JEITA-JSIA STRJ, HU Conference

Industry Economic Model

INTERNATIONAL SEMATECH
ISMI
MANUFACTURING INITIATIVE

Denis Fandel
Project Manager, MM&P
15 December 2004

JEITA-JSIA STRJ, HU Conference: December 2004 1

Outline

- **Project / Model Overview**
  - Background / Goal
  - Model Components / Principles
  - Industry Segmentation / Roadmaps
- **Strategic Productivity Paths**
  - Base Roadmap Results
  - Manufacturing Effectiveness
  - Technology Acceleration
- **Economic Industry Group**

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Opening comments

- **The Industry Economic Model (IEM) is a one-of-kind tool that integrates at an industry level**
  – many of the semiconductor technology, wafer diameter, factory and equipment configurations
  – along with many of the core strategic manufacturing and development planning functions
- **The IEM logistics, algorithms and assumptions have been validated and can generate scenarios that**
  – assess changes to technology and manufacturing assumptions
  – assess the impacts of demand fluctuation and business cycles
  – examine the drivers of past, present and future productivity

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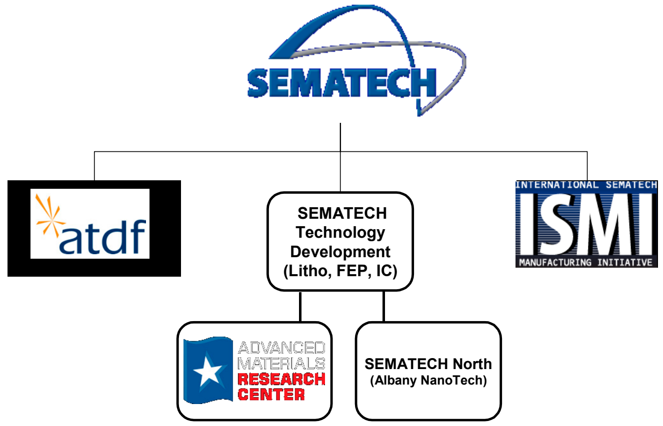
The SEMATECH Family



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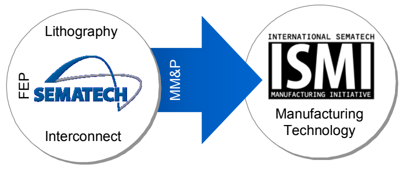
New Venture for Developing Manufacturing Technologies



- ISMI is a wholly owned subsidiary of SEMATECH
- Offering participation in ISMI to all chip manufacturers with fabs
- Companies may participate in ISMI without becoming a full member of SEMATECH
- Only organization in the world providing both tactical and strategic solutions to manufacturing challenges
- ISMI began operations in January 2004

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ISMI Mission

ISMI provides productivity solutions for current and future challenges in the manufacturing plants of our membership, so that our members will be achieve best in class productivity levels.

We will accomplish this by providing platforms for collaboration among our members and directing development activities in key areas identified by our members.

Manufacturing Infrastructure,
Manufacturing Effectiveness

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ISMI Productivity Programs

- **Fab Productivity**
  - Benchmarking, e-Manufacturing, Standards, Manufacturing Operations Analysis
  - Councils & Workshops: Manufacturing Methods, Facilities, Yield, Quality, Supplier Relations, Reliability, etc.
- **Equipment Productivity**
  - Equipment Productivity Improvement Teams, Spare Parts, Predictive Maintenance
- **ESH**
  - Resource and Water Conservation, Equipment ESH/Metrics, Life Cycle Assessment
- **Metrology**
  - Litho, Defects and Defect Sourcing

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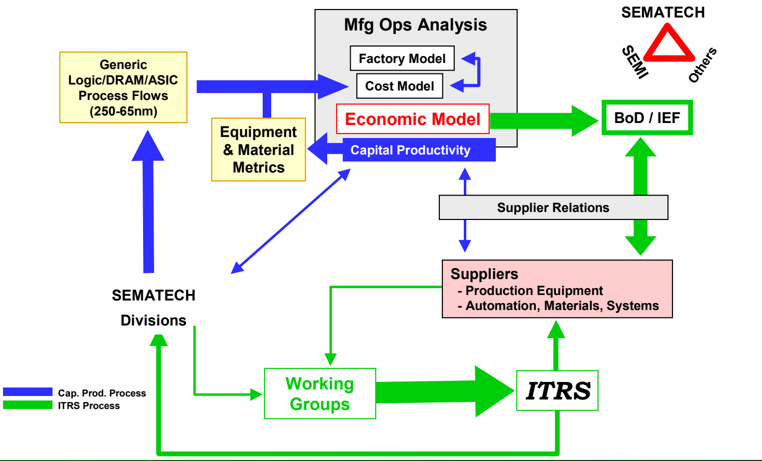
Industry Modeling Network



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IEM Goals

- **Develop unbiased studies to establish a quantitative foundation for a dialogue within the industry**
  - Assess impact of introduction pace of technology nodes and wafer diameter generations
  - Assess changing business / economic situations
  - Track and project trends of industry productivity
- **Develop and enhance a model to generate scenarios based on a comprehensive portfolio of metrics**
  - Customer Product Demand
  - Process Technology Roadmap
  - Fab / Equipment / Materials Assumptions

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Why Model?

- **Generally – understanding can only be shared through models (or common experiences)**
- **A model is “just” a set of assumptions about how things are and how they change**
  - Through a shared model we can align assumptions
- **Industry Economic Model (IEM)**
  - Built on many years of modeling work at SEMATECH
  - Cost of Ownership (static tool operational cost)
  - Cost Resource Model (static wafer-level cost)
  - Fab Simulation (dynamic fab configuration studies)

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Background

- **The Industry Economic Model was commissioned by the SEMATECH Board of Directors / Executive Committee to**
  - Support discussions with the supplier community regarding wafer diameter and technology introduction pace
  - Track industry productivity
- **The Industry Economic Model is being utilized primarily as a “*Resource for the Industry*” to**
  - Develop a future range of Fab capacity and supplier market perspectives which can be tracked for healthy and appropriate responses by chip manufacturer and supplier executives
  - Project future productivity trends to provide insight on technology, wafer diameter and performance strategies contained in the ITRS
  - Engage in discussion with business and government leaders on the economic fundamentals of semiconductor industry

