Security at Kernel Level

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Outline

- Why ?
  - Context
  - A new security model
  - Conclusion
- How ?
  - Taxonomy of action paths
  - Defending kernel space
  - Filtering in kernel space
- Implementations
  - LIDS
  - Existing projects
  - LSM

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We would like to be protected from

- Fun/hack/defacing
- Tampering
- Resources stealing
- Data stealing
- Destroying
- DoS
- . . .

- Thus we must ensure
  - Confidentiality
  - Integrity
  - Availability
- What do we do to ensure that ?
  - We define a set of rules describing the way we handle, protect and distribute information
    - ➥ This is called a security policy

To enforce our security policy, we will use some security software

- Tripwire, AIDE, bsign, . . . for integrity checks
- SSH, SSL, IP-SEC, PGP, . . . for confidentiality
- Passwords, secure badges, biometric access controls, . . . for authentication
- . . .

Can we trust them ? Do they work in a trusted place ?

The mice and the cookies

- Facts :
  - We have some cookies in a house
  - We want to prevent the mice from eating the cookies

The mice and the cookies

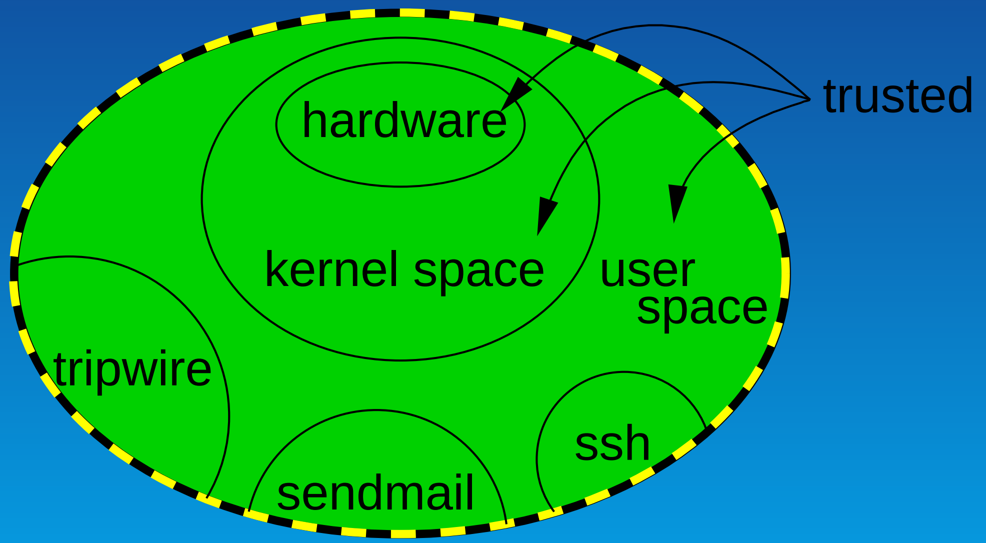
- Solution 1 : we protect the house
  - too many variables to cope with (lots of windows, holes, . . .)
  - we can't know all the holes to lock them.
  - we can't be sure there weren't any mice before we closed the holes

  I won't bet I'll eat cookies tomorrow.

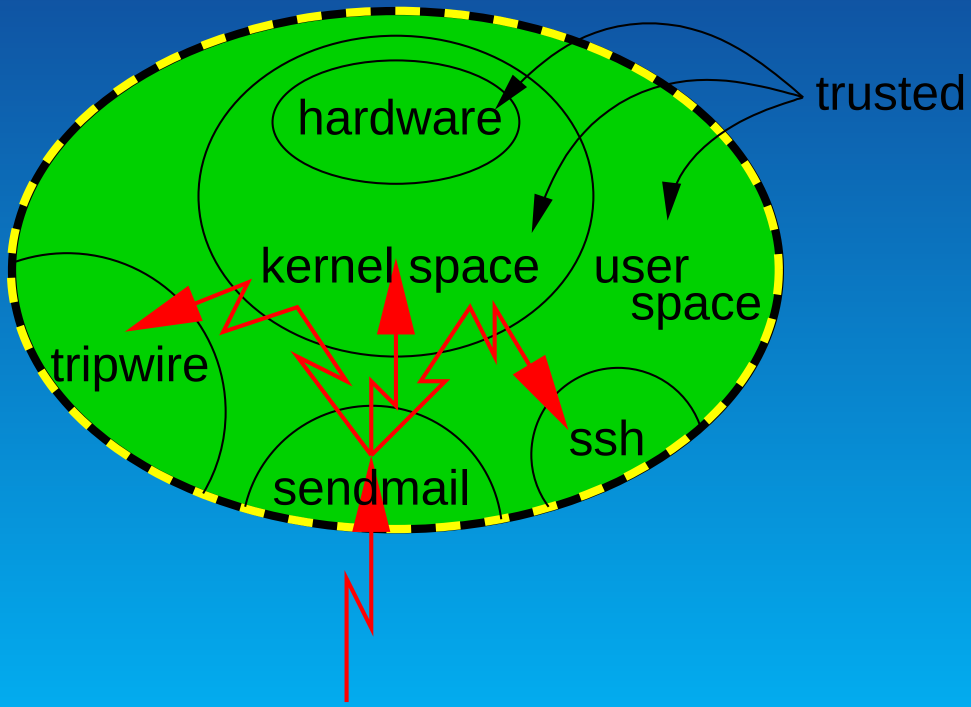
- Solution 2 : we put the cookies in a metal box
  - we can grasp the entire problem
  - we can "audit" the box
  - the cookies don't care whether mice can break into the house

  I'll bet I'll eat cookies tomorrow.

