FUTURE COMPUTING MODELS

TECHNOLOGY IN THE 2030-2040 HORIZON

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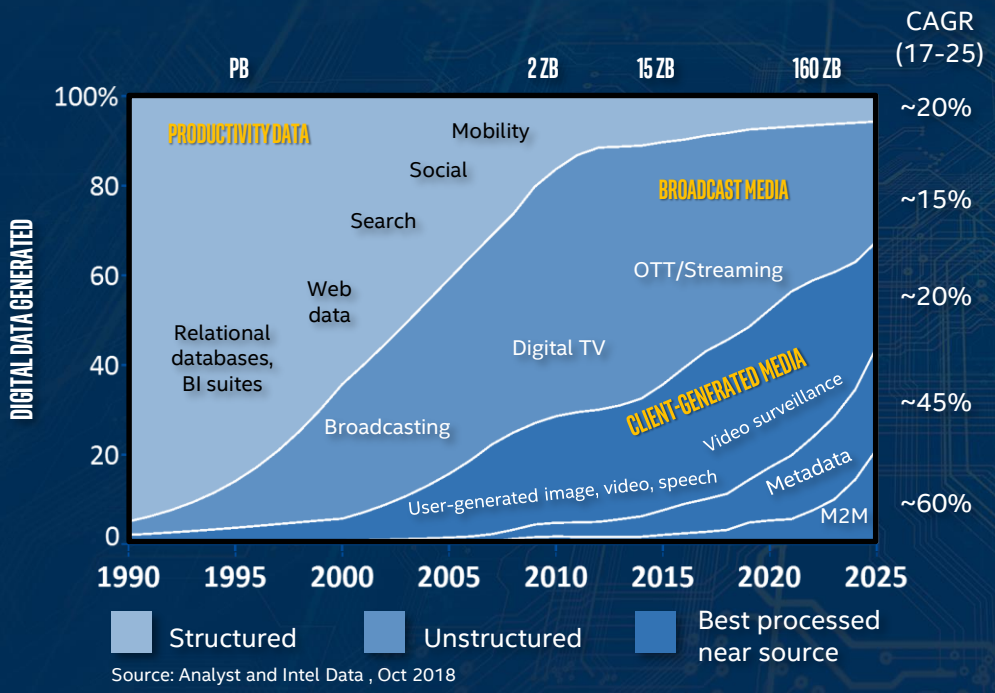
THE SHIFTING NATURE OF DATA…



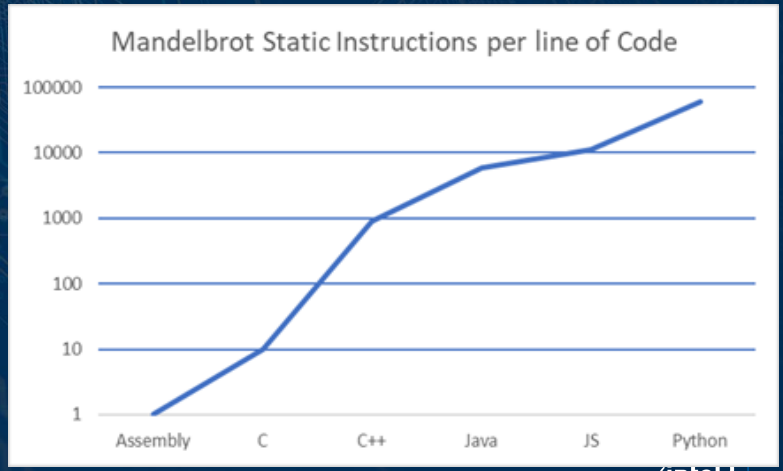
Source: Analyst and Intel Data , Oct 2018

