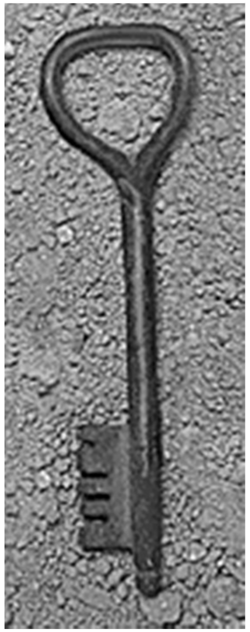
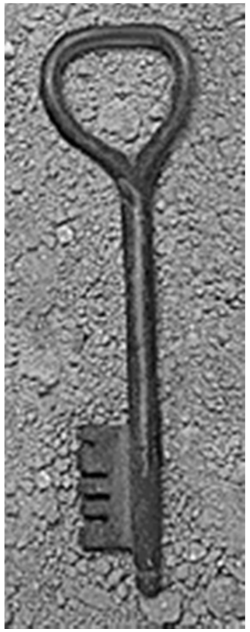


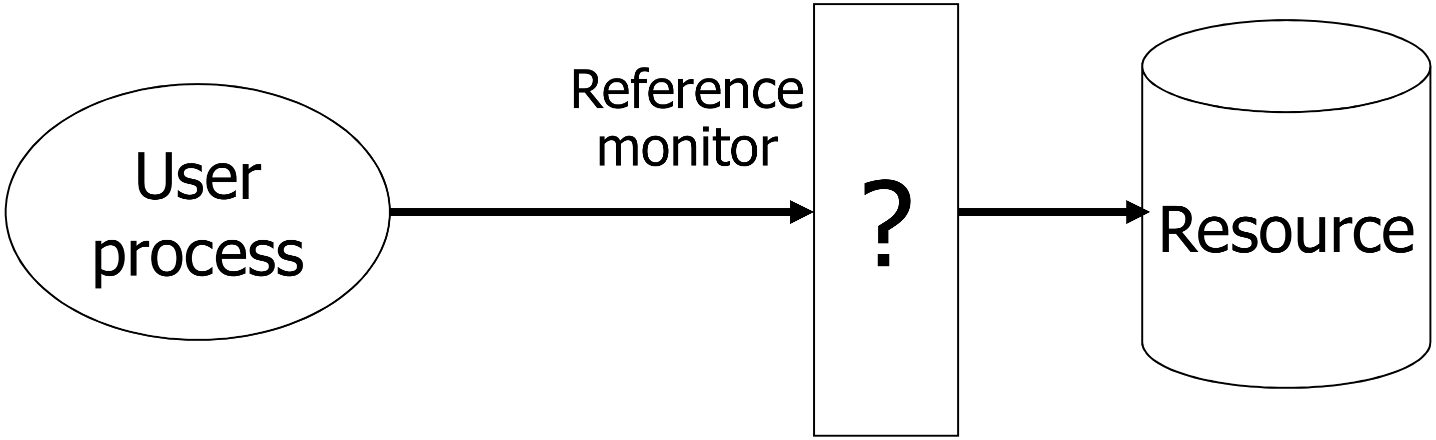
Authorization

- given who you are, what can you do?
- how do we control privileges?

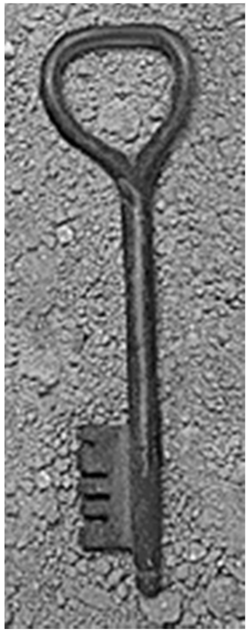


Authorization - Access Control

- Common Assumption
  - System knows who the user is
    - User has passed Identification & Authentication
  - Access requests pass through gatekeeper
    - System must be designed monitor cannot be bypassed



Decide whether user can apply operation to resource



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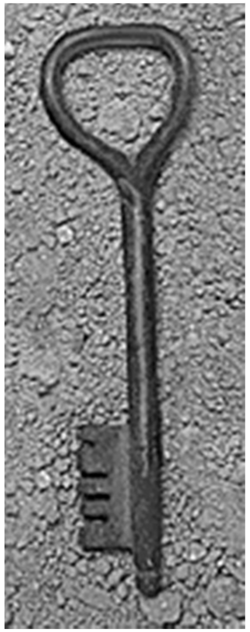
- Access matrix model
- Access control lists versus Capabilities
- Discretionary versus mandatory controls
- Bell-LaPadula model
- Advanced: Covert channels
- Advanced: Beyond MAC and DAC



Access Control Matrix

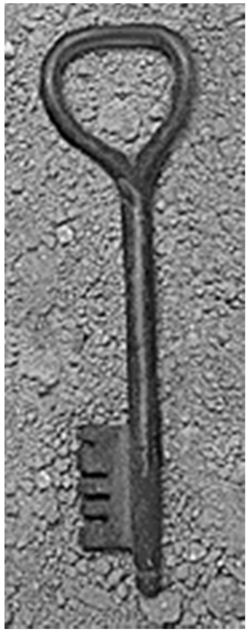
[Lampson 1971]

Objects

rights

Subjects

	File 1	File 2	File 3	...	File n
User 1	read	write	-	-	read
User 2	write	write	write	-	-
User 3	-	-	-	read	read
...					
User m	read	write	read	write	read

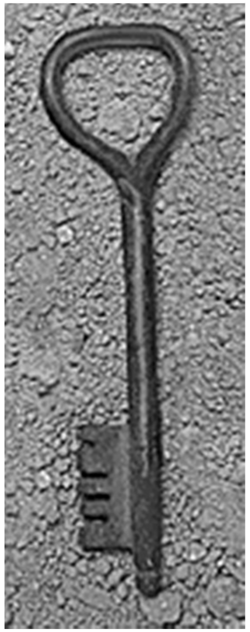


Access Control Matrix

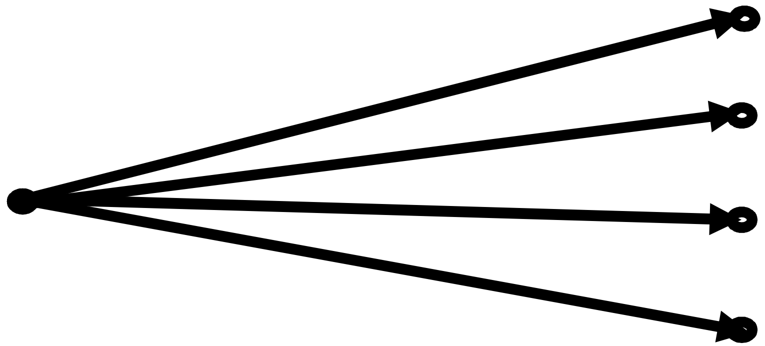
- Basic Abstractions
  - Subjects
  - Objects
  - Rights

	File 1	File 2	File 3	...	File n
User 1	read	write	-	-	read
User 2	write	write	write	-	-
User 3	-	-	-	read	read
...					
User m	read	write	read	write	read

- The rights in a cell specify the access of the subject (row) to the object (column)



Subjects = Users ?



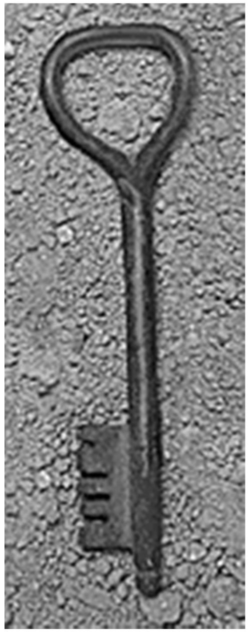
USERS

Real World User

PRINCIPALS

Unit of Access Control and Authorization

the system authenticates the user in context of a particular principal



Subjects = Users ?

JOE.TOP-SECRET

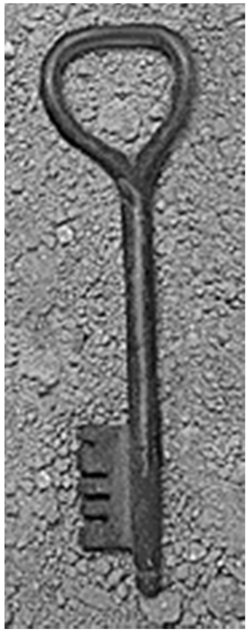
JOE.SECRET

JOE →

JOE.CONFIDENTIAL

JOE.UNCLASSIFIED

USER | **PRINCIPALS**



Subjects = Users ?

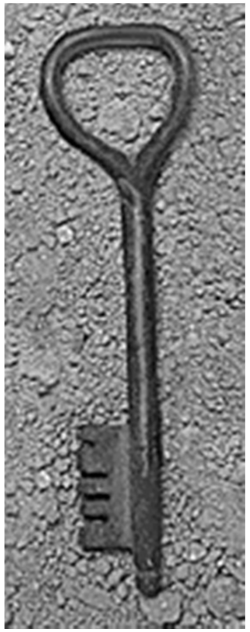
JANE → **JANE.CHAIRPERSON**

JANE → **JANE.FACULTY**

JANE → **JANE. EMPLOYEE**

JANE → **JANE.SUPER-USER**

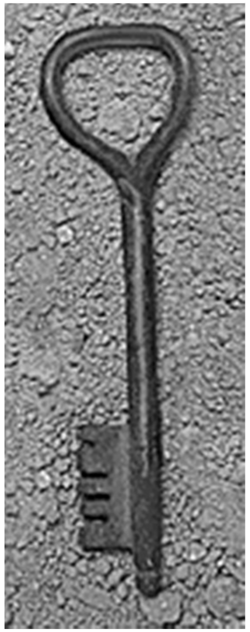
USER **PRINCIPALS**



Subjects = Users ?

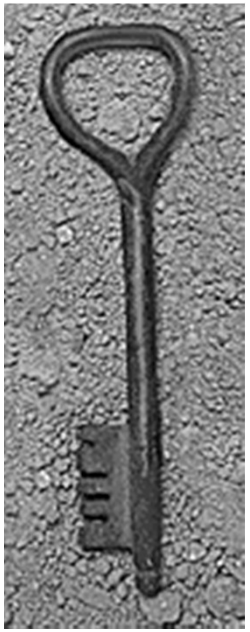
- ♦ There should be a one-to-many mapping from users to principals
  - a user may have many principals, but
  - each principal is associated with an unique user
- ♦ This ensures accountability of a user's actions

In other words, shared accounts (principals) are bad for accountability



Subjects = Users ?

