Nervous Systems (On Chip)

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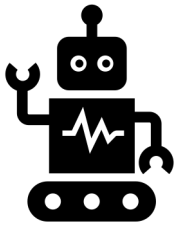
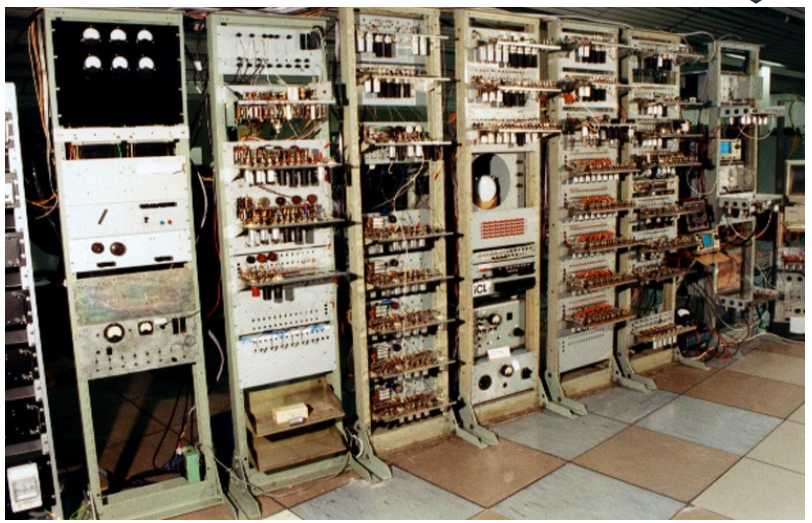
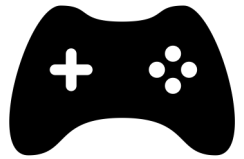
School of Physics, Engineering and Technology

Traditional Computing Hardware

… JUST WHAT IS A COMPUTER ANYWAY?

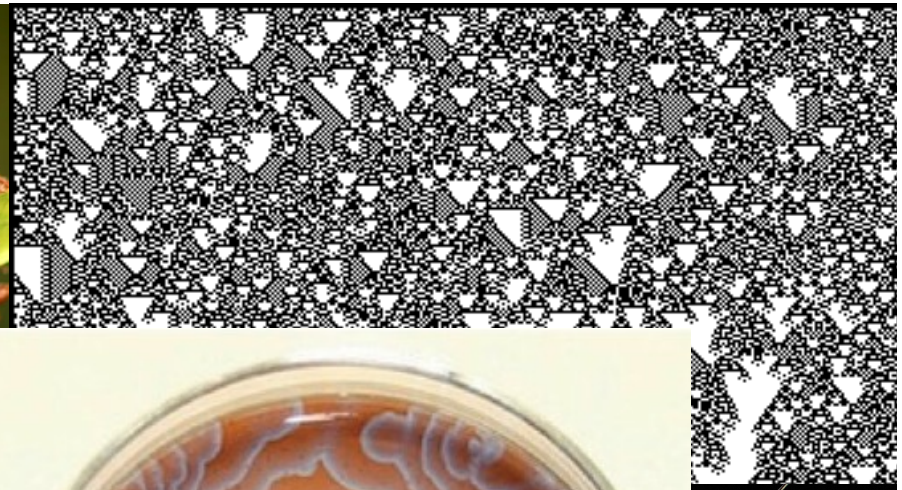


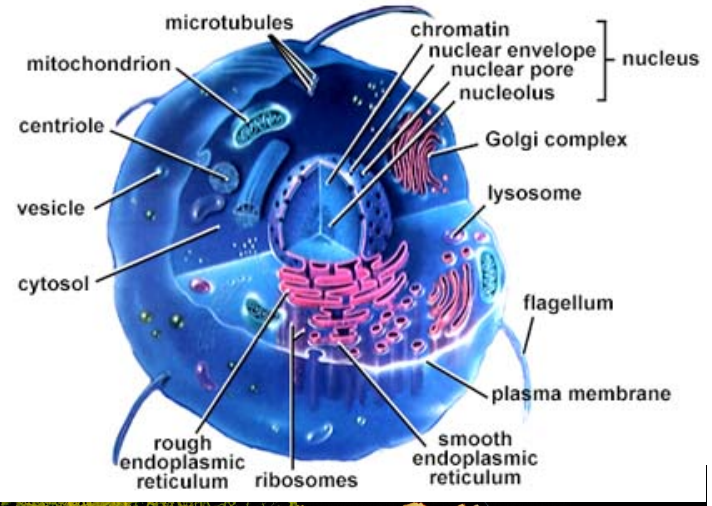


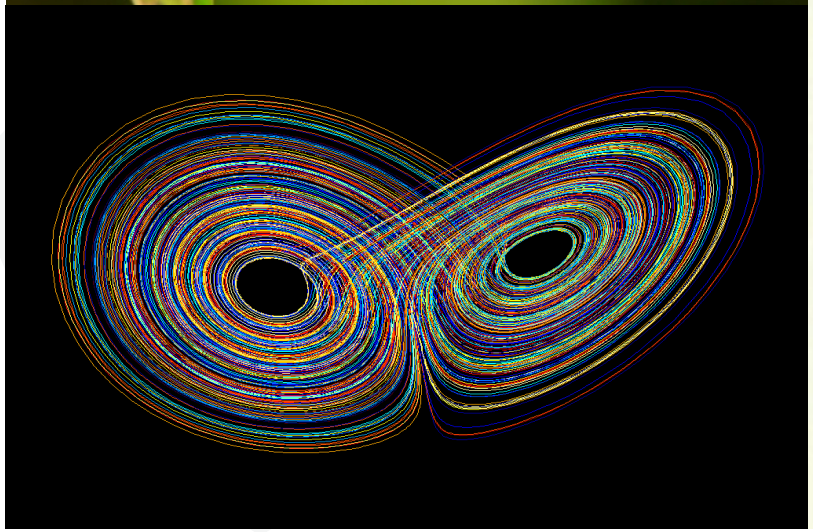


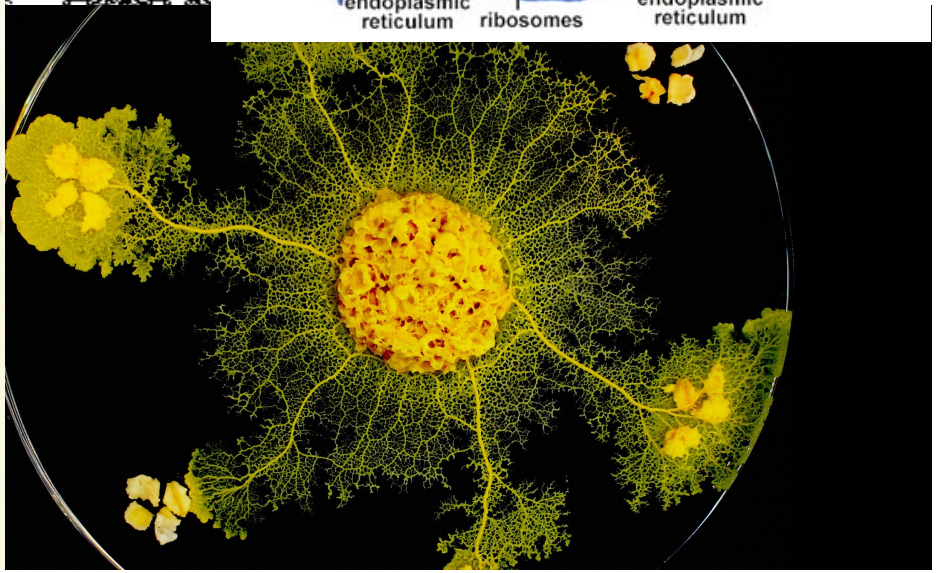
Unconventional Computing Hardware

BIO- / PHYSICS / CHEMISTRY / NATURE INSPIRED









Bio-inspired Hardware

- Multi-reconfigurable systems
- Evolutionary hardware design
- Design optimisation
- Fault-tolerant systems
- Adaptive neuromorphic hardware

Silicon “Primordial Soup”

