FPGAs in 2032: Challenges and Opportunities in the next 20 years

Convergence of Programmable Solutions

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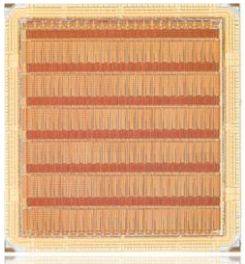
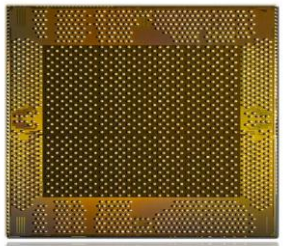
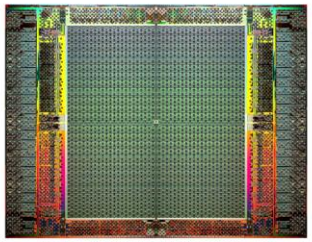
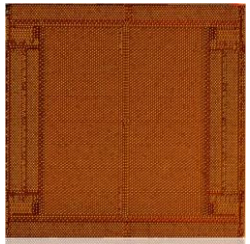
Tempting Topic Not Discussed Here

- Predictions from 1992 about 2012
  - Accurate ones
  - Hilarious ones
  - Probably more accurate than now predicting 2032

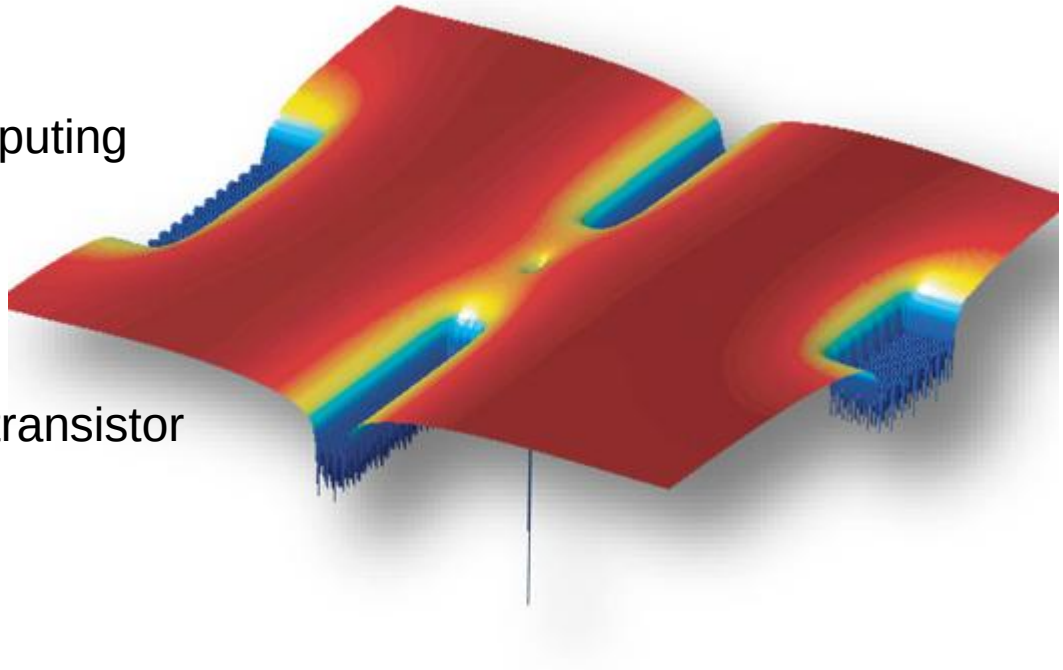
1990s **2010s**

Glue Logic	Heterogeneous Capabilities	High Integration/ Bandwidth	Hardened Subsystems	Cortex-A9 MPCore
				
Flex 6000 3µ process	Stratix I 130nm process	Stratix IV 40nm process	Stratix V 28nm process	SoC FPGA 28nm process

Tempting Topic Not Discussed Here

Quantum Computing

A single atom transistor



A controllable transistor engineered from a single phosphorus atom has been developed by researchers at the University of New South Wales, Purdue University and the University of Melbourne. The atom, shown here in the center of an image from a computer model, sits in a channel in a silicon crystal. (Credit: Purdue University)

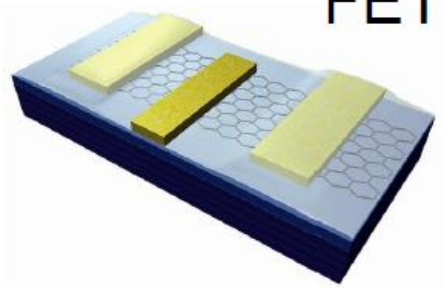
Tempting Topic Not Discussed Here

- DNA computing
  - Scientists at IBM are experimenting with using DNA molecules as a way to create tiny circuits that could form the basis of smaller, more powerful computer chips.

