TASTE MEETS TASTEBUD: AN INTRODUCTION TO THE CELL MATRIX

Nicholas J. Macias
Director, Cell Matrix Corporation

TALK OUTLINE

- Brief History of Computing: Scaling Down

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- Brief History of Computing: Scaling Down
- Nanotechnology: Scaling Up

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- Brief History of Computing: Scaling Down
- Nanotechnology: Scaling Up
- The Cell Matrix

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- Brief History of Computing: Scaling Down
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- Philosophy: Subject/Object Dualism

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- Brief History of Computing: Scaling Down
- Nanotechnology: Scaling Up
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- Philosophy: Subject/Object Dualism
- Self-Duality in the Cell Matrix

TALK OUTLINE

- Brief History of Computing: Scaling Down
- Nanotechnology: Scaling Up
- The Cell Matrix
- Philosophy: Subject/Object Dualism
- Self-Duality in the Cell Matrix
- Conclusions/Future Work/Questions

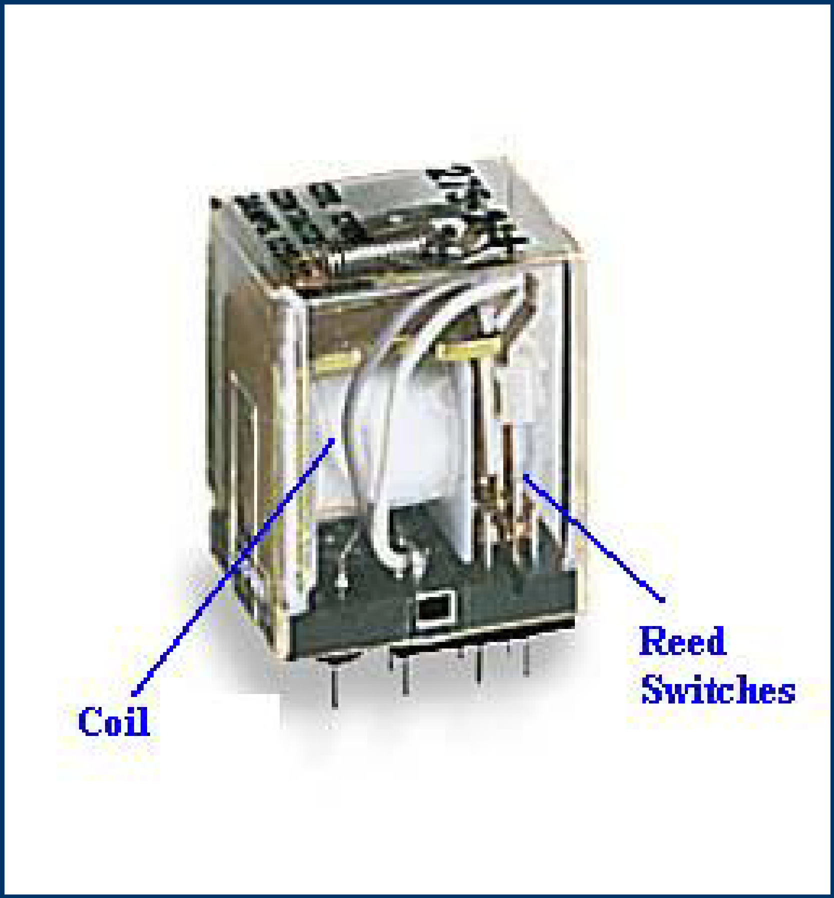
EDVAC
1944-1952

LAPTOP
2003

3 Million Times faster
4 Million times More Storage
1/3000 the price

SWITCHES

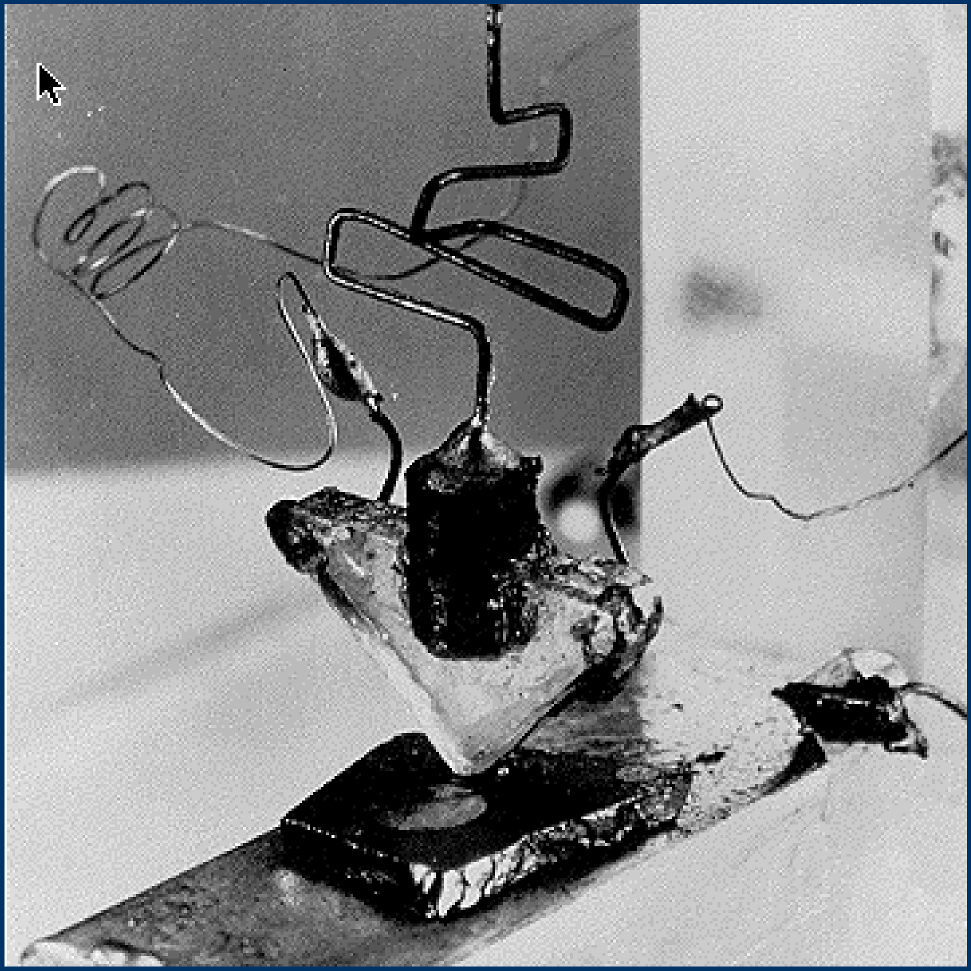
RELAY



VACUUM TUBE

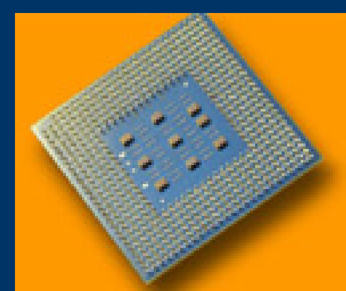
VACUUM TUBE

THE FIRST TRANSISTOR



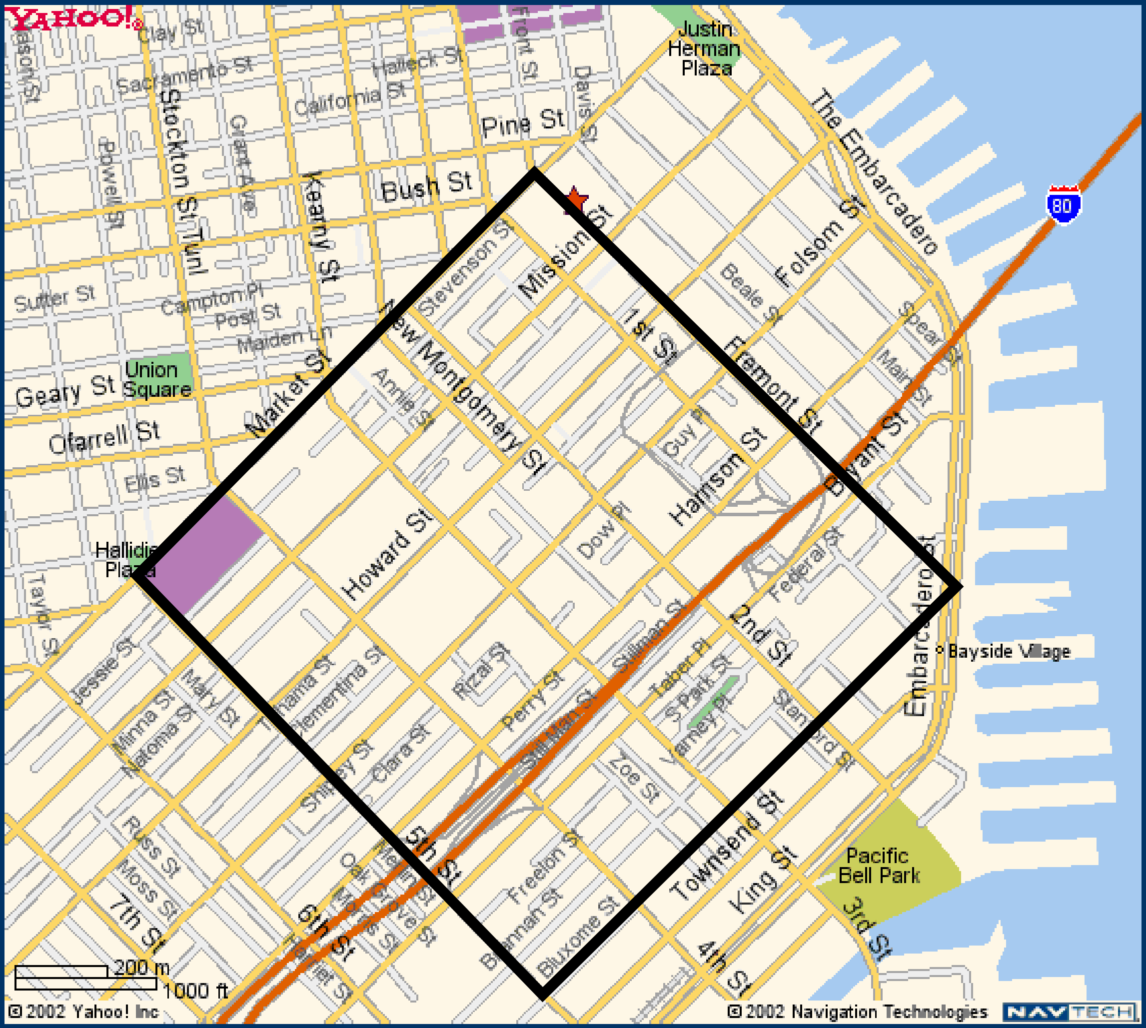
Bardeen, Brattain and Shockley, 1947

PENTIUM® 4



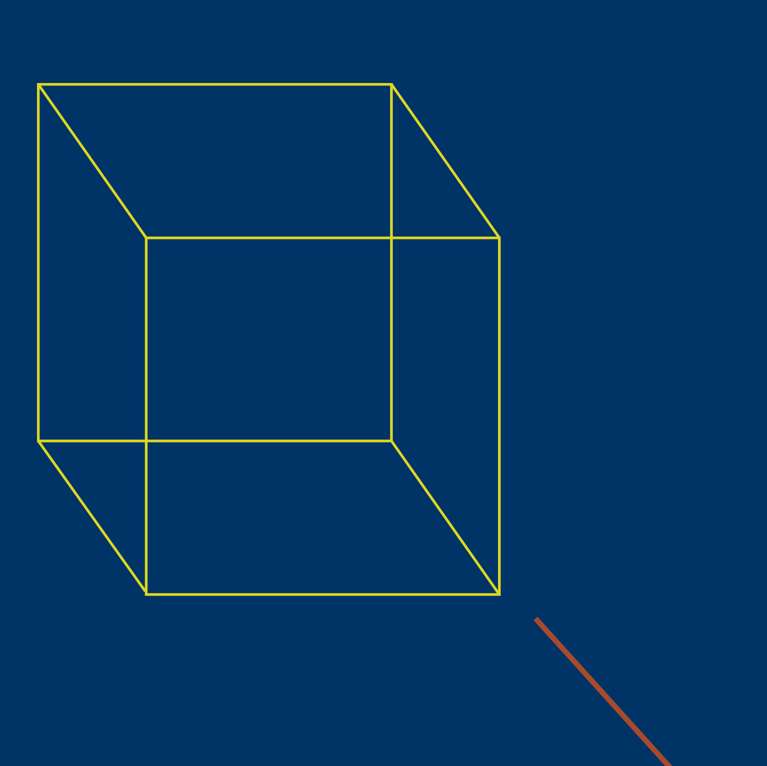
54 Million Transistors
2"x2"
Approximate Improvement: 500 Million X

PENTIUM® 4



3,700 Ft x 3,700 Ft x 6"

SCALING DOWN



This is certainly a promising trend...

but its nothing compared to what's coming next...

NANOTECHNOLOGY

"There's Plenty of Room at the Bottom"

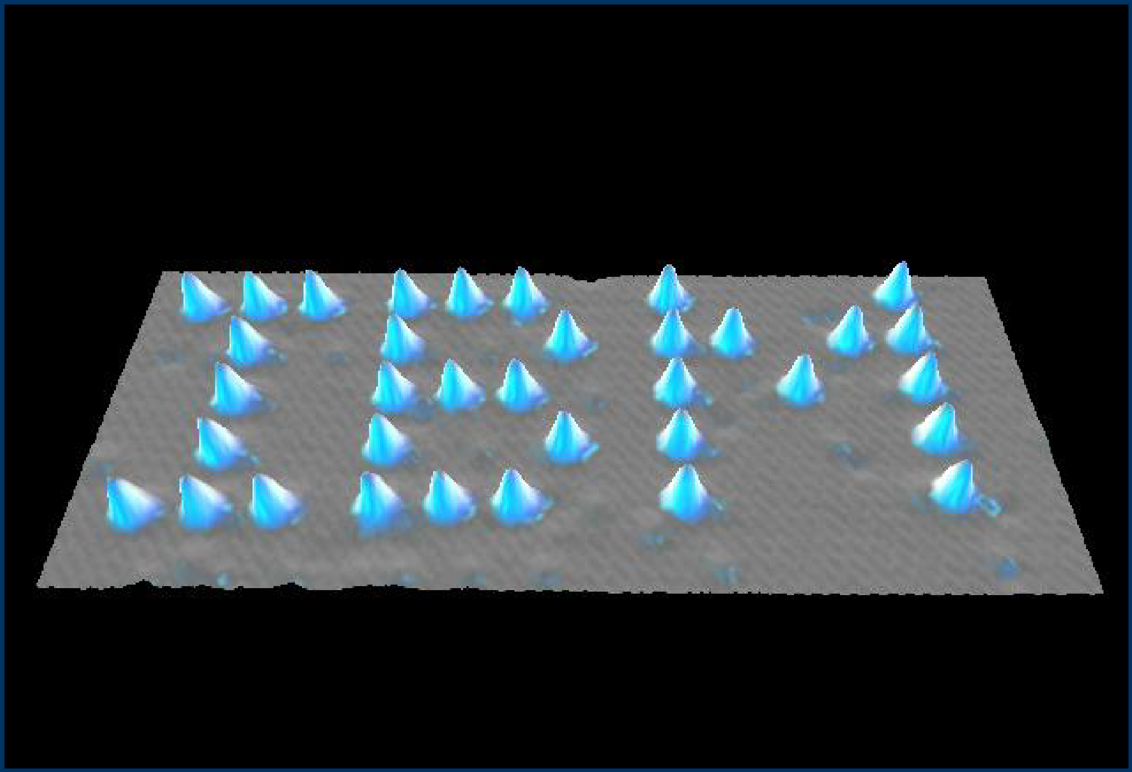
Richard P. Feynman

29 December 1959

NANOTECHNOLOGY

- Fabricate structures atom-by-atom

NANOTECHNOLOGY

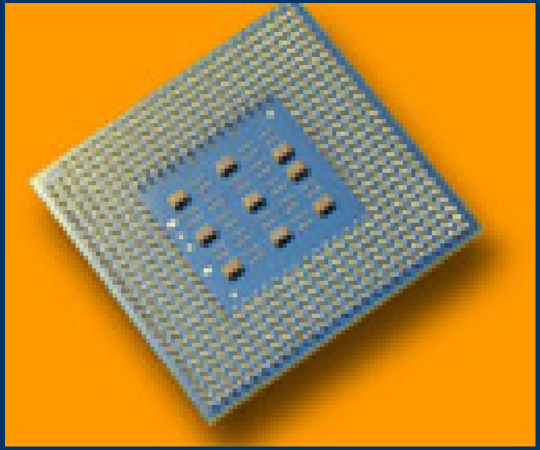


D.M. Eigler, E.K. Schweizer
Positioning single atoms with a scanning tunneling microscope.
Nature 344, 524-526 (1990).

NANOTECHNOLOGY

- Fabricate structures atom-by-atom
- Atoms are very small!

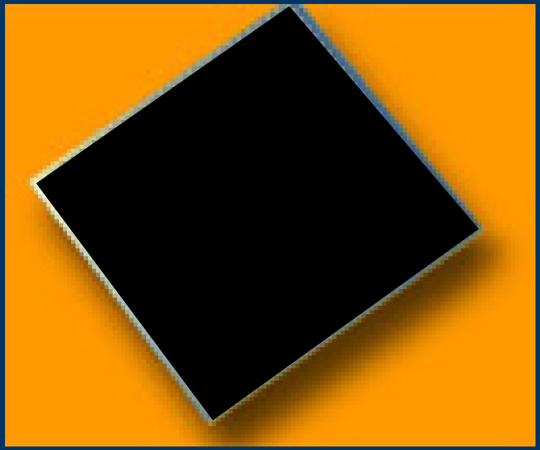
Pentium(R) processor:
54 Million transistors



NANOTECHNOLOGY

- Fabricate structures atom-by-atom
- Atoms are very small!

Pentium(R)-sized block of carbon:
32 cm^3 = 3.7×10^{24} atoms



NANOTECHNOLOGY

- Fabricate structures atom-by-atom
- Atoms are very small!

Pentium(R)-sized block of carbon:
32 cm^3 =3.7x10^{24} atoms

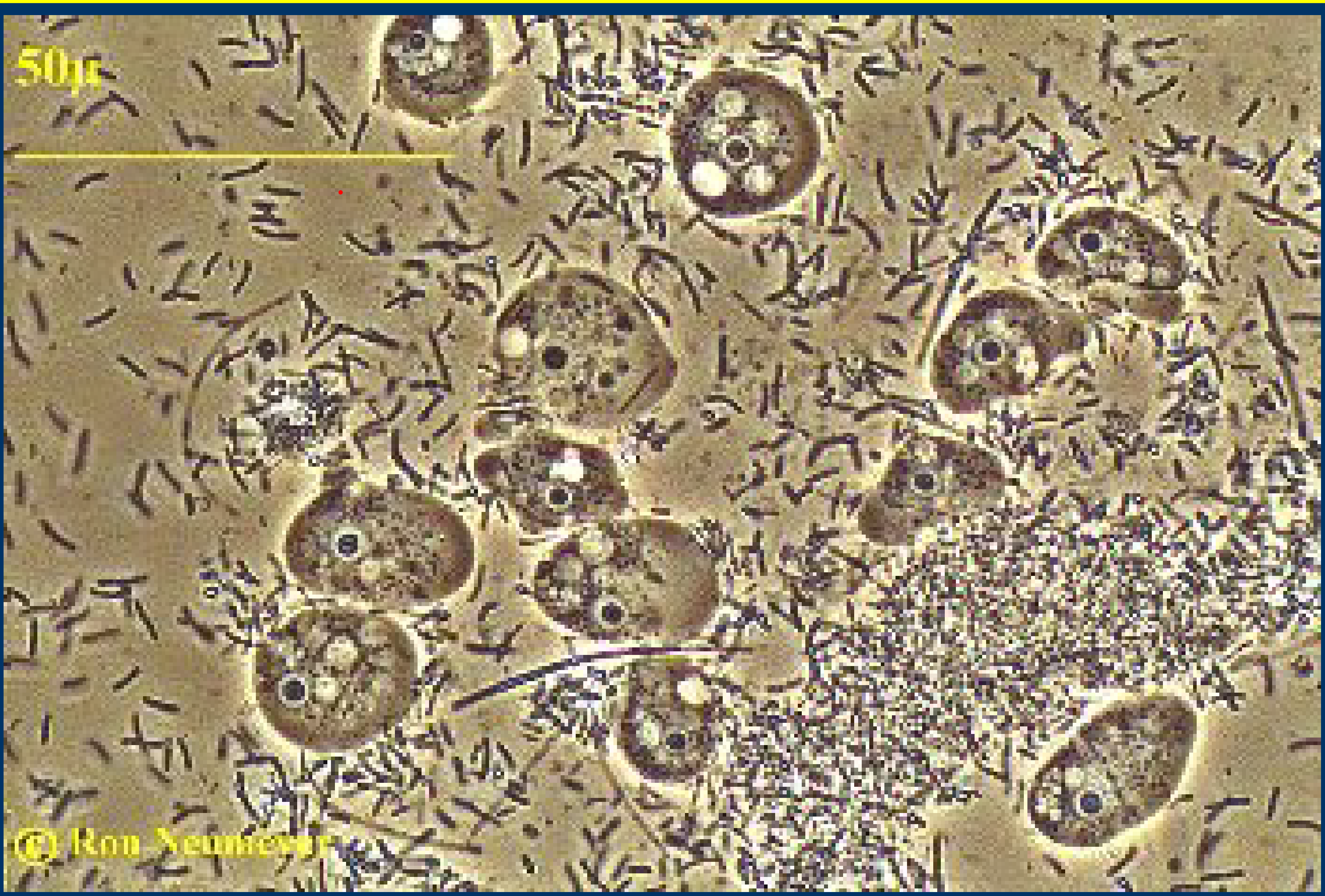
100 Atoms/Switch=
37,000 Billion Billion transistors=
700,000 Billion X more dense

SCALING DOWN WITH NANOTECHNOLOGY

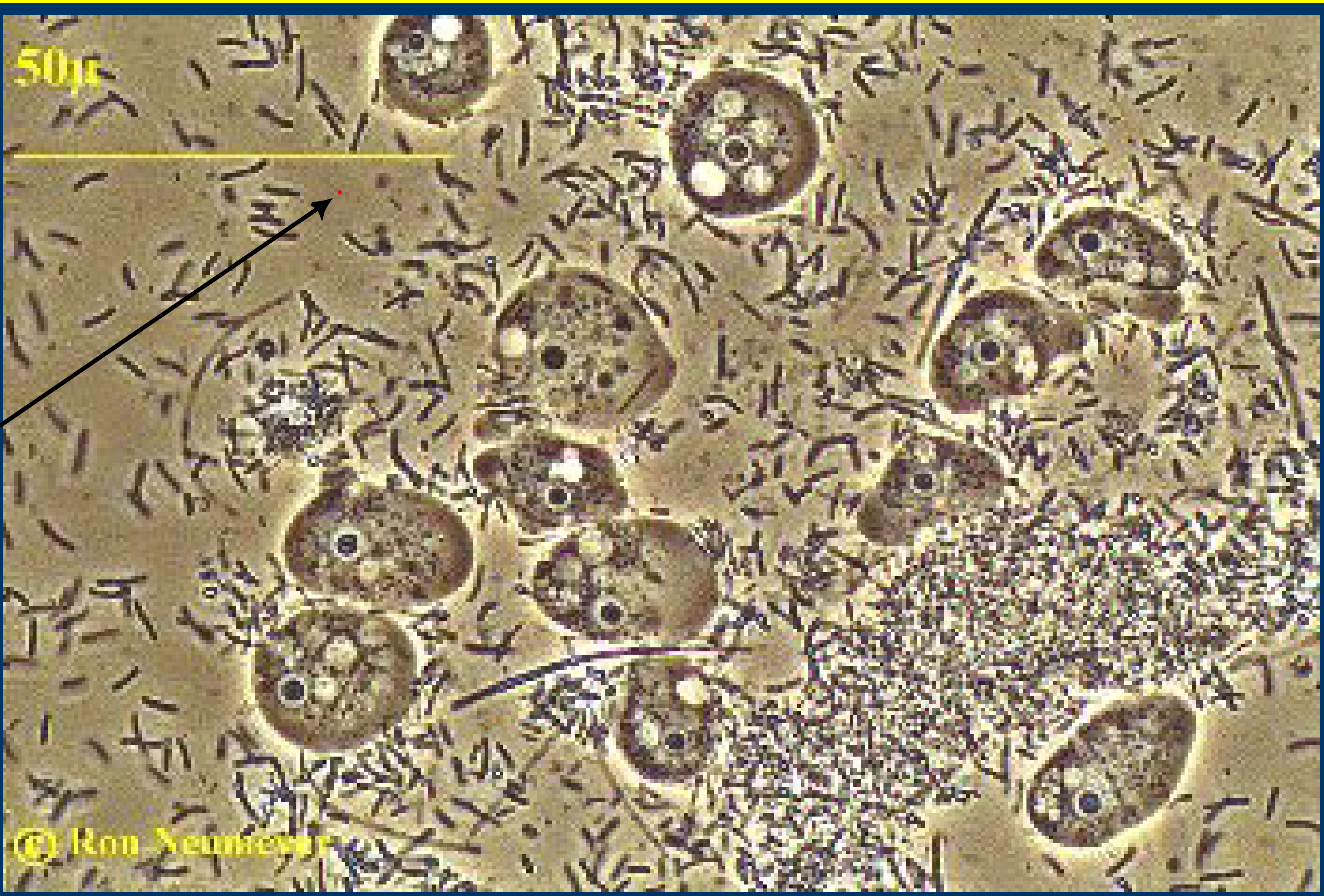
Can we continue the trend of scaling down?

