2011 DISKCON Program Notes and Comments

By Ron Dennison, Principal Consultant, Research Development Consultants Inc. 10/31/2011

Summary:

This was perhaps the smallest DISKCON USA event ever with only 15 exhibitors and a day and a half of Symposium Sessions. Although the conference was generally upbeat due to the ever increasing demand for storage, as could be expected, the events in Thailand were a continual topic of conversation in the halls.

The major topics covered were future technology for HDDs to enable continuing the historic areal density growth (~40% CAGR since 1956) and potential market shifts as a result of the Thai flooding, the march of technology and storage demand.

Clearly the next few quarters of restricted HDD availability presents an opportunity for increased profitability in the industry which may help offset some of the recovery costs not covered by insurers.

The material covered in the Symposium breaks down into two major areas, technology and market:

1. **Extension of technology to 1Tb/in2 doable with continuous improvement (Ken Johnson, HGST)**
2. **Shingled Magnetic Recording is next, may bifurcate market (Roger Wood, HGST)**
3. **Consensus is that HAMR will follow although MAMR is a possibility (Richard New, ASTC)**
4. **MAMR needs much more lab work (Richard New, ASTC)**
5. **BPM is further out due to current experimental results (1.2Gb/in^2), development still required and drive integration issues (Tom Albrecht, HGST)**
6. **High Temperature processing required for FePt HAMR media (Mike Russak, Intevac) suggests need for other alloys; 600C infeasible on Al and current glass substrates (special high temperature glass is required (Gil Argentina, Hoya—private communication)**
7. **Going forward, more data than can be stored is being created increasing demand for HDDs (John Rydning, IDC)**
8. **Thai flooding will impact HDD availability for at least 2 quarters; component vendor consolidation may be a consequence (Analysts Panel Discussion)**
9. **Hybrid HDDs may have a role in client space going forward, but Notebook manufacturers will determine whether hybrid or dual SSD/HDD architecture wins (Analysts Panel Discussion)**
10. **7mm Z-height hard drives are possible, but chicken and egg argument for spending development dollars; IF 7 mm happens, 9 mm will disappear (Analysts Panel Discussion)**

Day 1: SESSION 1A Magnetic Recording, the Next Generation

Wayne Rickard

HDDs: Disruptive Again?

MMI

Sugar Parallel - Value Chain

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The Black Swan - Taleb

Cloud Vendor Taxonomy

Replicated Object is new unit of Storage Measurement

Amazon S3

The Physical Cloud is HDDs! According to 451 Group research, cloud-based storage accounted for nearly 40% of the $1 billion core cloud infrastructure spending in 2010 – a market expected to quadruple in size over the next three years – making cloud storage market worth $1.6 billion by 2013.

2012 Data Center Expansion Plans Heating and Cooling are major issues

Hybrid best defense against SSDs in Notebooks

Cloud CAGR large, must address cooling and dense blade structures

Ken Johnson HGST

Extending TMR Media to 1Tb/in2

2006 Change to Perpendicular

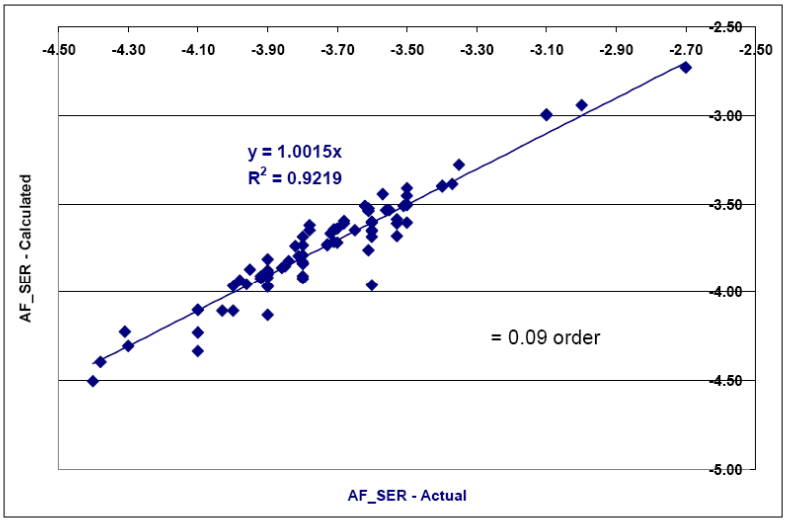
PMR Solves Trilemma Problem?

