AWS re:Invent

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STG302

Dive deep on Amazon S3

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Principal Engineer
Amazon S3

Using scale to our advantage … and yours

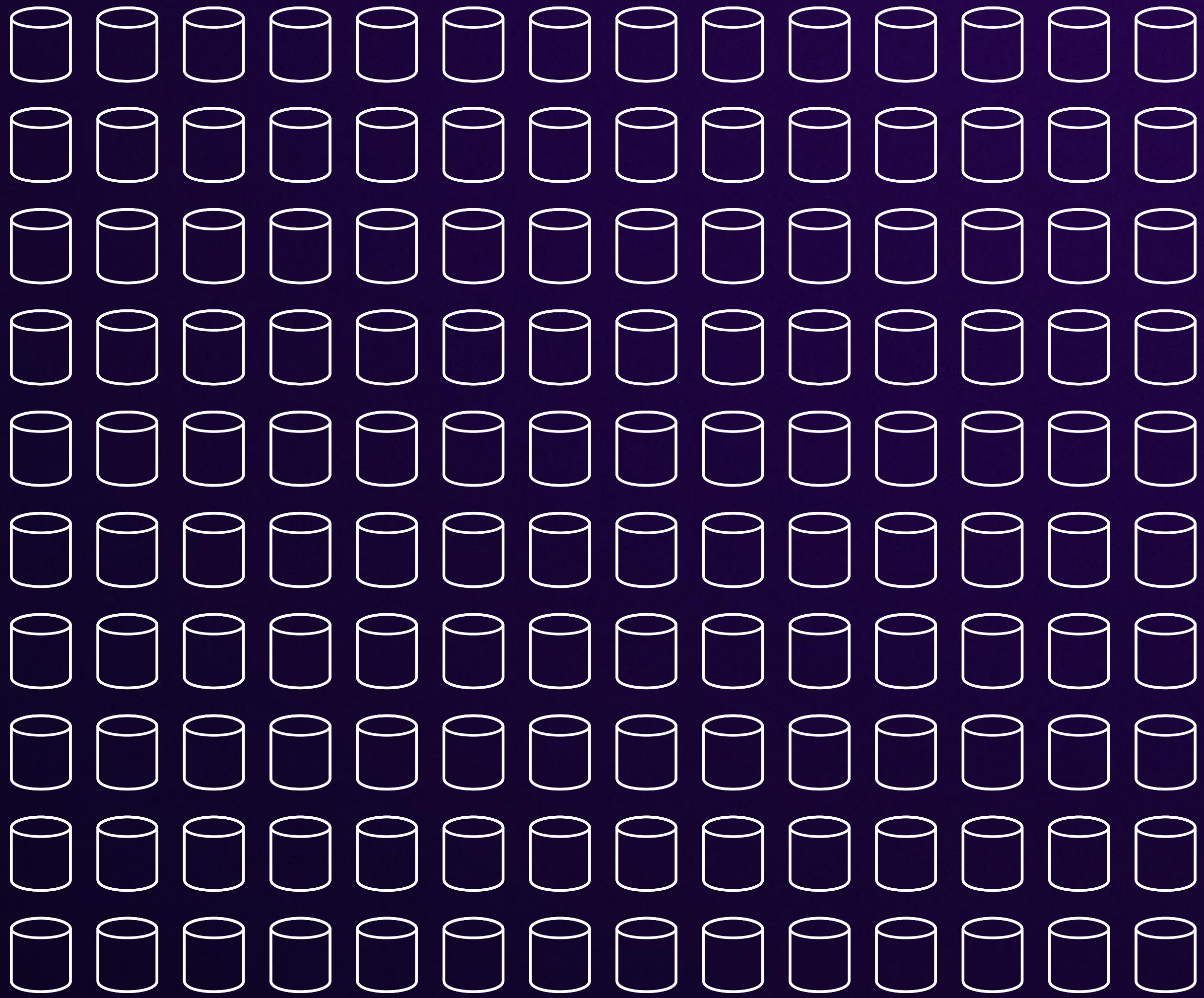
Amazon S3 at scale

Over 400 trillion objects

Over a quadrillion requests per year

Over 200 billion events daily

