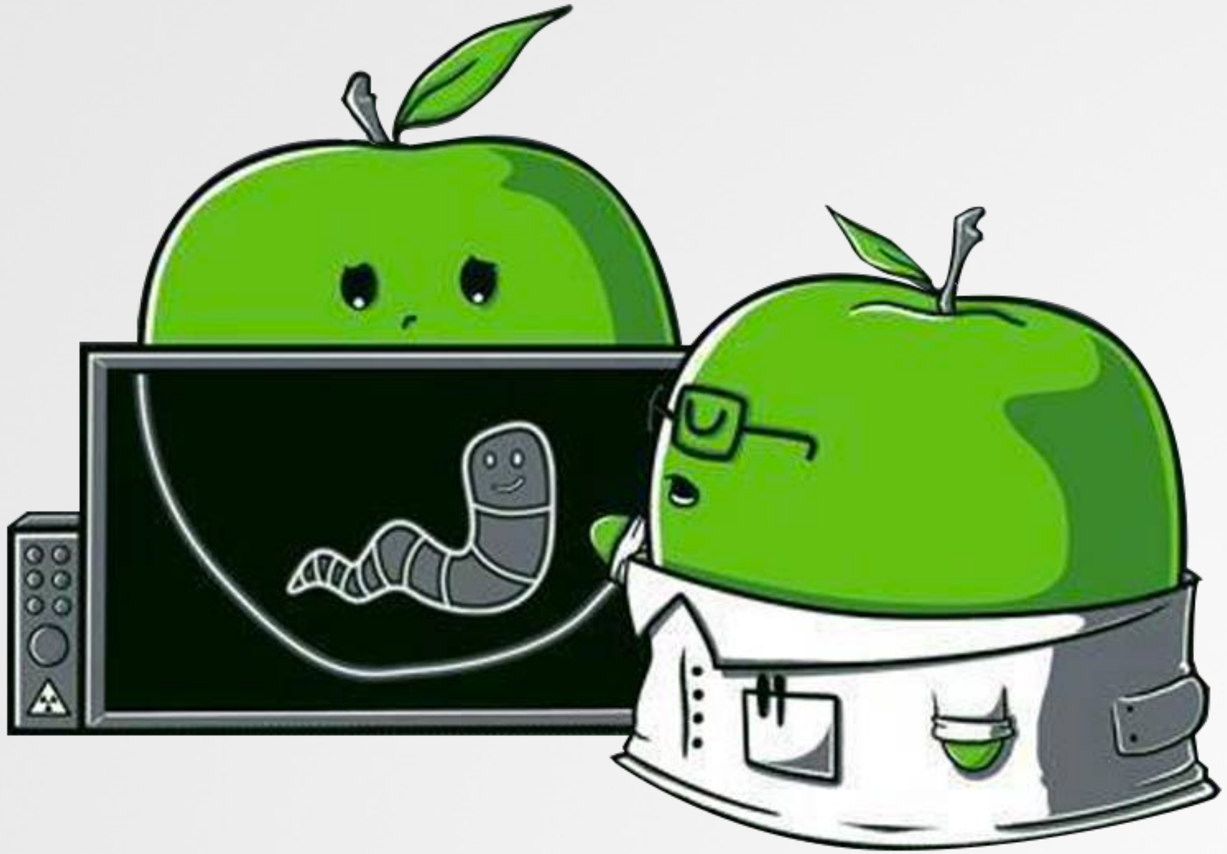
& breaking !

Demystifying macOS's

Background Task Management



% WHOAMI

Patrick Wardle

Objective-See Foundation, 501(c)(3)

- macOS security tools
- "The Art of Mac Malware" books
- "Objective by the Sea" conference

What You Will Learn

Although the talk is largely focused on macOS's Background Task Management (BTM) - we'll also cover topics of reversing, malware detection, macOS internals, and more!

1 

Internals of macOS's BTM

2 

Leveraging BTM to detect malware

3 

Bypassing BTM alerts & ES messaging

4 

Detecting these bypasses

How We're Going To Get There

Overview

Internals

Tools

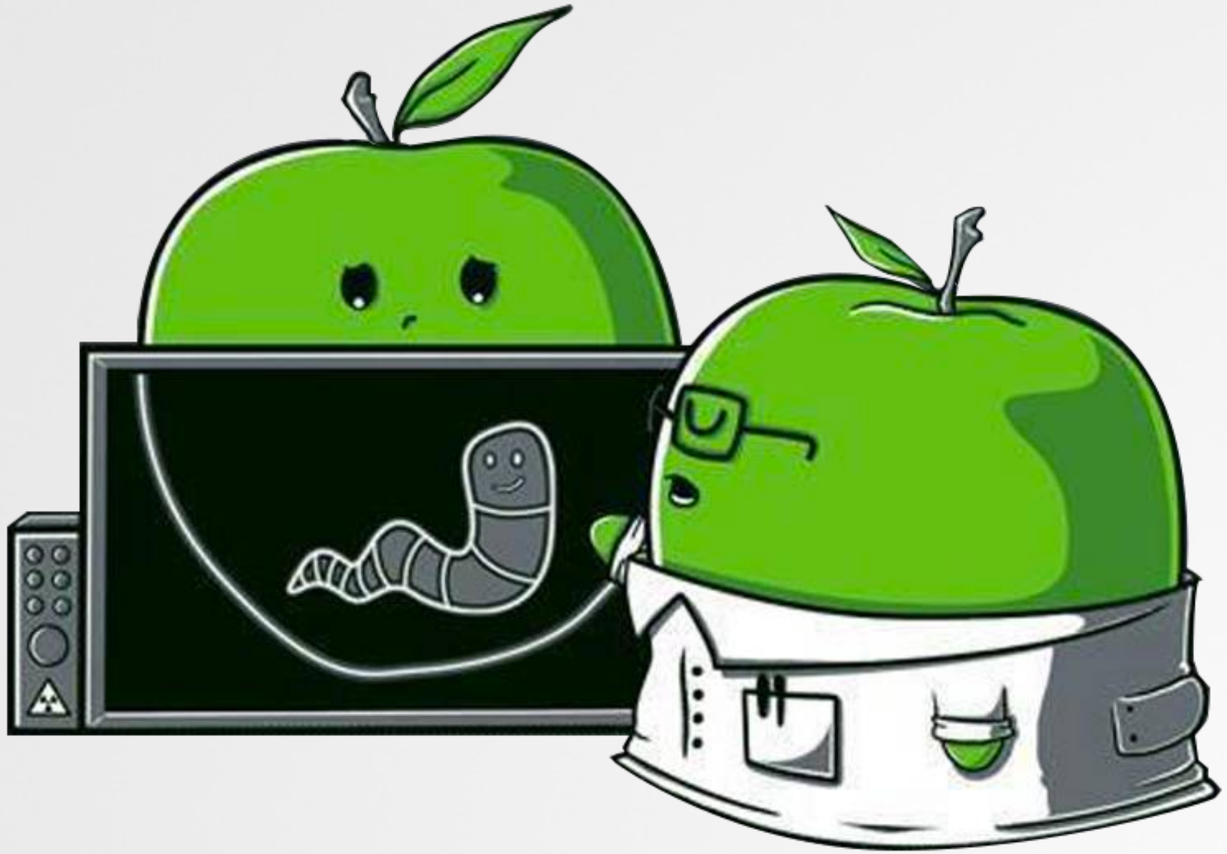
Bypasses

Detection

Dumper

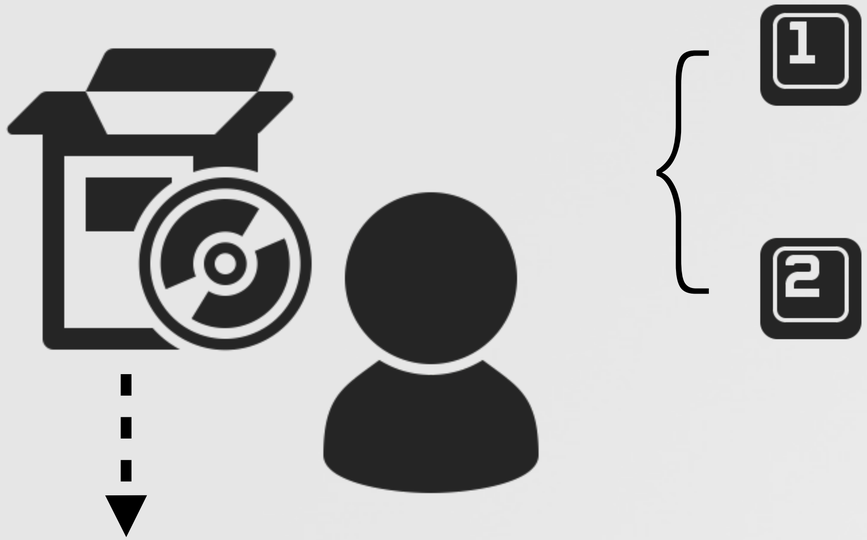
Monitor

Overview



So What is Background Task Management (BTM)?

governance of persistent items ("background tasks")



1

2

Background Items Added
Software from “Zoom Video Communications, Inc.” added items that can run in the background. You can manage this in Login Items Settings.

The installation was successful

You are on the version 5.15.0 (19644). View release notes

Automatically keep Zoom desktop client up to date

Tip: You can change this in "Settings - General"

Done

Search

Patrick Wardle
Apple ID

Wi-Fi
Bluetooth
Network
Notifications
Sound
Focus
Screen Time
General
Appearance
Accessibility

Login Items

Open at Login
These items will open automatically when you log in.

Item	Kind
OverSight	Application

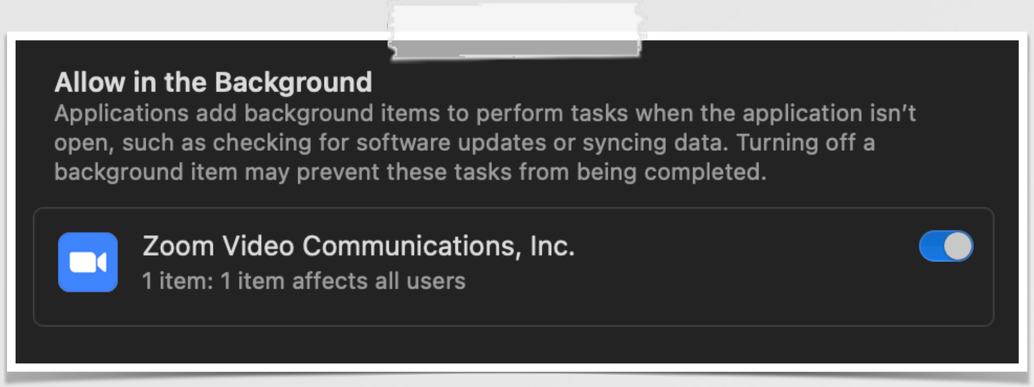
Allow in the Background
Applications add background items to perform tasks when the application isn’t open, such as checking for software updates or syncing data. Turning off a background item may prevent these tasks from being completed.

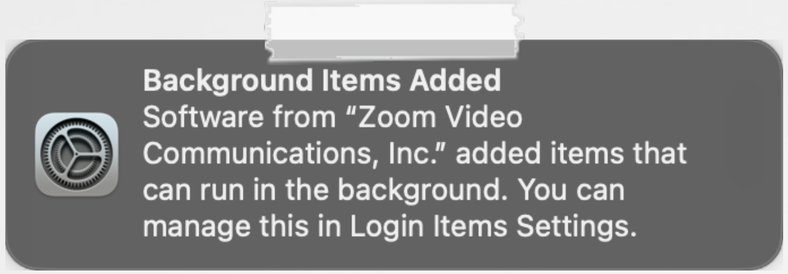
Zoom Video Communications, Inc.
1 item: 1 item affects all users

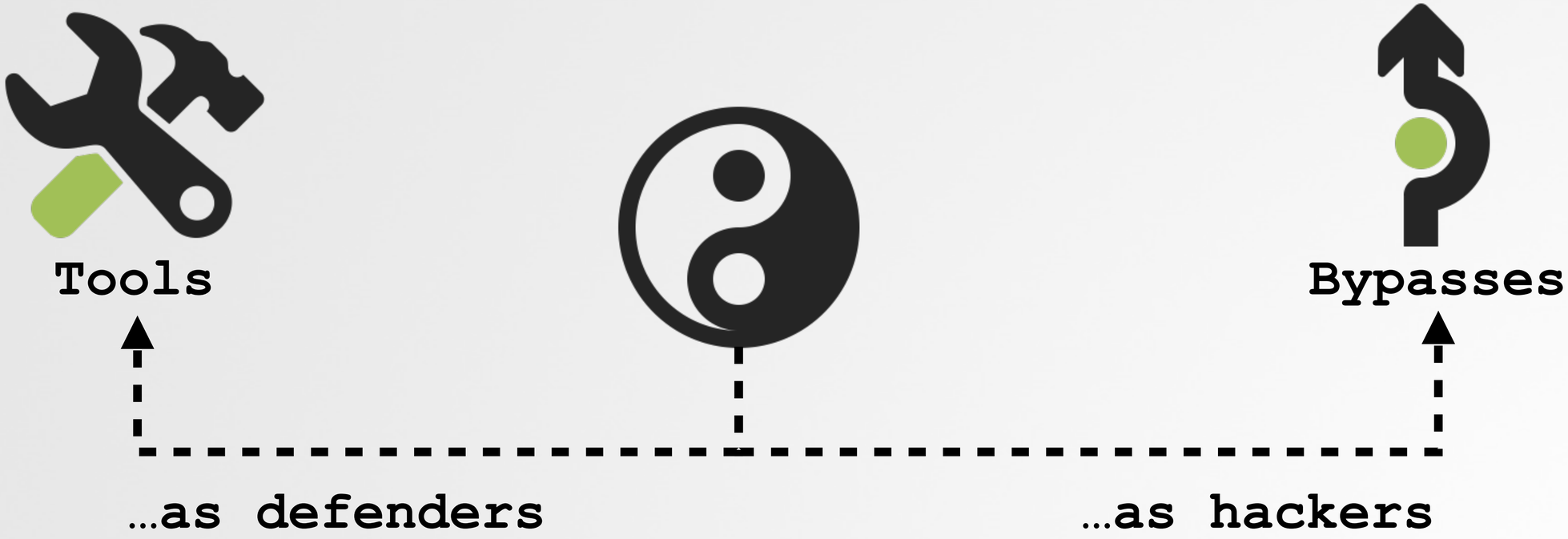
just installed item

Who Cares?

well, we do!



