Semiconductors and Artificial Intelligence: The Virtuous Cycle

2024 IEEE Electronic Design Process Symposium (EDPS)

October 3rd , 2024

Dr. Pushkar P. Apte

Strategic Technology Advisor and Smart Data-AI Initiative Lead

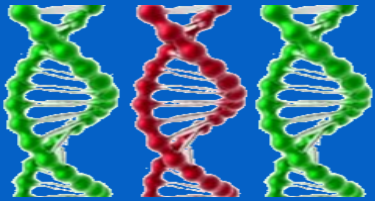CONNECT - **COLLABORATE** - INNOVATE - GROW - PROSPER

Semiconductors & AI: The Virtuous Cycle

AI-Powered Digital Twins to Accelerate Semiconductor R&D, Design & Manufacturing

Semiconductor System Innovation for Sustainable AI
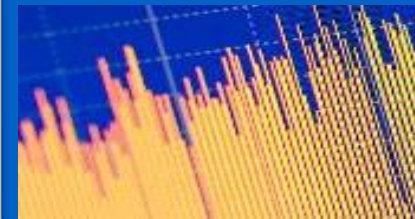
Data and AI Impact EVERYTHING!

Genomics

Security

Smart Data-AI Will Help Create the Intelligent Future

Smart Cities

Finance

Defense

Health Care

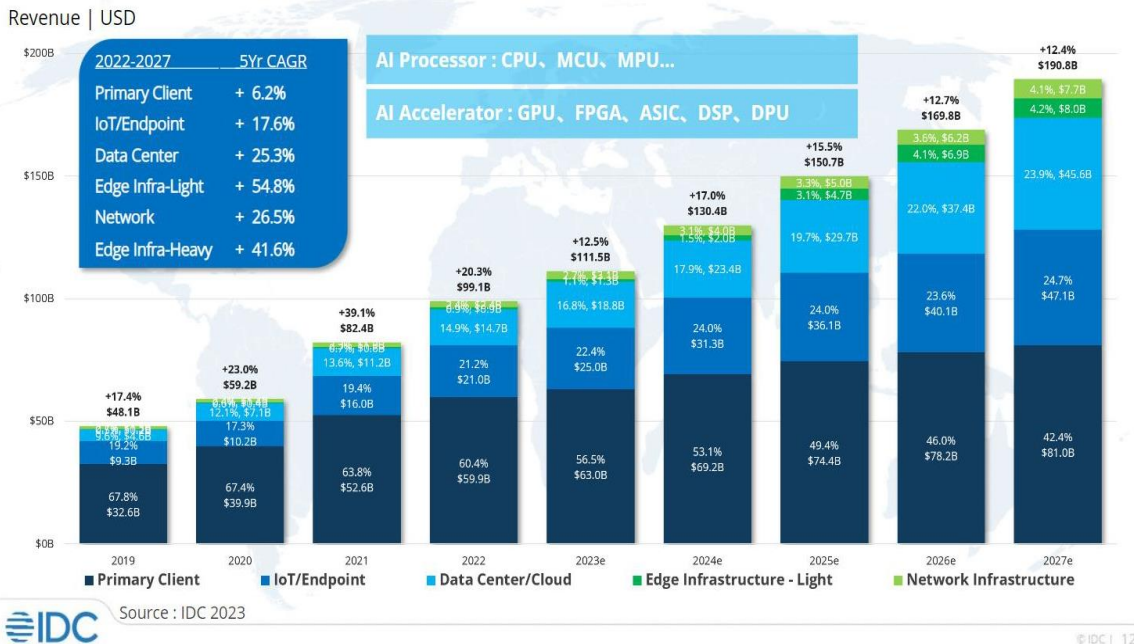**Government**

Science

semi | SMART DATA-AI

The Semiconductor Engine Drives the AI Revolution!
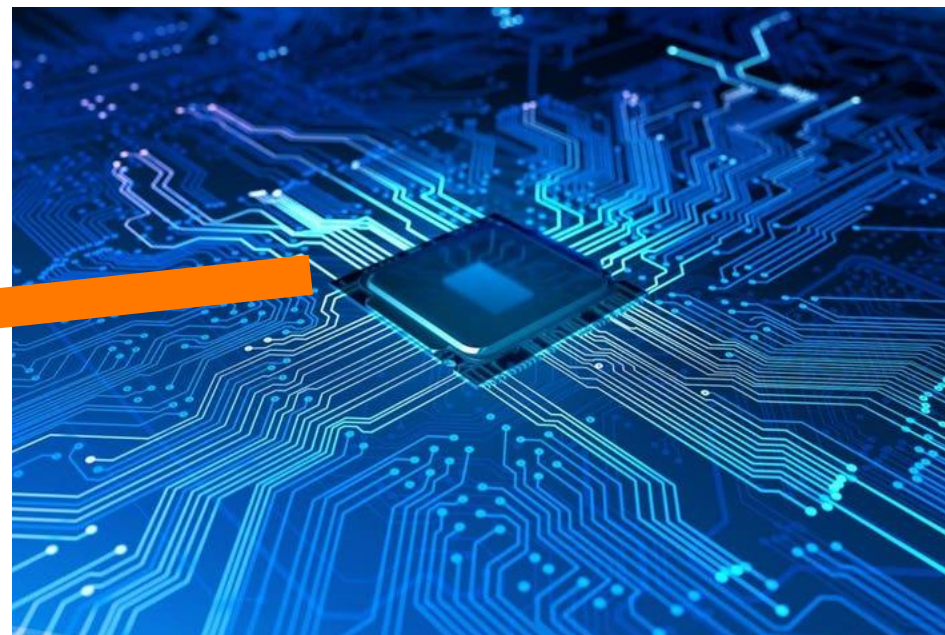
AI Is Critical for Semi Industry's Path to $1 Trillion

AI HW revenue projected to reach ~$200B by 2027…

AI Processor and Accelerator by **Deployment Share**

Revenue | USD

2022-2027	5Yr CAGR
Primary Client	+ 6.2%
IoT/Endpoint	+ 17.6%
Data Center	+ 25.3%
Edge Infra-Light	+ 54.8%
Network	+ 26.5%
Edge Infra-Heavy	+ 41.6%

AI Processor : CPU、MCU、MPU…

AI Accelerator : GPU、FPGA、ASIC、DSP、DPU

Source : IDC 2023

©IDC | 12

Primary Client ◼ **IoT/Endpoint** ◼ **Data Center/Cloud** ◼ **Edge Infrastructure - Light** ◼ **Network Infrastructure**
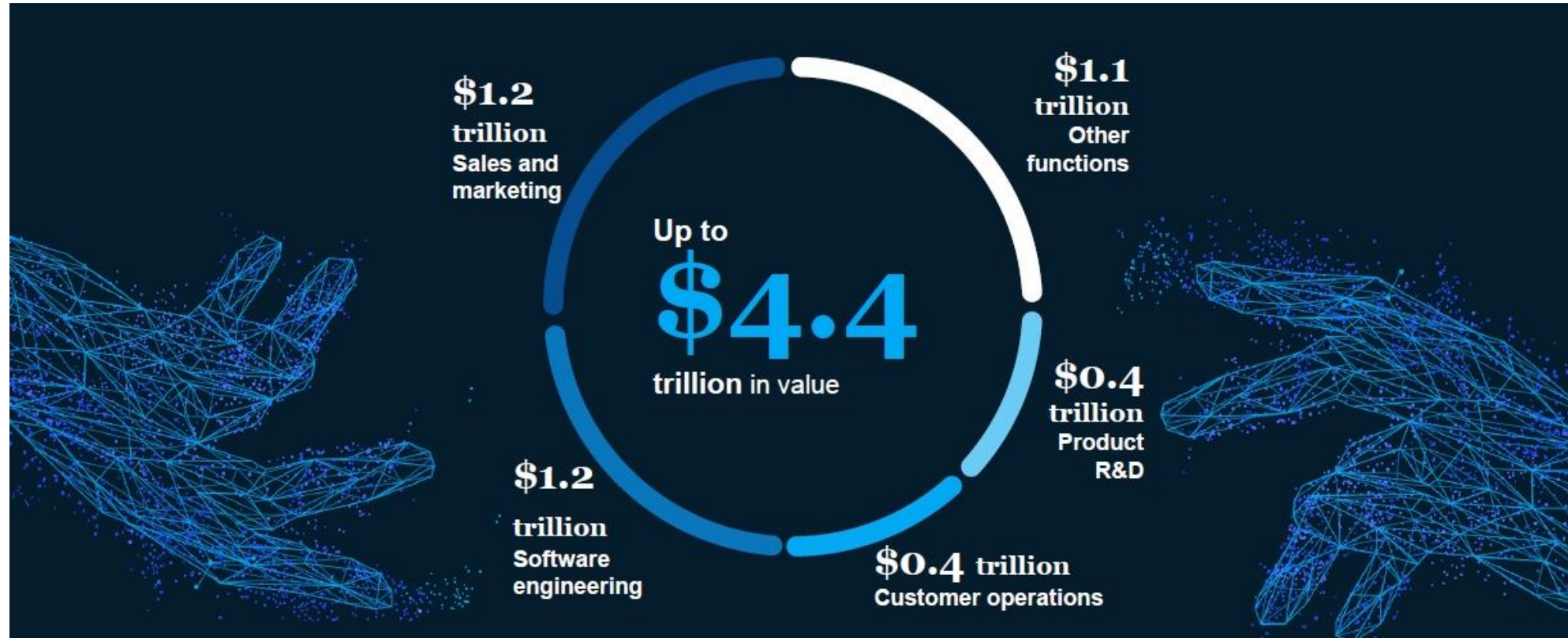
IDC

