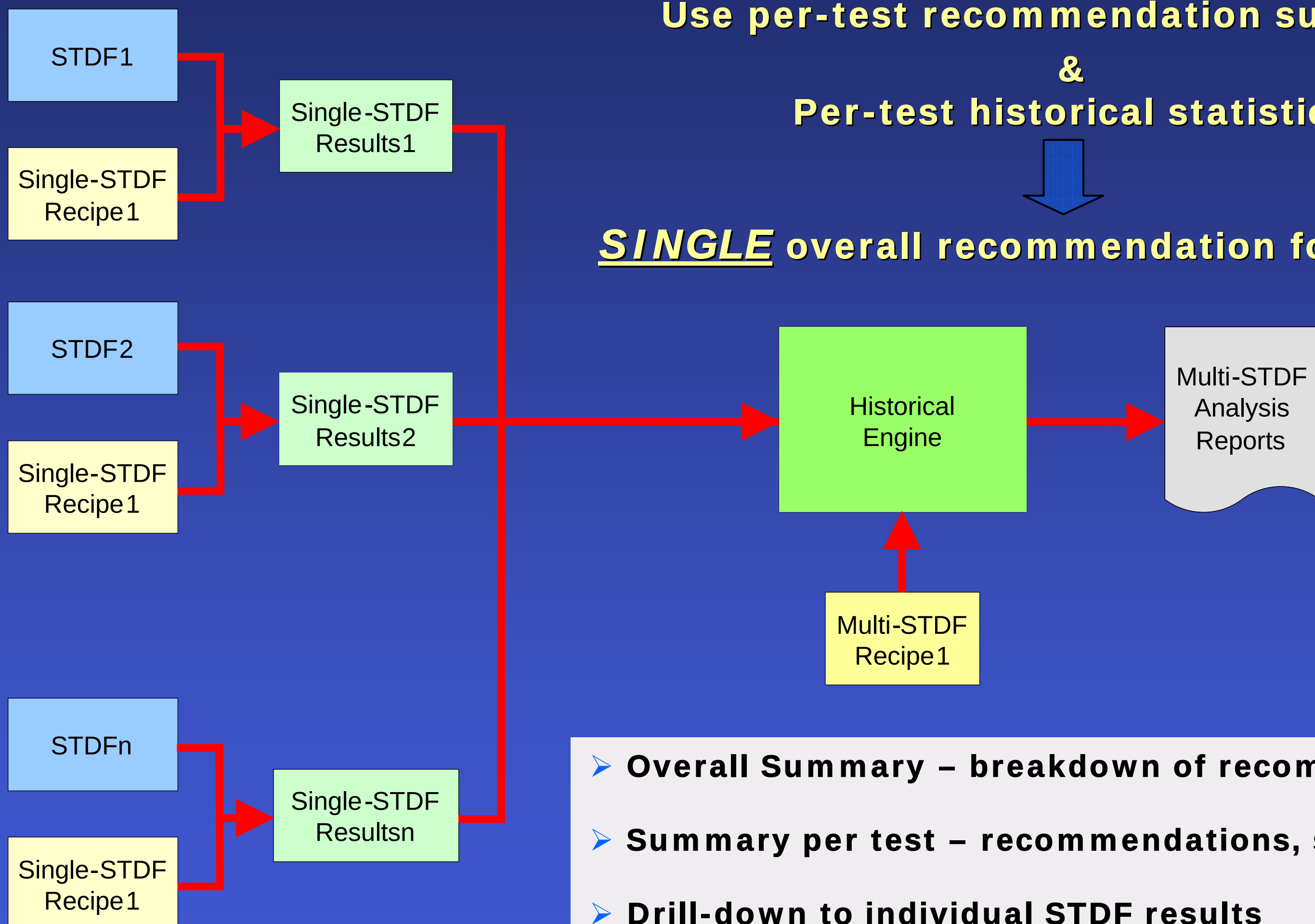
Tiered Analysis Strategy

Use per-test recommendation summary

&

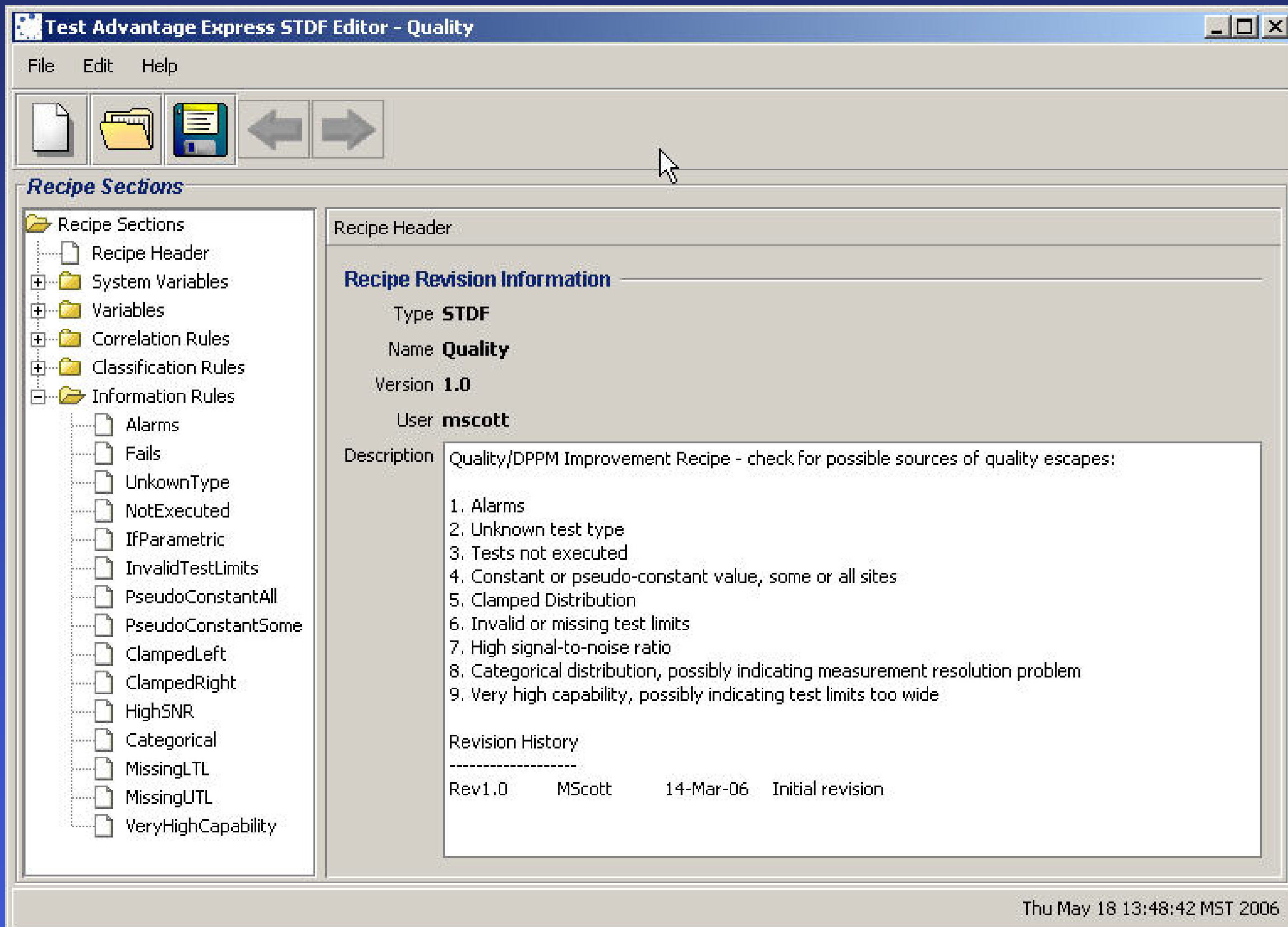
Per-test historical statistics

SINGLE **overall recommendation for each test**

