MRAM, XPoint, ReRAM PM Fuel to Propel Tomorrow's Computing Advances

Jim Handy
Objective Analysis

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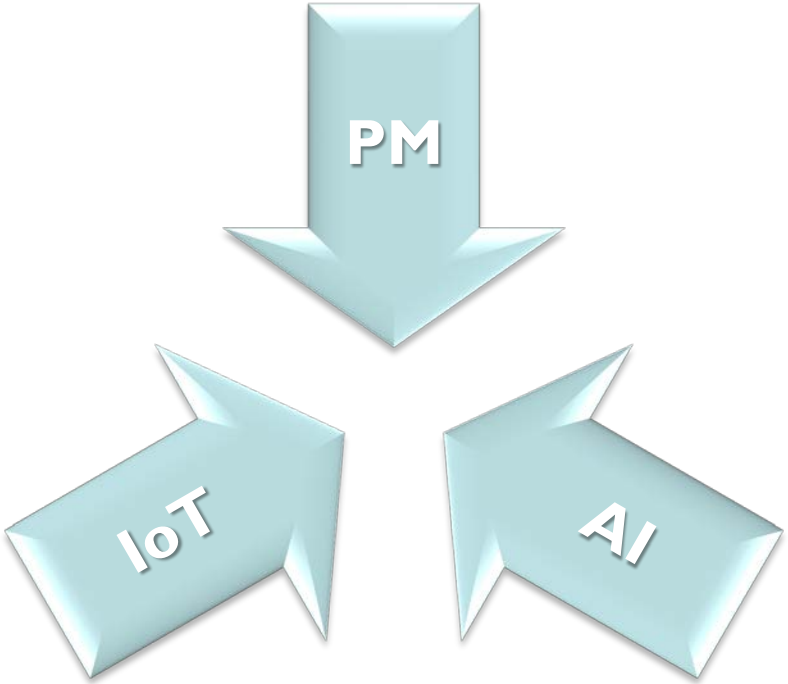
The Market is at a Nexus



Everything Is Changing!

Emerging Memory Technologies

- MRAM: Magnetic RAM
- ReRAM: Resistive RAM
- PCM: Phase-Change Memory (i.e. 3D XPoint)
- FRAM: Ferroelectric RAM
- Etc.

All are nonvolatile memories: “NVM”

What We learned at IEDM

- The field has not narrowed:
  - MRAM, PCM, ReRAM, & FRAM all well represented
- First big application is still unclear
  - Embedded NVM? Stand-alone? Embedded RAM? Neural nets?
  - Everybody points to ballooning “Big Data”
- Everybody’s participating
  - Samsung, SK hynix, Micron, Toshiba, Intel, TSMC, Macronix, etc.
- Flash might not be dead after all

Papers By Type

Technology	Papers
Flash	9
RAM	3
MRAM	13
ReRAM	17
FRAM	30
PCM	9
Neural Nets	25

- Neural Nets and FRAM take the prize
  - FRAM's suddenly "New" again!
- MRAMs had a conference of their own after IEDM
  - 10 more presentations
- ReRAM well represented
- Flash coverage surprising
  - It's not dead yet!

What We learned at IRDS Rebooting Computing and elsewhere

- IEEE events in November 2018 near Washington, D.C.
- End of Moore's Law scaling leading to new Computing Models
  - Approximate Computing
  - Adiabatic Computing
  - Neuromorphic Computing (often using emerging memory technologies)
  - Quantum Computing
- Rise of new architectures like RISC-V
- Development of special purpose application accelerators

Emerging Memory Report

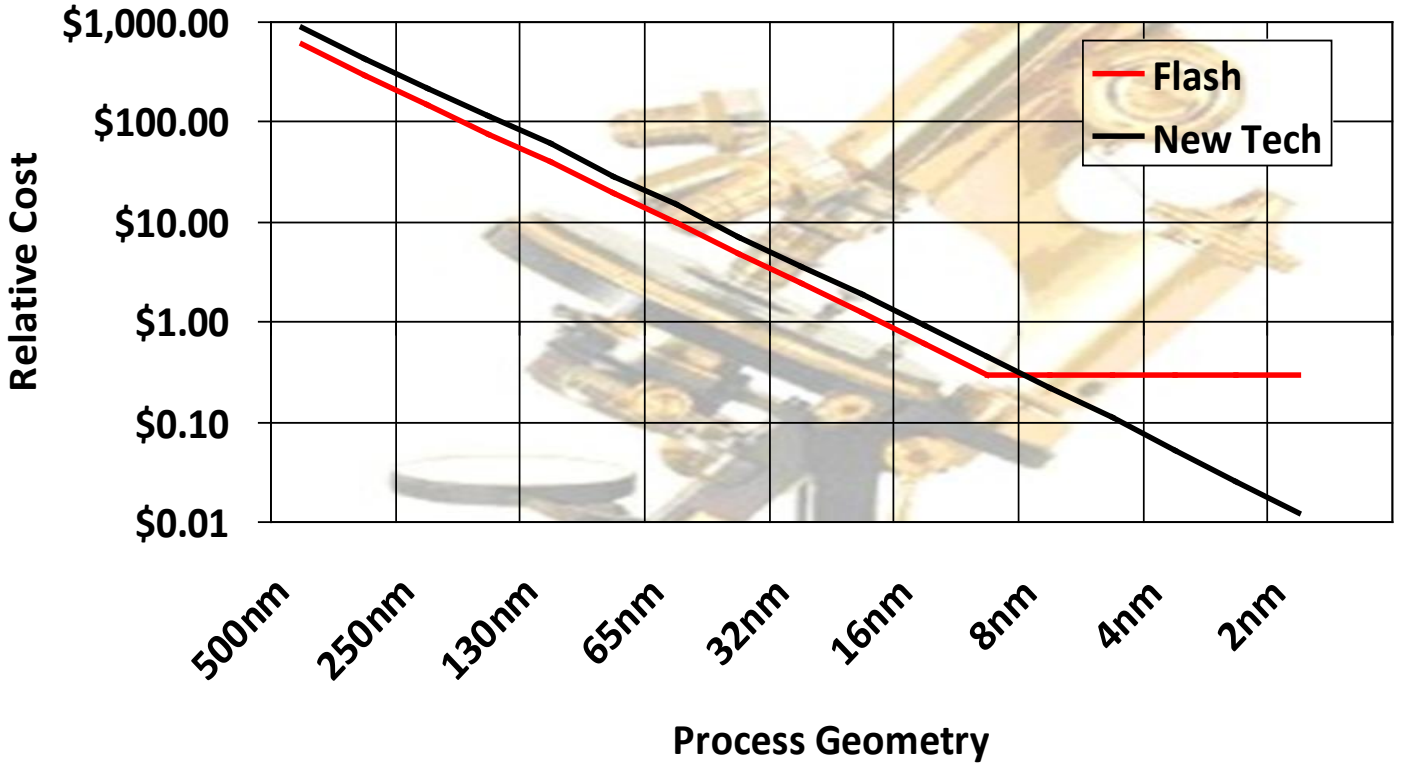
- Why Emerging Memories are Necessary
- Understanding Bit Selectors
- The Technologies
- Process Equipment Requirements
- Emerging Memory Companies
- Forecasting Emerging Memories

