Sustaining HPC Curricula at a Regional Institution

Karl Frinkle - Mike Morris

Work in Progress

since 2006 or so

Sustaining HPC Curricula
at a Regional Institution

HARDWARE

Sustaining HPC Curricula at a Regional Institution

WINDOW PRIZE!

WINDOW PRIZE!

What the heck is this?

WINDOW PRIZE!

Apple Lisa w/5M Profile HD!

Semi-interesting tidbit:

5M x 200 = 1G (5M was $2,000)

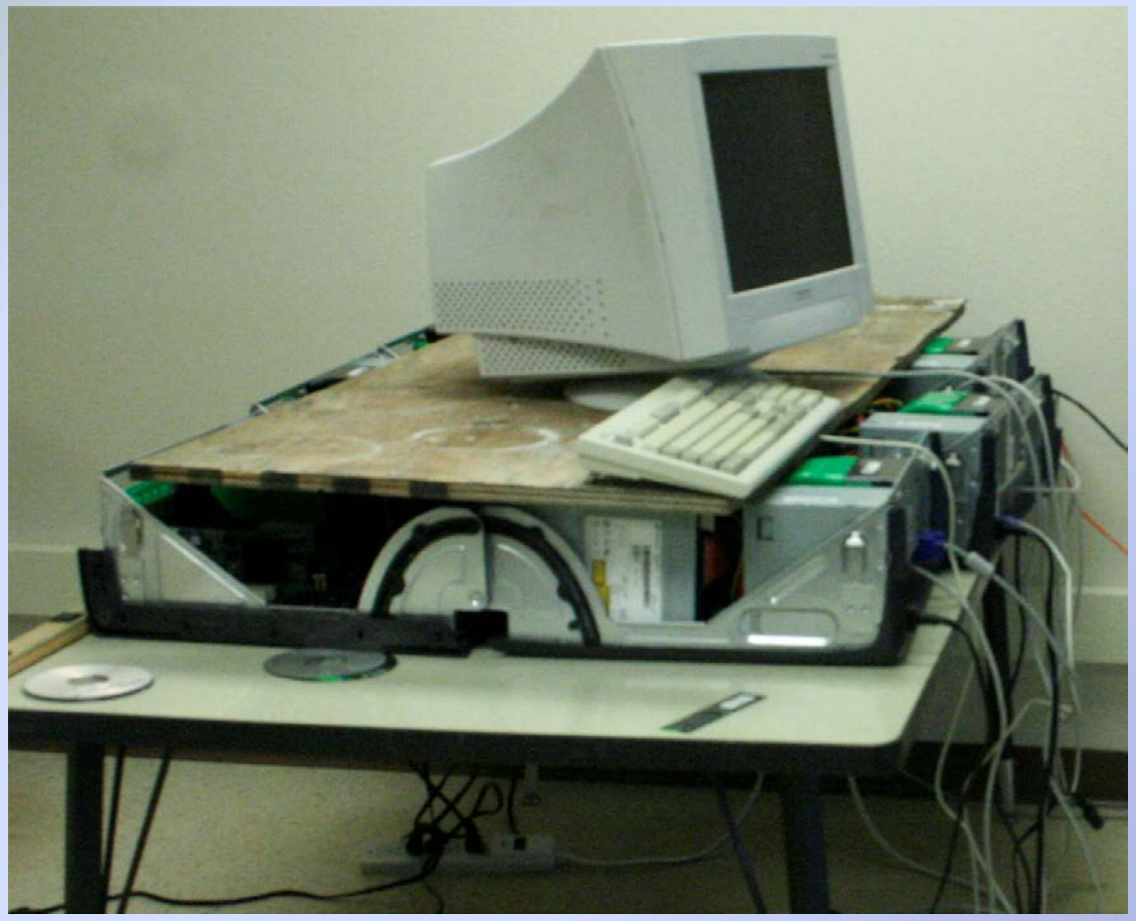
200 x 16 = 3,200

3,200 x $2,000 =

$6,400,000

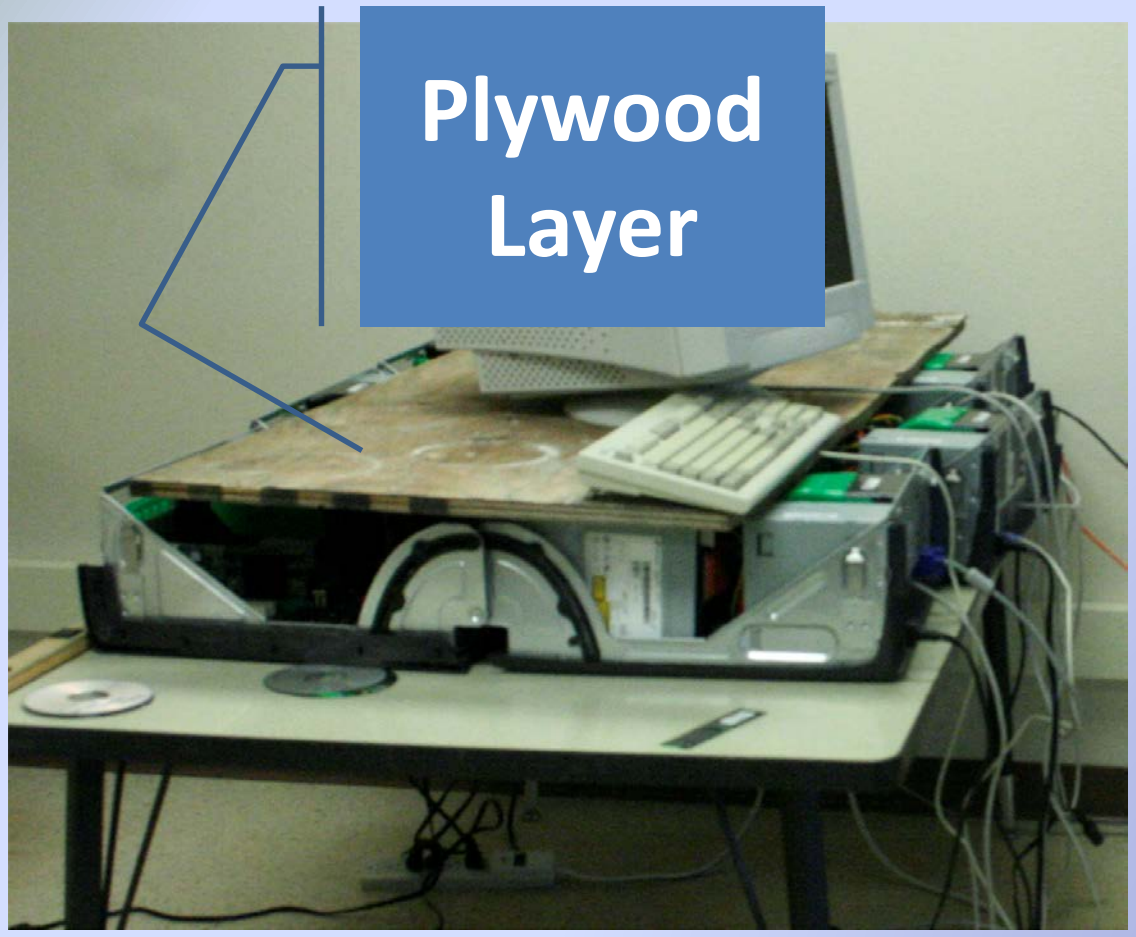
I got 16G in W-M for $5

2007 - Where Our HPC Began . . .



- **Dell Dimension 4500**
- **6 Pentium 4s @ 2.4GHz**
- **L1 Cache: 8K**
- **L2 Cache: 512K**
- **Main Memory: 512MB DDR @ 400MHz**
- **Hard Drive: 40GB**
- **OS – Fedora 10**

2007 - Where Our HPC Began . . .



Savage One

Progressing to . . .

- **Phone guys gave us a rack**
- **Much more photogenic**
- **Same computers**

Progressing to . . .

- Phone guys gave us a rack
- Much more photogenic
- Same computers
- Added a remote head node
- Custom Power Cord

Progressing to . . .

