Computer Security and Privacy

Principles of computer security

Slides made by Carmela Troncoso, SPRING Lab, additions by Thomas Bourgeat
Some slides/ideas adapted from: Philippe Oechslin, George Danezis, Emiliano de Cristofaro, Gianluca Stringhini

Basic principles to build Security Mechanisms

READING: J. Saltzer and M. Schroeder. *The Protection of Information in Computer Systems*. Proceedings of the IEEE, Invited Paper, (1975)
(Intro & Section 1)

8 (+ 2) principles at the core of security engineering practices

*"[…], experience has provided some useful principles that can **guide** the design and contribute to an implementation without security flaws"*

https://www.cl.cam.ac.uk/teaching/1011/R01/75-protection.pdf

The security design principles that we will see in this lecture will be principles that one must always try to follow.
Of course it may not be possible to follow all of them at the same time, but at least one must consider them.
If one principle is not followed, one must have a good reason to not consider it, and one must understand the risks associated with not following this principle.

Why should you care about principles from 1975

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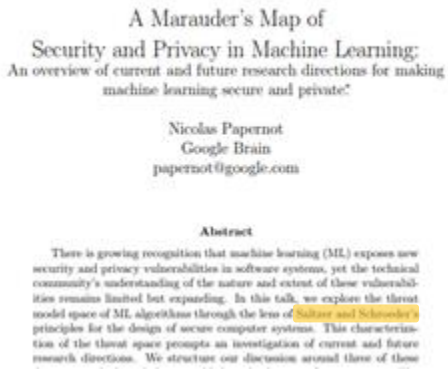

A Marauder's Map of
Security and Privacy in Machine Learning:
An overview of current and future research directions for making machine learning secure and private*

Nicolas Papernot
Google Brain
papernot@google.com

Abstract

There is growing recognition that machine learning (ML) exposes new security and privacy vulnerabilities in software systems, yet the technical community's understanding of the nature and extent of these vulnerabilities remains limited but expanding. In this talk, we explore the threat model space of ML algorithms through the lens of Saltzer and Schroeder's principles for the design of secure computer systems. This characterization of the threat space prompts an investigation of current and future research directions. We structure our discussion around three of these

Keynote at Workshop on Artificial Intelligence and Security

2018

The security principles that Saltzer and Schroeder laid down in 1973 are not only widely used to build secure systems, but are nowadays guiding principles to design secure and privacy-preserving machine learning systems.

These security principles are the bread and butter of every security engineer. Learning and internalizing them is essential to design and implementing secure systems.

Heartbleed 

The Heartbleed Bug: A "Simple" Flaw

- A critical vulnerability (CVE-2014-0160) reported in 2014 in the OpenSSL library - used to encrypt traffic (HTTPS).
- A feature called the "Heartbeat" allows a client to send a **small piece of data** and ask the server to send it back, just to prove the connection was alive.
- Issue: The attacker could **lie** about the size of their data.
  - Attacker sends 1 byte of data.
  - Attacker *claims* they sent 64,000 bytes.
  - The server, **without checking the actual length**, would reply with the attacker's 1 byte *plus* the next 63,999 bytes of whatever was in its private memory.

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- It seems (after 15mn research) that Heartbleed is also a trailblaizer in giving cybersecurity vulnerabilities "cool logos“. There were also sort-of catchy brand names before like the “ILOVEYOU” worm, but the logo thing was going to the next level. (I might be wrong though, would deserve more investigation). This branding had the effect of raising more public awareness.

The Heartbleed Bug: A "Simple" Flaw

- Feature Complexity:
  - The "Heartbeat" extension was a (very useful) non-essential feature added to the TLS protocol.
  - This *added complexity* created a *new attack surface*. The core function of TLS was secure without it.
- Codebase Complexity:
  - The OpenSSL codebase is massive, and difficult for anyone to understand:

Language	files	blank	comment	code
C	1617	85678	86364	559054
Perl	720	38736	32396	251473

  - The bug was a single missing line of code: a bounds check

```
if (request_size < actual_size) { error; }
```

  - This simple-but-deadly flaw hidden for *two years* because the overall complexity of the code made audit difficult.

