CSE467: Computer Security

22. Access Control

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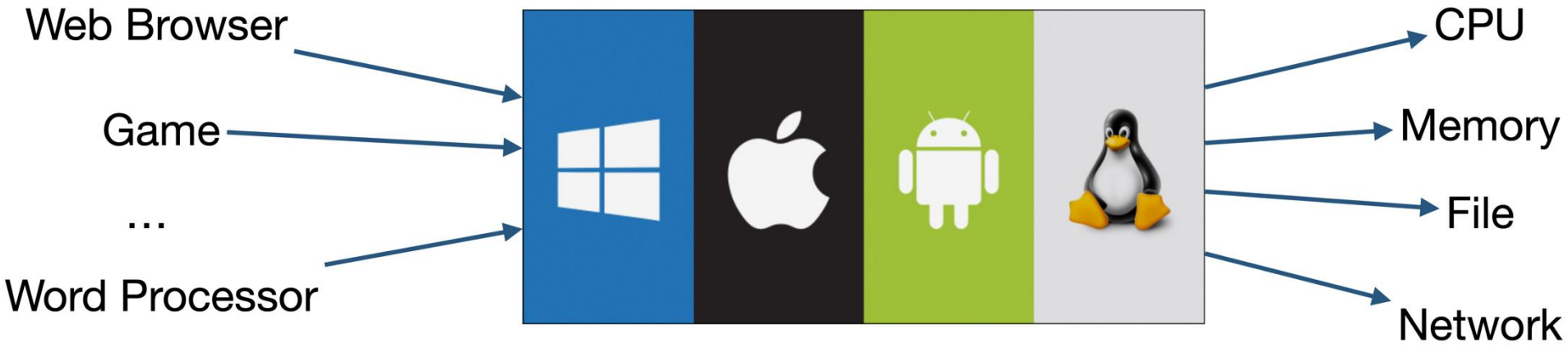
Notification: Final Exam

- Date: 6/18 (Class time)
- Scope: All contents learned in this semester

Operating System Security

- One of the main goal of OS: resource sharing
  - A lot of requests from multiple users/programs for resources

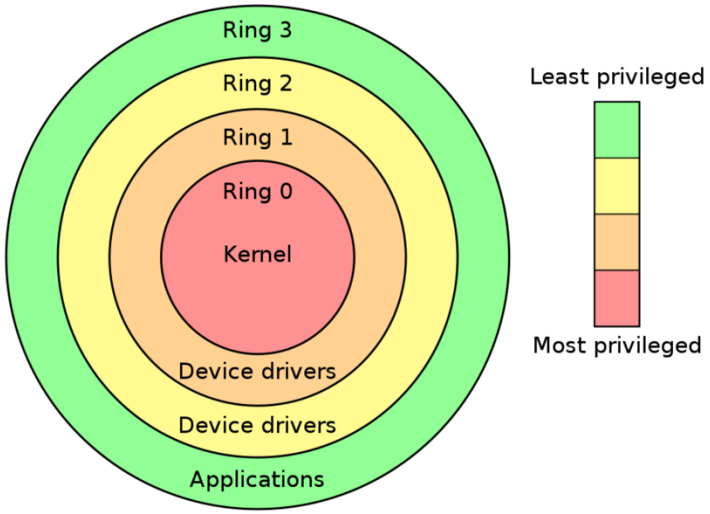


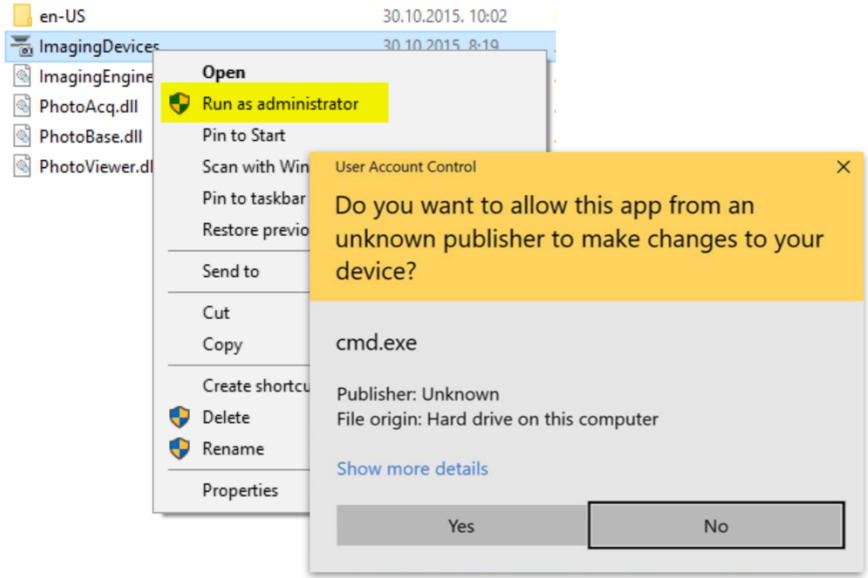
- Important question: how to **securely** share resources?
  - What if someone else abruptly read/write my data/code in memory?
  - What if someone else intentionally change my password?

Principle of Least Privilege

"Every program and every privileged user of the system should operate using the ***least amount of privilege*** *necessary to complete the job"*

- Jerome Saltzer, *Protection and the Control of Information Sharing in Multics,* CACM, 1973





Access Control

- ***Rules*** and ***policies*** that limit access to confidential information
- Determine what users have permission to do
- Permission is determined by identity (e.g., name, serial) or role (e.g., professor, TA, student)

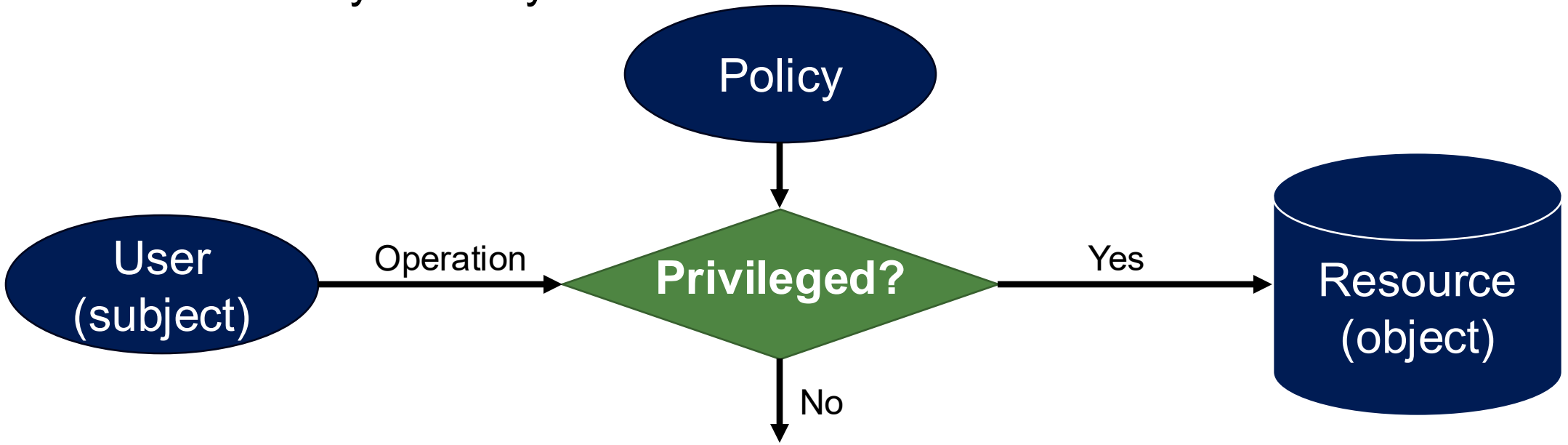
- Defense against attacks in the first place!
- Access control is every where: not only OS
  - E.g., hardware, databases, network, etc.

Question!

- What topics we covered in class are related to access control?

Access Control Method: Reference Monitor

- Check if a **subject (user)** can perform an operation on an **object (resource)**
- Three key properties:
  - Must be always invoked
  - Must be tamper-proof
  - Must be easy to verify



Access Control Policy

How does one grant the right level of permission to an individual?

- **Discretionary access control (DAC)**
  - All objects have owners
  - What permission to grant others? Owners can decide
  - E.g., Unix, Windows, etc.

- **Mandatory access control (MAC)**
  - What permission to grant others? Only the admin can decide
  - Users cannot change policy themselves
  - E.g., SELinux, military, etc.

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Access Control Matrix

- Relationship among **subjects** (users), **objects** (resources), and permissions

	/etc/passwd	/usr/bin/	/home/prof/exam/	/home/admin/
root	rw	rwx	rwx	rwx
professor	r	rx	rwx	-
ta	r	rx	r	-
student1	r	rx	-	-
student2	r	rx	-	-

Access Control Matrix

- Relationship among **subjects** (users), **objects** (resources), and permissions

Object

	/etc/passwd	/usr/bin/	/home/prof/exam/	/home/admin/
root	rw	rwx	rwx	rwx
professor	r	rx	rwx	-
ta	r	rx	r	-
student1	r	rx	-	-
student2	r	rx	-	-

Subject

Permission,
Access Control Entry (ACE)

Problems?

