Kernel approach for Security

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Open Source Developpers' European Meeting

Philippe Biondi

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Webmotion Inc.

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- Aim
  - Context
  - Trustfulness
  - Conclusion
- Technical description
  - Design
  - Untamperability
  - Unbypassability
- Existing projects
  - Openwall, Medusa, RSBAC, NSA SE Linux, LIDS
- Conclusion
  - GACI

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We are facing

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

- We must ensure
  - Confidentiality
  - Data integrity
  - Availability
- What we must do to ensure all of this :
  - We define a set of rules describing the way we handle, protect and distribute information.
    - This is called a security policy.

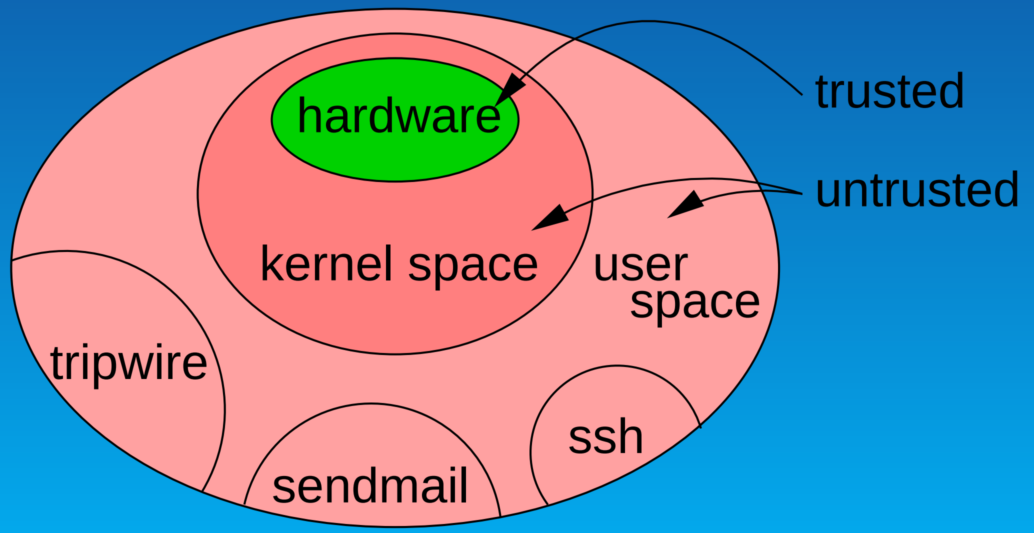
To enforce our security policy, we will use some security code

- Tripwire, AIDE, for data integrity
- SSH, SSL, IP-SEC, cryptography for confidentiality
- Password, secure badge, biometric access controls
- . . .

Can we trust them ?

The fortress built upon sand — D. Baker – *Proceedings of the New Security Paradigms Workshop*

- User space is untrusted and can take control of the kernel space (module insertion, `/dev/kmem`, `...`)
  $\Rightarrow$ kernel space is also untrusted :



