CSE543 - Computer and Network Security
Module: Mandatory Access Control

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Access Control and Security

- Claim: Traditional access control approaches (UNIX and Windows) do not enforce security against a determined adversary
  - (1) Access control policies do not guarantee secrecy or integrity
  - (2) Protection systems allow untrusted processes to change protection state
- Mandatory Access Control (MAC) solves these limitations
  - What is "mandatory"?
  - How do MAC models guarantee security?

Security Goals

- Secrecy
  - Don’t allow reading by unauthorized subjects
  - Control where data can be written by authorized subjects
    - Why is this important?
- Integrity
  - Don’t allow modification by unauthorized subjects
  - Don’t allow dependence on lower integrity data/code
    - Why is this important?
  - What is “dependence”?
- Availability
  - The necessary function must run
  - Doesn’t this conflict with above?

Trusted Processes

- Do you trust every process you run?

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Trusted Processes

- Do you trust every process you run?
  - To not be malicious?
  - To not be compromised?

Secrecy

- Does the following protection state ensure the secrecy of J's private key in O_1 (i.e., S_2 and S_3 cannot read)?

	O_1	O_2	O_3
J	R	RW	RW
S_2	-	R	RW
S_3	-	R	RW

Secrecy Threat

- Trojan Horse
  - *Some process of yours is going to give away your secret data*
    - Write your photos to the network

Integrity

- Does the following access matrix protect the integrity of J's public key file O_2?

	O_1	O_2	O_3
J	R	RW	RW
S_2	-	R	RW
S_3	-	R	RW

Integrity Threat

- Untrusted Input
  - *Process reads untrusted input when expects input protected from adversaries*
    - Read a user-defined config file
    - Execute a log file
    - Admin executes untrusted programs

Protection vs Security

- Protection
  - Secrecy and integrity met under *benign* processes
  - Protects against an error by a non-malicious entity
- Security
  - Secrecy and integrity met under *malicious* processes
  - Blocks against any malicious entity from performing unauthorized operations at all times
- Hence, For J:
  - Non-malicious processes shouldn't leak the private key by writing it to O_3
  - A malicious or compromised process may contain a Trojan horse that will write the private key to O_3

What Is Security?

- *In practice, security methods focus on security or functionality - but not both at the same time!*
- Security Is Foremost
  - Information Flow: No communication with untrusted
  - Advantage: Focus is security
  - Disadvantage: May prevent required functionality
- Restrict based on Functionality
  - Least Privilege: Only rights needed to execute
  - Advantage: Enables required functionality
  - Disadvantage: May not block all attack paths
- Let's look at the two common approaches
  - Least Privilege and Information Flow

Principle of Least Privilege

PennState

A system should only provide those privileges needed to perform the processes' functions and no more.

- Implication 1: you want to limit the process to the smallest possible set of objects
- Implication 2: you want to assign the minimal set of operations to each object
- Caveat: of course, you need to provide enough permissions to get the job done.

Least Privilege

- Limit permissions to those required and no more
- Suppose J_1-J_3 must use the permissions below
  - What is the impact of the secrecy of O_1?

	O_1	O_2	O_3
J_1	R	RW	-
J_2	-	R	-
J_3	-	R	RW

Least Privilege

- Can least privilege prevent attacks?
  - Trojan horse
  - Untrusted input

Least Privilege

- Can least privilege prevent attacks?
  - Trojan horse
  - Untrusted input
- Some. No guarantee such attacks are not possible

Information Flow

PennState

- Access control that focuses on information flow restricts the flow of information among subjects and objects
  - Regardless of functional requirements
- Confidentiality
  - Processes cannot read unauthorized secrets
  - Processes cannot leak their own secrets to unauthorized processes
    - Claim: Prevent Trojan horse attacks
- Integrity
  - Processes cannot write objects that are "higher integrity"
  - In addition, processes cannot read objects that are "lower integrity" than they are
    - Claim: Prevent attacks from Untrusted Inputs

Prevent Trojan Horses

- Information Flow Goal
  - Prevent Trojan horse attacks
- Intuition: Prevent flow of secrets to public subjects or objects

Information Flow

PennState

- Suppose O_1 must be secret to J_1 only
- No information flow from O_1 to either J_2 or J_3
  - What can you remove to protect the secrecy of O_1?

