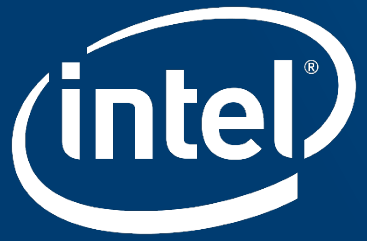

EnclaveDom

Privilege Separation for Large-TCB Applications in Trusted Execution Environments

Marcela S. Melara

Joint work with Mic Bowman, Michael J. Freedman (Princeton)

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Library-Centric Software Development

Save time and effort

Easy availability online

Library-Centric Software Development

Save time and effort

Easy availability online

No time/expertise to properly vet

Risky supply chain

Risky Third-Party Library Supply Chain

PC REVIEWS BEST PICKS HOW-TO NEWS SMART HOME BUSINESS SHOP

#FitbitVersa2 #SwitchLite #GoogleCalendarSpam #KernelPanic #iPhone11Rumors

News & Analysis

Malware Discovered in Popular Android App CamScanner

The malicious code was sourced back to a third-party advertising library on the app that could use a victim's Android phone to download additional malware. CamScanner says it will take 'immediate legal actions against' the scammers.

By Michael Kan August 28, 2019 2:29PM EST

ars TECHNICA BIZ & IT TECH SCIENCE POLICY CARS GAMING & CULTURE

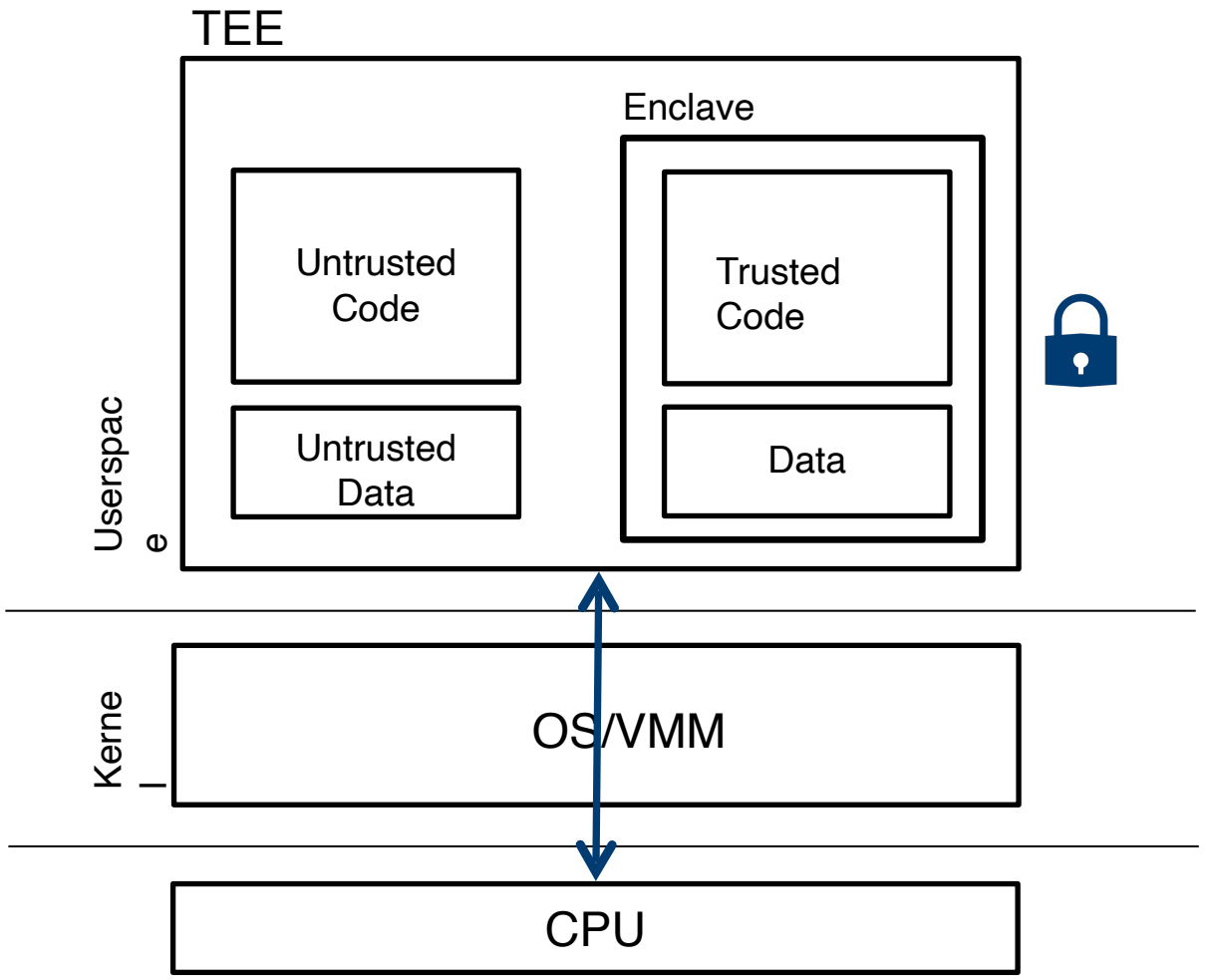
BIZ & IT —

Rage-quit: Coder unpublished 17 lines of JavaScript and "broke the Internet"

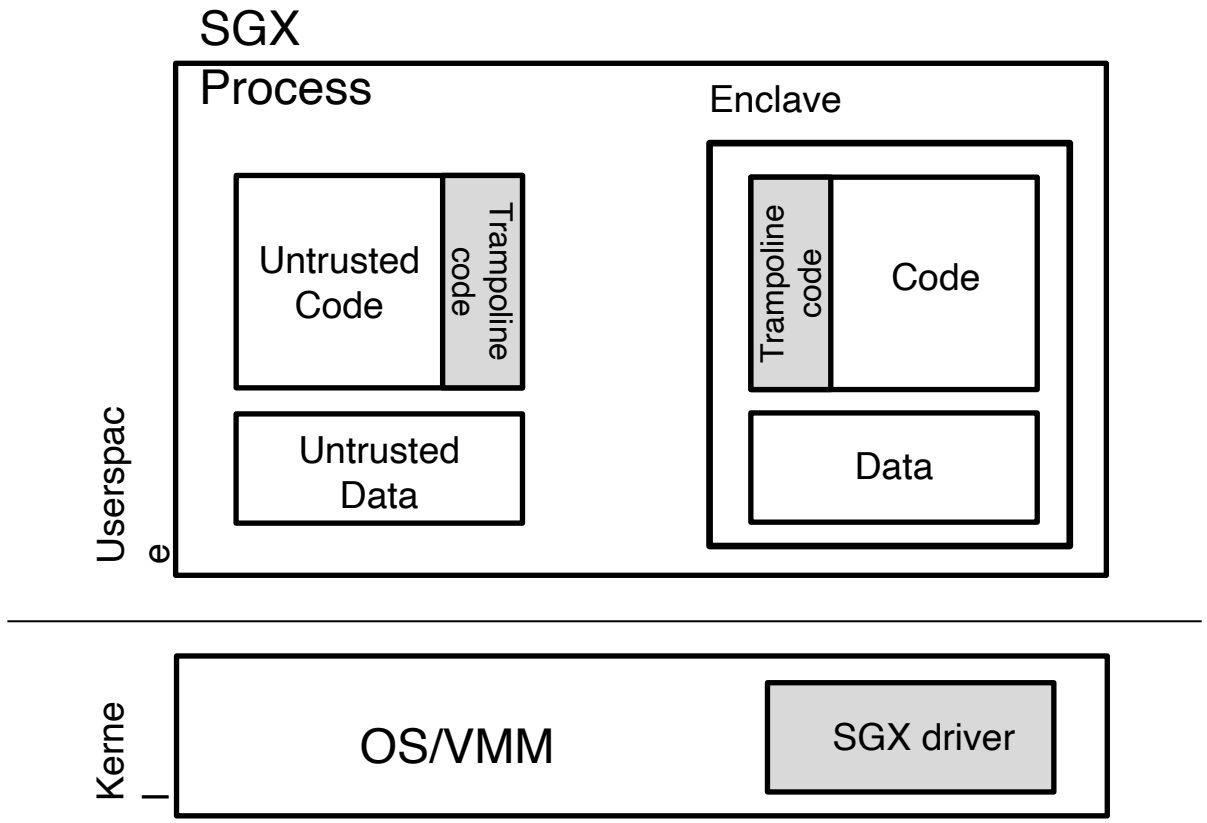
Dispute over module name in npm registry became giant headache for developers.

SEAN GALLAGHER - 3/24/2016, 10:10 PM

Trusted Execution Environments



Intel SGX Primer



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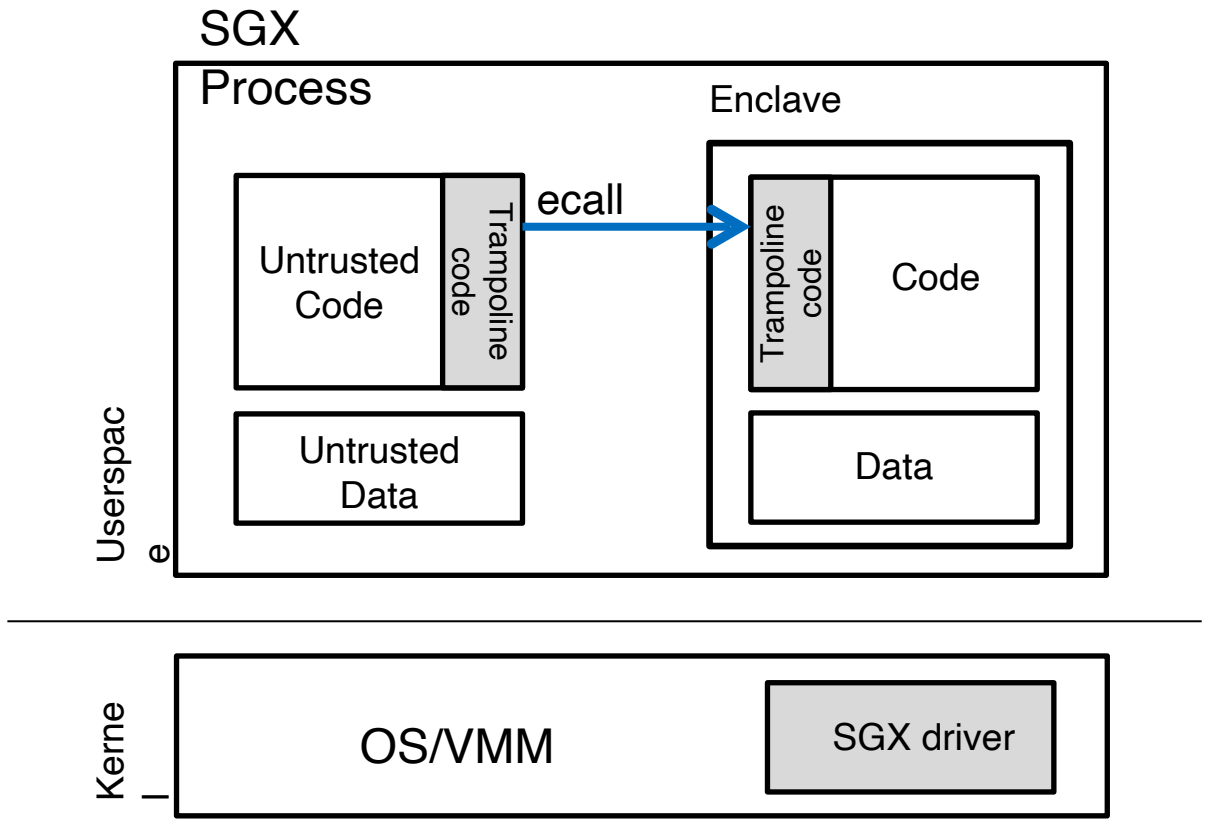

