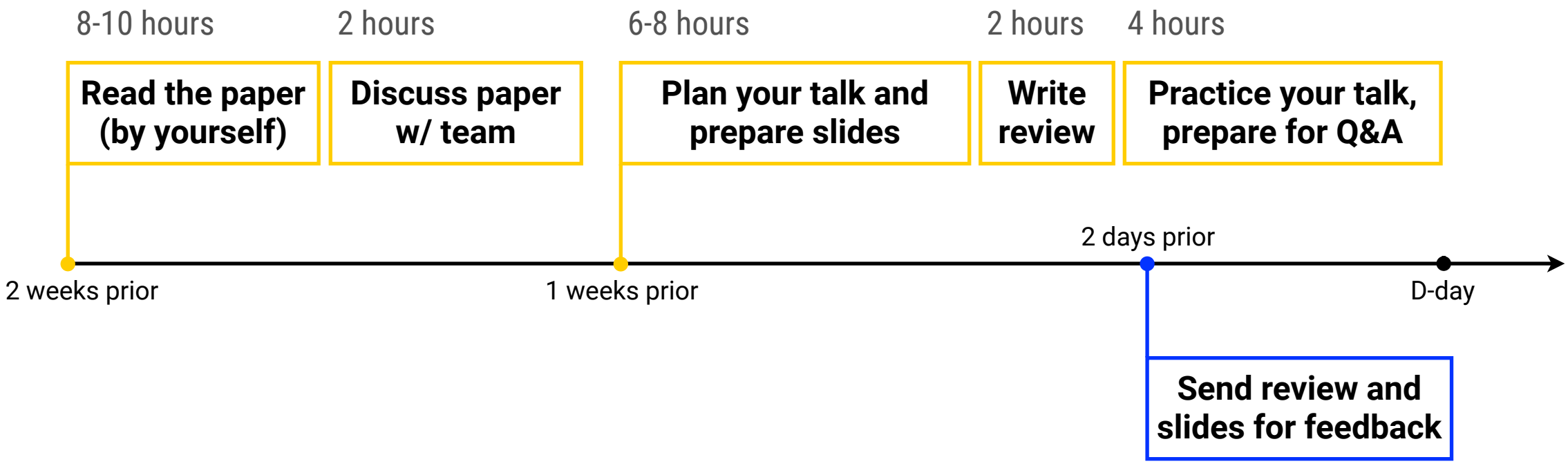
IOWA

CS5630

Datacenters (1): Computing at Warehouse-Scale

Prof. Supreeth Shastri
Computer Science
The University of Iowa

Preparing for Paper review and Presentations

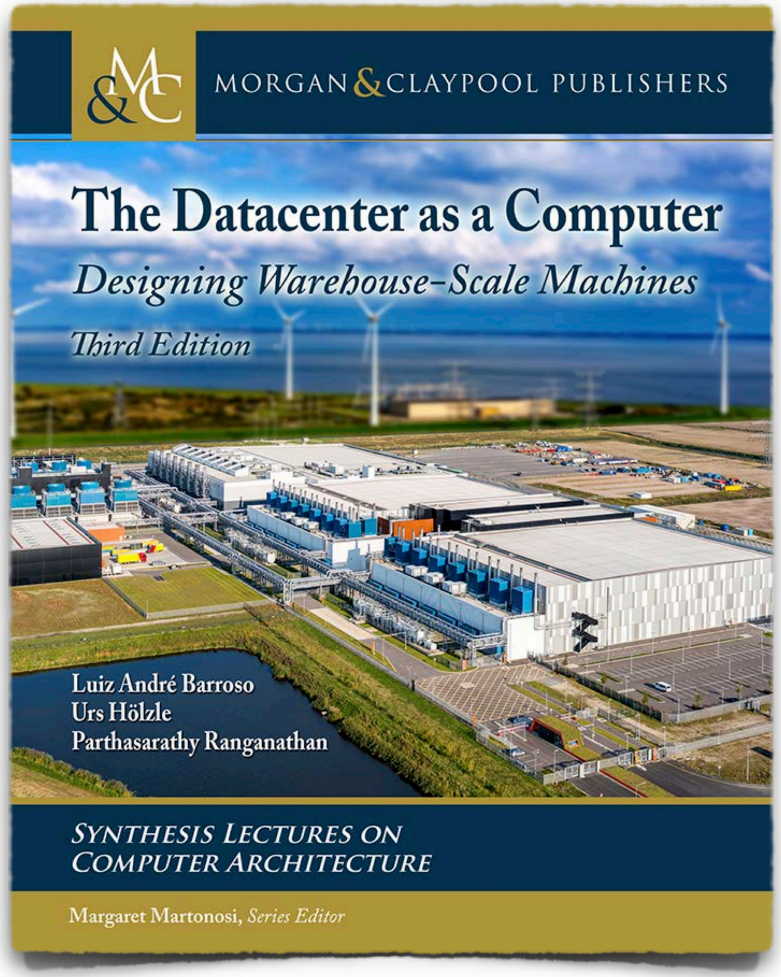


Expect to spend **~25 hours** (YMMV)