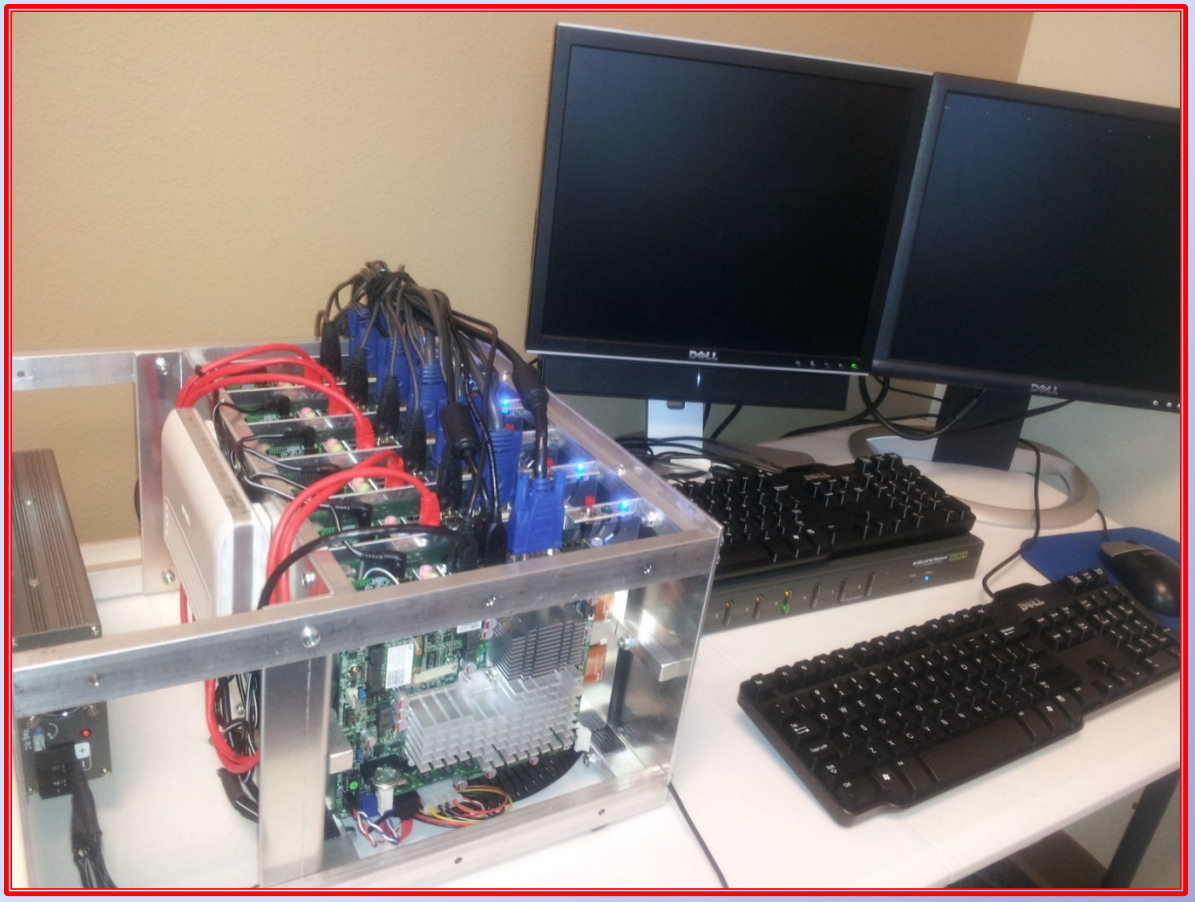
- Phone g
- Much m
- Same co
- Added a
- Custom

2009
Quake Server!
Grrr . . .

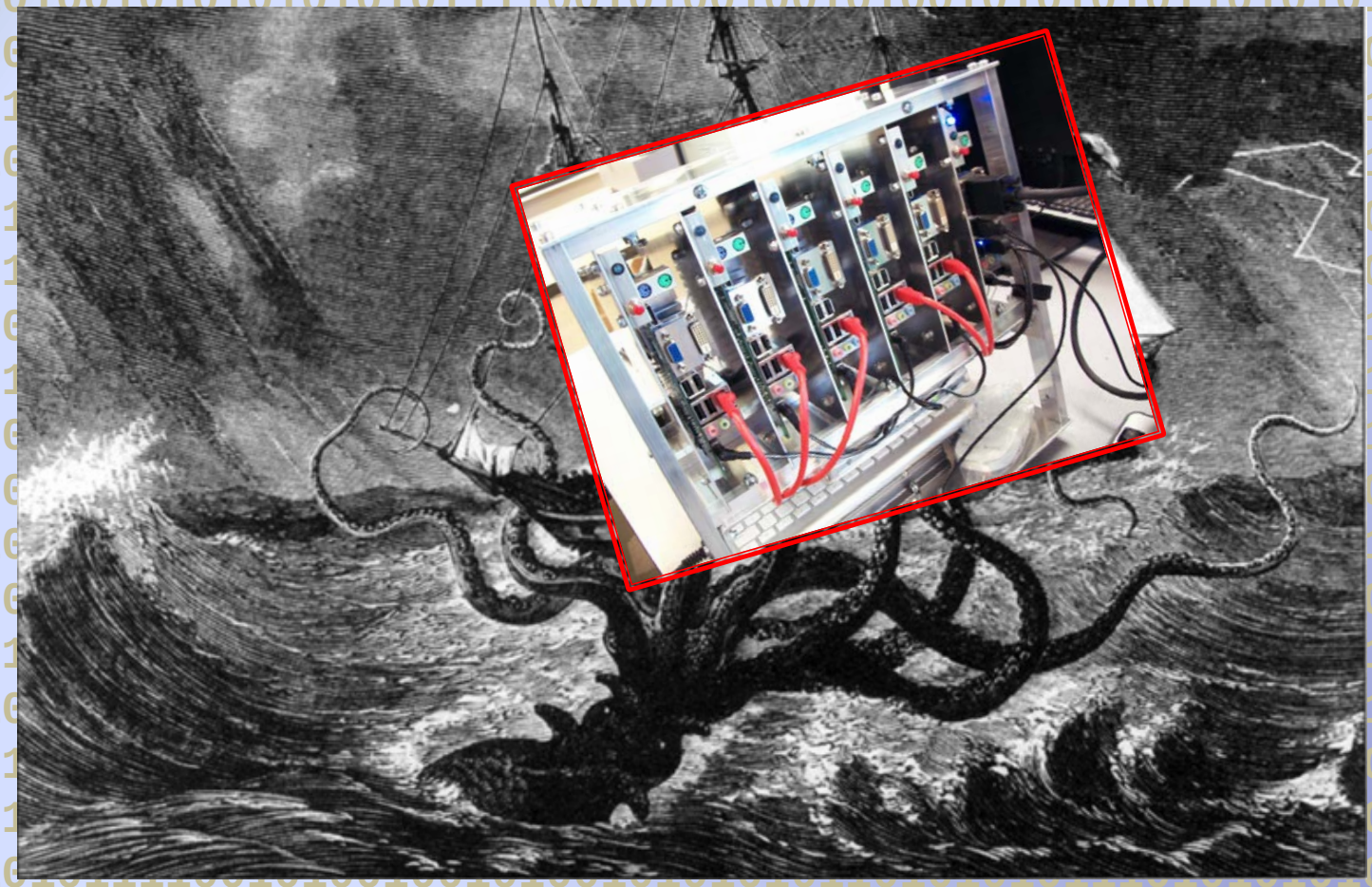
2011 – We Arrived . . .

We applied and were awarded a LittleFe! We felt that this would give our efforts a recognized legitimacy in the HPC world to inject this technology into our curriculum.

2011 – We Arrived . . .

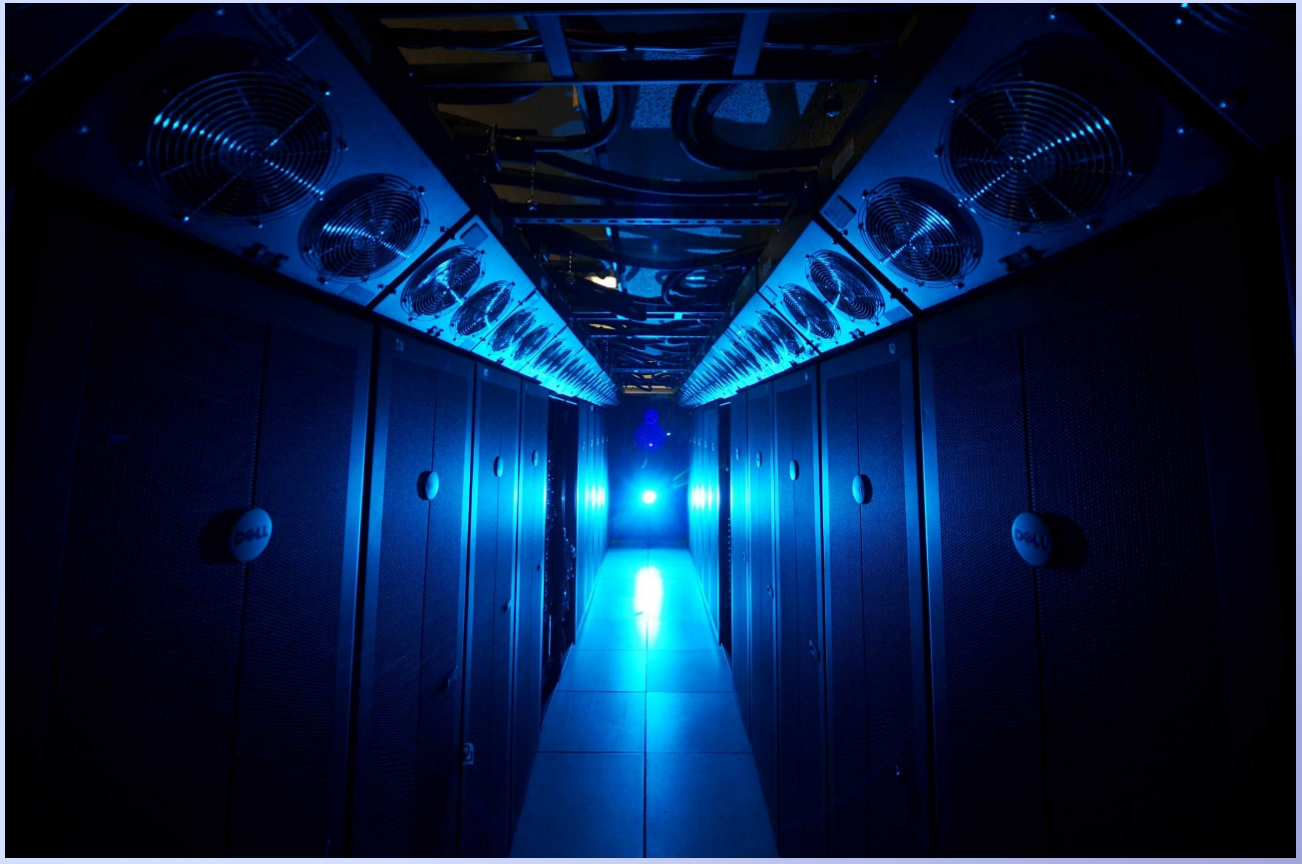


Our Wonderful LittleFe



We called it “The Kraken”

Then We Got Comfy with Sooner!