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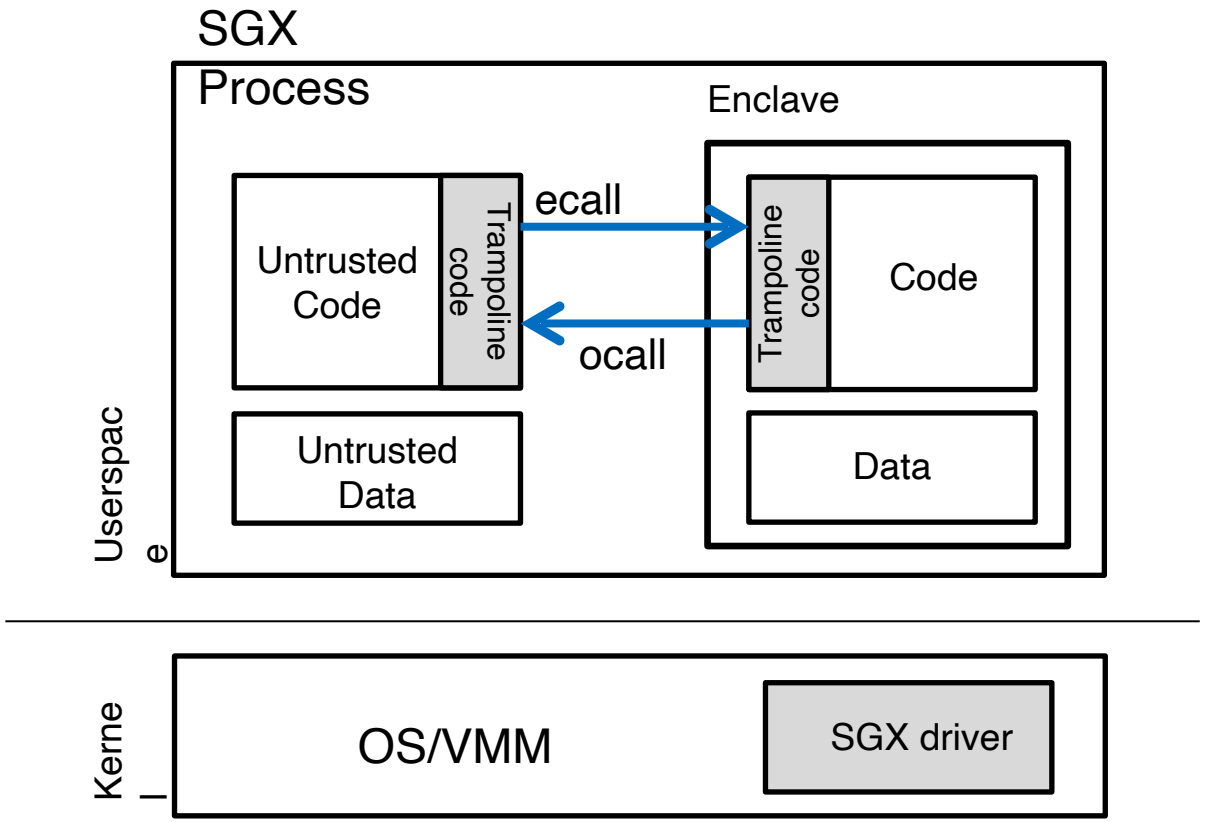
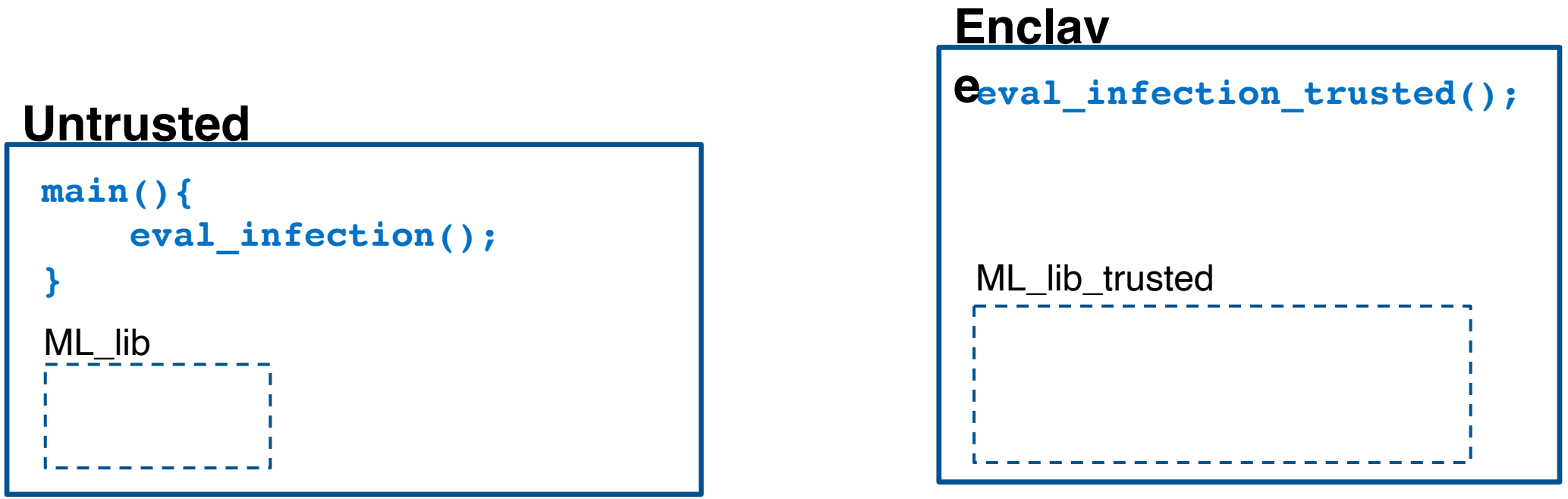


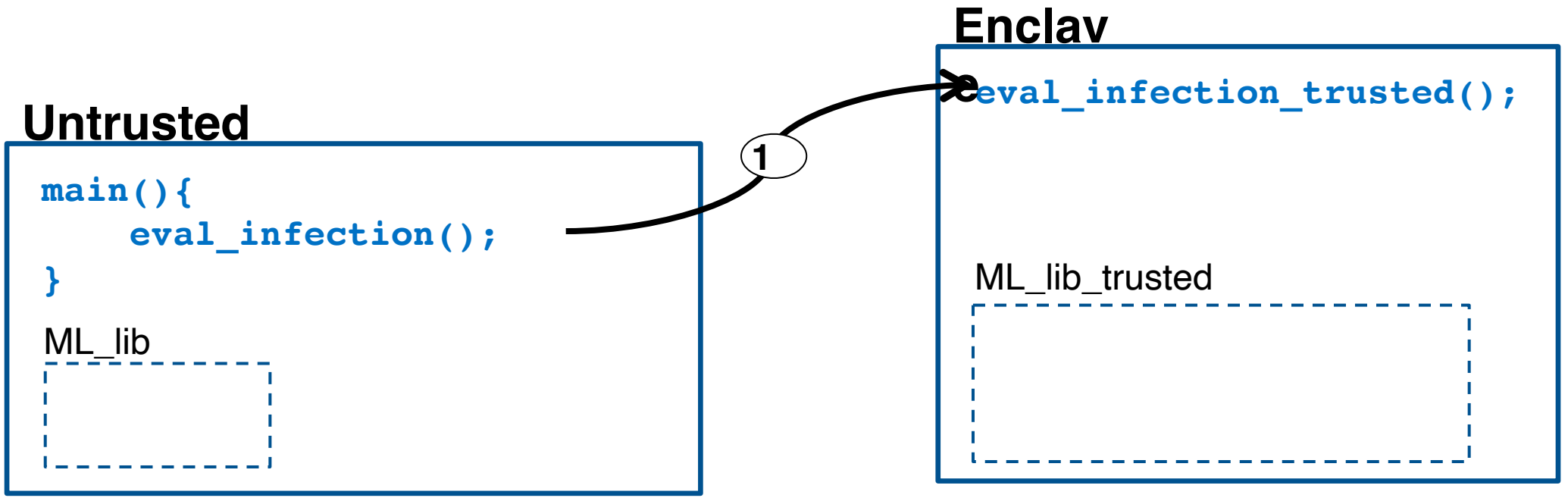
Toy Example: Image classification app

```
eval_infection(){
    ML_lib.load_training_set();

    data_file = open(“x-ray.jpg”);

    result = ML_lib.classify(data_file);
}
```