LAPTOP
2003

LAPTOP
2013?



LAPTOP
2013?

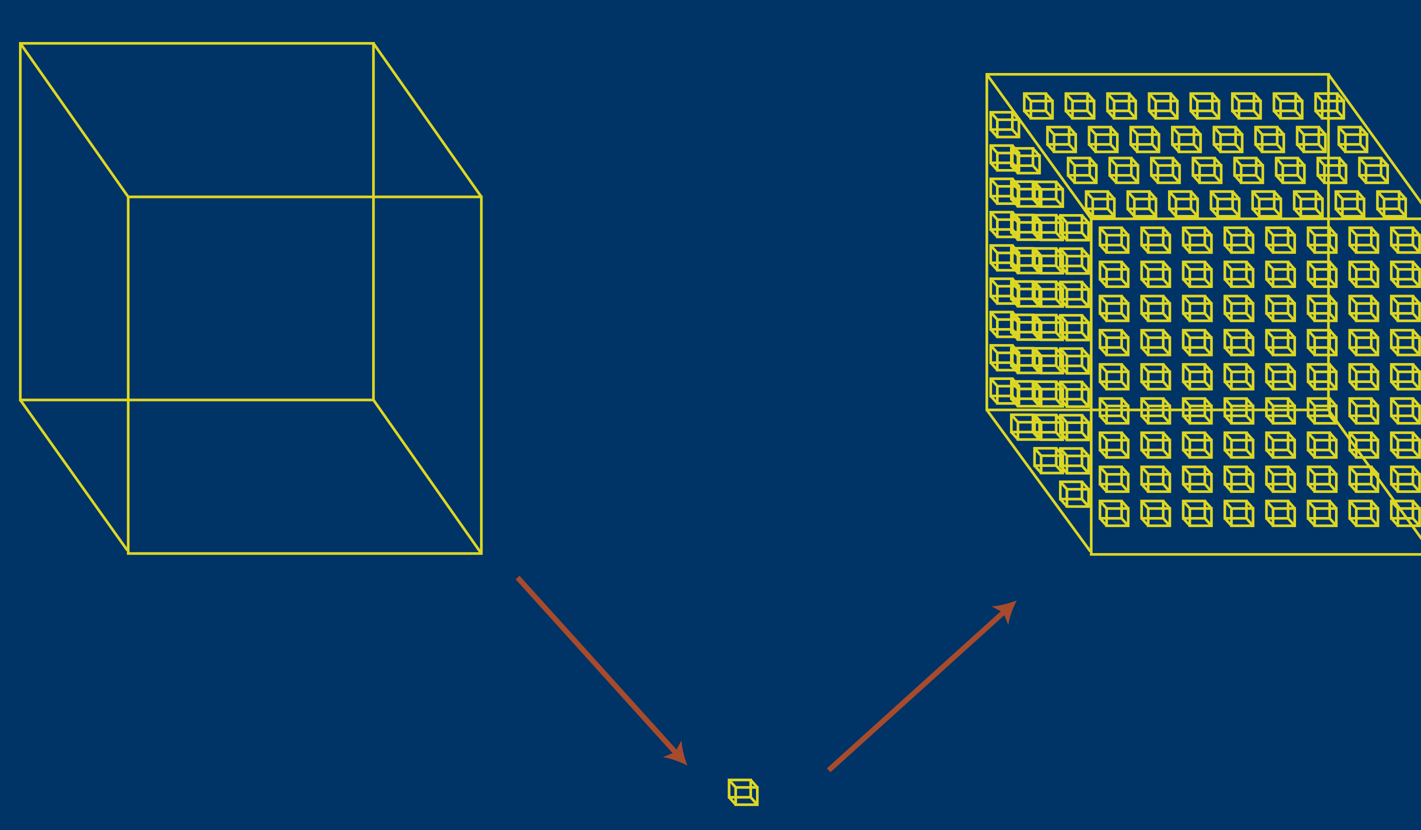


MORAL OF THE STORY

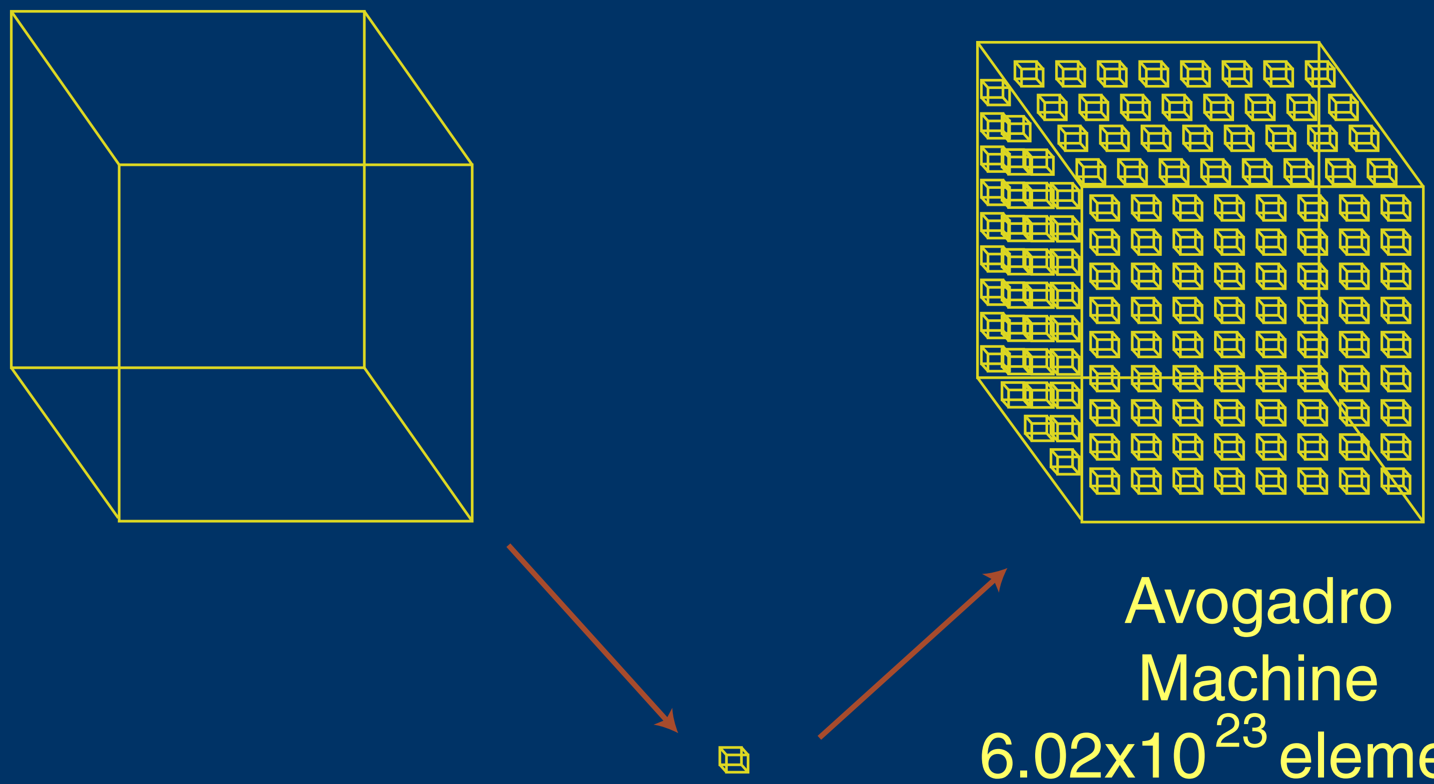
- There's plenty of room at the bottom, but we don't live at the bottom

So what does one do with such density?

SCALING UP



SCALING UP



Avogadro
Machine
6.02×10^{23} elements

WHY BUILD AN AVOGADRO MACHINE?

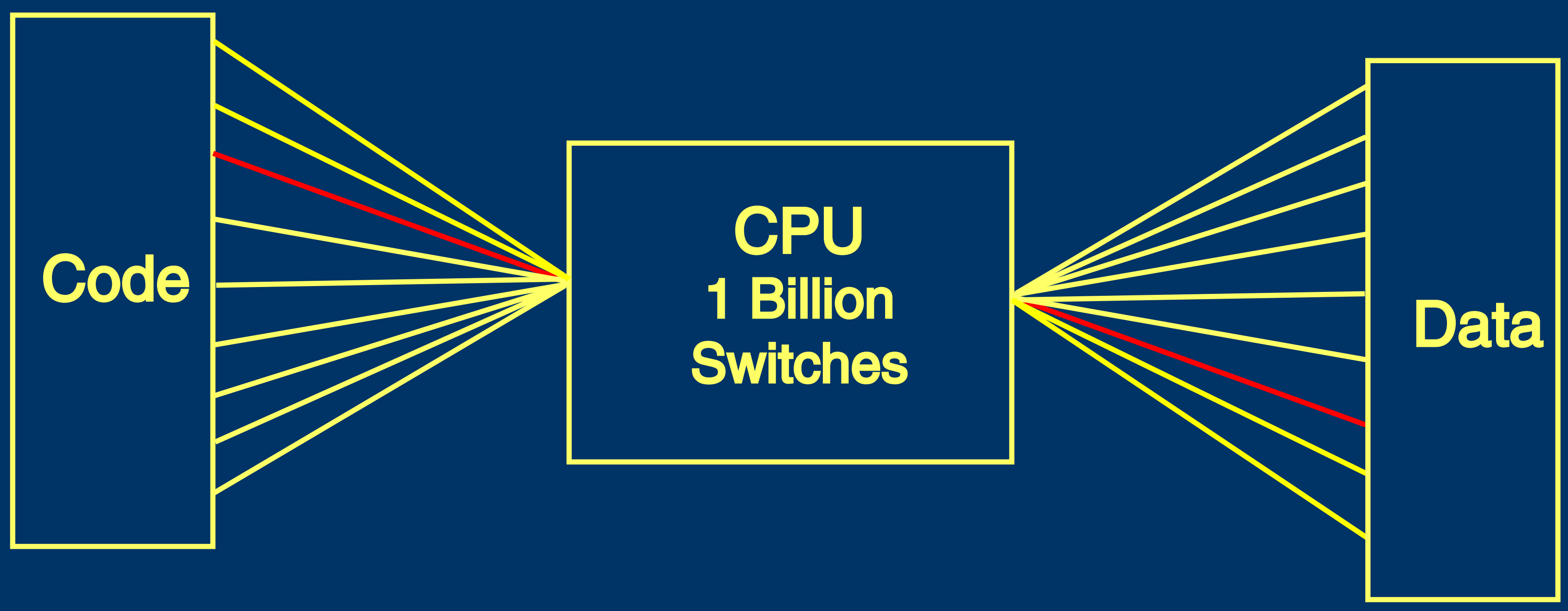
SPEED!

