

SEMICON West 2007

**Welcome
to the**

**ISMI
450mm
Industry
Briefing**

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ISMI
MANUFACTURING INITIATIVE

Meeting Outline

- Provide overview of the ISMI 450mm program
 - Outline manufacturing productivity and economic assumptions on which program is based
 - Describe analysis of 300mmPrime potential and the implications to 450mm
 - Describe Next Generation Factory Vision and Guidelines

Agenda

(1:00) Introduction – Scott Kramer

(1:15) Background – Tom Abell

(1:35) 300mm Prime Analysis

(1:35) Factory Simulation – Robert Wright & Eddy Bass

(2:10) Economic Analysis – Denis Fandel

(2:45) Next Generation Factory Vision– Tom Jefferson

(3:15) Key Messages & Next Steps – Tom Abell

(3:45) Summary/Closing – Scott Kramer

(4:00) Adjourn

[Note: Q&A time allowed in each presentation]

ISMI Members

SAMSUNG **NEC** **RENESAS** **Panasonic** **SPANSION™** **intel.** **Micron** **HEWLETT PACKARD** **AMD** **TEXAS INSTRUMENTS** **NXP** Founded by Philips **Infineon** technologies **Qimonda**

tsmc **IBM**

14 members

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300mm Transition Lessons Learned

- Industry coordination is crucial; early engagement of equipment and materials manufacturers
 - Determine fab architecture
 - Develop standards early
 - Consider bridge tools
- Support multiple leading-edge business models
 - High-volume/low-mix, High-volume/high-mix, etc.
- Assess business and economic models
 - Analyze cost, risk, benefit/ROI
- Continuously evaluate and adjust, including:
 - Impact of technology on timing
 - Market and industry dynamics

450mm Issues

- **ROI**
 - **Cost**
 - **Source of R&D funding**
- **Timing**
 - **Economics: product demand, industry cycles**
 - **Equipment capability & performance**
- **Technical feasibility**
 - **Silicon material: challenges for 450mm wafer manufacturing**
 - **Processes: robust unit processes across 450mm wafers, uniformity**

ISMI Approach

- Understand economic impact on industry
 - Opportunity to use modeling for careful analysis
- Build industry consensus
 - Equipment, materials, and chip manufacturers working together
- Build from lessons learned in 300mm transition

Benefits of the 300mmPrime / 450mm Path

- Target 300mmPrime redesigns to resolve biggest cost, productivity and cycle time limiters known from 300mm experience
 - Create upgrades to 300mm fab designs for a continuum of benefits and revenue
- Port 300mmPrime learnings to 450mm designs
 - Lower risk of major transitional changes
 - Lower developmental costs by demonstrating concepts at the cheaper 300mm wafer size

Perspective on ISMI Direction

- ISMI has developed a comprehensive strategy for near- and long-term productivity improvements
 - Next Generation Factory Vision and Guidelines covers the continuum of existing and future fabs from 300mm to 450mm
- An analysis of potential 300mm improvements shows 300mmPrime has cycle time opportunity but falls short of the traditional cost reduction required to stay on Moore's Law
 - Metric goal: 30% cost reduction and 50% cycle time improvement
 - The financial benefit of cycle time reduction is difficult to quantify for different business models
 - Faster new product introduction, time to money, faster product delivery to customers
- ISMI has developed a complementary forward-compatible approach of 300mmPrime to 450mm
 - Addresses the needs of our various member constituencies
 - Attempts to minimize the R&D expenditure by the industry
 - **Efficient use of industry resources is key**

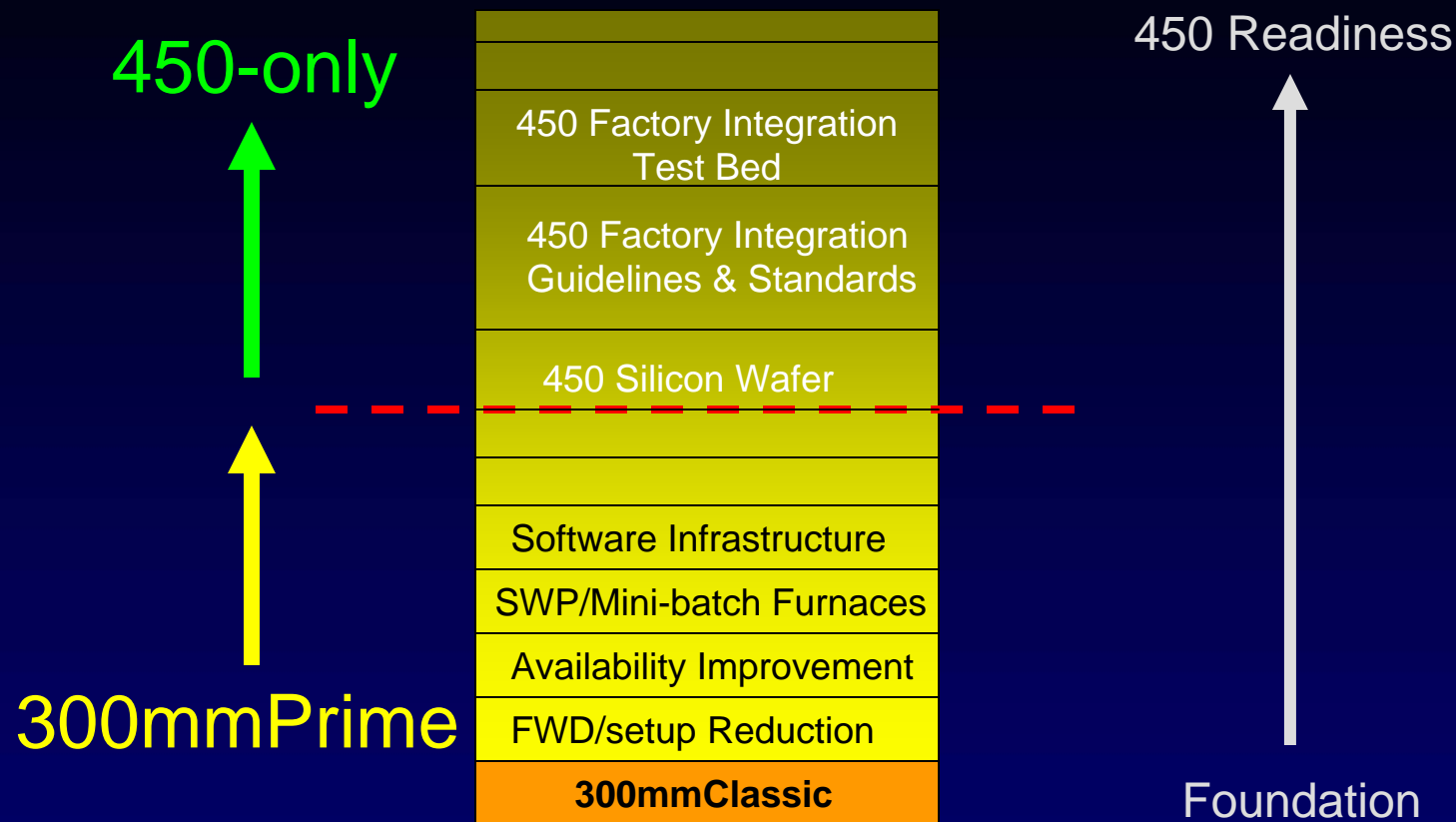
ISMI Perspective on 300mmPrime

- ISMI plans to pursue 300mm improvements that offer near-term productivity benefits in cycle time and cost reduction
 - Initial focus areas from modeling are:
 - First wafer delay and setup reduction
 - Availability improvement
 - Single wafer/mini-batch furnace process tools
 - Process capable and competitive on equivalent factory cost and footprint

ISMI Perspective on 450mm

- ISMI will initiate a 450mm Program dedicated to moving ahead with 450mm industry capability
 - New mission
 - New structure
- ISMI plans to pursue in 2008
 - Availability of 450mm silicon wafers
 - 450mm Factory Integration Guidelines & Standards
 - Creation of a 450mm Factory Integration Test Bed
 - Interoperability testing of prototype automation and equipment interfaces

Next Generation Factory Vision Realization



- ISMI is moving forward with complementary forward-compatible paths for 300mmPrime and 450mm
 - Realization of 450mm is built upon coordinated improvements from 300mmPrime and 450-only activities to efficiently utilize industry resources
- Collaboration is a critical success factor inside and outside ISMI

Summary

- **300mmPrime has cycle time opportunities but does not sufficiently address cost reduction needs to replace 450mm transition**
- **ISMI has developed a complementary forward-compatible approach of 300mm to 450mm**
 - Addresses the needs of our various member constituencies
 - Attempts to minimize the R&D expenditure by the industry
 - Efficient use of industry resources is key
- **Implications to ISMI programs**
 - **Initiate tangible 450mm activities to address long-term fundamental cost reduction**
 - *Cycle time also important for 450mm*
 - **Pursue 300mm improvements to enable significant near-term cycle time and cost reduction efforts**
 - **Initial 2008 activities efficiently guide two supplier groups**
 - **300mmPrime: Process & Metrology Equipment**
 - **450mm: Silicon & Factory Integration**

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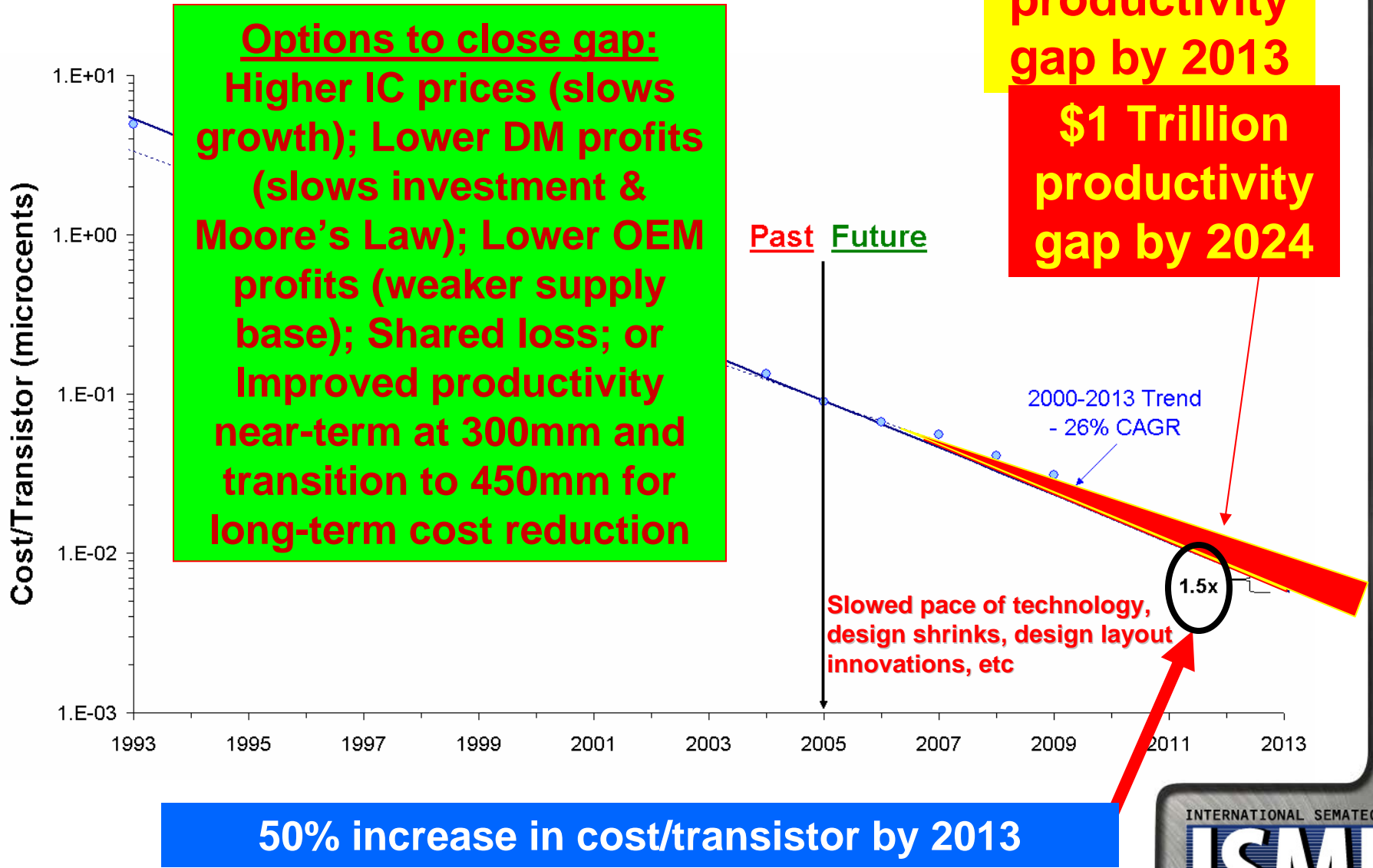
450mm Program Background

Tom Abell
ISMI 450mm Program
Manager

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Productivity Gap



ISMI 450mm Program Objectives

- Perform research, modeling, analysis and industry communication to support the transition strategy for 450 mm.
- Focus on creating a cost-effective 450 mm wafer size transition by **defining and incorporating a 300 mm next generation factory (300mmPrime) as the bridge.**

300mmPrime is a set of 300 mm factory and equipment designs focused on improving productivity for the next generation factory that has the capability of being scaled to 450 mm

300 Prime Core Guiding Principles

- 1. 300 Prime is a strategy for a 300mm productivity continuum bridge in the 450 mm transition**
- 2. An objective is to have forward-compatibility of the 300 Prime design and architecture in the 450mm factory**
- 3. Business model consideration needs to be applied to both 450mm and 300 Prime**
- 4. 300 Prime should provide productivity improvements (beyond 300 mm “classic”) that are scalable to 450mm**

ISMI 300 Prime/450 mm Core Targets

1. **Targets for 300 Prime or a 450 mm transition:**
 - **Historical 30% cost reduction/cm² of processed silicon**
and
 - **50% cycle time reduction in days per mask layer for normal production lots**
2. **Higher productivity and process controllability are required from process equipment, automation, and factory systems**
3. **First 300 Prime implementations are expected around 2008**
 - **Upgrades expected to deploy over several years**
 - **Adoption of 300 Prime is highly dependent upon risk and ROI**

Productivity Detractors

- **ISMI has compiled a list of “Productivity Detractors” based on:**
 - Problems our members have today...and...
 - Where our members want to be in the future
- **The rev.1 list is not a set of solutions**
- **It is a set of descriptions of overriding issues with explanations of their importance**
 - These are the issues that need solving
 - Solutions may require improvement on several detractors in order to realize productivity benefit
 - 28 “detractors” have been identified so far..
- **List has been publicly published since Dec’06**
 - No revisions to date