SGX in theory: Sensitive apps, minimal TCB



SGX in theory: Sensitive apps, minimal TCB



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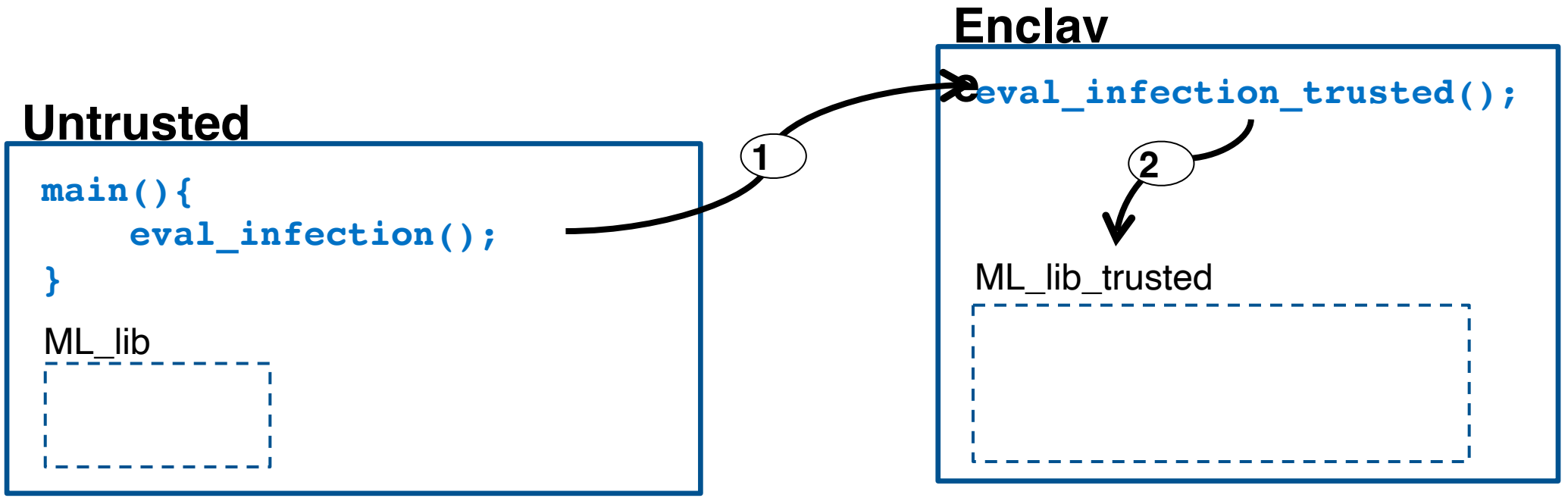
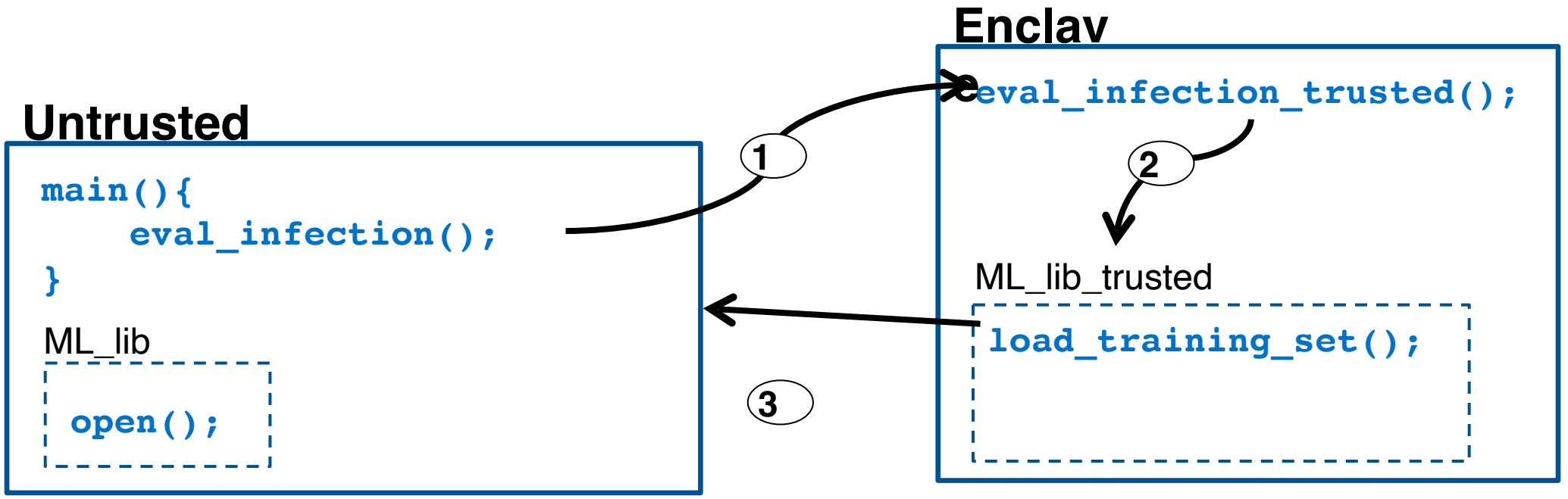
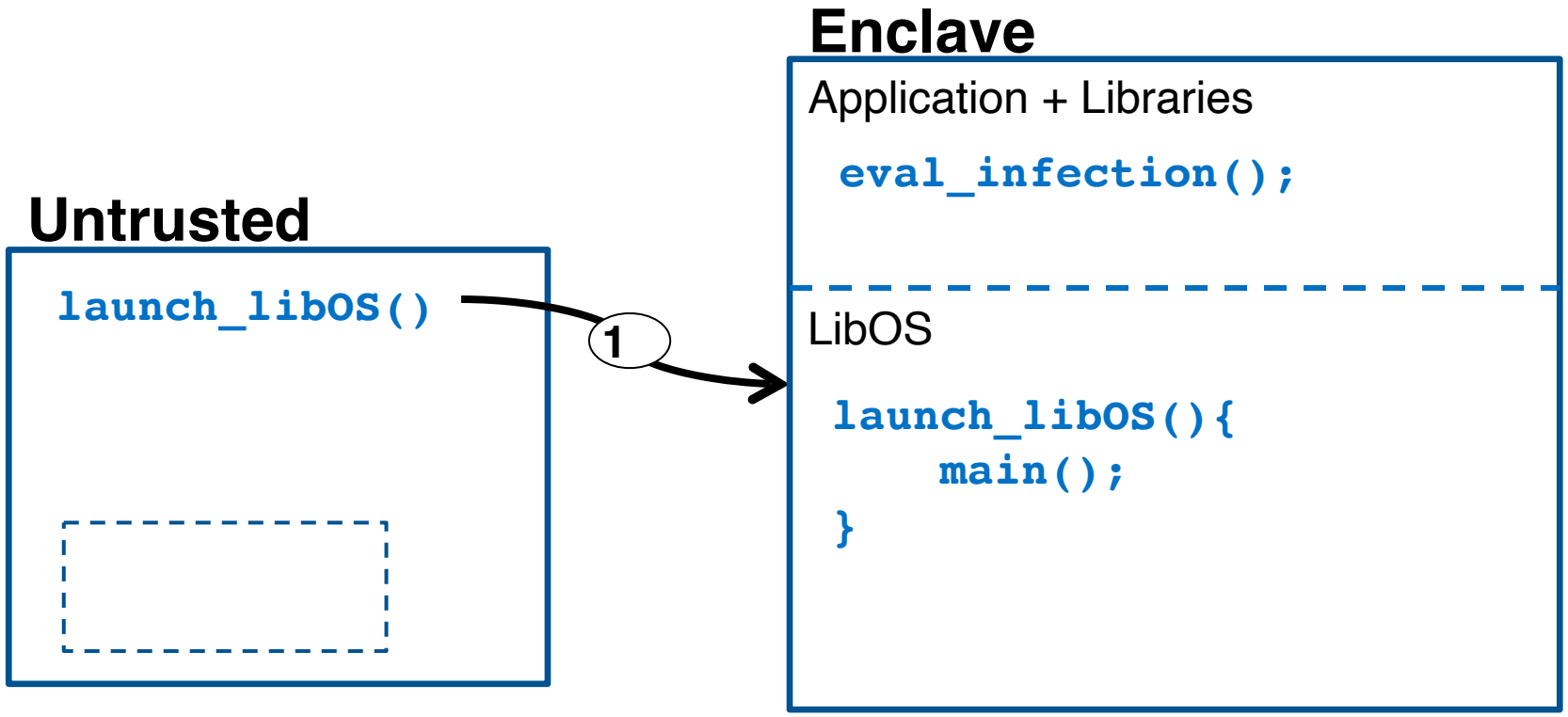


SGX in theory: Sensitive apps, minimal TCB

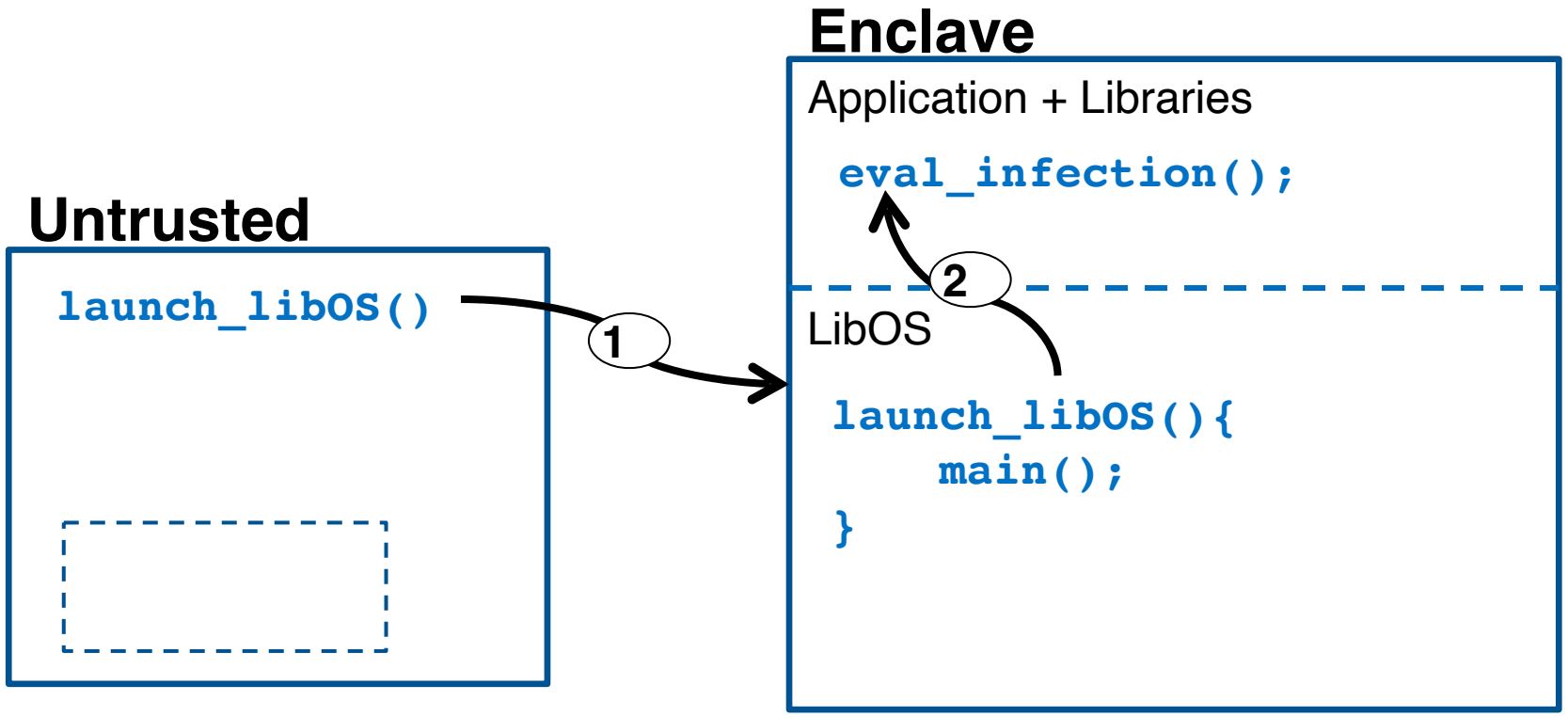


Native TEE programming requires a lot of integration efforts.

