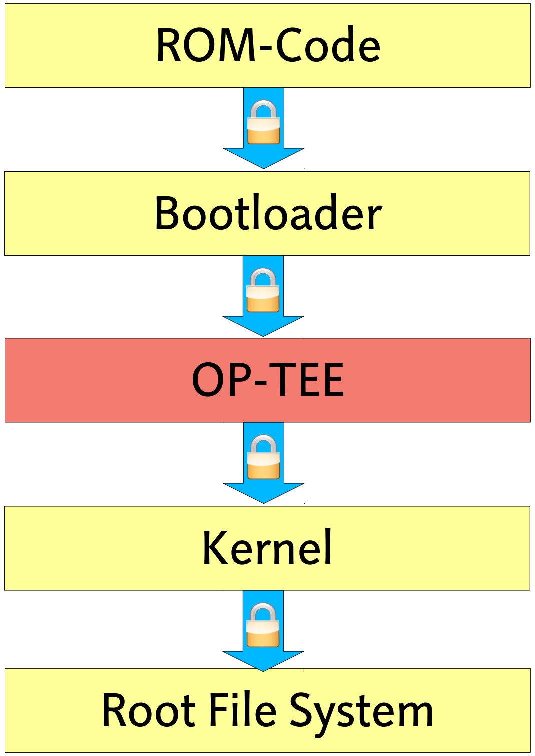
OP-TEE
Using TrustZone to Protect Our Own Secrets



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Overview

- ARM architecture overview
- ARM TrustZone
- Trusted Execution Environment
- Open Portable Trusted Execution Environment

What is a TEE?

- **T**rusted **E**xecution **E**nvironment
  - small OS-like environment
  - isolated from normal operating system (e.g. Linux) “rich OS”

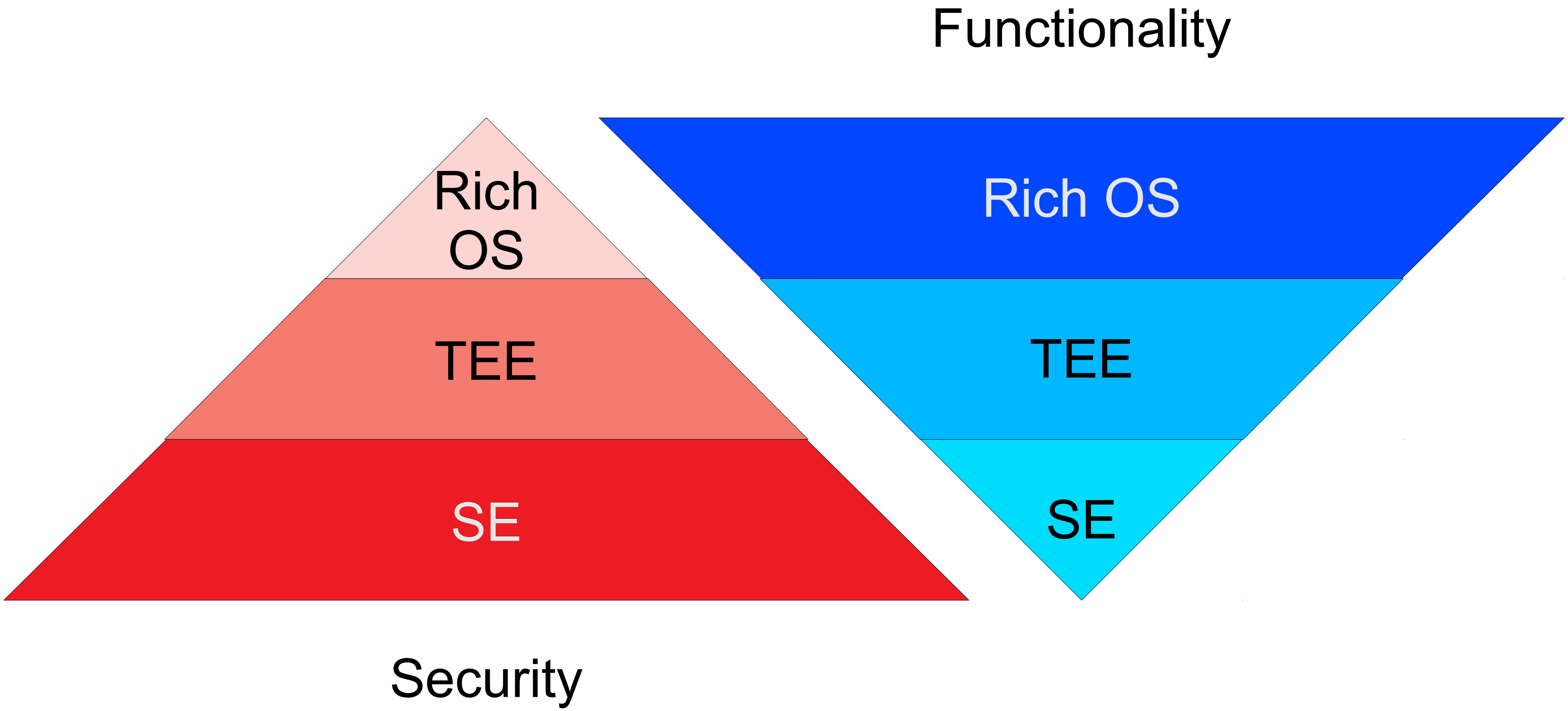
- Allows Applications to execute, process, protect and store sensitive data

