Beta Test results for a Yield Optimizer

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Agenda

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

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Executive Summary

- Goal: **To evaluate 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**%

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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.

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Process Modifications

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

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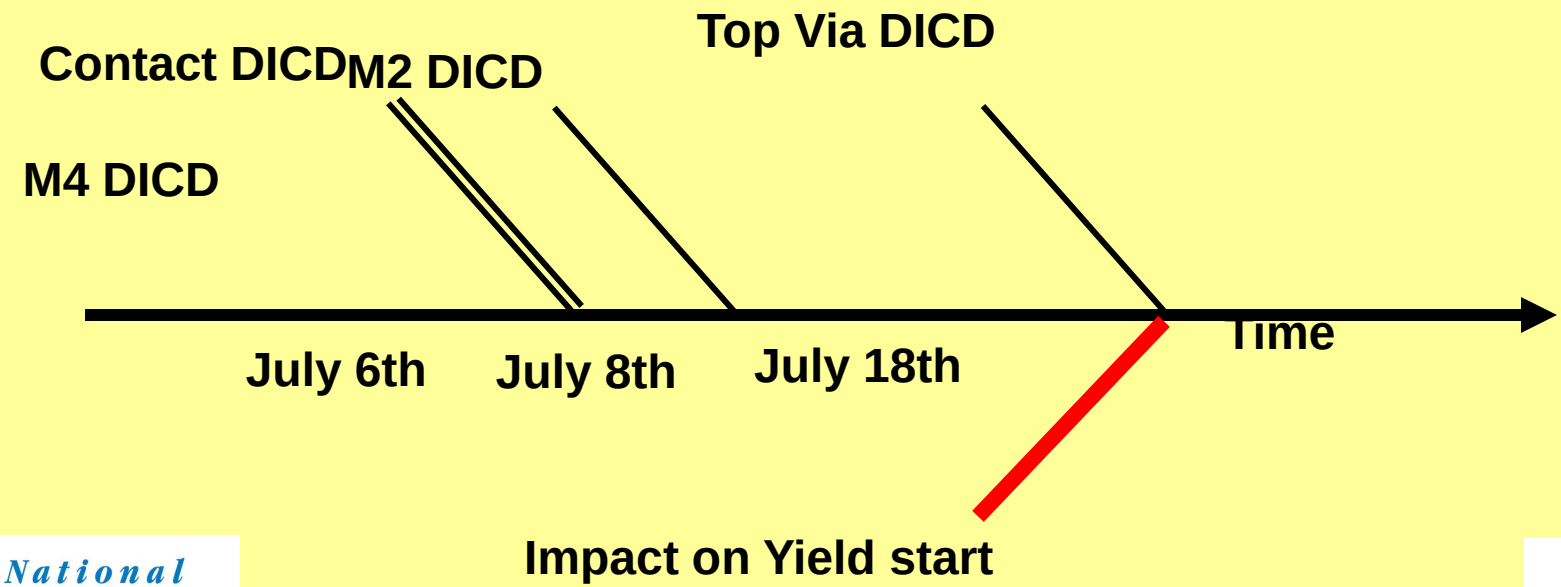
Summary of Modifications

- **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



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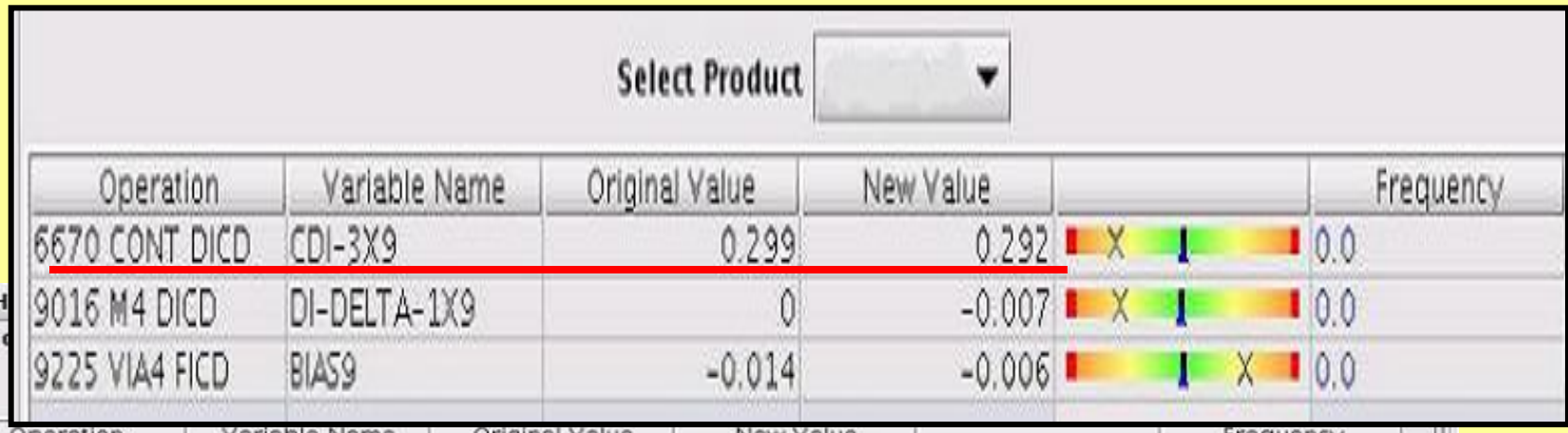
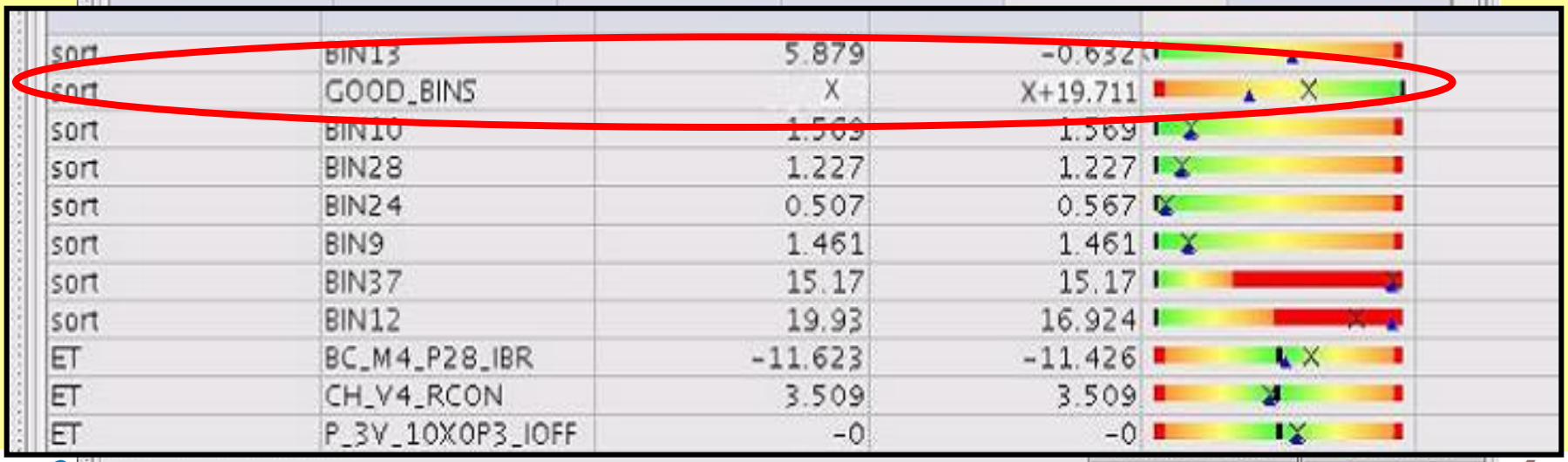
Contact DICD





