SEMICON Japan 2006

ISMI
300 Prime / 450mm Industry Briefing

Joe Draina
Associate Director
ISMI

December 6, 2006

INTERNATIONAL SEMATECH
ISMI
MANUFACTURING INITIATIVE

AGENDA – Wednesday, December 6, 2006

09:00 – 12:00 300 Prime / 450mm Industry Briefing

09:00	Introduction / Opening Remarks – Joe Draina, ISMI (IBM)
09:15	Overview of ISMI 450mm Program – Tom Abell, ISMI (Intel)
10:00	300 Prime/450mm Factory Architecture – K.T. Kuo, ISMI (tsmc)
10:30	Factory Simulation Updates – Robert Wright, ISMI
10:45	Economic Analysis Updates – Robert Wright, ISMI
11:15	450mm Starting Materials – Jackie Ferrell, ISMI
11:45	Next Steps / Closing Remarks – Joe Draina, ISMI (IBM)
12:00	Adjourn

ISMI Symposium

Introduction
&
Opening Remarks

Joe Draina

ISMI Associate Director

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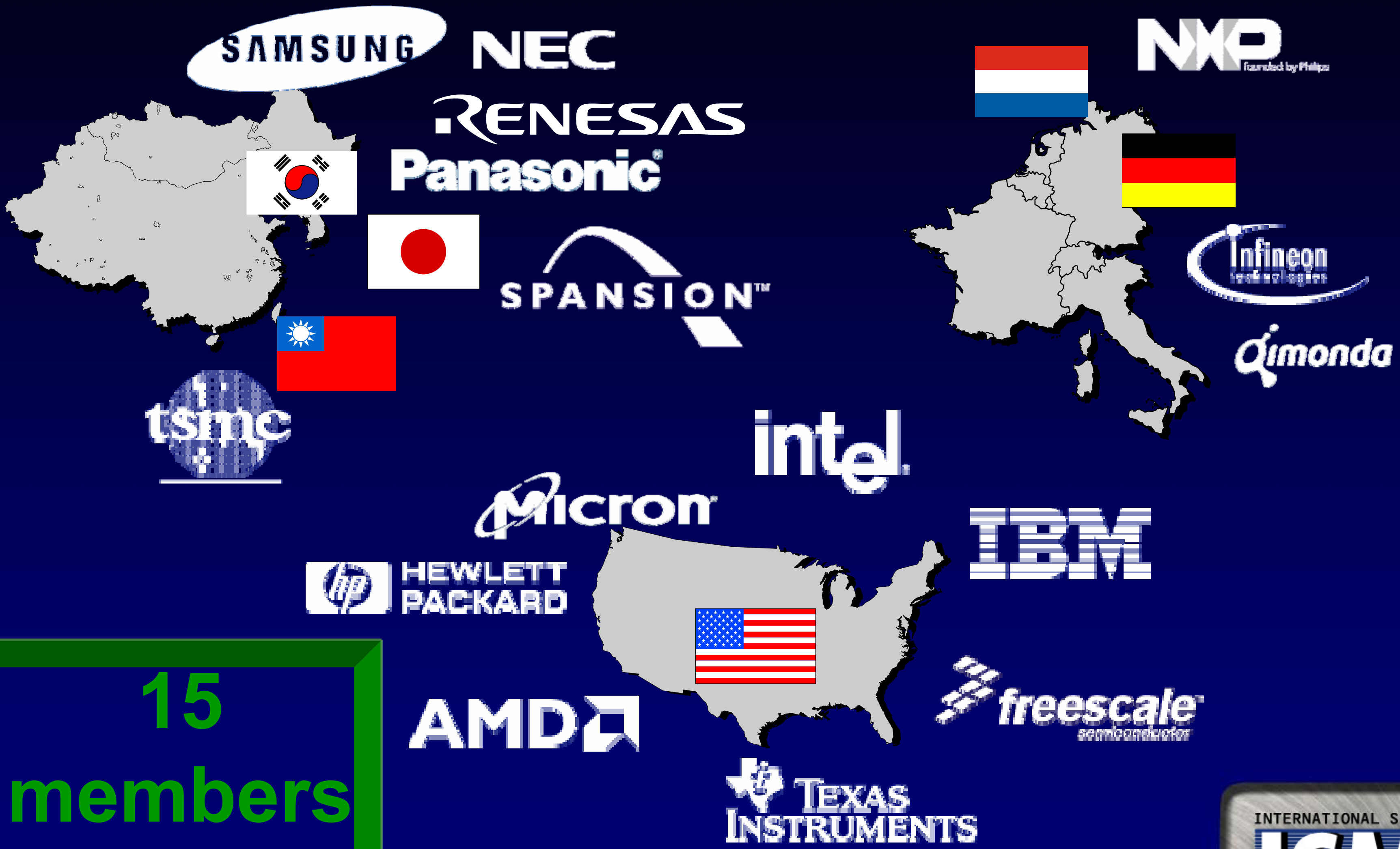
ISMI Members



15 members

Key Messages

- ISMI has a comprehensive productivity improvement strategy
  - covers existing fabs and future fabs

- A key ISMI Program (1 of the 5 programs) develops the Next Generation Factory Architecture
  - Productivity detractors are issues that need to be solved
  - Approach: Using 300 Prime guiding principles, assess 300 Prime productivity potential relative to 450mm
  - Factory Vision Components: targets, benefits, initial results
  - Analyses: economics foundation, data driven, industry collaboration

- Collaboration is a critical success factor
  - Inside ISMI
  - Outside ISMI

ISMI Programs

- Environment Safety and Health (ESH)
- Metrology
- 300 Prime/450mm
- Factory Productivity (FP)
- Equipment Productivity (EP)

Program Focused on Next Generation Factory Development

Driving Future Productivity
ISMI strategic directions

- Continuous Cost Reduction, Lean Manufacturing
- Short Cycle Time (Manufacturing)
- Equipment & Fab Agility
- Short Ramp-up Time (new product, yield)
- Complexity, High Mix Management
- Zero Defects, 100% Yield
- Equipment Productivity Improvement
- Short Ramp-up Time (new fab)
- People Productivity, Fully Automated Fab
- Next Wafer Size (450mm)
- Metrology
- Regulatory Challenges

450mm Challenges

- **Financial Analysis**
  - Return on Investment
  - Source of R&D funding
- **Timing of manufacturing insertion**
  - 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 Next Generation Factory Approach

- **Productivity and economic impact on industry**
  - Identify factory productivity detractors, steer industry for solutions, utilize 300 Prime guiding principles
  - Opportunity to use modeling for careful analysis

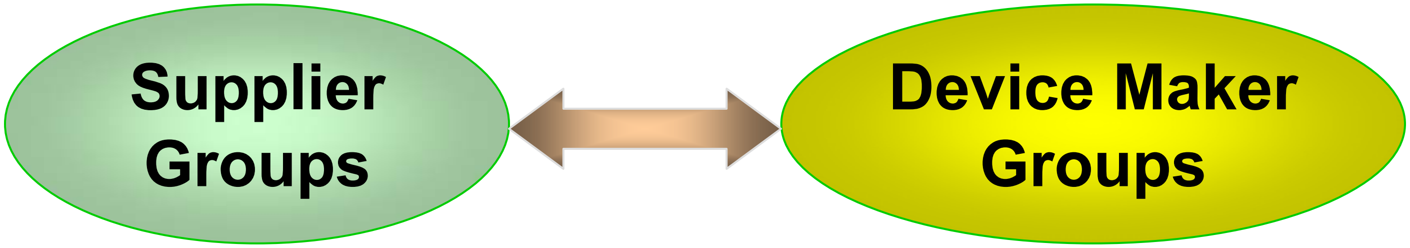
- **Build industry consensus**
  - Equipment, materials, and chip manufacturers working together

- **Build from lessons learned in 300mm transition**

300mm Lessons Learned

- **Industry coordination is crucial; early engagement of equipment and materials manufacturers**
  - Determine fab architecture
  - Develop standards early (but not prematurely)
  - Comprehend 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

Industry Collaboration Essentials



Organized and sponsored by industry organizations such as SEMI

Organized and sponsored by industry organizations/consortia such as ISMI

Participating together in industry forums

examples

JPWG

Economic analysis and Productivity Options

MTF

Recommend / Enable SEMI Standards Task Forces

ESG

SEMI sponsored equipment supplier group

SMG

SEMI sponsored silicon supplier group

Global Coordination and Consensus

ITRS International Technology Roadmap for Semiconductors

Industry roadmap

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semi

JPWG - Joint Productivity Working Group
JEAT - Joint Economic Analysis Team

Economic, business, and technology analysis

Member company consensus and industry communications

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300mm Prime Guiding Principles
Factory simulation
Factory vision and guidelines
Manufacturing requirements

semi

MTF - Manufacturing Technology Forum
PEA WG – Productivity Engineering Analysis Working Group

Prioritize technical standards

300 Prime / 450mm Industry Briefing

Objectives

- Convey our thoughts on the Factory Productivity Detractors
  - Forms a basis for 300 Prime
- Provide an update on progress made by ISMI Focus Teams
- Describe the 300 Prime analysis path

Expected Results

- Provide an industry insight to ISMI membership productivity issues. Begin momentum toward addressing issues.
- Industry communication of our progress in analysis, vision development and planning on 300 Prime direction.

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ISMI 450 mm Program Overview

SEMICON Japan

Thomas Abell

450 mm Program Manager

December 6, 2006

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450 mm Program Overview

Outline

- Introduction
- 450mm Program Objectives
- 300 Prime/450 mm Path
- Productivity Detractors
- 300 Prime/450mm Analysis
- Conclusion/Next Steps

Introduction

- 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
- What are these things that detract from the productivity of today’s 300mm factories and where should we be in the future?

ISMI 450 mm 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 (300 Prime) as the bridge.**

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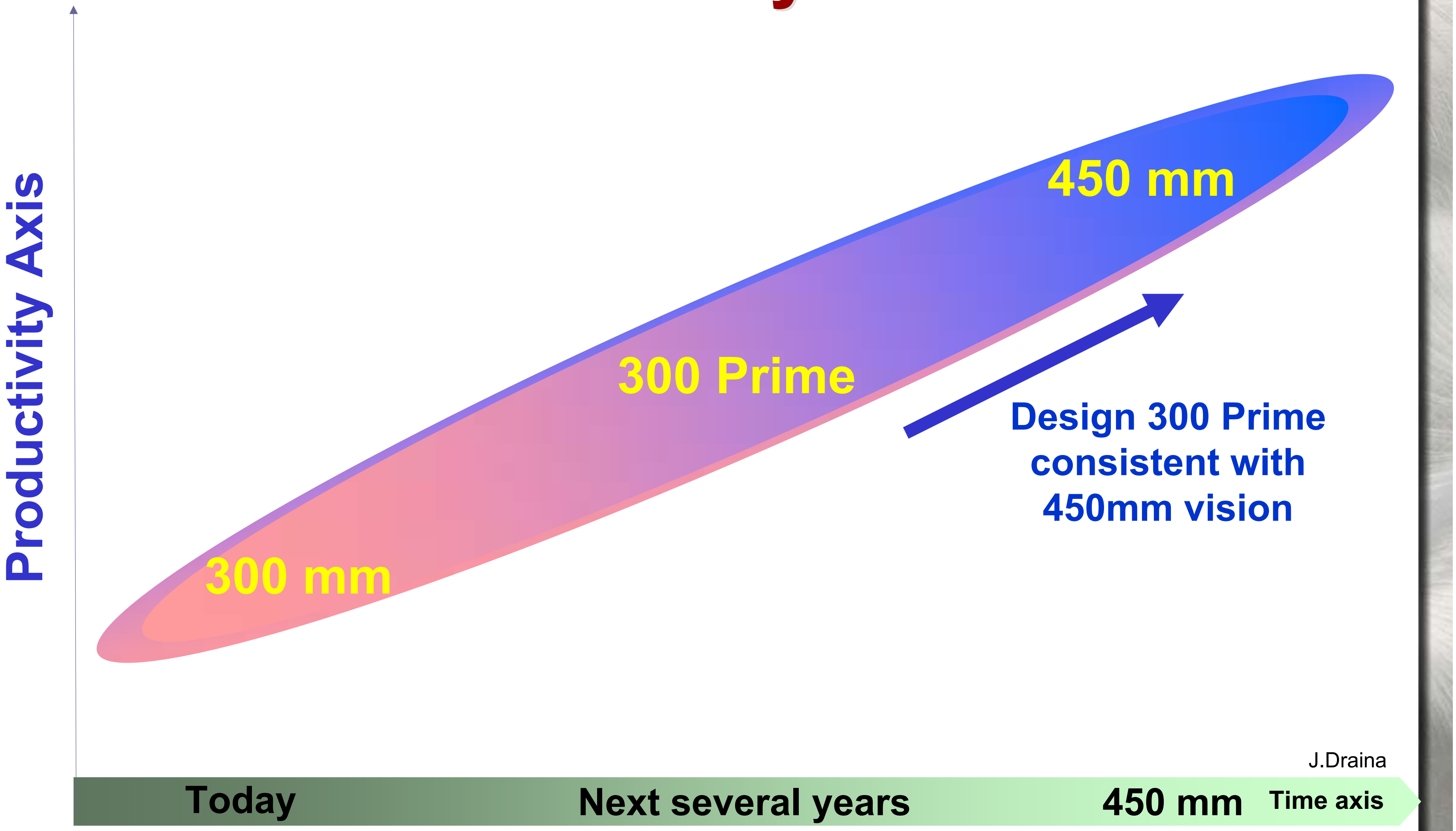
300 Prime Defined

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

Planned Evolutionary Transition



Productivity Axis

450 mm

300 Prime

300 mm

Design 300 Prime consistent with 450mm vision

J.Draina

Today

Next several years

450 mm

Time axis

300 Prime influenced by new & emerging business models

(high mix, smaller order sizes, shorter product life cycles …)

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/cm^2 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

Benefits of the 300 Prime/450 mm Path

- Target 300 Prime redesigns to resolve biggest cost, productivity and cycle time limiters known from 300 mm experience
  - Create upgrades to 300 mm fab designs for a continuum of benefits and revenue

- Port 300 Prime learnings to 450 mm designs
  - Lower risk of major transitional changes
  - Lower developmental costs by demonstrating concepts at the cheaper 300 mm wafer size

Biggest Limiters = Productivity Detractors

- **ISMI has consolidated a rev.1 list of "Productivity Detractors" based on:**
  - Problems the members have today…
  - …and where they want to be in the future
- **The rev.1 list is not a set of solutions**
- **It is a set of descriptions of over-riding issues and explanation of their importance**
  - These are the issues that need potential solutions
  - Solutions may need to involve several issues to deliver optimal productivity
  - 28 "detractors" have been identified so far..

