# A Complete System Approach to NAND in Computing

Dean Klein

Micron Technology, Inc.

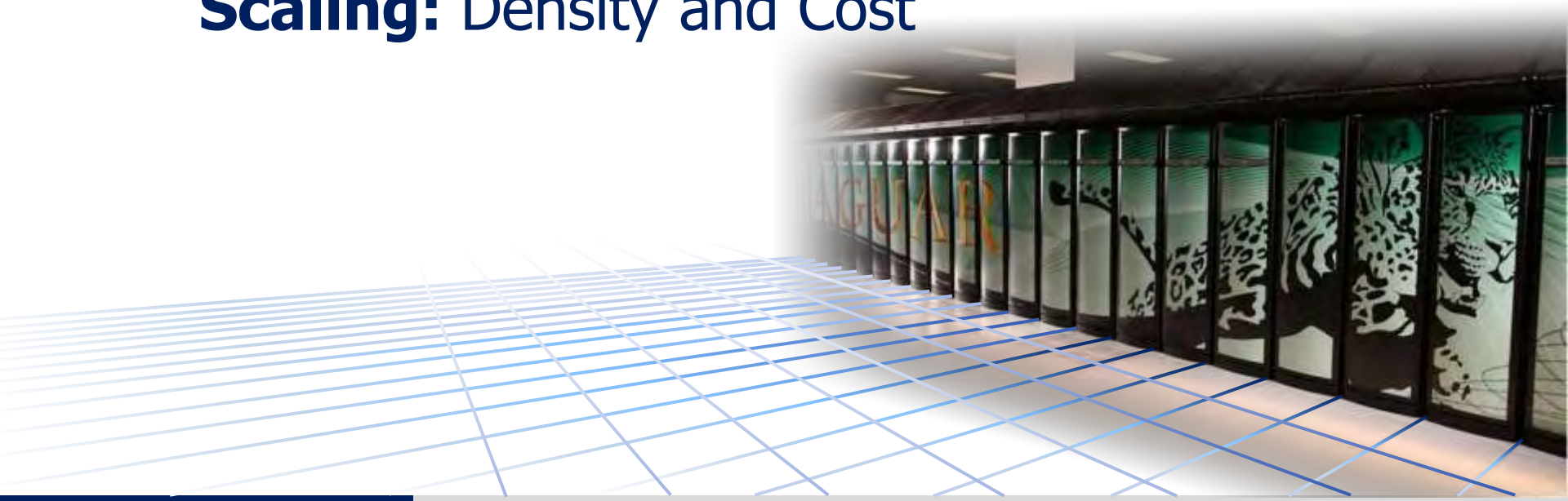
# Issues with Storage (aka: Memory)

