

Testing in the 3D NAND Zettabyte Era



LUCA FASOLI
Senior Vice President
Western Digital Corporation

Forward-looking Statements

Safe Harbor | Disclaimers

This presentation contains forward-looking statements within the meaning of federal securities laws, including statements regarding expectations for industry growth; NAND capacity developments; production and testing costs and cost reductions; testing strategies; bit growth and capital expenditure trends. These forward-looking statements are based on management's current expectations and are subject to risks and uncertainties that could cause actual results to differ materially from those expressed or implied in the forward-looking statements.

Key risks and uncertainties include volatility in global economic conditions; future responses to and effects of the COVID-19 pandemic or other similar global health crises; impact of business and market conditions; the outcome and impact of our ongoing strategic review, including with respect to customer and supplier relationships, regulatory and contractual restrictions, stock price volatility and the diversion of management's attention from ongoing business operations and opportunities; impact of competitive products and pricing; our development and introduction of products based on new technologies and expansion into new data storage markets; risks associated with cost saving initiatives, restructurings, acquisitions, divestitures, mergers, joint ventures and our strategic relationships; difficulties or delays in manufacturing or other supply chain disruptions; hiring and retention of key employees; our level of debt and other financial obligations; changes to our relationships with key customers; compromise, damage or interruption from cybersecurity incidents or other data system security risks; actions by competitors; risks associated with compliance with changing legal and regulatory requirements and the outcome of legal proceedings; and other risks and uncertainties listed in the company's filings with the Securities and Exchange Commission (the "SEC") and available on the SEC's website at www.sec.gov, including our Form 10-K filed with the SEC on August 25, 2022, to which your attention is directed. You should not place undue reliance on these forward-looking statements, which speak only as of the date hereof, and the company undertakes no obligation to update or revise these forward-looking statements to reflect new information or events, except as required by law.



Data storage
demand is
growing



Cost containment
is more important
than ever



Data integrity
is **essential**

Western Digital: Storing a breath of the World's Data



EMEA

54M Products Sold

146K Storefronts

CHINA

36M Products Sold

42K Storefronts

AMERICAS

41M Products Sold

92K Storefronts

APJ

52M Products Sold

29K Storefronts

INDIA

20M Products Sold

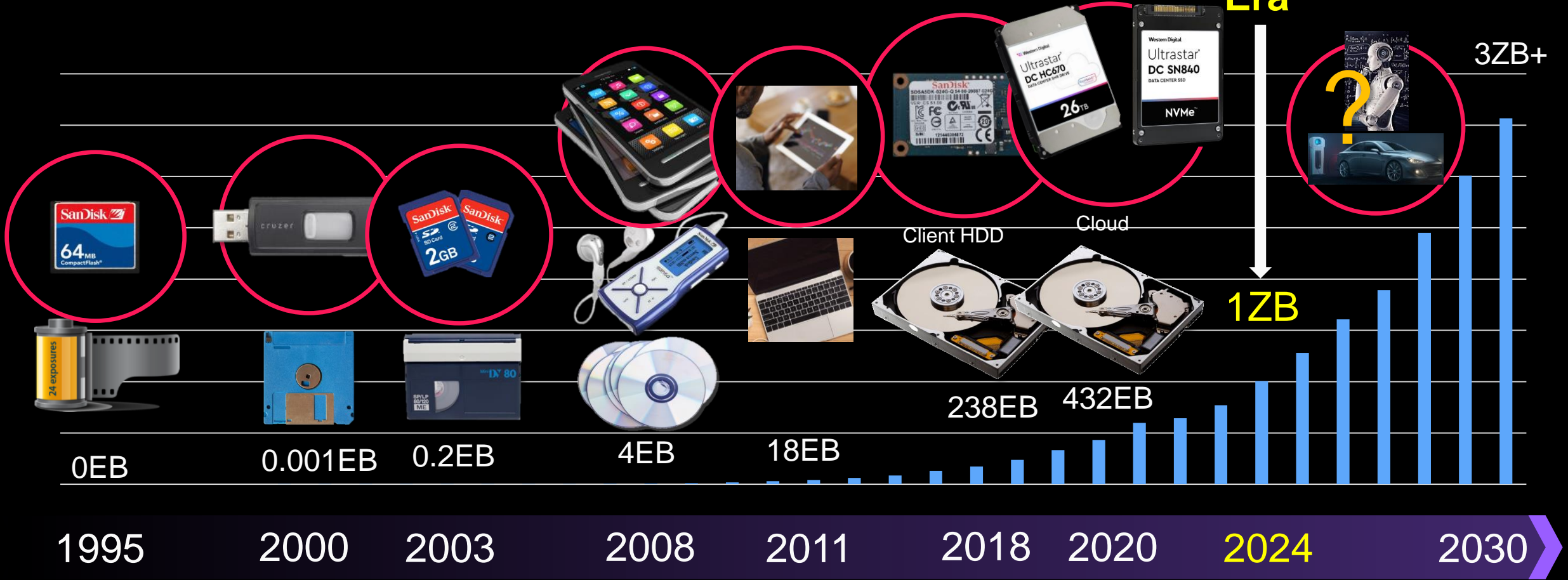
42K Storefronts

**WORLDWIDE
TOTAL**

202M
Products Sold

351K
Storefronts

Creative Disruption



*Estimates are averages from FI/IDC/Gartner/TF/Yole

Flash scaling has transformed industries

How big is a Zettabyte?