Problem #1: Matrix Size

- Relationship among **subjects** (users), **objects** (resources), and permissions

	/etc/passwd	/usr/bin/	/home/prof/exam/	/home/admin/
root	rw	rwx	rwx	rwx
professor	r	rx	rwx	-
ta				-
student1				-
student2		rx		-

As the number of subjects and objects increases, a large size of memory is required

Problem #2: Useless Space

- Relationship among **subjects** (users), **objects** (resources), and permissions

	/etc/passwd	/usr/bin/	/home/prof/exam/	/home/admin/
root	rw	rwx	rwx	rwx
professor	r	rx	rwx	-
ta	r	rx	r	-
student1	r	rx	-	-
student2	r	rx	-	-

Memory space is wasted

Solution

- Relationship among **subjects** (users), **objects** (resources), and permissions

	/etc/passwd	/usr/bin/	/home/prof/exam/	/home/admin/
root	rw	rwx	rwx	rwx
professor	r	rx	rwx	-
ta	r	rx		-
student1	r	rx		
student2	r	rx		

We need to manage metrics by row or column

Two Approaches for DAC

- Relationship among **subjects** (users), **objects** (resources), and permissions

	/etc/passwd	/usr/bin/	/home/prof/exam/	/home/admin/
root	rw	rwx	rwx	rwx
professor	r	rx	rwx	-
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student1	r	rx	-	-
student2	r	rx	-	-

Object-oriented approach: Access Control List (ACL)

Subject-oriented approach: Capability

Access Control List (ACL)

- **Object-centered** approach
- Widely used in many operating systems as a basic access control method
  - E.g., Unix file system
- Approve requests if the subject has privilege to perform the operation on the object

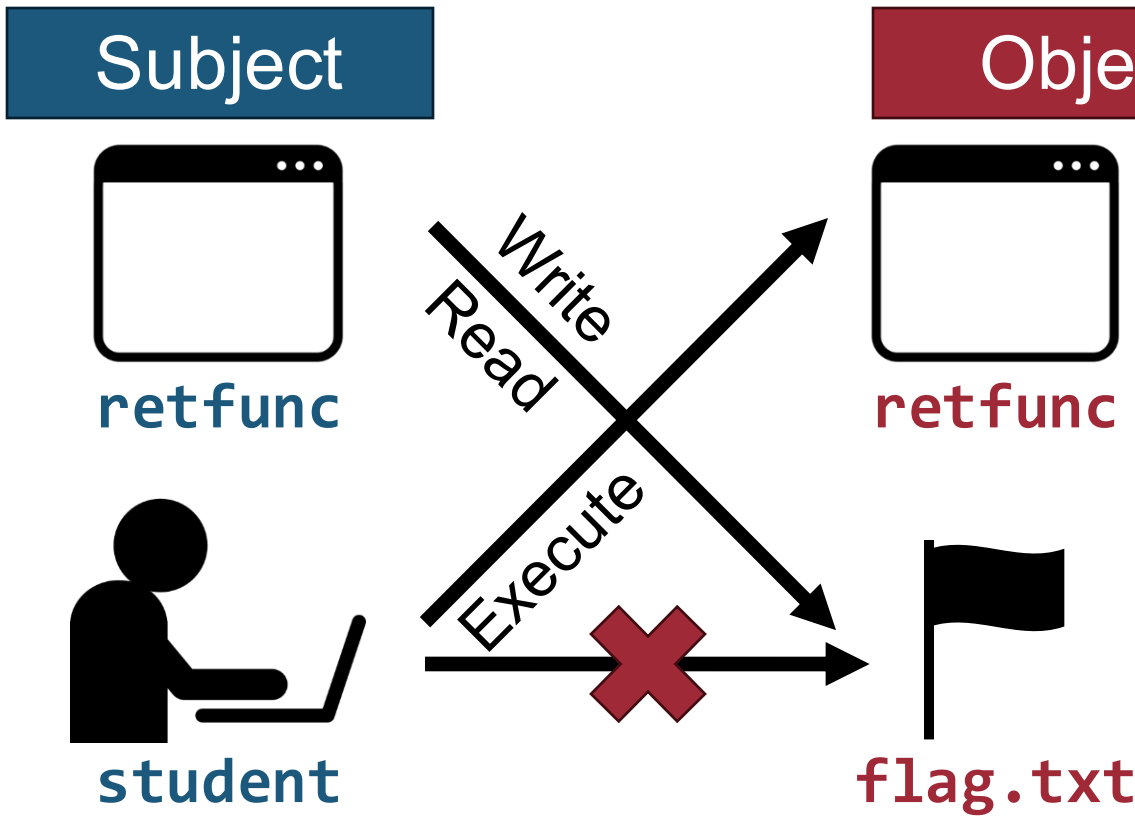
	/etc/passwd
root	rw
professor	r
ta	r
student1	r
student2	r