**Performance**: The Memory Wall

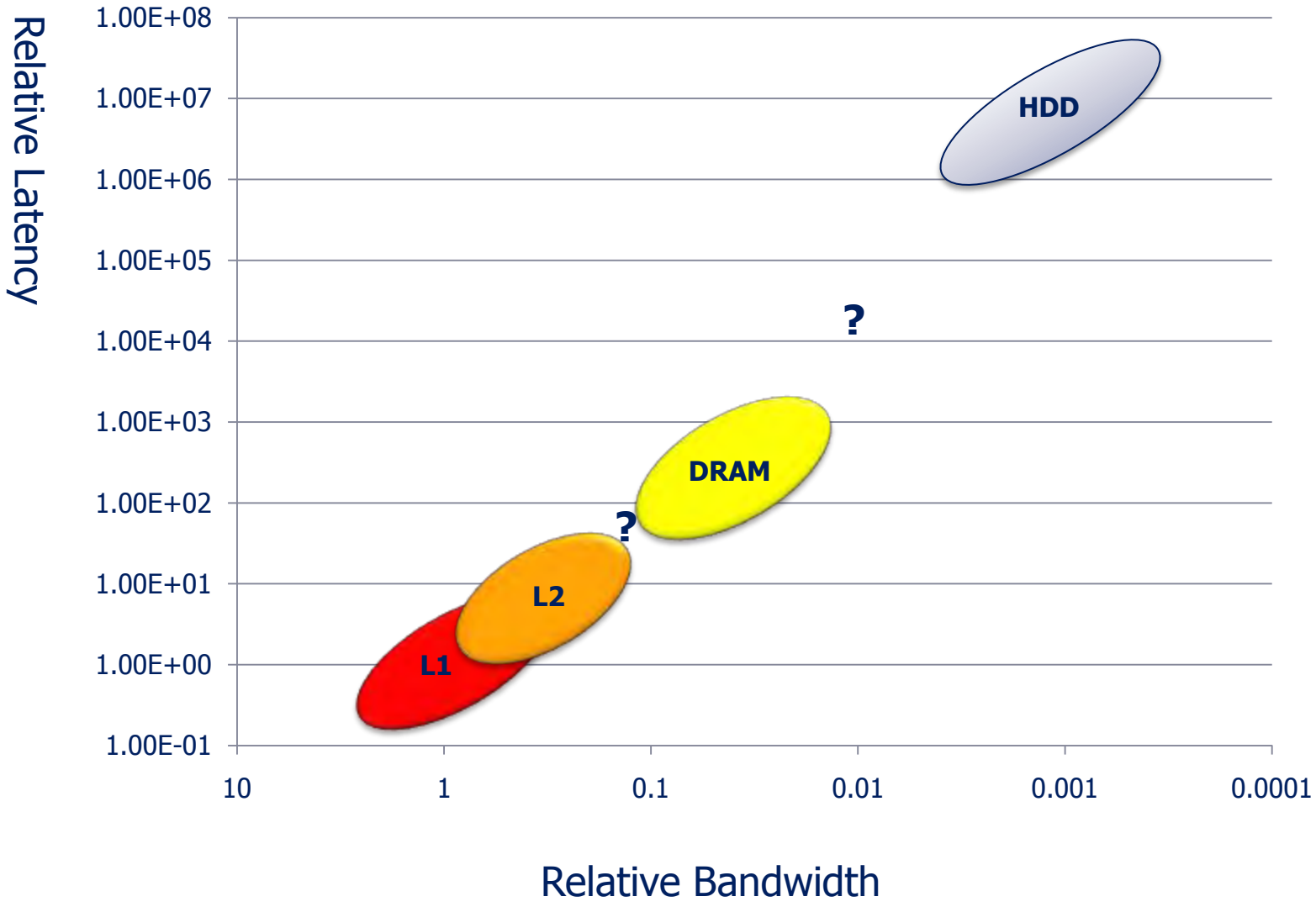
**Power**: Exabytes and Megawatts

**Reliability**: Redundancy and Resiliency

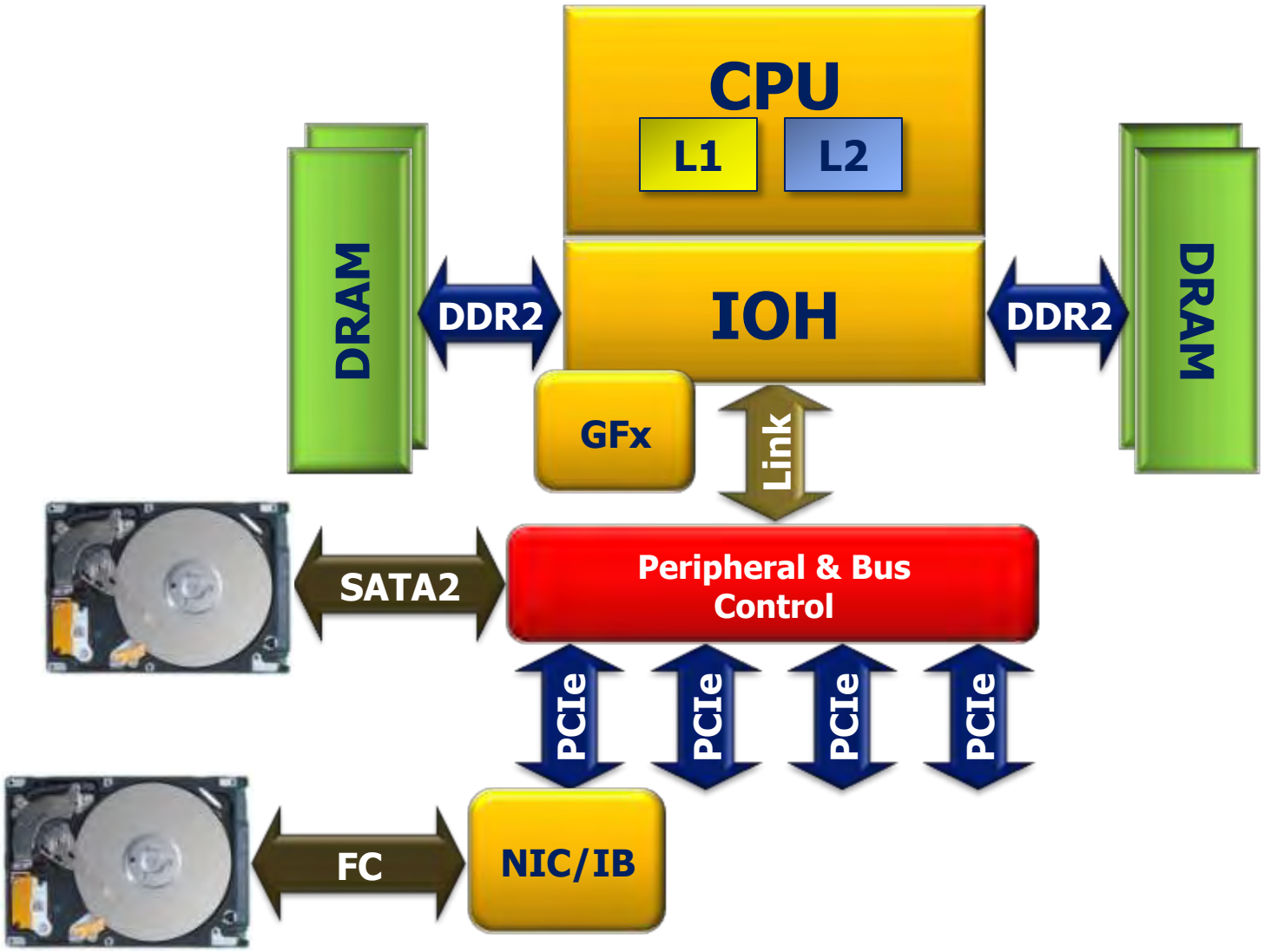
**Scaling:** Density and Cost



# Memory Hierarchy Gaps



# System Architecture