Better Microstructure for PMR!

SER Model: Error Rate Calculated from Recording Parameters

HITACHI Inspire the Next

$$AF\_SER = a*S_0NR + b*T_{50} + c*MCW + d$$

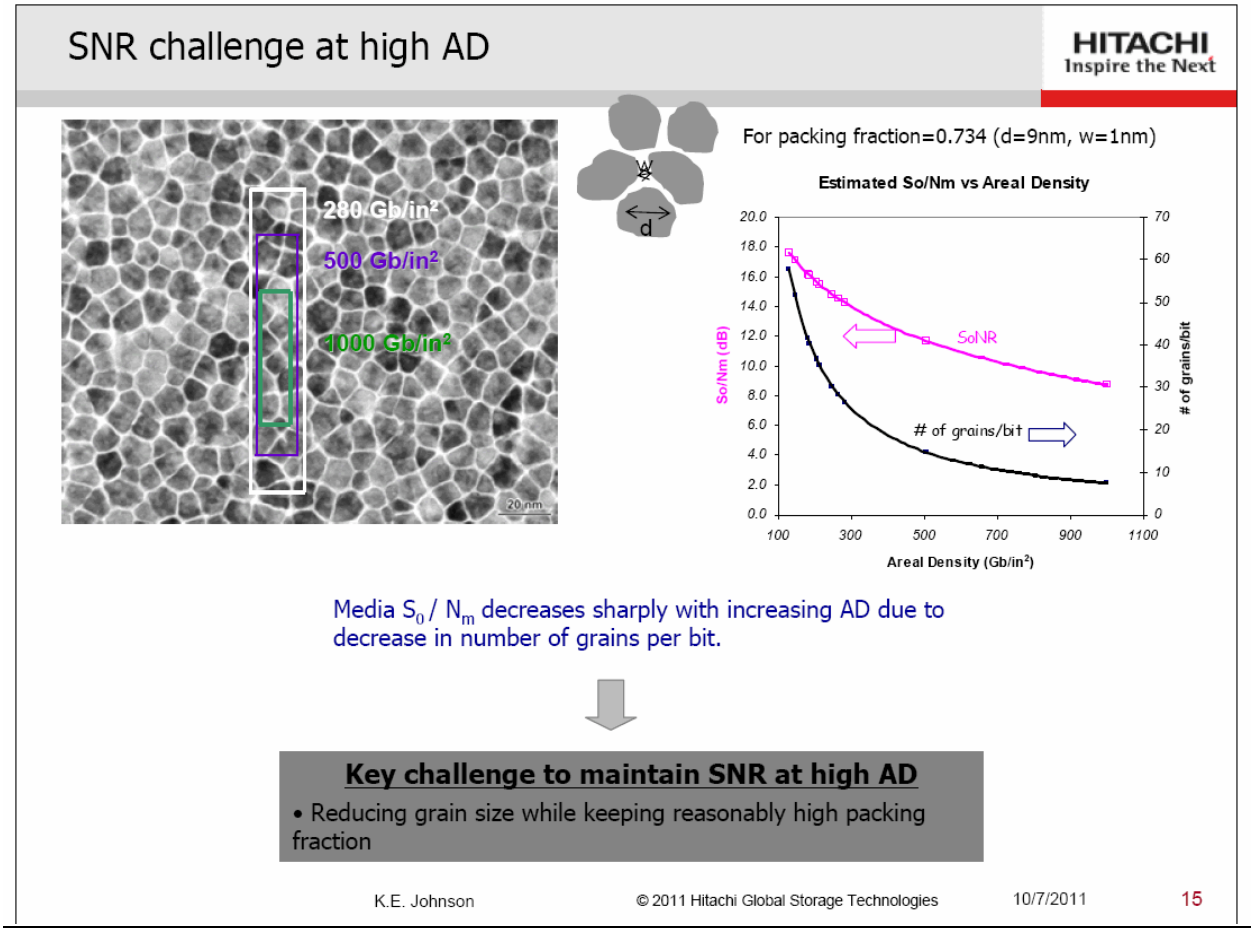


1. AF_SER = Error rate normalized to the magnetic core width
2. S_0NR – Isolated pulse amplitude over integrated noise
3. T_{50} – Rise time (nm)
4. MCW – Magnetic core width

