# Hardware design for Cloud-scale datacenters

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# Public Cloud

## Common Use Case Scenarios *

| Cloud Native Applications | Web Based Business Applications | e-business Hosting and Applications | Test Development Prototyping | Disaster Recovery / Business Continuity | Batch Computing |
|---|---|---|---|---|---|
| Architected specifically for Cloud | Custom and commercial, general purpose | SaaS Apps, Commerce Sites | Project oriented resourcing, timing | Storage & DB replication, failover sites | HPC, data analytics, modeling |
| Growing fast | Predictable bursting, usage, seasonality | Unpredictable bursting, peak intervals | Unpredictable bursting, demand | Provisioning for growth/scale | Large on-demand capacity |

Potential for mixed mode PaaS and IaaS optimization of Applications

** Source: Gartner, Lydia Leong, March 2012*

5.8+ billion
worldwide queries each month
bing



250+ million
active users
OneDrive

400+ million
active accounts
Outlook.com

2.4+ million
emails per day
Microsoft Exchange Hosted Services

8.6+ trillion
objects in Microsoft Azure storage
Microsoft Azure





48+ million
users in 41 markets
XBOX LIVE

50+ million
active users
Microsoft Office Web Apps

1 in 4
enterprise customers
Office 365

**50+** billion
minutes of connections handled each month
skype

# 200+ Cloud Services

1+ billion customers · 20+ million businesses · 90+ markets worldwide

# Server scale implications: Design

| | <10K SMB/Enterprise | 100K Hosters | 1M Cloud-Scale |
|---|---|---|---|
| # SKUs | Several | Limited | Extremely limited |
| Redundancy model | Hardware based (Hot-*) | Software based (Local datacenter) | Software based (Geo-distributed) |
| HW availability | 99.999% or higher | 99.9% - 99.999% | 99% - 99.9% |
| HW type | Enterprise SKU | Off-the-shelf design, custom integration | Custom designs, custom integration |
| Infrastructure co-design | None | Limited integration with Datacenter and Network | OS, Datacenter, Server and Network tightly integrated |

# Server scale implications: Operations

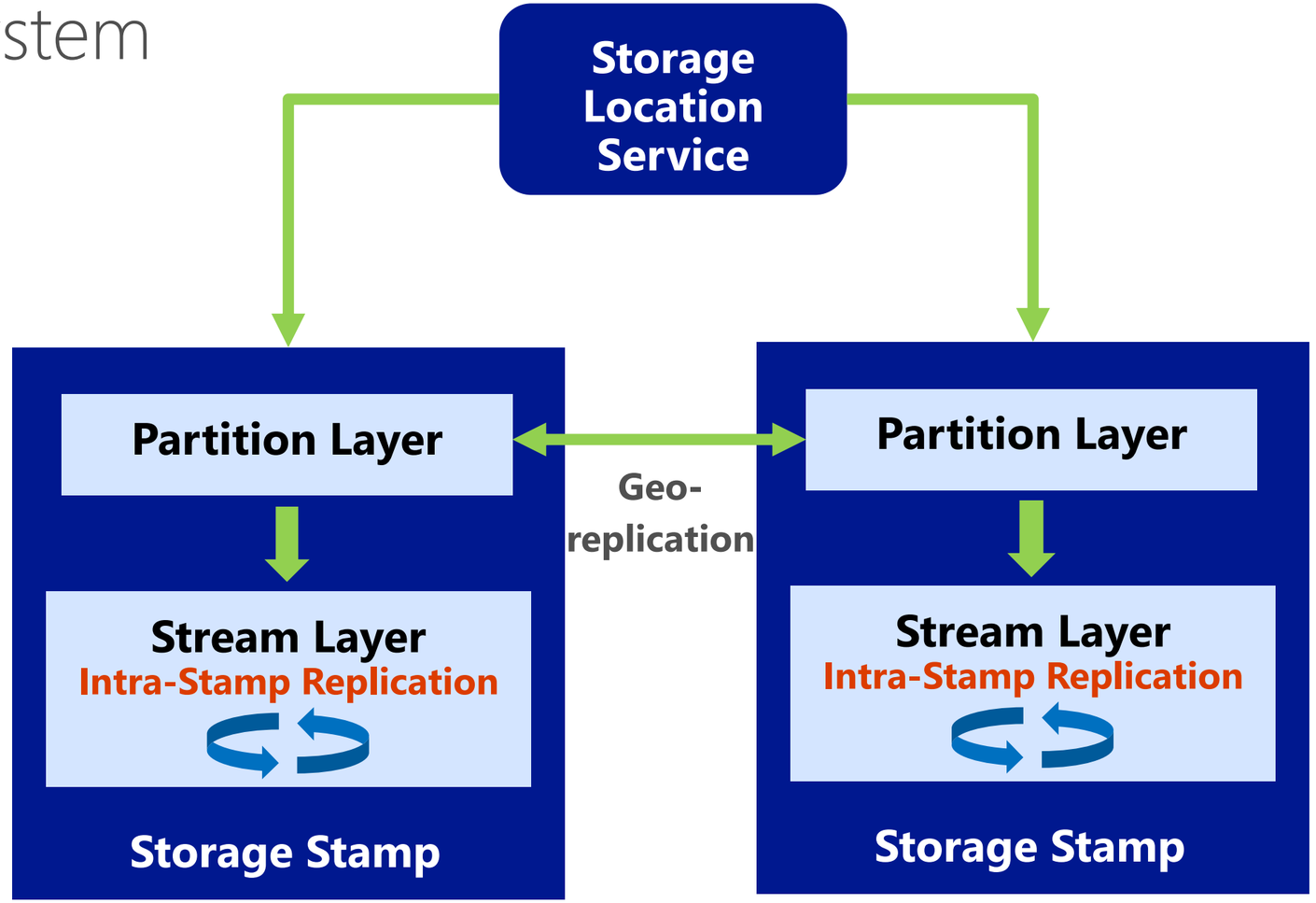
| | <10K SMB/Enterprise | 100K Hosters | 1M Cloud-Scale |
|---|---|---|---|
| Break/fix support | 24 hours x 7 days | 8 hours x 5 days | Up to 1-2 weeks |
| Issue triage model | IT admin | Some automation, Admin support | Fully automated, Machine learning |
| OOB HW management | Full command set, BMC required | Basic feature set, BMC required | Power On/Off only, No BMC |
| Management domain scale | 100's of servers | 1000's of servers | 10's of 1000's of servers |
| FRU granularity | Hot-swappable components | Component replacement | Entire server replacement |

# Cloud storage overview

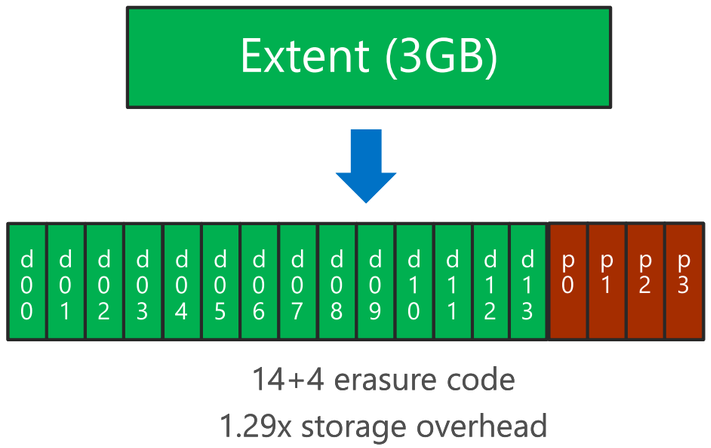
Append-only distributed file system
Replication within a stamp

