



Welcome to

## 7. Secure Systems Design and Implementation

KEA Kompetence Computer Systems Security

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Slides are available as PDF, kramse@Codeberg  
7-secure-systems-design.tex in the repo security-courses

# Goals



- Know the most important Design Principles, underpinning the whole of our industry
- Know what DNSSEC is, Know references to standards like DANE
- Inspire you to enable DNSSEC
- Discuss Access Control Lists vs capabilities vs setuid programs
- List Wedge, Pledge and Unveil as examples of containment
- Work with DNS, SMTPD settings - make recommendations for YOUR networks

# Plan



## Subjects

- Principle of least privilege, fail-safe defaults, separation of privilege etc.
- Files, objects, users, groups and roles
- Naming and Certificates
- Access Control Lists
- DNSSEC

## Exercises

- Data types – small programs with errors
- Real vulnerabilities found in Exim
- DNSSEC, SPF, DMARC - DNS based updates to your email domain security

## Reading Summary



MLSH chapter 7: SSH Hardening

MLSH chapter 8: Mastering Discretionary Access Control

Skim, Setuid demystified

Some thoughts on security after ten years of qmail 1.0

Wedge: Splitting Applications into Reduced-Privilege Compartments

# Principle of Least Privilege



**Definition 14-1** The *principle of least privilege* states that a subject should be given only those privileges that it needs in order to complete the task.

Also drop privileges when not needed anymore, relinquish rights immediately

Example, need to read a document - but not write.

Database systems can often provide very fine grained access to data

Original source: *The Protection of Information in Computer Systems*, 1975, Jerome Saltzer and Michael Schroeder

[https://en.wikipedia.org/wiki/The\\_Protection\\_of\\_Information\\_in\\_Computer\\_Systems](https://en.wikipedia.org/wiki/The_Protection_of_Information_in_Computer_Systems)

## Principle of Fail-Safe defaults



**Definition 14-3** The *principle of fail-safe defaults* states that, unless a subject is given explicit access to an object, it should be denied access to that object.

Default access *none*

In firewalls default-deny - that which is not allowed is prohibited

Newer devices today can come with no administrative users, while older devices often came with default admin/admin users

Real world example, OpenSSH config files that come with `PermitRootLogin no`

# Principle of Economy of Mechanism



**Definition 14-4** The *principle of economy of mechanism* states that security mechanisms should be as simple as possible.

Simple — > fewer complications — > fewer security errors

Use WPA passphrase instead of MAC address based authentication

## Principle of Complete Mediation



**Definition 14-5** The *principle of complete mediation* requires that all accesses to objects be checked to ensure that they are allowed.

Always perform check

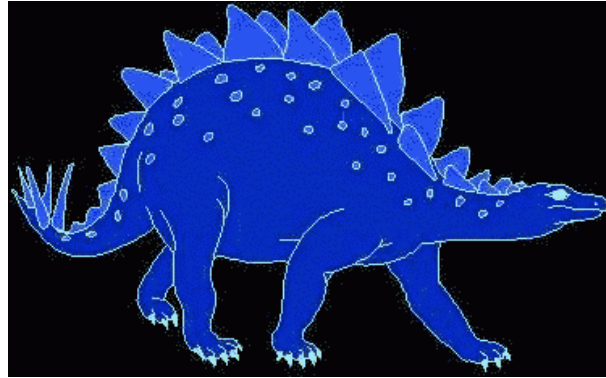
Time of check, time of use

Example Unix file descriptors - access check first, then can be reused in the future

Caching can be bad.



# Principle of Open Design



Source: picture from <https://www.cs.cmu.edu/~dst/DeCSS/Gallery/Stego/index.html>

**Definition 14-6** The *principle of open design* states that the security of a mechanism should not depend on the secrecy of its design or implementation.