	O_1	O_2	O_3
J_1	R	RW	-
J_2	-	R	-
J_3	-	R	RW

Denning Security Model

- Information flow model $FM = (N, P, SC, x, y)$
  - N: Objects
  - P: Subjects
  - SC: Security Classes
  - x: Combination
  - y: Can-flow relation
- N and P are assigned security classes ("levels" or "labels")
- $SC_1 + SC_2$ determines the resultant security class when data of security classes SC_1 and SC_2 are combined
- $SC_2 \longrightarrow SC_1$ determines whether an information flow is authorized from security class SC_2 to SC_1
- SC, $+$, and $\longrightarrow$ define a lattice among security classes

Denning Security Model

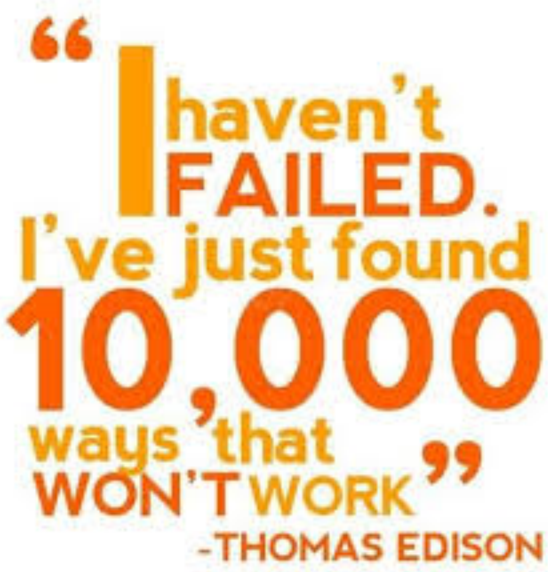
- Preventing Trojan horse attacks
  - Secret files are labeled SC_1 (secret)
  - Secret user logs in and runs processes that are labeled SC_1 (secret)
  - Public objects are labeled SC_2 (public)
  - Only flows within a class or from SC_2 to SC_1 are authorized (public to secret)
  - When data of SC_1 and SC_2 are combined, the resultant security class of the object is SC_1 (public and secret data make secret data)
- How does this prevent a Trojan horse from leaking data?

Information Flow

- Does information flow security impact functionality?

Information Flow

- Does information flow security impact functionality?
  - Yes, so need special processes to reclassify objects
    - Called guards, but are assumed to be part of TCB
      - "Require" formal assurance :-P



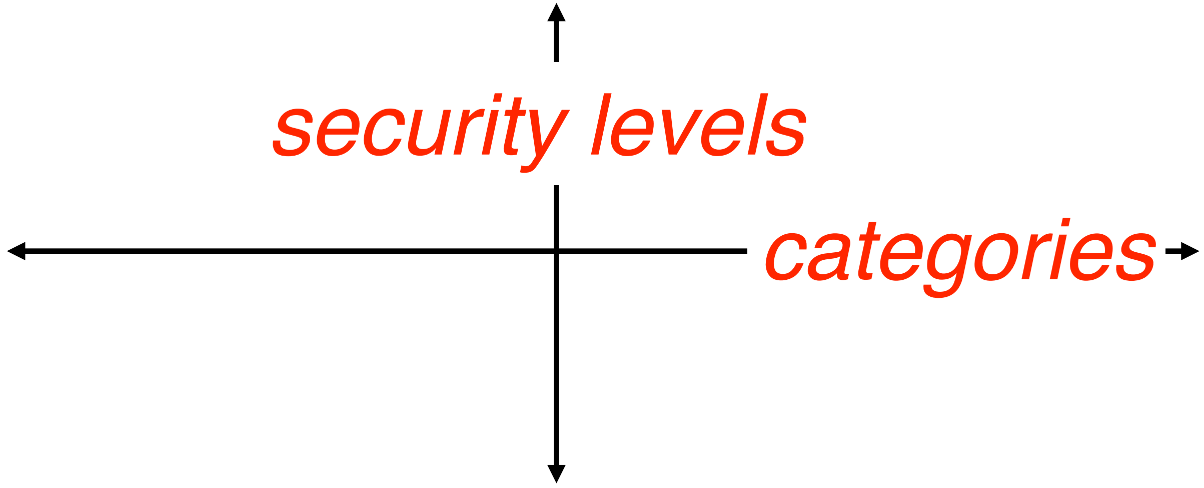
Information Flow Models

- Secrecy: Multilevel Security, Bell-La Padula
- Integrity: Biba, LOMAC

Multilevel Security

PennState

- A multi-level security system tags all objects and subjects with security tags classifying them in terms of sensitivity/access level.
  - We formulate an access control policy based on these levels
  - We can also add other dimensions, called categories which horizontally partition the rights space (in a way similar to that as was done by roles)



US DoD Policy

- Used by the US military (and many others), uses MLS to define policy

- Levels:

UNCLASSIFIED < CONFIDENTIAL < SECRET < TOP SECRET

- Categories (actually unbounded set)

NUC(lear), INTEL(igence), CRYPTO(graphy)

- Note that these levels are used for physical documents in the governments as well.