- Rich OS is often target of malware and attackers

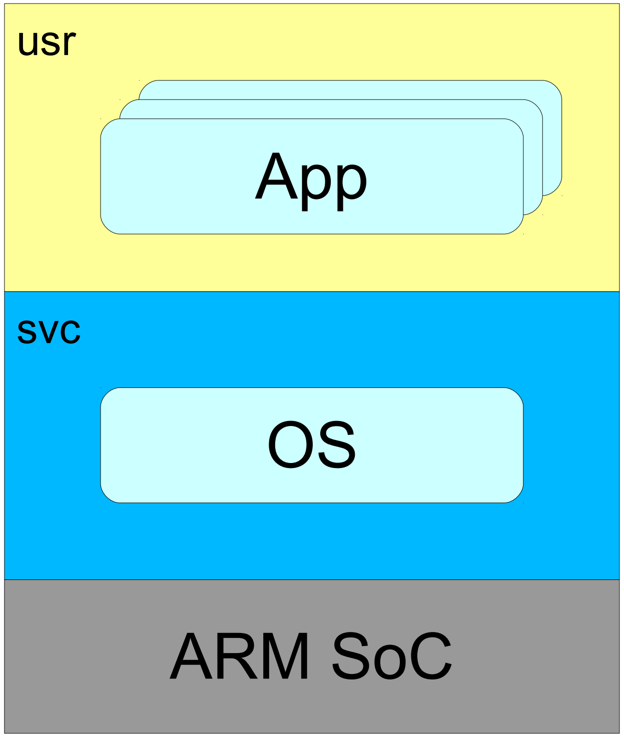
- Design applications so that sensitive functions can be offloaded to the TEE as Trusted Applications.

- API standardized by GlobalPlatform
  - TEE internal APIs for Trusted Application
  - communication interfaces between rich OS Applications and Trusted Applications