“Blue Diamond” Background

- 30% reduction in cost per area and 50% reduction in cycle time were set as the targets for 300 Prime or 450mm in Q2'06
- Analysis of 300 Prime potential against targets was decided in Q3'06 for completion by Q2'07
 - Determine whether 300 Prime can be expected to deliver 30% cost reduction and 50% cycle time (Blue Diamond Analysis)
 - 450mm could move out to an intermediate timeframe based on expected benefit of 300 Prime
 - OR
 - Accelerate 450mm planning and development
- Actions on 300 Prime analysis since SEMICON West 2006
 - >130 full factory dynamic simulations for benefit analysis
 - Static factory and economic modeling
 - ROI on improvement options (cost vs. benefit)
 - Development of Next Generation Factory Vision as a unified 450mm/300 Prime strategy.
 - Development of 19 Point Guidelines
 - Discussion/collaboration with SEMI and the industry during development process

Blue Diamond Analysis Data

- **Factory Simulations shown are based on 25-wafer carrier/lot size**
 - **Early 12-wafer simulations indicate greater dependence on equipment improvements to return expected small lot cycle time benefits**
 - **Additional work is required to increase the confidence required for industry-level decision making**
- **Economic analysis of cost vs. benefit for modeled scenario factors/multi-factors**

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Backup

ISMI Rev.1 Productivity Detractors List (1/4)

- 1. Non-optimized output per capital dollar spent results in degraded factory ROI**
- 2. Inability to meet short cycle times results in lost time to market**
- 3. Poor synchronization between process equipment, automation and factory control systems reduces total factory efficiency**
- 4. Unpredictable downtime of equipment induces disruption to factory lot logistics reducing factory efficiency and cycle time**
- 5. Delays in change-overs within process equipment negatively impacts cycle time (1st wafer delay, recipe-to-recipe, lot-to-lot etc.)**
- 6. Inability of process tools to seamlessly cascade lots with different processing requirements degrades cycle time**
- 7. AMHS and carrier exchanges are insufficient to keep tools utilized for high product-mix/small lot operation**

ISMI Rev.1 Productivity Detractors List (2/4)

- 8. Dependence on centralized storage and delivery distance-related delays results in under-utilized process equipment**
- 9. Large fixed-size carriers induce infrastructure inefficiencies when running small lot sizes (storage costs, etc.)**
- 10. Current lot scheduling capabilities and lack of information necessary for decisions result in inefficient factory operation**
- 11. Inability of factory and equipment systems to track at individual wafer level (vs. lot level) limits the flexibility of the fab for high product-mix operation**
- 12. Inability of process tools to provide sufficient data to factory control system limits lot/process scheduling, tool diagnostics and yield**
- 13. Inability of process tools to receive complex recipe and parameter instructions from factory control system limits flexibility of factory and yield**
- 14. Duration of process equipment installation is still too long and dependent on skilled installation personnel upon delivery**

ISMI Rev.1 Productivity Detractors List (3/4)

15. **Process equipment footprint and height restricts ability to optimize fab layouts**
16. **Need for equipment-related Non-Product Wafers reduces overall factory capacity for Product Wafers**
17. **Batch processing induces long delays at certain process steps that disrupt factory lot logistics and increases cycle time**
18. **Steady-state and peak utilities load from process equipment drives high cost of factory infrastructure**
19. **Long process equipment maintenance durations drive significant disruptions to factory lot logistics**
20. **Chambers on cluster tools with extended downtime issues cannot be easily replaced with functional chambers (long duration loss of process step capacity)**
21. **Long durations required for creating or modifying routes reduces factory flexibility/agility for high-mix operation**

ISMI Rev.1 Productivity Detractors List (4/4)

- 22. Current rate of identification, notification and containment of excursions is insufficient resulting in excessive loss of lots**
- 23. Vertical space inside fab is underutilized resulting in lower factory capacity**
- 24. Inefficient management of spare parts for process equipment results in additional downtime & factory disruption**
- 25. Downtime of large high-speed process tools impact lot logistics through a process step with little or no tool redundancy (1 of 2 tools down = 50% capacity loss for process step)**
- 26. Downtime of one chamber on a cluster tool restricts use of entire cluster (large loss of process step capacity)**
- 27. Logistics management of reticles is insufficient to keep litho tools utilized for high product-mix/small lot operation**
- 28. Uncontrolled atmosphere around wafers during transportation and long delays between process steps results in lower yield**

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300mmPrime Analysis

**Factory Simulation
Robert Wright, ISMI
Eddy Bass, Intel**

**Economic Analysis
Denis Fandel, ISMI**

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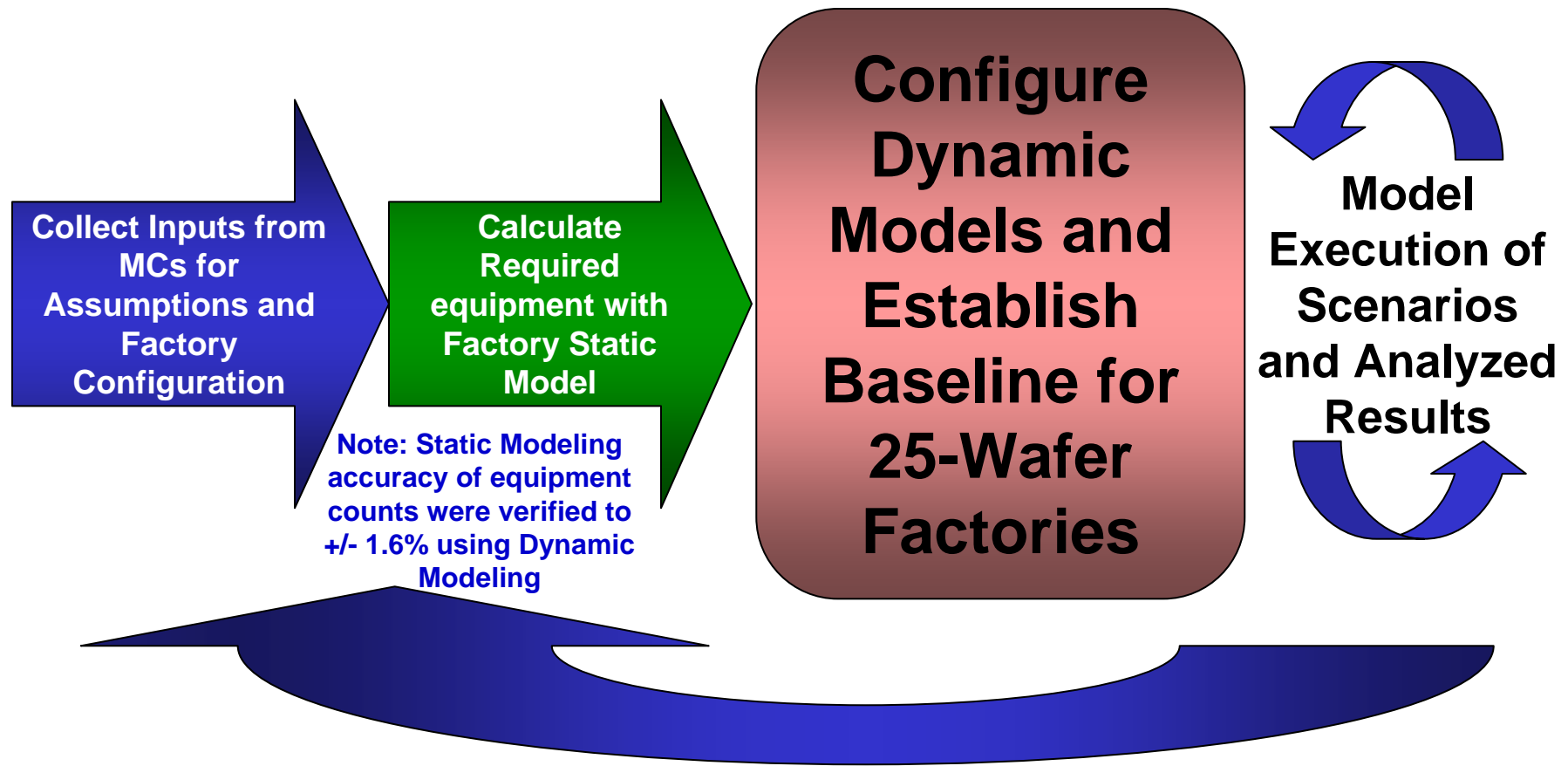
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MANUFACTURING INITIATIVE

Outline

- Modeling Approach
 - Task Cycle
 - Equipment Count Static Model
 - Benchmarks
- Simulation Background and Modeling Definitions
- Verified Factory Dynamics
- Key Scenarios
- 300mm Simulation Modeling Results
 - Low Mix and High Mix
- Observations
 - Low Mix and High Mix
- Challenges and Opportunities

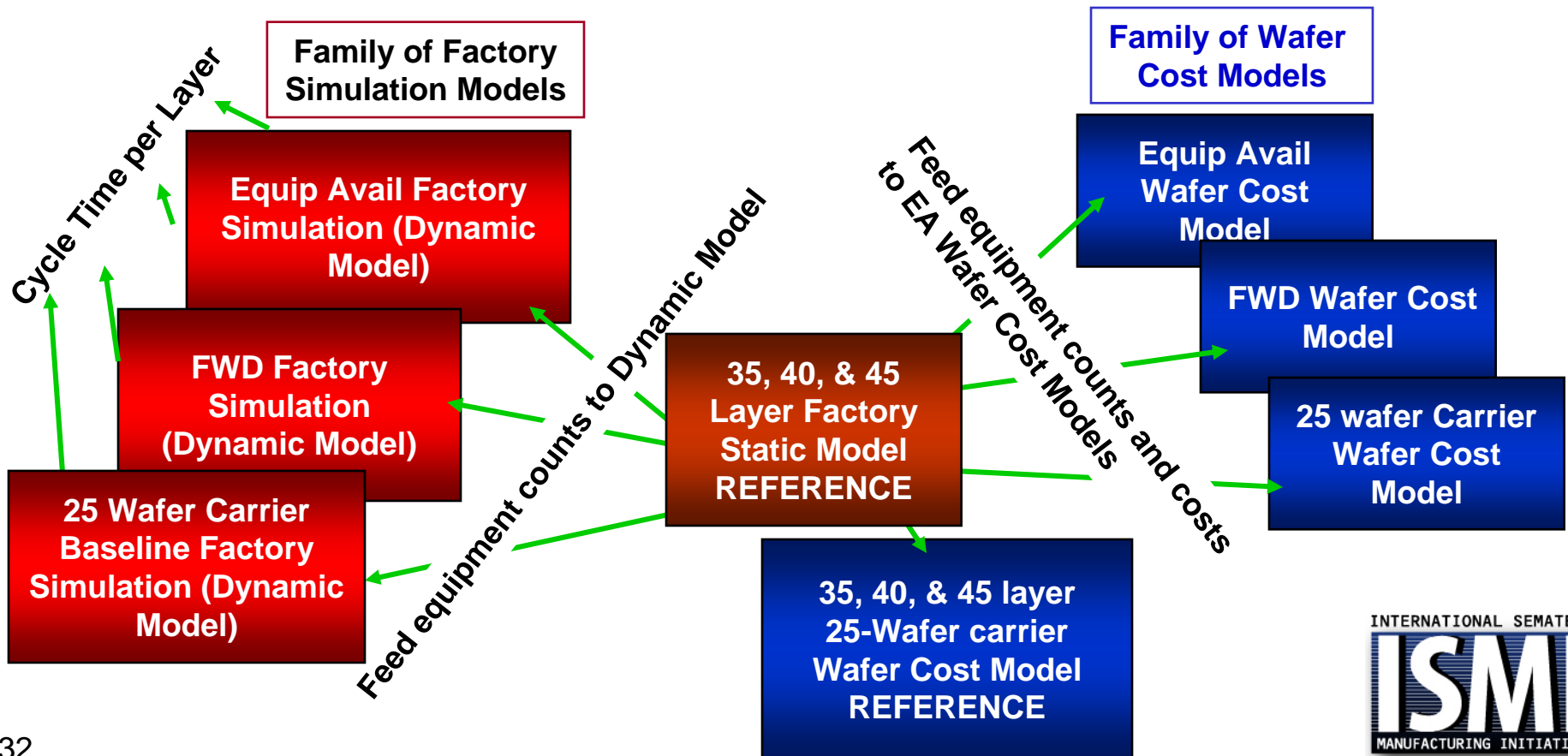
Modeling Approach and Task Cycle



Provided results and observations to member companies as feedback

Simulation and Modeling Approach

- Use Static model to provide equipment counts for Factory Simulation Scenarios
 - Aligned static model equipment count with the baseline 3 process flow Factory Simulation Model at 30k wspm
 - The Factory Simulation model will be used to determine Cycle Time per layer based on equipment counts from the corresponding static model
 - Relative wafer cost provided by economic analysis cost model/



Simulation Background and Modeling Definitions

- Simulation Software – AutoSched AP (ASAP), version 9.0.1, Build 103 – Discrete Event Simulator
 - **Use Semiconductor Extension**
- Reference models (baseline 300mm classic) were used to measure relative changes with each scenario to limit sources of error
- The Equipment Utilization / Equipment Availability (U/A) used as a benchmark of factory loading and identifies equipment constraints to the process
- Cascading: The ability many semiconductor equipment possess to allow the process start of multiple sequential wafers (and lots) before previously started wafers finish processing
 - **This capability can provide faster effective equipment run rates, thereby reducing the number of equipment required**
 - Implemented by different approaches (e.g., multiple chambers, multiple stages, etc.)
 - **To provide cascading in the simulator two ASAP features were used:**
 - Part Interval - to simulated time between process start of wafers for cascading
 - Minimum Queue and Minimum Run – to facilitate longer cascades
- “Extreme” Equipment Improvement Cases: These use scenario limits of First Wafer Delay (FWD), Setup, and Equipment Availability improvements
 - **FWD and Setup: 50% maximum reduction**
 - **Equipment Availability: 10% maximum increase (limited by International Technology Roadmap for Semiconductors “Red” Targets)**
 - ITRS Red Targets = 2010 and later: 98% for Metrology Equipment, 95% for Process Equipment
- High-Mix model has a larger percentage of wafer starts on shorter, older technology flows compared to leading edge low-mix flows

Verified Factory Dynamics

1. Cascading

- Cascading reduces the frequency of setups and FWDs (non-productive time)
- A trade-off of cascade size and frequency of setup and FWD can be exploited
 - Reducing cascade size increases frequency of setups and FWD, resulting in increased utilization of the equipment
 - As utilization of the equipment set increases, the cycle time advantages diminish. As the equipment set approaches or becomes the factory constraint the cycle time impact becomes negative (increasing)

2. Equipment Availability is key to reducing cycle time

- Equipment Availability has a larger effect on cycle time than other equipment improvements modeled

Verified Factory Dynamics

3. Single Wafer Processing (SWP)

- SWP can improve cycle time by eliminating the need to wait to form a batch
- Economies of batching are traded for cycle time reduction (Cost of SWP equipment must be considered)

