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Memory/Storage: HDD vs. NAND in the Datacenter with ex-WDC EVP, SanDisk Flash Business - Transcript and Takeaways

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We recently hosted a webinar with Robert Soderbery, former EVP at Western Digital who ran the Sandisk flash business, overseeing cloud, consumer, and AI storage markets. We discussed the dynamic of NAND vs. HDD in data centers as well as LTAs and HBF. This note is an edited transcript with key takeaways. A replay is available here.

Data center storage has shifted from a simple two-tier model - HDDs for capacity and small SSDs for compute - to a three-tier architecture driven by AI. Historically, HDDs represented about 80-85% of bits, but AI workloads created strong demand for high-capacity enterprise SSDs to support data prep and pre-compute tasks that HDDs cannot handle, pushing new AI storage deployments temporarily toward NAND.

Sharp NAND price increases have widened the ASP gap vs. HDD, slowed HDD-to-SSD substitution, and forced AI operators toward more cost-efficient tiered designs. SSD displacement of HDD is now economically unattractive for both hyperscalers and NAND suppliers. **The hyperscaler TCO crossover requires a ~2-3x NAND-to-HDD ASP gap**; the current gap exceeds 20x, making substitution uneconomic. For NAND suppliers, displacing HDD would require massive incremental capex across multiple node transitions at low returns and highly unlikely.

Two additional trends could reshape the NAND landscape. **First, the industry is moving toward true two-way long-term agreements** - replacing historically one-sided LTAs with contracts that include customer purchase commitments and financial guarantees, improving planning visibility and supporting investment (though severe downturns would likely prompt renegotiation over strict enforcement). **Second, any shift of compute from cloud to edge strongly favors NAND over HDD given NAND's advantages in space, power efficiency, and performance**.

NAND pricing is spiking because AI demand is concentrated on the latest-node, high-capacity NAND, which represents only ~30-35% of total industry capacity, so the concentrated demand is creating a very sharp increase in ASP. HDD pricing reflects a more conventional supply-demand imbalance: demand exceeds supply, but less extreme.

HDD vendors operate in a tight oligopoly and are intentionally avoiding capacity expansion. HDD technology remains complex enough - across HAMR, heads, mechanics, and materials science - that adding capacity has real friction, supporting LT supply discipline.

HBF uses similar-to-HBM stacking, wide interfaces, and advanced packaging to sit alongside GPUs, but exploits a key AI inference characteristic: data is often streamed rather than frequently rewritten. **Although NAND has slow dynamic read-write and higher latency, it can deliver very fast sustained throughput once streaming begins, making it well suited for AI inference**. By combining HBM-style bandwidth with NAND's much higher density and different cost structure, HBF could be compelling for AI workloads, though it is still early stage.

BERNSTEIN TICKER TABLE

			4 May 2026		TTM	Adjusted EPS				Adjusted P/E (x)	
Ticker	Rating	Cur	Closing Price	Price Target	Rel. Perf.	Cur	2025A	2026E	2027E	2025A	2026E	2027E
SNDK (SanDisk)	O	USD	1,255.86	1,700.00	3502.0%	USD	2.99	64.73	200.47	420.0	19.4	6.3
WDC (Western Digital)	O	USD	442.36	590.00	855.7%	USD	4.80	9.81	20.19	92.1	45.1	21.9
STX (Seagate)	O	USD	738.54	1,000.00	662.6%	USD	8.10	14.89	32.49	91.2	49.6	22.7
SPX			7,200.75									

O - Outperform, M - Market-Perform, U - Underperform, NR - Not Rated, CS - Coverage Suspended

Source: Bloomberg, Bernstein estimates and analysis.

DETAILS

We recently hosted a webinar with Robert Soderbery, former EVP at Western Digital who ran the Sandisk flash business, overseeing cloud, consumer, and AI storage markets. We discussed the dynamic of NAND vs. HDD in data centers as well as LTAs and HBF. This note is an edited transcript with key takeaways. A replay is available here.

This transcript has been edited for clarity and consistency.

Speaker Key:

RS: Robert Soderbery

MN: Mark Newman

MN: Good morning, everyone. I'm Mark Newman, Bernstein's US IT Hardware Analyst, and great pleasure to welcome Robert Soderbery today, as our special expert in the industry. Rob, I think it'll be really great, since your background, in flash and working at Western Digital, it'll be good to know, how you see the current mix of NAND versus HDD in data centers. How has that changed over time, and how do you expect that to evolve over time?
RS: Yeah, happy to help, Mark. I think to understand it, it's best to walk back a little bit, because the situation's gotten more complex with the arrival of the AI data center. But let's start with the conventional data center. And recognize that the hyperscalers don't differentiate in their purchasing, typically, between these two, so it can be actually quite hard to disentangle the whole thing. So, starting with the conventional data center, the world was pretty simple You used, Enterprise SSDs for compute, these are small drives - 2, 4 or 8TB drives, and you used, Enterprise Nearline HDDs for storage.

And so you had really a two-tier architecture. If you're going to measure in terms of gigabytes or exabytes, the vast quantity of that was in HDD, although, of course, those HDDs are much lower cost, so from a spend perspective, it's more balanced. That was a world that was 80/20, 85/15 HDD versus NAND.
Now, even in that data center, there was this idea that for some applications, they might benefit from having larger, high-performance storage. So, more than the 4, 8 terabytes of compute drive, so something similar to HDD, but something that would be very high performant, might be able to serve data-oriented workloads. And so we and the vendors were really working at, kind of lackadaisically, working at building higher capacity drives. And frankly, it was a tough sell because most hyperscale customers would say, it's really not worth the performance premium, the pricing premium to buy enterprise SSDs instead of an application to be served by HDD. That was the state of the world three to three and half years ago.
When the AI data center, started to get built out, essentially that world got replicated. So you had nearline HDDs, you had compute drives being sold into the GPU sockets, some ratio of compute drives to GPU. But at that point, something funny happened, which is what the AI providers realize is that even though at the compute was very performance-oriented, even pre-compute, so even in the data side of the stack, they were doing things like vectorization and embedding, and all this work that you have to do to take data and turn it into something that you can feed into your AI engine - and that was very performance intensive. And very quickly became clear that the nearline conventional HDD infrastructure was insufficient for that application.

