The Future

Fundamentals of Data Management

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Course outline

- What do we mean by “The Future”?!
  - The long-term challenges of data management and preservation
  - The technologies and economics that might, or might not, help

- After completing this lesson, you should be able to:
  - Describe some of the problems of scale (time and volume) in storing digital data
  - Understand the basic economics of future data management
  - Be equipped to engage in the debate on the future of scientific data ☺

Data, data everywhere…

- Our challenge: more and more data are less and less sustainable
  - digital instruments, business “keep-it-all” analytics etc.
- Possible solutions
  - store them in a repository
    - scale problem in managing and *describing*
  - put them in the Cloud
    - risks; ts & cs; bandwidth in and out
  - put them on the Web
    - description still a problem, volatility of web resources
  - throw them away
    - why are we trying to store everything?
- What are the economics of the “big data” future?

How far away is the future?

- Oldest carved stone writing
  - 3000 BC, Sumerian temple records (stick on damp clay)
- Oldest printed book
  - 868 AD, Diamond Sutra (wood-block print on paper)
- Oldest digital photo
  - 1957 AD, Russell Kirsch (176 × 176 pixel computer scan)
- Can you find that email from three years ago?

- Digital preservation is in its *absolute infancy*
- And yet more and more of our knowledge is born digital

Even 10 years is a long time…

- EPSRC expectations on storage of research data:
  - "Research organisations will ensure that EPSRC-funded research data is securely preserved for a minimum of 10 years […] from last date on which access to the data was requested by a third party;"

    http://www.epsrc.ac.uk/about/standards/researchdata/expectations
  - Which is potentially forever!
- If data volumes continue to increase exponentially…
  - (currently doubling every year)
- …where are they going to be stored?
- In repositories and data centres? In the Cloud?

AFR: the problems of scale

- On HDD data sheets, two measures are used for lifetime
  - AFR (annualised failure rate), calculated from field or stress-testing
  - MTTF (mean time to failure) in hours
- Top-end drives: MTTF of 1-1.5M hours = AFRs of ~0.6%
  - though note 2007 study by Schroeder & Gibson: typical annual replacement rates (ARRs) = 2-4%

https://www.cs.cmu.edu/~bianca/fast07.pdf

- If you have 10,000 disks in your data centre…
  - ARR = 2% $\Rightarrow$ replacing about 4 a week, or 1 every other day
  - That's expensive (mostly in terms of people!)
- Conclusion: long-term digital preservation is about economics

The economics of long-term storage

- Preserving paper is relatively cheap
- Preserving bits is less so
  - active-curation staff, storage and access hardware, electricity
- But how much does it actually cost, and where does the money go?
- All preservation cost studies point to this rule of thumb:
  - 50% goes on ingest
  - 33% goes on preservation (mostly storage)
  - 17% goes on access
- Ingest is an up-front cost, access is intermittent
- Preservation storage is the key long-term cost

Kryder's Law

- CPUs have Moore's Law
  - transistor density doubles every 18 months
- Disks have Kryder's Law
  - magnetic domain density doubles every… [redacted]
  - between 1990 and 2005, disk capacity increased 1,000-fold
  - True since 1980
- Consequence has been disk costs drop 30-40% per year
  - if you can afford to store data for 5 years you can afford to store it forever, because your long-term storage gets cheaper all the time!

