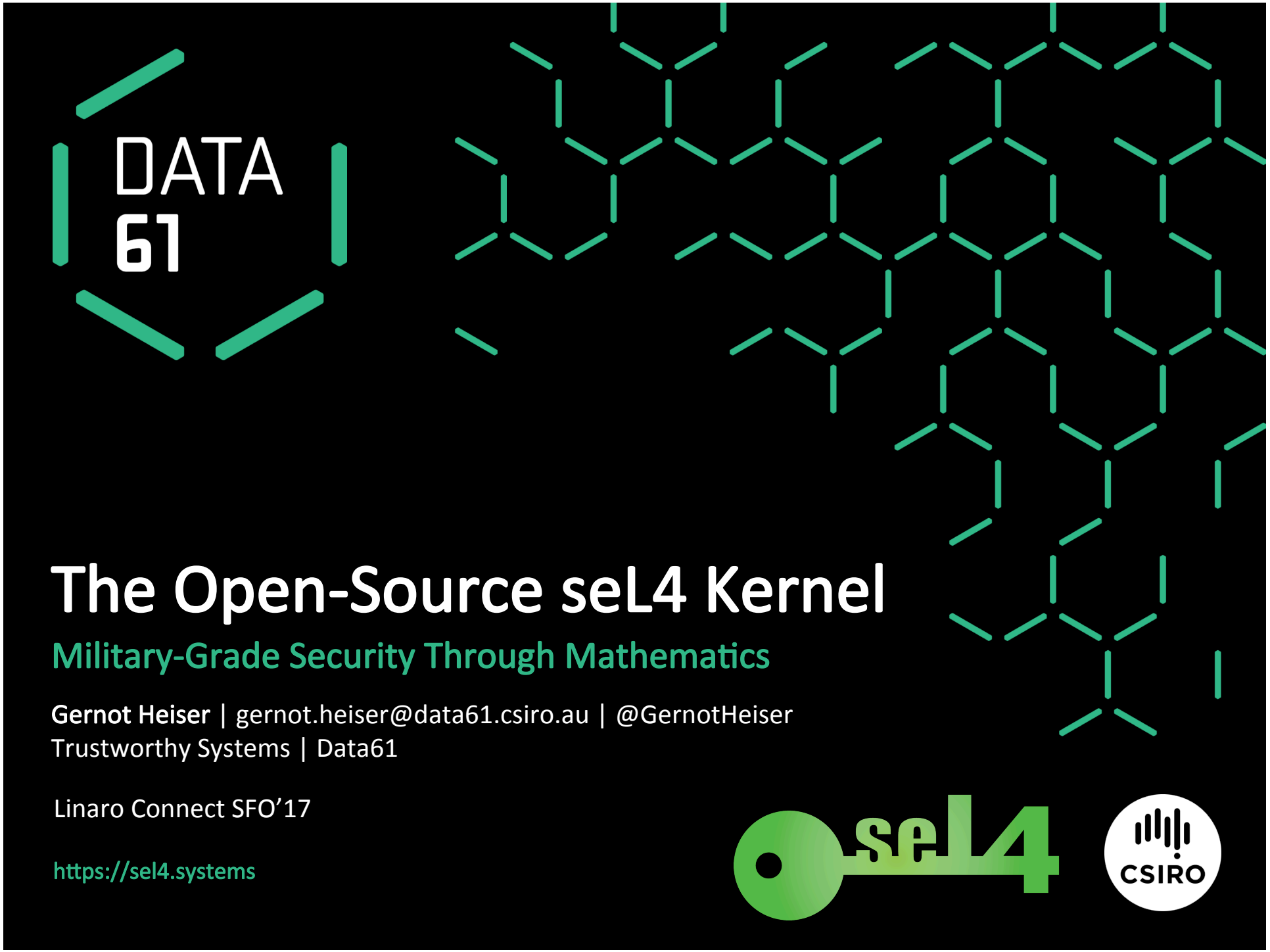


The Open-Source seL4 Kernel

Military-Grade Security Through Mathematics

Gernot Heiser | gernot.heiser@data61.csiro.au | @GernotHeiser
Trustworthy Systems | Data61

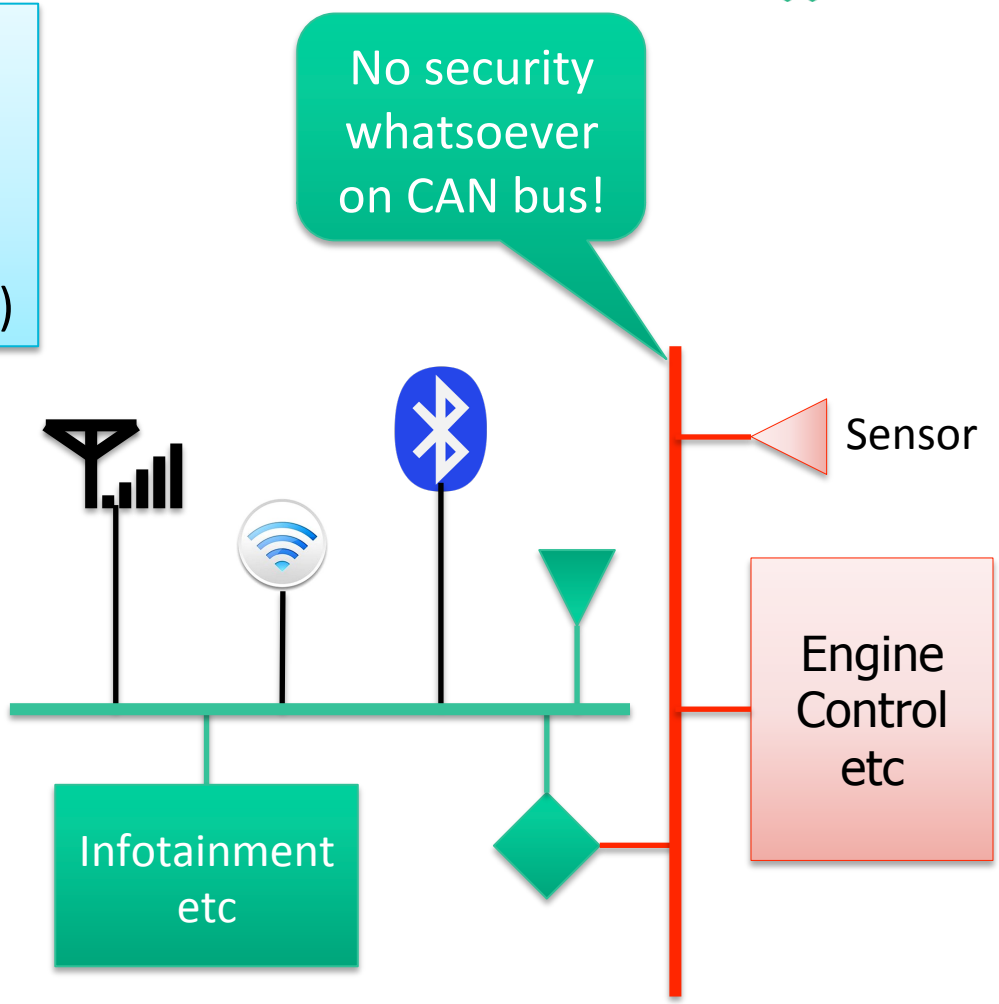
Linaro Connect SFO'17

https://sel4.systems

Car Hacking – What's Behind?