Over 1 PB/s transferred at peak



01 Physics of data

02 Designing decorrelated systems

03 Engineering for failure is engineering for velocity

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aws

The hardware, HDDs

Rotational latency
Seek time

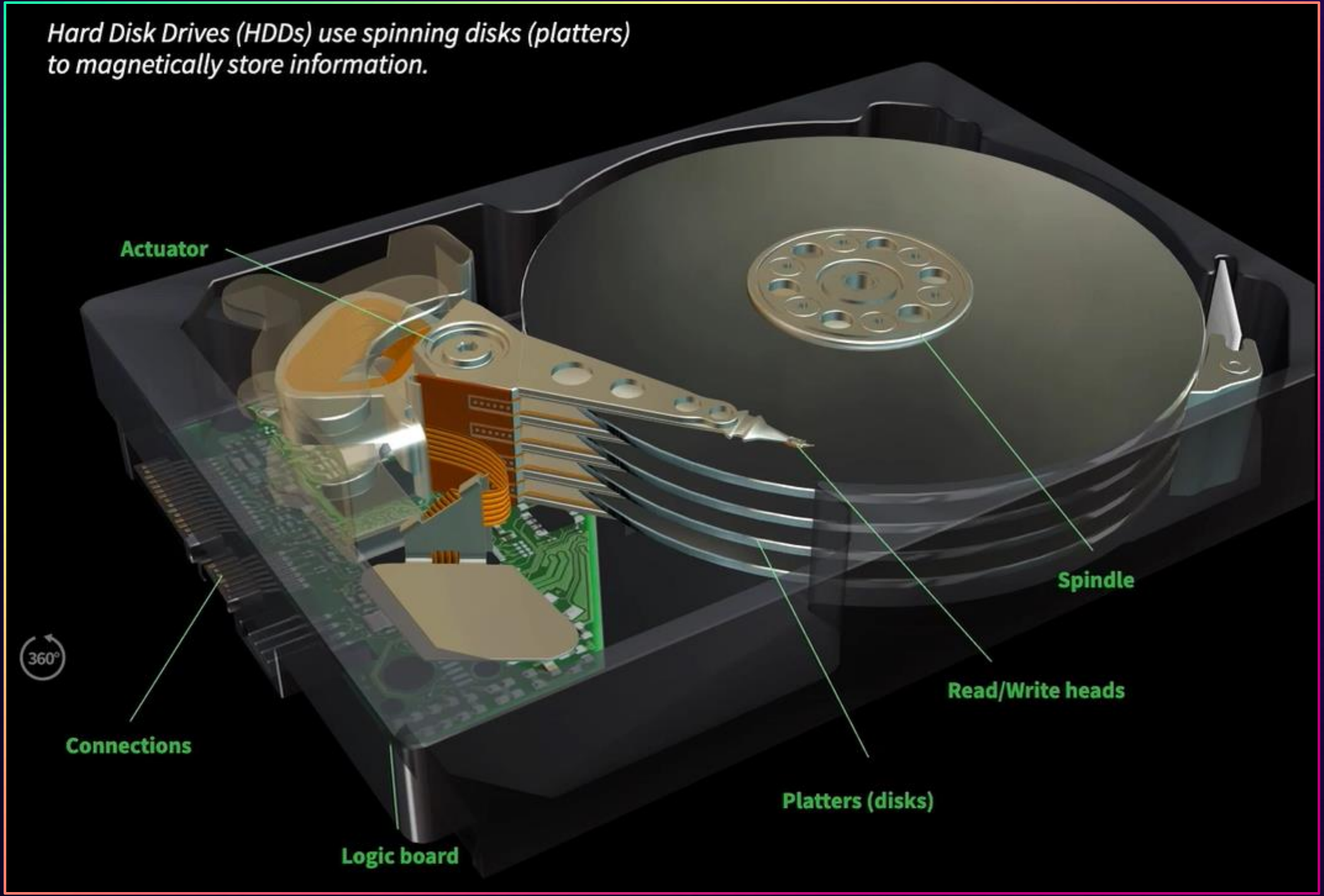
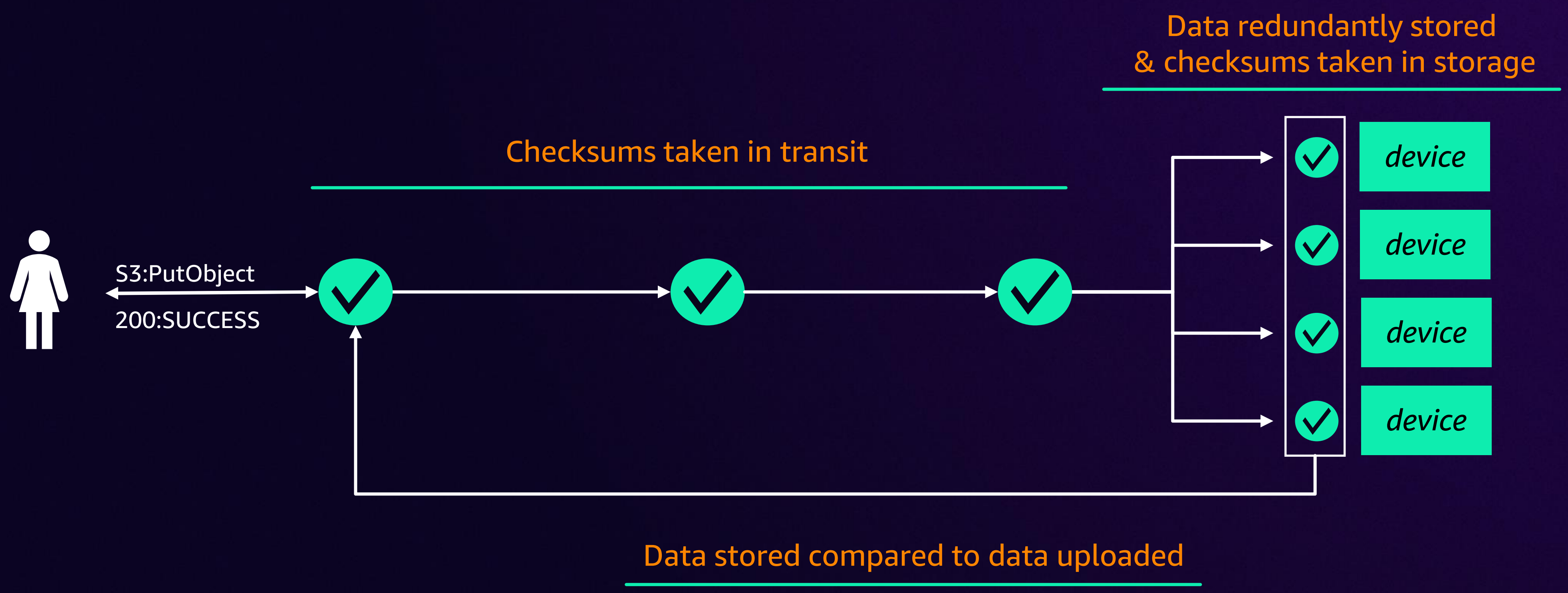
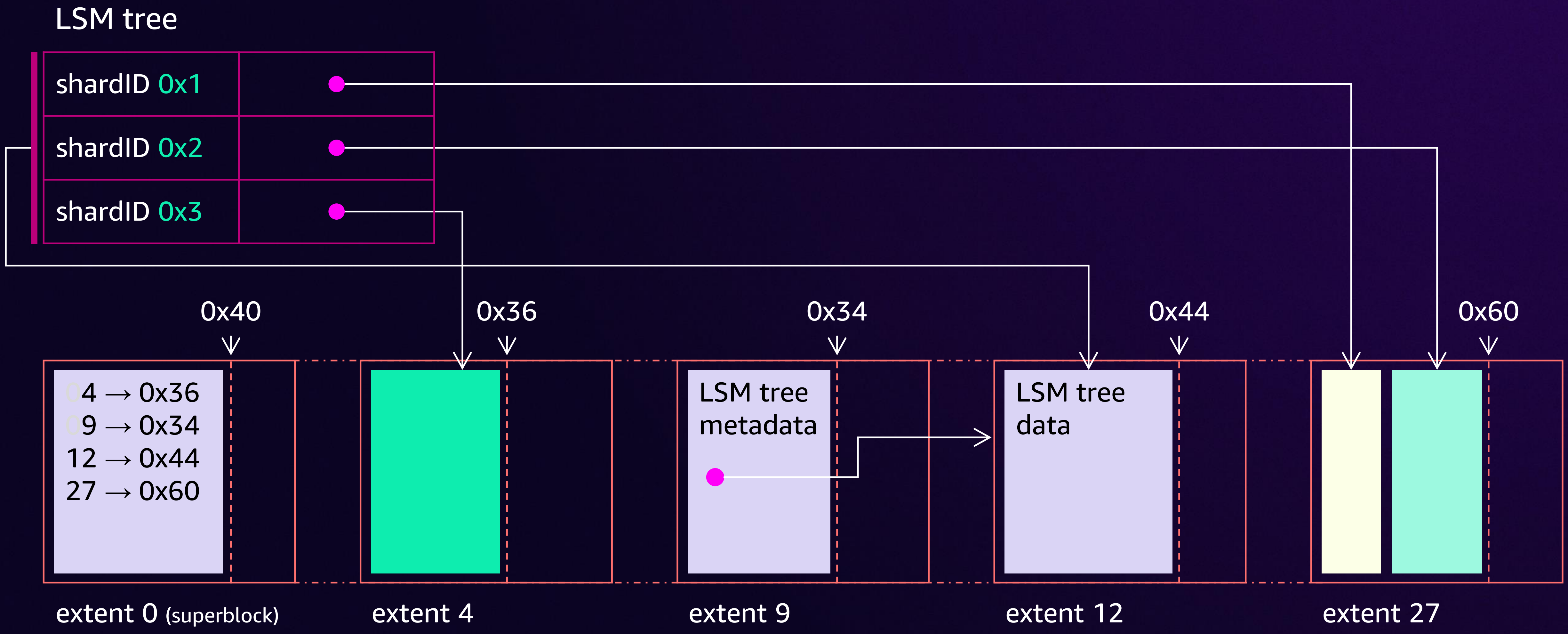


