Future Memories and Today's Opportunities

Tom Coughlin, Coughlin Associates

Jim Handy, Objective Analysis

Coughlin Associates

Cataclysmic Changes Coming Soon

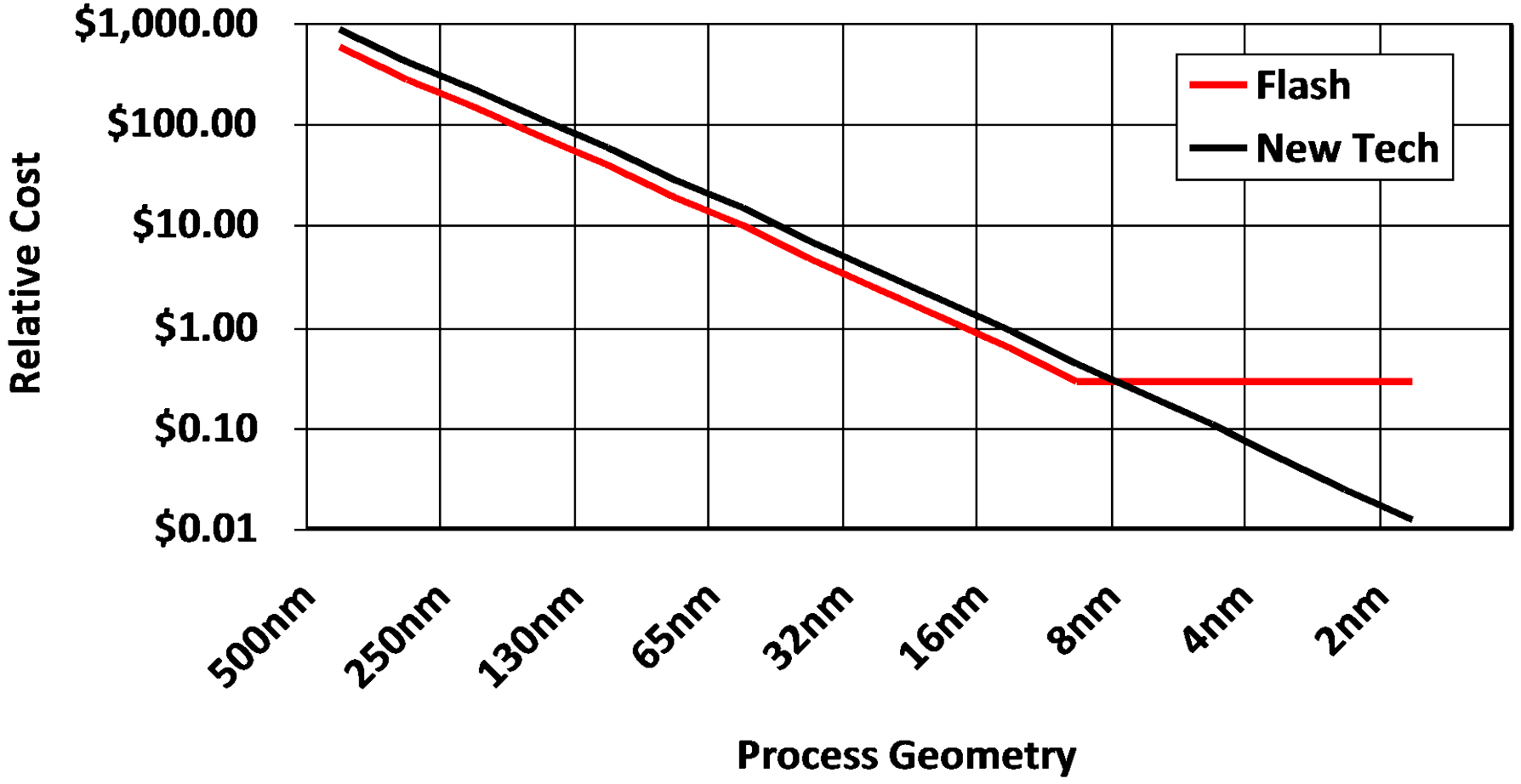
- Scaling Limits
  - We can't make transistors any smaller
- New Storage Hierarchies
  - You think SSDs were disruptive? Just wait!
- More Layers Will Be Added
  - It's all about touch rates and response time
- Processors Must Adapt

© 2016 Coughlin Associates & Objective Analysis

SCALING LIMITS

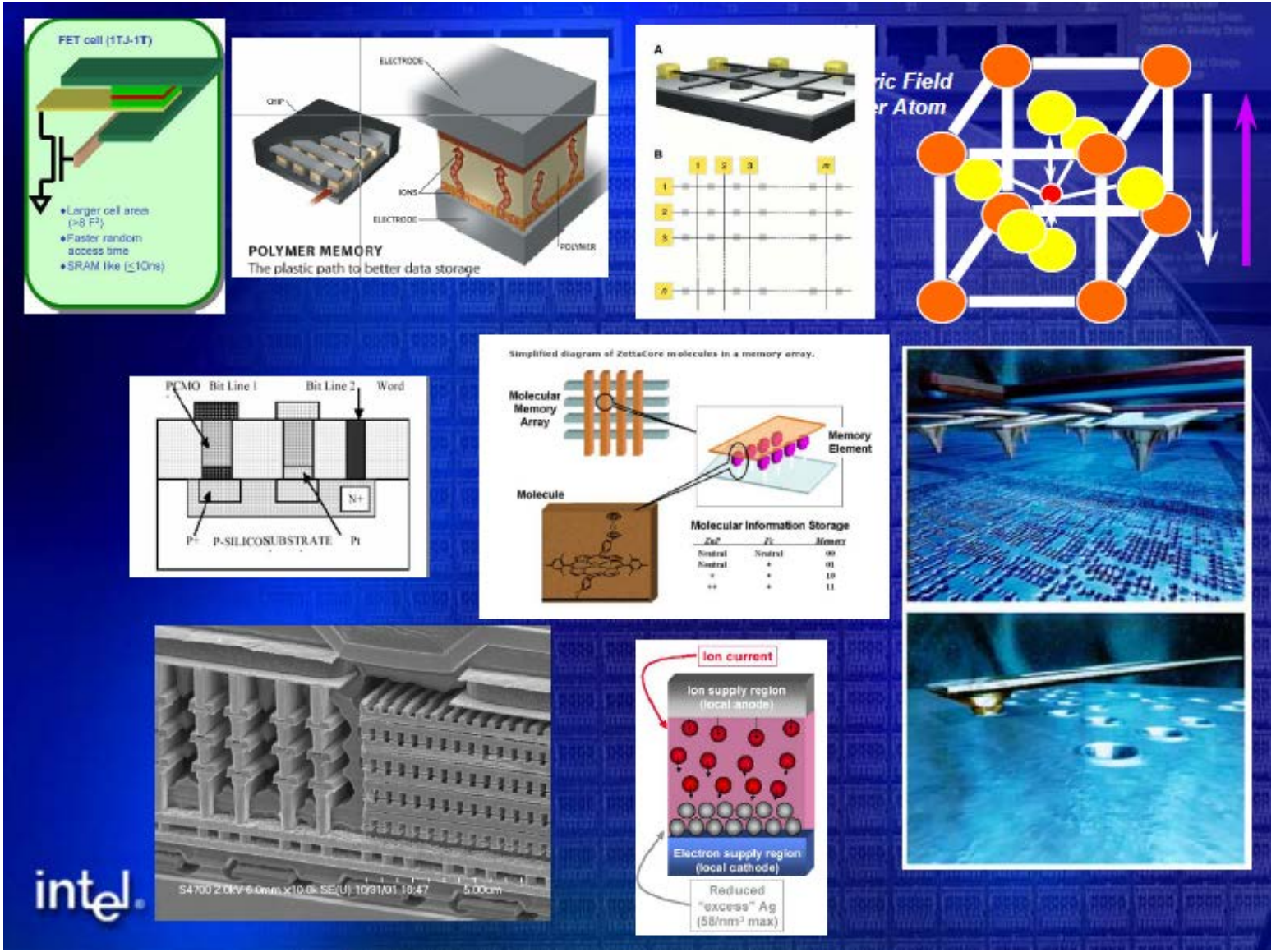
© 2016 Coughlin Associates & Objective Analysis