Content Scrambling System (CSS) used on DVD movies

Mobile data encryption A5/1 key - see next page

## Mobile data encryption A5/1 key



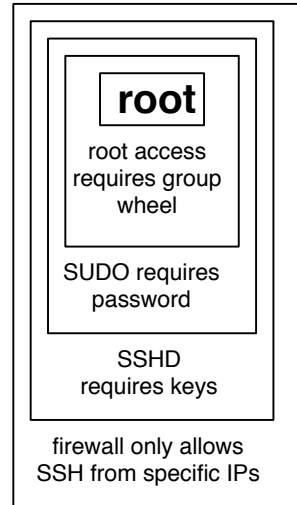
Real Time Cryptanalysis of A5/1 on a PC Alex Biryukov \* Adi Shamir \*\* David Wagner \*\*\*

Abstract. A5/1 is the strong version of the encryption algorithm used by about 130 million GSM customers in Europe to protect the over-the-air privacy of their cellular voice and data communication. The best published attacks against it require between 240 and 245 steps. ... In this paper we describe new attacks on A5/1, which are based on subtle flaws in the tap structure of the registers, their noninvertible clocking mechanism, and their frequent resets. After a 248 parallelizable data preparation stage (which has to be carried out only once), the actual attacks can be **carried out in real time on a single PC**.

The first attack requires the output of the A5/1 algorithm during the first two minutes of the conversation, and computes the key in about one second. The second attack requires the output of the A5/1 algorithm during about two seconds of the conversation, and computes the key in several minutes. ... The approximate design of A5/1 was leaked in 1994, and the exact design of both A5/1 and A5/2 was reverse engineered by Briceno from an actual GSM telephone in 1999 (see [3]).

Source: <http://cryptome.org/a51-bsw.htm>

# Principle of Separation of Privilege



**Definition 14-7** The *principle of separation of privilege* states that a system should not grant permission based on a single condition.

Company checks, CEO fraud

Programs like *su* and *sudo* often requires specific group membership and password

# Principle of Least Common Mechanism



**Definition 14-8** The *principle of least common mechanism* states that mechanisms used to access resources should not be shared.

Minimize number of shared mechanisms and resources

Also includes stack protection, randomization

# Principle of Least Astonishment



**Definition 14-9** The *principle of least astonishment* states that security mechanisms should be designed so that users understand the reason that the mechanism works the way it does and that using the mechanism is simple.

Security model must be easy to understand and targetted towards users and system administrators

Confusion may undermine the security mechanisms

Make it easy and as intuitive as possible to use

Make output clear, direct and useful

Exception user supplies wrong password, tell login failed but not if user or password was wrong

Make documentation correct, but the program best

Psychological acceptability - should not make resource more difficult to access

## Files, objects, users, groups and roles



**Definition 15-1** A *principal* is a unique entity. An *identity* specifies a principal.

Authentication binds a principal to a representation of identity internal to a computer.

Example files and URLs

Users represented by user IDs

Groups and roles, sets of entities

# Naming and Certificates



Naming and certificates, certificates binds cryptographic keys to identifiers

Book describes CA policies and processes in some detail

I recommend using Lets Encrypt <https://letsencrypt.org/>

Our main printed book uses these to describe NAT: 10.1.3.241 and 101.43.21.241

101.40/13 belongs to APNIC and was assigned to a real network!

Use the prefixes specifically documented for documentation when writing documentation see RFC3849 and RFC5737

The book also describes problems trusting IP addresses and DNS information, with some references to *cache poisoning* etc.

# Domain Name System Security Extensions (DNSSEC)



## Domain Name System Security Extensions (DNSSEC)

DNSSEC was originally specified in the following three RFCs:

RFC 4033 – DNS Security Introduction and Requirements

RFC 4034 – Resource Records for the DNS Security Extensions

RFC 4035 – Protocol Modifications for the DNS Security Extensions

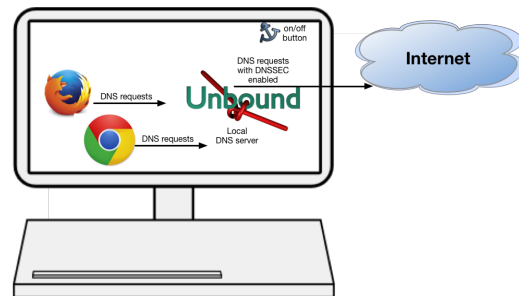
<https://www.internetsociety.org/resources/deploy360/2011/dnssec-rfcs-3/>