Image by Animagraffs
https://animagraffs.com/hard-disk-drive/

The software, Replication



The software, ShardStore



Individual workloads

- Individual workloads are bursty
- Provisioning for peak

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- Provisioning for peak
- Customer Example: FINRA

The physics of data

- Example:
  - 1 PB of data
  - 1 MB per object
  - Accessed in a single hour

The physics of data

- Rotation = 4 ms, average
- Seek = 4 ms, average
- 0.5 MB Transfer = 2 ms, average
- Total: 10 ms per read (100 reads/second)
- 50 MB per second at 0.5 MB/read

The physics of data

- 1 PB of data
- 275 GB per second

The physics of data

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  - 50 drives at 20 TB per drive
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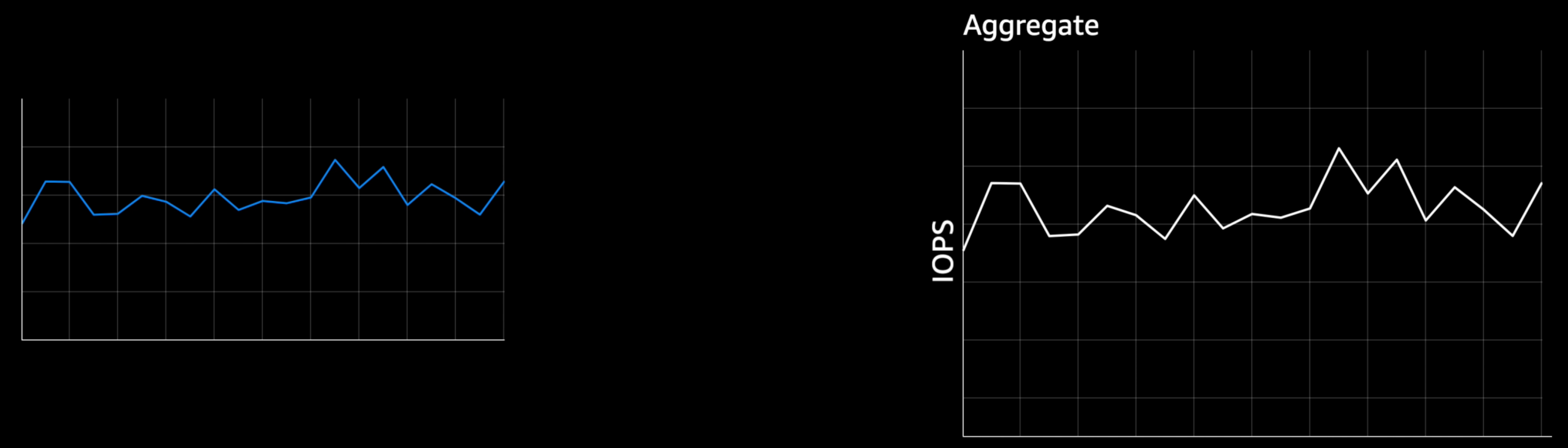
  - 5500 drives at 50 MB per second

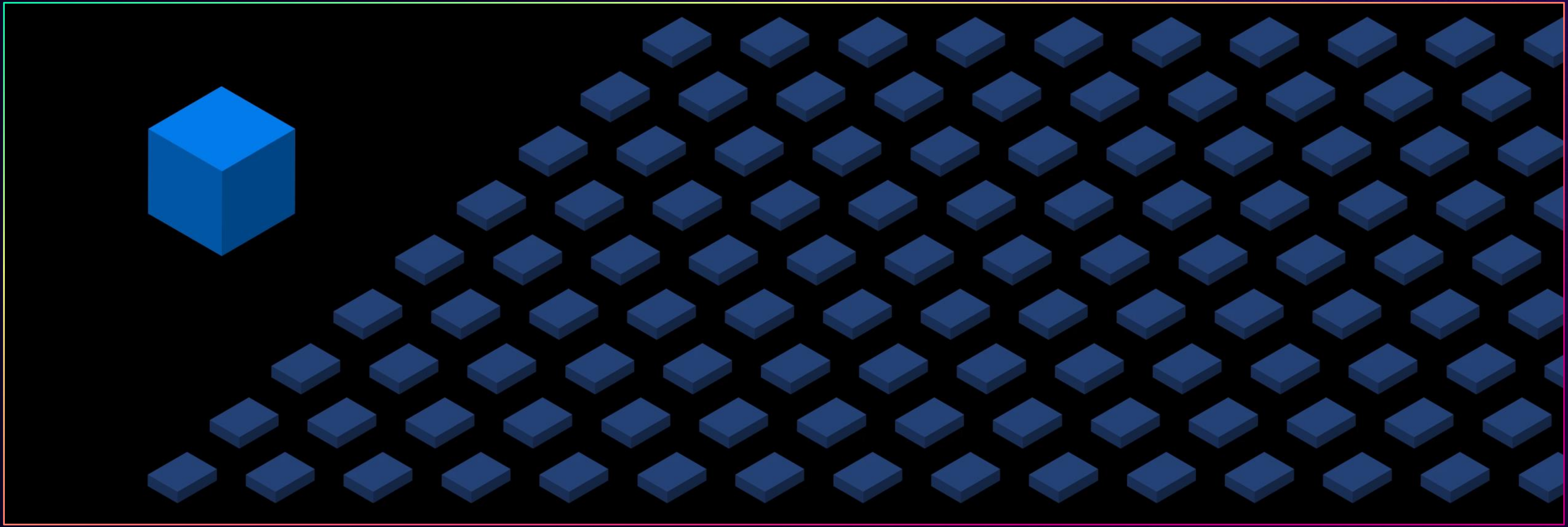
The physics of data

- 1 PB of data
  - 50 drives at 20 TB per drive
- 275 GB per second
  - 5500 drives at 50 MB per second
- 100x difference to support bursts!