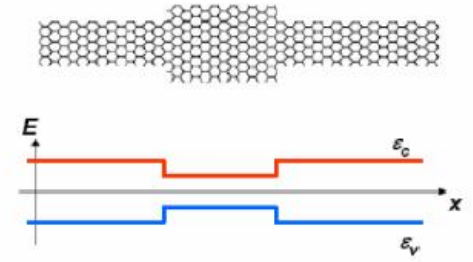
Tempting Topics Not Discussed Here

Conventional Devices

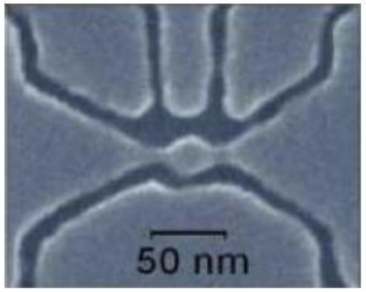
FET



Band gap engineered
Graphene nanoribbons

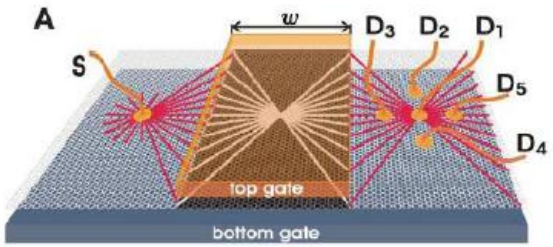


Graphene quantum dot



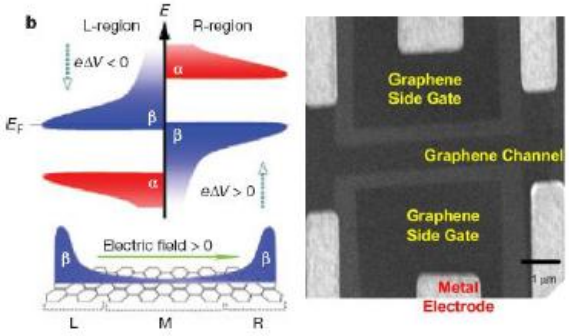
(Manchester group)

Nonconventional Devices



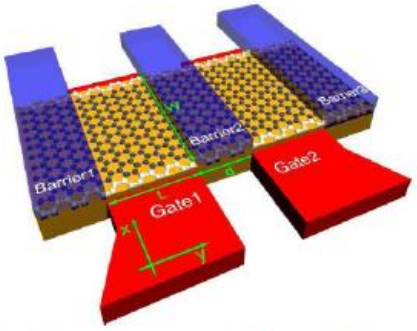
Graphene Veselago lense

Cheianov *et al. Science* (07)



Graphene Spintronics

Son *et al. Nature* (07)



Graphene pseudospintronics

Trauzettel *et al. Nature Phys.* (07)

P. Kim – Columbia U.

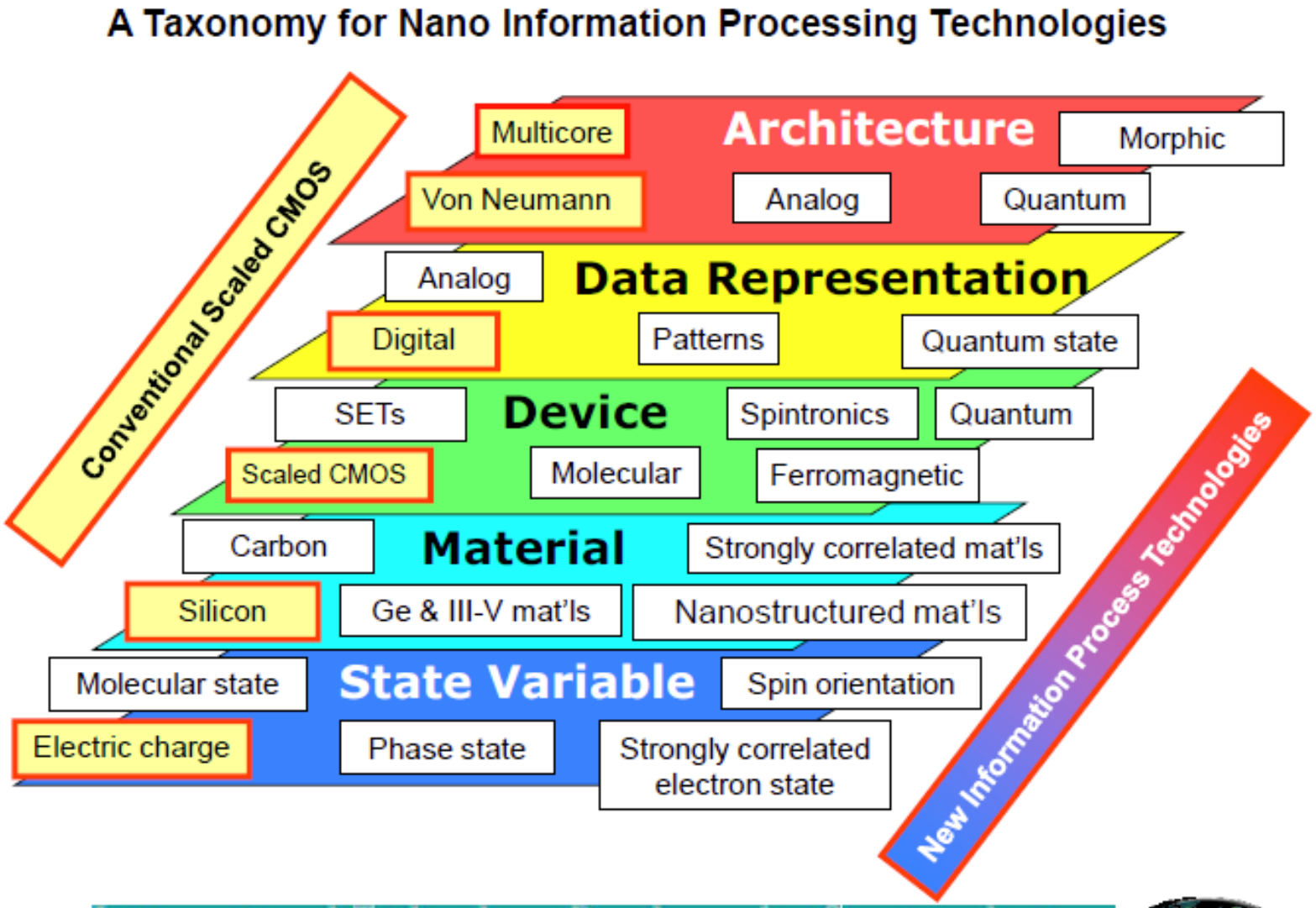
Tempting Topics Not Discussed Here

- Wonderful applications of technology in 2032
  - 6 billion connected people
  - 100 billion connected devices
    - Internet of Things
  - Wearable electronics
  - Genome informatics and personalized medicine
  - Intelligent robots and machines
    - Singularity
  - Many others…