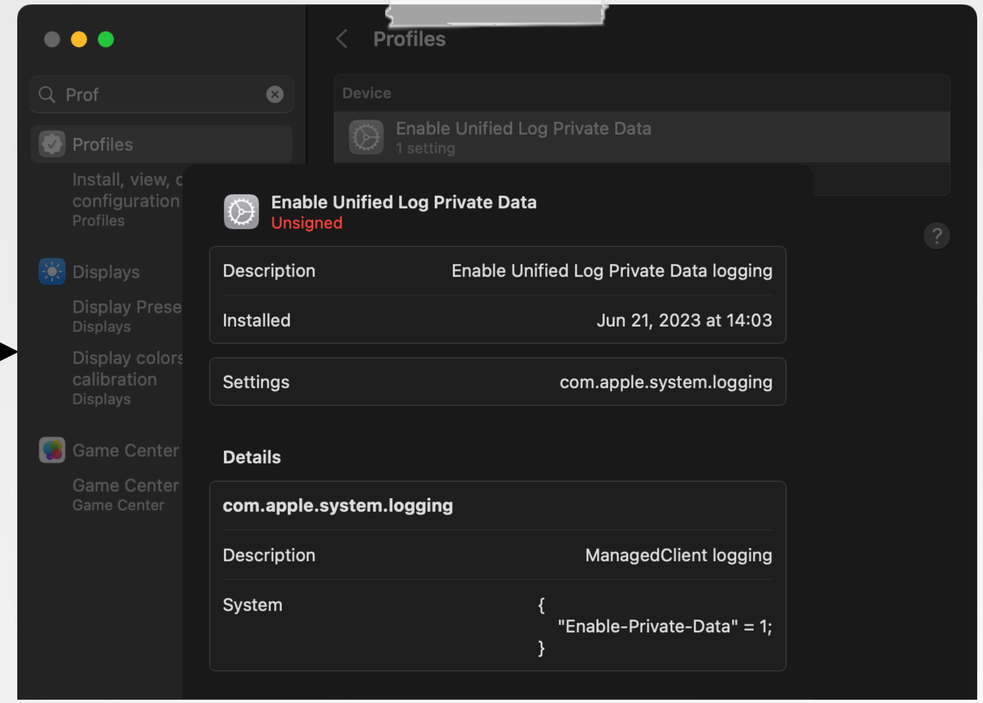




Where to Begin?

...to the logs (after enabling 'private' data)

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE plist PUBLIC "-//Apple//DTD PLIST 1.0//EN" ...>
<plist version="1.0">
<dict>
  <key>PayloadContent</key>
  <array>
    <dict>
      <key>PayloadDisplayName</key>
      <string>ManagedClient logging</string>
      <key>PayloadEnabled</key>
      <true/>
      <key>PayloadIdentifier</key>
      <string>com.apple.logging.ManagedClient.1</string>
      <key>PayloadType</key>
      <string>com.apple.system.logging</string>
      <key>PayloadUUID</key>
      <string>ED5DE307-A5FC-434F-AD88-187677F02222</string>
      <key>PayloadVersion</key>
      <integer>1</integer>
      <key>System</key>
      <dict>
        <key>Enable-Private-Data</key>
        <true/>
      </dict>
    </dict>
  </array>
  …
```



Private Data Logging
(installed profile)

"Unified Logs:
How to Enable Private Data"
(www.cmdsec.com)

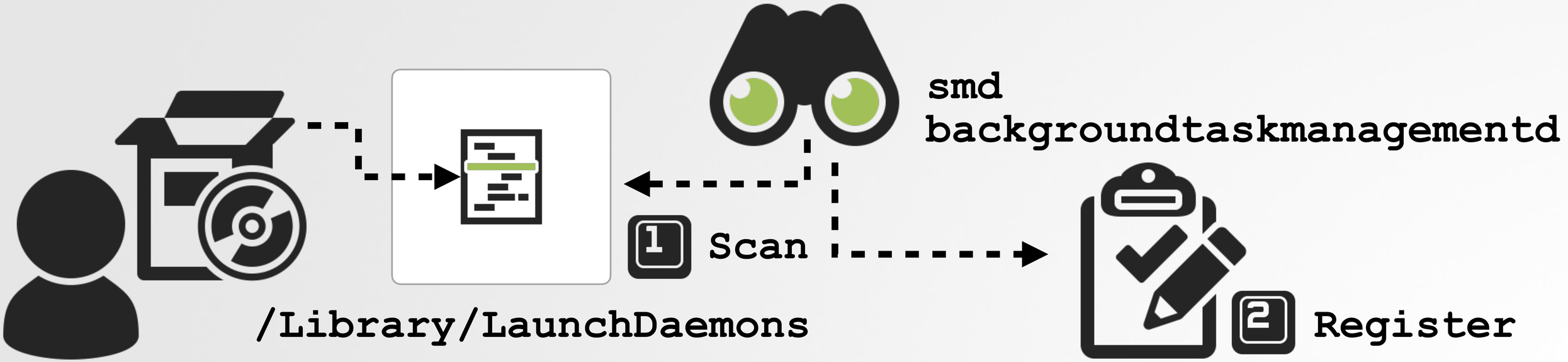
LOGGING

...while installing a launch daemon

```
% log stream --debug --info --predicate

smd: [com.apple.xpc.smd:all] Got a fsevent. Doing re-register
smd: [com.apple.xpc.smd:all] Bootstrapping legacy plists

backgroundtaskmanagementd: -[BTMService launchdWillScanPath:reply:]: /Library/LaunchDaemons

smd: (BackgroundTaskManagement) BTMManager.registerLaunchItemWithBundleURL

backgroundtaskmanagementd: registerLaunchItem: pid=0, uid=0, type=legacy daemon, parentURL=(null),
url=/Library/LaunchDaemons/us.zoom.ZoomDaemon.plist, config=
    BTMConfigArguments =
        "/Library/PrivilegedHelperTools/us.zoom.ZoomDaemon"
```

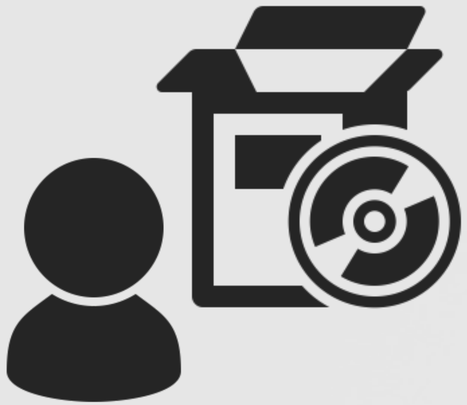
"launchd will scan path"

"register launch item"



System Management Daemon (SMD)

file system event notification, for new item



```
01  sub_100005a28
02  ...
03
04  0x1027c5a64    adr   x3, #0x1027d7243 ; argument "format"
05                                          ("Got a fsevent. Doing re-register")
06  0x1027c5a68    nop
07  0x1027c5a6c    mov   x4, sp    ; argument "buf"
08  0x1027c5a70    mov   x1, x19   ; argument "log"
09  0x1027c5a74    mov   w2, #0x0  ; argument "type"
10  0x1027c5a78    mov   w5, #0x2  ; argument "size"
11  0x1027c5a7c    bl    os_log()
```

log message: "Got a fsevent"

```
Process 300 stopped
smd`___lldb_unnamed_symbol:
->  0x100005a28 <+0>:  pacibsp

(lldb) po $x1
 <OS_xpc_dictionary: dictionary[0x13290d290]: { refcnt = 1, xrefcnt = 1, subtype = 1, count = 1, transport = 0,
 dest port = 0x0, dest msg id = 0x0, transaction = 1, voucher = 0x13290bff0 } <dictionary: 0x13290d290>
 { count = 1, transaction: 1, voucher = 0x13290bff0,
   contents = "XPCEventName" => <string: 0x131f06eb0> { length = 28, contents = "com.apple.xpc.smd.WatchPaths" }
 }>
```

"XPCEventName: com.apple.xpc.smd.WatchPaths"

debugging SMD

System Management Daemon (SMD)

file system event notification, for new item

```
01  <?xml version="1.0" encoding="UTF-8"?>
02  <!DOCTYPE plist PUBLIC "-//Apple//DTD PLIST 1.0//EN" ... >
03  <plist version="1.0">
04  <dict>
05      ...
06      <key>Program</key>
07      <string>/usr/libexec/smd</string>
08
09      <key>LaunchEvents</key>
10      <dict>
11         <key>com.apple.fsevents.matching</key>
12         <dict>
13            <key>com.apple.xpc.smd.WatchPaths</key>
14         <dict>
15         <key>Path</key>
16         <string>/Library/LaunchDaemons/</string>
17      </dict>
18      ...
```

file system watch events:

/Library/LaunchDaemons/

/Library/LaunchDaemons

SMD

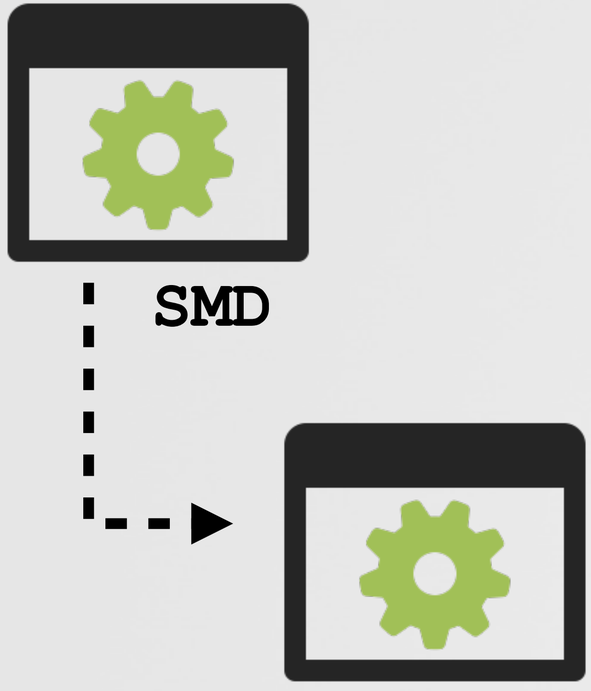
System Management Daemon (SMD)

...and its "remote" interactions

```
01  * @class BTMManager */
02  -(int)launchdWillScanPath:(int)arg2 {
03      x1 = arg1;
04      x2 = [arg2 retain];
05      x0 = [arg0 connection];
06
07      x21 = [x0 synchronousRemoteObjectProxyWithErrorHandler:...];
08      [x21 launchdWillScanPath:x2 reply:...];
```

<NSXPCConnection> connection to service named com.apple.backgroundtaskmanagement

launchdWillScanPath:
(BTM framework, linked into SMD)




```
Process 300 stopped
BackgroundTaskManagement`-[BTMManager launchdWillScanPath:]:

(lldb) po $x0
<__NSXPCInterfaceProxy_V2ServiceInterface: 0x131e0b690>

(lldb) x/s $x1
0x1d4037471: "launchdWillScanPath:reply:"

(lldb) po $x2
/Library/LaunchDaemons
```

"scan path":
/Library/LaunchDaemons

debugging SMD

BTM Daemon, backgroundtaskmanagementd

com.apple.backgroundtaskmanagementd.plist

```
01  <key>Label</key>
02  <string>com.apple.backgroundtaskmanagementd</string>
03
04  <key>MachServices</key>
05  <dict>
06     <key>com.apple.backgroundtaskmanagement</key>
07     <true/>
08     <key>com.apple.backgroundtaskmanagement.sfl</key>
09     <true/>
10     <key>com.apple.backgroundtaskmanagement.responses</key>
11     <true/>
12  </dict>
13
14  <key>RunAtLoad</key>
15  <false/>
16
17  <key>Program</key>
18  <string>/System/Library/PrivateFrameworks/BackgroundTaskManagement.framework/Resources/backgroundtaskmanagementd
19  </string>
20
21  <key>ProgramArguments</key>
22  <array>
23   <string>/System/Library/PrivateFrameworks/BackgroundTaskManagement.framework/Resources/backgroundtaskmanagementd
24   </string>
25   <string>-daemon</string>
26  </array>
```

Mach interfaces
(for entitled clients)

BTM daemon binary

BTM Daemon

```
% ps aux | grep backgroundtaskmanagementd
root  /System/Library/PrivateFrameworks/BackgroundTaskManagement.framework/Resources/backgroundtaskmanagementd -daemon
```

backgroundtaskmanagementd

(/System/Library/PrivateFrameworks/BackgroundTaskManagement.framework)

Entitlements:

```
01  {
02      "com.apple.private.backgroundtaskmanagement.notifications" = 1;
03      "com.apple.private.security.storage.backgroundtaskmanagement" = 1;
04
05      "com.apple.private.endpoint-security.submit.btm" = 1;
06
07      "com.apple.private.tcc.allow" =     (
08          kTCCServiceSystemPolicyAllFiles
09      );
10      ...
11  }
```

BTM specific

Endpoint Security

XPC Messages

...between SMD and BTM daemon