Effect of aggregating decorrelated workloads on net system load



Spread shards across a large number of diverse disks



Thermodynamics: Balancing the aggregates

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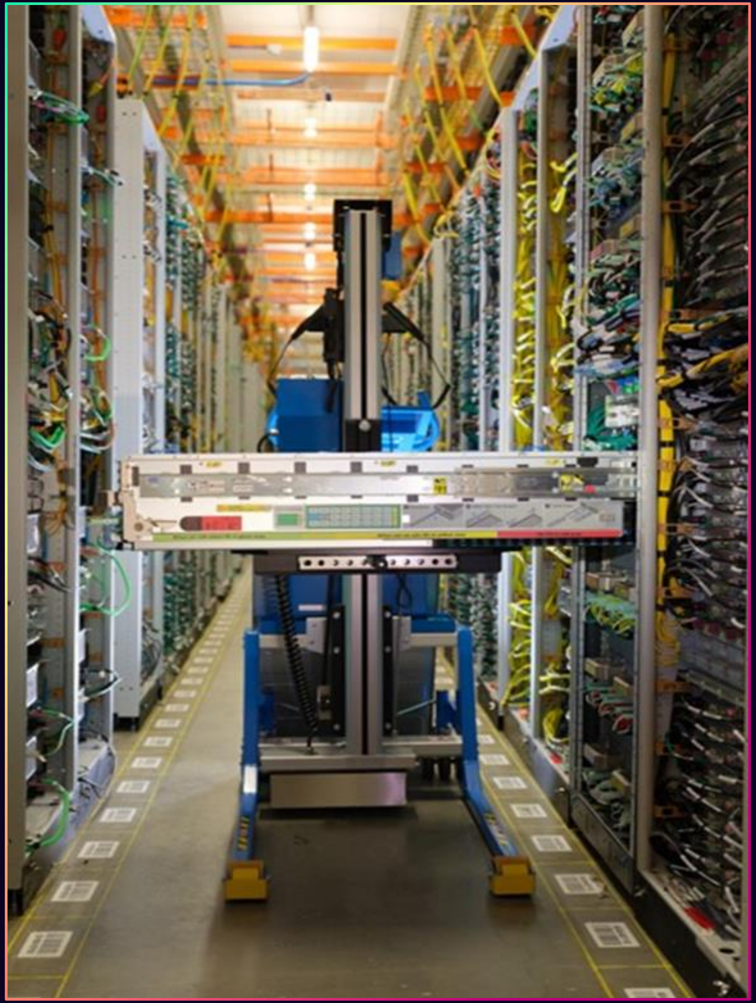
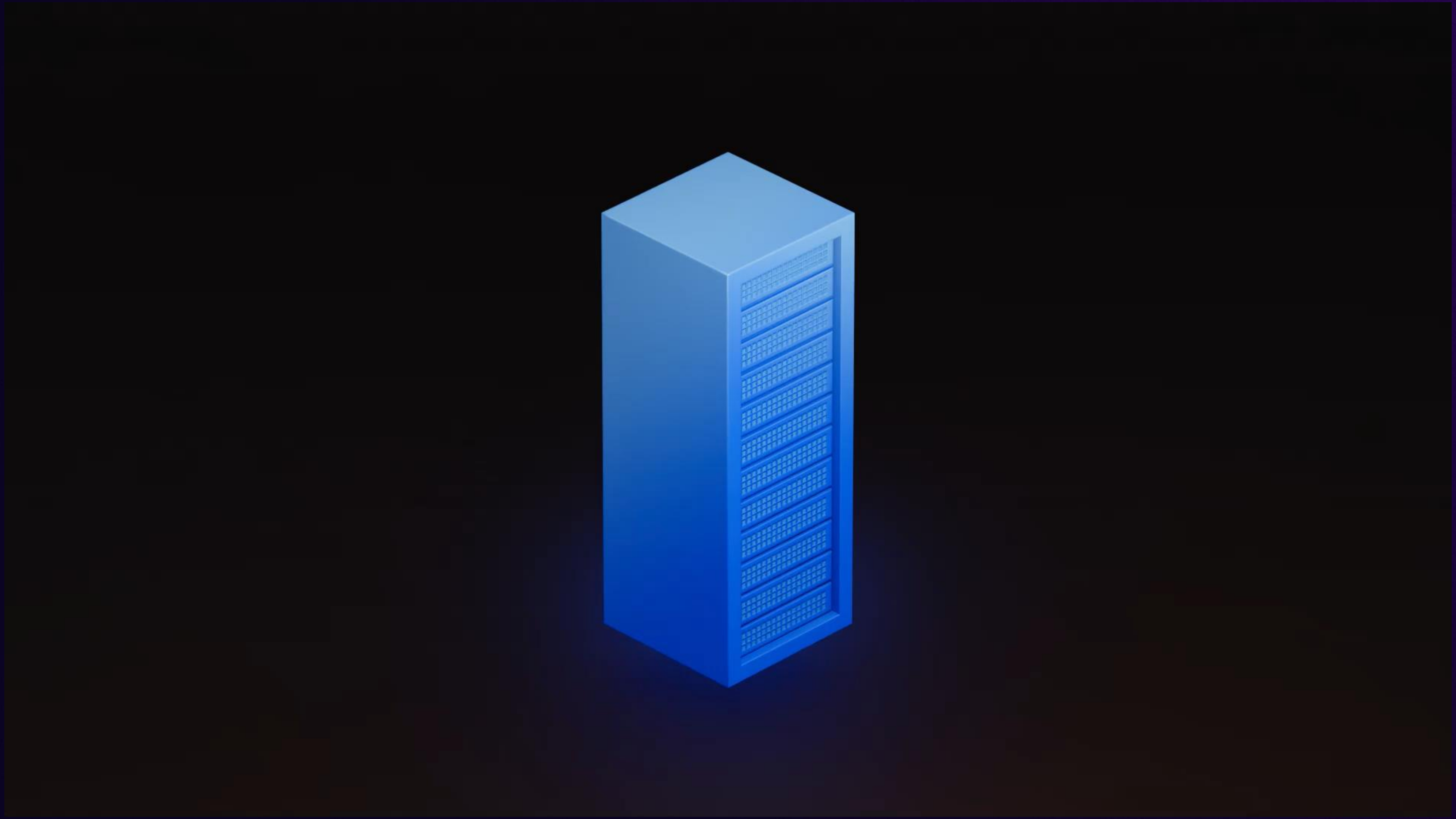
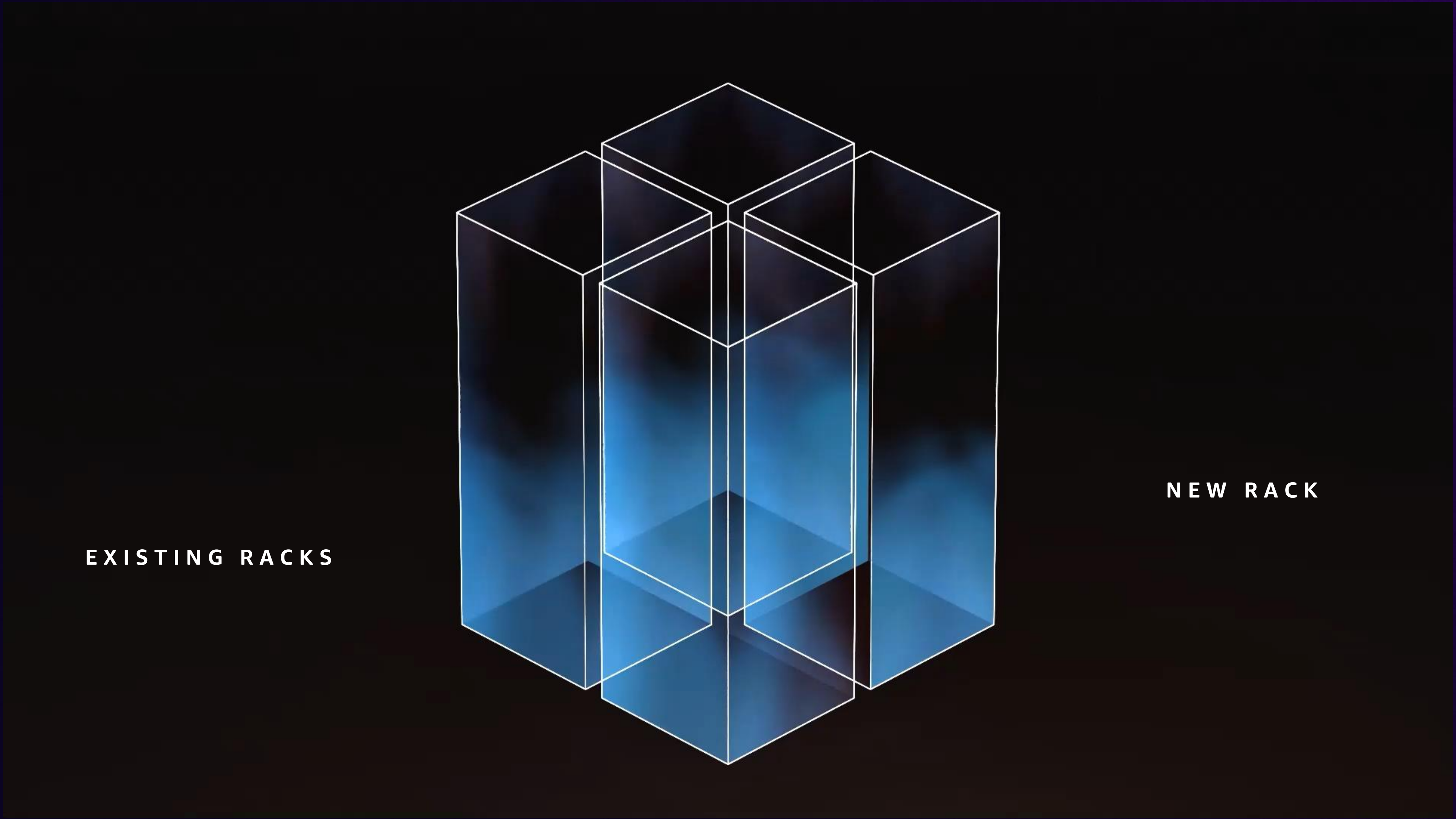
In-practice: Expanding capacity



