



Beta Test Results for a Yield Optimizer

***William Martin, Jill Card, An Carlson
NeuMath, Inc***

***Paul Fearon, Loren Krott, Aaron Dries
National Semiconductor Corporation***

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Agenda

- **Executive Summary**
- **Beta Test Overview**
- **Results**
- **Discussion**
- **Conclusion**

Executive Summary

- Goal: **Beta test NeuMath Yield Optimizer on production line**
- Data: **Mid-May to Mid Sep, 2005**
- Process modifications: **4 metrology target adjustments implemented**
- Results:
 1. Average **10.9%** yield improvement achieved when new target adjustments approached
 2. Best result **15.3%** increase for lot most closely achieving new metrology targets
 3. Average yield improvement from start of process changes is **8.2%**.
 4. Metrology target adjustments contribution estimated at **8%** to total Yield increase.
 5. Defect reduction activities estimated to increase Yield **2.9%**

Beta Test Overview

- Yield Optimizer was used on line for a CMOS process line to improve yield in real time.
- Yield refers to percent-good-die (good-bins in Yield Optimizer screenshots).
- Yield Optimizer takes metrologies as inputs, predicts final yield and ET results, and recommends adjustments to metrology targets.
- Total 15 products, 1025 lots are monitored.
- We focus on one product in this report.
- Final results are lot-based.

Process Modifications

- **Process modifications were determined based on the Yield Optimizer recommendations.**
- **Four metrology target adjustments were implemented**

Summary of Modifications

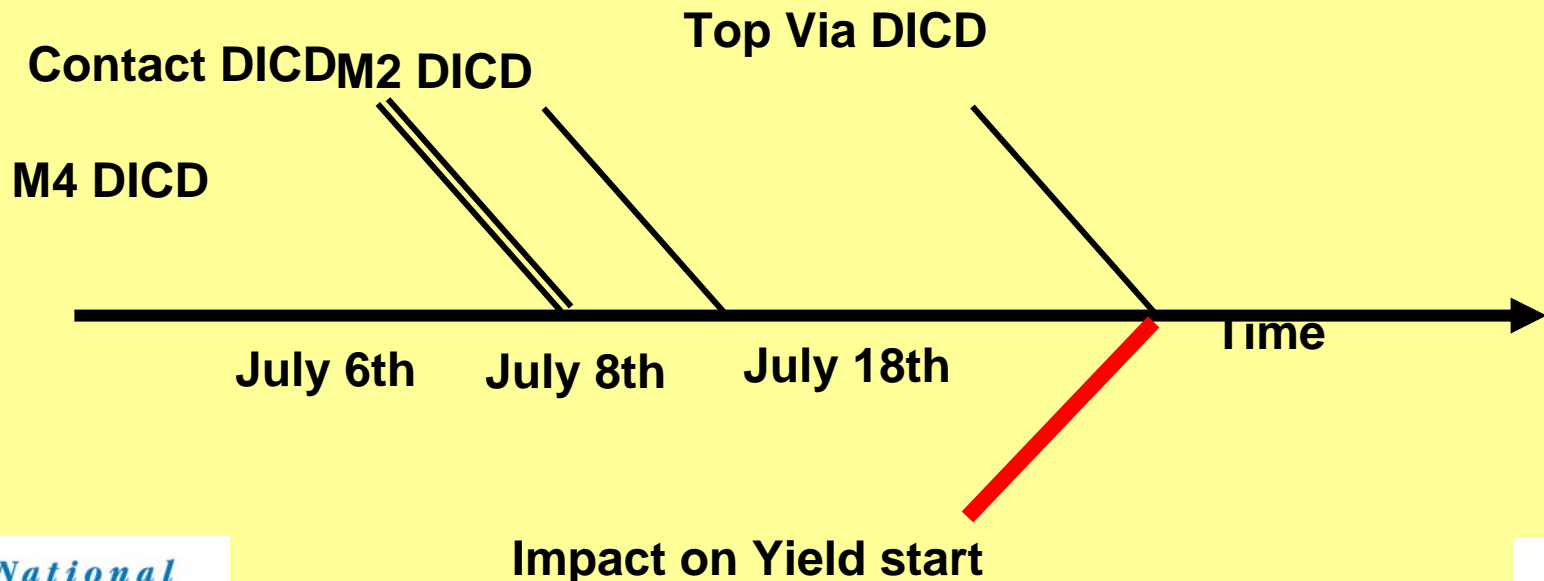
- **Process Modifications:**

Reduce Top Via DICD from .370 to .360

Reduce Contact DICD from .299 to .292

Reduce M2 DICD from .244 to .237

M4 FICD change from .280 to .289



Contact DICD

Select Product

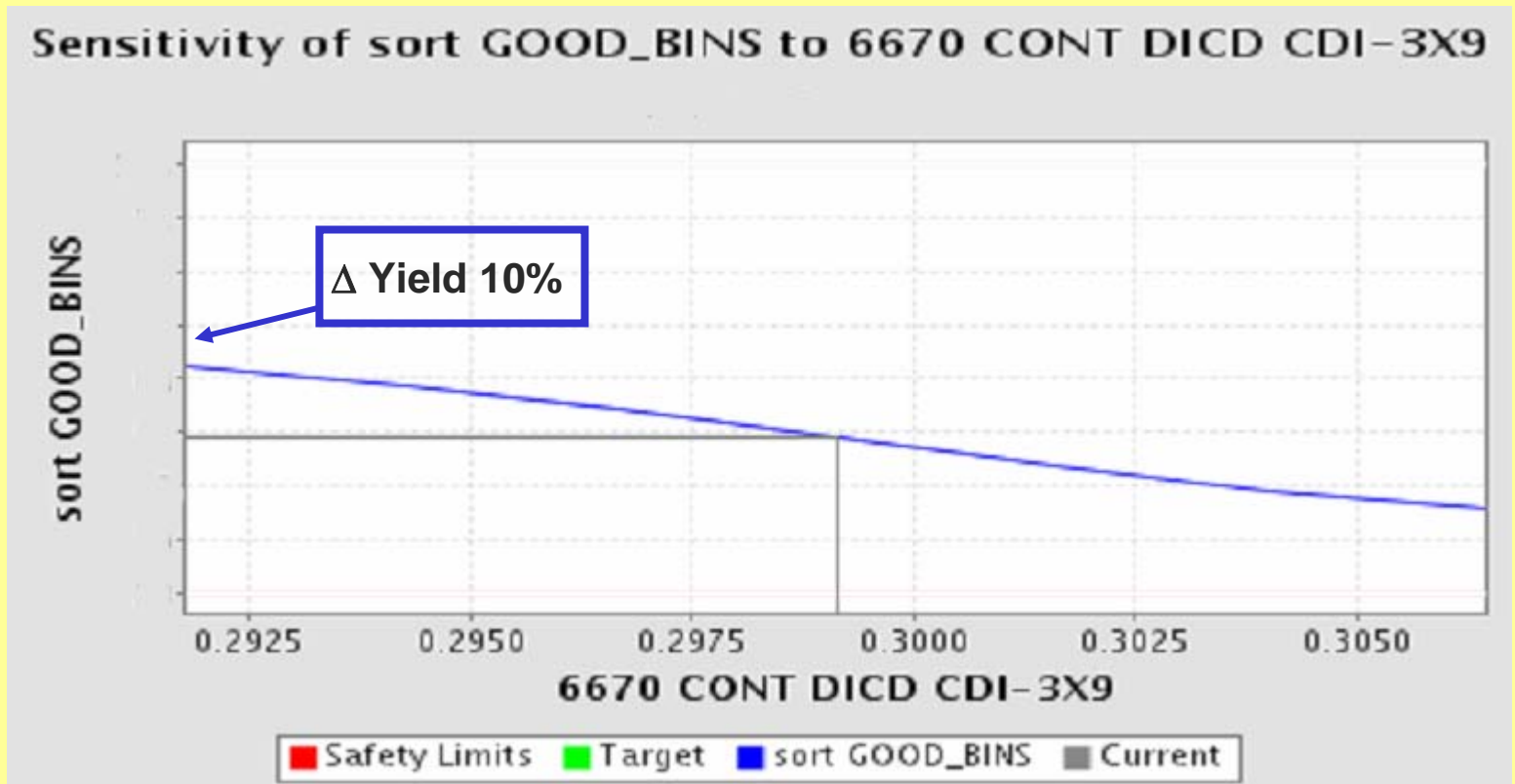
Operation	Variable Name	Original Value	New Value		Frequency
6670 CONT DICD	CDI-3X9	0.299	0.292	X	0.0
9016 M4 DICD	DI-DELTA-1X9	0	-0.007	X	0.0
9225 VIA4 FICD	BIAS9	-0.014	-0.006	X	0.0

