Fab Transition Strategy

Next Generation Factory Vision from 300mm to 450mm

Tom Abell
450mm Program Manager

Brad Van Eck
Factory Productivity Manager

October 25, 2007

ISMI Symposium
On Manufacturing Effectiveness

Agenda

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On Manufacturing Effectiveness

Fab Transition Strategy
October 25, 3:00 – 6:00pm

- **3:00 – 3:10 Introduction and Overview – Tom Abell**
- **3:10 – 3:30 Next Generation Factory Vision – Tom Abell**
- **3:30 – 4:00 300mm Projects – Brad Van Eck**
  - Overview of 300mm projects supporting Next Generation Factory Vision
- **4:00 – 4:40 450mm Transition Program – Tom Abell**
  - 450mm Transition Strategy Program
  - 450mm Silicon Readiness
  - 450mm Interoperability Test Bed
  - 450mm Guidelines and Standards
- **4:40 – 5:00 Questions & Answers**
- **5:00 – 6:00 NGF/450mm interactive session**
  - **in Live Oak Room**

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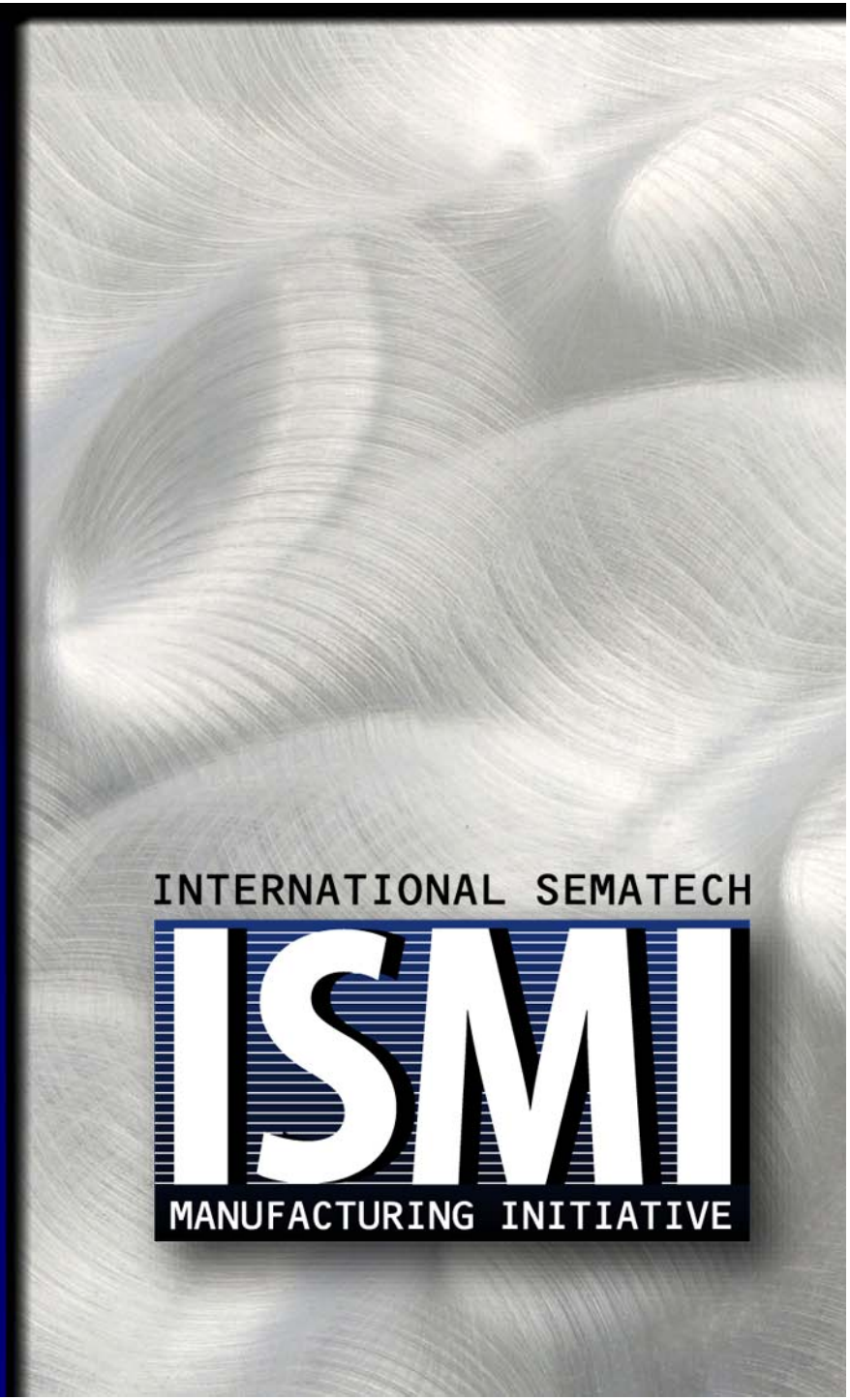
Introduction and Overview

Tom Abell
450mm Program Manager



Background

- ISMI member companies concur that major improvements in productivity are needed to sustain industry growth
- Significant changes in business conditions and business needs have revealed limitations in existing 300mm designs
- ISMI is investigating various paths to achieve significantly higher manufacturing productivity in the near- and far-future

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 300mm Prime 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 300mm Prime 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**

