Cyber Security

Operating System Security & Access Control

Dr Chris Willcocks

Lecture Content

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- Access Control
  - ACMs
  - ACLs
- Introduction to *NIX security - we'll cover this more due to server popularity (where most commercial assets are) - nearly all big server farms are *NIX based
  - https://www.exploit-db.com/search?platform=linux
- Briefly on Windows security:
  - https://www.exploit-db.com/search?platform=windows
- Confidentiality models
- Integrity models
- Briefly on security evaluation
- Protection rings

Access Control

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- Your computer contains lots of **subjects** (typically users, people) and lots of **objects** (typically documents, images, programs).
- Who chooses access rights?
  - The file owner?
    - Mandatory access control (MAC)
  - The system owner?
    - Discretionary access control (DAC)
  - Anyone who has rights
- What/how/where do we store access permissions?
  - Multiple approaches

Access Control Matrix (ACM)

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+ Easy to define, easy to verify
- Poor scalability, poor handling of changes, could get corrupted.

Objects

Subjects	**bill.doc**	**readme.txt**	**edit.exe**	**func.sh**
Alice	-	*{read}*	*{execute}*	*{execute, read}*
Chris	*{read, append}*	*{read}*	*{execute, read, write}*	*{execute}*
Greg	-	*{read}*	*{execute, write}*	-
Jess	*{read}*	*{read, write}*	-	-

Access Permissions

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*NIX has 8 access permission settings for 3 types of users:

- Owners, Groups, and Others
- Combination of read (r), write (w), and execute (x)
- Represented as numbers in base 8

```
---  all types of access denied
--x  execute access only
-w-  write access only
-wx  write and execute only
r--  read only
r-x  read and execute only
rw-  read and write access only
rwx  everything allowed
```

*NIX Permissions

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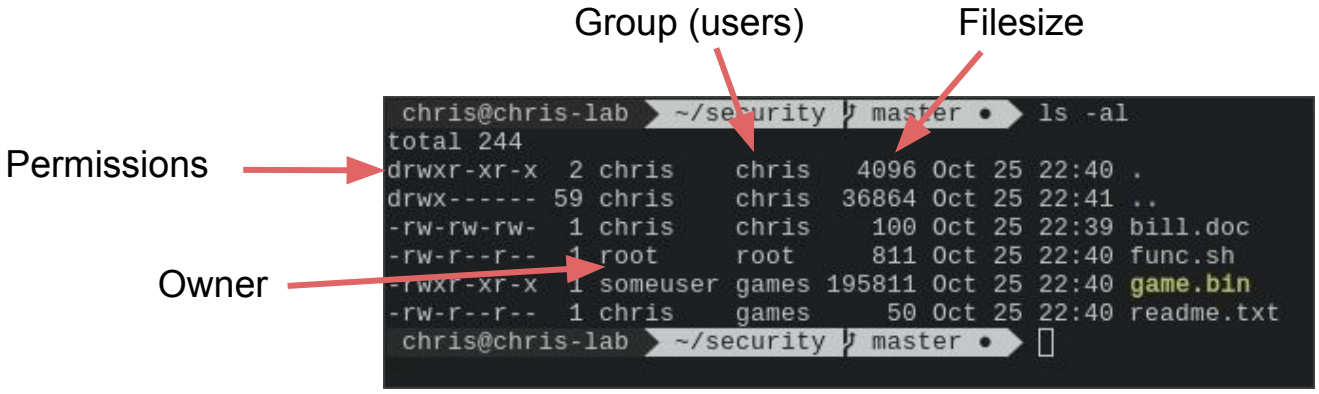

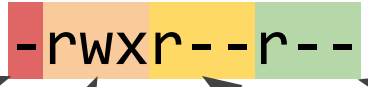

Resource type
- file
d directory
b block device
c character device
s socket
l symbolic link
p FIFO