Operation	Variable Name	Original Value	New Value		Frequency
6670 CONT DICD	CDI-3X9	0.299	0.292	X	0.0
9016 M4 DICD	DI-DELTA-1X9	0	-0.007	X	0.0
9225 VIA4 FICD	BIAS9	-0.014	-0.006	X	0.0

sort	BIN13	5.879	-0.632		
sort	GOOD_BINS	X	X+19.711	X	
sort	BIN10	1.569	1.569	X	
sort	BIN28	1.227	1.227	X	
sort	BIN24	0.507	0.567	X	
sort	BIN9	1.461	1.461	X	
sort	BIN37	15.17	15.17		
sort	BIN12	19.93	16.924	X	
ET	BC_M4_P28_IBR	-11.623	-11.426	X	
ET	CH_V4_RCON	3.509	3.509	X	
ET	P_3V_10X0P3_IOFF	-0	-0	X	

Contact DICD Sensitivity

Predicted 10% yield improvement.



Top Via DICD

Changed from .37 to .36 on July 18th
 Predicted 4% yield improvement

Select Product ▼

Operation	Variable Name	Original Value	New Value	
8020 M2 FICD	BIAS9	0.028	0.022	
9350 T-VIADICD	DI-DELTA-1X9	-0.004	-0.015	
sort	BIN 11	1.755	1.755	
sort	BIN 9	1.476	1.476	
sort	GOOD_BINS	Y	Y+4.640	
sort	BIN 12	20.539	9.263	
sort	BIN 37	15.352	13.081	

ET	CON_M5_P28_RCON	539.493	539.493	
ET	P_3V_OP22X10_IOFF	-0	-0	
ET	CH_V4_RCON	3.57	3.424	
ET	RC_P1V_P25_VBR	20	20	

Optimization 1 of 11 New Cost is 1339.45 Show Breakdown

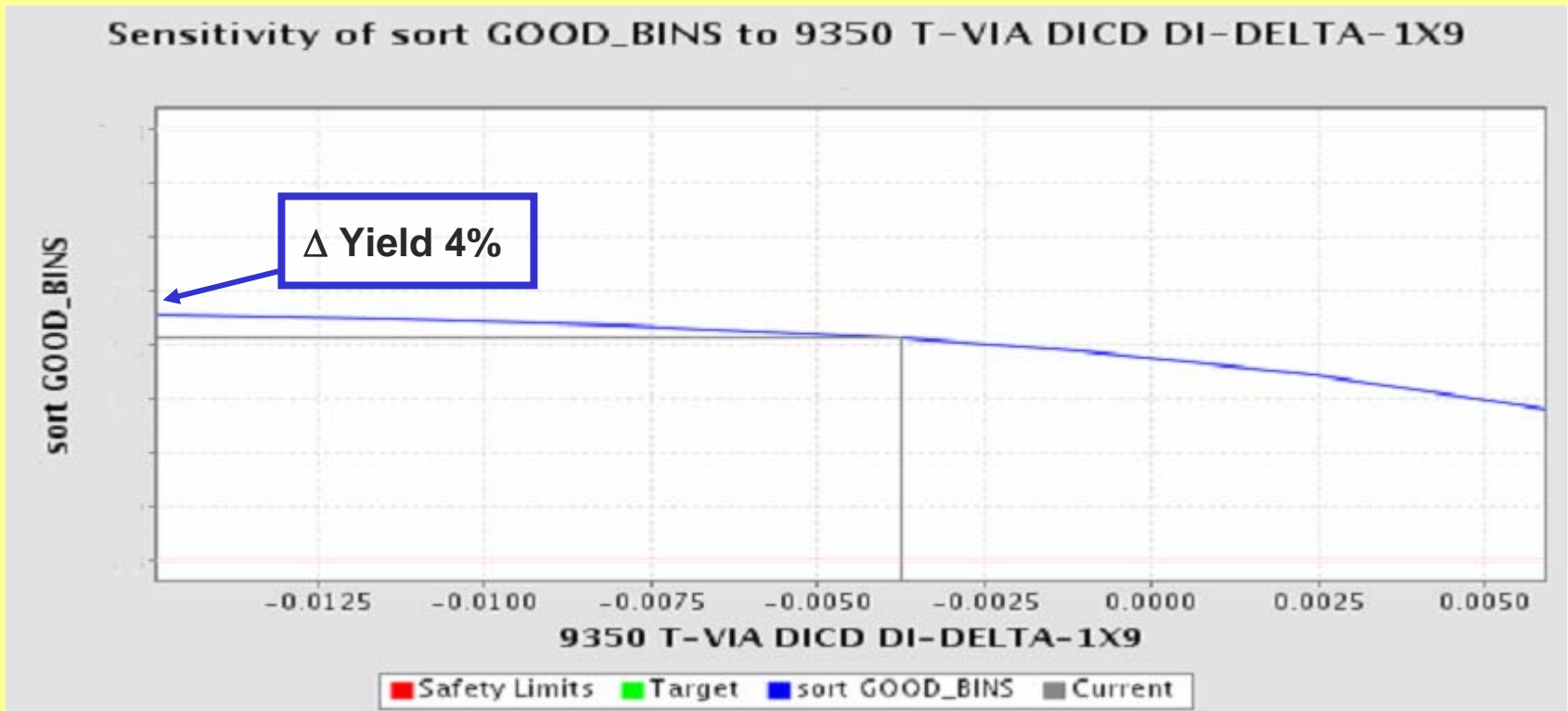
Baseline Prediction Optimizations Optimization Frequency Sensitivity