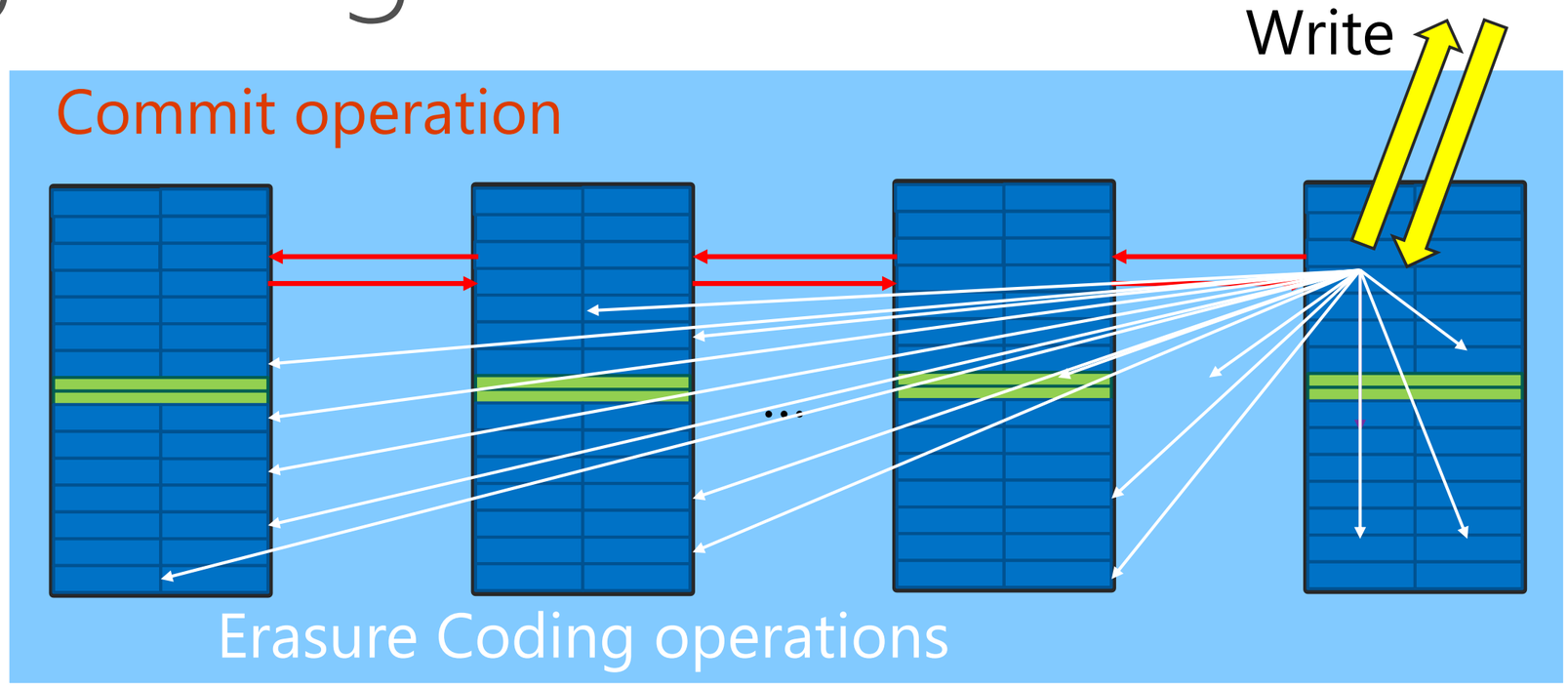
Extent:

- Unit of replication
- Sequence of blocks
- Size 3GB



# Cloud storage design tradeoffs



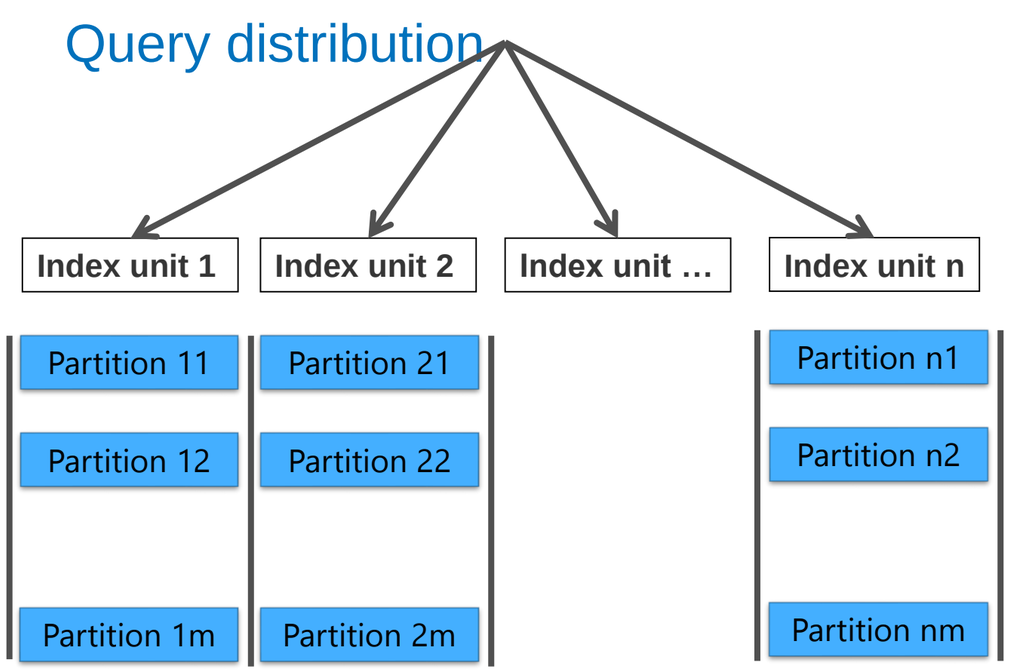



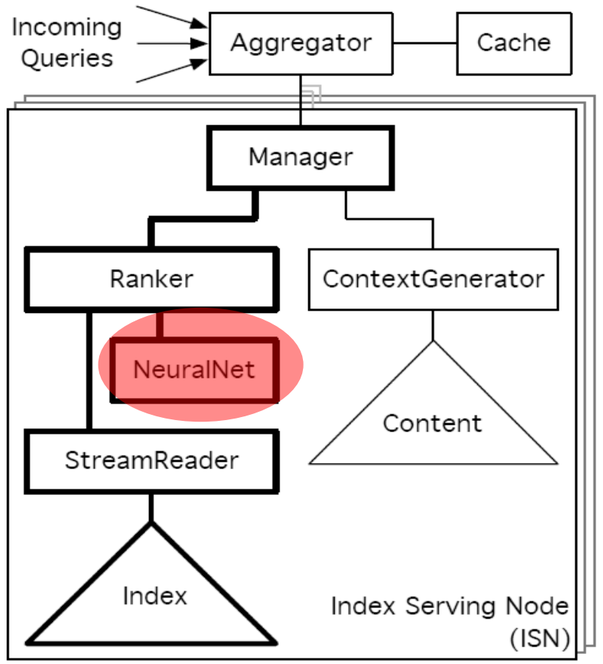

A single network I/O for a write entails:

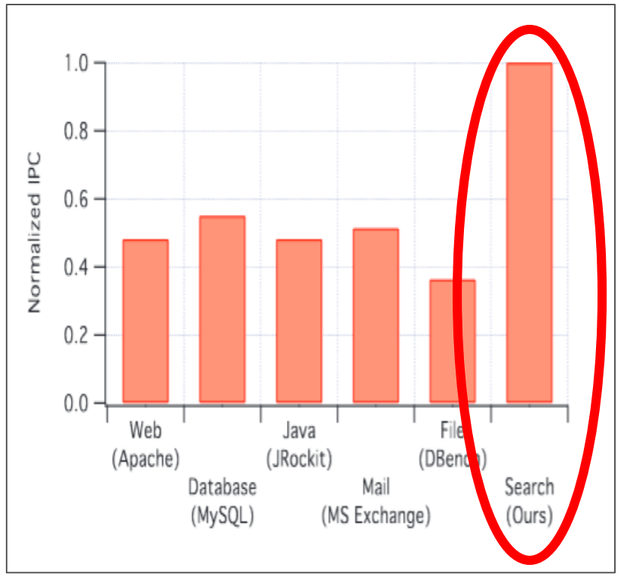
- 3 copy I/Os for initial commit (with responses)
- 18 writes for 14+4 erasure code
- Garbage collection

A single read can entail reading from multiple erasure coded extents

# Large scale cloud application: Web search




*Source: "Web search using mobile cores, ISCA 2010*

Query performance is measured as an aggregate of ALL compute nodes

Machine learning techniques used for ranking algorithms

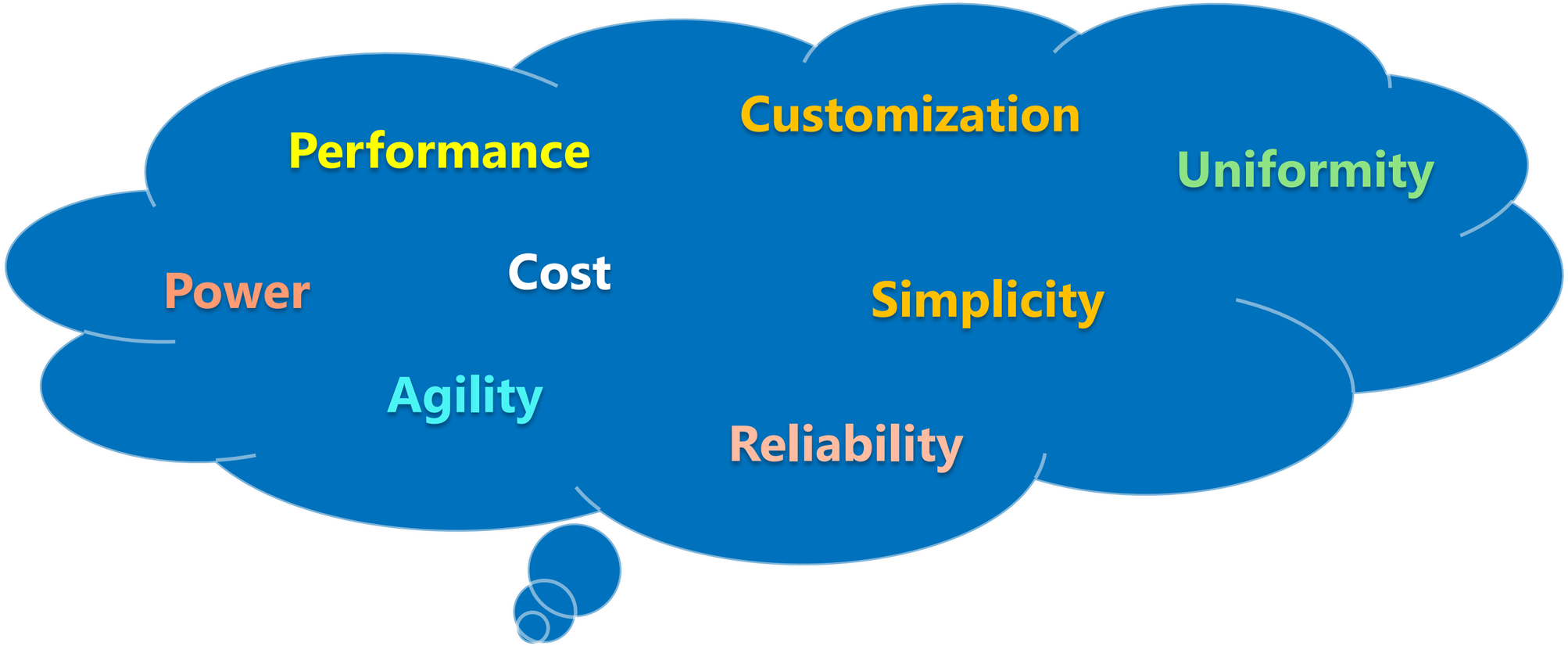
Search app is very CPU intensive

# Cloud workloads are different!

Examples:

- Several opportunities for offloading compute intensive tasks
- Read-mostly, write-once per day
- Sequential write streams for object stores
- Synchronous replication for data durability ; No RAID

# Goldilocks problem applied to Cloud servers




Infrastructure design challenges

# Other considerations …

## Architecture should be adapt to variety of cloud workloads

- E.g. Dense virtualization, Big data, HPC, Mailbox, Gaming, Media Streaming
- Varying requirements for Compute, Storage and Networking
- Allow for both generality and specialization in the same design

## Support for global datacenter operating environments

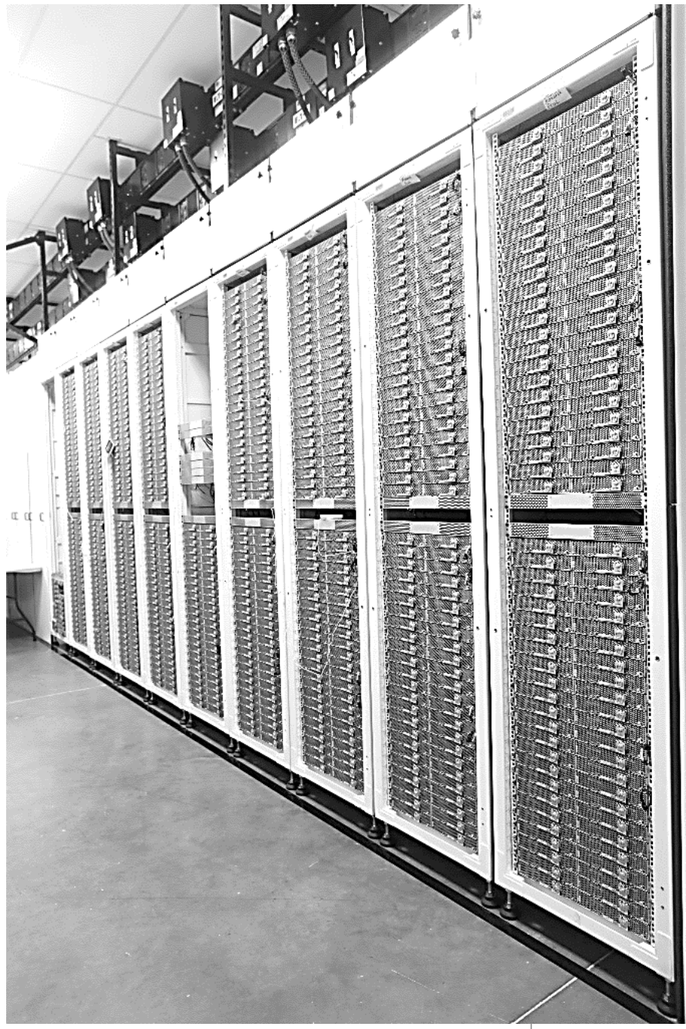
- Seamless integration with installed IT footprint, e.g. EIA 310D 19" rack compatibility
- EMI compliance (e.g. CISPR, ANSI, IEC), Safety Standards (e.g. UL, IEC, CSA)
- Electrical distribution and cooling

