Automated Correlation Wafer Management and Processing

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Presentation Contents

- Who is Delphi Electronics & Safety
- Current Correlation Wafer Process
  - Current Correlation Process Concerns
  - How Can The Process Be Improved
- What is Correlation Wafer Manager (CWM)
  - How CWM Functions
  - CWM Automated Map Manager
  - CWM Rule Setup Interface
  - Examples of CWM Maps
  - CWM Prober Messaging
- Conclusions
  - Benefits
  - ROI - Return on Investment
  - ROI Data

Who Is Delphi?

- Delphi is a world leader in mobile electronics and transportation components and systems technology
- Multi-national Delphi
  - Conducts its business operations through various subsidiaries and has headquarters in Troy, Mich., USA, Paris, Tokyo and São Paulo, Brazil.
- Delphi's two business sectors
  - Dynamics, Propulsion, Thermal, and Interior Sector
  - Electrical, Electronics, and Safety Sector
- Delphi has approximately 185,000 employees and operates 171 wholly owned manufacturing sites, 42 joint ventures, 53 customer centers and sales offices and 33 technical centers in 40 countries.

Delphi Electronics & Safety

Breadth of Product

Body

- Body Electronics
- Climate Controllers
- Head-up Displays
- Instrument Clusters
- Security Systems
  - Vehicle
  - Content

Powertrain

- Standalone & Engine Management System Controllers
  - Engine
  - Machine and Heavy Duty
  - Powertrain
  - Transmission
- Power Modules
- Semiconductors
- Software

Safety

- Airbags
  - Frontal, Side, Curtain
  - Inflators, Cushions, Covers
- Antilock Brake Control
- Belt Tension Sensor
- Seat Belts
- Steering Wheels
- Suspension Electronic Control
- Forewarn® Collision Warning Systems
  - Smart Cruise Control
  - Back-up Aid
  - Side Alert
- Restraint Systems Electronics
  - Crash Sensing
  - Occupant Sensing
- Steering Electronic Control

Integrated Media Systems

- Acoustic Systems
- Advanced Digital Audio
  - Playback Devices
  - Satellite Receivers
  - Digital Receivers
- Amplifiers
- Fuba® Advanced Antenna Systems
- Hands-free Connectivity
- Navigation Systems
- Premium Audio Systems
- Rear Seat Entertainment Systems
- Receivers
- Satellite Data Services and Communication
- Truck PC
- Wireless Networking

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Delphi Electronics & Safety
Delphi Microelectronics Center

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Key Semiconductor Technologies

Dept 8436 - Wafer Test, Saw and Sort

- 150 Products
  - CMOS, Bipolar, Smart Power, IGBT, Micro Machine, and Sensors
  - Flip Chip and Pad Devices
- 87 Test Cells
  - Teradyne A5xx, A3xx, J9xx, J750, Eagle 300 - Sentry - SZ M3020 - LTX 77, CP80, Synchro HT, Fusion HT, HF, CX
  - EG2001, EG4090 and TEL P8XL, WDF, WDP Probers
  - Offline Ink
- Test 1,000,000 Die Per Day
  - 3 Shifts, 5 Days/Week Operation
- Automatic Visual Inspect, Saw, and Sort
- Packaging and Final Test – DIP, QUAD PAK, SOIC, BGA…

Current Correlation Wafer Process

- Typical Correlation wafer uses:
  - Prior to Device / Product or hardware changeovers
  - After Corrective or Preventive Maintenance
  - Verify / validate test cell integrity anytime yield or test results are in question
- Current practice is to run an entire wafer to verify the test system setup based on the repeated yield of the correlation wafer.
  - Performed manually by an operator with simple pass/fail criteria. We use the good count +/-5% to determine a min and max number of good die.
  - The correlation wafer passes if the number of good die on subsequent runs falls within the min and max values.
  - This process is simple for the operator but it does not systematically indicate if the test system is performing optimally.

Current Correlation Process Concerns

- Correlation result integrity
  - What if we get more good die than the max number?
  - Are we now calling bad die good?
  - What does it mean if we get less good die than the min?
- Correlation wafer integrity and lifespan
  - A correlation wafer can be run 5, 10, 20 times before it is “worn out” or scraped
  - Often, one cannot tell if a failure is due to some part of the test system or due to the correlation wafer integrity
- Throughput cost
  - Test times range between 15 min and 3.5 hours per wafer
    - 600 to 10,000 die per wafer
- Correlation wafer cost
  - Typically correlation wafers are scraped which impacts revenue

How Can The Process Be Improved?