This list is expected to be refined and modified over time

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)

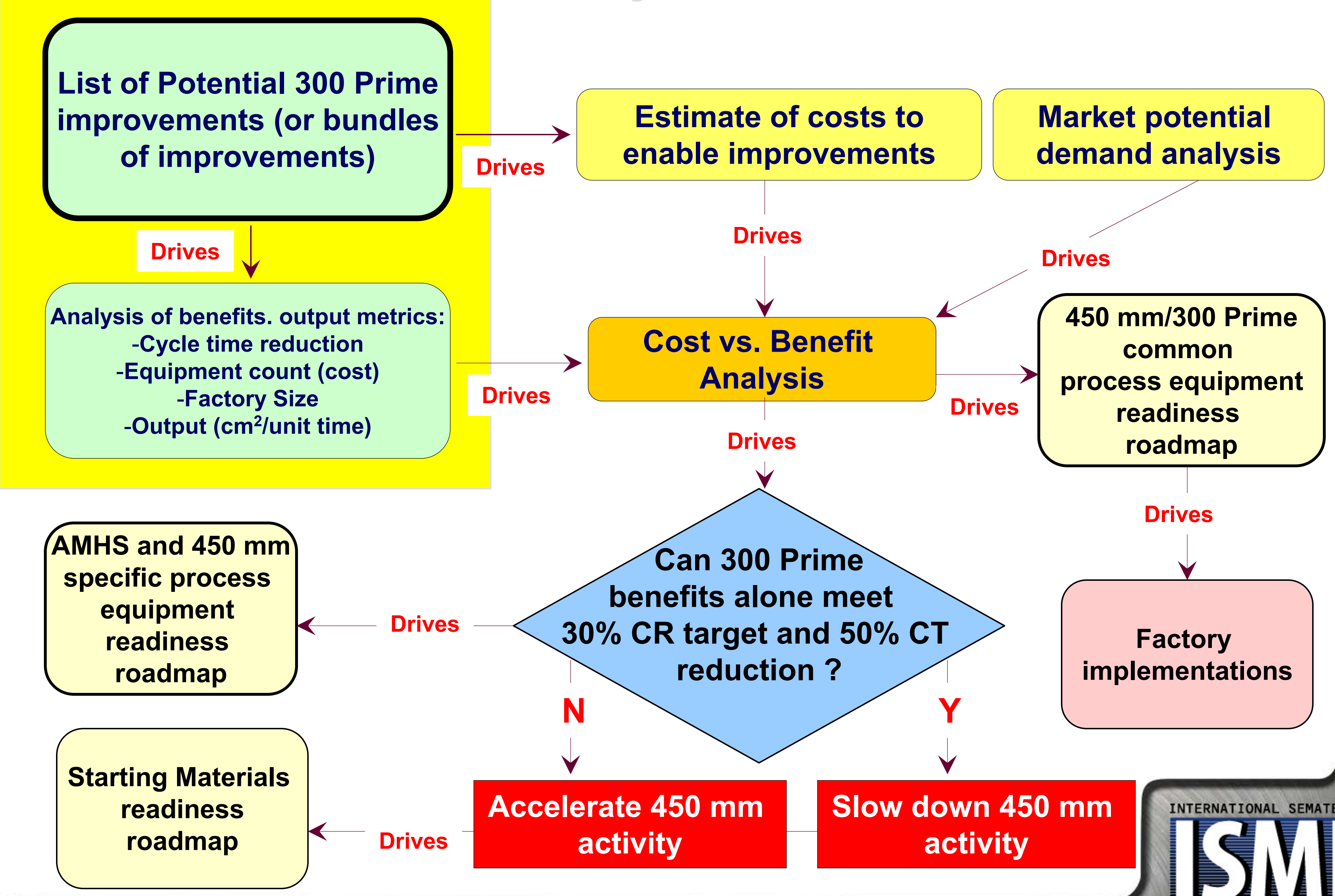
22. Current rate of identification, notification and containment of excursions is insufficient resulting in excessive loss of lots
23. Vertical space inside fab is underutilized resulting in lower factory capacity
24. Inefficient management of spare parts for process equipment results in additional downtime & 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

Critical Questions

- **Solutions to the Detractors List could be implemented at 300 Prime and/or at 450 mm**
- **But two critical questions surface:**
  - **Does 300 Prime have the potential to deliver significant productivity benefit?**
    - Could it be of wafer size transition magnitude?
    - Could 300 Prime reduce the near-term demand for 450 mm?
  - **What if 300 Prime can't deliver significant productivity benefit?**
    - How much benefit could it deliver?
    - When would 450 mm then be needed to stay on the productivity improvement curve?

These are critical questions to resolve for industry direction!

300 Prime/450 mm Analysis Decision Tree



List of Potential 300 Prime improvements (or bundles of improvements)

Drives

Estimate of costs to enable improvements

Market potential demand analysis

Drives

Drives

Drives

Analysis of benefits. output metrics:
-Cycle time reduction
-Equipment count (cost)
-Factory Size
-Output (cm^2/unit time)

Drives

Cost vs. Benefit Analysis

Drives

450 mm/300 Prime common process equipment readiness roadmap

Drives

Drives

Can 300 Prime benefits alone meet 30% CR target and 50% CT reduction ?

Factory implementations

AMHS and 450 mm specific process equipment readiness roadmap

Drives

N

Y

Accelerate 450 mm activity

Slow down 450 mm activity

Starting Materials readiness roadmap

Drives

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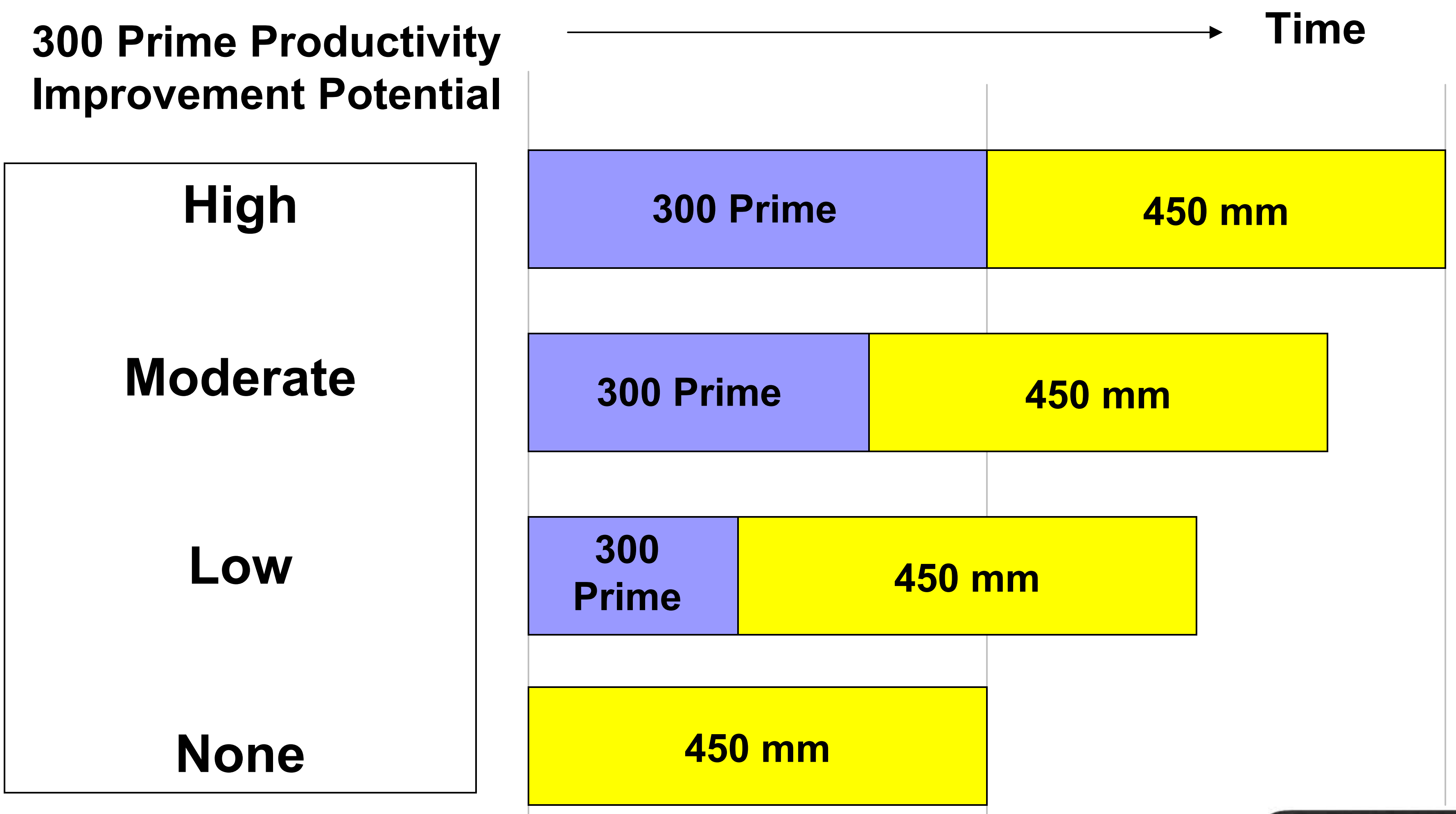
Possible 300 Prime/450 mm Scenarios



300 Prime Productivity Improvement Potential

Time

High: 300 Prime → 450 mm

Moderate: 300 Prime → 450 mm

Low: 300 Prime → 450 mm

None: 450 mm

Major factors affecting the realistic scope of 300 Prime are benefit potential, R&D difficulty, size of market, and implementation difficulty

ISMI 300Prime/450 mm Planning Process

List expectations from all members

What performance expectations do we each have from our future factories?

↓

Identify industry expectations

Which expectations do we all care about and share?

↓

Set goals and priorities based on mutual expectations

Which common expectations are the most important? Set metrics for desired performance.

↓

Determine factory options to meet expectations

What projects must be delivered for metrics to be achieved? (e.g., buffering, carrier capacities, etc.)

↓

Rationalize option list to create realistic factory vision

Conduct ROI analysis and determine limitations based on industry and resources.

↓

Develop guidelines and create initial designs/prototypes

Description of fab configuration with operational requirements; Test key options for early learning.

↓

Develop standards

Create detailed specifications and implementation requirements.

We are here now

T.Abell, J.Ferrell

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2006 ISMI 450 mm Focus Teams

Factory Architecture FT

Factory Simulation FT

Starting Materials FT

Economic Analysis FT

Member Company Experts

Note: 300Prime and 450 mm are evaluated in the same ISMI program

Focus Team Missions

Factory Architecture

- Provide factory vision and operational assumptions.
  - Key decisions on wafer carriers, production equipment, AMHS, and factory attributes.
- Translate the factory vision into actionable guidelines for suppliers and device makers.
- Determine the standards and industry best practices that must be created or modified and define closure through the appropriate channels.

Factory Simulation

- Provide factory simulation support to Factory Architecture decision making by quantifying impacts of possible options
  - Examples: Carrier capacity, product mix, equipment capacity, setup and first wafer delays

Focus Team Missions

Starting Materials

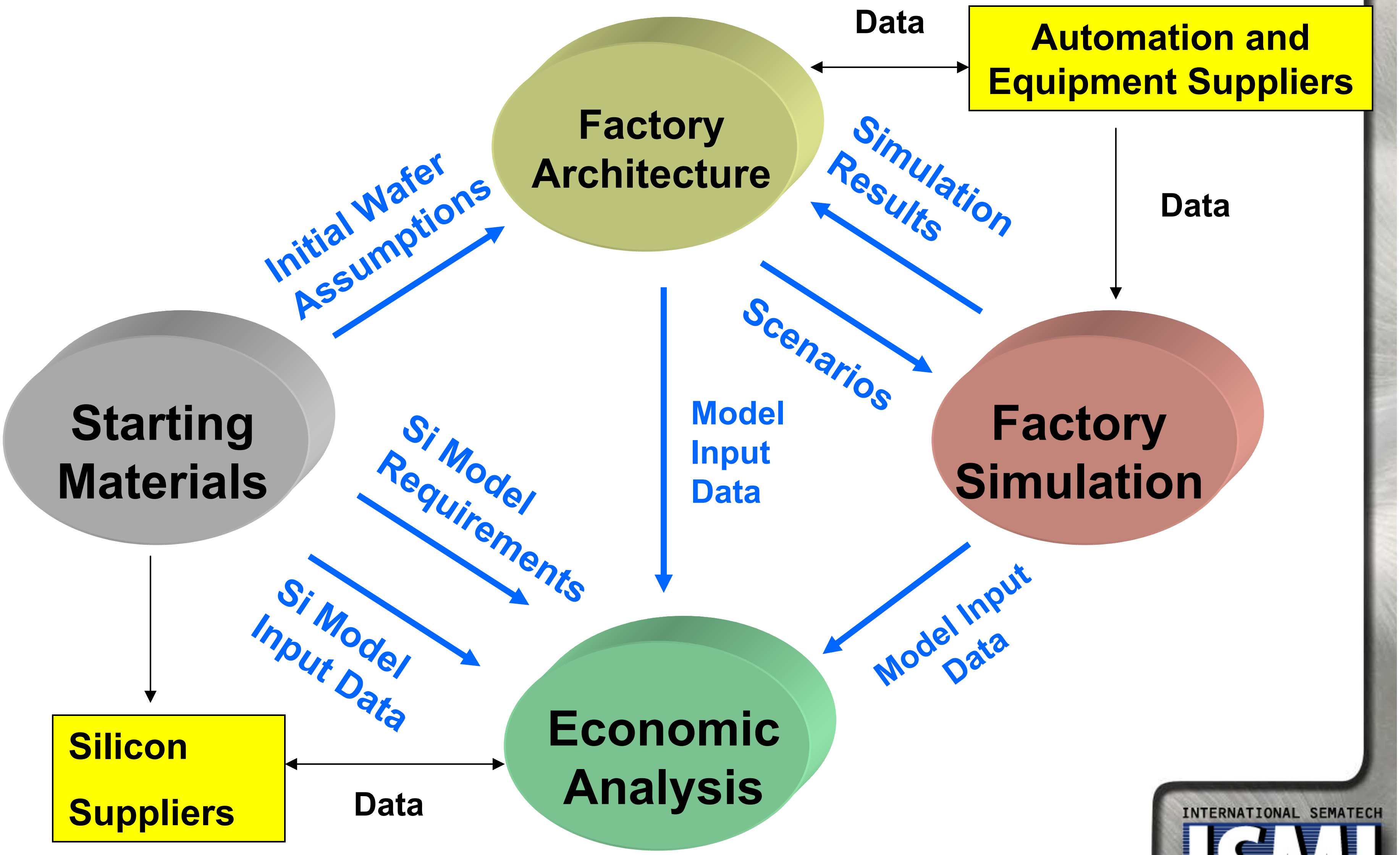
- <u>Define technical requirements</u> for 450 mm silicon and determine path for silicon supply readiness.

