TrueNorth : A Neurosynaptic Integrated Circuit with 1 Million Spiking Digital Neurons

Yutaka Nakamura

IBM Research - Tokyo

Acknowledgement

- IBM Cognitive Computing Team and Dharmendra Modha

- Cornell University

- DARPA (This talk does not represent their view….)

- And many other universities and government agencies.

Explosive Growth of Unstructured Data

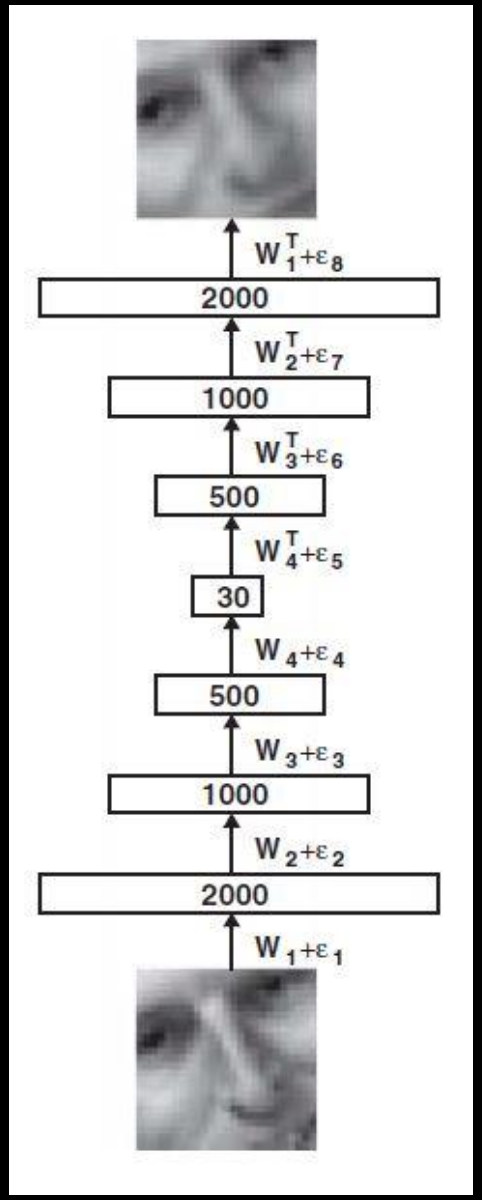
Reality of Today's VLSI Field

- Clock is not getting faster.
- Instruction level parallelism does not improve.
- Operation voltage does not go down.
- Leakage current is increasing.
- Cost per transistor is not getting cheaper.

- We need a new paradigm.

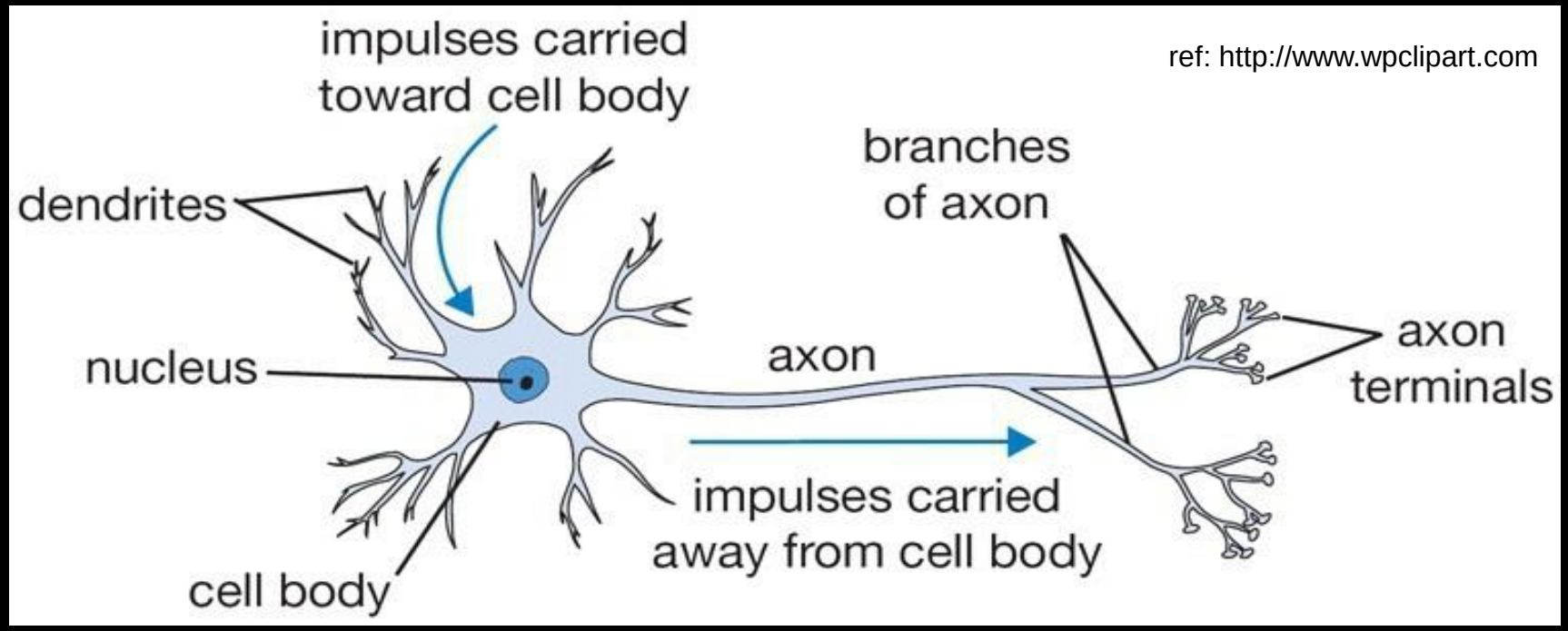
Neural Network Resurgence

- Deep Belief Network: many layer network outperforms conventional networks.
- There is a strong resurgence of interest in neural networks in the community.