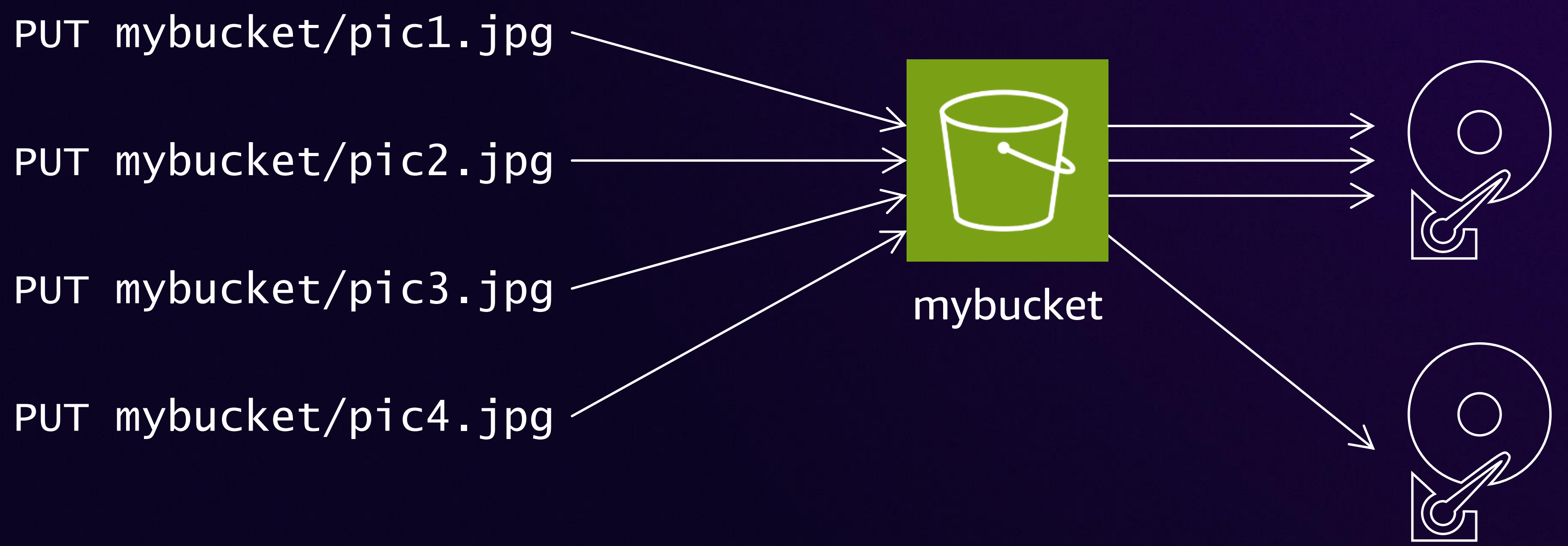
In-practice: Expanding capacity



In-practice: Expanding capacity



Assigning buckets to their storage



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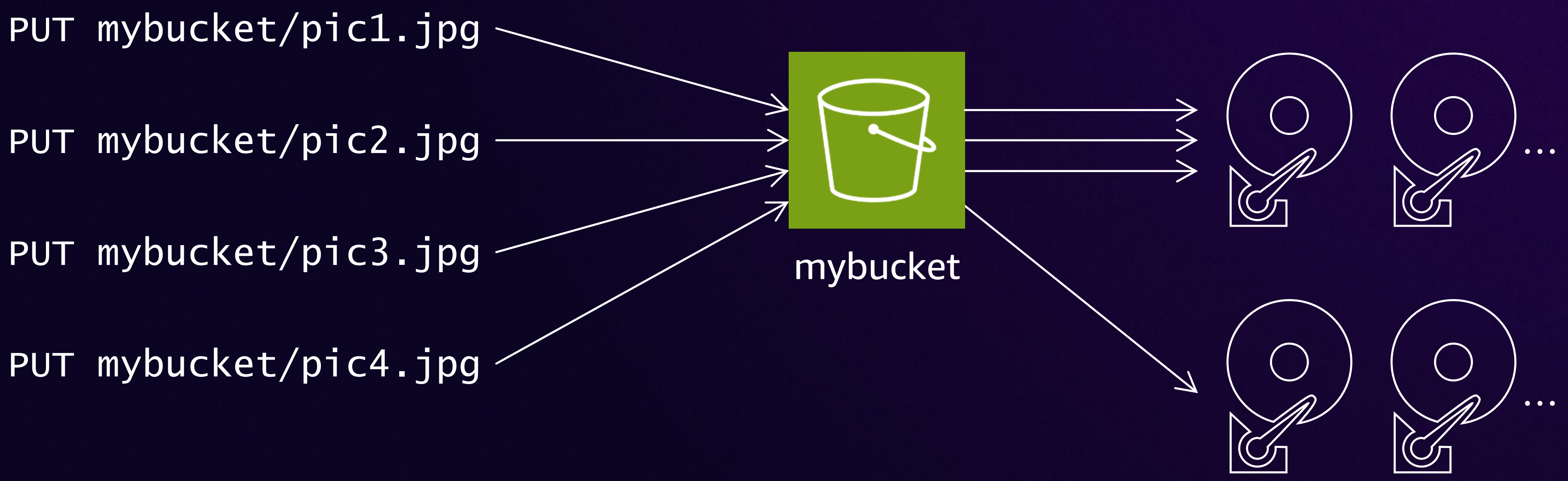