FIELD-PROGRAMMABLE TRANSISTOR ARRAY – FPTA

AMS 600nm

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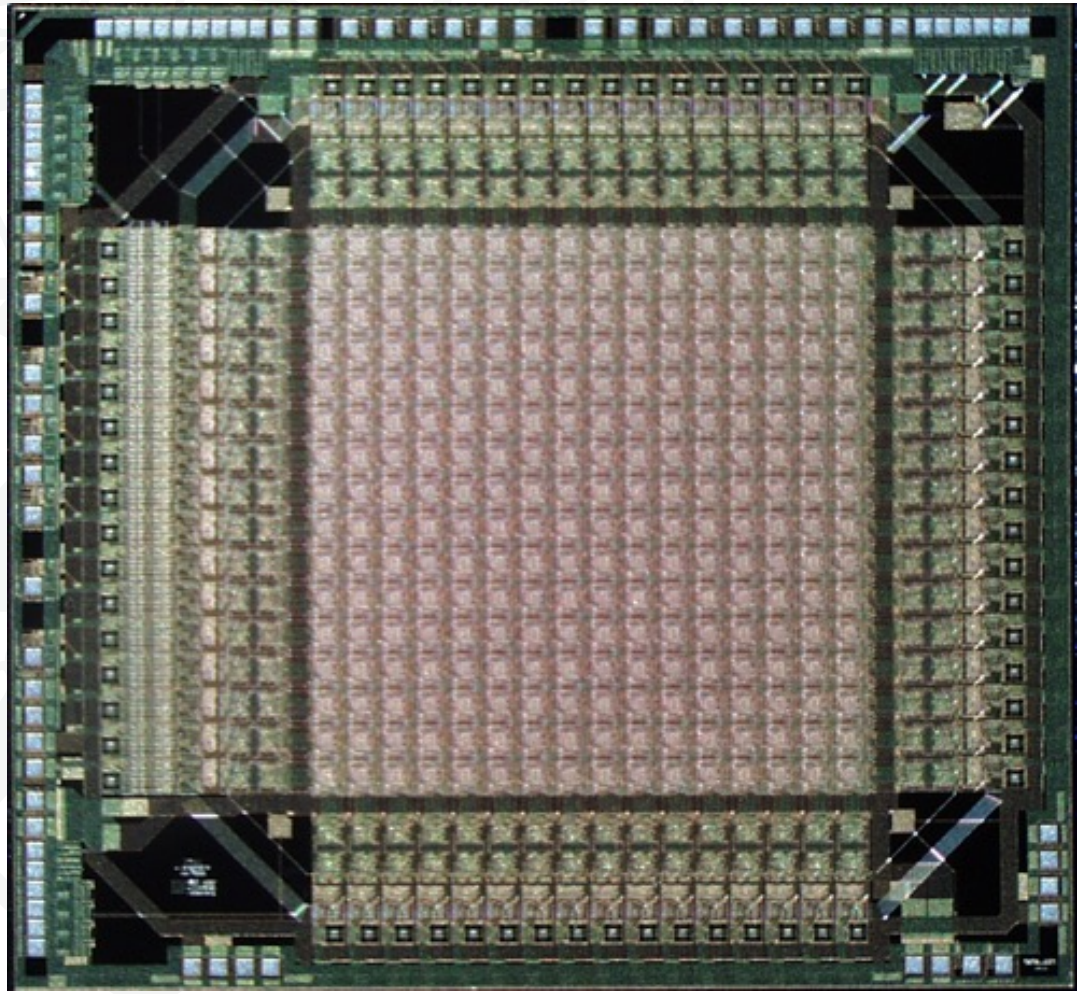
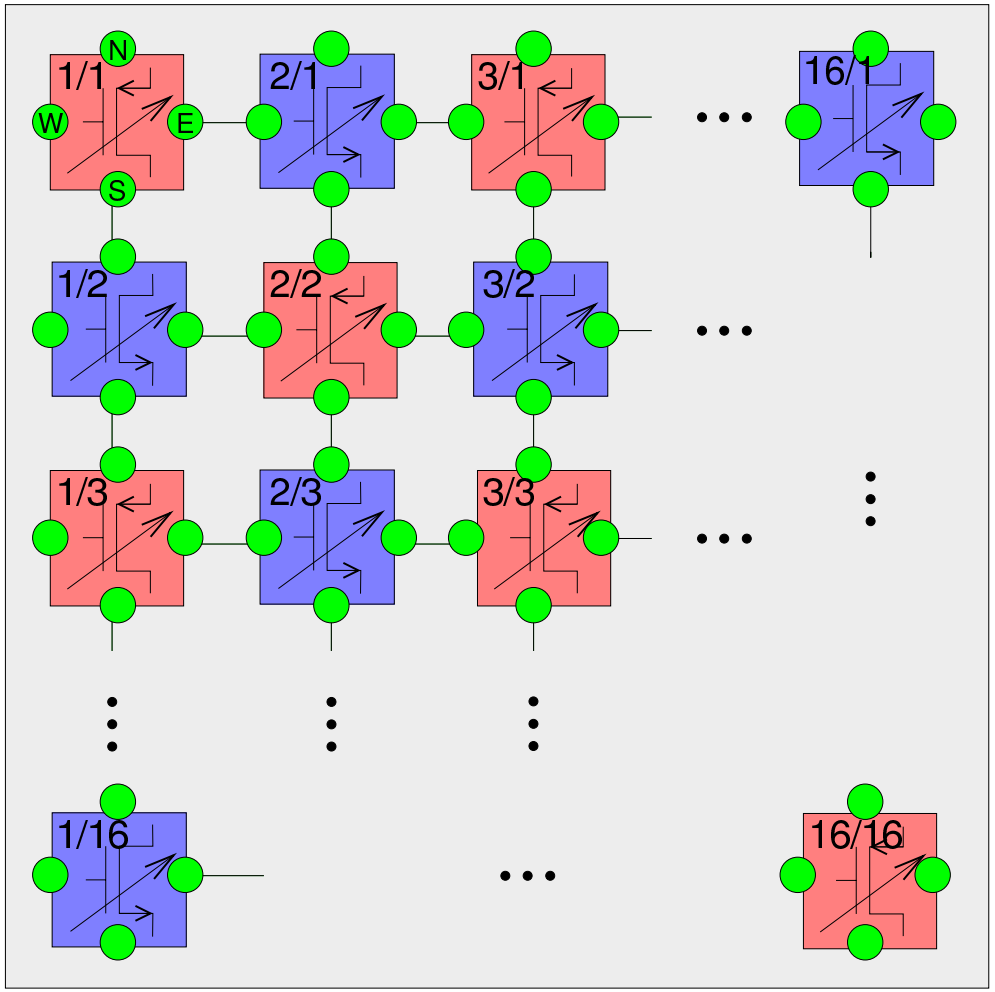
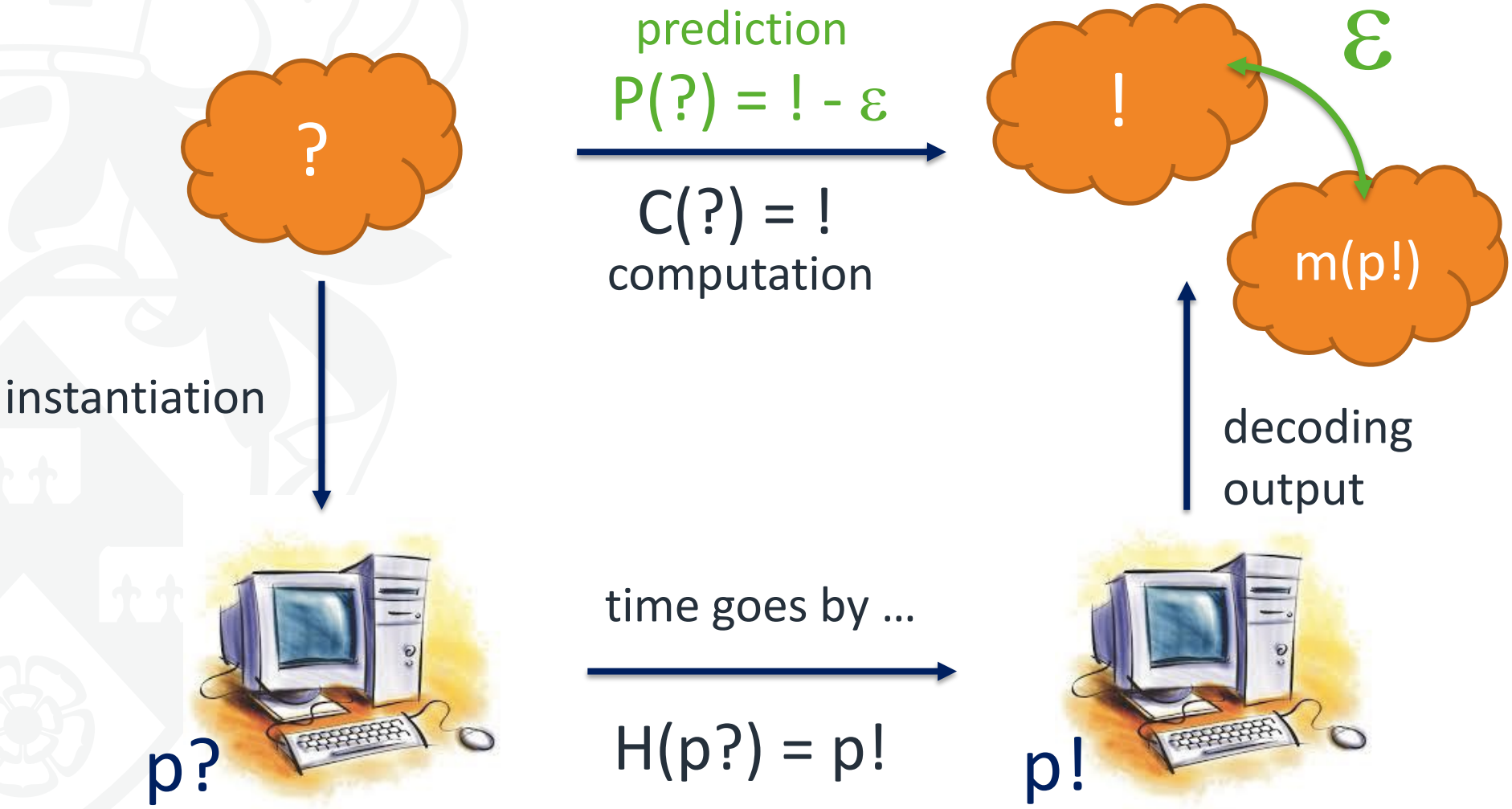
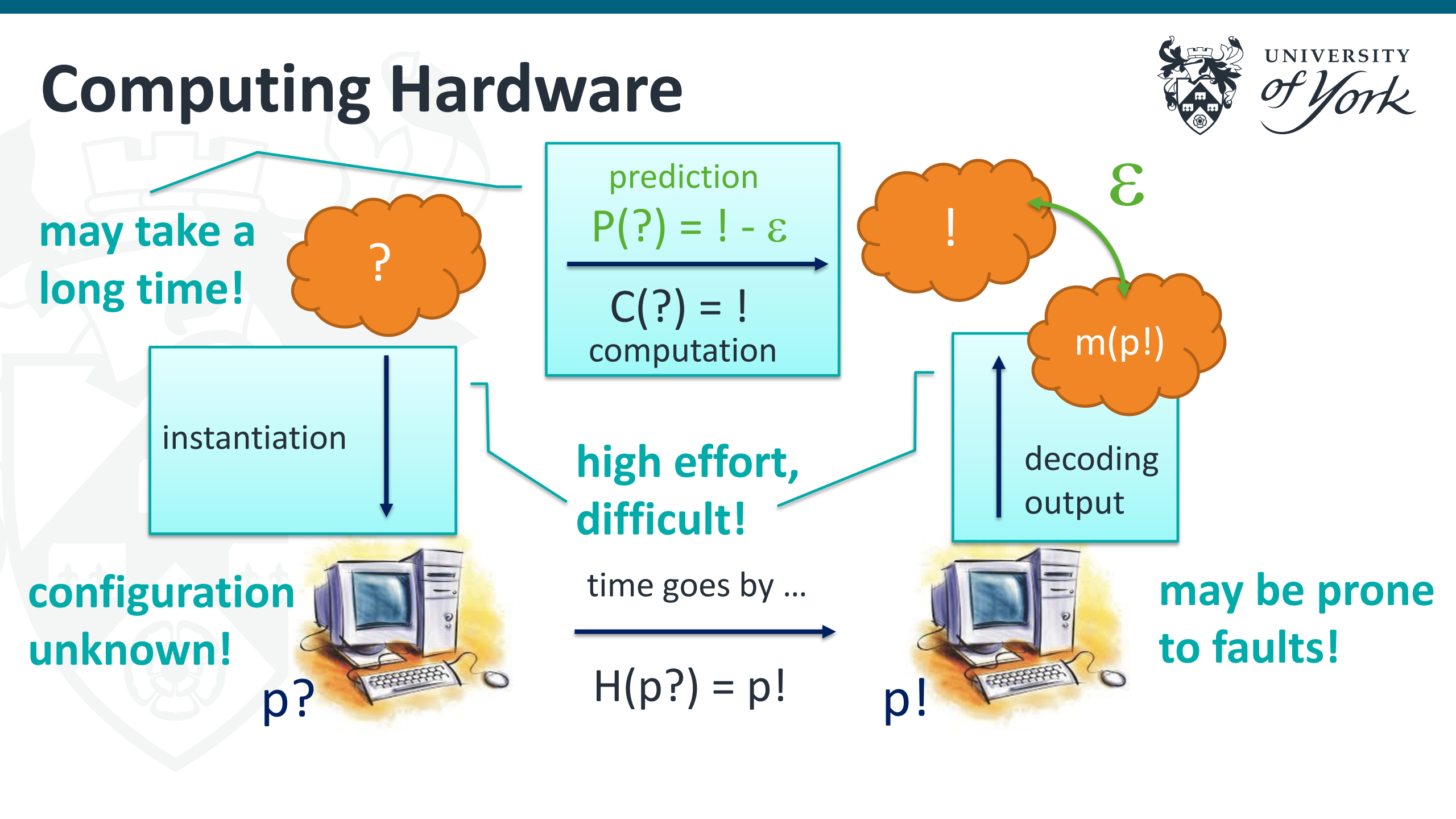




