Code safety (cont'd)

&& Access control

CS 161: Computer Security

Prof. Raluca Ada Popa

January 23, 2018

Announcements

- Homework 1 is out, due in a week
- Dean approved class expansion, three new discussion sections, stay tuned for details
- *Scraped* lecture slides available before class
    - Do not use them for answering in class
- Full lecture slides available after class

Precondition

- A precondition for a function *f()* is an assertion that must hold about the inputs to *f*
- *f()* is assumed to behave correctly and produce correct output as long as the precondition is met
- The caller must make sure the precondition is met
- The callee (the code inside *f()*) can assume that the precondition is met

Example

Q: What is the precondition?

```
int sum(int *a[], size_t n) {
      int total = 0;
      size_t i;
      for (i=0; i<n; i++)
            total += *(a[i]);
      return total;
}
```

Example

```
/* requires: a != NULL && size(a) >= n &&
for all j in 0..n-1, a[j] != NULL && (sum_i
*a[i]<=MAX_INT) */
int sum(int *a[], size_t n) {
      int total = 0;
      size_t i;
      for (i=0; i<n; i++)
            total += *(a[i]);
      return total;
}
```

Postcondition

- A postcondition on *f()* is an assertion that holds when *f()* returns
- The caller of *f()* can assume that the postcondition holds
- *f()* must make sure the postcondition holds

Example

Q: What is the postcondition?

```
void *mymalloc(size_t n) {
	void *p = malloc(n);
	if (!p) {
		perror("Out of memory");
	exit(1);
	}
	return p;
}
```

Example

```
/* ensures: retval != NULL && retval
points to n bytes of memory */
void *mymalloc(size_t n) {
     void *p = malloc(n);
     if (!p) {
          perror("Out of memory");
     exit(1);
     }
     return p;
}
```

Specification vs implementation

- A function has a specification = precondition+postcondition
- And an implementation that should meet the specification: for all inputs satisfying the precondition, it must satisfy the postcondition.

Reasoning about code

To prove that a function whose inputs satisfy the precondition, matches the postcondition, you can:

- Write down a precondition and postcondition for every line of code, and prove this
  - Each statement's postcondition must imply the precondition of the next statement. This is an invariant that is true at any point in time.
- Final postcondition is the postcondition for the function

Invariant examples

```
/* requires: n >= 0 */
void binpr(int n) {
      char digits[] = "0123456789"; /* n >= 0 */
      while (n != 0) { /* n>0 */
            int d = n % 10; /* 0<=d && d < 10 && n > 0*/
            putchar(digits[d]);
             n = n / 10; /* 0<=d && d<10 && n>=0*/
      }
      putchar('0');
}
```

What is the precondition?

```
int sumderef(int *a[], size_t n) {
    int total = 0;
    for (size_t i=0; i<n; i++)
        total += *(a[i]);
    return total;
}
```

What is the precondition?

```
/* requires: a != NULL &&
     size(a) >= n &&
            ???                                    */
int sumderef(int *a[], size_t n) {
    int total = 0;
    for (size_t i=0; i<n; i++)
         total += *(a[i]);
    return total;
}
```

What is the precondition?

```
/* requires: a != NULL &&
     size(a) >= n &&
     for all j in 0..n-1, a[j] != NULL
(&& sum *(a[i]) <= MAXINT )*/
int sumderef(int *a[], size_t n) {
    int total = 0;
    for (size_t i=0; i<n; i++)
        total += *(a[i]);
    return total;
}
```

```
char *tbl[N]; /* N > 0, has type int */


int hash(char *s) {
  int h = 17;
  while (*s)
    h = 257*h + (*s++) + 3;
  return h % N;
}

bool search(char *s) {
  int i = hash(s);
  return tbl[i] && (strcmp(tbl[i], s)==0);
}
```

```c
char *tbl[N];

/* ensures: ??? */
int hash(char *s) {
  int h = 17;
  while (*s)
    h = 257*h + (*s++) + 3;
  return h % N;
}
```

What is the correct postcondition for hash()?
(a) 0 <= retval < N, (b) 0 <= retval,
(c) retval < N, (d) none of the above.
Discuss with a partner.

```c
char *tbl[N];

/* ensures: 0 <= retval && retval < N */
int hash(char *s) {
  int h = 17;
  while (*s)
    h = 257*h + (*s++) + 3;
  return h % N;
}

bool search(char *s) {
  int i = hash(s);
  return tbl[i] && (strcmp(tbl[i], s)==0);
}
```

```
char *tbl[N];

/* ensures: 0 <= retval && retval < N */
int hash(char *s) {
  int h = 17;                    /* 0 <= h */
  while (*s)
    h = 257*h + (*s++) + 3;
  return h % N;
}

bool search(char *s) {
  int i = hash(s);
  return tbl[i] && (strcmp(tbl[i], s)==0);
}
```

```c
char *tbl[N];

/* ensures: 0 <= retval && retval < N */
int hash(char *s) {
  int h = 17;                         /* 0 <= h */
  while (*s)                          /* 0 <= h */
    h = 257*h + (*s++) + 3;
  return h % N;
}

bool search(char *s) {
  int i = hash(s);
  return tbl[i] && (strcmp(tbl[i], s)==0);
}
```

```c
char *tbl[N];

/* ensures: 0 <= retval && retval < N */
int hash(char *s) {
  int h = 17;                   /* 0 <= h */
  while (*s)                    /* 0 <= h */
    h = 257*h + (*s++) + 3;     /* 0 <= h */
  return h % N;
}

bool search(char *s) {
  int i = hash(s);
  return tbl[i] && (strcmp(tbl[i], s)==0);
}
```

```
char *tbl[N];

/* ensures: 0 <= retval && retval < N */
int hash(char *s) {
  int h = 17;                     /* 0 <= h */
  while (*s)                      /* 0 <= h */
    h = 257*h + (*s++) + 3;       /* 0 <= h */
  return h % N; /* 0 <= retval < N */
}

bool search(char *s) {
  int i = hash(s);
  return tbl[i] && (strcmp(tbl[i], s)==0);
}
```

```c
char *tbl[N];

/* ensures: 0 <= retval && retval < N */
int hash(char *s) {
  int h = 17;                      /* 0 <= h */
  while (*s)                       /* 0 <= h */
    h = 257*h + (*s++) + 3;        /* 0 <= h */
  return h % N; /* 0 <= retval < N */
}
```

Is the postcondition correct?
(a) Yes, (b) 0 <= retval is correct,
(c) retval < N is correct, (d) both are wrong.

```c
0);
}
```

```
char *tbl[N];

/* ensures: 0 <= retval && retval < N */
int hash(char *s) {
  int h = 17;                       /* 0 <= h */
  while (*s)                        /* 0 <= h */
    h = 257*h + (*s++) + 3;         /* 0 <= h */
  return h % N; /* 0 <= retval < N */
}

bool search(char *s) {
  int i = hash(s);
  return tbl[i] && (strcmp(tbl[i], s)==0);
}
```

```
char *tbl[N];

/* ensures: 0 <= retval && retval < N */
int hash(char *s) {
  int h = 17;                      /* 0 <= h */
  while (*s)                       /* 0 <= h */
    h = 257*h + (*s++) + 3;        /* 0 <= h */
  return h % N; /* 0 <= retval < N */
}

bool search(char *s) {
  int i = hash(s);
  return tbl[i] && (strcmp(tbl[i], s)==0);
}
```

```
char *tbl[N];

/* ensures: 0 <= retval && retval < N */
int hash(char *s) {
  int h = 17;                       /* 0 <= h */
  while (*s)                        /* 0 <= h */
    h = 257*h + (*s++) + 3;         /* 0 <= h */
  return h % N; /* 0 <= retval < N */
}

bool search(char *s) {
  int i = hash(s);
  return tbl[i] && (strcmp(tbl[i], s)==0);
}
```

```
char *tbl[N];

/* ensures: 0 <= retval && retval < N */
int hash(char *s) {
  int h = 17;                      /* 0 <= h */
  while (*s)                       /* 0 <= h */
    h = 257*h + (*s++) + 3;        /* 0 <= h */
  return h % N; /* 0 <= retval < N */
}
```

What is the correct postcondition for hash()?
(a) 0 <= retval < N, (b) 0 <= retval,
(c) retval < N, (d) none of the above.
Discuss with a partner.

```c
char *tbl[N];

/* ensures: 0 <= retval && retval < N */
int hash(char *s) {
  int h = 17;                   /* 0 <= h */
  while (*s)                    /* 0 <= h */
    h = 257*h + (*s++) + 3;     /* 0 <= h */
  return h % N; /* 0 <= retval < N */
}

bool search(char *s) {
  int i = hash(s);
  return tbl[i] && (strcmp(tbl[i], s)==0);
}
```

Fix?

```c
char *tbl[N];

/* ensures: 0 <= retval && retval < N */
unsigned int hash(char *s) {
  unsigned int h = 17;         /* 0 <= h */
  while (*s)                   /* 0 <= h */
    h = 257*h + (*s++) + 3;    /* 0 <= h */
  return h % N; /* 0 <= retval < N */
}

bool search(char *s) {
  unsigned int i = hash(s);
  return tbl[i] && (strcmp(tbl[i], s)==0);
}
```

Access Control and
OS Security

Types of Security Properties

- Confidentiality
- Integrity
- Availability

Access Control

- Some resources (files, web pages, …) are sensitive.
- How do we limit who can access them?