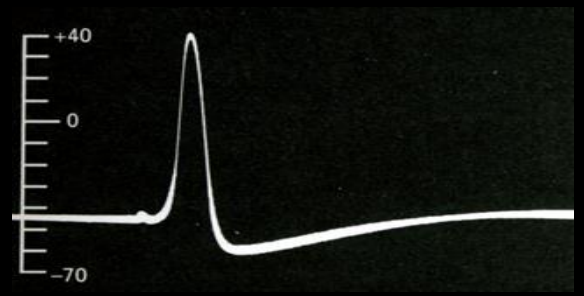


From Hinton 2006

Biological Inspiration → What Neurons Do

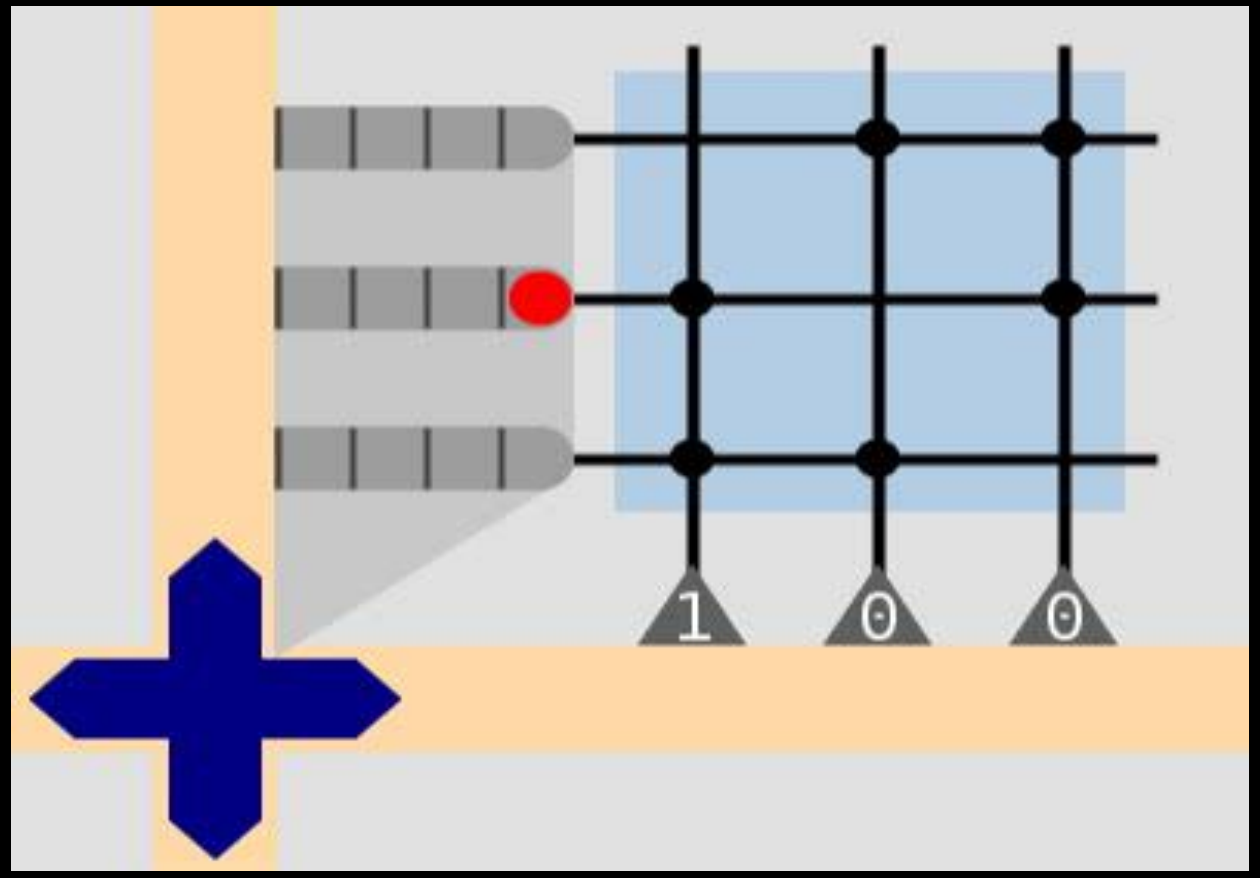


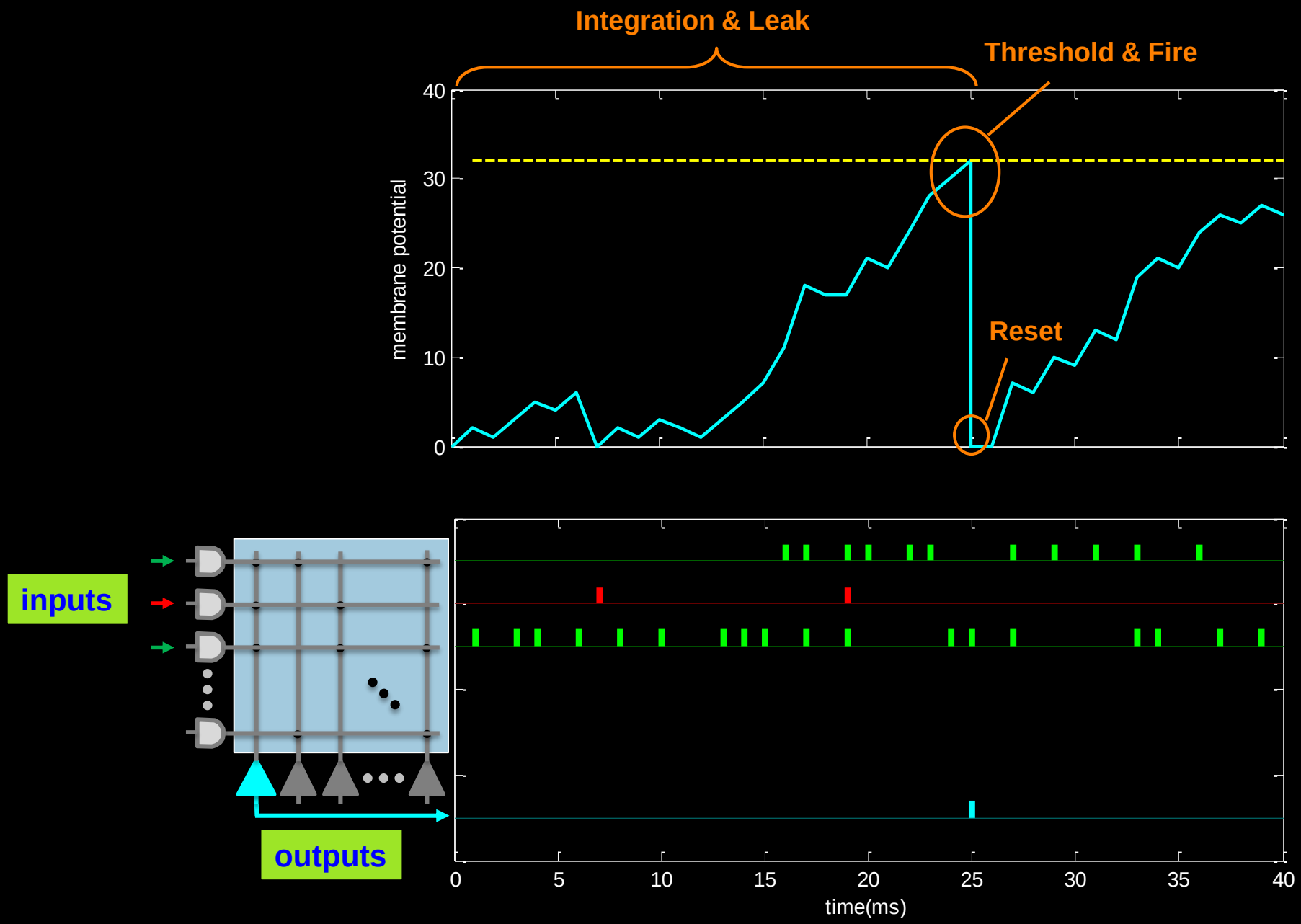
- Neuron integrates inputs received on dendrites
- Launches an electrical pulse - “spike” - down axon when a threshold is reached



