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State of the Solid State Drive (SSD): *The Transition from 2D NAND to 3D NAND*

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In addition, these presentation materials include references to non-GAAP financial measures. Reconciliations of the differences between the historical non-GAAP measures we provide in these presentation materials to the comparable historical GAAP financial measures are included in the appendix to the applicable presentation materials. We have not reconciled our non-GAAP financial measures related to future results to the most directly comparable GAAP measures because material items that impact these measures are out of our control and/or cannot be reasonably predicted. Accordingly, a reconciliation of the non-GAAP financial measures related to future results to the corresponding GAAP measures is not available without unreasonable effort.

Agenda

- **Market Forces**
- **2D NAND and Its Limitations**
- **Western Digital Delivery of 3D NAND**
- **Call to Action—Speak with our Experts**

Market Forces



44

Zettabytes of data in 2020
or 44 Trillion
Gigabytes of Data

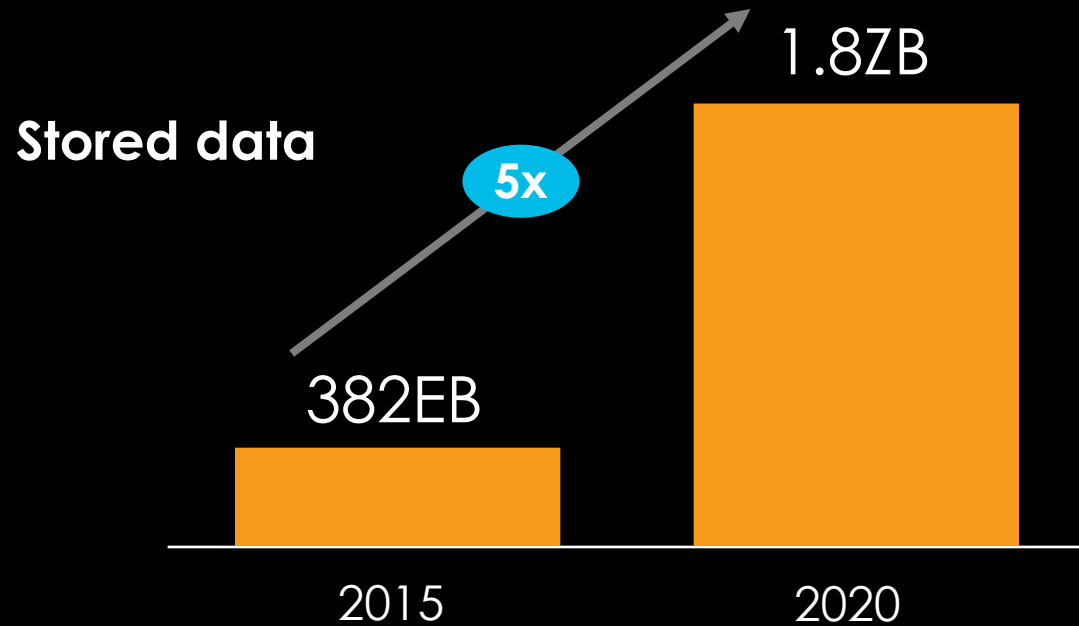
Source: IDC Digital Universe Study, sponsored by EMC, December 2014

The Rapid Rate of Data Generation



¹ IoT Units Installed Base
Sources: Global Cloud Index: Forecast and Methodology 2015-2020, Cisco, 2016; Visual Networking Index: Forecast and Methodology, 2015-2020, Cisco, 2015; Internet of Things Units Installed Base 2015-2020, Gartner, 2015; Self-driving Cars Report, DataFloq, 2016