SGX in practice: Library OSes



SGX in practice: Library OSes



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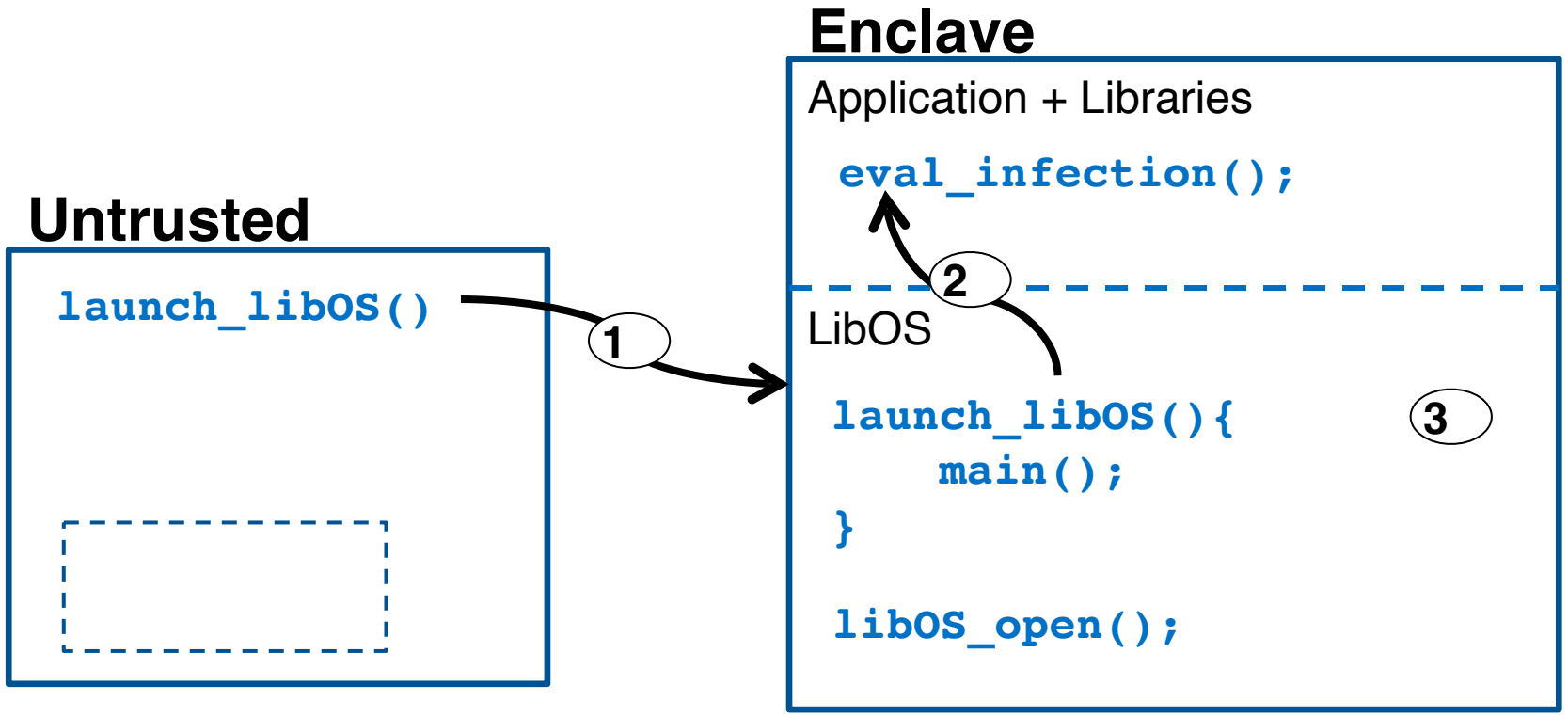
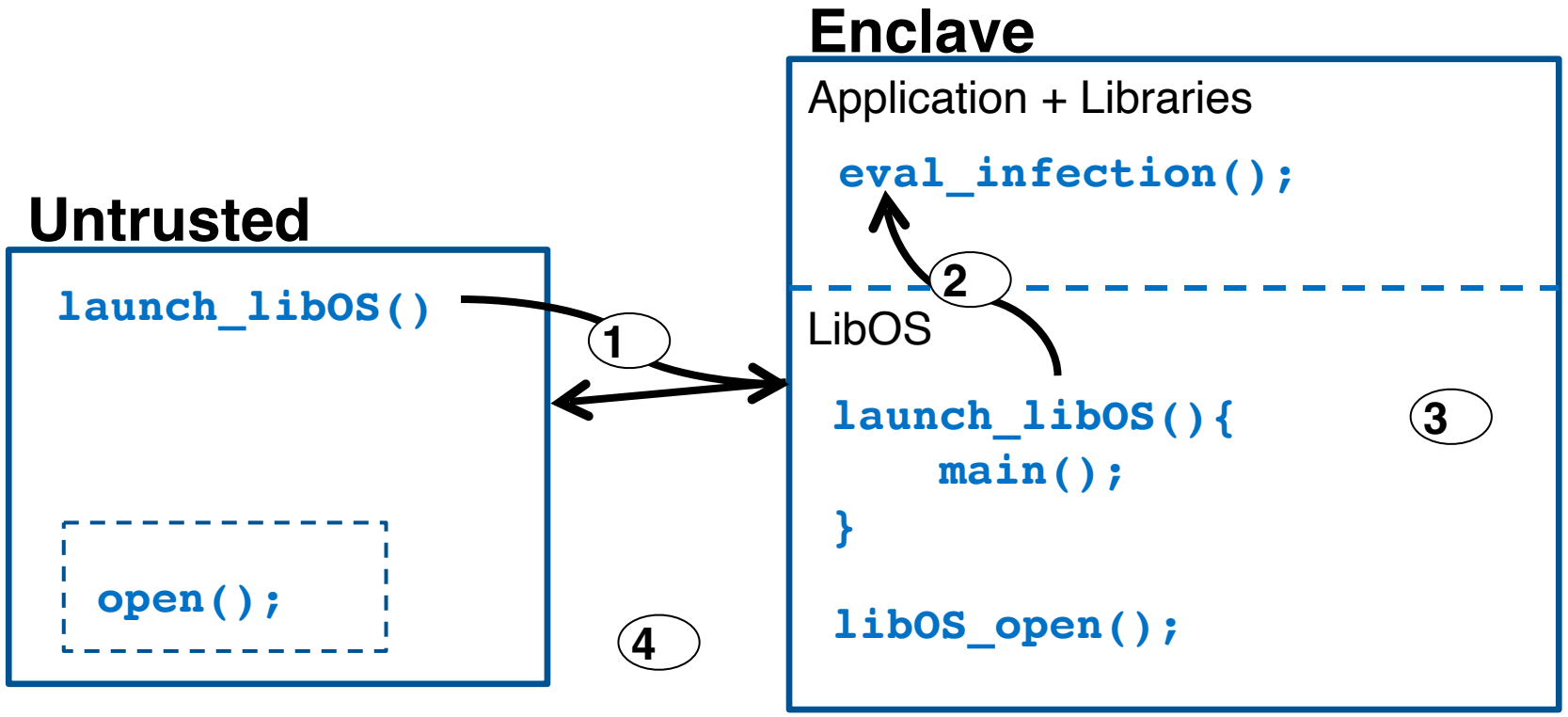
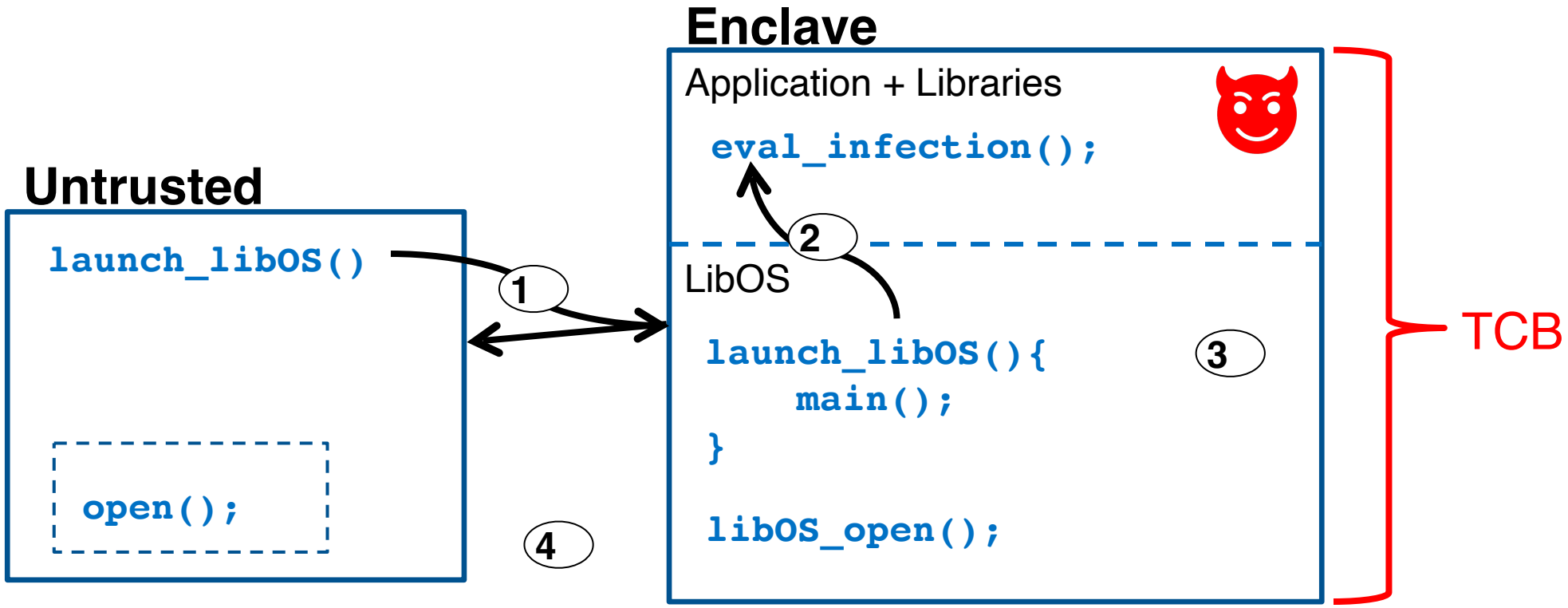


SGX in practice: Library OSes



Library OSes bring untrusted Libs into TCB!



Attack Vector: LibOS data structures

```
eval_infection(){




}
```

LibOS file descriptor table

FD	Path
0	stdin
1	stdout
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Attack vector: LibOS data structures

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LibOS file descriptor table

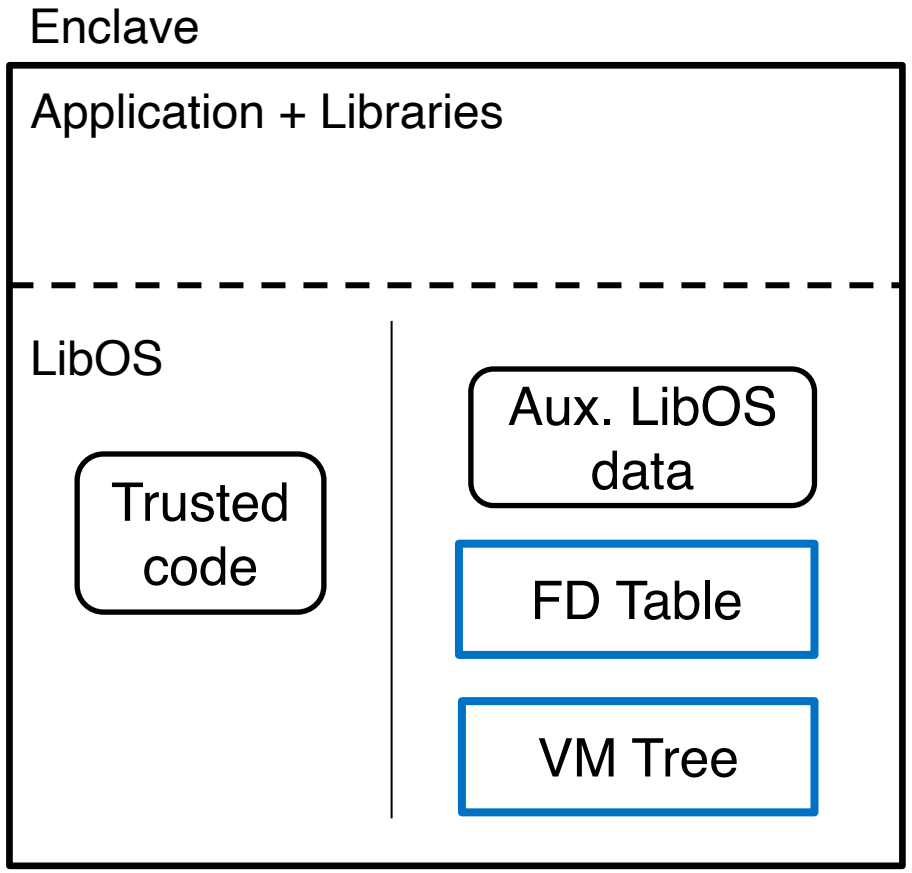
FD	Path
0	stdin
1	stdout
2	stderr
3	model.csv
4	healthy.jpg

Traditional OS: Prevented via privilege ring isolation!

