The *SpiNNaker* project

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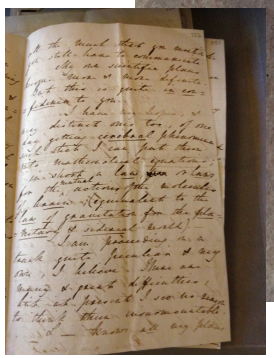
SpiNNaker
Biologically Inspired Massively Parallel Architectures

200 years ago…

- Ada Lovelace, b. 10 Dec. 1815

"*I have my hopes, and very distinct ones too, of one day getting cerebral phenomena such that I can put them into mathematical equations--in short, a law or laws for the mutual actions of the molecules of brain. …. I hope to bequeath to the generations a calculus of the nervous system.*"



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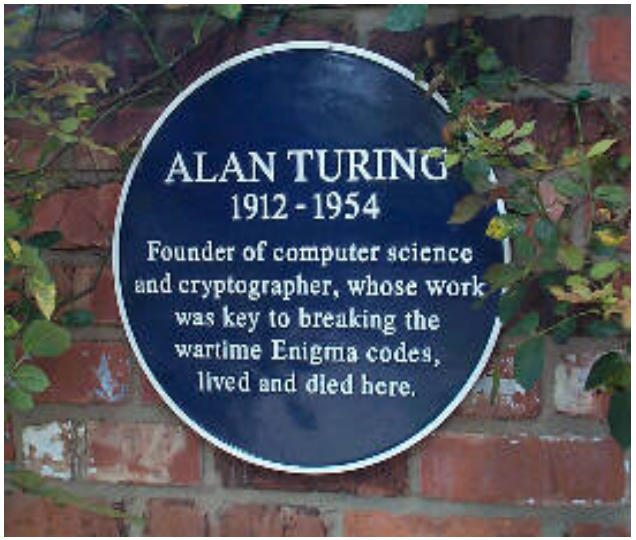
60 years ago…



VOL. LIX. No. 236.] [October, 1950

MIND

A QUARTERLY REVIEW

OF

PSYCHOLOGY AND PHILOSOPHY

I.—COMPUTING MACHINERY AND INTELLIGENCE

BY A. M. TURING

1. *The Imitation Game.*

I PROPOSE to consider the question, 'Can machines think?' This should begin with definitions of the meaning of the terms 'machine' and 'think'. The definitions might be framed so as to reflect so far as possible the normal use of the words, but this attitude is dangerous. If the meaning of the words 'machine' and 'think' are to be found by examining how they are commonly used it is difficult to escape the conclusion that the meaning and the answer to the question, 'Can machines think?' is to be sought in a statistical survey such as a Gallup poll. But this is absurd. Instead of attempting such a definition I shall replace the

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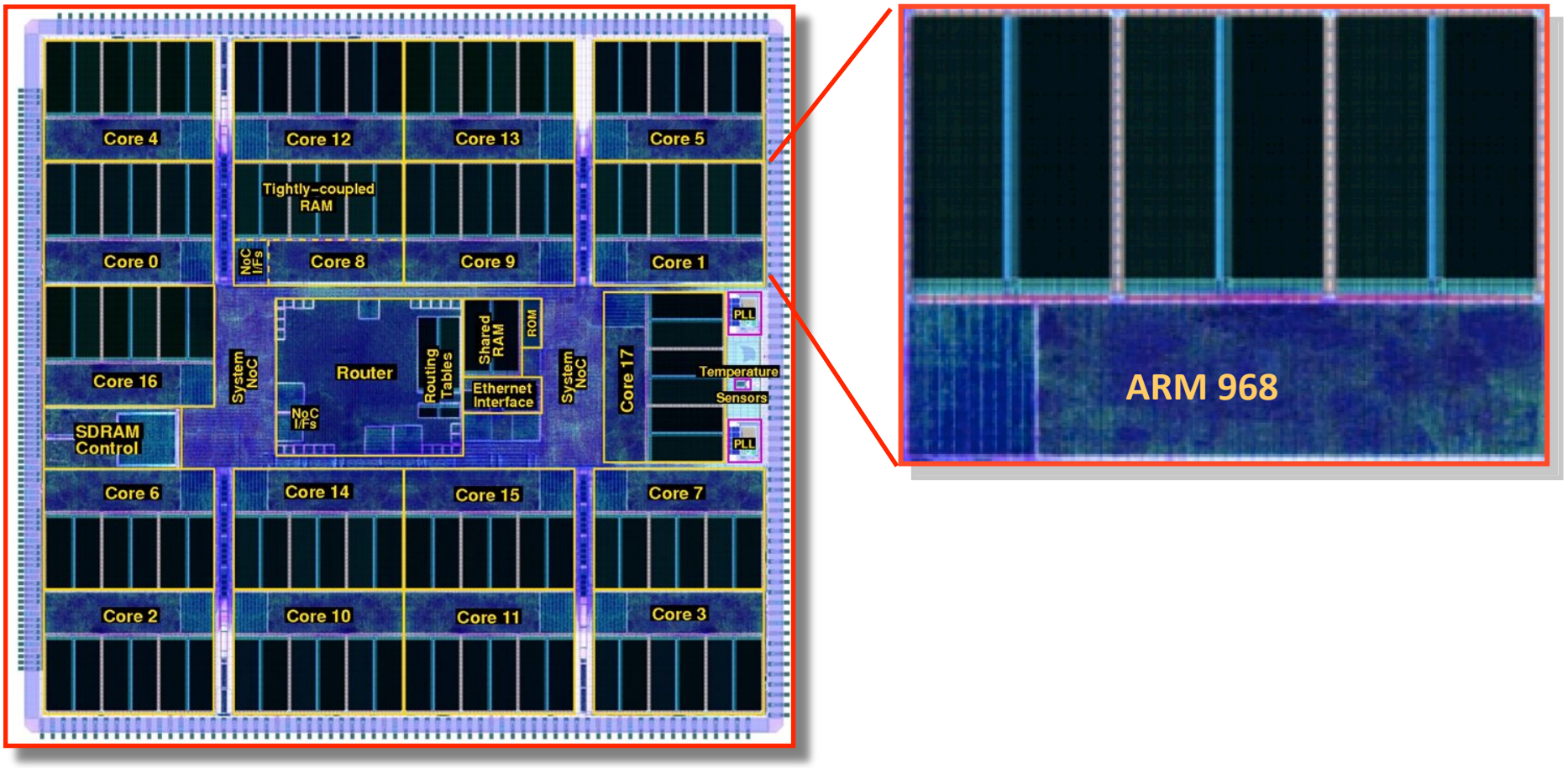
Manchester Baby (1948)

SpiNNaker CPU (2011)



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63 years of progress

- ***Baby:***
  - used 3.5 kW of electrical power
  - executed 700 instructions per second
  - 5 Joules per instruction
- ***SpiNNaker ARM968 CPU node:***
  - uses 40 mW of electrical power
  - executes 200,000,000 instructions per second
  - 0.000 000 000 2 Joules per instruction

(James Prescott Joule born Salford, 1818)

25,000,000,000 times better than Baby!

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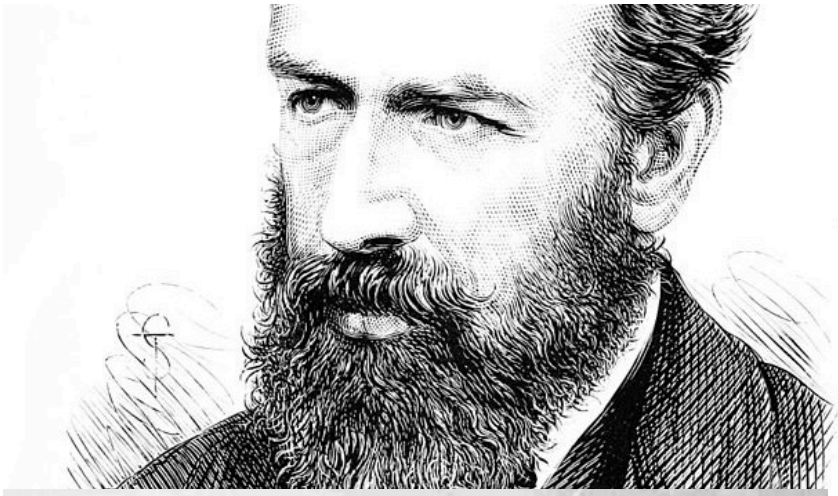
Jevons paradox

1865 "The Coal Question"

- James Watt's coal-fired steam engine was much more efficient than Thomas Newcomen's…
- …and coal consumption ***rose*** as a result



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Bio-inspiration

- Can massively-parallel computing resources accelerate our understanding of brain function?