- 3D Simulation/Modeling
- Large mathematical problems
- Large search spaces

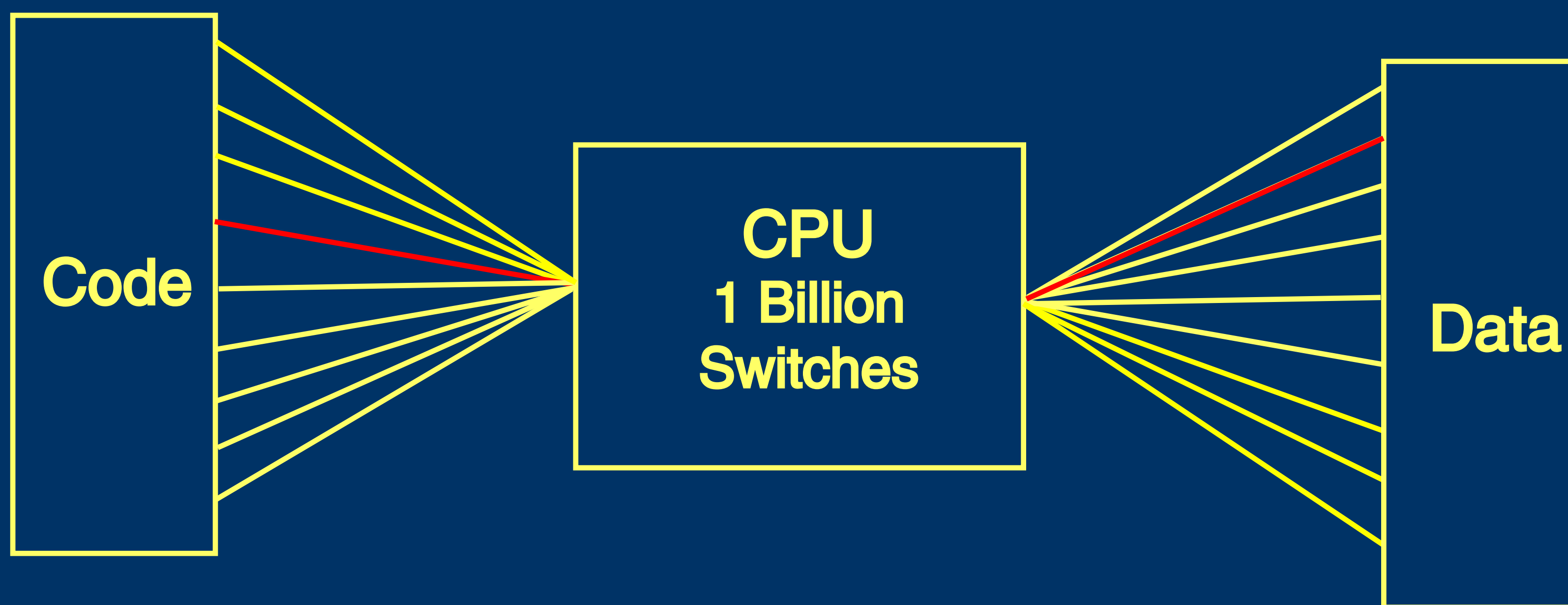
MANY COMPLEXITIES

- How to control all that HW
- How to manufacture
- How to handle faults

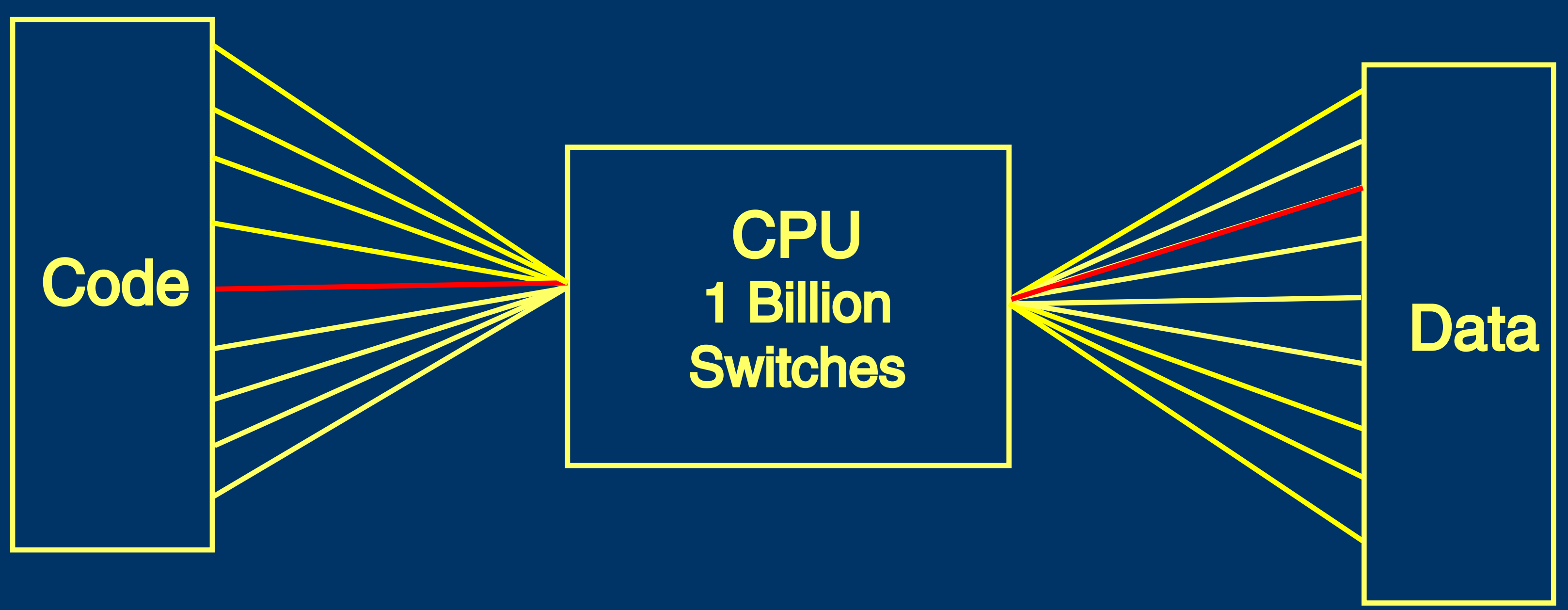
Traditional System



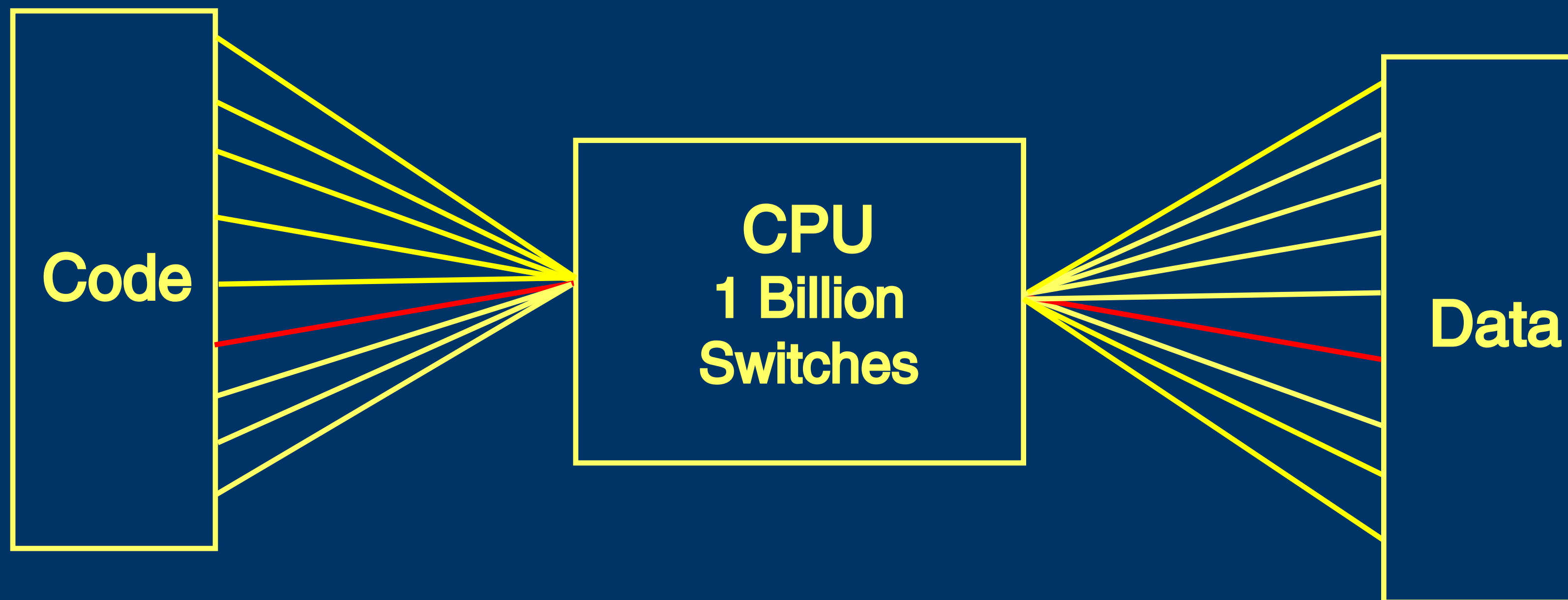
Traditional System



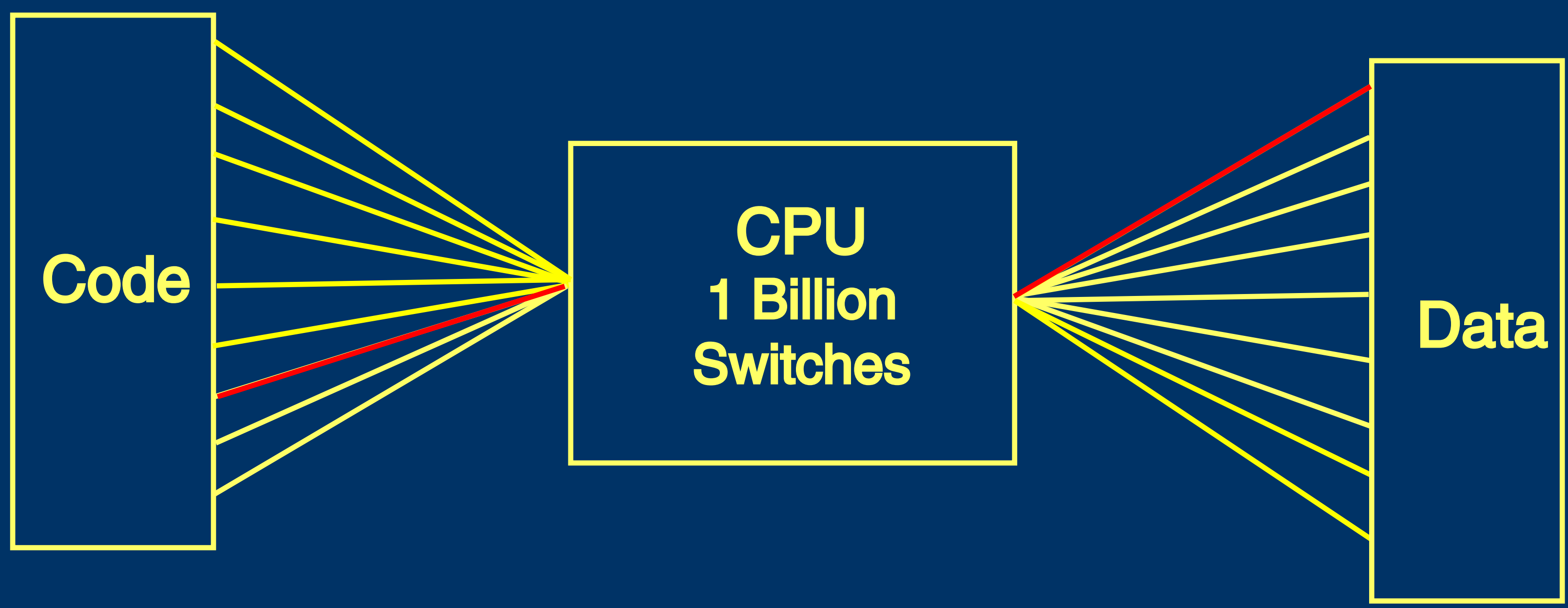
Traditional System



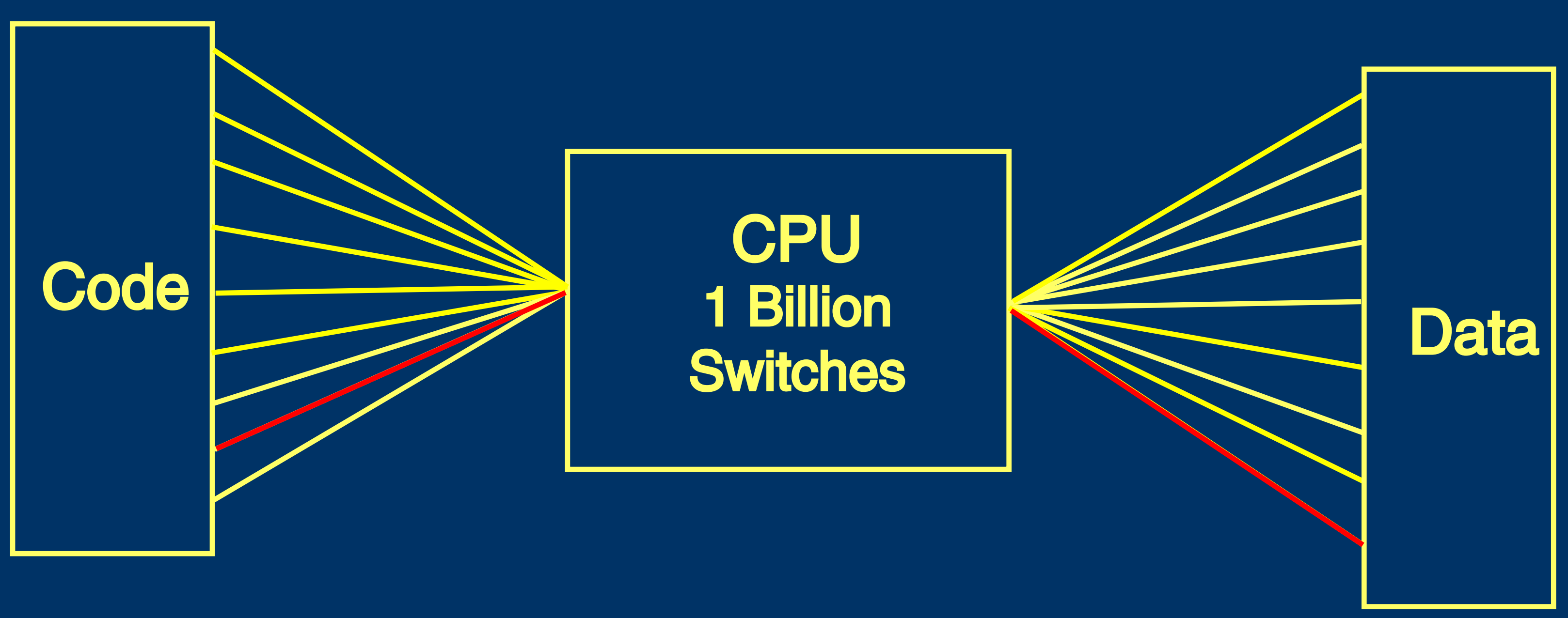
Traditional System



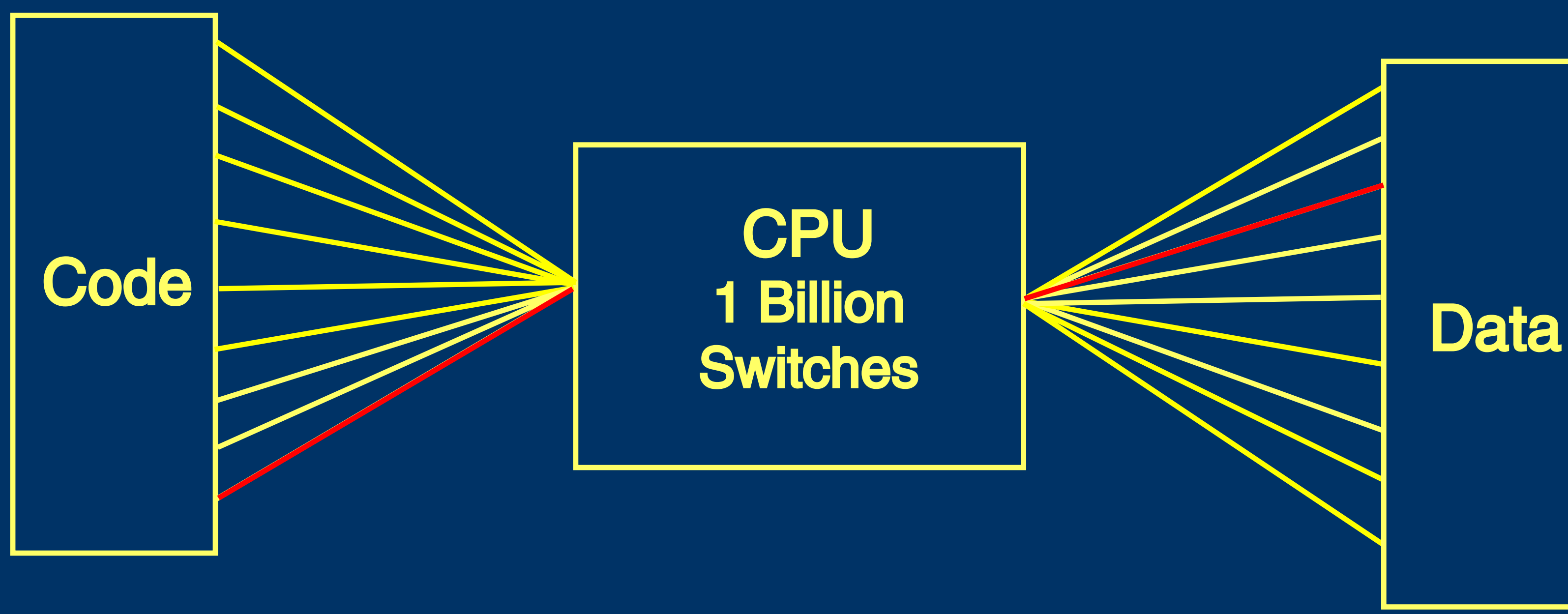
Traditional System



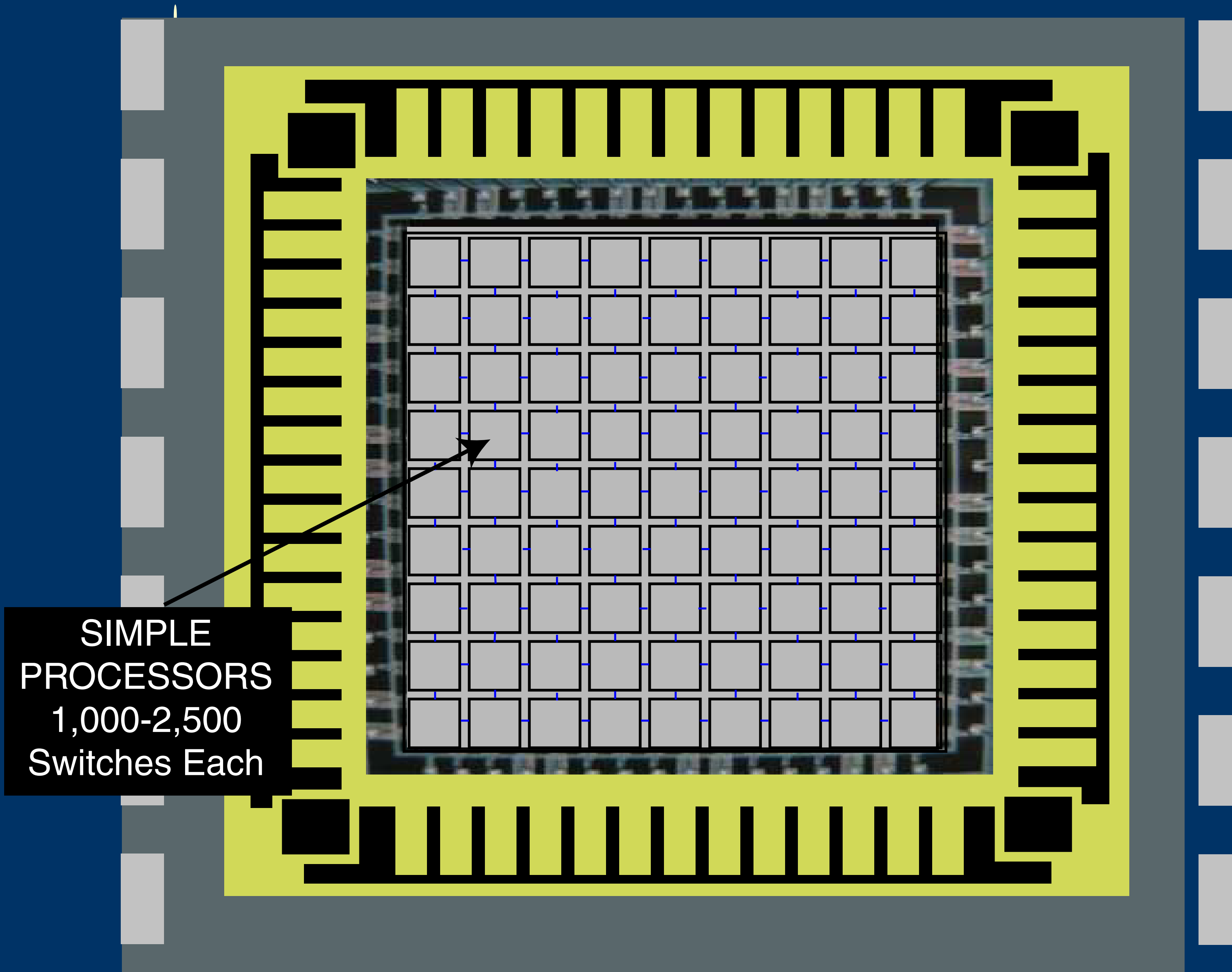
Traditional System



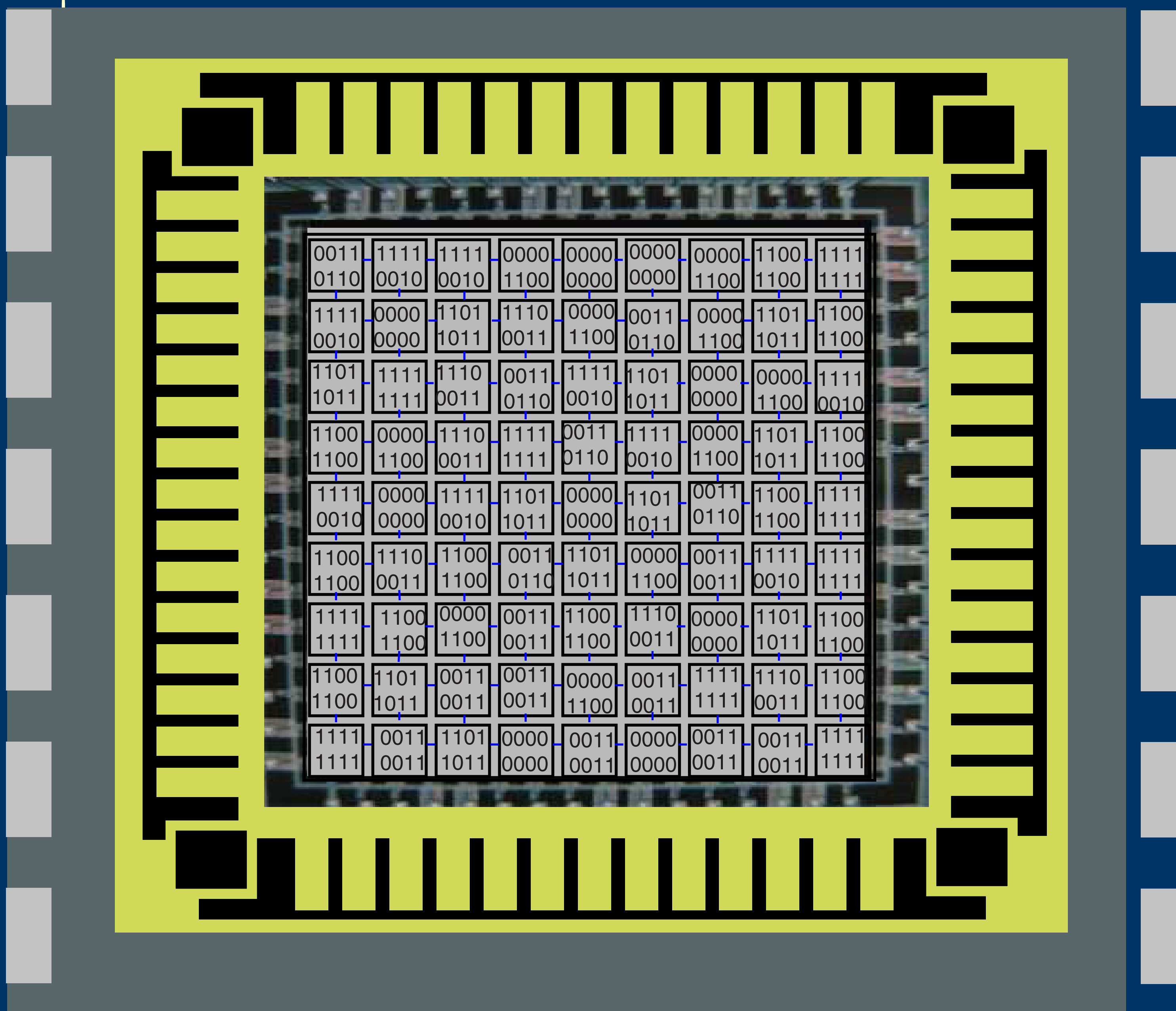
Traditional System



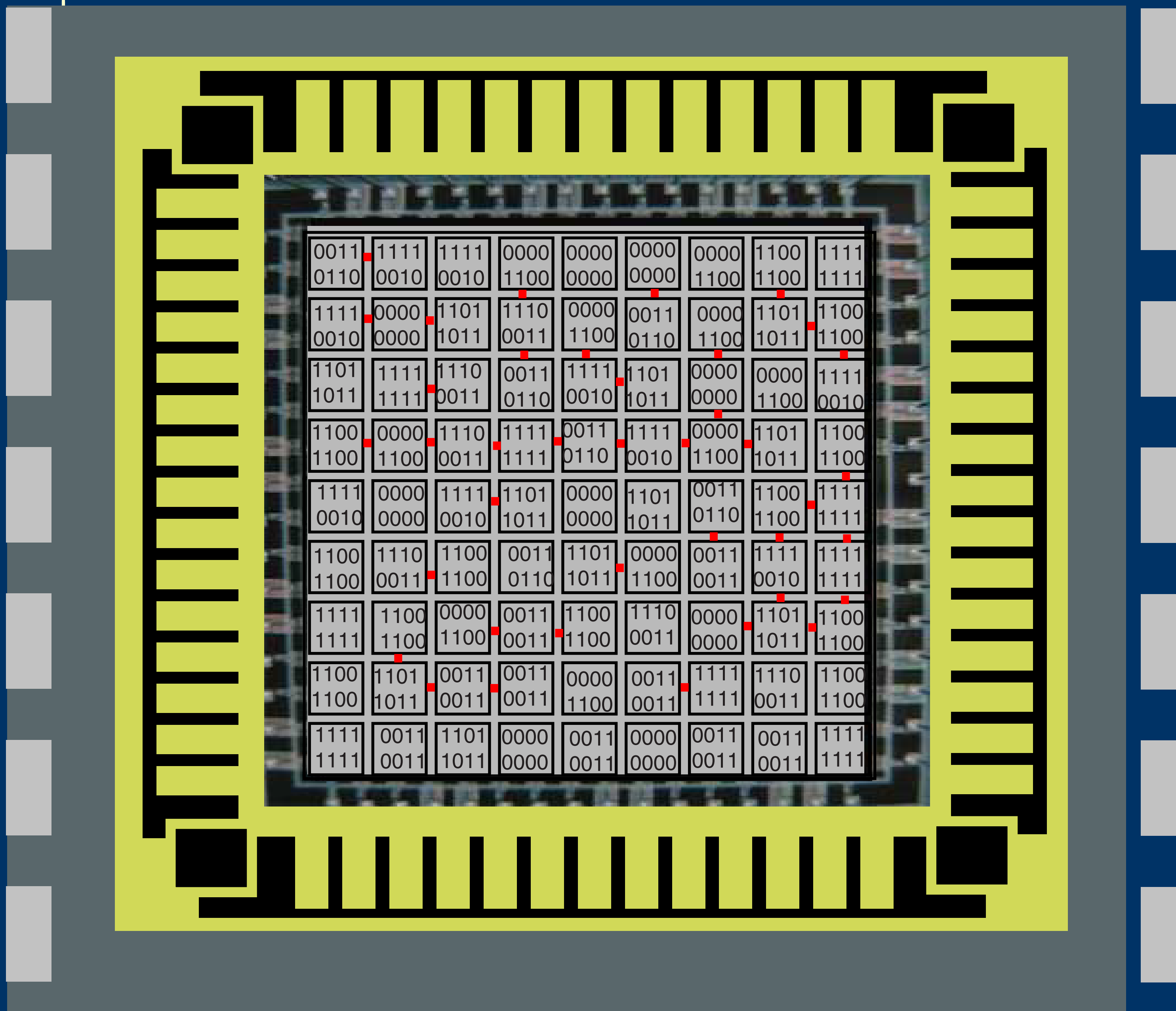
Cell Matrix Approach



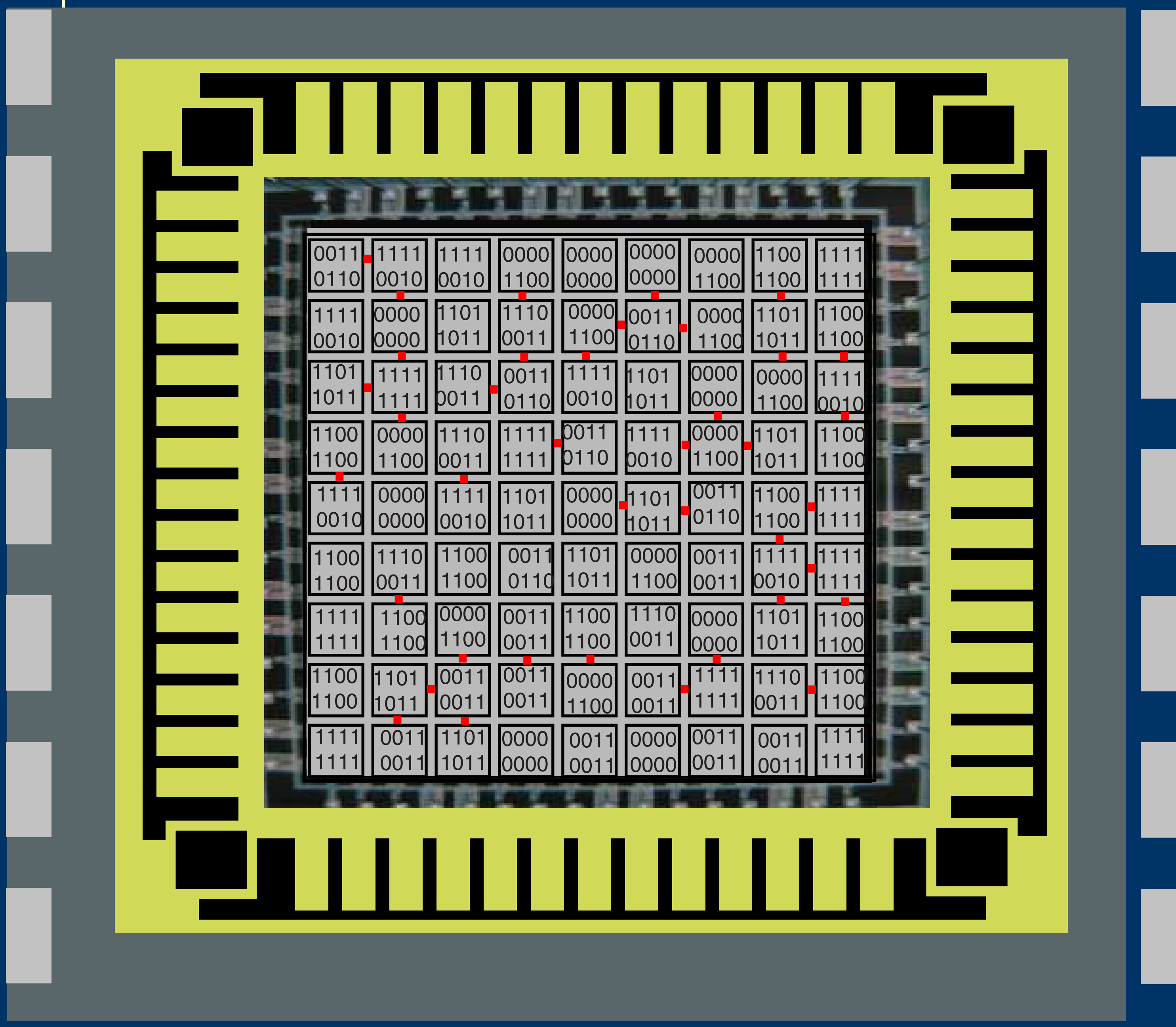
Cell Matrix Approach



Cell Matrix Approach



Cell Matrix Approach



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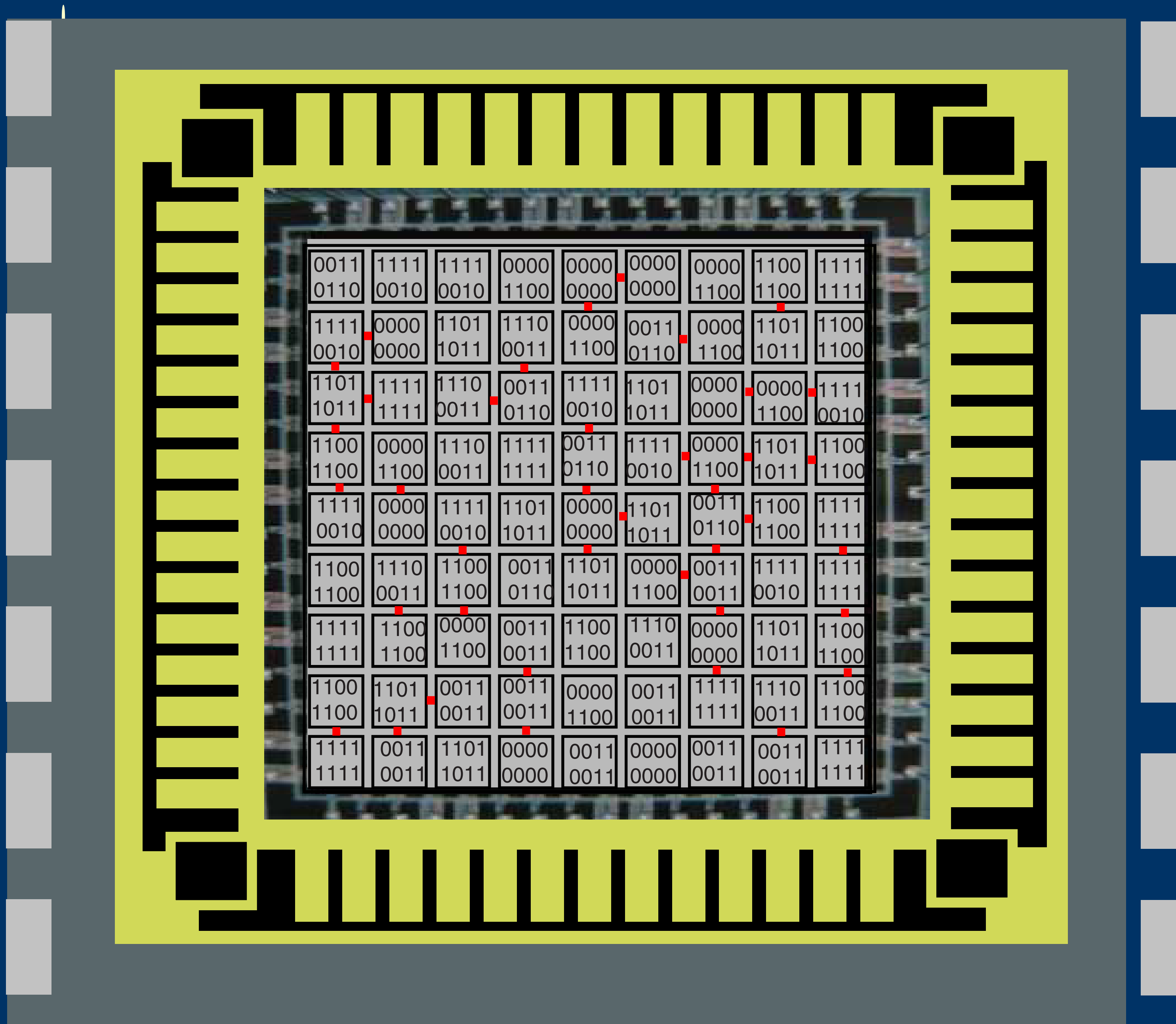

