BOOTKITTY: A Stealthy Bootkit-Rootkit Against Modern Operating Systems

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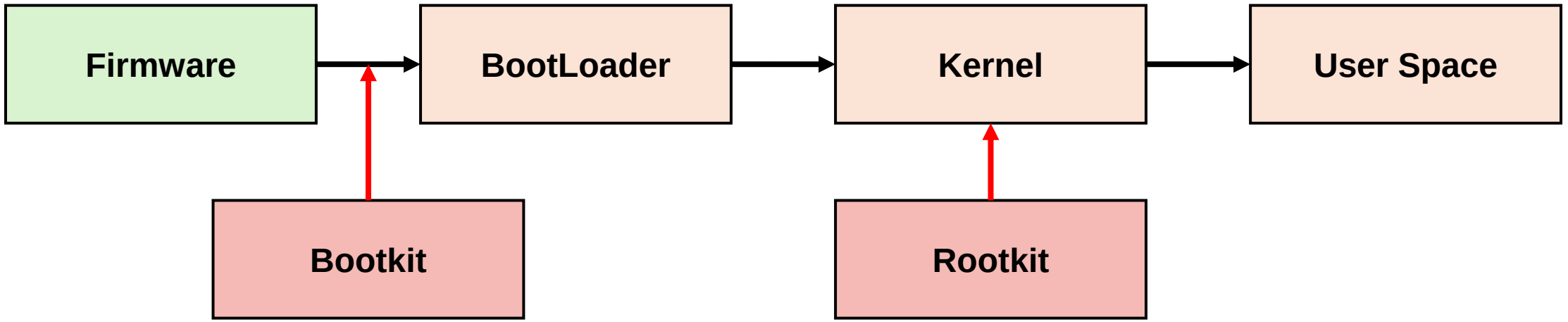
Bootkit

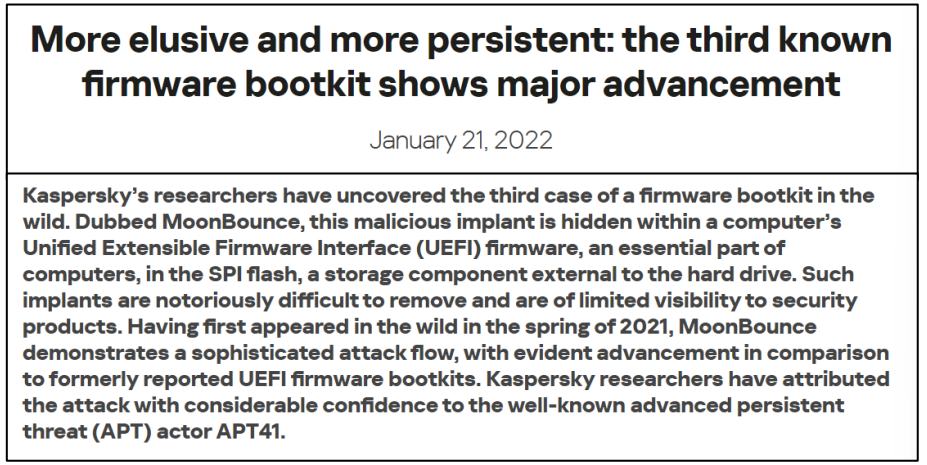
- **An advanced malware that hijacks a boot process**
  - Takes control of the system before the operating system launches

- **Bootkit vs. Rootkit**



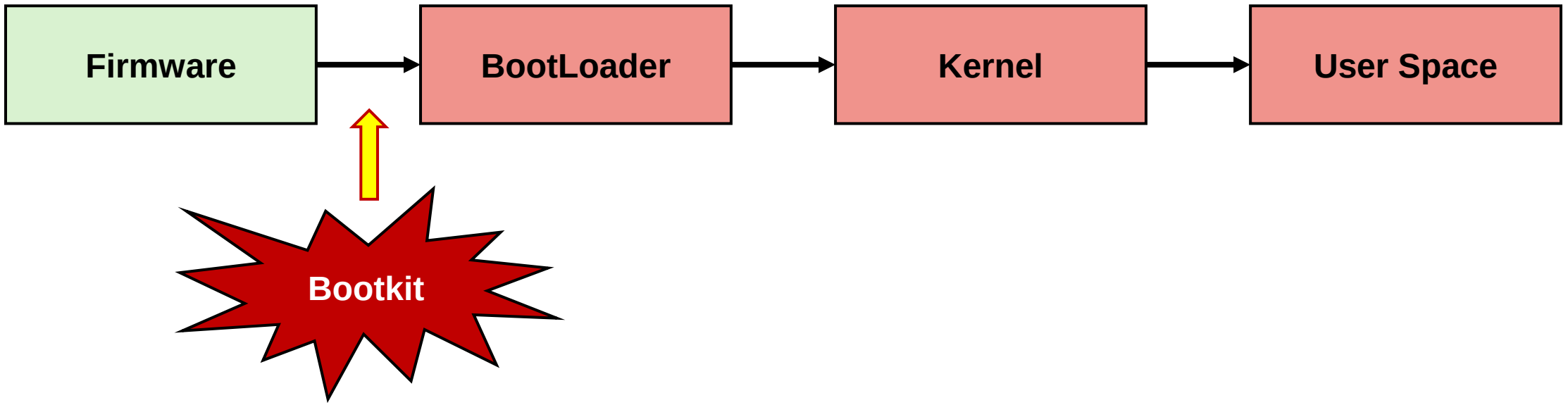
Bootkits as Persistent Threats

- Bootkits have been actively studied with annual reports



Why Dangerous?