Using DNSSEC we can put keys into DNS, not trusting the usual browser root CAs

Using the wrong NSEC can mean you can *walk the zone* and get all names! May or may not lead to finding testing and development systems - use NSEC3



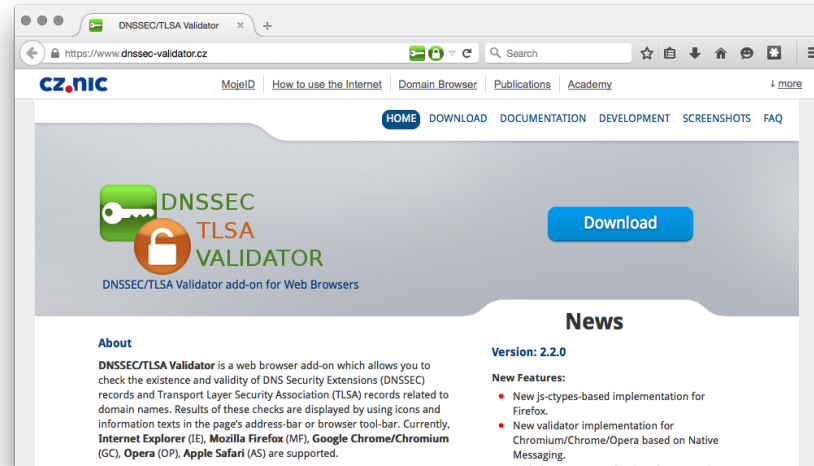
# DNSSEC trigger



DNSSEC-trigger secure local DNS server for your Windows or Mac laptop.

- DNSSEC Validator for Firefox  
<https://addons.mozilla.org/en-us/firefox/addon/dnssec-validator/>
- OARC tools <https://www.dns-oarc.net/oarc/services/odvr>
- <http://www.nlnetlabs.nl/projects/dnssec-trigger/>

# DNSSEC get started now



"TLSA records store hashes of remote server TLS/SSL certificates. The authenticity of a TLS/SSL certificate for a domain name is verified by DANE protocol (RFC 6698). DNSSEC and TLSA validation results are displayed by using several icons."

# DNSSEC and DANE



"Objective:

Specify mechanisms and techniques that allow Internet applications to establish cryptographically secured communications by using information distributed through DNSSEC for discovering and authenticating public keys which are associated with a service located at a domain name."

## DNS-based Authentication of Named Entities (dane)

# Access Control Mechanisms



Access control lists (ACL)

Used for file systems, as we know from Linux and Windows file systems

Term used for switch, firewall and router filters, network ACLs

Capabilities - used for docker in the Linux kernel

Privileges

*Capsicum: practical capabilities for UNIX* Robert N. M. Watson

Ring-based access control supported by CPUs for many years

Compare kernel mode vs user mode

# Setuid demystified



Access control in Unix systems is mainly based on user IDs, yet the system calls that modify user IDs (uid-setting system calls), such as setuid, are poorly designed, insufficiently documented, and widely misunderstood and misused. This has caused many security vulnerabilities in application programs.

*Setuid Demystified* Hao Chen, David Wagner, and Drew Dean, Proceedings of the 11th USENIX Security Symposium, August 05 - 09, 2002

- Sometimes a user need to modify resources not owned by themselves
- Most common example is changing their password in the user database
- So while the program `passwd` runs it has the privileges of the root user, `setuid-root` program
- Previously Unix systems would have several 100s of setuid programs, today OpenBSD has less than 30 I think, and privilege seperated see OpenSSH
- Note also the many differences in Unix variants!