Lecture goals

Technical introduction to datacenters and warehouse-scale computing

- *Genesis and impact of WSC*
- *Hardware organization in datacenters*
- *TBA*



Chapter 1

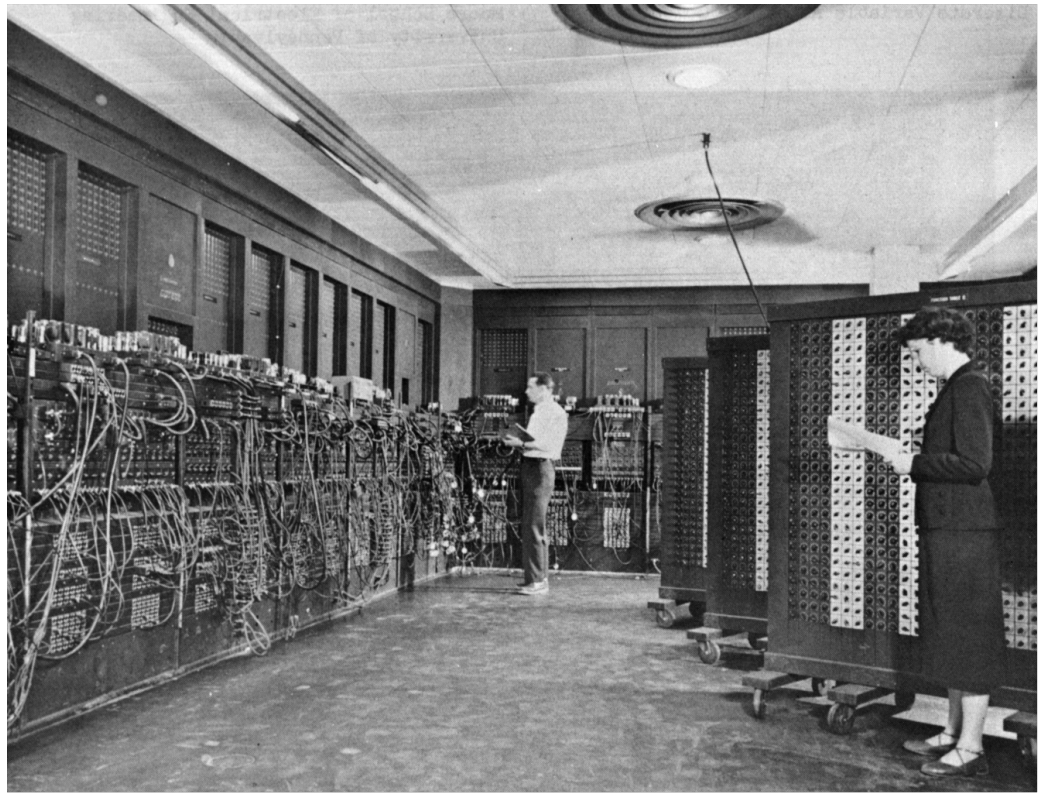
Datacenter

A building that houses computer systems, storage, and telecommunication equipment

Why a dedicated building?

- Complex, heavy, and elaborate machinery
- Component connectivity needed special accommodations
- Consumed significant amount of power and needed cooling
- Expensive; thus, needed security and isolation

Q: Is this a datacenter?



ENIAC (1946) at UPenn and Army Research Lab

Modern Datacenters

A building that houses computer systems, storage, and telecommunication equipment

- Built with commodity components
- O(10K - 100K) servers; O(100K) hard disks
- High-bandwidth commodity networking *(1—100Gbps Ethernet switches)*
- Dedicated power generators
- Heavily secured and guarded