Assigning Security Levels

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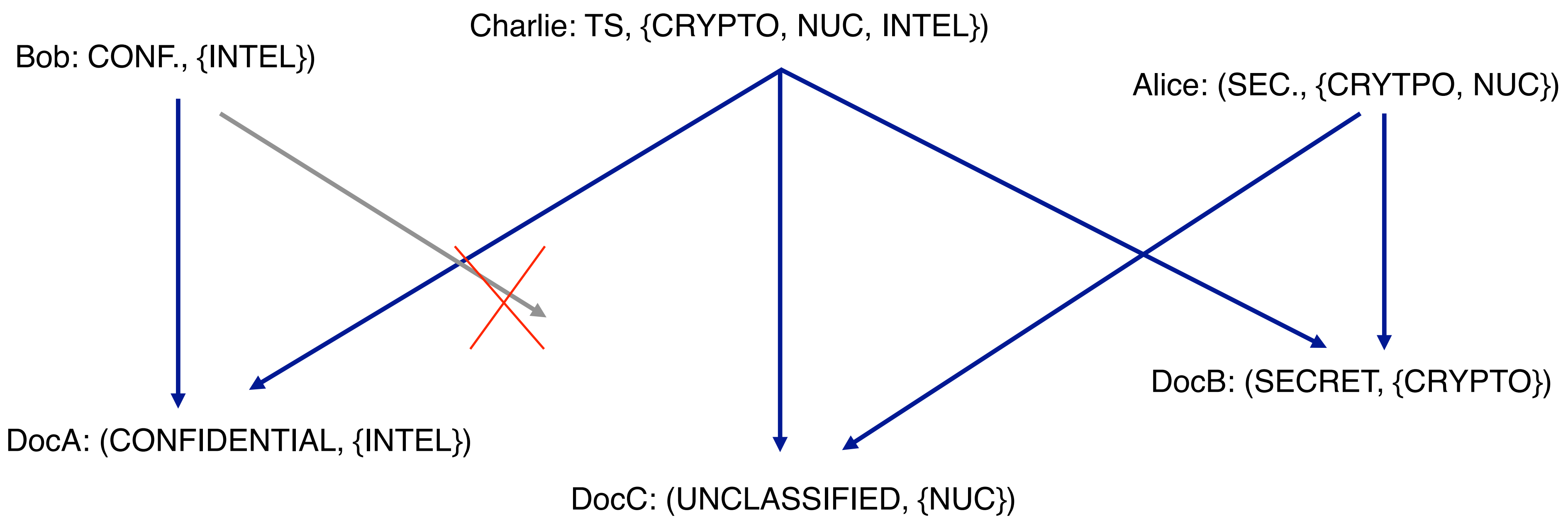
- All subjects are assigned clearance levels and compartments
  - Alice: (SECRET, {CRYTPO, NUC})
  - Bob: (CONFIDENTIAL, {INTEL})
  - Charlie: (TOP SECRET, {CRYPTO, NUC, INTEL})
- All objects are assigned an access class
  - DocA: (CONFIDENTIAL, {INTEL})
  - DocB: (SECRET, {CRYPTO})
  - DocC: (UNCLASSIFIED, {NUC})

