Flash Memory Summit

HPC Driven Motivations for Ordered Key-Value Based Computational Storage

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LA-UR-22-27931

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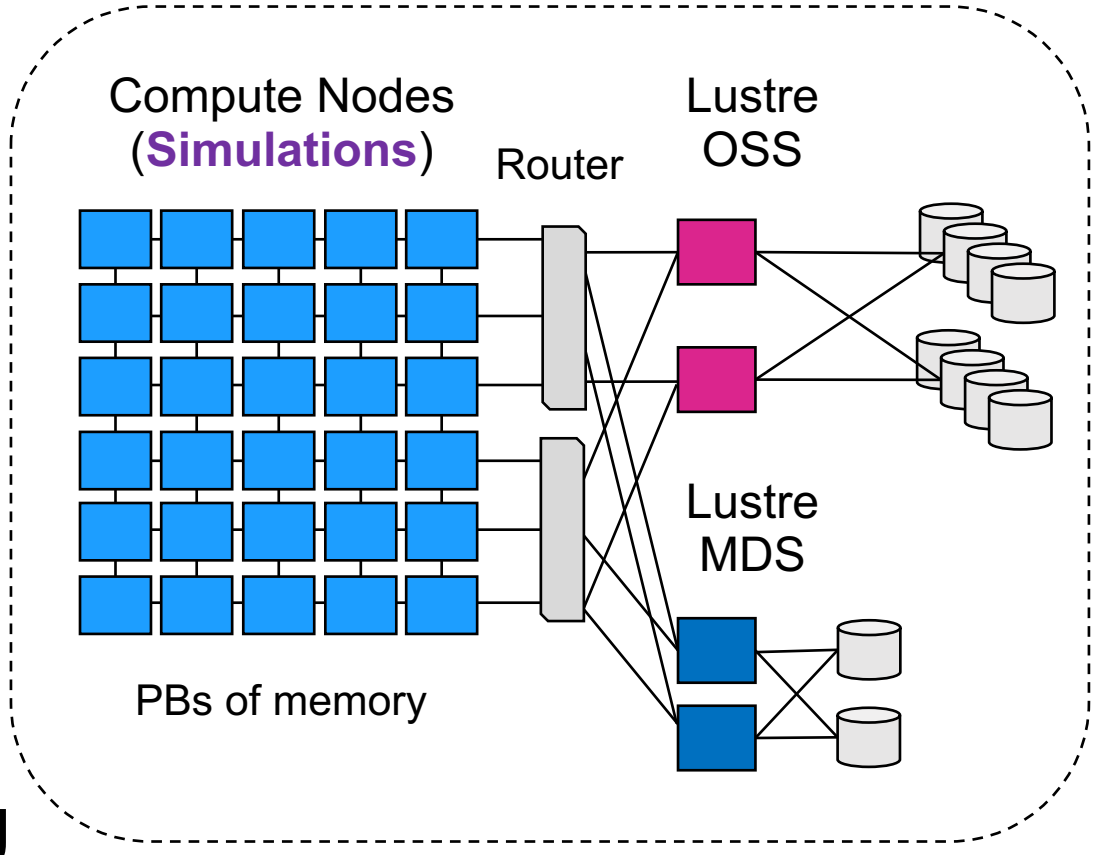
Typical HPC Simulation Workflow at LANL

- Simulation writes state to storage periodically
- Analysis code later reads data back for in-mem operations (e.g.: movie making)
- Data may not compress
- Performance depends on fully utilizing available storage bandwidth



Current HPC Platform

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Emerging Trends: Analysis Increasingly Selective

- Analysis used to require seeing all data records
- Today: queries tend only to hit a small subset of data
- Problem: how to retrieve just interesting rows?

