An Analysis Of Flash And HDD Technology Trends

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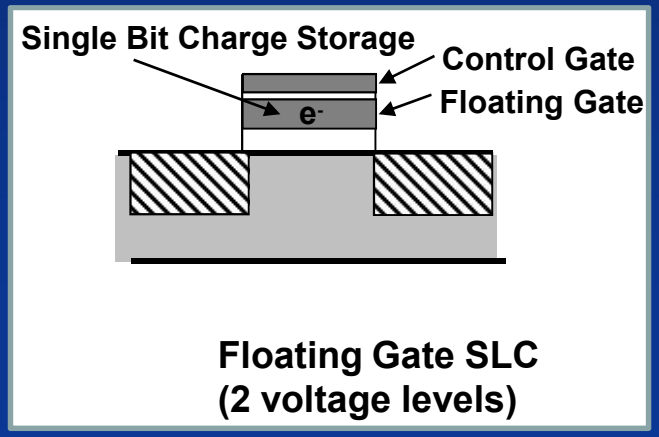
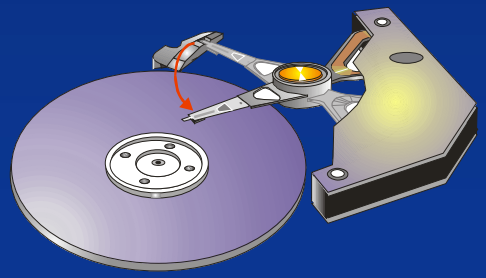
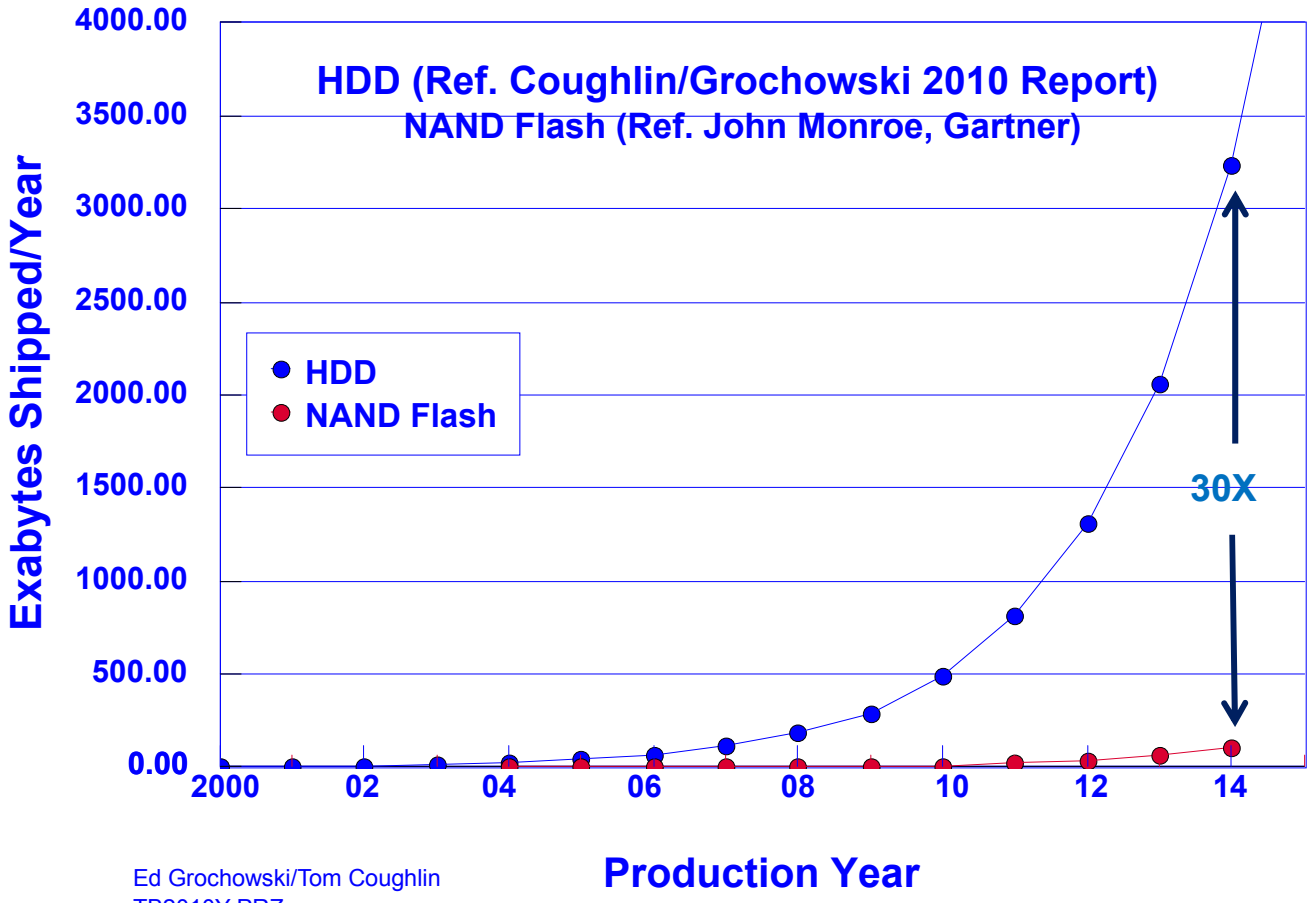
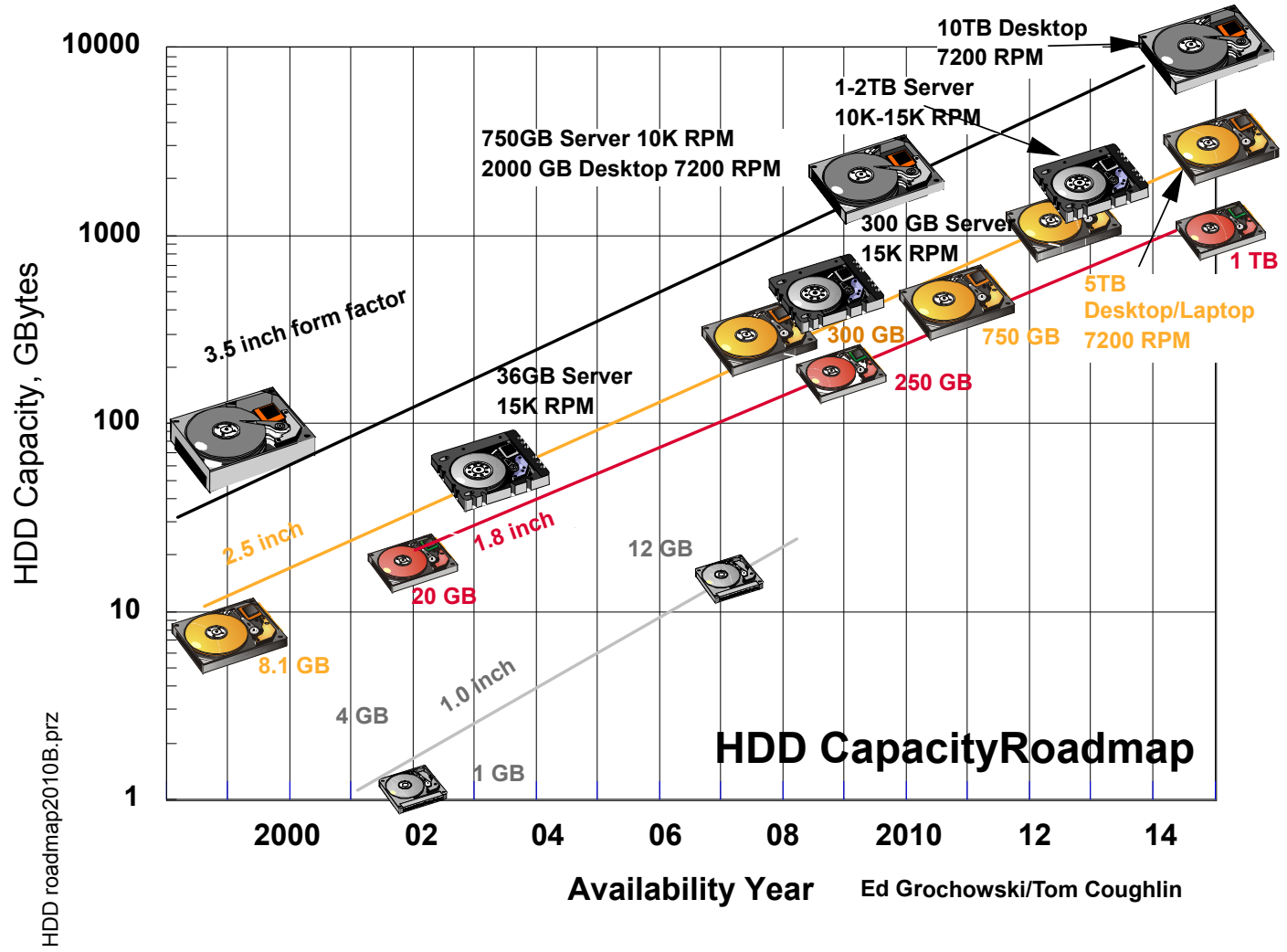