… MOTIVATES NEW OPTIMIZATIONS

Data at the edge, more unstructured

Distributed compute, more M2M

Unintended programming inefficiencies

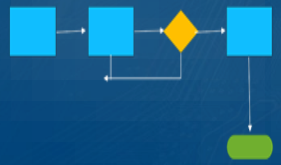


COMPUTE ARCHITECTURE PROGRESSION

Co-evolution of Software & Hardware Solutions

CONVENTIONAL

- Known procedures
- Generate answers

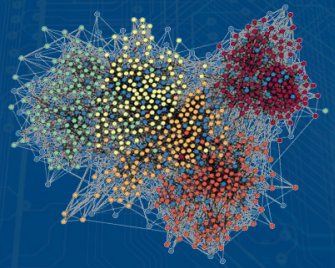


DEEP LEARNING

- Known answers
- Generate procedures with training

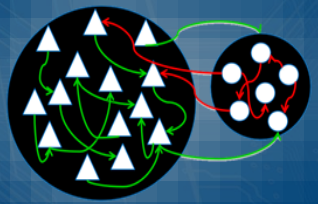
GRAPH ANALYTICS

- Graph edges and vertices represent relationships
- Big, sparse data structures



NEUROMORPHIC

- Many procedures
- Adapt the answer with reinforcement



QUANTUM

- Answers superimposed
- Select and measure the answer

2015-2025

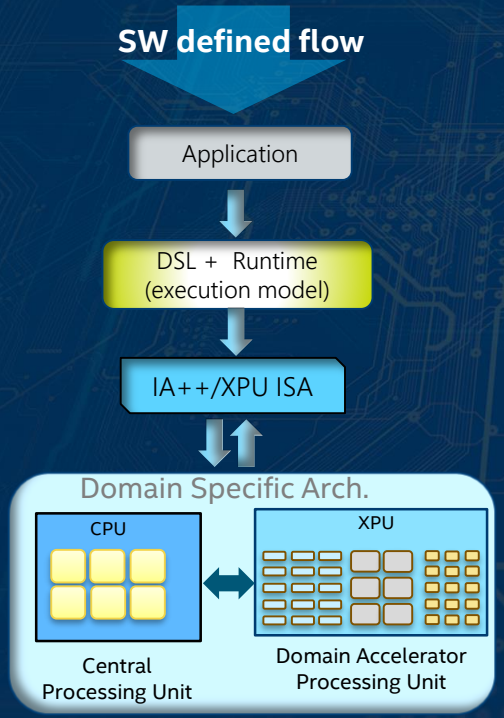
2020-2030

2025-2035

SW DEFINED HW

SDH Augments GP Processors

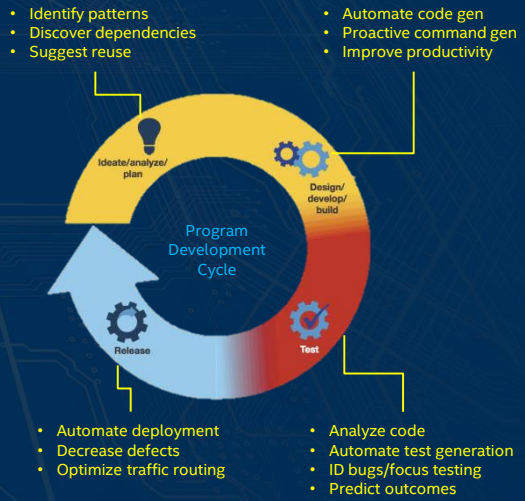
App
↓
Domain Specific Language
↓
Domain Specific Architecture
↓
H/W Product