User rules
r read
w write
x execute

Group rules
r read
w write
x execute

Other rules
r read
w write
x execute

setuid, setgid, and sticky bits

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```
chris@chris-lab  /usr/bin  ls -al ls
-rwxr-xr-x 1 root root 133688 Sep  3 16:21 ls
chris@chris-lab  /usr/bin  ls -al sudo
-rwsr-xr-x 1 root root 132592 Sep  7 12:01 sudo
chris@chris-lab  /usr/bin
```

setuid bit: users run executable with permissions of the executable's owner

Further reading:
https://wiki.archlinux.org/index.php/File_permissions_and_attributes

Setuid hacks:
https://gist.github.com/dergachev/7916152
https://null-byte.wonderhowto.com/how-to/hack-like-pro-finding-potential-suid-sgid-vulnerabilities-linux-unix-systems-0158373/

```
chris@chris-lab  /  ls -al
total 60
drwxr-xr-x  17 root root  4096 Apr 23  2017 .
drwxr-xr-x  17 root root  4096 Apr 23  2017 ..
lrwxrwxrwx   1 root root     7 Mar 26  2017 bin -> usr/bin
drwxr-xr-x   4 root root  4096 Sep 15 16:29 boot
drwxr-xr-x  19 root root  3380 Oct 21 13:45 dev
drwxr-xr-x  78 root root  4096 Oct 21 13:45 etc
drwxr-xr-x   3 root root  4096 Feb 16  2017 home
lrwxrwxrwx   1 root root     7 Mar 26  2017 lib -> usr/lib
lrwxrwxrwx   1 root root     7 Mar 26  2017 lib64 -> usr/lib
drwx------   2 root root 16384 Feb 16  2017 lost+found
drwxr-xr-x   5 root root  4096 Oct 13 11:03 mnt
drwxr-xr-x   6 root root  4096 Oct  7 19:49 opt
dr-xr-xr-x 287 root root     0 Oct 21 13:44 proc
drwxr-x---  17 root root  4096 Oct 25 22:40 root
drwxr-xr-x  17 root root   440 Oct 21 18:51 run
lrwxrwxrwx   1 root root     7 Mar 26  2017 sbin -> usr/bin
drwxr-xr-x   4 root root  4096 Dec  5  2016 srv
dr-xr-xr-x  13 root root     0 Oct 21 13:45 sys
drwxrwxrwt  43 root root  1300 Oct 26 13:59 tmp
drwxr-xr-x  13 root root  4096 Oct 11 11:56 usr
drwxr-xr-x  12 root root  4096 Oct 21 13:45 var
chris@chris-lab  /
```

sticky bit: prevents users with write/execute permissions from deleting the directory contained files

*NIX Permissions to ACM

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```
-rw-r----- 2 chris jess    2278  13  Oct 07:40  bill.doc
-rwx-wx--x 2 chris games   340   28  Oct 01:25  game.bin
-r-x--x--- 2 alice fun     748   1   Oct 21:43  func.sh
-rw----r-- 1 jess  jess    170   1   Oct 20:34  readme.txt
```

	bill.doc	game.bin	func.sh	readme.txt
Alice	-	{execute}	{read, execute}	{read}
Chris	{read, write}	{read, write, execute}	{execute}	{read}
Greg	-	{write, execute}	-	{read}
Jess	{read}	{execute}	-	{read, write}

Groups:
fun: chris
games: greg
jess: jess

Link Vulnerabilities

- Add new path to an inode.
- Multiple names for a single inode.
- For example, to overwrite /etc/passwd:

```
ln -s /etc/passwd file
./trusted_dump file < *passwd-entry*
```

e.g. a command which can read/write root owned files, but doesn't know the file is /etc/passwd

- Programs have to be aware of which files they are using.

