Engineering Database Hardware and Software Together
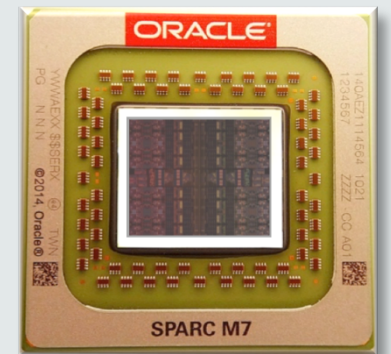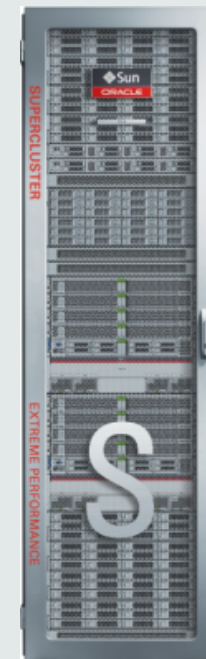
From Engineered Systems to SQL in Silicon

Juan Loaiza
**Senior Vice President**
Oracle

Safe Harbor Statement

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Engineering Database Hardware and Software

- Existing Engineered Systems deeply integrate Database Software with best-of-breed hardware
  - Exadata and Supercluster

- This year Oracle extends integration to the Microprocessor Level

- Customer Benefits:
  - Performance, Reliability, Cost, Security
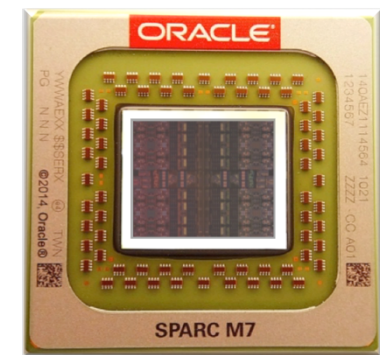
Oracle Exadata Database Machine
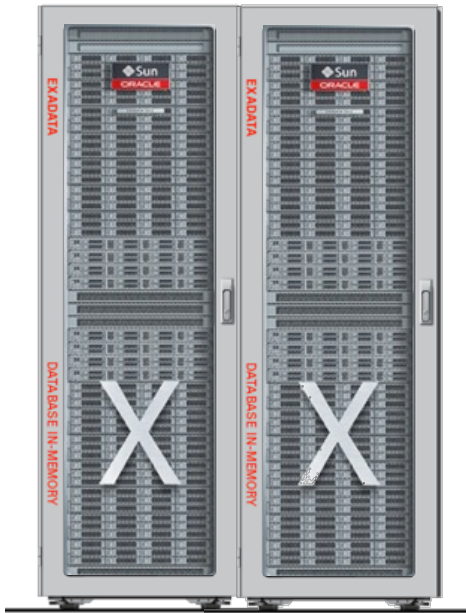
- Scale-out, database optimized compute, networking, and storage <u>hardware</u> for fastest performance and lowest costs

- Unique <u>software</u> and protocols enable fastest and most efficient <u>OLTP, Analytics, and Consolidation</u>

- Delivered integrated, optimized, automated, and supported end-to-end to reduce operations costs

