Security Analysis II

Analyzing Systems

- When presented with a system, how do you know it's secure?

- Often, you're called upon to analyze a system you didn't design —
  application architects and programmers build it; security people get to
  pick up the pieces. . .

- It's better to build security in from the start, but that doesn't happen
  nearly as often as it should

When to Analyze

- The earlier, the better

- Some design decisions are very hard to correct later on

- Better yet, have frequent reviews

- Early reviews concentrate on the broad architecture; later reviews can look at the pieces

Types of Analysis

- Individual programs

- Overall system flow

- Usually, a faulty program means a faulty system, but sometimes faults are containable

Individual Programs

- Look for typical errors: buffer overflow, race conditions, etc.

- Not as easy as it sounds — buffer sizes not always obvious:

```
void buildmsg(char *dst, char *s, char *msg)
{
        sprintf(dst, "Error: %s: %s\n", s, msg);
        return;
}
```

Which Programs to Check?

- Only check security-sensitive programs

- Which are those?

- Invoking `date` can be — how much output does it produce?

  ```
  $ date
  Mon Nov 17 21:51:03 EST 2008
  $ TZ=/usr/share/zoneinfo/Pacific/Guam date
  Tue Nov 18 12:51:11 ChST 2008
  $ TZ=/usr/share/zoneinfo/Pacific/Tahiti date
  Mon Nov 17 16:51:20 TAHT 2008
  ```

- Time zones aren't always 3 capital letters... (and remember the International Date Line)

- Also note: the *invoker* controls the time zone and hence the length

Another Lesson About Testing

- Blind testing, even in multiple time zones, wouldn't have found it

- Example: EEST — Eastern European Summer Time — applies during the summer

- Other time zones are in effect only during certain years

- You can write test cases if and only if you know there's something to test for

- What is the length of a time zone? At least three characters; maximum length is not specified

What To Look For

- Dangerous or potentially functions, i.e., `gets()`, `strcpy()`, `sprintf()`, etc.

- TOCTTOU races — look for `access()`, `stat()` instead of `fstat()`, etc.

- Trusting user input

This Isn't Easy!

- First step — `grep` for suspect functions

- Each hit requires investigation — and a large program will have hundreds of hits

- Most are obviously and trivially ok

- Most of the rest are ok anyway — but not obviously, and not trivially

Why is it Hard?

- Subprocedures make life difficult for the analyst

- Most routines are called from many different places, with different arguments

- The arguments passed may themselves be arguments from a higher-level procedure

- Buffers may be dynamically allocated, and of uncertain length

Flow Analysis

- We need to understand the *paths* to each suspect call

- Compilers already do that, albeit intra-module

- We can use compiler technology to help us understand complex paths

A Call Graph

```
$ cflow env/*.c
main() <int main (int argc,char **argv) at env/env.c:55>:
    setlocale()
    getopt()
    usage() <void usage (void) at env/env.c:94>:
        fprintf()
        exit()
    strchr()
    setenv()
    execvp()
    err()
    printf()
    exit()
```