So that set off this high-capacity Enterprise SSD, gold rush. Where, people like, VAST, most notably in the independent space, as well as the hyperscalers themselves, started to build higher, pure storage, obviously started to build higher capacity, higher performance, large capacity SSDs. And from a bit perspective, the numbers are eye-popping. So you get your 2, 4, 8 terabyte compute drive, all of a sudden it was 32 terabytes, 64TB, 128TB, 256TB, and also 256TB SSD, which is really what people are competing for right now. And so very quickly, from a bits perspective, AI started to consume just a ton of high-capacity SSD bits. Now, there is still plenty of room for HDD to be deployed in AI data centers. However, it's a gold rush, and two and a half, three years ago, at the price point of Flash, you might as well just deploy all Flash. And so, there was a jump ball, they were essentially deploying flash, you know, because there's no, no situation in which you wanted to be, dependent on it. And that has resulted in a much different mix of compute to high-cap enterprise to HDD, but it's really dominated by that high-capacity enterprise SSD. It's a little opaque in terms of exactly where the hyperscalers route their drives, but the big new business is probably 60-70% NAND, and the big new business is in those high-cap drives.
So that's sort of chapter 2 of the story. And then chapter 3 of the story, which we'll come back when we talk about TCO, was the conventional data center looked at those new, large, high-cap enterprise SSDs and said, oh, those are kind of interesting, maybe I should consider those in the non-AI data center. So we really ended up on both sides of the environment with a three-tier architecture: lower capacity, high-performance compute drives; higher capacity, lower performance enterprise NAND drives; and then nearline HDD.
MN: So there's basically been this new market created for NAND drives. Overall storage demand has increased dramatically, so benefiting both NAND and HDD, but in terms of relative growth of demand, it's been more beneficial for NAND.

RS: Yeah, and interesting enough, so HDD was already tightening. If you go back and carefully look at what was going on with the numbers, like, hard drive was already tightening in conventional data center, even before this kind of AI burst, and the hard drive recovered prior to NAND, out of the last down cycle. So hard drive has been on a, it's a little bit of a tortoise and hare. Hard drive's been on a slow, steady, upward tilt now, going on 2 to 3 years. I think the thing that happened in terms of the WD stock is people realized that it had some, longevity to it. Maybe a little skeptical that that was just the top of a, you know, yet another cycle, and so that's powered the hard drive. Now, the difference is that you really cannot run that AI data center without the high-cap enterprise SSDs, and without compute enterprise SSDs. So, if it's worth any amount of money in the world to stand up that AI data center, you can pay whatever you need to pay for those drives. And storage is still a relatively small part of your AI cost structure, so there's kind of no elasticity to speak of there.
MN: relatively price insensitive. So, you talked about, back when NAND prices were low, say in August, seems like it was more attractive, if there was, like, some borderline decisions, it was more attractive. Borderline meaning borderline between NAND and HDD, those were more likely to go to NAND flash, back in August, when the prices were about one quarter or one-fifth where they are today. The price gap may have been, in terms of dollars per gigabyte, maybe 4 or 5 times, whereas now it's about 20-25 times per gigabyte price difference. So given that huge increase in price, how is that changing the mix? Could it swing back a bit more to HDD? Sounds like both sides are growing, but it sounds like a little bit of mix went towards NAND. Could that come back towards HDD, given how NAND flash prices have gone up so much?
RS: Yeah, and in this construct, it's important to understand supply versus demand. In a capital-constrained world, in which you have disciplined providers. The supply is what the supply is, and therefore the mix is what the mix is, because that's the number of HDDs and flash drives we're producing. So the question is, does the demand curve change? Does the demand mix change? And for sure, the demand mix changes, I think, pretty significantly, and on both sides of that equation that we talked about.
So, starting with the conventional data center, when the ratio was 4 to 5X, the hyperscalers started looking at their the price performance, the TCO of NAND relative to HDD. And some of the hyperscalers, not all of them, would say that if the pricing converged at 1X, they would move to NAND. But some said that, actually, at a price difference of 3X, the TCO effects would swing to NAND's benefit. And that's primarily driven by two separate factors. The first is, power. And you, you're scurrying around the data center looking for more power to feed those GPUs, and it's much more power efficient, and power becomes a big driver. And the second is actually space. So that 128 terabyte drive I talked about, is in the device the size of this phone. So you're thinking about moving from, effectively, a rack of hard drives to a single SSD. And if you are, a very large hyperscaler with hundreds of data centers, and maybe 20-30% of that is all hard drives, being able to recapture all that space is an incredible value prop. And then finally, what they realized is that while the hard drive vendors were doing a good job at increasing capacities, they weren't increasing performance at the same rate that they were increasing capacity.
And so some workloads started, not like AI, where it's grossly malperforming, but some workloads started to push against that, and there's nothing a hyperscaler software application person likes less than to be held up by their storage infrastructure team. So the storage teams were thinking about that. Basically what they did, they came to people like us and said, look, if you could get this under 3X, we will start buying Flash instead of HDD.

And if you think about kind of a curve between 1X and 3X, my belief is, between probably 1.5x and 3X would be the transition zone, where most of the market would move at 1.5, and the initial markets would move at 3X.
MN: That's on a dollar per terabyte basis.