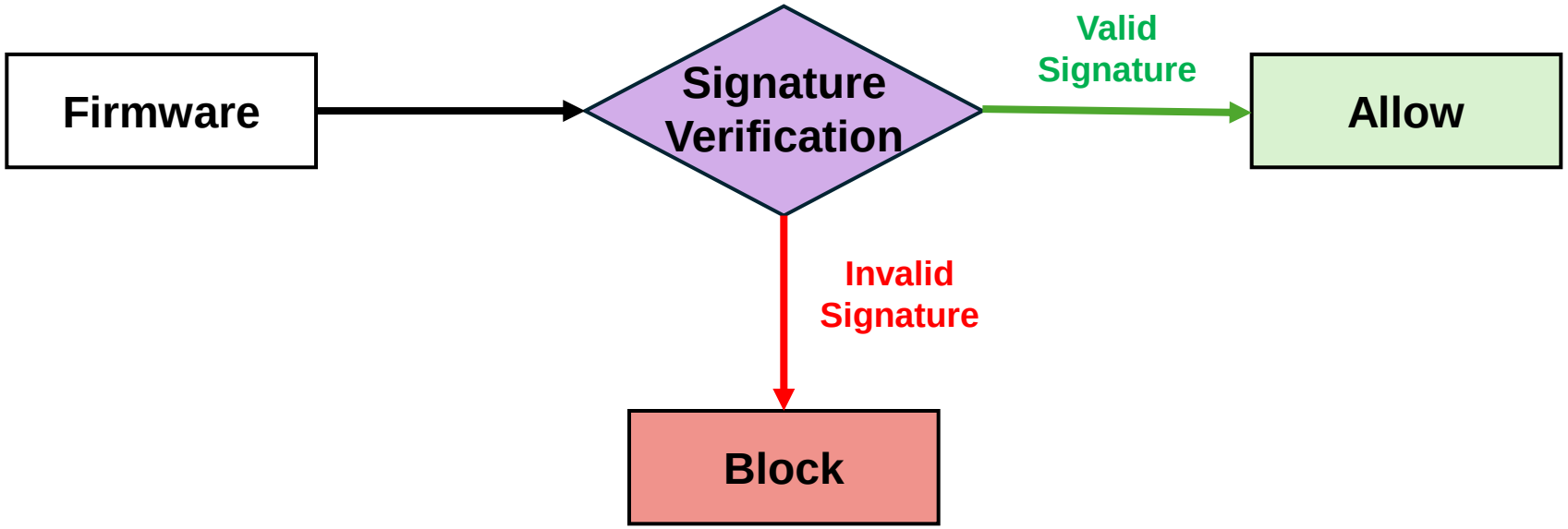
- **Stealth:** Attacks during pre-booting, bypassing anti-viruses or EDRs
- **Persistence:** Implants into a boot partition or firmware
- **Compromise:** Controls the system before kernel initialization



Existing Defense: Secure Boot

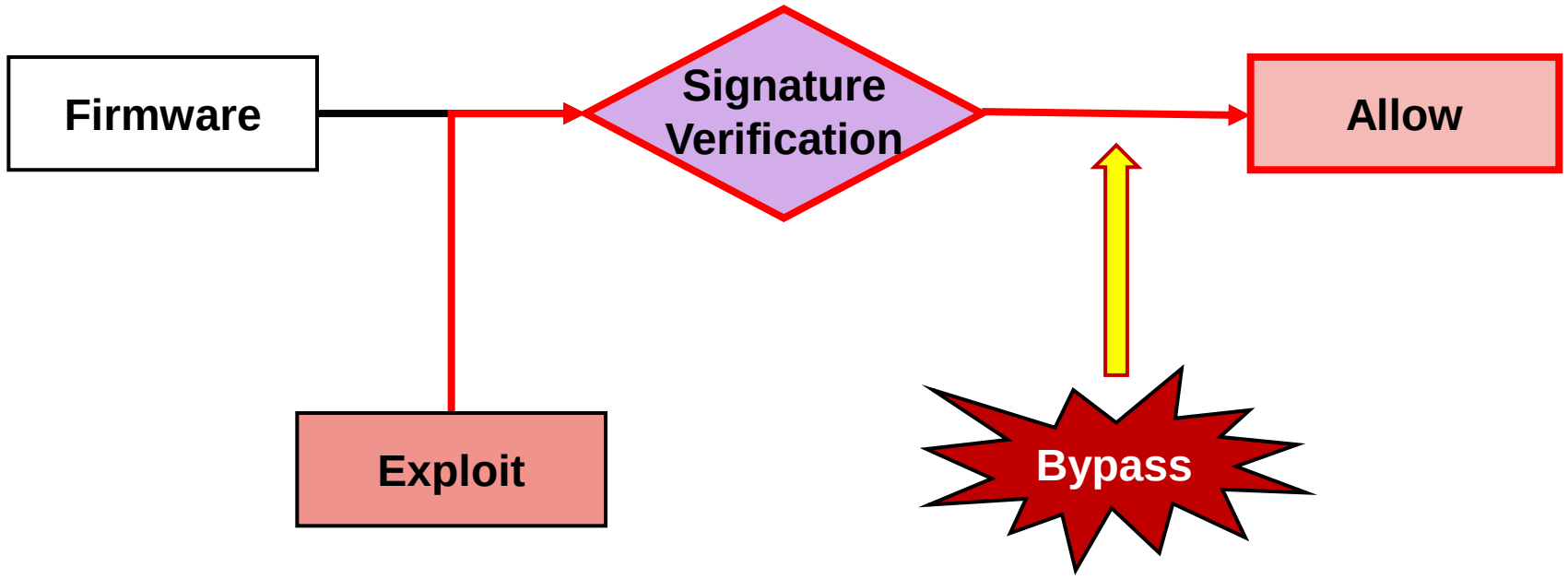
- **Signature verification: UEFI verifies a bootloader and kernel signatures**