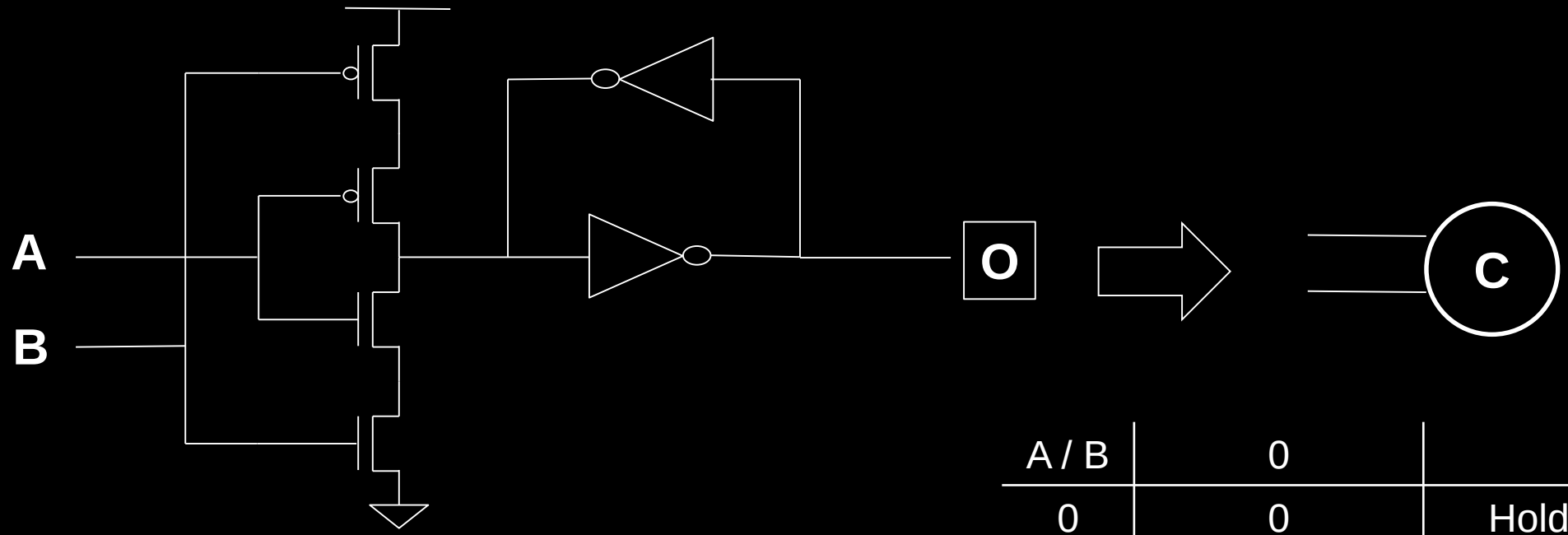
How It Works:

“neurons”, “synapses”, “axons”, “dendrites”




Integration & Leak
Threshold & Fire
Reset
membrane potential
40
30
20
10
0
inputs
outputs
0
5
10
15
20
25
30
35
40
time(ms)

