Cloud Computing Driving Infrastructure Innovation

Intel DCSG Distinguished Speaker Series

James Hamilton, 2012/9/25

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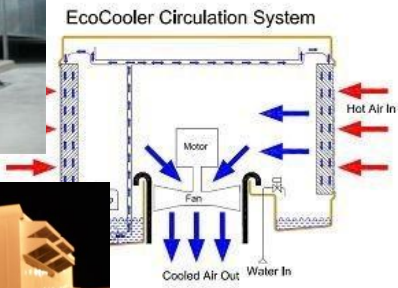
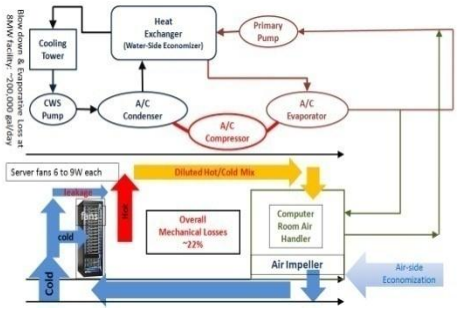
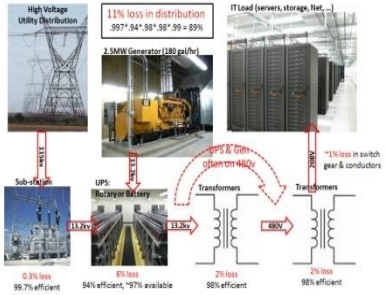
Agenda

- Cloud Computing Scaling & Costs
- Cloud Computing Economics
- Infrastructure Innovation
  - Power Distribution
  - Mechanical Systems
  - Data Center Building Design
  - Networking
  - Storage
- Cloud Computing Drives H/W Feature Use





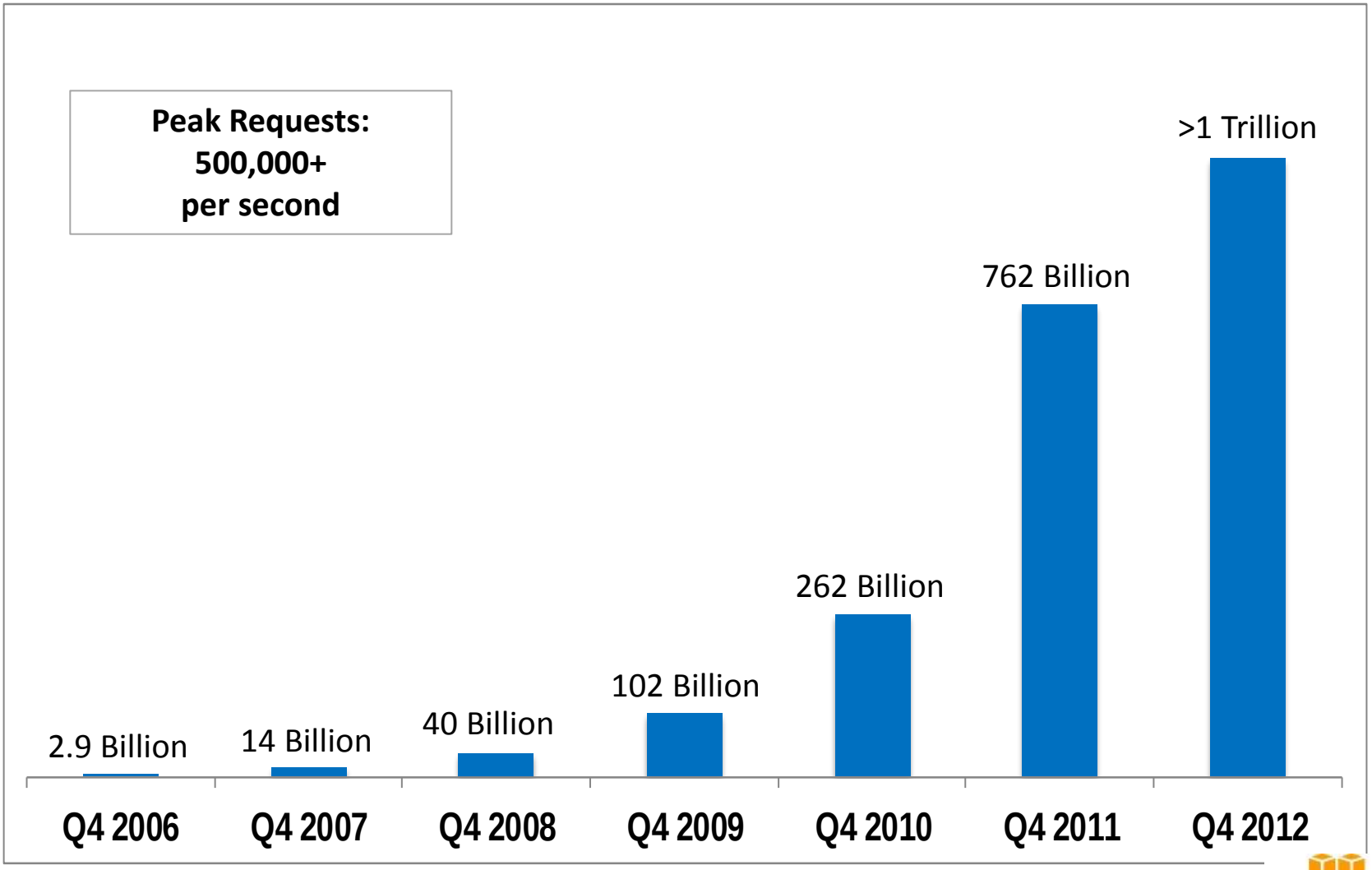


Pace of Innovation

- Datacenter pace of innovation increasing
  - More innovation in last 5 years than previous 15
  - Driven by cloud service providers and very high-scale internet applications like search
  - Cost of infrastructure dominates service cost
  - Not just a cost center
- High focus on infrastructure innovation
  - Driving down cost
  - Increasing aggregate reliability
  - Reducing resource consumption footprint