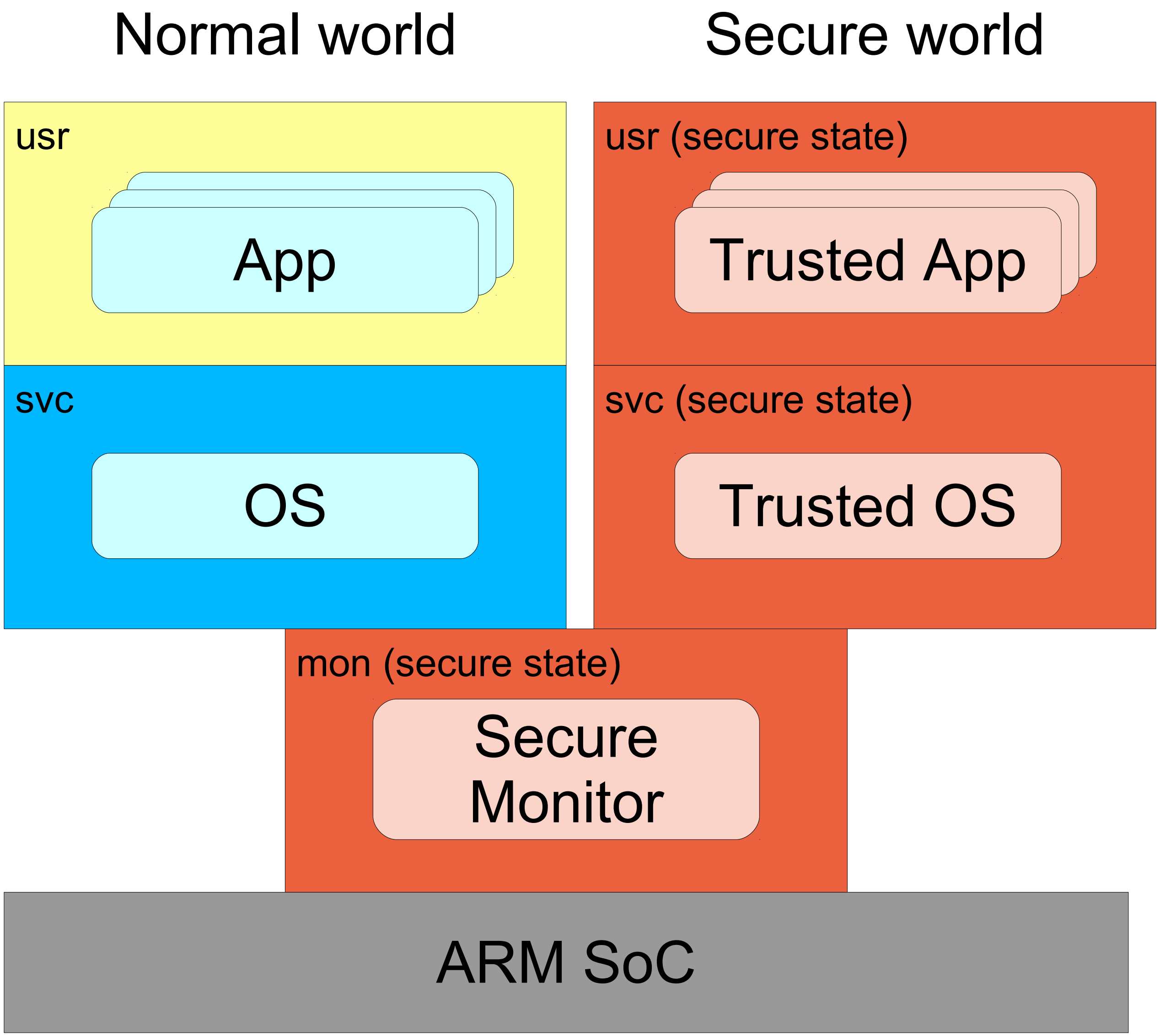
What is a TEE? (cont'd)