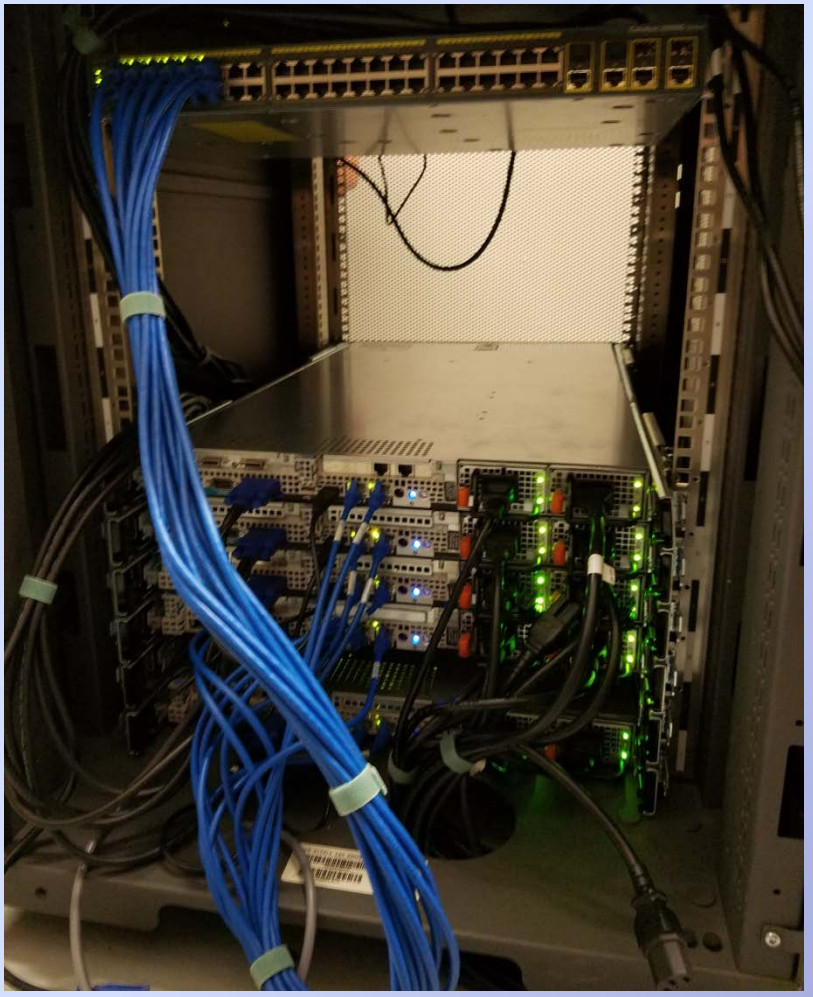


Moment of transition.

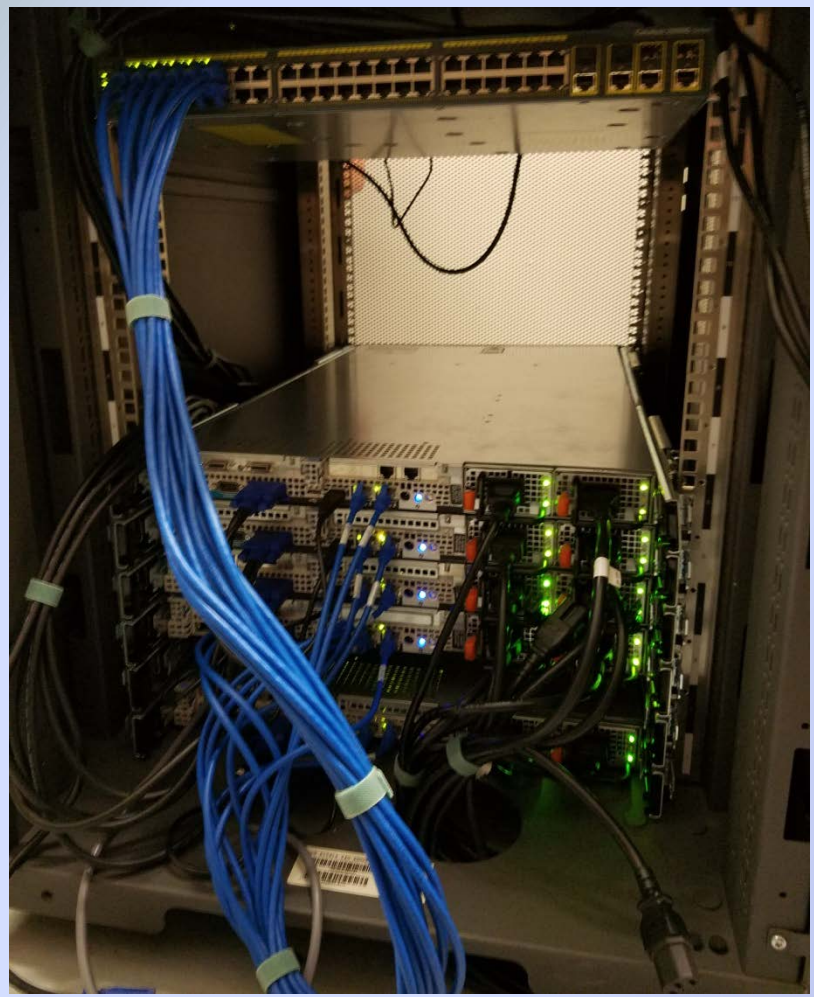
. . . and now a word from Karl . . .

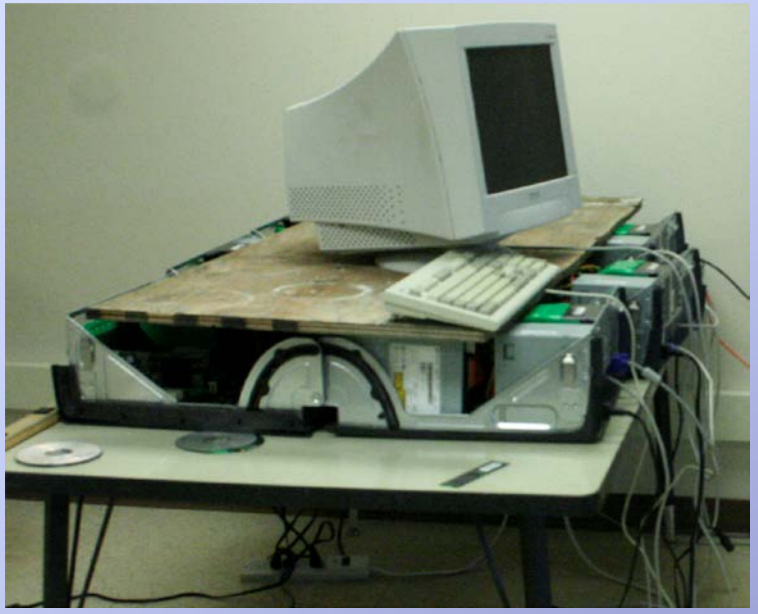
2014 – We Built Three "Junk" Clusters - Eerily Reliable!

2016 – We Struck Gold!



2016 – How Far We've Come!





2007

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HARDWARE CONCLUSIONS

HARDWARE CONCLUSIONS

- It's not hard to get or make a cluster –
  - a little OS help might be needed
- Almost any cluster will do the job -
  - the job of teaching HPC
- You're teaching concepts & methods -
  - not trying to get large work done.
- If you get to big data or need real speed, use a (free) HLHR*.

* Henry's Latest Hot Rod

Sustaining HPC Curricula
at a Regional Institution

WINDOW PRIZE!

WINDOW PRIZE!

What the heck is this?

WINDOW PRIZE!

In 1,000s of high schools.

8-bit Zylog Z80 Chip.

Commodore PET

Moment of transition.

. . . back to Mike . . .

Sustaining HPC Curricula at a Regional Institution

CURRICULA

CURRICULA CONCERNS

- Special Seminar – CS 49xx
- Greater Freedom
- Careful Naming
- Sometimes Low (or no) Pay
- Can Be Used as Electives
- Can Be “Repeated”

CURRICULA CONCERNS

- **Special Seminar – CS 49xx**

- **Special Seminar, Directed Reading, Special Studies, etc., these usually exist everywhere.**
- **They need little approval.**

- **Can Be Used as Electives**
- **Can Be "Repeated"**

CURRICULA CONCERNS

- Special Seminar – CS 49xx
- **Greater Freedom**

- **Teach what the heck you want or need.**
- **Ignore requirements like progress reports.**
- **Be flexible on times and techniques.**
- **Be prepared for varying class sizes.**
- **Give As or Fs at your pleasure.**
- **Be a "new wave" rogue edge professor.**

CURRICULA CONCERNS

- Special Seminar – CS 49xx
- Greater Freedom
- **Careful Naming**

- **Parallel Programming I (or II or III or X or whatever)**
- **Selected HPC Techniques**
- **Introduction to MPI**
- **Advanced Whatever**

CURRICULA CONCERNS

- Special Seminar – CS 49xx
  - You gotta do what you gotta do
  - After awhile our admin was more sympathetic to $$
  - Your CV will be greatly enhanced
- Sometimes Low (or no) Pay
- Can Be Used as Electives
- Can Be “Repeated”

CURRICULA CONCERNS

- Special Seminar – CS 49xx
- Making everything 4000-level is a boon to the effort
- Descriptive course names add to transcript prestige
- Elective status increases desirability
- Sometimes Low (or no) Pay
- **Can Be Used as Electives**
- Can Be "Repeated"