Perspective on Scaling

The Cloud Scales: Amazon S3 Growth



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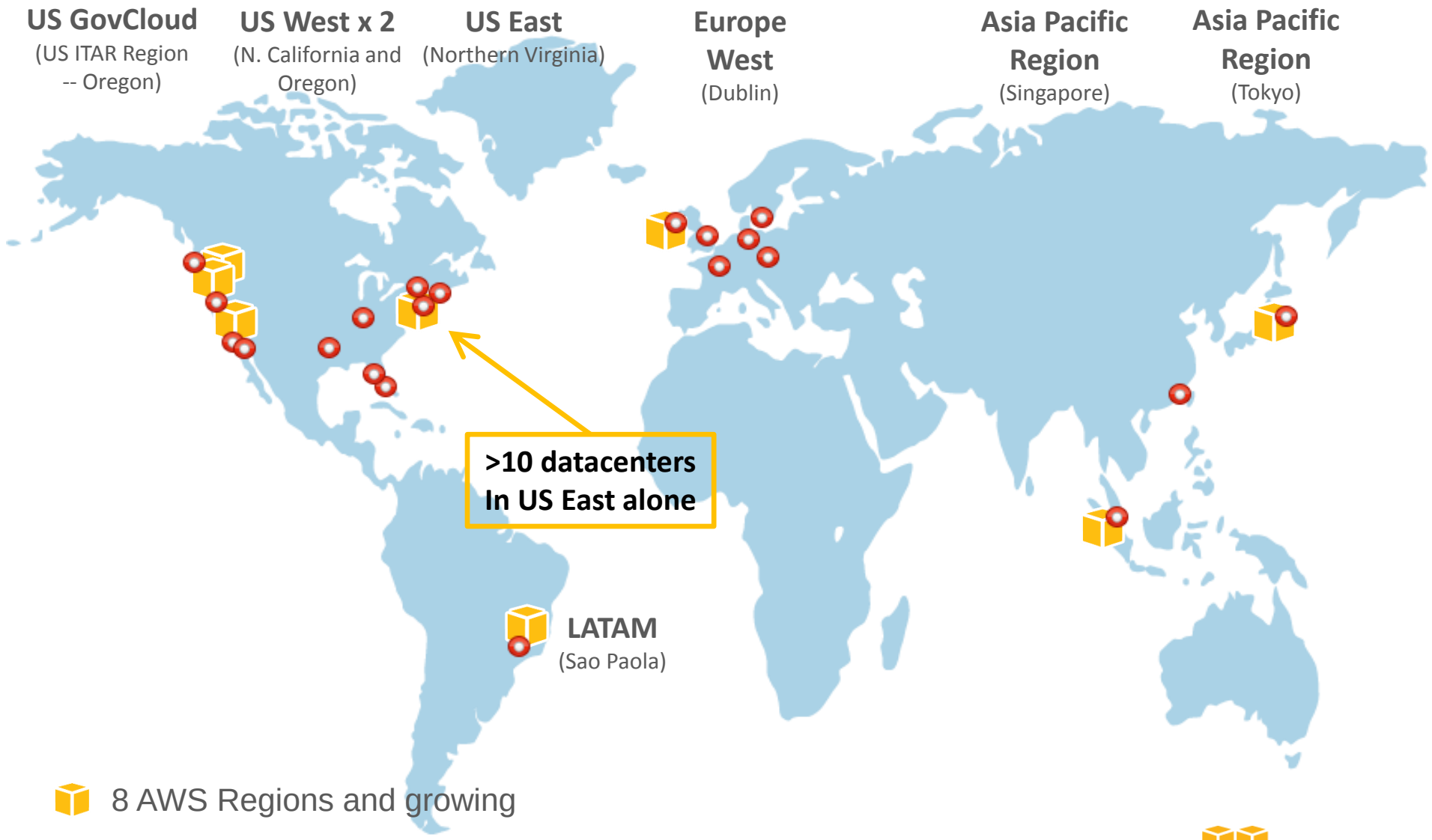
AWS Datacenters in 8 Regions



- 8 AWS Regions and growing
- 21 AWS Edge Locations for CloudFront (CDN) & Route 53 (DNS)

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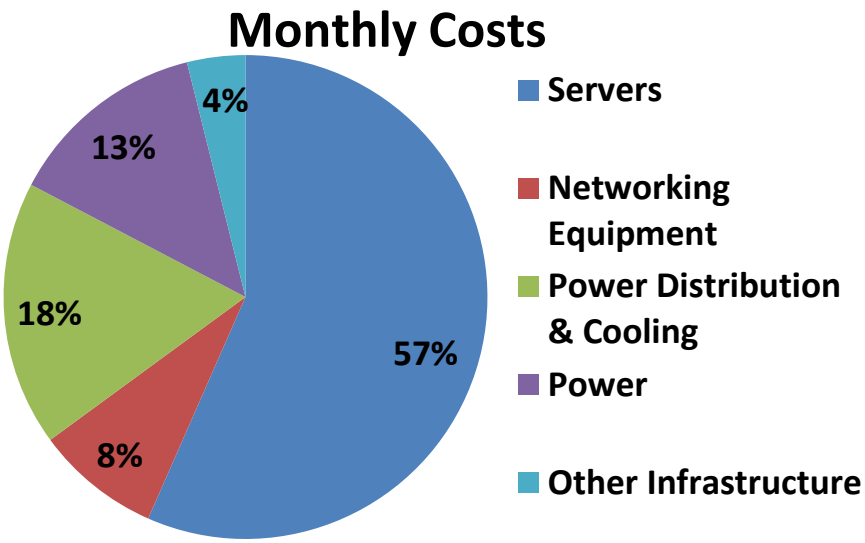
Where Does the Money Go?

