15-410

"Luckily the stack is a simple data structure."

The Process
Jan. 24, 2007

Dave Eckhardt

Bruce Maggs

Synchronization

P2/P3/P4 partners

- Partner deadline coming soon!
- If you already know who your partner is, please register now
  - It makes it easier for others to partner
  - It will stem the tide of annoying reminder e-mail

Synchronization

Anybody reading comp.risks?

This lecture

- **Chapter 3, but not exactly!**
  - **We are skipping 3.5 and 3.6, including the terrifying "POSIX Shared Memory"**

Outline

Process as pseudo-machine

- **(that's *all* there is)**

Process life cycle

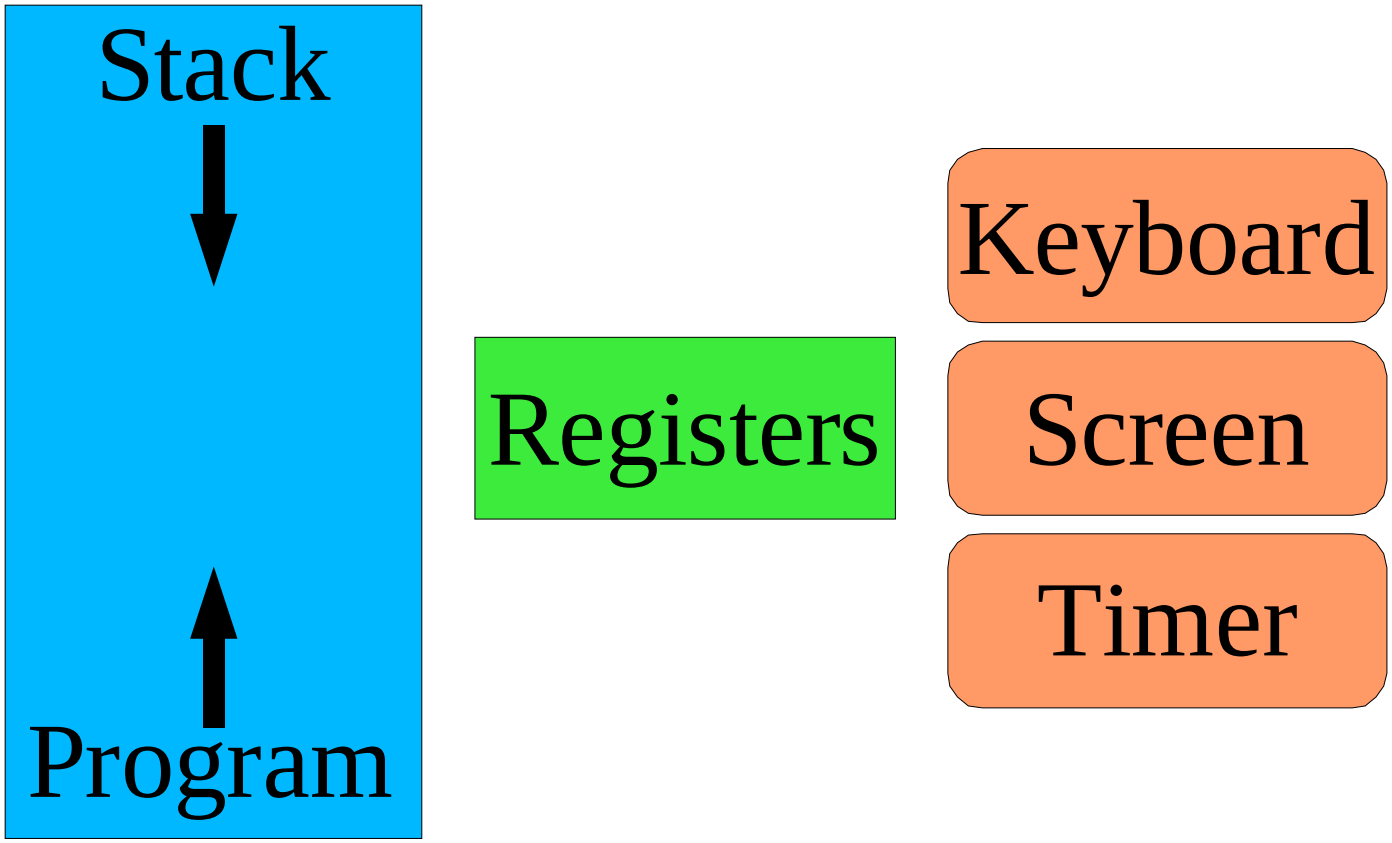
Process kernel states

Process kernel state

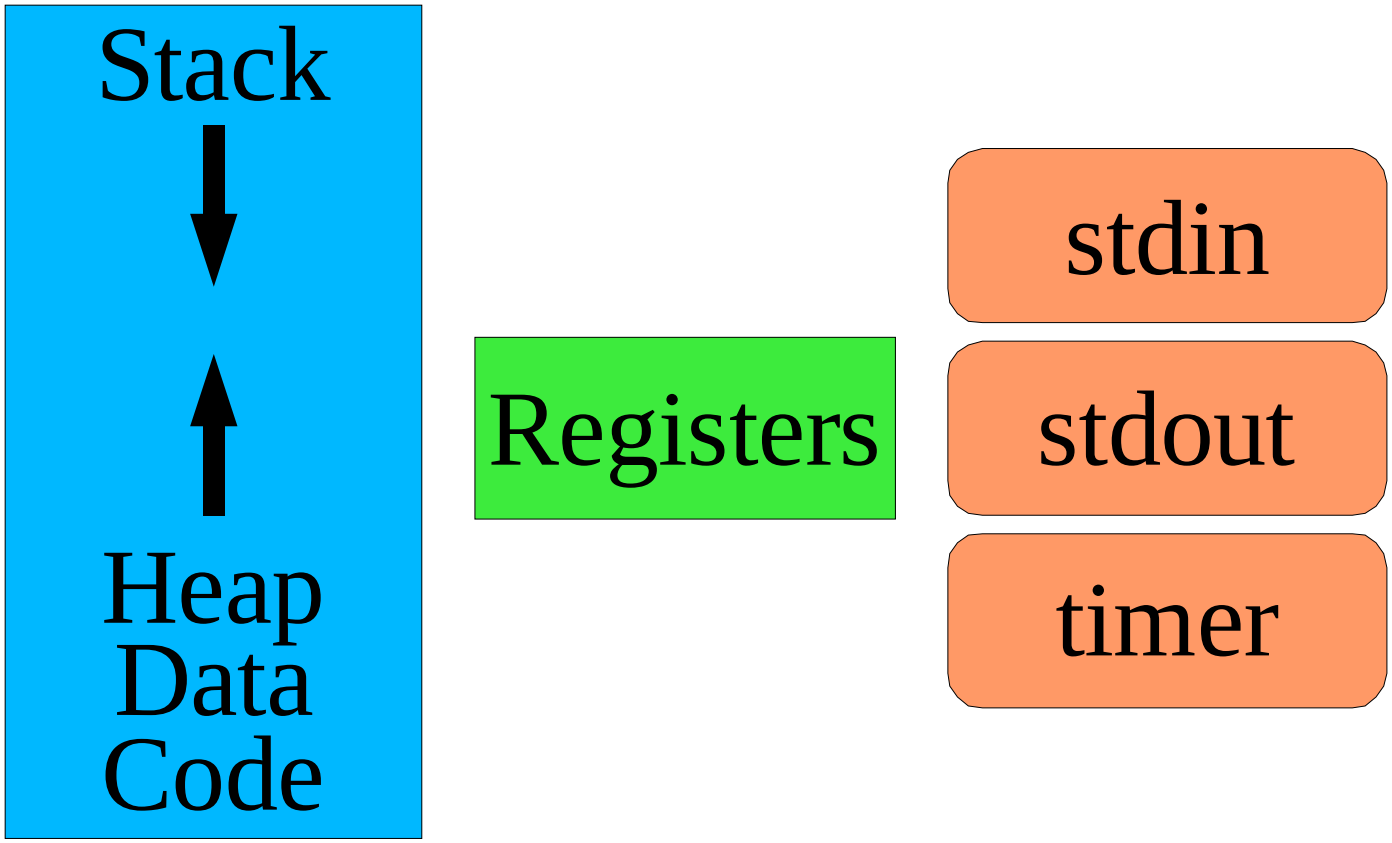
P1/P3 memory layout

- **(just a teaser for now)**

The Computer



The Process



Process life cycle

(nomenclature courtesy of The Godfathers)

Birth

- (or, well, fission)

School

Work

Death

Birth

Where do new processes come from?

- (Not: under a cabbage leaf, by stork, ...)