Baseline cost is 1522.84

Run Analysis Refresh



Top Via Sensitivity

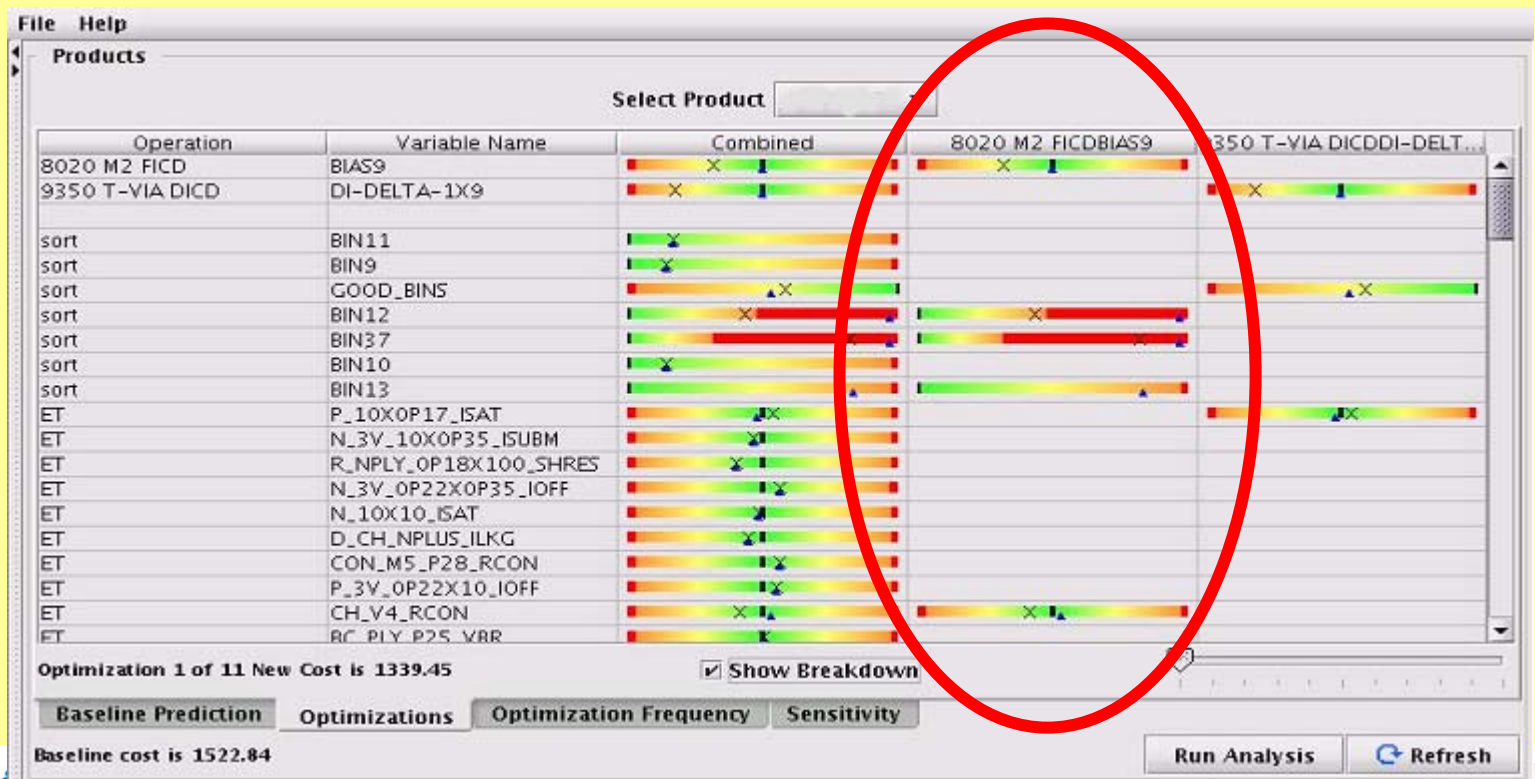


Tick mark is 10% yield

M2 FICD

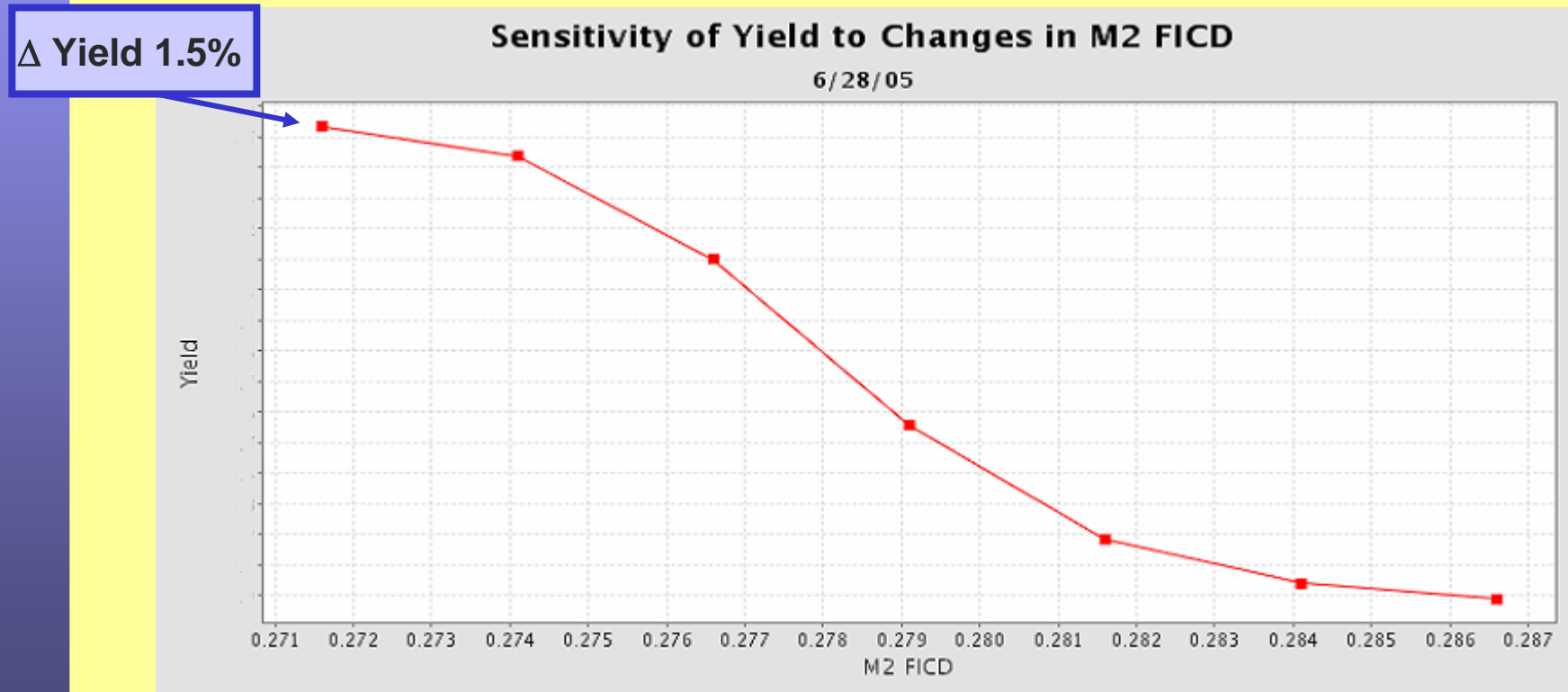
Changed on M2 DICD .244 to .237 on July 8th