- Implement automate statistical correlation wafer result analysis to improve correlation integrity
  - Rule based bin analysis
  - Good die remain good and bad die remain bad
- Enhance correlation wafer integrity and lifespan
  - Control the number of die tested with each correlation run
  - Control the number of touchdowns per die
- Reduce Cost
  - Improve throughput
    - Not necessary to probe the entire correlation wafer for a valid assessment of the test cell setup
    - Reduce test time used in correlation process
  - Reduce Correlation Wafer Cost
    - Extend the life of correlation wafers
    - Controlled use of the wafers enables them to be sold as product for revenue

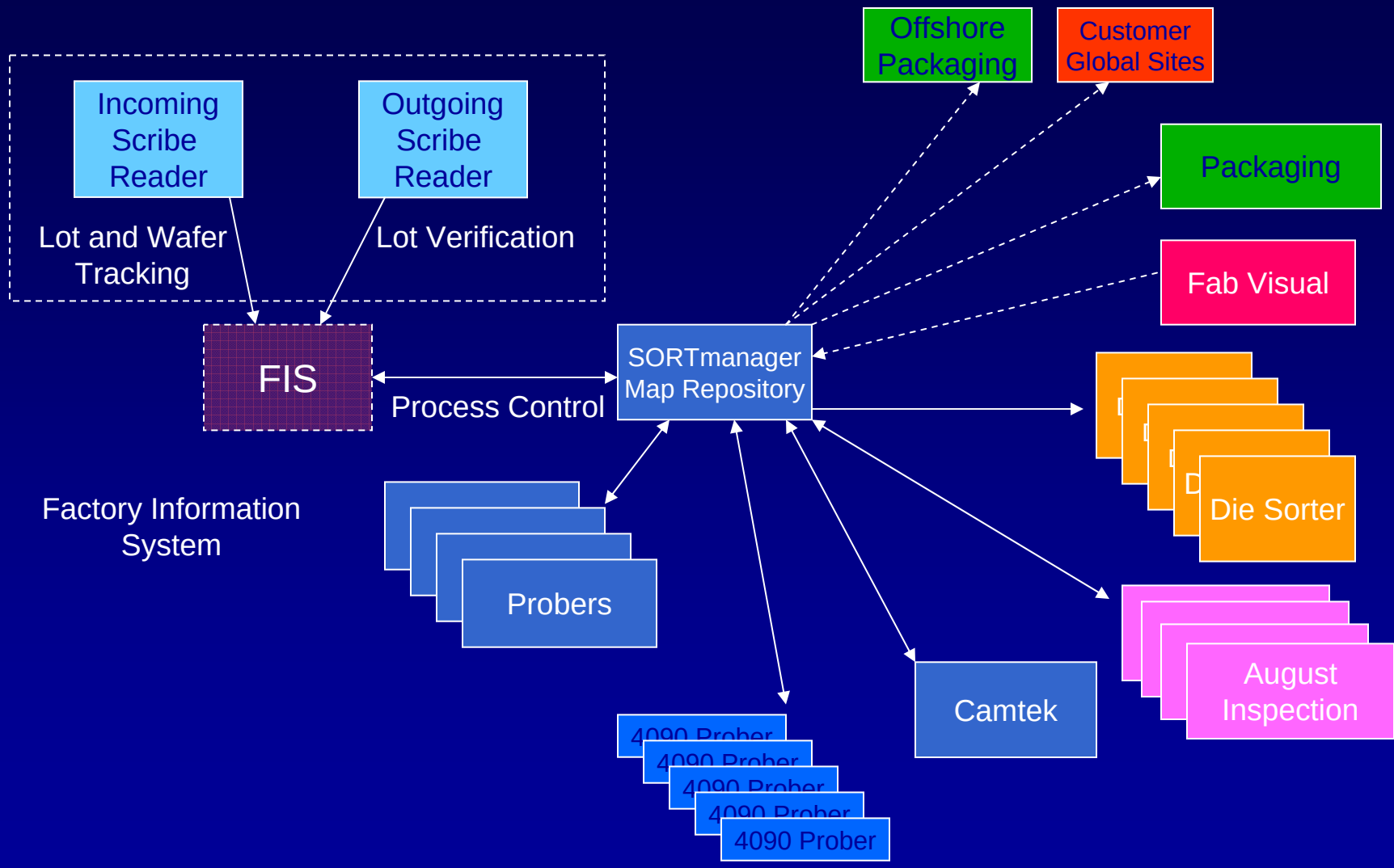
What is Correlation Wafer Manager (CWM)