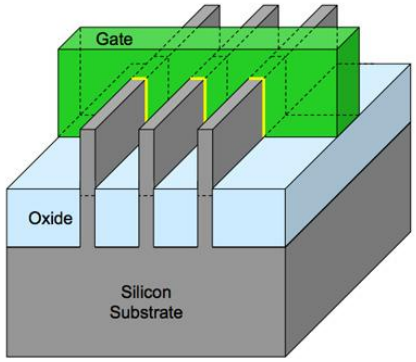
Topics Discussed Today

- Convergence of programmable platforms
- A need for programming models, languages and compilers for converged programmable platforms
- Summary

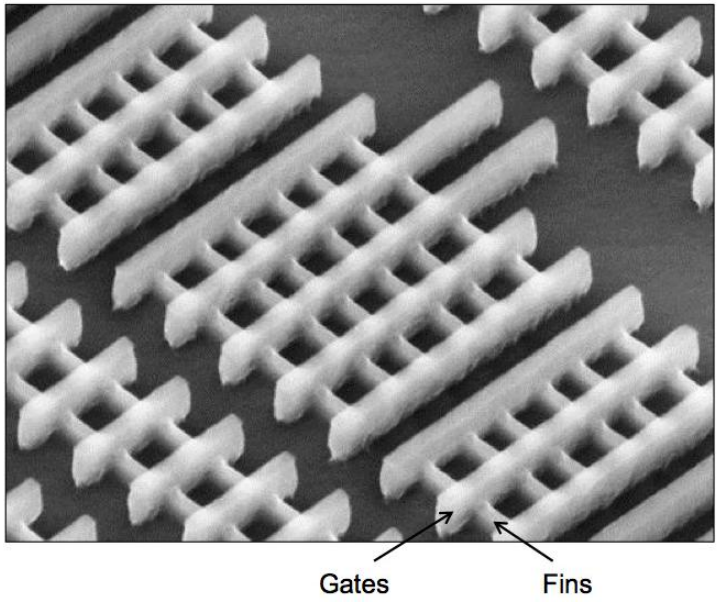
ITRS Roadmap Ends In 2026



Intel 22nm FinFET Announced May 2011



Process Name	P1266	P1268	P1270	P1272	P1274
Lithography	45 nm	32 nm	22 nm	14 nm	10 nm
1st Production	2007	2009	2011	2013	2015



- Claimed benefits relative to 32nm:
  - 18% faster at 1.0V, 37% faster at 0.7V
  - 50% lower power at same performance
  - 2-3% higher cost than planar process

“More Moore” Projections

Year	2012	2014	2017	2020	2023	2026	2029	2032
Node	20nm	14nm	10nm	7nm	5nm	3.5nm	2.5nm	1.8nm
# FETs per die (B)	8	14	28	56	113	222	453	887
M1 1/2 pitch (nm)	32	24	16.9	11.9	8.4	6	4.2	3
Lgate (nm)	22	18	14	10.6	8.1	5.9	4.2	3