```
# ps aux | grep backgroundtaskmanagementd
root  4643  /System/Library/PrivateFrameworks/BackgroundTaskManagement.framework/Resources/backgroundtaskmanagementd -daemon

# lsmp -p 4643
Process (4643) : backgroundtaskmanagementd
  name       ipc-object    rights      identifier   type
---------    ----------    ------
0x0000310b   0x66b39d3f    send        0x00001807   (300) smd

0x00003b0b   0x677147df    recv        0x0000000000000000
                   +      send        0x000010af   (300) smd
```

XPC messages
...to and from SMD

BTM deamon's XPC messages

```
Process 4643 stopped
-[BTMService launchdWillScanPath:reply:]
->  0x102da9634 <+0>:  pacibsp

(lldb) bt
  * frame #0: 0x0000000102da9634 [BTMService launchdWillScanPath:reply:]
    frame #1: 0x000000018547eca0 Foundation`__NSXPCCONNECTION_IS_CALLING_OUT_TO_EXPORTED_OBJECT_S2__ + 16
    frame #2: 0x0000000185a9e594 Foundation`-[NSXPCConnection _decodeAndInvokeMessageWithEvent:reply:flags:] + 1592
    frame #3: 0x0000000185a9fd88 Foundation`message_handler_message + 88
    frame #4: 0x0000000185a9f7f4 Foundation`message_handler + 152
    frame #5: 0x0000000184163e74 libxpc.dylib`_xpc_connection_call_event_handler + 152
```

call stack w/ XPC functions

call stack (BTM daemon)

Launch Item Registration
via "registerLaunchItemWithAuditToken:"

```
01  -[BTMService registerLaunchItemWithAuditToken:parentURL:type:relativeURL:configuration:uid:reply:]
02  0x102da9a24  adr    x3, #0x102dcf8cc  ; argument "format"
03                                          "registerLaunchItem: pid=%d, uid=%d, ... url=%@, config=%@"
04  0x102da9a28  nop
05  0x102da9a2c  add    x4, sp, #0x20     ; argument "buf"
06  0x102da9a30  mov    x1, x27           ; argument "log"
07  0x102da9a34  mov    w2, #0x0          ; argument "type"
08  0x102da9a38  mov    w5, #0x36         ; argument "size"
09  0x102da9a3c  bl     os_log()
```

registerLaunchItemWithAuditToken:
(BTM daemon)

```
Process 4643 stopped
-[BTMService registerLaunchItemWithAuditToken:parentURL:type:relativeURL:configuration:uid:reply:]
->  0000000102da9898 <+0>:  pacibsp

(lldb) po $x0
<BTMService: 0x129904630>

(lldb) po $x5
file:///Library/LaunchDaemons/us.zoom.ZoomDaemon.plist
```

plist, of launch item to register

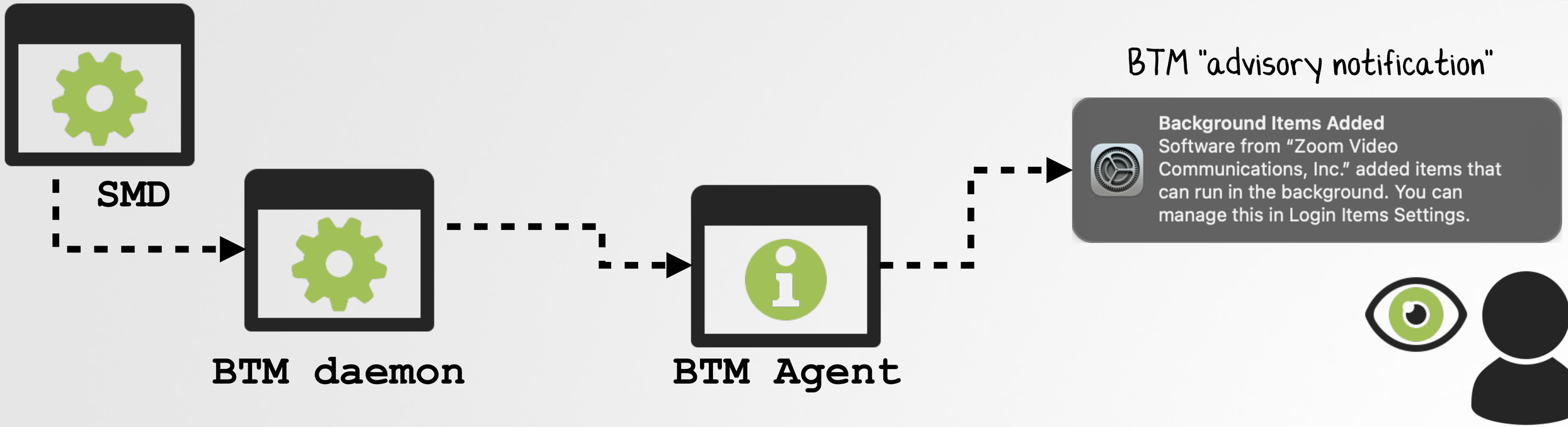
More Logging

BTM daemon & agent: posting "advisory" notification

```
% log stream --debug --info --predicate "subsystem = 'com.apple.backgroundtaskmanagement'"

backgroundtaskmanagementd: [com.apple.backgroundtaskmanagement:main] should post new container advisory=true for uid=501,
id=905C1526-CC7A-4343-9C97-55DED87CC397, item=Zoom Video Communications, Inc.

BackgroundTaskManagementAgent: [com.apple.backgroundtaskmanagement:main] Posting new container advisory notification
request: identifier=905C1526-CC7A-4343-9C97-55DED87CC397, body='Software from "Zoom Video Communications, Inc.…'
```

"should post advisory = true"

"posting new advisory notification"



BTM Agent: BackgroundTaskManagementAgent

com.apple.backgroundtaskmanagement.agent.plist

```
01  <key>Label</key>
02  <string>com.apple.backgroundtaskmanagement.agent</string>
03
04  <key>MachServices</key>
05  <dict>
06    <key>com.apple.backgroundtaskmanagementagent</key>
07    <true/>
08    <key>com.apple.backgroundtaskmanagement.notifications</key>
09    <true/>
10    <key>com.apple.usernotifications.delegate.com.apple.BTMNotificationAgent</key>
11    <true/>
12  </dict>
13
14  <key>RunAtLoad</key>
15  <false/>
16
17  <key>Program</key>
18  <string>/System/Library/PrivateFrameworks/BackgroundTaskManagement.framework/Support/
19  BackgroundTaskManagementAgent.app/Contents/MacOS/BackgroundTaskManagementAgent</string>
```

Mach interfaces (for by entitled clients)

BTM agent binary

BTM agent's property list

Agent : BackgroundTaskManagementAgent

```
% ps aux | grep -i backgroundtaskmanagementagent
patrick  /System/Library/PrivateFrameworks/BackgroundTaskManagement.framework/Support/BackgroundTaskManagementAgent.app/
Contents/MacOS/BackgroundTaskManagementAgent
```

BackgroundTaskManagementAgent

(/System/Library/PrivateFrameworks/BackgroundTaskManagement.framework/Support/BackgroundTaskManagementAgent.app/)

Entitlements:

```
01  {
02    "com.apple.private.backgroundtaskmanagement.manage" = 1;
03    "com.apple.private.backgroundtaskmanagement.responses" = 1;
04    "com.apple.private.coreservices.canaccessanysharedfilelist" = "read-write";
05
06    "com.apple.private.tcc.allow" =     (
07       kTCCServiceSystemPolicyAllFiles
08    );
09
10    "com.apple.private.usernotifications.bundle-identifiers" =     (
11       "com.apple.BTMNotificationAgent"
12    );
13  }
```

BTM specific

Notifications

Should Post New Container Advisory?

...interactions between SMD & BTM daemon

invoked by: -[DaemonNotificationManager postAdvisoryNotificationForContainer:uid:]

```
01  bl   [DaemonNotificationManager shouldNotifyUpdatingItem:...]
02  mov  x20, x0
03
04  cbz  w20, noNeedToPostNotification
05
06  rax = [rdi synchronousProxyForUID:...]
07  [rax postAdvisoryForContainer:rax reply:&var_B0]
08
09  rax = [NSDictionary dictionaryWithObjects:&var_68 forKeys:&var_70 count:0x1]
10  AnalyticsSendEvent(@"com.apple.BackgroundTaskManager.Notification", [rax retain])
11
12  noNeedToPostNotification:
13  ret
```

if true:
show notification
(via XPC message to BTM agent

"shouldNotifyUpdatingItem:" method check:

- If item is managed (MDM)
- Was allowed / was already notified
- "AlwaysPostNotifications" preference

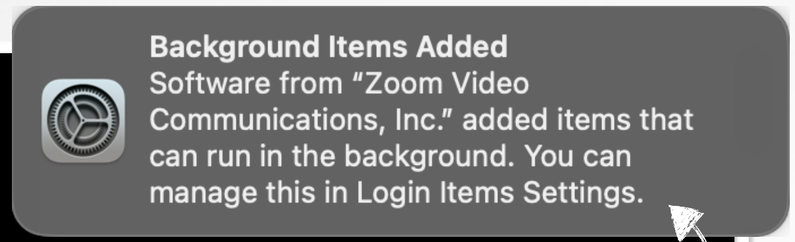
Should Post New Container Advisory?

...interactions between SMD & BTM daemon

in BTM Agent,
(invoked by BTM Daemon, via XPC)

```
01  /* @class NotificationManager */
02  -(void)postAdvisoryForContainer:(BTMItem*)item reply:(void *)arg3 {
03
04  content = [NotificationManager
05  copyAdvisoryContentWithBodyKey:@"NOTIFICATION_BODY_BACKGROUND_ITEM_ADVISORY" name:name];
06
07  notification = [UNNotificationRequest requestWithIdentifier:id content:content trigger:0x0];
08
09  notificationCenter = [NotificationManager notificationCenter];
10  [notificationCenter addNotificationRequest:notification withCompletionHandler:...];
```

```
% ps aux | grep BackgroundTaskManagementAgent
patrick   88262  /System/Library/PrivateFrameworks/BackgroundTaskManagement.framework
/Support/BackgroundTaskManagementAgent.app/Contents/MacOS/BackgroundTaskManagementAgent

(lldb) process attach --pid 88262

Target 0: (BackgroundTaskManagementAgent) stopped.
(lldb) po $x0
<UNMutableNotificationContent: 0x12684df10; title: Background Items Added, subtitle: (null), body: Software from "Zoom
Video Communications" added items that can run in the background. You can manage this in Login Items Settings.,
summaryArgument: , summaryArgumentCount: 0, categoryIdentifier: com.apple.BackgroundTaskManagement.advisory,
launchImageName: , threadIdentifier: , attachments: (
), badge: (null), sound: (null), realert: 0, interruptionLevel: 1, relevanceScore: 0.00, filterCriteria: (null)
```



notification (+content)

More Logging

BTM daemon, saving "BackgroundItems-v8.btm"

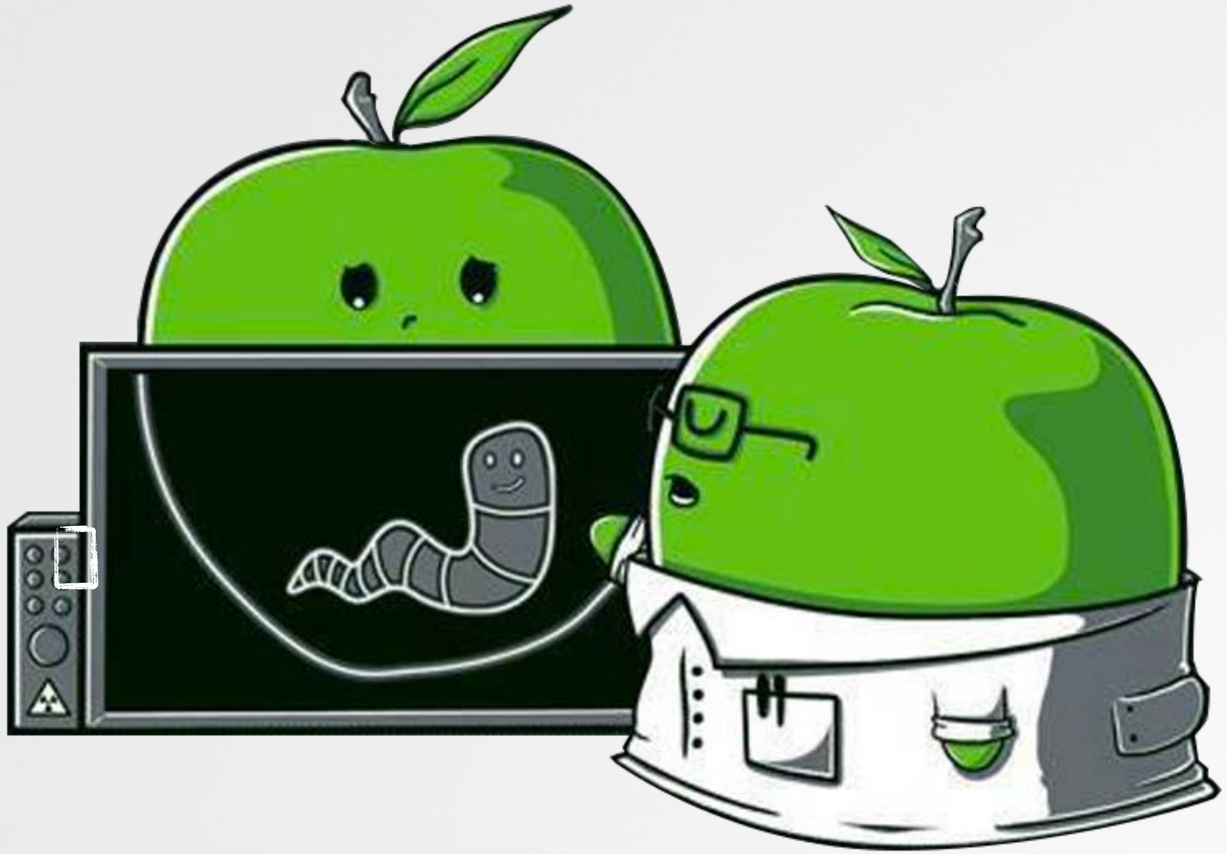
```
% log stream --debug --info --predicate "subsystem = 'com.apple.backgroundtaskmanagement'"

backgroundtaskmanagementd: [com.apple.backgroundtaskmanagement:main] BTMStore:
 store saved to /var/db/com.apple.backgroundtaskmanagement/BackgroundItems-v8.btm
```