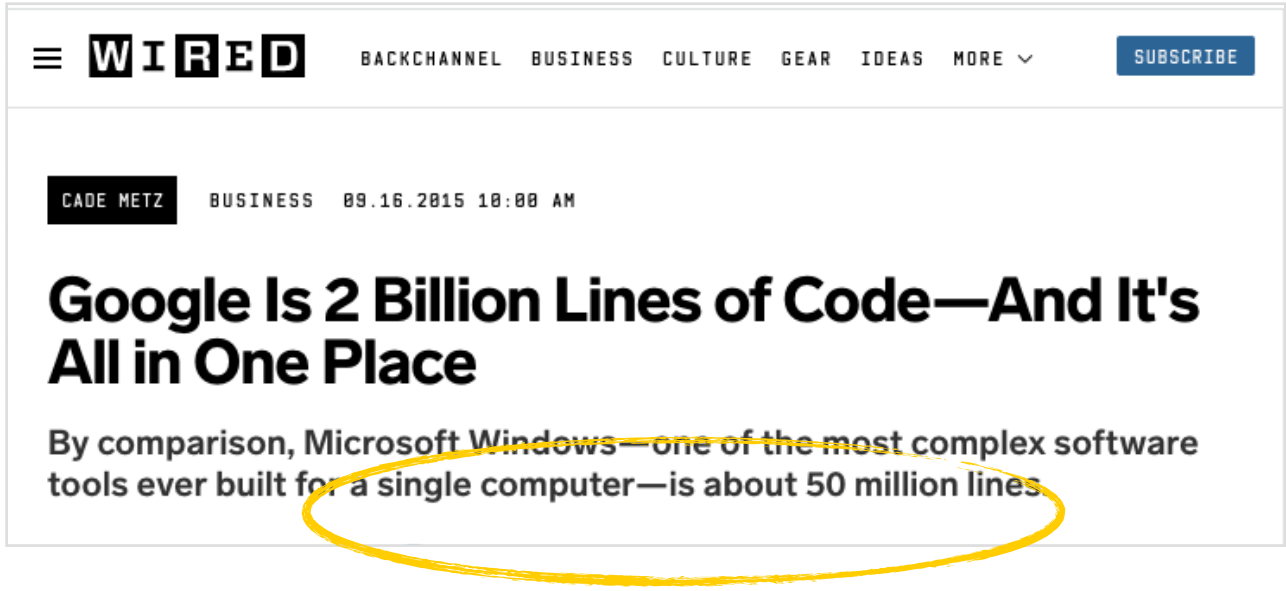
E.g., Google's datacenter in Amsterdam, Netherlands (CapEx: $1.1B)

Warehouse-Scale Computing

A paradigm of computing where applications require infrastructure at a massive scale (of the order of entire datacenters) to meet their performance goals

Consider **Google search**

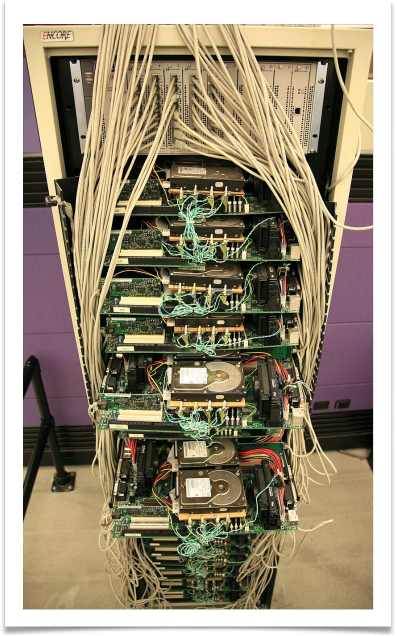
- it receives more than 5 billion queries per day (and has user base of a few billions)
- it takes over 200 factors into consideration before deciding on a search result
- and also…



Warehouse-Scale Computing: the genesis

In pioneer days they used oxen for heavy pulling, and when one ox couldn't budge a log, they didn't try to grow a larger ox. We shouldn't be trying for bigger computers, but for more systems of computers.

— Grace Hopper (1987)



Storage backend

No. of pages fetched: **24M**
WWW repository: **53.2GB**
Total system size: **108.7GB**

Google infrastructure (circa 1998)

Warehouse-Scale Computer

is the abstraction of a datacenter—internally consisting of hundreds of thousands of commodity components, but—providing a unified and massively scaled up view of computing

Warehouse-Scale Computing: impact

WSC has had significant impact on all aspects of hardware and software, performance and security

Scale of computing and storage

- No longer bound by the bottlenecks in processor/memory/interconnect architecture/capacity
- *For e.g., Moore's law (i.e the number of transistors on microchips doubles every two years) ended ~2010*