- A subject is a program (application) executing on behalf of a principal
- A principal may at any time be idle, or have one or more subjects executing on its behalf



Principles and Subjects

Mail Application

Word Processor

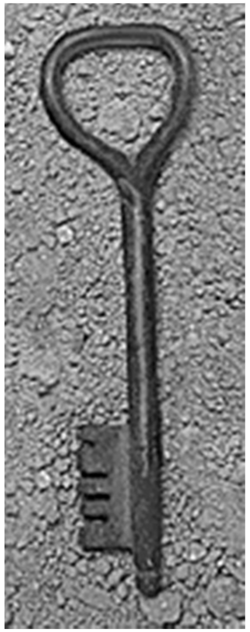
JOE.TOP-SECRET

Spreadsheet

Database Application

PRINCIPAL

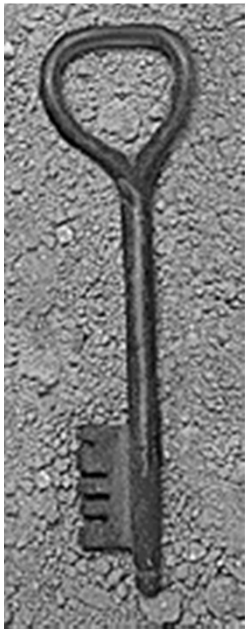
SUBJECTS



Principles and Subjects

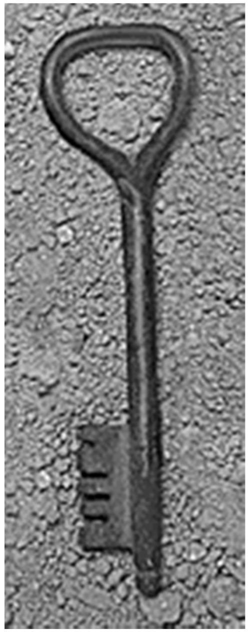
- Usually (but not always)
  - each subject is associated with a unique principal
  - all subjects of a principal have identical rights (equal to the rights of the invoking principal)
- This case can be modeled by a one-to-one mapping between subjects and principals

For simplicity, a principal and subject can be treated as identical concepts. On the other hand, a user should always be viewed as multiple principals



Objects

- An object is anything on which a subject can perform operations (mediated by rights)
- Usually objects are passive, for example:
  - File
  - Directory (or Folder)
  - Memory segment
- But, subjects can also be objects, with operations
  - Kill, Suspend, Resume



Access Control Matrix [Lampson]

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rights

Subjects

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User 2	write	write	write	-	-
User 3	-	-	-	read	read
...					
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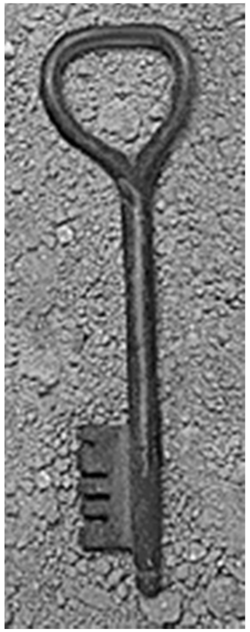

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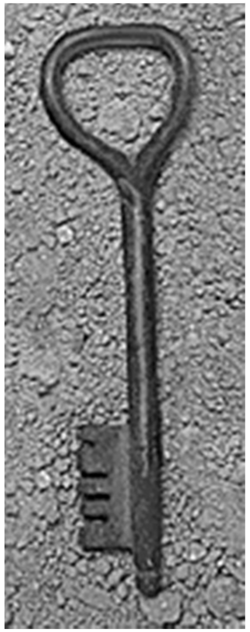
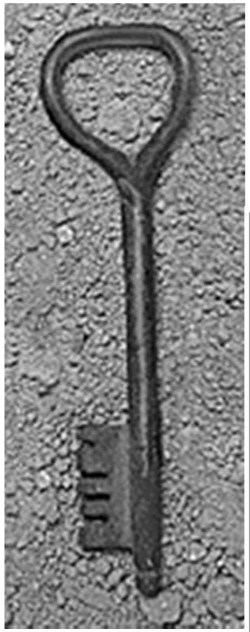


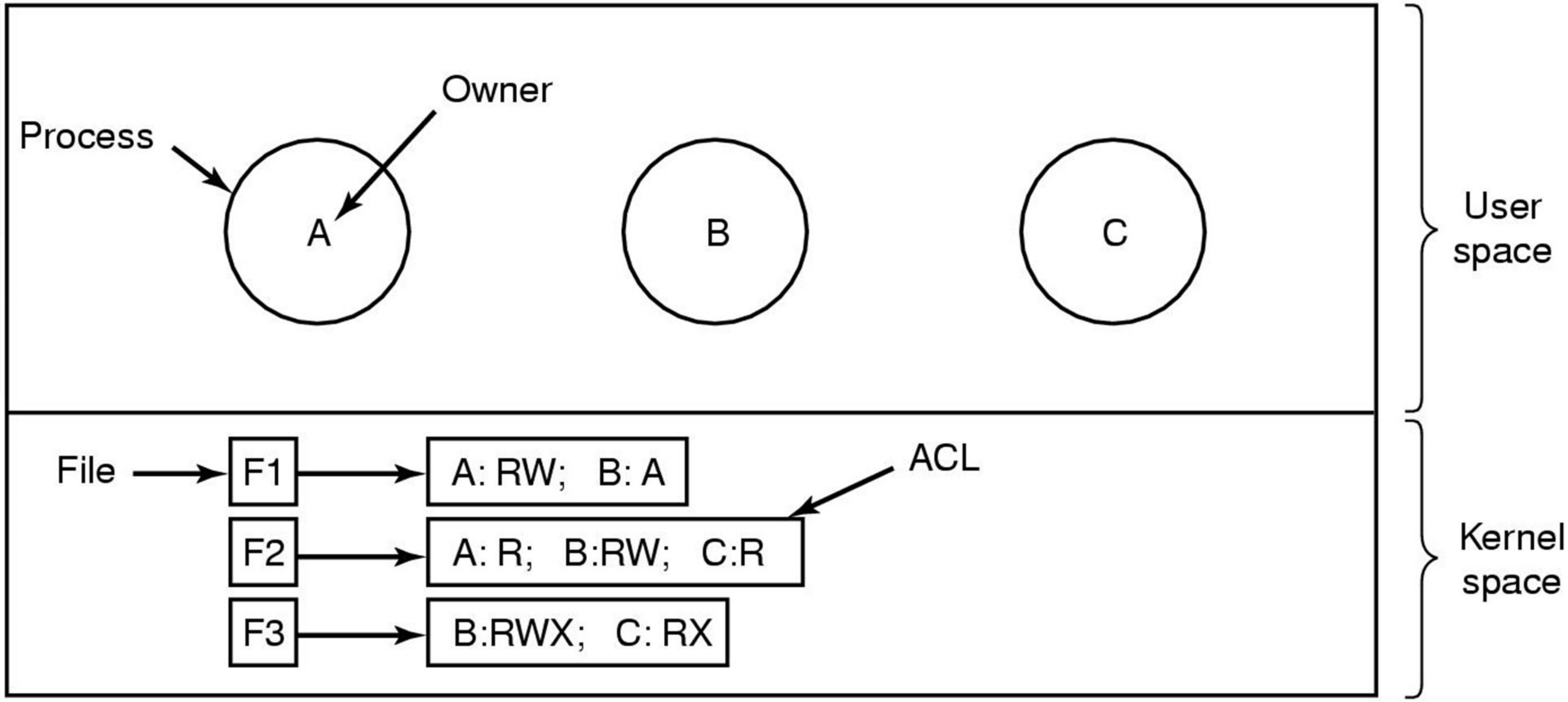
How to Implement ?

- Access control list (ACL)
  - Store column of matrix with the resource
- Capability
  - User holds a unforgeable “ticket” for each resource

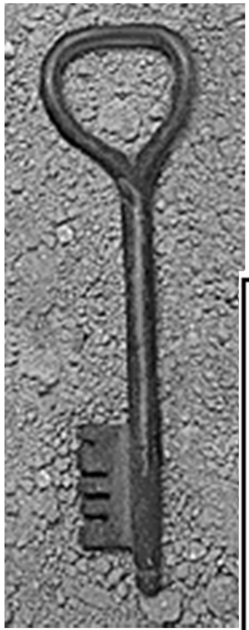
	File 1	File 2	...
User 1	read	write	-
User 2	write	write	-
User 3	-	-	read
...			
User m	read	write	write