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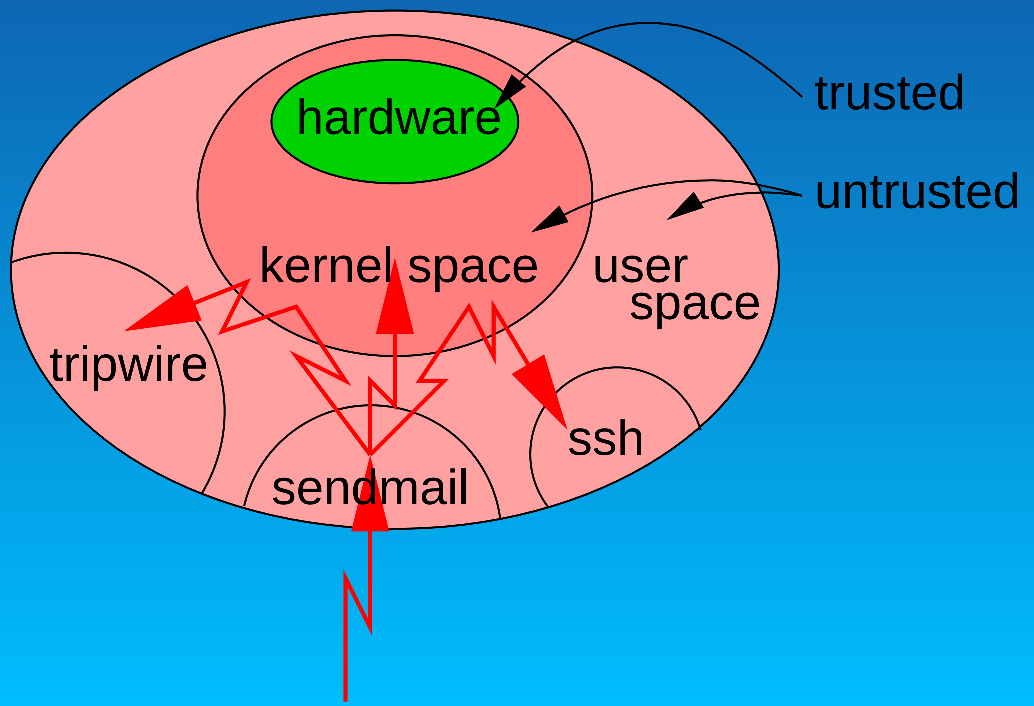
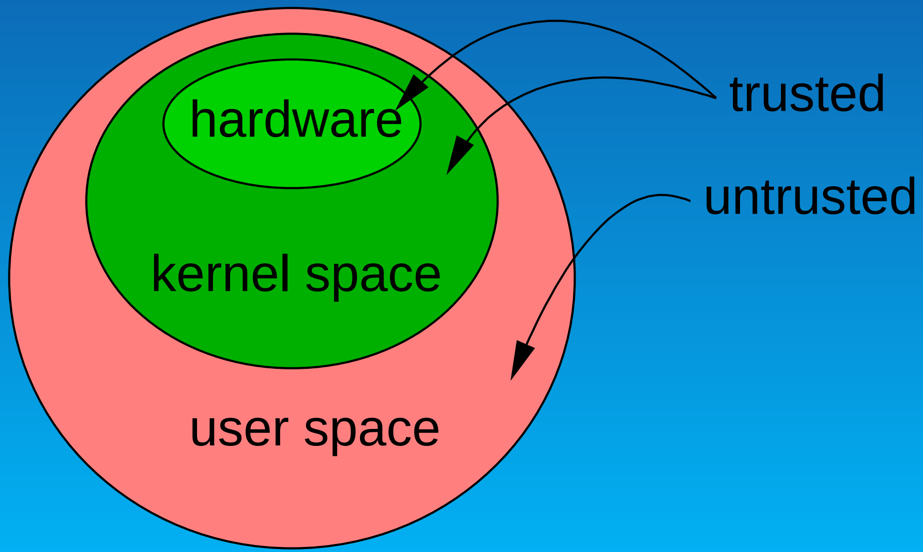


- Security must be built layer by layer.
- Each layer is built with the hypothesis the underlayer is trusted.
- It is not worth building security applications on untrusted layers

We need :



Why don’t we want user space to be trusted ?

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

  This protection can’t be trusted.

- Solution 2 : we put the cookies in a metal box
  - we can grasp the entire problem
  - if we trust the metal box, this solution has a good trusting level
  - the cookies don’t care wether mice can break into the house

  This protection can be trusted

To enforce our security policy, we need to add code to

- protect the kernel and the code itself
  - $\Rightarrow$ trusted kernel space
  - $\Rightarrow$ untamperability
- protect other code/data involved in the security policy
  - $\Rightarrow$ mandatory controls
  - $\Rightarrow$ unbypassability

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So, we need to

- make the kernel space trusted
  - we protect the kernel and the code itself
    - we must block everything coming from user space
- protect other code/data involved in the security policy
  - we rely on the fact that we trust kernel space
  - we add controls on user space
    - make our code a mandatory way

Why should the last layer be the kernel space ?