Economy of computing and storage

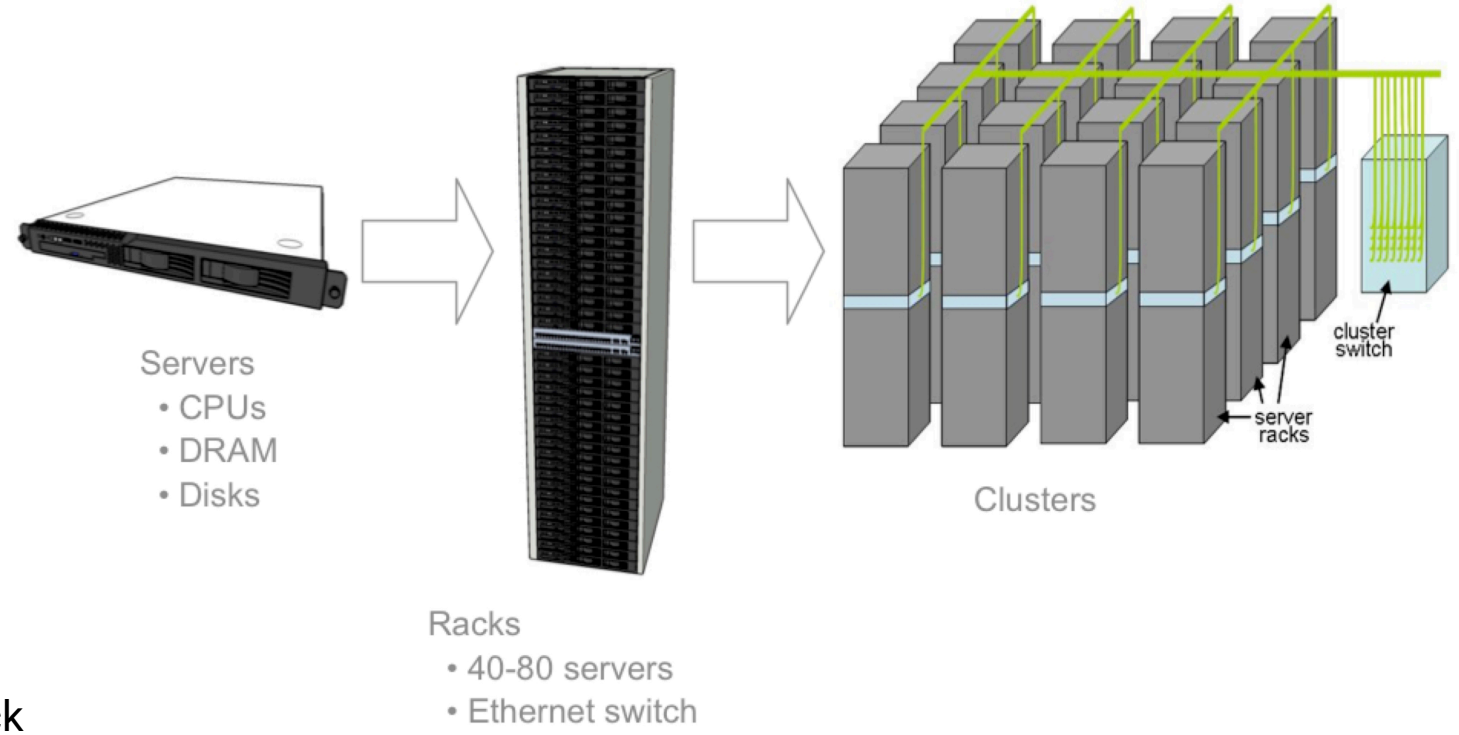
- Cost of computing/storage has fallen the fastest in the last decade (compared to any other time period)
- This has attracted more users and newer applications to cloud, further improving the economics

Reliability of computing and storage

- No longer limited by the electrical and physical laws of individual components
- *For e.g., AWS S3 offers eleven 9s of durability (there is no a storage system in the market with that feature)*
- New challenge: create warehouse-level fault-tolerance mechanisms/policies