C-element : State Device for Asynchronous Circuit

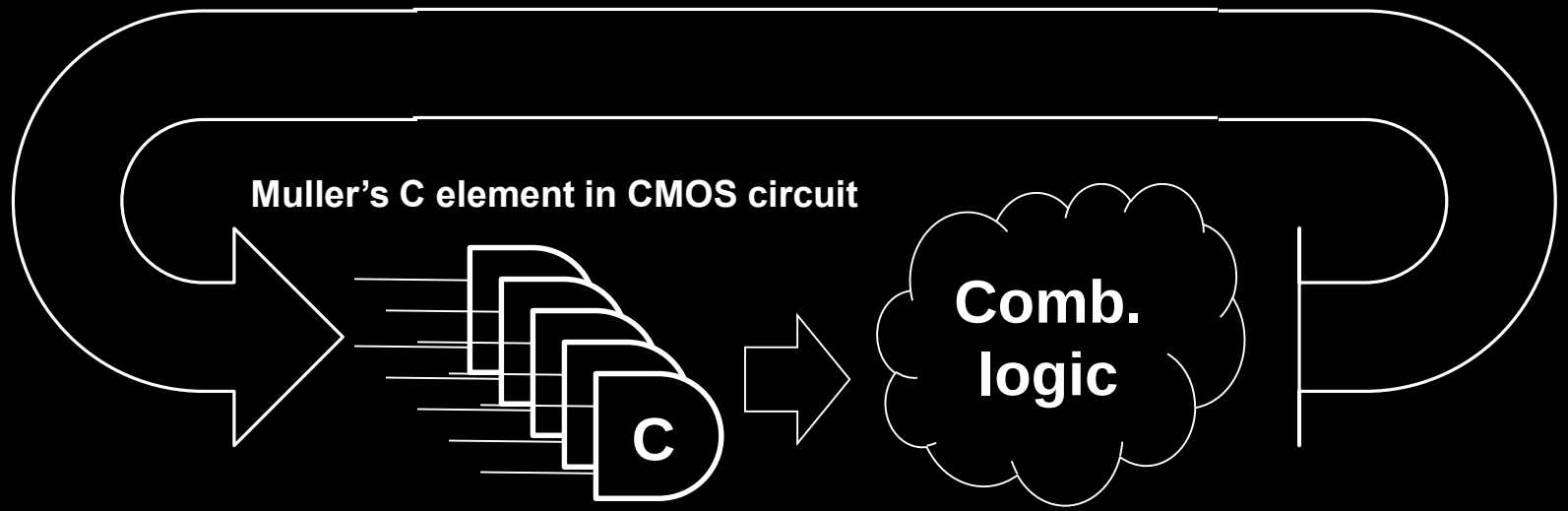


Muller’s C element in CMOS circuit

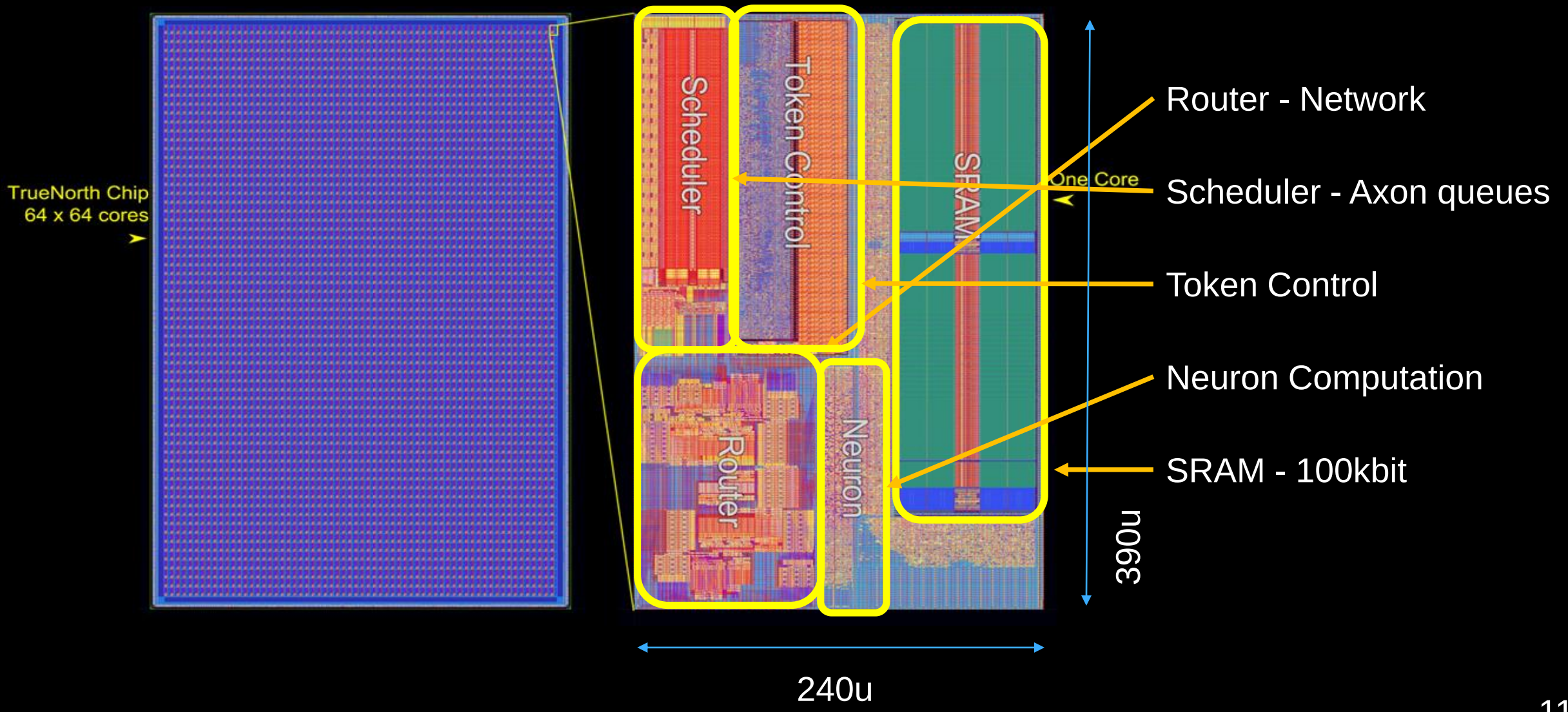
A / B	0	1
0	0	Hold value
1	Hold value	1

Asynchronous Circuit Properties

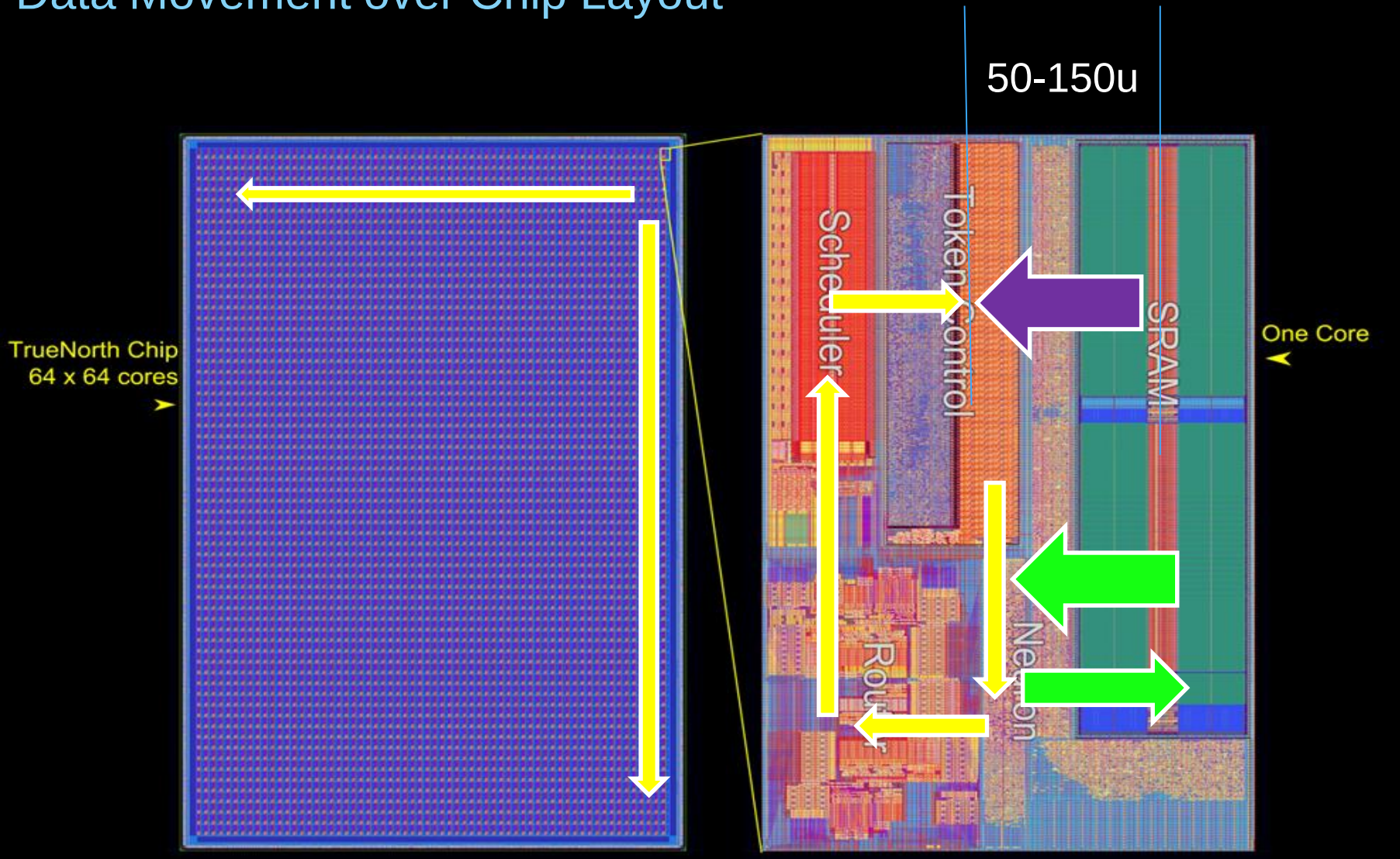
- **Circuit works in an event-driven fashion. No system clock.**
- **When there is no task to be performed, the circuit goes totally quiet.**