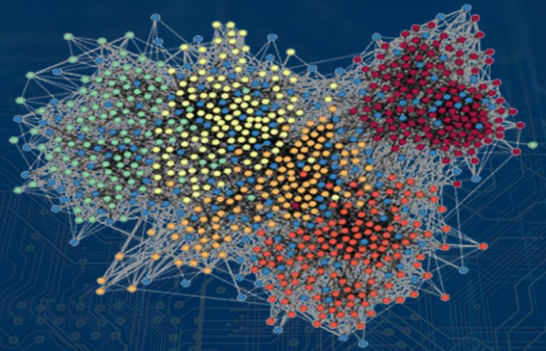
AI GENERATED SW

AI Driven SW Development

Design
↓
Intelligent Assist
↓
Code Generation
↓
Manage
↓
Test
↓
Maintain



GRAPH ANALYTICS



STATUS

Multiple query languages and processing engines

DARPA Graph Challenge

CHALLENGES

Sparse and irregular memory accesses

Small data accesses with frequent synchronization

Scaling to very large datasets

OPPORTUNITIES

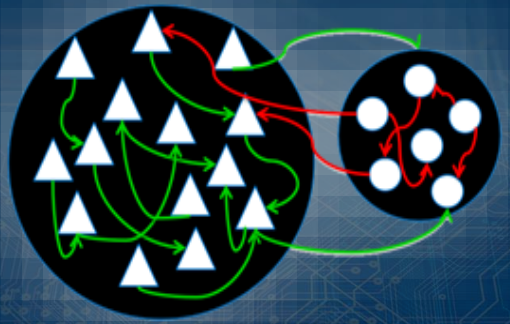
Real-time decision making

Fraud detection

Social network analysis

Anomaly detection

NEUROMORPHIC COMPUTING



STATUS

Complex neural network topologies

~1 billion neurons demonstrated

CHALLENGES

Neuroscience model development

Algorithm development

S/W & Simulation tools

OPPORTUNITIES

Constraint Satisfaction

Real-time Learning

Adaptive Control

Complex Systems Modeling

QUANTUM COMPUTING

STATUS

~100 organizations investing

8 qubit types

~100μs coherence time for SC

Hybrid classic-quantum algo's in dev't

CHALLENGES

Decoherence & error-correction

Low-latency qubit control