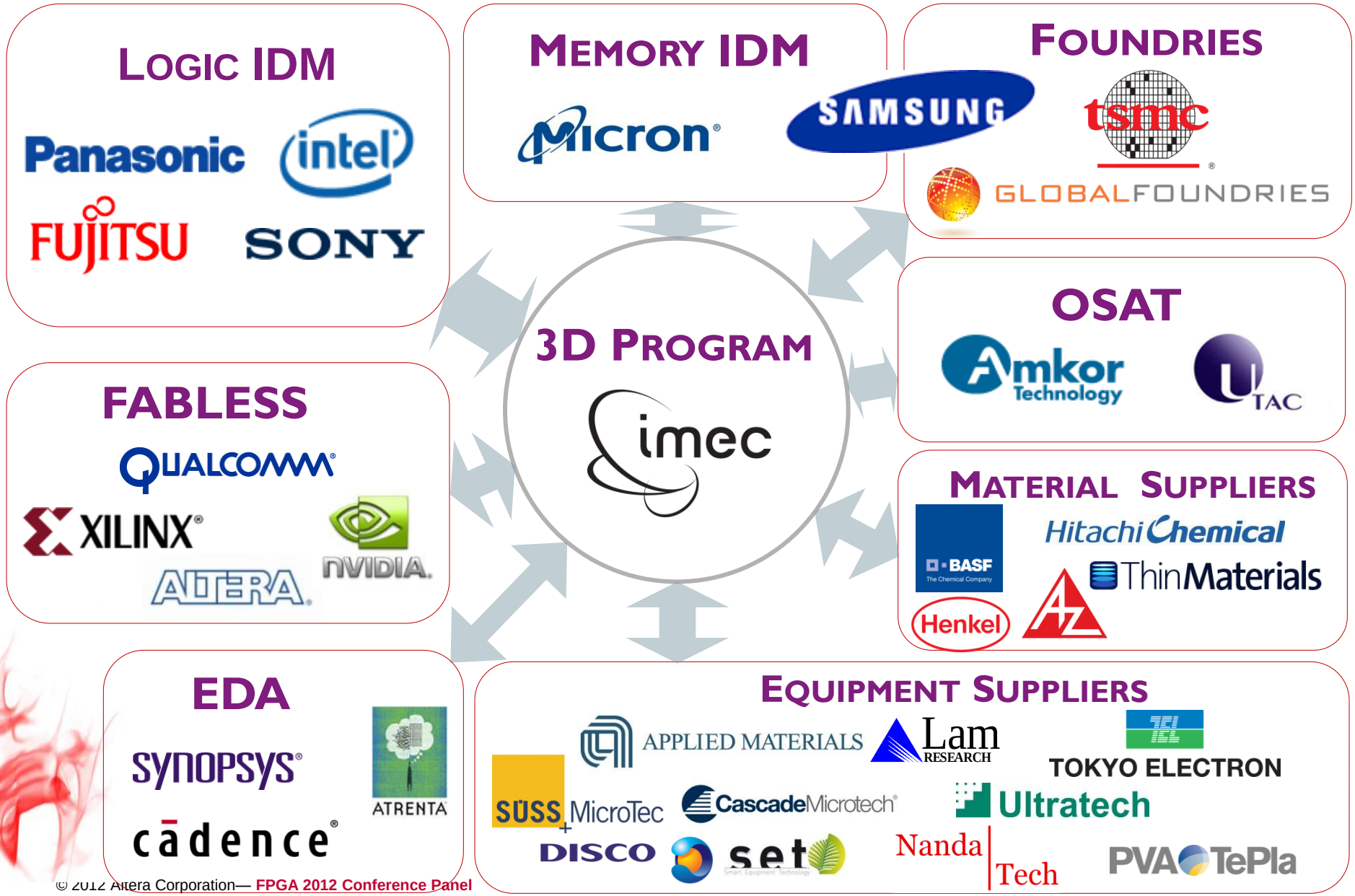
* Normalized to 20nm

- Sources: ITRS 2010, ITRS 2011, Altera projections beyond 2026

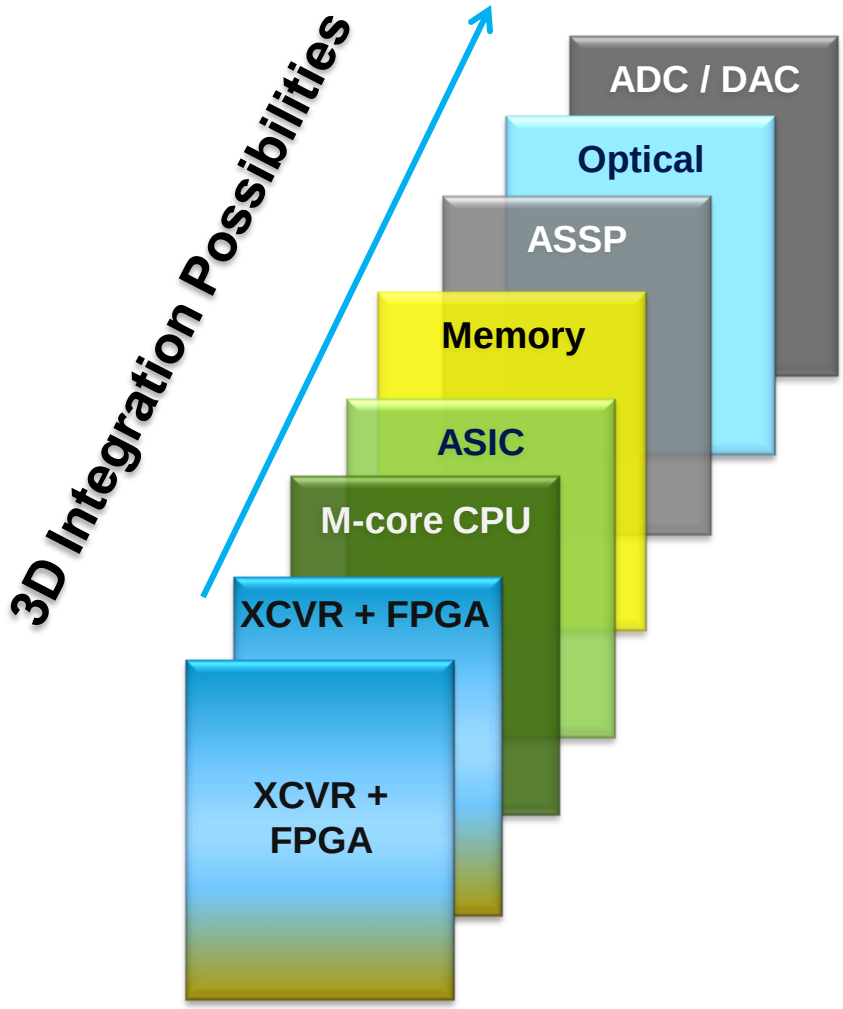
2032 Process Technology Extrapolation

- "More Moore" scaling produces:
  - ~1 Trillion transistors per die, >100X of 20nm technology
  - 250X increase in throughput compared to 20nm
  - Minimum features of ~13X silicon atomic spacing
  - Faster transistors, but much slower interconnect
- Many significant challenges exist
  - New materials and device structures are necessary
    - Long term options: Tunnel FET, nano wires, graphene, non-CMOS devices
- Slower scaling combined with 3D is an attractive alternative
- More Than Moore can achieve same transistor count as More Moore