2.2B

heartbeats
in a **lifetime**



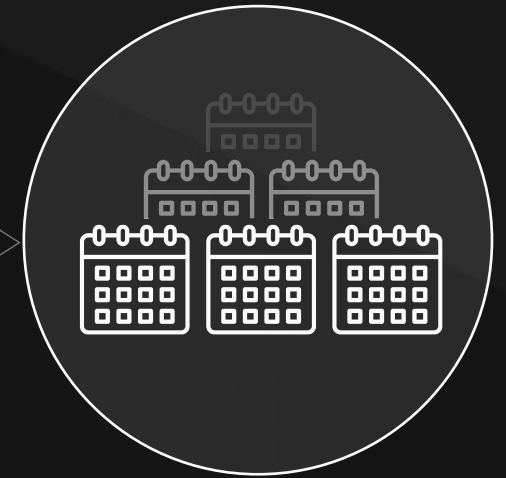
8.0B

people on
earth



57

Back-to-back generations
of hearts beating in
unison



3977

years later...

In **6000 A.D.**, we
will reach 1
Zetta-“beat”

3D NAND Scaling: Enabling the Zettabyte Era

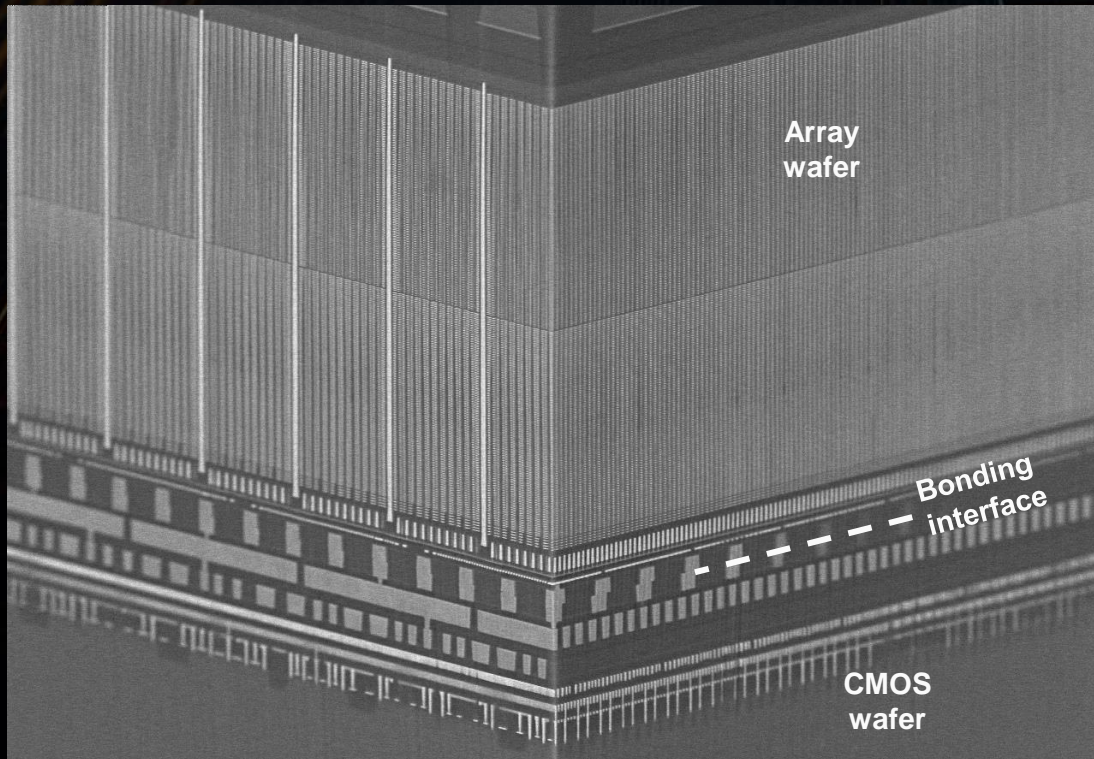


BiCS8: 8th Gen 218-layer NAND

Engineered for Datacenter Workloads

Circuit Bonded to Array (CBA)

