Enarx

Protection for data in use

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https://enarx.io

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Sr. Principal Engineer

Red Hat

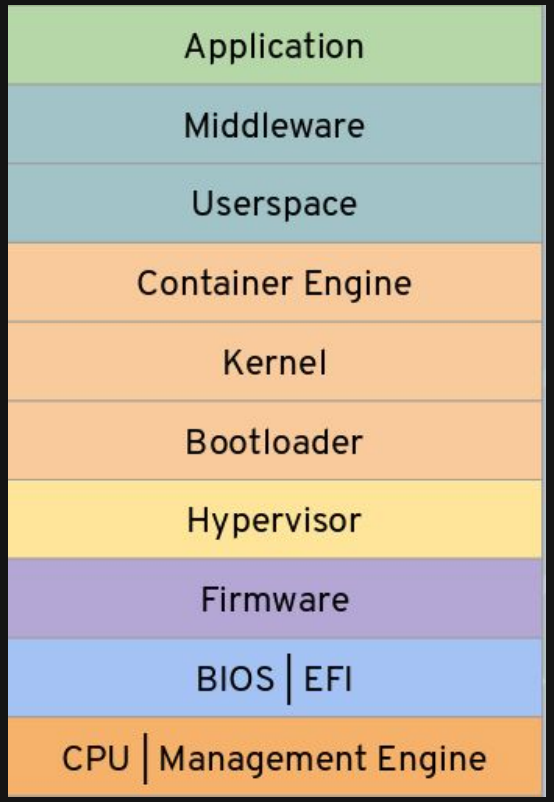
The Problem

The Need for Confidentiality and Integrity

- Banking & Finance
- Government & Public Sector
- Telco
- IoT
- HIPAA
- GDPR
- Sensitive enterprise functions
- Defense
- Human Rights NGOs
- ...

Virtualization Stack

Container Stack



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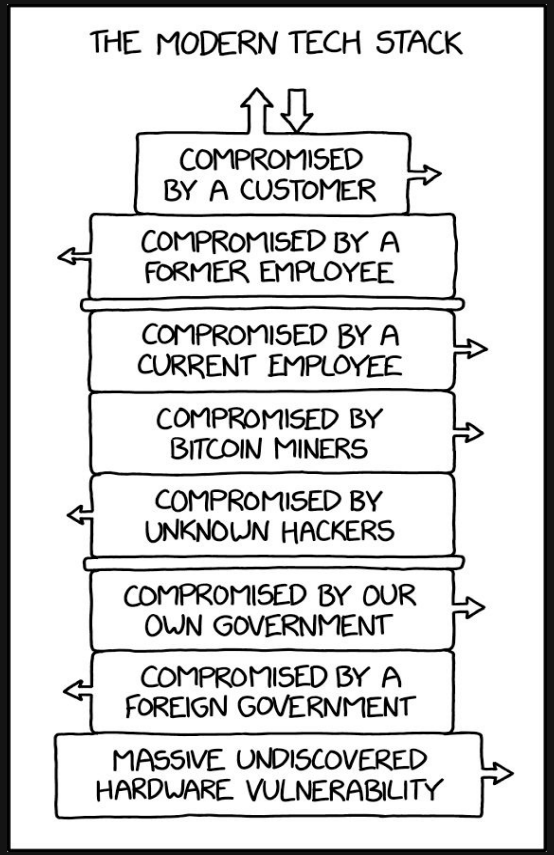
https://xkcd.com/2166/



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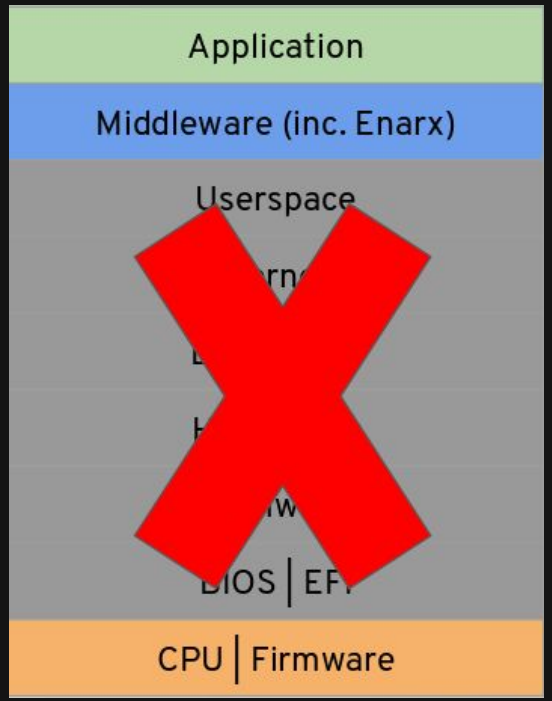
The Plan



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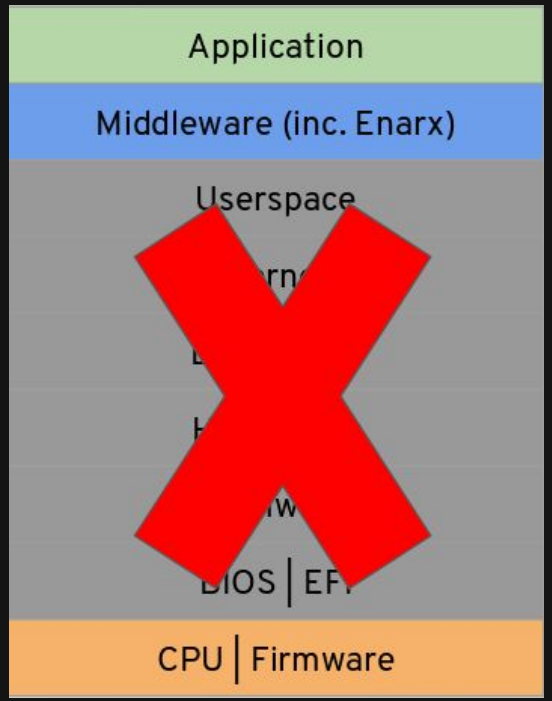
The Principles

Don’t trust the host
Don’t trust the host owner
Don’t trust the host operator
All hardware cryptographically verified
All software audited and cryptographically verified



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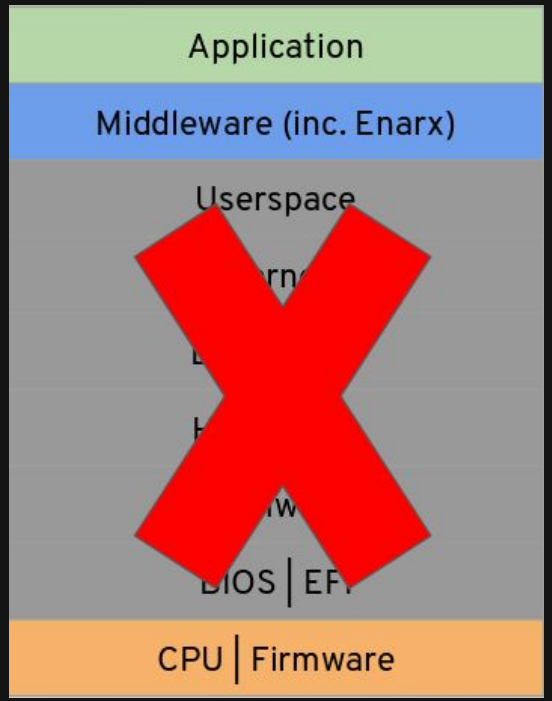

Well suited to microservices
Well suited to sensitive data or algorithms
Easy development integration
Simple deployment
Standards based: WebAssembly (WASM)

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Trusted Execution Environments

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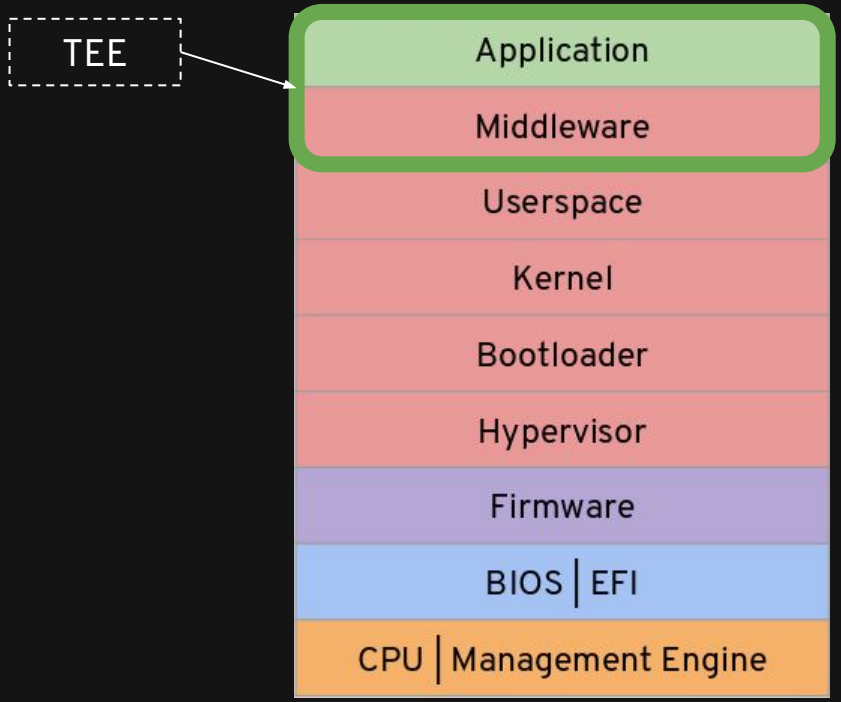
What's a TEE?



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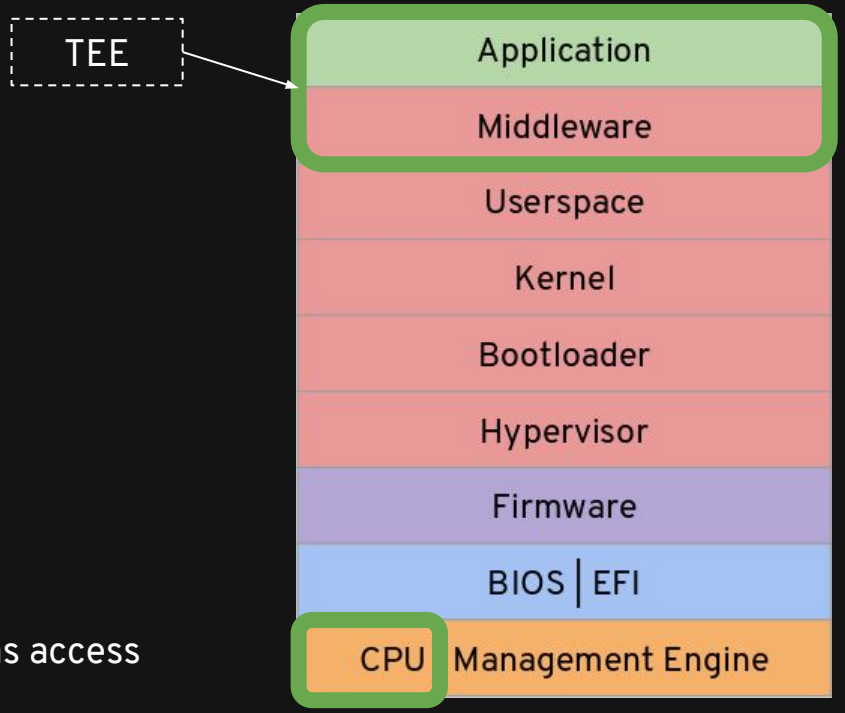

Only the CPU has access

Red Hat

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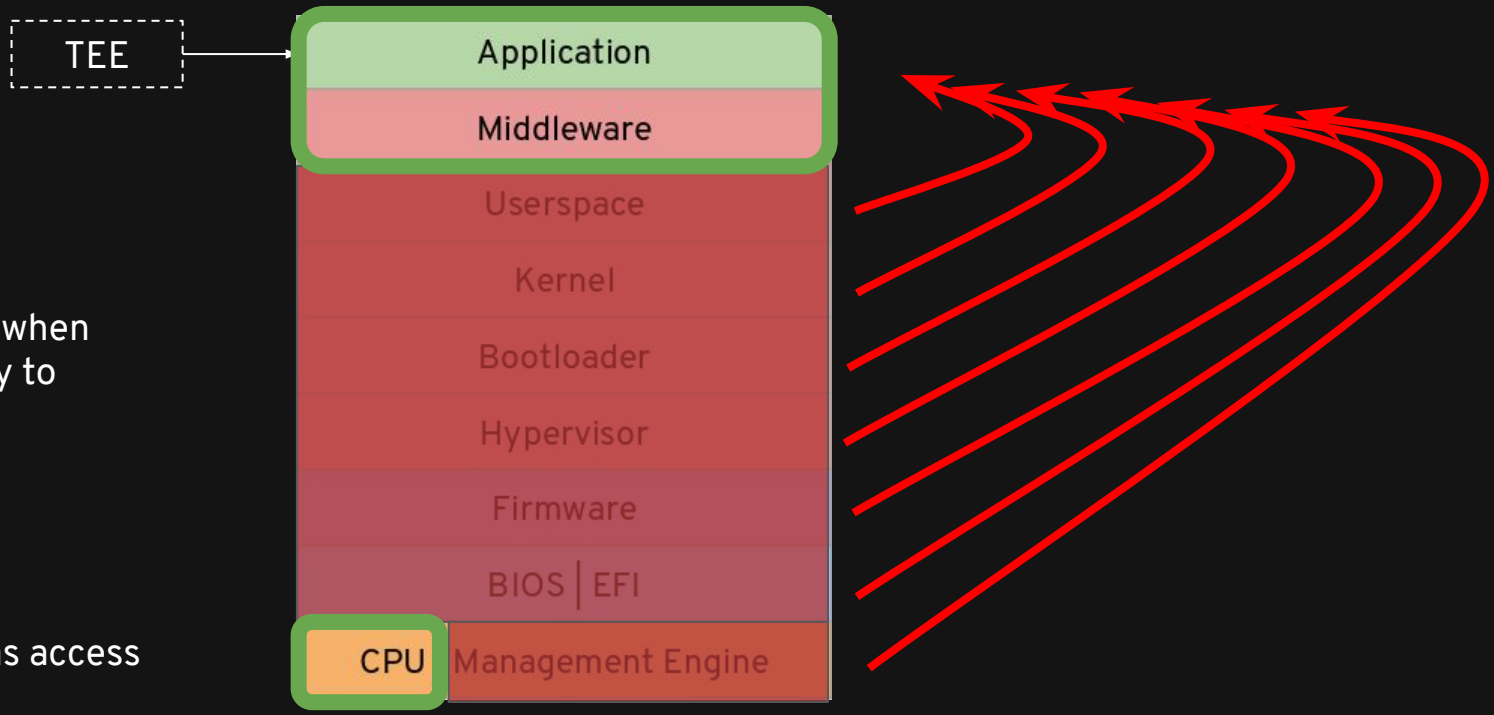
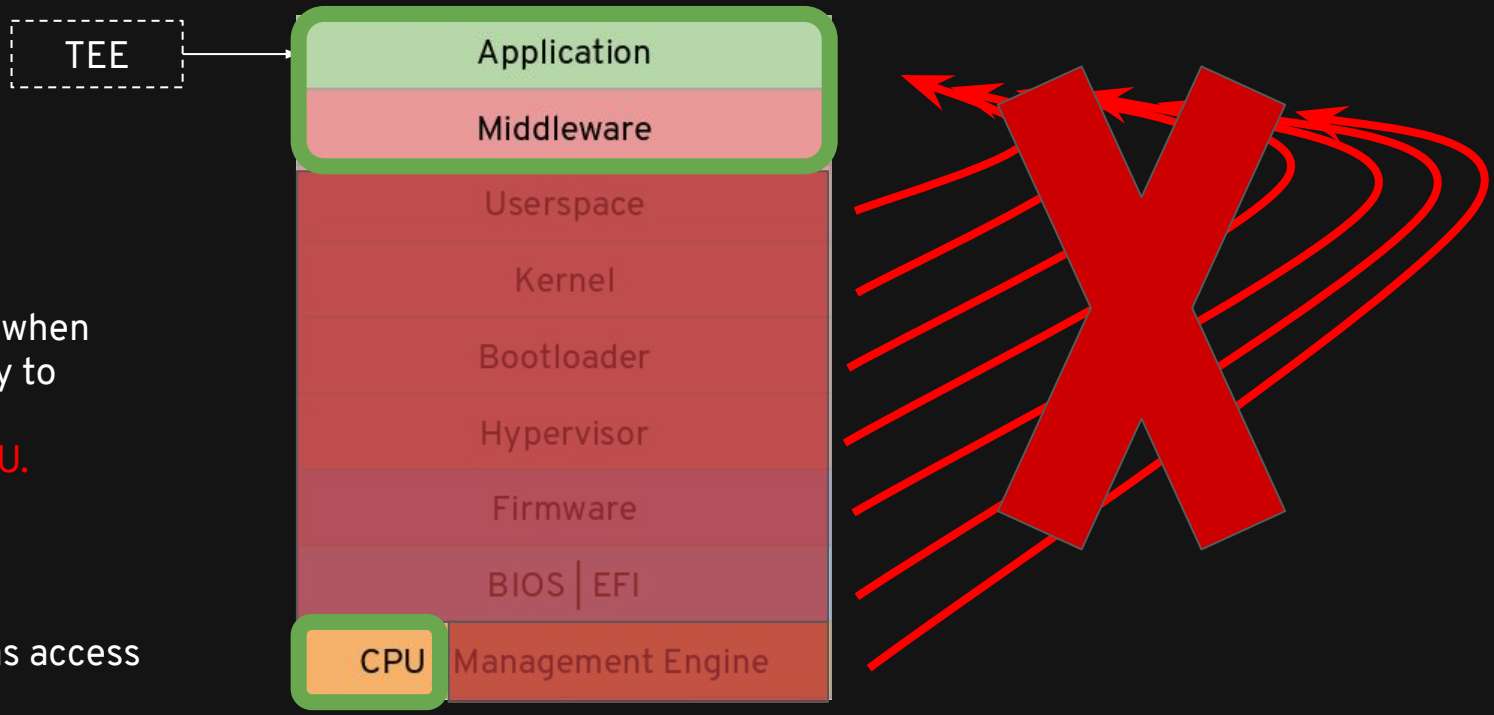


What happens when other layers try to access?

Only the CPU has access

Red Hat

What's a TEE?



What happens when other layers try to access?
Blocked by CPU.

Only the CPU has access

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Trusted Execution Environments

TEE is a protected area within the host, for execution of sensitive workloads

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TEE provides:

- Memory Confidentiality
- Integrity Protection
- General compute
- HWRNG

Trusted Execution Environments

Q. “But how do I know that it’s a valid TEE?”

TEE provides:

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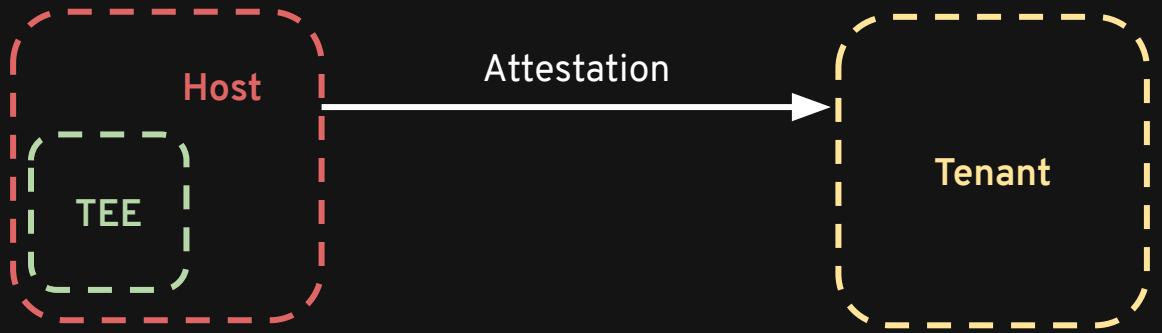
Trusted Execution Summary



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A. Attestation

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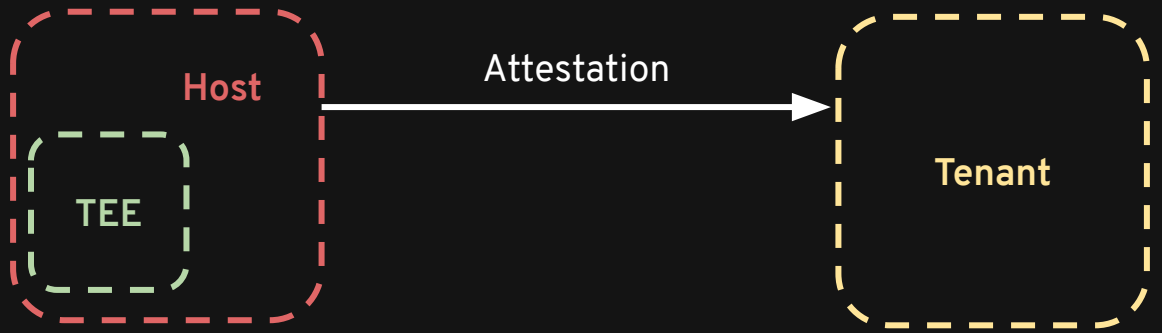

Attestation includes:

- Diffie-Hellman Public Key
- Hardware Root of Trust
- TEE Measurement

TEE provides:

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Trusted Execution Summary

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Trusted Execution Models

Process-Based

- Intel SGX (not upstream)
- RISC-V Sanctum (no hardware)

VM-Based

- AMD SEV
- IBM PEF (no hardware)
- Intel MKTME (no attestation[1])

