https://www.patreon.com/p_lkrg

LKRG
UNDER THE HOOD

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/USR/BIN/WHOAMI

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- Bughunting (Hyper-V, OpenSSH, gcc SSP/ProPolice, Apache, xpdf, more…) – CVE numbers
- Phrack magazine (Scraps of notes on remote stack overflow exploitation)
- The ERESI Reverse Engineering Software Interface

ACKNOWLEDGMENT

Alexander Peslyak (Александр Песляк)

a.k.a. Solar Designer

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Special thanks to the following people for the constructive criticism and brainstorming in the past stages of the project development:

- Rafał "n3rgal" Wojtczuk
- Brad "spender" Spengler
- PaX Team… I mean "pipacs"

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WHAT IS LKRG?

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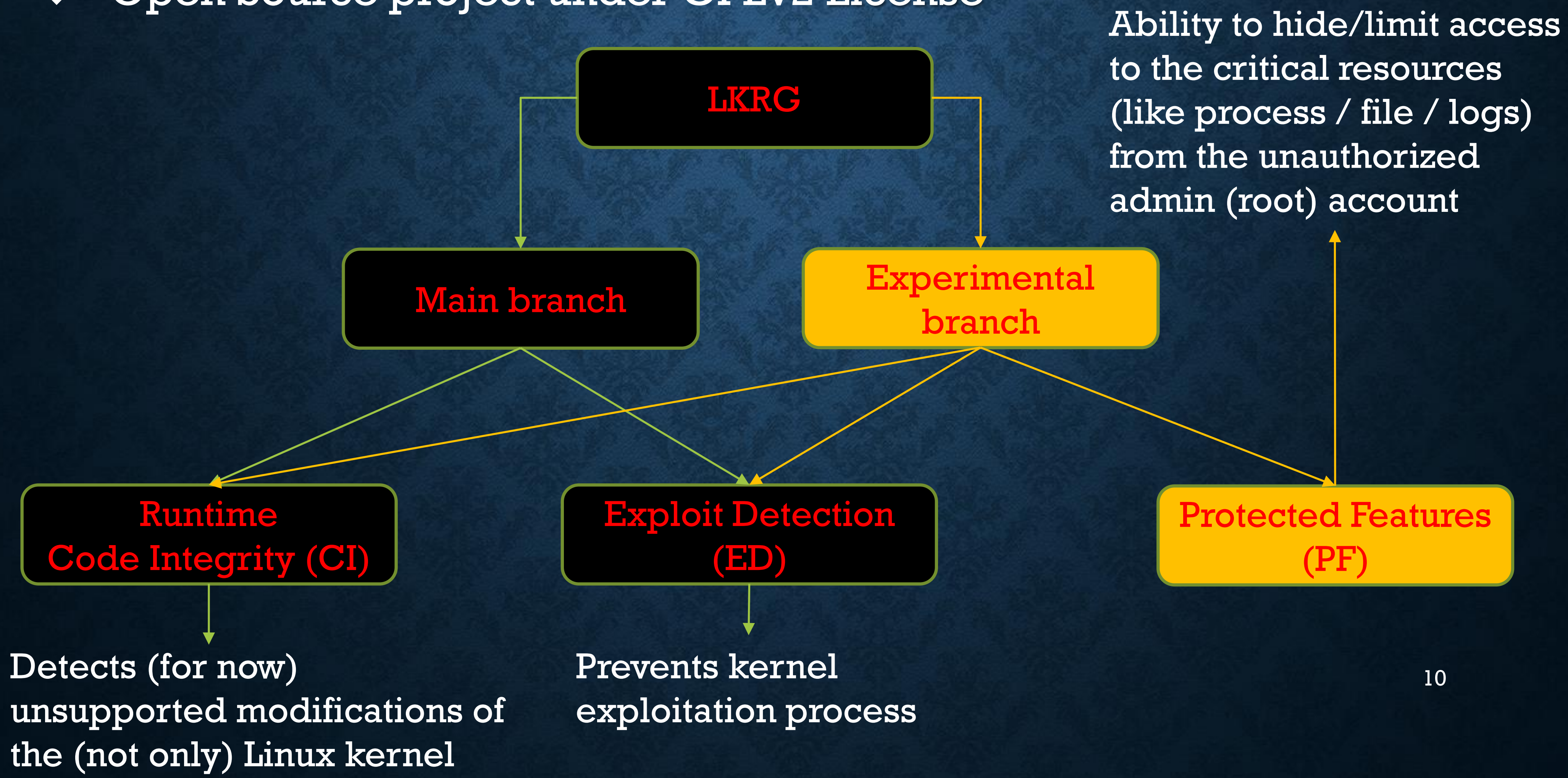