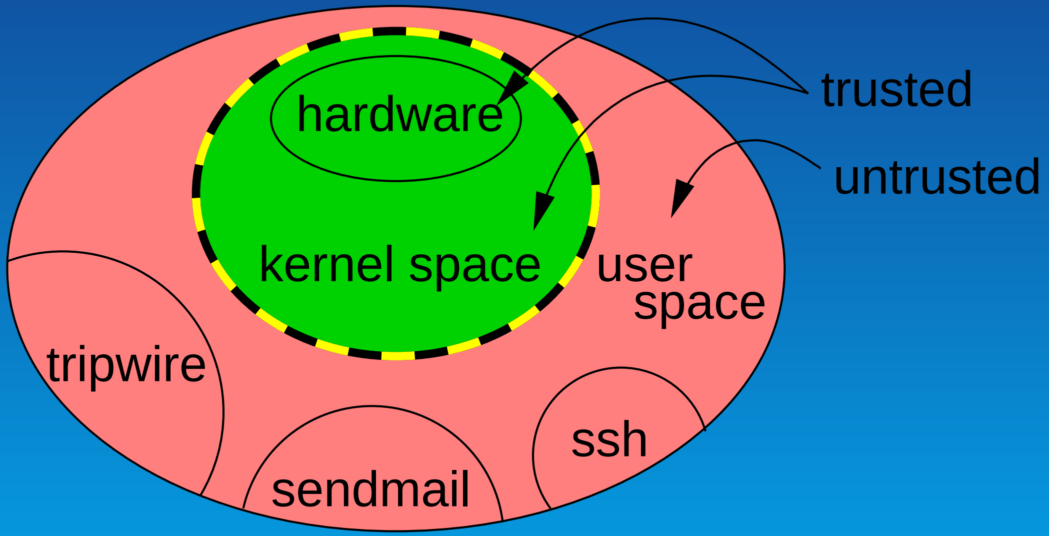
Usual security model



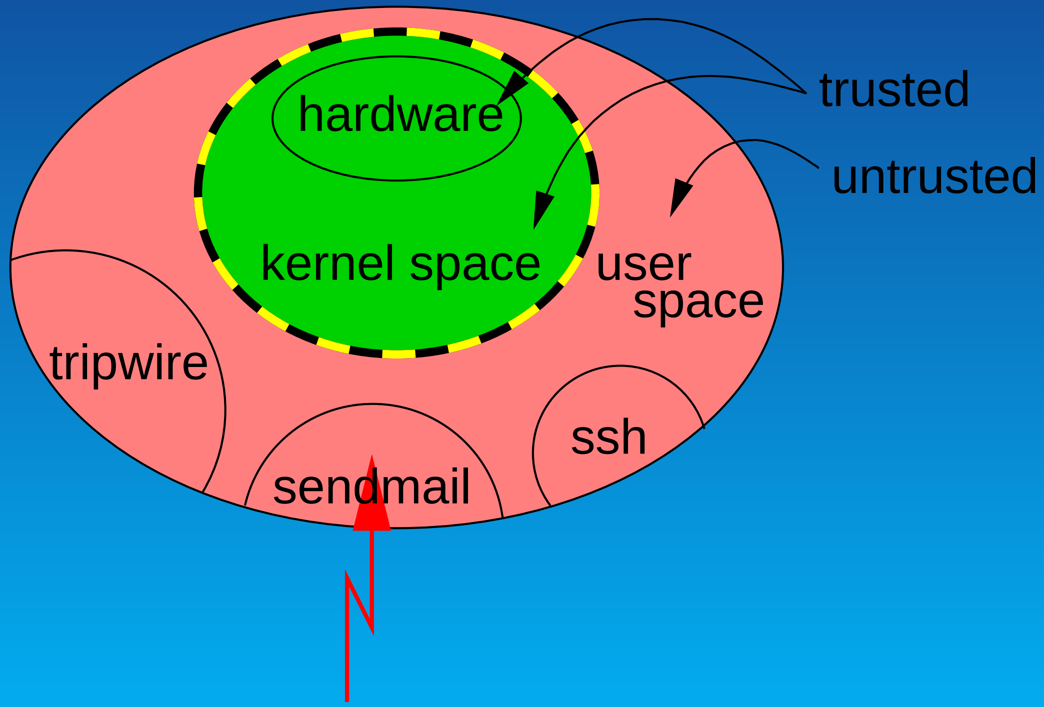
Usual security model



Kernel security model



Kernel security model



To use this model, we must patch the kernel for it to

- protect itself
  - ➥ trusted kernel space
- protect other programs/data related to/involved in the security policy