Scaling Limits Create Opportunities for New Memories



© 2016 Coughlin Associates & Objective Analysis

No Shortage of Options



© 2016 Coughlin Associates & Objective Analysis

Today's Memories Are Limited

	SRAM	DRAM	ROM	EEPROM	NOR	NAND
Nonvolatile	No	No	Yes	Yes	Yes	Yes
Erasable	Yes	Yes	No	Yes	Yes	Yes
Programmable	Yes	Yes	Factory	Yes	Yes	Yes
Smallest Write	Byte	Byte	N/A	Byte	Byte	Page
Smallest Read	Byte	Page	Byte	Byte	Byte	Page
Read Speed	V Fast	Fast	Fast	Fast	Fast	Slow
Write Speed	V Fast	Fast	N/A	Slow	Slow	Slow
Active Power	High	Med	Med	Med	Med	Med
Sleep Power	V Low	High	Zero	Zero	Zero	Zero
Price/GB	High	Low	Low	High	Med	V Low
Applications	Small Fast Main Memory		Stable Code Volume	Serial #, Trim	Code	Data

© 2016 Coughlin Associates & Objective Analysis

Emerging Memories Perform Better

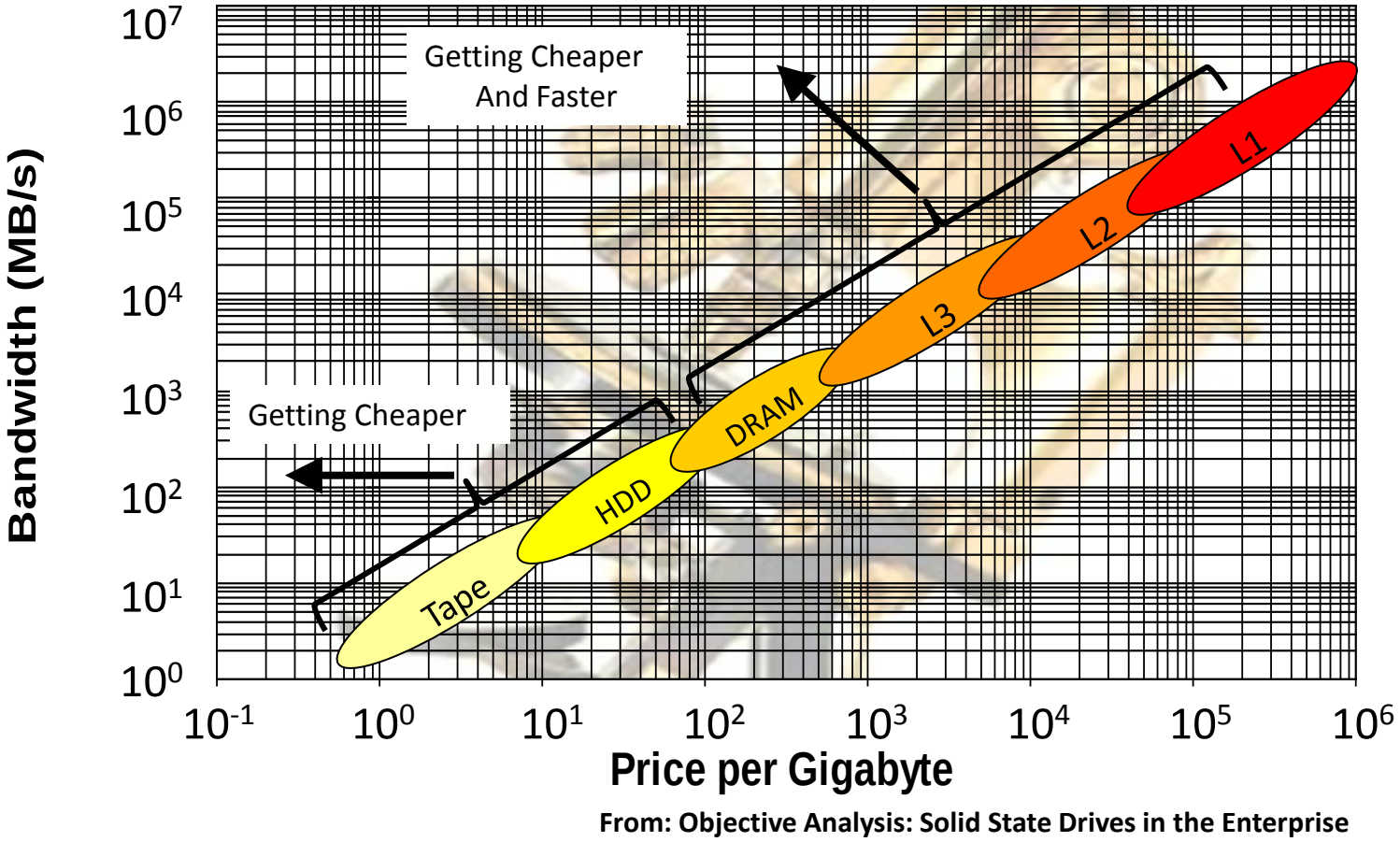
	MRAM	ReRAM	FRAM	PCM	XPoint
Nonvolatile	Yes	Yes	Yes	Yes	Yes
Erasable	Yes	Yes	Yes	Yes	Yes
Programmable	Yes	Yes	Yes	Yes	Yes
Smallest Write	Byte	Byte	Byte	Byte	Byte
Smallest Read	Byte	Byte	Byte	Byte	Byte
Read Speed	Fast	Fast	Fast	Fast	Fast
Write Speed	Fast	Fast	Fast	Fast	Fast
Active Power	Low	Med	Low	High	High?
Sleep Power	Low	Low	Low	Low	Low
Price/GB	High	High	High	High	High?
Applications	Niche	TBD	Low Power	Obsolete	Main Memory