Predicted to have small or no impact on yield directly






M2 FICD Sensitivity

A small (1-1.5%) yield improvement is possible



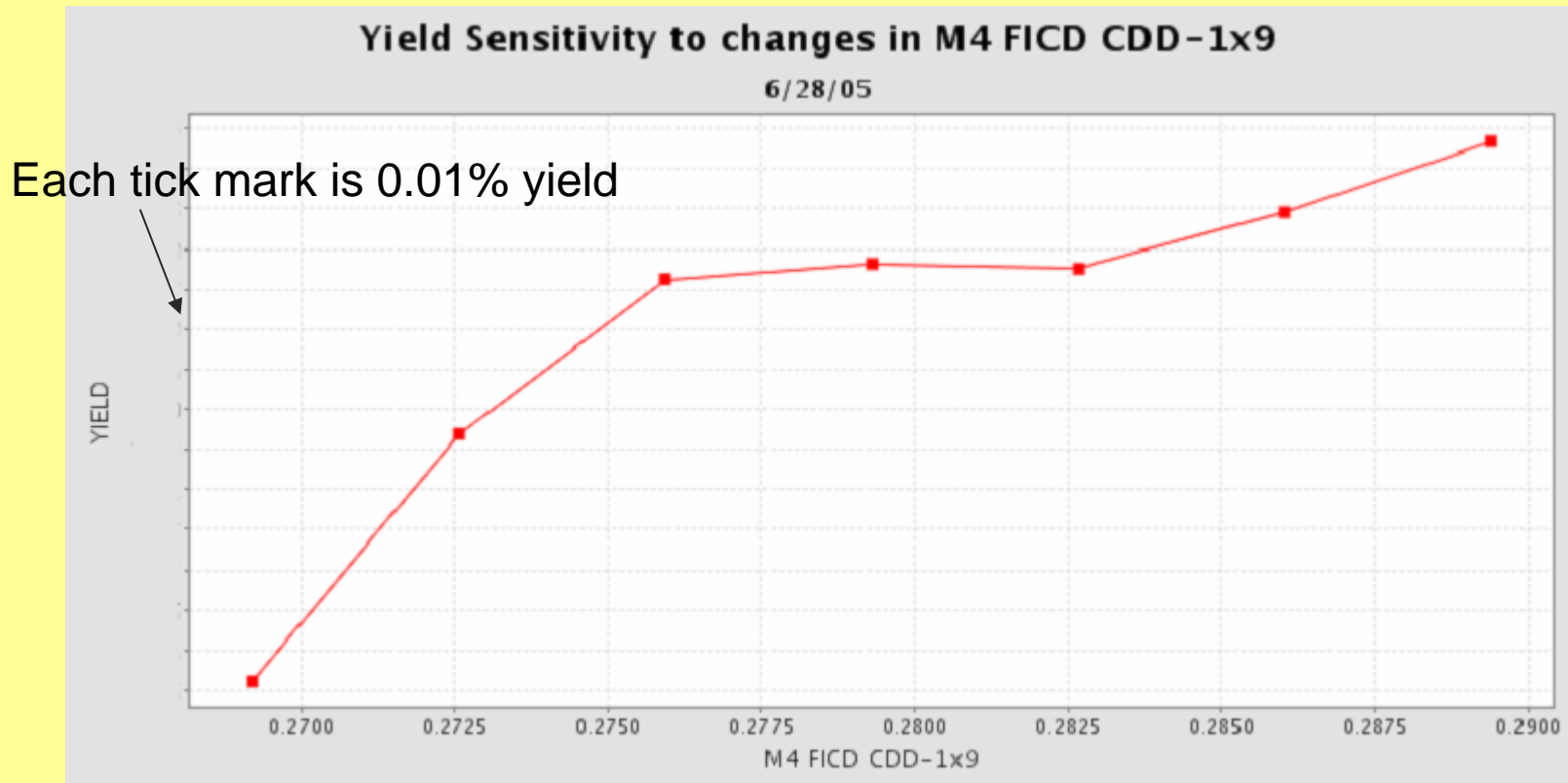
M4 FICD

Changed from 0.280 to 0.289

Operation	Variable Name	Original Value	New Value	
6670 CONT DICD	CDI-3X9	0.299	0.292	
9016 M4 DICD	WMR_TOP_RESULT	0.188	0.179	
9050 M4 FICD	CDD-1X9	0.279	0.289	