Data Center Growth Expected to Increase 5x by 2020

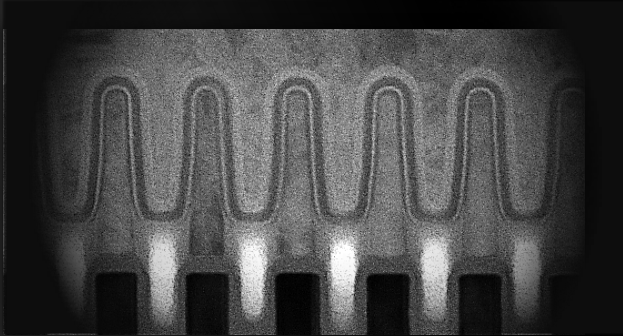


5x Growth in data center storage installed capacity

Source: Global Cloud Index: Forecast and Methodology 2015-2020, Cisco, <http://www.cisco.com/c/dam/en/us/solutions/collateral/service-provider/global-cloud-index-gci/white-paper-c11-738085.pdf>

2D NAND

2D NAND AND ITS LIMITATIONS



Magnified 15nm lithography

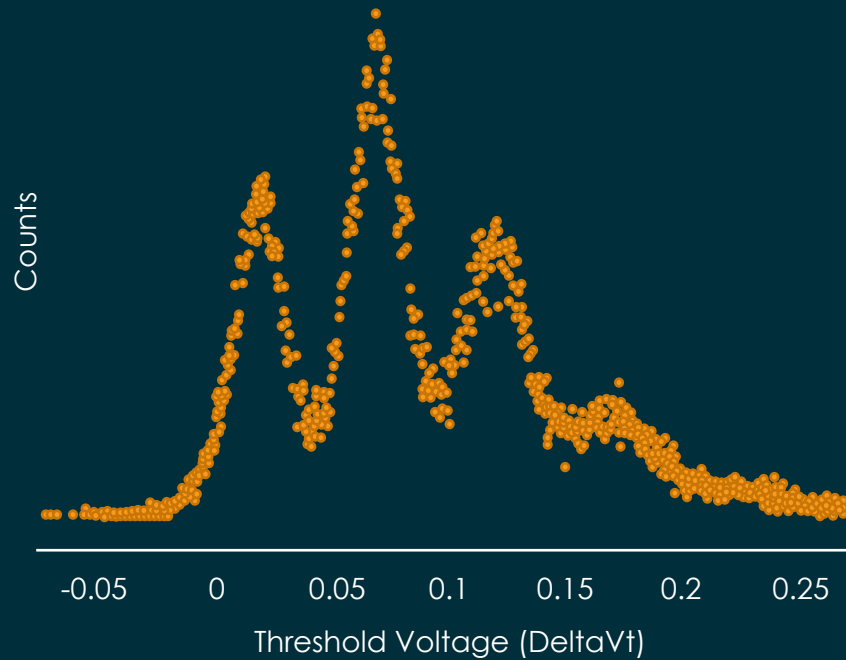
- 2D NAND is the basis of all the SSD products deployed the last few years
- SSD Capacities: 200GB - 4TB

- Shrinking NAND die size, i.e., moving from 43nm to 32nm, 19nm to 15nm, enabled SSD capacity growth
 - As cells gets closer, i.e., 15nm, the “Proximity Effect” kicks in; no longer able to shrink NAND die sizes
- Initially, 2D NAND SSD products stored 1 bit per cell, aka “Single-Level Cell” (SLC) flash, then:
 - Multi-Level Cell (MLC) – 2 bits per cell – doubles density capacity
 - Triple-Level Cell (TLC) – 3 bits per cell – additional 32%
 - Quad-Level Cell (QLC) – 4 bits per cell – 25% more
- **TRADEOFF:** More bits per cell for larger capacity points, but at the expense of endurance, i.e., DWPD (Drive Writes Per Day)