Not a TEE: TrustZone, TPM

1. Attestation is discussed here: https://patents.google.com/patent/US20190042463A1/en?oq=20190042463

Trusted Execution: Process-Based

PROS

- Access to system APIs from Keep

CONS

- Unfiltered system API calls from Keep
- Application redesign required
- Untested security boundary
- Fantastic for malware
- Lock-in

Trusted Execution: Virtual Machine-Based

PROS

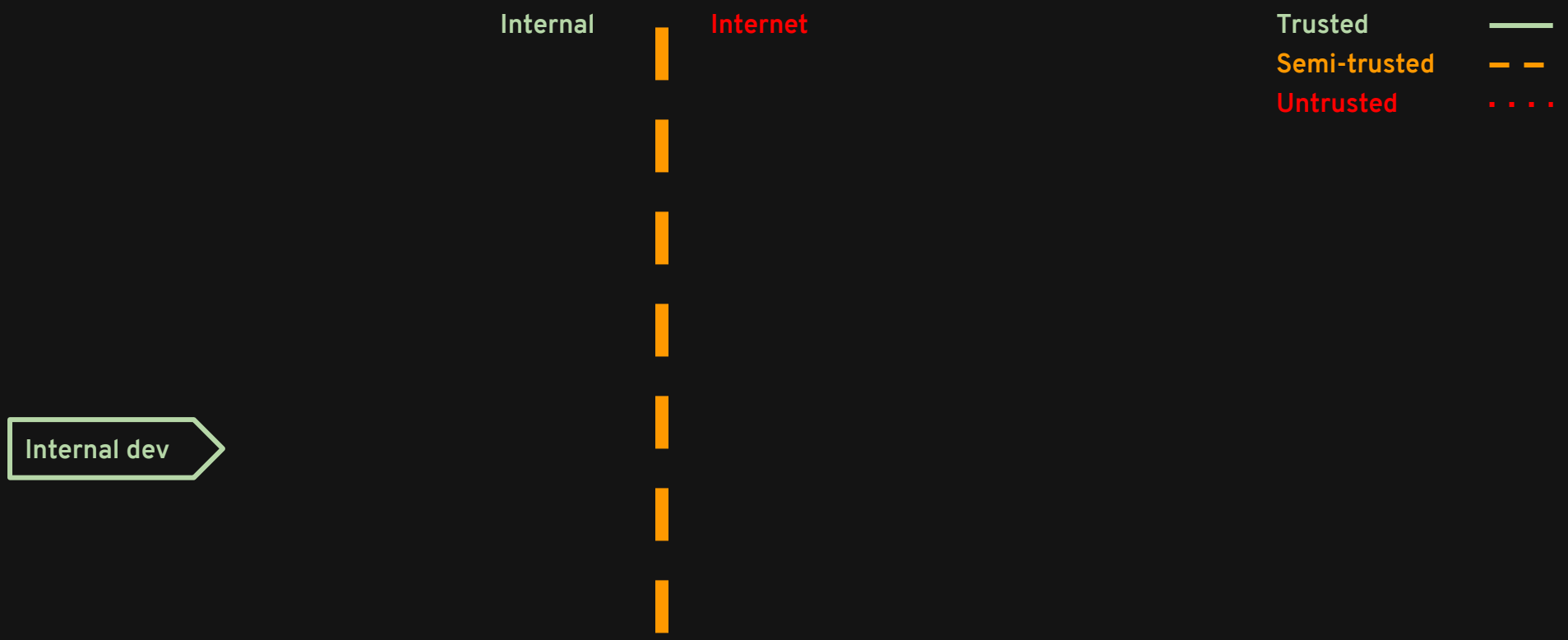
- Strengthening of existing boundary
- Run application on existing stacks
- Bidirectional isolation
- Limits malware

CONS

- Hardware emulation
- Heavy weight for microservices
- CPU architecture lock-in
- Duplicated kernel pages
- Host-provided BIOS

Open hybrid cloud and Enarx

Step 1: on premises



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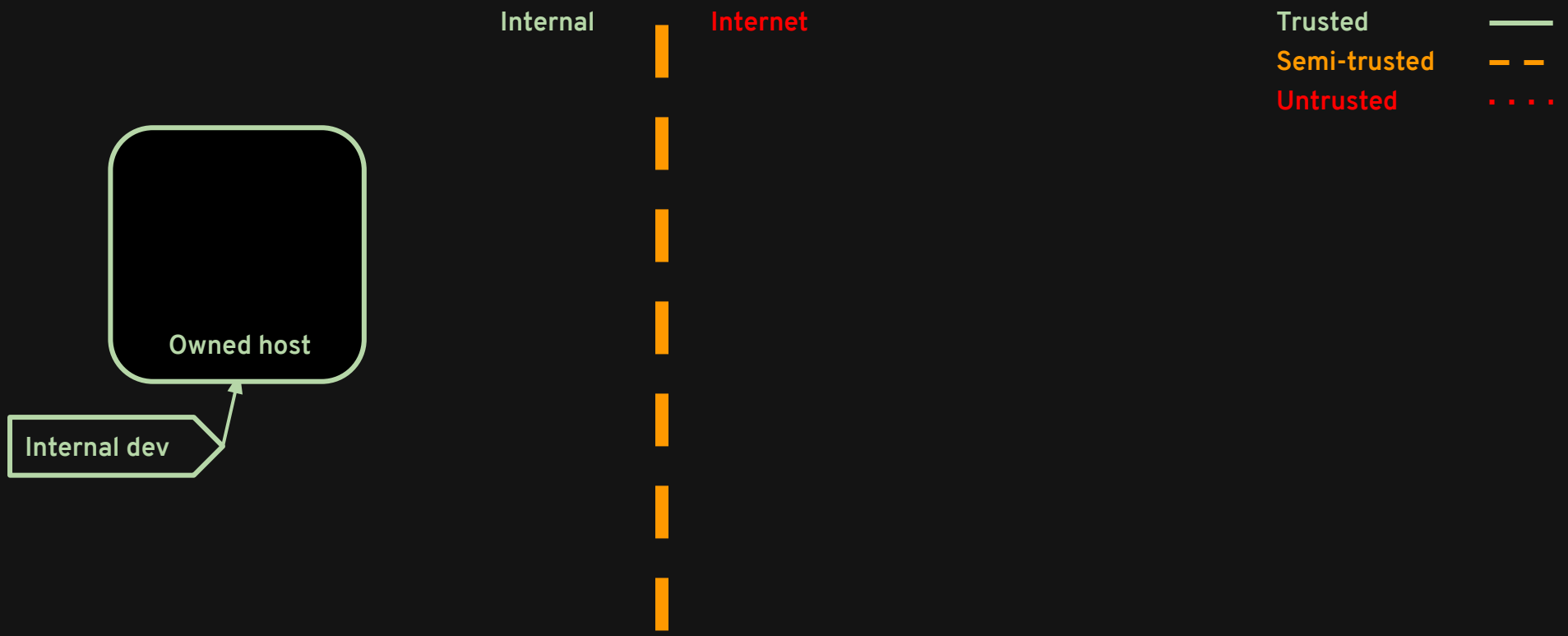
Step 1: on premises



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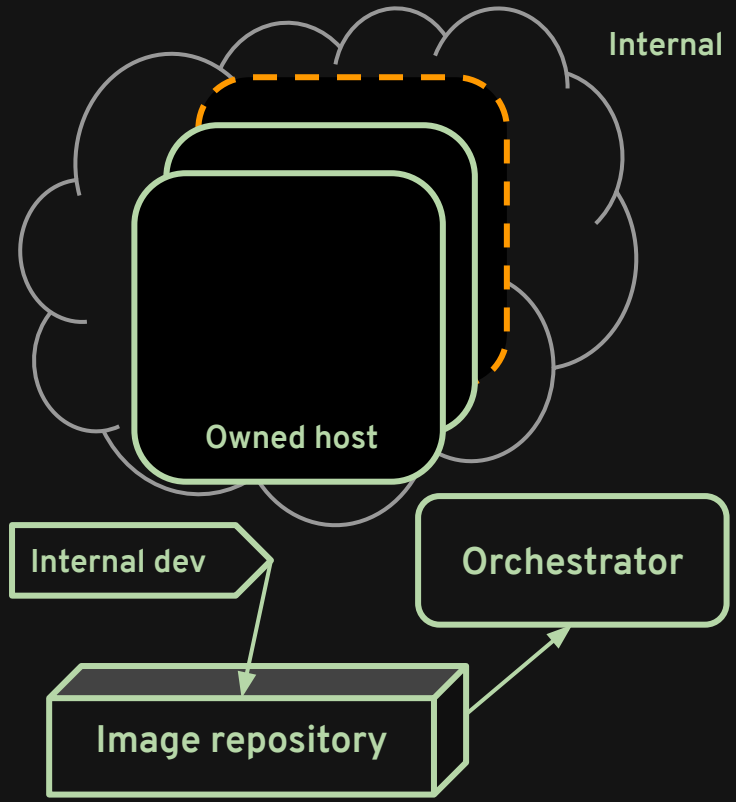
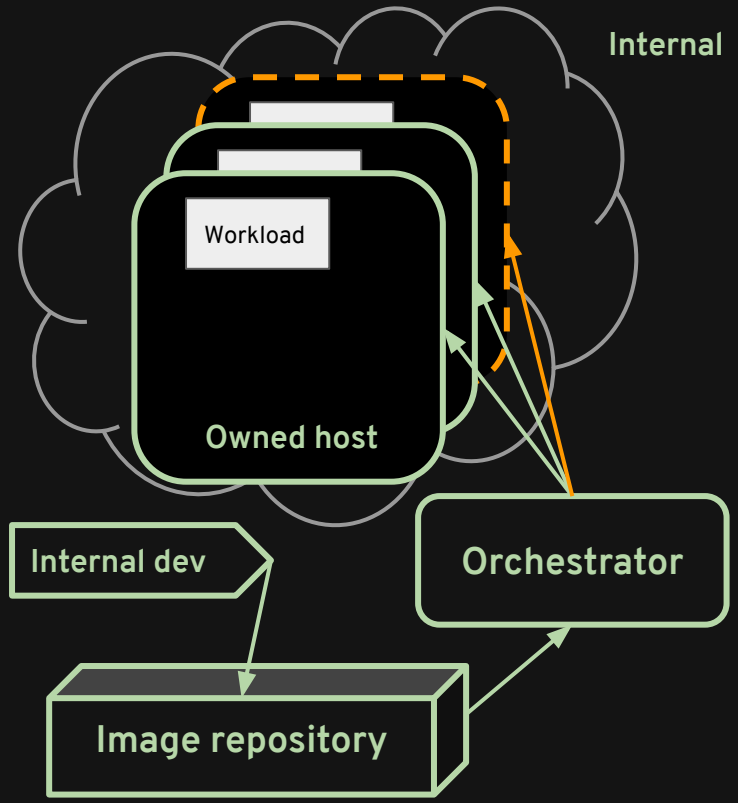
Step 2: private cloud



Trusted
Semi-trusted
Untrusted

Red Hat

Step 2: private cloud



Trusted
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Red Hat

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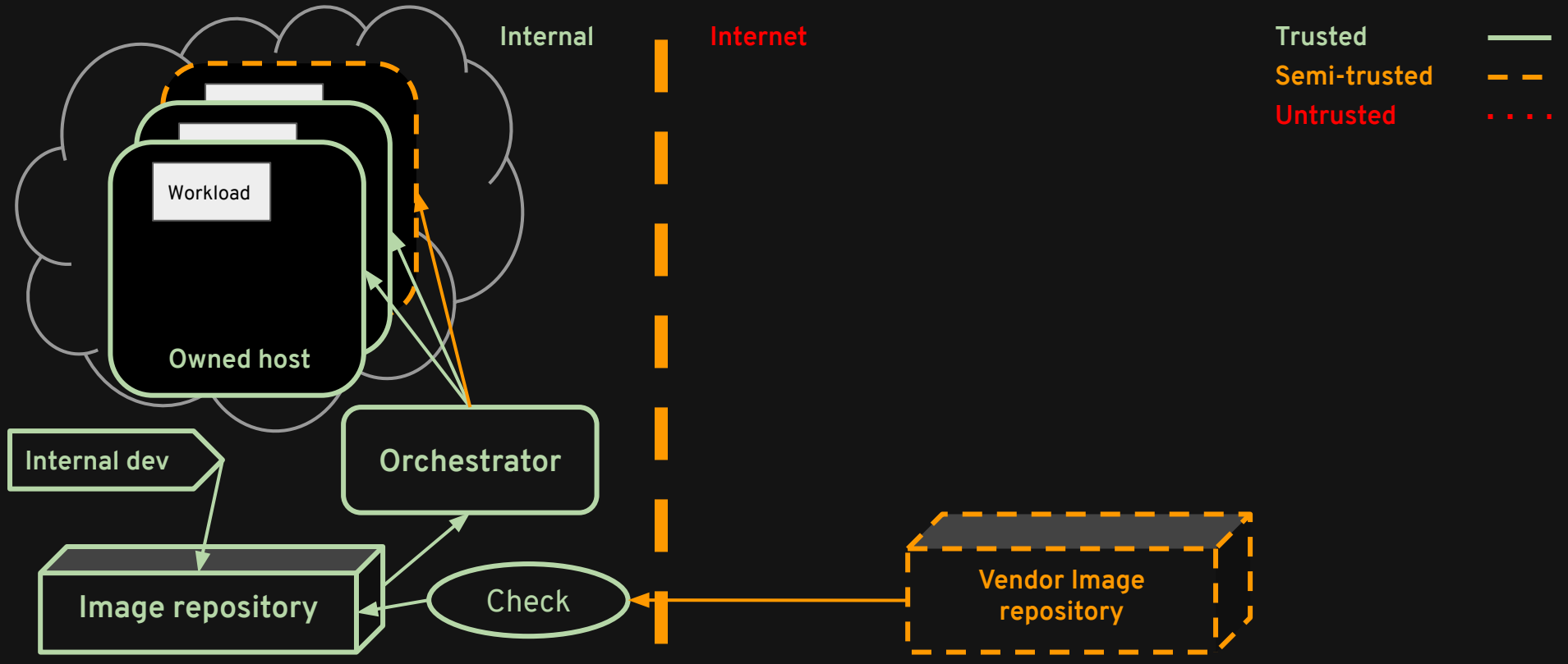
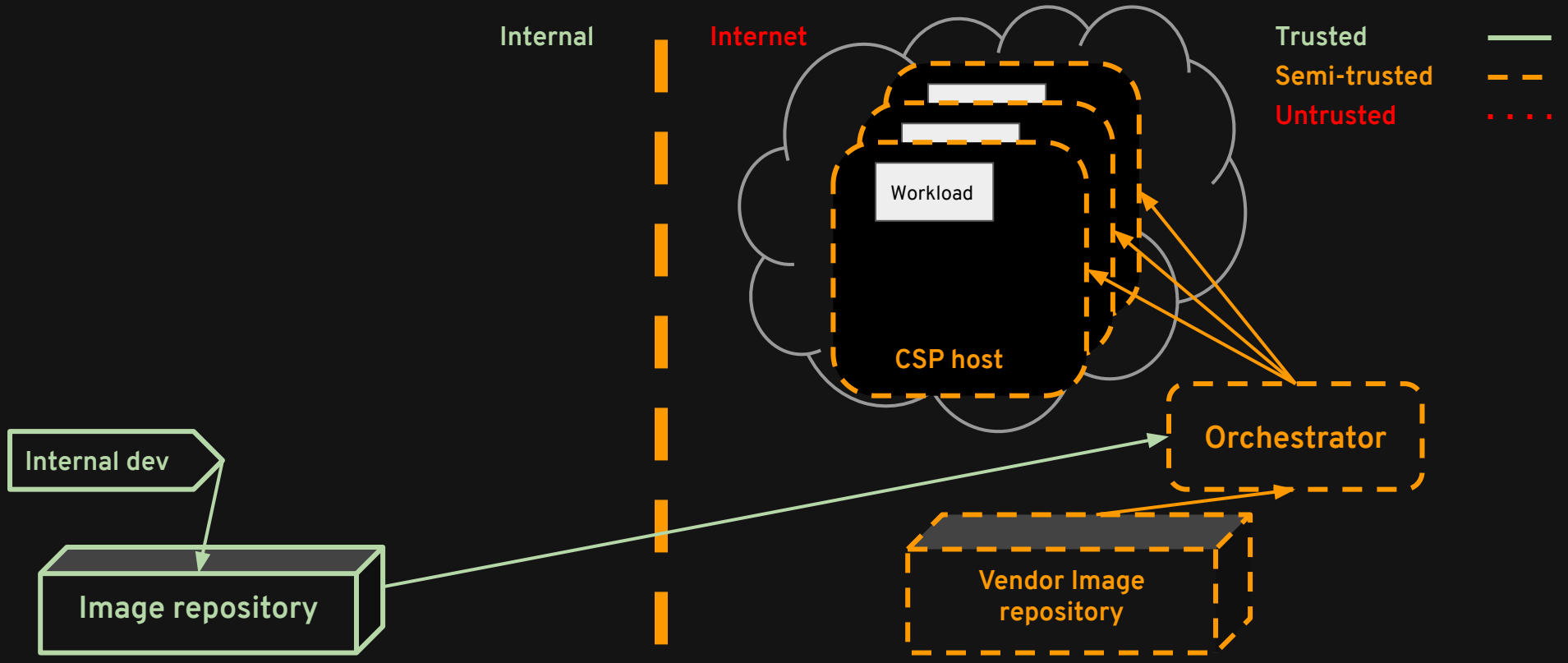
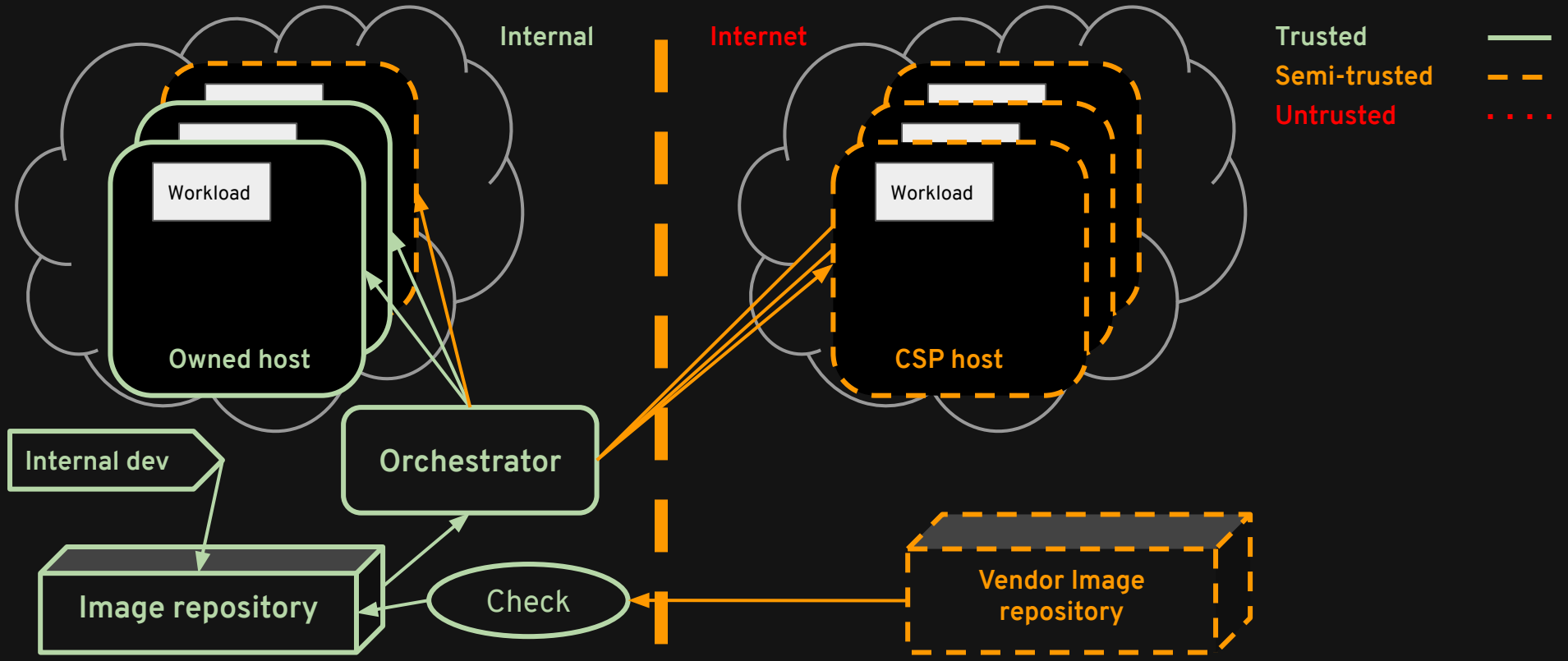