4. Product Mix

- Increased product mix drives an increase in setup and first wafer delays

5. Reducing First Wafer Delay (FWD) and Setup

- Reductions in FWD and setups drive reductions in the need for cascading as the non-productive time and cycle time are reduced

6. Increasing Equipment

- Purchasing additional equipment can improve cycle time
 - Further cycle time reduction can be obtained by reducing the cascade and/or batch size



Key Scenarios

- Sensitivity analysis of the following parameters were agreed to by the Factory Architecture and Factory Simulation Focus Teams:

Factory Parameters	Business Models	
	Low Mix (3 Process flows and 15 Products)	High Mix (5 Process Flows and 100 Products)
Carrier Capacity	25-Wafer, 12-Wafer, 6-Wafer	25-Wafer, 12-Wafer, 6-Wafer
First Wafer Delay and Setup Time	10%, 25% and 50% Reduction	25% and 50% Reduction
Equipment Availability	5%, 8%, and 10% Increase, limited by ITRS Targets	5% and 10% Increase, limited by ITRS Targets
	•ITRS Yellow Cap Availability (Metrology 96%, Process Tools 92%)	•ITRS Yellow Cap Availability (Metrology 96%, Process Tools 92%)
	•ITRS Red Cap Availability (Metrology 98%, Process Tools 95%)	•ITRS Red Cap Availability (Metrology 98%, Process Tools 95%)
Single Wafer Processing (SWP)	Normal Batching, Single Wafer Processing	Normal Batching, Single Wafer Processing
Combinations	•5%, 8%, and 10% Yellow Availability + 25% Reduction in FWD and Setup	•10% Yellow Availability + 25% Reduction in FWD and Setup
	•10% Red Availability + 50% Reduction in FWD and Setup ("Extreme" Case)	•SWP + 10% Yellow Availability + 25% Reduction in FWD and Setup
	•SWP + 5% Yellow Availability + 25% Reduction in FWD and Setup	



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Low Mix Modeling Assumptions and Results

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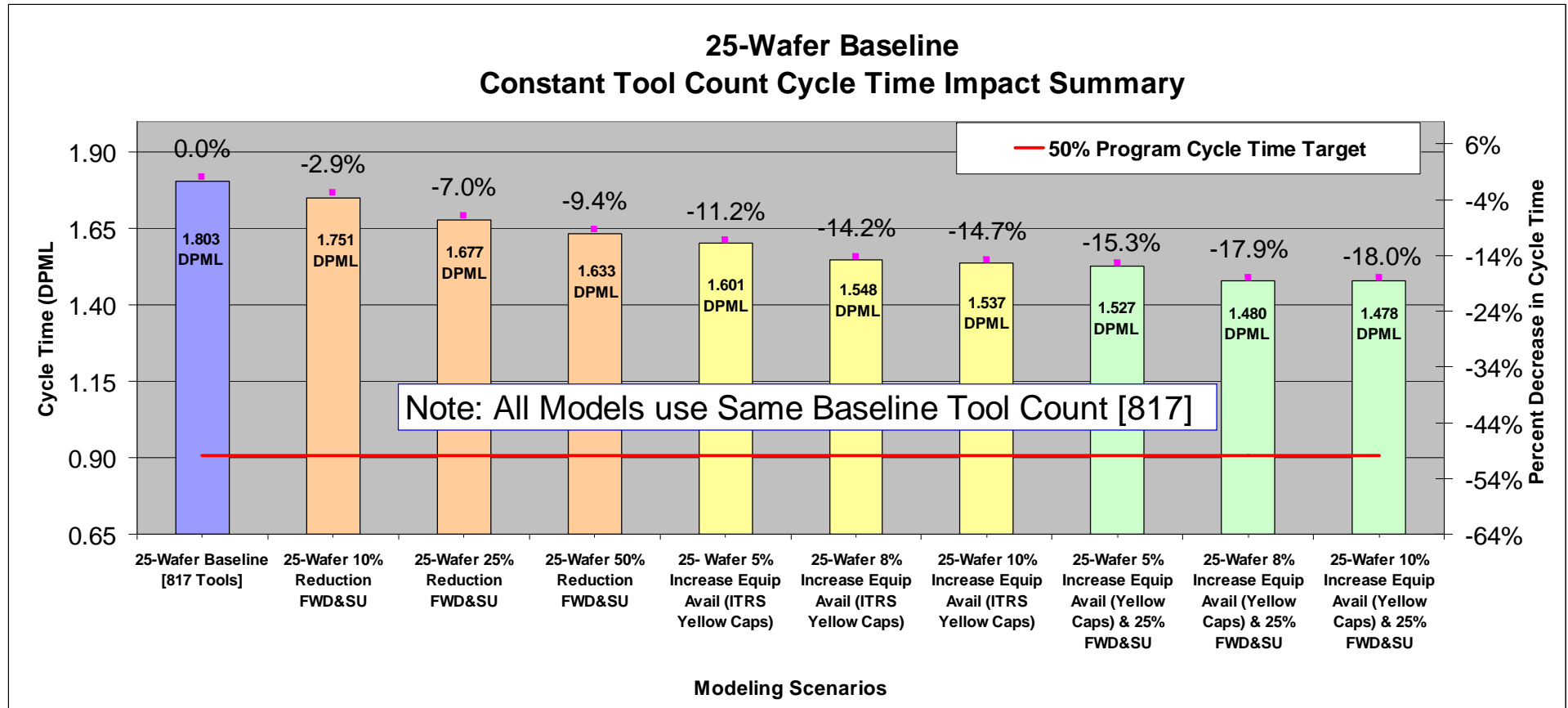
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300mm Classic Low Mix Factory Modeling Assumptions

- 34,500 wafer starts per month
 - Includes 15% Full Loop Equivalent (FLE) Non-production Starts
 - Priority Lots: 2% of wafer starts
- 25-Wafer Carriers
- Process flows: 3 High Performance Logic flows
 - 35, 40 and 45 mask layers
 - 15 Products
- Cascading Methodology
 - 4 Lot Minimum in queue for baseline models before allowing a setup
- Batching Equipment
 - Wet Benches process as a batch of 50 wafers and Furnaces process as a batch of 150 wafers
- AMHS Lot Moves per Hour (assuming two moves per step for Direct Transport System)
 - ~2,500 average moves per hour

Low-Mix Modeling Summary

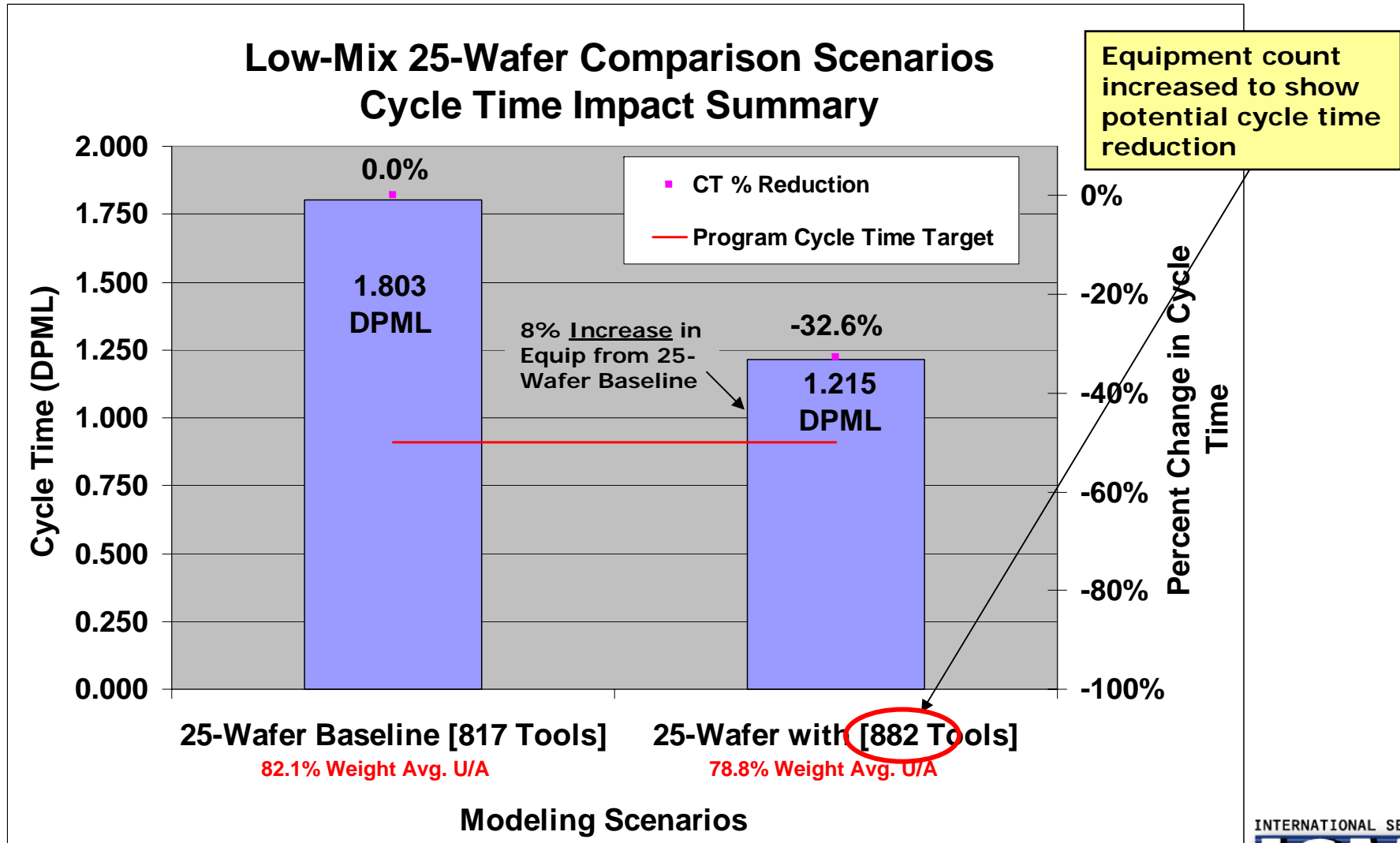
Combinations of Equipment Improvements



- Baseline Days Per Mask Layer (DPML)
- 10%, 25%, 50% FWD & SU DPML
- 5%, 8%, 10% Equip Avail (EA) DPML
- 5%, 8%, 10% EA + 25% FWD/SU DPML

Low-Mix Modeling Results

No R&D Expense Required

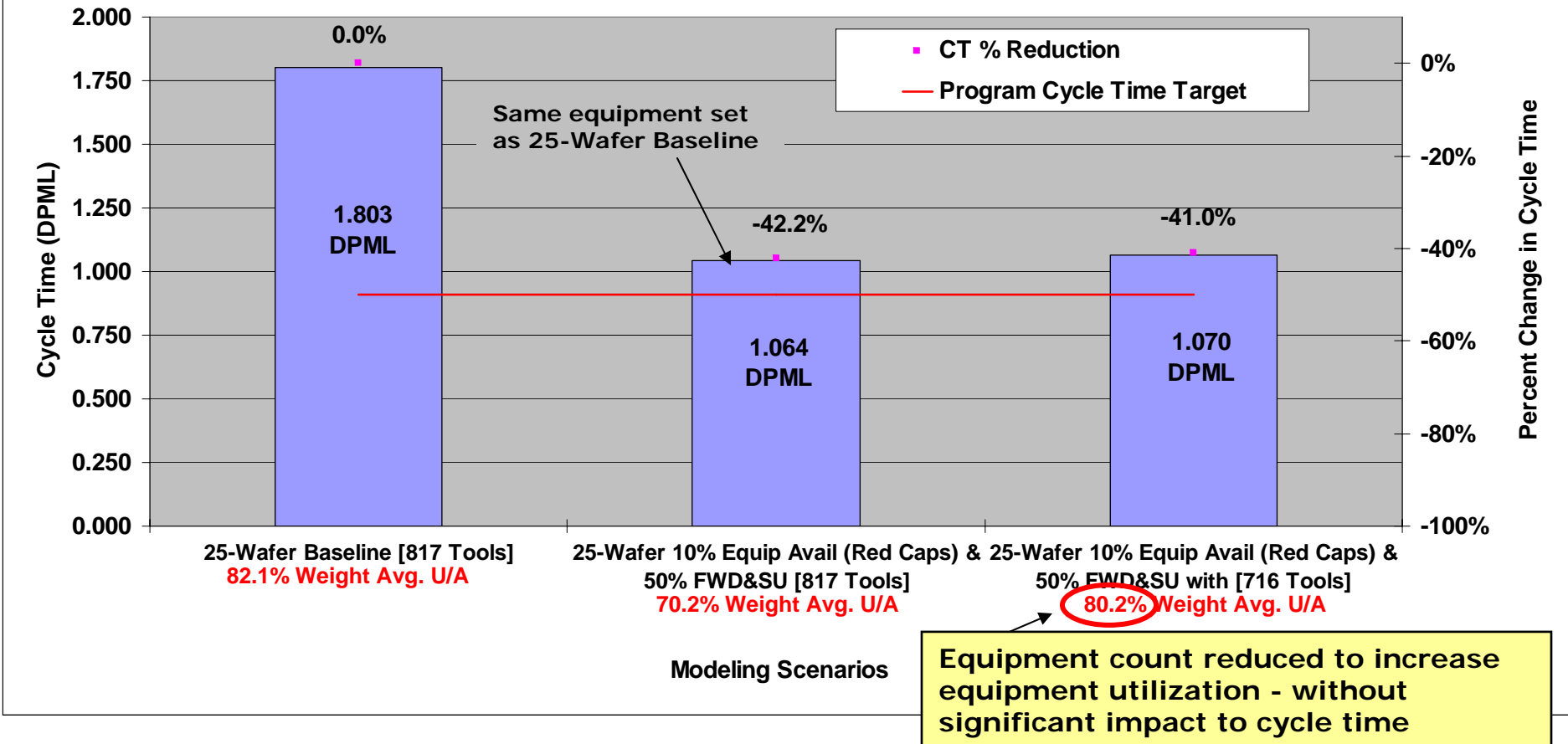


Note: This scenario shows the relationship for these flows between equipment count and cycle time. Buying tools adds no R & D cost to suppliers



Low-Mix "Extreme" Equipment Improvements

25-Wafer "Extreme" Equipment Improvement Scenarios
Cycle Time Impact Summary



Note: Combining "Extreme" equipment improvements such as FWD, Setup, and Availability provided significant reductions in cycle time.

