Syringe:
Extraterrestrial Control of Virtual Machines

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Why Externally Control Virtual Machines?

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Why we shouldn’t install security software in virtual machines (VMs):

1. Administrative headache

2. Wasted resources (disk space, CPU time, etc.)

3. Security risk

High-Level Problems

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- Administrative headache
  - Administrator needs to keep all machines updated
  - Need to install separate agents for everything (an anti-virus agent, a software update agent, etc.)
  - Less-than-seamless: if the user gets infected with a virus, it may disable the anti-virus. Then what? Administrator may need to restore the virtual machine to a previous clean state

High-Level Problems

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- Wasted resources
  - Why does each desktop need an update program when the enterprise desktops are all fairly homogenous?
  - Antivirus scans all files at least once per VM, although each VM mostly has the same files. The agent of each VM is working in isolation.
  - Having the same software installed on each VM wastes disk space
  - Performing the same scans on each VM wastes CPU resources

High-Level Problems

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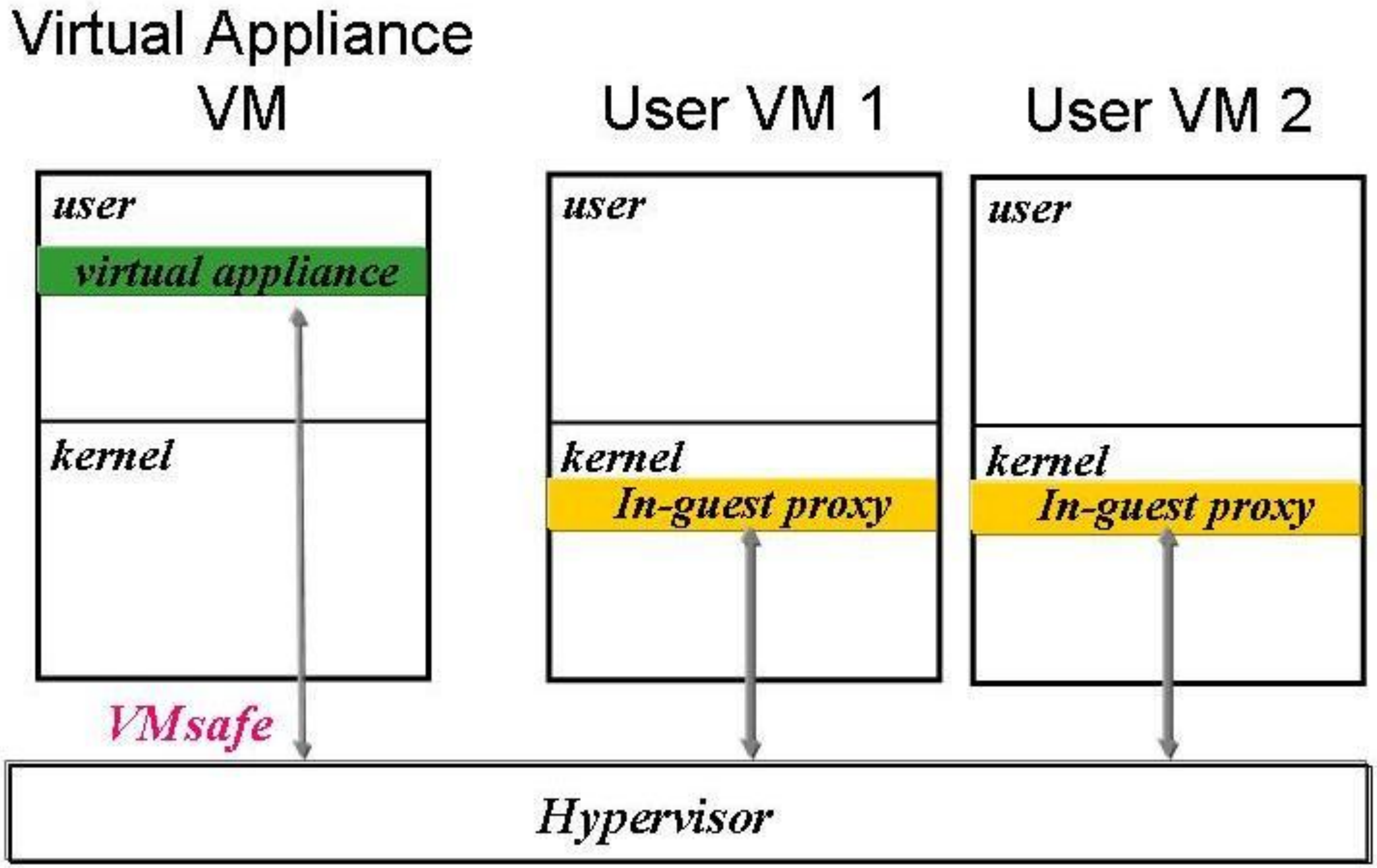
- Security risk
  - The classic problem of security software and threats operating at the same privilege level
  - If the security agent lives on the workstation, it can be disabled by undetected malware.
  - There is no way to reliable way to fix this situation except to boot from a rescue CD