	/usr/bin/
root	rwx
professor	rx
ta	rx
student1	rx
student2	rx

	/home/prof/exam/
root	rwx
professor	rwx

	/home/admin/
root	rwx

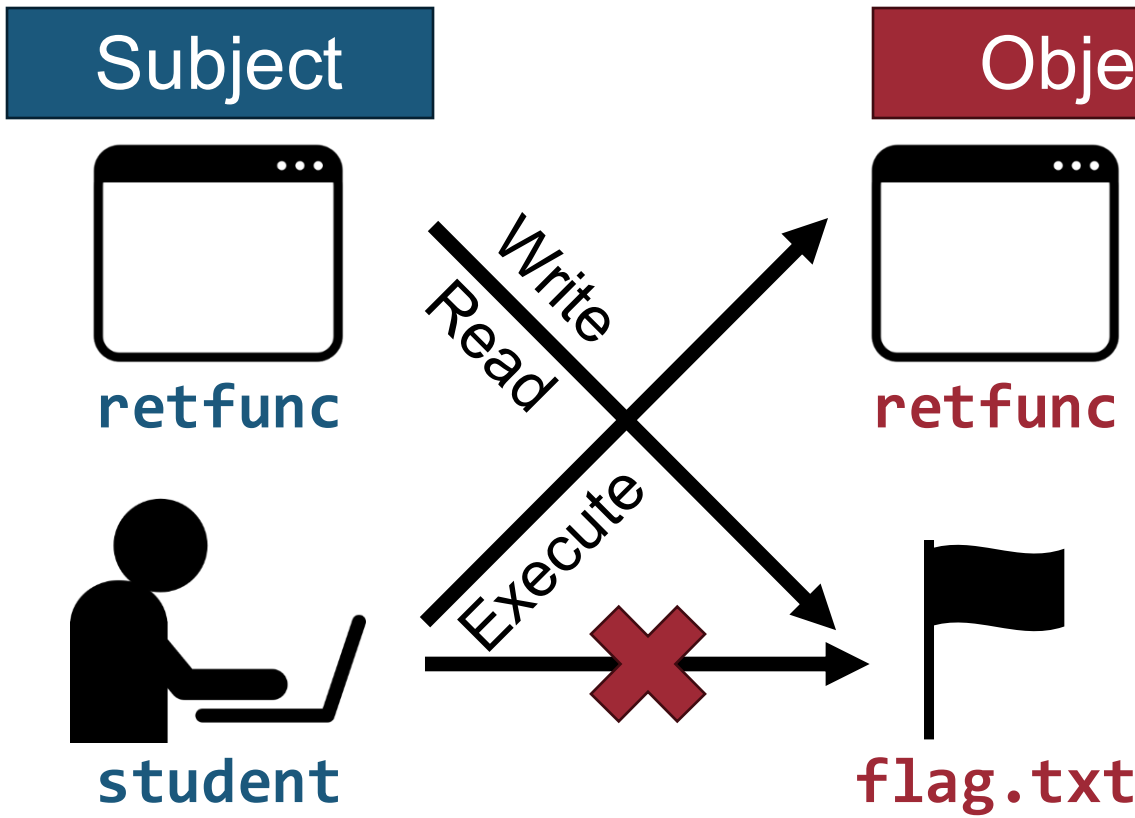
ACL – Example



	retfunc
retfunc	rx
student	x

	flag.txt
retfunc	rw
student	-

ACL – Example



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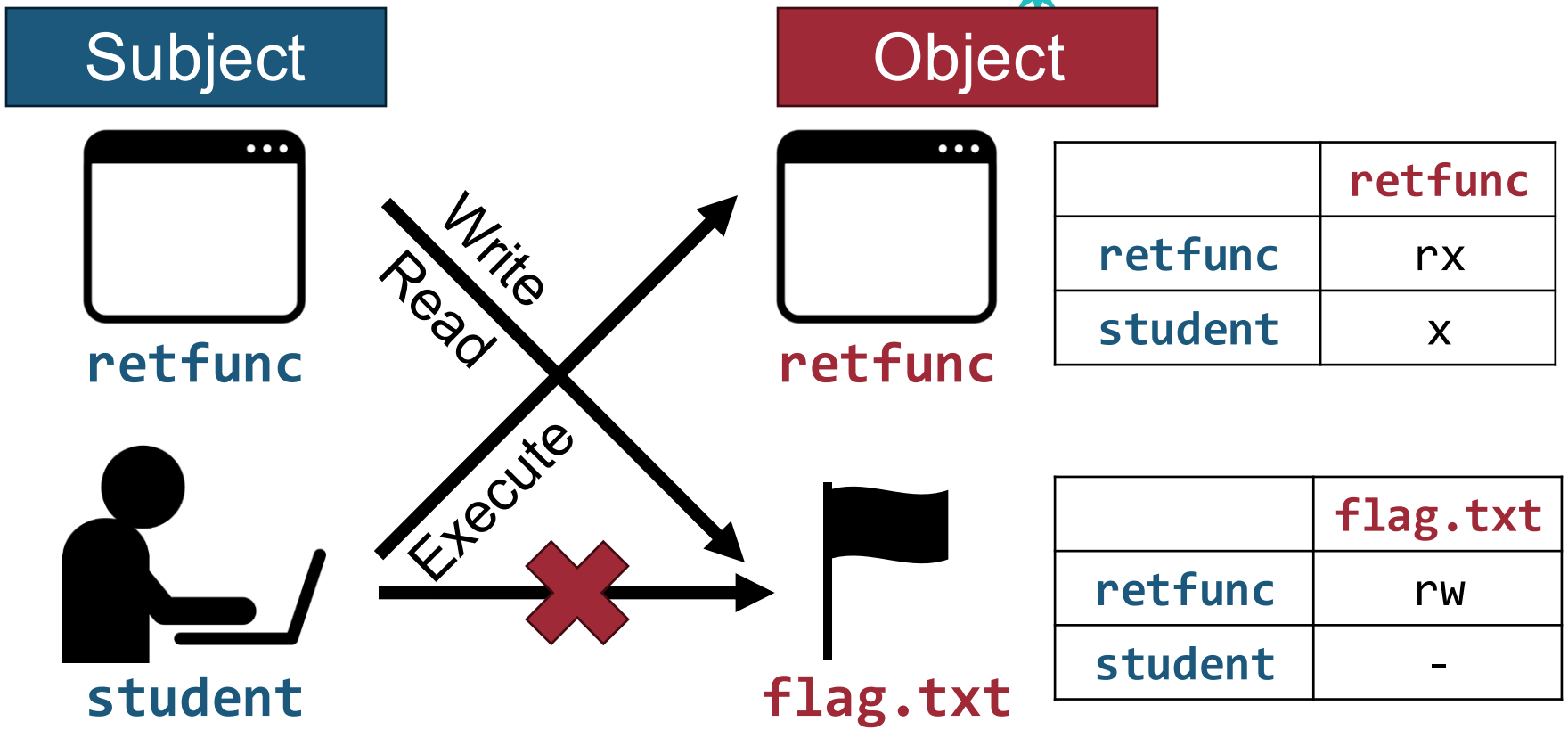
	flag.txt
retfunc	rw
student	-

Problem?

ACL Limitation: Confused Deputy Problem



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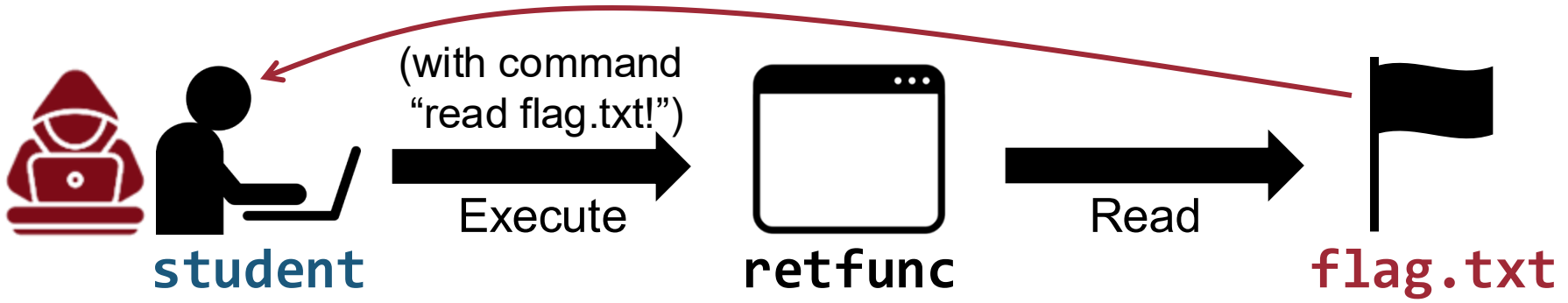
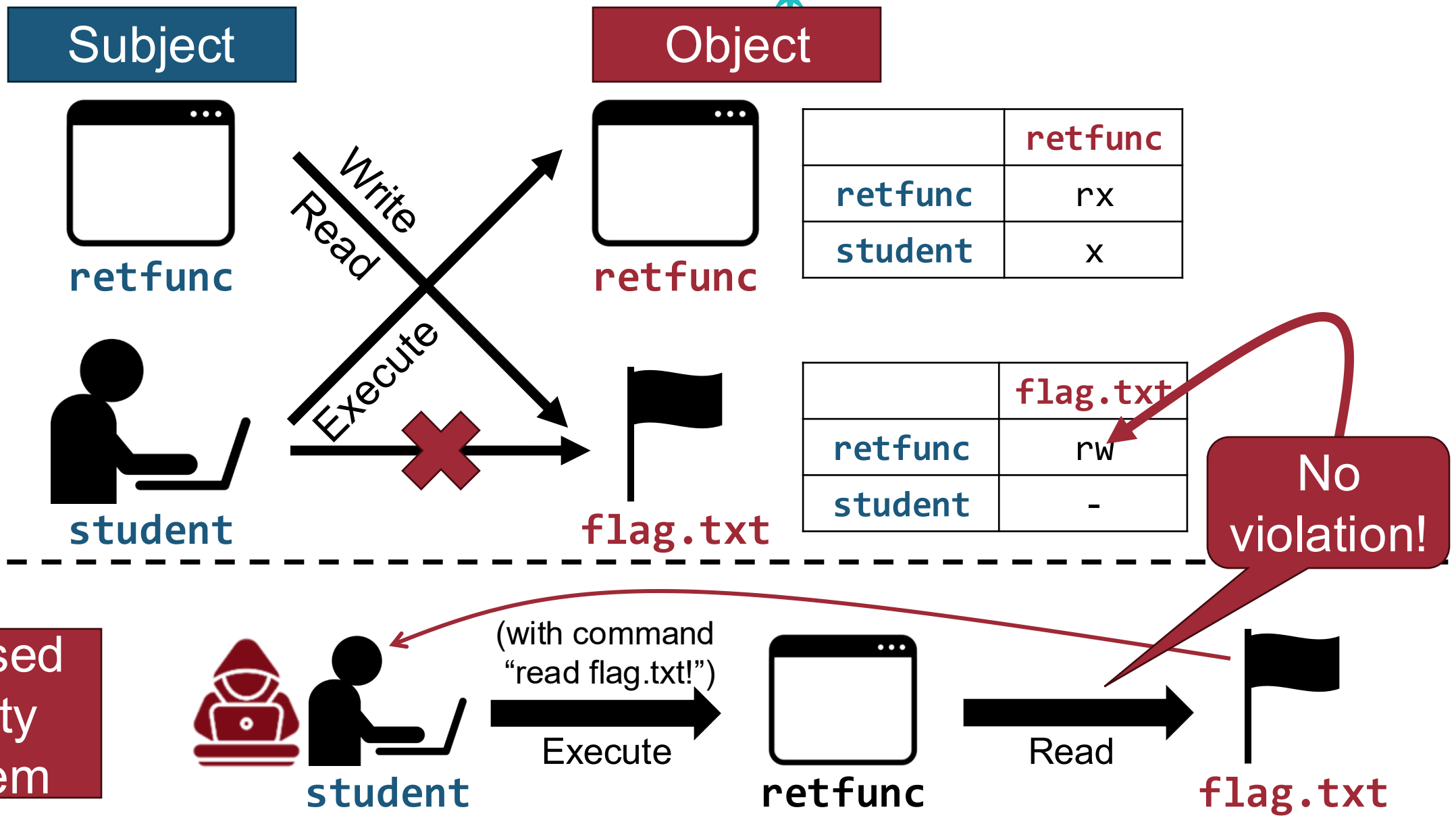
student	-

Confused Deputy Problem



ACL Limitation: Confused Deputy Problem



Confused Deputy Problem: Real-World Example

Confused deputy: How did the vulnerability affect Slack?

A major SAML vulnerability was found in Slack that granted expired login credentials permission into the system. Matt Pascucci explains how this 'confused deputy' problem was handled.

Matthew Pascucci

Security researchers found a major SAML vulnerability in Slack's implementation that led to what's called a *confused deputy* issue. How does the SAML vulnerability work, and what is the confused deputy problem?

AOSP > Secure > Bulletins

Android Security Bulletin—January 2021

Published January 4, 2021 | Updated January 7, 2021

The Android Security Bulletin contains details of security vulnerabilities affecting Android devices. Security patch levels of 2021-01-05 or later address all of these issues. To learn how to check a device's security patch level, see Check and update your Android version.

Android partners are notified of all issues at least a month before publication. Source code patches for these issues have been released to the Android Open Source Project (AOSP) repository and linked from this bulletin. This bulletin also includes links to patches outside of AOSP.

The most severe of these issues is a critical security vulnerability in the System component that could enable a remote attacker using a specially crafted transmission to execute arbitrary code within the context of a privileged process. The severity assessment is based on the effect that exploiting the vulnerability would possibly have on an affected device, assuming the platform and service mitigations are turned off for development purposes or if successfully bypassed.

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OS X 10.10 DYLD_PRINT_TO_FILE Local Privilege Escalation Vulnerability

Stefan Esser — 2015-07-07 17:30

The DYLD_PRINT_TO_FILE environment variable can be used for local privilege escalation in OS X Yosemite.