- CWM uses automated map management and rule based SPC to automate the correlation wafer process and provides substantial cost savings with increased production throughput
- CWM Features:
  - Identifies correlation wafer(s) from previously probed production wafers in the automated map manager
  - Manages correlation wafer usage
  - Creates correlation follow maps for the prober enabling the testing of a subset of the die on the correlation wafer
  - Analyzes the correlation results based on rules created for each product, or default rules
  - Messages the prober with correlation results
  - Provides simple solution for production with automated analysis and sends the prober a message indicating passage or failure, with failure details

How CWM Functions

- The Core Technology
  - Web-based
  - Automated map manager
  - Two-way prober communication
  - Statistical and graphical reporting engine provides SPC
- CWM Setup
  - Correlation wafer is selected
  - Correlation rules setup
  - Product recipe created for prober

CWM – Automated Map Manager Integration



How Many Die To Test?

- There are many variables in determining the correlation sample size. We assumed around 90% yield for the device and that Alpha would be 0.1 (90% confidence) and Beta would be 0.2 (risk of missing something significant). Based on that we looked at the comparison of two proportions and got the following:

1% shift	1,000 die
2% shift	275 die
3% shift	125 die
4% shift	75 die
5% shift	**50 die**
6% shift	40 die
7% shift	30 die
8% shift	25 die
9% shift	20 die

- The actual number is going to vary based on the individual device maturity and yield trend. Based on this testing 50 die will find a 5% shift while it will take over 100 to find a 3% shift. Looking for 1-2% shifts impacts the cost effectiveness and best utilized with immature devices.

Correlation Rules Setup

Web Interface for CWM Rule Setup

Correlation Rules Manager **Source(s):** PS478 CORR.txt

PS478 CORR.txt

Continue...