4

Exadata Hardware

Compute Server
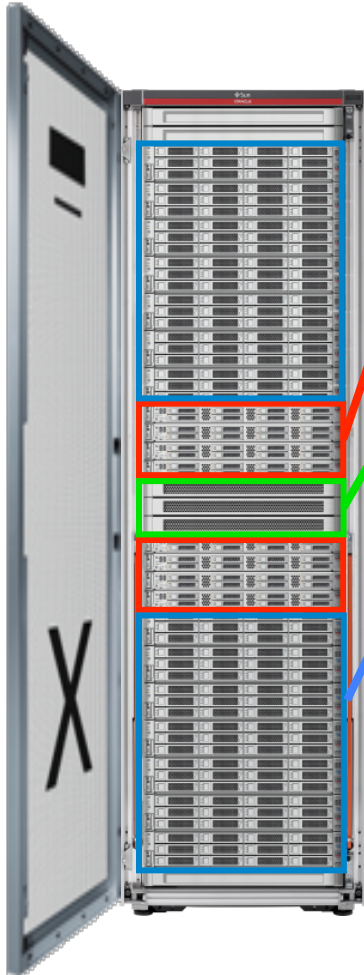
Storage Server

- **Compute Servers**
  - Latest fastest processors, largest memory

- **Unified Network -** InfiniBand for fastest performance

- **Storage Servers**
  - 2-socket servers - low-cost and power CPUs
  - Fastest PCIe flash combined with high capacity disk for best performance, capacity, and cost
  - Data is duplicated across storage servers for high availability

- **Scale by adding more compute or storage servers as needed**

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System Level Engineering of Database Software and Hardware

- **Data Warehousing**
  - SQL Offload to storage servers enables full flash bandwidth (100s of GB/sec)
  - Flash bandwidth is too high for network
- **OLTP**
  - Database calls InfiniBand NICs directly bypassing O/S to achieve millions of IOPS
  - Smart Flash logging accelerates commits
- **Availability**
  - Instant server death detection by integrating with InfiniBand switches
  - Sub-second I/O failover caps I/O latency
  - Mirroring of In-Memory Database data
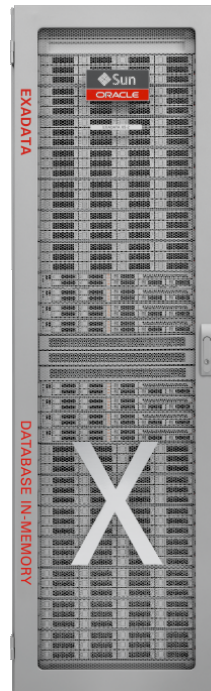
- **Storage**
  - Achieve flash speed with disk capacity by intelligently caching data in flash
  - Flash Cache automatically converts data to columnar format for faster analytics
- **Safe Consolidation**
  - I/Os prioritized in storage servers by database, or SQL user, or SQL job
  - Low latency network traffic uses separate network lanes from high bandwidth traffic
    - E.g. separate Commit message and Report

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Thousands of Mission Critical Deployments

- **Petabyte Warehouses**

- **Business Applications**
  - SAP, Oracle, Siebel, PSFT, ...

- **Online Financial Trading**

- **E-Commerce Sites**

- **Massive DB Consolidation**

- **Public SaaS Clouds**
  - Oracle Fusion Apps, NetSuite, Salesforce, ...

4 out of the 5 Largest Banks, Telecoms, Retailers Run Exadata

Deployments are Mix of OLTP and Analytics

- Half of deployments primarily OLTP, half Analytics
  - Many run mixed workloads
- Some say you need a specialized product for each workload, Oracle and the market disagree
  - Key is specialized <u>algorithms</u>, not specialized <u>products</u>
  - Specialty products die as specialized algorithms are added to general databases
- General databases have 4 big advantages
  - Handle mixed and complex use cases
  - Less need for complex cross product data motion
  - Much better operational attributes
    - Security, management, backup, availability, scaling, etc.
  - Simpler – less moving parts to learn/operate/patch/secure

Next Big Integration Focus: In-Memory Database

Oracle Database in Memory DB, Released Summer 2014

Real Time Analytics	**Directly on OLTP Data**	**No Changes to Applications**	**Trivial to Implement**

100x

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Row Format Databases vs. Column Format Databases