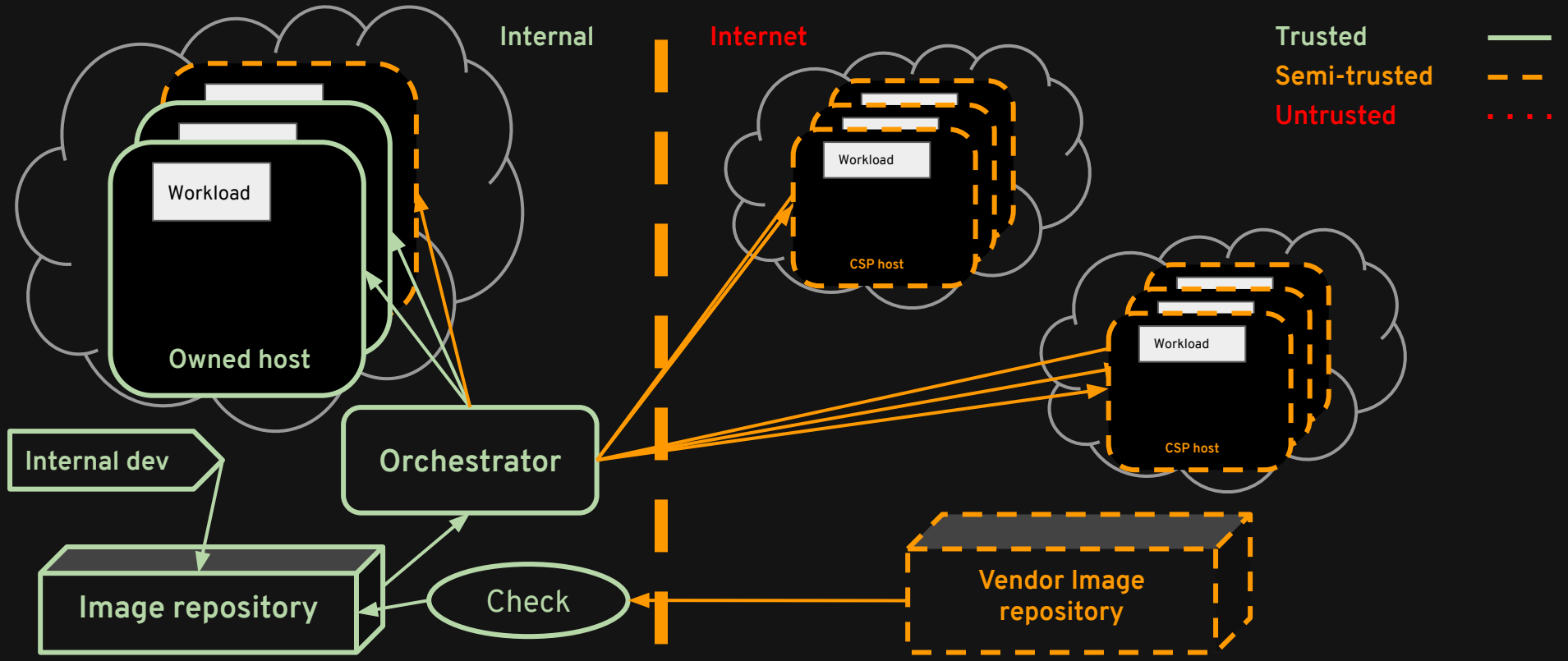
Step 3: public cloud



Step 4: hybrid cloud



Step 5: hybrid multicloud



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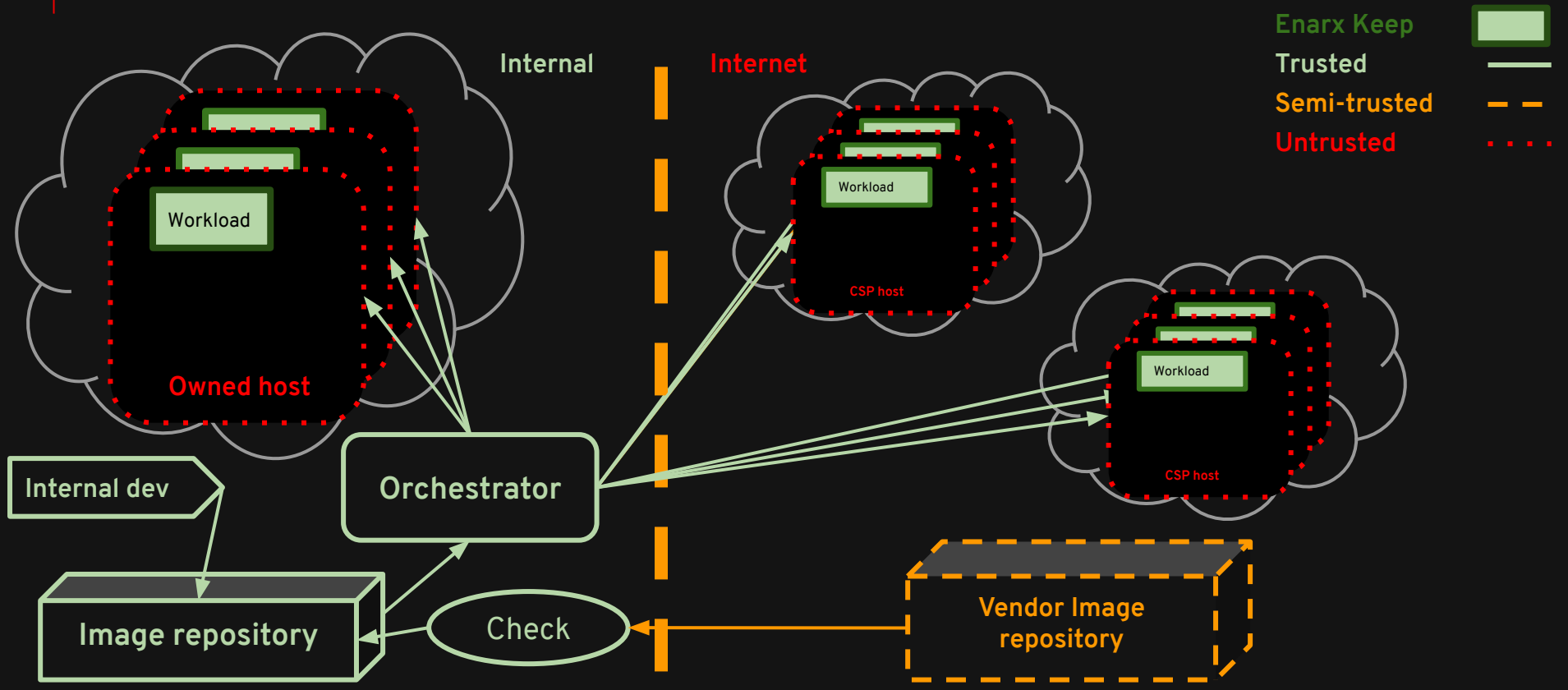
Step 6: Enarx hybrid multicloud



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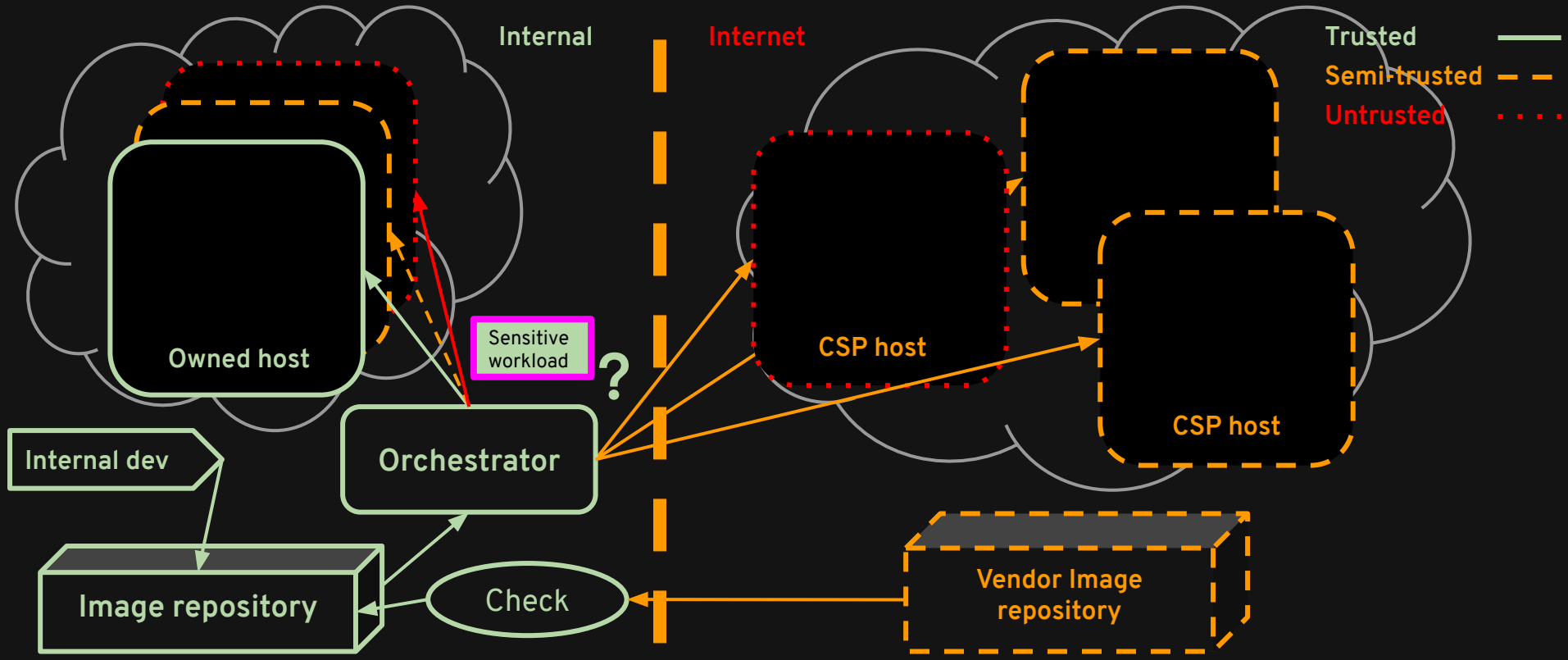
New options for workloads with Enarx

Mix and match for different workload types & Enarx



Red Hat

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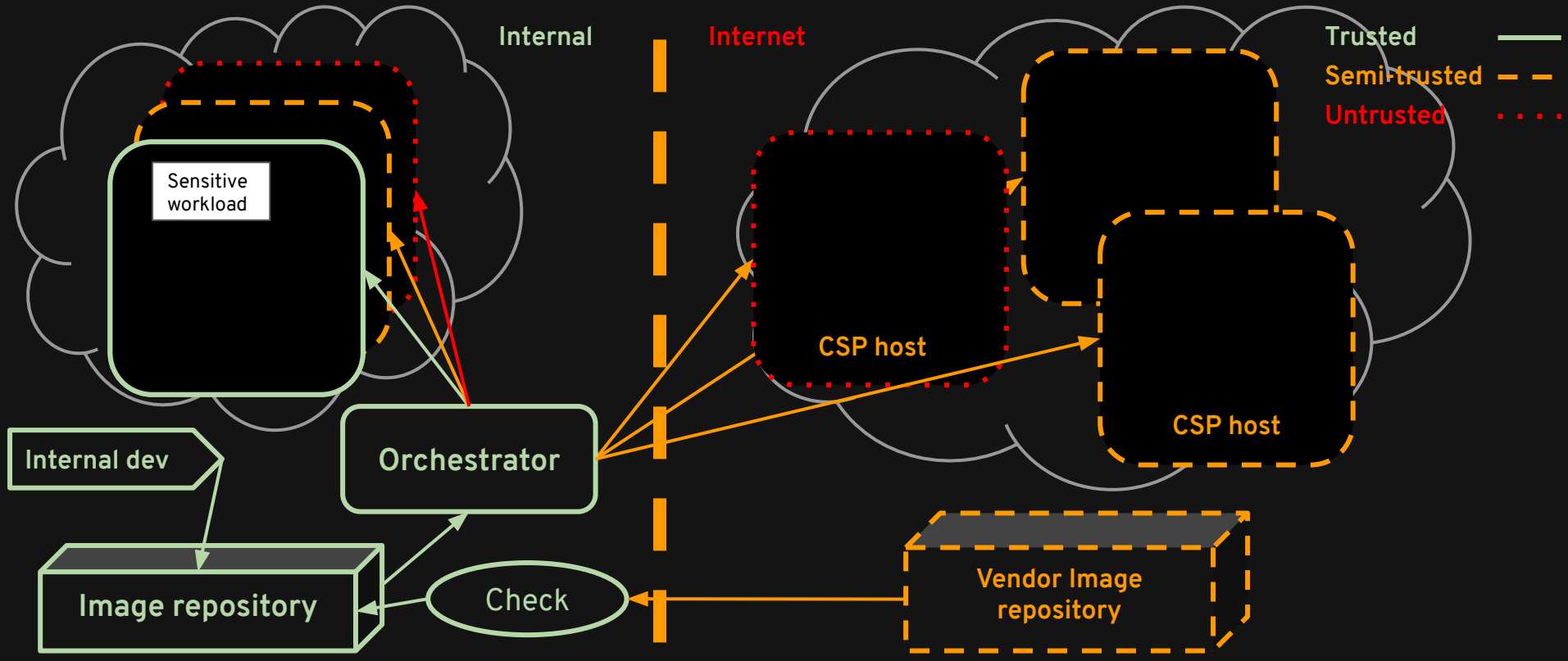

Red Hat

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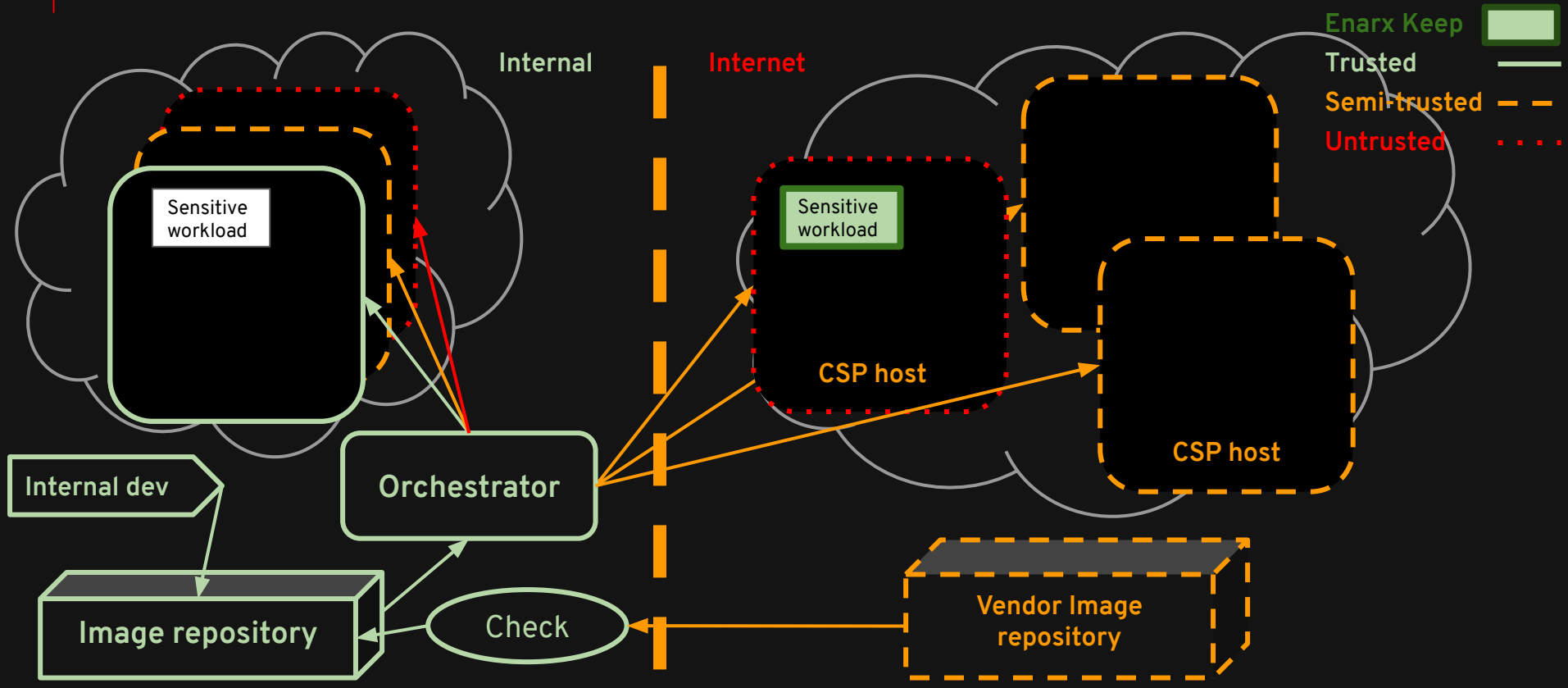

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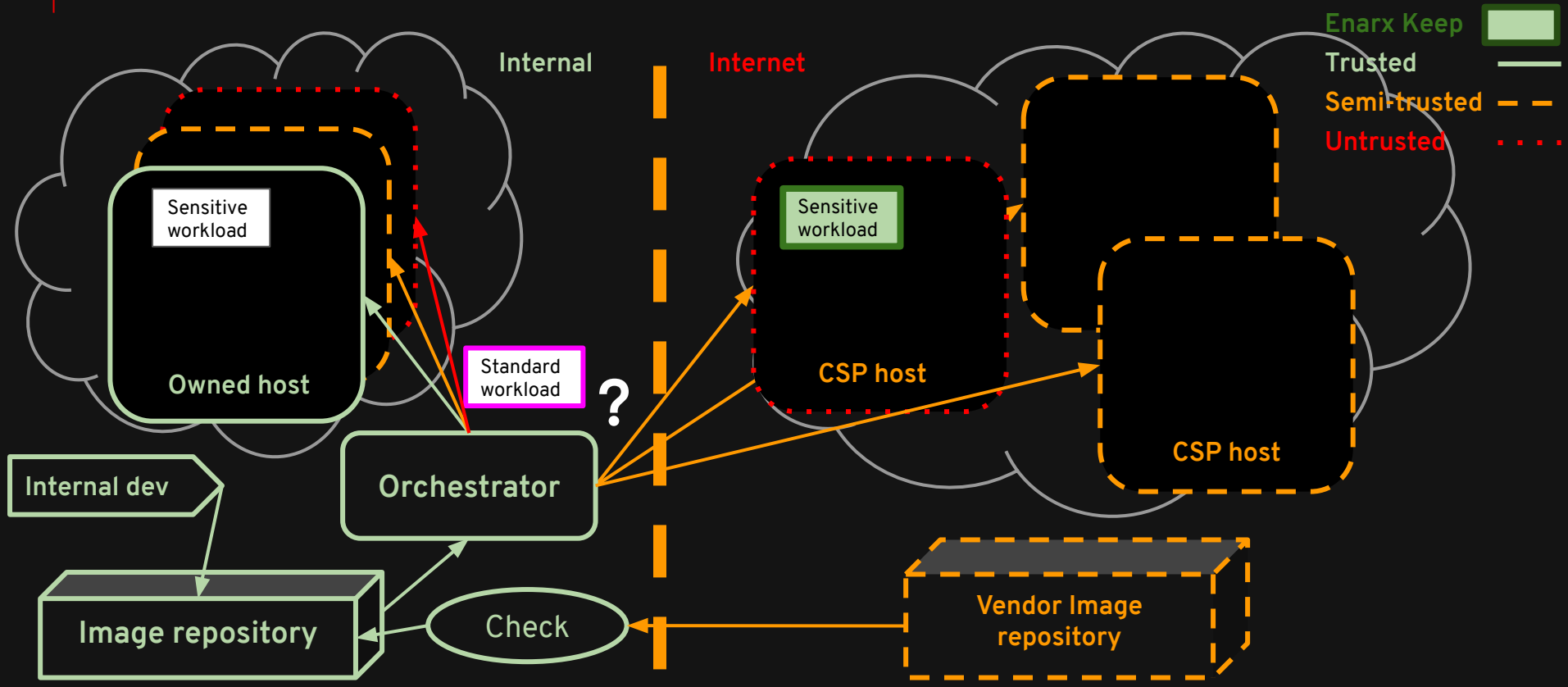

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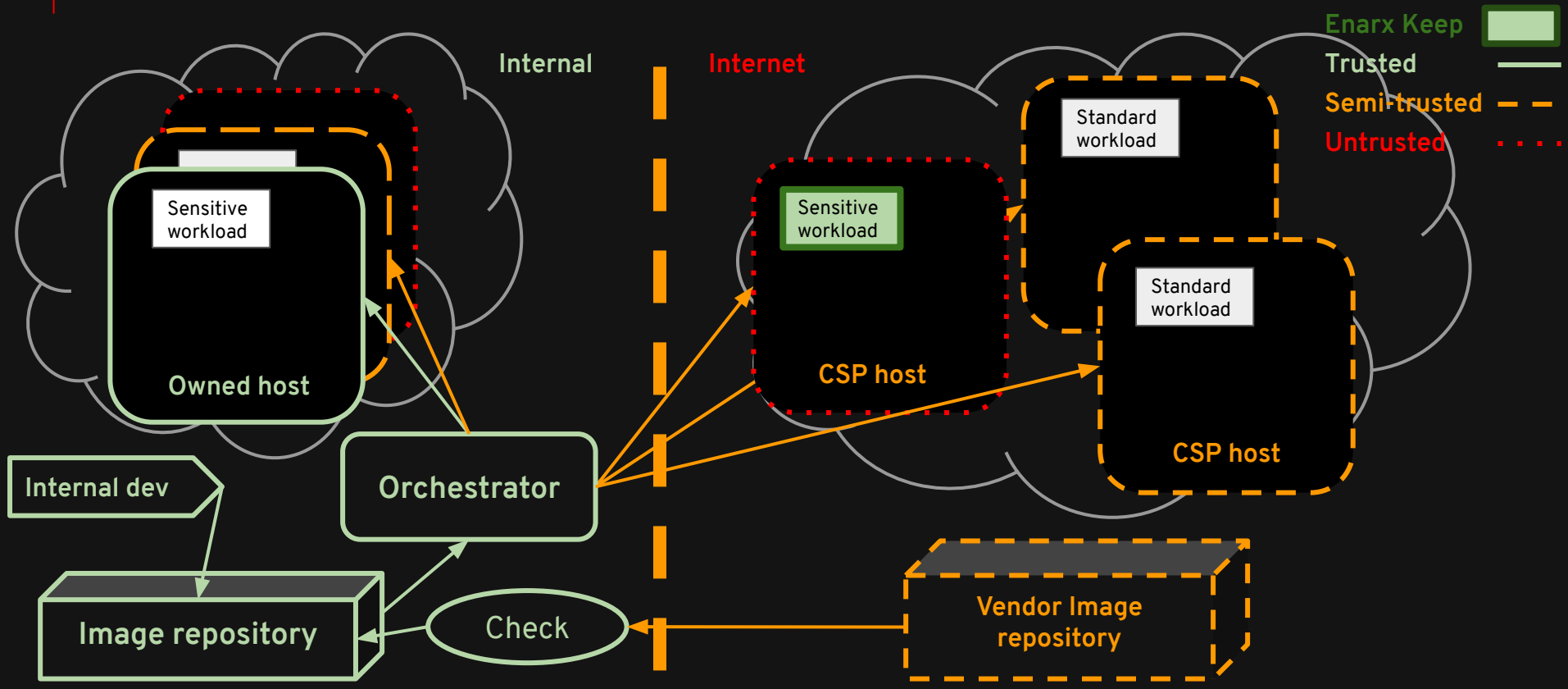

