Slides provided by

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http://www.cs.umd.edu/~dml/

Malware

Malicious code that is stored on and runs on a *victim's* system

- How does it get to run?
  - Attacks a user- or network-facing vulnerable service
    - E.g., using techniques you learned the past couple weeks
  - Backdoor: Added by a malicious developer
  - Social engineering: Trick the user into running/clicking/installing
  - Trojan horse: Offer a good service, add in the bad
  - Attacker with physical access downloads & runs it

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Potentially from any mode of interaction (automated or not), provided sufficient vulnerability

Malware

What can it do?

- Virtually *anything*, subject only to its permissions
  - Brag: “APRIL 1st HA HA HA HA YOU HAVE A VIRUS!”
  - Destroy:
    - Delete/mangle files
    - Damage hardware (more later this lecture)
  - Crash the machine, e.g., by over-consuming resources
    - Fork bombing or “rabbits”: while(1) { fork(); }
  - Steal information (“exfiltrate”)
  - Launch external attacks
    - Spam, click fraud, denial of service attacks
  - Ransomware: e.g., by encrypting files
  - Rootkits: Hide from user or software-based detection
    - Often by modifying the kernel
    - Man-in-the-middle attacks to sit between UI and reality

Malware

When does it run?

- Some delay based on a trigger
  - Time bomb: triggered at/after a certain time
    - On the 1st through the 19th of any month…
  - Logic bomb: triggered when a set of conditions hold
    - If I haven't appeared in two consecutive payrolls…
  - Can also include a backdoor to serve as ransom
    - "I won't let it delete your files if you pay me by Thursday…"

- Some attach themselves to other pieces of code
  - Viruses: run when the user initiates something
    - Run a program, open an attachment, boot the machine
  - Worms: run while another program is running
    - No user intervention required

Self-propagating malware

- Virus: propagates by arranging to have itself *eventually* executed
  - At which point it creates a new, additional instance of itself
  - Typically infects by altering *stored* code
  - User intervention required

- Worm: *self*-propagates by arranging to have itself *immediately* executed
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  - Typically infects by altering *running* code
  - No user intervention required

The line between these is thin and blurry
Some malware uses both styles

Technical challenges

- Viruses: Detection
  - Antivirus software wants to detect
  - Virus writers want to avoid detection for as long as possible
  - *Evade* human response

- Worms: Spreading
  - The goal is to hit as many machines and as quickly as possible
  - *Outpace* human response

Viruses

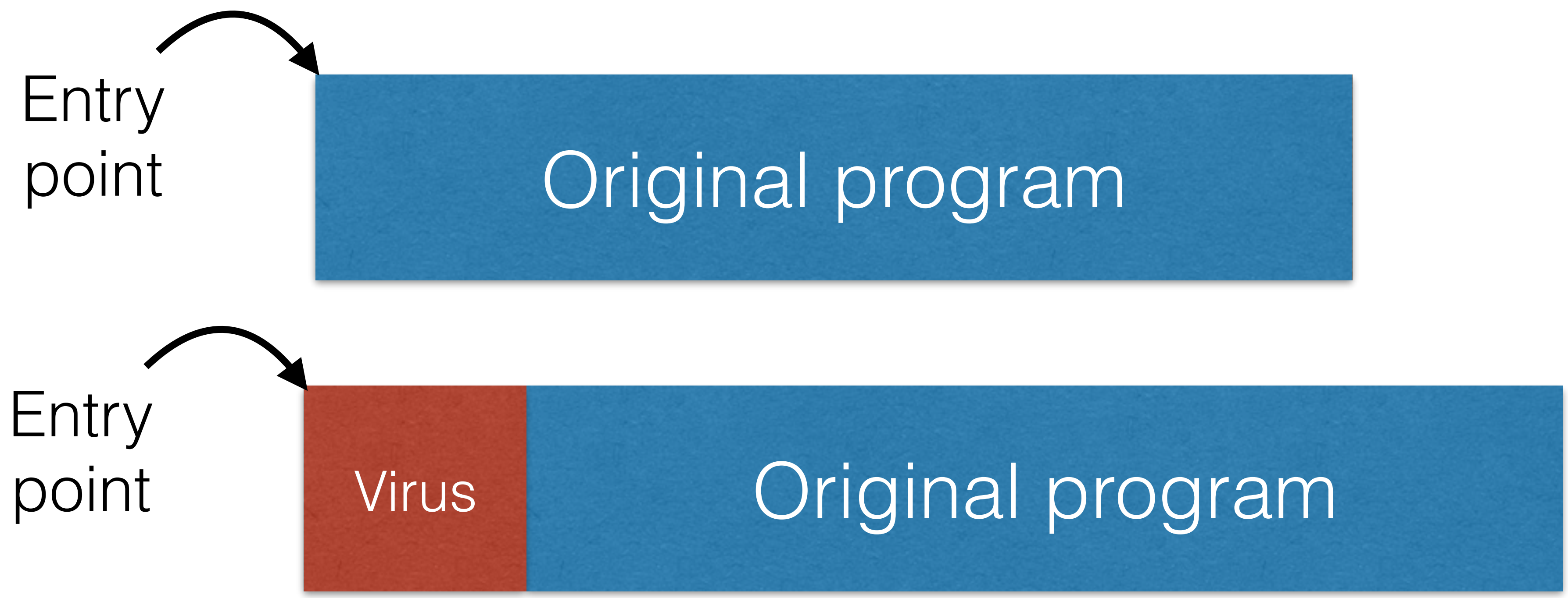
Viruses

- They are opportunistic: they will *eventually* be run due to user action
- Two *orthogonal* aspects define a virus:
  1. How does it propagate?
  2. What else does it do (what is the "payload")?
- General infection strategy:
  - Alter some existing code to include the virus
  - Share it, and expect users to (unwittingly) re-share
- Viruses have been around since at least the 70s

They have resulted in a technological arms race

How viruses infect other programs

How viruses infect other programs



Take over the entry point

Viruses are classified by what they infect

- Document viruses:
  - Implemented within a formatted document
  - Word documents (very rich macros)
  - PDF (Acrobat permits javascript)
- Boot sector viruses:
  - Boot sector: small disk partition at a fixed location
  - If the disk is used to boot, then the firmware loads the boot sector code into memory and runs it
  - What's *supposed* to happen: this code loads the OS
  - Similar: AutoRun
- Memory-resident viruses:
  - "Resident code" stays in memory because it is used so often

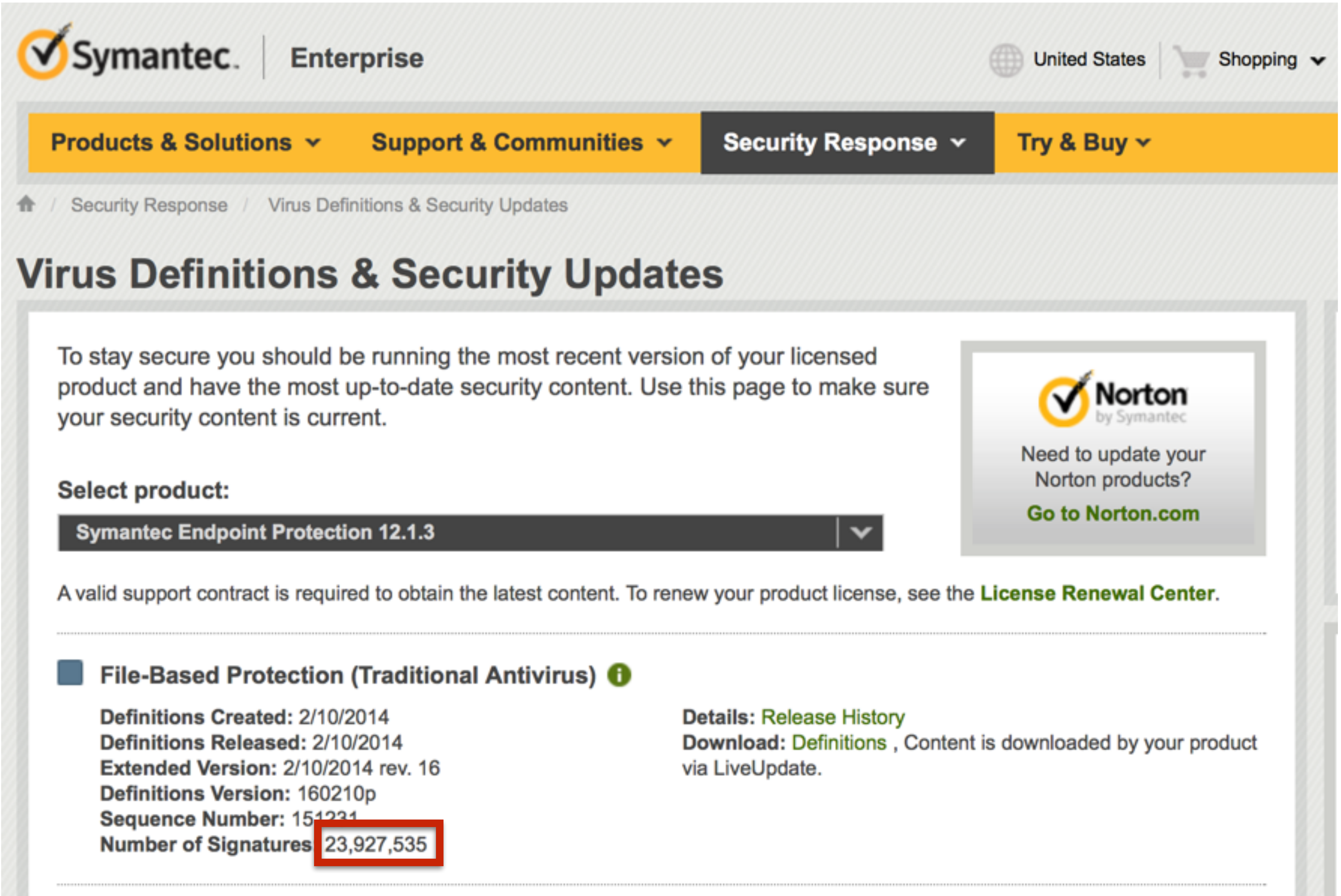
How viruses propagate

- First, the virus looks for an opportunity to run. Increase chances by attaching malicious code to something a user is likely to run
  - autorun.exe on storage devices
  - Email attachments

- When a virus runs, it looks for an opportunity to infect other systems.
  - User plugs in a USB thumb drive: try to overwrite autorun.exe
  - User is sending an email: alter the attachment
  - Viruses can also proactively create emails ("I Love You")

Detecting viruses

- Signature-based detection
  - Look for bytes corresponding to injected virus code
  - Protect other systems by installing a recognizer for a known virus
  - In practice, requires fast scanning algorithms
- This basic approach has driven the multi-billion dollar antivirus market
- #Recognized signatures is a means of marketing/competition
  - But what does that say about how important they are?


