Design of Secure Software

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“In computer security, paranoia is a good place to start.”
An Example

The Berkeley ‘lpr’ command has a –r flag that tells the lpr command to remove the file after printing. The lpr command used to run with super user privileges.

```c
int rflag;  /* -r: remove file after printing */
if (rflag) {
    if ((cp = strrchr(file, '/')) == NULL) {
        if (access(".", 2) == 0) return(1);
    } else {
        if (cp == file) fd = access("/", 2);
        else {
            *cp = '\0'; fd = access(file, 2); *cp = '/';
        }
        if (fd == 0) return(1);
    }
    printf("%s: %s: is not removable by you\n", name, file);
    return(0);
}
```
Is There a Problem?

Is there a problem with this code? (of course there is, otherwise it wouldn’t be on this slide :-)

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There is obviously some time between the check and the action...
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What if the code comes to the conclusion that *is* removable by you?...

There is obviously some time between the check and the action. . .

When the code issues the unlink system call that removes the file, the assumption need not be valid anymore!

An automated attack can be mounted
## Attacking lpr

<table>
<thead>
<tr>
<th>lpr code</th>
<th>assumption</th>
<th>attack code</th>
</tr>
</thead>
<tbody>
<tr>
<td>access(file)</td>
<td>access check valid</td>
<td>mkdir temp</td>
</tr>
<tr>
<td>open(file)</td>
<td></td>
<td>touch temp/passwd</td>
</tr>
<tr>
<td></td>
<td></td>
<td>lpr -r temp/passwd</td>
</tr>
<tr>
<td>unlink(file)</td>
<td>access check still valid</td>
<td>mv temp temp1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ln -s /etc temp</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Password file removed!</td>
</tr>
</tbody>
</table>

The window between the check and the action is small. However, with a computer, we can mount repeated attacks until one succeeds.

The developer must close *all* holes, the attacker only needs to find *one*. 
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We will tackle the problem of constructing secure software by viewing software with an attacker’s eye.
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This is *not* a course on cracking!
Structure

The lectures in this course fall in one of two classes:

• a lecture in which you get a narrow but deep understanding of some of the technical aspects of computer security, the attacks that can be mounted against insecure systems and how to defend against them; and

• a lecture in which you learn to apply this knowledge to the design of better systems, systems that are secure by design.

These lectures won’t be clearly separated; instead, there might be a “techniques” lecture next to a “design” lecture. Sometimes, a single lecture has both aspects. It is hoped that this won’t leave you all mixed up!
Overview

The lectures will cover these topics, not necessarily in this order:

• Software Design as Risk Management
• Buffer Overflows
• Time of Check, Time of Use (TOCTOU)
• Randomness
• Cryptography
• Password Management
• Authentication Protocols
• Input Validation
• Secure Coding Best Practices
Today’s Special

• Software Design as Risk Management
• What is Security Anyway?
• Security and Software Engineering
• Other Threats: Social Engineering
• Other Aspects of Security: Physical Security
Software Design as Risk Management

There are many things that can go terribly wrong while building software systems (secure or not)

About 50% of all software projects are never completed

Of those that are completed, many are late and over budget

The design of any software system is (among other things) an exercise in risk management

Risk management tries to identify the things that can go wrong before they happen so that the decision-makers are prepared if they happen
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I: Integrity. Information is protected against unauthorized changes that are not detectable by authorized users.

A: Authentication or Availability. Users are who they claim to be. Resources are accessible by authorized parties. For example, Denial-of-Service (DoS) attacks disrupt a service’s availability.
Grafting Security on Later

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You therefore must consider security in all phases of software development
**Software Lifecycle: Requirements**

What needs to be protected *from whom* and *for how long*?

Bad requirement: “The product should use cryptography whenever possible.” ⇒ solution without problem

Good requirement: “Credit card numbers must be protected against eavesdropping for the duration of the session because they are sensitive information.”

“The product must be at least as secure as the competition” is OK, provided that the requirement can be objectively validated (e.g., use standardized security guidelines).

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Without a specification, a system can never be wrong, only surprising!
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For each risk:

Step 1: Identify and name the risk

Step 2: Assign probability \( p \) estimate that risk will occur

Step 3: Estimate cost \( o \) if risk occurs

Step 4: Estimate cost \( m \) to mitigate risk

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Rank risks in order of decreasing severity, if its mitigation cost is less than the occurrence cost

If the risk is a deliberate attack, the probability $p$ should also reflect the cost of mounting that attack
Lifecycle: Risk Assessment (2)

Fixing a security bug under pressure is itself risky since there is usually no time to run all the regression tests (Microsoft Windows regression tests take about a week to run).

Risks tend to pop up during software development and in general cannot be specified comprehensively in advance.

Risk assessment should be done by impartial outsiders.
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Only after risks are ranked does testing become possible
Lifecycle: Risk Assessment (3)

Risk types:

• attacks, which are deliberate attempts to circumvent CIA
• accidents, acts of God or other uninsurable events: war, floods, storms, the cleaning woman unplugging the main server room because she needs the wall socket for her vacuum cleaner, the camera man who accidentally stumbles against the emergency stop button (happened to me!) etc.
• programming mistakes causing program crashes, which threaten a system’s CIA
Designing for Security

- What data flows through which components? Does that data need to be secured?
- Who uses the system in what roles? What rights do the roles have?
- Which components trust which other components? Can we modify the design to eliminate the need for trust?
Implementation

That’s the scope of the rest of this lecture :-(
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- Concurrent systems are essentially not verifiable.
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- Probes the system like an attacker would
- Should be directed by risks identified during system analysis
- Use coverage: if a piece of code was never exercised during testing, it is immediately suspect
Tradeoffs (1)

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Black box testing is cheap, but not as effective as white-box testing because there is nothing to be gained from not knowing the internals of the system under test.