- This is called the *access control* problem

Access Control Fundamentals

- *Subject* = a user, process, …
  (someone who is accessing resources)
- *Object* = a file, device, web page, …
  (a resource that can be accessed)
- *Policy* = the restrictions we'll enforce

- *access*(*S*, *O*) = true
  if subject *S* is allowed to access object *O*

Example

- *access*(Alice, Alice's wall) = true
  access(Alice, Bob's wall) = true
  access(Alice, Charlie's wall) = false

- *access*(raluca, /home/cs161/gradebook) = true
  access(Alice, /home/cs161/gradebook) = false

Access Control Matrix

- *access*(*S*, *O*) = true
  if subject *S* is allowed to access object *O*

	Alice's wall	Bob's wall	Charlie's wall	…
Alice	true	true	false	
Bob	false	true	false	
…				

Permissions

- We can have finer-grained permissions, e.g., read, write, execute.

- *access*(raluca, /cs161/grades/alice) = {read, write}
  access(alice, /cs161/grades/alice) = {read}
  access(bob, /cs161/grades/alice) = {}

	/cs161/grades/alice
daw	read, write
alice	read
bob	-

Access Control

- Authorization: who *should* be able to perform which actions
- Authentication: verifying who is requesting the action

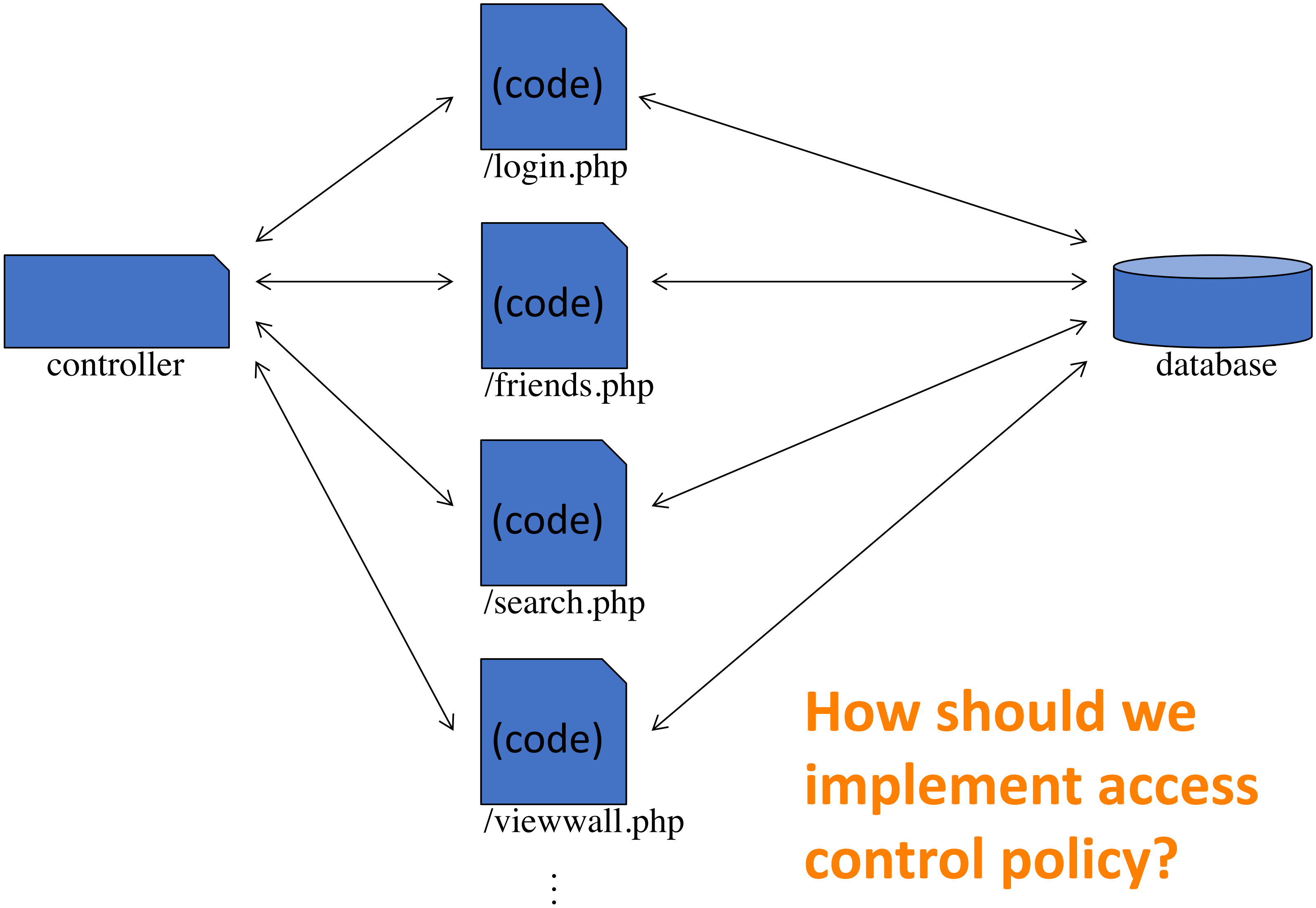
Access Control

- Authorization: who *should* be able to perform which actions
- Authentication: verifying who is requesting the action
- Audit: a log of all actions, attributed to a particular principal
- Accountability: hold people legally responsible for actions they take.

Web security

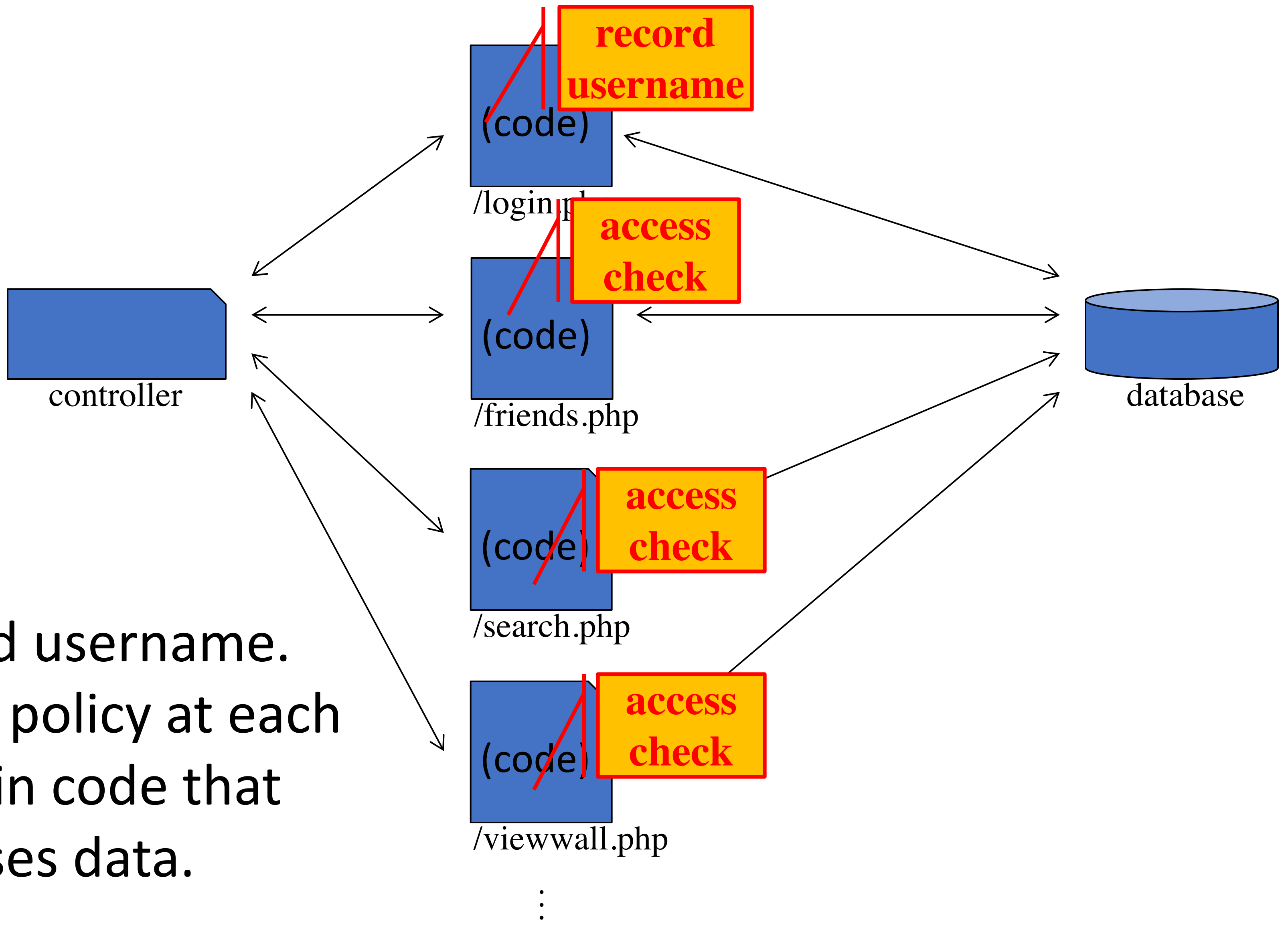
- Let’s talk about how this applies to web security…