Symantec. Enterprise
United States
Shopping
Products & Solutions
Support & Communities
Security Response
Try & Buy
Security Response / Virus Definitions & Security Updates
Virus Definitions & Security Updates
To stay secure you should be running the most recent version of your licensed product and have the most up-to-date security content. Use this page to make sure your security content is current.
Norton by Symantec
Need to update your Norton products?
Go to Norton.com
Select product:
Symantec Endpoint Protection 12.1.3
A valid support contract is required to obtain the latest content. To renew your product license, see the License Renewal Center.
File-Based Protection (Traditional Antivirus)
Definitions Created: 2/10/2014
Definitions Released: 2/10/2014
Extended Version: 2/10/2014 rev. 16
Definitions Version: 160210p
Sequence Number: 151231
Number of Signatures 23,927,535
Details: Release History
Download: Definitions , Content is downloaded by your product via LiveUpdate.

Um.. thanks?

FEATURE

Antivirus vendors go beyond signature-based antivirus

Robert Westervelt, News Director

This article can also be found in the Premium Editorial Download **"Information Security magazine: Successful cloud migrations require careful planning."**

Download it now to read this article plus other related content.

Security experts and executives at security vendors are in agreement that signature-based antivirus isn't able to keep up with the explosion of malware. For example, in 2009, Symantec says it wrote about 15,000 antivirus signatures a day; that number has increased to 25,000 antivirus signatures every day.

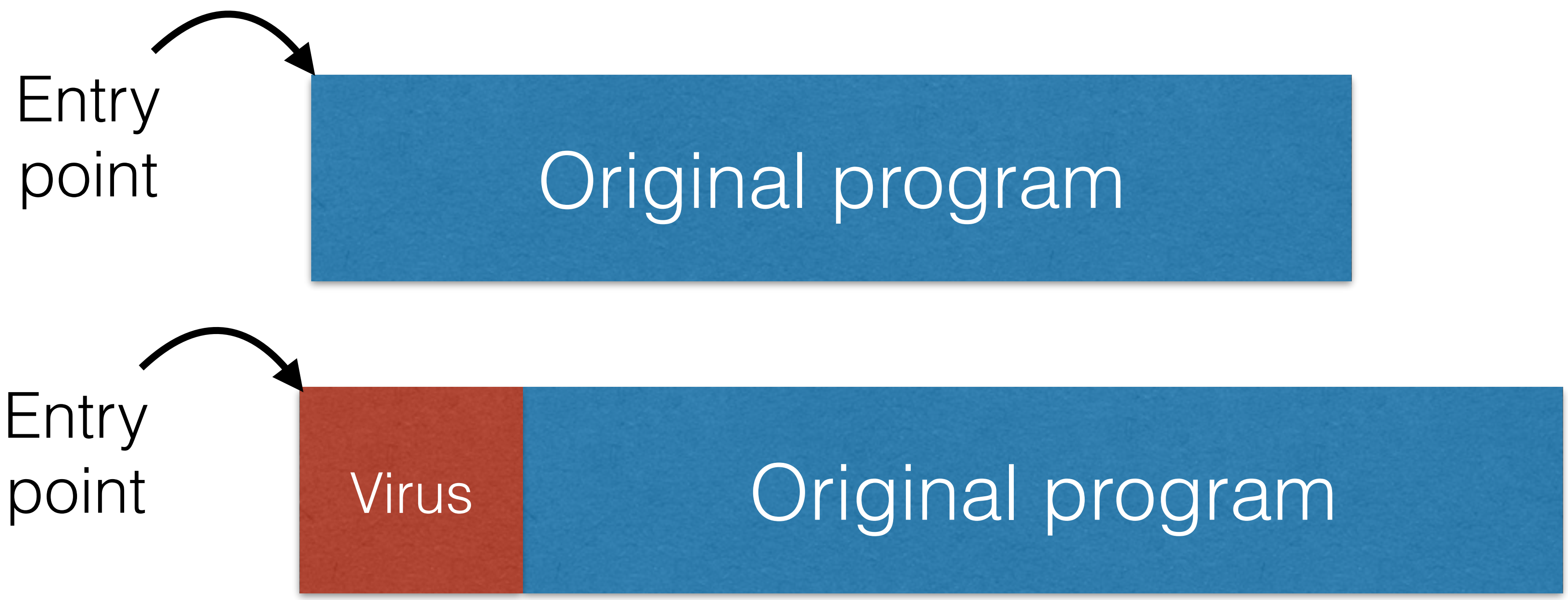
"Signatures have been dying for quite a while," says Mikko H. Hypponen, chief research officer of Finnish-based antivirus vendor, F-Secure. "The sheer number of malware samples we see every day completely overwhelms our ability to keep up with them."

Security vendors have responded by updating their products with additional capabilities, such as file reputation and heuristics-based engines. They're also making upgrades to keep up with the latest technology trends, such as virtualization and cloud computing.

You are a virus writer

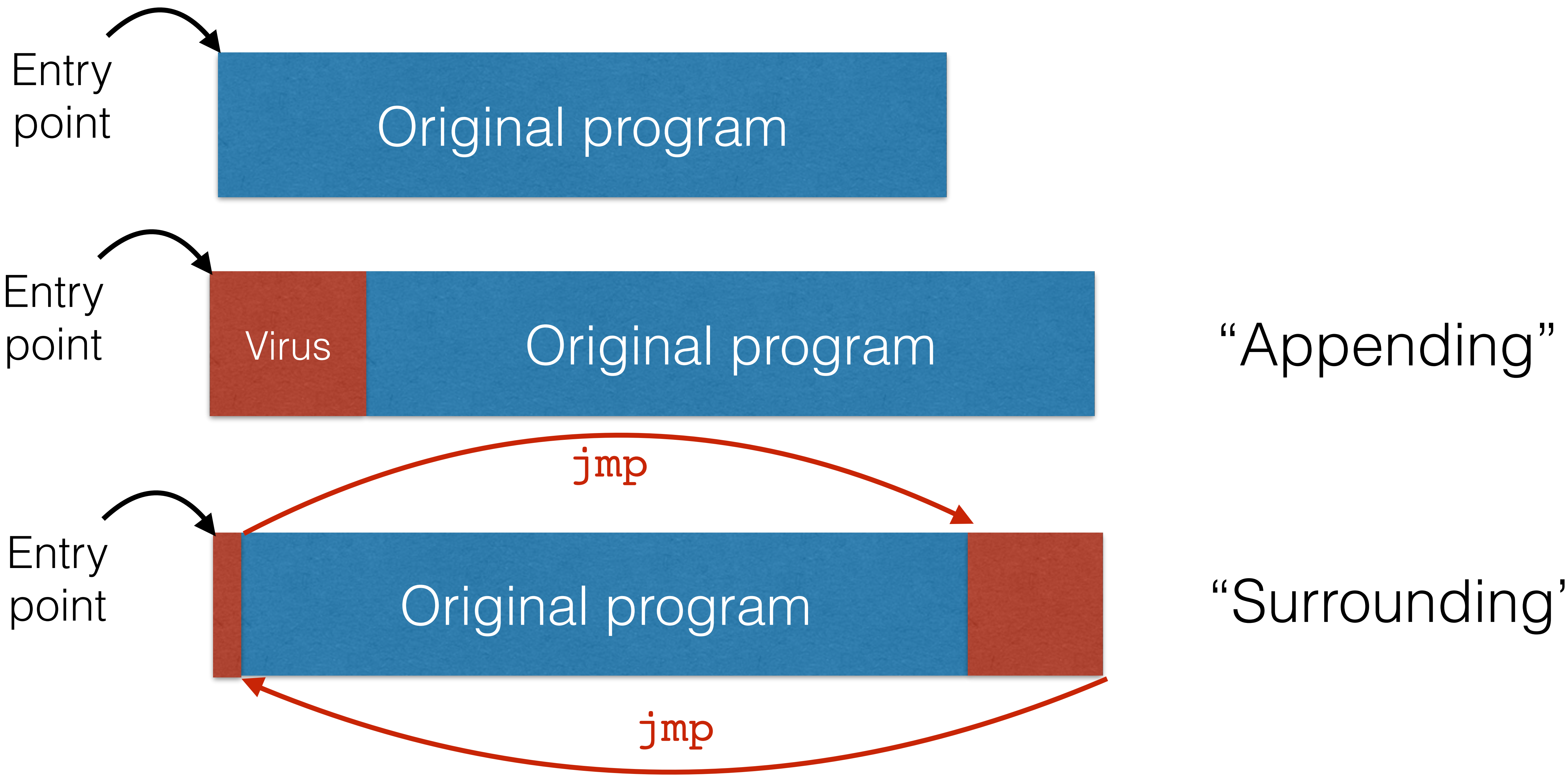
- Your goal is for your virus to spread far and wide
- How do you avoid detection by antivirus software?
  - Give them a harder signature to find

How viruses infect other programs



“Appending”