Kryder's Law: 1980 – 2010

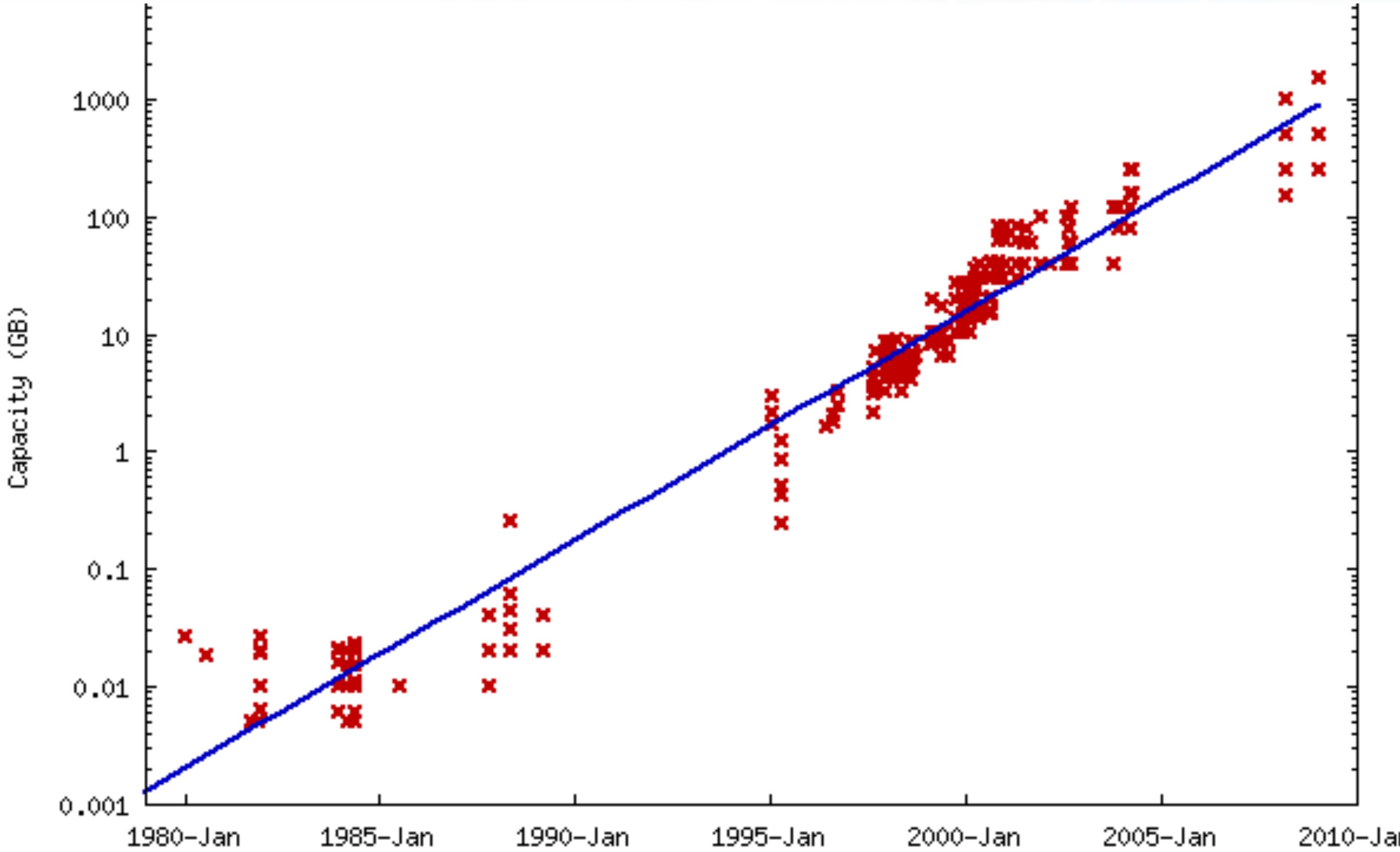


image from http://blog.dshr.org/2012/10/storage-will-be-lot-less-free-than-it.html

But…

BUT

How sustainable is this?

