CLIP OS: Building a defense-in-depth OS around Linux kernel security improvements

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About the ANSSI

- *Agence nationale de la sécurité des systèmes d'information*
- French authority in the area of cyberdefence, network and information security
- We are **not** an intelligence agency

Overview

CLIP OS ?

- Linux distribution developed by the ANSSI
- Initially only available internally
- Now open source, mostly under the LGPL v2.1+
- Code and issue tracker hosted on GitHub:
  - Version 4: available as reference and for upstream patch contribution[1]
  - Version 5: currently developed version, alpha status[2]

[1] https://github.com/CLIPOS-Archive
[2] https://github.com/CLIPOS

Hardened OS

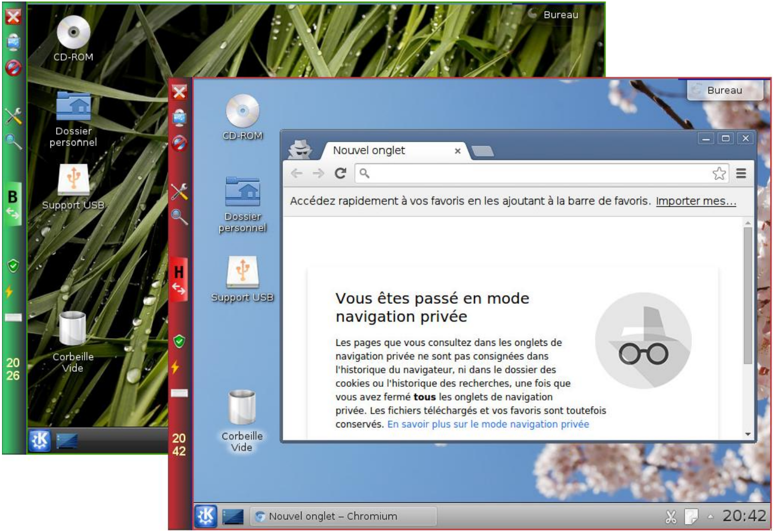
- Hardened Linux kernel and userspace
- Confined services
- "Unprivileged" admin, audit and update roles:

  ⇒ the *root* account is not usable
- Automatic updates using A/B partition model (similar to Android 7+)

Multilevel security OS

- Provide two isolated user environments: *low* and *high*
- Interactions follow the Bell-LaPadula model:
  - Write up: upload documents from *low* to *high*
  - Read down: *high* has read only access to untrusted USB devices
  - Trusted write down: encrypt documents from *high* to write them in *low*
- Level *high* can only access network through a VPN
- Per level user device assignment

Multilevel from the end user point of view



Accédez rapidement à vos favoris en les ajoutant à la barre de favoris. Importer mes...

Vous êtes passé en mode navigation privée

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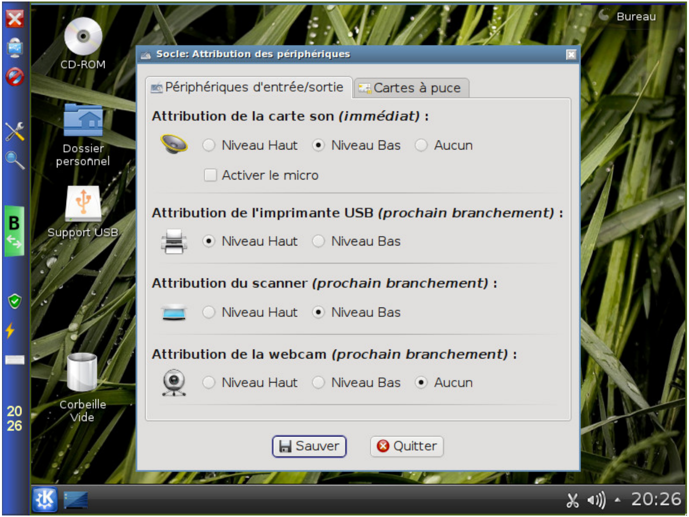
Admin panel: devices assignment per level



Socle: Attribution des périphériques

Périphériques d'entrée/sortie | Cartes à puce

Attribution de la carte son *(immédiat)* :

○ Niveau Haut ● Niveau Bas ○ Aucun

□ Activer le micro

Attribution de l'imprimante USB *(prochain branchement)* :

● Niveau Haut ○ Niveau Bas

Attribution du scanner *(prochain branchement)* :

