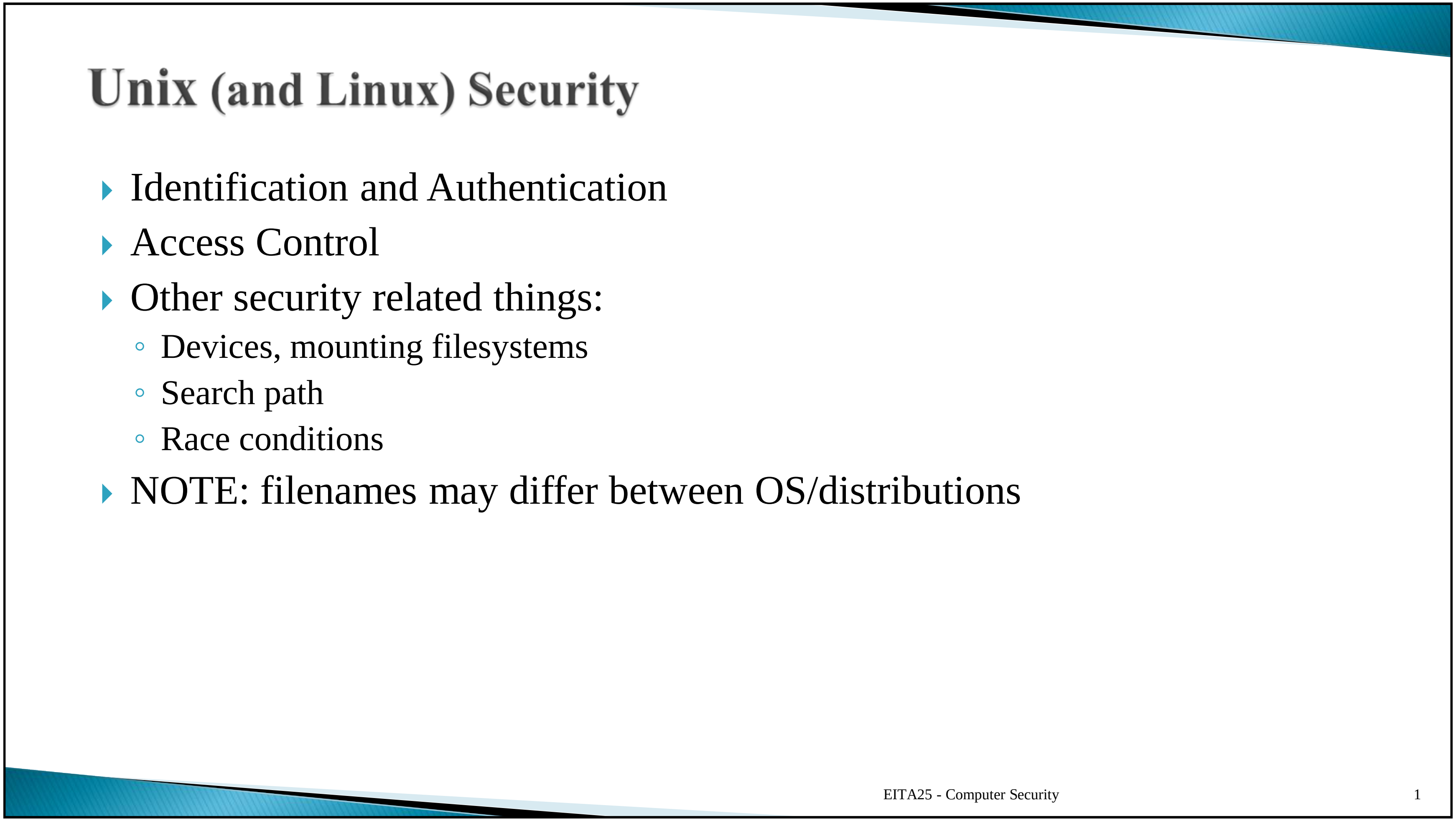
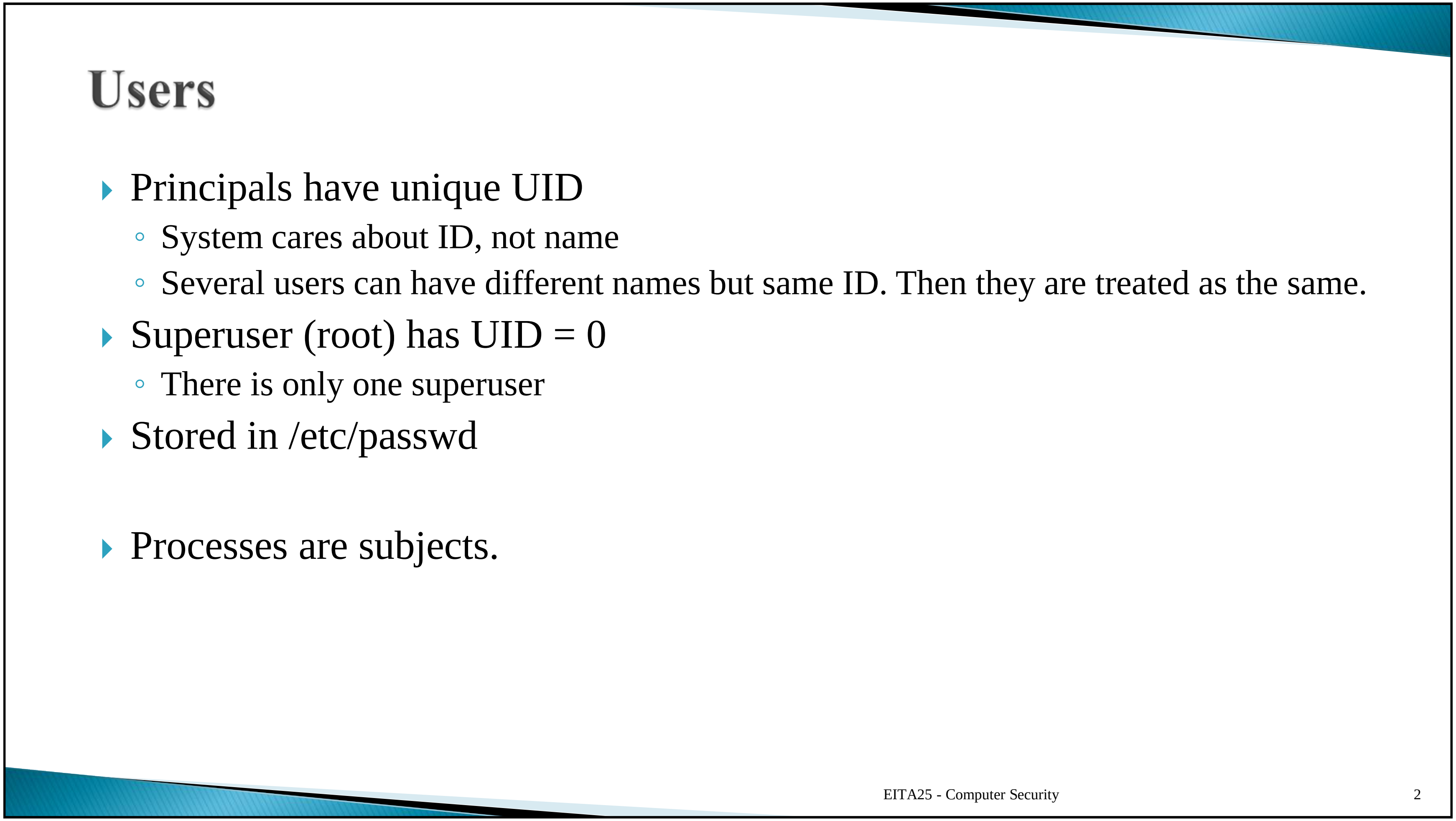


Unix (and Linux) Security

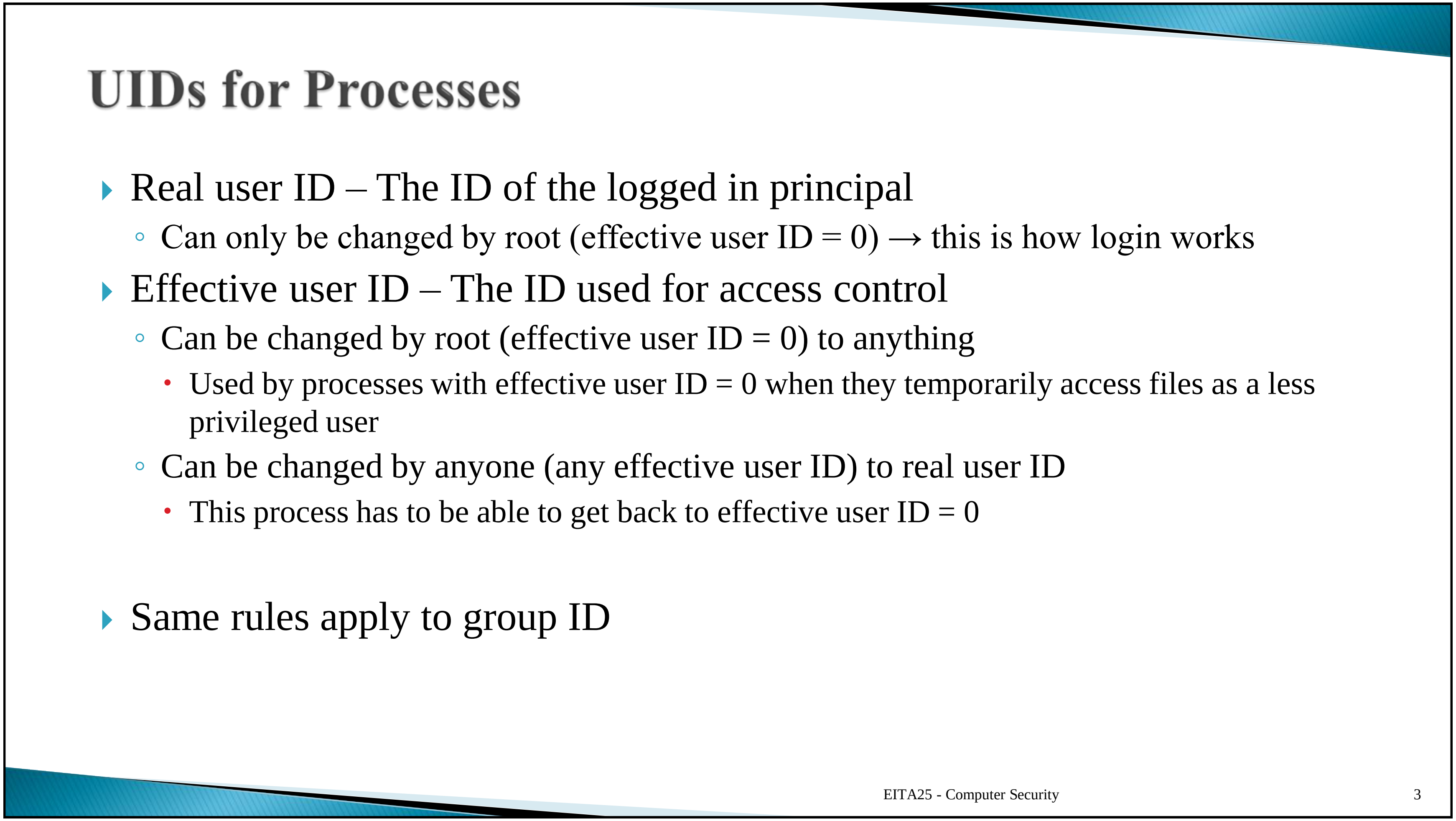
- Identification and Authentication
- Access Control
- Other security related things:
  - Devices, mounting filesystems
  - Search path
  - Race conditions
- NOTE: filenames may differ between OS/distributions



Users

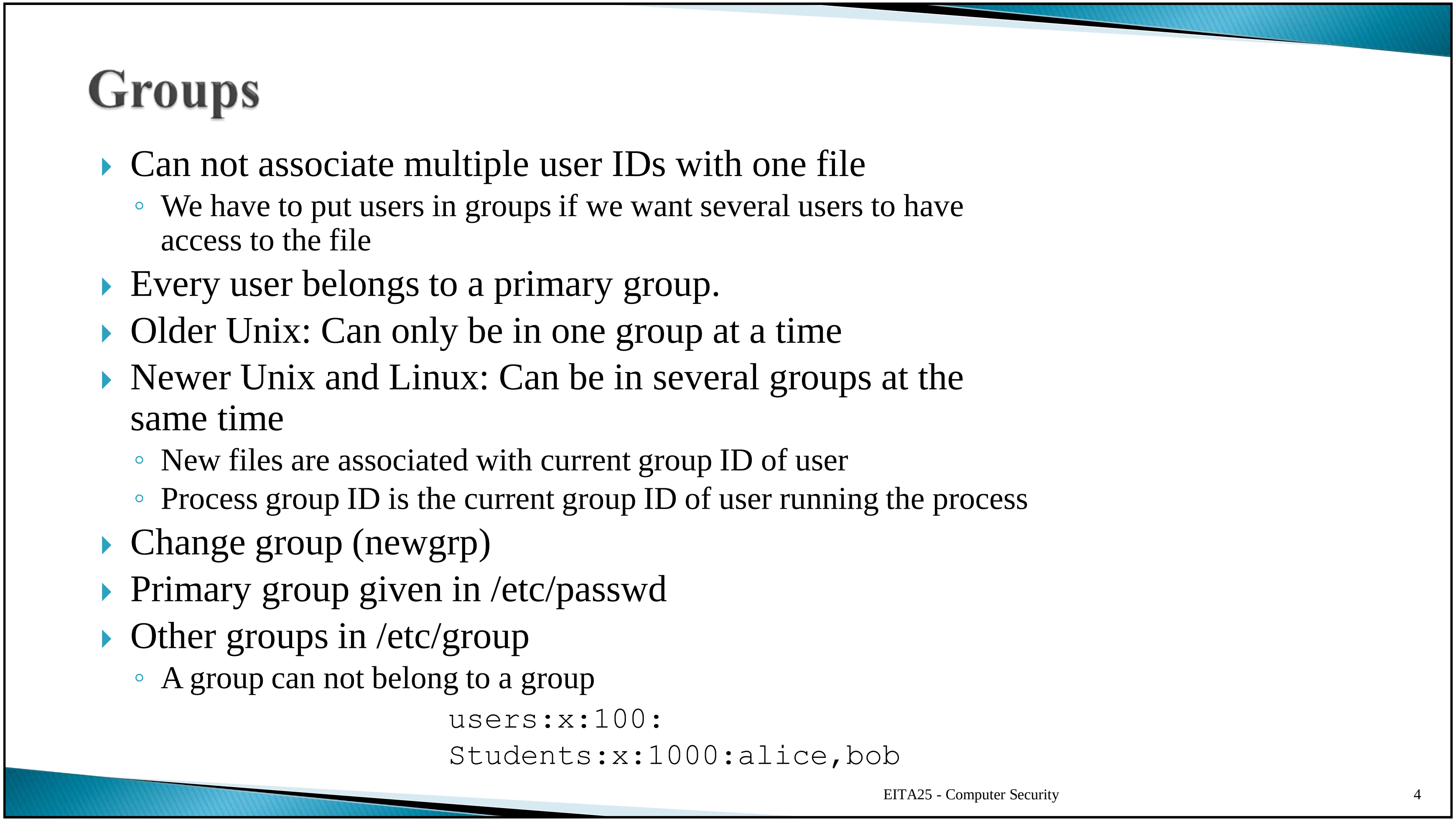
- Principals have unique UID
  - System cares about ID, not name
  - Several users can have different names but same ID. Then they are treated as the same.
- Superuser (root) has UID = 0
  - There is only one superuser
- Stored in /etc/passwd

- Processes are subjects.