What do we need?

- Memory contents
  - Text, data, stack
- CPU register contents (N of them)
- “I/O ports”
  - File descriptors, e.g., stdin/stdout/stderr
- Hidden “stuff”
  - timer state, current directory, umask

Birth

Intimidating?

How to specify all of that stuff?

- **What is your {name,quest,favorite_color}?**

Gee, we already have *one* process we like...

- **Maybe we could use its settings to make a new one...**
- **Birth via “cloning”**

Birth –fork() - 1

“fork” - Original Unix process creation system call

Memory

- **Copy all of it**
- **Later lecture: VM tricks may make copy cheaper**

Registers

- **Copy all of them**
  - **All but one: parent learns child's process ID, child gets 0**

Birth –fork() - 2

File descriptors

- Copy all of them
- Can't copy the *files!*
- Copy *references* to open-file state

Hidden stuff

- Do whatever is "obvious"

Result

- Original, “parent”, process
- Fully-specified “child” process, despite 0 parameters to fork()

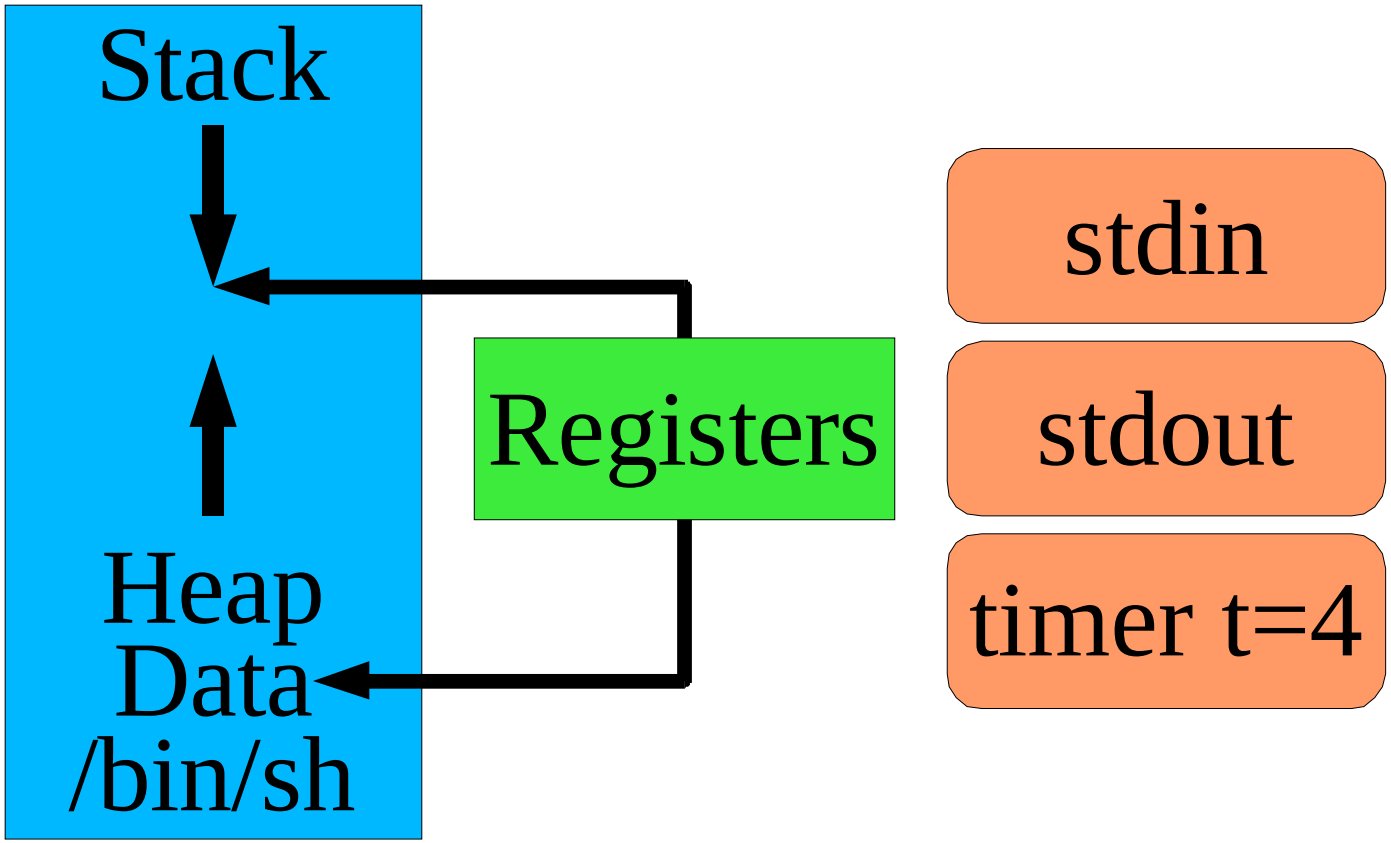
Now what?