IMEC 3D System Integration Program

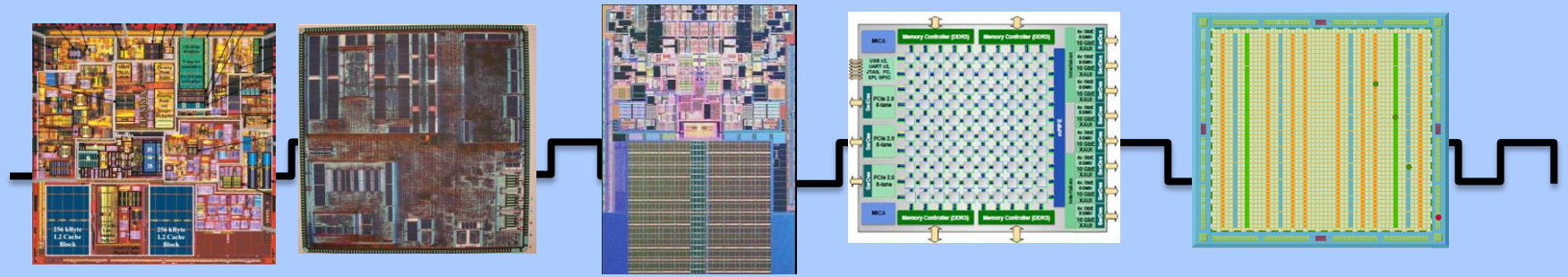


3D Integration Technology Opportunities



Programmable Platforms in 2012

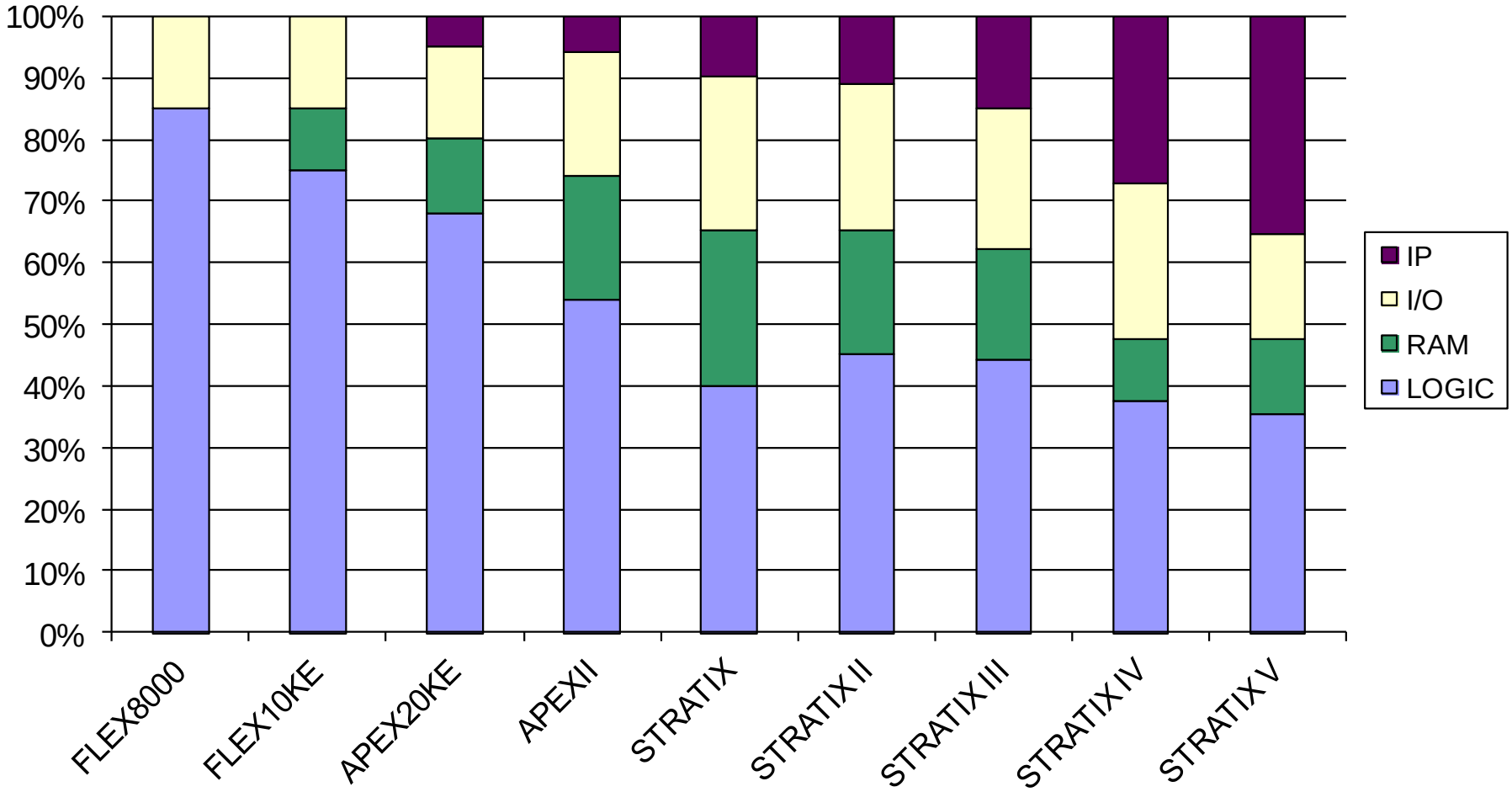
- Moore's law has enabled a range high density programmable platforms