## Setuid differences in Unix variants



**setuid()** Although setuid is the only uid-setting system call standardized in POSIX 1003.1-1988, it is also the most confusing one. First, the required permission differs among Unix systems. **Both Linux and Solaris** require the parameter newuid to be equal to either the real uid or saved uid if the effective uid is not zero. As a surprising result, setuid(geteuid()), which a programmer might reasonably expect to be always permitted, can fail in some cases, e.g., when ruid=100, euid=200, and suid=100. On the other hand, setuid(geteuid()) always succeeds in FreeBSD. **Second, the action of setuid differs not only among different operating systems but also between privileged and unprivileged processes.** In Solaris and Linux, if the effective uid is zero, a successful setuid(newuid) call sets all three user IDs to newuid; otherwise, it sets only the effective user ID to newuid. On the other hand, **in FreeBSD a successful setuid(newuid) call sets all three user IDs to newuid** regardless of the effective uid.

*Setuid Demystified* Hao Chen, David Wagner, and Drew Dean, Proceedings of the 11th USENIX Security Symposium, August 05 - 09, 2002

This is reality, and very confusing.

## Setuid example CVE-2018-14665



The three required commands, Hickey said, are:

```
cd /etc; Xorg -fp  
"Root::16431:0:99999:7:::" -logfile  
shadow :1;su
```

Source: Matthew Hickey, cofounder of security firm Hacker House

- The X11 Window System is often setuid root
- Requires access to screen memory, keyboard, mouse etc.
- Not the only problem found in X11 over the years, incomplete list at:  
[https://www.cvedetails.com/vulnerability-list/vendor\\_id-88/product\\_id-147/X.org-X11.html](https://www.cvedetails.com/vulnerability-list/vendor_id-88/product_id-147/X.org-X11.html)



Fortunately, we can note that there is a lot of symmetry present. If we have a **non-root user ID**, the **behavior of the operating system is essentially independent of the actual value of this user ID**, and depends only on the fact that it is non-zero. For example, the states  $(\text{ruid}, \text{euid}, \text{suid}) = (100, 100, 100)$  and  $(200, 200, 200)$  are isomorphic up to a substitution of the value 100 by the value 200, since the OS will behave similarly in both cases (e.g., `setuid(0)` will fail in both cases).

*Setuid Demystified* Hao Chen, David Wagner, and Drew Dean, Proceedings of the 11th USENIX Security Symposium, August 05 - 09, 2002

- The Setuid Demystified paper moves on to a formal model, but Reality bites again:  
<https://thehackernews.com/2018/12/linux-user-privilege-policykit.html>
- *Red Hat has recommended system administrators not to allow any negative UIDs or UIDs greater than 2147483646 in order to mitigate the issue until the patch is released.*
- `\fliptable` everything is insecure



# Qmail Security



The qmail security guarantee In March 1997, I took the unusual step of publicly offering \$500 to the first person to publish a verifiable security hole in the latest version of qmail: for example, a way for a user to exploit qmail to take over another account. My offer still stands. Nobody has found any security holes in qmail. I hereby increase the offer to \$1000.

*Some thoughts on security after ten years of qmail 1.0, Daniel J. Bernstein*

- Started out of need and security problems in existing Sendmail
- Bug bounty early on. Donald Knuth has similar for his books

## Qmail Security Paper, some answers



- Answer 1: eliminating bugs — > Enforcing explicit data flow, Simplifying integer semantics, Avoiding parsing
- Answer 2: eliminating code — > Identifying common functions, Reusing network tools, Reusing access controls, Reusing the filesystem
- Answer 3: eliminating trusted code — > Accurately measuring the TCB, Isolating single-source transformations, Delaying multiple-source merges, Do we really need a small TCB?

## Qmail vs Postfix



I failed to place any of the qmail code into untrusted prisons. Bugs anywhere in the code could have been security holes. The way that qmail survived this failure was by having very few bugs, as discussed in Sections 3 and 4.