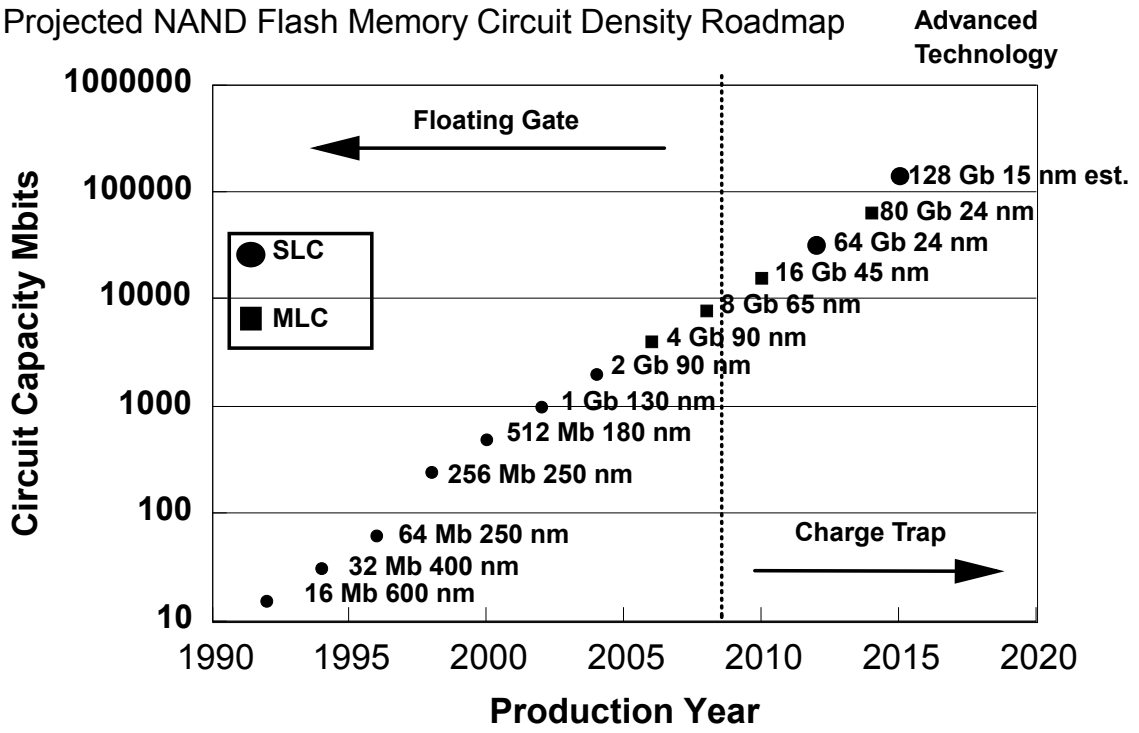


Introduction and Topics

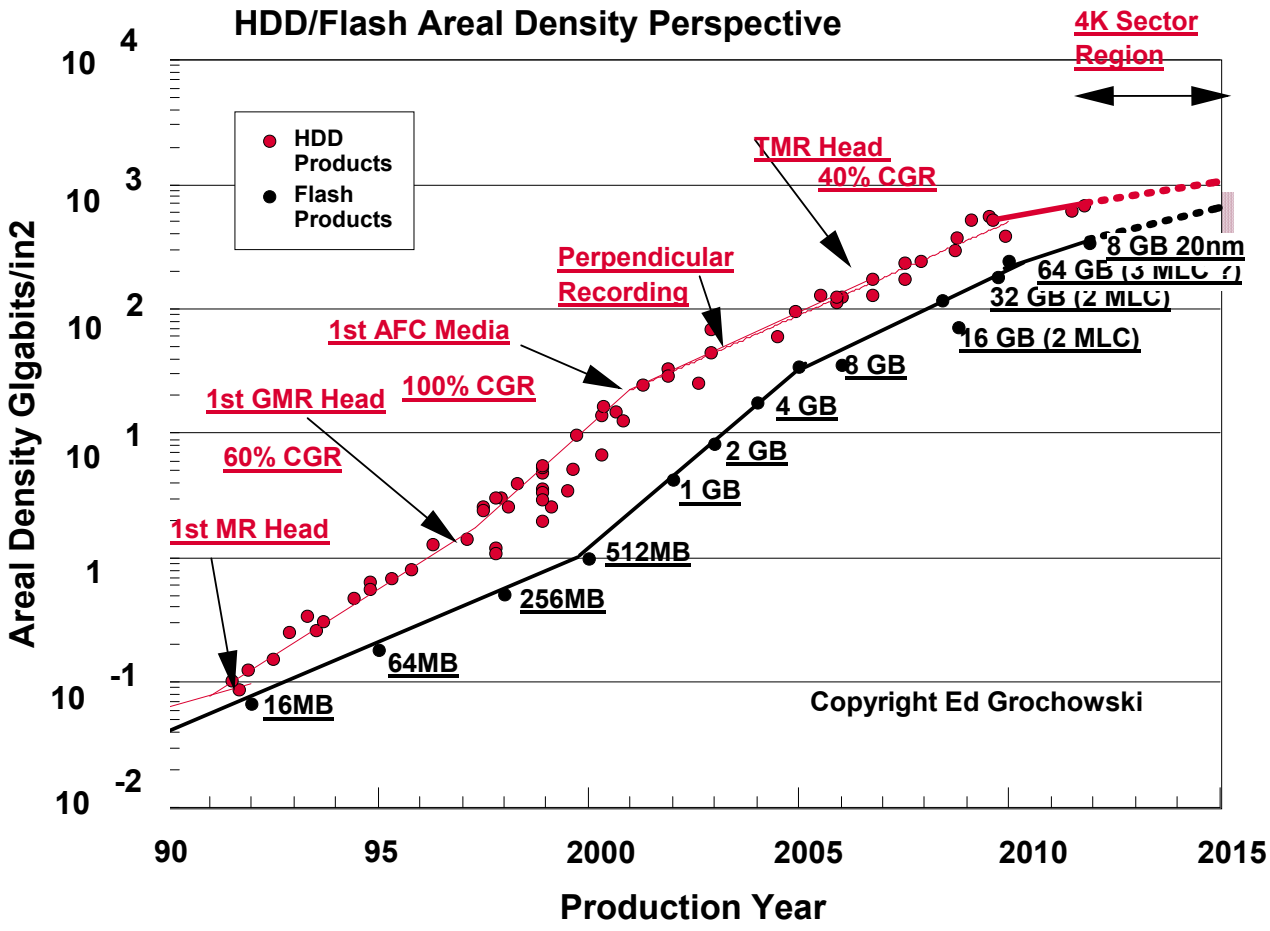
1. Analyze StorageTechnology Trends For Flash and HDD
2. Project To Where These Principal Storage Technologies Will Evolve
3. Discuss Concerns With These Evolutions
4. Project Data Densities
5. Project Costs per Gbyte
6. Analyze Lithography Challenges
7. Future Designs for Flash/HDD