CPUs | DSPs | Multi-Cores | Many-Core Arrays | FPGAs

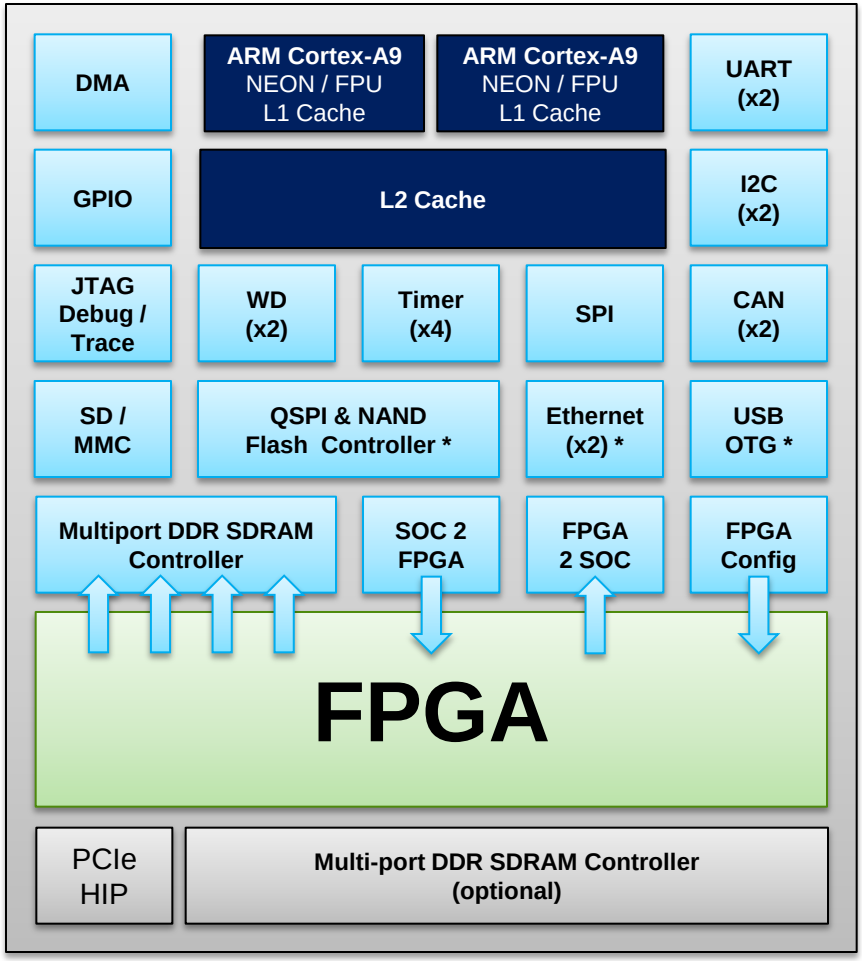
Single Cores	Multi-Cores Coarse-Grained CPUs and DSPs	Coarse-Grained Massively Parallel Processor Arrays	Fine-Grained Massively Parallel Heterogeneous Arrays

Augmenting Fine-Grained Fabric with Coarse-Grained Programmable Functions in FPGAs



Emerging SoC FPGAs

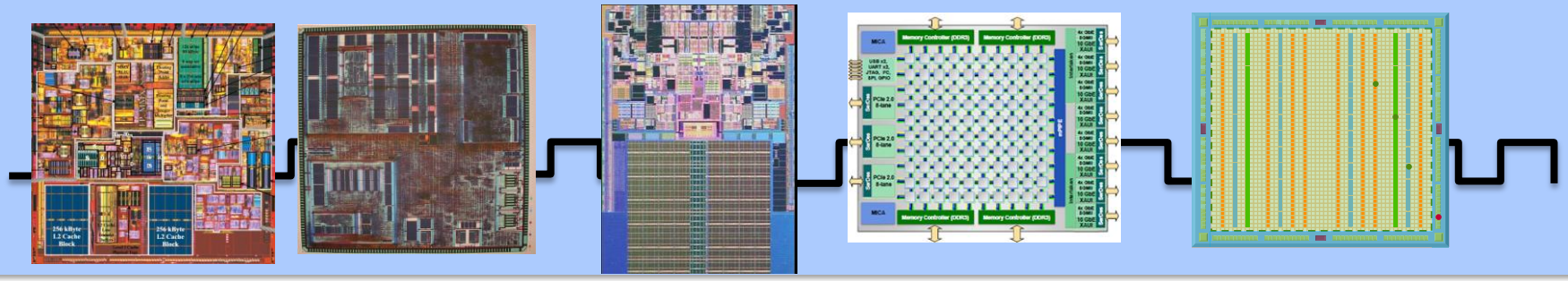
- Processor
  - Dual ARM Cortex-A9
- SDRAM Controller, Peripherals
- Other Hard IP
  - Serial protocols, memory interfaces
- FPGA programmable fabric
  - Multiple density options
- Programming model: C/C++ for ARM
  - Common operating systems
  - APIs for hardware accelerators developed in HDL (Verilog, VHDL, System Verilog), or C/C++ by using high-level-synthesis
  - OpenCL