Red Hat

New options for orchestration with Enarx

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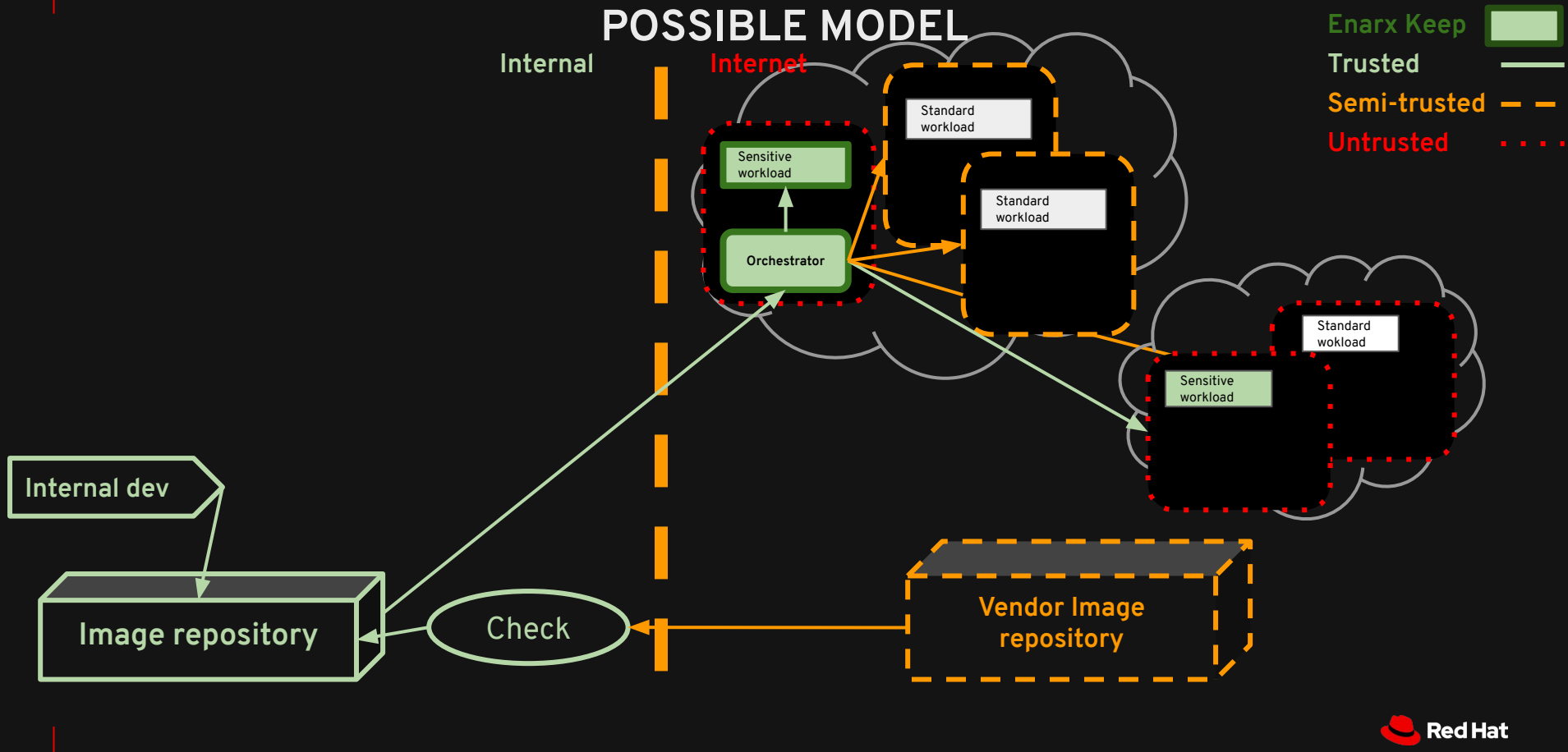

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Value of the trusted stack

How trusted stacks help

Hardware platform

Red Hat

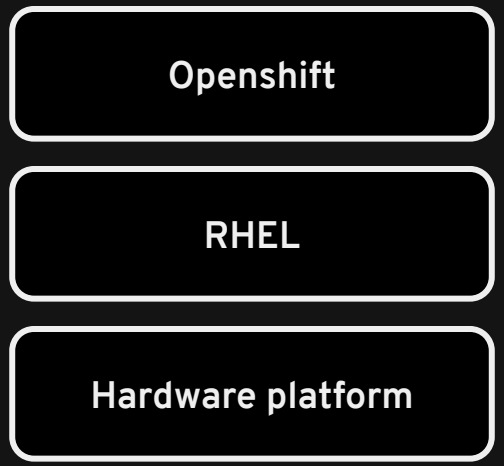
How trusted stacks help

RHEL

Hardware platform

Red Hat

How trusted stacks help



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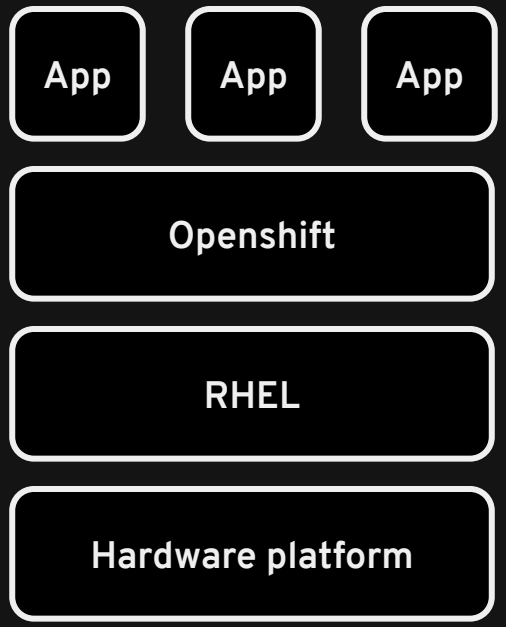

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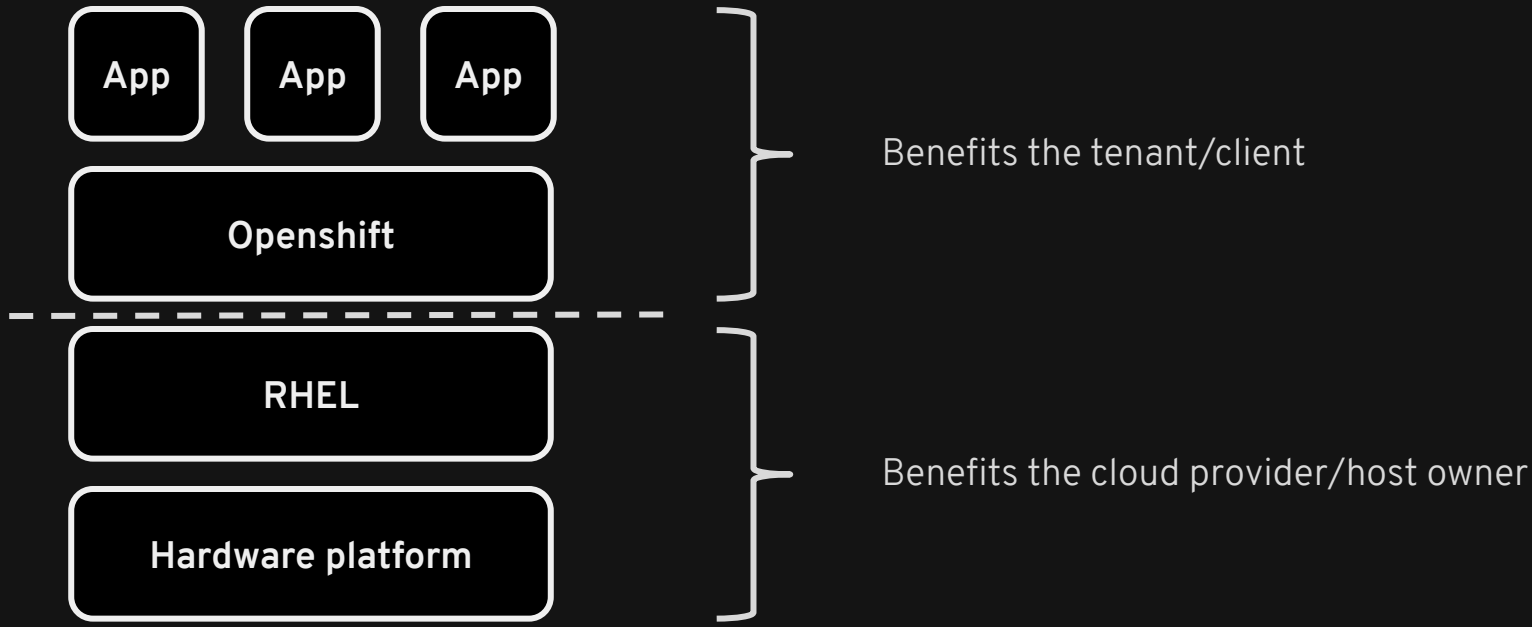
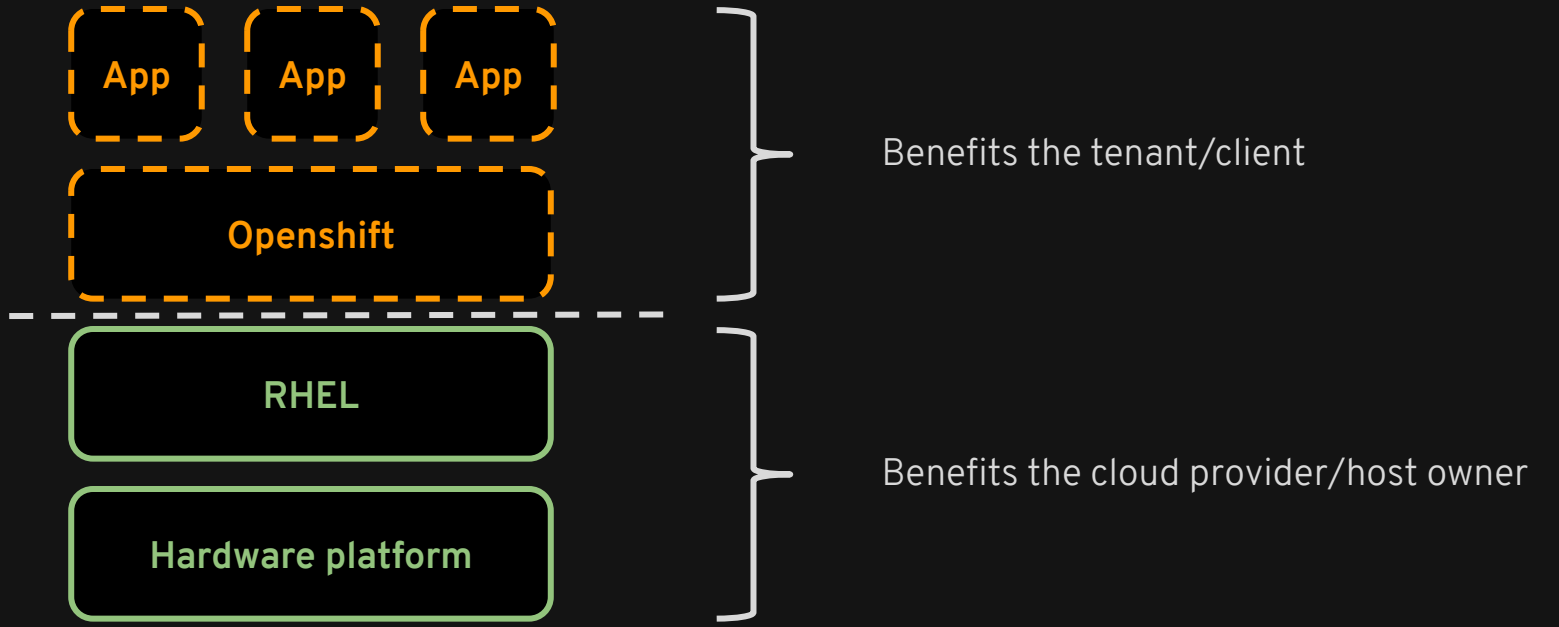


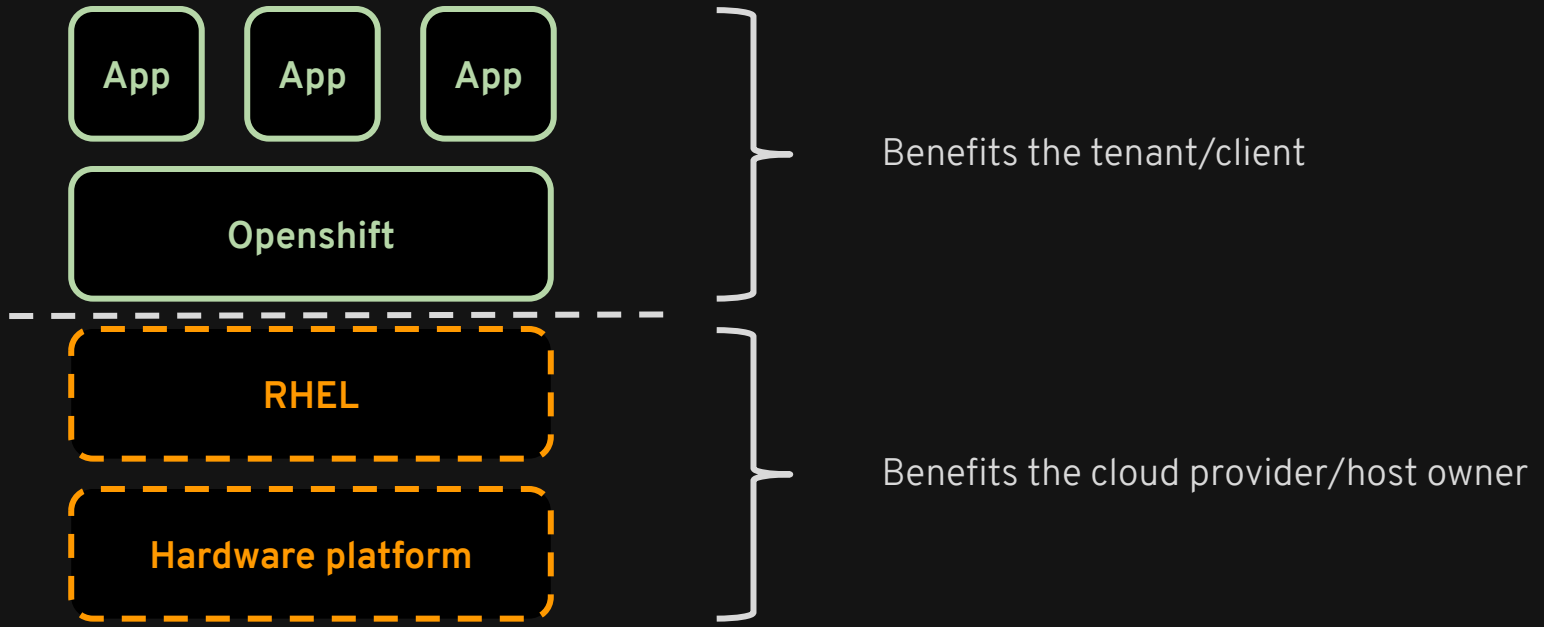
How trusted stacks help

Host view



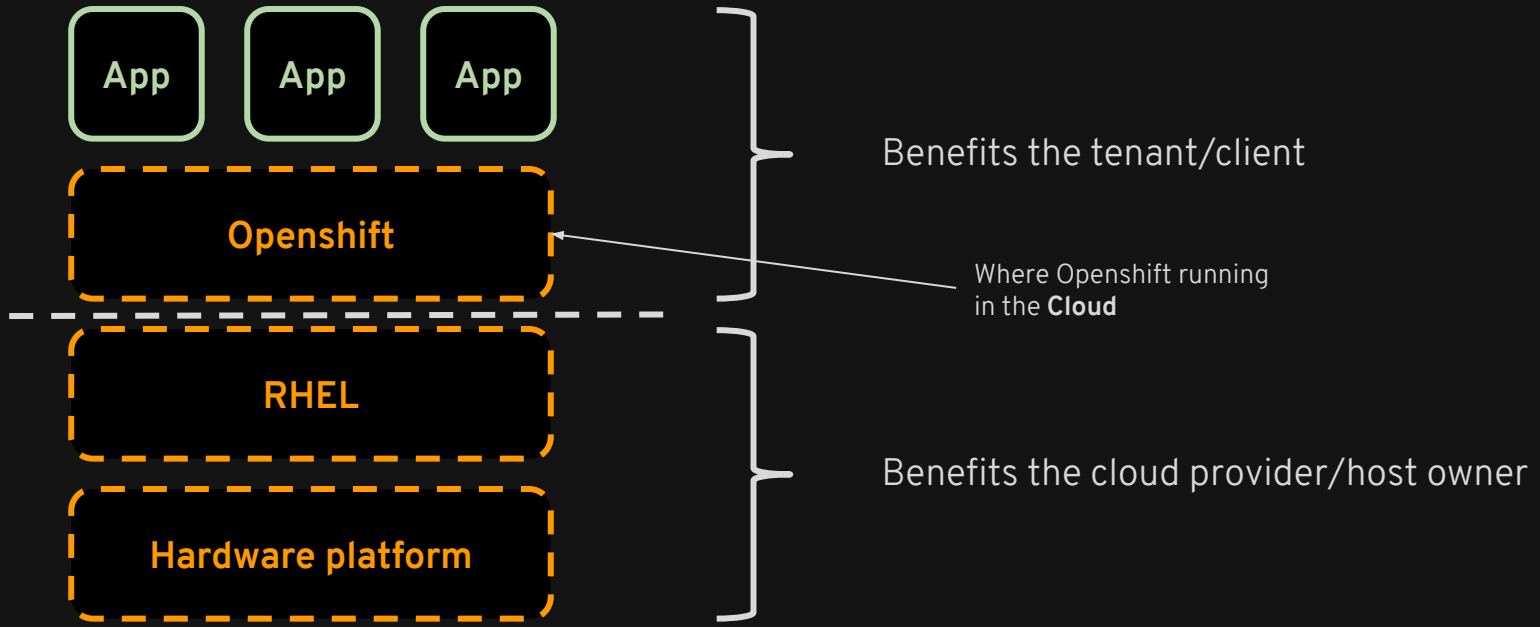
How trusted stacks help

Client view (hoped)



How trusted stacks help

Client view (actual)