- Kryd
- Here

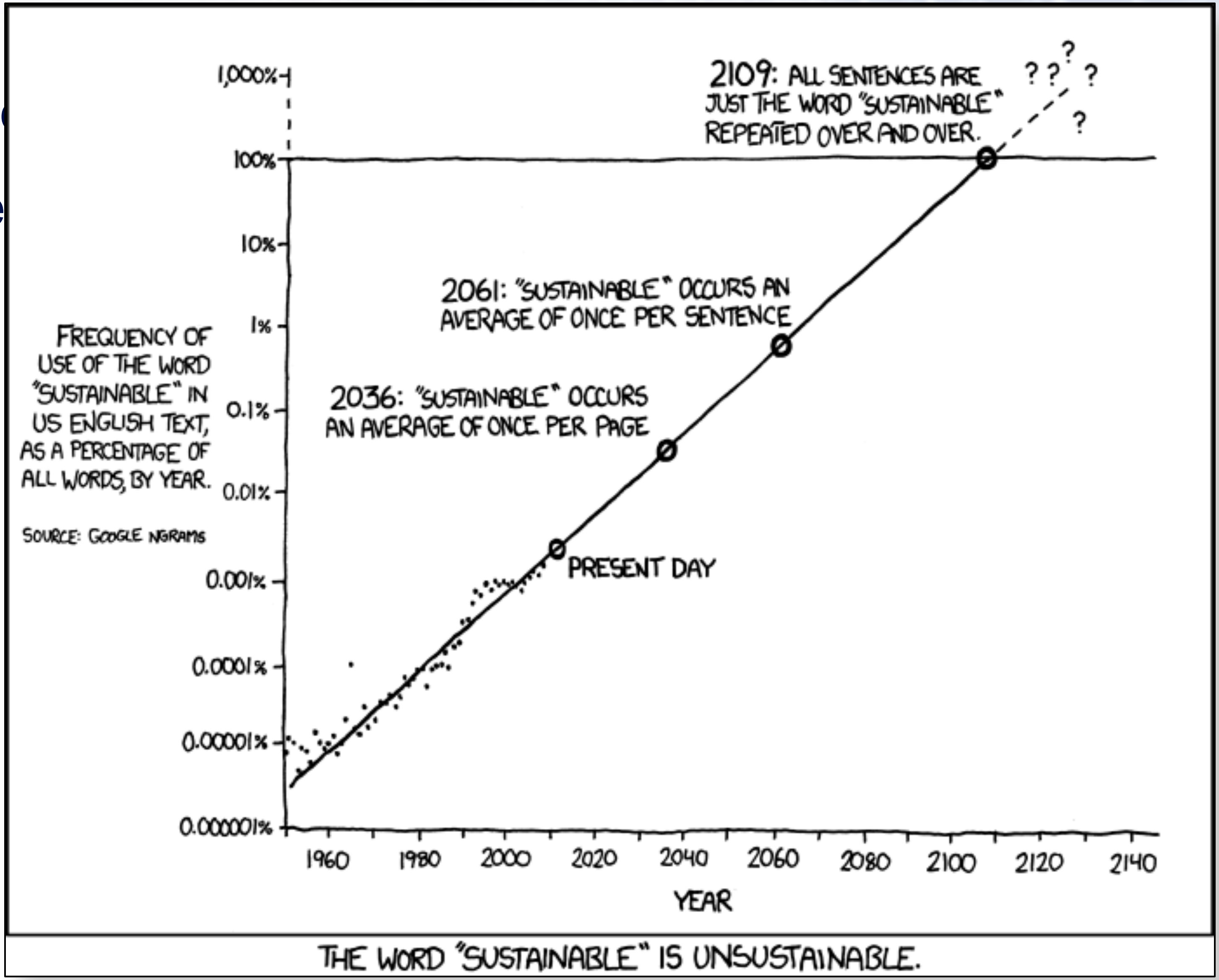