* Integrated DMA logic

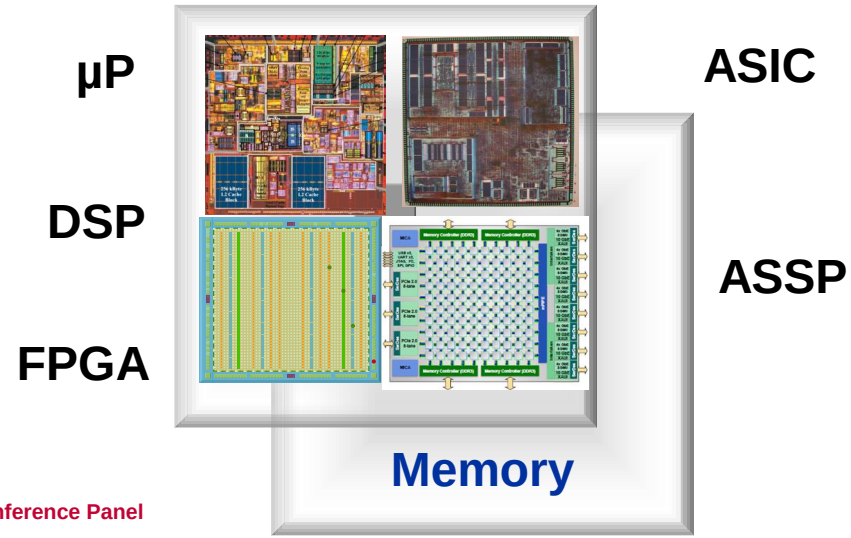
Programmable Convergence in 2022-2032

2012



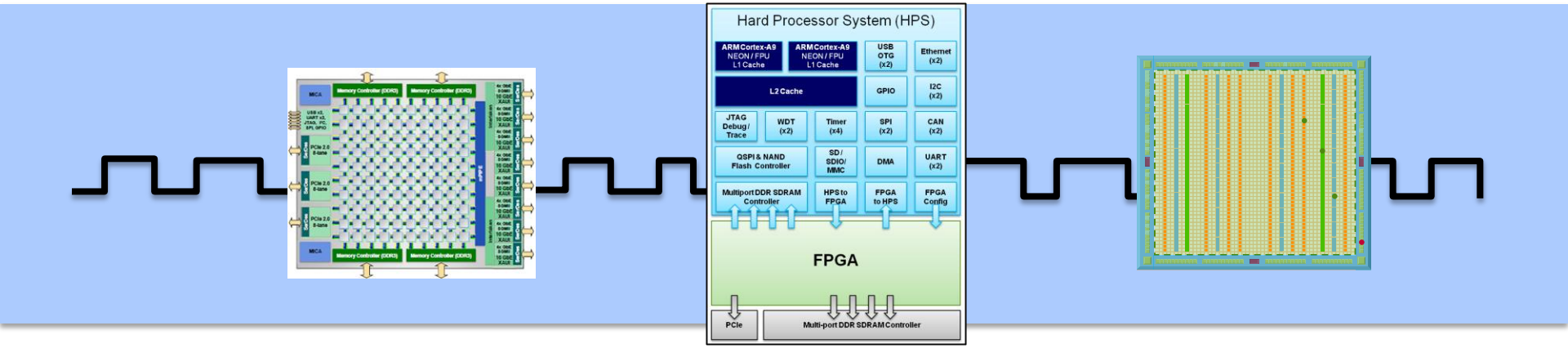
- From 2022 to 2032 all SoCs will be programmable, a combination of today's architectures

2022 –2032



Emerging Parallel Programming Models

- Parallel programming is still evolving for many-cores
- OpenCL emerging for many-cores, FPGAs and SOC FPGAs



Many-Core Arrays — **SOC FPGAs** — **FPGAs**

- CUDA, OpenCL for GPUs,
- Versions of C, C++ and bare-metal programming for many-cores

- OpenCL parallel programming for FPGAs and SOC FPGAs
- C/C++ for ARM with OpenCL for implementing and managing hardware accelerators