**Rows Stored Contiguously**

SALES

- **Transactions** run faster on row format
  - Example: Query or Insert a sales order
  - Fast processing few rows, many columns
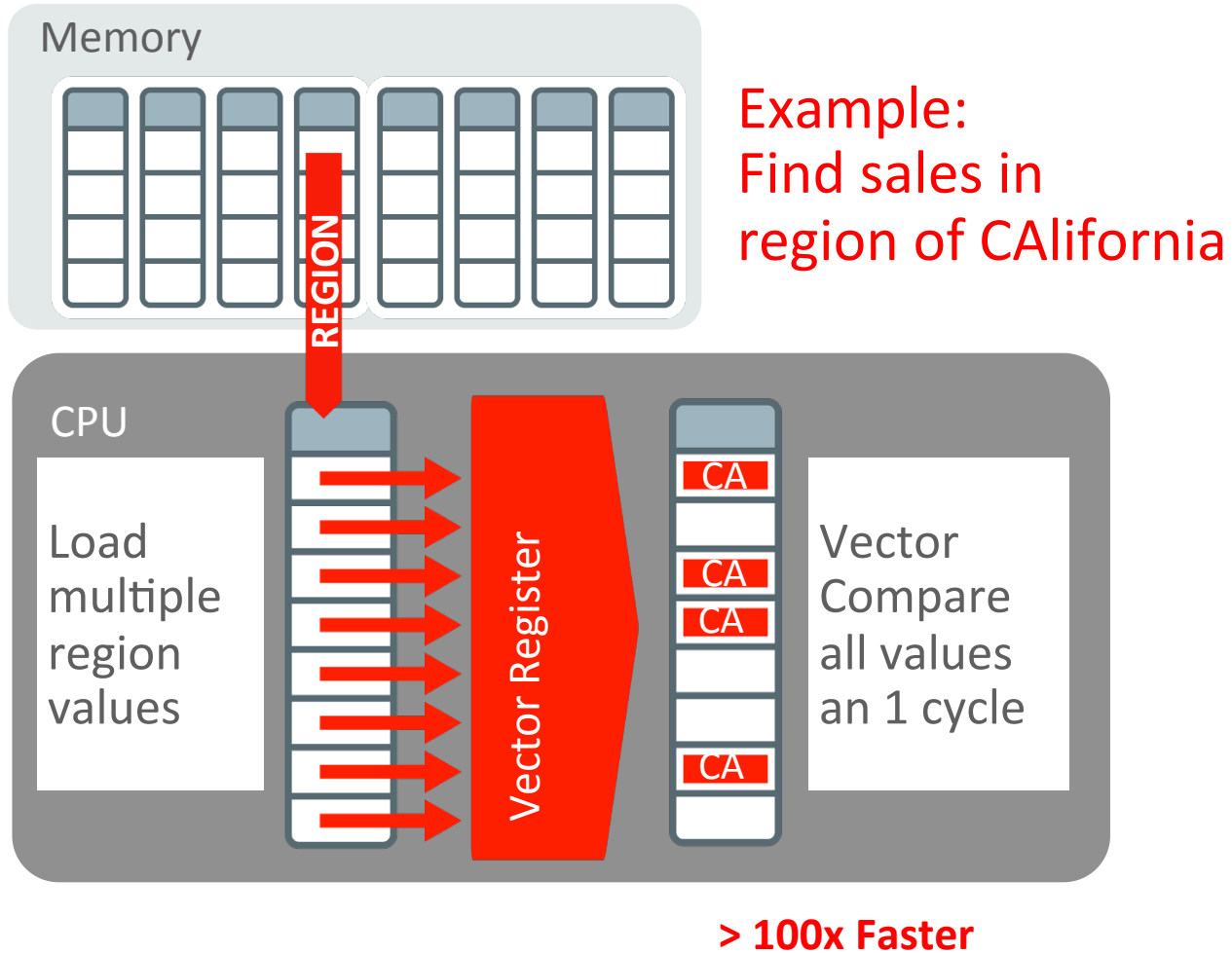
Columns Stored Contiguously

SALES

- **Analytics** run faster on column format
  - Example : Report on sales totals by region
  - Fast accessing few columns, many rows

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Oracle Dual Format Architecture