Introduction

With the release of OS X 10.10 Apple added some new features to the dynamic linker dyld. One of these features is the new environment variable **DYLD_PRINT_TO_FILE** that enables error logging to an arbitrary file.

```
DYLD_PRINT_TO_FILE
This is a path to a (writable) file. Normally, the dynamic linker writes all logging output (triggered by DYLD_PRINT_* settings) to file descriptor 2 (which is usually stderr). But this setting causes the dynamic linker to write logging output to the specified file.
```

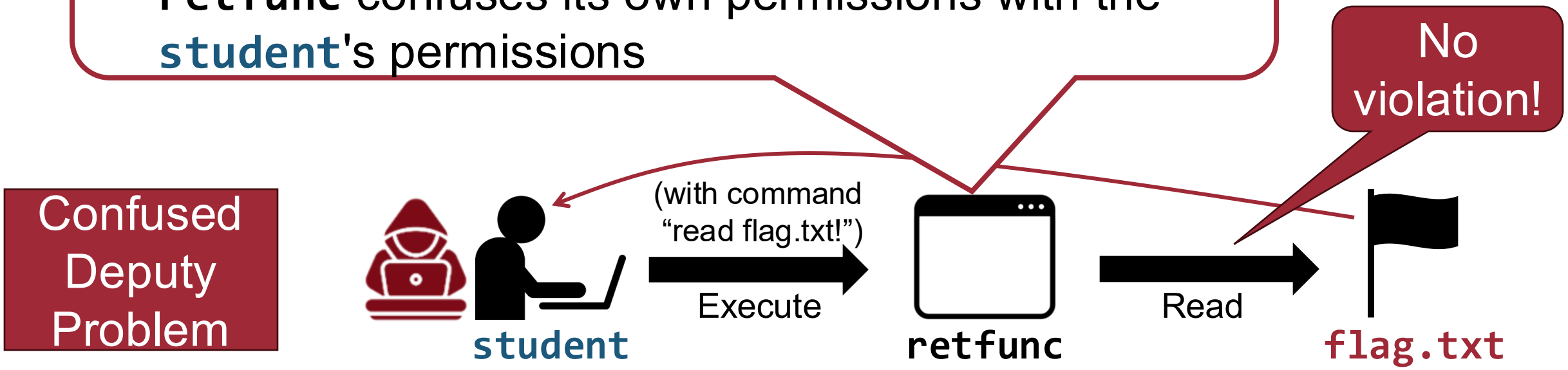
When this variable was added the usual safeguards that are required when adding support for new environment variables to the dynamic linker have not been used. Therefore it is possible to use this new feature even with SUID root binaries. This is dangerous, because it allows to open or create arbitrary files owned by the root user anywhere in the file system. Furthermore the opened log file is never closed and therefore its file descriptor is leaked into processes spawned by SUID binaries. This means child processes of SUID root processes can write to arbitrary files owned by the root user anywhere in the filesystem. This allows for easy privilege escalation in OS X 10.10.x.

Confused Deputy Problem: Root Cause

- A subject that is tricked by another subject (with fewer privileges) into misusing its authority
- It is a specific type of privilege escalation

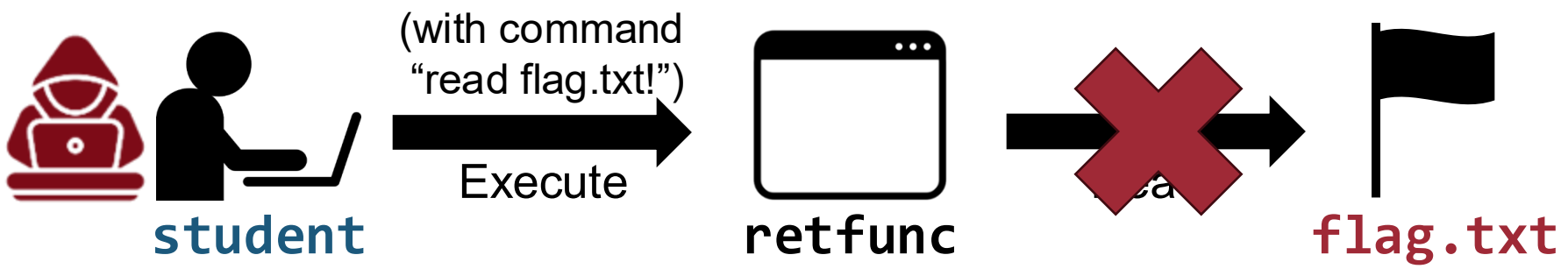
Root cause: the deputy (`retfunc`) got confused

- **`student`** is not permitted to read the **`flag.txt`** file
- **`retfunc`** confuses its own permissions with the **`student`**'s permissions



Simple Solution

Delegate authority:
`Student` should passing both the object (flag.txt)
it want to read, and a permission token (-)
⇒ Capability



Two Approaches for DAC

- Relationship among **subjects** (users), objects (resources), and permissions

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student2	r	rx	-	-

Object-oriented approach: Access Control List (ACL)

Subject-oriented approach: Capability

Capability

- Subject-centered approach
- **Capability**: a pair of an **object** and a set of privileges
- A deputy (**`retfunc`**) could ask its requester (**subject**) to provide a capability and use it to request resources
- Mostly used for more secure operating systems (E.g., KeyKOS)
  - Also partly used in main stream OS such as Linux