Two copies of the same process is *boring*

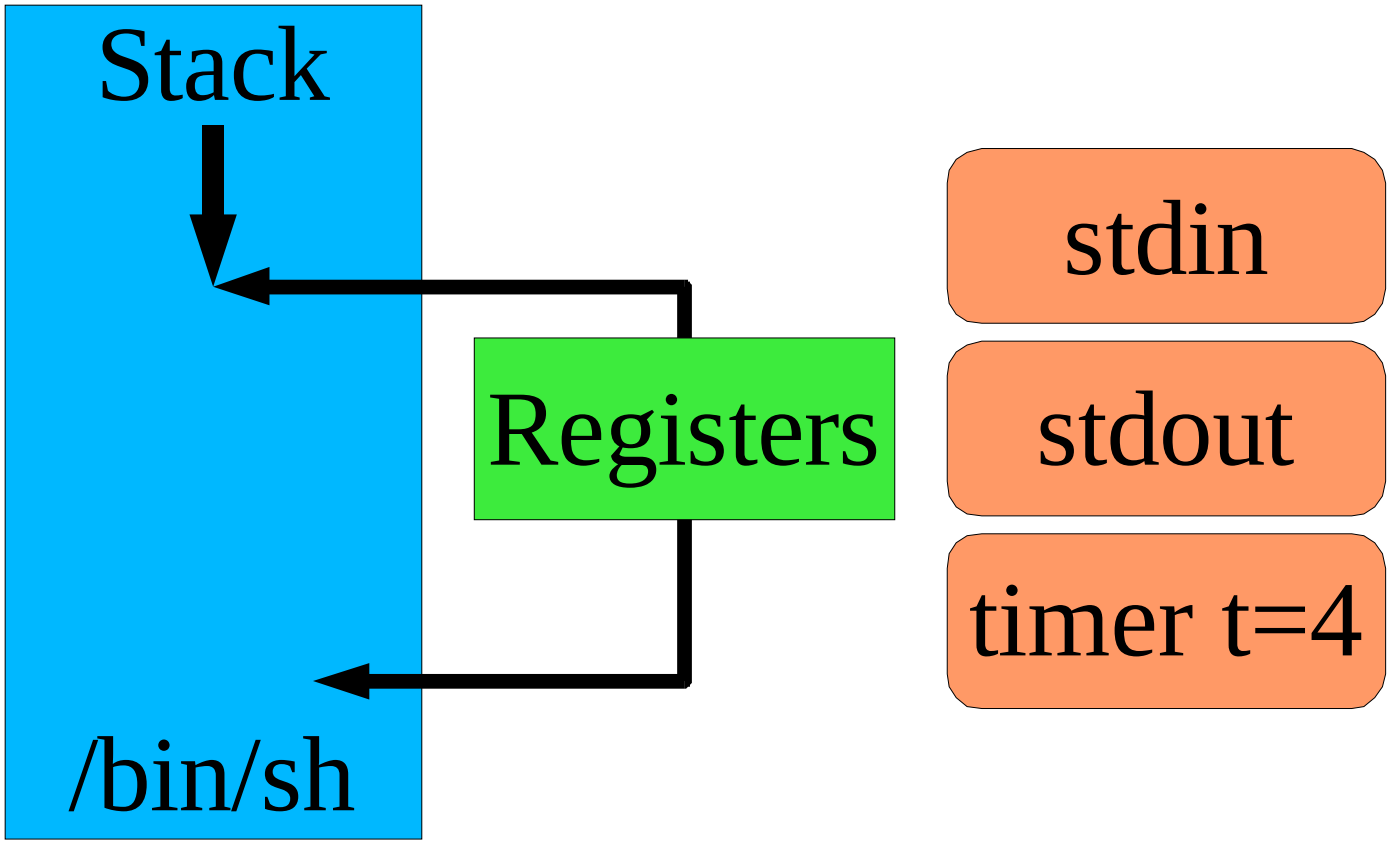
Transplant surgery!