Datacenters: A Technical Overview

Hardware Organization



Hierarchical structure

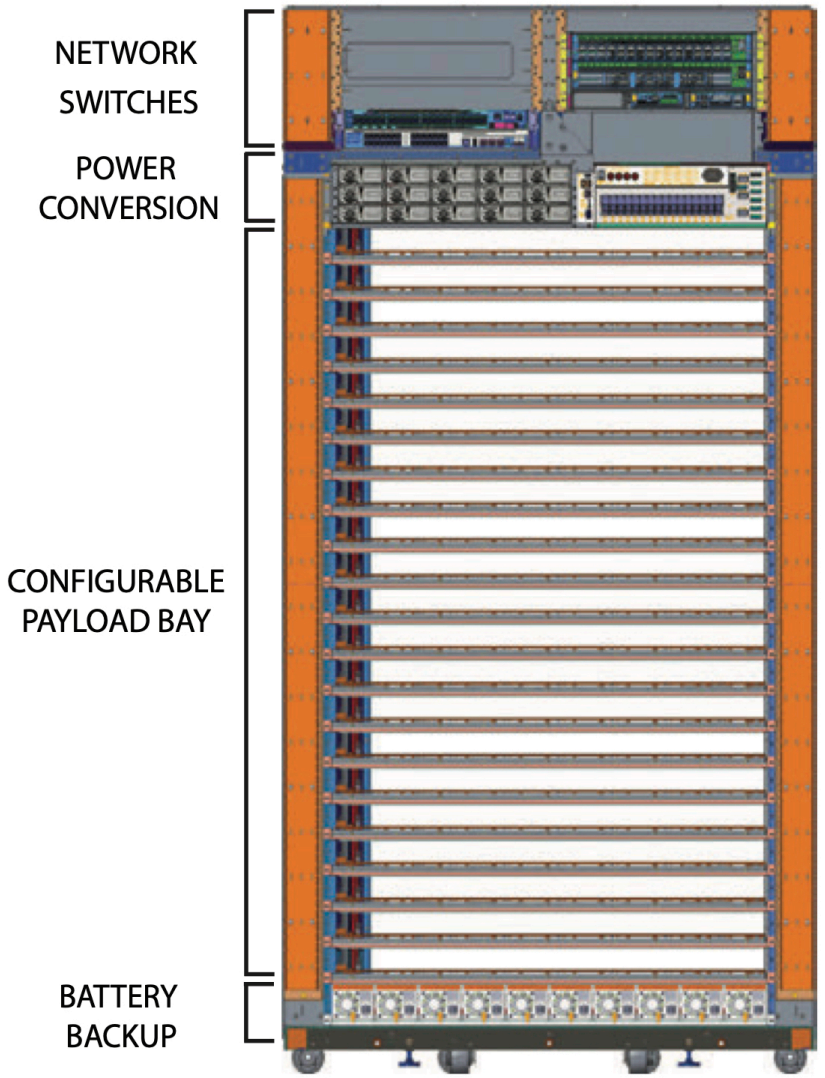
- low-end, commodity components
- Blade servers mounted within a rack
- Racks organized as clusters
- Ethernet switches (lower capacity at rack level, and denser interconnects at cluster level)

How do these schematics look in the real datacenters?

Hardware Organization

Racks up close!

- Network switches and power management on the top
- Compute and storage blades in the middle (10-40 Rack Units)
- Made of reinforced metal; open in the front and back; wheels for ease of movement



Hardware Organization

Compute + Networking

Server racks have 2-4 switches to which servers connect using different colored cables.

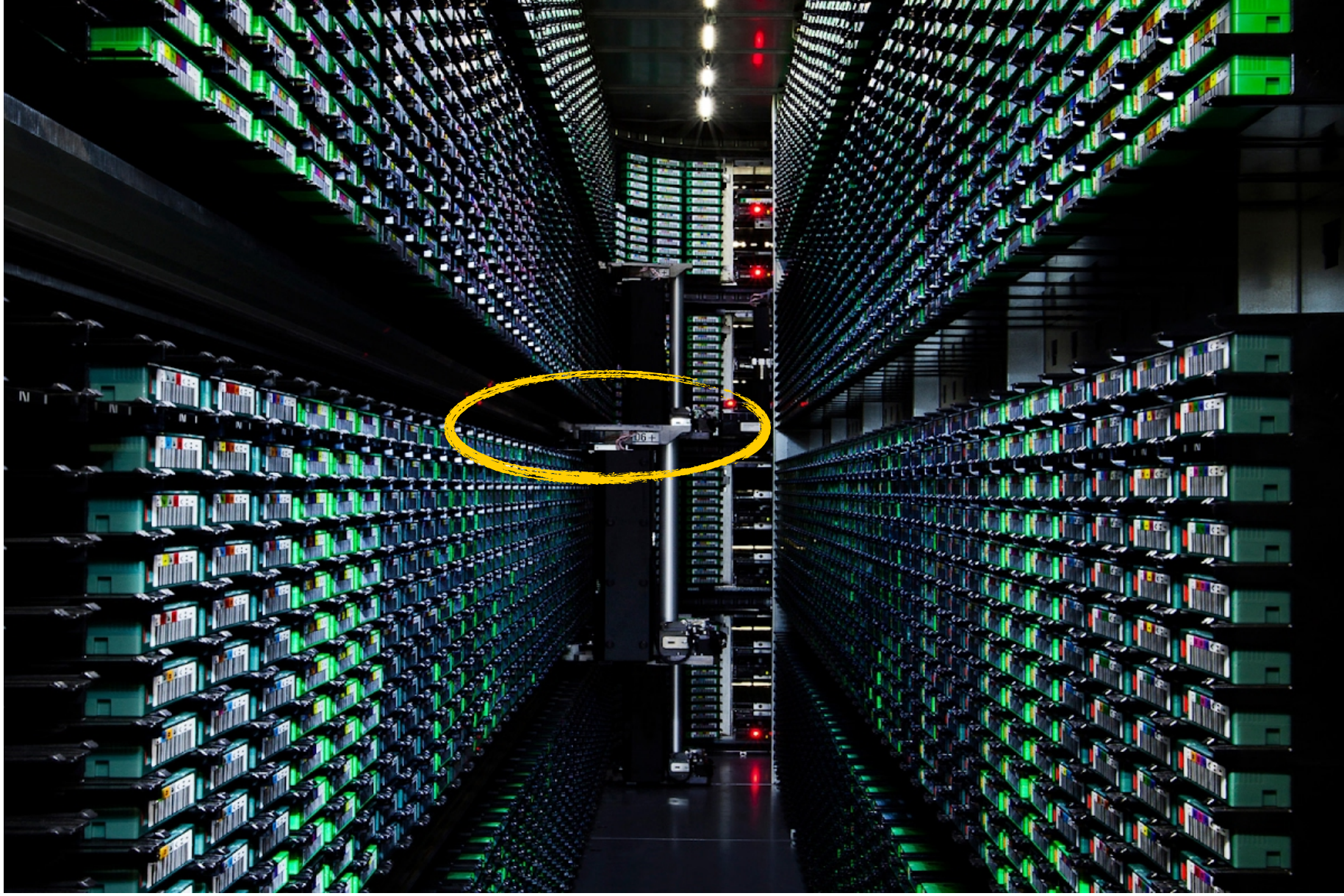
Fiber optic cables (running in yellow cable trays near the ceiling) provide connectivity to the Internet and other Google datacenters.