`O_NOFOLLOW` flag can be added to prevent following links, e.g. "`open(file, O_NOFOLLOW, mode)`"

Hardening

this slide won't be examined

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- SELinux
  - Make sure that programs only access what they're meant to
    - Hard to use in practise
- AppArmor
  - Similar/simpler to SELinux
- Slightly off-topic but will mention here:
  - ASLR
    - Randomize memory address (ret2libc)
  - PaX
    - Executable space protection

☐	apache	Allow httpd to act as a FTP server by listening on the	httpd_enable_ftp_server
☐	apache	Allow HTTPD to run SSI executables in the same dom	httpd_ssi_exec
☐	apache	Allow Apache to communicate with avahi service via (	allow_httpd_dbus_avahi
☑	apache	Allow httpd to use built in scripting (usually php)	httpd_builtin_scripting
☐	apache	Allow http daemon to send mail	httpd_can_sendmail
☐	apache	Allow httpd to access nfs file systems	httpd_use_nfs
☑	apache	Unify HTTPD to communicate with the terminal. Nee	httpd_tty_comm
☐	apache	Allow Apache to use mod_auth_pam	allow_httpd_mod_auth_ntlm_winbind
☐	apache	Allow HTTPD scripts and modules to connect to the r	httpd_can_network_connect
☑	apache	Unify HTTPD handling of all content files	httpd_unified
☐	apache	Allow apache scripts to write to public content. Dire	allow_httpd_sys_script_anon_write
☑	apache	Allow httpd to read home directories	httpd_enable_homedirs
☐	apache	Allow Apache to modify public files used for public fil	allow_httpd_anon_write
☐	apache	Allow Apache to use mod_auth_pam	allow_httpd_mod_auth_pam
☐	apache	Allow httpd to access cifs file systems	httpd_use_cifs
☑	apache	Allow httpd cgi support	httpd_enable_cgi
☐	apache	Allow HTTPD scripts and modules to network connect	httpd_can_network_connect_db
☐	apache	Allow httpd to act as a relay	httpd_can_network_relay
☐	bind	Allow BIND to write the master zone files. Generally t	named_write_master_zones
☐	cdrecord	Allow cdrecord to read various content. nfs, samba, r	cdrecord_read_content
☐	cron	Enable extra rules in the cron domain to support fcro	fcron_crond
☐	cvs	Allow cvs daemon to read shadow	allow_cvs_read_shadow
☑	domain	Allow unlabeled packets to work on system	allow_unlabeled_packets
☐	exim	Allow exim to connect to databases (postgres, mysq	exim_can_connect_db
☐	exim	Allow exim to create, read, write, and delete unprivile	exim_manage_user_files
☐	exim	Allow exim to read unprivileged user files.	exim_read_user_files
☐	ftp	Allow ftp to read and write files in the user home dire	ftp_home_dir
☐	ftp	Allow ftp servers to login to local users and read/writ	allow_ftpd_full_access
☐	ftp	Allow ftp servers to use nfs used for public file trans	allow_ftpd_use_nfs

Device File Vulnerabilities

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- Devices are represented as files
  - /dev/tty terminal
  - /dev/mem physical memory
  - /dev/kmem virtual memory
  - /dev/mouse mouse
- Created using mknod (only accessible by root)
  - Can bypass access control by getting access to memory
    - /dev/kmem or /dev/mem used to be “world” (other) accessible
- Can get access to user inputs
  - /dev/tty
    - See passwords, set keys
    - mesg n - prevents write access to current terminal

Access Control Lists (ACL)

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- Store by column (object-focused):

+ Easy to view object access control, easy to remove access rights if object removed
- Poor overview of access rights per subject, difficult to remove subject.

	bill.doc	game.bin	func.sh	readme.txt
Alice	-	{execute}	{read, execute}	{read}
Chris	{read, write}	{read, write, execute}	{execute}	{read}
Greg	-	{write, execute}	-	{read}
Jess	{read}	{execute}	-	{read, write}

ACL:

```
bill.doc      {Chris: read, write}, {Jess: read}
game.bin      {Alice: execute}, {Chris: read, write, execute},
              {Greg: write, execute}, {Jess: execute}
func.sh       {Alice: read, execute}, {Chris: execute}
readme.txt    {Alice: read}, {Chris: read}, {Greg: read},
              {Jess: read}
```

Capability-based Security

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- Store by row (subject-focused):

+ Easy to transfer ownership, easy inheritance of access rights.
- Poor overview of access rights per object, difficulty of revocation of object.