Normal Buffer Cache

SALES

Row Format

New In-Memory Format

SALES
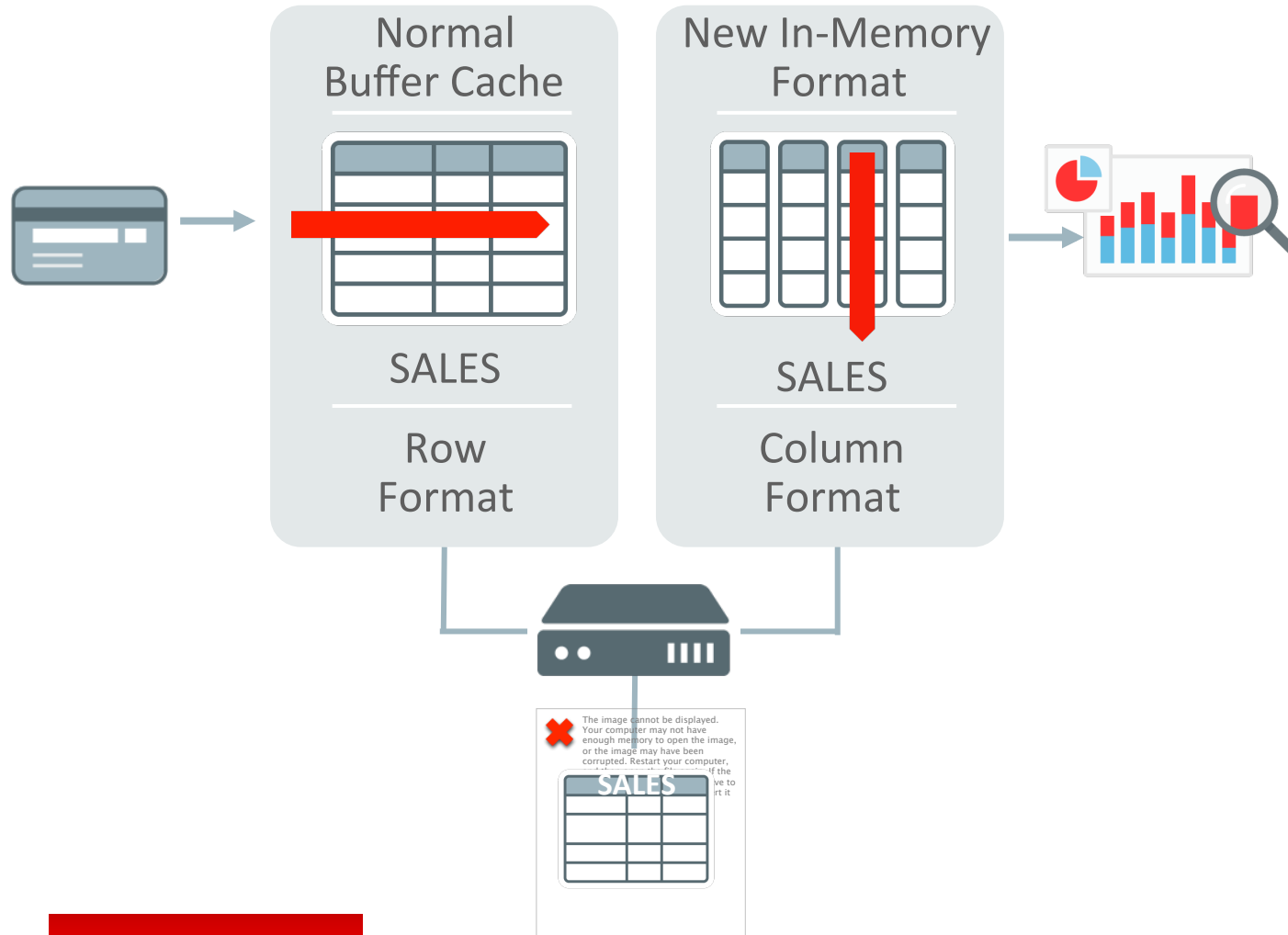
Column Format

- **BOTH** row and column formats for same table

- Simultaneously active and transactionally consistent

- OLTP uses proven row format

- Analytics & reporting use new in-memory Column format
  - Not persistent, and no logging
  - Quick to change data: **fast OLTP**