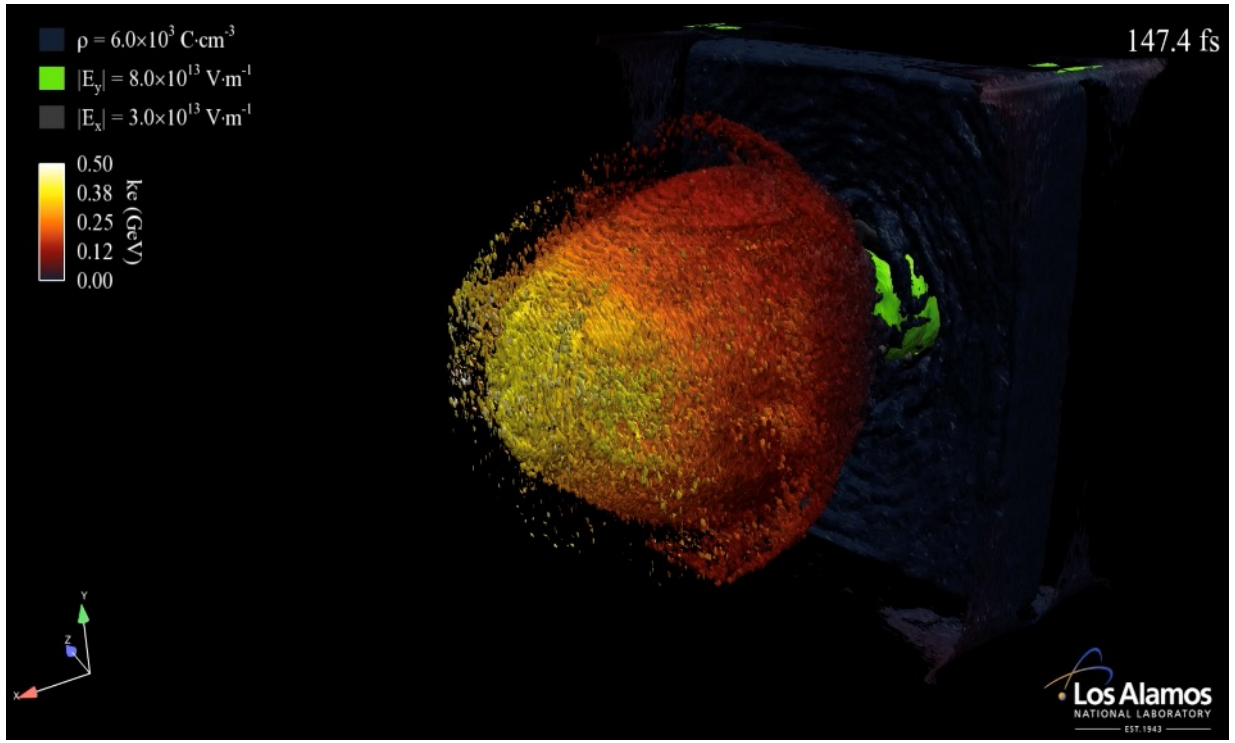

Image from LANL VPIC simulation done by L. Yin, et al at SC10

Example: SELECT X, Y, Z FROM particles **WHERE** E >= 1.5

Less than **0.1%** needs to be read from storage

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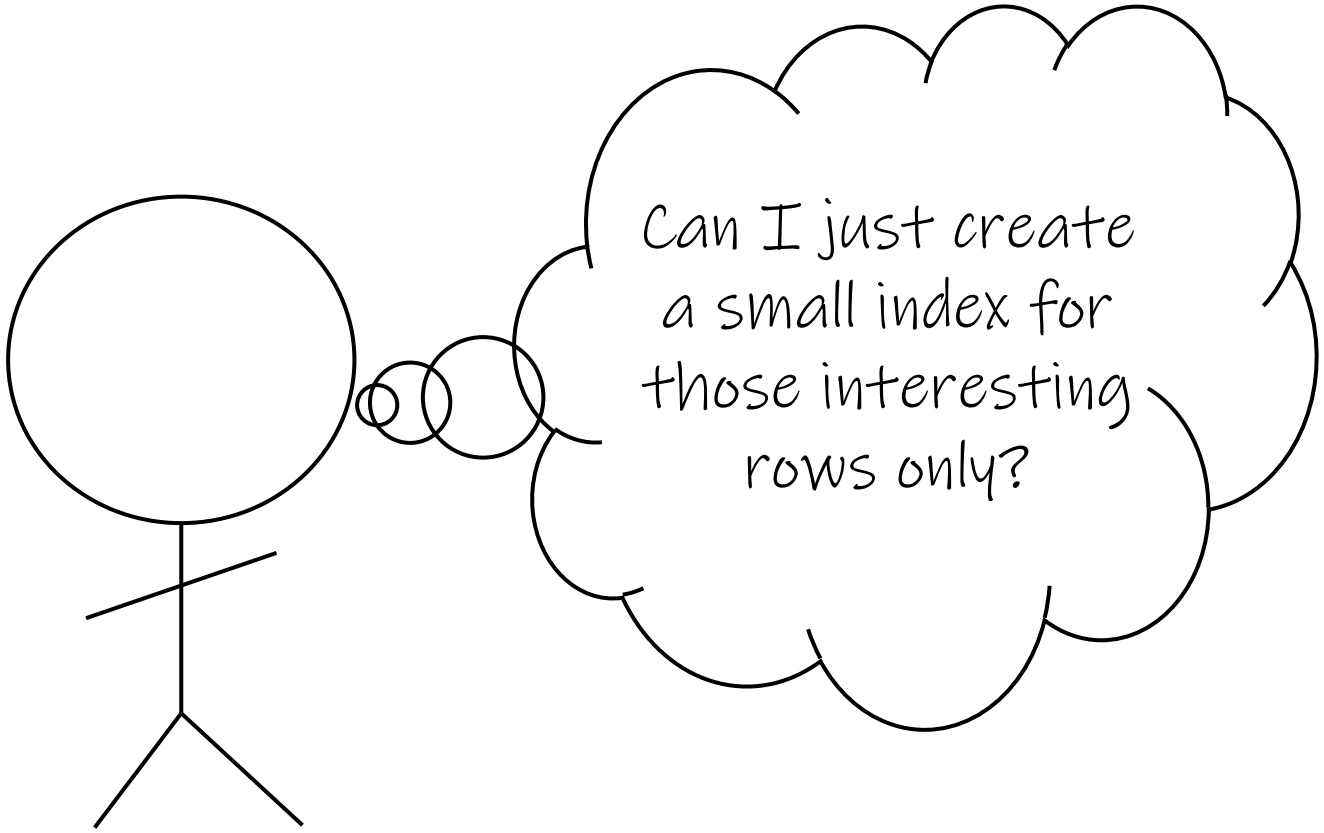
Reading Back Just Interesting Data is Non-Trivial