CURRICULA CONCERNS

- Special Seminar – CS 49xx
  - CS49xx needs a different name each semester
  - Students can take several courses if they want
  - This can almost develop into an art
  - Your institution's policies and support may vary
- Can Be Used as Electives
- **Can Be "Repeated"**

CURRICULA SCHEDULE

- Fall 2011 — Intro to Parallel Computing
- Spring 2012 — Matrix Multiplication
- Fall 2012
- Spring 2013
- Fall 2013
- Spring 2014
- Fall 2014
- Spring 2015
- Fall 2015
- Spring 2016
- Fall 2016

Matrix Multiplication

$$\begin{bmatrix} 3 & 4 & 2 & 6 & 7 & 8 \\ 8 & 0 & 9 & 6 & 5 & 4 \\ 6 & 1 & 2 & 3 & 0 & 8 \\ 4 & 8 & 9 & 5 & 7 & 6 \\ 0 & 5 & 4 & 0 & 0 & 9 \\ 8 & 6 & 1 & 1 & 0 & 7 \end{bmatrix} \times \begin{bmatrix} 6 & 7 & 5 & 4 & 3 & 0 \\ 2 & 8 & 0 & 9 & 5 & 4 \\ 2 & 4 & 7 & 6 & 5 & 4 \\ 9 & 0 & 5 & 0 & 0 & 1 \\ 4 & 2 & 8 & 6 & 7 & 5 \\ 5 & 0 & 9 & 1 & 2 & 6 \end{bmatrix} = \begin{bmatrix} - & - & - & - & - & - \\ - & - & - & - & - & - \\ - & - & - & - & - & - \\ - & - & - & - & - & - \\ - & - & - & - & - & - \\ - & - & - & - & - & - \end{bmatrix}$$

Matrix Multiplication

$$\begin{bmatrix} 3 & 4 & 2 & 6 & 7 & 8 \\ 8 & 0 & 9 & 6 & 5 & 4 \\ 6 & 1 & 2 & 3 & 0 & 8 \\ 4 & 8 & 9 & 5 & 7 & 6 \\ 0 & 5 & 4 & 0 & 0 & 9 \\ 8 & 6 & 1 & 1 & 0 & 7 \end{bmatrix} \times \begin{bmatrix} 6 & 7 & 5 & 4 & 3 & 0 \\ 2 & 8 & 0 & 9 & 5 & 4 \\ 2 & 4 & 7 & 6 & 5 & 4 \\ 9 & 0 & 5 & 0 & 0 & 1 \\ 4 & 2 & 8 & 6 & 7 & 5 \\ 5 & 0 & 9 & 1 & 2 & 6 \end{bmatrix} = \begin{bmatrix} - & - & - & - & - & - \\ - & - & - & - & - & - \\ - & - & - & - & * & - \\ - & - & - & - & - & - \\ - & - & - & - & - & - \\ - & - & - & - & - & - \end{bmatrix}$$

Each cell of product matrix is calculated independently of others,

so the problem screams, "Parallelize me!"

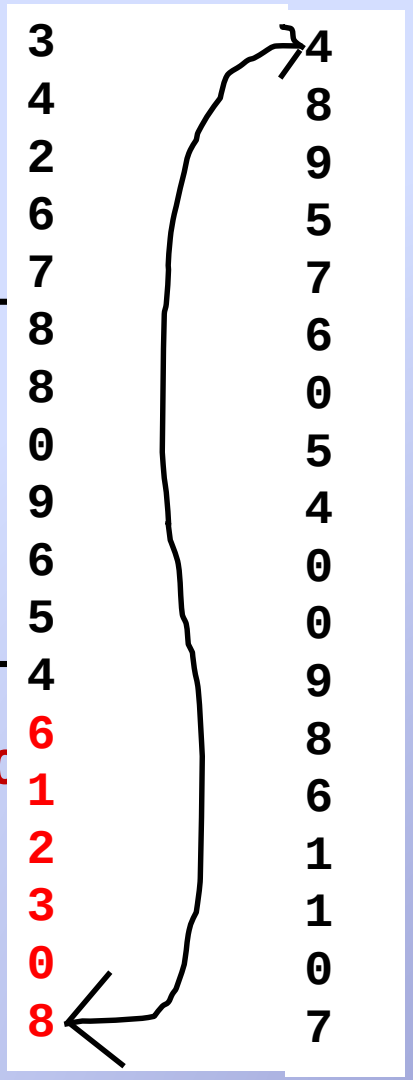
Matrix Multiplication

$$\begin{bmatrix} 3 & 4 & 2 & 6 & 7 & 8 \\ 8 & 0 & 9 & 6 & 5 & 4 \\ 6 & 1 & 2 & 3 & 0 & 8 \\ 4 & 8 & 9 & 5 & 7 & 6 \\ 0 & 5 & 4 & 0 & 0 & 9 \\ 8 & 6 & 1 & 1 & 0 & 7 \end{bmatrix} \times \begin{bmatrix} 6 & 7 & 5 & 4 & 3 & 0 \\ 2 & 8 & 0 & 9 & 5 & 4 \\ 2 & 4 & 7 & 6 & 5 & 4 \\ 9 & 0 & 5 & 0 & 0 & 1 \\ 4 & 2 & 8 & 6 & 7 & 5 \\ 5 & 0 & 9 & 1 & 2 & 6 \end{bmatrix} = \begin{bmatrix} - & - & - & - & - & - \\ - & - & - & - & - & - \\ - & - & - & - & * & - \\ - & - & - & - & - & - \\ - & - & - & - & - & - \\ - & - & - & - & - & - \end{bmatrix}$$

* = 6 x 3 + 1 x 5 + 2 x 5 + 3 x 0 + 0 x 7 + 8 x 2

Matrix Multiplication

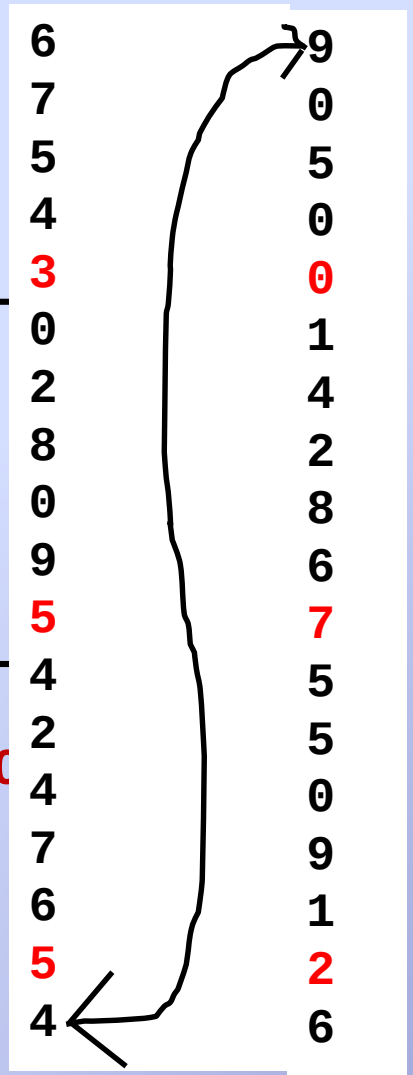
$$\begin{bmatrix} 3 & 4 & 2 & 6 & 7 & 8 \\ 8 & 0 & 9 & 6 & 5 & 4 \\ 6 & 1 & 2 & 3 & 0 & 8 \\ 4 & 8 & 9 & 5 & 7 & 6 \\ 0 & 5 & 4 & 0 & 0 & 9 \\ 8 & 6 & 1 & 1 & 0 & 7 \end{bmatrix} \times \begin{bmatrix} 6 & 7 & 5 & 4 & 3 & 0 \\ 2 & 8 & 0 & 9 & 5 & 4 \\ 2 & 4 & 7 & 6 & 5 & 4 \\ 9 & 0 & 5 & 0 & 0 & 1 \\ 4 & 2 & 8 & 6 & 7 & 5 \\ 5 & 0 & 9 & 1 & 2 & 6 \end{bmatrix} = \begin{bmatrix} - & - \\ - & - \\ * & - \\ - & - \\ - & - \\ - & - \end{bmatrix}$$



* = 6 x 3 + 1 x 5 + 2 x 5 + 3 x 0

Matrix Multiplication

$$\begin{bmatrix} 3 & 4 & 2 & 6 & 7 & 8 \\ 8 & 0 & 9 & 6 & 5 & 4 \\ 6 & 1 & 2 & 3 & 0 & 8 \\ 4 & 8 & 9 & 5 & 7 & 6 \\ 0 & 5 & 4 & 0 & 0 & 9 \\ 8 & 6 & 1 & 1 & 0 & 7 \end{bmatrix} \times \begin{bmatrix} 6 & 7 & 5 & 4 & 3 & 0 \\ 2 & 8 & 0 & 9 & 5 & 4 \\ 2 & 4 & 7 & 6 & 5 & 4 \\ 9 & 0 & 5 & 0 & 0 & 1 \\ 4 & 2 & 8 & 6 & 7 & 5 \\ 5 & 0 & 9 & 1 & 2 & 6 \end{bmatrix}$$



$$\begin{bmatrix} - & - \\ - & - \\ * & - \\ - & - \\ - & - \\ - & - \end{bmatrix}$$

* = 6 x 3 + 1 x 5 + 2 x 5 + 3 x 0

Matrix Multiplication – Add CUDA

$$\begin{bmatrix} 3 & 4 & 2 & 6 & 7 & 8 \\ 8 & 0 & 9 & 6 & 5 & 4 \\ 6 & 1 & 2 & 3 & 0 & 8 \\ 4 & 8 & 9 & 5 & 7 & 6 \\ 0 & 5 & 4 & 0 & 0 & 9 \\ 8 & 6 & 1 & 1 & 0 & 7 \end{bmatrix} \times \begin{bmatrix} 6 & 7 & 5 & 4 & 3 & 0 \\ 2 & 8 & 0 & 9 & 5 & 4 \\ 2 & 4 & 7 & 6 & 5 & 4 \\ 9 & 0 & 5 & 0 & 0 & 1 \\ 4 & 2 & 8 & 6 & 7 & 5 \\ 5 & 0 & 9 & 1 & 2 & 6 \end{bmatrix} = \begin{bmatrix} - & - & - & - & - & - \\ - & - & - & - & - & - \\ - & - & - & - & * & - \\ - & - & - & - & - & - \\ - & - & - & - & - & - \\ - & - & - & - & - & - \end{bmatrix}$$

*** = 6 x 3 + 1 x 5 + 2 x 5 + 3 x 0 + 0 x 7 + 8 x 2**

Each cell's required data is sent to a processor with MPI code.