- **Implant new memory!**
  - **New program text**
- **Implant new registers!**
  - **Old ones don't point well into the new memory**
- **Keep (most) file descriptors**
  - **Good for cooperation/delegation**
- **Hidden state?**
  - **Do what's “obvious”**

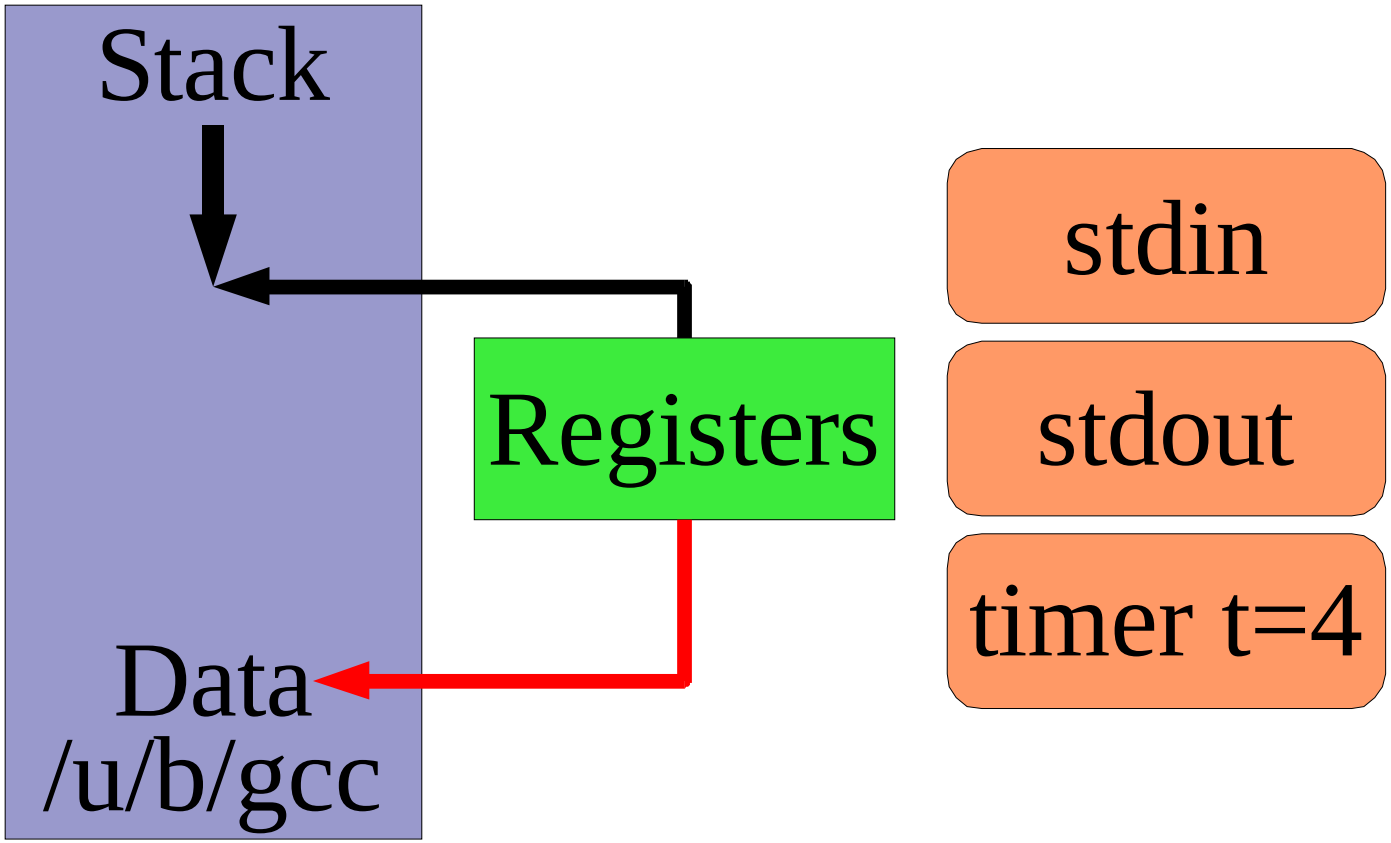
Original Process



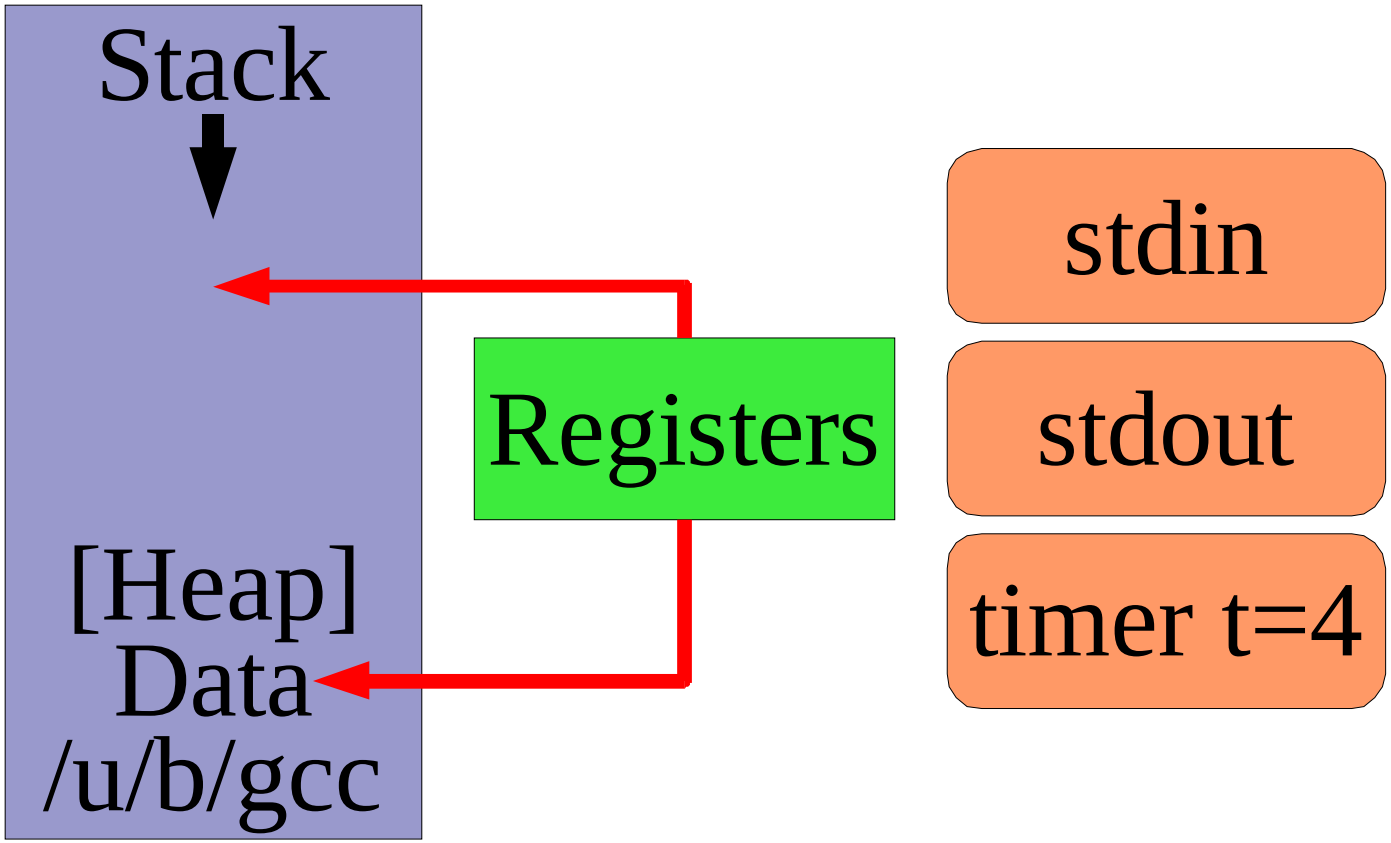
Toss Heap, Data