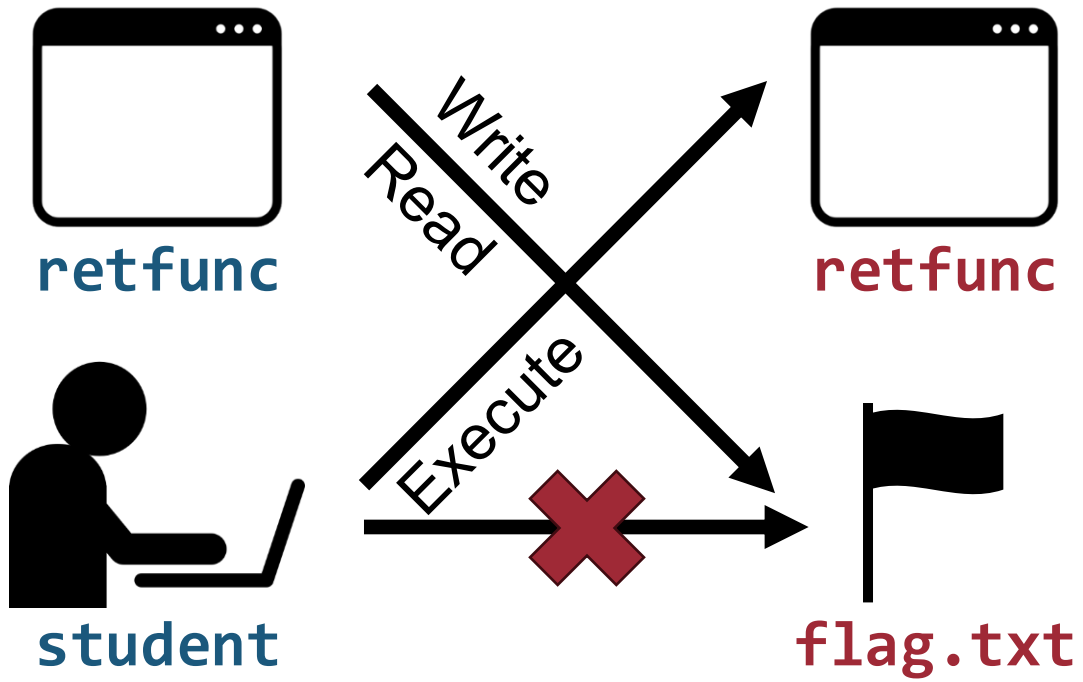
	`retfunc`	`flag.txt`
`student`	x	-

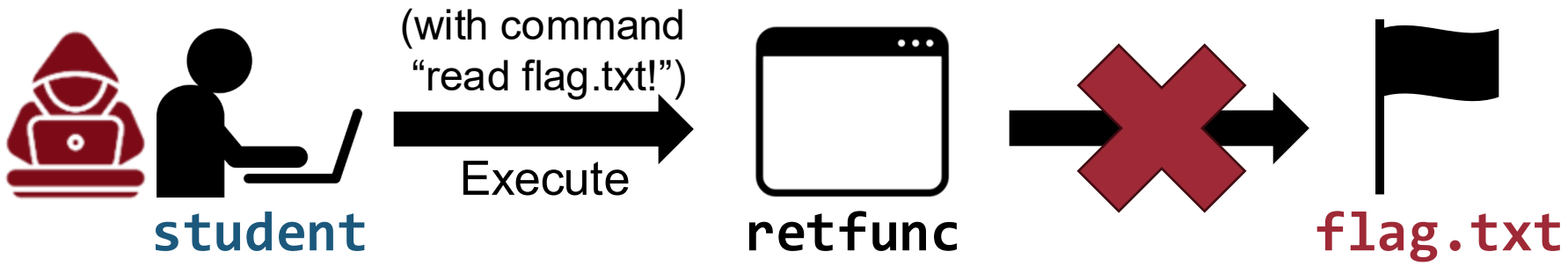
	`retfunc`	`flag.txt`
`retfunc`	rx	rw

Capability – Example

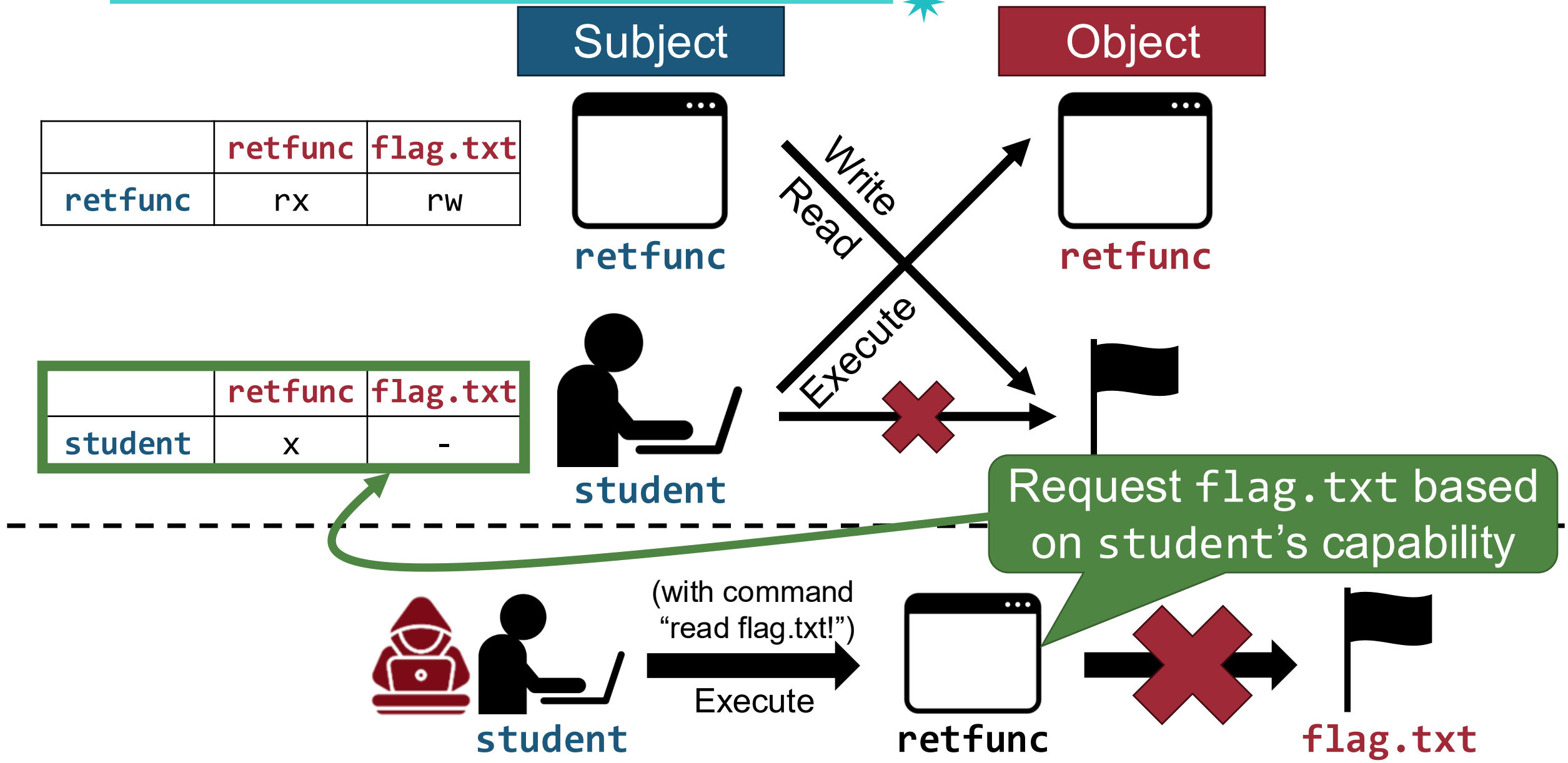
	retfunc	flag.txt
retfunc	rx	rw

	retfunc	flag.txt
student	x	-





Capability – Example



ACL vs. Capabilities

- ACL: “for each object, which subjects have permissions?”
  - More efficient to implement
  - Confused deputy problem
- Capabilities: “for each subject, which objects are allowed to be accessed?”
  - More secure by fine-grained access control
  - Easier to avoid the confused deputy (More secure)
  - More difficult to implement
- Then, capability-based approach is secure enough?

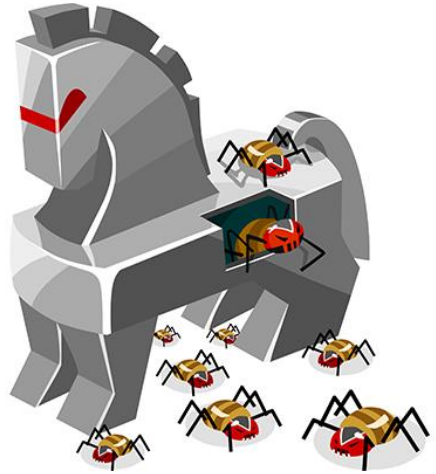
Trojan Horse

- A type of malware that disguises itself as legitimate code

Dear Professor,
I found and fixed a functional bug in the `retfunc`. Here is the patched one

```
void retfunc(...) {
    ...
+ if (user == “professor”) {
+   flag = read(“flag.txt”);
+   write(“/tmp/myown.txt”, flag);
+ }
}
```

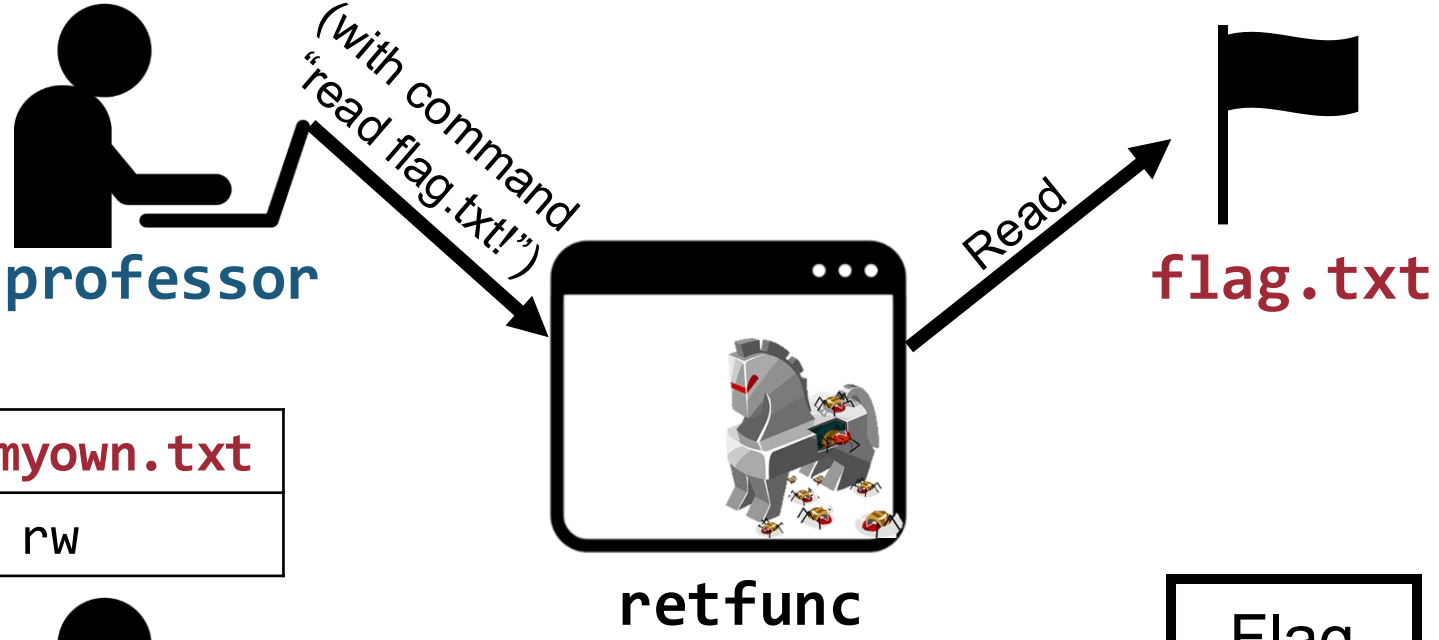
Thanks a lot! I will give you bonus points!