TrueNorth Chip Layout



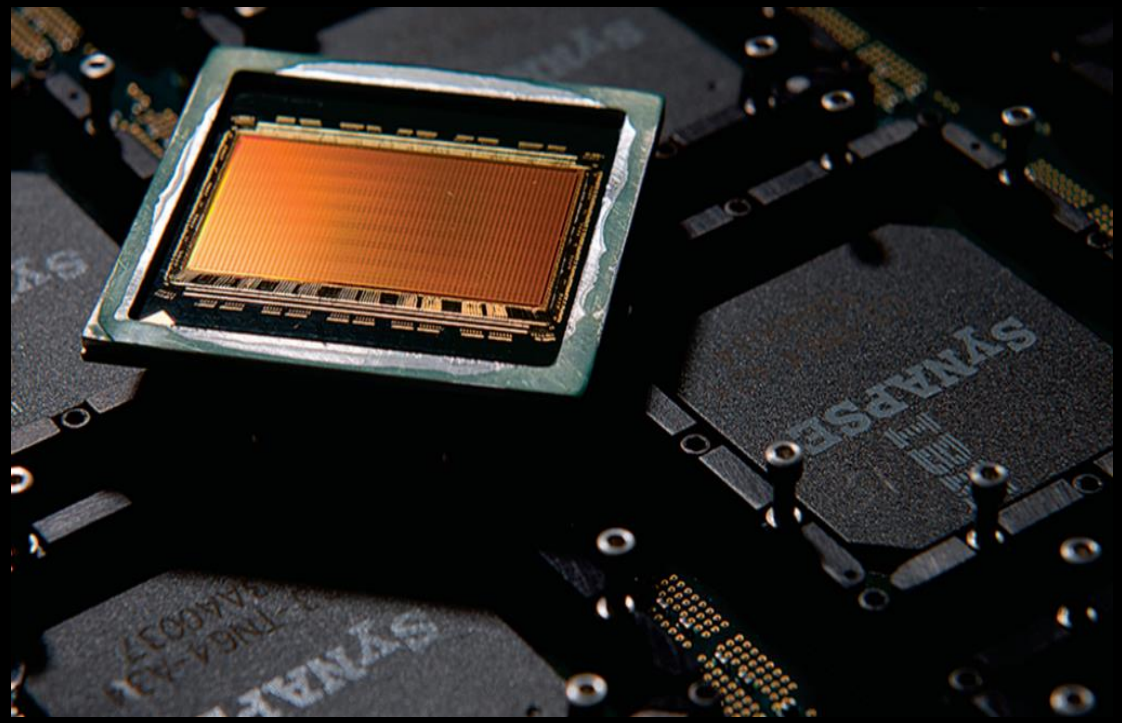
Data Movement over Chip Layout



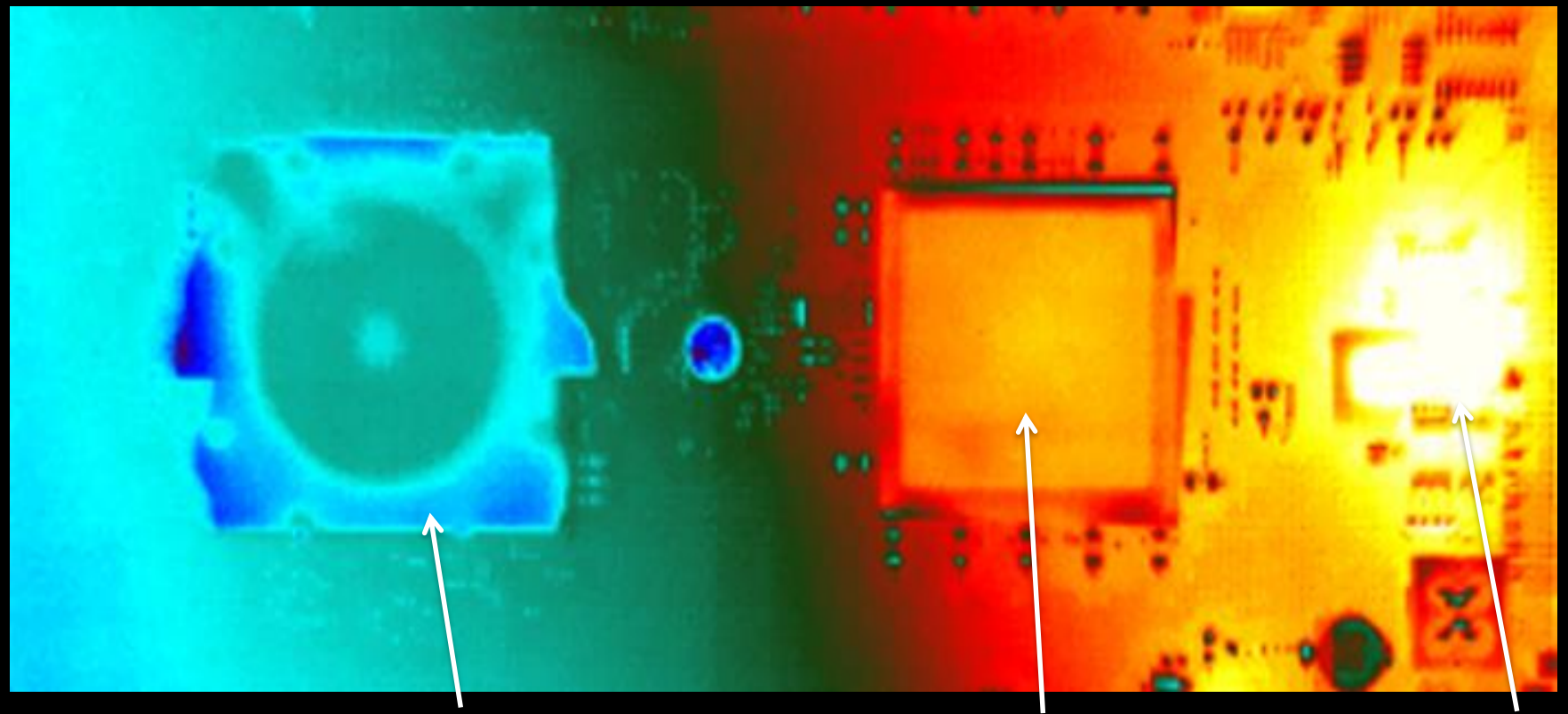
TrueNorth's Numbers

- Transistor Count： 5.4 Billion Transistors
- Die Area： 4.3 cm^2
- Cores: 4096
- Neuron Count: 1Million
- Synapse Count: 256 Million
- On Chip Memory: 428Mbits
- Event Trigger (Tick) : 1KHz
- Power Consumption: 72mW (at a operation point of average 20Hz neuron firing, 50% synaptic connectivity, 0.775V supply)

