Semiconductor Technology Research, Development, & Manufacturing: Status, Challenges, & Solutions

C. R. Helms*
Past President & CEO
International SEMATECH

*Professor Emeritus,
Stanford Univ.

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A New Paradigm in the Making?

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Agenda

- *Semiconductor Revenue Growth: Yes!*
- *Realize Which Roadmap?*
- *Technology Challenges*
- *R&D Cost*

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- *Semiconductor Revenue Growth: Yes!*
  - Historical Perspective & Extrapolation
- *Realize Which Roadmap?*
  - End Equipment & Product
  - Cost per Function
- *Technology Challenges*
  - Mask Availability, Cost, Cycletime
  - Post – 193nm Exposure Technology
  - New Materials
- *R&D Cost*
  - How Many Si Tech R&D Centers Can the Industry Support?
  - R&D Foundries, Partnerships, & Alliances Win!

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Semiconductor Industry Revenue Growth Summary

- 17% CAGR in the 70's and 80's
- Drove High Rates of Capital Investment and R&D
  - In Turn Drove Better Penetration of Existing Markets and the Opening of New Ones
    - In Turn Drove Revenue Growth
- This is a Cyclical Growth Industry with a 5-Year Period
- Maturation is Occurring
  - But not that Fast!

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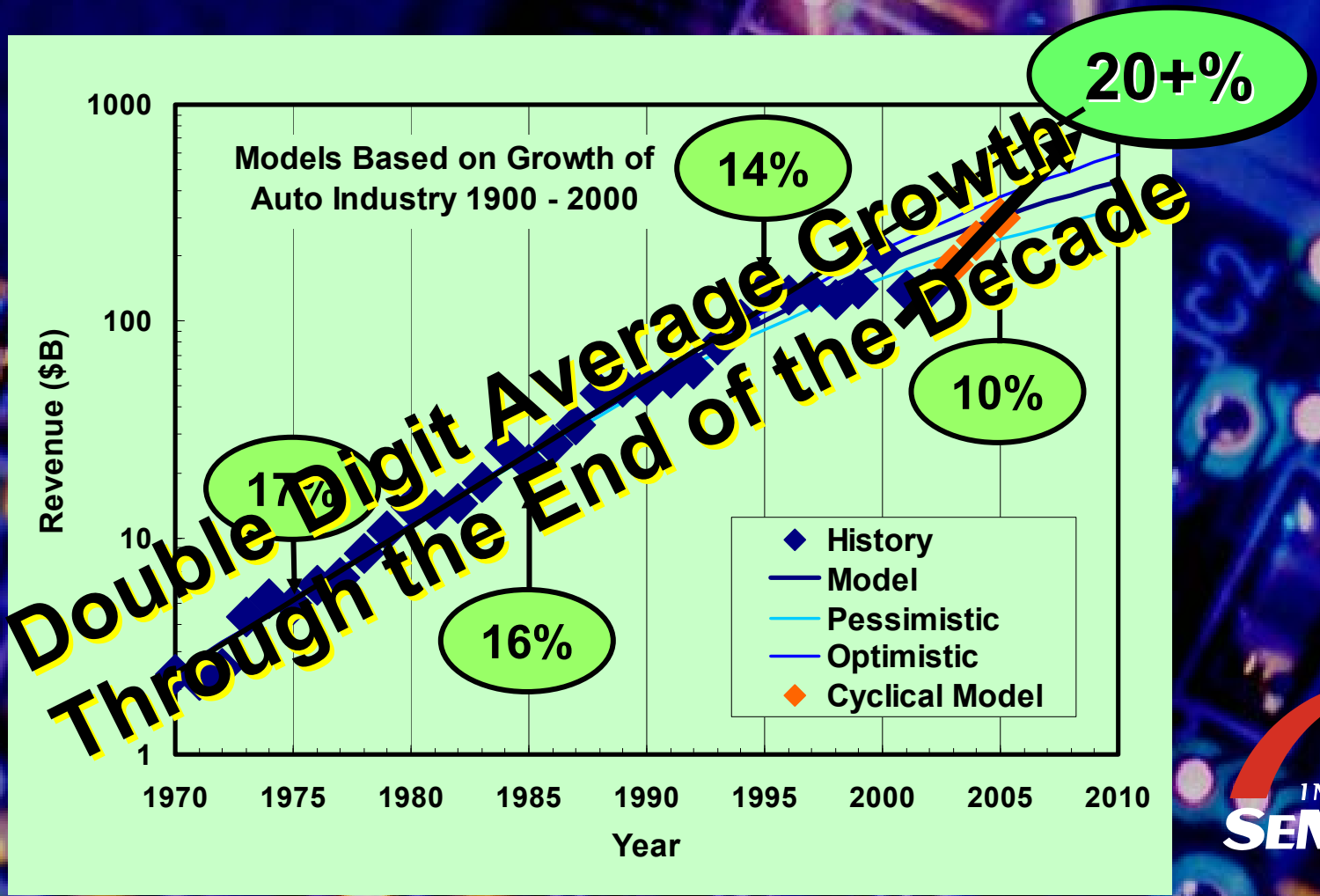
Projections from a Historical Study of Industry Growth Trends