Hardware Organization

STORAGE

A tape library in a South Carolina data center.

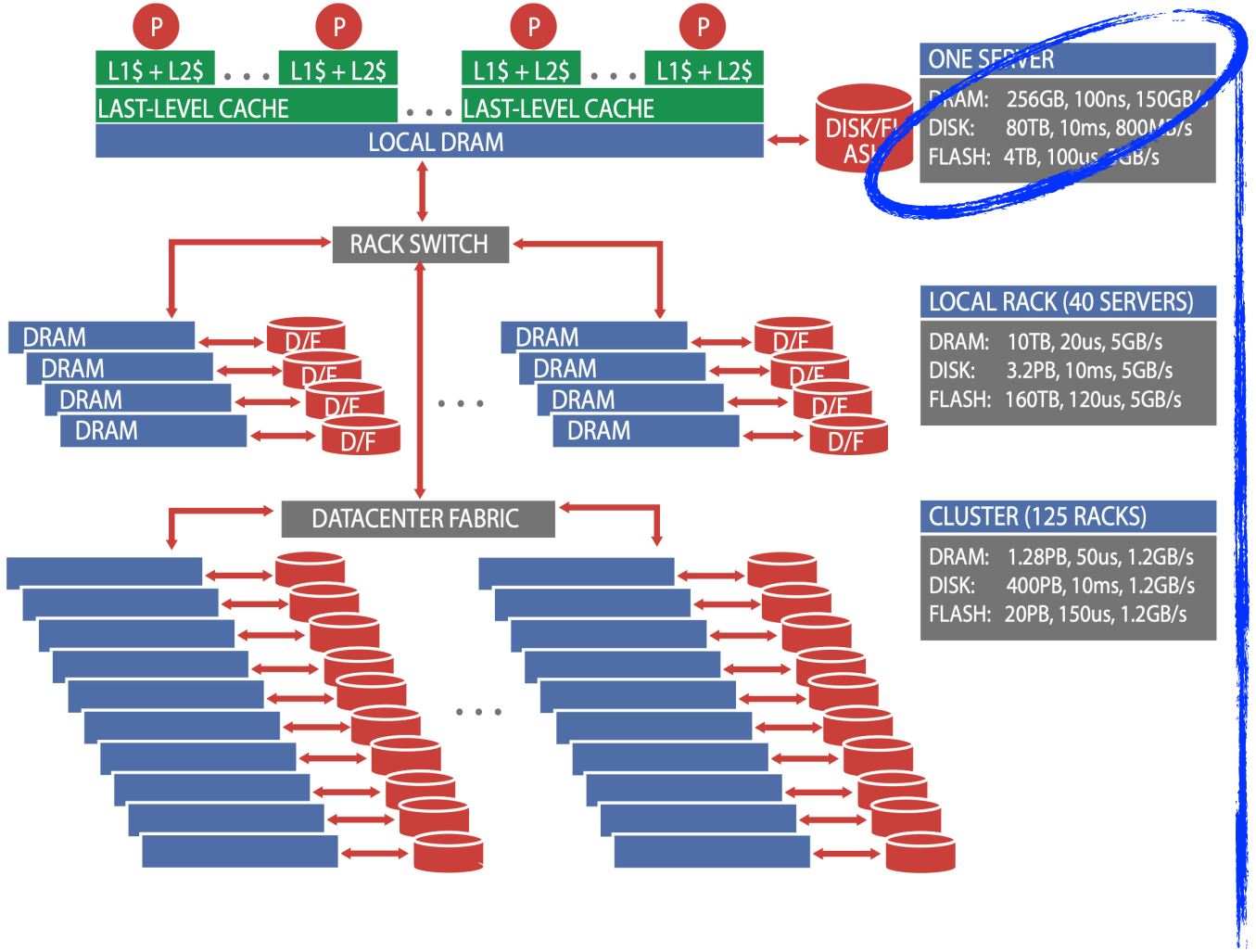
Robotic arms (visible at the end of the aisle) assist in loading and unloading of tapes when their data need to be accessed.