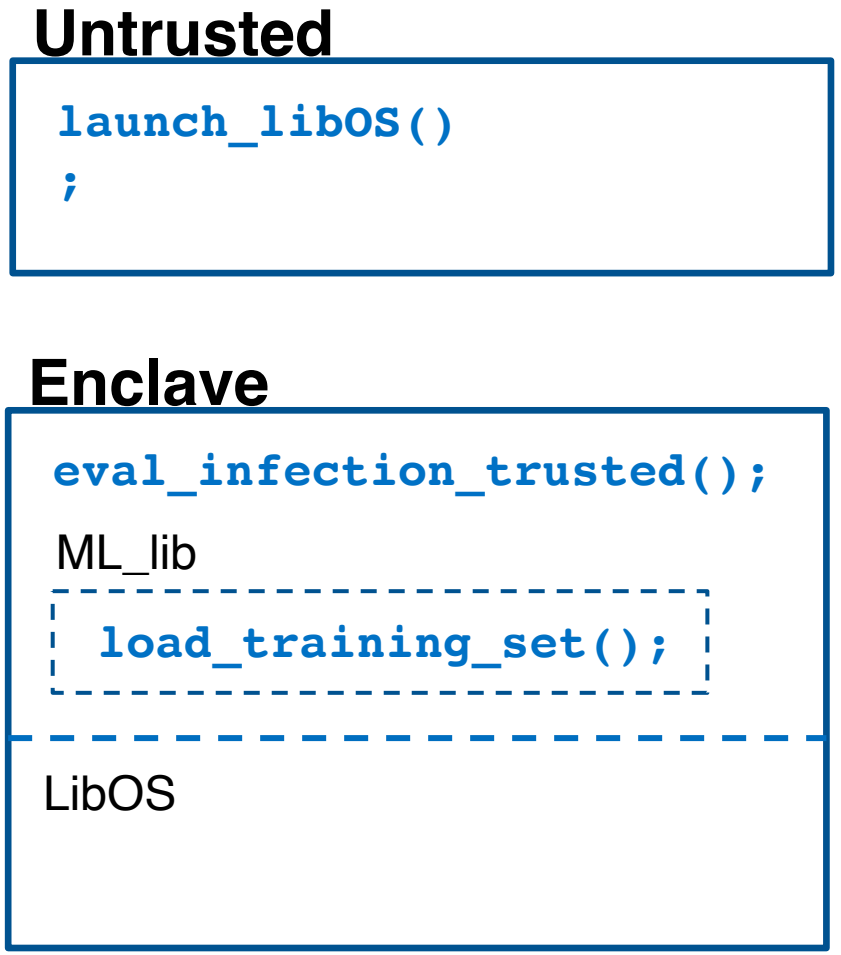
Problem:

No memory access restrictions *within* an enclave. Untrusted third-party code has unfettered access to all in-enclave data.

EnclaveDom: Privilege Separation in HW Enclaves



Strawman: Per-Domain Enclaves



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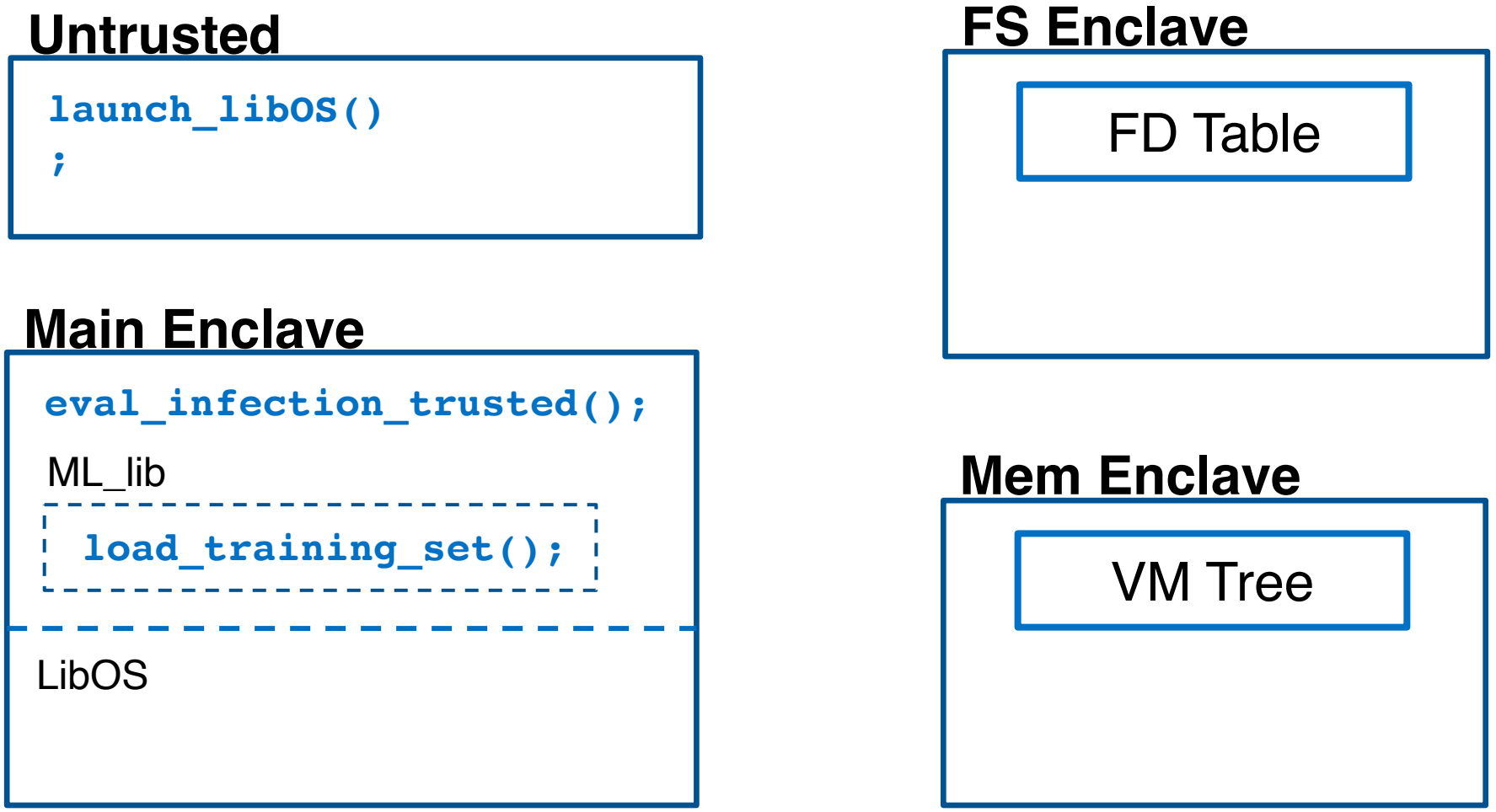

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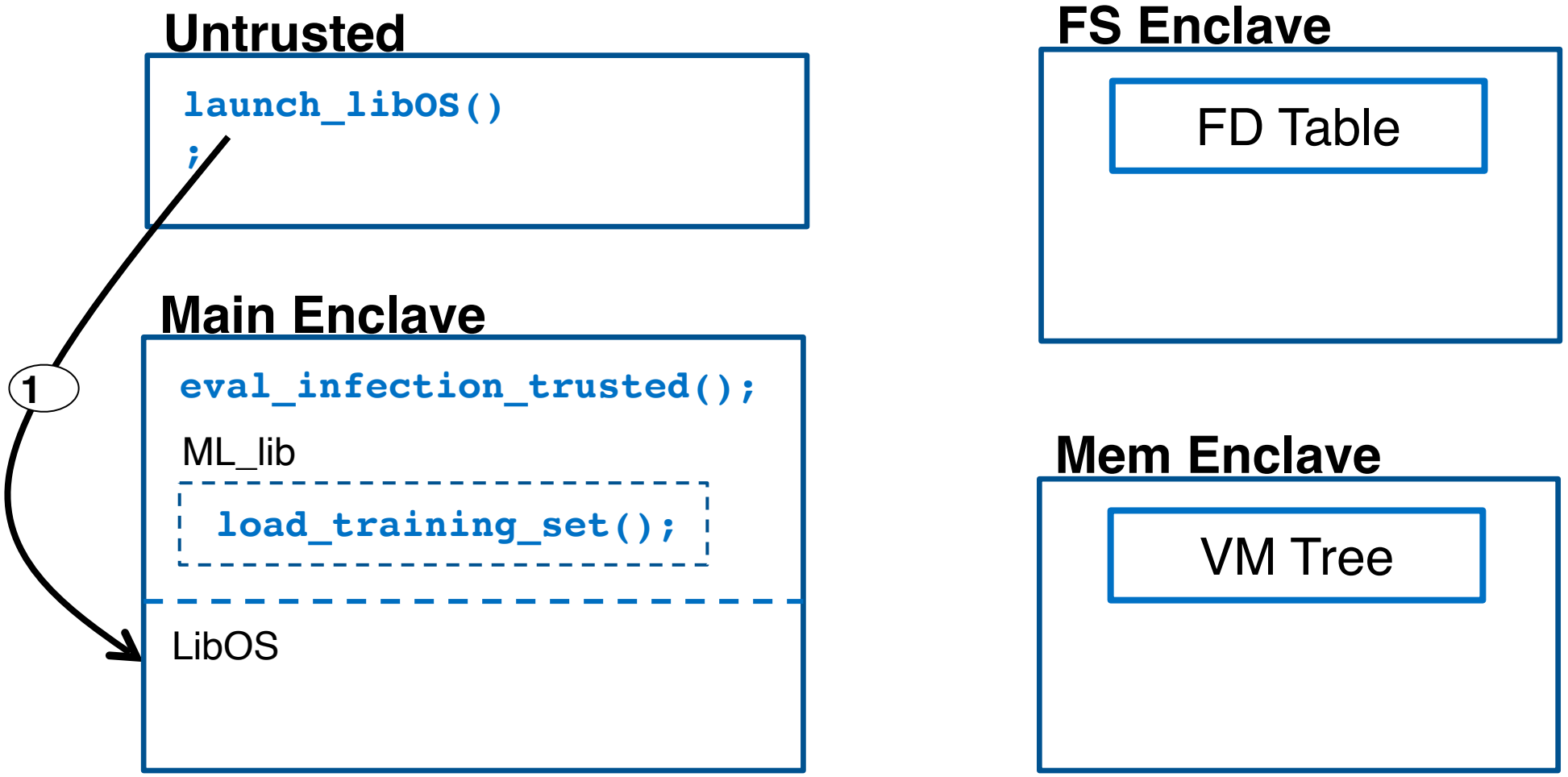