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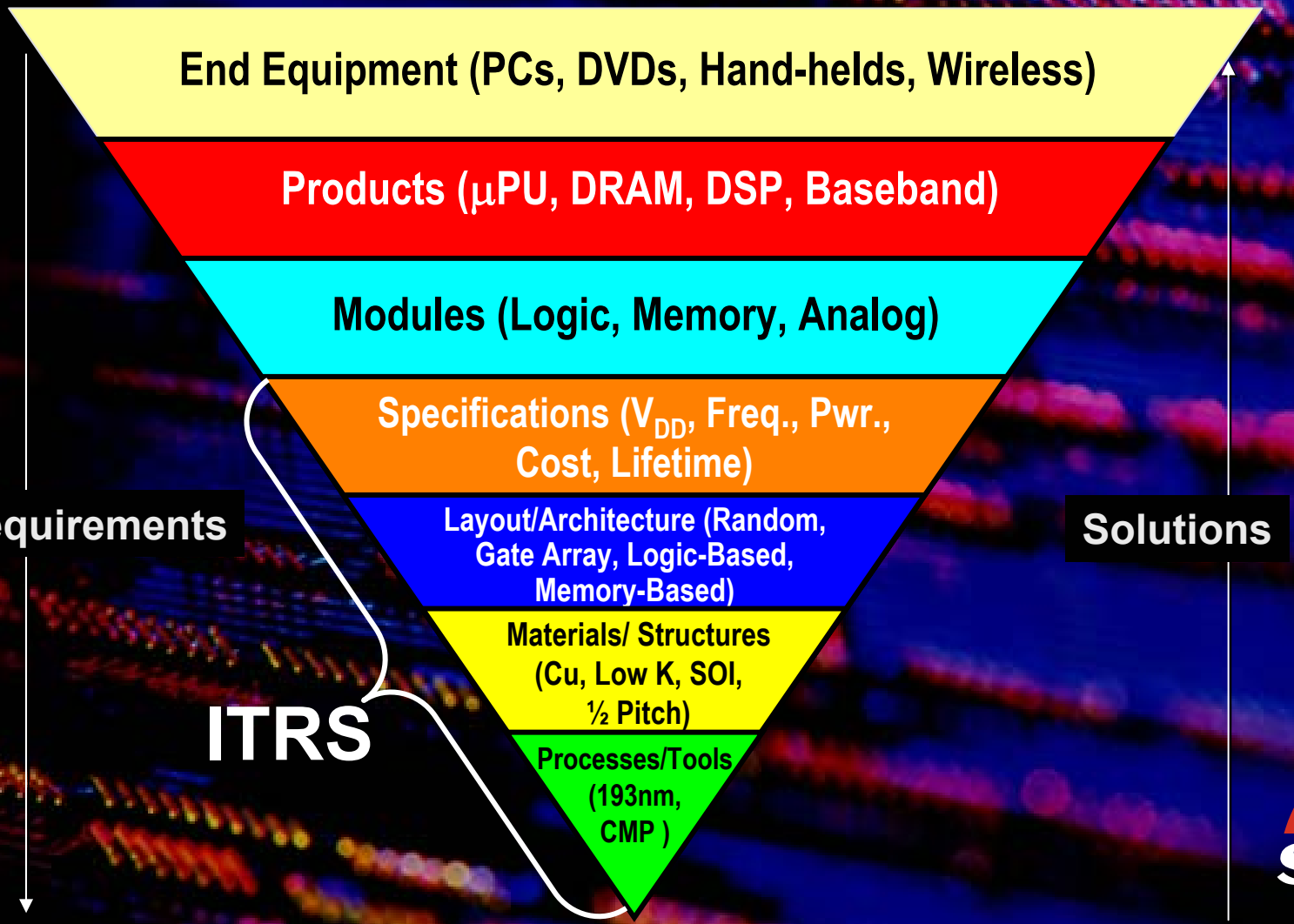
Roadmap Hierarchy



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Too Much Focus on the Lower Level "REQUIREMENTS" can Drive Unprofitable Investments, i.e.