A Graphical Call Graph via Cflow
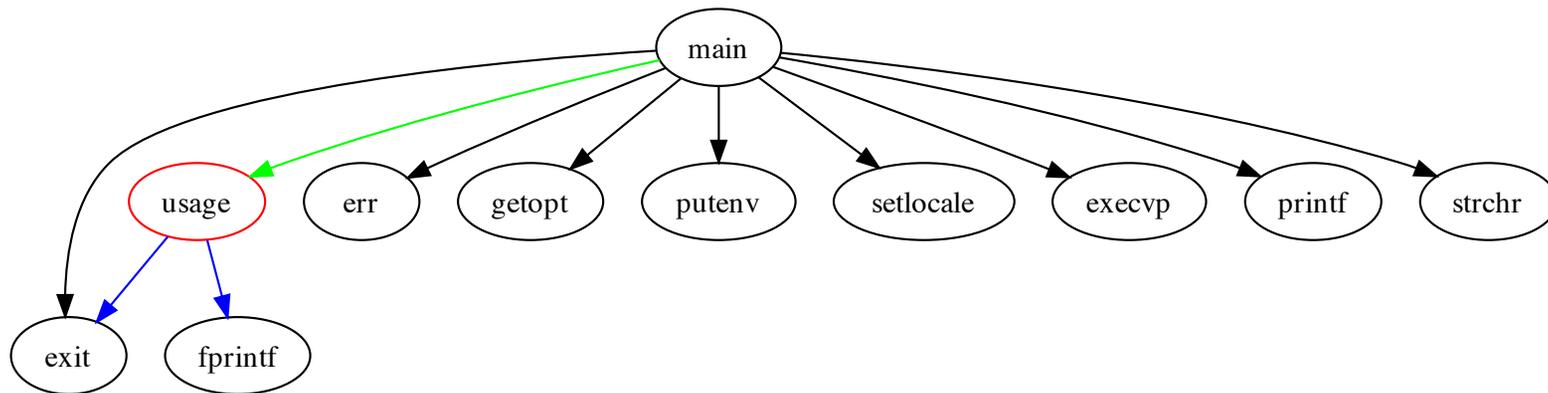
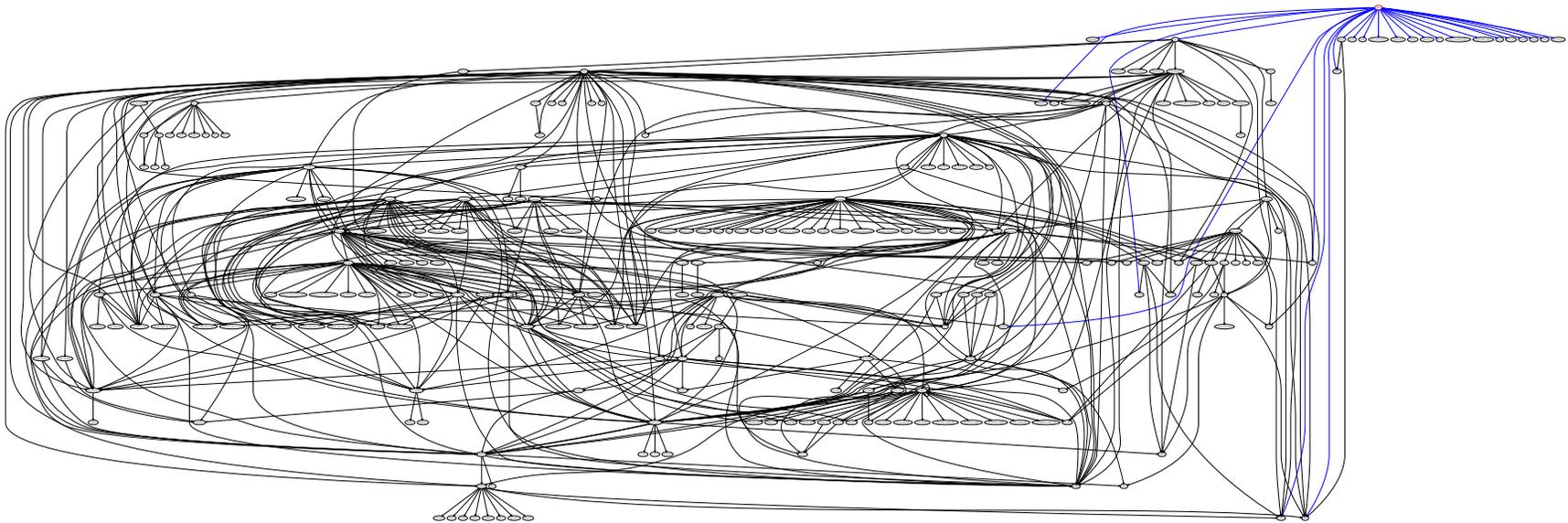# A Partial Reverse Call Graph

```
$ cflow --reverse env/*.c
err():
    main() <int main (int argc,char **argv) at env/env.c:55>
execvp():
    main() <int main (int argc,char **argv) at env/env.c:55>
exit():
    main() <int main (int argc,char **argv) at env/env.c:55>
    usage() <void usage (void) at env/env.c:94>:
        main() <int main (int argc,char **argv) at env/env.c:
fprintf():
    usage() <void usage (void) at env/env.c:94>:
        main() <int main (int argc,char **argv) at env/env.c:
```

Simple Tools Don't Always Work

Data Flow Analysis

```
int i=1, j=2, *pi;
pi = subr(&i, &j);
printf("%d", *pi);                    /* What will be printed? */
...
int *subr(int *v1, int *v2)
{
    int m;
    scanf("%d", &m);
    if (m > 0) return v1;
    else return v2;
}
```

Is This Analysis Necessary?

- If it's very hard to understand, perhaps the programmer got it wrong, too

- There is little downside to using safe functions if there is any doubt at all

- There may be a slight performance hit — but the hit tends to be localized, and most sections of code are a very small part of total *system* performance

A Word on Performance

- System performance is usually a property of the system, not any single component

- Most code is not performance-sensitive: it isn't executed at all, or it is executed only rarely

- Programmers' guesses about bottlenecks are rarely correct

- Major performance improvements generally come from algorithmic changes, not from minor tweaks

- Build first, then measure, then optimize — but don't surrender correctness

TOCTTOU is Harder

- Race conditions are generally part of multi-statement sequences

- Necessary to look for patterns — much more difficult

- Note: `grep` can only point to functions that are frequently involved in race conditions