```
# FileMonitor.app/Contents/MacOS/FileMonitor -pretty
{
  "event" : "ES_EVENT_TYPE_NOTIFY_CLOSE",
  "file" : {
    "destination" : "/private/var/db/
                     com.apple.backgroundtaskmanagement/BackgroundItems-v8.btm",
    "process" : {
      "name" : "backgroundtaskmanagementd",
      "path" : "/System/Library/PrivateFrameworks/
                BackgroundTaskManagement.framework/Versions/A/Resources/backgroundtaskmanagementd",
    }
...
```

BackgroundItems-v8.btm

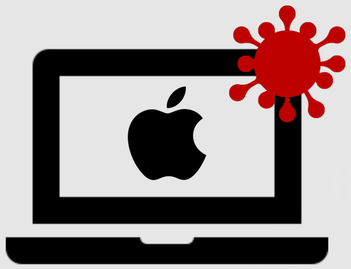
Tools (Part I)

leveraging BTM to detect persistent malware



Mac Malware

...the vast majority persists!



The Mac Malware of 2022 👾

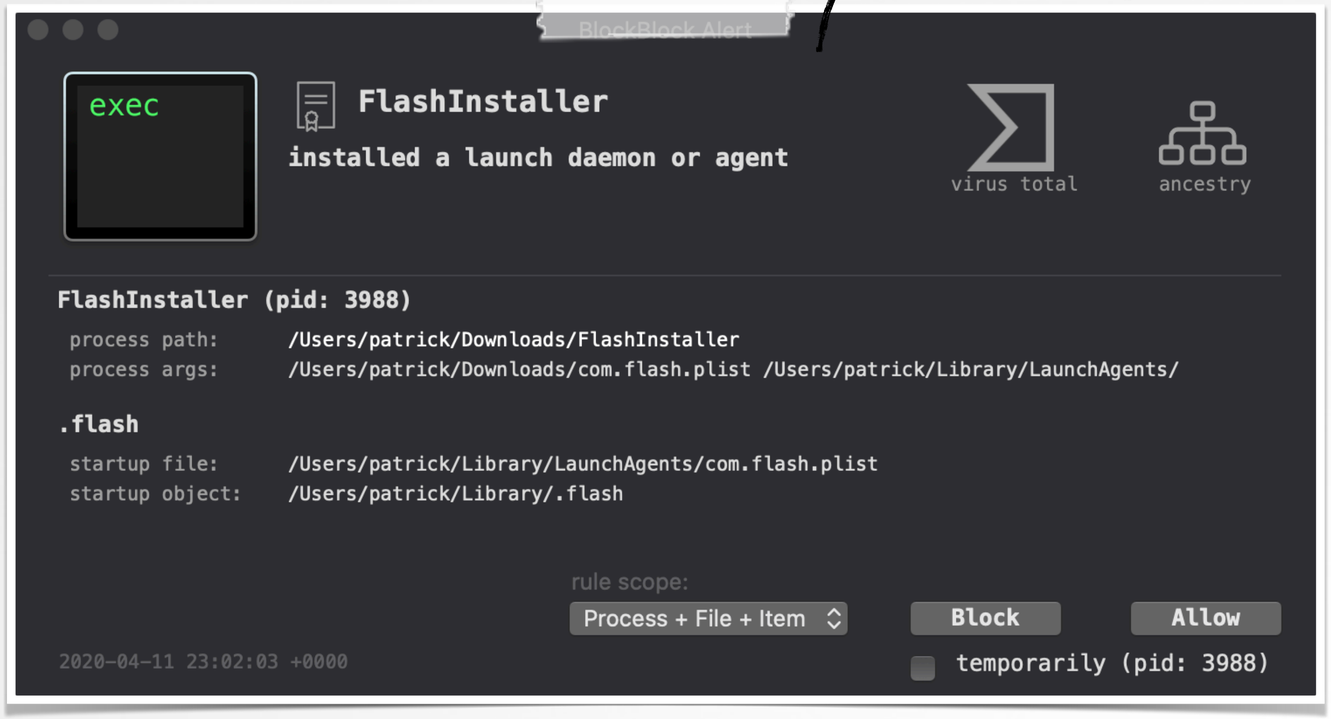
A comprehensive analysis of the year's new malware

by: Patrick Wardle / January 1, 2023

2022: ~80% persisted
(all as launch items)

2021: ~90% persisted
(all as launch items)

alert user when something persists !



BlockBlock (since 2015)

EXAMPLE: DAZZLESPY

…deployed via Safari 0days!

```
% strings - DazzleSpy/softwareupdate
...
%@/Library/LaunchAgents
/com.apple.softwareupdate.plist

launchctl unload %@
RunAtLoad
```

Embedded strings

```
# FileMonitor.app/Contents/MacOS/FileMonitor -pretty
...
{
  "event" : "ES_EVENT_TYPE_NOTIFY_CREATE",
  "file" : {
    "destination" : "~/Library/LaunchAgents/
com.apple.softwareupdate.plist",

    "process" : {
       "pid" : 1469
       "name": softwareupdate
       "path" : "/Users/user/Desktop/softwareupdate",
    }
  }
}
```

Launch agent persistence

(~/Library/LaunchAgents/com.apple.softwareupdate.plist)

DUMPING THE BTM DATABASE

…to enumerate persistently installed software

and malware!

```
# sfltool
Usage: sfltool csinfo|dumpbtm|archive|clear|
resetbtm|resetlist|list|list-info [options]
```

```
# sfltool dumpbtm
…
                  UUID: EAE1D8DC-2928-47C1-BC53-6274590FE3D1
                  Name: us.zoom.ZoomDaemon
        Developer Name: Zoom Video Communications, Inc.
       Team Identifier: BJ4HAAB9B3
                  Type: legacy daemon (0x10010)
           Disposition: [enabled, allowed, visible, notified] (11)
            Identifier: us.zoom.ZoomDaemon
                   URL: file:///Library/LaunchDaemons/us.zoom.ZoomDaemon.plist
       Executable Path: /Library/PrivilegedHelperTools/us.zoom.ZoomDaemon
            Generation: 1
     Parent Identifier: Zoom Video Communications, Inc.
```

`sfltool dumpbtm`

DUMPING THE BTM DATABASE

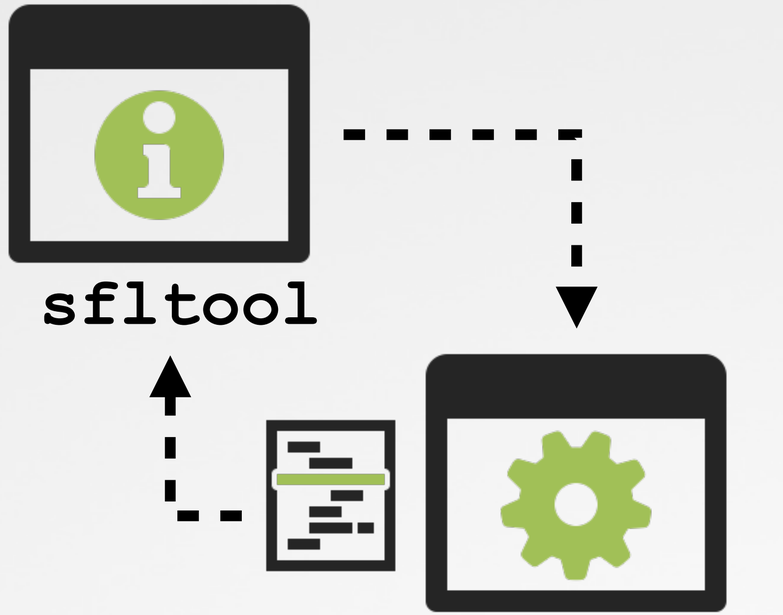
…to enumerate persistently installed software

and malware!

```
01  /* @class DumpBTMCommand */
02  -(int)run {
03      ...
04      rax = [BTMManager shared];
05      r12 = [rax dumpDatabaseWithAuthorization:r14 error:&var_28];
06      if(r12 != 0x0) {
07          r12 = [objc_retainAutorelease(r12) UTF8String];
08          puts(r12);
09      }
10      else {
11          NSLog(@"Error fetching the database dump: %@", r15);
12      }
```

sfltool decompilation

`[DumpBTMCommand run];`




```
% log stream …
```

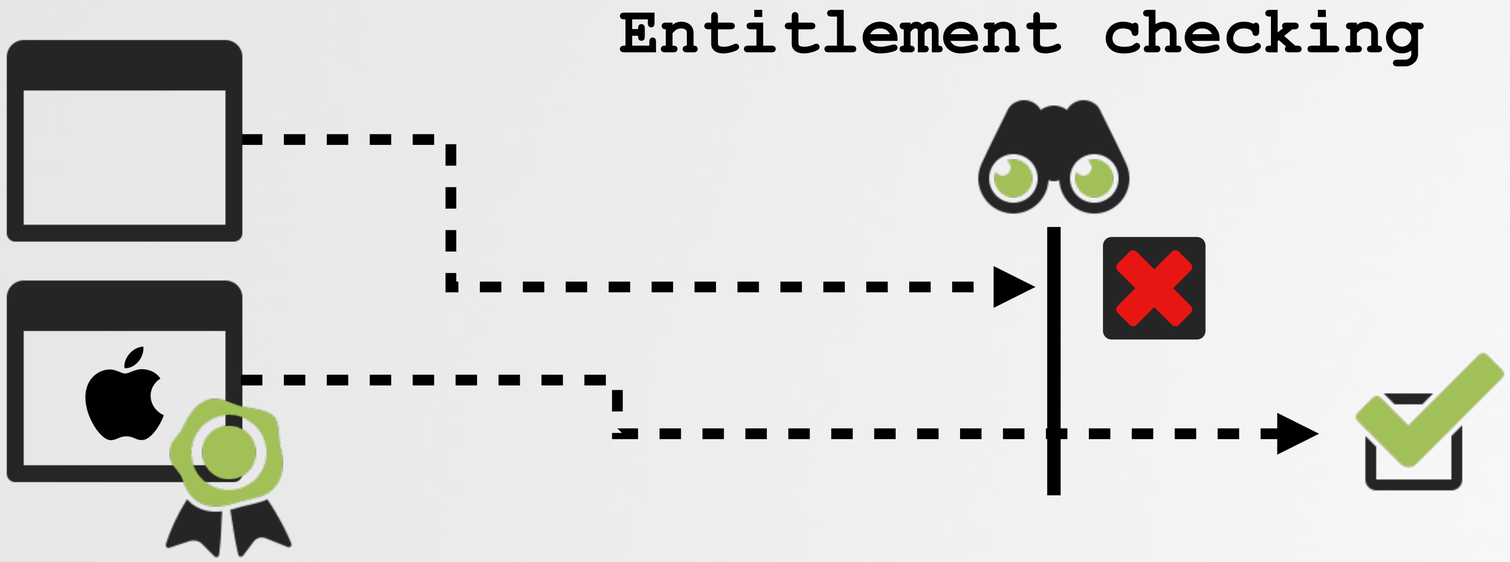
mach connection (from sfltool) to: com.apple.backgroundtaskmanagement"

```
backgroundtaskmanagementd: -[BTMService listener:shouldAcceptNewConnection:]:
connection=<NSXPCConnection: 0x152307aa0> connection from pid 52886 on mach service named
com.apple.backgroundtaskmanagement

backgroundtaskmanagementd: dumpDatabaseWithAuthorization: "noErr: Call succeeded with no error"
```

Dumping the BTM Database

…entitlement check(s)

```
01  /* @class BTMService */
02  -(BOOL) listener: (NSXPCListener *)listener shouldAcceptNewConnection:(NSXPCConnection *)newConnection {
03  …
04
05  rax = [r15 valueForEntitlement:@"com.apple.private.backgroundtaskmanagement.manage"];
06  if(rax == 0x0) {
07      rax = [r15 valueForEntitlement:@"com.apple.private.coreservices.canmanagebackgroundtasks"];
08  }
09
10  if(objc_opt_isKindOfClass(rax, objc_opt_class(@class(NSNumber))) == 0x0 || [rax boolValue] == 0x0) {
11
12      //leave, don't accept connection
13  }
```



Programmatically Dumping the BTM Database

mimicking: DumpBTMCommand run