Hardware Organization

A Programmer's View of Storage Hierarchy

- Each server consists of its own cache, memory, and disk/flash drive
- Each server has access to the three storage media of other servers in the same rack via Ethernet
- Each server can also access the storage media at the cluster level using the datacenter fabric
- Remote procedure APIs make these device accesses seamless

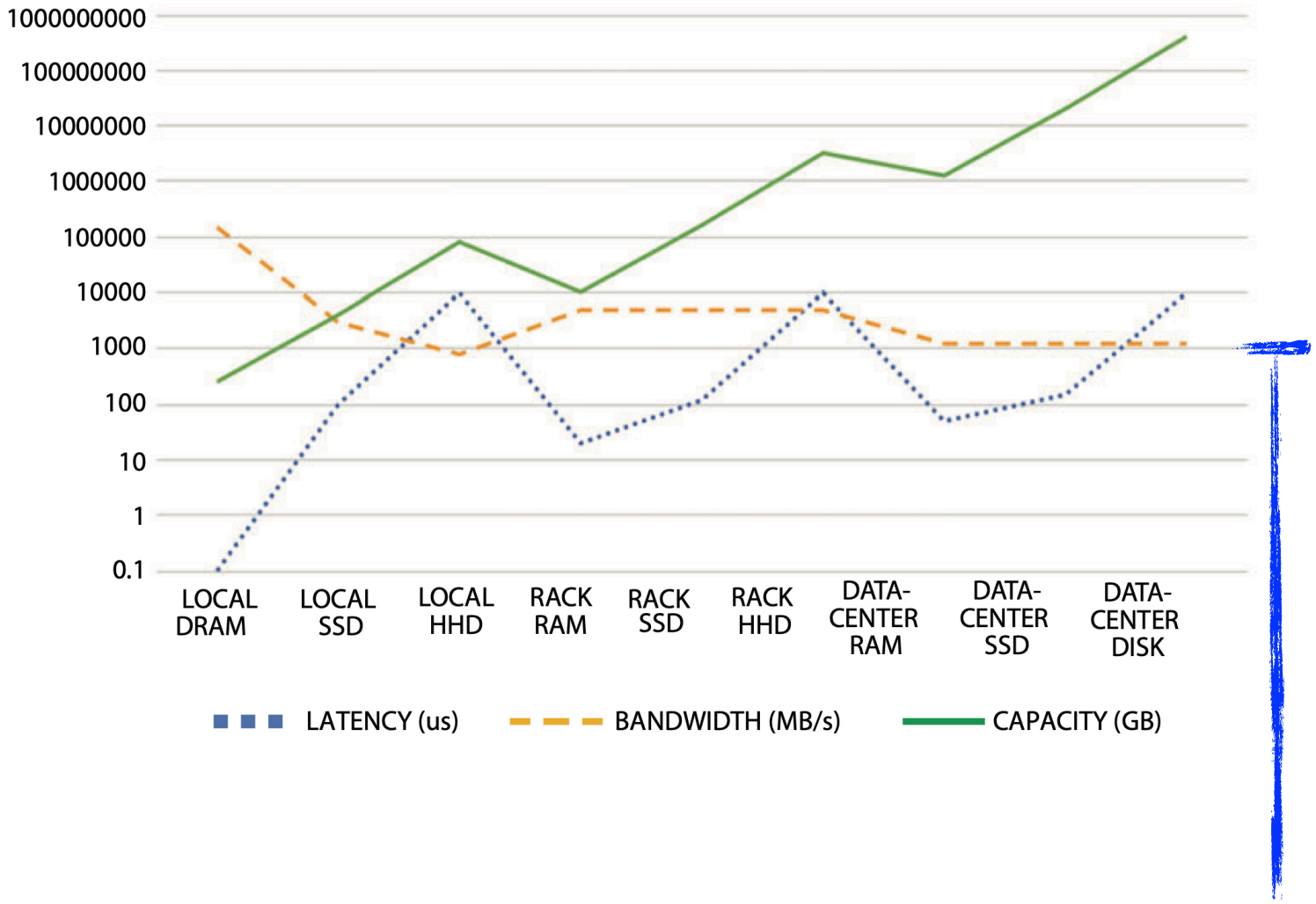


For reference: my laptop has 16GB DRAM, 500GB flash drive

Hardware Organization

A Programmer's View of Storage Hierarchy

- The choice of storage media should be governed by the needs of the application
- Local vs. remote phenomena is observable in latency, bandwidth, and capacity
- Network setup: 40Gbps rack-level switch supports 40 servers; cluster-level router provides a bandwidth of 10Gbps per rack (*oversubscribed*)



Storage bandwidth at rack/cluster level is largely governed by the network bandwidth (plateauing of the orange curve)

Hardware Organization

Putting it all together

Datacenter in Council Bluffs, Iowa provides 115,000 sq. feet of rack space.

