INTERNATIONAL TECHNOLOGY ROADMAP FOR SEMICONDUCTORS (ITRS) 2006 Update

Hsinchu, Taiwan
The Ambassador Hotel

Hosted
by
the Taiwan Semiconductor Industry Association (TSIA)

PRESS CONFERENCE

12/05/06

2006 Update Key Messages

presented by members of
the International Roadmap Committee (IRC)

ITRS History/Demographics	Paolo Gargini
Technology Pacing	Alan Allan
Lithography	Wolfgang Arden
Front End Processes/PIDS	Hidemi Ishiuchi
Test	Mong Song Liang
More than Moore	Mart Graef
450 mm Wafer Size	All

ITRS

2006 Update Executive Overview

The International Technology Roadmap for Semiconductors (ITRS) is the result of a worldwide consensus-building process. This document predicts the main trends in the semiconductor industry spanning across 15 years into the future. The participation of experts from Europe, Japan, Korea, and Taiwan as well as the U.S.A. ensures that the ITRS is a valid source of guidance for the semiconductor industry as we strive to extend the historical advancement of semiconductor technology and the worldwide integrated circuit (IC) market. These five regions jointly sponsor the ITRS.

The Semiconductor Industry Association (SIA) coordinated the first efforts of producing what was originally *The National Technology Roadmap for Semiconductors* (*NTRS*). The semiconductor industry became a global industry in the 1990s, as many semiconductor chip manufacturers established manufacturing or assembly facilities in multiple regions of the world. This realization led to the creation of the *International Technology Roadmap for Semiconductors* in the late 90s. The invitation to cooperate on the ITRS was extended by the SIA at the World Semiconductor Council in April 1998 to Europe, Japan, Korea, and Taiwan. Since then, full revisions of the ITRS were produced in 1999, 2001, 2003 and 2005; ITRS updates were produced in the even-numbered years (2000, 2002, and 2004).

The ITRS process is an ongoing event. The industry is dynamic—continually innovating; introducing new products; and achieving solutions. To keep the ITRS information as current as possible with this dynamic industry environment, during each year following an edition such as the *2005 ITRS,* the roadmap information is reviewed. Data adjustments, corrections, and new information items are agreed to among the ITWG members and by soliciting public feedback during the annual ITRS Summer Conference in San Francisco. For the *2006 ITRS Update* effort, all the ITRS tables were reviewed. If necessary, data and notations were updated to match industry advancements.

2006 Update Executive Overview (continued)

Overall, the *2006 ITRS Update* represents a minor modification to the *2005 ITRS*. The *2006 ITRS Update*, consistent with the *2005 ITRS*, removes the concept of "technology node" as the main pace setter for the IC industry. Users of the 2006 Update easily can determine specific numbers for DRAM metal half-pitch, NAND polysilicon half-pitch, or MPU and ASIC gate length, for example, to characterize the pace of that specific technology. The Overall Roadmap Technology Characteristics Tables and individual ITWG tables use these specific product timings to indicate the drivers for their requirements. For this purpose, the *2006 ITRS Update* addresses an independent measure of the technology pace of DRAM, of MPU, and of Flash products.

Several tables have been corrected or updated, as clearly indicated in blue. It is also rather easy to identify where the changes have occurred as indicated by "**IS"** in the far left column of an updated table. This Overview document contains an Appendix of all tables, figures, or textual changes for the *2006 Update* by chapter.

It is important to remind the reader that it is the purpose of the ITRS documents to provide a reference of requirements, potential solutions, and their timing for the semiconductor industry. This objective has been accomplished by providing a forum for international discussion, cooperation, and agreement among the leading semiconductor manufacturers and the leading suppliers of equipment, materials, and software, as well as researchers from university, consortia, and government labs.

The ITRS documents have become and remain a truly common reference for the entire semiconductor industry. Indeed, the cooperative efforts of the ITRS participants have fostered cooperation among international consortia, universities, and research institutions around the world. It is hoped that the *2006 ITRS* Update will further contribute to fuel cooperative R&D investments so that the financial burden can be more uniformly shared by the whole industry. It is also hoped that the ITRS will continue to stimulate the fundamental elements that encourage innovation in individual companies.