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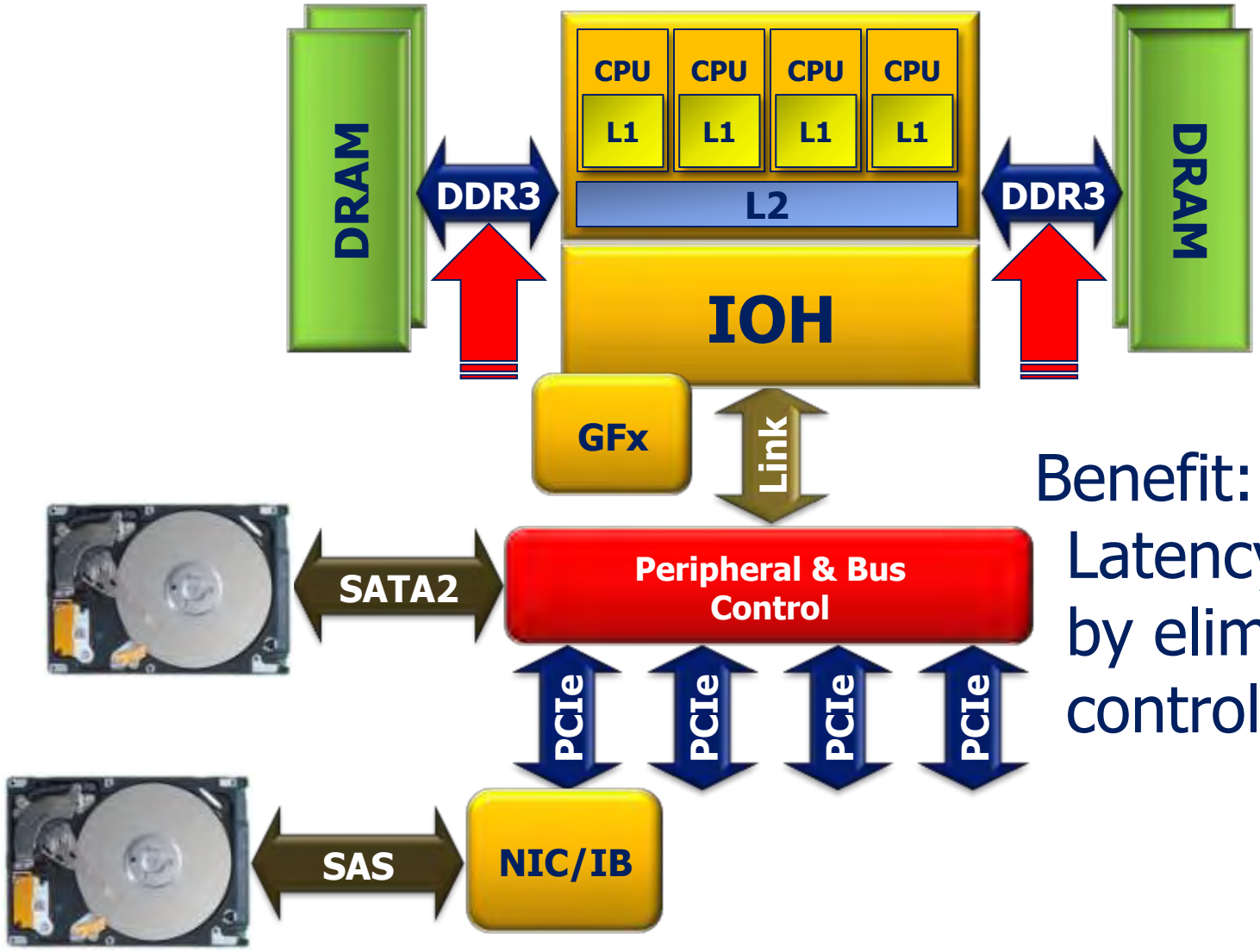


Benefit:

Latency reduction by elimination of controller "hops".

# **DDR4:** Memory Architecture Improvement

DDR4 is coming – High Bandwidth, Low Power, High Density

## **Major Advantages** of DDR4:

- High Bandwidth: **Up to 3.2 Gbps**
- Power Consumption: **1.2V** is 10-15% improvement over DDR3 & DDR3L
- High Density: 2Gb - 16Gb; **up to 8H** (128Gb stack); **single load**
- DDR4 **cost overhead** appears **better than** previous 1st gen technologies
- **Power, density and bandwidth:** Optimized for HPC and servers