UIDs for Processes

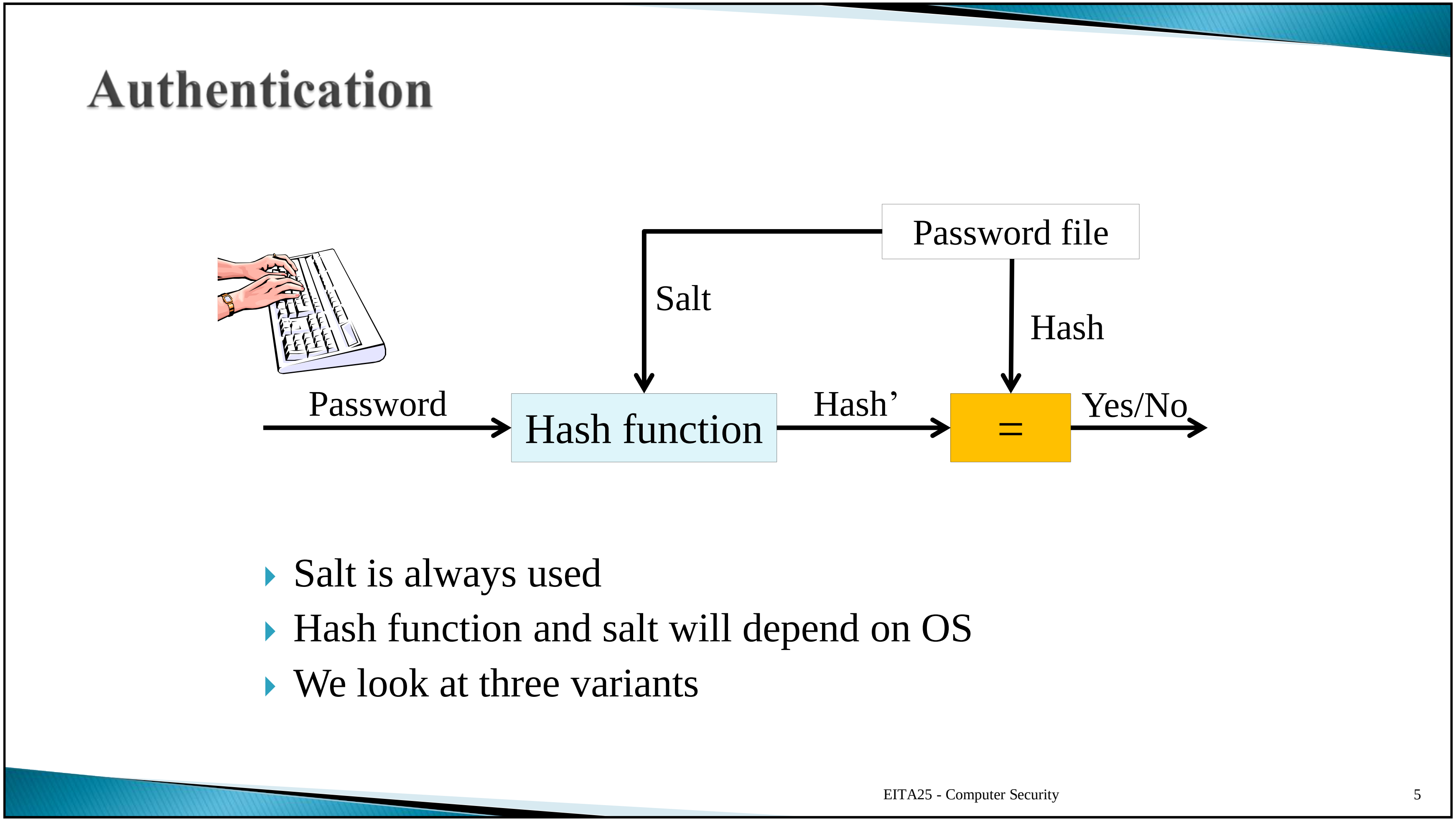
- Real user ID – The ID of the logged in principal
  - Can only be changed by root (effective user ID = 0) → this is how login works
- Effective user ID – The ID used for access control
  - Can be changed by root (effective user ID = 0) to anything
    - Used by processes with effective user ID = 0 when they temporarily access files as a less privileged user
  - Can be changed by anyone (any effective user ID) to real user ID
    - This process has to be able to get back to effective user ID = 0
- Same rules apply to group ID



Groups

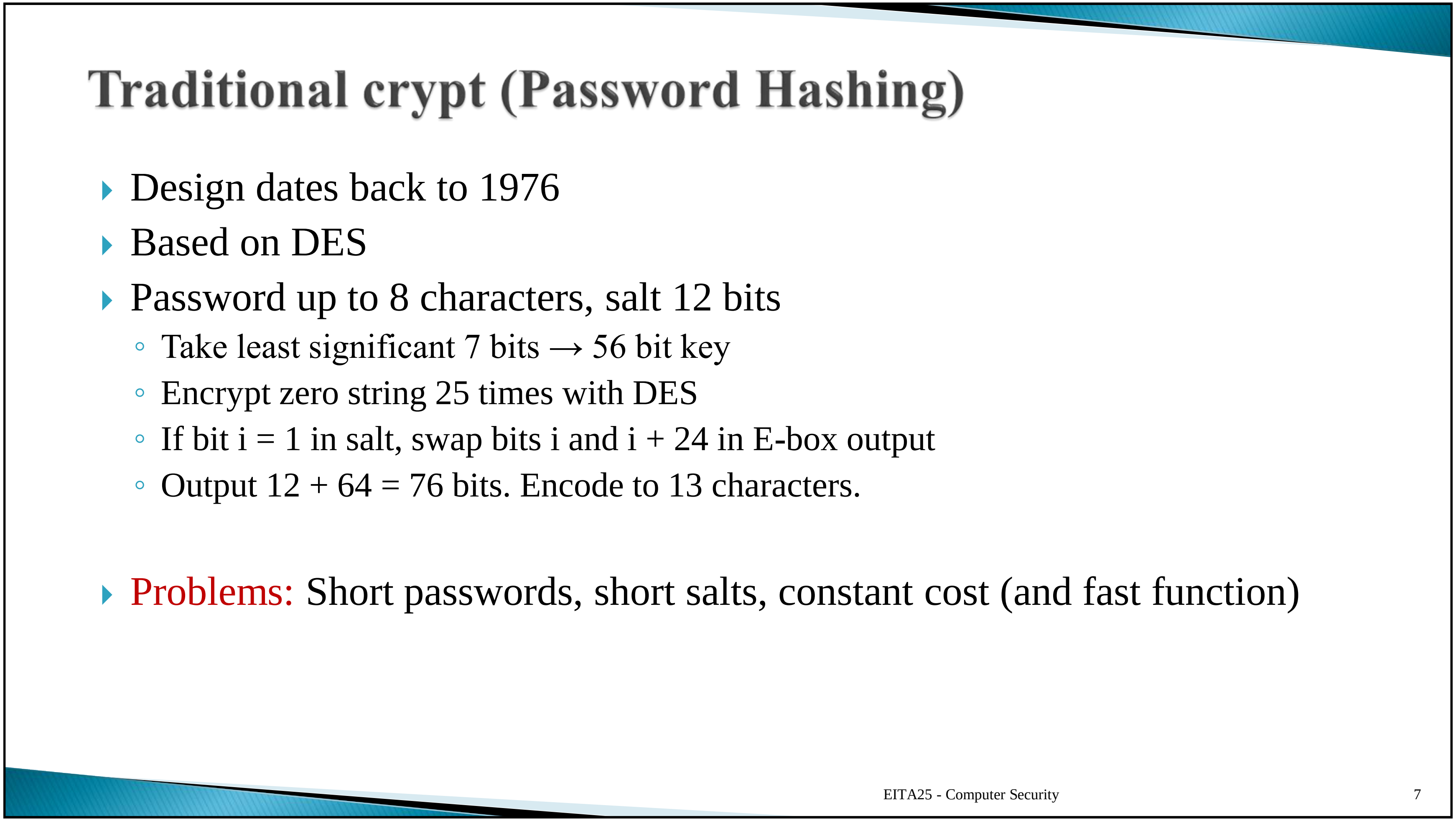
- Can not associate multiple user IDs with one file
  - We have to put users in groups if we want several users to have access to the file
- Every user belongs to a primary group.
- Older Unix: Can only be in one group at a time
- Newer Unix and Linux: Can be in several groups at the same time
  - New files are associated with current group ID of user
  - Process group ID is the current group ID of user running the process
- Change group (newgrp)
- Primary group given in /etc/passwd
- Other groups in /etc/group
  - A group can not belong to a group

```
users:x:100:
Students:x:1000:alice,bob
```



Authentication

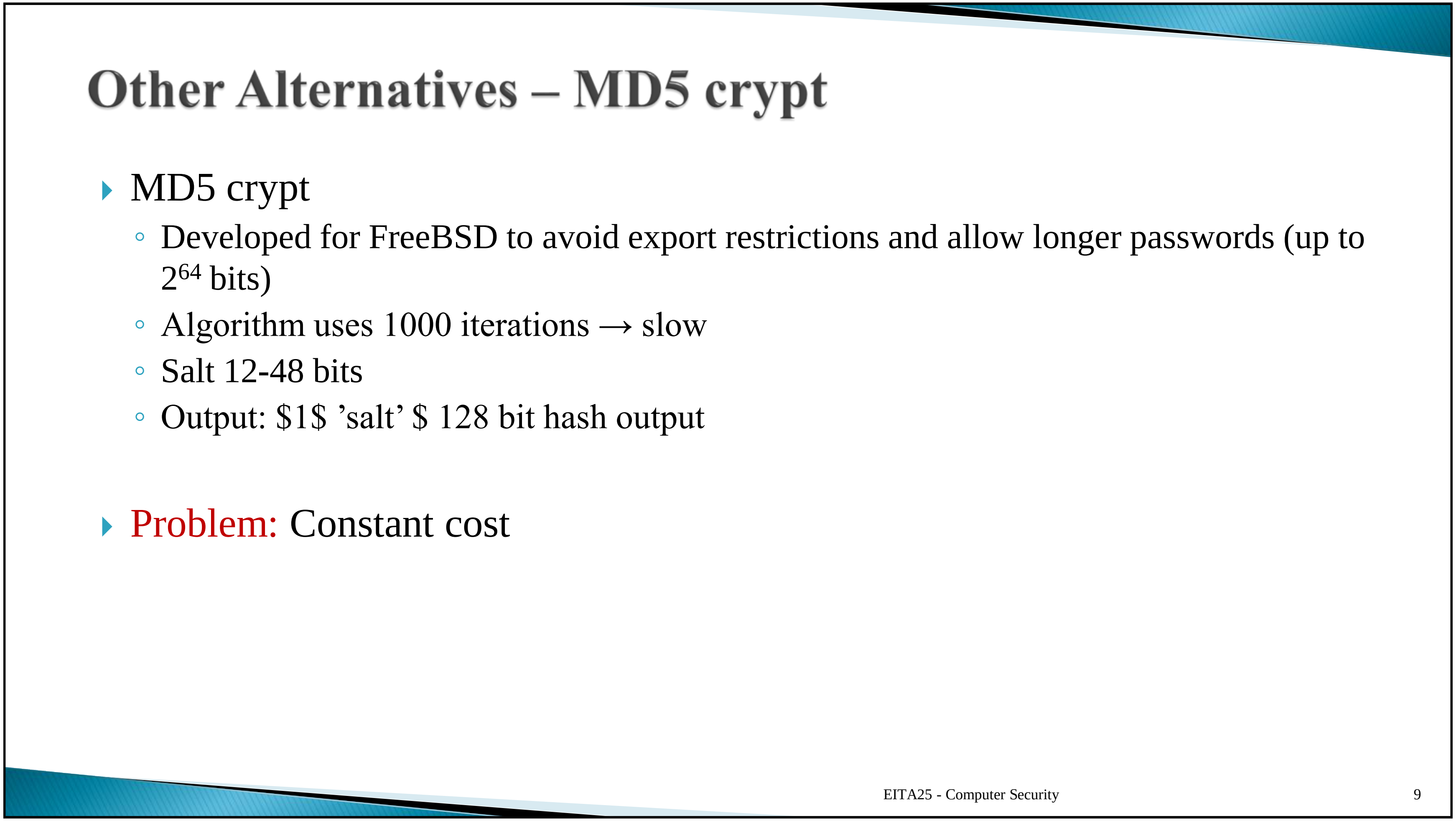
- Salt is always used
- Hash function and salt will depend on OS
- We look at three variants



Traditional crypt (Password Hashing)

- Design dates back to 1976
- Based on DES
- Password up to 8 characters, salt 12 bits
  - Take least significant 7 bits → 56 bit key
  - Encrypt zero string 25 times with DES
  - If bit i = 1 in salt, swap bits i and i + 24 in E-box output
  - Output 12 + 64 = 76 bits. Encode to 13 characters.