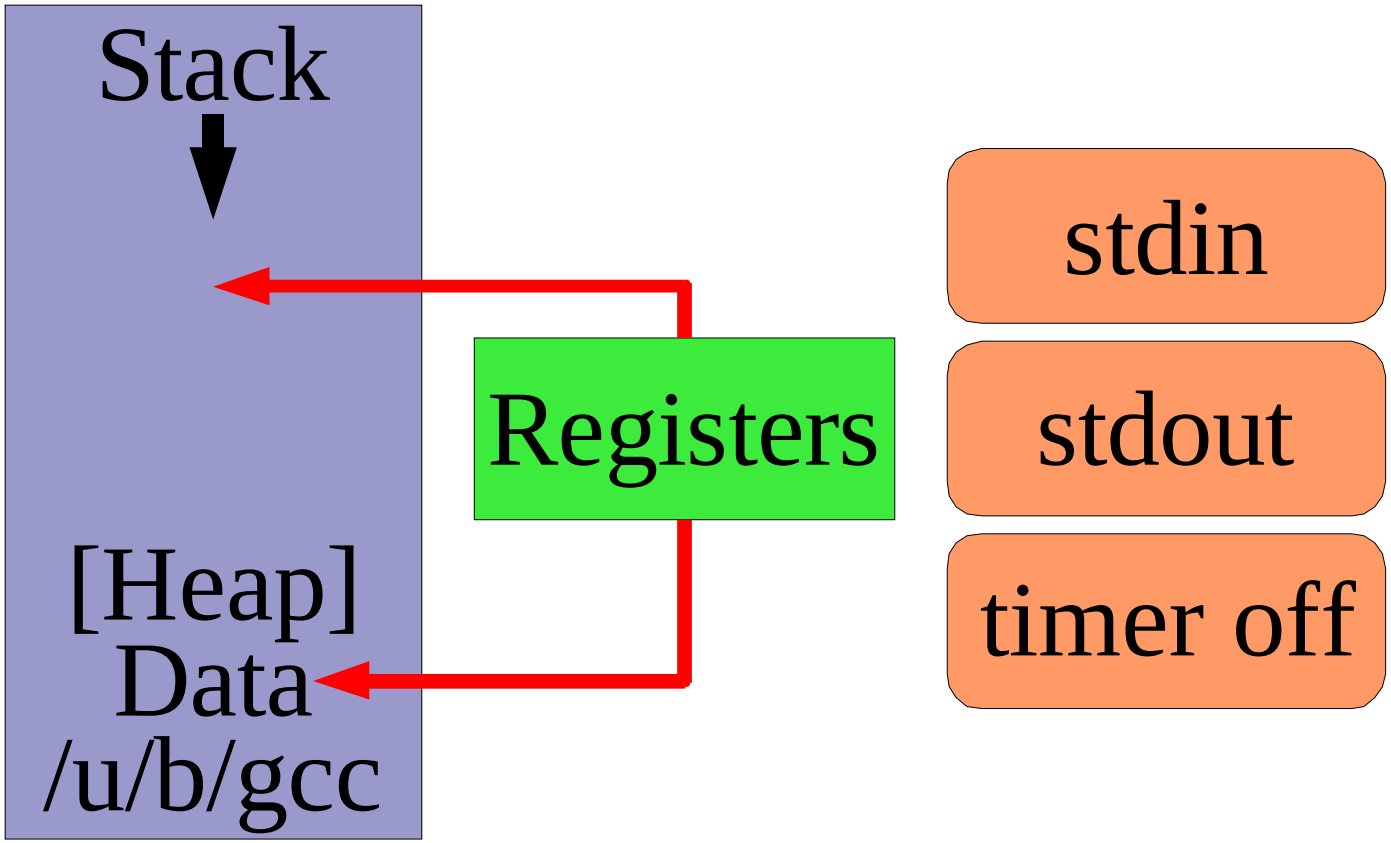
Load New Code, Data From File



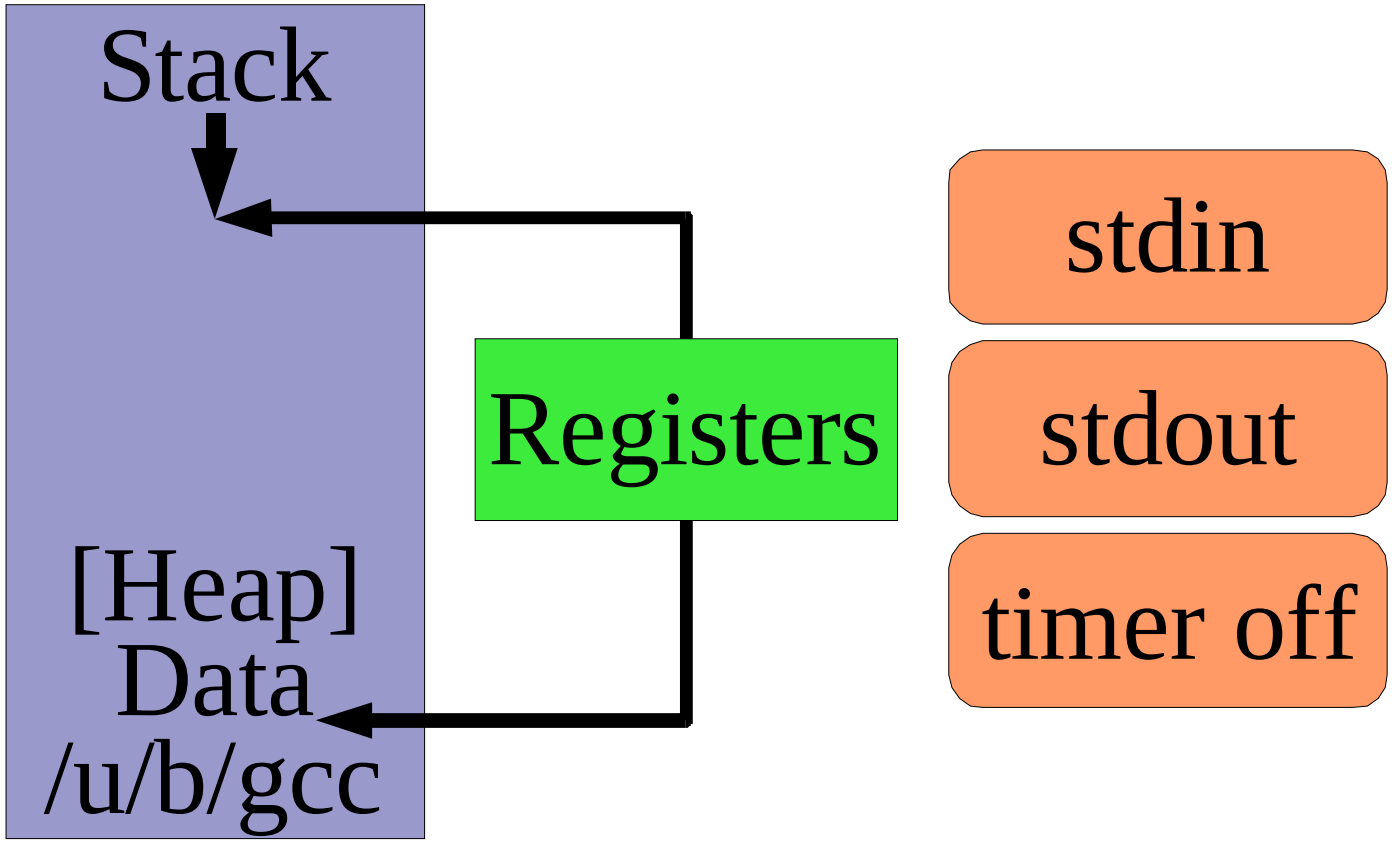
Reset Stack, Heap



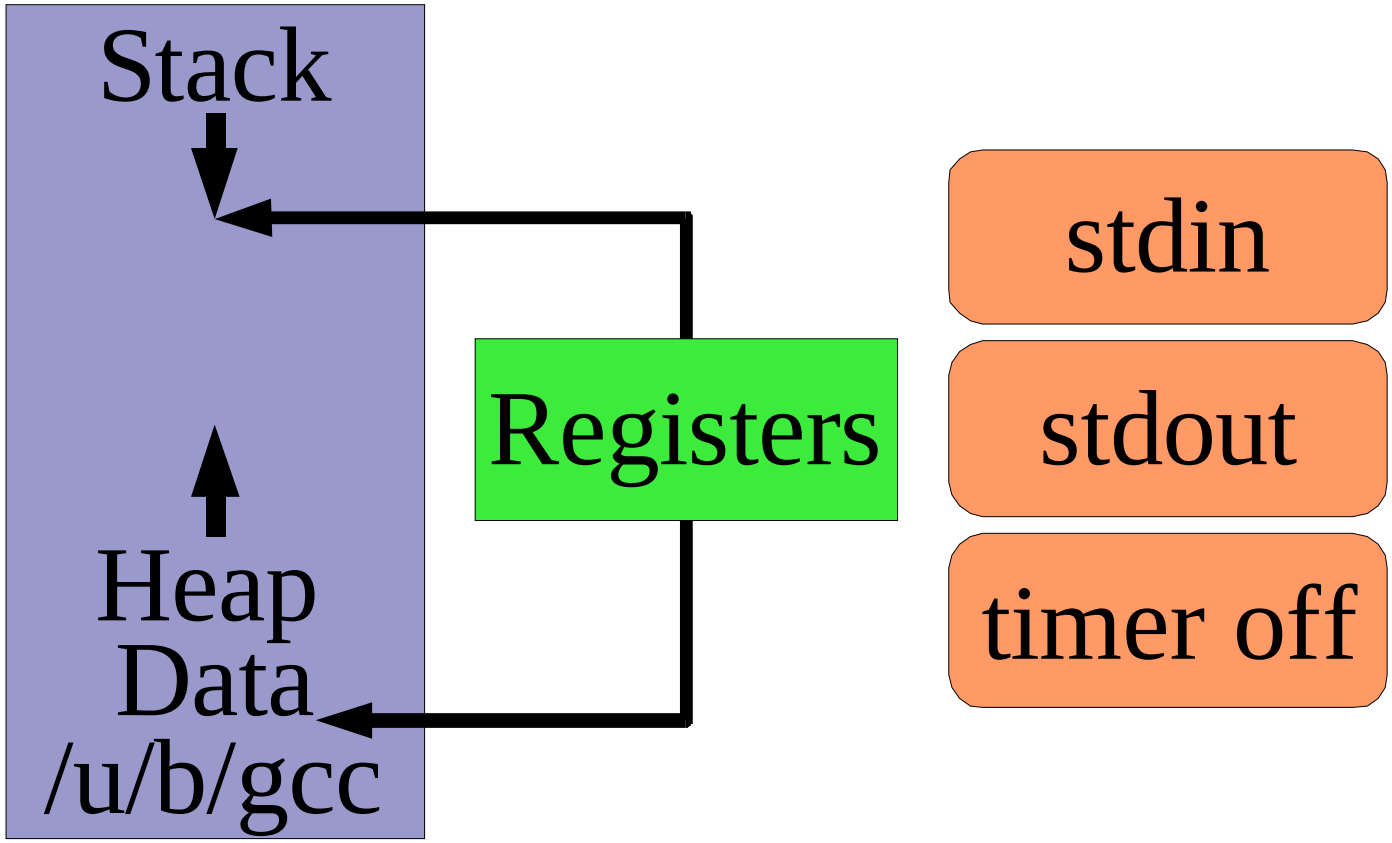
Fix “Stuff”



