Secure and Efficient Application Monitoring and Replication

Stijn Volckaert, Bart Coppens, Alexios Voulimeneas, Andrei Homescu, Per Larsen, Bjorn De Sutter, Michael Franz

Adobe Patches 10 Critical Vulnerabilities in Flash Player, Shockwave Player, and ColdFusion

Posted on April 9th, 2013 by Derek Erwin

Zero-Day Vulnerability Bypasses Apple's Security Featu ces: Updat

09 June 2012, 10:59

Adobe Flash update closes several critical holes

28 March 2016, 8:15 am EDT By Horia Ungureanu Tech Times

Adobe Issues Emergency Updates For Zero-Day Flaw in Flash Player

Memory corruption flaw is being exploited in the wild to distribute ransomware samples like Locky and Cerber.

Update Flash now! Adobe releases patch, fixing critical security holes

BY GRAHAM CLULEY POSTED 22 SEP 2015 - 09:24AM

stems.

Critical Adobe Flash bug under active attack currently has no patch

Exploit works against the most recent version; Adobe plans update later this week.

by Dan Goodin - Jun 14, 2016 12:50pm PDT

Firefox 45 browser update patches 22

(Another) Update To Adobe Flash Addresses Latest 0-Day Vulnerability

April 15, 2011

By Charlie Osborne for Zero Day | March 10, 2016 -- 10:01 GMT (02:01 PST) | Topic: Security

Adobe Releases Security Update for 19 'Critical' Vulnerabilities in Flash Player

DAVID BISSON

DEC 29, 2015 | LATEST SECURITY NEWS

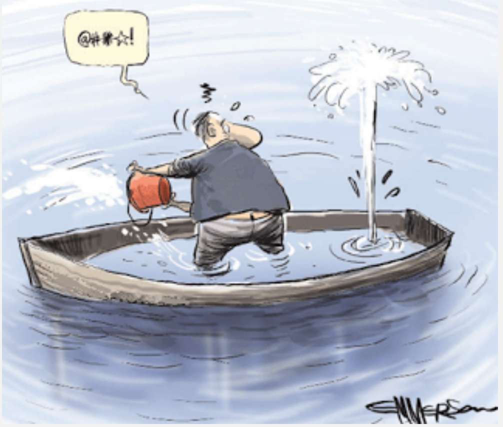
Adobe Fixes 18 Vulnerabilities in Flash Player

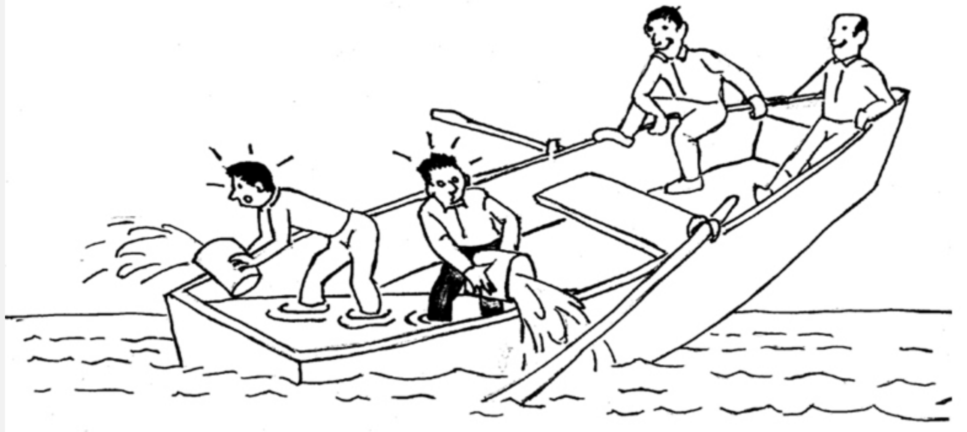
By Eduard Kovacs on November 12, 2014

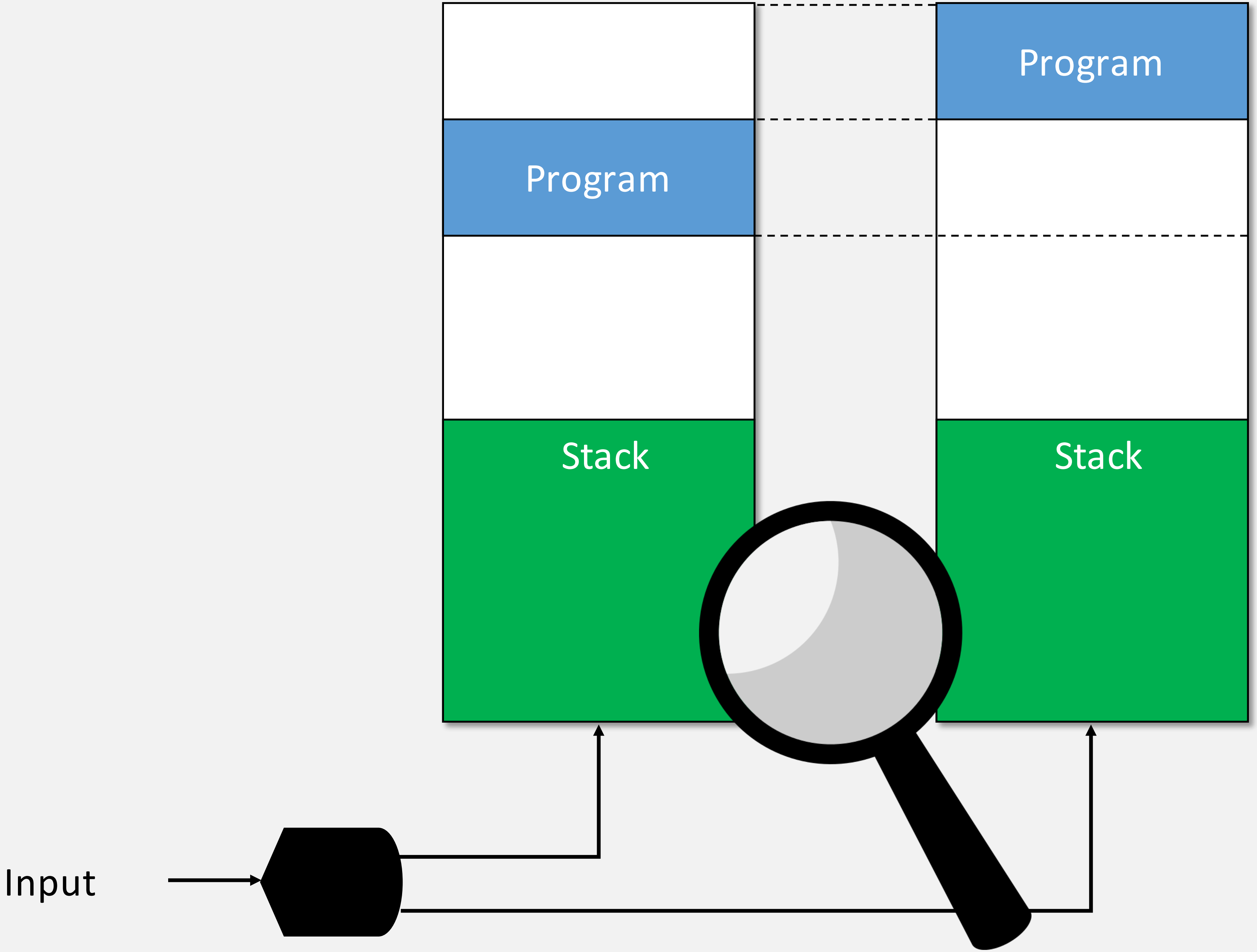
Possible Solutions

- ~~Type-Safe Languages (e.g. Rust)~~

- ~~Mitigations:~~
  - ~~Integrity-Based (e.g. CFI)~~
  - ~~Randomization-Based (e.g. ASLR)~~
- Multi-Variant Execution Environments (MVEEs)

