15-410

"Luckily the stack is a simple data structure."

The Process
Sep. 4, 2024

Dave Eckhardt

Synchronization

Reminder: syllabus!

Of particular relevance

- Learning Objectives
- Course Activity
- Getting Help
- Collaboration and Group Work
  - Statement on “tutoring” networks
  - Social media statement

But *everything* in the syllabus is relevant!

Learning Science Alert

Multiple upcoming topics will each be a series

- Threads & synchronization
- Deadlock
- Virtual memory

Learning Science Alert

Multiple upcoming topics will each be a series

- Threads & synchronization
- Deadlock
- Virtual memory

Tactical suggestion

- Review each lecture's predecessor
  - The evening before, or the morning before
- Having the “old” material refreshed will help the new material fit into your brain

Anybody Graduating?

The roster indicates "some" people plan to graduate this semester

- **We are supportive of the concept!**
- **"One weird trick": try doing things that sound weird that we suggest are supportive of success**

Anybody Graduating?

The roster indicates "some" people plan to graduate this semester

- **We are supportive of the concept!**
- **"One weird trick": try doing things that sound weird that we suggest are supportive of success**
  - **Maybe even weird "learning science" things**

TA-candidate Reminder

Interested in serving as an OS TA next semester?

- Please do *all* of the weird things
  - Coming to class a little early each day
  - Starting projects immediately
  - Reading and synthesizing
  - Multiple solutions for each problem
    - » Design charts
  - Documentation
  - Aiming to be done with projects early "just in case"

Synchronization

Project 0 due tonight

- Please make sure you can write into your hand-in directory *before 18:00* today
- Please see hand-in instructions on P0 web page
  - *Please make sure that your p0/ directory does not contain a p0/ directory!*
  - *Please make sure that your p0/ directory does not contain a p0/ directory!*
  - *Please make sure that your p0/ directory does not contain a p0/ directory!*

Synchronization

P2/P3/P4 partners

- 7 groups have signed up
- 2 groups have *partially* signed up
  - » *BOTH PARTNERS* must register
  - » *EACH PARTNER PERSONALLY AUTHENTICATED*
- 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

Reminders on collaboration

- Like Project 0, Project 1 will be *individual*
- Talking about code is ok
- Possessing the code of another is *not ok*
- Different classes have different policies
- We expect you to read and follow the policies of *this* class
  - (As found in the syllabus, which you are required to read)
  - If something is unclear, please mail us

Synchronization

What is source code "for"?

- **What is done with it?**

Synchronization

The purpose of code is for *people to read*

- **By a reviewer / security auditor**
- **By your group**
- **By your manager**
- **By your successor**
- **By you six months later (6 hours later if no sleep)**

Oh, yeah, the compiler reads it too

Synchronization

This lecture

- OSC: Chapter 3, but not exactly!
  - We are skipping 3.5 and 3.6, including the terrifying “POSIX Shared Memory”
- OS:P+P: Sections 3.1-3.3, but not exactly