RS: Yeah, and that was all anticipated. So this didn't actually happen. Obviously, instead of going from 5X to 3X, it went from 5X to 15x. And so those efforts kind of stopped in their tracks. I think there's another hidden issue here, though, which is on the AI side, like I said, it's a gold rush. In a gold rush, you rush. That's the rush part, and you can be sloppy. And the way the builders were sloppy is by deploying lots of high-cap enterprise SSD, because that made it super easy. All of a sudden, that's very expensive, and you can't even get it. And so now you start to think about, well, maybe I should go back to a three-tier architecture, think more efficiently. So I would expect to see some swing of the demand curve back to hard drive in AI data centers. It'll take a little while, because it's an architectural change. But it's somewhat inevitable.
MN: So potentially a bit of a swing back towards HDD. I mean, both of them are supply-constrained, it seems, so that limits how much it can swing by the way, but it did seem to swing a bit towards NAND last year, and it seems you're saying it could potentially swing a little bit more towards HDD, if there's enough supply there.
RS: Correct. It'll moderate a bit.

MN: Right, okay. And then, actually, that touches on my next question, which was around total cost of ownership. So it sounds like I mean, comparing NAND versus HDD, lots of clients ask, you know, where is that break-even on a TCO basis? And you think it's around 2 to 3X dollars per gigabyte between NAND and HDD?

RS: Yeah, and it's not a single number for the industry, so each hyperscaler has quite different architectures. So, for example, Google is quite well known for having a very sophisticated, multi-tier adaptive architecture, essentially, which is HDD-centric.So

it's mostly HDD, and then they automatically move workloads that require high performance to Flash. And they're very clever about it. If they have a little bit of data sitting on Flash that's not being used, they'll move it to HDD. If they have a little hotspot on the HDD, they'll move it back to Flash. They have a very sophisticated system to kind of extract the most out of their storage. So Google, as a result, they're the largest consumer of hard drives. And they've been the least interested, I'd say, in this transition. Obviously, they're heavily invested in their architecture. So I think they're probably more on the 1.5x side, which is important from an industry perspective. That's a lot of demand sitting in a more extreme position.
If you took someplace, like Meta, pretty different story. They had a more conventional storage architecture, much more focused on just getting their, you know, application performance and latest features to the users, and willing to do whatever they need on infrastructure to accomplish that. So, more leaning forward with respect to a TCO kind of economics. So, people in very different, very different positions.
The other thing that you'll see happen is that there are software levers to reduce storage demand, and so I guarantee you those hyperscalers are thinking really hard about, what can I do to better manage my storage, be more efficient, better think about tiering. You've got big teams of people.
MN: Does that include, compression technologies, or can you talk a little bit about that? Like, what potential is there for hyperscalers to reduce storage demand? How could they potentially do that?
RS: Yeah, deduplication has been a standard in enterprise for a long time. That would be an example technology you could deploy, for sure. In general, in boom times, you're sloppy about how you manage your storage. And when things get tight or expensive, you start to think harder about it. And so there's always some ability to more efficiently use storage and be smarter about what you do.

MN: Okay, so I want to change another topic, which is around contracts, and long-term agreements. We heard from SanDisk, basically your ex-company on Thursday, after the market closed, that they've entered, I think it was 5 NBMs, they call it, which are essentially long-term agreements, ranging from 3 to 5 years. They reported approximately $42 billion of purchase obligations, and $11 billion of financial guarantees as part of that. So I just wanted to talk to you about, how have you thought about, or how's the industry thought about long-term agreements in the past? How have things worked in the past? And what is your take from these updates? One from Sandisk, but we're also hearing from other companies, such as Micron and Samsung have also talked about, longer-term agreements, not just in NAND flash, but also in DRAM as well.

RS: Right, and the same phenomena is happening in hard drive, of course. The hard drive started, it predated the flash run-up. So, historically, this has been an extremely, extremely, purchaser-friendly world. So you had long-term agreements, we all talked about long-term agreements, but a long-term agreement was a very one-sided contract, which said you, supplier, would allocate some capacity. I, the customer, give you a price at which I'll buy that capacity. But if I don't need that capacity from you, I'm not gonna take it.
MN: One-sided, long-term agreements.

RS: Yeah, now, if I need it, and you don't provide it, I'm gonna be very upset, and I'm gonna try to extract it from you, right? So I'm gonna try to enforce it. So, that had two implications. One, it was very unfavorable. Two is there's no love lost between these negotiating parties, between the industry and the customer. Now, in certain places of the market, there was functional LTAs that worked, so the gaming industry, for example, used one-year fixed price, fixed quantity contracts, and those kind of chunked along. Does that fit the gaming console marketplace?

And in general, the client, hard drive consumers, or laptops and so on, they were the least predatory of the buyers. I would say that the hyperscalers were on the more predatory end, and then the mobile providers were very much, just, ruthless economic value-seeking. So you have this very complex environment, very difficult to do any sort of capital planning, very difficult to do allocation shifting to LTA is incredibly important, because that's what gives you confidence to actually make capital investments, such that you can, kind of grow the industry out of the current challenge. And we don't want the whole thing to start slowing down because of lack of components. So, the shift is on to move to these long-term agreements.