Initialize Registers



Begin Execution



What's The Implant Procedure Called?

```
int execve(
  char *path,
  char *argv[ ],
  char *envp[ ])
```

Birth - other ways

There is another way

- Well, two

spawn()

- Carefully specify all features of new process
  - Complicated
- Win: don't need to copy stuff you will immediately toss

Plan 9 rfork() / Linux clone()

- Build new process from old one
- Specify which things get shared vs. copied
  - “Copy memory, share files, copy environment, share ...”

School

Old process called

```
execve(
char *path,
char *argv[ ],
char *envp[ ]);
```

Result is

```
main(int argc,
     char *argv[ ],
     char *envp[])
{
  ...
}
```

School

How does the magic work?

- *15-410 motto: No magic*

Kernel process setup: we saw...

- Toss old data memory
- Toss old stack memory
- Load executable file

Also...

The Stack!

Kernel builds stack for new process

- Transfers argv[] and envp[] to top of new process stack
- Hand-crafts stack frame for __main()
- Sets registers
  - Stack pointer (to top frame)
  - Program counter (to start of __main())

Work

Process states

- Running
  - User mode or kernel mode
- Runnable
  - User mode or kernel mode
    - » Be sure to understand this
- Sleeping
  - “Blocked” awaiting some event
  - Scheduler: “do not run”
  - Q: User mode, kernel mode, both, neither?

Work

Other process states

- Forking
  - Probably obsolete, once used for special treatment
- Zombie
  - Process has called exit(), parent hasn't noticed yet

“Exercise for the reader”

- Draw the state transition diagram

Death

Voluntary

```
void exit(int reason);
```

Hardware exception

- **SIGSEGV - no memory there for you!**

Software exception

- **SIGXCPU –used "too much" CPU time**

Death

System call - kill(pid, sig);

- "Deliver `sig` to process `pid`"
  - (negative values of `pid` have "interesting" behaviors)
- Keyboard `^C` ⇒ equivalent of
  - `kill(getpid(), SIGINT);`
- Start/stop logging
  - `kill(daemon_pid, SIGUSR1);`
  - `% kill -USR1 33`
  - `% kill -USR2 33`
  - This is a "non-kill" use of kill()
- Any other key uses of `kill()`?

Death

System call - kill(pid, sig);

- "Deliver `sig` to process `pid`"
  - (negative values of `pid` have "interesting" behaviors)
- Keyboard `^C` ⇒ `kill(getpid(), SIGINT);`
- Start/stop logging - `kill -USR1 33`
- "Lost in Space"!!
  - `kill(Will_Robinson, SIGDANGER);`

Death

System call - kill(pid, sig);

- "Deliver `sig` to process `pid`"
  - (negative values of `pid` have "interesting" behaviors)
- Keyboard `^C` ⇒ `kill(getpid(), SIGINT);`
- Start/stop logging - `kill -USR1 33`
- "Lost in Space"!!
  - `kill(Will_Robinson, SIGDANGER);`
  - I apologize to IBM for lampooning their serious signal

Death

System call - kill(pid, sig);

- "Deliver `sig` to process `pid`"
  - (negative values of `pid` have "interesting" behaviors)
- Keyboard `^C` ⇒ `kill(getpid(), SIGINT);`
- Start/stop logging - `kill -USR1 33`
- "Lost in Space"!!
  - `kill(Will_Robinson, SIGDANGER);`
  - I apologize to IBM for lampooning their serious signal
    - » No, I apologize for that apology...

Process cleanup

Resource release

- Open files: close() each
  - TCP: 2 minutes (or more)
  - Solaris disk offline - forever ("*None* shall pass!")
- Memory: release

Accounting

- Record resource usage in a magic file

Gone?

“All You Zombies...”

Zombie process

- Process state reduced to exit code
- Waits around until parent calls wait()
  - Exit code copied to parent's memory
  - PCB deleted from kernel

Kernel process state

The dreaded "PCB"

- (polychlorinated biphenol?)

Process Control Block

- “Everything without a user-visible memory address”
  - Kernel management information
  - Scheduler state
  - The “stuff”