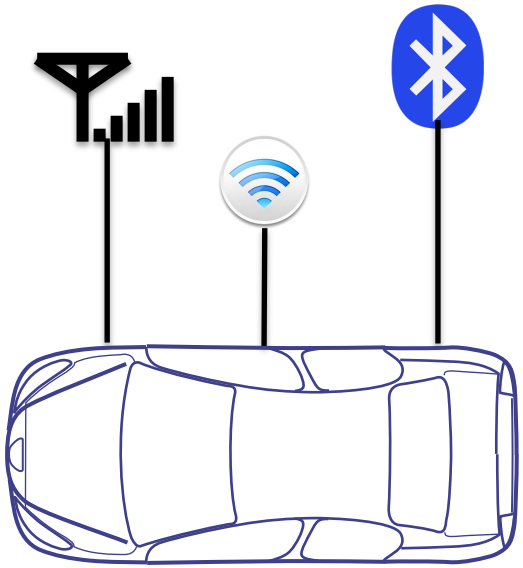
Networking for:

- Entertainment
- Connected car
- Safety (tire pressure…)
- Maintenance (OTA upgrades)



Challenge of Networking

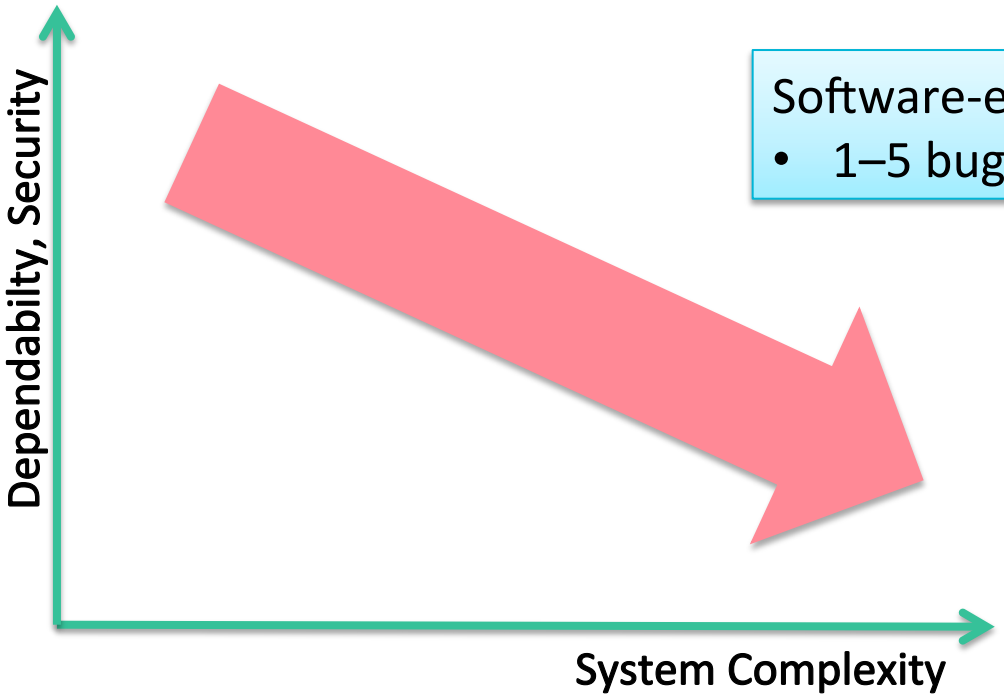
Networking creates remote attack opportunities
- from passengers (wifi, Bluetooth)
- from nearby cars (wifi, Bluetooth) – drive-by shooting, spread of viruses
- from anywhere (cellular)



BlueBorne

Attack vectors:
- Insecure protocols
- Reusing crypto keys
- Software vulnerabilities

Software Vulnerabilities



Software-engineering rule of thumb:
- 1–5 bugs per 1,000 lines of ***quality*** code

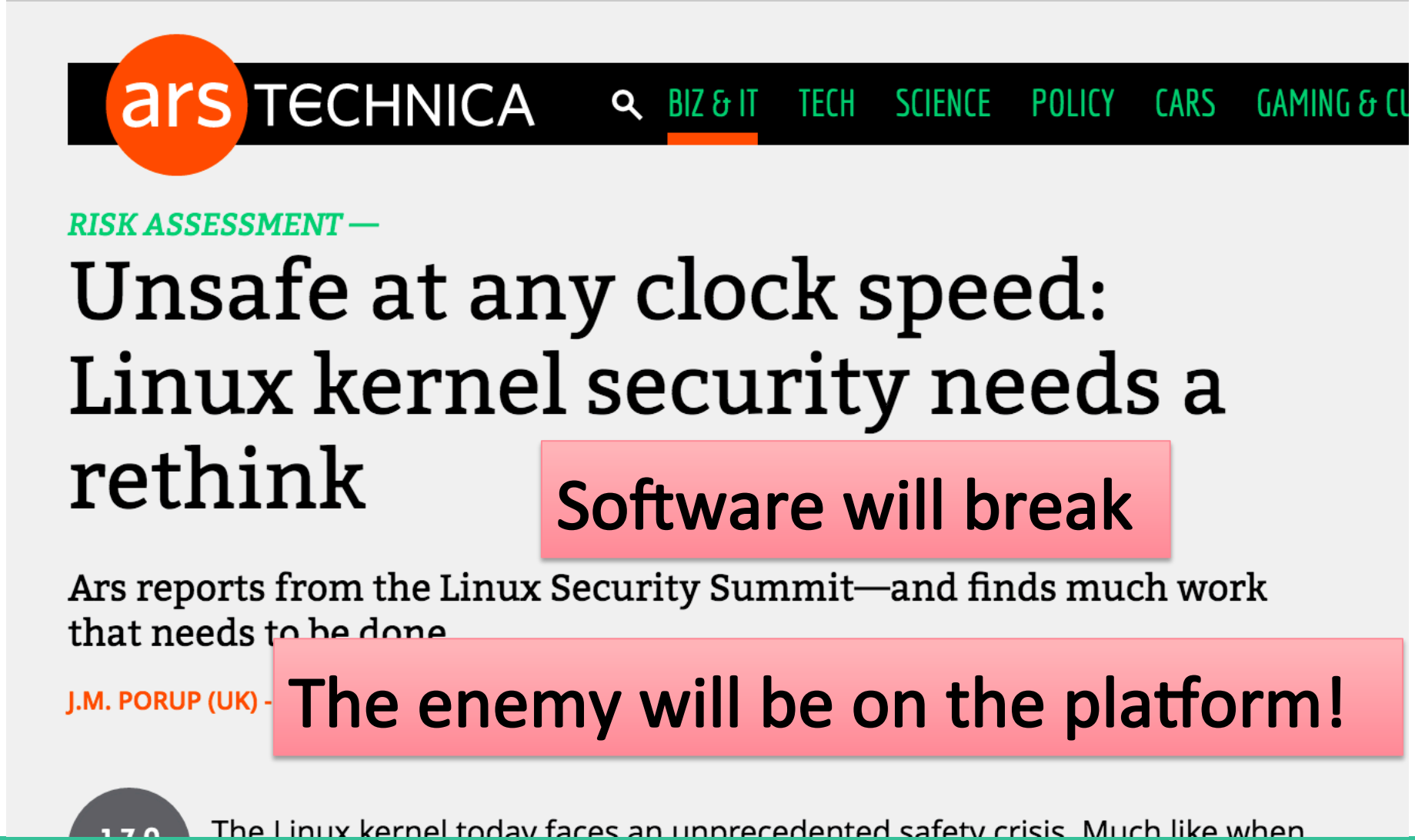
Bluetooth protocol stack:
Multiple 100,000 lines

Linux kernel:
Tens of millions lines

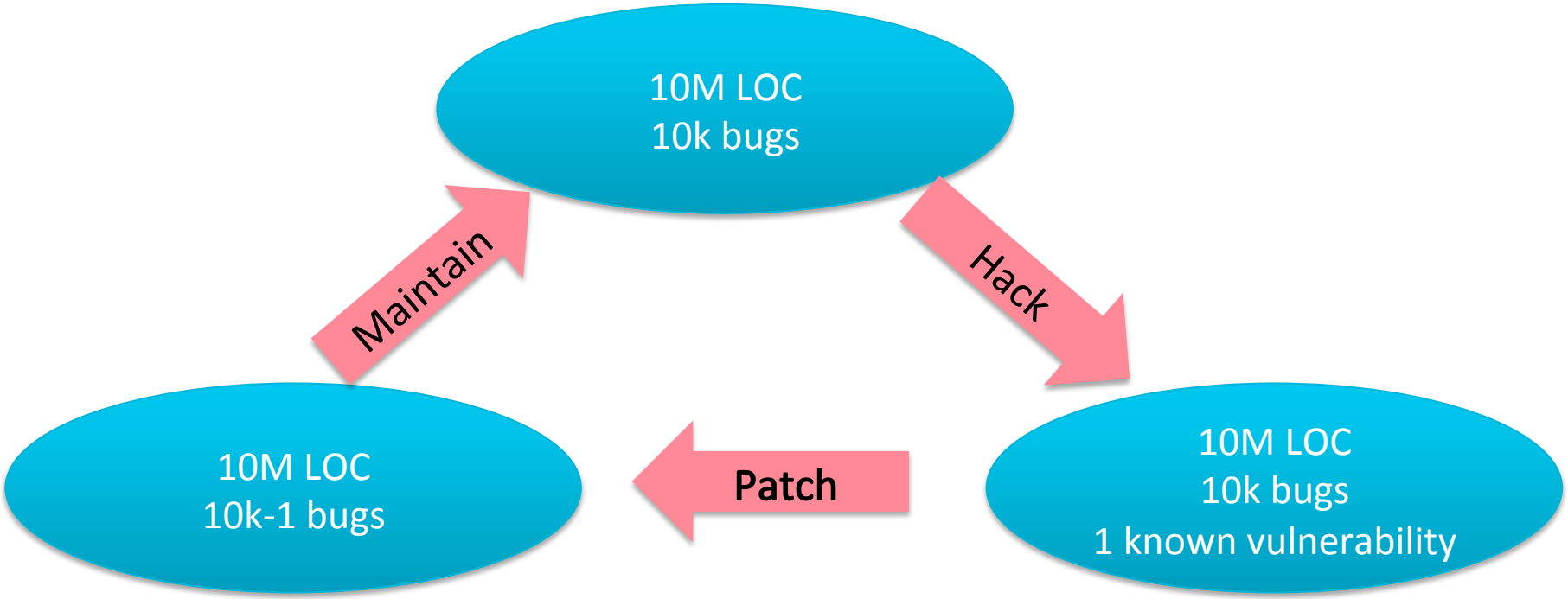
Complexity Drivers

- Features/functionality
- Legacy reuse

Linux “Security”