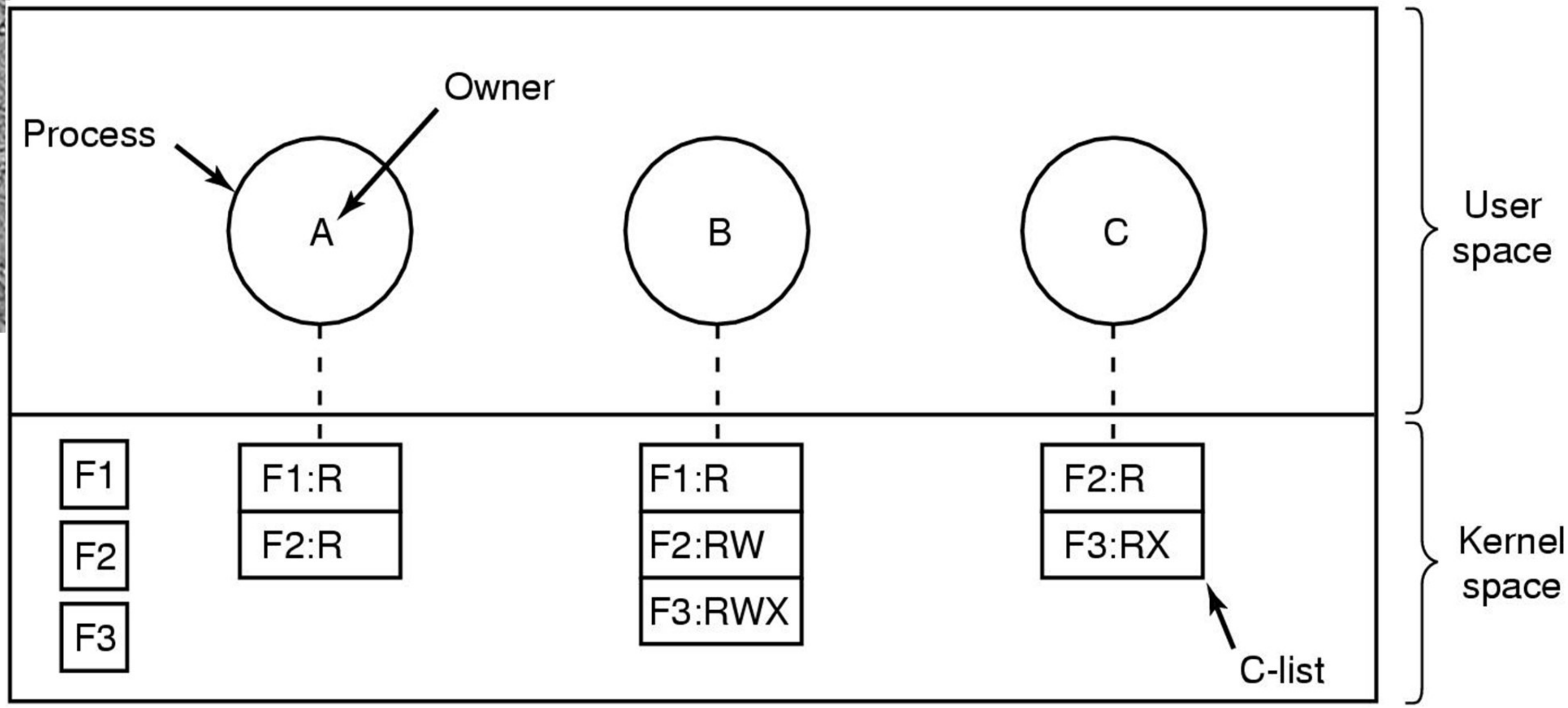
Access Control Lists (1)



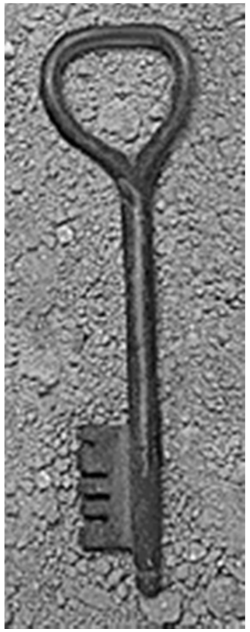
Use of access control lists of manage file access



Capabilities (1)

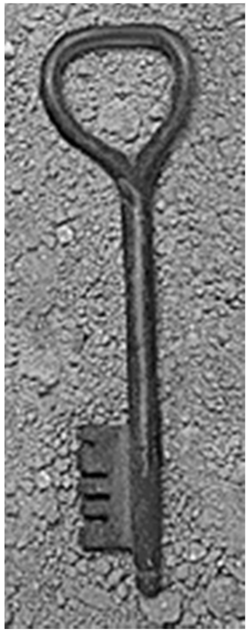


Each process has a capability list



ACL'S vs Capabilities

- ACL's require authentication of subjects
- Capabilities do not require authentication of subjects, but do require unforgeability and control of propagation of capabilities



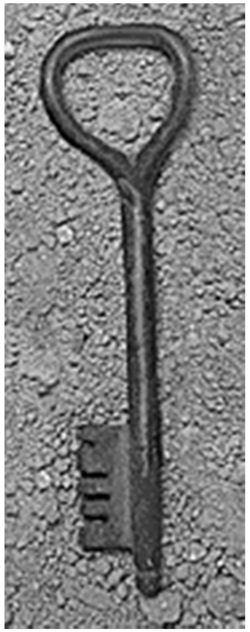
ACL'S vs Capabilities

Access Review

- ACL's provide for superior access review on a per-object basis
- Capabilities provide for superior access review on a per-subject basis

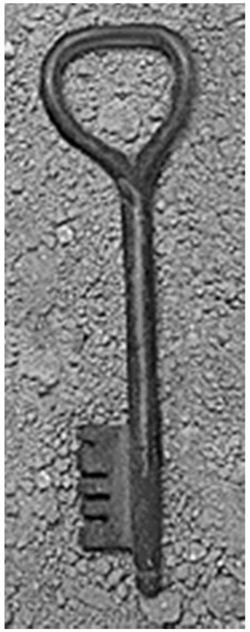
Revocation

- ACL's provide for superior revocation facilities on a per-object basis
- Capabilities provide for superior revocation facilities on a per-subject basis



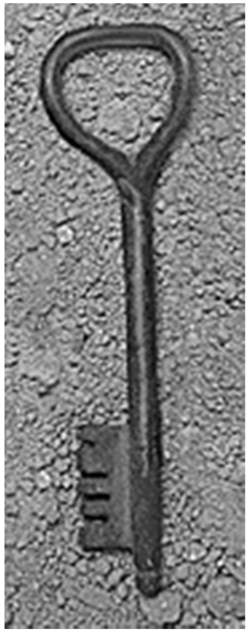
ACL usually wins out !

- The per-object basis usually wins out so most Operating Systems protect files by means of ACL's
- Many Operating Systems use an abbreviated form of ACL's with just three entries (Like Unix)
  - Owner, Group, Other
  - rwx-rwx-rwx



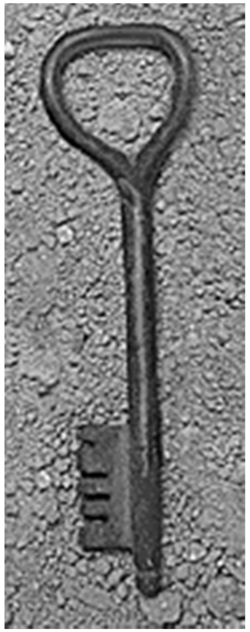
Case Study: UNIX O.S.

- Unix and other operating systems using access lists for file management often "abbreviate" the lists by dividing users into categories based on their relationships
- Typical categories
  - **User** who ***owns*** the file
  - Users in the same ***group*** as the file's owner
  - All ***other*** users (or everyone else in the ***world***)



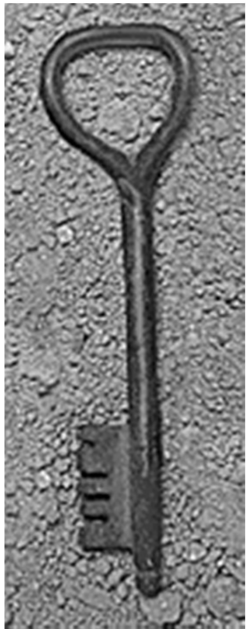
Unix-style representation

- We minimize the privileges in Unix-like systems to: **R**ead, **W**rite, E**x**ecute
- We therefore need nine bits to represent a file’s access list:
  - First three: owner bits
  - Second three: group bits
  - Third three: world/other bits



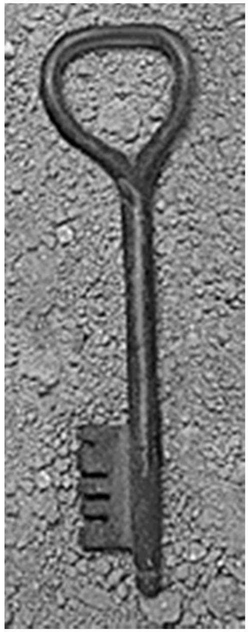
Equivalent Expressions

R W X	R X	R
1 1 1	1 0 1	1 0 0
7	5	4



Issues

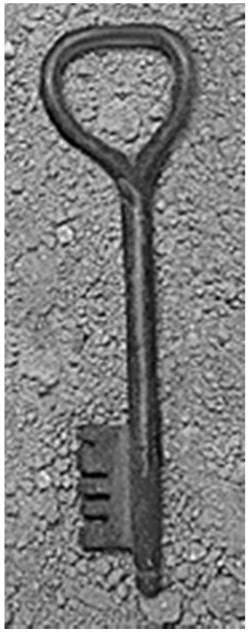
- We have traded *space* reduction and speed of checking for reduced flexibility in expressing an access control policy
- Some operating systems (DEC VMS, some variants of HPUX) allow these abbreviated access lists to be augmented by additional entries - such as the ability to add privileges for a specific user or more than one group.



Capabilities ?

Least Privilege

- Capabilities provide for finer grained least privilege control with respect to subjects, especially dynamic short-lived subjects created for specific tasks



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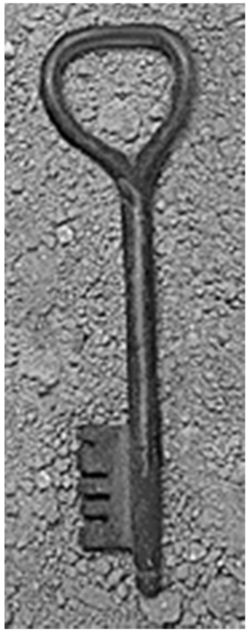
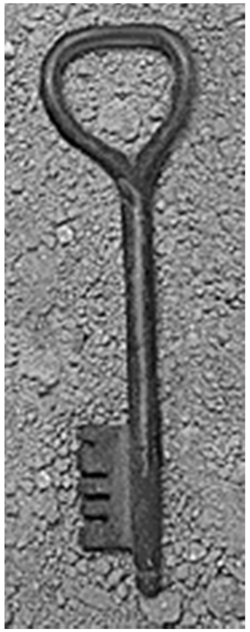


Discretionary vs Mandatory Access Controls

- Discretionary Access Controls (DAC) allow access rights to be propagated from one subject to another

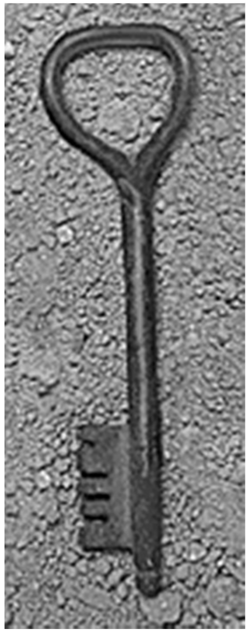
  Possession of an access right by a subject is sufficient to allow access to the object

- Mandatory Access Controls (MAC) restrict the access of subjects to objects on the basis of security labels



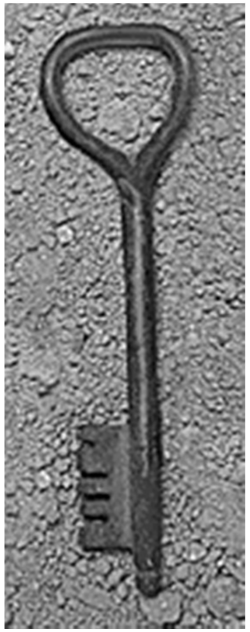
Inherent Weakness of DAC

- Unrestricted DAC allows information from an object which can be read to any other object which can be written by a subject
- Suppose our users are trusted not to do this deliberately. It is still possible for Trojan Horses to copy information from one object to another.