K.E. Johnson © 2011 Hitachi Global Storage Technologies 10/7/2011 13

SNR, MCW and T_{50}

10 grains/bit at 1Tb/in2 but in last 5 years gains in Areal Density not from grain size!



Maybe cluster size reduction?

Magnetic Core Width reduction

G1-3 are oxide layers; Hk graded media

T_{50} gets smaller with lower head media spacing; ~0.1 order of BER per Angstrom

Overcoat going from 25-30 A to 20

Recent products 600-650 Gb/in^2

Hitoshi Iwasaki, Toshiba

High Sensitivity Reader using nanocontact MR; possible reader candidate technology beyond TMR to 2.5Tb/in2 contact ~1nm

FeCo areas in Al then post anneal to oxidize FeCoAlSi NOL

Lead Resistance an issue

40% delR/R with RA = 0.2 ohmuM^2

No real parts yet which have better performance than current technology

Nick Granger-Brown, Xyratex

He gas filling and extraction in HDD production

370k tpi now

Reynolds Number = density x velocity x length /dynamic viscosity

He advantages: Lower density, less turbulence, better heat transfer, inert; more stable on track performance for writes

Strong Box or simultaneous flush/fill

He recovery necessary

Permanent He era?! Temporary seal in process + final after test permanent seal

Low He cost due stockpile depletion

Major source natural gas

H2 not a possible substitute

3-5 year He retention questionable plus long term price for permanent He fill of HDDs

Roger Wood, HGST

Shingled Writing and 2D recording; **Shingled next, 2D more problematic due to servo and signal processing issues.**

1 bit/grain with Shannon erasure channel (TMRC 2008)