Low K Interconnects

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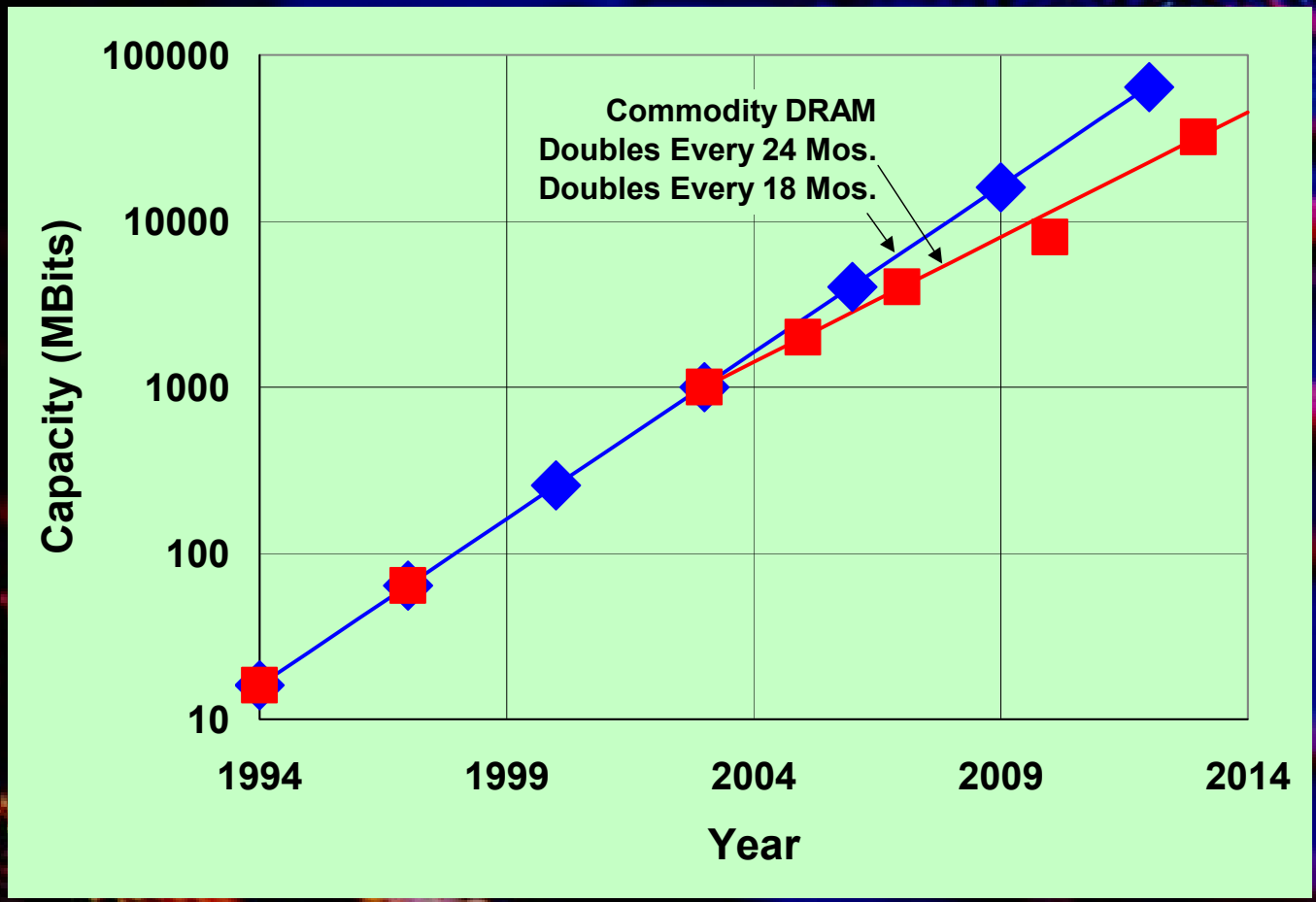
Commodity DRAM Product Roadmap



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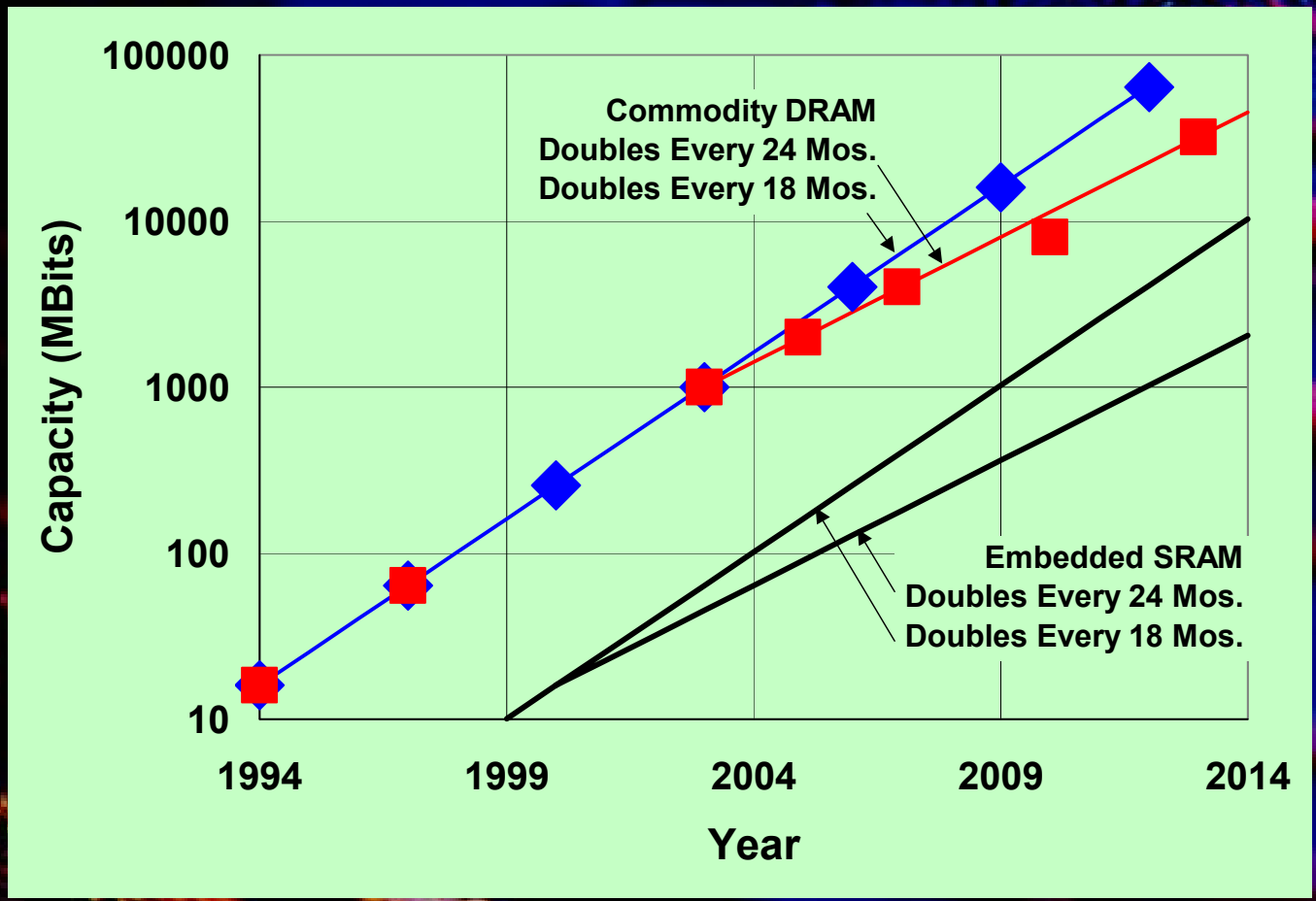
Commodity DRAM & Embedded SRAM Product Roadmap