Economic Analysis

- <u>Provide a quantitative assessment of the costs, risks and benefits</u> associated with the timing of a highly productive, flexible factory architecture that supports multiple business models with both 300 mm and 450 mm starting materials.

➢ **Teams will provide greater detail on their progress in the following presentations.**

Focus Team Interactions



provided by Tom Abell, Intel – 3/9/06

450mm Program Highlights for 2006

- **Initiated program and built functioning teams**
  - PAG, working group, and 4 focus teams with member company co-chairs
- **High-level objectives for 300 Prime identified through 300P Survey and agreed to by PAG**
  - 30% cost reduction and 50% cycle time reduction
  - Many supporting tactical requirements & directions identified
  - Productivity Detractors list generated
- **Initial 300 Prime/450mm progress communicated to suppliers at Semicon West, ISSM Seminar and ISMI Symposium**
- **Industry collaborations developed jointly with SEMI**
  - JPWG/JEAT to assess high-level 300/450mm economics
  - MTF and MTF/PEA to address SEMI standards pipeline
- **Focus teams underway in vision development, factory simulation, economic analysis and starting materials**
  - 450mm initial silicon assessment done

Conclusion/Next Steps

- ISMI's 450 mm program has identified a list of Productivity Detractors and has defined a process for analyzing the potential of 300 Prime.

Next Steps

- Define a "next generation factory" vision
- Analyze the potential benefit/limitations of 300 Prime
- Consult with suppliers on issues, solutions and feasibility
- Assess potential timing of 450mm relative to achievable 300 Prime benefits

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ISMI
Factory Architecture Focus Team Status Update

Kun-Tsang Kuo (TSMC)

Tom Jefferson (Intel)

December 6, 2006

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Factory Architecture Update Agenda Summary

1. Team Mission and Initial Objectives
2. Factory Vision Components and Attributes
3. Development and Status of Next Generation Factory Vision
4. 450mm Carrier/Loadport Architecture - Summary of Analysis to date
5. 2007 Plans
6. Summary

Team Mission and Initial Objectives

Mission

- Provide **factory vision** and **manufacturing operations assumptions**; Make key decisions on wafer carriers, production equipment, AMHS, and related factory attributes.
  - **Vision: a set of key factory productivity attributes and how they can be optimized to serve multiple business models**

Initial Objectives

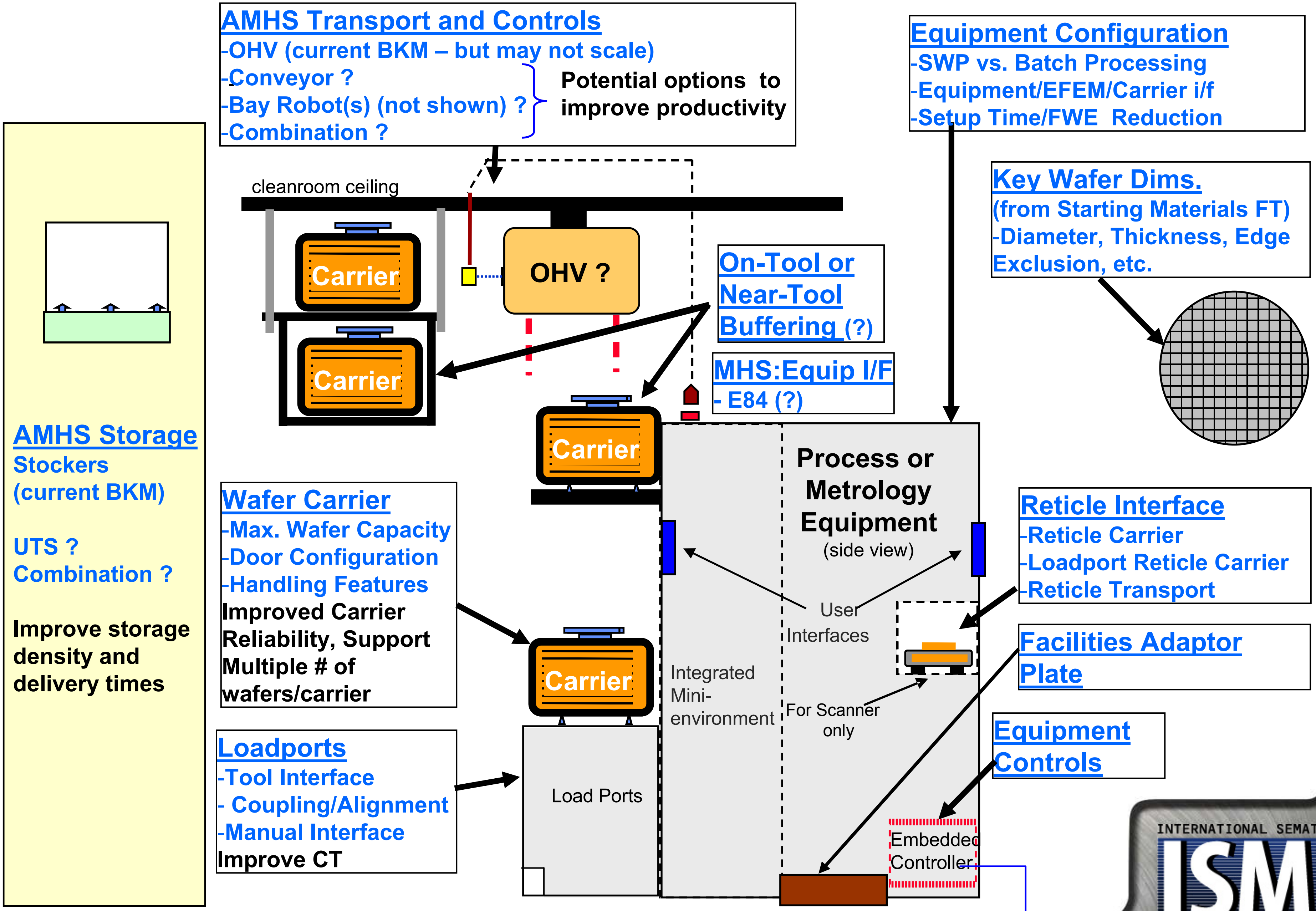
- Provide the initial factory architecture (wafer, carrier, AMHS) guiding assumptions, options, and boundaries to Factory Simulation Focus Team.
- Evaluate factory simulation results and document key decisions in a Factory Vision.

Factory Architecture Vision

The ISMI FA Focus Team will create a consistent factory architecture vision for 300 Prime/450 mm that aligns with current productivity detractors as defined by ISMI member companies

- The vision will define core attributes from which to build guidelines and requirements
  - Vision will not indicate specific solutions but will set directions
- How improvements are dispositioned is beyond the scope of vision creation
- Individual business models and ROI will drive adoption timing

Factory Vision – Core Components



AMHS Transport and Controls
- OHV (current BKM – but may not scale)
- Conveyor ?
- Bay Robot(s) (not shown) ?
- Combination ?

Potential options to improve productivity

Equipment Configuration
- SWP vs. Batch Processing
- Equipment/EFEM/Carrier i/f
- Setup Time/FWE Reduction

Key Wafer Dims.
(from Starting Materials FT)
- Diameter, Thickness, Edge Exclusion, etc.

On-Tool or Near-Tool Buffering (?)

MHS:Equip I/F
- E84 (?)

AMHS Storage
Stockers (current BKM)

UTS ?
Combination ?

Improve storage density and delivery times

Wafer Carrier
- Max. Wafer Capacity
- Door Configuration
- Handling Features

Improved Carrier Reliability, Support Multiple # of wafers/carrier

Loadports
- Tool Interface
- Coupling/Alignment
- Manual Interface

Improve CT

Reticle Interface
- Reticle Carrier
- Loadport Reticle Carrier
- Reticle Transport

Facilities Adaptor Plate

Equipment Controls

Next Generation Factory Vision Drivers

- Background
  - 300mm Vision Driver: Productivity through Pervasive Automation
- 300Prime/450mm Driver: Productivity Improvement through:
  - 30% Cost Reduction (cm^2)
  - 50% Cycle Time Reduction
  - ISMI Productivity Detractors List outlines barriers to productivity improvement

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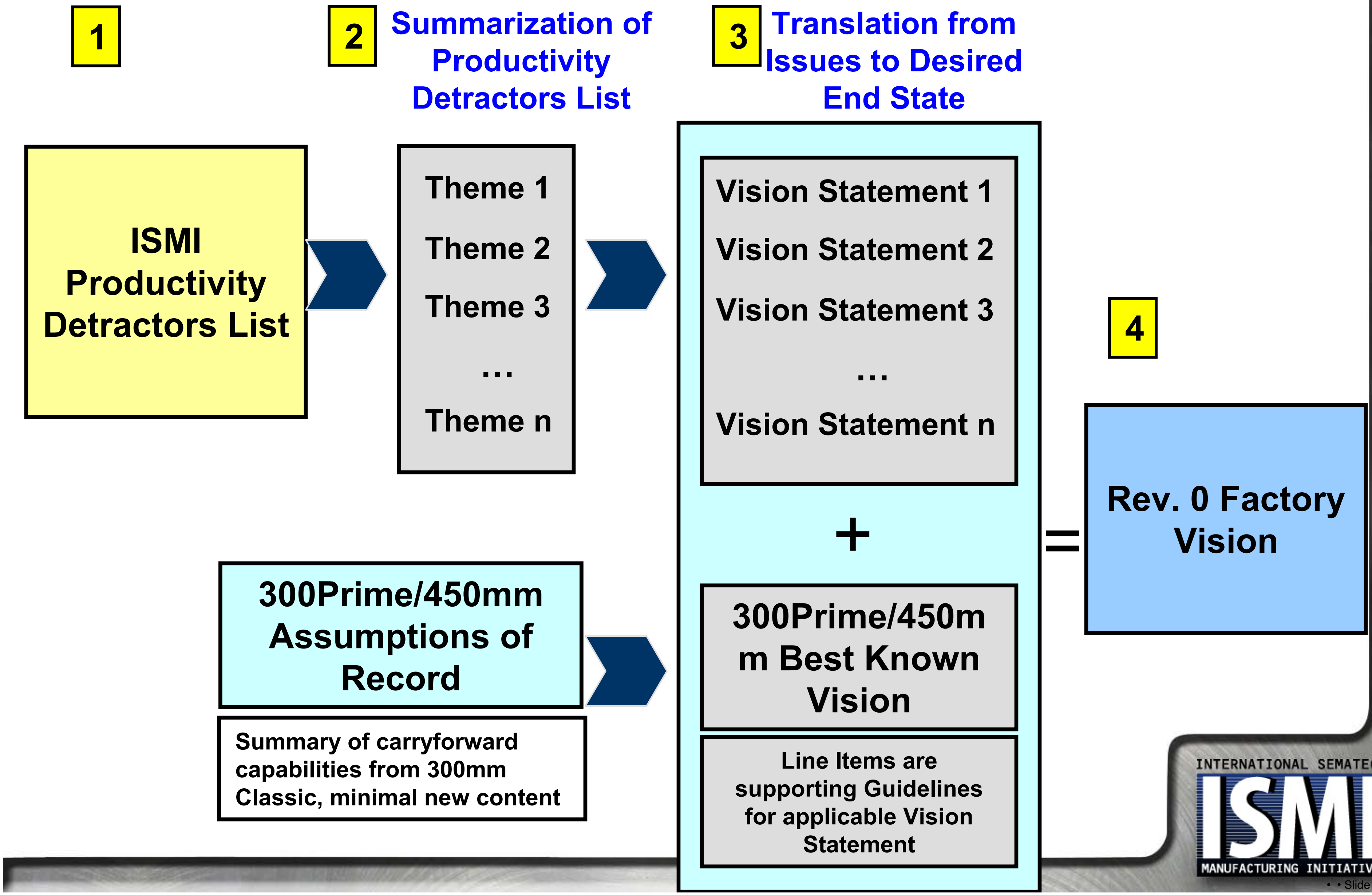
Alignment of Vision to 300Prime/450mm Program Drivers