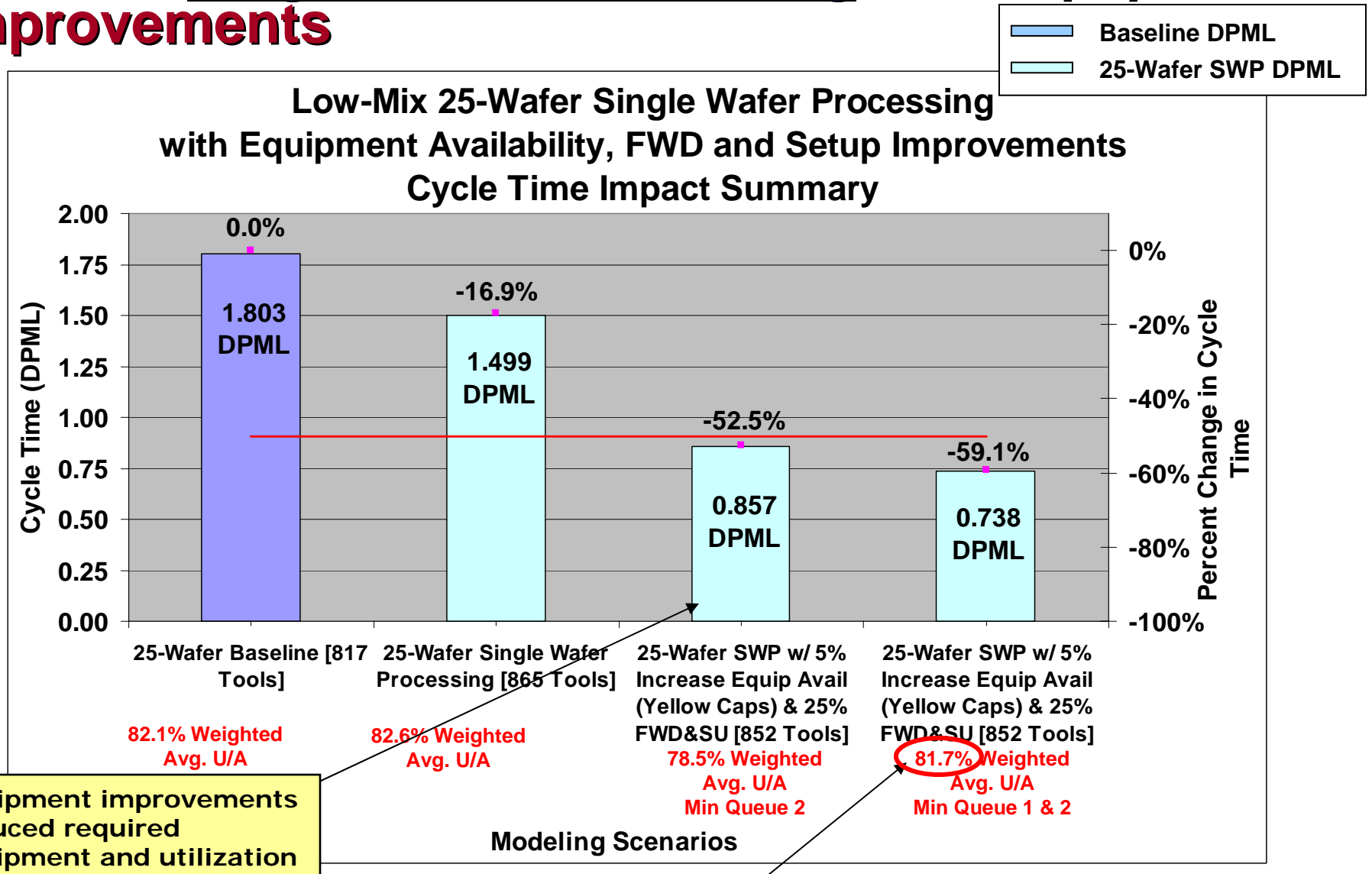


300mm Low Mix Single Wafer Processing Modeling Assumptions

- 34,500 wafer starts per month
 - Includes 15% Full Loop Equivalent (FLE) Non-production Starts
 - Priority Lots: 2% of wafer starts
- 25-Wafer Carrier 300mm Classic Baseline
- Process flows: 3 High Performance Logic flows
 - 35, 40 and 45 mask layers
 - 15 Products
- Cascading Methodology
 - 4 Lot Minimum in queue for baseline models before allowing a setup
- All batch equipment (Wet Etch, Wet Clean and Furnace Operations) are completed as single wafer processing
- AMHS Lot Moves per Hour (assuming two moves per step for Direct Transport System)
 - ~2,500 average moves per hour

Changes from
Baseline = Blue Text

Low-Mix Single Wafer Processing with Equipment Improvements



Equipment improvements reduced required equipment and utilization

Manual optimization of cascading (i.e., adjusting Minimum Queue requirements) increased U/A and further reduced cycle time)



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High Mix Modeling Assumptions and Results

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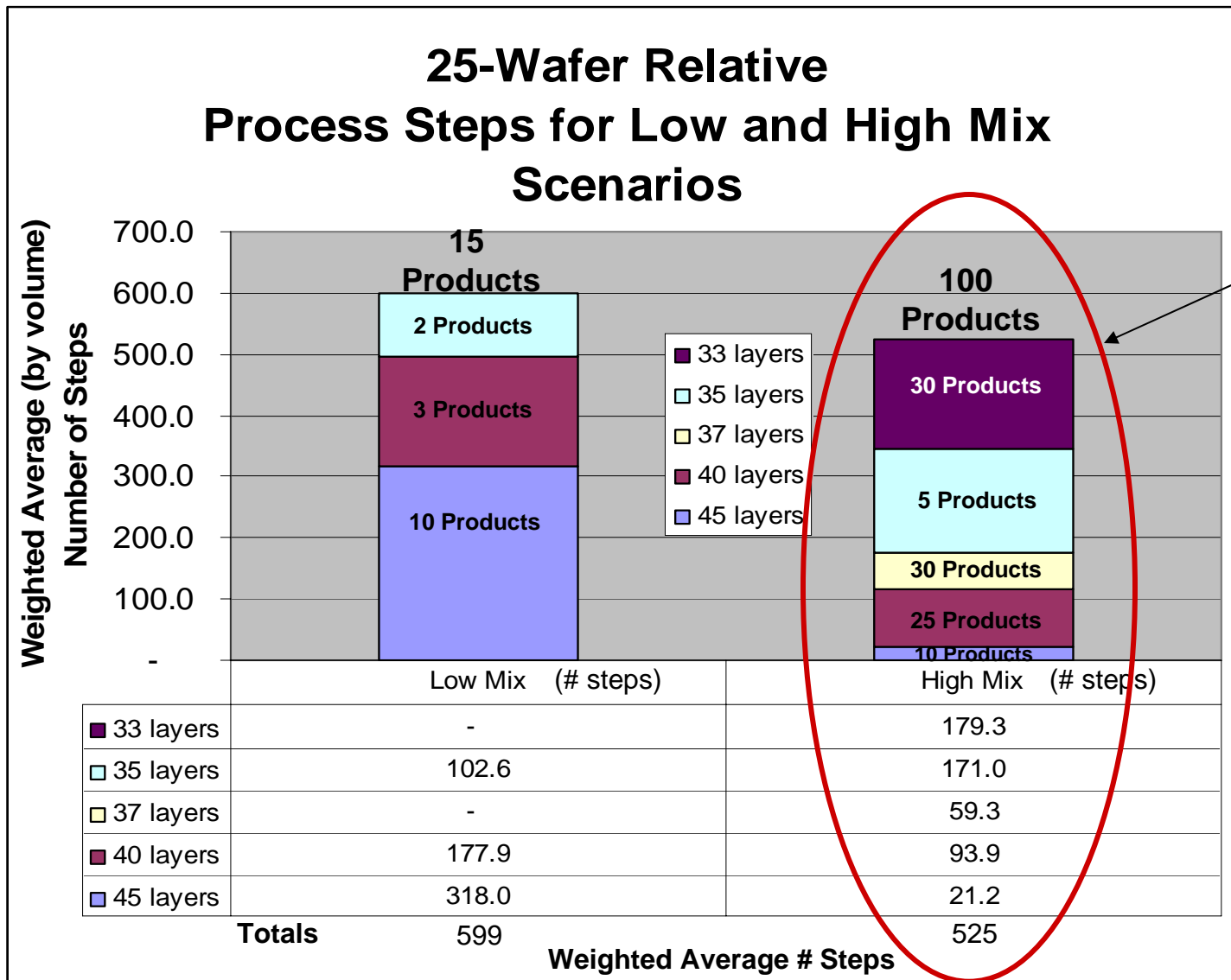
MANUFACTURING INITIATIVE

300mm Classic High Mix Factory Modeling **Assumptions**

- 34,500 wafer starts per month
 - Includes 15% Full Loop Equivalent (FLE) Non-production Starts
 - Priority Lots: 2% of wafer starts
- 25-Wafer carriers
- Process flows: 5 High Performance Logic flows
 - 33, 35, 37, 40 and 45 mask layers
 - 100 Products
- Cascading Methodology
 - 2 Lot Minimum in queue before allowing a setup in baseline models
- Batching Equipment
 - Wet Benches process as a batch of 50 wafers and Furnaces process as a batch of 150 wafers
 - 45 mask layer flow
 - Furnaces: 50 - 100 wafers + wait no longer than ½ batch processing time
- AMHS Lot Moves per Hour (assuming two moves per step for Direct Transport System)
 - ~2,200 moves per hour

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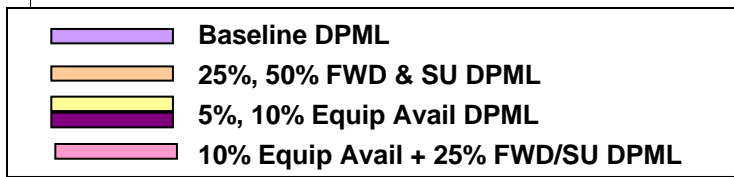
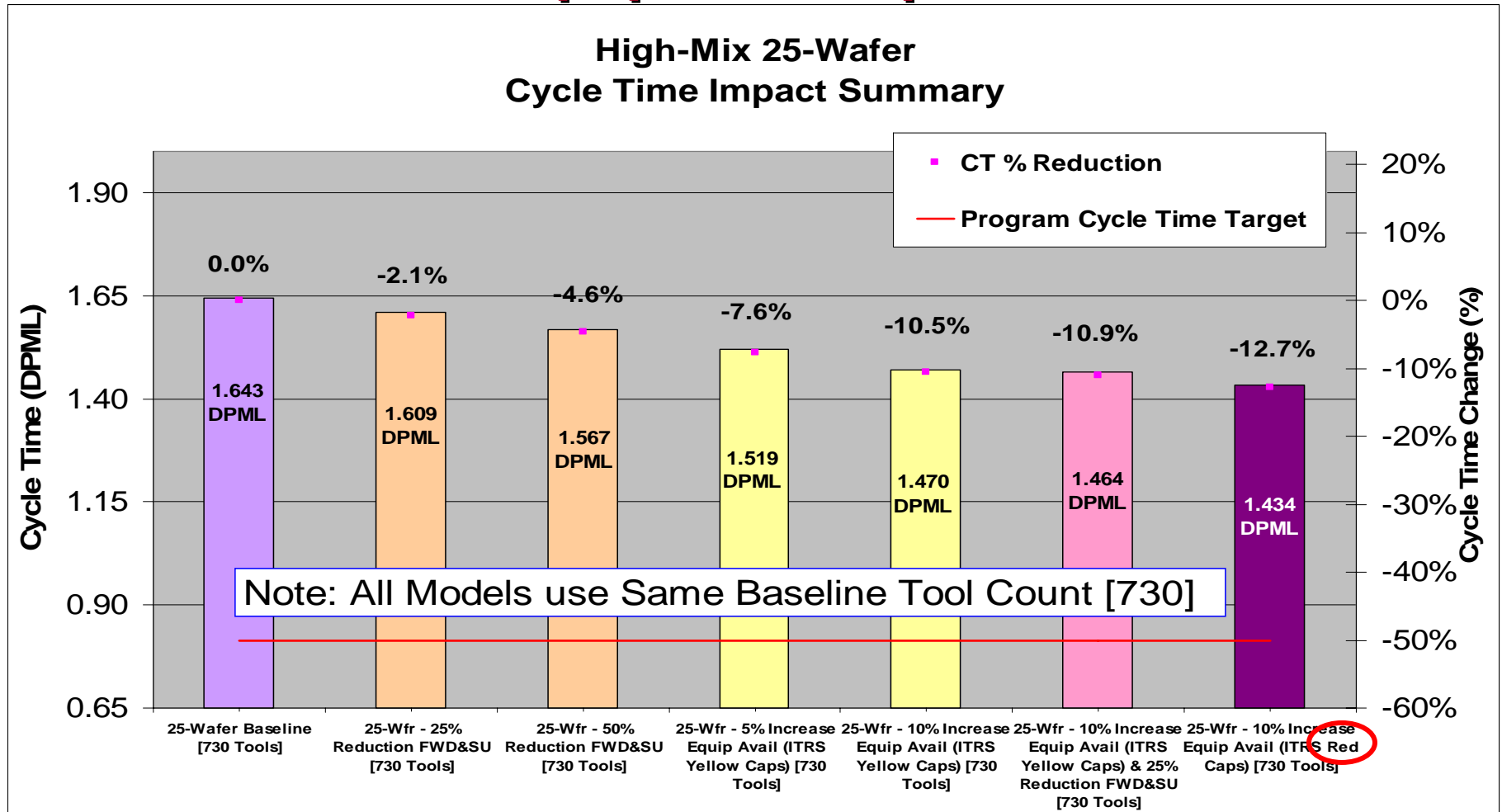
Low to High-Mix Relative Process Flow and Step Comparison



Higher volume of older technology (shorter process flows)