ITI = Inter Track Interference

2D penalized by multiple passes needed or multi reader head

Squeeze events rare/occasional so don't have to process 2D all the time

ITI Cancellation graph from LSI? 8% improvement

Interesting future graph at end - data tub or bit bucket

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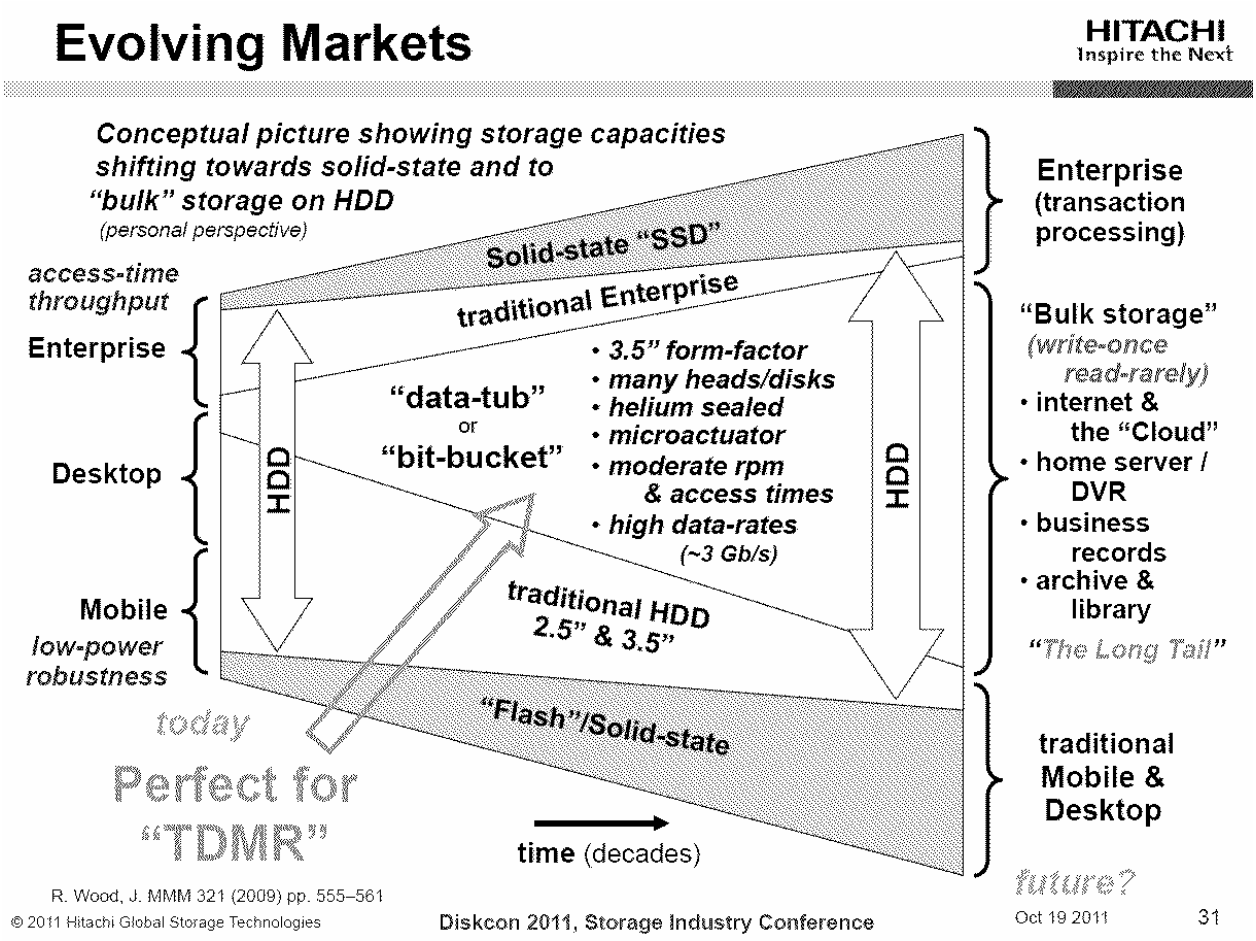

Jonathan Coker, HGST

Algorithms for Shingled Magnetic Recording, SMR drives

Algorithm aggregates small block random into physically sequential track

On the fly defrag in background

Because of higher sequential performance, overall performance still higher, especially for small blocks; helps to overprovision

1000 queue depth

24/7 operation

indirection system required like SSDs

Richard New, HGST, ASTC

ASTC Update (Chairman)' HDD Technology Roadmap

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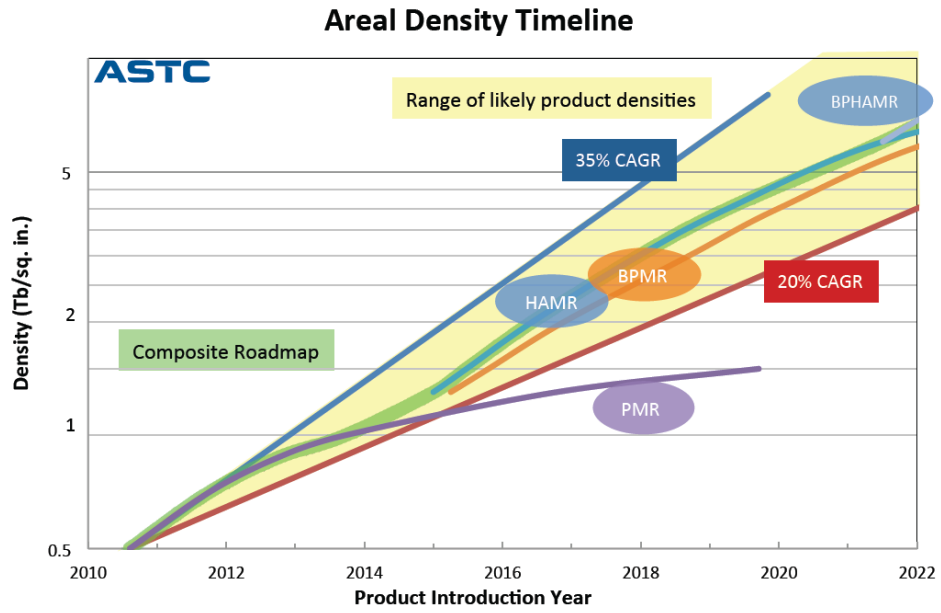

pro-competitively

MAMR less emphasis

2015 intro for HAMR OR BPMR 20-35% CAGR in official roadmap from mid-2010 .5Tb/in2 to 8Tb/in2 on 20% curve for 2022?