Now available for online purchase

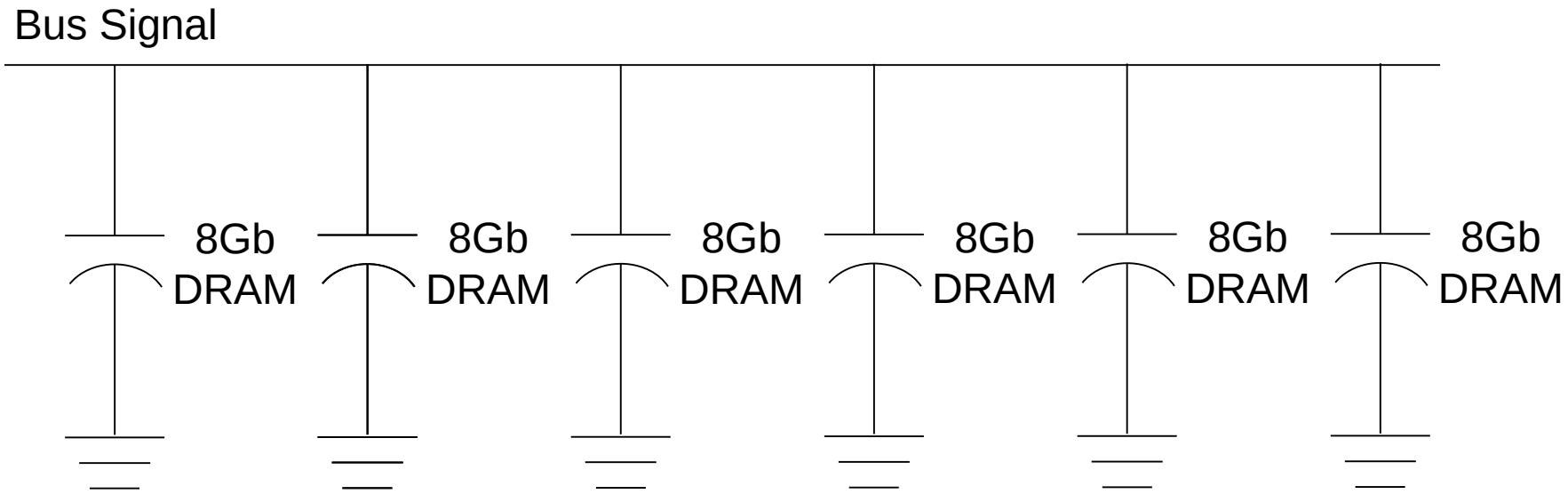
Why Emerging Memories are Necessary

- Flash can't scale with process advances
  - NAND flash went 3D at 15nm
    - 3D is not cost-effective in a CMOS logic process
  - NOR scaling stops with FinFET
    - 28nm & smaller processes need something new
- Low DRAM densities load down the memory bus
- AI is expensive on a von Neumann machine, hence new computer architectures

How Scaling Limits Help New Memories

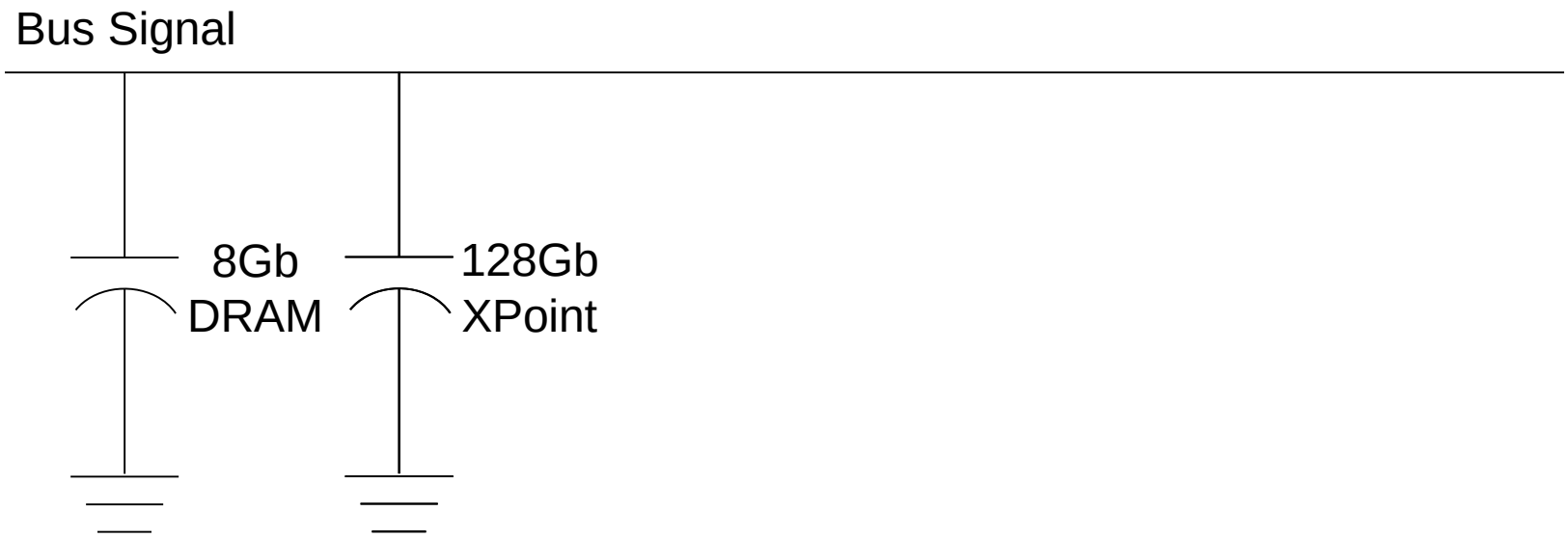


Biggifying Memory with DRAM



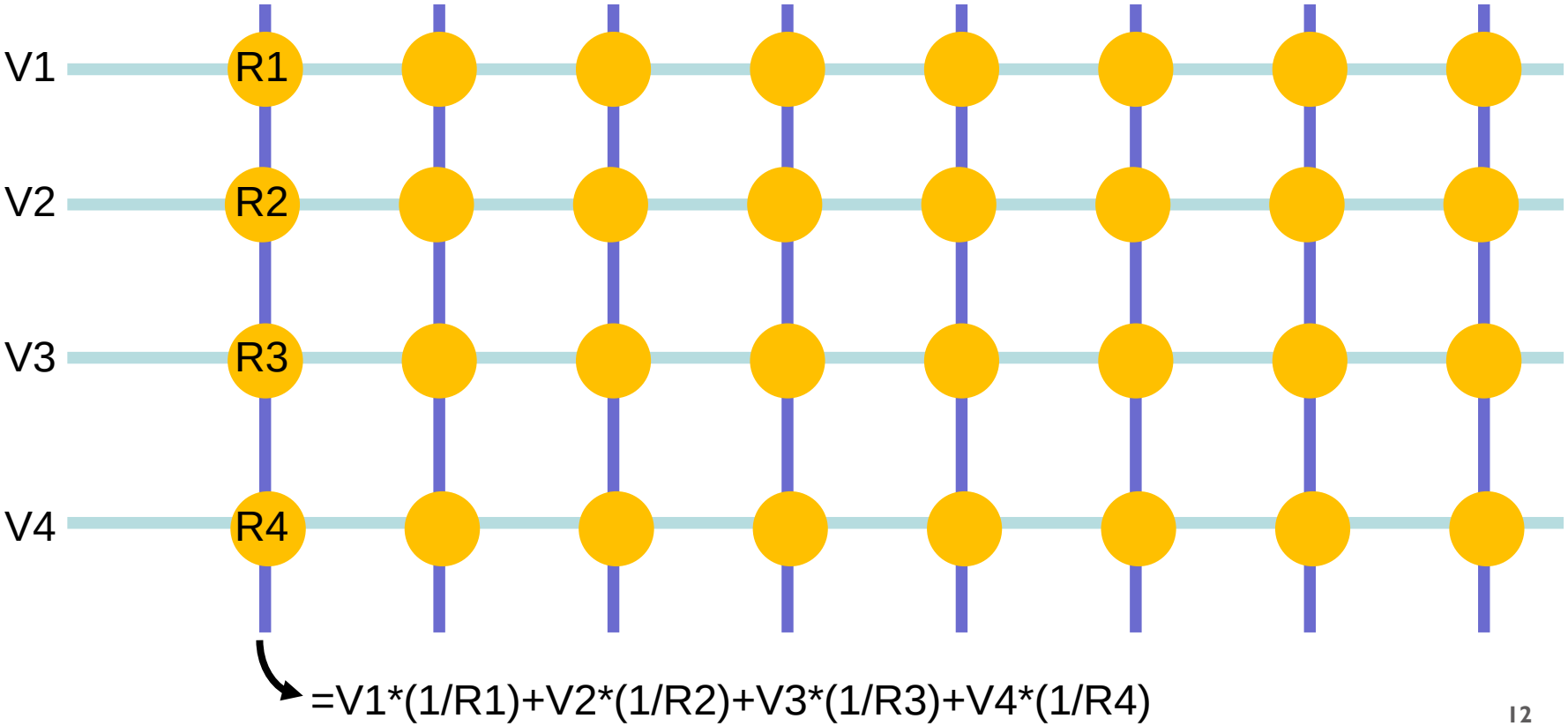
SNIA has made important contributions!