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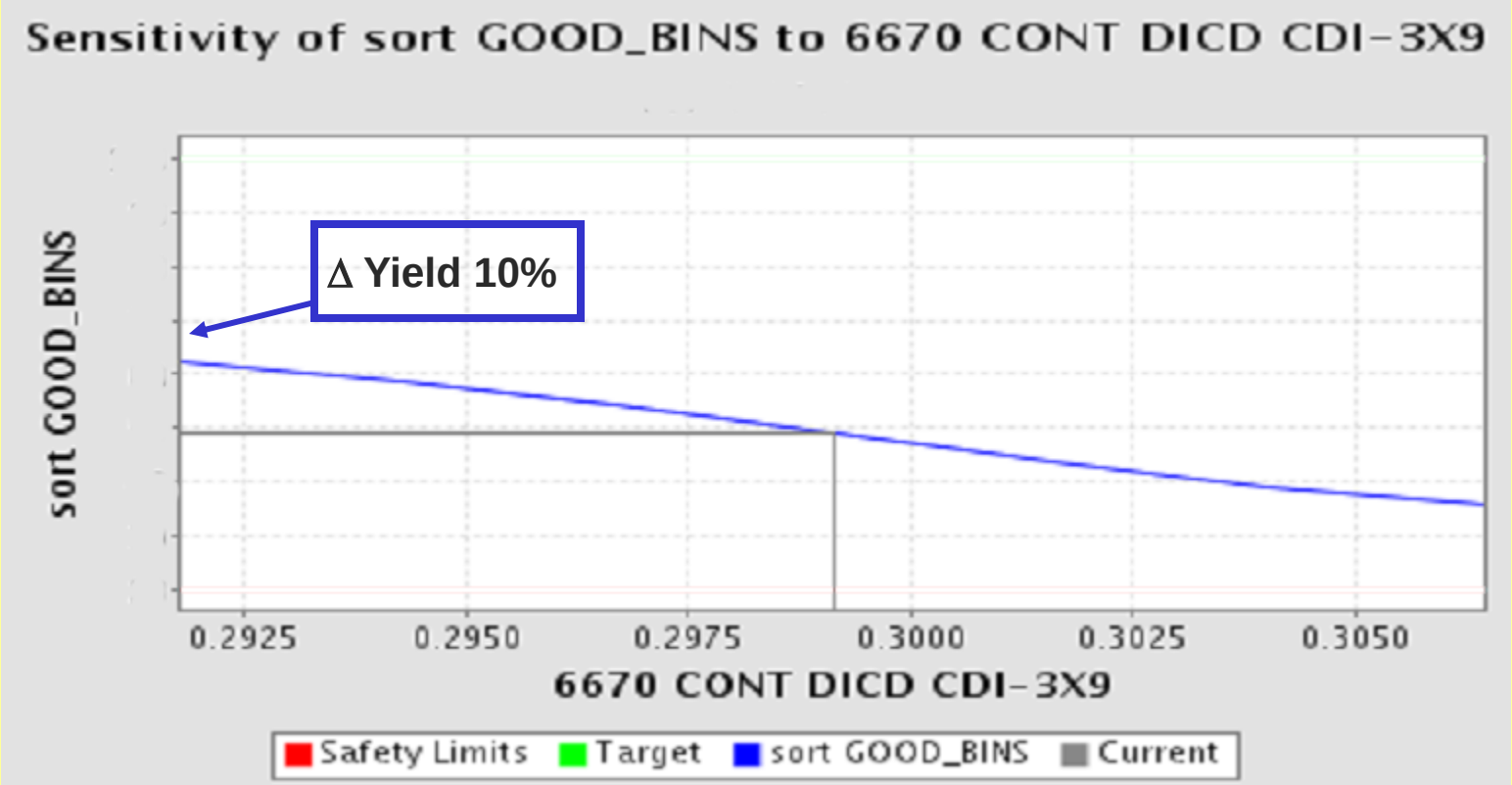
Contact DICD Sensitivity

Predicted 10% yield improvement.