- Data known to be interesting only at simulation end
- Indexing only works when all rows are indexed at all timesteps
- Compute node resources are limited
- Sorting only helps one query



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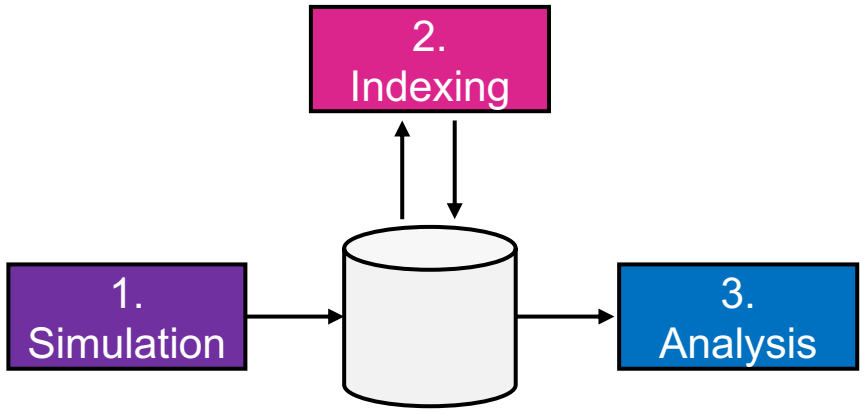
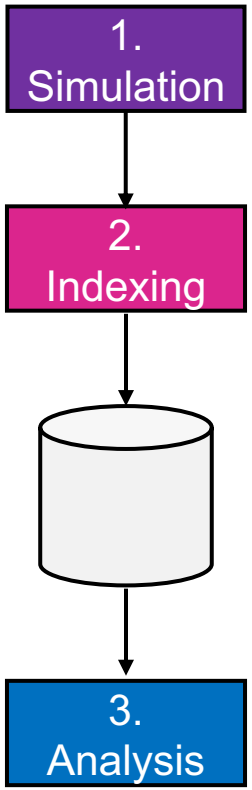
Existing Solutions Fall Short in Different Ways