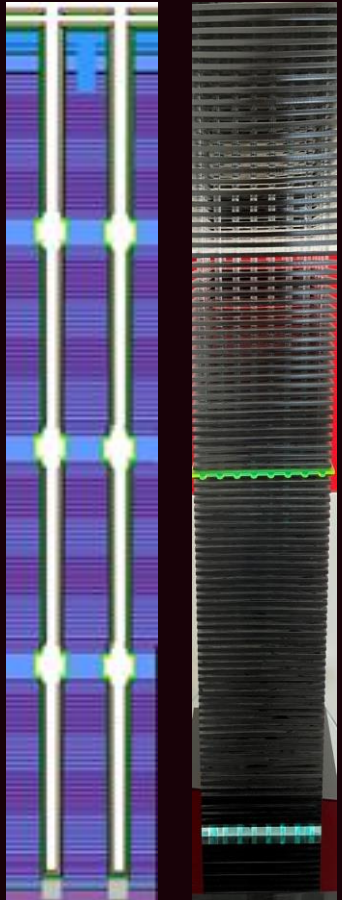
Scalable Technology with better specs



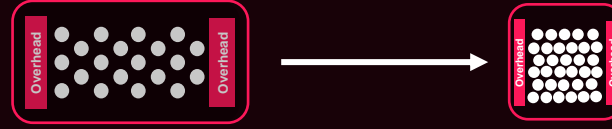
Metric	Improvements Over Prev. Gen
Memory Density	>50%
Layer Density	13%
Program Bandwidth	18%
Read Latency	16%
Transfer Speed	60%

The Five Vectors of 3D NAND Scaling

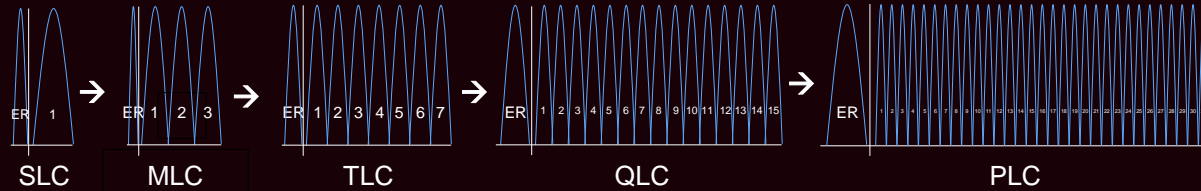
Vertical Scaling



Lateral Scaling



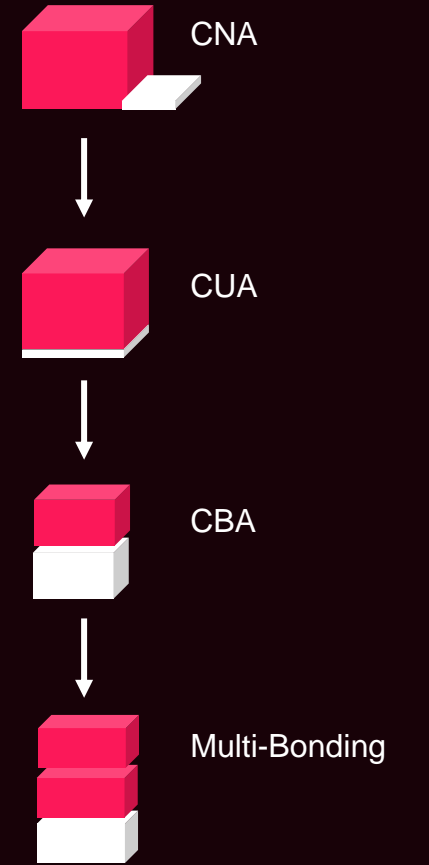
Logical Scaling



Test Cost



Architectural Scaling



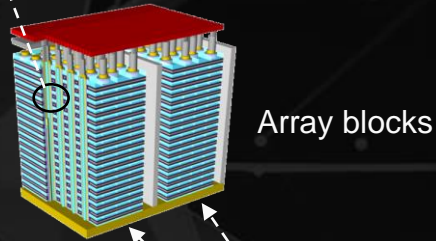
To Test or Not to Test...