- **Assumptions:**
  - Facility: ~$88M for 8MW critical power
  - Servers: 46,000 @ $1.45k each
  - Commercial Power: ~$0.07/kWhr
  - Power Usage Effectiveness: 1.45



3yr server & 10 yr infrastructure amortization

- **Observations:**
  - 31% costs functionally related to power (trending up while server costs down)
  - Networking high at 8% of overall costs & 19% of total server cost (many pay more)

From: http://perspectives.mvdirona.com/2010/09/18/OverallDataCenterCosts.aspx

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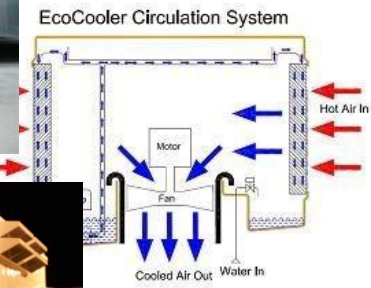

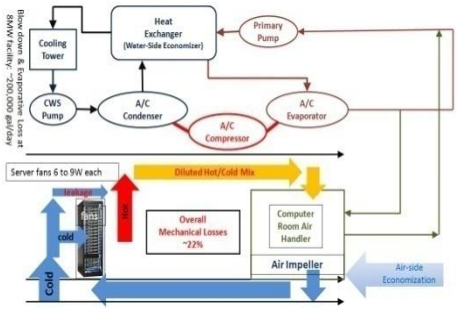

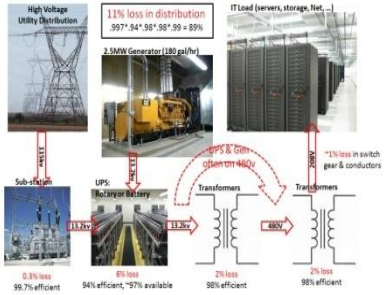

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Utilization & Economics

- Server utilization problem
  - 30% utilization VERY good &10% to 20% common
    - Expensive & not good for environment
  - Solution: pool number of heterogeneous services
    - Non-correlated peaks & law of large numbers
- Pay as you go & pay as you grow model
  - Don’t block the business
  - Don’t over buy
  - Transfers capital expense to variable expense
  - Apply capital for business investments rather than infrastructure
- Charge back models drive good application owner behavior
  - Cost encourages prioritization of work by application developers
  - High scale needed to make a market for low priority work

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Data Center Efficiency

- Datacenter design efficiency
  - Average datacenter efficiency low with PUE over 2.0 (Source: EPA)
    - Many with PUE over 3.0
  - High-scale cloud services in 1.2 to 1.5 range
  - Lowers computing cost & better for environment
- Multiple datacenters
  - At scale multiple datacenters can be used
    - Close to customer
    - Cross datacenter data redundancy
    - Address international markets efficiently
- Avoid upfront datacenter cost with years to fully utilize
  - Scale supports pervasive automation investment

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Scale Effects

- Custom service-optimized hardware
  - ODM sourced
- Purchasing power at volume
- Supply chain optimization
  - Shorter supply chain drives higher server utilization
    - Predicting next week easier than 4 to 6 months out
  - Less over buy & less capacity risk
- Networking transit costs strongly rewards volume
- Cloud services unblocks new business & growth
  - Remove dependence on precise capacity plan

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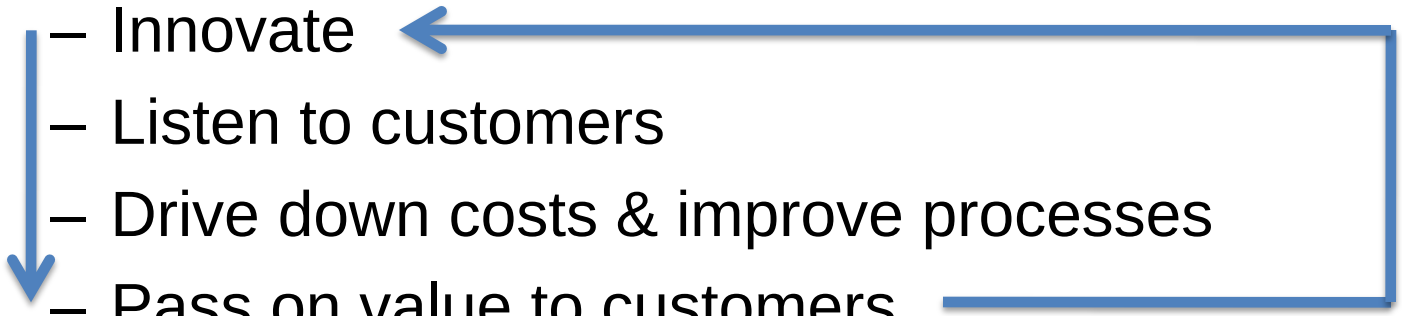
Amazon Cycle of Innovation

- 15+ years of operational excellence
  - Managing secure, highly available, multi-datacenter infrastructure
- Experienced at low margin cycle of innovation:
  - Innovate
  - Listen to customers
  - Drive down costs & improve processes
  - Pass on value to customers
- 19 AWS price reductions so far
  - Expected to continue