Now, with a long-term agreement, you'll typically have a capacity allocation, you're going to have a price point, you may have an equation or some, you know, governors around that pricing over some duration. And that will have some penalty associated with it, should you not take that product up to and including full take or pay. And those contracts, of course, are enforceable and well understood in the industry, and, Broadcom and has been using those for a long time. The only challenge you face here is that anything's negotiable. And so, in a downturn environment the power shifts back to the customer. So I would expect if the market were to tighten, it won't be as bad as the old - don't take, don't pay agreement. But if the market were to soften, there'll be negotiated outcomes for all these things, where you'll spread it over a longer period of time and arious ways to sort of blunt it. But, but it's very encouraging for the industry as a whole.
MN: So you're saying, basically, before, these long-term agreements were just only really commitments on the supply side, with

very little commitment on the customer side, at least NAND flash and memory, whereas hard disk drive had had more, kind of, longer-term agreements with purchase orders already.
RS: Right.

MN: For NAND flash, you didn't have that, and so now you're starting to get actual two-way long-term agreements, where there are commitments on the customer side to buy a certain amount of product at some kind of price. So that's a meaningful change, but in terms of how enforceable that is. You're saying that it is enforceable, there are legal terms in there to enforce it, however, if the market deteriorates significantly, then they may come to some kind of resolution to spread it out. So it may not be completely 100% enforced, if market.
deteriorates rapidly, is that what you're saying?
RS: Yeah, correct. If market deteriorates rapidly, I have to think about where I'm going to ship my bits for the next 3 to 5 years. And so I, as the supplier, may want to give up a little bit of that excess profit in order to re-secure my capacity going forward. So there's always an eye on what is the NPV of the forward transaction, and how do I balance the profit-taking on the current transaction versus that.
MN: I mean, for example, if you look to these numbers, Sandisk reported 42 billion purchase obligations, of which $11 billion is financial guarantee, so it's just over a quarter of the budget's obligations are guaranteed, financially. So presumably, if the price were to fall only 10-20% or so, then those are fully enforced. But presumably, the question would be if the price fell rapidly, like 50%, is the right way to think about it, that the hyperscaler is more motivated to tear up the contract, pay the $11 billion fine, and then buy at 50% discount. So, effectively.
RS: Correct.

MN: they'll just be better off doing that, is that the right way to think about it?

RS: That's right, you would think about it. And practice, because I have to keep buying. Tearing up means I just renegotiate for a longer term, and you know, I'm a baseball player on the end of my contract, and I'm making 20 million a year, and I want to play 3 more years, so I sign a new deal that's a lower deal, but I get more years out of it, type of thing.
MN: Yeah, it's still meaningful benefit. It reduces the ASP decline by 25%.

RS: Very, very significant, yeah.

MN: Right, so if you're saying this, and if the market deteriorated rapidly down 50%, then their effective, and just using these rough numbers, their effective price decline would actually be 25%. Because they've already got 25%. There's no other details I don't know about, which is $11 billion guarantees of the $42 billion purchase obligations, that's 25%.

RS: Yeah, I can tell you David Goeckeler has been waiting a very long time to write that contract. And I'm highly confident he wrote it in an extremely favorable fashion for SanDisk.
MN: That's good to know.

RS: He's looking after your shareholders.

MN: I have one more question of my own, but let me just look, because I have a bunch of questions from the audience. How will the NAND and HDD mix be affected as the next leg of compute shifts from cloud to edge?

RS: I'd say that anything that shifts compute to edge is very favorable for NAND. NAND has better TCO on the edge, edges are space-constrained, edge tends to be more performance-oriented, so, edge compute demand is nothing but beneficial for NAND. And in general, even though the AI Data center is what's driving the economics of these high-cap enterprise SSD drives, everybody benefits. So, that technology all of a sudden becomes a super interesting, you know, piece of technology available to all market participants.

MN: And then another question here, although HDD prices have risen, the pace has been far more benign than in NAND. What do you think has held HDD vendors back from implementing steeper ASP increases, like what we've seen from DRAM and NAND makers?

RS: Yeah, I think the phenomena driving HDD versus NAND has been fundamentally different. I would call the HDD phenomenon a more normal situation, where there's more demand than there is supply, vendors are raising price, they're trying to find a market balance. But there wasn't a huge dislocation. In the case of HDD, there is more ability to allocate existing HDD reserves, essentially, against smart workloads and applications. In NAND, very different, you cannot deploy that AI data center without the high-capacity NAND, so you're just stuck. And you have hundreds of billions of dollars of capital that could potentially be

orphaned if you don't get that specific NAND.

The other thing that's happening in NAND is that … let me back up. We haven't talked about the nodal transitions. So, NAND, there are generations of NAND. They're named slightly different, but you can think of them - the current generations that are in play are generations 5, 6, 7, 8, soon to be 9. And not all generations can serve all applications. So, and particularly both the highest performance compute drives, as well as the high-capacity, need the latest NAND node. So what you're seeing here is not just demand on the NAND market, you're seeing demand on a very small part of the NAND market, which is the capacity available on the latest node, and there's such a bidding war for that capacity, which might only be 30% or 35% of the total capacity, because the NAND vendors have been under huge financial pressure, so they haven't put in the normal amount of capital through the system that they would have put to get the entire NAND estate to that latest node. So you had the combination of an AI use case that really needed the capacity, and then this constraint on the available capacity, and that's resulted in this peak.

MN: So NAND is very capex and asset intensive. And NAND fabs are almost always run at 100% utilization versus HDD which is not always run at 100%, although HDDs are running at pretty much full utilization right now. So, I think that's another thing that's different. How about QLC? Sandisk talked about their QLC Stargate product. They're qualifying, gonna be released fairly soon. Do you see an opportunity for QLC?