Security enthusiasts, check the code! https://github.com/openssl/openssl/commit/731f431497f463f3a2a97236fe0187b11c44aead

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- The core was secure, the problem was not in the “critical crypto part”, but in a simple unsuspicious-looking side-feature.

1 - Economy of mechanism

"Keep the [security mechanism / implementation] design as simple and small as possible"

Why?

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The first principle says that the security mechanisms must be as simple as possible. (Also known as the KISS principle – Keep it Simple Stupid)

When security mechanisms are small and simple it is easy to check everything it does and verify that the operations are correct.
Reasoning about the security of complex mechanisms with many dependencies, and auditing them, is extremely hard. How do you know you have taken into account all of the possible options?

Operational testing, such as one would do to test the functionality of the system, cannot provide any security guarantees. Security is not about normal operation, and not even about faulty operation (errors in the implementation or caused at random by the environment). It is about what can go wrong when the adversary uses particular inputs on the system, and one cannot test all possible inputs…
This is not to say that penetration testing, whereby one tries to find flaws in the design or implementatoins is useless. The more things you try the more sure you are you have covered a big surface of "what could go wrong". But it cannot give you assurance that nothing can go wrong.

The (desirably small) security mechanism in which the system relies on to maintain the

security policy is called the ***Trusted computing base (TCB)***

1 - Economy of mechanism

"Keep the [security mechanism / implementation] design as simple and small as possible"

Why?

It needs to be easy to audit and verify.

(operational testing is not appropriate to evaluate security)

[Penetration testing is valuable]

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"**Trusted Computing Base**" **(TCB)**: Every component of the system on which the security policy relies upon

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The "Trusted Computing Base" (TCB)

Every component of the system on which the security policy relies.

Hardware / firmware / software

The TCB is **trusted** to operate correctly for the security policy to hold

The only proper use of the verb "to trust" in Security Engineering:

"X trusts Y will do Z"

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The (desirably small) security mechanism in which the system relies on to maintain the security policy is called the ***Trusted computing base (TCB)***

By definition, if something goes wrong outside of the TCB security is not affected! The TCB contains every component that must operate correctly for the security policy to hold. If something goes wrong outside, the TCB is still working and thus the security policy cannot be violated.

However, if the TCB gets compromised or fails, then the security of the system cannot be guaranteed anymore

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…and if something goes wrong outside the TCB?

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…and if something goes wrong outside the TCB?

The TCB must be kept small to ***ease verification*** (economy of mechanism) and ***diminish the attack surface***

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2 – Fail-safe defaults

"Base access decisions on permission rather than exclusion" **[SS75]**

If something fails, be as secure as if it does not fail

→ errors / uncertainty should err on the side of the security policy

Do not try to fix!!

Use **Whitelist**, do not use blacklist

→ lack of permission is easy to detect and solve

Examples:

- Security door: if no permission, do not open
- Form input: if no permission to write in X, do not write anywhere

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The insight behind this principle is that permissions are given after thought. If a permission is given, we know that the principal is allowed to do the action and this action is safe. On the contrary, the space of non-permissions is infinite and we do not know exactly what happens. We cannot list them all and there will be uncertainty. By basing decisions on permission, you are sure that no matter what is executed, had permission and cannot harm.

Achieving the goal of security under failure with blacklisting is hard. One can never make sure th at all harmful events are blacklisted.

Do not try to fix the errors. If something went wrong, the safe step is to go back to a known safe state. Once there is an error, one does not know what is the state of the system, so one cannot be sure that steps forward towards a solution are safe.

A 2017 ransomware epidemic

Some of it due to fail-safe defaults!

Ransomware – What is it?

