Tech Talk on HDD Areal Density

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Safe Harbor Statement

This document contains forward-looking statements within the meaning of Section 27A of the Securities Act of 1933, and Section 21E of the Securities Exchange Act of 1934, each as amended, including, in particular, statements about our plans, strategies and prospects and estimates of industry growth for the fiscal quarter ending October 2, 2015 and the fiscal year ending July 1, 2016 and beyond. These statements identify prospective information and may include words such as “expects,” “intends,” “plans,” “anticipates,” “believes,” “estimates,” “predicts,” “projects” and similar expressions. These forward-looking statements are based on information available to the Company as of the date of this document and are based on management’s current views and assumptions. These forward-looking statements are conditioned upon and also involve a number of known and unknown risks, uncertainties, and other factors that could cause actual results, performance or events to differ materially from those anticipated by these forward-looking statements. Such risks, uncertainties, and other factors may be beyond the Company’s control and may pose a risk to the Company's operating and financial condition. Such risks and uncertainties include, but are not limited to: the uncertainty in global economic conditions, as consumers and businesses may defer purchases in response to tighter credit and financial news; the impact of the variable demand and adverse pricing environment for disk drives, particularly in view of current business and economic conditions; the Company’s ability to successfully qualify, manufacture and sell its disk drive products in increasing volumes on a cost-effective basis and with acceptable quality, particularly the new disk drive products with lower cost structures; the impact of competitive product announcements; currency fluctuations that may impact our margins and international sales; possible excess industry supply with respect to particular disk drive products; and disruptions to our supply chain or production capabilities. Information concerning risks, uncertainties and other factors that could cause results to differ materially from the expectations described in this document is contained in the Company's Annual Report on Form 10-K filed with the U.S. Securities and Exchange Commission on August 11, 2015, the “Risk Factors” section of which is incorporated into this document by reference and other documents filed with or furnished to the Securities and Exchange Commission. These forward-looking statements should not be relied upon as representing the Company’s views as of any subsequent date and the Company undertakes no obligation to update forward-looking statements to reflect events or circumstances after the date they were made.
Seagate: Storage Leader

Seagate is a 35 year High Tech manufacturing provider of data storage solutions

Provide storage for enterprise, desktop, mobile computing, surveillance, consumer electronics and retail markets

Vertically integrated storage technology
Leadership in Heads, Media, ASICs
~9,000 Patents

~52,000 employees worldwide
Global manufacturing footprint
Seagate’s Technology Leadership

Technology leaders in demonstrating HAMR, TDMR and SMR

First to market with Hybrid, SMR

Utilize 53 of the periodic table’s elements

Manufacture over 220M HDD per year

Integrate over 45B components per year

Leveraging Cloud Systems and Solutions Portfolio

Flash Platform development with Hybrid, SAS, and PCIe technology

Takeaways
• Continue investments in technology innovations
• Leverage technical innovations into product roadmap
• Enables low cost, high performance and reliable products
Innovations Driving Areal Density Growth

33% CAGR
- Ferrite Head
- Oxide Disc

30% CAGR
- Thin Film Inductive Head
- Hydrodynamic Air Bearing
- Sector Servo

23% CAGR
- MR Head
- Thin Film Disc
- Zoned Recording
- PRML Channel

56% CAGR
- GMR Head
- Glass Disc
- Ramp Load/Unload

52% CAGR
- PMR
- TMR Head
- Femto Slider
- PRML Channel
- Fluid Bearings

25% CAGR
- SMR (Shingled Mag. Recording)
- LDPC Channel
- 4K Sectors
- µPempto Slider
- Dual Stage Actuator

15-30% CAGR (est)
- HAMR (Heat Assisted Mag. Recording)
- TDMR (Two Dimensional Mag. Rec.)
- BPM

Cost/GBps vs Areal Density (GBps) - 2000 - 2015

- Total Hdd Enterprise
- Total Hdd Market
- HDD Areal Density (Gb/in2)
The Challenges to Increasing Drive Capacity

**Thermal Stability**
- Increase AD / drive capacity:
  - Reduce grain size
  - Make grains harder to switch

**Writer/Reader Scalability**
- Reduce bit width
- Reduce bit length

**Fixed Form Factor**
- Increase areal density
- Add heads and disk

**Solution:**
- Heat Assisted Magnetic Recording (HAMR)
- Writer- Shingled Magnetic Recording (SMR) & HAMR
- Reader- Two-D Magnetic Recording (TDMR)
- Advanced Mechanical Designs
- Helium Drives
- Form factors optimized for racks
Advanced Mechanical Designs

Rearward Coils
Larger Coil outer radius

Top Disk Separator Plate

Bonded Pivot Bearing

Sealed HDA Features

• Process cover-Seals over Motor, HSA, and VCMA
• Internal Environmental control

Takeaways

• Motivation- Increase drive capacities for enterprise & cloud applications
• Solution- Design to reduce turbulence
Emerging Technologies For Capacity Growth

Perpendicular Magnetic Recording
- AD Up to ~1.0 Tb/in²
- Current Mainstream Products

Hybrid/Enhanced Magnetic Recording
- SSD-Like Performance

Shingled Magnetic Recording
- Shipping in Various Markets

Two Dimensional Magnetic Recording
- Product Integration 2016+

Heat Assisted Magnetic Recording
- AD ~1.2 to 5.0 Tb/in²
- Product Integration 2016+

Heated Dot Magnetic Recording
- ~5.0 to 10.0 Td/in² AD
- Initial Product Integration >2025
Shingled Magnetic Recording

- SMR- increase capacity over conventional recording
- Allows more narrow tracks to be written
- Performance transparent in the vast majority of use cases
Two Dimensional Magnetic Recording Works

- 2 or more readers on the same track or partially on adjacent tracks
- Current areal density gains in the 5-10% range
- Future work to get larger areal density gains
Heat Assisted Magnetic Recording Making Significant Progress

• HAMR need for increase in areal density.
• HAMR areal density attainment is \(1.5 \text{ Tb/in}^2\)
• Still focusing on reliability and area density
Heated Dot Magnetic Recording = BPM + HAMR

Continuous FePt film patterned @ 1Tdpsi to 5Tdpsi

Takeaways
- BPM: Multiple grains per bit to a single magnetic island per bit
- Demonstrated 1.5 Tdpsi Spinstand
- HDMR at 5Tdpsi and beyond looks feasible

Spinstand testing and drive integration

BER = -2.43 @ 1Tb/in²
Emerging Technologies for Performance

- Caching Technology
- Kinetic
- Drives Optimized for Subsystems
- Parallelism
- Enhanced Processing Drives
Summary

**Scale**
- Technology - most precise, complex, and dynamic in the world
- Design, develop and manufacture over 50 Million HDDs per quarter
- Ranked 16th best supply chain in the world by Gartner in 2015

**Scope**
- Complex, spanning multiple disciplines
- Drives utilize 53 of the periodic table’s elements
- Head flying at couple of angstroms over media
- Aligned to Product Roadmap

**Innovation**
- Nominated by Thomson Reuters 3 straight years
- ~9000 patent/disclosures
- First to market – Hybrid and SMR drives
- HAMR maturing
- Performance boost – Enhanced cache
- Continued investment to deliver Flexible and Aggressive technologies