  → blocks untrusted code



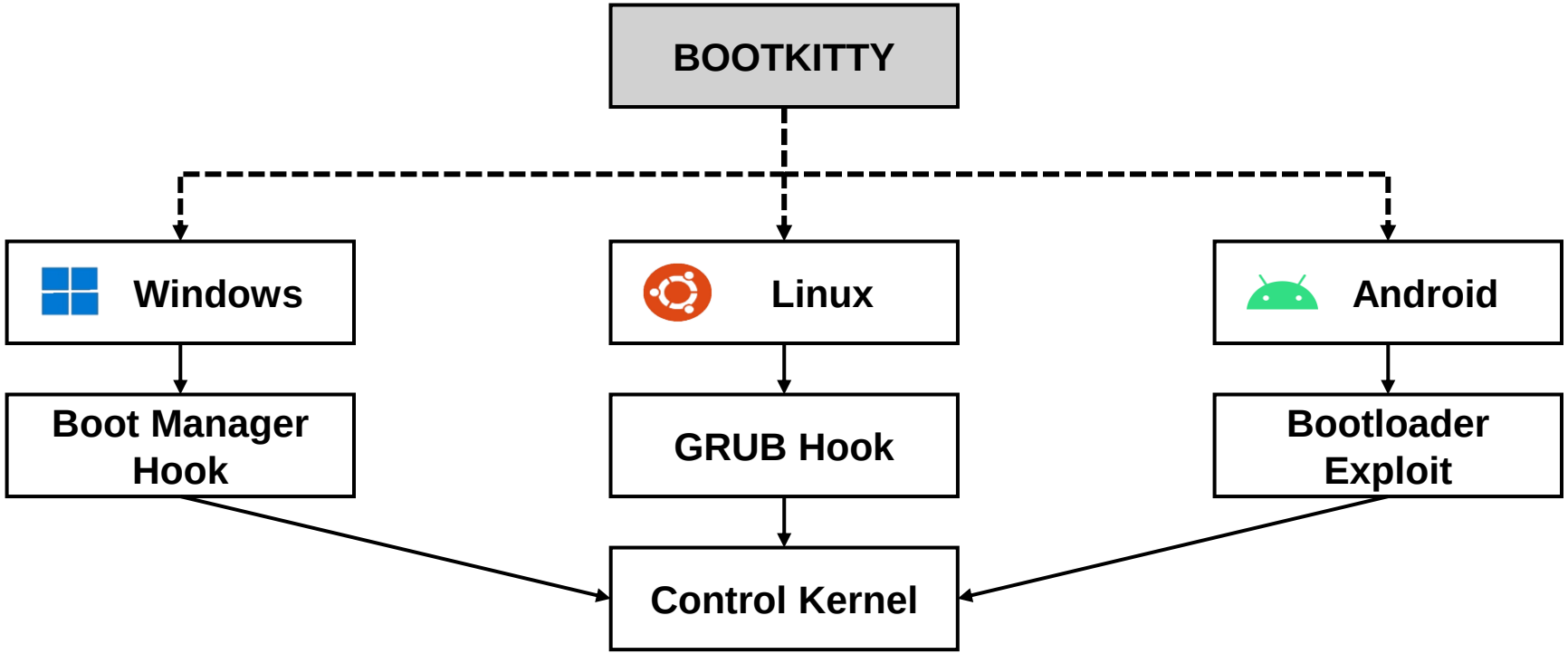
Limitations of Secure Boot: Not Fully Secure

- Secure boot has vulnerabilities in firmware and certificate management
- These vulnerabilities can be leveraged to bypass Secure Boot

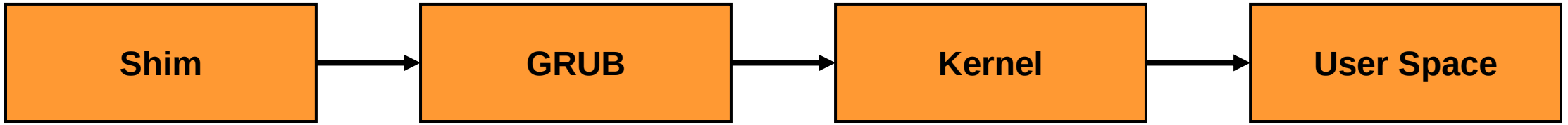


BOOTKITTY: Hybrid Bootkit-Rootkit

- BOOTKITTY hijacks the boot process and injects a stealth rootkit

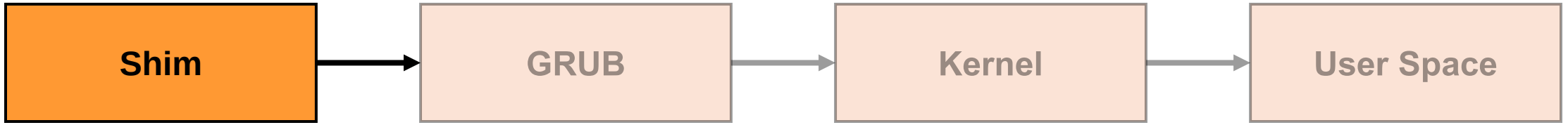


Linux Boot Process



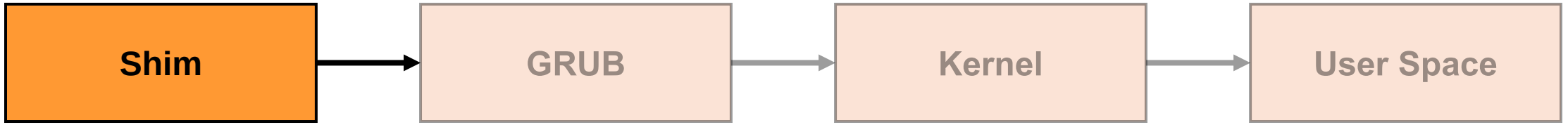
1. UEFI loads Shim
2. Shim loads GRUB
3. GRUB loads the Kernel
4. Kernel initializes the user space

Attack Surface: Linux Shim



- Verifies a bootloader signature
- Loads GRUB

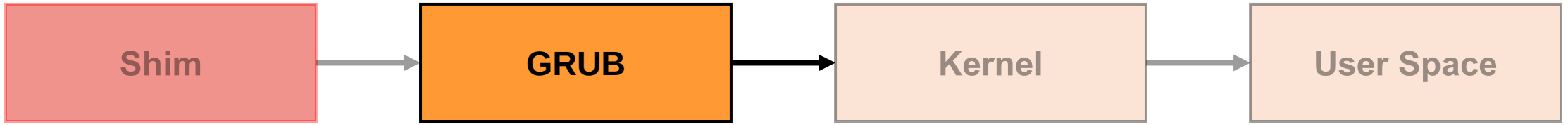
Attack Surface: Linux Shim



Attack Methods

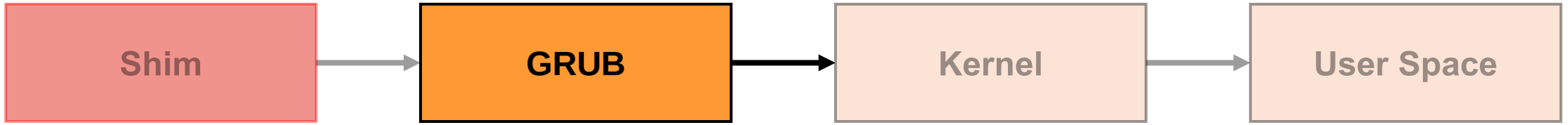
- Shim binary tampering
- Runtime hooking

