# Estimating Hardware Storage Costs

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Scitor Corporation

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## Overview

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- **RAID storage deflation research became a priority when data was provided for estimates in terms of storage volume, rather than a bill of materials (BOM)**
  - Needed way to translate volume into cost to support future estimates
  - Past research across multiple agencies has provided conflicting results on cost and how it changes over time
- **Agenda**
  - Storage Background
  - RAID Details
  - Storage Deflation
  - Data Analysis
  - Conclusions
  - Next Steps

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## Types of Storage

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- **Types of storage typically seen in government programs to be estimated:**
  - Tape storage
    - Utilizes tape drives and tape libraries
    - Still used for long-term storage, but has become less prevalent as costs for disk storage have decreased
  - Disk storage
    - Current standard for short to mid-term storage and often used for long-term archival purposes
    - Most commonly seen type of storage in recent cost estimates
  - Solid-state storage
    - High-performance plug-and-play storage device that contains no moving mechanical components
    - Likely to see expanded use in the next several years, but pricing is currently prohibitive for many government programs
- **RAID = Redundant Array of Independent Disks**
  - Combines two or more physical drives into a logical unit presented as a single hard drive to the operating system
  - Different configurations (called "levels") of RAID utilize multiple techniques to provide varying degrees of reliability (ability to withstand drive failure) and availability (speed of Input/Output)

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## RAID Terms

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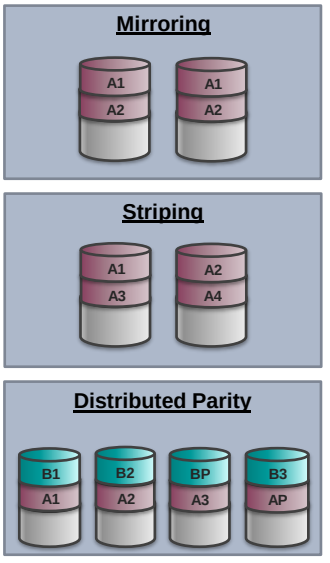
- **Mirroring: Duplicating data to more than one disk**
  - Can speed read times because the system can read data from more than one disk
  - Can slow write times if the system must confirm that data is correctly written to each disk
- **Striping: Writing data across a number of disks in parallel**
  - Speeds read/write performance
- **Parity: Redundancy information is calculated for each piece of data stored**
  - If a drive fails, the missing data can be reconstructed from the remaining data and parity data

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## RAID Levels

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| Level | Striping | Mirroring | Parity | Notes | Storage for ~1 TB |
|---|---|---|---|---|---|
| RAID 0 | X | | | Provides no fault tolerance | 1 TB |
| RAID 1 | | X | | Provides fault tolerance, but can cause a slight drag on performance | 2 TB |
| RAID 2 | X | | | Striping at bit (rather than block) level; not currently used | Not Used |
| RAID 3 | X | | X | Byte level striping with a dedicated parity disk; rare in practice | Not Used |
| RAID 4 | X | | X | Block level striping with a dedicated parity disk; rare in practice | Not Used |
| RAID 5 | X | | X | Block level striping with parity data distributed across all member disks; fault tolerance against one drive failure | 1.5 TB |
| RAID 6 | X | | X | Block level striping with two parity blocks distributed across all member disks; fault tolerance against two drive failures | 2 TB |
| RAID 10 | X | X | | Stripe set composed of two or more mirrored sets; can operate as long as drives on both mirror sets do not fail | 2 TB |
| RAID 0+1 | X | X | | Mirror set composed of two or more stripe sets; low level of scalability | 2 TB |
| RAID 50 | X | | X | Striping data across multiple RAID 5 sets; can sustain up to 4 drive failures | 1.5 TB |

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## Calculating Storage Volume

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- **Typically estimate storage costs in one of two ways:**
  - Include cost of BOM
    - Other individuals determine hardware needs and obtain vendor quotes
  - Estimate storage based on the amount of data to be received, which requires consideration of
    - Downlink limitations
    - Amount of data compression that will occur
    - Removal of data that is not usable
    - Products, reports, and metadata that must be stored (in addition to the original data)
    - Storage policies (i.e., requirements for duration of storage)
    - Chosen RAID level
    - Standard 15-20% additional open storage recommended to ensure the system does not slow down

**Notional Example**

**1 TB/day** received from source → **.5 TB/day** after removing unusable data → **.25 TB/day** after compression → **.75 TB/day** with products and metadata → **1.5 TB/day** For RAID level 6 → **1.8 TB/day** with 20% open storage