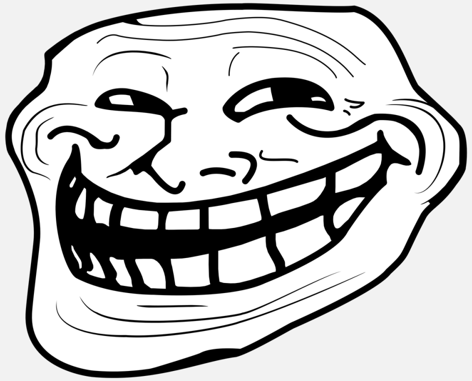


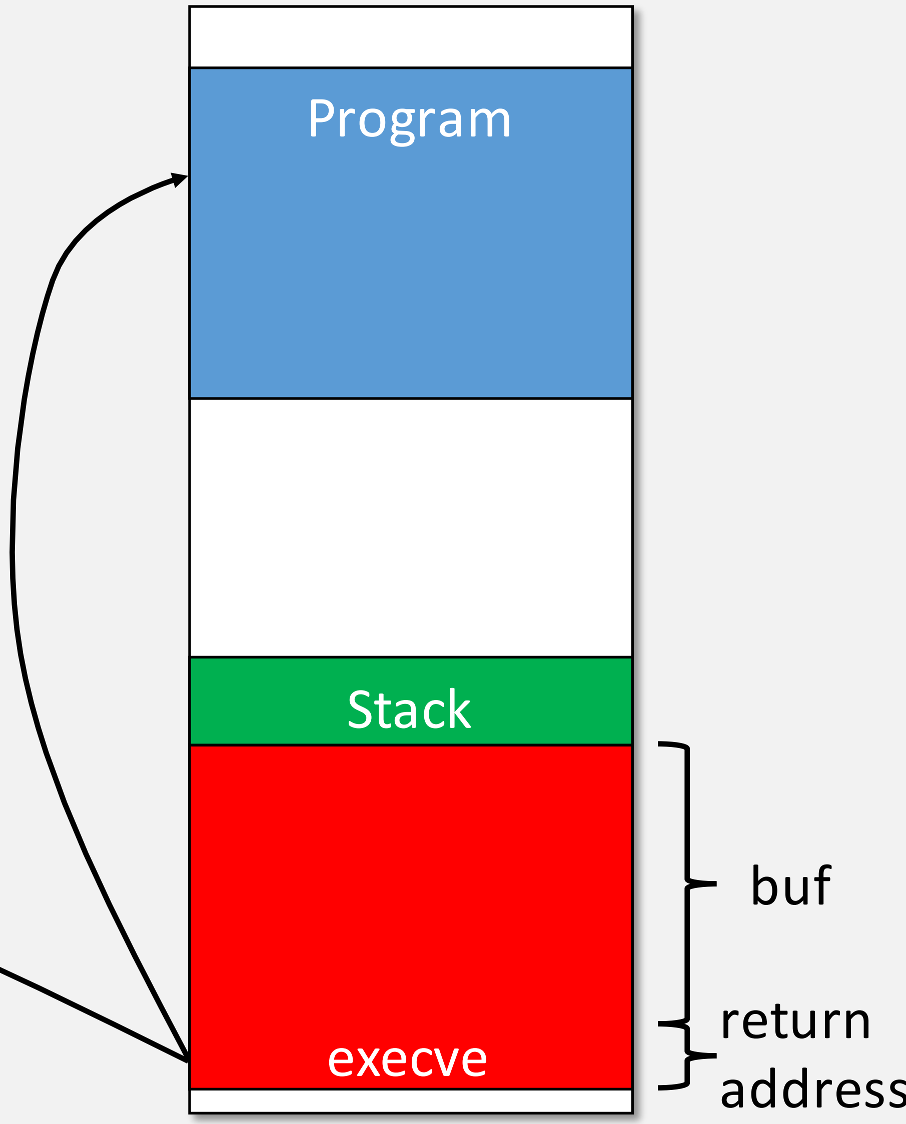


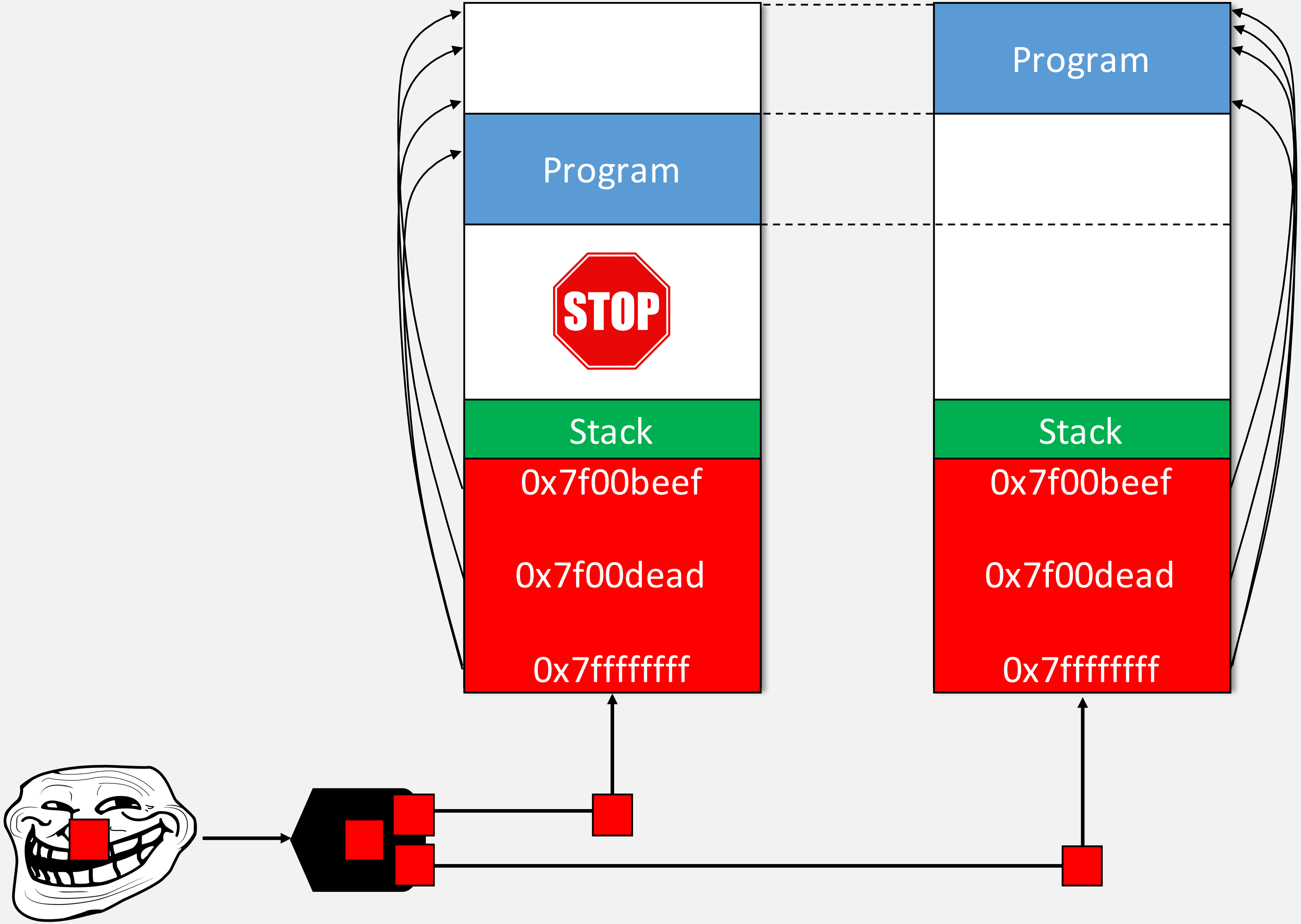

Program
Program
Stack
Stack
Input

Memory Corruption Attacks

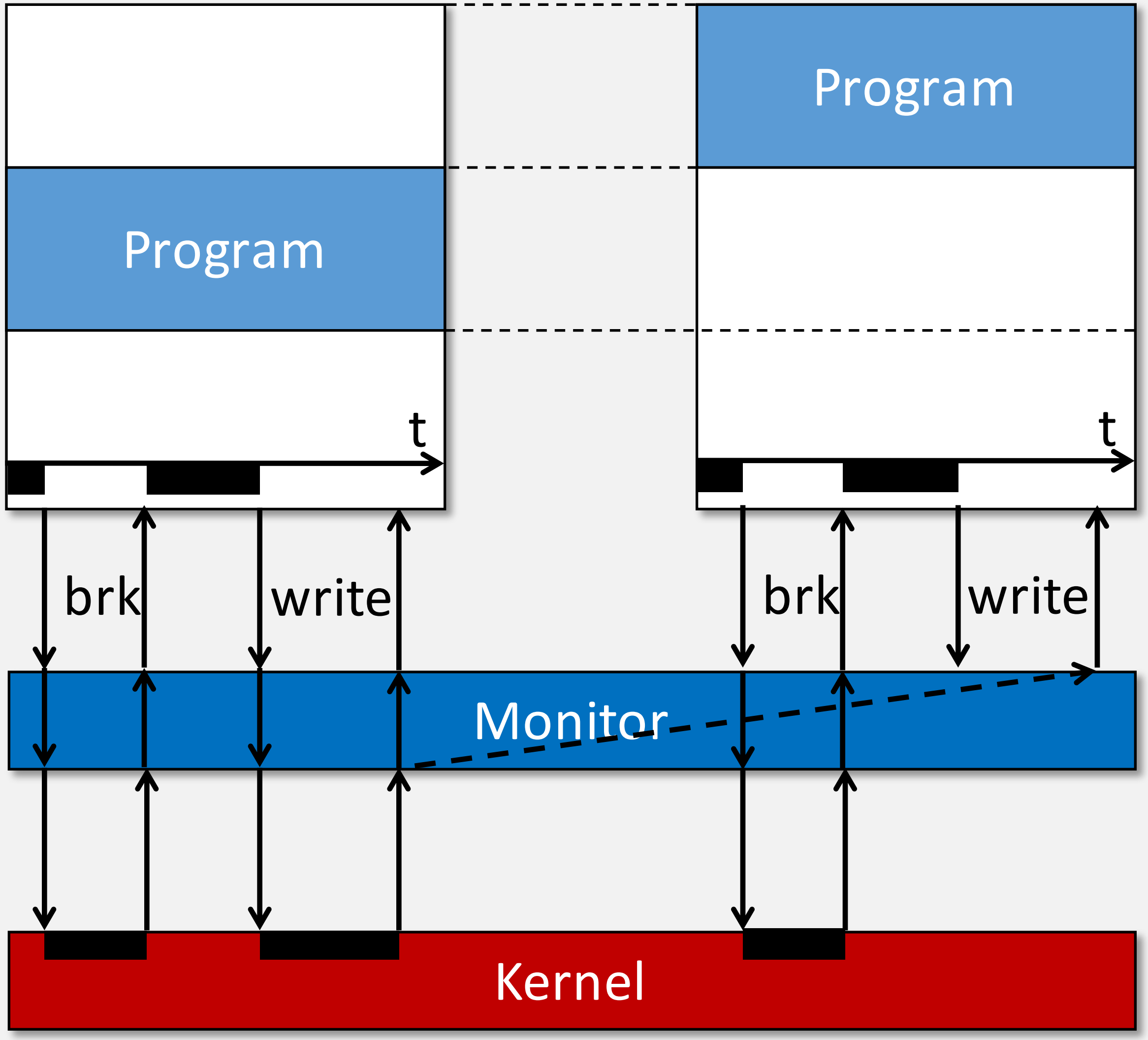
```
void foo() {
    char buf[256];
    gets(buf);