Trojan Horses

- A Trojan Horse is rogue software installed, perhaps unwittingly, by duly authorized users
- A Trojan Horse does what a user expects it to do, but in addition exploits the user's legitimate privileges to cause a security breach



Trojan Horse Example

ACL

File F

A:r

A:w

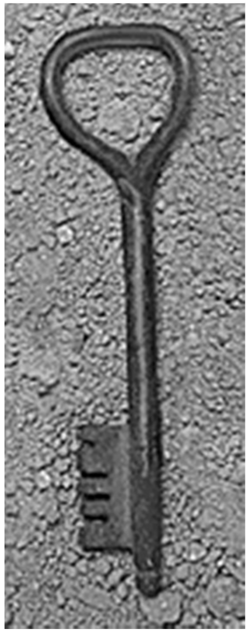
File G

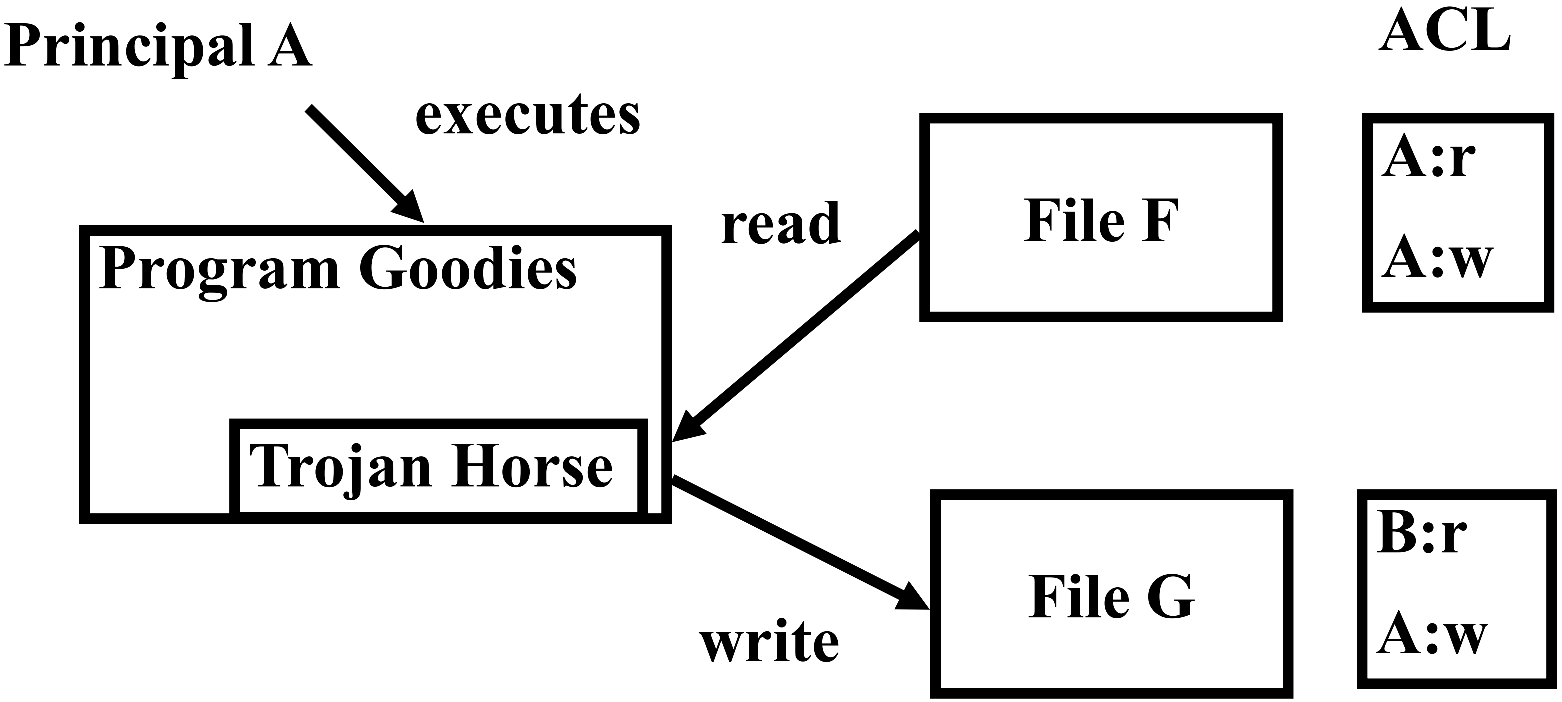
B:r

A:w

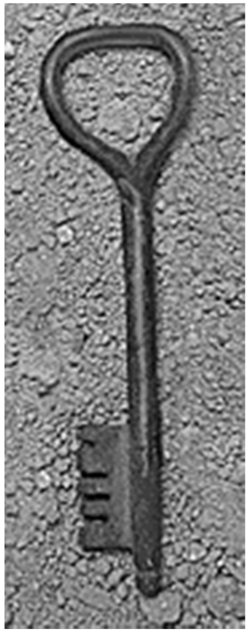
Principal B cannot read file F

Trojan Horse Example



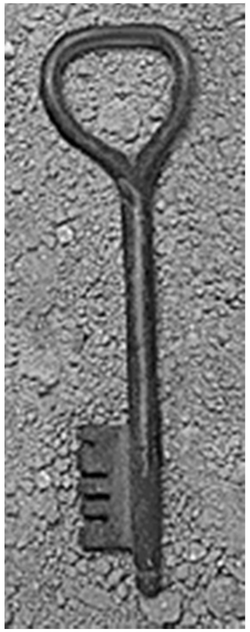


Principal B can read contents of file F copied to file G



Trojan Horses – very hard to handle

- Trojan Horses are the most insidious threat
- Viruses and logic bombs are examples of Trojan Horses
- It is possible to embed Trojan Horses in hardware and firmware (Ex. Printer Virus in Yugoslavia War)
- It is possible to embed Trojan Horses in critical system software such as compilers and Database Management Systems (Ex. The Thompson's C Compiler)



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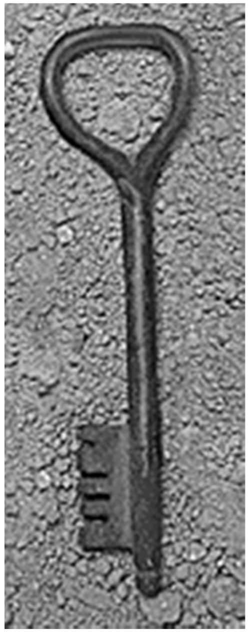
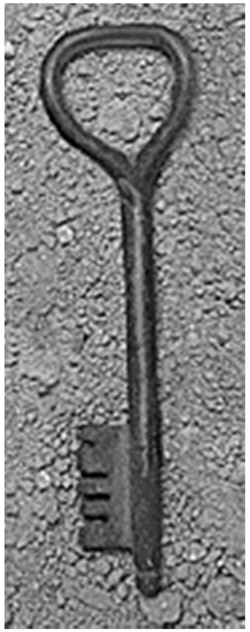


Mandatory Access Control

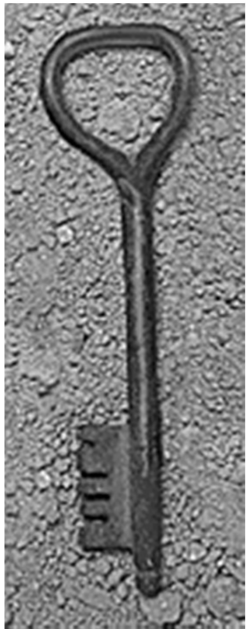
- Goal: prevent the unauthorized disclosure of information
  - Usually used in Military Applications
  - Deals with the "Hidden" information flow
- Multi-level security models are best-known examples
  - Bell-LaPadula Model (BLP) basis for many, or most, of these