Outline

Process as pseudo-machine

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

Process life cycle

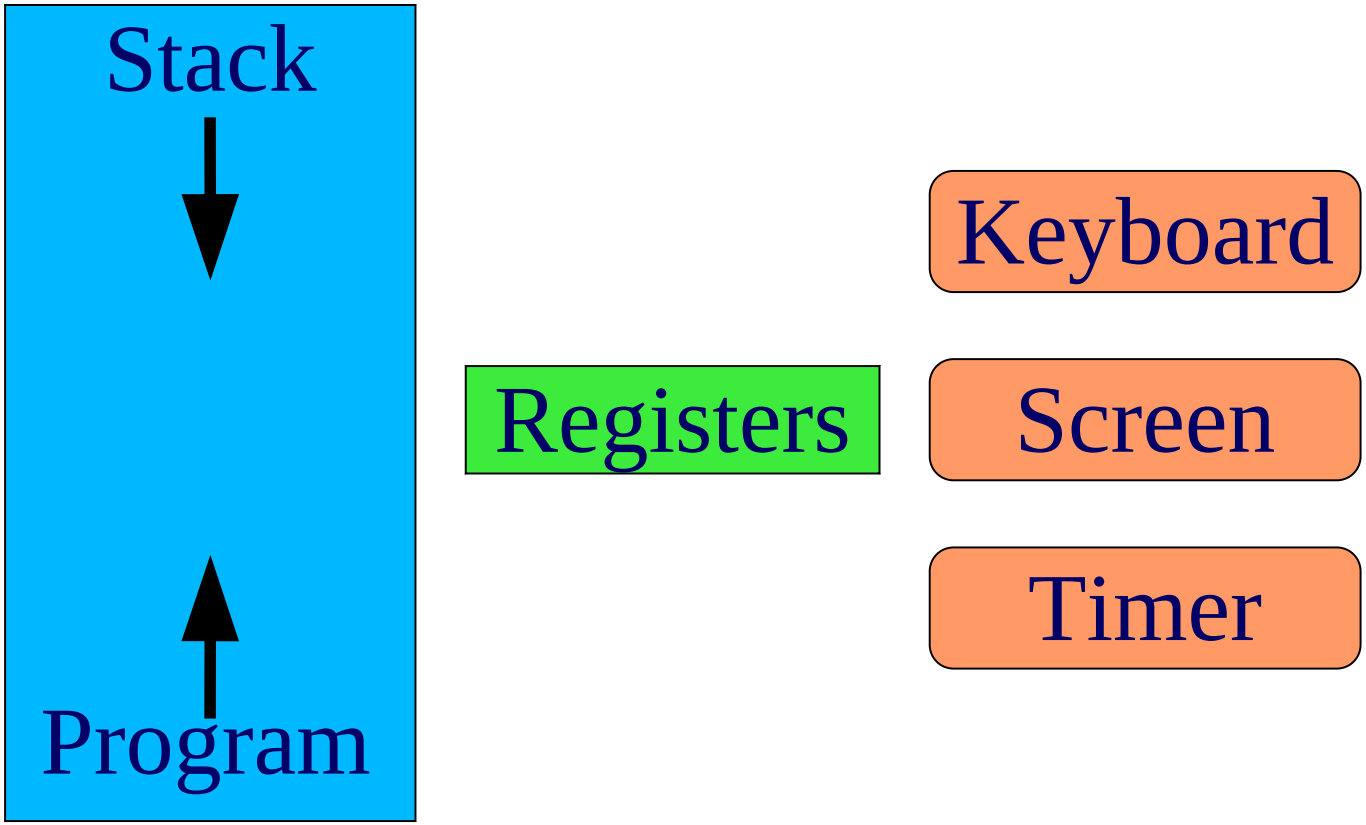
Process kernel states

Process kernel state

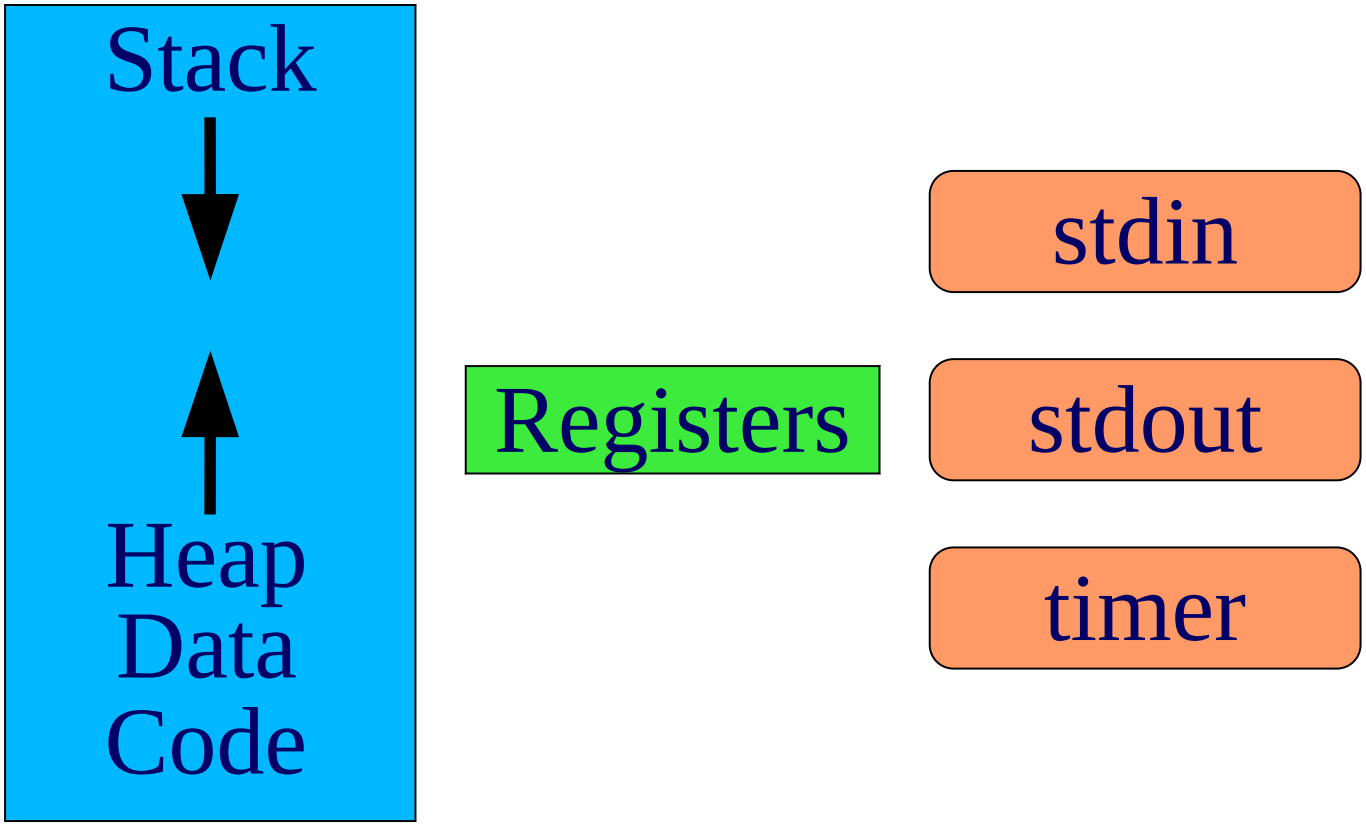
P1/P3 memory layout

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

A Computer



A Process



Process life cycle

Life cycle

- Birth
  - (or, well, fission)
- School
- Work
- Death

Nomenclature

- Courtesy of The Godfathers [1988]