- Problems: Short passwords, short salts, constant cost (and fast function)

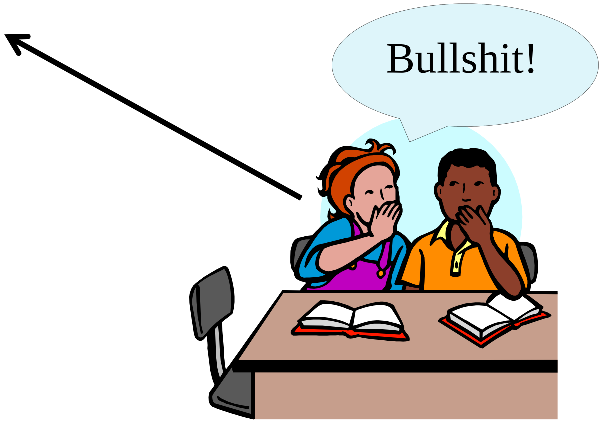


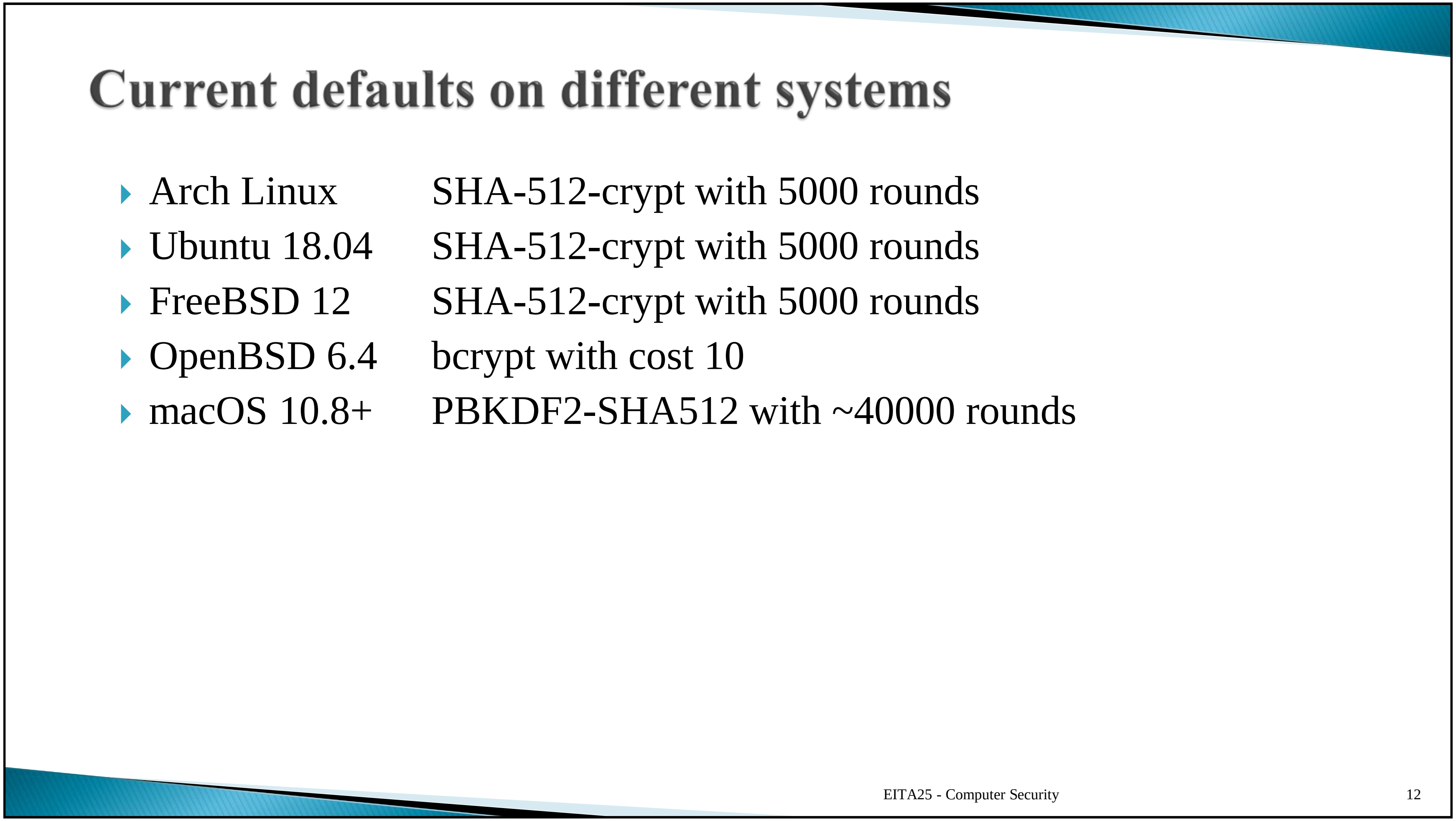
Other Alternatives – MD5 crypt

- MD5 crypt
  - Developed for FreeBSD to avoid export restrictions and allow longer passwords (up to 2^{64} bits)
  - Algorithm uses 1000 iterations → slow
  - Salt 12-48 bits
  - Output: \$1\$ ’salt’ \$ 128 bit hash output
- Problem: Constant cost

Other Alternatives – bcrypt

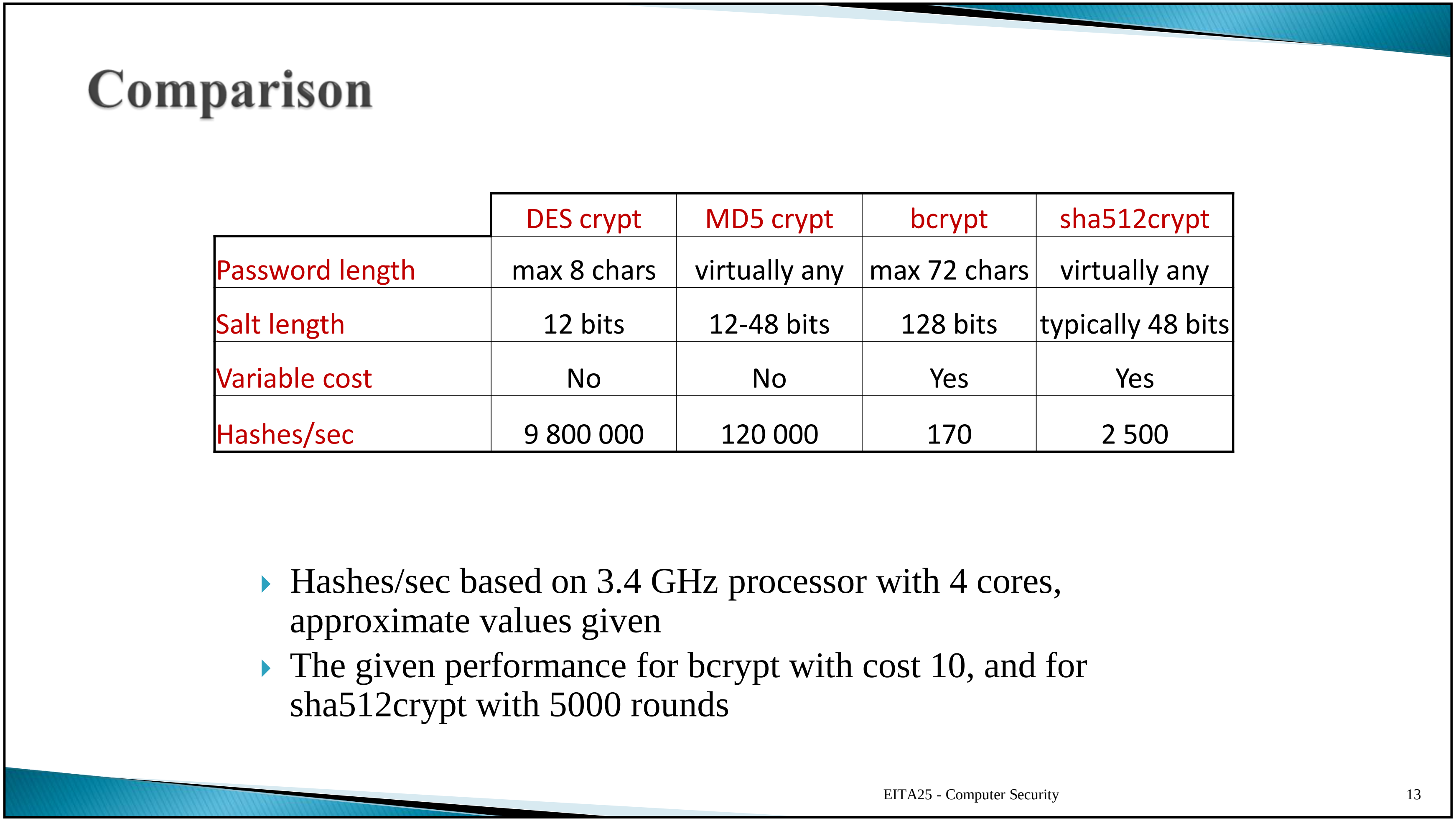
- Based on block cipher blowfish
- Password up to 72 characters, 128 bit random salt
- Internal loop with variable cost
- Output $2a$cost$salt + 192 bit hash output
- Default in OpenBSD
- All problems solved





Current defaults on different systems

Arch Linux	SHA-512-crypt with 5000 rounds
Ubuntu 18.04	SHA-512-crypt with 5000 rounds
FreeBSD 12	SHA-512-crypt with 5000 rounds
OpenBSD 6.4	bcrypt with cost 10
macOS 10.8+	PBKDF2-SHA512 with ~40000 rounds



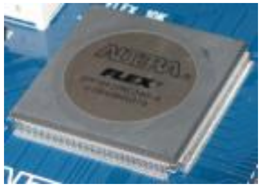
Comparison

	DES crypt	MD5 crypt	bcrypt	sha512crypt
Password length	max 8 chars	virtually any	max 72 chars	virtually any
Salt length	12 bits	12-48 bits	128 bits	typically 48 bits
Variable cost	No	No	Yes	Yes
Hashes/sec	9 800 000	120 000	170	2 500

- Hashes/sec based on 3.4 GHz processor with 4 cores, approximate values given
- The given performance for bcrypt with cost 10, and for sha512crypt with 5000 rounds

Final words on our password discussion

- ”All problems solved” is kind of bullshit
- Some devices can be really fast to a low cost
  - With enough money they are really really really fast
  - Several instances can be implemented in parallel
- Can no longer compare
  - CPU – ”needed” when verifying password
  - GPU, FPGA, ASIC – used by attackers

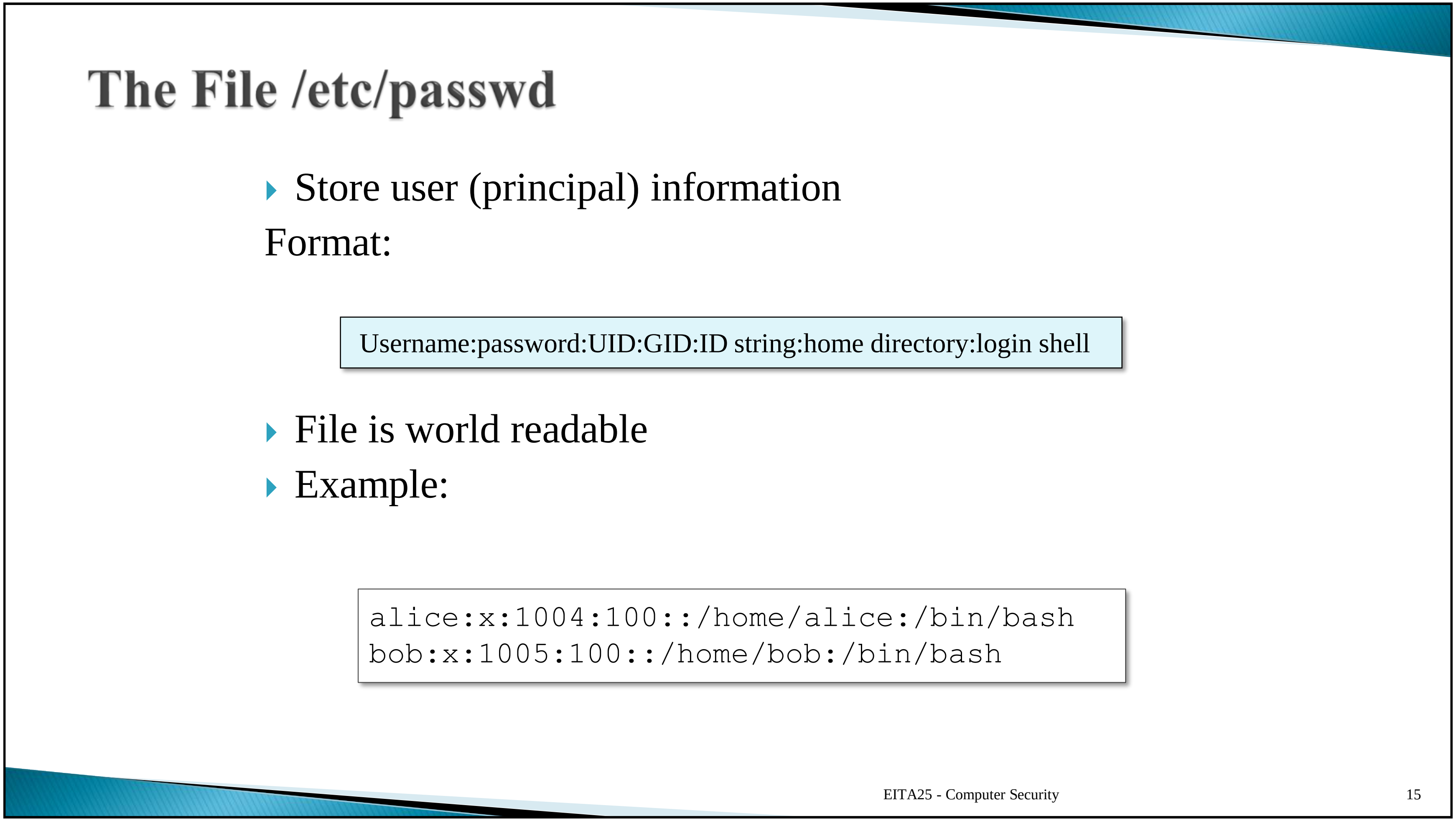


FPGA/ASIC

GPU

- Make this more fair by making hashing more difficult (costly) for GPUs, FPGAs and ASICs