We Need Tools

- Simple tools such as `grep` are just a starting point

- Custom-built tools can do a better job

- The benefit of tools is that they reduce the search space — they eliminate the many false alarms that `grep` will produce

Inappropriate Trust

- Some scans are relatively easy

- Example: look at `fopen()` calls and see if the input ultimately came from untrusted data

- The trick is knowing the sensitive destinations; depending on the program, it may or may not be easy

Digression: Run-Time Checks

- Sometimes, it's easier to do the checks at run-time

- Best example: Perl's "taint mode"

- Data from untrustworthy sources — command-line arguments, environment variables, file input, etc. — is marked as "tainted"

- Any variable derived from a tainted variable is marked "tainted"

- Certain operations cannot be performed with tainted input; a run-time exception is generated

- You can produce untainted variables by a regular expression memory reference; Perl assumes that you know what you're doing

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Other Checks

- See how user inputs are read

- Is the data examined and, if necessary, rejected immediately?

- Are fixed-length buffers used or is **malloc()** called?

- The declaration

```
char buf[1024];
```

  is a danger flag

- For C++, is **String** used?

Analyzing Systems

- Both easier and harder

- Easier, because there are fewer components than lines of code

- Harder, because many of the details are abstracted away

Overall Flow

- Identify the separate system elements

- Identify the data flows

- Look for security barriers

- Look for untrusted inputs

System Elements

- System elements are things like web servers, database engines, etc.

- Each of these is itself a complex system that needs to be analyzed

- Establish the properties of each element: where its inputs come from, what its outputs are, what can happen if something is corrupted

Protecting Elements

- What are the forms of access?

- What sorts of access controls are there?

- What is logged? To where? (Who looks at the logs?)

Data Flows

- Who talks to whom?

- How do they talk?

- Is the link exposed to the outside? Is it encrypted? Authenticated?

- Is the protocol otherwise safe?

Security Barriers

- Do they block all attack vectors?

- Are they strong enough?

- Are they flexible enough?

Input Filtering

- Where can enemy input enter the entire *system*?

- Is it properly checked?

- What about back channels, such as DNS?

System Management

- How will the elements be managed?

- Is more connectivity needed?

- Are other network services used?

- How do system management functions authenticate themselves?

Backups

- How are disks backed up?

- Again, is more connectivity needed?

- How are the backup media protected?

Drilling Down

- Is there other connectivity, such as to the organization?

- If there isn't now, might there be in the future? (The answer to that one is usually "yes"...) What provisions are made for such connectivity?

- What parts of the design seem more vulnerable?

Weak Spots

- What parts of the design seem problematic?

- Some pieces are weaker than others

- Experience counts here — "trust your feelings, Luke"

Weak Spots: Web Server

- Web servers are quite complex

- CGI or ASP scripts are often locally written, and may have received less scrutiny

- How is the web server checked for intrusions?

- What are the consequences if it falls?

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Outcomes of a Review

- All is cool (don't be afraid to say so, but it rarely happens...)

- A few fixable flaws

- Serious, unfixable problems

- Not deployable

Serious, Unfixable Problems

- There may be flaws that can't easily be fixed

- Example: a piece of vital third-party software that does stupid things

- Can you layer on something else to provide necessary protection?

- Example: to protect a vendor product that used plaintext passwords, you could add firewalls or a VPN

Not Deployable

- Sometimes, that's the right answer

- However — how important is the project?

- What is the *business* cost of not deploying it?

- It's important to be both honest and realistic — and that's a delicate balancing act

Software Engineering Code of Ethics

1. PUBLIC - Software engineers shall act consistently with the public interest.

2. CLIENT AND EMPLOYER - Software engineers shall act in a manner that is in the best interests of their client and employer consistent with the public interest.

3. PRODUCT - Software engineers shall ensure that their products and related modifications meet the highest professional standards possible.

4. JUDGMENT - Software engineers shall maintain integrity and independence in their professional judgment.

. . .

(See `http://www.acm.org/serving/se/code.htm` for the rest.)

Making "No" Stick

- Be prepared to back up your assessment

- Demonstrate *exactly* how an enemy could get in

- Estimate the likelihood of the attack

- Estimate the *business* loss if it happens

- If you can't do that, it's more likely the previous category

Bad Excuses You'll Hear

- It's closed source; no one knows how it works

  ☞ It's a lot easier to figure such things out than it appears to those who have never done it

  ☞ What about corrupt insiders?

- Who'd attack us?

  ☞ Some people will attack anything

- No one would try that

  ☞ Some people will try anything

Making Recommendations

- This is often a political process

- Concrete suggestions for improvement are better than "this rots"

- Suggestions should be realistic in terms of cost, benefit, and business situation

- Security is *engineering*; it's not an absolute goal to be pursued at any cost

- There are always legacy systems you can't touch