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NTRS* Roadmap Editions

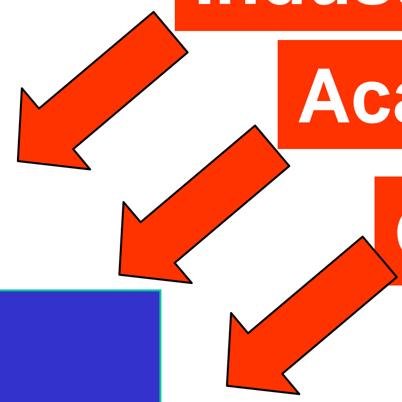
USA Only

1991
Micro Tech 2000
Workshop Report

1992NTRS

1994NTRS

1997NTRS



Industry

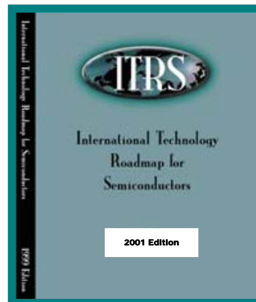
Academia

Government

*National Technology Roadmap for Semiconductors

Roadmap Editions

http://public.itrs.net



1991
Micro Tech 2000
Workshop Report

1992NTRS

1994NTRS

1997NTRS

USA

Taiwan

Korea

Japan

Europe

1998ITRS Update

1999ITRS

2000ITRS Update

2001ITRS

2002ITRS Update

2003ITRS

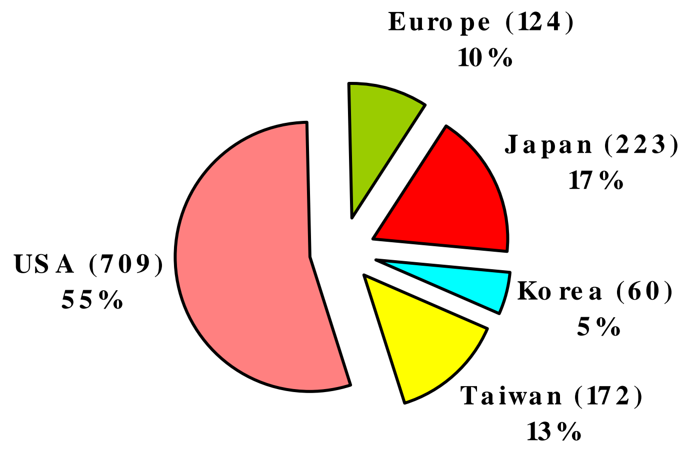
2004ITRS Update

2005ITRS

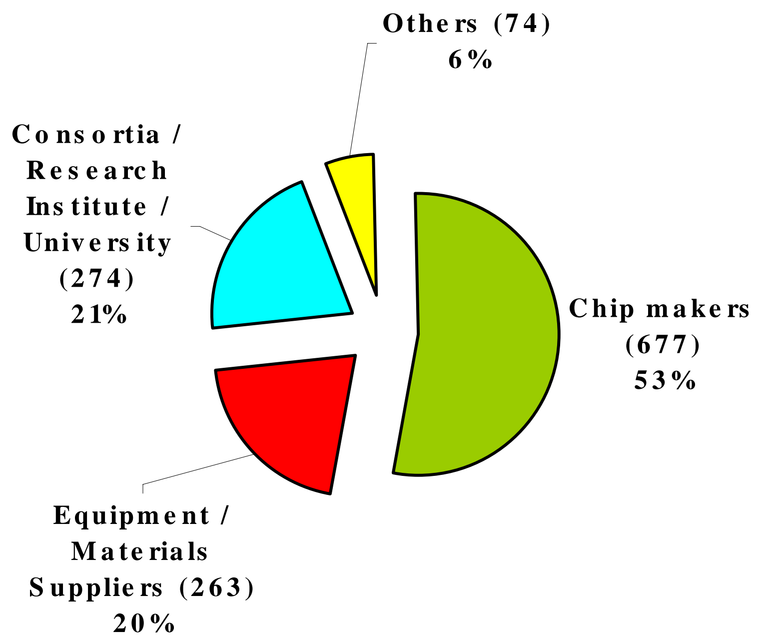
2006ITRS Update

ITRS Demographics

2005 ITRS Members by Region

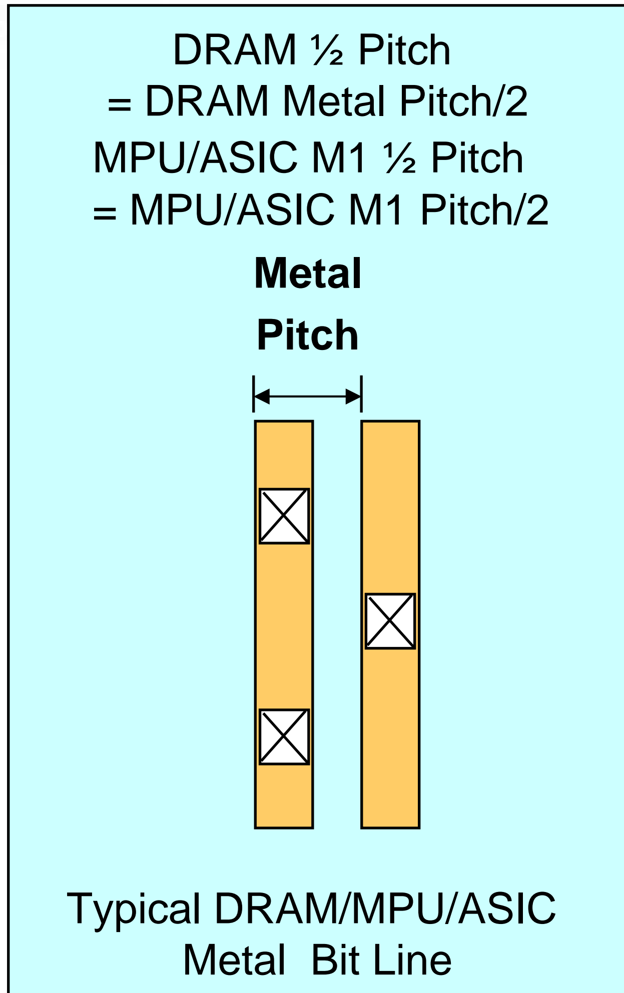


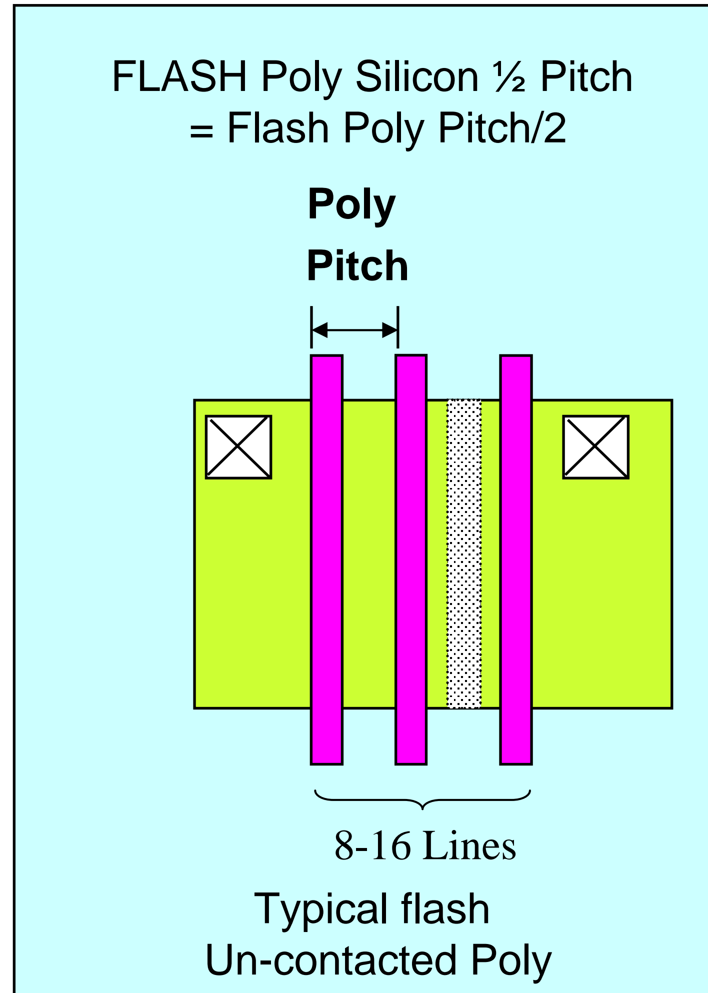
2005 ITRS Members by Affiliation



2005 Definition of the Half Pitch - unchanged

[No single-product "node" designation; DRAM half-pitch still litho driver; however, other product technology trends may be drivers on individual TWG tables]





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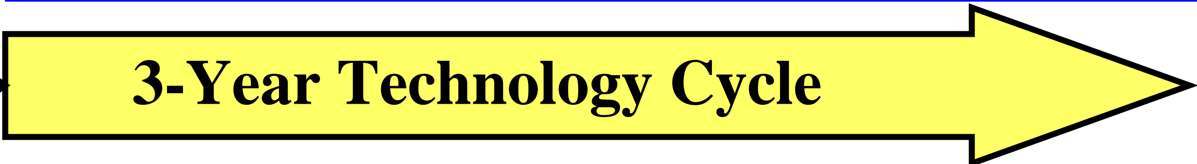
2006 ('05-'20) ITRS Technology Trends DRAM M1 Half-Pitch : 3-year cycle

All unchanged

Year of Production	2000 [Actual]	2001	2002 [Actual]	2003	2004	2005	2006	2007	2008	2009	2010	2012	2013	2015	2016	2018	2019	2020
Technology - Contacted M1 H-P (nm)	180	151	130	107	90	80	71	65	57	50	45		32		22		16	14