- **Example**: Argon2 – variable cost in both time and memory



The File /etc/passwd

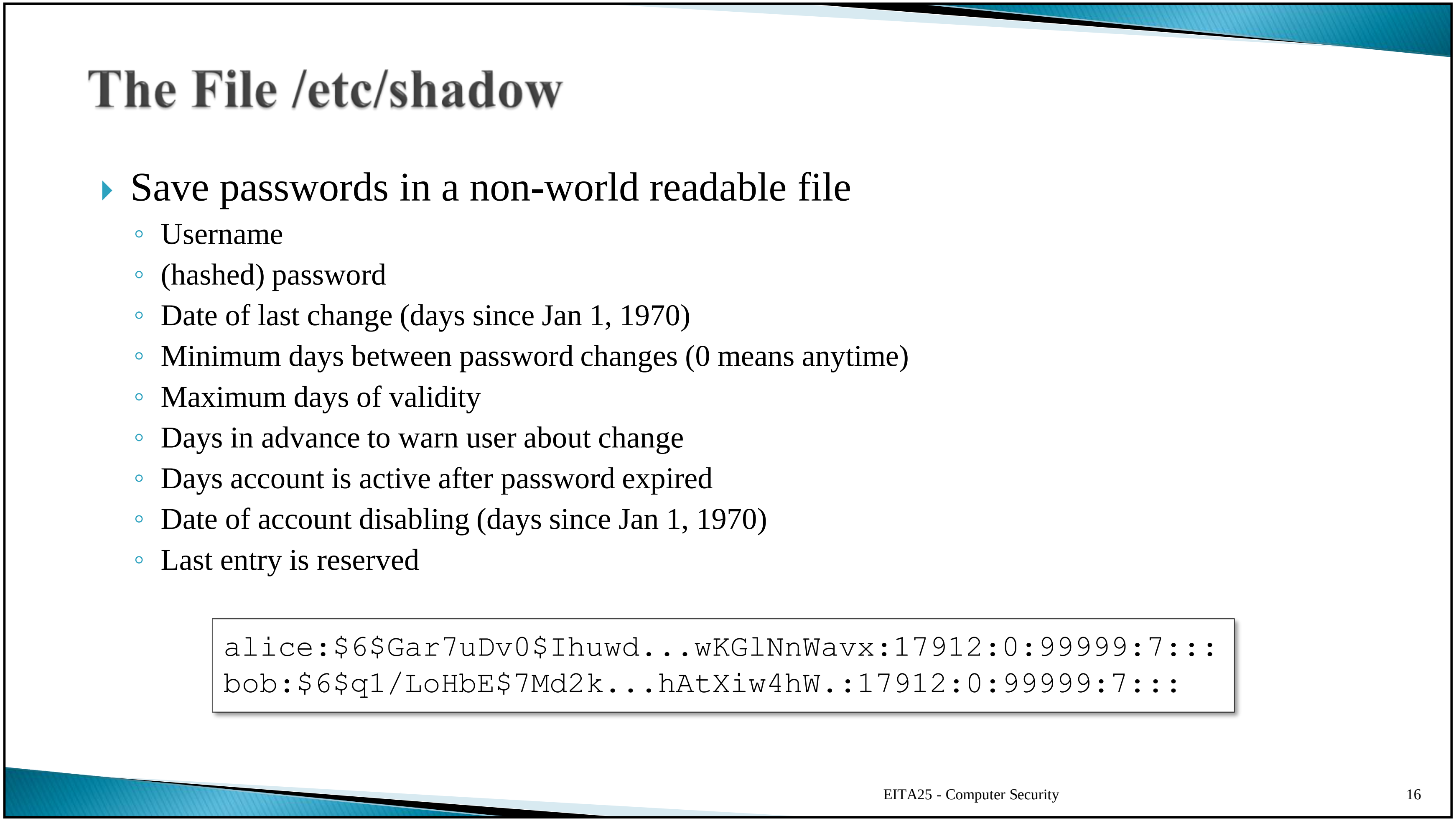
- Store user (principal) information

Format:

```
Username:password:UID:GID:ID string:home directory:login shell
```

- File is world readable
- Example:

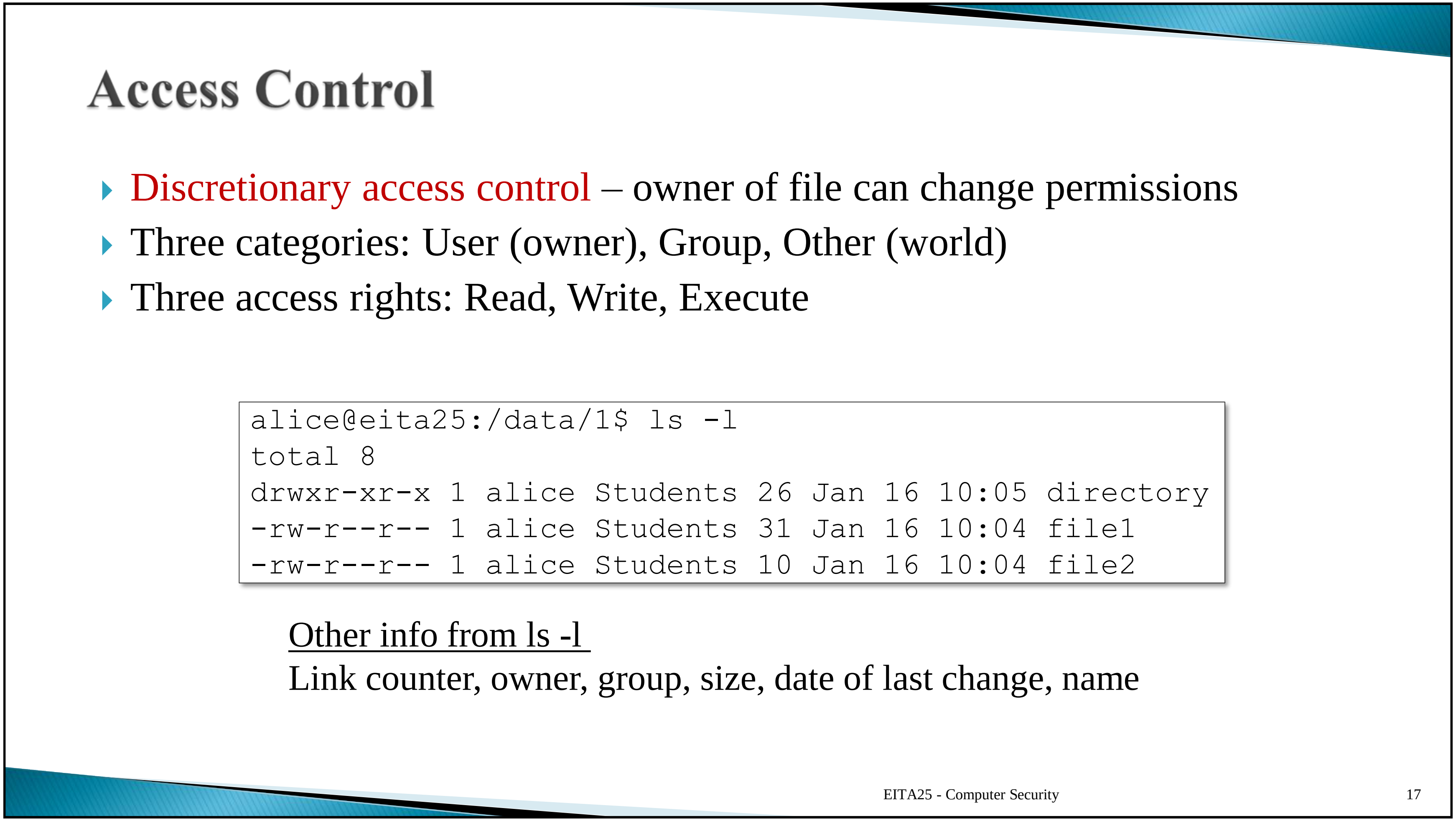
```
alice:x:1004:100::/home/alice:/bin/bash
bob:x:1005:100::/home/bob:/bin/bash
```



The File /etc/shadow

- Save passwords in a non-world readable file
  - Username
  - (hashed) password
  - Date of last change (days since Jan 1, 1970)
  - Minimum days between password changes (0 means anytime)
  - Maximum days of validity
  - Days in advance to warn user about change
  - Days account is active after password expired
  - Date of account disabling (days since Jan 1, 1970)
  - Last entry is reserved

```
alice:$6$Gar7uDv0$Ihuwd...wKGlNnWavx:17912:0:99999:7:::
bob:$6$q1/LoHbE$7Md2k...hAtXiw4hW.:17912:0:99999:7:::
```



Access Control

- Discretionary access control – owner of file can change permissions
- Three categories: User (owner), Group, Other (world)
- Three access rights: Read, Write, Execute

```
alice@eita25:/data/1$ ls -l
total 8
drwxr-xr-x 1 alice Students 26 Jan 16 10:05 directory
-rw-r--r-- 1 alice Students 31 Jan 16 10:04 file1
-rw-r--r-- 1 alice Students 10 Jan 16 10:04 file2
```

Other info from ls -l

Link counter, owner, group, size, date of last change, name

Order of Checking

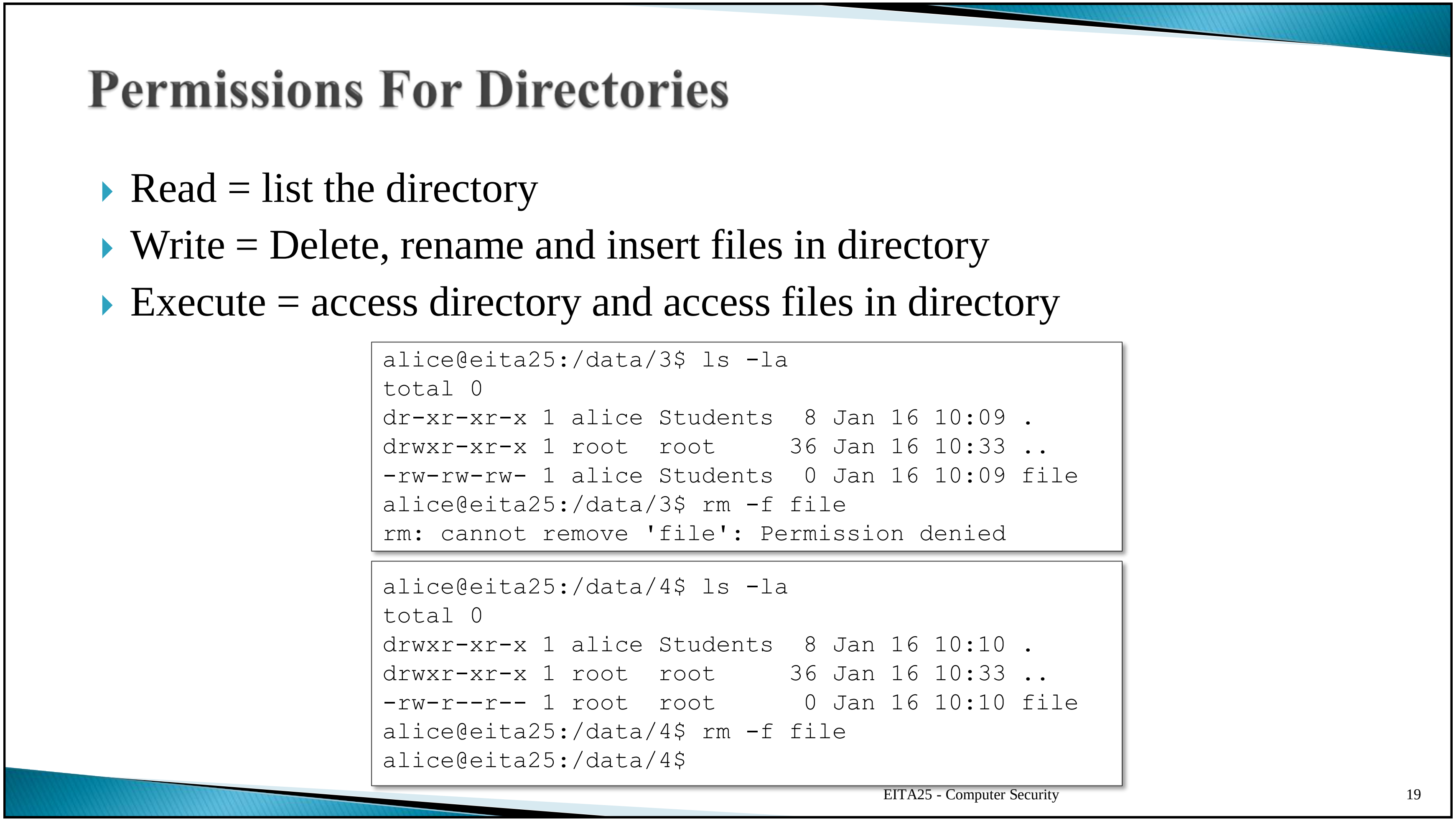
1. Owner
2. Group
3. Other

Consequence:

if owner = r and other = rw then owner has no write permission

```
alice@eita25:/data/2$ ls -l
total 0
-r--rw-rw- 1 alice Students 0 Jan 16 10:06 file
alice@eita25:/data/2$ echo hello > file
bash: file: Permission denied
```

```
bob@eita25:/data/2$ ls -l
total 0
-r--rw-rw- 1 alice Students 0 Jan 16 10:06 file
bob@eita25:/data/2$ echo hello > file
bob@eita25:/data/2$
```

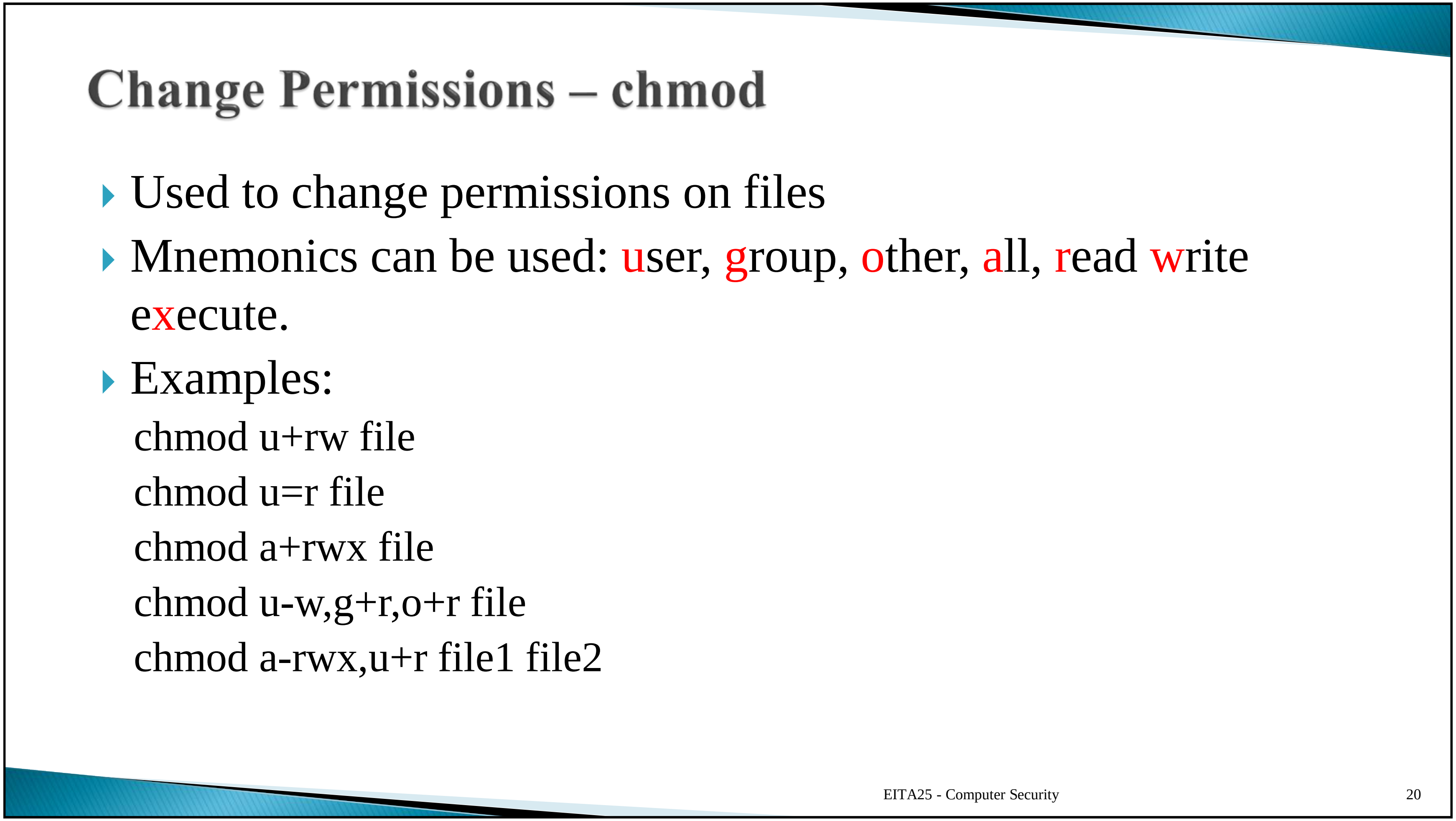


Permissions For Directories

- Read = list the directory
- Write = Delete, rename and insert files in directory
- Execute = access directory and access files in directory

```
alice@eita25:/data/3$ ls -la
total 0
dr-xr-xr-x 1 alice Students  8 Jan 16 10:09 .
drwxr-xr-x 1 root  root     36 Jan 16 10:33 ..
-rw-rw-rw- 1 alice Students  0 Jan 16 10:09 file
alice@eita25:/data/3$ rm -f file
rm: cannot remove 'file': Permission denied
```

```
alice@eita25:/data/4$ ls -la
total 0
drwxr-xr-x 1 alice Students  8 Jan 16 10:10 .
drwxr-xr-x 1 root  root     36 Jan 16 10:33 ..
-rw-r--r-- 1 root  root      0 Jan 16 10:10 file
alice@eita25:/data/4$ rm -f file
alice@eita25:/data/4$
```