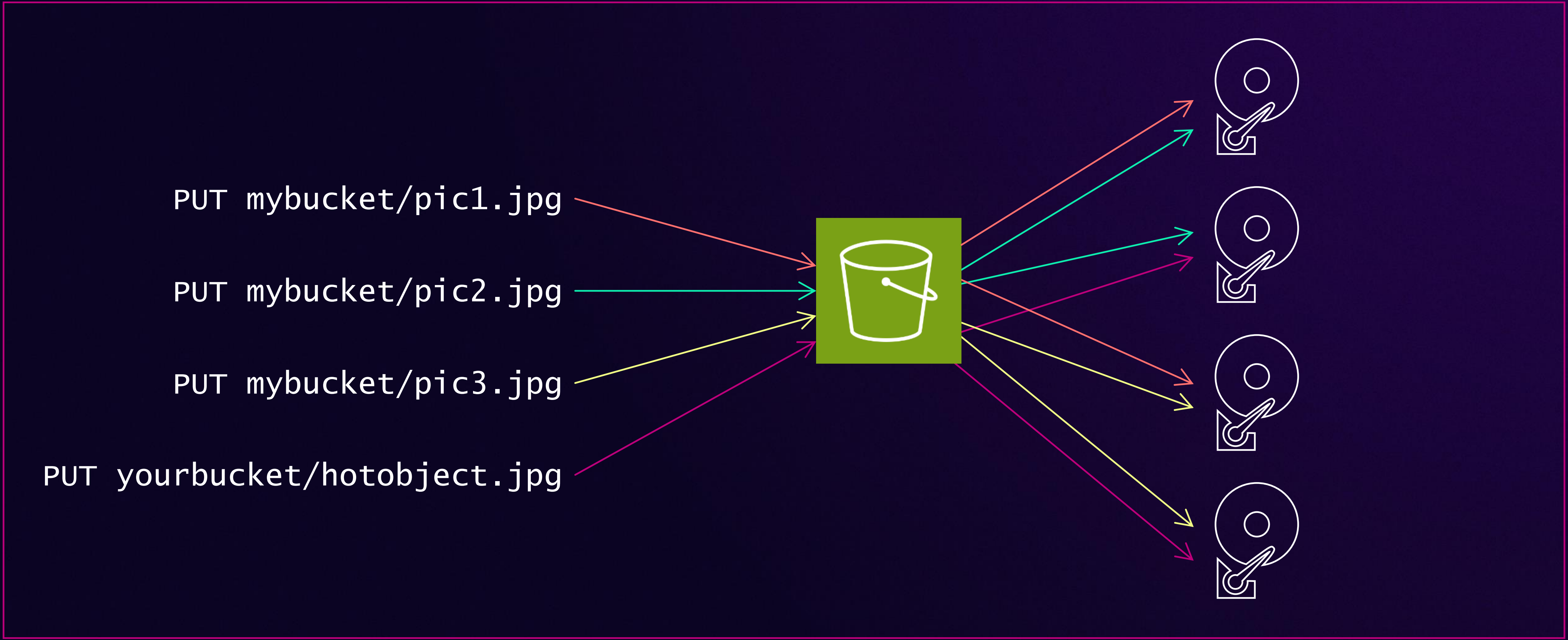
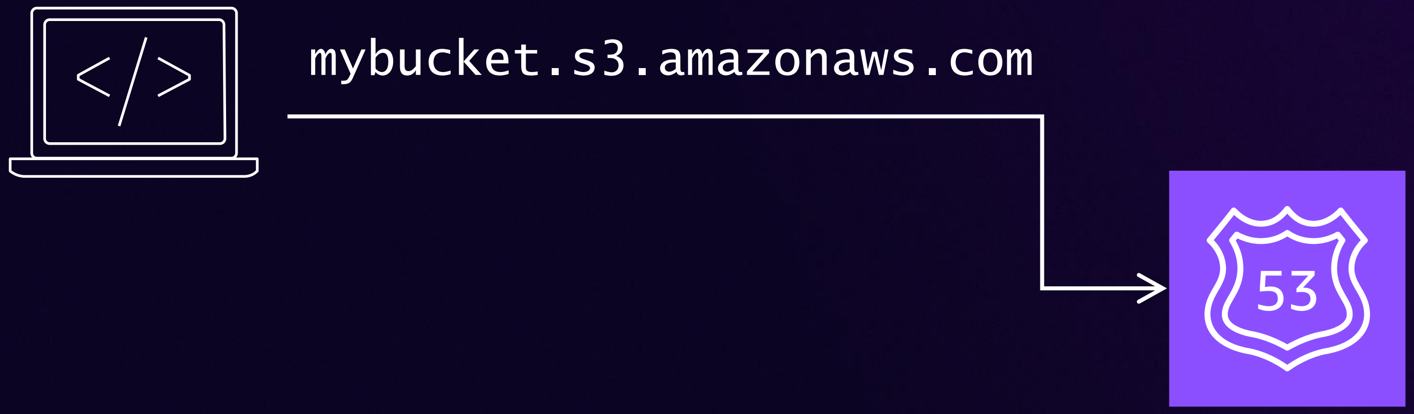


Shuffle sharding



“Elastic” means any S3 customer should be able to use every drive in our fleet on demand – so long as they don't interfere with each other