	bill.doc	game.bin	func.sh	readme.txt
Alice	-	{execute}	{read, execute}	{read}
Chris	{read, write}	{read, write, execute}	{execute}	{read}
Greg	-	{write, execute}	-	{read}
Jess	{read}	{execute}	-	{read, write}

Capabilities:

```
Alice    {game.bin: execute}, {func.sh: read, execute},
         {readme.txt: read}
Chris    {bill.doc: read,write}, {game.bin: read, write, execute},
         {func.sh: execute}, {readme.txt: read}
Greg     {game.bin: write, execute}, {readme.txt: read}
Jess     {bill.doc: read}, {game.bin: execute}, {readme.txt: read,write}
```

Windows

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- Windows registry
  - Core place for system control
  - Target for hackers
  - Controls multiple computers
- Windows domain
  - Computers sharing things such as passwords
- Principles:
  - SAM format - old but used in most places
  - UPN - more modern
- Login - happens in different ways depending if computer is alone or part of a network
- More levels than *NIX
  - Hardware, System, Administrator, Users

Windows

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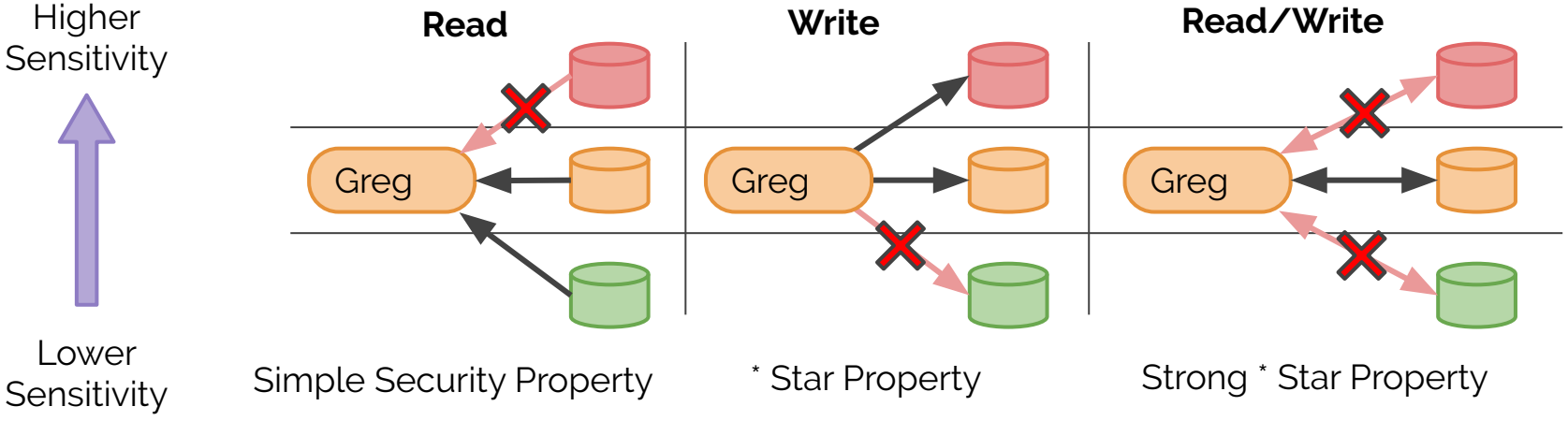
- Library loading is a problem.
- Viruses are very common and easy.
- Windows adding features to make OS less predictable
  - Image randomization (OS boots in one of 256 configurations)
  - Services restart if failed (not the best practise for security):
    - Vista+ sets some critical services to only restart twice, then manual restart required giving attackers just 2 attempts
- NTFS is much more secure than FAT32 & DOS.
  - Adds two ACLs:
    - DACL: Reading, writing, executing, deleting by which users or groups.
    - SCAL: for defining which actions are audited/logged, e.g. on activity being successful/failed.
  - Compression, encryption.

