Facts, Figures and Insights from 250,000 Hard Drives

Andrew Klein, Storage Cloud Evangelist, Backblaze
Overview

- Where do these 250,000 drives live and work
- What is a drive failure?
- Drive failure and…
  - Power cycling
  - Time
  - Temperature
- Predicting drive failure
1.8 Exabytes
Available data storage

4 data centers
California (2), Arizona & Holland

178,166
Active HDD data drives

260,461
Total HDD data drives

246,100,245
Lifetime drive days
Where the drives work

* 20 =

60 drives

20 drives is 1 tome * 60 tomes in a 1 vault
= 1,200 drives in 1 vault
Collecting Drive Data

- Use smartmontools package to collect S.M.A.R.T. data
  - https://www.smartmontools.org
- Collect data once a day from each drive
- Started keeping data in April 2013
- Open Sourced the data in February 2015
### Drive Data Collected Each Day

<table>
<thead>
<tr>
<th>date</th>
<th>serial_number</th>
<th>model</th>
<th>capacity_bytes</th>
<th>failure</th>
<th>Smart_1_normalized</th>
<th>Smart_1_raw</th>
</tr>
</thead>
<tbody>
<tr>
<td>6/7/21</td>
<td>Z305B2QN</td>
<td>ST4000DM000</td>
<td>4000787030016</td>
<td>0</td>
<td>98</td>
<td>2766</td>
</tr>
<tr>
<td>6/7/21</td>
<td>PL1331LAHG154H</td>
<td>HGST HMS5SC4040ALE640</td>
<td>4000787030016</td>
<td>0</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>6/7/21</td>
<td>ZACH007</td>
<td>ST8000NM0055</td>
<td>8001563222016</td>
<td>1</td>
<td>81</td>
<td>139015</td>
</tr>
<tr>
<td>6/7/21</td>
<td>ZA130TTW</td>
<td>ST8000DM002</td>
<td>8001563222016</td>
<td>0</td>
<td>83</td>
<td>100901</td>
</tr>
<tr>
<td>6/7/21</td>
<td>ZA18CEBF</td>
<td>ST8000NM0055</td>
<td>8001563222016</td>
<td>0</td>
<td>81</td>
<td>140551</td>
</tr>
<tr>
<td>6/7/21</td>
<td>PL2331LAH3WYAJ</td>
<td>HGST HMS5SC4040BLE640</td>
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</tr>
</tbody>
</table>

**Smart Stats:** There are 255 pairs of values per drive. Examples:
- Smart_1: Read Error Rate
- Smart_5: Reallocated Sector Count
- Smart_9: Power On Hours


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**Drive Day:** The data collected for one drive for one day.
What is Drive Failure?

- The drive will not spin up or connect to the OS.
- The drive will not sync, or stay synced in a storage array.
- The statistics we track show persistent values above our thresholds.
Two Types of Failures

Reactive Failure
- We react to the failure

Proactive Failure
- Triggered by SMART stats, FSCK, etc.
- Reviewed by Backblaze before action is taken

In Either Case
- Removed drives are quarantined until they are no longer needed.
  - Cloning, fault analysis, etc.

Data Center: Sac0
Pod: pod-000-1113-01
Drive: drive_0057
Tasks: Replace Data Drive
Action: Proactive
Reason: High Offline Uncorrectable (SMART)
Brand: HGST
Model: HGST HUH721212ALN604
Serial: 8AJK007BH
Size: 12TB Drive
Notes: 5 Reallocated_Sector_Ct - 82
197 Current_Pending_Sector - 276
198 Offline_Uncorrectable - 266
199 UDMA_CRC_Error_Count - 0
9 Power_On_Hours - 23422
Found ATA error that is 2 hours old - CONSIDER REPLACING THIS DRIVE
Annualized Failure Rate

1. Define AFR cohort and period:
   a. Cohort = Model ABC123
   b. Period = Q2 2021

2. Obtain Drive Days and Drive Failures for the cohort and period.
   a. Drive Days = 409,124
   b. Drive Failures = 17
   c. Drive Count = 5,000