OK, So Let's Patch Regularly

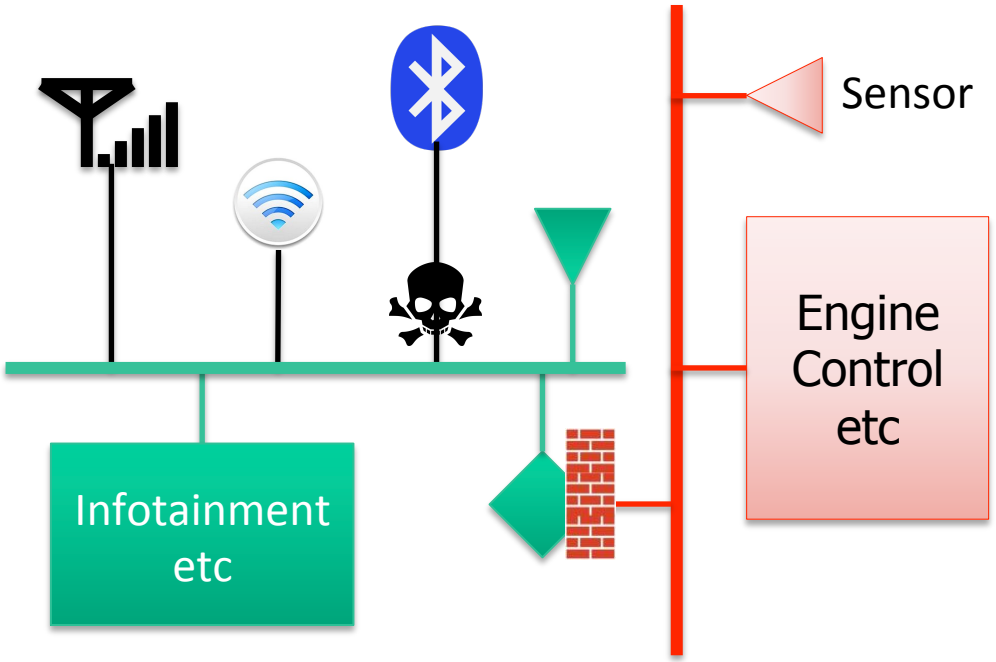


Patch-and-Pray: A losing proposition

So, Let's Use Firewalls!

- Imposes overhead (SWaP) or
- Runs on vulnerable OS ⇒ worthless if OS compromised
- Even more code – may *increase* attack surface
- No help for valid messages that trigger bugs in software

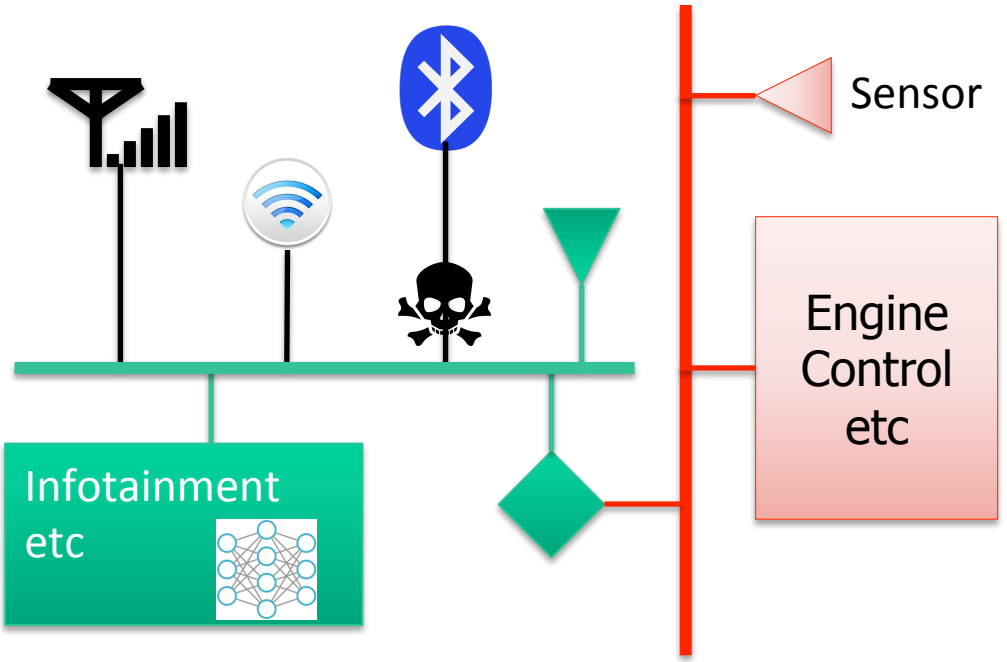
Firewalls treat symptoms, not causes of problems!



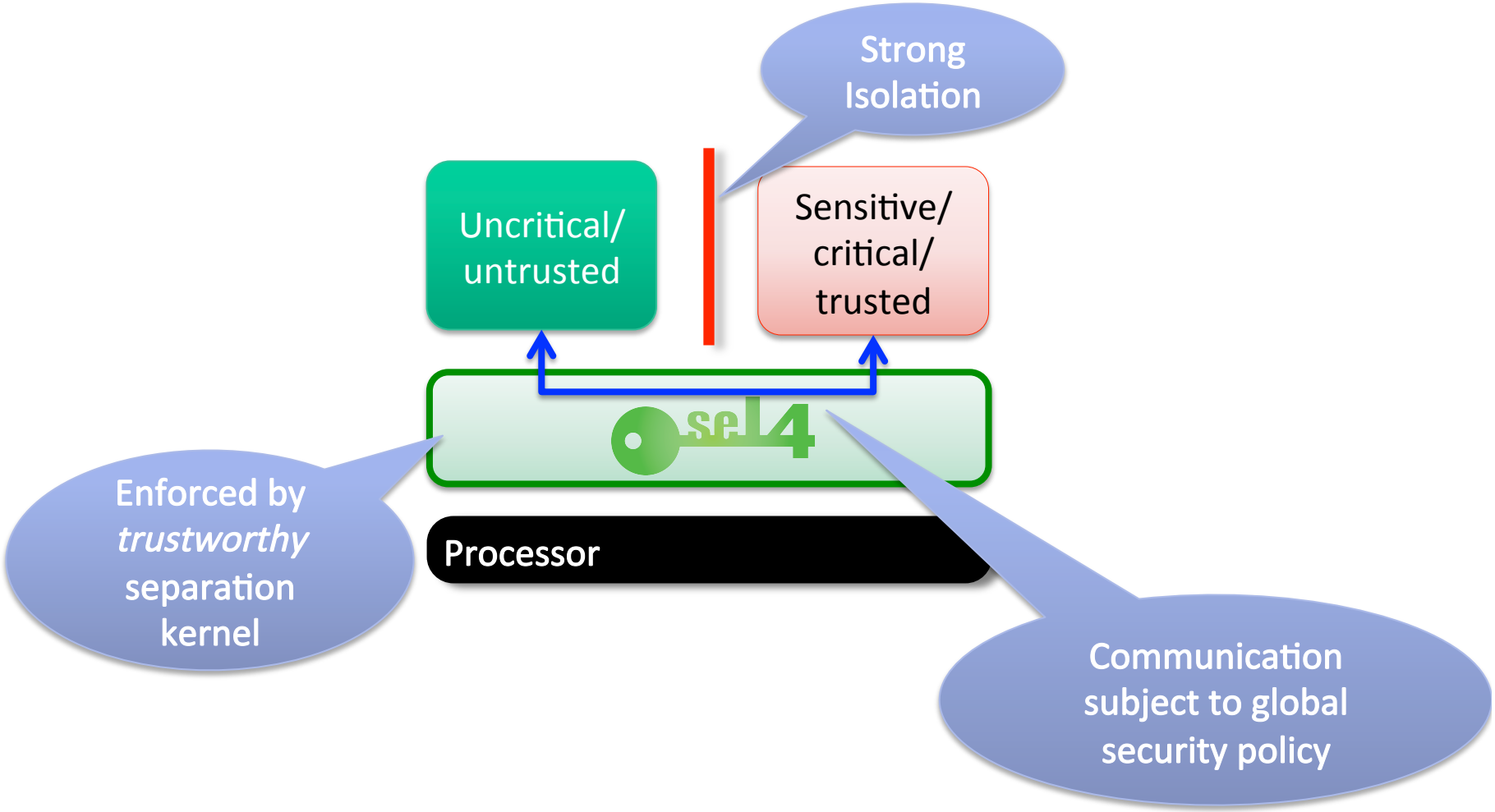
Let's Use AI to Detect Compromise!