That processor sends out all multiplications to the GPUs by using CUDA code.

CURRICULA SCHEDULE

- Fall 2011 — Intro to Parallel Computing
- Spring 2012 — Matrix Multiplication
- Fall 2012 — Parallel Computing II
- Spring 2013 — Intro to CUDA
- Fall 2013 — HPC Concepts
- Spring 2014 — Parallel Programming
- Fall 2014 — HPC Math Programming
- Spring 2015 — Cluster Building & OS Study
- Fall 2015 — HPC Aps – Genome Studies
- Spring 2016 — Programming Contest Prep
- Fall 2016 — Intro to Parallel Computing

Sustaining HPC Curricula at a Regional Institution

WINDOW PRIZE!

WINDOW PRIZE!

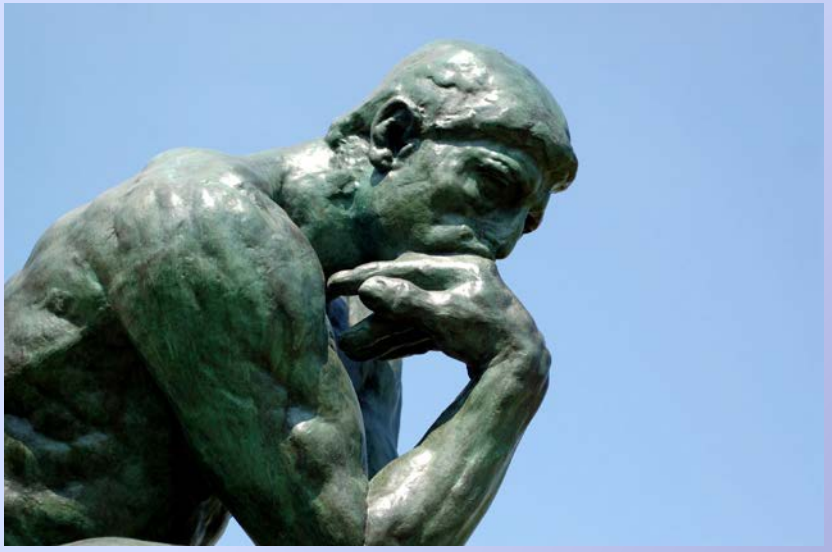
What the heck is this?

WINDOW PRIZE!

Apple III w/5M Profile

CURRICULA . . . NEXT ?

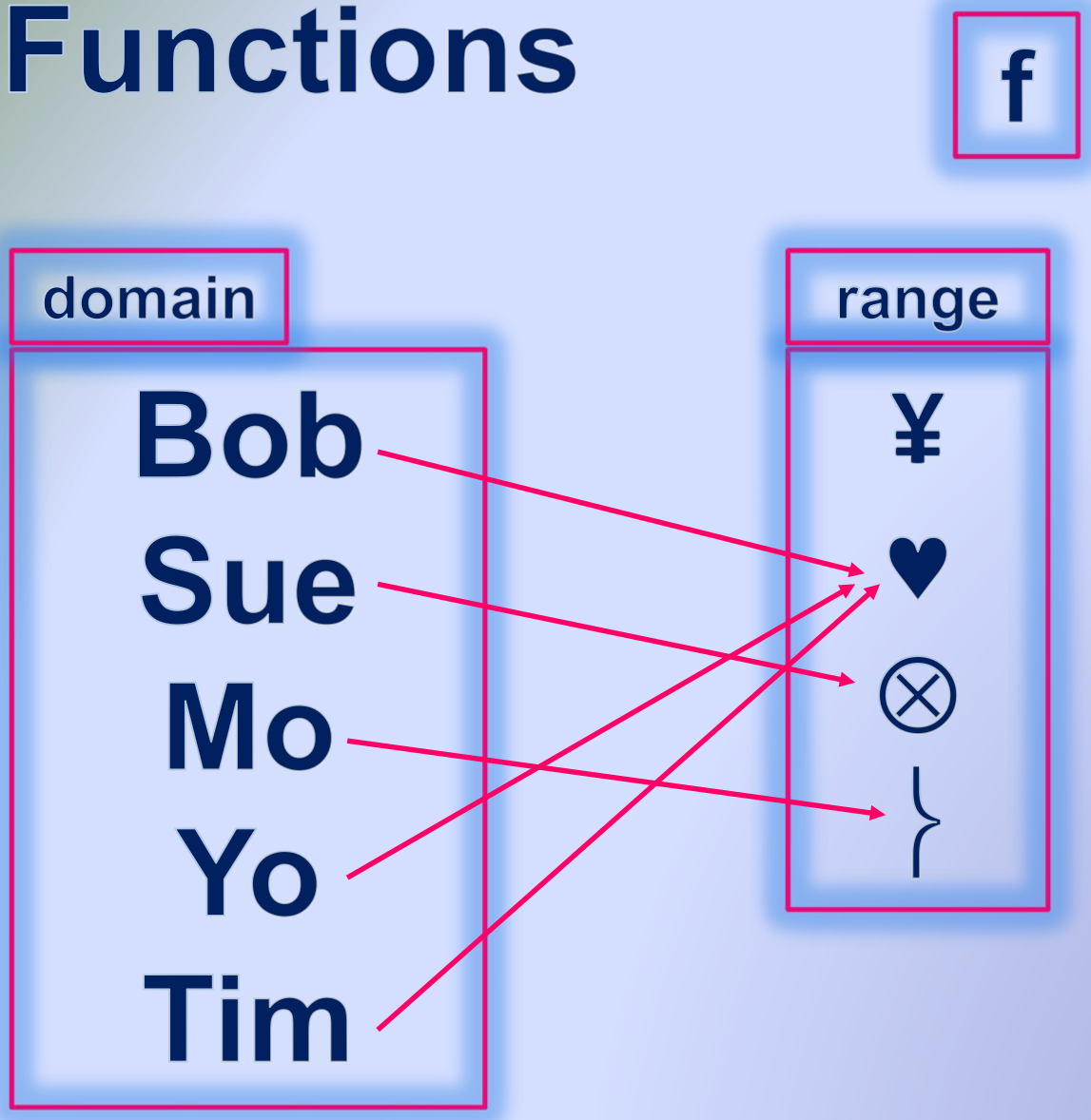
Unknown for Spring 17



CURRICULA . . . NEXT ?

Cycle Project

Functions



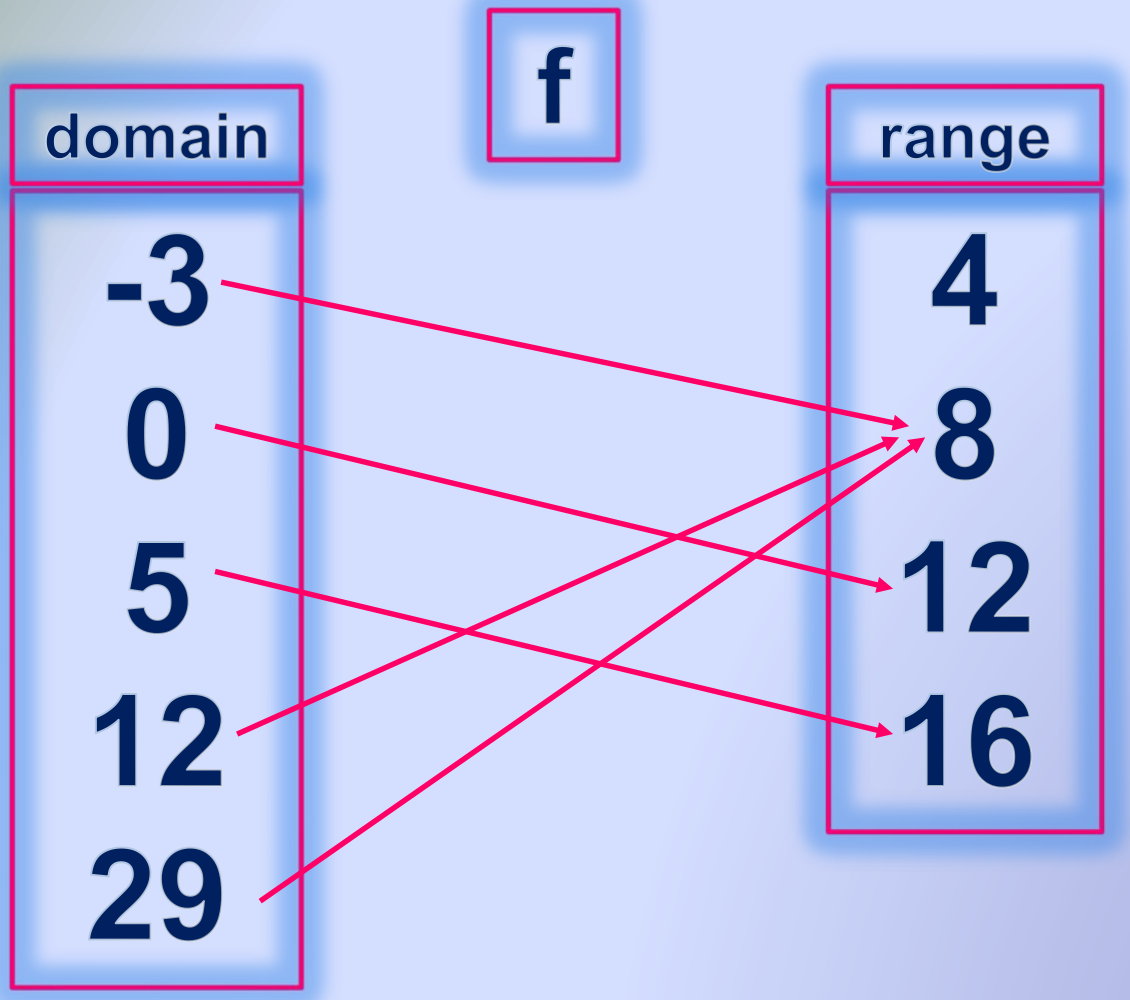
f is said to be a function from the domain into the range