- Can our growing understanding of brain function point the way to more efficient parallel, fault-tolerant computation?

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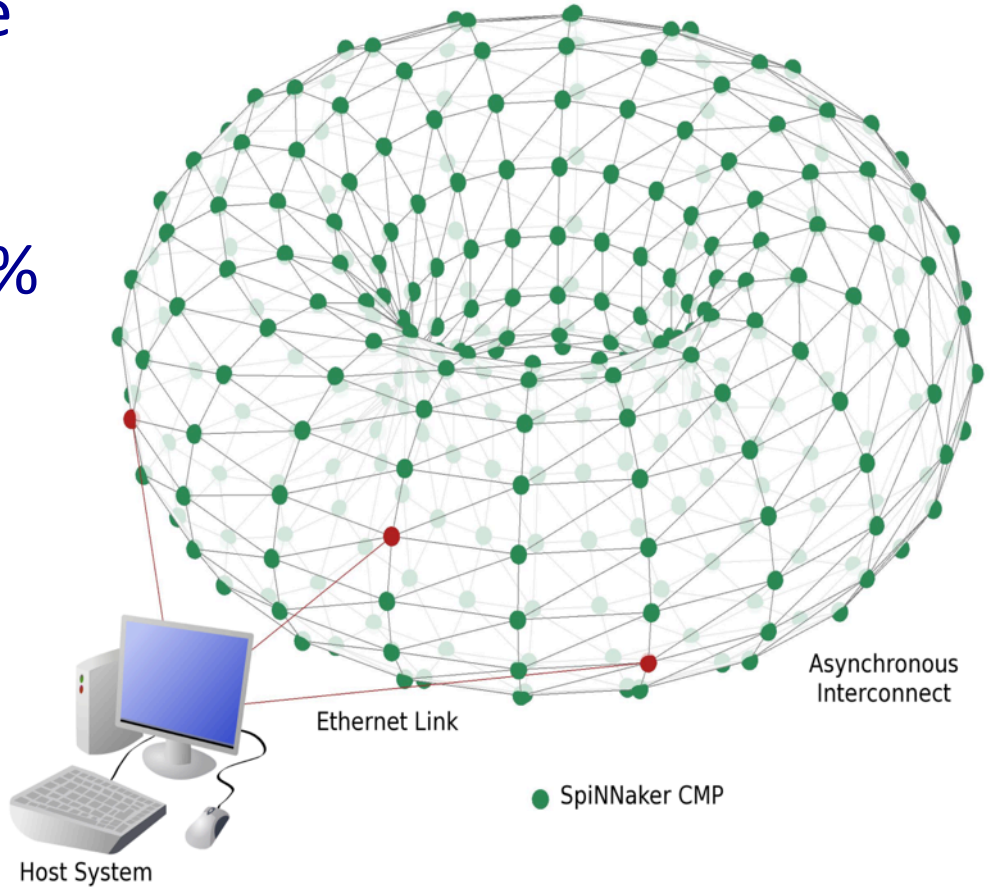
SpiNNaker project

- A million mobile phone processors in one computer
- Able to model about 1% of the human brain…
- …or 10 mice!

EPSRC



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Design principles

- *Virtualised topology*
  - physical and logical connectivity are decoupled
- *Bounded asynchrony*
  - time models itself
- *Energy frugality*
  - processors are free
  - the real cost of computation is energy

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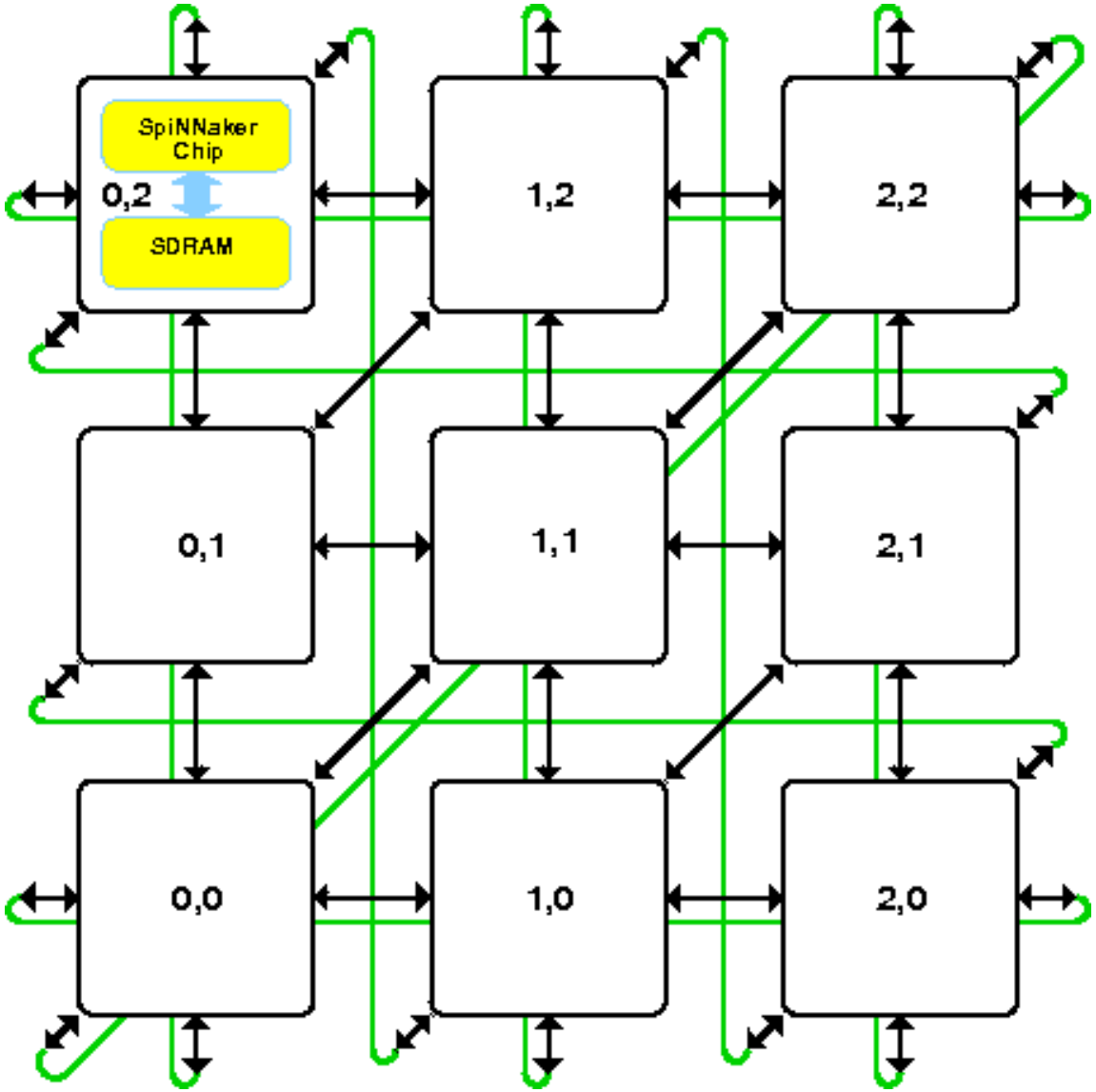
SpiNNaker system