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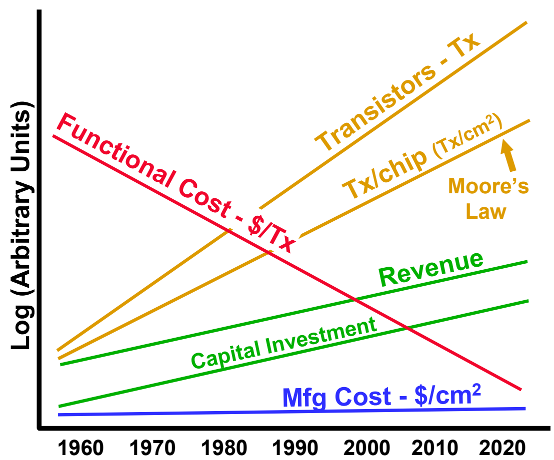
Industry Economics – Basic View



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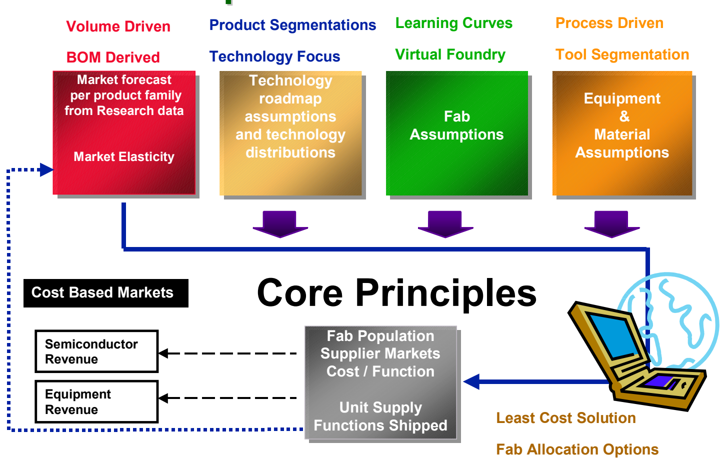
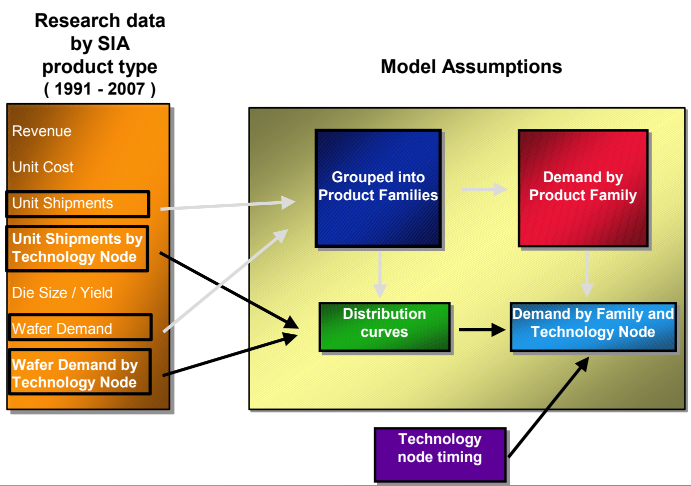
Design Concepts / Attributes

- **Leverage prior modeling efforts**
  - Cost of Ownership (static tool operational cost)
  - Cost Resource (static processed wafer cost)
  - Fab Simulation (dynamic fab configuration studies)
- **Utilize common tools / ease of use**
  - Excel Workbooks / Visual Basic
  - User Interface / Color Keyed
- **Coupled interwoven structure**
  - Multiple data segmentation options
  - Internal relationships are maintained
- **User defined functionality**
  - Industry, Enterprise, Fab
  - Attachable design for new capabilities

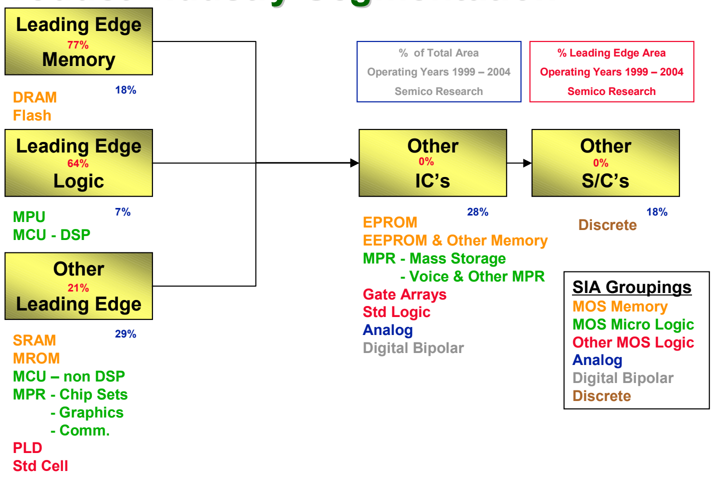
Model Components



IC Market Segmentation



Product Industry Segmentation



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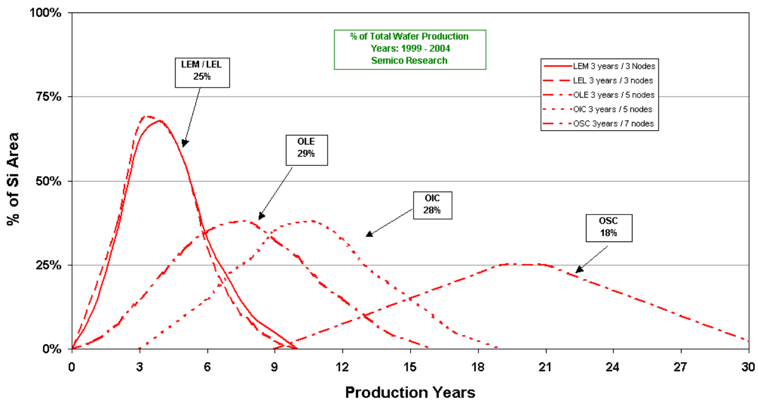
Historical Technology Life Cycles



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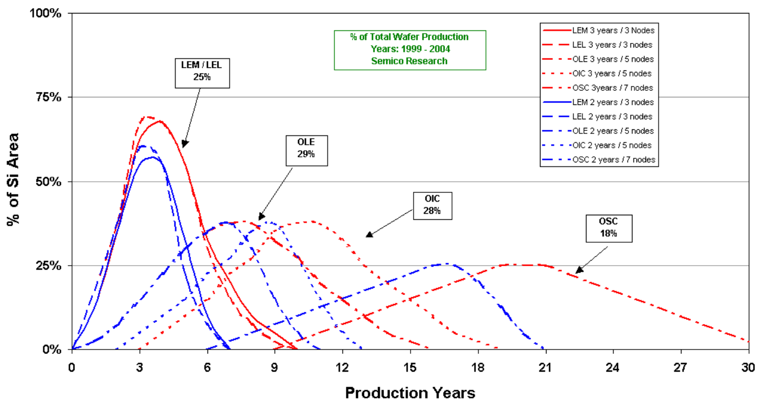
Accelerated Technology Life Cycles