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     a. Attacking user mode process in running state
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  - name of the process
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  ← Containers / namespace escape

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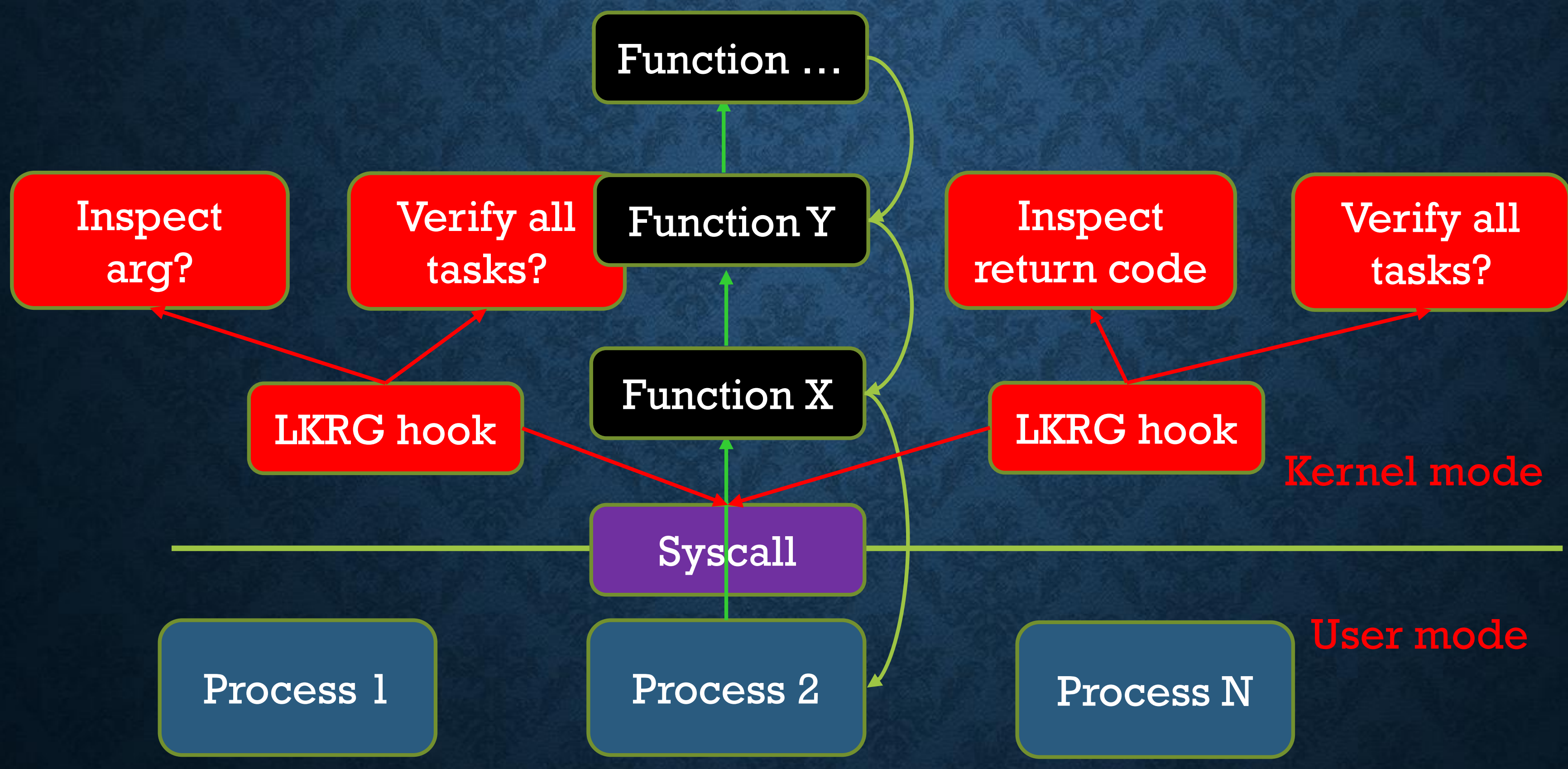