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## *Storage Deflation*

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## Storage Deflation

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- **As technology has advanced over time, the cost of storage has decreased**
  - Change largely driven by decreasing cost of disk drives
  - While other types of HW have also evolved, they have not demonstrated the same consistent decrease in cost
    - Ex: Capability of servers increase while price stays about the same
- **Groups estimate the changing cost of storage differently**
  - Some estimate a consistent annual decrease in storage costs (X% each year), leading to a lower total cost of storage over time
  - Others have indicated that while storage deflation does occur, a group may just purchase additional storage to compensate for the cost of deflation (results in no cost change over time, but expanded storage capability)

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## Deflation Estimating Challenges

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- **Estimating using projected volume and a $/TB that includes the cost of all peripheral HW/SW may be misleading**
  - While storage costs deflate, other associated COTS HW/SW costs may not
    - Need a full breakout of COTS purchases to apply deflation to only storage
  - Must ensure that the $/TB used is applicable
    - Avoid double counting or underestimating other COTS HW/SW products
  - Using a $/TB that includes multiple types of HW makes capturing unique recap costs difficult (e.g., recap the physical rack every 15 years, but replace COTS SW every 3 years)
- **Deflation has occurred historically, but previous research does not indicate when/if deflation might slow or cease entirely (i.e., does a floor exist?)***
  - Storage may have already deflated so much that it is only a small portion of the total $/TB
  - Cost of materials and production may limit how low the cost of storage can become
- **Storage deflation does not take into account the possibility of additional technology advances**
  - Deflation estimates may not cover a program's transition to a new, more expensive type of storage
  - If a type of storage becomes obsolete, the cost of that storage may actually begin to increase
- **Existing burdens (e.g., SEITPM, maintenance) do not take deflation into account**
  - Unlikely that it will become less expensive to manage and maintain more complex HW
  - Burdens may be correlated more with volume of storage rather than cost

* Earlier Research: "Cost Deflation vs. Technology Inflation of RAID Storage Systems" Converse, Watkins, SCEA, 2006

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## Data Collection

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- **General research**
  - Confirms trend of decreasing cost per TB, but unclear on future impacts
    - How long will cost continue to decrease?
    - How will external factors impact cost?
      - State of economy
      - Transition to Infrastructure as a Service approach
      - Recovery from 2011 Asian tsunami
- **Data collected from available BOMs**
  - Searched for commonality within a single BOM and between different BOMs
  - Looked for procurement of the same piece of equipment in multiple years
    - Avoided HW with vague descriptions because a piece of HW with the same general name can have multiple configurations
    - Ensured apples-to-apples comparison
      - Did not compare prices that include maintenance with ones that did not
      - Evaluated individual pieces of HW, rather than aggregate $/TB (based on level of information available)
  - Unable to determine whether costs were influenced by purchasing agreements or enterprise licenses

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## Combined Data View

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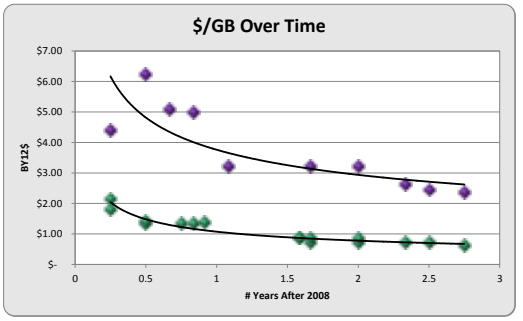


- **All available data points shown**
  - Data available from 2008 to 2011
  - Color indicates different disk drive Revolutions Per Minute (RPMs: **green** = 7200 RPM, **purple** = 15K RPM)
- **Graph indicates that disk drive RPM is a determining factor for cost and rate of deflation**

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## 7200 RPM Disk Drive Data

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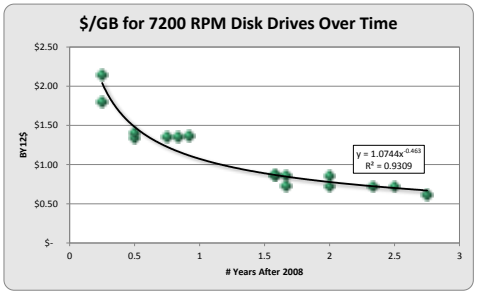
- **RPM: Revolutions per minute**
  - The faster the disk spins, the faster the drive operates
- **Data used**
  - Equipment: Disk Drive, 1 TB or 500 GB, 7200 RPM, SATA
  - 16 data points available
- **Strong $R^2$ for data set**
  - Line of best fit indicates that annual change in cost is not as consistent as other research has indicated




