Flash Memory SUMMIT

Accelerating the Pace of SSD Innovation

10 HARD disk drive LESSONS

Chuck Sobey
Chief Scientist
ChannelScience

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ChannelScience
Detecting the Future of Data Storage SM

Lesson 1: Don't Do It!

Don't casually get into the storage industry

It is must be your mission and core-competency

You are only as good as your next design and always as bad as your worst failure

Lesson 2: If You Must do it, Go All In!

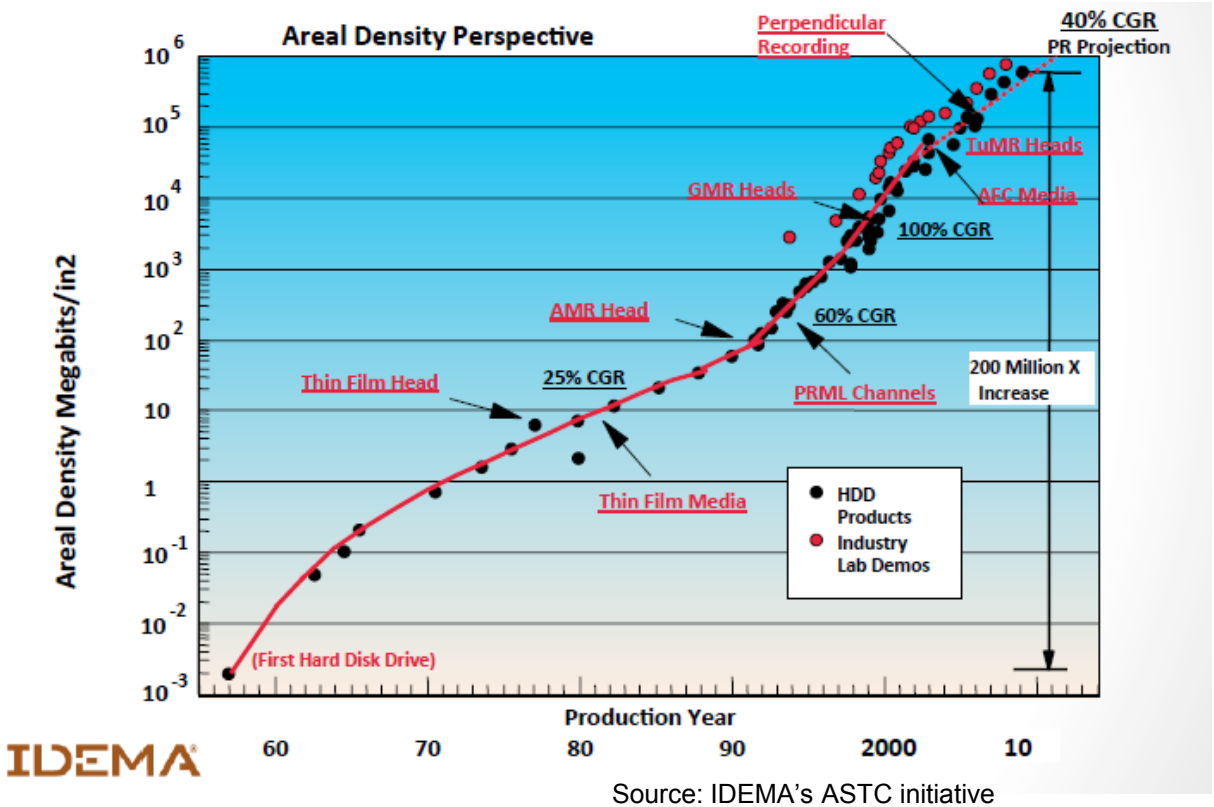
Build a company, or standalone business unit, that is completely responsible for its success or failure

ALL stored data must be considered mission-critical and private

When the volumes are huge, the execution must be world-class

Lesson 3: Understand the Key Industry-Trend Metric(s)

The HDD industry's key metric is areal density (Gb/sq in, or Gb/sq mm) through time



Source: IDEMA's ASTC initiative

Key Industry-Trend Metric for SSD?

Gb/die (“capacity”) through time?

Moore’s law: NAND process geometry through time?

Areal Density?

- Defined how?
- Is it still as relevant?

Proposals

Goal: A single number to keep score and to mark the limits of current capability

Proposals:

- Phase 1 - Areal density of stored bits in the flash array
- Phase 2 – Areal density of the stored user bits in the flash array
- Phase 3 – Volumetric density of the stored user bits in the flash arrays (3D)

Warning!

A “density” can only be counted if it is achieved with reasonable

- Retention
- Endurance
- Speed
- Power
- (and yield must follow)

Lesson 4: Only Storage Physics gets to Limit the Pace of Density Growth Over the Long-term

For HDD

- The physics of the heads and media

Everybody sees the same physics!