High-Mix Modeling Summary

Combinations of Equipment Improvements



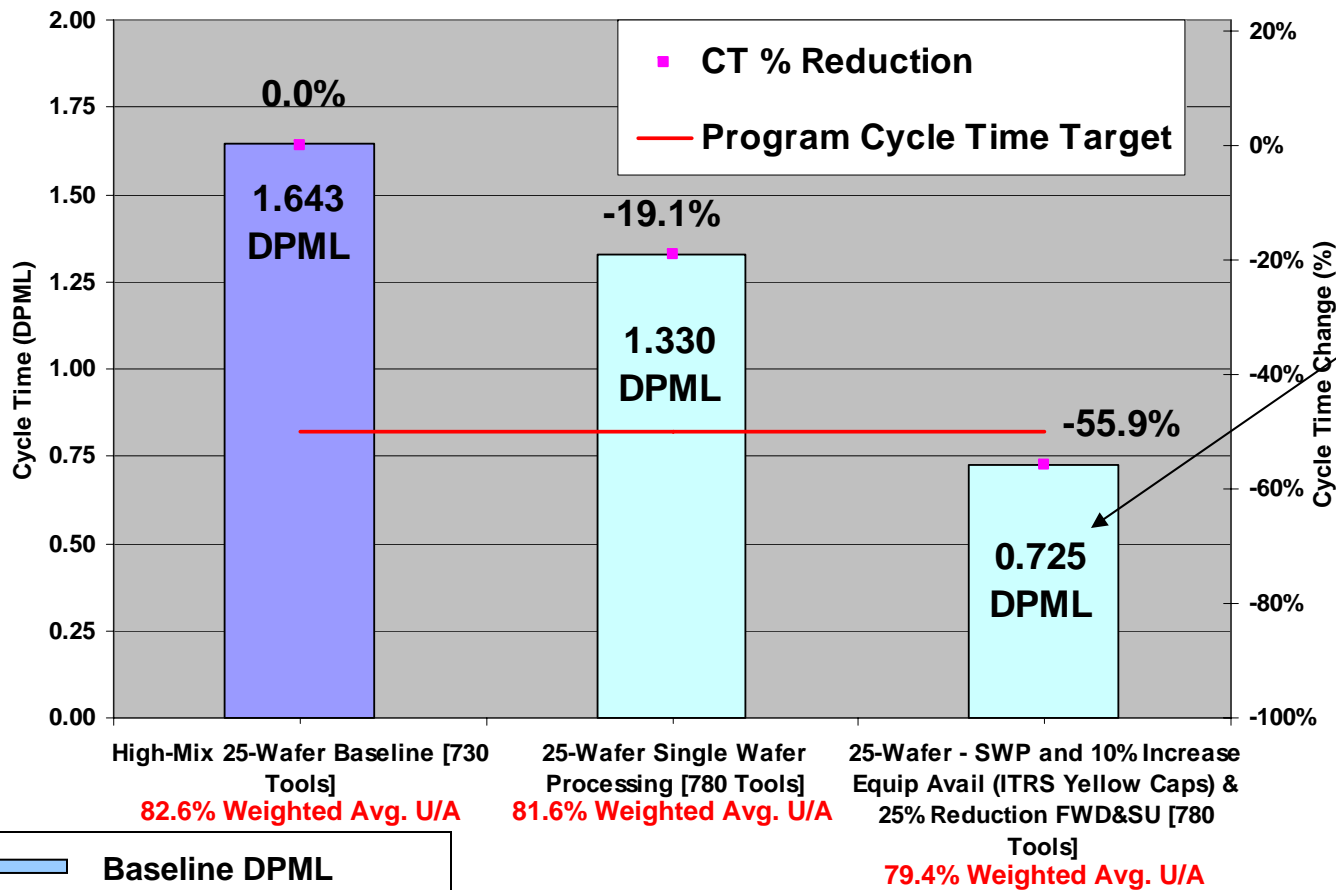
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 - ~2,200 moves per hour

Changes from Baseline
= Blue Text

High-Mix Single Wafer Processing with Equipment Improvements

High-Mix 25-Wafer Single Wafer Processing with Equipment Improvements Cycle Time Impact Summary



Equipment Improvements and manual optimization of cascading (i.e., adjusting Minimum Queue requirements) increased U/A and further reduced cycle time)

■ Baseline DPML
■ 25-Wafer SWP DPML

Modeling Scenarios



Low-Mix Observations

- Add equipment = get cycle time improvements
- With equipment improvements significant cycle time reductions can be obtained with reduced equipment count
- Due to assumed slower processing rates of single wafer processing replacements, significant equipment improvements are needed to reduce the need for additional equipment

High-Mix Observations

- Add equipment = get cycle time improvements
- The limited ability of High-Mix operations to cascade diminishes the potential cycle time reduction with the same equipment improvements as low-mix
- High mix results are similar to Low-Mix, but less cycle time benefit is realized because of the high product mix complexity
 - Easier to use less equipment in high mix

Challenges and Opportunities

- The inability of currently available simulation software to effectively and efficiently model small lot operations
 - Challenges in exploring potential cycle time benefits of small lot operations
 - Low confidence in non-dynamic simulation modeling options - e.g., static and static queuing models

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“Blue Diamond” Economic Analysis

Denis Fandel, ISMI

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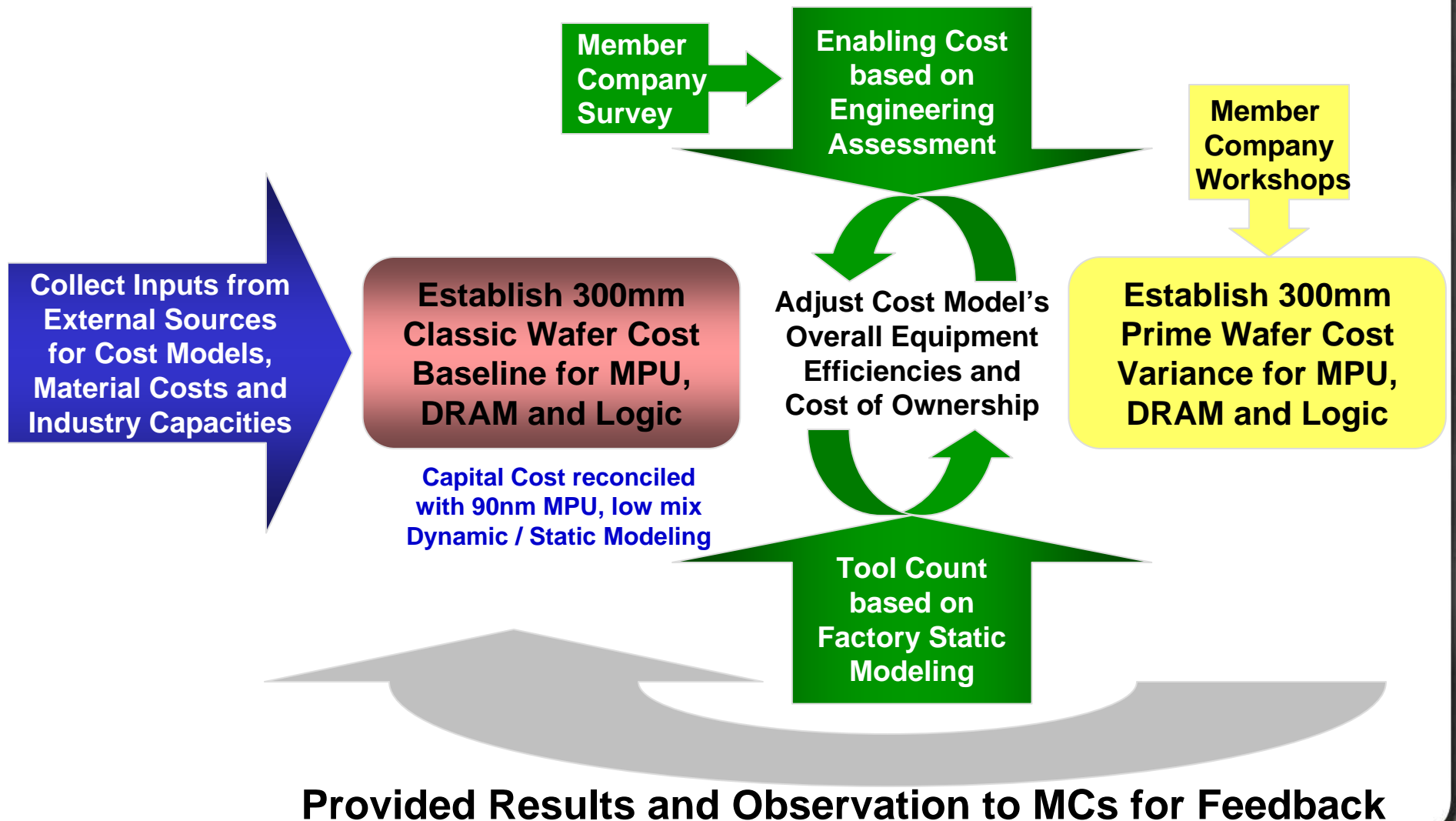
Outline

- **Introduction**
 - Opening Comments, Overview, Methodology
- **300mm Classic Cost Baseline**
 - Assumptions, Trends, Observations
- **300mm Prime Cost / Benefit Analysis**
 - Cost Variance, Scenario Details
- **Summary**
 - Closing Comments

Opening Comments

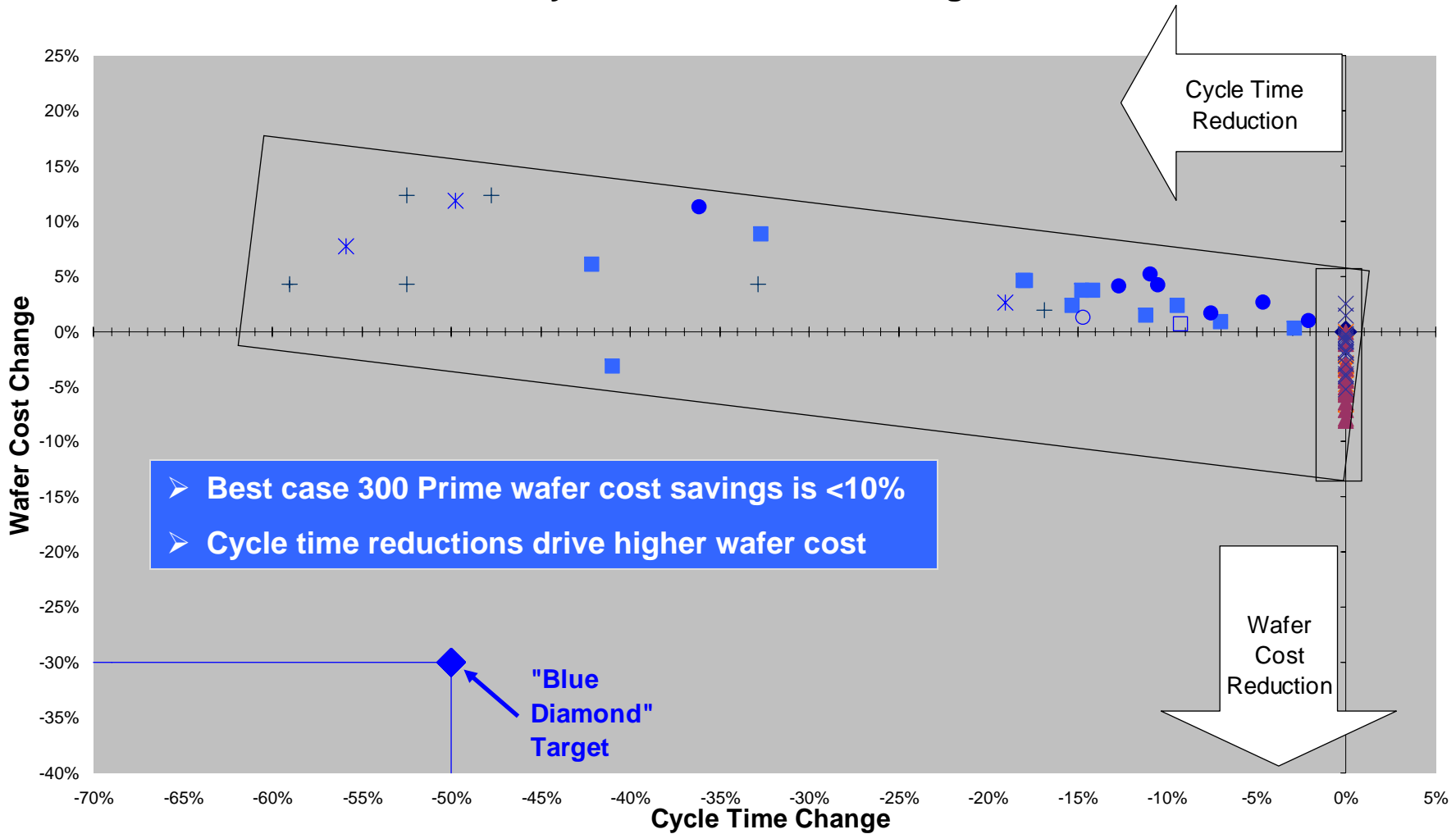
- Scenarios have been selected to understand the boundaries of fab operating performance and is not based on any specific path or solutions
 - Assumptions based on a combination of practical experience / professional judgment / educated guess
- Driven by technology evolution, all leading edge product have a significant wafer processing cost challenge to address by 2012 / 2013
 - If 3 year pace (29%-34%), if 2 year pace (48%-59%)
- No scenario or combination of scenarios met both the blue diamond analysis 50% cycle time and 30% wafer cost reduction targets

Economic Analysis Modeling Approach



Scenarios Overview (All Business Models)

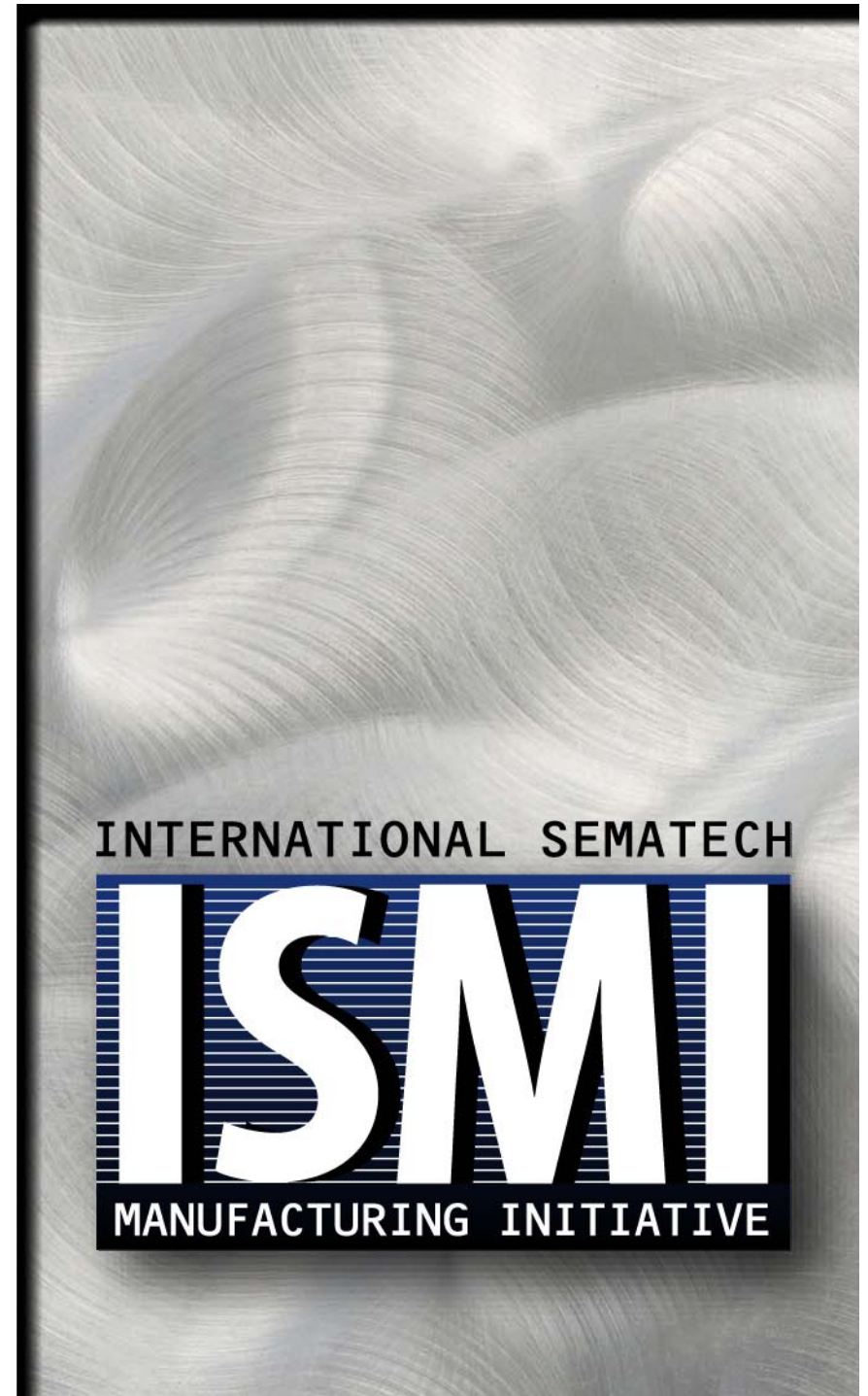
Cycle Time vs. Wafer Change



- Low Mix + with Single Wafer Processing □ SWP (wet benches only)
- High Mix * with Single Wafer Processing ○ SWP (wet benches only)