Change Permissions – chmod

- Used to change permissions on files
- Mnemonics can be used: user, group, other, all, read write execute.
- Examples:

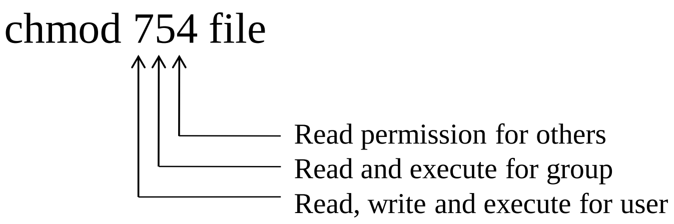
```
chmod u+rw file
chmod u=r file
chmod a+rwx file
chmod u-w,g+r,o+r file
chmod a-rwx,u+r file1 file2
```

Change Permissions – chmod

- Alternatively, numbers can be used.
- See each group of permissions as one number.
  - Read = 4
  - Write = 2
  - Execute = 1

Sum gives permission

- Example:



chmod 754 file

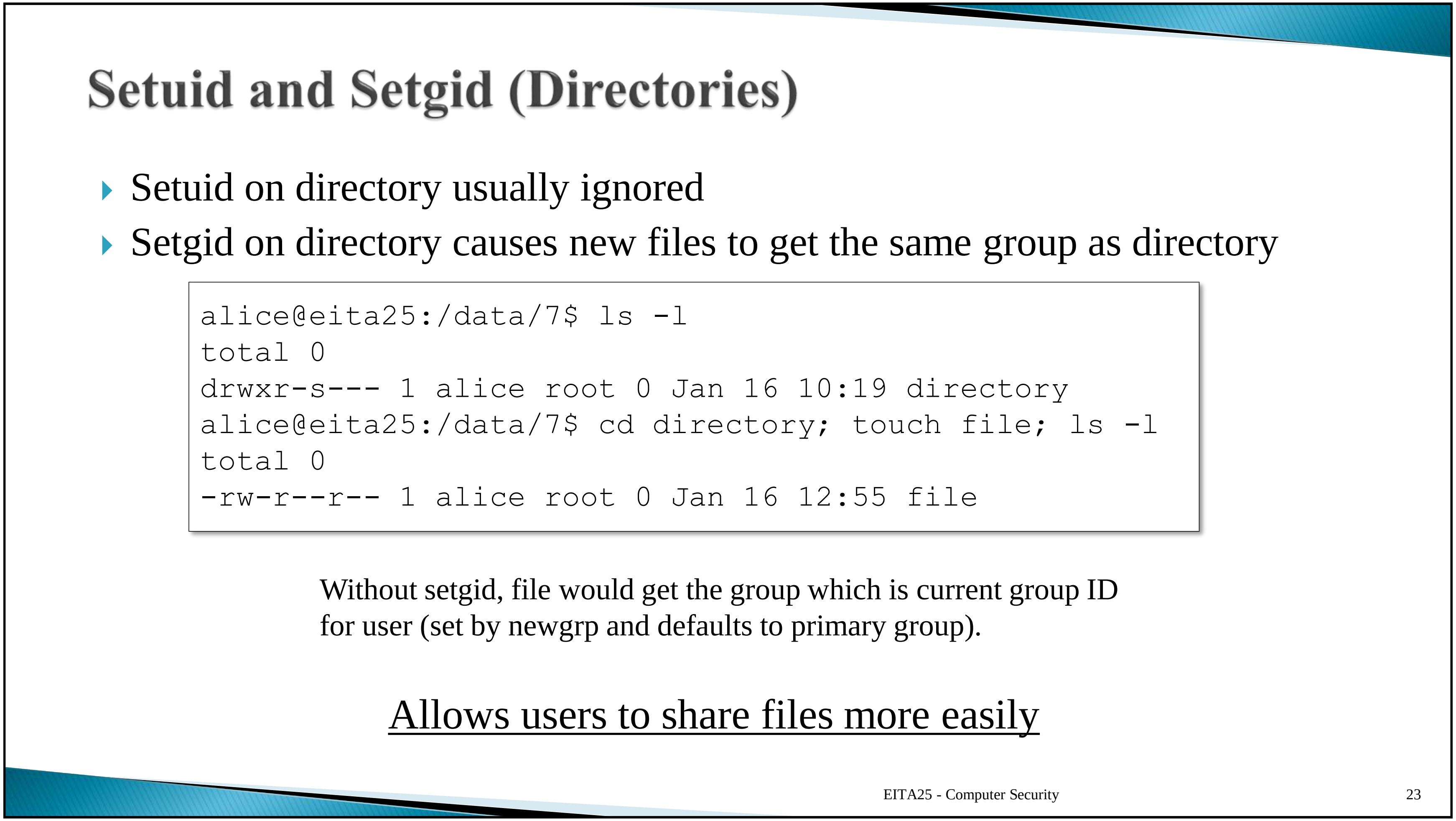
Read permission for others
Read and execute for group
Read, write and execute for user

```
alice@eita25:/data/5$ chmod 754 file; ls -l file
-rwxr-xr-- 1 alice Students 0 Jan 16 10:12 file
```

Setuid and Setgid (programs)

- Controlled invocation
- Effective ID of process is ID of program owner (usually root)
  - Here is the situation when RUID ≠ EUID
- Used to temporarily change access rights
- *x* is replaced by *s*

```
alice@eita25$ ls -l
total 40
-rwxr-sr-x 1 root root 16568 Jan 16 10:17 prog_setgid
-rwsr-xr-x 1 root root 16568 Jan 16 10:17 prog_setuid
alice@eita25$ ./prog_setuid &
[1] 249
alice@eita25$ ./prog_setgid &
[2] 250
alice@eita25$ ps -C prog_setgid,prog_setuid -o pid,ruser,euser,rgroup,egroup,args
  PID RUSER    EUSER    RGROUP   EGROUP   COMMAND
  249 alice    root     users    users    ./prog_setuid
  250 alice    alice    users    root     ./prog_setgid
```



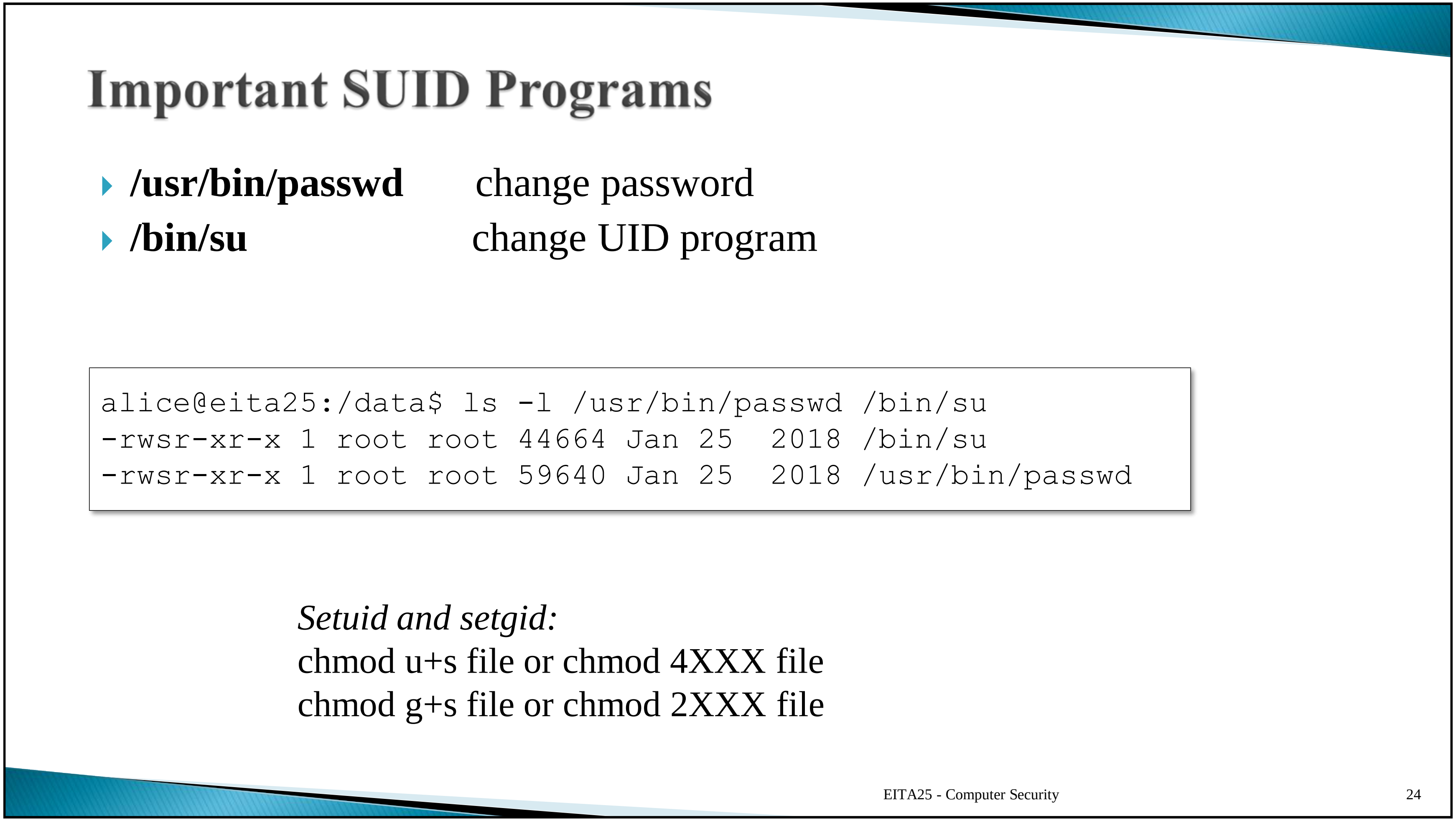
Setuid and Setgid (Directories)

- Setuid on directory usually ignored
- Setgid on directory causes new files to get the same group as directory

```
alice@eita25:/data/7$ ls -l
total 0
drwxr-s--- 1 alice root 0 Jan 16 10:19 directory
alice@eita25:/data/7$ cd directory; touch file; ls -l
total 0
-rw-r--r-- 1 alice root 0 Jan 16 12:55 file
```

Without setgid, file would get the group which is current group ID
for user (set by newgrp and defaults to primary group).

<u>Allows users to share files more easily</u>

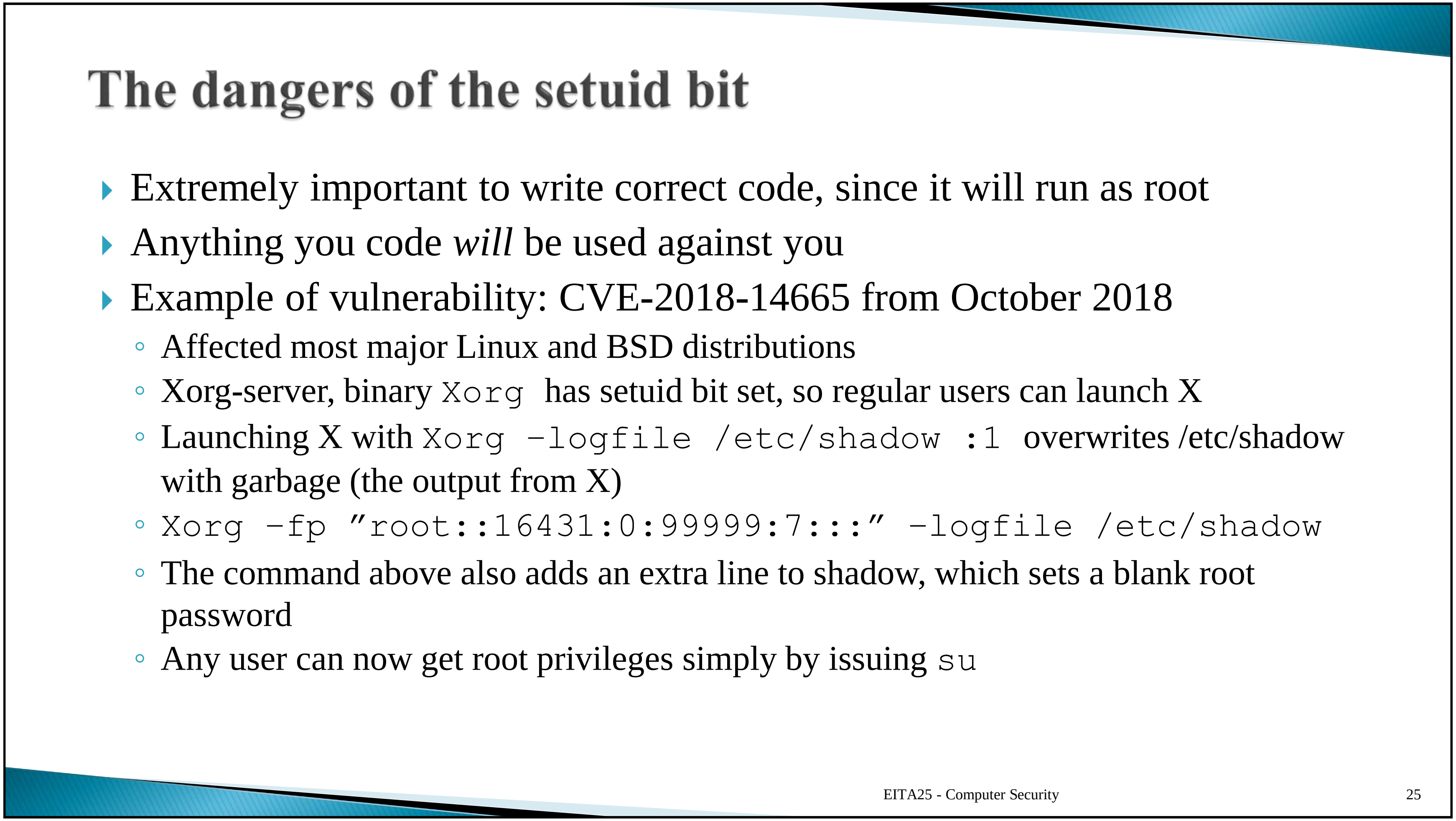


Important SUID Programs

- **/usr/bin/passwd** change password
- **/bin/su** change UID program

```
alice@eita25:/data$ ls -l /usr/bin/passwd /bin/su
-rwsr-xr-x 1 root root 44664 Jan 25  2018 /bin/su
-rwsr-xr-x 1 root root 59640 Jan 25  2018 /usr/bin/passwd
```