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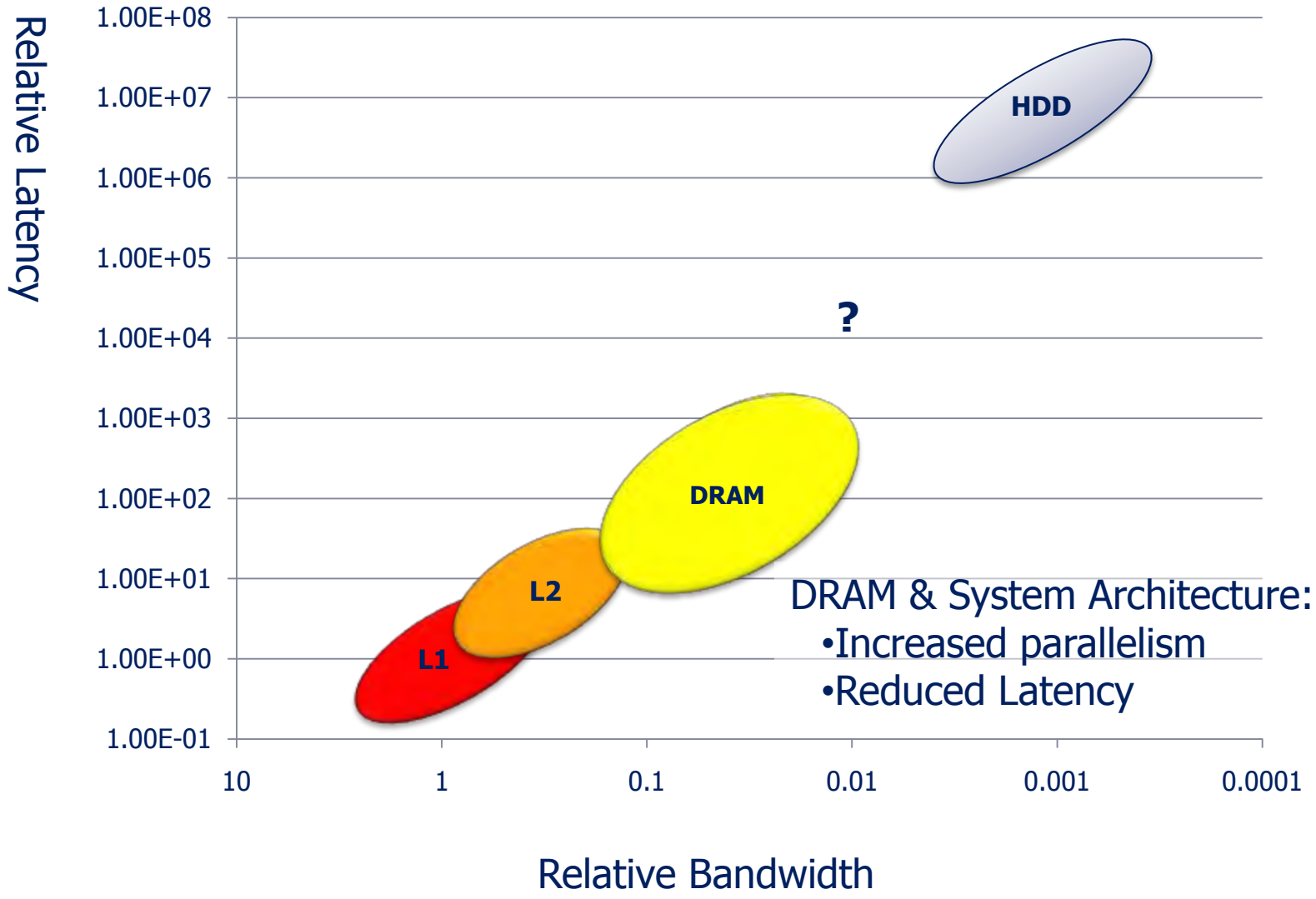