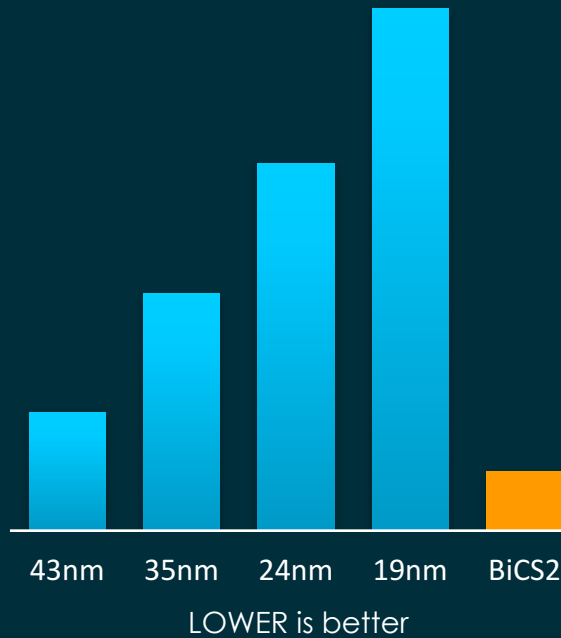
NAND DIE SIZE IS A PROXY FOR THE COST OF SSD PRODUCTS

No Moore's Law for 2D NAND

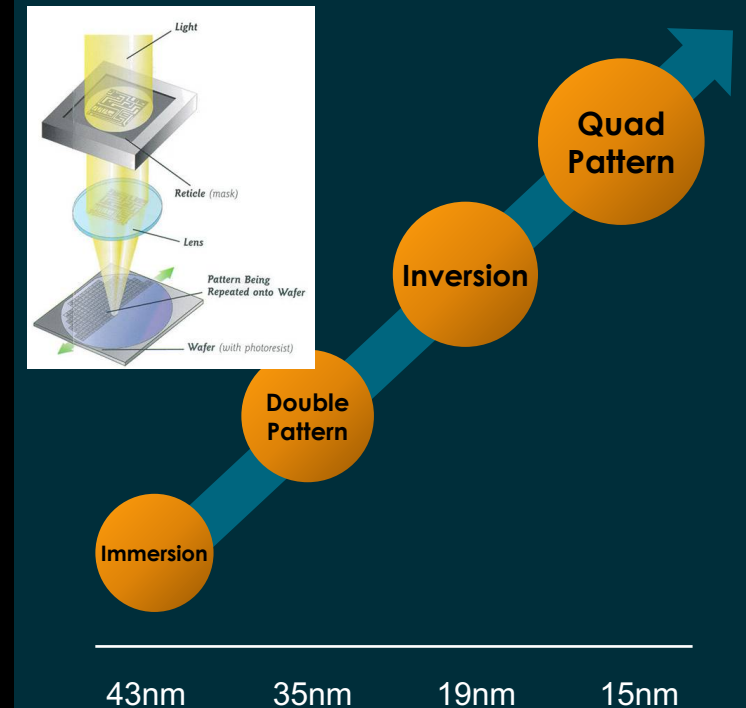
We don't have enough electrons



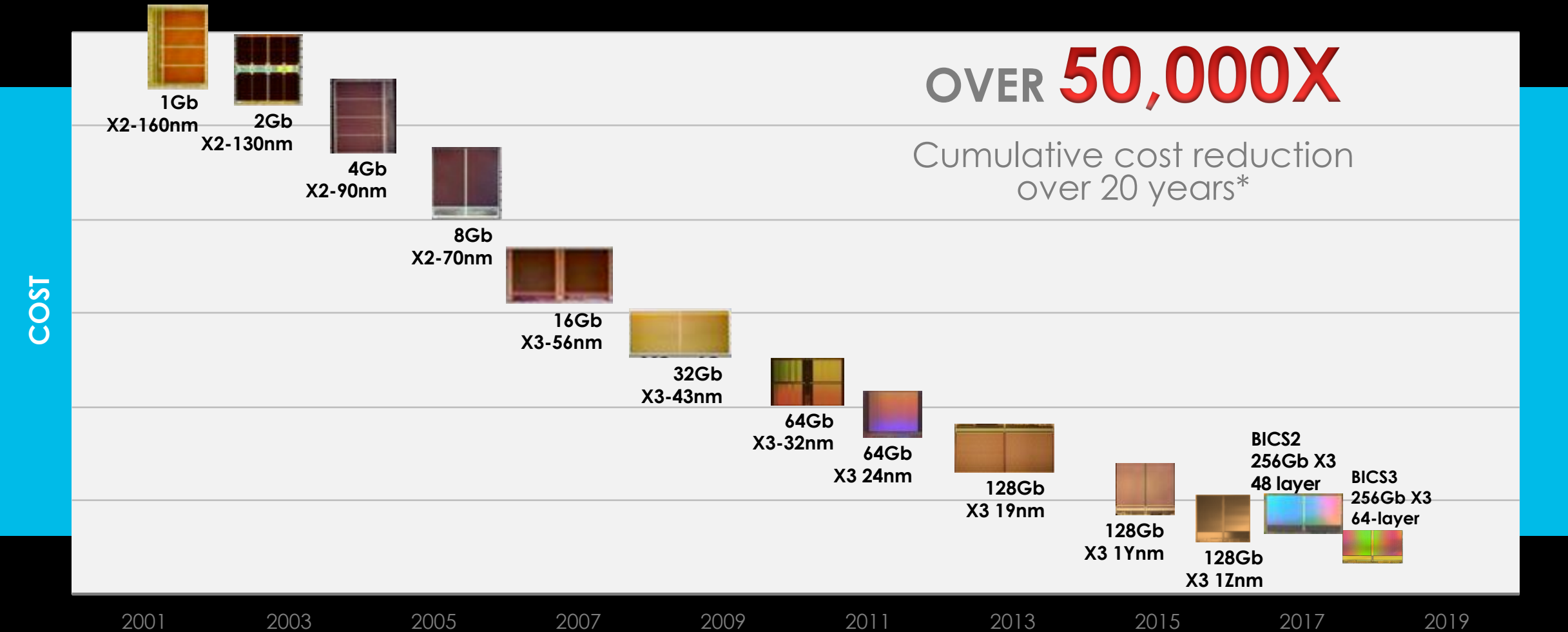
As cells get closer, proximity effect worsens