M4 FICD Sensitivity

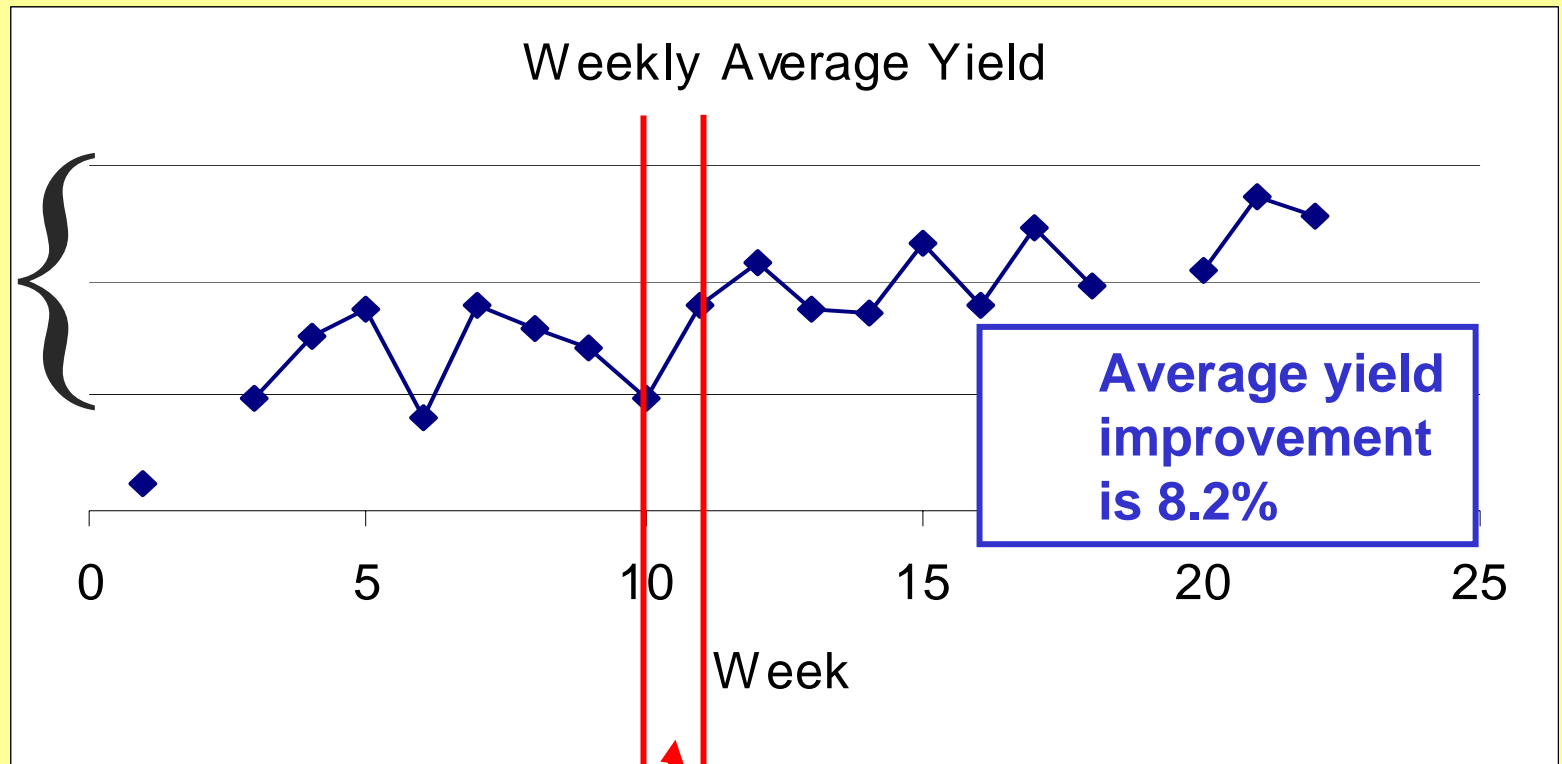
A minor (0.15%) yield improvement is possible



Results

- **Compare yield before and after the process modifications**
- **Compare the yield for lots which met (or approached) the target - to lots which did not meet the target**
- **Compare the results with Yield Optimizer predictions**

Yield Before, During and After the Modifications



During the modifications

Yield During the Modification Period

Group	Delta Yield	Top_Via_DICD	Contact_CD	M2_DICD	M4_FICD	Number of lots
No Changes (stand error)	0 = Baseline	0.371 0.001	0.297 0.001	0.250 0.000	0.276 0.001	30
Changed Only M4 FICD (stand error)	5.22	0.372 0.002	0.293 0.001	0.251 0.001	0.282 0.002	6
Changed M2 DICD and M4 FICD (stand error)	7.51	0.386 0.000	0.294 0.000	0.247 0.000	0.273 0.000	1
Changed Top Via and M4 FICD (stand error)	5.49	0.371 0.000	0.307 0.000	0.245 0.000	0.287 0.000	1
Changed Top Via, M2 DICD and M4 FICD (stand error)	8.73	0.366 0.002	0.296 0.001	0.241 0.002	0.280 0.001	9
All 4 Changes (stand error)	8.16	0.362 0.001	0.291 0.000	0.242 0.001	0.286 0.001	29

Yield increases even during the modification process, indicating that moving towards the new targets alone benefits the final yield, even if targets are not met .

Results

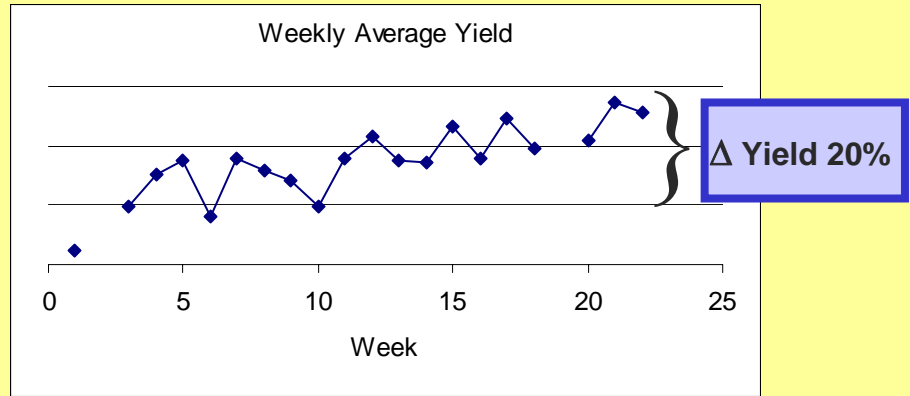
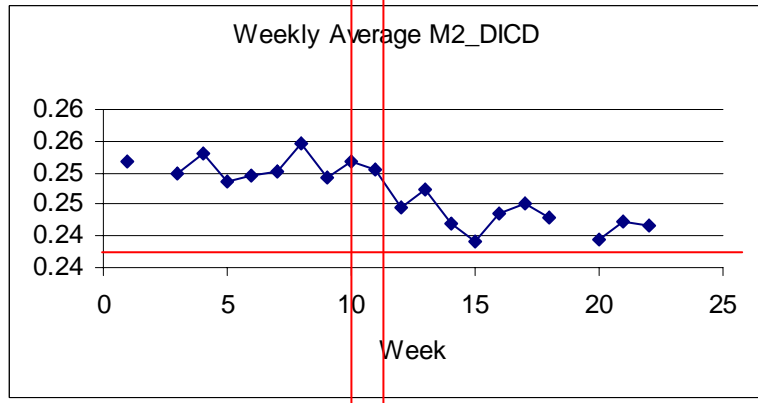
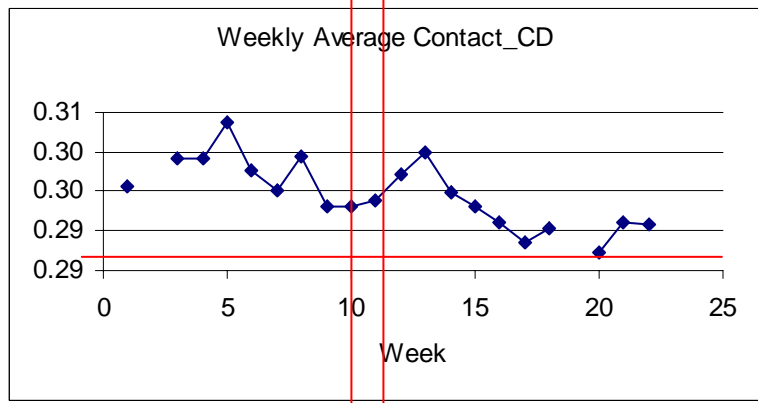
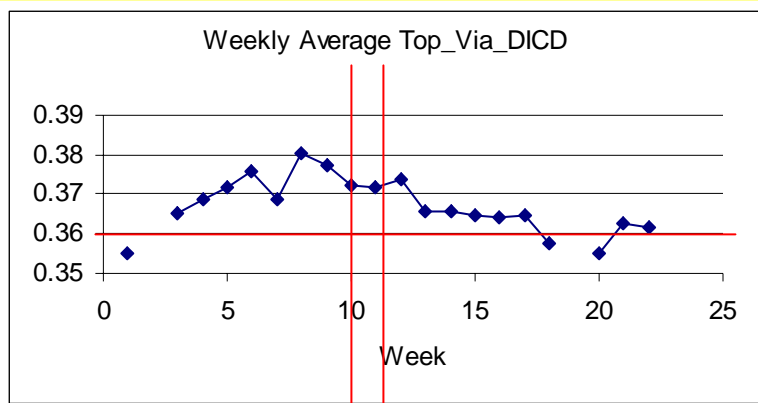
- Compare yield before and after the process modifications
- **Compare the yield for lots which met (or approached) the target - to lots which did not meet the target**
- Compare the results with Yield Optimizer predictions