Biggifying Memory with 3D XPoint

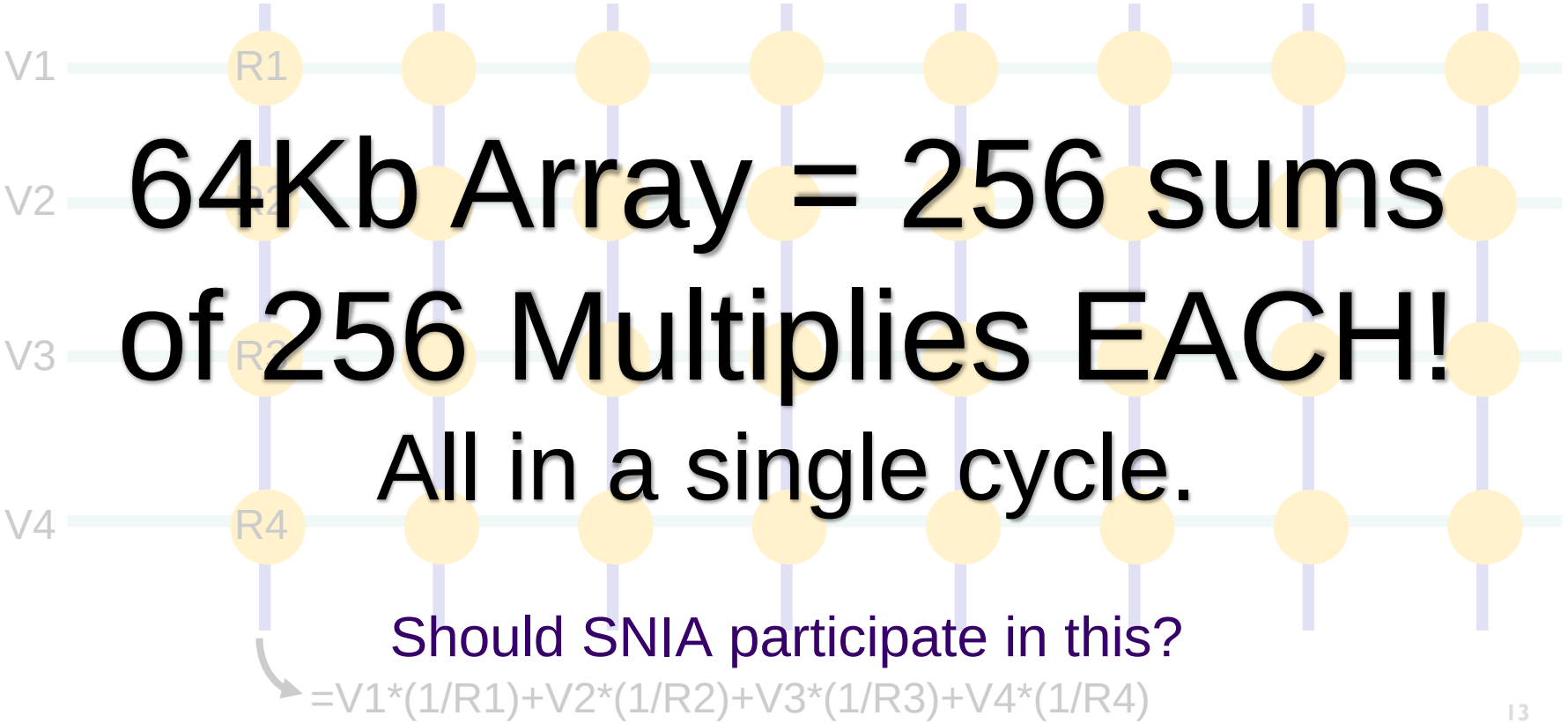


SNIA has made important contributions!

Simplifying AI



Simplifying AI



64Kb Array = 256 sums of 256 Multiplies EACH!

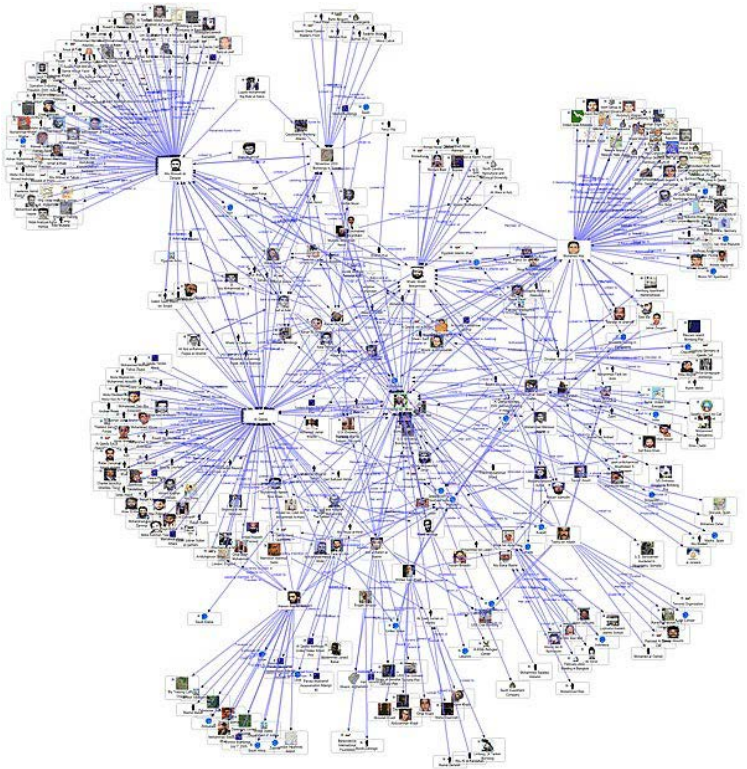
All in a single cycle.

Should SNIA participate in this?