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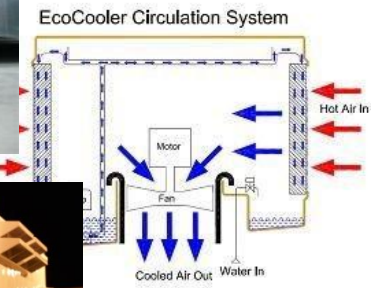
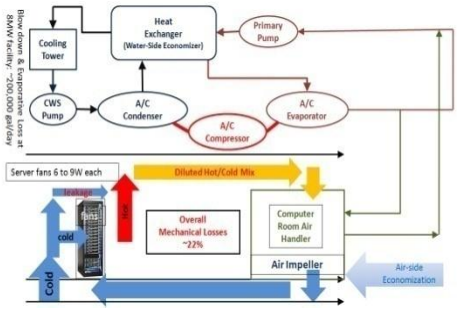
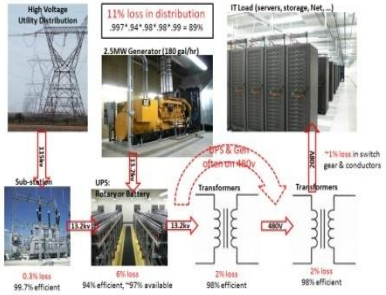




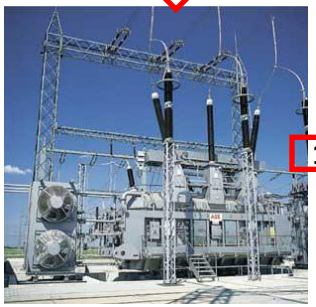


Power Distribution

High Voltage Utility Distribution

115kv

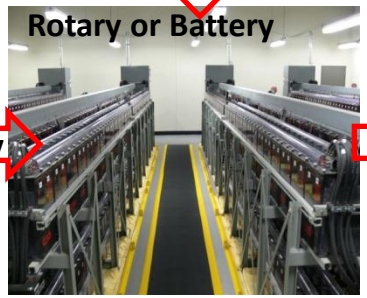
Sub-station



0.3% loss
99.7% efficient

13.2kv

UPS:
Rotary or Battery



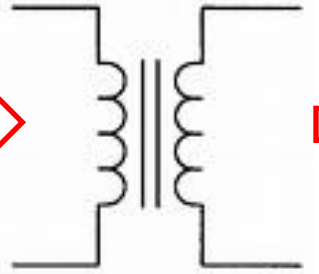
6% loss
94% efficient, ~97% available

Generators

13.2kv

13.2kv

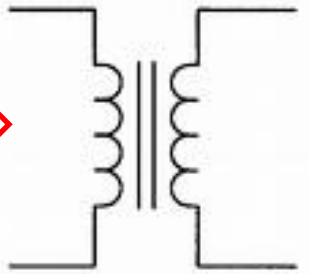
Transformers



2% loss
98% efficient

480V

Transformers



2% loss
98% efficient

208V

IT Load (servers, storage, Net, …)