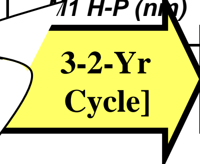


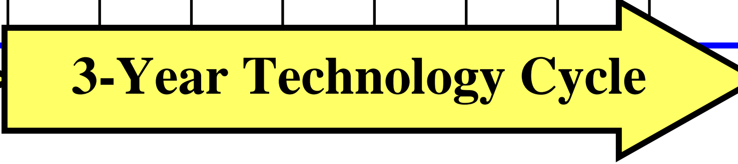
2005 ITRS Flash Poly Half-Pitch Technology: 2.0-year cycle until 1yr ahead of DRAM @65nm/'06

Year of Production	2000 [Actual]	2001	2002 [Actual]	2003	2004	2005	2006		2008	2009	2010	2012	2013	2015	2016	2018	2019	2020
Technology - Uncontacted Poly H-P (nm)	180	151	130	107	90	76	65	57	50	45		32		22		16		13

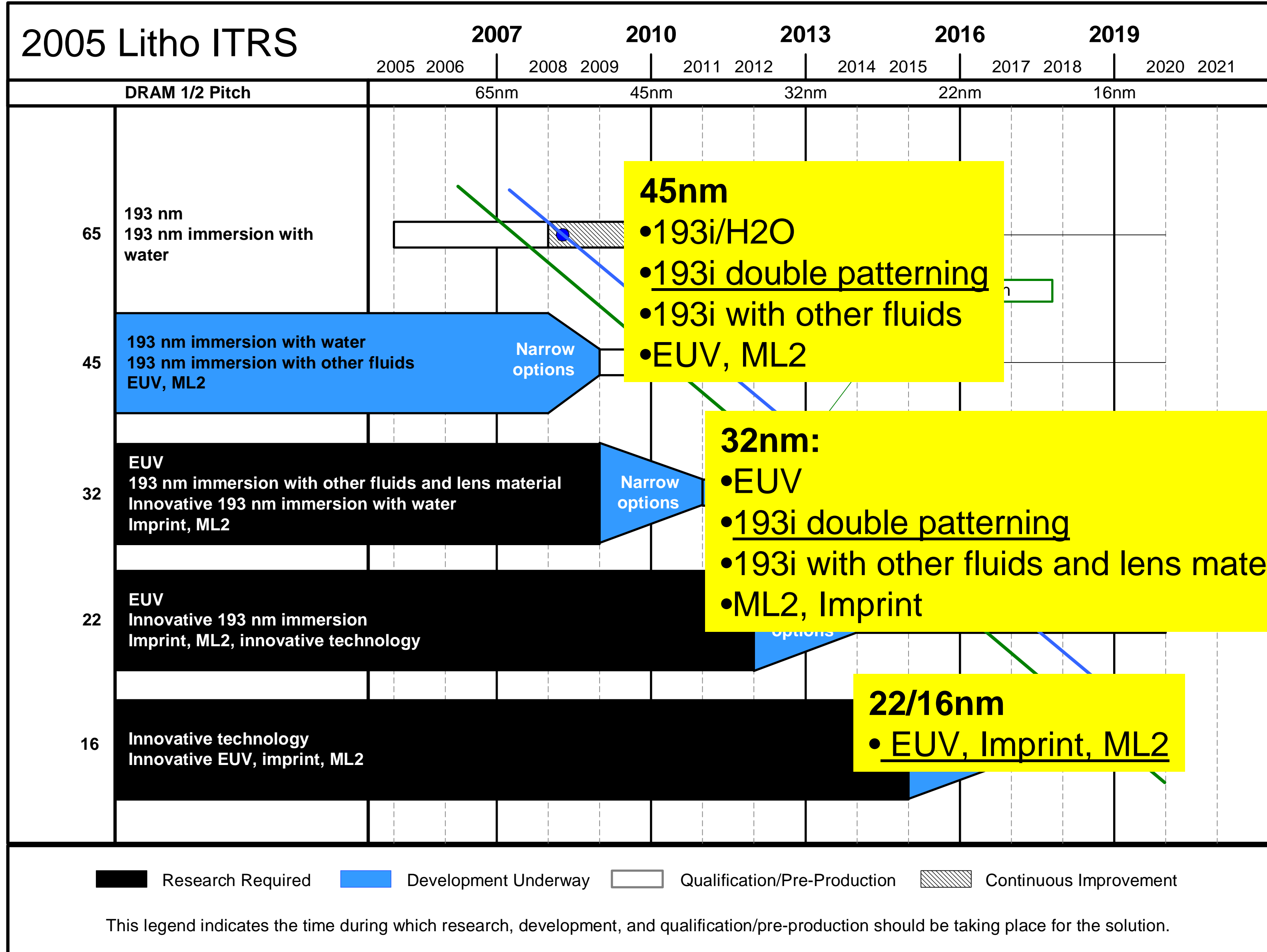
2005 ITRS MPU M1 Half-Pitch Technology: 2.5-year cycle; then equal DRAM @45nm/2010

Year of Production	2000	2001	2002 [July'02]	2003	2004	2005	2006	2007 [July'08]	2008	2009	2010	2012	2013	2015	2016	2018	2019	2020
Technology - Contacted M1 H-P (nm)	180	157	136 [130]	119	103	90	78	68 [65]	59	52	45		32		22		16	14