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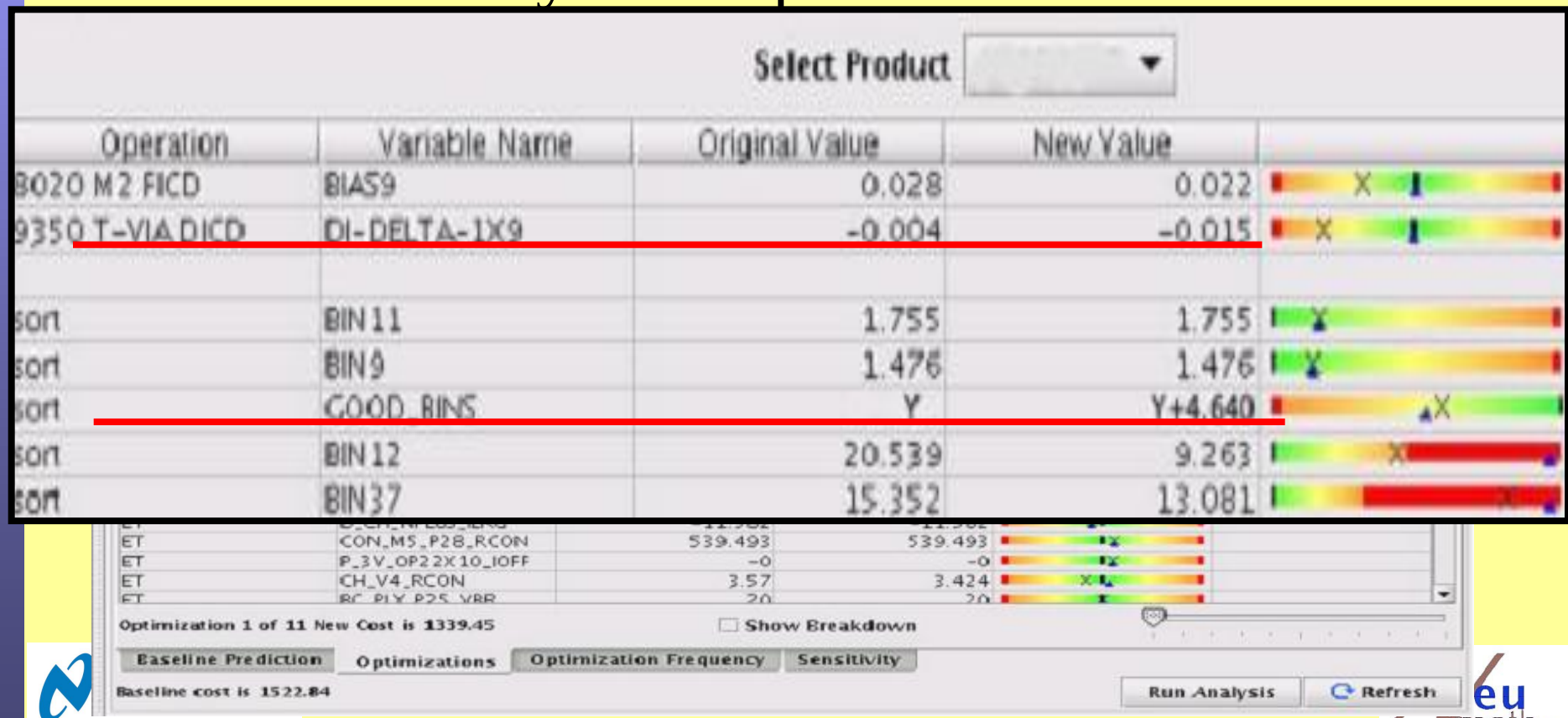
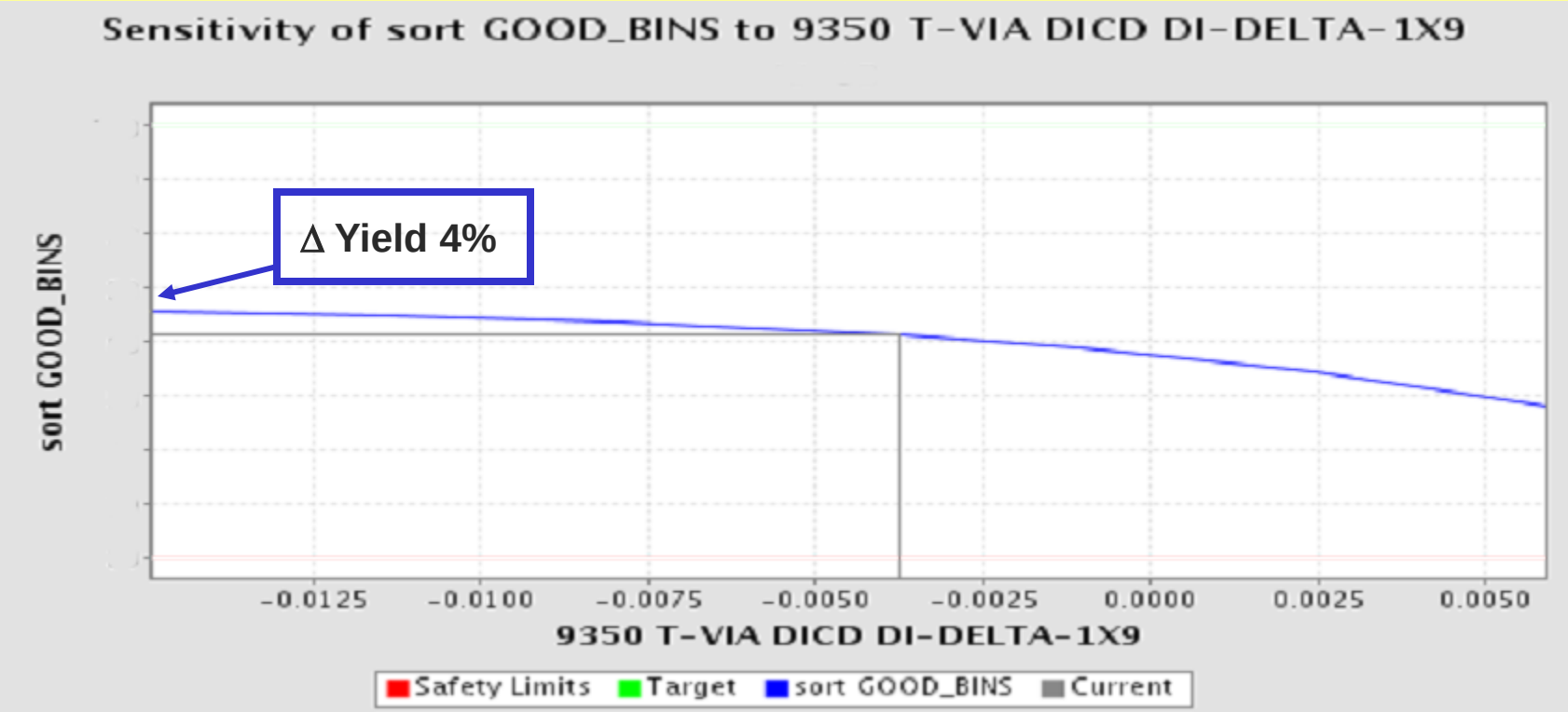
Top Via DICD