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  - Existing projects
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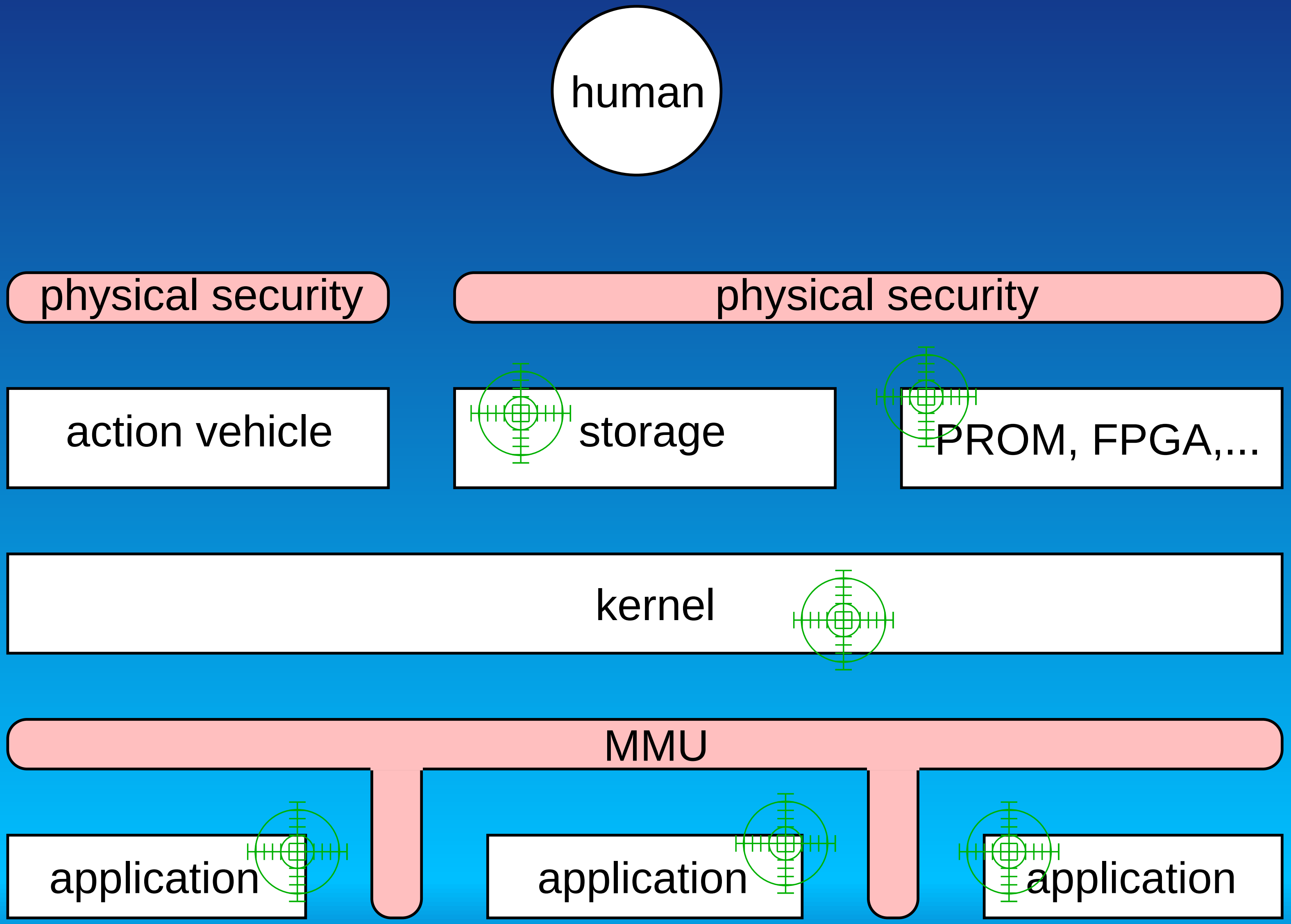
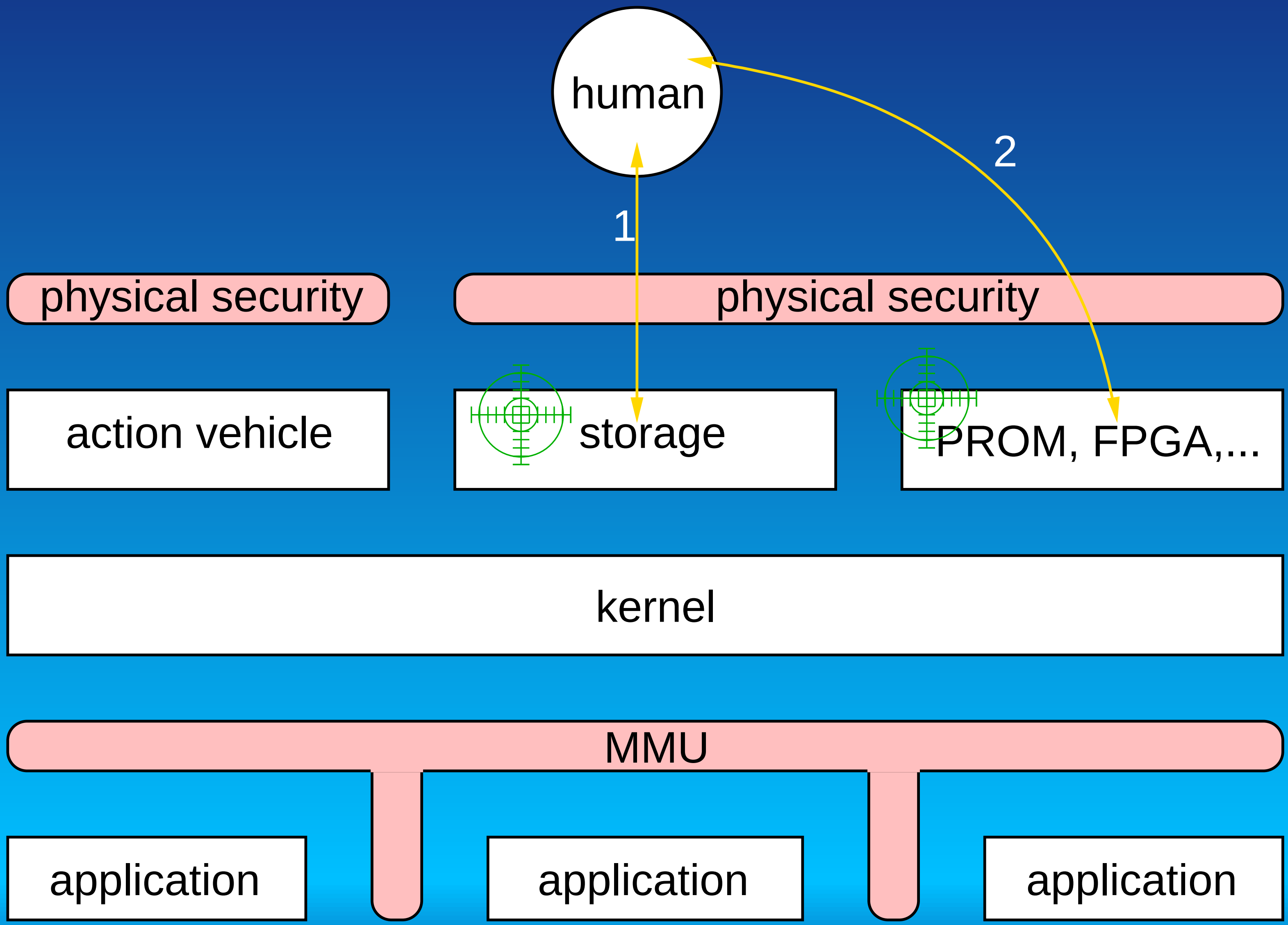
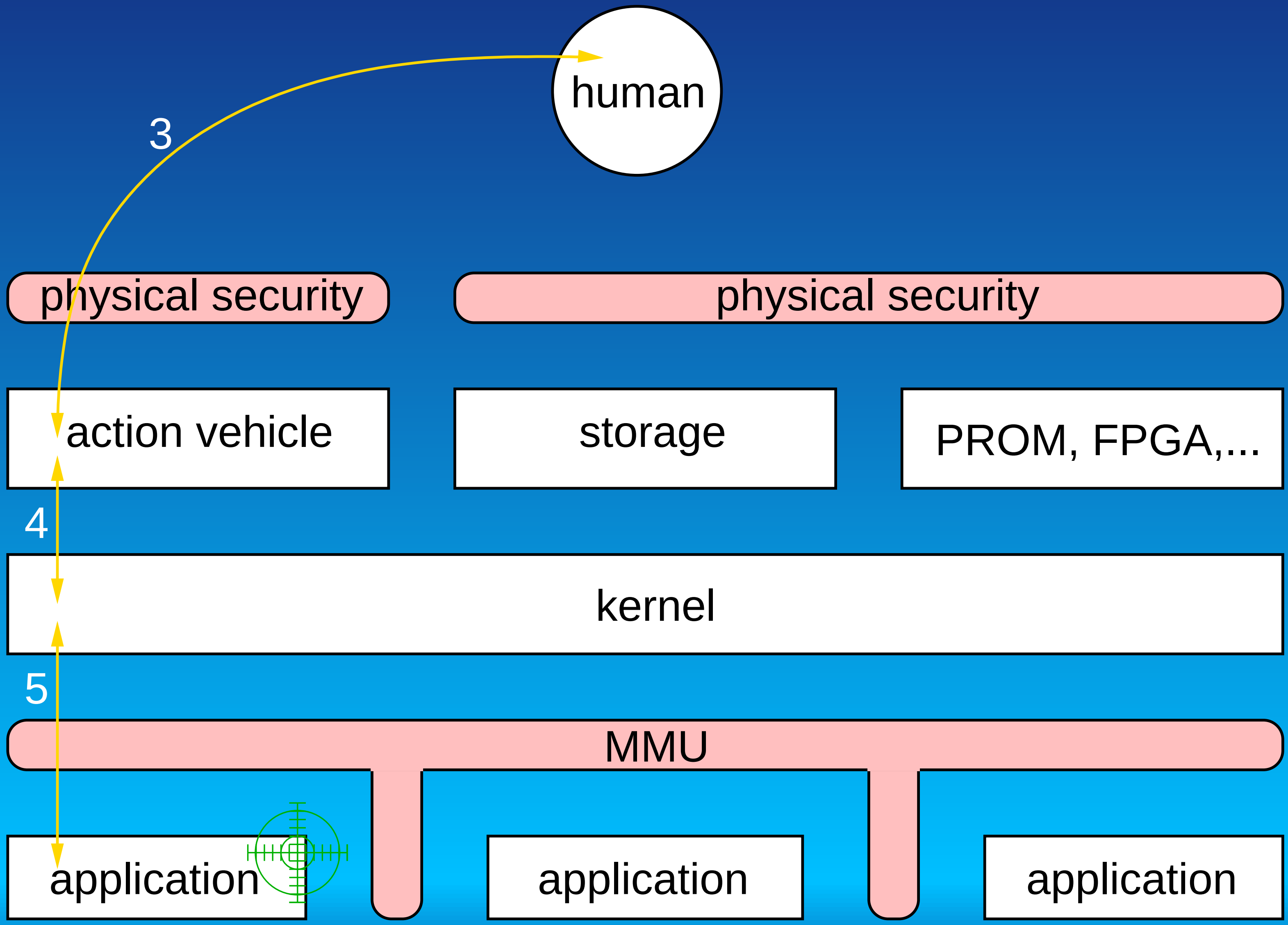
Targets