Setuid and setgid:
chmod u+s file or chmod 4XXX file
chmod g+s file or chmod 2XXX file



The dangers of the setuid bit

- Extremely important to write correct code, since it will run as root
- Anything you code *will* be used against you
- Example of vulnerability: CVE-2018-14665 from October 2018
  - Affected most major Linux and BSD distributions
  - Xorg-server, binary `Xorg` has setuid bit set, so regular users can launch X
  - Launching X with `Xorg -logfile /etc/shadow :1` overwrites /etc/shadow with garbage (the output from X)
  - `Xorg -fp ”root::16431:0:99999:7:::” -logfile /etc/shadow`
  - The command above also adds an extra line to shadow, which sets a blank root password
  - Any user can now get root privileges simply by issuing `su`

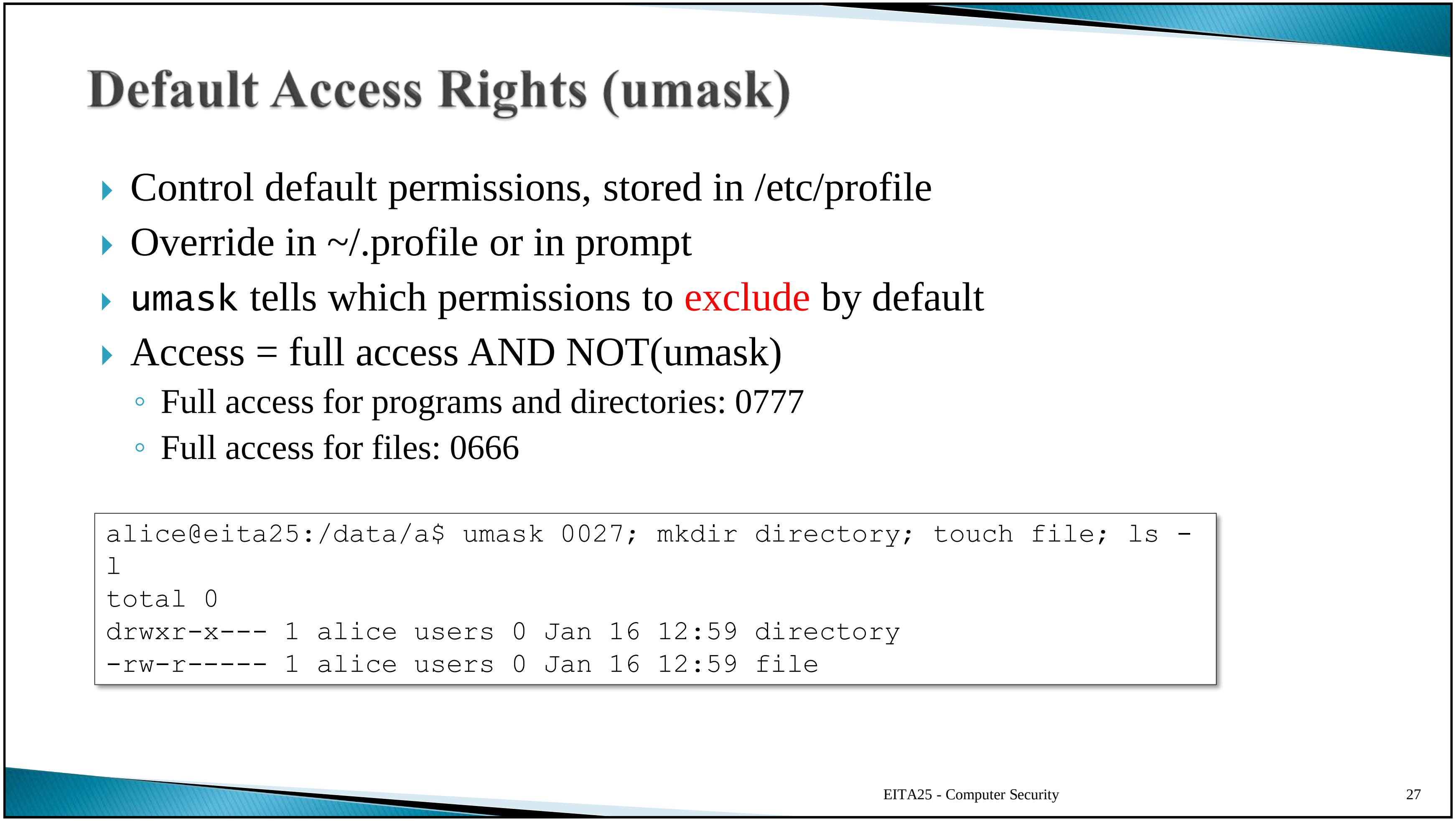
Sticky Bit

- Historically used to keep program code in memory when exiting program (still the case in, e.g. HP-UX)
- Now used to only let owner delete file
  - directory owner and superuser can also delete it

```
bob@eita25:/data/8$ ls -la
total 0
drwxrwxr-t 1 alice Students  8 Jan 16 10:26 .
drwxr-xr-x 1 root  root     36 Jan 16 10:33 ..
-rw-rw-r-- 1 alice Students  0 Jan 16 10:26 file
bob@eita25:/data/8$ rm file
rm: cannot remove 'file': Operation not permitted
```

```
bob@eita25:/data/9$ ls -la
total 0
drwxrwxr-x 1 alice Students  8 Jan 16 10:26 .
drwxr-xr-x 1 root  root     36 Jan 16 10:33 ..
-rw-rw-r-- 1 alice Students  0 Jan 16 10:26 file
bob@eita25:/data/9$ rm file
bob@eita25:/data/9$
```

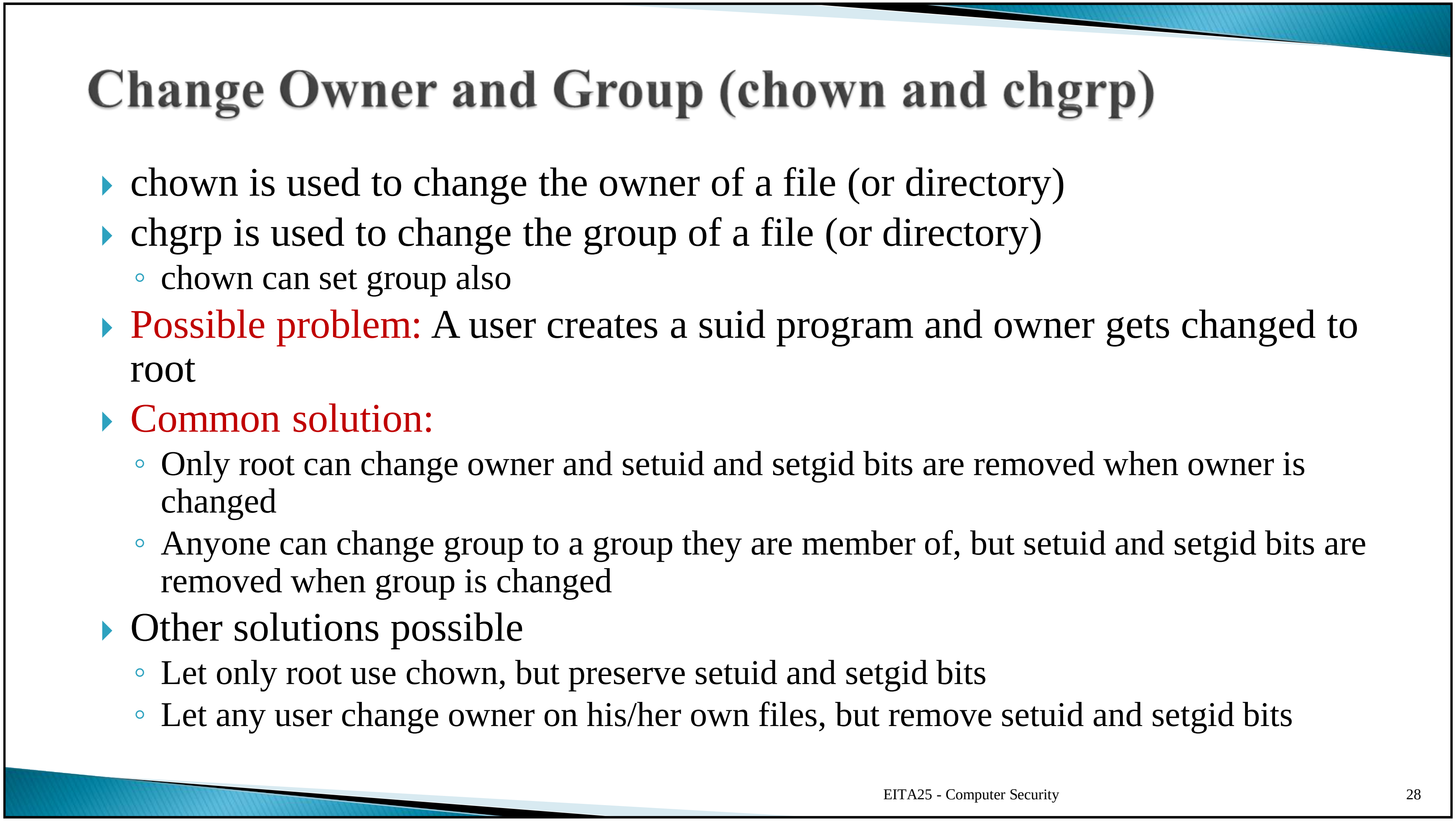
- Typical example: the directory /tmp has sticky bit set



Default Access Rights (umask)

- Control default permissions, stored in /etc/profile
- Override in ~/.profile or in prompt
- `umask` tells which permissions to exclude by default
- Access = full access AND NOT(umask)
  - Full access for programs and directories: 0777
  - Full access for files: 0666

```
alice@eita25:/data/a$ umask 0027; mkdir directory; touch file; ls -
l
total 0
drwxr-x--- 1 alice users 0 Jan 16 12:59 directory
-rw-r----- 1 alice users 0 Jan 16 12:59 file
```

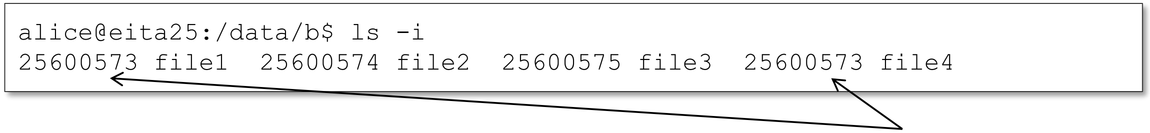


Change Owner and Group (chown and chgrp)

- chown is used to change the owner of a file (or directory)
- chgrp is used to change the group of a file (or directory)
  - chown can set group also
- Possible problem: A user creates a suid program and owner gets changed to root
- Common solution:
  - Only root can change owner and setuid and setgid bits are removed when owner is changed
  - Anyone can change group to a group they are member of, but setuid and setgid bits are removed when group is changed
- Other solutions possible
  - Let only root use chown, but preserve setuid and setgid bits
  - Let any user change owner on his/her own files, but remove setuid and setgid bits

The inode

- Stores file information
- Directory contains filename and inode number



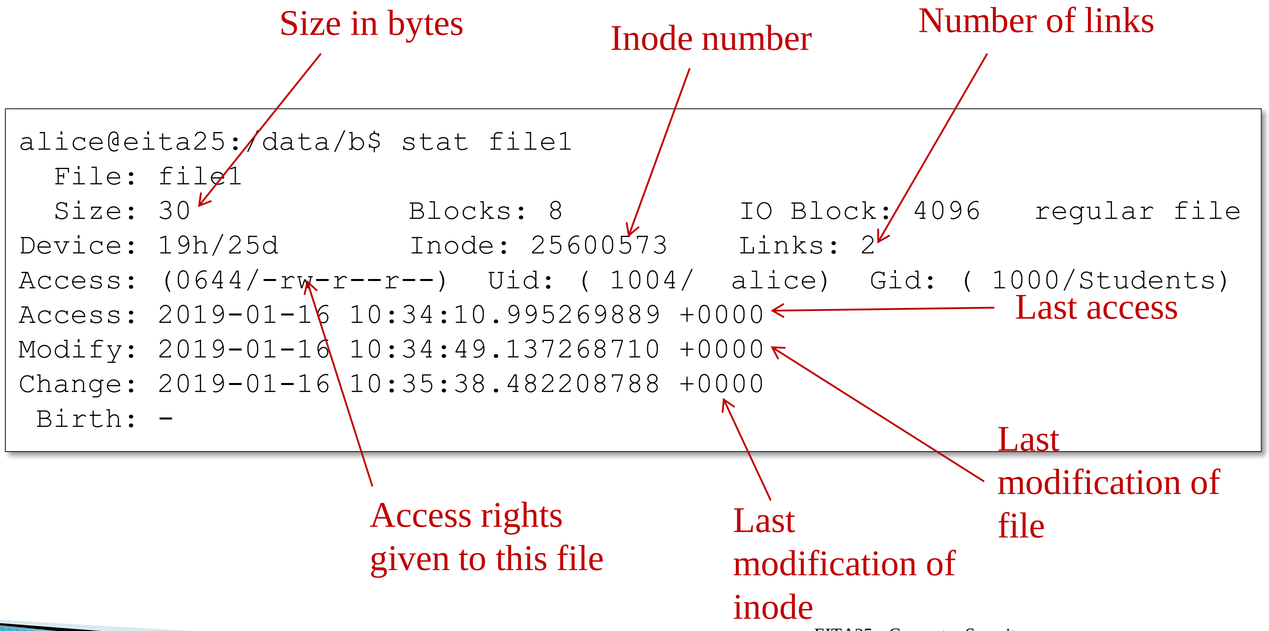
```
alice@eita25:/data/b$ ls -i
25600573 file1  25600574 file2  25600575 file3  25600573 file4
```

Note that file1 and file4 points to the same inode

- inode contains e.g.:
  - Access rights
  - Owner (UID)
  - Group (GID)
  - Time of latest access, modification and change
  - Size of file
  - Pointers to block of data

inode Information (stat)