=V1*(1/R1)+V2*(1/R2)+V3*(1/R3)+V4*(1/R4)

Big Data Analytics

- A big topic at ***Rebooting Computing***
- Graph problems: High Communication/Computation ratio
- Feature recognition: Works OK with low precision (i.e. Analog)



Lightspeeur® 2802M, Production AI Accelerator Chip with MRAM (from 2019 CES)

- Includes: The GME (Gyrfalcon MRAM Engine)
- 9.9 TOPS/W in a 22nm ASIC
- Produced via TSMC Collaboration
- Industry leading features, like Non-Volatile Memory

~ 40 MB of Memory	Large embedded models	
	Multiple AI models :	
	Image Classification	Facial recognition
	Voice identification	Voice Commands
	Text to speech	And others…..
Power Savings	20-50% when compared to SRAM or "other MRAM"	
Custom Designs	One Time Programmable Memory	
	Up to 10 ns Read Speed (~30 TOPS/W)	
	Non-Power Leakage	

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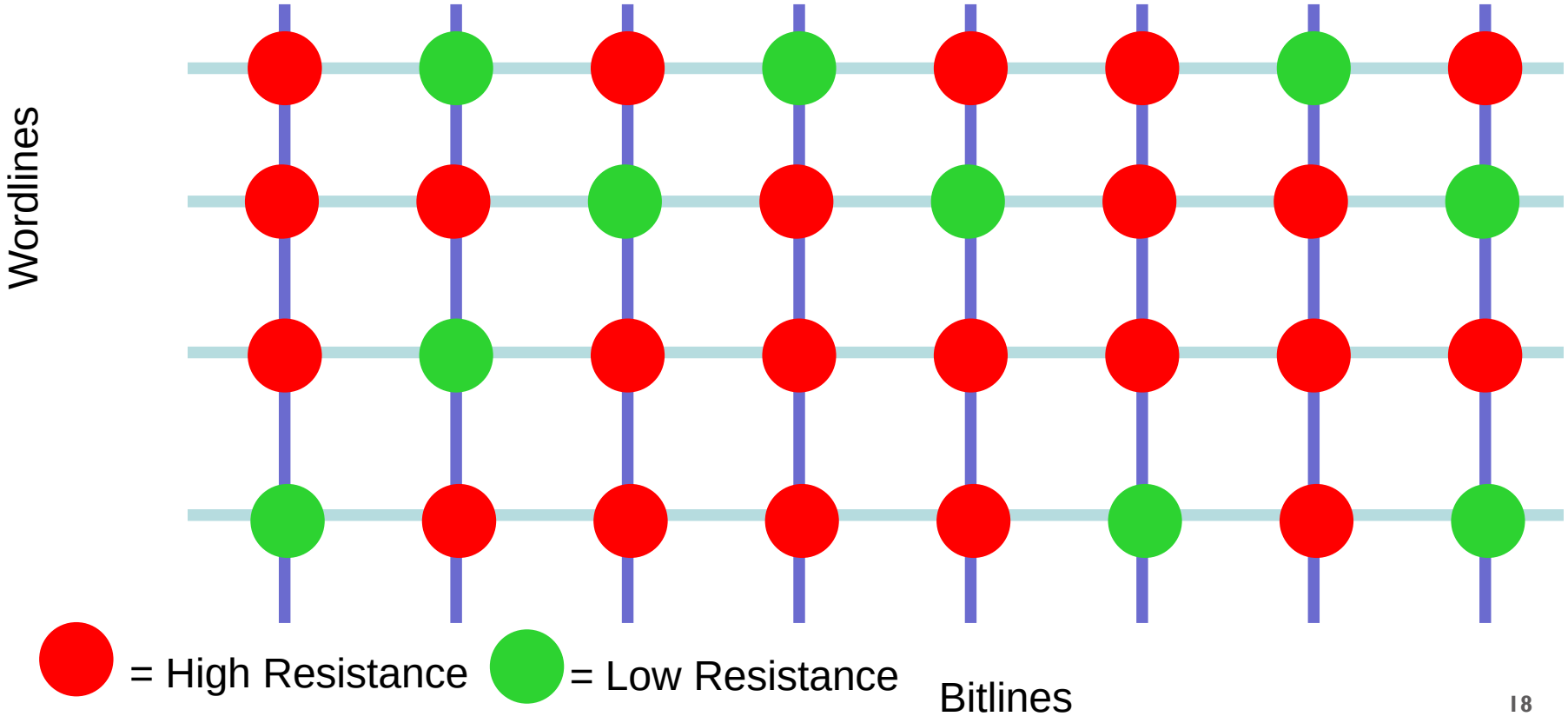
Bit Selectors

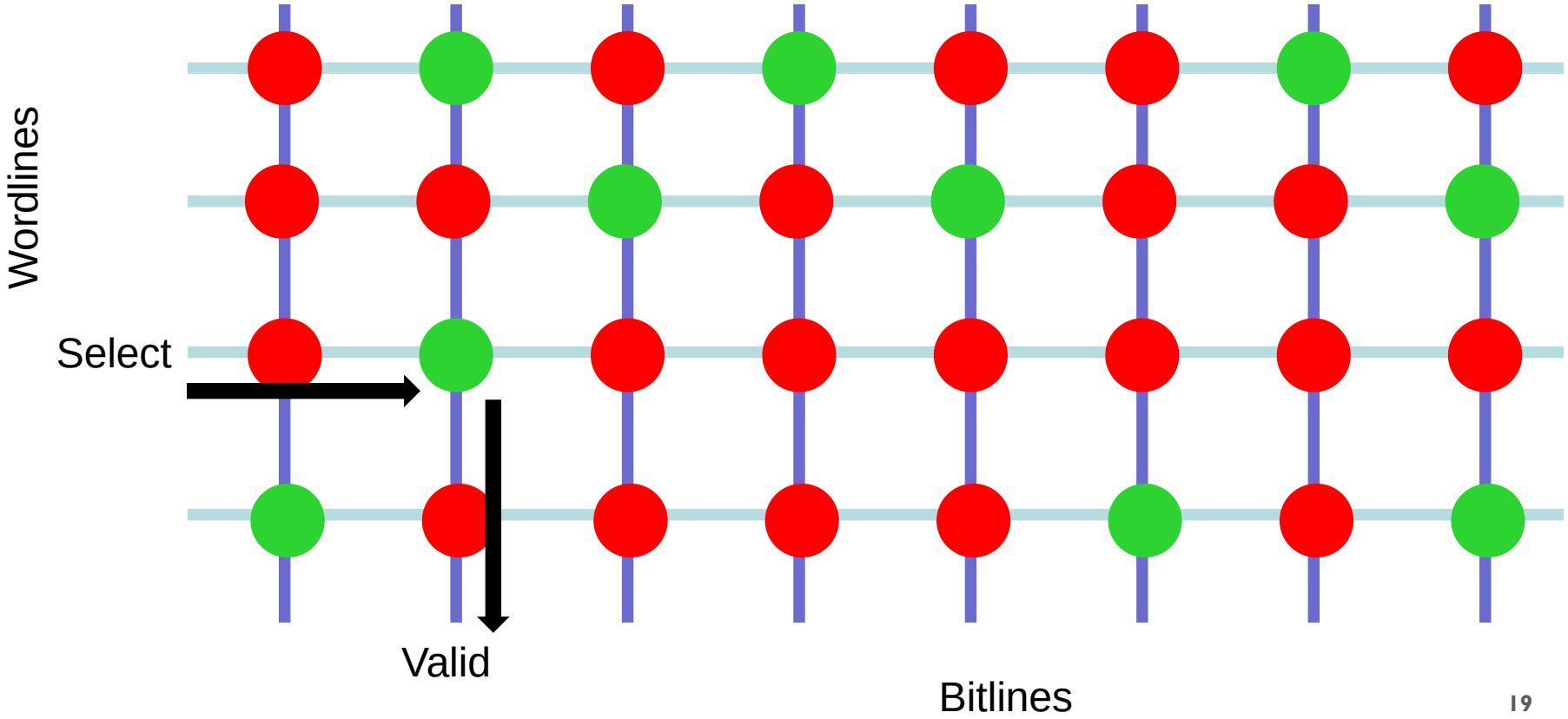
“The select device is a big issue:
How to combine it with the memory element?
You can make a ReRAM out of an eggshell,
but you can’t scale that!”