human
physical security
physical security
action vehicle
storage
PROM, FPGA,...
kernel
MMU
application
application
application

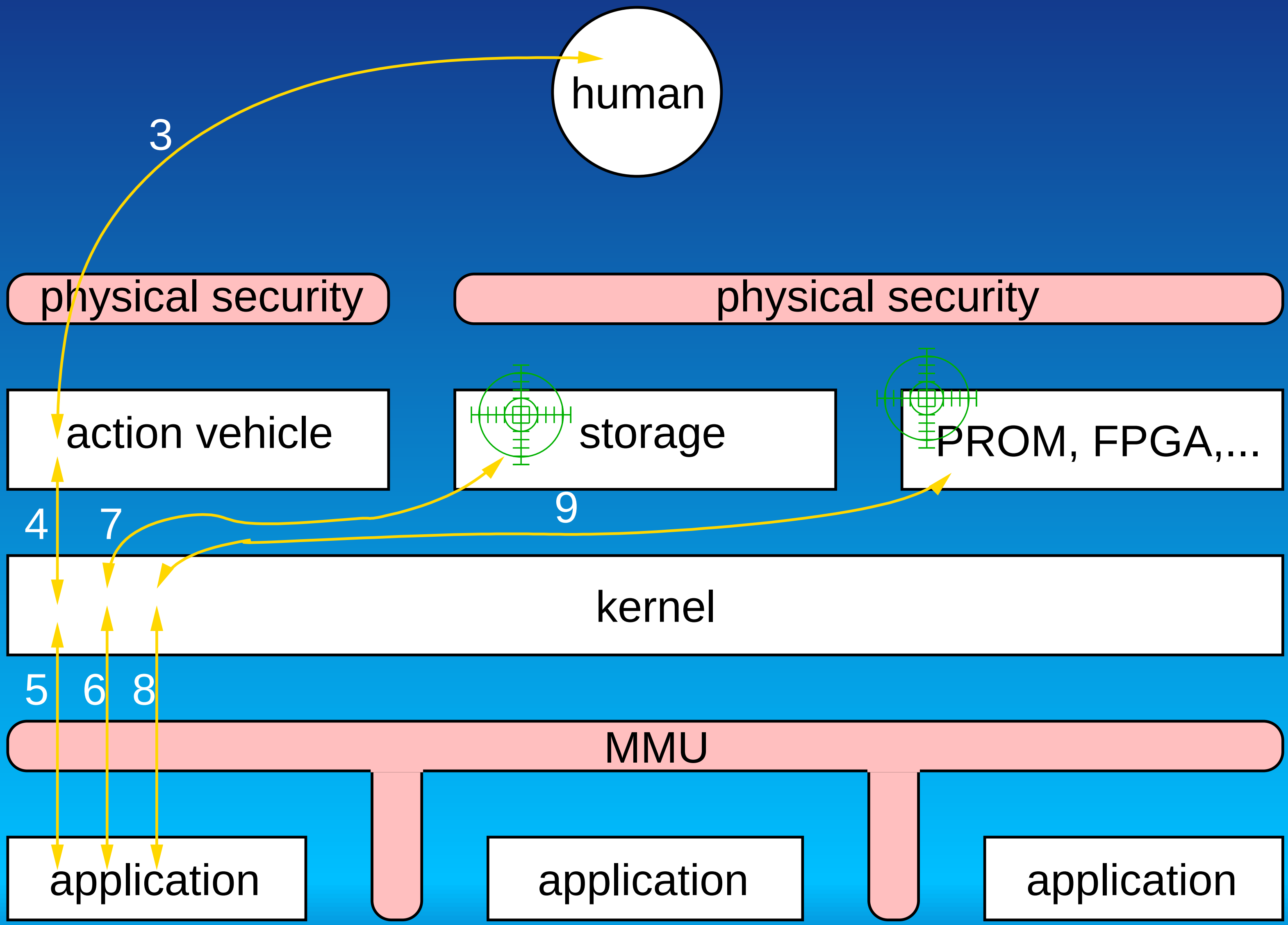
Targeting storage or PROM with direct access to the box