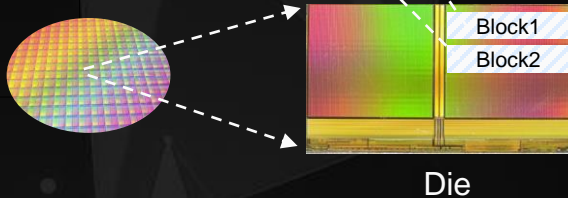
BIT



BLOCK

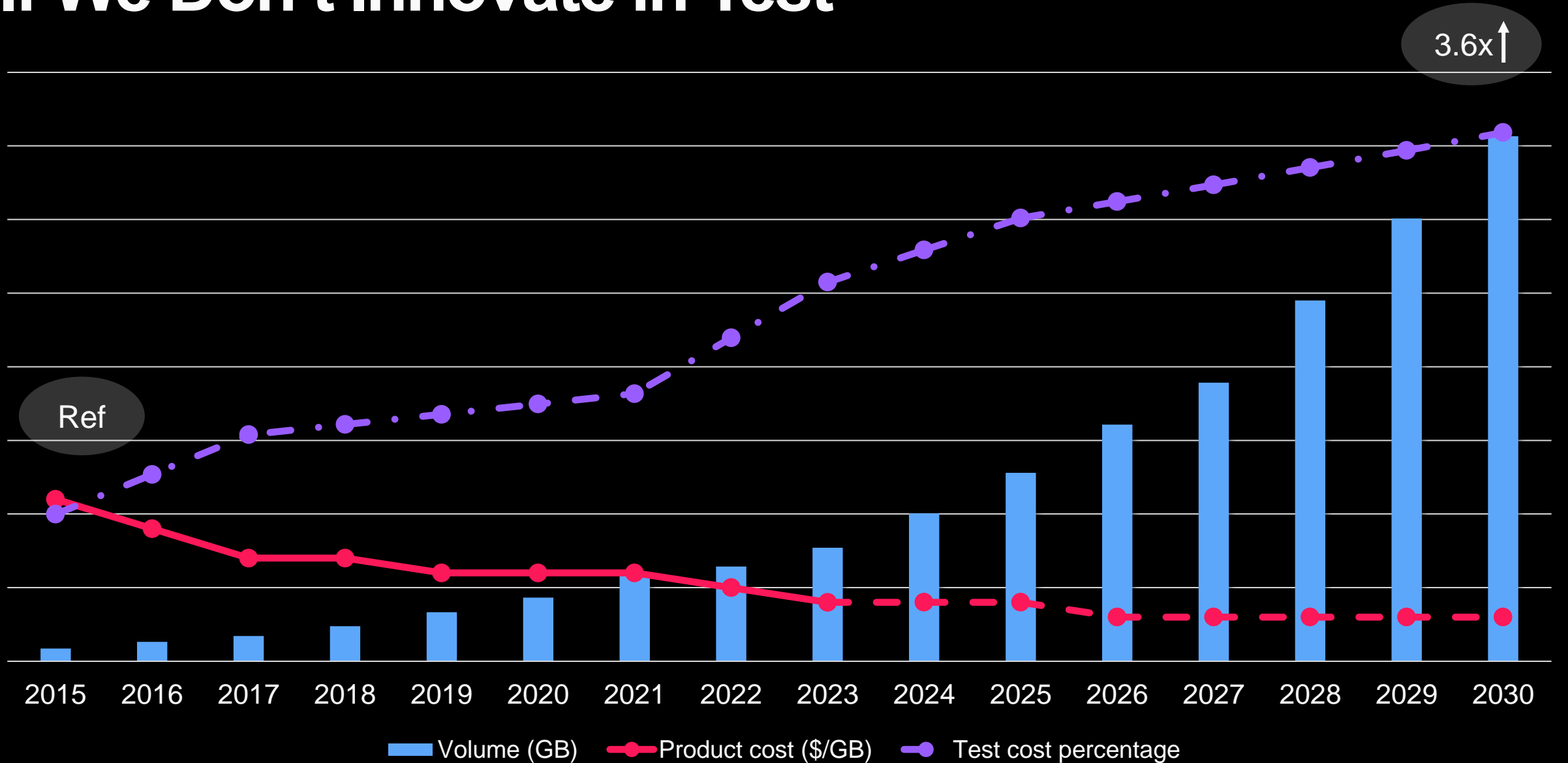


DIE

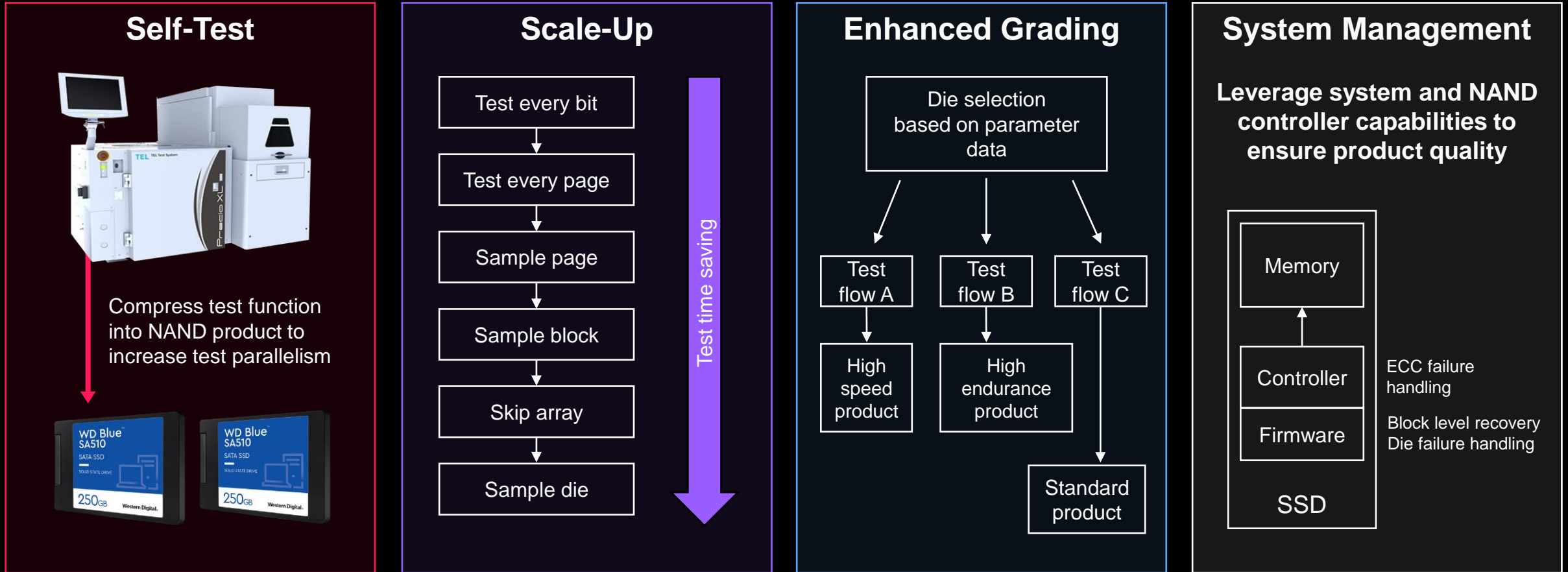


Impact on Customer Experience	Test Strategy
<p>Least impact due to in-field correction</p>	<p>No test or at package level</p>
<p>Moderate impact only if exceed system management capability threshold</p>	<p>Wafer or at package level</p>