# Cloud scale servers: Design Principles

Standardization & Modularization

Design Simplicity

Operations Excellence



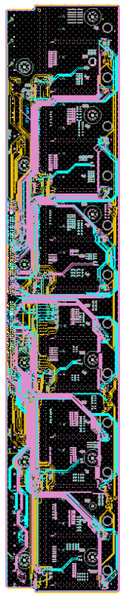
# OpenCompute Project contribution

*Open CloudServer (OCS) design*

## Open Source Code

Chassis management

Operations Toolkit



## Board Files & Gerbers

Power Distribution Backplane

Tray Backplane



## Specifications

Chassis, Blade, Mezzanines

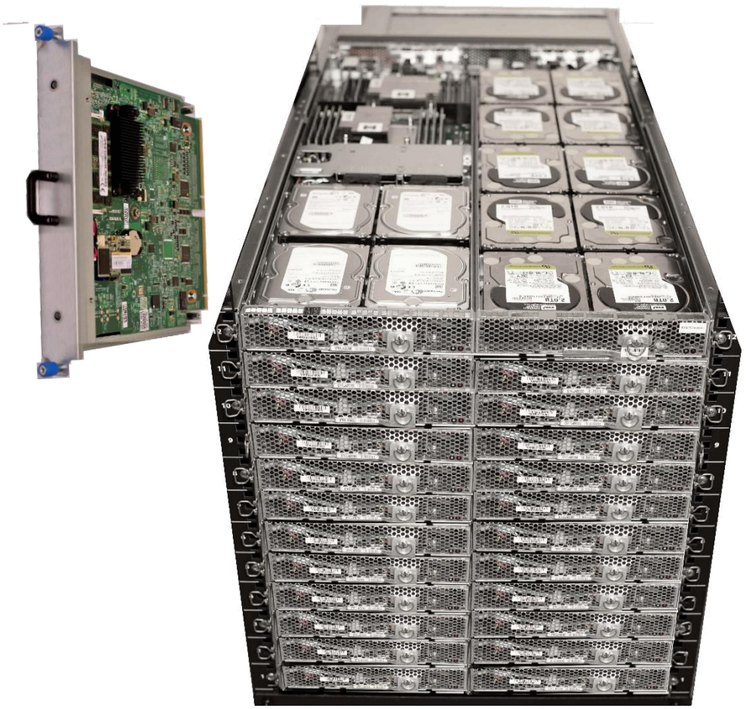
Management APIs

Certification Requirements




## Mechanical CAD Models

Chassis, Blade, Mezzanines

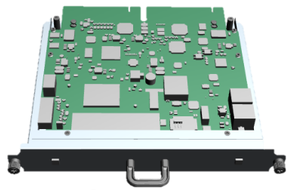


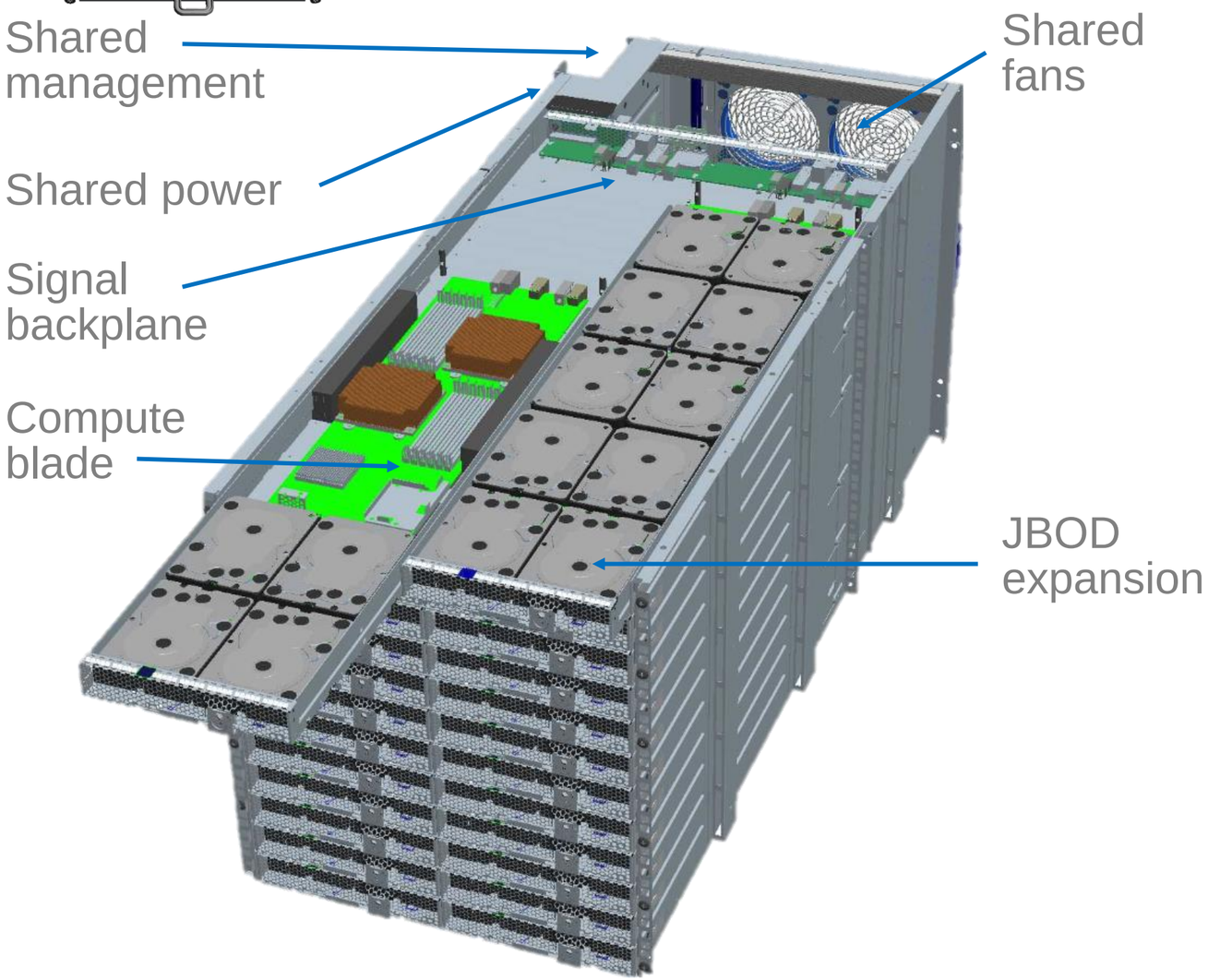
http://www.opencompute.org/wiki/Server/SpecsAndDesigns