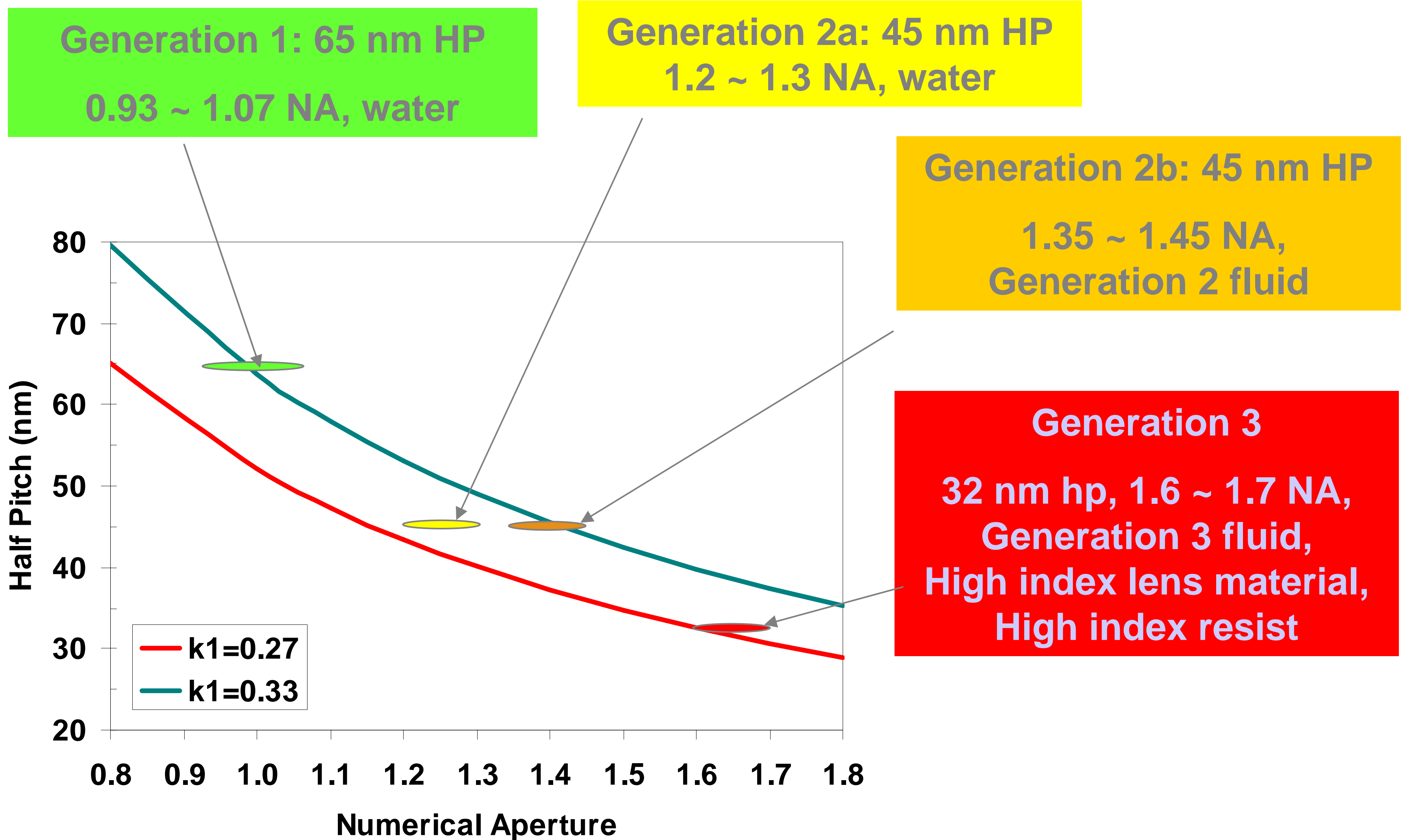




Lithography Potential Solutions 2006 Update

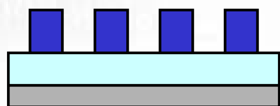
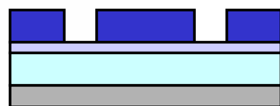


Optical Lithography Immersion Generations

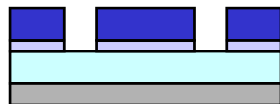


Lithography Double Exposure/Etch (DE/DE)]

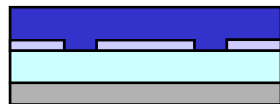
Conventional Single Expose | **Double Exp/ Double Etch**

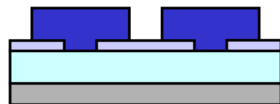
Expose #1



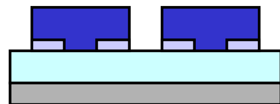
Hard Mask Etch



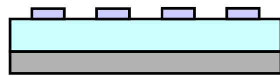
Coat #2



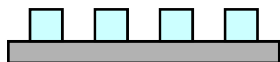
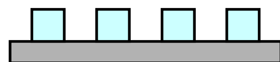
Expose #2



Etch Hard Mask



Etch

- **Resist**
- **Hard Mask**
- **Under Layer**
- **Substrate**

Double Exposure/Etch Challenges

- Resist / Process
- Overlay
- DFM: DE split CAD
- COO

Variety of application dependent processes

From Andrew Grenville.

International Technology Roadmap for Semiconductors
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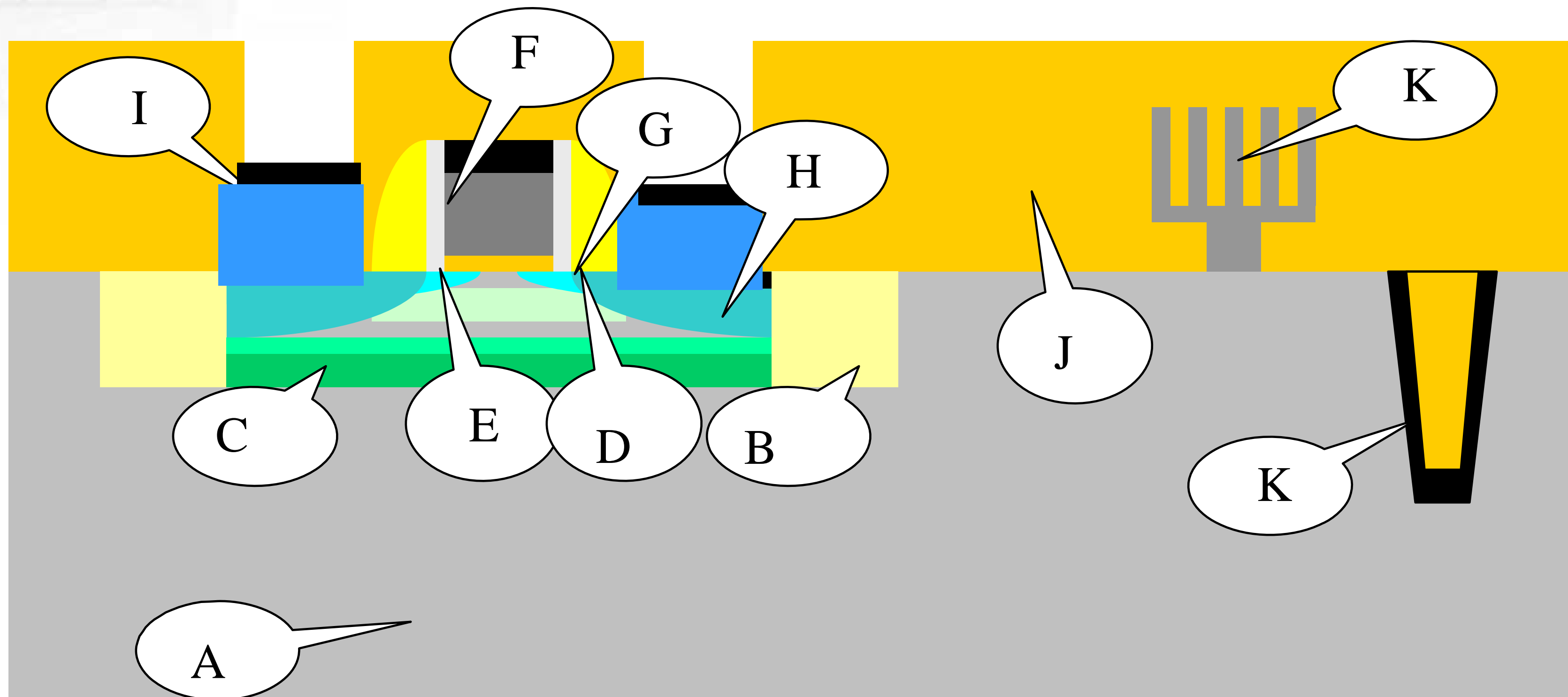
Front End Process (FEP)/Process Integration Devices & Structures (PIDS) - Transistor Challenges