Computing Hardware

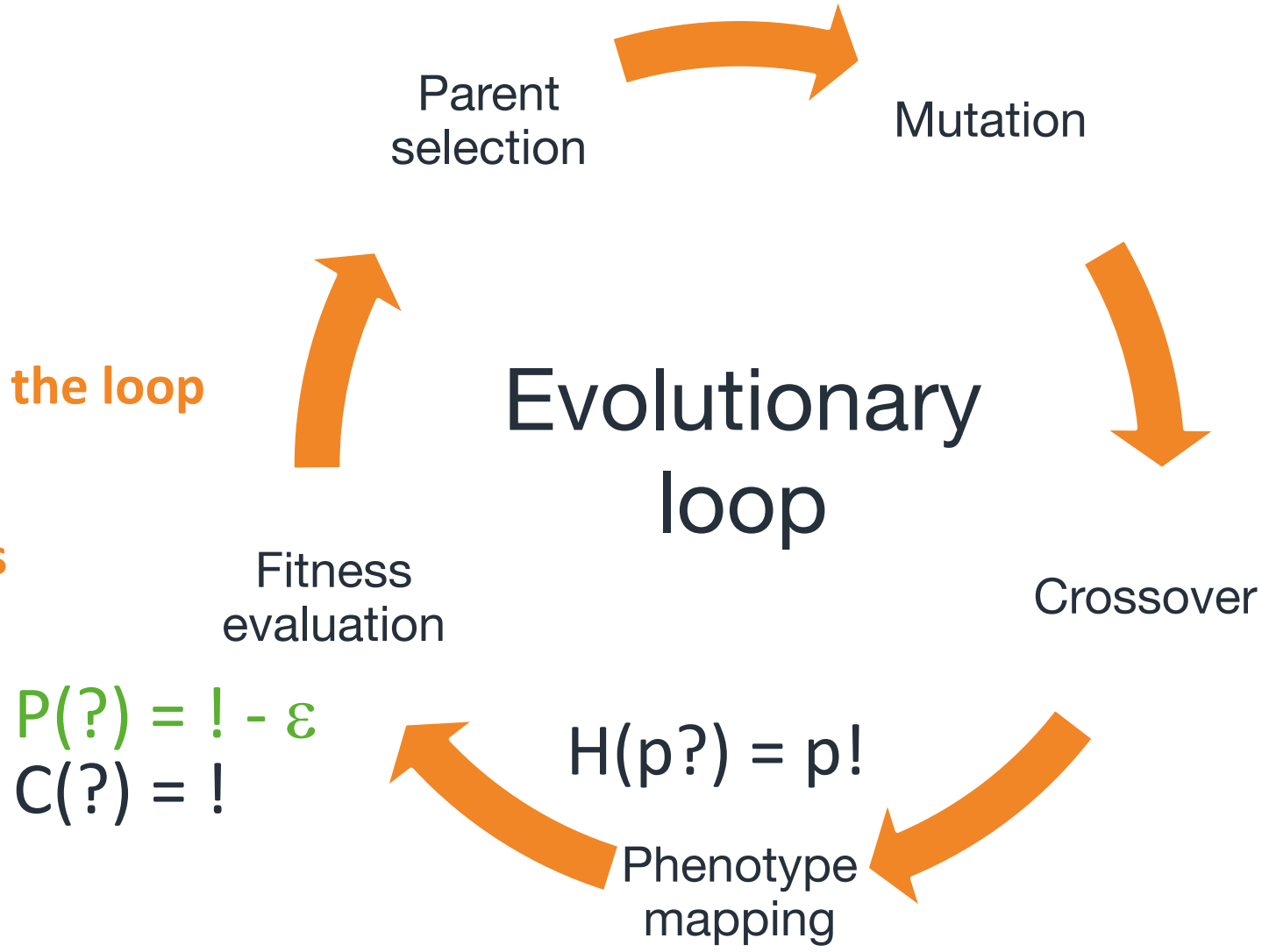


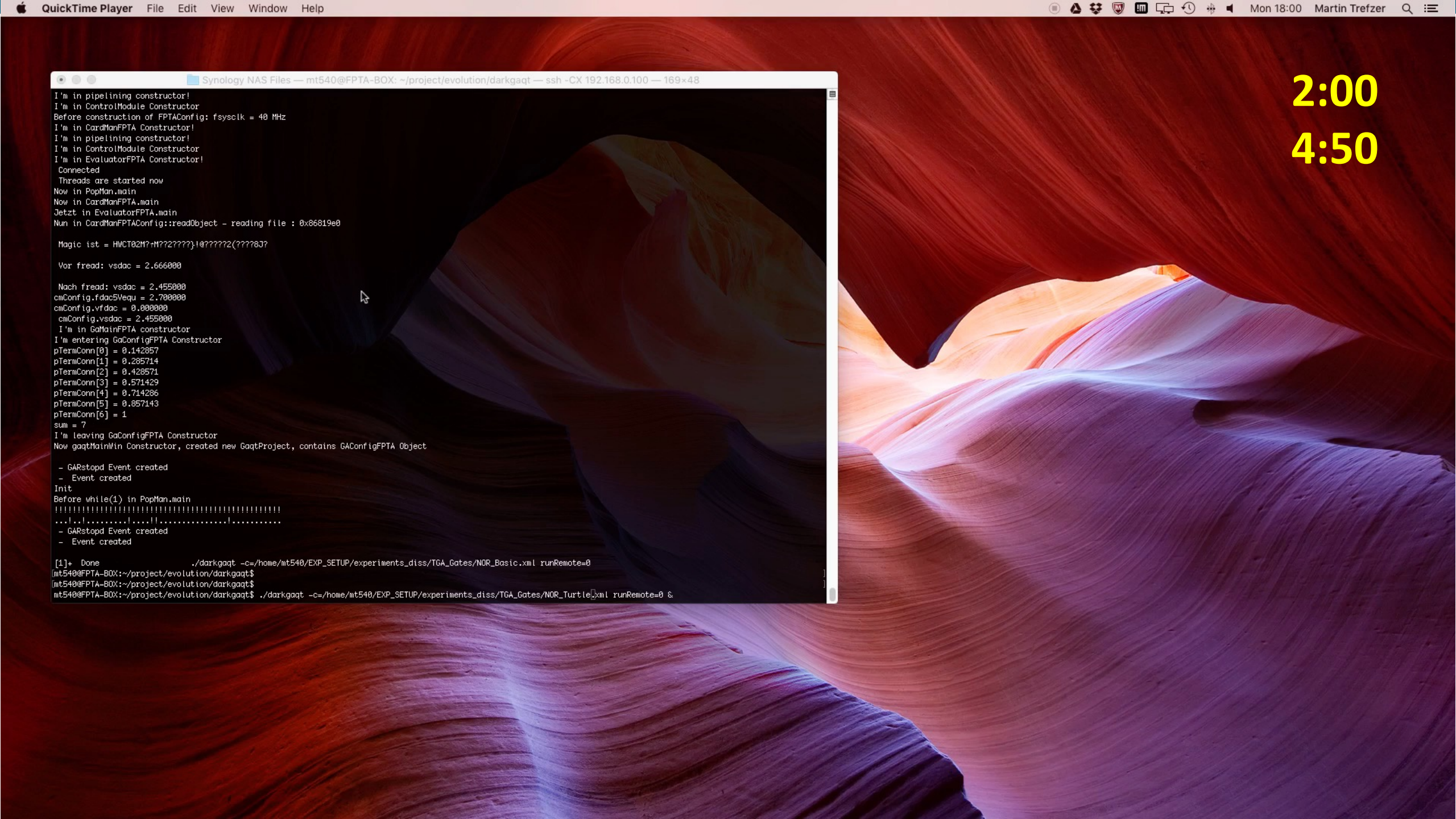
Computing Hardware



Evolutionary *Configurable* Hardware

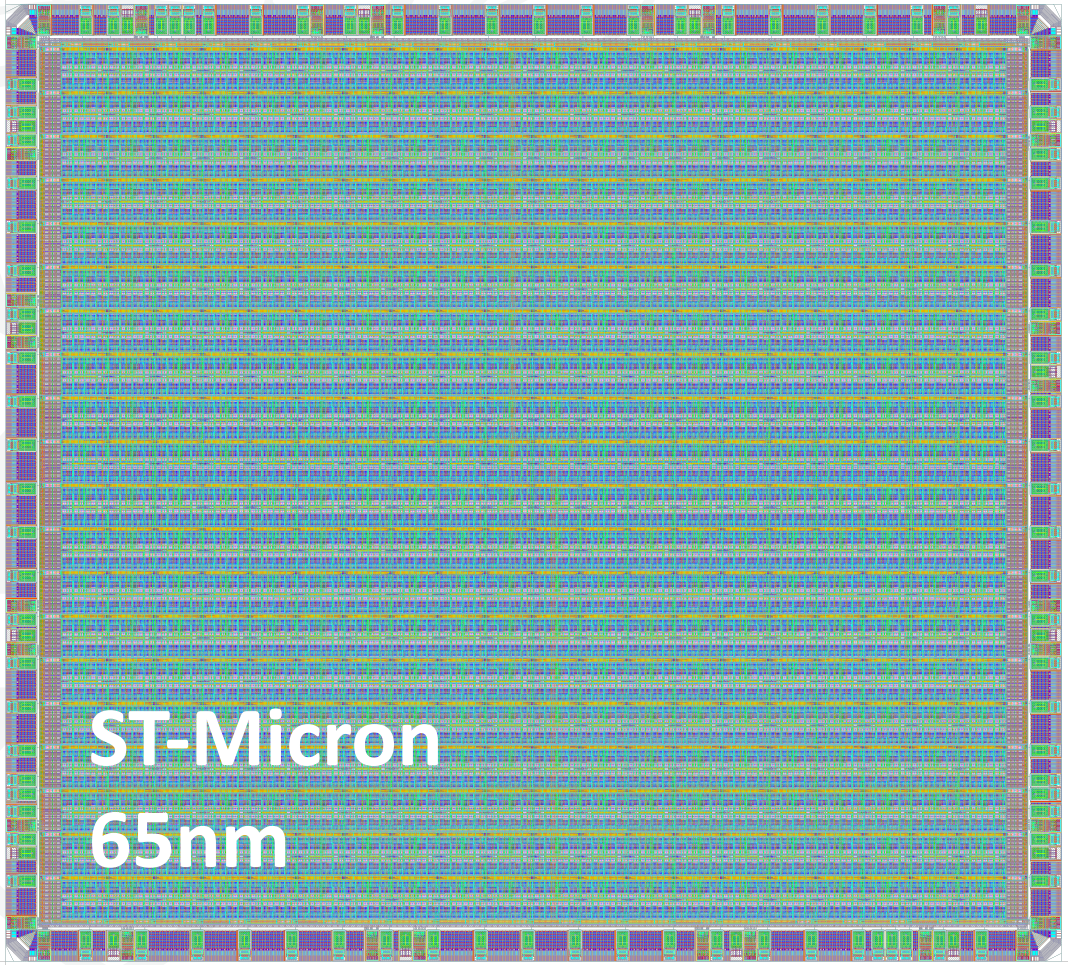
- May take a long time!
  - automated optimisation
- High effort, difficult!
  - configurable hardware in the loop
- Prone to faults
  - robustness part of fitness
- Configuration unknown!
  - black box