High-Level Solution

- Eliminate the need for software to run within each VM
  - Do shared work from a central location (hypervisor / trusted VM)
    - Example: file scanning
  - However, we still need to be able to do some things inside the guest VM.
    - Example: OS-specific remediation (kill a process)

- Benefits
  - Don't need to maintain software in each VM
  - Perform a task once globally instead of once per VM
  - No software/code in VM (nothing for malware to disable)

Syringe: Architecture

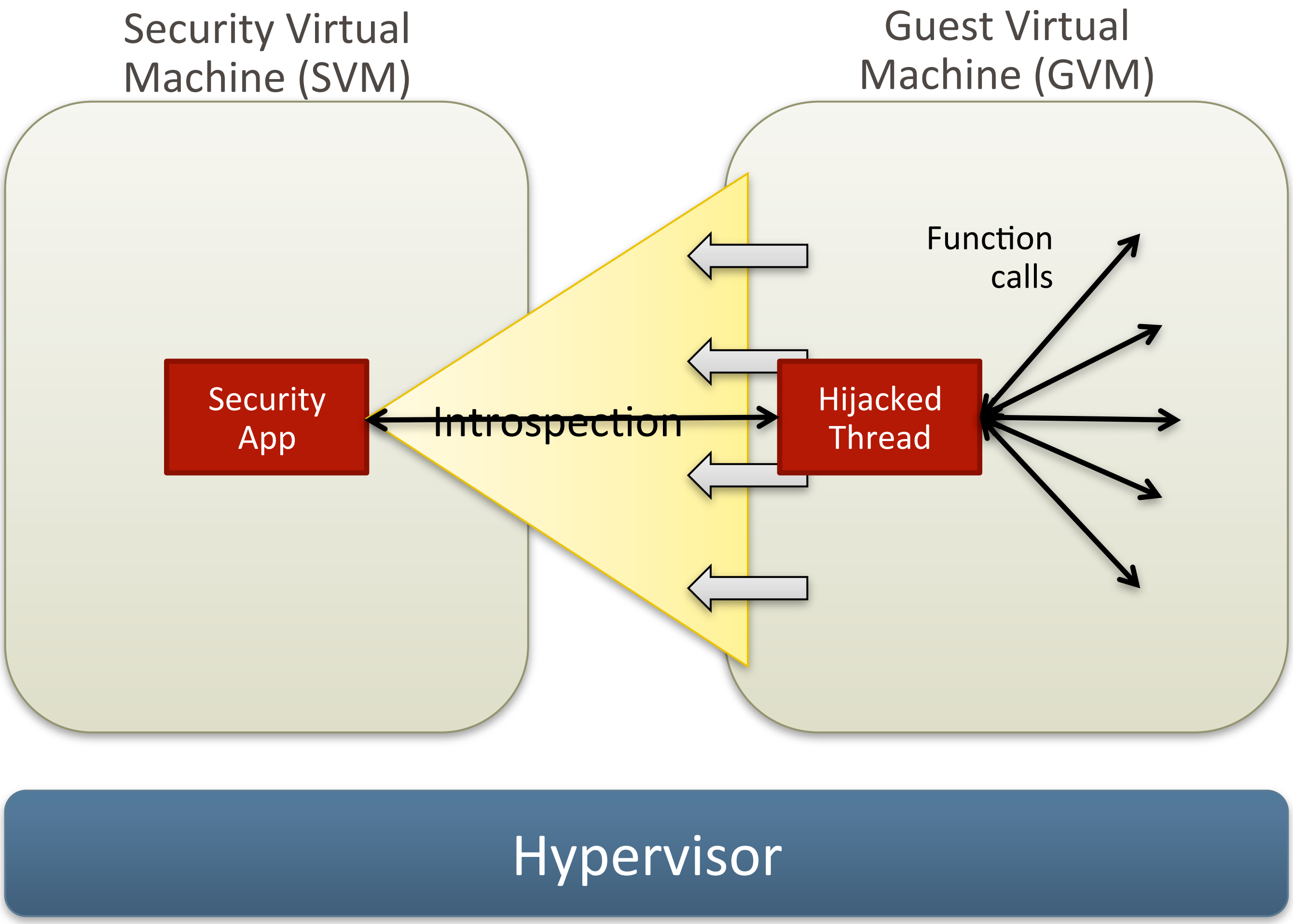


Syringe: Background

- We want to understand what's going on in the virtual machine
  - It's hard to do this properly from outside the virtual machine
  - We see only memory and CPU state (when peering into a virtual machine from the outside)
  - Virtual machine introspection is a hard problem
  - Requires recognizing and understanding the memory.
  - This lack of context is known as the **semantic gap**

- Trivial example: How can we determine the OS version?
  - Inside OS it's easy: call the `RtlGetVersion` API
  - From the outside? Not so easy…

Syringe: Background



Assuming VMware ESX Server + VMsafe for the rest of the talk

Function Call Injection (FCI): Introduction

- What do we want?
  - The ability to invoke arbitrary GVM user/kernel functions from the SVM without having to rely on an in-guest agent (software running in the VM)
  - We want to “borrow” (or hijack) some existing thread to call an API on our behalf, get the result, and then return the hostage thread as if nothing happened
  - Before: A -> B -> C
  - After: A -> B -> Z -> C

Function Call Injection (FCI): Introduction

- Why do we want to do that?