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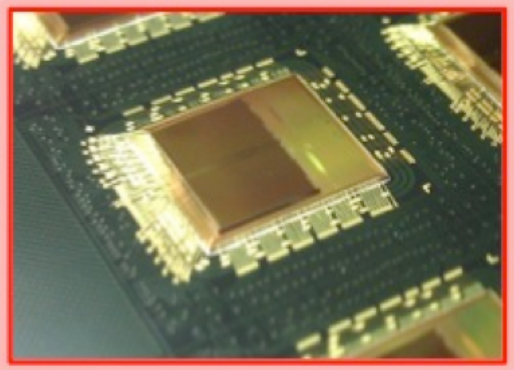
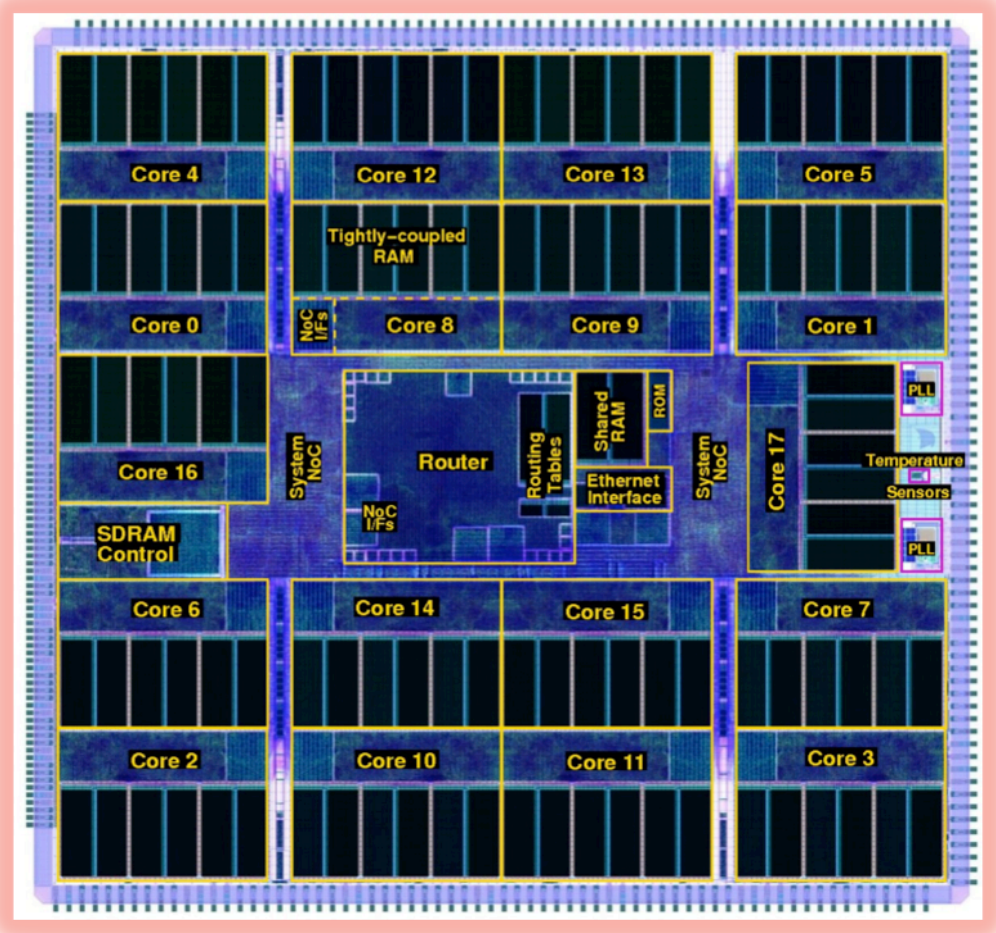
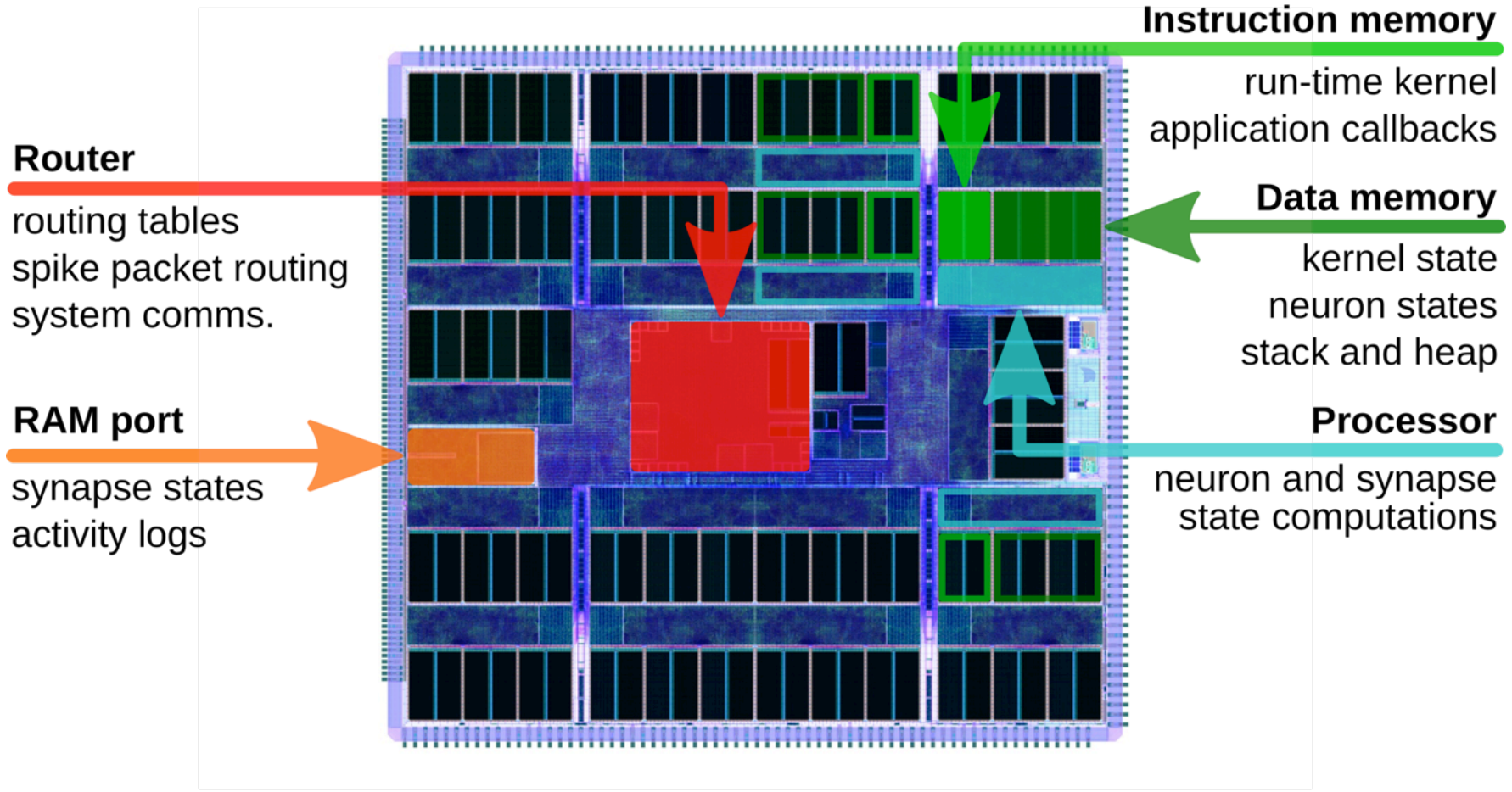
SpiNNaker chip