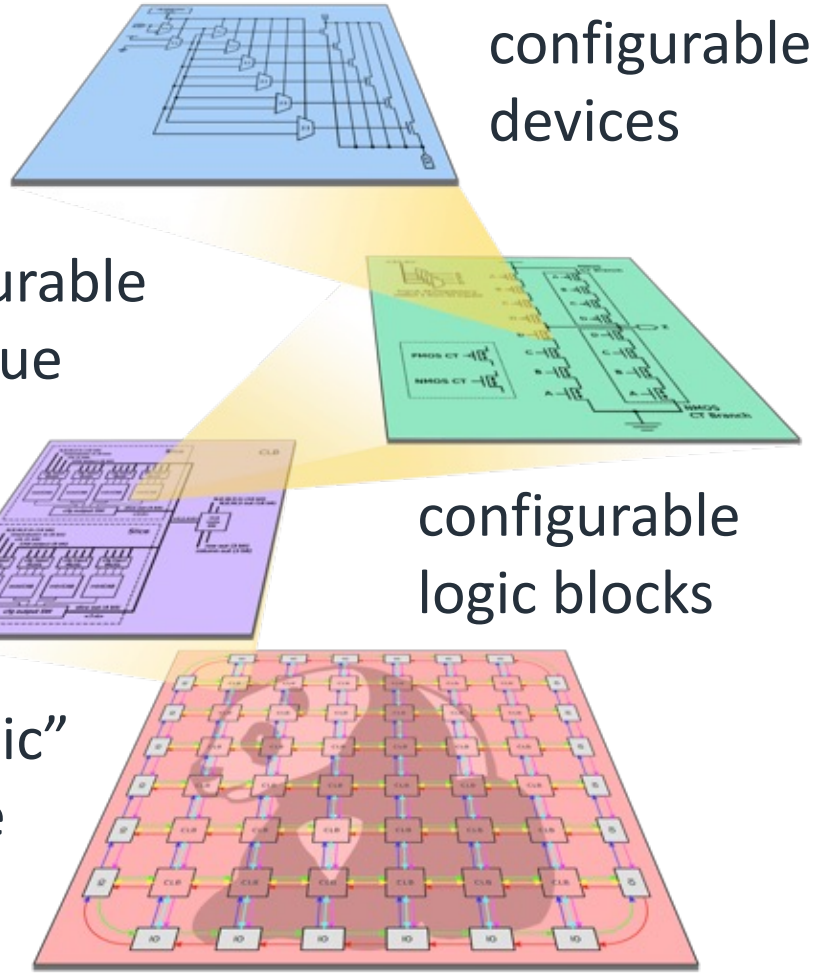



QuickTime Player File Edit View Window Help
Mon 18:00 Martin Trefzer
2:00
4:50
Synology NAS Files — mt540@FPTA-BOX: ~/project/evolution/darkgaqt — ssh -CX 192.168.0.100 — 169×48
I'm in pipelining constructor!
I'm in ControlModule Constructor
Before construction of FPTAConfig: fsysclk = 40 MHz
I'm in CardManFPTA Constructor!
I'm in pipelining constructor!
I'm in ControlModule Constructor
I'm in EvaluatorFPTA Constructor!
Connected
Threads are started now
Now in PopMan.main
Now in CardManFPTA.main
Jetzt in EvaluatorFPTA.main
Nun in CardManFPTAConfig::readObject - reading file : 0x86819e0
Magic ist = HWCT02M?+M??2????}!@?????2(????8J?
Vor fread: vsdac = 2.666000
Nach fread: vsdac = 2.455000
cmConfig.fdac5Vequ = 2.700000
cmConfig.vfdac = 0.000000
cmConfig.vsdac = 2.455000
I'm in GaMainFPTA constructor
I'm entering GaConfigFPTA Constructor
pTermConn[0] = 0.142857
pTermConn[1] = 0.285714
pTermConn[2] = 0.428571
pTermConn[3] = 0.571429
pTermConn[4] = 0.714286
pTermConn[5] = 0.857143
pTermConn[6] = 1
sum = 7
I'm leaving GaConfigFPTA Constructor
Now gaqtMainWin Constructor, created new GaqtProject, contains GAConfigFPTA Object
- GARstopd Event created
- Event created
Init
Before while(1) in PopMan.main
!!!
...!..!.........!....!!.................!...........
- GARstopd Event created
- Event created
[1]+ Done ./darkgaqt -c=/home/mt540/EXP_SETUP/experiments_diss/TGA_Gates/NOR_Basic.xml runRemote=0
mt540@FPTA-BOX:~/project/evolution/darkgaqt$
mt540@FPTA-BOX:~/project/evolution/darkgaqt$
mt540@FPTA-BOX:~/project/evolution/darkgaqt$ ./darkgaqt -c=/home/mt540/EXP_SETUP/experiments_diss/TGA_Gates/NOR_Turtle.xml runRemote=0 &

Multi-reconfigurable Hardware

PROGRAMMABLE ANALOGUE AND DIGITAL ARRAY – PANDA





configurable devices

configurable analogue blocks

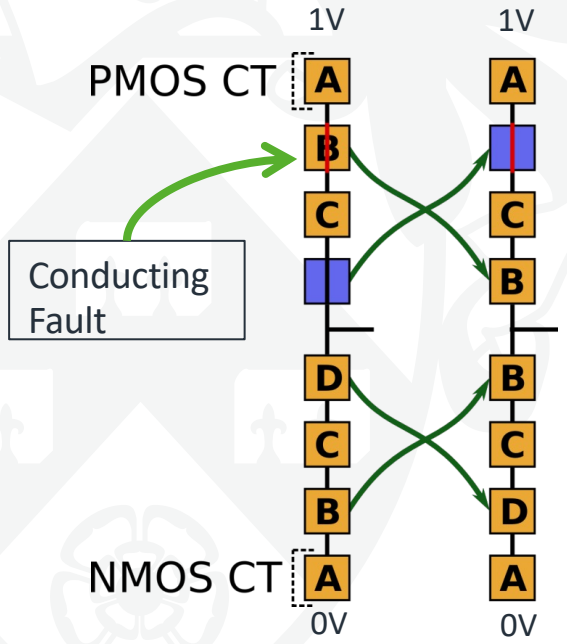
configurable logic blocks

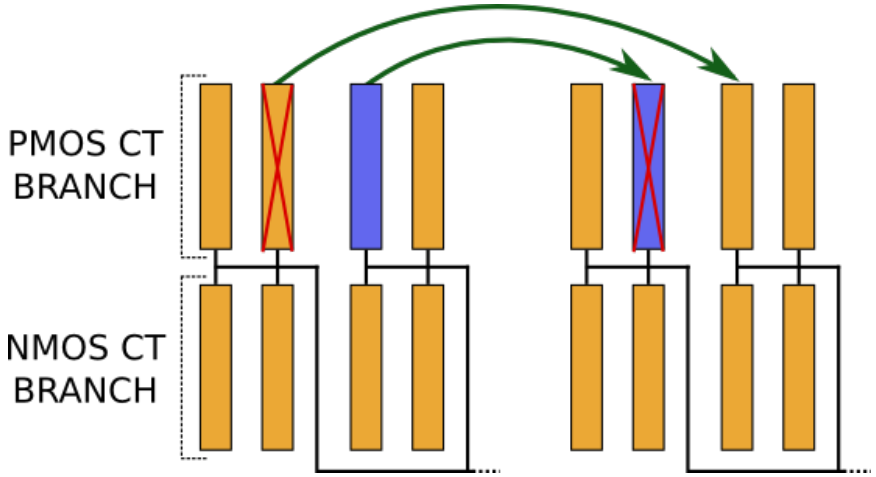
“Heterotic” Adaptive FPGA

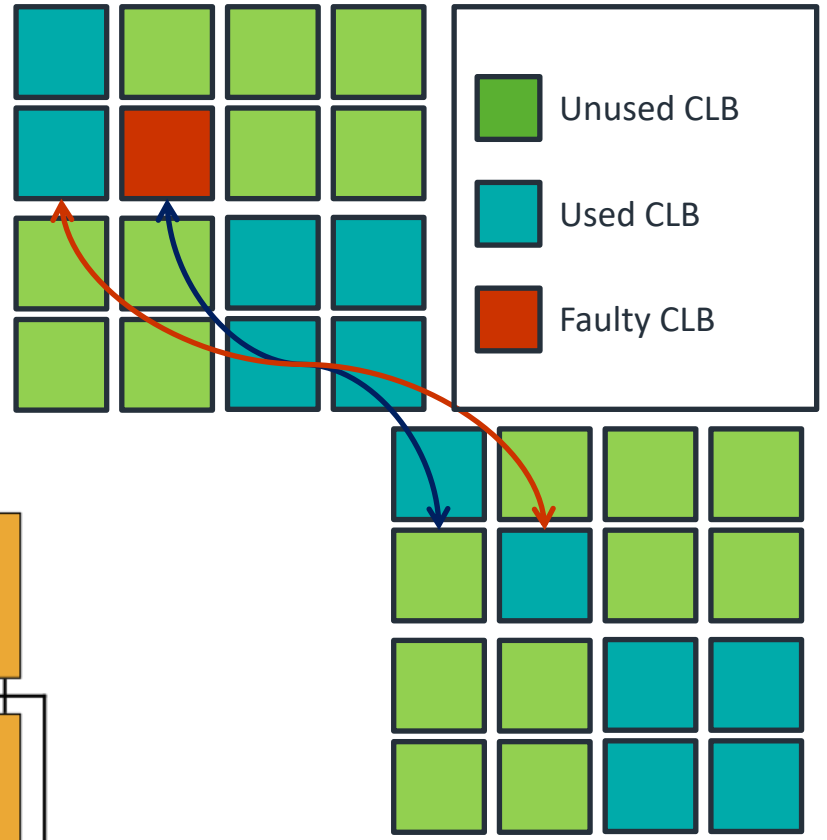
Fault Tolerance

PROGRAMMABLE ANALOGUE AND DIGITAL ARRAY – PANDA

- Evolution of fast hierarchical repair strategies
- Swap CLBs, CABs, Branches, CTs