How viruses infect other programs



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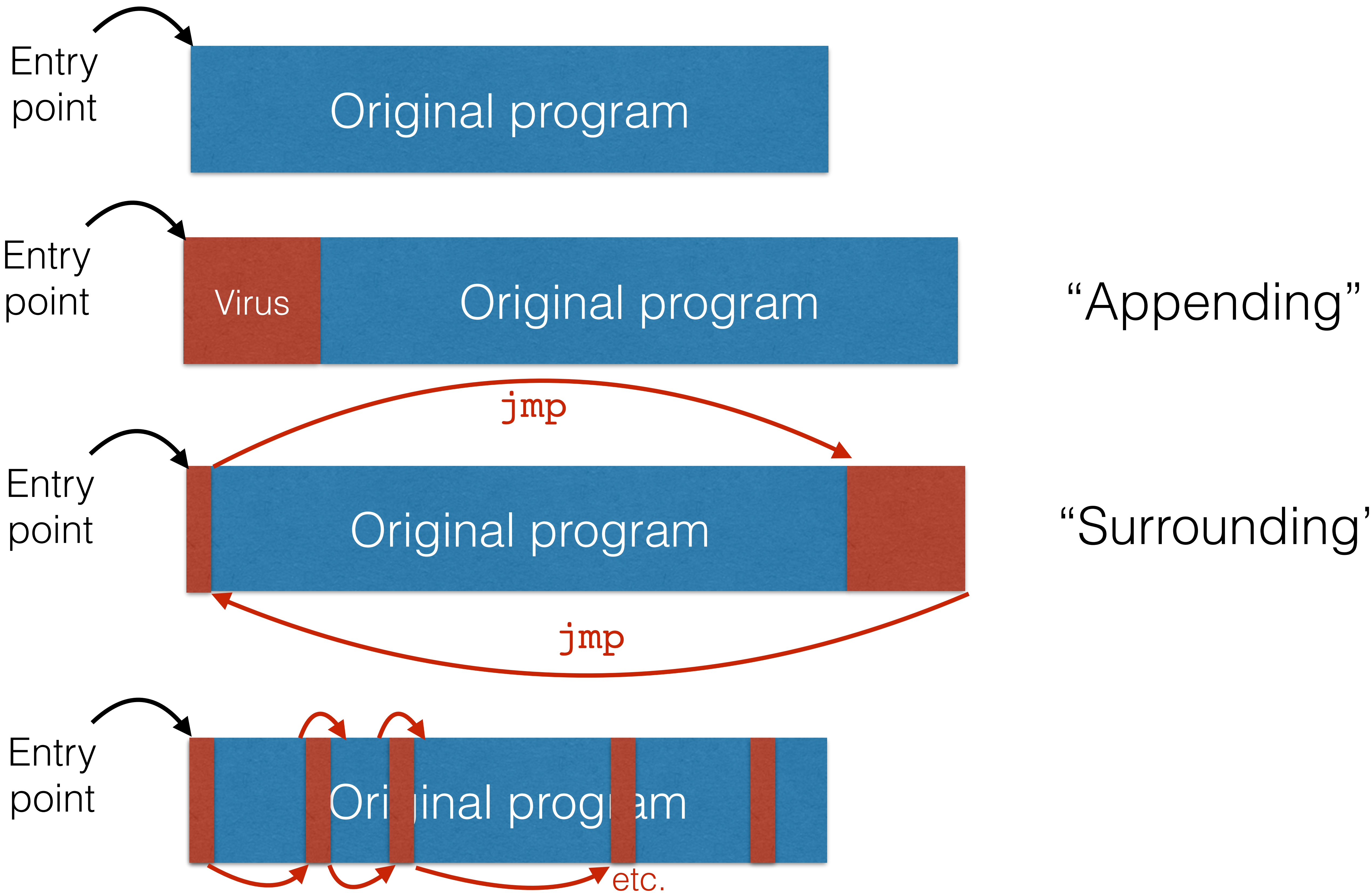

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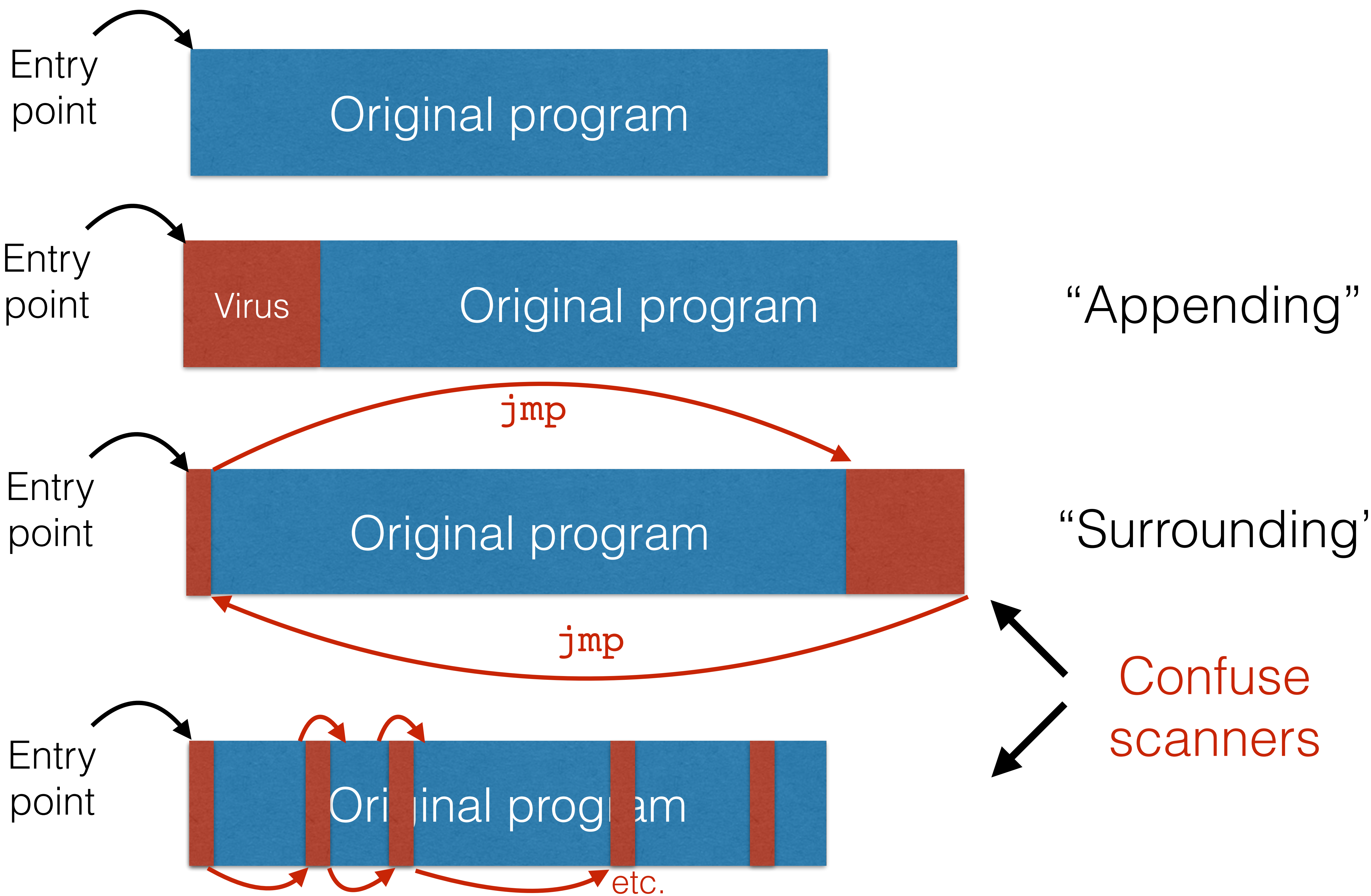

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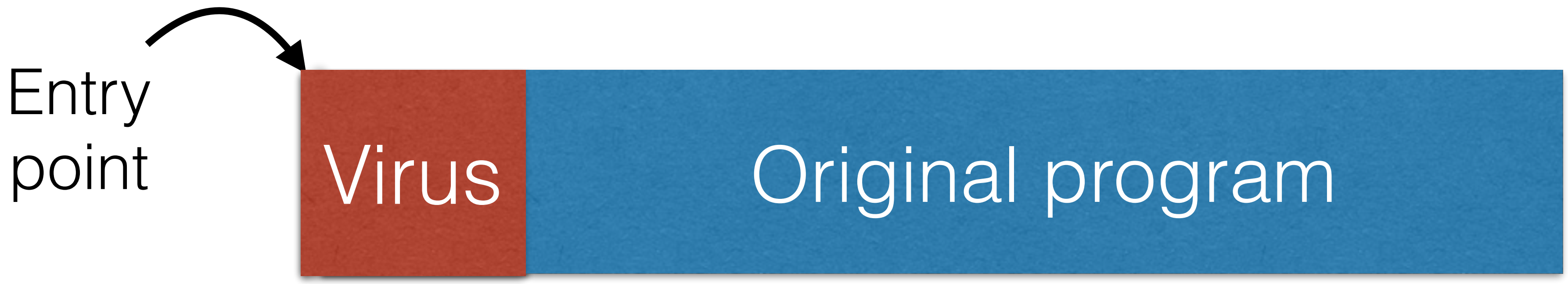
Mechanize code changes:

Goal: every time you inject your code, it looks different

Polymorphic viruses



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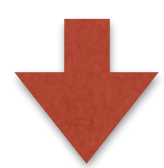

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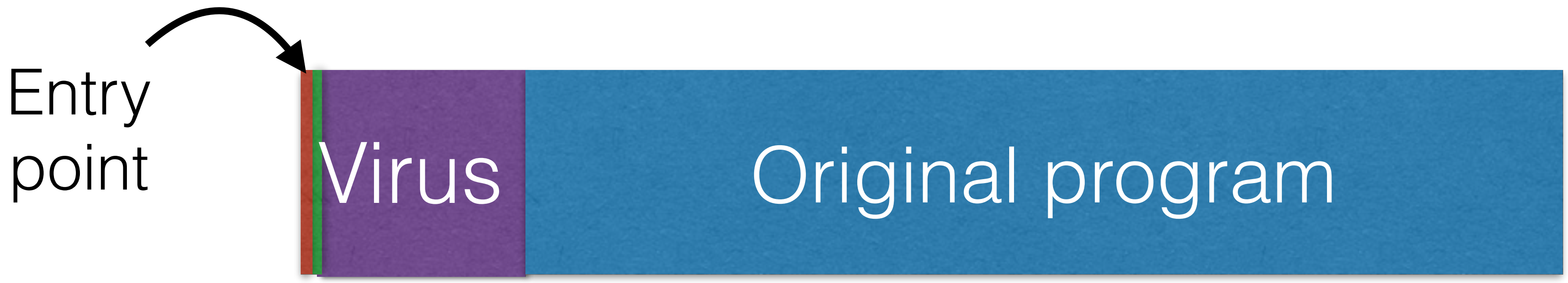

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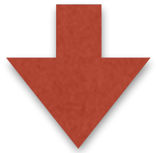