ARM architecture



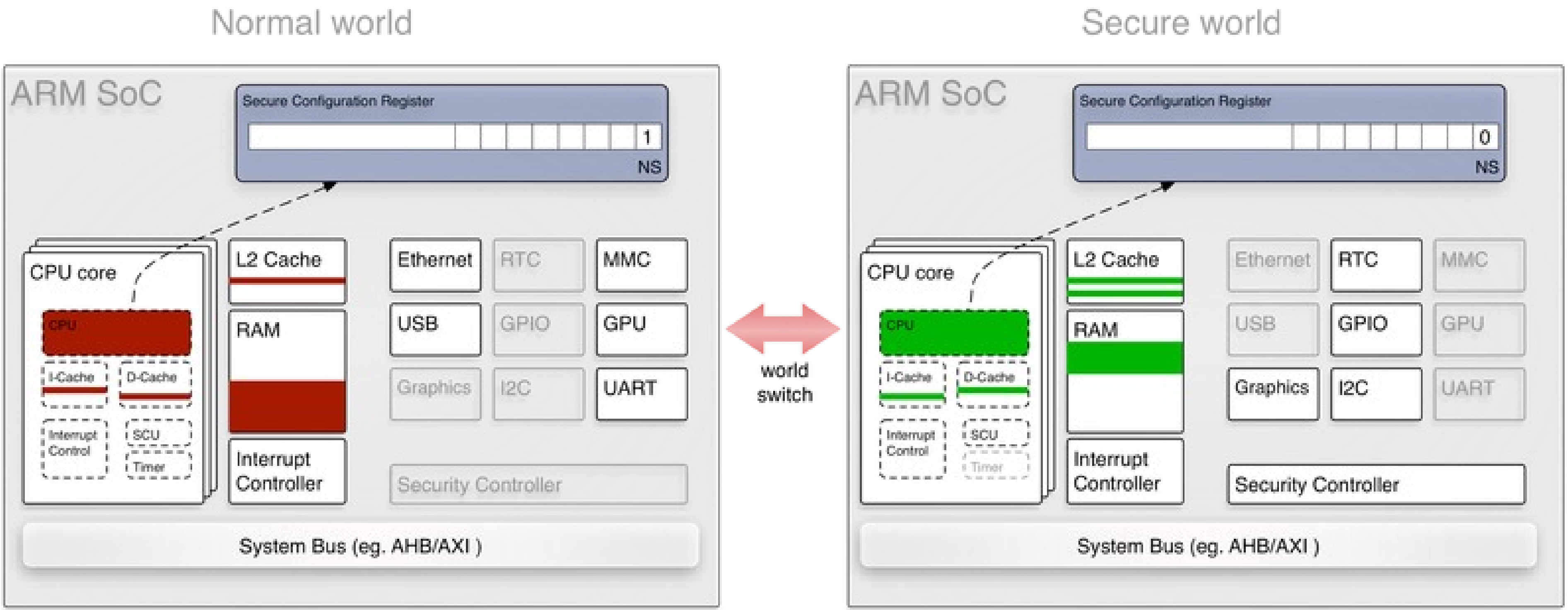
ARM architecture with TrustZone



ARM architecture with TrustZone (cont'd)

- Provides a complete “virtual system” for secure computing
- Divide hardware and software into separate partitions (“worlds”)
  - one is trusted (“secure world”)
  - the other not (“Normal world”)
- Limited and tightly defined ways to get from one world to the other
  → secure monitor

ARM TrustZone in detail



Source: http://genode.org/documentation/articles/trustzone

ARM TrustZone in detail (cont'd)

- Security Extensions to ARM processors

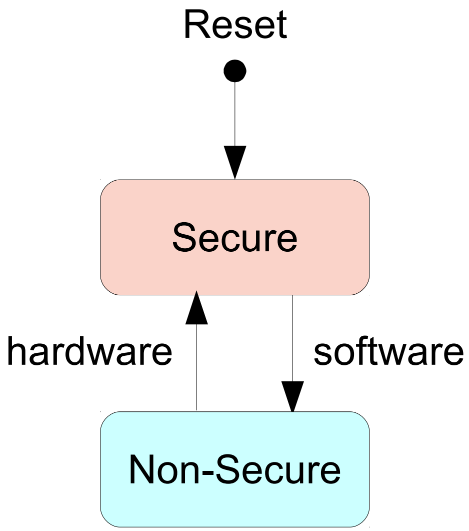
- Supported by
  - ARM1176
  - Cortex-A series (ARMv7-A, ARMv8-A)
  - ARMv8-M

- System-wide hardware isolation
  - SRAM
  - DRAM
  - CPU configuration registers
  - peripherals