    printf("%s", buf);
}

int main(int argc, char** argv) {
    foo();
    return 0;
}
```






Program
Program
STOP
Stack
Stack
0x7f00beef
0x7f00dead
0x7ffffffff
0x7f00beef
0x7f00dead
0x7ffffffff

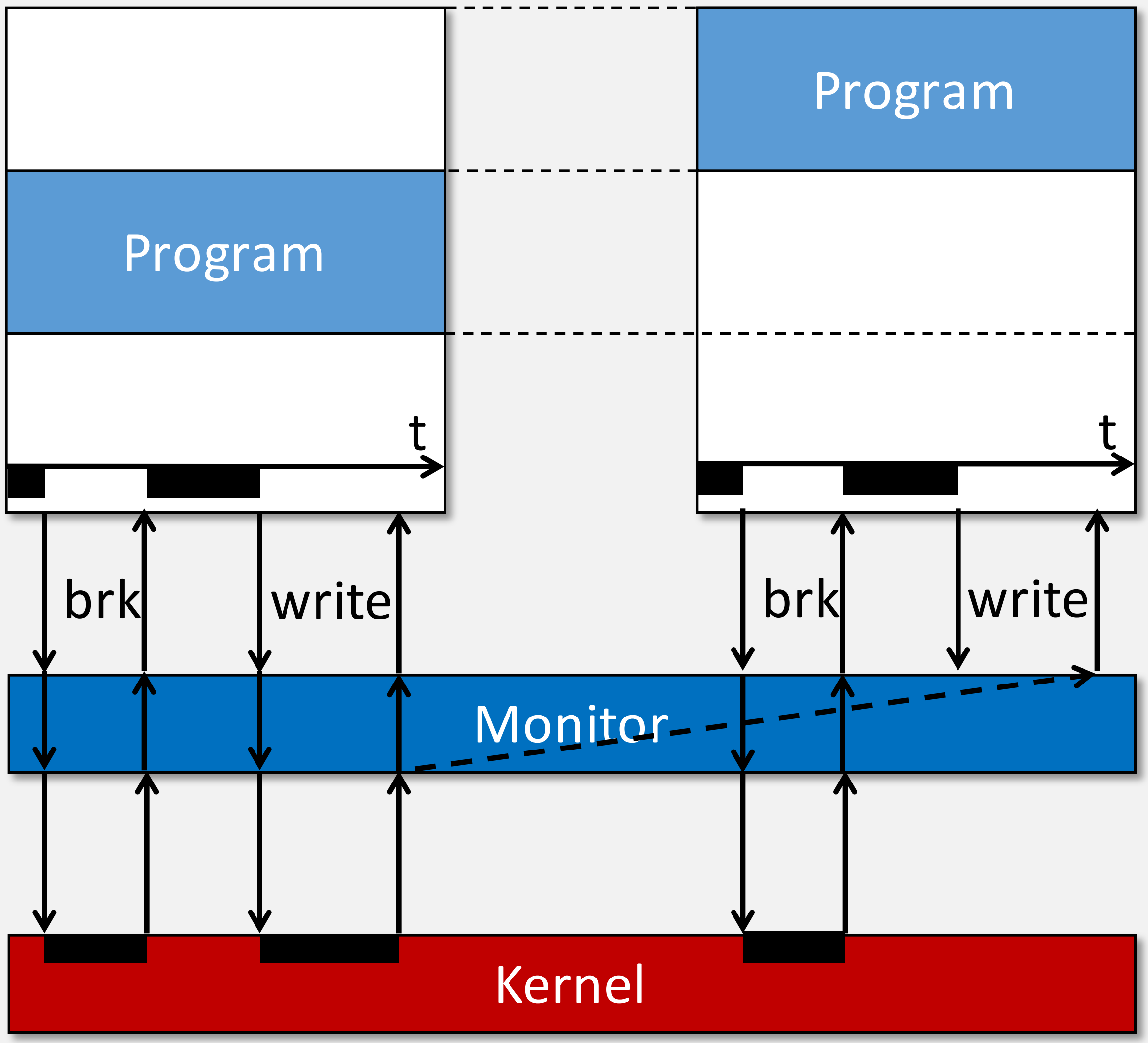
Multi-Variant Execution Environments (MVEEs)