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



Top Via Sensitivity



Tick mark is 10% yield

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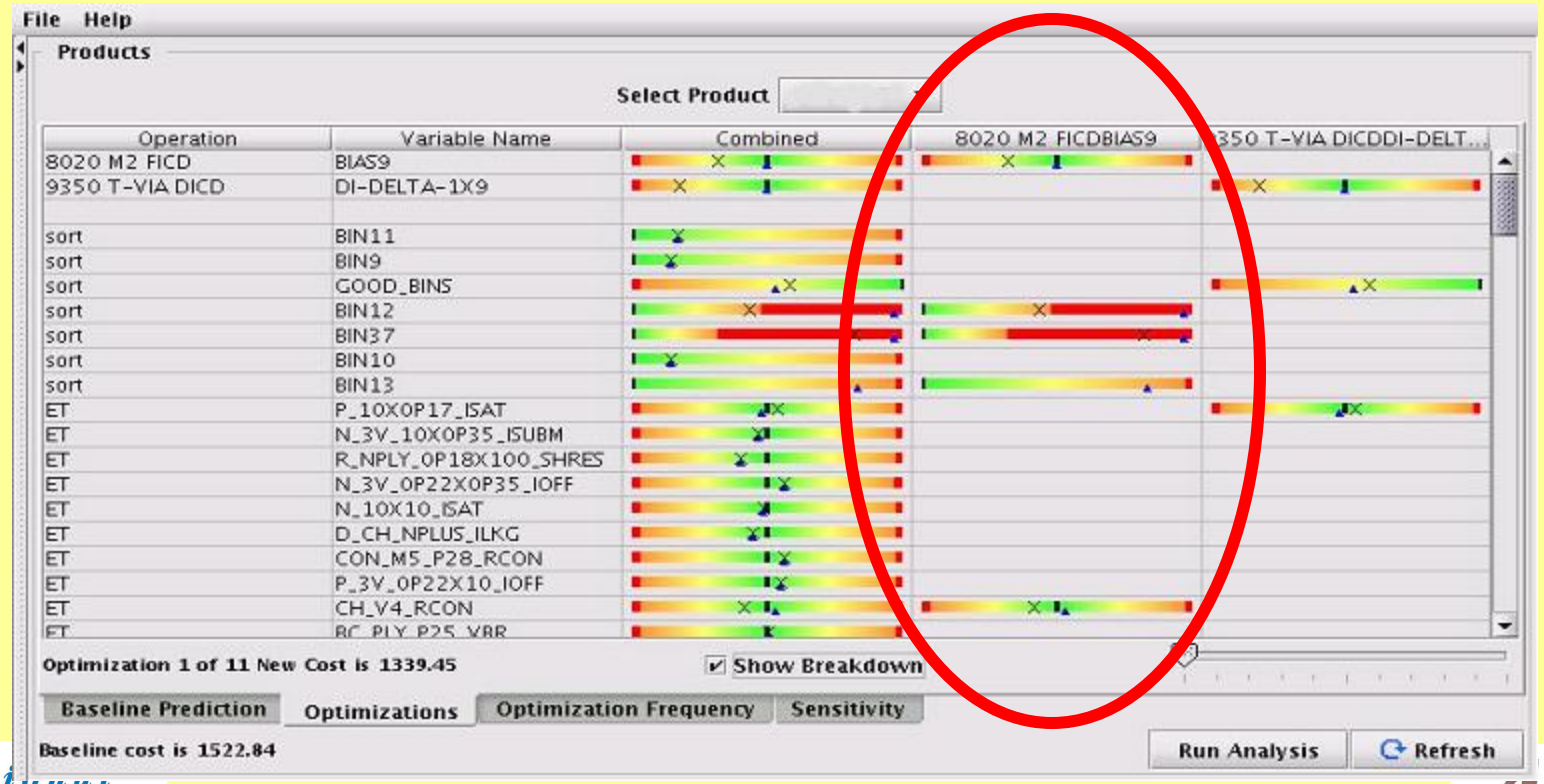
M2 FICD

Changed on M2 DICD .244 to .237 on July 8th
Predicted to have small or no impact on yield directly



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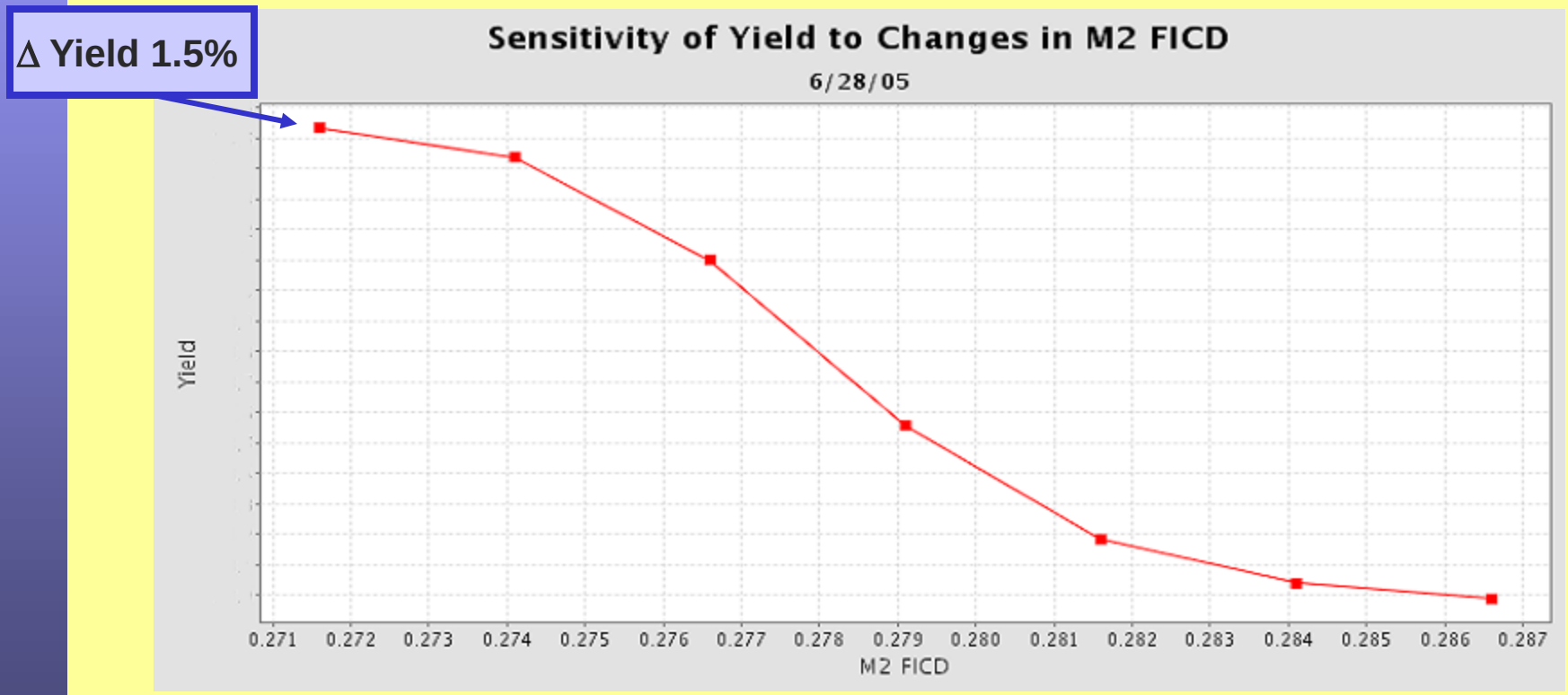
M2 FICD Sensitivity