RS: Well, virtually all of the high-capacity AI drives are QLC drives. That's the only way you can get to a 128TB or 256TB drive. QLC was a very hard technology. Essentially QLC requires 4 bits per cell. Which means, in a single little bucket, you're essentially storing electrons in a bucket. And you have to store one of 16 levels in that bucket with QLC, and so that is a very sensitive thing, and it's hard to make that thing go fast, and it's hard to make it reliable, and so on. So there's differentiation between vendors and how well they're delivering against QLC. I think that Sandisk and Kioxia together have done quite well. Samsung has had struggles. You know, Micron has had an early lead, but then some question. So the different vendors are performing at different rates. And again, this is all on the latest node. So, QLC, for sure, will be consumed by these high-cap enterprise workloads, and when the NAND vendors talk about achieving 20% or achieving 30% growth year-over-year, the expansion due to QLC is built into that number. So the actual growth in like-for-like non-QLC is actually lower, right? That's sort of behind the scenes. QLC is one of the ways that they're getting the growth that they're achieving out of their capital investments.

MN: Great, another question here, do you think Jensen Huang's vision of NAND for KV Cache will realize? That's, I believe, talking about the Vera Rubin platform, where he talked about a new NAND tray, like storage trays. There's a tray full of NAND, basically, for KV Cache. Do you think that, Jensen Huang, that vision will be realized and create even larger demand for NAND soon, or is KV Cache still just going to be more of an HBM DRAM story?

RS: I don't have a good insight. Maybe I can talk about the latter part of that. And that I haven't spent a lot of time looking at the market forces behind actually getting the KV Cache to work. In general, I am bullish that there are more interesting demands for performance-oriented and capacity-oriented NAND in the AI pipeline. If you look at people like VAST, they use NAND really, really inefficiently in a high-performance cache tier between the big high-cap and the AI system. So there are people that have figured out that, if you could deliver high-performance NAND, there's interesting things you can do with it. And there's lots of interesting things you could do with it. You can build KV caches, you can build caches for high-cap drives, and then you could build, of course, HBF, which I think is on the list to talk about here, but the notion of being able to use NAND instead of DRAM for the actual on-GPU semiconductors.

MN: HBF, yeah. Let's come back a little bit to HBF a little bit later. You mentioned Pure Storage at the beginning of the call. Can you talk about what are the prospects for Pure Storage's direct flash module technology?

RS: So, Pure Storage is a very interesting company. They're my colleagues from Veritas Software that founded the company, so I know them quite well. What Pure Storage's basic technical trick was, they ignored the drive form factor. So every other market participant has only been building enterprise SSDs around a very specific form factor, which harkens all the way back to the hard drive era, and they've all fit in these form factors, which of course is the base of open computing, and you can plug these in anywhere. Pure Storage said that we think there's substantial productivity to be gained by ignoring that, and really architecting around the best possible platform and layout for NAND in a high-capacity fashion, and their direct flash module. And of course, they're very loudly evangelizing that. One of the things they did is they shifted from that as a motion into traditional enterprises to shifting to that as a motion selling into the hyperscalers. And they've gotten quite a bit of momentum into the hyperscaler community, essentially serving, and effectively having hyperscalers kind of outsourcing some of their storage engineering capability to Pure. Where Pure then ships the modules and the software, Hyperscaler will buy the NAND directly from the NAND vendor, assembles the whole thing, and consumes it. So, in general, that architecture is a good architecture. You know, there's

always debate between that versus the volume benefits of the more traditional enterprise SSDs, but it's worked well for Pure Storage, for sure.

MN: Some more questions from the audience. Despite a strong demand environment, why have HDD vendors been reluctant to add capacity? With capex intensity nowhere close to NAND, supply expansions should theoretically be more straightforward. Is that a correct assumption or not?

RS: Yeah, so there's only two and a half HDD vendors, right? So you have WDC, you have Seagate, and then you have Toshiba, which is sort of constantly under some cloud of dysfunction and doesn't quite have the wherewithal of the other two guys. So, you know, they should be able to manage this thing as an oligopoly. And the first rule of oligopoly is don't add capacity unless you're making the margins you want to make. And it's just hard enough to add capacity, that there's enough friction to allow the oligopoly to work. You know, the HDDs are an extraordinarily complicated device, right? So this is basic science, material science, gases, you know, all of the work that goes in, all the innovation around HAMR. I mean, these are very sophisticated devices, there are very complicated supply chains, lots of components, so it's just hard enough, even though you're not writing $100 million checks to LAM, right? It is just hard enough that there's sort of friction in adding capacity, and they've been through a 10-year oversupply era, and don't intend to go back to that. So, I think the way to think about the outcome as an investor is, you know, you would expect these guys to actually operate their oligopoly correctly, and, you know, deliver returns for a long time to investors, and not worry too much about how much capacity they're delivering to customers.

MN: Yeah, yeah, it's funny you mention that, because I think a lot of investors, people just think HDD is just very low-tech compared to solid-state drives, but there's definitely a lot of technology that goes in there, and there are very, very small particles that they're using sputtering equipment to sputter on top of the disk, so...

RS: The heads and the mechanics, and there were more PhDs on the HDD side of Western Digital than there were on the NAND side.

MN: Is that right?

RS: Yeah, absolutely.

MN: That's interesting. That's a good stat. Another question from the audience, is there still a risk for HDDs to be replaced by SSDs in AI data center deployments?

RS: Yeah, so this is the super interesting question, which is, 3 years ago, we thought, oh wow, look, you know, Flash is just gonna take out HDD. Now we're sitting in a situation where that seems inconceivable. The question is, let's project forward. You know, if I'm holding the HDD stocks in 2030, 2032, what does the future hold at that point? And I think that it's a nuanced story. So, first of all, from a cost perspective, NAND costs are going to get to the point where the 3X, you know, structural cost difference between HDD and NAND is broken. Where NAND will be within 3X of the cost of HDD. So, if they're both priced at similar gross margins, you know, that would be a point where you would start to see this mix shift from HDD into Flash.