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Manufacturing Cost per Function Roadmaps

- Driven by Transistors per Area and Cost per Area

	2-Year Cycle	3-Year Cycle
Annual Transistor per Unit Area Increase	40%	25%
Average Cost per Unit Area Increase – Constant Wafer Size	8%	4%
Average Cost Reduction for Wafer Size Conversion Every 10 Years	4%	4%
Predicted Annual Cost per Function Decrease	**27%**	**21%**

2-Year Cycle Wins!

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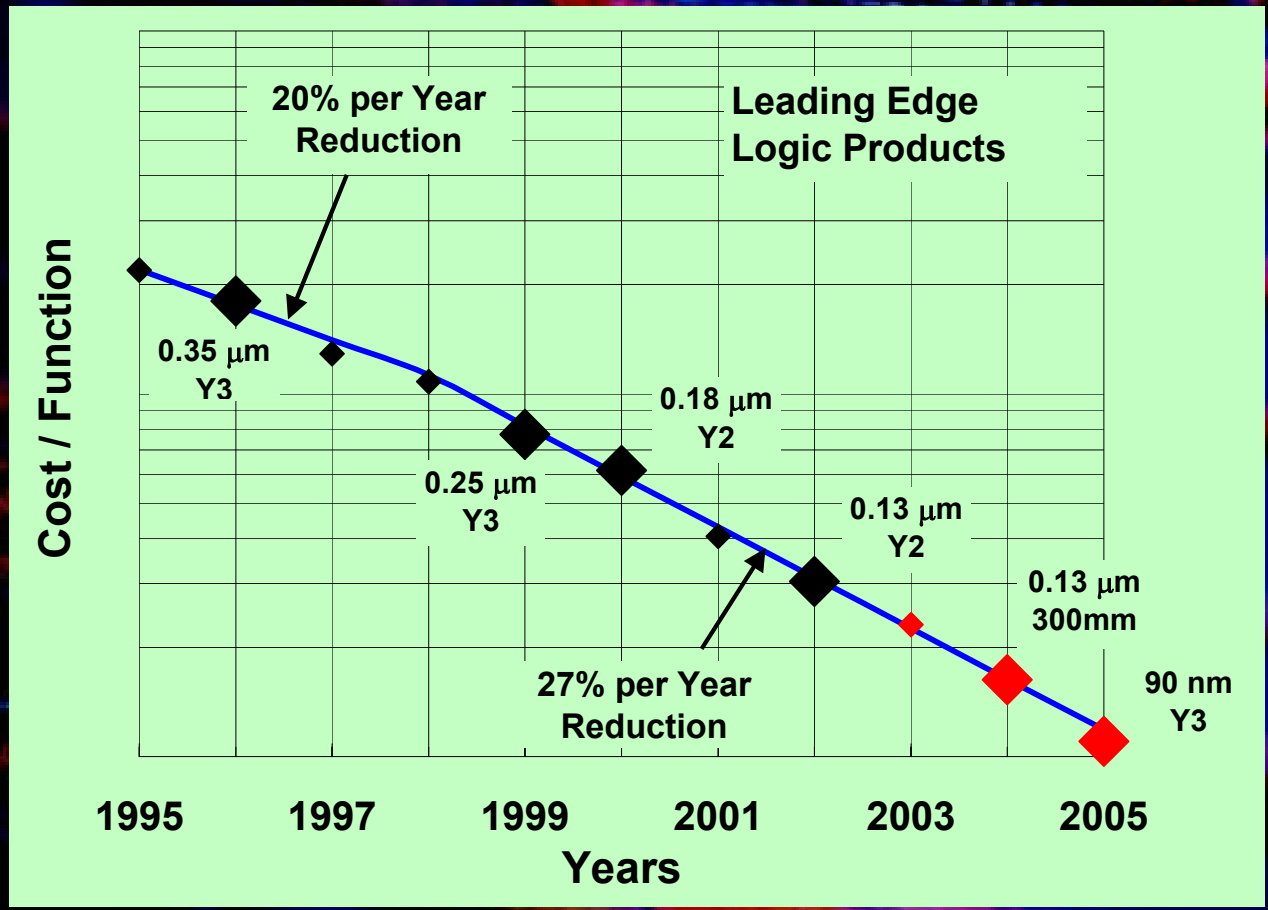
Validated ISMT Cost per Function Model