1

2 Summarization of Productivity Detractors List

3 Translation from Issues to Desired End State

4

ISMI Productivity Detractors List

Theme 1
Theme 2
Theme 3
…
Theme n

Vision Statement 1
Vision Statement 2
Vision Statement 3
…
Vision Statement n

+

300Prime/450mm Best Known Vision

Line Items are supporting Guidelines for applicable Vision Statement

=

Rev. 0 Factory Vision

300Prime/450mm Assumptions of Record

Summary of carryforward capabilities from 300mm Classic, minimal new content

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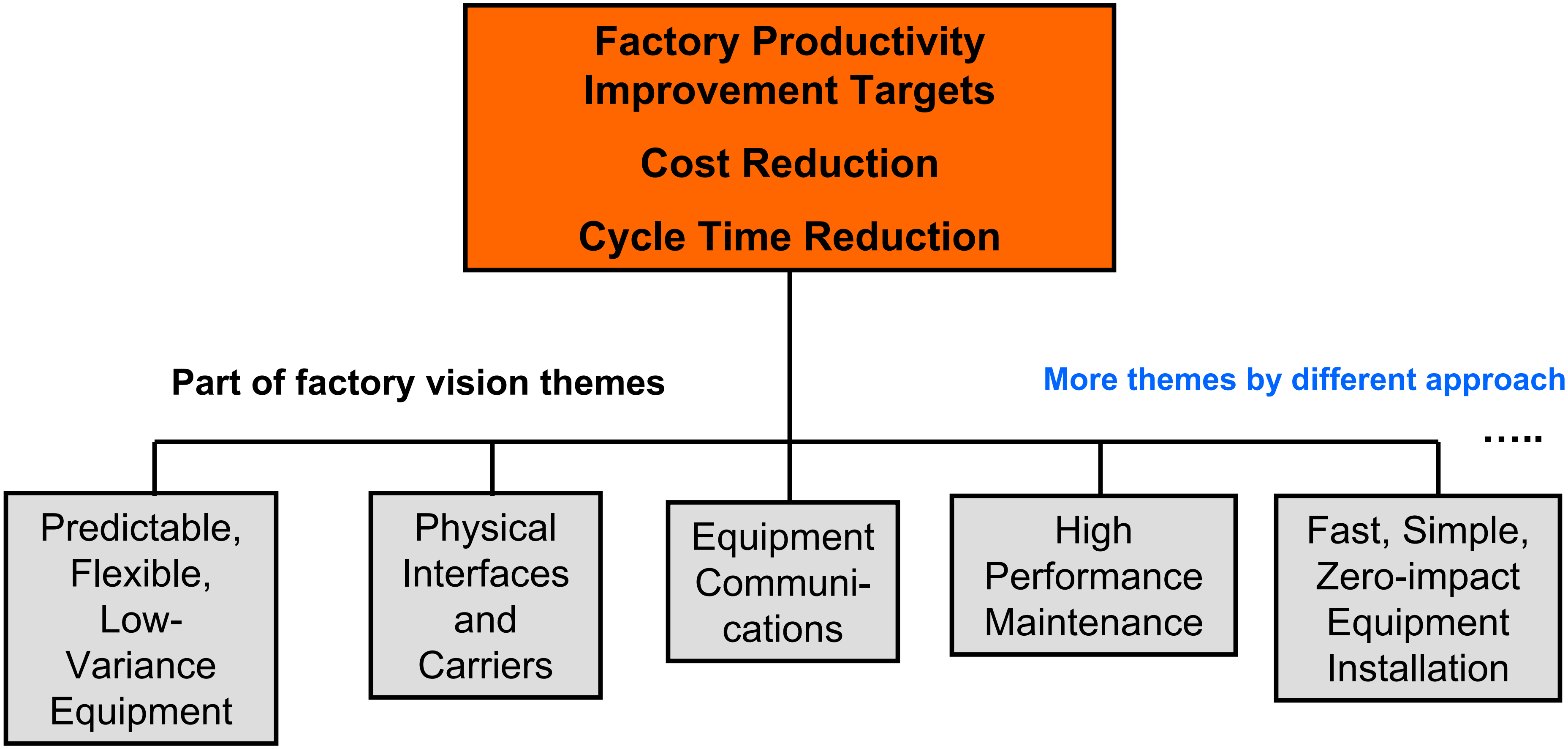
Factory Vision Themes



Factory Productivity Improvement Targets

Cost Reduction

Cycle Time Reduction

Part of factory vision themes

More themes by different approach..

…..

- Predictable, Flexible, Low-Variance Equipment
- Physical Interfaces and Carriers
- Equipment Communi-cations
- High Performance Maintenance
- Fast, Simple, Zero-impact Equipment Installation

Productivity Detractors Common Themes

ISMI member companies are working together on next generation factory vision themes by reviewing different approach methods.

Vision Focus Area/Theme: Predictable, Flexible, Low-Variance Equipment

Vision Statement

Process equipment shall be designed with an emphasis on:

- **Elimination of all equipment-driven processing delays**
- **Ability to predict, determine and communicate equipment failures or degradation in performance**

Supporting Productivity Detractors (partial list only)

- 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

Supporting Guidelines to Enable Realization of Vision

TBD: H1'07 Activity

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Vision Focus Area/Theme: AMHS and Carriers

Vision Statement

Flexible Physical Interfaces, Wafer Carriers, and AMHS that can cost-effectively support multiple operational models are required to enable best-achievable process equipment utilizations and yield

Supporting Productivity Detractors

- 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 fixed-size carriers induce infrastructure inefficiencies when running small lot sizes (storage costs, etc.)
- Logistics management of reticle is 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

Supporting Guidelines to Enable Realization of Vision

TBD: H1'07 Activity

Vision Focus Area/Theme: Equipment Communications

Vision Statement

Equipment shall have the ability to maintain continuous, real-time communication with factory automation systems of any tool-generated messaging (down to wafer level data), via standardized messaging formats and open architecture communication protocols.

Supporting Productivity Detractors

- 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
- Long durations required for creating or modifying routes reduces factory flexibility

Supporting Guidelines to Enable Realization of Vision

TBD: H1’07 Activity

Vision Focus Area/Theme: High Performance Maintenance

Vision Statement

Process and Metrology equipment and their supporting systems shall be designed to realize near- zero variability maintenance.

Supporting Productivity Detractors

- 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

Supporting Guidelines to Enable Realization of Vision

TBD: H1'07 Activity

Vision Focus Area/Theme: Efficient Factory Design and Fast, Simple Equipment Installation

Vision Statement

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

Supporting Productivity Detractors

- 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

Supporting Guidelines to Enable Realization of Vision

TBD: H1'07 Activity

An example for future consideration:

Approaches to organizing the information in detail that enhances our ability to understand attributes, benefits and priorities are ongoing

Data Management

Mapping to Original Detractor List	Productivity Detractors Limiting Next Generation Manufacturing Objectives	Area of Impact (Capacity, Cost, CT)	Area for Improvement	Owner of Improvement (Equipment Vendor, Material Handling Vendor, IC Maker/3rd Party Software Vendor, SEMI Standards)
12	No standards and testing for EDA data quality, time stamping, protocol	Cost	EDA standards and testing	Equipment Vendor SEMI Standards
11	Factory control systems data management cannot support single wafer lot size	Cycle Time	Data logging and capture	IC Maker/3rd Party Software Vendor
12	Tool health models using EDA data do not exist	Cost	Framework for tool health models by tool-type	Equipment Vendor IC Maker/3rd Party Software Vendor

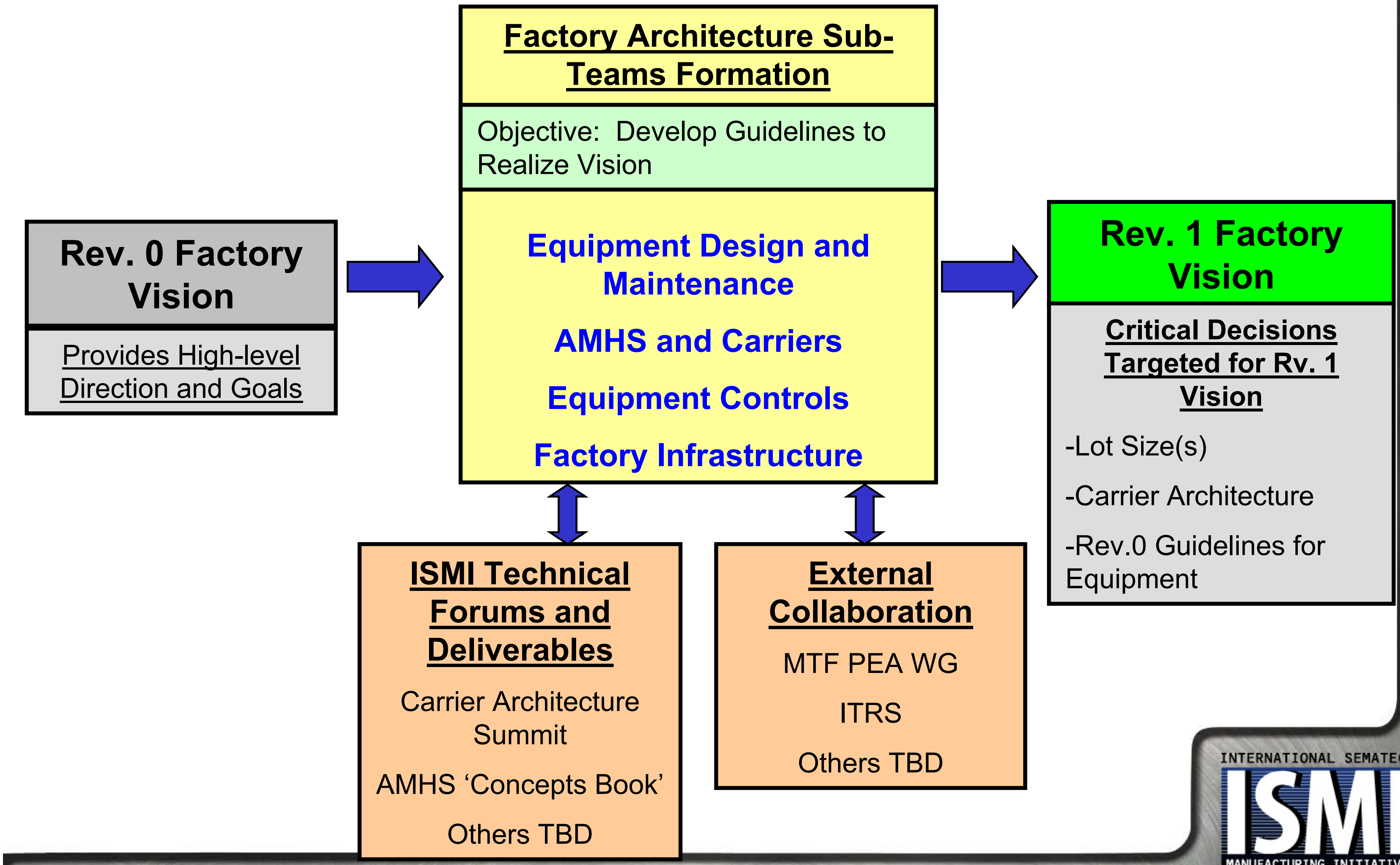
Carrier Architecture Learnings to Date
- From ISMI supplier surveys

- Primary FOUP Advantages seen as Knowledge Base and Carrier:Shipper compatibility
- Primary BOP Advantages seen as Door Sealing, Flexibility, Loadport cycle time, and centered carrier Center of Gravity
- Primary technical challenges: Cleanliness, Door Sealing, Wafer Stability

Preliminary Takeaways:

- Both Carrier Architecture options should be scaleable to 450mm, but pros and cons not yet fully understood
- No obvious best solution yet identified – Analysis is on-going

Factory Architecture and Vision Development Next Steps



Rev. 0 Factory Vision

Provides High-level Direction and Goals

Factory Architecture Sub-Teams Formation

Objective: Develop Guidelines to Realize Vision

Equipment Design and Maintenance

AMHS and Carriers

Equipment Controls

Factory Infrastructure

Rev. 1 Factory Vision

Critical Decisions Targeted for Rv. 1 Vision

-Lot Size(s)

-Carrier Architecture

-Rev.0 Guidelines for Equipment

ISMI Technical Forums and Deliverables

Carrier Architecture Summit

AMHS 'Concepts Book'

Others TBD

External Collaboration

MTF PEA WG

ITRS

Others TBD

Factory Architecture Summary

1. Starting assumptions to enable factory simulation of options have been defined, and modeling is in progress.
2. Carrier and loadport options analysis is in progress with focus on wafer carrier and loadport architecture
3. ISMI will generate the rev.0 Factory Vision in early 2007
4. The Factory Architecture team will generate a Rev.1 vision by mid-2007.

ISMI Factory Architecture Focus Team Contacts

- **Kun-Tsang Kuo, tsmc**
  kt.kuo@ismi.sematech.org

- **Tom Jefferson, Intel**
  Thomas.Jefferson@intel.com

AGENDA – Wednesday, December 6, 2006

09:00 – 12:00 300 Prime / 450mm Industry Briefing

09:00	Introduction / Opening Remarks – Joe Draina, ISMI (IBM)
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Factory Simulation Focus Team

Robert Wright, ISMI
Eddy Bass, Intel Assignee

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2006 ISMI Industry Briefing
Factory Simulation Agenda

- Factory Simulation Deliverables
- Key Questions for Factory Simulation
- Modeling Approach and Simulation Scenarios
- Baseline Model
  - Assumptions
  - Early Results
- Summary

Factory Simulation Focus Team Mission and 2006 Objectives

- Mission
  - Use Factory Architecture focus team decisions providing guidance to simulations and assessing factory simulations to ensure relevance to member company operations and credibility of results
- Primary 2006 Objectives
  - Determine fab assumptions applicable to simulations, bounding the operating scenarios and sensitivity analyses of 300 Prime and 450 mm factories and comparing cycle time and completed wafer area to 300 mm classic factories
  - Engage with member company simulation teams to address technical features and to validate simulations
  - Provide manufacturing assumptions for Economic Modeling analysis