Enarx Keep
Trusted
Semi-trusted
Untrusted

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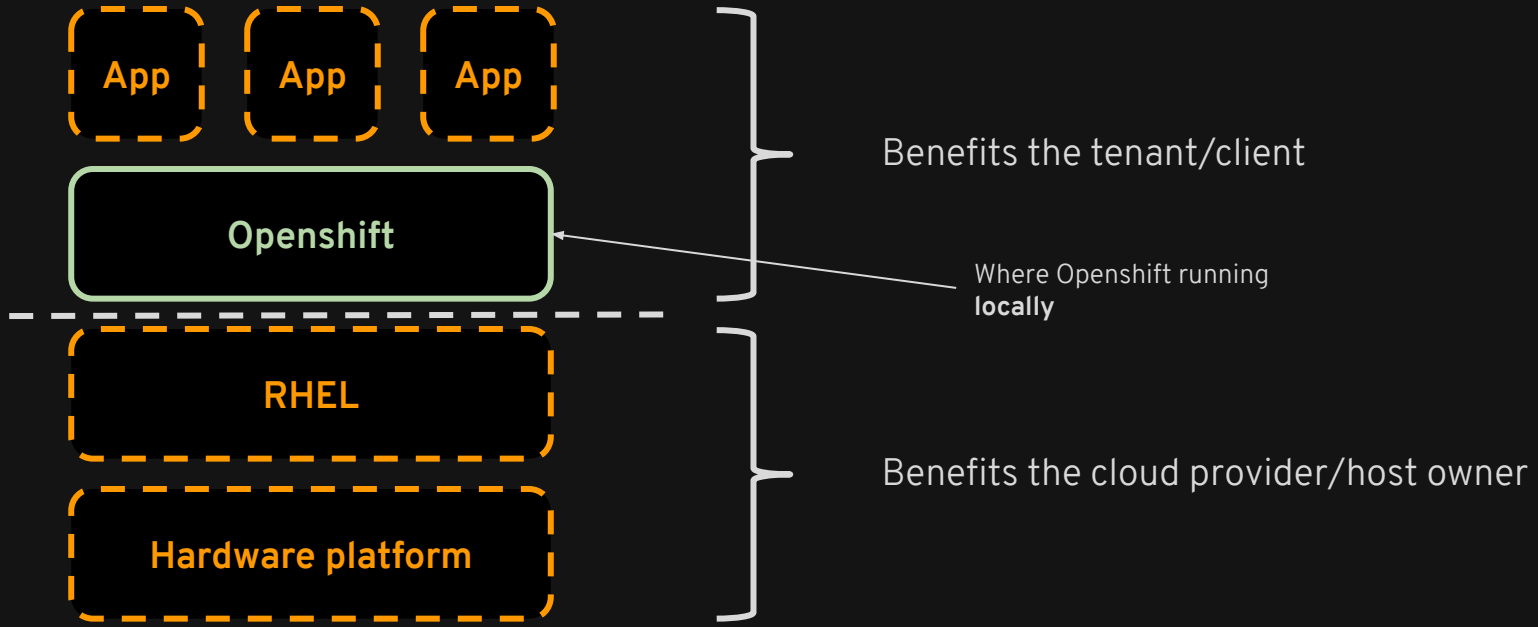
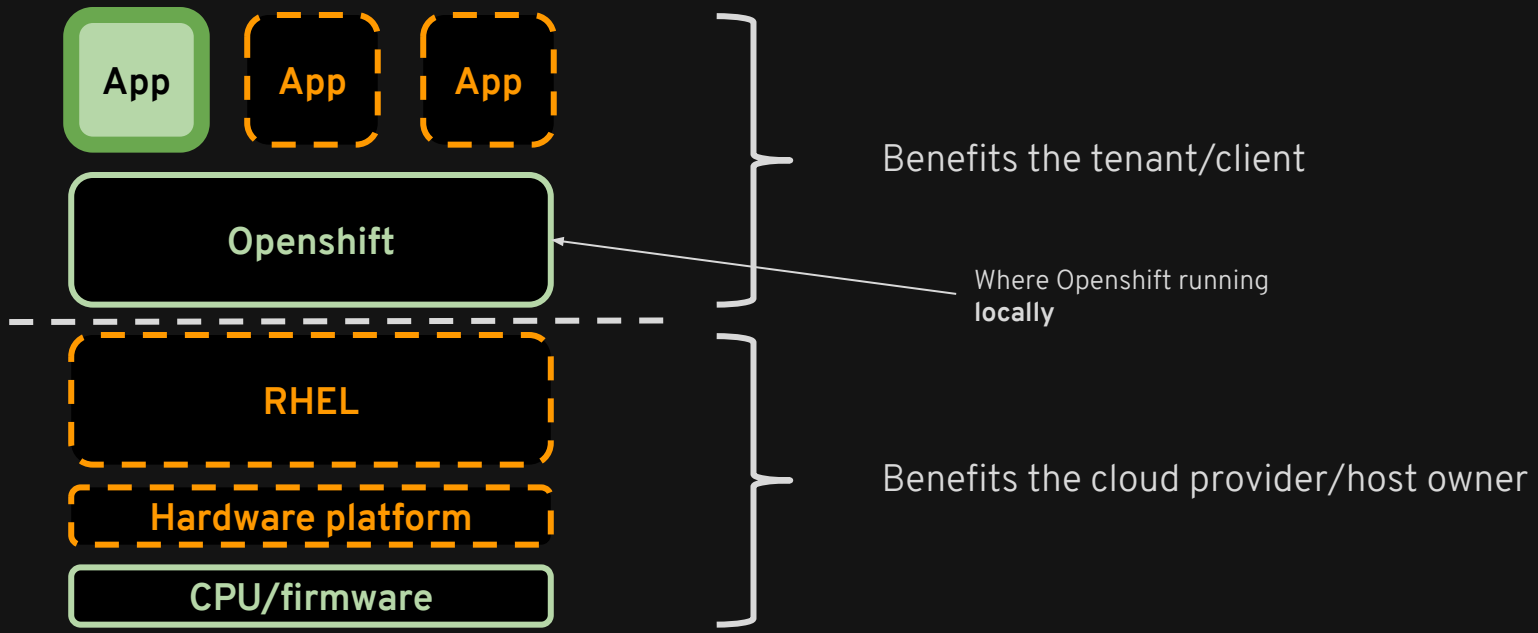
How trusted stacks help

Client view (actual)



How trusted stacks help

Client view (with Enarx)



How trusted stacks help

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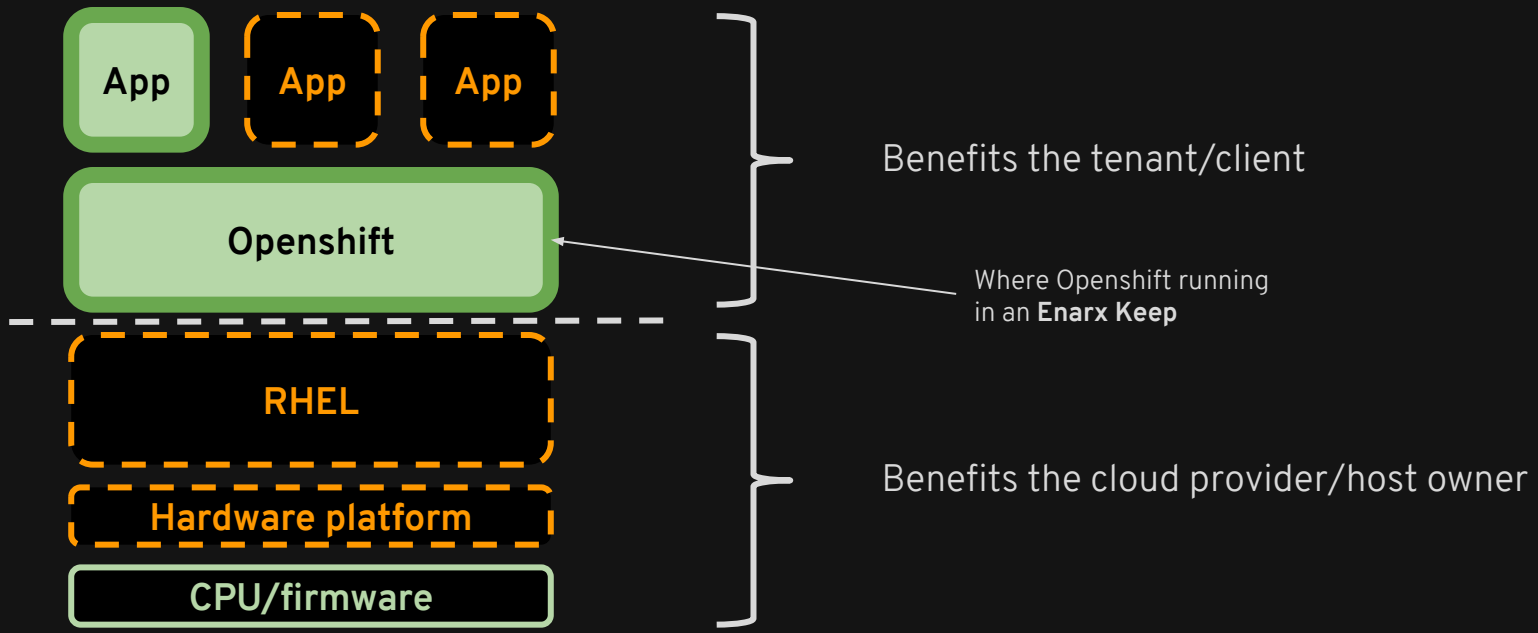
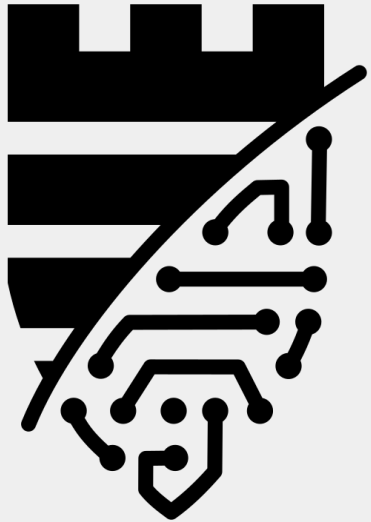


On which technology do I build my application?

Introducing Enarx



Red Hat

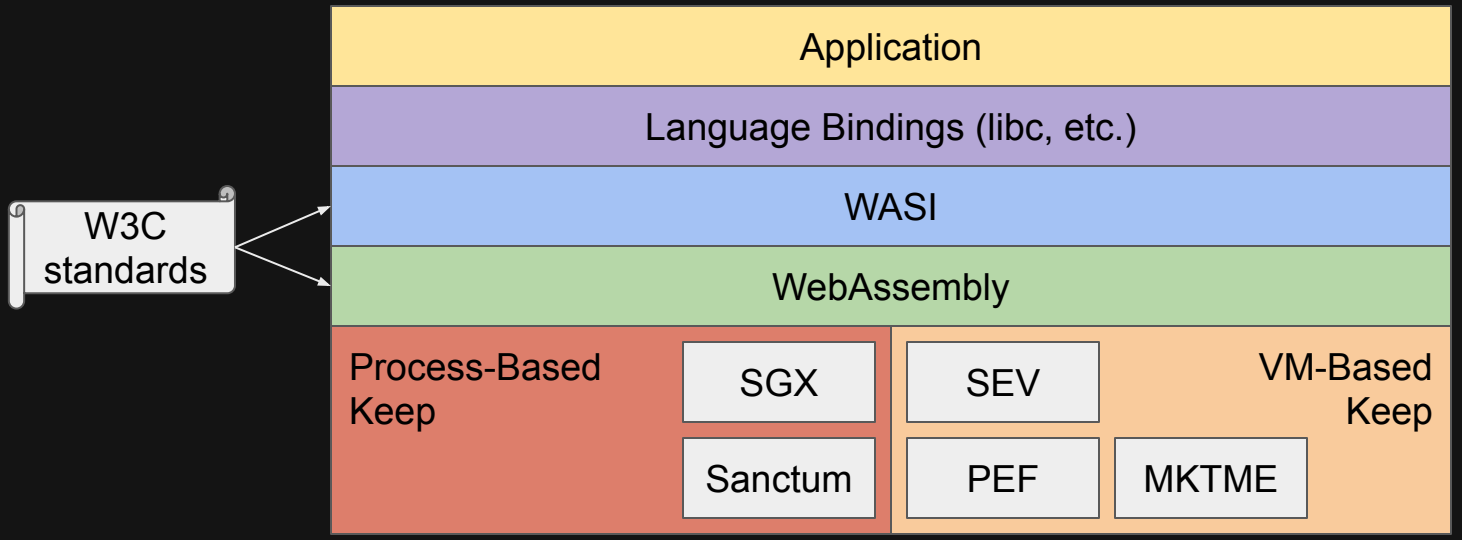
Enarx Principles

1. We don’t trust the host owner
2. We don’t trust the host software
3. We don’t trust the host users
4. We don’t trust the host hardware
    a. … but we’ll make an exception for CPU + firmware

Enarx Design Principles

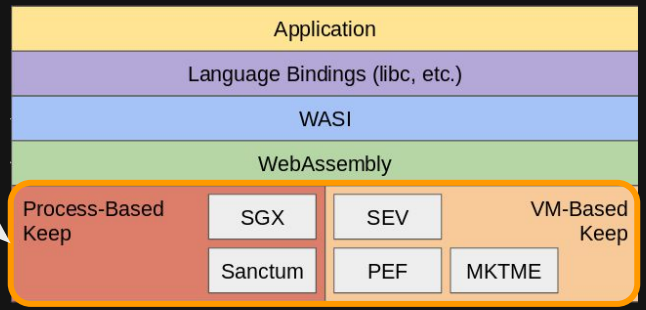
1. Minimal Trusted Computing Base
2. Minimum trust relationships
3. Deployment-time portability
4. Network stack outside TCB
5. Security at rest, in transit and in use
6. Auditability
7. Open source
8. Open standards
9. Memory safety
10. No backdoors

Enarx Architecture



Keep - process or VM-based

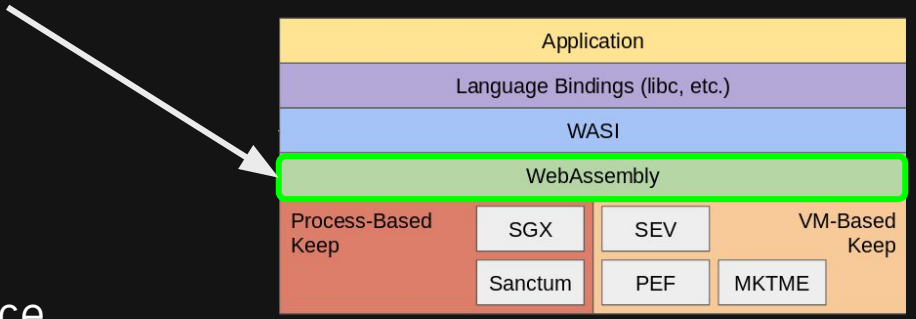
- Core Keep
- Platform-specific
  - Hardware (CPU): silicon vendor
  - Firmware: silicon vendor
  - Software: Enarx



Architecture varies between VM/Process-based platforms

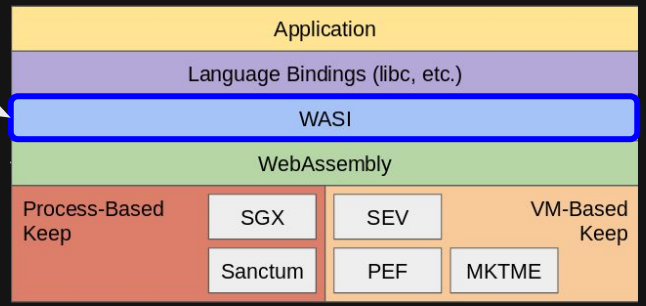
WebAssembly (WASM)

- W3C standard
- Stack Machine ISA
- Sandboxed
- Supported by all browsers
- Exploding in the “serverless” space
- Implementations improving rapidly
  - cranelift and wasmtime



WebAssembly System API (WASI)

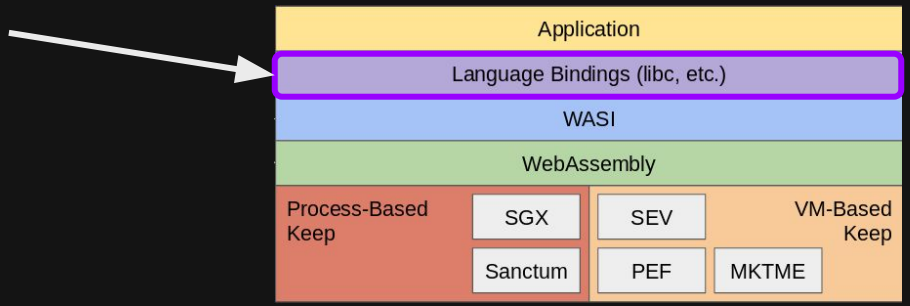
- W3C Standards Track
- Heavily inspired by a subset of POSIX
- Primary goals:
  - Portability
  - Security
- libc implementation on top
- Capability-based security:
  - No absolute resources
  - Think: openat() but not open()



Language Bindings (libc, etc.)

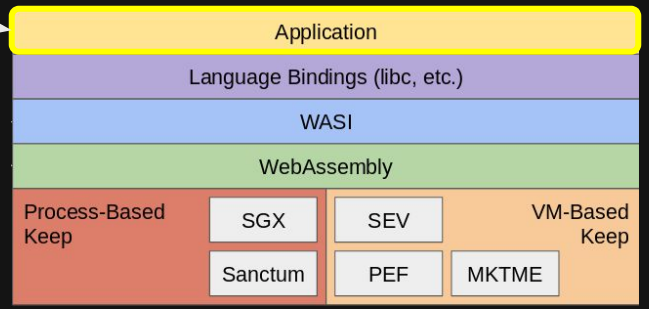
Compilation targets and includes, e.g.

- Rust: `--target wasm32-wasi`

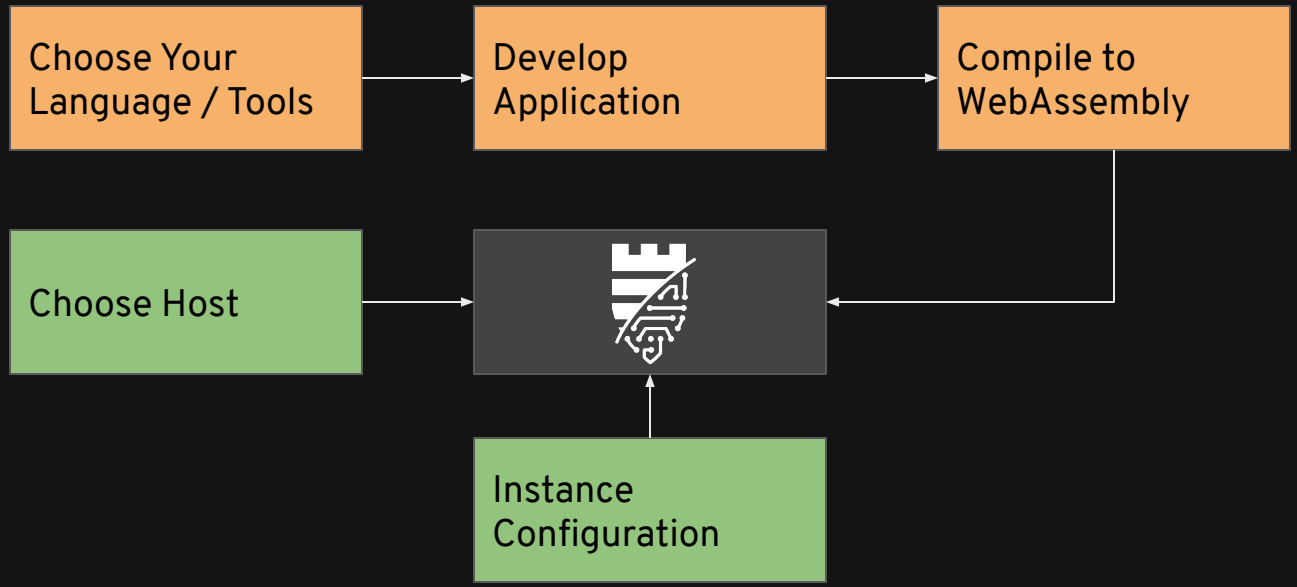


Application

- Written by
  - Tenant (own development)
    OR
  - 3rd party vendor
- Standard development tools
- Compiled to WebAssembly
- Using WASI interface

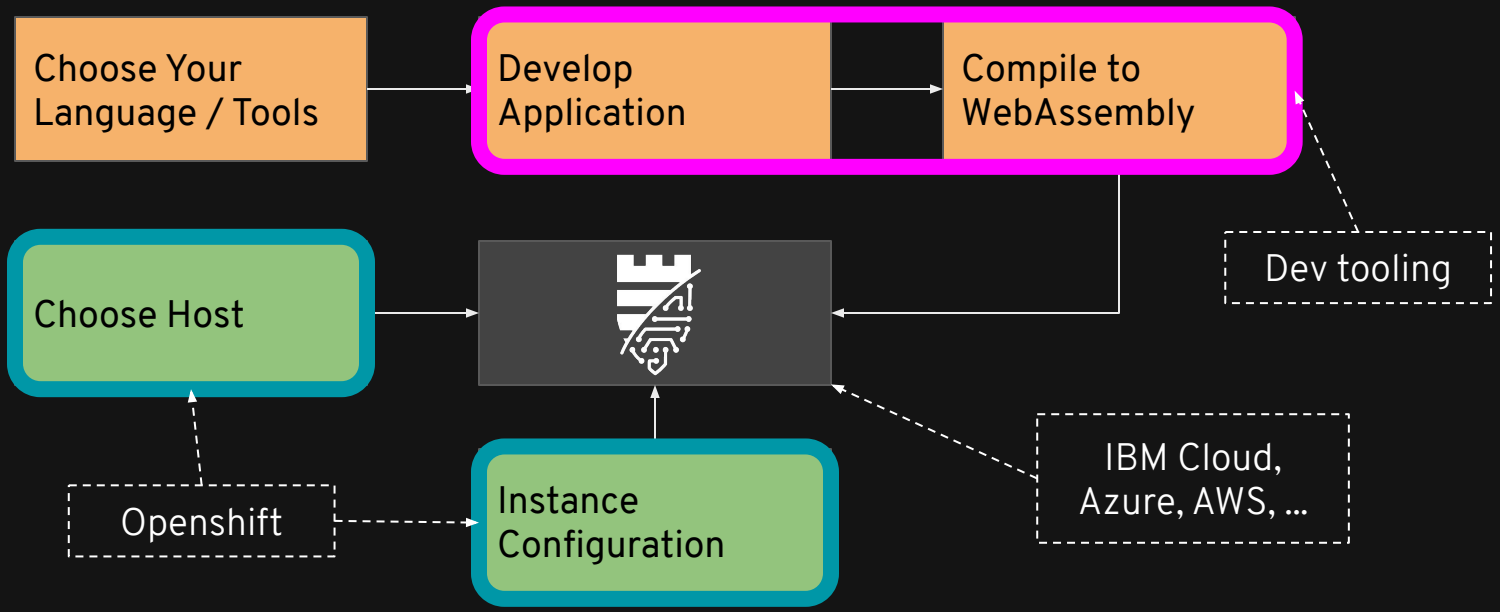


Enarx is a ~~Development~~ Deployment Framework



Enarx is a ~~Development~~ Deployment Framework

(Example components)