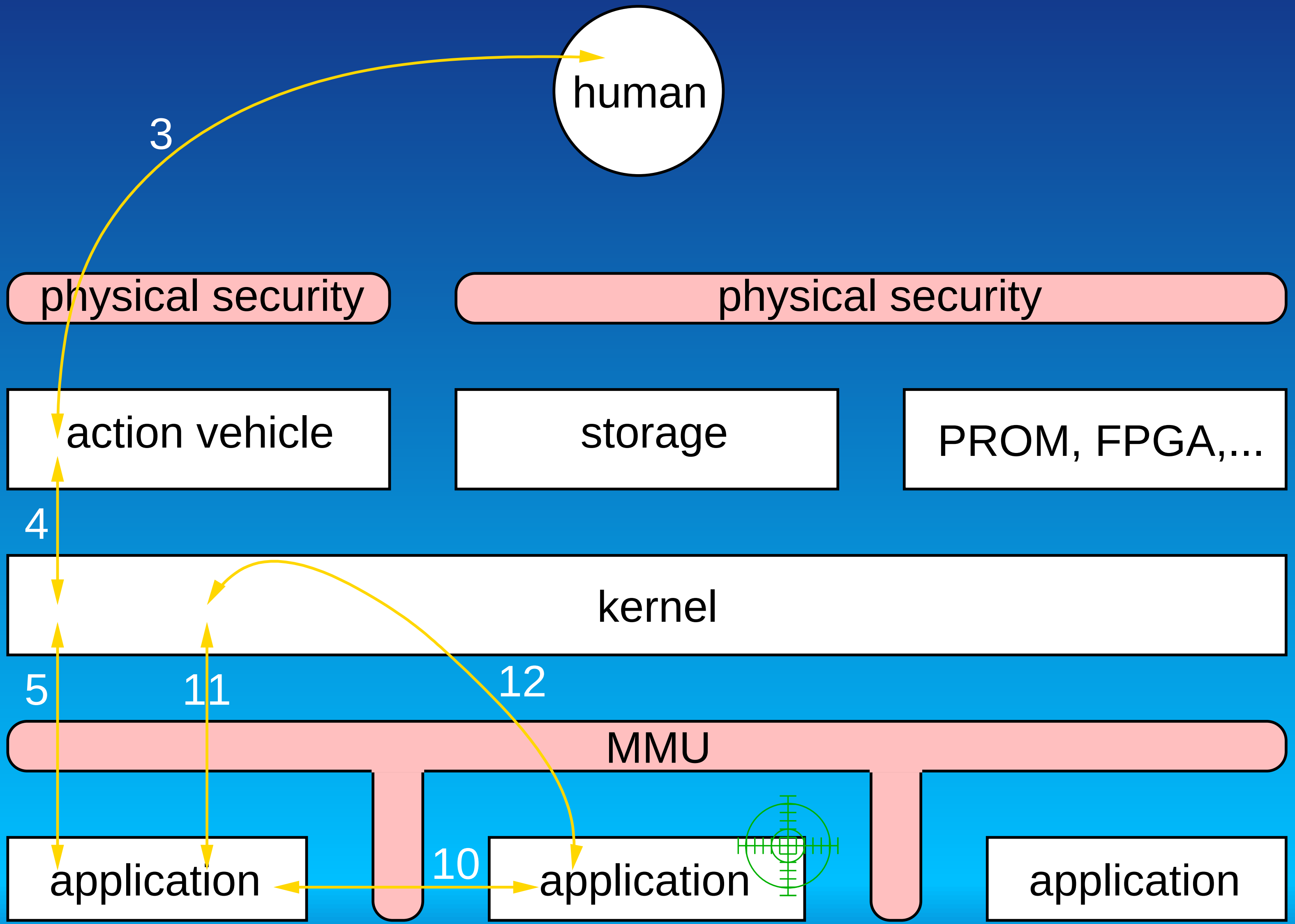
Targeting an application accessible with keyboard, network, . . .



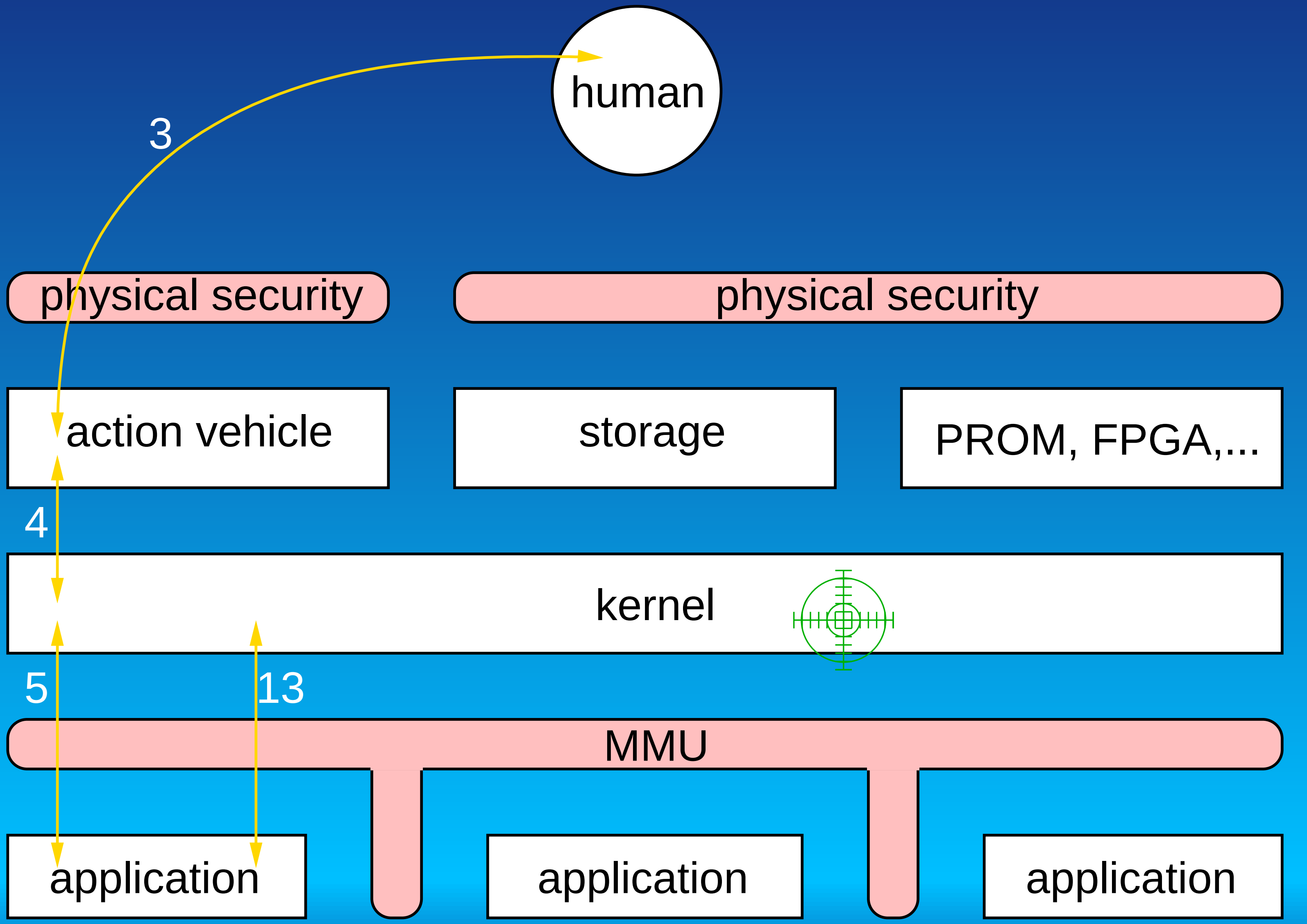
Targeting storage or PROM through an accessible application