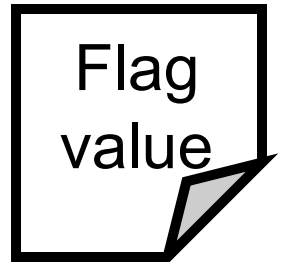
Trojan Horse

```
if (user == “professor”) {
+    flag = read(“flag.txt”);
+    write(“/tmp/myown.txt”, flag);
+ }
```

	retfunc	flag.txt	/tmp/myown.txt
professor	x	rw	rw



	retfunc	flag.txt	/tmp/myown.txt
student	x	-	rw



Trojan Horse

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if (user == “professor”) {
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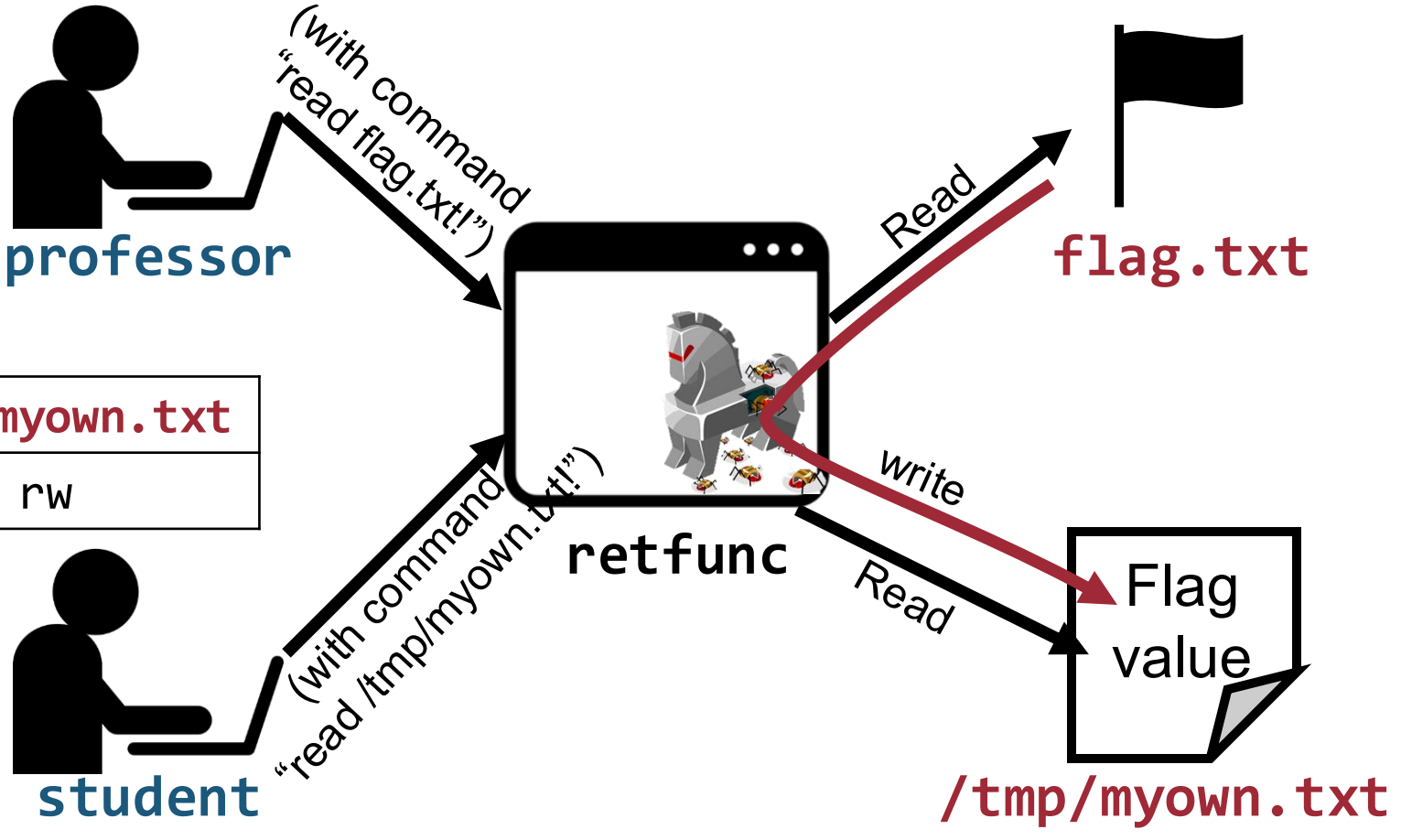
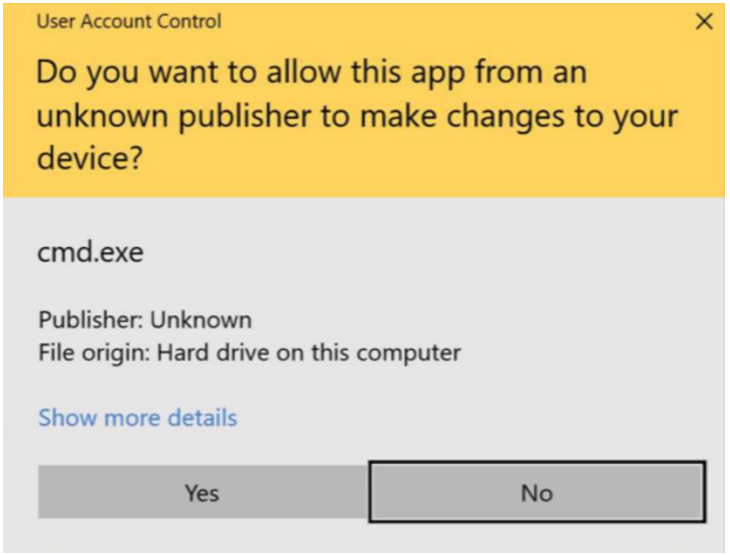
	retfunc	flag.txt	/tmp/myown.txt
professor	x	rw	rw

	retfunc	flag.txt	/tmp/myown.txt
student	x	-	rw



Exploitation

- Why this happen?
  - Malware or buggy SW
  - Attacker's intention with the user's privileges
  - No way to tell the difference between the legitimate software and a Trojan



- How to avoid this?
  - More restrictive access control (later this lecture)
  - Program analysis (later this semester)

Lessons from DAC

- Access control: not an easy problem
  - Balance between usability and security

- Well-known issues
  - Confused deputy: protected by capability-based systems
  - Trojan horse: do not trust programs from unknown sources

Real World Example: Unix

- Each process has a user id
  - Inherit from the parent process
  - Special root id: all access allowed

```
su3604@ubuntu:~$ cat /etc/passwd
root:x:0:0:root:/root:/bin/bash
daemon:x:1:1:daemon:/usr/sbin/nologin
bin:x:2:2:bin:/bin:/usr/sbin/nologin
sys:x:3:3:sys:/dev:/usr/sbin/nologin
```

User id

- Each **file** has an access control list (ACL)
  - Grants permission to users
  - Owner, group, other

	File1	File2	File3	…
User1	rw	rwx	rwx	rwx
User2	r	rx	rwx	–
User3	r	rx	r	–
…	r	rx	–	–

Unix File Access Control List

- Each file has an owner and group
- Permissions set by owners
  - {read, write, execute} x {owner, group, other}

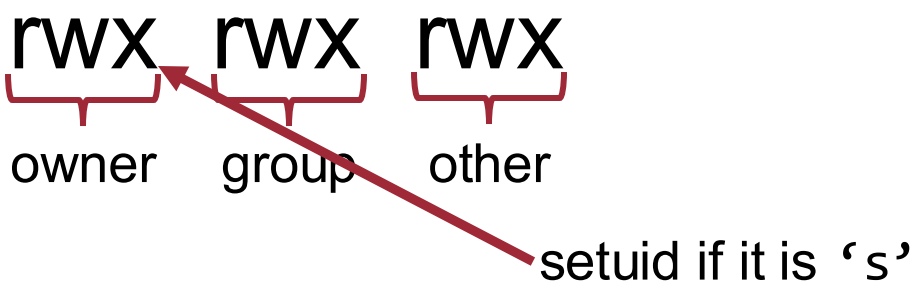
- Only owners and root can change permissions

Unix File Access Control List

- Each file has an owner and group
- Permissions set by owners
  - {read, write, execute} x {owner, group, other}

- Only owners and root can change permissions
- Q: How can we run processes on behalf of someone else?
  - E.g., password change (`passwd`)

```
retfunc@ubuntu$ ls -l /etc/passwd
-rw-r--r-- 1 root root 2970 Oct 22  2023 /etc/passwd
```



User ID

- Each process has three IDs in Unix
- Real user ID (RUID)
  - Same as the user ID of the parent
  - To determine which user started the process
- Effective user ID (EUID)
  - From "Set User ID" bit on the file being executed or system calls
  - To determine the permissions for the process
- Saved user ID (SUID)
  - To restore previous EUID

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```
retfunc@ubuntu$ ls -al /usr/bin/passwd
-rwsr-xr-x 1 root root 68208 Feb  6  2024 /usr/bin/passwd
```

User ID

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- Say
  - To restore previous EUID

If you execute `/usr/bin/passwd`, the EUID of the process is "`root`"

```
retfunc@ubuntu$ ls -al /usr/bin/passwd
-rwsr-xr-x 1 root root 68208 Feb  6  2024 /usr/bin/passwd
```

It is possible to write data from `/usr/bin/passwd`