# OCS key features

## Shared infrastructure for efficiency and TCO optimization

- Power delivery, mechanicals, thermals/cooling, management
- Optimized for mass contract manufacturing and assembly

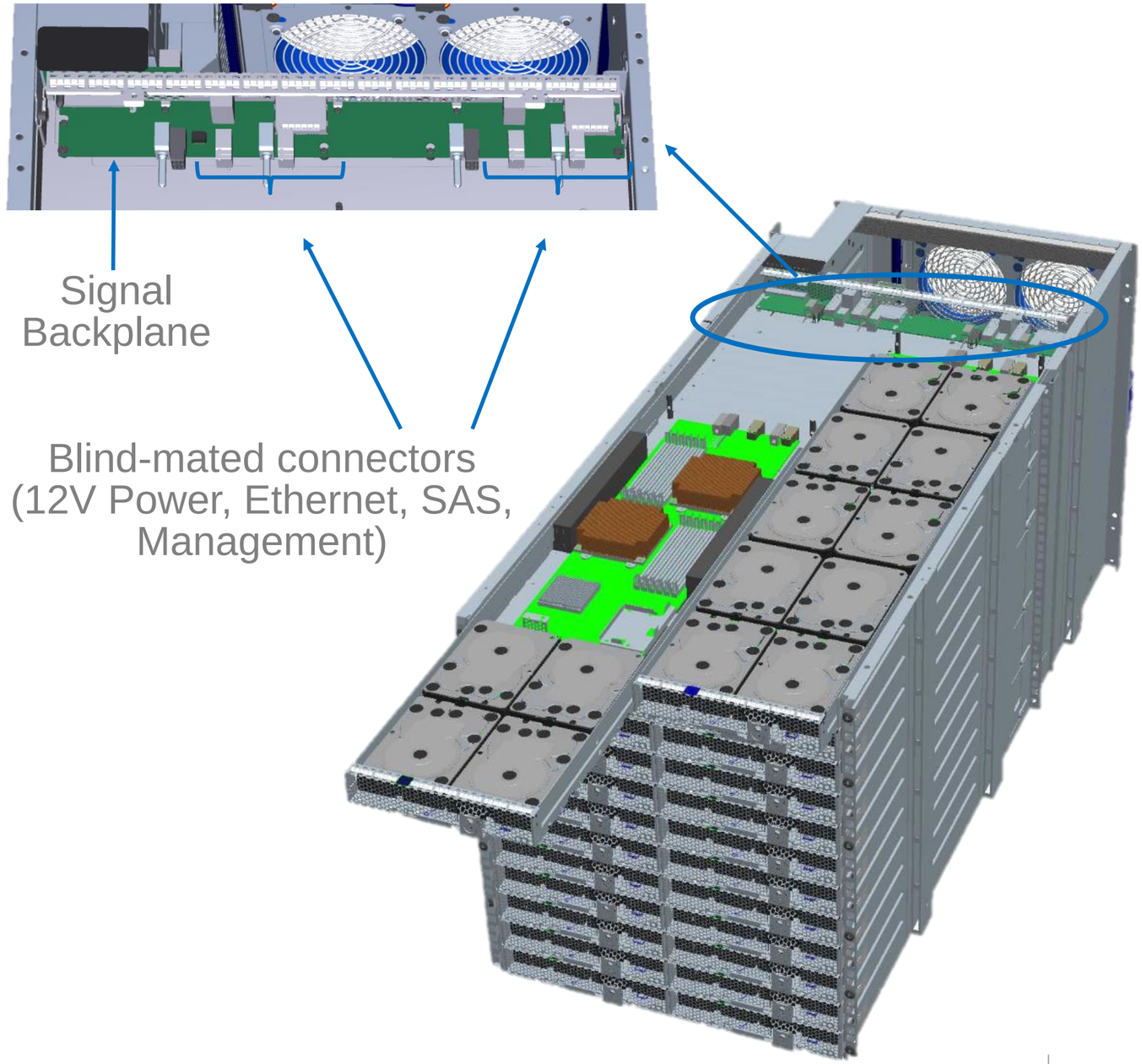


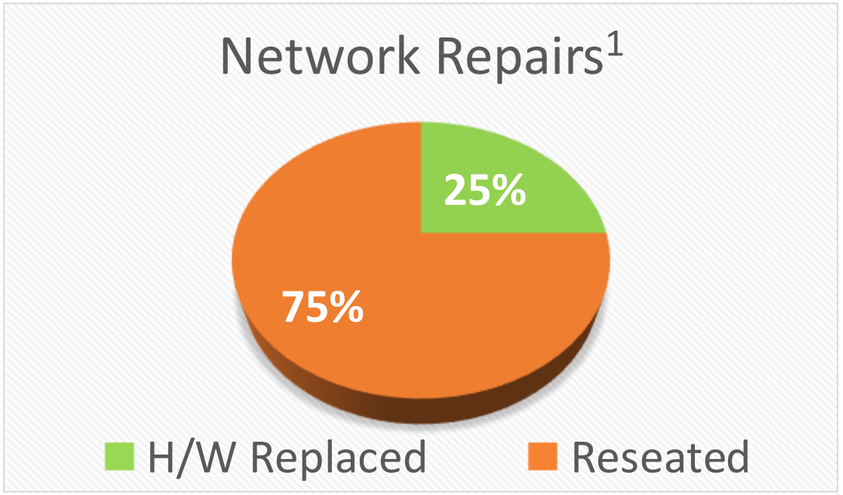


# Chassis features

## Blind-mated signal connectivity

- Simplified installation and repair
- Cable free design for significantly fewer operator errors during servicing
- Reduces need for cabling reseats