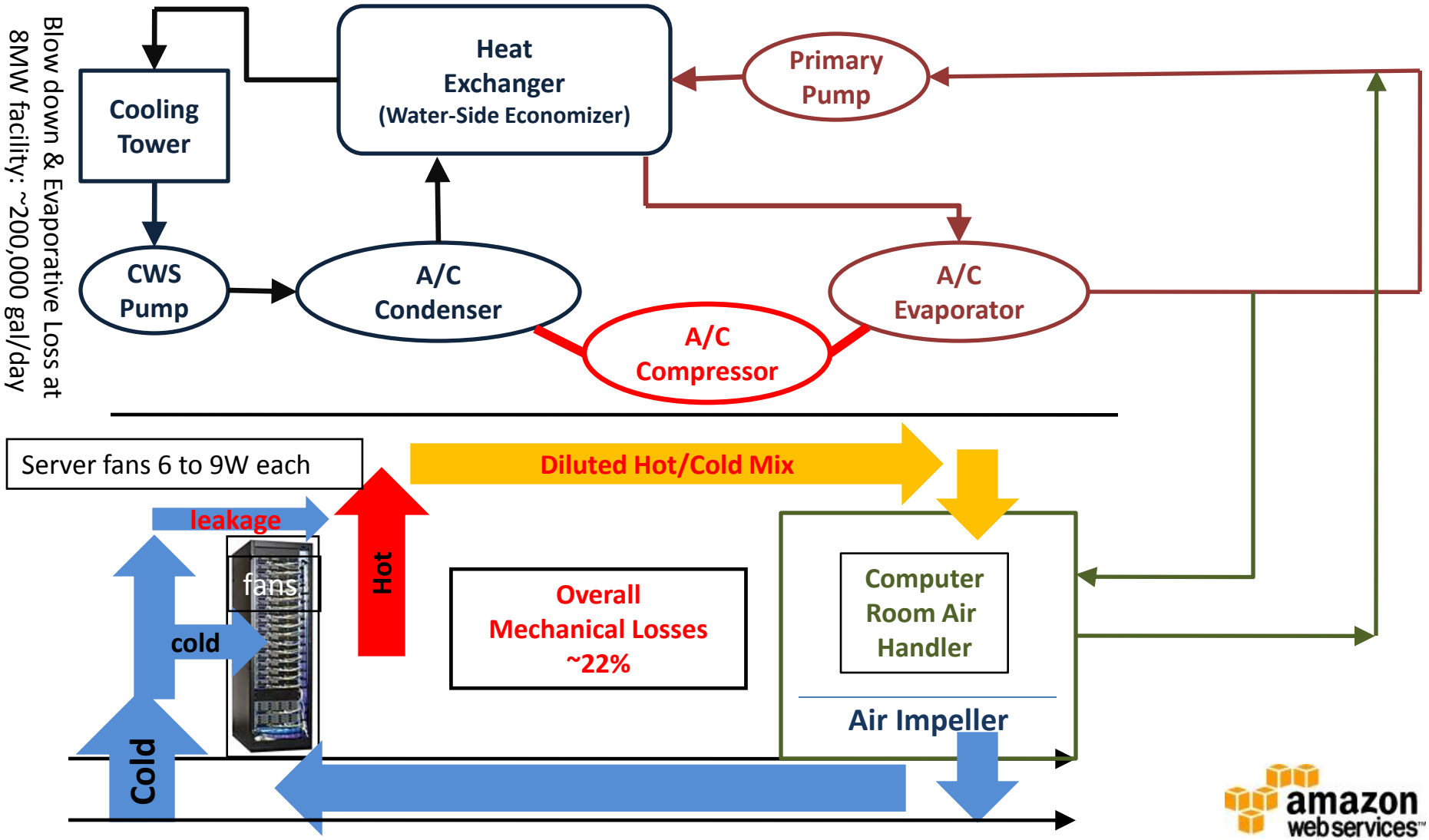
UPS & Gen
often on 480V

~1% loss in switch gear & conductors

~11% lost in distribution
.997*.94*.98*.98*.99 = 89%

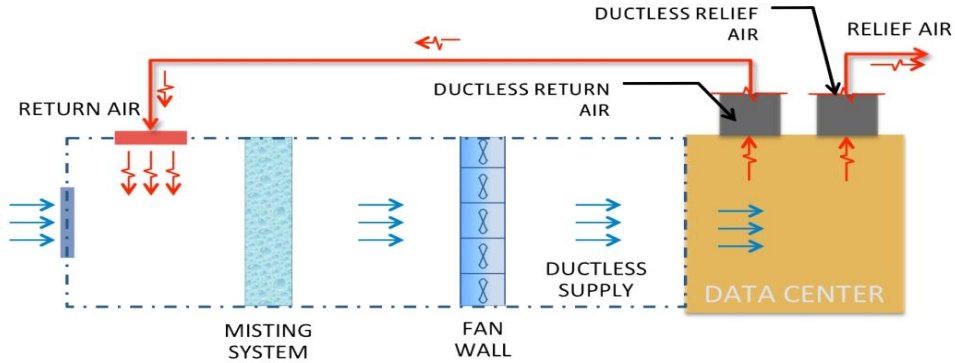
Note: Two more levels of power conversion at server

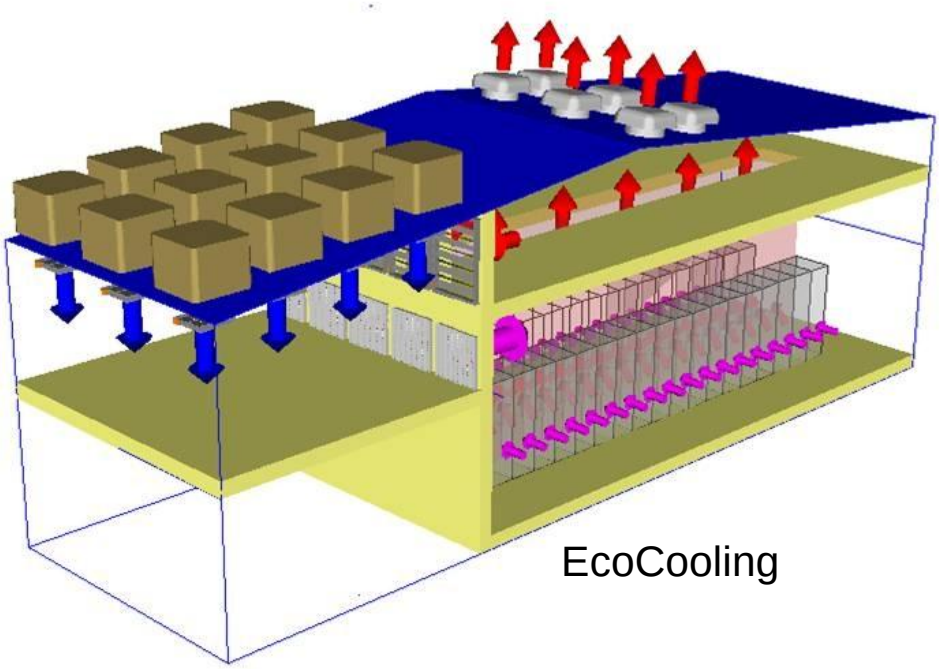
Mechanical Systems



Innovative Building Designs

- Evaporative cooling only
  - Right: High pressure misting
  - Below: Wet media cooler
- Ductless full building cooling