<p>Catastrophic impact with the exception of product allowing any die failure</p>	<p>Wafer level</p>

If We Don't Innovate in Test

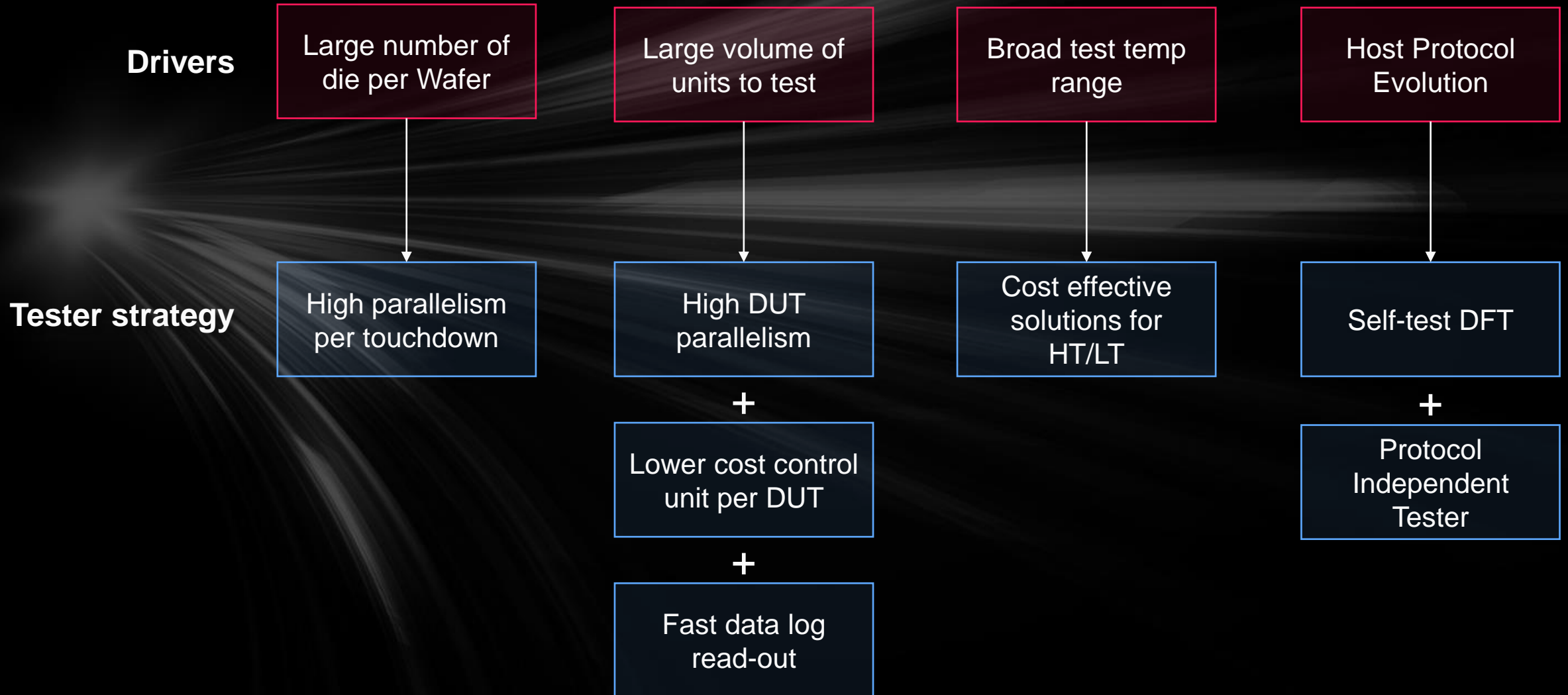


Unique Aspects of NAND Testing



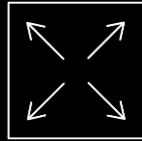
Achieve Test Cost Reduction and Meet Quality Assurance