f(Sue) = ⊗

etc.

Functions - Injection

Cycle Project

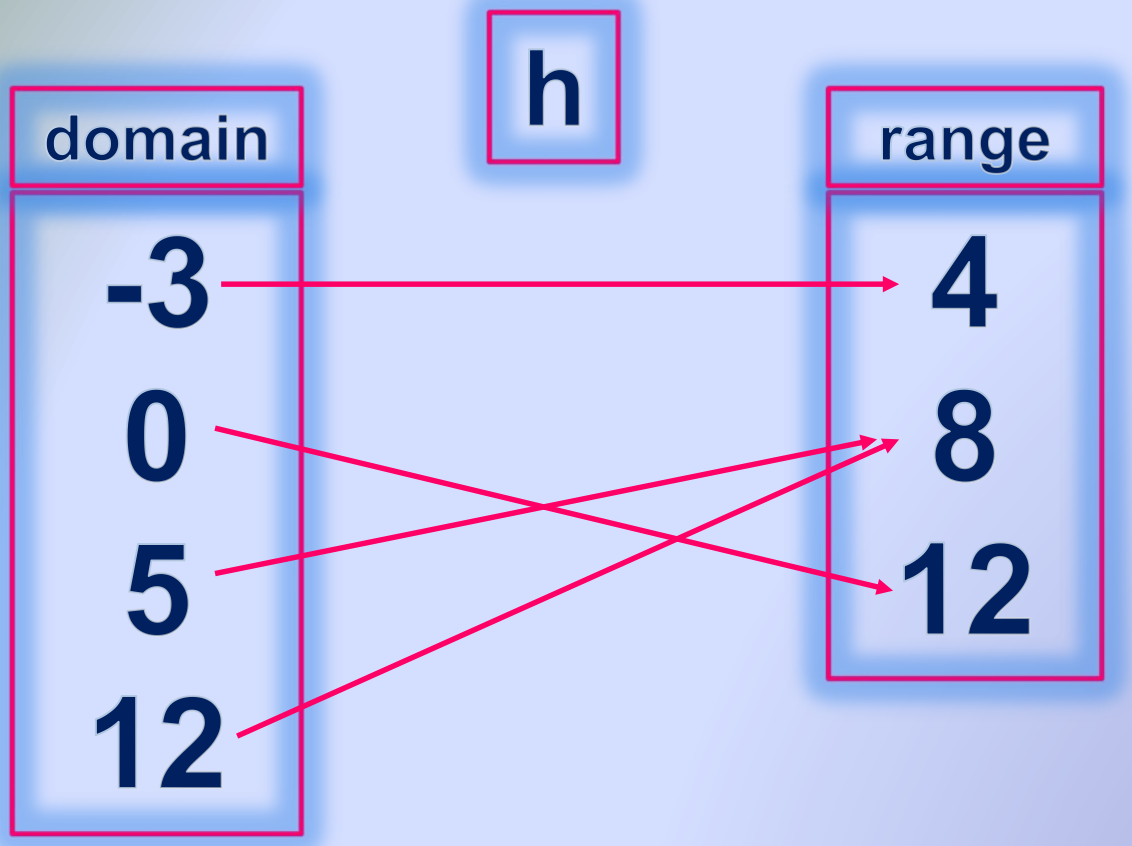


f is said to be a function from the domain into the range

f(5) = 16
etc.