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()

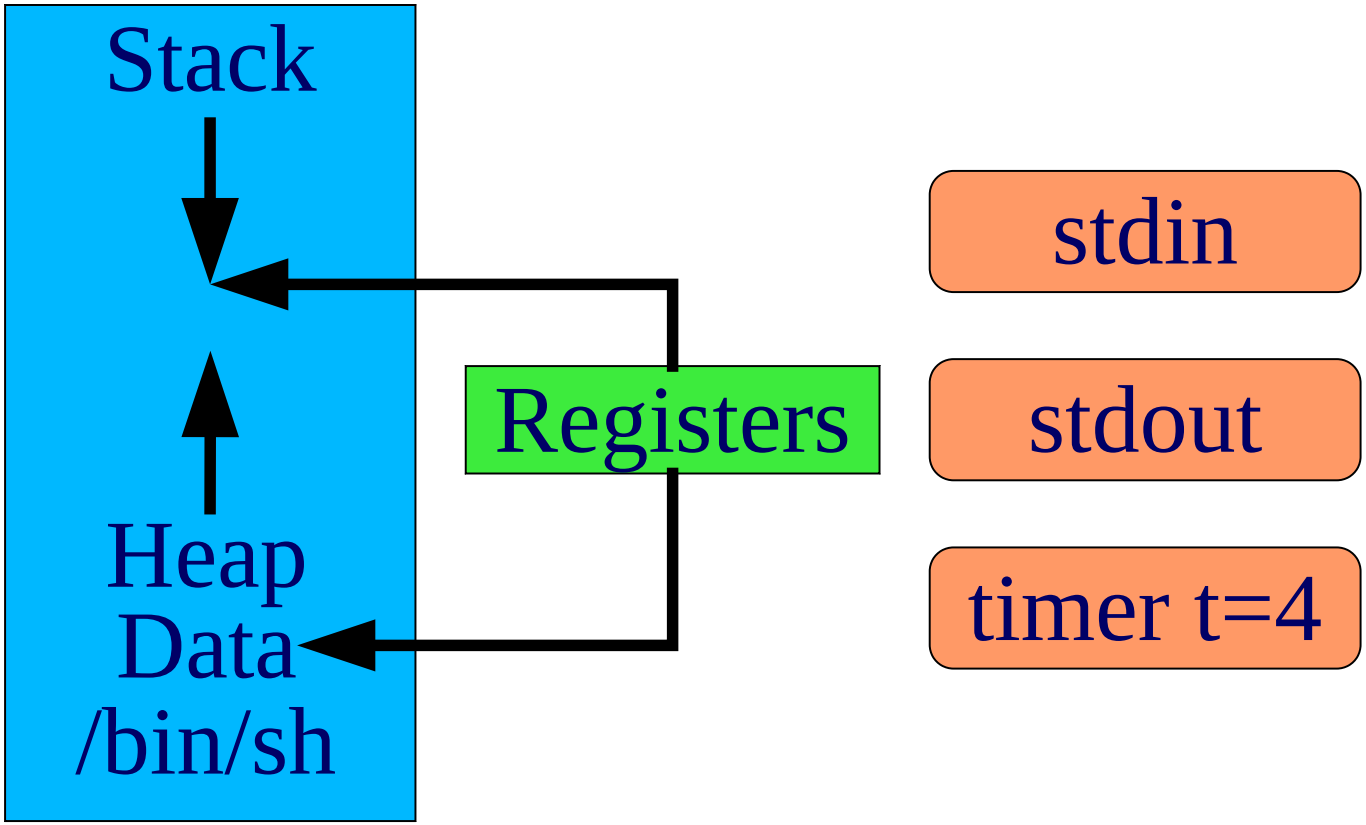
Now what?