TECH

Nvidia passes Alphabet in market cap and is now the third most valuable U.S. company

PUBLISHED WED, FEB 14 2024·5:33 PM EST

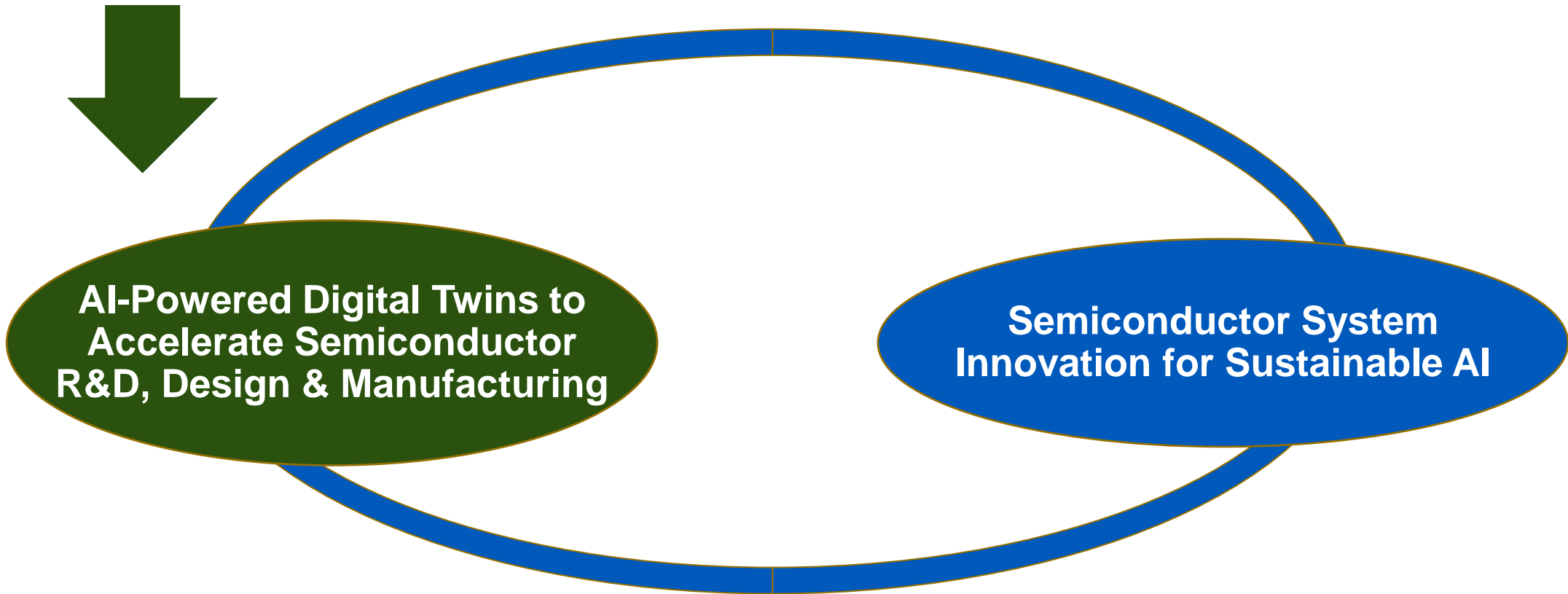"Semi used to be a four-letter word in the Valley, but now it's sexy,"

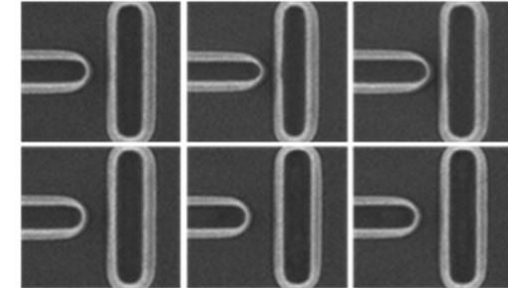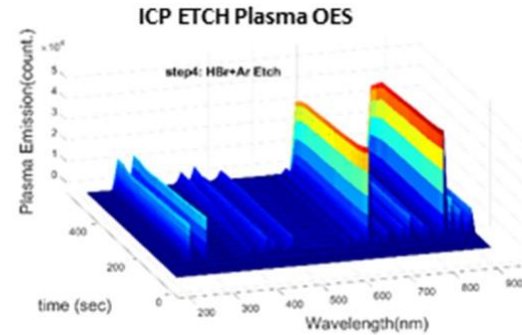*Sriram Viswanathan, founding managing partner at San Francisco-based Celesta Capital.*

semi | **SMART DATA-AI**

Gen AI Is Especially Hot

Source: McKinsey & Co. Analysis

Semiconductors & AI: The Virtuous Cycle

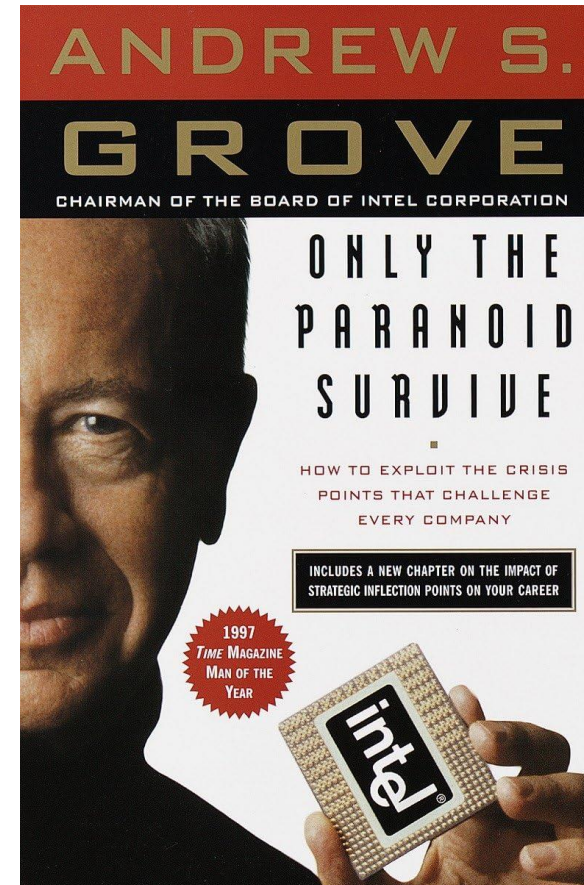# Challenges: Data-Formatting
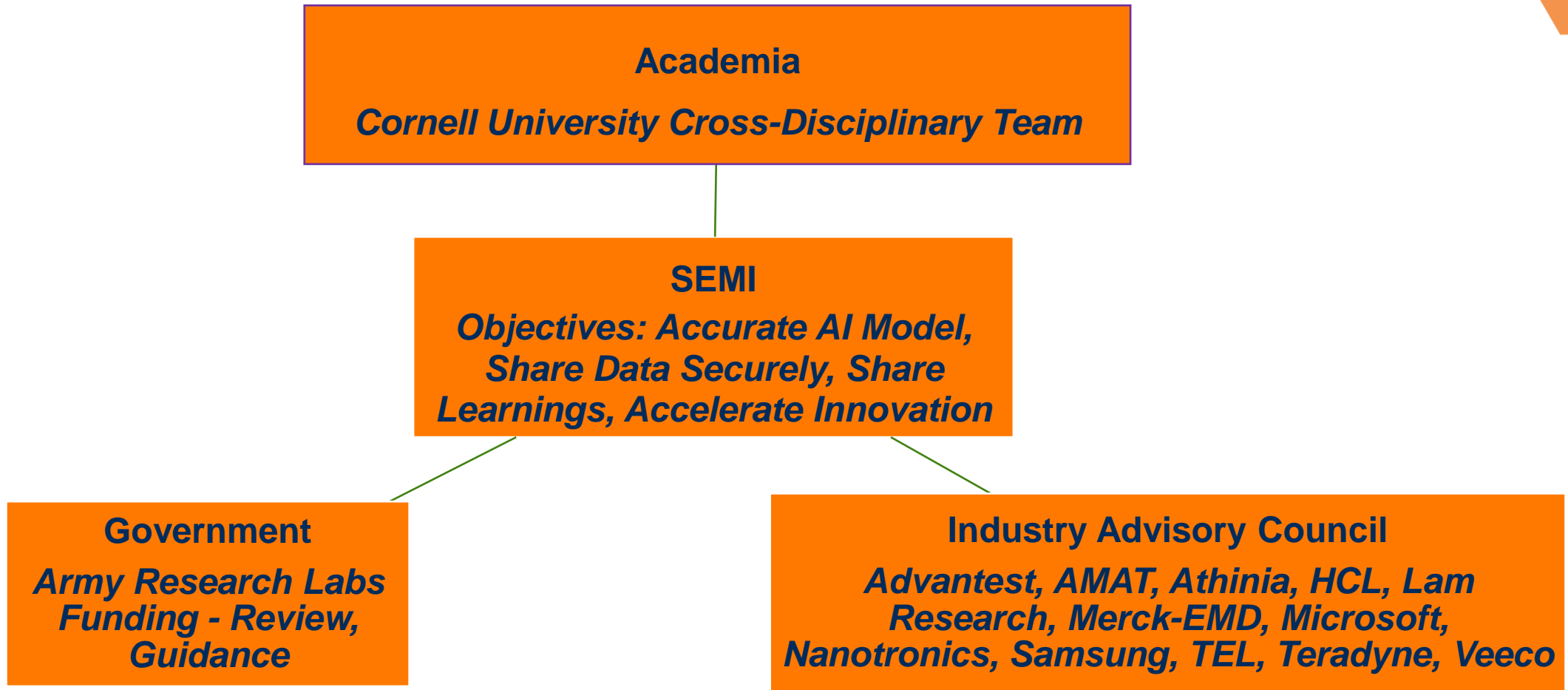