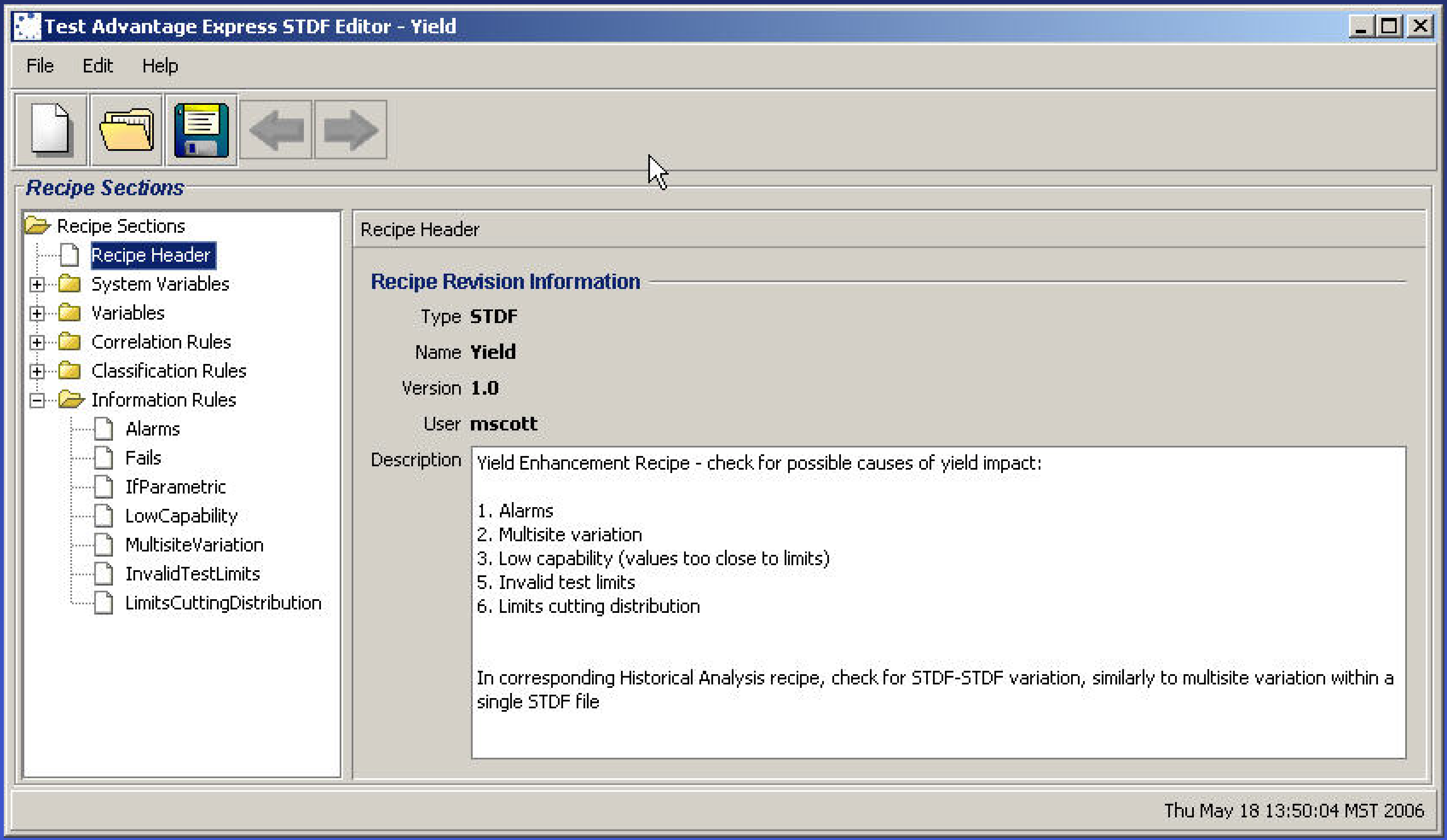


- **Overall Summary – breakdown of recommendations**
- **Summary per test – recommendations, statistics**
- **Drill-down to individual STDF results**
- **Single-click access to interactive charts**