But there's a couple of things that make that less likely to happen. So it takes, of course, massive amounts of capital in order to get your NAND cost structure to that point. And remember, the HDD business, from a Bit consumption perspective, is still much, much larger than the NAND business. So you have to build a lot of capital, and you have to put in enough capital to provide a meaningful dent against that HDD business. And it takes about - remember I talked about nodes of NAND, it takes about $50 billion for the industry to move from node N to node N + 1. And you get about 50% more bits. Now, actually to start replacing HDD, you'd need to do that 2 or 3 times, move from 7th, 8th, 9th, 10th generation, so think about maybe $150 billion of capital. And that's ignoring the capital you need to serve the AI market. This is just the capital you would need to go after HDD.

So you need this immense amount of capital, and the only way you can get monetized for that capital is selling your product at 30% gross margin. Right? And from an investor perspective, you know, I'd rather sell - I'd rather own a 50% gross margin or 80% gross margin, you know, AI storage company than a 29% gross margin NAND company that's got a volume story, right? So I think what'll happen is there's just sort of natural resistance in the marketplace to actually doing the takeout.

MN: Well, yeah, I mean, if you look at back when the prices were 4 to 5X, and that's still not enough for the TCO crossover. You're talking about 2 to 3X for TCO crossover, but even back in August, when the price difference was 5X, maybe 4x if you're using QLC, it was still, I mean, the NAND makers were making, like, 20% gross margin, so it's not...

RS: Right, exactly.

MN: So no one would add capacity at that margin. The ROIC, return on capital, is just not attractive at all, so no capacity gets added, so they would not take any share at all. In fact, they'd lose share to HDD at that margin, which is maybe what's happening right now, because they didn't invest at that margin level, which is partly why NAND is so short right now. And then, I think if you also look, cost declines. In the end, price has to follow cost, right? And cost declines in NAND are slowing. Whereas in HDD, HAMR cost declines are actually accelerating compared to previous PMR technology, so now, although historically NAND had been declining costs much, much faster than the HDD, now they're pretty comparable, and in fact, HAMR might actually be slightly faster cost decline than 3D NAND now.

RS: Yeah, NAND moved from 2D scaling, which was good old-fashioned Moore's Law semiconductor scaling, to just building more layers. And it's like anything, you know, building a 100-story building is actually twice the cost of building a 50-story building. Maybe it's more, because you have to have thicker steel, and have to do more engineering, and so on, so you're really seeing diminishing returns on the ability of the NAND vendors to drive that cost reduction. I think we have, like, maybe one more squeeze of the lemon there before, you know, they're gonna have to - you know, move to a new generation of exotic ways to try to get that cost reduction. Meanwhile, HDD was very, kind of, a modest, you know, single-digit type cost reductions, and then HAMR essentially gives you a little kick in the butt, and so you're seeing maybe converged cost reduction curves. So yeah, I think all that points to the real threat being quite far out to the right.

MN: Great, and another question from the audience. When do you think NAND manufacturers will finally commit to meaningful capex spending?

RS: Well, so there's a lot that has to happen to accomplish that. Essentially, you have to get confidence in the durability of the demand. Because you would have to invest forever, and every single one of these NAND vendors bears the scars of the last few years. Like, NAND has been a terrible, terrible business for 5, 7, 9 years. . So, there's a lot of caution on the NAND side, a lot of understanding that it's not imperative that NAND vendors add capacity. It's just not. Just like it wasn't imperative that buyers paid more for NAND back in the day, right? So, pragmatically, the NAND industry has tried to hit a 20-30% type growth rate. And, in order to continue to serve the AI market, they need to continue to migrate bits from these lower nodes to more advanced nodes, so I would expect that number to be kind of a target figure that's in the back - from a NAND industry perspective, that'll all be in nodal migration, and mostly that'll be to get to nodes that can better serve the high-cap and high-performance AI demand. Of course, LAM can only make so much gear, right? And so you can have extended lead times in terms of capital equipment. It's about a year, even in normal lead times, about a year to get a piece of equipment, and then another couple months to get it working. So you're talking about a 15-month, kind of, planning horizon. So you can kind of think that… prices had to go up. They had to go up and stay up for a few quarters, so we get confident that this is going to be more enduring, and then we need 5 quarters, and then capacity can come online.

MN: So, they need to make a bit more money, a bit more confidence this is sustainable before they go out and add a bunch of capex.

RS: Right.

MN: Another question, I'm not sure if you can talk to this, it's fine if you want to skip it, but this is another one from the audience, asking if you could talk about the third-party financial instruments that Sandisk mentioned to make long-term agreements enforceable. Does it make them any different? This is something that was just mentioned by Sandisk just very recently, so I'm not sure if you're aware of it. Is there anything there that you are aware of that you can talk about?

RS: That's too recent for me to comment.

MN: Okay, no worries. Another question here, does selling in data centers make NAND or HDD products less commoditized than before? Versus DRAM, or does AI just change the demand? I mean, is there anything regarding commoditization here that's happening?

RS: So if you stand back and you say, you know, what does commoditization mean? There's really sort of two things going on there. One is that the products between the different vendors are similar enough that they can be substitutes for each other. And the fact that it's a capital-intensive market means it's a true market. So this is for, like, we all have econ undergrad degrees, we all saw those curves. This is a supply-demand, economically driven market. By and large, most of the DRAM market is like that as well. Now, from time to time, you deliver differentiated solutions. That is what has happened with HBM. Where both technically, the design of the solution, or from a capacity constraint, because there's a limited amount of advanced packaging gear and so

on, you end up with a situation where you have pockets of very unique premium priceable technology. So we should think about this as this large swath of bits with these pockets of very high-value components. I think what's happened here with AI is the number of those pockets of high-value things has gone up. Because you're seeing more innovation. More innovation allows for more differentiation, more technical demands, all that leads to a less commoditized world, versus the old world of every data center looks the same, every device in every data center looks the same, everyone's just chugging along, kind of building the same stuff. So ultimately, this is both a supply-demand story and a differentiation story coming together.