EcoCooling

Facebook Prineville above & below

Modular and Pre-fab DC Designs

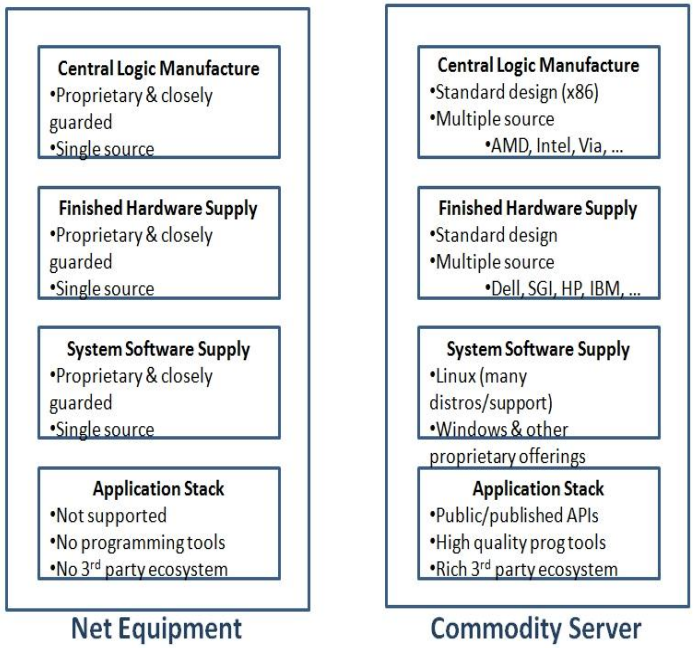
Microsoft ITPAC

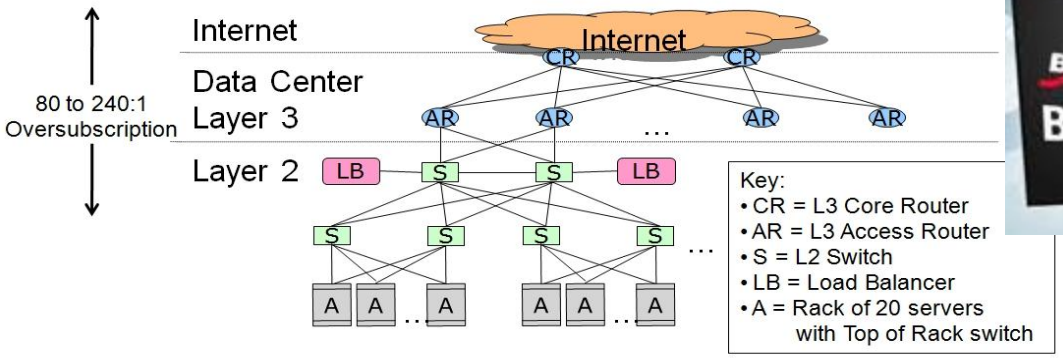
Amazon Perdix

- Fast & economic deployments
- Sub-1.15 PUE designs
- Air-side economized
  - No mechanical cooling
- ISO standard shipping containers offered by Dell, HP, SGI, IBM, …

Sea Change in Networking

- Current networks over-subscribed
  - Forces workload placement restrictions
  - Goal: all points in datacenter equidistant
- Mainframe model goes commodity
  - Competition at each layer over vertical integ.
- Get onto networking on Moores Law path
  - ASIC port count growth at near constant cost
  - Competition: Broadcom, Marvell, Fulcrum,…





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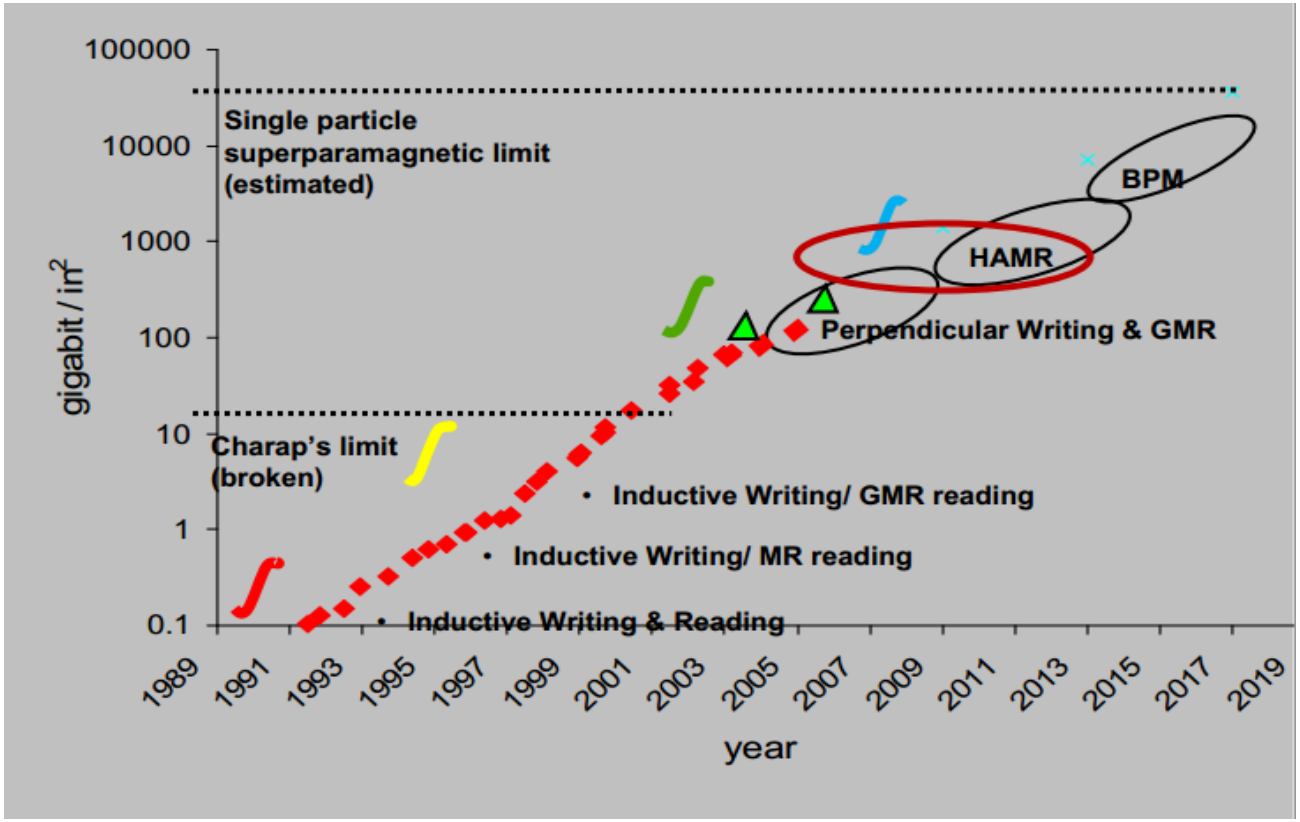
HDD: Capacity