- Full Scale-Out and Scale-Up

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Orders of Magnitude Faster Analytic Data Scans

Memory

REGION

CPU

Load multiple region values

Vector Register

Example:
Find sales in region of CAlifornia

CA
CA
CA
CA

Vector Compare all values an 1 cycle

> 100x Faster

- Each CPU core scans local in-memory columns

- Scans use fast SIMD vector instructions

- **Billions of rows/sec** scan rate per CPU core
  - Row format is millions/sec

Coming in 2015: SPARC M7 SQL in Silicon

SPARCing a SQL Performance Revolution

SQL in Silicon
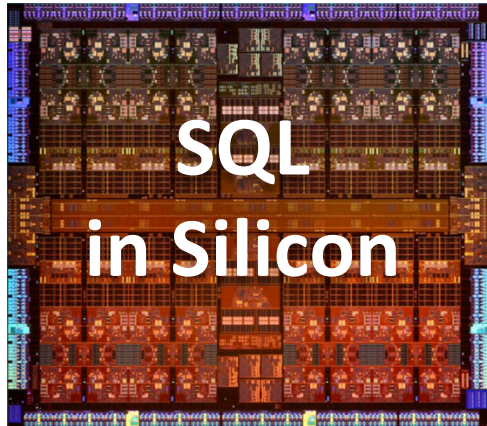
- Traditional DB algorithms too complex for chips
  - Code is large with lots of branches and random accesses
  - Speedups came from more CPU cores, bigger caches, etc.

- Big Change: In-memory columnar is much simpler

- 5 years ago Oracle initiated a revolutionary project
  - Build fastest ever conventional microprocessor
    - 32 cores, 16 DDR4 Channels, 160 GB/sec measured bandwidth
  - Add **In-Memory DB** operations directly on chip

- First high-volume CPU with native SQL optimizations
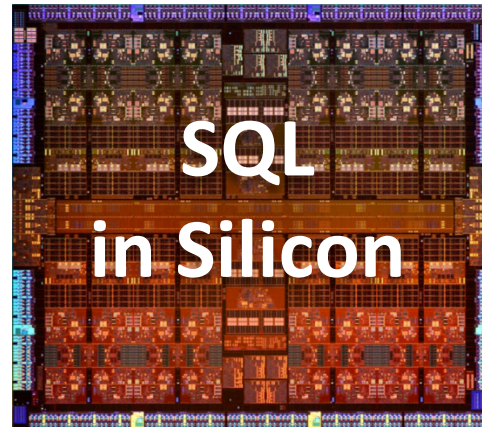 - High-volume key to keeping up with Moore's Law

In-Memory Algorithms Natively Implemented on Silicon

Performance

DB In-Memory Acceleration Engines

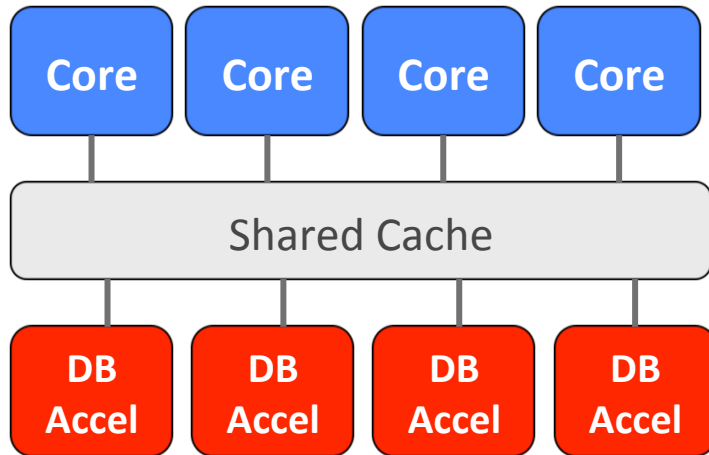**Reliability/Security**

Application Data Integrity

SQL in Silicon

Capacity

Decompression Engines

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Performance: Database In-Memory Acceleration Engines

SPARC M7

| Core | Core | Core | Core |

Shared Cache

| DB Accel | DB Accel | DB Accel | DB Accel |

32 Database Accelerators (DAX)

- SIMD Vectors instructions were designed for graphics, not database

- New SPARC M7 chip has 32 optimized database acceleration engines (DAX) built on chip

- Independently process streams of columns
  - E.g. find all values that match 'California'
  - Up to 170 Billion rows per second!