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



Tick mark is 0.1% yield

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	

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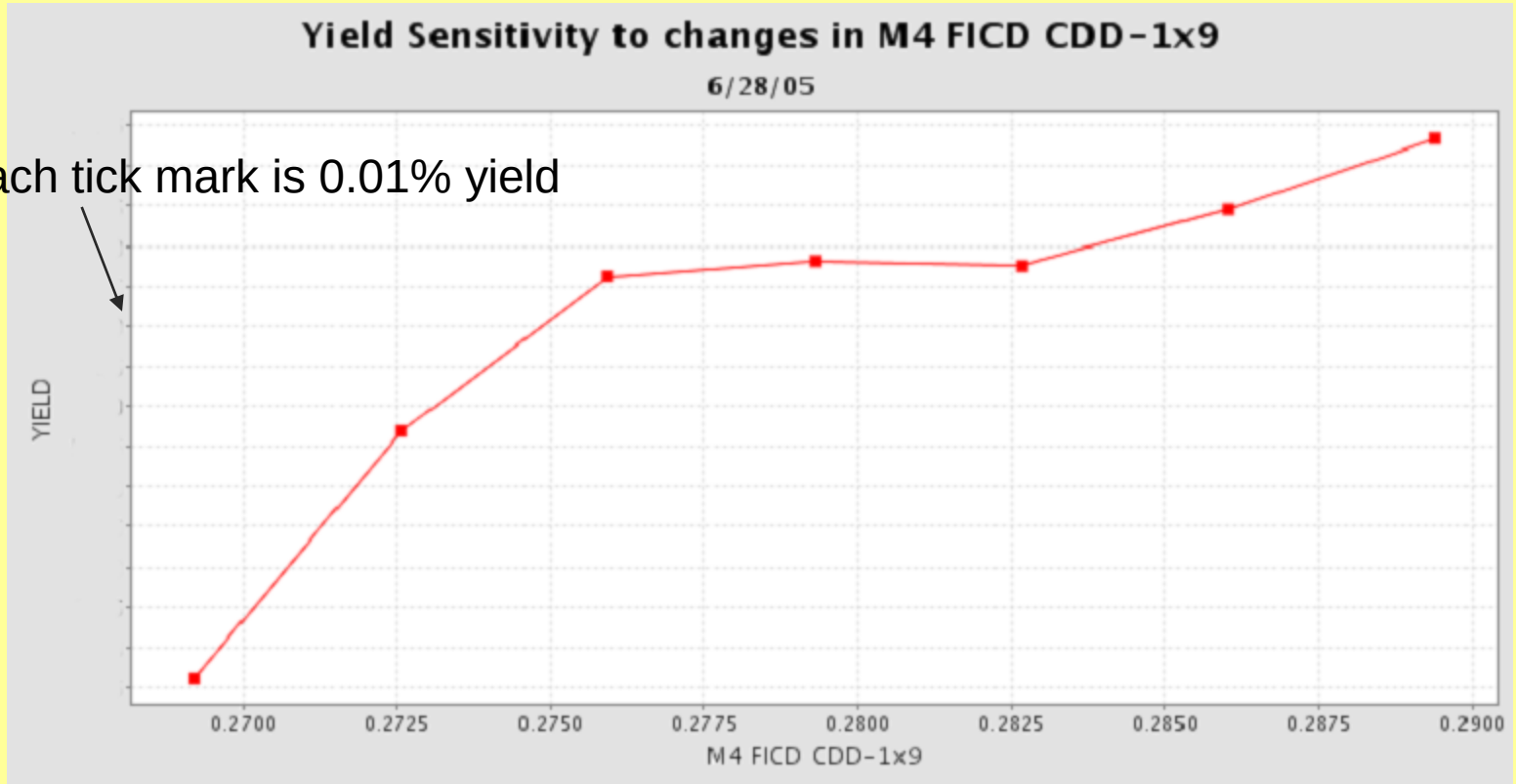
M4 FICD Sensitivity

A minor (0.15%) yield improvement is possible



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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**