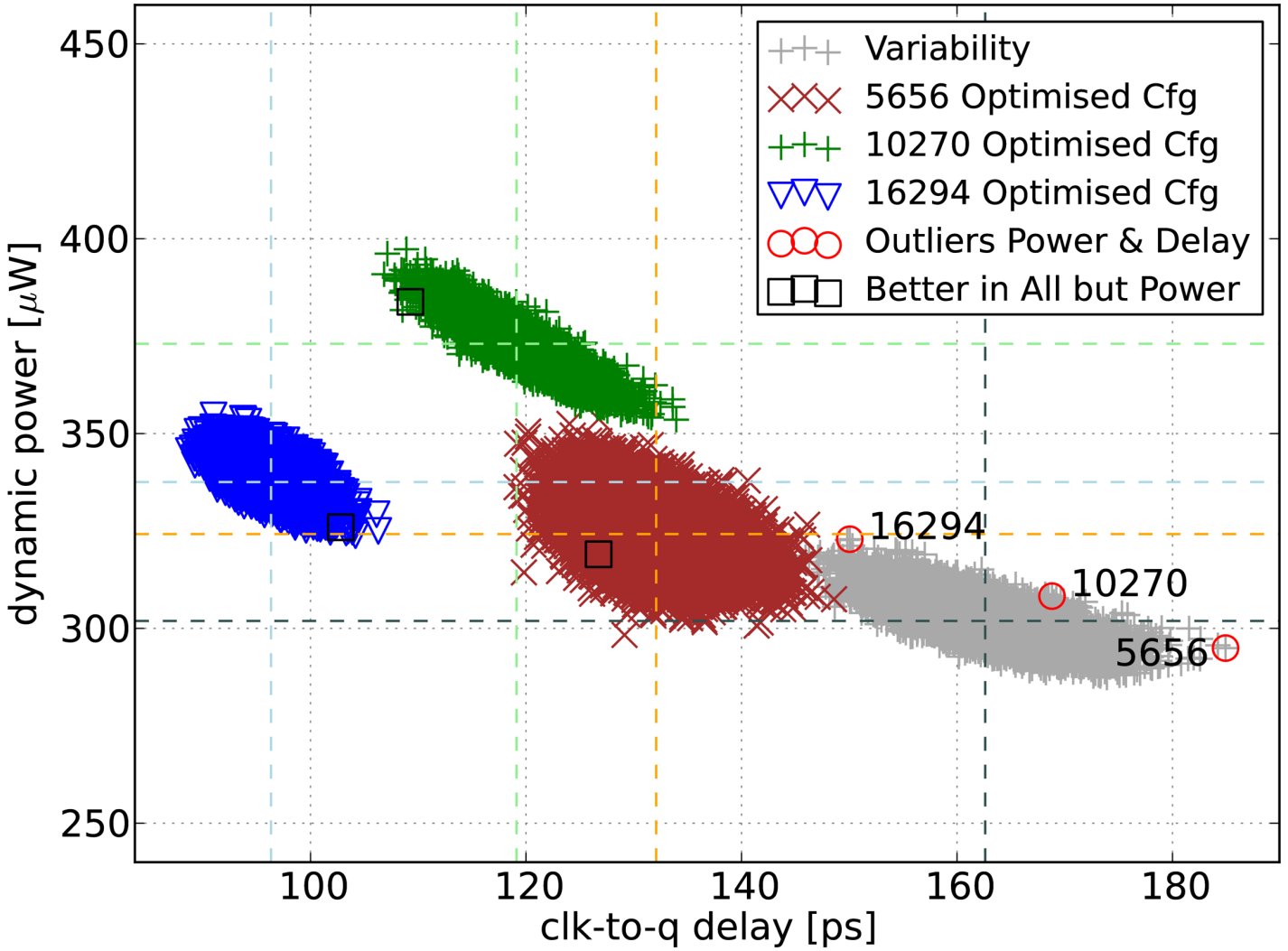






Variability Mitigation

PROGRAMMABLE ANALOGUE AND DIGITAL ARRAY – PANDA

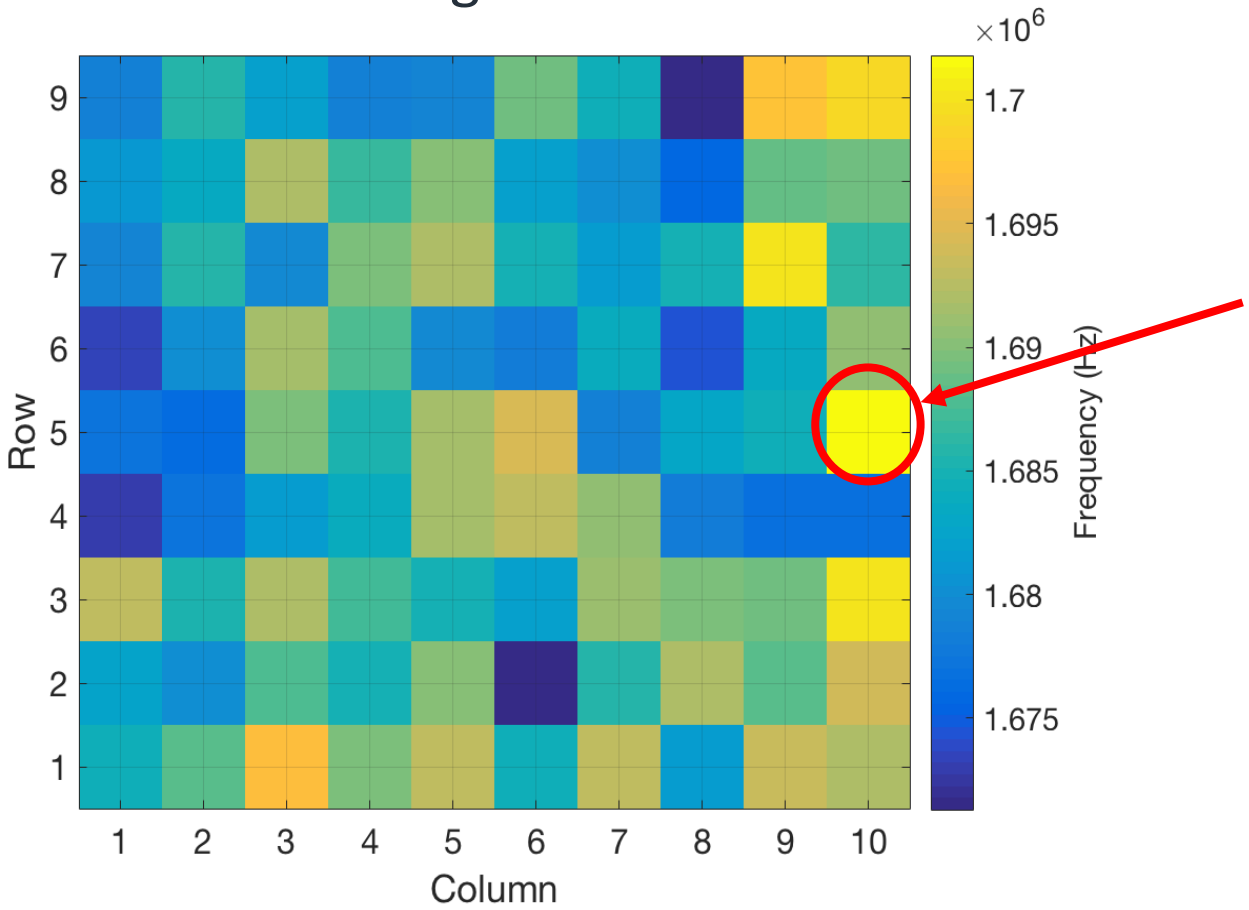


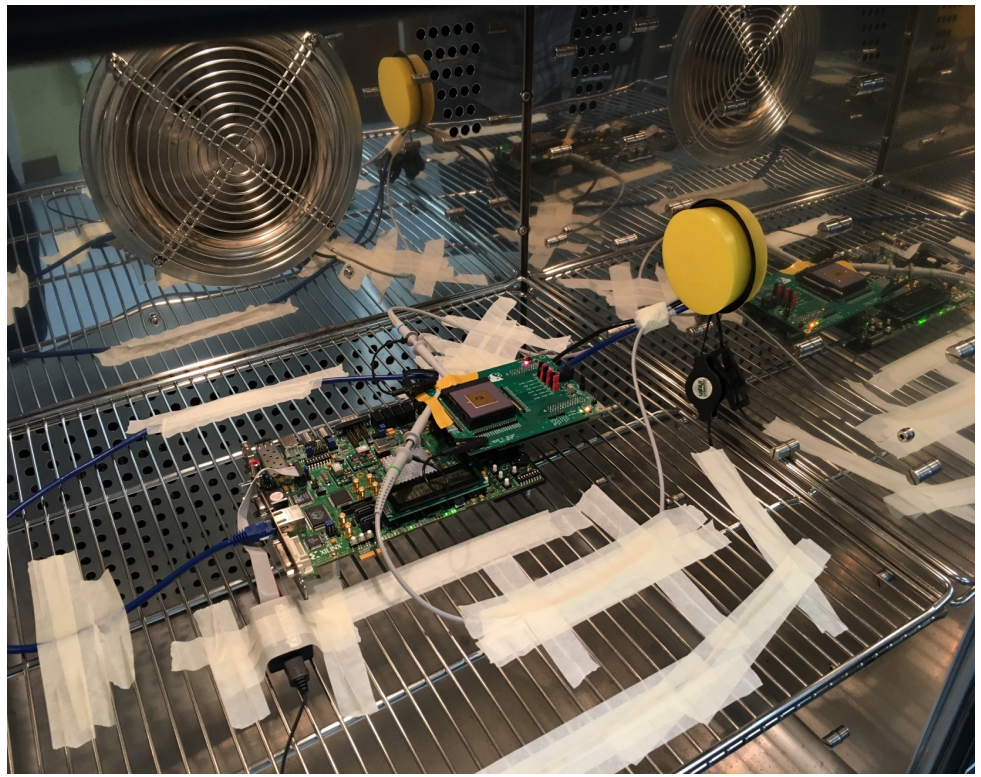
- Standard cell optimization
- Robustness against variability