Two copies of the same process is *boring*

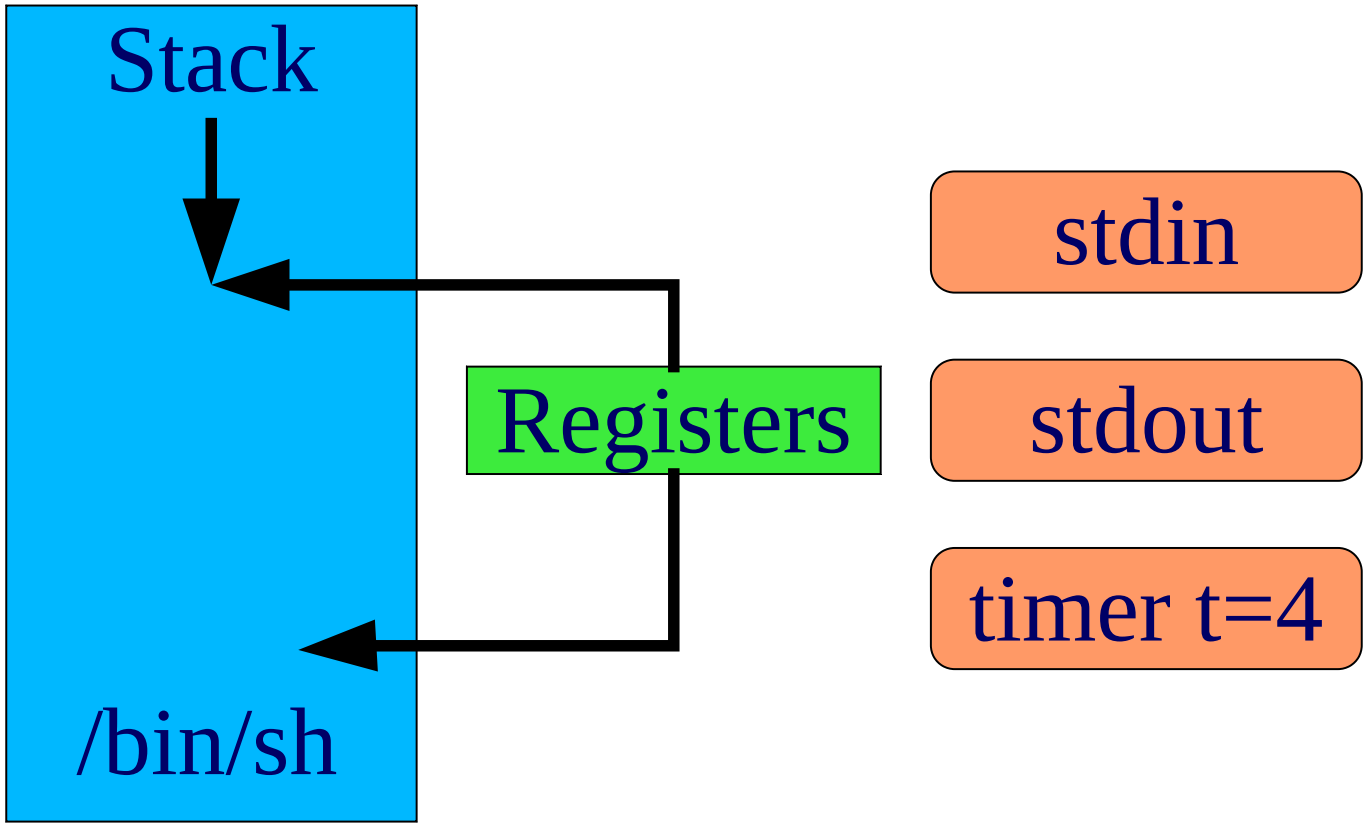
Transplant surgery!

- 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”