Lithography Process Complexity



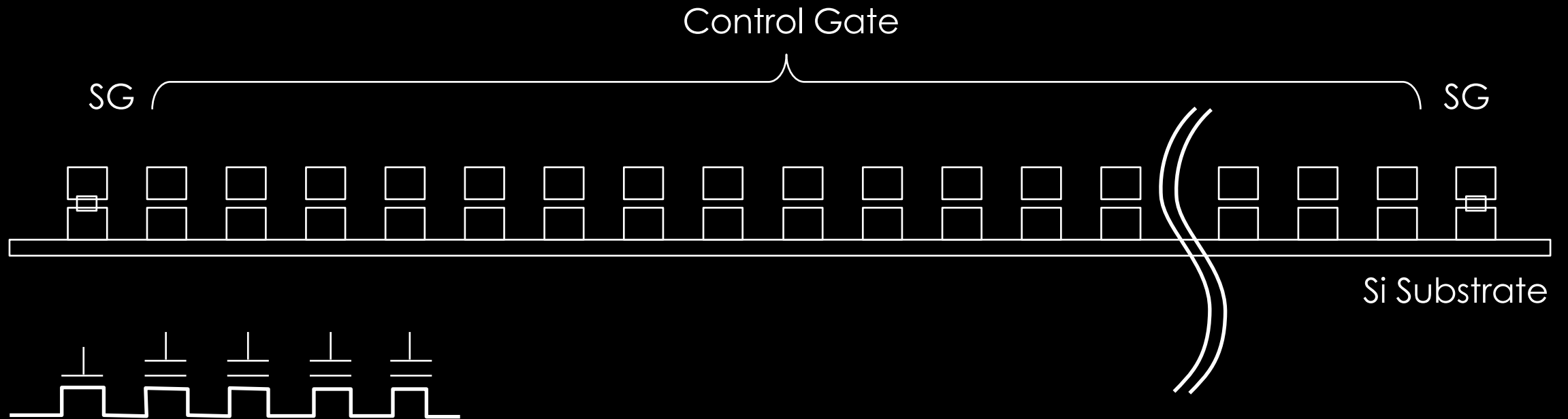
In NAND We Trust!