Functions - Surjection

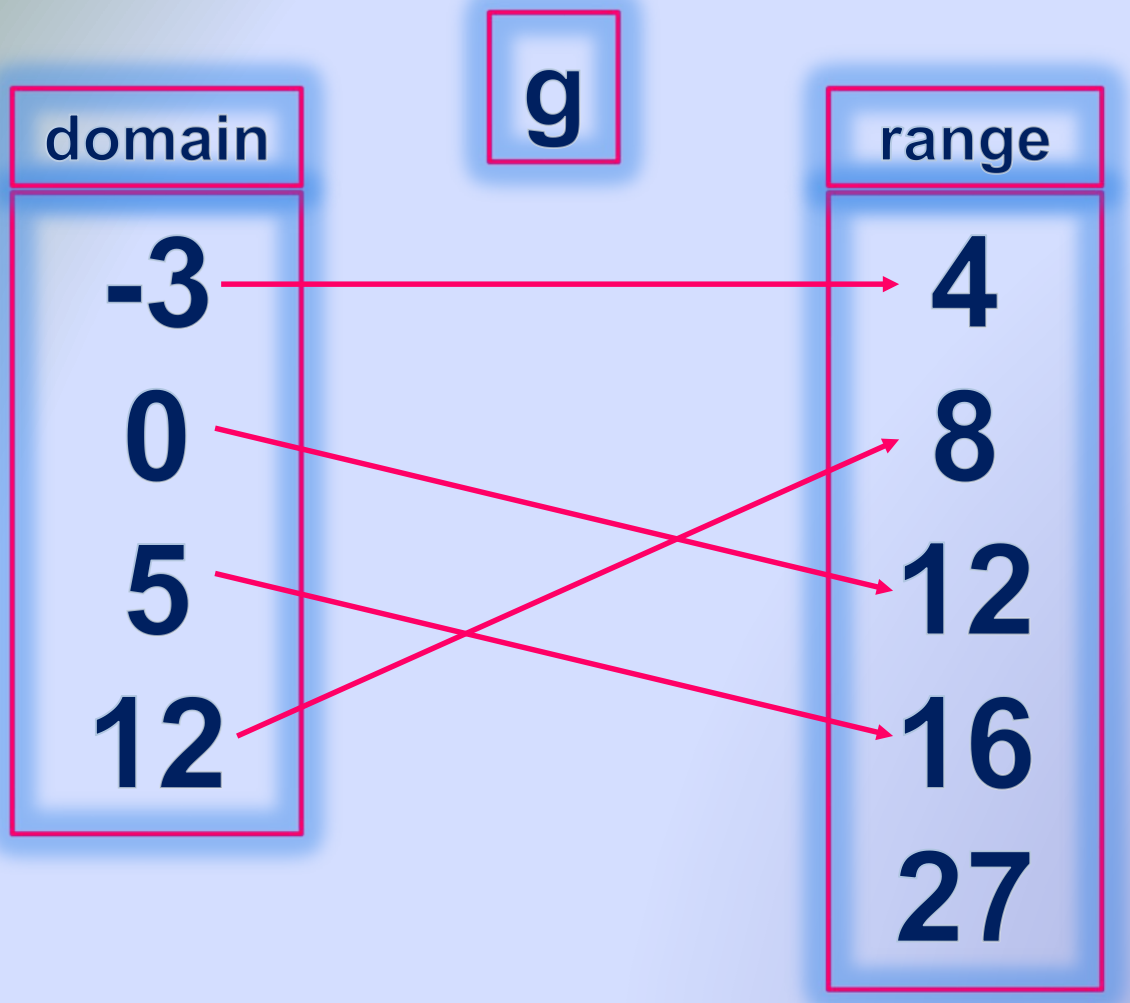
Cycle Project



h is said to be a function from the domain <u>onto</u> the range

Functions – 1-to-1

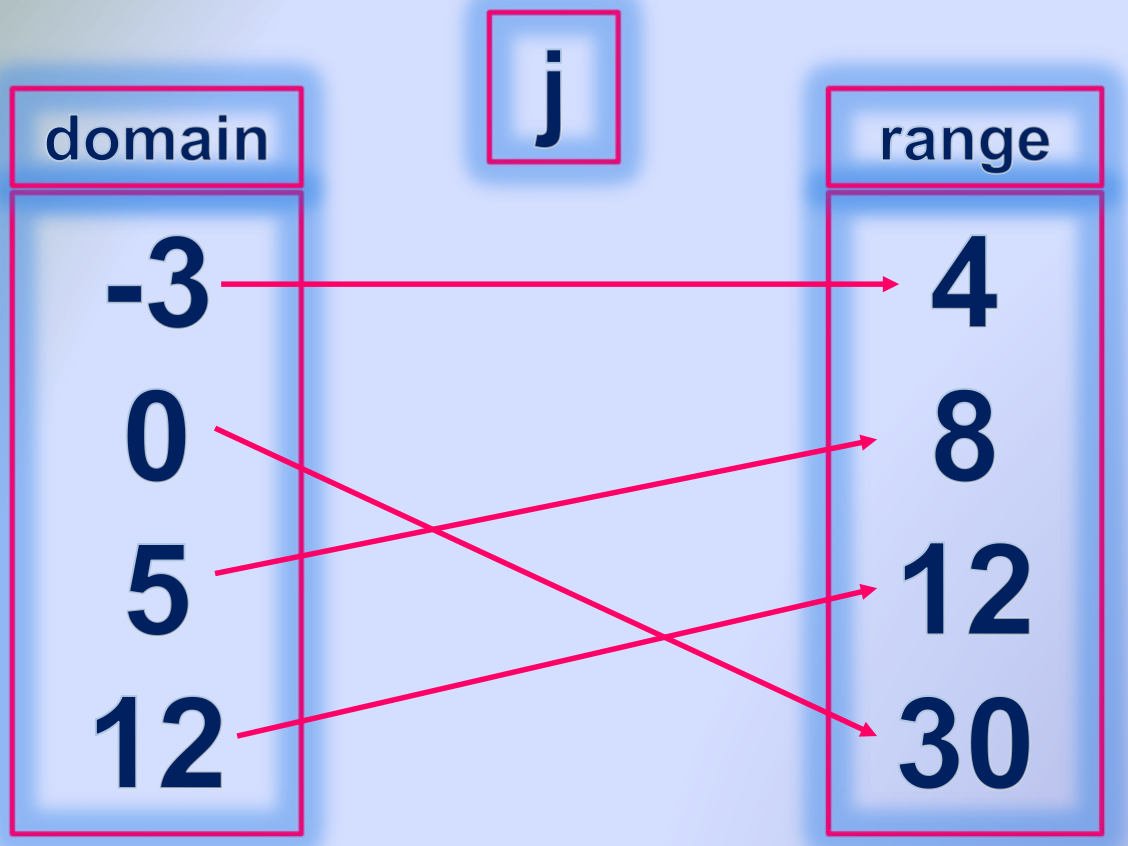
Cycle Project



g is said to be a function from the domain into the range that is 1-to-1

Functions - Bijection

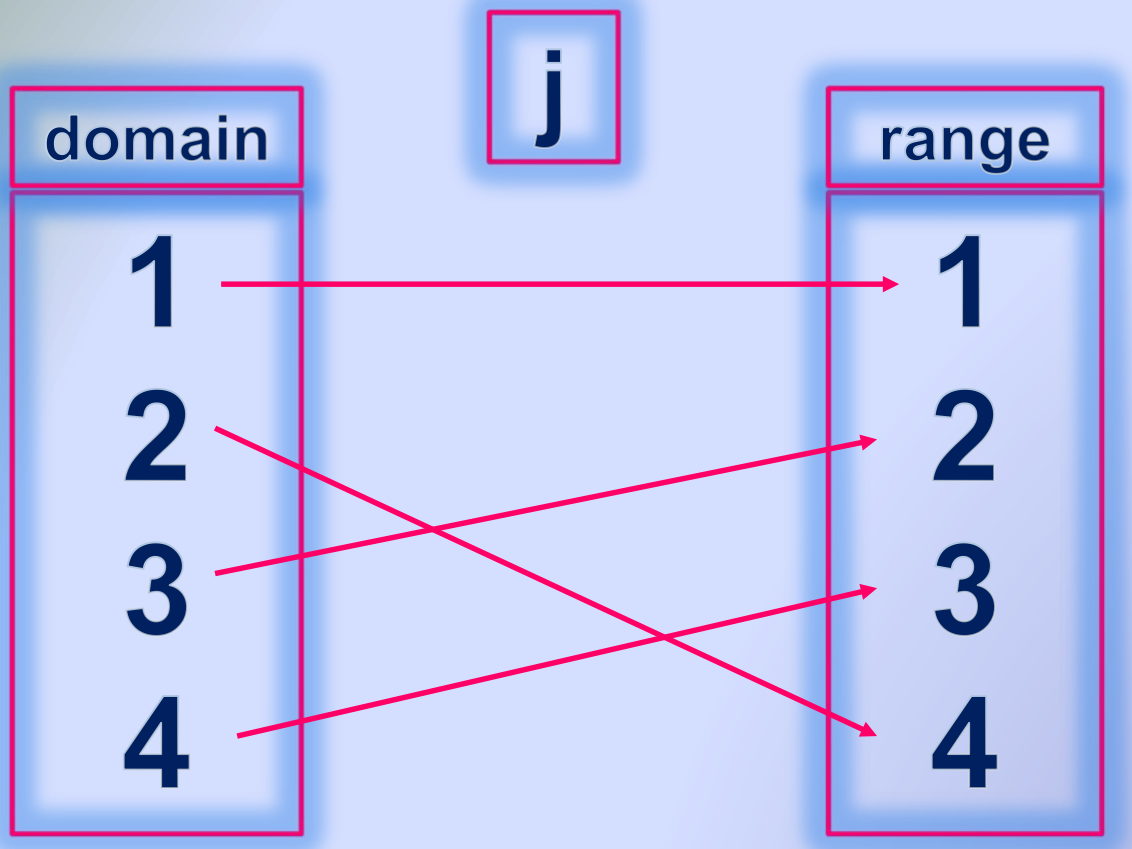
Cycle Project



a function that is both onto and 1-to-1 is called a bijection

Functions

Cycle Project



We are interested in a special subset of bijections.

Moment of transition.

. . . Karl kontinues . . .

Permutations

Define:

$$Z_n = \{1, 2, 3, 4, \ldots, n\}$$

so $Z_6 = \{1, 2, 3, 4, 5, 6\}$ etc.

Permutations

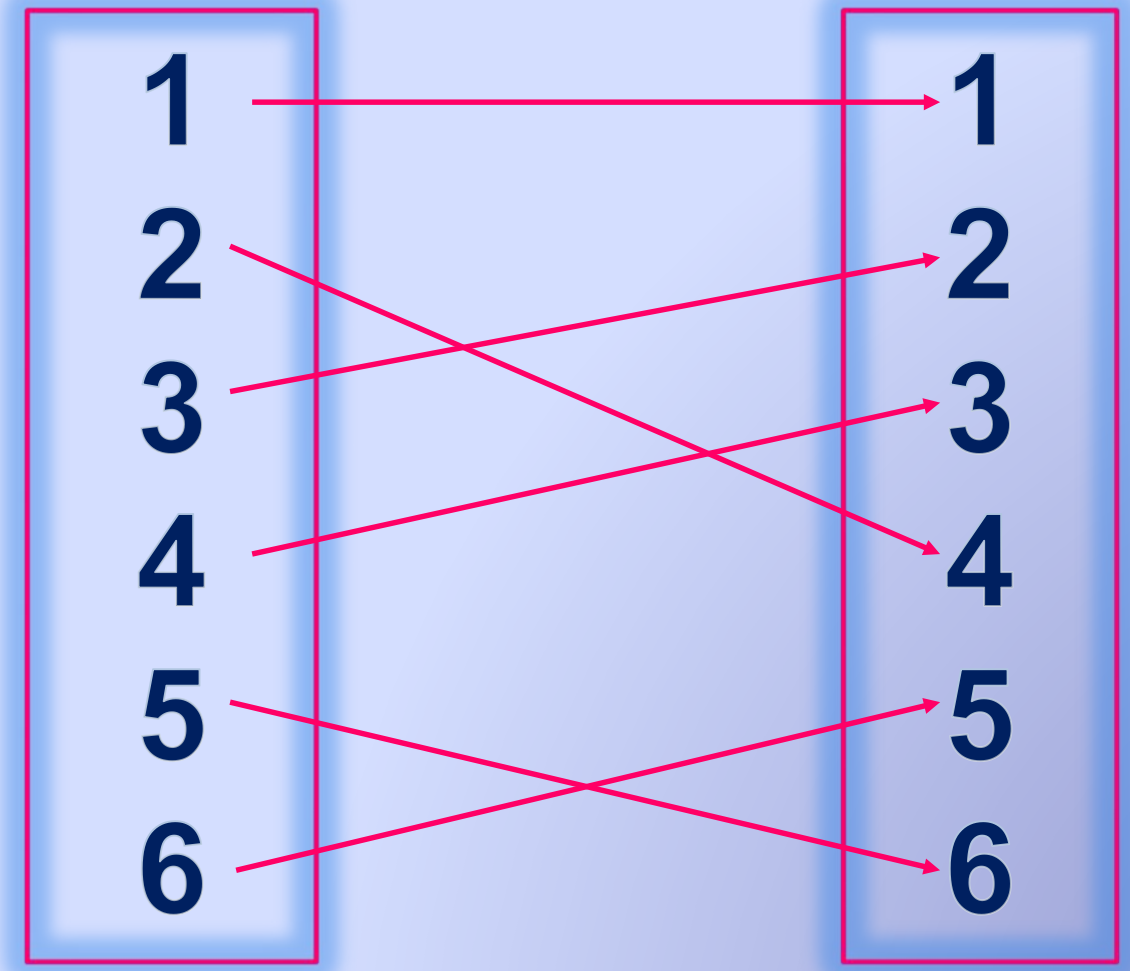
Define:

A permutation is a bijection whose domain and range are both Z_n.