Structure of a web application



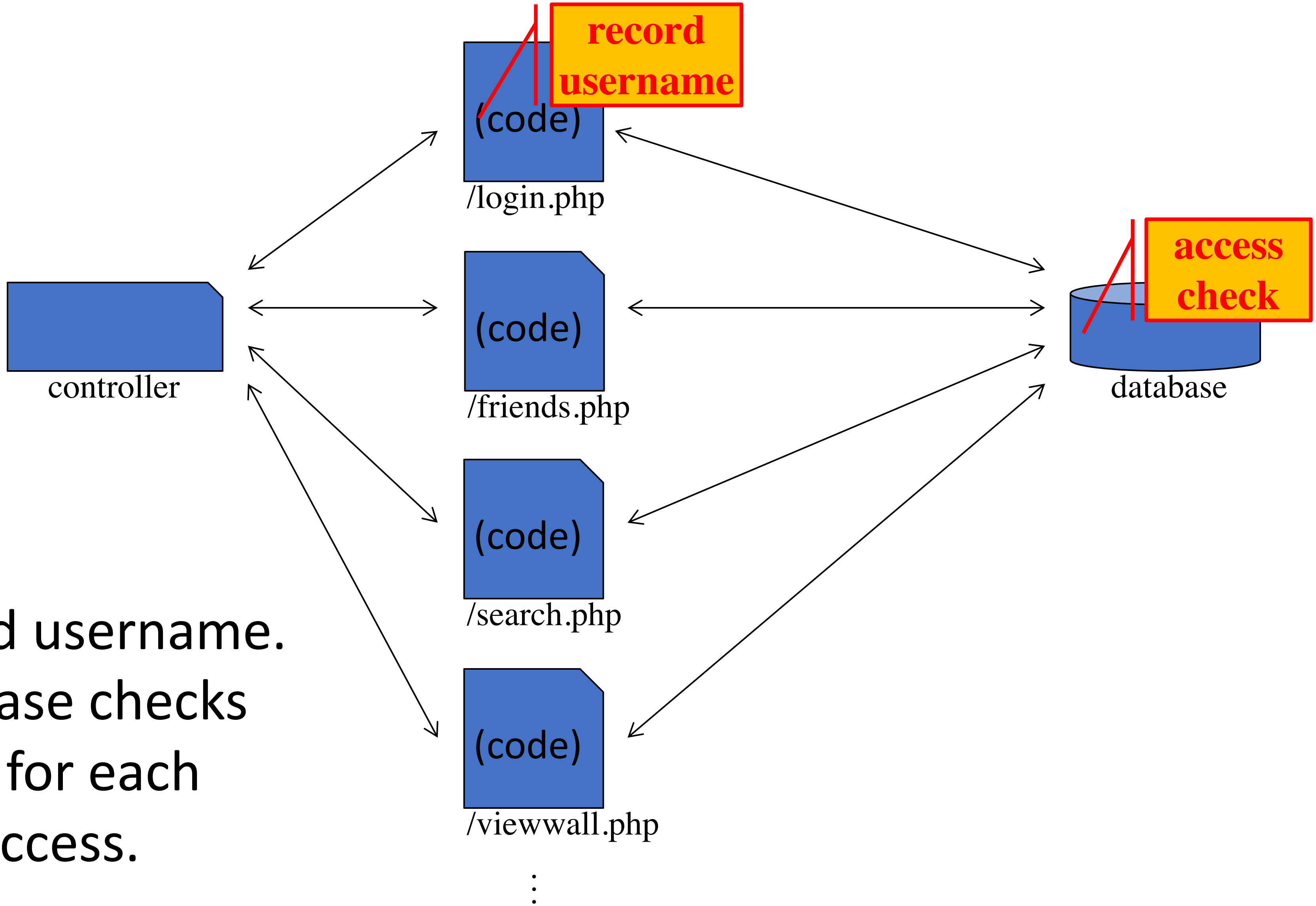
How should we implement access control policy?

Option 1: Integrated Access Control



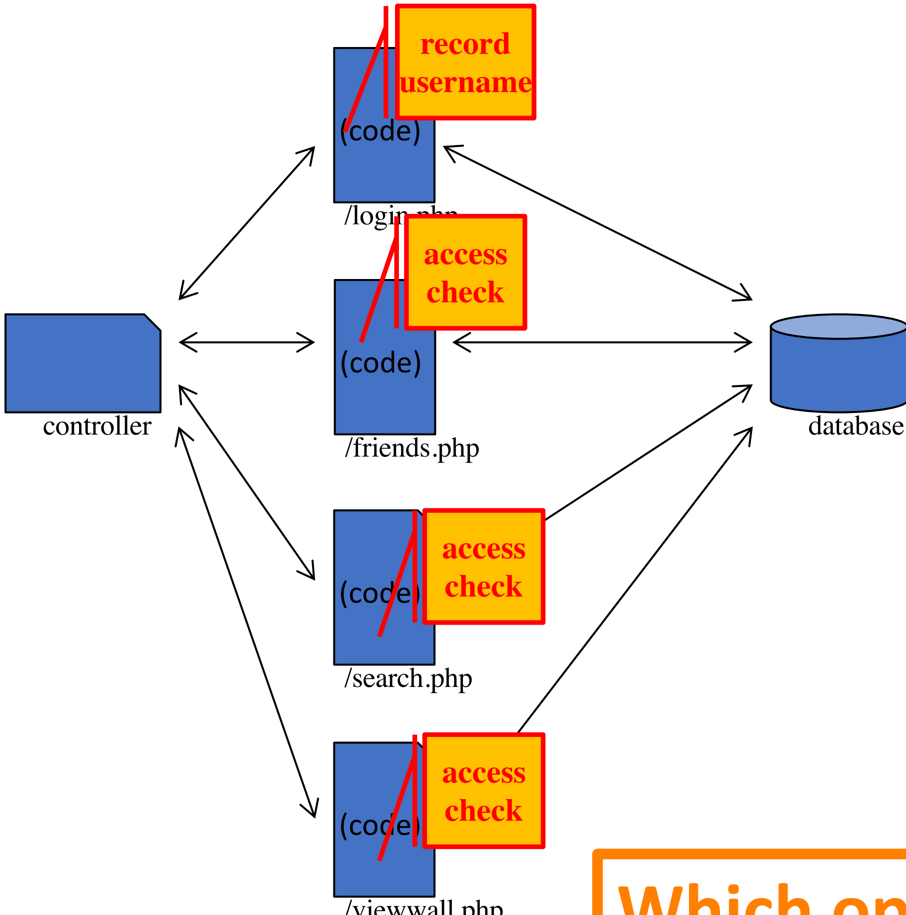
Record username.
Check policy at each place in code that accesses data.