MN: Right. So actually, since you touched on HBM, I'd like to just talk a bit about this high bandwidth flash, or HBF. Can you talk about what it is, how is it different than conventional NAND flash, or HBM, which is DRAM-based? And just first of all, if you can talk about what it is, and then we could talk a little bit about, do you think there's much promise to this?

RS: So HBF is a form of NAND technology, which is an analog of HBM. So it uses all the same techniques, uses stacking, uses large VIA arrays, uses chip-to-chip packaging, and so on. So, think of a direct drop-in replacement for HBM. You'll have this big square thing, the GPUs in the middle, there'll be stacks of memory on the outside. Now, it takes advantage of a very interesting trick. Which is, a lot of AI and particularly AI inference workload, is you're streaming large sets of coefficients into the model. So I just need to take this big bank of numbers that's in my memory, and I need to shove it in the GPU, I need to turn the crank once, then I need to go get the next set of coefficients and shove that into the GPU. What you're not doing is you're not rewriting it in a conventional sense, like you would in a computer. And so this is fundamental for NAND, because NAND's actually a very fast technology, except it has two problems. Its dynamic read-write is slow. Right? And it has latency associated. But once you actually start streaming the bits, it's actually quite fast. So the idea with HBF is, first of all, we use the HBM trick. We give you a very wide bus, we'll stack these things up, but then we're going to give you this new kind of memory, which allows you to stream and load your GPU, but because it is NAND, it's much more dense, has a much different cost structure, and is very interesting. So, HBF, for sure, is a super interesting technology for AI. We're still in the innovation phase. So it still needs to be demonstrated that it can be delivered at the right power and performance and reliability and all those kinds of issues. But if the teams can deliver what they're claiming to deliver, it will be another one of these pockets of highly differentiated technology.

MN: So, is your view - I know you've been out of Sandisk for just over a year now, is your view that it's got a higher chance of success, or do you still think it's a bit too early to know?

RS: I think it's still a bit early. I mean, my view is it's very promising. And whether or not they hit the bullseye with HBM replacement, there could be applications like Jensen's KV Cache situation. So, you know, it's a dynamic world. There might be good news as well as bad news from here. So I think the idea that innovation is alive and well in NAND is true. And that, you know, investors can think of these upside opportunities, whether it be HBF or some sort of related set of technologies.

MN: Thanks very much, Rob. And one more question here from the audience. What is VAST Data's claim to fame? You mentioned VAST earlier on. Is it superior software orchestration for commodity multi-tier drives? Or can you talk about that?

RS: I think VAST Data's claim to fame is that they were the first people to really understand the nature of this AI workload. So they understood the specific needs of the AI data preprocessing layer, and they were able to build an architecture which was easily scalable for very large capacities, to serve that. Frankly, VAST used the same approach that - there's probably hundreds of startups that tried to do these distributed storage arrays. I don't quite know how VAST was the one that won, but they did it. And they used a bunch of tricks in terms of having multiple tiers, having a cache layer. They actually used the old Intel high-performance memory technology to do that caching. So just a really good job at executing against these high-capacity SSDs. So I think over time it commoditizes, but they did a really nice job.

MN: Yeah, we're running out of time, so I'm just gonna maybe get one or maybe two quick ones in. Prices are up sharply in NAND flash over the last several quarters. Where do you think prices go from here?

RS: I think what'll happen from here, first of all, we'll have a pause here, in that prices are getting to the point where you're going to have a suppression of demand. You know, we're just gonna stop shipping to consumer markets, client computing companies are gonna - so instead of shipping 1TB drives, they'll ship 256GB drives, you know, you don't need a terabyte of SSD in your phone, so you're seeing already some compression of demand as a result of the pricing. So that should tend to sort of moderate the pricing. As capacity comes on, I would expect to see pricing sort of return to a normal price performance curve, but I don't think we're headed for a precipitous fall in pricing. I think we're headed to a new normal, effectively, from this point going forward. And other than a full AI bubble collapse, I don't think there's much that's going to change that basic trajectory.

MN: Okay, Rob, I think we're just about out of time. There were a few other questions from the audience I didn't get to, but, you know, it'd be a good time to wrap up right now, and anyone, sorry if I didn't get to your question, feel free to reach out to me

directly, or your salesperson, and we'll try to get back to you with those questions. And Rob, thanks very much again for joining us today.

RS: Hey, Mark, it's great fun.

MN: Thanks, everyone. Have a great day.

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We value Sandisk at $1700 on 11x our 4-year through cycle (FY26-29) EPS. This implies 8.5x our FY27 EPS.

Western Digital Corp

We reiterate **WDC Outperform,** TP $590, on 21x our FY28 EPS. PE of 21x is inline with recent market multiple and arguably conservative given its 5 year EPS CAGR of 60% (FY25-30E).

Seagate Technology PLC

We value Seagate at 21x our FY28 EPS of $47.19, implying $1,000 per share. We believe Seagate's improving fundamentals, >60% 5year EPS CAGR, and HAMR leadership easily justifies a 21x P/E, and arguably much higher.

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SanDisk Corp

The biggest risks to the downside on Sandisk and to our price target are that: 1) Near-term numbers look high and face cyclical downside from NAND; 2) SNDK's disclosures and broader investor communications have been confusing, potentially dissuading more quality-focused investors; and 3) NAND weakness could extend beyond the current cycle and be more structural, in which case Sandisk's DCF value could be structurally lower and the impaired value of its assets may be materially below replacement cost.