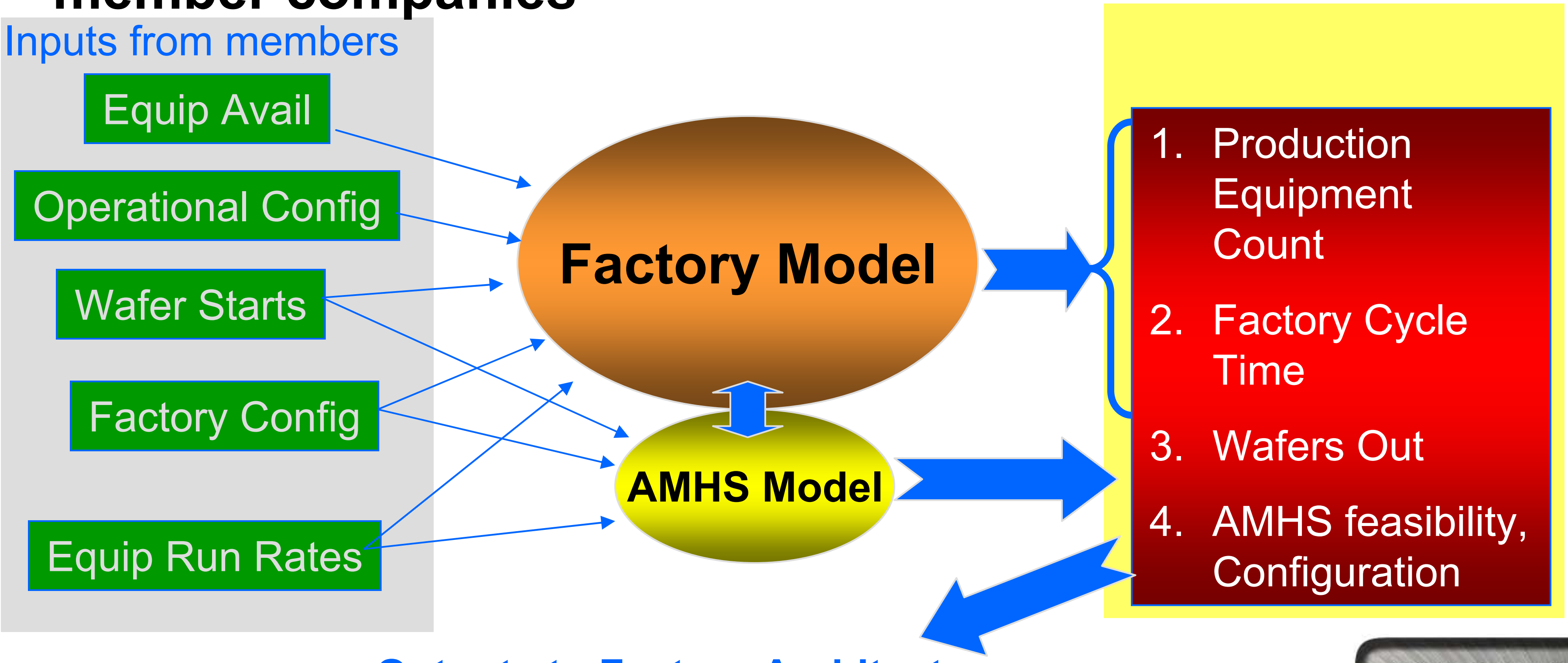
Key Questions for Factory Simulation

1) Is a 300 Prime factory capable of reducing cycle time by 50% <u>and</u> cost per square centimeter by 30%?
   - What are the assumptions to achieve this goal?
2) What is the relative (i.e., vs. 300 mm classic) cycle time and cost per square centimeter impact of
   - reducing carrier capacity from 25 to 13 and 13 to 6 wafers?
   - increasing product mix from 15 products to 500 products?
   - decreasing first wafer delay time by 75%, 50%, and 25%
3) What are the AMHS transport requirements (moves per hour and average distance) for worst-case factory scenarios?

Modeling Approach

- Requires inputs and assumptions from member companies

- Based on modeling program objectives, the following key outputs & variability are expected



Inputs from members

Equip Avail

Operational Config

Wafer Starts

Factory Config

Equip Run Rates

Factory Model

AMHS Model

1. Production Equipment Count
2. Factory Cycle Time
3. Wafers Out
4. AMHS feasibility, Configuration

Outputs to Factory Architecture & Economic Analysis

Top 3 Factory Scenarios (30k WSPM)

Factor	Base Scenario	Carrier Capacity	Products	Setup time
Products	15	15	**250, 350, 500**	15
Wafers per Carrier	25	**13, 6, 2**	25	25
Lot Setup time by tool type (minutes)	nominal value (x)	nominal value (x)	nominal value (x)	**0X, .25x, .5x, .8x**
CMP	10	10	10	**0X, .25x, .5x, .8x**
Etch	12	12	12	**0X, .25x, .5x, .8x**
Litho	2	2	2	**0X, .25x, .5x, .8x**
Implant	7.5	7.5	7.5	**0X, .25x, .5x, .8x**
Wet clean	5	5	5	**0X, .25x, .5x, .8x**
Thin Film	6	6	6	**0X, .25x, .5x, .8x**
Furnace	12	12	12	**0X, .25x, .5x, .8x**

Details of Baseline Model Data

- Factory maturity: Fully ramped mature factory
- Process flows: 3 high performance logic flows
  - 35, 40 and 45 mask layer flows
- Products: 15 total distributed as shown in the Table 1 below
- Carrier size: 25 wafers / Lot size: 1 carrier
- Process and metrology tool count → 672 tools to support 30,000 wafer starts per month
- Steady state WIP at ~3,100 production lots
- AMHS lot moves per hour
  - ~2,000 production moves
- Note: Non-production lots not included

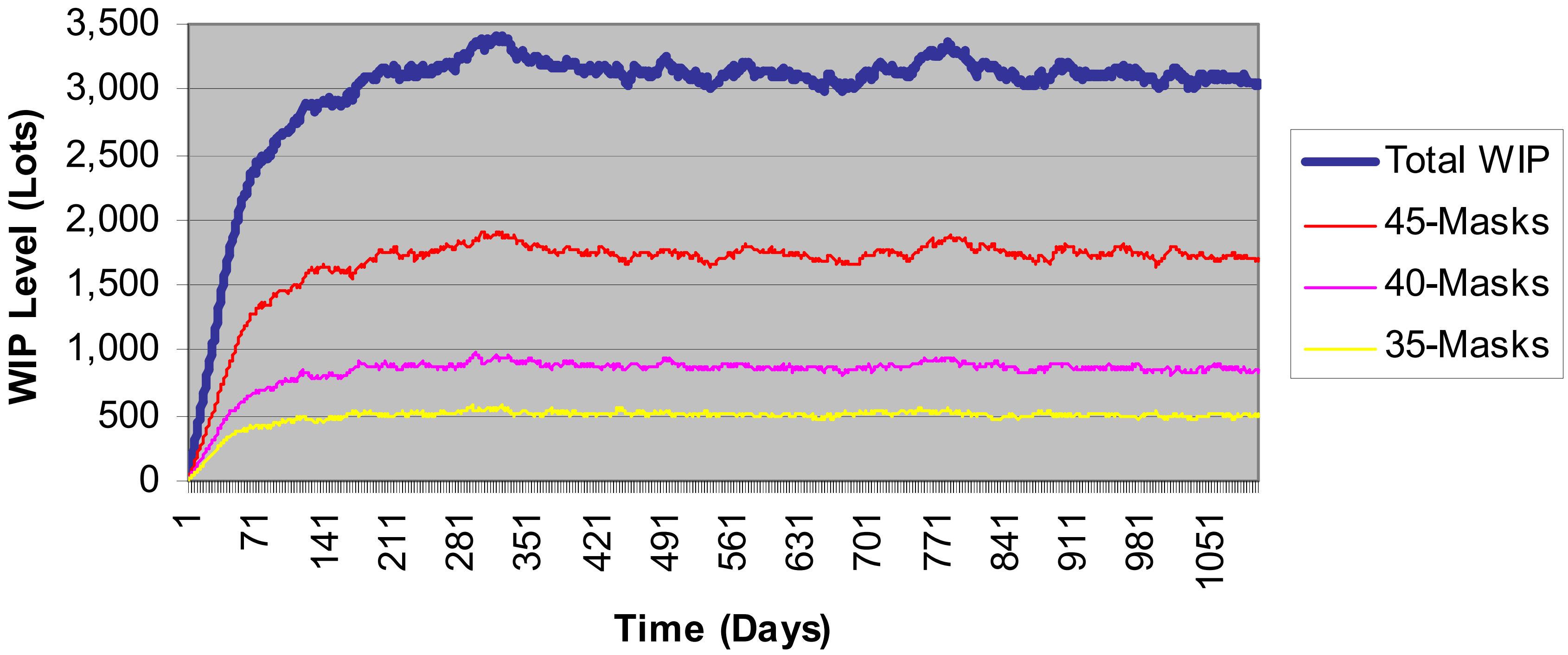
Table 1. Key Baseline Modeling Input/Outputs

Total volume
30000 Wafer Starts Per Month

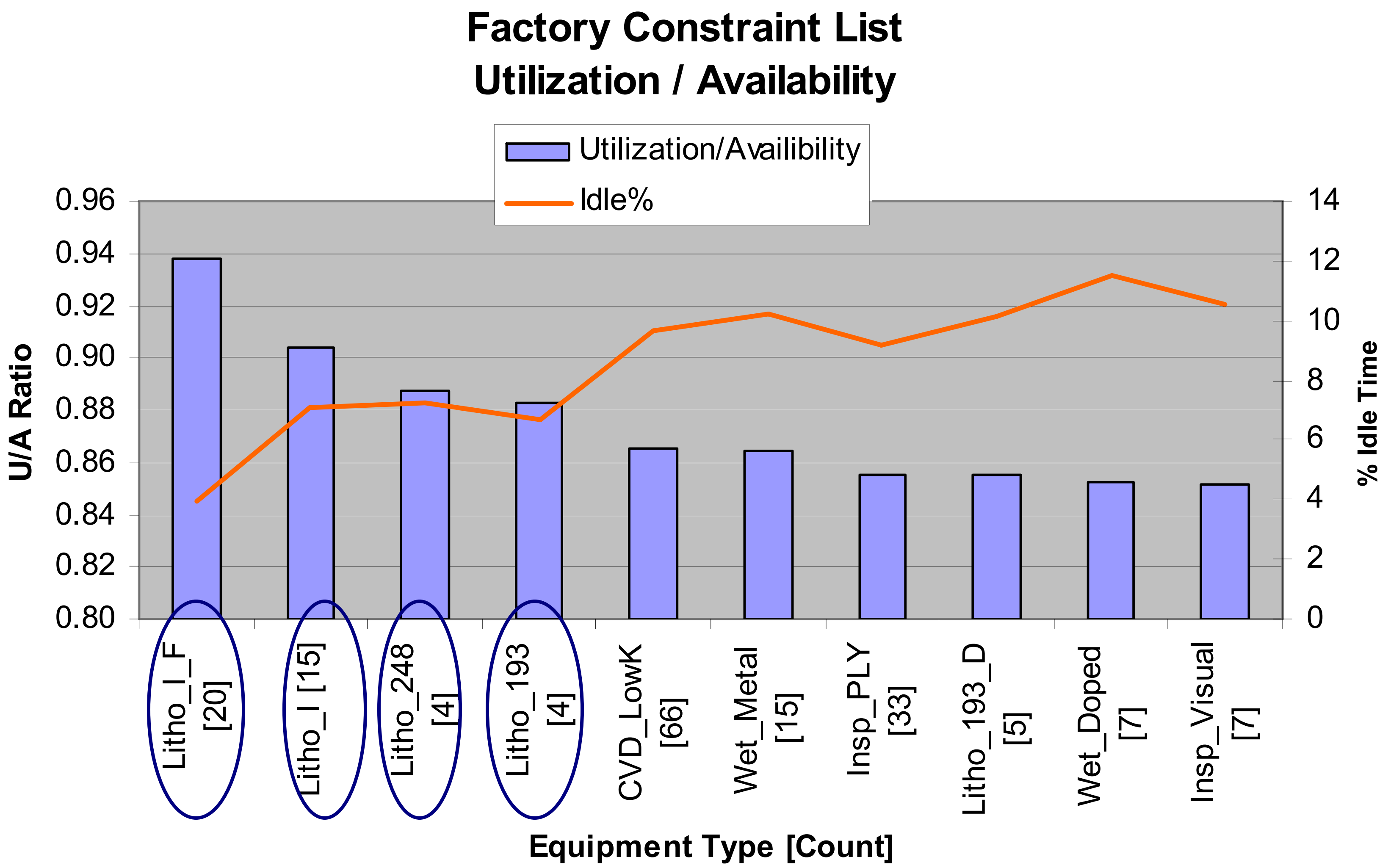
Processes (Mask Layers)	# of products	Process % total volume	Volume (wspm)	Raw Process CT (days)	Raw Process CT/Layer (days/layer)	Raw Process CT/Layer (Hrs/layer)	Process CT	Process CT/layer	X Factor
35	2	20%	6,000	11.8	0.337	8.09	62.1	1.77	5.26
40	3	30%	9,000	13.6	0.340	8.16	71.3	1.78	5.24
45	10	50%	15,000	15.2	0.338	8.11	86.7	1.93	5.70
			Average	13.53	0.34	8.12	73.37	1.83	5.40
			Weighted Avg	14.04	0.34	8.12	77.16	1.85	5.48

WIP Level by Process Flow

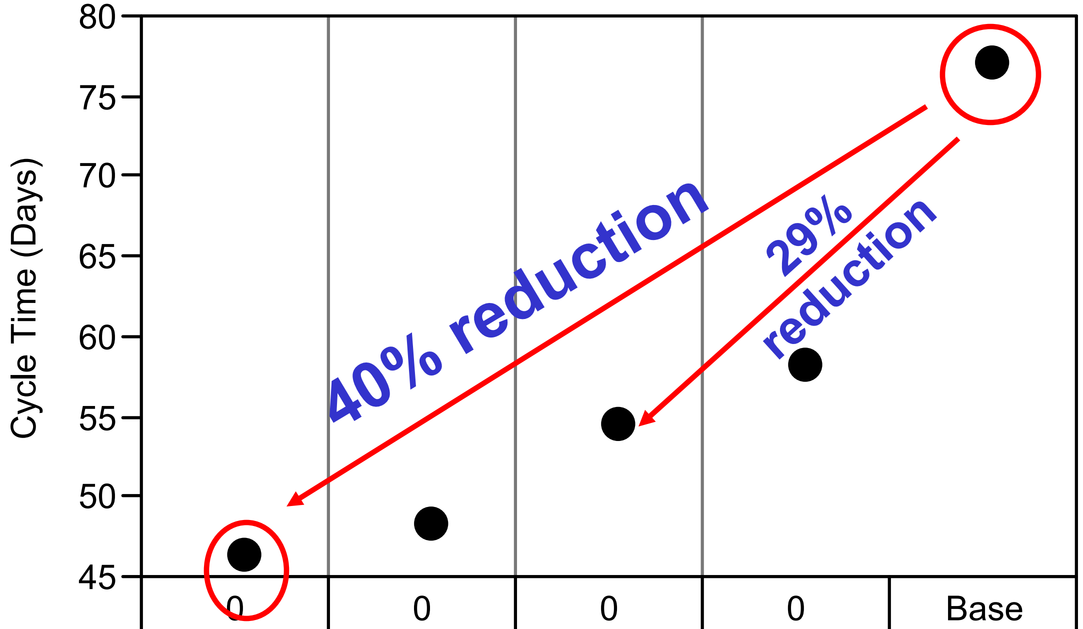
30k wafer starts per month



Base Model Equipment Utilization



Simulation Results Cycle Time with Common Equipment Set (Early results 10/24/06) 25-wafer carriers



0	0	0	0	Base	Preventive Maintenance
0	Base	0	Base		Setup & First Wafer Delay
0		Base			Unscheduled Down Time

Combined effects of Setup & 1st Wafer Delay & Unscheduled Down Time 40% Reduction in Cycle Time

Base: Assumed value
"0": Removed all effect

Summary

- Modeling inputs and top three factory scenarios have been defined
- Baseline model aligns with member company expectations
  - Includes minimum desired feature set
  - Early results reasonable
- Gauging impact of initial sensitivity scenarios on cycle time
- Supplier participation needed to determine AMHS solutions
  - Contact **eddy.bass@ismi.sematech.org**
    robert.wright@ismi.sematech.org

Next Steps

- Finalize baseline model
  - In progress
    - Add Hot Lots and Priority Lots
    - Add Non-product Wafers
  - Obtain lot moves for AMHS analysis
- Begin simulating
  - sensitivity of carrier capacity
  - increased product mix
  - varying first wafer delay
- Continue boundary condition models
  - Develop 13-wafer and 6-wafer carrier models

Acknowledgements

- ISMI Factory Simulation Focus Team

- University of Texas Interns
  - Emrah Zarifoglu
  - Emrah Tanriverdi
  - Jake Chang
  - Kranthi Adusumilli
- Contact Information:
  - eddy.bass@ismi.sematech.org
  - robert.wright@ismi.sematech.org

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Economic Analysis

Robert Wright - ISMI
for
Marcus Lentz - AMD
Denis Fandel - ISMI

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Outline

- Focus Team
- Core Analysis Tools
- Baseline Assumption / Results
- Sensitivity Analyses
- Summary & Next Step

Economic Analysis Focus Team

Mission

- Provide a quantitative assessment of the cost risks and benefits associated with the timing of a highly productive, flexible factory architecture which support multiple business models with both 300 mm and 450 mm starting materials.