Numerical · Structured Text · Time Series · Images(2D data)

- **Fab Data is in multiple formats**
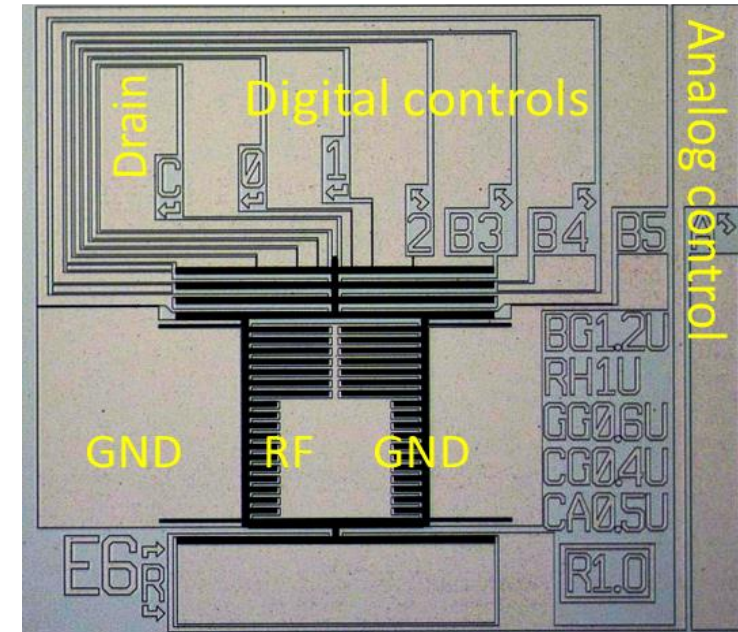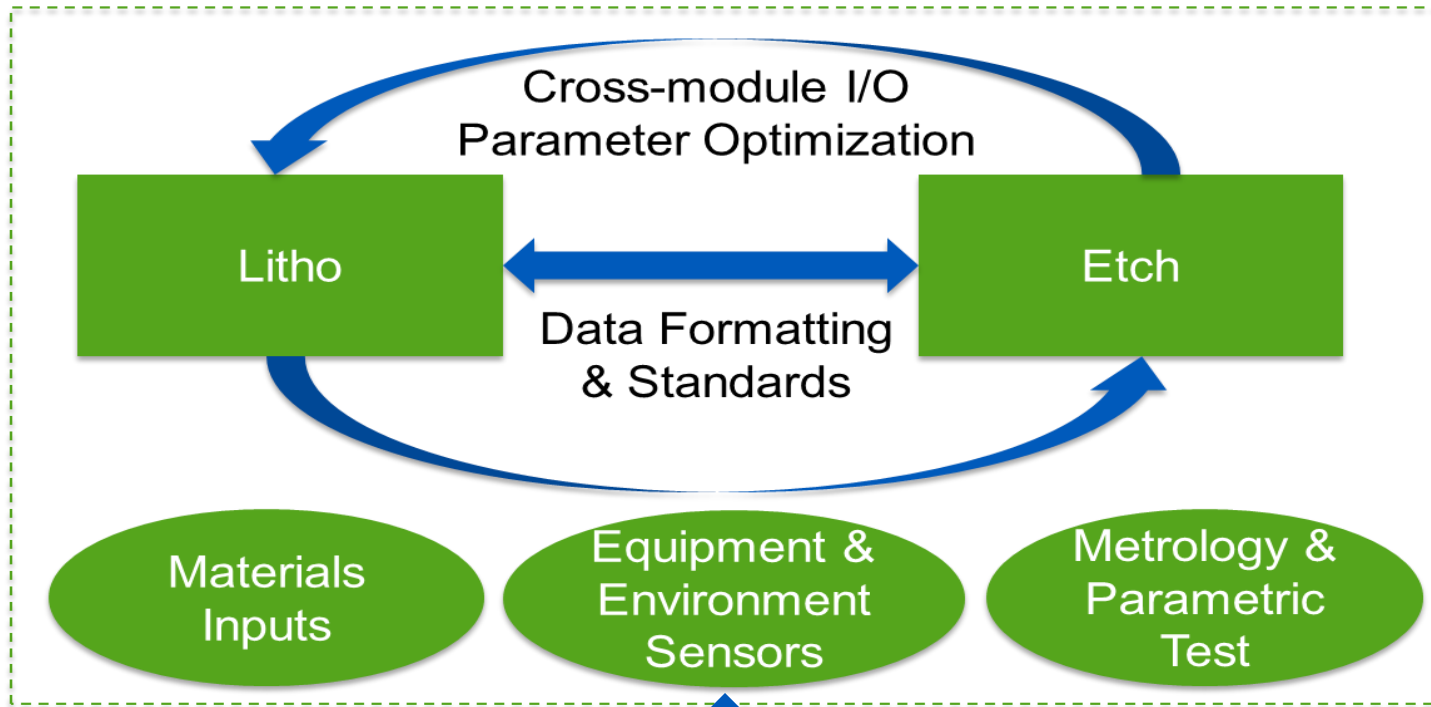- **Harmonizing for AI algorithms is non-trivial!**

Challenges: Data-Sharing

Created by:
cimetrix
by PDF/SOLUTIONS®

95 GB equipment data collected

3,174 good die shipped

2.31 wafer starts

9.6 GB EUV data collected

240 process steps completed

360,000 recipe step events

300 recipes downloaded

75,000 wafer move events

600 FOUPs moved

15,000 specialty sensor readings

6,000 FDC models evaluated

900 Control Jobs executed

ANDREW S. GROVE

CHAIRMAN OF THE BOARD OF INTEL CORPORATION

ONLY THE PARANOID SURVIVE

HOW TO EXPLOIT THE CRISIS POINTS THAT CHALLENGE EVERY COMPANY

INCLUDES A NEW CHAPTER ON THE IMPACT OF STRATEGIC INFLECTION POINTS ON YOUR CAREER

1997 TIME MAGAZINE MAN OF THE YEAR

intel

Starting on a Solution Path: Collaborative Proof-of-Concept (POC) Project

Academia

Cornell University Cross-Disciplinary Team

SEMI

Objectives: Accurate AI Model, Share Data Securely, Share Learnings, Accelerate Innovation