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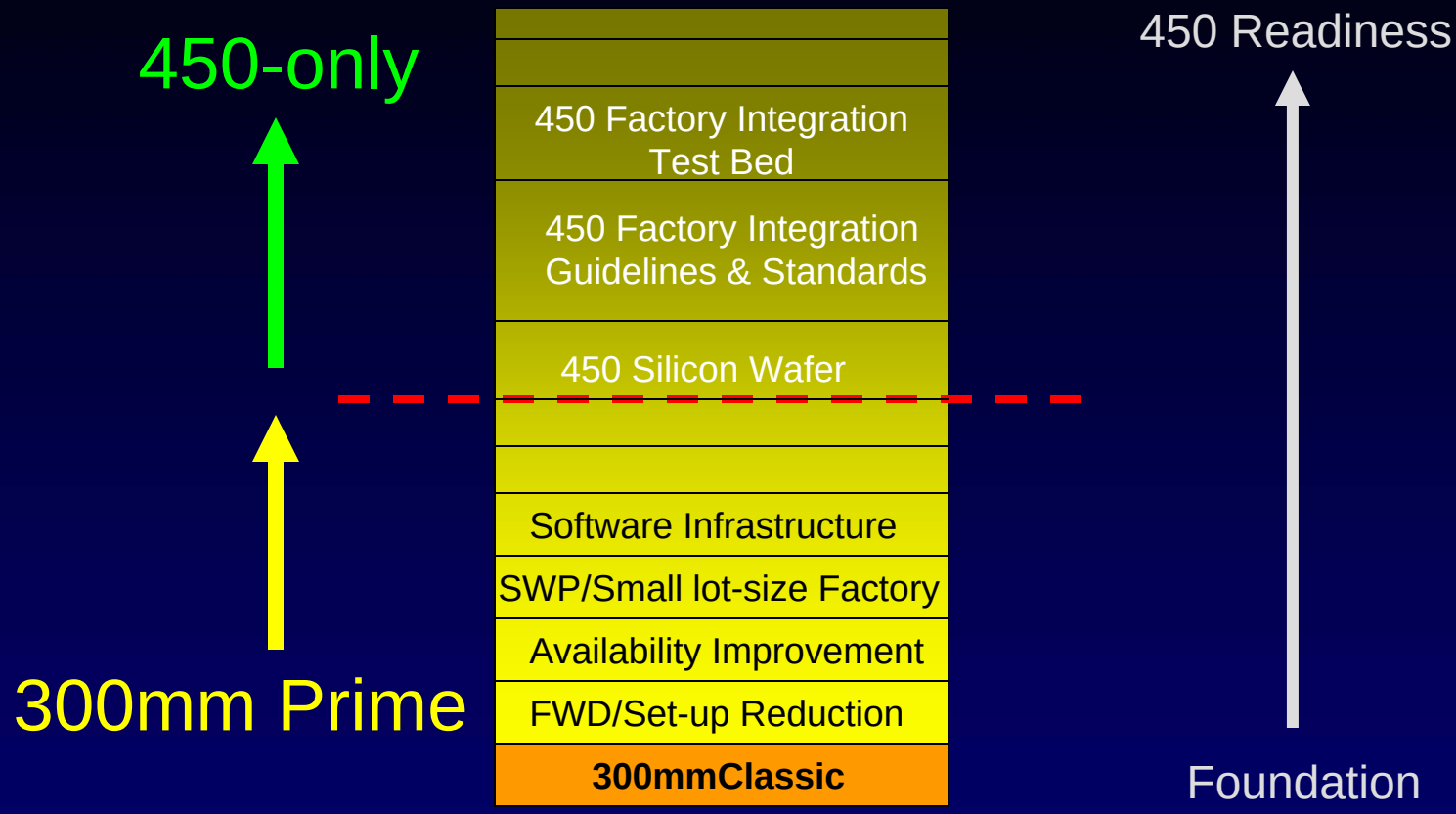
Next Generation Factory Vision Realization



- **ISMI is moving forward with complementary forward-compatible paths for 300mm Prime 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**

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ISMI Perspective on 300mm Prime

- **ISMI plans to pursue 300mm improvements that offer near-term productivity benefits in cycle time and cost reduction. This includes future optimized high productivity factories.**
  - Initial focus areas include:
    - Next Generation Factory Realization Project
    - First Wafer Delay/Set-up Reduction
    - Predictive Preventative Maintenance
    - Equipment Data Quality
    - Factory for Small Lot Size
  - Production equipment reliability is a key opportunity for continuous improvement

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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

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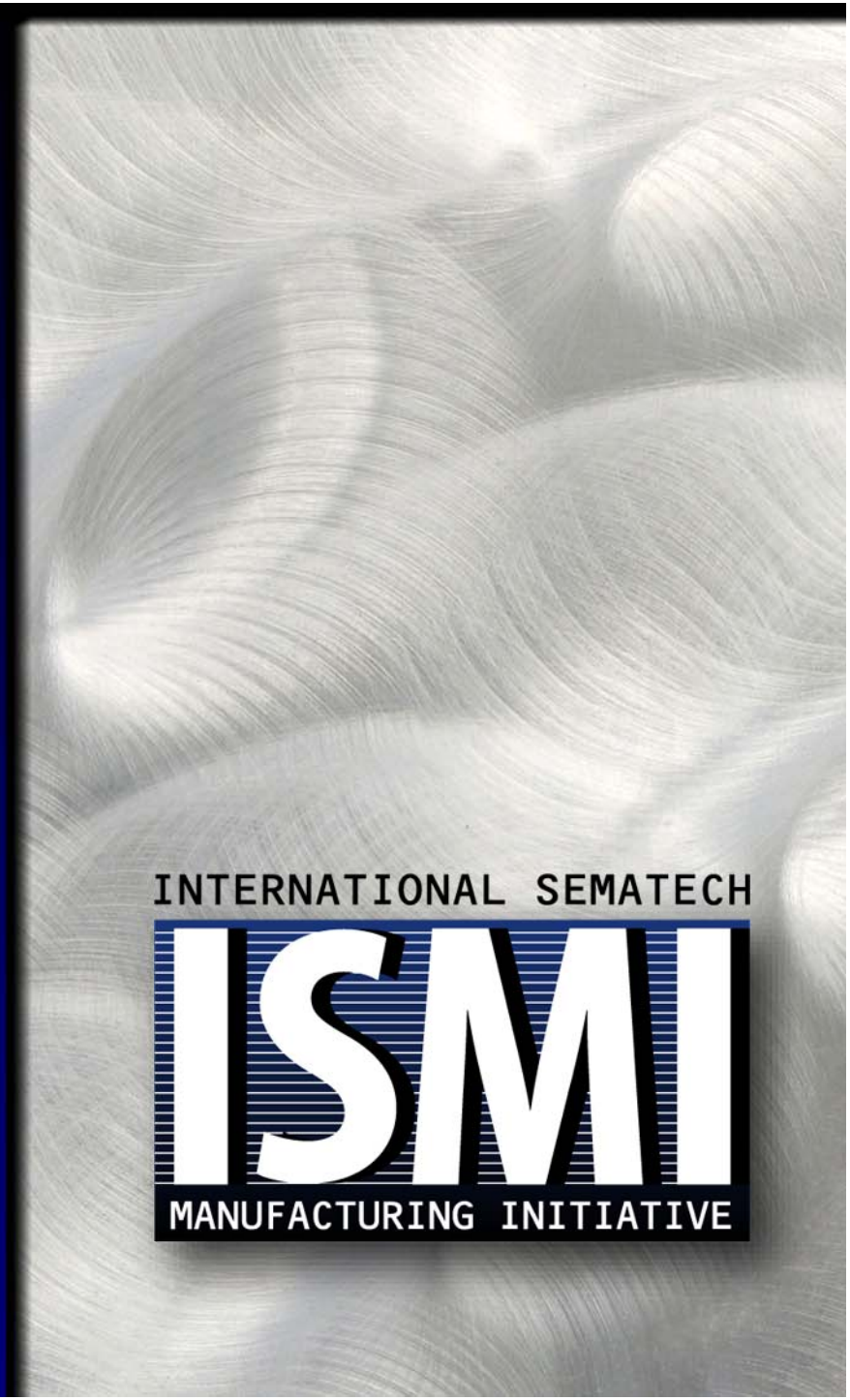
Next Generation Factory Vision