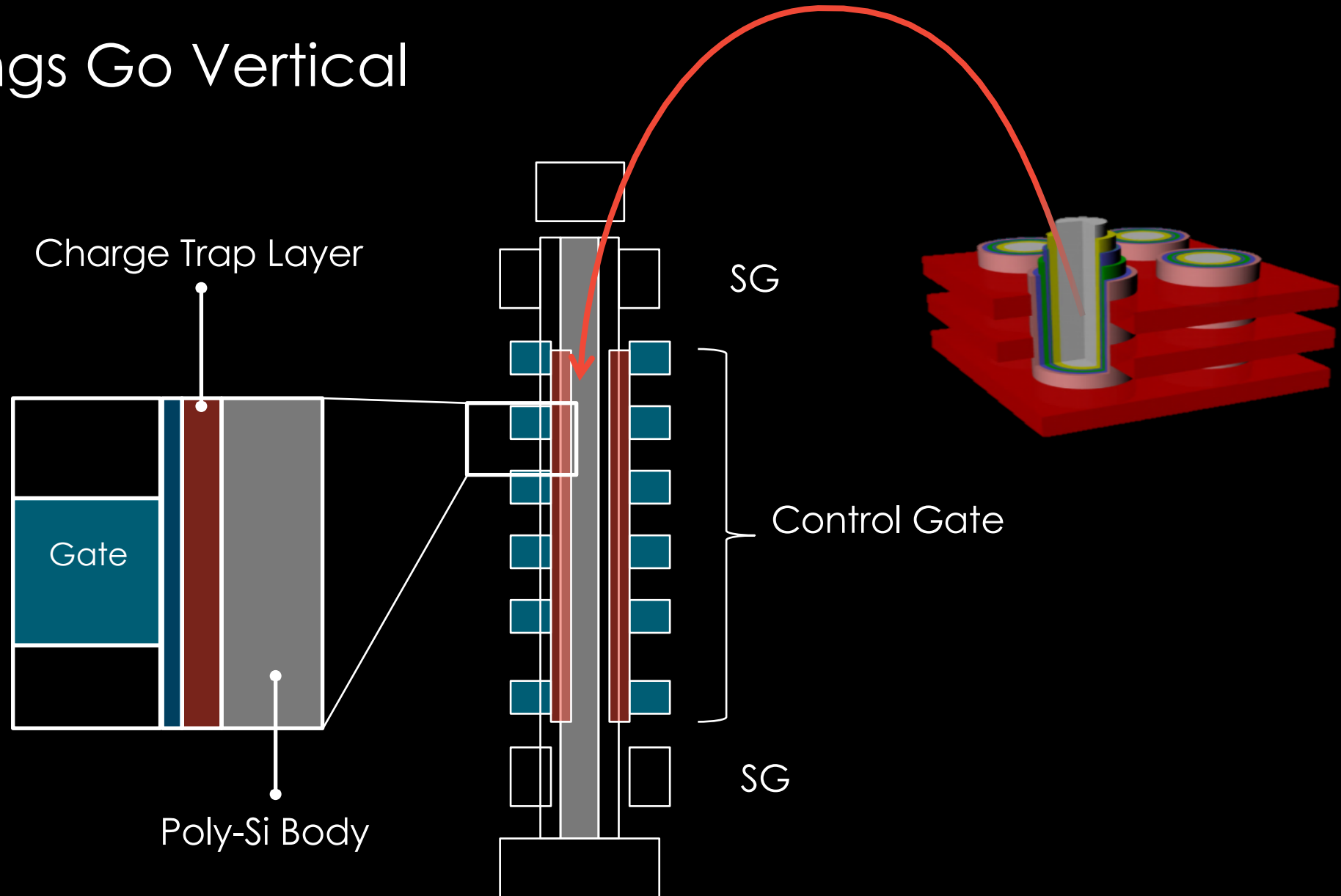
Note: Images not to scale *Based on historical SanDisk NAND pricing 1992*