Option 2: Centralized Enforcement



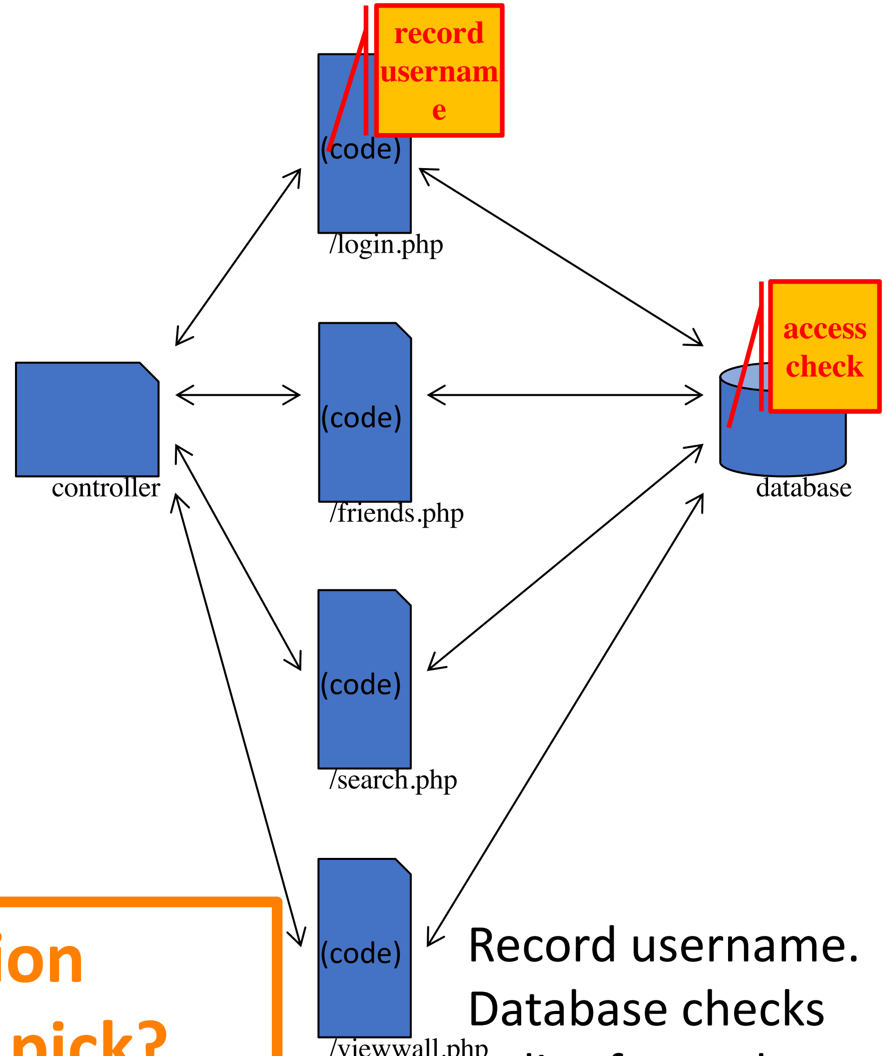
Record username.
Database checks
policy for each
data access.

Option 1: Integrated Access Control



Record username.
Check policy at each place in code that accesses data.

Option 2: Centralized Enforcement



Record username.
Database checks policy for each data access.

Which option would you pick? Discuss.

Analysis

- Centralized enforcement might be less prone to error
  - All accesses are vectored through a central chokepoint, which checks access
  - If you have to add checks to each piece of code that accesses data, it's easy to forget a check (and app will work fine in normal usage, until someone tries to access something they shouldn't)
- Integrated checks might be more flexible

Complete mediation

- The principle: complete mediation
- Ensure that all access to data is mediated by something that checks access control policy.
  - In other words: the access checks can’t be bypassed

If you don’t have complete mediation, your access control will fail

Reference monitor

- A reference monitor is responsible for mediating all access to data

- Subject cannot access data directly; operations must go through the reference monitor, which checks whether they're OK

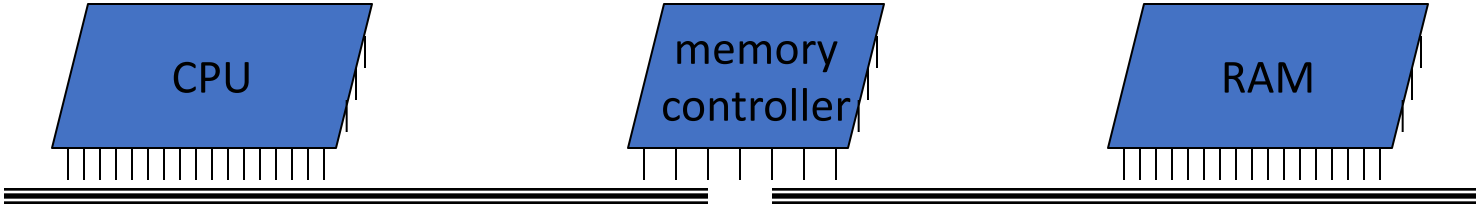
Criteria for a reference monitor

Ideally, a reference monitor should be:

- Unbypassable: all accesses go through the reference monitor
- Tamper-resistant: attacker cannot subvert or take control of the reference monitor (e.g., no code injection)
- Verifiable: reference monitor should be simple enough that it's unlikely to have bugs

Example: OS memory protection

- All memory accesses are mediated by memory controller, which enforces limits on what memory each process can access



TCB

- More broadly, the trusted computing base (TCB) is the subset of the system that has to be correct, for some security goal to be achieved
  - Example: the TCB for enforcing file access permissions includes the OS kernel and filesystem drivers
- Ideally, TCBs should be unbypassable, tamper-resistant, and verifiable

Robustness

- Security bugs are a fact of life
- How can we use access control to improve the security of software, so security bugs are less likely to be catastrophic?

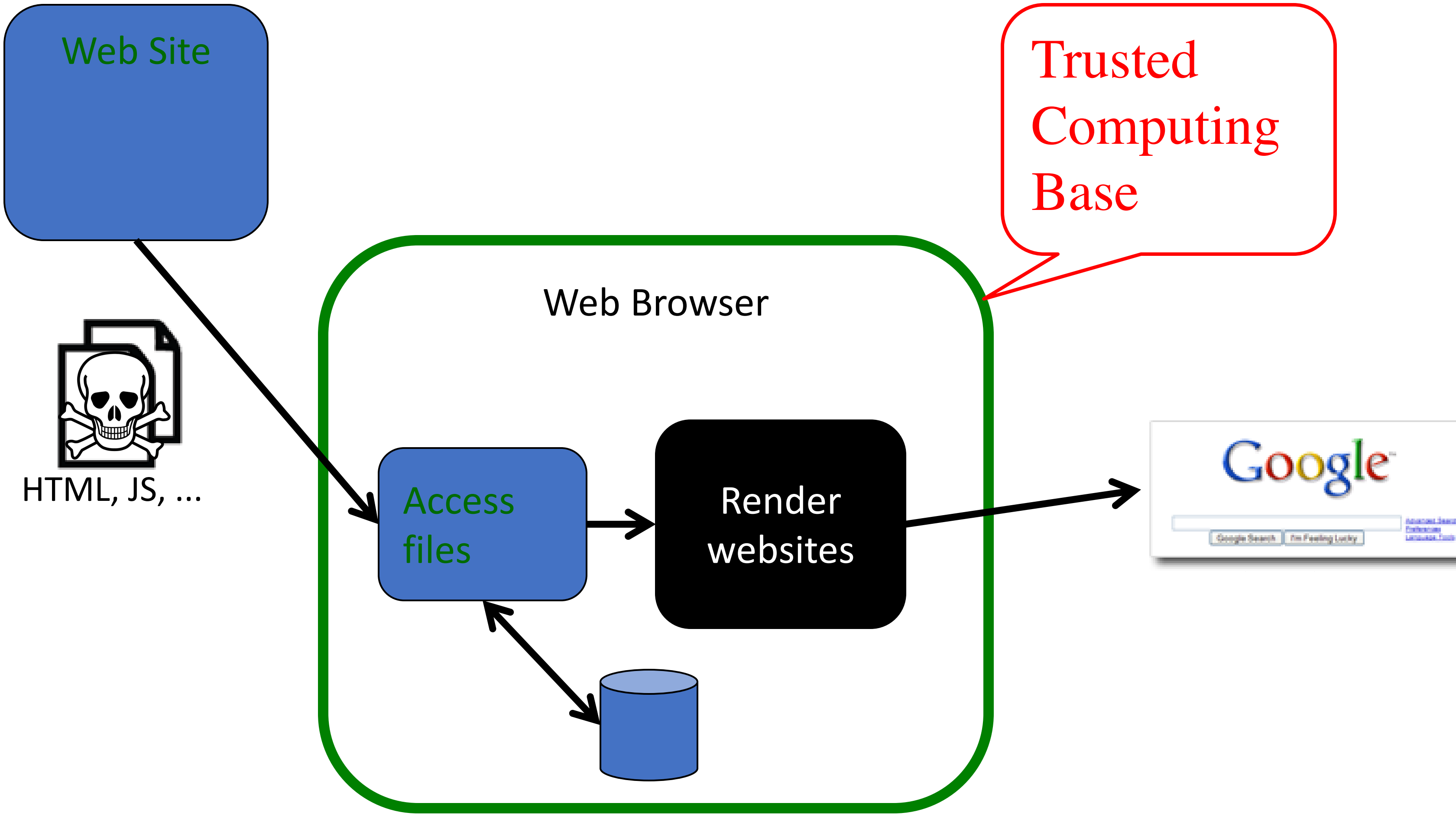
Privilege separation

- How can we improve the security of software, so security bugs are less likely to be catastrophic?

- Answer: privilege separation. Give each module only the privilege it needs.

  - In particular, architect the software so it has a separate, small TCB.
  - Then any bugs outside the TCB will not be catastrophic.