In a nutshell:

- Run multiple program variants in parallel
- Variant system calls executed in lock-step
- Suspend them at every system call
- Compare system call numbers/arguments
- Master/Slave replication for I/O

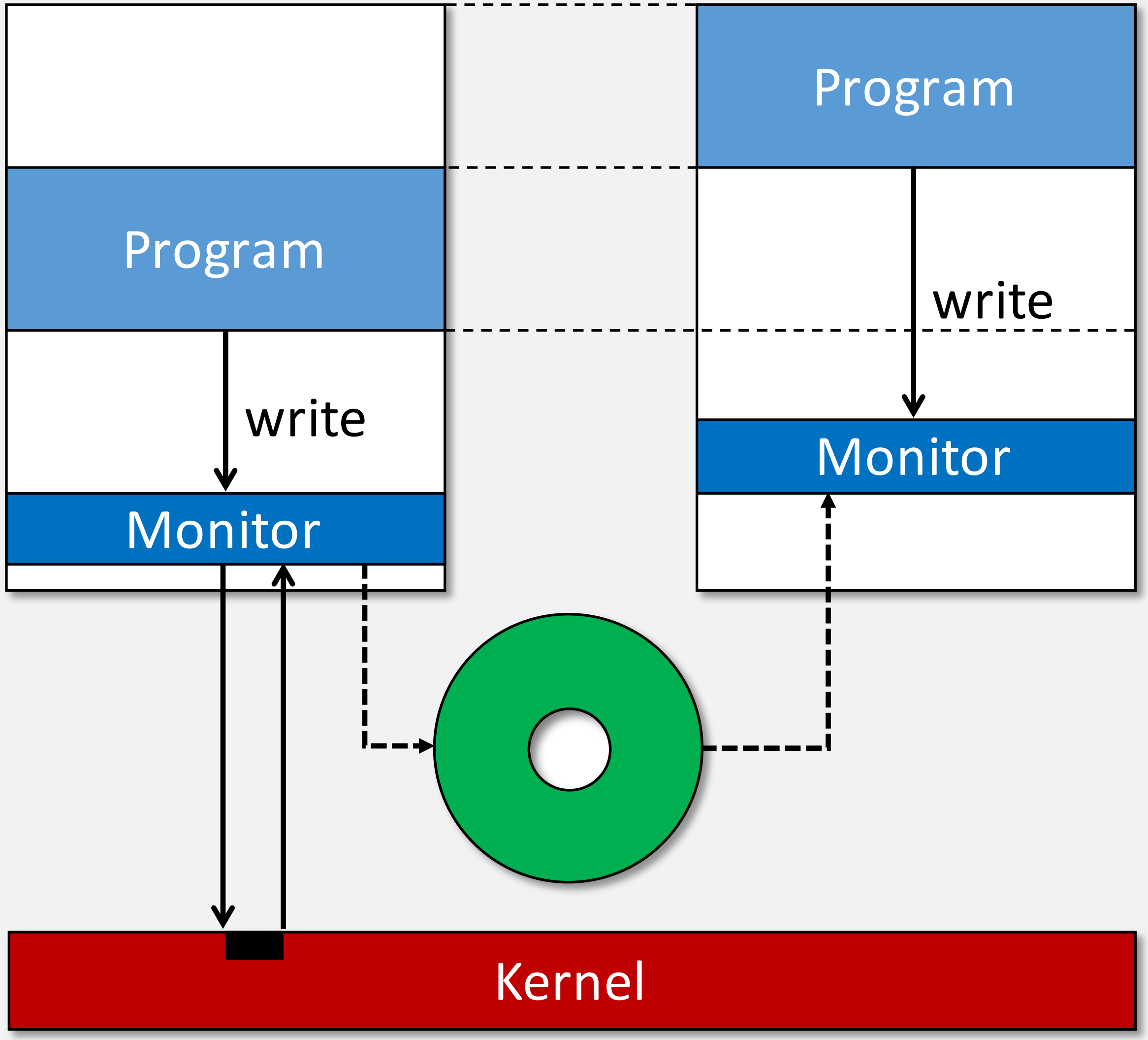
Performance Considerations



Programs can execute at **native speed** (assuming you have enough idle CPU cores and memory bandwidth)

BUT system call interception is **SLOW!**

Alternative Design



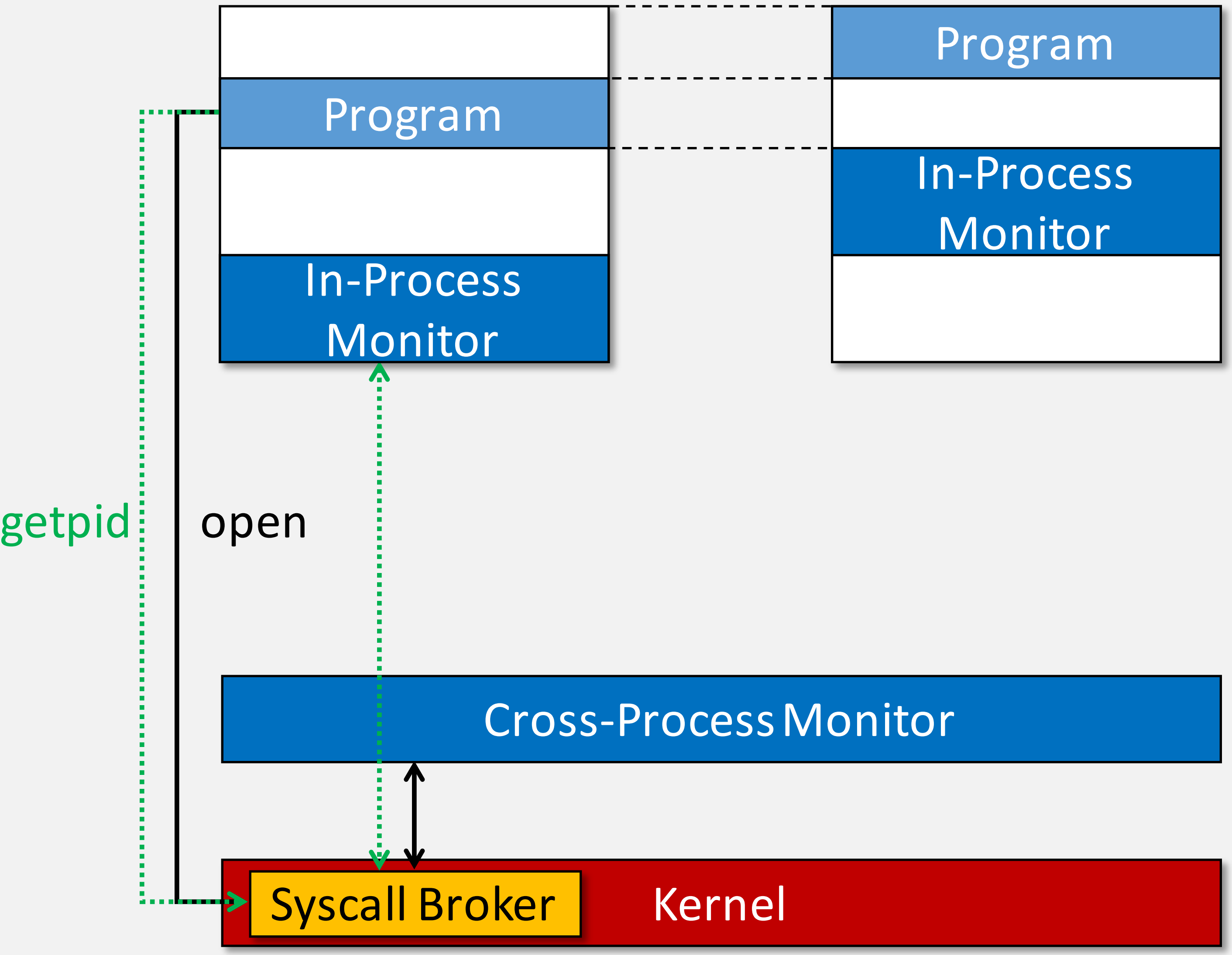
Efficient Monitoring:

- Load monitor into variants' address spaces
- Replicate results through a shared buffer
- Let master run ahead of slaves

BUT:

- Malicious syscalls can circumvent monitor
- Shared buffer data can be tampered with

ReMon



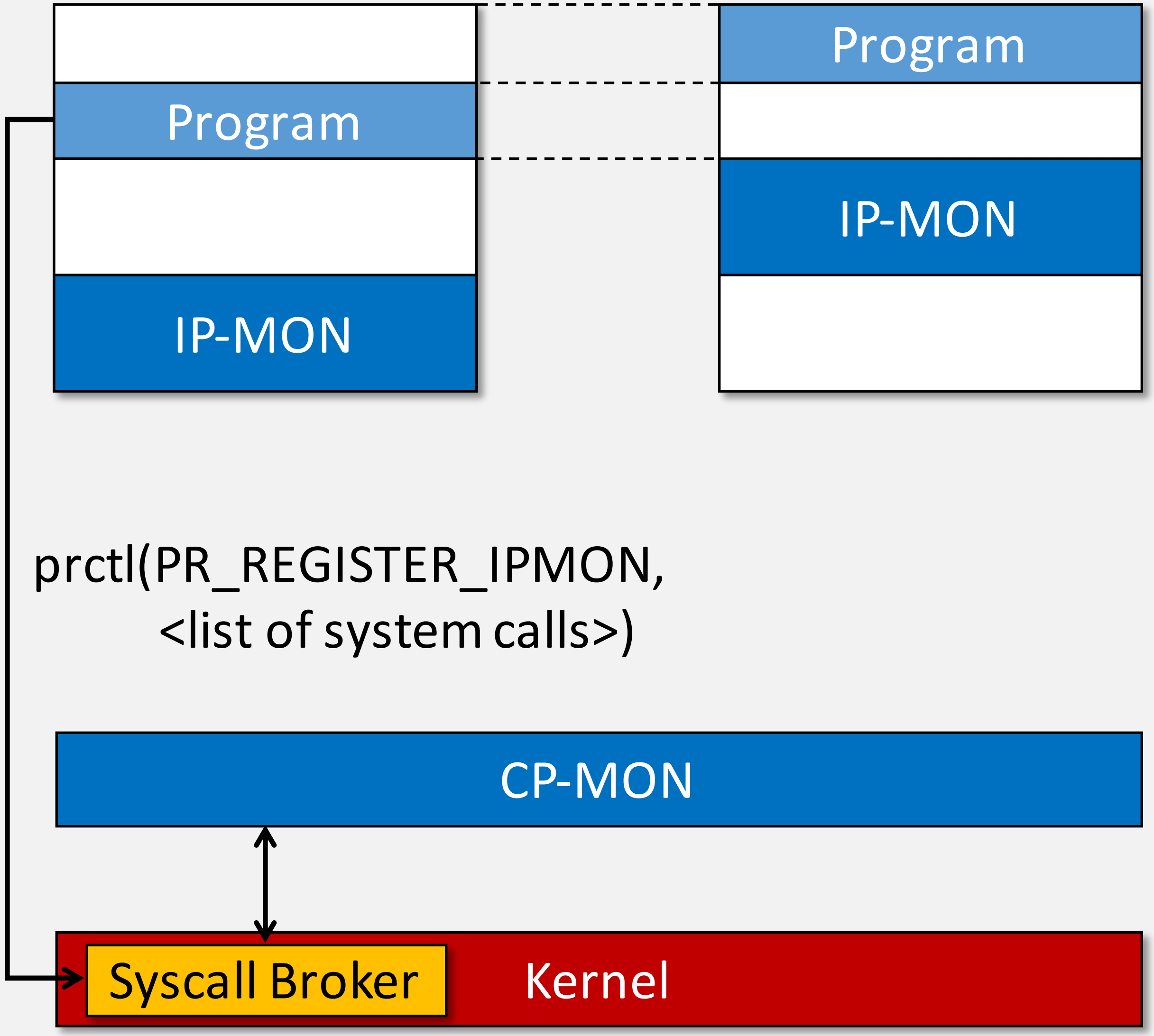
Split-Monitor Design:

- Handle security-sensitive system calls in **Cross-Process Monitor (CP-MON)**
- Handle non-sensitive system calls in **In-Process Monitor (IP-MON)**
- Configurable relaxation policies

Relaxation Policies

- 3 different policies:
  - Syscalls unconditionally handled by IP-MON (e.g. sys_getpid)
  - Syscalls conditionally handled by IP-MON (e.g. sys_write for non-socket files)
  - Syscalls probabilistically handled by IP-MON (**not implemented**)