Slope Change in 1998 due to 2-Year Cycle

300mm Cross-Over Predicted in 2004



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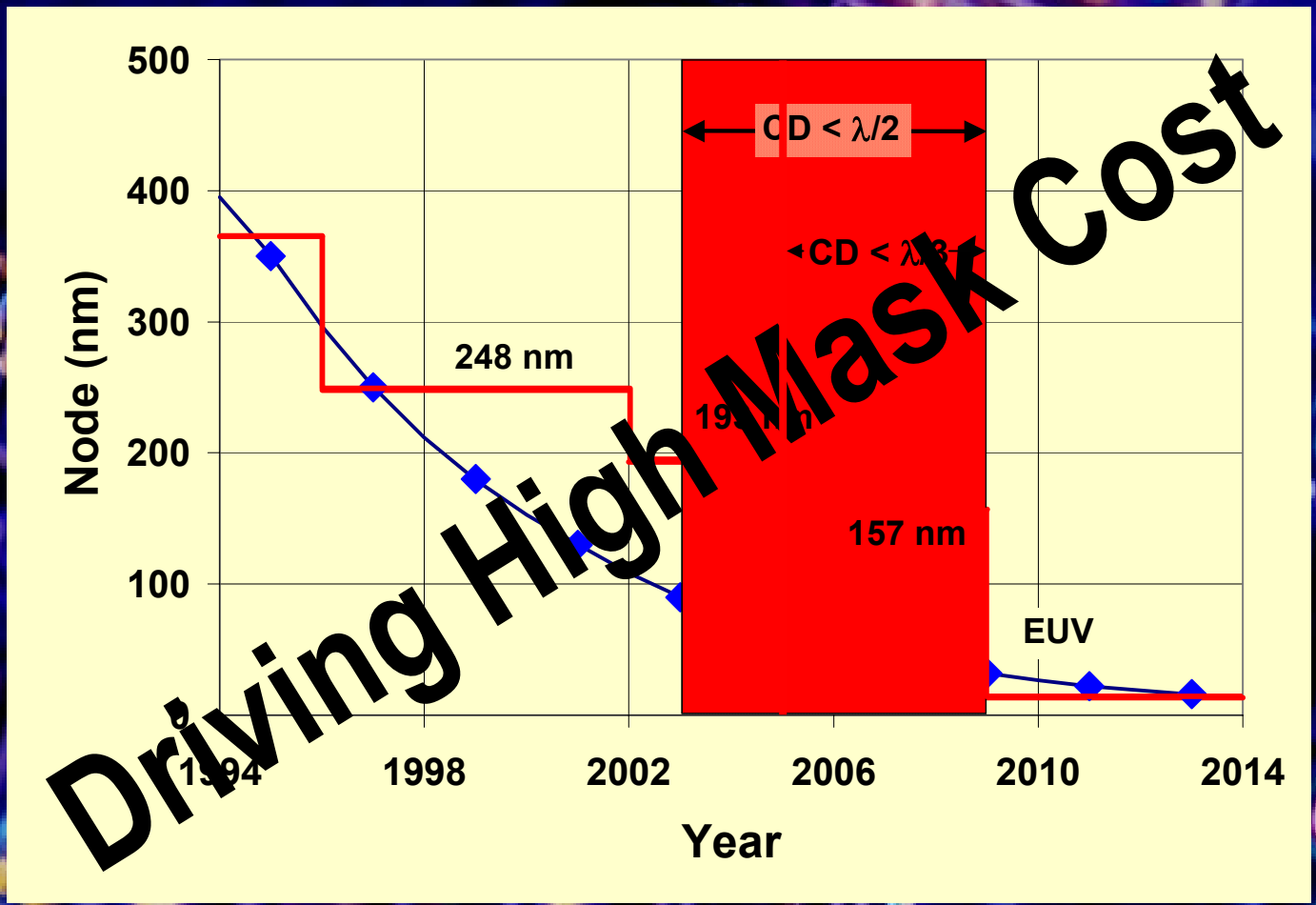
Major Technology Challenge: The Sub – ½ Wavelength Red Zone



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Mask Issues

- Phase Shift & OPC Requires 2x+ Resolution Improvement
- Infrastructure Development Cost not Supported by Revenue
- Database Size Exploding
- Cost Going up 2x per Generation
  - Manufacturing 130nm $ 600K
  - 90nm $1200K
  - 65nm $2400K ?