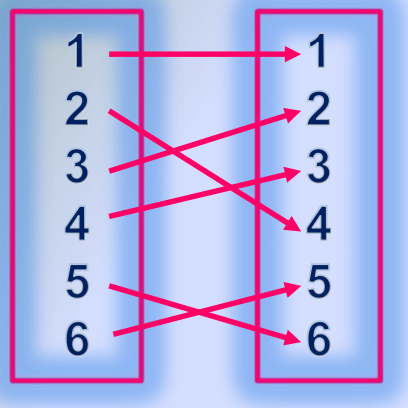
Permutations

Cycle Project

Example:



Permutations



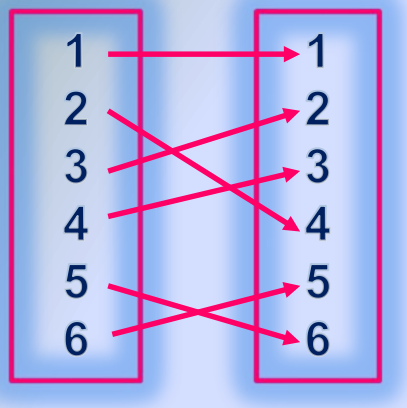
We refer to such a function as a cycle and represent it as follows:

$$(1)(2\ 4\ 3)(5\ 6)$$

or

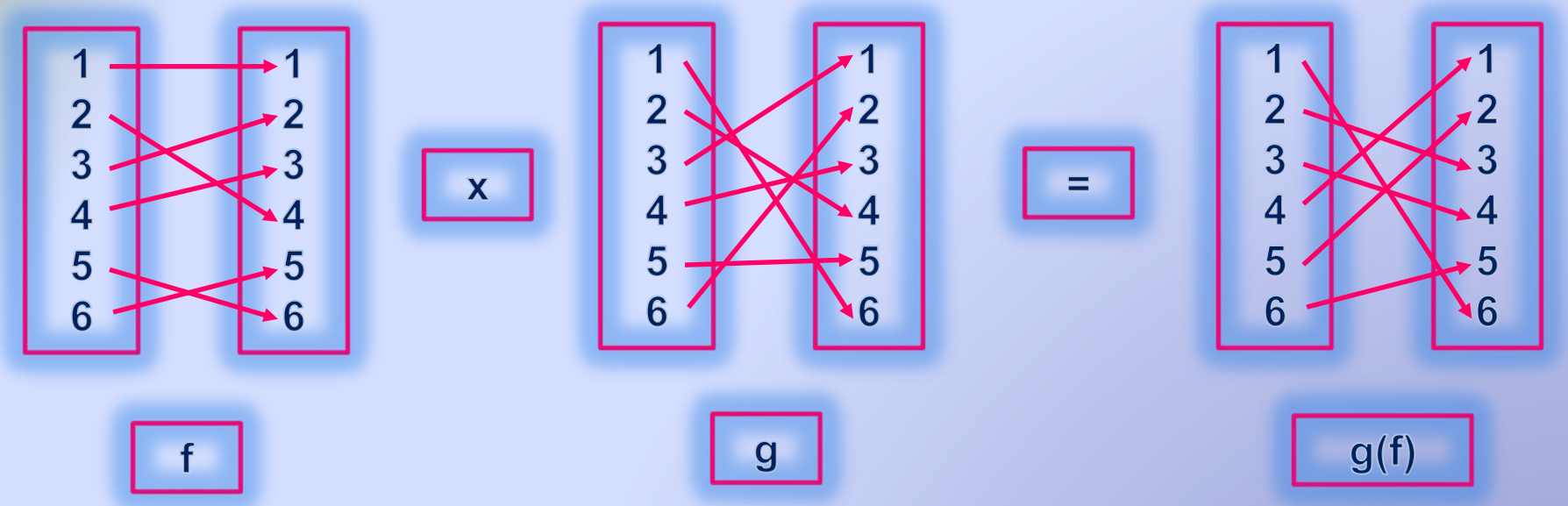
$$(2\ 4\ 3)(5\ 6)$$

Permutations

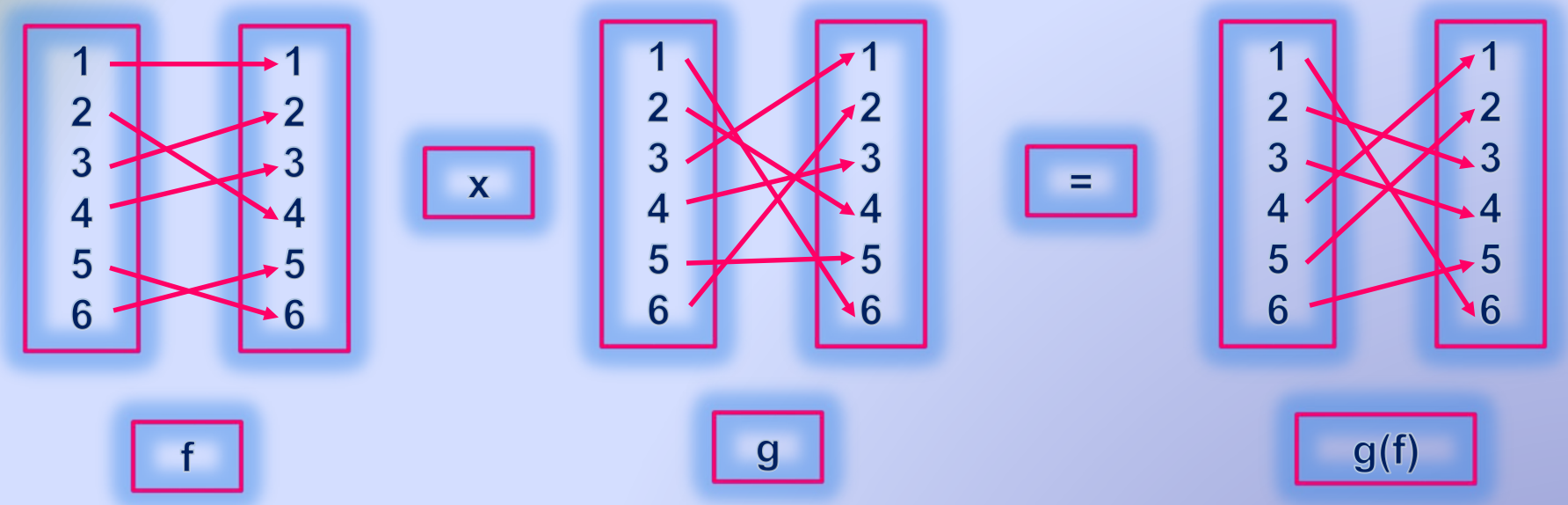


We expand this notion and define multiplication in terms of composition, by:
if f and g are cycles, then f x g is defined to be $g \circ f$ or $g(f(n))$.

Permutations



Permutations



$$(2\ 4\ 3)(5\ 6)\ \mathbf{x}\ (1\ 6\ 2\ 4\ 3)\ =\ (1\ 6\ 5\ 2\ 3\ 4)$$

Permutations

Cycle Project

So . . . things like . . .

$$[(2\ 4\ 3)(5\ 6)]^8$$

. . . make sense!

Permutations

Cycle Project

It doesn't take too long for things to start getting a little wacky real fast and you realize some serious computing power would help get some results.

After careful pondering, we decide to investigate:

$$(1,2,3,\ldots,n_1)^{k1} \times (1,2,3,\ldots,n_2)^{k2} = ?$$

It's more than a semester's work.

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at a Regional Institution

CURRICULA CONCLUSIONS

CURRICULA CONCLUSIONS

- This is very subjective – use your judgement
- Make sure students get the basics of MPI
  - Use the heck out of "Hello World"
- Use C++ and C. It's good to get the diversity
- Call upon your peers
  - Karl has a great library of programs
- **Remember that HPC is where it's at and where it's going!!!**

. . . Mike announces another . . .

WINDOW PRIZE!

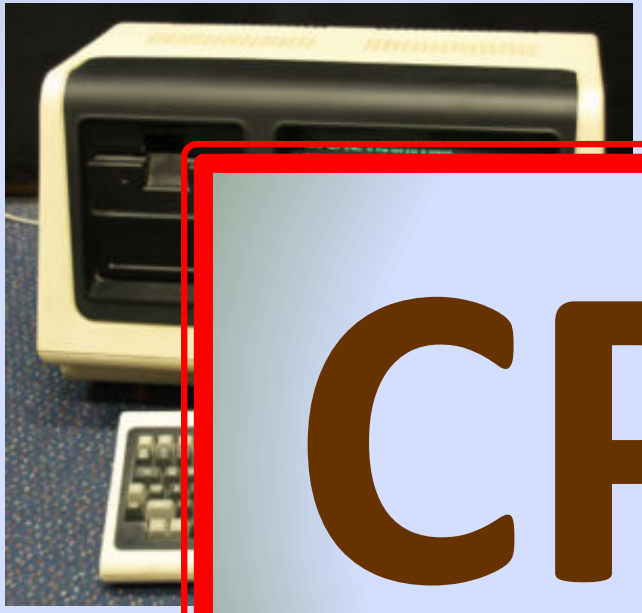
WINDOW PRIZE!

What the heck is this?

WINDOW PRIZE!

This Televideo 802 dog had a Zilog Z-80 8-bit processor. What was the name of its very popular OS?

WINDOW PRIZE!



This Televideo 802 dog
8-bit
was
very

CP/M

Thank You!

We especially thank Henry Neeman and everyone else associated with OU IT, the excellent mentorship we've received from OneOCII, the SOSU IT guys, Charlie Peck & the LittleFe gang and all of our colleagues and friends in the educational community involved with HPC, for all the help we have received over the last few years, and thankfully continuing today..

Karl Frinkle
Mike Morris