Tester Strategy for Cost Reduction

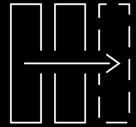


Tester Platform Strategy for Cost Reduction

Large volume of units to test

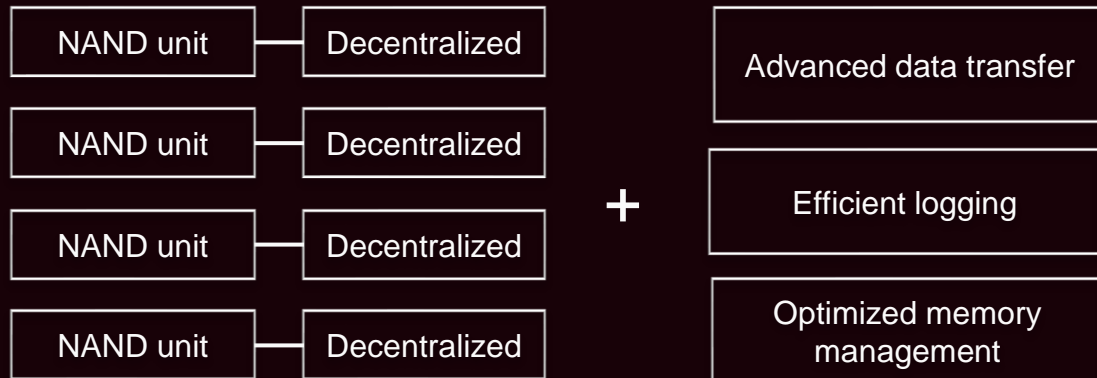


Host Protocol Evolution



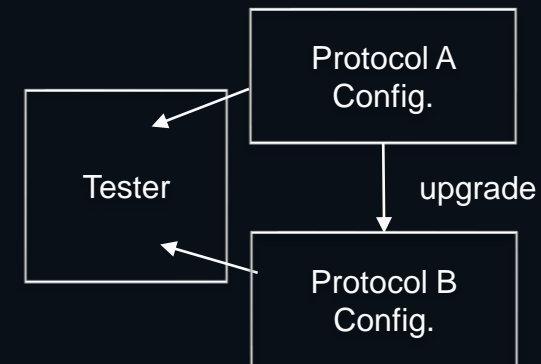
High parallelism, smart testing, lowest cost per DUT

- Lower cost control unit per DUT
- Fast data log read-out
- Long term reuse

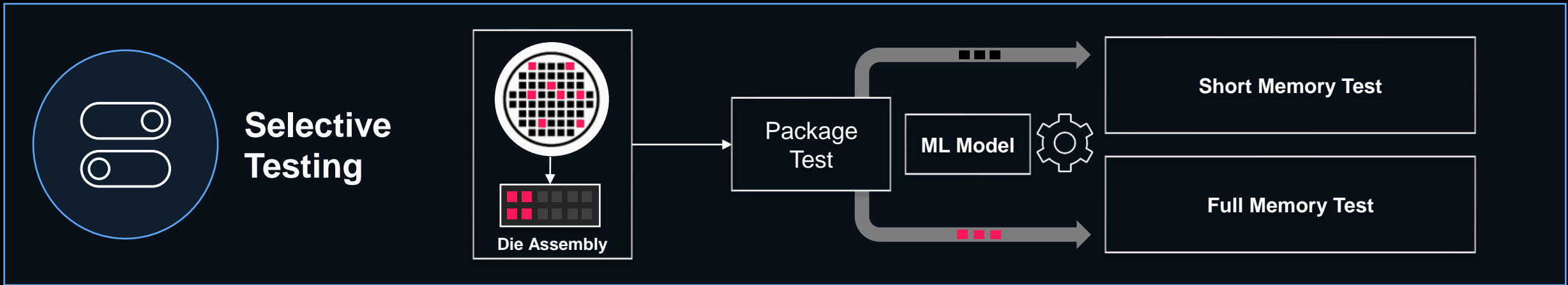
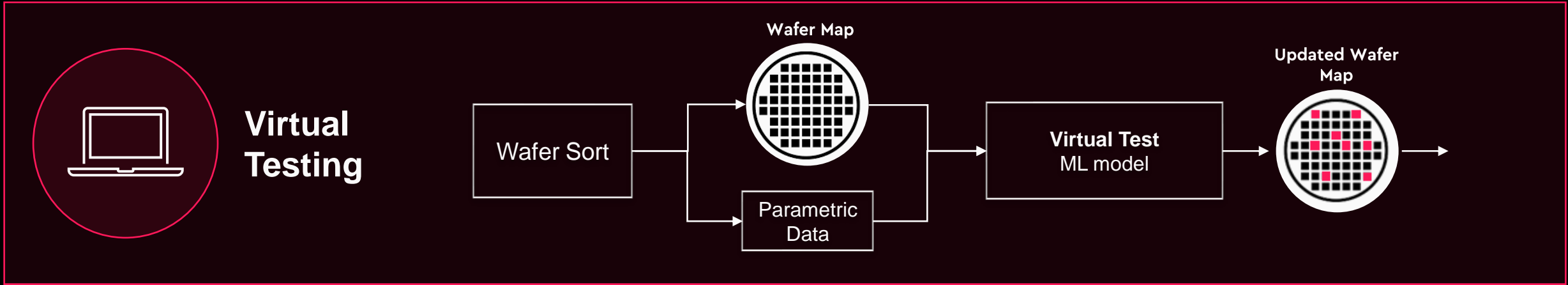


Platform that adapts to new protocol and delivers low-cost solution

- Allow upgrade to adapt new interface
- Pin electronics reuse and same footprint
- **Long-term** upgrade capability with lowest cost