- Some information about an inode can be found using `stat`



```
alice@eita25:/data/b$ stat file1
  File: file1
  Size: 30              Blocks: 8          IO Block: 4096   regular file
Device: 19h/25d         Inode: 25600573    Links: 2
Access: (0644/-rw-r--r--)  Uid: ( 1004/   alice)   Gid: ( 1000/Students)
Access: 2019-01-16 10:34:10.995269889 +0000
Modify: 2019-01-16 10:34:49.137268710 +0000
Change: 2019-01-16 10:35:38.482208788 +0000
 Birth: -
```

Size in bytes

Inode number

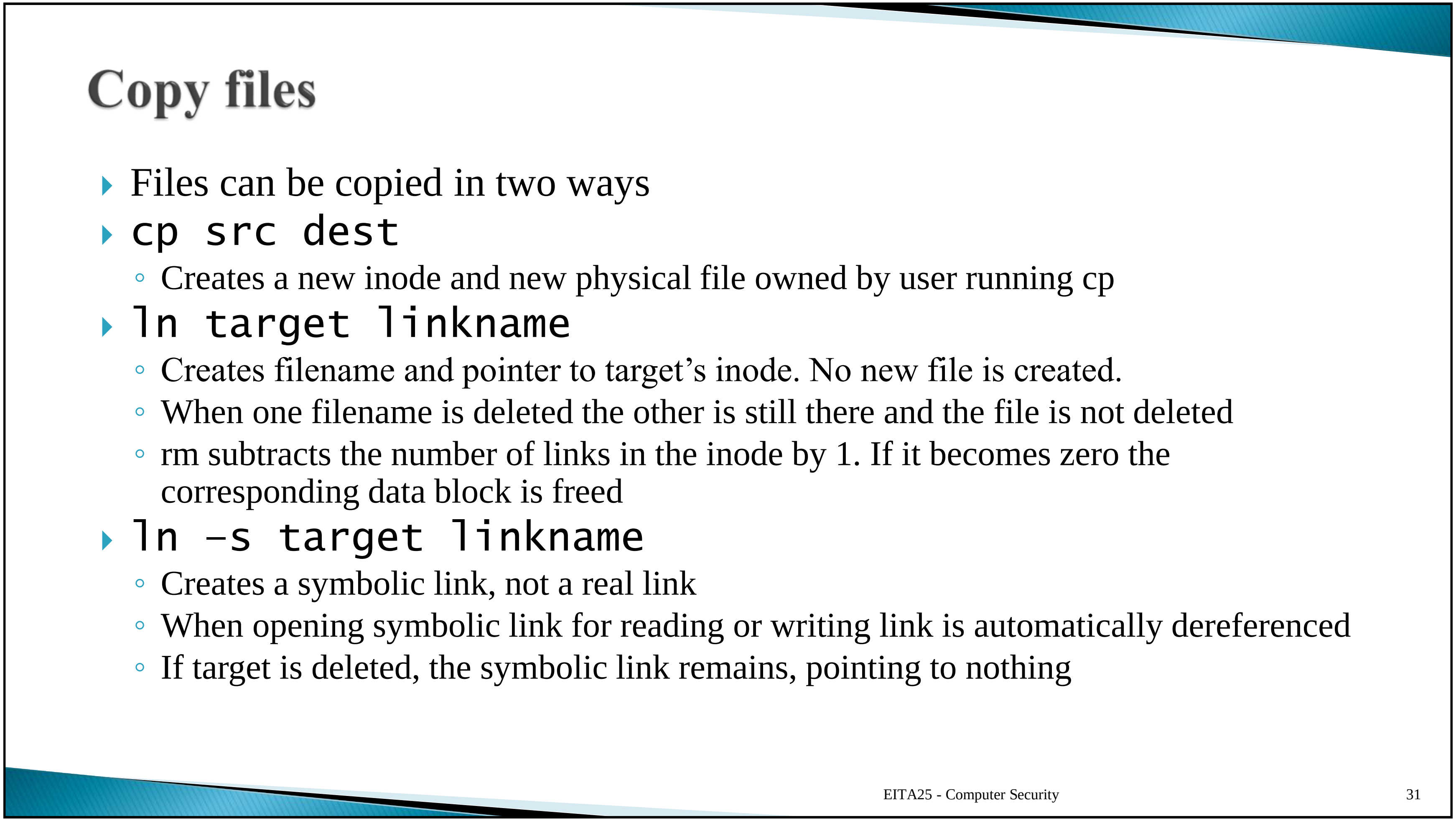
Number of links

Last access

Access rights given to this file

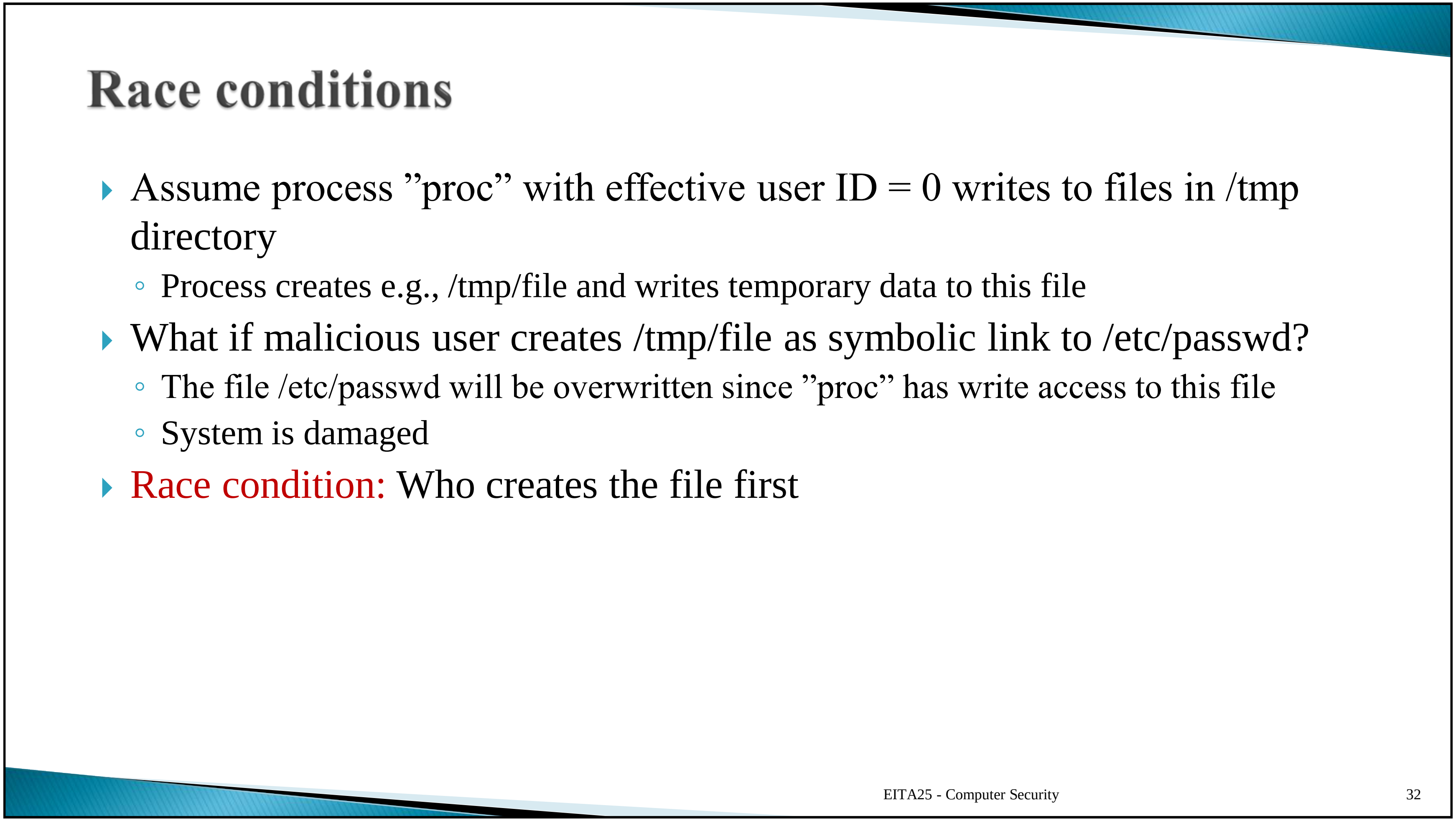
Last modification of inode

Last modification of file



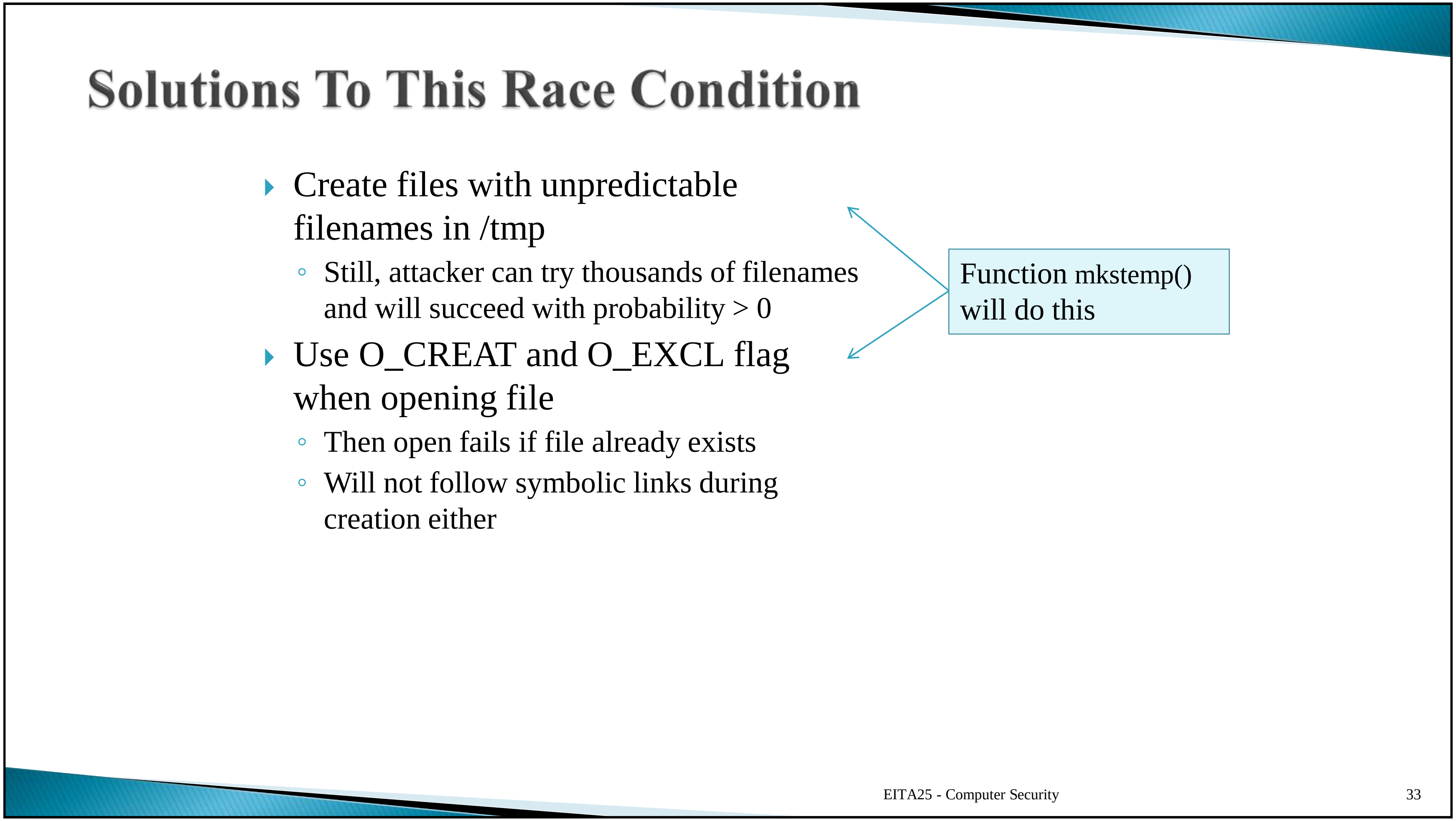
Copy files

- Files can be copied in two ways
- `cp src dest`
  - Creates a new inode and new physical file owned by user running cp
- `ln target linkname`
  - Creates filename and pointer to target’s inode. No new file is created.
  - When one filename is deleted the other is still there and the file is not deleted
  - rm subtracts the number of links in the inode by 1. If it becomes zero the corresponding data block is freed
- `ln –s target linkname`
  - Creates a symbolic link, not a real link
  - When opening symbolic link for reading or writing link is automatically dereferenced
  - If target is deleted, the symbolic link remains, pointing to nothing



Race conditions

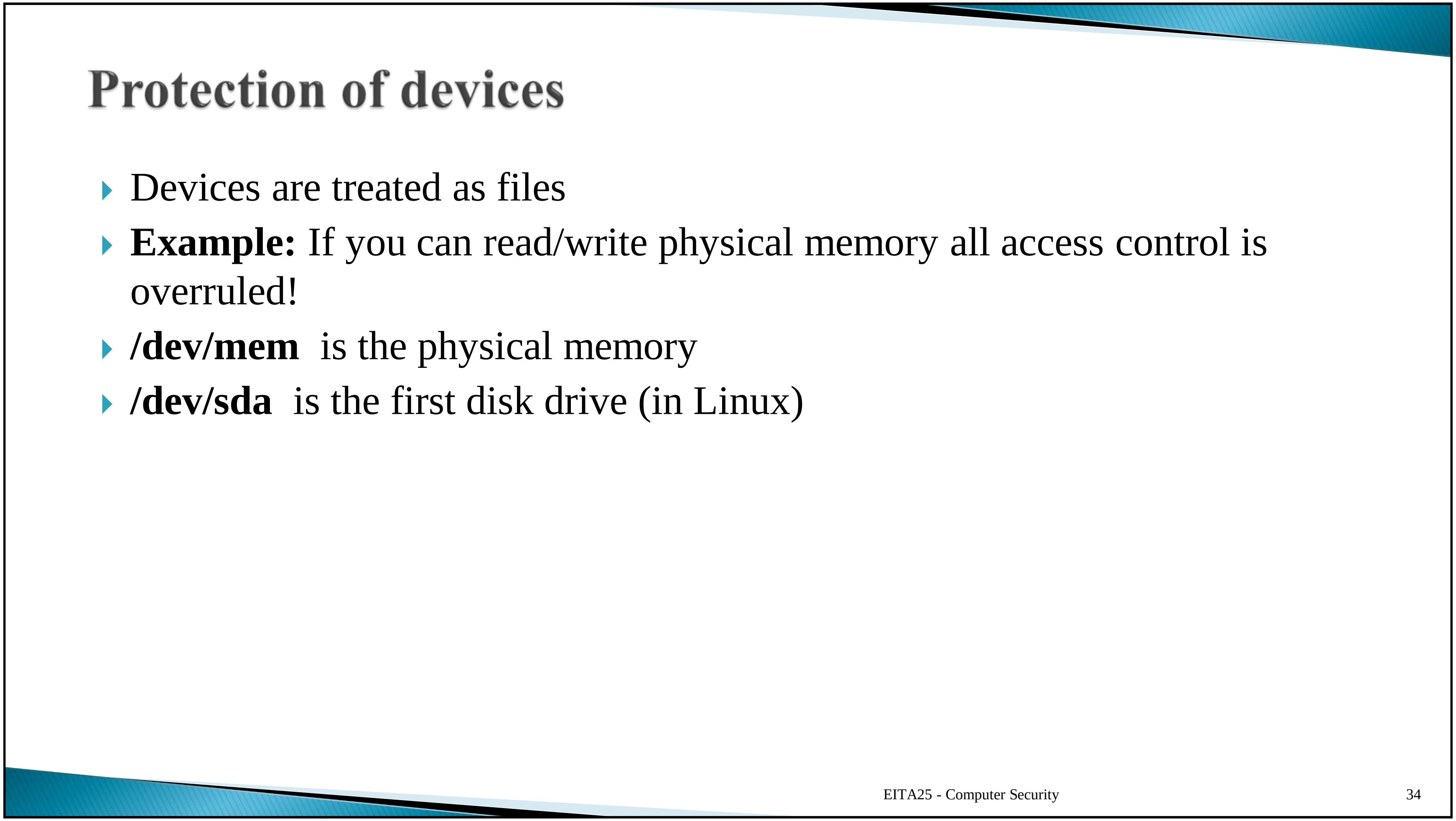
- Assume process ”proc” with effective user ID = 0 writes to files in /tmp directory
  - Process creates e.g., /tmp/file and writes temporary data to this file
- What if malicious user creates /tmp/file as symbolic link to /etc/passwd?
  - The file /etc/passwd will be overwritten since ”proc” has write access to this file
  - System is damaged
- Race condition: Who creates the file first