- A Ransomware **denies you access to your own data**, most commonly by **encrypting your files**
- Attacker then demands a **ransom payment** in exchange for the private key required to decrypt your files

- **Some History of Ransomware - 1989**
  - Someone mailed 20,000 infected **5.25-inch floppy disks** (This thing: 💾) to attendees of a WHO AIDS conference. The disks were labeled "AIDS Information Introductory Diskette"
  - After 90 boot, the malware activate. It used simple (broken) encryption to encrypt all *filenames* on the C: drive and hide directories
  - A message appeared on the screen demanding the user send $189 via **postal mail to a P.O. Box in Panama** to receive the decryption key
  - Leaflet with floppy said that the software could *"adversely affect other program applications"* and, *"you will owe compensation and possible damages to PC Cyborg Corporation and your microcomputer will stop functioning normally"*

- Prevalence of ransomware exploded with the arrival of cryptocurrencies

Overall story is disturbing, source: https://cyberalarm.police.uk/blog/?article=2024-12-17-the-first-ransomware, more sources in the notes

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Source:
https://cyberalarm.police.uk/blog/?article=2024-12-17-the-first-ransomware
https://en.wikipedia.org/wiki/AIDS_(Trojan_horse)
https://www.theatlantic.com/technology/archive/2016/05/the-computer-virus-that-haunted-early-aids-researchers/481965/

"When they realised their drives had been compromised some victims panicked and deleted their drives, according to press reports an Italian AIDS organisation lost 10 years of invaluable research data."

The case of MongoDB – Ease of Use Vs Security

- Database software (You will learn about databases in CS-300!). MongoDB is flexible and scalable, storing data in JSON-like documents (CS-214, Week 9).
- For a while, the "out-of-the-box" default installation was wide open on some systems:
  - Authentication was turned OFF by default (no admin password was required).
  - It defaulted to **binding to all network interfaces (0.0.0.0) (CS-202)**, not just the secure localhost (127.0.0.1).
- Consequences: attackers ran scripts that **scanned the entire internet** for open MongoDB instances. The scripts would connect without a password, steal the data, delete/encrypt the originals, and leave a ransom note demanding Bitcoin.
- "[…]on some systems the default configuration has the database listening on a publicly accessible port as soon as it's installed. Users are *supposed to read the manual** and set up access control and authentication after installing the software *but it seems that plenty of them don't***. The result is an internet-connected database with no access control or authentication."

(*) 

(**) 

Source: https://news.sophos.com/en-us/2017/01/11/thousands-of-mongodb-databases-compromised-and-held-to-ransom/

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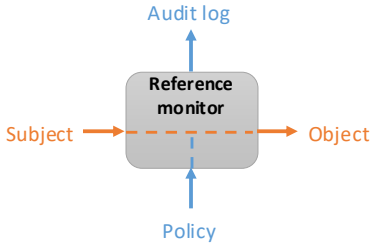
Very similar attack on Elasticsearch, security features apparently originally only for paid versions (?) one would need to double check:
https://www.percona.com/blog/elasticsearch-ransomware-open-source-database-security-part-2/

3 – Complete mediation

"Every access to every object must be checked for authority" [SS75]



mediates **ALL** actions from subjects on objects and ensures they are according to the policy

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Ideally, all actions should be checked before allowing them to happen.

The **reference monitor** is the component (both in design and implementation) that mediates actions and ensures they are according to the policy.

Implenting the ideal reference monitor in reality is very hard:

- If you check every action there would be a big performance hit (think how many memory access per second your computer does!)
- It is not straightforward to decide when the reference monitor should operate: between a check and an execution the state may have changed. How do we ensure the check is correct?

- In distributed systems resources are spread across machines and even networks. Subjects and objects may not even be on the same machine! Where should the reference monitor be? If we don't distribute it, not all checks can be run. If we distribute it, it becomes very complex and hard to know if it is correct

Scenario

- Imagine you're building a new service like Netflix/Youtube/generic content platform. Users can subscribe or unsubscribe to the "Gold Member" with one click.
- **Your Goal:** Protect your gold feature/content so only "Gold Members" can see the gated content
- **The "Easy" Logic:** To be fast, your code checks the user's status *only once* at login
  - User logs in
  - Code checks database: "Is user a Gold Member?" -> Yes
  - Code creates a session cookie that says: {'user': 'Alice', 'status': 'paid'}
- **The Flaw:** For every video request after this, your code *only* looks at the cookie, it doesn't re-check the database. *This is a violation of Complete Mediation*

Missing Mediation - An Attack

- Alice pays a Gold Membership for one day, logs in as a "Gold Member." Her session cookie says 'status': 'paid'
- She goes to her account page and clicks "Unsubscribe." The database is correctly updated to "unpaid"
- She then tries to access the privileged content. Your code **only checks the cookie**.
- **Result:** Alice, now an unpaid user, can still watch all premium content until her original session expires.