Post-processing

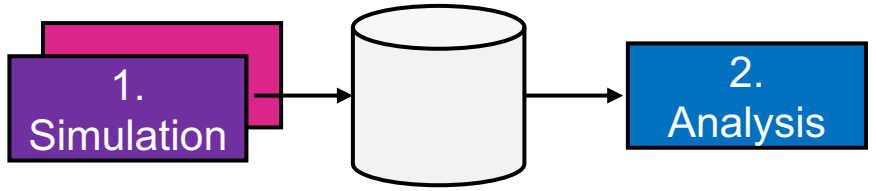


Excessive data movement

In-transit processing



In-situ processing



May only produce indexes
on 1 or few columns

Requires additional compute nodes than the job

Does not work for larger jobs

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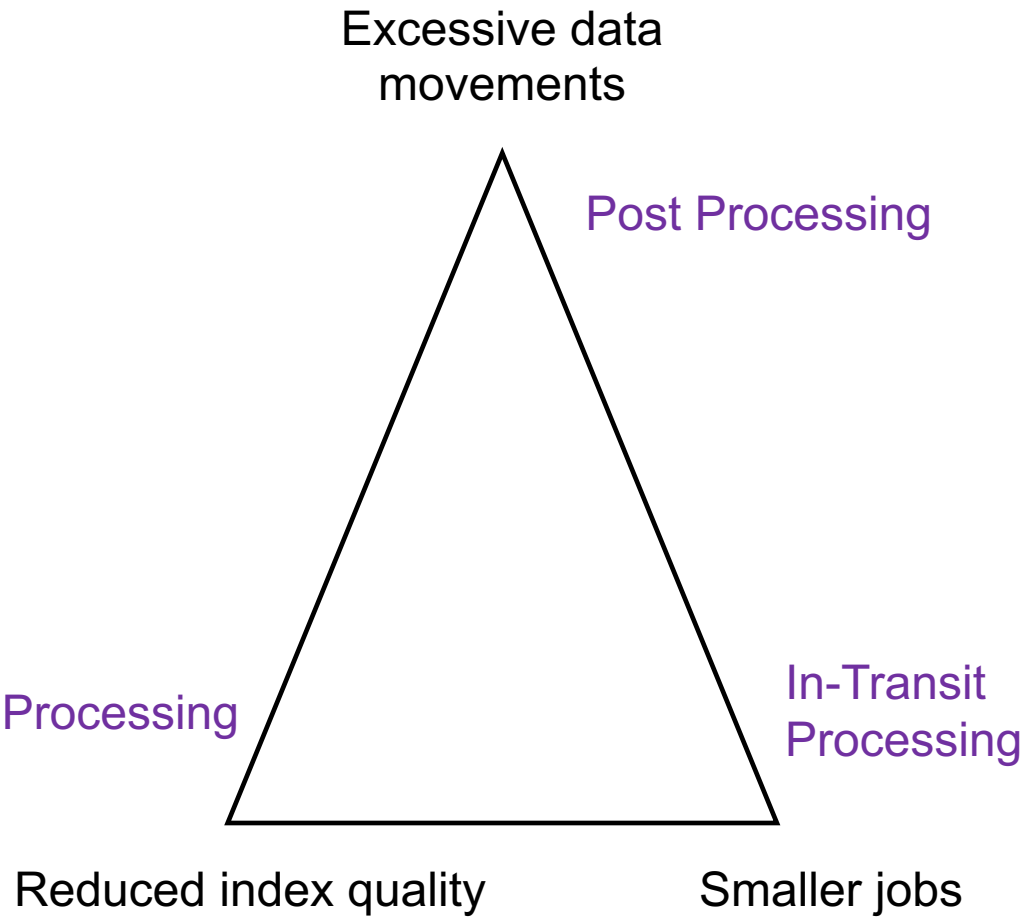
Opportunities for Rapid Query Acceleration

- Today: all computation takes place on compute nodes
- Excessive data movements or reduced index quality or increased per-job resource footprint
- Computational storage allows for overcoming existing solution limitations