Variability Mitigation

PROGRAMMABLE ANALOGUE AND DIGITAL ARRAY – PANDA

- Ring-oscillator frequency optimisation
- Substrate homogeneisation

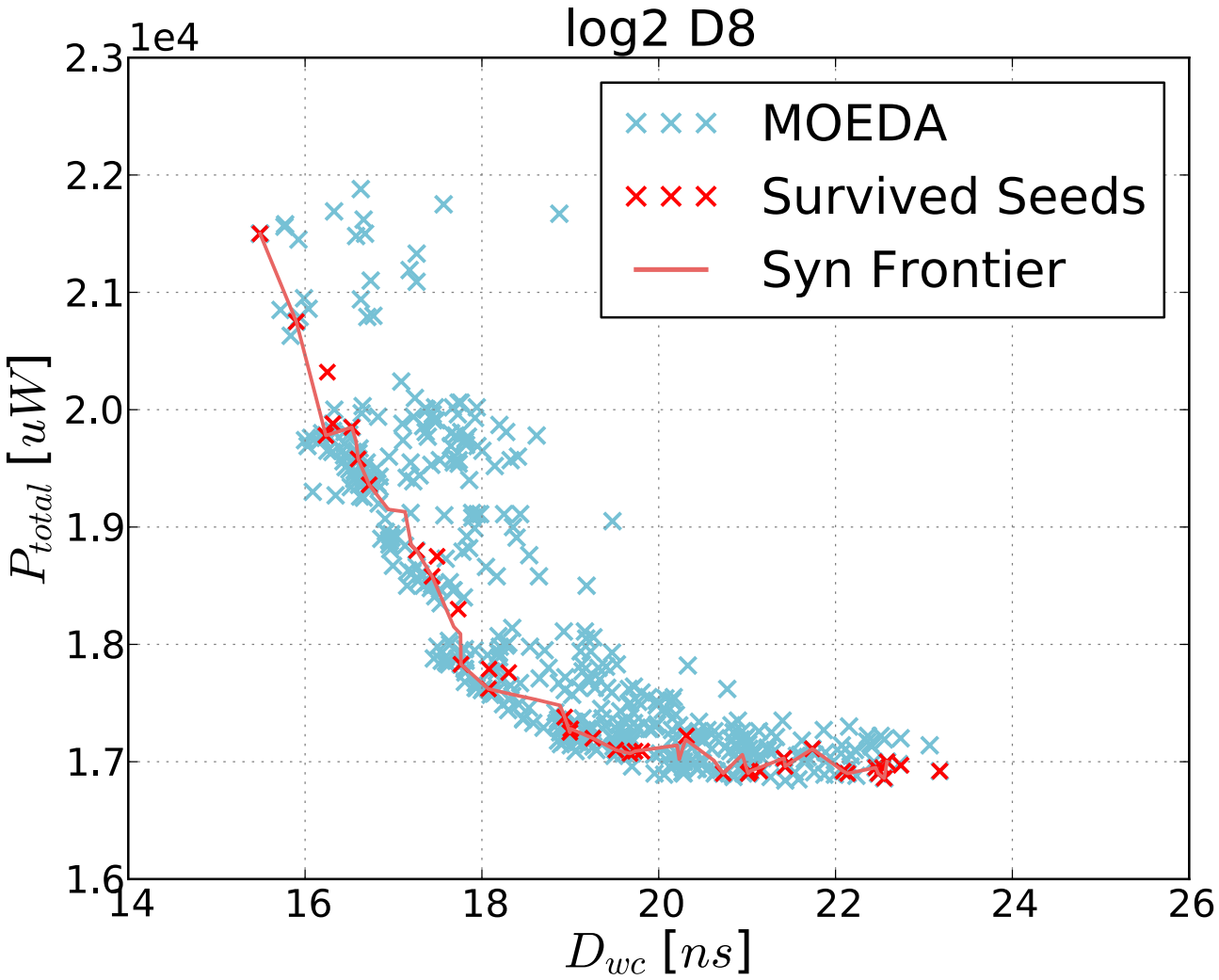




- Temperature-controlled setup

Cell Mapping in VLSI EDA Flow

OPTIMISING DRIVE STRENGTH MAPPING IN INDUSTRIAL EDA FLOW



- Log2 Circuit
- 32k complex gates
- Multi-objective optimization for PPA

RTM of Many-core Systems

RUNTIME MANAGEMENT OF DISTRIBUTED SYSTEMS

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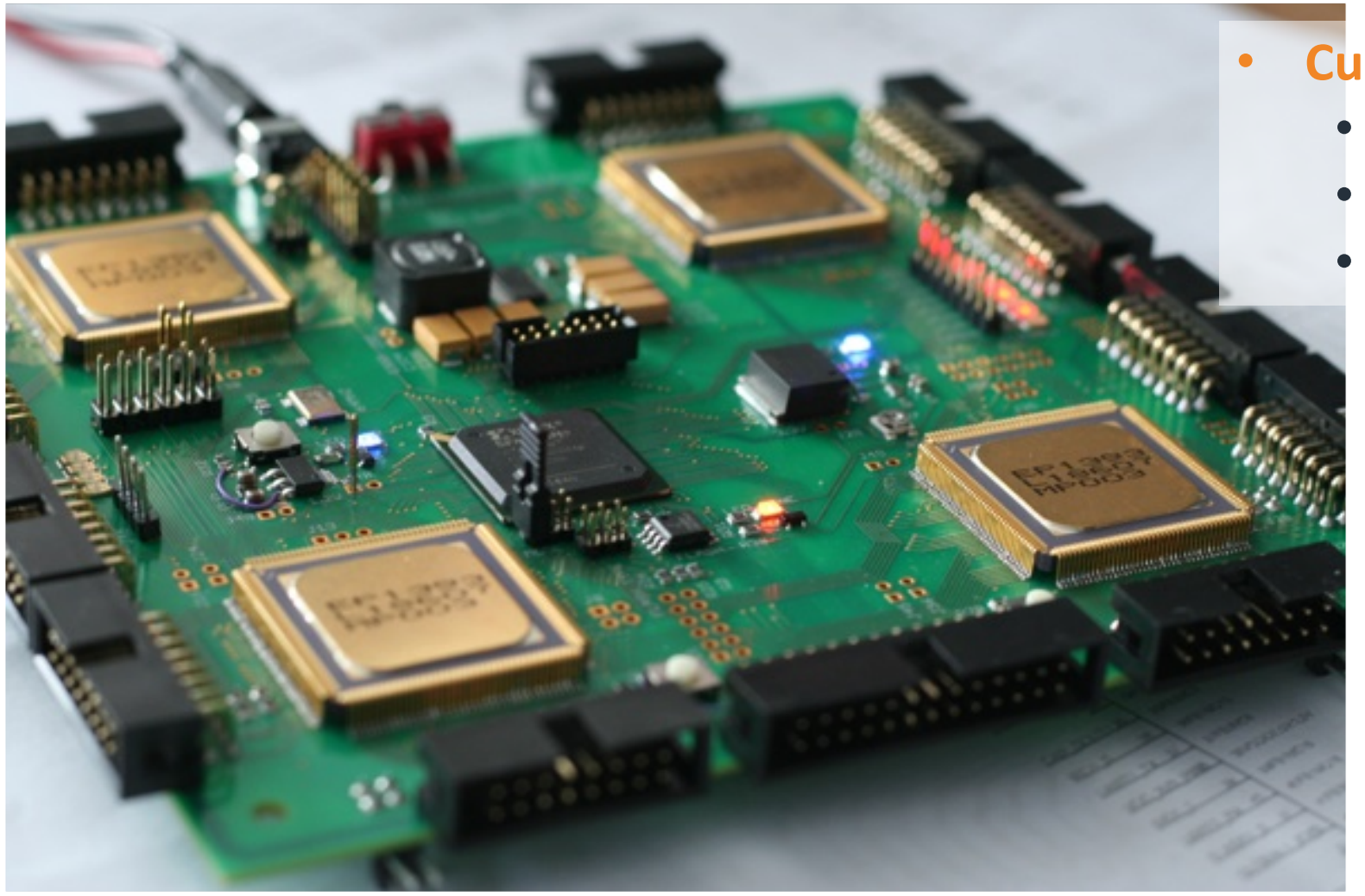


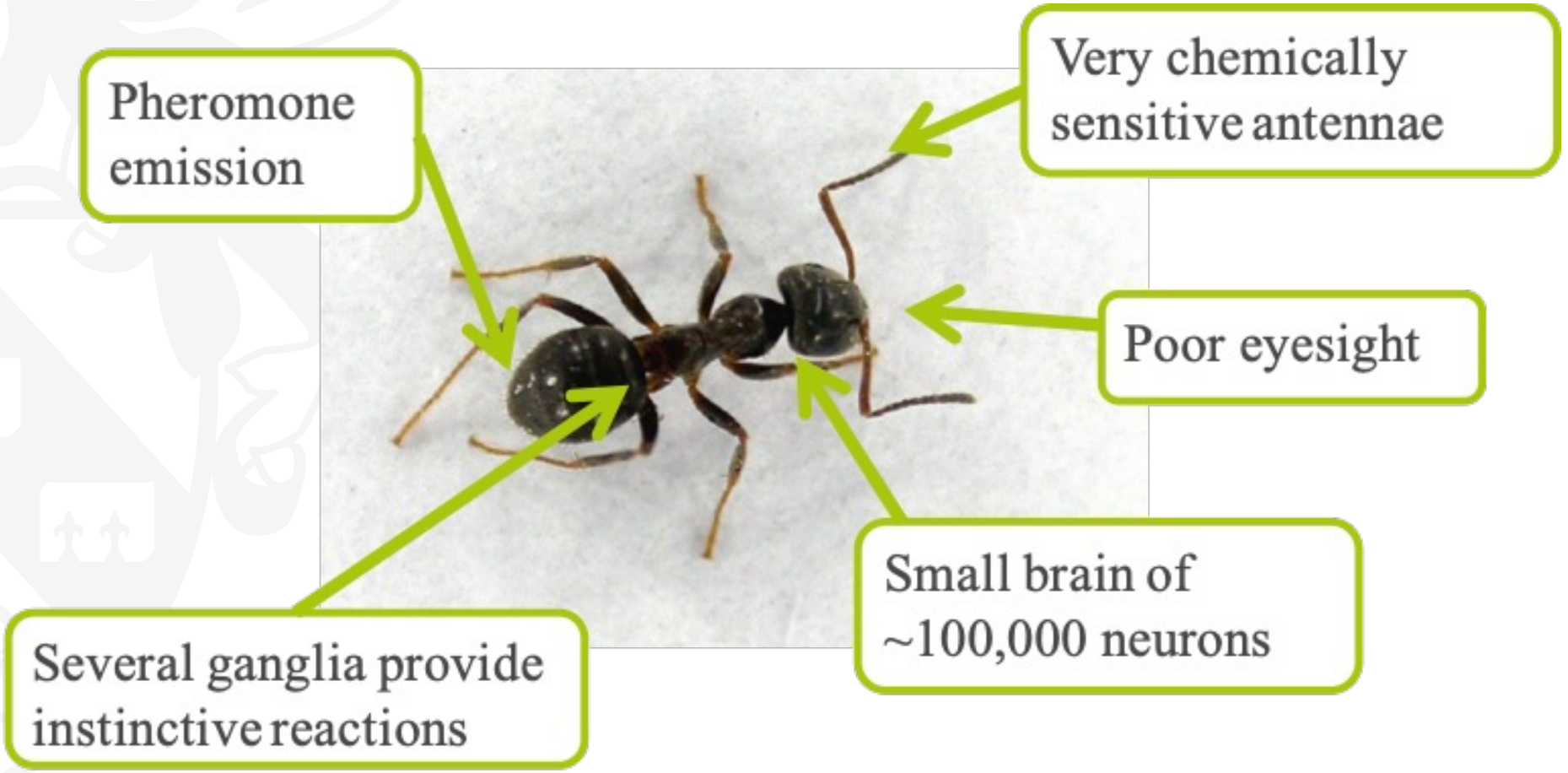
- **Custom-built many-core systems**
  - **RISA (180nm TSMC)**
  - **Centurion (Xilinx Virtex-7)**
  - **Graceful (Xilinx ZYNQ-7020)**