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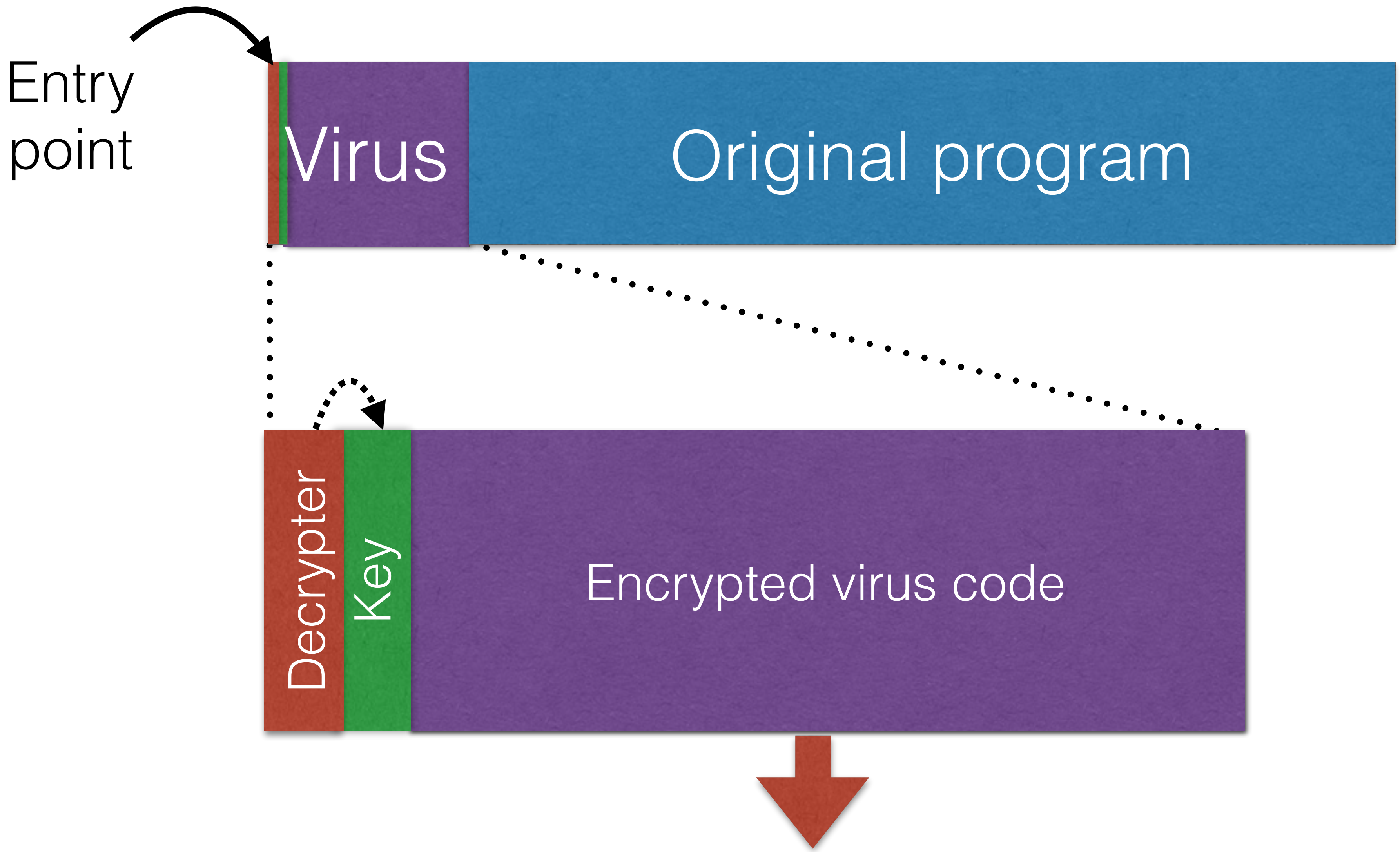

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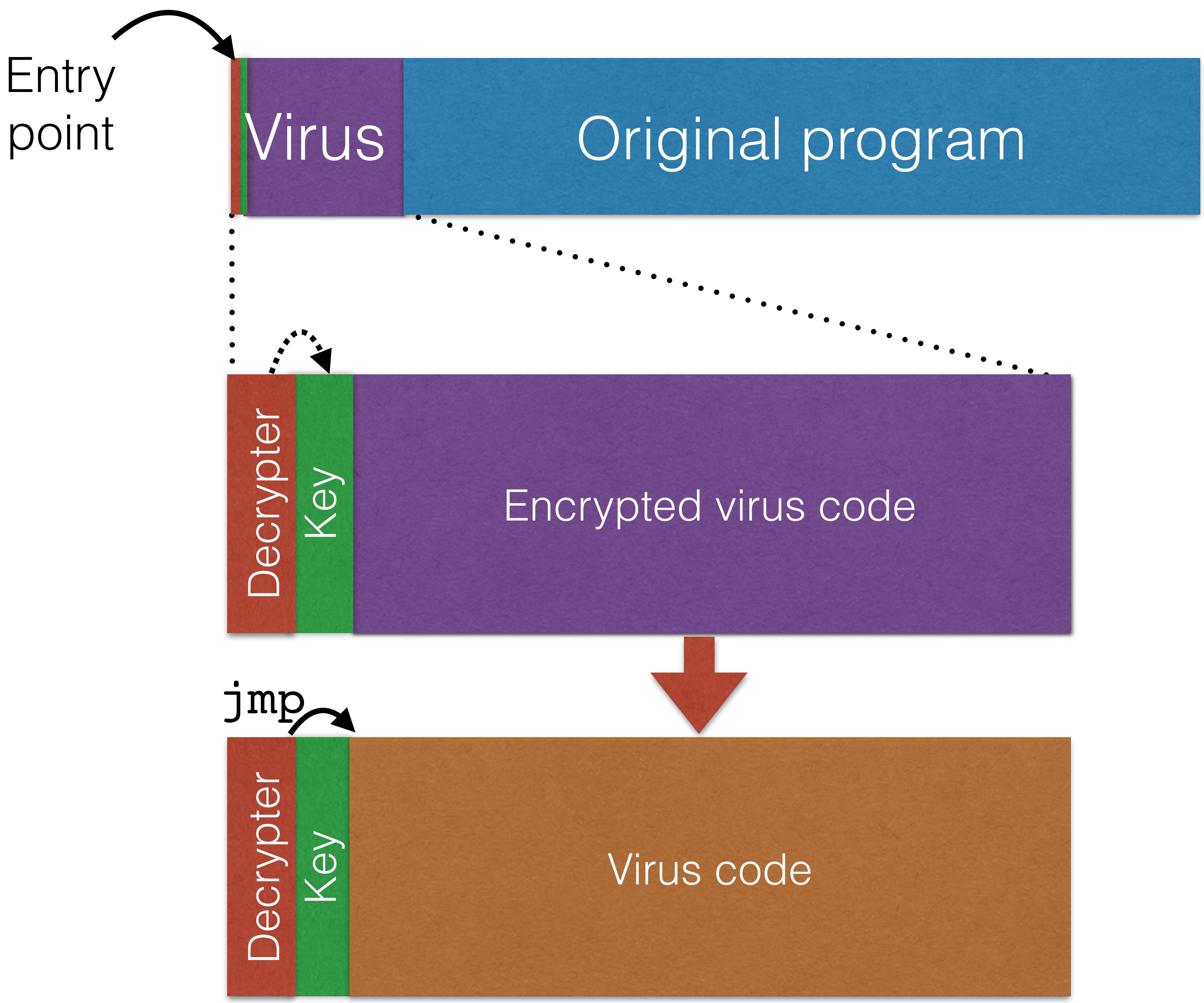