MAMR Spin Torque easiest to integrate but feasibility undetermined

HAMR next; head wafer process, assembly and metrology; media prod more difficult than transition to perpendicular

BPMR only one not requiring unproven small grain media BUT radical changes to disk fab, higher disk manf cost, large and untested chaanges to servo, signal processing and write timing

SMR changes to system

Bit Aspect Ratio 4 to 4.5 now

SESSION 1B: Touching the Future of Magnetic Recording

Paul Hofemann, Molecular Imprints

May be used for head litho as well as NAND Flash litho in addition to BPM

3 sigma Critical Dimension Uniformity 0.75nm, daughter masks also <1nm

Achieving ~10nm 3 sigma final product

2013 Semi adoption

TFH defectivity much less than semi due smaller active area

Print whole row bar at once!

Cost target $1-2/disk (above current $5-7/disk)

End use bifurcation

New product HD7500 in 2015

Si vs quarftz masters

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First "real" product semiconductor in 2013

Tom Albrecht, HGST

Grain sizes not scaling

Most of gain in media performance from signal processing over last few years

Drag Tester results

Challenge: high volme, low cost

Self assembly for bit multiplication on e-beam seed pattern

0.75nm 3sigma master CDU good for 4Tb/in

Dots not best choice: how to make rectangular using self assembly by doing 2 perpendicular cuts

Spacer based line doubling

13.5nm pitch shown = 6.75nm node!

Planarization possible by many techniques incl. CMP (smoother than conventional!)

Modeling says 2-4 Tb/in2 but demo 1.2 Tb/in2 w/o HAMR and 1.5 Tb/in2 with

Mike Russak, Intevac

Technology Elements for High Throughput Advanced Disk Manufacturing

1.2B disks this year

Intevac 200 Lean comes in groups of 4 modules; today typically 20 chambers

20 stations 5s process 700 disks/hr and 24 stations 3s process 1000 disk/hr for BPM in addition to current equipment

650C! processing capability for new alloys

Triatron and multilayer sources

High temp resistive heater melted disk (glass disk?)

FePt 450-550C processing needs preheat to 600C! [Suggests other alloys need/will be found for HAMR]

20 station tool standard today; therefore double equipment footprint for BPM!

Chanmin Su, Brubaker-Nano (AFM)

Matching Challenges of HDD Roadmap with Scanning Probe based Metrology

PTR and R/W pole tip measurements

Patterned media application

Conventional 1 line/s so 4-8 min for a single image; nN force erodes tip, not material composition sensitive

High Throughput: 2.5s per image 256 line image therefore ~100 images in 4 min

To accomplish use closed loop control of probe, smaller cantelever

~1 min for typical PTR measurement vs 10 min

Peak Force Tapping about 10pN vs 1nN force Tapping Mode

Physical Property Characterization

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Modulus, Hardness, Tribo ahesion, therefore ID surface defects: oil vs thermal asperity, lube coverage sub-nM resolution

Substantial improvement in scanning probe microsocpy!

Day 2: Session 2: Analysts Speak

Tom Coughlin, Coughlin Associates

Content Distribution: Optical Disks incl Blu-ray DL, USBs

BW limitations mean that rich content (video esp HD) is still being distributed by physical means (DVD sales shrinking thru 2015 but Blu-ray increasing)

Ultra HD (8k x 4k), 3D and interactive coming

Smartphone is (mobile) thin client dependent on Cloud

$.04/GB for local storage vs. $.25/GB for Cloud

STX Goflex—personal mobile cloud, also Kingston flash based device

John Chen, TRENDFocus

Ultrabooks: Thin and Light (Again)

A MacBook Air for PCs

<21mm for 14” and <18mm for 13.3”

Intel Rapid Start for faster wake from sleep

5+ hour battery life, integrated battery

Sandy Bridge CPUs migrating to Ivy Bridge in 2012

Storage includes HDD, SSD, both

Sub-$1000 price tier

Intel’s response to table/ARM

BOM cost $435-645 (retail typically 2x BOM), therefore $700 price point difficult

Dual storage caching issues dealt with by UB manufacturer

SSD models may require personal/public cloud

Does potential market justify development of <7mm HDD?