Correlation Rules Add New

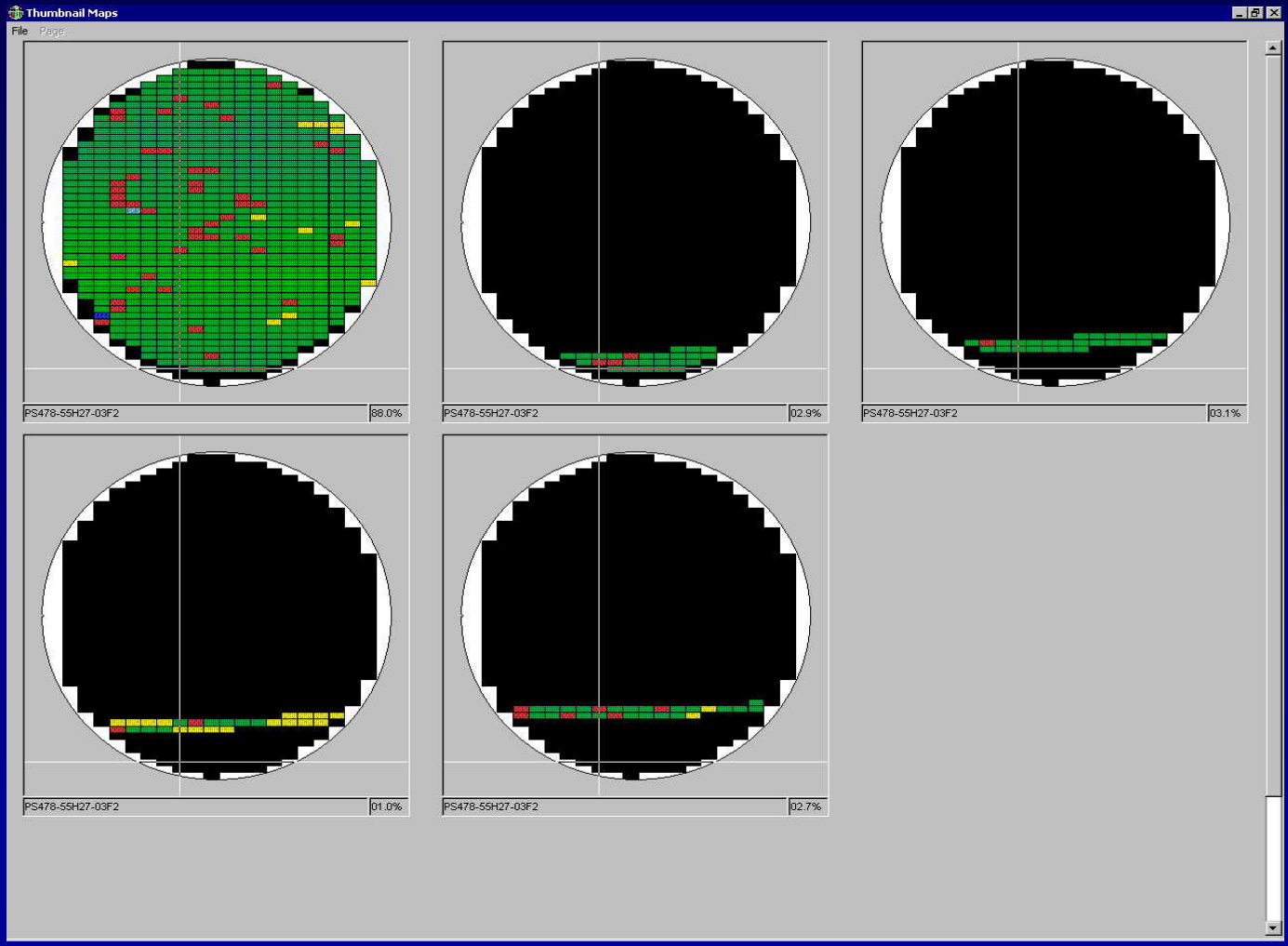
Back to Limits List

If Bin is -1, the Bin Group is used. Bin Groups can contain wildcards. "Min # to Test" is the minimum number of die of this bin/bingroup to test. "Min % Match" is the minimum allowed % of die of this bin remaining this bin. "Max % Transition" is the maximum allowed % of die not of this bin to change to this bin.

		Bin	Bin Group	Min # To Test	Min % Match	Max % Transition
Edit	Delete	1	*	25	90	100
Edit	Delete	2	*	0	0	0
Edit	Delete	6	*	0	0	0
Edit	Delete	7	*	0	0	0
Edit	Delete	9	*	0	0	0