Because of the design of the CPU (PMMU),

- we have few entry points
  - untamperability
- we can force everything to go through kernel space
  - unbypassability

- The kernel space is unreachable by user space code
- The execution of some defined kernel code can be triggered
  - system calls
  - devices
  - procfs
  - hardware interruptions
- Few entry points, opened by the kernel side
  - `/dev/mem`, `/dev/kmem`
  - `/dev/port`, ioperm and iopl
  - insmod and rmmod
  - reboot and halt

- Because of protected mode mechanisms, kernel coders don't do buffer overflows programming faults (?).

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;
```

- `/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;
[...]
```

Reboot/halt can’t be forbidden :

- UPS must be able to shutdown
- Reboot is mostly user space stuff, the kernel just reboot the CPU
- No difference with a runlevel change

$\Longrightarrow$ We need to guarantee a safe boot sequence, which is a huge problem

Boot sequence

► POST	Console vulnerable
► Boot loader	Console vulnerable / rely on boot disk
► Kernel	Rely on boot disk (kernel image)

► booting process (init, rc scripts, daemons, . . .)

► working state

What must we protect ?

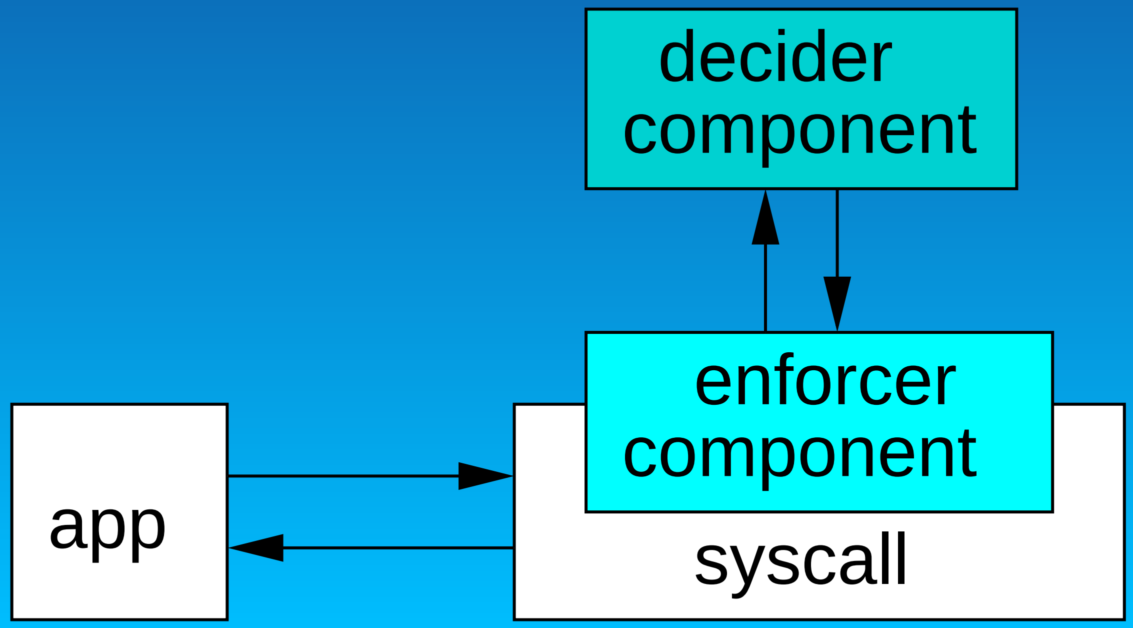
- What is in memory
  - Processes
  - Kernel configuration (firewall rules, etc.)
- What is on disks or tapes
  - Files
  - Metadata (filesystems, partition tables, boot loaders, . . .)
- Hardware
  - EPROMs, configurable hardware, . . .