HDD (Ref. Coughlin/Grochowski 2010 Report)
NAND Flash (Ref. John Monroe, Gartner)
Exabytes Shipped/Year
4000.00
3500.00
3000.00
2500.00
2000.00
1500.00
1000.00
500.00
0.00
HDD
NAND Flash
30X
2000
02
04
06
08
10
12
14
Production Year
Ed Grochowski/Tom Coughlin
TB2010Y.PRZ


10000
1000
100
10
1
HDD Capacity, GBytes
2000
02
04
06
08
2010
12
14
Availability Year
HDD CapacityRoadmap
Ed Grochowski/Tom Coughlin
HDD roadmap2010B.prz
10TB Desktop
7200 RPM
1-2TB Server
10K-15K RPM
750GB Server 10K RPM
2000 GB Desktop 7200 RPM
300 GB Server
15K RPM
1 TB
5TB
Desktop/Laptop
7200 RPM
3.5 inch form factor
36GB Server
15K RPM
300 GB
750 GB
250 GB
2.5 inch
1.8 inch
12 GB
20 GB
8.1 GB
1.0 inch
4 GB
1 GB



NAND Roadmap 2011X.prz



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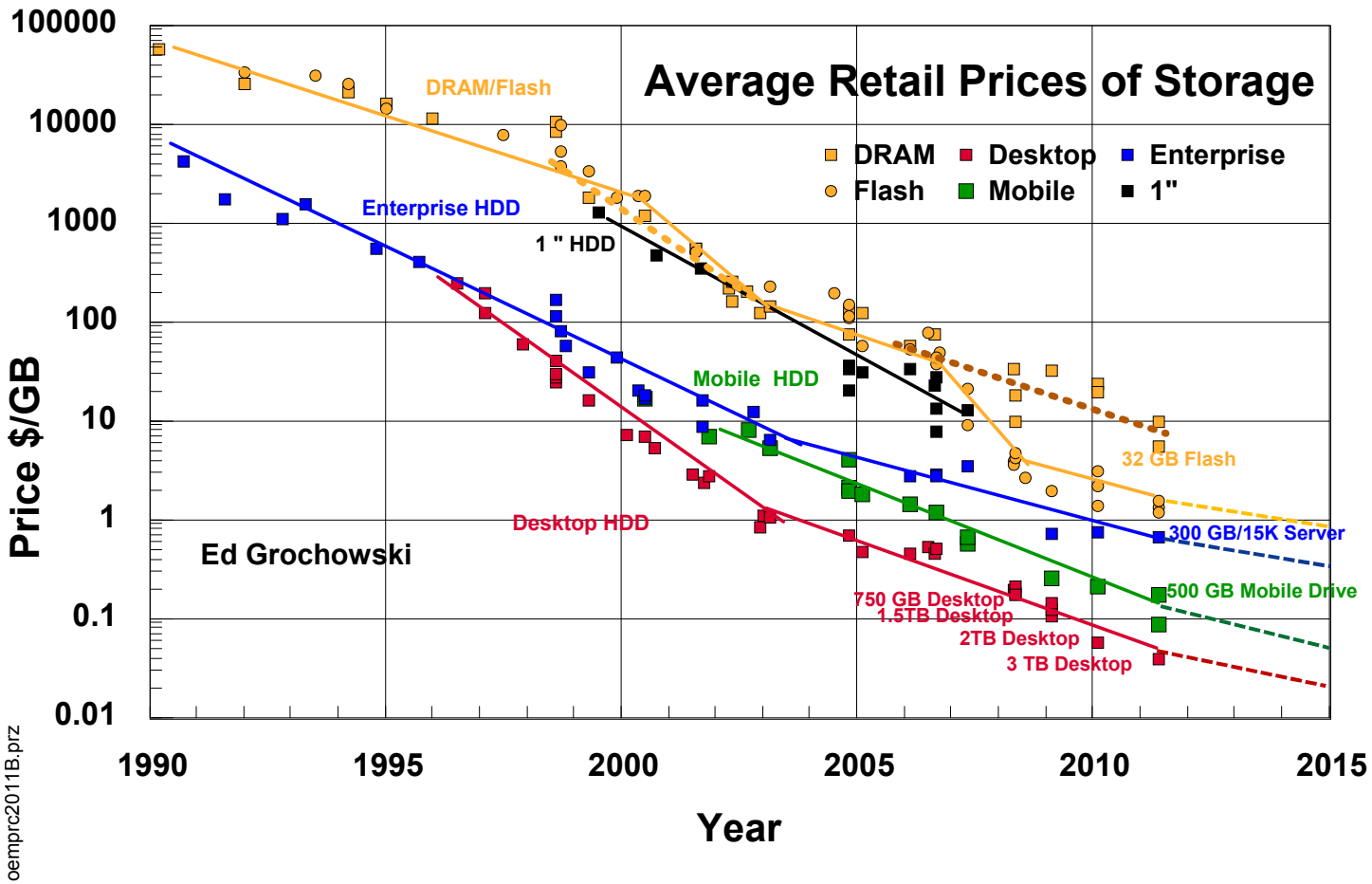
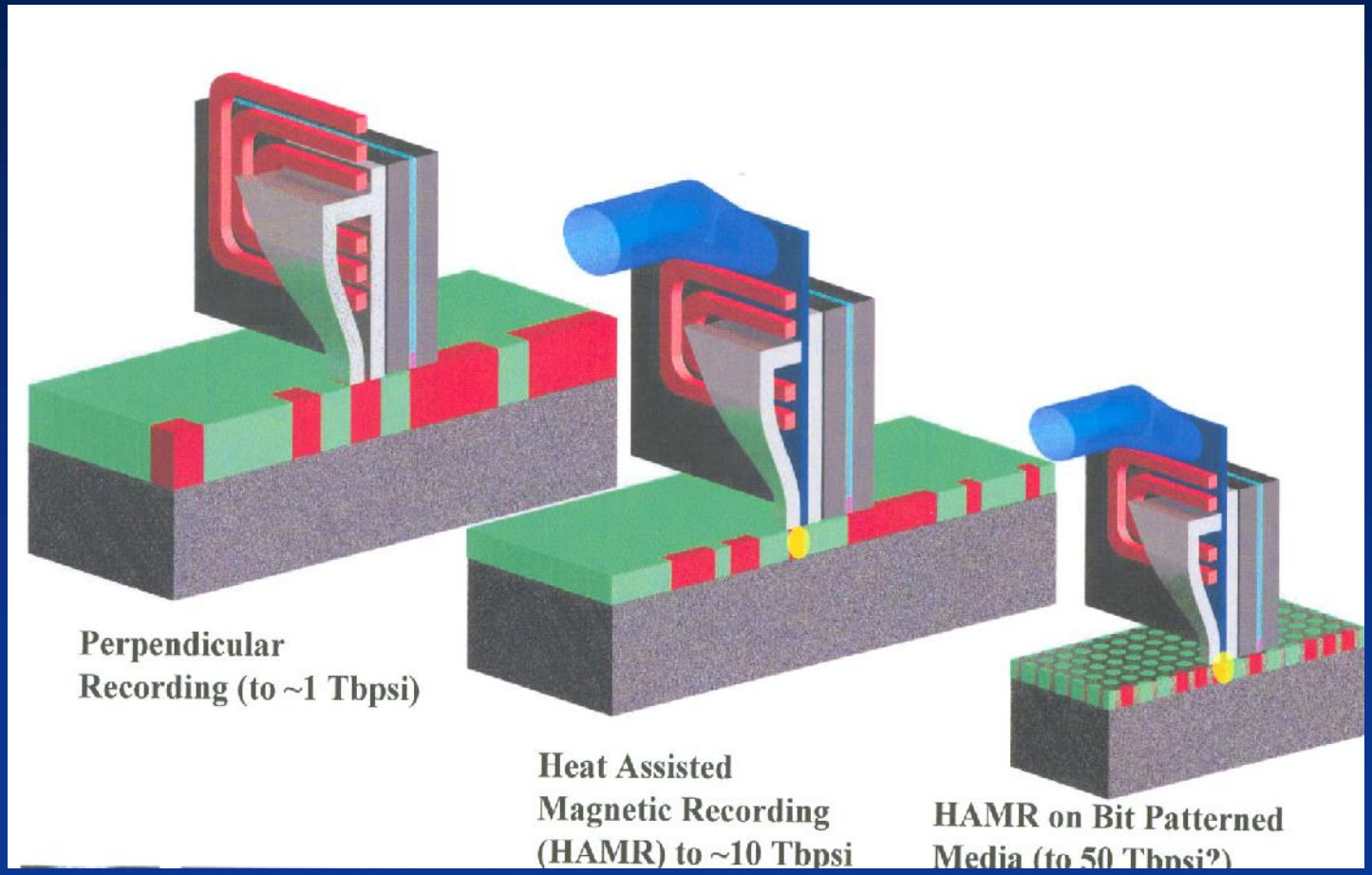

Average Retail Prices of Storage
DRAM
Flash
Desktop
Mobile
Enterprise
1"
DRAM/Flash
Enterprise HDD
1 " HDD
Mobile HDD
Desktop HDD
32 GB Flash
300 GB/15K Server
500 GB Mobile Drive
750 GB Desktop
1.5TB Desktop
2TB Desktop
3 TB Desktop
Ed Grochowski
Price $/GB
100000
10000
1000
100
10
1
0.1
0.01
1990
1995
2000
2005
2010
2015
Year
oemprc2011B.prz