Tom Abell
450mm Program Manager



Next Generation ISMI Factory Vision Themes
- Categories and boundaries for guidelines and standards

1. **Process equipment shall be designed with an emphasis on elimination of all equipment-driven processing delays and per-lot overhead (including multi-lot batching)**
   - **Enables rapid lot-to-lot setup/changeover at a competitive Cost of Ownership that is independent of lot size, with no negative impact to reliability**
2. **Process equipment and their supporting systems shall be designed to enable the realization of near-zero variability maintenance**
3. **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.**
4. **Process equipment shall have the ability to maintain continuous, real-time communication with host systems**
   - *Includes all tool-generated messaging (down to wafer level data), via standardized messaging formats and open architecture protocols.*
5. **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)**
   - *Required to enable best-achievable equipment utilizations and yield*

Process Equipment Themes

Communication/Controls Themes

Carriers/AMHS Themes

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“19 Point” Guidelines to enable Next Generation Factory 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 allowing Automated reticle transport

Carriers and AMHS

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

Equipment Design

15. Enable Continuous processing of material
16. Wafer-level instruction at any time before processing
17. Single Point of Control for factory system command/control
18. Equipment to provide data to enable external monitoring
19. Carrier:Slot integrity flexibility

Equipment Controls

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ISMI Guideline Development Priorities

300mm

- Elimination of First Wafer Delay (#12) is the top priority guideline for 300mm NGF
- Predictive Maintenance (#8), Ability to perform Maintenance and Operations Simultaneously (#9), Continuous Operation (#15), and Equipment Engineering Data for Monitoring (#18) are important and with high benefit.

450mm

- Front-opening, 25 wafer, purge-able carriers (#'s1-3) are top priority for 450mm
- Elimination of First Wafer Delay (#12) is important and with high benefit
- 300mm equipment improvements and learnings expected to be applicable to 450mm

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Summary

- **300mm Prime 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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Background

300mm Prime Analysis and Next Steps

300mm Transition Lessons Learned

- Industry coordination is crucial; early engagement of equipment and materials manufacturers
  - Determine fab architecture
  - Develop standards at the appropriate time
  - 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

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ISMI 450mm Program Objectives

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

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

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“Blue Diamond” Background

- 30% reduction in cost per area and 50% reduction in cycle time were set as the targets for 300mm Prime or 450mm in 2Q06
- Analysis of 300mm Prime potential against targets was decided in 3Q06 for completion by 2Q07
  - Determine whether 300mm 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 300mm Prime

      OR
    - Accelerate 450mm planning and development
- Actions on 300mm 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 / 300mm Prime strategy
    - Development of 19 Point Guidelines
    - Discussion/collaboration with SEMI and the industry during development process

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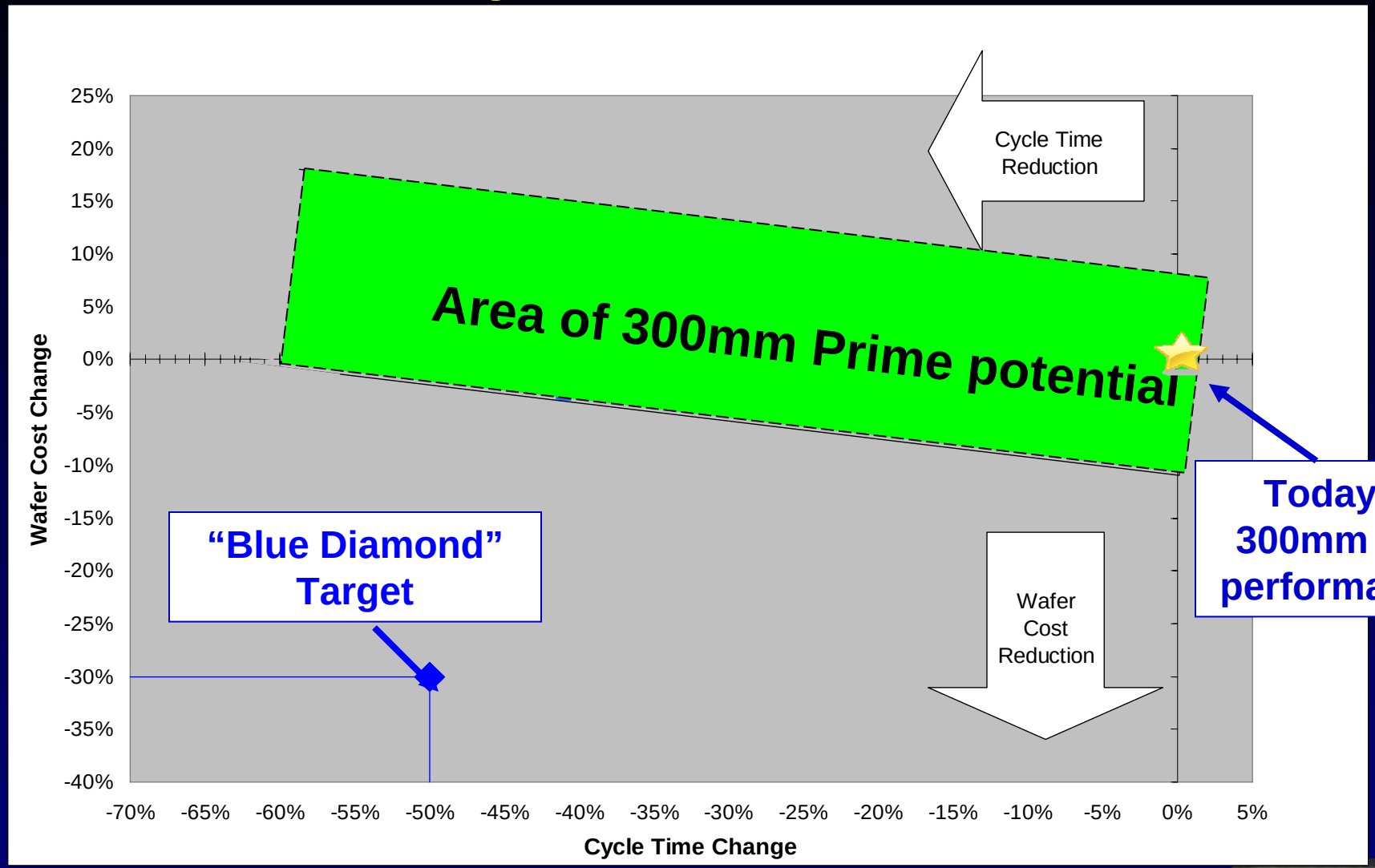
300mm Prime - Cycle Time vs. Wafer Cost View