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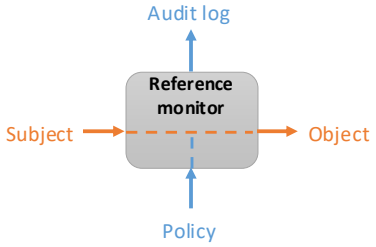

mediates **ALL** actions from subjects on objects and ensures they are according to the policy

Difficult to implement

- Performance?
  - Checking everything is slooooooow
- Time to check vs. time to use
- Modern distributed systems
  - You can only check what you see!

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4 – Open design

"The design should not be secret" [SS75]

"The design of a system should not require secrecy"

Kerckhoff
La Cryptographie Militaire
(*1883*)

"The enemy knows the system"

"one ought to design systems under the assumption that the enemy will immediately gain full familiarity with them"

Shannon
Communication Theory of Secrecy Systems
(*1949*)

Baran
Security, secrecy, and tamper-free considerations
(*1964*)

"The Paradox of the Secrecy About Secrecy"

"Without the freedom to expose the system proposal to widespread scrutiny' by clever minds of diverse interests, is to increase the risk that significant points of potential weakness have been overlooked"

https://www.rand.org/pubs/research_memoranda/RM3765/RM3765

These are three views on why secrecy is not a good underlying requirement for security:

Kerchoff: every secret in a system creates a potential failure point. Secrecy, in other words, is a prime cause of weakness. Openness, helps having less points of failure.
Shannon: designing assuming the adversary does not know the system gives advantage to the adversary, as he is out of the threat model
Baran: designing in secret is hard, as it prevents conversations that could help identifying weaknesses and better security mechanisms

4 – Open design

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Kerckh
La Cryptograph
(188

When you design… algorithms are public! Only key elements are kept secret

Crypto: only keep the key secret
Authentication: only keep password secret
Obfuscation: only keep the used noise secret

non
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Open design results in better & easier auditing

Linus' law: *"given enough eyeballs, all bugs are shallow"*

(More of a mantra, need many eyeballs, defect density is high)

Raymond
The Cathedral and the Bazaar (*1997*)

Secrecy is unrealistic!!

Way to build a bad threat model!

Famous failure of a closed design:

- GSM encryption

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Open designs can be revised by experts to revise who find vulnerabilities and propose ways to fix them.

This is a classic metric in software engineering, known as defect density. There is no single, universally agreed-upon number, as it varies based on the project's quality, testing, and maturity. Though, industry studies provide a range .The rate of all bugs is generally cited in the range of: 15 to 50 bugs per 1,000 lines of code. Security vulnerabilities are a smaller subset of all bugs. While there is less consensus https://www.sei.cmu.edu/library/predicting-software-assurance-using-quality-and-reliability-measures-2/ provides a baseline: About 5% of all bugs are found to be security vulnerabilities. i.e. ~of the order of 1 per 1000 LoC. (I was not fully convinced at the paper though). (Fun recent follow up: https://www.sei.cmu.edu/blog/using-chatgpt-to-analyze-your-code-not-so-fast/ "These results of our analysis show that ChatGPT 3.5 has promise, but there are clear limitations.")