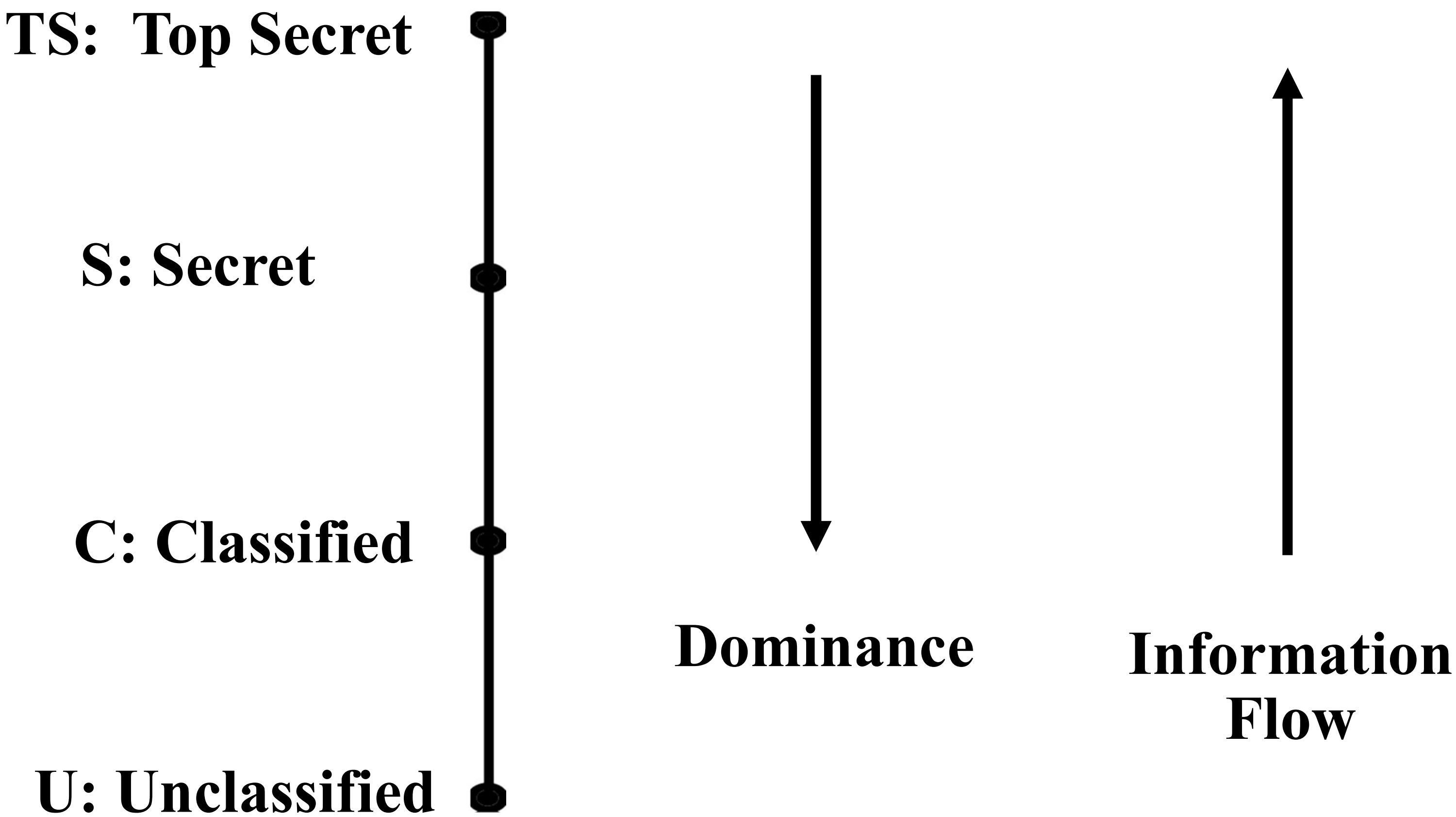


Bell-LaPadula Model, Step 1

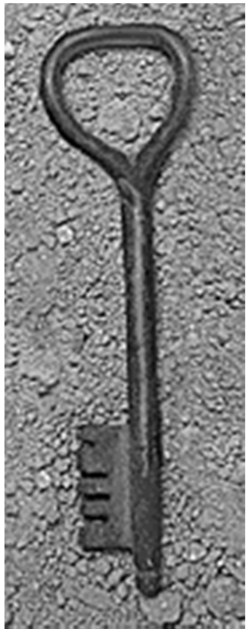
- Security levels arranged in linear ordering
  - Top Secret: highest
  - Secret
  - Confidential
  - Unclassified: lowest
- Levels consist of *security clearance* $L(s)$
  - Objects have *security classification* $L(o)$

Multilevel Security





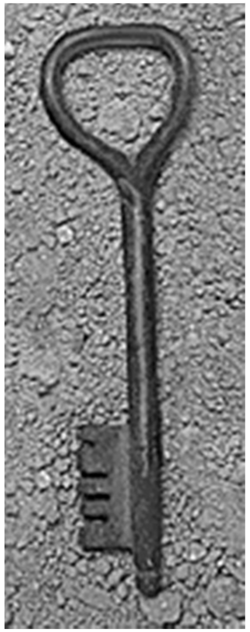
Lattice of security labels



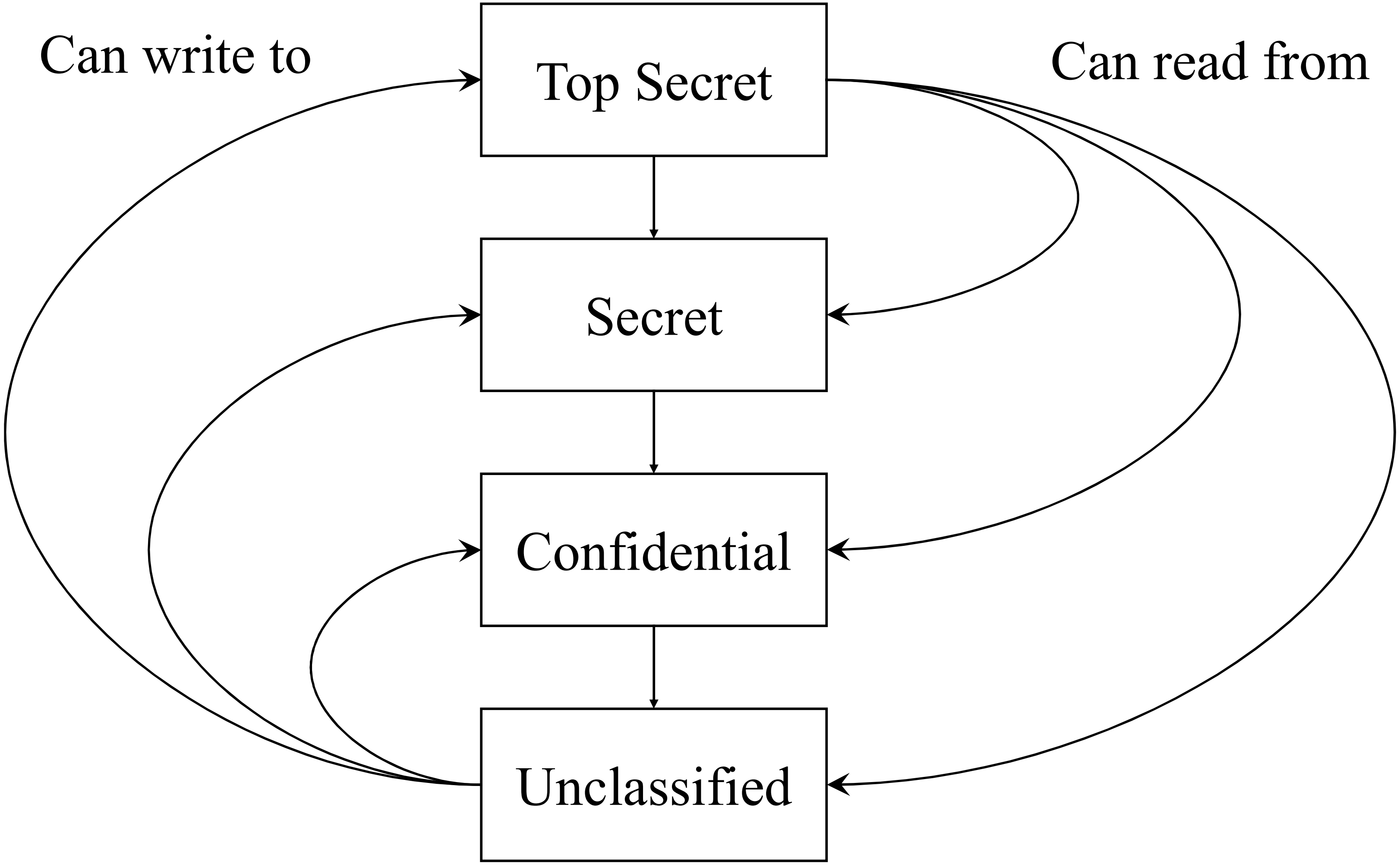
Example

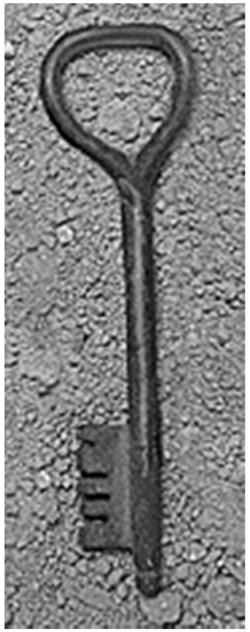
security level	*subject*	*object*
Top Secret	Tamara	Nuclear Files
Secret	Samuel	Battleship Files
Confidential	Claire	Logistics Files
Unclassified	Alice	Telephone Lists

- Tamara can read all files
- Claire cannot read Nuclear or Battleship Files
- Alice can only read Telephone Lists



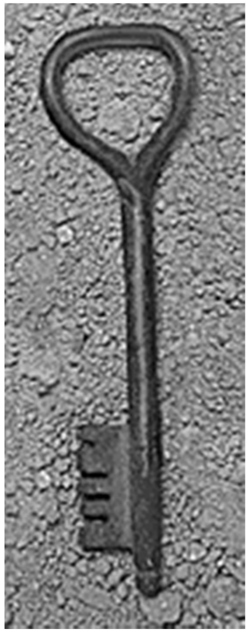
Linear Access Level Lists





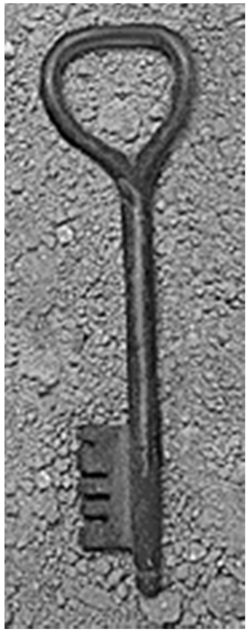
Reading Information

- Information flows *up*, not *down*
  - "Reads up" disallowed, "reads down" allowed
- Simple Security Condition (Step 1)
  - Subject *s* can read object *o* iff, $L(o) \leq L(s)$ and *s* has permission to read *o*
    - Note: combines mandatory control (relationship of security levels) and discretionary control (the required permission)
  - Sometimes called "no reads up" rule



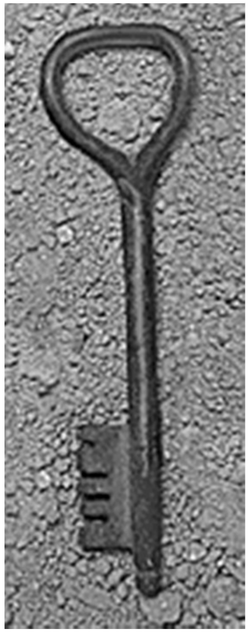
Writing Information

- Information flows up, not down
  - “Writes up” allowed, “writes down” disallowed
- *-Property (Step 1)
  - Subject *s* can write object *o* iff $L(s) \leq L(o)$ and *s* has permission to write *o*
    - Note: combines mandatory control (relationship of security levels) and discretionary control (the required permission)
  - Sometimes called “no writes down” rule