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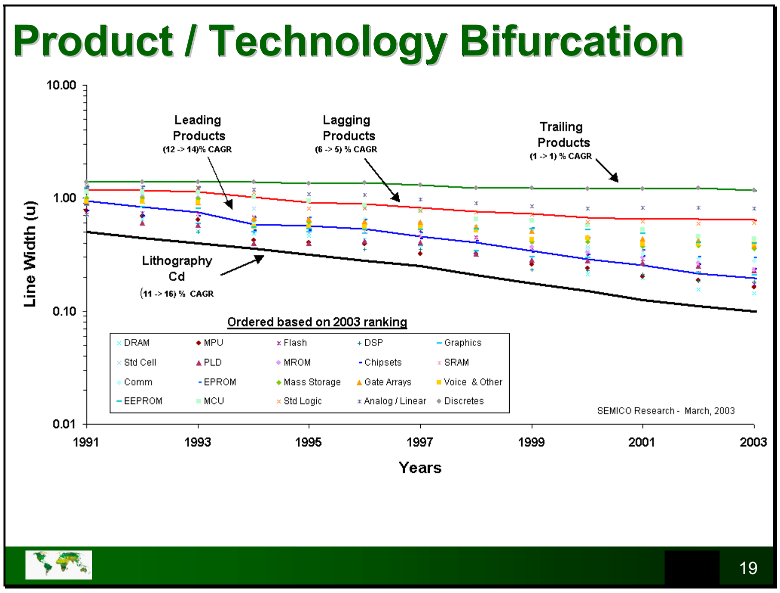
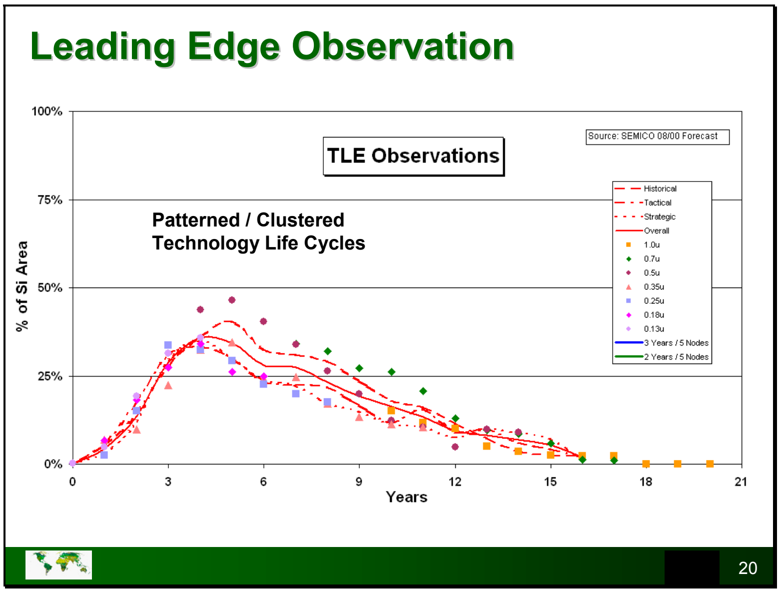
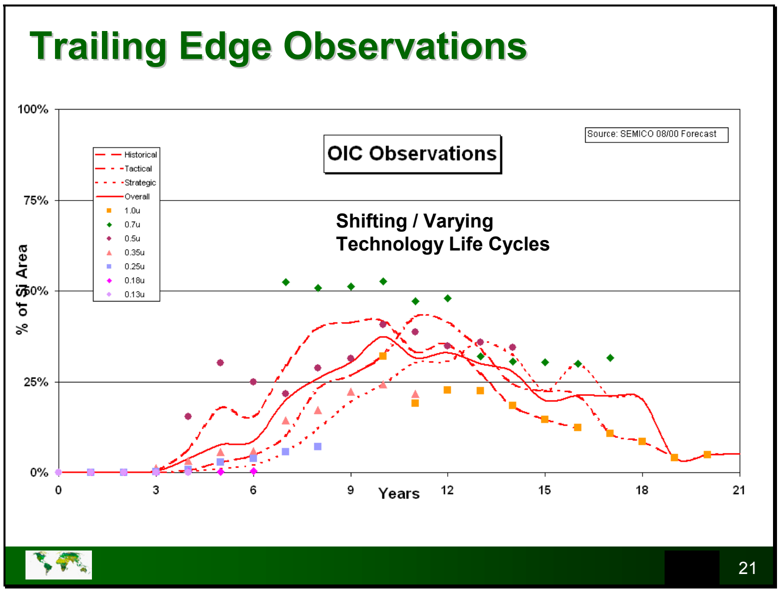
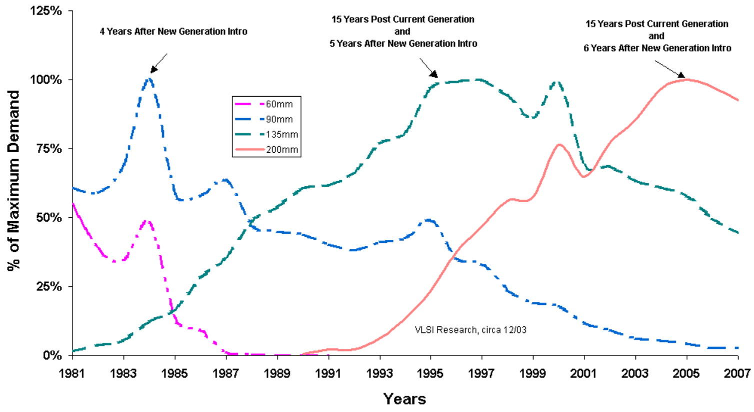

Product / Technology Bifurcation
10.00
1.00
0.10
0.01
Line Width (u)
Leading
Products
(12 -> 14)% CAGR
Lagging
Products
(6 -> 5) % CAGR
Trailing
Products
(1 -> 1) % CAGR
Lithography
Cd
(11 -> 16) % CAGR
Ordered based on 2003 ranking
DRAM
MPU
Flash
DSP
Graphics
Std Cell
PLD
MROM
Chipsets
SRAM
Comm
EPROM
Mass Storage
Gate Arrays
Voice & Other
EEPROM
MCU
Std Logic
Analog / Linear
Discretes
SEMICO Research - March, 2003
1991
1993
1995
1997
1999
2001
2003
Years
19


Leading Edge Observation
100%
75%
50%
25%
0%
% of Si Area
TLE Observations
Source: SEMICO 08/00 Forecast
Patterned / Clustered
Technology Life Cycles
Historical
Tactical
Strategic
Overall
1.0u
0.7u
0.5u
0.35u
0.25u
0.18u
0.13u
3 Years / 5 Nodes
2 Years / 5 Nodes
0
3
6
9
12
15
18
21
Years
20