© 2016 Coughlin Associates & Objective Analysis

NEW STORAGE HIERARCHIES

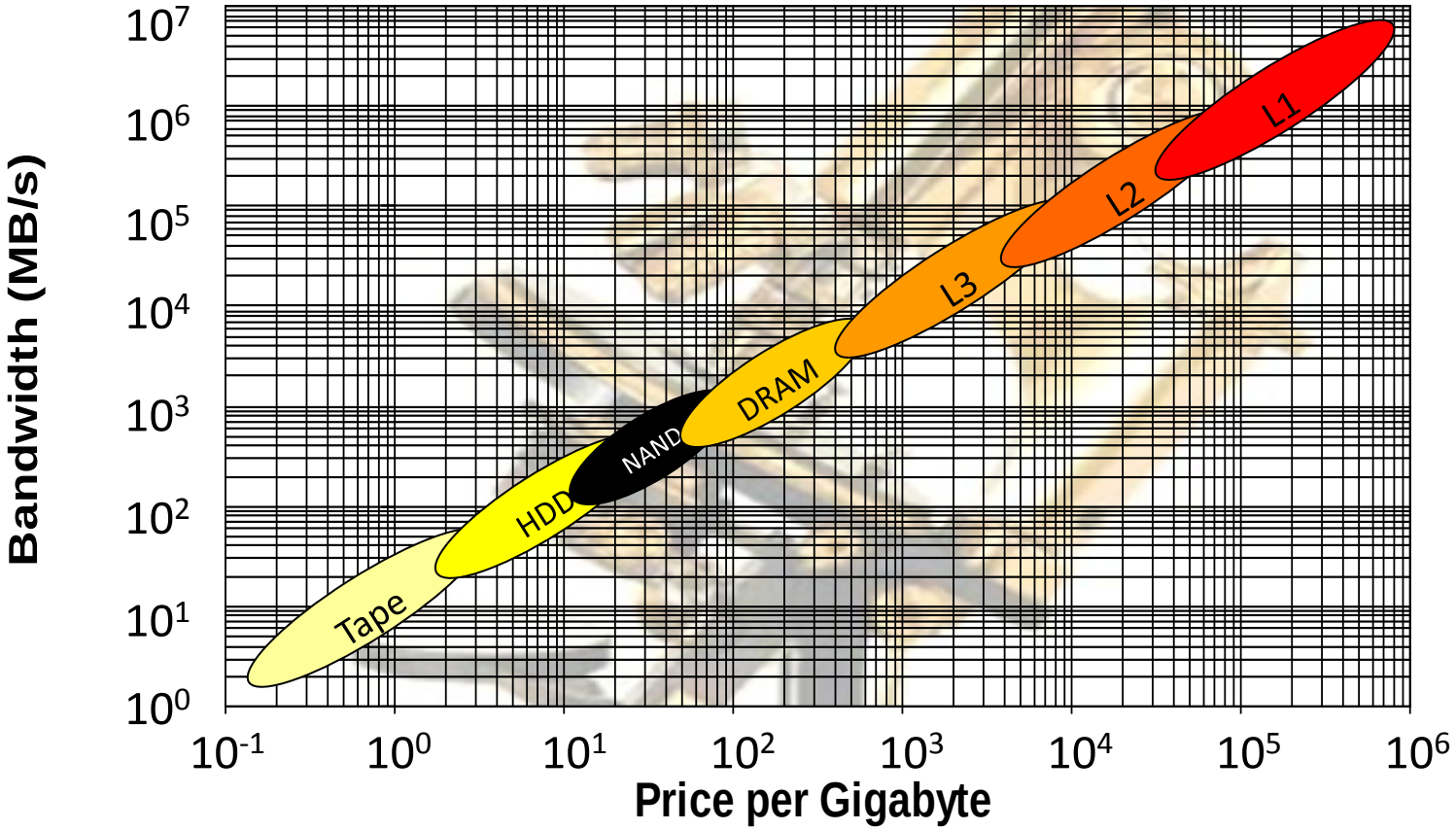
© 2016 Coughlin Associates & Objective Analysis

Memory/Storage Hierarchy 2000



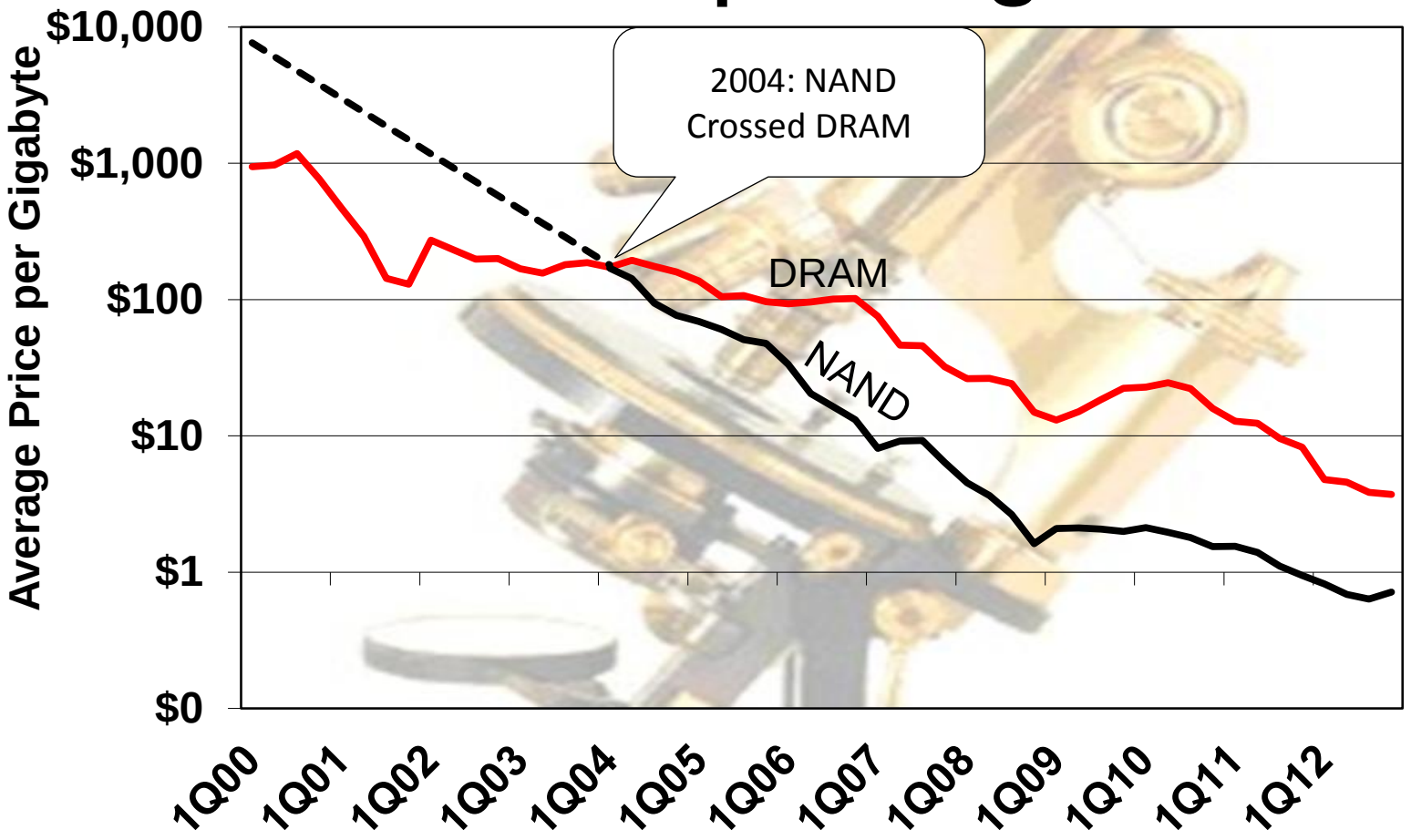
From: Objective Analysis: Solid State Drives in the Enterprise