- FCI is like Jedi mind control…
  - Utilizes existing threads, existing drivers and processes to do momentarily our bidding
  - The only way to detect this is to notice a thread deviates from its normal behavior (takes longer, calls different sequence, etc.)
  - For a hostile threat in a GVM to detect and block this, it will essentially be fighting his own shadow (FCI can be performed in any context)

Function Call Injection

- Core technique: ***Function Call Injection***
  1. Use introspection to modify registers (EIP + ESP) and memory (stack)
  2. When GVM resumes execution, it does so as if a function call had just been executed.

  Result: Inter-VM RPC (Remote Procedure Call across virtual machines)

  – Terminology:

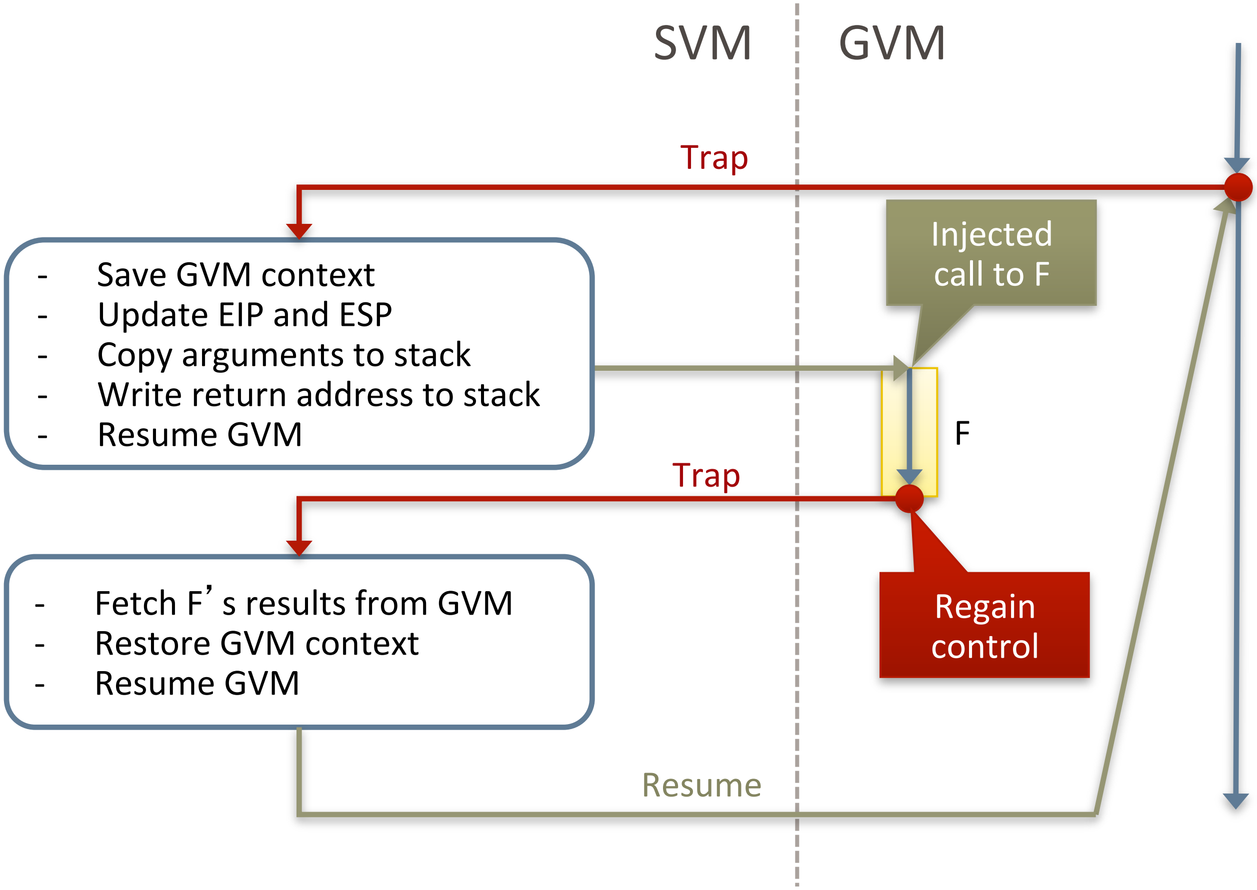
  ESP = Stack Pointer (Stack used by functions to track state)

  EIP = Instruction Pointer (Points to the current executing instruction)

  API = Application Programming Interface (API call / function call)

Function Call Injection

Injecting a call to function F…



- Save GVM context
- Update EIP and ESP
- Copy arguments to stack
- Write return address to stack
- Resume GVM