Multi-chip packaging by UNISEM Europe

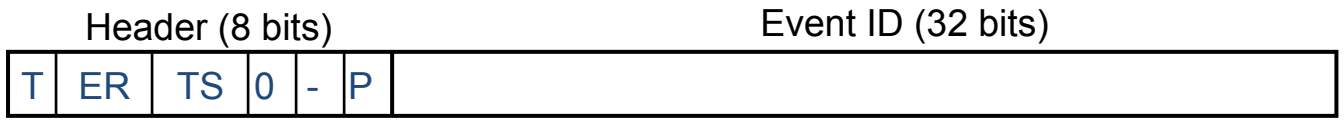


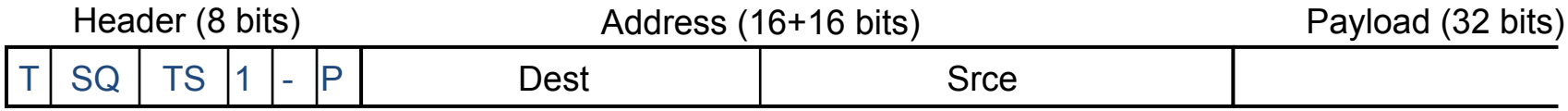
Chip resources



Network – packets

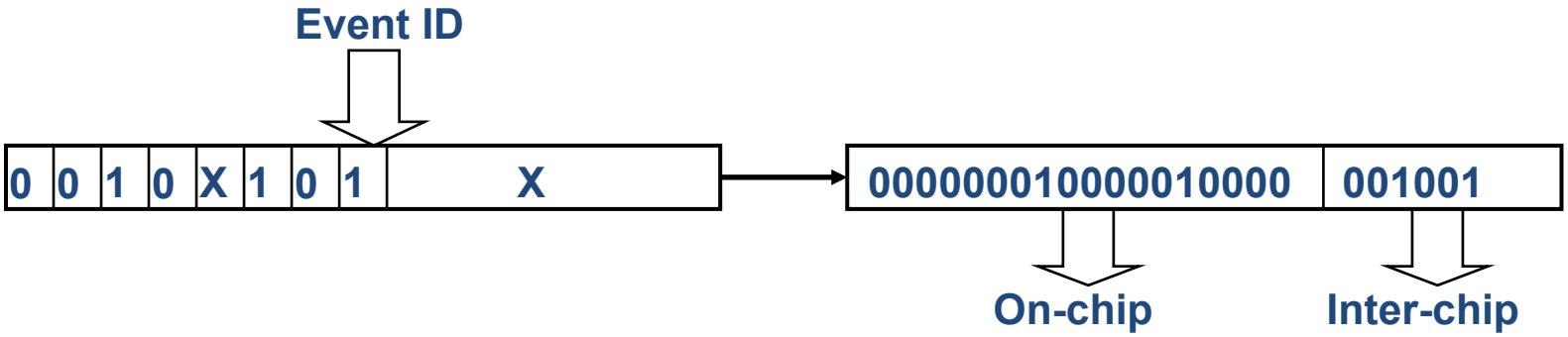
- Four packet types
  - MC (multicast): source routed; carry events (spikes)
  - P2P (point-to-point): used for bootstrap, debug, monitoring, etc
  - NN (nearest neighbour): build address map, flood-fill code
  - FR (fixed route): carry 64-bit debug data to host
- Timestamp mechanism removes errant packets
  - which could otherwise circulate forever