A: Starting Material
C: Well Doping
E: Channel Doping and Channel Strain
G: Extension Junction and Halo
I: Elevated Junction and Contacts
K: DRAM Stack/Trench Capacitor & FeRAM Storage

B: Isolation
D: Channel Surface (Preparation)
F: Gate Stack (Including Flash) and Spacer
H: Contacting Source/Drain Junction
J: Premetal Dielectric

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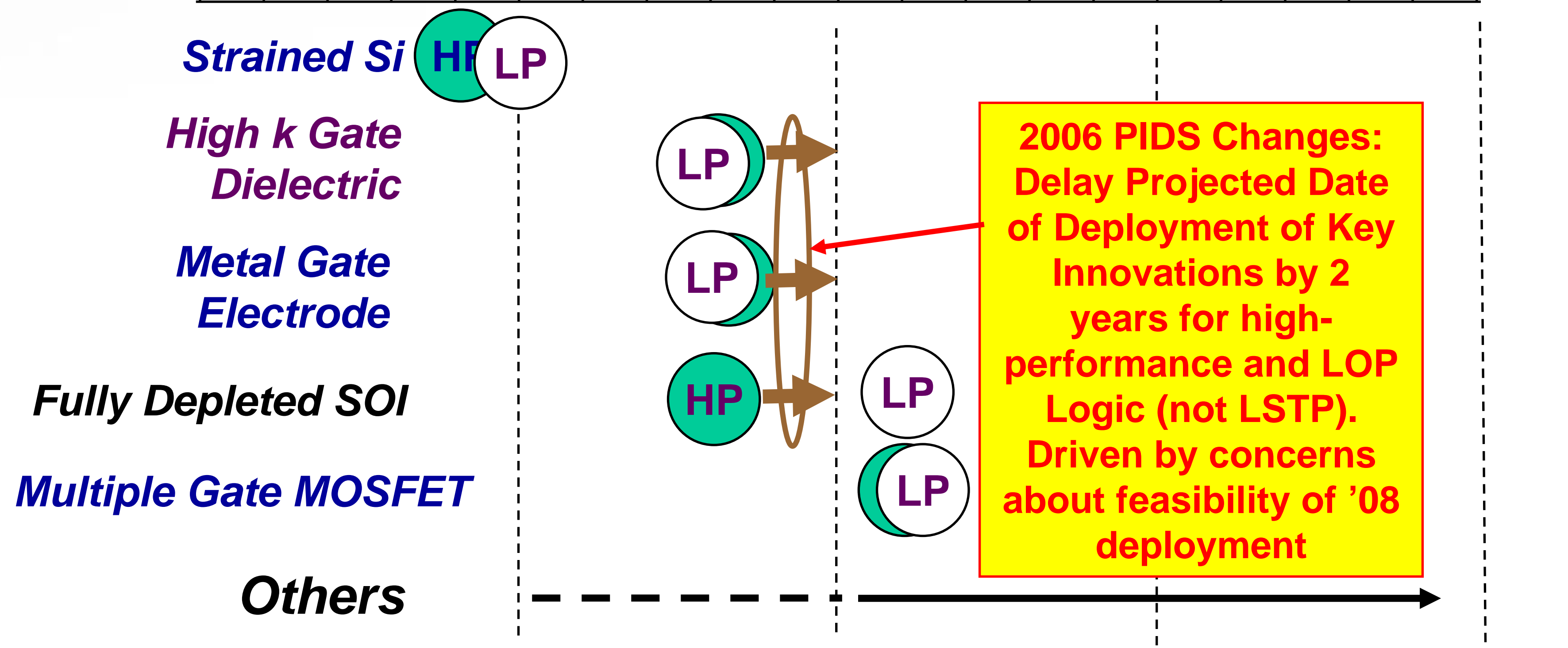
PIDS - The "CMOS Change Crunch" Multiple, Big Technology Innovations Over Next 5 Years



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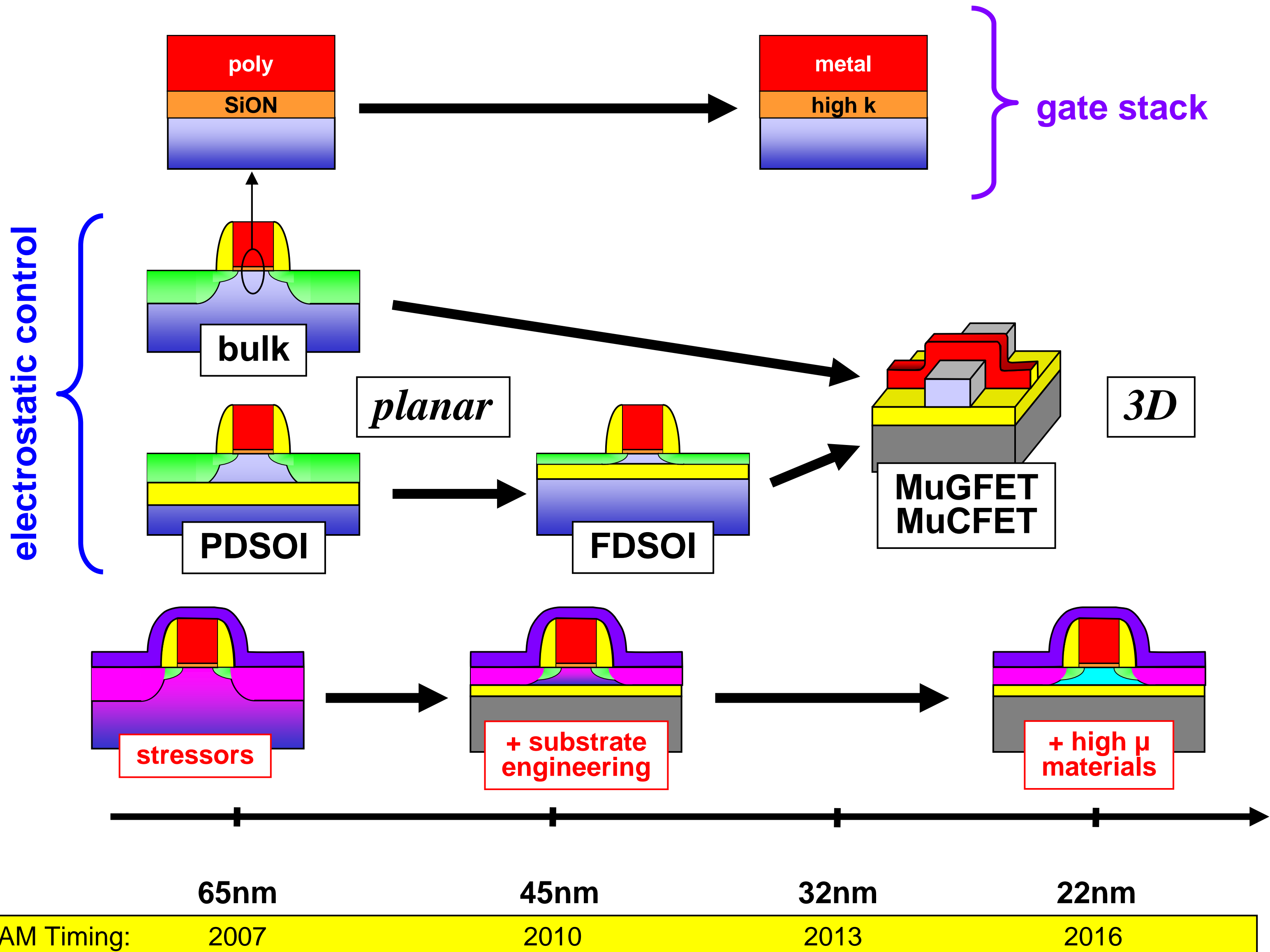
PIDS - Multiple Parallel Paths for High-Performance Logic in ITRS