Magnetic Recording Cell

- The unique attribute of the magnetic bit cell in a hard disk drive (HDD) is that the bits are unpatterned ➔ tremendous cost advantage
- The bit length is “sub lithographic”
- Bits are “magnetically” templated into the media using a single photo lithographically defined magnetic transducer
- Bit width is determined by the lithography used to form the write transducer. The smallest lithographically defined feature in the magnetic head is the read transducer ~ ½ Track Pitch = **F**
- Bit length is determined without lithography! It is sub lithographic! It is defined by the distance the disk rotates during the time interval that alternating current pulses are applied to the write yoke.
- Bit length is limited by the resolution of the sensor, i.e. the read gap with dimensions **G** determined by depositions, not lithography
- An HDD Product Example (635 Gbit/in² Areal Density)
  - Minimum Lithography 37 nm = F
  - Bit Cell 74 nm x 13 nm
  - Smallest Bit Feature 13 nm ➔ ~ 33% F, ~ 50% IC F

Three Major HDD Innovations



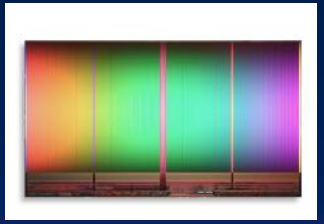
HDD Shingled Write

1. **Is A Band Technology, Not A Sector Or Track (Marginally)**

2. **Ideally Suited For Streaming Applications (>>Gbyte Movies)**
3. **Many Potential Ideas For Writing Tracks**

4. **Requirement For Correct Choices On Buffer Tracks And Band Sizes**
5. **Involves Rewriting On Disk Or Buffer electronics Within Drive**
6. **If Changes To OS Or System Electronics, Delays Are Probable, If Drop-in Technology, Applications Will Arrive Soon**

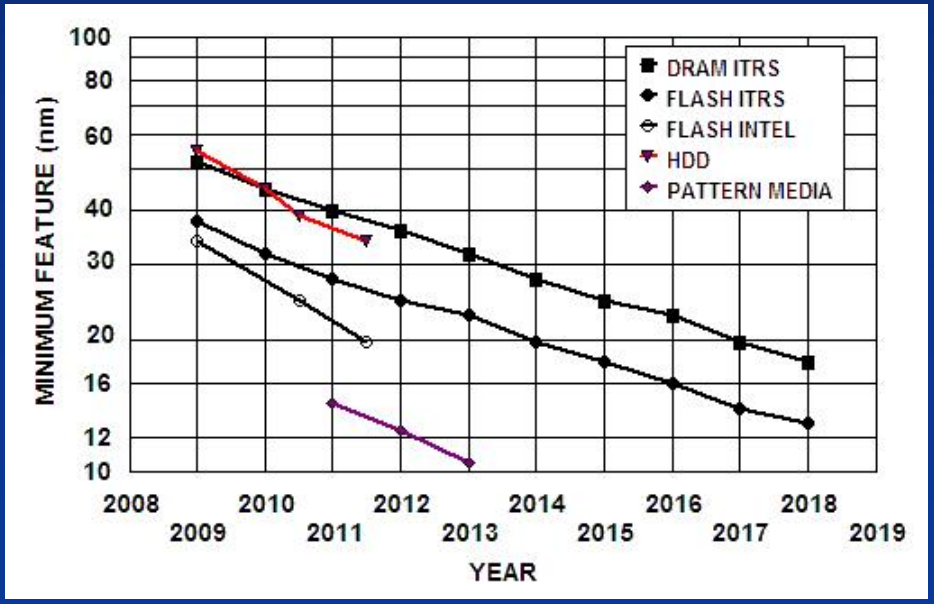
Cell Size Comparison



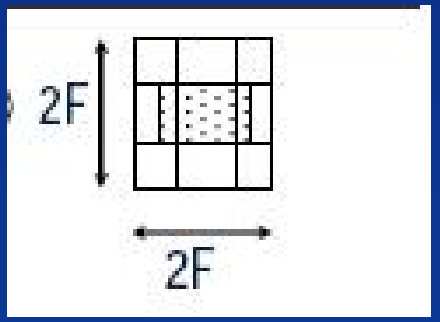
	8GB NAND Flash	8GB NAND Flash	375 GB 1 surface HDD
Surface Dimensions (Chip or Disk)	16.5 mm x 10.1 mm	12.5 mm x 9.5 mm	87.0 mm disk diameter 24.0 mm hub diameter 1.5 mm edge exclusions
Memory Surface Area	167 mm²	118 mm²	5491 mm²
Active Memory Area	~ 122 mm² (73%)	~ 71 mm² (65%)	~ 4969 mm² (90%)
Minimum Lithography	F = 25 nm	F = 20 nm	F = 37 nm
Active Bit Cell Area	1906 nm² = 3.0 F²	1109 nm² = 2.8 F²	981 nm² = 0.7 F²
Bit Cell Dimension	44 nm x 44 nm	33 nm x 33 nm	74 nm x 13 nm
Maximum Areal Density	330 Gb/in²	560 Gb/in²	635 Gb/in²