Photo: Deanne FitzMaurice for Science 2014



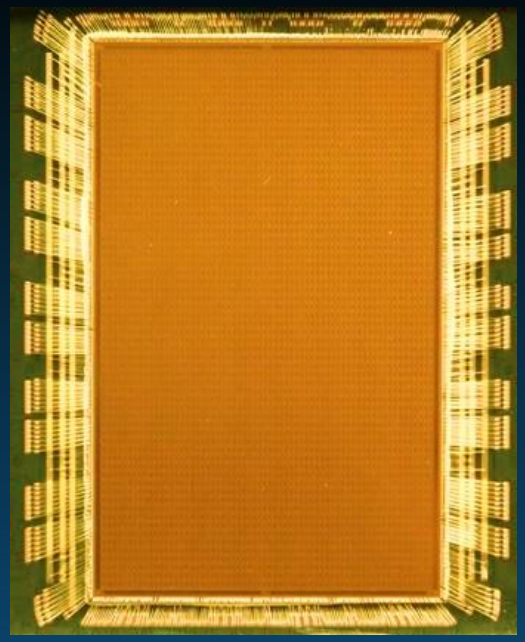
Cool Chip



Simulator Hardware Equivalence

Input

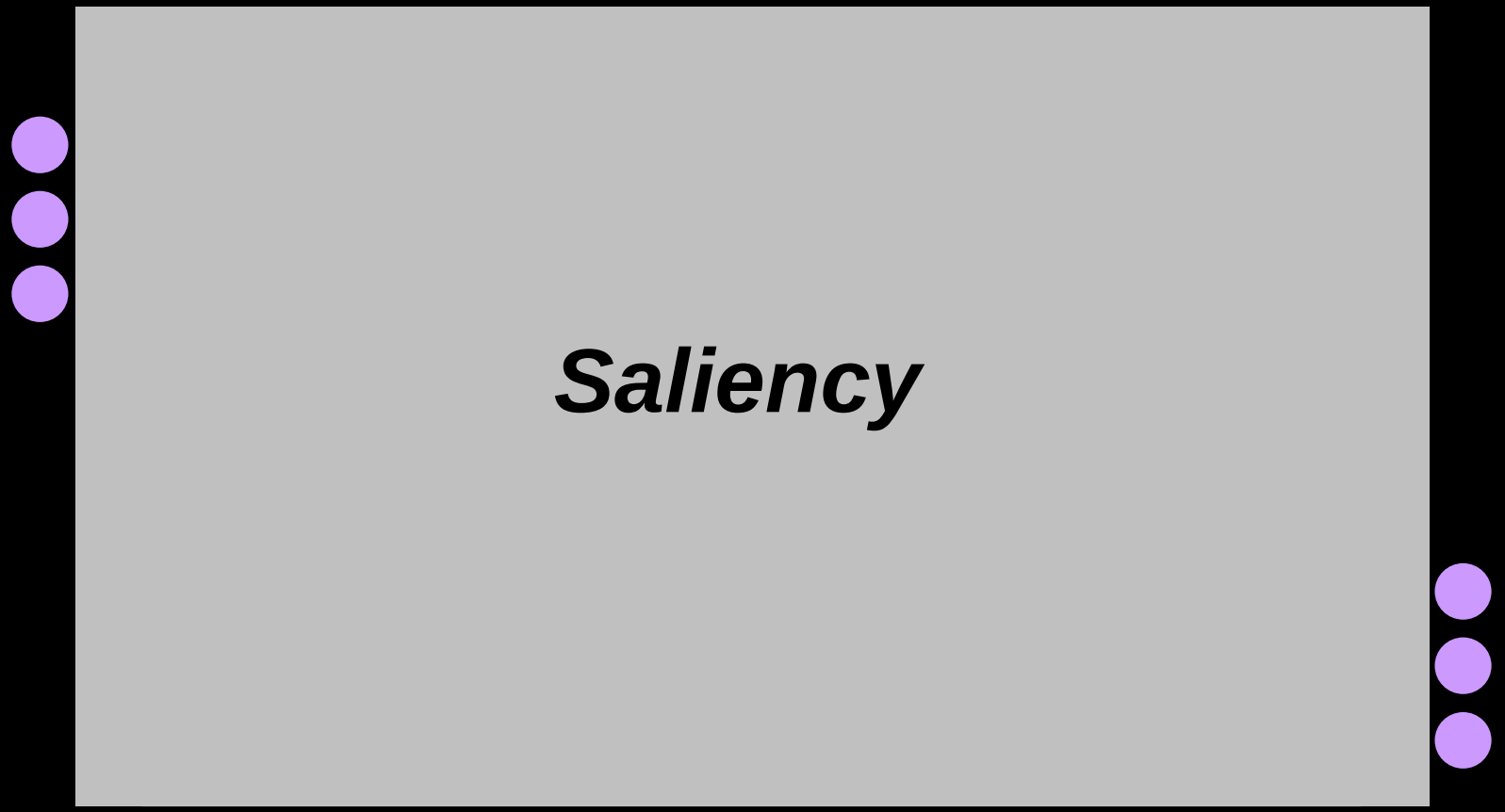
=



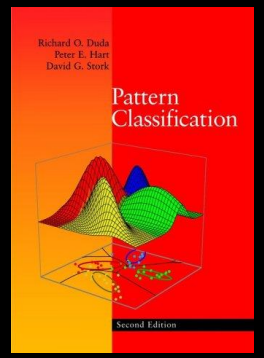
Output

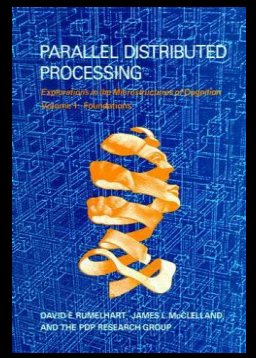
“Program”