Year in Production		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Physical Lgate (High Performance)	nm	32	28	25	22	20	18	16	14	13	11	10	9	8	7	6	5

Multiple parallel paths reflects most likely scenario:

- Some companies will extend planar bulk CMOS as long as possible
- Others will switch to FDSOI and/or multiple gate earlier
    - Initial deployment of FDSOI is delayed in 2006 ITRS
- Ultimate MOSFET is multiple gate
- Similar multiple paths for low-power logic

PIDS/FEP - Simplified Transistor Roadmap



ITRS DRAM Timing:	2007	2010	2013	2016

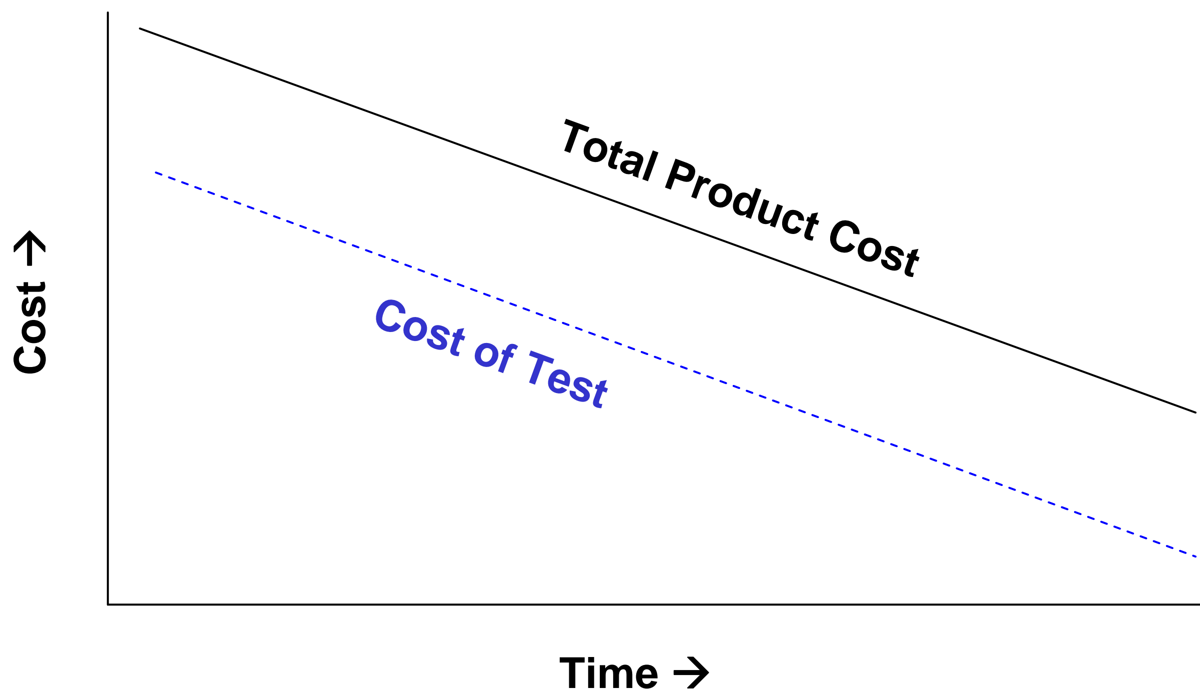
Source: ITRS, European Nanoelectronics Initiative Advisory Council (ENIAC)

Test TWG - Roadmap Drivers Since 2000

- Adoption of High speed serial I/O
- Widespread use of Known Good Die (KGD)
- Multi-Chip Package, System on Chip & System in Package need to become routine
- NAND!
- Increased integration of Analog/Radio Frequency
- Rapid increase in test parallelism
- Litho roadmap and core voltage reduction driving tightened Signal-to-Noise window

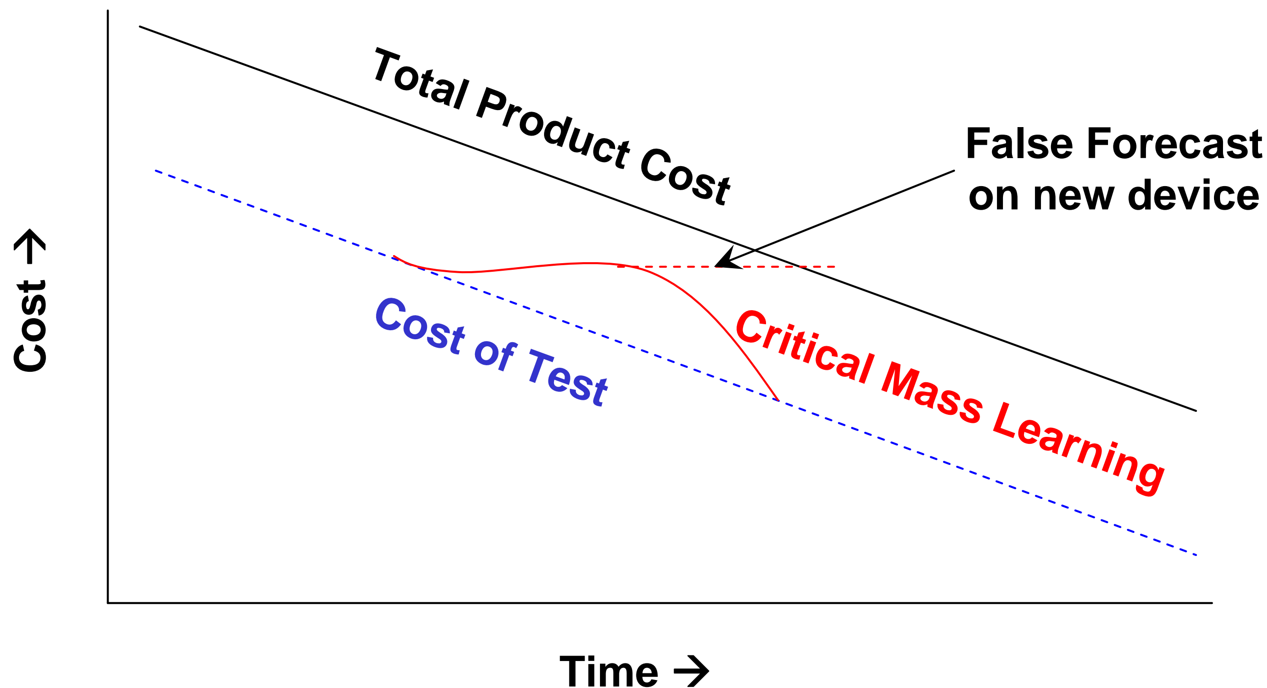
Test TWG - Cost of Test

- Goal: Keep test % of overall product cost flat
  - Test cost per transistor must follow Moore's Law
  - Predictable on well known devices