Government

Army Research Labs Funding - Review, Guidance

Industry Advisory Council

Advantest, AMAT, Athinia, HCL, Lam Research, Merck-EMD, Microsoft, Nanotronics, Samsung, TEL, Teradyne, Veeco

Project Overview
Optimize Litho & Etch Modules for demonstration device - NEMS switch for RF wakeup

Funded @ ~$1.1K including from ARL + industry match

2 phases completed

POC Project Achievements

- Effective framework for academia-industry-government collaboration

- **Accurate AI model to predict device dimensions from process parameters**

  - Data preparation methodologies

  - Virtual metrology solutions

  - Optimal AI algorithm selection

- Data-sharing solutions – co-optimized HW-SW encryption solutions
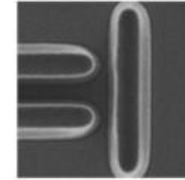
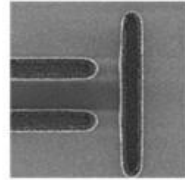- Model portability via Microsoft Azure cloud

Data Preparation Methodologies

ASML DUV

Gamma post-litho tool
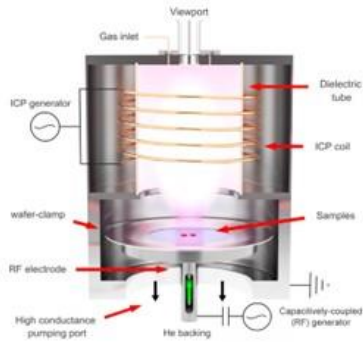
Oxford ICP Ethcher with optical emission spectroscopy sensor
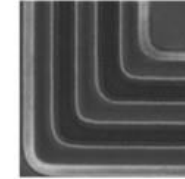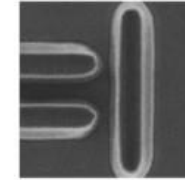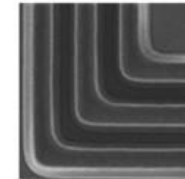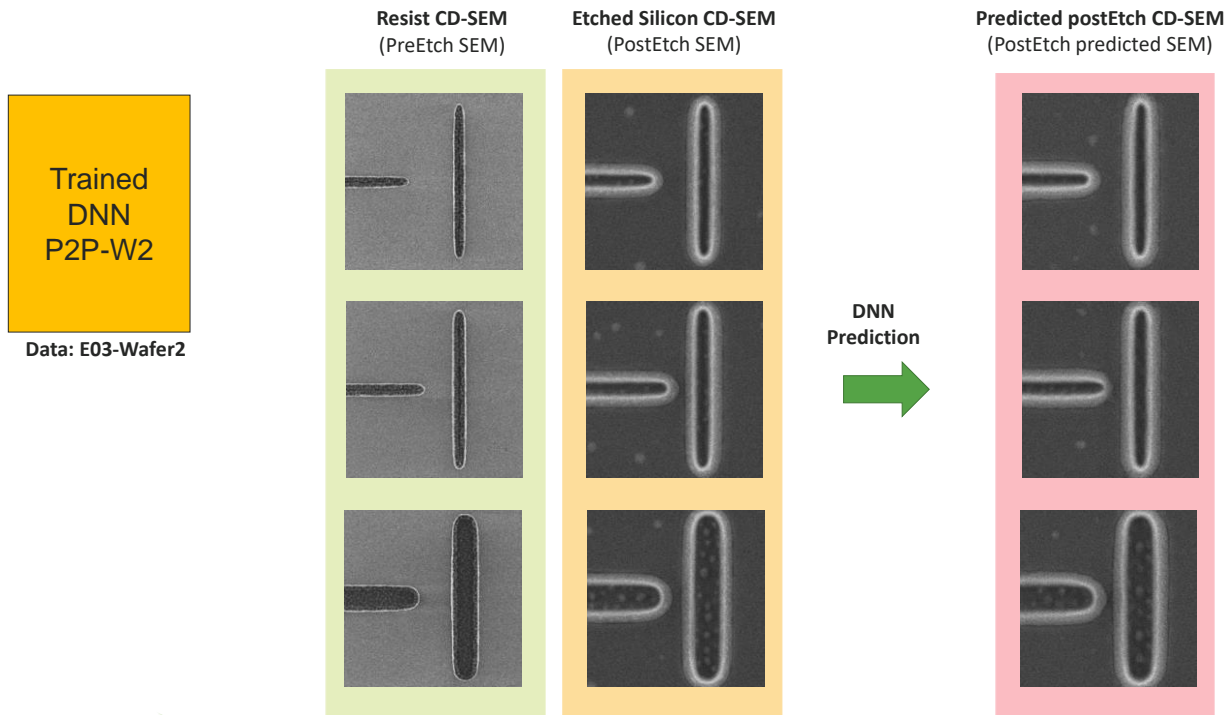

- ~ 100,000 CD-SEMS collected to parametrize against litho parameters and mask parameters (gaps and linewidths)