Yield / DPPM Recipes



Yield / DPPM Recipes



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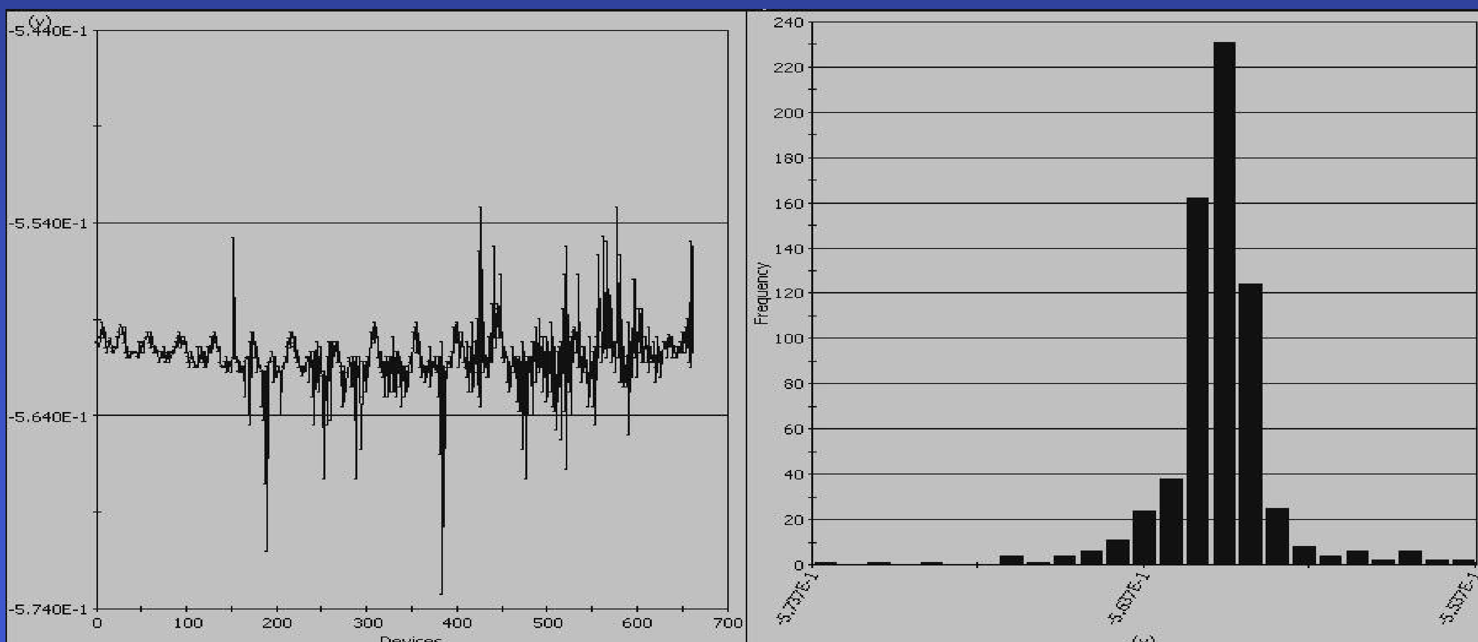
Hidden Data Opportunities for Improved Outlier Detection Coverage !