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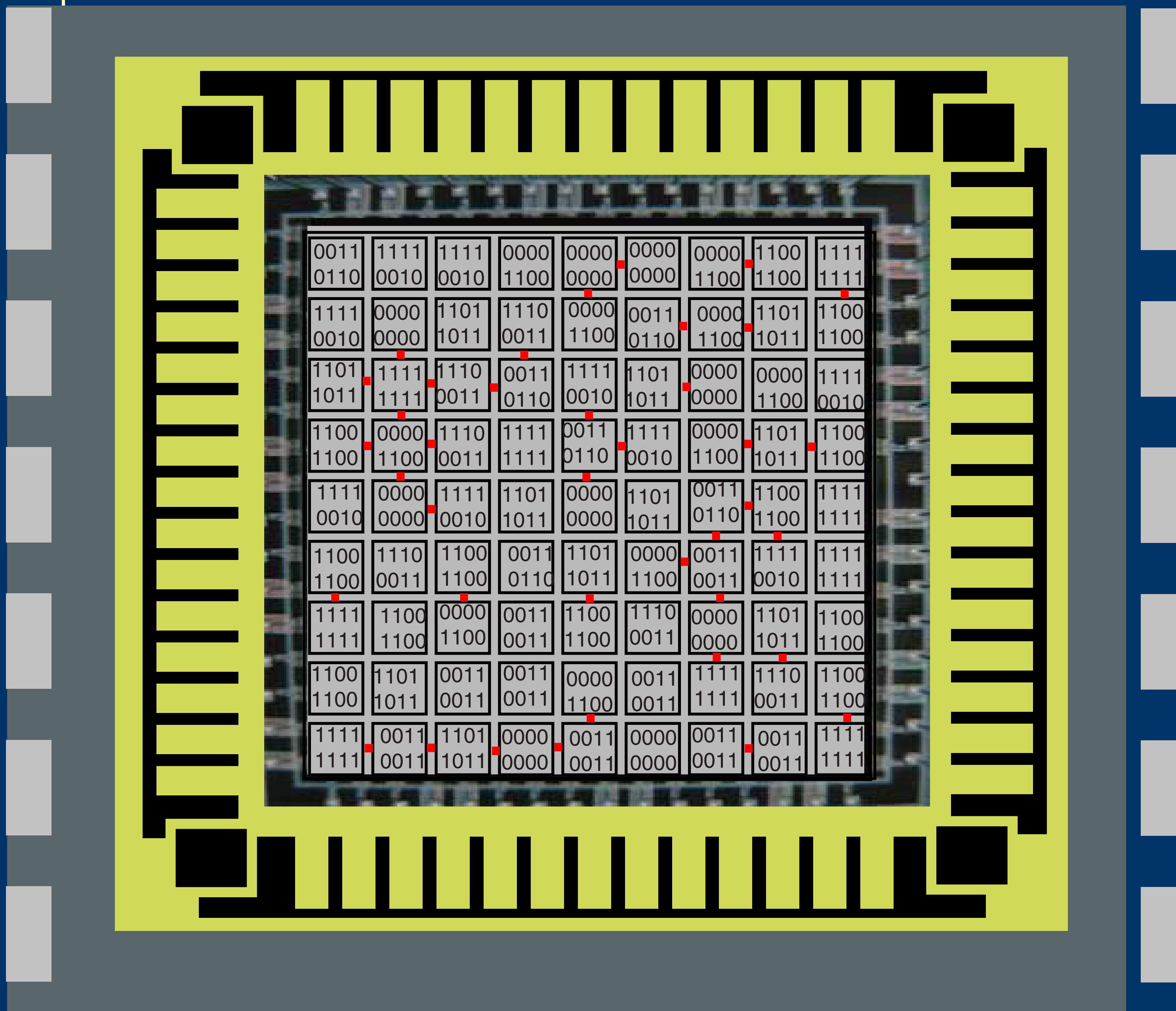
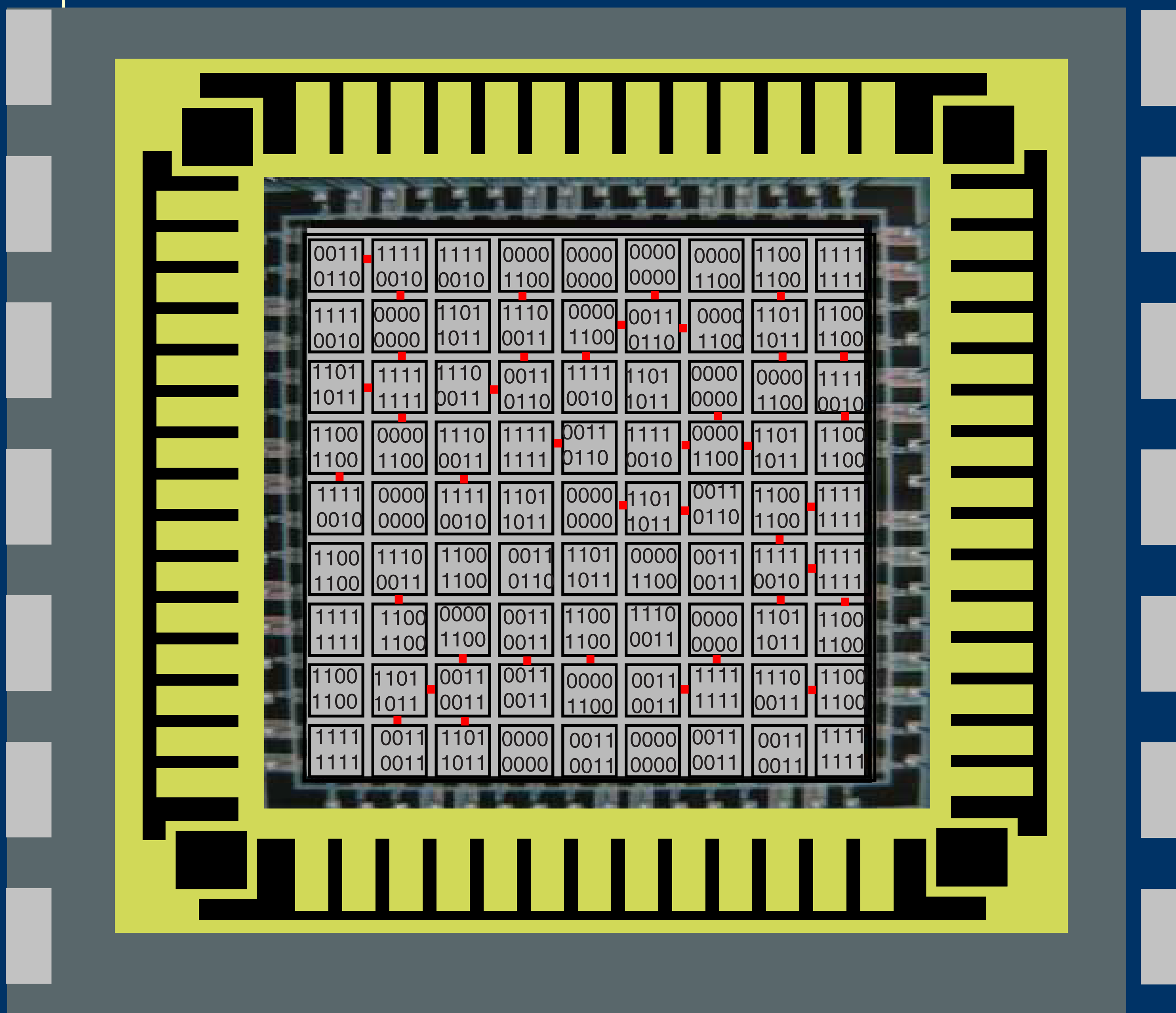
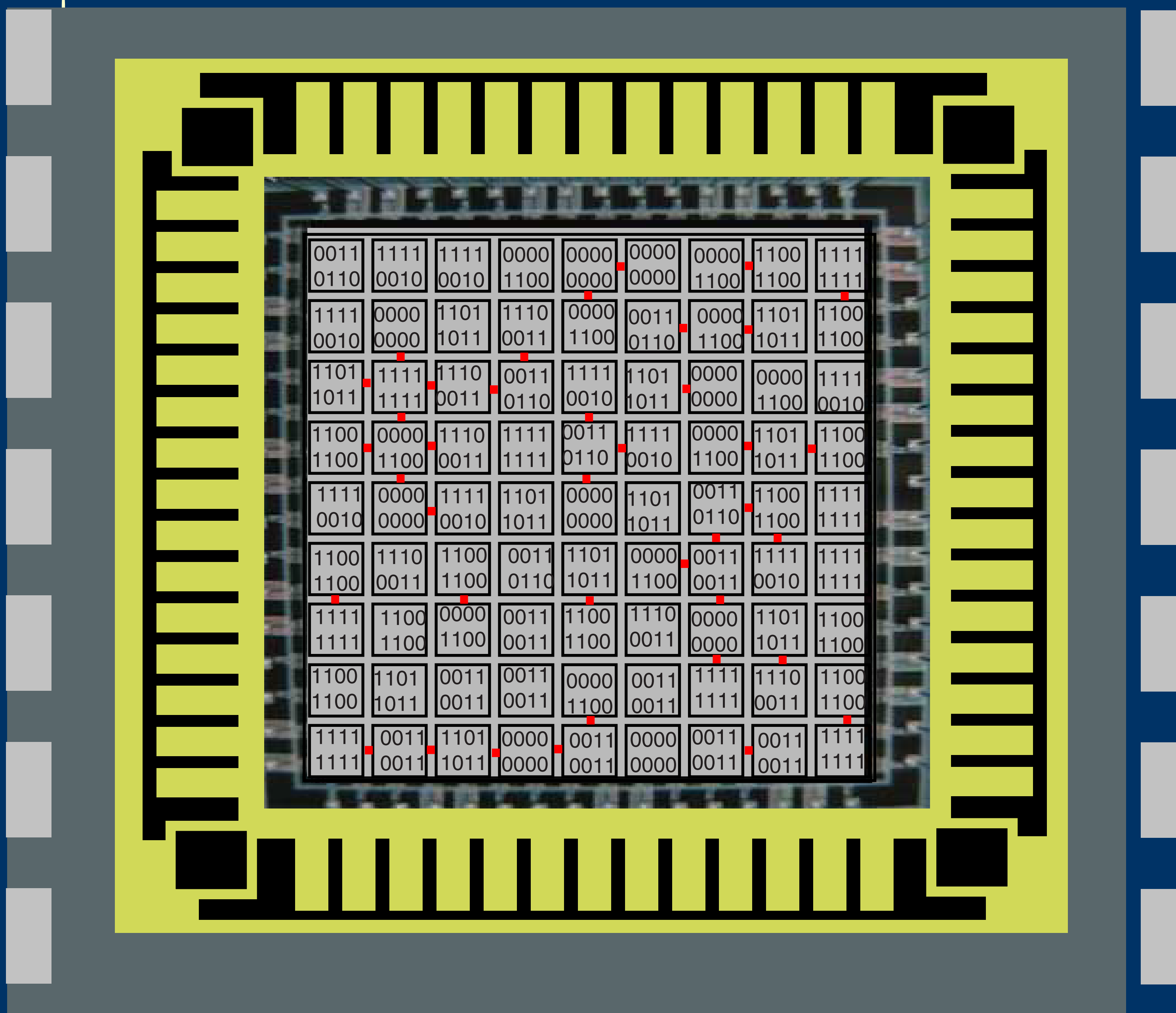


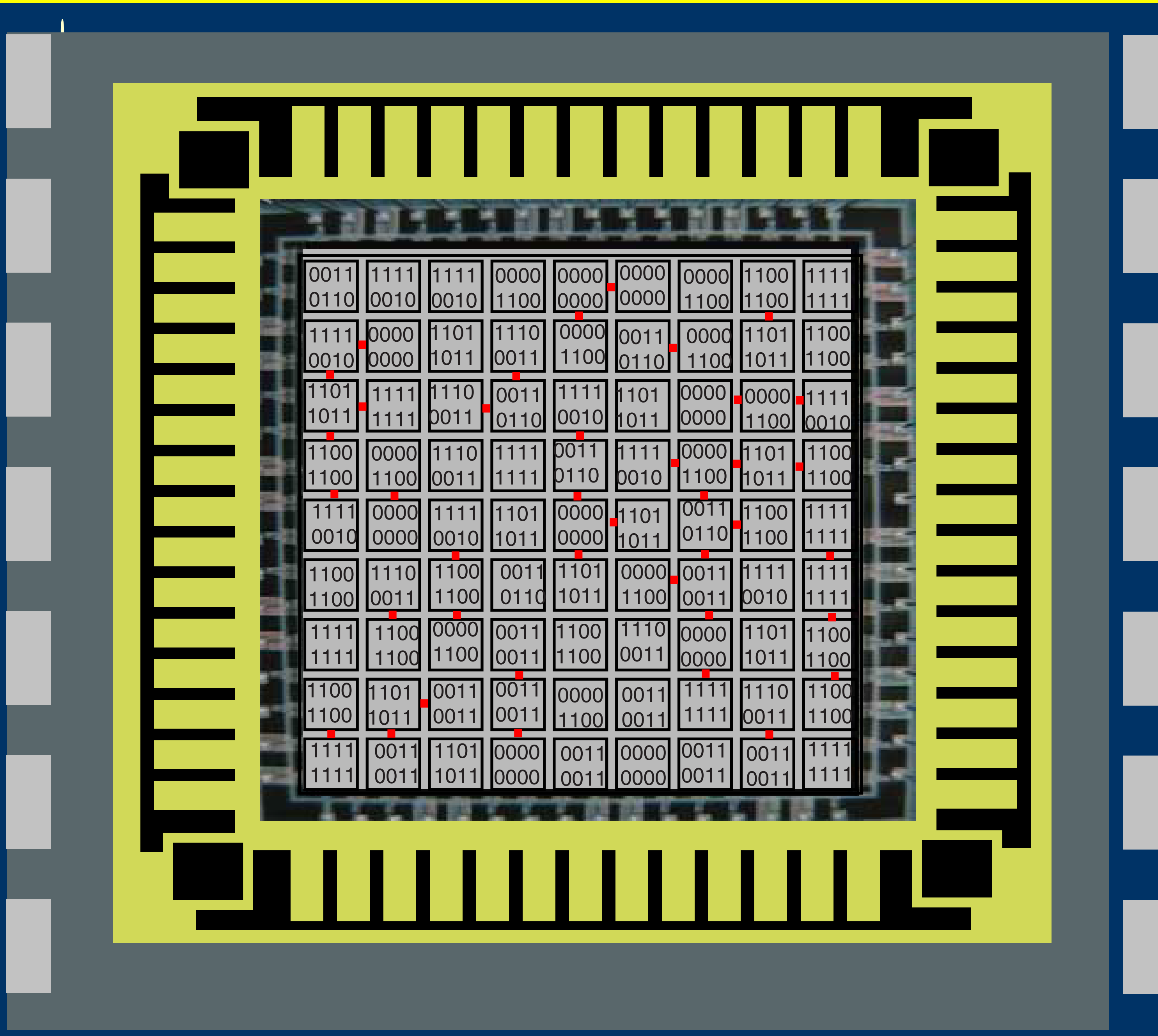
Cell Matrix Approach



Cell Matrix Approach

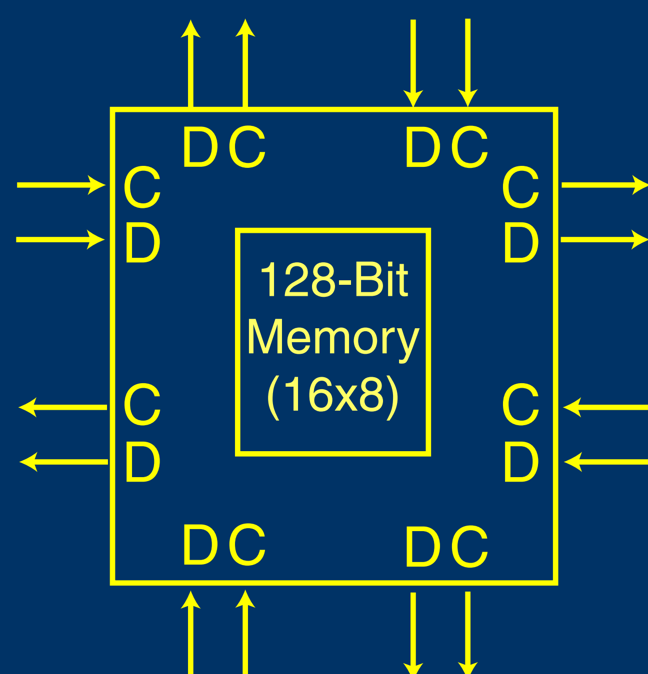


Cell Matrix Approach

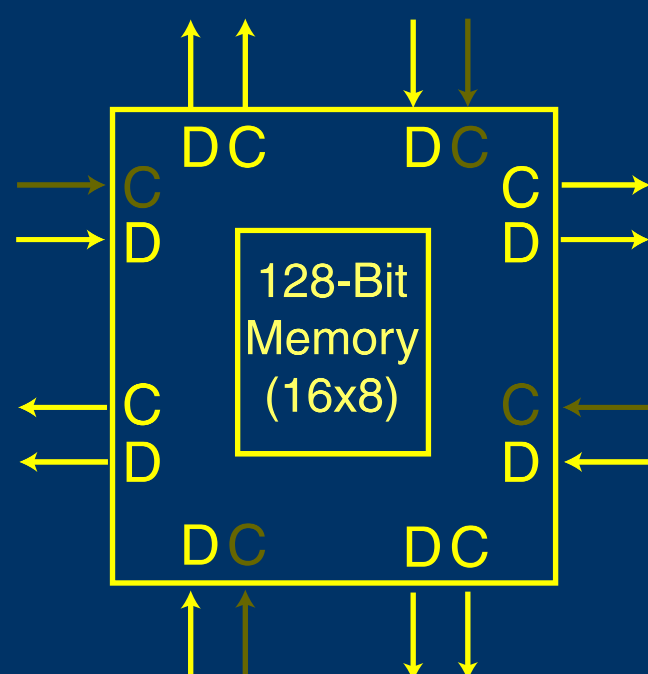


WHAT IS A CELL MATRIX?