DVD Encryption (1996): the algorithm was called Content Scramble System (CSS). Propietary 40-bits algorithm (US export law at the time forbid larger keys). It's use was tied to a license – only if one has the license, obtained under a non-disclosure agreement, one can decrypt the content. Every licensee got a decryption key, and in every DVD the encryption key of the content is encrypted to all the licensees, so that all can read the

content. Eventually, one careless reader developer did not encrypt properly their decryption key. Hackers could get it and with that read any DVD to enable copies. There were many secrets, when one was leaked the full system broke (more: https://www.schneier.com/essays/archives/1999/11/dvd_encryption_broke.html)
This is not a clear cut, as what leaked was the key of a player, the encryption scheme was also semi-opened. It is still often given in example.

GSM Encryption (1987): A5/1, with a key length of 54 bits (short, so that it could be found via brute force by secret services). It was reverse engineered, and since then many attacks, some of them very serious have been found. As of today, one can decrypt A5/1 in real time without knowing the secret key.

*The Cathedral and the Bazaar: Musings on Linux and Open Source by an Accidental Revolutionary (*E. Raymond), describes the open design process: software is developed by a group of engineers, but made available for others to check, comment, and improve.

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Key principle behind the academic discipline devoted to understanding computer security

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The “hidden” instance

- In June 2017, the personal data (names, addresses, birthdates, and *political profiling*) of 198 million US voters was found exposed online.
- The 1.1 TB database was compiled by Deep Root Analytics, a data firm contracted by the RNC.
- The server was publicly accessible.
  - It had no password and no authentication required to access it
  - The only thing “protecting” this data was that the URL (dra-dw.s3.amazonaws.com) was "semi-secret" (“**D**eep **R**oot **A**nalytics, **D**ata **W**arehouse”)
  - Security through Obscurity did not work
- A security researcher discovered the URL, and disclosed the issue and later wrote a detailed report, for a while the entire 1.1 TB database was technically open for anyone on the internet to download.
  - It is unknown if this data was stolen by malicious actors.

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https://www.upguard.com/breaches/the-rnc-files

Back-of-the-envelope calculation – addresses are not safe

- How many IPv4 addresses are there on the internet (CS-202)?
  - 32-bits addresses (8*4) = 4B possibilities
  - How long does it take to ask these 4B how many of them are hosting a website/running a service on a given port?
    - 3 minutes in 2013*
- Similarly, if you run your own service (website, database, your next great startup idea) :
  - picking a random port (CS-202 ports are numbers between 0-65535) **is not hiding the service**

Source *: https://web.archive.org/web/20250215174330/https://blog.erratasec.com/2013/09/masscan-entire-internet-in-3-minutes.html

5 – Separation of privilege

"No single accident, deception, or breach of trust is sufficient to compromise the protected information" [SS75]

*A **privilege** allows a user to perform an action on a computer system that may have security consequences, e.g., create a file in a directory, access a device, write to a socket for communicating over the Internet.*

Require multiple conditions to execute an action improves security

Examples: two keys to open a safe, two-factors to authenticate

Problems

- Availability?
- Responsibility?
- Complexity!

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The separation of privilege principle indicates that having only one entity/process/user/… responsible for a (critical) security task is undesirable. If that responsible fails, the system's security is compromised. Instead, one must try to divide responsibility so that if one entity gets compromised the full system does not break.

While having two or more conditions helps with security, it has downsides:
- Now one needs all conditions to use a service. What happens when you don't have your phone to log in on your bank account?
- When the conditions are related to people, this dilutes responsibility: no one in particular is responsible. This may also lower security, and also makes it more difficult to establish liabilities.
- Having to meet more than one condition increases complexity! How are they combined? When should they be considered? Does order matter? Remember "economy of mechanism" principle.

Scenario- IT system in a typical business

System: Payment system for a business (order stuff from vendors)

Security Goal: Attacker must not be able to steal money

Principals: Employees (submit order request), Vendors, Managers (Approve new vendor, approve orders, inherits Employee)

Threat Model: Attacker can corrupt *at most one* principal (No collusion threat model)

A *single* corrupted employee can execute the entire attack:

- **Create Vendor:** They add a fake shell company (e.g., " M.T. Pockets Consulting" which the adversary secretly own) as a "New Vendor"
- **Create Order:** Submit fake order requests for this vendor
- **Approve:** Use their own authority to "Approve Expenses"

Solution is to split roles:

- **Role A (Procurement):** Can **ONLY** create/approve new vendors. Cannot approve payments
- **Role B (Finance Manager):** Can **ONLY** approve payments for vendors *already in the system*. Cannot create new vendors

Separation of Privileges is a bit reminiscent of the "Separation of Power" principle or the idea of "checks and balances" in political sciences

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Recap

Economy of mechanism. Keep it simple!