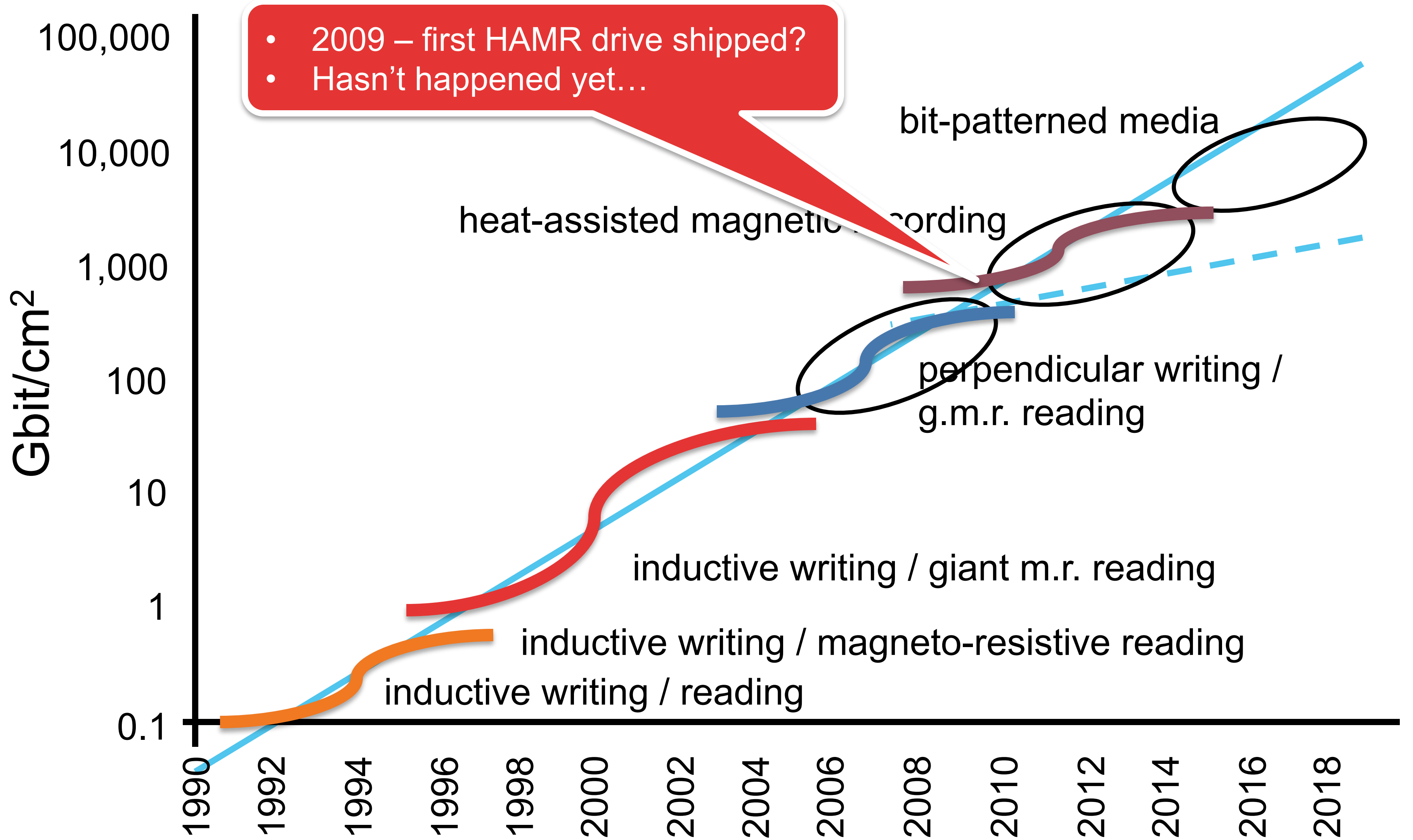