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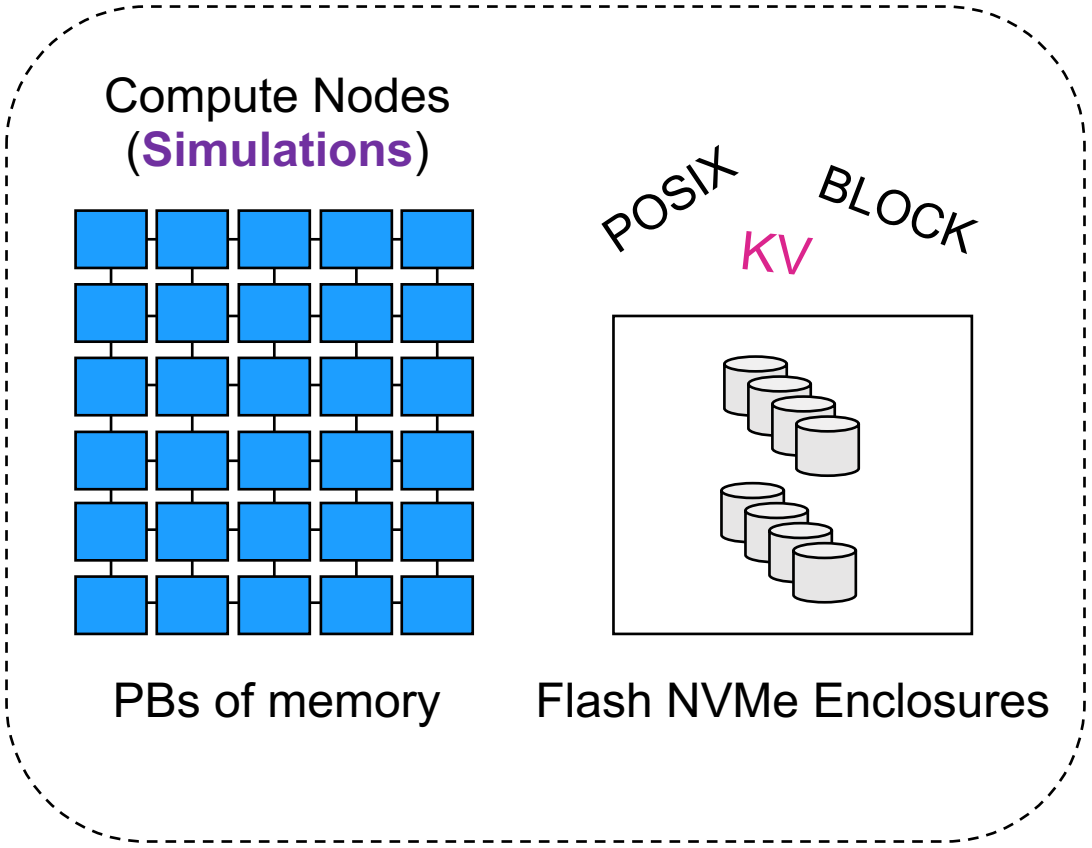
Towards KV-Based Storage Spaces for HPC

- KV namespaces in addition to POSIX and block for accelerated data indexing & analytics
- No one-size-fits-all: app chooses the best abstraction for the job at hand
- Dynamic platform: portions of KV change over time



Next-Gen HPC Platform

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HPC-Driven KV Storage API

- Data insertion:
  - Bulk KV put operations
- Reads:
  - Range queries
  - Secondary indexes
  - Histogram construction
- Management:
  - Compaction control
  - Per key space data export

SK hynix

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PAVILION

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LANL is collaborating with industry for accelerated KV storage that speeds up scientific discovery

