# Software LOPA

## Approach to Performing a Layers of Protection Analysis for Complex Software

OpenTech

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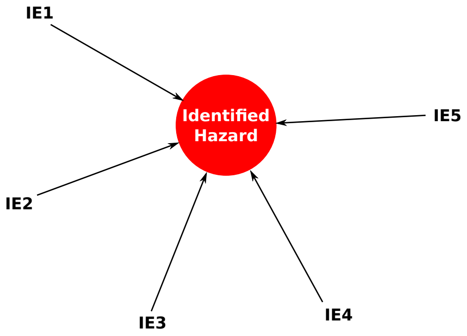
*"Yet further concerns relate to whether a consequence can be so severe that the frequency of the hazardous situation should not be taken into account, thus negating the concept fo 'risk' in selecting the appropriate set of implementation techniques. In order to address this concern IEC 61511 formalised the concept of 'layers of protection' requiring diversity between the different layers."*

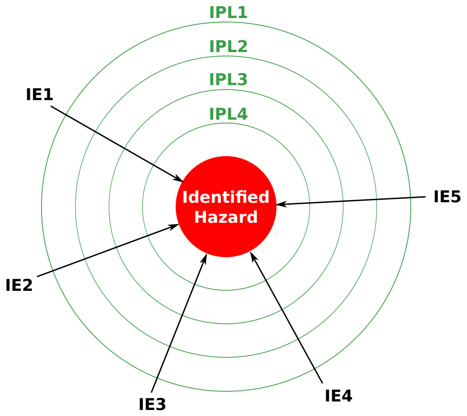
*Audrey Canning*, in: Functional Safety: Where have we come from? Where are we going?

# LOPA Principle



IE1-IE5 . . . **I**nitiating **E**vents
IPL1-IPL4 . . . **I**ndependent **L**ayers of **P**rotection

## LOPA Principle



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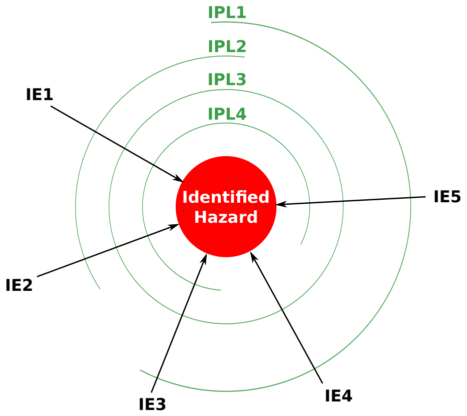

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## LOPA Basics Properties

- Independence
- Effectiveness
- Auditability

## Auditability

Open-Source Rules!

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If a Software LOPA is doable at all, then open-source software is definitely the prime suspect.

## Effectiveness

Do the IPLs actually mitigate against the hazard?

## Independence

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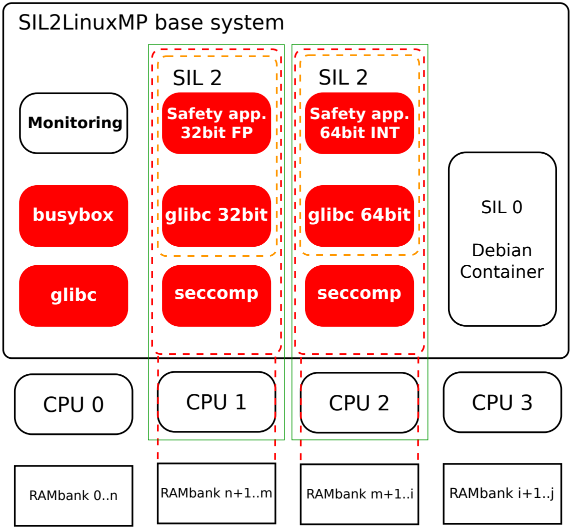
**BUT**

*"Independence is an important concept, although absolute independence is generally not achievable. ... However, IPLs should be sufficiently independent such that the degree of interdependence is not statistically significant."* [1, *Section*3.2]

## Prospective SW IPLs
**(SIL2LinuxMP Context)**

- seccomp
- cgroups
- CPU-shielding
- Namespaces
- PALLOC
- . . .
- Code Review (assure restricted use of syscalls)
- Static Code Analysis (coccinelle)
- Error Handling to detect faults

## Hardened NooM Container



## Independence of Layers

How to perform LOPA and show **INDEPENDECE** of those different protection layers?