NAND Flash SSDs Today Make Sense



From: Objective Analysis: Solid State Drives in the Enterprise

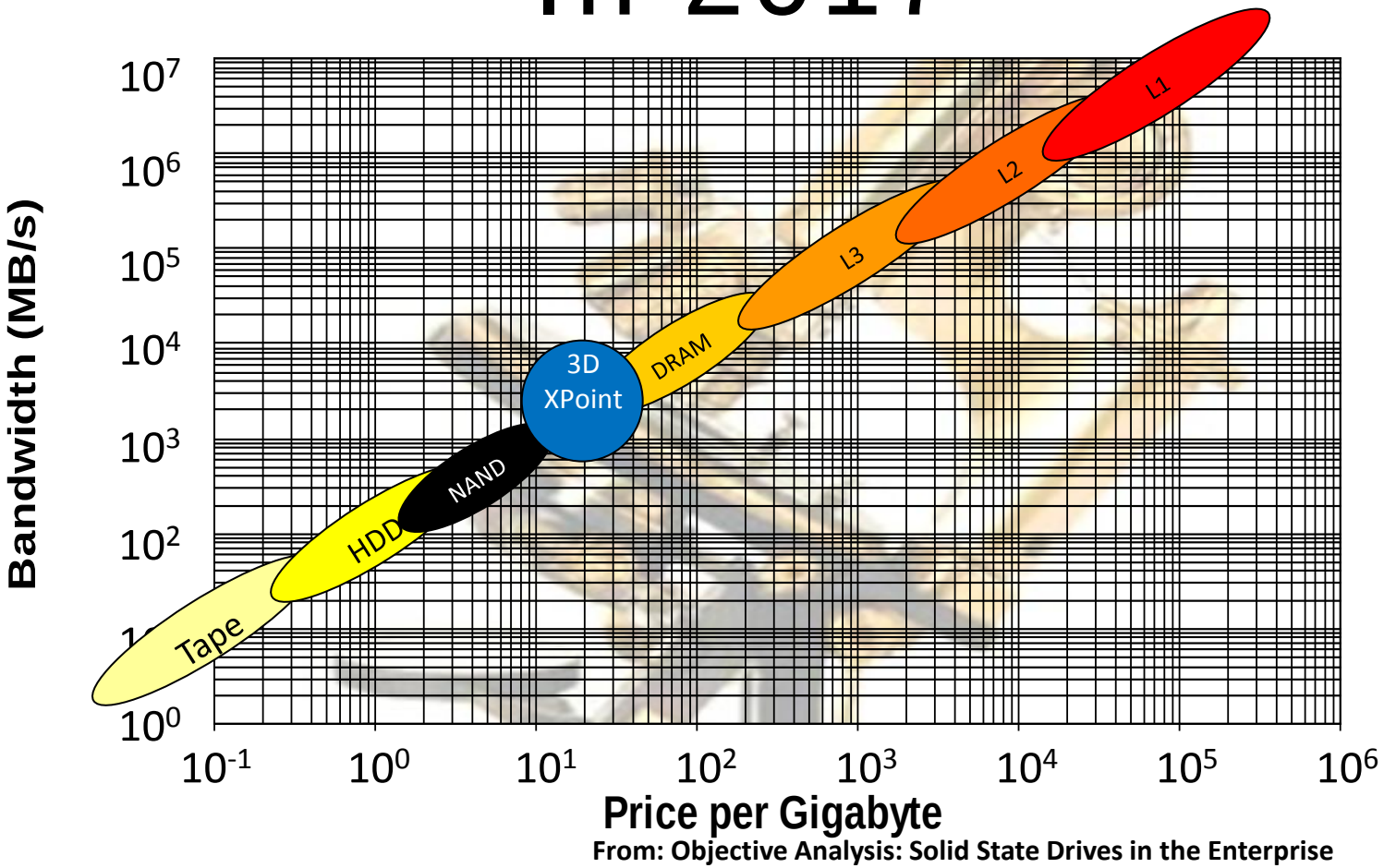
Cost Brought Flash Into Computing



From: Objective analysis: Hybrid Drives: How, Why, & When?

© 2016 Coughlin Associates & Objective Analysis

3D XPoint Will Do The Same In 2017



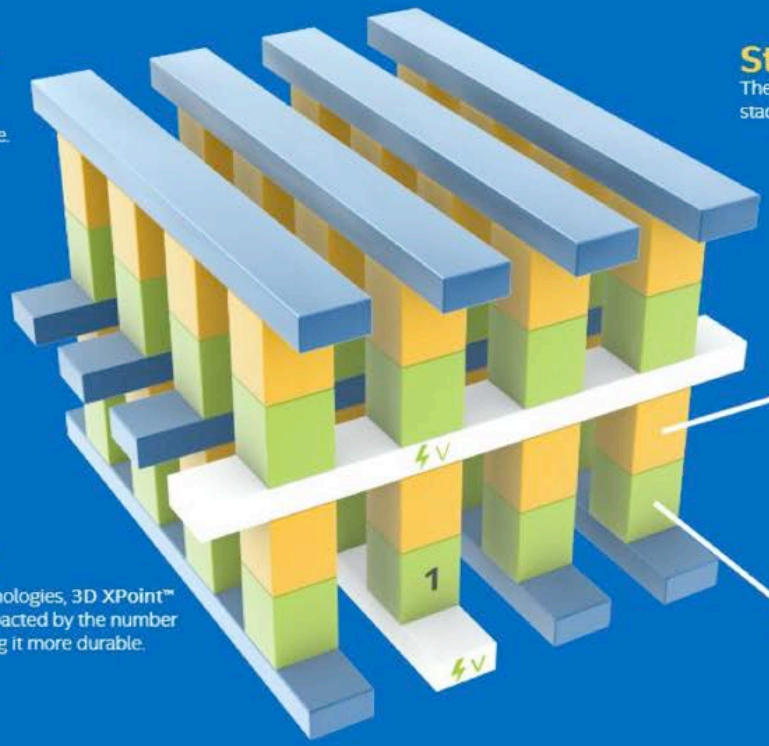
From: Objective Analysis: Solid State Drives in the Enterprise

Intel's & Micron's 3D XPoint Intro

3D XPoint™ Technology:
An Innovative, High-Density Design

Cross Point Structure
Perpendicular wires connect submicroscopic columns. An individual memory cell can be addressed by selecting its top and bottom wire.

Stackable
These thin layers of memory can be stacked to further boost density.



Non-Volatile
3D XPoint™ Technology is non-volatile—which means your data doesn't go away when your power goes away—making it a great choice for storage.

Selector
Whereas DRAM requires a transistor at each memory cell—making it big and expensive—the amount of voltage sent to each **3D XPoint™ Technology** selector enables its memory cell to be written to or read without requiring a transistor.

High Endurance
Unlike other storage memory technologies, **3D XPoint™ Technology** is not significantly impacted by the number of write cycles it can endure, making it more durable.

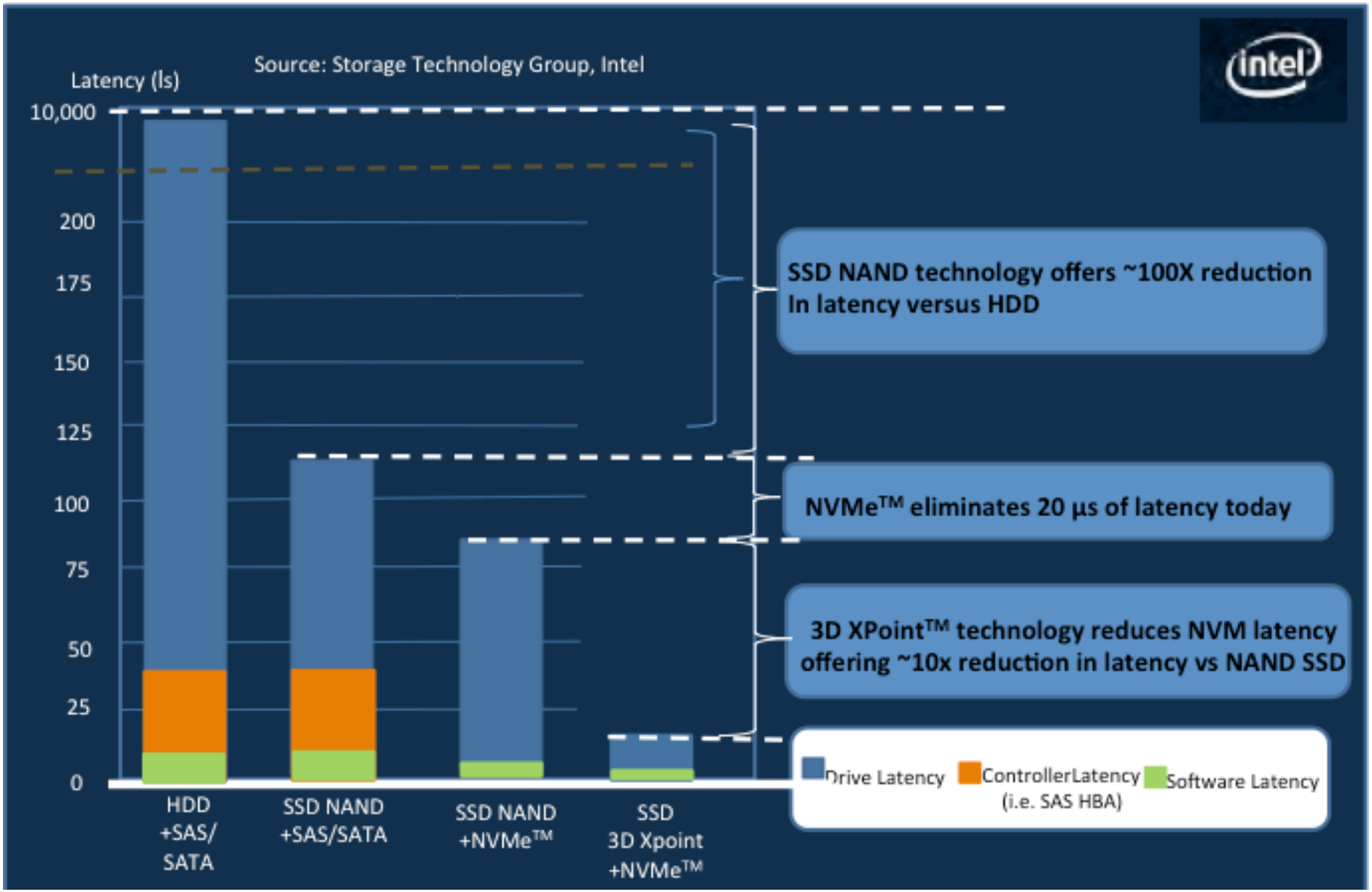
Memory Cell
Each memory cell can store a single bit of data.