Attack Surface: Linux GRUB



- Loads the kernel
- Transfers control to the kernel

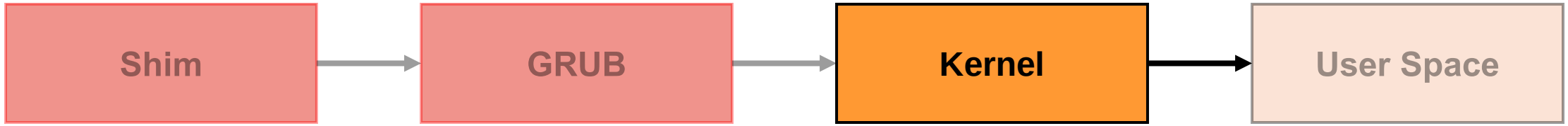
Attack Surface: Linux GRUB



Attack Methods

- GRUB modification and hooking
- Chaining hooks from Shim → GRUB → Kernel

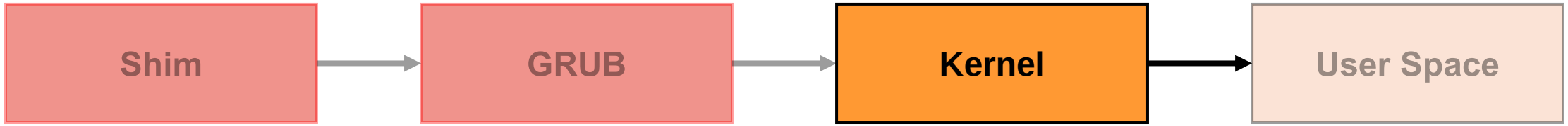
Attack Surface: Linux Kernel



Kernel loading

- Compresses the kernel
- Decompresses the kernel

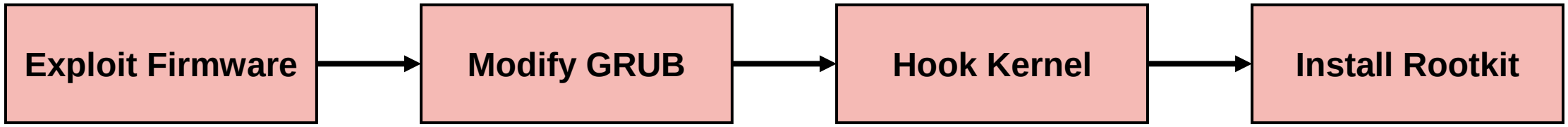
Attack Surface: Linux Kernel



Attack Methods

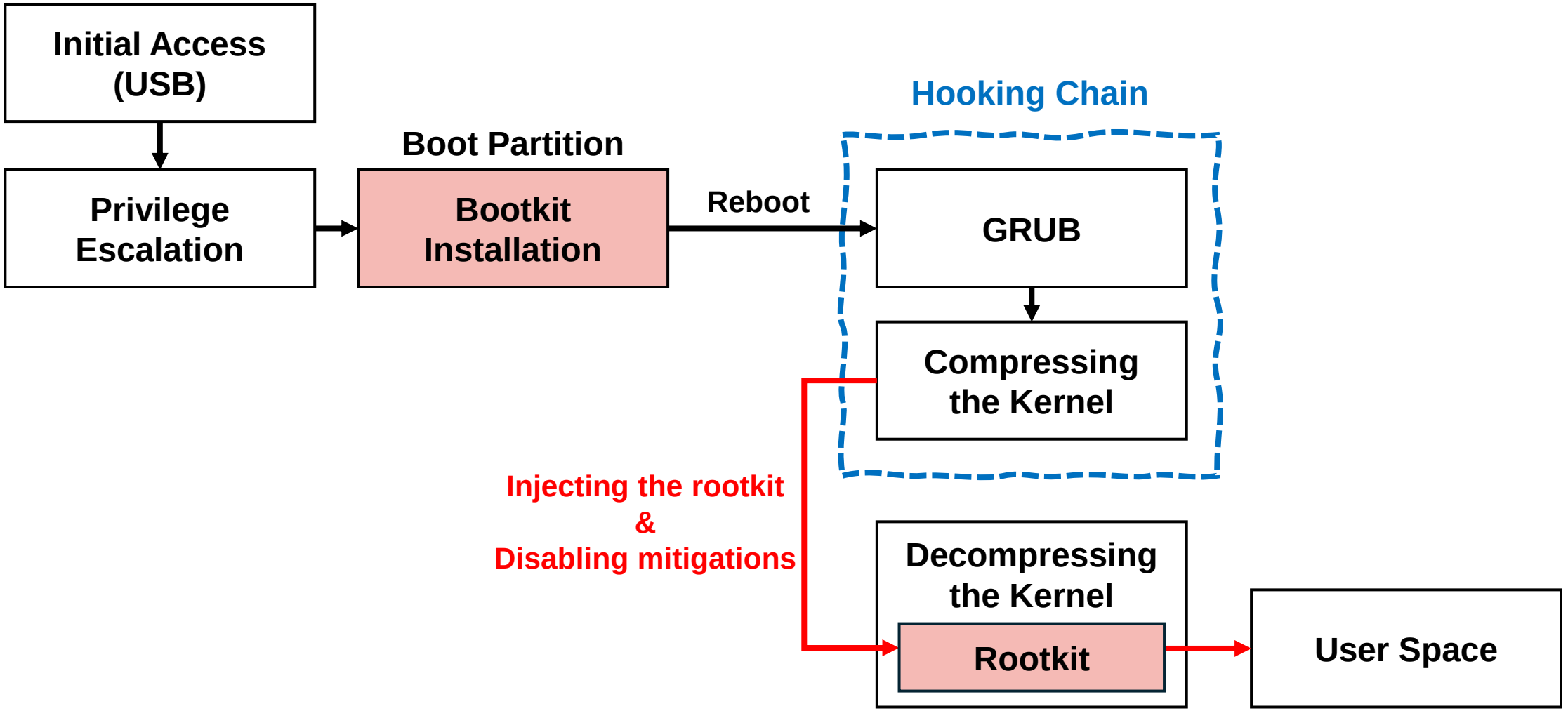
- **Before the decompression phase:** Hooks a decompression function
- **After the decompression phase:** Disable mitigations (lockdown, kernel module signing)