Fail-safe defaults. Safe defaults, and if there is a problem, your move should comply with the policy

Complete mediation. Verify *every* action

Open Design. Make the design (and implementation) of your mechanism available

Separation of Privilege. Try to never rely on *only one* entity or action

6 – Least privilege

"Every program and every user of the system should operate using the least set of privileges necessary to complete the job" [SS75]

Rights added as needed, discarded after use

Damage control
- Minimize high privilege actions & interactions

"Need-to-know" principle
- Examples
  - Guest accounts @ EPFL
  - Data minimization principle (Data Protection)

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The least privilege principle indicates that one should be very careful when assigning permissions to principals. They should always have the minimal set of permissions necessary to carry out their task. This helps limiting how much damage can a principal cause in the system. If a principal does not have privileges, any error/misbehaviour of this principal cannot create huge damage on the system.

The least privilege principle is very related to the fail safe principle. It ensures that if there is an error or compromise the compromised principal cannot execute unauthorized actions, helping staying on a safe state.

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What principle is this related to?

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7 – Least common mechanism

"Minimize the amount of mechanism common to more than one user and depended on by all users" [SS75]

"Every shared mechanism represents a potential information path between users and must be designed with great care to be sure it does not unintentionally compromise security"

Remember "Economy of mechanism"

- (Design) Interactions make it hard to validate the security design
- (Implementation) Interactions may lead to unintentional leaks of information
  - Unintended channels: use of /tmp, shared cache

Having common mechanisms makes the system more complex (against economy of mechanism).

At the design level, interactions are difficult to model completely. It is hard to guarantee one has considered all of the possible cases and thus the validation holds in reality

The number of common flows and unintentional information channels introduced by the use of common resources when implementing systems tends to grow: for efficiency, computers share a lot of resources!

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(Implementation) Interactions may lead to unintentional leaks of information

Unintended channels: use of /tmp, shared cache

Note that this refers to mechanisms! Not to the code. Reusable code that has been tested many times is helpful for security. **The problem is the isolation of data**

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CS-200 Throwback

- Who remembers what are symbolic links?
- **Refresher (What is a Symlink):** A symbolic link (or "symlink") is simply a "shortcut" file. When the operating system tries to access the symlink, it is automatically redirected to the *real* file or directory the link is pointing to.

Exercise – Find the vulnerability

Principal 1: A "root/admin" program that predictably writes a log file to a `/tmp/starting.log`. Something like:

```
echo "Service is starting..." > /tmp/starting.log
```

Principal 2: The “root/admin” logging subsystem.

Principal 3: A user that can run nonroot programs. Has write accesses to `/tmp` too.

Security Goal: Preserve log integrity (integrity of the files written by Principal 2)

Threat model: Adversary can corrupt Principal 3

Solution – Violation of the Least common mechanism

The Common Mechanism:

- The `/tmp` directory on a Linux/Unix machine. This directory is shared between low-privilege users and high-privilege 'root' processes. Both can (and do) write temporary files here.

Attacker simply creates a symlink:

```
ln -s /var/log/dmesg /tmp/starting.log
```

Actually it does not work anymore on modern Linux, there is a mitigation for /tmp! But it works if the symbolic link is in /home/user

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8 – Psychological acceptability

"It is essential that the human interface be designed for ease of use, so that users routinely and automatically apply the protection mechanisms correctly" [SS75]

Hide complexity introduced by security mechanisms

Security mechanisms should not make the resource more difficult to access than if it was not present

Mental model of the (honest) users must match security policy and security mechanisms

Cultural acceptability – not all mechanisms are acceptable everywhere

(Authentication) Face recognition not suitable in cultures that cover their face

(Safety) Register of everyone who sleeps in a dorm

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In order for security mechanisms to succeed, users need to feel comfortable with them:

- They need to be able to use them, and they cannot cause a burden. When the mechanisms are complicated and hard to interact with, users start following insecure practices.
- The threat model against which the mechanism is designed must be understandable by honest users. If users do not perceive the threat, they are unlikely to make good use of the mechanism.
- The mechanism must not go against any social/cultural norm. Otherwise, users will ignore it or try to circumvent it.