And it’s not just drives that shuffle shard



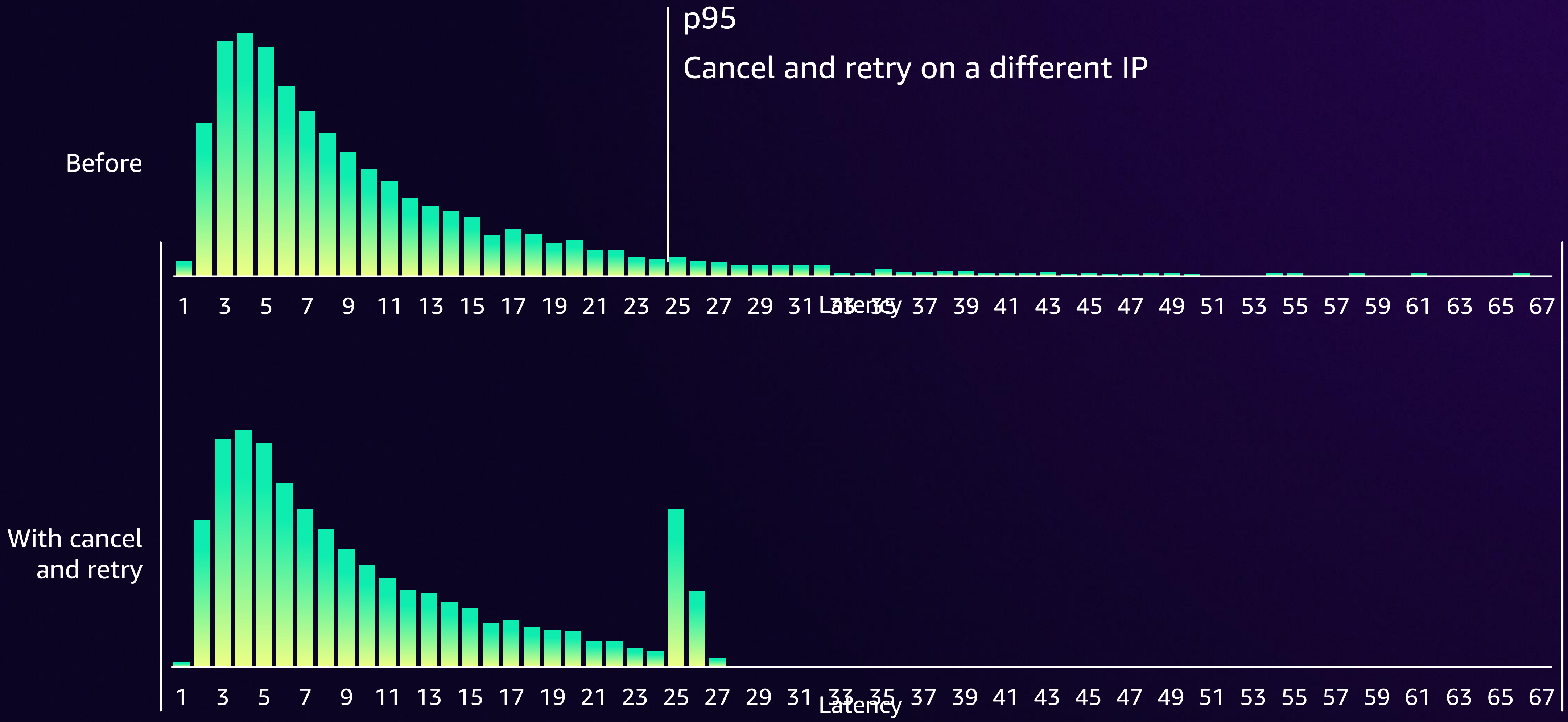

```
Non-authoritative answer:
mybucket.s3.amazonaws.com
canonical name = s3-us-west-2-
w.amazonaws.com.

Name:s3-us-west-2-w.amazonaws.com
Address:52.92.195.9
Name:s3-us-west-2-w.amazonaws.com
Address:52.92.131.57
Name:s3-us-west-2-w.amazonaws.com
Address:52.218.236.243
...
```

And it's not just drives that shuffle shard

Shuffle sharding for fault tolerance

Shuffle sharding in AWS Common Runtime (CRT)

RETRIES CAN ACTUALLY *IMPROVE* PERFORMANCE

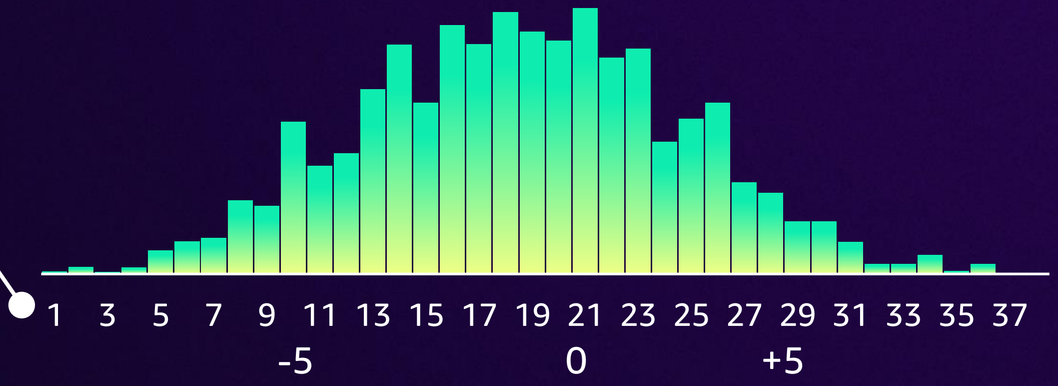


Placing data for shuffle sharding

PUT mybucket/pic1.jpg

Placing data for shuffle sharding

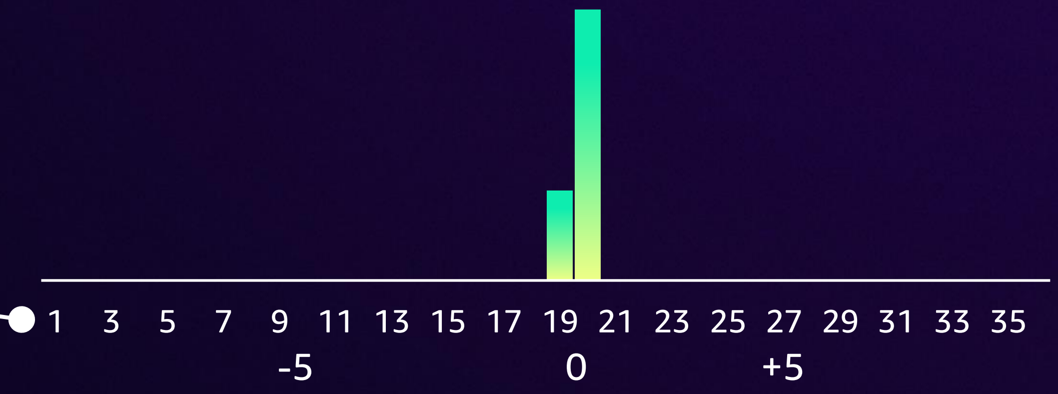
Choose a random drive



PUT mybucket/pic1.jpg

mybucket

"The power of two random choices"
Look at just two random drives and choose the better one



Engineering for decorrelation

- **Shuffle sharding** decorrelates customers and workloads
- It also enables **scale** and **fault tolerance**
- Use **two random choices** to balance shards

Workload isolation using shuffle sharding
Amazon Builder's Library

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At scale, failures are a fact of life

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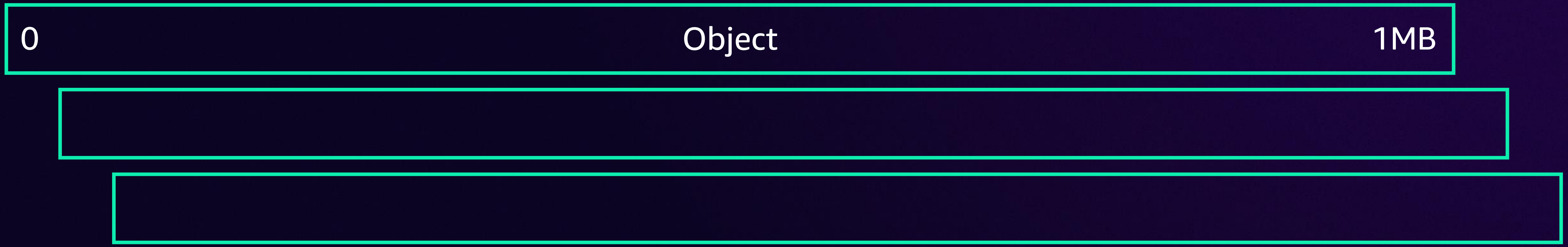
Erasure coding for fault tolerance