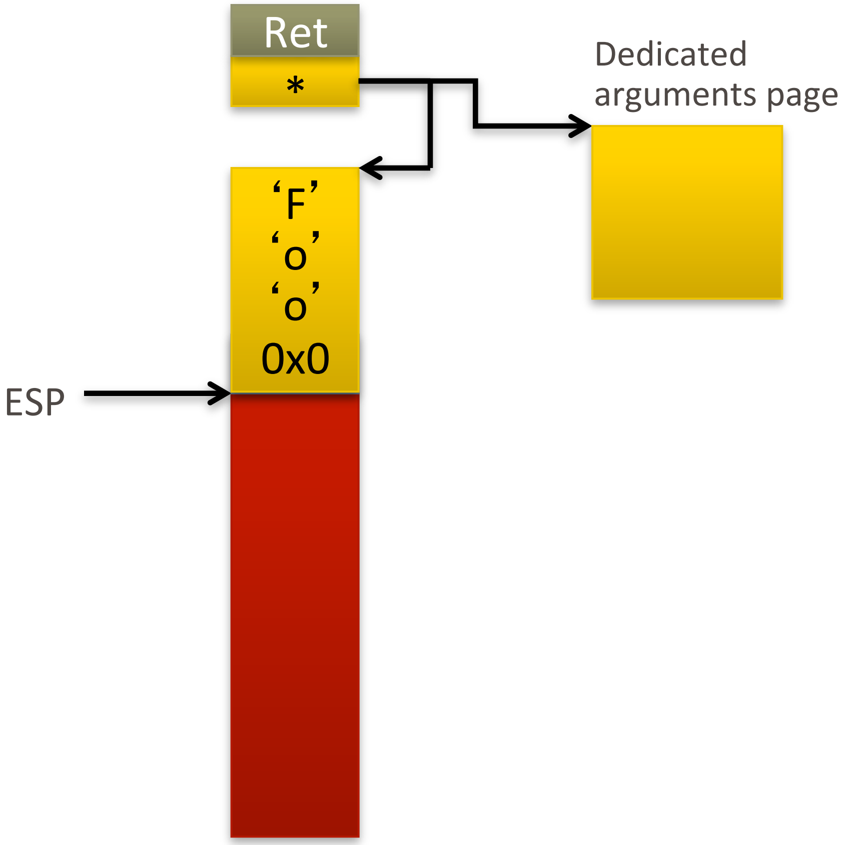
- Fetch F’s results from GVM
- Restore GVM context
- Resume GVM

FCI: Argument Passing on the Stack

SVM

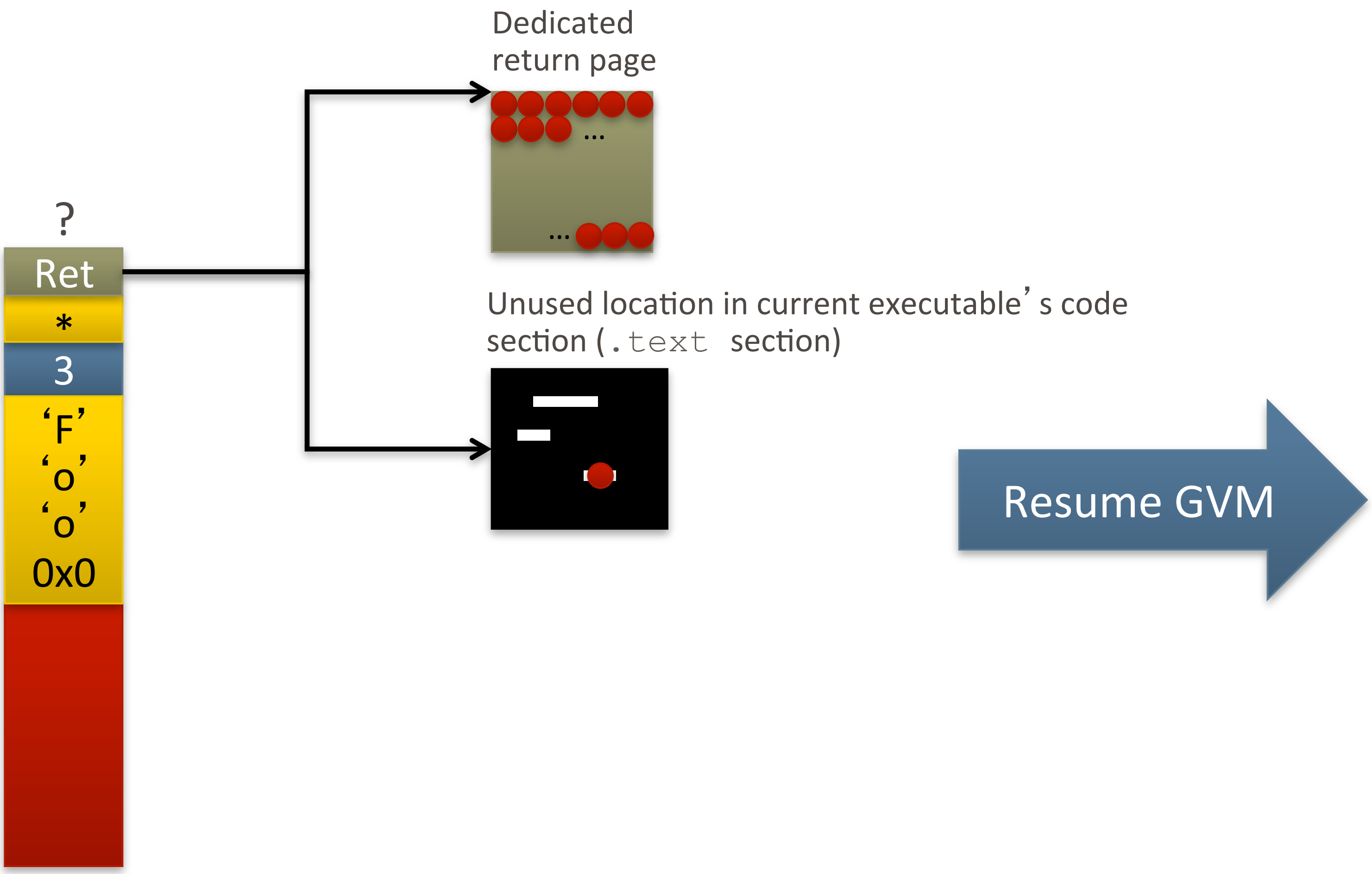
```
F(char *str, int n);

char *s = “Foo”;
F(s, 3);
```