```
01  @interface BTMManager : NSObject
02
03  +(id)shared;
04  -(id)dumpDatabaseWithAuthorization:(SFAuthorization*)arg1 error:(id*)arg2;
05
06  @end
07
08  void *handle = dlopen("/System/Library/PrivateFrameworks/BackgroundTaskManagement.framework/Versions/
09  A/BackgroundTaskManagement", RTLD_LAZY);
10
11  Class BTMManager = NSClassFromString(@"BTMManager");
12  id sharedInstance = [BTMManager shared];
13
14  SFAuthorization *authorization = [SFAuthorization authorization];
15  [authorization obtainWithRight:"system.privilege.admin", ...];
16
17  id dbContents = [sharedInstance dumpDatabaseWithAuthorization:authorization error:NULL];
```

```
% log stream …
```

GTFO …you're not entitled

```
backgroundtaskmanagementd: -[BTMService listener:shouldAcceptNewConnection:]: process with pid=20987
lacks entitlement 'com.apple.private.coreservices.canmanagebackgroundtasks'
```

fail :

What about the (Raw) BTM Database

…a binary plist, containing serialized objects

```
% file /var/db/com.apple.backgroundtaskmanagement/BackgroundItems-v8.btm

Apple binary property list

% plutil -p /var/db/com.apple.backgroundtaskmanagement/BackgroundItems-v8.btm
{
  "$archiver" => "NSKeyedArchiver"
  "$objects" => [
    0 => "$null"
    1 => {
      "$class" => <CFKeyedArchiverUID 0x600003e57640 [0x1e69087f8]>{value = 142}
      "itemsByUserIdentifier" => <CFKeyedArchiverUID 0x600003e57660 [0x1e69087f8]>{value = 2}
      "mdmPaloadsByIdentifier" => <CFKeyedArchiverUID 0x600003e57680 [0x1e69087f8]>{value = 140}
      "userSettingsByUserIdentifier" => <CFKeyedArchiverUID 0x600003e576a0 [0x1e69087f8]>{value = 134}
   ...
```

BTM database (contains NSKeyedArchiver)

Serialization, saves objects to a persistent archive (e.g. BTM database)

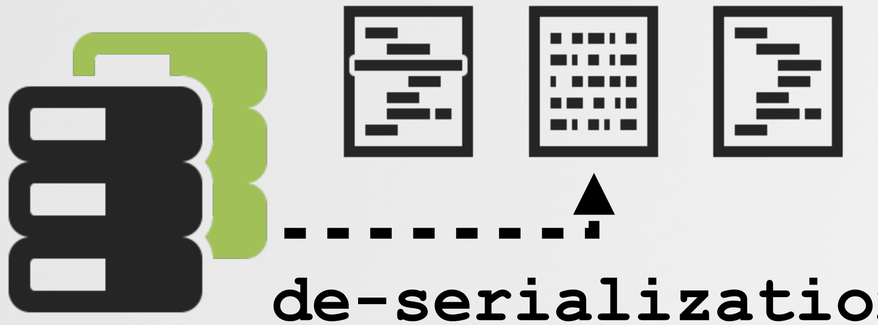
sftool's Item De-serialization

…implemented in an initWithCoder: method

```
01  /* @class ItemRecord */
02  -(void *)initWithCoder:(NSCoder *)decoder {
03
04      rax = objc_opt_class(@class(NSUUID));
05      rax = [r14 decodeObjectOfClass:rax forKey:@"uuid"];
06
07      rax = objc_opt_class(@class(NSString));
08      rax = [r14 decodeObjectOfClass:rax forKey:@"executablePath"];
09
10      rax = objc_opt_class(@class(NSString));
11      rax = [r14 decodeObjectOfClass:rax forKey:@"teamIdentifier"];
12
13      …
```

method automatically invoked to de-serialize stored objects

BTM Daemon
[ItemRecord initWithCoder];



de-serialization

ItemRecord

Tag Scope

Idx	Name
173	-[ItemRecord uuid]
174	-[ItemRecord setUuid:]
175	-[ItemRecord identifier]
176	-[ItemRecord setIdentifier:]
177	-[ItemRecord disposition]
178	-[ItemRecord setDisposition:]
179	-[ItemRecord generation]
180	-[ItemRecord setGeneration:]
181	-[ItemRecord url]
182	-[ItemRecord setUrl:]
183	-[ItemRecord modificationDate]
184	-[ItemRecord setModificationDate:]
185	-[ItemRecord executablePath]
186	-[ItemRecord setExecutablePath:]
187	-[ItemRecord executableModificationDate]
188	-[ItemRecord setExecutableModificationDate:]
189	-[ItemRecord teamIdentifier]
190	-[ItemRecord setTeamIdentifier:]

'ItemRecord' properties

Item De-serialization

…reimplemented in our own code

```
01  @interface ItemRecord : NSObject <NSSecureCoding>
02  @property NSInteger type;
03  @property(nonatomic, retain)NSURL* url;
04  @property(nonatomic, retain)NSUUID* uuid;
05  …
06  @property(nonatomic, retain)NSString* executablePath;
07  @property(nonatomic, retain)NSString* teamIdentifier;
08  @property(nonatomic, retain)NSString* bundleIdentifier;
09
10  @end
11
12  -(id)initWithCoder:(NSCoder *)decoder
13  {
14      ...
15      self.url = [decoder decodeObjectOfClass:[NSURL class] forKey:@"url"];
16      self.uuid = [decoder decodeObjectOfClass:[NSUUID class] forKey:@"uuid"];
17      self.executablePath = [decoder decodeObjectOfClass:[NSString class] forKey:@"executablePath"];
18      self.teamIdentifier = [decoder decodeObjectOfClass:[NSString class] forKey:@"teamIdentifier"];
19      self.bundleIdentifier = [decoder decodeObjectOfClass:[NSString class] forKey:@"bundleIdentifier"];
20      ...
```

ItemRecord deserialization
(custom initWithCoder: method)

Programmatically Dumping the BTM Database

…reimplemented in our own code

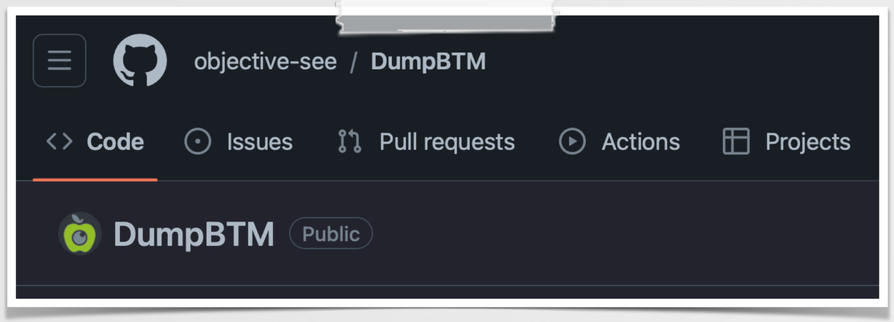
```
01  //load
02  // path set to BTM database
03  NSData* data = [NSData dataWithContentsOfURL:path options:0 error:NULL];
04
05  //init keyed unarchiver with database data
06  NSKeyedUnarchiver* keyedUnarchiver = [[NSKeyedUnarchiver alloc] initForReadingFromData:data error:NULL];
07
08  //de-serialize
09  // will trigger call to "initWithCoder:" and de-serialize all objects
10  Storage* storage = [keyedUnarchiver decodeObjectOfClass:[Storage class] forKey:@"store"];
11
12  //print out all items
13  for(NSString* key in storage.items) {
14
15      NSArray* items = storage.items[key];
16
17      for(ItemRecord* item in items){
18          printf(" #%d\n", ++itemNumber);
19          printf(" %s\n", [[item dumpVerboseDescription] UTF8String]);
20
21      }
22  }
```

Programmatically Dumping the BTM Database

…reimplemented in our own code

link in the 'dump btm' library


```
01  #include "dumpBTM.h"
02
03  int main(int argc, const char * argv[]) {
04
05      //set if you want
06      // a custom btm file
07      NSURL* btmPath = nil;
08
09      //dump stdout
10      // (aka sfltool dumpbtm)
11      dumpBTM(btmPath);
12
13      //or parse into a dictionary...
14      NSDictionary* contents = parseBTM(path);
15      ...
16
```



github.com/objective-see/DumpBTM

DUMPBTM OUTPUT

...no root access required

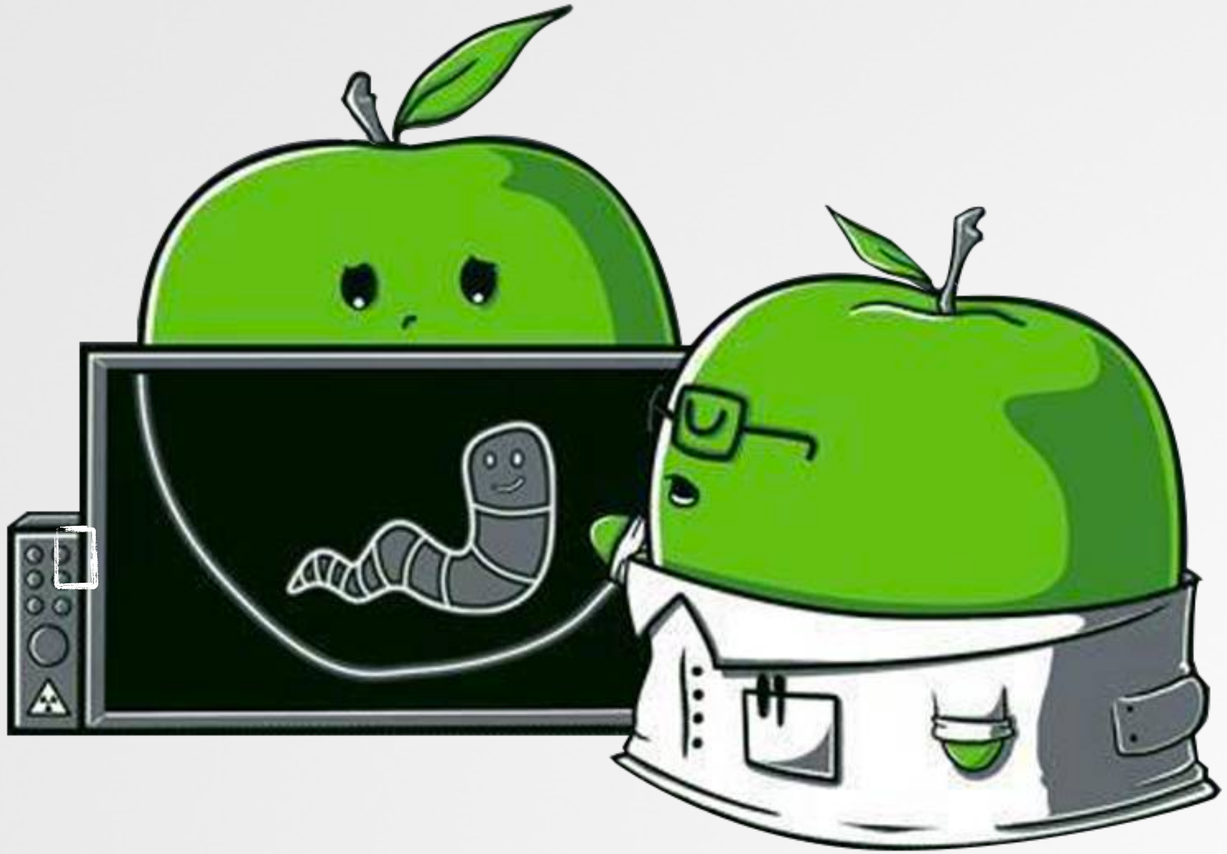
```
% ./dumpBTM
Opened /private/var/db/com.apple.backgroundtaskmanagement/BackgroundItems-v8.btm

=========================
 Records for UID 0 : FFFFEEEE-DDDD-CCCC-BBBB-AAAA00000000
=========================

...
 UUID:                EAE1D8DC-2928-47C1-BC53-6274590FE3D1
  Name:                us.zoom.ZoomDaemon
  Developer Name:      Zoom Video Communications, Inc.
  Team Identifier:     BJ4HAAB9B3
  Type:                legacy daemon  (0x10010)
  Disposition:         [enabled allowed visible notified] (11)
  Indentifier:         us.zoom.ZoomDaemon
  URL:                 file:///Library/LaunchDaemons/us.zoom.ZoomDaemon.plist
  Executable Path:     /Library/PrivilegedHelperTools/us.zoom.ZoomDaemon
  Generation:          2
  Assoc. Bundle IDs:   [us.zoom.xos]
  Parent Identifier:   Zoom Video Communications, Inc.
```

our "Dump BTM" output

KnockKnock

Tools (Part II)

leveraging BTM to detect persistent malware



BTM Daemon's References to "Endpoint Security"

```
% strings - backgroundtaskmanagementd | grep ES

submitItemAddToES: No URL provided, cannot submit event to EndpointSecurity
submitItemAddToES: Invalid BTMItemType, cannot submit event to EndpointSecurity
```

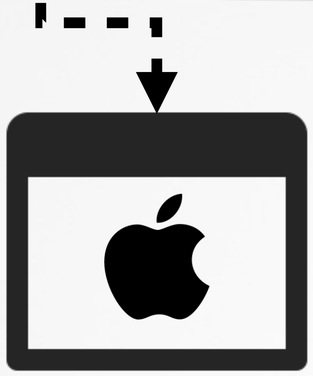
References to 0x100007b84

Search

Address	Value	
0x10000383b (-[SFLClientProcess addURL:managed:reply:] + 0x677)	call	submitItemAddToES
0x1000038ac (-[SFLClientProcess addURL:managed:reply:] + 0x6e8)	call	submitItemAddToES
0x100005053 (-[BTMService registerLaunchItemWithAuditToken:parentURL:type:relativeUR...	call	submitItemAddToES
0x100005084 (-[BTMService registerLaunchItemWithAuditToken:parentURL:type:relativeUR...	call	submitItemAddToES
0x10000519c (-[BTMService registerLaunchItemWithAuditToken:parentURL:type:relativeUR...	call	submitItemAddToES
0x1000051cc (-[BTMService registerLaunchItemWithAuditToken:parentURL:type:relativeUR...	call	submitItemAdd
0x1000065dd (-[BTMService addItem:uid:reply:] + 0x1ef)	call	submitItemAdd
0x100006611 (-[BTMService addItem:uid:reply:] + 0x223)	call	submitItemAdd

Cancel