- Best-case 300mm Prime wafer cost savings modeled are <10%
- Cycle time reductions >50% modeled but may drive higher wafer cost

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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 measure 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**

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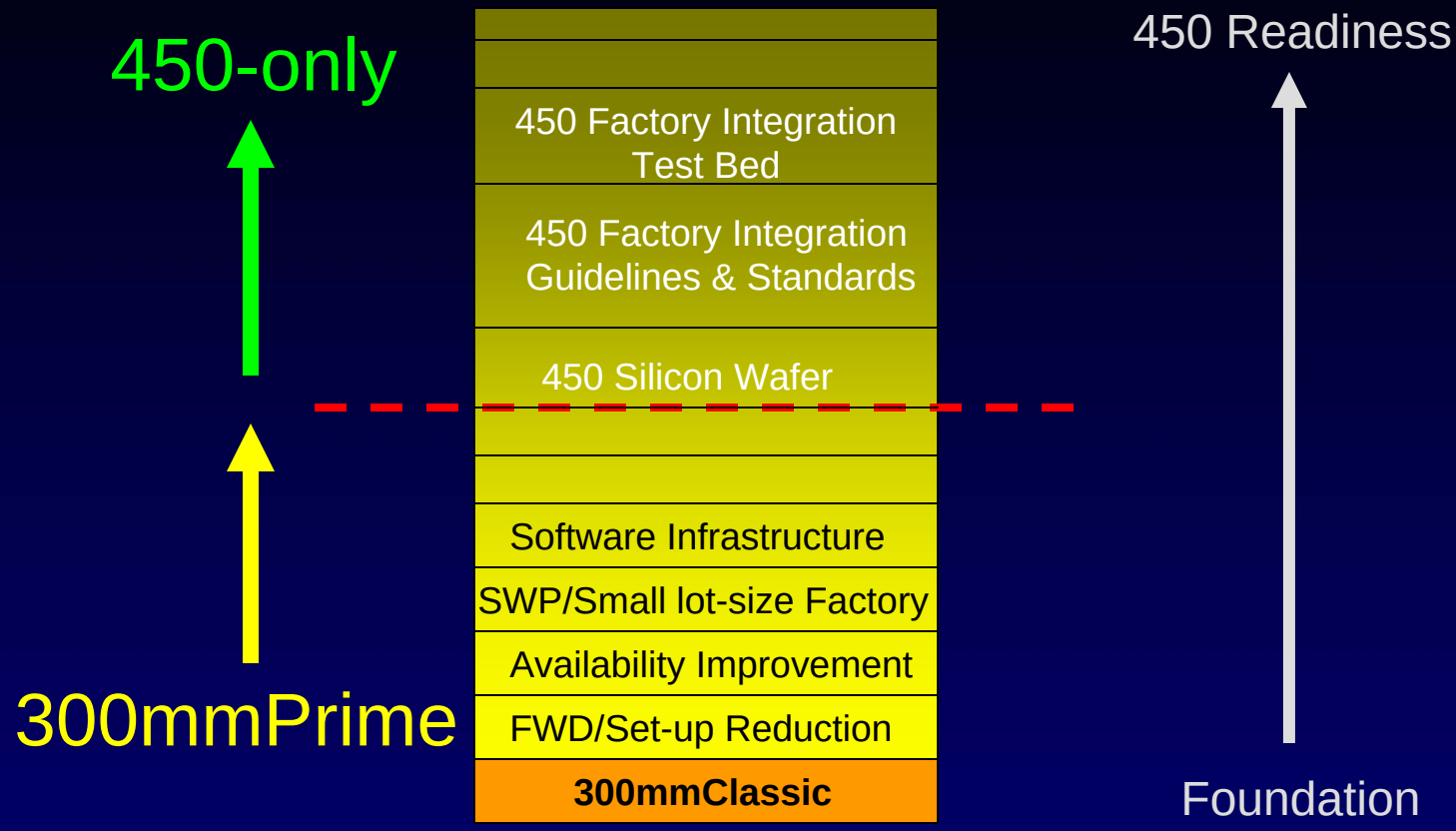
300mm Projects

Brad Van Eck
FP Program Manager

Next Generation Factory Vision Realization



- **ISMI is moving forward with both complementary forward-compatible paths for 300mmPrime as well as 300mm continuous improvement projects**
- **Collaboration is a critical success factor: Inside and Outside ISMI**

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ISMI Perspective on 300mm Prime

- **ISMI plans to pursue 300mm improvements that offer near-term productivity benefits in cycle time and cost reduction. This includes future optimized high productivity factories.**
  - Initial focus areas include:
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    - First Wafer Delay/Set-up Reduction
    - Predictive Preventative Maintenance
    - Equipment Data Quality
    - Factory for Small Lot Size

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ISMI 300mm Projects

- Next Generation Factory Realization Project

Objective : Develop a member company consensus of the critical equipment and factory level attributes and capabilities for Next Generation Factory (NGF)

- Develop member company consensus of key NGF attributes
- Prioritize equipment/factory productivity opportunities
- Communicate consensus prioritization to suppliers
- Identify guidelines and SEMI standards required for NGF
- Develop productivity and cycle time metrics, targets, and timelines
- Perform benefit analyses (ROI) and simulation
- Develop strategy and engage suppliers in the delivery of NGF solutions

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ISMI 300mm Projects

- First Wafer Delay (FWD)/Setup Reduction

***Objective** : Reduction in the time between the delivery of a lot to a process tool and the time the first wafer begins processing*

- **Member company consensus of the tools that offer the greatest potential improvement**
  - **Pareto tools with longest FWD and Setup Delays**
- **Supplier engagement to identify root causes and development of improvement plans**
- **Target solutions that are economically viable**

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ISMI 300mm Projects

- Predictive, Preventative Maintenance (PPM)

***Objective** : Establish member company requirements, guidelines, and feasibility for the use of data to improve equipment availability and productivity through PPM*

- **Define member company requirements for both on-board and off-tool equipment PPM capabilities**
- **Define factory and equipment data required for PPM**
- **Engage equipment and software suppliers to implement and demonstrate selected PPM capabilities**
- **Champion and promote the adoption and implementation of PPM methods for the industry**

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ISMI 300mm Projects

- Equipment Data Quality

***Objective** : Establish member company requirements, guidelines, and best practices for availability/delivery of high quality data. Identify, select, and address top issues*

- **Define member company consensus requirements, scenarios, methods, and best practices**
- **Champion a data quality SEMI standard**
- **Develop data quality evaluation method**
- **Demonstrate selected supplier data quality improvements**
- **Demonstrate benefits of fab-wide time synchronization**
- **Educate industry to accelerate the adoption of data quality / time synchronization requirements**