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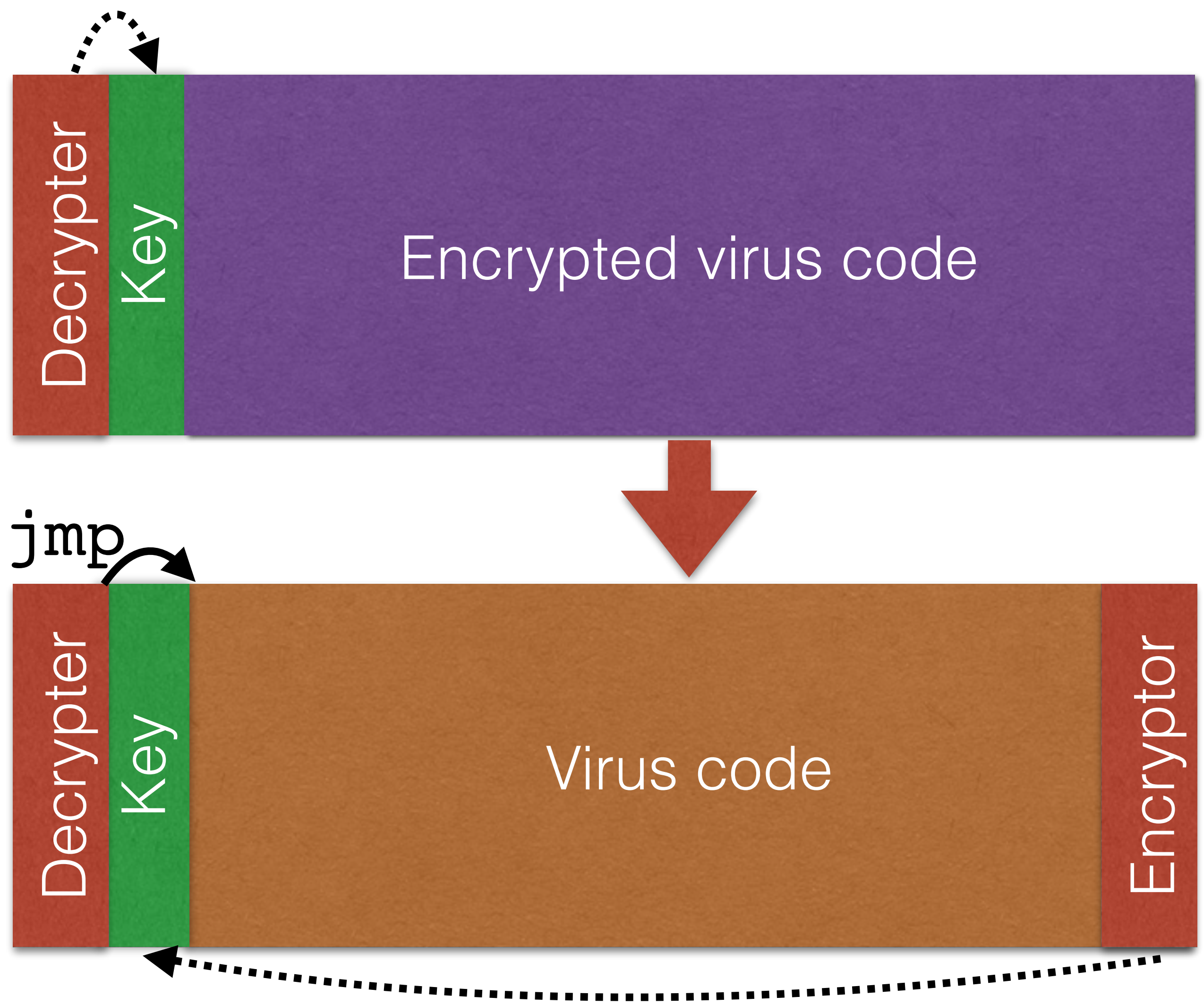
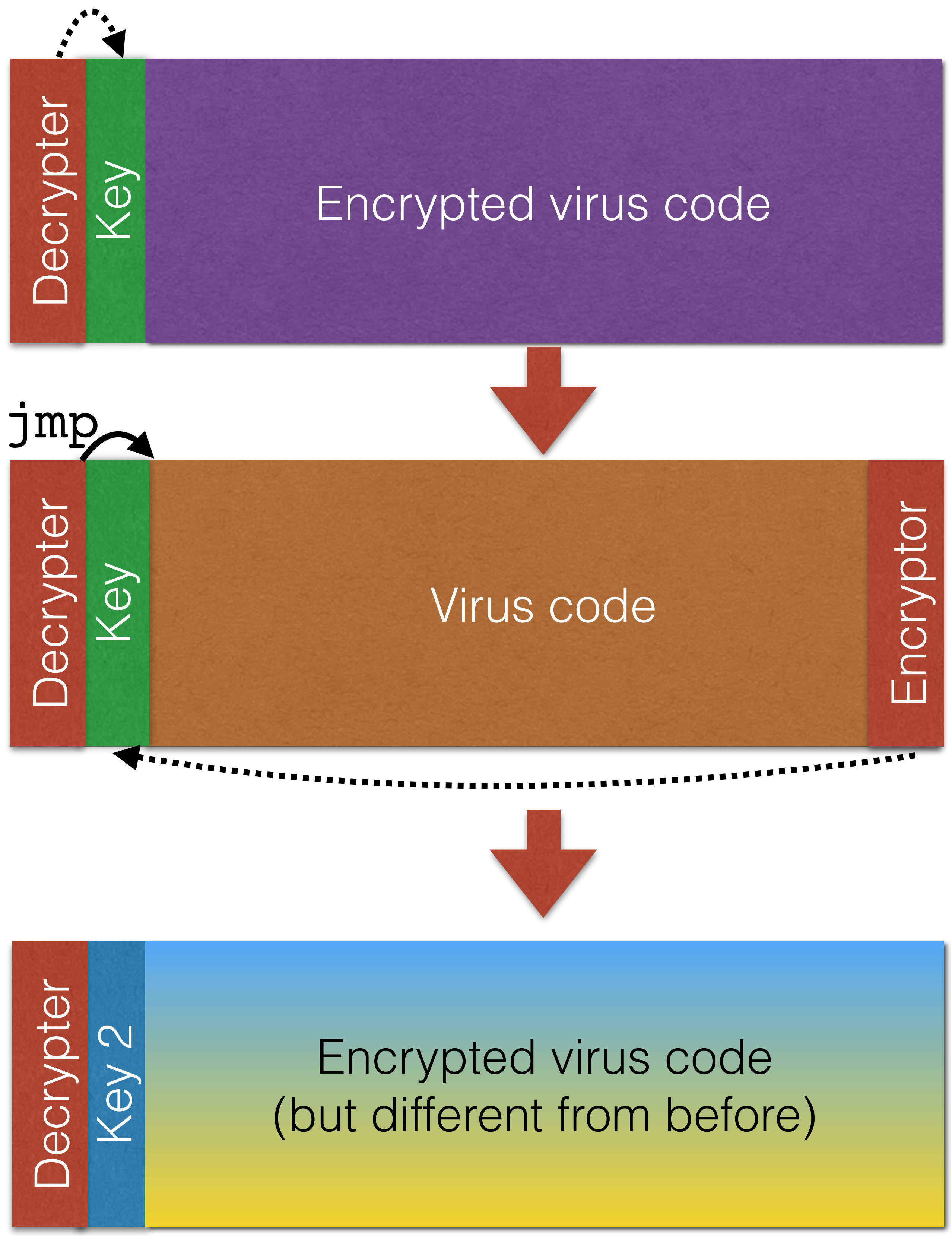
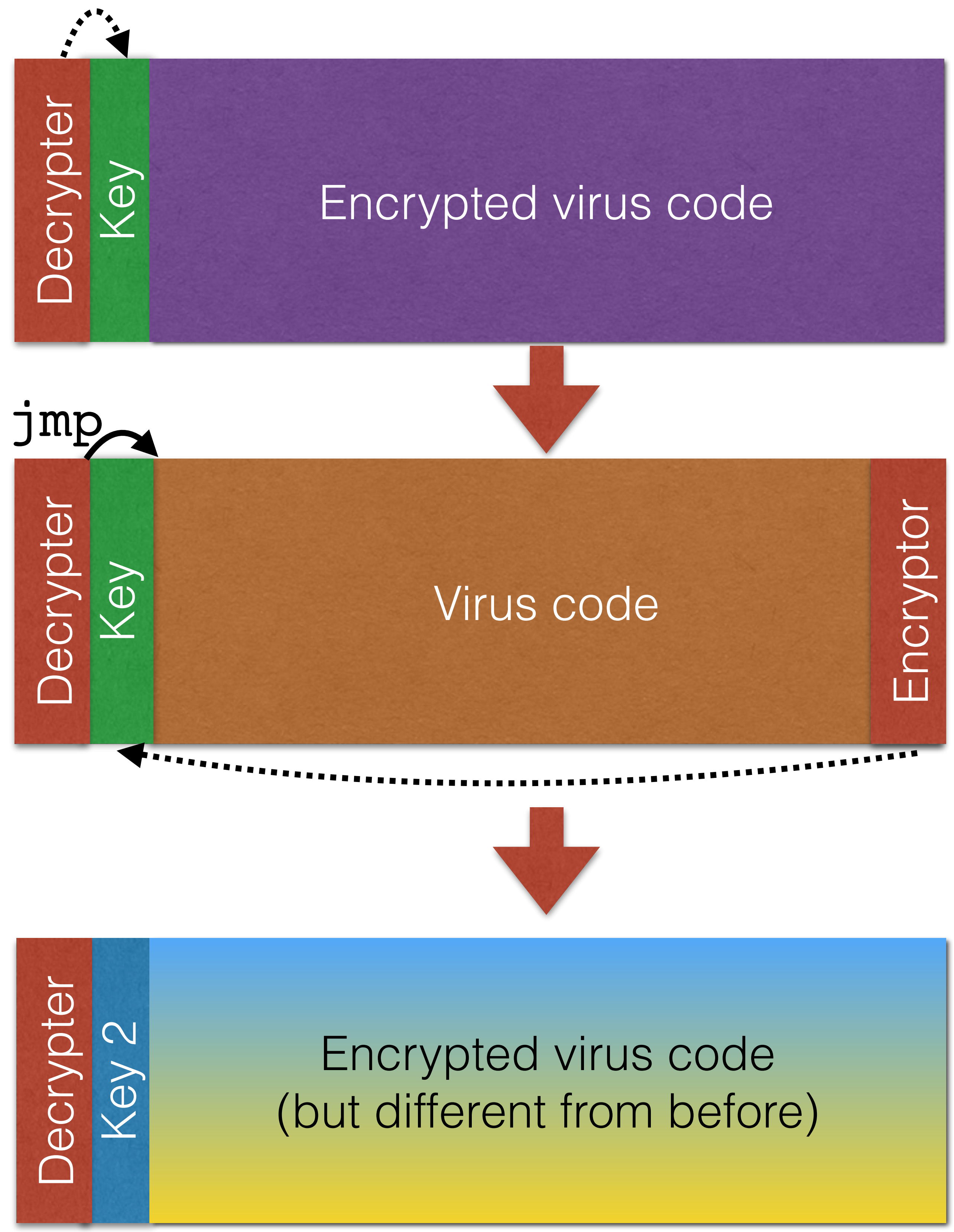


Polymorphic viruses



Polymorphic viruses



When used properly, encryption will yield a different, random output upon each invocation

Polymorphic viruses: Arms race

Now you are the antivirus writer: how do you detect?

Polymorphic viruses: Arms race

Now you are the antivirus writer: how do you detect?

- Idea #1: Narrow signature to catch the decryptor
  - Often very small: can result in many false positives
  - Attacker can spread this small code around and `jmp`
- Idea #2: Execute or statically analyze the suspect code to see if it decrypts.
  - How do you distinguish from common "packers" which do something similar (decompression)?
  - How long do you execute the code??

Polymorphic viruses: Arms race

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Now you are the *virus* writer again: how do you *evade*?

Polymorphic countermeasures

- Change the decryptor
  - Oligomorphic viruses: change to one of a fixed set of decryptors
  - True polymorphic viruses: can generate an endless number of decryptors
    - e.g., brute force key break
    - Downside: inefficient

Metamorphic code

Metamorphic code

- Every time the virus propagates, generate a *semantically different* version
  - Higher-level semantics remain the same
  - But the way it does it differs
    - Different machine code instructions
    - Different algorithms to achieve the same thing
    - Different use of registers
    - Different constants….

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    - Different use of registers
    - Different constants….

- How would you do this?
  - Include a code rewriter with your virus
  - Add a bunch of complex code to throw others off (then just never run it)

```
5A              pop  edx
BF04000000      mov  edi,0004h
8BF5            mov  esi,ebp
B80C000000      mov  eax,000Ch
81C288000000    add  edx,0088h
8B1A            mov  ebx,[edx]
899C8618110000  mov  [esi+eax*4+00001118],ebx

58              pop  eax
BB04000000      mov  ebx,0004h
8BD5            mov  edx,ebp
BF0C000000      mov  edi,000Ch
81C088000000    add  eax,0088h
8B30            mov  esi,[eax]
89B4BA18110000  mov  [edx+edi*4+00001118],esi
```

Figure 4 Win95/Regswap using different registers in new generations

```
a. An early generation:

C7060F000055   mov      dword ptr [esi],5500000Fh
C746048BEC5151 mov      dword ptr [esi+0004],5151EC8Bh

b. And one of its later generations:

BF0F000055     mov     edi,5500000Fh
893E           mov     [esi],edi
5F             pop     edi
52             push    edx
B640           mov     dh,40
BA8BEC5151     mov     edx,5151EC8Bh
53             push    ebx
8BDA           mov     ebx,edx
895E04         mov     [esi+0004],ebx

c. And yet another generation with recalculated ("encrypted") "con-
stant" data.

BB0F000055     mov     ebx,5500000Fh
891E           mov     [esi],ebx
5B             pop     ebx
51             push    ecx
B9CB00C05F     mov     ecx,5FC000CBh
81C1C0EB91F1   add     ecx,F191EBC0h ; ecx=5151EC8Bh
894E04         mov     [esi+0004],ecx
```