- Runs on vulnerable OS ⇒ worthless if OS compromised
- Even more code – may *increase* attack surface
- Can only detect that system is **already compromised**

Intrusion detection: admission of defeat



Fundamental Security Requirement: Isolation



Trustworthiness: Can We Rely on Isolation?

A system is **trustworthy** if and only if:

- it behaves **exactly** as it is specified,
- in a **timely** manner,
- while ensuring **secure** execution

Claim:

A system must be considered *untrustworthy* unless *proved* otherwise!

Corollary [with apologies to Dijkstra]:

Testing, code inspection, etc. can only show *lack of trustworthiness*!

seL4 Provably Secure Operating System

~10,000 lines of C and ASM code

⬇

Small attack surface,
Amenable to full verification

Non-kernel code can only access resources and communication channels if explicitly authorised with a per-object access token (capability)

⬇

- **Confined damage**
- **Least privilege**

Small,

fast,

capability-based,

operating system kernel

World's fastest (5–10x faster) operating system designed for security and safety

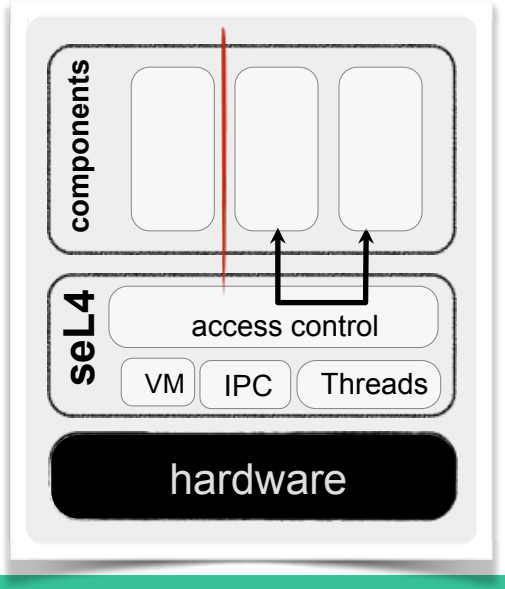
⬇

Suitable for real-world deployment

Code that runs in privileged mode of the hardware

⬇

Most critical part

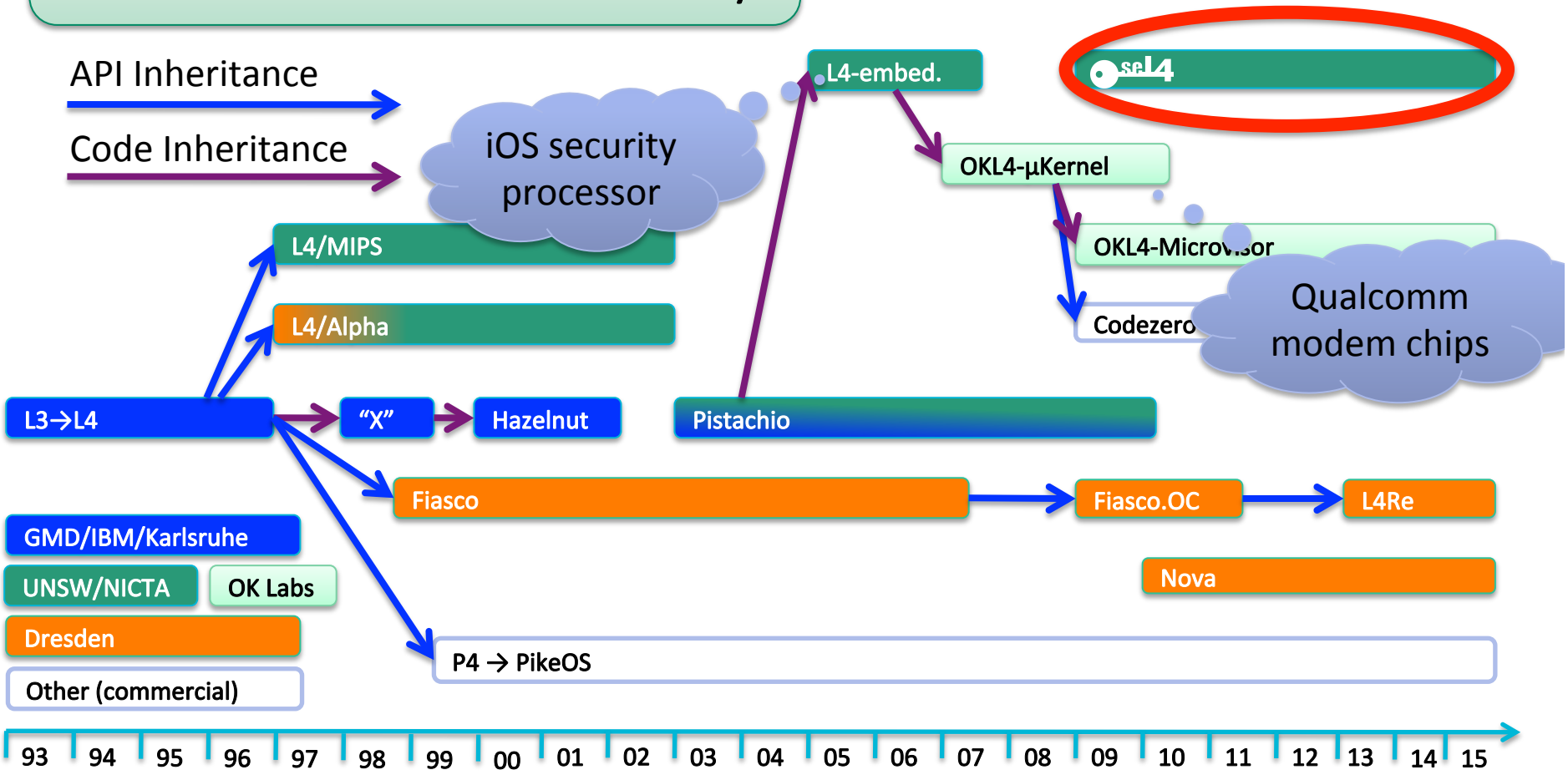


Unprivileged mode

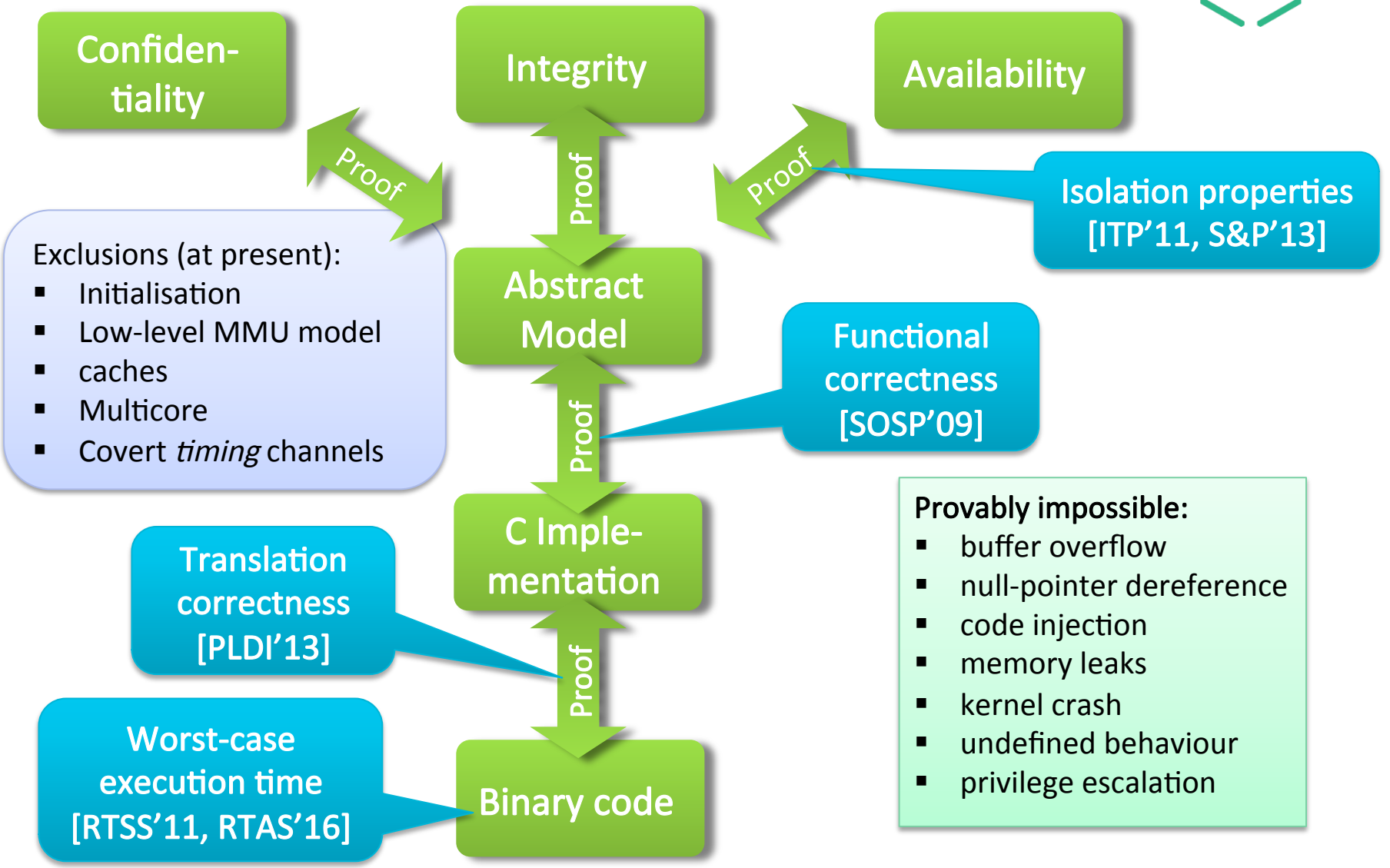
Privileged mode

20+ Years of L4 Microkernel R&D

seL4: The latest (and most advanced) member of the L4 microkernel family



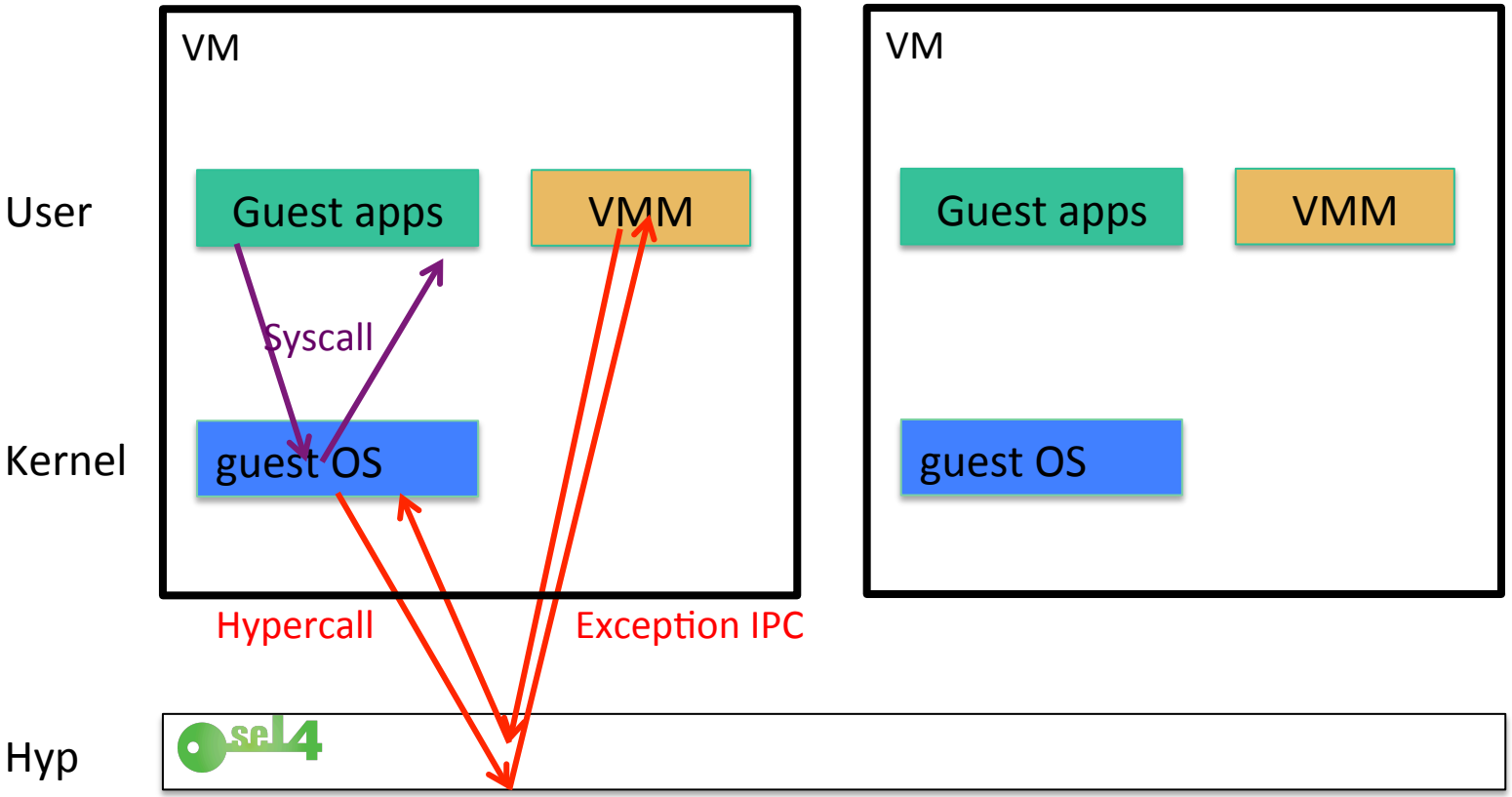
Proving Trustworthiness of seL4



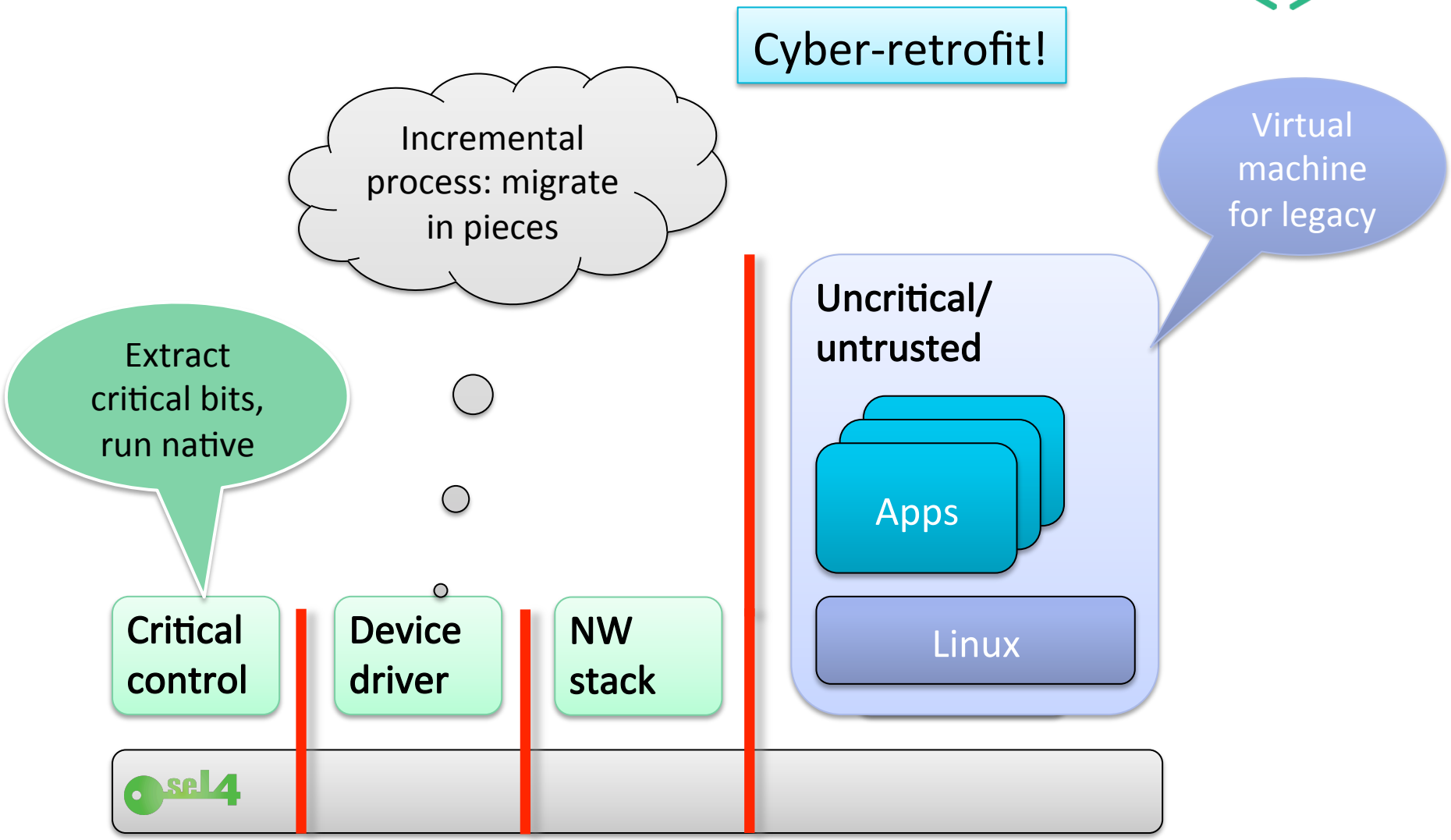
How Does seL4 Compare?