- Canonical example: Password on a sticky note

Amazon S3 Buckets

- **S3** stands for **S**imple **S**torage **S**ervice, a cloud storage service from AWS
- Think of it as a limitless "hard drive in the cloud." You store data as "Objects" (files, videos, backups) inside containers called "Buckets“
- It's the backbone of the modern internet, used for everything from hosting website images to storing data and application logs
- Access to S3 buckets is controlled by a sophisticated system of permissions

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Sources:

https://stackoverflow.com/questions/41092658/what-are-s3-default-grantees-any-authenticated-aws-user-and-aws-account-alia
https://www.upguard.com/breaches/the-rnc-files
https://www.helpnetsecurity.com/2017/07/18/dow-jones-customer-data-exposed
https://www.upguard.com/blog/cloud-misconfiguration

The Confusion

- Psychological acceptability is not just for end users!
  System administrators are also "users" of a configuration UI
- The S3 bucket permission UI included a potentially misleading option: grant access to **"Any Authenticated AWS User"**
  - **What admins *thought* it meant:** "Any authenticated user *in my account*."
  - **What it *actually* meant:** "ANY person on Earth with ANY AWS account (which is free to create)."
- Consequences: several leaks starting in 2017 (RNC, DowJones, …)
- New layer of default failsafe in 2023
  - https://aws.amazon.com/about-aws/whats-new/2022/12/amazon-s3-automatically-enable-block-public-access-disable-access-control-lists-buckets-april-2023

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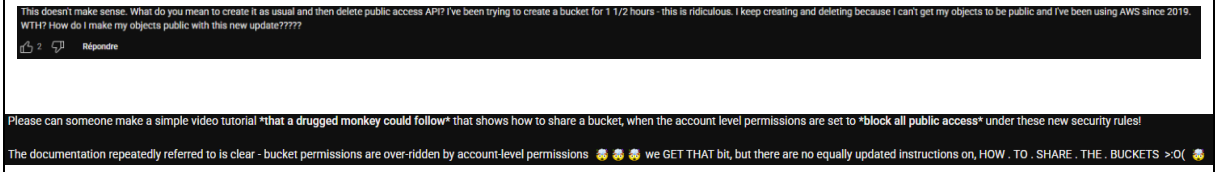
Sources:

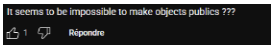
https://stackoverflow.com/questions/41092658/what-are-s3-default-grantees-any-authenticated-aws-user-and-aws-account-alia
https://www.upguard.com/breaches/the-rnc-files
https://www.helpnetsecurity.com/2017/07/18/dow-jones-customer-data-exposed

Interesting link for cloud configuration and what to look for:
https://www.upguard.com/blog/cloud-misconfiguration

Safer default have tradeoffs

Youtube comments when Amazon advertised their new policy in a release video





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Extra principles from physical security
9 - Work factor

DIFFICULT TO TRANSPOSE TO COMPUTER SECURITY!!

"Compare the cost of circumventing the mechanism with the resources of a potential attacker" [SS75]

It helps **refining** the threat model!

Quantifying **cost** is hard**?**

- cost of compromising insiders?
- cost of finding a bug?
- monetization?

Difficult to quantify

This principle is useful to reason about security and may help to better define the threat model (making very explicit the capabilities of the adversary), but it is very hard to completely transpose to computer security.

Cost is hard to define and quantify for many cases. What is the cost of corrupting an employee? Or of finding a bug? Time? Expertise?. Also at the end of the day it is about cost vs benefit. How many people will be able to use the exploit? What will be the benefit for the adversary that uses the exploit? And what if the cost of individuals is small, but many individuals can use the exploit.