Scott deBoer, Micron Fellow, 7/28/15

Bit Selectors & Sneak Paths



Bit Selectors & Sneak Paths



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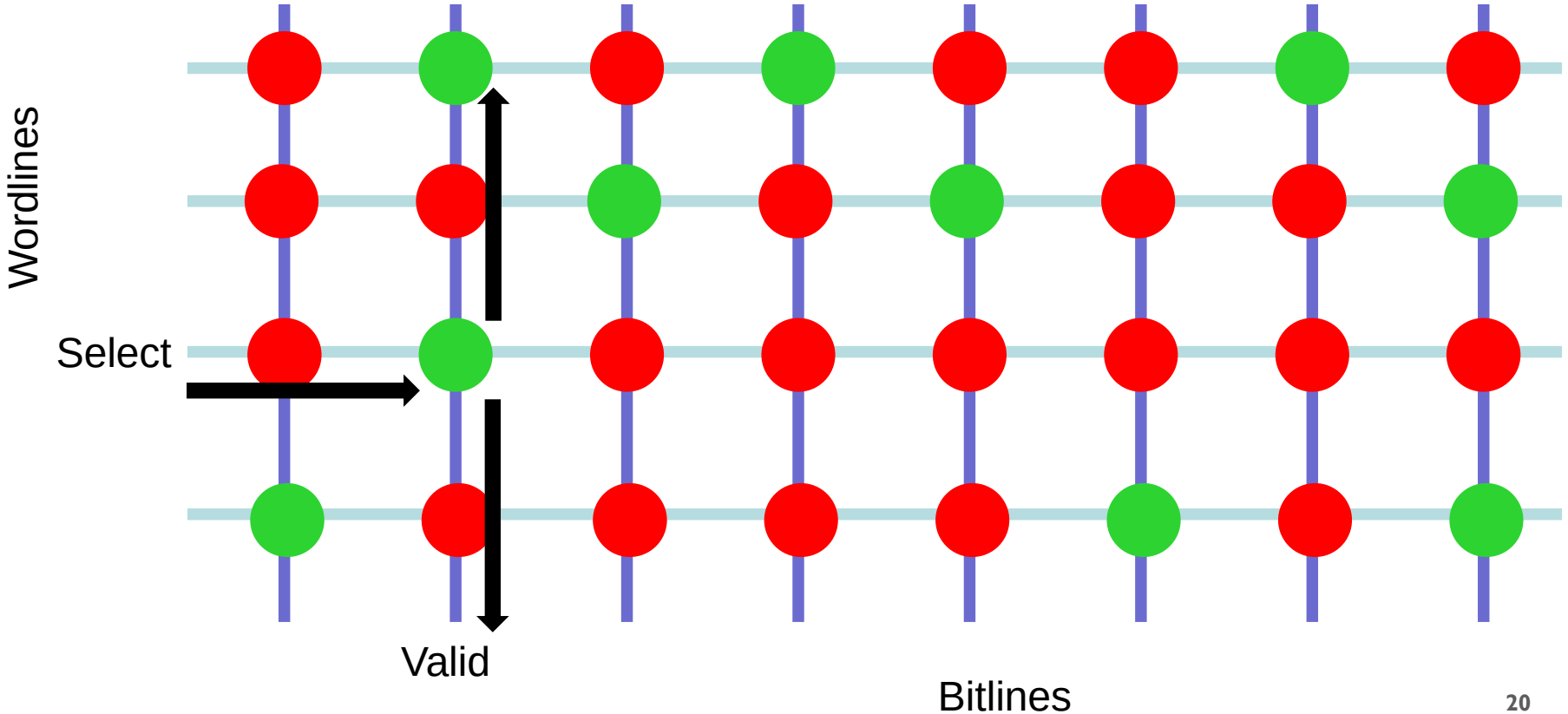

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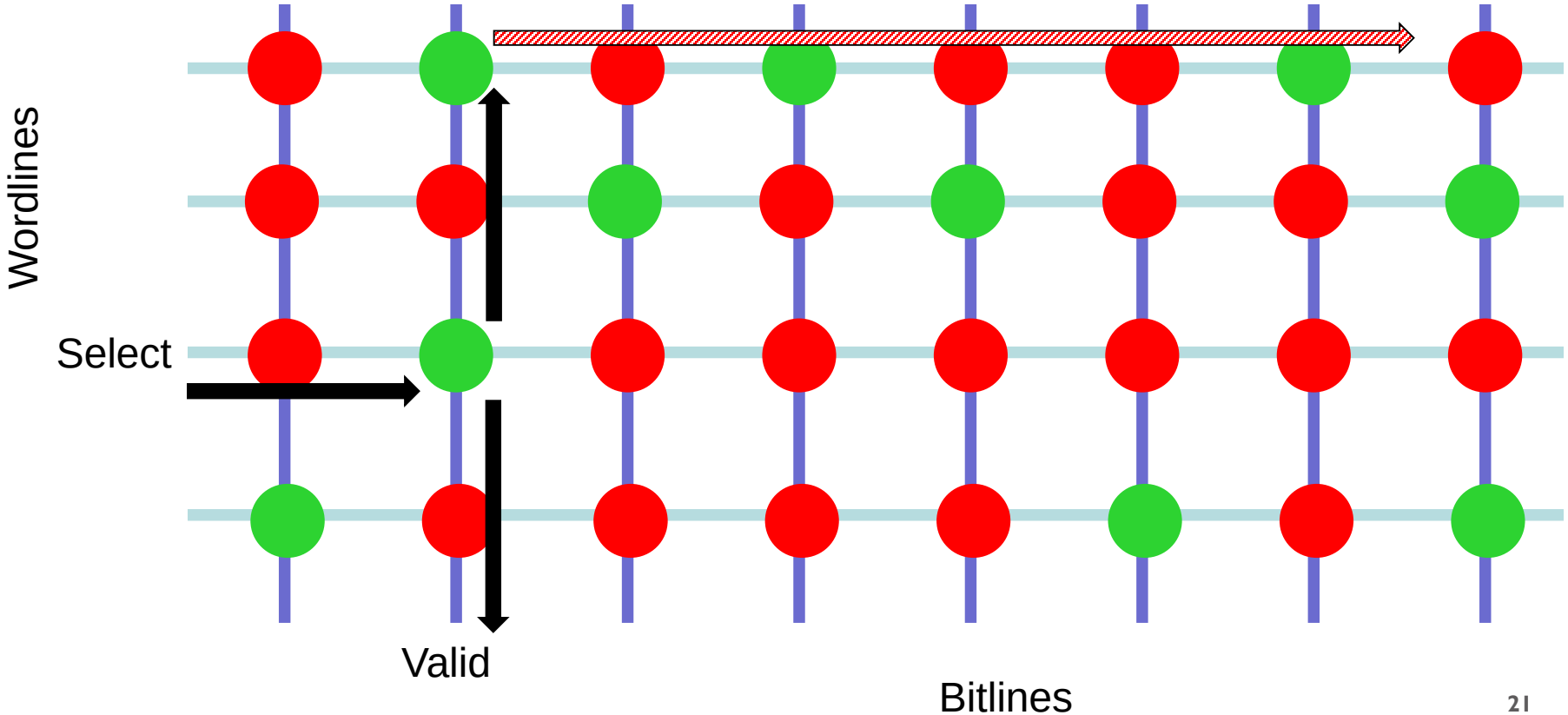