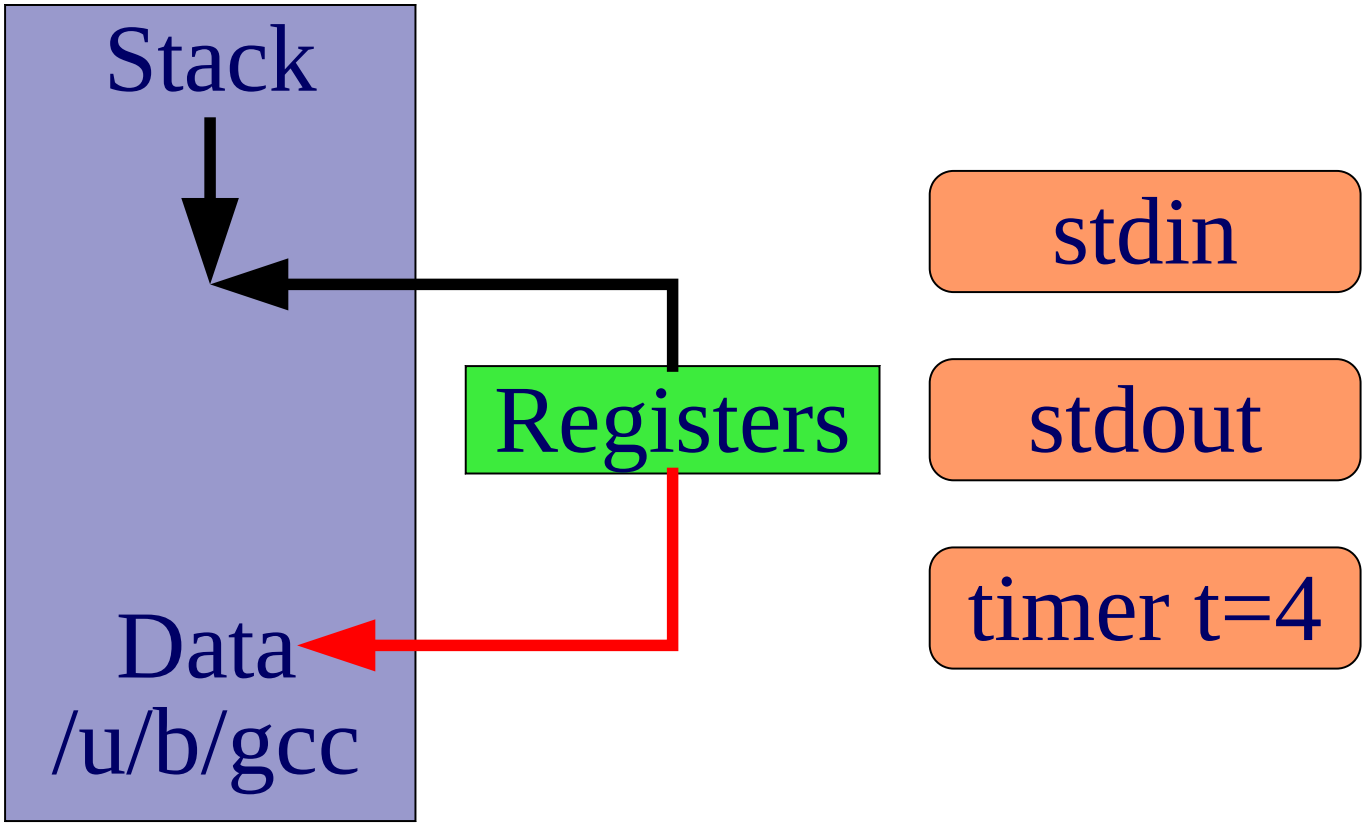
Original Process State



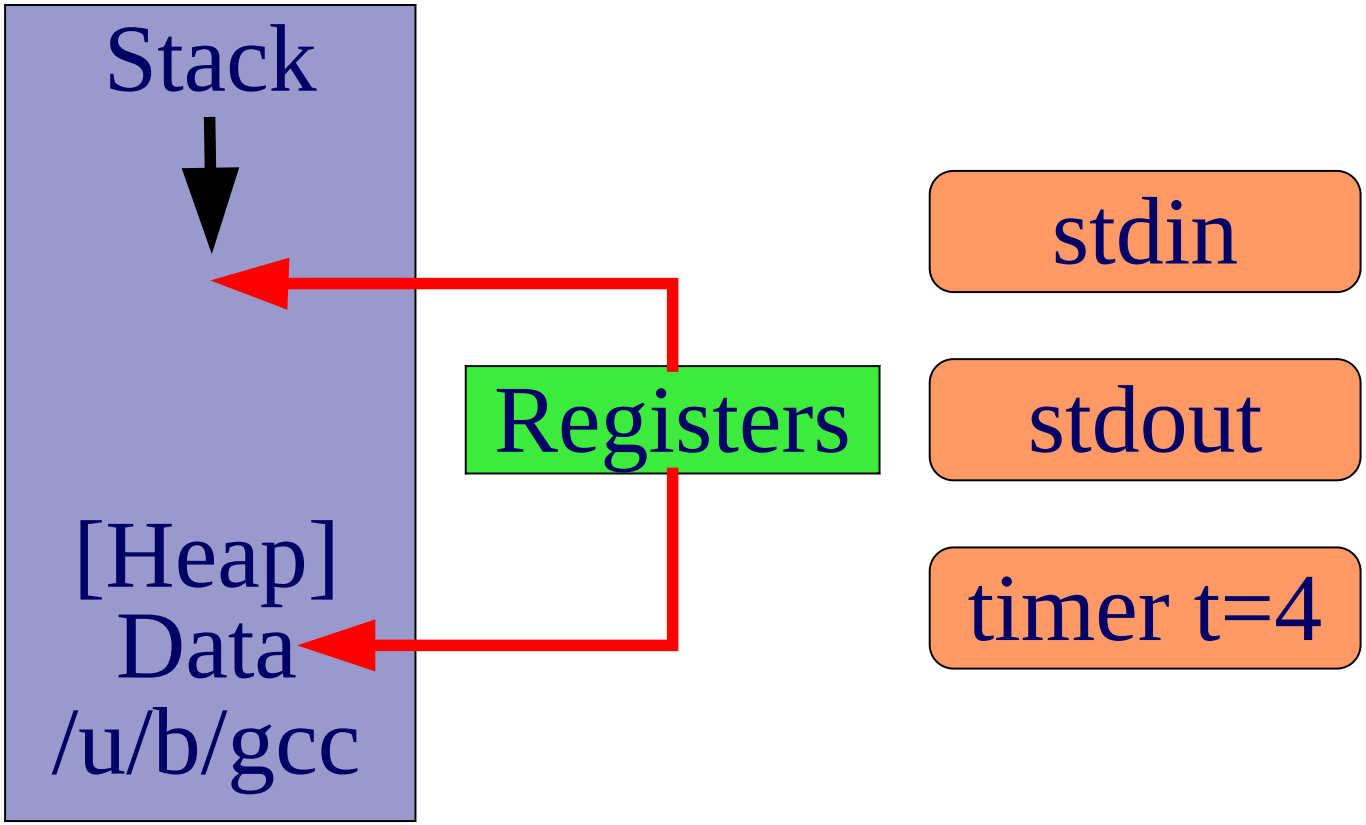
Toss Heap, Data



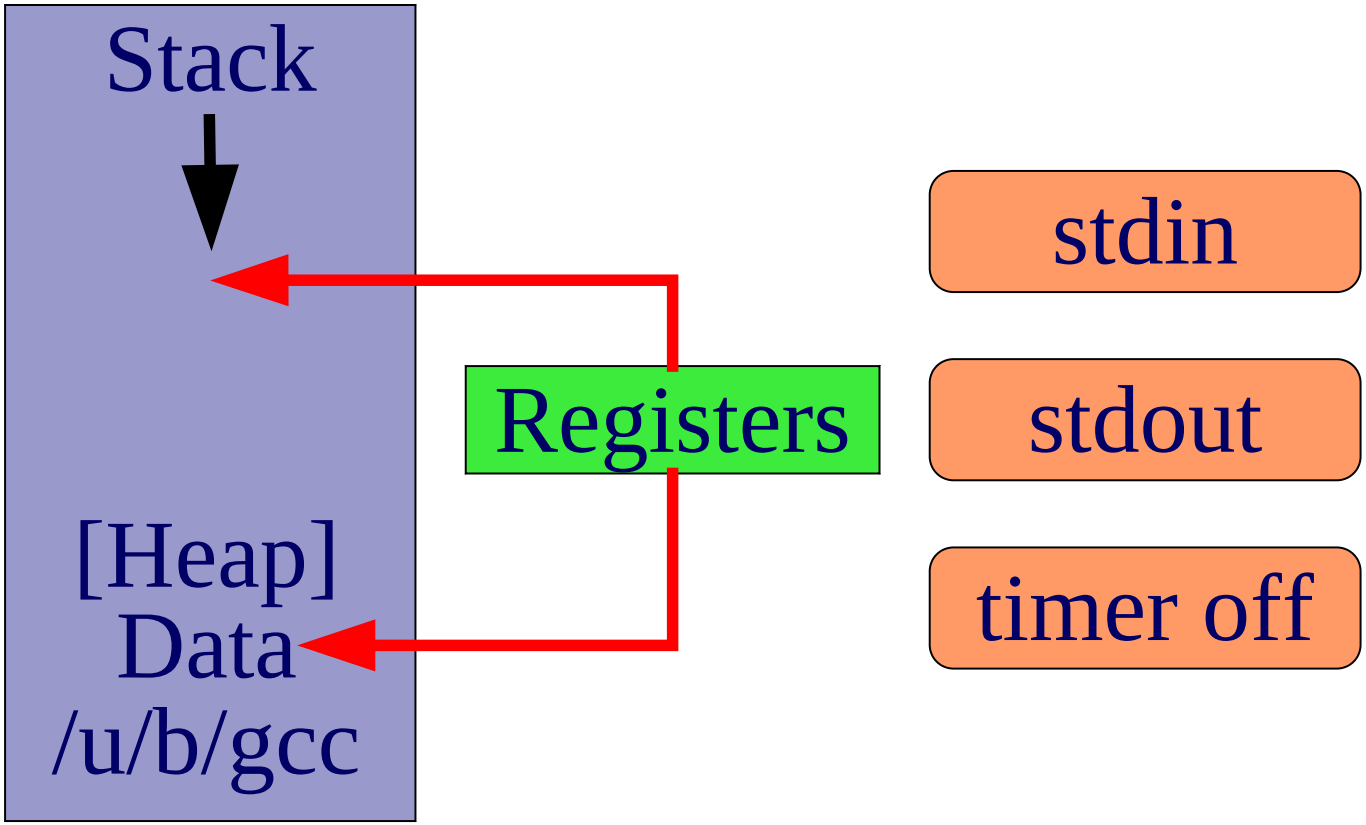
Load New Code, Data From File