EXPLOIT DETECTION

- How does LKRG build/maintain its own tasks list and update legit attributes changes?
- When does LKRG enforce integrity check?
  - setuid / setgid / seteuid / setegid / setreuid / setregid / setresuid / setresgid / setfsuid / setfsgid
  - setgroups
  - fork
  - execve
  - exit
  - do_init_module (covers init_module as well as finit_module)
  - delete_module
  - may_open (it is executed every time a user wants to open any resources in the system)
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- Checks are done for every process in the system, not just for the one which executed syscall (excluding may_open() for perf reasons). This list is not closed and will be evolving.

EXPLOIT DETECTION

Limitations

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  - Directly attack the userspace via kernel (e.g. DirtyCOW)

EXPLOIT DETECTION

DEMO

RUNTIME CODE INTEGRITY

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    - IDT entry point and size
    - IDT itself (as blob of memory)
    - MSRs:
      - MSR_IA32_SYSENTER_CS, MSR_IA32_SYSENTER_ESP, MSR_IA32_SYSENTER_EIP, MSR_IA32_CR_PAT, MSR_IA32_APICBASE, MSR_EFER, MSR_STAR, MSR_LSTAR, MSR_CSTAR, MSR_SYSCALL_MASK

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  - Additionally, LKRG keeps information about:
    - How many (V)CPUs/cores are available in the system
    - How many online (V)CPUs/cores are available in the system
    - How many offline (V)CPUs/cores are available in the system
    - How many possible (V)CPUs/cores might be available in the system

RUNTIME CODE INTEGRITY

- Guarded regions - continued:
  - Entire Linux kernel .text section
    - This covers almost entire Linux kernel itself, like syscall tables, all procedures, all function, all IRQ handlers, etc.
  - Linux kernel exception table
  - Entire Linux kernel .rodata section
  - Optionally IOMMU table
  - Modules

RUNTIME CODE INTEGRITY

- Guarded regions – continued – Modules:
  - For each individual module the following information is tracked based on module linked list:
    - Struct module pointer (a.k.a. THIS_MODULE)
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  - For each individual module the following information is tracked based on KOBJs:
    - Struct module pointer (a.k.a. THIS_MODULE)
    - Pointer to the 'module_kobject' structure
    - Entire KOBJ structure (except from list_head and kref information)
    - Name
    - Pointer to the module_core
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- Guarded regions – continued – Modules:
  - Both pieces of information must match (if they exist in both places) and each of them is being tracked individually. Additionally, the following information is being tracked down:
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    - Specific order of linked list in module list
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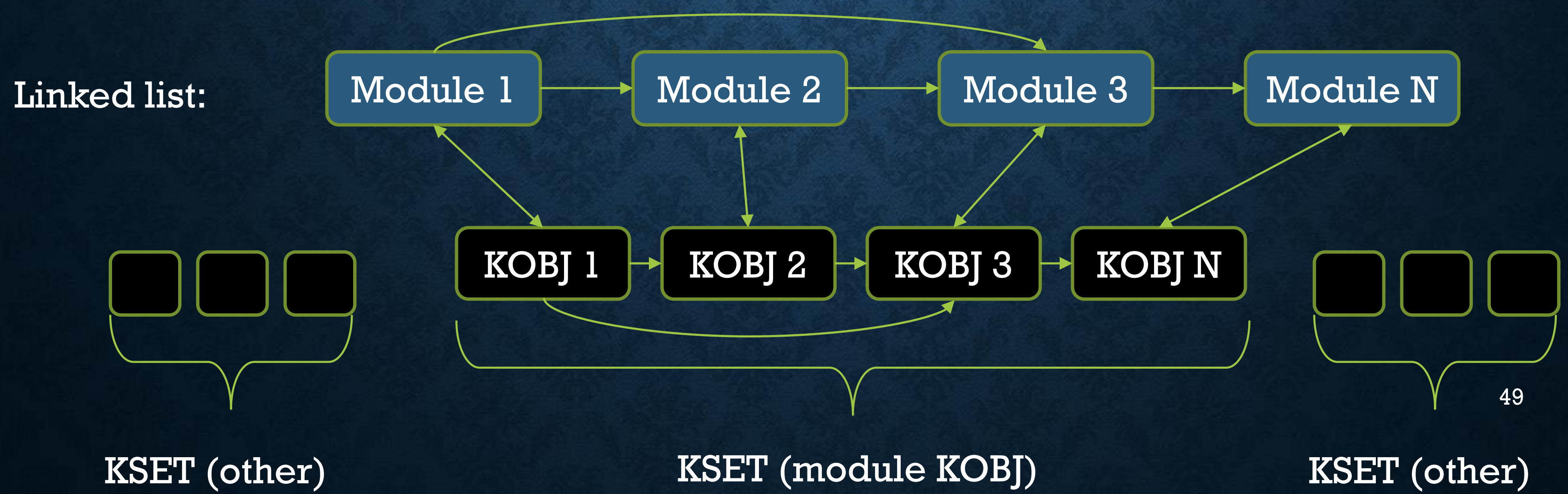