- Pix2Pix DNN was able to be trained to predict lithography outcomes

Virtual Metrology Solutions
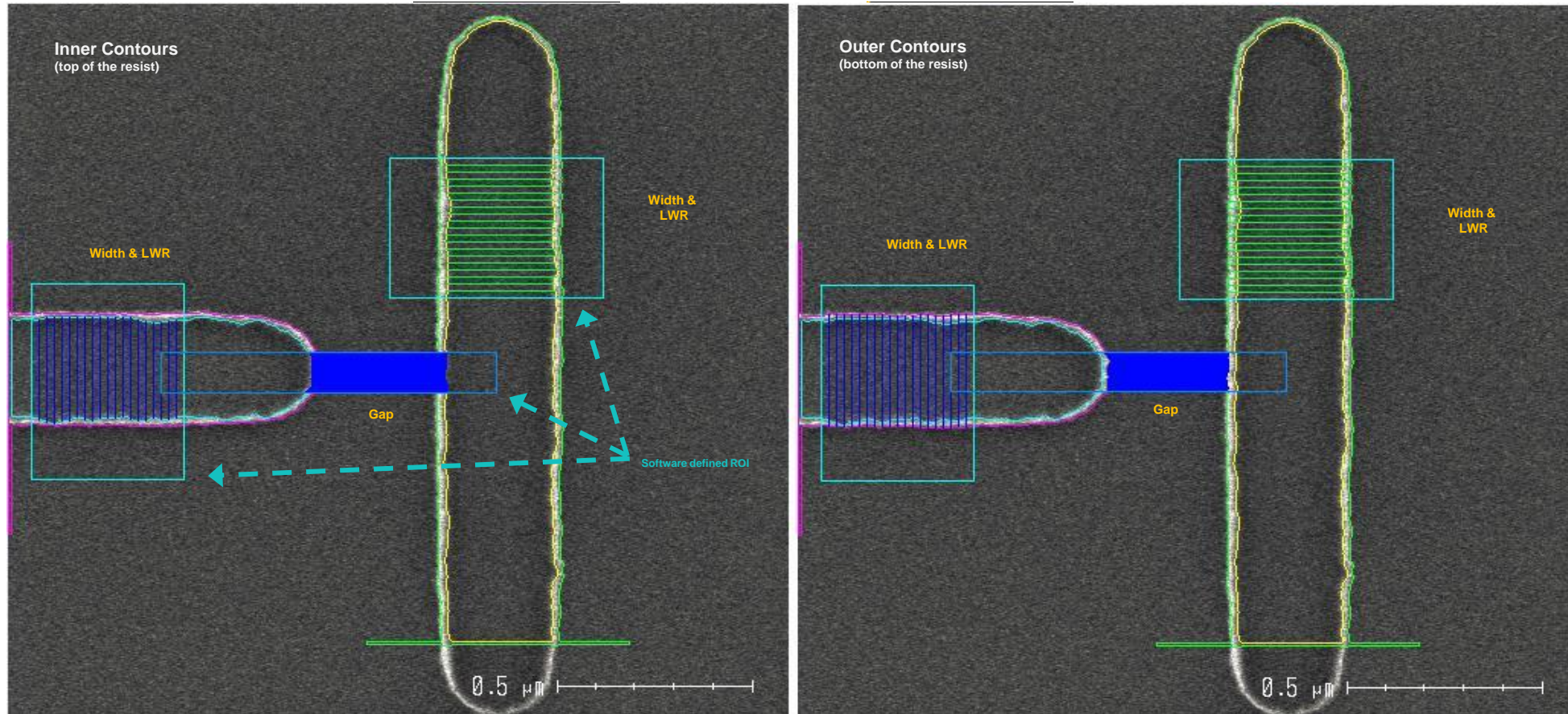
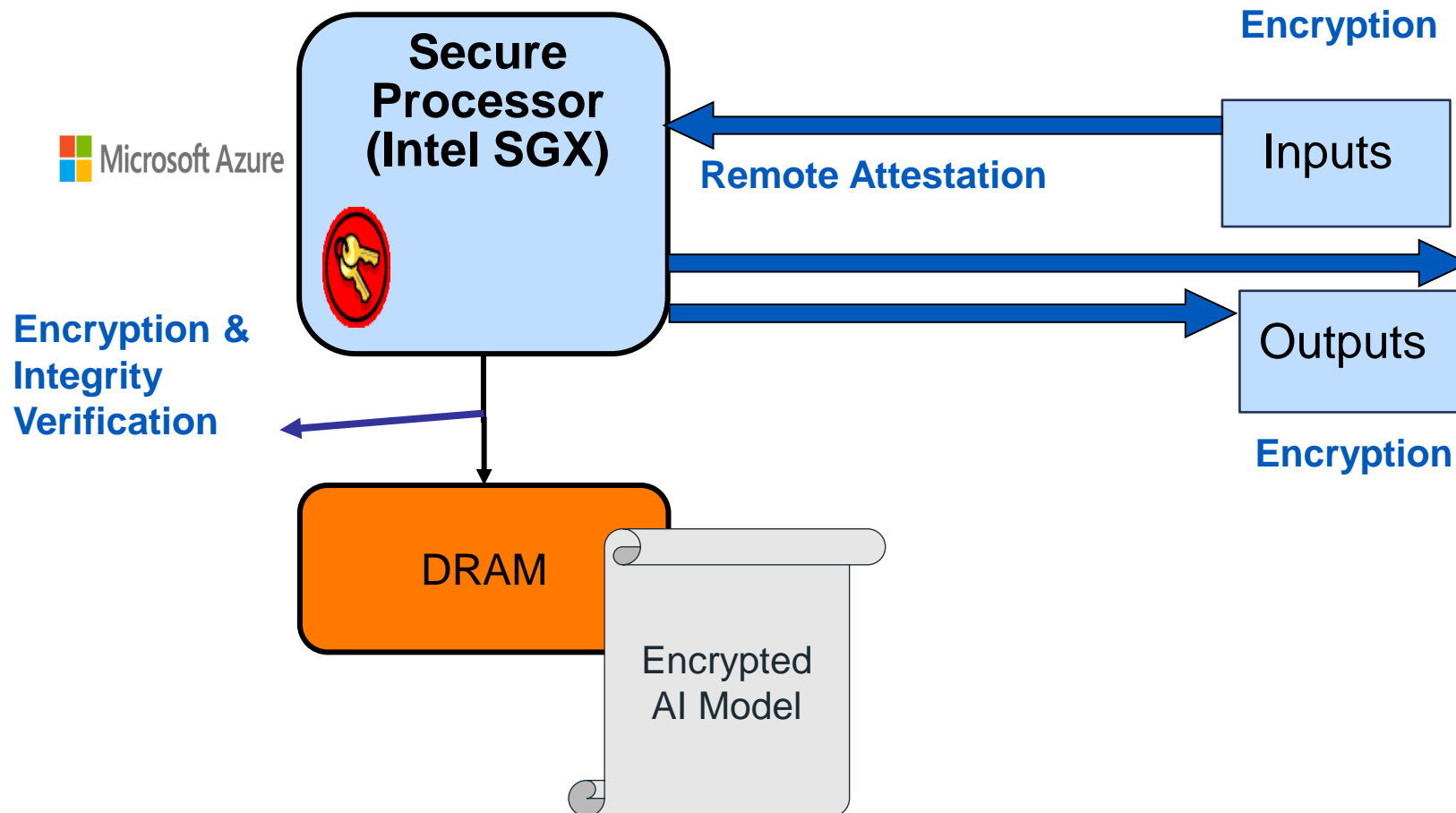# Algorithm Selection & Accurate AI Model

DNN results for Plasma Etch

Secure Data-Sharing

Digital Twin Driven Virtual Innovation Environment

Digital Twin 1

Unit Process 1 → Unit Process 2
- Equipment 1
- Equipment 2

Digital Twin 2

Unit Process 3 → Unit Process 4
- Equipment 3
- Equipment 4

....

Electrically and Structurally Measurable Device
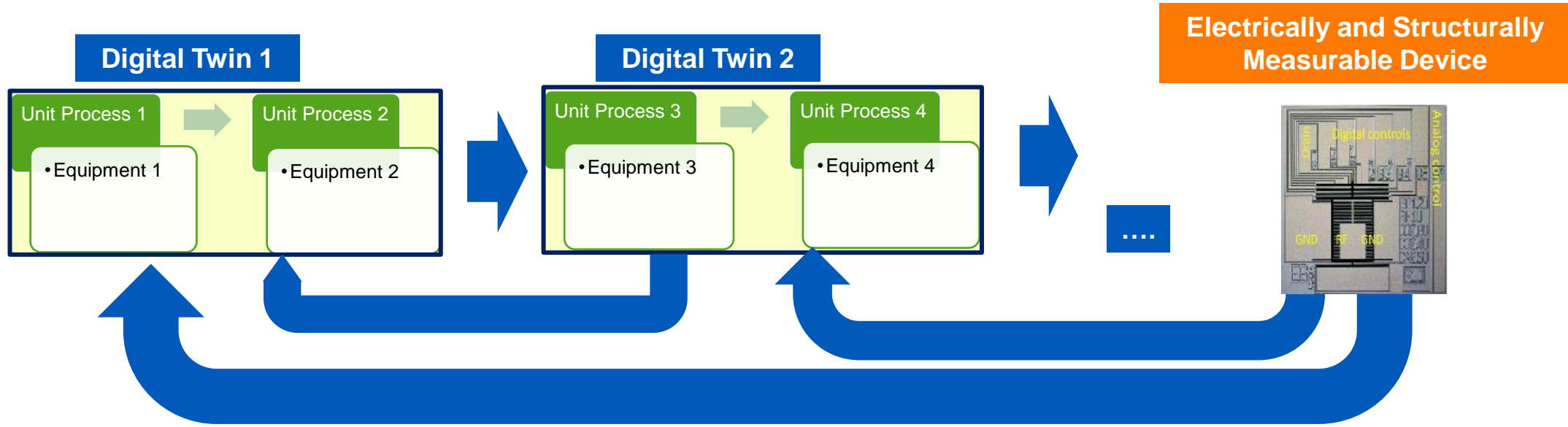
…Driving to towards industry standards…