Trailing Edge Observations
100%
75%
50%
25%
0%
% of Si Area
OIC Observations
Source: SEMICO 08/00 Forecast
Historical
Tactical
Strategic
Overall
1.0u
0.7u
0.5u
0.35u
0.25u
0.18u
0.13u
Shifting / Varying
Technology Life Cycles
0
3
6
9
12
15
18
21
Years
21

Wafer Size Distributions



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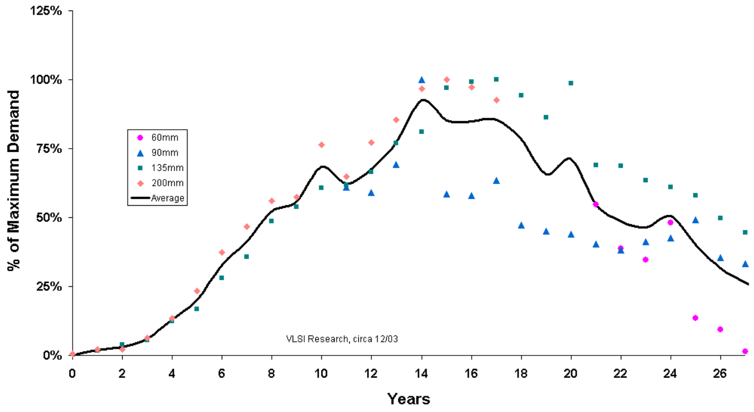
Nominal Wafer Distributions



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IEM Roadmap Scenario Names / Pace

Base Technology Roadmap

C: 2003 ITRS: Technology / Wafer Size (with Demand Shift)

Node Range	.35 ц .40 - .30	.25 ц .29 - .22	.18 ц .21 - .16	.13 ц .15 - .11	.09 ц .10 - .08	.065 ц .07 - .06	.045 ц .05 - .04	.032 ц .037 - .027	.022 ц .026 - .020
"C"	1994	1997	1999	2001	2003	2006	2009	2012	2015

Metric English	"90"mm 3 & 4 inch	"135"mm 5 & 6 inch	200mm 8 inch	300mm 12 inch	450mm 18 inch
"C"	1973	1982	1991	2001	2012

Other Technology Roadmap

A: Historic / Academic: Technology - 3 years, Wafer Size - 9 years

D: ITRS + 2: 65nm -> 45nm, Technology - 2 year, Wafer Size - Productivity Neutral

B: ITRS + 4: 65nm -> 22nm: Technology - 2 year, Wafer Size - Productivity Neutral

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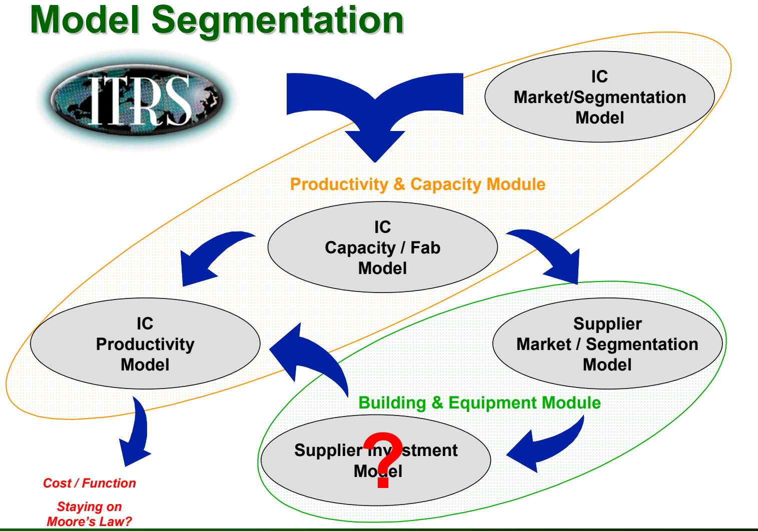
Model Segmentation



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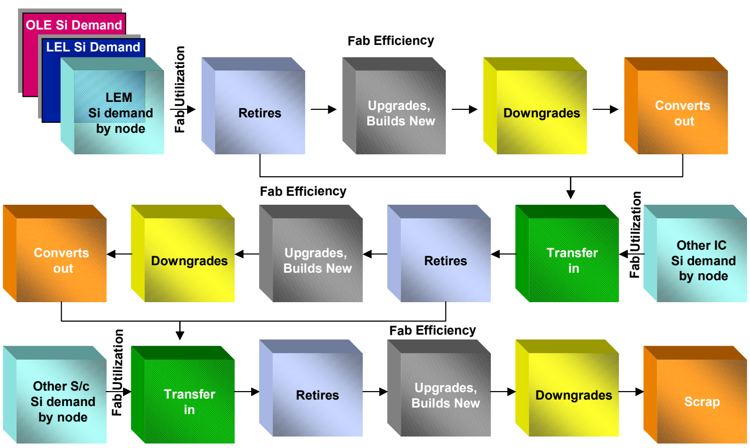
Capacity Allocation Process



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Cost Time Factors

- Throughput Learning
  - new technology introduction
  - new wafer size introduction
- Depreciation Factor
  - equipment (straight 5 years)
  - building (straight 20 years)
- Wafer processing cost
  - throughput learning
  - depreciation factor

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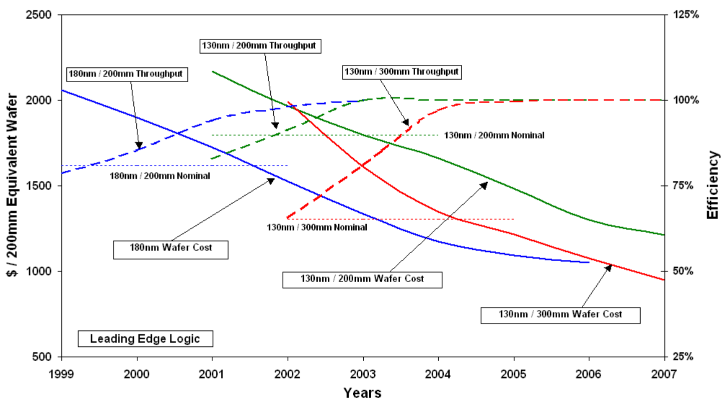
Fab Industry Learning



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Building & Equipment Assumptions

- **Process Flows**
  - Complex generic: multi-transistor
  - Graduated by product hierarchy
- **Fab Capacity**
  - User defined Fab Size
  - Green Field & Upgrade
  - Uni- & Multi-process / product
- **Equipment / Material parameters**
  - Throughput / Usage: nominal values
  - Value: CPI extrapolated cost