Western Digital Corp

The biggest risks to the downside on WDC and to our price target are that: 1) The HDD market is heavily exposed to hyperscale cloud, and could be impacted by a cloud capex digestion or else incremental pressure from changes in hyperscaler buying patterns; 2) NAND could see better than expected technology improvement and take share from HDDs; and 3) WDC could face significant risks ahead with its HAMR technology transition which could provide a drag on gross margin and EPS.

Seagate Technology PLC

The biggest risks to the downside on Seagate and to our price target are that: The HDD market is heavily exposed to hyperscale cloud, and could be impacted by a cloud capex digestion or else incremental pressure from changes in hyperscaler buying patterns. 2) WDC could close the gap in HAMR more quickly than expected, shrinking the scope for market share gain and margin improvement. 3) NAND could see better than expected technology improvement and take share from HDDs.

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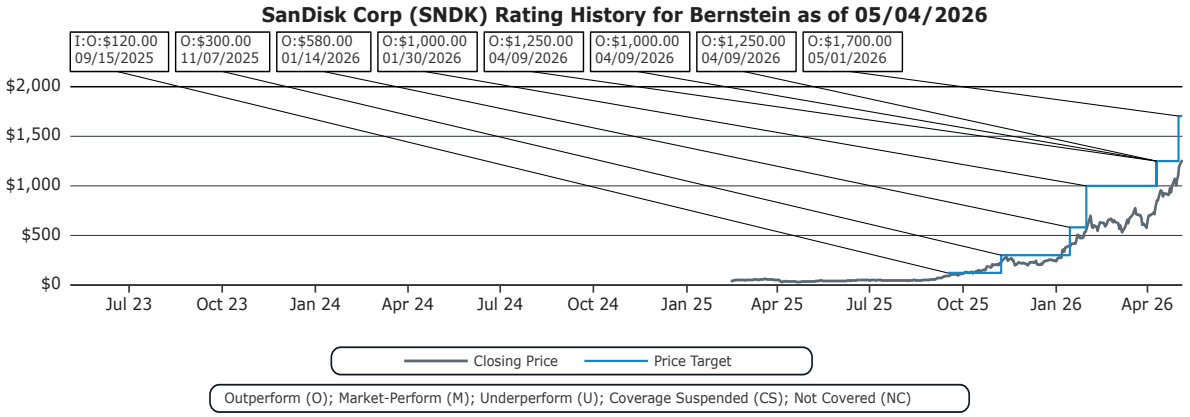

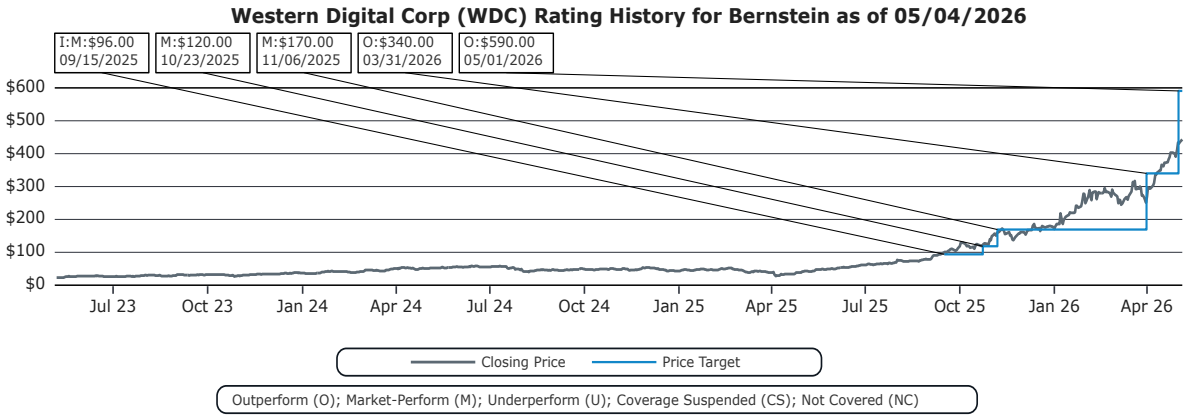

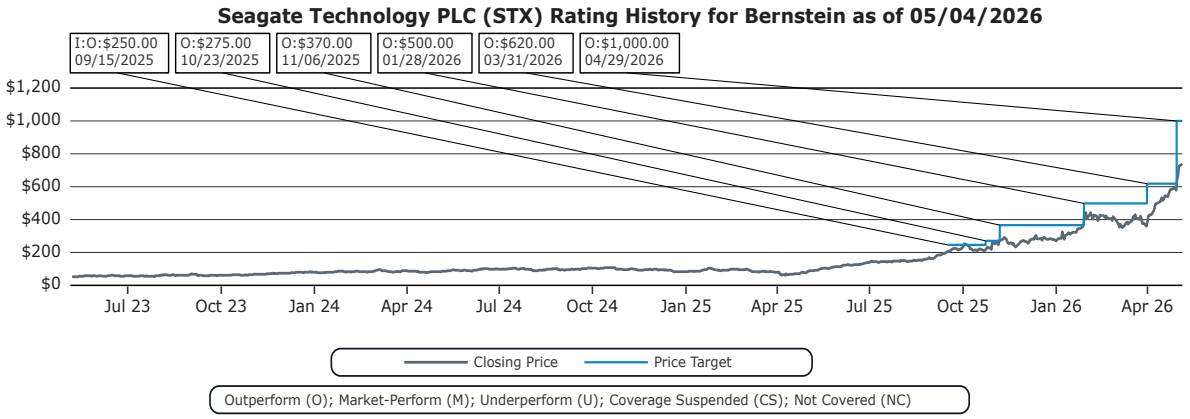

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