How BOOTKITTY Compromised the Boot Process on Linux

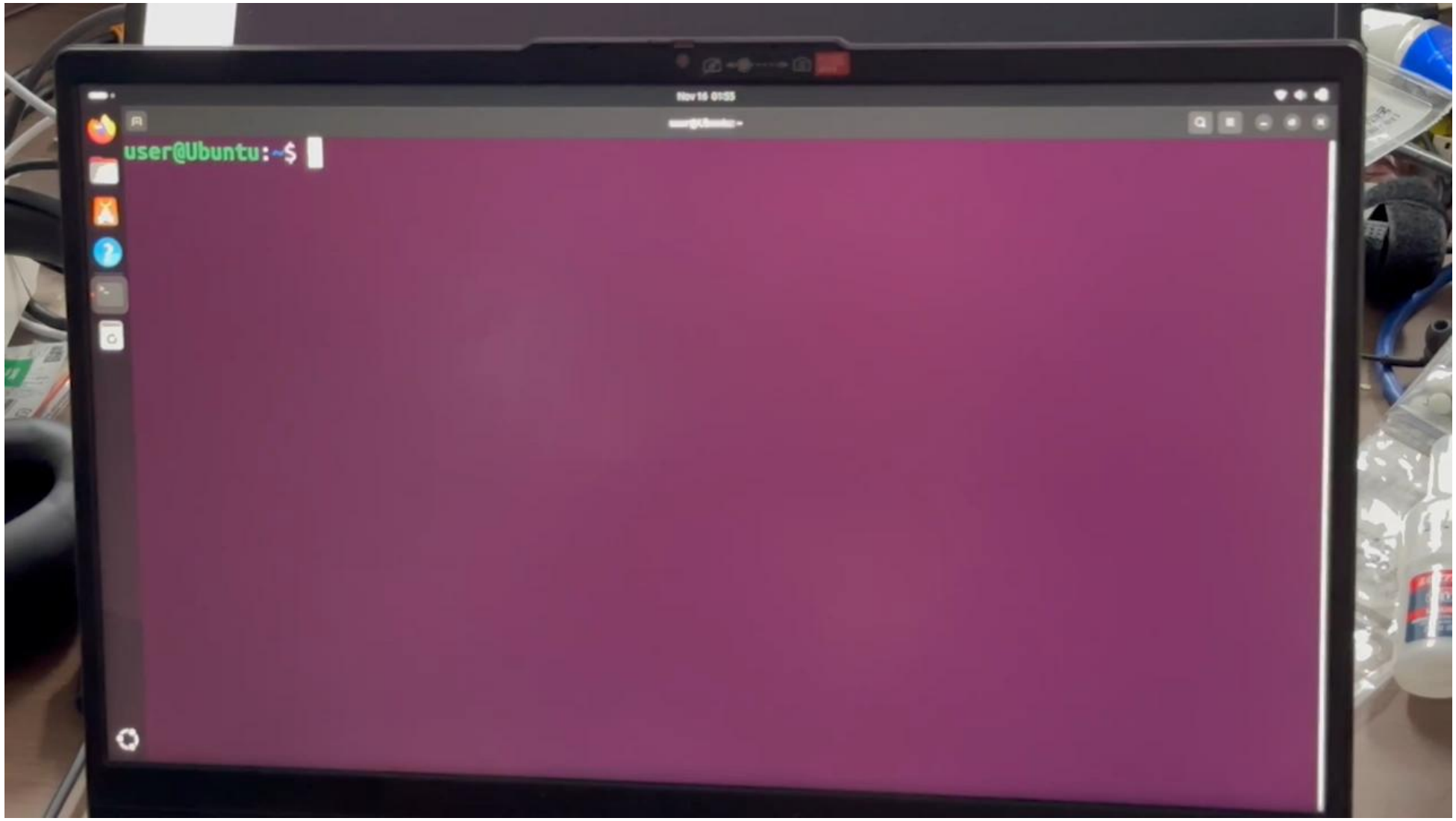


- LogoFAIL (***CVE-2023-40238***) → GRUB compromise
- GRUB modification via the firmware bug
- Chains hijacking: GRUB → kernel