- Like adding 32 additional specialized cores to chip
 - Using less than 1% of chip space

Capacity: Decompression Engines
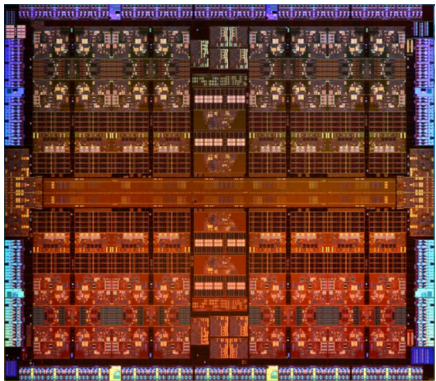
Doubles Memory Capacity

- Compression is key to putting more data in-memory
  - Databases compress repeated symbols, e.g. repeat of 'California'
  - Don't compress bit patterns - letter 'e' more common than 'z'
  - Bit pattern compression gives approximately 2X more capacity

- <u>De</u>compression is far more import for databases than compression

- Bit pattern decompression in normal cores is slow
  - Performance of decompress on today's processors is fine for disk data, slow for flash, huge bottleneck for in-memory database
  - 64 CPU cores needed to decompress at full memory speed

- SPARC M7 adds 32 decompress engines
 - Run bit-pattern decompress at memory speed