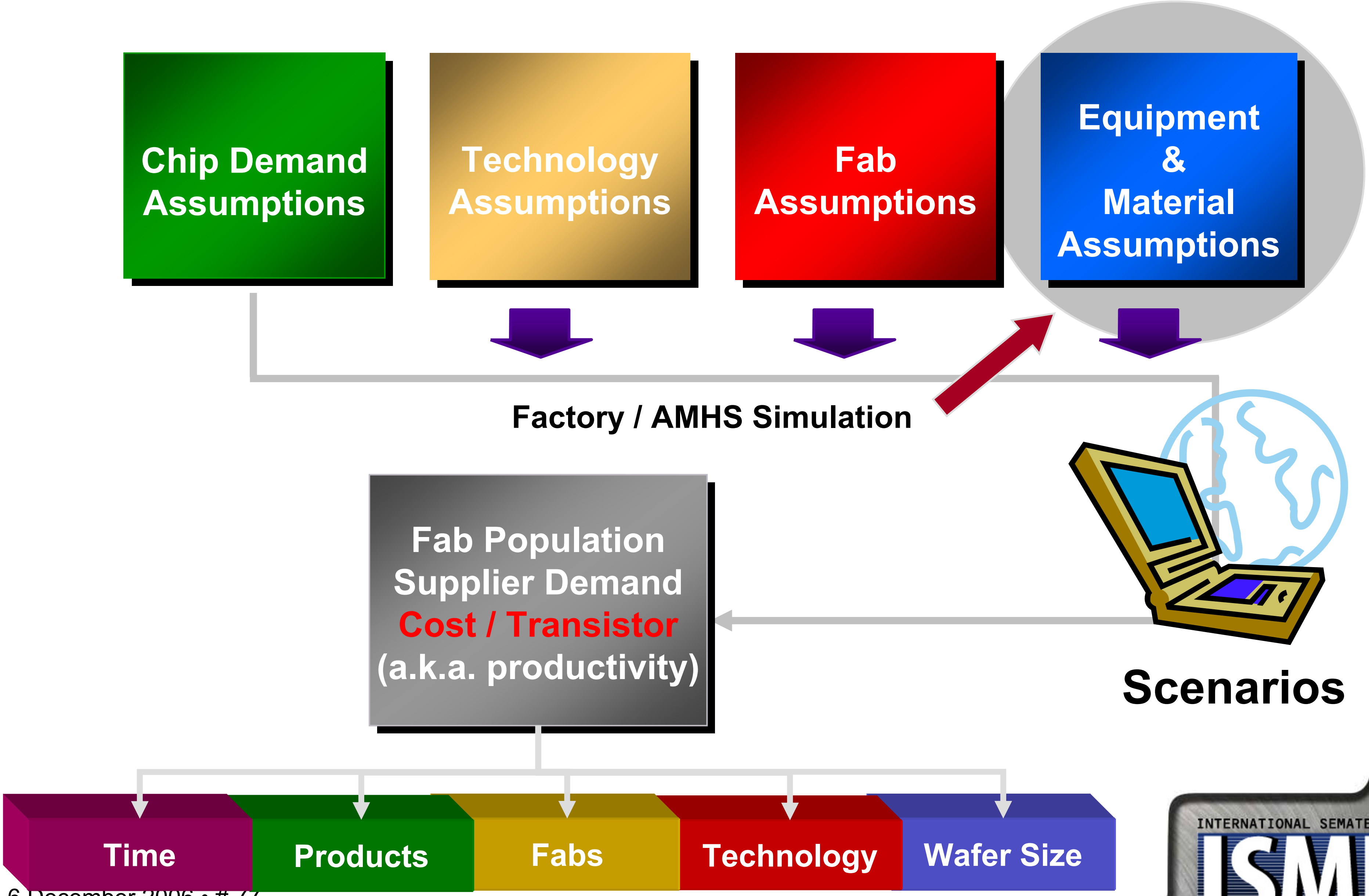
Objectives

- Provide chip manufacturing R&D and production metrics and assumptions by time and by product.
- Determine building, equipment, and material production and R&D metrics and assumptions by time based on source data, where available.
- Concur with methodology & software tools used and assess scenarios & sensitivity analysis validity and relevance.

2006 Key Milestones

- **Develop a 300mm industry productivity baseline for evaluating new initiatives**
  - Initialize with industry research material
  - Ratify with member company feedback
  - Reconcile with suppliers, when possible
- **Evaluate the productivity potentials of 300 Prime attributes based on factory vision and simulation results utilizing the above development process**

Industry Economic Model (IEM)



Chip Demand Assumptions

Technology Assumptions

Fab Assumptions

Equipment & Material Assumptions

Factory / AMHS Simulation

Scenarios

Fab Population
Supplier Demand
Cost / Transistor
(a.k.a. productivity)

Time

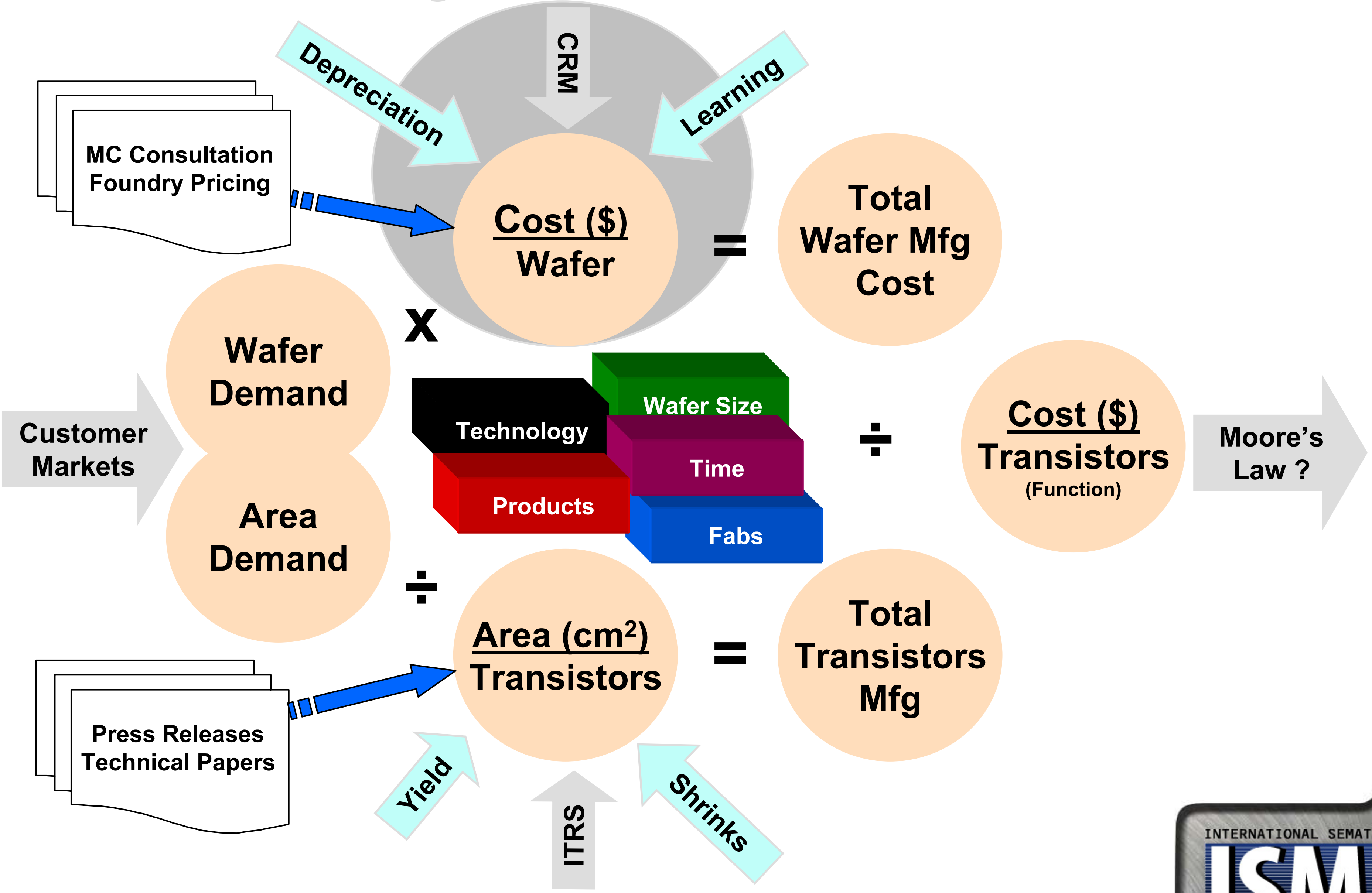
Products

Fabs

Technology

Wafer Size

Productivity Calculation

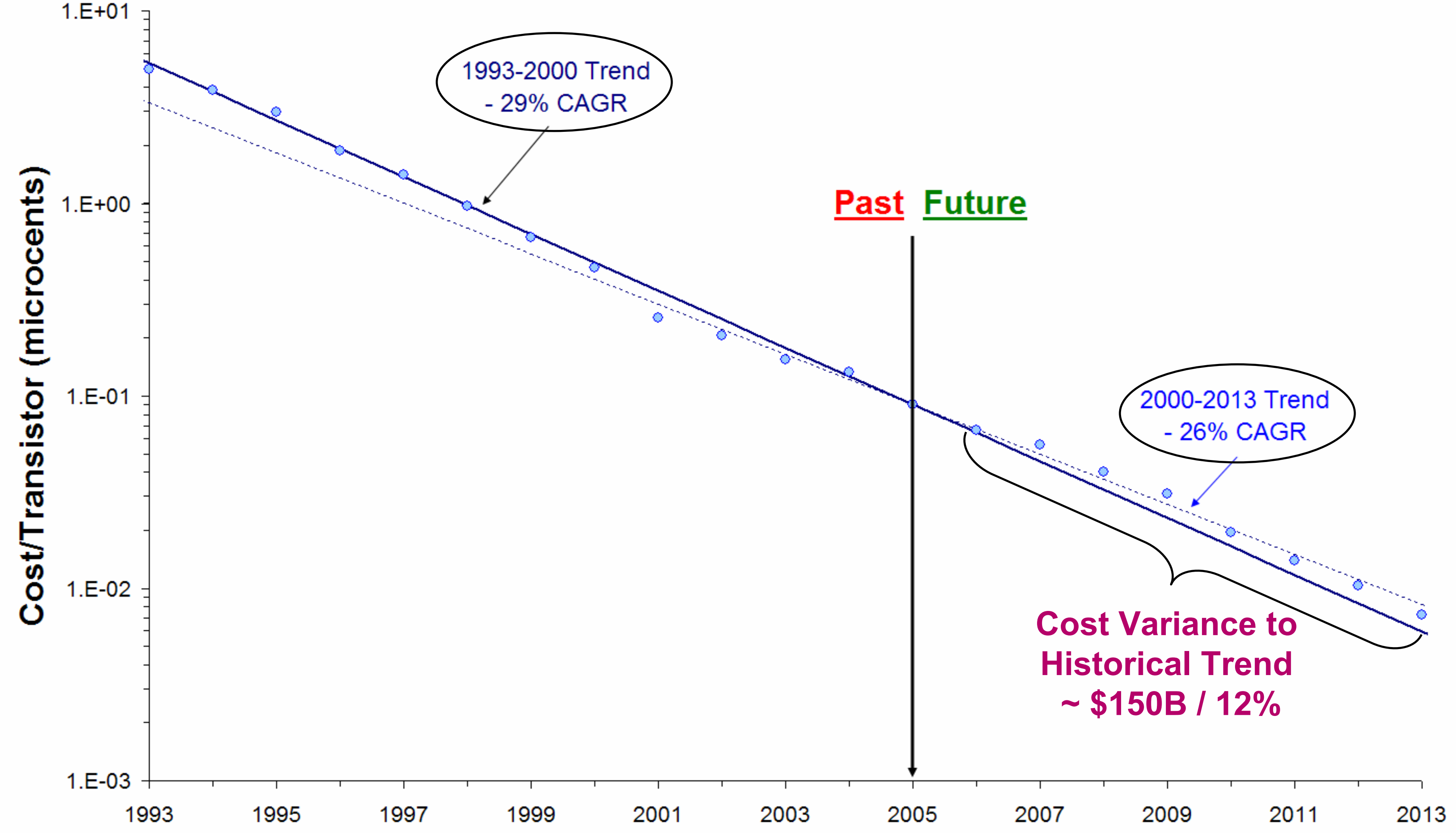


Base Case *(Realize the Roadmap - RR)*

- **Objective:**
  - – Determine the productivity trends based on utilizing the best known industry strategic assumptions
- **Observations:**
  - – Slower 300mm vs. 200mm volume ramp
  - – Slower technology introduction pace
- **Growth Trends (1993-2000 vs. 2000-2013)**
    - Silicon Area Demand (10.5% vs. 7%)
  - – Transistors/Area (41% vs. 37%)
    - Transistor Supply (56% vs. 47%)
  - – Cost/Area (0.5% vs. 1.5%)
    - Wafer Cost of Good Sold (11% vs. 9%)
  - – Cost / Transistor (-29% vs. -26%)