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  - Dynamic module loading can be disabled via LKRG sysctl interface

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  - On demand via a LKRG sysctl interface
  - Whenever any module activity is detected (e.g. loading / unloading)
  - Whenever a new (V)CPU or core activity is detected (hot CPU plug[in/off])
  - On various random events in the system (see next slide)

RUNTIME CODE INTEGRITY

- The following events are monitored:
  - CPU idle – probability 0.005%
  - CPU frequency – probability 10%
  - CPU power management – probability 10%
  - Network device (e.g. device up/down) – probability 1%
  - Network event (e.g. ICMP redirects) – probability 5%
  - Network device IPv4 changes – probability 100%
  - Network device IPv6 changes – probability 100%
  - Task structure handing off – probability 0.01%
  - Task going out – probability 0.01%
  - Task calling do_munmap() – probability 0.005%
  - USB changes – probability 100%
  - Global AC events – probability 100%

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      - If NOP is modified to JMP, destination of the instruction is still pointing to the inside of the same function (symbol name) where the modification happened. We decode this JMP instruction to validate if the target is still pointing inside the same symbol name range. If yes, it is most likely a 'legit' modification.
      - If JMP instruction was changed, we only allow it to be replaced by long NOP instruction.
    - Any other modifications are banned
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      http://openwall.info/wiki/p_lkrg/Main#JUMP_LABEL

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    - Only for kernel core – not modules

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- Caveats:
  - IPI problem
    - There is an undesirable situation in SMP Linux machines while sending an IPI. Unfortunately, it might influence the state of the kernel and generate very confusing logs. They appear to suggest that the problem resides on the correct execution context which is killed and dumped, but not on the actually problematic context, which might not be dumped. This makes it hard to root-cause the problem even if one is aware of this shortcoming of the killings and the logging. More details about it can be found here:

      http://lists.openwall.net/linux-kernel/2016/09/21/68

COMMUNICATION CHANNEL

- Sysctl interface:

root@pi3-ubuntu:~/p_lkrg-main# sysctl -a | grep lkrg

lkrg.block_modules = 0

lkrg.clean_message = 1

lkrg.force_run = 0

lkrg.log_level = 1

lkrg.random_events = 1 (perf impact is around 2.5% for fully enabled LKRG, or around 0.7% for LKRG with code integrity checks on random events disabled)

lkrg.timestamp = 15

PERFORMANCE IMPACT

==================================

Project: john-1.8.0-jumbo-1

Configuration: ./configure CFLAGS='-O0'

Testing: make clean; time make -j 8

==================================

+02.513%

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log_level=0, NO_EVENTS_CI		log_level=0, without_CI		log_level=0, Full LKRG	
real	+00.668%	real	+00.551%	real	+02.513%
user	-00.069%	user	-00.183%	user	-00.004%
sys	+07.200%	sys	+08.089%	sys	+08.355%

Full LKRG: ~2.5%

LKRG without random events: ~0.7%

LKRG IN RING -1

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  6. Some of the servers / machines can't be rebooted (rebootless)

LKRG IN RING -1

When "Wild West of ring -1" becomes more unified, it'll be easy to add "ring -1" extension for LKRG which will guard "ring 0" instance. We will have 2 modes of operation: "weaker" without "ring -1" assist and stronger with hypervisor warranties – if environment supports it (still not the right time for it now!).

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- General:
  - Better self-defense:
    - Hash from the internal database
    - Hash from LKRG itself
  - Hypervisor extension (ring -1)
  - Probably more which I'm not aware of now :P

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