3. Apply Formula: \[ AFR = \left( \frac{\text{Drive Failures}}{\left( \frac{\text{Drive Days}}{365} \right)} \right) \times 100 \]

   \[ AFR = \left( \frac{17}{\left( \frac{409,124}{365} \right)} \right) \times 100 = 1.52\% \]

This method accounts for drives with different drive days within the period.
Drive Failure and …

Power cycling, time, temperature…
### Average Number of Power Cycles for Each Drive

<table>
<thead>
<tr>
<th>Drive Type</th>
<th>Per Year</th>
<th>Lifetime</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good Drives</td>
<td>3.20</td>
<td>7.46</td>
</tr>
<tr>
<td>Failed Drives</td>
<td>3.95</td>
<td>11.24</td>
</tr>
</tbody>
</table>
Power Cycling

Number of Power Cycles a Failed Drive Experienced over Time

R² = 14.6%
Annualized Failure Rate Over Time (Quarters)
Temperature of Operational versus Failed Drives

**Operational (Good) Drives**
- Average: 29.1 (83.4°F)
- Median: 29.0
- Mode: 28.0

**Failed Drives**
- Average: 29.8 (85.6°F)
- Median: 29.0
- Mode: 30.0

AFR for observation period: 1.04%
Relationship of Drive Temperature to Drive Age

Operational (Good) Drives

Failed Drives

AFR for observation period: 1.04%
Temperature versus Drive Size

Average temperature of all operational data drives by size

Average Temp. 29.1
Predicting Drive Failure

Yesterday and Today
# SMART Attributes as Failure Detection

Percentage of drives with SMART attribute RAW value > 0

<table>
<thead>
<tr>
<th>Drive Status</th>
<th>SMART 5 Reallocated Sectors Count</th>
<th>SMART 187 Reported Uncorrectable Errors</th>
<th>SMART 188 Command Timeout</th>
<th>SMART 197 Current Pending Sector Count</th>
<th>SMART 198 Uncorrectable Sector Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operational</td>
<td>1.1%</td>
<td>0.5%</td>
<td>4.8%</td>
<td>0.7%</td>
<td>0.3%</td>
</tr>
<tr>
<td>Failed</td>
<td>42.2%</td>
<td>43.5%</td>
<td>44.8%</td>
<td>43.1%</td>
<td>33.0%</td>
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1) Failed drives as of one day prior to being marked as failure
## 2021 versus 2017

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<td><strong>2017</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td><strong>2021</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operational</td>
<td>2.7%</td>
<td>23.5%</td>
<td>0.0%</td>
<td>99.8%</td>
<td>0.5%</td>
</tr>
<tr>
<td>Failed</td>
<td>47.9%</td>
<td>57.1%</td>
<td>10.9%</td>
<td>43.1%</td>
<td>26.1%</td>
</tr>
</tbody>
</table>
Voted off the Island

### 2017

| SMART 187 Reported Uncorrectable Errors | 0.5% | 43.5% |
| SMART 197 Current Pending Sector Count | 0.7% | 43.1% |

- Only reported by Seagate 4TB drives
- Does not decline/reset

### 2021

| SMART 187 Reported Uncorrectable Errors | 23.5% | 57.1% |
| SMART 197 Current Pending Sector Count | 99.8% | 43.1% |

- Most larger drives report, but value is the same as SMART 1
- Non-sensible values for SMART 197
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Predicting Drive Failure with SMART Stats

- **2016**
  - Predicting Disk Replacement towards Reliable Data Centers.

- **2021**
  - Interpretable Predictive Maintenance for Hard Drives
    - Maxime Amram, Jack Dunn, Jeremy J. Toledano, Ying Daisy Zhuo
    - Optimized Decision Trees
Summary

- Where do these 250,000 drives live and work
- What is a drive failure?
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Thank You

Please take a moment to rate this session.

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