Productivity Impact: ~ $150B / 12%

Industry Productivity Trend



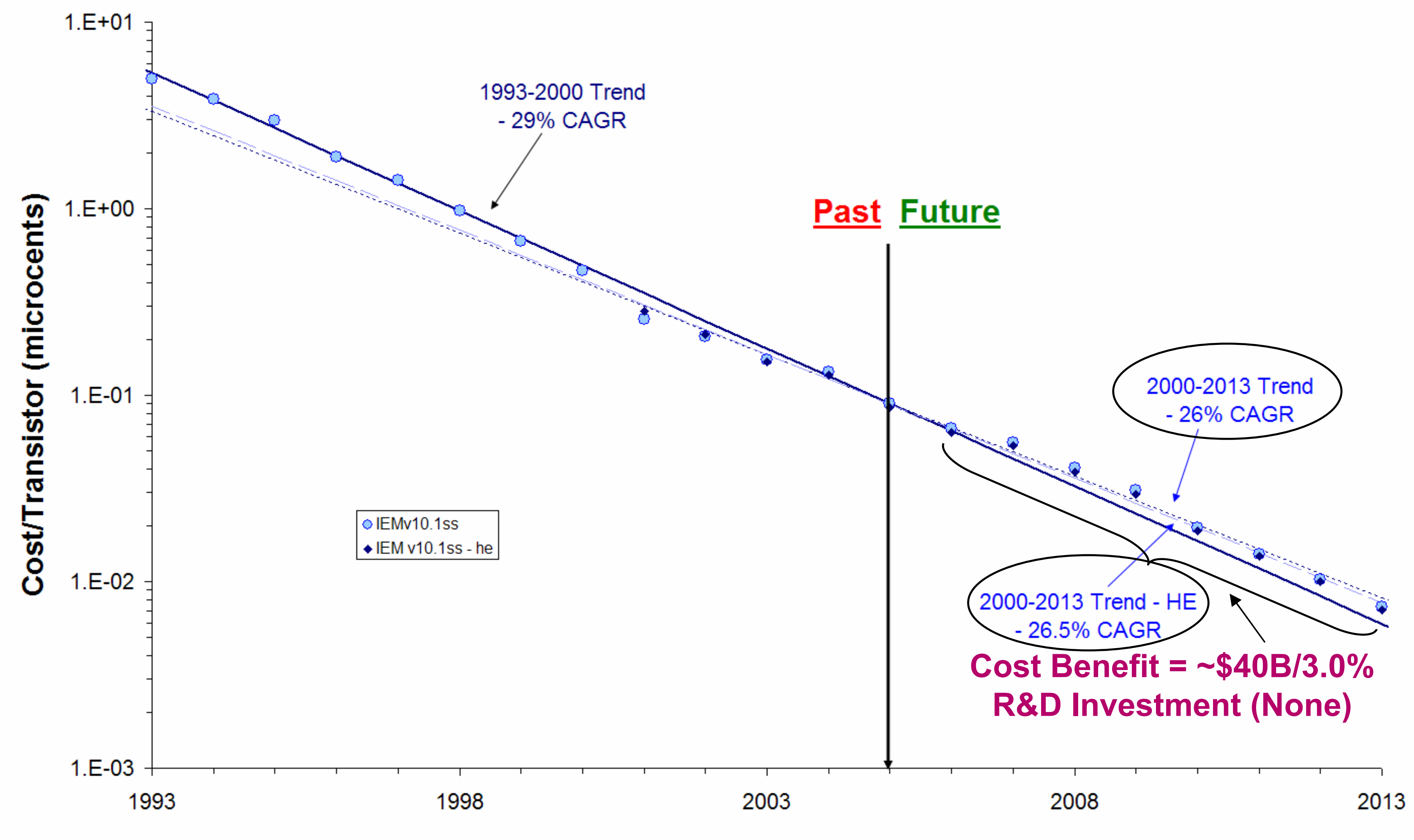
Cost Variance to Historical Trend ~ $150B / 12%

Sensitivity Case *(Historical Extrapolation - HE)*

- **Objective:**
  - Determine the impact to productivity due to the change in industry silicon area growth (10.5% vs. 7%)
- **Observations:**
  - 300mm ramp returned to historical pace
- **Growth Trends Changes (2000-2013 RR vs. HE)**
    - Silicon Area Demand (7% vs. 10.5%)
  - Transistors/Area (37% vs. 36.5%)
    - Transistor Supply (47% vs. 51%)
  - Cost/Area (1.5% vs. 0.5%)
    - Wafer Cost of Goods Sold (9% vs. 11%)
  - Cost / Transistor (-26% vs. -26.5%)

Productivity Benefit: ~ $40B / 3.0%

Industry Productivity – Historical Extrapolation



1993-2000 Trend
- 29% CAGR

Past **Future**

2000-2013 Trend
- 26% CAGR

2000-2013 Trend - HE
- 26.5% CAGR

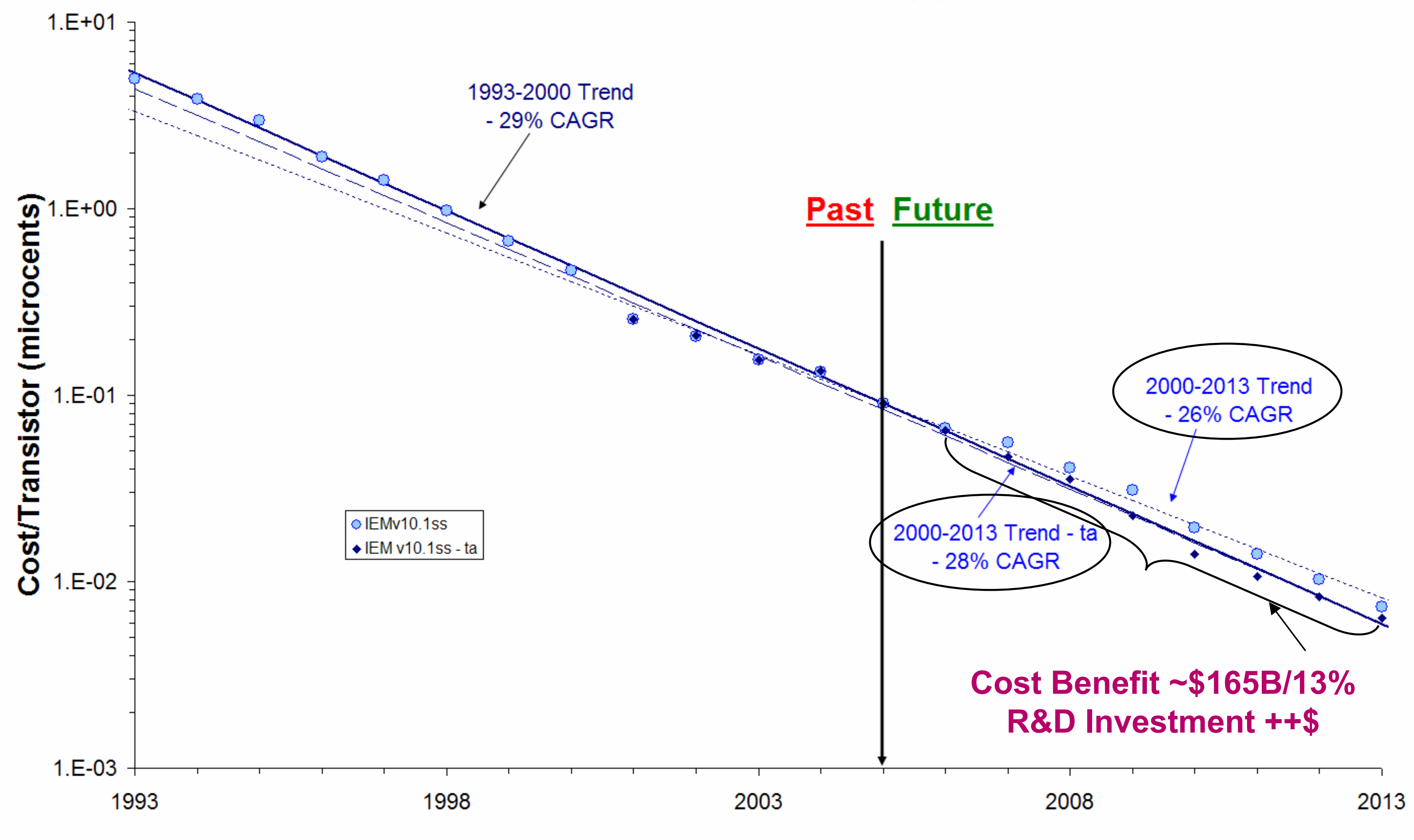
Cost Benefit = ~$40B/3.0%
R&D Investment (None)

Sensitivity Case *(Technology Acceleration - TA)*

- **Objective:**
  - Determine the impact to productivity by accelerating technology pace by 1 year / node, 65nm through 32nm
- **Observations:**
  - Introduction: 65nm - 2006, 45nm - 2008, 32nm - 2010
- **Trends Changes (2000-2013 RR vs. TA)**
    - Silicon Area Demand (None)
  - Transistors/Area (37% vs. 41.5%)
    - Transistor Supply (47% vs. 51.5%)
  - Cost/Area (None)
    - Wafer COGS (None)
  - Cost / Transistor (-26% vs. -28%)

Productivity Benefit: ~ $165B / 13%

Industry Productivity – Technology Acceleration



Cost Benefit ~$165B/13%
R&D Investment ++$

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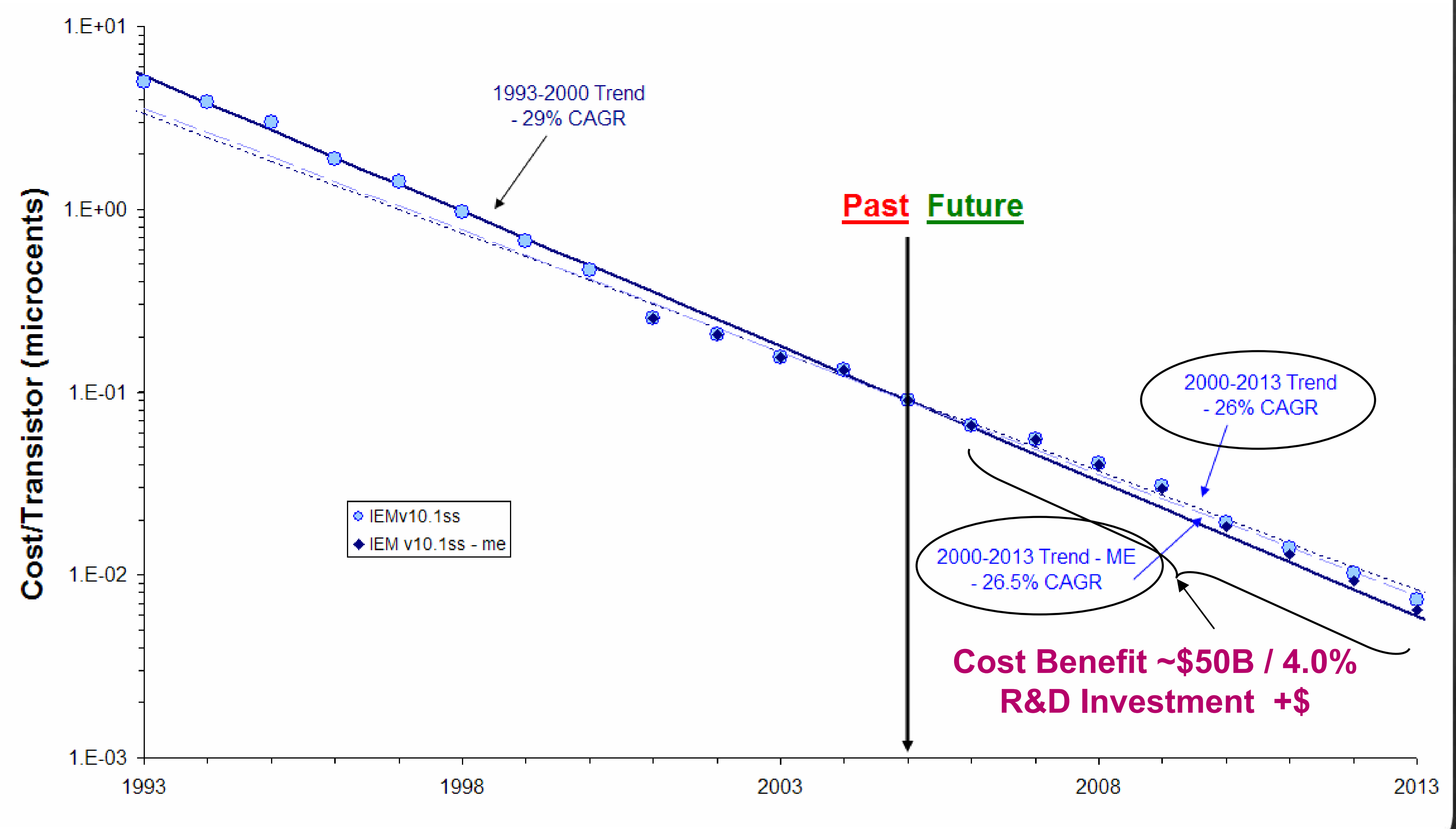
Sensitivity Case *(Manufacturing Effectiveness - ME)*

- **Objective:**
  - Determine the impact to productivity by improving overall factory effectiveness by 30% in cost / processed area
- **Observations:**
  - Required tool throughput improvement: +60% wafers/hr
- **Trends Changes (2000-2013 RR vs. ME)**
    - Silicon Area Demand (None)
  - Transistors/Area (None)
    - Transistor Supply (None)
  - Cost/Area (1.5% vs. 1.0%)
    - Wafer COGS (9.0% vs. 8.0%)
  - Cost / Transistor (-26% vs. -26.5%)

Productivity Benefit: ~ $50B / 4.0%

Industry Productivity – Manufacturing Effectiveness



1993-2000 Trend
- 29% CAGR

Past Future

2000-2013 Trend
- 26% CAGR

2000-2013 Trend - ME
- 26.5% CAGR

Cost Benefit ~$50B / 4.0%
R&D Investment +$

Case Summary

- Growing product demand would have the greatest impact to R&D by creating additional industry wealth that could be distributed throughout the supply chain
- Accelerating the technology introduction pace created the most positive effect on productivity trend but needs to be further evaluated to comprehend technical feasibility and supply chain R&D affordability
- Increasing tool throughput only to achieve the cost target could prove to be as technically challenging as hastening the pace of process technology introduction

IN NET

- Some part if not all of the productivity levers will be required to alter the direction of the projected trend.