GVM



Current GVM stack

FCI: Returning Control

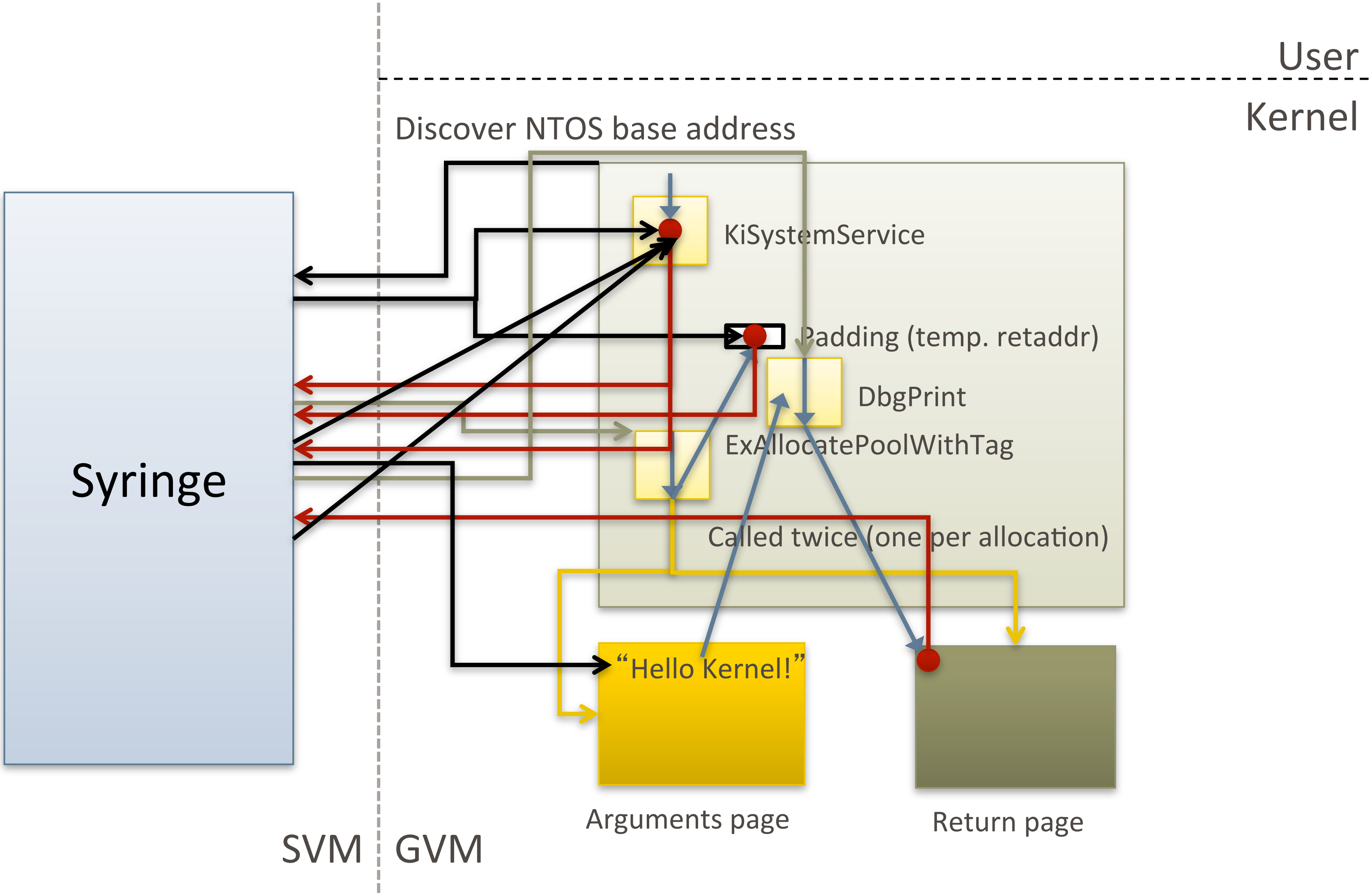


Injection Scope

- Types of in-guest software agents
  - Kernel-mode agent (kernel driver)
    - Invokes public kernel functions (e.g, Windows WDK API)
  - User-mode agent (process)
    - Invokes library API functions (e.g, DLL-based Windows API)
- Our goal is to be able to impersonate both agent types using FCI
  - Kernel-mode FCI
  - User-mode FCI