In this sense, computer security is very different from physical security mechanisms where in general the cost is easy to see (breaking a lock, climbing a wall) and the benefit is limited to the people that are physically present.

Extra principles from physical security
10 - Compromise recording

DIFFICULT TO TRANSPOSE TO COMPUTER SECURITY!!

"Reliably record that a compromise of information has occurred [...] in place of more elaborate mechanisms that completely prevent loss" [SS75]

Keep **tamper-evidence logs,**

they may enable recovery (integrity)

Logs **are not magic**:

What if you cannot recover? (if confidentiality mechanisms were in place)

How to keep integrity?

Logs may be a vulnerability (Privacy)?

Logging the log? (Availability)

Logging is not a guarantee that the compromise is detected.

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Creating secure logs in a digital environment is much harder than in a physical environment.

The main reason is that you need a new security mechanism for them!

Having a log that helps detecting an attack does not guarantee that the system can recover. For instance, if the attack deletes keys, even if you know the attack happened and who made it you cannot recover information

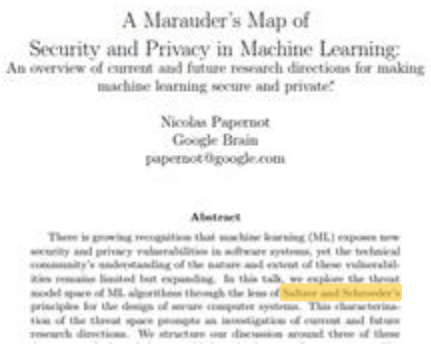
How do we keep their integrity: if the adversary attacking the system can tamper the log, then there is no use in having a log

Logs may contain information that leak the content of confidential exchanges (e.g., a record of a patient talking to an oncologist very frequently reveals the patient health status even if the patient's records are confidential)

Availability is crucial: how do we make sure that the log is not deleted or that access to the log is not prevented?

Thinking about the principles helps designing good logging systems

Why principles are important?



A Marauder's Map of
Security and Privacy in Machine Learning:
An overview of current and future research directions for making machine learning secure and private*

Nicolas Papernot
Google Brain
papernot@google.com

Abstract

There is growing recognition that machine learning (ML) exposes new security and privacy vulnerabilities in software systems, yet the technical community's understanding of the nature and extent of these vulnerabilities remains limited but expanding. In this talk, we explore the threat model space of ML algorithms through the lens of Saltzer and Schroeder's principles for the design of secure computer systems. This characterization of the threat space prompts an investigation of current and future research directions. We structure our discussion around three of these

Least privilege. Let the ML learn as little as possible so that information cannot be extracted

Least Common Mechanism. Get samples labelled from different origins

Psychological acceptability. Users must be able to understand why models classify or misclassify an input

Work factor. The cost of the attack, e.g., in terms of number of calls to an API, matters for its relevance

Compromise recording. Ideally we would like to be able to log all steps inside the algorithm

Summary of the lecture

"Since no one knows how to build a system without flaws, the alternative is to rely on eight design principles, which tend to reduce both the number and the seriousness of any flaws: Economy of mechanism, fail-safe defaults, complete mediation, open design, separation of privilege, least privilege, least common mechanism, and psychological acceptability" [SS75]

Principles allow us to identify safe and unsafe *patterns* in when designing security mechanisms

Do not use principles as a blind checklist!

Use principles as tools to weight design decisions.

The principles are deeper than they look, and they are easy to violate – typically caused by improperly evaluated tradeoffs.

Example of tradeoffs:

- Default configuration (make it easier to use to not need to request a certificate to host a website)
- Simple/Minimal TCB vs Simplicity of writing the code

Principles like all principles are endless and very difficult to understand. About entropy (and so indirectly second principle of thermodynamics) "You should call it entropy, for two reasons. In the first place, your uncertainty function has been used in statistical mechanics under that name, so it already has a name. In the second place, and more importantly, no one knows what entropy really is, so in a debate you will always have the advantage." Von Neumann to Shannon