Sample PCB contents

Pointer to CPU register save area

Process number, parent process number

Countdown timer value

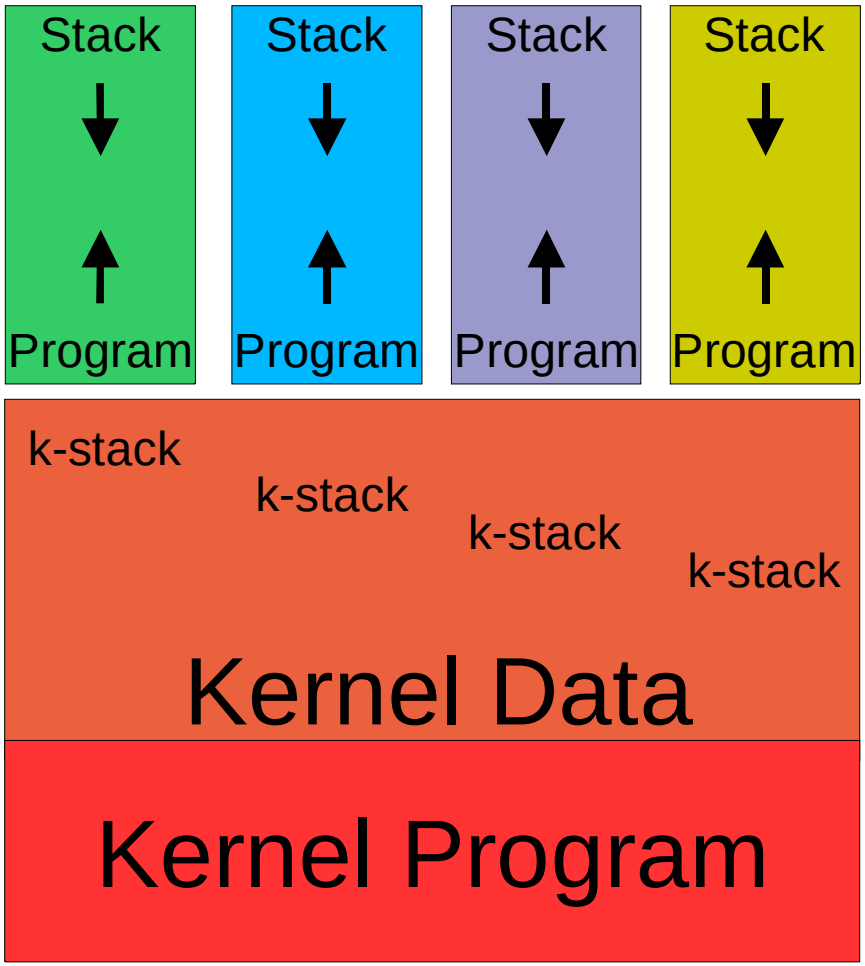
Memory segment info

- **User memory segment list**
- **Kernel stack reference**

Scheduler info

- **linked list slot, priority, “sleep channel”**

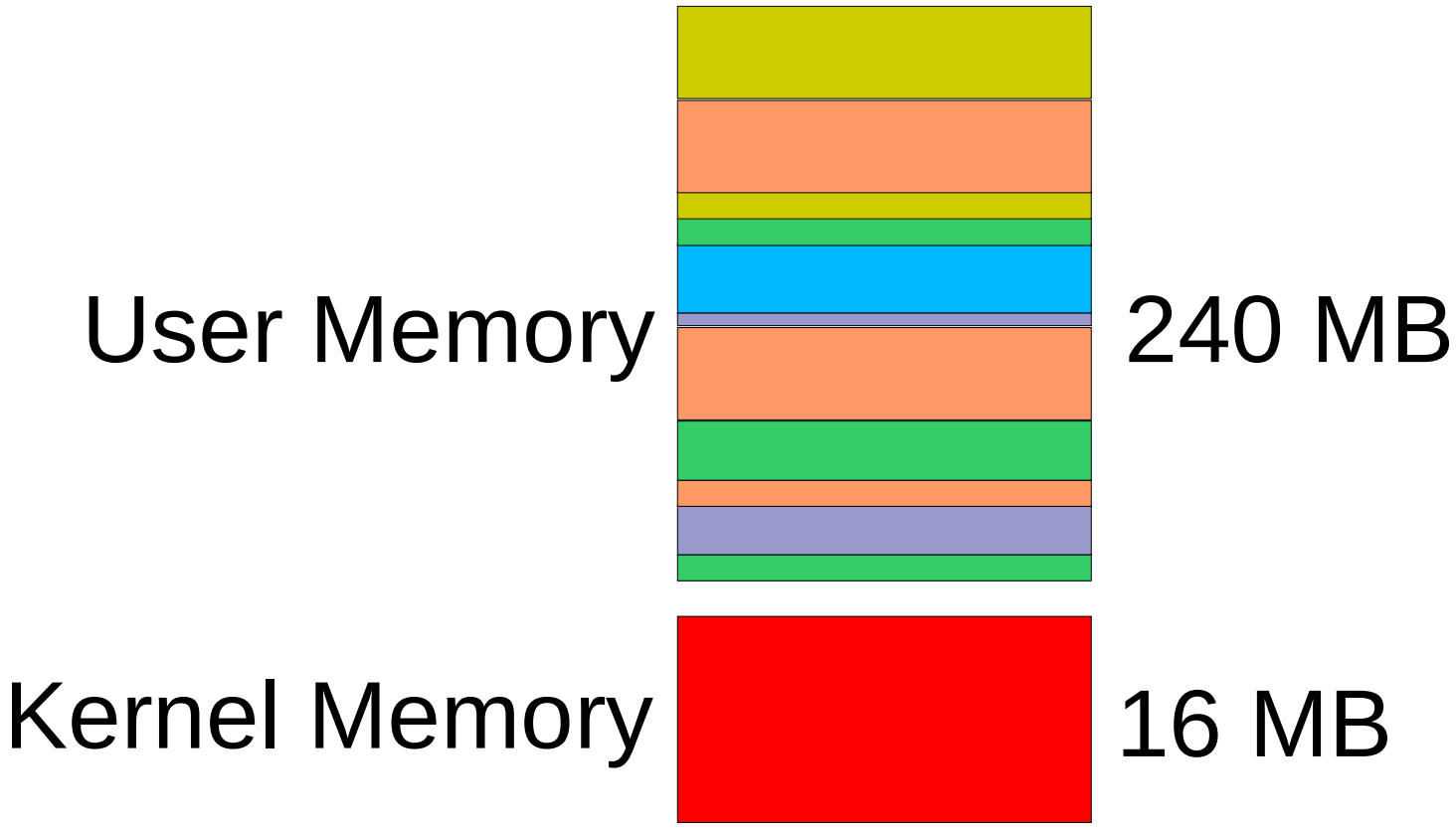
15-410 Virtual Memory Layout



4080 MB

16 MB

15-410 Physical Memory Layout



Ready to Implement All This?

Not so complicated...

- **getpid()**
- **fork()**
- **exec()**
- **wait()**
- **exit()**

What could possibly go wrong?

Summary

Parts of a Process

- Physical – Memory pages, registers, I/O devices
- Virtual – Memory regions, registers, I/O "ports"

Birth, School, Work, Death

"Big Picture" of system memory – both of them

- (Numbers & arrangement are 15-410–specific)