- Capacity growth continues unabated

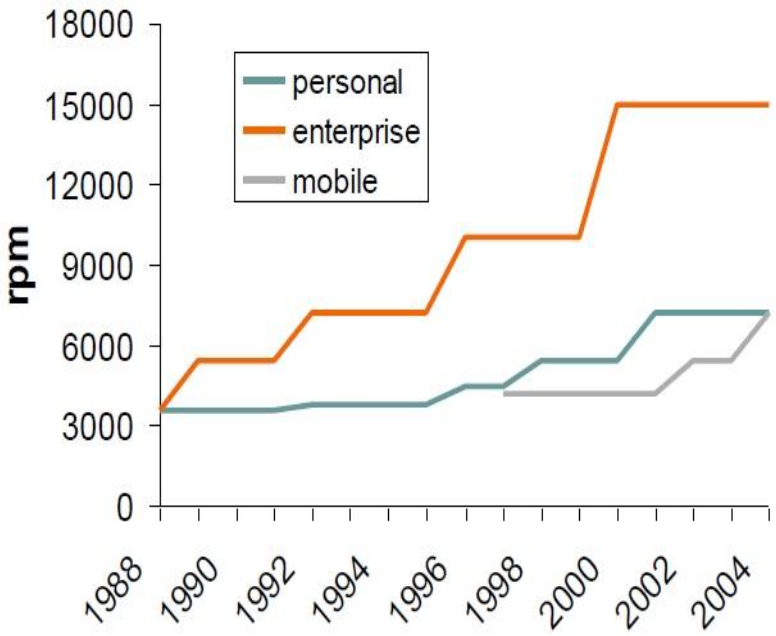


- Capacity isn't the problem
  - What about bandwidth and IOPS?

Source: Dave Anderson/Seagate

HDD: Rotational Speed

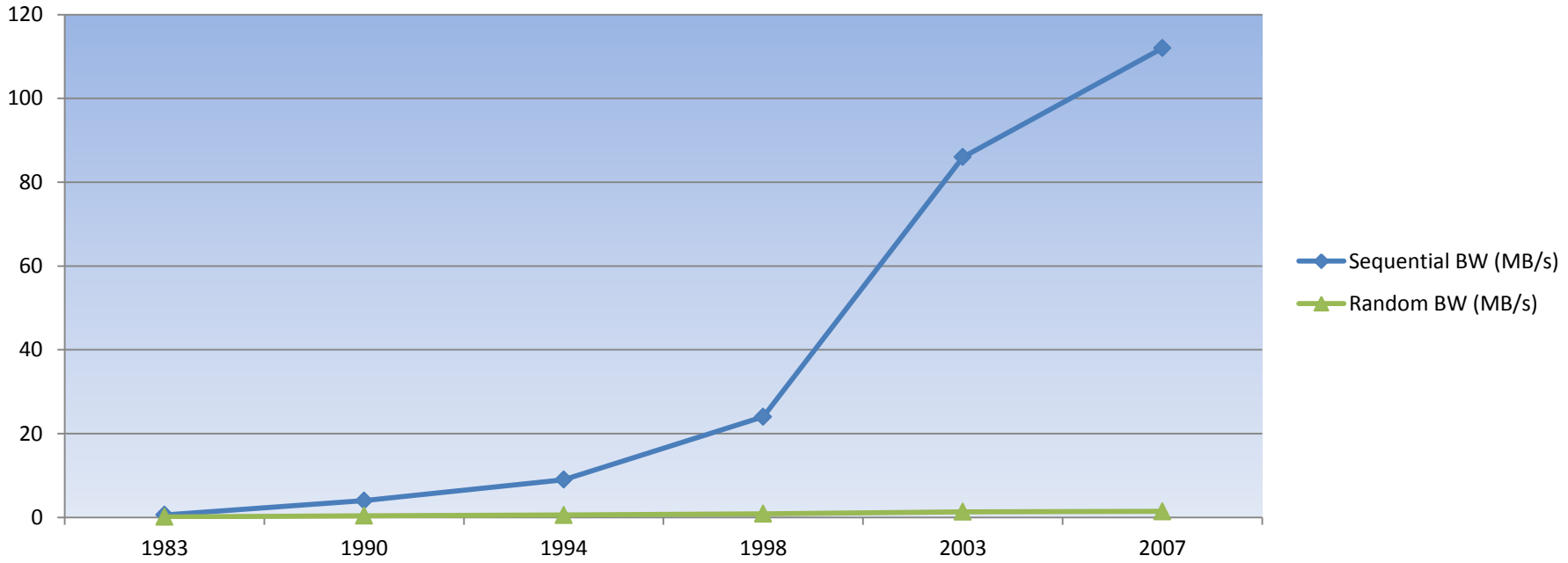
- RPM contributes negatively to:
  - rotational vibration
  - Non-Repeating Run Out (NRRO)
- Power cubically related to RPM
- >15k RPM not economically viable
  - no improvement in sight
- RPM not improving & seek times only improving very slowly
- IOPS improvements looking forward remain slow
- Even sequential BW growth insufficient



product information for Seagate and Control Data disc drives since 1988, mobile includes Toshiba drives since 1997

Source: Dave Anderson

HDD Random BW vs Sequential BW



- Disk sequential BW growth slow
- Disk random access BW growth roughly 10% of sequential
- Storage Chasm widening
  - BW a long term problem &IOPS growth very slow