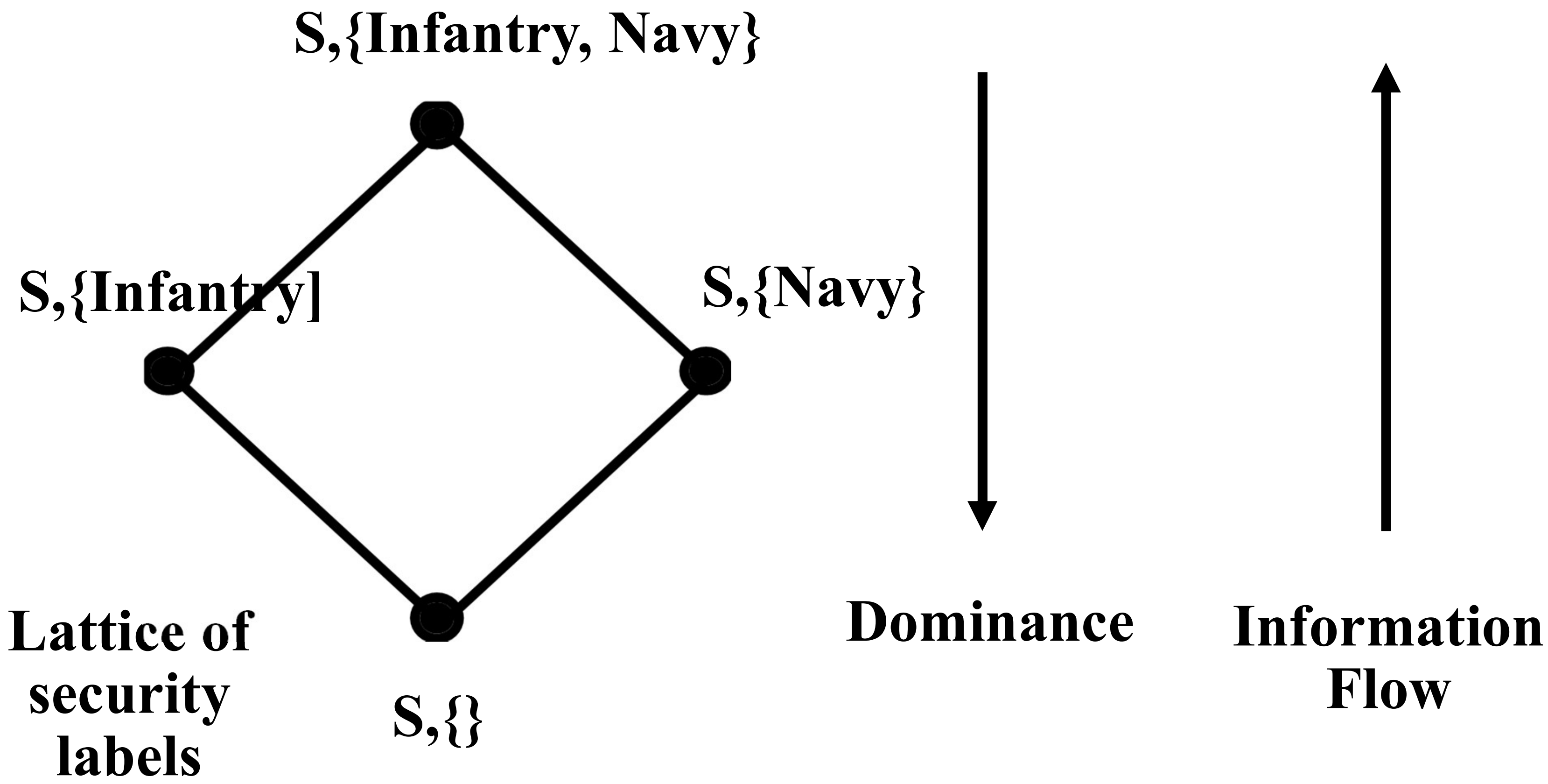


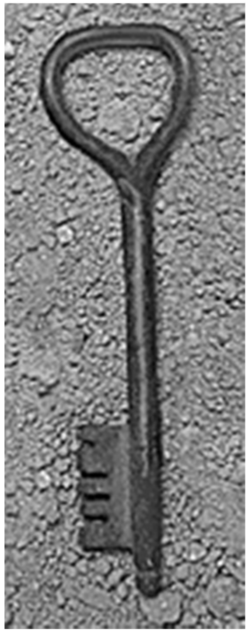
Bell-LaPadula Model, Step 2

- Expand notion of security level to include categories
- Security level is (*clearance*, *category set*)
- Examples
  - (Top Secret, { General Staff, Infantry, Navy })
  - (Confidential, { General Staff, Infantry })
  - (Secret, { General Staff, Navy })
  - (Unclassified, { Navy })



MULTILEVEL SECURITY





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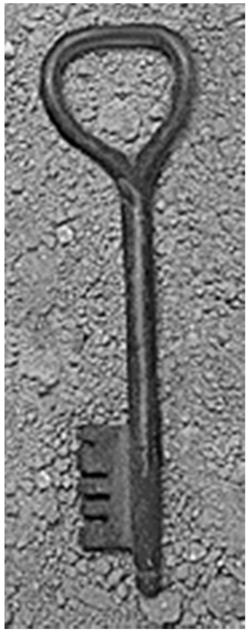
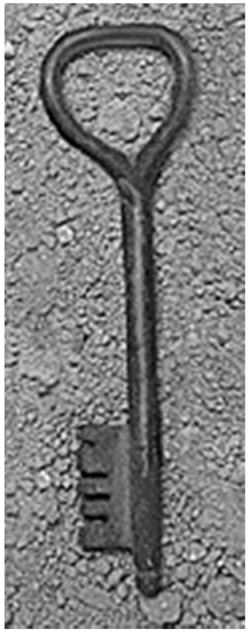
- Discretionary versus mandatory controls
- Bell-LaPadula model
- Covert channels
- Beyond MAC and DAC

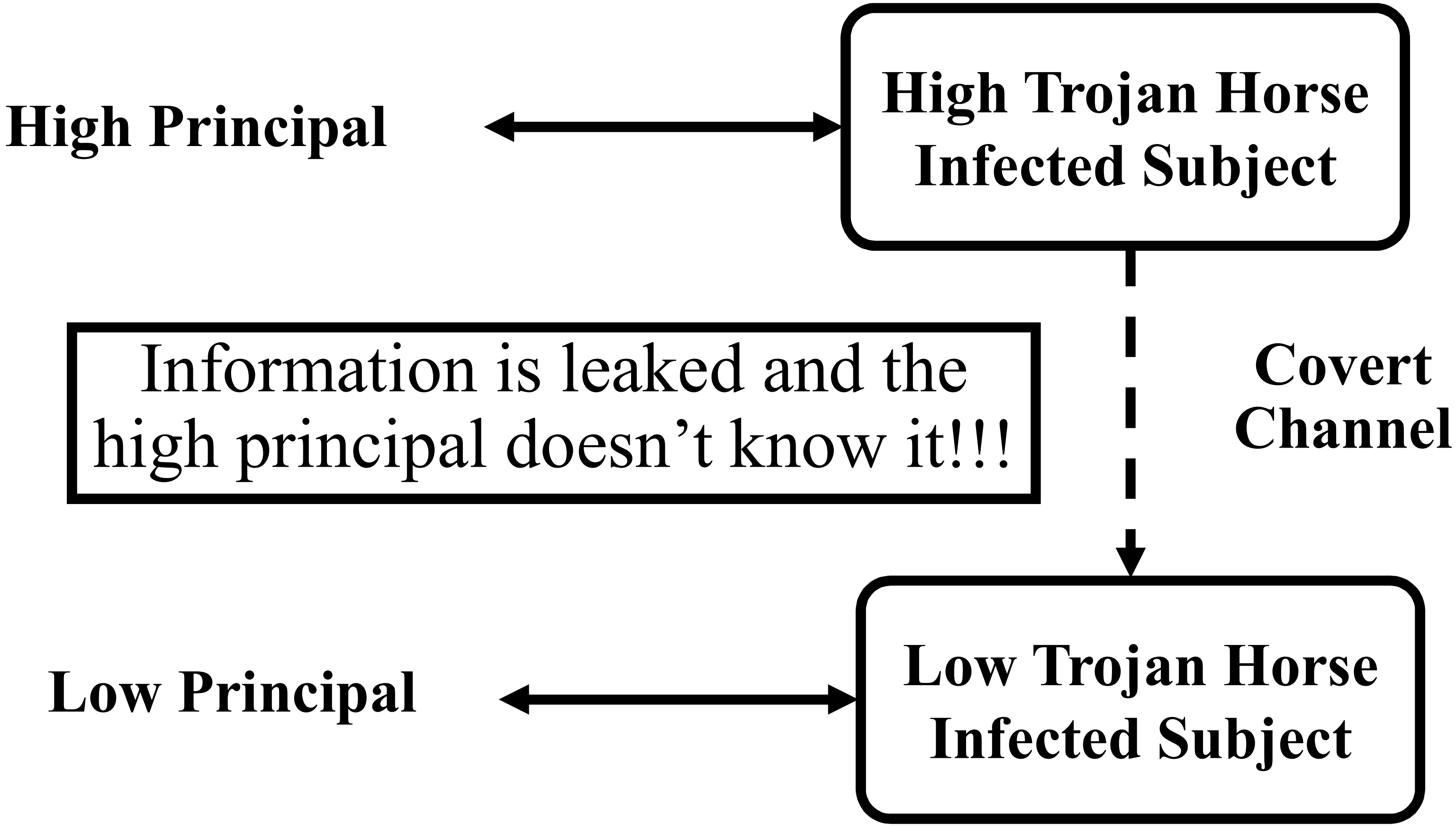


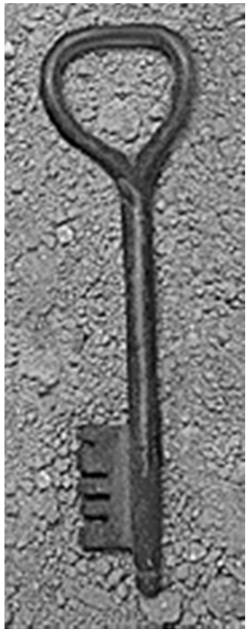
Covert Channels

- A covert channel is a communication channel based on the use of system resources not normally intended for communication between the subjects (processes) in the system