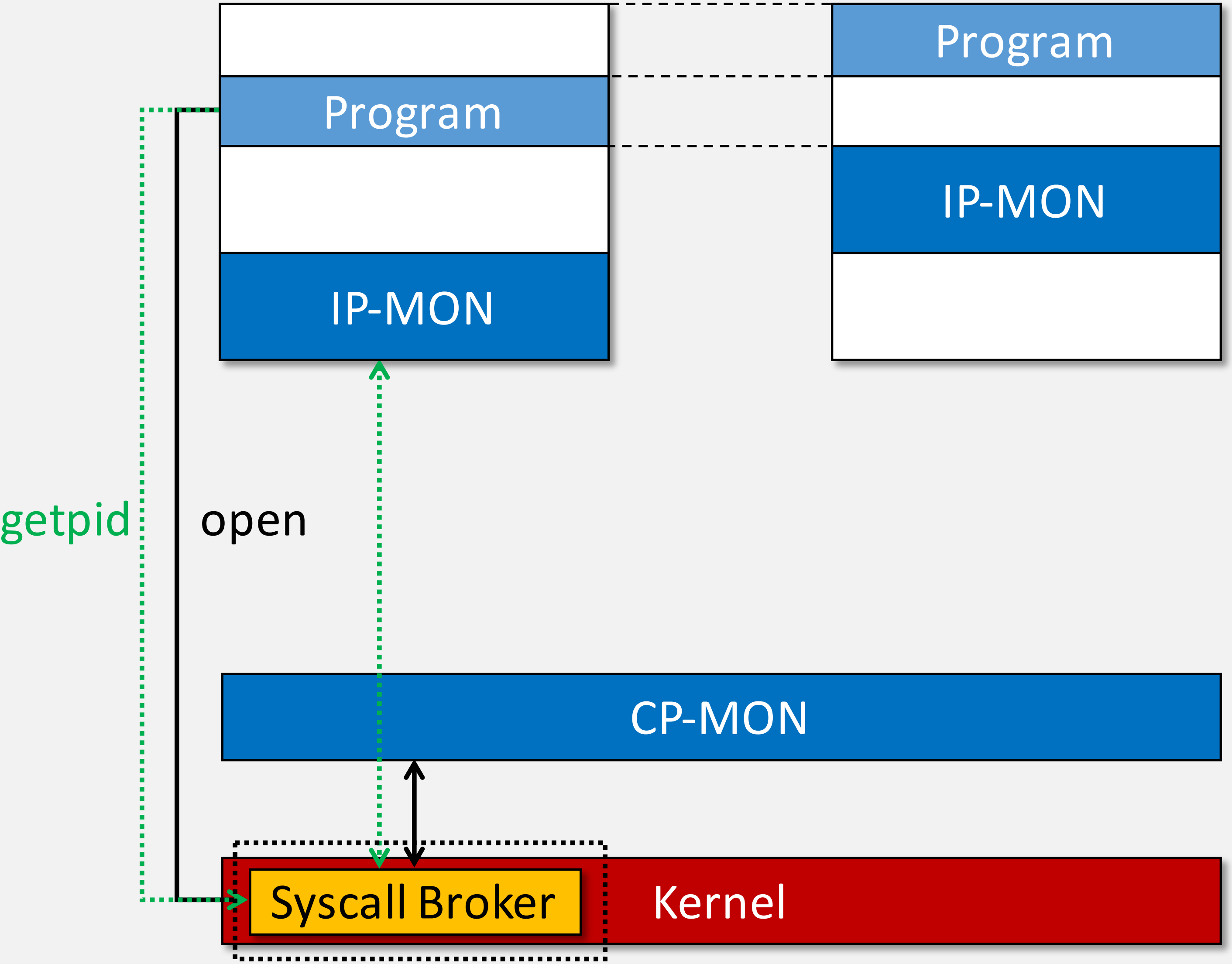
Initializing the In-Process Monitor



Registering IP-MON:

- Call sys_prctl with list of non-security-sensitive system calls as argument
- This sys_prctl call will **ALWAYS** be reported to CP-MON
- If the call succeeds, all of the syscalls in the list will be forwarded to IP-MON from that point onward

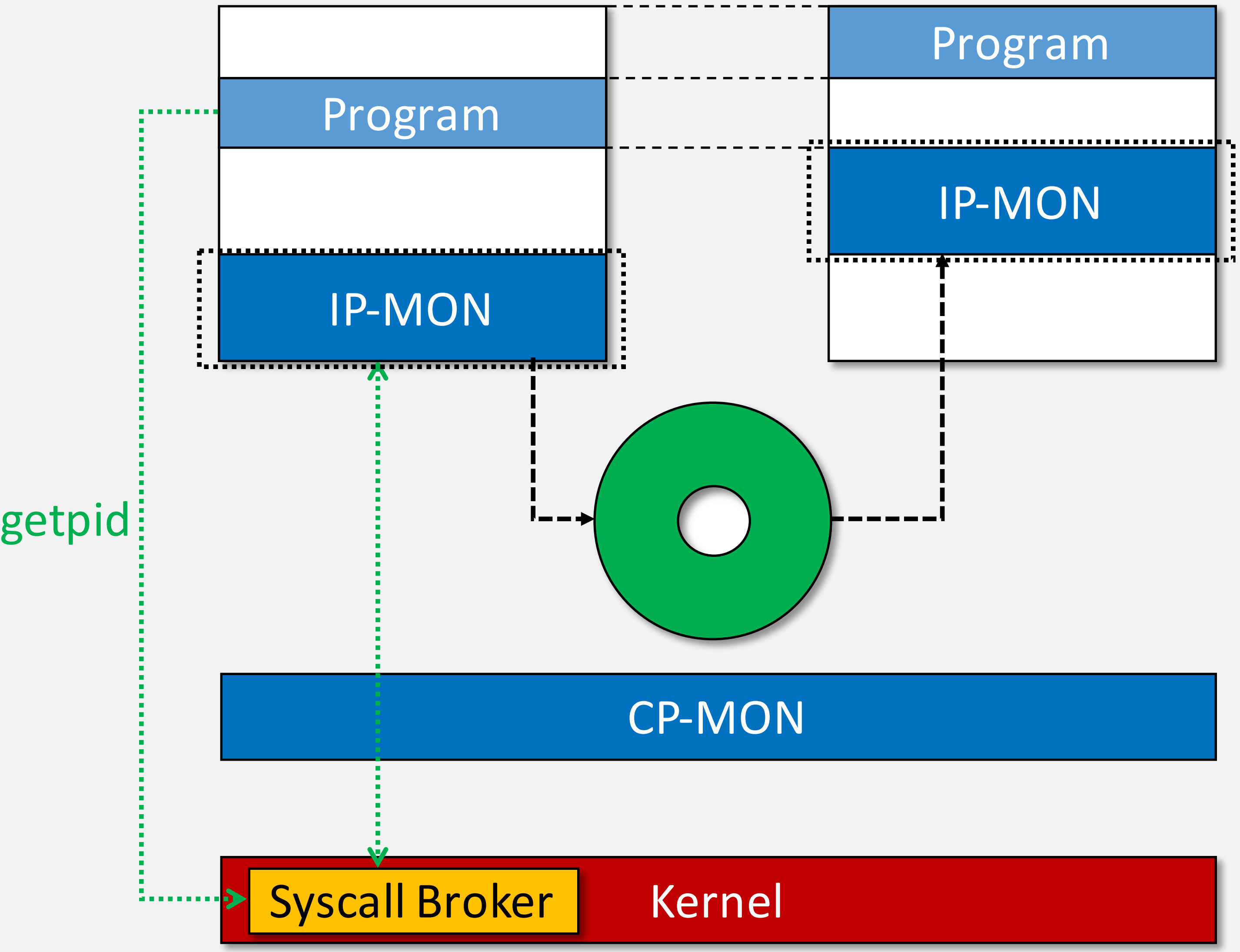
ReMon Components



System Call Broker:

- Intercept system calls as they enter kernel
- Forward them to appropriate monitor based on active relaxation policy
- Authenticate system calls when resumed by monitor