Feature	seL4	Other hypervisors, RTOSes, separation kernels
Performance	Fastest	2–10 × slower
Functional correctness	Proved	No Guarantee
Isolation	Proved	No Guarantee
Worst-case latency bounds	Sound & complete	Estimates only
Storage channel freedom	Proved	No Guarantee
Timing channel prevention	Low overhead	None or High Overhead
Mixed-criticality support	Fully supported, high utilisation	Limited, resource-wastive

Virtualisation



Security by Architecture



Real-World Example: DARPA HACMS

Boeing Unmanned Little Bird

Retrofit existing system!

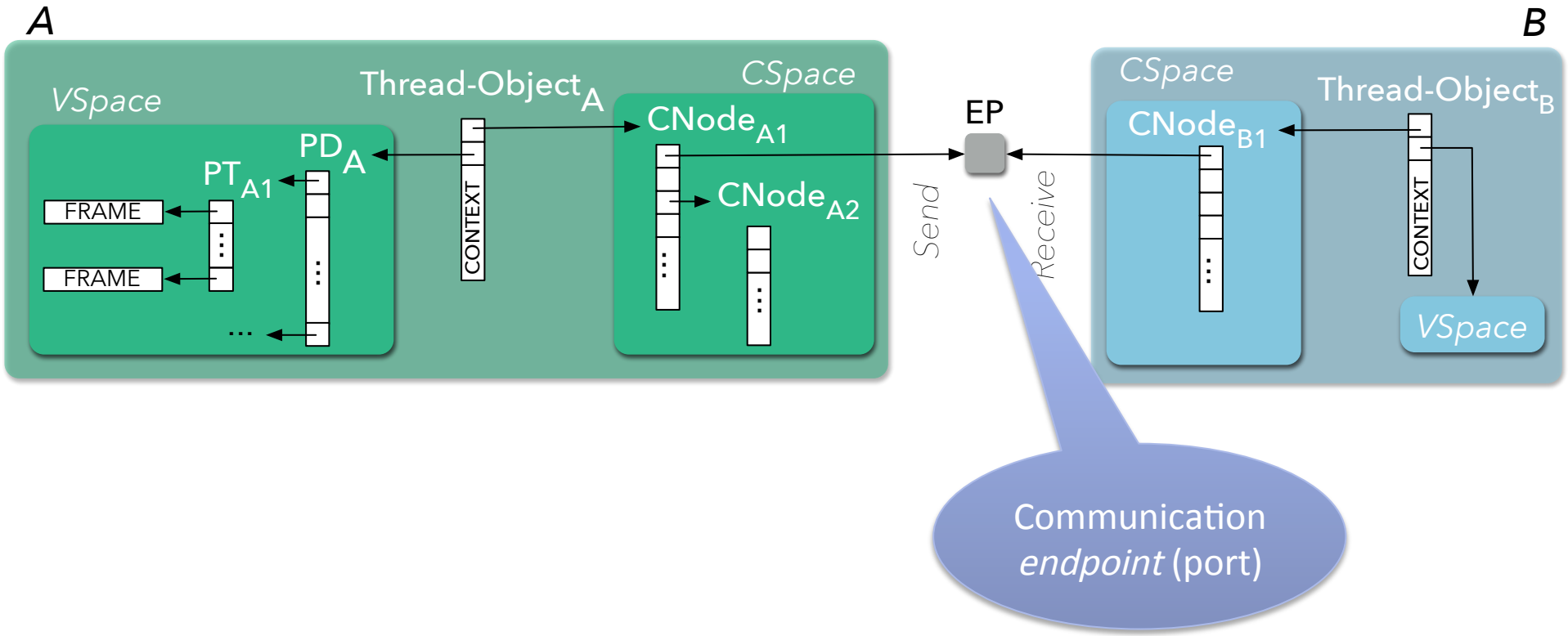
US Army Autonomous Trucks

SMACCMcopter Research Vehicle

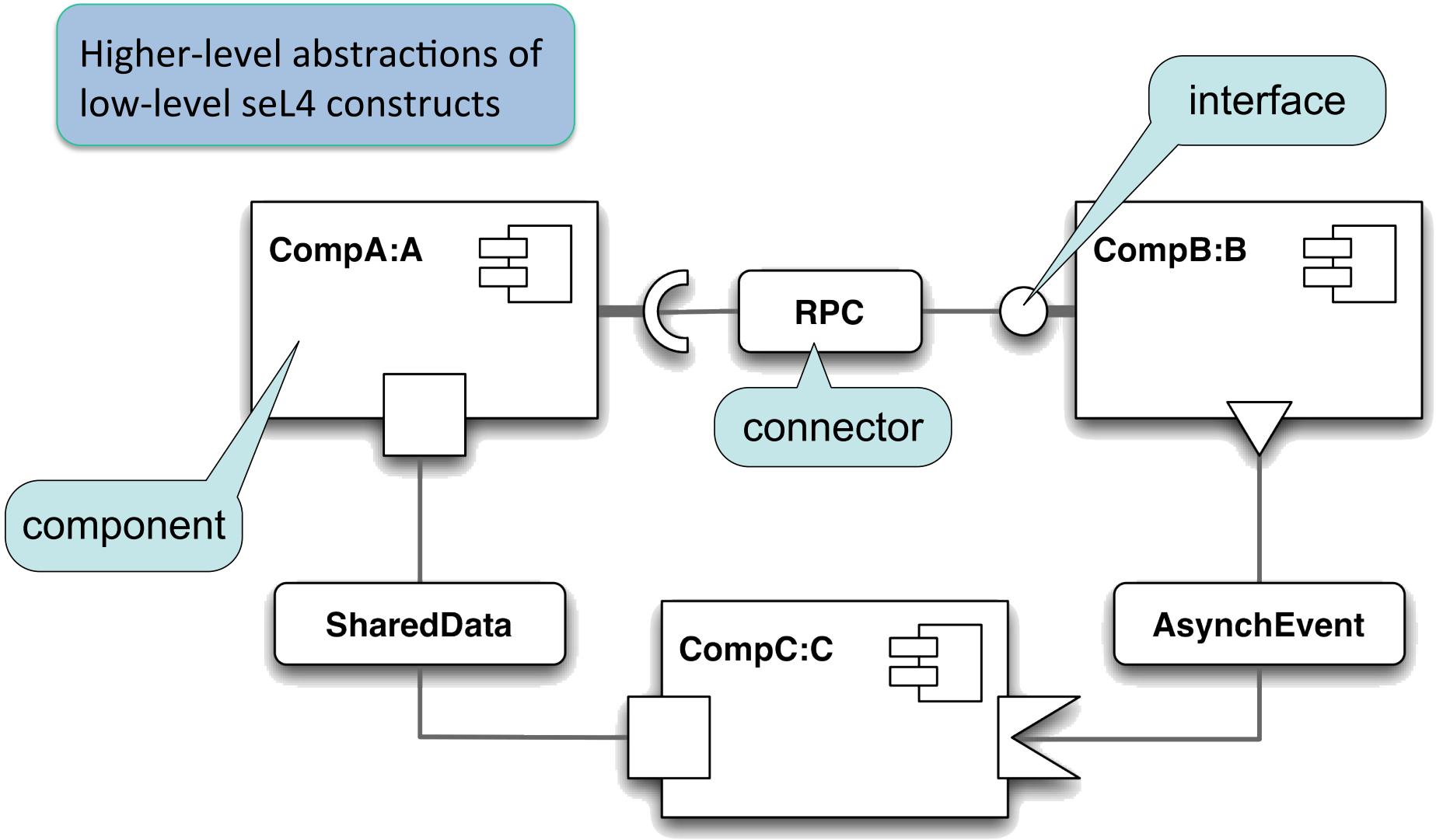
Develop technology

TARDEC GVR-Bot

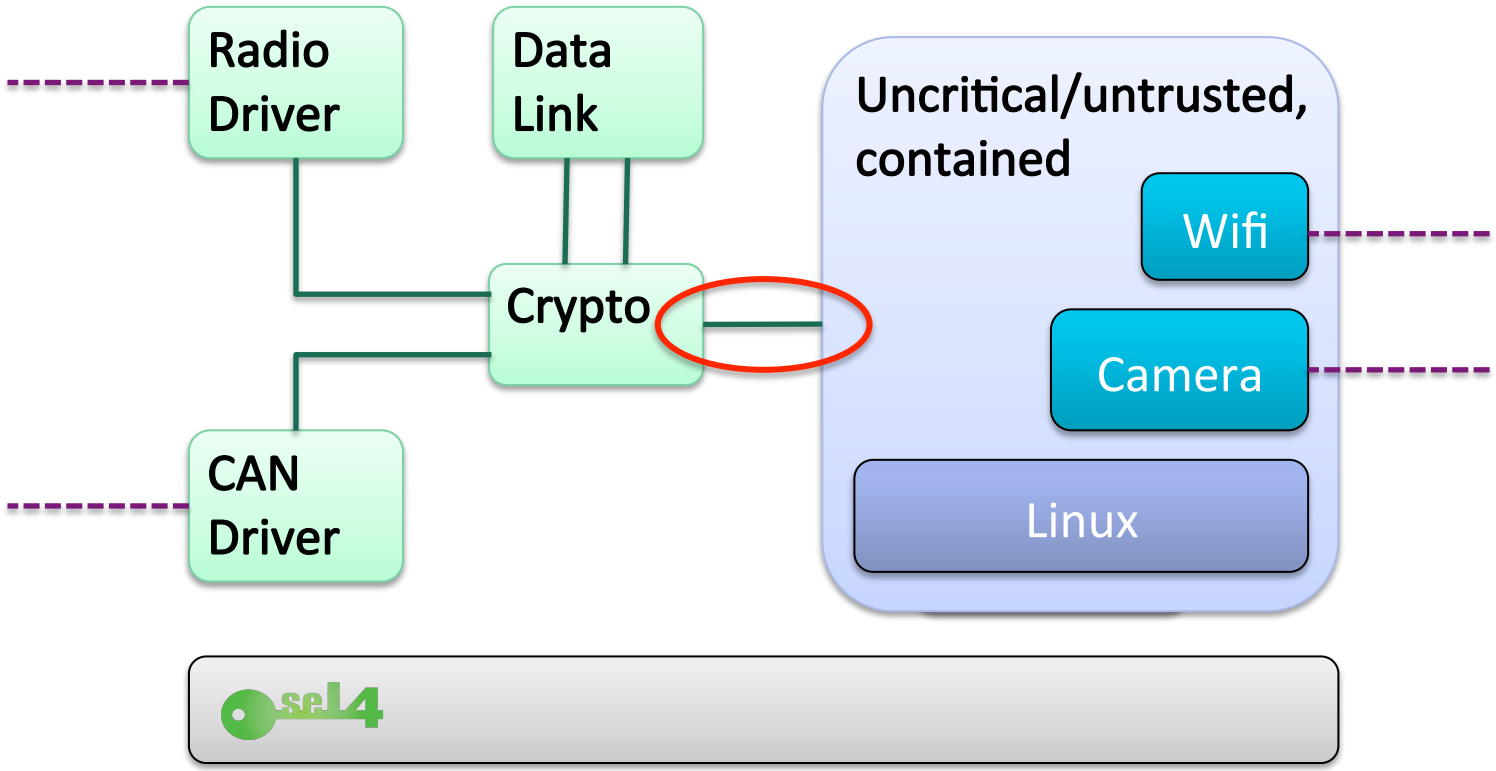
Example: Communicating Processes



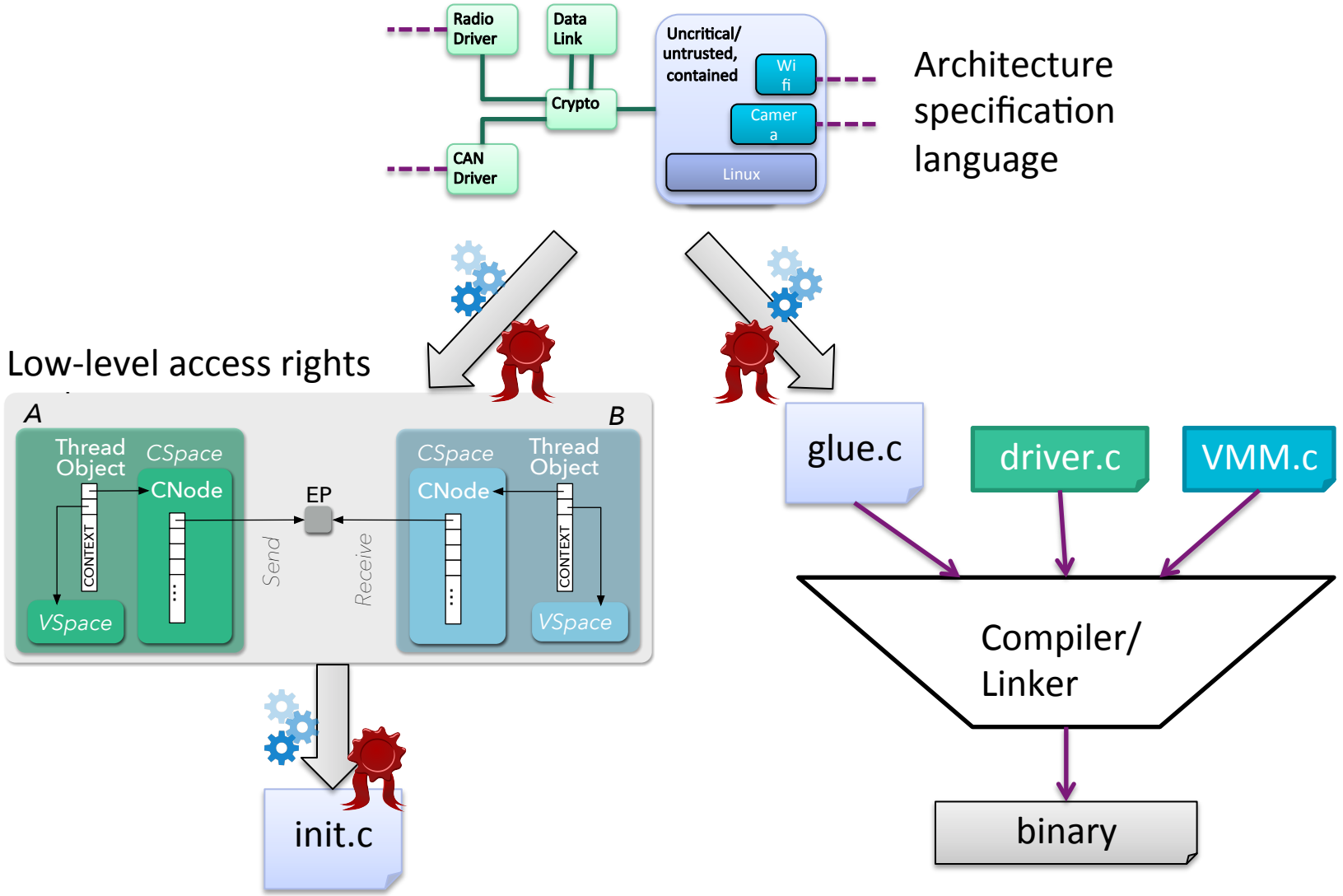
Component Middleware: CAmkES



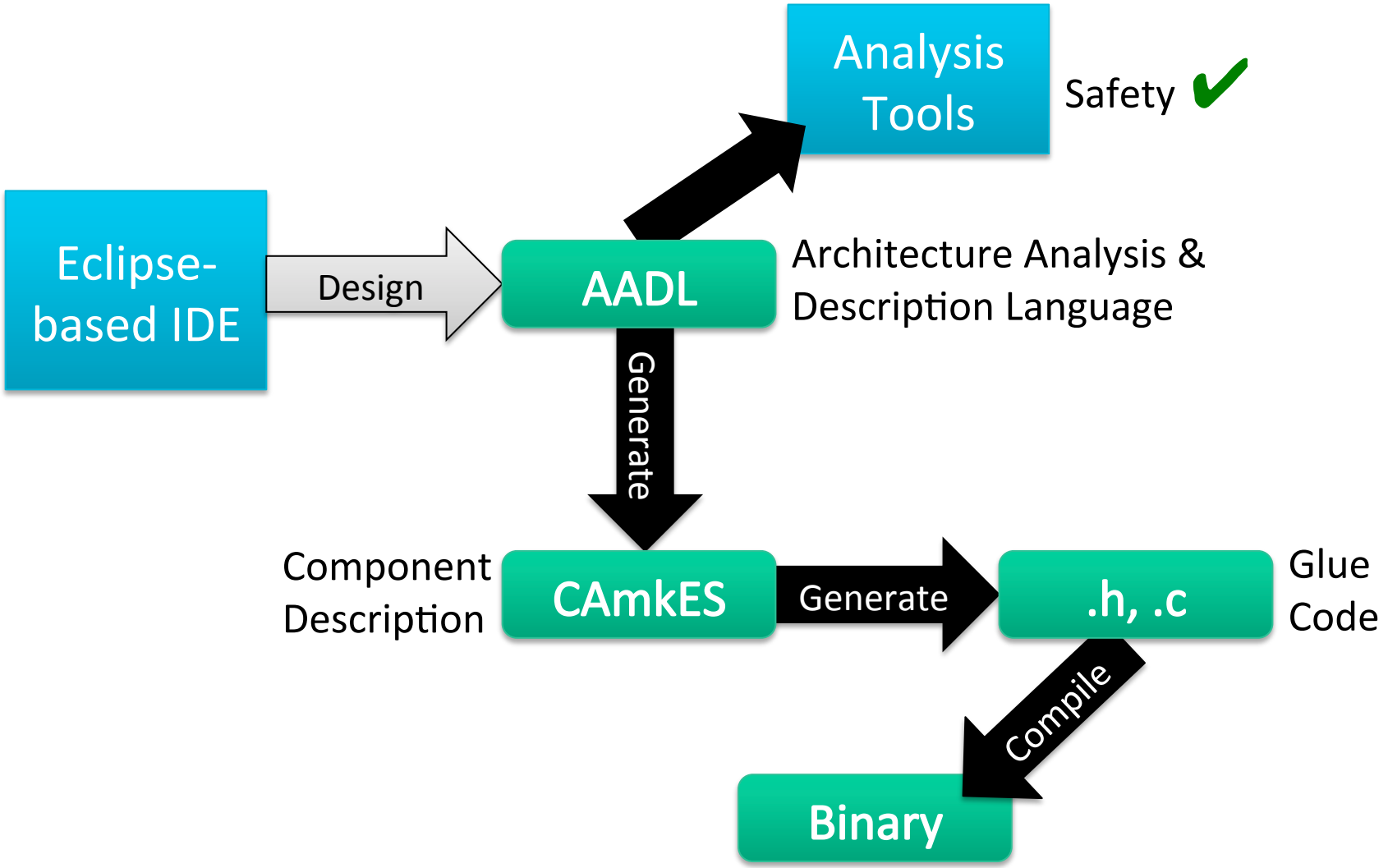
Example: Simplified HACMS UAV



Enforcing the Architecture



Open-Source Architecture Analysis



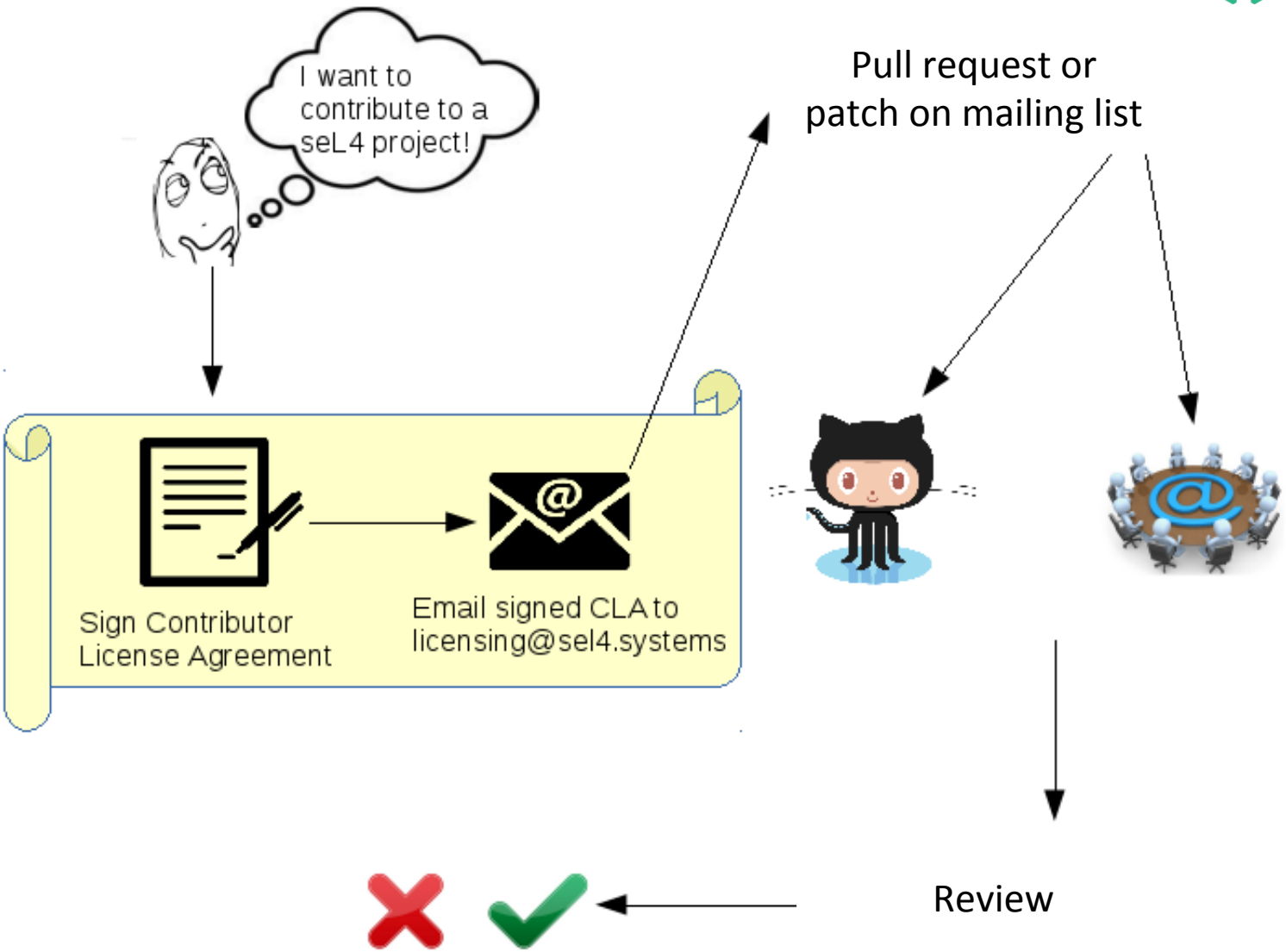
Military-Grade Security

Cross-Domain Desktop Compositor

Multi-level secure terminal
- Successful defence trial in AU
- Evaluated in US, UK, CA
- Formal security evaluation soon

Pen10.com.au crypto communication device undergoing formal security evaluation in UK

seL4 Contributions



Thank you

Robin Randhawa

Please check out https://sel4.systems

Military-Grade Security for You!

Security is no excuse for poor performance!

Gernot Heiser | gernot.heiser@data61.csiro.au | @GernotHeiser
Linaro Connect SFO'17

http://sel4.systems