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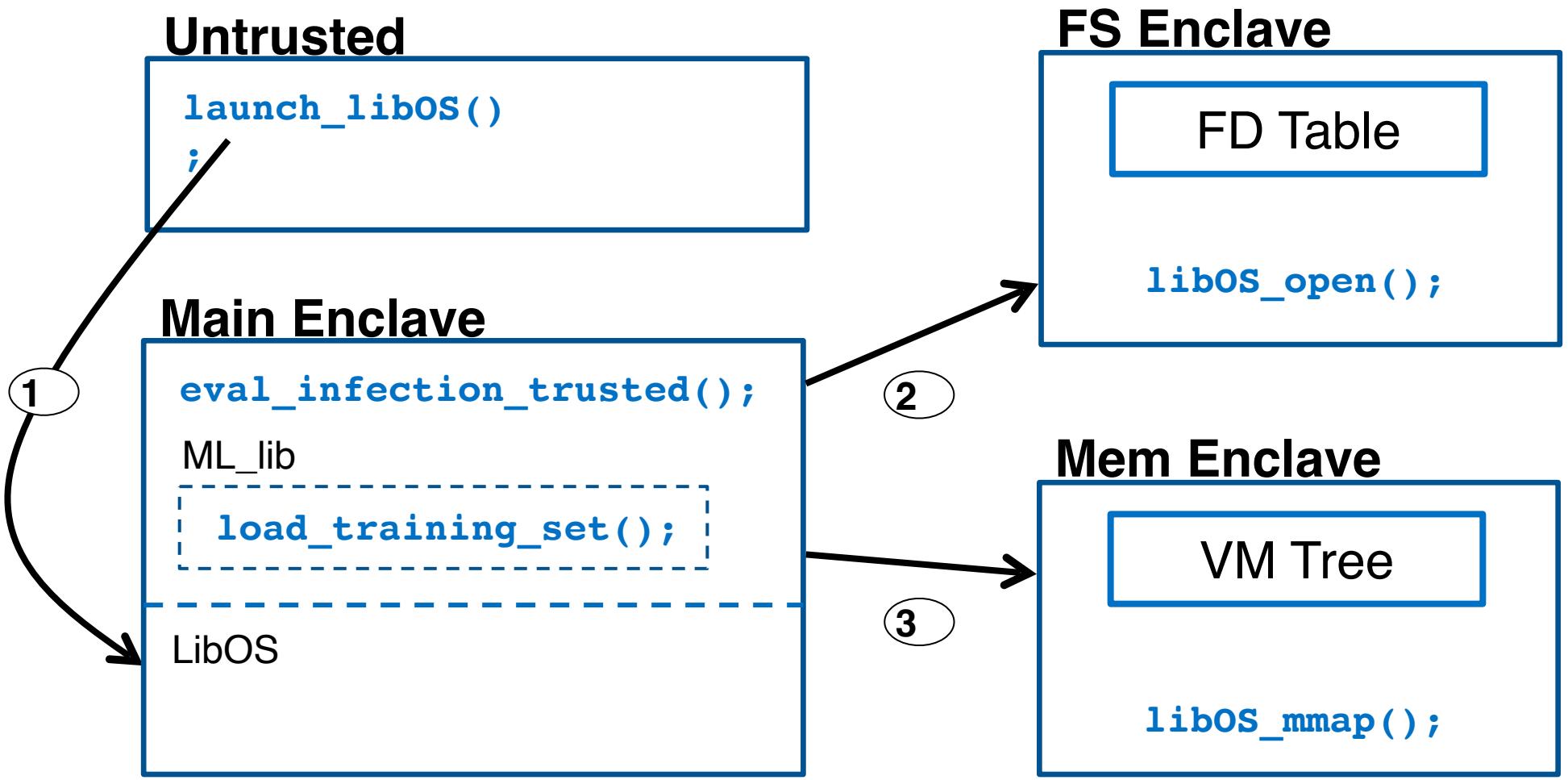

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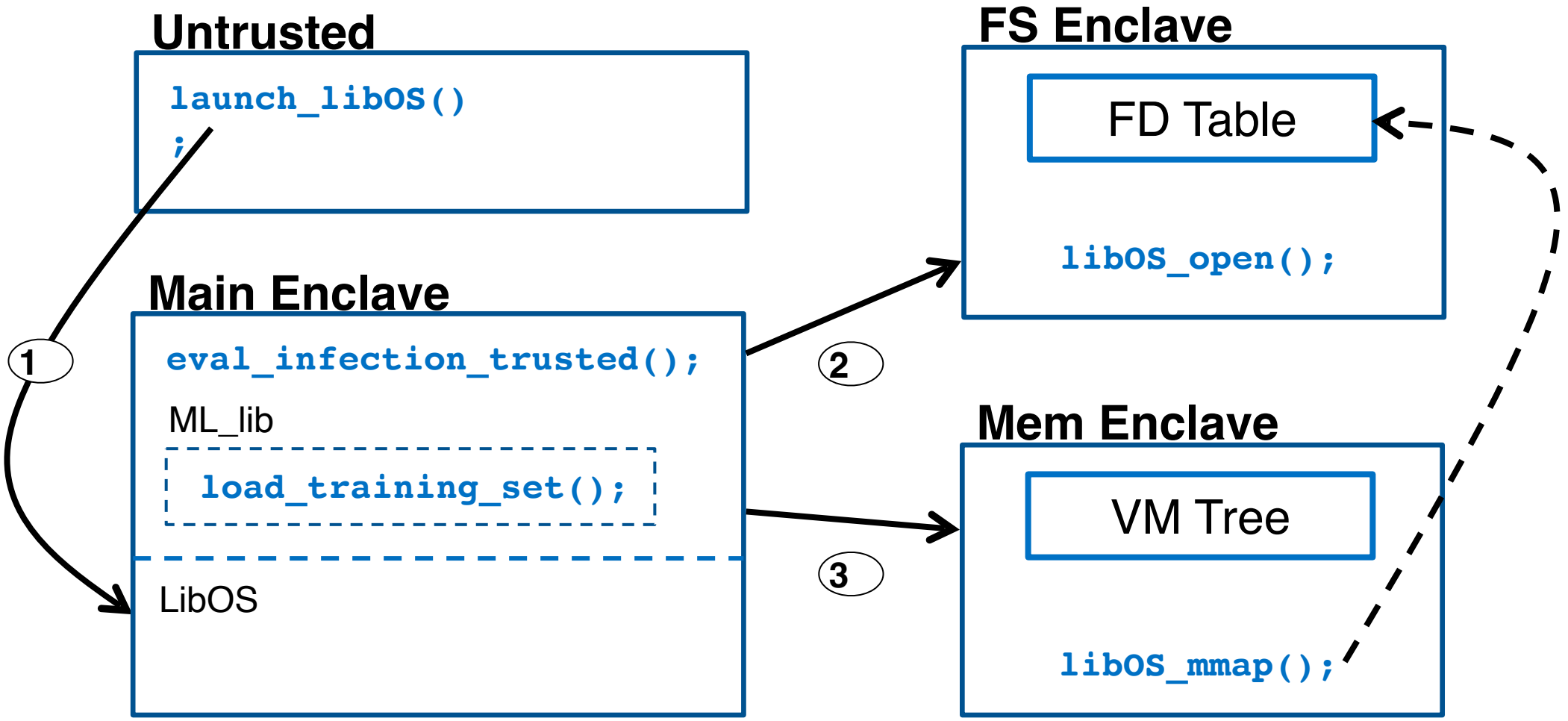
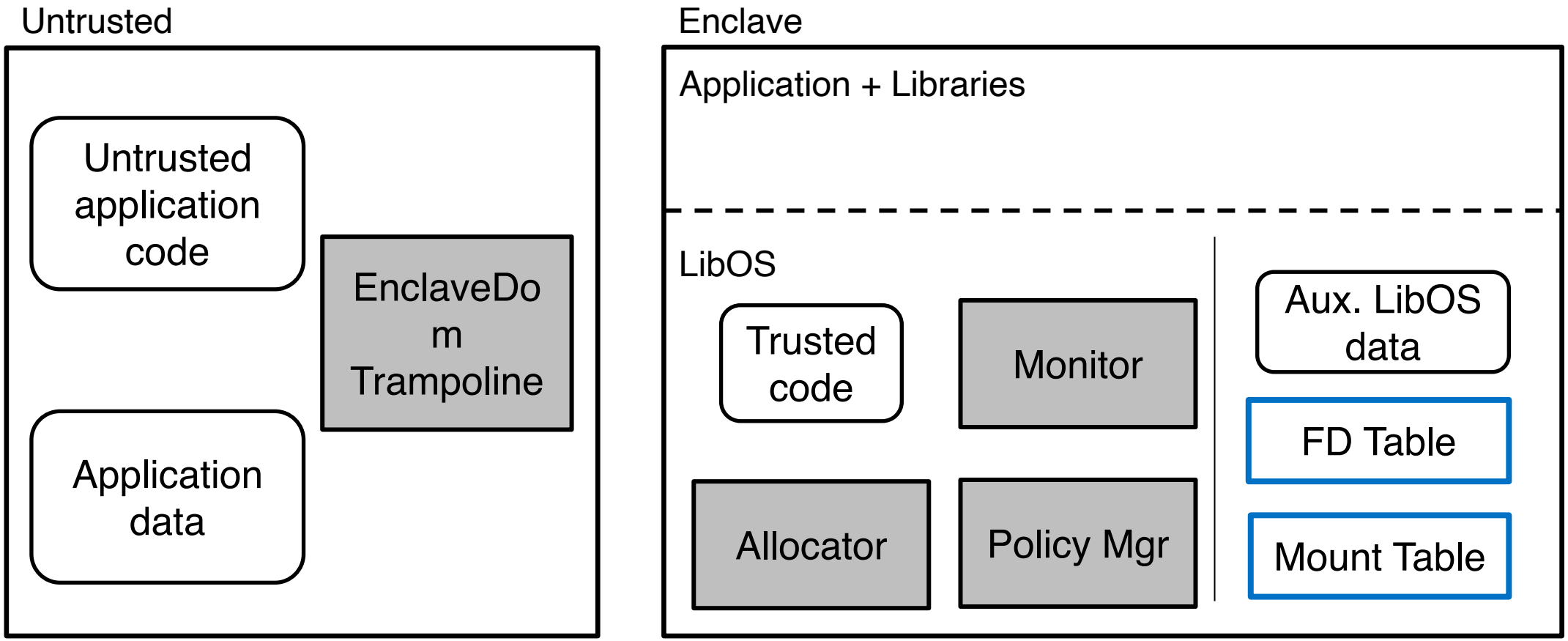