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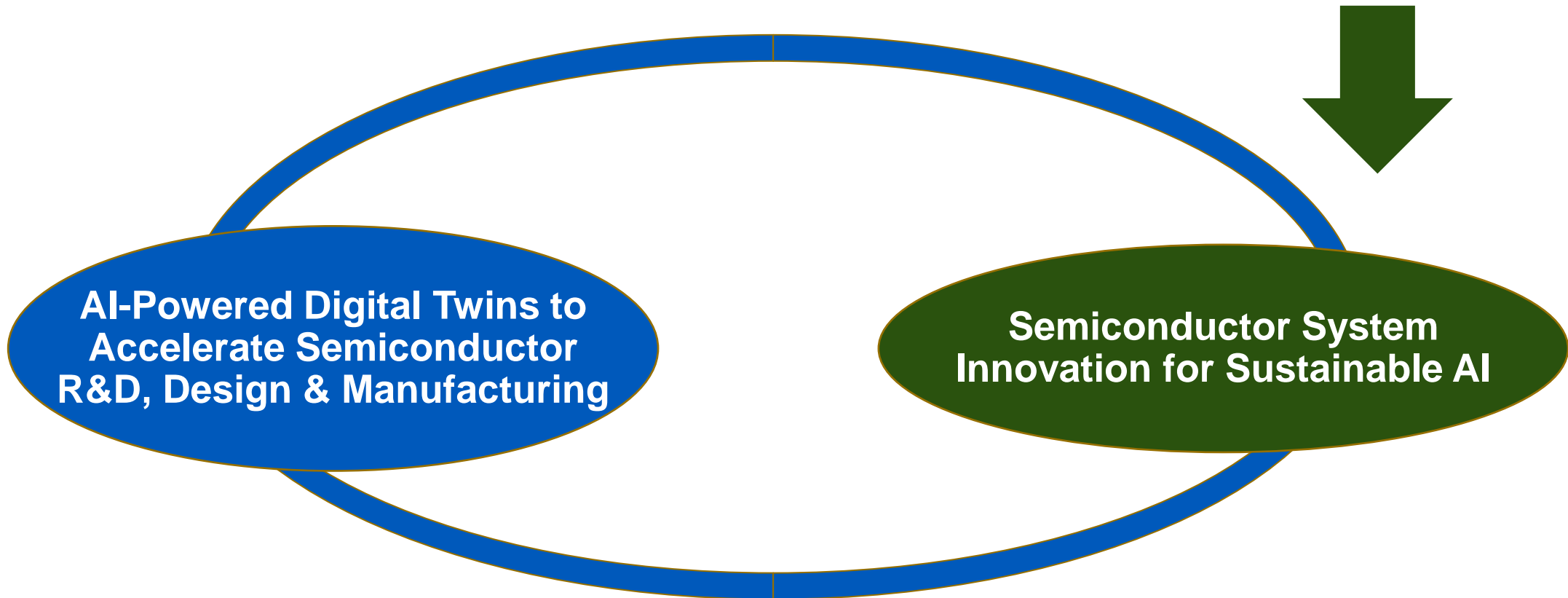
Challenges: AI & Data Requirements Are Outpacing HW