Lithography and NAND Flash

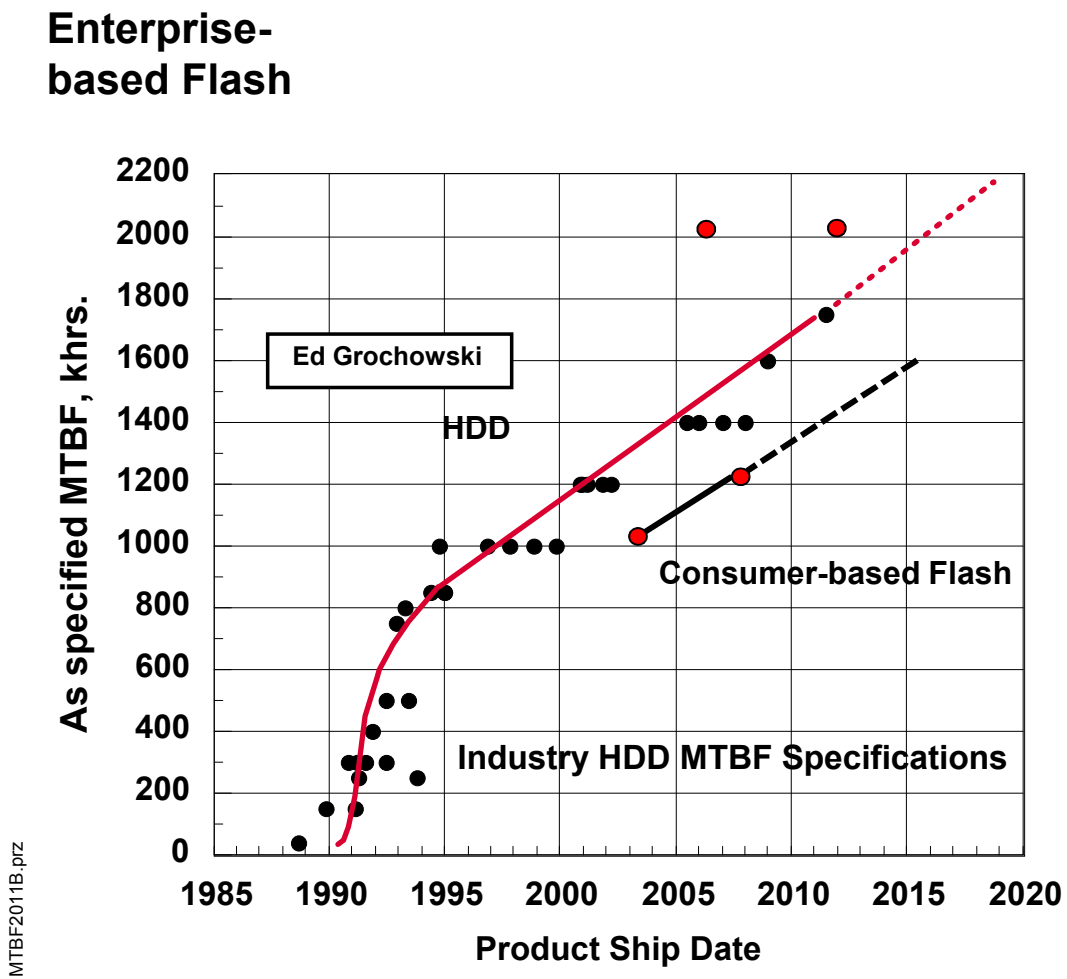
- Typical NAND cells formed with sub 30 nm lithography with Intel-Micron providing leading edge devices at 25 nm to 20 nm
- Bit cell area approaches 2.5 F^2 (F is the minimum lithographic feature) for Self Aligned STI multi level (2 bit per cell) designs
- HDD cells formed with minimum features close to DRAM requirements
- Patterned Media cells will require substantial “invention” in lithography to meet density goals