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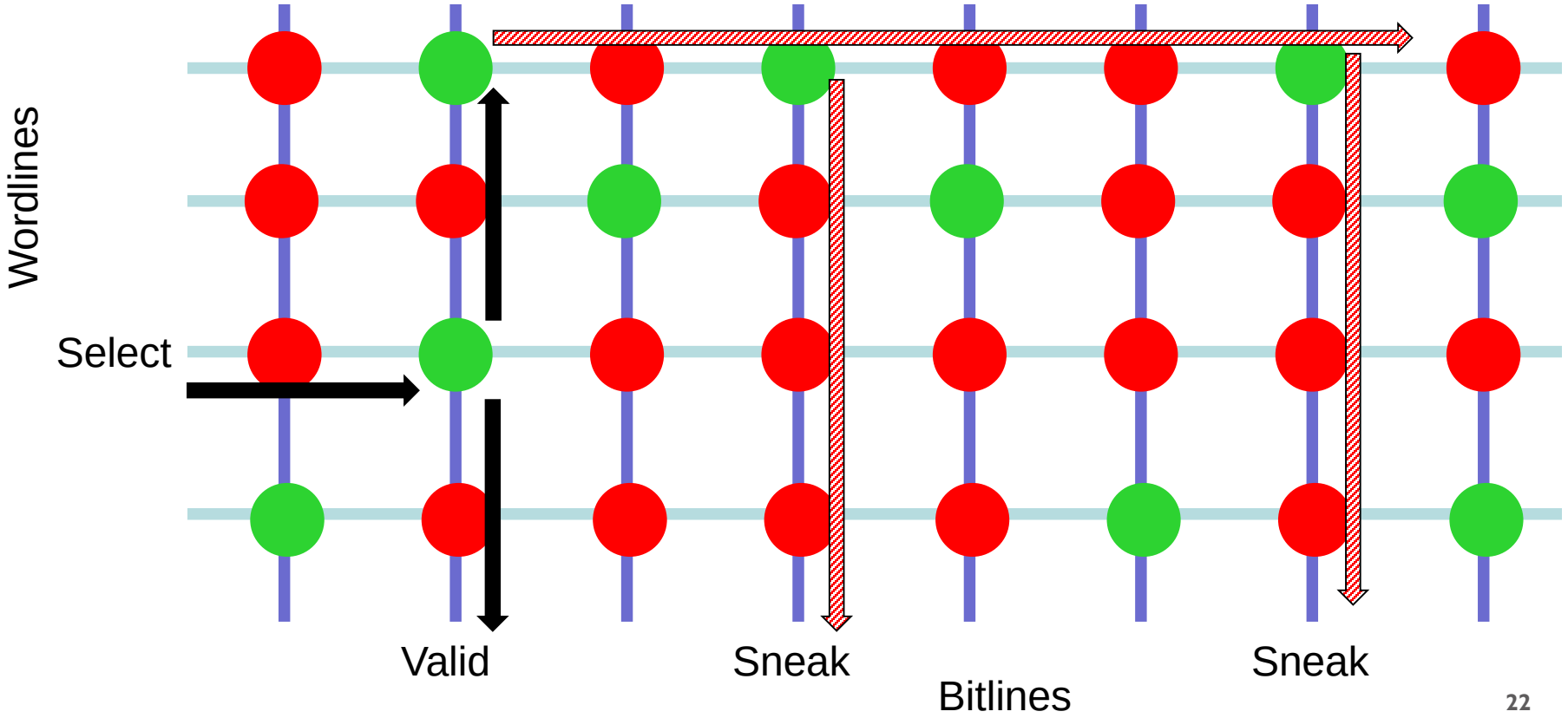

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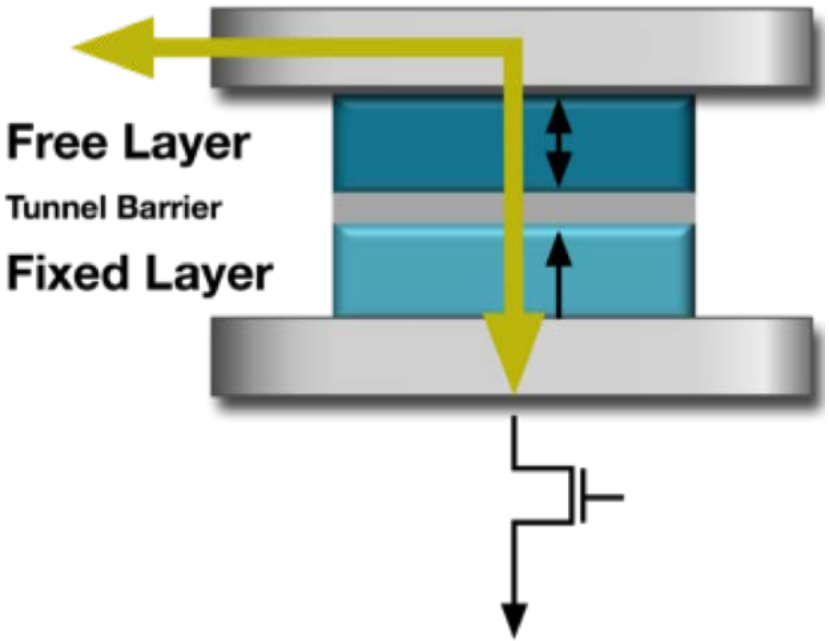
Emerging Memory Technologies

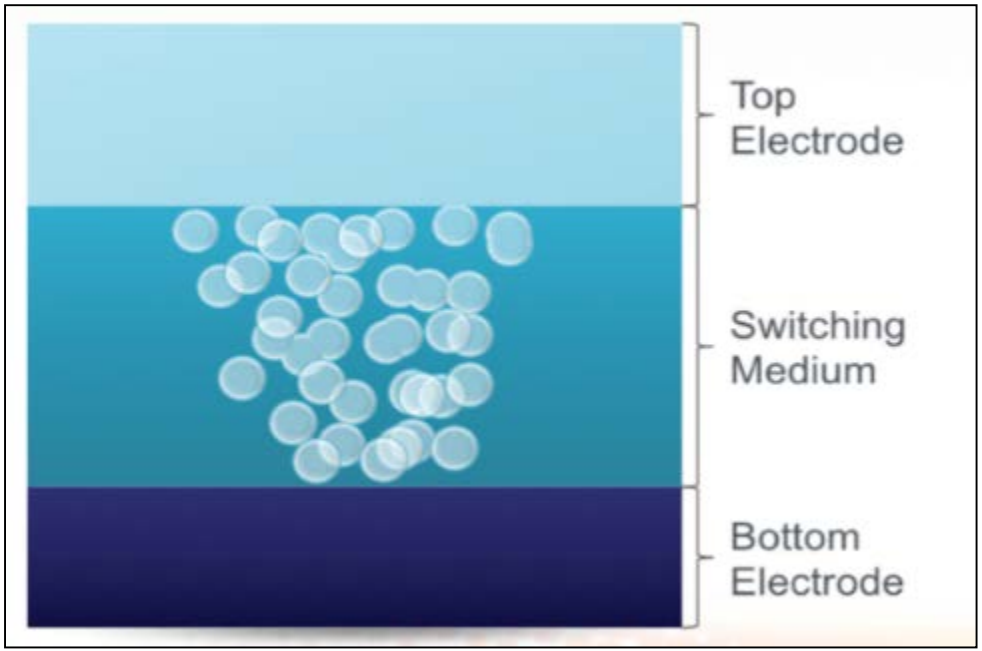
- MRAM
- ReRAM
- PCM/Xpoint
- FRAM
- Other technologies

Magnetic RAM (MRAM)