It supports services including Search and YouTube

Hardware Organization

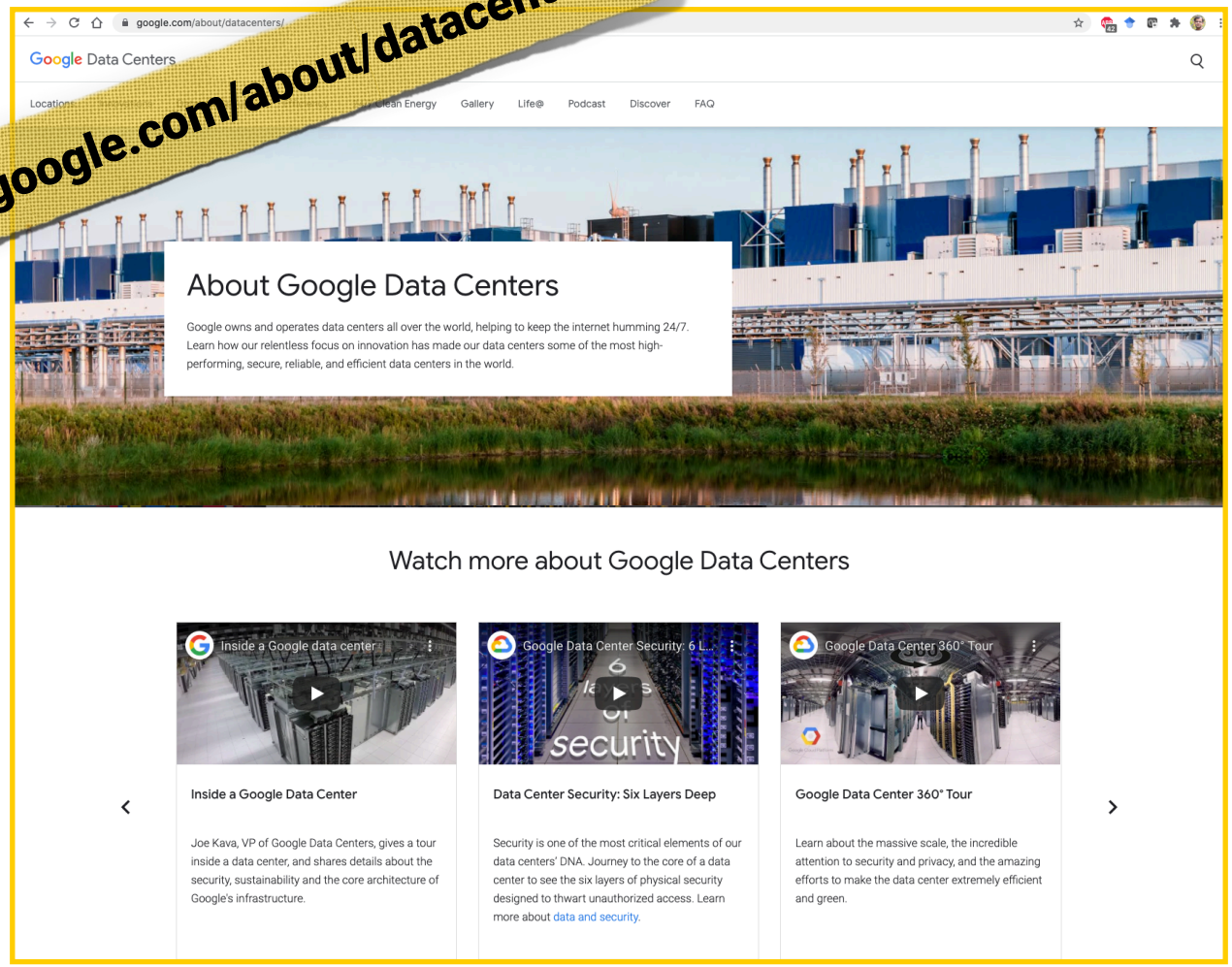
Zooming out

85 datacenters in 28 locations worldwide

No. of servers estimated to be 2.5M (circa 2016)

… there is more (a lot more) to learn about datacenters

https://www.google.com/about/datacenters/



Spot Quiz (ICON)