Yield Difference - Lots Meet or Approach Targets

**All lots are after the modification.
All show at least 5% yield improvement over lots before modifications**

GROUP	Δ Yield	TOP				
Change Recommended		(0.371)				
Before Test: No Changes	0% (Baseline)	0.371	0.297	0.251	0.276	30
After test: Approach targets but none hit target	8.24%	0.370	0.293	0.243	0.283	11
Hit Only M4 FICD		0.298	0.245	0.289		2
Hit Only M2 DICD		0.299	0.235	0.281		1
Hit Only Contact		0.292	0.245	0.282		8
Hit Only Top Via		0.299	0.243	0.284		2
Hit Contact and M4 FICD		0.292	0.249	0.286		3
Hit Contact and M2 DICD	8.12%	0.348	0.291	0.239	0.281	1
Hit Top Via and M4 FICD	12.64%	0.359	0.290	0.246	0.289	2
Hit Top Via and M2 DICD	12.11%	0.361	0.287	0.237	0.286	3
Hit Top Via and Contact	8.67%	0.361	0.292	0.244	0.282	7
Hit All but M2 DICD	9.94%	0.360	0.292	0.243	0.290	5
Hit All but Top Via	15.22%	0.367	0.292	0.236	0.296	1

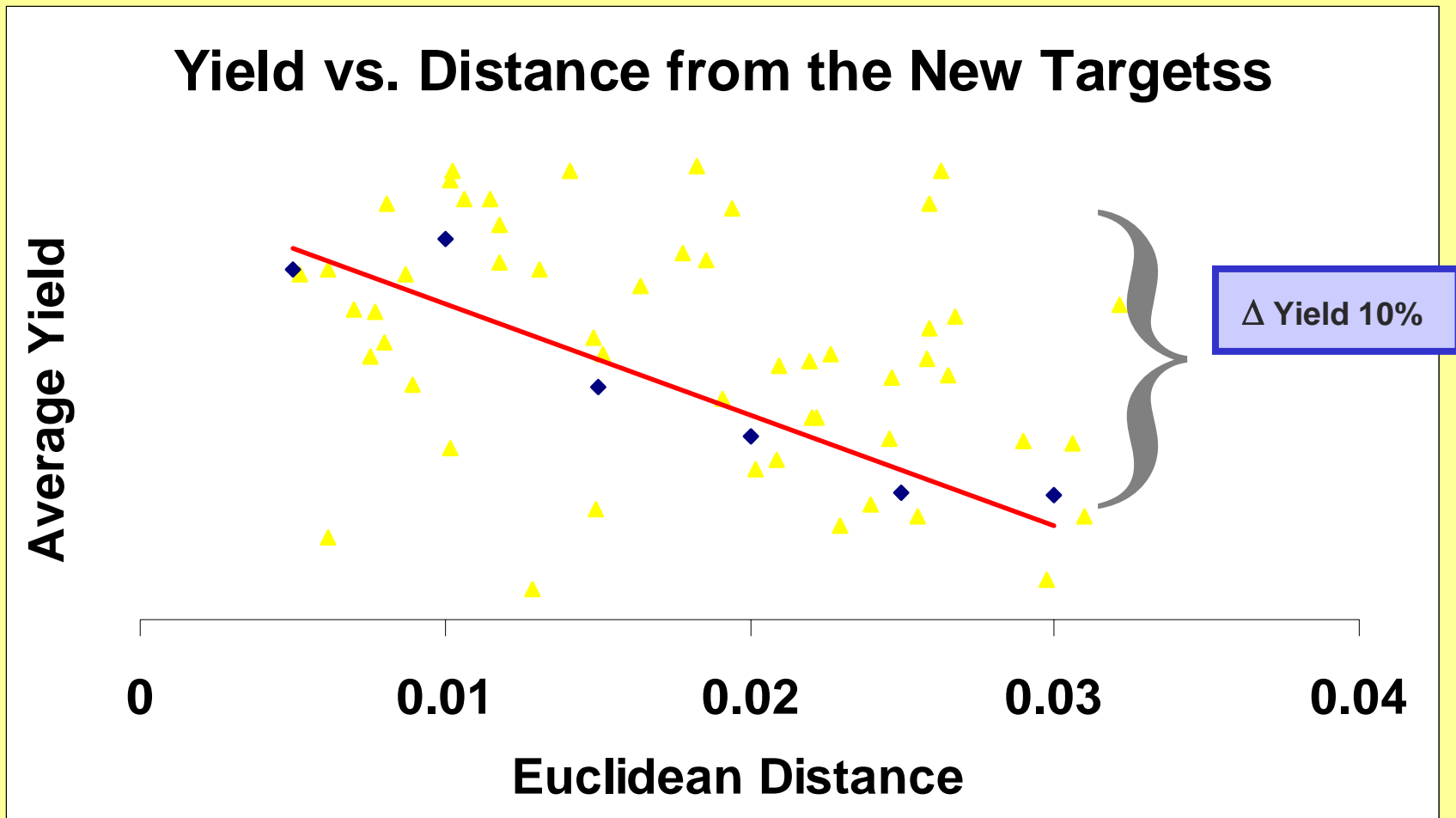
When most of the targets are met, highest yield is achieved



When the metrologies gradually move towards new targets, yield increases correspondingly.