Centurion
E7X

Graceful

Social-insects Inspired Behaviour

RUNTIME OPTIMISATION, ONLINE LEARNING, FAULT TOLERANCE



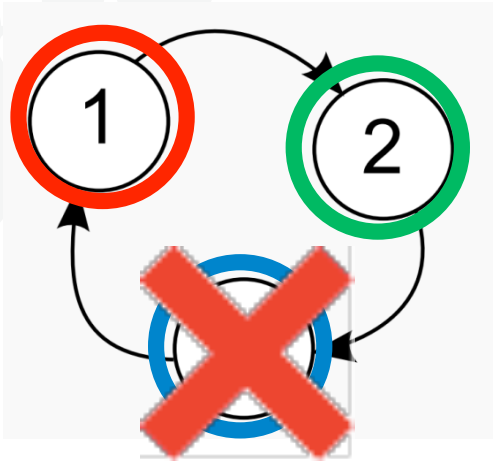
Social-insects Inspired Behaviour

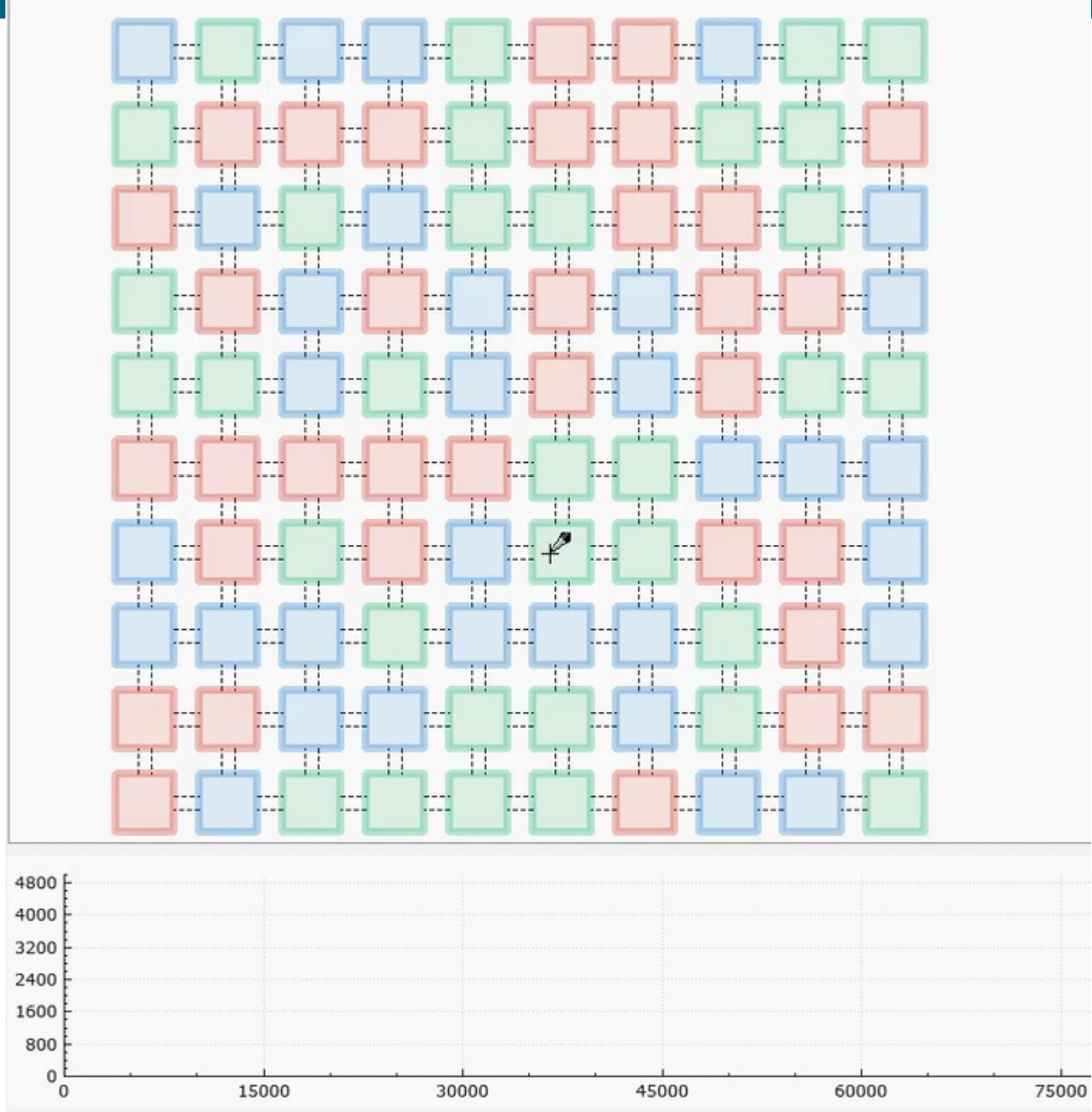
RUNTIME OPTIMISATION, ONLINE LEARNING, FAULT TOLERANCE

Social insects-inspired Behaviour

ANT-INSPIRED RUNTIME MANAGEMENT
AND FAULT TOLERANCE
IN MANY-CORE SYSTEMS

- Self-organization
- Distributed decision making
- Autonomous fault tolerance

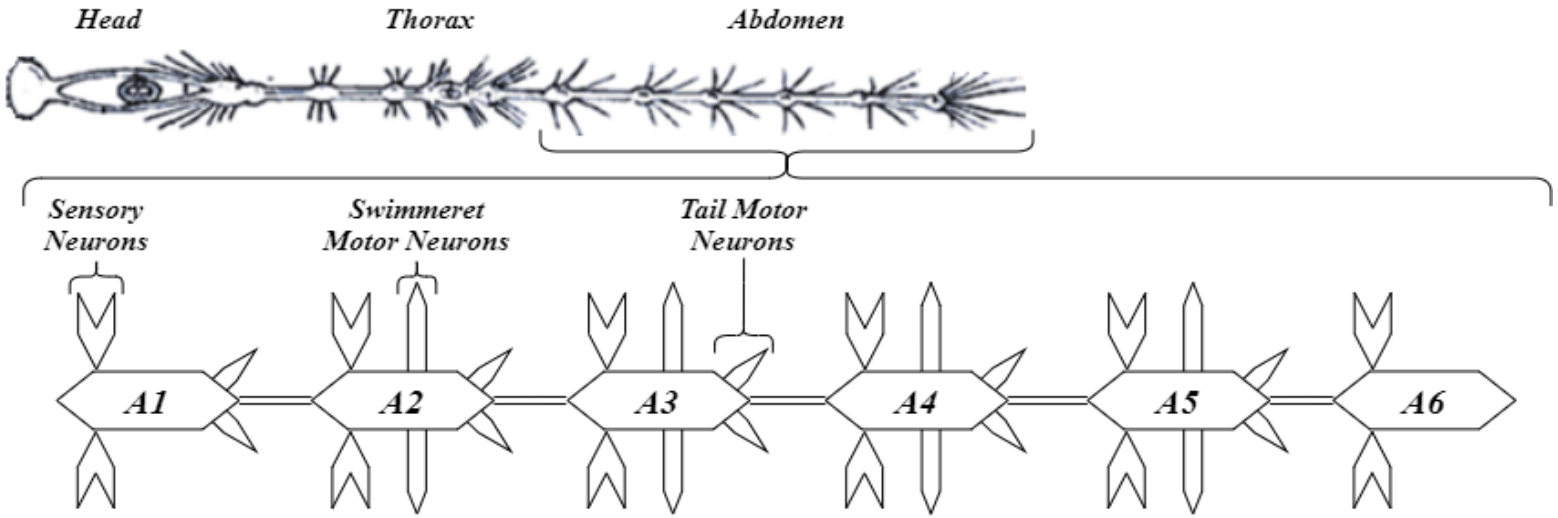


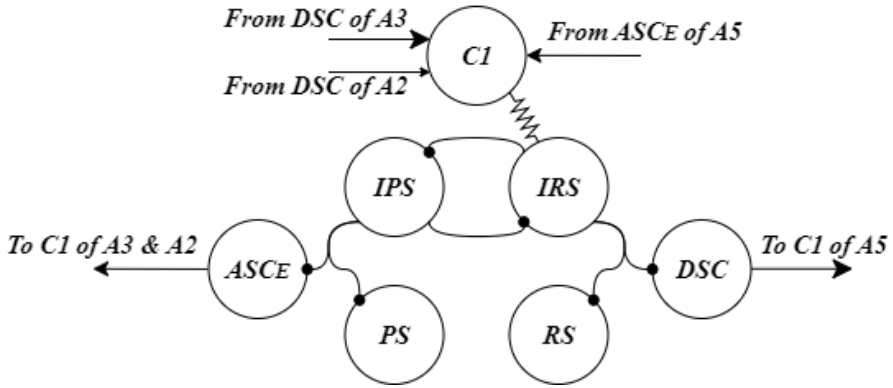


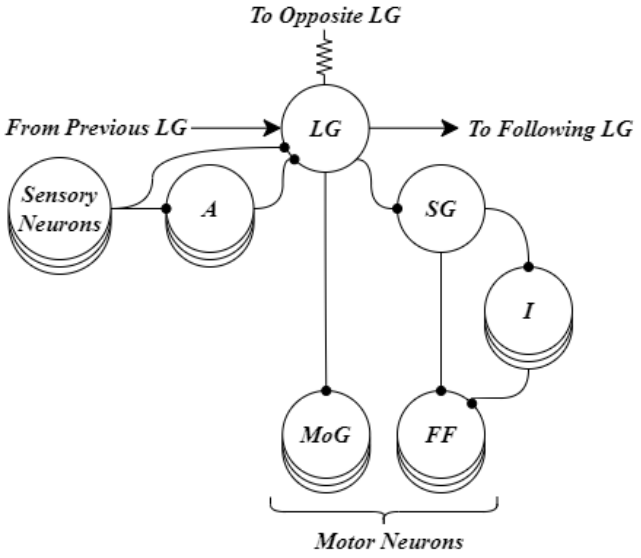
Artificial Neural Microcircuits

NEURAL MICROCIRCUITS AS EMBEDDED “NERVOUS SYSTEM”

Crayfish tail reflex

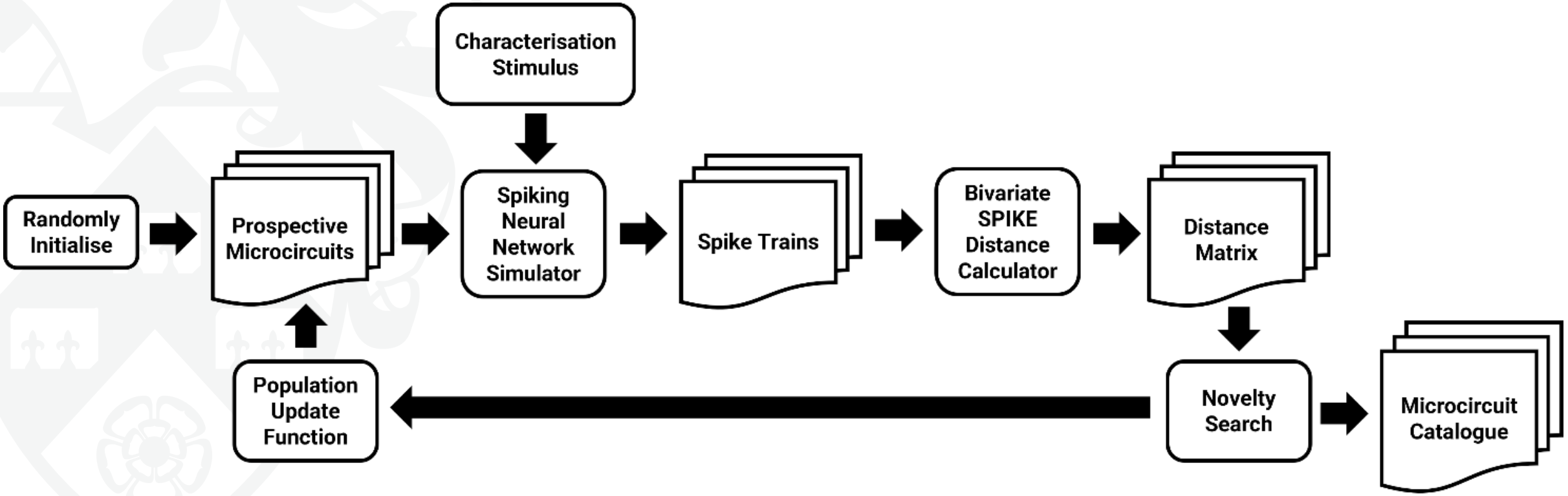






Making Neural Microcircuits

EVOLUTIONARY NOVELTY SEARCH AND TASK SEARCH



Embedding Neural Microcircuits

NEORV32 RISC-IV CPU

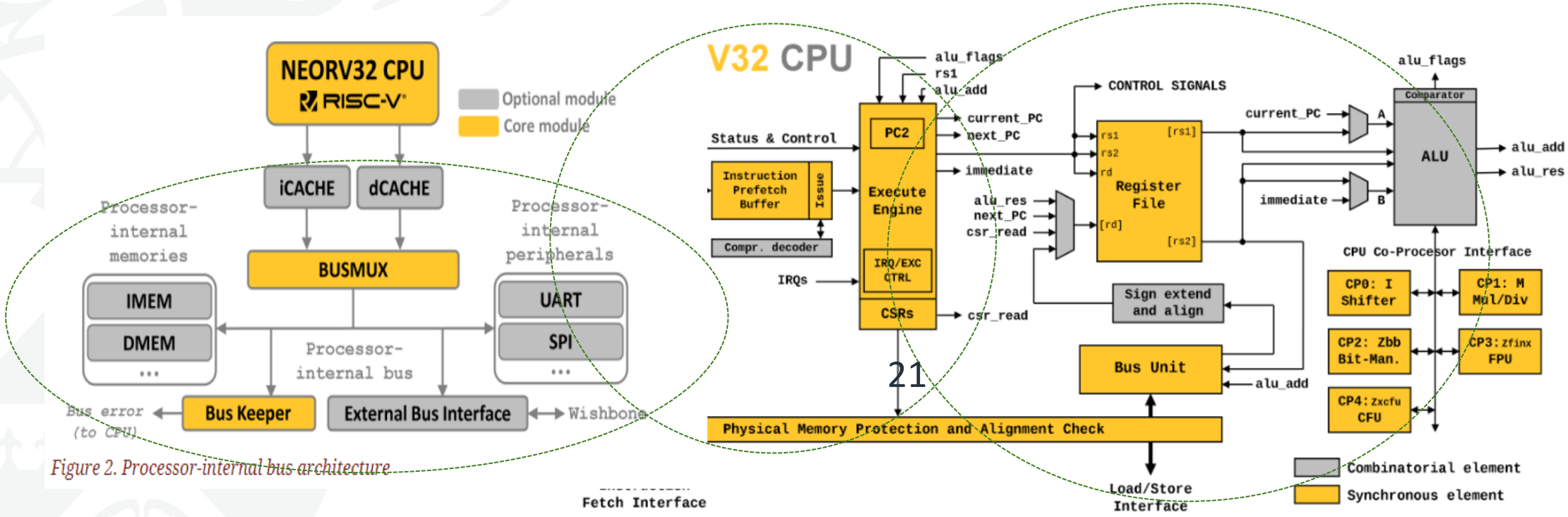


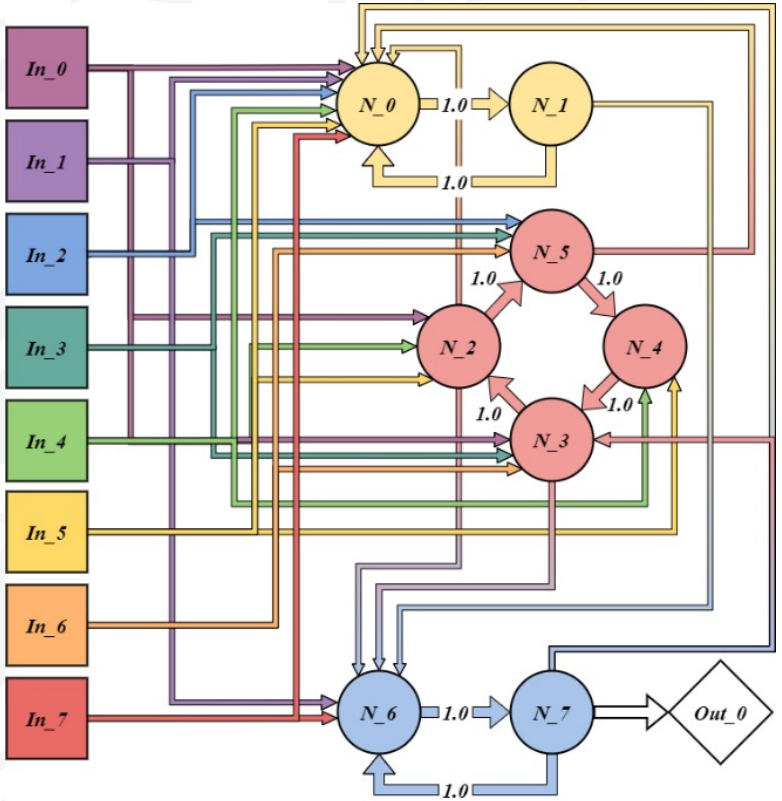
Figure 2. Processor-internal bus architecture