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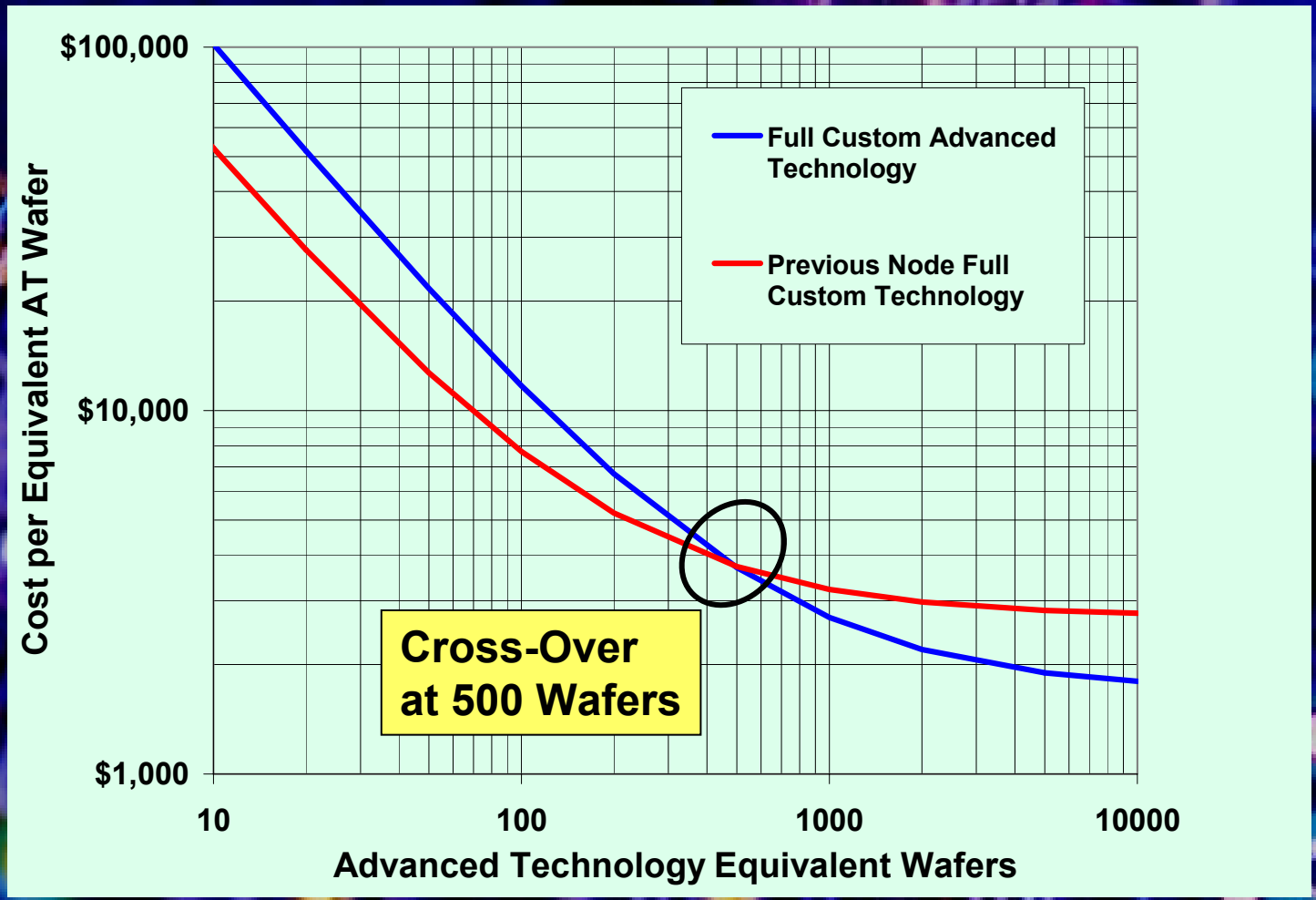
Mask Cost Analysis 130nm to 90nm

Only Manufacturing Considered



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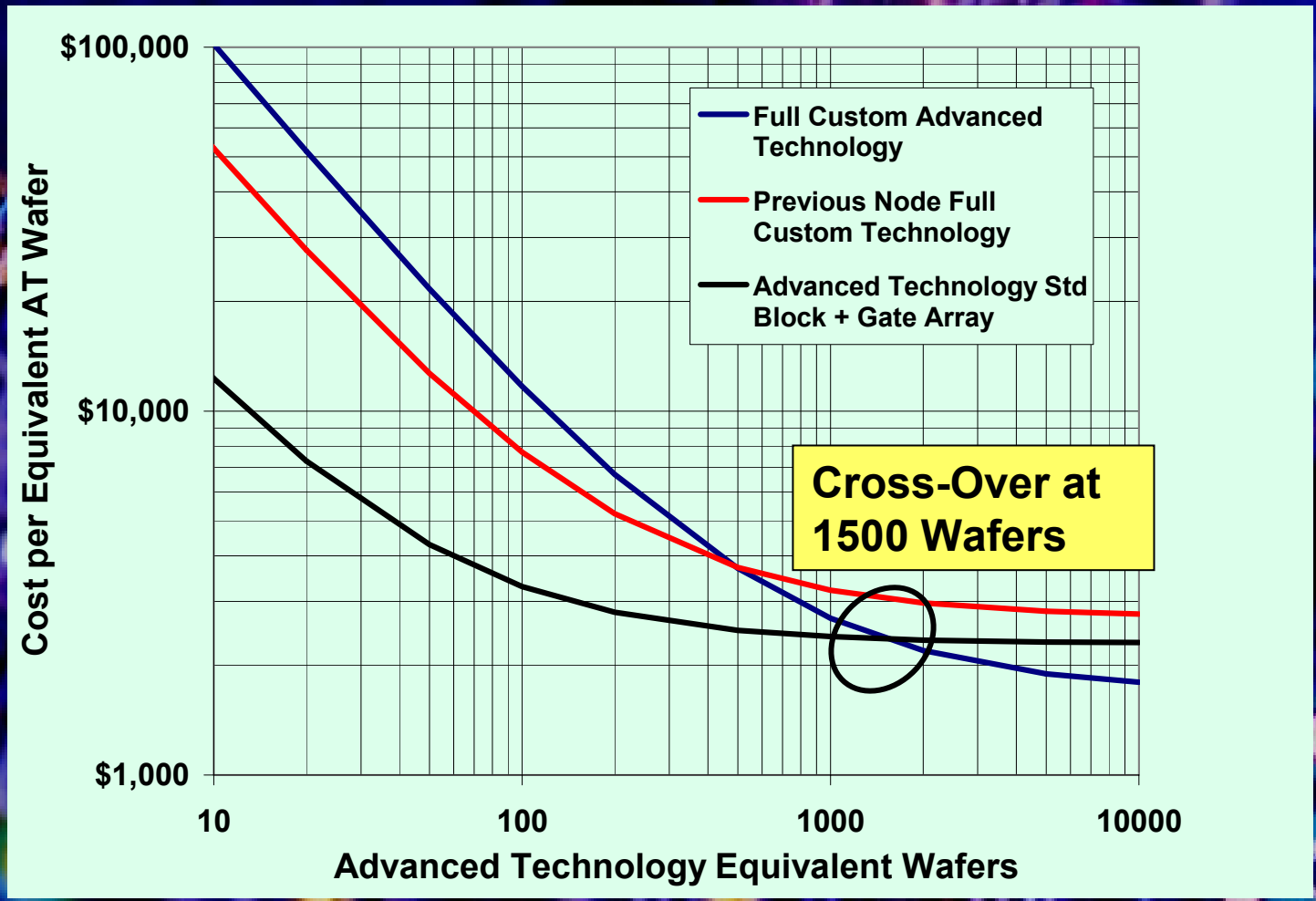
Smart Gate Arrays Become More Attractive