Improving Outlier Detection Coverage

- Tests with high outlier density
- Categorical low measurement resolution tests
- Correlated tests that have a directly relatable performance attribute may be considered for Regression Outlier analysis
- Corrective actions must be implemented for engineer-specified Crucial Parametric tests

Identify Tests with High Outlier Density

Test Index	Test Number	Test Name	Type	Recommendation	Information	Executed	Fails	Unique Count	UTL	LTL	Alarms	Inliers
15	15	Test_00015	P	HighOutlierDensity		665	0	62	-0.2500	-0.9000	0	623
51	51	Test_00051	P	HighOutlierDensity		659	0	228	1.000	0.07000	0	586
91	91	Test_00091	P	HighOutlierDensity		653	0	52	1.000e-05	-1.000e-05	0	601
100	100	Test_00100	P	HighOutlierDensity		653	0	386	2.000	0.3000	0	608
101	101	Test_00101	P	HighOutlierDensity		653	0	348	2.700	0.3000	0	609

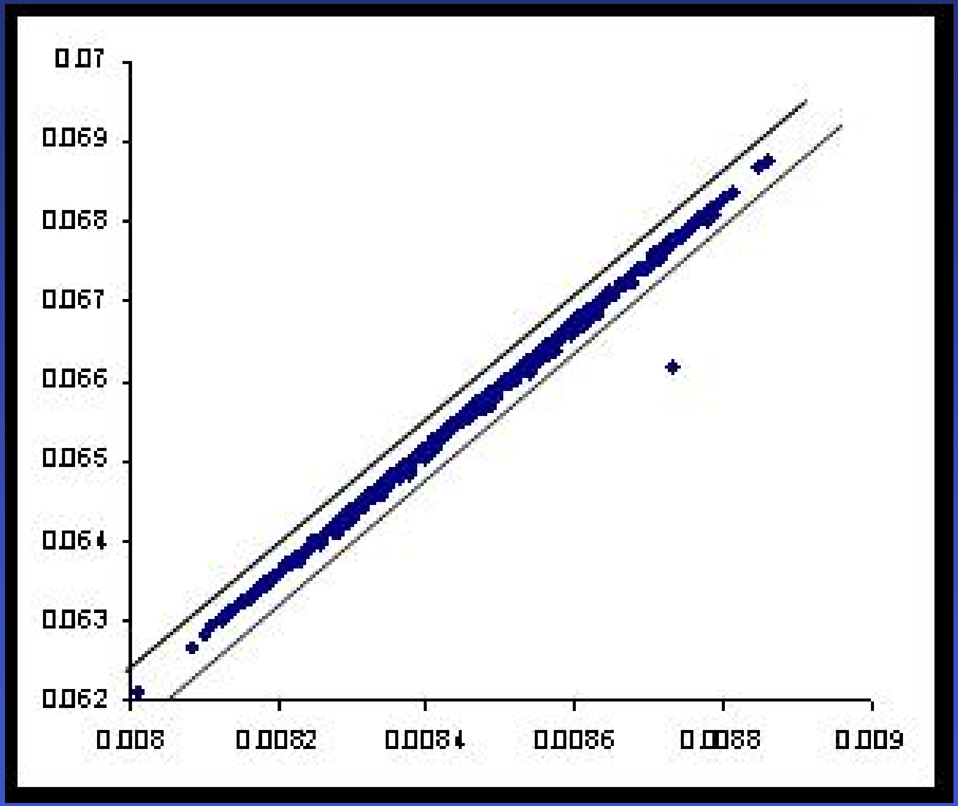


Regression Outliers

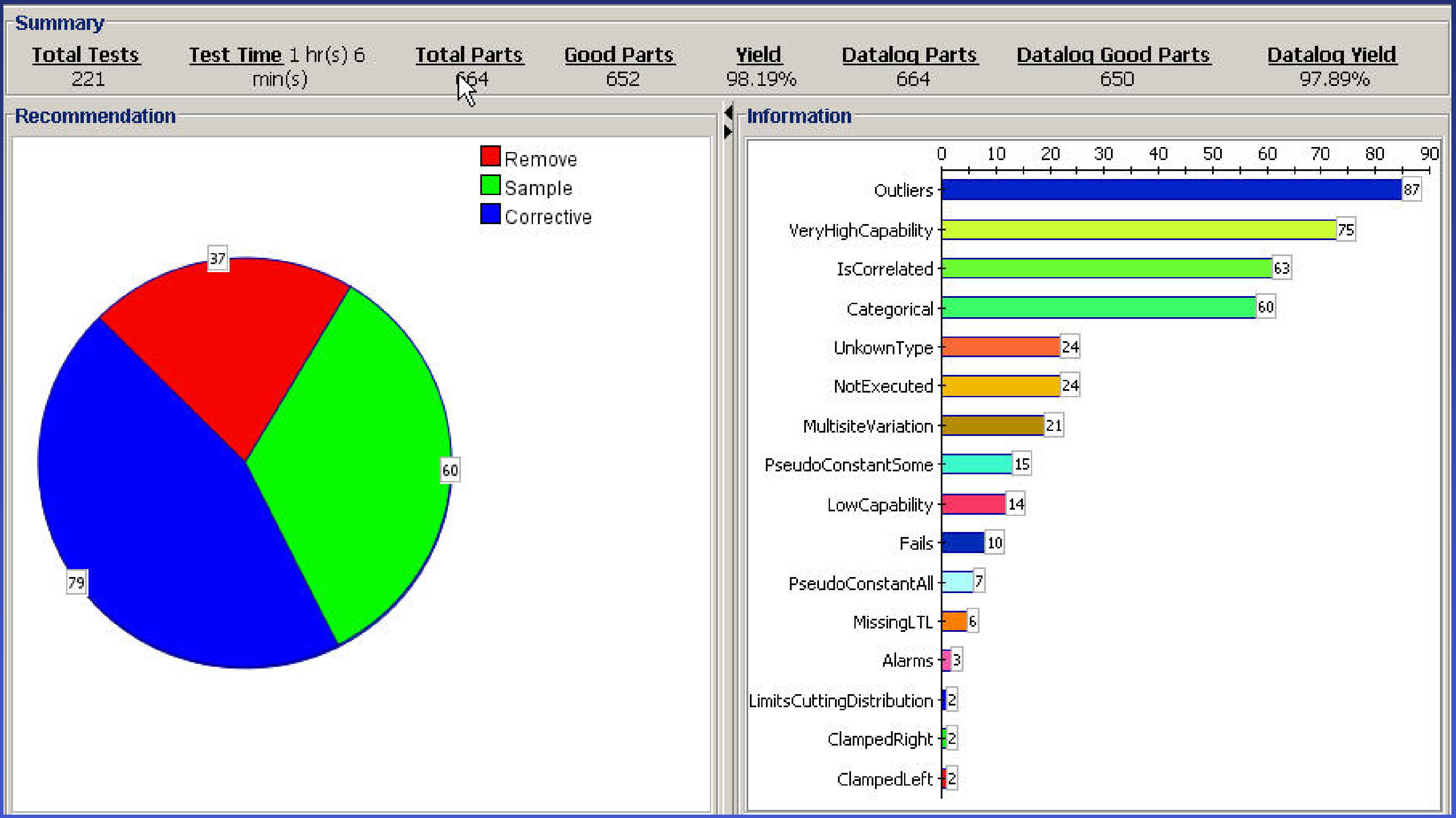
TestNumber	TestName	RuleType	RuleIndex	RuleName	RuleExpression	RuleValue	CORR_THRESHOLD	CorrTests
20	Test_00020	MAIN	1	Correlated	IsCorrelated	TRUE	0.87500	[26.0, 32.0]
23	Test_00023	MAIN	1	Correlated	IsCorrelated	TRUE	0.87500	[25.0]
25	Test_00025	MAIN	1	Correlated	IsCorrelated	TRUE	0.87500	[23.0]
26	Test_00026	MAIN	1	Correlated	IsCorrelated	TRUE	0.87500	[20.0, 32.0]
29	Test_00029	MAIN	1	Correlated	IsCorrelated	TRUE	0.87500	[31.0]
31	Test_00031	MAIN	1	Correlated	IsCorrelated	TRUE	0.87500	[29.0]
32	Test_00032	MAIN	1	Correlated	IsCorrelated	TRUE	0.87500	[20.0, 26.0]