Transforming the Memory Hierarchy
For the first time, there is a fast, inexpensive and non-volatile memory technology that can serve as system memory and storage.

~8x to 10x Greater Density than DRAM[1]
3D XPoint™ Technology's simple, stackable, transistor-less design packs more memory into less space, which is critical to reducing cost.

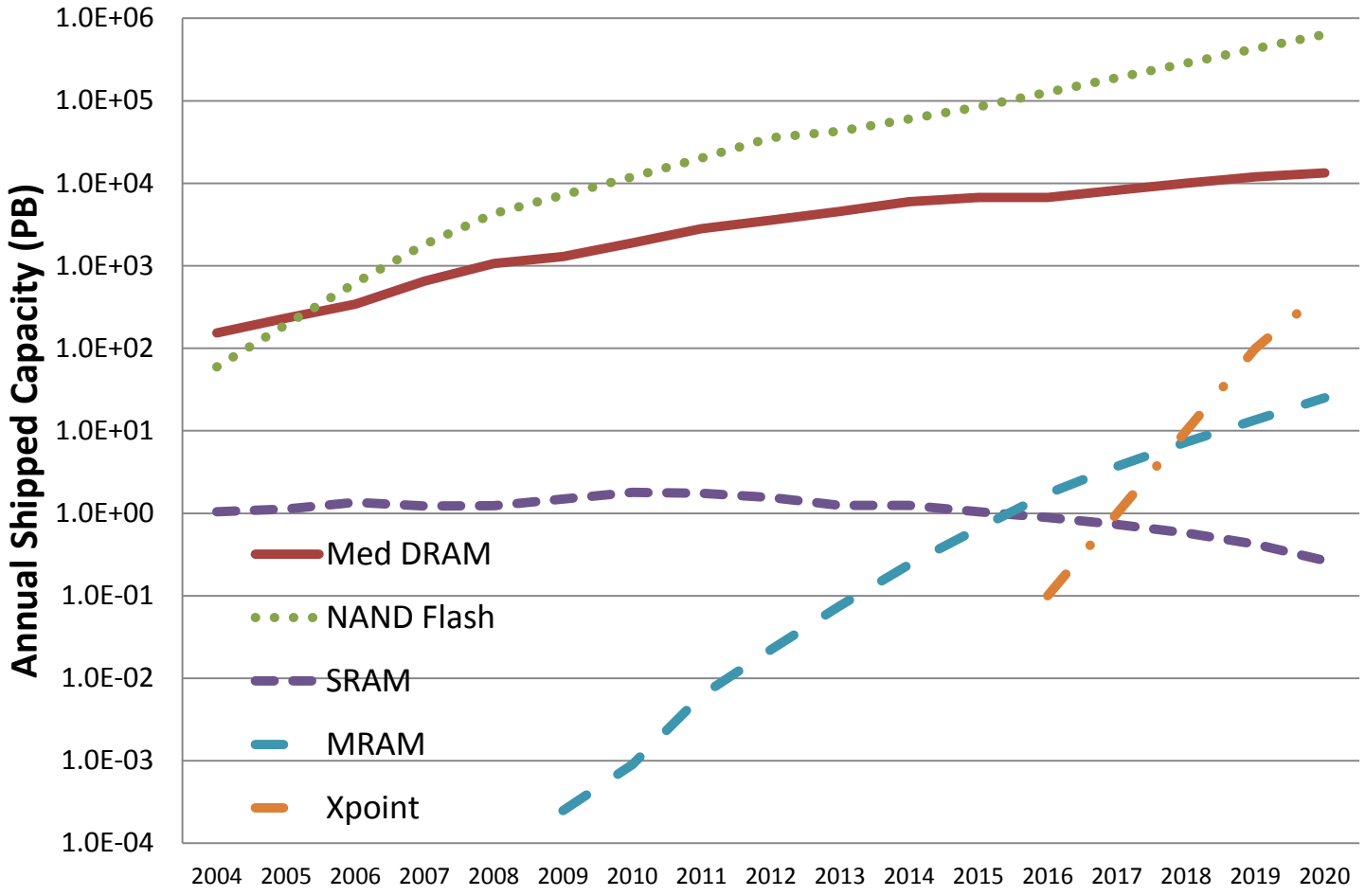
© 2016 Coughlin Associates & Objective Analysis