Figure 6: Example of code metamorphosis of Win32/Evol

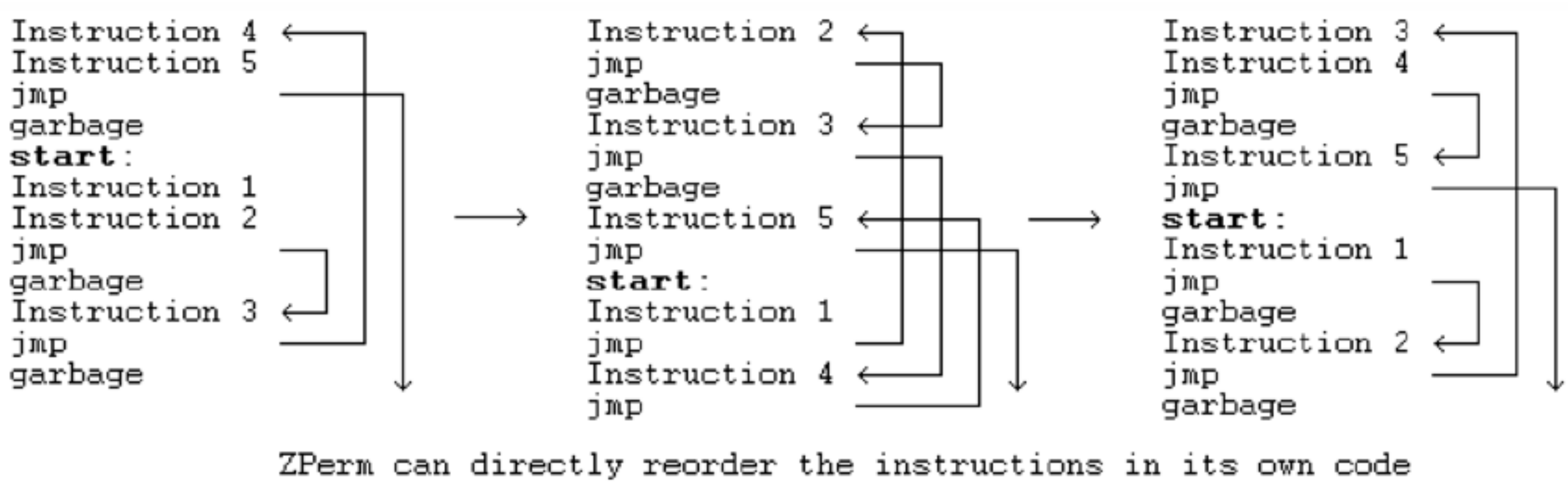
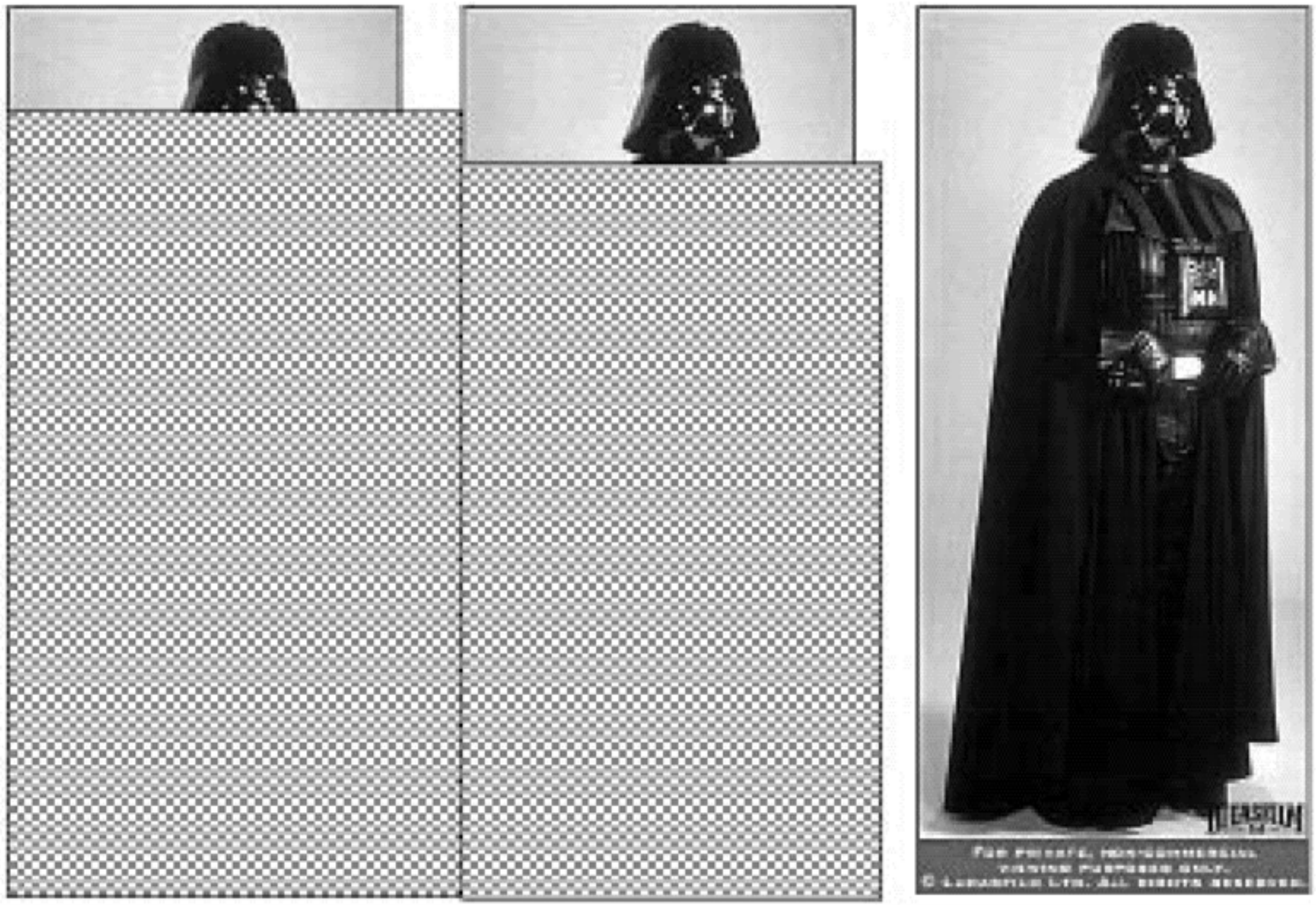


Figure 7. Zperm.A inserts JMP instruction into its code

Polymorphic



When can you successfully scan?

Figure 8: A partial or complete snapshot of polymorphic virus during execution cycle

Metamorphic

When can you successfully scan?

Figure 10: T-1000 of Terminator 2

Detecting metamorphic viruses

- Scanning isn't enough: need to analyze execution behavior
- Two broad stages in practice (both take place in a safe environment, like gdb or a virtual machine)
  1. AV company analyzes new virus to find behavioral signature
  2. AV system at the end host analyzes suspect code to see if it matches the signature

Detecting metamorphic viruses

- Countermeasures
  - Have your virus change slowly (hard to create a proper behavioral signature)
  - Detect if you are in a safe execution environment (e.g., gdb) and act differently
- Counter-countermeasures
  - Detect detection and skip those parts
- Counter-counter-counter…. Arms race

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Attackers have the upper hand:
AV systems hand out signatures, thus serving as an *oracle*

Putting it all together sounds hard

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- Any scriptkiddy can use them