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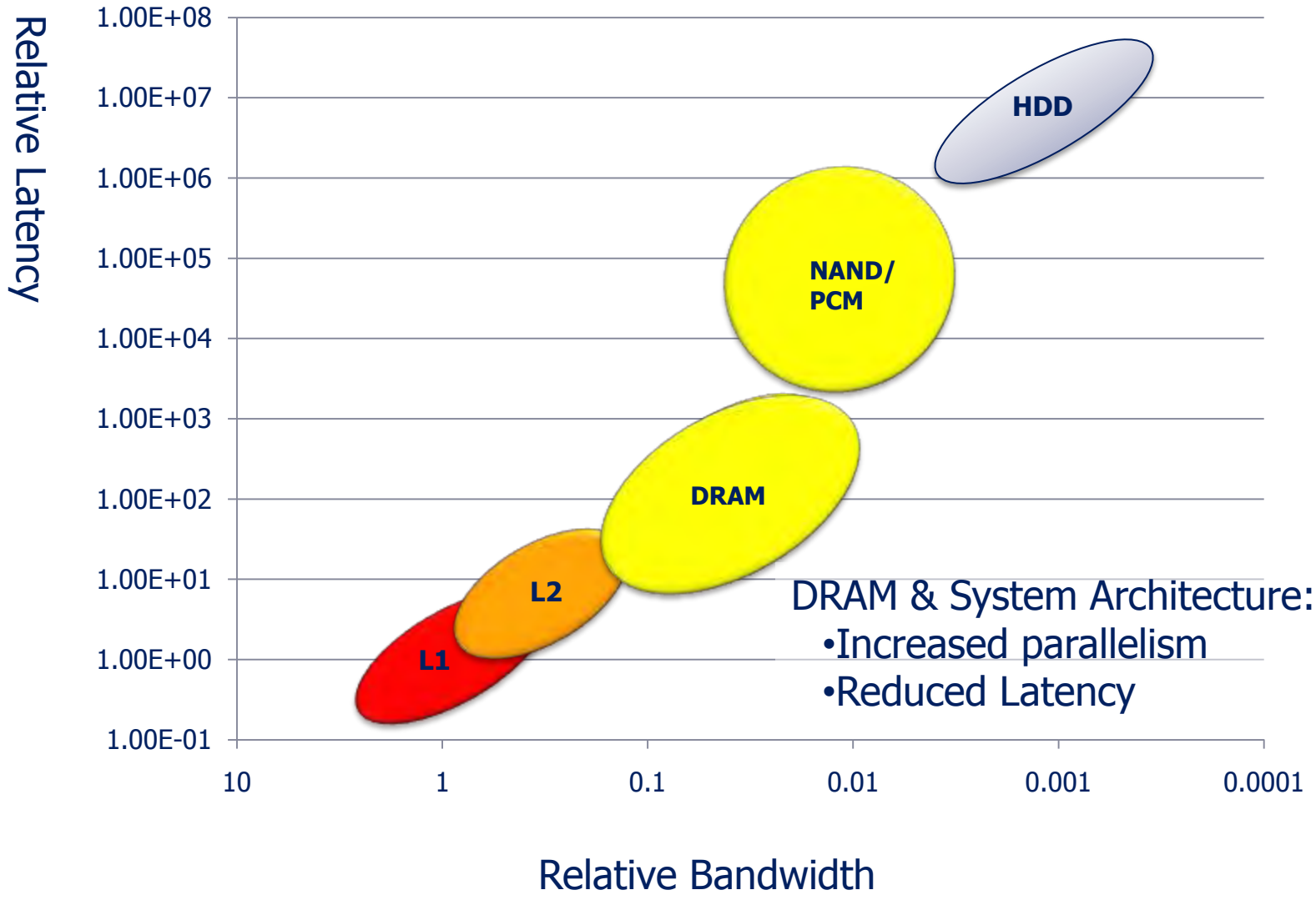


# Requirements

- Low random latency:
  - As the number of CPU cores (and thus the parallel tasks) increase the traffic becomes increasingly random.
  - As the use of VM's increase the traffic becomes increasingly random.
- High endurance:
  - Accepted DRAM endurance is >1E15 cycles.
  - Accepted NAND endurance is <1E5 cycles or 3E3 cycles.
- Intelligent management

# Closing the Storage to DRAM Gap

- Technical requirements:
  - Low latency
  - High endurance
  - Symmetric read and write
  - Block-based architecture
  - Able to use existing interfaces
- Economic requirements:
  - Lower cost/bit than DRAM
  - Lower power than DRAM