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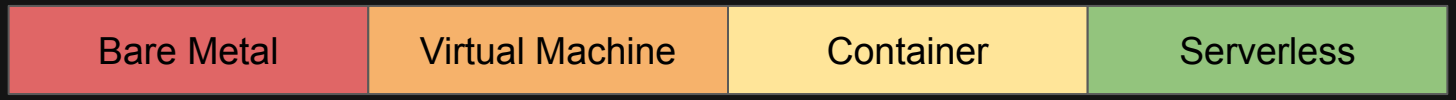
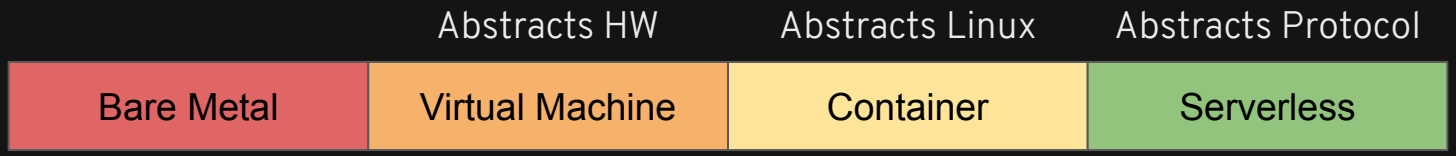
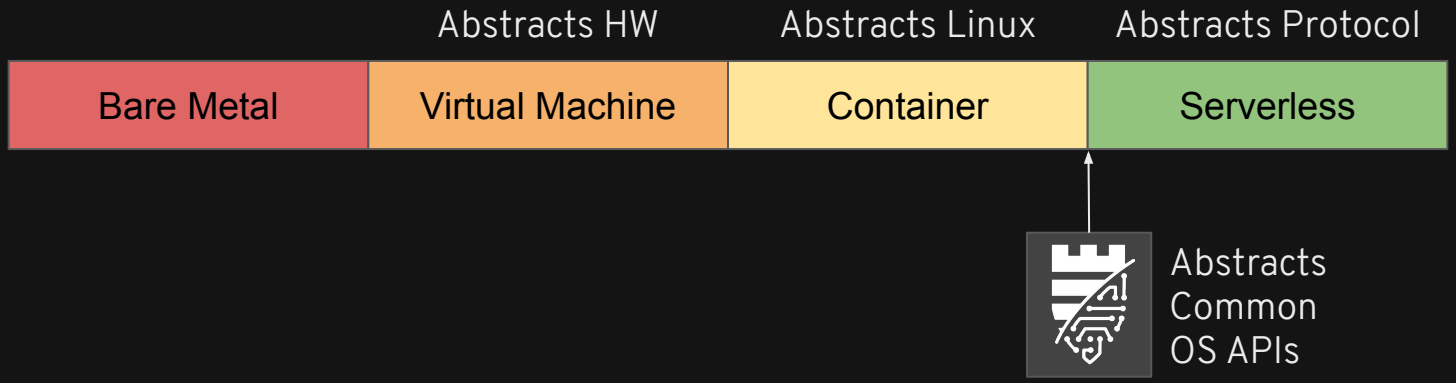
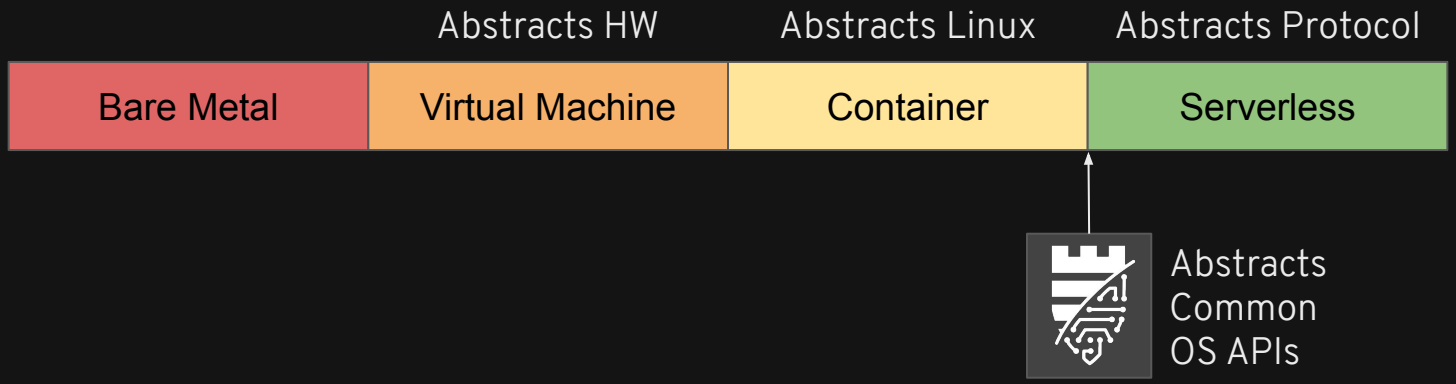
Best Practices? On By Default.

1. No Plaintext Networking (see **`cipherpipe`**)
2. No Plaintext Persisted Data
3. Independent Keep RNG
4. All Host APIs reviewed for data leakage


Bare Metal
Virtual Machine
Container
Serverless


Abstracts HW
Abstracts Linux
Abstracts Protocol
Bare Metal
Virtual Machine
Container
Serverless

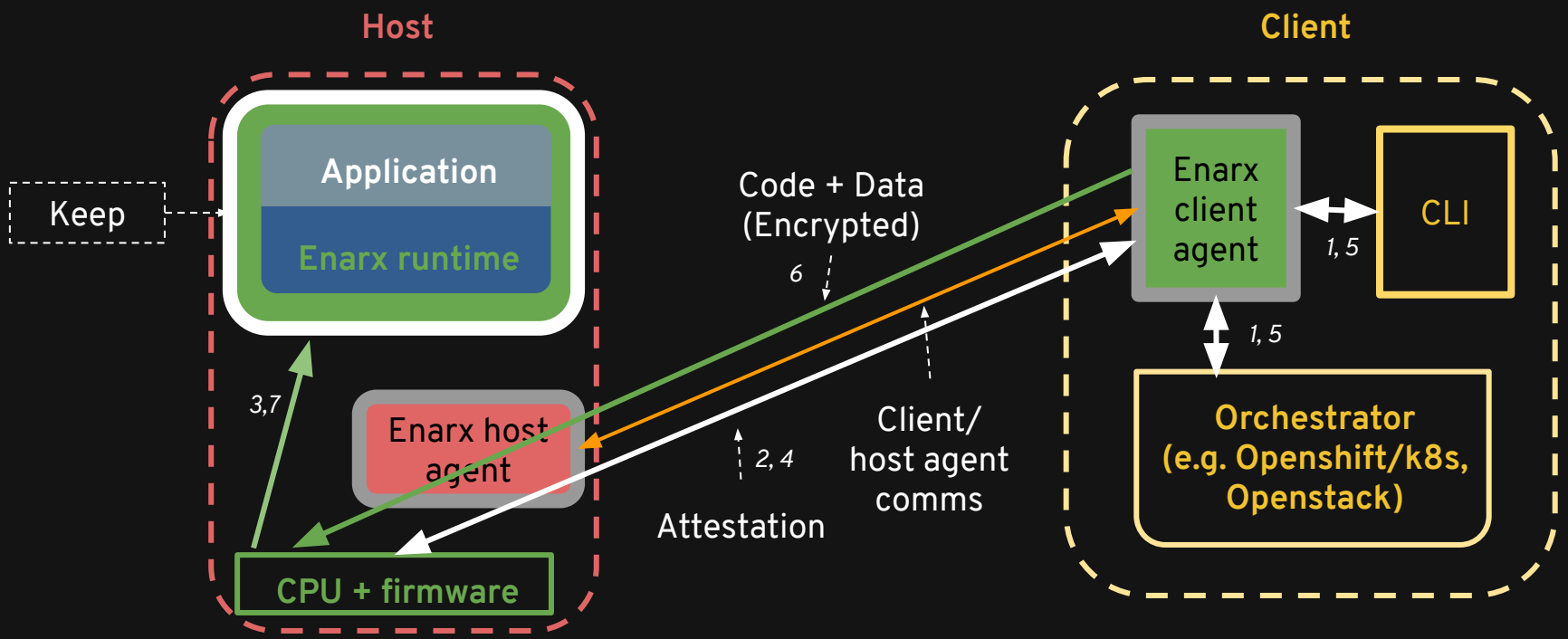

Abstracts HW
Abstracts Linux
Abstracts Protocol
Bare Metal
Virtual Machine
Container
Serverless
Abstracts
Common
OS APIs



Just enough legacy support to enable trivial application portability.
Homogeneity to enable radical deployment-time portability.
No interfaces which accidentally leak data to the host.
Bridges process-based and VM-based TEE models.
No operating system to manage.

Process flow

Enarx architectural components



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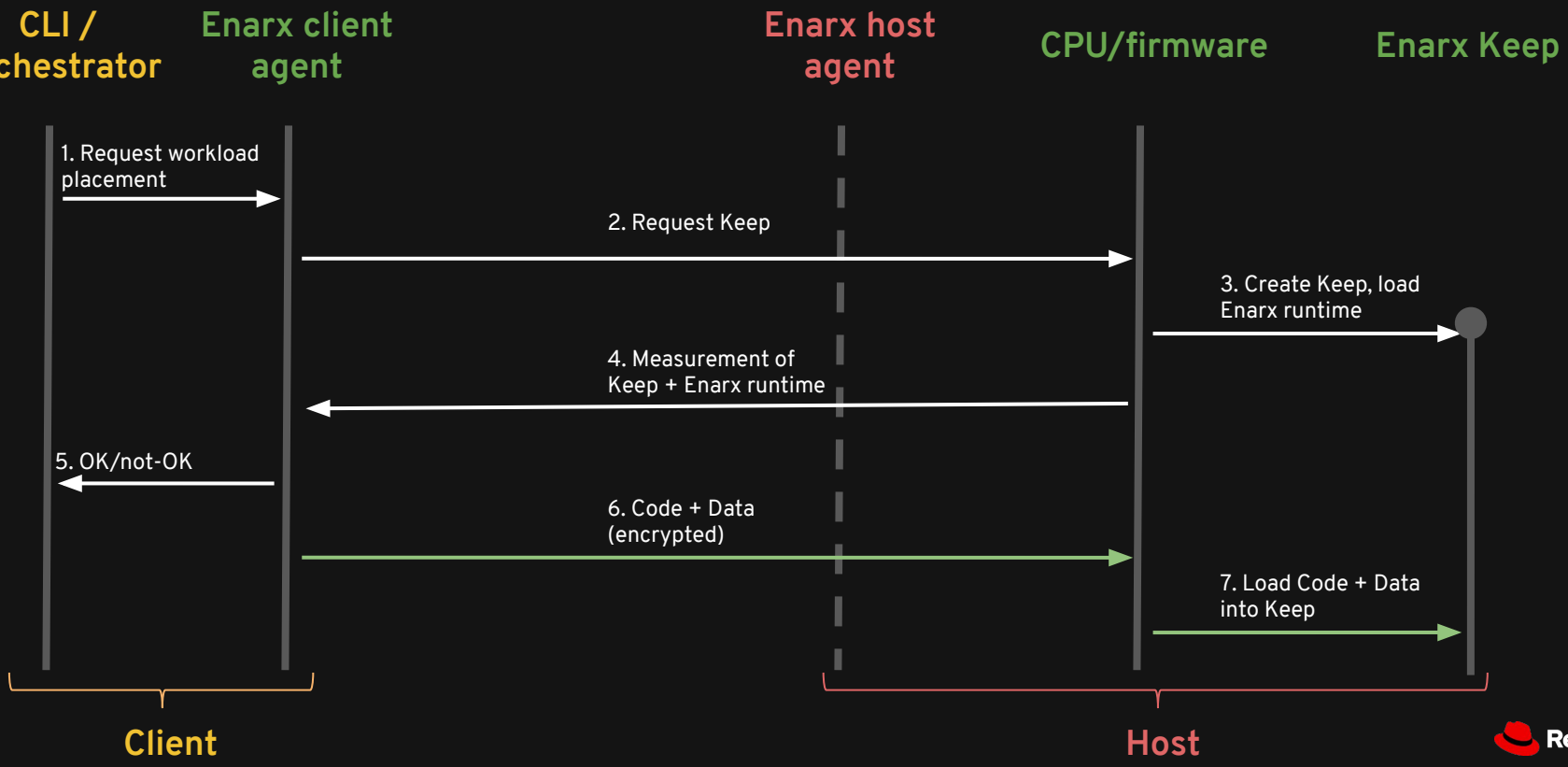
Enarx attestation process diagram



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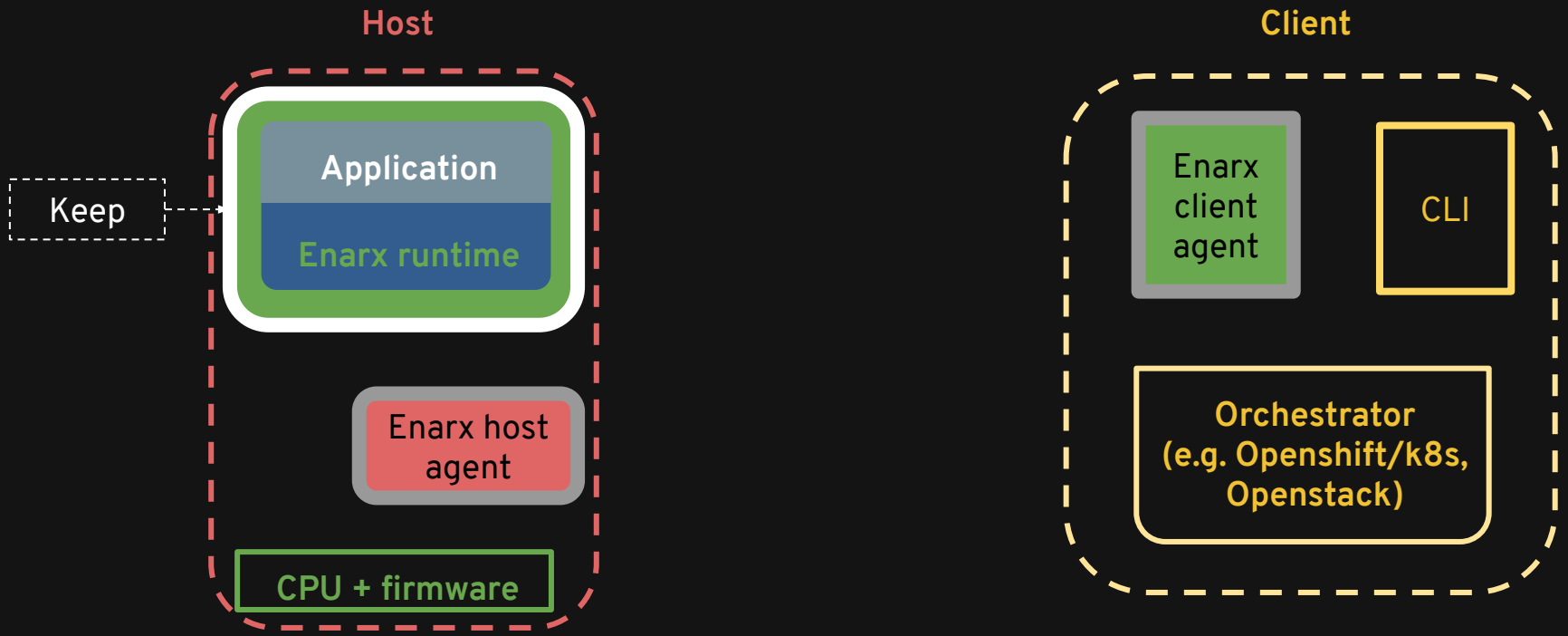
Enarx architectural components



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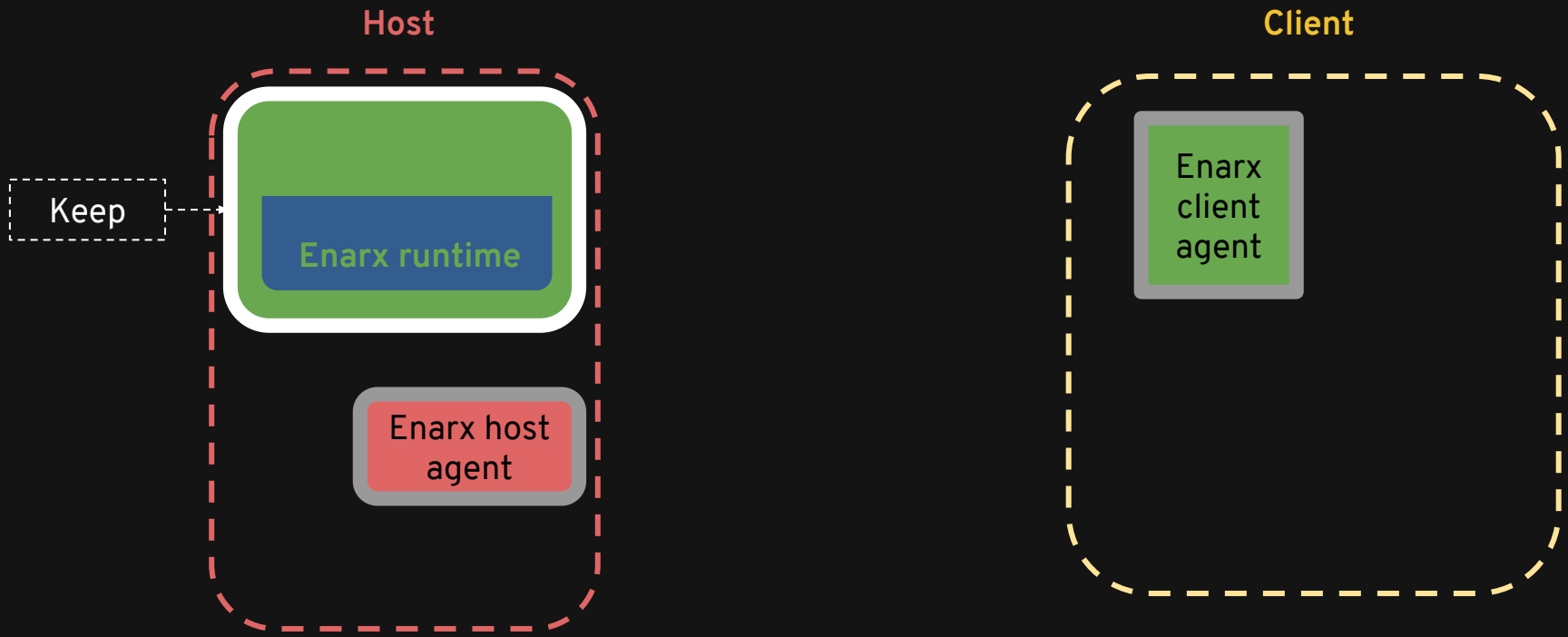
Enarx architectural components



Enarx architectural components

Enarx Keep - trusted
Measured and attested
WebAssembly+WASI runtime
Inside a TEE instance

Enarx client agent

Enarx client agent - trusted
Works with orchestration/CLI
Manages attestation
Applies policy
Encrypts and transports workload

Enarx host agent

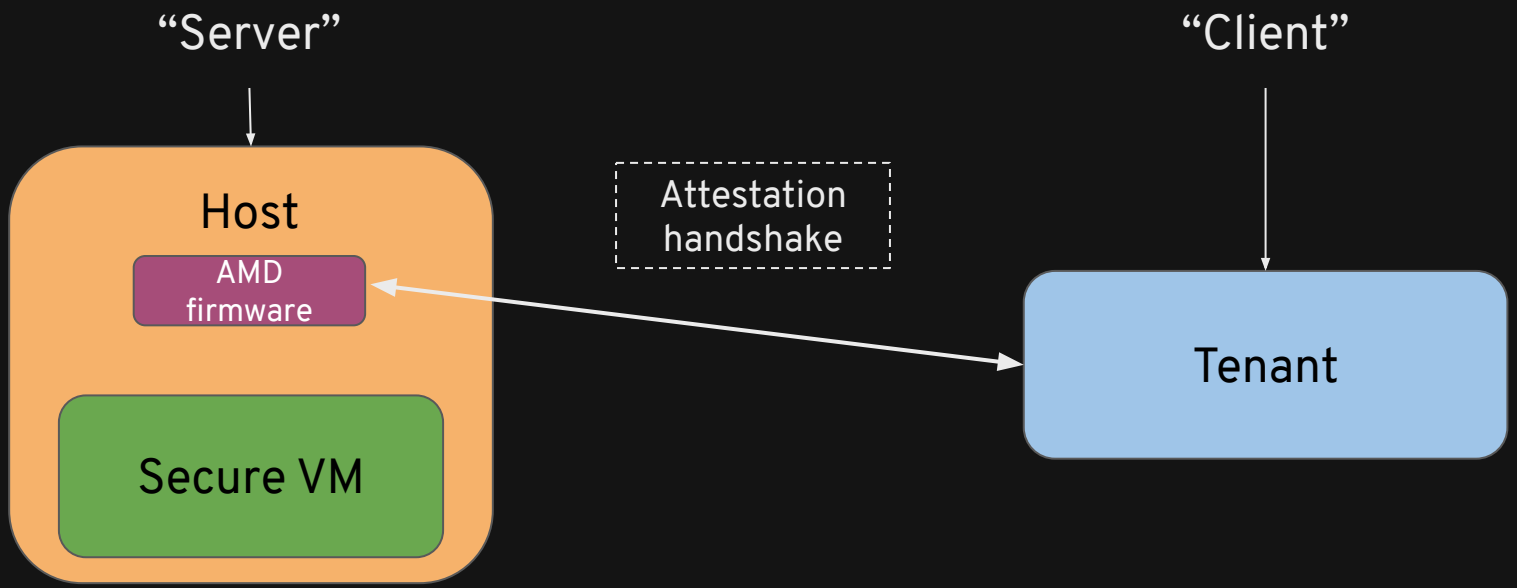
Enarx host agent - untrusted
Acts a proxy between Enarx client agent and:

- CPU/firmware
- Enarx Keep

Demo Time!

What will I see?

What will I see?