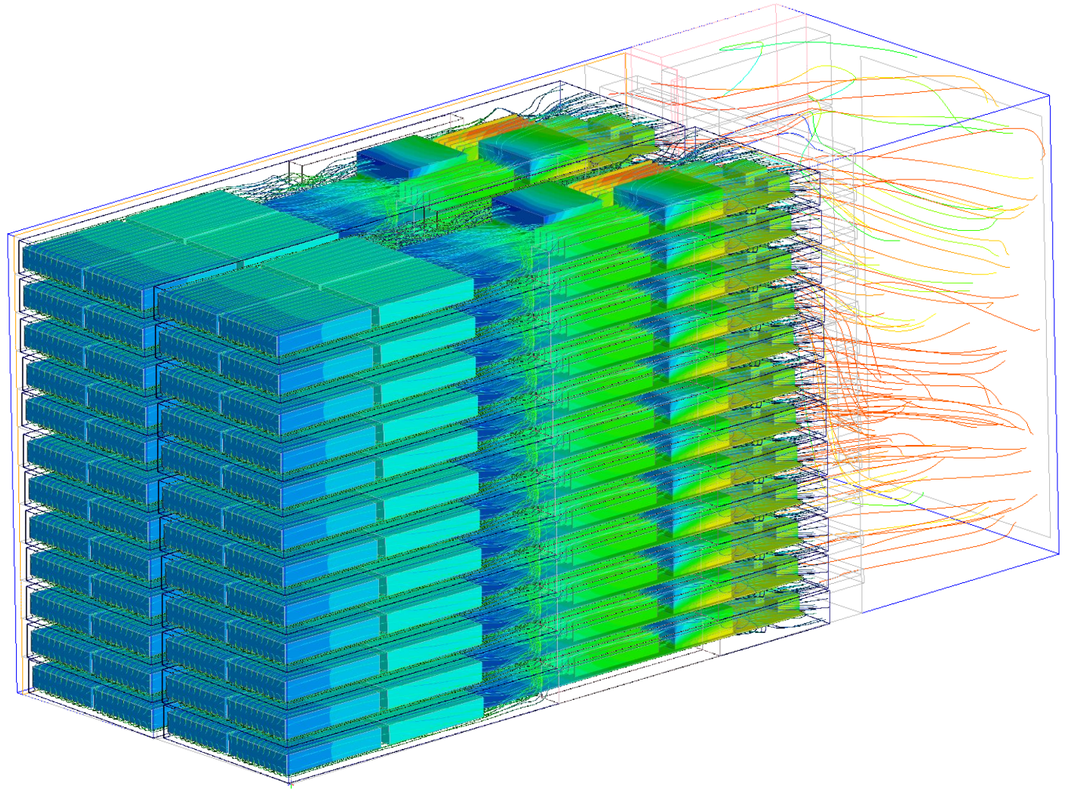
# Thermally architected for reliability

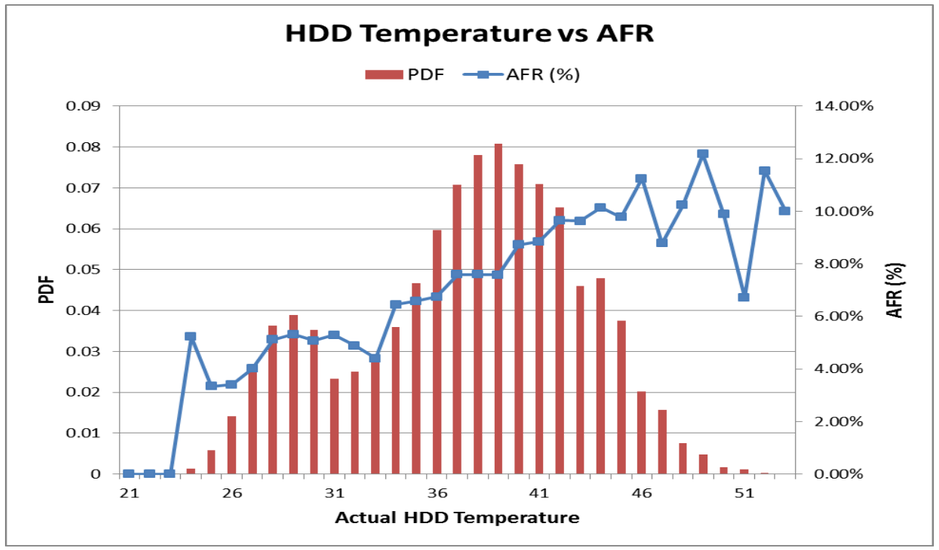
## HDDs are #1 failure item

- AFR increases with temperature[1]

## Simplified fan control cools HDDs

- HDDs in front of hot motherboard
- Closed loop fan moderates temperatures



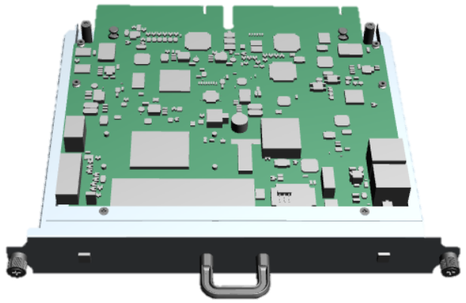



[1]DSN 2011: Impact of Temperature on Hard Disk Drive Reliability in Large Datacenters

# Chassis and blade management

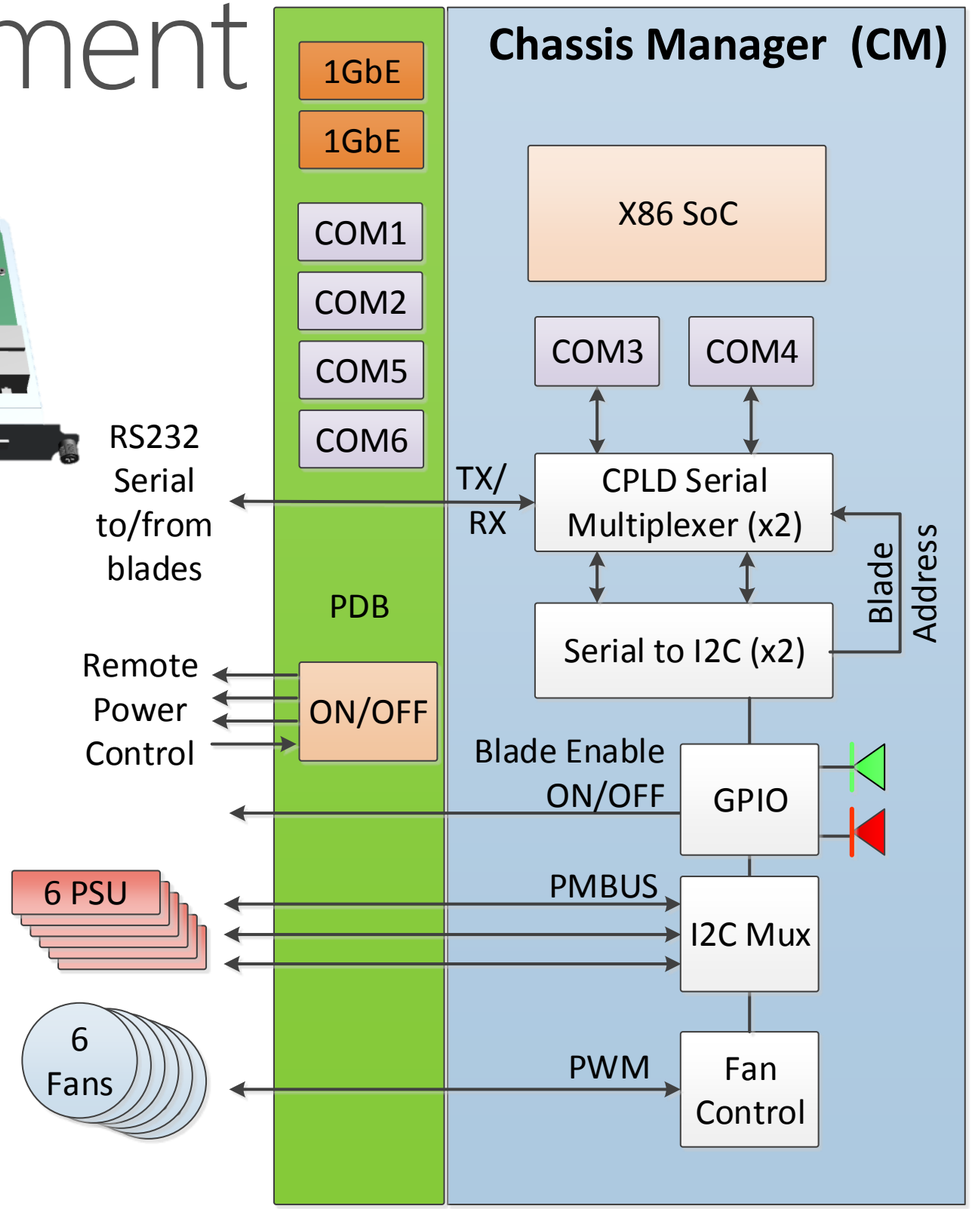
## Secure OOB management

- Low-cost embedded x86 SoC
- REST API for machine management
- CLI interface for human operations