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ISMI 300mm Projects

- Factory for Small Lot Size

***Objective** : Define the equipment and manufacturing systems impacts, capabilities, user requirements, member company consensus guidelines, standards, usage scenarios and test criteria required to enable small lot size for hi-mix or accelerated Cycle Time factories*

- **Establish consensus vision/requirements for small lot size factory: equipment, transport, factory systems, operations**
- **Create fab behavior models to identify and prioritize system wide impacts and opportunities**
- **Engage in feasibility studies, prototypes, and pilots for the challenge points including the creation of a test bed virtual fab**
- **SEMI standards development as required**

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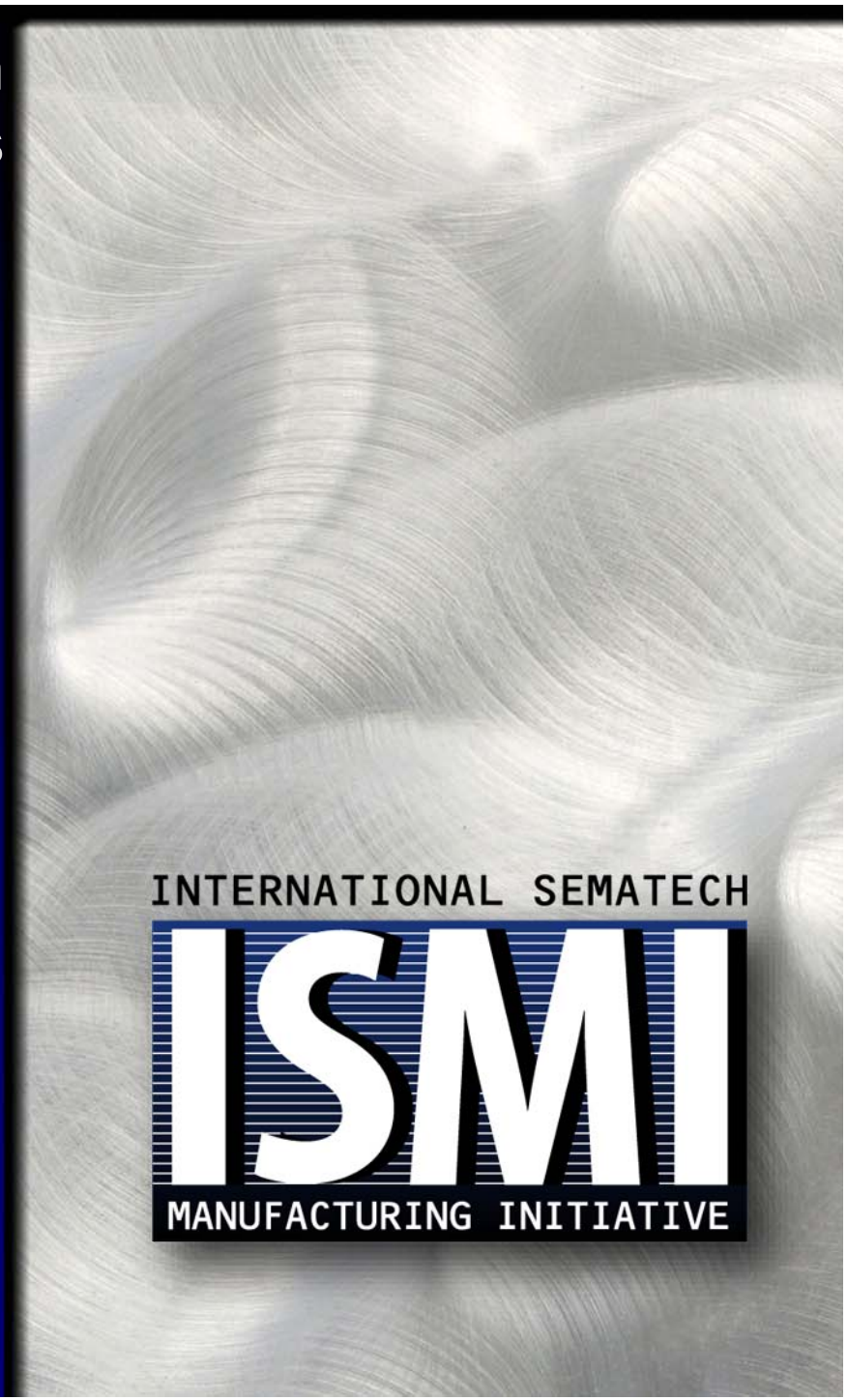
ISMI 450mm Program Update

Tom Abell
450mm Program Manager

October 2007



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

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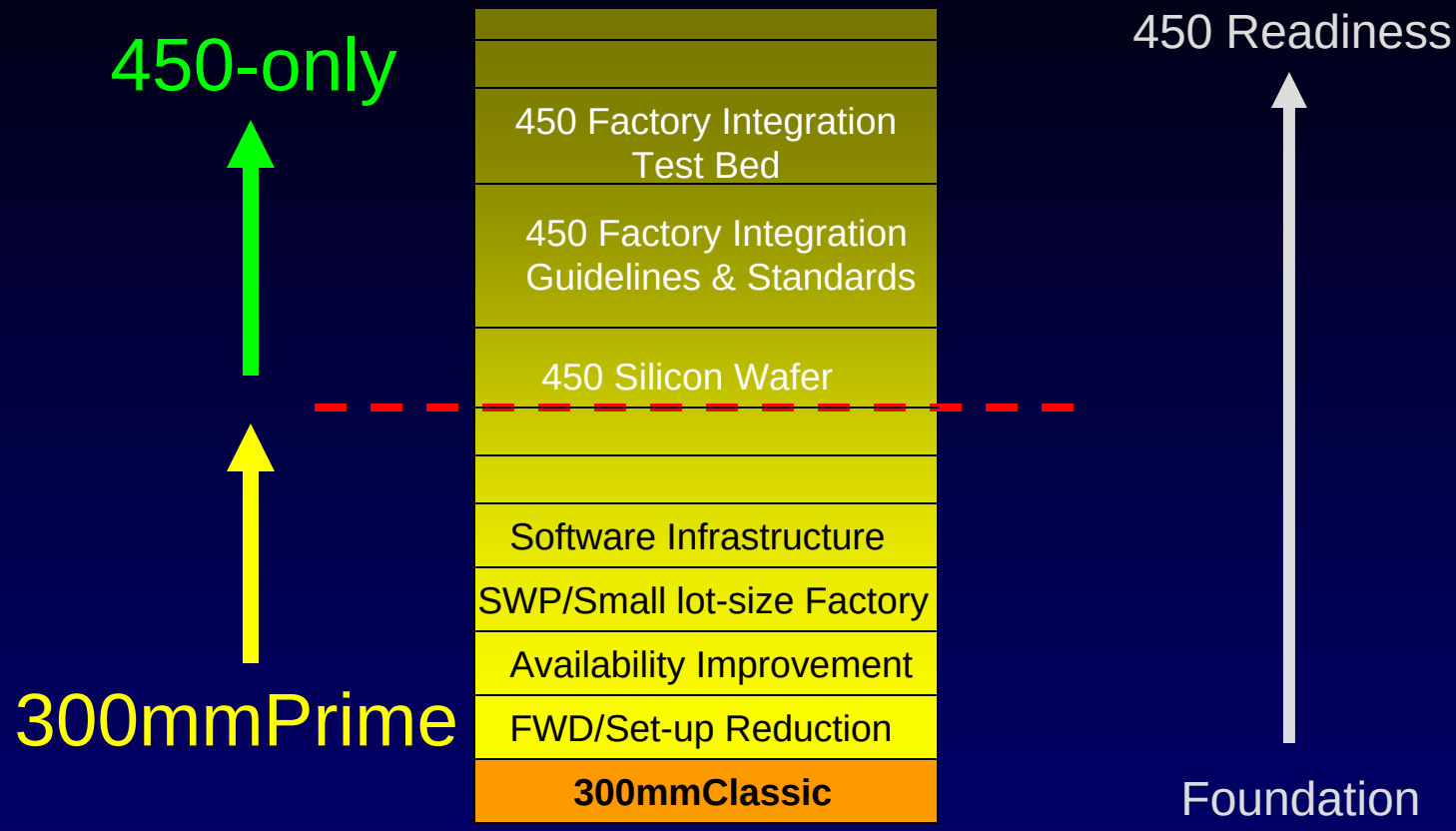
Next Generation Factory Vision Realization