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Summary of Top Technical Challenges

- Mask Availability, Cost, and Cycletime
  - Especially for Custom Products
- Post 193nm Litho Exposure Tools
  - 157nm in Mainstream Production in 2006/2007
  - EUV in Mainstream Production in 2009/2010
- New Materials
  - Low K's
  - High K's
  - Memory Materials

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The New Economy for Microelectronics

- A New Factory (Fab) Runs 130nm Technology with Cu Wiring at 300mm
- At a Capital Cost of $2B - $4B
  - *Increasing at a Rate of 15% per Year*
- Technology R&D to Support 2-Year Major & 1-Year Minor Product Cycles
- At a Cost of > $500M per Year for a Tier 1 Logic Manufacturer
  - *Increasing at a Rate of > 20% per Year*

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Table Stakes for Independent Semiconductor Manufacturer

- Cap Ex of $1B per Year or Min. of 20% of Revenues
  - *Implies Revenues of $5B/yr*
- Technology R&D Investment of $500M per Year
  - *If Requirement of <5% of Revenues for IDM Implies Revenues of $10B/yr*

Manufacturing and R&D Partnerships

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R&D Partnership Risks & Rewards

- Rewards
  - Faster Speed of Execution
  - Lower Costs
- Risks
  - Sacrifice of IP & Potential Competitive Advantage
  - Cultural, Geographic, and NIH Factors can Slow Progress
  - Divergence of Interests

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Summary

- *Semiconductor Revenue Growth: Yes!*
  - > 10% CAGR Through the Decade
- *Realize Which Roadmap?*
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- *Technology Challenges*
  - Mask Availability, Cost, Cycletime
  - Post – 193nm Exposure Technology
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  - Consolidation of Si Tech R&D Centers Required
  - R&D Foundries, Partnerships, & Alliances Win!