Bell-LaPadula Model

- Bell-LaPadula confidentiality policy, **“read down, write up”**
  - Simple security property
    - Subject (Greg) cannot read object of higher sensitivity
  - Star property (* property)
    - Subject cannot write to object of lower sensitivity.
  - Strong star property (Strong * property)
    - Subject cannot read/write to object of higher/lower sensitivity.



Biba Integrity Model

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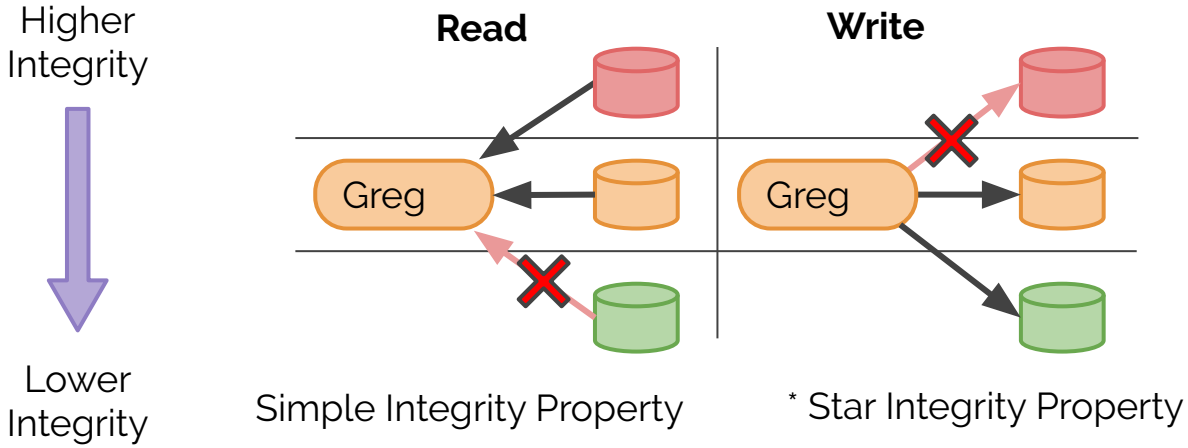
- Biba integrity model - **“read up, write down”**
  - Simple security property
    - Subject (Greg) cannot read object of lower integrity
  - Star property (* property)
    - Subject cannot write to object of higher integrity.
  - Invocation property
    - Subject/process cannot request higher integrity access.



Clark-Wilson Integrity Model

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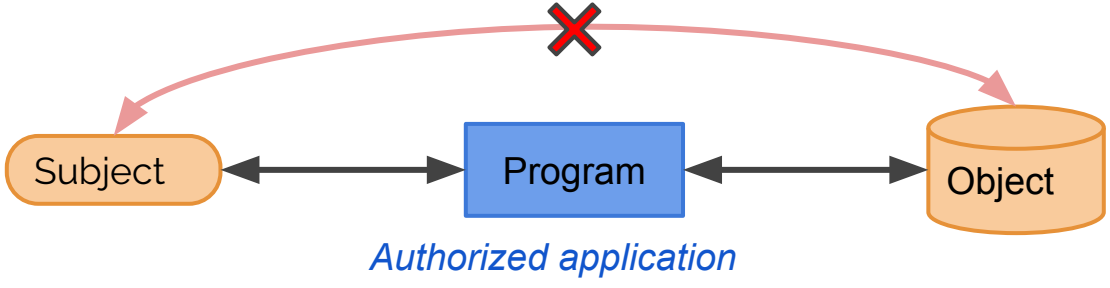
- Bell-LaPadula is good for **confidential** systems
- Biba is good for **integrity-preserving** systems
- What about businesses/industry processes where you need both?
  - Clark-Wilson Model
    - Limits direct interaction between subjects and objects
    - Prevent unauthorized subjects from modifying objects
    - Prevent authorized subjects from making invalid modifications to objects
    - Maintain internal/external consistency



Other Models (not examined)

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- Brewer and Nash model (Chinese wall model)
  - Allows dynamically changing access permissions.
  - Designed to mitigate conflict of interest.
- Graham-Denning Model
  - Computer security model.
  - Concerned with how subjects/objects are created/deleted securely, how privileges are assigned, and how ownership is assigned.
- Harrison-Ruzzo-Ullman (HRU) model
  - Extends on Graham-Denning model, maps subjects (S) objects (O) and access rights to an access matrix (P) where each cell contains the rights (R).
  - Constrains subjects from access to specific commands that would gain additional privileges, for example restricting access to a command that would grant read access to other documents.