## Hard-wired management

- On/Off to blade power cut-off circuit
- IPMI-over-serial out of band communication
- Fan and PSU control and monitoring
- Remote switch and CM power control



# Security: defense in depth

## Security at all layers

Hardware, UEFI, APIs, User Management

## Trusted Platform Module v1.2

Blades and Chassis manager

## UEFI Firmware v2.3.2

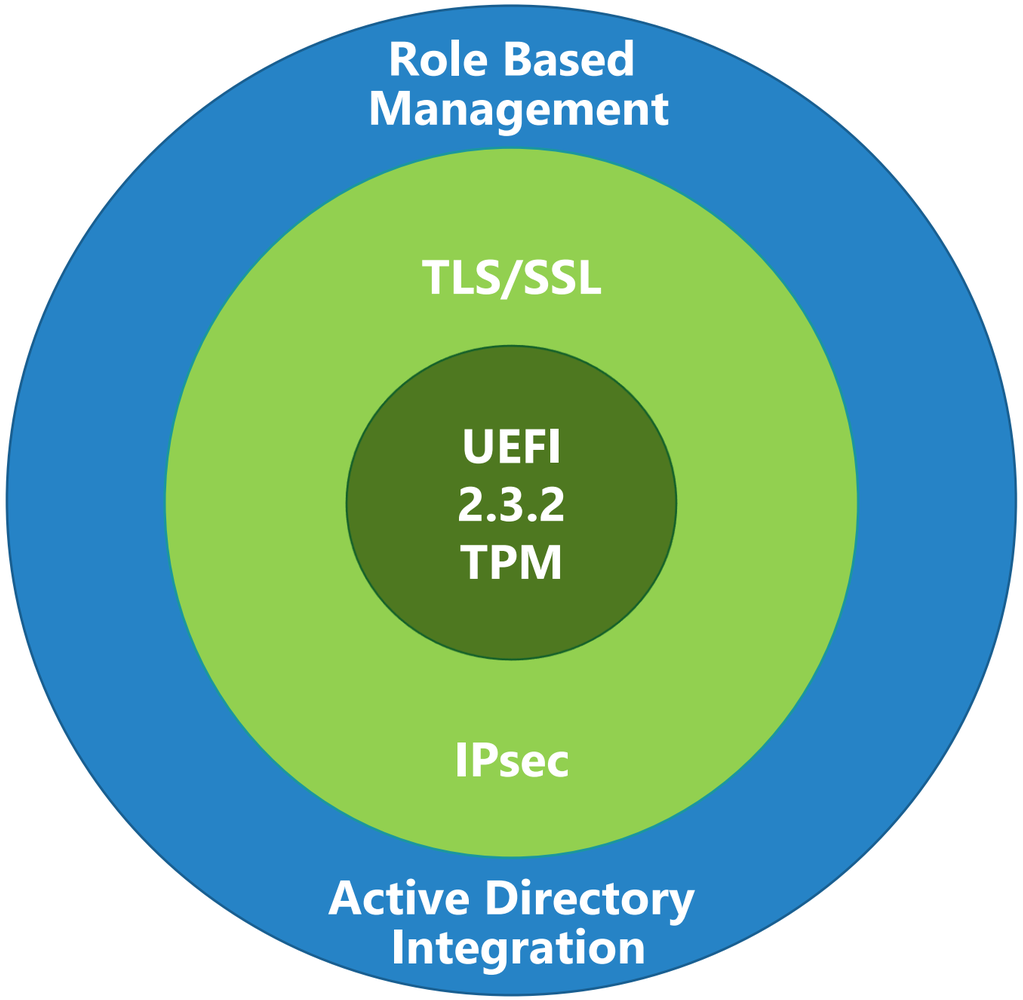
Secure BIOS and Boot

## Chassis manager interfaces

TLS (SSL) and IPsec for communication encryption

## User Management

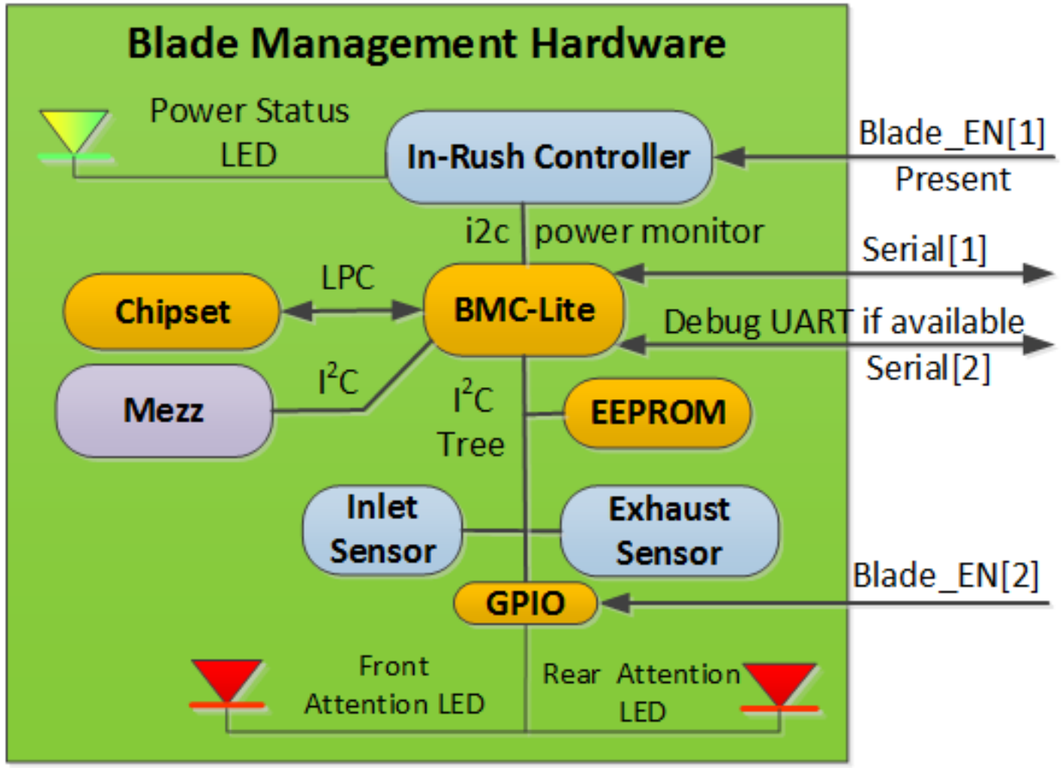
Active Directory integration and authentication