35	Test_00035	MAIN	1	Correlated	IsCorrelated	TRUE	0.87500	[40.0, 41.0, 42.0, 43.0, 44.0, 45.0, 46.0, 47.0, 48.0, 54.0, 65.0, 129.0,
37	Test_00037	MAIN	1	Correlated	IsCorrelated	TRUE	0.87500	[38.0]
38	Test_00038	MAIN	1	Correlated	IsCorrelated	TRUE	0.87500	[37.0]
40	Test_00040	MAIN	1	Correlated	IsCorrelated	TRUE	0.87500	[35.0, 41.0, 42.0, 43.0, 44.0, 45.0, 46.0, 47.0, 48.0, 54.0, 65.0, 129.0,
41	Test_00041	MAIN	1	Correlated	IsCorrelated	TRUE	0.87500	[35.0, 40.0, 42.0, 43.0, 44.0, 45.0, 46.0, 47.0, 48.0, 54.0, 65.0, 129.0,
42	Test_00042	MAIN	1	Correlated	IsCorrelated	TRUE	0.87500	[35.0, 40.0, 41.0, 43.0, 44.0, 45.0, 46.0, 47.0, 48.0, 54.0, 65.0, 129.0,
43	Test_00043	MAIN	1	Correlated	IsCorrelated	TRUE	0.87500	[35.0, 40.0, 41.0, 42.0, 44.0, 45.0, 46.0, 47.0, 48.0, 54.0, 65.0, 129.0,
44	Test_00044	MAIN	1	Correlated	IsCorrelated	TRUE	0.87500	[35.0, 40.0, 41.0, 42.0, 43.0, 45.0, 46.0, 47.0, 48.0, 54.0, 65.0, 129.0,
45	Test_00045	MAIN	1	Correlated	IsCorrelated	TRUE	0.87500	[35.0, 40.0, 41.0, 42.0, 43.0, 44.0, 46.0, 47.0, 48.0, 54.0, 65.0, 129.0,
46	Test_00046	MAIN	1	Correlated	IsCorrelated	TRUE	0.87500	[35.0, 40.0, 41.0, 42.0, 43.0, 44.0, 45.0, 47.0, 48.0, 54.0, 65.0, 129.0,
47	Test_00047	MAIN	1	Correlated	IsCorrelated	TRUE	0.87500	[35.0, 40.0, 41.0, 42.0, 43.0, 44.0, 45.0, 46.0, 48.0, 54.0, 65.0, 129.0,
48	Test_00048	MAIN	1	Correlated	IsCorrelated	TRUE	0.87500	[35.0, 40.0, 41.0, 42.0, 43.0, 44.0, 45.0, 46.0, 47.0, 54.0, 65.0, 129.0,