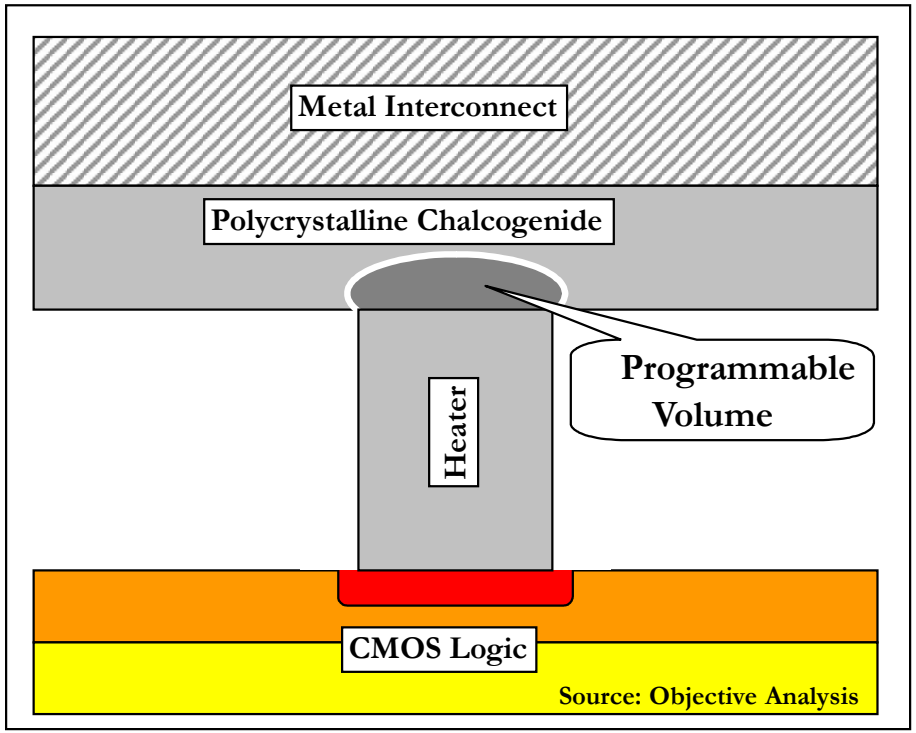
- Bit is set/reset through magnetization

Resistive RAM (ReRAM)



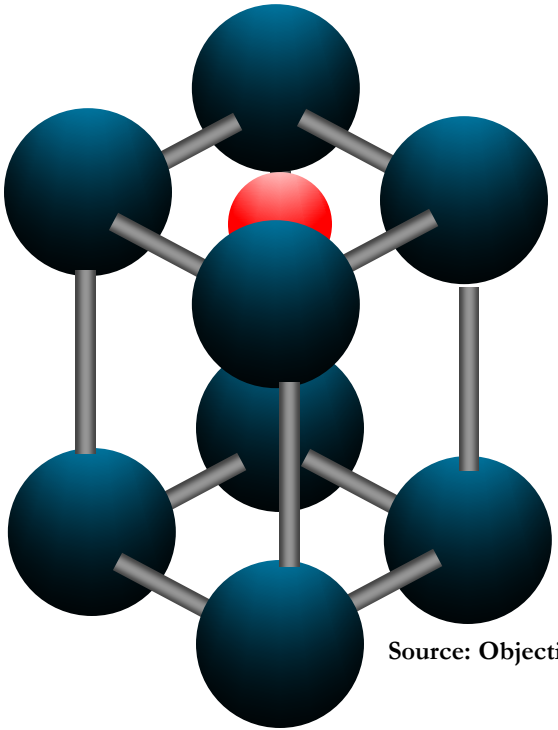
- Two main types:
  - Conductive Bridge
  - Oxygen Vacancy

Phase Change Memory (PCM)



- Bit set via heat/cool cycle
  - Crystalline conducts
  - Amorphous insulates

Ferroelectric RAM (FRAM)



Source: Objective Analysis

- Central atom is up or down

Other Technologies

- Carbon Nanotubes
- Graphene Memories
- Conductive Electron RAM (CeRAM)
- Polymeric ferroelectrics
- Ferroelectric tunnel junctions (FTJ)
- Ferroelectric FETs (FeFETs)
- Interfacial PCM/TRAM
- Magnetoelectric RAM (MeRAM)
- Racetrack Memory

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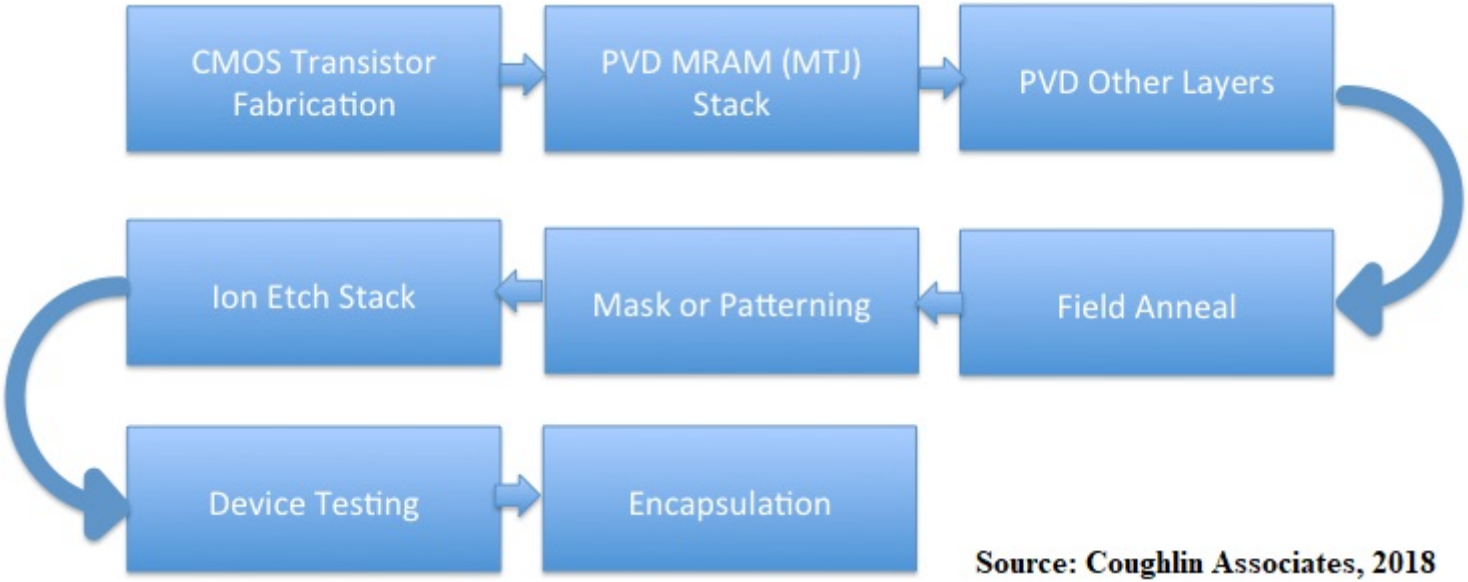
Process Equipment Requirements

- All new memories are built between metal layers
  - Tool sets are similar for MRAM, PCM, ReRAM, etc.



Source: Coughlin Associates, 2018

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Emerging Memory Companies

- New Technology Developers
- Chip Makers
- Equipment Makers

4DS Memory	Cypress Semiconductor	imec	MicroSense	Samsung Semiconductor	Thin Film Electronics
Adesto Technologies	EverSpin	Integral Solutions (ISI)	Nantero	Seagate Technology	Tokyo Electron
Applied Materials	Ferroelectric Memory Co.	Intel	NEC	Singulus Technologies	Toshiba Memory Corp.
Avalanche Technology	Fujitsu Semiconductor	Jusung Engineering	Neoark	SK hynix	TowerJazz
BAE Systems	Global Foundries	Keysight Technologies	NVE	SMIC	TSMC
BeSang	Grandis	KLA Tencor	Ovonyx	Sony Corporation	Ulvac
Canon-Anelva	Hitachi High Technology	Knowm	Panasonic	Spin Memory	UMC
Capres A/S	Honeywell	Lam Research	Qualcomm	Symetrix	Unidym
Cobham-Aeroflex	HPE	Magnetic Solutions	Rambus	TCLab	Veeco
Crocus Technology	Hprobe	MagOasis	Ramtron	TDK	Weebit Nano
Crossbar	IBM	Micron Technology	Renesas Electronics	Texas Instruments (TI)	Western Digital/SanDisk