Naïve web browser



"Drive-by malware": malicious web page exploits a browser bug to read/write local files or infect them with a virus

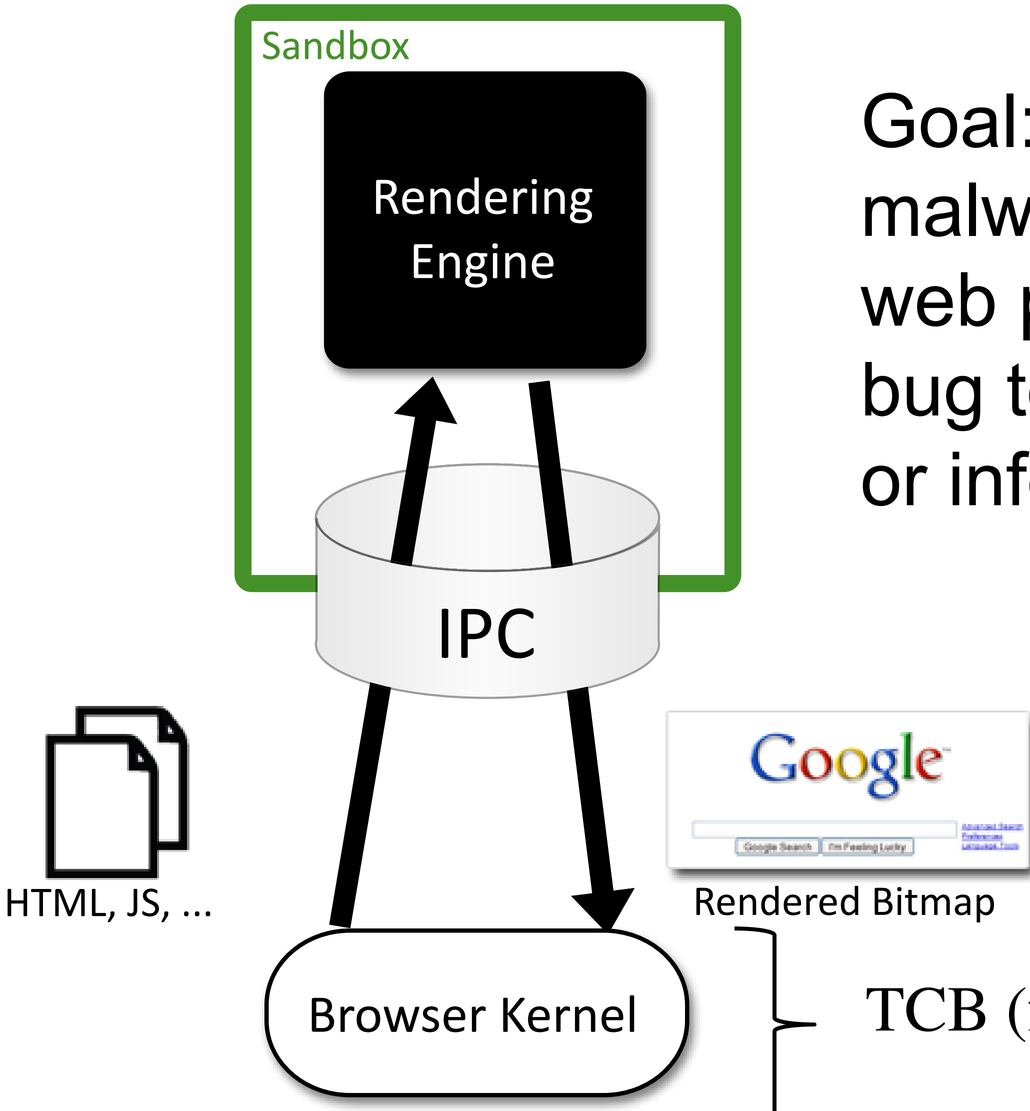
The Chrome browser

Two pieces: rendering engine and browser kernel

Rendering engine:
- Interprets HTML and turns it into bitmap image to display on screen
- Most bugs are here so it is ran inside a sandbox
- Sandbox isolates the engine from the rest of the system, including files,and allows only narrow API to the outside

Browser kernel:
- Mediates all access to the file system

The Chrome browser

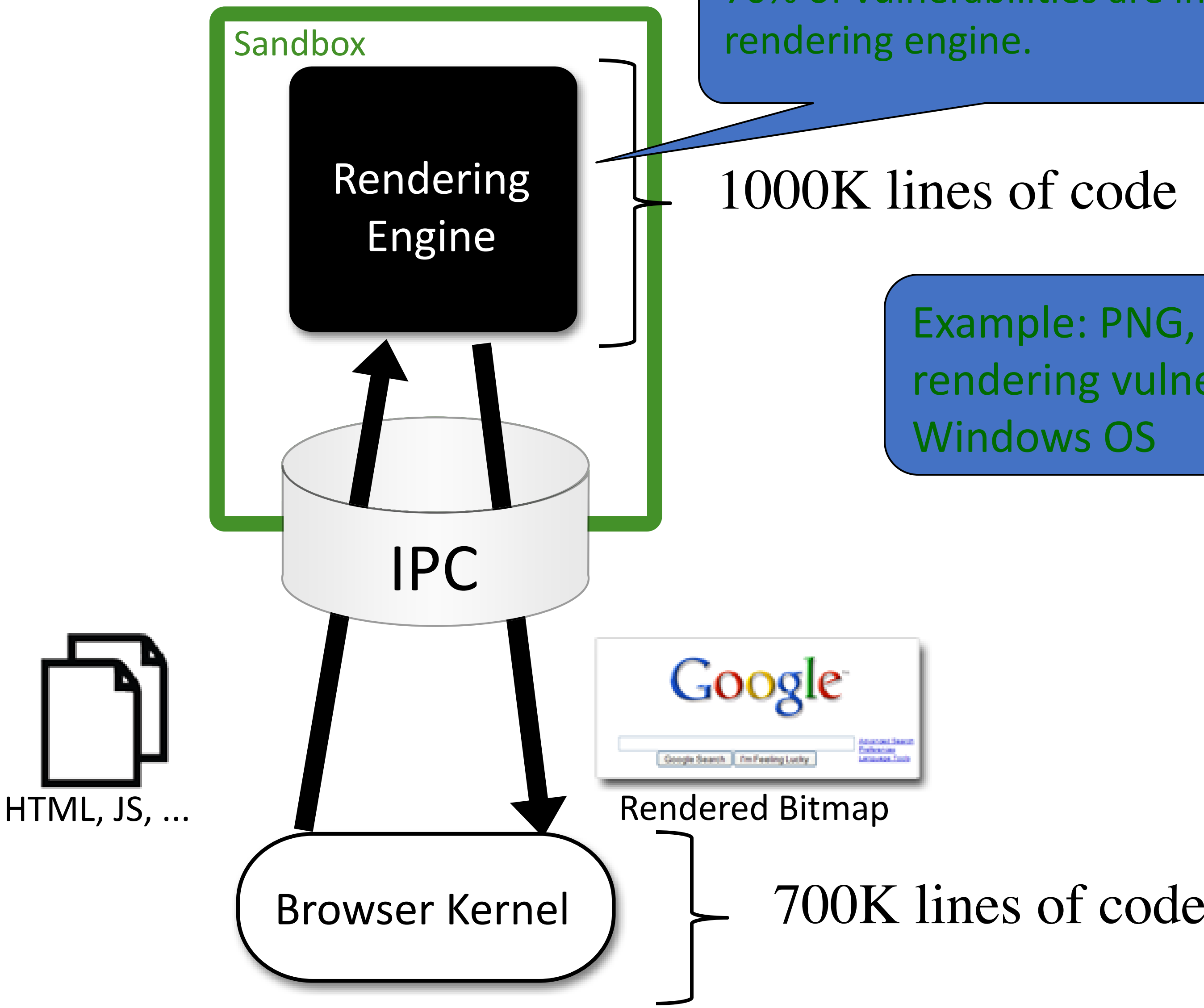


Goal: prevent "drive-by malware", where a malicious web page exploits a browser bug to read/write local files or infect them with a virus

TCB (for this property)