300mm Classic Benchmark

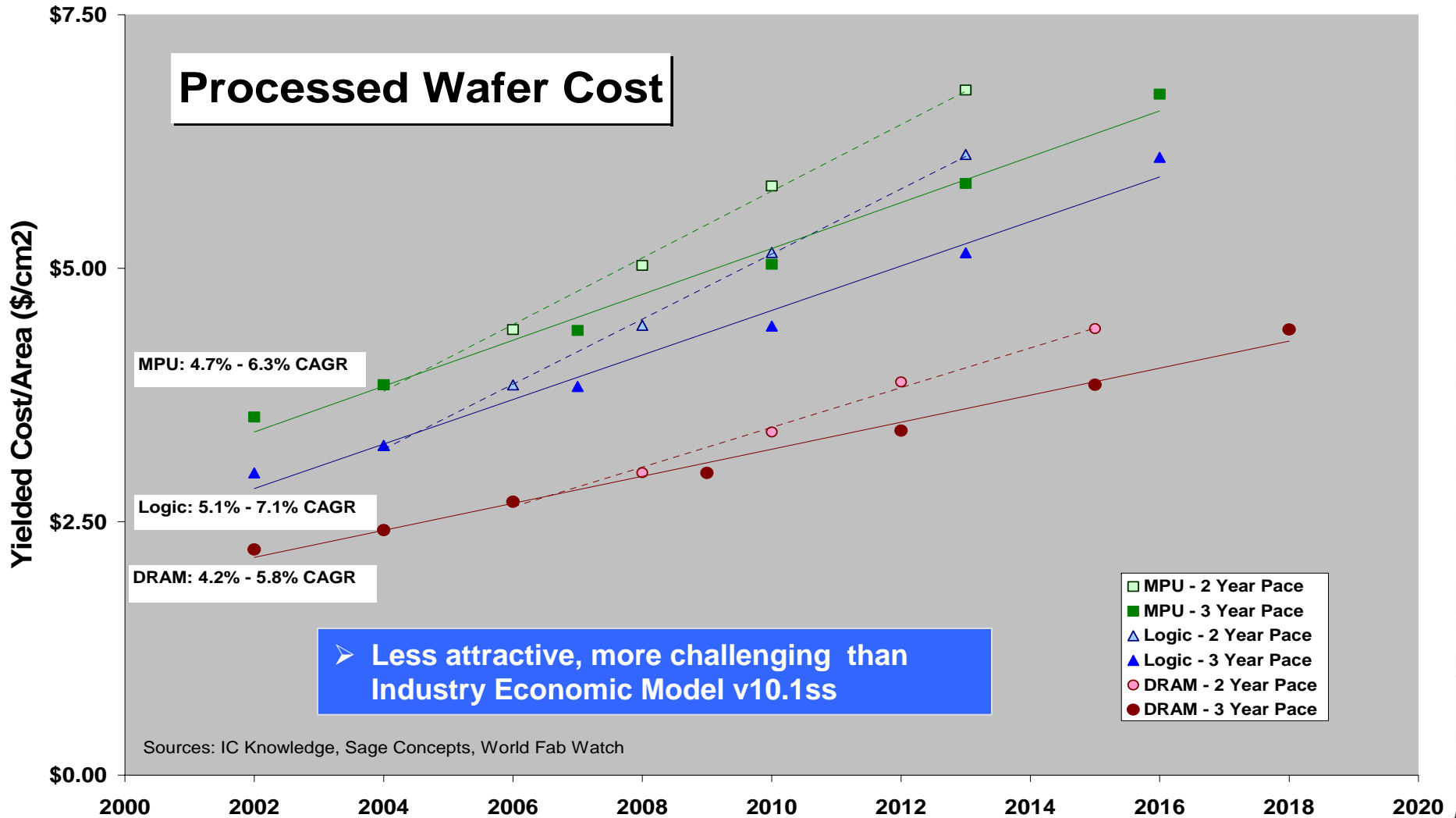
Wafer Cost Profile



Cost Model Assumption

- Wafer Size: 300mm
 - Types: CZ, Epi & SOI
- Capacity: 35,000 Wafers/month
 - Fab Type: New Greenfield
 - Production Loading: 30,450 Wafers/month
- Depreciation Rates:
 - Equipment & Installation 20%, Automation 10%
- Technology Introduction Pace: 65nm – 32nm
 - Base Case: 2006 ITRS, Three year intervals
 - Acceleration Case: Two year interval
- Continuous Improvement Program
 - Overall Equipment Effectiveness: +1%/node
- Wafer Process Yield: 99%

Industry Wafer Cost Trends



➤ Less attractive, more challenging than Industry Economic Model v10.1ss

2002-2012/13 Cost Growth: MPU +65–92%, DRAM +53-74%, Logic +73-105%



Wafer Cost Observations

- Driven by technology evolution, all leading edge products have a significant wafer processed cost challenge (11.5% – 15.4% / node) to address
 - Process Complexity: +9.4% – 10.7% / node
 - Equipment Complexity: +8.7% - 12.4% / node
- Based on current technologies (65nm / 70nm), depreciation expense is the largest component (52.9% – 58.2%) of the wafer processed cost
 - Process Equipment: 66.9% - 68.9% / depreciation
 - Metrology Equipment: 6.2% - 7.0% / depreciation
 - Automation Equipment: 3.7% - 3.8% / depreciation
 - Equipment Installation: 7.3% - 7.6% / depreciation

300mm Prime Cost / Benefit Analysis

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300mm Prime Needs / Key Levers

Developed by ISMI/SEMI Joint Productivity Working Group

- 1. First Wafer Delay** **Scenarios with 10%, 25% & 50% FWD/Set-up Reduction**
 - a. Average setup time per tool including recipe change
 - b. Average time per tool to start processing first wafer after recipe change)

- 2. Tool Variability** **Scenarios with 5%, 8% & 10% Availability Improvements**
 - a. % of down time that is unscheduled (%) – (ability to predict process performance)
 - b. Variability of time between down time (sigma) – (predictable down time)
 - c. Variability of Repair Time (sigma)

- 3. Transport & Storage** **Assumed to be a non-limiting simulation factor**
 - a. Average wafer wait time at the tool (not being processed) inside carrier
 - b. Variability of carrier delivery time (sigma)
 - c. Variability of WIP waiting for tool availability (sigma)

ISMI Engineering Assessment Survey

**Considering all aspect of the supply chain,
evaluate each scenario using the
following criteria:**

- Development effort: (Degree of Difficulty)
 - Easy, Moderate, Hard
- Enabling time: (# of Years / Technology Nodes)
 - < 3years, 3-5years, >5years
- Implementation probability: (Risk vs. Benefit)
 - High, Medium, Low

Engineering Assessment Results

300mm Prime Initiatives		Needs / Key Levers		Approaches
Evaluation Criteria	Metric	First Wafer Delay / Setup Time (% Decrease)	Equipment Availability (% Increase)	Single Wafer Processing (Tool Group)
Development Effort (Degree of Difficulty)	EASY	(first 10% of 50)		(Wet Benches)
	MODERATE	(next 15% of 50)	(first 5% of 10)	
	HARD	(last 25% of 50)	(last 5% of 10)	(Furnaces)
Enabling Time (# of Years)	< 3 years	(first 10% of 50)		(Wet Benches)
	3-5 years	(next 15% of 50)	(first 5% of 10)	
	> 5 years	(last 25% of 50)	(last 5% of 10)	(Furnaces)
Implementation Probability (Risk vs. Benefit)	HIGH	(first 10% of 50)		(Wet Benches)
	MEDIUM	(next 15% of 50)	(first 5% of 10)	
	LOW	(last 25% of 50)	(last 5% of 10)	(Furnaces)

300mm Prime Cost / Benefit – Low Mix

300mm Prime Initiatives		Needs/Key Levers		Approaches
Cost / Benefit	Evaluation Criteria / Metric	First Wafer Delay / Setup Time (% Decrease)	Equipment Availability (% Increase)	Single Wafer Processing (Tool Group)
Cycle Time Benefit (% of Cycle Time Change)	EASY, < 3 years, HIGH	-2.9% (first 10% of 50)		-9.2% (Wet Benches)
	MOD, 3-5 years, MED	-4.1% (next 15% of 50)	-11.2% (first 5% of 10)	
	HARD, > 5 years, LOW	-2.4% (last 25% of 50)	-3.5% (last 5% of 10)	-7.8% (Furnaces)
Optional: Cost Benefit (% of Capital Expense Change)	EASY, < 3 years, HIGH	-1.8% (first 10% of 50)		+0.4% (Wet Benches)
	MOD, 3-5 years, MED	-3.5% (next 15% of 50)	-6.7% (first 5% of 10)	
	HARD, > 5 years, LOW	-3.4% (last 25% of 50)	-4.3% (last 5% of 10)	+0.8% (Furnaces)
Enabling Cost (% of Capital Expense Change)	EASY, < 3 years, HIGH	+0.5% (first 10% of 50)		+0.5% (Wet Benches)
	MOD, 3-5 years, MED	+0.9% (next 15% of 50)	+2.2% (first 5% of 10)	
	HARD, > 5 years, LOW	+2.2% (last 25% of 50)	+3.4% (last 5% of 10)	+1.0% (Furnaces)

Single Factor Impact

300mm Prime Cost / Benefit – High Mix

300mm Prime Initiatives		Needs/Key Levers		Approaches
Cost / Benefit	Evaluation Criteria / Metric	First Wafer Delay / Setup Time (% Decrease)	Equipment Availability (% Increase)	Single Wafer Processing (Tool Group)
Cycle Time Benefit (% of Cycle Time Change)	EASY, < 3 years, HIGH			-14.7% (Wet Benches)
	MOD, 3-5 years, MED	-2.1% (first 25% of 50)	-7.6% (first 5% of 10)	
	HARD, > 5 years, LOW	-2.5% (last 25% of 50)	-2.9% (last 5% of 10)	-4.4% (Furnaces)
Optional: Cost Benefit (% of Capital Expense Change)	EASY, < 3 years, HIGH	-3.4% (first 10% of 50)		+1.1% (Wet Benches)
	MOD, 3-5 years, MED	-3.1% (next 15% of 50)	-7.0% (first 5% of 10)	
	HARD, > 5 years, LOW	-5.9% (last 25% of 50)	-3.5% last 5% of 10)	+0.7% (Furnaces)
Enabling Cost (% of Capital Expense Change)	EASY, < 3 years, HIGH	+0.9% (first 10% of 50)		+0.5% (Wet Benches)
	MOD, 3-5 years, MED	+1.7% (next 15% of 50)	+2.3% (first 5% of 10)	
	HARD, > 5 years, LOW	+4.3% (last 25% of 50)	+3.5% (last 5% of 10)	+1.0% (Furnaces)

Single Factor Impact

Wafer Cost Variance (Maximize Cycle Time Benefit)

300mm Prime Initiatives		Needs/Key Levers		Approaches
Product Group	Evaluation Criteria / Metric	First Wafer Delay / Setup Time (% Decrease)	Equipment Availability (% Increase)	Single Wafer Processing (Tool Group)
MPU (Low mix)	EASY, < 3 years, HIGH	+0.3% (first 10% of 50)		+0.6% (Wet Benches)
	MOD, 3-5 years, MED	+0.6% (next 15% of 50)	+1.4% (first 5% of 10)	
	HARD, > 5 years, LOW	+1.5% (last 25% of 50)	+2.2% (last 5% of 10)	+1.3% (Furnace)
DRAM (Low mix)	EASY, < 3 years, HIGH	+0.3% (first 10% of 50)		+0.7% (Wet Benches)
	MOD, 3-5 years, MED	+0.6% (next 15% of 50)	+1.5% (first 5% of 10)	
	HARD, > 5 years, LOW	+1.6% (last 25% of 50)	+2.4% (last 5% of 10)	+1.3% (Furnace)
Logic (High mix)	EASY, < 3 years, HIGH	+0.6% (first 10% of 50)		+1.2% (Wet Benches)
	MOD, 3-5 years, MED	+1.2% (next 15% of 50)	+1.7% (first 5% of 10)	
	HARD, > 5 years, LOW	+3.2% (last 25% of 50)	+2.6% (last 5% of 10)	+1.4% (Furnace)