3D NAND

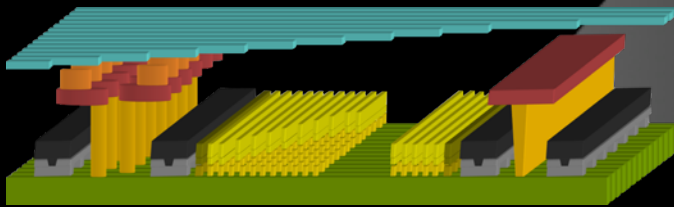
NAND Strings Go Vertical



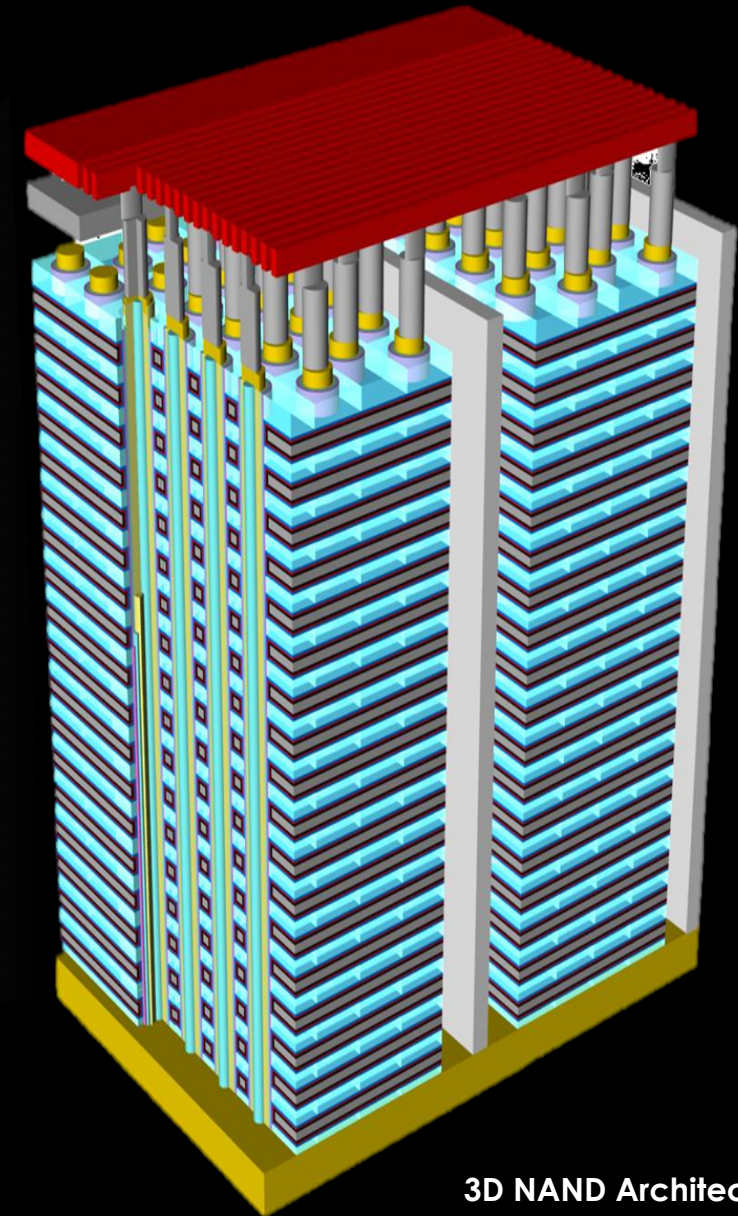
NAND Strings Go Vertical



From the Suburbs to Downtown

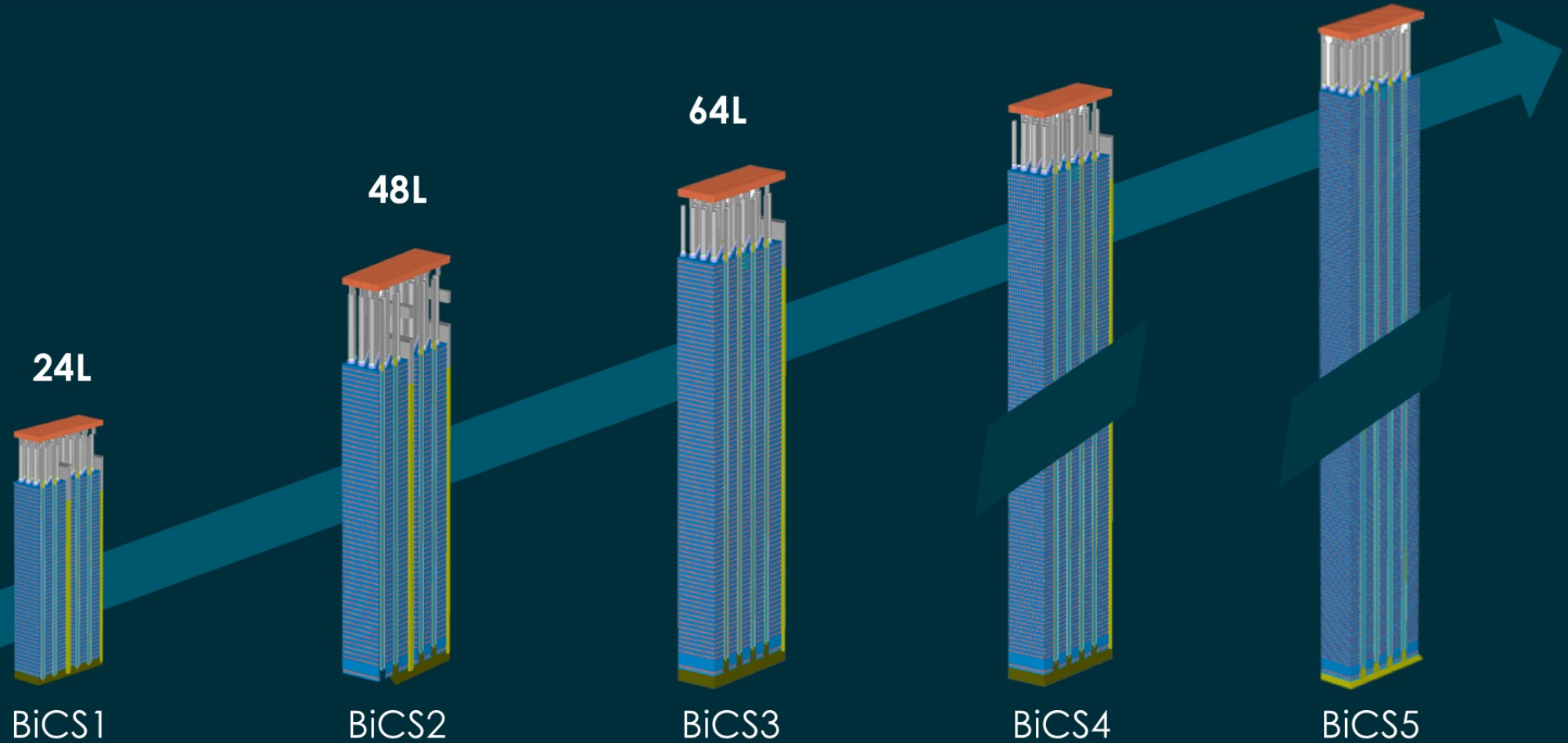


2D NAND Architecture



3D NAND Architecture

64 Layer BiCS3: First Commercially Viable 3D NAND Technology



Predictable scaling path: x, y, z and logical scaling

NAND Flash Vertical Integration: Key Competitive Advantage

Low Cost

High Service Level

Low Cycle Time

High Quality

Low Inventory

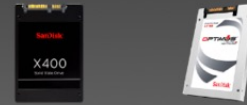
High Agility

Malaysia

Integrated SSD
Manufacturing



Integrated SSD manufacturing
from wafer to finished drive



China

IC Packaging
and Test



World-class assembly house