```
01  submitItemAddToES:
02   ...
03
04   bl          ess_notify_btm_launch_item_add
```



"ess_notify_btm_launch_item_add" Google

Your search - **"ess_notify_btm_launch_item_add"** - did not match any documents.

very undocumented :/

implemented in:

libEndpointSecuritySystem.dylib

Endpoint Security

ES_EVENT_TYPE_NOTIFY_BTM_LAUNCH_ITEM_ADD event

```
01  /* The valid event types recognized by EndpointSecurity */
02  typedef enum {
03  ...
04
05  // The following events are available beginning in macOS 13.0
06  ...
07     ES_EVENT_TYPE_NOTIFY_BTM_LAUNCH_ITEM_ADD,
08     ES_EVENT_TYPE_NOTIFY_BTM_LAUNCH_ITEM_REMOVE
```

REGISTERING FOR ES EVENTS

ES_EVENT_TYPE_NOTIFY_BTM_LAUNCH_ITEM_ADD event

```
01  //client/event of interest
02  es_client_t* esClient = NULL;
03  es_event_type_t events[] = {ES_EVENT_TYPE_NOTIFY_BTM_LAUNCH_ITEM_ADD};   1
04
05  //new client
06  //callback will process 'ES_EVENT_TYPE_NOTIFY_BTM_LAUNCH_ITEM_ADD' events
07  es_new_client(&esClient, ^(es_client_t *client, const es_message_t *message)
08  {
09     //TODO: handle event
10  }                                                                          2  callback for BTM events
11
12  //subscribe
13  es_subscribe(endpointProcessClient, events, sizeof(events)/sizeof(events[0])));   3
14
```

ES BTM Monitor
(ES_EVENT_TYPE_NOTIFY_BTM_LAUNCH_ITEM_ADD)

1. Specify events of interest
2. Create callback for events
3. Subscribe for events

HANDLING ES NOTIFICATIONS

ES_EVENT_TYPE_NOTIFY_BTM_LAUNCH_ITEM_ADD event

```
01  typedef struct {
02    es_process_t * instigator;
03    es_process_t * app;
04    es_btm_launch_item_t * item;
05    es_string_token_t executable_path;
06  } es_event_btm_launch_item_add_t;
```

es_event_btm_launch_item_add_t

our helper function

```
01  NSString* toString(es_string_token_t* token) {
02
03        return [[NSString alloc]
04                   initWithBytes:token->data
05                   length:token->length
06                   encoding:NSUTF8StringEncoding];
07  }
```

```
01  //new client
02  // callback will process 'ES_EVENT_TYPE_NOTIFY_BTM_LAUNCH_ITEM_ADD' events
03  es_new_client(&esClient, ^(es_client_t *client, const es_message_t *message) {
04
05     NSLog(@"Item URL: %@", toString(&message->event.btm_launch_item_add->item->item_url);
06     NSLog(@"Item Executable: %@", toString(event btm_launch_item_add->executable_path);
07
08     es_process_t* app = message->event.btm_launch_item_add->app;
09     if(NULL != app) NSLog(@"App: %@", toString(&app->executable->path));
10
11     es_process_t* instigator = message->event.btm_launch_item_add->instigator;
12     if(NULL != instigator) NSLog(@"Instigator: %@", toString(&instigator->executable->path));
13     ...
```

Handler for ES_EVENT_TYPE_NOTIFY_BTM_LAUNCH_ITEM_ADD

It (was) Broken

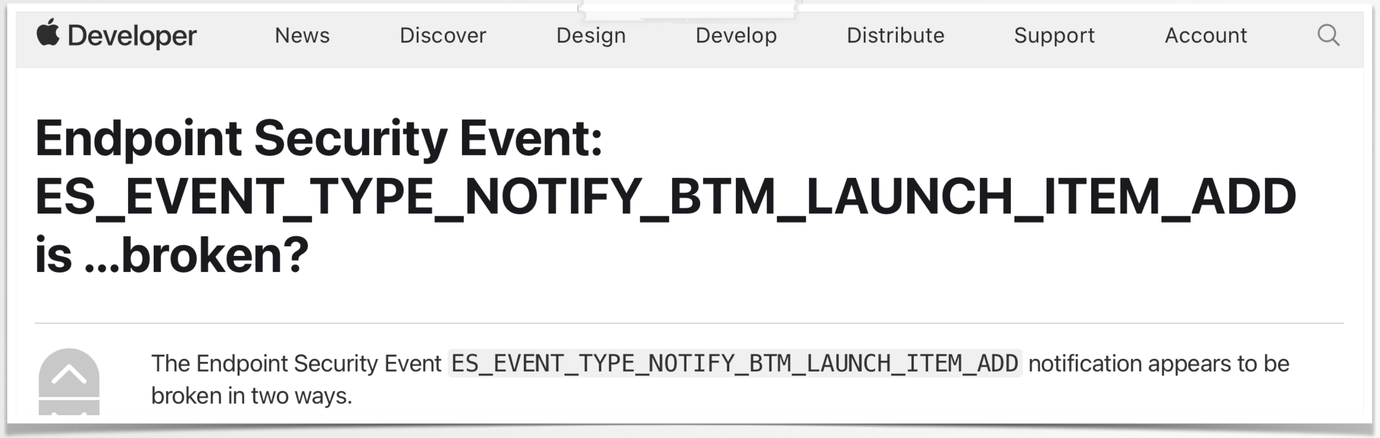
...in two separate ways 🤦

1️⃣ **ES_BTM_ITEM_TYPE_AGENT / ES_BTM_ITEM_TYPE_DAEMON:**

When a new item installed, it would deliver a notification for *every* installed item.

2️⃣ **ES_BTM_ITEM_TYPE_LOGIN_ITEM:**

When a new was item installed, no notification would be delivered.



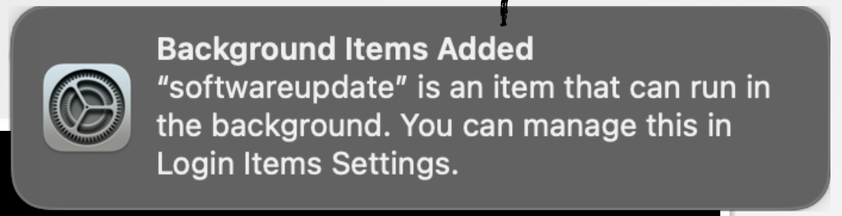
(my) bug report

...fixed in macOS 13.3

Hooray, Persistent Malware Detection

...via ES_EVENT_TYPE_NOTIFY_BTM_LAUNCH_ITEM_REMOVE

system alert



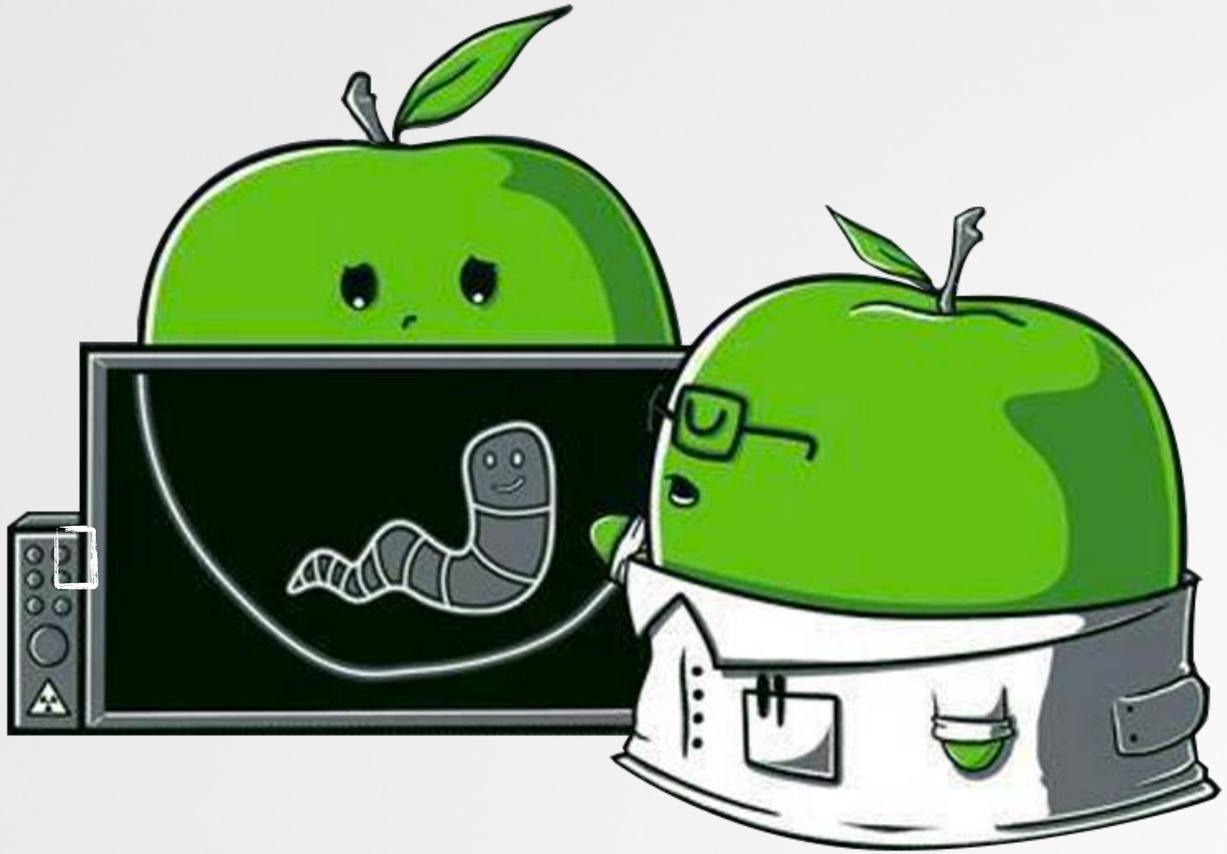

```
# ./btm_monitor
New Event: 'ES_EVENT_TYPE_NOTIFY_BTM_LAUNCH_ITEM_ADD'

Type: ES_BTM_ITEM_TYPE_AGENT

Instigator: /usr/libexec/smd

Agent exe: /Users/User/.local/softwareupdate
Agent url: /Users/User/Library/LaunchAgents/com.apple.softwareupdate.plist
```

Persistence detection
(OSX.DazzleSpy)

Note: No delivery of BTM removal events
(ES_EVENT_TYPE_NOTIFY_BTM_LAUNCH_ITEM_REMOVE) ...broken!

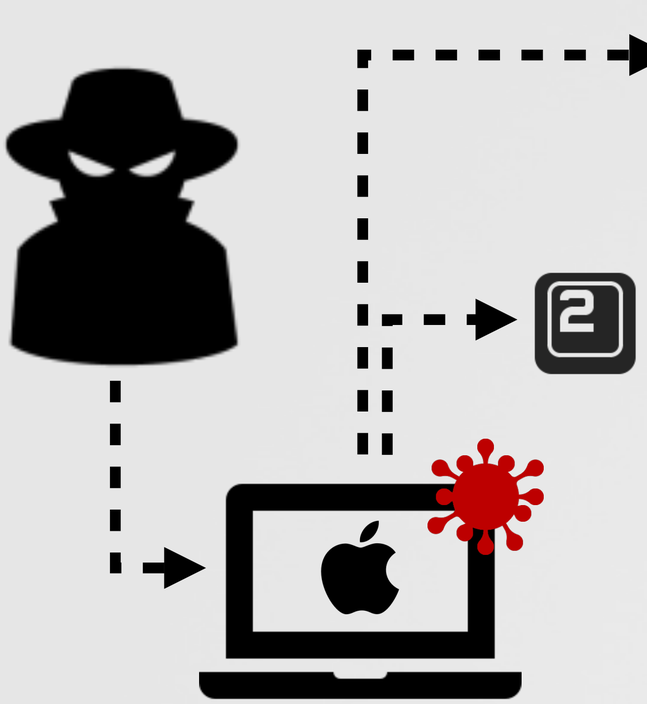
Breaking

...avoiding BTM alerts & ES messages



Hackers Hate Alerts & Messages

...that can give away the attack!



1

Background Items Added
"softwareupdate" is an item that can run in the background. You can manage this in Login Items Settings.

2

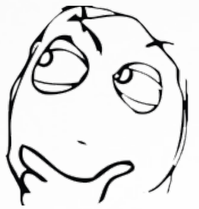
```
# ./btm_monitor
New Event: 'ES_EVENT_TYPE_NOTIFY_BTM_LAUNCH_ITEM_ADD'

Type: ES_BTM_ITEM_TYPE_AGENT
Agent exe: /Users/User/.local/softwareupdate
Agent url: /Users/User/Library/LaunchAgents/com.apple.softwareupdate.plist
```

OMG, i've been hacked!!

Can we (as hackers) prevent:

A: The system notification?

B: The Endpoint Security event?



Persist "Outside" BTM

...avoid it all together!