*Some thoughts on security after ten years of qmail 1.0, Daniel J. Bernstein*

- This is NOT a complete comparison of Qmail and Postfix <http://www.postfix.org/>!
- Postfix is comprised of many processes and modules. These modules typically are also chrooted and report back status only through very restricted interfaces
- It is also possible to turn off many components, allowing the system run with less code
- No Postfix program is setuid, all things are run by a master control process. A small setgid program used for mail submission - writing into the queue directory

Source: being a Postfix user and *Secure Coding: Principles and Practices* Eftir Mark Graff, Kenneth R. Van Wyk, June 2009

# Wedge Reduced-Privilege Compartments



We present *Wedge*, a system well suited to the splitting of complex, legacy, monolithic applications into fine-grained, least-privilege compartments. *Wedge* consists of two synergistic parts: OS primitives that create compartments with default-deny semantics, which force the programmer to make compartments' privileges explicit; and *Crowbar*, a pair of run-time analysis tools that assist the programmer in determining which code needs which privileges for which memory objects.

*Wedge: Splitting Applications into Reduced-Privilege Compartments* Andrea Bittau, Petr Marchenko, Mark Handley, Brad Karp NSDI'08 Proceedings of the 5th USENIX Symposium on Networked Systems Design and Implementation, San Francisco, California — April 16 - 18, 2008

# Pledge, and Unveil, in OpenBSD



Compare to Pledge, and Unveil, in OpenBSD

- Applies to multiple different sorts of programs, privsep, privdrop unprivileged
- Illegal operations crash the program. (SIGABRT)
- Pledge: Realistic subsets of POSIX functionality
- The pledge system call forces the current process into a restricted-service operating mode  
<https://man.openbsd.org/pledge.2>
- Ping pledges “stdio inet dns” - only need these, no read,write,create-path need to access file system!
- Unveil limit filesystem access. Many very simple: unveil(“/dev”, “rw”)
- The first call to unveil removes visibility of the entire filesystem from all other filesystem-related system calls (such as open(2), chmod(2) and rename(2)), except for the specified path and permissions.  
<https://man.openbsd.org/unveil.2>

Source: man-pages and

<https://www.openbsd.org/papers/BeckPledgeUnveilBSDCan2018.pdf>

## Hardenize - web sites with testing



Multiple sites provide testing of domains and configurations

<https://www.hardenize.com/>

<https://internet.nl/>

<https://observatory.mozilla.org/> - try [www.zencurity.dk](http://www.zencurity.dk) which fails

<https://www.ssllabs.com/>

<https://securityheaders.com/>

<https://webbkoll.dataskydd.net/en>

Using the available protocols can make your *cookies* better protected, use the *secure* and *http only* along with HSTS, strict transport etc.

Now we will check our own sites, and create plans. Which parts are most interesting to you? Not having your domains abused for spamming or headers and security of your own web sites?

## Bonus: OpenBSD OpenSMTPD vulnerabilities



The OpenBSD project produces a FREE, multi-platform 4.4BSD-based UNIX-like operating system. Our efforts emphasize portability, standardization, correctness, proactive security and integrated cryptography. As an example of the effect OpenBSD has, the popular OpenSSH software comes from OpenBSD.

OpenBSD is freely available from our download sites.

- OpenBSD does a fantastic job in securing systems and software, but some ugly bugs have haunted OpenSMTPD
- Bonus: look at 2020 OpenSMTPD vulns
- LPE and RCE in OpenSMTPD (CVE-2020-7247)

<https://www.openwall.com/lists/oss-security/2020/01/28/3>

<https://blog.qualys.com/laws-of-vulnerabilities/2020/01/29/openbsd-opensmtpd-remote-code-execution-vulnerability-cve-2020-7247>

- Local information disclosure in OpenSMTPD (CVE-2020-8793), and others CVE-2020-8794

<https://www.openwall.com/lists/oss-security/2020/02/24/4>

# Exercise



Now lets do the exercise

## **i** Small programs with data types 15min

which is number **34** in the exercise PDF.



# Exercise



Now lets do the exercise

**! Real Vulnerabilities up to 30min**

which is number **35** in the exercise PDF.

# Exercise

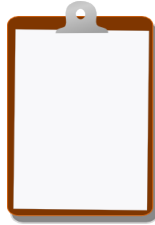


Now lets do the exercise

## ⚠ Email Security – up to 45min

which is number **36** in the exercise PDF.

## For Next Time



Think about the subjects from this time, write down questions

Check the plan for chapters to read in the books

Visit web sites and download papers if needed

Retry the exercises to get more confident using the tools