- SoC design has impact on practical usefulness of security features

ARM TrustZone switching worlds

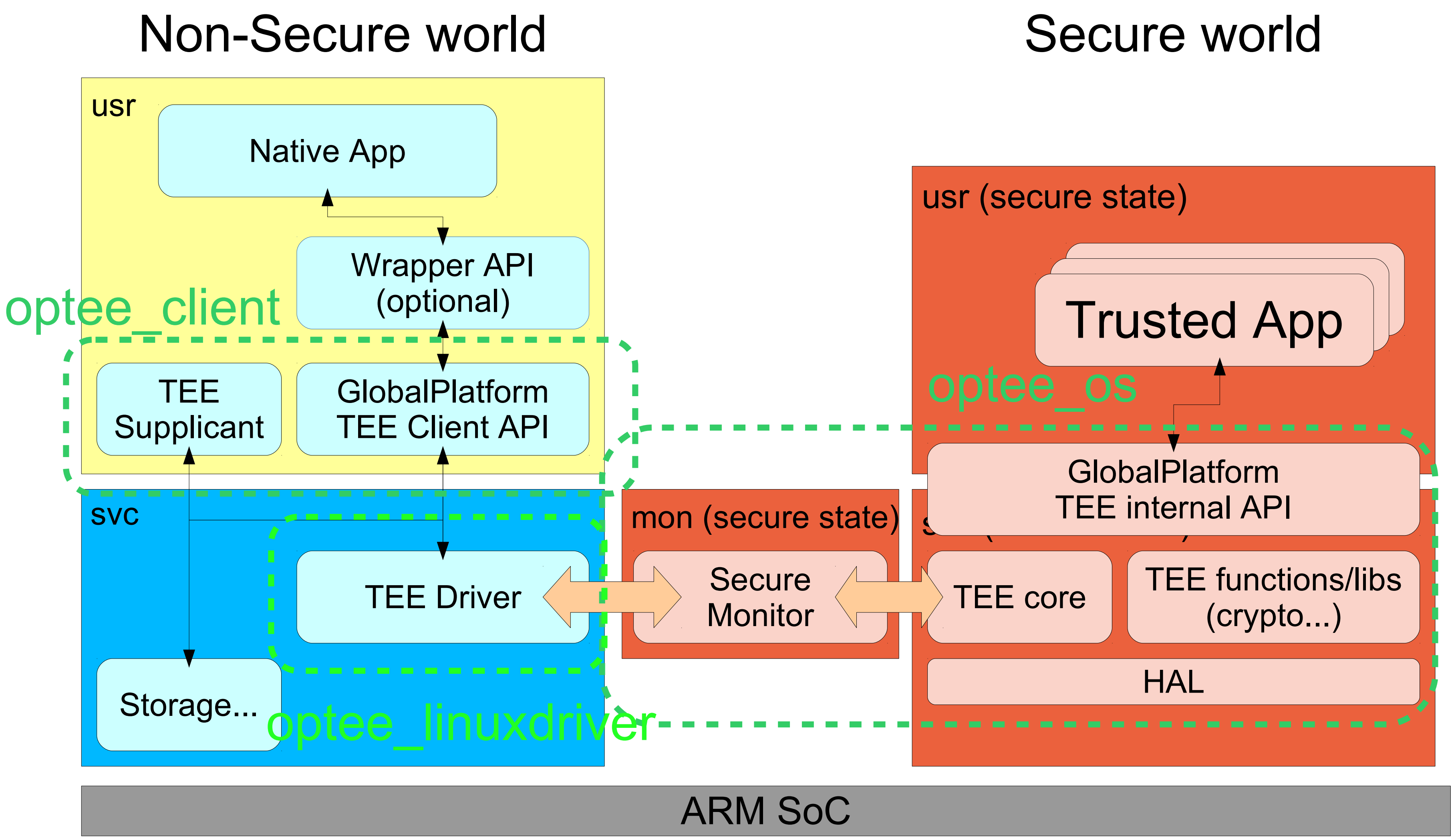
- Secure World entry
  - Hardware-controlled
    - automatic
    - partly configurable
  - By exception
    - Reset
      - CPU always starts secure
    - Secure Monitor Call
      - SMC #n instruction
      - analogous to Supervisor Call (SVC)
      - always handled in Secure World
    - IRQ, FIQ, Data abort
      - configurable (by secure software)
- Non-Secure World entry
  - Software-controlled
  - Typically
    - set SCR.NS
    - return from execption



What is OP-TEE?