image from Randall Monroe, http://xkcd.com/1007/

Kryder's Law: a closer look



HDD roadmap 2015

Robert Fontana, IBM @ http://www.digitalpreservation.gov/meetings/storage15.html

- Remember: HAMR was due in 2009
- First drive now due 2017-2018?

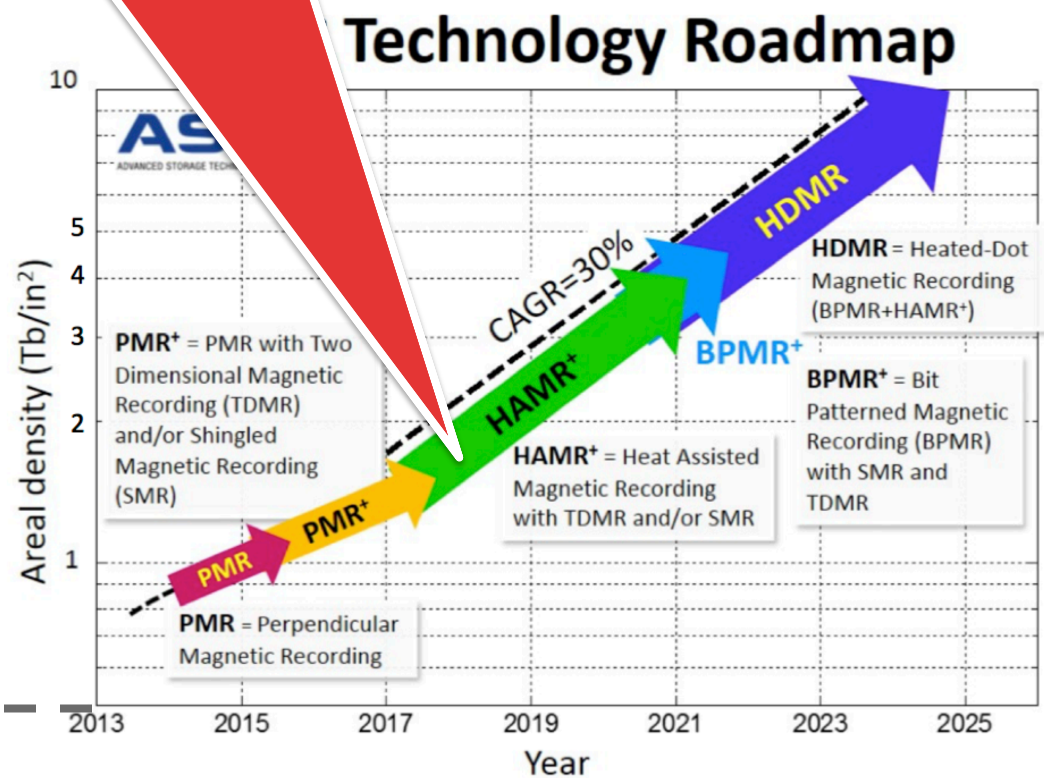
HDD Roadmap

eal density increase is ~ 1.4X or 18% per year.