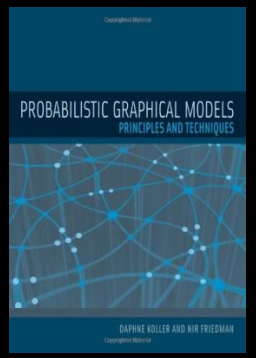
Corelet Programming

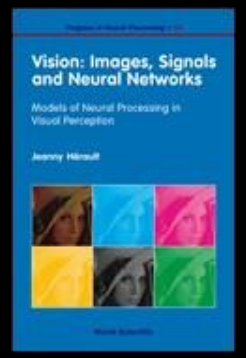


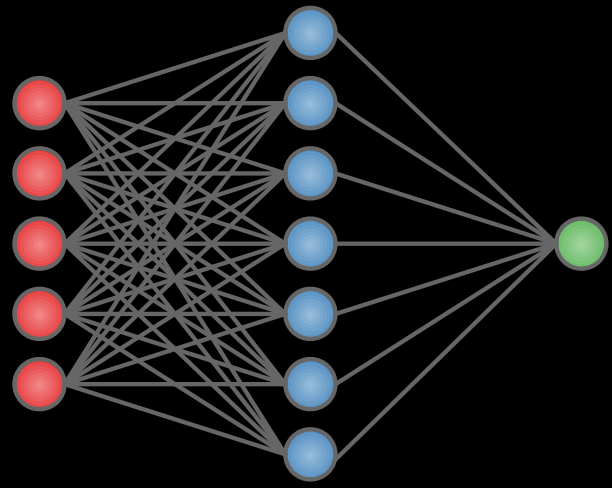
Corelet Programming





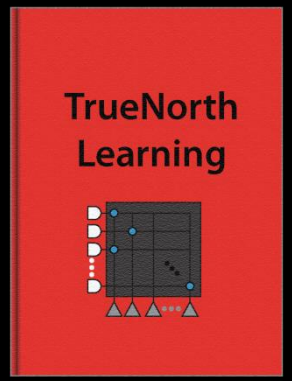


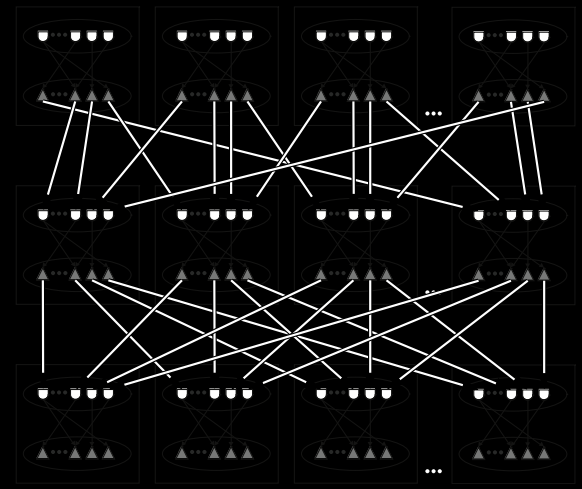




Traditional Space

TrueNorth Space

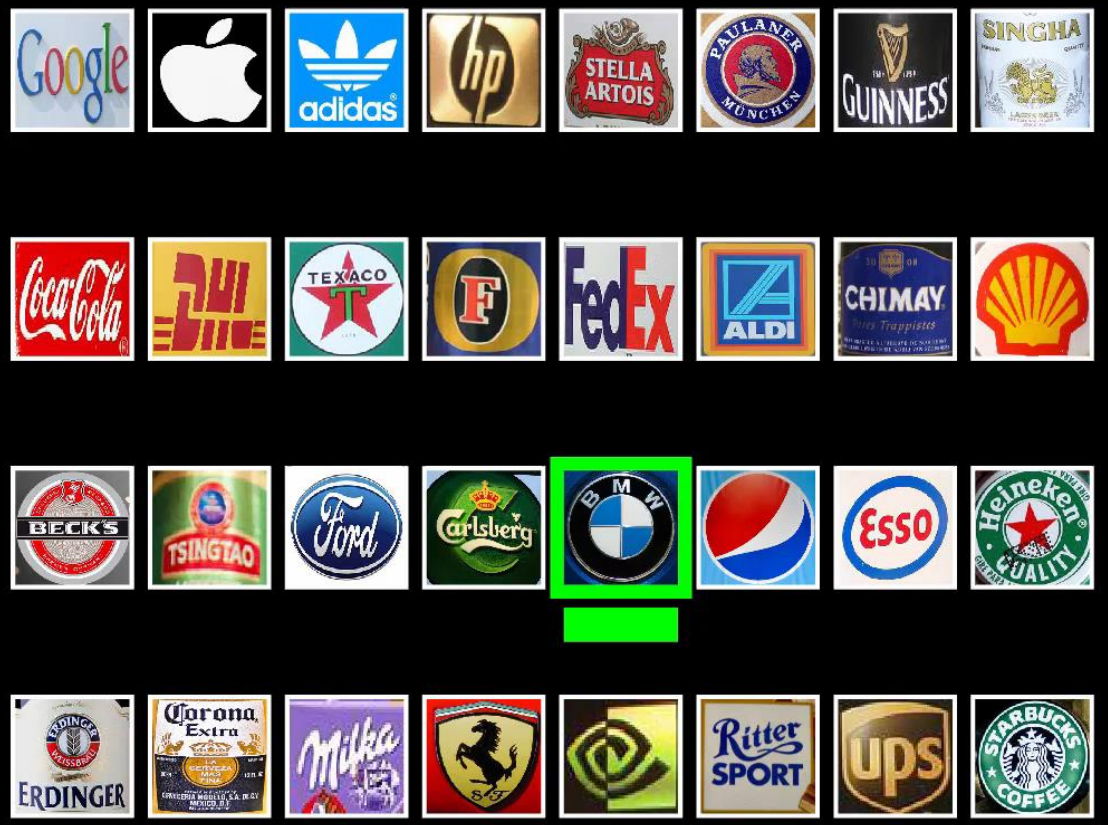




Heli Video Recognition with a single TrueNorth chip

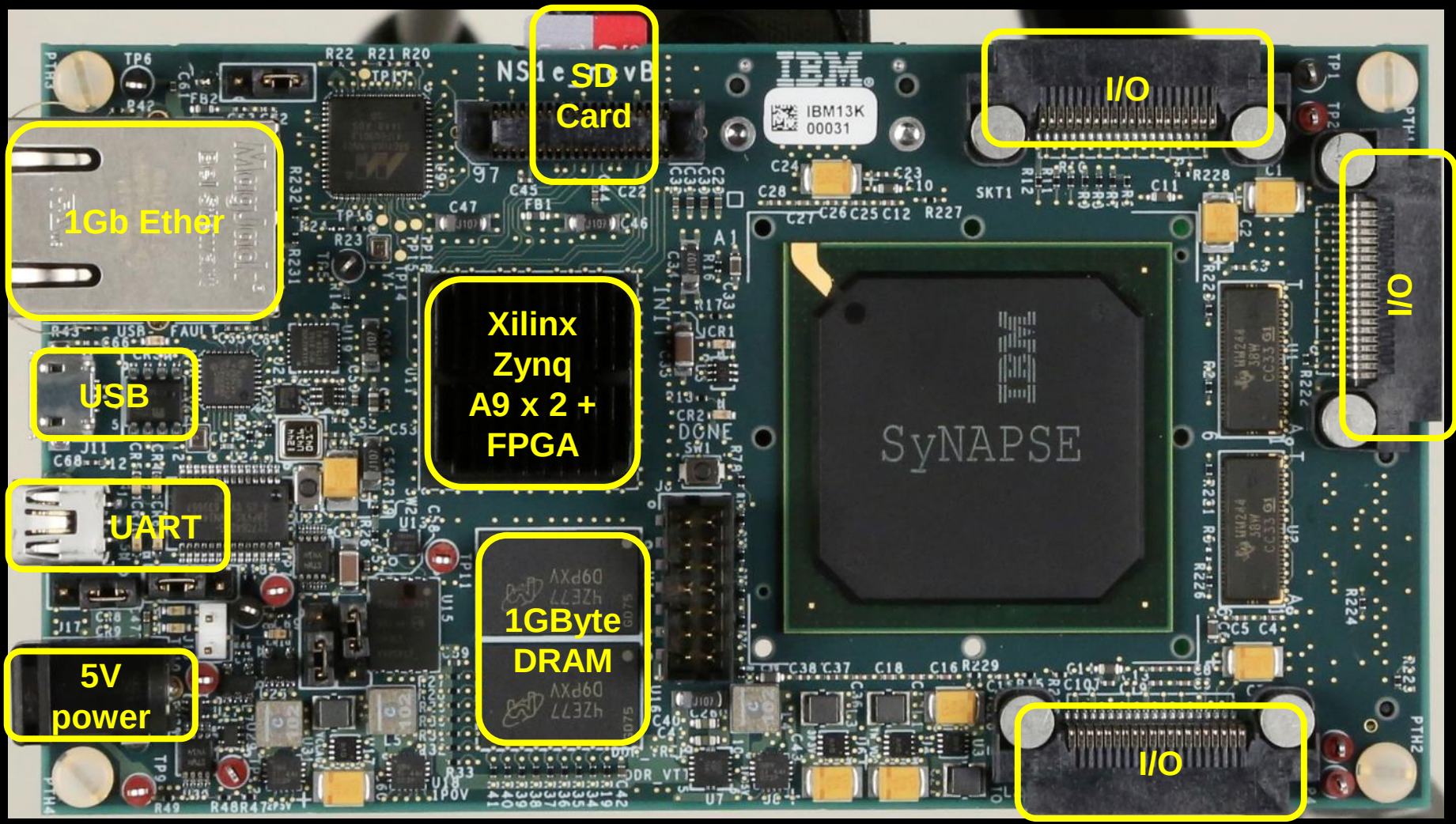
Logo 32 Demo


BMW


Google
adidas
STELLA ARTOIS
PAULANER MÜNCHEN
GUINNESS
SINGHA
Coca-Cola
TEXACO
FedEx
ALDI
CHIMAY
BECK'S
TSINGTAO
Ford
Carlsberg
BMW
Esso
Heineken
QUALITY
ERDINGER
Corona Extra
Milka
Ritter SPORT
ups
STARBUCKS COFFEE