Isolation
vs
Complexity & Performance

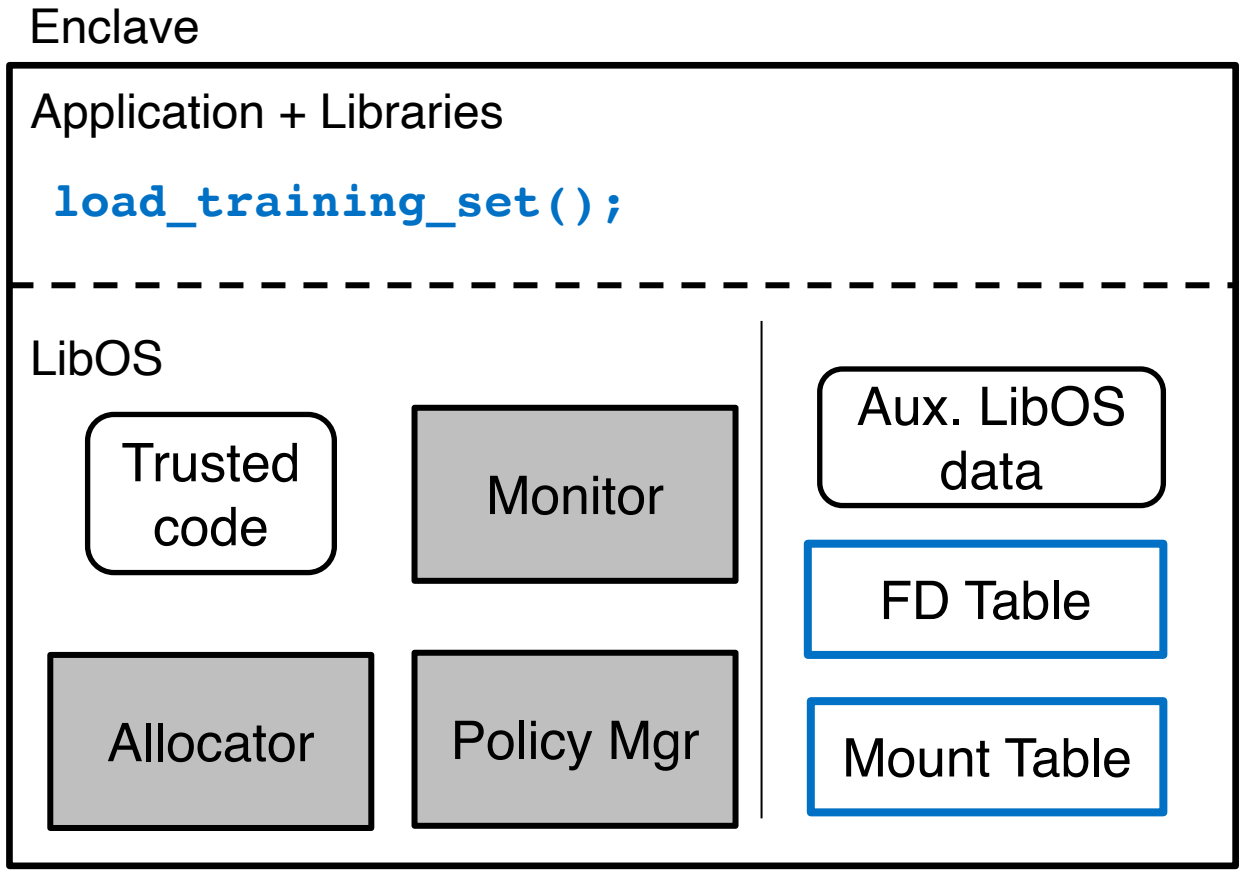
EnclaveDom LibOS Architecture



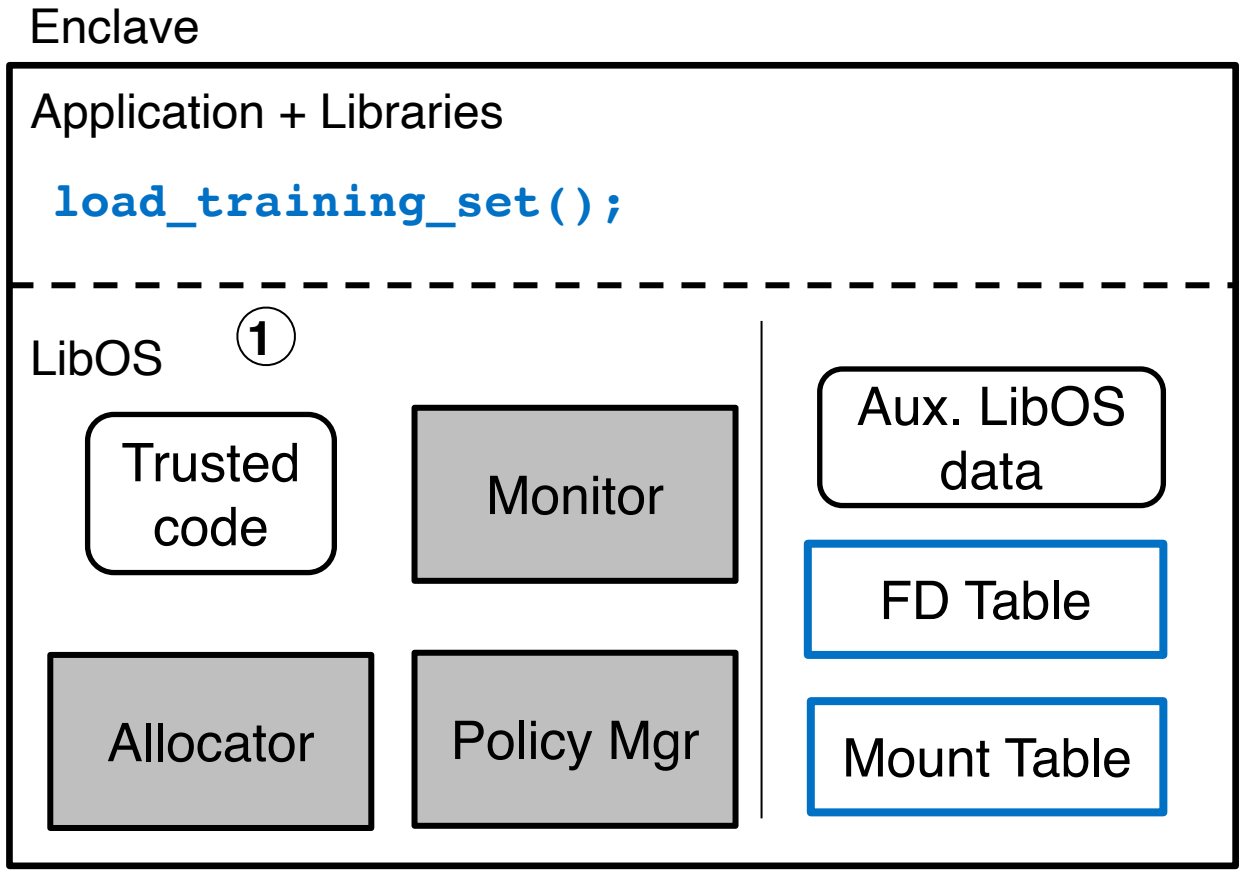
EnclaveDom Memory Domains: Intel MPK

- Memory protection keys: hardware memory page tagging
- Per-CPU register stores R/W access privileges to 16 tags
- Domain access bits in register check on every memory access

EnclaveDom Access Checks



EnclaveDom Access Checks



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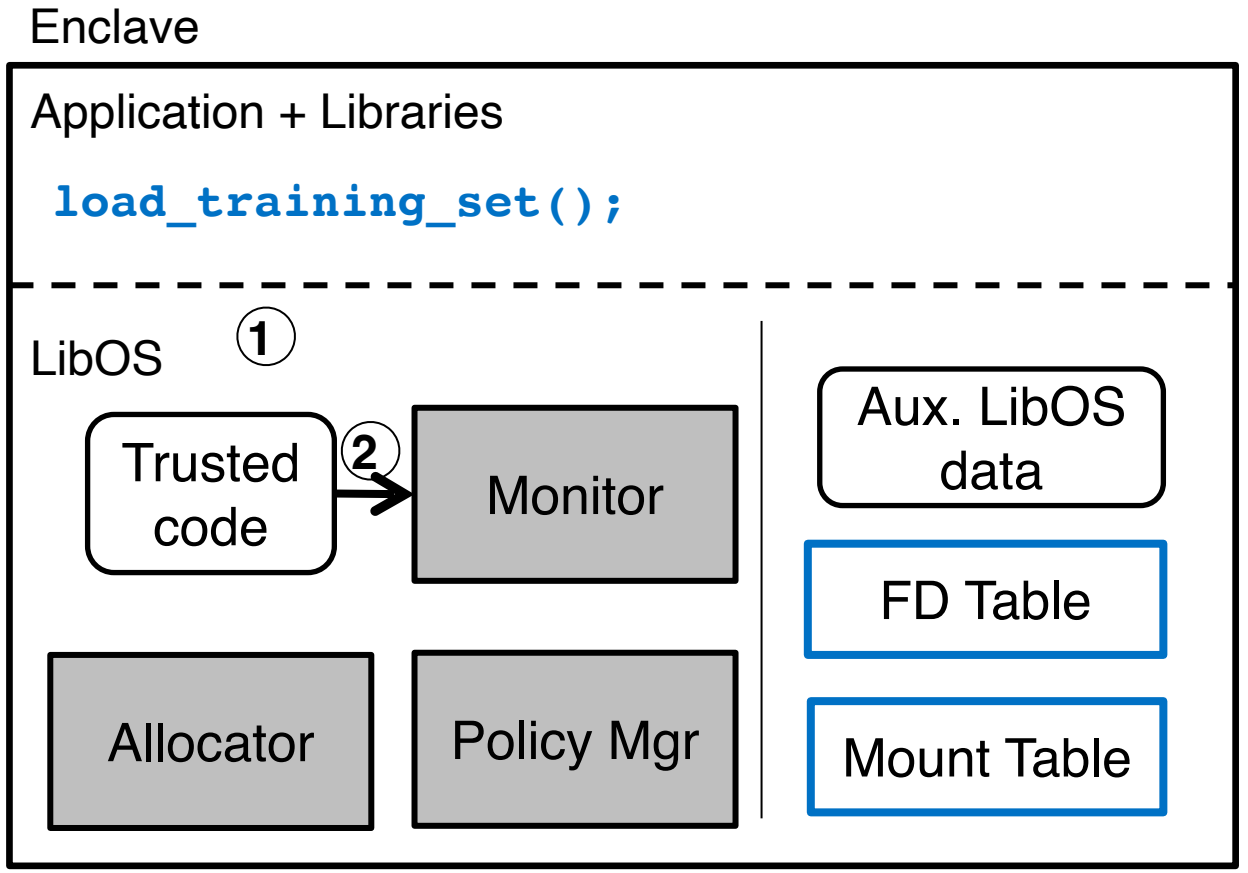