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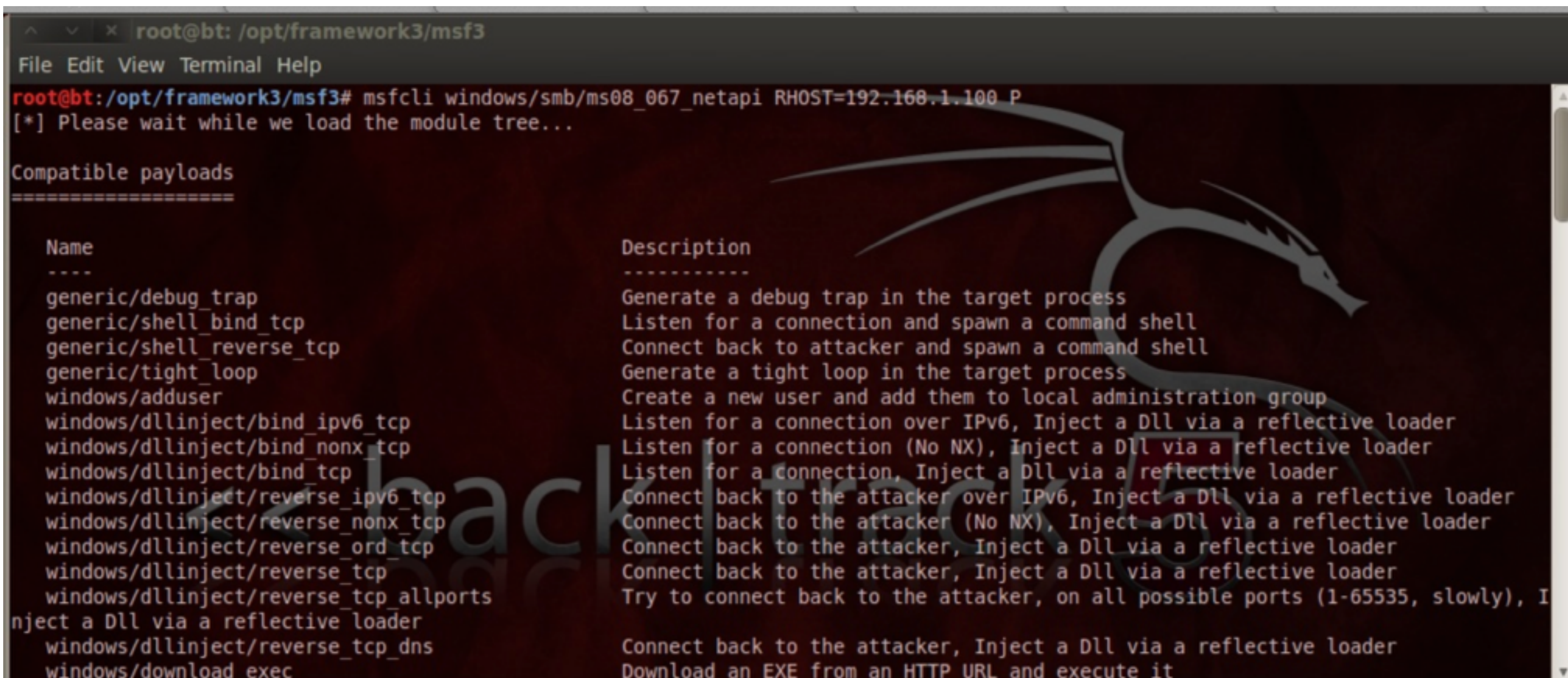
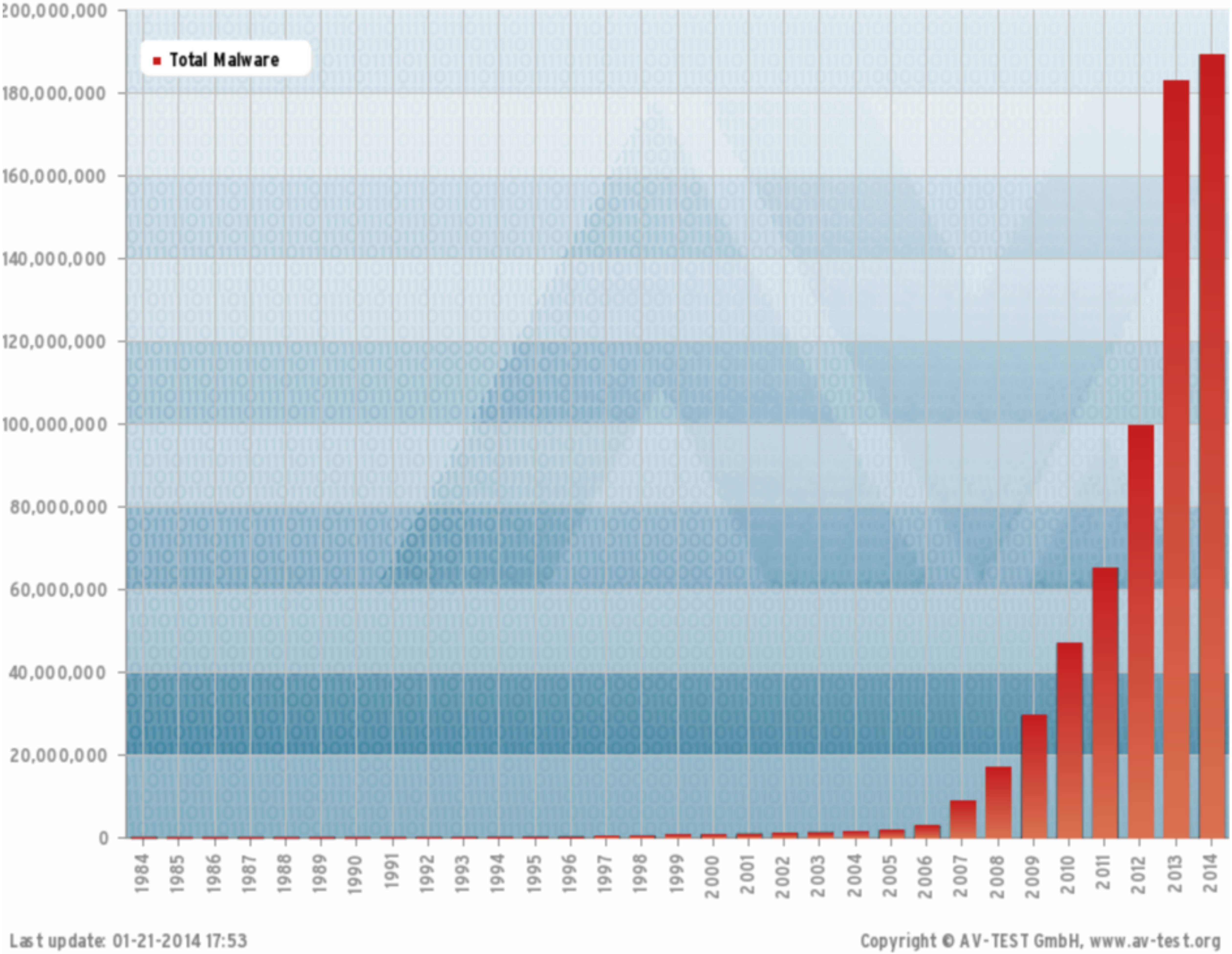


So how much malware is out there?

- Polymorphic and metamorphic viruses can make it easy to *miscount* viruses
- Take numbers with a grain of salt
  - Large numbers are in the AV vendors' best interest


Total Malware
200,000,000
180,000,000
160,000,000
140,000,000
120,000,000
100,000,000
80,000,000
60,000,000
40,000,000
20,000,000
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1984
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2006
2007
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2009
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2011
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2014
Last update: 01-21-2014 17:53
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How do we clean up an infection?

- Depends what the virus did, but..
- May require restoring / repairing files
  - A service that antivirus companies sell
- What if the virus ran as root?
  - May need to rebuild the entire system
- So what, just recompile it?
  - What if the malware left a backdoor in your compiler?
    - Compile the malware back into the compiler
  - May need to use original media and data backups

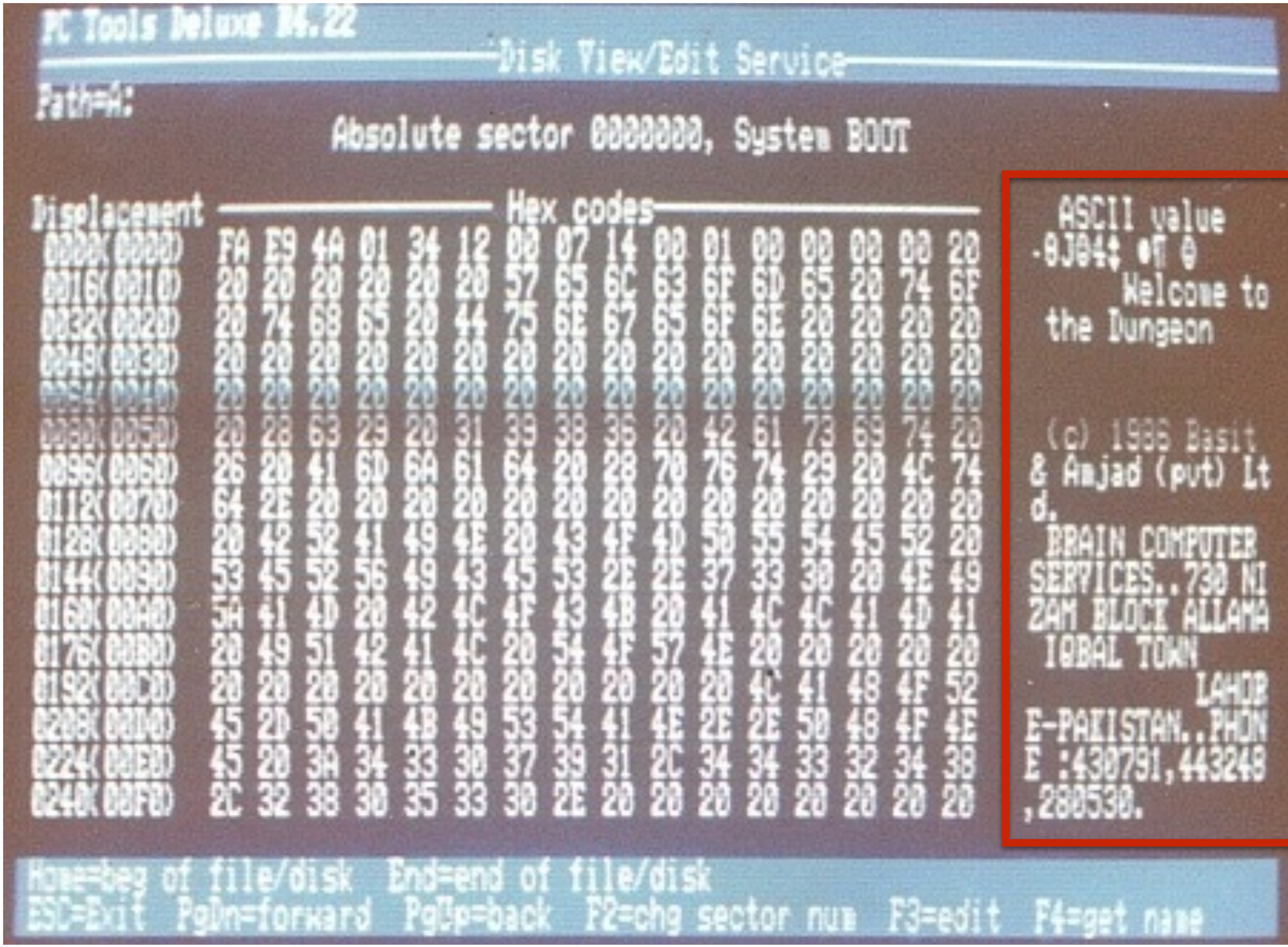
Virus case studies

Brain

First IBM PC virus (1987)

- Propagation method
  - Copies itself into the boot sector
  - Tells the OS that all of the boot sector is “faulty” (so that it won’t list contents to the user)
    - Thus also one of the first examples of a stealth virus
  - Intercepts disk read requests for 5.25” floppy drives
    - Sees if the 5th and 6th bytes of the boot sector are 0x1234
    - If so, then it’s already infected, otherwise, infect it

- Payload:
  - Nothing really; goal was just to spread (to show off?)
  - However, it served as the template for future viruses



PC Tools Deluxe R4.22
Disk View/Edit Service
Path=A:
Absolute sector 0000000, System BOOT
Displacement
Hex codes
0000(0000) FA E9 4A 01 34 12 00 07 14 00 01 00 00 00 00 20
0016(0010) 20 20 20 20 20 20 57 65 6C 63 6F 6D 65 20 74 6F
0032(0020) 20 74 68 65 20 44 75 6E 67 65 6F 6E 20 20 20 20
0048(0030) 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20
0080(0050) 20 28 63 29 20 31 39 38 36 20 42 61 73 69 74 20
0096(0060) 26 20 41 6D 6A 61 64 20 28 70 76 74 29 20 4C 74
0112(0070) 64 2E 20 20 20 20 20 20 20 20 20 20 20 20 20 20
0128(0080) 20 42 52 41 49 4E 20 43 4F 4D 50 55 54 45 52 20
0144(0090) 53 45 52 56 49 43 45 53 2E 2E 37 33 30 20 4E 49
0160(00A0) 5A 41 4D 20 42 4C 4F 43 4B 20 41 4C 4C 41 4D 41
0176(00B0) 20 49 51 42 41 4C 20 54 4F 57 4E 20 20 20 20 20
0192(00C0) 20 20 20 20 20 20 20 20 20 20 20 4C 41 48 4F 52
0208(00D0) 45 2D 50 41 4B 49 53 54 41 4E 2E 2E 50 48 4F 4E
0224(00E0) 45 20 3A 34 33 30 37 39 31 2C 34 34 33 32 34 38
0240(00F0) 2C 32 38 30 35 33 30 2E 20 20 20 20 20 20 20 20
ASCII value
Welcome to the Dungeon
(c) 1986 Basit & Amjad (pvt) Ltd.
BRAIN COMPUTER SERVICES..730 NIZAM BLOCK ALLAMA IQBAL TOWN LAHORE-PAKISTAN..PHONE :430791,443248,280530.
Home=beg of file/disk End=end of file/disk
ESC=Exit PgDn=forward PgUp=back F2=chg sector num F3=edit F4=get name