3D XPoint Slashes Latency



© 2016 Coughlin Associates & Objective Analysis

ANNUAL SHIPPED CAPACITY (PB) FOR DRAM, NAND FLASH, SRAM, MRAM AND 3D XPOINT



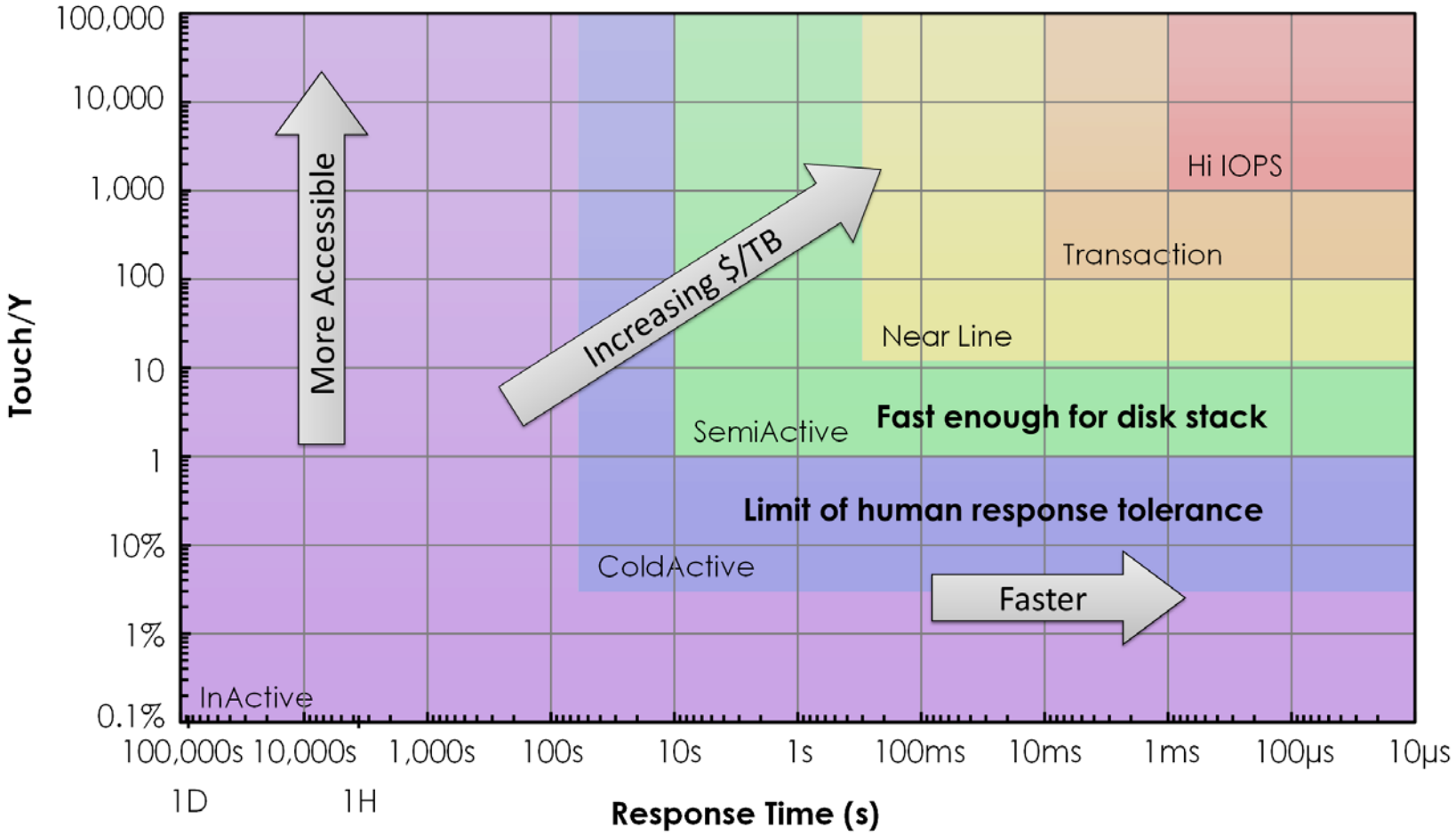
2015 EMERGING NON-VOLATILE MEMORY & SPIN LOGIC TECHNOLOGY AND MANUFACTURING REPORT, Coughlin Associates, 2015, http://www.tomcoughlin.com/techpapers.htm

© 2016 Coughlin Associates & Objective Analysis

WHY MORE STORAGE LAYERS

© 2016 Coughlin Associates & Objective Analysis

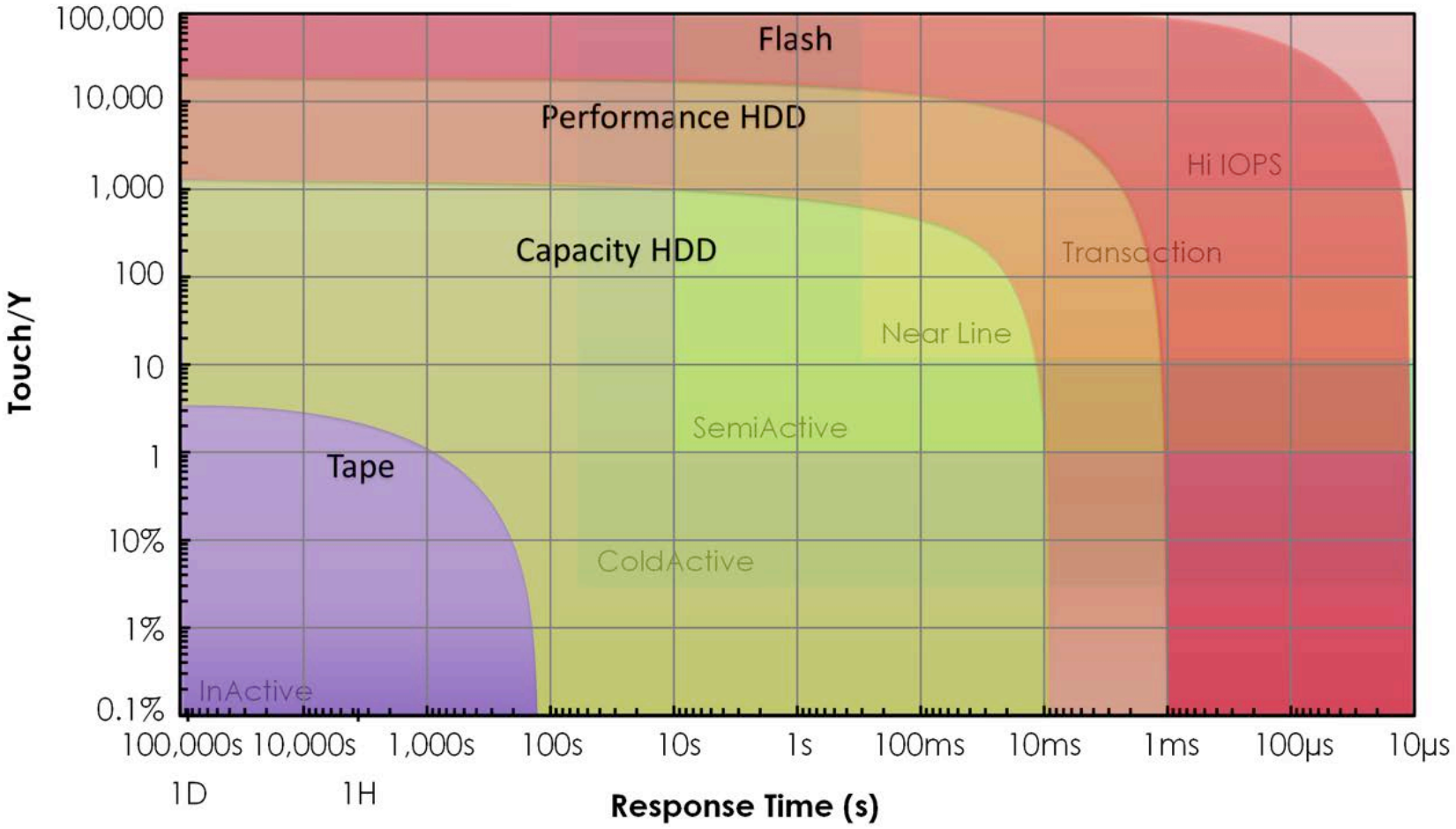
“Touch Rates” vs. Response Time By Application



2015 EMERGING NON-VOLATILE MEMORY & SPIN LOGIC TECHNOLOGY AND MANUFACTURING REPORT, Coughlin Associates, 2015, http://www.tomcoughlin.com/techpapers.htm