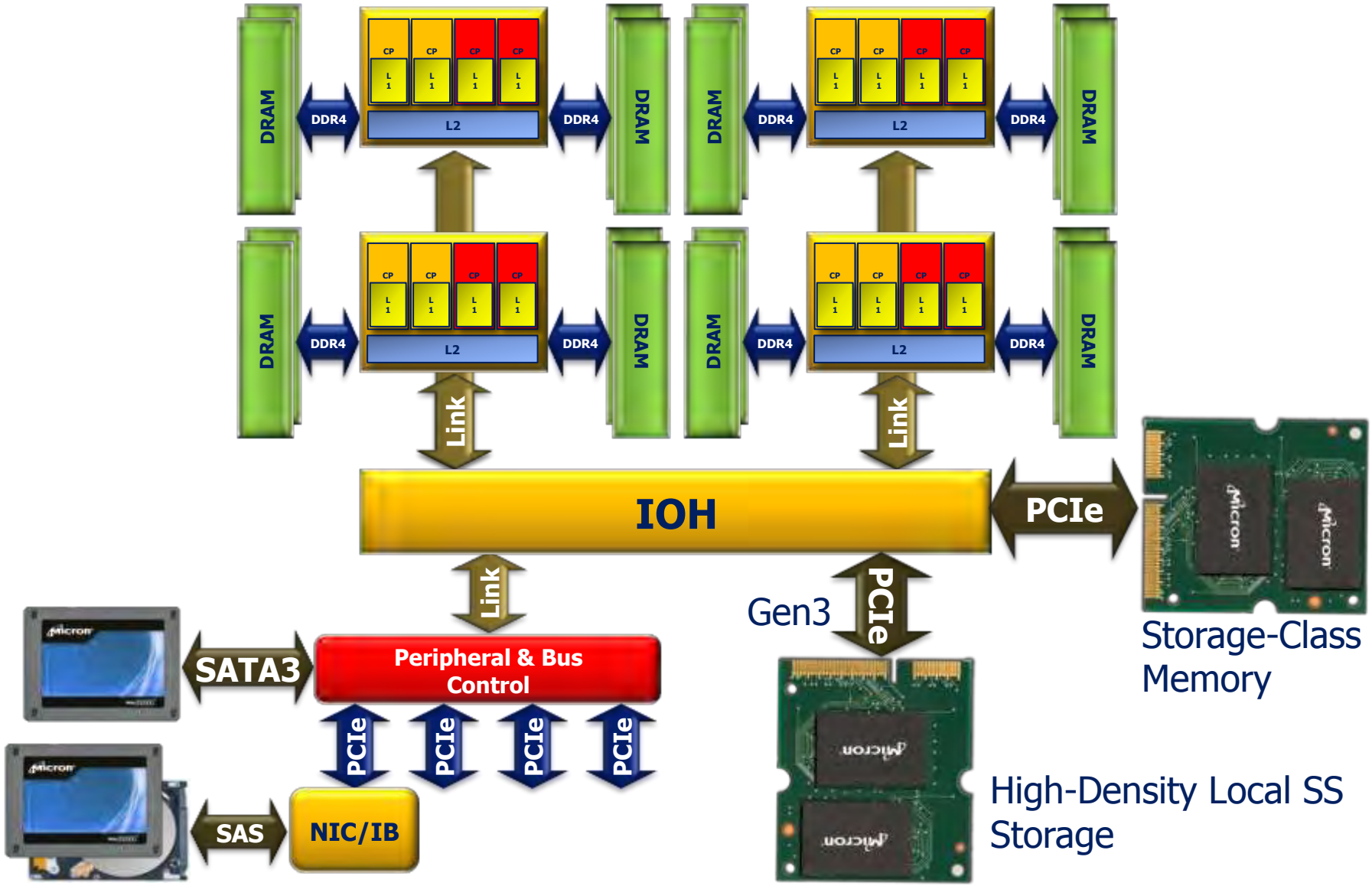
**STEP 1: SSD**

**STEP 2: SCM**

# NAND Endurance

- NAND Process and Design
  - + Improved processes: new materials and structures
  - - Smaller geometries: fewer electrons and more interference
- SSD Architecture and Algorithms
  - + Improved error handling and efficiency
  - ++ NAND optimizations

# Fast Forward: Future System Architecture



# Solid State Storage as the Ultimate Cache

- Pinnable, secure, high performance.
- System software can:
  - Mitigate wear
  - Allow graceful degradation
  - Accelerate slower storage, both local and remote
- Fits with SSD today and PCM tomorrow.
- Can take advantage of lower latency, higher bandwidth connections.
- Optimized solution is integrated solution.

# The Holistic Approach to Storage

- The gap between CPU and main memory is being closed by architecture and DRAM advanced.
- The gap between DRAM and storage is widening.
- Increasing randomization of storage traffic demands a storage system with low random latency.
- Endurance requirements will dictate advanced NAND management, and must include system software as a part of the solution.
- NAND, and ultimately PCM, will close the storage gap.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