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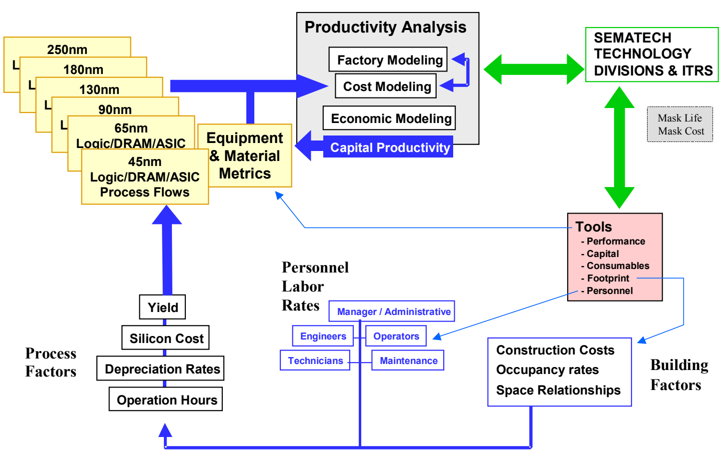
Static Cost Modeling



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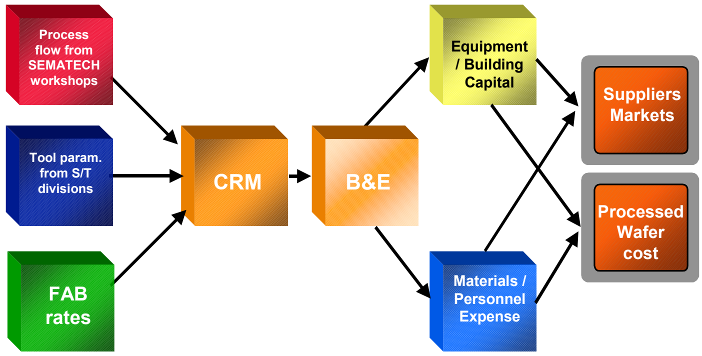
Building & Equipment Process



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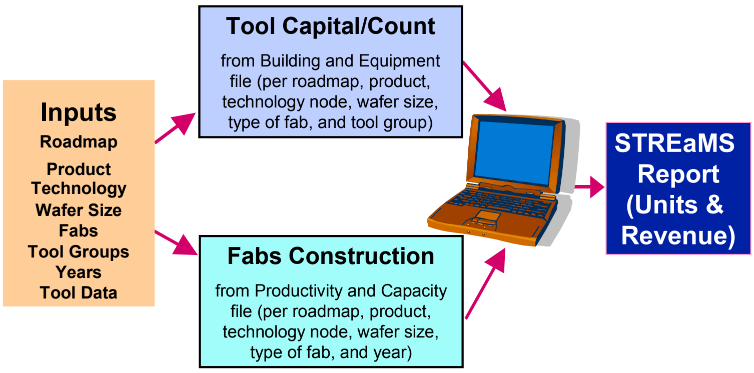
Supplier Segmentation Logistics



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Model Summary

- **IEM is a tool for discussing the past, the present, and the future**
  - Integrates at an industry-impact level all the manufacturing configuration with the ITRS performance strategies
  - Benchmark the industry IC manufacturing capacity / utilization and equipment consumption / capitalization
  - Scrutinize productivity trends / drivers based on alternative technology roadmaps or manufacturing strategies
- **Broad based, highly interactive user group is key for continued beneficial results**
  - Infrastructure are calibrated through historical validation
  - Metrics are continuously improved through collaboration

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Strategic Productivity Paths

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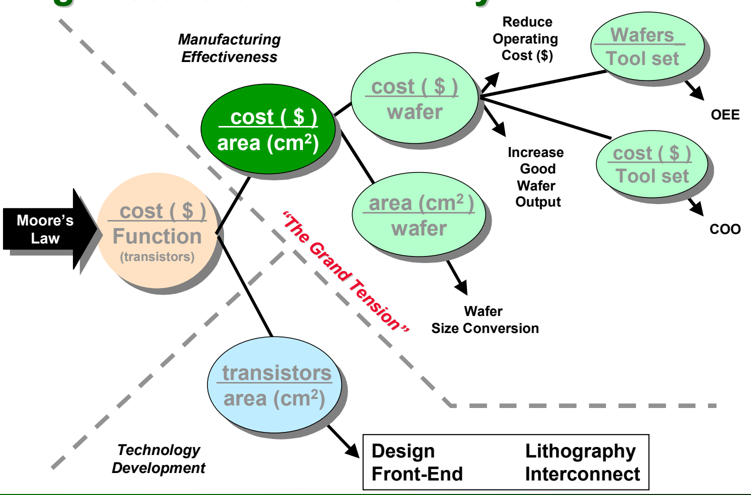
Big Picture of Productivity



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Grand Tension Equilibrium

- **Productivity Rule of Thumb**
  - Productivity enhancements are required periodically to offset *cost* increases (if wafer diameter, then every nine years or so)
  - For each year the technology roadmap is accelerated, wafer diameter introduction *can be* delayed a year

Example

IEM Roadmap "A" ~ 1994 NTRS, IEM Roadmap "C" = 2003 ITRS

Node Range	.5 ц .65 - .45	.35 ц .40 - .30	.25 ц .29 - .22	.18 ц .21 - .16	.13 ц .15 - .11	.09 ц .10 - .08	.065 ц .07 - .06	.045 ц .05 - .04	.032 ц .037 - .027
"A"	1991	1994	1997	2000	2003	2006	2009	2012	2015
"C"	1991	1994	1997	1999	2001	2003	2006	2009	2012

Metric English	200mm 8 inch	300mm 12 inch	450mm 18 inch
"A"	1991	2000	2009
"C"	1991	2001	2012

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Realize the Roadmap Scenario

Assumptions

- Constant area demand (Elasticity = 1)
- Product densification based on ITRS node definition
- Manufacturing metric, post 65nm/300mm, extrapolated

IEM Roadmap C (before 90nm shift)

Node	.13 μ	.09 μ	.065 μ	.045 μ	.032 μ	.022 μ
Range	.15 - .11	.10 - .08	.07 - .06	.05 - .04	.037 - .027	.026 - .020
"C"	2001	2004	2007	2010	2013	2016