- Injection point requirements
  - Sufficiently high execution frequency
  - Safe, consistent state (e.g., no locks held that could cause deadlocks)

Kernel-Mode FCI: The Full Process



Kernel-Mode FCI: Example APIs

Ntos!RtlGetVersion() → Retrieve GVM’ S Windows kernel version

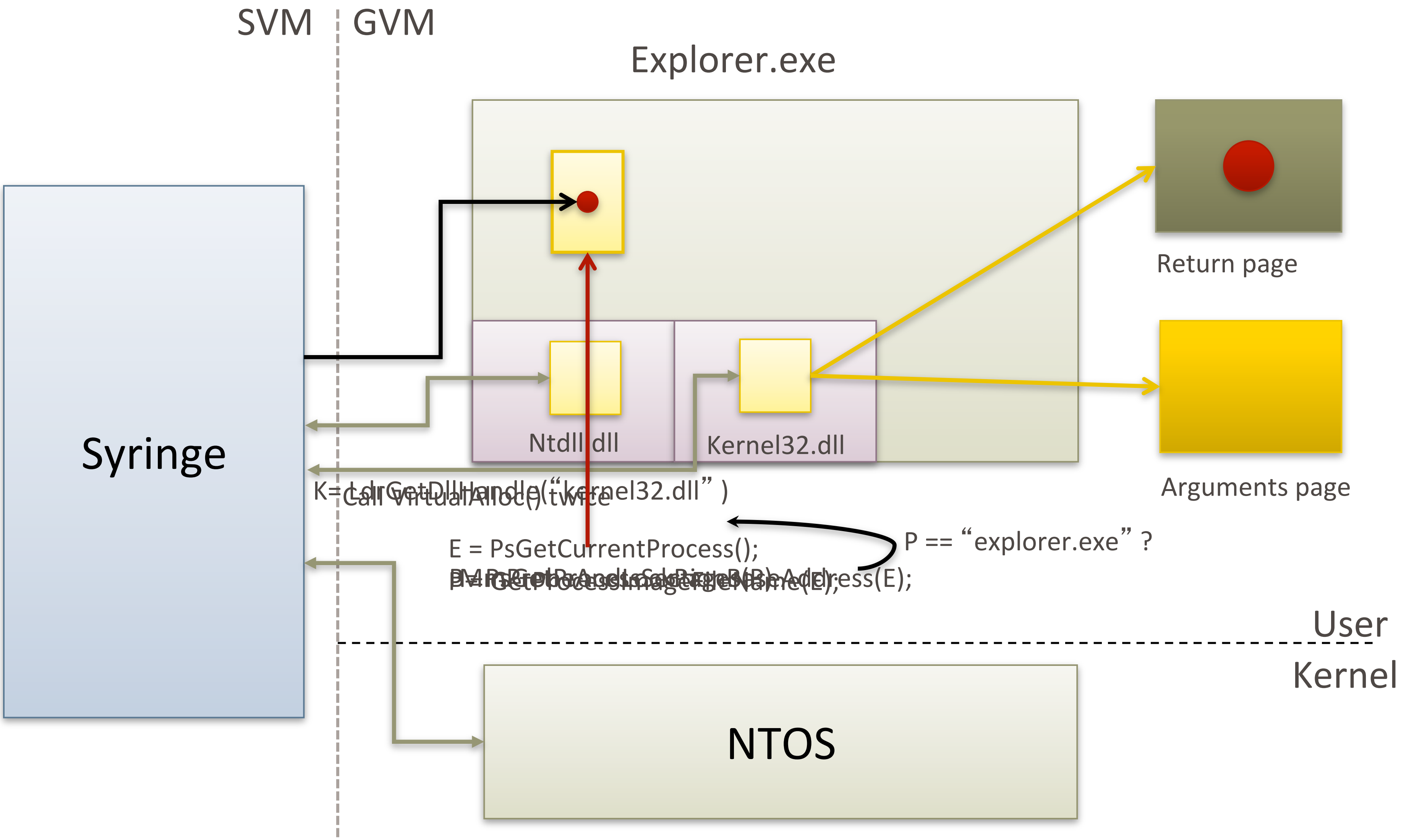
Ntos!PsCreateSystemThread() → Create a kernel-level thread in the GVM

User-Mode FCI

- API at a preferable abstraction level as compared to kernel-mode
- Host process *H* must be chosen
  - Option 1: Resident, high-privilege system process (svchost.exe)
  - Option 2: Resident process that interacts with desktop and runs as a user
  - `Explorer.exe` (Windows Explorer) was chosen for this first prototype

- We have to rely on kernel-mode FCI to bootstrap!
  - Kernel is always running and always available, but Explorer is not
  - User-mode processes are constantly being swapped
  - Need to detect when the currently executing process is Windows Explorer

User-Mode FCI: The Full Process



K=LdrGetDllHandle(“kernel32.dll”)

Call VirtualAlloc() twice

E = PsGetCurrentProcess();

B=PsGetProcessSectionBaseAddress(E);

MmProbeAndLockPages(B)

P= GetProcessImageFileName(E);

P == “explorer.exe” ?