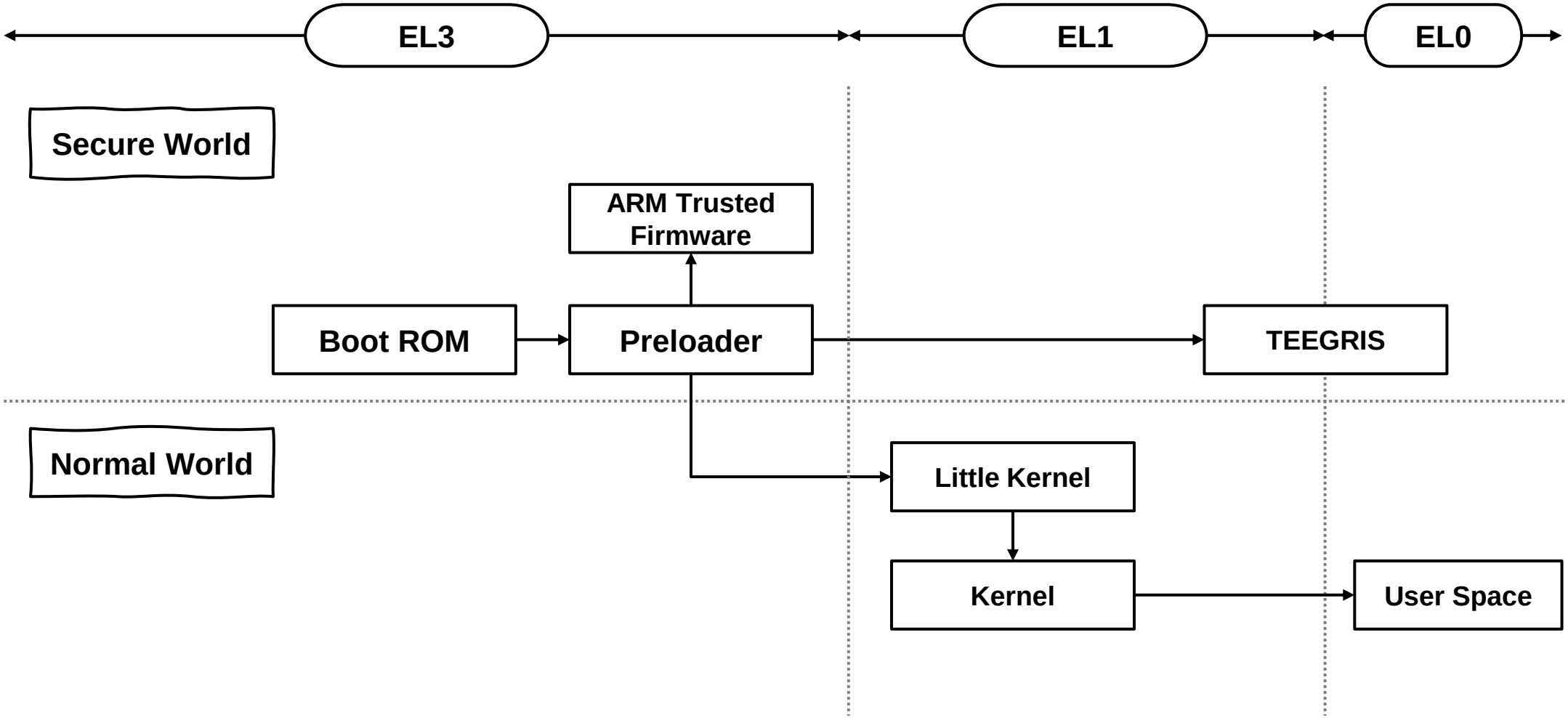
BOOTKITTY on Linux: USB Attack Scenario



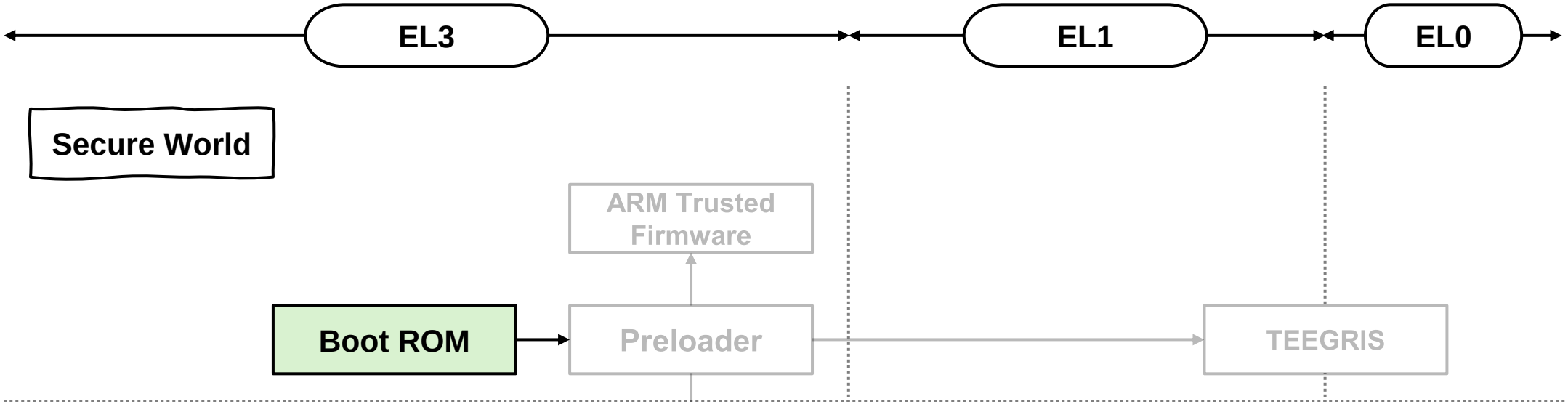
Linux Demo: Bootkit-Only



Android Boot Process: Exception Levels



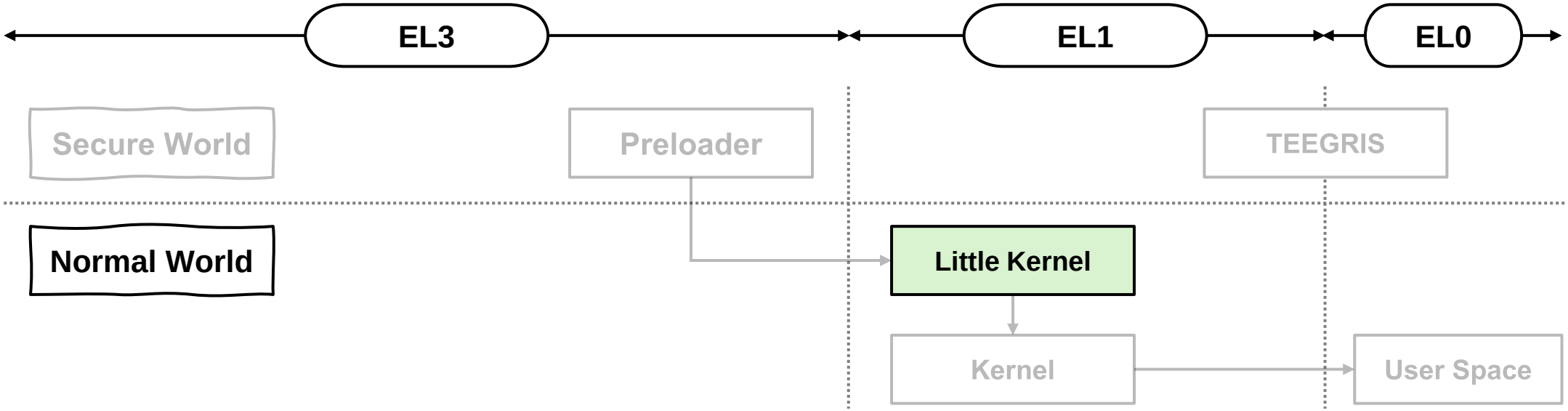
Attack Surface: Boot ROM (EL3)