Resurgence of smaller FF HDDs unlikely, need 500GB, not 220GB/platter (1.8”)

Thin HDD must be standardized to allow multiple sources, consolidation in industry could make this easier

19% of NB market in 2013, 12% in 2012 (same as current price distribution of NB mkt)

Conclusions:

Re-tool BOM cost

HDDs will play a role in keeping costs down

Ultrabooks will have to go head-to-head with Apple

If <7mm developed then 9mm will disappear

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Jeff Janukowicz, IDC

SSDs and Enterprise Storage

Usual SSD pro arguments Performance, Efficiency, Cost (Lower TCO, $/IO)

Challenge List pretty standard

HDD history Unit volume vs number of OEMs

Digital Universe 1.2 to 7.9ZB 2010 to 2015

Short on real data

John Rydning, IDC

The Changing Landscape for Digital Storage

Joseph Schumpeter, Economist, Harvard

Capitalism is the perennial gale of creative destruction

8-Track-Cassette transition; hybrid products often don't do well. NB vs Tablet

"It does so thru a series of vicissitudes, the severity of which is proportional to the speed of advance."

First 3 quarters of shipments of iPod, iPhone, iPad

Social Networking content created/yr vs viewed/yr 14PB created vs 10,000 PB consumed

Bytes of content creation vs bytes of available storage: content exceed storage by substantial margin

Big Data example: amount of data retained from reading article

9.8EB of data storage purchased by Cloud in 2010

Sensors will create much of additional data going forward

323 Sensors on new MN bridge, camera in classroom

Paul Saffo, "Never mistake a clear view for a short distance."

Data Storage Demand Increasing rapidly due to:

- **Data Consumption**
- **Metadata**
- **Sensor Data**
- **Innovative ways to capture, use and analyze data**

Panel:

Thai flood: a lot not yet known

WD Conference call: HDD TAM 180M drives to 150M

How quickly can component manufacturers recover

WD head back-end under water

Nidec under water

Significant supply constraint over next 2 quarters

More consolidation among component suppliers will probably occur as recovery proceeds

STX-Samsung

Virtually a done deal

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JJ- Client side will reduce to those with access to NAND media quickly; Enterprise side more opportunity

JC- Hybrid drive future: PC OEMs will determine whether dual or Hybrid; flash cache development works with multiple OEMs; Hybrids not necessarily the same from multiple HDD OEMs

JR- A lot of different factors favor/disfavor the Hybrid; Need standardized hybrid

TC- SSD makers want to work with HDDs for dual configuration; flash will have greater role in NBs and PCs in future as cost declines

JJ- Dual boot makes NAND management easier from durability standpoint

TC- DVRs are natural for SMR, perhaps by next year

Insurance will help Thai situation!

JR- HDD market bifurcating to Very High capacity/disk and lower/stable capacity/disk

5 vs 7 mm Q: what's the real value;

TC- allows more battery space!

JJ- 5mm is SSD height

Q-For byte box is 5-1/4 reasonable? TC-yes JC-areal density of today may not be possible in 5"

TC- 1.8" may live again!