○ Niveau Haut ● Niveau Bas

Attribution de la webcam *(prochain branchement)* :

○ Niveau Haut ○ Niveau Bas ● Aucun

Sauver Quitter

Differences with Qubes OS

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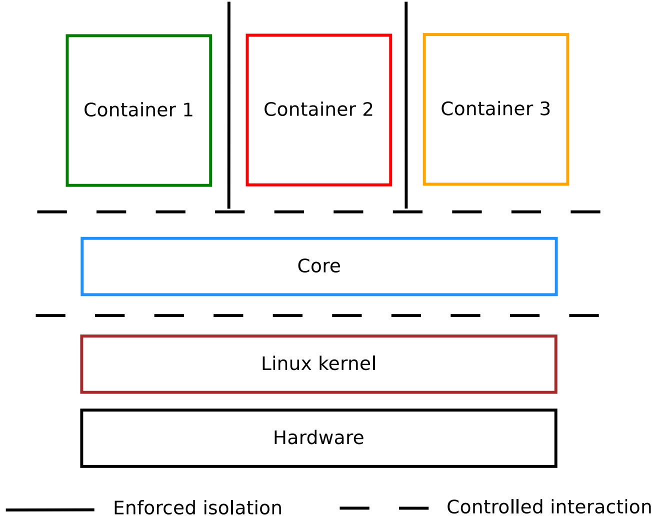
Technical point of view

- Hypervisor vs. supervisor isolation
- Limited access right, even for the administrator

Architecture



CLIP OS 4

Hardening mechanisms

Gentoo Hardened

- Hardened toolchain
- Flexible patching

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- Kernel self-protection (e.g., memory protection, CFI)
- Multiple userspace hardening features (e.g., chroot, TPE)

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CLIP LSM

- Complement the Linux permission model
- Leverage Linux-VServer and grsecurity/PaX

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Avoid arbitrary code execution and persistent attacks, improve multilevel isolation

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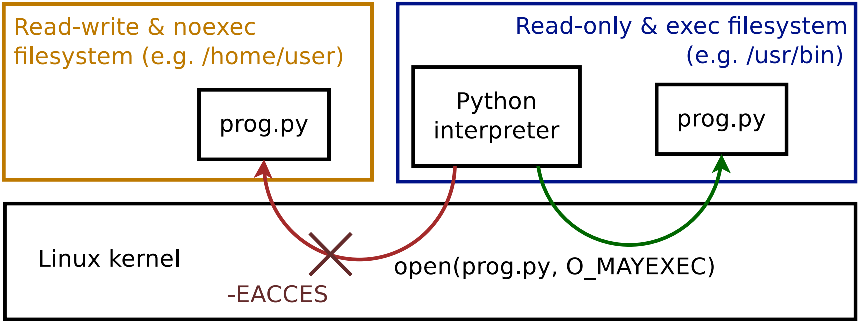
The O_MAYEXEC flag

Enforce and extend W ⊕ X from mount points to scripts (via interpreters)

O_MAYEXEC


Read-write & noexec filesystem (e.g. /home/user)
prog.py
Read-only & exec filesystem (e.g. /usr/bin)
Python interpreter
prog.py
Linux kernel
-EACCES
open(prog.py, O_MAYEXEC)

Partitioning

Hardened containers

- Leverage Linux-VServer *admin* and *watch* (audit) concepts
- New capability bounding sets: for root and per container
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Container content and interaction

- Tailored filesystem layouts per service
- Container management with `vsctl` and `clip-libvserver` (self-jailing)

Veriexec and permissions (CLIP-LSM)

Goal

- Split Linux capabilities (e.g., Fuse, unshare)
- Add new permissions (e.g., network, XFRM)
- Can be tied to an XID
- Does not use xattr (thus independent from the filesystem)