User-Mode FCI: Example APIs

Kernel32!CreateFile()
Kernel32!WriteFile()
Kernel32!CloseFile()

→

File Copying
SVM -> GVM

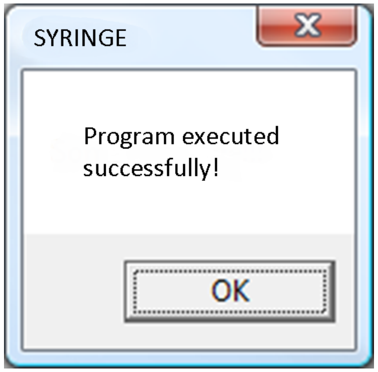
Kernel32!CreateProcess()

→

Execute copied file in GVM

User32!MessageBoxA()

→



Program executed successfully!

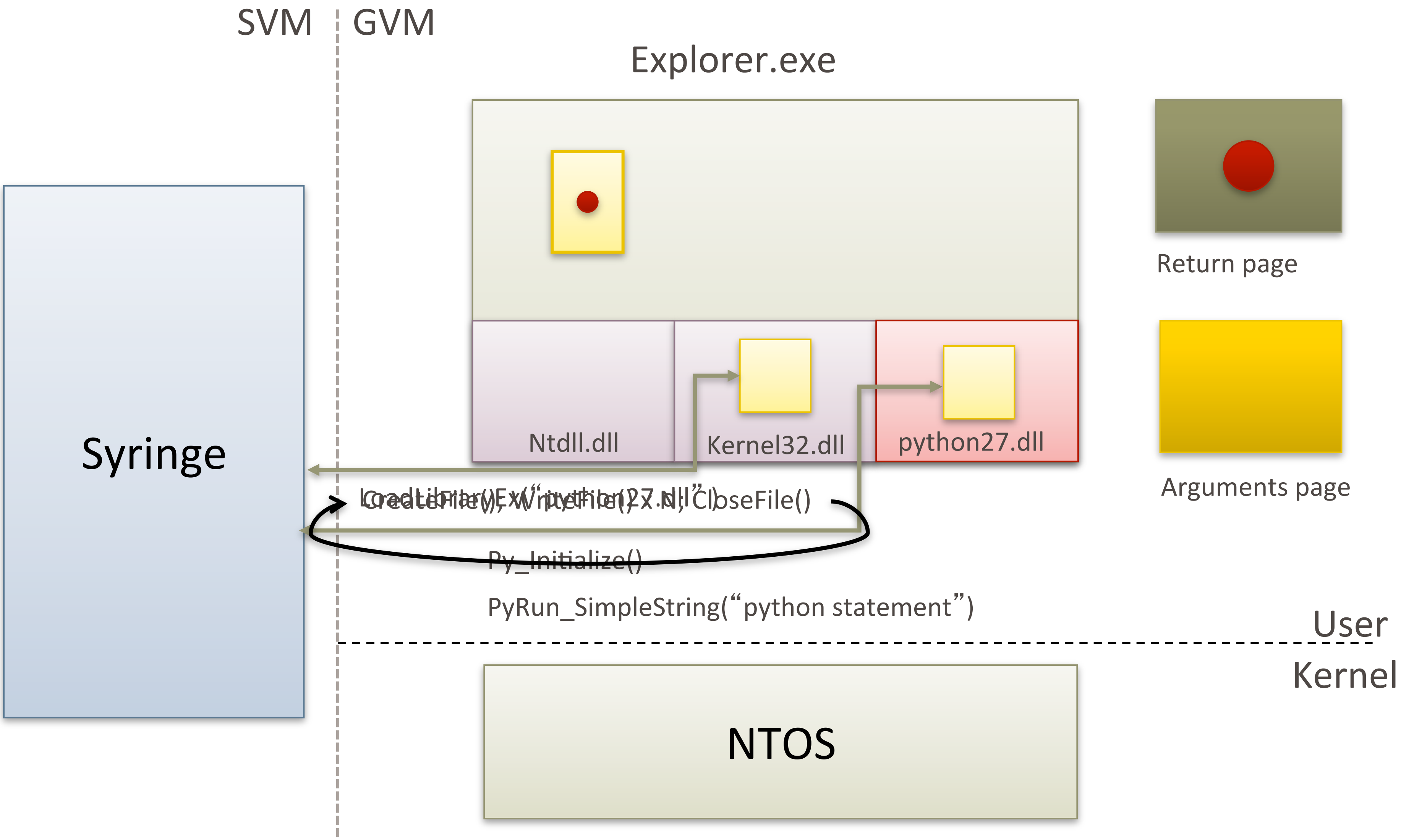
Making FCI OS Independent

- So far we have been focusing on Windows…
- …but FCI is actually an OS-independent technique!