- Started as closed source implementation by some mobile, telco and chip vendors
- Since 2015 Open Source (BSD license), owned and maintained by Linaro
- In 2017 the TEE driver went mainline with v4.12
- Small and simple TEE
- Relies on rich OS to schedule TEE
- Based on ARM TrustZone to provide isolation of the TEE from the rich OS in hardware
- Runs on ~20 platforms
  - 32 bit: ARMv7-A
  - 64 bit: ARMv8-A

OP-TEE architecture



Source: https://www.linaro.org/blog/core-dump/op-tee-open-source-security-mass-market/

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OP-TEE in detail

- The OP-TEE consists of three parts

- Normal World, User Mode
  - TEE client library
  - tee-supplicant
    - file system access
    - access to shared resources

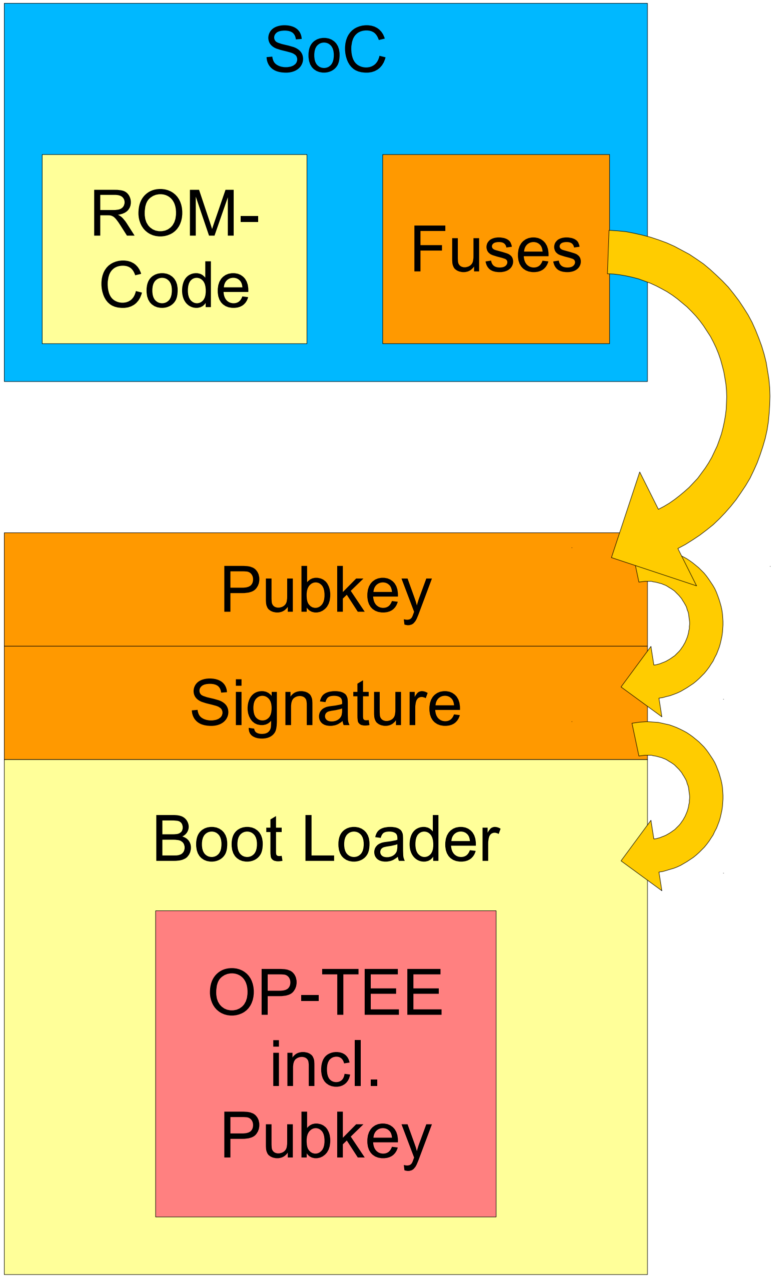
- Normal World, Priviledged Mode
  - Linux kernel TEE subsystem
  - Linux kernel TEE device driver

- Secure world, Priviledged Mode
  - Trusted OS (optee_os)