- Can utilize high correlation factors to identify inter-dependent tests
- Outlier devices do not conform to the underlying relationship, but may still be within main distribution for both tests
- Computationally intensive – need to identify candidate tests up front

Regression Outliers



Recommendations



Highly Efficient DPPM Improvement Programs Depend on Pre-production and Post-probe Data Analysis

Outlier Detection is a Key Component of Robust Electronic Devices Processing

Elements for Comprehensive Outlier Detection

- Automatic processing of ALL data distribution types
- Automatic application of outlier detection algorithms on a per wafer per test basis
- Operates on ALL parametric tests automatically
- Comprehension of Test Limits and asymmetrical data distributions in determining control limit locations
- Advanced Spatial Outlier Detection
- Ease of setup with revision controlled Recipes

Geographic Analysis Requirements

Comprehend test fail bins and parametric analysis bin results per ***Electrical Wafer Sort Flow***

Flexible recipe defined Spatial Analysis

- Detection of repeating patterns
- **Good** die in **Bad** neighborhood
- Cluster Detection

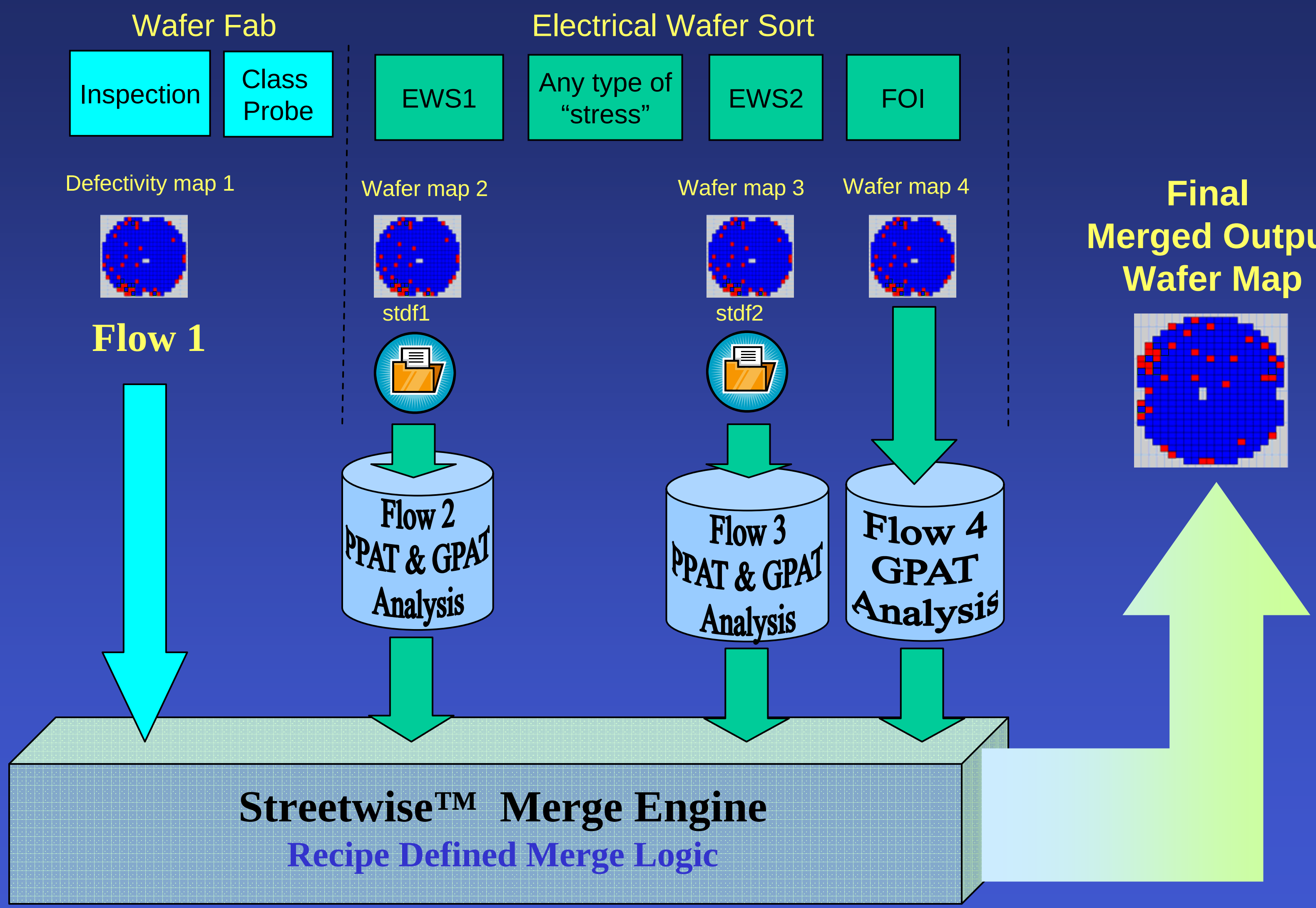
Proximity Analysis Based on a Specified Bin number or numbers

- Wafer edge weighting
- Corner weighting
- Guard banding
- Smoothing

Composite Lot Analysis

- Superimpose lot level wafer maps and perform analysis per X/Y coordinate based on user defined defect density.

Multi-Flow Analysis & Support

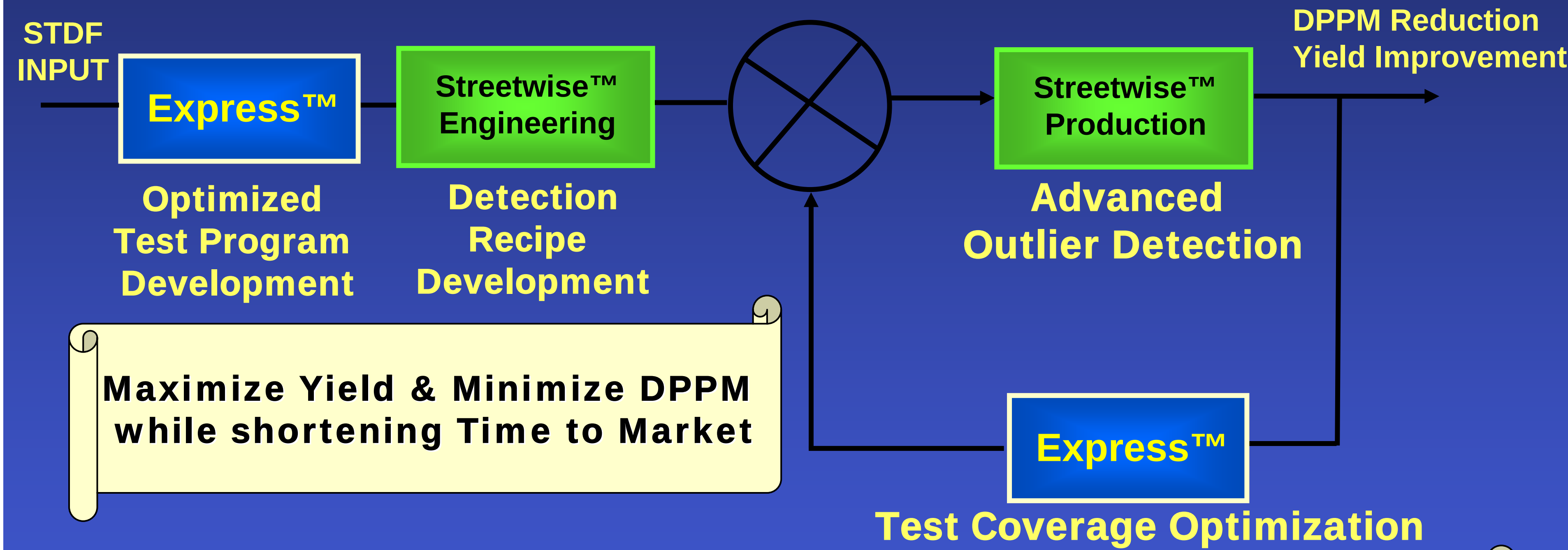


Highly Efficient DPPM Improvement Programs Depend on Pre-production and Post-probe Data Analysis