The Chrome browser

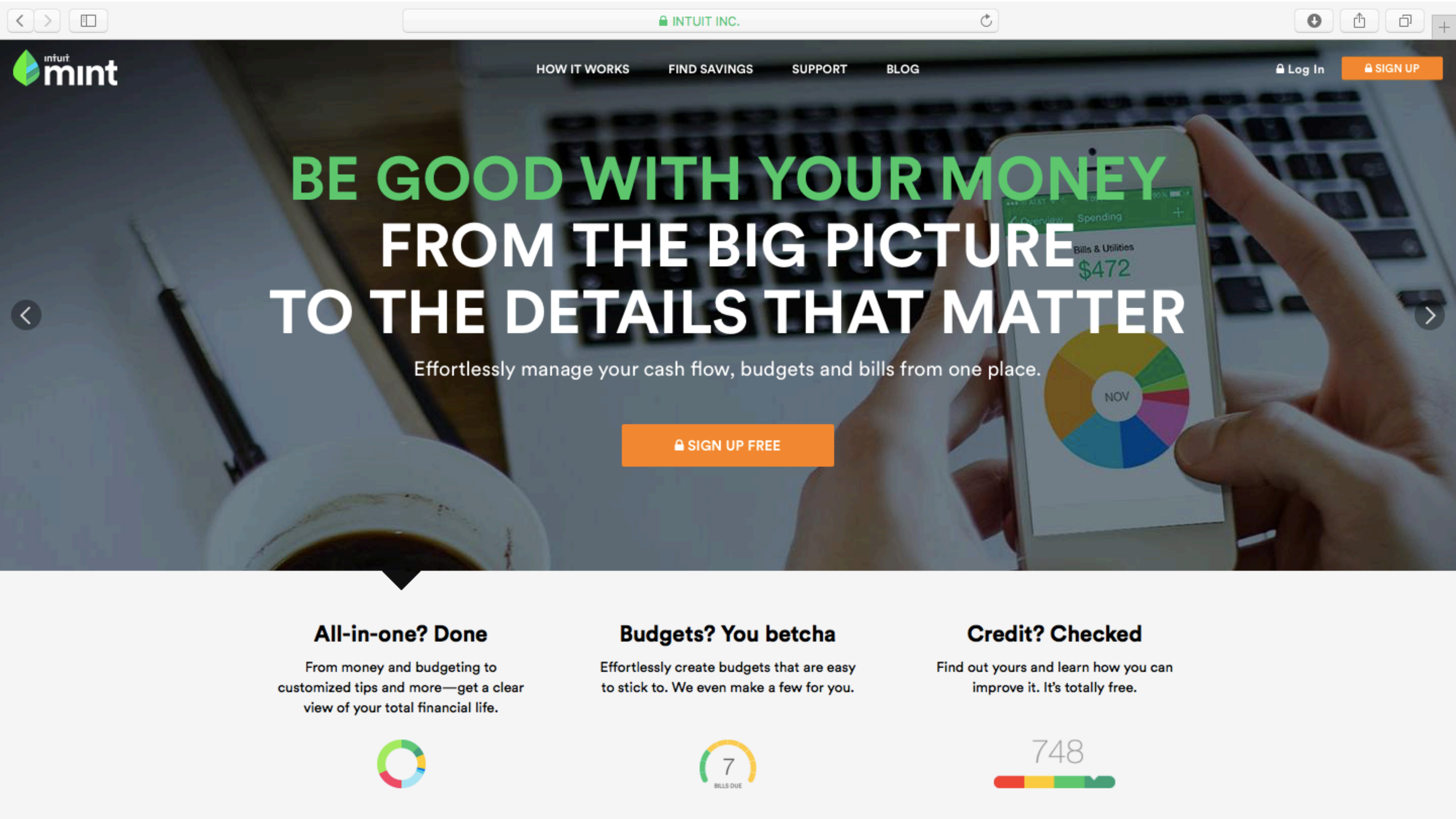
70% of vulnerabilities are in the rendering engine.



Example: PNG, WMF, GDI+ rendering vulnerabilities in Windows OS

Benefit of Secure Design

Browser	Known unpatched vulnerabilities					
	Secunia					SecurityFocus
	Extremely critical (number / oldest)	Highly critical (number / oldest)	Moderately critical (number / oldest)	Less critical (number / oldest)	Not critical (number / oldest)	Total (number / oldest)
Internet Explorer 6	0	0	4 17 November 2004	8 27 February 2004	12 5 June 2003	534 20 November 2000
Internet Explorer 7	0	0	1 30 October 2006	4 6 June 2006	10 5 June 2003	213 15 August 2006
Internet Explorer 8	0	0	0	1 26 February 2007	8 5 June 2003	123 14 January 2009
Internet Explorer 9	0	0	0	0	2 6 December 2011	26 5 March 2011
Firefox 3.6	0	0	0	0	0	1 20 December 2011
Firefox 38	0	0	0	0	0	0
Google Chrome 42	0	0	0	0	0	0
Opera 11	0	0	0	0	1 6 December 2011	2 6 December 2011
Safari 5	0	0	0	1 8 June 2010	0	2 13 December 2011


INTUIT INC.
intuit mint
HOW IT WORKS
FIND SAVINGS
SUPPORT
BLOG
Log In
SIGN UP
BE GOOD WITH YOUR MONEY
FROM THE BIG PICTURE
TO THE DETAILS THAT MATTER
Effortlessly manage your cash flow, budgets and bills from one place.
SIGN UP FREE
Spending
Bills & Utilities
$472
NOV
All-in-one? Done
From money and budgeting to customized tips and more—get a clear view of your total financial life.
Budgets? You betcha
Effortlessly create budgets that are easy to stick to. We even make a few for you.
Credit? Checked
Find out yours and learn how you can improve it. It's totally free.
7
BILLS DUE
748

Discuss with a partner

- How would you architect mint.com to reduce the likelihood of a catastrophic security breach?
  - E.g., where attacker steals all users' stored passwords or empties out all their bank accounts overnight

Summary

- Access control is a key part of security.
- Privilege separation makes systems more robust: it helps reduce the impact of security bugs in your code.
- Architect your system to make the TCB unbypassable, tamper-resistant, and verifiable (small).