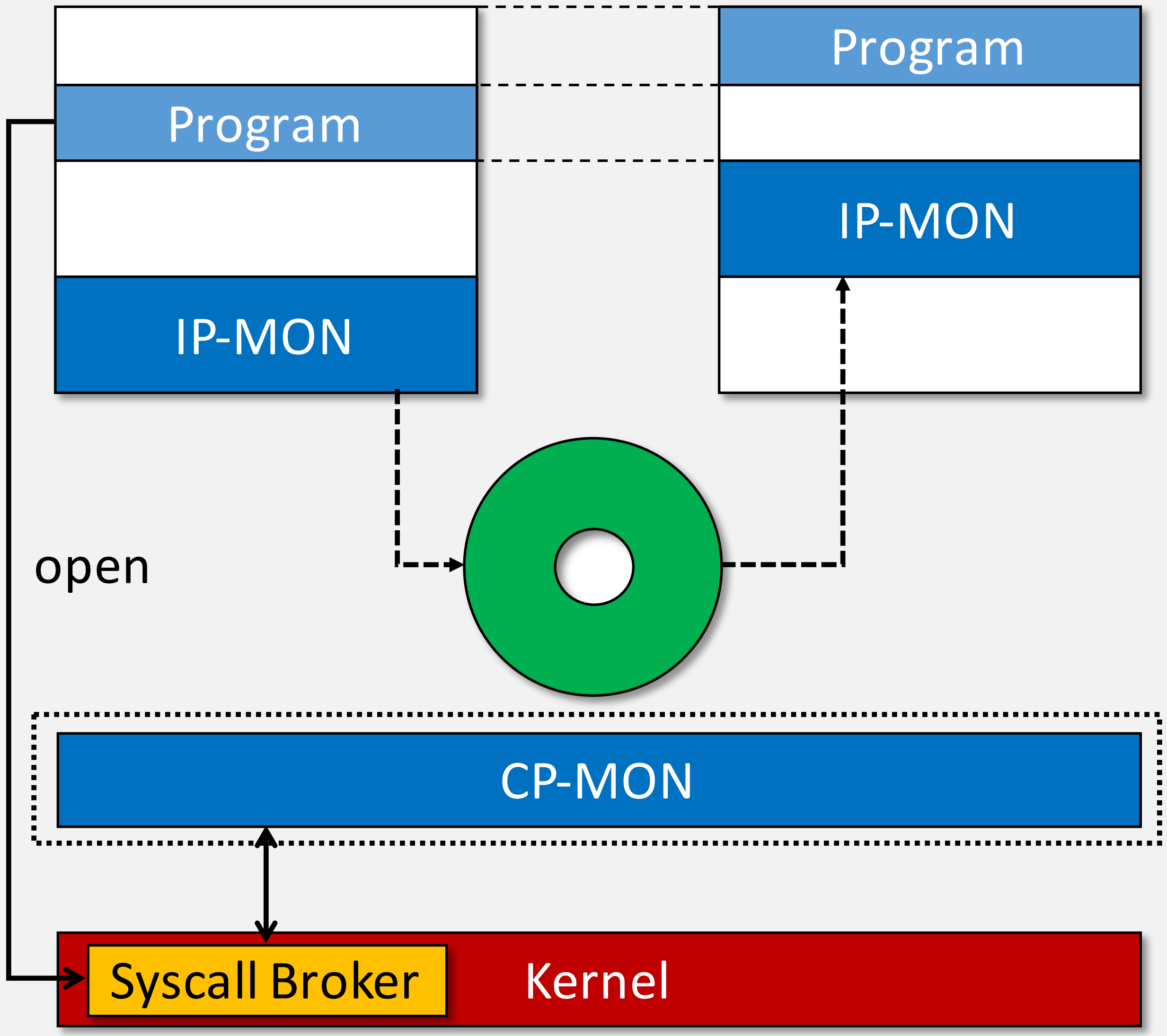
ReMon Components



In-Process Monitor:

- Authorized to execute forwarded calls w/o intervention by cross-process monitor
- Replicates system call results through shared buffer

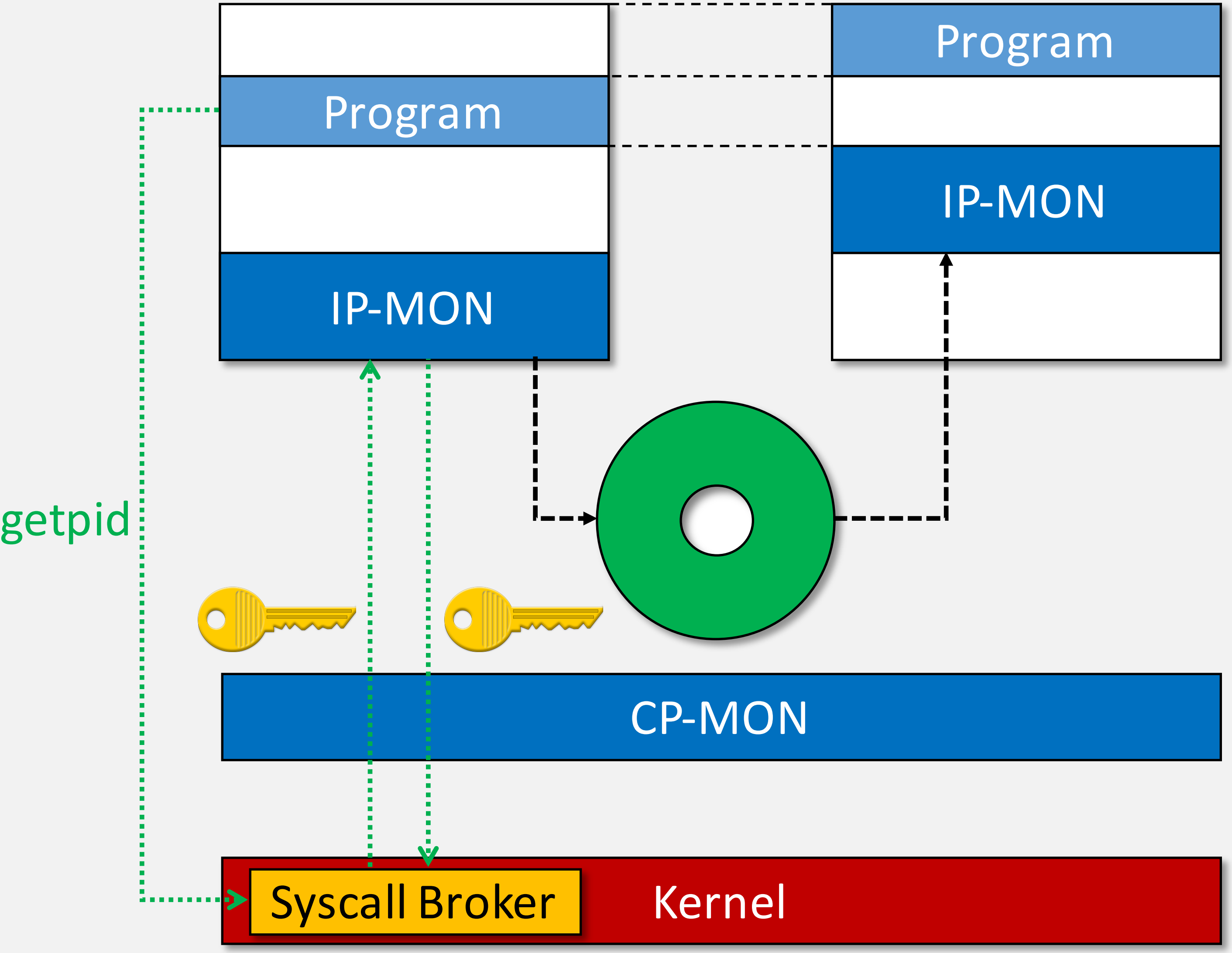
ReMon Components



Cross-Process Monitor:

- Standard **ptrace-based** monitor
- Completely isolated from variants

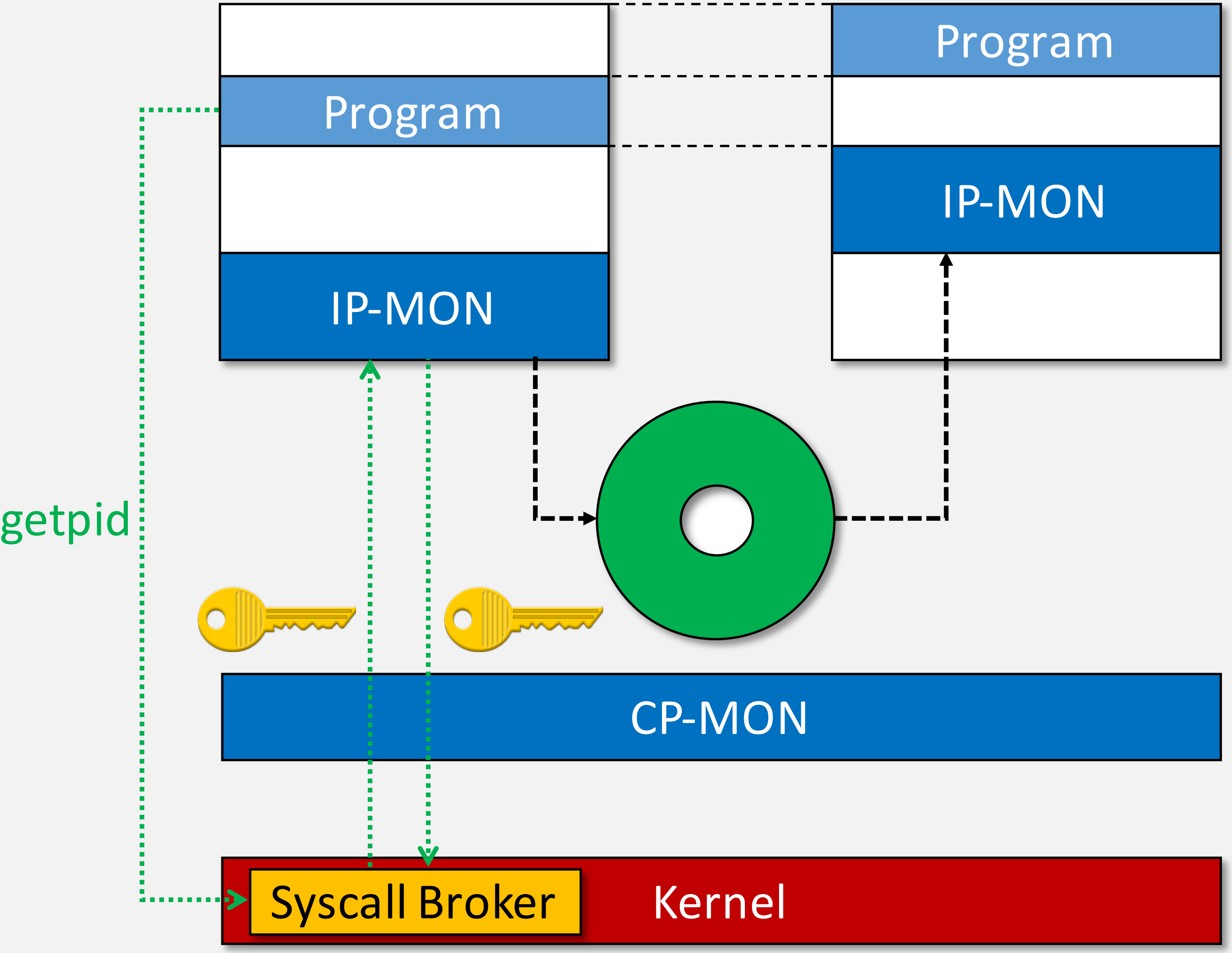
In-Process Monitor Security



No abuse of monitor privileges:

- Monitor cannot execute system calls that did not pass through the broker first
- Broker generates **authentication key** and loads it into register when forwarding call to monitor
- Key must be intact to finish execution of forwarded call

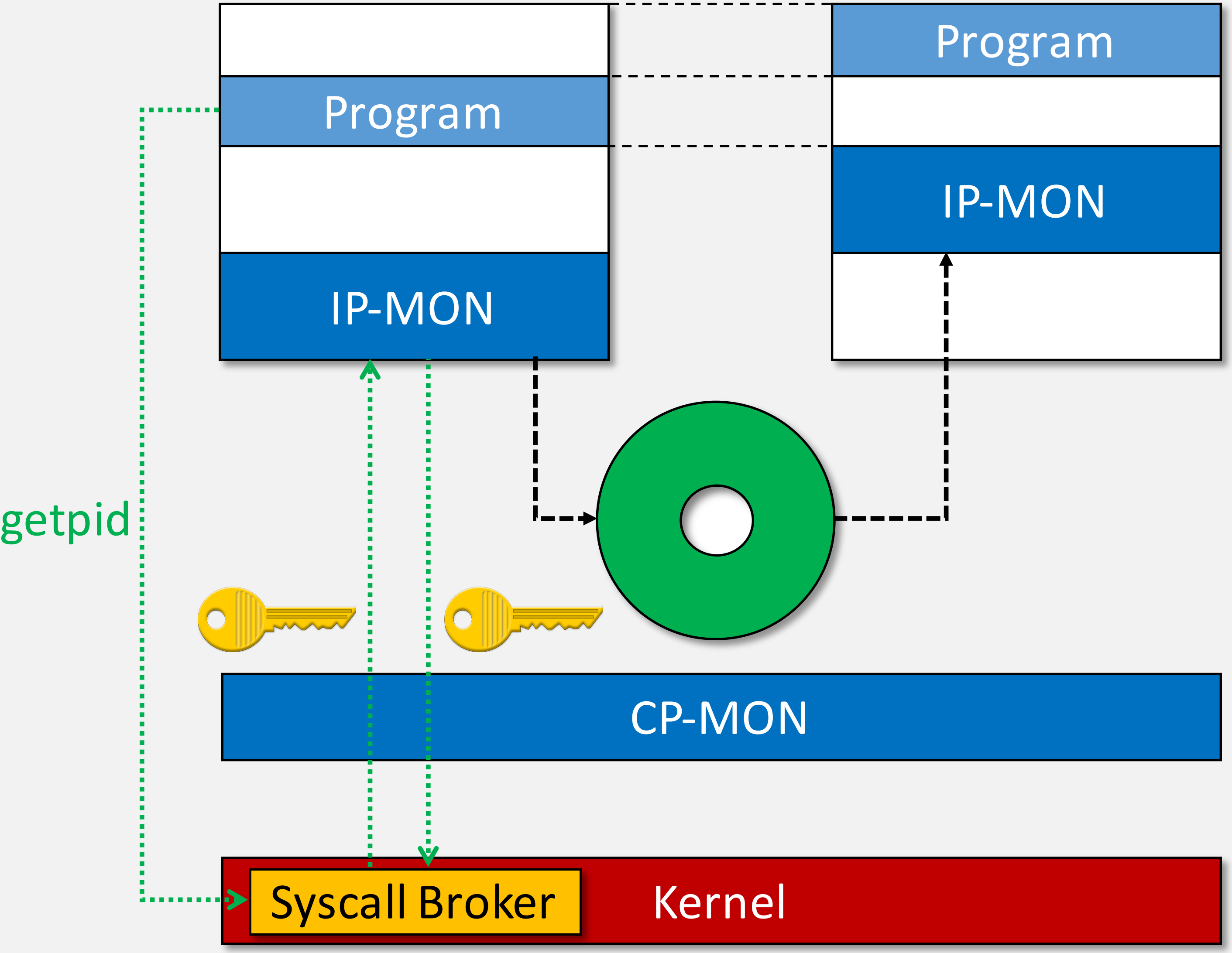
In-Process Monitor Security



No tampering with monitor data:

- Locations of monitor and shared buffer are only known to broker
- Pointers to monitor and buffer are never visible in user space

In-Process Monitor Security



Leak Prevention:

- Sensitive values (e.g. pointers, authorization key) only stored in registers and never leaked or spilled
- Monitor has no indirect branches => control flow cannot be diverted to malicious code

Performance

- Dual Intel Xeon E5-2660 – 20Mb Cache each
- 64Gb ECC DDR3 RAM
- Linux 3.13.11
- Server Benchmarks:
    - Local loopback
    - Gbit Link – 2ms
    - Gbit Link – 5ms
- 2 variants of the protected program
- 4 worker threads for multi-threaded benchmark suites (PARSEC/SPLASH-2x)

Performance

Benchmark	CP-MON only	ReMon
SPEC CPU 2006	6.37%	**3%**
PARSEC 2.1	22%	**11%**
SPLASH-2x	29%	**10%**
Server Benchmarks	up to 1249%	**<3.5%**

Conclusions

- Existing Security-Oriented MVEEs:
  - Secure but **SLOW**
- Existing Reliability-Oriented MVEEs:
  - Fast but **INSECURE**
- ReMon:
  - **FAST** and **SECURE**

https://github.com/stijn-volckaert/ReMon