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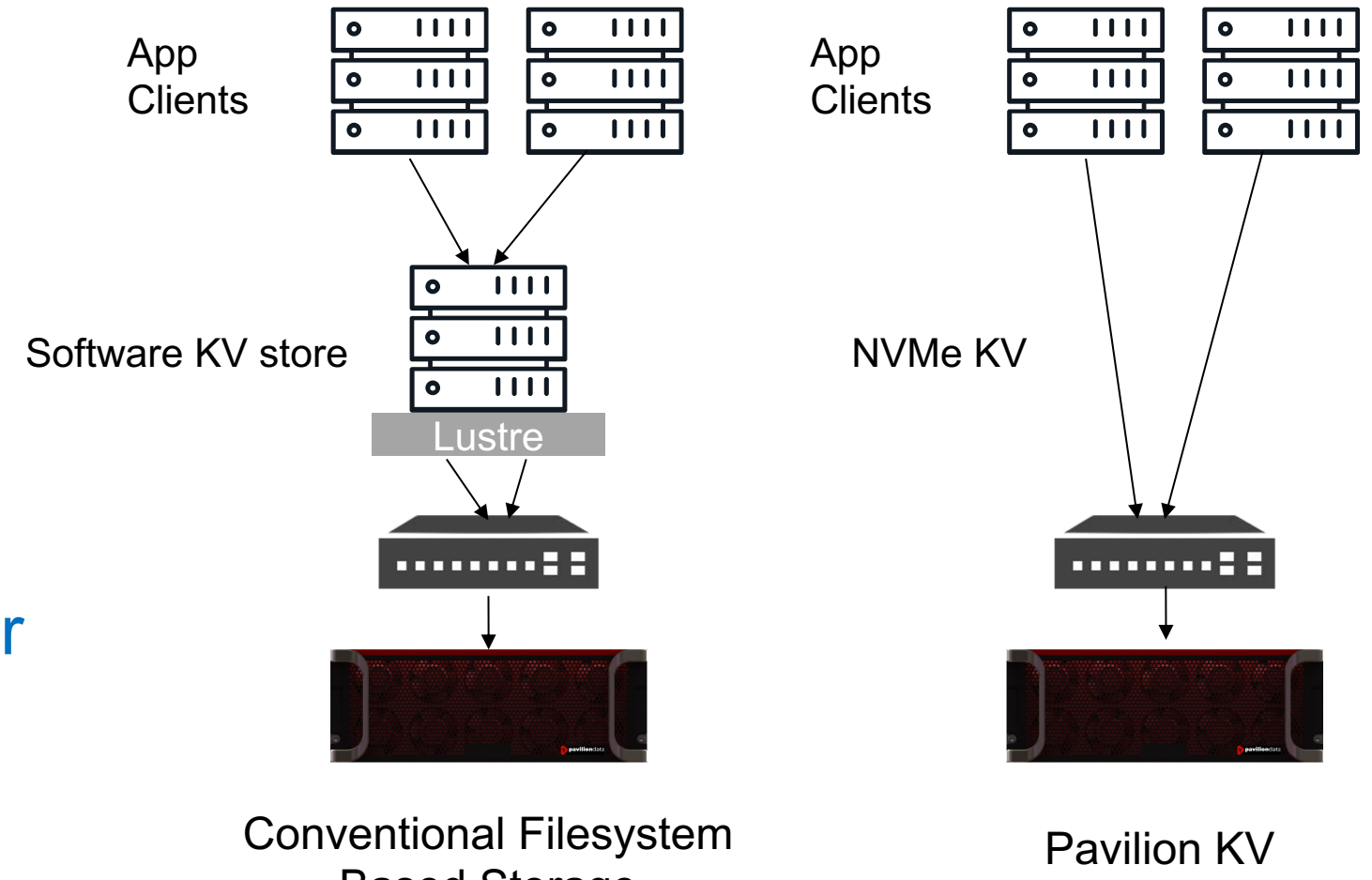
Pavilion Next-Gen KV Storage

- Server-based accelerated KV storage
- Access via NVMeOF
- Orders of magnitude faster than software KV



Conventional Filesystem Based Storage

Pavilion KV

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SK Hynix KV-CSD Prototype

- FPGA-based, hardware accelerated KV SSD
- Access via local PCIe
- ZNS storage for increased performance and longer SSD life span