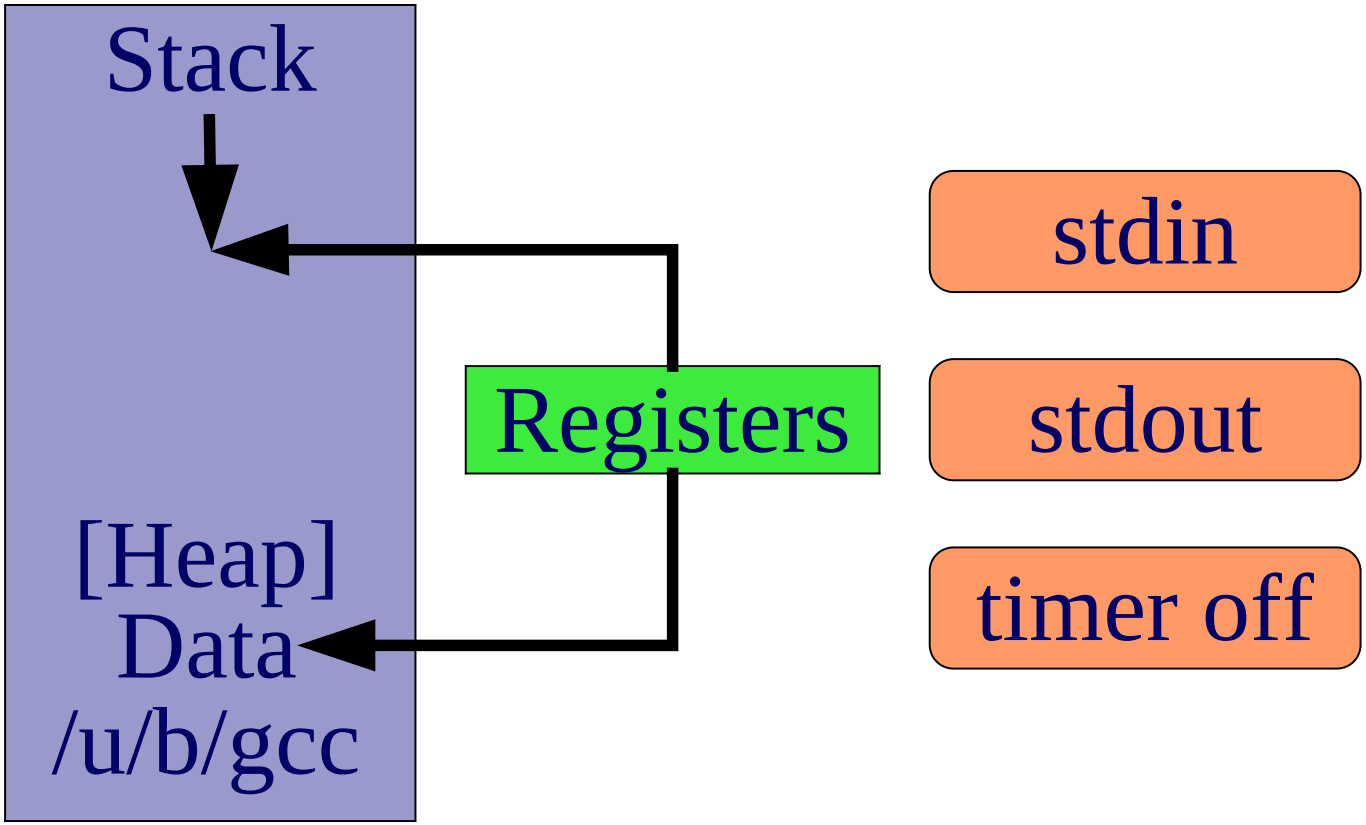
Reset Stack, Heap



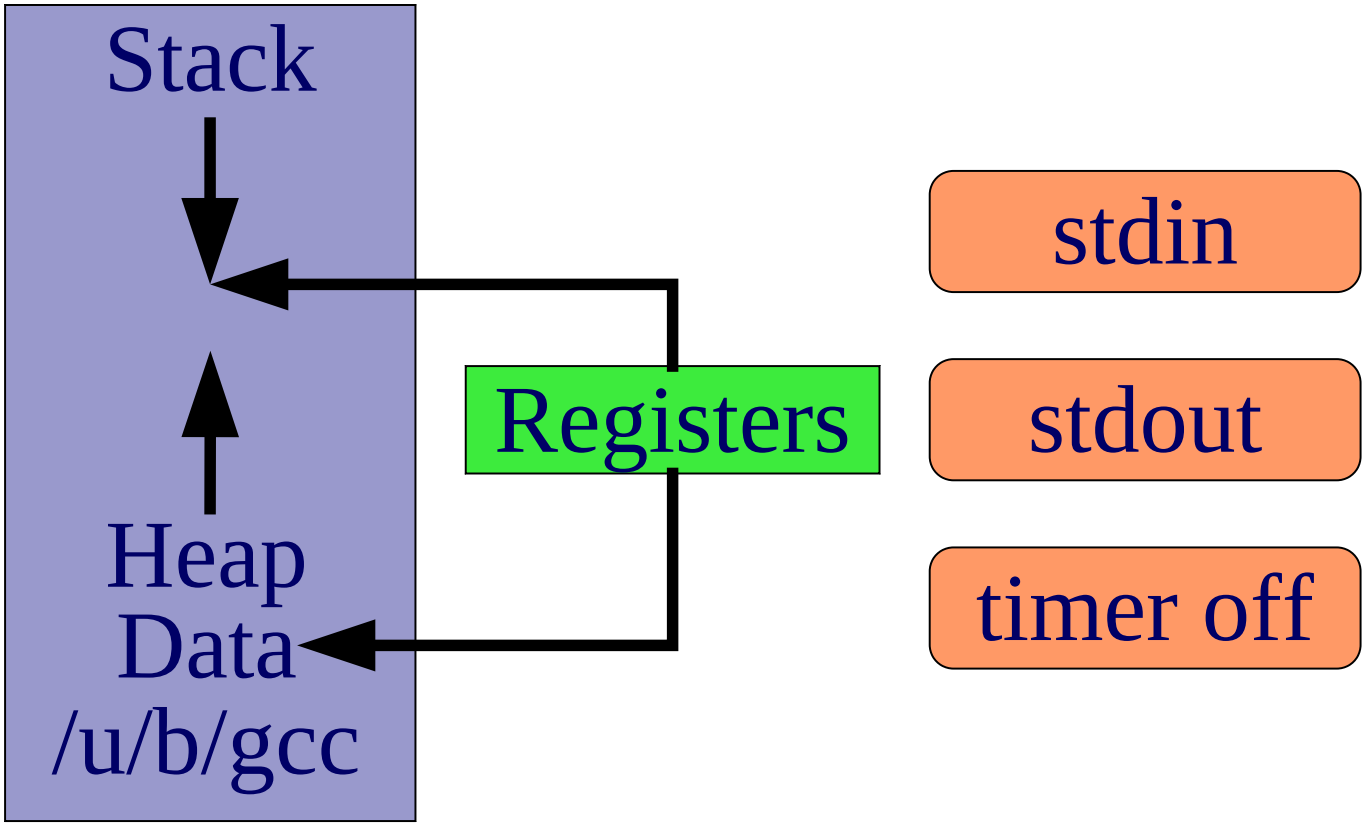
Fix “Stuff”



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

Birth - other ways

There is another way

- **Well, two**

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 program 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 address-space reload: we saw...