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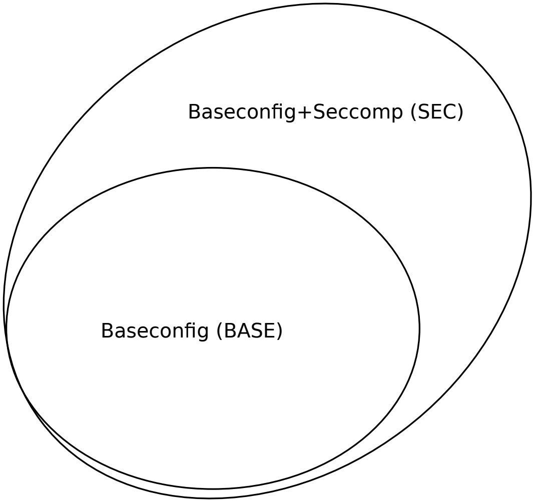
- Static code analysis
- Development data

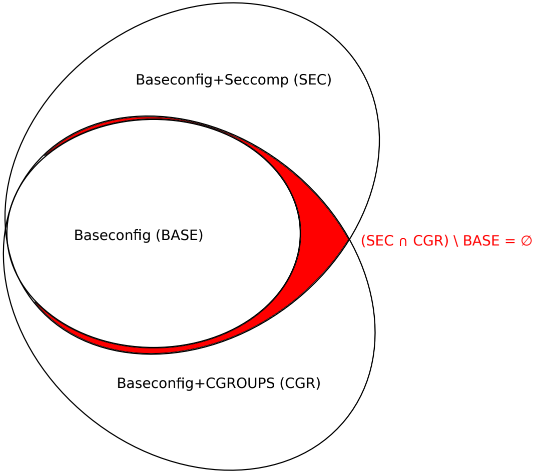
## Static Code Analysis

- Analyze functions called by subsystems (callgraphs)
- Find and analyze overlaps in callgraphs

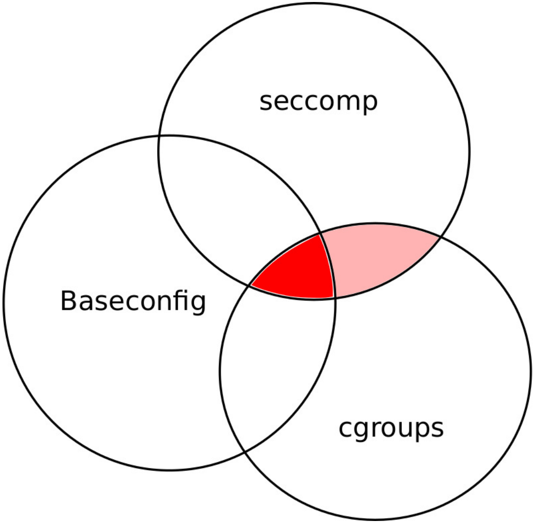
## Intersection of Configurations



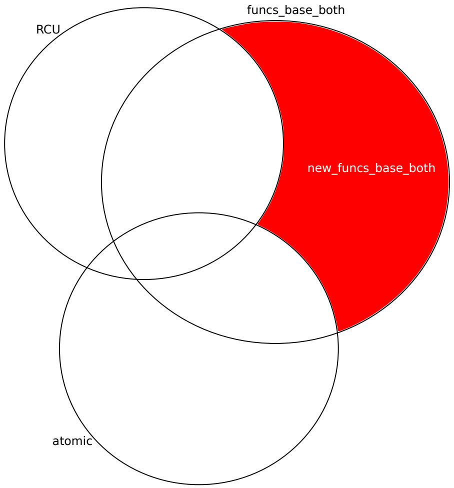
## Intersection outside of Baseconfig



## Intersection in Baseconfig



## Analysis of Subsystems



## Preliminary Results

| Set | Nr. Functions |
|---|---|
| baseconfig | 20829 |
| baseconfig+seccomp | 21401 |
| seccomp | 572 |
| baseconfig+cgroups | 21120 |
| cgoups | 679 |
| both_not_in_baseconfig | 0 |
| funcs_base | 13792 |
| funcs_base_seccomp | 7131 |
| funcs_base_cgroups | 7391 |
| funcs_base_both | 6665 |
| rcu_funcs | 6511 |
| atomic_funcs | 294 |
| new_funcs_base_both | 185 |

## Developers Overlap

| | seccomp | | cgroups | |
|---|---|---|---|---|
| Author | cur | hist | cur | hist |
| Kees Cook | 2740 | 26 | 4 | 2 |
| Arnaldo Carvalho de Melo | 50 | 2 | 18 | 6 |
| Linus Torvalds | 44 | 15 | 1 | 139 |
| Daniel Borkmann | 61 | 5 | 201 | 6 |
| Paul Mundt | 10 | 1 | 1 | 1 |
| Al Viro | X | 1 | X | 10 |
| Andrew Morton | X | 1 | X | 2 |
| Fabian Frederick | X | 1 | X | 2 |
| James Morris | X | 2 | X | 6 |
| Stephen Rothwell | X | 2 | X | 2 |
| David Howells | X | 3 | X | 5 |

cur . . . Number of lines in v4.9.18 .  hist . . . Number of commits in all versions.