Multilevel Security

- Access is allowed if

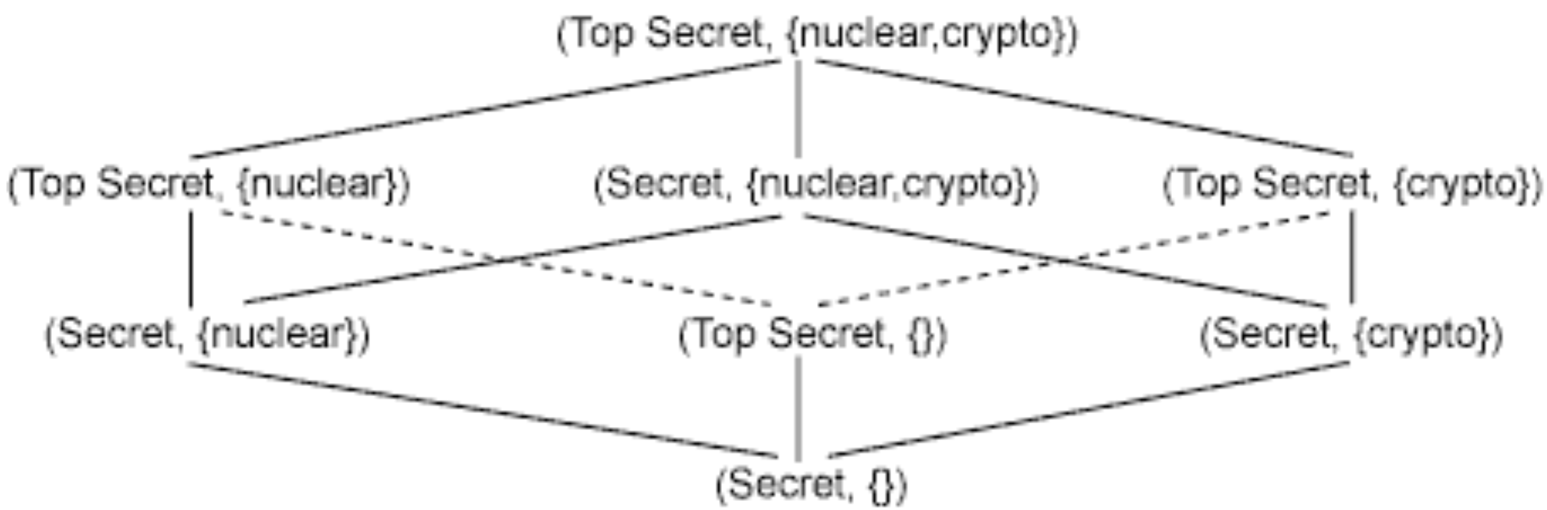
  subject clearance level >= object sensitivity level *and* subject categories $\supseteq$ object categories (*read down*)



- Q: What would *write-up* be?

Bell-La Padula Model

- A Confidentiality MLS policy that enforces:
  - *Simple Security Policy*: a subject at specific classification level cannot read data with a higher classification level. This is short hand for "*no read up*".
  - ** (star) Property*: also known as the confinement property, states that subject at a specific classification cannot write data to a lower classification level. This is shorthand for "*no write down*".



How about integrity?

- MLS as presented before talks about who can "read" a secret document (confidentiality)
- Integrity states who can "write" a sensitive document
  - Thus, who can affect the integrity (content) of a document
  - Example: You may not care who can read DNS records, but you better care who writes to them!
- Biba defined a dual of secrecy for integrity
  - Lattice policy with, "no read down, no write up"
    - Users can only *create* content at or *below* their own integrity level (a monk may write a prayer book that can be read by commoners, but not one to be read by a high priest).
    - Users can only *view* content at or *above* their own integrity level (a monk may read a book written by the high priest, but may not read a pamphlet written by a lowly commoner).

Biba (example)

- Which users can modify what documents?
  - Remember "*no read down*, *no write up*"

Charlie: (TS, {CRYPTO, NUC, INTEL})

Bob: (CONF., {INTEL})

Alice: (SEC., {CRYTPO, NUC})

?????

DocB: (SECRET, {CRYPTO})

DocA: (CONFIDENTIAL, {INTEL})

DocC: (UNCLASSIFIED, {NUC})

Window Vista Integrity

- Integrity protection for writing
- Defines a series of protection level of increasing protection
  - installer (highest)
  - system
  - high (admin)
  - medium (user)
  - low (Internet)
  - untrusted (lowest)
- Semantics: If subject's (process's) integrity level dominates the object's integrity level, then the write is allowed

Vista Integrity

S1(installer)

O1(admin)