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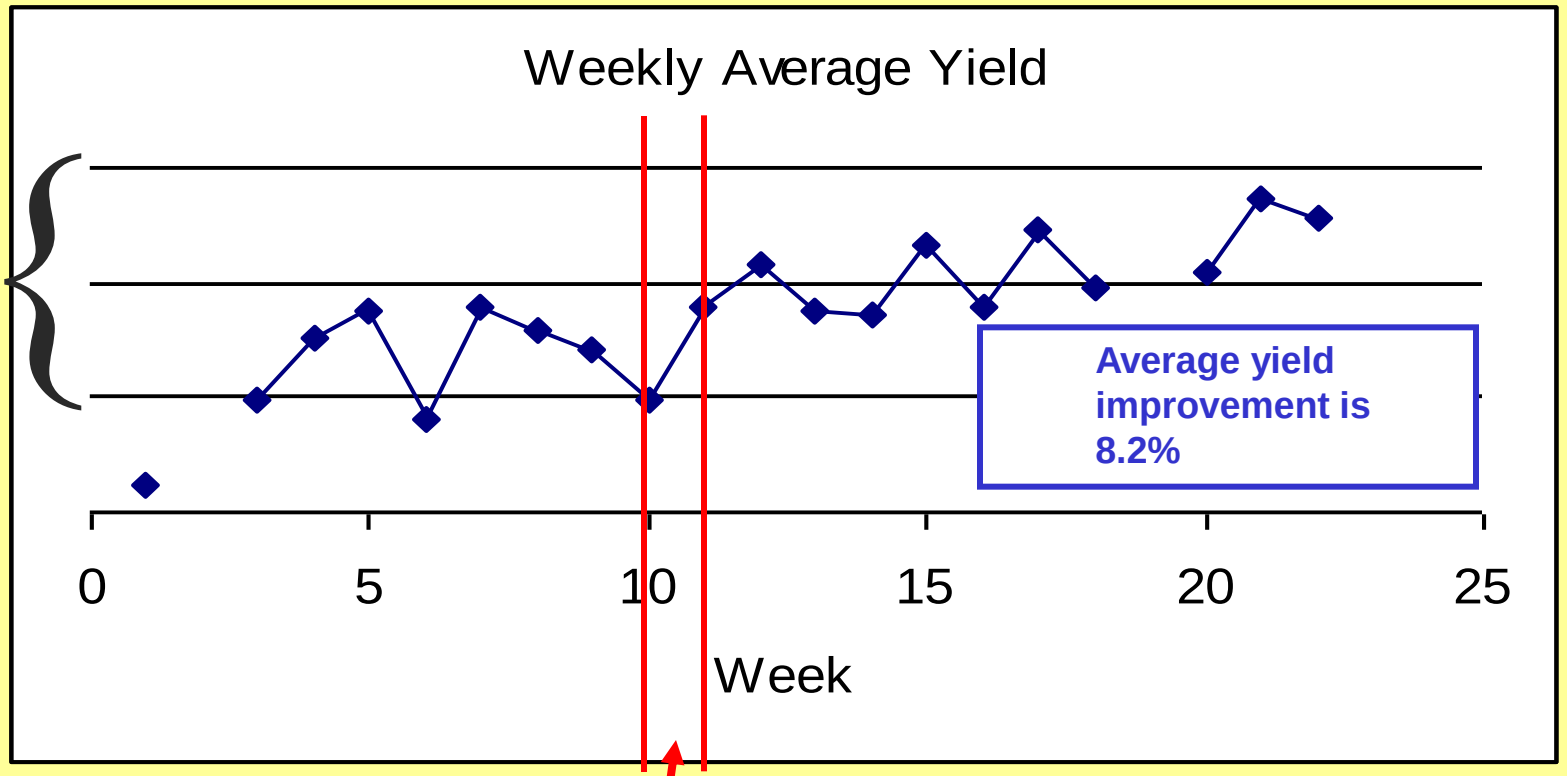
Yield Before, During and After the Modifications



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Yield During the Modification Period

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

There are yield increases even during the modification process, indicating that moving the metrologies towards the new targets alone will benefit the final yield, even if targets are not met .

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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

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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		(0.370 to 0.360)	(0.299 to .0292)	(0.244 to 0.237)	(0.280 to 0.289)	
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			298	0.245	0.289	2
Hit Only M2 DICD			299	0.235	0.281	1
Hit Only Contact			292	0.245	0.282	8
Hit Only Top Via			299	0.243	0.284	2
Hit Contact and M			292	0.249	0.286	3
Hit Contact and M2 DICD	8.12%	0.340	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	8.87%	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