Q Another HDD startup? : JC Cornice last due IP issues

Session 3: Sustaining Areal Density Growth

Devon Johnson, Xyratex

Defect Detection has Evolved to Defect Classification

Basic defects: Area, Line, Point

Complex defects: combinations of the three

Defect Characteristic Chart

Critical particle size moving from 100nm to 50nm in 2013-14; depth sensitivity ~1nm

All disks with complex defects are rejected

But classification is subjective and higher resolution desirable at 2000 pph (parts/hr)

20k rpm defect size detection window is too large

Peter Goglia, Xyratex

Challenges in HDD Slider Manufacturing

Critical dimensions, bar angular measurement, defect types, defect measurement options

Good Areal Density Chart

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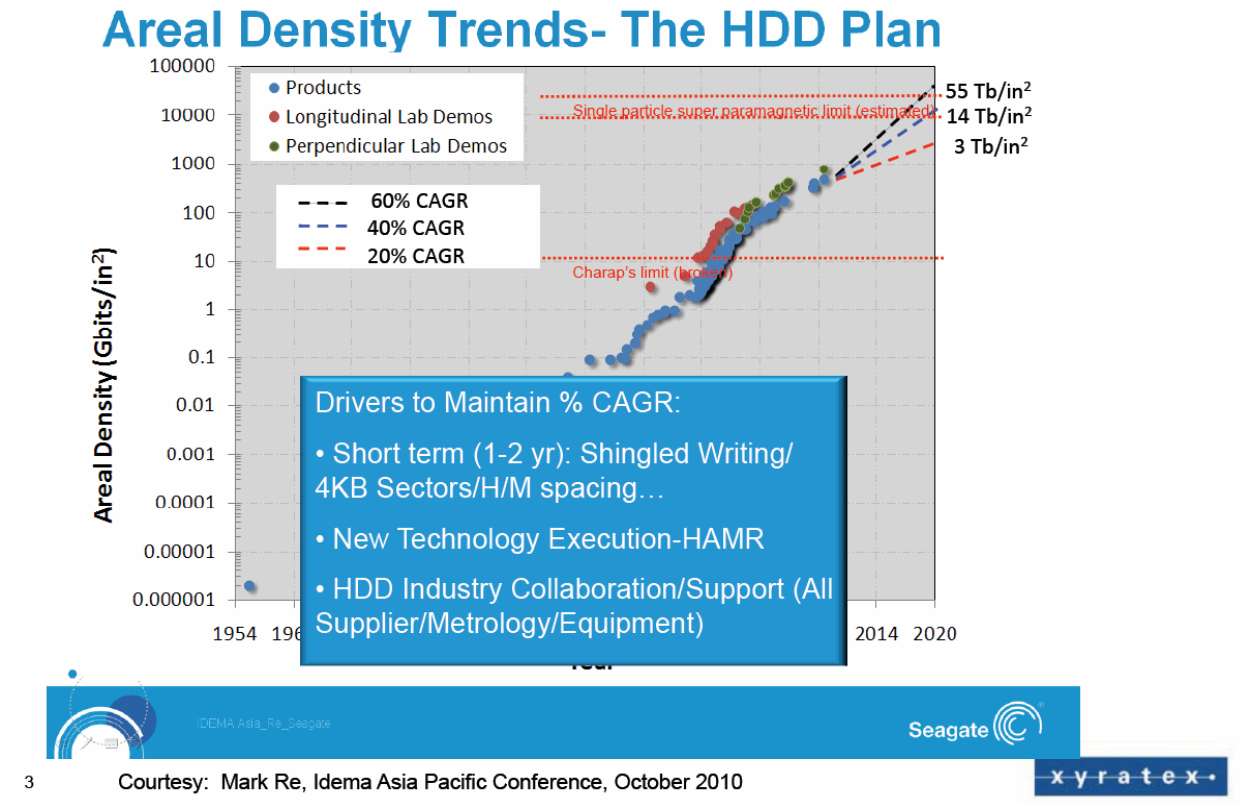
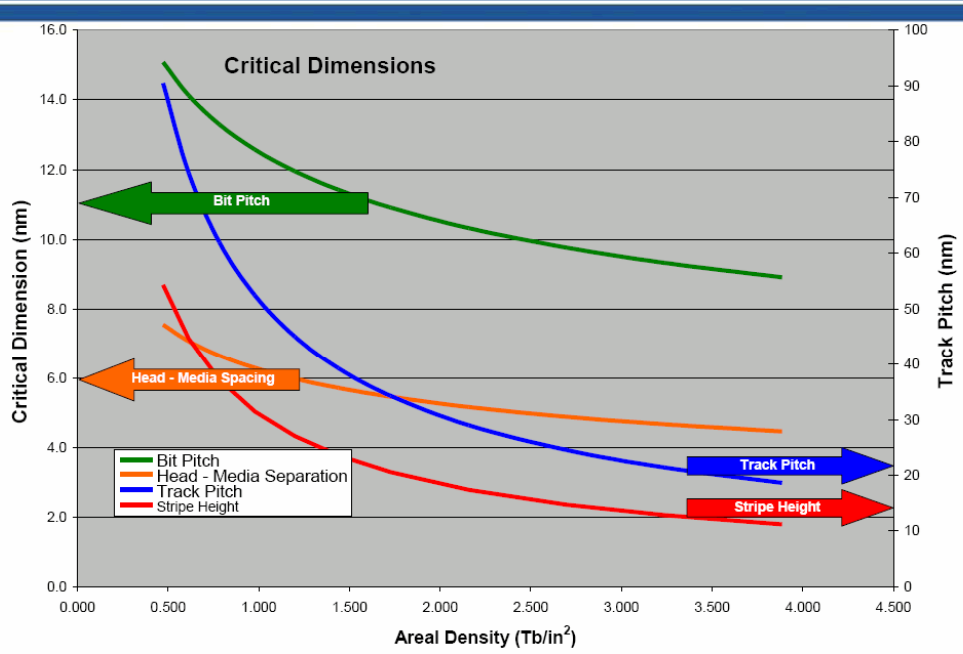
Trends and Projections – Areal Density