```
01  def format(self, src, des, uc):
02    ...
03    if not os.path.isfile(des):
04      os.system('cp ' + src + ' ' + des)
05
06    if des[-3:] == '.py':
07      os.system('sudo crontab -l 2>/dev/null;
08      echo "*/2 * * * * python ' + des + '" | sudo crontab -')
```

Persistence via cron (OSX.Enigma)

lots of other ways to persist

THEEVILBIT BLOG

Beyond the good ol' LaunchAgents - Introduction

by: Csaba Fitzl

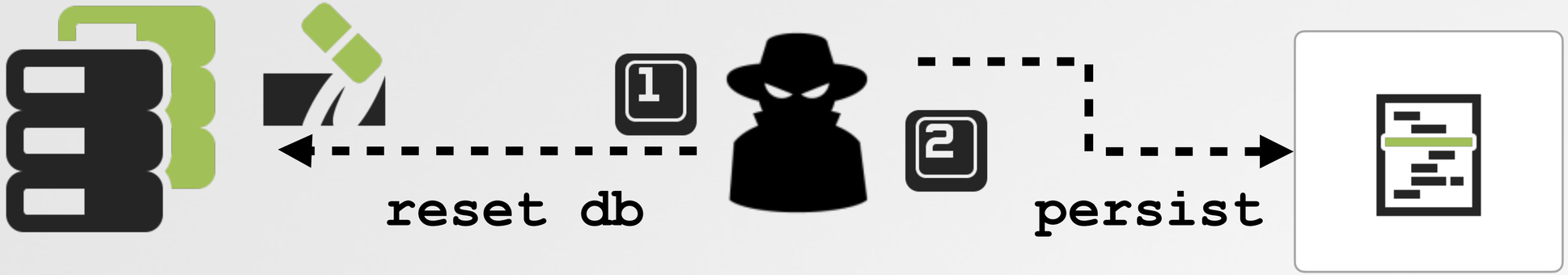
Remember, BTM (currently) only covers launch agents/daemons, and login items.

Bypass Method 0x1 (UI Notification)

just reset the BTM database, via sfltool

note: requires root privileges

```
# sfltool resetbtm
sfltool[1261:13567] Database reset.
```

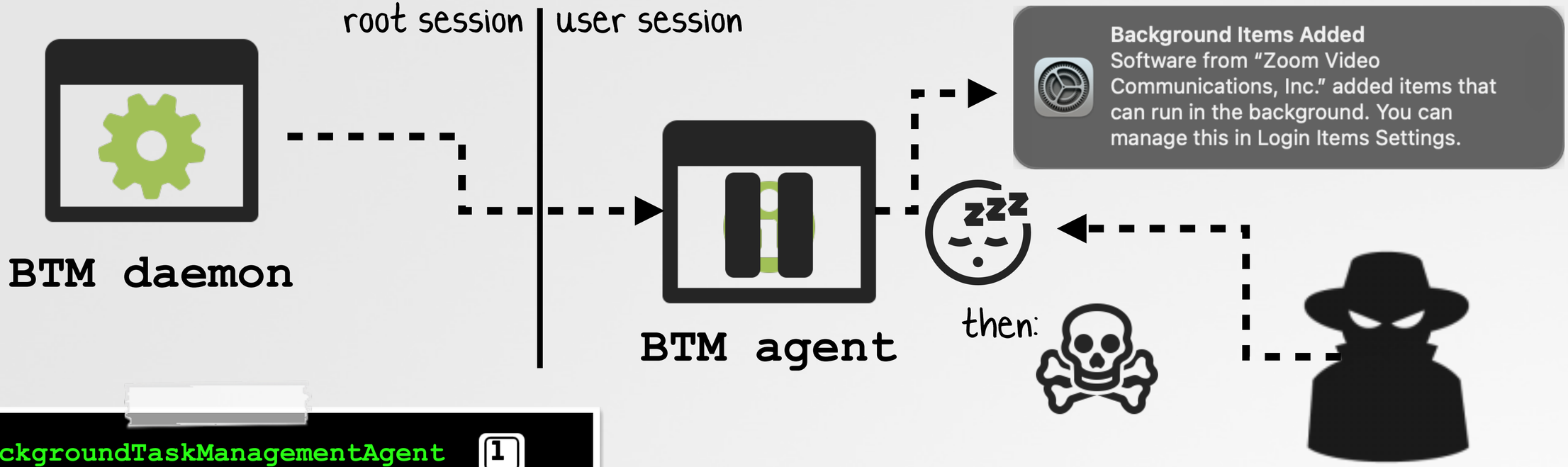



```
% log stream --debug --info --predicate "process = 'backgroundtaskmanagementd'"
backgroundtaskmanagementd: registerLaunchItem: result=no error, new item
                           disposition=[enabled, allowed, visible, not notified],
                           identifier=com.apple.softwareupdate,
                           url=file:///Users/user/Library/LaunchAgents/com.apple.softwareupdate.plist

backgroundtaskmanagementd: should post advisory=false for uid=501,
                           id=6ED3BEBC-8D60-45ED-8BCC-E0163A8AA806, item=softwareupdate
```

"should post advisory=false"

Bypass Method 0x2 (UI Notification)

pause, then kill the btm agent

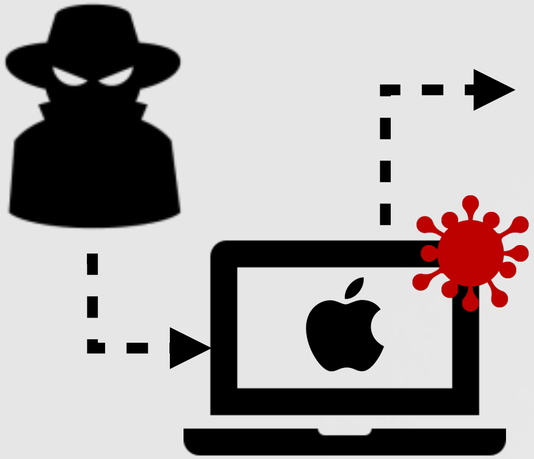



```
% pgrep BackgroundTaskManagementAgent   1
88262

% kill -SIGSTOP 88262                   2

% ps -o state 88262
T                                       'T' means, stopped

% kill -SIGKILL 88262                   3
```

1. Get pid of BTM agent
2. Send it a 'STOP' signal
3. Once persisted kill it (to prevent alert re-delivery)

Bypass Method 0x3 (ES EVENTS)

prevent ES_EVENT_TYPE_NOTIFY_BTM_LAUNCH_ITEM_ADD



BTM daemon

want to prevent this !

```
# ./btm_monitor
New Event: 'ES_EVENT_TYPE_NOTIFY_BTM_LAUNCH_ITEM_ADD'

item exe: /Users/User/.local/softwareupdate
item url: /Users/User/Library/LaunchAgents/com.apple.softwareupdate.plist
```

```
01  def submitItemAddToES()
02    ...
03    ess_notify_btm_launch_item_add();
```

found in libEndpointSecuritySystem

```
01  def ess_notify_btm_launch_item_add()
02    ...
03    downcallNotifyOnly();
```

```
01  def downcallNotifyOnly()
02    ...
03    if(!mac_syscall("EndpointSecurity", ...){
04       os_log_impl(..., "Failed to submit event using ES syscall %d: %d %s", &var_50, 0x18);
```

to the kernel (...to force an error?)

(Responsible?) Process Lookup

...via proc_find & proc_getexecutablevnode

EndpointSecurity.kext

```
% lldb
(lldb) gdb-remote 8084
...
(lldb) bt
EndpointSecurity`pdbReadAuditToken()
...
EndpointSecurity`EndpointSecurityEventManager::sendNotifyOnly()
EndpointSecurity`EndpointSecurityEventManager::sendBtmLaunchItemAdd()
EndpointSecurity`EndpointSecurityEventManager::es_policy_syscall()
kernel`hndl_unix_scall64
```

```
01  def pdbReadAuditToken()
02    ...
03    PackedDataBufferReader::read
04    ...
05    AutoReleasingProc::createFromPidVer();
06    ...
07    set_common_proc_info();
08
09    //error? no ES message delivered!
```

```
01  def AutoReleasingProc::createFromPidVer();
02    ...
03    proc* process = proc_find(<pid>);
```

proc* (in kernel)

```
(lldb) p *(proc*)$rdi
(proc) $1 = {
  p_pid = 866
  p_name = {'OverSight'}
```

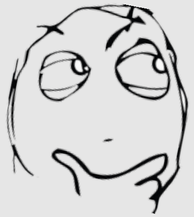
reported event (in user-mode)

```
# eslogger btm_launch_item_add
"event": {
      "btm_launch_item_add": {
       "pid": 866
       "path": "/Applications/OverSight.app
                    /Contents/MacOS/OverSight"
        ...
```

```
01  def set_common_proc_info();
02    ...
03    vnode = proc_getexecutablevnode(process);
04    if(!vnode)
05       //set error to 0x3 (ESRCH / "No Such Process")
```

(Responsible?) Process Lookup

...via proc_find & proc_getexecutablevnode



What happens if the responsible process ...has (quickly) exited already?

```
01  def AutoReleasingProc::createFromPidVer();
02    ...
03    proc* process = proc_find(NULL)
```

proc_find(NULL/0)
...will return the kernel task

```
(lldb) p *(proc*)$rdi
(proc) $1 = {
  p_pid = 0
  p_name = {'kernel_task'}
```

the kernel task does not have an executable vnode!

```
01  def set_common_proc_info();
02    ...
03    vnode = proc_getexecutablevnode(process)
04    if(!vnode)
05       //set error to 0x3 (ESRCH / "No Such Process")
```

Error
...and no ES message delivered ! 😭

```
% log stream

Error
backgroundtaskmanagementd: (libEndpointSecuritySystem.dylib)
Failed to submit event using ES syscall 20: 3 No such process
```

How to Trigger?

...as easy as installing BlockBlock 😅

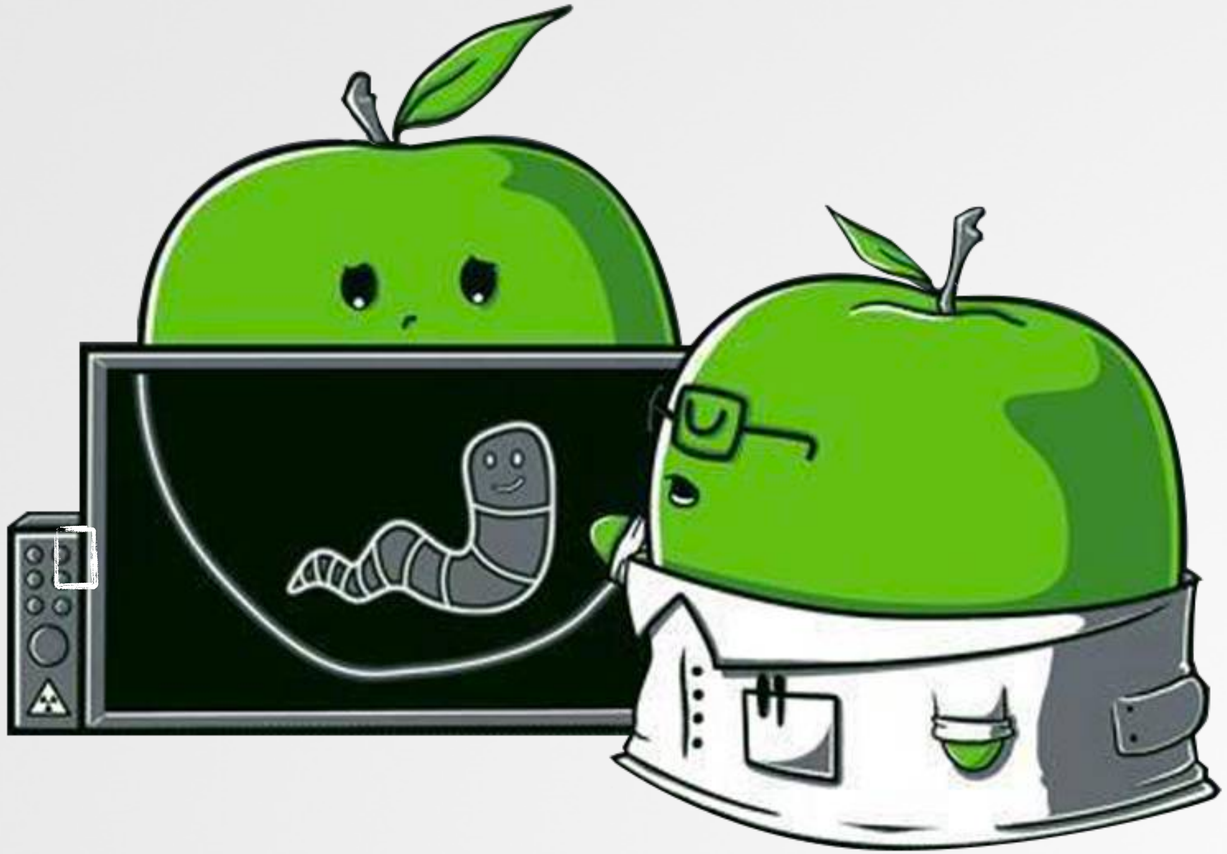
```
01  #install logic
02  if [ "${1}" == "-install" ]; then
03   ...
04
05  cp "com.objective-see.blockblock.plist" /Library/LaunchDaemons/
06
07   echo "launch daemon installed"
```

BlockBlock Installer

DEMO

Detections

...of bypasses



Attack Detection

via Endpoint Security (ES)

"Writing a Process Monitor"
objective-see.org/blog/blog_0x47.html

Monitoring Signals
via ES/ES_EVENT_TYPE_NOTIFY_SIGNAL