Metric	300mm	450mm
English	12 inch	18 inch
"C"	2001	2013

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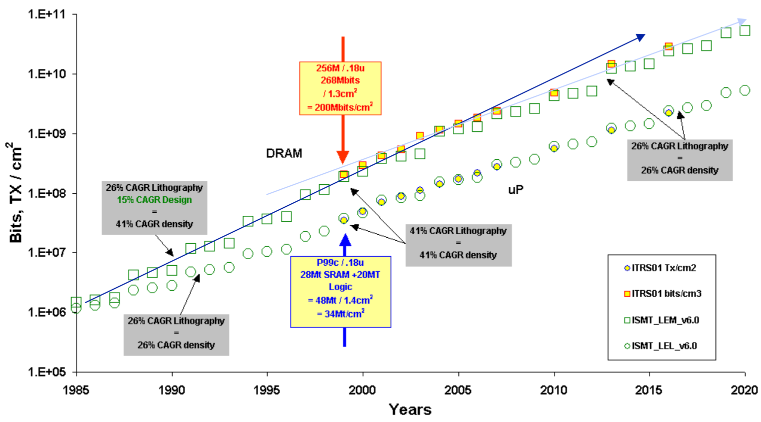
Product Density (Roadmap C)



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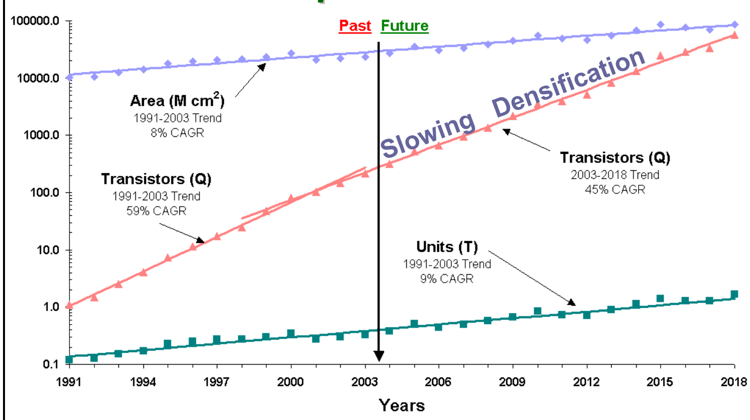
Demand Assumptions



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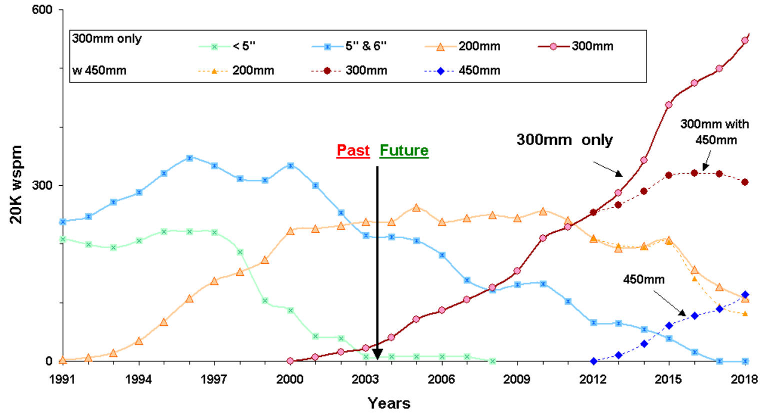
Fab Capacities Profile



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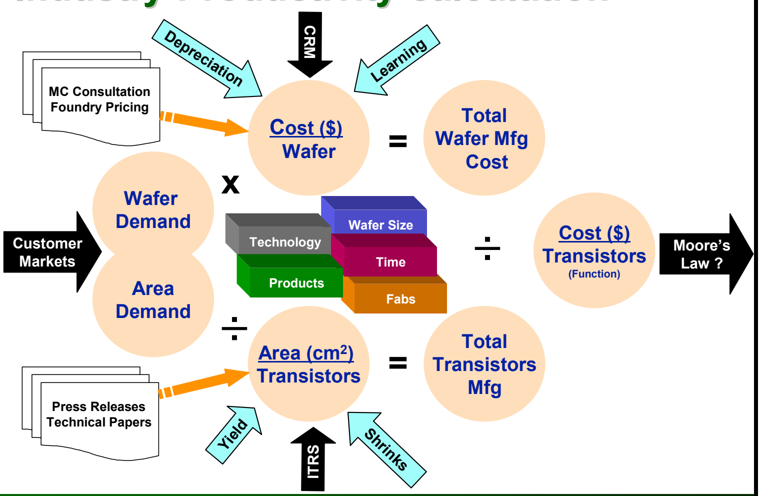
Industry Productivity calculation



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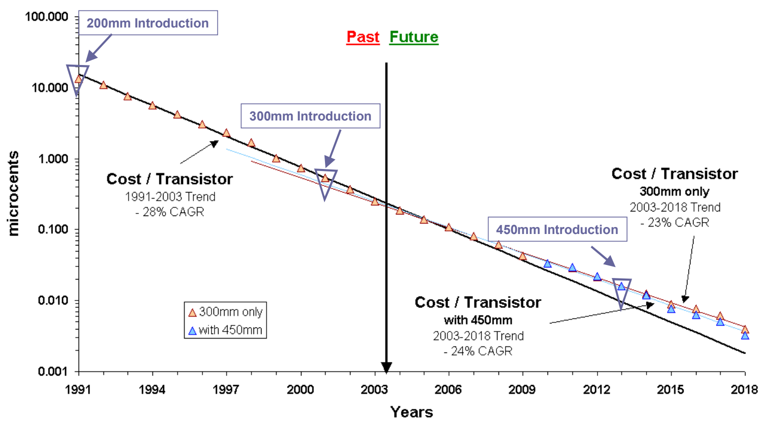
Scenario Productivities



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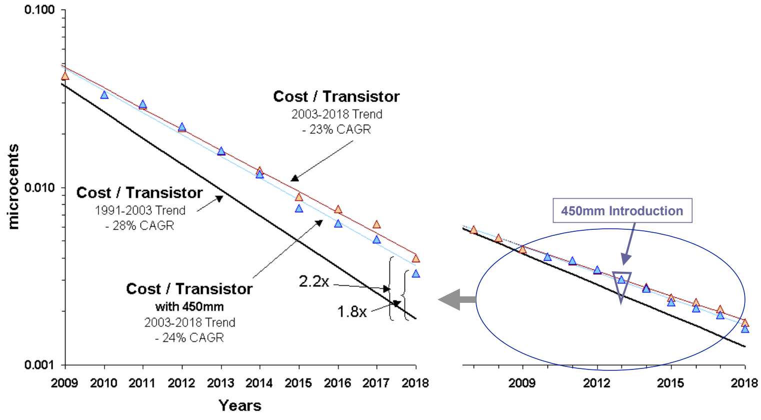
Scenario Productivities



Productivity Drivers

Potential of existing productivity mechanisms

- Yield ~ 100%
- Density (3 → 2 → 3 year)
  - Patterning (26% → 41% → 26% / year)
  - Design (15% → 0% → 0% / year)
    - Software
- Manufacturing methods
  - OEE, OFE and new paradigms (“450mm wafers”)

Economics of implementation

- Can the industry afford this?