# Compute blade BMC-Lite

## BMC-Lite

- ✓ IPMI basic mode over Serial
- ✓ I2C Master (SDR)
- ✓ UART I/O
- ✓ System Event Log
- ✓ Power Control
- ✗ ~~KVM, Video drivers~~
- ✗ ~~Ethernet, Network Stack or SOL~~
- ✗ ~~USB~~
- ✗ ~~Full IPMI Command Set~~



# OCS open source Operations Toolkit

## Targeted for deployment and production support

Collection of PowerShell scripts, applications, and utilities

3rd party utilities and applications can be integrated with the scripts

Runs under Windows Dekstop and Server OS and WinPE

## Features

Diagnostics to reduce repair times

Stress tools for higher quality validation

Automated updates to eliminate human errors

http://github.com/MSOpenTech/OCSOperationsToolKit

# Diagnostics example - Defect Identification

## Identify defective components by physical location

- Read BMC SEL and SSD/HDD status to determine failed components
- Runs in-band on compute blade
- Identifies disks, DIMM, motherboard, adapters reporting errors

## Summarize data for quick repairs

- Provide physical location of component (internal lookup tables)
- Automatically run during operation and add info to repair requests (tickets)

```
SYSTEM HEALTH DEGRADED - FOUND ERRORS...

-------------------------------------------------------------------
Location          # Errors    Last Error
-------------------------------------------------------------------
DIMM A1                   2    Uncorrectable ECC - [10/15/2014 12:30:57 PM]
```

# Diagnostics example – View Configuration

## View configuration command - View-WcsConfig

```
PS C:\WcsTest> view-wcsconfig
-------------------------------------------------------------------
System Info
-------------------------------------------------------------------
   Computer                       WCSAZ31SUST001
   TotalMemmory                   137403125760 (128.0 GiB)
   TotalProcessors                20
-------------------------------------------------------------------
Software Info
-------------------------------------------------------------------
   BIOS Version                   T6M_3C05
   BMC Version                    4.05
   OS Name                        Microsoft Windows Server 2012 R2 Datacenter (Version 6.3.9600)
-------------------------------------------------------------------
FRU Info
-------------------------------------------------------------------
   Chassis Part Number            X873021-001
   Chassis Serial Number          QTFCTM4250001
   Board Manufacturer             Microsoft
   Board Name                     C1020
```

# Diagnostics example – View Configuration

## View-Disk, View-Dimm, View-Nic, View-Fru, etc

```
------------------------------------------------------------------------
DIMM Info
------------------------------------------------------------------------
   DIMM B1                      Samsung M393B2G70QH0-YK0 Speed: 1333   Size: 16.0 GiB   SN: 37E84179
   DIMM B2                      Samsung M393B2G70QH0-YK0 Speed: 1333   Size: 16.0 GiB   SN: 37E84180
   DIMM C1                      Samsung M393B2G70QH0-YK0 Speed: 1333   Size: 16.0 GiB   SN: 37E8417A
   DIMM C2                      Samsung M393B2G70QH0-YK0 Speed: 1333   Size: 16.0 GiB   SN: 37E8417B
   DIMM E1                      Samsung M393B2G70QH0-YK0 Speed: 1333   Size: 16.0 GiB   SN: 37E848EA
   DIMM E2                      Samsung M393B2G70QH0-YK0 Speed: 1333   Size: 16.0 GiB   SN: 37E84918
   DIMM F1                      Samsung M393B2G70QH0-YK0 Speed: 1333   Size: 16.0 GiB   SN: 37E848E9
   DIMM F2                      Samsung M393B2G70QH0-YK0 Speed: 1333   Size: 16.0 GiB   SN: 37E8491E
------------------------------------------------------------------------
Disk Info
------------------------------------------------------------------------
   SB-2-Top                     SAMSUNG MZ7WD480HAGM-00003 FW: DXM87W3Q   Size: 480.1 GB   SN: S16MNEADA06135
   SB-2                         ATA SAMSUNG MZ7WD480 SCSI Disk Device FW: 7W3Q   Size: 480.1 GB   SN: S16MNEADA06205
   SB-3                         ATA SAMSUNG MZ7WD480 SCSI Disk Device FW: 7W3Q   Size: 480.1 GB   SN: S16MNEADA06136
   SB-4-Top                     SAMSUNG MZ7WD480HAGM-00003 FW: DXM87W3Q   Size: 480.1 GB   SN: S16MNEADA06134
   SB-4                         ATA SAMSUNG MZ7WD480 SCSI Disk Device FW: 7W3Q   Size: 480.1 GB   SN: S16MNEADA06131
   SB-5                         ATA WDC WD4000FYYZ-0 SCSI Disk Device FW: 1K02   Size: 4.0 TB   SN: WD-WMC130389880
------------------------------------------------------------------------
NIC Info
------------------------------------------------------------------------
   NIC                          Mellanox ConnectX-3 Pro Ethernet Adapter FW: N/A  Connection: 2 (10 gbit/s)   MAC: C4:54:44:56:E0:8C
------------------------------------------------------------------------
Mellanox Firmware Info
------------------------------------------------------------------------
   Mellanox                     DeviceID: 4103   FW: 2.30.5010  PXE: 3.4.151  UEFI: 10.2.57
------------------------------------------------------------------------
```

# Diagnostics – Manage Error Logs

## Check, clear, and log the Windows System Event Log and BMC SEL

- Check for hardware specific errors

## View contents of BMC SEL

- View with decode of some hardware error entries

```
PS C:\WcsTest> view-wcssel
0001 [10/15/2014 12:29:15 PM] SEL cleared
0002 [10/15/2014 12:30:57 PM] DIMM A1 Correctable ECC
0003 [10/15/2014 12:30:57 PM] DIMM A1 Uncorrectable ECC
0004 [10/15/2014 12:31:35 PM] Voltage exceeded threshold. Sensor C4 EvtData(3-1) 0xE1D050
0005 [10/15/2014 12:31:37 PM] Voltage within threshold. Sensor C4 EvtData(3-1) 0xC3D050
```

- View without decode for raw data

```
PS C:\WcsTest> view-wcssel -NoDecode
0001 RecordType: 0x02 TimeStamp: 543E689B GenID: 2000 EvMRev: 04 SensorType: 10 Sensor: 8A Ev
0002 RecordType: 0x02 TimeStamp: 543E6901 GenID: 0001 EvMRev: 04 SensorType: 0C Sensor: 87 Ev
0003 RecordType: 0x02 TimeStamp: 543E6901 GenID: 0001 EvMRev: 04 SensorType: 0C Sensor: 87 Ev
```

# System Updates

## Commands…

- System Identification (Select update based on FRU/BIOS info)
- Dependency checking
- Logging
- Sequencing (can update from any version if possible)

## Example: Update-WcsConfig Command

- Single command to update multiple components
- Example: Update blade BIOS, BMC, NIC and HBA FW
- Simplifies learning curve for repair technicians

# Summary

- Cloud workloads are extremely diverse - need for balance uniformity with specialization

- Designing for cloud-scale based on simple principles:

  Modularity, Simplicity and Operations Excellence

- Open sourced server designs present opportunity to drive innovation on common platforms and leverage battle-tested tools

# Q & A