```
retfunc@ubuntu$ ls -l /etc/passwd
-rw-r--r-- 1 root root 2970 Oct 22  2023 /etc/passwd
```

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- **Discretionary access control (DAC)**
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  - E.g., Unix, Windows, etc.

- **Mandatory access control (MAC)**
  - What permission to grant others? Only the admin can decide
  - Users cannot change policy themselves
  - E.g., SELinux, military, etc.

Mandatory Access Control (MAC)

- The system assigns both **subjects** and **objects** special security attributes
  - E.g., top secret, unclassified

- Privileges cannot be changed by users but by **system administrators**
- More restrictive and secure than discretionary access control
- Mostly used in security-critical systems (e.g., military)

Multilevel Security (MLS)

- Most common form of mandatory access control

- Developed by the US Department of Defense
  - All **information (objects)** possesses a classification
  - All **person (subject)** posses a classification (or clearance)

- Access is allowed if the **person**'s class is *higher than* the **information**' class

Security Classification

- Two components: **security level** (sensitivity) and **compartment** (category)

- **Security level**: a total ordered (small) set
  - Access is allowed if the **subject**'s level is *higher than* the **objects**' level
  - e.g., UNCLASSFIED < CONFIDENTIAL < SECRET < TOP SECRET

- **Compartment**: a set of categories
  - Access allowed if **subject**'s compartments *includes* **object**'s compartments
  - E.g., {MILITARY, ECONOMY, ENVIRONMENT}

Classification Lattice

- The combination of **security level** and **compartment** forms a *lattice*
  - E.g., Security level = {TOP SECRET, SECRET},
    Compartment = {Army, Nuclear}

- Lattice (SC, $\sqsubseteq$): a **partially ordered set** that satisfies the followings (SC = Security level + Compartment)
  - Reflexivity: $\forall x \in SC. \boldsymbol{x} \sqsubseteq \boldsymbol{x}$
  - Transitivity: $\forall x, y, z \in SC. \boldsymbol{x} \sqsubseteq \boldsymbol{y} \wedge \boldsymbol{y} \sqsubseteq \boldsymbol{z} \implies \boldsymbol{x} \sqsubseteq \boldsymbol{z}$
  - Anti-symmetry: $\forall x, y \in SC. \boldsymbol{x} \sqsubseteq \boldsymbol{y} \wedge \boldsymbol{y} \sqsubseteq \boldsymbol{x} \implies \boldsymbol{x} = \boldsymbol{y}$
  - Order: $\langle S1, C1 \rangle \sqsubseteq \langle S2, C2 \rangle \Leftrightarrow \boldsymbol{S1} \leq \boldsymbol{S2} \wedge \boldsymbol{C1} \subseteq \boldsymbol{C2}$

Classification Lattice – Example

- The combination of **security level** and **compartment** forms a *lattice*
  - E.g., Security level = {TOP SECRET, SECRET},
    Compartment = {Army, Nuclear}
  - All possible set:
    - Security level: TOP SECRET or SECRET
    - Compartment: ∅, {Army}, {Nuclear}, {Army, Nuclear}

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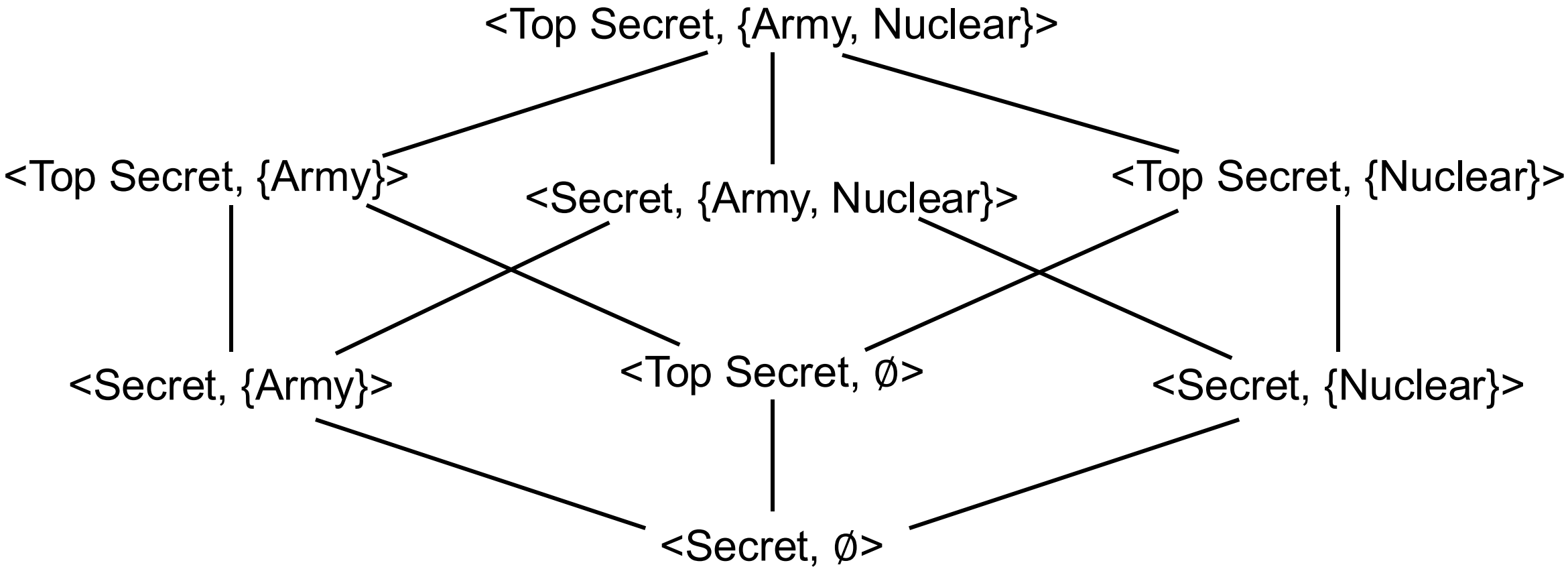

Classification Lattice – Example

- The combination of **security level** and
  - E.g., Security level = {TOP SECRET, SECR
    Compartment = {Army, Nuclear}

File's classification:
<Top Secret, {Nuclear}>

<Top Secret, {Army, Nuclear}>

<Secret, {Army, Nuclear}>

<Top Secret, {Nuclear}>

User's classification:
<Secret, {Army}>

Access denied

<Secret, {Army}>

<Top Secret, ∅>

<Secret, {Nuclear}>

<Secret, ∅>

Classification Lattice – Example

- The combination of **security level** and ce
  - E.g., Security level = {TOP SECRET, SECR
    Compartment = {Army, Nuclear}

File's classification:
<Top Secret, {Nuclear}>

<Top Secret, {Army, Nuclear}>