with industry-leading scale



Japan

Semiconductor
Fabs



Largest NAND production
site in the world



SSD
Assembly

IC
Packaging

Wafer
Manufacturing

Market Segmentation

Enterprise

Client Compute

Mobility

Embedded Emerging Markets

On-Premise

Data Center/Cloud

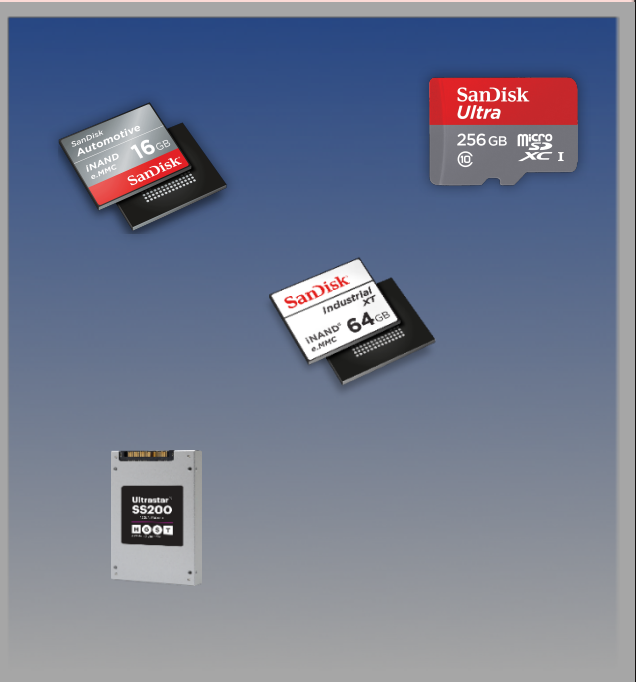
Desktops

Notebooks

Smart Phones &
Tablets

Automotive
Industrial

Surveillance
Connected Home/Gaming



Call to Action for Service Providers

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- Higher concurrent IOPS at lower latency
- Accelerate migration to cloud-native applications

Data Center Architects

- Greater compute & storage densities
- Reduced heat, power & cooling
- ARM® Processors and GPU-Intensive deployments