- **ISMI is moving forward with both complementary forward-compatible paths for 300mmPrime as well as 300mm continuous improvement projects**
- **Collaboration is a critical success factor: Inside and Outside ISMI**

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450mm Program Structure for 2008

450mm Transition Program (Exclusive 450mm Focus)

- Si Wafer Readiness
- Factory Integration Guidelines and Standards
- Factory Integration Interoperability Test Bed

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450mm Transition Program

2008 Objective:

Coordination and support of 450mm transition projects and strategic industry activities

Goals

- Complementary forward-compatible approach for 300mm Prime and 450mm
- Timely and open communication with suppliers and at industry forums
- Active supplier engagement with ISMI (Test Bed, silicon readiness, guidelines)
- Coordinated industry standards activities (SEMI MTF, PEA, standards, ESG, etc.)
- Ongoing economic monitoring responsive to changing industry dynamics for 450mm
- Clear understanding of 450mm EHS challenges

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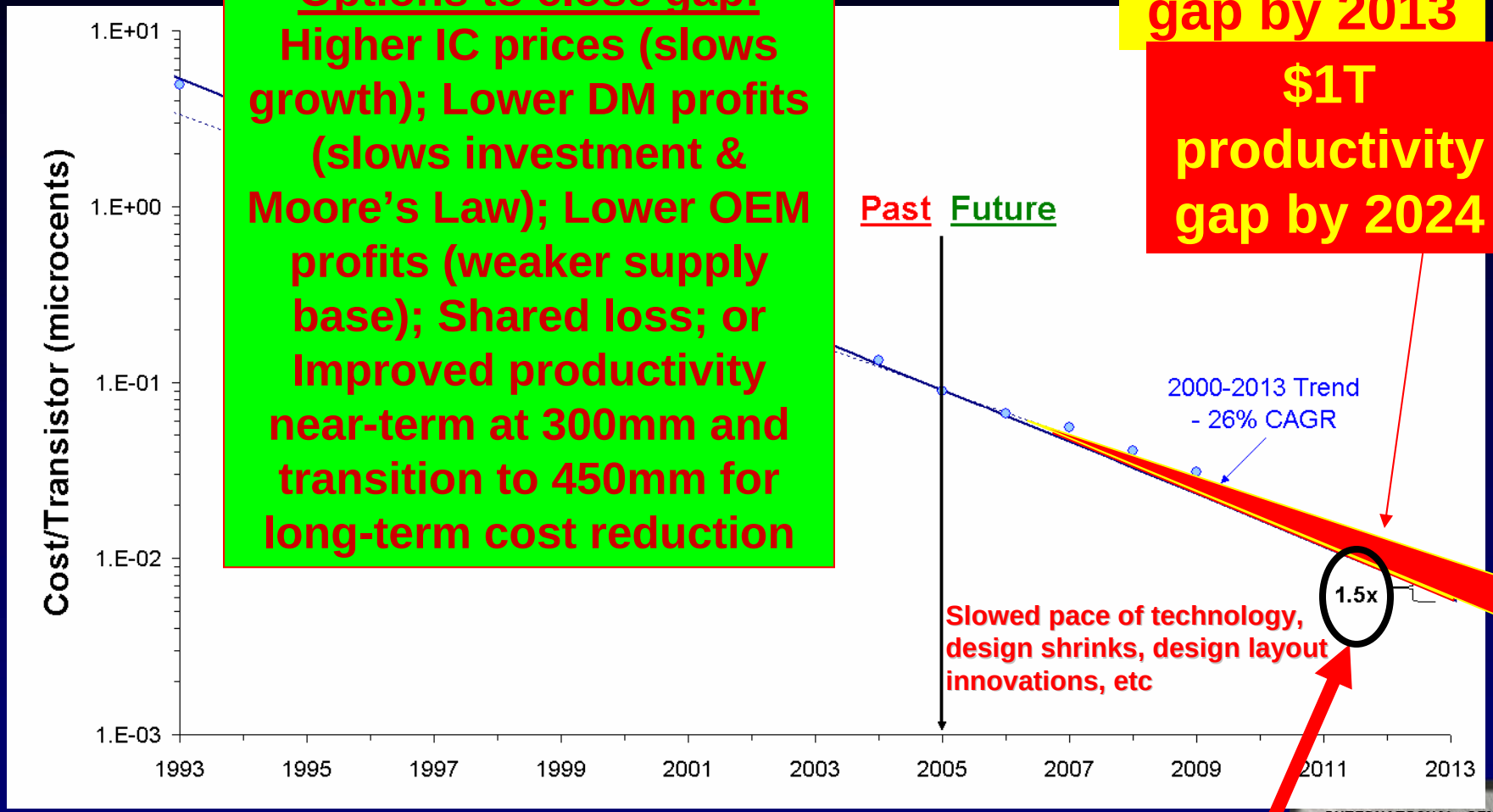
Productivity Gap

