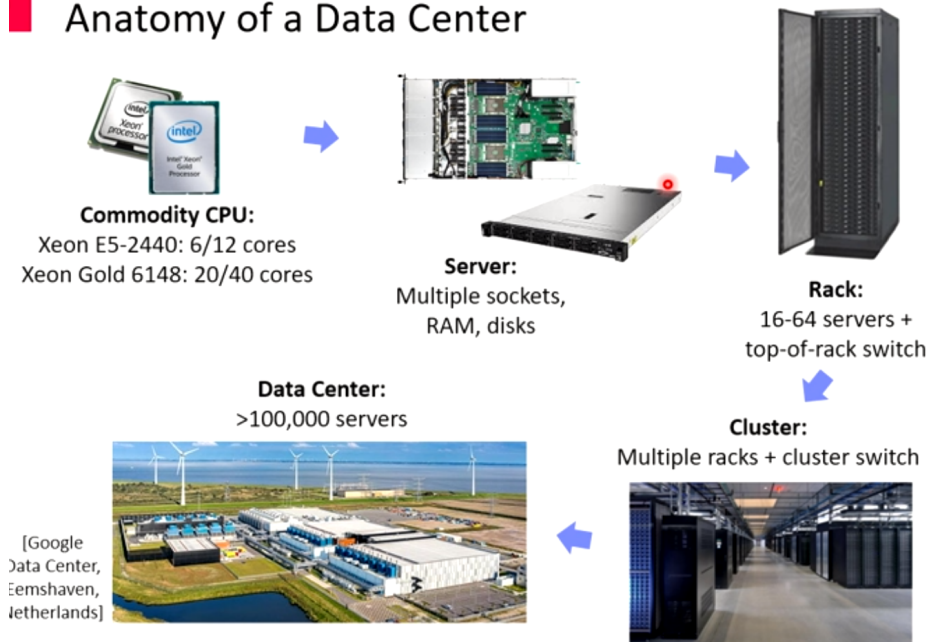


## Anatomy of a Data Center

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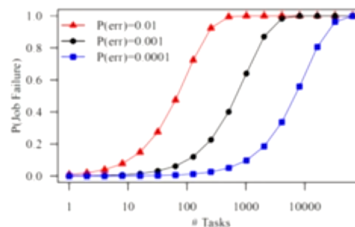
## Fault Tolerance

### Yearly Data Center Failures

- ~0.5 **overheating** (power down most machines in <5 mins, ~1-2 days)
- ~1 **PDU failure** (~500-1000 machines suddenly disappear, ~6 hrs)
- ~1 **rack-move** (plenty of warning, ~500-1000 machines powered down, ~6 hrs)
- ~1 **network rewiring** (rolling ~5% of machines down over 2-day span)
- ~20 **rack failures** (40-80 machines instantly disappear, 1-6 hrs)
- ~5 **racks go wonky** (40-80 machines see 50% packet loss)
- ~8 **network maintenances** (~30-minute random connectivity losses)
- ~12 **router reloads** (takes out DNS and external v IPs for a couple minutes)
- ~3 **router failures** (immediately pull traffic for an hour)
- ~dozens of minor 30-second blips for dns
- ~1000 **individual machine failures** (2-4% failure rate, at least twice)
- ~thousands of **hard drive failures** (1-5% of all disks will die)

### Recap: Error Rates at Scale

- Cost-effective commodity hardware
- Error rate increases with increasing scale
- Fault Tolerance for distributed/cloud storage and data analysis



### Cost-effective Fault Tolerance

### Other Common Issues

- Configuration issues**, partial SW updates
- Transient errors**: no space left on device,

### Cost-effective Fault Tolerance

- BASE** (basically **available**, soft state, **eventual**)
- Effective techniques
  - ECC (error correction codes), CRC (cyclic)
  - Resilient storage**: replication/erasure co
  - Resilient compute**: task re-execution / s