Solutions To This Race Condition

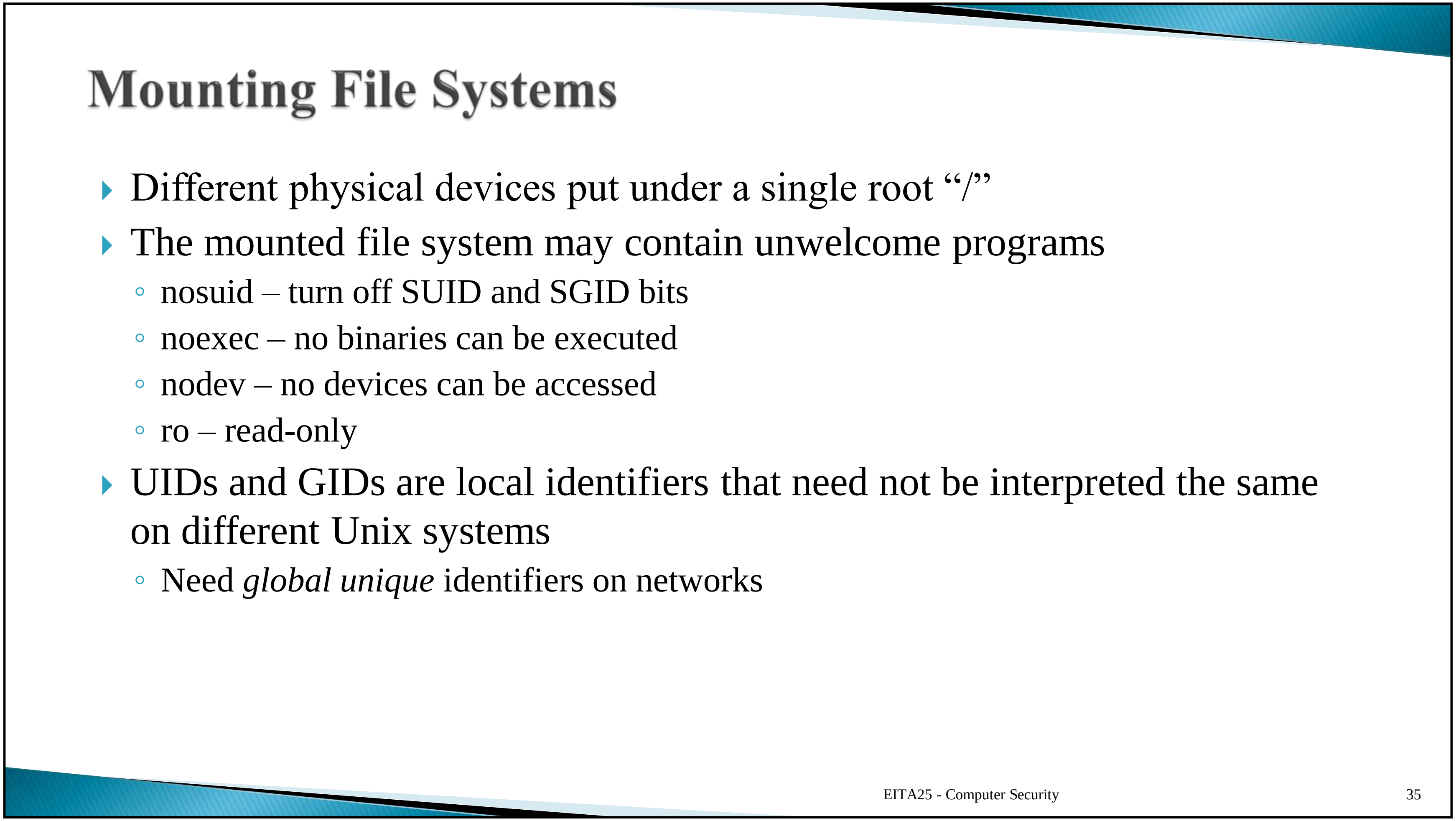
- Create files with unpredictable filenames in /tmp
  - Still, attacker can try thousands of filenames and will succeed with probability > 0
- Use O_CREAT and O_EXCL flag when opening file
  - Then open fails if file already exists
  - Will not follow symbolic links during creation either

Function mkstemp() will do this



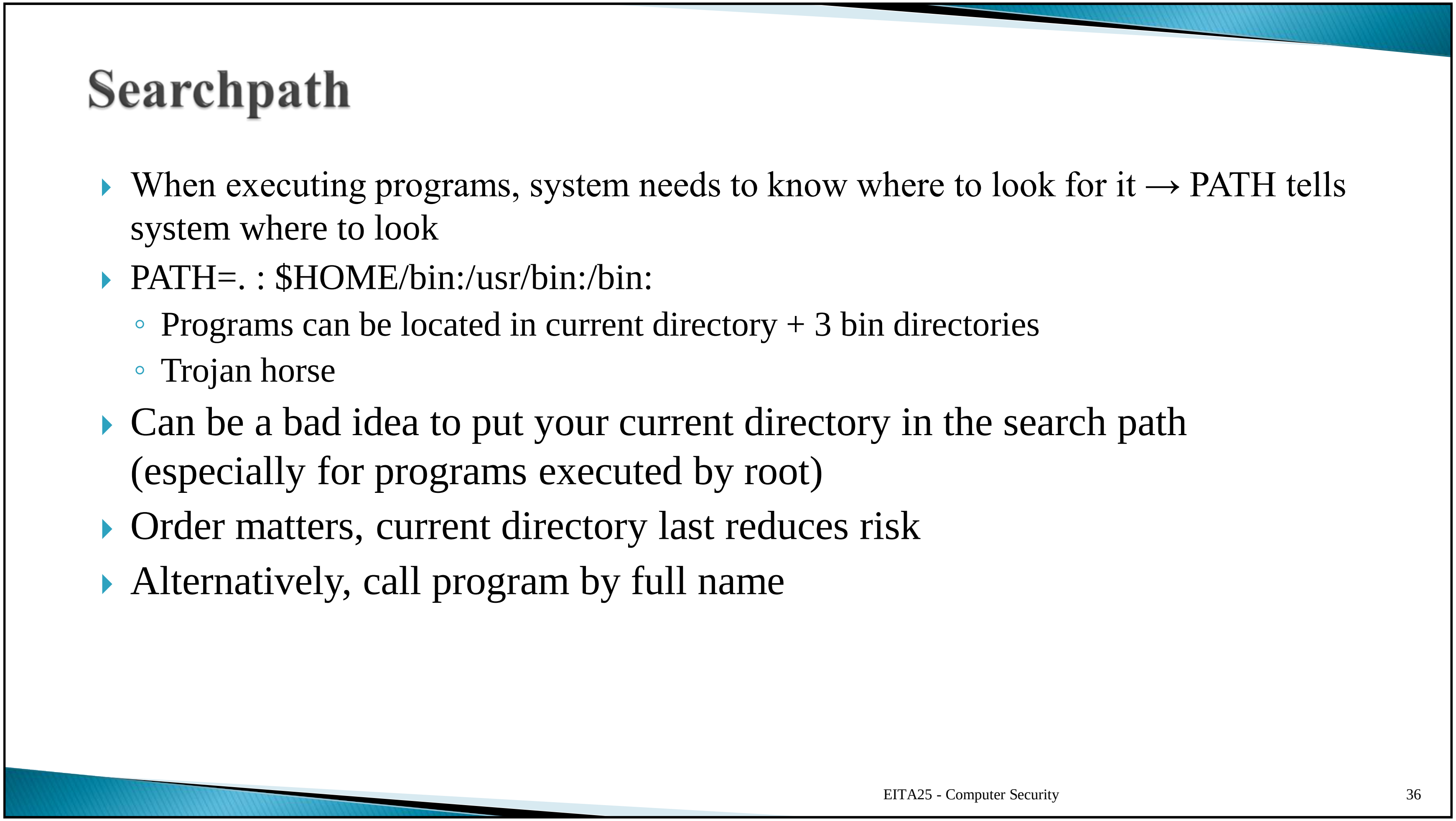
Protection of devices

- Devices are treated as files
- **Example:** If you can read/write physical memory all access control is overruled!
- **/dev/mem** is the physical memory
- **/dev/sda** is the first disk drive (in Linux)



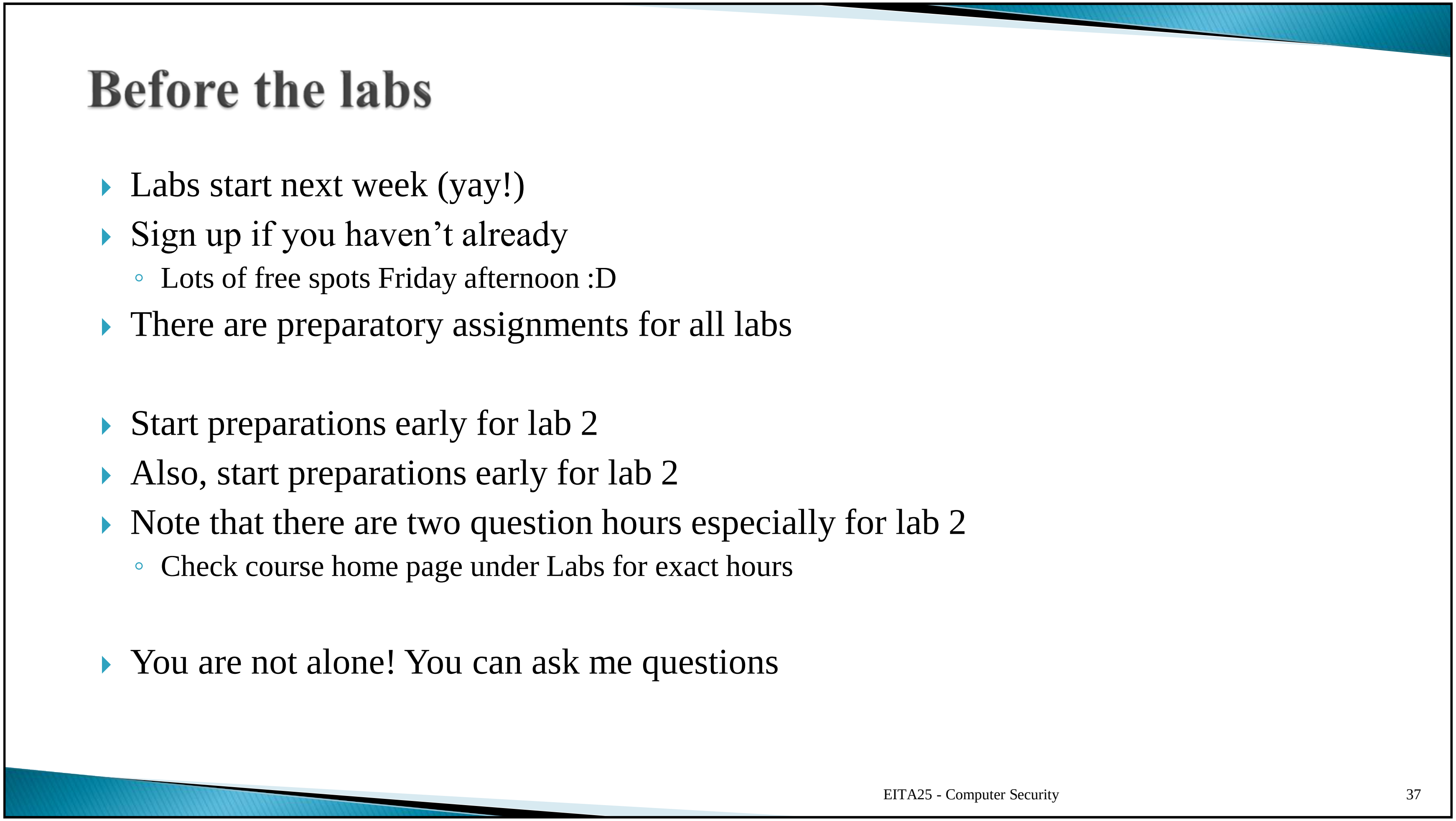
Mounting File Systems

- Different physical devices put under a single root “/”
- The mounted file system may contain unwelcome programs
  - nosuid – turn off SUID and SGID bits
  - noexec – no binaries can be executed
  - nodev – no devices can be accessed
  - ro – read-only
- UIDs and GIDs are local identifiers that need not be interpreted the same on different Unix systems
  - Need *global unique* identifiers on networks



Searchpath

- When executing programs, system needs to know where to look for it → PATH tells system where to look
- PATH=. : $HOME/bin:/usr/bin:/bin:
  - Programs can be located in current directory + 3 bin directories
  - Trojan horse
- Can be a bad idea to put your current directory in the search path (especially for programs executed by root)
- Order matters, current directory last reduces risk
- Alternatively, call program by full name



Before the labs

- Labs start next week (yay!)
- Sign up if you haven't already
  - Lots of free spots Friday afternoon :D
- There are preparatory assignments for all labs

- Start preparations early for lab 2
- Also, start preparations early for lab 2
- Note that there are two question hours especially for lab 2
  - Check course home page under Labs for exact hours

- You are not alone! You can ask me questions