User space can’t access these items without asking the kernel

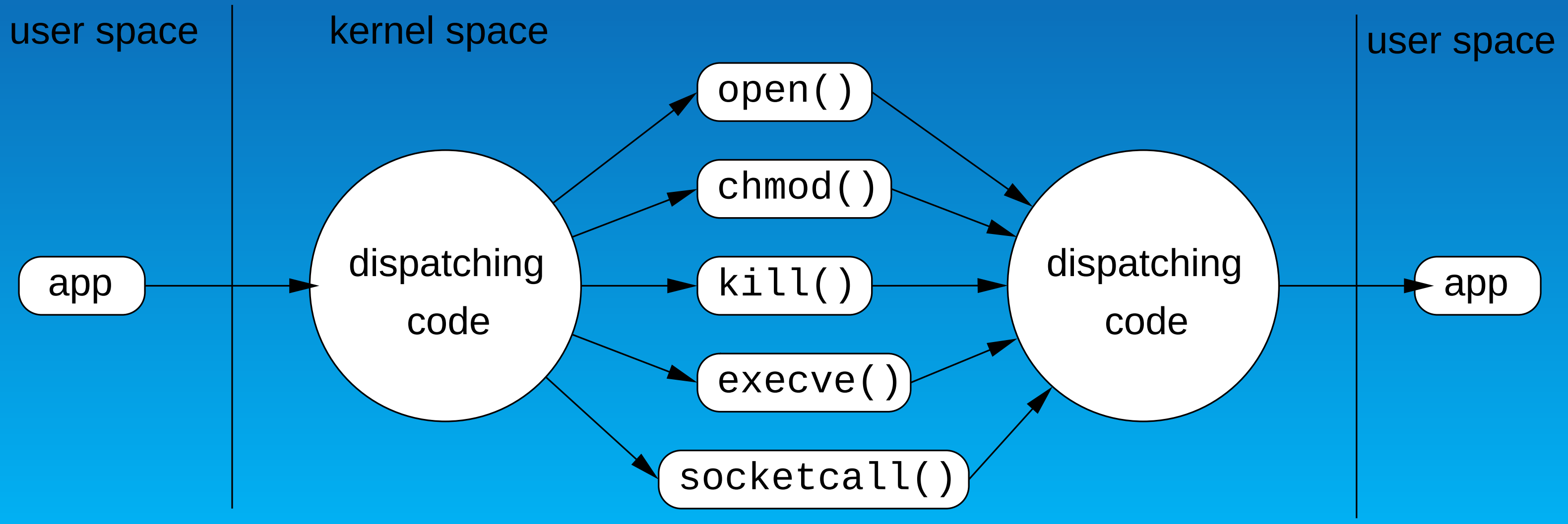
- system calls are a place of choice for controlling accesses

We’ll use a modular architecture to control syscalls : 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 syscalls ?
  - Syscall interception
  - Syscall modification
- 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
  - Each of the syscall must be altered (near 200 syscalls)

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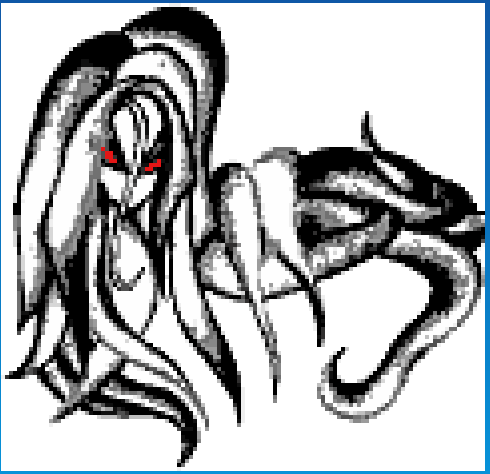
Collection of security-related features for the Linux kernel.

- 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

Medusa DS9



Authors : Marek Zelem Milan Pikula Martin Ockajak

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

Authors : Amon Ott, Simone Fischer-Hübner, Morton Swimmer

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), . . .