Next Steps

- Continue to work with our member companies, their suppliers to ratify 300mm Classic baseline
- Evaluate 300mm Prime factory & equipment attributes based on their realized cost benefit
  - Collaborative studies with suppliers to assess all future IC manufacturing productivity options
  - Integrate new business logic and infrastructure as needed to assess future manufacturing initiatives
- Analyze longer term productivity options based on projected production cost & R&D expense
  - Update model with latest research consultant forecast and incorporate detailed 32, 22 & 16nm technology assumptions

Acknowledgements

- ISMI Economic Analysis Focus Team
- ISMI/SEMI Joint Economic Analysis Team
- Contact Information:
  - marcus.lentz@amd.com
  - denis.fandel@ismi.sematech.org

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ISMI 300 Prime/450 mm Industry Briefing

450 mm Starting Materials Update

December 6, 2006

Jackie Ferrell, ISMI
Mike Goldstein, Intel
Tom McKenna, TI

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Introduction

- The ISMI Starting Materials Focus Team is currently investigating the economics, technical feasibility, and timing of a next diameter (450 mm) wafer.

- This presentation focuses on 3 aspects of 450 mm silicon wafer development:

1. Summary of identified 450 mm wafer development challenges
2. Technical assumptions for a 450 mm mechanical (handling) wafer
3. A roadmap of standards development in relation to wafer development
   - Relative timing

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Starting Materials Challenges Summary
Key Cost Issues (p. 1 of 2)

1) **CZ puller utilization and energy cost**
   - Reduced pulling speed/throughput required for growing defect-free crystal

2) **Poly silicon supply and utilization**
   - Supply chain capacity (PV market competition)
   - Yield (weight) losses at crystal and wafer shaping operations

3) **Manufacturing equipment utilization and maintenance:**
   - – No apparent *fundamental* barriers to manufacture 450 mm wafers
   - – Greater level of complexity both for ingot pulling and wafer slicing, grinding, and polishing:
   - Handling of larger, heavier ingots
   - Larger consumables and spare parts
   - Throughput does not scale linearly (e.g., wafer slicing)
   - Temperature control solutions for wafer slicing and polishing

Starting Materials Challenges Summary

Key Cost Opportunities (p. 2 of 2)

4) **Characterization equipment development**
   - Tools capable of full diameter wafer analysis
   - Focus on edge exclusion compatibility

5) **Replacement of destructive test methods (wafer and slug form)**
   - Oxygen percipitates (BMD)
   - Radial and axial resistivity
   - Oxygen induced stacking faults
   - Radial and axial concentrations of oxygen and carbon
   - Surface boron concentration (annealed wafers)
   - etc…

6) **Wafer specification standardization**
   - Edge profile
   - Laser mark (content, format, and location)
   - Optional fiducial mark or/and two-dimensional barcode

Starting Materials Challenges Summary
Key Technical Issues (p. 1 of 2)

1) Crystal pulling challenges:
   - Process compared to 300 mm
     - Slower pull rate
     - Longer time to grow the same length crystal
     - Lower crystal yield, for the same length crystal
     - Bigger silicon charge
   - Equipment design optimization for the larger size:
     - Safety; larger and heavier crucibles; larger hot zones; heat shielding

2) Wafer thickness:
   - Chipping and breakage during processing and handling
   - increased risk of slip and breakage during thermal processing due to stress from temperature gradients and gravity
   - The degradation of bow and warp during processing
   - Wafer yield (cost)

3) Ingot slicing development:
   - Wafer shape control; manufacturability

Starting Materials Challenges Summary
Key Technical Issues (p. 2 of 2)

4) Wafer shaping processes

- (Grind, polish, CMP) development with equal or better capability than 300 mm over a 2X increase in surface area.

Challenge is to maintain ITRS flatness guidelines

5) Thermal annealing of individual wafers (slip prevention)

- Thermal processing for oxydonor annihilation, epi, annealing, and similar steps will require development work.
- The challenge is to optimize the ramp rates, the temperature gradients and the wafer support without inducing slips.

6) Prime Wafer Requirements:

The challenge is to achieve the key ITRS parameters:

- Defects, particles/LLS/COPs, electrical, Oi, purity

As required by the technology node at the time of introduction.

7) Application specific wafers

- (epi, SOI, SiGe…) will generate additional challenges.

Proposed Wafer Types

Type	Application	Key Parameters
Handling TW	Robotics and Carrier Testing	Diameter, Thickness, Edge Profile, Mechanical Integrity
General TW	Process and Metrology Equipment RandD, Process Monitoring	Global Flatness, Metals, LLS, Particles, COPs, Surface Roughness/Haze
Product wafer	HVM	Particles, Defects, Electrical, Chemical, LLS, Global/Site Flatness, NT, etc.

Contributed by Mike Goldstein, Intel

#	Total Wafer Characteristics	Units	Nominal	Tolerances	Notes
1	Diameter	mm	450	+/-0.2	
2	Thickness, Center point	µm	825	+/-20	
4	Total Thickness Variation (max)	µm	10		
5	Warp (max)	µm	100		
6	Edge Profile	µm	See Edge Profile Template		T/4 Template★
7	Orientation fiducial		Notch		Laser inscribed fiducial an option
8	Notch depth	mm	1.0	+.025; -0.00	
9	Notch angle	Degree	90	+5; -1	
10	Back surface condition		Supplier-customer agreement		Polished
11	Edge surface finish condition		Supplier-customer agreement		Polished
12	Visual Inspection criteria		No chips and cracks		
13	Wafer ID		Supplier-customer agreement		T7 with optional A/N
14	Edge Exclusion ★	mm	1.5		Not required. Provided for information only
15	LLS	nm	45		Not required. Provided for information only

450 mm Handling Test Wafer - initial assumptions

★ To be reviewed if new SEMI edge standard is released

450 mm vs. 300 mm Silicon Wafers

- **Differences:**
  - **Wafer diameter**
  - **Wafer thickness**
- **Unchanged:**
  - **Edge profile (to be reviewed after new SEMI edge standard is released)**
  - **Scribe**
  - **Node-specific requirements – edge exclusion, defects, metals, flatness, particles…**
- **Optional change**
  - **Notch from identical to 300 mm to notchless wafers with fiducial laser inscribe**

Contributed by Mike Goldstein, Intel

Model Validation

Model was validated with actual measurement of 200 mm and 300 mm data and modeled estimation for 400 mm and 450 mm wafers from Japan SSI initiative:

- **For 200 mm, 300 mm, and 400 mm wafers, our simulation matches SSI data within 0.8%**
- **For 450 mm wafers, our simulation matches SSI estimates by 7%**

Contributed by Mike Goldstein, Intel

Thickness Modeling and Evaluation Summary

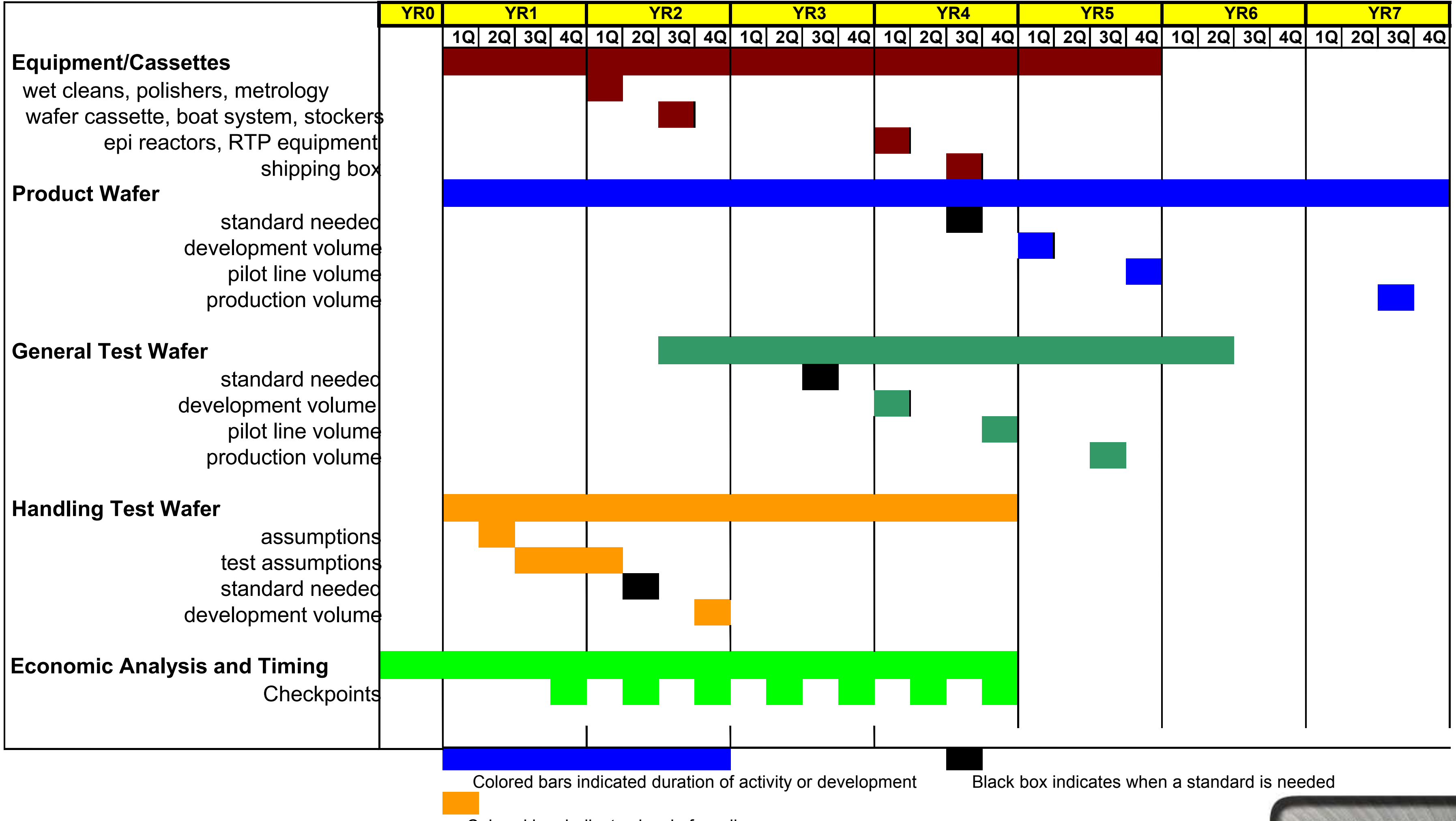
Effect	Acceptable Thickness	Comments
Mechanical integrity due to film deposition and gravity/handling	775 µm +Buffer	Stresses induced by front-end process film deposition and gravity << than Si bulk failure stress
Mechanical Integrity due to thermal stress	775 µm + Buffer	Wafer thickness has minimal effect on flash anneal and CVD
Cost	775 µm + Buffer	Manufacturability at Si suppliers and reclaim by device manufacturers

Proposed nominal thickness for 450 mm wafer
= 775µm + 50µm buffer = 825µm

Contributed by Mike Goldstein, Intel

Dependency Timing Chart

Starting Materials Dependencies Timing Chart



ISMI consensus on timing for 450 mm transition depends on 300 Prime and 450 mm productivity analysis

Summary

- Technical and cost challenges
  - Technically feasible, but need industry collaboration to address in cost-effective manner
- Handling wafer assumptions
  - Diameter and thickness are key initial wafer attributes
    - Required for early carrier and handling designs
  - Additional testing is required to validate assumptions
- Long lead-time of wafer R&D and standards needs to be comprehended

ISMI Starting Materials Focus Team Contacts

- Tom McKenna, TI
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- Mike Goldstein
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- Jackie Ferrell, ISMI
  jackie.ferrell@ismi.sematech.org

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Next Steps & Closing Remarks

Joe Draina

ISMI Associate Director

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In Review

- Provided overview of the ISMI 450mm program
  - Reviewed the Productivity Detractors that need to be resolved. Formed basis for 300 Prime.
  - Described the 300 Prime analysis path and relationship to 450mm
  - Provided updates on work already underway
    - Economic analysis, starting materials, factory architecture, factory simulation

Key Learning from 300mm experience

Industry coordination is crucial

- Early consensus - fab architecture
- Develop standards early (but not premature)
- Comprehend bridge tools

Support multiple leading-edge business models

- High-volume/low-mix, High-volume/high-mix, etc.

Assess business and economic models

- Analyze cost and risk

Continuously evaluate and adjust, including:

- Impact of technology on timing
- Market and industry dynamics

Opportunities for Involvement

- Concepts and recommendations are needed to help define the productivity improvements and solutions at 300 Prime or 450mm
  - This is critical for determining benefits and ROI for 300mm Prime versus a 450mm wafer size transition
  - Suppliers are encouraged to contact ISMI to discuss productivity opportunities
    - Contact Thomas Abell at ISMI for further information
      tom.abell@ismi.sematech.org
  - Suppliers are encouraged to participate in SEMI (MTF, etc.) and SEMI/ISMI forums (JPWG, etc.)
    - Contact Bettina Weiss at SEMI for further information
      bweiss@semi.org
- Today’s proceedings can be found at:
  - http://ismi.sematech.org/meetings/archives.htm
    - Scroll down to “Others”

Closing Messages from ISMI

- Productivity detractors are the issues that need to be solved
- Analysis focused on determining productivity potential of 300 Prime and then assess 450mm demand
  - Analysis needs to be data driven with industry engagement
- Suppliers are encouraged to engage in industry collaboration forums

In Conclusion:

- ISMI's 450 mm program will be analyzing the potential of 300 Prime in 2007 to assess demand for 450mm relative to achievable 300 Prime benefits

- ISMI welcomes input, feedback and industry collaboration to determine the optimum path for the industry and its membership.

Questions?

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