Qubit scale-up

Algorithms/Compilers

Workloads for testing

OPPORTUNITIES

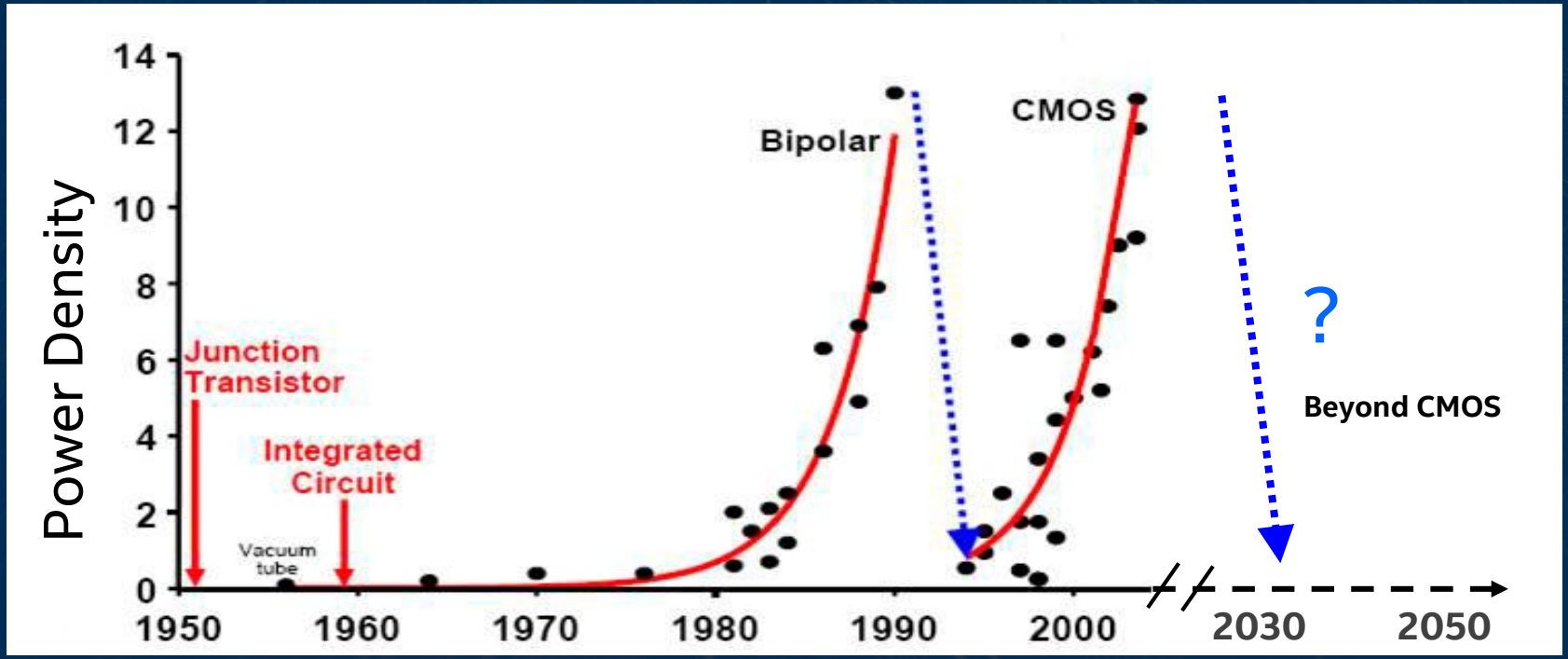
Molecular structure

Materials science

Pharmacology

Cryptography

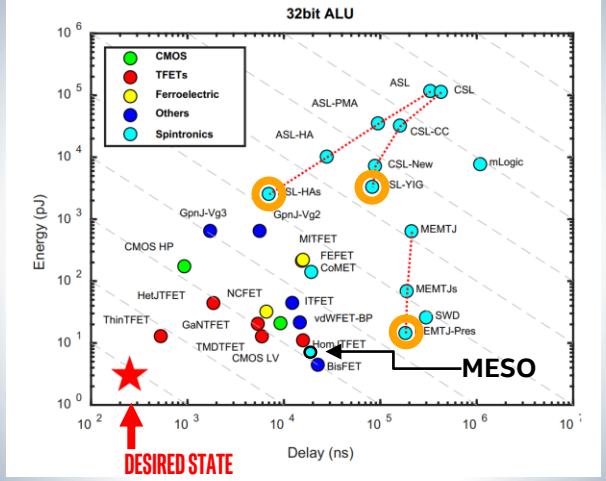
POWER/THERMALS DRIVES BEYOND CMOS



R. Schmidt et. al., IBM J R&D (2002)

BEYOND CMOS

NOVEL DEVICES IMPROVING

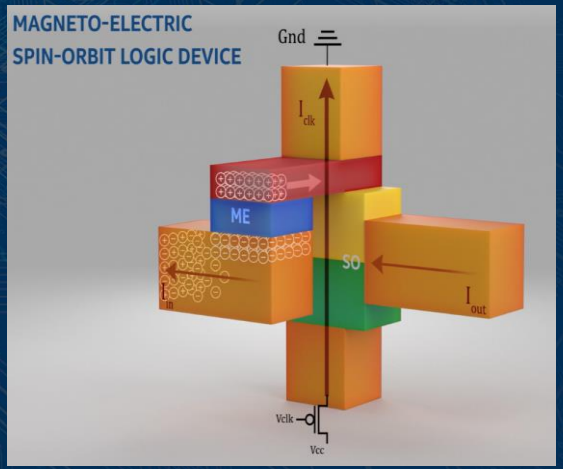


Source: C. Pan; A. Naeemi. "An Expanded Benchmarking of Beyond-CMOS Devices Based on Boolean and Neuromorphic Representative Circuits" IEEE Jan 2018 10.1109/JXCDC.2018.2793536

Improved switching efficiency

Better understanding of logic circuits

EXAMPLE: MESO



Magneto-Electric Spin-Orbit

100mV operation

10X-30X better power/perf than CMOS

ENABLED BY ACADEMIC-INDUSTRY-GOVERNMENT

SUMMARY

New architectures and new technologies needed to manage massive workloads

The new data era will shift compute toward data and S/W-centric H/W

Power & Thermal drive the need to move beyond CMOS

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