More info: SARC-302-1: Computational Storage Solutions

1:25pm Ballroom G

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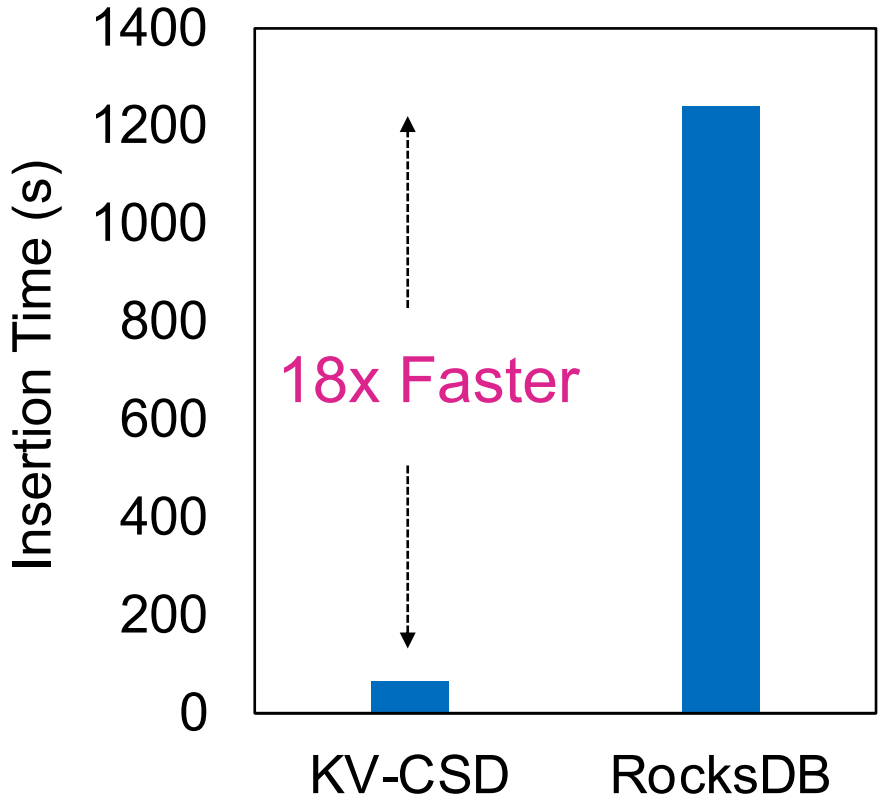
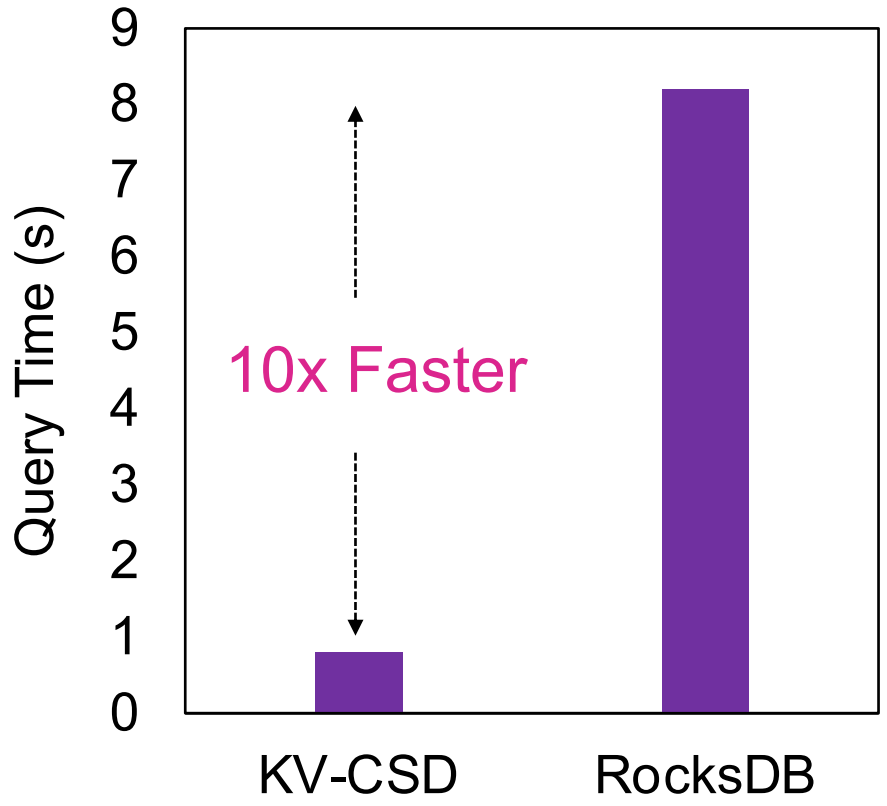
Preliminary Results: SK KV-CSD vs RocksDB