IC Manufacturing Strategic Thrusts

- **“Monitor free” Manufacturing**
- **Plug and Play Equipment**
- **Short Cycle Time**
- **Green Fab**
- **Maskless Processing**
- **“Lights Out” Fab**
- **Next Wafer Size Transition**
- **People Productivity**

Manufacturing Effectiveness Scenario

Assumptions

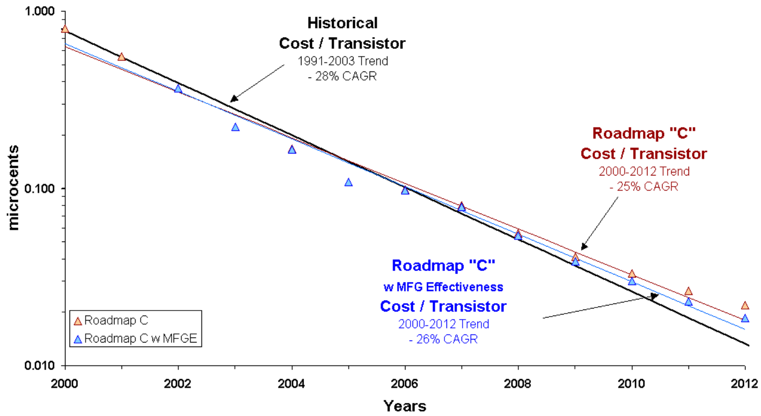
- Constant area demand (Elasticity = 1)
- Product densification based on ITRS node definition
- Equipment throughput uplift (20% compounded per node)
- Manufacturing cost uplift (5% compounded per node)

IEM Roadmap C (after 90nm shift)

Node	.13 ц	.09 ц	.065 ц	.045 ц	.032 ц	.022 ц
Range	.15 - .11	.10 - .08	.07 - .06	.05 - .04	.037 - .027	.026 - .020
"C"	2001	2003	2006	2009	2012	2015

Metric	300mm	450mm
English	12 inch	18 inch
"C"	2001	2012

Scenario Productivities



Technology Acceleration Scenario

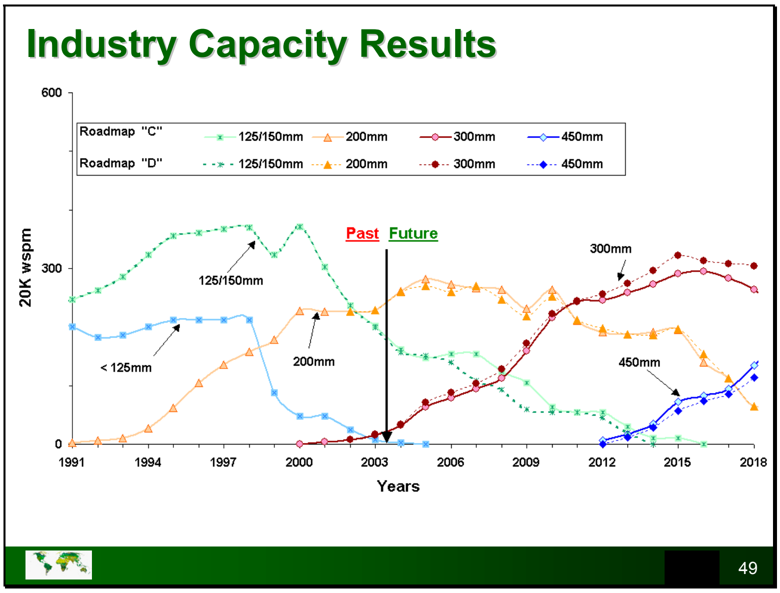
Assumptions

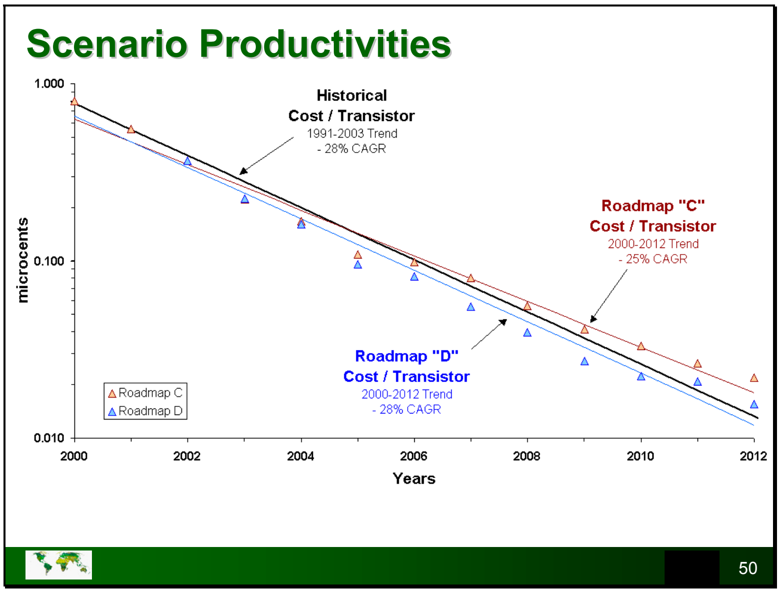
- Constant area demand (Elasticity = 1)
- Product densification based on ITRS node definition
- Equipment capital uplift (5% compounded per node)

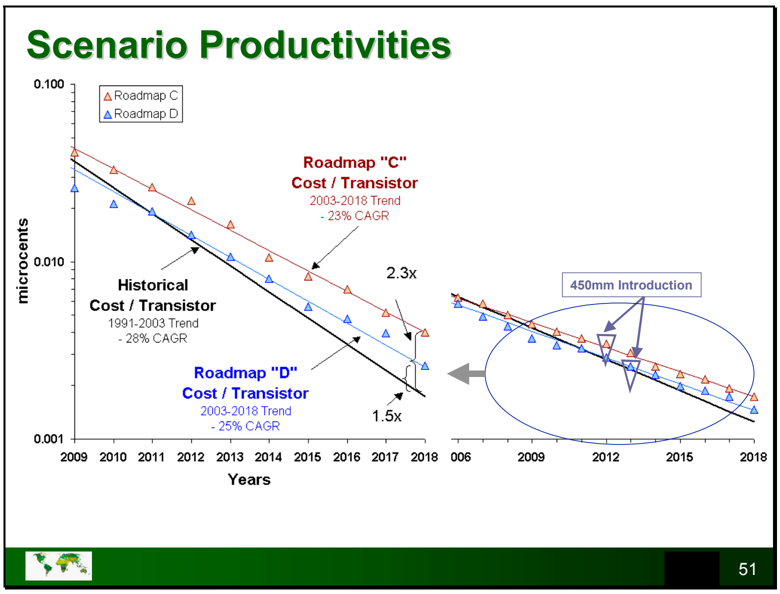
IEM Roadmap D

Node	.13 ц	.09 ц	.065 ц	.045 ц	.032 ц	.022 ц
Range	.15 - .11	.10 - .08	.07 - .06	.05 - .04	.037 - .027	.026 - .020
"C"	2001	2003	2006	2009	2012	2015
"D"	2001	2003	2005	2007	2010	2013