Database Accelerators (DAX): Pipelined Streaming Engines
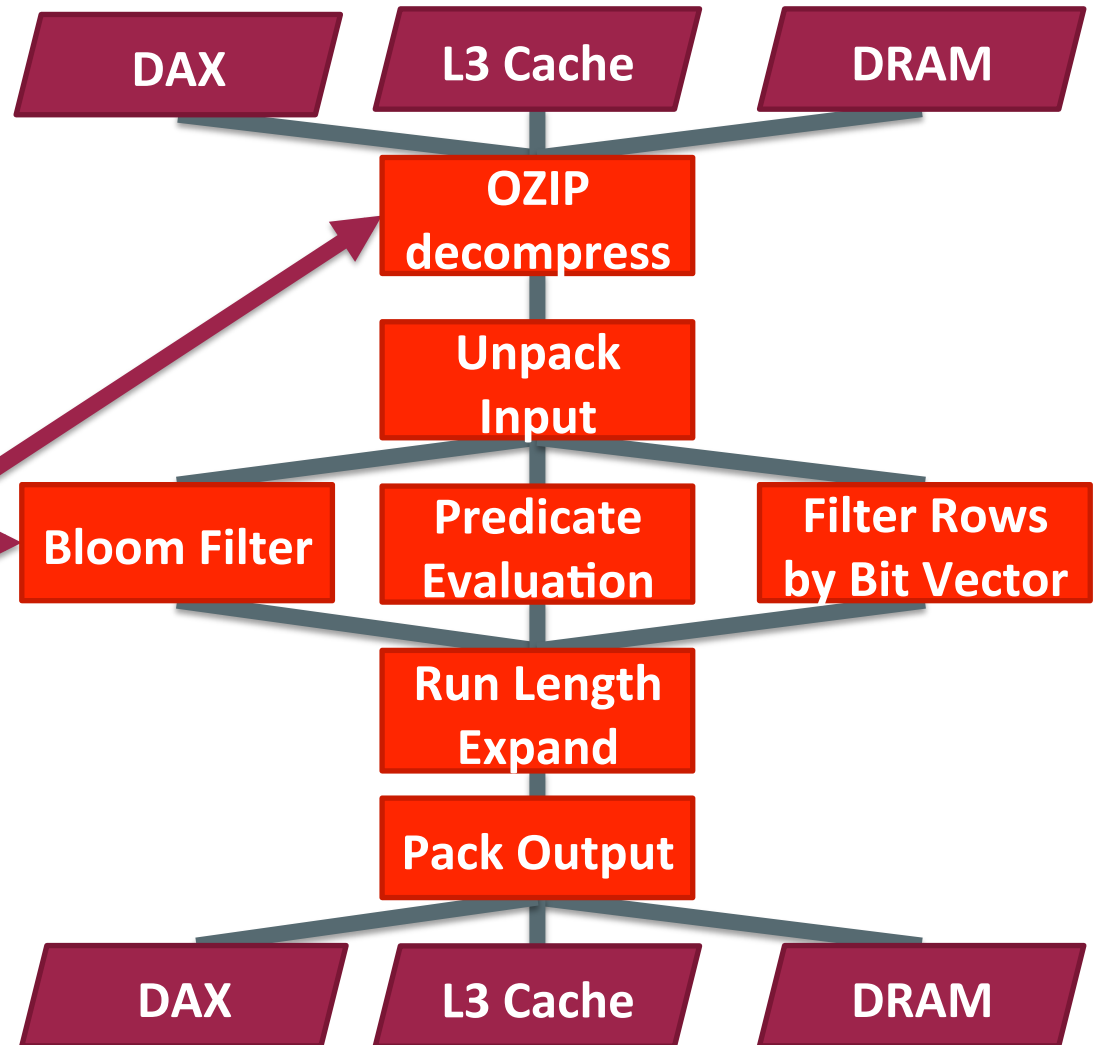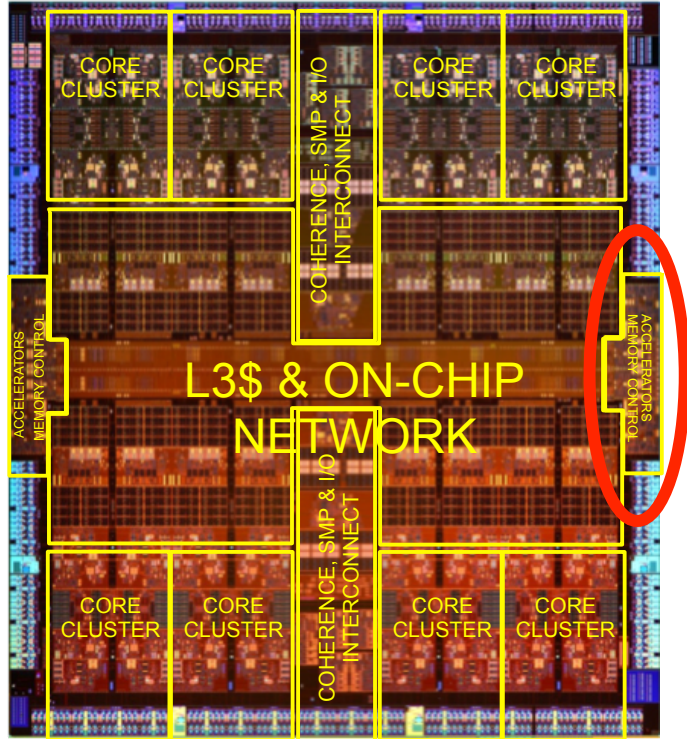
Equivalent of 32 extra vector cores plus 64 extra decompress cores

# Reliability & Security: Application Data Integrity

- Database In-memory places terabytes of data in memory
  - More vulnerable to corruption by bugs/attacks than storage

- SPARC M7 Application Data Integrity implements fine grained memory protection with negligible impact on performance

- Hidden "color" bits added to pointers (key), and content (lock)

- Pointer color (key) must match content color or program is aborted

  - Set on memory allocation, changed on memory free

- Helps prevent access off end of structure, stale pointer access, malicious attacks, etc. plus improves developer productivity