Replication is a simple way to tolerate faults – both individual drives and entire Availability Zones – but comes with high overhead



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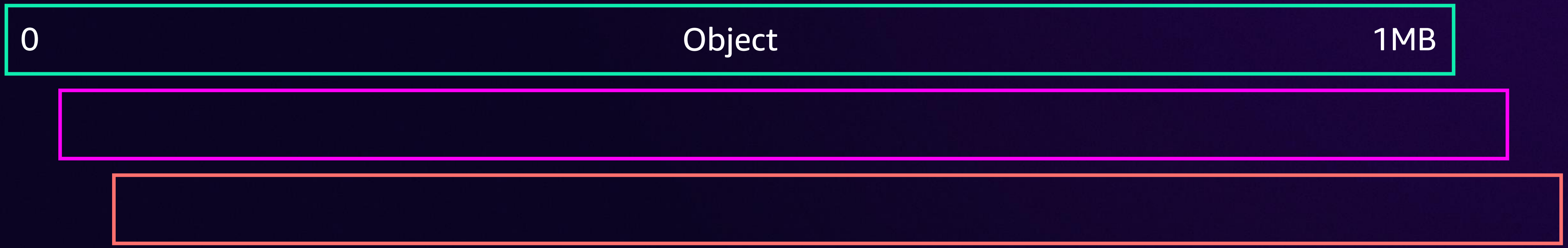

Erasure coding for fault tolerance

Erasure coding uses math to split the object into **shards** and create extra **parity** shards; the object can be rebuilt from **any K of the shards**

0	Object	1MB

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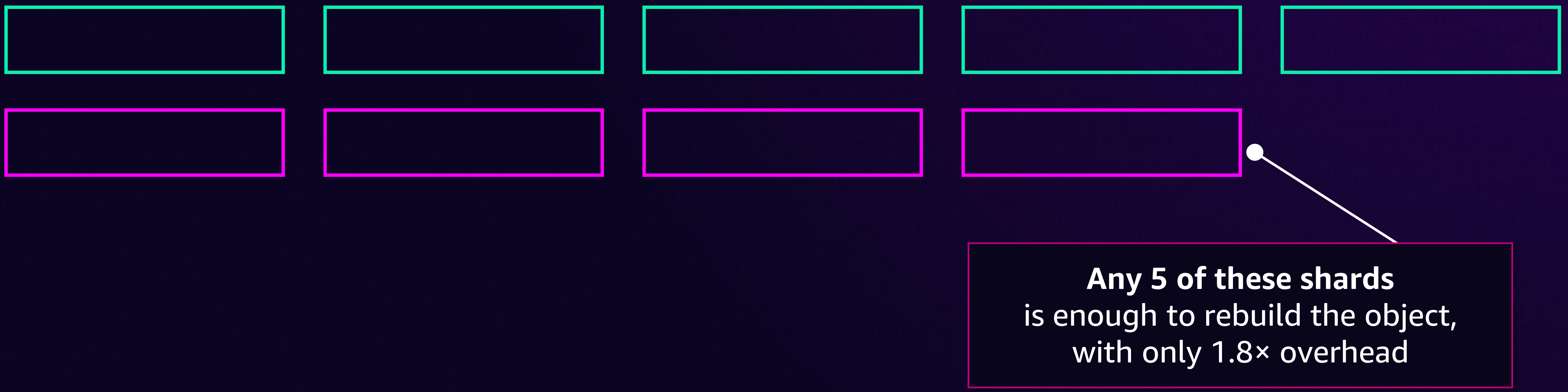

Erasure coding for fault tolerance

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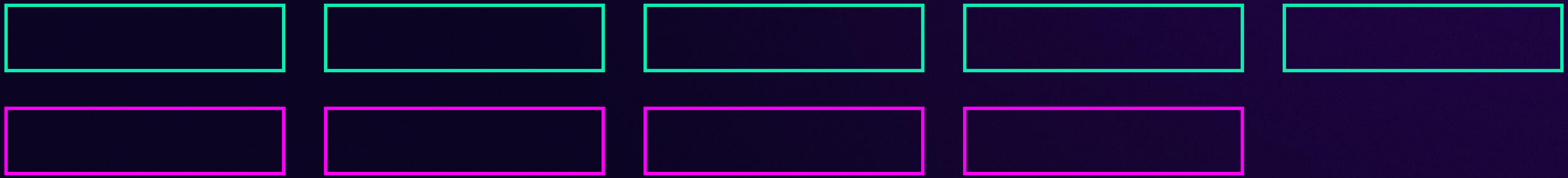
Fault tolerance also gives velocity

Erasure coding allows us to deploy new software or hardware safely by **exposing only a few shards** to the changes



Fault tolerance also gives velocity

Erasure coding allows us to deploy new software or hardware safely by **exposing only a few shards** to the changes

Fault tolerance and shuffle sharding

The **birthday paradox** tells us that shuffle sharding will expose **some** object to too much risk; we need to layer in constraints

Fault tolerance and shuffle sharding

The b ne
objec

Using Lightweight Formal Methods to Validate a Key-Value Storage Node in Amazon S3

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Abstract

This paper reports our experience applying lightweight formal methods to validate the correctness of ShardStore, a new key-value storage node implementation for the Amazon S3 cloud object storage service. By "lightweight formal methods" we mean a pragmatic approach to verifying the correctness

Using Lightweight Formal Methods to Validate a Key-Value Storage Node in Amazon S3. In *ACM SIGOPS 28th Symposium on Operating Systems Principles (SOSP '21), October 26–28, 2021, Virtual Event, Germany*. ACM, New York, NY, USA, 15 pages. https://doi.org/10.1145/3477132.3483540

1 Introduction

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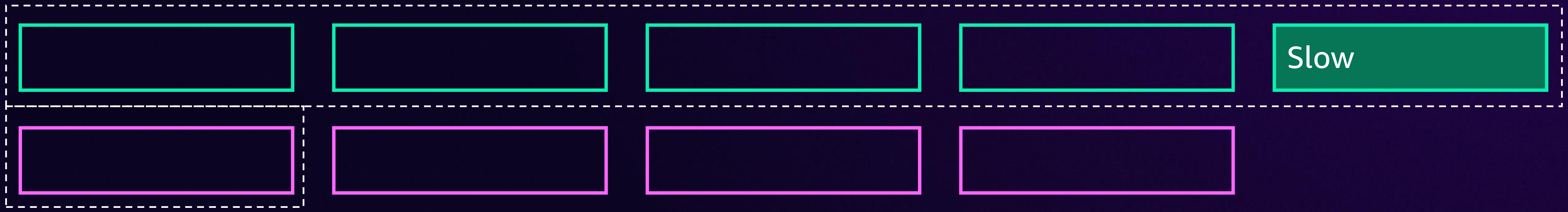
Improved performance through fault tolerance

Additional shards and shuffle sharding allow us to hedge against tail latency by **overreading**



Fault tolerance and velocity

- Failures are common at scale, and **fault tolerance is more than design**
- Fault tolerance, used wisely, also **improves developer velocity**

ShardStore

Physics of data

Engineering for decorrelation

Fault tolerance and velocity

Thank you!

Please complete the session survey in the mobile app

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