Limitations

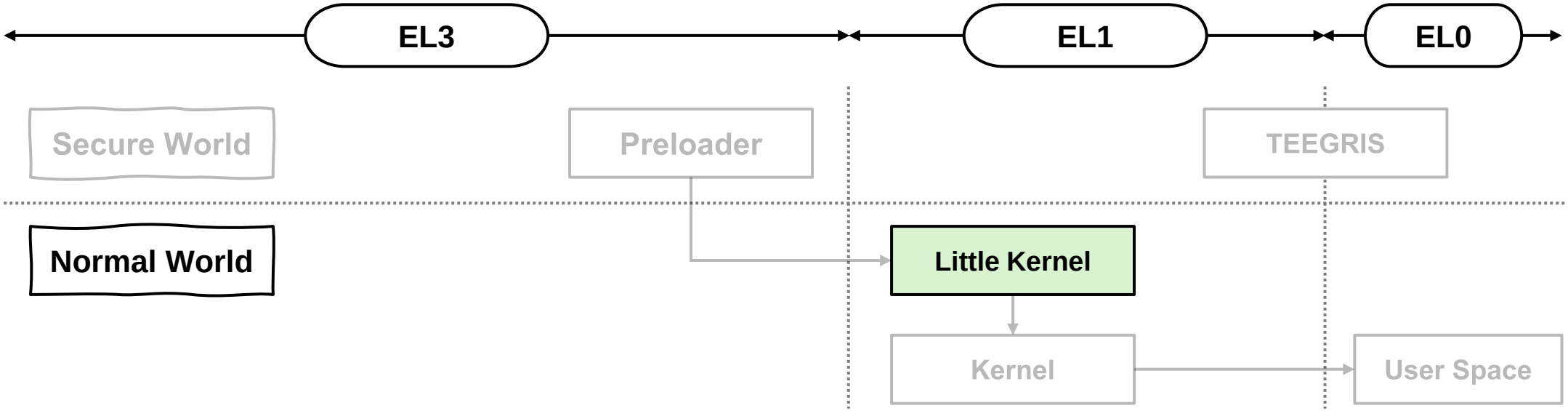
- Difficult to hook or infect
- Hard to access with software attacks

Attack Surface: Little Kernel (EL1)



- Verifies a kernel signature
- Loads the kernel
- Transfers control to the kernel

Attack Surface: Little Kernel (EL1)

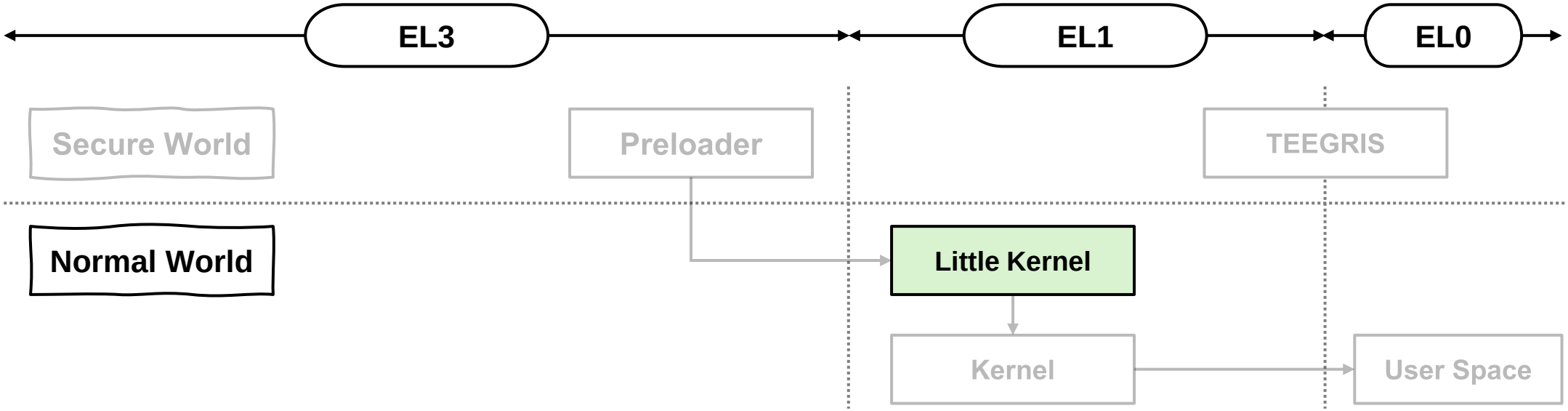


Attack Methods

- Exploits bootloader vulnerabilities

  → **Arbitrary code execution**

Attack Surface: Little Kernel (EL1)