s are needed

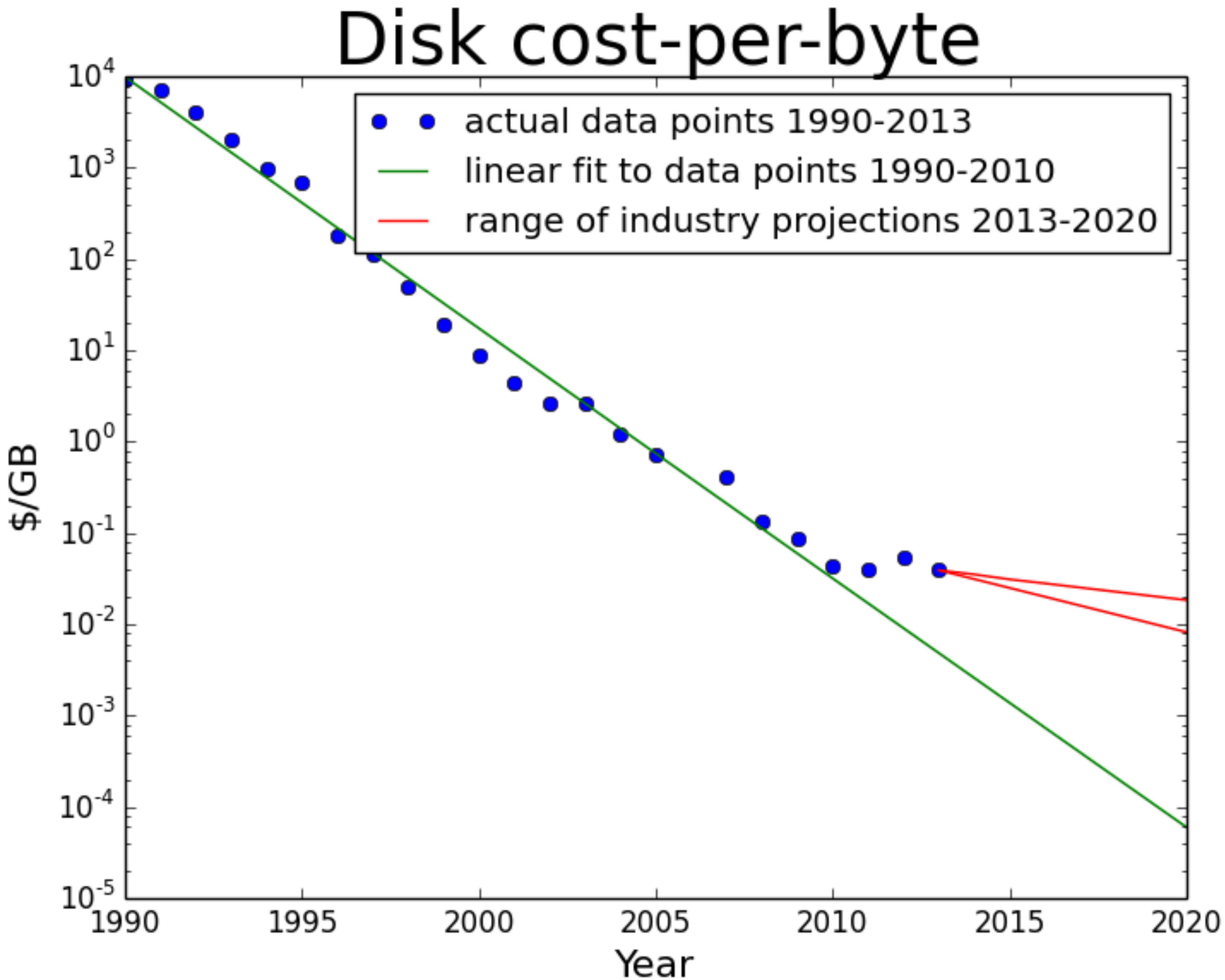
- bit e ally ble
- ler bit have er grains
- aller bit ls require proved ensors

2009?



* Operating within the existing IDEMA framework, ASTC is a forum for collaborative joint R&D efforts among storage industry participants, customers, suppliers, universities and laboratories with a goal to shorten the time from invention to productization.

We’ve fallen off the curve



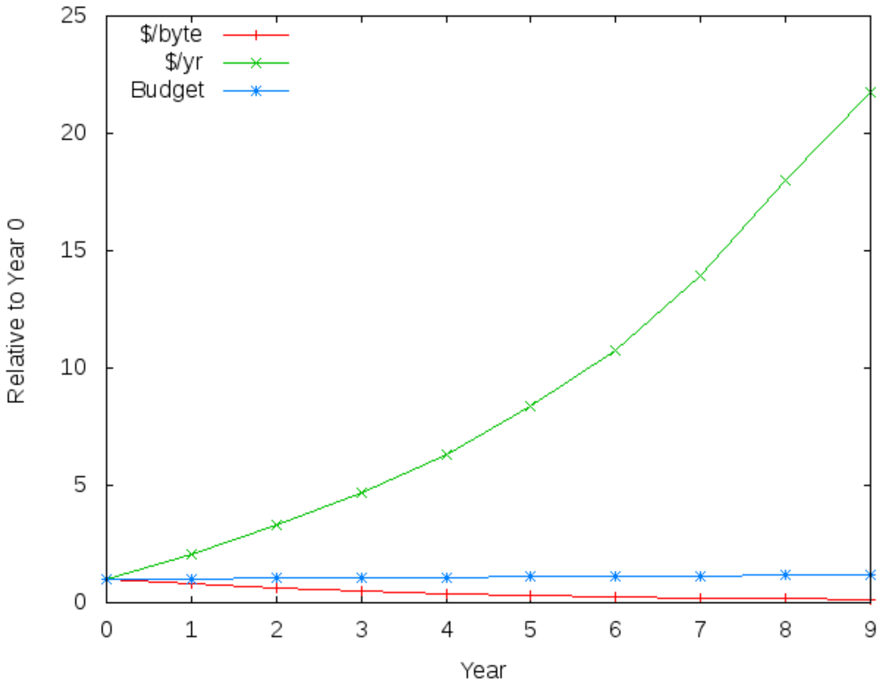
Gupta, P. et al: An Economic Perspective of Disk vs. Flash Media in Archival Storage. MASCOTS 2014 conference