© 2016 Coughlin Associates & Objective Analysis

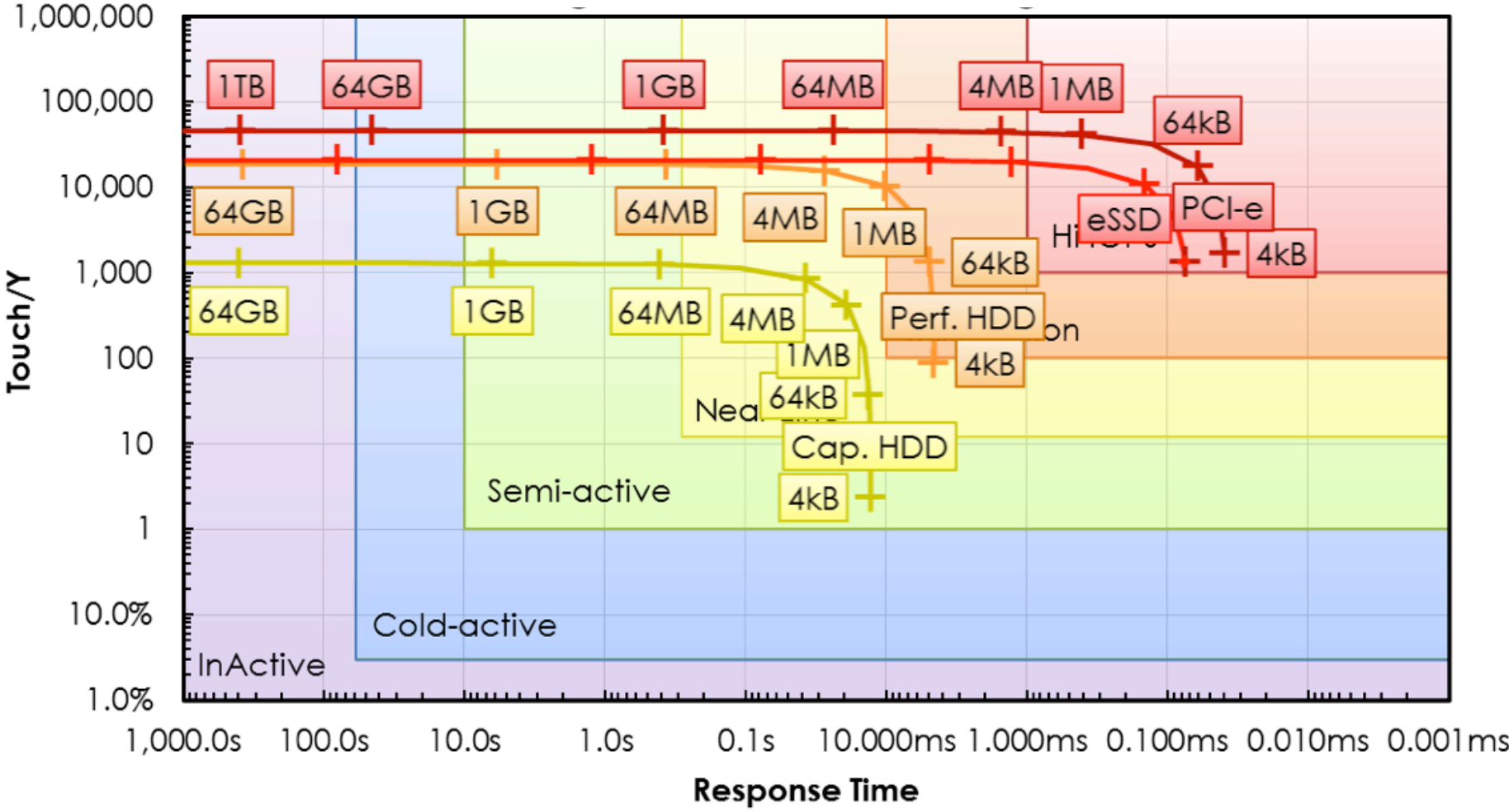
Mapping This To Storage Technologies



2015 EMERGING NON-VOLATILE MEMORY & SPIN LOGIC TECHNOLOGY AND MANUFACTURING REPORT, Coughlin Associates, 2015, http://www.tomcoughlin.com/techpapers.htm

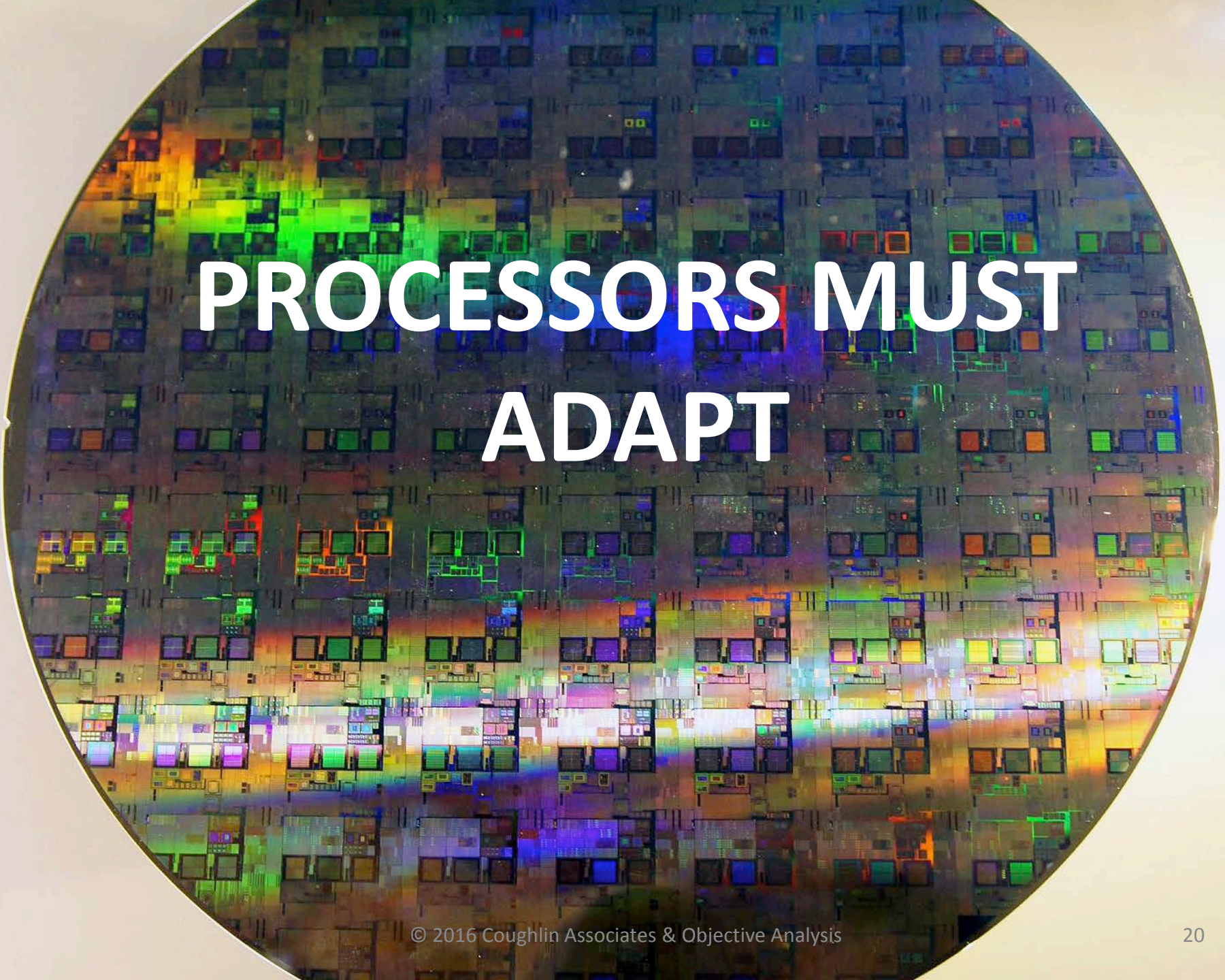
© 2016 Coughlin Associates & Objective Analysis