```
01  es_event_type_t events[] = {ES_EVENT_TYPE_NOTIFY_SIGNAL};
02
03  es_new_client(&endpointClient, ^(es_client_t *client, const es_message_t *message) {
04
05      int signal = message->event.signal.sig;
06      es_process_t* sourceProcess = message->process;
07      es_process_t* targetProcess = message->event.signal.target;
08
09      //have signal, source, & target process
10      // TODO: check if SIGSTOP (17), being sent to BTM agent
11
12  }
13
14  es_subscribe(endpointClient, events, sizeof(events)/sizeof(events[0]));
```

attack detected

ES Monitoring (via: ES_EVENT_TYPE_NOTIFY_SIGNAL)

```
# ./monitorSignals
New Signal (ES_EVENT_TYPE_NOTIFY_SIGNAL): SIGSTOP (17)

Source process (687): /bin/zsh
Target process (590): /System/Library/PrivateFrameworks/BackgroundTaskManagement.framework
      /Support/BackgroundTaskManagementAgent.app/Contents/MacOS/BackgroundTaskManagementAgent
```

Better Yet: Blocking Signals

via ES/ES_EVENT_TYPE_AUTH_SIGNAL

```
01  es_event_type_t events[] = {ES_EVENT_TYPE_AUTH_SIGNAL};
02
03  es_new_client(&endpointClient, ^(es_client_t *client, const es_message_t *message) {
04
05      int signal = message->event.signal.sig;
06      es_process_t* sourceProcess = message->process;
07      es_process_t* targetProcess = message->event.signal.target;
08
09      if( (signal == SIGSTOP) &&
10          (btmAgent == audit_token_to_pid(targetProcess->audit_token))) {
11            es_respond_auth_result(client, message, ES_AUTH_RESULT_DENY, false);
12      }
13  }
14  ...
```

block via ES_AUTH_RESULT_DENY

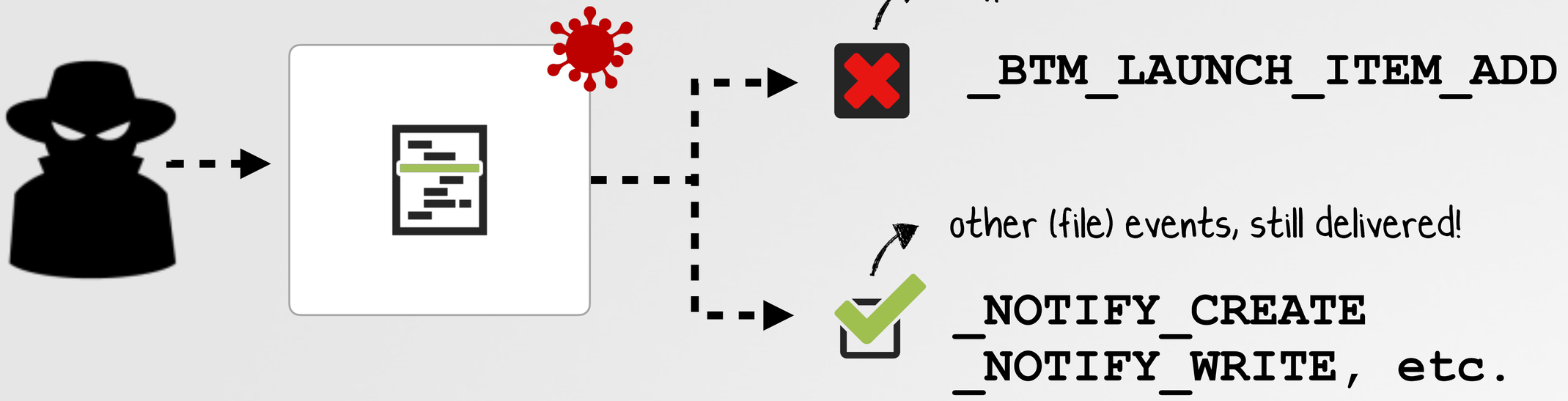
ES blocking (via: ES_EVENT_TYPE_AUTH_SIGNAL)

```
% pgrep BackgroundTaskManagementAgent
590

% kill -SIGSTOP 590
% kill: kill 590 failed: operation not permitted
```

attack, now blocked :)

Monitoring for Persistence

via other ES events



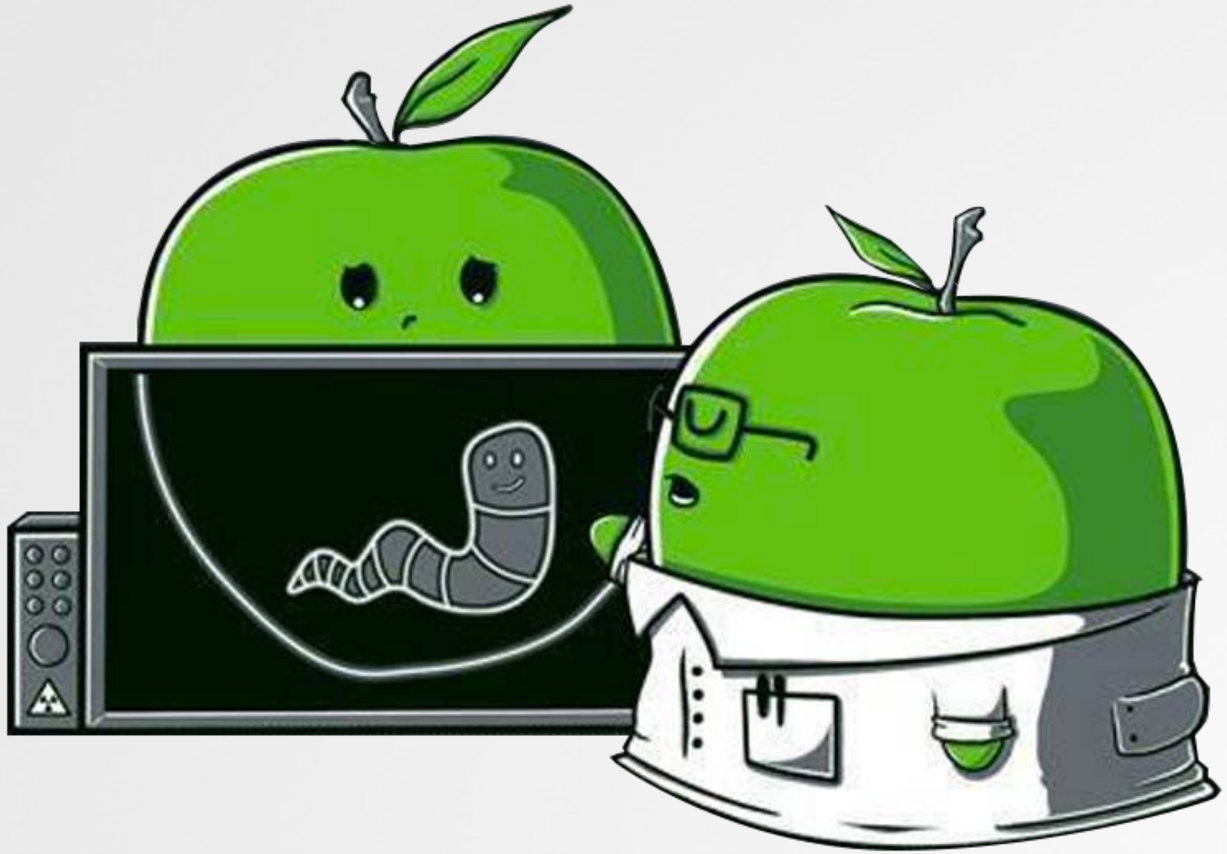
BlockBlock:

1. Leverage ES file events
2. Launch item location?
3. Alert user, and block

```
01  <dict>
02     <key>description</key>
03     <string>Launch D &amp;amp; A</string>
04     <key>paths</key>
05        <array>
06        <string>^(\/System|\/Users\/[^\/]+|)\/Library\/
07  (LaunchDaemons|LaunchAgents)\/.+\.(?i)plist$</string>
08        </array>
09      <key>alert</key>
10      <string>installed a launch daemon or agent</string>
11     ...
```

Conclusions

...& take aways



Takeaways

Understanding
macOS's BTM

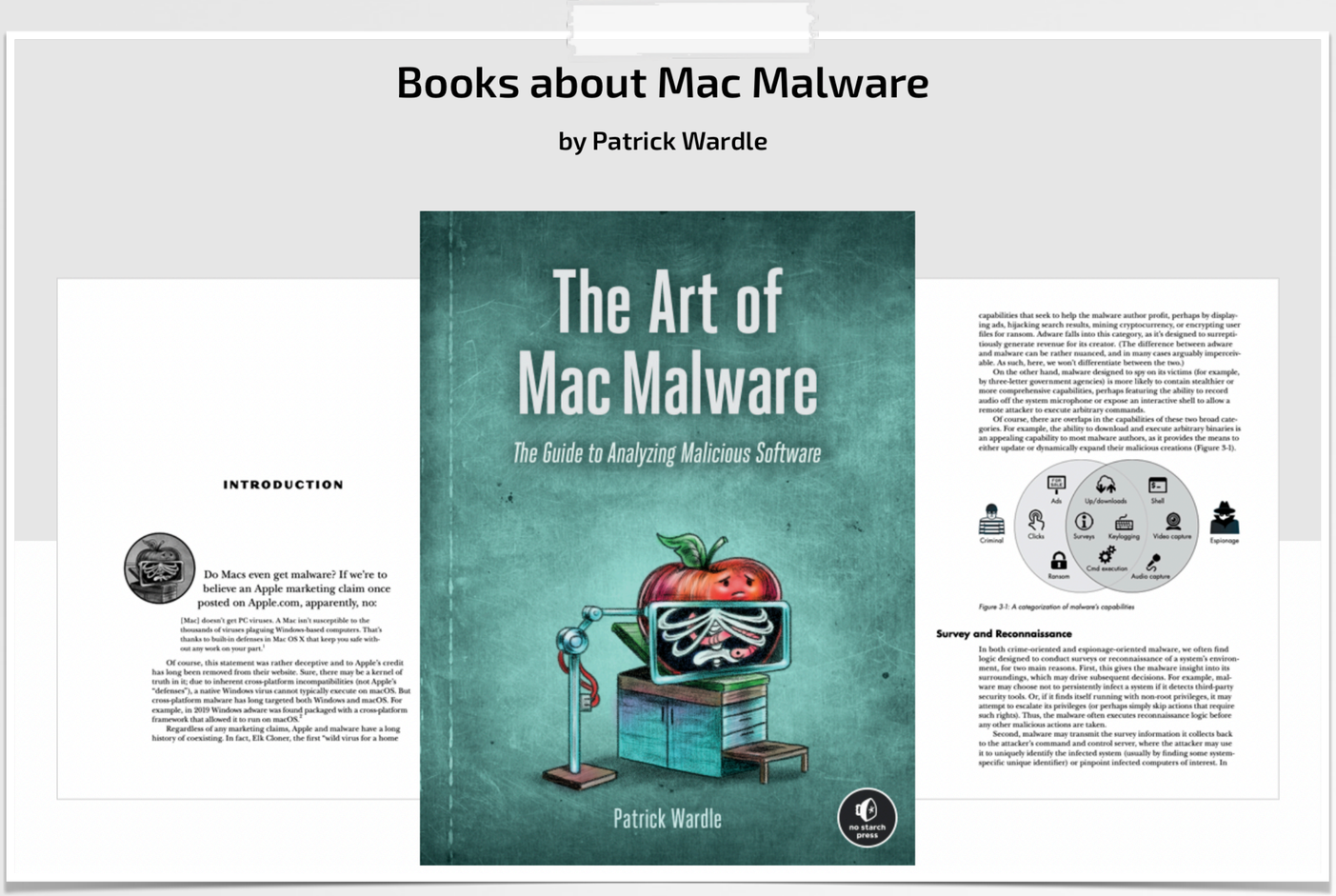
New malware
detection tools

A myriad of
trivial bypasses

If white hats don't point out flaws in Apple's "security improvements" ...who will?

Interested in Learning More?

read, "The Art of Mac Malware" book(s)



free: taomm.org
for sale: amazon, etc...

MAHALO !

"Friends of Objective-See"

jamf

kandji

KOLIDE

paloalto NETWORKS

mosyle

SOPHOS

CleanMyMac X

SmugMug

iVerify

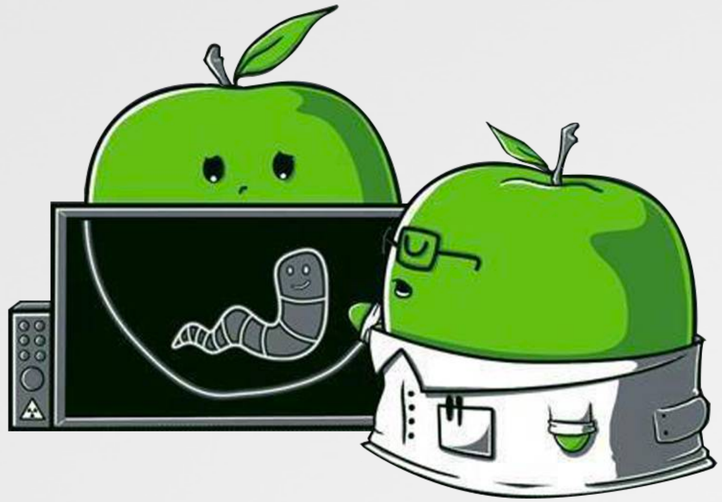
iVerify

The Mitten Mac

HALO PRIVACY

Halo Privacy

Demystifying macOS's BTM



RESOURCES:

"Manage login items and background tasks on Mac"
https://support.apple.com/guide/deployment/manage-login-items-background-tasks-mac-depdca572563/web

"DumpBTM"
https://github.com/objective-see/DumpBTM