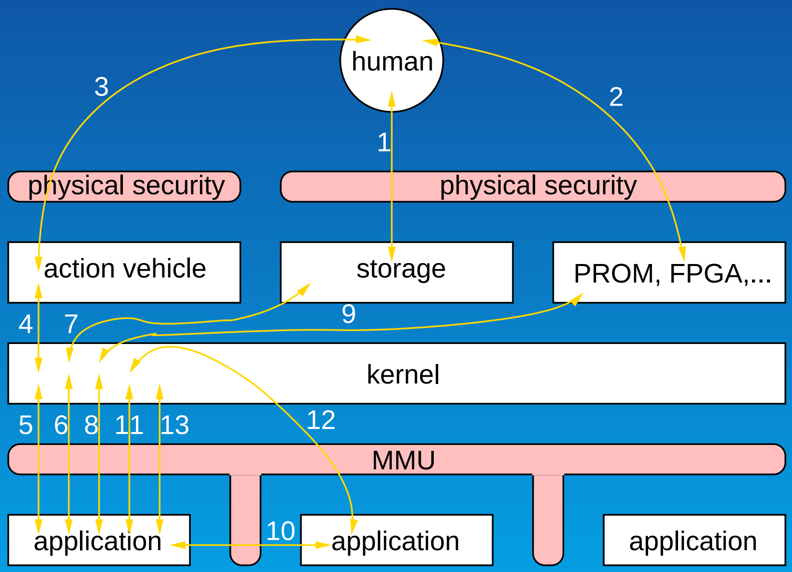
Targeting an unaccessible application through an accessible one



Targeting kernel directly or through an accessible application



- Bugless interfaces
  - network stack, kbd input, ...
  - kernel calls
- Defence
  - `/dev/mem`, `/dev/kmem` ...
  - `create_module()`, `init_module()`, ...
- Filtering
  - Queries to reach a storage device or PROMs, FPGAs, ...
  - Queries to reach another process' memory



Is the bugless interface hypothesis ok ?

- Protected mode mechanisms $\Longrightarrow$ harder to do programming faults (IMHO) (bugs are still possible, race conditions for ex.)

`linux/drivers/char/rtc.c`

```
static int rtc_ioctl(struct inode *inode, struct file *file, unsigned int cmd,
                     unsigned long arg)
{
        unsigned long flags;
        struct rtc_time wtime;

        switch (cmd) {
[...]
        case RTC_ALM_SET:       /* Store a time into the alarm */
        {
                unsigned char hrs, min, sec;
                struct rtc_time alm_tm;

                if (copy_from_user(&alm_tm, (struct rtc_time*)arg,
                                   sizeof(struct rtc_time)))
                        return -EFAULT;
```

How to protect kernel space against a user space intruder ?

Block everything from user space that can affect kernel space.

- Attacks can come through :
  - system calls
  - devices files
  - procfs
- Few entry points, opened by the kernel
  - `/dev/mem`, `/dev/kmem`
  - `/dev/port`, ioperm and iopl
  - `create_module()`, `init_module()`, ...
  - `reboot()`

- `/dev/mem`, `/dev/kmem` and `/dev/port` protection :

```
static int open_port(struct inode * inode,
                     struct file * filp)
{
        return capable(CAP_SYS_RAWIO) ? 0 : -EPERM;
}
```

- Module insertion control :

```
asmlinkage unsigned long
sys_create_module(const char *name_user, size_t size)
{
        char *name;
        long namelen, error;
        struct module *mod;

        if (!capable(CAP_SYS_MODULE))
                return -EPERM;
[...]
```

What must we protect ?

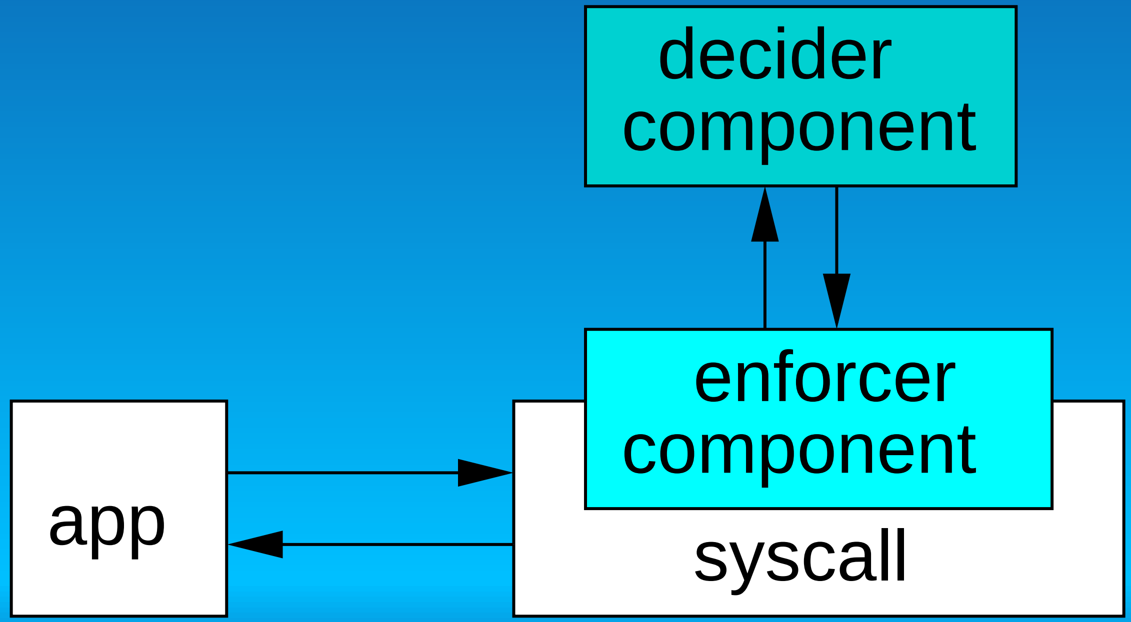
- What is in memory
  - Processes (memory tampering, IPC, network communications, . . .)
  - Kernel configuration (firewall rules, etc.)
- What is on disks or tapes
  - Files
  - Metadata (filesystems, partition tables, . . .), boot loaders, . . .
- Hardware
  - Devices (ioctl, raw access, . . .)
  - EPROMs, configurable hardware, . . .

How to protect that ?