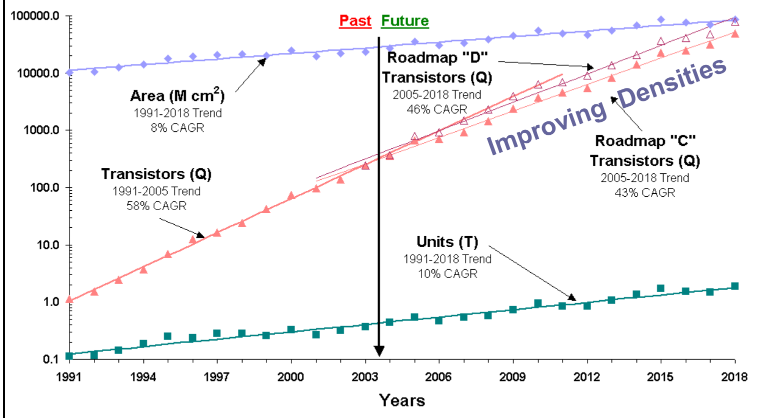
Metric	300mm	450mm		300mm	450mm
English	12 inch	18 inch		12 inch	18 inch
"C"	2001	2012	"D"	2001	2013


Industry Capacity Results
600
300
0
20K wspm
Roadmap "C"
Roadmap "D"
125/150mm
200mm
300mm
450mm
Past
Future
125/150mm
< 125mm
200mm
300mm
450mm
1991
1994
1997
2000
2003
2006
2009
2012
2015
2018
Years
49


Scenario Productivities
1.000
0.100
0.010
microcents
Historical
Cost / Transistor
1991-2003 Trend
- 28% CAGR
Roadmap "C"
Cost / Transistor
2000-2012 Trend
- 25% CAGR
Roadmap "D"
Cost / Transistor
2000-2012 Trend
- 28% CAGR
Roadmap C
Roadmap D
2000
2002
2004
2006
2008
2010
2012
Years
50


Scenario Productivities
0.100
0.010
0.001
microcents
Roadmap C
Roadmap D
Roadmap "C"
Cost / Transistor
2003-2018 Trend
- 23% CAGR
2.3x
Historical
Cost / Transistor
1991-2003 Trend
- 28% CAGR
Roadmap "D"
Cost / Transistor
2003-2018 Trend
- 25% CAGR
1.5x
450mm Introduction
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
006
2009
2012
2015
2018
Years
51

Demand Results



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Findings / Summary

- Initial studies indicate that historical productivity trends can not be maintained with current roadmaps
- Manufacturing effectiveness can be an important element in driving productivity improvements
- Pace of technology introduction / adoption can significantly influence productivity direction
- Further collaborative studies are required to explore / assess future manufacturing productivity options

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Economic Industry Group

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Project Manager, MM&P
15 December 2004

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Economic Industry Group

- **Objective**
  - **To examine strategic issues impacting industry productivity**
- **Membership Enrollment**
  - ISMT/ISMI Member Company Representatives
  - SIA/SEMI Member Company Representatives
  - Invited members of Academia / Research / Government
- **Membership Agreements**
  - Participate in the Economic Analysis Workshop
  - Actively evaluate model results and report on activities monthly
  - Utilize ECONtalk network and participate in Webex meetings
- **Schedule of Key Dates**
  - Fall, 2004 Workshop: November 18th
  - Winter 2005 WEBEX Sessions: Wednesday, 3PM Central
    December 15th; January 19th ; February 16th ; March 16th; April 20th

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Program Overview

- **Membership Enrollment**
  - ISMT/ISMI Member Company Representatives
  - SIA/SEMI Member Company Representatives
  - Invited members of Academia / Research / Government
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    December 15th; January 19th ; February 16th ; March 16th; April 20th

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Focus Team Objectives

- **To evaluate the structure, algorithm, and parameters of the model and recommend changes that will enhance its overall acceptability and credibility in the industry**
- **To provide a forum for the working group members to contribute in the project results by participating at various levels more aligned with their areas of expertise and/or interest**

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Boundaries / Domain

Program members to co-chair focus teams for each industry economic model major segment as follows:

- **Demand Assumptions – Fandel**
  - Area / Units / Transistors
  - Product / Technology Mix
- **Fab Assumptions – Wright**
  - Size / Type
  - Utilization / Learning
- **Equipment Assumptions – Brown**
  - Throughput
  - Value
- **Material Assumptions – Gayle**
  - Usage
  - Value

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Summary

- **Industry Economic Model is a public tool for discussing the past, the present, and the future**
  - Open model → Open dialogue and objective assessment of the impact of assumptions and algorithms leads to better understanding and better decisions
  - Integrates *at an industry-impact level* all the semiconductor technology and factory and equipment configuration and performance strategies contained in the ITRS
- **Economic Analysis Group and associated workshop can be an influential, collaborative industry team**
  - Provide broad based evaluations of model metrics for the next generation technology and wafer diameter
  - Generate economic scenarios for alternative / optional solutions of roadmap challenges

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Next Steps

- **Model development plan constituted**
  - End Market Segmentation
  - IDM / Foundry Segmentation
- **Future symposiums/workshop venues**
  - Spring 2005, May 18th , Denver, CO
  - Fall 2005, November 16th, Dallas, TX
- **Continued *"Resources for the Industry"***
  - Economic Analysis Workshop – Industry Productivity Trends
  - Capacity Utilization Activities – Monitoring Market Behaviors

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In Closing

- **IEM works, been validated and has a challenging development strategy in place.**
- **IEM is being used by wide range of participants**
  - Data Mining within core scenarios
  - Create independent evaluations / analysis
  - Evaluate internal investment strategies
- **IEM is a powerful industry tool due to its robust design and comprehensive linked data bases**
- **ISMI studies can assist in setting the industry's tactical and strategic manufacturing direction**

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