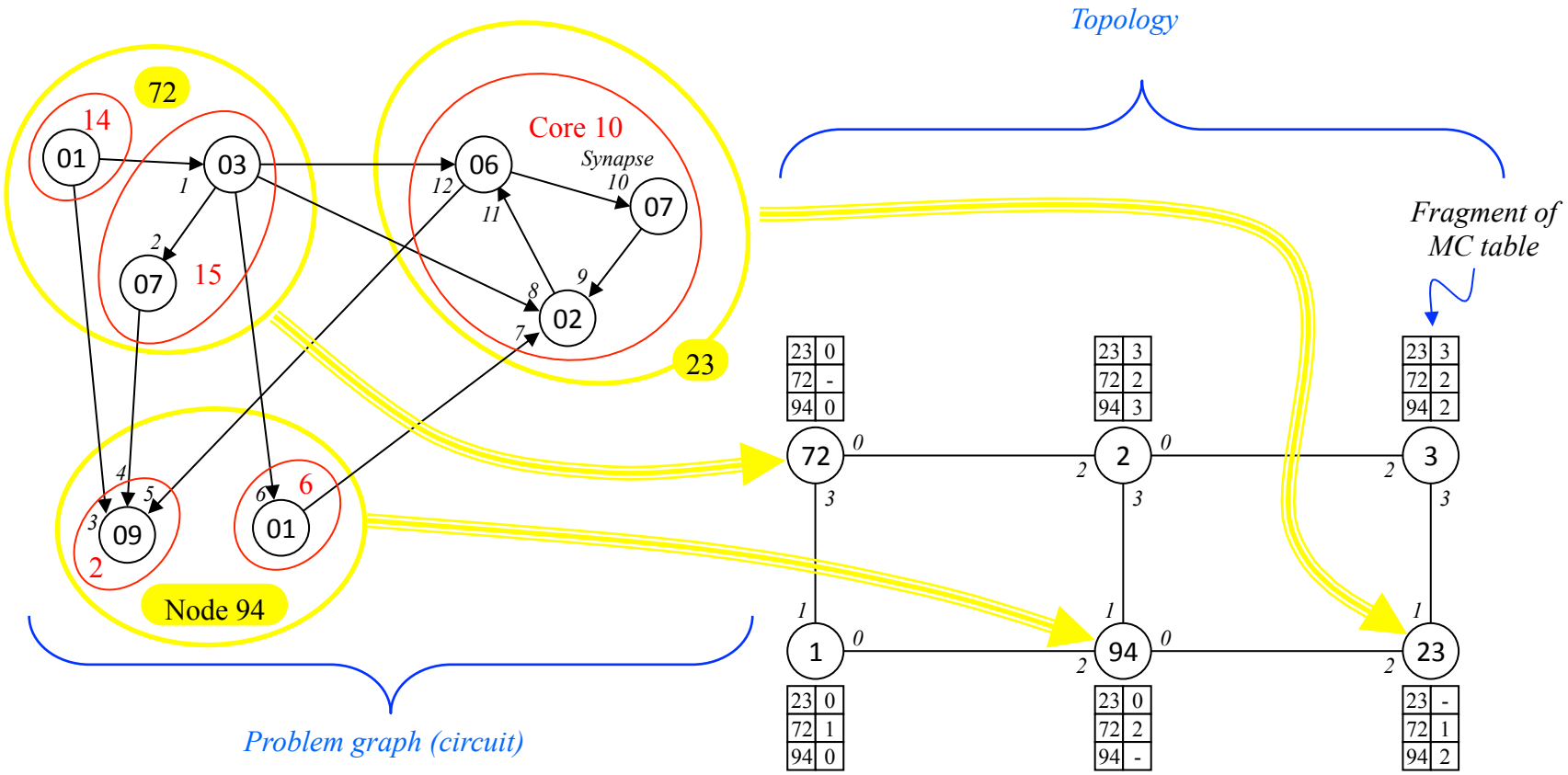


Network – MC Router

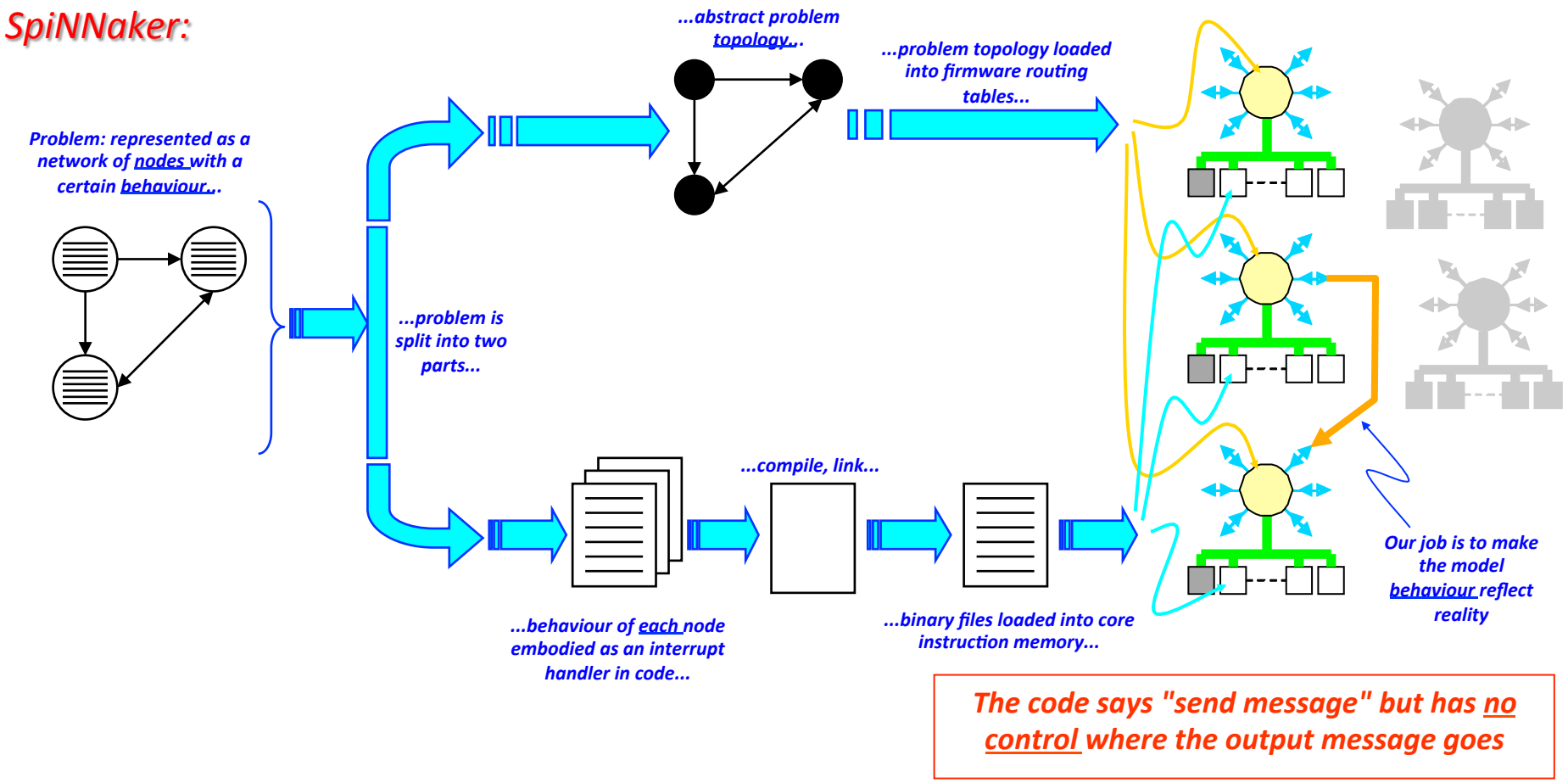
- All MC spike event packets are sent to a router
- Ternary CAM keeps router size manageable at 1024 entries (but careful network mapping also essential)
- CAM 'hit' yields a set of destinations for this spike event
  - automatic multicasting
- CAM 'miss' routes event to a 'default' output link