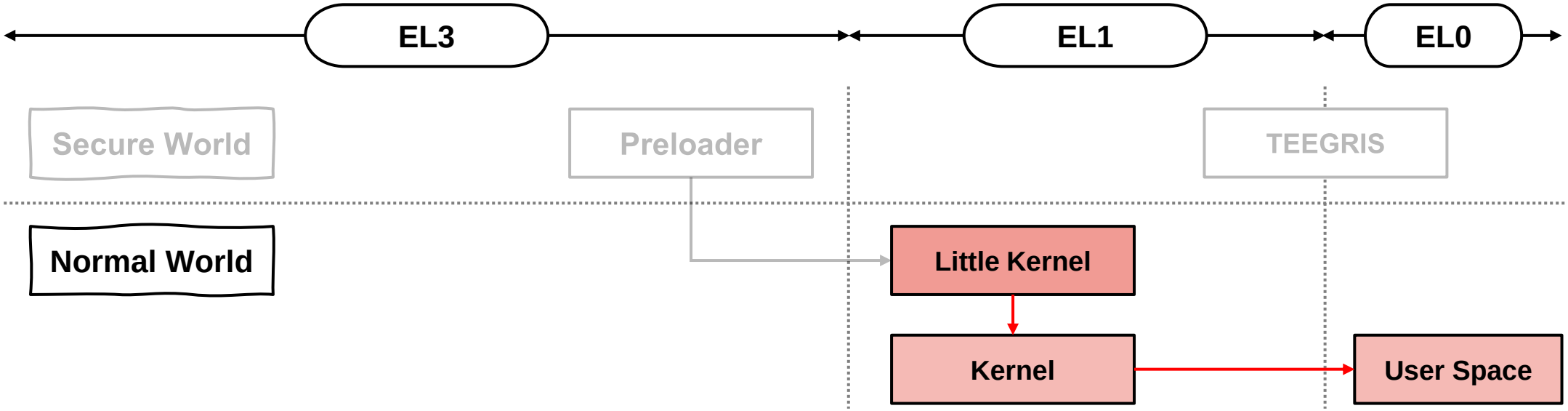
Attack Methods

- Injects a hook at the kernel load point

  → **Disabling mitigations**

  → **Deploying the rootkit**

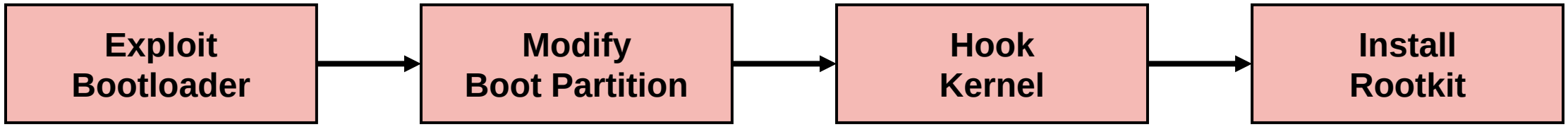
Attack Surface: Kernel (EL1 ~ EL0)



Attack Methods

- **Before kernel execution:** Exploits bootloader vulnerability to disable mitigations (Real-time Kernel Protection, SELinux)
- **After kernel loading:** Injects and executes a rootkit before applying security policies

How BOOTKITTY Compromised the Boot Process on Android



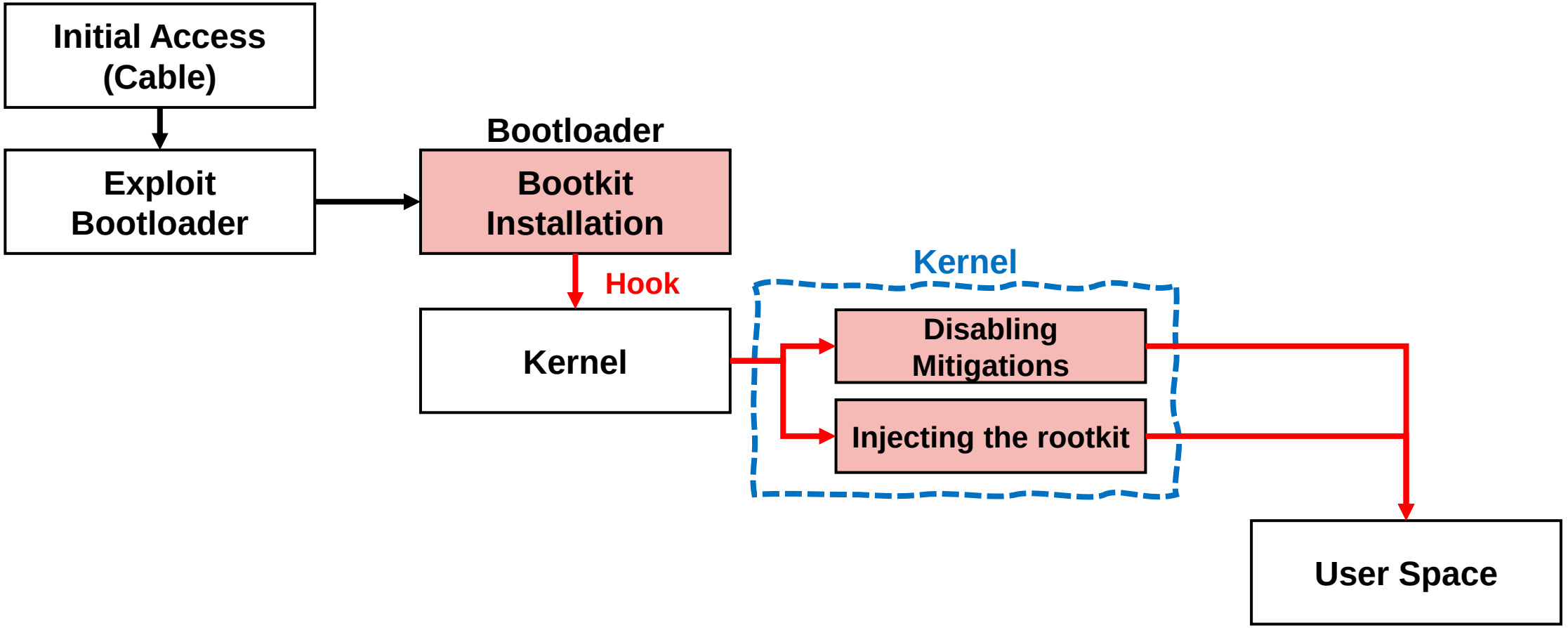
- Bootloader vulnerabilities (***CVE-2024-20832***, ***CVE-2024-20865***)

  → Boot partition compromise

- Bootkit installation via bootloader bugs

- Full-chain hijacking: Bootloader → Kernel

BOOTKITTY on Android: Bootloader Attack Scenario



Android Demo: Bootkit-Only

Key Takeaways

- Pre-kernel hooking → full system compromise
- *Hardening the boot process* and *boot-chain integrity verification* are essential

What We Have Not Talked About

- BOOTKITTY on windows
  - Windows boot process structure
  - Attack surfaces within the Wi ocess
  - Bootkit implementati Windows
- OS-specifi echniques and bypass methods
- Rootkit deplo ent flow

Please read our paper!

Artifacts

- **VM link**

(https://zenodo.org/records/15501870)

- **QEMU link**

(https://zenodo.org/records/15582744)