Critical Dimensions chart

Challenges - Critical Dimensions



- Track pitch is decreasing much faster than the bit pitch
- Reader & Writer critical dimension challenges
- Tighter lapping control needs
- Critical defect size reduction
- Servo / Servo write improvements

4

xyratex

Track pitch decreasing much faster than bit pitch; puts pressure on head/slider dimensional control

Lapping puts final critical dimension on stripe height and Wt (stripe eight 30 nm +/- 10% for 1 Tb/in2)

Computerized Autocollimator for closed loop angular control

Slider Defect Detection

Critical defect today ~1um, scales with Wt

Automatic visual analysis by region with results written to database

Golden images, neural networks,

2 Systems/Products:

1. ABS and Pole region defect inspection system
2. Automated bond pad inspection and sort

Mike Fitzpatrick, Toshiba

Side Effect of Increasing Areal Density: Increasing Data Rate

Priam, STX, Fujitsu, Toshiba

In the last 25-28 years controller integrated into HDD

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Focus on the effects of the technology, not the technology itself

Review of 4k transition

Universal sector alignment conversion tool became impossible; XP still doesn't recognize 4kn

10% efficiency improvement, better SNR, improvement in defect handling

SAS Roadmap

SSDs are changing the IF speed required landscape

SFF8639 Connector proposed

2 Camps of SCSI over PCIe T10 (Full SCSI compatibility) vs. Intel (NVMe)

New PCI look is backplane

Do we need to put PCIe IF on HDDs??

Gen 3 PCI 8Gb/s; 12Gb/s SCSI may need 6m cable limit vs 12m for 6 Gb/s; could use optical cables

SATA IF will stay capped at 6Gb/s for Client market

Matthew Roman, Electrostatic Technologies

Static Charge protection thru Micro Fiber Technology

Spinning disk is Static generator

Air in air bearing doesn't conduct

Microfiber works by contact and by non-contact (presence in field of 2um tip diameter concentrates field and causes discharge)

Radial contact common historically, but use axial and radial contact for air bearings in HDD equipment

10um diameter microfibers

Nelson Sorbo, Cool Clean Technologies

CO2 Processes in HDD manufacturing

Composite spray: Solids and gas together, can add trace solvent or lubricant, get liquid at surface due impact of solid

Can remove fingerprint oils

Phase Diagram

Composite spray technology dates from ~1995

Machining: 2x deeper cut at same feed rate, 10x tool life, superior surface finish, substrate remains at room temperature

Silicone monomer cleanup for medical

Just beginning media cleaning tests: challenges fixturing and results measurement

Target 2-3s/disk both sides

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