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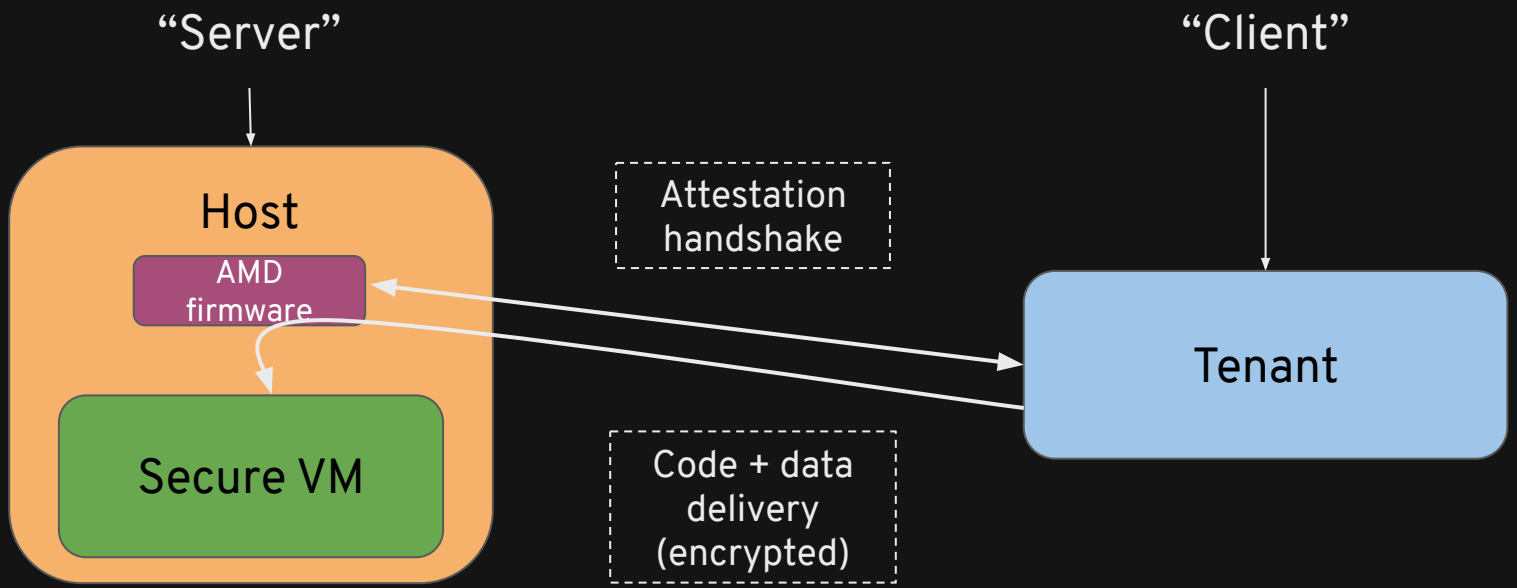
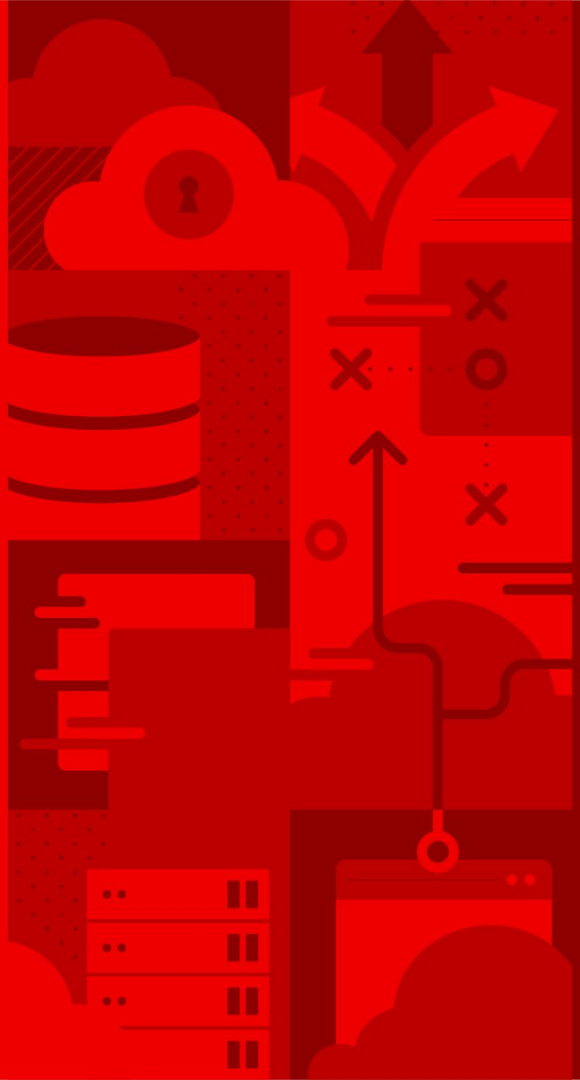
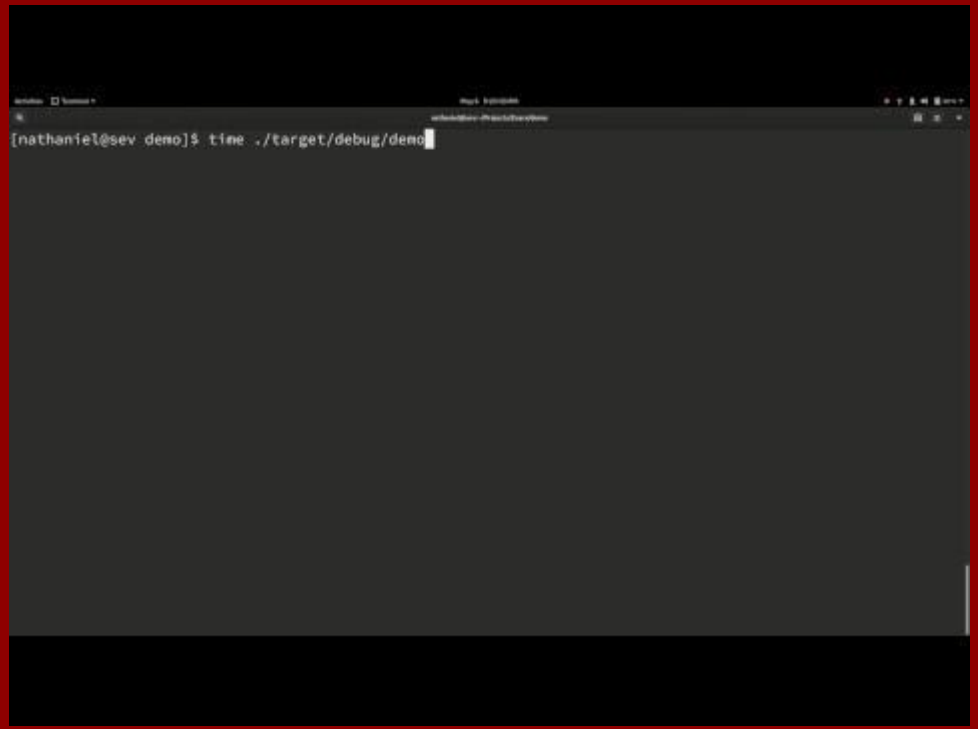


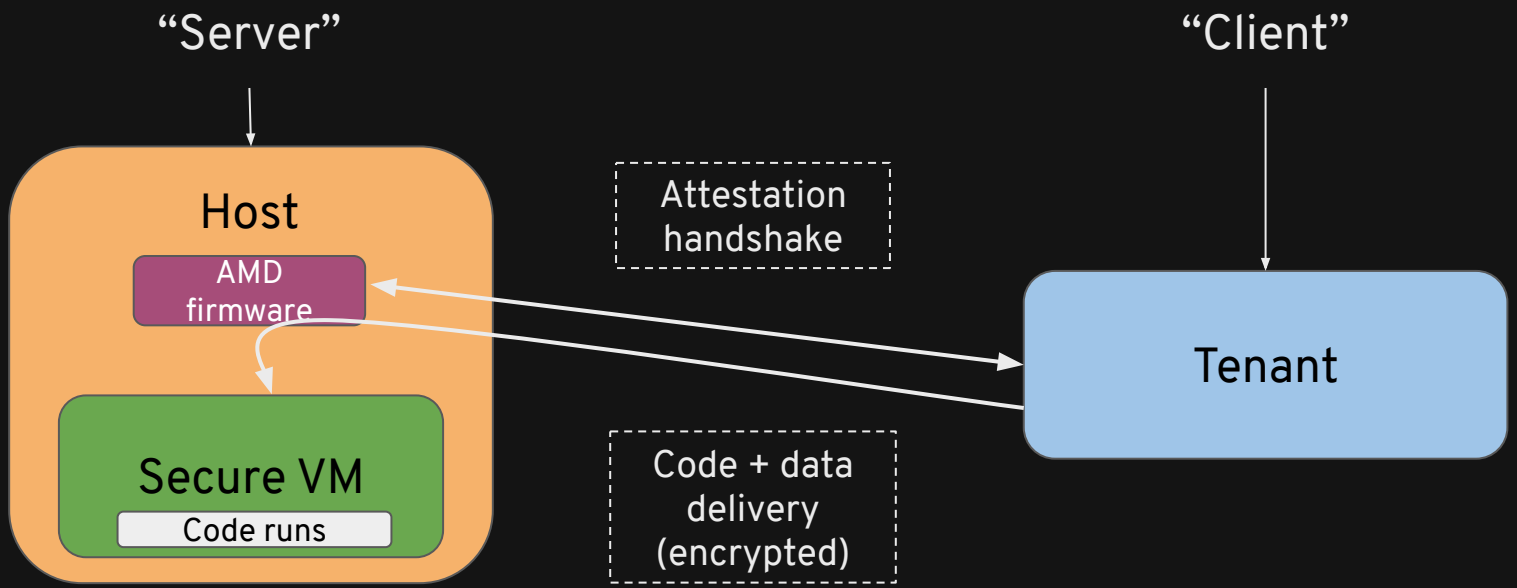
Red Hat



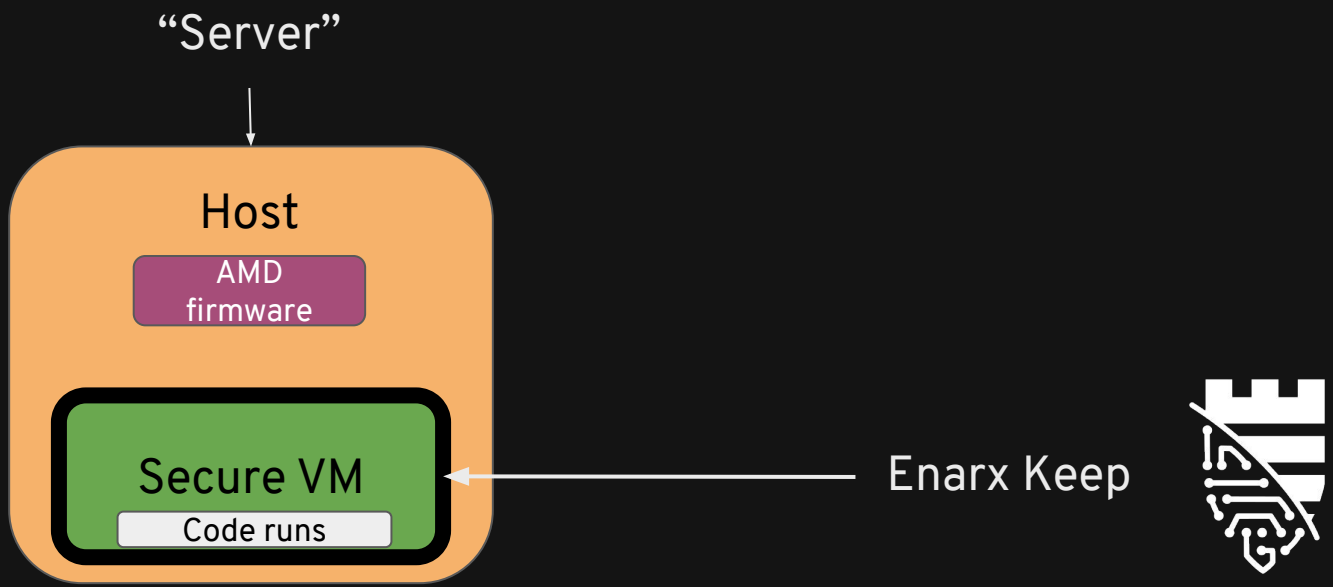


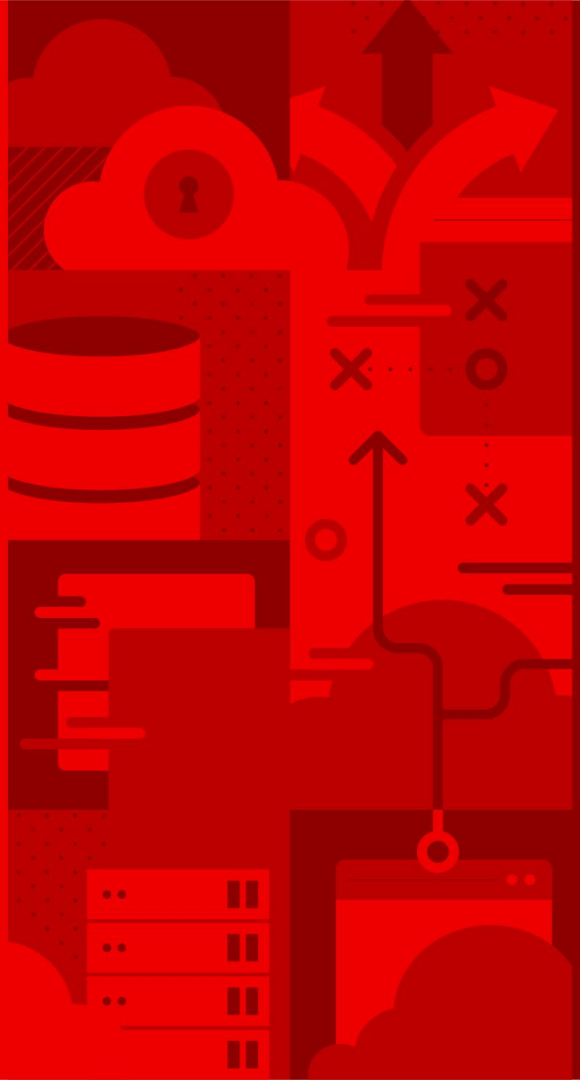
Red Hat

What did I see?



What did I see? (SEV)

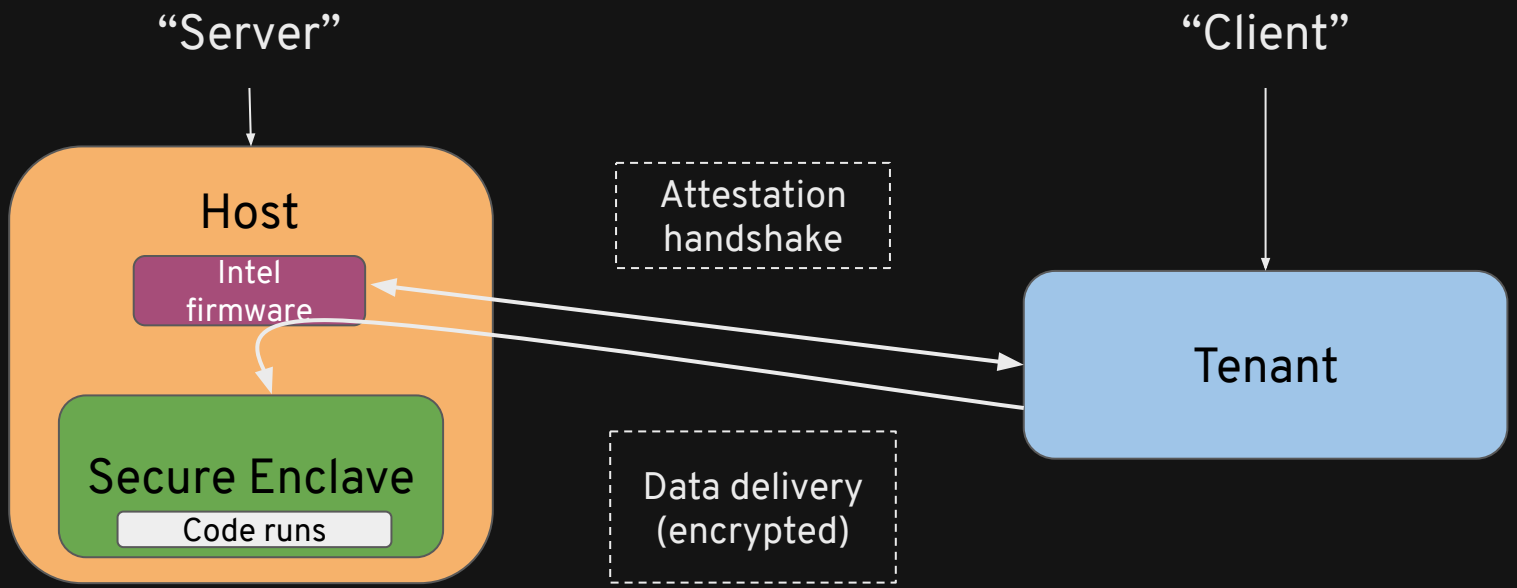




```
enarxnuc@enarxnuc:~$ cd Repos/enarx/demo/intel-sgx/
enarxnuc@enarxnuc:~/Repos/enarx/demo/intel-sgx$ time ./target/debug/attestation-tenant pck_cert_chain.pem 3 4
CLIENT < SERVER: Quote (Attestation)
CLIENT:          PCK cert chain OK
CLIENT:          Quote signature OK
CLIENT:          Attestation Key signature OK
CLIENT:          Enclave report hash OK

CLIENT:          Attestation Complete
CLIENT > SERVER: Tenant PubKey and Encrypted Data

7

real    0m0.647s
user    0m0.008s
sys     0m0.004s
enarxnuc@enarxnuc:~/Repos/enarx/demo/intel-sgx$
```


Red Hat

What did I see (SGX)?