Yield vs. Distance From New Targets



Results

- Compare yield before and after the process modifications
- Compare the yield for lots which met (or approached) the target - to lots which did not meet the target
- **Compare the results with Yield Optimizer predictions**

Testing Yield Optimizer

- **Contact DICD:**
Predicted 10%, achieved estimated 7%
- **Top Via DICD:**
Predicted 4%, achieved estimated 9%
- **M2 FICD:**
Predicted 0-1.5%, achieved estimated 1%
- **M4 FICD:**
Predicted 0.1%, achieved estimated 1%

Impact on Yield from Percent clean-die Improvement

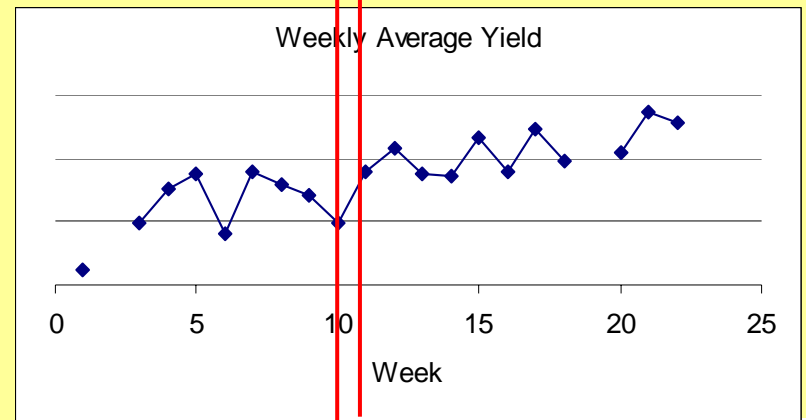
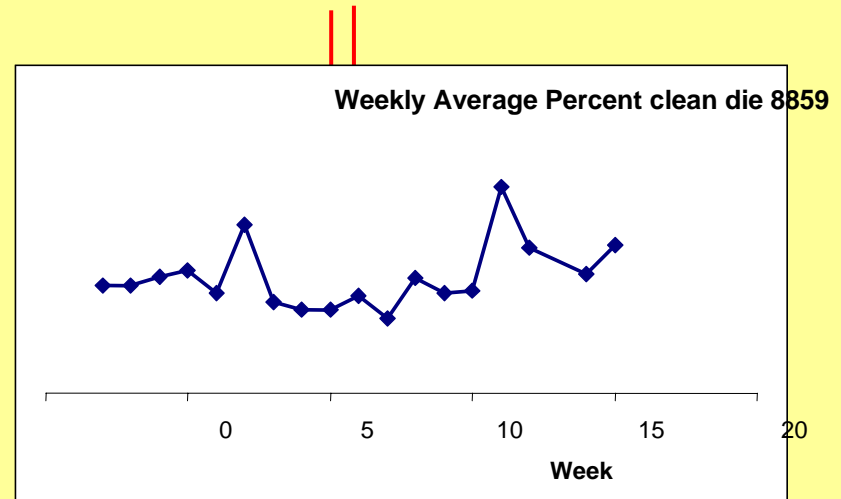
Percent_clean_die Information

❖ No clear correlation between 24 percent_clean_die inputs and yield are found during the testing period.

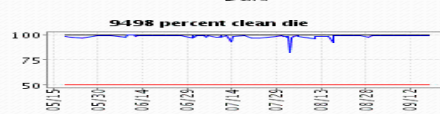
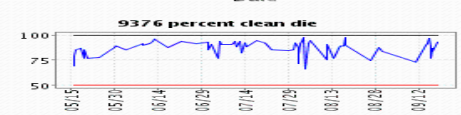
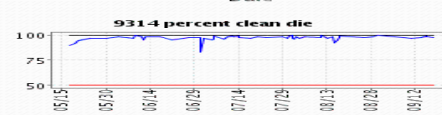
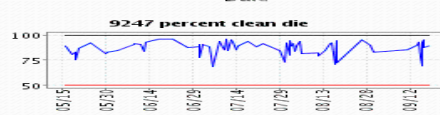
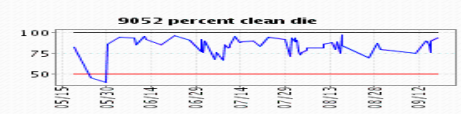
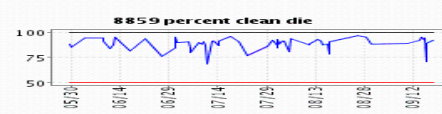
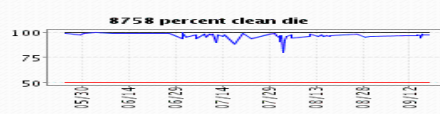
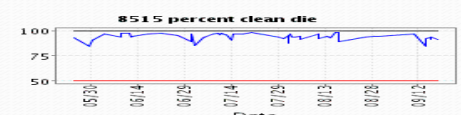
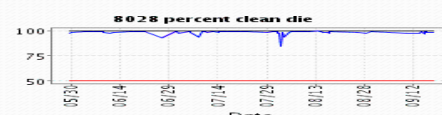
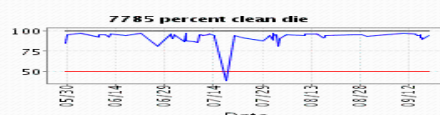
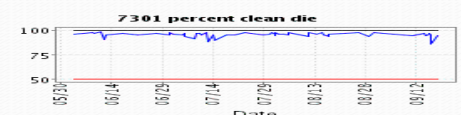
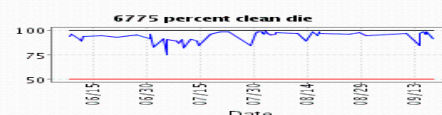
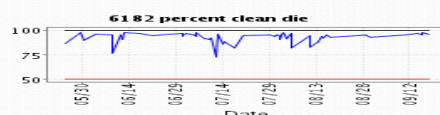
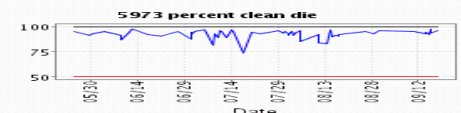
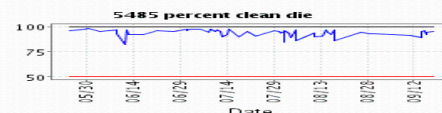
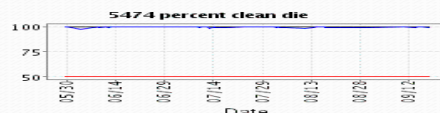
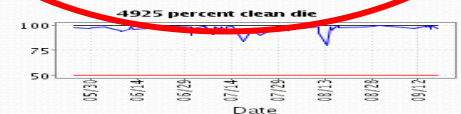
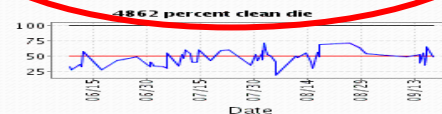
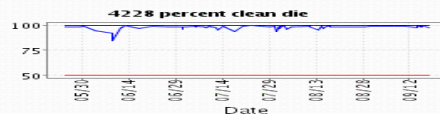
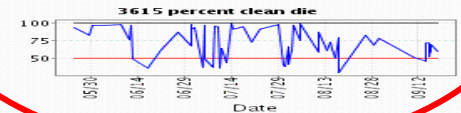
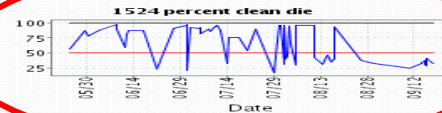
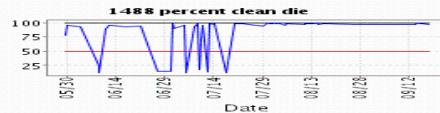
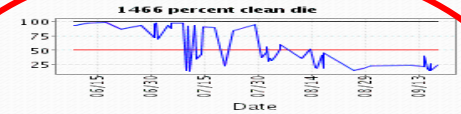
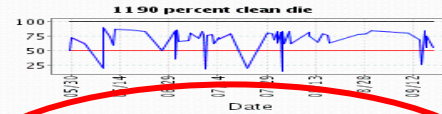
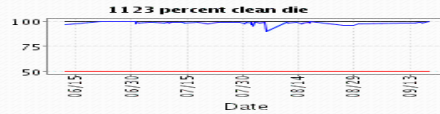
❖ One example (on lot based data) is shown on the right.