## Analysis of Effectiveness

Similar to traditional LOPA . . .

- Identify all IEs (Hazard Analysis)
- Identify suitable IPLs for each identified IE
- Choose IPLs that are used

## Example

Scenario: An application uses 2 devices, one is only written to, the second one is only read from.

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IE: Writing to the read-only device leads to a hazardous situation.

- Error handling.
- Source-code review/audit.
- cgroups device controller rules prevent wrong access to devices.
- seccomp rules check if system calls to wrong usage are performed.

## Evidence

Let's check it out!

## Literature

[0] IEC 61511: Functional safety – Safety instrumented systems for the process industry sector
[1] Guidelines for Initiating Events and Independent Protection Layers in Layer of Protection Analysis, Center for Chemical Process Safety
[2] Safety Integrity Level Selection – Systematic Methods Including Layer of Protection Analysis, *Ed Marszal and Eric Scharpf*
[3] Lines of Defence/Layers of Protection Analysis in the COMAH Context, *Prepared by Amey VECTRA Limited for the Health and Safety Executive* ,
*http://www.hse.gov.uk/research/misc/vectra300-2017-r02.pdf*
[4] Functional Safety: Where have we come from? Where are we going? *Audrey Canning*

# Questions?

Ask now, or e-mail me later!

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## Seccomp Developers
### Lines in current version

```
linux-stable$ find . -name *seccomp*\.[ch] | \
 xargs git log --no-merges --format="%an" | sort | \
 uniq -c | sort -nr
     27 Kees Cook
      7 Will Drewry
      7 Andy Lutomirski
      7 Alexei Starovoitov
      5 Daniel Borkmann
      4 Mickaël Salaün
      4 Matt Redfearn
      3 Ralf Baechle
      3 David Howells
      3 Andrea Arcangeli
```

## cgroup developers
### Lines in current version

```
linux-stable$ find . -name *cgroup*\.[ch] | \
  xargs git log --no-merges --format="%an" | sort | \
  uniq -c | sort -nr
    641 Tejun Heo
    137 Li Zefan
     42 Paul Menage
     29 Vivek Goyal
     22 Al Viro
     18 Aristeu Rozanski
     15 Ben Blum
     13 Lai Jiangshan
     12 Daniel Wagner
     11 Johannes Weiner
```

## seccomp developers
### commits over all versions

```
linux-stable$ for FILE in $(find . -name *seccomp*\.[ch]); do \
  git blame --line-porcelain $FILE | egrep "^author "; done | \
  cut -d " " -f 2- | sort | uniq -c | sort -nr
   2740 Kees Cook
    241 Will Drewry
    100 Andy Lutomirski
     89 Tycho Andersen
     69 Matt Redfearn
     61 Daniel Borkmann
     55 AKASHI Takahiro
     50 Arnaldo Carvalho de Melo
     48 David Howells
     44 Linus Torvalds
```

## cgroups developers

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   8772 Tejun Heo
    907 Paul Menage
    492 Aristeu Rozanski
    407 Aneesh Kumar K.V
    366 Aleksa Sarai
    318 Serge E. Hallyn
    288 Li Zefan
    211 Sargun Dhillon
    204 Daniel Borkmann
    192 Aditya Kali
```

## seccomp

Default behavior – deny all system calls:

```
ctx = seccomp_init(SCMP_ACT_KILL);
```

Add used, safe system calls explicitly:

```
seccomp_rule_add_exact(ctx, SCMP_ACT_ALLOW,
SCMP_SYS(read), 1, SCMP_A0(SCMP_CMP_EQ, fd));
```

## cgroups

- Add a new cgroup (device controller):

```
# cd /sys/fs/cgroup/devices/
# mkdir newgroup
# cd newgroup
```

- Access Permissions per cgroup (read/write/mknod) are defined per device:

```
# echo a > devices.deny
# echo 'c 1:3 w' > devices.allow
```

- Add application to cgroup:

```
# echo $$ > tasks
```

- EPERM is returned by systemcalls that violate cgroups device controller rules:

```
open("/dev/urandom", O_RDWR) = -1 EPERM (Operation not permitted)
```