Tiger Team testing is also often ineffective, because results are inconclusive (“the team found no flaws; now what does that mean”) and usually does not take long enough to find any bugs.
Common Criteria (CC)

U.S. Government-approved standard for design and evaluation of (all kinds of) security-critical systems (including software), grew from DoD and NSA’s “Orange Book”, 1985

- Stakeholders define a *protection profile*;
- profile is evaluated according to the CC to ensure consistency and completeness;
- vendors produce products according to profile
- accredited evaluation labs evaluate product according to profile

“Canadian Trusted Computer Products Evaluation Criteria”

EU: “Information Technology Security Evaluation Criteria” (ITSEC)
"[N]ewer efforts such as the Common Criteria (CC) have taken this flexibility-at-any-cost approach to a whole new level so that a vendor can do practically anything and still claim enough CC compliance to assuage the customer.

One problem with the CC is that it’s so vague—it even has a built-in metalanguage to help users try and describe what they are trying to achieve [these are the protection profiles, ed.]—that it is difficult to make any precise statement about it, which is why it isn’t mentioned in this work except to say that everything presented herein is bound to be compliant with some protection profile or other.” — Peter Gutmann
Secure Software Design

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...and there is no silver bullet!
Social Engineering

Security is *not* a purely (or particularly) technical matter. Kevin Mitnick was touted as the most dangerous computer criminal by the FBI while he was on the run. He broke into several highly sensitive systems mostly by social engineering, not hacking. He was eventually caught in February 1995. The authorities were so afraid of his social engineering skills that they forbade him the use of a telephone while in jail.
Social Engineering: Example

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Later, I pass myself off as another employee and call Michael in R&D in the same company. After some small talk:
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**Me:** “By the way Michael, just before Tom Smith went on vacation, he asked me to review the new design. I just talked with Robert Jones and he said you should just fax it to me. My fax number is 123-1234. Could you do it as soon as possible? Thanks.”
Social Engineering: Why It Works

- People want to help
- If someone appears to be lost, the *instinctive reaction is to help*, probably because we want to be liked by people
- If you don’t help, you *look like a jerk* (you can put people under pressure this way)
- If you know the *names of the people involved*, and if you *know the jargon*, people will *assume that you belong*
Social Engineering: What Can Be Done?

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Good luck (especially enforcing the policy against your own Executive Officers)!
Physical Security: Facilities

From RISKS digest Vol. 18, Issue 65, 9 December 1996:

Today I attended a meeting in a large office building of a Major Computer Company. [T]he organizer [...] was trying to find a way to lower the projection screen [...] On the wall next to the door was a push-button switch [...] The organizer [...] pressed the button. Needless to say, the screen did not descend. The ventilation fans went off, though.
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Several minutes later, a fellow poked his head in the door and asked, “Did someone touch that switch?” [...] “Yes, [...] we were trying to get the screen down.”

“Don’t touch the switch,” said the man in the door, “It turns off the computer room next door.”
Physical Security: Disk Sanitation


In August 1998, one of the authors purchased 10 used computer systems from a local computer store. The computers, most of which were three to five years old, contained all of their former owners data. One computer had been a law firm’s file server and contained privileged client attorney information. Another computer had a database used by a community organization that provided mental health services. Other disks contained numerous personal files.
More On The Scope Of This Lecture

Social engineering and neglect are IMHO two of the most important methods to get security-relevant information.

Yet, we will not cover social engineering or neglect in this course (because we are in the computer science department, and not in the social sciences).

We will focus instead on the technology of security; and even within the area of technology, we focus on the design and implementation of secure software.

The lecture therefore has a very narrow focus, which cannot hope even to scratch the surface of an area as vast as computer security.
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You have to start somewhere!
Recurring Themes
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• Plan for *defense in depth* (i.e., layered defenses): do *not* rely on silver bullets because they don’t exist
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- Plan for *defense in depth* (i.e., layered defenses): do *not* rely on silver bullets because they don’t exist
- Think like a paranoiac
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• Think like a blackhat
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- Think like a paranoiac
- Think like a blackhat
- Don’t believe in silver bullets
Summary

- Software Design as Risk Management
- What is Security Anyway?
- Security and Software Engineering: Requirements, The need for specifications, Risk Assessment and Ranking, Testing in its various forms
- Other Threats: Social Engineering
- Other Aspects of Security: Physical Security
Resources: The Web

- RISKS digest: http://catless.ncl.ac.uk/Risks/
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- SecurityFocus: http://www.securityfocus.com/
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- Link Farm: http://www.cs.auckland.ac.nz/~pgut001/
- Link Farm: http://www.st.cs.uni-sb.de/~neuhaus/
**Resources: The Web**

- RISKS digest: [http://catless.ncl.ac.uk/Risks/](http://catless.ncl.ac.uk/Risks/)
- Link Farm: [http://www.st.cs.uni-sb.de/~neuhaus/](http://www.st.cs.uni-sb.de/~neuhaus/)
- IEEE Security & Privacy
Resources: The Web

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- Bugtraq, a mailing list hosted by SecurityFocus, http://www.securityfocus.com/
- Link Farm: http://www.cs.auckland.ac.nz/~pgut001/
- Link Farm: http://www.st.cs.uni-sb.de/~neuhaus/
- IEEE Security & Privacy
- Usenix Security: http://www.usenix.org/events/sec03
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Resources: Books

- Viega, McGraw, *Building Secure Software*, Addison-Wesley
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- Peter Gutmann, *Cryptographic Security Architecture, Design and Verification*, Springer
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Full book details available from my link farm or from the lecture web page.