+2.9% if enabling expense doubles

+3.0% if enabling expense doubles

+3.7% if enabling expense doubles

Single Factor Impact

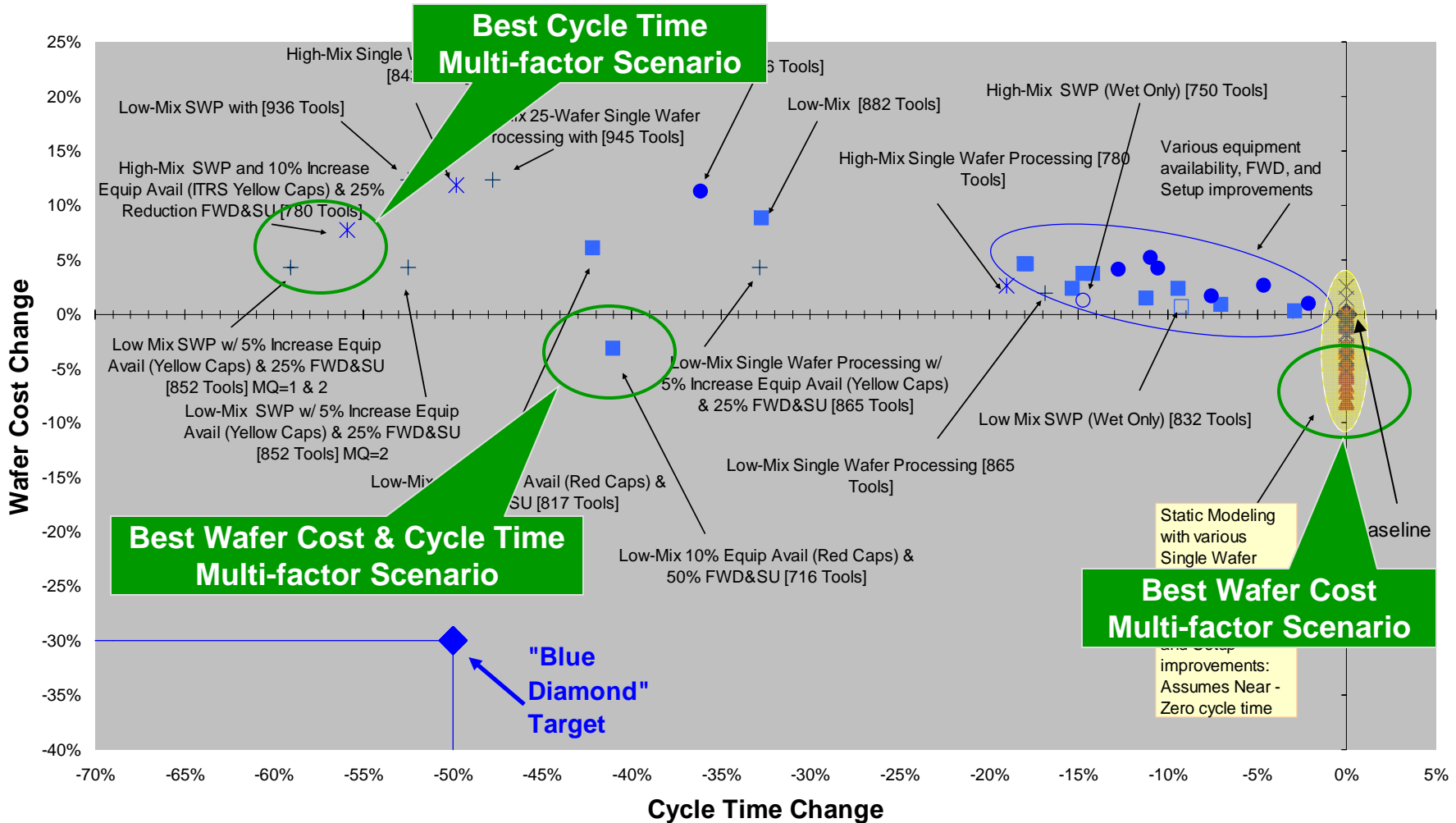
Wafer Cost Variance (Maximize Wafer Cost Benefit)

300mm Prime Initiatives		Needs/Key Levers		Approaches	
Product Group	Evaluation Criteria / Metric	First Wafer Delay / Setup Time (% Decrease)	Equipment Availability (% Increase)	Single Wafer Processing (Tool Group)	
MPU (Low mix)	EASY, < 3 years, HIGH	-1.1% (first 10% of 50)		+0.6% (Wet Benches)	
	MOD, 3-5 years, MED	-1.9% (next 15% of 50)	-3.4% (first 5% of 10)		-14.6% if enabling expense is zero
	HARD, > 5 years, LOW	-1.2% (last 25% of 50)	-1.2% (last 5% of 10)	+0.7% (Furnace)	
DRAM (Low mix)	EASY, < 3 years, HIGH	-1.1% (first 10% of 50)		+0.7% (Wet Benches)	
	MOD, 3-5 years, MED	-2.2% (next 15% of 50)	-3.9% (first 5% of 10)		-15.7% if enabling expense is zero
	HARD, > 5 years, LOW	-1.1% (last 25% of 50)	-1.1% (last 5% of 10)	+1.3% (Furnace)	
Logic (High mix)	EASY, < 3 years, HIGH	-2.3% (first 10% of 50)		+1.2% (Wet Benches)	
	MOD, 3-5 years, MED	-1.3% (next 15% of 50)	-4.3% (first 5% of 10)		-19.2% if enabling expense is zero
	HARD, > 5 years, LOW	-1.8% (last 25% of 50)	-0.3% (last 5% of 10)	+1.4% (Furnace)	

Single Factor Impact

Scenarios Details (with Multi-factor options)

Cycle Time vs. Wafer Cost



- Low Mix + with Single Wafer Processing □ SWP (wet benches only)
- High Mix * with Single Wafer Processing ○ SWP (wet benches only)

Closing Comments

- No scenario or combination of scenarios met both the blue diamond analysis 50% cycle time and 30% wafer cost reduction targets simultaneously.
- While decreasing cycle time may provide overall benefit in some business models, most cycle time reductions may incur an increase in wafer cost.
- Wafer cost benefit (realistically < 10%) could be realized at the expense of cycle time benefit when reducing first wafer delay / setup and increasing tool availability.

Acknowledgements

- **ISMI Economic Analysis Focus Team**

Contributing Companies:

- AMD, Intel, Qimonda, Samsung, tcmc

- **ISMI / SEMI Joint Productivity Working Group**

Contributing Companies:

- Applied Materials, ASML, Axcelis, Brooks Automation, Tokyo Electron

- **Source Material**

Contributing Companies:

- IC Knowledge, Sage Concepts, Semico Research, VLSI Research, World Fab Watch

**ISMI Industry Briefing
July 16, 2007**

Next Generation Factory Vision

**Thomas Jefferson, Intel
Kun Tsang Kuo,
tsmc/ISMI**

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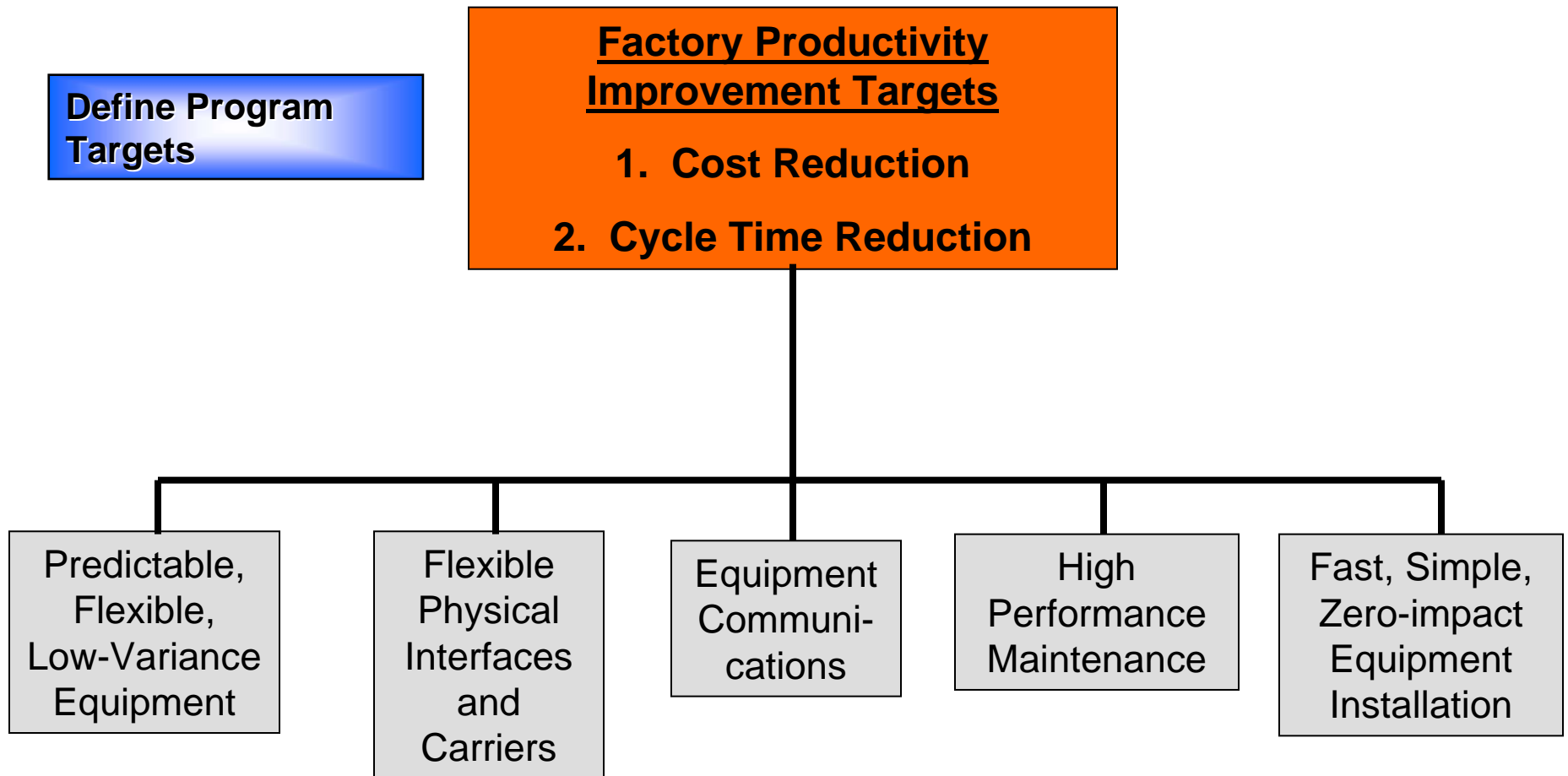
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ISMI Unified 450mm/300mm Prime Vision and Guidelines - Development Approach

<u>Timeline</u>	<u>Deliverable</u>	<u>Result</u>	<u>Additional Detail</u>
Q2'06	Define Program Targets	Cost Reduction, Productivity Improvement	
Q3'06	Define Problem Statement(s)	ISMI 300mm Productivity Detractors List	ISMI Member Company Consensus on 28 300mm Productivity Detractors
Q1'07	High-Level Direction to Resolve Detractors	ISMI Rev.0 Factory Vision	<p>Consolidation of 28 Detractors into 5 Vision 'Themes':</p> <ul style="list-style-type: none"> - Equipment Capability and Design - Equipment Communication & Control - Equipment Maintenance - AMHS, Carriers Performance - Reduced Installation time and Utilities Consumption
Q3'07	Methods to Realize Vision	ISMI Unified 450mm / 300mm Prime Guidelines (Rev.1 Vision)	19 Guidelines to realize Factory Vision and re-use of fundamental 300mm guidelines and concepts

Factory Vision Development



Define Problem Statement(s)

Common Themes from Productivity Detractors



Vision Theme #1: Predictable, Flexible, Low-Variance Equipment

Vision Statement

High-Level Direction to Resolve Detractors ...

Process equipment shall be designed with an emphasis on elimination of all equipment-driven processing delays and per-lot overhead (including multi-lot batching) to enable rapid lot-to-lot setup/changeover at a competitive Cost of Ownership that is independent of lot size, with no negative impact to reliability

Supporting Productivity Detractors (partial list only)

Source: ISMI Member company inputs



- **Batch processing induces long delays** at certain process steps that disrupt factory lot logistics and increases cycle time
- **Delays in *equipment-driven* change-overs** within process equipment negatively impacts cycle time (1st wafer delay, recipe-to-recipe, lot-to-lot etc.)
- **Inability of process tools to seamlessly cascade lots** with different processing requirements
- **Need for equipment-related Non-Product Wafers** reduces overall factory capacity for Product Wafers

... Driven by Problem Statement(s)

Vision Theme #2: AMHS and Carriers

High-Level Direction to
Resolve Detractors ...

Vision Statement

Flexible physical interfaces and wafer carriers, and high-speed, low variability AMHS that can cost-effectively support multiple operational models (including the potential for small-lot manufacturing) are required to enable best-achievable equipment utilizations and yield

Supporting Productivity Detractors Source: ISMI Member company inputs



- **AMHS delivery speeds** insufficient to keep tools utilized for high product-mix/small lot operation
- **Dependence on centralized storage** and delivery distance-related delays results in under-utilized process equipment
- Large carriers induce infrastructure **inefficiencies when running small lot sizes** (storage costs, etc.)
- **Manual reticle delivery insufficient** to keep litho tools utilized for high product-mix/small lot operation
- **Uncontrolled environment around wafers** during transportation and long delays between process steps results in lower yield

... Driven by Problem
Statement(s)

Vision Theme #3: Equipment Communications

Vision Statement

High-Level Direction to
Resolve Detractors ...

Process equipment shall have the ability to maintain continuous, real-time communication with host systems for all tool-generated messaging (down to wafer level data), via standardized messaging formats and open architecture protocols.

Supporting Productivity Detractors

Source: ISMI Member company inputs



- **Inability of process tools to receive complex recipe and parameter instructions** from factory control system limits flexibility of factory and yield
- **Current rates of identification, containment, and notification of excursions** are insufficient, resulting in excessive loss of lots
- **Inability of process tools to provide sufficient data to factory control system** limits lot/process scheduling, tool diagnostics and yield
 - Eg; Inability of factory and equipment systems to track at individual wafer level (vs. lot level) limits the flexibility of the fab for high product-mix operation
 - Eg; Current lot scheduling capabilities and lack of data necessary for decisions result in inefficient factory operation
- **Poor synchronization between process equipment, automation and factory control systems** reduces total factory efficiency

... Driven by Problem
Statement(s)

Vision Theme #4: High Performance Maintenance

Vision Statement

High-Level Direction to Resolve Detractors ...