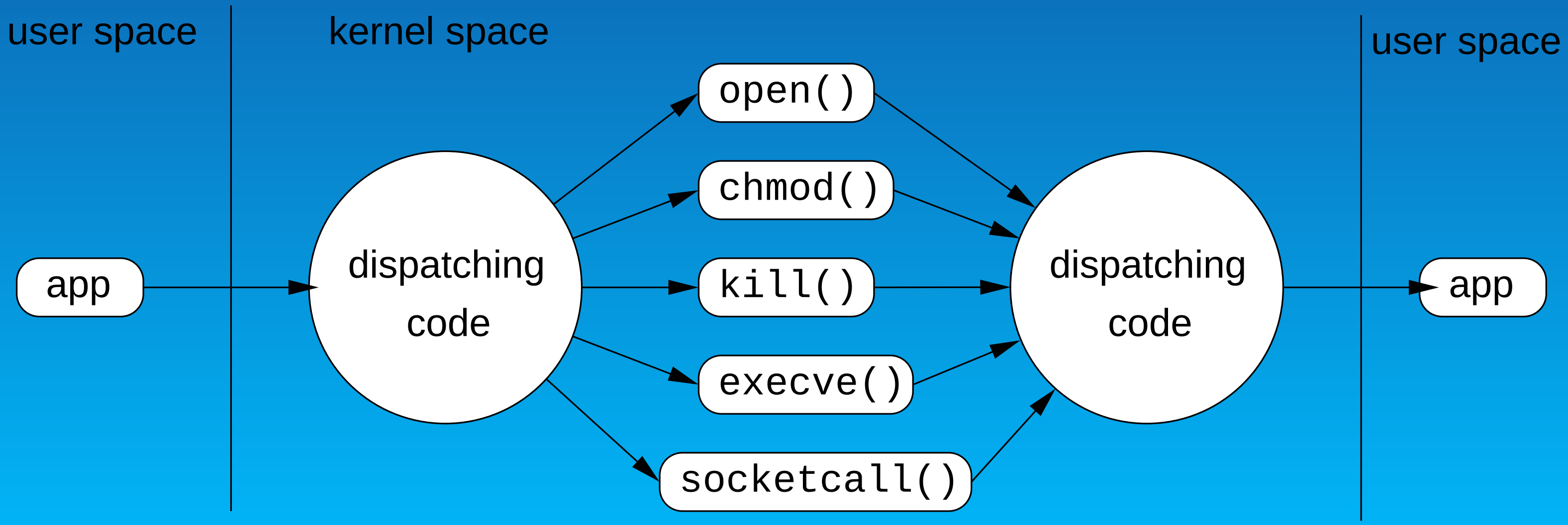
- Queries are done only via the kernel
- System calls, sysctls and devices drivers are a place of choice for controlling accesses
  - ↪ We have to modify their behaviour consistently to be able to enforce a complete security policy.

A good way is to use a modular architecture to control kernel calls : there will be

- An enforcer component
- A decider component
  - Lots of access control policies (DAC, MAC, ACL, RBAC, IBAC, . . .)



- How to add the enforcer code to the kernel calls ?
  - kernel call interception
  - kernel call modification
- ex: system call anatomy :



Syscall interception example : Medusa DS9
`linux/arch/i386/kernel/entry.S`

```
[...]
        GET_CURRENT(%ebx)
        cmpl $(NR_syscalls),%eax
        jae badsys

 #ifdef CONFIG_MEDUSA_SYSCALL
        /* cannot change: eax=syscall, ebx=current */
        btl %eax,med_syscall(%ebx)
        jnc 1f
        pushl %ebx
        pushl %eax
        call SYMBOL_NAME(medusa_syscall_watch)
        cmpl $1, %eax
        popl %eax
        popl %ebx
        jc 3f
        jne 2f
1:
#endif

        testb $0x20,flags(%ebx)         # PF_TRACESYS
        jne tracesys
[...]
```

- Syscall interception advantages
  - general system
  - low cost patch
- Drawbacks
  - kind of duplication of every syscall
  - need to know and interpret parameters for each different syscall
  - architecture dependent

Syscall modification example : LIDS

`linux/fs/open.c`

```
asmlinkage long sys_utime(char * filename, struct utimbuf * times)
{
        int error;
        struct nameidata nd;
        struct inode * inode;
        struct iattr newattrs;

        error = user_path_walk(filename, &nd);
        if (error)
                goto out;
        inode = nd.dentry->d_inode;

        error = -EROFS;
        if (IS_RDONLY(inode))
                goto dput_and_out;
#ifdef CONFIG_LIDS
        if(lids_load && lids_local_load) {
                if ( lids_check_base(nd.dentry,LIDS_WRITE)) {
                        lids_security_alert("Try to change utime of %s",filename);
                        goto dput_and_out;
                }
        }
#endif
        /* Don’t worry, the checks are done in inode_change_ok() */
        newattrs.ia_valid = ATTR_CTIME | ATTR_MTIME | ATTR_ATIME;
        if (times) {
```

- Syscall modification advantages
  - Syscall parameters already interpreted and checked
  - Great tuning power. We can alter the part of the syscall we want.
- Drawbacks
  - Lot of the 200+ syscalls must be altered

To be out soon in the kernel : LSM

`linux/kernel/module.c`

```
sys_create_module(const char *name_user, size_t size)
{
        char *name;
        long namelen, error;
        struct module *mod;
        unsigned long flags;

        if (!capable(CAP_SYS_MODULE))
                return -EPERM;
        lock_kernel();
        if ((namelen = get_mod_name(name_user, &name)) < 0) {
                error = namelen;
                goto err0;
        }
        if (size < sizeof(struct module)+namelen) {
                error = -EINVAL;
                goto err1;
        }
        if (find_module(name) != NULL) {
                error = -EEXIST;
                goto err1;
        }

       /* check that we have permission to do this */
       error = security_ops->module_ops->create_module(name, size);
       if (error)
               goto err1;
```

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Linux Intrusion Detection System

- Self-protection
- Processes protection
- Files protection
- Online administration
- Special (controversial) features
  - Dedicated mailer in the kernel
  - Kind of portscan detector in the kernel

Self-protection

- Modules insertion/deletion, `/dev/mem`, . . . , ioperm/iopl,. . . filtered
- Boot process protected
  - Can forbid the execution of non-protected programs (not flawless)
- Sealing mecanism
  - fsck or insmod can run when booting
  - no human intervention is needed to seal the protection
  - after the seal, we are in the working state. Everything is locked

Processes protection

- Rely on the linux capabilities bounding set
  - Hardware protection
  - Processes privacy (ptrace, promiscuous mode, . . . can be forbidden)
  - Network administration locked, . . .
- Daemons can be made unkillable
- Processes can be made invisible
- Processes can be granted capabilities

```
lidsconf -A -s /usr/sbin/sshd \
   -o CAP_NET_BIND_SERVICE 22-22 -j GRANT
```

Files protection

- MAC-like approach :

```
lidsadm -A -s /usr/sbin/httpd \
    -o /home/httpd -j READ
```