Covert Channels

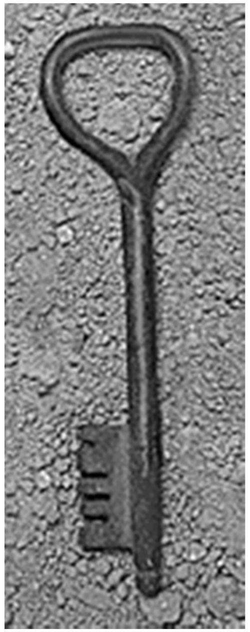






Covert Channels

- The concern is with subjects not users
  - users are trusted (must be trusted) not to disclose secret information outside of the computer system
  - subjects are not trusted because they may have Trojan Horses embedded in the code they execute
- *-property prevents overt leakage of information and does not address the covert channel problem



Resource Exhaustion Channel

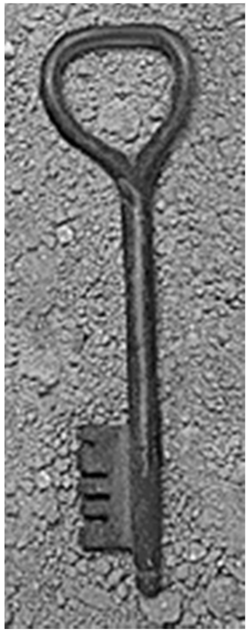
Given 5MB pool of dynamically allocated memory

High-Level Process

- bit = 1 $\Rightarrow$ request 5MB of memory
- bit = 0 $\Rightarrow$ request 0MB of memory

Low-Level Process

- request 5MB of memory
- if allocated then bit = 0 otherwise bit = 1



Load Sensing Channel

High-Level Process

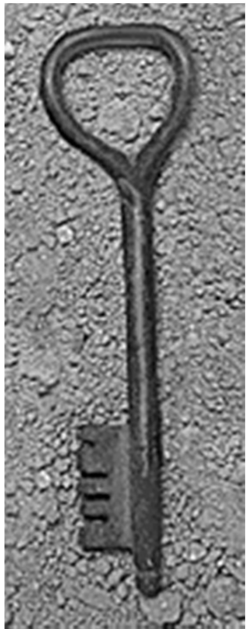
bit = 1 $\Rightarrow$ enter computation intensive loop

bit = 0 $\Rightarrow$ go to sleep

Low-Level Process

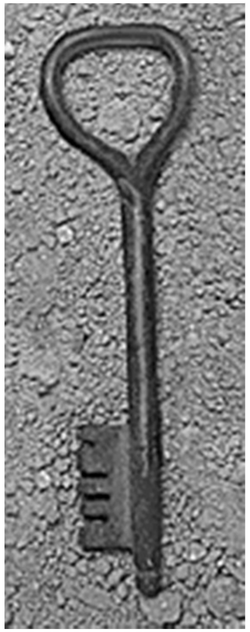
perform a task with known computational requirements

if completed quickly then bit = 0 otherwise bit = 1



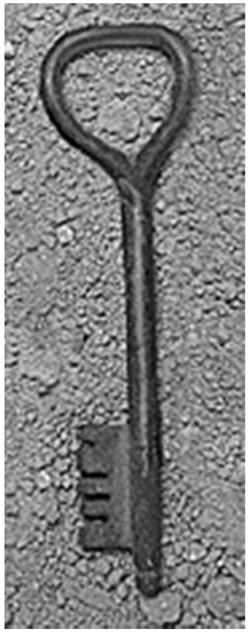
Coping with Covert Channels

- After Identification
  - close the channel or slow it down
  - detect attempts to use the channel
  - tolerate its existence



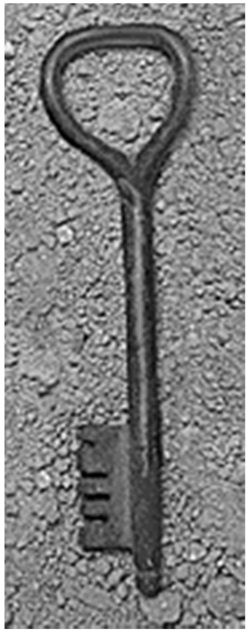
Orange Book Criteria (TCSEC)

- ♦ Level D
  - – No security requirements
- ♦ Level C
  - – Discretionary Access Control (DAC)
- ♦ Level B, A
  - – Must enforce Bell-LaPadula model (MAC)



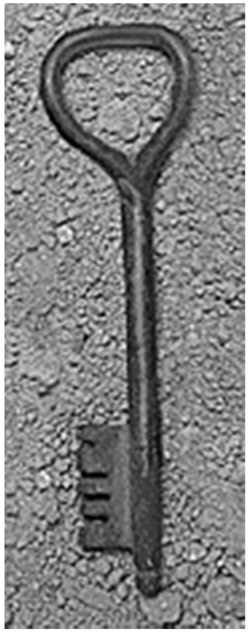
Orange Book Criteria (TCSEC)

- C1
  - Cooperating users at same level of sensitivity
  - Access control; users can protect their own data
  - Discretionary access control
- C2
  - Finer granularity of control
  - Better audit functions; each individual access to each object can be tracked



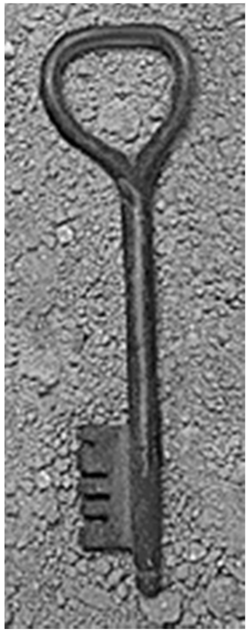
Orange Book Criteria (TCSEC)

- B1
  - Non-discretionary access control; subjects and (most) objects assigned a security level
  - Bell-LaPadula model + DAC to further limit access
- B2
  - Independent modules
  - Design and implementation go through more thorough review/testing based on verifiable top-level design
  - Principle of least privilege



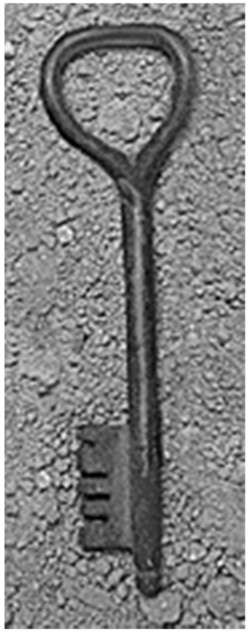
Orange Book Criteria (TCSEC)

- B3
  - Security functions small enough for extensive testing/review and tamperproof
- A1
  - Verifiable design
  - Formal model and proof of consistency



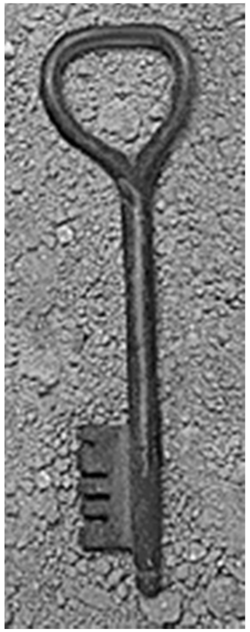
Covert Channels and the Orange Book

C2	No labels
B1	Labels with Bell-LaPadula controls, but no need to address covert channels
B2	Must address storage channels (such as resource exhaustion channel)
B3	Must also address timing channels (such as load sensing channel)
A1	Must use formal techniques (where available)



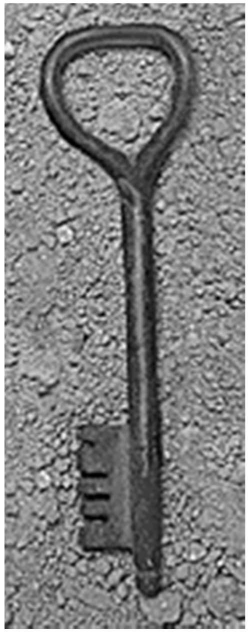
Agenda

- Access matrix model
- Access control lists versus Capabilities
- Discretionary versus mandatory controls
- Bell-LaPadula model
- Covert channels
- Beyond MAC and DAC