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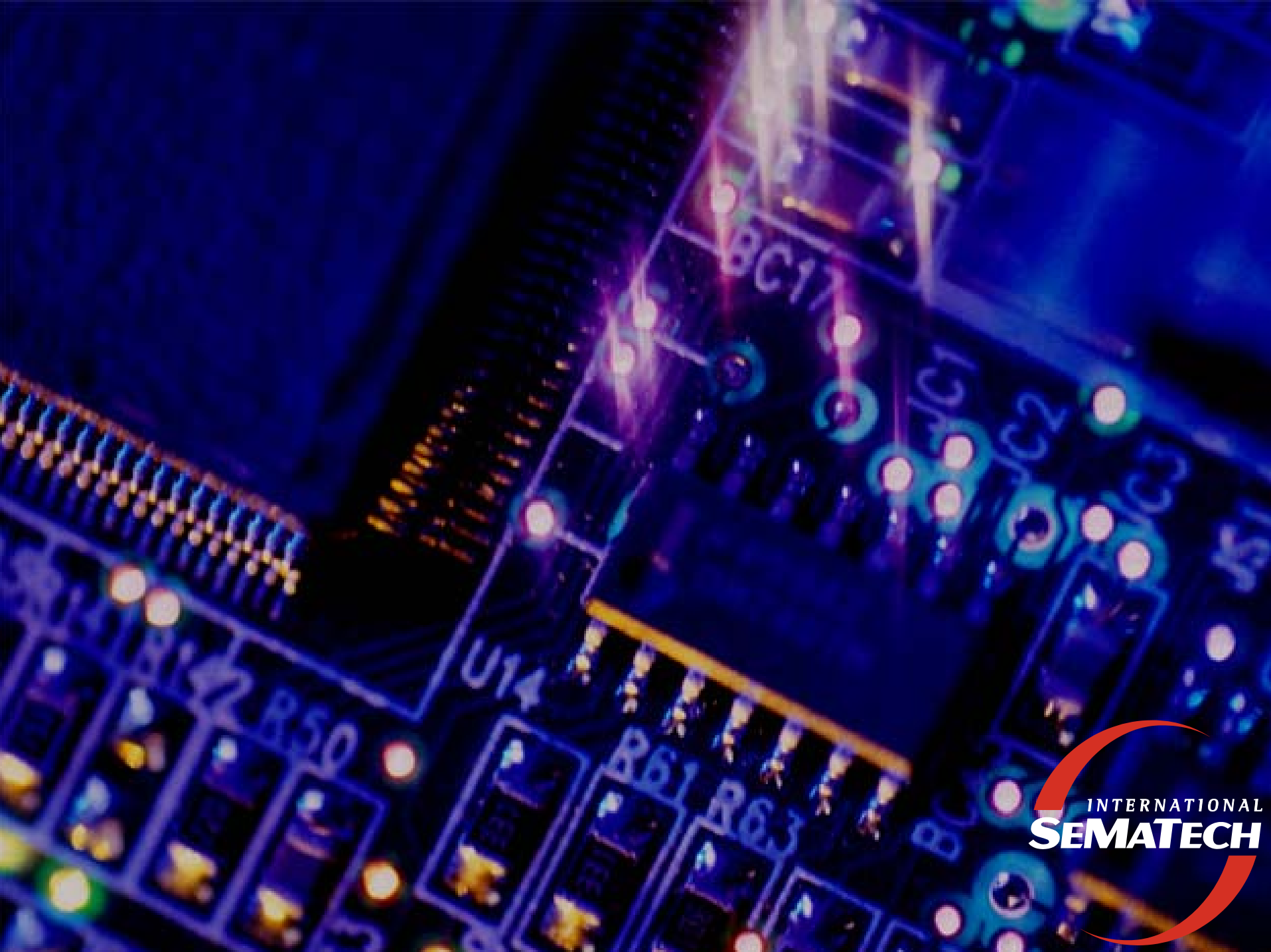
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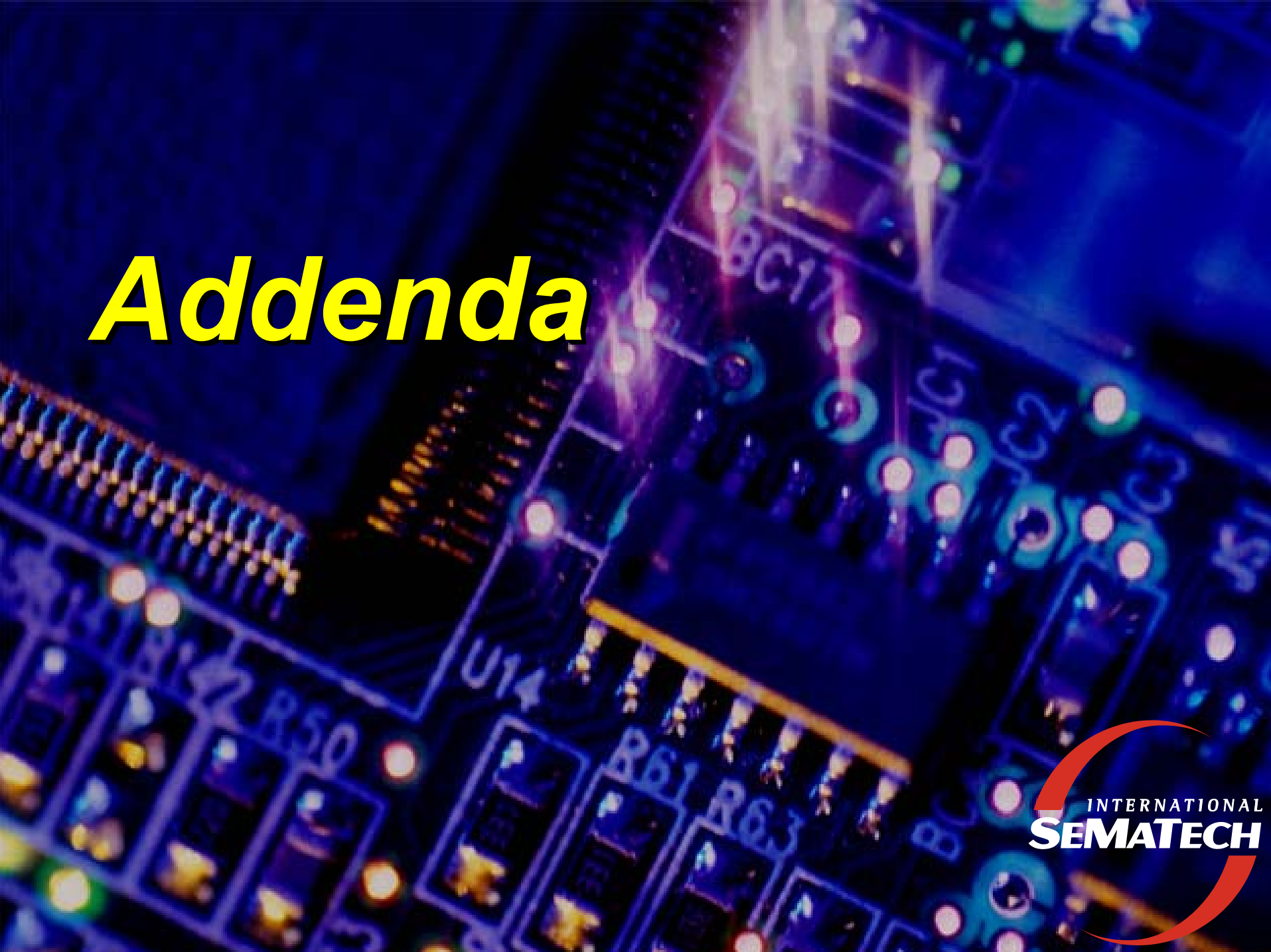
Addenda
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Killer App for the Future?

- Enabler Products
  - Broadband
  - 3+G Wireless
- Voice Recognition
  - No Keyboards
- BioMedical Electronics
  - Reduced Cost of Health Care
- Enabler Technologies
  - MEMS (MicroElectroMechanicalSystems)
  - NanoTechnology - NanoElectronics
  - Biotechnology - BioElectronics

Silicon Core CMOS – The Platform of Choice

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