Source: https://medium.com/riselab/ai-and-memory-wall-2cb4265cb0b8
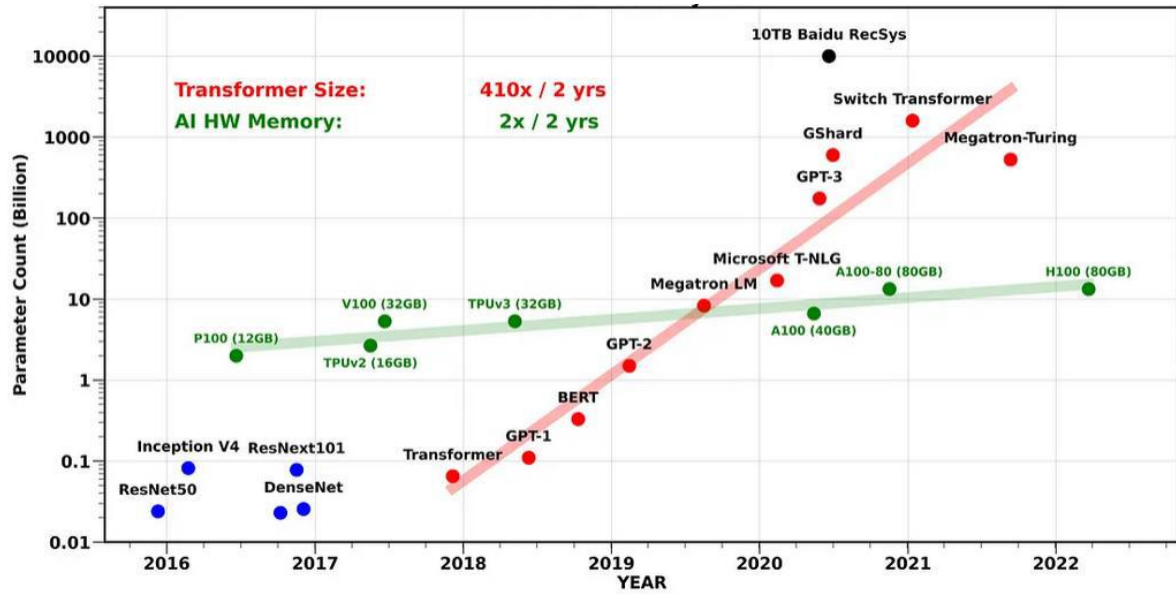
Challenges: Sustainability & Equity
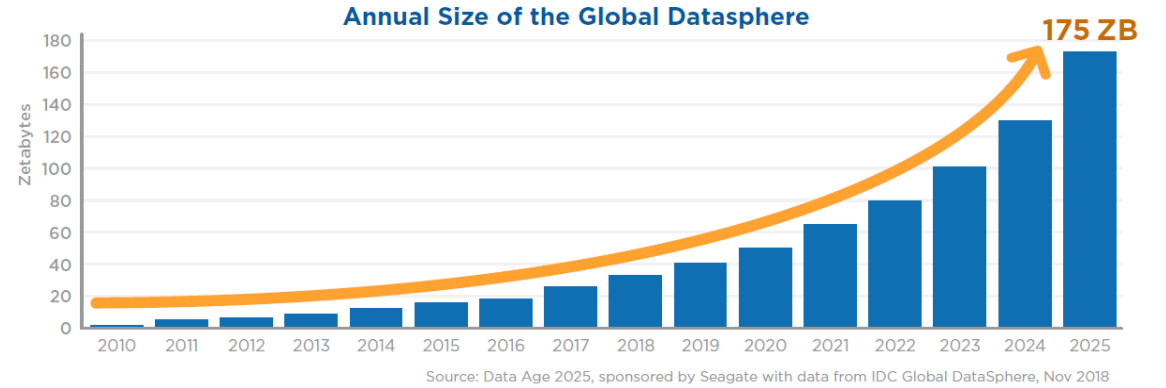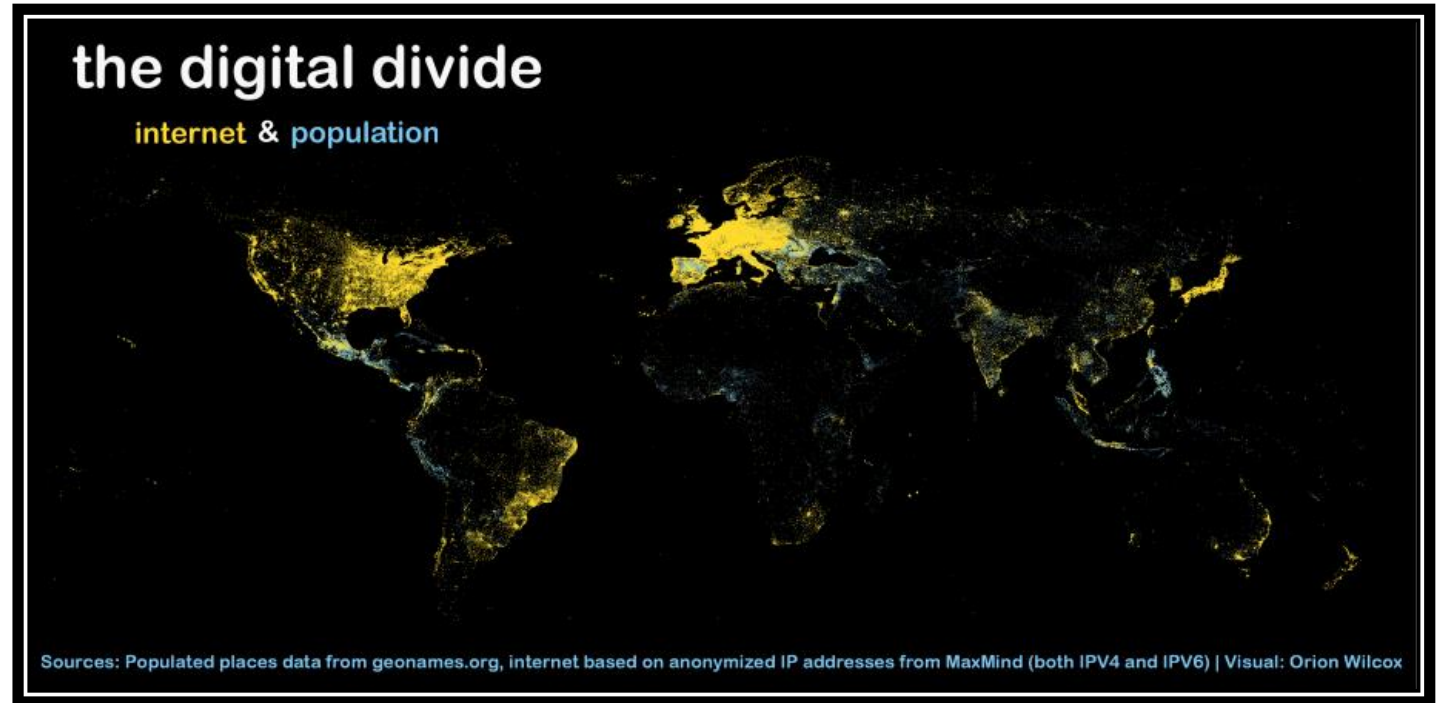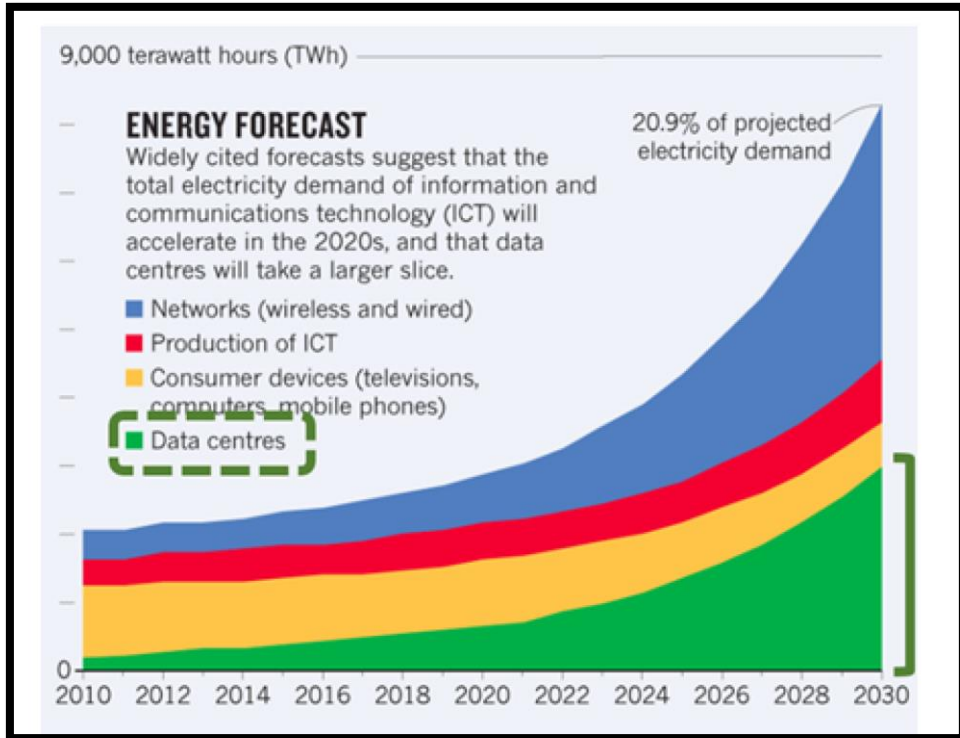
Challenges: Technology Slowing, Power Growing
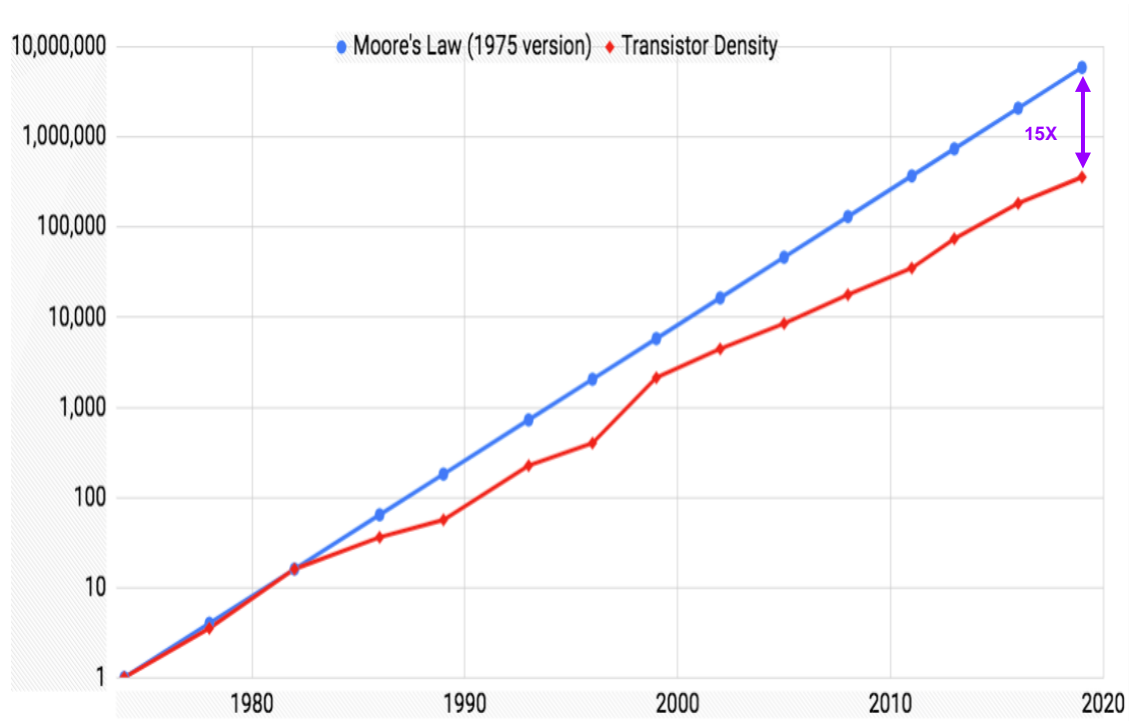
Moore, Gordon E. "No exponential is forever: but 'Forever' can be delayed!"
Solid-State Circuits Conference, 2003.
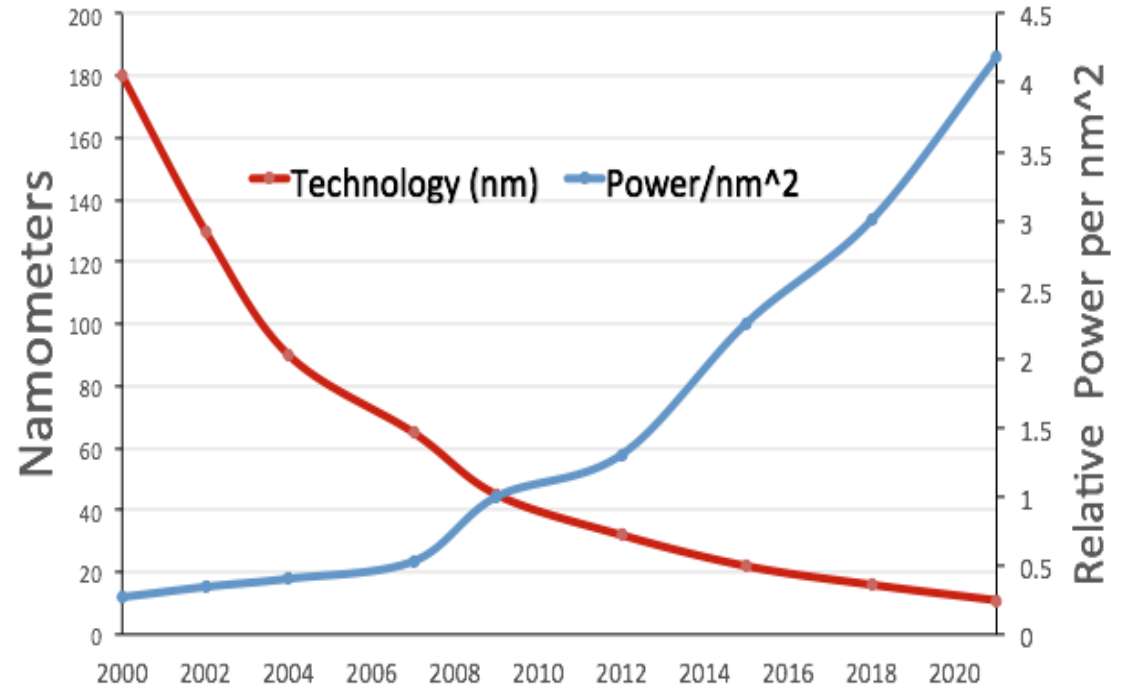
Power consumption based on models in "Dark Silicon and the End of Multicore Scaling," Hadi Esmaelizadeh, *ISCA,* 2011