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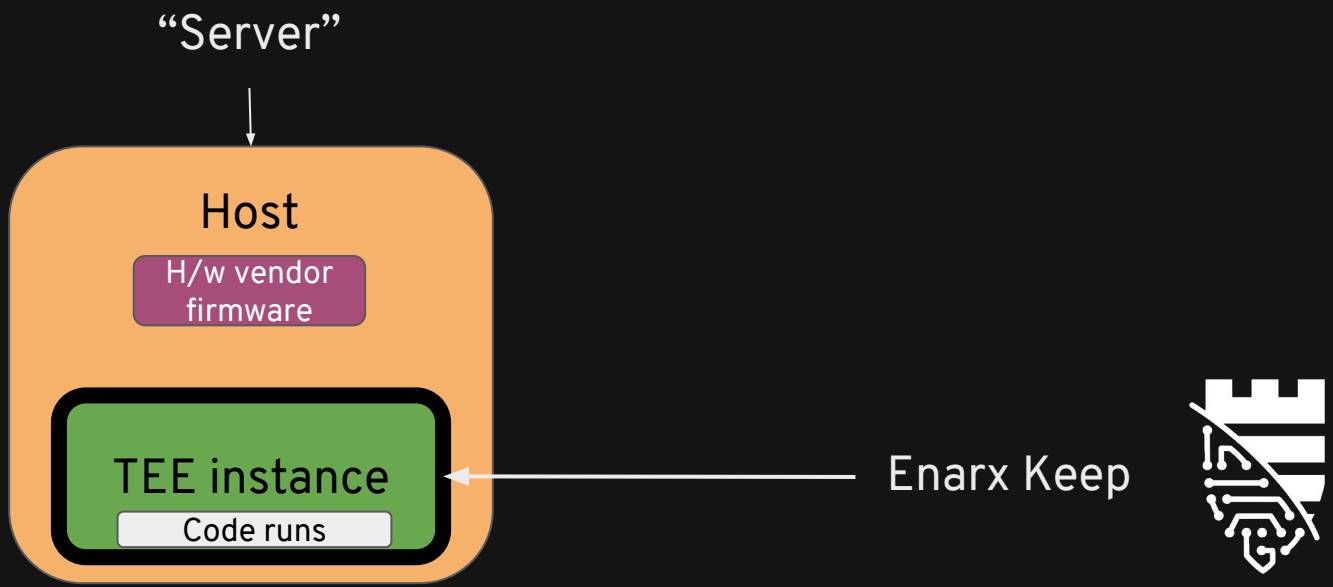
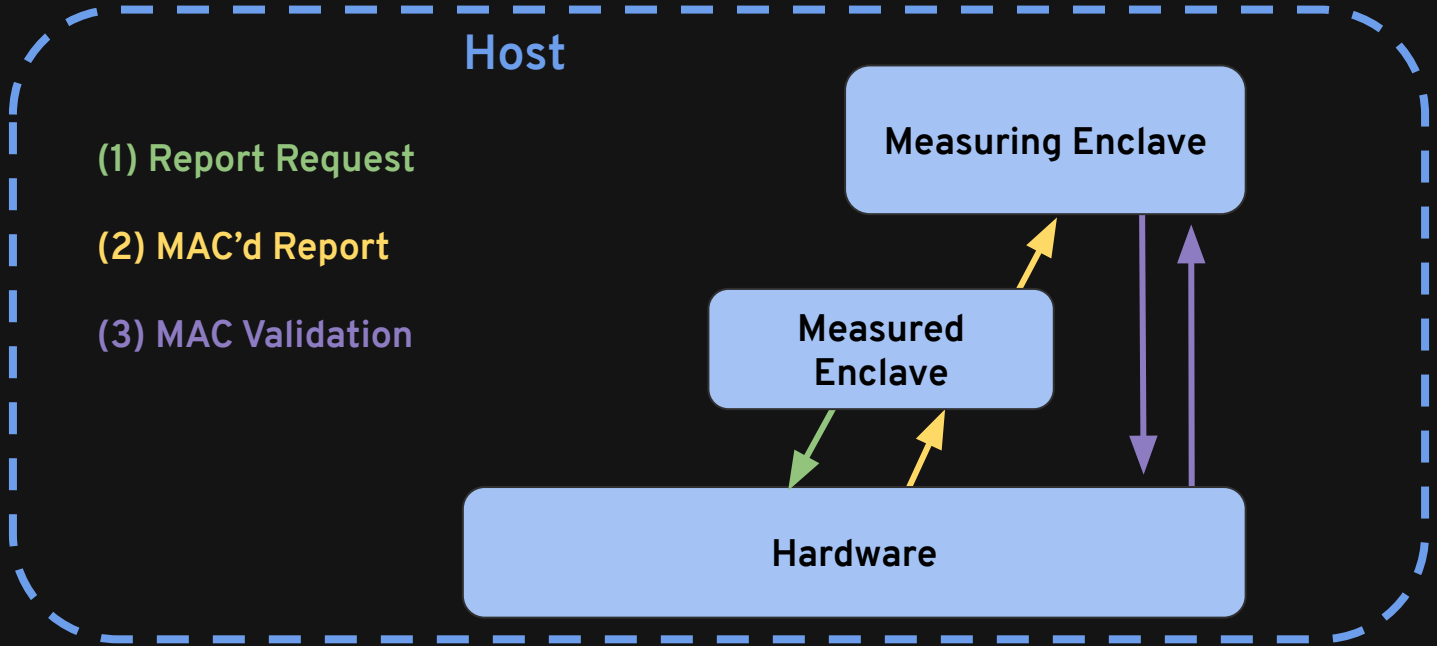
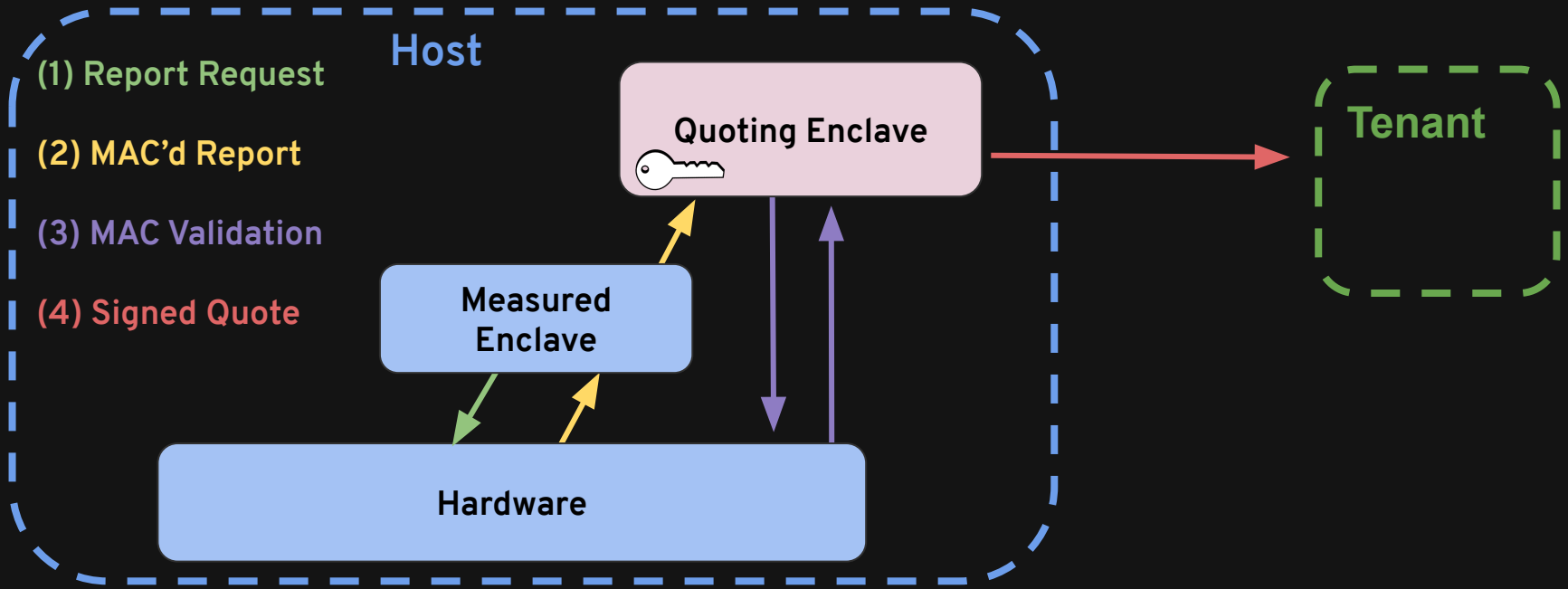


Intel SGX

SGX Local Attestation



SGX Remote Attestation



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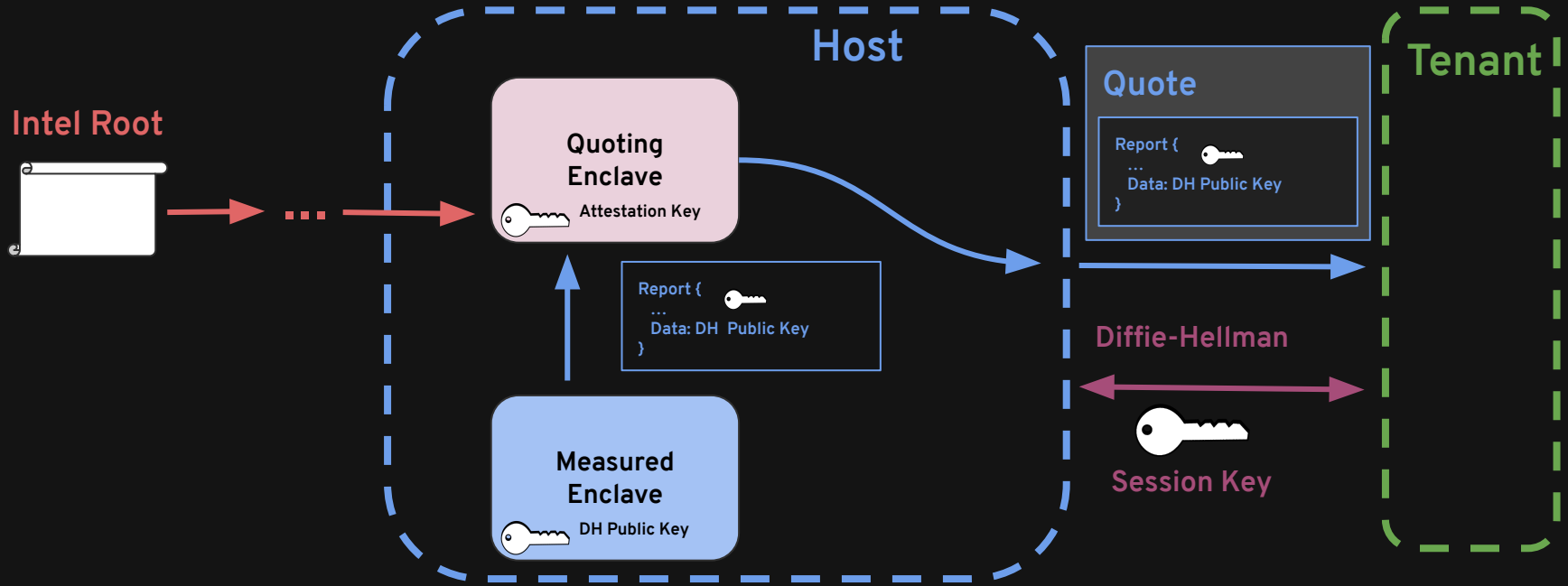
SGX Secure Session



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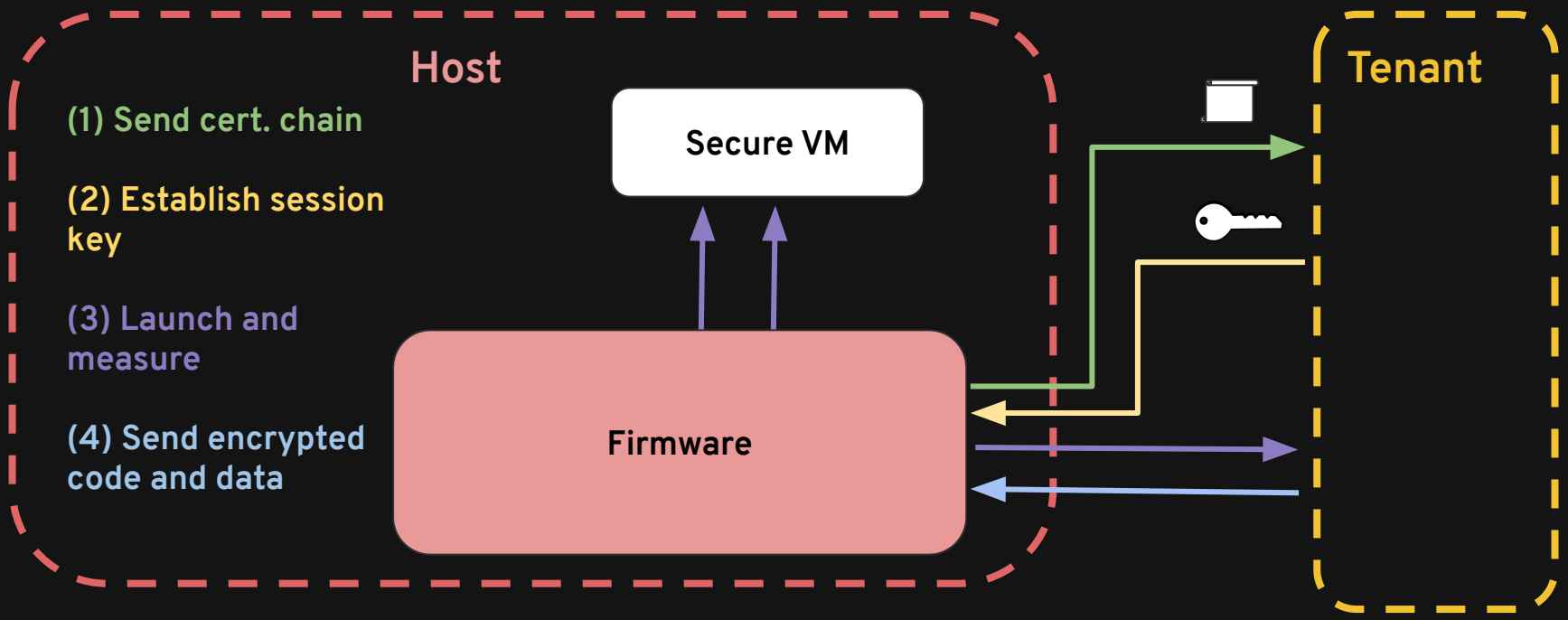
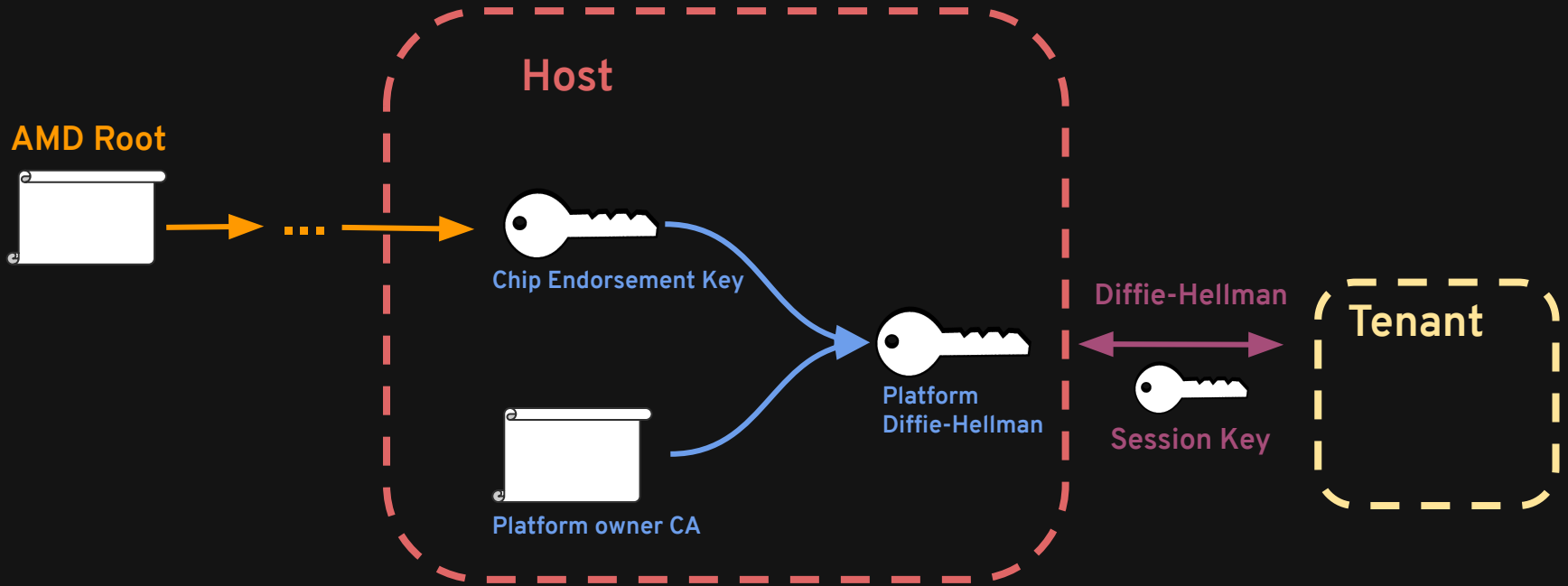
AMD SEV

SEV Attestation



SEV Secure Session



Red Hat

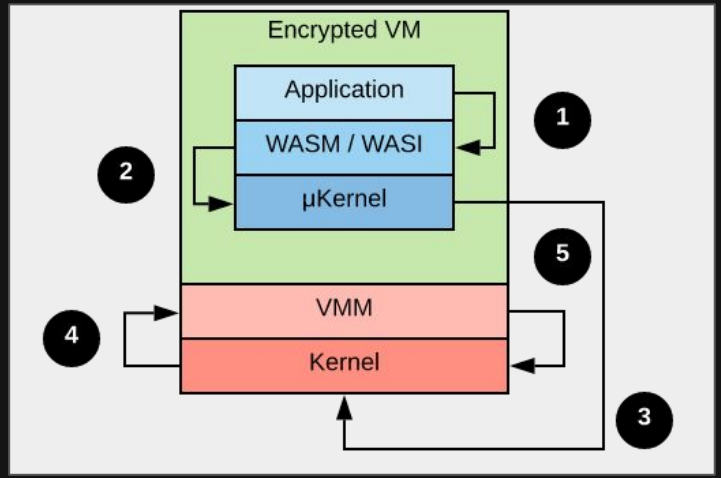
Enarx Virtualization Architecture

Red Hat

VM-based Keep

Syscall Propagation - VM-based

1. An Enarx application, compiled to WebAssembly, makes a WASI call, causing a transition from the JIT-compiled code into our guest userspace Rust code.



https://github.com/enarx/enarx/wiki/Enarx-Syscall-Proxy

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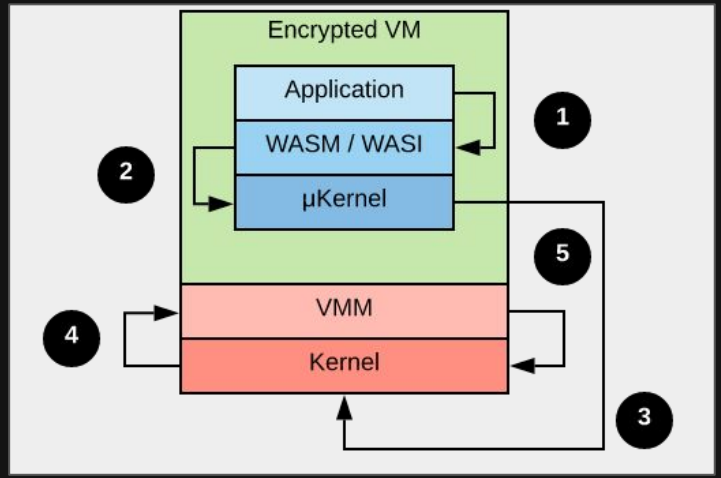

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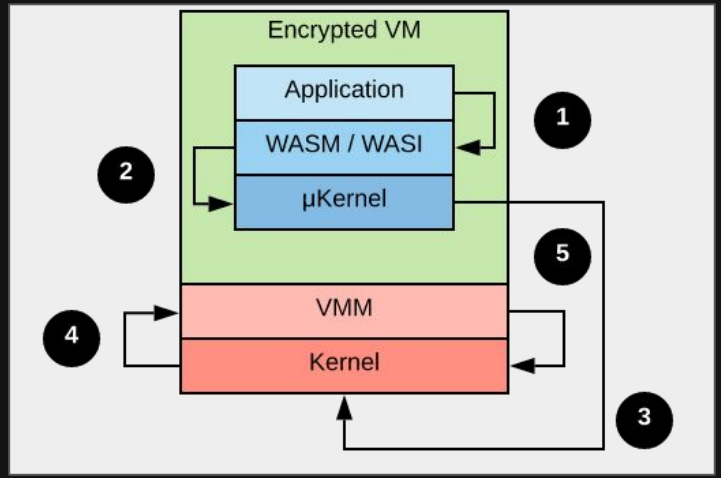

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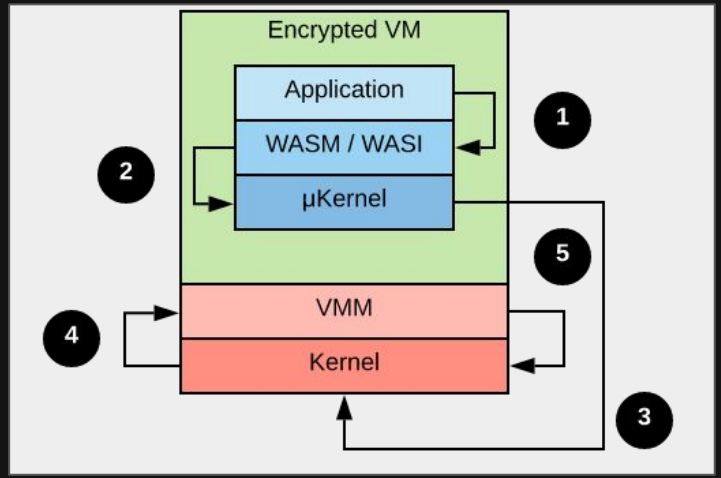

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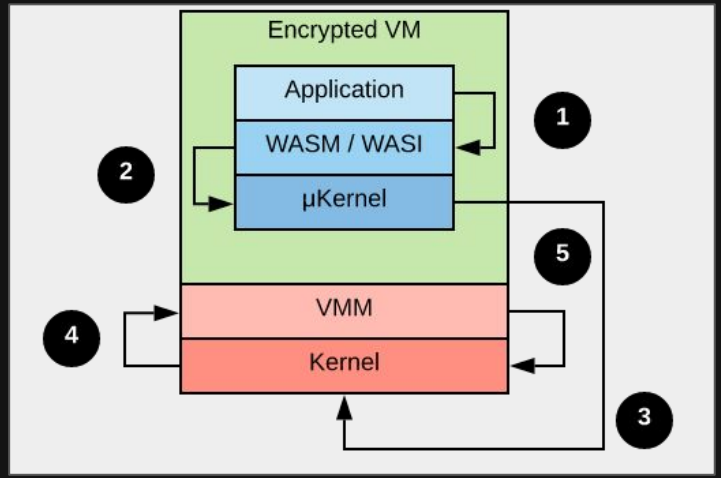

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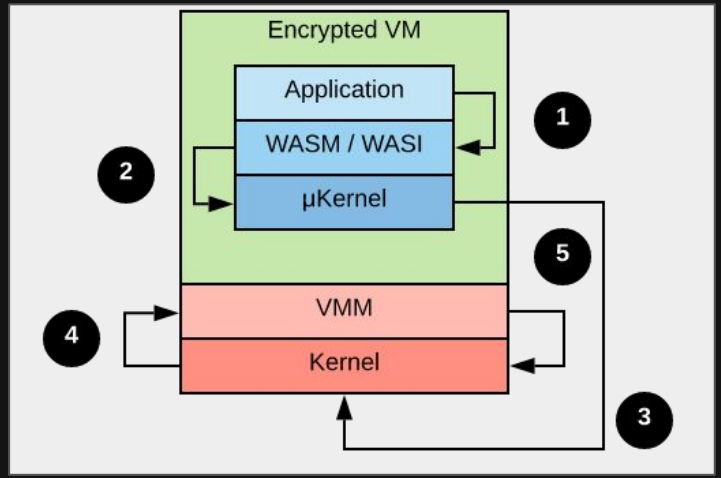

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Enarx Status

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Current Status

1. SEV: Fully attested demo w/ custom assembly.
    a. Ketuvim: KVM library with SEV support
2. SGX: Fully attested demo w/ data delivery.
3. PEF: Ongoing discussions with POWER team.
4. WASM/WASI: Demo with some basic WASI functions.

Still To Do

https://github.com/enarx/enarx/issues/1

- Merge Ketuvim with rust-vmm
- Build:
  - Hypervisor
  - µKernel
  - WASI syscall propagation?
- Complete WASM JIT
- TLS networking stack
- Secure Clock?
- Research new platforms
- Openshift integration
- Much more...

Enarx Design Principles

1. Minimal Trusted Computing Base
2. Minimum trust relationships
3. Deployment-time portability
4. Network stack outside TCB
5. Security at rest, in transit and in use
6. Auditability
7. Open source
8. Open standards
9. Memory safety
10. No backdoors

We Need Your Help!

Website: https://enarx.io

Code: https://github.com/enarx

Gitter: https://gitter.im/enarx/

Master plan: https://github.com/enarx/enarx/issues/1

License: Apache 2.0

Language: Rust

Daily stand-ups open to all! Check the website wiki for details.

Questions?

https://enarx.io

Red Hat