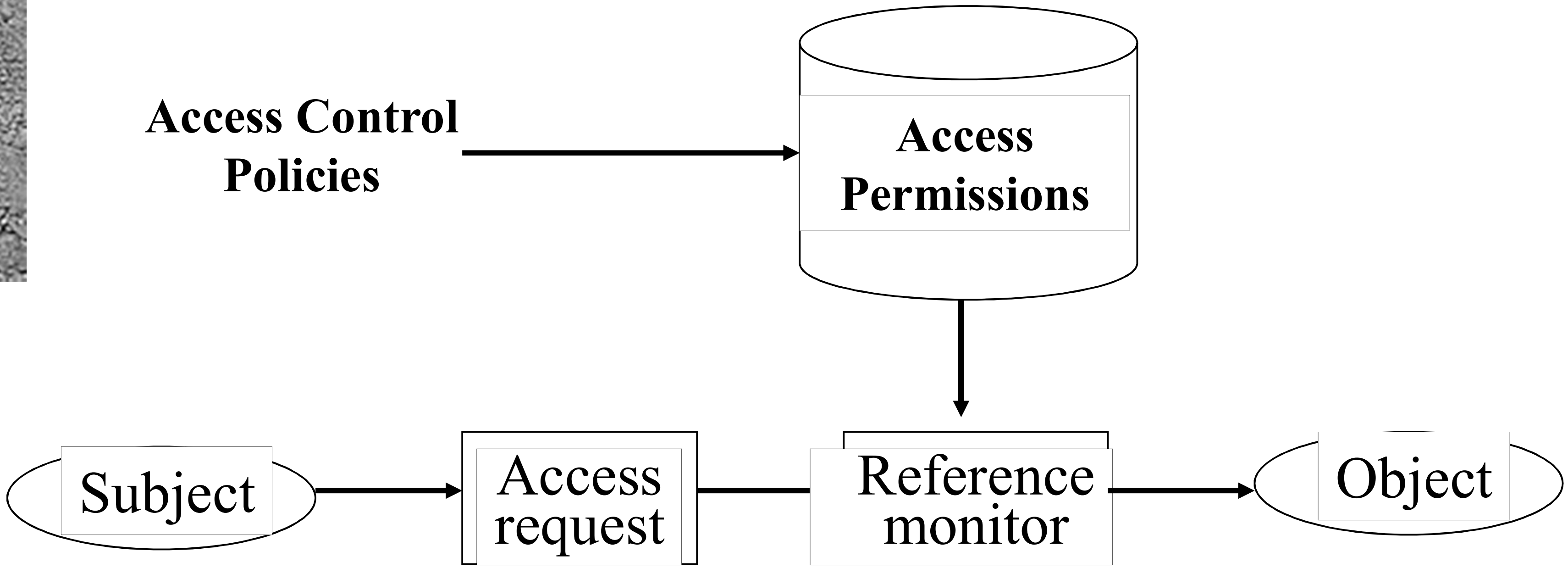


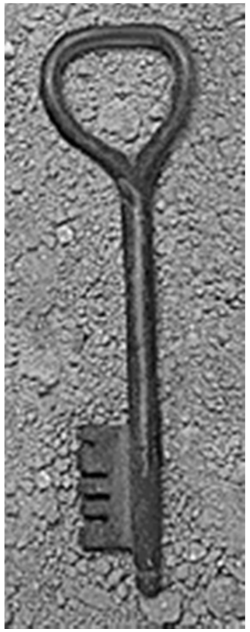
Beyond MAC/DAC

- DAC and MAC are extreme points of a continuum of access controls
- There are legitimate policies that fall in between, for example:
  - Document release: a document cannot be released by a scientist without first obtaining approvals from a patent-officer and a security-officer
  - Originator control: information in an object should not be propagated without permission of the owner of the object



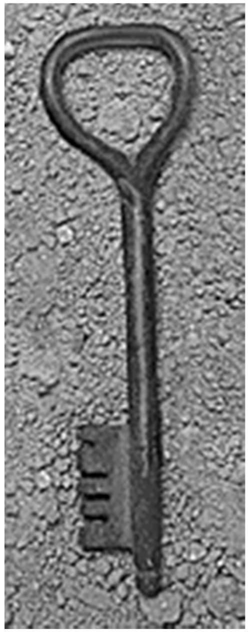
Access Control Policies





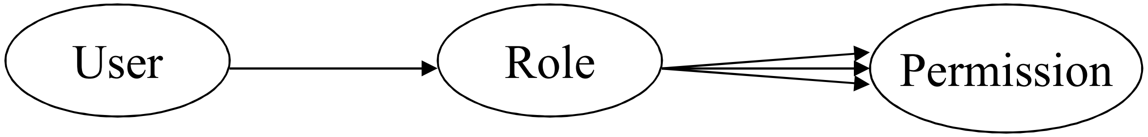
Content Dependent Access Control

- Content dependent controls such as
  - you can only see salaries less than 50K, or
  - you can only see salaries of employees who report to you
- Beyond the scope of Operating Systems and usually are provided by Database Management Systems

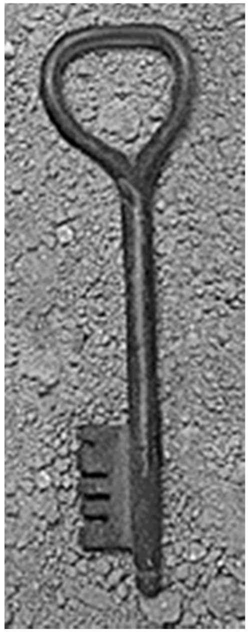


Role-Based Access Control

- Sandu et al. formalized Role-Based Access Control in 1996



- User U acting in role R is granted permission P
  - Advantage: greatly improved efficiency
  - Disadvantage: cannot specify fine-grained rules

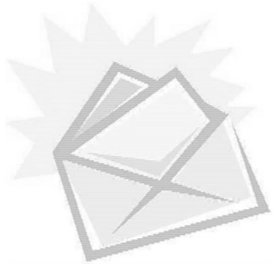


Context-Based Access Control

- What is “context”?
  - Circumstances in which an event occurs

Name
Age
ID
Location

Subject

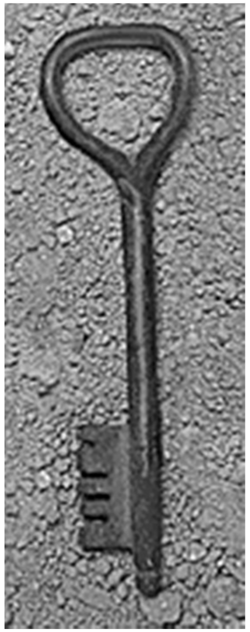


Read
Write
Delete
Owner

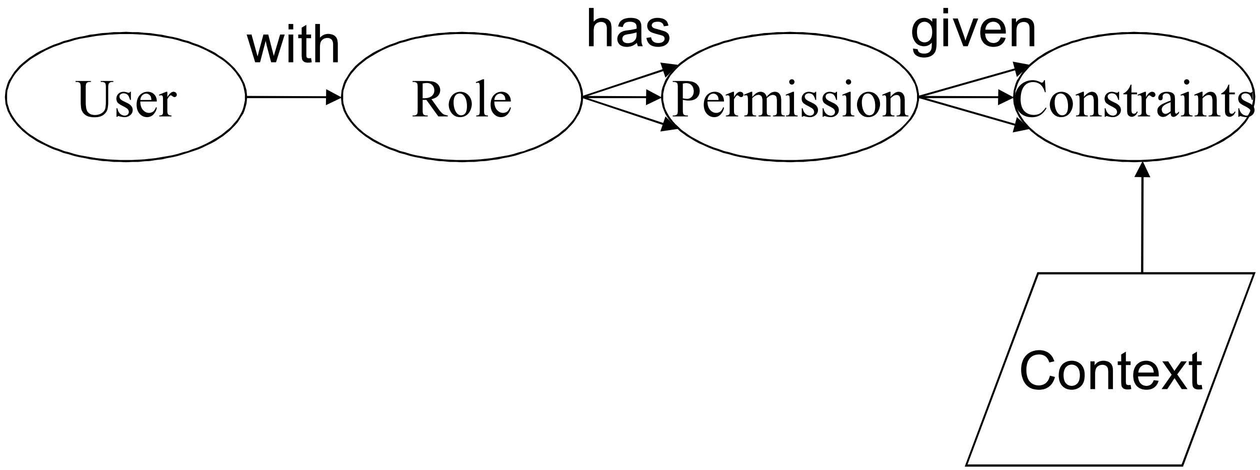
Object

System

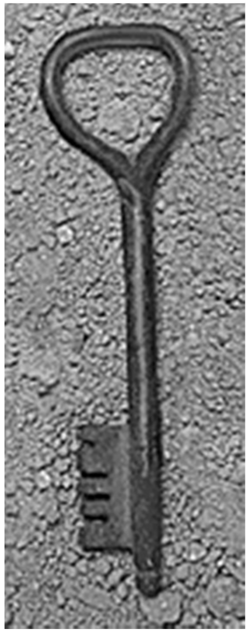
Time
Date
CPU Load



Context-Based Access Control

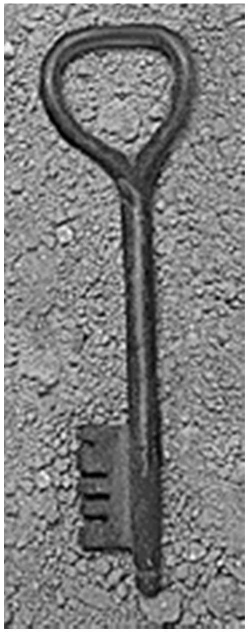


- ♦ Advantage: access control is context-aware
- ♦ Disadvantage: this is still a static model



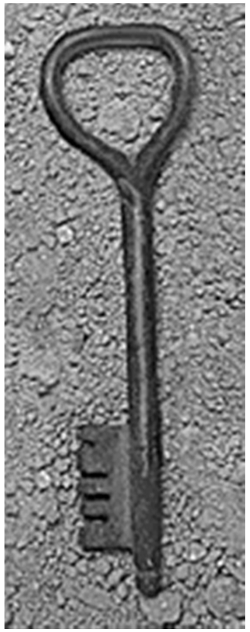
Context-Based Access Control

- Examples 1: Cannot access classified information via a remote login
- Examples 2: Salary information can be updated only at year end
- Examples 3: Company's earnings report is confidential until announced at the stockholders meeting
- can be partially provided by the Operating System and partially by the Database Management System
- more sophisticated context dependent controls such as based on past history of accesses definitely require Database support



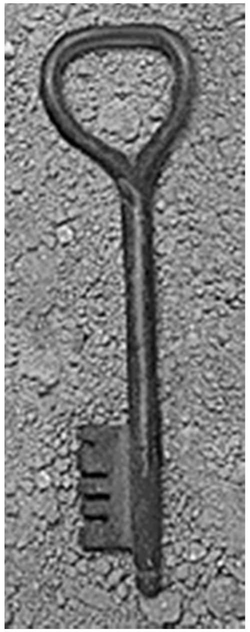
What Else Might We Add?

- Default Rule (Telephone Sys. Example)
  - General default: Receive
  - Object default: Call Internal
- Time-based access
  - Allow long distance call after hours?
- History-based access



Access Control by History

- Example: Statistical Database
  - Allows queries for general statistics
  - But not individual values
- Valid queries: Statistics on 20+ individuals
  - Total salary of all Deans
  - Salary of Computer Science Professors
- See a problem coming?
  - Salary of CS Professors who aren't Deans



Solution: Query Set Overlap Control (Dobkin, Jones & Lipton '79)

- Query valid if intersection of query coverage and each previous query < r
- Given K minimum query size, r overlap:
  - Need $1 + (K-1)/r$ queries to compromise
- Can represent as access control matrix
  - Subjects: entities issuing queries
  - Objects: *Powerset* of records
  - $O_s(i)$: objects referenced by s in queries $1..i$
  - $A[s,o]$ = read iff $\forall_{q \in O_s(i-1)} |q \cap o| < r$