$150B productivity gap by 2013

$1T productivity gap by 2024

Options to close gap:
Higher IC prices (slows growth); Lower DM profits (slows investment & Moore's Law); Lower OEM profits (weaker supply base); Shared loss; or Improved productivity near-term at 300mm and transition to 450mm for long-term cost reduction



50% increase in cost/transistor by 2013

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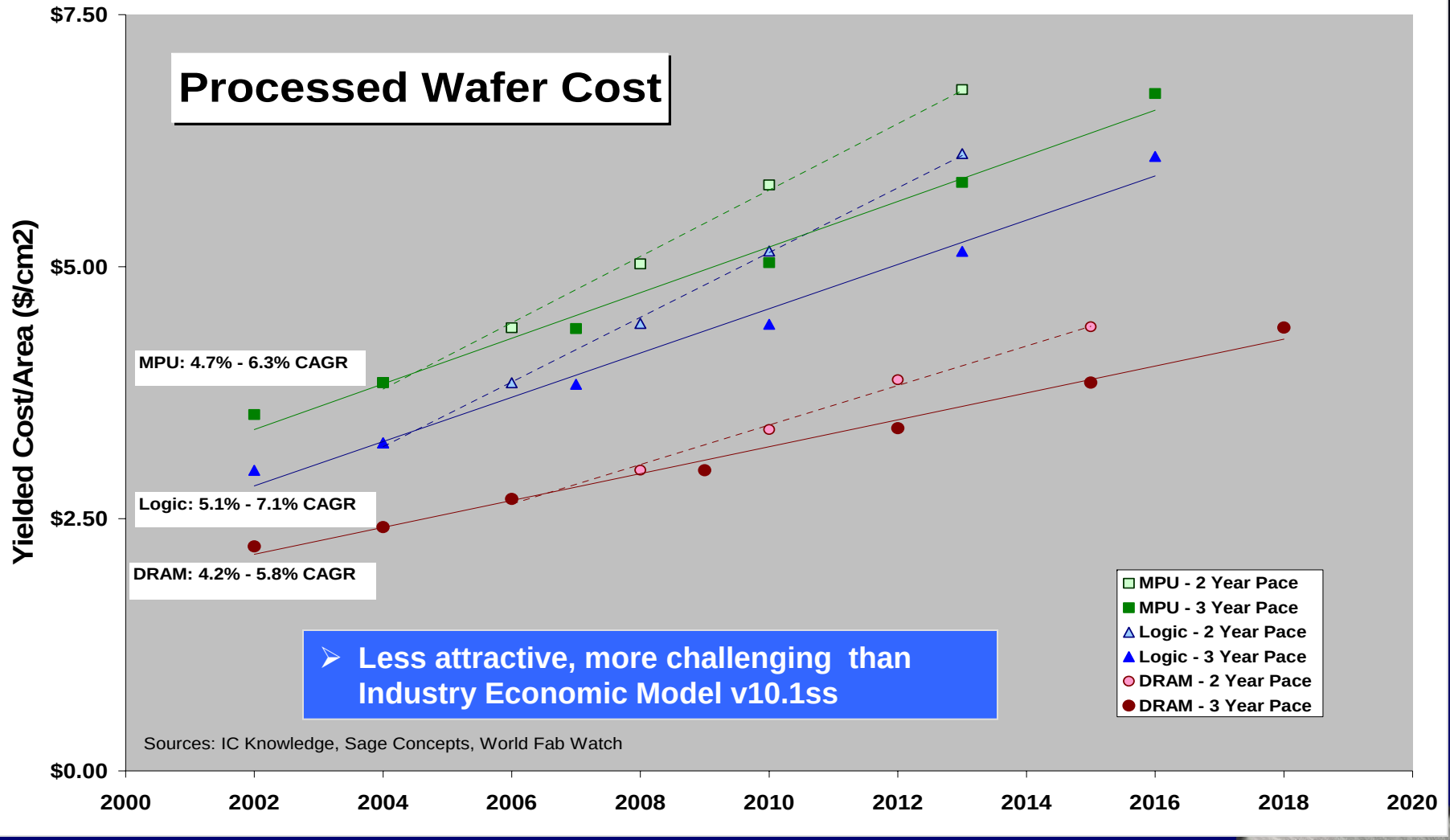
Industry Wafer Cost Trends



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

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450 mm Silicon Wafer Readiness Project

2008 Objective: ***450mm wafer availability to enable 450mm development***

Goals

- Validation of 450mm handling wafer & process test grade wafer assumptions
- SEMI 450mm silicon handling wafer & process test grade wafer standards
- Assessment of technical feasibility, supplier commitment, and implementation plans for silicon, inspection and silicon manufacturing infrastructure
- A supply of functional 450mm silicon handling test wafers

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450 mm Handling Wafer Standardization

- Goal is to limit changes from 300mm wafer as much as possible
  - Thickness is a critical decision
  - Notch is likely for 450mm wafer
  - Wafer diameter tolerance may reduce
- 450mm wafer assumptions require validation and feasibility studies by silicon suppliers
- Edge profile may need to be standardized for 450mm
- Shippers/Carriers for 450mm wafers need to be standardized in the near term

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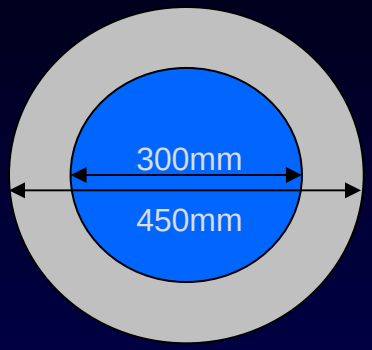
Sintered Wafer Strategy

- Sintered silicon ingots and wafers have been developed to jump start the 450mm manufacturing activities
  - Can reduce the silicon manufacturing learning curve
  - Can provide wafers with the mechanical and optical characteristics for wafer carrier, automation and OEM development work

- Hybrid test wafers will supply material for characterization equipment development and provide OEMs with preliminary wafers for process development

- Sintered and hybrid silicon wafers are not replacement of single crystal silicon wafers required in IC manufacturing.

Hybrid test wafers



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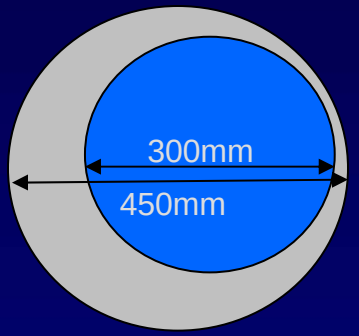

eccentric

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Wafer and Manufacturing Equipment Infrastructure Status

- The silicon suppliers infrastructure (pullers, crucibles, DSP polishers..) is moving toward 450mm support. The characterization equipment is still lagging behind.
- Mechanical test wafers (sintered) have been manufactured starting H2/06 and CZ single crystal pulling feasibility studies were completed.