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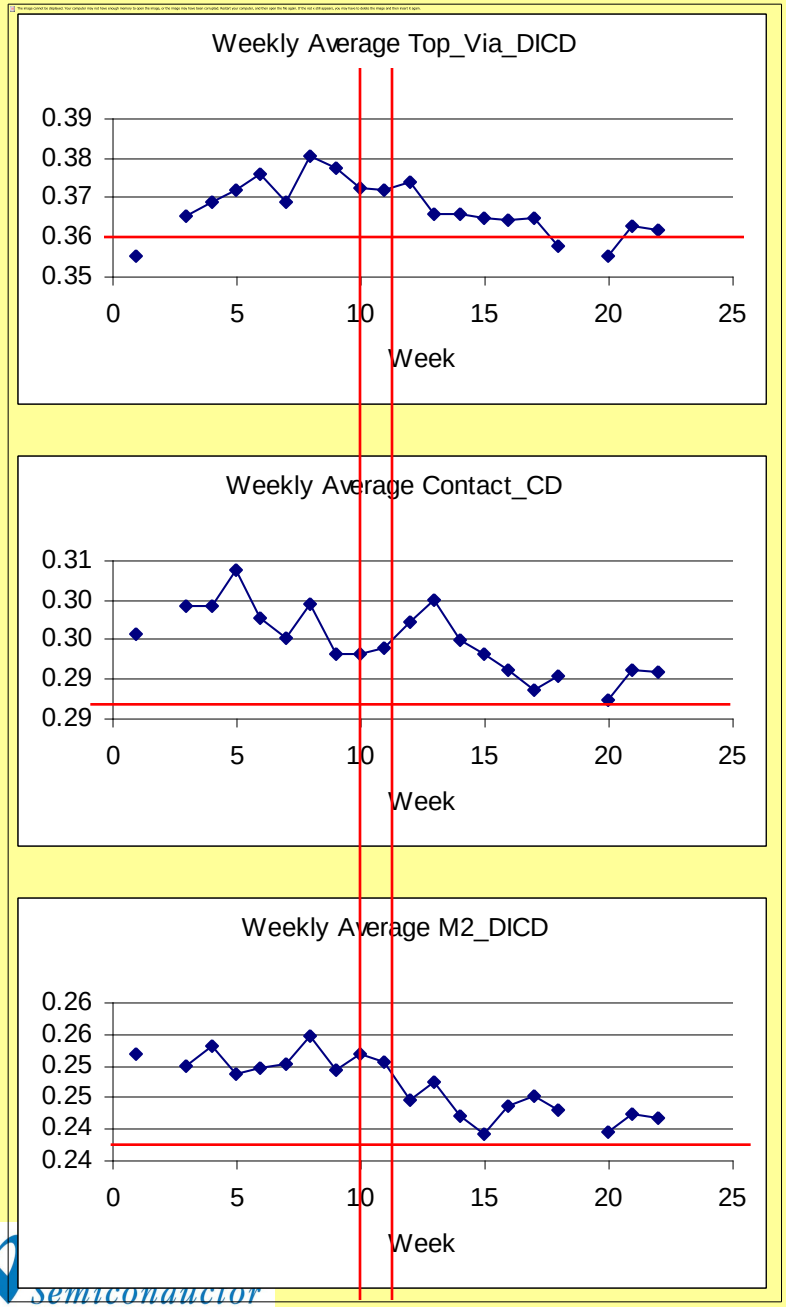
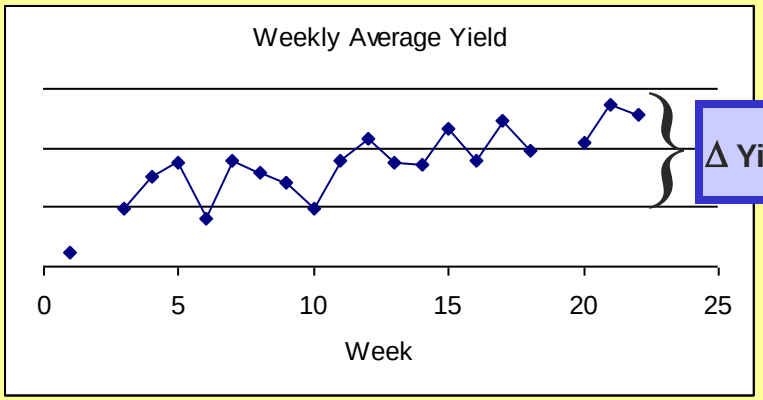
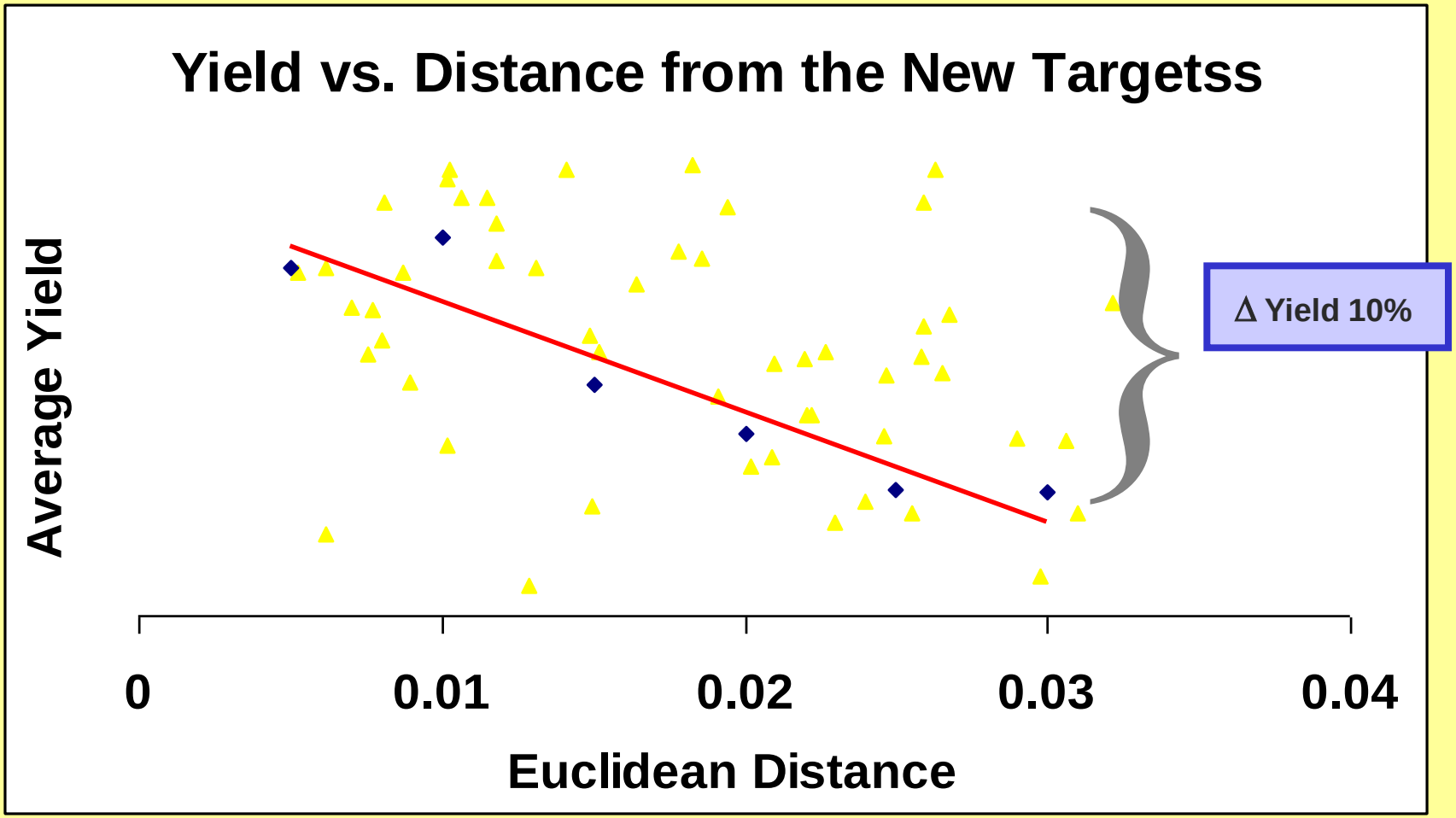




When the metrologies gradually move towards new targets, yield increases correspondingly.