Atomic Unit of Cell Matrix



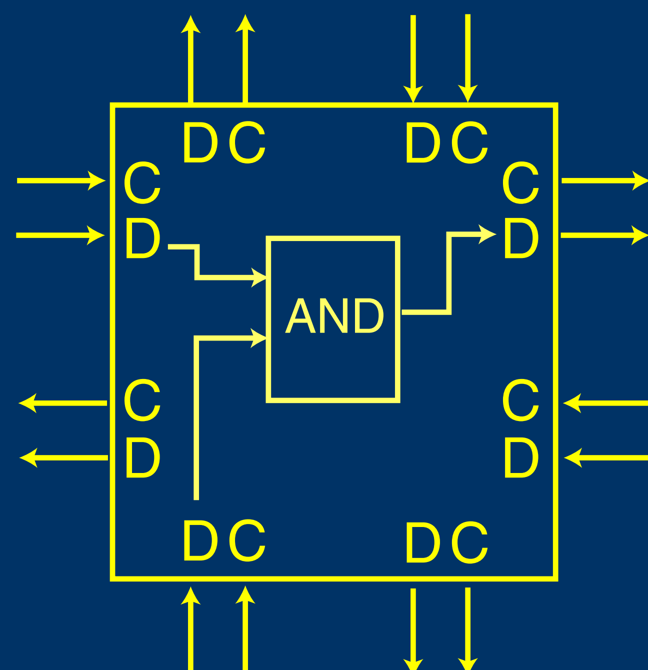
Atomic Unit of Cell Matrix



Cell Matrix Truth Table

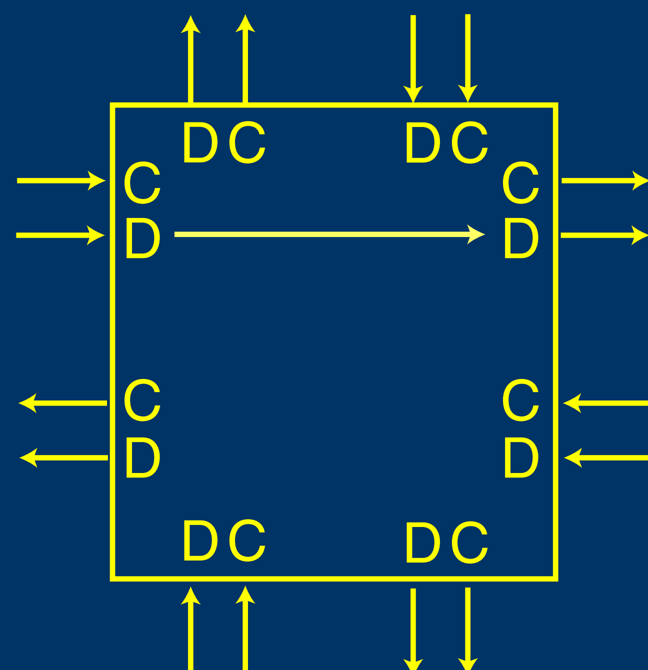
INPUTS				OUTPUTS							
DN	**DS**	**DW**	**DE**	**CN**	**CS**	**CW**	**CE**	**DN**	**DS**	**DW**	**DE**
0	0	0	0	1	0	0	0	0	1	0	0
0	0	0	1	0	0	0	0	0	1	0	0
0	0	1	0	0	0	0	0	0	1	0	1
0	0	1	1	0	0	0	0	1	1	0	1
0	1	0	0	0	0	0	0	0	0	1	0
0	1	0	1	0	0	0	0	0	0	1	0
0	1	1	0	0	0	0	0	0	0	1	1
0	1	1	1	0	0	0	0	1	0	1	1
1	0	0	0	0	0	0	0	0	1	0	0
1	0	0	1	0	0	0	0	0	1	0	0
1	0	1	0	0	0	0	1	0	1	0	1
1	0	1	1	0	0	0	1	1	1	0	1
1	1	0	0	0	0	0	1	1	0	1	0
1	1	0	1	0	0	0	0	0	0	1	0
1	1	1	0	0	0	0	0	0	0	1	1
1	1	1	1	0	0	0	1	0	0	1	1

Cells Implement Simple Logic Functions



DE_{out}=DS_{in}.AND.DW_{in}

Sometimes Very Simple

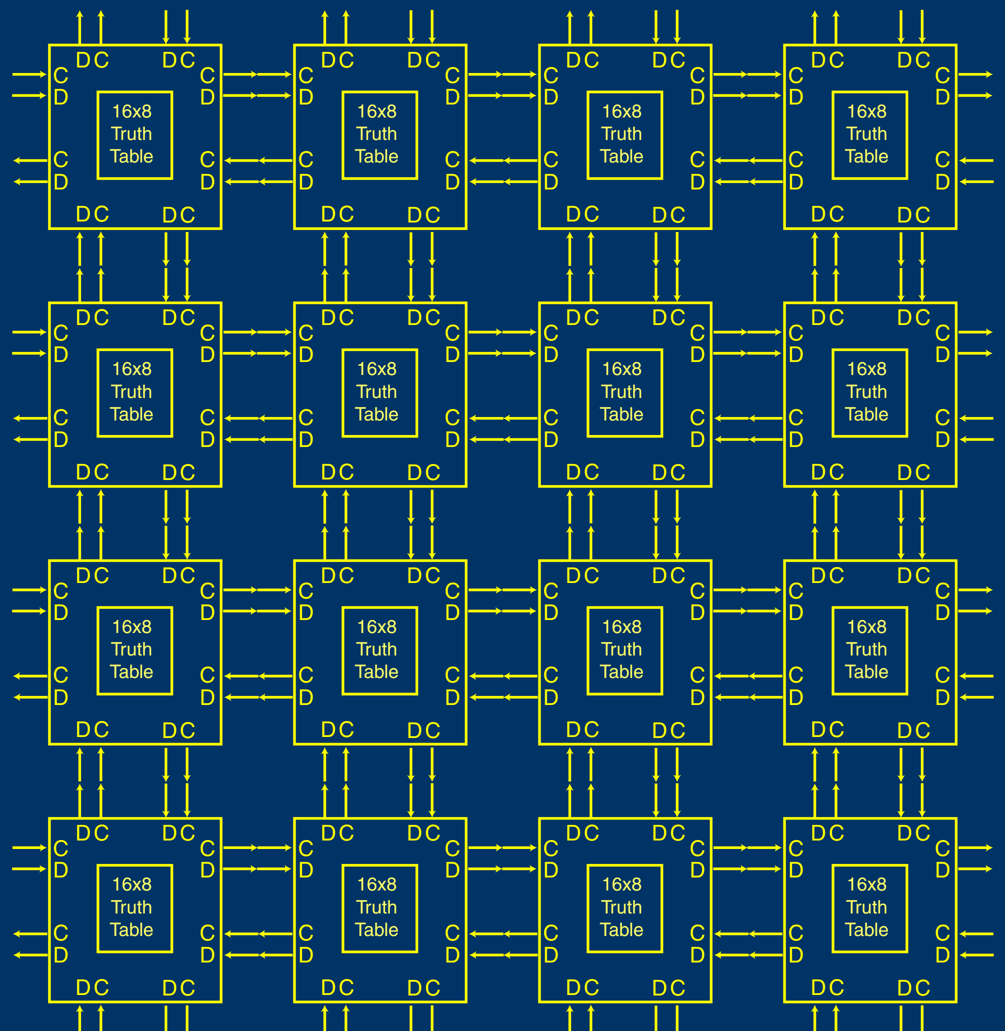


$DE_{out}=DW_{in}$

Truth Table for DW->DE

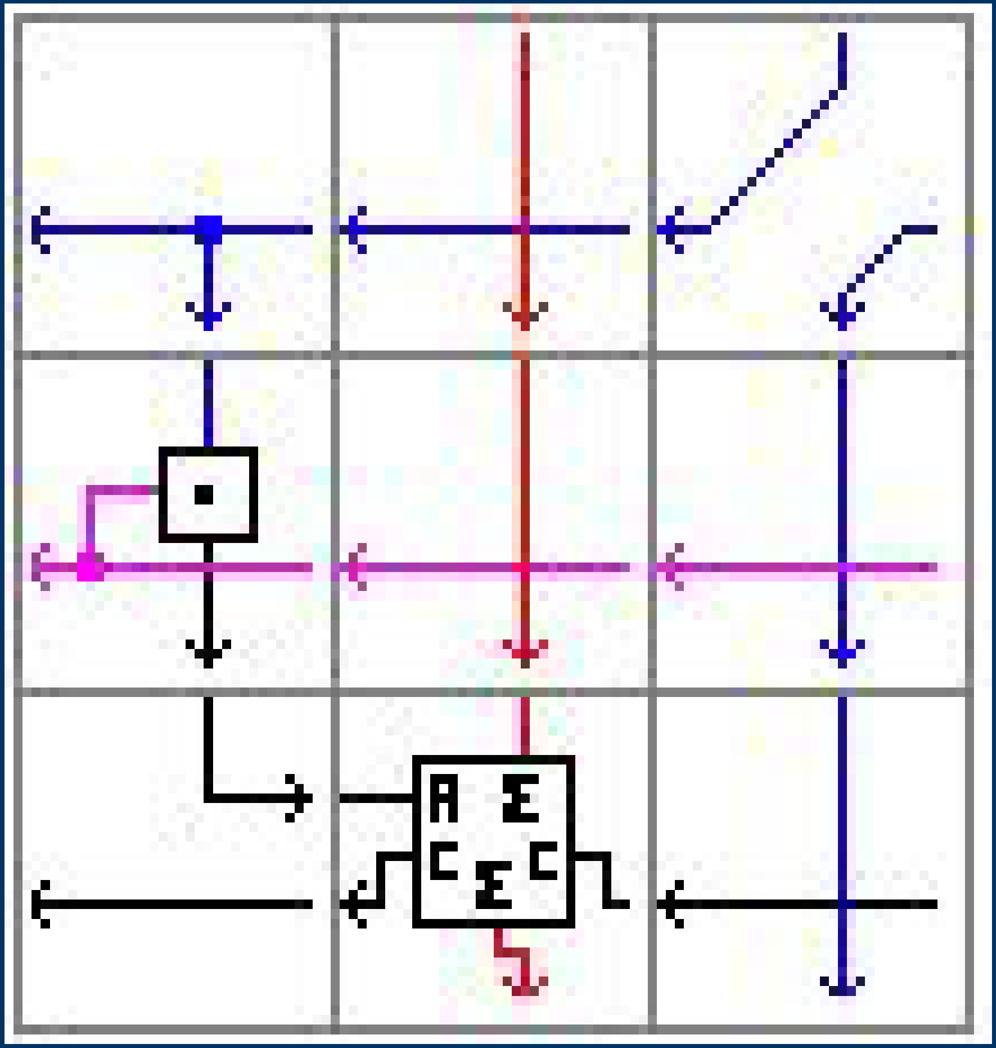
DN	DS	DW	DE	CN	CS	CW	CE	DN	DS	DW	DE
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	1	0	0	0	0	0	0	0	0
0	0	1	0	0	0	0	0	0	0	0	1
0	0	1	1	0	0	0	0	0	0	0	1
0	1	0	0	0	0	0	0	0	0	0	0
0	1	0	1	0	0	0	0	0	0	0	0
0	1	1	0	0	0	0	0	0	0	0	1
0	1	1	1	0	0	0	0	0	0	0	1
1	0	0	0	0	0	0	0	0	0	0	0
1	0	0	1	0	0	0	0	0	0	0	0
1	0	1	0	0	0	0	0	0	0	0	1
1	0	1	1	0	0	0	0	0	0	0	1
1	1	0	0	0	0	0	0	0	0	0	0
1	1	0	1	0	0	0	0	0	0	0	0
1	1	1	0	0	0	0	0	0	0	0	1
1	1	1	1	0	0	0	0	0	0	0	1

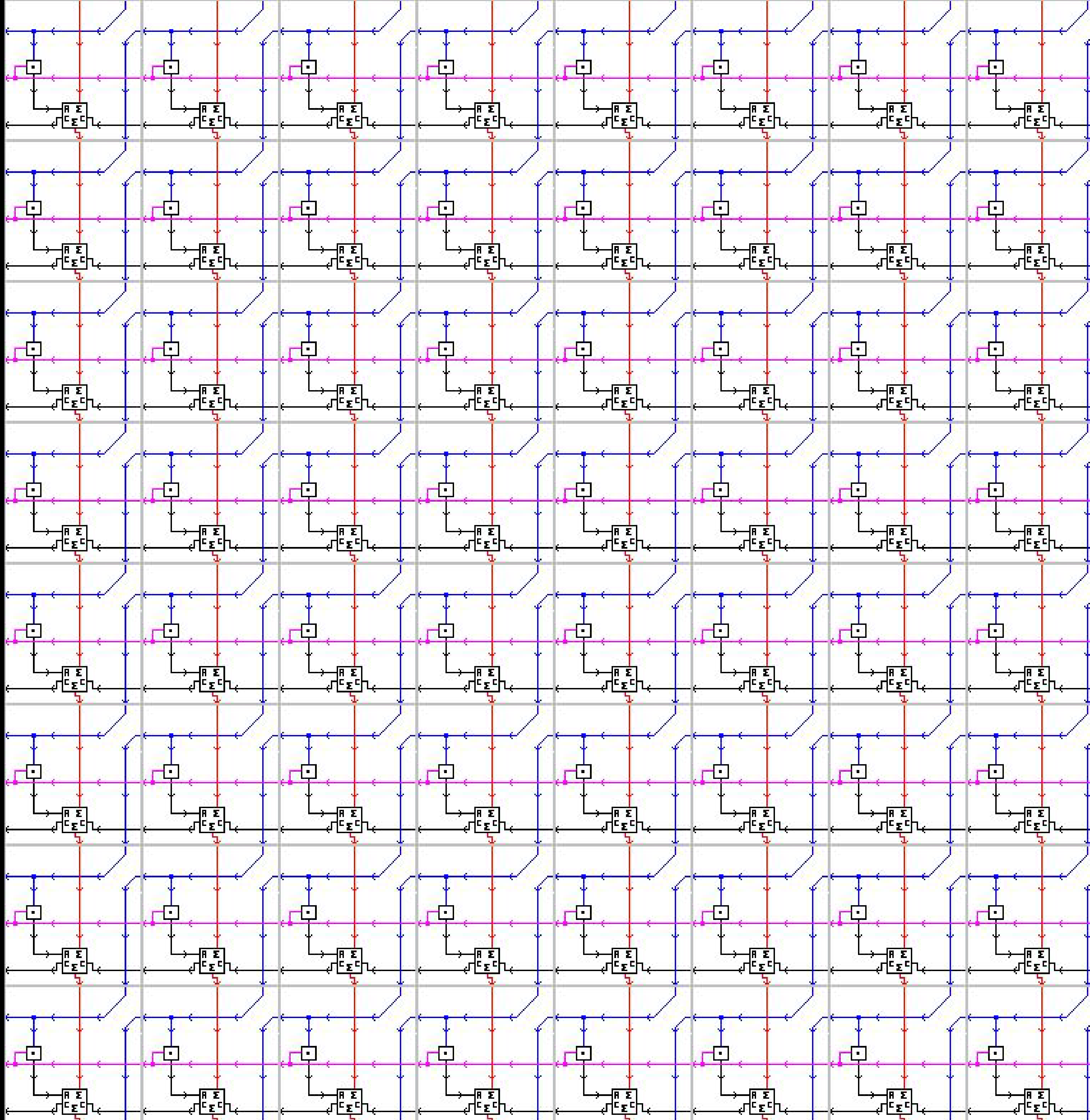
Tiling of Cells



Cells work together to perform higher-order functions

One-Bit Multiplier





DNA SEQUENCE ALIGNMENT

```
GATCTACCTACGGATCAT
GATCTACGTACGGATCAT
 ATCTACTACGGATCATTC
```

DNA SEQUENCE ALIGNMENT

```
GATCTACCTACGGATCAT
GATCTACGTACGGATCAT
 ATCTACTACGGATCATTC
```

DNA SEQUENCE ALIGNMENT

```
GATCTACCTACGGATCAT
GATCTACGTACGGATCAT
 ATCTAC TACGGATCATTC
```

Sequence Alignment Algorithm

```
Algorithm Similarity
    input: sequences s and t
    output: similarity between s and t
    m ← |s|
    n ← |t|
    for i ← 0 to m do
        a[i, 0] ← i × g
    for j ← 0 to n do
        a[0, j] ← j × g
    for i ← 1 to m do
        for j ← 1 to n do
            a[i, j] ← max(a[i − 1, j] + g,
                          a[i − 1, j − 1] + p(i, j),
                          a[i, j − 1] + g)
    return a[m, n]
```

FIGURE 3.2

Basic dynamic programming algorithm for comparison of two sequences.

Source: Introduction to Computational Molecular Biology
J. Setubal and J. Meidanis

Sequence Alignment Flow

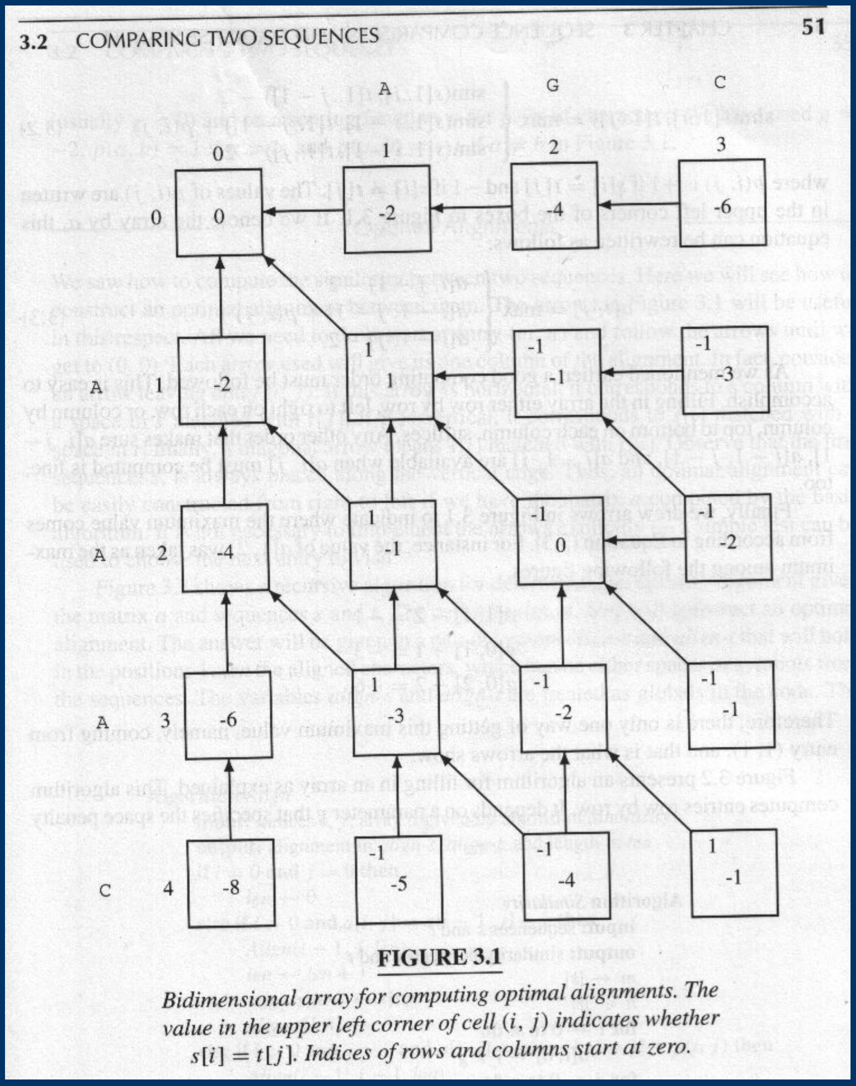
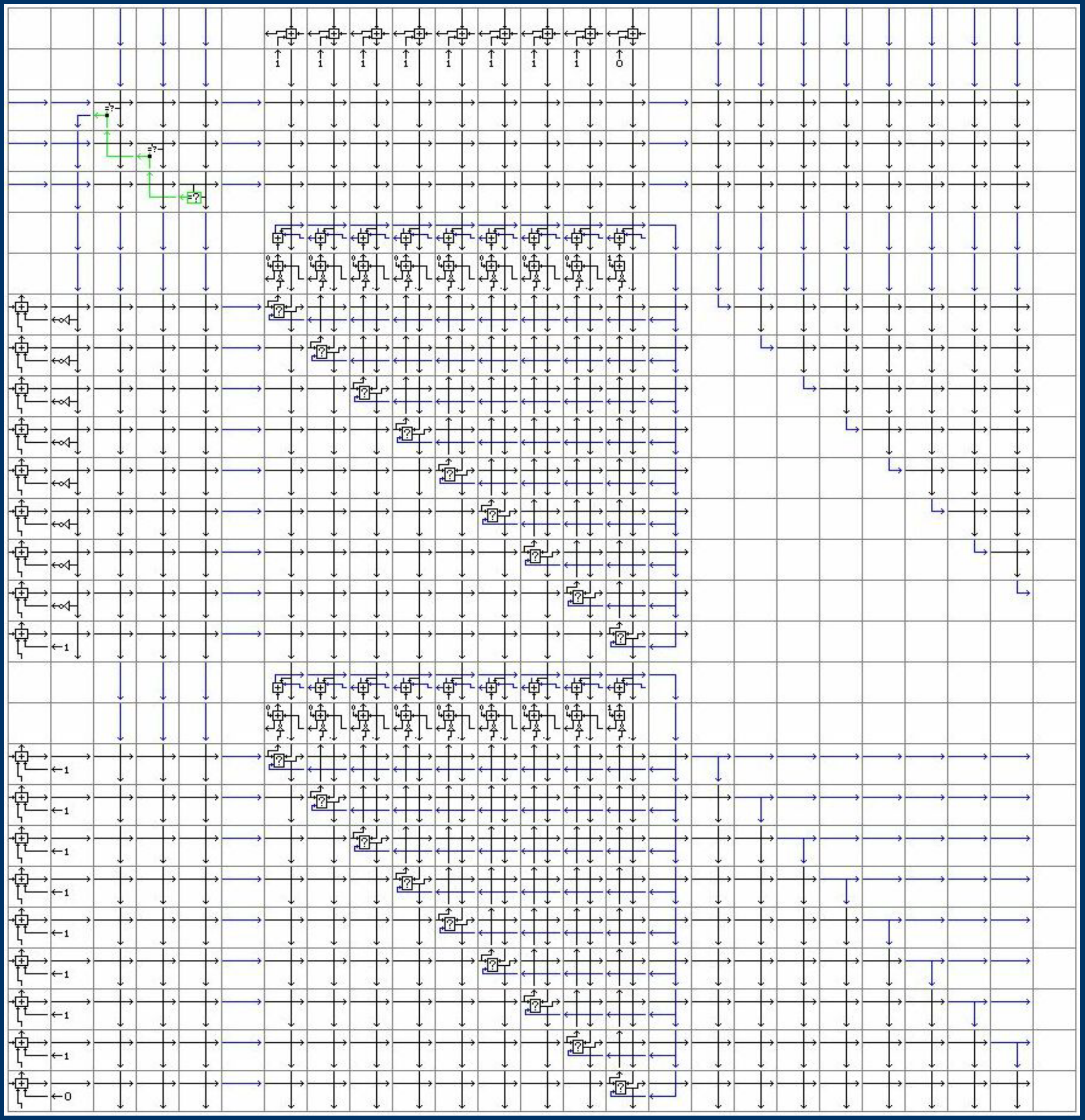


FIGURE 3.1

Bidimensional array for computing optimal alignments. The value in the upper left corner of cell (i, j) indicates whether s[i] = t[j]. Indices of rows and columns start at zero.

Source: Introduction to Computational Molecular Biology
J. Setubal and J. Meidanis

Sequence Alignment Circuit



Source: Bin Wang's Master's Thesis
Utah State University
2001

CONSEQUENCES

- Scalable
- Extremely flexible
- Inherent fault isolation
- Universal Computation
- One Machine-One Problem
- Huge *potential* for parallelism

APPLICATIONS

- Evolvable Hardware/NN/AI
- Bioinformatics
- Large Search Problems
- DES Cracking
- Simulation
- Finite Element Analysis
- Modeling

NANOTECH IMPLICATIONS

Can help with nanotech development:

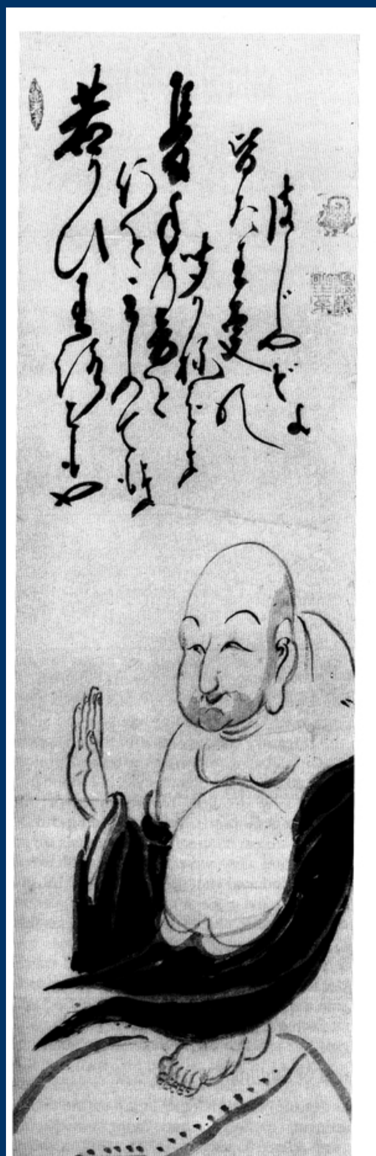
- Fault isolation
- Defect location and analysis
- Correction of imperfect hookup
- Correction of imperfect stacking
- Nano-scale control system

THE CELL MATRIX IS NOT A PARTICULAR MACHINE

It is an ARCHITECTURE

It is a blueprint for organizing matter to do useful work

HOW ARE CELLS CONFIGURED?