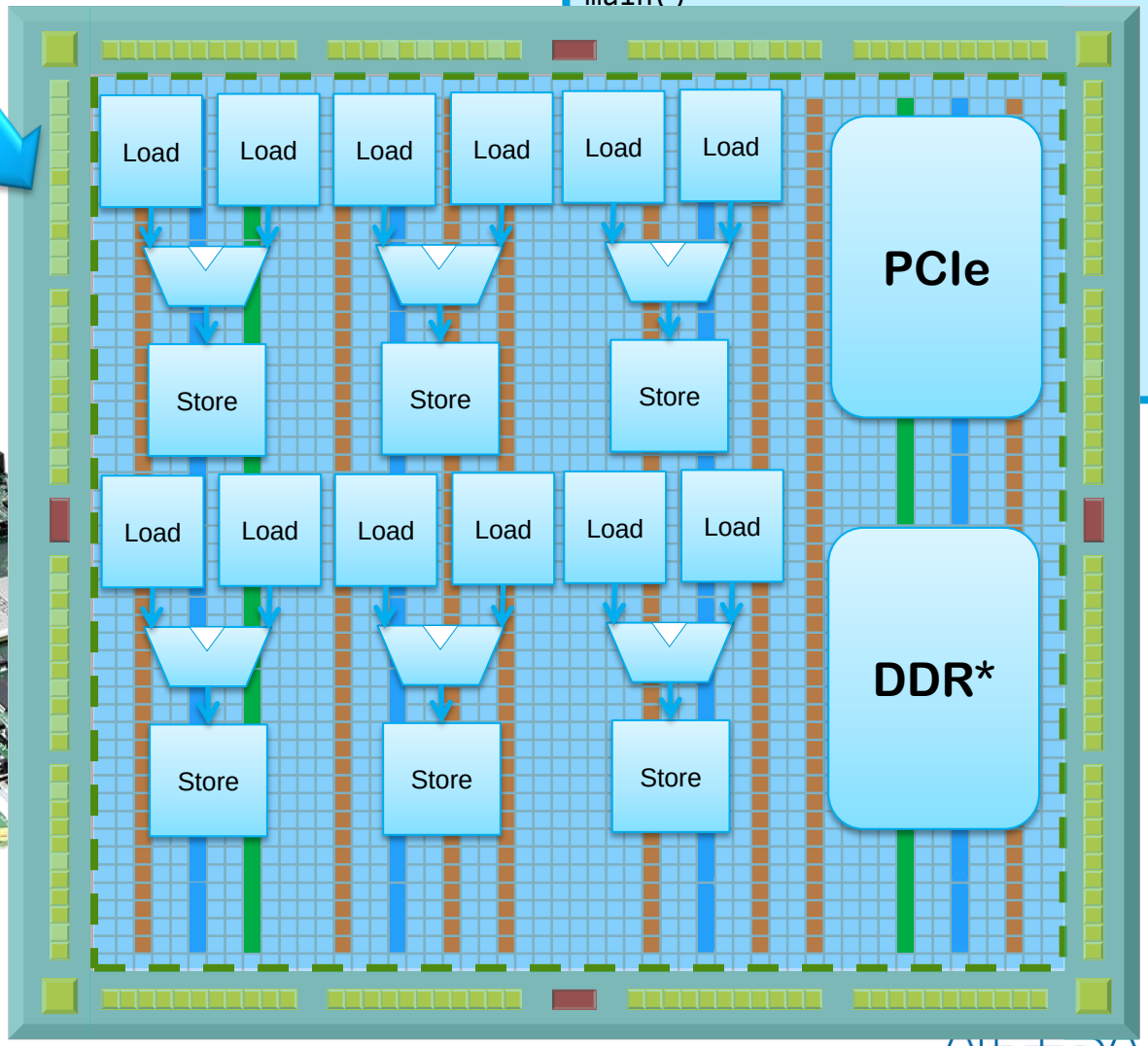
OpenCL Compiler for FPGAs

Host Program

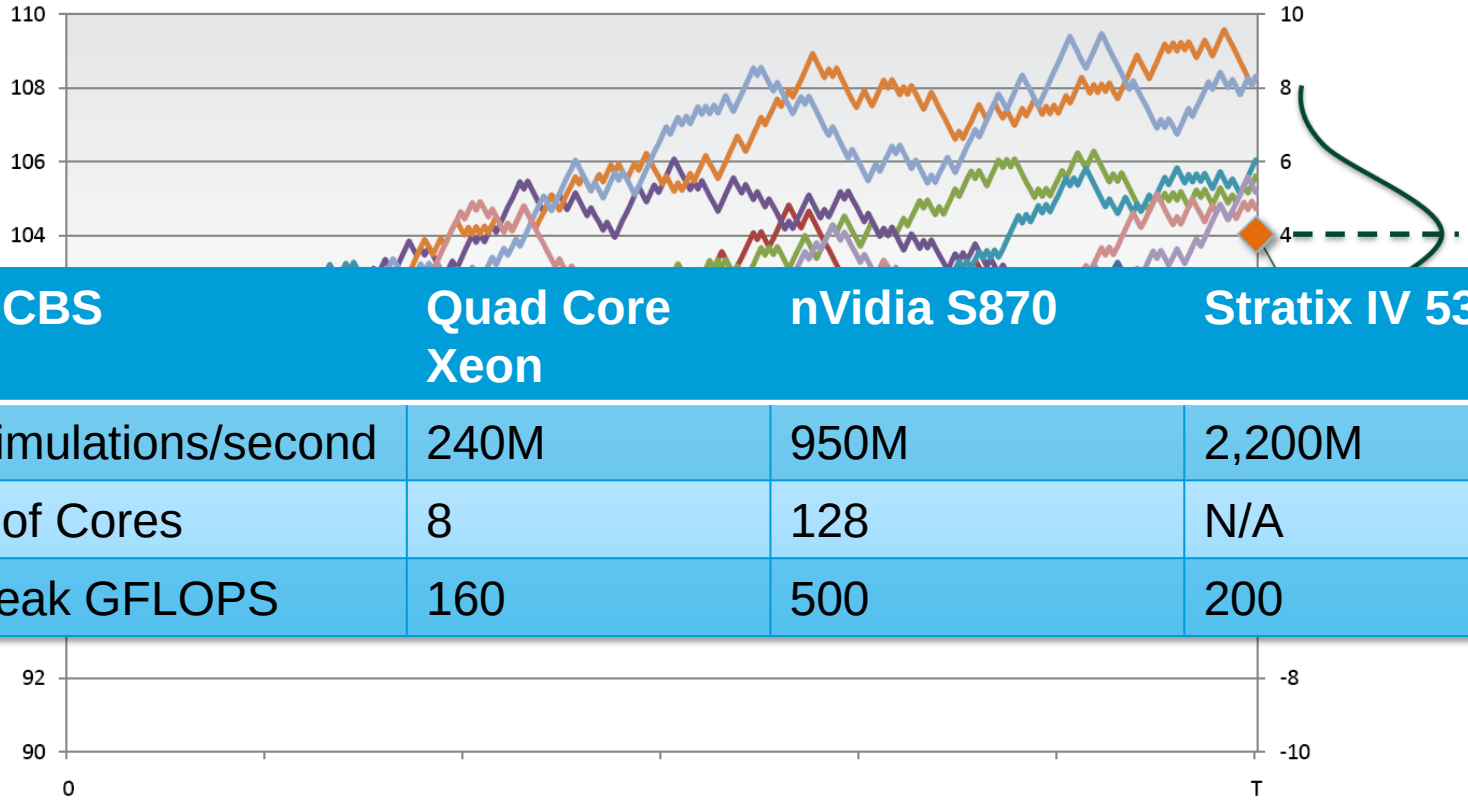
```
__kernel void
sum(__global const float *a,
__global const float *b,
__global float *answer)
{
int xid = get_global_id(0);
answer[xid] = a[xid] + b[xid];
}
```

```
int xid = get_global_id(0);
answer[xid] = a[xid] + b[xid];
}
```

```
main()
```



Finance : Equity Derivative Pricing



MCBS	Quad Core Xeon	nVidia S870	Stratix IV 530
Simulations/second	240M	950M	2,200M
# of Cores	8	128	N/A
Peak GFLOPS	160	500	200

- Monte Carlo simulation of all possible paths for the underlying equity value

Summary

- Key directions to 2022 and 2032
  - Convergence of programmable platforms
    - Heterogeneous architectures
  - Programming models and compilers for the converged programmable platforms

Thank You