More principles for designing more secure software

TL-15

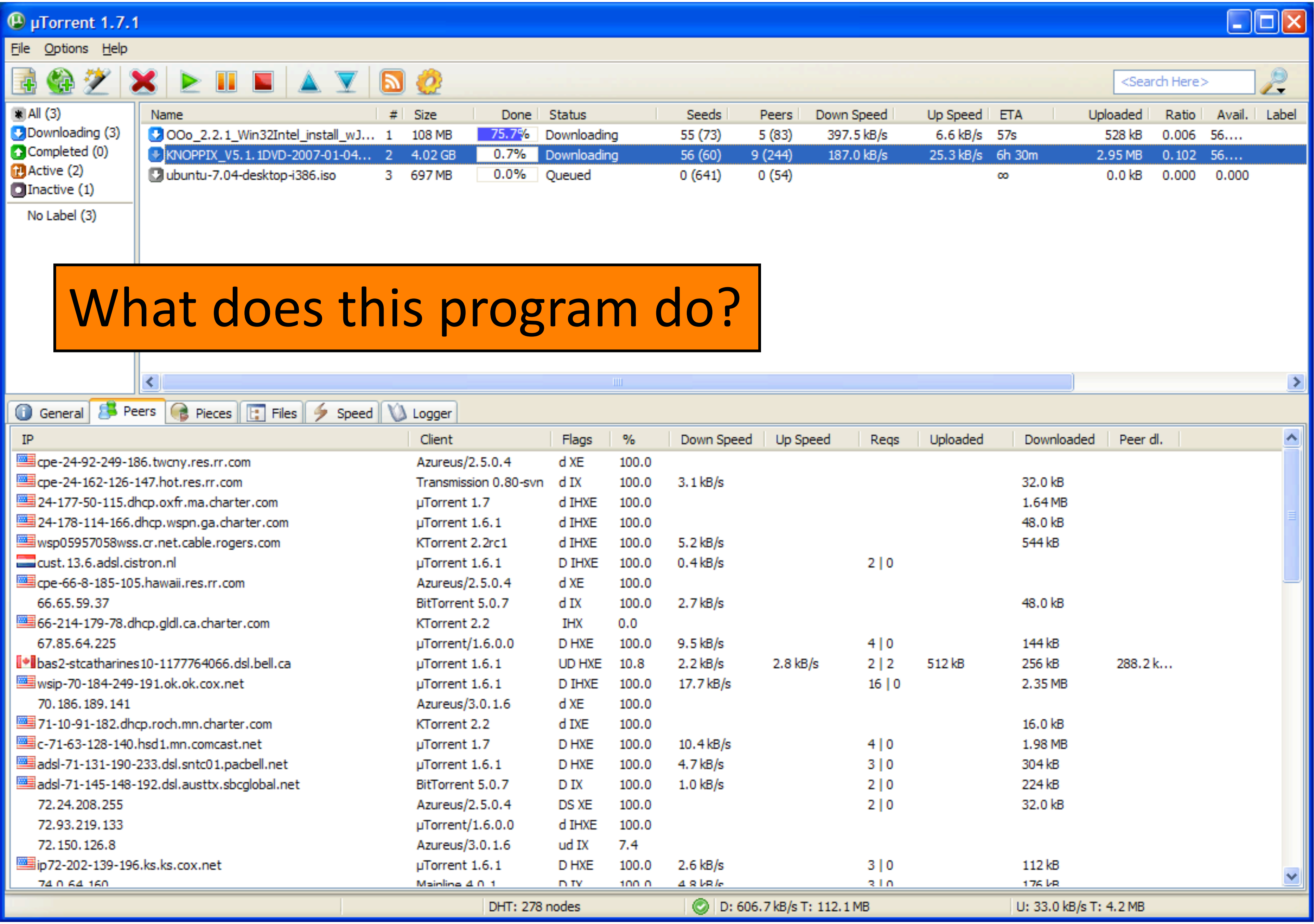
TL-30

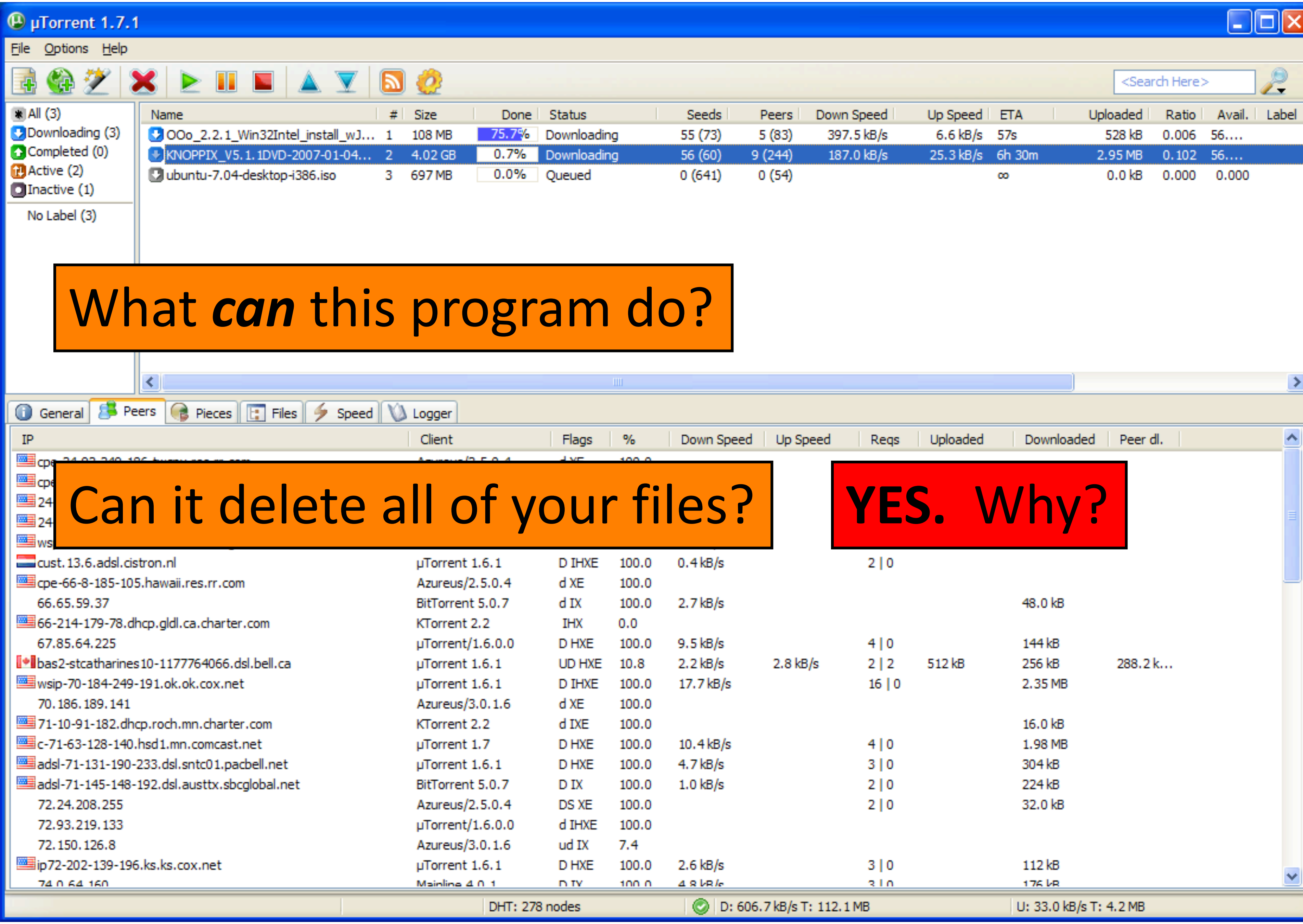
TRTL-30

TXTL-60

“Security is economics.”

What does this program do?





What *can* this program do?

Can it delete all of your files?

YES. Why?

“Least privilege.”

Touchstones for *Least Privilege*

- When assessing the security of a system's design, identify the *Trusted Computing Base* (**TCB**).
  - What components does security rely upon?
- Security requires that the TCB:
  - Is correct
  - Is complete (can't be bypassed)
  - Is itself secure (can't be tampered with)
- Best way to be assured of correctness and its security?
  - **KISS** = *Keep It Simple, Stupid!*
  - Generally, Simple = ***Small***
- One powerful design approach: privilege separation
  - Isolate privileged operations to as small a component as possible
  - (See lecture notes for more discussion)

Check for Understanding

- We've seen that PC platforms grant applications a lot of privileges
- Quiz: Name a platform that does a better job of least privilege

“Ensure complete mediation.”

Ensuring Complete Mediation

- To secure access to some capability/resource, construct a *reference monitor*
- Single point through which all access must occur
  - E.g.: a network firewall
- Desired properties:
  - Un-bypassable ("complete mediation")
  - Tamper-proof (is itself secure)
  - Verifiable (correct)
  - (Note, just restatements of what we want for TCBs)
- One subtle form of reference monitor flaw concerns *race conditions* …

TOCTTOU Vulnerability

```
procedure withdrawal(w)
   // contact central server to get balance
   1. let b := balance

   2. if b < w, abort
```

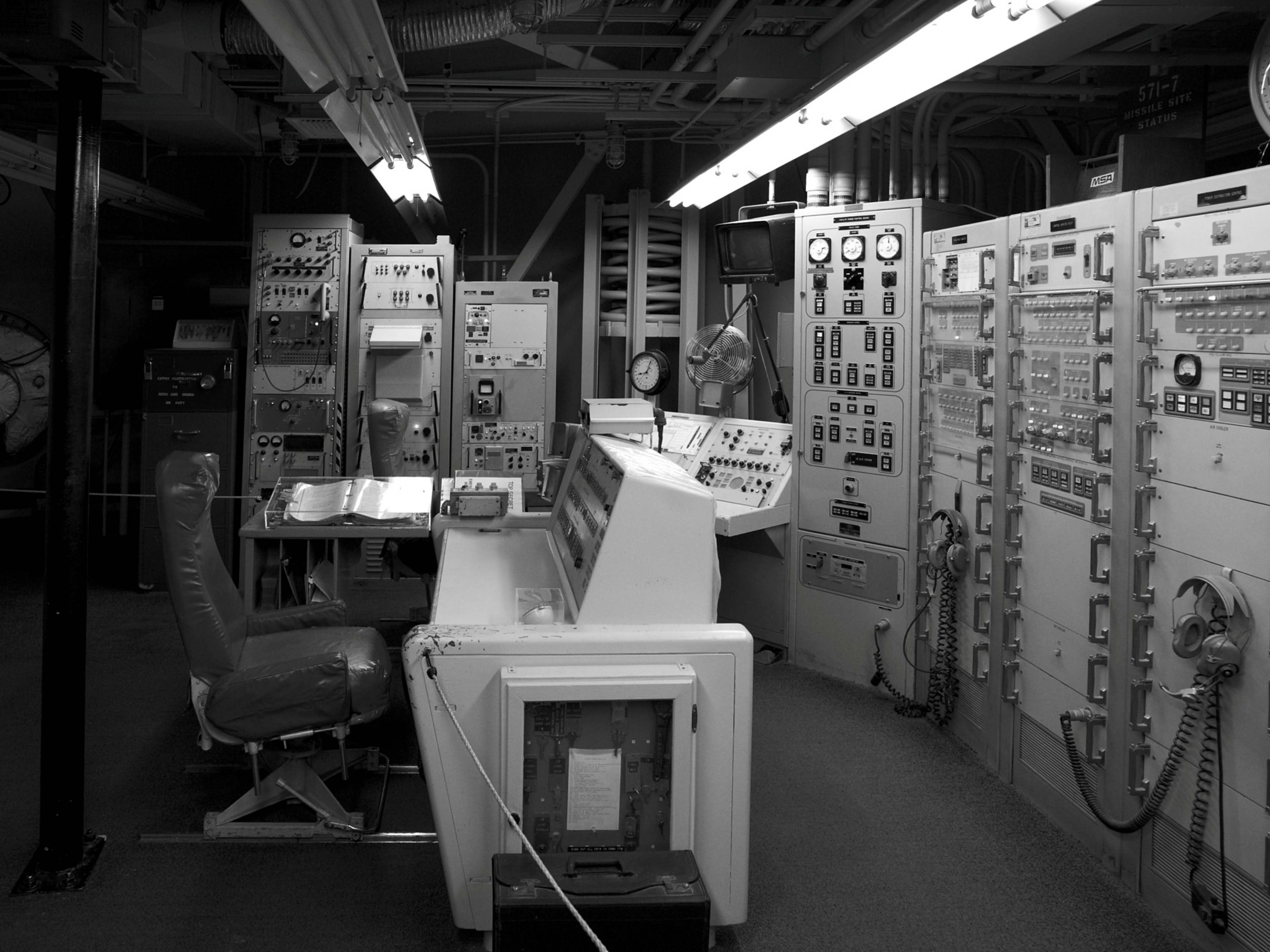
Balance could have decreased at this point due to another action