Briefly on Security Evaluation

- you won't be examined on acronyms in this slide!

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- Common Criteria (CC)
  - Originated with ITSEC, CTCPEC, and TCSEC
  - Concepts for evaluation (TOE, PP, ST, SFRs, SARs, EAL)
  - Often criticized as an expensive (hundreds of thousands £) government-driven process with poor track-record of actually detecting vulnerabilities.
    - Researcher suggests CC discriminates against FOSS-centric organisations.
  - Success stories:
    - Smart cards
  - Failure cases:
    - Operating systems
- UK government uses alternatives to fast track certain scenarios, but these aren't recognised internationally.

Protection Rings

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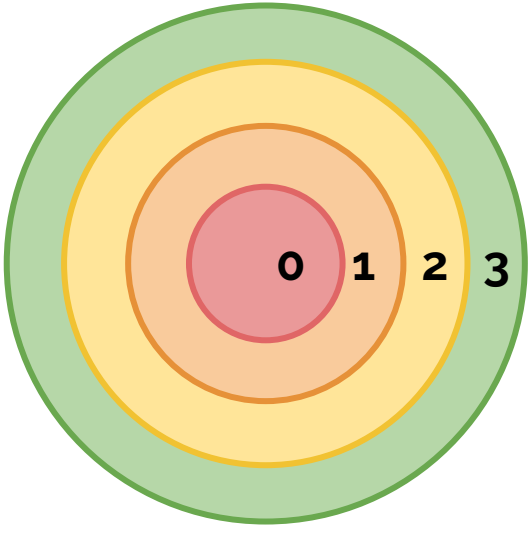
- Hardware based access control.
  - Also used to protect data and functionality from faults.
- Each subject and object are assigned a number based on importance.
- Decisions are made by comparing numbers:
  - If subject < object, disallow access.
- x86 CPUs offer four rings, but typically (Windows/UNIX) only two (0,3) are used.
- ARM implements 3 levels (application, operating system, and hypervisor).

0: Operating system kernel.
1: Operating system.
2: Utilities.
3: User processes.



Granting Root Privileges

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Real situation not long ago:

- Phil is a PhD student who has not taken this security course. He's deploying his mathematical model to the web for the industry that's funding him.
- His supervisor, Jacob, has a big UNIX server with 30 other PhD projects and lots of highly-sensitive data.
- Phil says "Jacob, I don't have permission to copy the files to /var/www - can you give me sudo access?"
- Jacob googles "How to add another user as root", finds the command: "`sudo adduser phil sudo`", types it in. Jacob goes back to his office. Done!

This kind of situation is VERY common.

*NIX Recap

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- UID 0 & root
- inode data structure & nearly everything is a file
- /etc/passwd
- /etc/shadow
- /etc/group
- File access - RWX
  - Can be converted to ACM
- Link vulnerabilities
  - Link to secure file, run command on linux to make real file insecure
- Devices file
  - /dev/tty
    - Often read/write to all
- Don't give lots of people root
  - setuid, sudo

Securing BIOS and Bootloader

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- BIOS should have a password for changing the settings
  - If you have physical access, then you can reset bios easily by resetting the CMOS
  - So lock the machine physically (require a key)
- Bootloader (e.g. GRUB) should have a password for changing the settings
  - Go into edit mode, then append to the linux kernel options in init=/bin/bash
  - This will directly boot in a shell with root privileges
- On Windows there is a bootable USB that you can make that allows full access to the registry that allows you to edit users/passwords
  - http://www.chntpw.com/burn-to-cd-usb/

Hardware Keylogger