Summary and Results
Key Elements for Success

Closed-Loop Framework

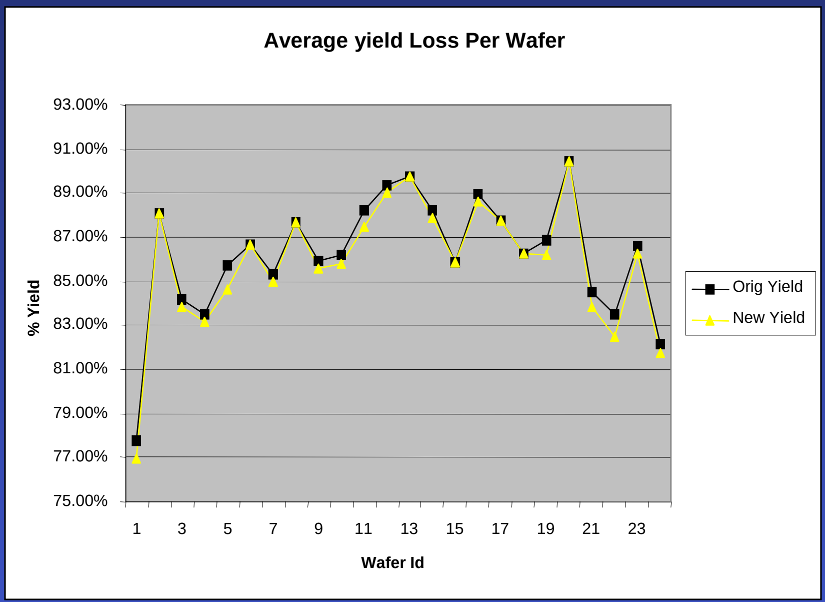
Streetwise™ & Express™ Processes



Maximize Yield & Minimize DPPM while shortening Time to Market

Continuous productivity improvement from initial production release through product maturity phases

Accurate Post-Probe Outlier Detection



Wafer id	Parts	Passed	Failed	Critical Outlier	Orig Yield	New Yield	Delta
2	256	199	57	2	77.73%	76.95%	-0.78%
3	294	259	35	0	88.10%	88.10%	0.00%
4	291	245	46	1	84.19%	83.85%	-0.34%
5	285	238	47	1	83.51%	83.16%	-0.35%
6	287	246	41	3	85.71%	84.67%	-1.05%
7	292	253	39	0	86.64%	86.64%	0.00%
8	293	250	43	1	85.32%	84.98%	-0.34%
9	301	264	37	0	87.71%	87.71%	0.00%
10	277	238	39	1	85.92%	85.56%	-0.36%
11	275	237	38	1	86.18%	85.82%	-0.36%
12	280	247	33	2	88.21%	87.50%	-0.71%
13	291	260	31	1	89.35%	89.00%	-0.34%
14	294	264	30	0	89.80%	89.80%	0.00%
15	280	247	33	1	88.21%	87.86%	-0.36%
16	290	249	41	0	85.86%	85.86%	0.00%
17	290	258	32	1	88.97%	88.62%	-0.34%
18	294	258	36	0	87.76%	87.76%	0.00%
19	284	245	39	0	86.27%	86.27%	0.00%
20	290	252	38	2	86.90%	86.21%	-0.69%
21	283	256	27	0	90.46%	90.46%	0.00%
22	284	240	44	2	84.51%	83.80%	-0.70%
23	291	243	48	3	83.51%	82.47%	-1.03%
24	299	259	40	1	86.62%	86.29%	-0.33%
25	274	225	49	1	82.12%	81.75%	-0.36%

Average Yield Loss -0.35%

Typical yield impact -0.35%

Highly Efficient DPPM Reduction with Minimum Yield Loss

Toward Zero Defect Production

- Automated Data Analysis for Optimized Test program Development
  - Reduced Time to Market
  - Maximum Test Data Quality
  - Enhanced Outlier Detection Coverage
  - Continuous Production Efficiency Improvement
- Accurate and Efficient Outlier Detection Methodology
  - Adaptive Per Wafer Per Test Analysis
  - Parametric Outlier Device Classification
  - Advanced Flexible Geographic Analysis
  - Complete, Fully Integrated Automatic Production Solution

Automated Closed Loop Process Optimization