What is the sound of one hand clapping?

THREE CASES OF SUBJECT/OBJECT DUALISM

Not intended to prove a point
Rather, the goal is to be
thought provoking

René Descartes (1596-1650)

PROOF BY CONTRADICTION

"I do not believe the table exists."

PROOF BY CONTRADICTION

"I do not believe the table exists."

Could not find a contradiction

PROOF BY CONTRADICTION

"I do not believe other people exist."

PROOF BY CONTRADICTION

"I do not believe other people exist."

Still could not find a contradiction

PROOF BY CONTRADICTION

"I do not believe I exist."

PROOF BY CONTRADICTION

"I do not believe I exist."

Now there's a problem...

PROOF BY CONTRADICTION

"I doubt that I exist,
therefore I do exist."

PROOF BY CONTRADICTION

"I believe that I exist,
therefore I do exist."

PROOF BY CONTRADICTION

"I think, therefore I am."
(Cogito ergo sum)

SUBJECT AND OBJECT ARE THE SAME

"I do not believe I exist."

Subject

Object

THIS IS A POWERFUL CONCEPT...

"I do not believe I exist."

Subject

Object

"I do not believe the table exists."

WHEN ARE SUBJECT AND OBJECT INDEPENDENT?

"I see the table"

WHEN ARE SUBJECT AND OBJECT INDEPENDENT?

"I see the table"

But can you just "see"?

WHEN ARE SUBJECT AND OBJECT INDEPENDENT?

"The soda tastes sweet"

WHEN ARE SUBJECT AND OBJECT INDEPENDENT?

"The soda tastes sweet"

Can you simply "taste"?

WHEN ARE SUBJECT AND OBJECT INDEPENDENT?

"The soda tastes sweet"

Is the soda "sweet" without something to taste it?

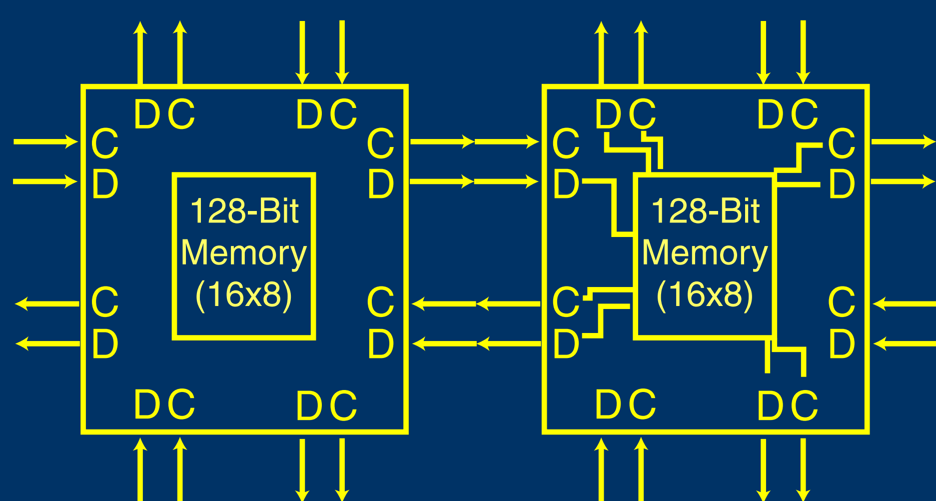
ARE TASTE AND TASTEBUD TRULY INDEPENDENT?

Can they be separated, or
do they necessarily co-exist?

How are Cells Configured?

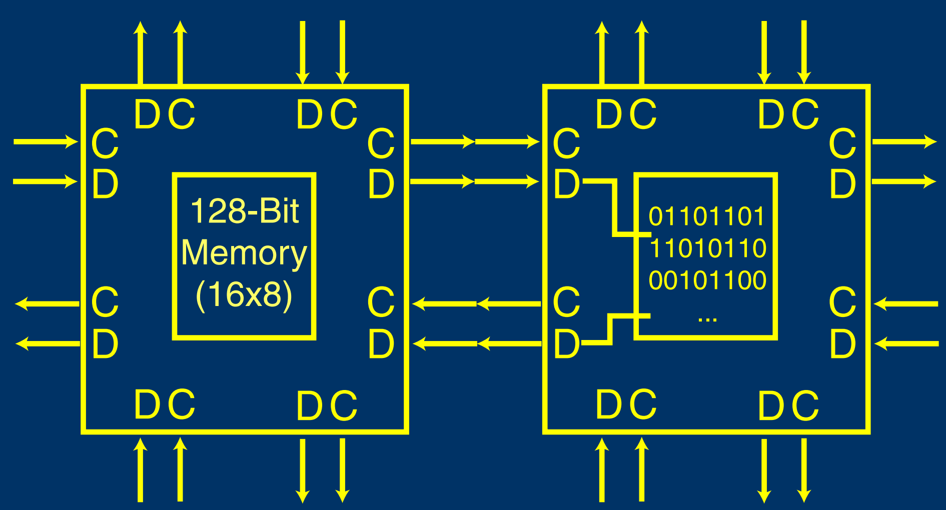
How are Cells Configured?

- Cells typically pass *data* to their neighbors
  - That data is processed via cell's Truth Table (*code*)



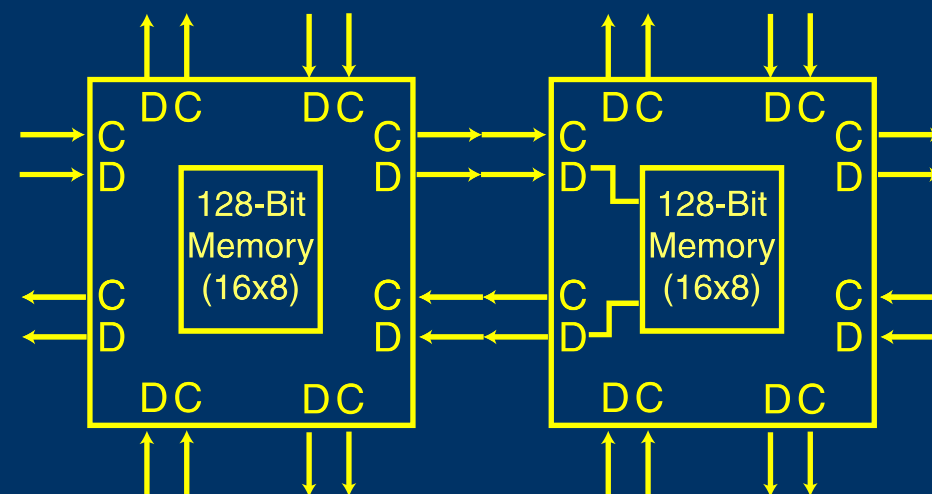
There is a Dual Mode...

- Under certain circumstances, cells may pass *truth tables* (code) to neighbors

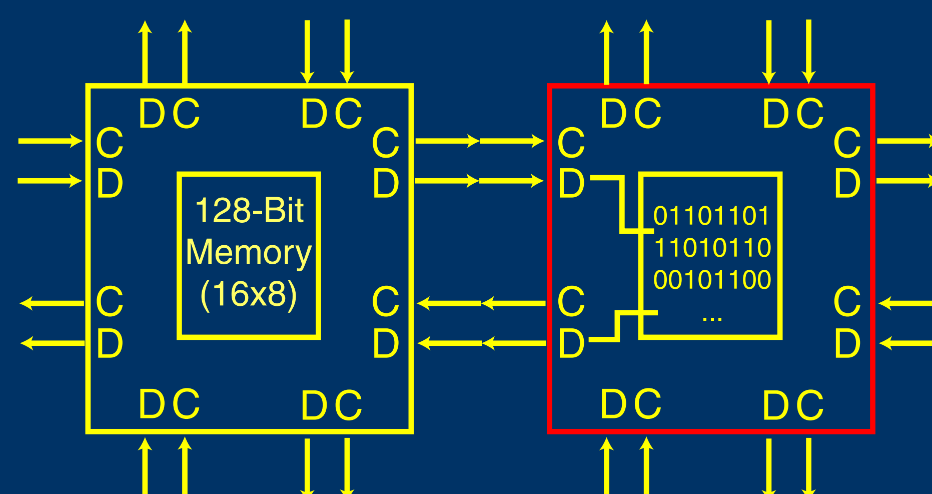


Each Cell Operates in One of Two Modes

D-Mode:
Cells Exchange DATA

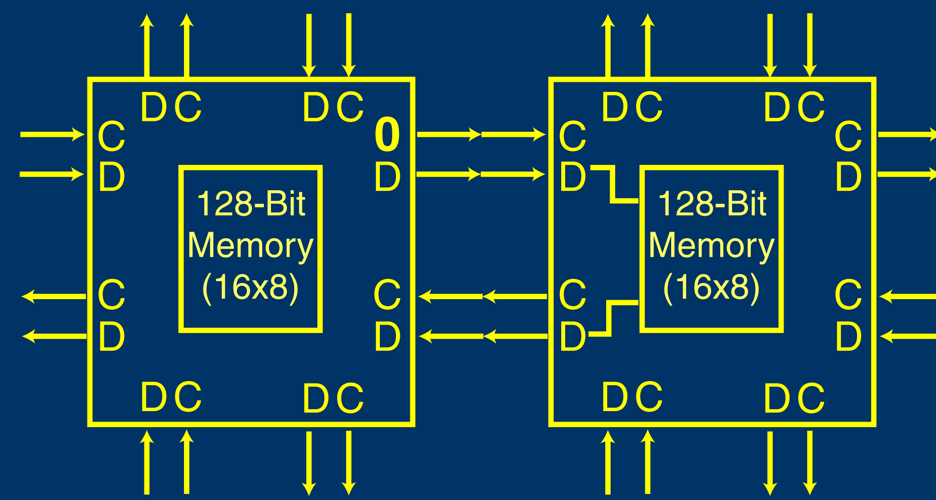


C-Mode:
Cells Exchange CODE

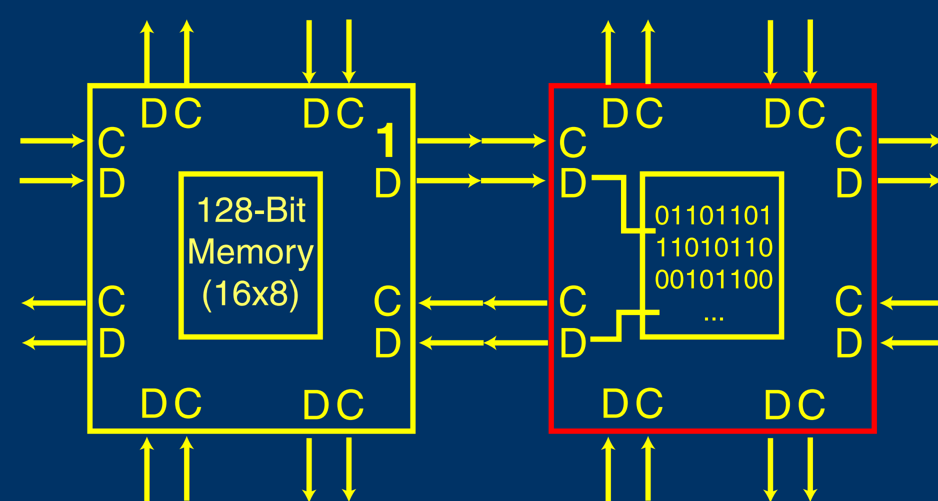


C-Mode is Indicated by Setting a C Input to1

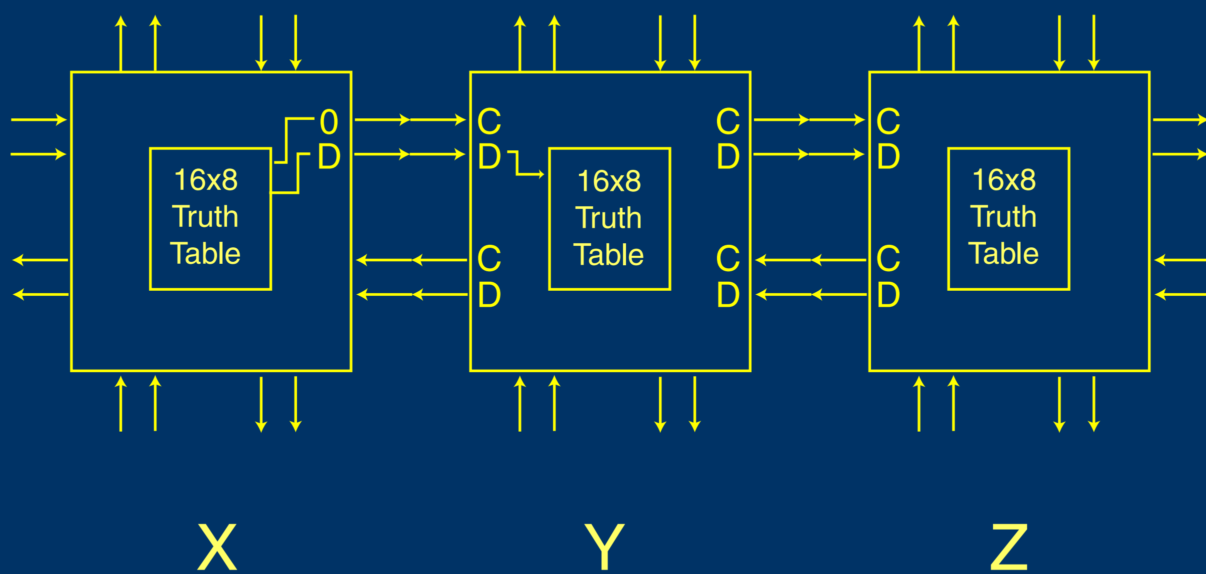
D-Mode:
Cells Exchange DATA



C-Mode:
Cells Exchange CODE

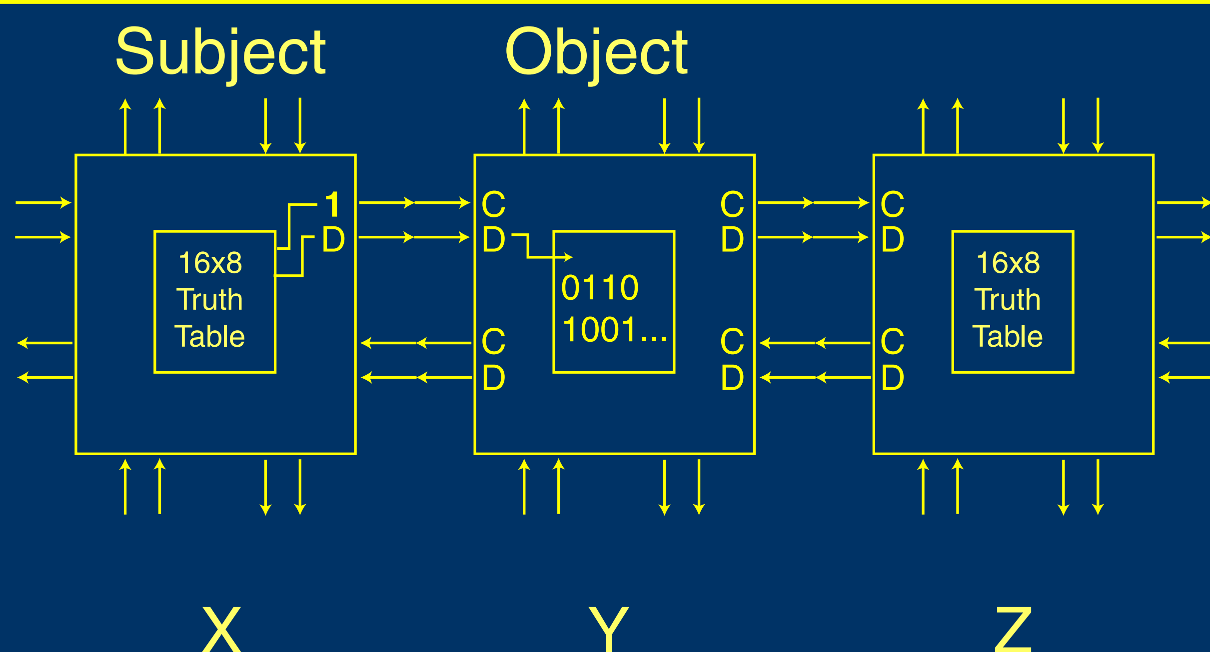


X May Pass Data to Y



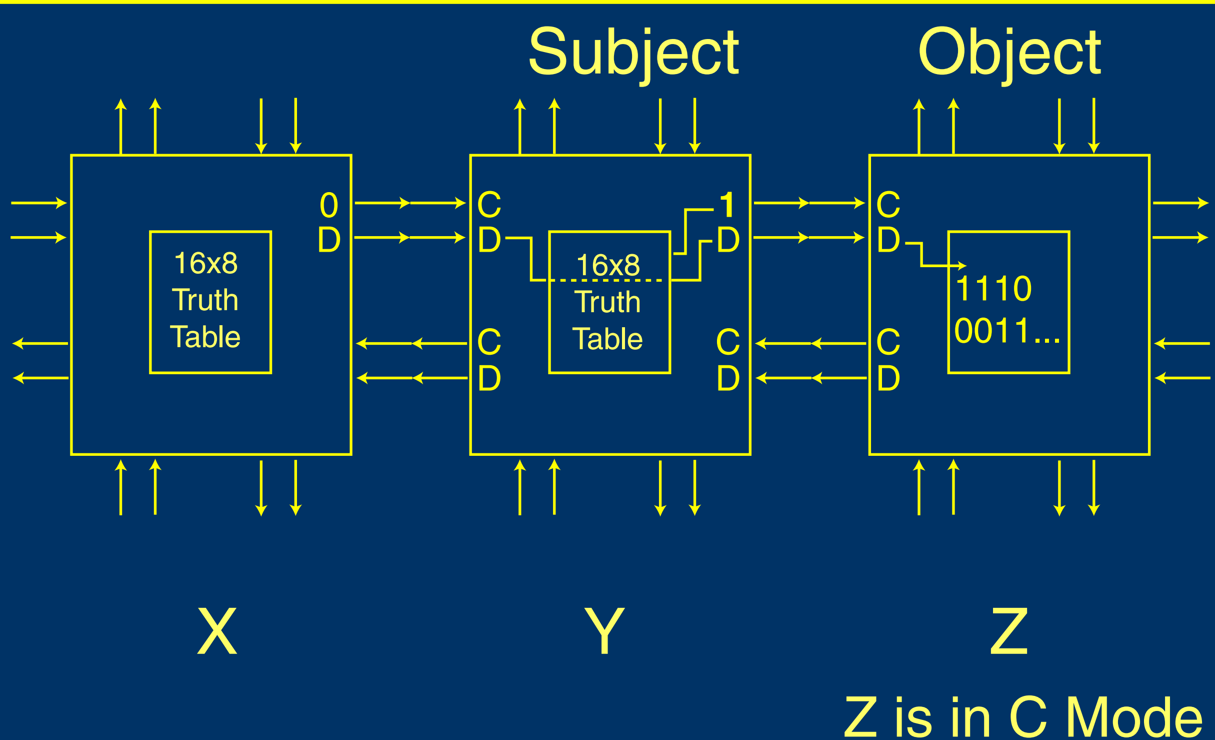
Y is in D Mode

X May Configure Y

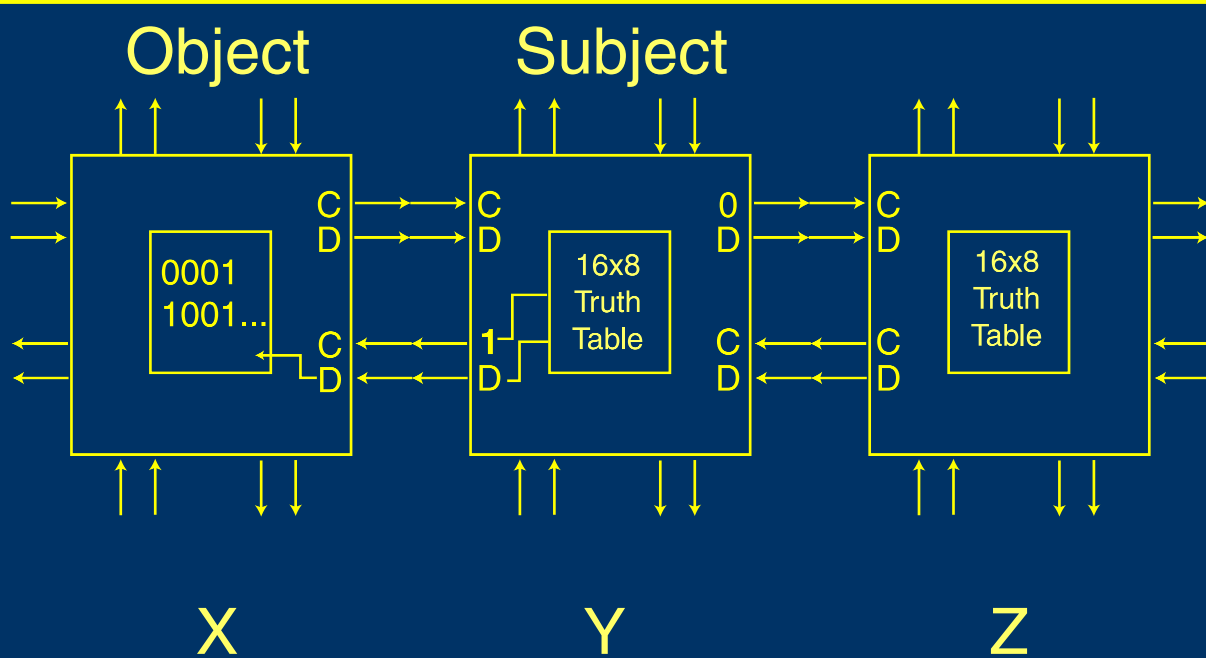


Y is in C Mode

Y May Then Configure Z



Or Y May Reconfigure X



X is in C Mode

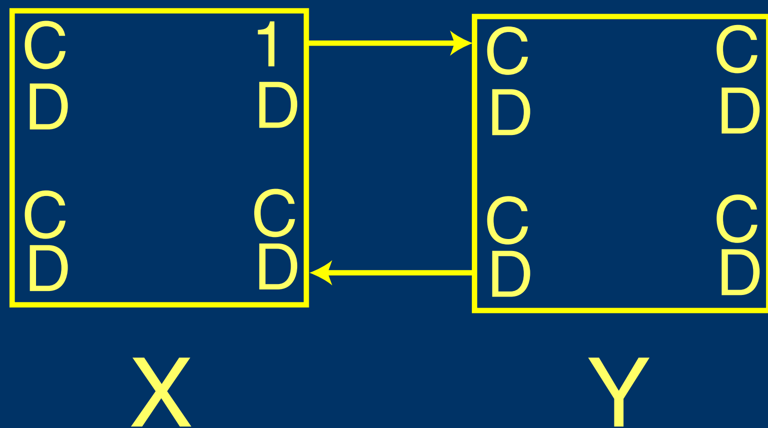
SELF DUALITY

There is a perfect interchangability between the subject and object of configuration

SELF CONFIGURABILITY

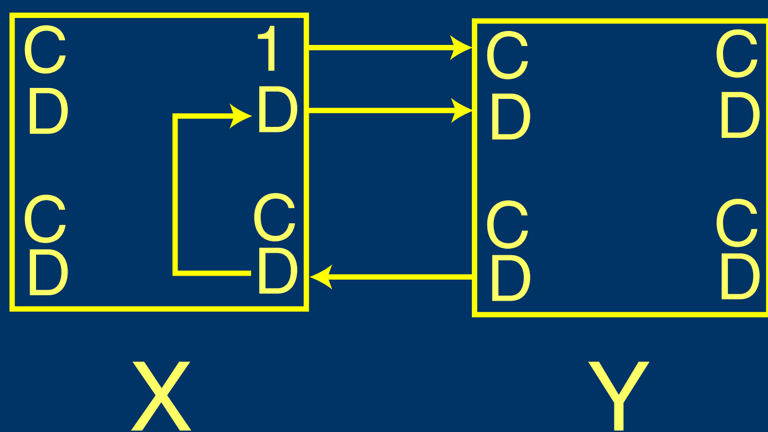
The Cell Matrix is able to read, modify and write its own configuration information.