Access allowed

<Top Secret, {Nuclear}>

User's classification:
<Top Secret, {Army, Nuclear}>

et, {Army, Nuclear}>

<Secret, {Army}>

<Top Secret, ∅>

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<Top Secret, {Nuclear}> ⊑ <Top Secret, {Army, Nuclear}>

Classification Lattice – Example

- The combination of **security level** and **compartment** forms a *lattice*
  - E.g., Security level = {TOP SECRET, SECRET},
    Compartment = {Army, Nuclear}

<Top Secret, {Army, Nuclear}>

Access allowed

User's classification:
<Top Secret, {Army, Nuclear}>

<Top Secret, ∅>

File's classification:
<Top Secret, ∅>

<Top Secret, ∅ > ⊑ <Top Secret, {Army, Nuclear}>

The Bell-LaPadula Model (BLP)

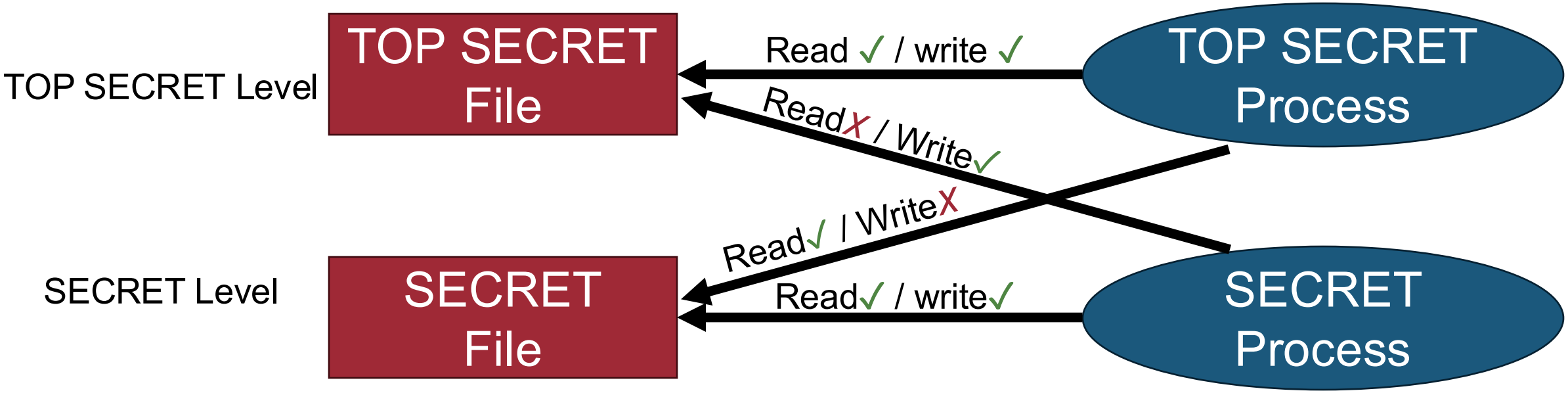
- The first mathematical model of a multilevel secure system in 1973

- Main concern: **prevent information leak** (confidentiality)
  - Ensures that information do not flow from higher security class to lower/incomparable class

- Idea:
  - Lower class subjects **cannot read higher** class objects (NO READ UP)
  - Higher class subjects **cannot write lower** class objects (NO WRITE DOWN)

The BLP Model: Properties

- Simple property (NO READ UP):
  - a **subject** at a given security level may not read an **object** at a higher security level
- *-property (NO WIRTE DOWN)
  - a **subject** at a given security level may not write to any **object** at a lower security level



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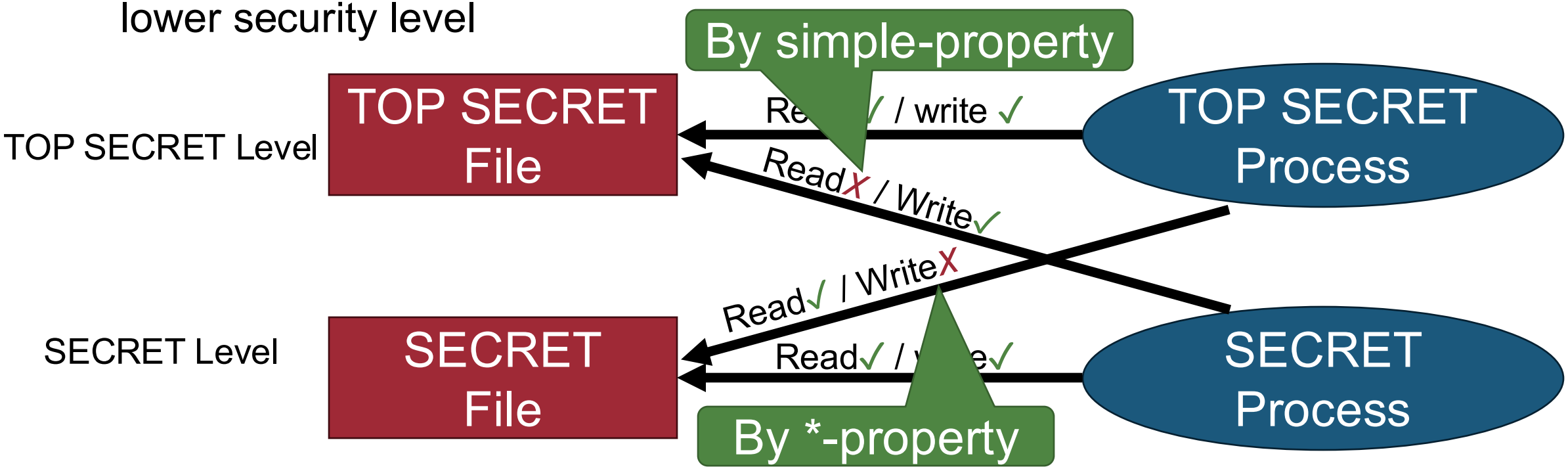


Pros and Cons of BLP

- Pros: confidentiality
- When is BLP useful?
  - NO READ UP, NO WRITE DOWN = READ DOWN, WRITE UP
  - Reporting system (e.g., government, military, school)

- Cons: integrity
  - Attackers cannot read secret information, but what about write?
  - E.g., fake announcement

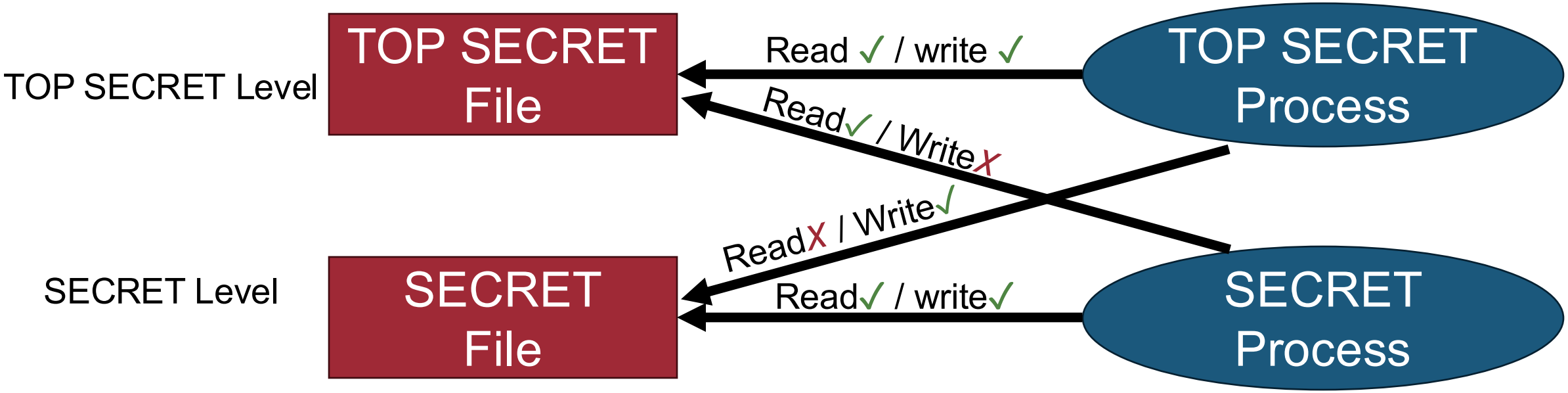
The Biba Model

- Dual of BLP
- Main concern: **prevent unauthorized change** (integrity)
  - from **lower class** to **higher class**

- Idea:
  - Lower class subjects **cannot write higher** class objects (NO WRITE UP)
  - Higher class subjects **cannot read lower** class objects (NO READ DOWN)

The Biba Model: Properties

- *-property (NO WRITE UP):
  - a **subject** at a given security level may not write an **object** at a higher security level
- Simple property (NO READ DOWN)
  - a **subject** at a given security level may not read to any **object** at a lower security level



The Biba Model: Properties

- *-property (NO WRITE UP):
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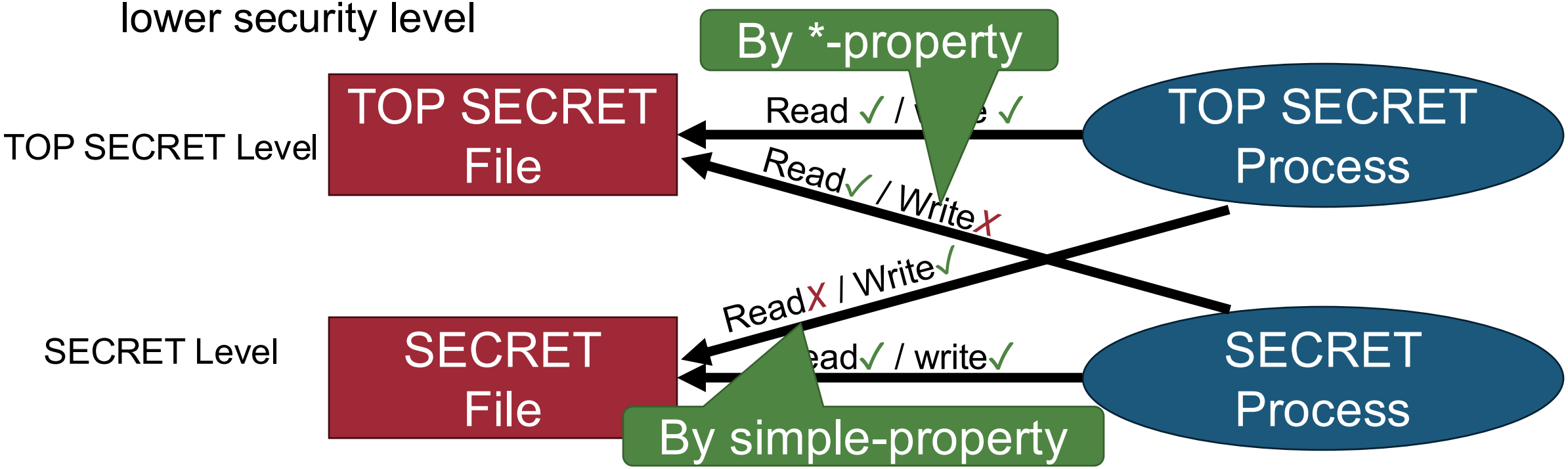
- Simple property (NO READ DOWN)
  - a **subject** at a given security level may not read to any **object** at a lower security level



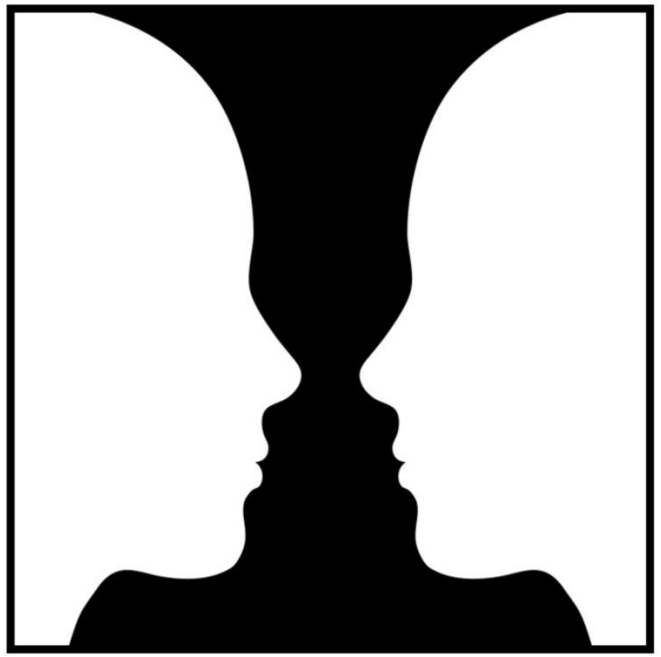
Pros and Cons of Biba

- Pros: integrity
- When is BLP useful?
  - NO WRITE UP, NO READ DOWN = WRITE DOWN, READ UP
  - Notification system (i.e., important notice won't be compromised)

- Cons: confidentiality

BLP vs. Biba

- BLP and Biba are mutually exclusive in the same classification
- But, confidentiality and integrity can coexist in the same system
  - In their own independent classifications



Summary

- Access control: determine what users have permission to do
- Discretionary access control (DAC): owner's discretionary
  - ACL-based: more usable but the confused deputy problem can occur
  - Capability-based: more secure but still Trojan can occur
- Mandatory Access Control (MAC): admin's policy
  - BLP (confidentiality) vs Biba (integrity)
- Which (combination of) models to choose? depending on the systems and goals