- Files identified by VFS device/inode ⇒ works on every fs

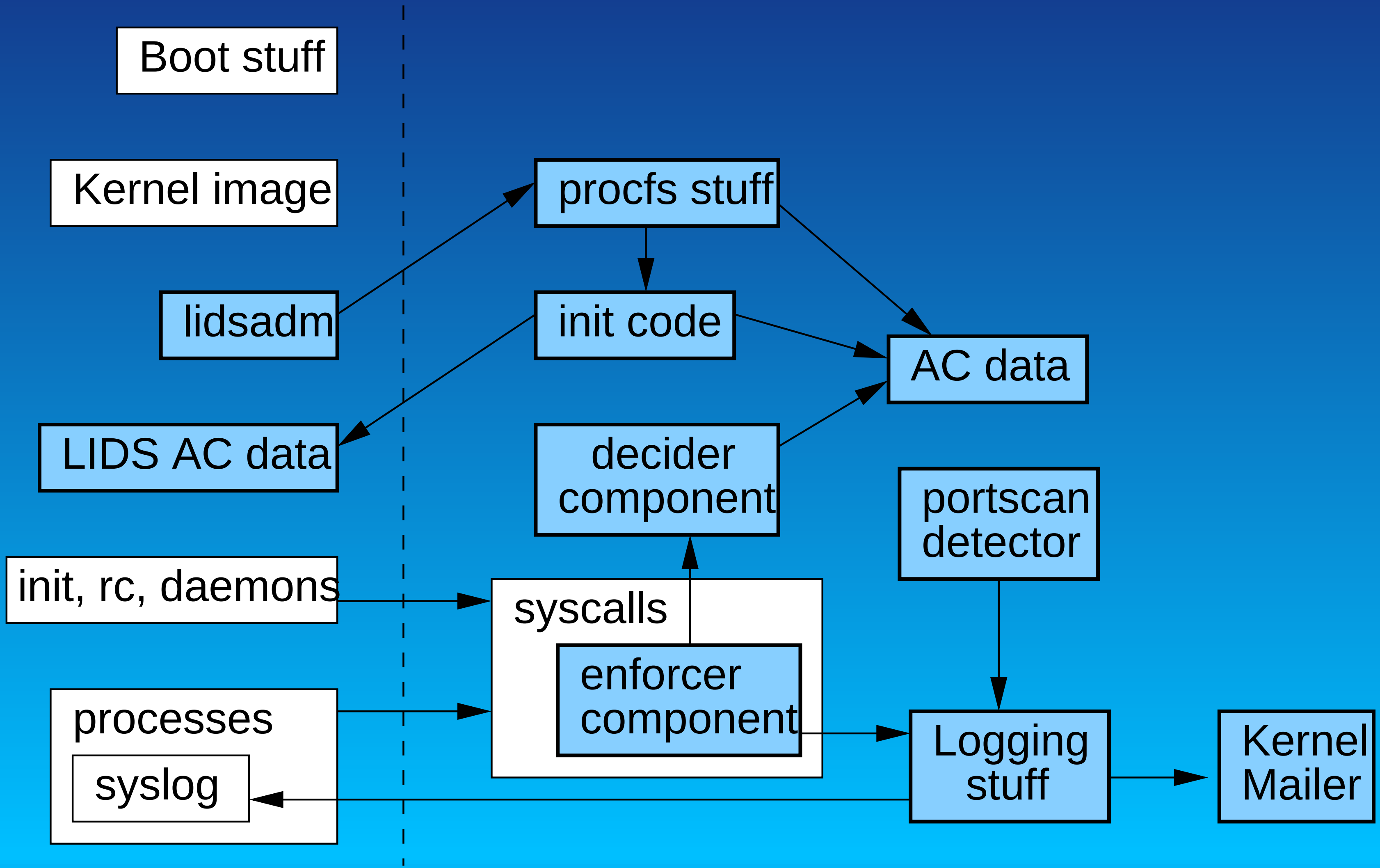
Online administration

- LIDS can be disabled globally
- LIDS can be reconfigured on the fly
- LIDS can be disabled only for a shell and its children

Special features

- Mailer in the kernel
  - Can make a network connection (TCP or UDP)
  - Can send a scriptable session (mail, syslog, . . .)
  - Does not rely on anything in user space
- Scan detector in the kernel
  - Kind of interrupt driven $\Rightarrow$ no load at all
  - Does not need the promiscuous mode
  - Works on all interfaces at the same time
  - Detect only connect/syn scans
  - Detect only what reach the TCP or UDP stack

LIDS general architecture



Other projects

- Openwall
- GrSecurity
- Medusa DS9
- RSBAC
- LoMaC
- SE Linux
- . . .

Openwall : Collection of security-related features for the Linux kernel.

- Non-executable user stack area
- Restricted links in `/tmp`
- Restricted FIFOs in `/tmp`
- Restricted `/proc`
- Special handling of fd 0, 1, and 2
- Enforce `RLIMIT_NPROC` on execve

GrSecurity : General Security for Linux

- Kernel hardening from Openwall
- ACL system

Medusa DS9 : Extending the standard Linux (Unix) security architecture with a user-space authorization server.

- layer 1
  - Hooks in the original kernel code
- layer 2
  - kernel space code
  - called from hooks.
  - do basic permission checks
  - check for cached permissions
  - call the communication layer if necessary
- layer 3
  - communication layer
  - communicate with a user space daemon

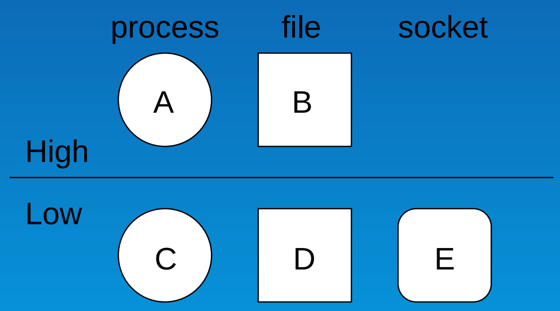
- User space daemon
  - decider component
- Miscellaneous
  - syscall interception
  - can force code to be executed after a syscall

RSBAC : Rule Set Based Access Control

- It is based on the Generalized Framework for Access Control (GFAC)
- All security relevant system calls are extended by security enforcement code.
- Different access control policies implemented as kernel modules
  - MAC, ACL, RC (role control), FC (Functional Control), MS (Malware Scan), . . .

LOMAC : Low Water-Mark Integrity

- Initialization
  - Some specified directories (B) are high
  - Other directories (D) and sockets (E) are low
- Execution
  - Processes created from B are high
  - Processes created from D are low
- Reading
  - A can read B. C can read D or E
  - C can't read B
  - if A reads D or E, A goes into the low level
- ...



SE Linux : NSA's Security Enhanced Linux

- Based on the Flask architecture
  (Flexible architecture security kernel)
- Enforcer / decider components
- Pays a lot of attention to the change of the access control policy (revocation)

Linux Security Modules : to be included in 2.5

- Kernel Summit 2001 : Linus decides that linux should support security enhancements
- LSM patch is a set of hooks in the kernel syscalls
  - ➥ Linux kernel provide the enforcer component
- Modular enough for the decider component to become a LKM

That's all folks. Thanks for your attention.

You can reach me at **`<phil@lids.org>`**

These slides are available at
`http://www.cartel-securite.fr/pbiondi/`