Disk is not the answer

- In 2010 Kryder's Law stopped
- HAMR technology has not made it out of the lab
- So in 2020, disk will be around 200 times more expensive than we thought in 2010
  - *Most optimistic* price drop projections are now 20% / year
- Long-term storage needs something else

Rosenthal: a little bit of economics

- Annual growth in demand for storage: ~60%
- Annual growth of disk-drive bit density: ≤ 20%/year
- Annual growth in IT budgets: between 0%/year and 2%/year



- **“If storage is 5% of your IT budget this year, in 10 years it will be more than 100% of your budget”**
  - D. Rosenthal
    - http://blog.dshr.org/2013/06/brief-talk-at-elpub-2013.html

Longer-term storage technologies?

- Linear tape
  - Tape technology still has Kryder's Law headroom
  - Will hit the same magnetic recording issues as disk in 5-10 years
- Optical
  - DVD, 5GB / disk, lifespan of 30-100 years?
  - Blu-ray, 25GB / disk, lifespan of 100-150 years?
    - used by Facebook for cold storage
  - M-disk, 5 or 25 GB / disk, lifespan of 1000 years?
- Solid state: TLC flash
  - Triple-level cell flash: stores 3 bits per flash cell
  - Can sustain c. 1,000 rewrites before failing
  - May be suitable for archiving – write once read sometimes

Cloud storage

- Cloud storage seems attractive
  - Someone else will worry about the hardware
- But the Cloud is just a way of hiding disk + tape + other offline storage
  - So the same economics apply
- Cloud is also constrained by Internet bandwidth
  - Uploading and downloading is time consuming and expensive
- Once a Cloud provider has your data, they can charge you whatever they like!
- Consumer-grade t’s & c’s offer no guarantee of data safety
  - “We may lose your stuff. We’ll say sorry.”

Future data management

- The Cloud model highlights a key point
- Moving data around is getting more and more expensive
- Wherever we store data, we need to move away from the "click to download" model

More Datascopes?

- Harmonising data and compute
- Store the data next to HPC/cluster compute facilities
  - The original archive?
  - Automatically-created replicas?
  - Or a more dynamic caching strategy?
- Move the compute to the data
  - This is not a new idea!
  - Need to support rich analytic environment
  - Does virtualisation solve every case?
  - Are general-purpose computers suitable?
  - Do we need more domain-specific "Datascopes"?
    - Machines built around a particular (big) data set

Less data to store?

- Is the future of data management less data and more smart instrument design?
- The storage industry manufactures around 600 EB/year new capacity (2013)
  - Disk, tape, flash; active and archive
- How much more compute do we need to move into the instruments, into the data streams?
  - LHC triggers from 300 GB/s → 300 MB/s
  - EBI accept data straight from gene sequencers
  - SKA raw detector data rates will be around 6 PB/s
- What hardware will we need to put in place?
  - GPGPUs, FPGAs, DSPs

Summary

- Some take-home questions…

- Can we continue to generate data in such high volumes?
- Do we need to start to prioritise data?
  - scientific observations > scientific measurements > everything else
- What will happen to our iTunes collections in 20 years' time?
- How will I view my family photos in 30 years' time?
- Where will the scientific record be in 100 years' time?

Acknowledgements

- Inspiration and sources:
  - David Rosenthal: http://blog.dshr.org/