Source: Dave Patterson with James Hamilton updates

Disk Becomes Tape

- Random access disk latency increasingly impractical
- Random read 4TB disk:
  - 41.3 days @ 140 IOPS with 8kb page
  - Disk increasingly impractical for random workloads
- Sequential read is over 11 hours
- Trending below tape price point
  - Tape only cost effective at very high scale
  - Disk wins at top and scales down better

Tape is Dead
Disk is Tape
Flash is Disk
RAM Locality is King

Jim Gray
Microsoft
December 2006

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Flash Becomes Disk

- All random workloads to Flash
- Flash 4 to 6x more expensive capacity
- Log structured block store
  - Compress
  - De-dupe
  - Sparse provision
- Approaches HDD capacity price point

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Client Storage Migration

- Client device disk replaced by semiconductor caches
  - Much higher performance, Lower power dissipation, smaller form factor, greater shock resistance, scale down below HDD cost floor, greater humidity range, wider temp range, lower service costs, …
  - Flash is primary client storage media

- Clients storage drives cloud storage
  - Value added services, many data copies, shared access, indexed, classified, analyzed, monetized, reported, …
  - Overall client storage continuing to expand rapidly but primarily off device in the cloud

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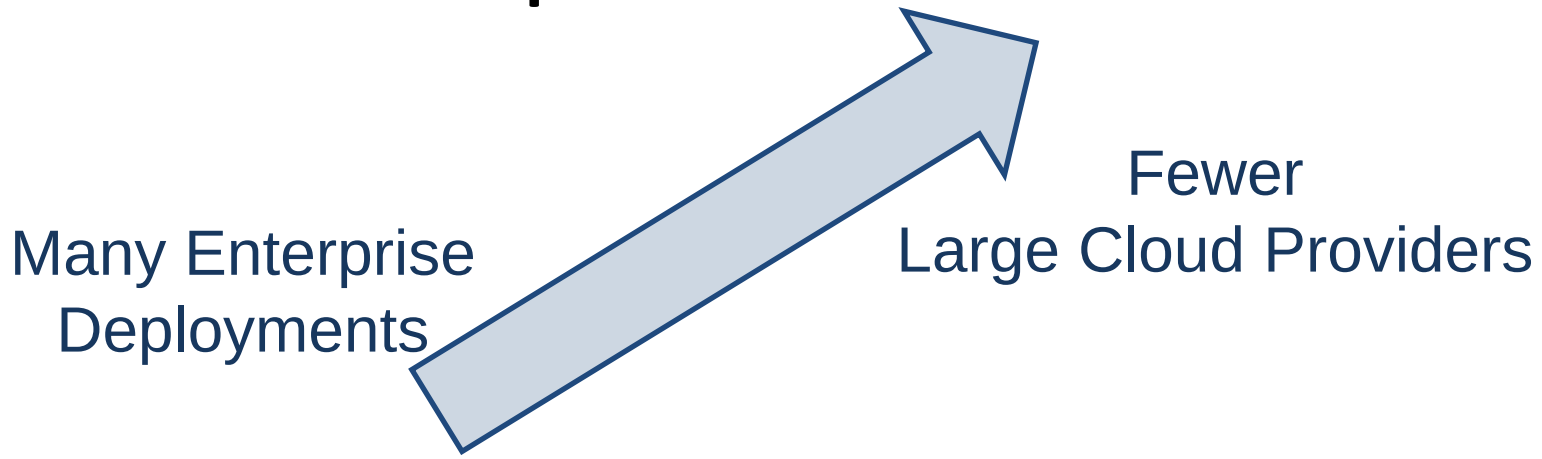
Enterprise to Cloud



- Cloud computing 5x to 10x improved price point
  - Low margin, high volume business
  - Yet still profitable, sustainable, & supporting re-investment
  - Incompatible with on-premise enterprise S/W & H/W profit margins
- Expect many cloud winners rather than single provider
- Direct component supplier relationship with major operators rather than via distribution channel
- Custom server & networking equipment

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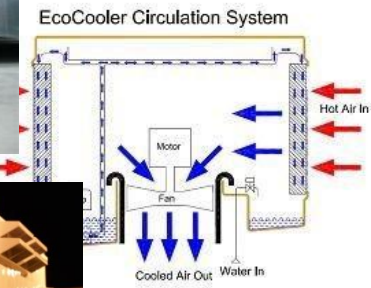

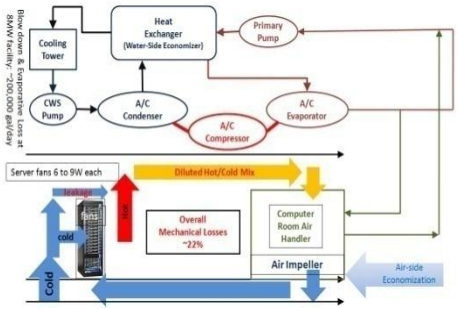

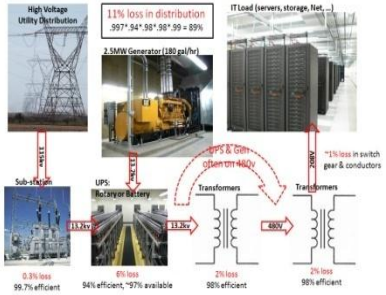

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Accelerating Compute & Storage Growth

- Rapidly declining cost of computing
  - Driven by technology improvements & cloud computing economies of scale
- Traditional transactional systems scale with business
  - Purchases, ad impressions, pages served, etc.
  - Computational trading & machine-to-machine transactions limited only by value of transaction & cost of infrastructure
- Warehousing & analytical systems scale inversely with cost
  - Cheaper storage allows more data to be analyzed
  - Lower compute costs allows deeper analysis

Questions?

- **Perspectives Blog:**
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