**Trendline Predictions - 7200 RPM**

| FY | BY12$/GB | % Change |
|---|---|---|
| 2009 | $1.07 | |
| 2010 | $0.78 | 27% |
| 2011 | $0.65 | 17% |
| 2012 | $0.57 | 12% |
| 2013 | $0.51 | 10% |
| 2014 | $0.47 | 8% |
| 2015 | $0.44 | 7% |
| 2016 | $0.41 | 6% |
| 2017 | $0.39 | 5% |
| 2018 | $0.37 | 5% |
| 2019 | $0.35 | 4% |
| 2020 | $0.34 | 4% |
| 2021 | $0.33 | 4% |
| 2022 | $0.32 | 3% |
| 2023 | $0.31 | 3% |
| 2024 | $0.30 | 3% |
| 2025 | $0.29 | 3% |
| 2026 | $0.28 | 3% |
| 2027 | $0.27 | 2% |
| 2028 | $0.27 | 2% |
| 2029 | $0.26 | 2% |
| 2030 | $0.26 | 2% |

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# 15K RPM Disk Drive Data

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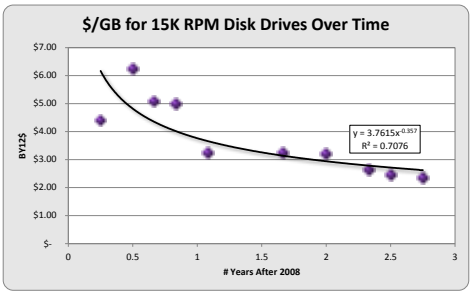
- **Higher RPM = higher performance disks**
- **Data used**
  - Equipment: Disk Drive, 300 or 144 GB, 15K RPM, 4 GB, FC
  - 10 data points available
- **$R^2$ not as strong as for 7200 RPM disk drives**
  - Limited number of available data points
- **Cost per TB higher than 7200 RPM, but deflation occurs more slowly**




Trendline Predictions - 15K RPM

| FY | BY12$/GB | % Change |
|---|---|---|
| 2009 | $3.76 | |
| 2010 | $2.94 | 22% |
| 2011 | $2.54 | 13% |
| 2012 | $2.29 | 10% |
| 2013 | $2.12 | 8% |
| 2014 | $1.98 | 6% |
| 2015 | $1.88 | 5% |
| 2016 | $1.79 | 5% |
| 2017 | $1.72 | 4% |
| 2018 | $1.65 | 4% |
| 2019 | $1.60 | 3% |
| 2020 | $1.55 | 3% |
| 2021 | $1.51 | 3% |
| 2022 | $1.47 | 3% |
| 2023 | $1.43 | 2% |
| 2024 | $1.40 | 2% |
| 2025 | $1.37 | 2% |
| 2026 | $1.34 | 2% |
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| 2028 | $1.29 | 2% |
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# Disk Drive Summary

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Cost per TB significantly different

Deflation for 15K RPM consistently lower

7200 RPM disk drives deflate more quickly

Trendline Predictions - 15K RPM

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## Estimating Applications

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- **Method described on previous slides is most accurate when storage is provided as a service or shared between multiple programs**
  - If storage is a service, a program can be charged for a portion of a rack
  - If storage is purchased by programs individually, a program might have to buy an entire rack when only half of a rack is needed
- **To fully estimate storage costs, must capture additional HW needed to support disk drives**
  - Includes chassis, servers, networking equipment, etc.
  - May need to include cost of COTS SW licenses if not captured separately
  - Equipment needs appear to change with relative frequency
    - Ex: Rarely buy the same server to support storage when it is time for a recap

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## Conclusions

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### General storage conclusions

- Must consider the chosen storage strategy when estimating storage costs
  - RAID level contributes to the volume of storage required
  - RPMs and other attributes of storage impact total cost and rate of cost deflation
- Receipt of detailed BOMs improves costing insight, especially in conjunction with volume data
  - Provides details on storage costs vs. other HW/SW costs
  - Allows for accurate application of RAID deflation and estimation of recaps

### Disk drive deflation conclusions

- Cost of disk drives decreases over time, approaching a floor
  - Suggests use of a single factor to estimate deflation may not be sufficient
  - Could be used as a cross check for programs with more detailed storage costs available
- Results of research conflicts with some previous storage deflation studies
  - Research shows deflation rate decreasing, rather than remaining constant
  - Need more detailed data to reconcile varying results

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## Next Steps

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- **Evaluate impacts of pricing agreements typically offered to the government**
- **Investigate life expectancy of disks at different RPMs**
  - Also consider different usage (e.g., long or short-term storage)
- **Research impacts to factors and CERs**
  - Assess changes over time due to variation in storage costs
- **Consider impacts of potential shifts in storage needs (e.g., solid state drives)**

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***Back-ups***

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## Contact Information

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## Recognition

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