❖ Only 1 defect measurement of percent_clean_die has positive impact on yield in this beta test

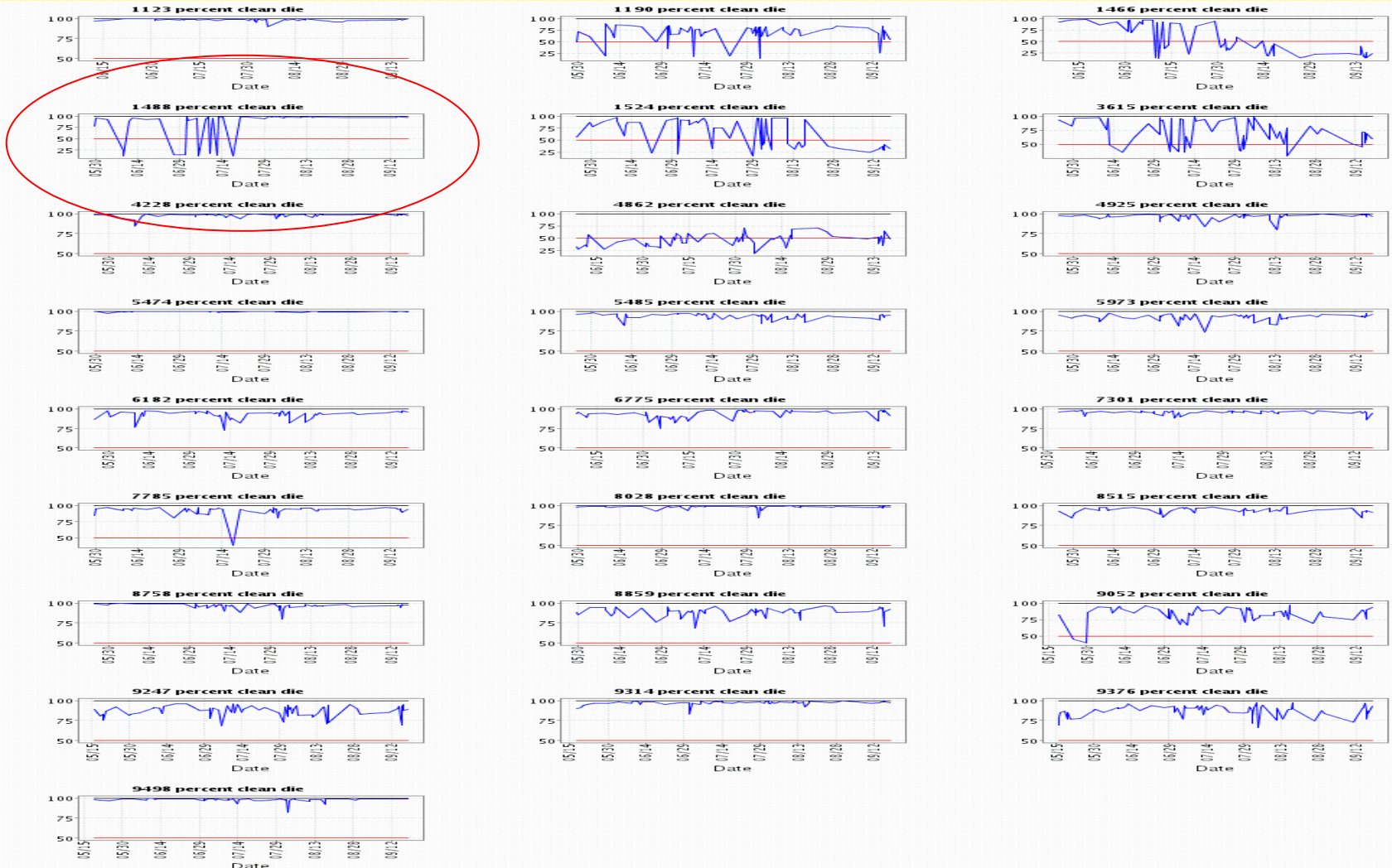
❖ All percent_clean_die are listed in the next slide



Three measures decrease during the course of the study



One Defect Measurement (#1488) shows positive impact on Yield



Estimate the Impact of Percent Clean Die improvement

- Out of all percent clean die, Only one (1488) showed impact on yield, which increased from 61.73 to 95.610 at around 7/21.
- We estimated that the 1488 pct clean die contributed to about 2.907% yield improvement, where the process modification contributed 10.9%, i.e, additional 8%.

Variable	Target Values		
	Baseline	Scenario 1	Scenario 3
Top Via DICD	0.370	0.370	0.360
Contact DICD	0.299	0.299	0.292
M2 DICD	0.244	0.244	0.237
M4 FICD	0.280	0.280	0.289
1488 Pct Clean Die	61.730	95.610	95.610
Yield Change	Baseline	2.907	10.921

Discussion

- **Yield benefit is clear if Yield Optimizer's recommendation is followed**
- **Best results are achieved when the new targets were met accurately and consistently**
 - Consider a tool level controller (DNC) to be used in conjunction with Yield Optimizer.
- **Fast process adjustment (convergence to new targets) means achieve higher yield more quickly**
 - Consider a tool level controller (DNC) to be used in conjunction with Yield Optimizer.

Conclusion

- **The NeuMath Yield Optimizer provided excellent opportunities for National to improve yield**
 - ✓ On average **8.2%** yield increase is shown after the process modifications
 - ✓ Consistent Pct clean die improvement contributed to about 2.9% of yield improvement; consistent process modifications contributed additional **8%**.
 - ✓ Best result (**15.2%***) yield increase is shown when most of the new targets are met. (*Average of lots most closely meeting targets **10.9%**)