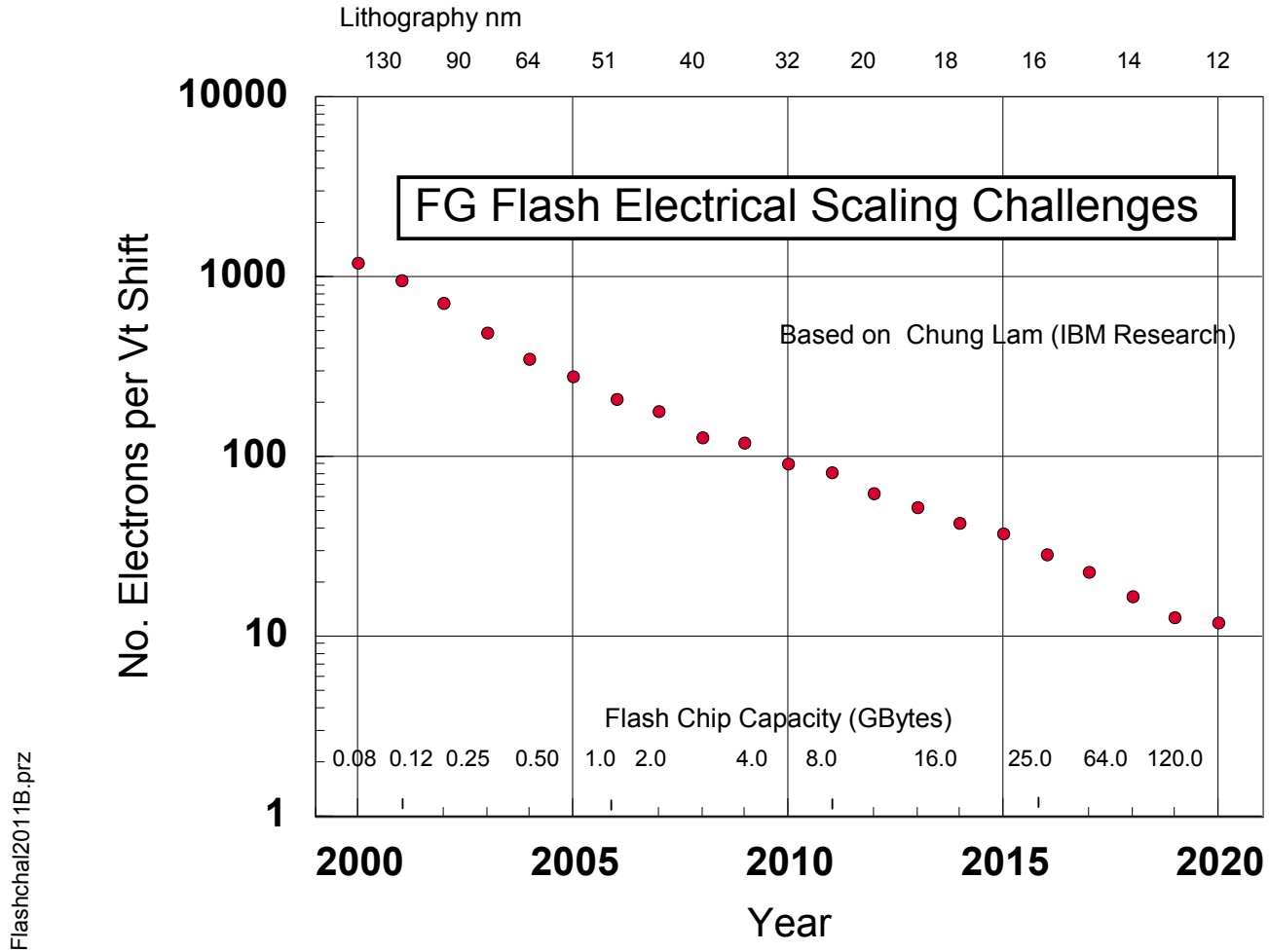
Multi Level NAND Cell



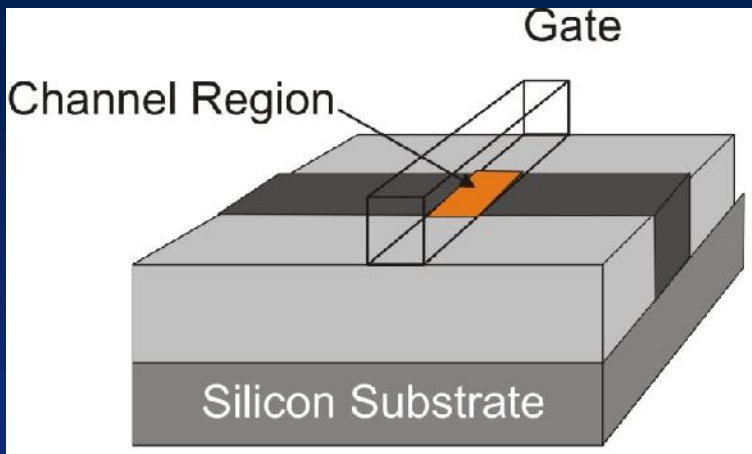
MTBF Specifications



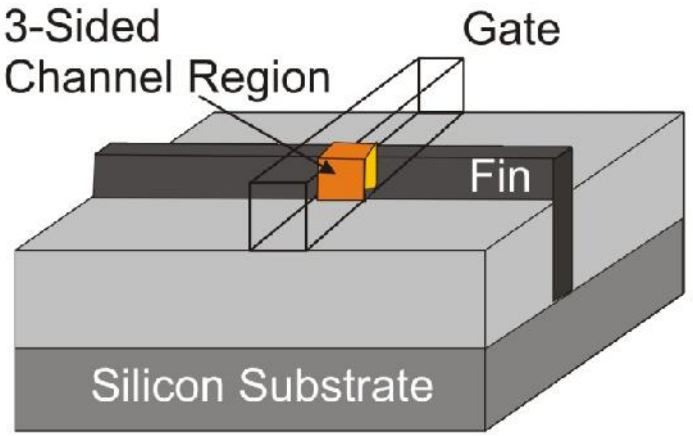
Flash Scaling



New Transistor Designs



Standard Transistor



3D Transistor (INTEL)

1. Better Current Control

2. Reduces Current Leakage

3. Allows Closer Packing

Flash Scaling Challenges

1. >15 nm Lithography (EUV Technology Too Expensive For Flash, Also HDD)
2. Fewer Electrons >> 100 (Leakage >1 Electron Per Month)
3. Electric Field Stress During Programming Too High
4. Write Endurance Degrades

Conclusion

1. **Expect Significantly Reduced Scaling And Capacity Progress- Flash And HDD-In Future**
2. **New Processing And Structural Techniques Limited By Implementation Costs**
3. **Storage Requirements Will Continue Vigorous Demands For Both Flash And HDD Products**
4. **Door Is Open For Alternative Technologies (FeRam, MRAM Are Imbedded Technologies; PCM Is Crosspoint)**