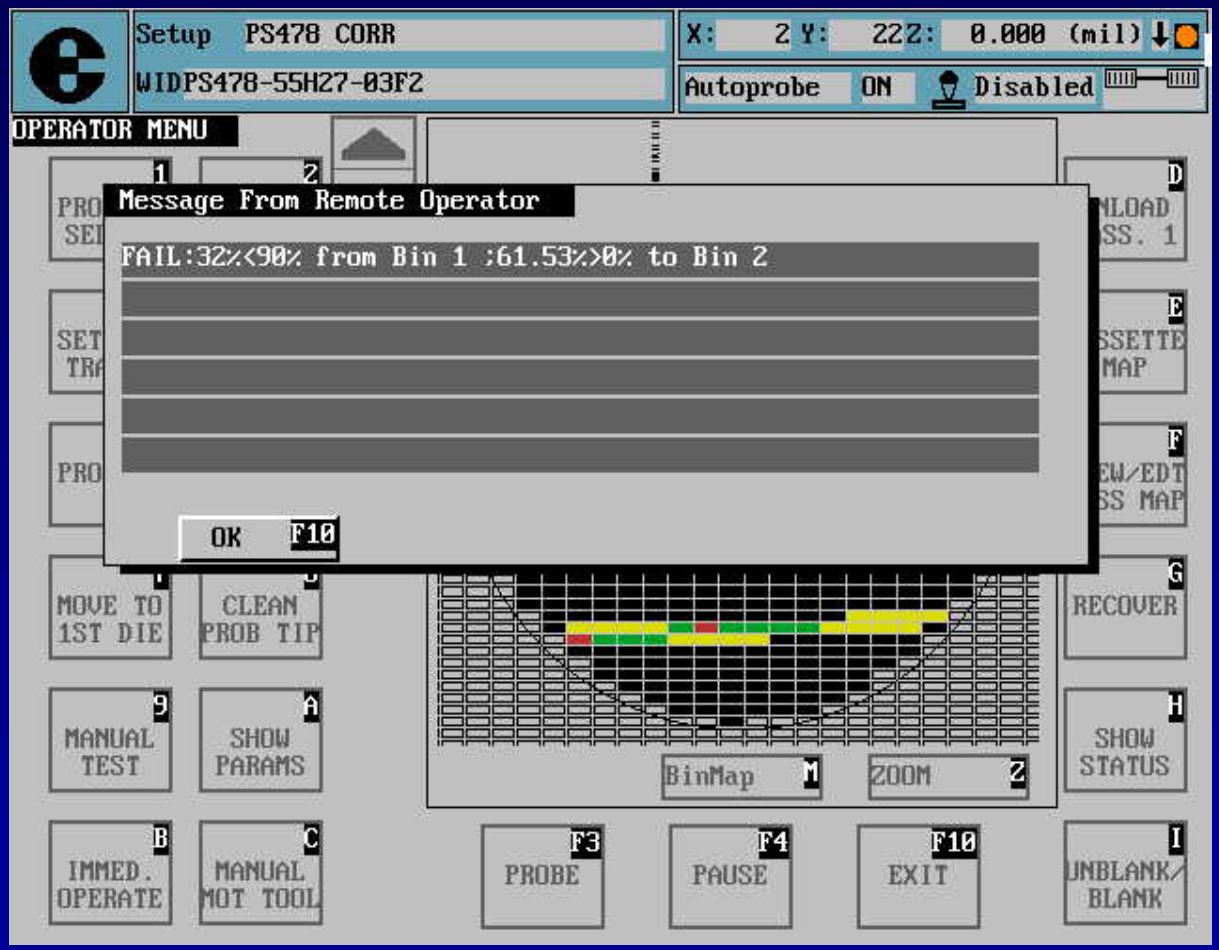
CWM Map Examples

- Initial correlation wafer
- (4) Individual correlation regions of the wafer used for correlation



CWM Prober Message Example = Fail

The Correlation “Failed” the Bin 1 Transition Rule



Conclusions - Benefits

- Correlation Analysis Integrity
  - Implement automate statistical correlation wafer result analysis to improve correlation integrity
    - Rule based bin analysis
    - Good die remain good and bad die remain bad.
    - Removed operator analysis portion (pass/fail) (subjective), making it a statistical rule based decision made by CWM
    - CWM is integrated one device at a time with the flexibility to easily change number of die to test, number of times to probe a wafer section and pass/fail criteria.
- Correlation Wafer Management
  - CWM provides a record of correlation wafer inventory and usage
- Enhanced correlation wafer integrity and lifespan
  - Control the number of die tested with each correlation run
  - Control the number of touchdowns per die
- Reduced Cost
  - Improve throughput
  - Extend the life of correlation wafers

Conclusions -ROI (Return-on-Investment)

- Annual ROI = $1,487,250
- Cost of Test Improvements
  - Savings
    - Test Time Reduction
      - Reduced tester time for correlations by 75%
    - Correlation Wafer Usage
      - Reduced annual number of correlation wafers by 80%
      - Extended life of correlation wafers used
  - Additional Revenue
    - Reduced correlation test time = 16 additional revenue lots per year
    - Shipping correlation wafers verses scrapping

CWM ROI Data

Testing a Portion of the Wafer Verses the Whole Wafer = Test Time Savings									
	Number of Die Used for Correlation	Correlation Wafer Runs Per Day	Correlation Time Per Wafer (Minutes)	Correlation Time Per Day (Hours)	Annual Production (Days)	Annual Correlation Time (Days)	Annual Correlation Time (Hours)	Annual Correlation Time (Seconds)	Annual Correlation Test Time Cost ($.09 Per Second)
Previous Method	Complete Wafer	7	60	7	300	88	2,100	7,560,000	$680,400
Using CWM	50	7	15	1.75	300	22	525	1,890,000	$170,100
Savings	n/a	n/a	45	5.25	n/a	66	1,575	5,670,000	**$510,300**
75% savings in time used for correlation									

Cost Savings Due to Extended Life of Correlation Wafer				
	Number of Runs Per Wafer	Total Correlation Wafers Per Year	Correlation Wafer Cost	Annual Correlation Wafer Cost
Previous	15	324	$1,000	$324,000
New Method (80% less wafers needed)	75	64.8	$1,000	$64,800
		259.2	Savings	**$259,200**

Additional Test Time for Production Wafers & Revenue (Average 15 Minutes Per Wafer Test Time)			
Additional Production time Hours	Additional Production Wafers	Additional Production Lots	Additional revenue at $1000 Per Wafer
1575	393.75	15.75	**$393,750**

Cost Savings If We Decide to Ship Correlation Wafers After Use (there are several quality of product issues to consider with this decision)				
Number Products / Devices	Annual Correlation Wafer Usage Per Device	Total Correlation Wafers Per year	Correlation Wafer Cost	Annual Correlation Wafer Cost
81	4	324	$1,000	**$324,000**

CWM Savings	
Test Time Reduction	$510,300
Extended Life of Corr Wafers	$259,200
Total Savings	**$769,500**

CWM Additional Revenue	
Increased Production	$393,750
Shipping Corr Wafers	$324,000
Additional Revenue	**$717,750**

CWM Savings	$769,500
CWM Revenue	$717,750
Combined	**$1,487,250**