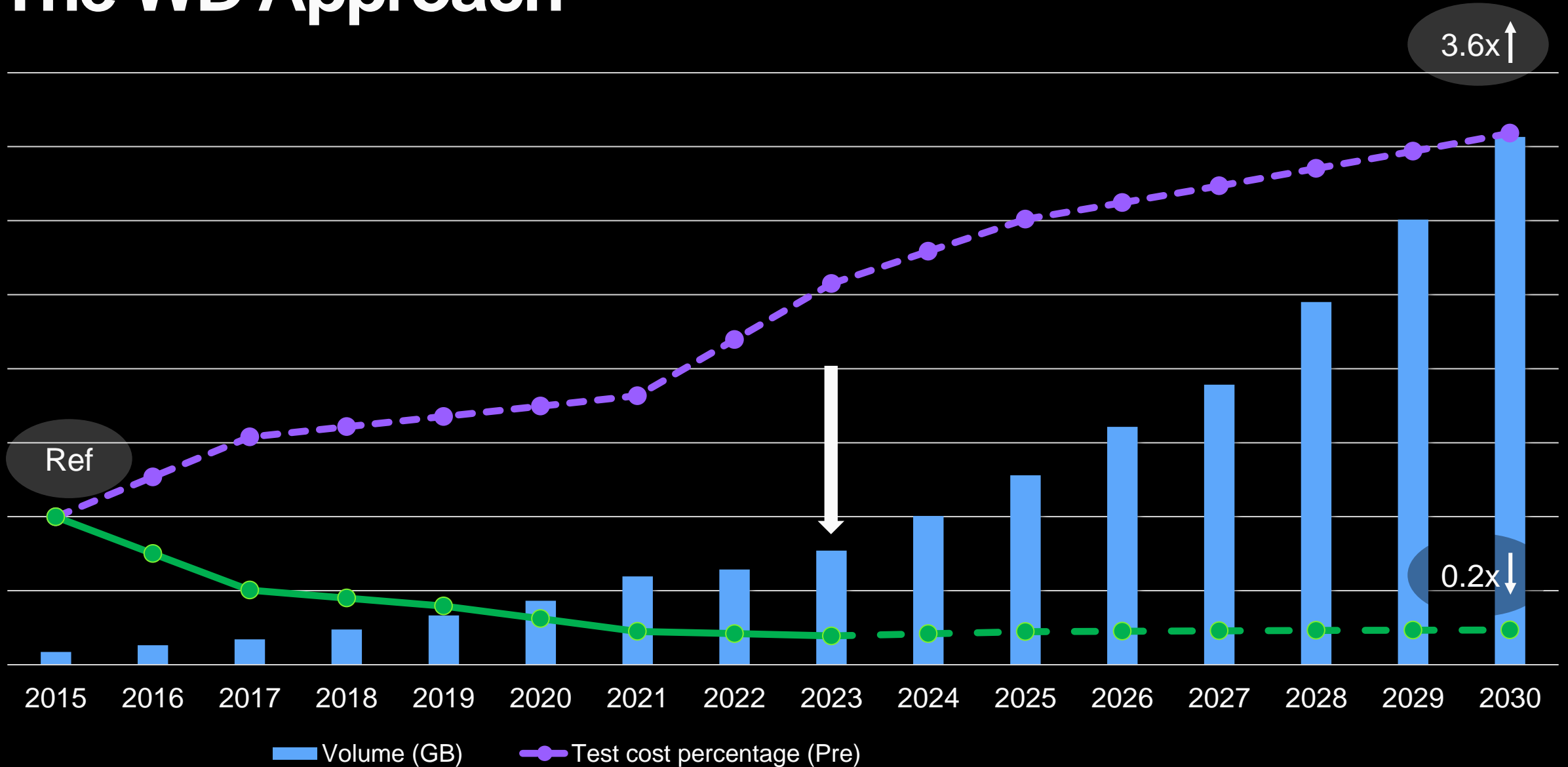


ML-Based Testing for Cost Reduction



20%+ CapEx Savings

The WD Approach



Long Term View

Many to Single



+



Wafer

One Insertion



+

+



Backend

One Insertion

Digital vs. Analog

Digital

Traditional

Rigid

ML limited



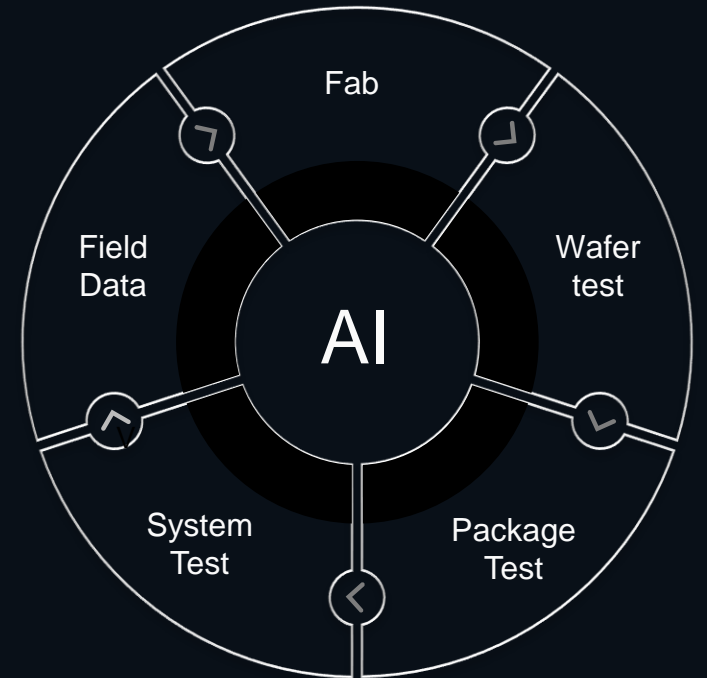
Analog

More Precise

Flexible

ML friendly

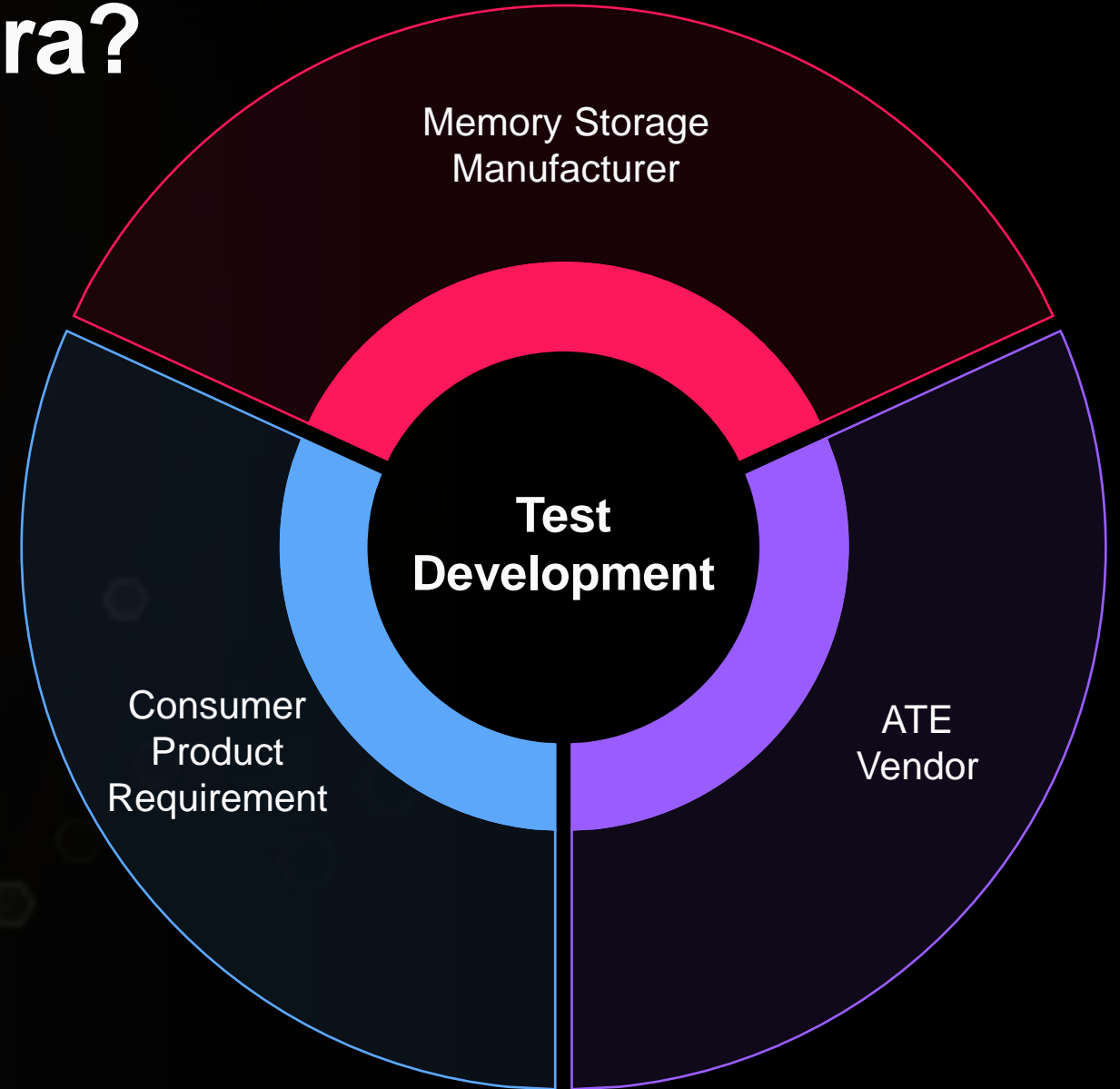
Real-Time Decision Making



Ready for the Zettabyte Era?

Ecosystem to develop:

- ✓ Ultra Efficient Test Flow
- ✓ Massive Test Parallelism
- ✓ Lowest Cost Solution
- ✓ Low Power Consumption
- ✓ Re-use of the Platform
- ✓ ML/AI Processing in Tester
- ✓ Standardized Test Infrastructure





Data storage
demand is
growing



Cost containment
is more important
than ever



Data integrity
is **essential**



Western Digital®

Create What's Next