Logo32 Real-time

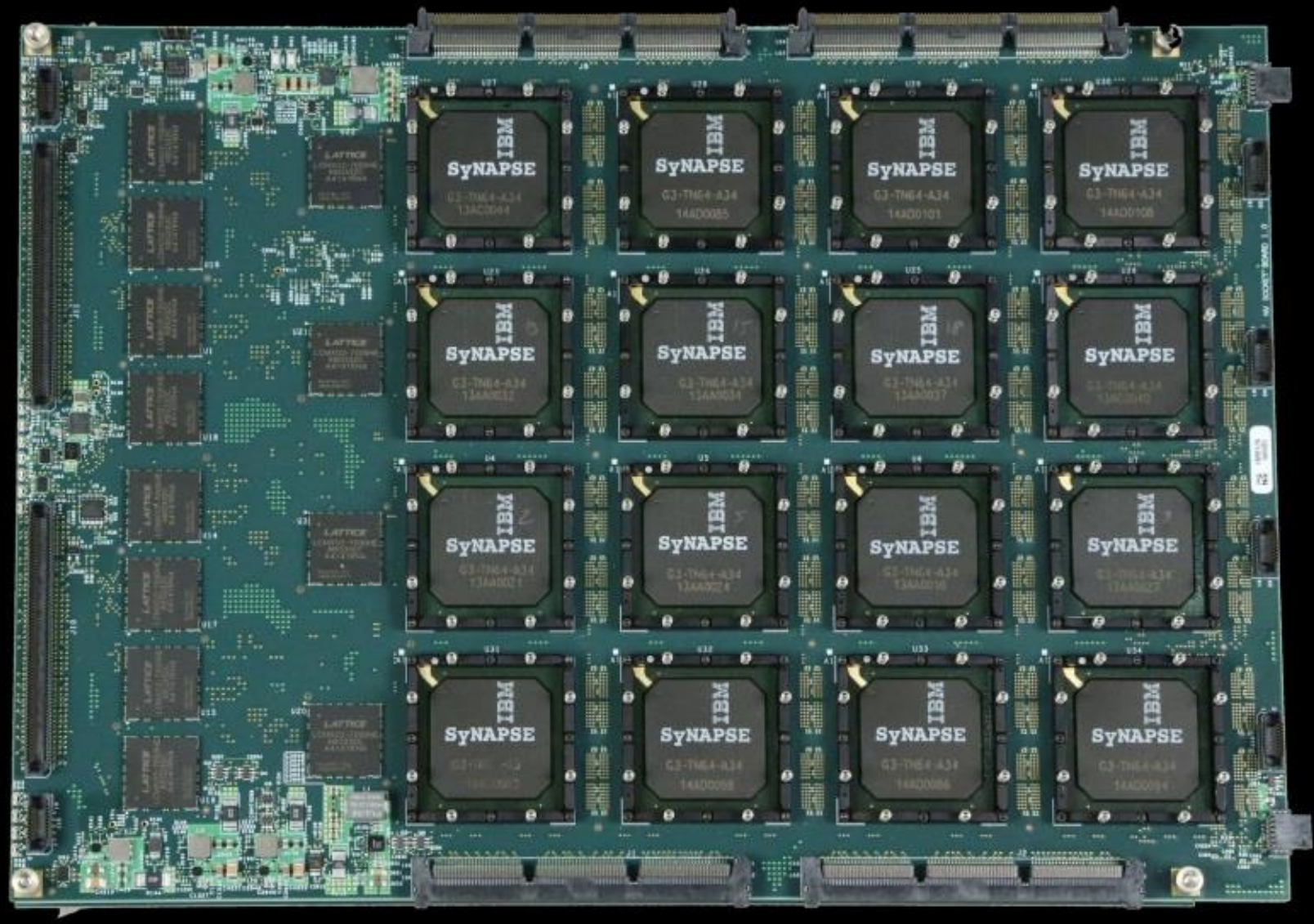
NS1e Single Chip Evaluation Board



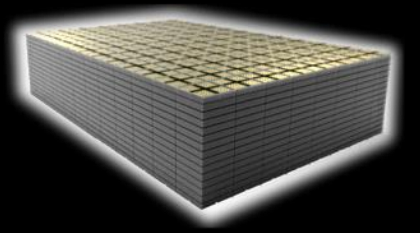
Low Power
Low Weight
Miniature Form
Real Time
User Friendly

NS16e Board

- 4x4 grid of TrueNorth communicating with a built-in interface.
- PCIe connecter to the host machine.

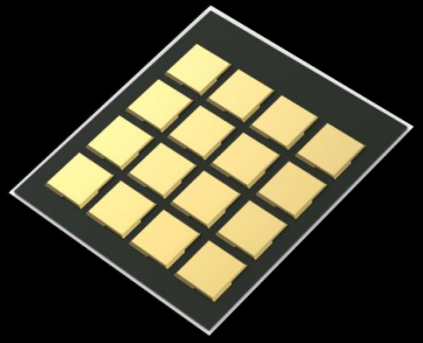


TrueNorth Scaling Possibility

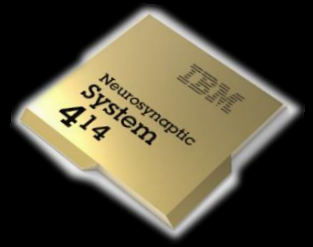


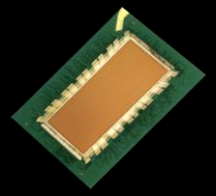
96 Rack Cluster
40 kW (chip power only)
100 trillion synapses
Human Scale

4096 Chip Rack
400W (chip power only)
1 trillion synapses
Cat Scale



16 Chip Board
1.6W (chip power only)
4 billion synapses





1 Chip
100mW
256 million synapses
Bee Scale

TrueNorth Training Boot Camp

- We are trying to work with government agencies, universities, and other companies.
- In summer 2015, we invited 50+ collaborators to IBM and 3 week Bootcamp.
- Bootcamp alumni are already providing us enormous feedback.
- We expect to have another Bootcamp some time in near future.

More Reading

- “A million spiking-neuron integrated circuit with a scalable communication network and interface”, Science 2014 Aug.
- “Real-time Scalable Cortical Computing at 46 Giga-Synaptic OPS/Watt with ~100x Speedup in Time-to-Solution and ~100,000x Reduction in Energy-to-Solution”, SC 2014 Nov.
- “TrueNorth - Design and Tool Flow of a 65mW 1 Million Neuron Programmable Neurosynaptic Chip”, TCAD 2015 Oct.