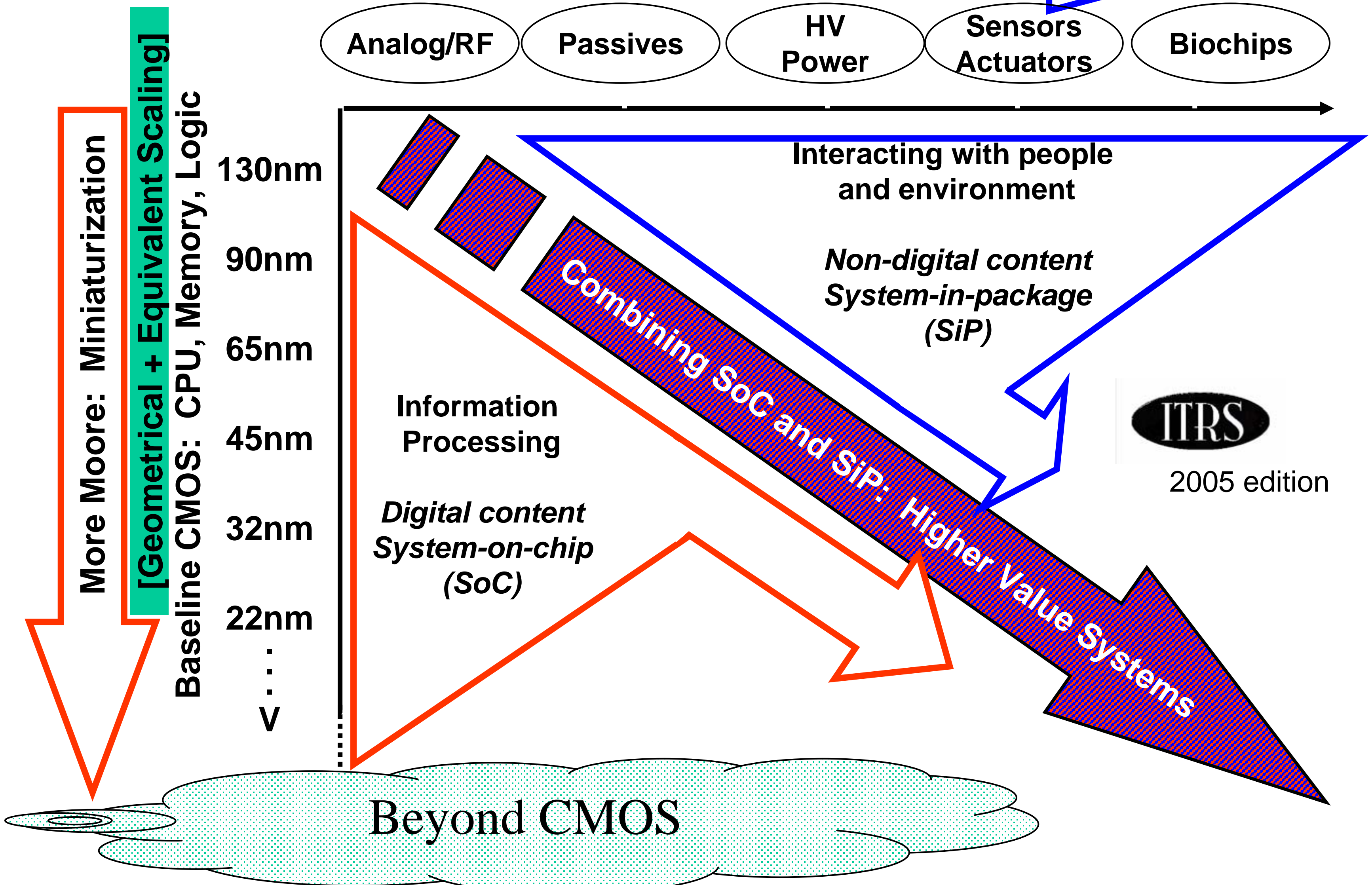


Test TWG - Cost of Test

- Test may initially lag learning curve on new devices, integrations or architectures
  - Drove mid 90’s forecast of increasing test cost > die cost
  - Critical mass learning necessary to define low cost methods



Pursuing the race for added value for the end customer by combining on-chip ULSI and off-chip integration



“More Moore” + “More than Moore”

- Past
  - Geometrical Scaling (G) → Moore’s Law

- Future
  - Equivalent Scaling (E) → “More” Moore
    (digital)

    +

    Functional Diversification → More than Moore (MtM)
    (non-digital)

Market Drivers for Technology Roadmap

Technologies

Memory

CMOS HP

CMOS LP

RF/AMS

Power

Analog/HV

Sensors Actuators

System in Package

Data Proc. Office

Communication Wireline Wireless

Consumer Portable Stationary

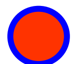
Auto-motive

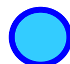
Industrial

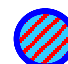
Medical

Markets

Legend:


More Moore (scaling)

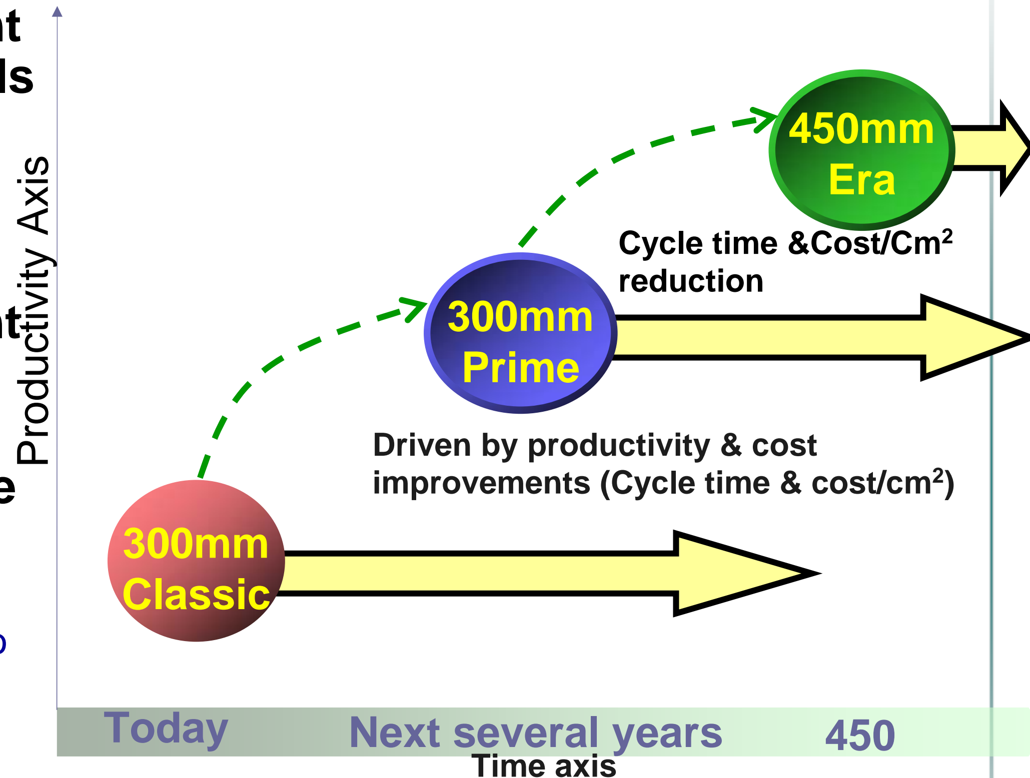

More than Moore (non-scaling)