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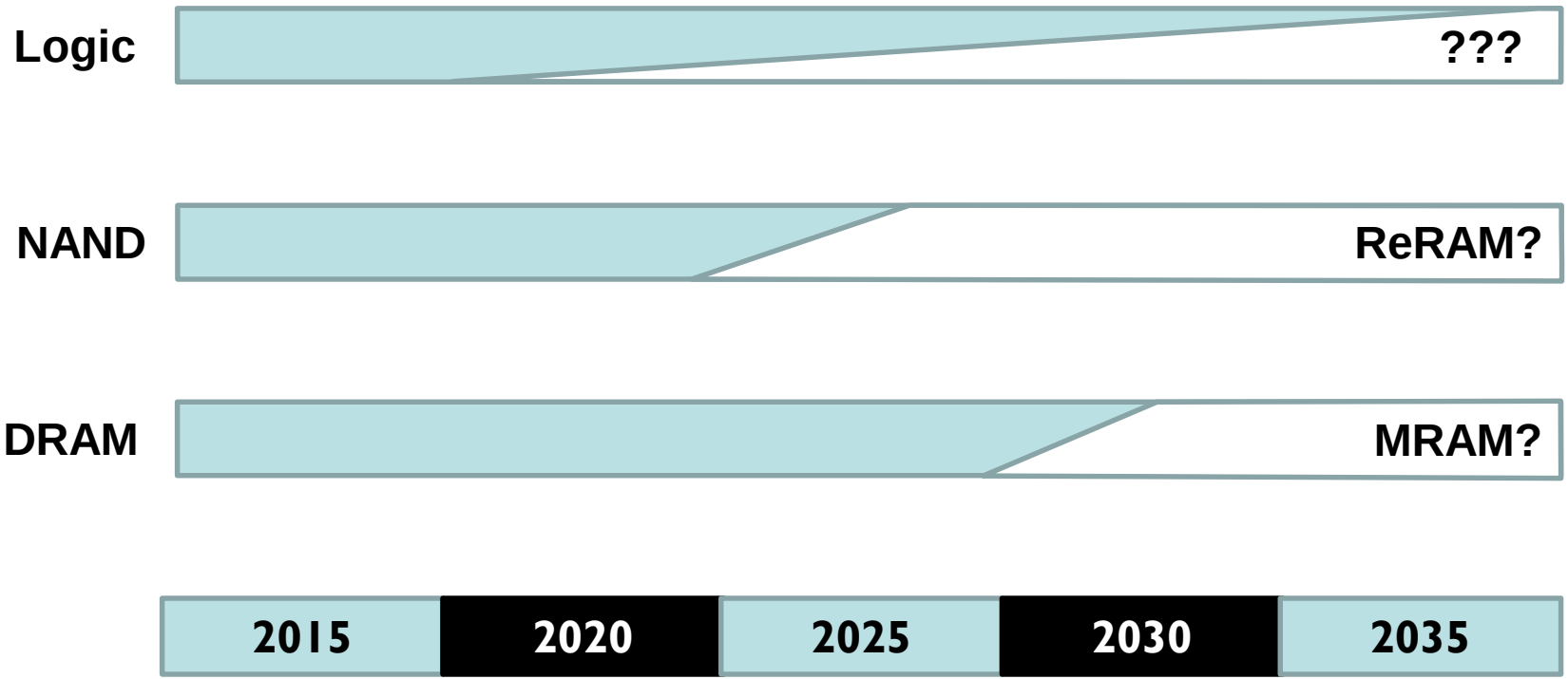
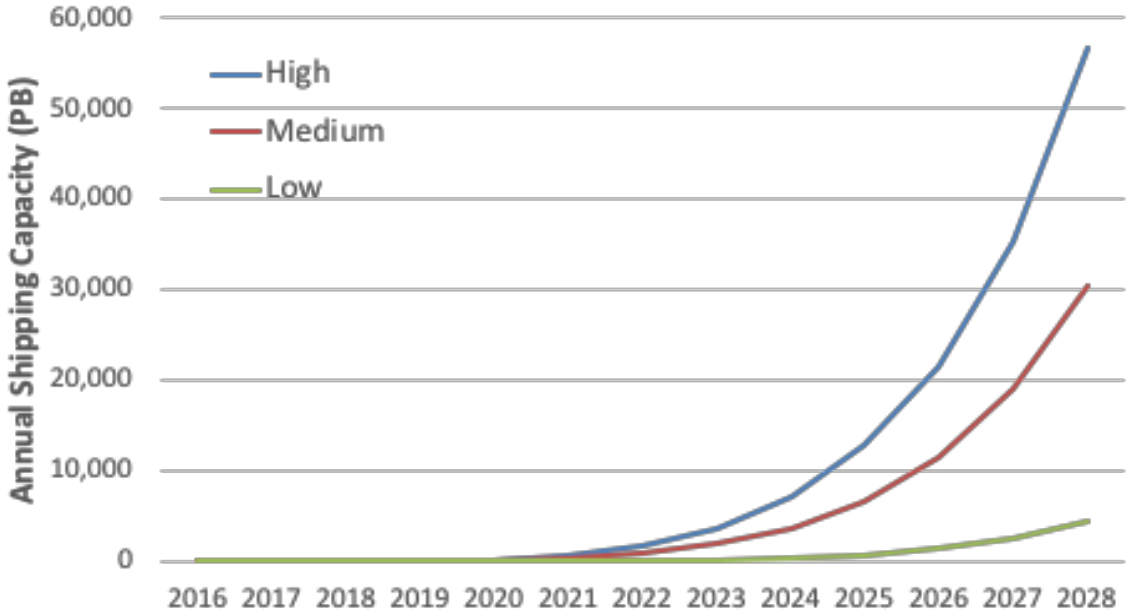
Timeline for Change



Source: Objective Analysis, 2018

Emerging Memory PB Shipments

Emerging NVM market could exceed $6B by 2028!



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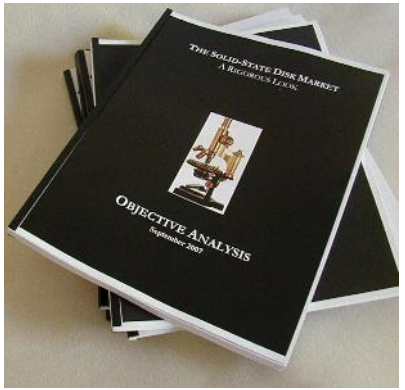
The Report

- Emerging Memories Poised to Explode
  - In-depth coverage of everything in this presentation
  - 160 pages, 111 figures, 31 tables
  - Can be purchased on-line for immediate download
- Two ways to order:
  - https://Objective-Analysis.com/reports/#Emerging
  - http://www.TomCoughlin.com/tech-papers.htm



Questions?

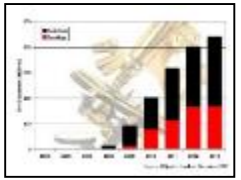
- Technical and Market Analysis
- Consulting
- Reports and Newsletter
  - Emerging Memories Poised to Explode: Emerging Memory Report
  - Digital Storage in Media and Entertainment
  - Digital Storage Technology Newsletter

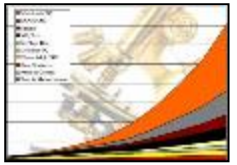
Objective Analysis

Profound Analysts

Reports & Services

Custom Consulting





Objective Analysis

Semiconductor Forecast Accuracy

Year	Forecast	Actual
2008	Zero growth at best.	-3%
2009	Growth in the mid teens	-9%
2010	Should approach 30%	32%
2011	Muted revenue growth: 5%	0%
2012	Revenues drop as much as -5%	-2.7%
2013	Revenues increase nearly 10%	4.9%
2014	Revenues up 20%+	9.9%
2015	Revenues up ~10%	-0.2%
2016	Revenues up ~10%	1.1%
2017	Revenues up ~20%	22%
2018	Strong start supports 10+% growth	TBD