- However, the ***data*** we are injecting and accessing…
  - Function names, addresses, parameters, etc.
- …are OS-dependent.

- Is there some way we could simply abstract all of that?

Inject a cross-platform interpreter (e.g., Python)



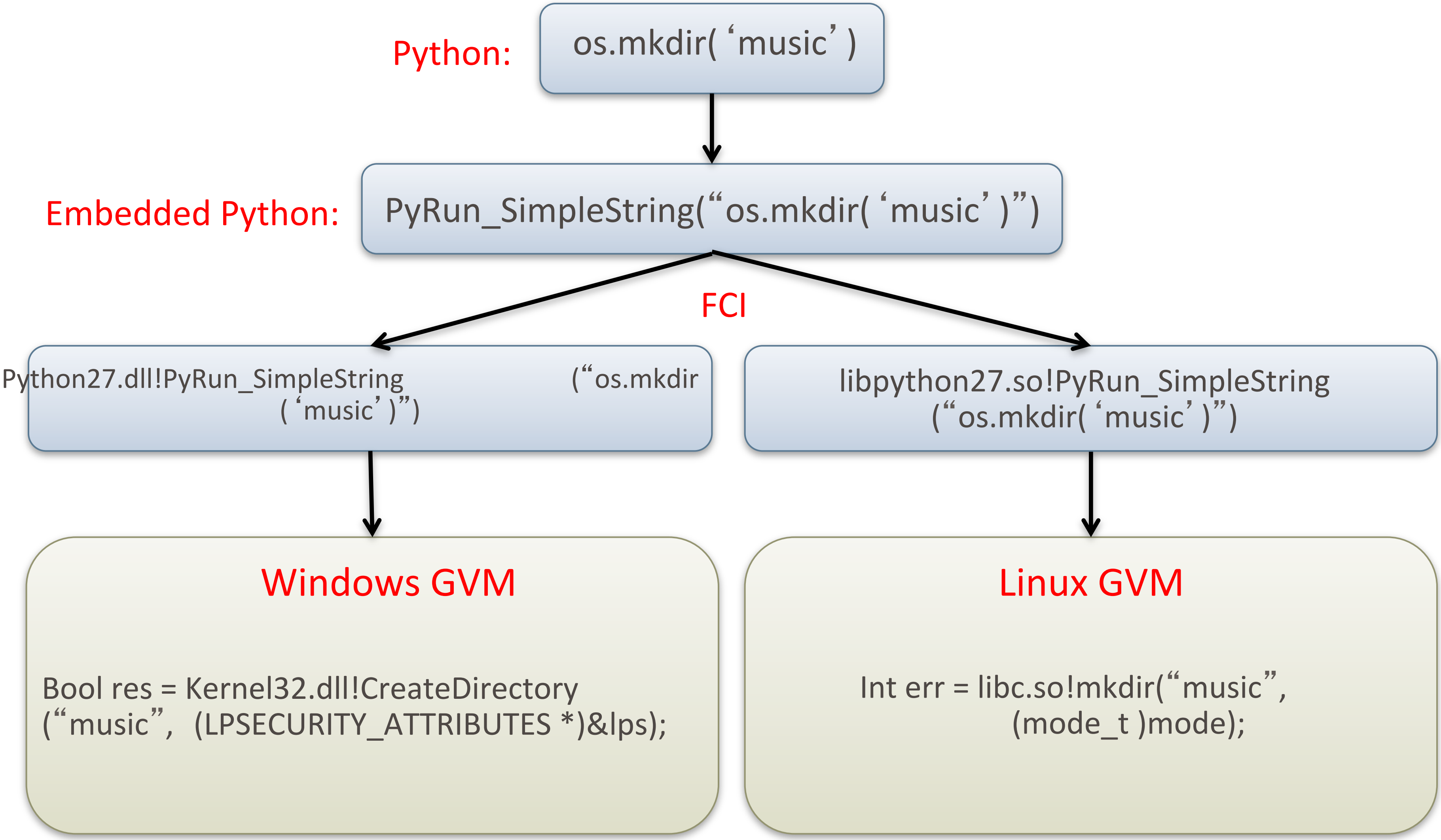
LoadLibraryEx(“python27.dll”)

CreateFile(), WriteFile() x N, CloseFile()

Py_Initialize()

PyRun_SimpleString(“python statement”)

Example



Python: os.mkdir(‘music’)

Embedded Python: PyRun_SimpleString(“os.mkdir(‘music’)”)

FCI

Python27.dll!PyRun_SimpleString (“os.mkdir (‘music’)”)

libpython27.so!PyRun_SimpleString (“os.mkdir(‘music’)”)

Windows GVM

Bool res = Kernel32.dll!CreateDirectory (“music”, (LPSECURITY_ATTRIBUTES *)&lps);

Linux GVM

Int err = libc.so!mkdir(“music”, (mode_t)mode);

Demo / Questions?

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