mixed

Bubble size = driver impact

Productivity Improvement Roadmap drivers

- **Comprehend the needs of different IC maker/Foundry business models**
  - These models (including high mix) will influence current 300mm configurations before transition to 450mm occurs
- **300 Prime will close the gaps identified in current 300 equipment**
  - New capabilities extendible to 450
- **450mm transition can be a simplified scale-up from 300 Prime**
  - Compared to 200mm → 300mm transition
  - Extending 300mm capability to 450mm
  - Minimizing the number of configurations to develop, test and deploy
- **Global participation is very important to define requirements, priorities and due dates**



Key drivers are significant cycle time and cost/cm² reduction → Productivity Improvements

What is needed for 450mm transition

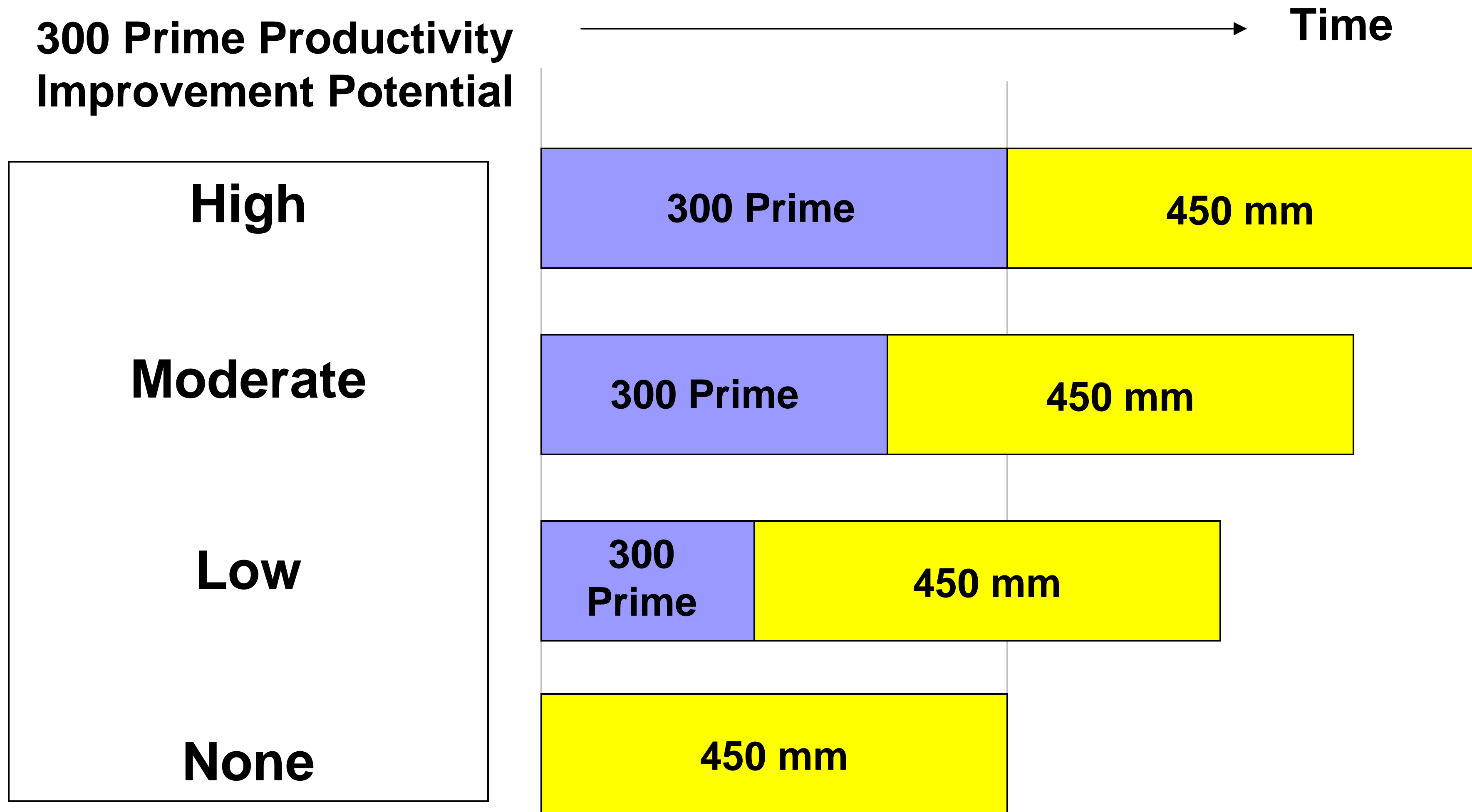
Scope/Timeline will be sync'd with ISMI 450mm program

	2005	2006	2007	2008	2009	2010	2011	2012?
Interoperability Testing & Reliability Verification →						300mm to 450mm, New		
Factory Control System Standards →		Process Control & Yield Data Standards, Carrier delivery time, Decision Making Time, Data Flow						
Direct Transport Standards →		Direct transport concepts, carrier/wafer delivery time, overall throughput, efficient storage concepts						
Production Equipment Standards →		Single wafer vs. mini-batch, cleanliness, interface standards, productivity targets relative to 300mm						
450mm wafer Standards →		Material, Size, Thickness, ID, Registration, Edge Exclusion						
Carrier & lot-size determination →		# of Wafers per lot, Size, Door Type, AMHS Strategy, ID						
	2005	2006	2007	2008	2009	2010	2011	2012

Bottom Opening Pod?

Many technology issues in 300Prime/450mm need to be addressed!
FI is working with ISMI 300Prime/450mm Program to be in-sync.
Need to Sync. with IRC on 2012 interception point

Possible 300 Prime/450 mm Scenarios



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

Summary

- Over 1200 engineers, scientists, and technologists from five world-wide regions contributed to the 2006 Update.
- Technology pace for the top three leading-edge product groups is unchanged from the 2005 ITRS.
- Lithography—Double-patterning was added as an additional potential solution.
- Front-end Process and Process Integration—Delayed projected deployment of high-k and metal gate and FDSOI by two years, until 2010.
- Test—Test costs still challenging, but returning to historical trends
- More than Moore—ITRS to cover non-digital functionality and market drivers
- 450mm—Industry-wide planning for 300 Prime and 450mm is underway

for more information…

http://www.itrs.net