- TEE contains public key

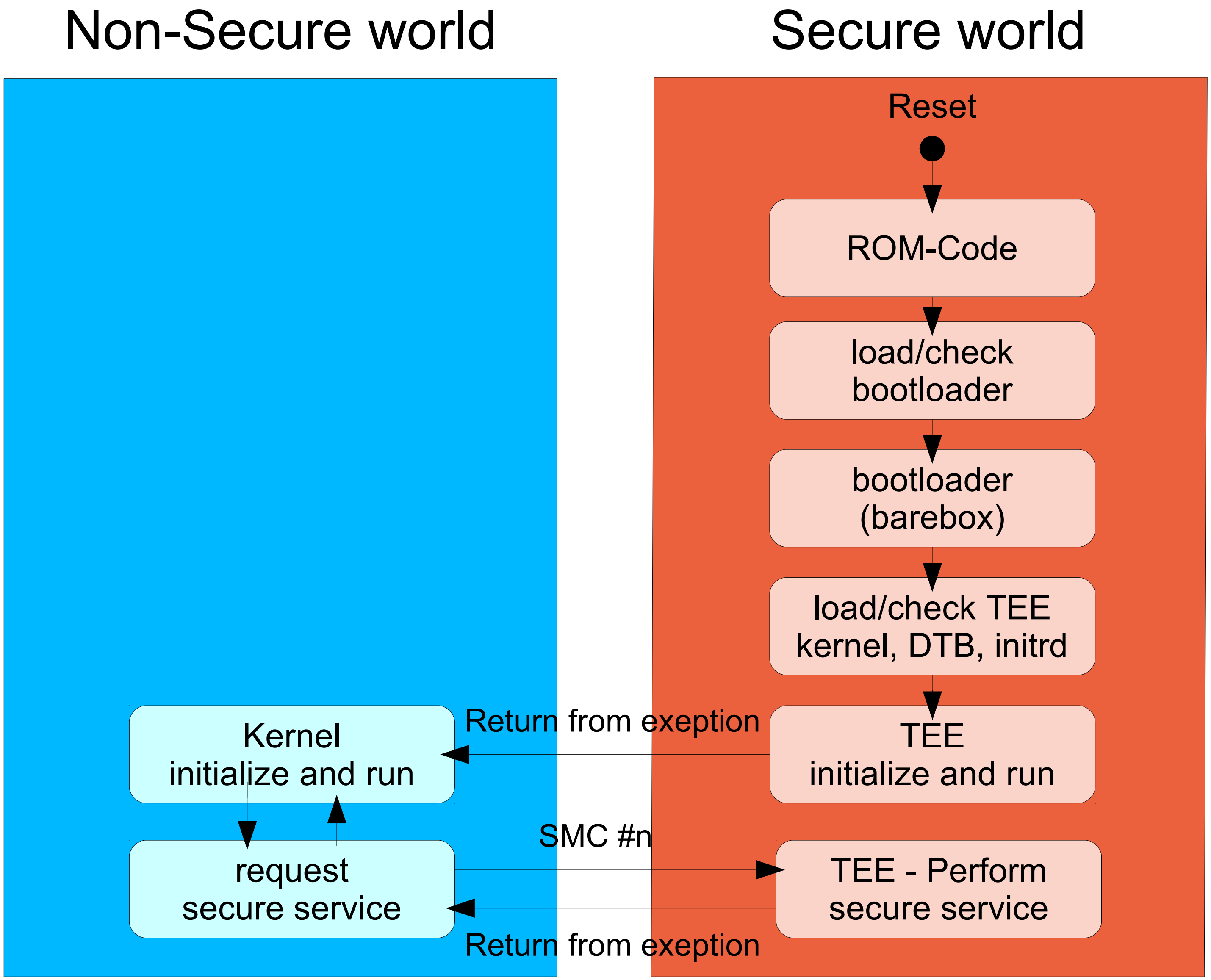
- Trusted Applications are singed and can be loaded from the Normal World into the TEE

OP-TEE - Trusted Boot ARMv7-A: i.MX6



For details on trusted boot see my talk from ELCE 2016.

OP-TEE - Boot sequence in ARMv7-A: i.MX6



Observations & What's Missing?

- Better SoC support
  - more SRAM
  - TrustZone support missing in some peripherals

- TrustZone: From my (limited) point of view:
  - The concept of moving peripherals into Secure World is “complicated” on todays SoCs.
  - Think about turning off the clock of the Secure World's I2C, PWM or Ethernet Controller.