Cell Reader



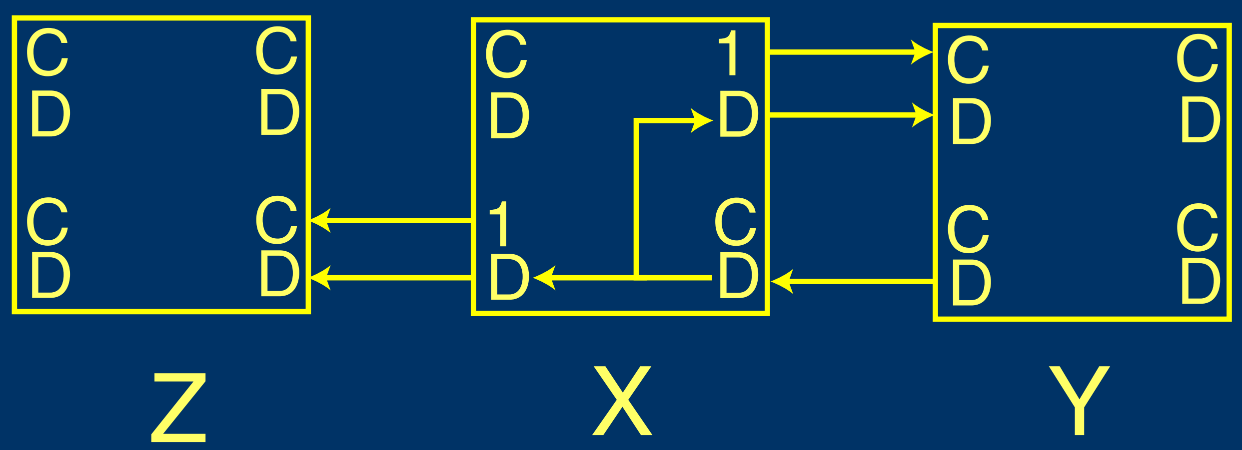
X is reading Y's Truth Table

Non-Destructive Cell Reader



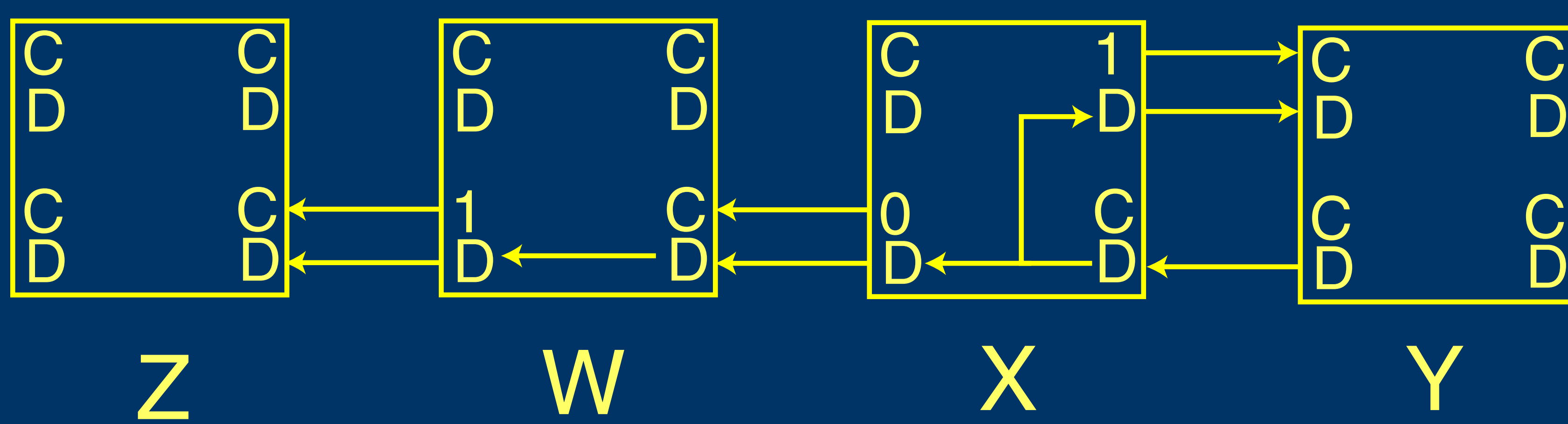
X is reading Y's Truth Table
and copying it back to Y

Cell Replicator



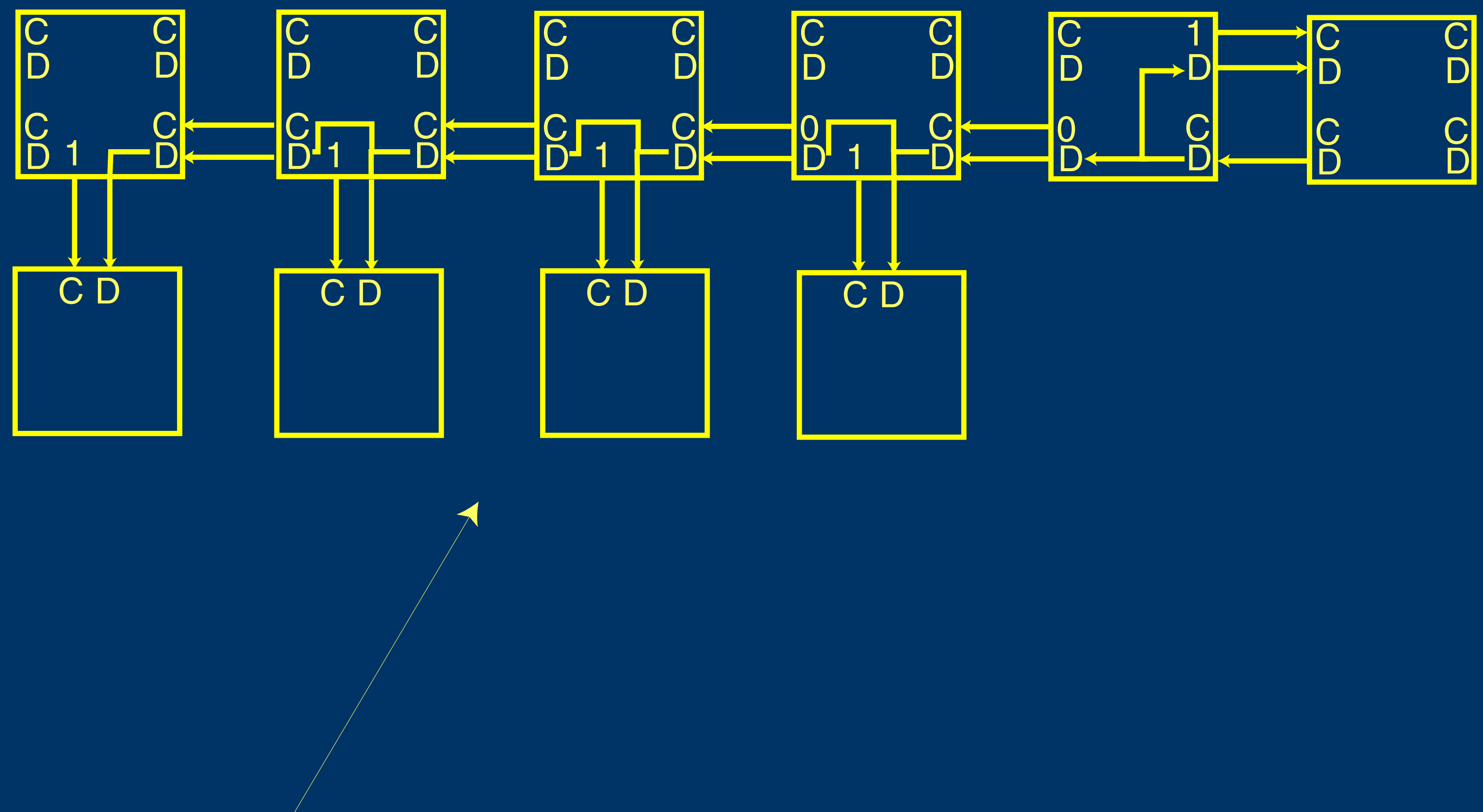
X is reading Y's Truth Table,
copying it back to Y,
and also copying it to Z

Remote Cell Replicator



X is reading Y's Truth Table,
copying it back to Y,
and also copying it to Z

Medusa Circuit



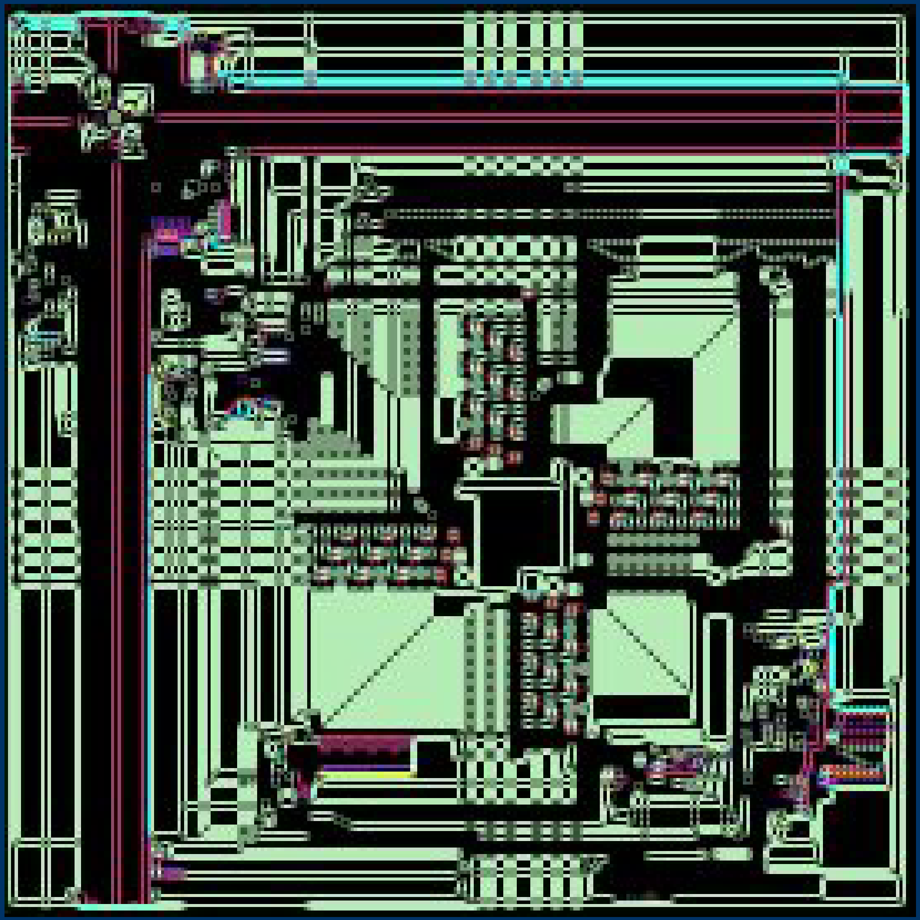
FOUR CELLS CONFIGURED SIMULTANEOUSLY

CASE STUDY: Autonomous Self-Repairing Circuits

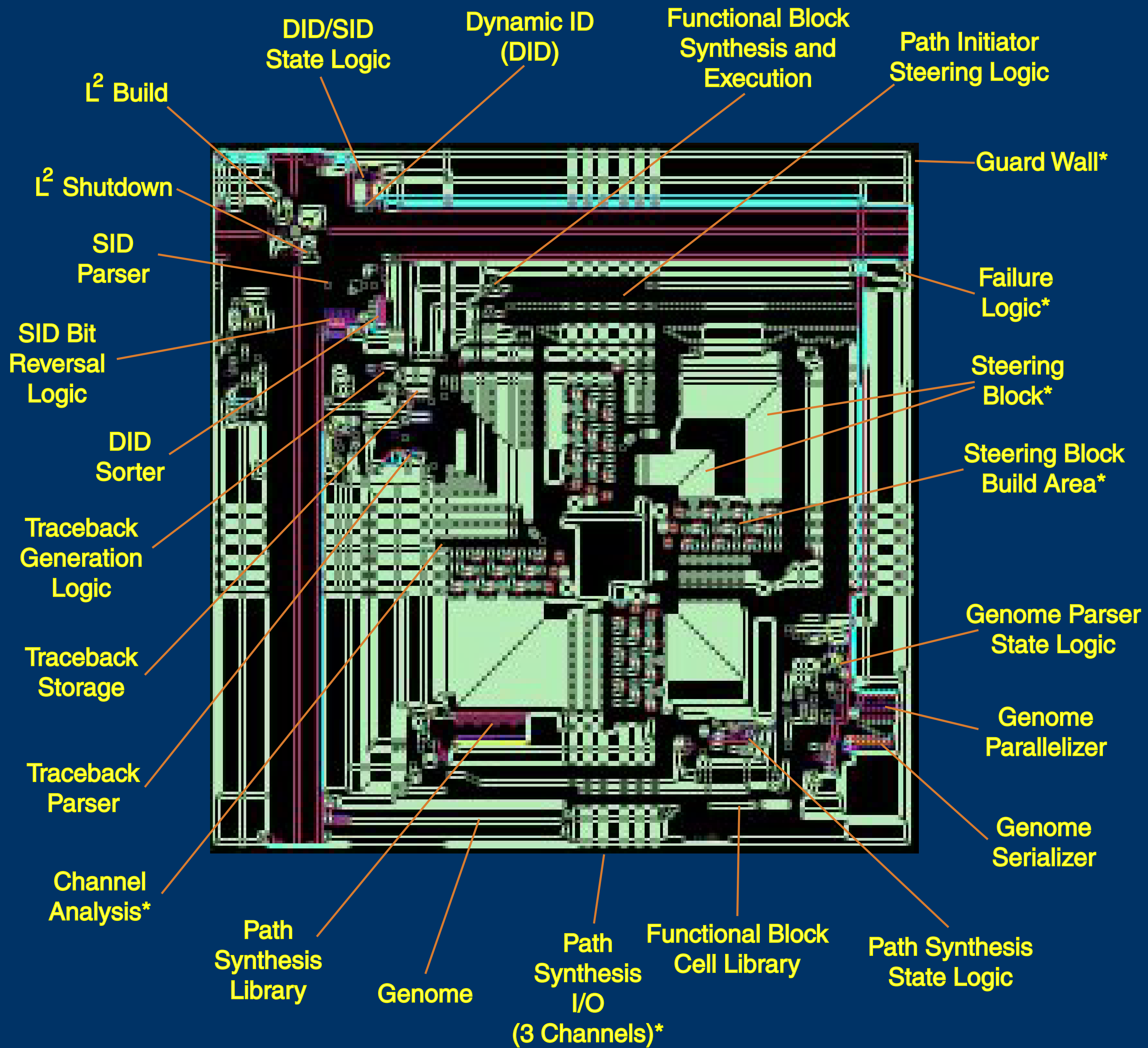
Funded in part under
NASA SBIR
NAS2-01049

February-August 2001

Supercell Image

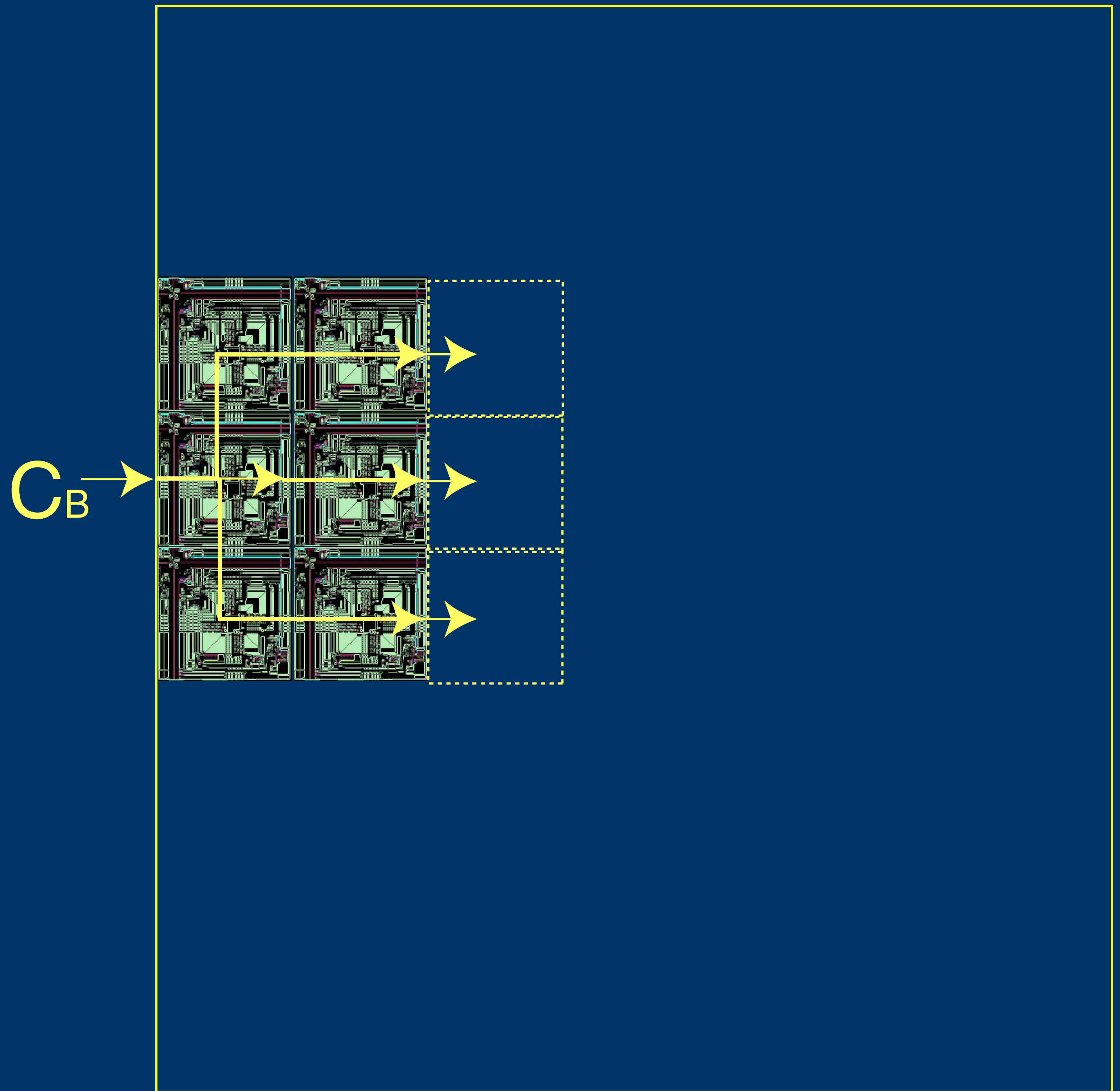


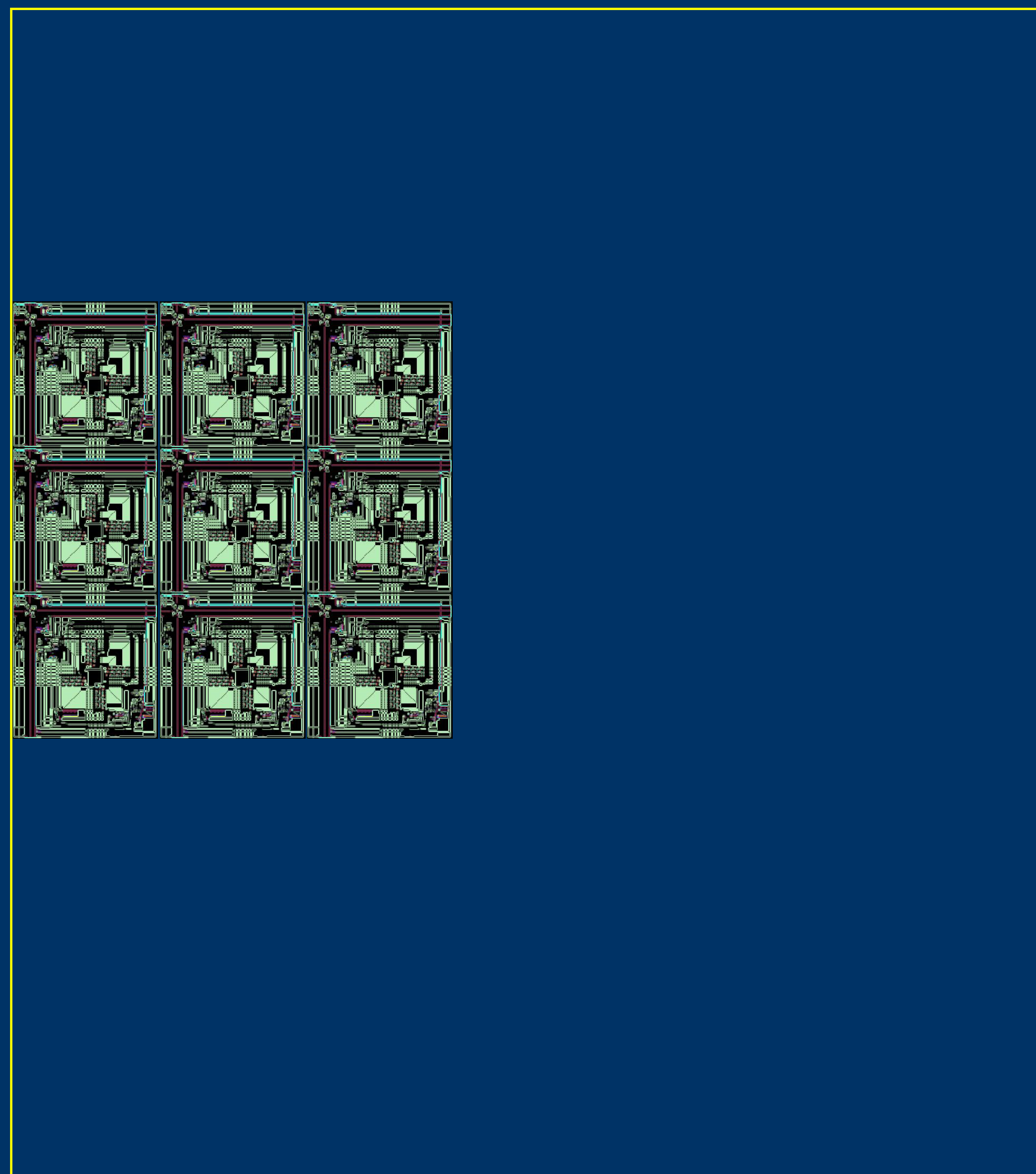
72,900 Cell Matrix Cells
270x270



L2 Build
DID/SID State Logic
Dynamic ID (DID)
Functional Block Synthesis and Execution
Path Initiator Steering Logic
Guard Wall*
L2 Shutdown
SID Parser
SID Bit Reversal Logic
DID Sorter
Traceback Generation Logic
Traceback Storage
Traceback Parser
Channel Analysis*
Failure Logic*
Steering Block*
Steering Block Build Area*
Genome Parser State Logic
Genome Parallelizer
Genome Serializer
Path Synthesis Library
Genome
Path Synthesis I/O (3 Channels)*
Functional Block Cell Library
Path Synthesis State Logic