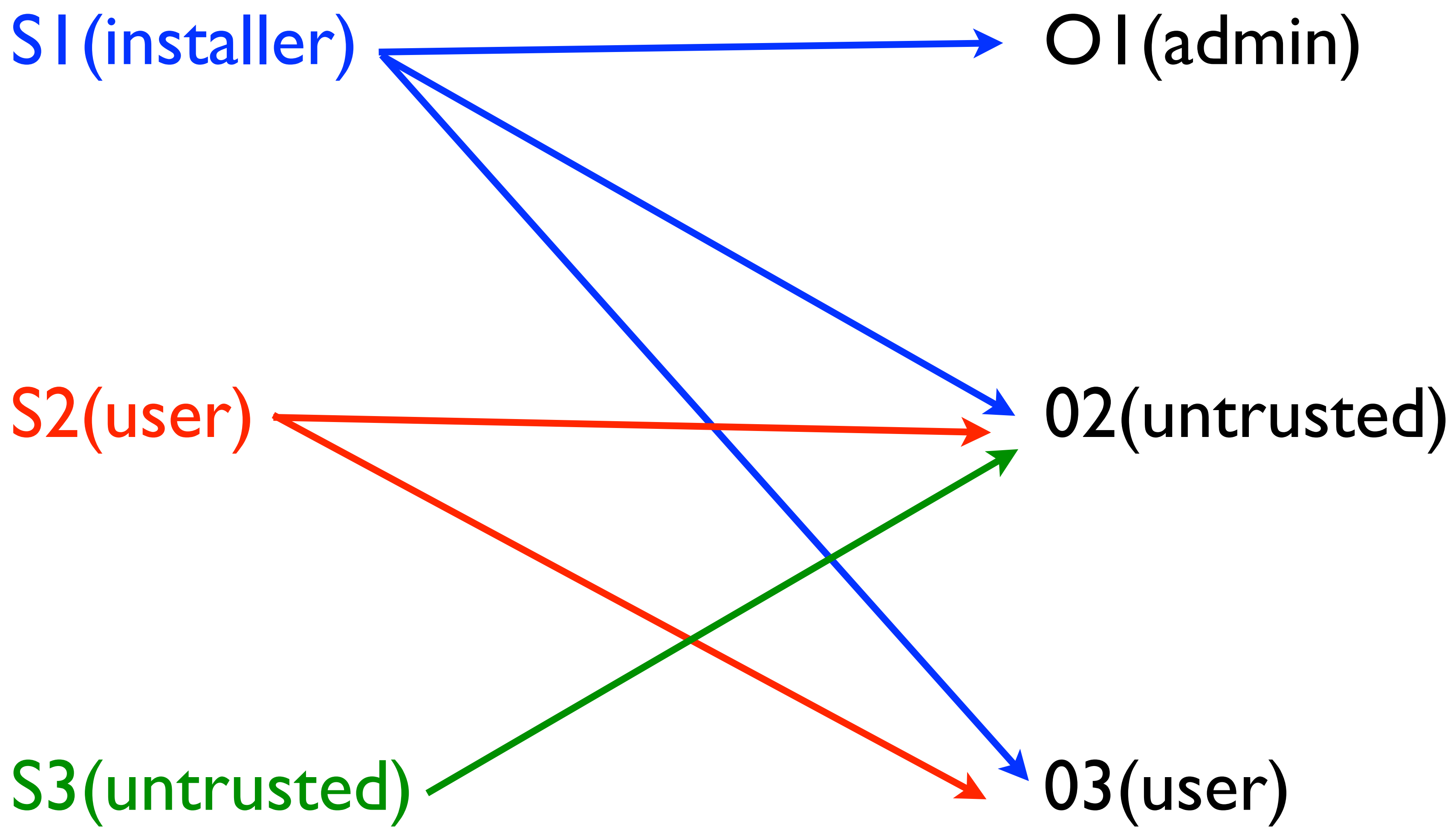
S2(user)

02(untrusted)

S3(untrusted)

03(user)

Vista Integrity



Reduce Integrity Restrictiveness

- Can we allow processes to read lower integrity data without compromising information flow?
  - Still don't trust the process to handle lower integrity inputs without being compromised
- Insight: Could change the integrity level of each process based on the data it accesses

LOMAC

- Low-Water Mark integrity
  - Change integrity level based on actual dependencies

- Subject is initially at the highest integrity
  - But integrity level can change based on objects accessed
- Ultimately, subject has integrity of lowest object read

Integrity, Sewage, and Wine

- Mix a gallon of sewage and one drop of wine gives you?
- Mix a gallon of wine and one drop of sewage gives you?

Integrity is really a contaminant problem: you want to make sure your data is not contaminated with data of lower integrity.

Take Away

- Claim: Traditional access control approaches (UNIX and Windows) do not enforce security against a determined adversary
  - (1) Trojan horses and confused deputies violate security goals
  - (2) DAC models prevent goals from being enforced
- Mandatory Access Control (MAC) is the way these can be achieved
  - MAC policies
    - Information flow models (MLS, Biba)
    - Least privilege MAC is often used (see SELinux)