Stakeholders: IoT, Analytics, Open Source, Commerce, AR/VR, Cognitive/AI, etc.

- SSDs are a key enabling technology
- Purpose-built appliances
- Containerized delivery

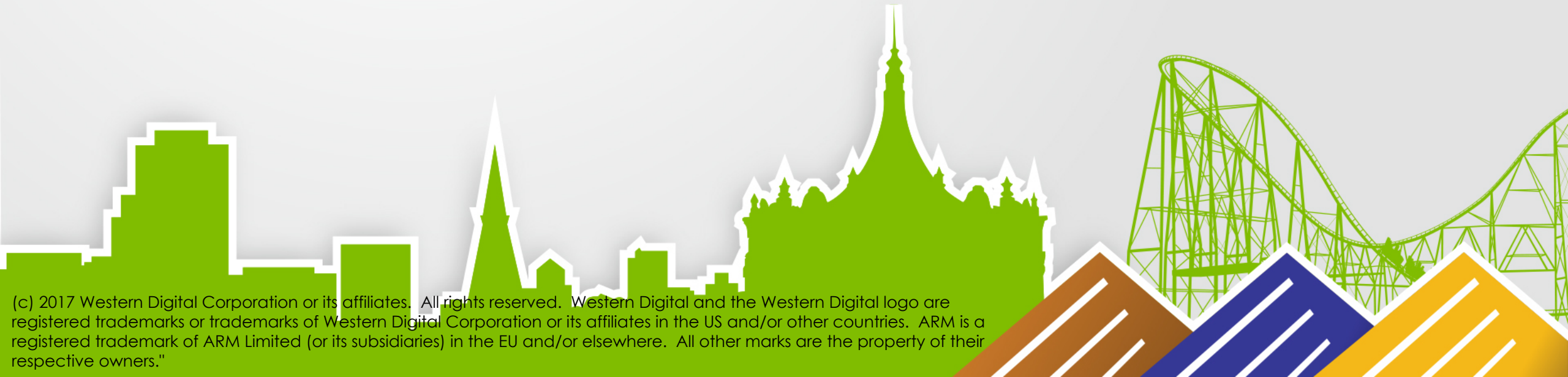
The background of the slide is black, featuring a dynamic, abstract graphic on the right side. This graphic consists of numerous thin, overlapping lines and streaks that fan out from the right edge towards the center. The colors of these streaks include bright orange, yellow, red, and magenta, creating a sense of motion and energy. The text 'Speak with our Experts' is positioned on the left side of the slide, centered vertically relative to the graphic.

Speak with our
Experts



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