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450mm Factory Integration Guidelines and Standards

2008 Objective: ***Timely creation of testable Next Generation Factory Architecture guidelines and standards to accelerate 450mm***

Goals

- "Rev. 2" level detail of the Unified Guidelines which comprehend and identify needed 450mm FI standards
  - e.g., Carriers, Shipping Boxes, Load Ports, Equipment Platforms, AMHS, etc.
- Defined tests and evaluation of early prototypes in support of ISMI 450mm Test Bed for interoperability and standards development
- Factory integration standards coordinated in timeframe required for 450mm early adopters

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Guideline Development Approach

Motivation:

The current version of the 19 point guidelines have varying degrees of maturity/detail. Assessing current level of detail is a critical next step to enable suppliers to begin development and implementation of solutions

Approach:

1. Establish the current level of maturity/detail for each guideline
2. Define the required end-state level of detail for each guideline.
3. Prioritize guidelines via survey inputs to understand where to focus work
4. Qualitatively estimate scope/content for top priority guidelines

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ISMI 450mm Guideline Development Priorities

- Front-opening, 25 wafer, purge-able carriers (#'s1-3) are top priority for 450mm
- Elimination of First Wafer Delay (#12) is important and with high benefit
- 300mm equipment improvements and learnings expected to be applicable to 450mm

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450 mm Factory Integration Test Bed Project

2008 Objective: ***Prototype Testing of 450mm Factory Integration Interoperability Challenges***

Goals

- **Prototype 450mm equipment developed for testing by Carrier, Loadport/EFEM, Equipment Mainframe, and AMHS suppliers**
  - **Equipment integrated and demonstrated/tested at ISMI facility**
- **Test plans defined, planned, and executed for key 450mm technical challenges**
- **Defined 450mm factory integration requirements supported by structured testing and evaluation**
  - **E.g., Carrier wafer support, wafer pitch, wafer handling, purging/sealing, reference platform interface standardization,, etc.**
- **Standards activities enabled by published low-level testing results and learnings**

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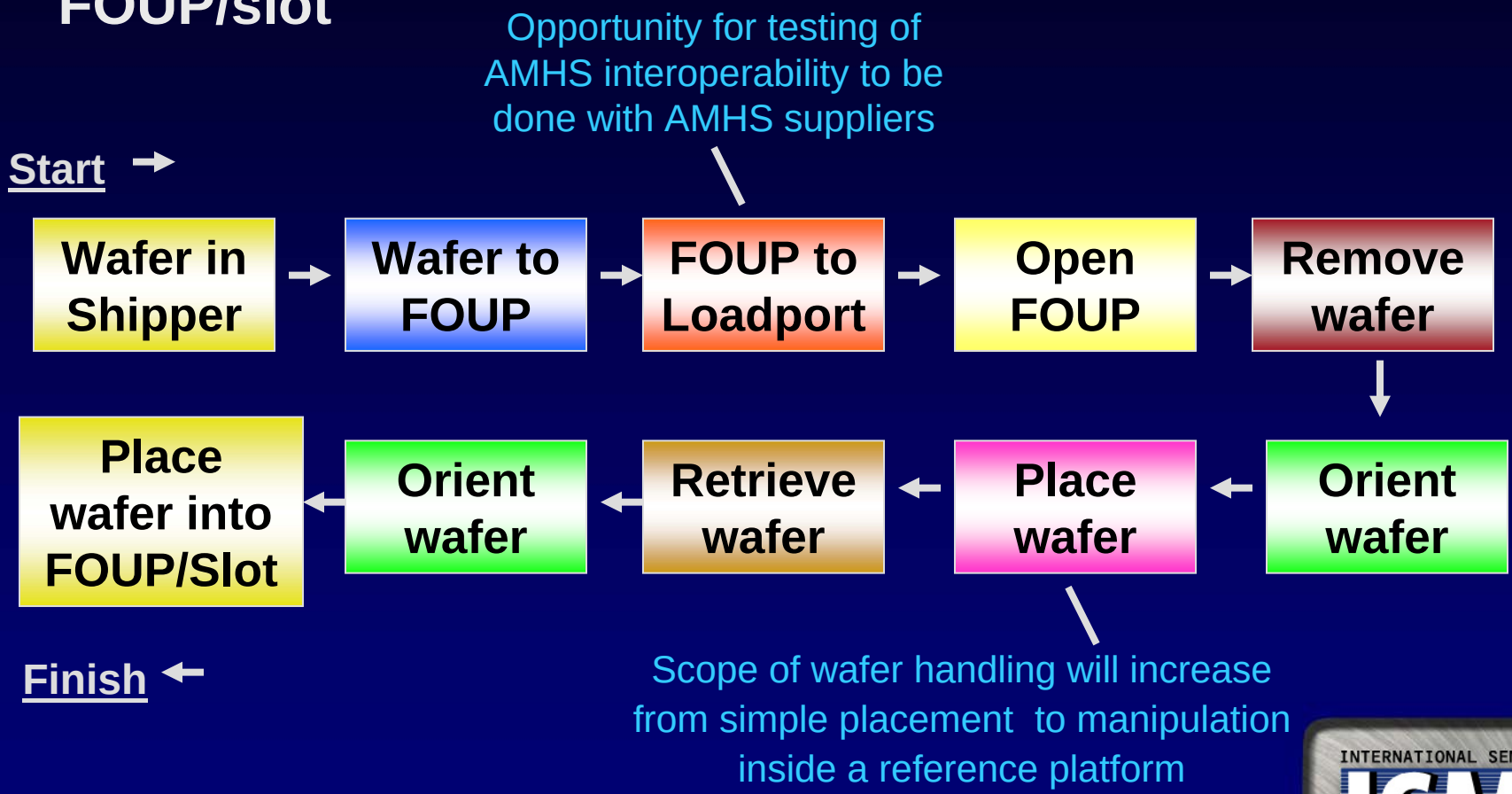
450mm FI Test Bed Approach

- **Demonstrate and identify challenges moving silicon from shippers through an EFEM returning to a desired FOUP/slot**



Suppliers are encouraged to participate in Test Bed activities

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Summary

- **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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Next Steps for ISMI

- 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 SEMICON Japan in Dec'07
- Increase synergy between 300mm & 450mm programs
  - Efficient use of industry resources is key
    - Complementary forward-compatible paths

➢ Proceed consistent with our principle that 300mm Prime is a productivity continuum to 450mm

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For more Information…

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

To initiate individual discussions with the ISMI Team, please contact:

Brad Van Eck (brad.van.eck@ismi.sematech.org)

- Fab Productivity Program Manager

Tom Abell (tom.abell@ismi.sematech.org)

- 450mm Program Manager

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