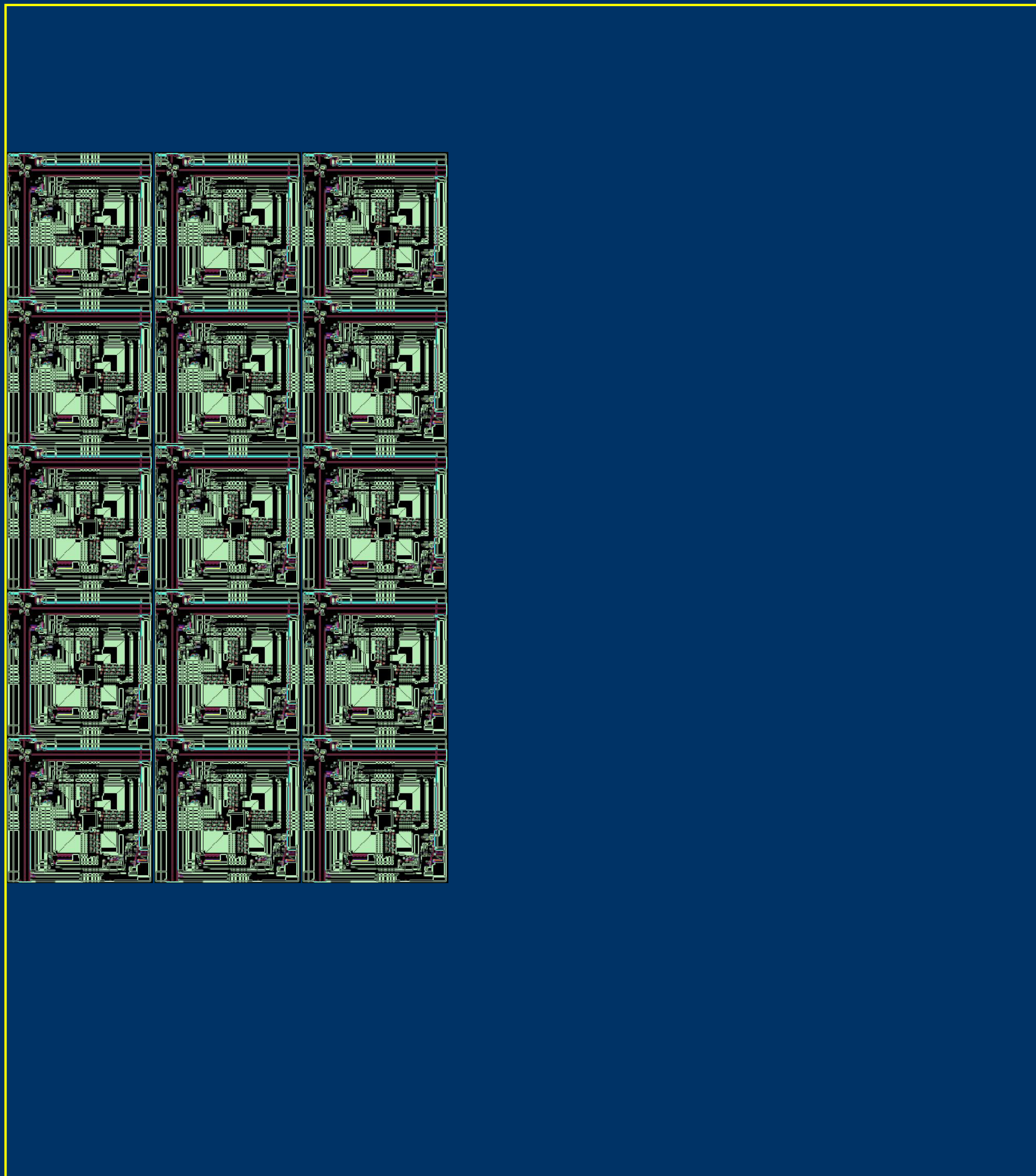
Supercells Create New Supercells



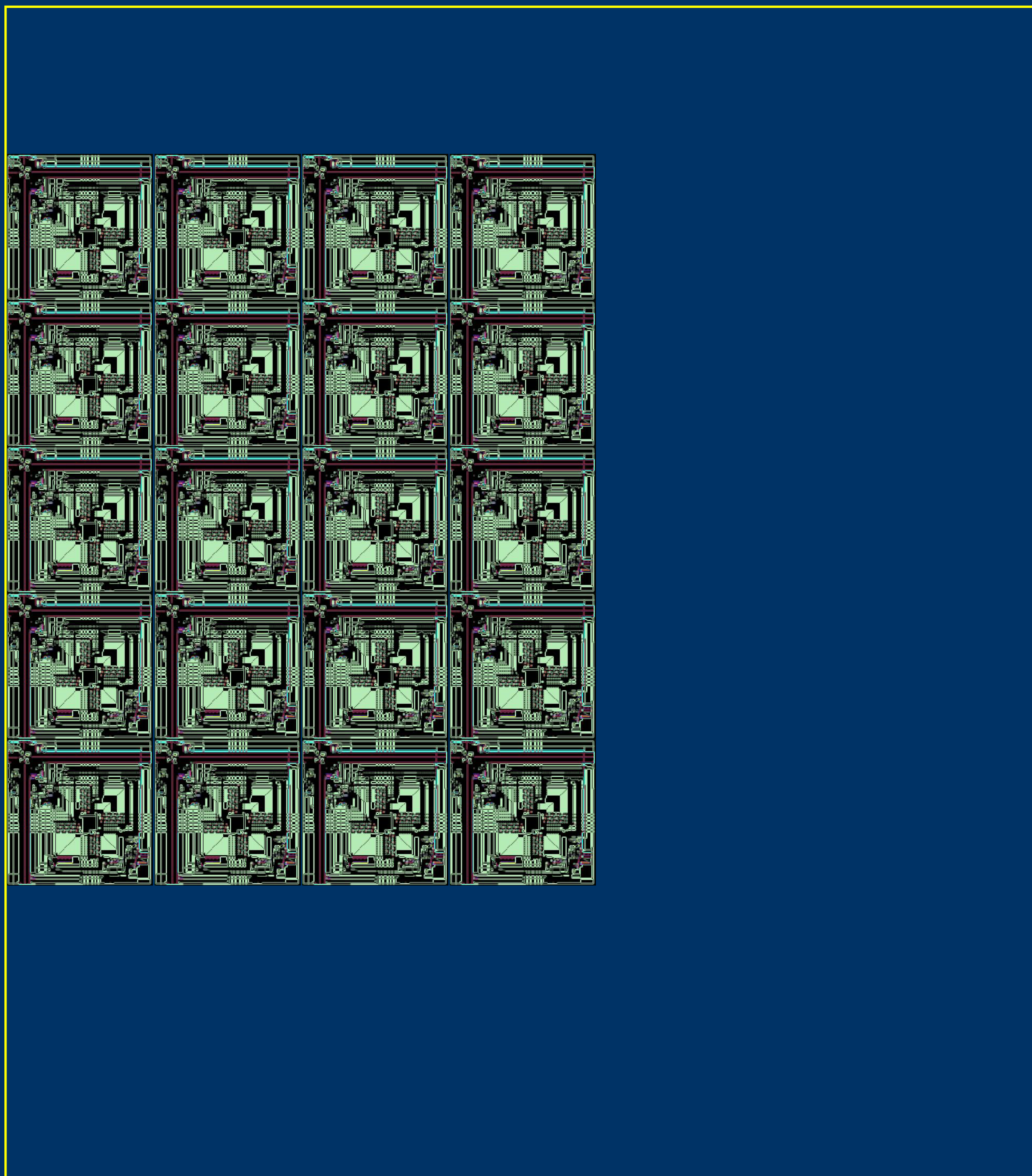


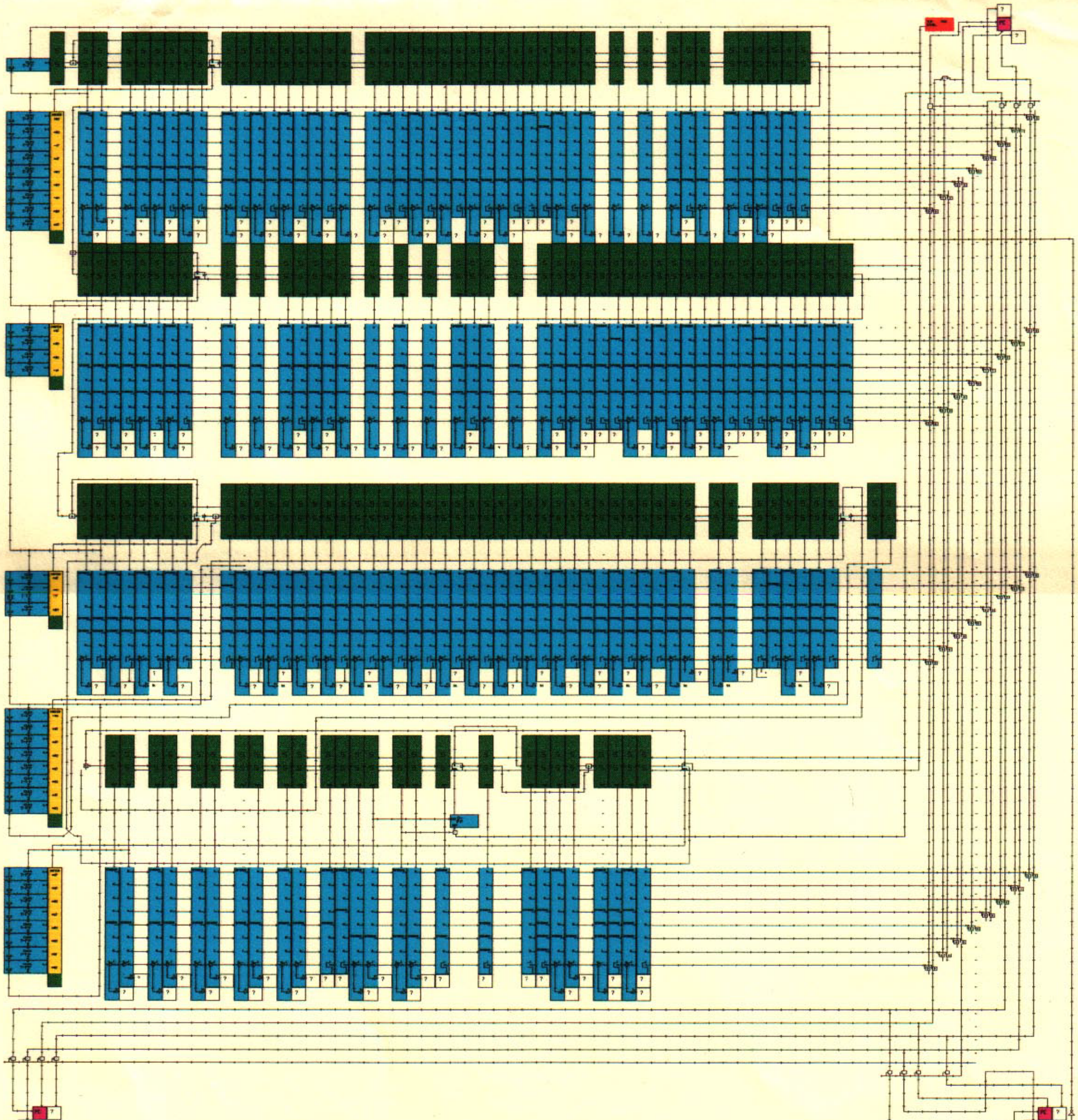
and those create more supercells...

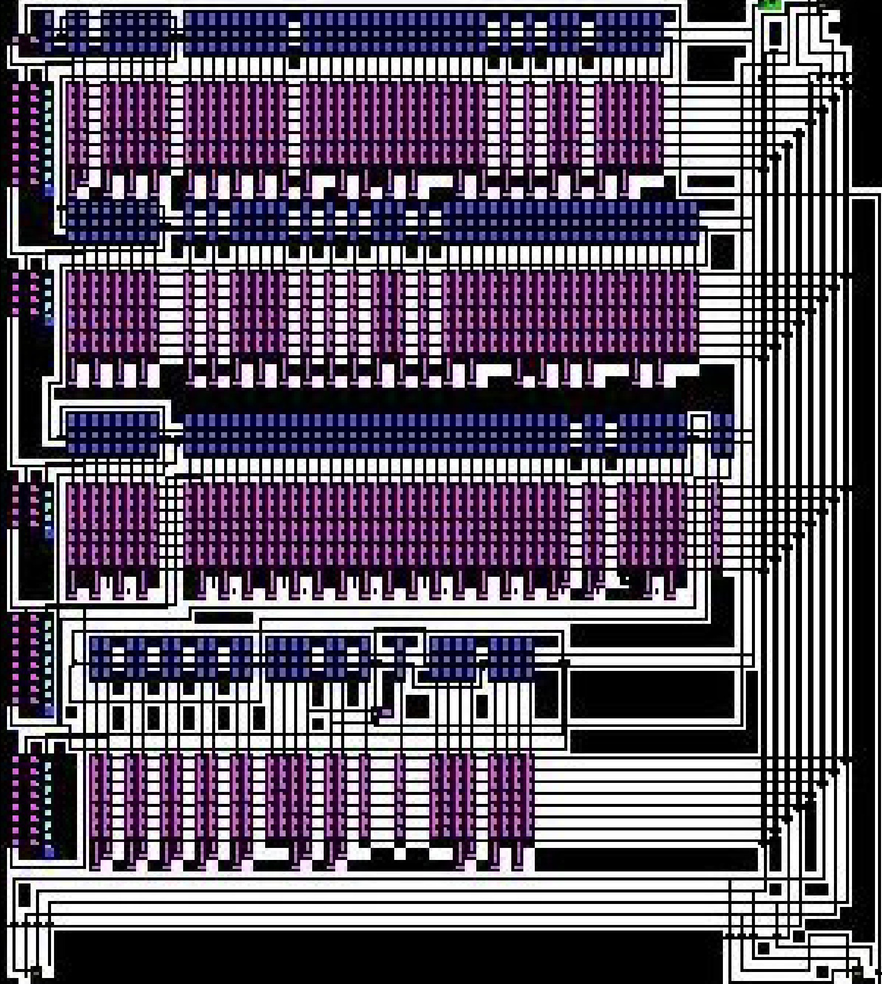
and so on...

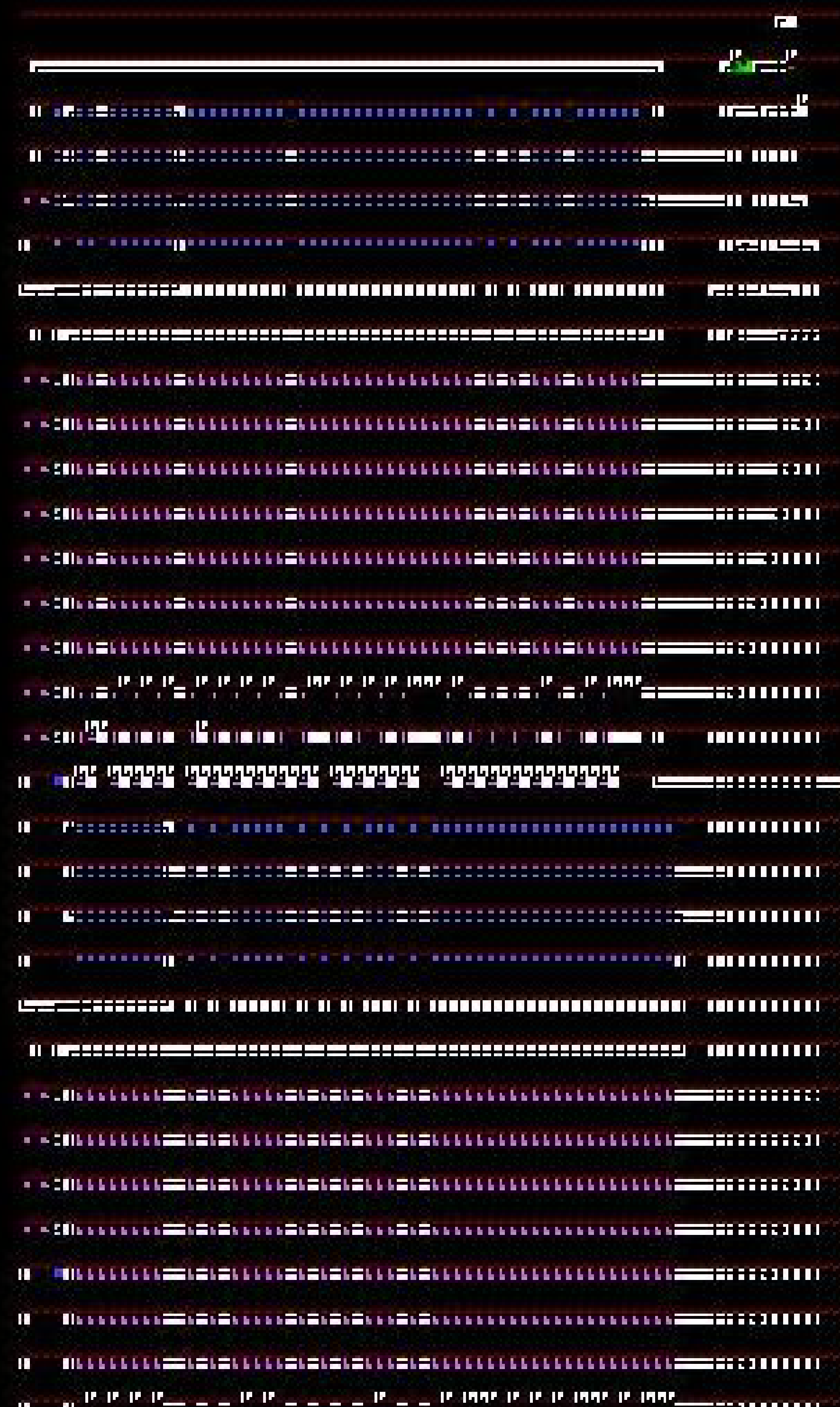


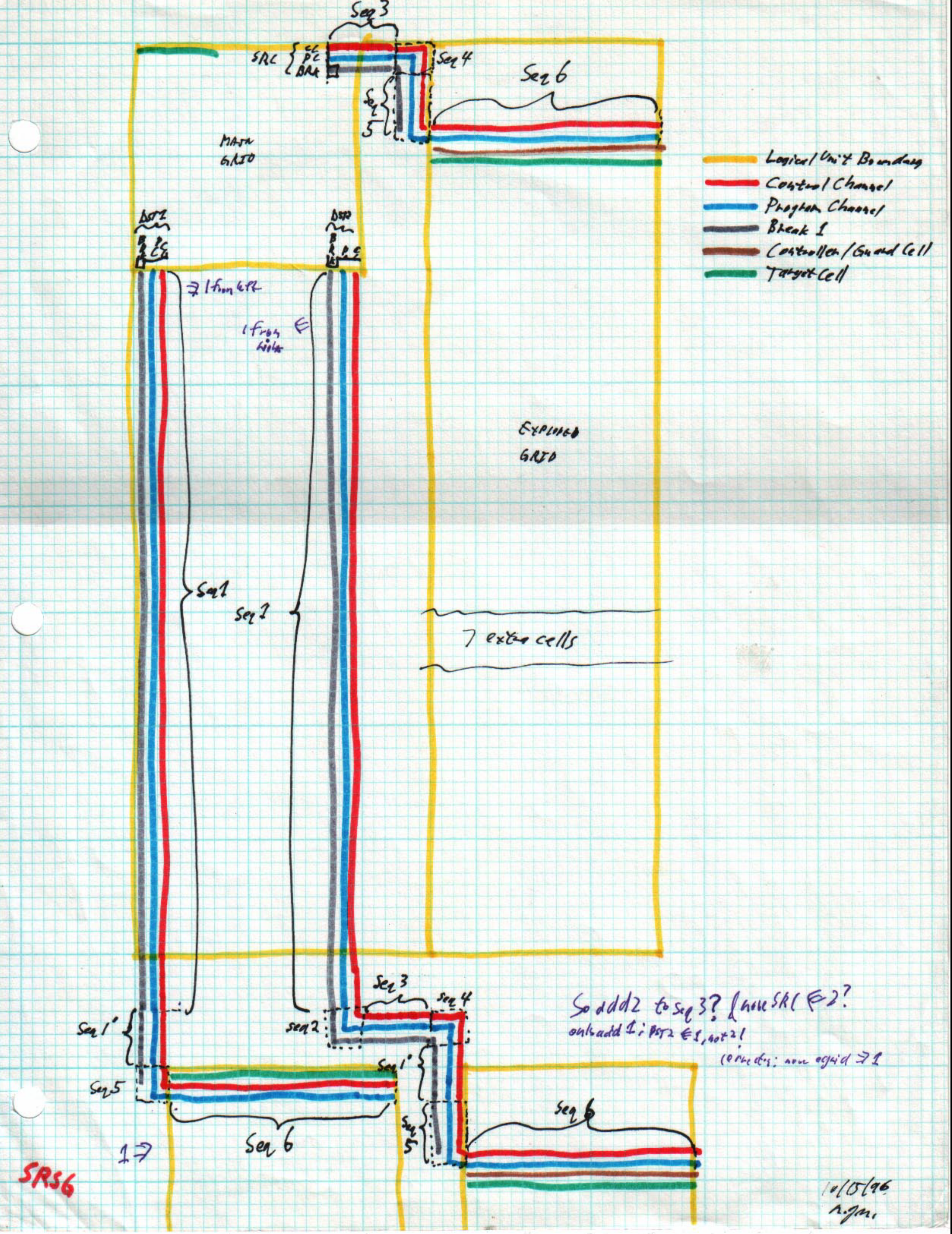
and so on...











Seq 3
SRC
CC
PC
BRK
Seq 4
Seq 5
Seq 6
MAIN GRID
Logical Unit Boundary
Control Channel
Program Channel
Break 1
Controller/Guard Cell
Target Cell
DST2
B
PC
CC
∋ 1 from left
1 from ∈ right
EXPLORED GRID
Seq 1
Seq 2
7 extra cells
Seq 3
Seq 4
Seq 1'
Seq 2
Seq 5
Seq 1'
Seq 6
Seq 5
Seq 6
1 ∋
So add 2 to seq 3? (now SRC ∈ 2?
only add 1; DST2 ∈ 1, not 2!
(or rather: now egrid ∋ 1
SRS6
10/15/96

SUMMARY

- Nanotech->Scale Up
- Avogadro machine-High power
- Cell Matrix can handle complexity
- Can also aid nanotech development
- Fault isolation/handling is key
- Self-Duality may be important in ways not yet fully understood

FUTURE WORK

- 3D structures
- I/O hooks
- Nano-supportive structures
- Fine-grained fault tolerance
- Physical self-assembly
- Super-self-duality

FOR MORE INFORMATION...

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