Data Insertion: Up to 18x faster

Queries: Up to 10x faster

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Conclusion

- Massively-parallel computing and full bandwidth utilization will continue to matter
- But efficiently handling massive amounts of small objects and highly selective queries will be as critical going forward
- Implications: more diverse storage abstractions, more extensive processing offloading

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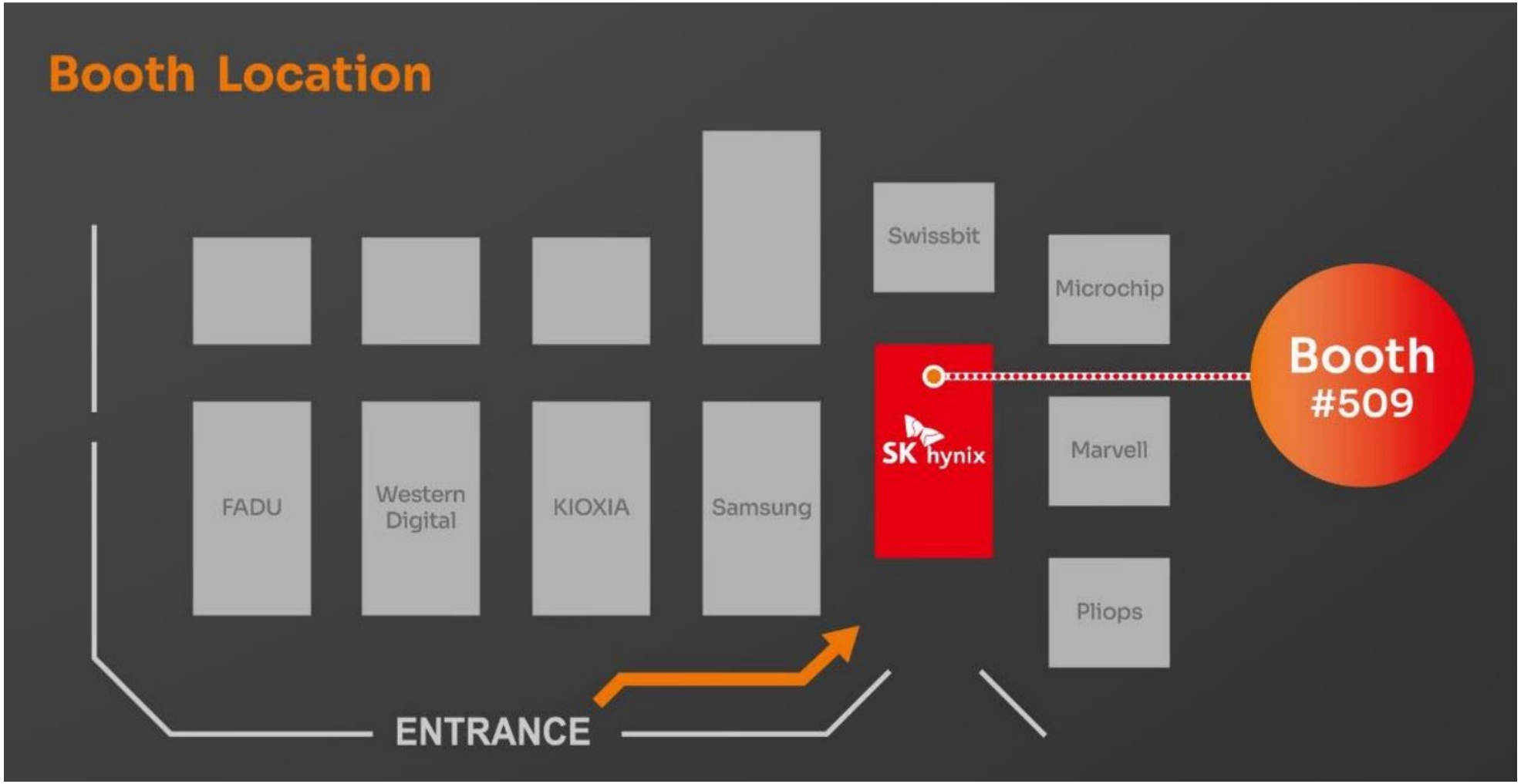
Co-Demonstration with SK Hynix



See you there!

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