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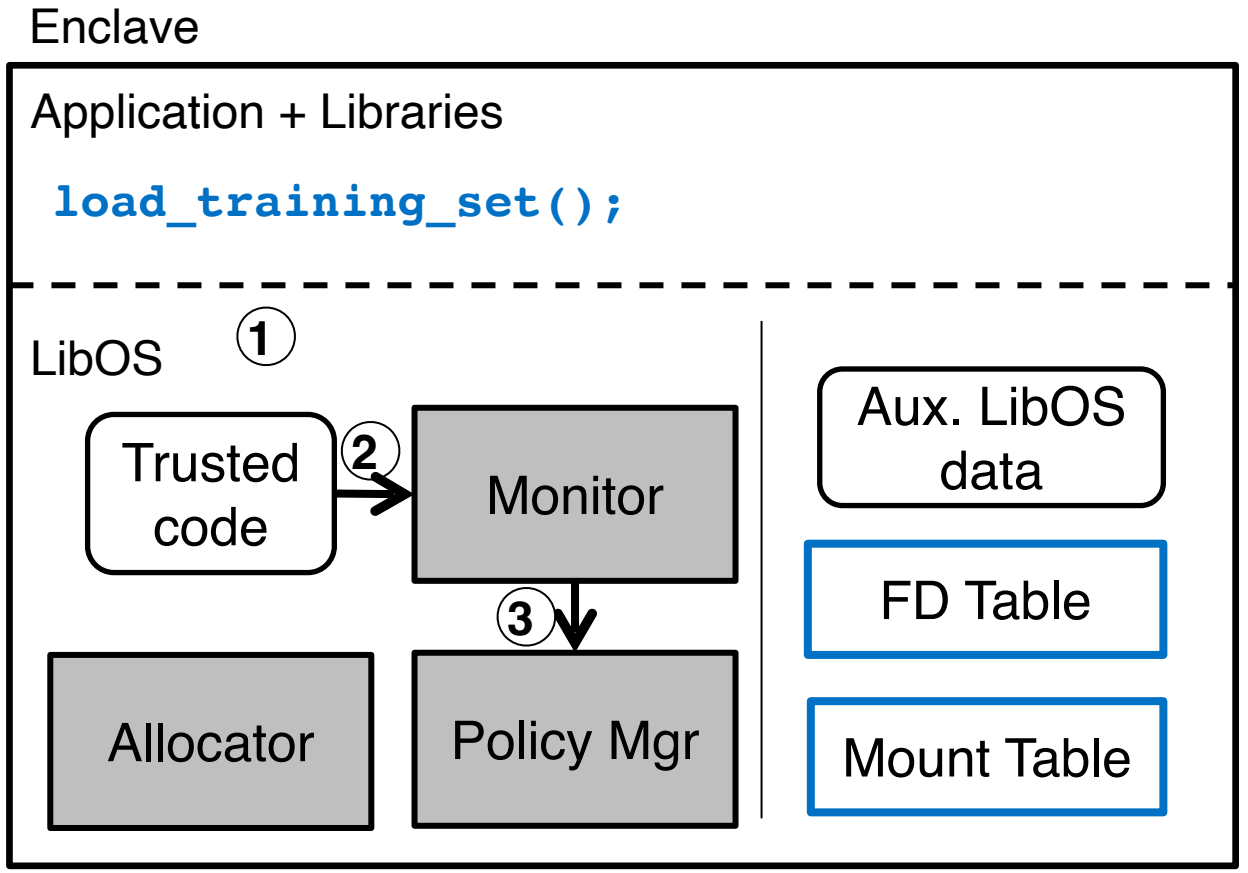
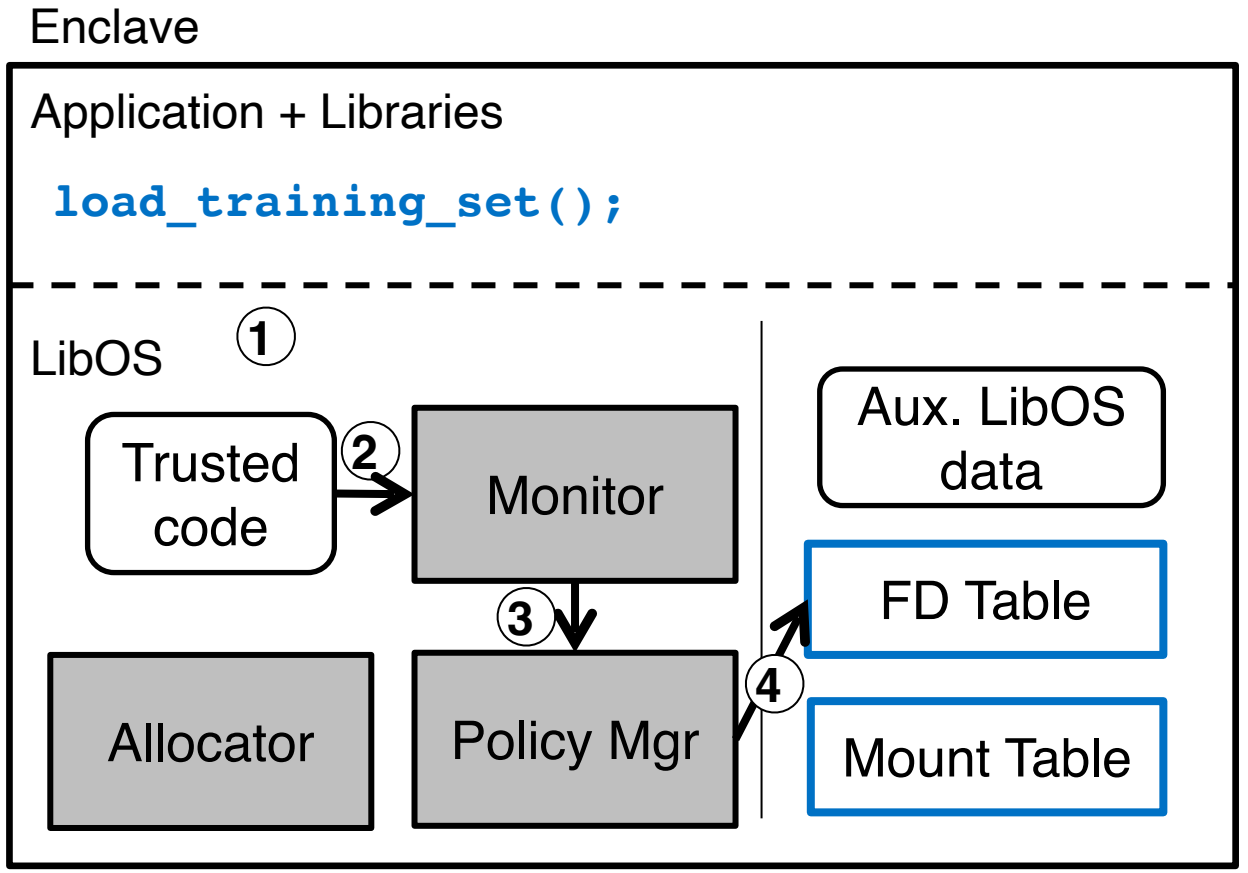
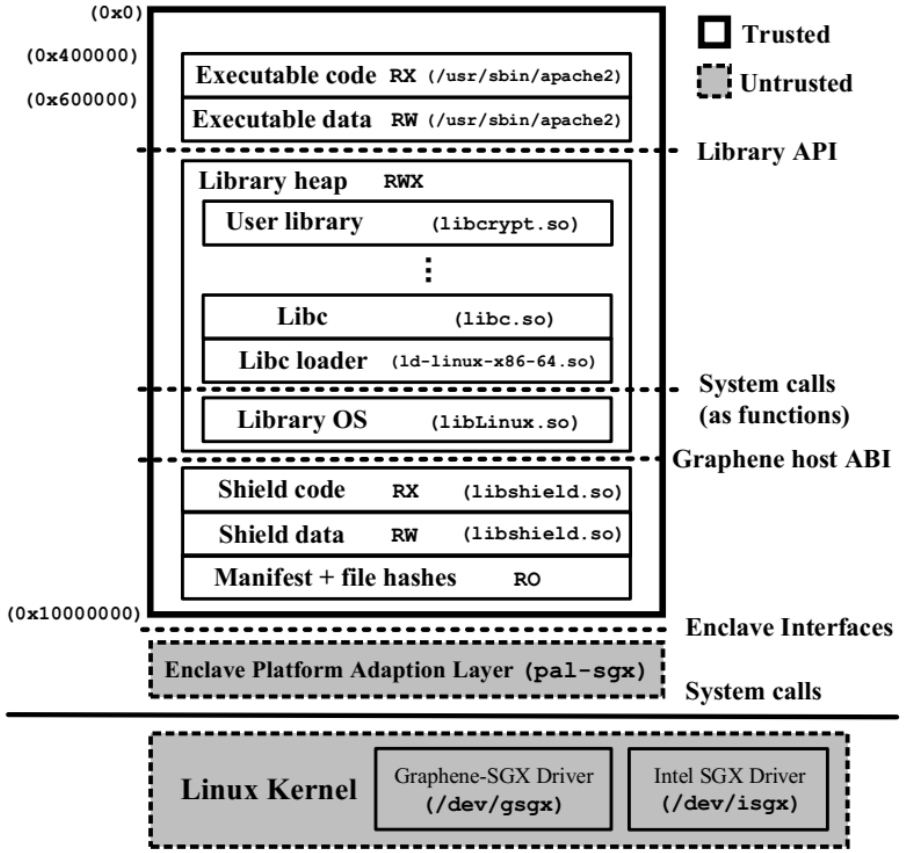


EnclaveDom Access Checks



Porting EnclaveDom to Graphene



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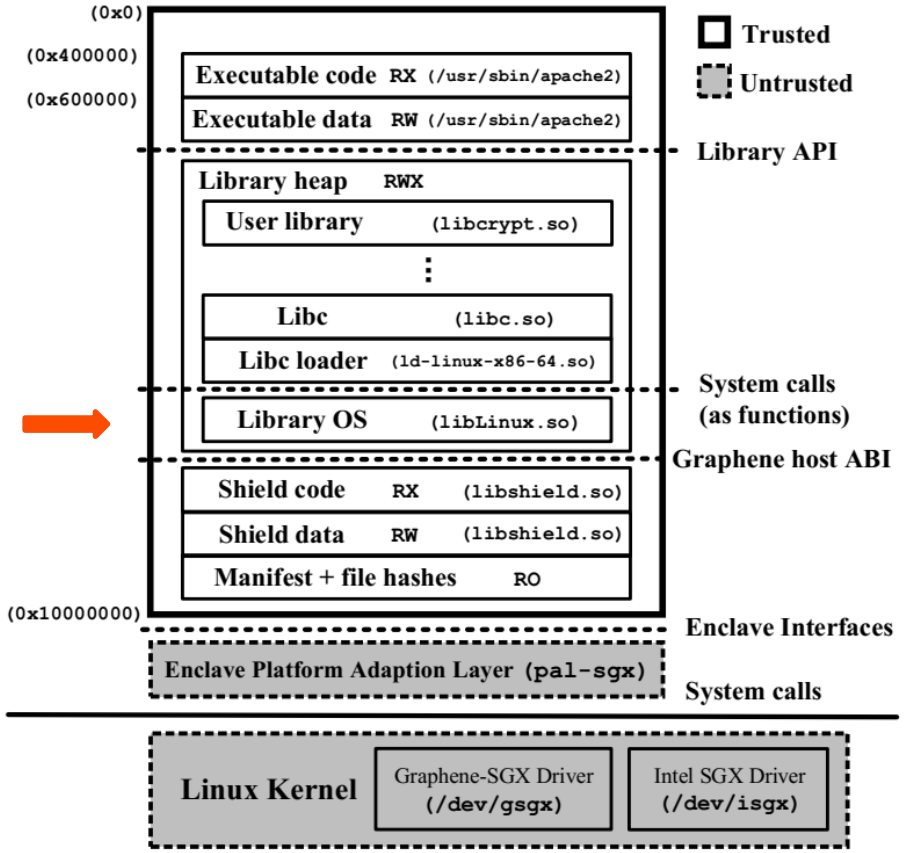

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EnclaveDom Testing Platform

- Intel 10th generation CPU
- Linux kernel 5.3 (Ubuntu 18.04)
- Userspace EnclaveDom API for domain management in C++
- Graphene-SGX March 2019 pre-release

EnclaveDom Performance Evaluation

	% time in EnclaveDom	accessed memdom(s)
`open`	6.4	handle, fs
`close`	49.1	handle
`stat`	49.9	fs
`fstat`	50.1	handle, fs
`mmap`	0.8	handle

Graphene shim layer microbenchmarks

System configuration: Intel 10th gen CPU, Linux kernel 5.3 (Ubuntu 18.04), userspace EnclaveDom API in C++, Graphene SGX March 2019 pre-release

EnclaveDom Memory Usage

	memory usage (in bytes)
handle_dom	98
fs_dom	1030
Total	1200

Graphene shim layer microbenchmarks

System configuration: Intel 10th gen CPU, Linux kernel 5.3 (Ubuntu 18.04), userspace EnclaveDom API in C++, Graphene SGX March 2019 pre-release

EnclaveDom Open Research Questions

- How can EnclaveDom provide fine-grained isolation within the app itself?

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- How to protect OS-level MPK interface against misuse?

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- How to provide fine-grained isolation within the app itself?
- How to protect MPK interface against compromised host OS?
- Scalability of MPK: How to support more than 16 domains?

EnclaveDom Recap

Target Large-TCB Apps

SGX + MPK

Privilege Isolation for LibOSes

Thank you!

Contact: marcela.melara@intel.com

Twitter: @mas0mel

Github: @masomel