Memory Pointers

STOP

Memory Content

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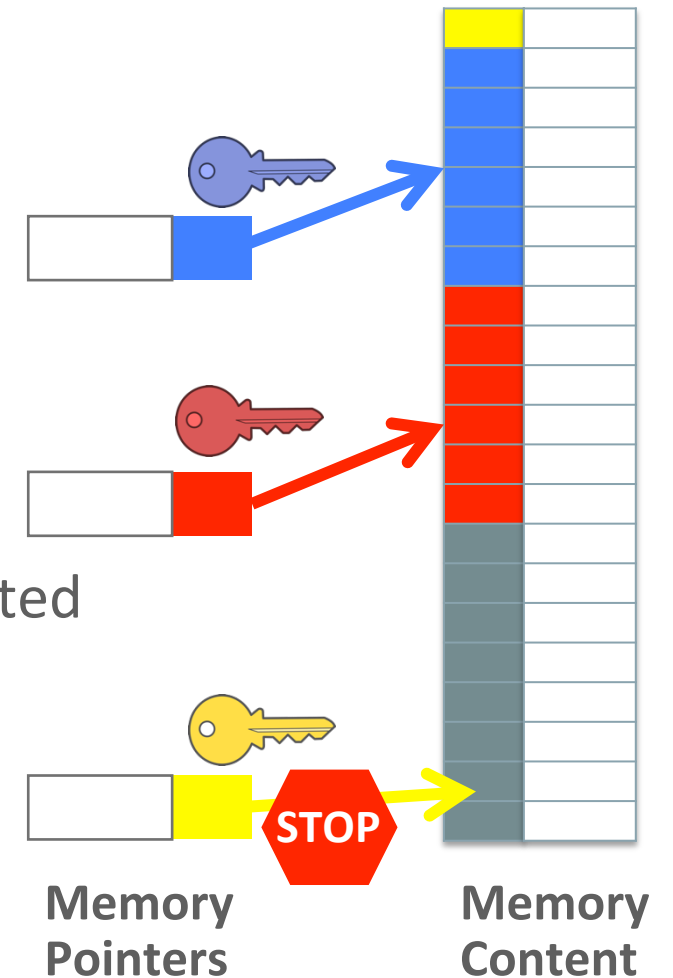
How Data Protection Works
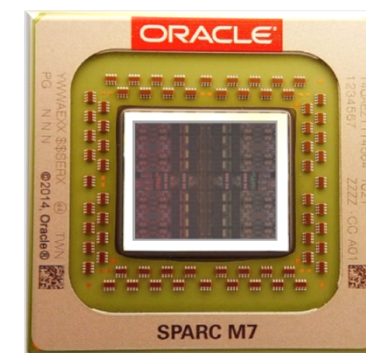

64-bit Pointer

Color Bits	Virtual Address
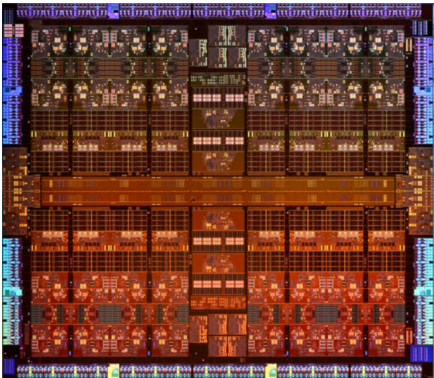
- Color bits kept in upper bits of pointers
- Color bits kept for every 64 byte aligned memory region
  - Similar to ECC (Error Correction) bits but designed to protect data from for software failures not hardware
  - 2 to 5 orders of magnitude finer granularity than OS pages
- Color bits present in entire memory architecture:
  - All memory paths
  - Full Cache Hierarchy
  - All Chip Interconnects
  - Color bits checked by core load/store units

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Conclusion

- Engineering Database Hardware and Software
  - Faster, More Reliable, More Cost Effective, More Secure databases

- Oracle Exadata is a Hardware Platform integrated with the Database at the System Level

- This year Oracle Sparc M7 extends database integration to the Microprocessor – SQL in Silicon

- The beginning of a new era of Database integration
  - **Many opportunities for future research and algorithms**