Rootkits

- Recall: a rootkit is malicious code that takes steps to go undiscovered
  - By intercepting system calls, patching the kernel, etc.
  - Often effectively done by a man in the middle attack
- Rootkit revealer: analyzes the disk offline and through the online system calls, and compares
- Mark Russinovich ran a rootkit revealer and found a rootkit in 2005…

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- Mark Russinovich ran a rootkit revealer and found a rootkit in 2005… **installed by a CD he had bought.**

Sony XCP rootkit

Detected 2005

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- Goal: keep users from copying copyrighted material

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Detected 2005

- Goal: keep users from copying copyrighted material
- How it worked:
  - Loaded thanks to autorun.exe on the CD
  - Intercepted read requests for its music files
  - If anyone but Sony's music player is accessing them, then garble the data
  - Hid itself from the user (to avoid deletion)

Sony XCP rootkit

Detected 2005

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- How it worked:
  - Loaded thanks to autorun.exe on the CD
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  - If anyone but Sony's music player is accessing them, then garble the data
  - Hid itself from the user (to avoid deletion)
- How it messed up
  - Morally: violated trust
  - Technically: Hid *all files* that started with "sys"
  - Seriously?: The uninstaller did not check the integrity of the code it downloaded, and would not delete it afterwords.

Stuxnet: Propagation

June 2010

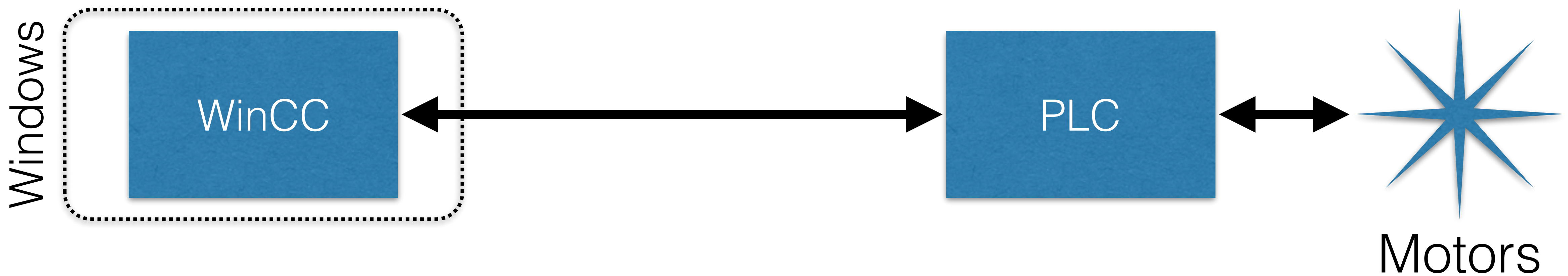
- Virus in that it initially spread by infected USB stick
  - Once inside a network, it acted as a worm, spreading quickly

- Exploited **four** zero-day exploits
  - Zero-day: Known to only the attacker until the attack
  - Typically, one zero-day is enough to profit
  - Four was unprecedented
    - Immense cost and sophistication on behalf of the attacker

- Rootkit: installed *signed* device drivers
  - Thereby avoiding user alert when installing
  - Signed with certificates stolen from two Taiwanese CAs

Stuxnet: Payload

- Targets industrial control systems by overwriting programmable logic boards
- Man-in-the-middle between Windows and Siemens control systems; looked like it was working properly to the operator



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- Result: Destroy (or at least decrease the productivity of) nuclear centrifuges

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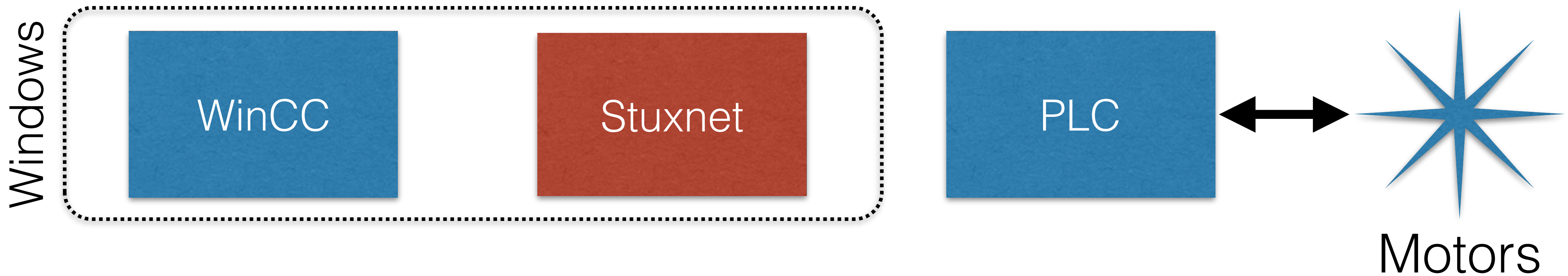

- In reality, it sped up and slowed down the motors
- Result: Destroy (or at least decrease the productivity of) nuclear centrifuges

Stuxnet: Payload

- Targets industrial control systems by overwriting programmable logic boards

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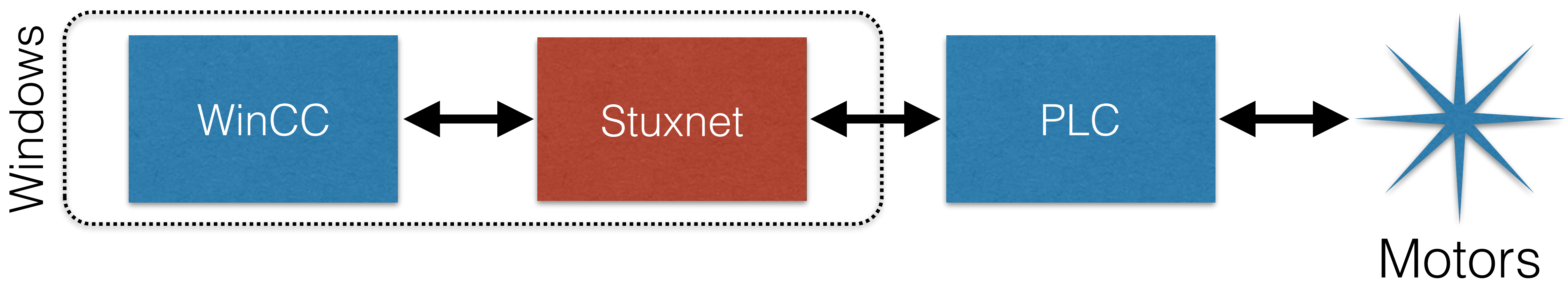

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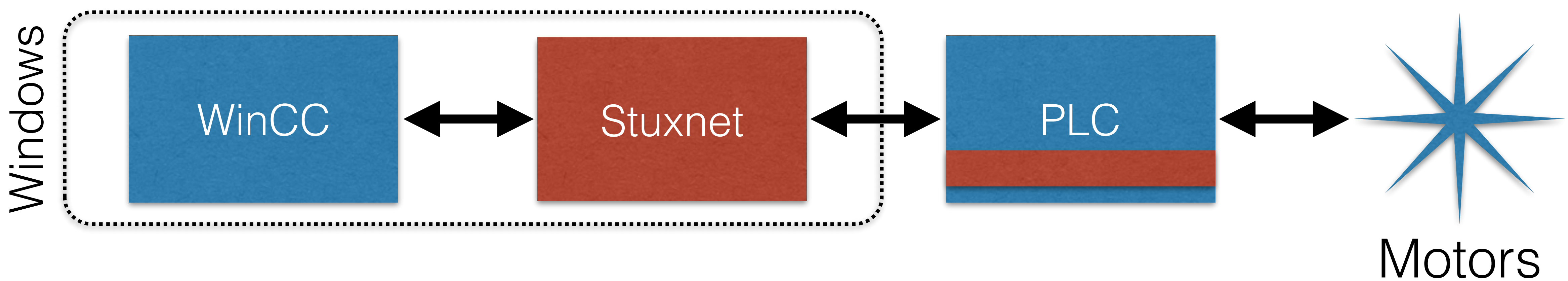

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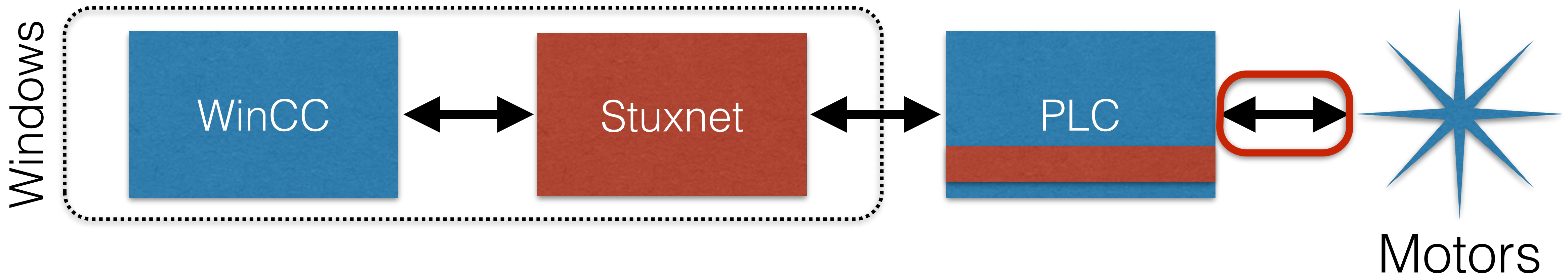

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Stuxnet: Fallout

- Iran denied they had been hit by Stuxnet
- Then claimed they were, but had contained it
- Understood now that it took out 1k of Iran's 5k centrifuges
- Security experts believe the U.S. did it (possibly along with Israel) due to its sophistication and cost
- Legitimized cyber warfare

Viruses

- Technological arms race between those who wish to detect and those who wish to evade detection
- Started off innocuously, capable by only a few very clever people
- But viruses have become commoditized; any scriptkiddy can launch one (creation remains hard)
- No longer purely of academic interest
  - Economic pursuits (zero-day markets)
  - Cyber warfare

Worms

**Due to the snow storm,
we'll cover worms when we get to networking**

This time

Continuing with
Software Security

Getting sick with
Malware

- Types of malware
- How viruses work
- Detecting viruses (and counter-measures)
- Case studies