Process equipment and their supporting systems shall be designed to enable the realization of near-zero variability maintenance



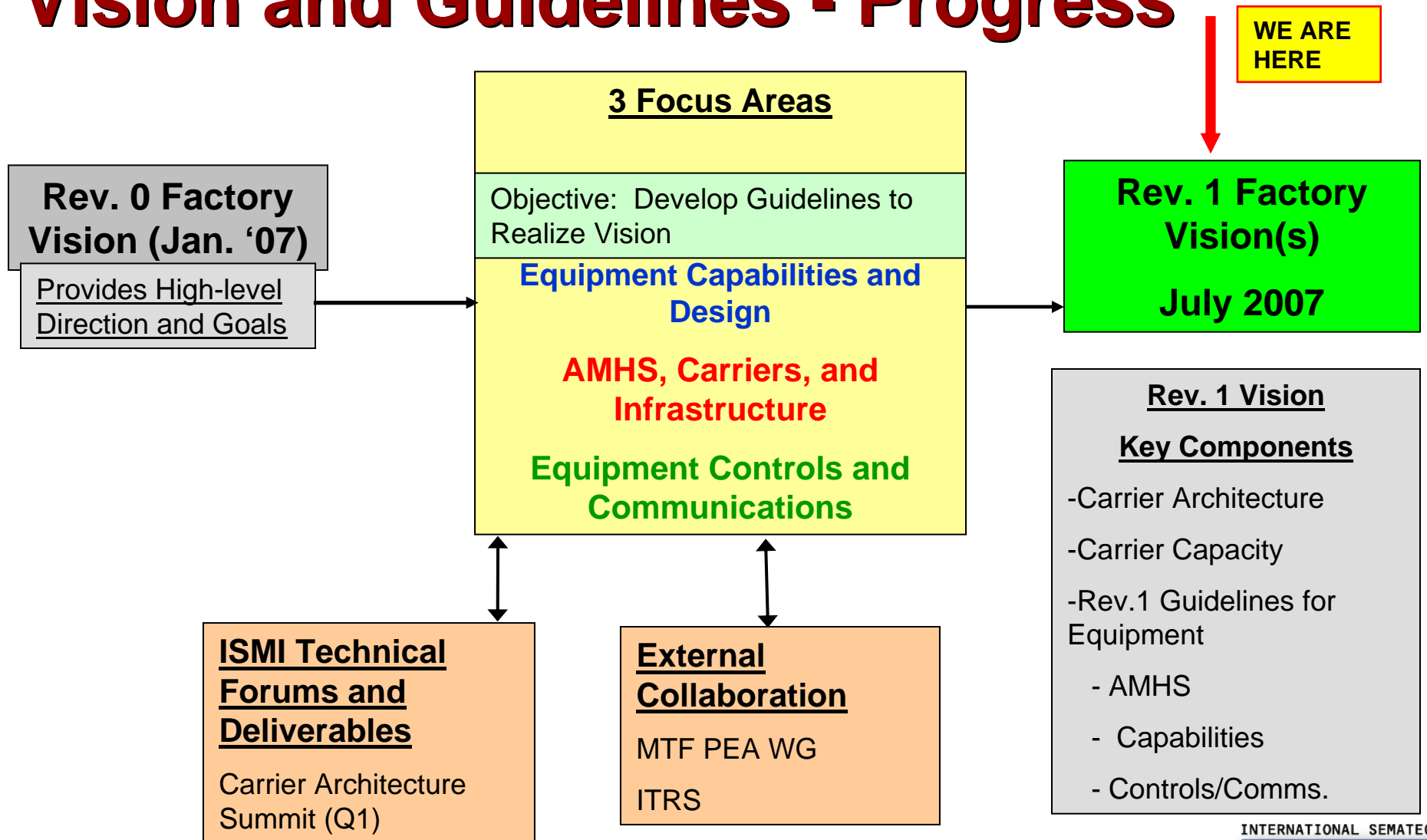
Supporting Productivity Detractors

Source: ISMI Member company inputs

- **Long process equipment maintenance durations** drive significant disruptions to factory lot logistics
- **Downtime of large high-speed process tools** impact lot logistics through a process step with little or no tool redundancy (1 of 2 tools down = 50% capacity loss for process step)
- **Downtime of one chamber on a cluster tool restricts use of entire cluster** (large loss of process step capacity)
- **Inefficient management of spare parts** for process equipment results in additional downtime & factory disruption

... Driven by Problem Statement(s)

Unified 450mm / 300mm Prime Factory Vision and Guidelines - Progress



Vision Theme #5: Efficient Factory Design and Fast, Simple Equipment Installation

Vision Statement

High-Level Direction to Resolve Detractors ...

Next-generation equipment shall realize a significant reduction in the time required to install and qualify new toolsets, and shall be designed to reduce utilities and non-product wafer consumption.



Supporting Productivity Detractors

Source: ISMI Member company inputs

- **Duration of process equipment installation is still too long** and dependent on skilled installation personnel upon delivery
- **Process equipment footprint and height restricts ability to optimize fab layouts**
- **Vertical space inside fab is underutilized** resulting in lower factory capacity
- Steady-state and peak **utilities load from process equipment drives high cost** of factory infrastructure

... Driven by Problem Statement(s)

“19 Point” Guidelines – Highlights

Methods to Realize
Vision

1. Maximum 450mm carrier capacity and specification for early prototypes
2. Front Opening 450mm wafer carriers
3. Carriers Designed for efficient Purging with standardized purge locations
4. MHS Design to assume infrequent, anomaly manual handling only
5. Design to allow automated reticle transport
6. Standardized interfaces - equipment mainframe:process chambers
7. Standardized locations for low-cost buffers on tools (beyond loadports)
8. Equipment to be Predictive Maintenance friendly
9. Equipment maintenance and operation in parallel
10. “Smart Idle” mode for equipment
11. Facility adaptor plates
12. Equipment First wafer delay reduction
13. Single Wafer or Mini-batch (vs. Batch) processing tools
14. Equipment design for flexible capacity increments
15. Enable Continuous processing of material
16. Wafer-level instruction at any time before/during processing
17. Single Point of Control for factory system command/control
18. Equipment data to enable external monitoring
19. Carrier:Slot integrity flexibility

Carriers and
AMHS

Equipment
Design

Equipment
Controls



For Additional Information ...

- **Next Generation Factory Vision: Unified 450mm/300mmPrime Guidelines Workshop**
 - Today, 4:30-6:00
 - Workshop Objective: Discuss in more technical detail the ISMI Unified 450mm / 300mmPrime Factory Vision and Guidelines, and Outline Related Next Steps

**ISMI Industry Briefing
July 16, 2007**

Key Messages & Next Steps

**Tom Abell
ISMI 450mm Program
Manager**

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Perspective on ISMI Direction

- ISMI has developed a comprehensive strategy for near- and long-term productivity improvements
 - **Next Generation Factory Vision and Guidelines covers the continuum of existing and future fabs from 300mm to 450mm**
- An analysis of potential 300mm improvements shows 300mmPrime has cycle time opportunity but falls short of the traditional cost reduction required to stay on Moore's Law.
 - **Metric goal: 30% cost reduction and 50% cycle time improvement**
 - **The financial benefit of cycle time reduction is difficult to quantify for different business models**
 - **Faster new product introduction, time to money, faster product delivery to customers**
- ISMI has developed a complementary forward-compatible approach of 300mmPrime to 450mm
 - **Addresses the needs of our various member constituencies**
 - **Attempts to minimize the R&D expenditure by the industry**
 - **Efficient use of industry resources is key**

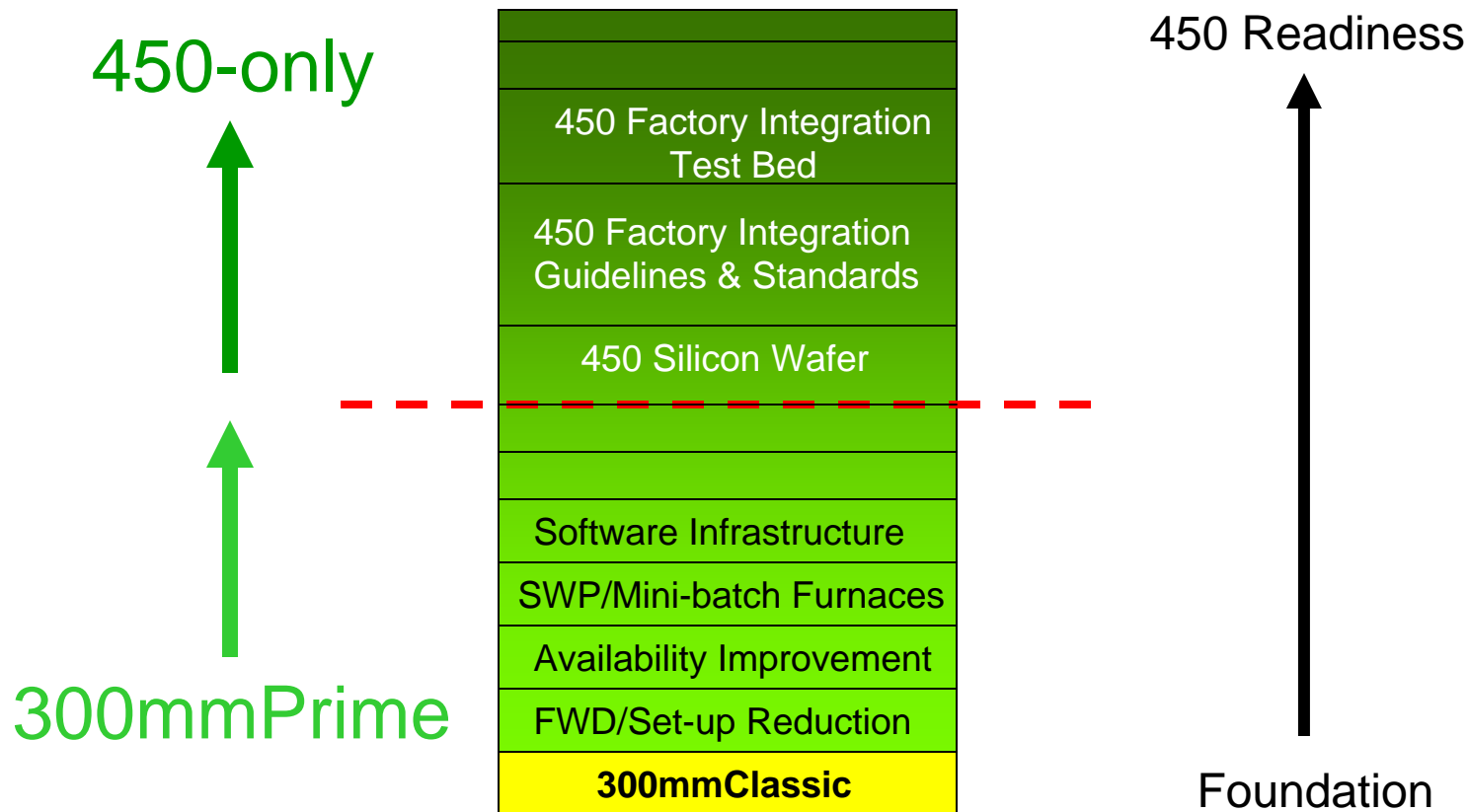
ISMI Perspective on 300mmPrime

- ISMI plans to pursue 300mm improvements that offer near-term productivity benefits in cycle time and cost reduction
 - **Initial focus areas from modeling are:**
 - First Wafer Delay and Set-up reduction
 - Availability improvement
 - Single Wafer/Mini-batch furnace process tools
 - Process capable and competitive on equivalent factory cost and footprint

ISMI Perspective on 450mm

- **ISMI will initiate a 450mm Program dedicated to moving ahead with 450mm industry capability.**
 - **New mission**
 - **New structure**
- **ISMI plans to pursue in 2008:**
 - **Availability of 450mm silicon wafers**
 - **450mm Factory Integration Guidelines & Standards**
 - **Creation of a 450mm Factory Integration Test Bed**
 - **Interoperability testing of prototype automation and equipment interfaces**

Next Generation Factory Vision Realization



- ISMI is moving forward with complementary forward-compatible paths for 300mmPrime and 450mm
 - Realization of 450mm is built upon coordinated improvements from 300mmPrime and 450-only activities to efficiently utilize industry resources
- Collaboration is a critical success factor: Inside and Outside ISMI

300mmPrime Actions for Suppliers

- **Pursue 300mm improvements to achieve significant near-term cycle time and cost reduction opportunities**
 - **Reduce FWD and set-ups at 300mm and use learnings for elimination at 450mm**
 - **Improve equipment availability and predictability at 300mm and use learnings for high-performance 450mm**
 - **Pursue productive and cost-effective 300mm SWP or mini-batch furnace tools with equivalent process performance to batch and plan them for 450mm**

Future Expected Directions to Suppliers

- **Develop capabilities to ensure lots arrive in time at tools and maintain cascading benefits**
 - **AMHS and lot exchange times & variability**
 - **Advanced scheduling and dispatch**
 - **Minimum near-tool buffering (AMHS controlled) or additional loadports (without affecting tool footprint)**
- **Clear expectation from our members for suppliers to take proactive steps to propose and pursue productivity improvements and to meet guideline requirements**

ISMI Next Steps on Improvements

- **Identify key tools and best opportunities for FWD and set-up reduction**
 - Clear definitions/measurement criteria
 - Increased resolution from MC data
 - Work with suppliers on data and improvement roadmaps
- **Assess maximum “realizable” improvements vs. simulation assumptions**
 - FWD, set-up and availability by tool/tool type
 - SWP vs. mini-batch cost vs. benefit vs. quality assessment
- **Increase scope of factory simulations**
 - Limiters for small lot operation
 - AMHS for different carrier sizes
 - Buffering
 - Optimization of multi-factor models for cost-reduction

Small Lot Operation Investigation

- There is interest in a smaller carrier size for certain business models, but the analysis of operational parameters required to demonstrate feasibility will require additional time.
- Need to explore:
 - What is right carrier size for small lot operation?
 - How much can FWD, Setup Time and availability be reasonably expected to improve?
 - What are the associated carrier delivery, loadport exchange and wafer handling requirements and can they be addressed?
 - What is the required increase in AMHS transaction rate and is it feasible?
 - What improvements in factory control (flexibility of scheduling/dispatch) are required and what will it take to get there?
 - What is minimum optimal buffering on- or near-tools?
- ISMI will continue its simulations to answer these questions and report back to the industry in the next year to answer the question of whether a smaller carrier size will join 25 wafer as a guideline.

Next Steps for ISMI in H2'07

- Meet with interested suppliers to discuss 300mm and 450mm implications & opportunities
- Continue to investigate small carrier size options and implications for Next Generation Fabs
- Continue development of Next Generation Factory Guidelines for more detailed level guidance & global perspective
- Update industry on detailed 2008 450mm plans at ISMI Symposium in Oct'07
- Increase synergy between 300mm & 450mm programs
 - Efficient use of industry resources is key
 - Complementary forward-compatible paths
 - Proceed consistent with our principle that 300mmPrime is a productivity continuum to 450mm

Agenda

(1:00) Introduction – Scott Kramer

(1:15) Background – Tom Abell

(1:35) 300mm Prime Analysis

(1:35) Factory Simulation – Robert Wright & Eddy Bass

(2:10) Economic Analysis – Denis Fandel

(2:45) Next Generation Factory Vision– Tom Jefferson

(3:15) Key Messages & Next Steps – Tom Abell

(3:45) Summary/Closing – Scott Kramer

(4:00) Adjourn

[Note: Q&A time allowed in each presentation]

**ISMI Industry Briefing
July 16, 2007**

Concluding Remarks

**Scott Kramer
ISMI Director**

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Summary

- **300mmPrime has cycle time opportunities but does not sufficiently address cost reduction needs to replace 450mm transition**
- **ISMI has developed a complementary forward-compatible approach of 300mm to 450mm**
 - Addresses the needs of our various member constituencies
 - Attempts to minimize the R&D expenditure by the industry
 - Efficient use of industry resources is key
- **Implications to ISMI programs**
 - **Initiate tangible 450mm activities to address long-term fundamental cost reduction**
 - *Cycle time also important for 450mm*
 - **Pursue 300mm improvements to enable significant near-term cycle time and cost reduction efforts**
 - **Initial 2008 activities efficiently guide two supplier groups**
 - **300mmPrime: Process & Metrology Equipment**
 - **450mm: Silicon & Factory Integration**

For more Information...

This presentation material will be made available for download at the SEMATECH public website:
www.ismi.sematech.org

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