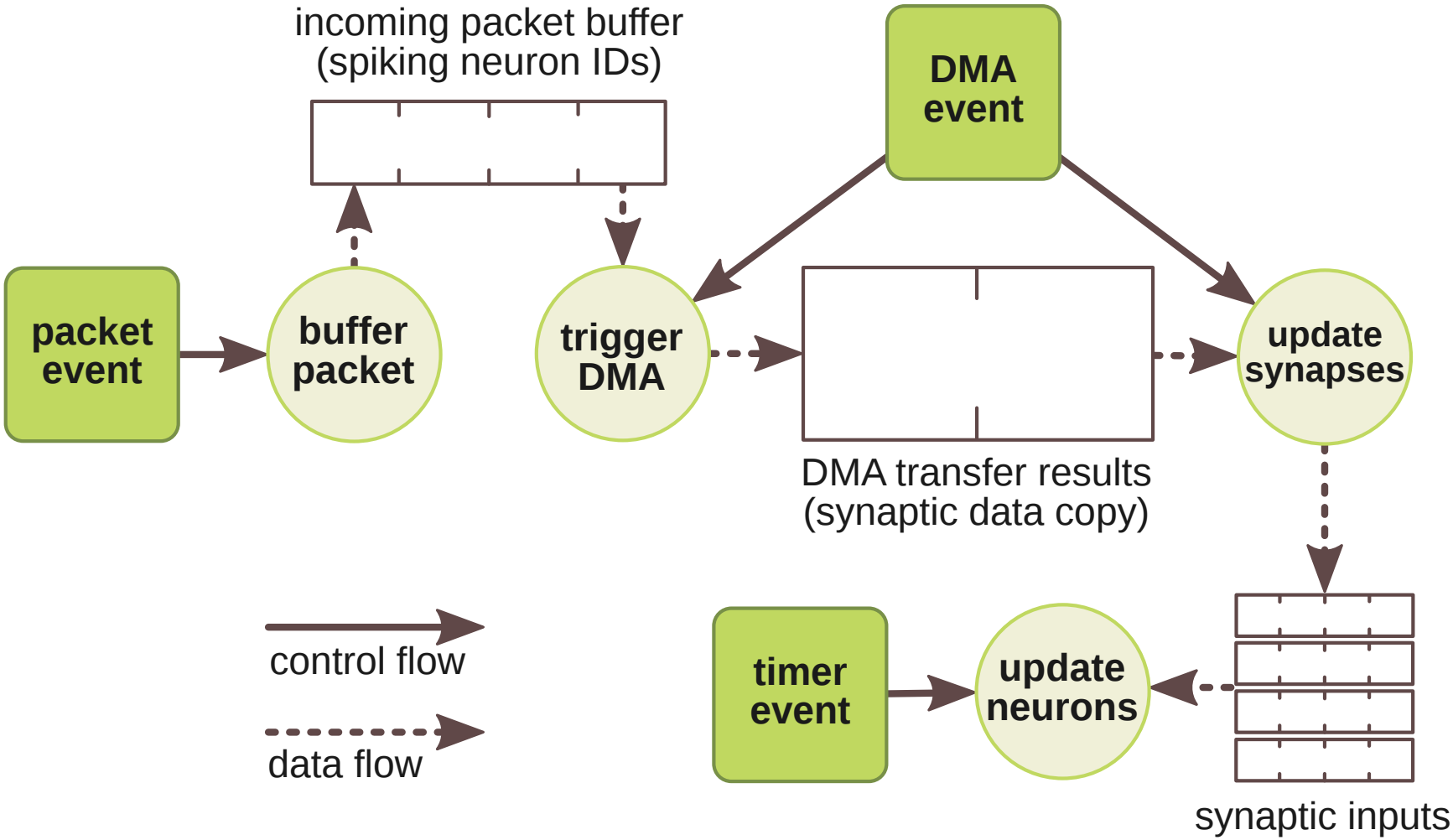
Topology mapping



Problem mapping



Event-driven software



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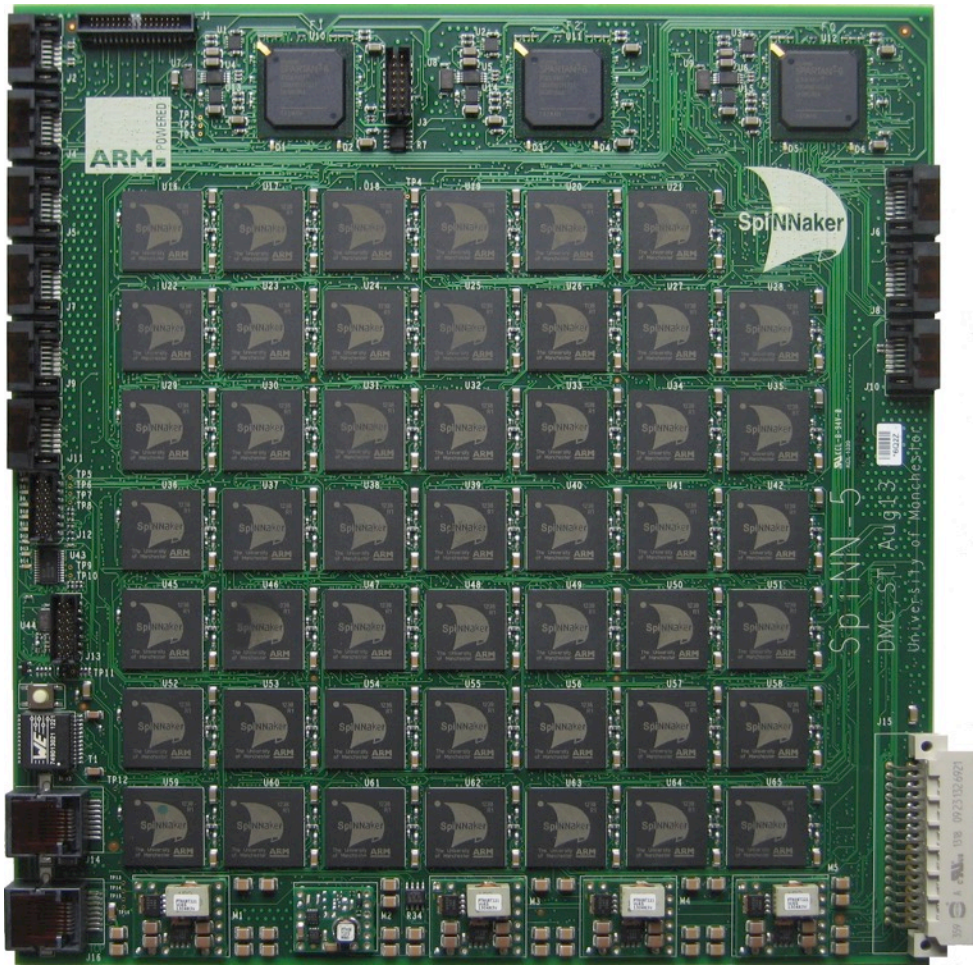
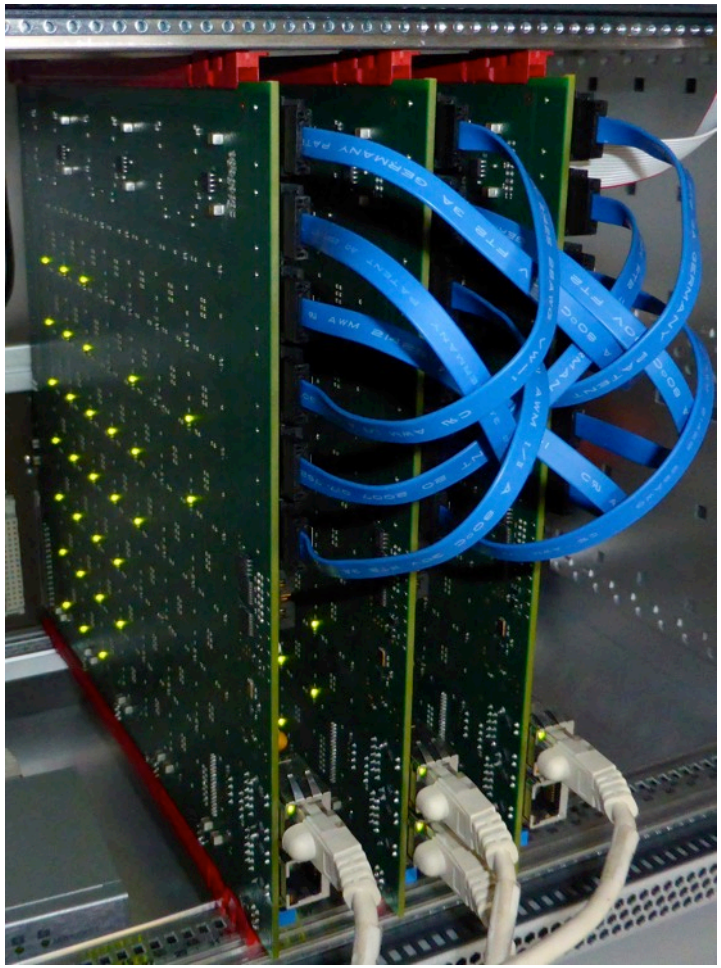
48-node PCB



864 cores



2,592 cores

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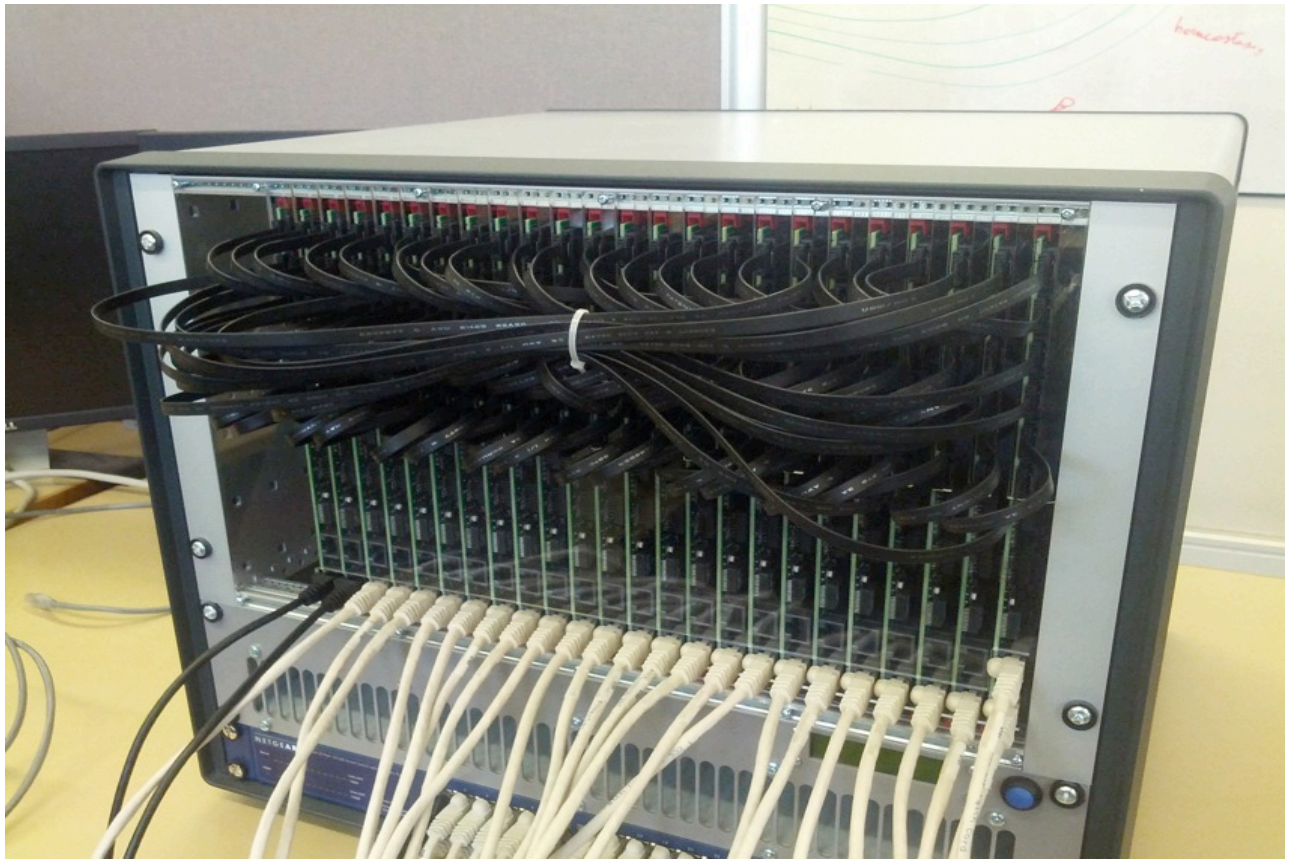
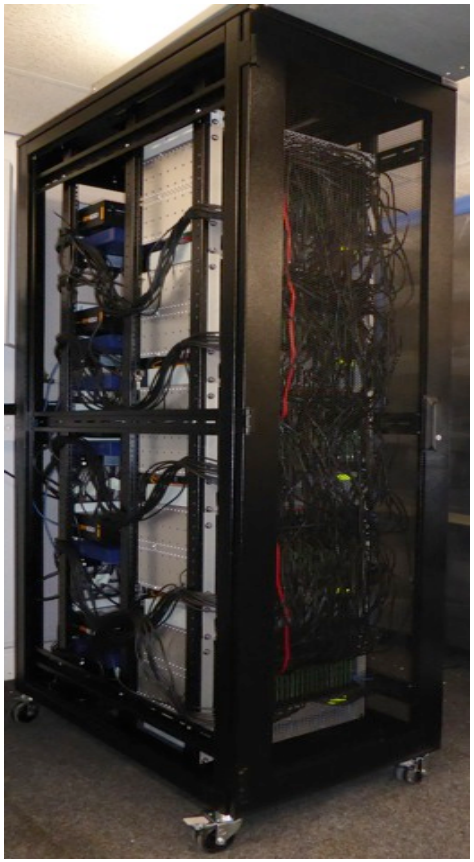
SpiNNaker machines