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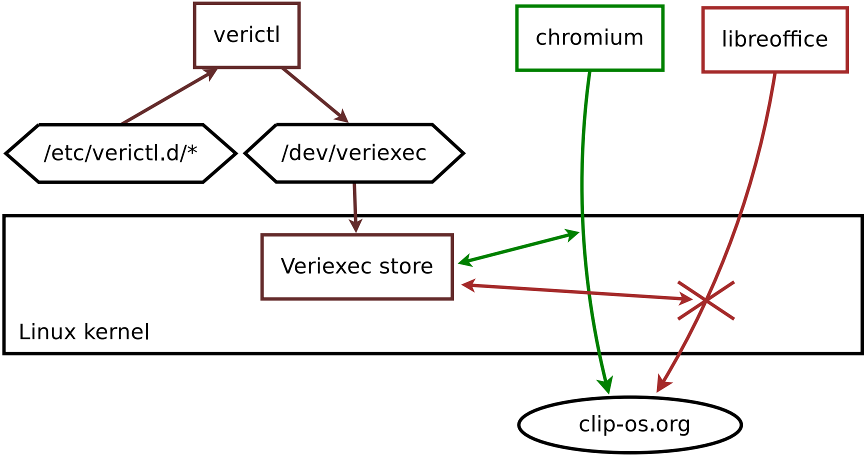
Configuration example: `/etc/verictl.d/chromium`

```
/usr/.../chrome-sandbox 1002 e
  SETUID|SETGID|SYS_CHROOT SETUID|SETGID|SYS_CHROOT -
  cUP sha256 45bcbd1...
```

Veriexec example



CLIP OS 5

General Linux kernel hardening

- Strict whitelist of kernel options, but easily composable sets
- Paranoid command line
  - iommu=force, pti=on, spectre_v2=on, etc.
- Strict sysctl defaults
  - kernel.kptr_restrict, kernel.yama.ptrace_scope, etc.

Enabling Linux kernel hardening

Goals

- Protecting the kernel from itself and from userspace
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Interaction with upstream & KSPP

- Include in-progress or ready-for-upstream patches
- Integrate and validate patches in a single tree
- Maintain hardening patches for latest stable kernel

Patch series: linux-hardened

Features

- Memory hardening improvements, including:
  - better userspace ASLR
  - slab allocators hardening (mostly SLUB)
  - simpler page sanitizing
- Various restrictions: TIOCSTI ioctl, perf subsystem, device timing side channels, etc.
- Miscellaneous additions: more BUG_ONs, more __ro_after_init, etc.

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- Development status: **In progress**
- CLIP OS status: **Merged**
- Upstream status: **Most changes unlikely to be merged upstream**

Upstream contribution integration: Lockdown

Features

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Upstream contribution integration: STACKLEAK

Features

- Reduce information leaks and block attacks using uninitialized kernel stack variables:
  - Erase the stack before returning from system calls
- Improve runtime detection of kernel stack overflows (e.g. Stack Clash):
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Features

- Enables *seccomp-bpf*-like self-sandboxing for unprivileged processes
- Stackable LSM
- Powered by eBPF
- Dynamic filesystem access control using whitelists & blacklists
- See landlock.io

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- Development status: **Initial feature set ready**
- CLIP OS status: **Planned**
- Upstream status: **Work in progress**

Upstream contribution: VServer-like LSM

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- Adds a single kernel enforced indentifier for confined environments
- Similar in principle to VServer XID or to "Container IDs"
- Inspired by the VServer patch
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Conclusion

Take away

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Ongoing project

- Contributions welcome
- Browse the doc and the sources to find more interesting features: docs.clip-os.org

Thanks!

🌎 clip-os.org ✉ clipos@ssi.gouv.fr

🌎 v4: github.com/CLIPOS-Archive

🌎 v5: github.com/CLIPOS

We're hiring! (but not directly for CLIP OS)

Linux system security expert

https://www.ssi.gouv.fr/emploi/expert-en-securite-des-systemes-linux/

Boot chain and root partition integrity protection

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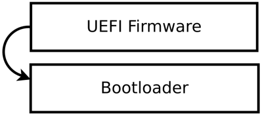

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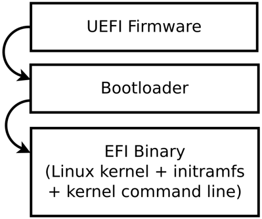

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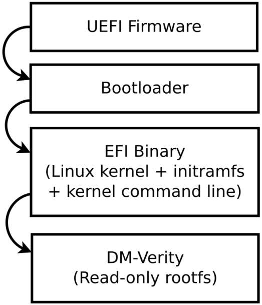
4. DM-Verity partition:
   - DM-Verity root hash set in kernel command line
   - Forward error correction support (FEC)
   - Read only uncompressed SquashFS root filesystem


UEFI Firmware
Bootloader
EFI Binary
(Linux kernel + initramfs
+ kernel command line)
DM-Verity
(Read-only rootfs)