- Competitive advantage comes from manufacturing, algorithms, coding, reputation, …

For SSD

- The physics of the storage cells (for now, the floating-gate transistors)

Lesson 5: Create Teams that Take Turns Improving Density

HDD areal density advances ping pong between

- Increasing track density
- Increasing bit density

SSD areal density: Proposal – Ping pong between

- Increasing retention/endurance/speed
- Increasing areal bit-density (process shrink)

SSD volumetric density: Proposal

- Third team added to increase “stacking” density

Lesson 6: Add Intelligence to the Storage Device

Standardize the outward-facing interface; innovate relentlessly on the "other side"

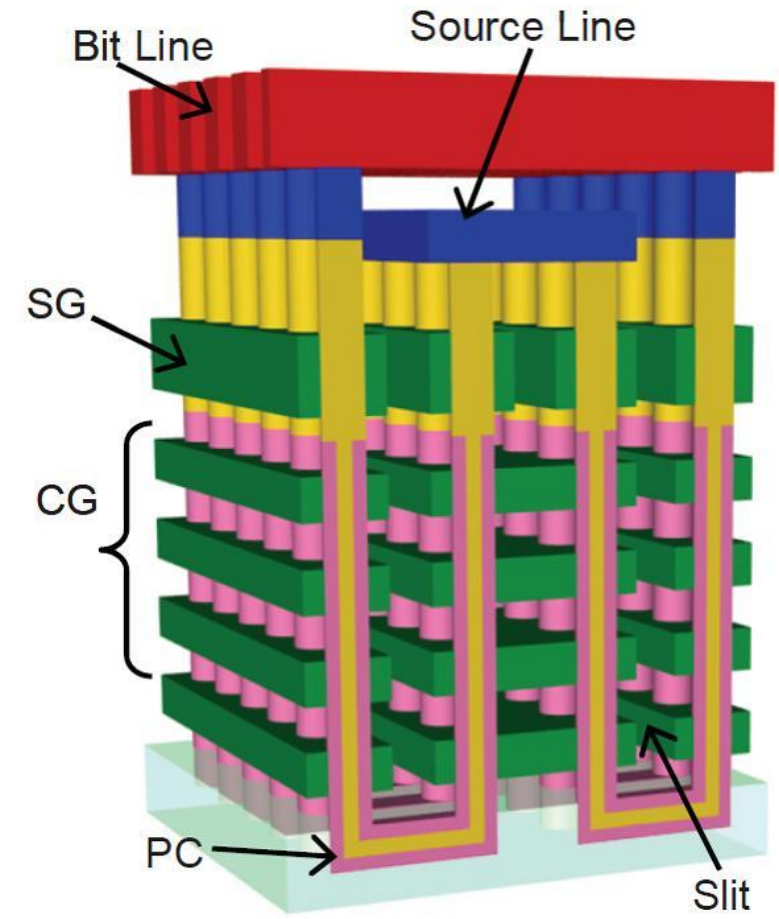
The controller is key! (as you know)

Expect more codes and signal processing: teach device physics to your detection algorithm

Flash has the unique ability to drive intelligence down to the storage array itself!

The new challenge may be balancing on-die intelligence with multi-channel-controller intelligence

Opportunity to Amortize High on-die Intelligence over MANY Bits



Source: Toshiba

Lesson 7: One-time non-Process Density Boosts Must be Adopted by All

Signal-processing, coding, and detection improvements provide great gains in storage density

Each gain is a one-time boost

However, any company that does not implement the boost is doomed to always be behind the competition when using the same process geometry scaling advances

Lesson 8: The Storage Industry Cares about the "Worst-Case"

- The customer does not by an "average" unit
- Their most sensitive data will be stored on the least reliable cells!
- Random testing?
  - Customers want to test the worst-case patterns under the worst-case conditions
- The device's intelligence must not be used to deceive the customer
  - *E.g.*, support a direct-write mode; enable V_t variation and control of other internal parameters

Lesson 9: Recognize when the Balance-of-Power Shifts

In the beginning, component suppliers (NAND manufacturers) know their product best and can dictate terms

The balance-of-power shifts when the purchaser (SSD manufacturer) knows more about the best usage methods and error modes than the supplier

NAND manufacturers must work closely with controller and drive manufacturers, or they will enable your competition

Lesson 10: Calm Down! Successful Storage Technologies are Abandoned Very Slowly

Tape is still used (and is still being developed) because it has unique characteristics not found in HDDs

DVDs, too

Unless SSDs can completely eclipse every benefit available from HDDs, expect HDDs to be around in some applications for a long time

Work to be complementary with HDDs rather than adversarial

More Lessons (for another time)!

Making and losing money from technology transitions

When is it OK to add cost to the storage device?

No company is “too successful to fail”

Predicting the evolution of complexity

Complementary and adversarial storage technologies

Recognizing which new technologies to adopt

When to adopt them and into what market segment

Utilizing “zoned” data storage

Creating defensive IP portfolio

The constant risk of over-provisioning and parallelism

… and many more …

… and, There is Always Room for New Ideas (that HDD Never Tried)

- Discarded solid-state storage devices still work
  - Enable garage inventors around the world to utilize them in new creations
  - Crowd-source innovation and you can experiment in new markets cheaply
    - Set your datasheets free (consider removing the NDA requirement for older products)! This can get you design-ins!
  - Prepare for the advent of ink-jet-printable circuits and 3D printers for garage-based prototyping

Moral of the Story: There are Good Lessons and Bad Lessons

Reviewing HDD developments accelerates SSD innovation by providing uniquely-relevant, clear, worked-examples

However, not every HDD lesson applies. It is important to be able to tell the difference.

Read *The Innovator's Dilemma* by Clayton M. Christensen, so you don't repeat this part of the past!

3 Actions You can Take to Accelerate the Pace of SSD Innovation

Add HDD industry veterans to your SSD teams

Provide all with structured learning opportunities about the intricacies of flash and its technology development to enable them to make bigger contributions sooner

Develop and implement a ping pong strategy for increasing storage density according to a physics-based density trend line

Questions?

Thank you very much!

Let's continue the discussion!

- Do you have more lessons to share?
- Do you disagree with some lessons?
- Examples of what HDD *didn't* try, but SSD should?

Please feel free to contact me

- Chuck Sobey
  - csobey@ChannelScience.com
  - http://twitter.com/channelscience
  - http://www.linkedin.com/in/chucksobey

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