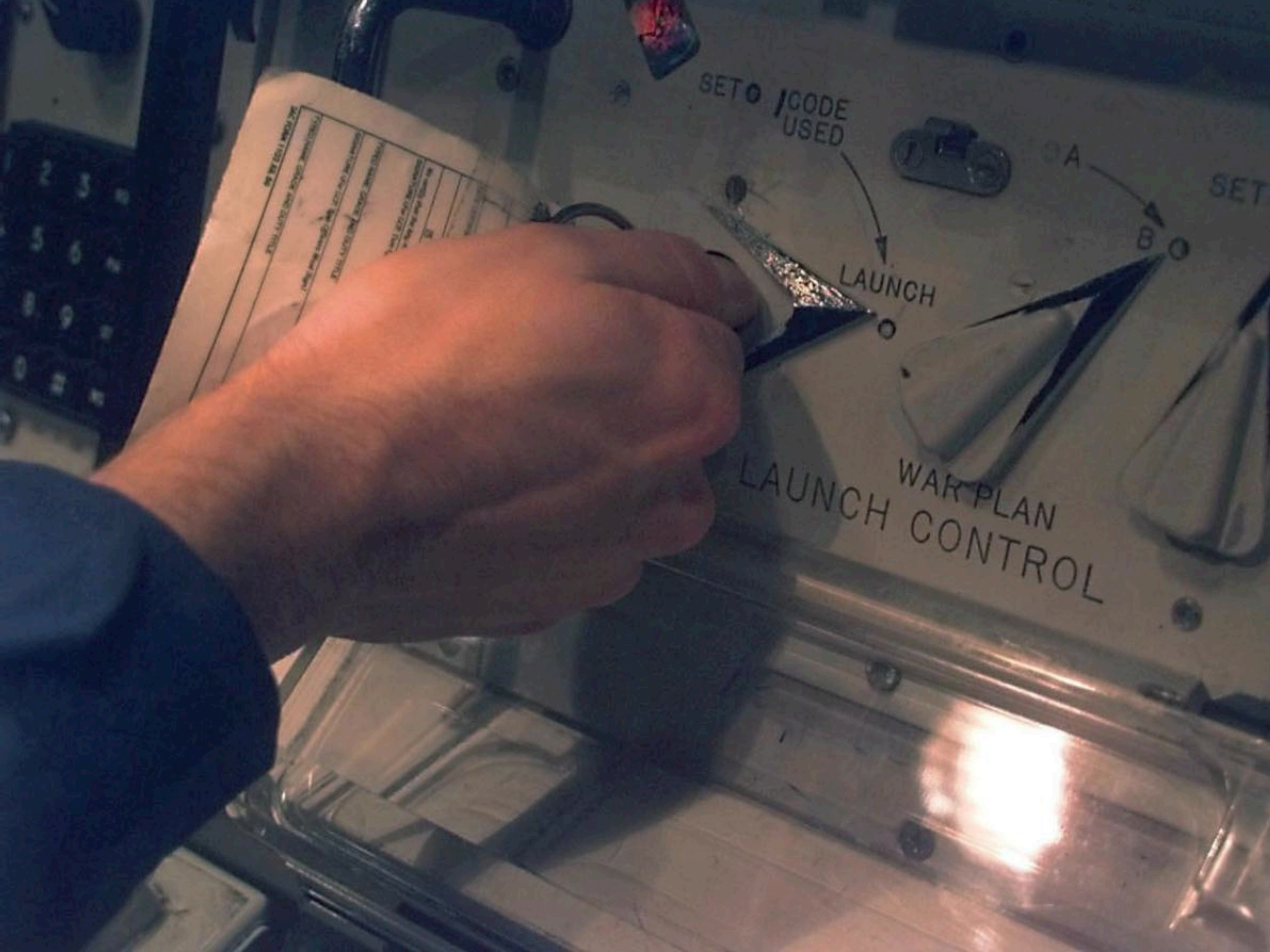
```
   // contact server to set balance
   3. set balance := b - w

   4. dispense $w to user
```

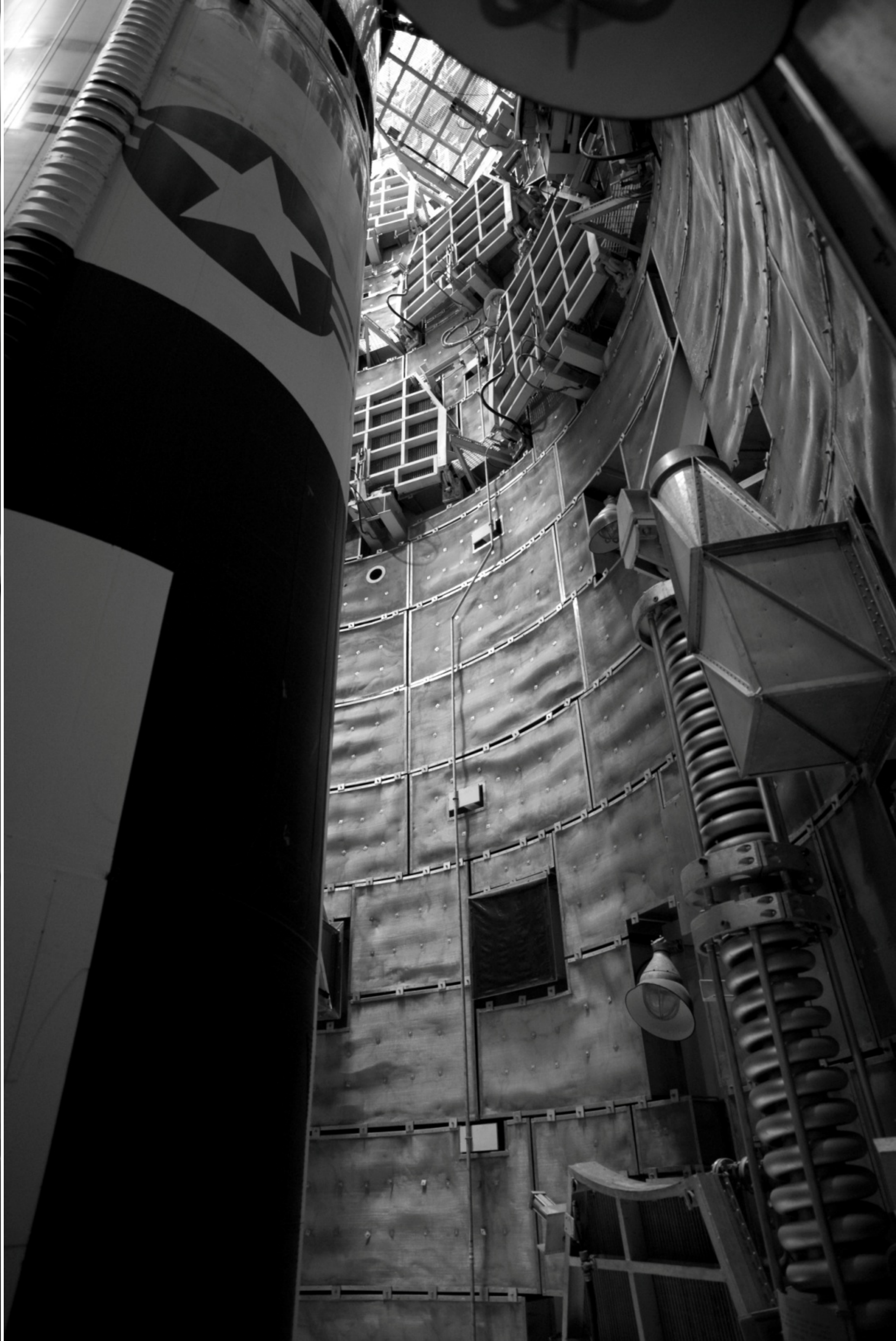
TOCTTOU = Time of Check To Time of Use

```
public void buyItem(Account buyer, Item item) {
   if (item.cost > buyer.balance)
     return;
   buyer.possessions.put(item);
   buyer.possessionsUpdated();
   buyer.balance -= item.cost;
   buyer.balanceUpdated();
 }
```


571-7
MISSILE SITE
STATUS
MSA
TOP SECRET


SET
CODE USED
LAUNCH
A
B
SET
WAR PLAN
LAUNCH CONTROL


NO LONE ZONE
SAC TWO MAN POLICY
MANDATORY
CAUTION
DO NOT KEY RTMX IN L/D
EXCEPT IN CASE OF AN
EMERGENCY-MUST BE AT
LEAST 5FT FROM MSL.
E-F-G



“Division of trust.”

- reduce the trust in each party


California
THE IDES OF MARCH
THE RUM DIARY
PARANORMAL ACTVITY 3