Starting on a Solution Path: Connecting the Dots
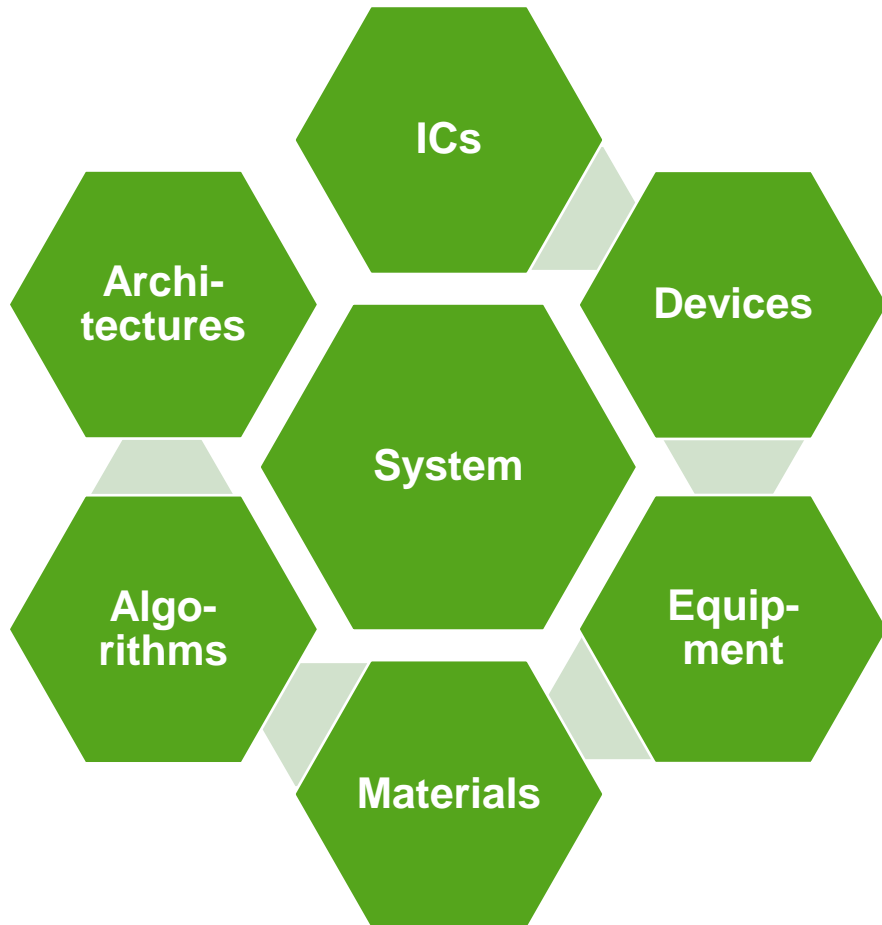
SEMI Future of Computing Workshops

- **October 2023: Domain-Specific Architectures**

- **July 2024: AI Hardware Innovation, Quantum & Integrated Photonics**

- **October 2024: System-level Innovation for Sustainable AI**

Oct 2023: Domain-Specific Architectures

Overview of Participants

July 2023: AI HW Innovation & Quantum

Novel Architectures and Device

Prof. Subhasish Mitra, Stanford University

Wendy Zhu, McKinsey & Company – "From Silicon to System: Unveiling Demand and Hardware Innovation Driven by GenAI"

Jim Sexton, IBM Research Europe - "Future of Computing Challenges and Opportunities"

John Hu, Nvidia – "Accelerating Intelligent Computing By Rapidly Evolving AI Technology"

Paul Master, CTO, Cornami - "The Collision of Big Data, Big Compute and Big AI - The End of the Von Neumann Era"

Quantum Sensing and Computing

Carlos Augusto, QuantumSemi - "New CMOS-Compatible Metamaterials for Classic and Quantum Photonics"

Celia Merzbacher, Quantum Economic Development Consortium - "Use cases for quantum sensors & computers: Feasibility & impact"

Charles Chung, IBM - "Quantum for Semi: Applying Quantum Computing to Semiconductor Challenges"
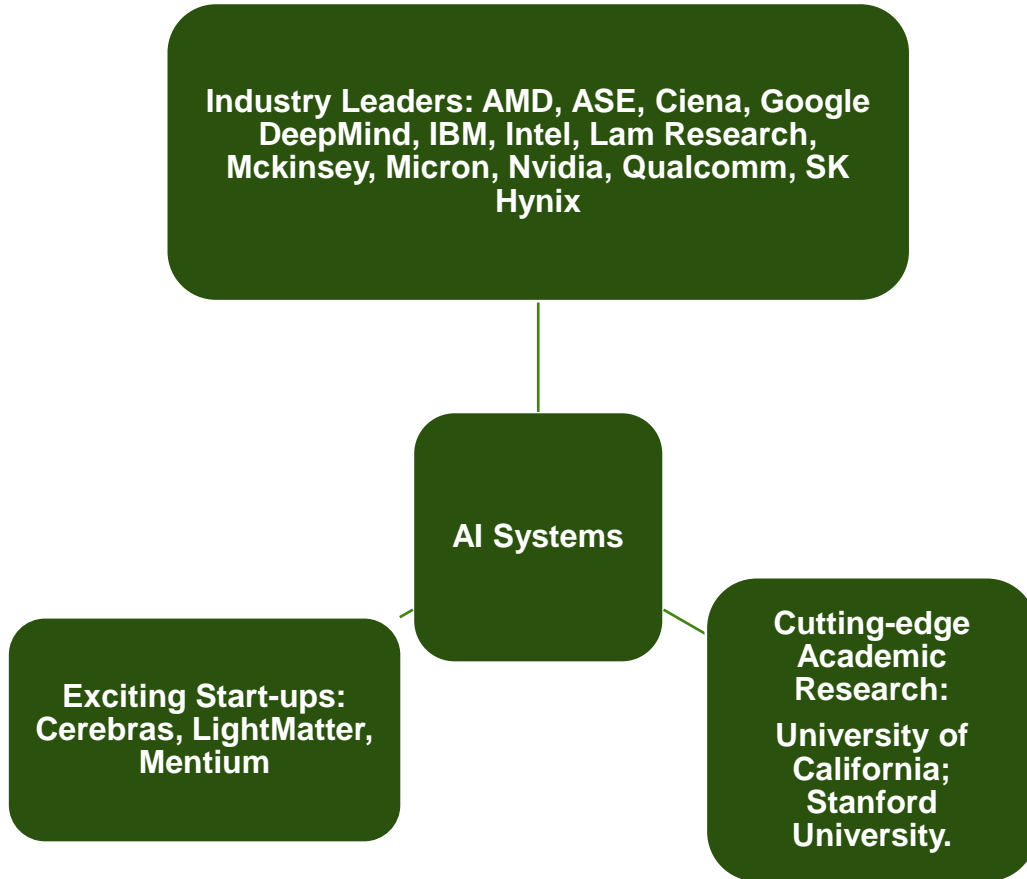
Andrew Wagner, Semiconductor Research Engineer, Intel - "From transistors to qubits – scalable silicon-based quantum computing"

Piia Konstari, VTT Research Center Finland - "Technologies to scale up superconductive quantum computers."

2X oversubscribed!

Oct 2024: System Innovation for Sustainable AI
Assembling the Village!

Industry Leaders: AMD, ASE, Ciena, Google DeepMind, IBM, Intel, Lam Research, Mckinsey, Micron, Nvidia, Qualcomm, SK Hynix

AI Systems

Exciting Start-ups: Cerebras, LightMatter, Mentium

Cutting-edge Academic Research: University of California; Stanford University.

- **Strategic and Market Overviews: The Big Picture**
- **Panels**
  - **Novel Devices and Materials**
    - **2D Materials, Memories & Analog Computing**
  - **Critical Enabling Technologies**
    - **Advanced Heterogeneous & 3D Packaging, Photonic-Electronic Integration, Chiplets**
  - **Novel Architectures and Algorithms - Edge AI**
    - **Energy efficiency, IoT integration, Rapid Communication**
  - **Novel Architectures and Algorithms - Data Center & Cloud**
    - **High Performance, HW-SW Co-optimization**

semi | SMART DATA-AI

Semiconductor-Enabled AI Future Is Bright
If We Can Address the Challenges

Improve Human Health…   **… And Planet Health…**   **… Reduce Emissions…**   **… Predict Climate Disasters…**

And Many More Opportunities We Haven't Even Considered Yet!

Looking Ahead – What Is Needed?

- **Accurate Digital Twins**

- **Data and Digital Twin Standards**

- **Rapid, low-cost R&D and Innovation**

- **Global optimization of AI Systems**

- **Innovations for Sustainability**

THANK YOU!