- Support for existing private key storages
  - inside the Linux kernel
  - opengpg/ssh
  - TPM

- build system feels Android centric
- make use more use of DT
- convert config #ifdef to kconfig

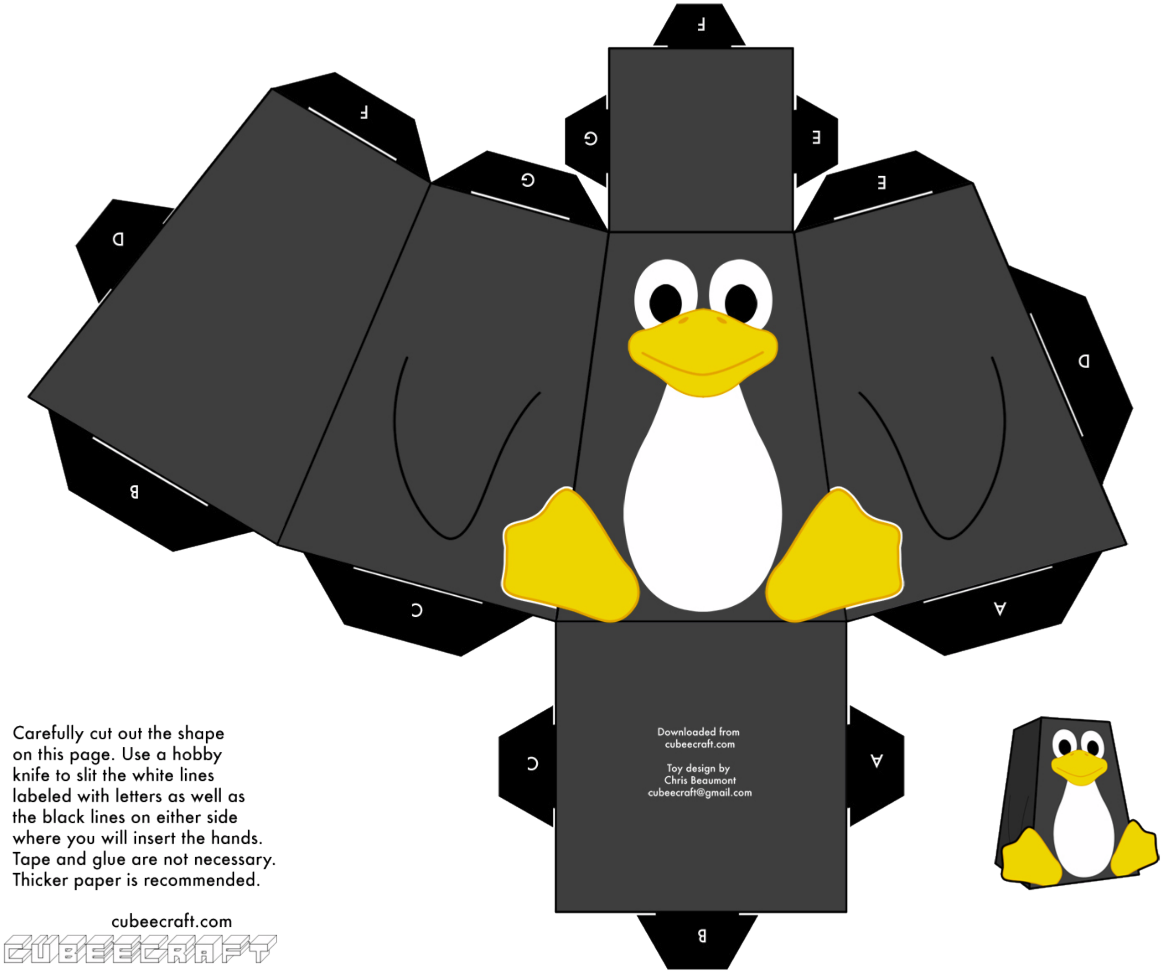
Summary

- TEE – Trusted Execution Environment
  - Set of APIs to split applications into normal and secure part

- TrustZone
  - Security extension for ARM processors to partition one SoC into Normal and Secure World
  - Practical usefulness depends on SoC design

- OP-TEE – Open Platform TEE
  - Implements TEE on ARM using TrustZone

Q & A



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