SE Linux

NSA Security Enhanced Linux

- It is 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)

LIDS

Authors : Xie Huangang, Philippe Biondi

Linux Intrusion Detection System

- Self-protection
- Files protection
- Processes protection
- Online administration
- Special features
  - Dedicated mailer in the kernel
  - Scan 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

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

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

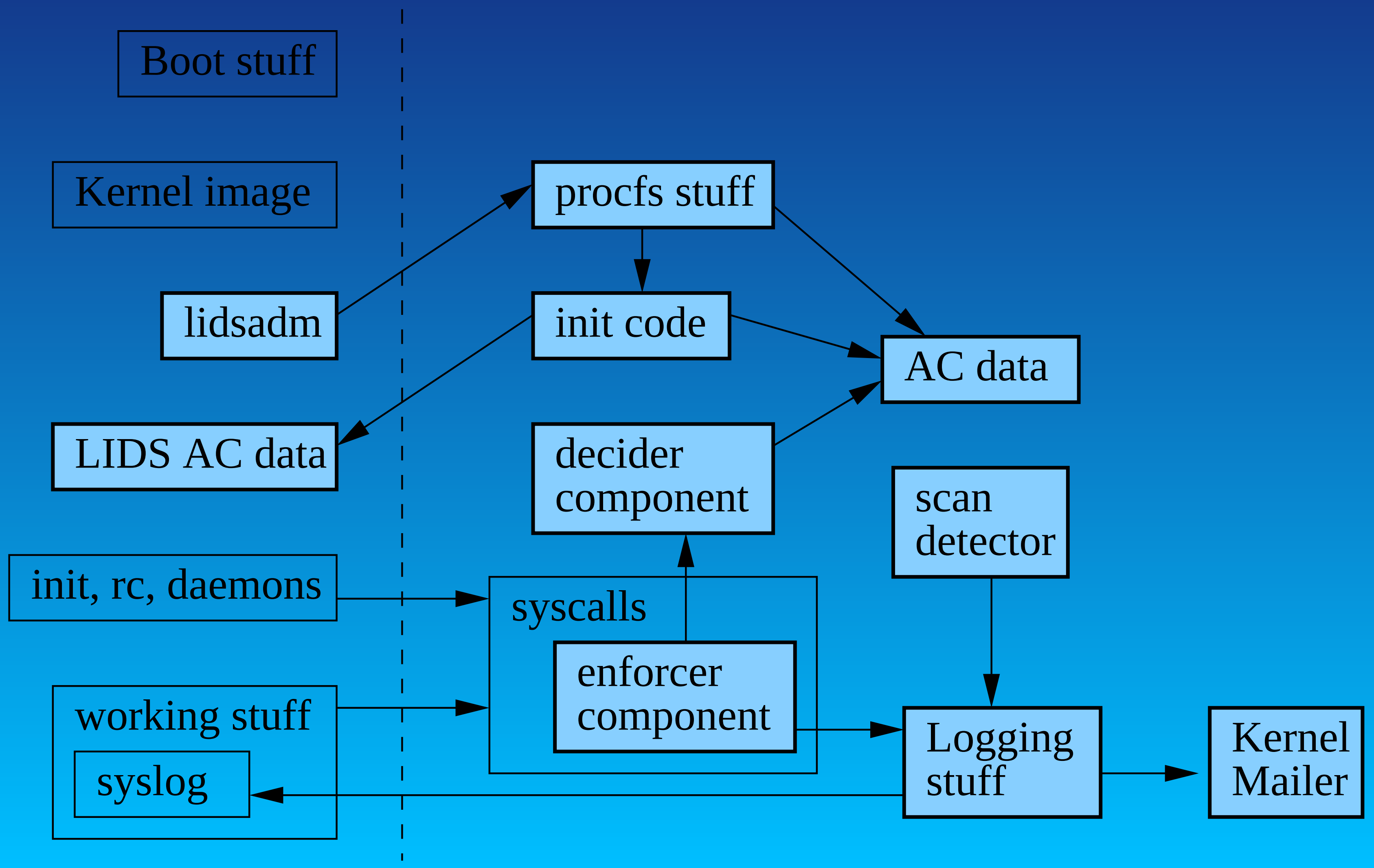
Online administration

- LIDS can be disabled globally
- LIDS can be reconfigured on the fly
- LIDS can be totally 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 every interface

LIDS general architecture



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General Access Control Interface

- Very young project, at the very beginning
- Aims to be the security interface for Linux 2.5
- Gathers coders from Medusa, RSBAC and LIDS