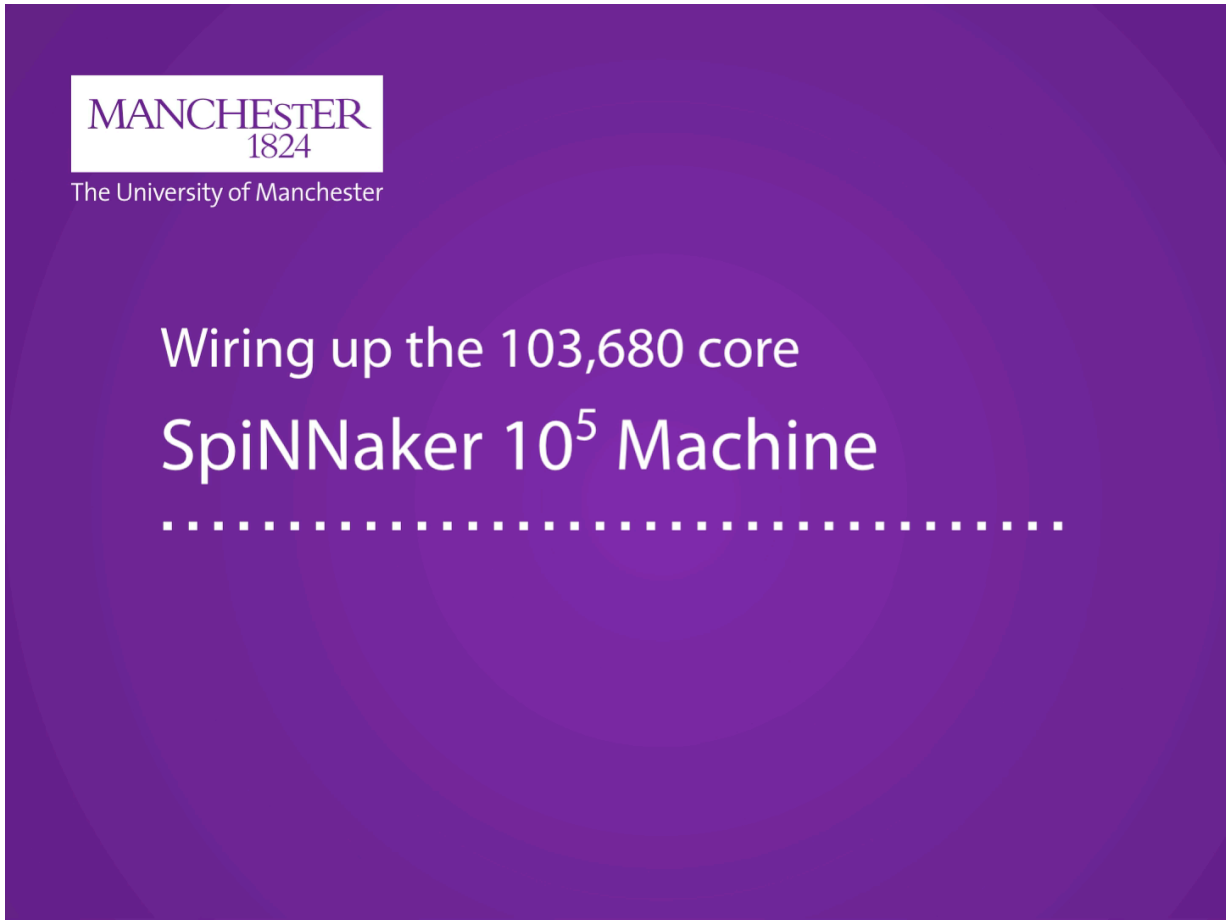


20,000 cores

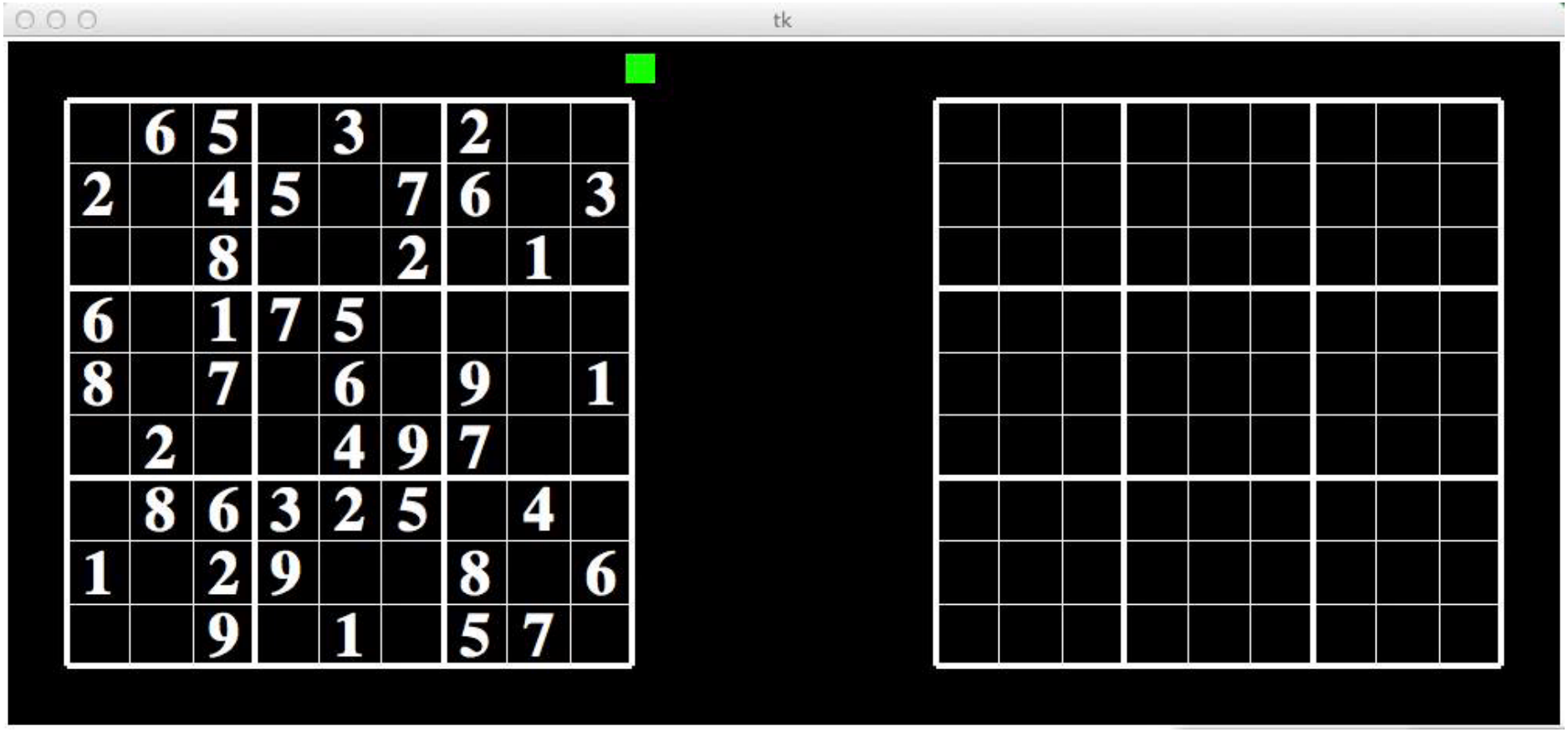


100,000 cores

Building the 105 machine

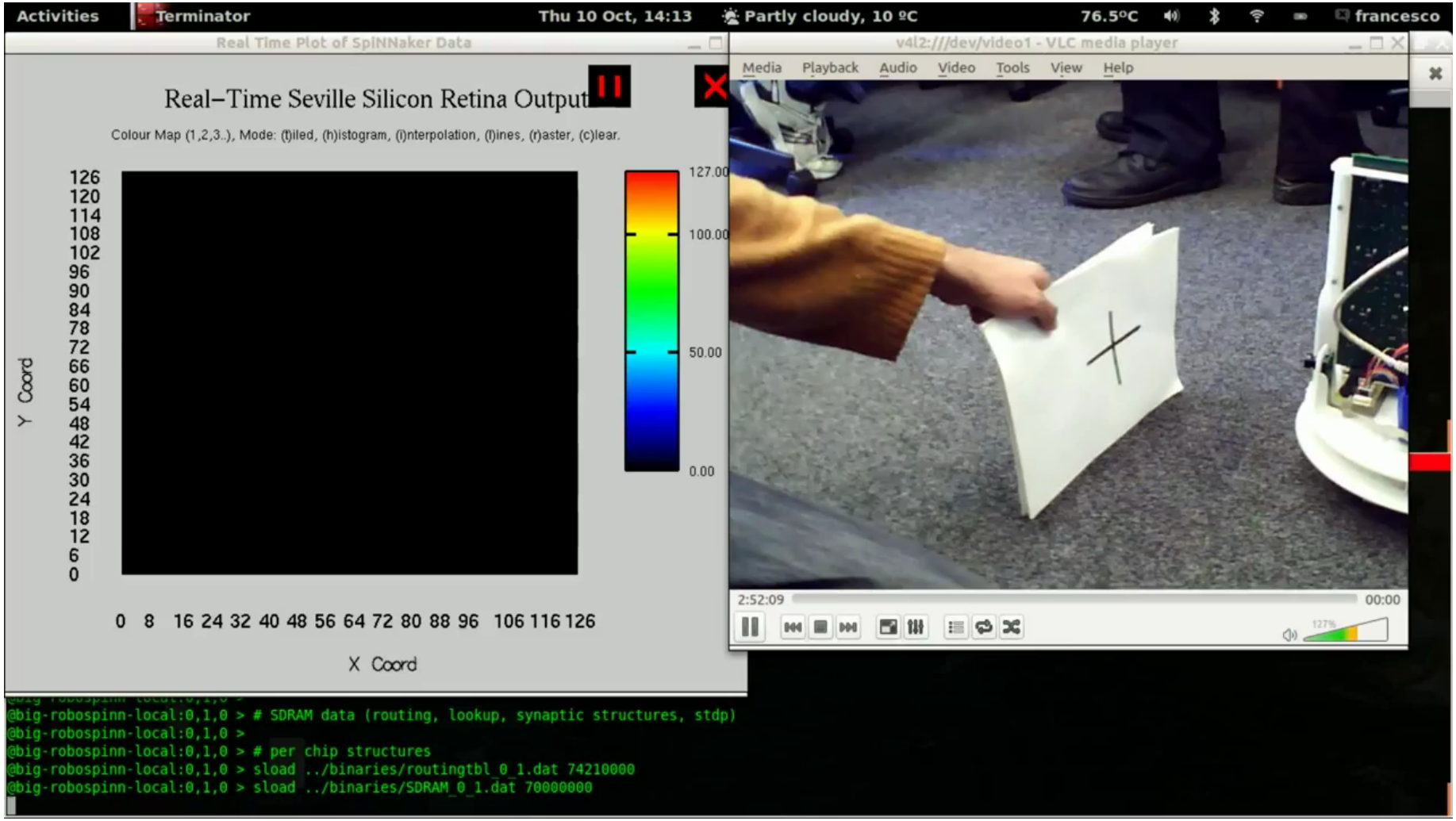


Sudoku on *SpiNNaker*



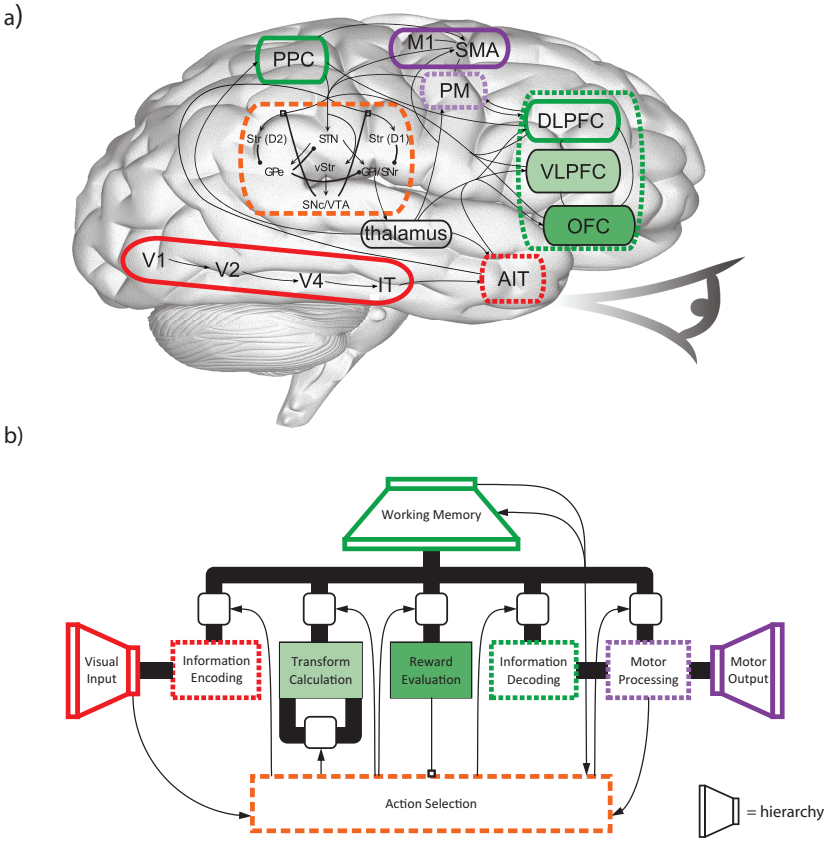
SpiNNaker model developed by Evie Andrew, based on:
S. Habenschuss, Z. Jonke, and W. Maass, "Stochastic computations in cortical microcircuit models", PLOS Computational Biology, 9(11):e1003311, 2013.

SpiNNaker robot control



Spaun

- Spaun:
  - 2.5M neurons
  - ~100Hz firing rates
  - ~500 inputs/neuron
  - 125G conn/s
  - 2-3 hours/s on cluster
- Real-time Spaun:
  - 25,000 ARMs
  - 30x 48-node PCBs
  - by end Q2 2014?
- Other promising models:
  - HTM? Leabra?



Chris Eliasmith et al, Science vol. 338, 30 Nov 2012

SpiNNaker port by Andrew Mundy

Conclusions

- *SpiNNaker:*
  - has been 15 years in conception…
  - …and 8 years in construction,
  - and is now ready for action!
- ~40 boards with groups around the world
- 20,000 and 100,000 core machines built
  - 1M core machine to follow soon
  - large models: Spaun, HTM?, Leabra?
- HBP is supporting s/w development
  - leading to open access