Yield vs. Distance From New Targets



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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**

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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%

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Impact on Yield from Percent clean-die Improvement

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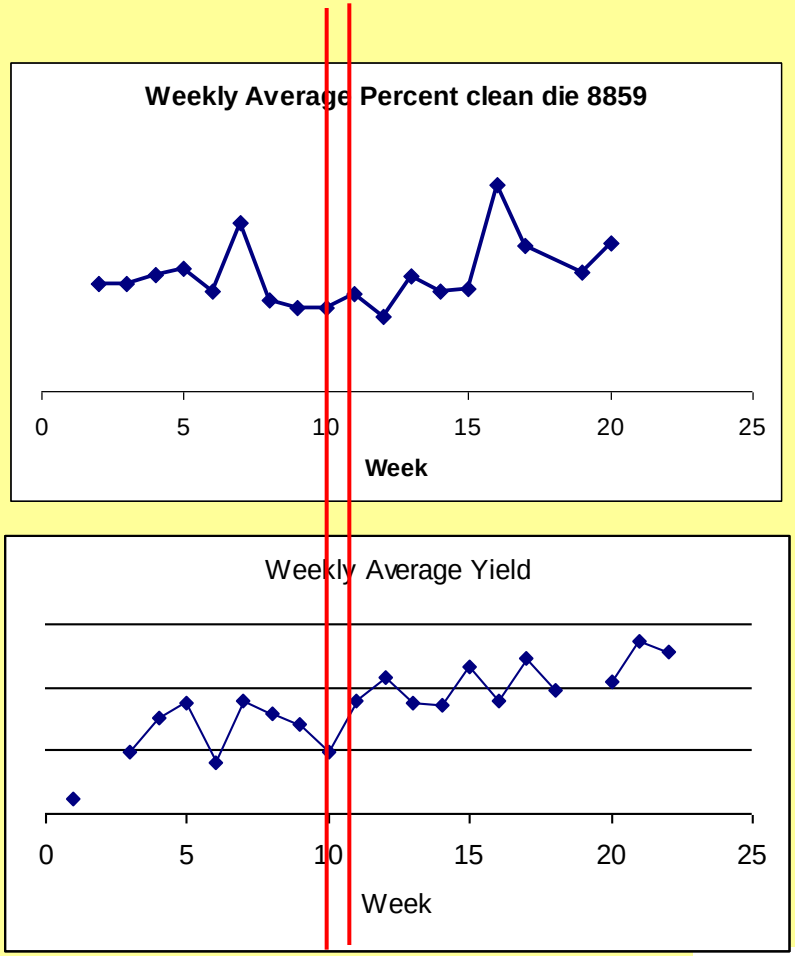
Percent_clean_die Information

- No clear correlation between 24 percent_clean_die defect measure 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



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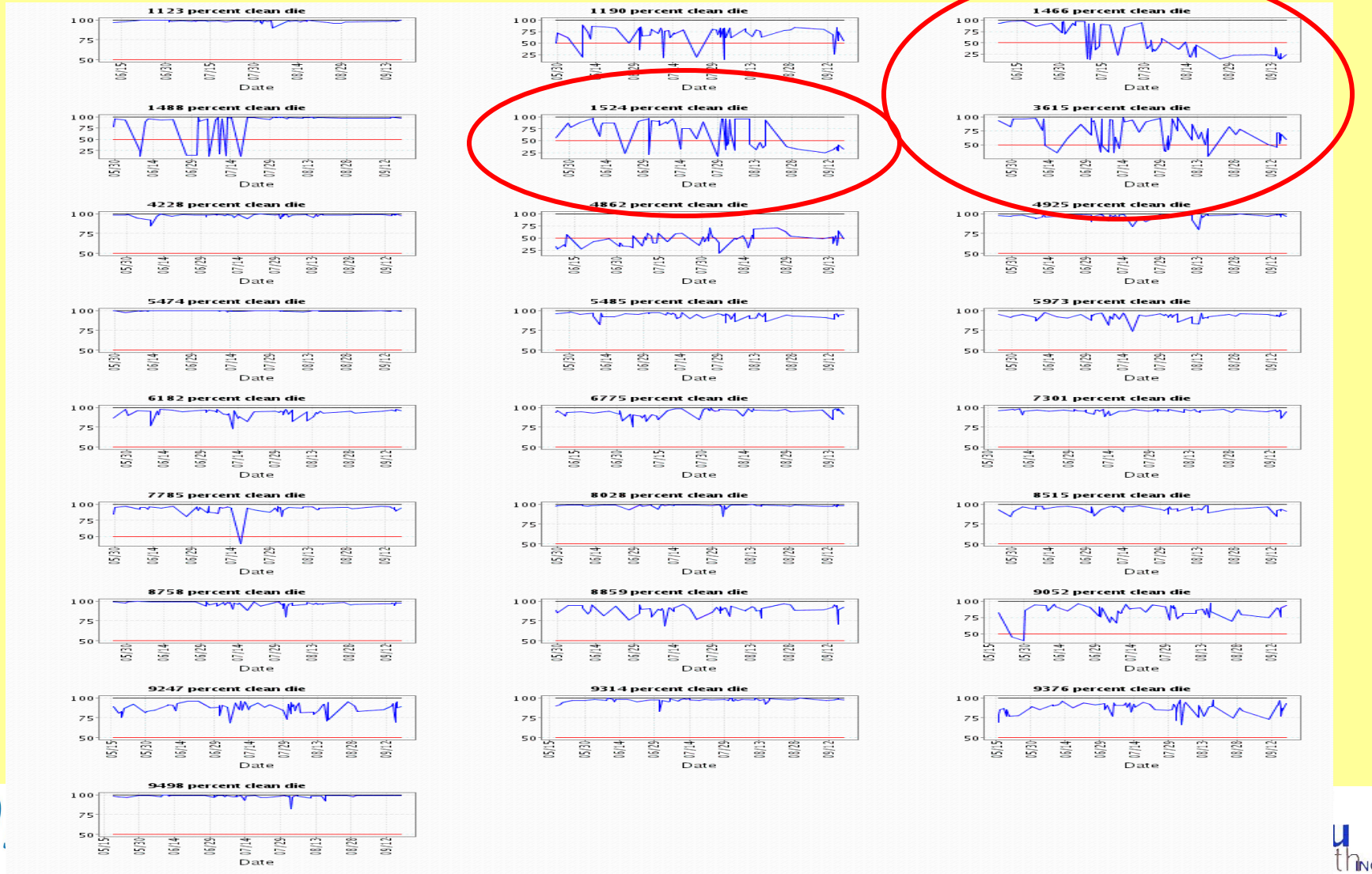
Three measures decrease during the course of the study



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%.

	Target Values		
Variable	**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.

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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%)

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