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

Also...

The Stack!

Kernel builds new stack for the new program

- Transfers argv[] and envp[] to top of new 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
- Blocked
  - Awaiting some event
    - » I/O completion, exit of another process, message, ...
    - » Maybe sleeping for a fixed period of time
  - Scheduler: “do not run”
  - Q: Definitely user mode, definitely kernel mode, either, something else?

Work

Process states

- Running
  - User mode or kernel mode
- Blocked
  - Awaiting some event
    - » I/O completion, exit of another process, message, ...
    - » Maybe sleeping for a fixed period of time
  - Scheduler: “do not run”
  - Q: Definitely user mode, definitely kernel mode, either, something else?
- Runnable
  - Q: Definitely user mode, definitely kernel mode, either, something else?
    - » Be sure to understand this

Work

Other process states

- Forking
  - 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?)**

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

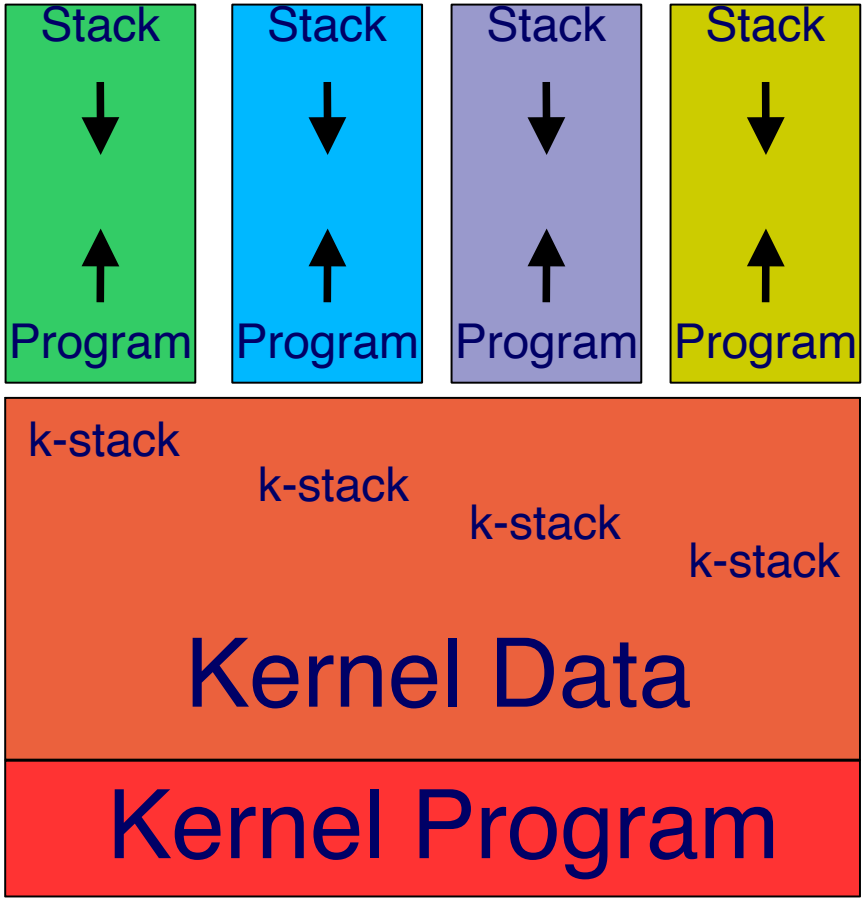
Memory segment info

- User memory segment list
- Kernel stack reference

Scheduler info

- linked list slot, priority, “sleep channel”

15-410 Virtual Memory Layout

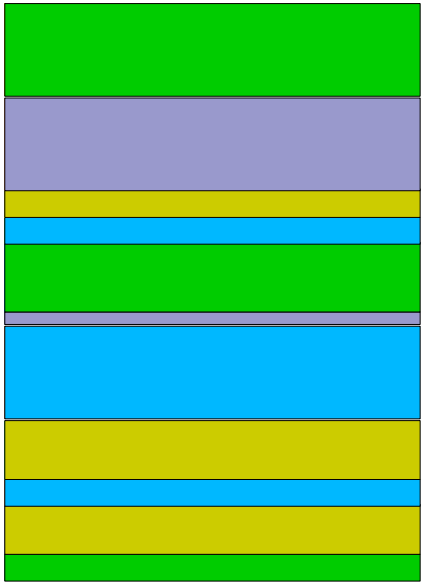


4080 MB

16 MB

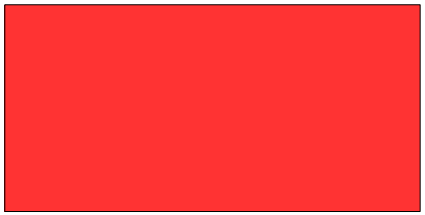
15-410 Physical Memory Layout

User Memory



240 MB

Kernel Memory



16 MB

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)