Real Products Mapped



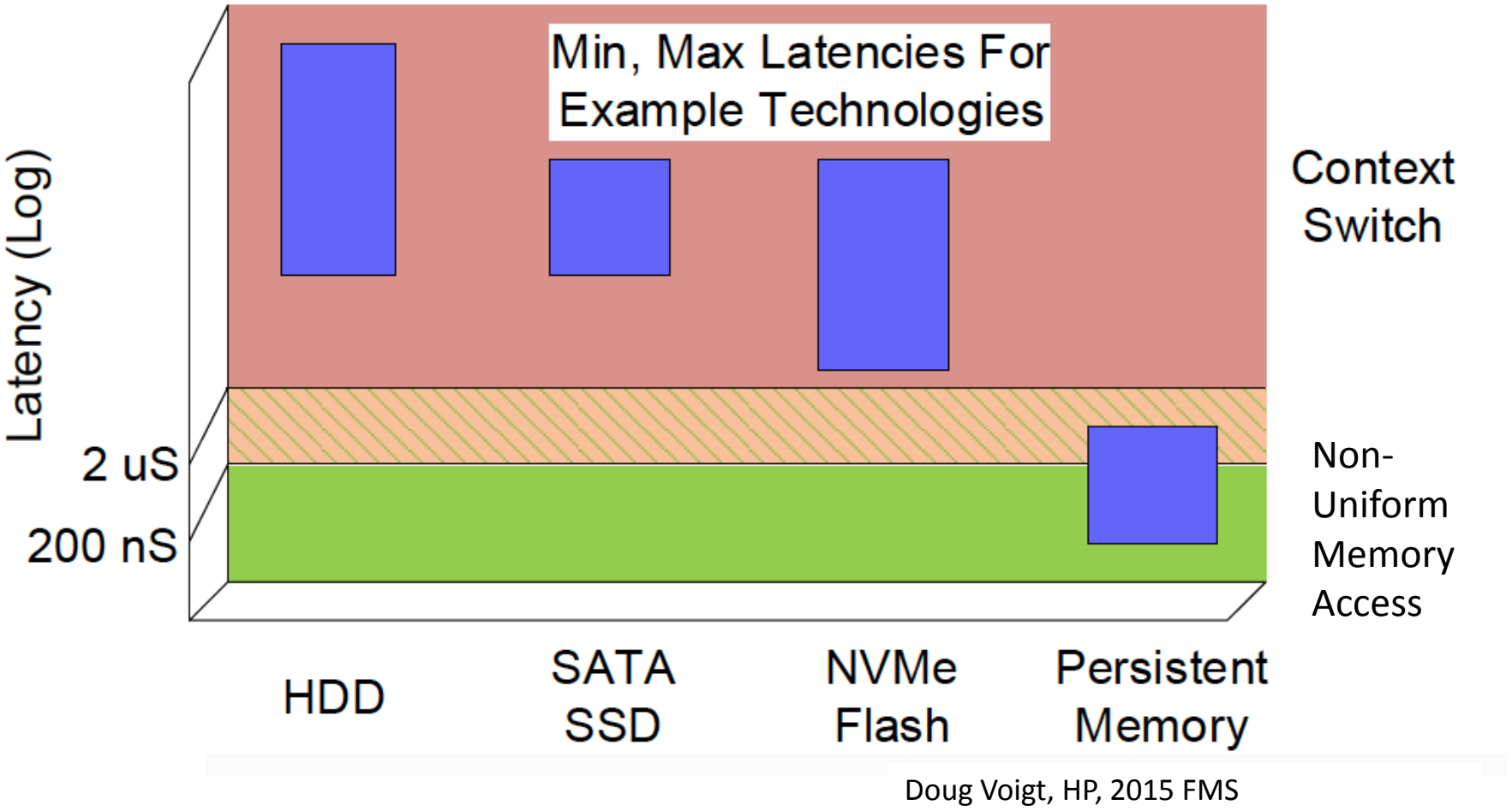
2015 EMERGING NON-VOLATILE MEMORY & SPIN LOGIC TECHNOLOGY AND MANUFACTURING REPORT, Coughlin Associates, 2015, http://www.tomcoughlin.com/techpapers.htm

© 2016 Coughlin Associates & Objective Analysis



© 2016 Coughlin Associates & Objective Analysis

Context Switches Become The Issue



Doug Voigt, HP, 2015 FMS

© 2016 Coughlin Associates & Objective Analysis

Persistent Memory Implications

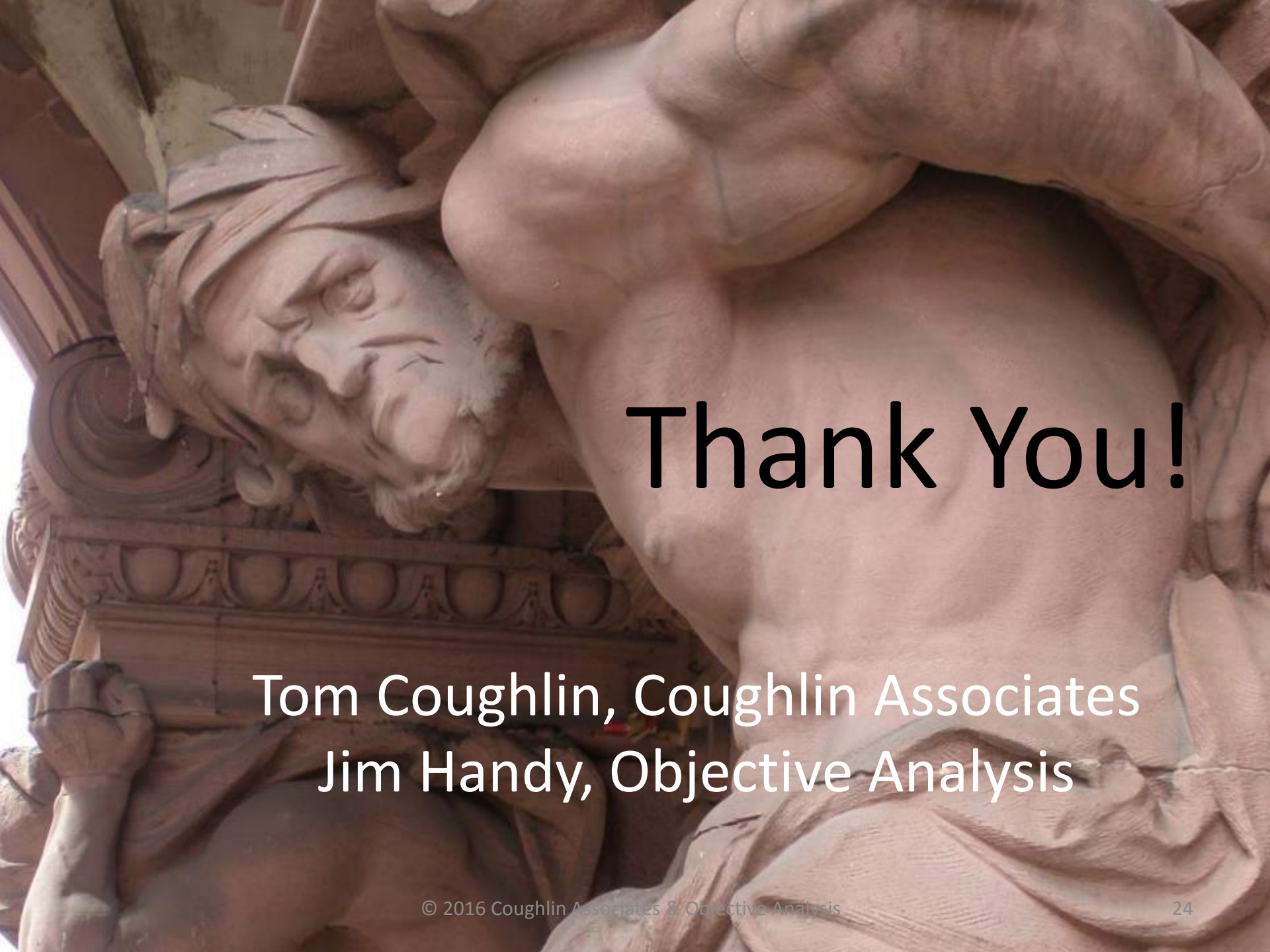
- Retains data during a power loss
  - Instant recovery of state before power down
- Lower latencies than disk
- Lower power than DRAM
- Allows persistent states for Remote Direct Memory Access (RDMA)
- Supports “logic-in-memory architecture”
  - Could lead to new distributed computer architectures

© 2016 Coughlin Associates & Objective Analysis

Summary

- Scaling limits open doors to new memories
  - New architectures will create other opportunities
- NAND is NOW
  - 3D XPoint is coming soon
- Performance drives need for new layers
- New layers will drive new processor architectures
  - Application programs will also adapt

© 2016 Coughlin Associates & Objective Analysis



Thank You!

Tom Coughlin, Coughlin Associates
Jim Handy, Objective Analysis

© 2016 Coughlin Associates & Objective Analysis