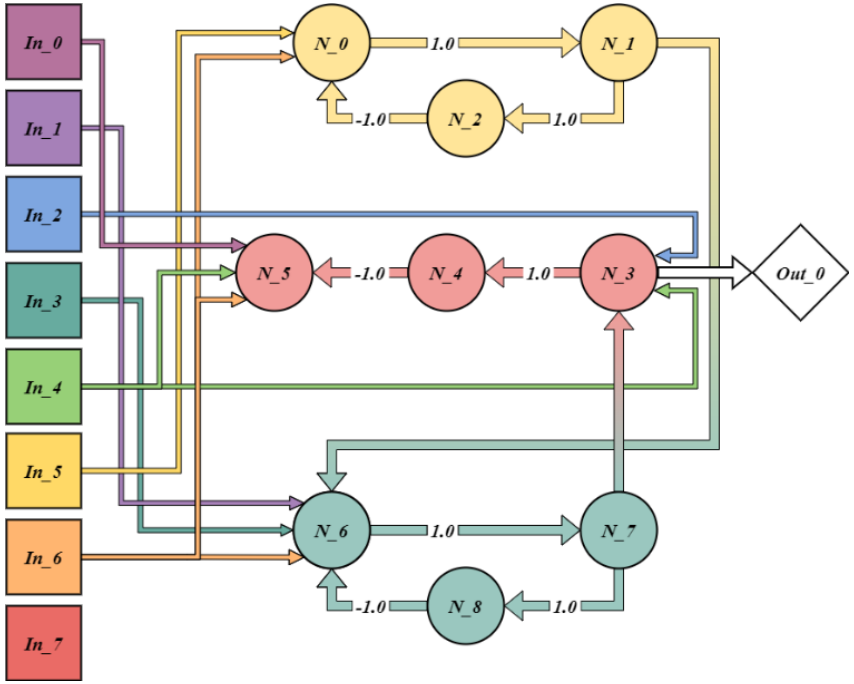
21

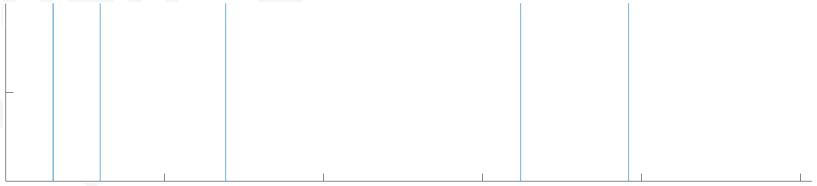
Location 1 Location 2 Location 3

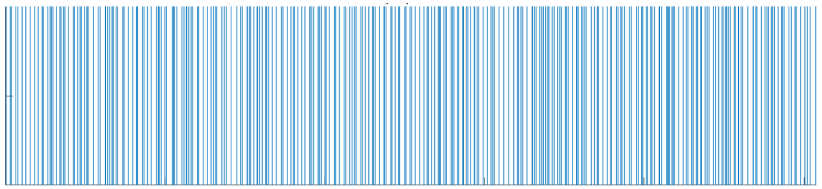
Neural Microcircuit Responses

RESPONDING TO “IRRADIATED” MEMORY / PROGRAMS



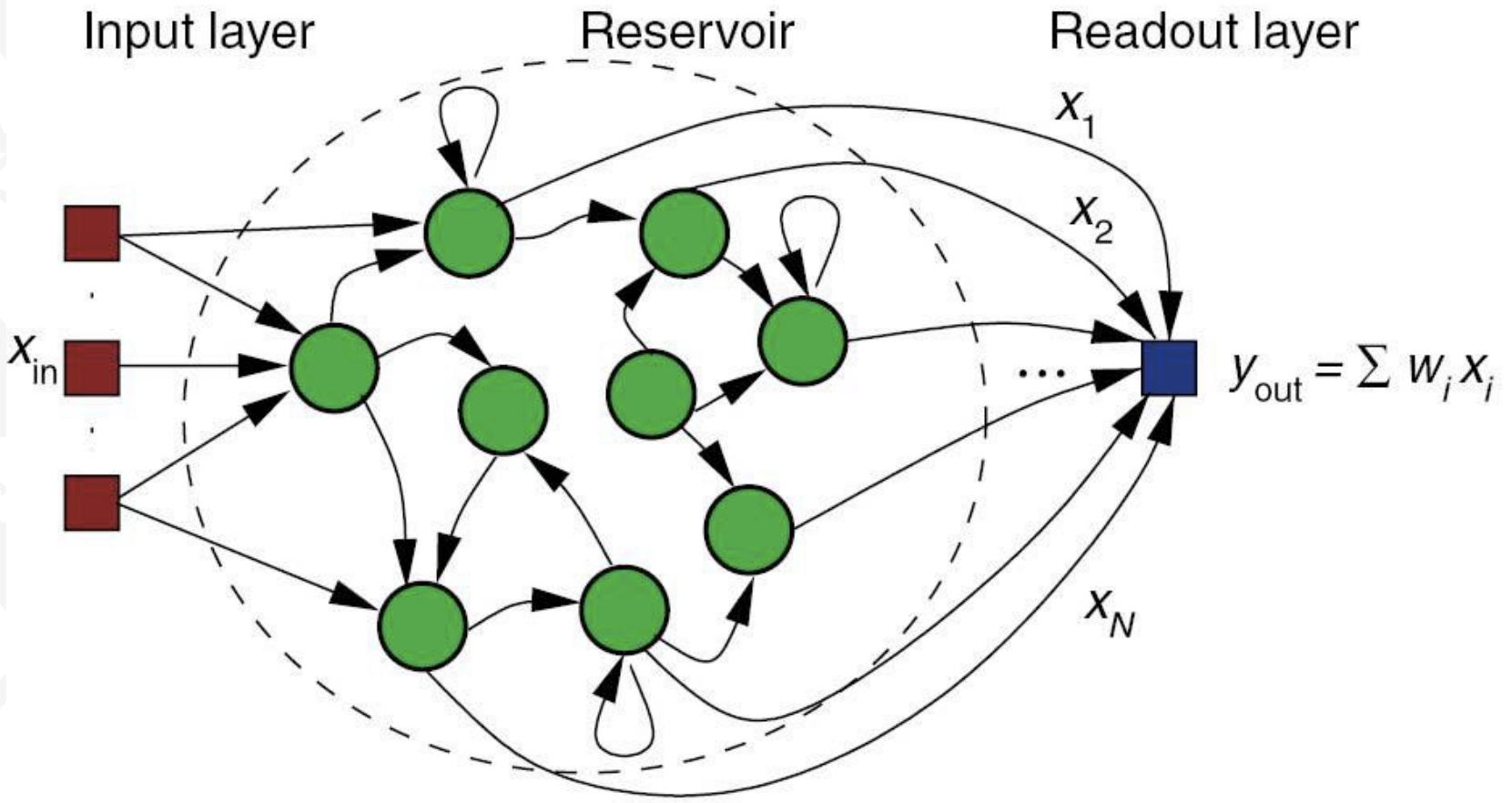






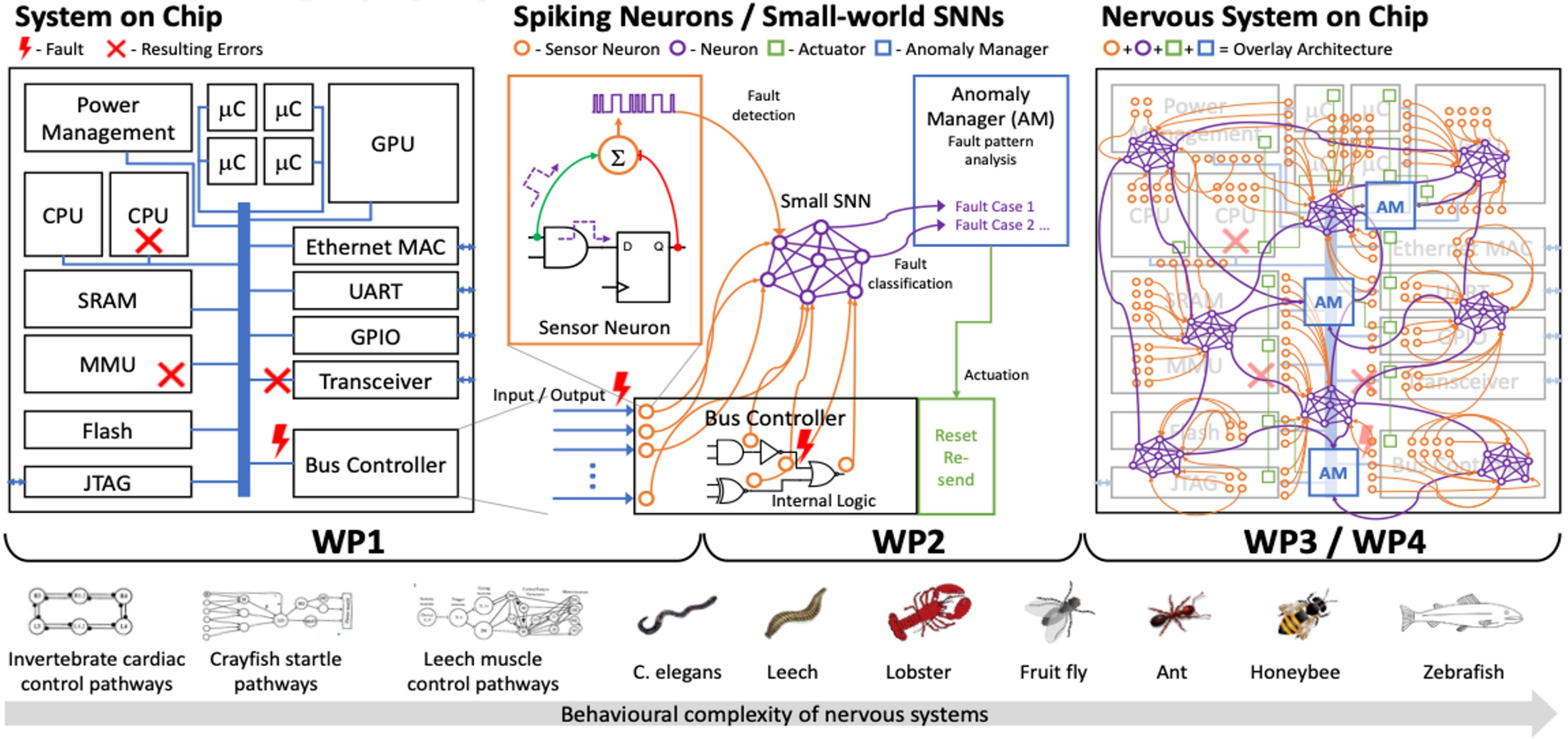
System-level Learning with SNNs

SPIKING NEURAL NETWORKS WITH RESERVOIR COMPUTING



Nervous Systems On Chip

NEUROMORPHIC FAULT TOLERANT HW – LEARNING WHAT IS AN ANOMALY



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